A History and Test of Planetary Weather Forecasting

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A HISTORY AND TEST OF PLANETARY WEATHER FORECASTING

A Dissertation Presented
by

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ABSTRACT

A HISTORY AND TEST OF PLANETARY WEATHER FORECASTING

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A unique methodology for forecasting weather based on geocentric planetary alignments originated in ancient Mesopotamia. The method, called astrometeorology, was further developed by Greek, Arab, and Renaissance scientists including Ptolemy, Al-Kindi, Tycho Brahe and Joannes Kepler. A major 17th century effort to test the method in a Baconian fashion was made by John Goad. Building on the ideas of Kepler and Goad, I test an isolated component of the method, specifically a correlation between geocentric Sun-Saturn alignments and cold temperatures, using modern daily temperature data from New England, Central England, Prague and other locations. My hypothesis states there is a correlation, shown in daily temperature records, between cooling trends in specific regions and the geocentric alignments of the Sun and the planet Saturn. The hypothesis is supported by a number of tests that show lower temperatures on days when Sun-Saturn alignments occur, especially when near the equinoxes. The astronomy of this positioning suggests that tidal forces on the atmosphere may be part of a mechanism that would explain the apparent effect. The abandonment of planetary weather forecasting by the intellectual elite in 16th and 17th century Europe is next organized as a history and discussion. In the final section, applications of the methodology to climate cycles is explored, particularly in regard to a 1536-year recurring cycle of outer planets and a cycle of similar length found in climate records. In addition, an account of biological processes that are structured around astronomical cycles is presented.

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CHAPTER 1

A HISTORY OF NATURAL ASTROLOGY

Until about 350 years ago, scientists and natural philosophers thought that the Sun, Moon and planets play an important, if not causal and dominant, role in modulating the weather on Earth. Correlations between planetary motions and weather changes were observed and recorded for millennia and forecasting techniques were developed and applied. This methodology is called astrometeorology and it is still practiced today by a very few who, for the most part, adhere to many of the same procedures that were established over the centuries. While its practitioners claim they can predict weather trends in a given region years ahead of time, their methodology has not been embraced by the meteorological profession. One reason for this is that astrometeorology offers no mechanism to explain itself and another is that its methodology is complex and subject to modification depending on circumstances. But does the system work *in any way* – or is 3,000 plus years of empirical observation of the Earth's weather patterns in various regions, the multi-generational consensus regarding correlations of weather with planets and planetary alignments, and the translation of both into a set of rules, nothing more than a tradition of chasing rainbows?

My thesis attempts to better understand astrometeorology both historically and scientifically. After a historical overview of the subject I report in Section II on studies in which I have tested a single component of traditional astrometeorological methodology against daily weather records. Section III presents historical circumstances coincident with the decline of astrometeorology in the 17th century. Section IV suggests that the subject, and the larger category it falls into, natural astrology, persists under different names.

1.1 Ptolemaic Distinctions

From the height of the Roman Empire to the Renaissance, the scientific writings of a single author defined both astronomy and astrology. Claudius Ptolemy (c. 150), often referred to as the greatest scientist of the ancient world, was the author of the *Almagest* (or *Syntaxis Mathematica*), a detailed, mathematically sophisticated work on the movements of the solar system. In it the circular motions of the Sun, Moon and planets in an Earth-centered universe were explained and demonstrated. In order to do this, Ptolemy's mathematics moved towards trigonometry, and in regard to his analysis of angles using chords, he is credited with being one of the founders of that branch of mathematics. The geocentric cosmos that Ptolemy mathematically modeled could predict with reasonable accuracy where amongst the stars the Sun, Moon and planets could be found in the future. The need to refine this useful model was therefore not pressing and so the Earth remained at the center of the cosmos in the minds of natural philosophers for centuries. Even Copernicus, whose heliocentric model produced only slightly better results, hesitated to topple this ancient structure.

In addition to astronomy, Ptolemy authored a major work on astrology. The work is generally known as the *Tetrabiblos* or *Quadripartitum* (four books on astrology) though the title *Mathematical Treatise in Four Books* is found in some manuscripts.[1] In it, Ptolemy introduced the subject material of astrology, organized it into sections, and discussed it theoretically. He treated astrology as a demonstrable system, with consistent rules and methods, but he gave no examples or indication that he actually practiced it. His masterful description defined the boundaries of the astrology and raised it to the status of a science, and placed its contents in an order that has been followed, for the most part, ever since.

Ptolemy approached astrology as a systematic description of nature that requires prerequisite knowledge of astronomy, mathematics, and natural philosophy. Astronomy, which he expounded in great length in the *Almagest*, he defined as:

That whereby we apprehend the aspects of the movements of the Sun, Moon and stars in relation to each other and to the Earth as they occur from time to time. [2]

Astrology he defined as:

That in which by means of the natural character of these aspects themselves we investigate the changes which they bring about in that which they surround.[3]

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1 Three English translations are readily available. The 19th century Ashmand translation, often used by astrologers, relied on Latin translations of a paraphrase attributed to Proclus. The 20th century Robbins translations (Loeb Classical Library) was based on Ptolemy's Greek text but suffers from errors and a condescending and judgmental attitude toward the subject material. A more recent translation by R. Schmidt improves upon these previous translations.

2 Ptolemy, *Tetrabiblios*, Robbins, trans., (1940) 3.

3 Ibid., 3.

According to Ptolemy, astrology is a less exact, and less self-sufficient, science than astronomy, which deals, for the most part, with perfect spheres. Astrology is characterized by the unpredictability of the material qualities found in individual things and presents problems because certain parts of it are so difficult for some to understand that they come to regard the subject itself as incomprehensible. Having stated these problems, Ptolemy began his exposition of the subject matter with a stated intention to examine both the possibility and usefulness of astrology.

At the start of the second book Ptolemy made an important distinction in regard to the subject of astrology, and one that is central to my thesis – the division of astrology into two fundamental categories: *universal*, or general, and *genethlialogical*. The former is concerned with natural phenomena such as regional and collective factors, climate, weather, agriculture, plagues, etc., and the later was concerned with the affairs of individual humans. Universal astrology encompassed genethlialogical astrology; that is human-centered astrology ultimately yielded to the larger and more general influences of universal astrological influences. This is how Ptolemy defined universal or general astrology:

Of the general inquiry itself, a part, again is found to concern whole countries, and a part to concern cities; and further, a part deals with the greater and more periodic conditions, such as wars, famines, pestilences, Earthquakes, deluges, and the like; and another with the lesser and more occasional, as for example the changes in temperature in the seasons of the year, and the variations of the intensity of storms, heat, and winds, or of good and bad crops, and so on.[4]

This distinction was accepted for the most part for the next 1500 years although, due to the complications raised by the nature of medical astrology, the subject matter of political prognostications, and the varying approaches to the subject by individual practitioners, it can be argued that astrology might be divided in other ways. However, by the late Middle Ages, these two general branches were still distinguished by writers on the subject and had come to be identified as *natural* and *judicial* astrology. I believe this is a good working distinction and from here on I will refer to them by these names. To be specific and consistent with historical usage, judicial astrology will be defined here as a category subsuming three practices: *nativities*, which concern the temperament and life history of humans, *questions* or *interrogations* which are the immediate concerns of humans, and *elections*, the times during which humans consciously choose

[4] Ibid., 119-121.

to take action. The only area of inquiry within the domain of natural astrology that concerns humans has to do with the experiences faced by groups, cities and regions. This component of natural astrology regards the experiences of human collectives as similar categorically to the experiences of the Earth itself when changes in weather, earthquakes, etc. occur. Both human collectives and the Earth are subject to the same influences from the Sun, Moon and planets and the same astrological methodologies have been applied to both. Today this component of natural astrology is sometimes referred to as mundane astrology.[5]

In the first book of the *Tetrabiblos,* Ptolemy very briefly addressed the problem of exactly how the Sun, Moon and planets, and also stars, produce effects on the Earth, its processes and inhabitants. Ptolemy explained astrological phenomena in a way that differs somewhat from that of Aristotle.[6] The later's doctrine involved the transmission of motion from the outer celestial sphere downwards towards the Earth. Ptolemy argued that the planets have their own life force, can move themselves and they move with respect to each other like a flock of birds, each pacing themselves without touching. The planets also move in perfectly circular orbits by their own volition within a space-filling ether that is a medium through which motion-energy is transmitted. The motions of the Sun, Moon and planets then transfer their energy through the ether down to the sublunar region that is surrounded by the primary elements fire and air, which, in turn, transfer this energy to the more Earthly elements water and earth.[7]

1.2 Origins of Western Astrology

Having defined the subject material, I now turn to the origins of Western astrology which can be traced to ancient Mesopotamia.[8] It was in this region of the world that humans first established

[5] In many respects the domain of natural astrology has affinities with the field of geography, that subject taken to include geological and climatic processes as well as human social processes. There is also the matter of medical astrology which is first concerned with the astrological signatures of illness, and secondly with the use of healing herbs. In the context of religious world views that draw a sharp distinction between the physical body and mind, will, and soul, medical astrology might then be classified as a branch of natural astrology as well.

[6] A more extensive account is given in another text by Ptolemy, *On the Hypotheses of the Planets*, a translation of which is contained as Appendix I in Ptolemy, *Tetrabiblos*, Schmidt, trans., (1994) 50-57.

[7] Ibid., 3.

[8] Astrology also originated, or at least developed in its own characteristic way, in India, China and Mesoamerica. Indian, also known as Hindu or Vedic astrology, clearly owes some of its qualities to Western astrology, these attributed to Alexander's intrusion into the region bringing with him Greek scholars. There is, however, an indigenous astrological tradition, mentioned in the Vedas, that is based on the lunar cycle. The astrological system of China is almost completely different in that it tracks planetary cycles and applies these on several scales. While there are some similarities between Chinese astrology and the astrological tradition that developed in ancient Mesoamerica, the later differs in fundamental ways.

permanent settlements, developed agricultural techniques and became organized into towns and cities. Social and cultural evolution accelerated and eventually religions, laws and other means of organizing large groups of people became institutionalized. An important turning point came around 3000 BCE when the Sumerians, a non-Semitic peoples who had settled on Bahrain Island, took over a number of older settlements and established major centers at Ur, Uruk, and Babylon. About this time, a complex religion/mythology was established and propagated, and a kind of writing on clay tablets, called cuneiform writing, became widely used to record kinship linkages, ownership, commercial transactions, mythology and astrological omens. The Sumerians were the major cultural founders of the Mesopotamian region but they were replaced about 2400 BCE by Sargon, King of Akkad (today northern Iraq), a Semite, who built the region's first empire by joining Sumer in the south and Akkad in the north. For the next two millennia empire followed empire. Of note were the empires of Babylon and Assyria, 1800-800 BCE, during which time the development of what many regard as the roots of science occurs. The decline of this long age of empires came about in 612 BCE with the destruction of Assyrian capital Nineveh, and in 539 BCE when Babylon was captured by the Persians.

Of special interest to my thesis are the contents of the Royal Library of Nineveh. The learned king Ashurbanipal, King of Assyria from 668 BCE, searched for, collected and organized historic tablets (of clay, wood, and wax) for his library, which became a time-capsule for Mesopotamian intellectual achievements. The library was discovered in 1853 and, in addition to intricate relief sculptures lining the walls, it contained thousands of tablets which were shipped to the British Museum where they have been repaired, organized and translated. The contents of these tablets is mostly omen literature, astrology and entrail divination, but also included are the Epic of Gilgamesh, ritual texts, medical formulas, dream books, etc.

Amongst the thousands of tablets found in Ashurbanipal's library, and also at other archaeological sites in Mesopotamia, are two distinct collections. One is a text listing astronomical events and star positions. Another is a set of tablets is called the Enuma Anu Enlil, or book of Anu (god of heaven) and Enlil (god of Earth). It is the primary astrological text, essentially a compilation of astrological interpretations of astronomical phenomena from ancient Mesopotamia organized perhaps around 1000 BCE, though it contains information dated to as early as the 17th century BCE. The Enuma Anu Enlil is composed of 68 to 70 tablets and about 7000 omens, depending on which of the existing copies is referred to.[9]

It is apparent from the dating and contents of the Enuma Anu Enlil that astrology developed over a long period of time, probably in several traditions that were integrated around the time the compilation was created. The astrology contained in it was concerned with the affairs of the king, the state and the weather. With the exception of the king's affairs, this body of information was essentially natural astrology. The people who produced the interpretations were organized in teams composed of both experts and trainees who systematically recorded astronomical data. These astrologer/astronomers maintained an unbroken watch of the sky and used sighting devices and water-clocks to measure the positions and the timing of astronomical events such as risings, settings, conjunctions and oppositions of the Sun, Moon, planets and stars. Omens, basically astronomical events with interpretation, were then reported to the king. The astrologers, being principal advisors to the royal courts, were king-supported and this institution of professional astrologers lasted well into the 2nd century BCE.[10]

The tablets of the Enuma Anu Enlil are organized in the following manner. The first twenty-two are concerned with the Moon, its appearance and its eclipses, and the next eighteen are based on the Sun. Meteorological omens, interpretations based on meteorological phenomena such as fog, clouds, storms, and thunder, comprise the next nine tablets. The individual planets, constellations and stars form the basis of the remaining tablets. The oldest part of the Enuma Anu Enlil, a complete astrological text in itself, is a listing of Venus phenomena and respective interpretations that date from the mid 17th century BCE called the Venus Tablets of the Babylonian King Ammisaduqa. These tablets list Venus' first and last visibility above the horizon, exactly the same phenomena that the Maya recorded in their codices and used as a fundamental rhythm for their astronomical, astrological and calendrical systems.[11] The full synodic cycle of Venus, the cycle of relationship between Venus and the Sun, takes 584 days and consists of two primary phases that

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[9] See Thompson, *The Reports of the Magicians and Astrologers of Nineveh and Babylon in the British Museum,* (1900), for early translations of tablets, including many that are meteorological, and Baigent, *From the Omens of Babylon: Astrology and Ancient Mesopotamia,* (1994) 59 ff.., for a history of the collection and organization of the tablets that make up the Enuma Anu Enlil.

[10] See Baigent (1994) and Rochberg, *The Heavenly Writing: Divination, Horoscopy, and Astronomy in Mesopotamian Culture*, (2007) for details on Mesopotamian astrology.

[11] The Maya Dresden Codex contains elaborate tables that allow computation of Venus' 584-day synodic cycle and offer specific astrological delineations for each of the five eastern/morning star appearances of the planet. Other codices and inscriptions also refer to this planet and its synodic cycle. See Aveni, *Sk.y.watchers of Ancient Mexico*, (1980) 184-195.

we know as morning and evening star. The astrologers of these Mesopotamian Venus tablets, like the Maya astrologers 2,000 years later, saw these phases as having differing influences on terrestrial phenomena such as rainfall, food supply, outcome of wars, and the king's affairs. The existence of these Venus tablets indicates that by roughly 1900-1600 BCE astrology had become a systematic, specialized and descriptive body of knowledge.

In the *Enuma Anu Enlil* combinations of planetary appearances, alignments, risings and settings, number of days into a month that a sighting occurred, etc. each had specific omens attached to them that described social, economic and meteorological conditions. Lunar eclipses were associated with winds, lightning, thunder, and earthquakes. The Sun's eclipses were generally considered sinister; predictors of invasions and the destruction of both people and crops. Mercury was a planet that stimulated commerce, and also rain, but this depended on exactly where in the sky it might be found. Venus brought either prosperity or the destruction of crops by winds and floods, again depending on where in the sky it might be found. Jupiter was considered a good planet that brought successful harvests and rains, but Mars brought plague, and Mars in conjunction with Saturn, famine. Some examples are:

When Mercury culminates in Marcheswan, the crops of the land will prosper. When Scorpio is dim in the center, there will be obedience in the land. (Mercury stands within Scorpio.) When in the flaming light of Scorpio (Ishara) its breast is bright, its tail is dark, its horns are brilliant, rains and floods will be dry in the land; locusts will come and devour the land; devastation of oxen and men; the weapon is raised and the land of the foe is captured. [12]

When Jupiter grows bright, the king of Akkad will go to pre-eminince. When Jupiter grows bright, there will be floods and rains. When Jupiter culminates, the gods will give peace, troubles will be cleared up, and complications will be unraveled.[13]

Venus is now disappearing at sunset. When Venus grows dim and disappears in Ab, there will be a slaughter of Elam. When Venus appears in Ab from the first to the thirtieth day, there will be rains, the crops of the land will be prosperous.[14]

It is apparent from the *Enuma Anu Enlil* that individual qualities were ascribed to the planets, the Sun and the Moon. How and why this labeling system, a kind of taxonomy, came to be is not clear. It has been suggested that the color of the planet, the rate of its motion relative to the stars, and the nature of the myths and god associated with it established its astrological qualities. But

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12 Thompson, (1900) lxxii-lxxiii.
13 Ibid, lxvi.
14 Ibid, lxx.

was the planet named for the god or the god for the planet? What is even more interesting is the fact that many of these planetary combinations were interpreted the same way by astrologers over the following three millennia, and likewise in India, China and Mesoamerica.[15] What each planet signified was never changed by decree or religious reform. Astrologers have always stated that the astrological qualities of the planets are the a result of a sustained empirical approach to noting correlations between astronomy and terrestrial phenomena and not the projection of a theory onto the phenomena. Further, each of the individual planets, and the Sun and Moon, have retained a more or less specific set of descriptors with little deviance over the centuries.

In ancient Mesopotamia, astrology as a system of sky-divination was used only for practical purposes; the subject lacked an orbital theory and it didn't require complex mathematics. From this tradition, however, we have inherited the 360-degree circle, sexagesimal notation, the 12-sign zodiac, and the notion of conjunctions and oppositions of planets (which includes the new and full Moon and eclipses) as coinciding with meteorological events and developments in human affairs.

1.3 Greek and Roman Astrology

In early Greece, a separate type of astrological tradition developed, best illustrated by Hesiod's *Works and Days*, an almanac-like text written in the 7th century BCE that considers the cycle of the year and the cycle of the month in the context of agricultural life.[16] The first, and larger, portion of *Works and Days* describes the cycle of the year and how a resourceful and honest person might live in attunement to natural rhythms; astronomical references in the text inform the reader as to when specific agricultural activities should be commenced. Having outlined the cycle of the year, which is based on the movement of the Sun and its relationships to the prominent constellations, Hesiod then addressed the synodic cycle of the Moon, about 29.5 days, which was counted by the appearance of the crescent after new Moon and divided into waxing and waning halves, and also by a division of the cycle into thirds. Hesiod used all three counting traditions to describe the various points in the Moon's cycle that are favorable or unfavorable for one activity or another. He first counted the entire cycle, referring to the positive qualities of the first, fourth,

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[15] The issue of consistency in astrological interpretation in regard to Venus has been raised by archaeoastronomers. I have responded to this apparent discrepancy arguing that deeper psychological qualities associated with the planets, as revealed in myths and symbols, are actually consistent globally. See Scofield, *Signs of Time,* (1993) 157-162.

[16] See Evelyn-White, trans., *Hesiod: The Homeric Hymns and Homerica*, (1972).

and seventh days of the Moon (the first day being the day on which the crescent appears after the New Moon, about 1 to 1.5 days after the New Moon). He then shifted into another way of counting the cycle stating the sixth day of the mid-month is bad for plants. This day, six days into the second third of the cycle, is also the 16th day of the Moon, the day after the Full Moon. Hesiod's "good and bad" days of the lunar month, appears to be a kind of indigenous Greek astrology that offered information for farmers. In this sense it could be considered the world's first "farmers" almanac.

Following the conquests of Alexander the Great in the third century BCE, Mesopotamian astrology entered the now expanded Greek world where it became a more rigorous discipline, taking forms that have survived to the present day.[17] Egypt emerged as a center of astrological studies, which tended to obscure earlier Mesopotamian origins. An early and very popular astrological manual attributed to Petosiris and Nechepso, the former referring to an Egyptian king of the 6th century BCE and the later a high priest of the 4th century BCE, who were probably not the authors, established conventions in astrological interpretation. During this period the horoscope, a time-slice sky-mapping technique, was introduced as a method for evaluating the specific time of a birth or event. The mixing of Mesopotamian astrology with Greek mathematics and four element theory took place in Alexandria, and also in the eastern Mediterranean where an important school of astrology was established by the Babylonian priest Berosus on the island of Cos in 280 BCE. Astrology was thus launched at this time as a unified body of knowledge that quickly assumed a dominant position in Greek, and then Roman, culture. At the same time it became an important component of one of the ancient world's most important philosophies, Stoicism.

For about 500 years, from the 3rd century BCE to the 2nd century, Stoicism was probably the most widely-embraced philosophical tradition in the ancient Greco-Roman world and one that was informed in many ways by astrology. Founded in 300 BCE in Greece by Zeno of Citium (c. 336-263 BCE), Stoicism evolved into a rigorous intellectual system that included not only ethics, for which it is best known, but also a complete metaphysics. Historians of philosophy have argued that the Stoics brought very little that was completely new into Greek philosophy, but they have also recognized that the power of Stoic philosophy lay in its ability to synthesize and extend

[17] See Tester, *A History of Western Astrology*, (1987), Barton, *Ancient Astrology*, (1994), and Neugebauer, *Greek Horoscopes*, (1959) for accounts of the diffusion of astrology from Mesopotamia to the Mediterranean cultures.

existing doctrines – including astrology. Stoicism was a syncretic body of ideas that evolved and stayed current with intellectual developments in the Greek and Roman worlds for hundreds of years. It appealed to the intelligent of all classes and, in many respects, occupied a similar position in Roman society as does our modern, scientific world view.

Only fragments of the of the major Stoic writings have survived. One fact that is known for certain is that the Stoics believed the cosmos, that is the orderly, physical universe, to be a living, intelligent being. Zeno taught that the cosmos is a material, biological organism, and its animating principle (pneuma) is the element fire. Zeno's successor, Cleanthes, also taught that everything living is alive precisely because it has heat or fire, the vital force of the universe, within it. Later Stoics added that the cosmos grows continuously, gradually incorporating non-living matter into itself. Stoic natural philosophy ignored Plato's ideal, transcendent forms and instead developed into a materialistic vitalism that some historians of philosophy have labeled a "cosmobiology."[18] According to the Stoics, the universe does not completely die. Periodic destructions, followed by a renewal of growth, do occur, and these were said to be structured by long-term astronomical cycles marked by rare conjunctions of all the planets. Of the four primary qualities in nature, the elements fire, air, earth and water, fire was considered the one element capable of transformation. The universe was thought to be imbued with fire and was explained as a pulsing, cycling organism that is eternally created and destroyed, ideas behind a cosmological doctrine of both catastrophism and eternal recurrence. Later Stoics, or those strongly influenced by Stoic philosophy, include the Roman emperor Marcus Aurelius and Claudius Ptolemy, whose previously mentioned work on astrology summarized the subject for centuries.

Posidonius of Rhodes (circa 135-51 BCE) was one of the most influential Stoic teachers and a transmitter of astrology to the larger Mediterranean world. His influence on many Roman intellectuals, including Seneca and Cicero, is attested to by references to him. The few surviving fragments of his writings suggest that he was a powerful writer with a very wide-ranging and synthetic view of the world. Galen called him the most scientific of the Stoics. Like most of the Stoic teachers, Posidonius embraced astrology because astrological theory, which had developed rapidly since the mixing of Mesopotamian and Greek ideas, was compatible with the Stoic philosophy of nature. Fundamental to this astrological philosophy was the "doctrine of

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[18] Hahm, *The Origins of Stoic Cosmology*, (1977) 136 ff.

signatures," a system of classification that assumes real correspondences among the various components of the living Earth, as well as between Earth and celestial phenomena. According to this cornerstone of ancient astrological theory, all phenomena were classifiable by a symbolic language of the planets. Each planet had a domain and was thought to "rule" or resonate with a specific set of phenomena within that domain. An alignment or positioning of a specific planet was thought to produce a kind of vibration that was able to affect, through "sympathy," all the objects, organisms and systems of the living Earth that were receptive to that specific planetary energy. Thus, for example, all things that resonate with Mars, i.e. lie within its domain, would be affected by that planet's motions and configurations. Venus would affect still other things, and so on for the other planets and the Sun and Moon.

In the Stoic view, nature is composed of diverse parts, but these parts are interconnected in complex ways that are describable through the language of astrology. The empirical justification for this taxonomy of quasi-organic linkages was the actual astrological effect of the planets, which few contested. No one questioned universal or natural astrology, which concerned the effects, i.e. weather, climate, earthquakes, plagues, etc., of the planetary positions on the physical Earth. Those who argued against astrology generally reacted to judicial astrology, which concerned the effects of planets on individual humans. More specifically, their criticism centered on the issue of fate vs. free will. In other words, astrology was not criticized on scientific grounds (as an explanation for the physical world), but on philosophical, moral, and religious ones. These same arguments reappeared in the Renaissance and will be discussed in more detail in Section III.

In Stoic natural philosophy, astrology was considered evidence of the anima mundi or living Earth. In search of proof for such a connection, Posidonius traveled to Gades (Cadiz) in Spain and for a time observed the Atlantic Ocean tides, which have far more extreme highs and lows than those in the Mediterranean. He regarded his field observations, that the sea responds to the movement of the Moon, as evidence of an inter-connected cosmos.[19] In regard to the Sun, Posidonius thought it to be much larger than the Earth and composed of pure fire, the animating principle of Stoic physics. He thought the Sun was the cause of many Earthly phenomena, including the generation of plants, animals and crystals, and he was interested in volcanoes as evidence of a subterranean fire that also stimulated life.

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[19] Sandbach, *The Stoics*, (1975) 131.

By the time of Ptolemy in the 2nd century CE, astrology had become an integral component of Roman life. It was practiced by both professionals and charlatans. Emperors, including Tiberius and Hadrian studied and used it. The poet Manilius (early 1st century) wrote a long poem on astrology that expressed the Stoic philosophical perspective and Vettius Valens, a contemporary of Ptolemy, wrote a major text describing his methods and his casework. Both survive. Recently, many other writings on astrology from the time of the Greeks and Romans have been translated into English and it now is widely accepted by historians that astrology occupied a prominent and significant position in the Hellenistic and Roman world. Even words from these times have come down to us in our language, eg. "consider" – to use the stars to make a decision, "disaster" – against the stars, and "aspects" – the planetary angles which describe the qualities of a given time or situation. Descriptors of personality based on astrological typology also survive; mercurial, venal, lunacy, martial, jovial and saturnine. A summary of standard astrological terms and symbolism, in use for over 2,000 years, is presented as Table 1 below.

To summarize, astrology was an empirical science in ancient Mesopotamia, a multifaceted subject of great interest in Hellenistic times and common knowledge in the Roman world. Its practice included both the natural and judicial branches of the subject, although writings on later are far more abundant than the former. In the next section I consider the historical techniques employed in the practice of natural astrology, specifically astrological weather forecasting which is generally called astrometeorology.

Table 1. A Short Glossary of Astrological Terms

Planets, Sun and Moon: These moving astronomical bodies symbolize basic concepts which have remained more or less consistent from the origins of astrology in Mesopotamia to the present day. The order of the Sun, Moon and visible planets has traditionally been given in terms of their rate of motion against the stars. The traditional associations with the planets, Sun and Moon are, in order of their daily motion as perceived geocentrically:

Moon – reactivity, femininity, nurturance, feeding, instinctive behaviors.
Mercury – cognition, communication, neutrality, agency, thought, calculation.
Venus – mating urge, attraction, social skill, negotiation, creative enhancement.
Sun – vitality, leadership, masculinity, centrality, integration.
Mars – self-preservation, competition, conflict, activity, initiative, drive.
Jupiter – trust, perspective, faith, growth, extension, reach.
Saturn – structure, clarification, boundaries, exclusion, judgment.

Signs of the zodiac: Most of these 30-degree sections of the ecliptic (path of the Sun) were named for animals. The sequence of signs (not to be confused with the constellations of the zodiac) begins at the vernal equinox with Aries. The twelve signs are symmetrically divided into polarities, qualities and elements. The zodiac appears to be a symbolic sequence of phases, thought to modify the influence of any astronomical body, that follows the annual cycle of the Sun. From this perspective the zodiac could be considered a time-template that is based on photoperiod, the changing day/night ratio.

Elements: Four elements underlie the principles of three signs each spaced 120 degrees apart. There are three cycles of the four elements in the zodiac. Aries is the first fire sign and is followed by Taurus/earth, Gemini/air, Cancer, water. Leo/fire begins the second series of elements and Sagittarius the third. In astrological delineations the elements modulate the basic nature of the planets; fire enlivens, earth solidifies, air communicates and water reacts.

Polarities: Signs alternate between active/masculine (fire/air) and receptive/feminine (earth/water) beginning with Aries.

Qualities: Three qualities underlie the principles of signs spaced 90 degrees apart. Cardinal signs initiate, fixed signs stabilize and mutable signs modulate. Cardinal signs begin at the equinoxes and solstices, the four quadrants of the year. Fixed and mutable signs, in that order, follow each cardinal sign.

Mundane Houses: Twelve sectors of space surrounding any given time and place. Beginning with the eastern horizon, the space along the ecliptic is divided into twelfths, but not necessarily in 30 degree segments. Various methods of house division have been proposed and used throughout the history of astrology. Houses, basically a grid for the diurnal cycle, function in some ways like a temporary zodiac; they modulate the influence of planets.

Aspects: The angular separation of planets, Sun and Moon measured in longitude along the ecliptic. Ptolemy recognized the conjunction (0 degrees between points) and four aspects: the opposition (180 degrees), the trine (120 degrees), the square (90 degrees) and the sextile (60 degrees). These are based on division of the 360 degrees by an integer (2, 3, 4, and 6). Many other angular separations have been added since Ptolemy's time. Note that the zodiac of 30 degree sections includes the above aspects, but not angles based on 360 divided by 5, 8, 9, etc.

1.4 Astrometeorology

Four meteorological traditions with ancient roots can be discerned. Applied weather lore, built mostly on the writings of Theophrastus, Aristotle, Pliny, Lucretius and others, is concerned with obvious, visual phenomena correlated with weather. Weather signs such as clouds, halos, rainbows, and other sky phenomena, and also bird, frog and insect behaviors that occur with certain types of weather are examples. Another related tradition are annual weather patterns correlated with the rising of specific stars. An example of the later would be the flooding of the Nile which occurs when the star Sirius rises heliacally.[20] Such an annual list of correlations was called parapegmata in ancient Greece. The term refers to the moving of calendar pegs against a listing of regular weather patterns, necessary because the Greek calendar, like others of the time, was not synchronized with the seasons.

Meteorology proper is different. Aristotle included meteorology as one of the five subjects of natural philosophy, the others being physics, astronomy, zoology/botany, and the transformations of the four elements in growth and decay. He defined meteorology as the study of things that happen naturally, but with less regularity, in the sublunar region that borders the movements of the stars. The phenomena in this region includes comets, meteors, and phenomena of air and water (winds, earthquakes, thunderbolts). Although much of his "Meteorologica" is theoretical and correlational, Aristotle does make a few statements that bring astronomy into his exposition. He noted that the Sun's annual movement through the zodiac regulates heat and the rise and fall of moisture, including rain which is a wet exhalation.[21] In other words, the Sun drives the cycle of the year which displays seasonal variations of moisture. He also wrote that earthquakes are caused by winds (a dry exhalation) that get trapped in hollows in the Earth – but some occur at lunar eclipses which cause winds to run into the Earth.[22] Other than these statements, there is nothing in his writings that is astrological. The roots of modern meteorology, in the sense that observations are made and mechanisms proposed, however, lie in Aristotle.

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[20] A heliacal rising, that is when a star is visible for only a few minutes before being obliterated by the light of the rising Sun, is an excellent timer for the annual cycle. As the Sun moves ahead in the zodiac at the rate of about one degree per day, due to the Earth's changing orbital position, there will come a point at which a known star will cease to be visible as the Sun approaches it. The last day on which the star is visible just before dawn is a reliable calendar marker as it will happen on the same day each year.

[21] Aristotle, *Meteorologica*, (1952) 71– I.ix.

[22] Ibid., 215 – II viii.

The description and forecast of weather using horoscopes and planetary alignments is something completely different from the above meteorological traditions. As the scope of astrology was so vast, and as practitioners moved easily from nativities, medical judgments, weather forecasting, etc., a separate name for this branch probably did not seem necessary. However, the name astrometeorology was in use by the Renaissance and was considered a sub-discipline of astrology. There are differences of opinion today as to what this activity should be called, and also what the term astrometeorology should precisely refer to. Bos and Burnett suggest it should simply be called "weather forecasting."[23] They argue the term astrometeorology is unnecessary because most weather forecasting of this type, while it was done by astrologers, was excluded in the condemnation of astrology. Lehoux has also confused the matter further by using the term as a designation for both Hesiod's *Works and Days*, which is Greek and at least partially astrological, and also the parapegmata, the established practice of linking seasonal phenomena to the regular risings and settings of stars on public displays.[24] On the other hand, Jenks regards astrometeorology as a useful term that describes the attempt to predict weather astrologically.[25] The most important work on the subject in the 17th century, John Goad's *Astro-Meteorologica*, used the term exactly as Jenks does (though hyphenated), and as I will do in this writing.

Ptolemy, in the *Tetrabiblos*, Book II, left an early description of the techniques employed in astrometeorology. He lists four approaches to the subject, the first three involve the calculation of horoscopes, the fourth similar to the other meteorological traditions described above. The first method, used to describe the weather for each quarter of the year, utilizes horoscopes calculated for the new or full Moon that most closely precedes the equinoxes and solstices. This requires a knowledge of precisely when the syzygy of Sun and Moon occur, then taking that time and calculating a map of the sky for that moment. From this "time slice" an analysis of the Sun and Moon is made, this being based on zodiacal position (signs), position in terms of diurnal cycle and relation to the horizon (houses) and angular distances (aspects) from the other planets. Using information about the signs, houses and aspects that is consistent with the other branch of astrology (judicial), the condition of the weather for the next quarter would then be read from the data.

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23 This argument apparently defines astrology as only judicial astrology. See Bos & Burnett, *Scientific Weather Forecasting in the Middle Ages: The Writings of Al-Kindi,* (2000).
24 See Lehoux, *Astronomy, Weather, and Calendars in the Ancient World: Parapegmata and Related Texts in Classical and Near-Eastern Societies*, (2007).
25 Jenks, Astrometeorology in the Middle Ages. *Isis,* (1983) 185.

Ptolemy's second technique involves the calculation of horoscopes for the first new or full Moon (lunations) that occurs in the signs following those of the equinoxes and solstices. These horoscopes are interpreted as those for the quarters, though he mentions the importance of the latitude of the Moon as a factor in determining the strength of the chart. The latitude of the Moon, measured in degrees, is an indication of exactly how far north or south of the ecliptic it lies. A high latitude implies a large distance between Sun and Moon in spite of the fact that they are in either conjunction or opposition. A low latitude of the Moon moves them closer and the same latitude produces an eclipse. The planets in these charts are also considered, specifically in regard to sign position, which would describe wind patterns for the next month. The third technique is another extension of the basic principle of horoscopes calculated for Sun-Moon alignments, in this case done for the quarter Moons.

In his section on weather Ptolemy talks of the hour-to-hour tensioning and relaxing of the weather, and how this is related to the Moon and tides. The conditions of the air are said to change when the Sun and Moon occupy the angles, that is the rising/setting and culminating/lower culminating positions relative to the observer. An extension of these ideas comprises his fourth methodology in which phenomena such as the Sun's appearance at Sunrise gives indications for the weather of the day, and at Sunset for the weather at night. He draws attention to the Moon's appearance (clarity, halos, etc.) plus or minus three days before the quarters as important signs of coming weather. Ptolemy brings in the stars as indicators of weather by their color and magnitude, and also comets as indicators of winds and droughts. This fourth section clearly has far more in common with the meteorology outlined by Aristotle, his pupil Theophrastus, and others than with astrometeorology proper. It seems that Ptolemy's meteorology was quite inclusive.

Non-horoscopic weather predicting from planetary positions or alignments themselves, basically a continuation of Mesopotamian approaches, continued as an element in the tradition of Hellenistic astrology. In the text of Paulus Alexandrinus, which itself is primarily about judicial astrology, there is a section on predicting winds based on the position of the Moon in signs of the same element, and also by its application by aspect to other planets. For example, the Moon moving through the fire signs Aries, Leo and Sagittarius was thought to produce easterly winds, their strength depending on the planet toward which the Moon is moving.[26]

1.5 Astrology in Arabic Civilization and the Middle Ages

As Mediterranean civilization declined a few centuries after Ptolemy, astrology, which requires regular and sophisticated astronomical observations, declined as well. It's next resurgence occurred in the Middle East, in the empire of Islam. Arab learning, which was extensive and included astrology as a subject of central importance, was centered in Baghdad, itself founded in 762 under the direction of an astrologer.[27] Here was the House of Wisdom, established by the Caliph Al-Mansur and aided by the learned Jew Jacob Tarik, which concerned itself with the translation and assimilation of Greek, Persian and Indian science. One of the great names in this rich intellectual tradition was Al-Kindi (c.796-873), known as the "Philosopher of the Arabs." Al-Kindi translated many works on a variety of subjects and also wrote extensively himself. Little of his writing survives, but the first work by him to be printed in Latin, combined with one on the same topic written by his student the celebrated and influential astrologer Abu-Mashar (c.787-886), was a treatise on astrometeorology.[28] For religious reasons, Arab astrology concerned itself primarily with those parts of astrology that did not deal with individuals. Natal astrology was not practiced, but astrology applied to history was a major theme as was astrometeorology, interrogations and elections, and medical astrology.

An astrometeorological work by Al-Kindi titled *De Mutatione Temporum* (On the Change of the Weather) was apparently a compilation of other writings, including two "letters," ascribed to him.[29] Its contents are almost exclusively practical techniques and methodologies for predicting weather, especially rains – which makes good sense given the dry nature of the eastern and southern Mediterranean region. Al-Kindi stated that the weather forecasting techniques he outlined were relative to the normal climate and weather of a particular region and at points in the text he suggested modifications for different latitudes. Overall, his writing in this text is completely astrological, highly technical in methodology, with little theory and few examples.

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26 Paulus Alexandrinus, *Introductory Matters*, trans. Schmidt, (1993) 39.
27 Bobrick, *The Fated Sk.y.*, (2005) 74-75.
28 See Thorndike, *A History of Magic and Experimental Science,* (1923) Vol I: 641-652.
29 See Bos and Burnett (2000) for translations of Al Kindi's writings.

According to Al-Kindi the probability for rain in the Middle East becomes greater near a new or full Moon when all the planets are retrograde in a specific quadrant of the year, usually winter. Also, the motion of the planets must be moving in the zodiac toward the Sun and Moon. Further details amplify or decrease the possibility of rain. The Moon, Venus and Mercury are most responsible for moisture and rains, more so when they are located in specific 13-degree sections of the ecliptic. These sections, taken from Indian astrology and called lunar mansions, evidence the eclectic nature of Arabic astrology. Other techniques, including zodiacal sign positioning, aspects between planets, aspects to the quarters of the Moon (which naturally involve the Sun) and entrances into the equinoctial sign Libra, all contribute to the art of weather forecasting.[30]

Al-Kindi wrote that the Sun, Moon and planets generate heat and light due to their friction with the air. The closer they are to Earth, the hotter they become and this leads to dryness and certain types of winds. The heat produced by planets varies according to the distance they are from the zenith and also due to general proximity to the Earth, which occurs when they are retrograde. Further, heat is modulated according to the size and motion of the individual planets and by positions in the zodiac, more exactly the quadrants designated by the equinoxes and solstices, which is why rains may even occur during periods of retrogradation which generally produces hot and dry weather.[31] Al-Kindi's rules of astrometeorology are naturally complex as they are based on the ever-changing dynamics of the solar system, where planetary configurations never recur in exactly the same way.

In a work titled *On the Stellar Rays*, Al-Kindi rationalized astrology and its alleged effects on the Earth. Not since Ptolemy had an astrologer attempted to explain the linkages between the heavens and Earth in a theory, and Ptolemy did this mostly in an Aristotelian context using the four elements. In Aristotle's model the operations of the higher realms constituted one type of mechanism which differed from that which operated in the distinct lower, sublunar realm, the "energy" of the former being transferred down to the later via the ether. The basic Aristotelian-Ptolemaic model of astrology theorized that planetary motions keep the four elements in a constant state of change and in doing so produce variations of hot, cold, dry and wet which then operate on substances in the sublunary region. The result is physical change in the sublunary region and therefore planetary motions are the ultimate causes of phenomena on Earth. In regard

30 Ibid., 178-192, 253 ff.
31 Ibid., 164-166.

to astrological theory, Al-Kindi offered something very different, a single mechanism involving rays that are propagated along straight lines from the planets to the Earth. His physics is Neoplatonic in the sense that the cosmos is seen more as a living continuum rather than a series of bounded spheres. Al-Kindi's rays (from the word radius) are forces that link the various components of nature together which produces a celestial harmony. These forces are essentially the astrological energies that drive change in the sublunary realm. He writes that every planet or star has its own nature which is projected in rays to specific objects under its influence (within the parameters of the doctrine of signatures), but combinations with other rays from other stars or planets is also possible. Further, rays from the center of stars or planets vary in strength according to the obliquity of their angle to the horizon – but can be fortified by the rays of other planets or stars. This is clearly in line with astrological horoscopic analysis in which planetary strength is related to latitude, declination, angularity, etc.[32] Al-Kindi's astrological mechanism was also a supportive metaphysics behind magic and alchemy, other subjects of great interest during the Arab enlightenment.

Early Medieval European writers on astrology in general were not well acquainted with the subject and church law placed it among the diabolical arts. The last great compiler of Classical knowledge, Isidore of Seville (7th C), was a source of information on astrology for later writers and he described the subject as being partly natural and partly superstition. The former, natural astrology, was acceptable and included astrological medicine and astrometeorology. Isidore thought the Moon ruled over fruits, the brains of animals, oysters and sea urchins, and that comets were prophetic, but he completely rejected judicial astrology.[33] Isidore's judgments on the subject were influential for centuries and to the middle of the 12th century astrology was only an academic discussion, few real texts on the subject were known. By the middle of the 12th century, however, the bulk of Aristotle's writings entered Europe via the Arab world and with them so did most of the important works on astrology, including Ptolemy, Abu-Mashar, Alchabitius and Messahala. Abu-Mashar's *Introductorius Maius* was the first major astrological work to enter Europe and its synthesis of Greek astrological and astronomical science had a profound influence on Medieval thought.[34]

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32 Al Kindi, *On the Stellar Rays*, Zoller trans, (1993) 7-10.
33 Thorndike (1923) I: 632-633.
34 Wedel, *The Medieval Attitude Toward Astrology*, (1920) 27, and Lemay, The True Place of Astrology in Medieval Science and Philosophy: Towards a Definition, in Curry , ed. (1987) 65-69.

The theory of the great conjunctions, an important astrological topic that falls into the general category of natural astrology, also came to the West via the Arab world. It was the Stoics who first elaborated on the idea of the universe cycling over and over again, this rhythm being established by great conjunctions of planets, but it was Al-Kindi and Abu-Mashar, in particular, who developed the idea. Using primarily the cycles of Jupiter and Saturn, these astrologers interpreted history and gave meaning to the idea of a historical period. Crises in history such as the beginnings and endings of kingdoms, the rise and fall of leaders and the occurrence of natural disasters were thought to be synchronized to the drumbeat of slow-moving and relentless planetary cycles. The planets were seen to be signals of change in the sublunary world – signs of causes, actually. This historical model also circumscribed religion in that it located the origins of prophets and the rise of believers precisely in a cyclic framework – something that was perceived by religious authorities as sacrilegious to the Church. The idea of recurrences marked by planetary cycles that repeat themselves was later an influential concept in regard to the idea of the Renaissance itself – a return or revival of former greatness.[35]

In their writings the Dominicans, Albertus Magnus (1193-1280), his pupil Thomas Aquinas (1225-1274), and the Franciscan Roger Bacon (1214-1294), discussed astrology in great detail. Albertus addressed the subject theoretically in a work dedicated to the subject, *Speculum Astronomiae*, and reconciled it with Christianity. He saw the planets not as causes, but as signs and instruments of God's will that could have physical and even psychological effects (influences). In general, both Albertus and Aquinas concluded that Aristotle's cosmology legitimized the rule of the stars over nature and corporeal bodies, which meant astrometeorology and astrological medicine were completely legitimate. On the other hand, judicial astrology presented some problems for Christian beliefs. Aquinas wrote that the stars/planets have no sway over the human will and intellect because these are not corporeal. But the stars do affect the physical body and most people are governed by their passions – hence they can be affected by the stars/planets.[36] Given this view, precise predictions would have to be impossible – or mediated by demons. Bacon went further and, influenced by Arabic conjunctionism, wrote that astrology had a kind of taxonomic role in the history of religions which he justified by the notion that God created correlations between planets and people as a way to increase the sense of wonder and

[35] See Pingree, *The Thousands of Abu Mashar,* (1968) for the Arabic methodology and also Garin, *Astrology in the Renaissance,* (1976) 1-28, for a discussion on its impact on Renaissance thinking.
[36] Wedel (1920) and Thorndike (1923) Vol. II: 517-615.

love for him. The mechanism behind religious cycles were groupings of the 20-year conjunctions of Jupiter and Saturn.[37]

Europeans were reading and writing manuscripts on astrometeorology by the 14th and 15th centuries (the late Middle Ages). One of the centers of this early renaissance was Merton College, Oxford. Here, astrometeorological manuscripts on were studied; the twelve most popular written before 1350 included five by Arab authors and seven by Western Latin authors. These manuscripts were copied, annotated and commented on by knowledgeable writers including university professors, court astrologers, princes, monks and friars. General introductory treatises existed among these manuscripts which demonstrated the determination of weather patterns accomplished by a weighted astrological scoring system. In this methodology the relative strengths of planets, quantified, in a weather chart were added up and then compared in order to reach a conclusion. More comprehensive and technical works for the professionals presented even more complex and subtle methodologies.[38] William Merle of Oxford (d. 1347) studied astrometeorology by collecting his own weather data. He even published a report on a seven-year astrometeorological weather study, certainly one of the first attempts at what would later be called a Baconian research program.[39]

The astrometeorological treatises of the Middle Ages were not concerned with weather phenomena of economic significance for Northern Europe. Rainfall was a topic, as it was in Arab astrometeorology, but so were earthquakes and the aurora borealis. These treatises were intellectual exercises for students of astrology, not a source of useful information for farmers or merchants. During the course of the 14th and 15th centuries the level and complexity of serious astrometeorological writing rose in comparison to the beginner treatises. The subject, now extremely technical, was confined to specialists – academic authorities, experts and professionals – who apparently were consulted by clergy and aristocracy in regard to weather. Demonstrations of the success or failure of specific forecasts have, unfortunately, not survived.

As previously discussed, meteorology had three divergent lines – weather lore, astrometeorology, and Aristotle. The later tradition, considered a branch of natural philosophy, involved

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37 Thorndike (1923) Vol. II: 672-673.
38 Jenks (1983).
39 See Thorndike (1923) Vol. III: Chapt. 8.

descriptions of all natural processes that occurred in the region of air including clouds, winds, lightning, meteors, comets, rainbows, etc. By mid 16th century this "science" of meteorology had become distinct from astrological weather forecasting and was now the study of the causes and the description of the effects of phenomena in the sphere enclosed by the Moon, i.e. sublunary occurrences. However, astrometeorology in Europe had become deeply integrated into the intellectual culture of the time and was classed as a separate kind of scientific knowledge. This classification persisted into the Renaissance. Between 1545 and 1555, the Swiss naturalist and bibliographer Conrad Gesner published his four volume *Bibliotheca universalis*, a work that organized all existing knowledge into 21 books. Book VIII was on astronomy, Book IX was on astrological weather forecasting, and Book XIV was Aristotelian meteorology in the context of natural philosophy.[40]

1.6 Almanacs and Astrology in the Renaissance: 1450-1650

Throughout Europe, from Italy to Germany to England, astrology prevailed during the early Renaissance. From the elite to the vulgar, astrology and its notions had become deeply embedded into the cultural fabric appearing as a theme in art and literature. Individual astrologers were supported by highly placed patrons and intellectual discussions on the subject were carried on in the universities. Astrology as a component of a generally accepted world view pervaded scientific thought – physiology, medicine, botany, metallurgy, psychology, weather, and agriculture. This situation began to change following a late 15th century attack on the subject from Pico della Mirandola, discussed at length in Section III of this thesis, that put astrologers in a defensive situation for the next 150 years.

Natural astrology, as well as judicial astrology, had became familiar to the public in the second half of the 15th century due to the rise of print technology. Prior, it had been customary for individual astrologers to offer manuscripts containing tables of planetary positions as well as prognostications for the year ahead to their patrons, which may have included royalty, the wealthy, a town council, or the university where they were employed. Printing changed this situation profoundly by enlarging the potential audience for such information. The first printed

40 Sirkka Havu, *Conrad Gesner: Father of Bibliography*, Helsinki University Library, Finland, http://www.fla.fi/frbr05/GesnerByHavu2005.pdf, (2005) (accessed March, 2010). See also Heniger, *A Handbook of Renaissance Meteorology*, (1960).

almanacs containing tables of planetary positions appeared in the mid 15th century and the number printed grew during the 1470's. Prognostications, a separate kind of publication that offered predictions for the year, appeared about 1470 and publications containing both tables and predictions soon became a common format. During the late 15th century almanacs also appeared in Germany, France, Italy, Hungary, the Netherlands and Poland. Not only were almanacs and prognostications among the earliest works printed (Gutenberg began printing almanacs in 1448), but they were among the best-selling. A tradition of Flemish almanacs and prognostications, established by the master astrologer Johannes Laet, became very successful and these were published annually from 1469 to the mid 16th century. Translations of the Laet almanacs and prognostications were shipped to England where English printers soon began to arrange for their own translations and this led to a separate English almanac tradition.[41]

Continental almanacs, and later English almanacs, maintained a similar form and were dedicated to the year at hand and thus disposable, requiring a new copy to be purchased each year. This form typically included the following: astronomical tables, political predictions for the coming year, disease and weather forecasts, medical notes often involving astrology, times for agricultural activities, a listing of religious holidays and their dates during the year, and other miscellaneous information. Individual writers of almanacs competed with each other and the quality of the product varied. Astrological prophecies were made, some of them outlandish, but most almanac writers at least sought to publish the best astronomical data available. Due to their widespread circulation and the scientific interests of their writers, almanacs became vehicles that spread new ideas to every level of society. Many almanac writers popularized Copernicanism, argued that Earth was a sphere, and that astronomical bodies were spaced at great distances. The astrologers who wrote the almanacs were often advocates for the new science and hostile to ancient astronomical notions. A detailed look at the contents of a mid 16th century almanac from England is instructive in regard to the content and tone of these publications.

The *Prognostication Everlasting of Right Good Effect* was an early English Almanac written and published by Leonard Digges, the father of the astronomer Thomas Digges. Digges, the son, was an early Copernican who is credited with correcting and augmenting the almanac's astronomical sections. The *Prognostication Everlasting* was first published in 1553 but was reprinted many

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41 See Capp, *English Almanacs 1500-1800,* (1979) 25 ff ., for a history of the merged almanac and prognostication which he sees as reaching its fully-developed standard form in England by the later part of the 16th century.

times, its everlasting quality referring to the fact that the almanac contained the standard methodology for predicting the weather. With this almanac came the year's planetary positions along with a "do-it-yourself" manual. I have examined two versions of this almanac, one from 1555 and the other from 1605, both very similar.

In the introduction, where the reader is addressed as a "dear Christian," Digges launched into a defense of astrology dropping names like Ptolemy, Bonatus, Cardano and Melanchthon. This near rant, supposedly sanitizing the publication by associating it with intellectual celebrity and pious Christianity, illustrates the defensive position towards their subject taken by astrologers in the later part of the 16th century. This introduction is followed by a geometrical diagram/template for a sighting device, that Digges suggests be made out of metal a foot square, to be used for locating planets and stars. Following this is a diagram showing the relative sizes of the Sun and planets, the inner planets being small but Jupiter and Saturn being about ⅔ the size of the Sun. Next is a long section showing how to judge the weather by each of the five planets, Sun and Moon. First is how to judge weather by the color of the body, for example a red Sun in the morning implies wind and rain. Omens of future weather from comets, clouds and rainbows comes next followed by weather judged from planetary aspects, that is the Ptolemaic aspects. Saturn, the planet that moves slowest, is listed first and includes a delineation for each of its aspects with the other bodies. For aspects between Saturn, Jupiter, and Mars with the Sun, Digges writes the following:

The conjunction, quadrature and opposition of Saturne with the Sunne, chiefly in cold signs, shows dark weather, hail, rayne, thunder and colde days.

The conjunction, quadrature and opposition of Jupiter with the Sunne, great and moist vehement winds.

The conjunction, quadrature and opposition of Mars with the Sunne in fiery signes, drought; in watry, thunder and rayne.[42]

While all this appears straightforward – that one simply finds an aspect in the ephemeris section of the almanac, then looks up the forecast – it is actually far more complicated. To begin with, there are often multiple combinations of aspects forming at the same time, making the isolation of a single aspect an infrequent occurrence. Further, the Moon's aspects with the planets form and

42 Digges, *A Prognostication Everlasting,* (1605) 10.

dissolve rapidly over a matter of hours. Digge's offered some clues as to integrating this "minute hand" factor in making weather predictions:

The conjunction, quadrature and opposition of the Moon with Saturne, in moist signs, bryngeth a cloudy daye, colde ayre, according to the nature of the signe: If they go from Saturne, to the Sunne, by conjunction or otherwyse, harder weather ensueth.

The conjunction, quadrature and opposition of of the Moon with the Sunne in moist signes, rayny weather: the more if the Moon go from the Sunne to Saturne.[43]

What these branching recipe-like descriptions require is a substantial knowledge of astrology. First the zodiacal sign must be incorporated into the procedure; each has its own specific modification for each planet, Sun and Moon. Then, the sequence of astronomical events must be considered. The Moon passing from a conjunction with the Sun to a conjunction with Saturn is different, more in this case weatherwise, then if the Moon conjuncts Saturn first, then the Sun.

After a few pages of aspect delineations, Digges' then described each planet's effects in the signs of the zodiac. After that is a method of making a prognostication for the year ahead based on the day of the week on which New Year's Day falls, a technique used at least since the Middle Ages. The procedure is described and short delineations for each day of the week (which are, in the Romance languages, named for the Sun, Moon and planets) are given. Further discussion of meteors, i.e. thunder, earthquakes, rainbows, etc. leads to some very specific delineations of trends coincident with lunar aspects. A table showing what sign the Moon is in on any day of the year also states whether or not that day is good for purging, bloodletting, or for bathing. A woodcut showing a man with his body parts linked to the 12 signs of the zodiac is part of this quasi-medical astrology section. Calendrical tables follow that locate events such as Lent over a range of years. More tables show the length of the day and the night, and the time sunrise and sunset, throughout the year for several localities. There is then a "peculiar kalendar" which treats each month at a time astronomically, followed by a "general kalendar" which lists fairs and events. Next are tables of the Sun's altitude and a diagram of a quadrant that may be employed by the user for this measurement. Finally, in a section called "Brief Collections," are a series of pieces of information on topics like how to track moveable feasts and how to know how long the Moon will shine on a given day. The almanac concludes with a section by Thomas Digges in

43 Ibid., 11.

which he made a few corrections to his father's work and then promoted the Copernican model of the solar system, complete with diagram.

Digges' almanac is not a simple read aimed at the masses. It is far more complicated than the farmer's almanacs of the present time. Even if it were re-written in modern English it is doubtful how many people today would actually understand much of it, let alone do their own calculations and weather forecasting. The fact that this widely-selling common publication, full of astrology, was promoting Copernicanism not long after Copernicus' work itself was published, raises questions about how who was educating the masses, at least in astronomy.

William Lilly was the most successful astrologer of 17th century England. He was consulted by people of all stations, he published an annual almanac for nearly forty years, wrote books on astrology and an autobiography, and he improved his station in life through strategic marrying. Lilly wrote perhaps the definitive textbook of astrology of his time which he titled *Christian Astrology*. This again says something about the pressure astrologers faced in regard to religion, and although most astrologers were religious to some degree, the clergy was almost unanimously set against the judicial branch of the subject. Lilly's almanacs were extremely popular selling in the tens of thousands, and in addition to offering the usual astronomical, weather and calendar data, he regularly published often quite accurate political predictions. The title of his 1646 almanac (published over a year earlier) reads:

Anglicus, or ephemeris for 1646. Delivering mathematically the success of this years actions, between the king and parliament of England. With astrological aphorisms, expedient for physicians and others, useful for students in this science. To which is added the nativity of prince Rupert.[44]

In 88 pages is an apology for astrology, an ephemeris and aspectarian (listing of the aspects made by the planets), and a listing month by month in which Lilly makes both political and meteorological predictions. Also included is a table of houses (mathematical data for mapping the sky) used in calculating horoscopes and a specific political section called "a general judgment of the affairs of England." The almanac concludes with 50 astrological aphorisms relevant to the practice of medicine and another 50 relevant to the practice of horary astrology, and a delineation of the horoscope of Prince Rupert.

44 Lilly, *England's Prophetical Merlin,* (1644).

1.7 The Attempt to Reform Astrology

The reform of astrology began in the 16th century. It was carried out on an individual basis by an impressive list of European and English intellectuals, including Brahe, Bacon, and Kepler, who either practiced astrology or supported it in principle. No coordinated reform movement was ever launched though at least one group was formed in the 17th century in London, some years before the formation of the Royal Society. This group, the Society of Astrologers of London, met periodically though the organization only lasted a decade and failed a second time years later when an attempt was made to revitalize it. It appears that this organization was more of a social and trade association than a research motivated group.[45] Natural astrology, specifically astrometeorology was one branch of astrology that was given special attention by reformers such as Kepler who developed a simple investigative methodology. John Goad later produced a body of work that took astrometeorological research to new levels, and he was in contact with members of the Royal Society. It has been argued that the much of science during the 17th and 18th centuries contained (or inherited) elements of the natural astrology tradition, particularly in regard to subject matter methodology.[46]

Until about 1700 the boundaries between the scientific and astrological communities overlapped and many astrologers were associated with leading scientists of the time. Some in the Royal Society were sympathetic to the subject. Robert Boyle was known to consult with the astrologer John Bishop and members, e.g. Robert Hooke, included astrological data in some of their experiments.[47] The scientific reform of astrology, both natural and judicial, turned out to be an enormous problem. In my view, the major obstacles in this regard were that (1) no single astrological influence could be quantified – there were no units to be analyzed, (2) descriptions of alleged astrological effects, including possible explanatory mechanisms, were by necessity qualitative and of infinite variety, making predictions extremely difficult conceptually and also a challenge to translate into the vernacular, and (3) the field included those of lower social ranks, a factor that limited opportunities for research due to lack of funding, lack of education, and fear of social marginalization.[48] Further, the practice of natural astrology was mostly conducted by the

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[45] See Curry, *Prophecy and Power: Astrology in Early Modern England*, (1989) 40-44.
[46] Ibid., 138 ff.
[47] Capp (1979) 189.
[48] Translation from astrological symbolism to the vernacular presents real problems. Those versed in astrological symbolism will understand a given situation from within the context of the specific planetary configurations involved.

same people who practiced judicial astrology, which was itself in conflict with religious conservatives and with Renaissance notions of free-will.[49] There was also the problem of charlatans as the practice of astrology was not regulated. During the course of the 17th century astrology moved from being generally accepted knowledge with many practitioners and advocates in high social positions, to a small collection of educated amateurs and a larger group of almanac writers, and also some quacks, that wrote and worked for the lower classes. More of this in Section III.

1.8 Dee and Bacon

John Dee (1527-1608), mathematician and astrologer to Elizabeth I and for a time part of the Louvain group of astrologers in Belgium, proposed astrological reforms that introduced quantification and even technology. In his *Propadeumata Aphoristica*, published originally in 1558, he argued that there was a need for greater precision in astrology.[50] For a few years he kept detailed weather records, like Kepler and Goad were later to do, that were part of his effort to develop a more quantified astrology.[51] For Dee, astrology was essentially a practical application of astronomical geometry with a goal toward capturing, or more accurately, harnessing (in his case through the use of mirrors) a planet's light, which he thought was the carrier of planetary effects to the sublunar realm. He pointed to the distances of the planets from the Earth at perigee and apogee, and also the precise length of time a planet spends above the horizon during its diurnal cycle (its declination) as important factors by which astrological influence could be better known, and therefore quantified, and he called for better tables of planetary positions.

In addition to more precise measurements (which Tycho Brahe began to do at about this time for similar reasons) Dee proposed a kind of computational method that involved assessing what he determined as the 25,335 variations of astrological effects based on the relative commingling of the rays of the planets – and this figure applies to conjunctions alone! Clearly such an attempt to put astrology on a more mathematical foundation by quantifying astrological influences would require splitting hairs and years of training. It is most likely that Dee was being facetious and

Such an understanding involves symbols, not ordinary language, and as such limits understanding to those who know the code.

49 This third point will be considered in Section III in the discussion of the social factors in the decline of astrology. The other two points will be discussed later in this section.

50 Dee, *Propadeumata Aphoristica* (1568) trans. Schumaker (1978).

51 Vanden Broecke, *The Limits of Influence: Pico, Louvain, and the Crisis of Renaissance Astrology,* (2003) 208-209.

drawing attention to the fact that astrological interpretation required extreme subtlety.[52] His contemporary, Jofrancus Offusius, whom Dee accused of plagarism, also tried to reform astrology by introducing a method of quantification.[53] In his 1556-1557 *De Divina Astrorum Facultate*, Offusius presented numerical values for qualitative factors used in astrological interpretation. Using the four qualities and figures for planetary distance, he arrived at specific formulae which one could use to calculate the strength of a planet.

While Francis Bacon was not a student or practitioner of the subject, he was definitely open to an astrology which studied general conditions. Bacon was critical of astrological doctrines concerned with nativities, elections, and inquiries, nearly all of which, he noted, were plainly refuted by obvious physical conditions. Essentially, he wanted to remove anything occult or mysterious from the subject and make it a "sane astrology", as reasonable as any of the other sciences. Bacon actually laid out a plan for the reform of astrology with a focus on aspects and elevations:

In the first place, let there be received into Sane Astrology the doctrine concerning the commixture of rays; that is the conjunctions, oppositions, and other combinations or aspects planets with regard to one another. And to this same part also I refer the passage of the planets through the signs of the zodiac, and their position under the same signs; for the position of a planet under a sign is a kind of conjunction of it with the stars of that sign. …Second, let there be received the approaches of each individual planet to the perpendicular, and its regressions from it, according to the climate of countries. For every planet, no less than the Sun, has its summer and winter, in which as its rays fall more or less perpendicular, their force is stronger or weaker.[54]

In this program attention is drawn toward the aspects, seen here as the convergence of rays, and also to the position in the zodiacal signs. And again, as with Dee, the elevation of a planet should be considered – for, presumably, Baconian testing. Bacon also called for attention to the apogees and perigees of the planets, their changes in motion from direct to retrograde, their distance from the Sun, any increases and decreases of light, etc. All of this is strictly astronomical, quantifiable and real, but Bacon was practical and had broad vision. He stated that the ideas of the historic astrologers ought not be completely rejected and that the particular natures of the planets as handed down by tradition should be considered carefully; and further that the subject needed to

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52 Ibid., p. 191.

53 See Bowden, *The Scientific Revolution in Astrology: the English Reformers, 1558-1686,* (1975) 78-85.

54 Bacon, *Philosophical Works,* Robertson, ed. (1970) 464.

be approached experimentally and include a search for physical causes.[55] The usual subject matter of judicial astrology, i.e. people, questions, etc., was a part of Bacon's proposed reform, though he completely rejected celestial magic, such as that practiced by Ficino, and put limits on elections and the use of horoscopes in establishing reliable rules of prediction. The subject areas that astrology should be most confidently applied to, in terms of making predictions, are essentially what was called natural astrology:[56]

…all kinds of meteors, of floods, droughts, heats, frosts, earthquakes, irruptions of water, eruptions of fire, great winds and rains, the various seasons of the year, plagues, epidemic diseases, plenty and dearth of grain, wars, seditions, schisms, transmigrations of peoples, and in short of all the commotions or greater revolutions of things, natural as well civil.[57]

Bacon's plan of reform did not enter into the debate over astrology in his time which had to do with the supposed influence of the planets on man and the consequences regarding human autonomy, and also the precise location of God in all this. This debate, which ran the course of the 16th and 17th centuries, was fundamentally concerned with the preservation of human free-will and the omnipotence of Christian religion – there was little argument in regard to any general planetary effect on nature itself, particularly the weather. The branch of astrology called astrometeorology was practiced without censorship or intrusion of the religious purists by many leading astronomers; Tycho Brahe and Johannes Kepler, for example, were expected by their patrons to make weather forecasts as well as political predictions, and its principles and techniques were taken quite seriously by both men.[58] Tycho's astrology was traditional, but Kepler was a particularly enthusiastic astrological reformer as has been previously described.

1.9 Johannes Kepler's Reformed Astrology

Johannes Kepler (1571-1630), a major figure in the history of science, is primarily known for being the first to mathematically model the solar system as we know it today.[59] He is equally

[55] Ibid., 465.
[56] The term mundane astrology is used more frequently today among astrologers and, in addition to astrometeorology, includes historical astrology (correlating historical changes with planet cycles), political astrology (analyzing popular trends and predicting the outcome of elections), and economic astrology (stock market predictions).
[57] Bacon, (1970) 465.
[58] In the Renaissance the word astrometeorology was often hyphenated, but in this paper I will leave it as one word, as does Jenks and other modern writers, except where it occurs in the title of Goad's book.
[59] Much of this brief biography of Kepler was derived from Casper, *Kepler*, (1993), Gingerich, "Johannes Kepler" in *Dictionary of Scientific Biography*, (1973), Koestler, *The Sleepwalkers*, (1963), and also my familiarity with Kepler's own writings.

important in the history of astrology in that he made specific recommendations for a reform, and he also included astrology in his attempted grand unification of the cosmos. In regard to the subject of astrology itself, Kepler was a brutal reformer. He completely rejected some standard components of Ptolemaic astrology including houses and signs, regarding these as artificial divisions created by people, useful for positioning planets on a grid, but not much else. Kepler published three books on astrology including *More Certain Fundamentals of Astrology (De Fundamentis Astrologiae Certerioribus)* in 1602, *The New Star of 1604 (De Stella nova in pede Serpentarii)* in 1606 and *Third Party Intervening (Tertius Interveniens)* in 1610.[60] In *Harmonics of the World*, published in 1618, Kepler presented a detailed and all-embracing synthesis of geometry, music, astrology, astronomy and epistemology. He probably considered this book to be his magnum opus and it contains large sections in which he presented his resonance theory of astrology.[61]

For his highly-place patrons, and as a teacher of mathematics and astronomy, Kepler was required to publish astrological annuals which contained weather forecasts as part of his job. He took this part of astrology seriously and sought to improve accuracy by keeping weather records, which he began in 1593, and comparing the data with the planetary alignments operative at the time.[62] He was apparently quite good in some of his forecasts and he received some attention after accurately predicting a major cold spell and the invasion of the Turks.

A part of the reform of astrology, mostly as a response to the late 15th century criticisms of Pico della Mirandola, was the problem of explaining exactly how astrology worked.[63] Kepler's ideas on this problem, which were never static and changed as he learned of new discoveries, included both Aristotelian and Pythagorean/Platonic notions. In regard to the how the Sun, Moon and planets affected the Earth he assumed two basic Aristotelian qualities, warming and humidification, and two primary forces that could transmit the two qualities.[64] The first force, the

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[60] *De Fundamentis.* Field, trans., (1984) is a lengthy introduction to the almanac for that year and it includes his weather forecasts. *Tertius Interveniens* (Negus, trans., 2007) is a passionate argument in favor of astrology in which Kepler responds to criticism of the subject. At present, only *The New Star of 1604, which concerns a nova that appeared and its astrological meaning,* has not been translated into English.

[61] The usual translation, *Harmony of the World*, or *World Harmony*, completely misses the point of the work which presents a Neo-Pythagorean theory of resonance as the key to understanding the universe. Much of the astrology in the *Harmonics* is found in Book IV.

[62] A sample of his diary was published by Kepler in *Tertius Interveniens*, (2007) 196-198.

[63] Pico's attack on astrology was broad, but a major argument in the work was the failure of astrologers to account for how the planets, though not the Sun or Moon, could be the causes of anything. See Section III for a discussion on Pico's attack.

[64] Kepler, (1984) 238.

carrier of heat, was light itself which Kepler viewed as a non-material property similar to sound, smell, warming from heat, attraction of a magnet, etc. From his work on optics, he knew light transported colors and he connected this with the actual colors of the planets – Mars being reddish, Jupiter blue, Saturn yellow, etc.[65] The second force, the carrier for humidification is reflected light. With light being strongest in the Sun, and moisture in the Moon, Kepler summarized these two primary forces as also pertaining to the planets themselves. He thought at the time that the planets both radiated and reflected light, and this accounted for their heating and humidifying properties.[66] Two qualities carried by direct and reflected light were not enough to account for the complex effects of the planets on the air and material beings so Kepler proposed three ways that light and humidification could vary; by excess, moderation or deficiency. Combining these non-physical qualities together in various ways created a wider variety of distinctions, or shades of astrological effects. Kepler wrote:

Therefore we have two faculties – warming and humidification – in any of three degrees – Excess, Mean and Defect. Let us see what diversity may be deduced from this. First the faculties may exist alone: Heat in Excess, Mean or Defect. Humidification in excess, mean or defect. From this we have six distinctions. Then from the combinations of both the faculties we have nine distinctions, as is clear from the table given below. Therefore in all we have fifteen distinctions.[67]

Having argued for a non-material mechanism, that is light, for the transmission of the qualities hot and wet from the Sun, Moon and planets, Kepler went further and proposed another non-material astrological factor based on what he thought was the most important component of the astrological toolbox, the aspects. The angular separations of the planets were the core of his reformed astrology as they established Pythagorean/Platonic geometric ratios like those of musical tones. In traditional astrology, the aspects are the harmonics produced by the numbers 1, 2, 3, 4, and 6 divided into 360 degrees, which correlate to the conjunction, opposition, trine, square and sextile. To this traditional list Kepler added the 5th and the 8th harmonics and he experimented with others as well.[68]

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65 Kepler, (2007) 84.
66 Kepler, (2007) 85-86. Galileo's telecopic observations of Venus in 1613, revealing its phases, caused Kepler to change his mind in regard to radiation emanating from the planets.
67 Kepler, (1984) 238.
68 The 5th harmonic series, $^{360}/_{5}$, produces aspects of 72 and 144 degrees. The 8th harmonic series, $^{360}/_{8}$ produces aspects of 45 and 135 degrees. These aspects were adopted by astrologers and are commonly used in the modern period.

Kepler thought that the aspects, which were analogous to musical to ratios of musical tones, made astrology work through resonance. When aspects were exact they produced a non-material tone that could be "heard" by a responder. His unique reform proposal was that astrological effects occurred because of the existence of an animal-like faculty by which the humans can sense occult changes in the sky. In order to explain weather as an astrological phenomena he proposed a fourth type of soul in addition to Aristotle's animal, vegetable, and human souls – the Earth soul (animate faculty). The effects of the astrological aspects are then not caused by the planetary bodies themselves, but by the reactions of individual souls to very specific proportions or harmonies based on numbers. Therefore, the Earth is the true cause of astrology, the planets are only the instruments and the means is through resonance. The individual differences between the planets, Sun and Moon are accounted for by the non-material transmission, via light, of the qualities in varying degrees of intensity.

In the *Harmonics of the World*, Kepler presented his ideas on the animate faculty of the Earth.[69] First he commented on the Platonic doctrine of the world soul and argued that if there is a soul (i.e. non-material living essence) of the universe (which, for Kepler, was the solar system), it probably resides in the Sun. As for the Earth, the effects of astrological aspects on the weather were proof enough for him that it is alive. Kepler's ideas about the living Earth are suggestive of certain key concepts of the Gaia hypothesis. He thought that the soul of the Earth is distributed throughout its sphere, both on the surface and below it. Kepler also suggested that there is no essential difference between minerals and the various life forms on the Earth; they are all part of a continuum. He further believed that the Earth breathes, as evidenced by the tides. Kepler recognized the apparent overall stability of natural phenomena and speculated on the causes of this balance. He considered the fact that the oceans of the Earth never overflow from the continuous inflow of rivers and suggested that this stability was due to the Earth's absorption of sea water in a kind of feeding process. He thought that the evaporation/rain cycle served a balancing function in an organic cosmos, one that was necessary for the nourishment of plants according to season. Kepler thought that the Earth's animate powers actually regulated the minerals, temperature, and water levels of the Earth, and that the Earth could "hear" the astrological aspects and respond to them. These ideas suggest that Kepler was aware of, but unable to express in units, the idea of a self-regulating system. He also wrote that the soul (life

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[69] See Kepler, *The Harmony of the World*, Trans. by E.J. Aiton, A.M. Duncan, and J.V. Field, (1997) Chapter VII, Epilogue on Sublunary Nature and on the Inferior Faculties of the Soul, Especially Those on which Astrology Depends.

force) of the Earth comes from the Sun and that there are no essential differences between living things on Earth.

Kepler approached astrology as a careful scientist in his collection of data (weather records) and testing by correlation with planetary aspects and he never doubted that there was a real, percievible astrological effect. But in his rejection of other components of traditional astrology he was almost alone among his astrological contemporaries and he also had doubts about the subject ever being a science. Kepler complained that astrology was based on personal experience, it was complicated, abused by malpractice and misunderstood by the public.[70] He compared astrology to medicine, which he says is also based on experience and therefore not an exact science, and it too had its own share of questionable practitioners. In *Third Party Intervening,* Kepler defended almanacs and weather predictions but regarded the activity as annoying, which he eventually quit. One problem, according to Kepler, was a gap between the complexity of the astrologer's work and the common language he had to use to transmit his interpretation to the readers.

And as the common man usually knows nothing of the abstractions of generalities, he perceives only concrete things, and often praises an almanac when it hits the mark, and he scolds the almanac when the weather does not come about as he had anticipated, even though the almanac really had hit the mark in its generality covering many possibilities.[71]

Kepler was expressing frustration with astrology as a practice (almanac writer) because it was hard to quantify and was likely to be misunderstood and criticized. He was also frustrated with the methodologies of astrology and was ready to abandon many traditional astrological notions

and forge ahead into a limited astrology based on a theory of resonance. But he did defend the subject and he attempted a reform, but his impact was minimal.[72] He had very few followers.

1.10 John Goad's *Astro-Meteorologica*

In 1686, one year before the appearance of Newton's *The Mathematical Principles of Natural Philosophy (Principia Mathematica)*, John Goad (1616-1687) published a major work on

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[70] Field, "A Lutheran Astrologer," in *Archive for the History of the Exact Sciences* (1984) 260.
[71] Kepler, (2007*)* Thesis 133, 194.
[72] Beer and Beer, eds., *Kepler, Four Hundred Years,* (1975) 439-448. Morius, a contemporary of Goad and an astrological writer who had a great influence in the field of astrology, rejected Kepler.

astrology entitled *Astro-Meteorologica, or Aphorisms and Discourses on the Bodies Celestial, their Natures and Influences*. In it he compared weather records with the angular separations of the planets, thus establishing himself as one of the very few astrologers who attempted to apply the newly emerging experimental method to his subject. The *Astro-Meteorologica* is a comprehensive work of over 500 pages, many of them samples of his weather log, and it presents many difficulties for the reader not fully versed in the language and concepts of astrology.[73] John Goad was perhaps the only significant follower of Kepler's general astrological reforms. Although he disagreed with him on many points, Goad understood the value in testing astrology. He embraced the empirical method that Bacon advocated and Kepler practiced, he compiled one of the earliest detailed weather diaries, and he published his results. John Goad's *Astro-meteorologica* was probably the most scientific work that focused on astrometeorology, and certainly the most ambitious, to appear during the entire 17th century.

Born in London, John Goad was the headmaster of the Merchant Taylors School, which he had attended himself. In 1680, during the Popish Plot, he was charged with Catholic leanings concealed in the content of some material he had written for the use of his students and was dismissed from his post. Goad's opponent in this affair, a Dr. John Owen, was successful in placing his nephew in Goad's former position. Goad then opened a private school and, in 1686, the year before his death, he declared himself a Roman Catholic. Among Goad's writings are some sermons, a comment on the catechism of the Church of England, a comment on monarchy as a form of government, and a method of teaching students Latin. He had also written a treatise on plagues, but it was destroyed while in press during the Great Fire of London (1666). His major work was the *Astro-Meteorologica* which earned him a great reputation, to the extent that he discussed his findings with Charles II. A version of this work without the weather records titled *Astrometeorlogia Sana* was published in Latin in 1690.[74]

John Goad was a contemporary of numerous contributors to the scientific revolution and he was familiar with the scientific currents of his time. Goad mentioned the Royal Society's call for navigators to make notes of ocean currents and asserted that astrology could help solve such

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73 Goad, *Astro-Meteorologica,* (1686).

74 Smith, *Dictionary of National Biography* (1921-22) 8:18-19, Thorndike (1923), Vol. 8, 347-349, and Thomas, *Religion and the Decline of Magic,* (1971) 327-329.

problems.[75] Elias Ashmole, a founding member of the Royal Society, regularly corresponded and collaborated with him and Joseph Williamson, the president of the Society, was impressed with Goad's research.[76] Goad, who saw himself as a natural philosopher doing scientific research, applied a Baconian method to astrometeorology by collecting data for some thirty years, which were then used to check traditional doctrines. This experimental approach towards astrology led Goad to believe that, for the most part, it conformed to these doctrines and was therefore a valid body of knowledge. Mary Ellen Bowden commented that Goad's work was "the most conscientiously executed research of any work inspired by Bacon in the 17th century."[77]

Goad lived during rapidly changing times socially, politically and intellectually and a curious combination of the old and the new, typical of 17th century science, is found in the *Astro-Meteorologica*. His work was accomplished when the systems of Aristotle and Ptolemy had not yet been completely discarded and he published his work just as the Newtonian synthesis was emerging. Goad's natural philosophy was not unified, as Newton was concurrently doing. He used the four elements to explain how the planets affected the separate sublunary world, and frequently referred to Ptolemy, Pliny and other ancient authorities, though he frequently questioned the need to submit to every tradition in natural science and made it clear that in the end he would let the data speak for itself.

In regard to his astronomical views on the solar system, Goad was also transitional. Copernicanism was still not universally accepted, and in the mid 17th century one alternative was the compromise system of Tycho Brahe. Goad wrote that he leaned towards the Tychonic system (in which Venus and Mercury orbit the Sun which in turn orbits a stationary Earth), but would be willing to believe that the Copernican system was correct. He made the point, however, that a planet's position relative to the Earth would be the same no matter which system was eventually proven to be true.[78] The fact that the true structure of the solar system, and its laws, were of considerably less importance to the astrologer than a planet's exact location in the sky probably accounted in part for the accelerating separation, first intellectually and then socially, of astrologers from astronomers during this period.

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75 Goad, *(1686)* 213. Goad noted that conjunctions of Mars and the Sun seem to affect ocean currents. See also Curry (1989) 69, and Capp (1979) 185 in regard to Royal Society connections.
76 Bowden (1975) 186.
77 Bowden (1975) 187.
78 Goad, (1686) 121, 264.

In the middle of the 17th century critics of astrology were increasing in number and the reform of the subject became more urgent, a fact reflected in the emotionally-charged defenses and apologies for the subject that introduce typical works on astrology published at this time.[79] This attempt at reform, in England, is described by Capp as "a massive undertaking" which ultimately failed as the intellectual status of the subject slowly declined.[80] John Goad was a major figure in this attempt at reform and throughout the *Astro-Meteorologica* he maintained a defensive posture against the critics of astrology. At the same time he displayed considerable confidence that he was not pursuing a lost cause, and he challenged critics to look carefully at his data and to continue to follow his findings for another twenty five or thirty years.[81] Goad remarked that his critics, who want nothing less than exact effects, do not study nature closely enough and consequently will be disappointed and will likely reject his work. He pointed out that his conclusions about the various planetary combinations are not meant to be a total explanation of natural phenomena, but they reveal a natural predisposition in nature. In other words, the principles of astrometeorology cannot be reduced to absolute laws that will work consistently, but rather patterns can be perceived when one examines the data over long periods of time.[82] Still, Goad believed astrology could be upgraded and remarked "how suddenly the celestial knowledge would be advanced, if our ancestors' defect herin could be made up by some private re-search, or voluntary contribution."[83] Apparently not many dedicated or affluent persons were concerned about funding astrology in Goad's time, and without resources not much gets done. Why this was so will be discussed in more detail in Section III.

At a time when Aristotle was being abandoned by those who are now regarded as the founders of modern science, Goad used Aristotelian explanations for meteorological phenomena. He thought all planetary effects were ultimately reducible to the interaction of heat and moisture (leading to the four categories hot, cold, dry and wet), the Sun being the principal warming agent. But unlike Ptolemy, who presented the planets as capable of producing varying proportions of heat and

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79 For example, see the introductions to Lilly, (1644) and Wilsford, *Nature's Secrets*, (1642).
80 See Capp (1979) 180-190 for an excellent discussion on how astrologers and natural philosophers interacted during this time and how astrology contributed much in regard to educating the public about the new scientific discoveries.
81 Goad, (1686) 63.
82 The weather is a system and reducing it to parts and getting results acceptable to a linear, mechanical science is the problem here. This problem is not unlike that of the naturalist studying organisms in nature, though the influence of the planets appears to have been a far slippery subject to observe, sketch and dissect.
83 Goad, (1686) 491.

moisture according to their nature, Goad argued that the Sun, Moon and planets only transmit varying amounts of heat via light and that moisture is an effect that is pulled from the Earth.

...we say that though there be two Contrarities to be inquired into, first of Hot and Cold, then of Moist and Dry, Ours will be but only after the First Contrariety, in as much as the Second is an Affix, an Appendage to the First. Because it will be very easy to say, from what has been said before, that every Planet as it partakes of Warmth, is thereby apt to produce Moisture; whence the Sun itself being Hot must also be defined as to be moist: for though the Sun dryeth up the Moisture, yet the same Warmth first attracted the Vapor, and the Vapor so attracted, with a little help from the Contrary Quality (of which we have said we cannot always be sensible) condenth it into a Drop: for the Sun and Moon are Moist only by an extrinsic Denominaton, as much as they contribute to the attraction of it.[84]

Goad argued that Moon and planets carried heat via reflected light and that this light altered the air by warming, a lot, in the case of the Sun, which is the original source of light, or very little in the case of Saturn. He viewed the Earth's atmosphere as a "terrestrial spirit, regulated according to its vicissitudes, from the modification of the light celestial."[85] This explanation of planetary effect on the Earth differed in one sense to Kepler's notion of the living Earth where its inhabitants were responders to cosmic harmonies. For Kepler, the angular separations of the planets produced a measurable but non-physical harmonic resonance which could be "heard" by the living Earth which has a pronounced reaction to certain proportions or harmonics which were produced when the light rays of the planets were at specific angular separations.[86]

Goad attributed the cause of meteorological phenomena to the "alteration of the air" by warming which in turn, he said, is caused by the angular relationships of the planets relative to the Earth and the blending of the converging light rays. The wind, according to Goad, changes or shifts according to this alteration of air, and he noted that the divinatory powers of animals in regard to the weather is not miraculous in the least; these animals are simply sensitive to the alterations of the air, which leads back to the planets.[87] This explanation does not differ much from that of Ptolemy who associated the angular separations of the planets with "variations of quality in our ambient."[88]

[84] Ibid., 27-28.
[85] Ibid., 40.
[86] Kepler, *Concerning the More Certain Fundamentals of Astrology*, (1987) 14-17.
[87] Goad, (1686) 3, 11, 23.
[88] Ptolemy, (1940) 45.

For Goad, as for Ptolemy, the principal cause of the weather was the Sun. Second in importance is the soli-lunar cycle, but these two factors in themselves are not enough to explain the great variations in the weather. If it were, Goad pointed out, the weather patterns would be completely predictable over the 19-year Metonic cycle.[89] The other planets, Mercury, Venus, Mars, Jupiter and Saturn are then necessary to explain the phenomena more fully. Though Goad's basic principles of astrometeorology represented a continuation of those of Aristotle and Ptolemy, there were certain differences that emerged from his Baconian approach to the subject. He found that his own observations were generally in agreement with the classical principles set out in the *Tetrabiblos*, with the exception of the effects of Jupiter. Ptolemy regarded that planet as a producer of heat and humidity, but Goad found it to be cool and dry.[90] Goad believed that his findings, resulting from an analysis of many observations, represented a correction of previous defects, or at least an effect consistent with the climate of England, as opposed to Ptolemy's Egypt.[91]

Methodologically, Goad's work also reflects the transitional period in science through which he lived, a time when instrumentation was just being invented and developed. In addition to his own qualitative diaries, Goad used other non-instrumental data, including weather records made by John Dee and those from Kepler's nine year diary of the weather in Linz and Ulm (1621-1629), to confirm some of his findings. He did observe some thermometer readings and barometric fluctuations, which he compiled around the time that these inventions were in developmental stages, but these do not appear in his published weather diary.[92] He apparently owned some instruments, but he only recorded the temperature when it was out of the ordinary, and he also regretted that he did not use a horizontal plate with a compass for measuring the wind direction exactly. His methodology on which he based his results was then completely descriptive, and in spite of his consistency in making weather records, all of it was subject to his own judgment. Compare this with a suggested method for making a record of the weather written by his younger contemporary Robert Hooke (1653-1703) who advocated the use of three existing primitive measuring devices: the thermometer, the baroscope and the hygroscope. Hooke, while critical of astrology had astrologers as friends and visited Goad, advocated recording the longitude of the

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89 The Metonic cycle brings the lunar month into correlation with the solar year. 235 lunar months equals 19 years less 2 hours.

90 Digges, (1555) states that the Sun and Jupiter produce moist vehement winds.

91 Goad, (1686) 29.

92 The barometer was invented by Toricelli in 1643. The thermometer underwent development for centuries, but attained something like the modern form by the middle of the 17th century.

Sun and Moon and their phase angle or angular separation alongside the weather data for each day. It has been suggested, due to Hooke's associations with astrologers such as Goad and Childrey who were concerned with making scientific weather records a decade earlier, that Hooke borrowed some of their ideas.[93]

Like Kepler, Goad did not accept the astrological methodology of Ptolemy and Arab astrologers of making weather predictions based on the planetary configurations occurring at the time of the new or full Moon immediately preceding the entrance of the Sun into the solsticial or equinoctial signs. Kepler pointed out that this approach is subject to gross inaccuracies due to the difficulty of timing the exact moment of a Sun-Moon alignment, or the passage of the Sun through a solstice point or equinox.[94] Both Goad and Kepler were critical of these ingress horoscopes and choose to work only with planetary configurations, rather than from the uncertainties of an astrological chart calculated from faulty tables. This is perhaps the most significant feature of Goad's astrology, his de-emphasis of the zodiacal sign positions of the planets and luminaries and his emphasis on their angular separation, which makes astrology into an analysis of vectors converging on the Earth. In this regard Goad was a follower of Kepler.[95]

In the *Astro-Meteorologica* weather records are correlated with the traditional angular separations between the planets (Ptolemaic aspects are 0, 60, 90, 120, and 180 degrees) and in some cases with those aspects added by Kepler (30, 36, 72, 150, and others). Each combination of planets is treated separately. Goad was pragmatic about the effects of the aspects, and wrote that they were not founded on harmonic proportions but followed physical and optical principles. He rejected some of those advocated by Kepler, which he called pseudo-aspects, and mentioned that other astrologers were "sick of them" as they increased the already abundant daily lunar aspects. Ultimately he rejected all but two of Kepler's additions, 30 and 150 degrees, based on the 12th harmonic, which he claimed his observations confirmed.[96] In publishing his data, however, Goad utilized only the traditional Ptolemaic aspects, calculated to the date of exactness. These partile

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93 See Sprat, (1667) 173-179; Thomas, (1971) 351-352, Capp (1979) 189-190, and Curry (1989) 68. See also Vaughan, *Earth Cycles*, (2002) 60-61, who points out that Hooke's methodology did not specify taking weather records at regular interval, but instead advocated taking readings on when changes occurred – exactly what Goad and Childrey were doing a decade before Hooke's ideas were presented to the Royal Society. Goad began his weather diary in 1652, a year before Hooke was born.
94 Kepler, (1942) 14-17.
95 To my knowledge, no other writers on astrology in the mid 17th century appeared to be following Kepler's lead in regard to reforming astrology by basing the system almost entirely on aspects.
96 Goad, (1686) 39-40, 61.

(exact) aspects, were the points in time against which the weather was tracked. Further, his methodology involved tracking the weather before and after an aspect forms, the stretch room called the "orb of influence" in astrology.

Confining therefore the conjunction, and with that the rest of the configuration to the same sign and degree, and allowing the Acme of the aspect to take place the precise Astronomical Time, with proportional allowance of vigor or abatement, according to the scruples of access and recess; yet it is true that the physical influence of an aspect, exerts itself before and after, i.e. as long as the Heavenly Movables keep within the terms of the definition.[97]

The *Astro-Meteorolgica* systematically considers the angular separations of the various planetary combinations in the order of their frequency of occurrence, beginning with the Sun and Moon and ending with Jupiter and Saturn. In Book I, after a lengthy introduction covering his basic principles, Goad examined the various Sun-Moon aspects. Beginning with the conjunction (new Moon), he analyzed its correlations with the weather over a seven year period of 87 conjunctions. He next considered the opposition between the Sun and Moon (full Moon). Next come the quarters (90 degrees), the trines (120 degrees) and the sextiles (60 degrees). Goad sought to examine the frequencies of various kinds of weather patterns occurring during the range of time that he thought each aspect was effective. If there was a correlation between aspect and weather pattern more than half the time, Goad maintained that the influence of the aspect was demonstrated. This was as far towards statistics, which wasn't a developed branch of mathematics at the time, as Goad ventured.

A closer look at Goad's Sun-Moon data will better serve to illustrate his methodology. He treated each aspect as a separate study and included the relevant portions of his weather diary alongside his discussion. In the case of the Sun-Moon conjunctions (new Moon), this was an account of seven consecutive years (1671-1677) of 87 conjunctions. Conjunctions during this seven year period that occurred during a particular month were listed for that month, necessitating twelve monthly tables. Using a range of three days (from midnight to midnight) for the aspect, the weather conditions in London during that designated period were recorded, often to the hour, for a total of 251 days. The resulting data are qualitative; he used a descriptive vocabulary of the variety of meteorological phenomena to specify the type of weather at that time (windy, dashing rains, frosty nights, etc.). The direction and nature of the winds, notes on the temperature, and the

97 Ibid., 41.

exact time of any weather change, or as Goad understood it, the effect of the aspect, were also noted. The results were then tallied in the following list of 87 Sun-Moon Conjunctions.[98]

Cold frost nights – 63
Clouds pregnant – 72
Fog or grosser mist – 2
Fila – 2
Frosty days – 34
Hail – 4
Halo – 0
Hot days – 28
Nights – 8
Lightning nocturnal – 2
Mist – 47
Northeast – 30
Northwest – 31
Rain moderate – 109
Violent – 28

Serene, Fair – 31
Trajections – 19
Thunders – 3
Warm – 31
Wind – 101
Wind change – 29
Wind tempestuous – 37
North wind – 40
East -45
West – 44
South – 18
Southeast – 16
Southwest – 58
Northeast – 36
Northwest – 12

The analysis of these results in the *Astro-Meteorologica* is thorough. First, Goad defended his Baconian methodology in a number of ways. He pointed to the care in recording the hour of meteorological events, but also the value of extending the observation period for the conjunction to three days to capture weather trends that were indicated by the aspect but did not appear when it was partile. He also took care to record weather events relative to the season, that is cold in summer would be warmth in winter. Goad directed some words toward critics of astrology, who wondered how and why each planet has its peculiar properties, arguing that his data was a solid foundation on which the true astrological nature of a planet could be determined. Most of his defensive comments, however, are directed toward astrologers who might not accept some of Goad's findings as they contradict, in a few places, traditional notions of planetary influence. And he was not above criticizing Kepler for discounting the influence of the new Moon, even referring to Kepler's own weather diary from 1621-1629 to prove that his finding were confirmed in Kepler's own records.[99] Everywhere Goad shows a commitment to the data he produced and delight in his discoveries, most of which support traditional astrological notions, with some minor exceptions already noted.

[98] Goad, (1686) 54.
[99] Goad, (1686) 62.

The full Moon investigation was presented next and Goad's records show that some form of moisture was recorded in his weather log on 75 of the 87 aspect events during the same seven-year period. After a lengthy analysis of the findings and a comparison to the new Moon record, Goad moves on to the squares (for which he also presents medical data in a separate table), the trines, and finally, the sextiles.

At the conclusion of his study of the five Sun-Moon aspects, Goad summarized his findings in a table. Each type of weather condition is listed in a vertical column on the left and the number of days that each kind of weather had occurred at the time of each aspect is noted horizontally at the top.[100] The weather record suggested that there were more wet days at the full Moon than at the new Moon and that the second half of the Sun-Moon cycle, or the later trine, square and sextile, were generally warmer than the first half. Goad suggested that this was possibly due to the fact that the Moon rises before the Sun in these positions and adds warmth to the air.[101] Goad observed that it rained consistently on the full Moons falling in April and August, and that the actual meteorological events occurred much closer to the time of the exact opposition (within four hours) than was the case with the conjunction. A further observation concerning moisture was in response to the high figures for the first sextile (60 degrees after the new Moon) and the second trine (60 degrees after the full Moon). This result, more rain about five days after the new and full Moon, surprised him; he had expected that the traditionally more powerful aspects, the conjunction and the opposition, would account for the most moisture.

Goad's observation of rainfall peaks five days after new and full Moons was confirmed to some extent by a study done in the 1960's, published in *Science*. Donald A. Bradley and Max A. Woodbury examined precipitation data over the continental United States for a 50-year period (1900-1949) and found that maximum precipitation events over broad areas appears to be related to the Sun-Moon cycle. The study was duplicated in a New Zealand weather record. Both studies show above average precipitation just after the new and full Moons at points very close to Goad's first sextile and second trine.[102]

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[100] Goad, (1686) 115.

[101] A recent study published in *Science* actually found a slight global warming occurring around the full Moon. See Balling and Cerveny, "Influence of Lunar Phase on Daily Global Temperatures," *Science* (1995) 1481-1482.

[102] Bradley and Woodbury, "Lunar Synodical Period and Widespread Precipitation," *Science,* (1962) 137:748-750. Bradley (1925-1974), an engineer, was also a technical astrologer who published in astrology journals under the name Garth Allen. He was a strong advocate for the sidereal zodiac and the use of precession-corrected return charts used in forecasting. He also published a statistical study of birthdates and professions and is know for the Bradley Model of stock market forecasting.

Book II of the *Astro-Meteorologica* analyzed the aspects of the inferior planets, Mercury and Venus, to the Sun and the other planets. Each planetary pair has its own chapter which begins with an overview of the traditional interpretations along with frequent references to the opinions of Kepler, Cardano and others. A discussion of Goad's findings follows along with his weather records, which unlike the lunar tables, cover a wider range of years. His Sun-Mercury study (1668-1680), in addition to correlations with the usual weather events, are also linked to earthquakes, thunder and lightning. Goad's range of weather observations for the Sun and Mercury were dependent on Mercury's daily motion at the time of the conjunction, this varying from three days at inferior conjunction (Sun-Mercury-Earth) to five days at superior conjunction (Mercury-Sun-Earth). His observations suggested that Mercury was a rainy planet, though the ancients considered it windy, and wrote that since he is confined to London, he cannot speak confidently for its influence in other climates. To further examine this possible contradiction, Goad introduced some nautical observations from a voyage to the East Indies, the ship's captain having been a friend of his. This additional data did not prove to Goad's satisfaction that Mercury was a windy planet, and he was inclined to think the bulk of evidence supported his correlation of the Sun-Mercury conjunction with rain.

While on the subject of Mercury's influence, Goad clearly articulated his most basic position regarding planetary influence on the weather. He noted that, while a few planetary pairs in aspect tended to show very high correlations with a certain type of weather, in most cases the weather was conditioned by several planetary patterns. In examining each aspect pair separately, Goad's only recourse was to try to narrow the range of days around the partile (mathematically exact) aspect in hopes of catching a glimpse of its purest meteorological manifestation, but that was not always successful. In some cases, particularly with the Sun and Saturn, Goad found the effects to be strongest when the planets were separated by several degrees. He clearly realized that this situation, the impossibility of finding a consistent effect for each single aspect, was not likely to convert many investigators of nature. What Goad is saying here is that he is dealing with a system that cannot be reduced to a single aspect. In his own words:

We have said, we make no one aspect an adequate cause of the effect; only Eminent and Considerable; which much be assisted with its neighbors: We have other aspects which put in for their share of the business; we shall see them in the following chapters, and surfeit on them.

There is scarce conjunction or opposition, yea, sometimes trine or square, but steps in to help at a dead lift.[103]

With the Sun-Venus conjunctions (records from 1655 to 1681), those with Venus in retrograde motion (inferior conjunction) are separated from those which occurred when they were in direct motion (superior conjunction). In this section, Goad referred to Kepler's diary for further data and noted that when the aspect occurred in a "state of destitution," that is not involved with other planets, cool, clear air was produced. If the aspect was "assisted" by others, that is if other aspects were forming at the same time either to the Sun-Venus conjunction or separately, the trend was towards warmth, clouds, and rain. He also suggested that since Venus was closer to the Earth when retrograde its influence might be more potent when in that position. Goad's records showed an extremely high correlation between conjunctions of Venus and Mercury with rains and storms. Again, a foreign diary is produced to support what he insisted was an obvious positive correlation.

Goad's findings in Book II are generally non-specific with the exception of the Mercury-Venus conjunctions. Mars was found to be associated with varied effects, though it tended toward storms and tempests when with Venus and towards dryness when with Mercury. Goad pointed out that because the Sun, Mercury and Venus can never be too distant from each other, there tended to be a mingling of their respective influences making an exact analysis of their pure influences nearly impossible.[104] But being as that were, he found that Saturn produced cold when roughly in aspect to the Sun but did the same when in exact aspect to Venus. Jupiter was found to be cold in some positions and appeared to be associated with drought. As to the satellites of Jupiter, Goad speculated that they do not influence our weather but perhaps they affect Jupiter itself. He observed that the zodiacal sign positions of Venus, when in aspect to another planet, had some bearing on its "effect" but that he "must believe his eyes" and notice that his results fly in the face of traditional astrological assumptions about zodiacal influence.

In Book III, Goad examined the aspects between the three superior planets, Mars, Jupiter and Saturn. Saturn and Mars were observed to show a correlation with storms and thunders in both his diary and those of foreign records. He noted that when Mars and Saturn were separated by

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103 Goad, (1686) 147.

104 Recall that a century earlier John Dee gave 25,335 as the number of possible combinations produced by the various combinations of aspects.

exactly thirty degrees – Kepler's semisextile – there was usually a violent effect. Goad pointed out that with these slower moving planets, three or four days for effect meant nothing, they defined longer periods of time, even months. Jupiter and Mars brought "monstrous frosts" and, when in opposition and with assistance from other planets, thunder and lightning. The longest cycle of the visible planets is the Jupiter-Saturn cycle of twenty years to which Goad devoted many words. One observation he made with some confidence was that drought commonly occurred when these planets were in conjunction and that nearly half the time they "produced" comets.

Throughout Books II and III Goad developed his basic principles, which were not rigid, from his observations. He generally hesitated to make fixed definitions for the effects of an aspect, but he specified the direction it appeared to incline toward, at least in the climate of London. He also clearly pointed out that planetary aspects associated with a certain kind of meteorological phenomenon in London during the summer, for example, would have a similar but modified effect in other seasons and climates.[105] If rain is more likely to fall during a particular climate's rainy season, then he would expect a higher probability of rain to concur with a planetary aspect associated with precipitation or moisture during that season rather than during a dry season. If it does not normally rain in a certain month at a certain locality, Goad would maintain that the moisture-producing aspects occurring during that month would indicate a possible increase in moisture at that time, perhaps in the form of humidity.

Goad was of the opinion that astrometeorology was ultimately interpretive in the sense that only rarely was the pure effect of an aspect felt, more often the blending of several was the rule. Further, the aspects often did not have to be mathematically exact at the time of the observed meteorological effect. He noted that in stormy weather the distances between several planets was frequently close to 10 degrees which is well over the standard orb for most aspects.[106] He observed that snow often fell three to ten days after an exact conjunction of the Sun and Saturn. Overall, Goad was making a case for an interpretive astrometeorology which accepted less than exact angular separations between planets, but yet within a few degrees of their exact focus which he referred to as "platic distance." But this was still a traditional tenet of astrology which had

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105 Goad, (1686) 63.
106 The 11.25 degree aspect, one quarter of the square of 90 degrees, is used by some modern astrological researchers and regarded as a significant angular separation.

doctrines of planetary orbs or effective distances. In sharp contrast to this was Kepler who stressed that only partile aspects could produce effects, including the case of Jupiter-Saturn conjunctions.[107] In Goad's view, Kepler proposed numerous additional aspects to account for changes in the weather when no traditional aspects were forming in order to save his theory of astrology.

In summary, the evidence Goad gathered indicated that there were few consistent clear-cut effects from any single planetary combination (the Venus-Mercury conjunctions were apparently an exception) because most of the time several planetary combinations were in effect at the same time. Allowing for his "platic distance" made this boundary-blurred situation worse. Kepler's solution of adding more aspects was not supported by Goad's observations and he rejected it, leaving himself with an art and not a science, which is what astrology, as a practice, is. But this is not to say the subject is entirely unscientific; modern meteorologists, seismologists, economists, medical diagnosticians, etc., in making predictions, find themselves working with scientific data which must be reduced and interpreted in much the same way. And they have yet to develop consistently accurate long-term prediction techniques, and they often fail in short term predictions. Dynamical systems are very hard to constrain to the point where predictions are possible.

John Goad's *Astro-Meteorologica* is a remarkable piece of astrological writing both in content and in historical placement. His careful correlation between planetary alignments and observed meteorological events, a Baconian way of dealing with the material he was investigating and the scale of his study, was unique in 17th century astrology. But unlike Kepler working on Tycho's collected astronomical data, Goad had no real units to work with and therefore no way of mathematizing any correlations and thus lacked the kind of proof rapidly becoming fashionable in scientific circles during his time. Goad's weather records only showed somewhat higher frequencies of a particular kind of weather when pairs of planets were in some aspect to each other. Evaluating his observed data in terms of probability and statistics, which appears to be the next logical step from our vantage point in the twentieth century, was impossible – such approaches were not to develop until much later. In his Baconian reform of astrometeorology, Goad had come to a dead end and the reform of astrology had failed. He had applied experimental

107 Goad, (1686) 446.

methodology to a subject which lacked quantitative data and required a more complex scientific evaluation technique than was available in his time. In addition to this, the accumulation of certain kinds of data that he needed, such as long term planetary conjunctions of Jupiter and Saturn which occur only every 20 years, required the work of several lifetimes or some very accurate historical records. Goad was testing a subject that, in the final analysis, does not lend itself to reductionism but was mostly interpretive in nature.

The fact that the *Astro-Meteorologica* was published just one year before Newton's *Principia* is ironic. Kepler's astronomy was a major key to Newton's gravitational theory. Kepler's astrology was a major influence on Goad's astrology. Although Goad disagreed with Kepler on certain points, he was in some ways a follower of Kepler, and it might be said that he was the one who took Kepler's reformed astrology of planetary aspects as far as it could go, given the intellectual climate and procedural limitations of the time. Not until the early twentieth century did Kepler's ideas once again begin to influence astrological theory in the works of the German astrologer Alfred Witte.[108] Goad himself was recognized for his pioneering work by the British astrologer A.J. Pearce (1840-1923), but otherwise appears to have been forgotten by modern astrologers and meteorologists alike.[109]

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108 Alfred Witte (1878-1941), founder of the radical Hamburg school of astrology, utilized some of Kepler's astrological reforms and techniques in creating a highly original method of doing astrology. This school influenced the practice of astrology throughout Europe and the United States during the 20th century and continues to have some influence under the name Uranian astrology.

109 Pearce, *The Text-Book of Astrology,* (1879, 1970).

CHAPTER 2

A SIGNAL FROM SATURN IN DAILY TEMPERATURE DATA

2.1 Astrometeorology: Then and Now

Astrometeorology has not been taken seriously by the scientific community since the late 17th century. The idea of planets affecting the Earth's weather is today regarded as preposterous and any association with the idea, or with those who hold such ideas, could ruin an academic reputation. However, a few scientific studies have confirmed an influence of the Moon on weather. In one case, a finding was consistent, to some extent, with one of John Goad's findings. His weather diary recorded more moisture at the first sextile (60 degrees after the new Moon) and the second trine (60 degrees after the full Moon). This result, basically indicating more rain about five days after the new and full Moon, surprised him; he had expected that the traditionally more powerful aspects, the conjunction and the opposition, would account for the most moisture.

In 1962 a study by Donald A. Bradley and Max A. Woodbury was published in *Science* that examined precipitation data over the continental United States for 50 years (1900-1949).[110] Bradley and Woodbury found that precipitation over broad areas appears to be related to the Sun-Moon cycle. The study utilized US Weather Service records of the dates and places of maximum 24-hour precipitation. When these dates of maximum rainfall were plotted against the lunar synodic cycle the result was a curve with peaks of rainfall occurring near the middle of the first and third weeks of the synodic month. The second and fourth weeks were found to be deficient in heavy precipitation. This study was duplicated in New Zealand with similar results.[111]

Not only does the study by Bradley and Woodbury examine the same phenomena as does Goad in a section of the *Astro-Meteorologica*, but their conclusions 300 years later are similar to his. Both modern studies, United States and New Zealand, show above average precipitation after the new and full Moons, very close to Goad's first sextile and second trine. It should be made clear, however, that Goad's data measures total days (out of 261) on which rain occurred, while the modern study measures record dates of maximum precipitation.

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[110] Bradley and Woodbury, (1962).
[111] *Science* 1962, same issue.

A number of studies indicating a possible lunar effect on thunderstorm frequency, diurnal pressure changes, hurricanes, among other meteorological phenomena, have been published in reputable science journals. One recent study by Balling and Cerveny reports a correlation between lunar phase and lower tropospheric global temperature anomalies. Using daily satellite data they show a temperature modulation between new and full Moons with the later phase being slightly warmer.[112]

No specific mechanism is currently accepted in regard to these correlations between the Moon and weather although most assume they involve lunar atmospheric tides. Several hypotheses have been proposed including the meteoric hypothesis which argues that dust in the plane of the ecliptic, which may serve as cloud condensation nuclei, is modulated by lunar gravity. Lunar distortions of the Earth's magnetic tail have been proposed as a mechanism behind correlations with thunderstorm activity which appears to be more intense at full Moon. Lunar tidal affects on the atmosphere have been suggested as affecting basic circulation patterns, especially subtropical high pressure belts. Another mechanism may involve increased infrared emission from the Moon when it is full.

There are two daily tides that modulate the Earth's atmosphere. The lunar semidiurnal atmospheric tide is equivalent to the lunar ocean tides, except that the Moon is moving the atmosphere. These tides have been difficult to measure. Unlike the oceans, there is no top boundary layer, but data is found in barometric pressure readings at altitude. The amplitude of the lunar diurnal atmospheric tide is small, measured in microbars, and ranges from 10 at about 50 degrees north latitude to greater than 90 at the equator. This difference is accounted for by the gravitational pull of the Moon being stronger at lower latitudes where the plane of the Moon's orbit is at the zenith. In addition to the semidiurnal tide, the atmospheric tides also have larger periods driven by the oscillation of the orbital plane of the Moon and the orbital plane of the Earth's orbit (ecliptic) which is 18.6 years, and also the apogee orbital period of 8.8 years.[113]

The second daily atmospheric tide, the solar daily atmospheric oscillations, are driven by the Sun. These are diurnal thermal tides caused by the heating and expansion of the atmosphere as it passes under the Sun's rays. The effects of this tide are evidenced in wind patterns and, as with

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[112] Balling and Cerveny, "Influence of Lunar Phase on Daily Global Temperatures," *Science,* (1995).
[113] Chapman and Lindzen, *Atmospheric Tides: Thermal and Gravitational*, (1970).

the lunar tides, have a higher amplitude at lower latitudes. Modulation of weather by Moon and Sun have therefore been studied to some extent, and are assumed to have a physical basis that will eventually be worked out in more detail. The influence of planets on the weather is a much longer stretch, and knowledge of their real or imagined effects are embedded in a Renaissance astrological methodology which I will attempt to explain in the following paragraphs.

Annual "farmers" almanacs published in England and New England typically contained weather forecasts based on astrometeorology.[114] For the most part, the methodology used in making almanac weather predictions was originally based on geocentric planetary alignments, i.e. the aspects, though in more recent years other approaches have been used, with mixed results.[115] Aspects are the geocentric angular separations between the planets, Sun and Moon. The aspects described in Ptolemy's book on astrology, the *Tetrabiblios*, are separations in zodiacal longitude of 0, 60, 90, 120 and 180 degrees, these being the conjunction, sextile, square/quadrature, trine and opposition, respectively. In the geometry of the circle the aspects are divisions by whole numbers, 0=360/360, 60=360/6, 90=360/4, 120=360/3, 180=360/2. These aspects are called the Ptolemaic aspects. Kepler and others since his time introduced additional aspects based on divisions of 360 by 5, 7, 12, 16, 24, and 32.

In astrometeorology aspects are described in various ways. First are the different "families" of aspects, i.e. those based on division by 4, 5, 6 etc. Second there is what is called the "orb of influence" which attempts to measure the relative strength of an aspect from maximum to minimum. These are normally given as a range which may vary as to whether the aspect is forming (applying) or dispersing (separating), the former generally considered much stronger than the later.[116] Aspects are also considered stronger if the bodies forming them are at the same latitude or declination, the later consideration bringing in the importance of the equinoxes where declination is zero. Planets equidistant from the equinoxes are more likely to have a similar declination. Joshua Childrey, one of the several 17th century English astrologers that attempted to

[114] The "Old Farmer's Almanac" published out of Dublin, NH has been using a combination of a secret formula presumably based on the exact time of a lunation (full or new Moon) and data based on predicted solar activity. The accuracy of the extended weather forecasts are claimed to be 89% though studies point to rates well below 50%.
[115] See footnote above. A call to the editor's office of the Old Farmer's Almanac inquiring as to how weather forecasts were made elicited an astonishingly hostile response and very little information. From what I could gather they were using averages over 30-year periods for long-range forecasts that incorporated any variations induced by the sunspot cycle for their forecasting section, and the secret formula for the monthly almanac pages – but this is a guess on my part.
[116] Dean, *Recent Advances in Natal Astrology,* (1977) 284.

reform the subject in accordance with experimental science, was critical of the aspects used by astrologers and was an advocate of a heliocentric astrology. He pointed out that only the conjunctions and oppositions with the Sun were alignments that occurred in both a geocentric and heliocentric framework.[117]

The astrological aspects could be thought of as harmonics, which is how Kepler handled them. Division of a cycle by a specific integer determines the number of waves that occur within that cycle length. For example, division by four produces four waves spaced 90 degrees apart. The subject of aspects seen as harmonics, or in the context of Platonism or wave theory, is complex and involves many details that have been discussed elsewhere.[118] For the purposes of this study I wish to limit the definition of aspects to specific angular separations (Ptolemaic and lower harmonics) along the ecliptic (celestial longitude), distance north or south of the ecliptic (celestial latitude) and distance north or south of the equator (declination).

There are many examples in nature where pure geometry forms a basis for certain physical phenomena. Crystal symmetry, where an extension of the geometric arrangement of atoms is modeled by axis geometry, mostly involves angles (or rotations) of 180, 120, 90 and 60 degrees. Another example, this one on a solar system level, are the Lagrange points in planetary orbits. These points locate where the combined gravitational forces of two large masses (the Sun and a planet) balance the centrifugal forces on a smaller mass. There are several Lagrange points spaced at angles of 180 and 90 degrees geocentrically that are used when placing a satellite in a stationary orbit. The stable Trojan asteroids on Jupiter's orbit are located at Lagrange points. Another example of pure geometry in physics is found in television antenna placement relative to a signal where angles of 90 and 45 degrees have special properties.

During the 1950's and 60's, John H. Nelson, a radio engineer working for RCA, perfected a method for forecasting radio wave transmission disturbances by analyzing planetary alignments relative to the Sun.[119] He charted the planets on a 360 degree grid and located dates when planets formed alignments of 360, 180, 120, 90 and other angles to each other. His methodology allowed him to predict solar storms and his forecasts proved to be over 90% accurate. Nelson's

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[117] Childrey, *Indago Astrologica,* (1652).
[118] The geometry of the aspects was seen as validation of Plato's forms by many Renaissance astrologers. See also Dean and Mather, *Recent Advances in Natal Astrology*, (1977) 277-370.
[119] See Nelson, J.H., *Cosmic Patterns*, (1974).

heliocentric planetary alignment maps were so similar to astrological horoscopes, and his interpretive skills comparable to those of practicing astrologers, that for many years Nelson was a welcome speaker at professional astrology conferences. Certain aspects of methodology have not consistently produced results, however, and his work has been criticized by skeptics.

Nelson's findings in regard to heliocentric planetary alignments and disturbances in short wave radio signals include the following: Radio wave disruption occurred when at least 3 or 4 aspects formed within a 24-hour period. Among those formed, conjunctions have a weaker effect (in disturbing radio signals) than do squares or oppositions. Linkages of trines and squares occurring simultaneously are strong, but if these aspects are not linked the effects are weak. Major radio wave disturbances involve planets separated by multiples of 30 and 45 degrees. Distance above or below the plane of the ecliptic does not seem to make much of a difference in the effects of these aspects. Planets near their node (intersection of the planet's orbital plane with that of the Earth's) have increased strength while planets near aphelion decreased strength. All planets, including Pluto, have an effect but the slower planets tend to establish a field which the faster planets then activate.[120]

More recent work done by astronomer Percy Seymour has shown a correlation between peaks of solar activity and the peaks of the combined tidal effects on the Sun that are generated by the Earth, Venus, and Jupiter.[121] In other words, these particular planets can combine to form tides on the Sun, and these tides make the Sun active. He has proposed a theory of magneto-tidal resonance which states that the pull of two or more planets moving together around the Sun will pull the plasma of the Sun (just as the Moon pulls the oceans of the Earth, creating the ocean tides). However, their combined effect can be much greater than the simple sum of their gravitational influence. Like Nelson, Seymour is suggesting that the aspect theory of the ancient astrologers is not incredible at all; it has simply not been measured quantitatively - until recently.

The study presented in this section tests one type of geocentric alignment that has long been used in the astrometeorological tradition. Like the tidal effects on the Sun's chromosphere described by Seymour, any geocentric planetary tidal effects will most likely be seen in the Earth's

120 Dean and Mather, (1977).

121 Seymour, Willmott, and Turner, "Sunspots, Planetary Alignments and Solar Magnetism: A Progress Review," in *Vistas in Astronomy* (1992).

atmosphere. It follows that, like the lunar synodic cycle, the highest tides would be found where there are oppositions (full Moon) or conjunctions (new Moon). When such alignments occur near the equinoxes the tidal bulge produced should be compensated by a lowering of the atmosphere at the polar regions, because the gravitational force at the equinoxes is at right angles to the poles. Therefore, the declination of a body, this being its distance north or south of the celestial equator, should be considered in the study.

2.2 The Sun, Saturn and Cold

In traditional almanacs, the aspects between the planets, Sun and Moon, from an Earth-centered perspective, were associated with meteorological phenomena including heat, cold, rain, winds, storms, etc. One established family of alignments for predicting cold weather are the aspects between the Sun and Saturn. The following are quotes from leading writers on astrometeorology since the Middle Ages in regard to Sun–Saturn alignments:

Gerolamo Cardano (1501-1576) – Whenever Saturn is joined to the Sun the heat is remitted and the cold increased, which alone may be a sufficient testimony of the truth of astrology.[122]

Leonarde Digges (1520-1559) – The conjunction, quadrature, or opposition of Saturn with the Sunne, chiefly in colde signs; snow, dark weather, haile, rayne, thunder and cold days.[123]

Johannes Kepler (1571-1630) – the effect of this [Sun-Saturn] conjunction is quite general and gives nature at least an opportunity to cause turbulence in the air…this purifies the air, brings freezes, snow and rain. [Astrologers] ….observe when Saturn stands opposite the Sun in the summertime, when no other planet is aspecting the Sun, and observe that the weather is cool and rainy.[124]

John Goad (1616-1687) – [Saturn and Sun] produce cold and frost and misty weather, clouds and dark air with snow.[125]

122 Cardan, "The Choicest Aphorisms of the Seven Segments," in *The Astrologer's Guide*. (1970) 88.
123 Digges, (1605).
124 Kepler, (2007) Theses 135 and 45.
125 Goad, (1686) 275.

Thomas Wilsford – Saturn and Sun, in conjunction, square, or opposition do cause generally rain, hail, and cold weather, both before and after, especially in the water signs, or in Sagittarius or Capricorn, and is called Apertio Potarum, or opening the Cataracts of Heaven. Particularly their effects in spring are cold showers; in summer producing much thunder and storms of hail, in autumn rain and cold, in winter snow or moist, dark, and cloudy weather, and oftentimes frost.[126]

Ebenezer Sibly (1752-1799) – Saturn and the Sun in conjunction, quartile, or opposition, is Apertio Potarum, especially if it happens in a moist constellation; for then, in the spring time, it threatens dark and heavy clouds; in summer, hail, thunder, and remission of heat; in autumn, rain and cold; in winter, frost, and cloudy weather.[127]

Alfred John Pearce (1840-1923) – Saturn's action, when configured with the Sun, is to condense aqueous vapour, to lower the temperature of the air, and to excite tempests. When the atmosphere happens to be quiescent under Saturn's ascendancy, it is often dark and foggy. When Saturn crosses the equator, the atmosphere is greatly disturbed and such effects last for several months.[128]

Meteorological phenomena in astrometeorology are not listed in separate categories as much as considered as part of a syndrome expected with the particular aspect. The above statements in regard to Sun and Saturn are not completely consistent, but a common theme of coolness is apparent in phrases such as "cold increased," "remission of heat," and "bitter frost." Below is a table organizing the various descriptive words of the above authors, which shows that all do agree on an association of cold with the Sun-Saturn aspects. Doing reductionist science on a complex system such as the weather presents many problems, the greatest of which is to isolate the variable to be tested. In my study described below, only temperature will be investigated, although I wish to state clearly that this is not the only factor thought by astrometeorologists to be brought about by the Sun and Saturn's geocentric alignments.

126 Wilsford, (1665).
127 Sibley, *An Illustration of the Celestial Science of Astrology,* (1798).
128 Pearce, (1970).

Table 2. Descriptive terms for Sun-Saturn aspects in Astrometeorology

Source	**Cold**	**Frost**	**Snow**	**Hail**	**Rain**	**Thunder**	**Fog**	**Dark Clouds**
Bonatti	x							
Schoener	x	x	x		x	x	x	
Digges	x			x	x	x		x
Kepler	x	x	x		x			
Goad	x	x			x			
Wilsford	x	x	x	x	x	x		x
Sibley	x	x	x	x	x	x		x
Pearce	x						x	x

In times where no instruments were available to quantify weather data meteorologists had to resort to descriptive language. In his book *Tertitus Interveniens*, essentially a discussion and debate between a skeptical doctor, a questioning scientist and an astrologer, Kepler brought his arguments in favor of natural astrology to a climax by presenting a 17-year diary documenting the weather around the time of Sun-Saturn conjunctions.[129] This section appears below in its entirety.

As concerns the aphorism that the conjunction of Saturn and the Sun in Capricorn and Aquarius should cause cold weather -- on which the astrologers rely, and about which Dr. Feselius says that they are stuck in it in a graceless manner -- I want to make a whole philosophical process out of it. First I shall compile the weather data of this conjunction, as far as my observations go.

1592, July 9 (New Style) - I had not yet begun to list data with Cancer. Chytraeus, however, writes that the whole summer, especially around this time, was cold and wintry.

1592, July 24, in the beginning of Leo. There was a myriad of aspects. Sun, Venus, Saturn were in conjunction; Mars in sextile to Jupiter and in addition, Mercury was separating from an opposition to Jupiter and moving to a trine with Mars. The 20th, 21st, and 22nd much rain, hale, changeable. The 23rd cloudy, the 24th there was fog a day or more in a row; overcast, then warm. This [was recorded] in Tuebingen.

1594, August 7th and 8th, there was much rain around Raab; I lost my data for this year.

1595, 21st & 25th of August, at the end of Leo, in Graetz in Steiermark: thunder the whole night, hail stones, one day before and after sultry weather; cloudy.

1596, 4th of September in Virgo; cold rain.

1597, 18th of September. Again a great myriad of aspects. Saturn, Sun and Mercury made three conjunctions, and all three running in square to Mars. Then after several days there came rainy weather on the 13th, very cold air, became cold and overcast the 14th, 15th & 16th, 17th somewhat warmer, often drizzled, the 18th cold rainy air, Sun pale, 19th pleasant, 20th April weather the whole day, etc.

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[129] Kepler, (2007) Thesis 134: 196.

1598, 1st October in Libra. It rained heavily, also the whole week before, then at the same time a conjunction of Mars and Mercury, along with a lengthy sextile of Mars and Venus.

1599, 13th and 14th October in Libra. On the 12th, rain, cold. The 13th overcast, cold. The 14th cold, Sunshine. From that time on the Sun and Moon appeared red through a heavy, smoke-like, low-lying material, in such a way that the high mountain tops protruded from it, as from fog. This became a general condition.

1600, the 24th and 25th of October in the beginning of Scorpio, in Prague. The 24th, rain and Sunshine. The 25th, cold wind, freezing; the freeze lasted almost to the end of the month.

1601, the 5th & 6th of November, conjunction of Saturn, Sun and Mercury, the 1st wintry cold, 2nd strong wind, 3rd & 4th snow, 5th and 6th rain.

1602, the 17th of November at the end of Scorpio. the 16th fog, overcast. 17th fog, cold, then pleasant. 18th wintry cold, pleasant, because of a cold wind.

1603, the 29th of November, in Sagittarius. Then a transit of Sun to Jupiter to Saturn, with Venus present. Until the 27th it was mild; then wind began, on the 28th there was a freeze, from a southeast wind. Afternoon a thaw, the 29th it froze again, wind and rain in the evening, similarly on the 30th.

1604, the 8th and 9th of December; the 7th 8th and 9th cold air, bringing a freeze. At the same time a sextile of Jupiter and Venus, therefore on the 10th and 11th replaced with fog.

1605, the 20th and 21st of December at the end of Sagittarius. The 19th, 20th 21st and 22nd there was cold air, a deep freeze and pleasant weather. Before and after because of aspects of Mercury it became mild and wet.

1606, end of December and beginning of January 1607, in the beginning of Capricorn a conjunction of Saturn and Sun, also in sextile with Mars. The 30th and 31st of December heavy rain. On January 1st and 2nd, snow and rain heavy.

1608, the 12th of January an even greater myriad of aspects, then Saturn, Sun and Mercury running in sextile with Mars. On the 11th it began to thaw after a long cold period, hail, west wind, on the 12th and 13th snow flurries and strong west wind blew down walls.

1609, 22nd and 23rd of January in the beginning of Aquarius. Before it was a trine of Jupiter and Mercury, after it a semisextile of Saturn and Venus. The 19th rain, the 20th overcast and colder, the 21st frozen and snow, the 22nd snow and cold, the 23rd cold air and pleasant, the 24th change to rain.[130]

While Kepler used this data as evidence of astrology for the doctor he was arguing with, he also speculated on why there is such an effect. He thought the conjunction actually causes atmospheric turbulence through a kind of warming, which purifies the air in winter, bringing freezes and snow

[130] With permission from the translator, Ken Negus.

made from existing moisture, and in summer brings rains. He then chastised the astrologers for relying on traditional zodiacal rulerships as the basis of their theories, which he regarded as fiction and stated flatly that no single aspect rules alone over the weather. Kepler was here warning the astrologers against their own form of reductionism in regard to astrometeorological principles.

A half century later John Goad presented sections of his weather diary in his book *The Astrometeorologica* in order to illustrate the effects of the individual planetary aspects. For the Sun and Saturn he lists data only for the conjunctions, which occur once a year, though he reports on the other major aspects. His diary listed the day of the month followed by a qualitative description of the weather; the portion published for the Sun-Saturn conjunction begins 9 days before and ends 14 days after the event. Here below is his daily record for the Sun-Saturn conjunction of October 25th, 1660, (in bold) which runs from October 16 to November 8.[131]

16. Close m. p. coasting showr some places S.W.
17. Rain a.l. fiar, somet, overcast. Nly.
18. Fair, some clouds. N.W.
19. Fair, fr. Overc. 10m Nly. Mist below. N.W.
20. Fr. Fog N W, at 0.E. clear p.m. N. E.
21. Frost, black thick clouds in S. Sun occ., clear and fair. E.N.
22. Frost, clear, some wind. N.E.
23. Cloudy, windy, Nly, fiar 9 m. N.
24. Fr. Fair, windy. S.W.
25. Fr. Cold, windy, cloudy; frequent clouds in S.SW. NE.
26. Fr. Clouds curdled, close day. W.
27. Dry, cold wdy, Hail and R. 1 p. a shower 3 p.
28. Rain after mids. Cloudy.
29. Fr. Curdled clouds. N.
30. Fr. Fair; Venus seen half an hour after Sun.
31. Fr. Mist belwo, aboutr Horizon; some rain, close and most even. W.
1. Close, cloudy, windy, dry yet threatening. W.
2. Fr. Venus seen half an hour after Sun rising. N.W.
3. Mist, some clouds even incling to moisture. S.W.
4. Close and cloudy. W.
5. Fog below, fleecy clouds. S.W.
6. Fair, windy. N.
7. Open, windy, storm of rain 11 m. S.E.
8. Fr. And fair; freeze hard at n. W.

131 Goad, (1686) 277.

I present these two diaries as examples of early attempts to constrain the alleged affects of planets on the weather. In the next section, I attempt to do the same thing, essentially a correlation analysis, but this time using instrumental data and focusing on a single element among the several that comprise the traditional astrometeorological description of the Sun-Saturn aspects.

2.3 Testing Sun-Saturn Aspects: Harvard Forest, Central Massachusetts

Hypothesis: There is a correlation, shown in daily temperature records, between cooling trends in specific regions and the geocentric alignments of the Sun and the planet Saturn.

If the planet Saturn has an influence on the Earth's atmosphere, previous studies of lunar cycle modulation of rainfall and temperature suggest that it is most likely to be a tidal effect. I have already noted that the planets (including Saturn) are capable of raising tides in the Sun's atmosphere and, when in certain alignments, can pull the Sun in excess of one solar diameter away from the center of mass of the solar system. Assuming Saturn can have a similar gravitational effect on the Earth's atmosphere, any possible tidal effects from Saturn should be apparent in the dataset when (1) Saturn is in opposition or conjunction with the Sun (a straight line), (2) when it is nearest to the Earth in its orbit (opposition), (3) when it is at perigee, (4) when it is at 90 degrees to the poles (at low declinations near the equinoxes), and (5) when an alignment includes the Moon or other planets in addition to the Sun and Saturn. Failure to find correlations between these and cold temperatures will nullify the hypothesis.

Materials: A daily time-series from the Shaler Meteorological Station at Harvard Forest, Petersham, MA, containing daily data from 1964 to 2002 was initially utilized in this study.[132] The database was downloaded from the Harvard Forest website and sorted for use in both Excel and Open Office Calculate and then transferred to Minitab and Kaleidagraph software for graphing. The time-series contains the daily minimum, maximum, and mean temperature, and the precipitation for each day of the 39-year period. The time-series is not complete, 3.47% of the daily data is missing. In preparing a listing of anomalies from the mean I replaced these missing data with estimates based on the daily temperature recordings before and after, or the mean.[133] I

[132] Boose E, Gould E. 1999. Shaler Meteorological Station (1964-2002). Harvard Forest Data Archive: HF000.

[133] Single missing dates were replaced with the mean of the prior and following dates. Two to five consecutive missing dates were replaced with a graduated mean based on the temperatures on the date prior to the missing section and the

do not believe that the missing data has contributed to any distortions in my study. Ephemeris data for planetary alignments was calculated using *Solarfire 5.1* software in addition to data compiled in the *American Ephemeris for the 20th Century* and 2001-2010.[134]

Methods: The exact date of each Ptolemaic aspect and the parallel, beginning with the conjunction, is taken as the midpoint of a 21-day sample of daily mean temperatures (Tavg). The daily mean of all the 21-day samples centered on the Sun-Saturn aspect for the 39-year period is then calculated. This "test " is done for the conjunction, opposition, trine, square and sextile aspects, listed in order of the synodic cycle of the Sun and Saturn. The 21-day records of Sun-Saturn aspects are also examined according to Saturn's location relative to the equinoxes for any amplification or diminishing of the alleged cooling effects. Attention is given to temperature patterns on or very close to day 0, the exact (*partile*) Sun-Saturn aspect. Also of interest is the amplitude in temperature, the range within which the temperature changes. Finally, it will be kept in mind that a long-standing tradition distinguishes aspects that are forming (applying) from those that are separating, the former considered more acute and precipitous with results that occur before the aspect becomes exact.

Establishing Significance: The high variance and consequent "noise" in the dataset, and in the results of each test, presents some problems in assessing and evaluating results. Three ways of handling significance are used in this study. First, the standard deviation from the mean of anomalies from the dataset is calculated. This figure is then added or subtracted from the mean to mark the ~68% confidence level. Twice the standard deviation added or subtracted from the mean marks the ~95% confidence level. The standard deviation for the Shaler dataset is 4.38 degrees, therefore any departure from the mean of over 8.76 degrees would be considered statistically significant. This method can also be used to measure the significance of a temperature departure from any point in the sample.

Second, significance is found in correlations that are consistent with possible tidal factors. Results that show a temperature low on or within a day of the exact (partile) alignment, when

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date following the missing section. More than five consecutive dates were replaced with the figures of the 39-year mean. This approach has been followed in all other datasets used in this study. I have been told that a revised Shaler database, with estimates based on nearby stations, will soon be available.

134 *Solarfire 5.1* software from Astrolabe Software, Brewster, MA. See also Michelsen, *The American Ephemeris for the 20th Century,* (1980, 1997).

tidal effects would be strongest (see above), are considered at least suggestive of an effect, especially if similar results are also found in more highly focused tests and in other datasets.

Third, significance is established by contrast with controls. Several controls were used in the studies using randomly generated dates, dates equidistant from the test dates, and studies of alignments involving planets other than Saturn. Controls replicating test results would have falsifying power, controls presenting no consistent pattern would strengthen any consistencies found in test results.

Test 1. Ptolemaic aspects: I began by testing the Ptolemaic Sun-Earth-Saturn alignments used in traditional almanac weather forecasting in the manner established by Kepler and Goad over the course of the Sun-Saturn synodic cycle. A synodic cycle is one in which two bodies are moving relative to each other, the best know example being the lunar synodic cycle of new Moon, first quarter, full Moon and third quarter. The rate of the Sun's motion, geocentrically, is 59'8" or 0.9855 degrees per day. Saturn's motion varies widely due to retrogradation and this makes every synodic cycle different - the aspects will not occur at fixed intervals. However, Saturn's average forward daily motion in longitude is 0.0335 degrees per day - roughly a degree a month or 2 minutes of arc a day. It therefore takes the Sun extra time, and extra distance, to catch up with Saturn in order to make the various aspects as the 378-day average synodic cycle unfolds. Since the synodic cycle of Sun and Saturn is longer than the solar year, conjunctions and the other aspects move roughly two weeks ahead each year making a complete cycle in about 29 years, which is the figure for Saturn’s orbit around the Sun. In a 39-year dataset, there will be 38 of each type of aspect.

Here the conjunction, opposition, trine, square, and sextile are investigated by harmonic (360 divided by integers) beginning with the conjunction (0) followed by the opposition (2), the trine (3), the square (4) and the sextile (6). There are 38 data points for each of the 21-days in a sample. Graphs produced by the data appear below as Figures 1.a-h.

Figures 1.a-h. Shaler Temperatures 1964-2002 in the Sun-Saturn Synodic Cycle.

Figure 1.a

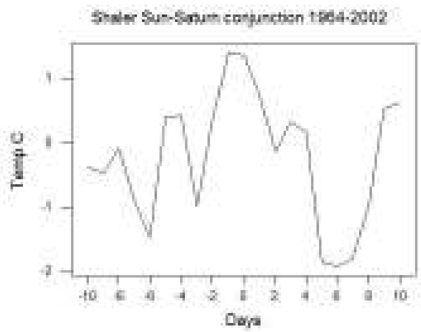


Figure 1.b

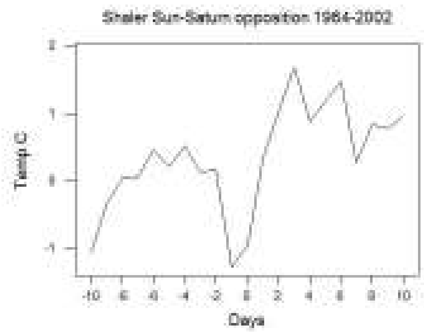


Figure 1.c

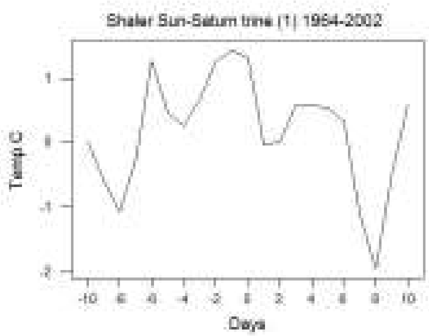


Figure 1.d

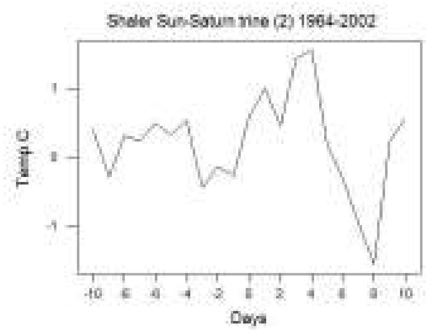


Figure 1.e

Figure 1.f

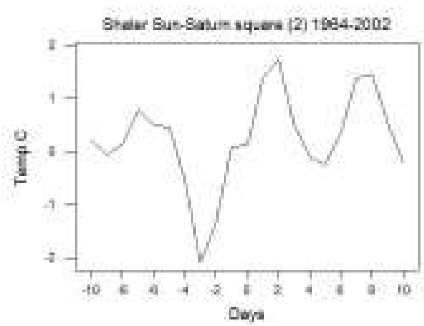


Figure 1.g

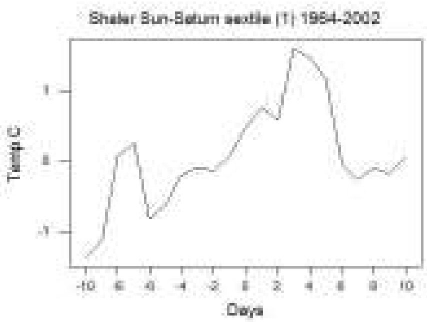
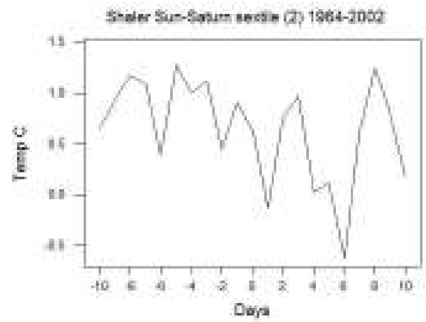


Figure 1.h



Conjunction (Figure 1.a): The Sun-Saturn conjunction, from a geocentric perspective, places Saturn behind the Sun. The alignment is Earth-Sun-Saturn. This is the aspect that Kepler recorded for 17 years and published, and one that Goad published his data for in *The Astro-Meteorlogica*. Goad reported weather on or near the Sun-Saturn conjunction to be cold, dark, or cloudy most of the time, but of course in central Europe and England, respectively. Kepler, while acknowledging that there often was cold, thought it was a warming aspect that disturbed the atmosphere.[135] Here I am testing only for temperature in Central Massachusetts, results from England and central Europe are presented in later sections of this study. The graph for the conjunction below shows a relatively high amplitude in temperature, a range of about 3 degrees during the 21-day sample, and an increase in temperature peaking at the time of the conjunction and dropping by over 3 degrees six days later.

Opposition (Figure 1.b): Note that the Sun-Saturn opposition occurs when Saturn is closest to the Earth, about 190 days after conjunction. The alignment is Saturn-Earth-Sun. Goad thought that the opposition was colder than the conjunction, but he didn't show his data.[136] The sample begins with a low at day -10, rises then falls to a low at day -1 remaining low on day 0. Between day 0 and day +3 the temperature rises nearly 3 degrees. A similar test of the opposition for daily minimum temperatures (not shown) indicated an amplitude about 24% greater than that of the daily mean temperature. Of the above eight phases of the Sun-Saturn synodic cycle, the opposition data appears to show a more marked correlation to the date of the partile aspect. This has some significance for the hypothesis in regard to astronomical distance.

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135 Kepler, (2007) 200.
136 Goad, (1686) 285.

Trine 1 (Figure 1.c): This waxing trine comes between the conjunction and opposition when the Sun has advanced 120 degrees in longitude from Saturn. The temperature data shows a decline of about 1.5 degrees between day -2 and day 0.

Trine 2 (Figure 1.d): This waning trine comes between the opposition and conjunction when the Sun has advanced 240 degrees in longitude from Saturn. It is completely different than the waxing trine, shows less amplitude, and a steep 3.5 degree drop from day +4 to day +8.

Square 1 (Figure 1.e): This waxing square comes half-way in time between the conjunction and opposition when the Sun has advanced 90 degrees in longitude from Saturn. Within a range of 2.5 degrees there is instability near the date the aspect is partile with temperatures moving up and down for several days.

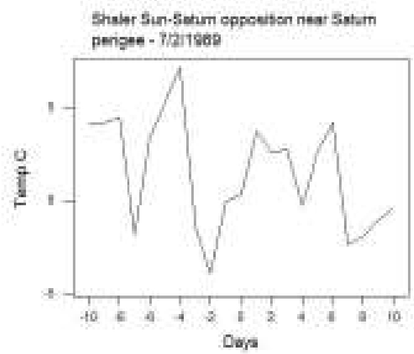
Square 2 (Figure 1.f): This waning square comes between the opposition and conjunction when the Sun has advanced 270 degrees in longitude from Saturn. There is a higher amplitude than the waxing square and a steep temperature increase of nearly 4 degrees between day -3 to day +2.

Sextile 1 (Figure 1.g): This waxing sextile occurs when the Sun has advanced 60 degrees in longitude from Saturn (about two months time). The sextile was considered the weakest of the Ptolemaic aspects and in this sample shows a warming trend from day -6 to day +3. The amplitude of the sample is about 3 degrees.

Sextile 2 (Figure 1.h): This waning sextile occurs when the Sun has advanced 300 degrees from Saturn, about two months before the next conjunction. The sample shows very low amplitude, some instability, and a low on day +6.

Test 2. Astronomical distance. The Sun-Saturn opposition occurs when Saturn is closest to the Earth. When the Earth is furthest from the Sun at aphelion, and Saturn is closest to the Sun at perihelion, the two bodies are as close as they can be. At the present time, Earth is at aphelion on July 4th. If Sun-Saturn oppositions are actually coincident with cold air, then oppositions occurring on or about the date of maximum Saturn perigee, which happens only once every 29 years, should coincide with lower temperatures - if distance and gravity are factors. The most recent opposition of this type occurred in 1989 on July 2 when the daily temperature average dropped by 10 degrees, over two standard deviations from the mean, between day -4 and day -2 shown in Figure 2 below.

Figure 2. Astronomical Distance.



Test 3. Interference. Historical writers on astrometeorology emphatically stated that the effect of one planetary pair cannot be isolated from the constantly changing configurations of the other planets, Sun and Moon relative to the Earth. An example is the Sun-Saturn opposition of December 3rd, 2001. In Figure 3.a below while the temperature reached a low on day zero, the day of the Sun-Saturn opposition, there is also a low on day -7, the day when the Moon was opposite the Sun (full Moon). Further, day 7, the date on which the temperature reached its lowest point in the entire 21-day period, a drop of over twice the standard deviation, was the day of a Venus-Saturn opposition. This illustrates how difficult evaluation and interpretation of data becomes as it is impossible to completely isolate a single aspect from others forming at the same, or nearly the same time, producing what appears to be “noise.”

If gravity is the force modulating the atmosphere then it would follow that the additional mass of the Moon should show in the data. In the 39-year database the following Sun-Saturn conjunctions (6) and oppositions (8) occurred within two days of a full or new Moon. The average of these 14 events is shown in Figure 3.b where the low is on day 0. On September 26, 1996 a lunar eclipse occurred on the same day as a Sun-Saturn conjunction, where the Moon is conjunct Saturn and both opposite the Sun. The data surround this event appears in Figure 3.c where temperatures during the entire period are well below the mean. These events were measured in celestial longitude only, coincidence in latitude or possibly declination would indicate a more precise alignment.

Figures 3.a-c. Complex Alignments.

Figure 3.a

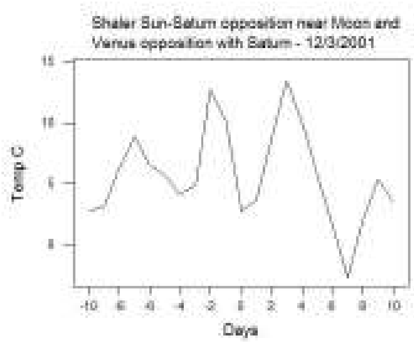


Figure 3.b

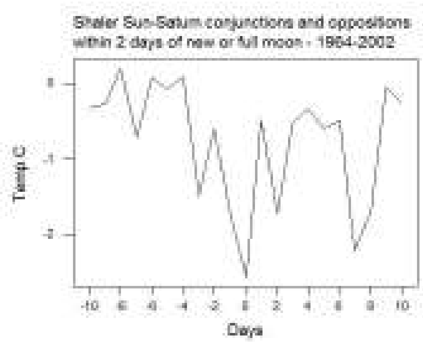
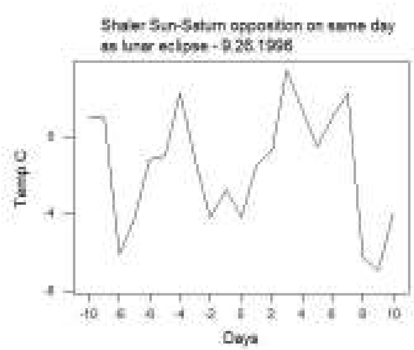


Figure 3.c



Test 4. 500 millibar data: If temperatures at the surface near the time of the geocentric alignment Sun opposition Saturn are lower that before or after, what is happening higher in the atmosphere? A dataset of Petersham (location of the Shaler dataset) 500 millibar (mb) level for the period 1964-2002 was obtained. The dates of the Sun-Saturn oppositions were taken from this dataset and stacked and a mean calculated. The graph, Figure 4.a, shows a drop in height of the 500 mb level indicating colder, dense air closer to the surface. An annual mean of 500 mb data for the entire period was calculated and this was subtracted from the dataset giving a table of anomalies from the mean. Figure 4.b shows Sun-Saturn oppositions during the range of this new dataset which replicate the general pattern of the first graph.

Figures 4.a-b). 500 mb Temperatures at Oppositions.

Figure 4.a

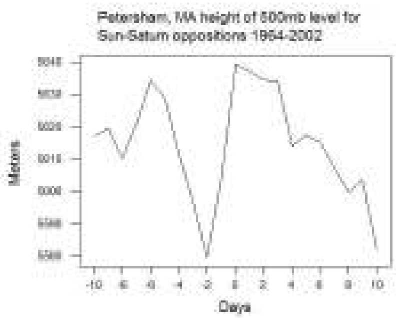
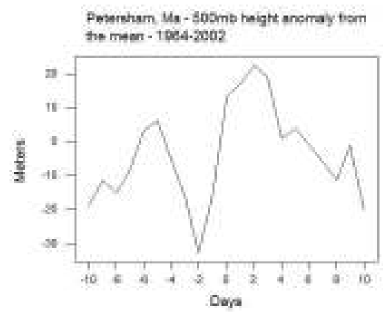


Figure 4.b



Test 5. Declination. Planetary positions are normally measured in the ecliptic coordinate system, specifically in celestial longitude along the zodiac, which is the astronomical positioning examined so far in this study. But planets are also located in space by a vertical component, in the case of the ecliptic coordinate system, by latitude. If one uses the equatorial coordinate system, the planetary positions are given in right ascension and declination (which are analogous to longitude and latitude). Ptolemy and Al-Kindi based their weather forecasting on time-slices calculated for the solar equinox passages, points in the year when the Sun's declination is zero and therefore planets near these points are simultaneously close to the plane of the latitude-like component in both coordinate systems. In regard to this study, tidal effects focused at the equator are simultaneously at right angles to the poles. This causes a tidal bulge at the equator and lowers the height of the atmosphere towards the poles, moving colder air to toward the surface (see diagram at the end of this section).

Although not one of the original Ptolemaic aspects, the parallel is been used in astrometeorology. It is measured in degrees of declination north or south of the celestial equator and it occurs when two planets are equidistant from the celestial equator and on the same side of it. In Figure 5.a below (78 events), measuring the temperatures when the Sun and Saturn occupy the same declination, a very small dip at partile is followed by a warming trend. Overall, the amplitude is very low.

When planets are located near the equinoxes, they have a low declination, which makes them closer to each other in terms of alignment on a "vertical" axis. Since the planets orbit close to the plane of the Earth's orbit around the Sun, they will have their lowest declination when they are near the intersection of the ecliptic and the celestial equator, which is where the Sun is located at the equinoxes. Figure 5.b (23 events) below measures Sun-Saturn parallels with a declination of less than 10 degrees north or south of the equator, which is equivalent to about two weeks before and after the equinox. Figures 5.c (7 events) and 5.d (2 events) are parallels within 3 and 1 degree respectively. These last two graphs produce results on day 0 that are statistically significant, two standard deviations from the mean being roughly equivalent to the 95% confidence level.

Figures 5.a-d. Parallel of Declination.

Figure 5.a

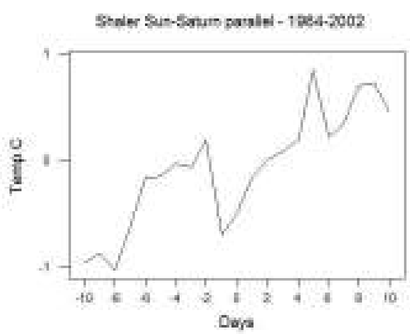


Figure 5.b

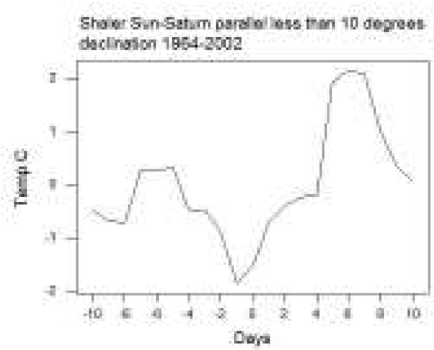
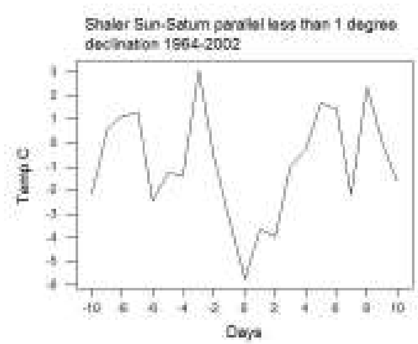


Figure 5.c

Figure 5.d



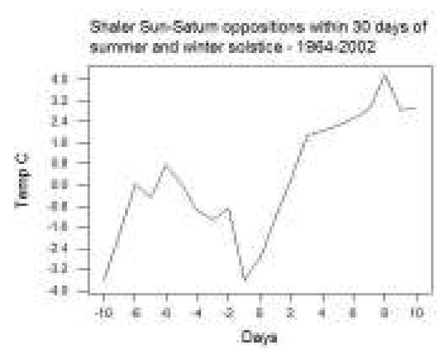
Sun-Saturn oppositions (13) within 30 days of the equinoxes are graphed below in Figure 6.a. The declination of Sun and Saturn extend +/– 12 degrees at the outer limits of this 60-degree constraint in celestial longitude. There is a low one day before partile aspect, but a rise immediately afterwards. Amplitude is high with a rise of about 3.5 degrees in the week after this low. Figure 6.b samples those oppositions (12) that occur within 30 days of the solstices where declinations range between 20 and 23.5 degrees.

On March 18, 1967 the Sun and Saturn were both located within three degrees longitude of the vernal equinox and at the same declination, one degree south of the ecliptic. The graph (Figure 6.c) for the period shows high amplitude with temperatures dropping to a statistically significant low on day 0. Given this extreme result, both the surface and 500mb data were examined on a daily basis from day -6 to day +6 using maps from the online NCEP/NCAR Reanalysis NOAA Earth System Research Laboratory.[137] The surface map (not displayed) shows a compact cold cell between Greenland and Baffin Island that broke down by day 0 with cold air then extending south into the Northeastern US. The 500 mb maps (displayed below as figures 6.d-i) show this cell, much enlarged, stationary over Baffin Island and Greenland and breaking down abruptly on day -1 (Figure 6.g) and spreading out over the Northeast over the next day, day 0. Based on other observations of weather and planetary alignments, it appears that as close alignments between planets form, existing weather patterns will move or break up. This is anecdotal and at present I have not devised a means of testing such a phenomena.

Figures 6.a-j. Oppositions Near the Equinoxes.

Figure 6.a

Figure 6.b



[137] http://www.esrl.noaa.gov/psd/data/gridded/data.nmc.reanalysis.html (accessed Oct. 2009))

Figure 6.c

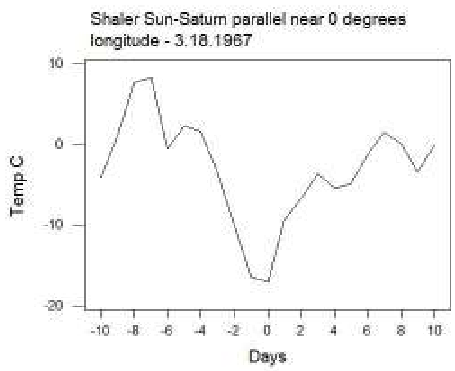


Figure 6.d (3.12.1967)

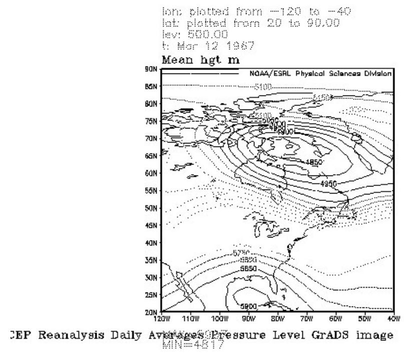


Figure 6.e (3.14.1967)

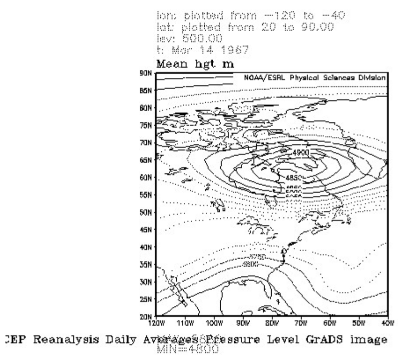


Figure 6.f (3.16.1967)

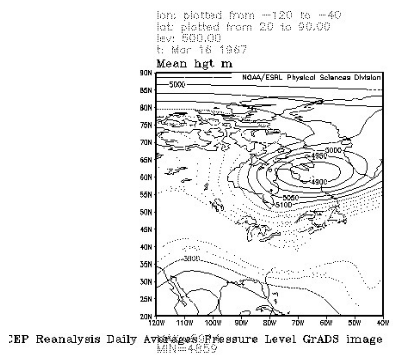


Figure 6.g (3.17.1967)

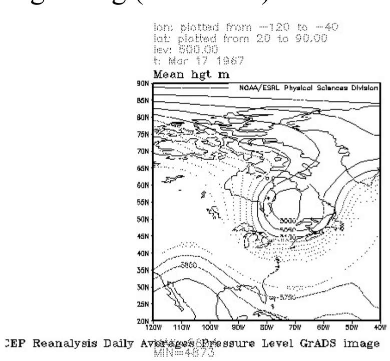


Figure 6.h (3.18.1967)

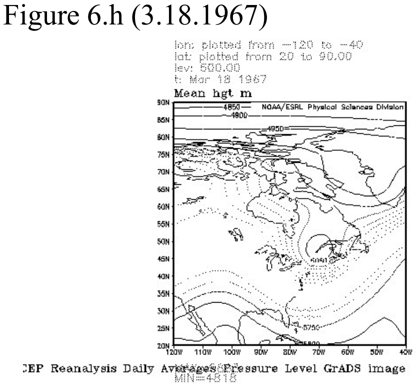


Figure 6.i (3.20.1967)

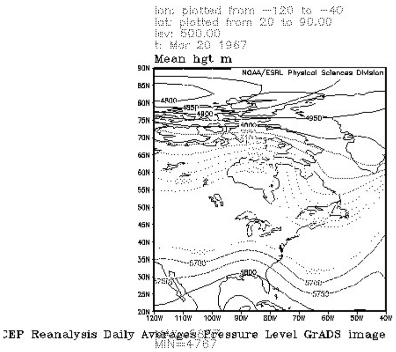
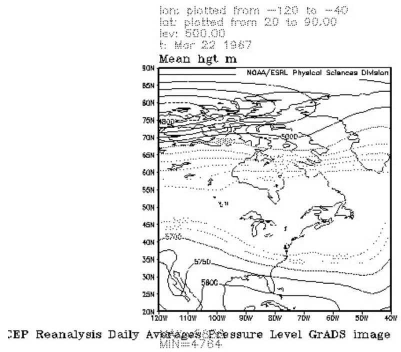
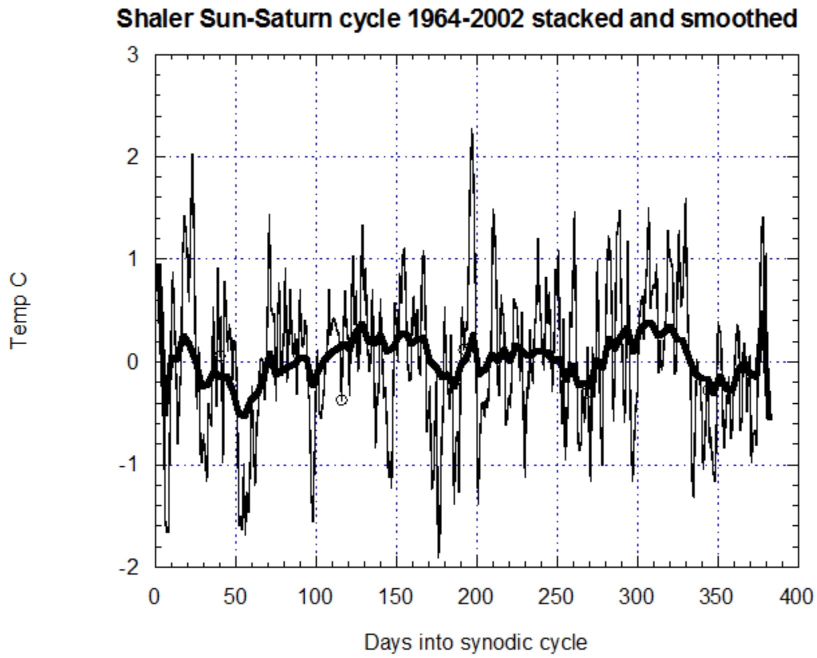


Figure 6.j (3.22.1967)



Test 6. The Sun-Saturn synodic cycle: Here (Figure 7) temperatures, expressed as anomalies from the mean, are correlated with the 378-day Sun-Saturn synodic cycles between 1964-2002. The data has also been smoothed as shown by the thicker line. Cycle length varies from approximately 377 to 383 days over the course of Saturn's 29.5-year orbit around the Sun and the data produced by stacking data for 38 synodic cycles was not adjusted, therefore the overlap is approximate, not exact. The opposition, which occurs 190 days on average after the conjunction is visible, preceded by a steeper drop at about 180 days and followed by a temperature peak at about 200 days. Note also drops at about 100 days, the waxing square occurring at an average of 101 days. The colder temperatures located at about 50-55 days into the synodic cycle appear to be quite pronounced and may be a reflection of the seventh harmonic, the septile aspect of 51.43 degrees of longitude which is 360 degrees divided by seven. It may also be part of the seventh harmonic of the ~378-day synodic cycle itself, which occurs about 59 days after the conjunction.

Figure 7. Sun-Saturn Cycle 1964-2002.



Test 7. The septile: The data for days 45-65 of the stacked anomalies from the means are graphed in Figure 8.a and show a strong drop focused between 52 and 58 days after conjunction which approximates the seventh harmonic ($^{360}/_{7}$). As the stacking of the Sun-Saturn synodic cycle data does not exactly correlate angular separations precisely, Figure 8.b was calculated for the exact day of the septile (seventh harmonic) aspect of 51.43 degrees between the Sun and Saturn which occurs 57-60 days after conjunction. It shows a low occurring 1-3 days before partile aspect, followed by a high amplitude rise of about 3 degrees over the next three days. Harmonics based on 5, 7, and 8 were introduced by Johannes Kepler.

Figures 8.a-b. The Seventh Harmonic.

Figure 8.a

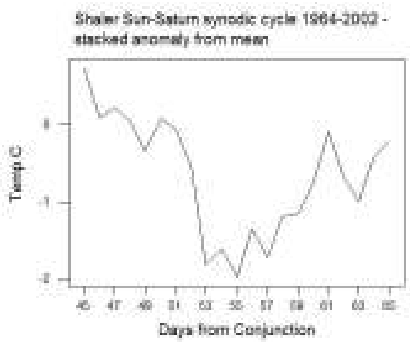
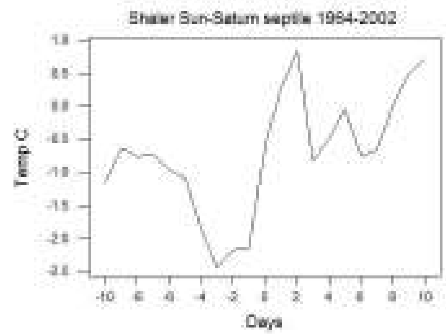


Figure 8.b



Test 8. Fourier analysis: A Fourier analysis was performed on the anomaly from the mean data in the following manner. Beginning at each conjunction, 512 days of temperature variations were taken and placed against each other and an average for each day was calculated. 512 days was necessary as the software used requires datasets that are a multiple of 2, and since the Sun-Saturn synodic cycle averages 378 days, the next lowest figure, 256, does not encompass the entire cycle. This means that 134 days on average will overlap with the data for the next conjunction and that the first 134 days on average of each cycle will be represented twice, frontweighting the sample. In addition to this frontweighting, the fact that the cycle length varies from 376 to 383 days does not allow for an exact overlap of the various aspects, which would soften any focal points that may exist. Ideally, the test should be performed on the entire 39-year dataset. However, at the time of this writing it has not been done as the appropriate software was not available.

The results of the test indicate the magnitude of various frequencies found in the data. The index frequency corresponding to each magnitude is divided into 1 to determine the number of days of the wave in the sample. The six highest magnitudes appear in Table 1 below arranged in order of frequency from higher to lower.

Table 3. Frequency and Magnitude of Shaler Sun-Saturn Cycle Data.

Index Frequency	Real	Imaginary	Magnitude	Phase	Periodogram	1/Frequency
0.00977	0.086	-0.008	0.086	-0.092	1.209	102.4 days
0.02344	-0.052	0.135	0.144	1.939	3.389	42.7
0.04297	0.086	-0.013	0.087	-0.145	1.244	23.3
0.04492	0.106	0.118	0.159	0.838	4.097	22.3
0.06641	0.061	-0.046	0.077	-0.649	0.958	15.0
0.08398	-0.012	0.079	0.080	1.727	1.048	11.9

What appears to be present in this data are approximations of at least the 16th and 4th harmonics of a cycle (360 divided by these numbers) which are 22.5 and 90 degrees, aspects based on multiples of 2. Note that the waxing square between the Sun and Saturn occurs between 97 and 105 days after conjunction, the average being 101 days. The 16^{th} harmonic, 22.5 degrees, may be shown by the 22.3 and 23.3 day frequencies. Also, the fifth highest magnitude in the analysis is at a frequency of 0.08398 which is 11.9 days, about half of 23 days, which may account for the low temperatures seen preceding the opposition by about ten to twelve days. Also of note is a 15-day frequency, the fifth highest in the list, which is the 24^{th} harmonic a component of the trine and sextile aspects based on 120 and 60 degrees. These minor angular separations were used by John Nelson in his work on radio disturbance forecasting.

Test 9. Controls. Four controls were calculated. The first two are based on randomly generated dates, one for each year of the time-series. These were generated using an online random number generator which allowed a range from 1 to 365. (http://www.randomizer.org/form.htm). The randomly-generated dates were used as the date of the aspect and 21 days were taken from the dataset and analyzed consistent with the methodology employed in this study.

Random control #1 – Figure 9.a. This control consists of 39 randomly generated dates, one for each year of the study period. The figure resembles several of the graphs above, particularly the trines and sextiles. There is less of a focus on the day of partile aspect than in the case of the opposition and squares.

Random control #2 – Figure 9.b. This control, using the same method as in control #1, shows a peak just before the day of partile, but like control #1, the amplitude is only about 2.5 degrees.

Random control #3 – Figure 9.c. This control consists of 39 dates randomly selected within the 1964-2002 range. Some years have two or more dates, other years have none.

Control #4 – Figure 9.d. This control uses the dates of the Sun-Saturn oppositions between 1964 and 2002 as day #1. Day 0 on the graph is ten days after the event. The low temperatures about 15 days after the opposition may correspond to the 15-day frequency found in the Fourier analysis.

Figures 9.a-c. Shaler Controls.

Figure 9.a

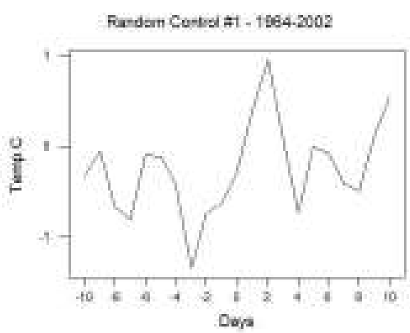


Figure 9.b

Figure 9.c

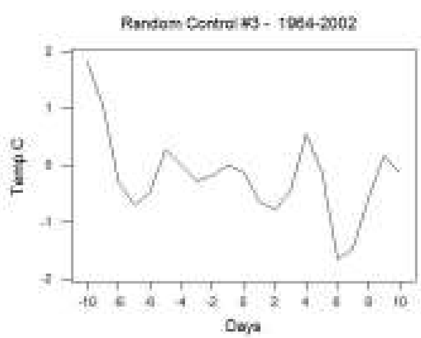


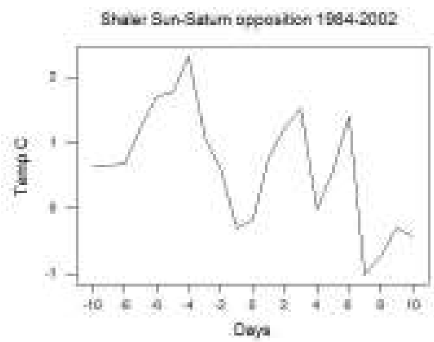
Figure 9.d

Controls by segment: The above two randomly-generated controls do not appear significantly different from other results generated by this study so far. A further set of controls takes the samples for the aspect and also for the randomly-generated dates and divides them into the first and second halves of the period, chronologically. Data for the actual aspect, previously presented as the opposition, are graphed below as Figures 10.a and 10.b. The first graph is based on the first half of the data, the second on the second half. Note that in both cases, temperature drops to the date before the aspect is partile.

Figures 10.a-b. Shaler Controls by Segment.

Figure 10.a

Figure 10.b



The same approach was done with the two randomly-generated controls. Below as Figures 11.a and 11.b is random control #1 split in half, the first 20 years and the second nineteen, chronologically. This division produces two very different patterns though both show a low near day 0.

Figures 11.a-b. Random Controls: First Half.

Figure 11.a

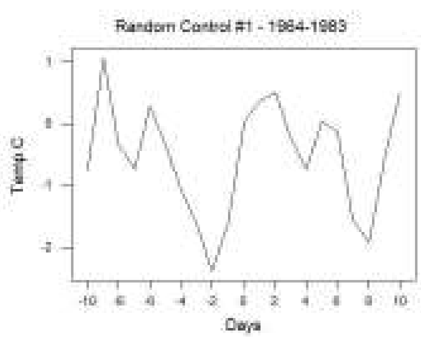
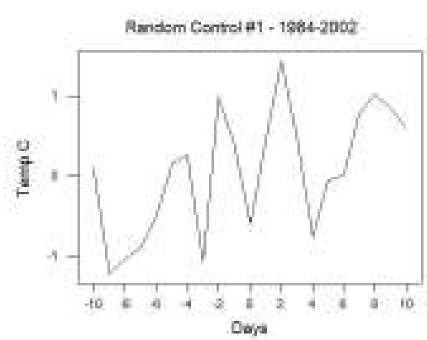


Figure 11.b

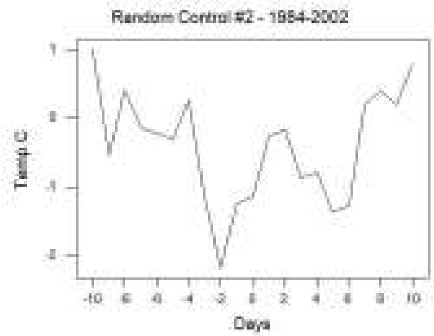


The second randomly-generated control, divided into first and second half, appear as Figures 12.a and 12.b below. These two appear even more unrelated.

Figures 12.a-b. Random Controls: Second Half.

Figure 12.a

Figure 12.b



Jupiter as a control: The third control runs the test for Sun-Jupiter oppositions taken from the Shaler dataset. Sun-Jupiter oppositions also occur only once a year. In this control, the Jupiter-Sun oppositions during the period covered by the Shaler data were calculated and organized in the same way as the Saturn-Sun oppositions. Figure 13.a below shows an increase in temperature during the period within a moderate amplitude of 3 degrees. Figure 13.b shows Sun-Jupiter oppositions correlated with precipitation, apparently positively, one of the traditional meteorological correlates with that planet.

Figures 13.a-b. Jupiter as a Control.

Figure 13.a

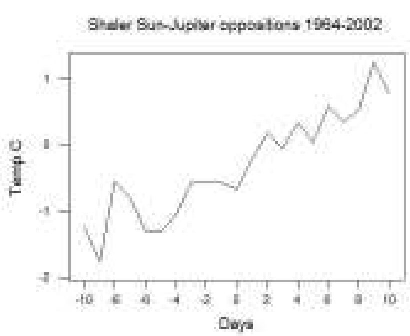
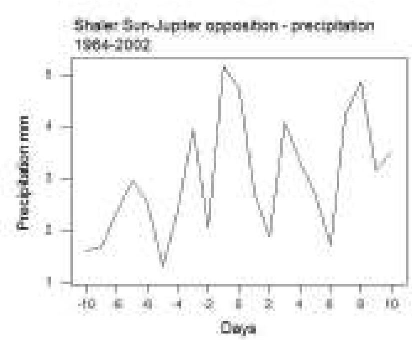


Figure 13.b



Discussion: The testing of specific planetary alignments thought to correlate with certain kinds of weather presents many problems and does not lend itself to simple statistical analysis. Such difficulties are typically encountered when testing isolated components of any complex system.

There is much noise in the data and sorting it out has proven difficult and not completely convincing. In general, geocentric aspects between the Sun and Saturn do not show a high correspondence with cold or falling temperatures in the Shaler database. However, the opposition between the Sun and Saturn, which occurs when the Earth is closest to Saturn, appears to correlate with a small drop in temperature to day -1, which become amplified when occurring near a lunation (new or full moon) or at perigee. Drops in temperature also appears to occur when the Sun and Saturn are located near the equinoxes, a factor minimizing vertical distance between each other. The oppositions, where Saturn is closer to the Earth, and positioning at the equinoxes, where it is located at right angles to the poles, suggest some kind of gravitational factor that is also reflected in the 500 mb altitude. It is possible that a weak gravitational effect from Saturn, perhaps modifying the gravitational tidal force of the Sun, is actually capable of moving portions of air masses near the poles which then travel southward. When at the equinoxes, the tidal effect of a body is to pull along equator and flatten at the poles, a process by which colder air could be brought to the surface in the higher latitudes.

2.4 Testing Sun-Saturn Aspects: Amherst, Massachusetts

The study was expanded with a 120-year daily temperature from Amherst, MA, longitude 40 W 23, latitude 42 N 20.[138] The location, like the Shaler dataset, is located in central Massachusetts, about 25 miles to west southwest. The daily temperature data was prepared in two formats. A daily mean for each calendar day was calculated for the entire 120 years, and from this a 120-year dataset the anomaly from the mean was created. (Amherst 1885-2004 dataset: standard deviation = 4.95) A second dataset of 30 years was prepared in a similar way, with the mean calculated for the period 1971-2000.

Test 1. Ptolemaic aspects: Graphs for the eight Ptolemaic aspects were first derived from the 1971-2000 dataset. The results, as expected, are similar to those found in the Shaler dataset. These appear as Figures 14.a-f below, with the opposition being the most striking, and with a

[138] Amherst College Weather Station Records, 1835-1924, 1948-present. Climatological data recorded by Professor Ebenezer Strong Snell (Class of 1822) and his daughter Sabra Snell from 1835 to 1902; observations recorded by the Hatch Experimental Station at the Massachusetts Agricultural College from 1891 to 1924; and by Dr. Philip Ives (Class of 1932) from 1984 to date.

slightly higher amplitude than that found in the Shaler data, although the first square also shows a more focused temperature drop. (Amherst 1971-2000 dataset: standard deviation = 5.29).

Figures 14.a-f. Amherst Temperatures 1971-2000 in the Sun-Saturn Synodic Cycle.

Figure 14.a

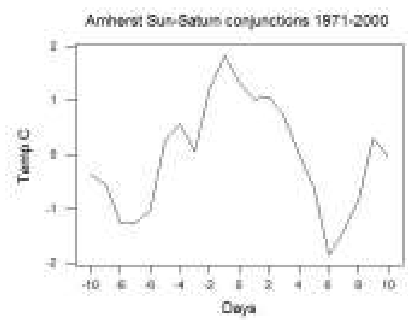


Figure 14.b

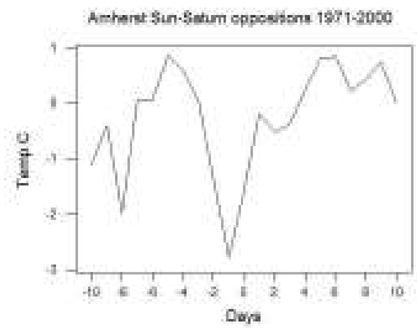


Figure 14.c

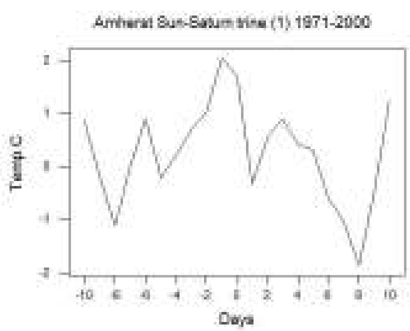


Figure 14.d

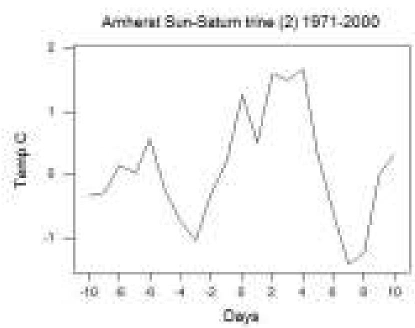


Figure 14.e

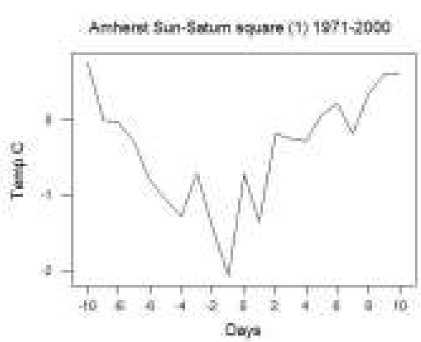


Figure 14.f

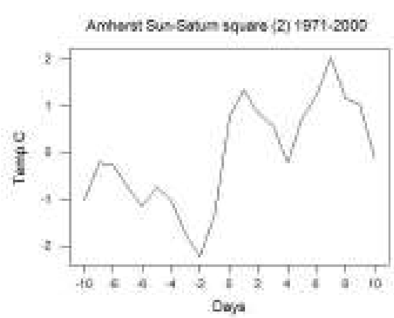


Figure 14.g

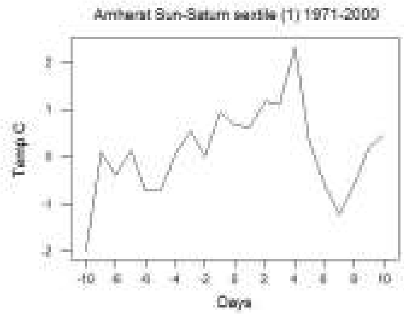
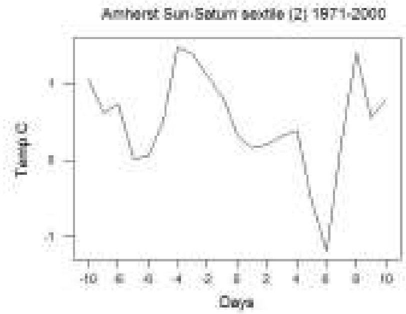


Figure 14.h.\



Test 2. Sun-Saturn opposition: The Sun-Saturn opposition sample was expanded to include the entire 120-year dataset which appears as Figure 15.a. The low temperature on day -1 is still present, but the amplitude is considerably less. Sun-Saturn oppositions in this sample that occurred with two days of a lunation (new or full moon), a total of 34, are shown in Figure 15.b. There are two lows in the 21-day sample, the second being on day 0. Figure 15.c reduces the range for oppositions near a lunation to 0.5 days, a total of 9 for the 120-year period. The temperature range, almost 7 degrees, is well over one standard deviation.

Figures 15.a-c. Amherst Sun-Saturn Oppositions.

Figure 15.a

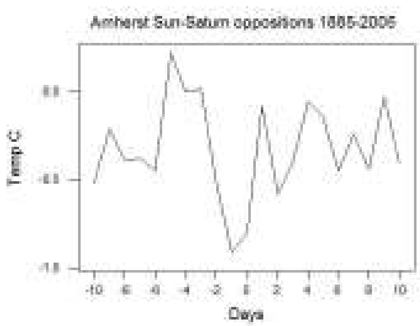


Figure 15.b

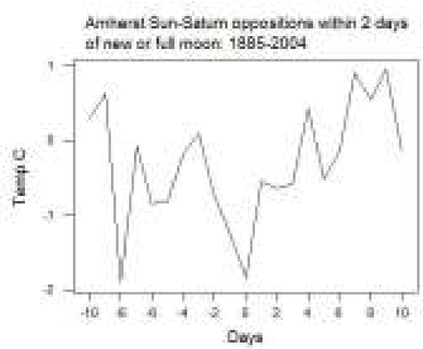
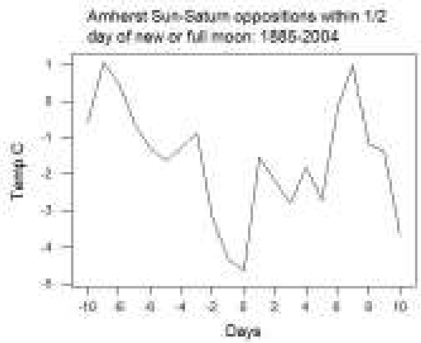


Figure 15.c



Test 3. Controls: Two controls were prepared for comparison with Figure 15.b. These, Figures 16.a and 16.b, are nine 21-day samples taken a year after and before, on the same dates as the test itself. These do not seem to be focused on day 0, although there is plenty of “noise” and considerable amplitude in both controls throughout the period.

Figures 16.a-b. Amherst Controls.

Figure 16.a

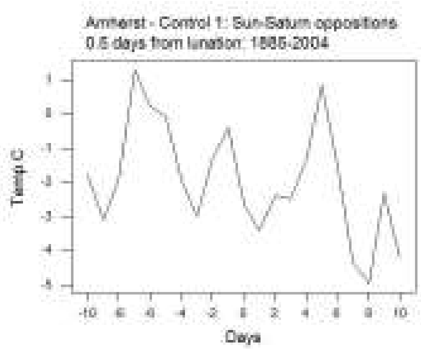
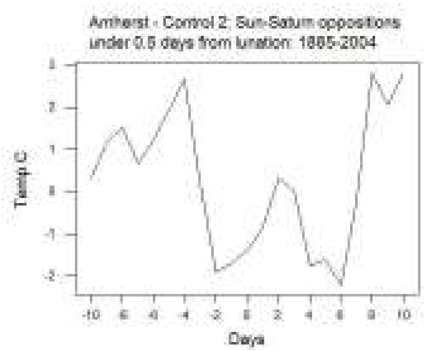


Figure 16.b



Test 4. Declination: The parallel of declination within 10 degrees of 0 declination, which occurs at the equinoxes, was calculated for 1971-2000 and appears as Figure 17.a. This distance was also constrained to within 3 degrees for the full dataset and appears as Figure 17.b. Both show something of a focus near day 0 with 17.b showing a steep two degree drop centered on day 0.

Figures 17.a-b. Amherst Parallels of Declination.

Figure 17.a

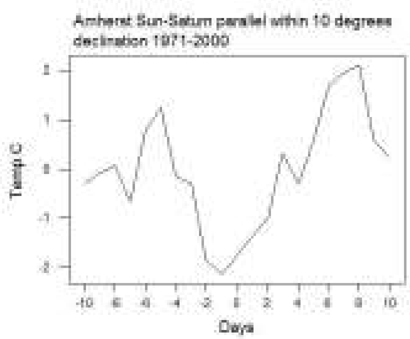
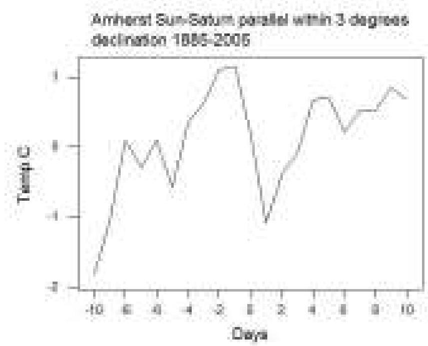
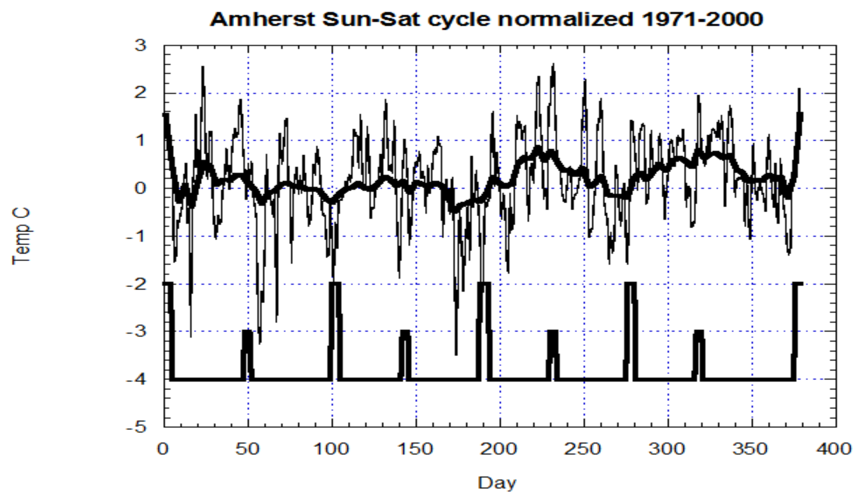


Figure 17.b



Test 5. Synodic cycle analysis: The 378-day average Sun-Saturn synodic cycle was normalized for the period 1971-2000. Using a random number generator, days were added to those cycles less than 378 days and subtracted to those over that figure, resulting in 29 cycles of equal length from conjunction to conjunction. The results were graphed (Figure 18) and smoothed and markers indicating the 4th and 8th harmonic positions are included in the graph, the 4th (conjunction, squares and opposition) being more extended than the 8th (semisquare – 45 degrees, and sesquiquadrate – 135 degrees). Visually, there appears to be a rough correspondence, particularly with the first and third quarters of the cycle.

Figure 18. Amherst Sun-Saturn Cycle Analysis.



2.5 Testing Sun-Saturn Aspects: Central England

The Hadley Centre Central England Temperature (HadCET) dataset is the longest instrumental record of temperature in the world. The mean daily data begins in 1772 and mean maximum and minimum daily and monthly data begin in 1878. The HadCET dataset daily temperatures are representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol.[139] A portion of the dataset was prepared by compiling a mean for 1971-2000 and subtracting it from the daily temperatures. Standard deviation of dataset from 1971-2000 is 2.63.

Test 1. Ptolemaic aspects: Here the conjunction, opposition, trine, square, and sextile of the 378-day Sun-Saturn synodic cycle are investigated in harmonic number sequence as was done for the Shaler and Amherst datasets. These appear as Figures 19.a-h.

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139 Parker, D.E., T.P. Legg, and C.K. Folland. 1992. A new daily Central England Temperature Series, *1772-1991. Int. J. Clim.,* ***Vol 12****, p317-342*. Manley (1953,1974) compiled most of the monthly series, covering 1659 to 1973. These data were updated to 1991 by Parker et al (1992), when they calculated the daily series. Both series are now kept up to date by the Climate Data Monitoring section of the Hadley Centre, Met Office. Since 1974 the data have been adjusted to allow for urban warming.

Figures 19.a-h. HadCET Temperatures 1971-2000 in the Sun-Saturn Synodic Cycle.

Figure 19.a

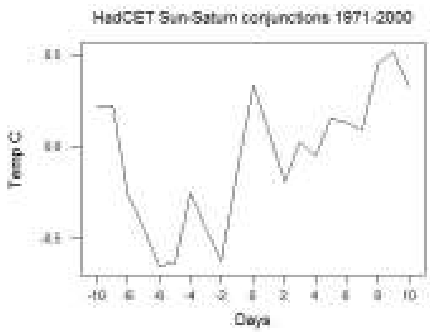


Figure 19.b

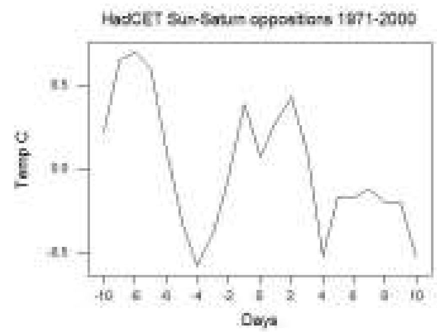


Figure 19.c

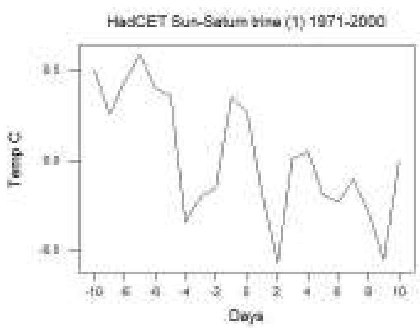


Figure 19.d

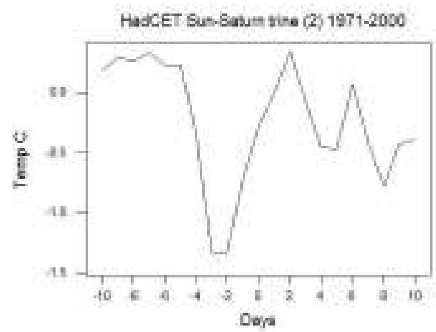


Figure 19.e

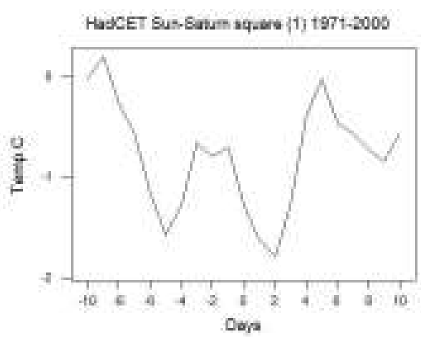


Figure 19.f

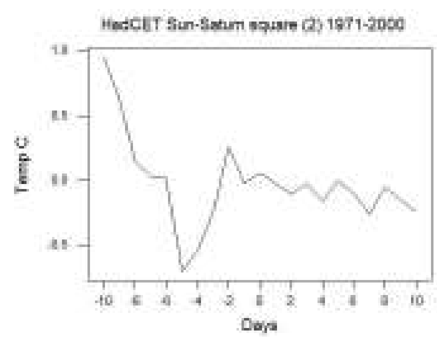


Figure 19.g

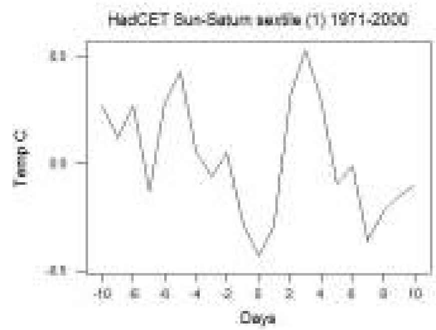
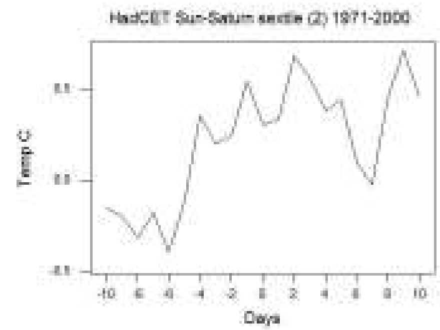


Figure 19.h



The conjunction (Figure 19.a): The Sun-Saturn conjunction shows an increase in temperature peaking at, day 0, the date of the exact conjunction.

The opposition (Figure 19.b). The graph shows symmetrical lows at day -4 and day +4, centered on day 0, and a drop in temperature beginning on day -8 reaching a low on day -4.

The trine (Figure 19.c): The temperature data for the waxing trine shows a steep, though low amplitude, drop on day 0 to day +2.

The trine (Figure 19.d): This graph for the waning trine shows a steep 1.5 degree drop to a low on days -3 and -2.

The square (Figure 19.e): For the waxing square most of the sample temperatures are below the mean with the low on day +2.

The square (Figure 19.f): For the waning square a low point is reached on day -5, followed by a rise.

The sextile (Figure 19.g): The graph for the waxing sextile shows a drop of about 1 degree from day -5 to a low on day 0, followed by an immediate rise to the high of the sample on day +3. The amplitude of the sample is only about 1 degree.

The sextile (Figure 19.h): For the waning sextile a low on day -8 is followed by a rise in temperature to a peak on day +2. Most of the temperatures in the sample are above the mean.

This test of the Ptolemaic aspects does not appear to obviously correlate with cold temperatures or a focus on day 0, with the exception of the waxing square and waxing sextile.

Test 2. The Parallel. The parallel is measured in degrees of declination north or south of the celestial equator and it occurs when two planets are equidistant from the celestial equator and on the same side of it. In Figure 20.a below there is a drop in temperature beginning on day -8 and reaching bottom on day -3. Overall, however, the amplitude is very low. Figure 20.b tests Sun-Saturn parallels with declinations of 3 degrees or less north or south of the celestial equator, these falling about a week before and after the equinoxes. Again, temperatures begin to fall on day -8 but reach the low on day +3.

Figures 20.a-b. HadCET Parallels of Declination.

Figure 20.a

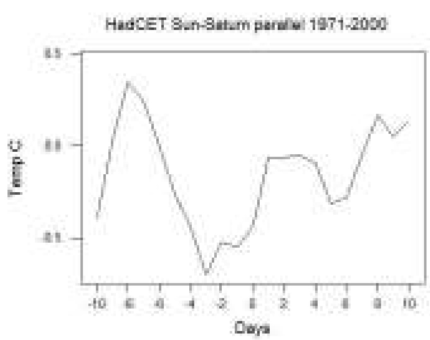
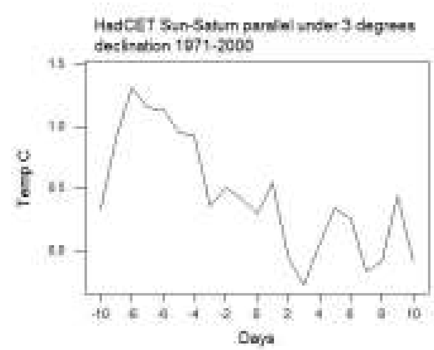


Figure 20.b



Aspects having similar celestial latitude indicate more focus in gravitational vectors. Astronomical bodies having the same latitude and located near the equinoxes will also have similar declination. Conjunctions or oppositions that occur near the equinoxes will have declinations that range between 0 and 10 degrees, in contrast to those at the solstices where declinations can be as high as 23.5 degrees. Figure 21.a below is based on a sample of Sun-Saturn conjunctions within one month of the equinoxes, a total of 10 conjunctions between 1971 and 2000. A steep temperature drop occurs on day -4 and reaches a low on day +2. The entire period is below the mean. Figure 21.b graphs 77 conjunctions within one month of the equinoxes from 1772-2008. Here a 10-day drop in temperatures reaches a low on day 0, with a second low on day +9. The low on day 0 is more pronounced (to -0.6) when vernal equinox conjunctions are separated from the sample and graphed (not shown).

Figures 21.a-b. HadCET Conjunctions Near Equinoxes.

Figure 21.a

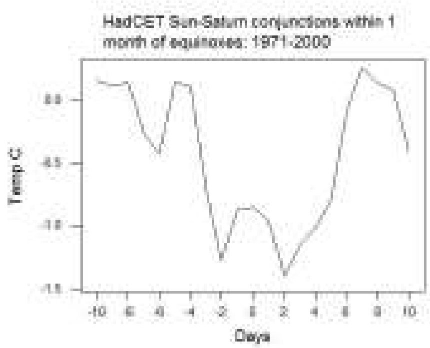
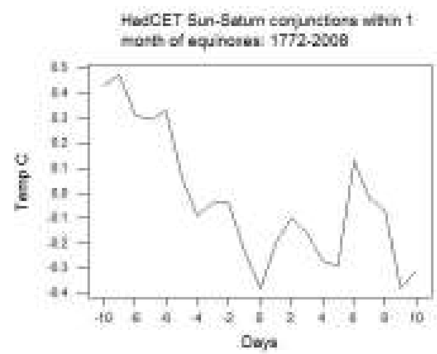


Figure 21.b



Test 3. Controls. The next graph, Figure 22.a, shows Sun-Jupiter conjunctions in the equinoctial signs for the same period. The sample, a total of ten conjunctions, shows a low on day -4 that rises to a peak on day +1. Figure 22.b shows the five Sun-Mars conjunctions in the same time period.

Figures 22.a-b. HadCET Controls.

Figure 22.a

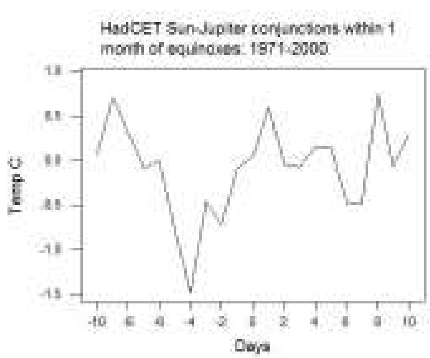
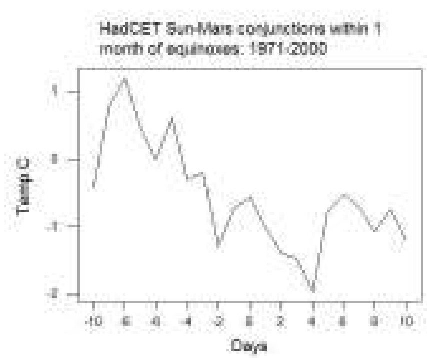


Figure 22.b



Discussion: In the above studies, a strong correlation between Sun-Saturn Ptolemaic aspects and cold temperatures is shown only in the waxing sextile. Unlike the Shaler central Massachusetts weather data, the opposition in England does not show a pronounced correlation with cold temperatures. However, the Sun-Saturn conjunctions in equinoctial signs shows some correlation, especially so in the larger dataset, when they occur near the equinoxes.

2.6 Testing Sun-Saturn Aspects: Prague, Czech Republic

A 225-year dataset for Prague was prepared by calculating a mean for the entire period, then subtracting this from the daily mean temperature (standard deviation = 2.47). A second dataset was similarly prepared for the period 1971-2000 (standard deviation = 3.69) using the mean for that period.[140] This location was selected as a study site because of the long daily temperature series and because Johannes Kepler spent many years in Prague where he studied the weather and noted correlations with planetary aspects.

Test 1. Ptolemaic aspects: Here the conjunction, opposition, trine, square, and sextile of the 378-day Sun-Saturn synodic cycle are investigated in harmonic number sequence as was done for the Shaler and Amherst datasets. These appear as Figures 23.a-h.

Figures 23.a-h. Prague Temperatures 1971-2000 in the Sun-Saturn Synodic Cycle.

Figure 23.a

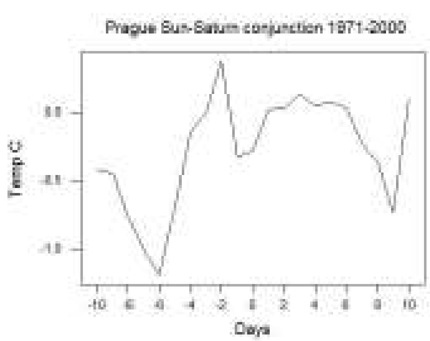


Figure 23.b

140 European Climate Assessment & Dataset (eca&d), November 2008: Klein Tank, A.M.G. and Coauthors, 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Int. J. of Climatol., 22, 1441-1453. Data and metadata available at http://eca.knmi.nl This is the blended series of location CZECH REPUBLIC, PRAHA (location-ID: 24).

Figure 23.c

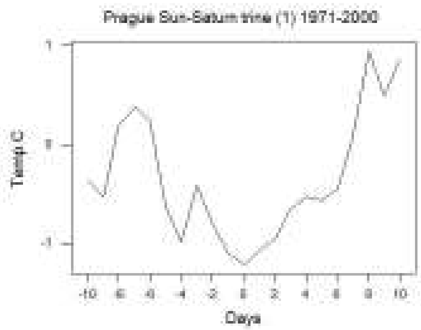


Figure 23.d

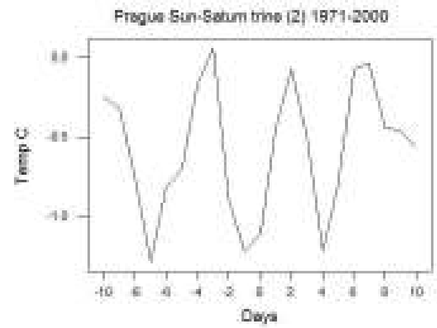


Figure 23.e

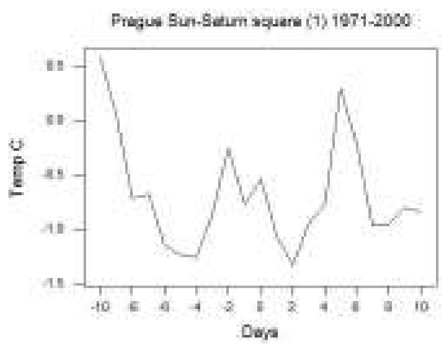


Figure 23.f

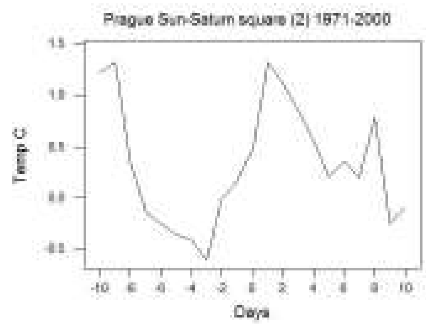


Figure 23.g

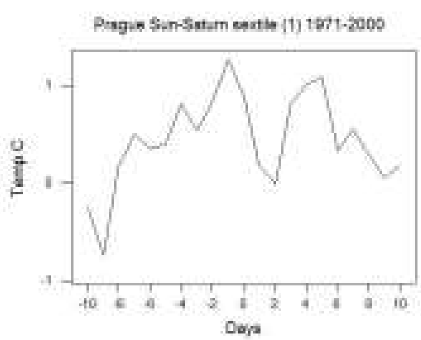
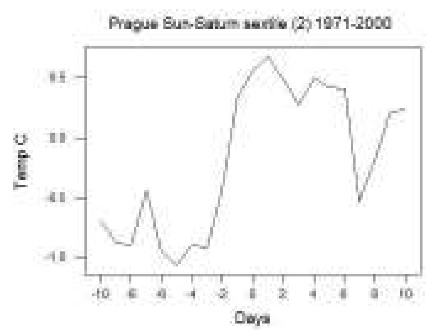


Figure 23.h



The conjunction (Figure 23.a): The graph shows a steep increase in temperature from day -6 peaking on day -2, followed by a small and temporary drop to day 0. Most of the data points are below the mean.

The opposition (Figure 23.b): The data shows a jagged drop in temperature beginning at day -1 and continuing to day +9.

The trine (Figure 23.c): The data for the waxing trine shows a low on day 0 with temperatures below the mean from day -5 to day +7.

The trine (Figure 23.d): This graph for the waning trine shows highly unstable temperatures, lower than the mean, during the entire 21-day period. Temperature changes are abrupt and evenly spaced.

The square (Figure 23.e): Most of the period for the waxing square is below the mean with lows on days -4 and +2.

The square (Figure 23.f): Most of the period for the waning square is above the mean with a low on day -3.

The sextile (Figure 23.g): The period for the waxing sextile is mostly above the mean with drop from day -1 to day +2.

The sextile (Figure 23.h): From day -5 to day +1 the waning sextile shows a strong rise in temperatures from below to above the mean.

With the exception of the waxing trine, a strong correlation between day 0 and cold temperatures is not apparent.

Test 2. Sun-Saturn oppositions: Using the entire Prague dataset of 226 years (standard deviation = 2.47), Sun-Saturn oppositions were calculated. The results are in Figure 24 which show very little amplitude and only one steep drop from day +2 and 3 to day 6.

Figure 24. Prague Temperatures 1775-2005 for Sun-Saturn Oppositions.

The oppositions from 1775 to 2005 were then organized by months, with 15-20 oppositions per month. These appear below as Figures 25.a-l. In this test, organization by civil calendar, rather than zodiacal sign, was chosen as an alternative means of breaking the data into annual sections. The graphs for April and October, the months after the equinoxes, show the most robust indications of movement toward lower temperatures on day 0.

Figures 25.a-l. Prague Sun-Saturn oppositions 1775-2005 by Month.

Figure 25.a

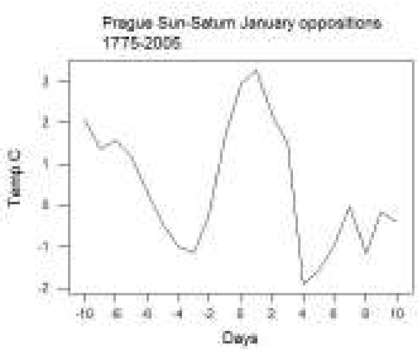


Figure 25.b

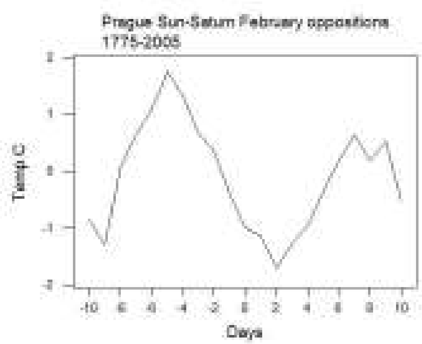


Figure 25.c

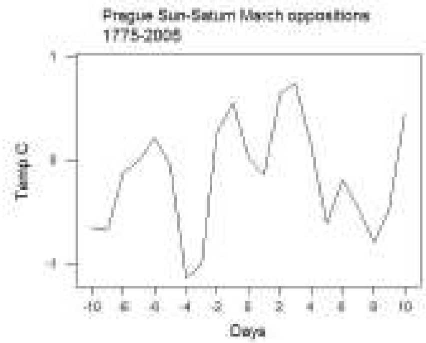


Figure 25.d

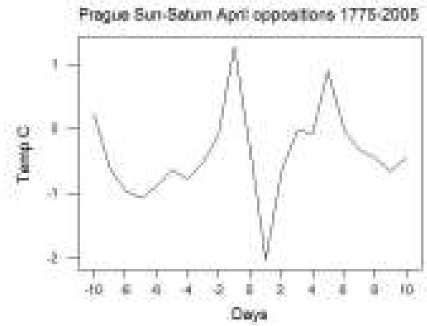


Figure 25.e

Figure 25.f

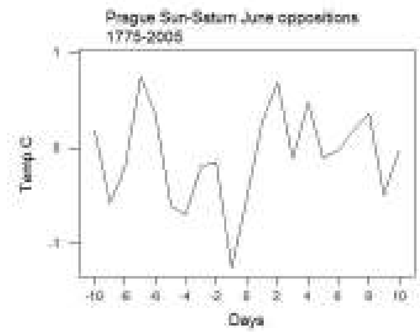


Figure 25.g

Figure 25.h

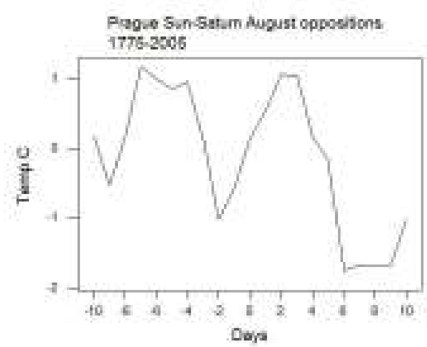


Figure 25.i

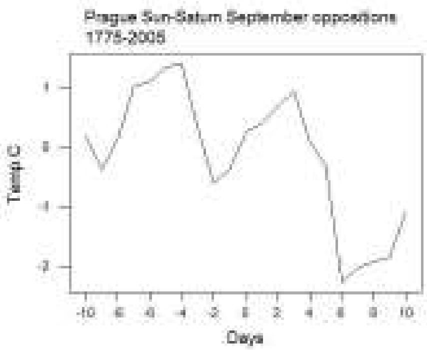
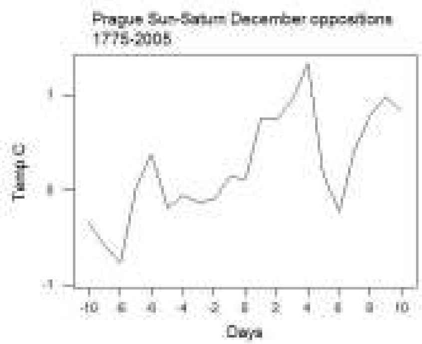


Figure 25.j

Figure 25.k

Figure 25.l



Test 3. Equinox oppositions: Given the hypothesis that proximity to Earth and right angles to the poles should correspond to possible tidal effects, a combination of both factors is selected from the dataset. The oppositions that occurred within 3 degrees of the equinoxes between 1775 and 2004, a sample of six, were averaged and graphed and appear as Figure 26.a. The abrupt temperature drop of about 3.5 degrees from day -1 to day +1 is over one standard deviation.

Test 4. Apogee distance: During the 226-year dataset Sun-Saturn oppositions occurred six times within a few days of Earth apogee in early July. The six oppositions were averaged and appear as Figure 26.b. Here temperatures reach lows on day -2 and day 0.

Figures 26.a-b. Prague Sun-Saturn Equinox and Apogee Oppositions.

Figure 26.a

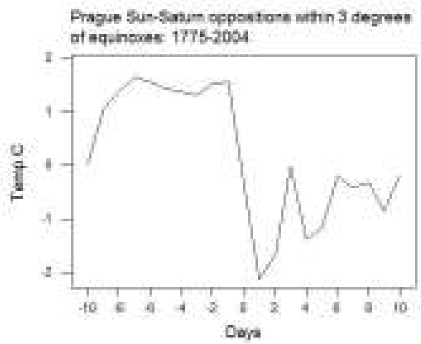
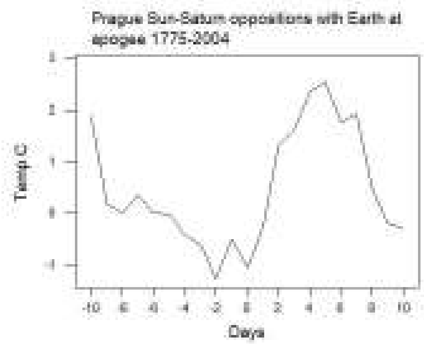


Figure 26.b



Test 4. Control – Sun and Mars: Kepler wrote that Sun-Mars conjunctions correlate with warmer temperatures. These alignments occur once every two years on average. Temperature data for both Sun-Mars conjunctions and oppositions were graphed and appear as Figures 27.a and 27.b. A warming is observed in the conjunction, but the reverse occurs in the opposition.

Figures 27.a-b. Prague Sun-Mars Controls.

Figure 27.a

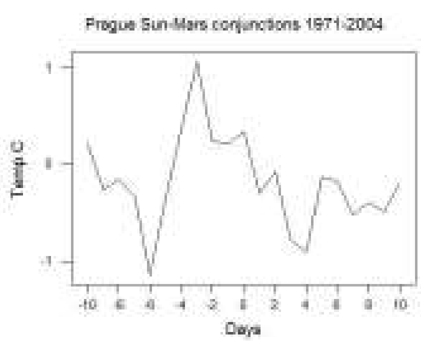


Figure 27.b

Test 5. Fourier: The entire 225-year dataset for Prague was analyzed for frequencies. The highest magnitudes, frequency and 1/frequency expressed in years are listed below.

Table 4. Frequency and Magnitude of Prague Sun-Saturn Cycle Data.

Frequency	Magnitude	1/frequency in years
0.000015	2.802188	182.53
0.000076	1.134976	36.03
0.000580	1.127842	4.72
0.000153	1.004247	17.89

The frequency with the highest magnitude, 182.53 years is nearly the length of the dataset, although it is suggestive of the Seuss solar cycle. The second and fourth highest frequencies, 36.03 and 17.89, may reflect the roughly 18-year cycle of lunar nodes, which are found in other databases.

2.7 Testing Sun-Saturn Aspects: Other Datasets

Temperature studies centered on Sun-Saturn oppositions and conjunctions were done for selected locations at higher northern latitudes around the Earth. The resultant graphs are not shown.

Materials: Datasets from the following sources:

Danish Meteorological Institute Ministry of Transport Technical Report 01-11
Observed Daily Precipitation, Maximum Temperature and Minimum Temperature from Ilulissat and Tasiilaq, 1873-2000, Ellen Vaarby Laursen, Copenhagen 2001

Environment Canada, http://www.climate.weatheroffice.ec.gc.ca/climateData/dailydata

Klein Tank, A.M.G. and Coauthors, 2002. Daily dataset of 20th-century surface
air temperature and precipitation series for the European Climate Assessment.
Int. J. of Climatol., 22, 1441-1453. Data and metadata available at http://eca.knmi.nl

Mount Washington Observatory. Grant, A. N., A. A. P. Pszenny, and E. V. Fischer. 2005: The 1935-2003 air temperature record from the summit of Mount Washington, New Hampshire. *Journal of Climate* #18, pp.4445-4453.

NOAA Satellite and Information Service. National Environmental Satellite, Data, and Information Service. http://www7.ncdc.noaa.gov/CDO/cdosubqueryrouter.cmd

The Sun-Saturn conjunction at high latitudes, 1964-2002 – from west to east:

Ottawa, Canada: 45°N25' 075°W42' (Environment Canada) Temperatures are generally higher centered around day 0.

Mount Washington Observatory: 44°N16' 071°W18' A minor 1.5 degree drop about two day before day 0 is followed by a high amplitude 3.5 degree drop reaching the low about six days later.

Tasiilaq, Greenland: (Danish Meteorological Institute Ministry of Transport) Similar to MWO, high before and after day 0 with a low a week later.

Novosibirsk, Russia: 55°N02' 082°E55' (NOAA Satellite and Information Service) A small decline in temperature follows day 0 by about a day, followed by rising temperatures.

Jakutsk, Russia: 62N00 129E40. (NOAA Satellite and Information Service) Rising temperatures occur at the time of the conjunction.

The Sun-Saturn opposition at high latitudes, 1964-2002 – from west to east:

Fairbanks, AK: 64°N50' 147°W43' (NOAA Satellite and Information Service)
Here a general cooling trend extends for about five days before and after the opposition with the low occurring five days after day 0.

Yellowknife, Canada. 62N27 114W21 (Environment Canada) This location is where, or near where, cold air masses that eventually move south and southeast to the United States form. Here the mean temperature drops 3 degrees in six days starting at day 0.

Saskatoon, Canada: 52°N07' 106°W38' (Environment Canada) A drop in temperature occurs about five days before day 0 followed by a rise culminating on day 0.

Ottawa, Canada: 45°N25' 075°W42' (Environment Canada) This pattern is similar to that found in the Shaler dataset. A low is reach about two days before day 0.

Mount Washington Observatory: 44N16' 071°W18' This graph is similar to the Shaler dataset and Ottawa, Ontario with a low about two days before day 0.

Halifax, Canada: 44N39 063W36 (Environment Canada) The low of the entire 21-day sample occurs the day before day 0.

Igaluit, Baffin Island, Canada. 63N45, 68W03. Here the temperature drops two degrees between the day before day 0 to two days afterward.

Tasiilaq, Greenland: 65N37, 37W41 (Danish Meteorological Institute Ministry of Transport) A low in the sample occurs from 4 to 2 days before day 0, followed by a rise in temperature.

Oslo, Norway: 59N55 10E45 (European Climate Assessment) Here the low of the 21-day period is located five days before day 0, with a second low one day before.

Moscow, Russia: 55N45 037E35 (European Climate Assessment) Two lows are reached before and after day 0, but these are not equidistant and of very low amplitude.

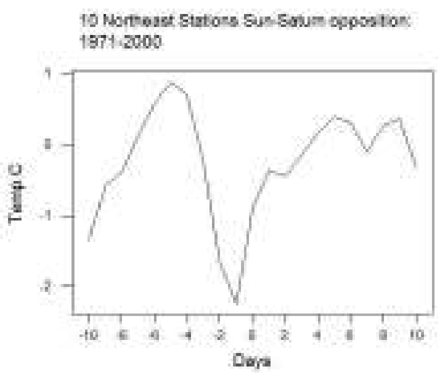
Novosibirsk, Russia: 55N02 082E55 (NOAA Satellite and Information Service) This dataset from southern Siberia shows a two degree drop over a five-day period beginning at day +1.

Jakutsk, Russia. 62N00 129E40. (NOAA Satellite and Information Service). A steep drop of over two degrees begins 4 days before day 0 and extends until two days after.

Discussion: The opposition appears to correlate more consistently with lows near day 0 in the eastern North American datasets and Greenland. It appears as if cold temperatures move southwest across North America with the lowest temperatures reaching the Northeast on or about day -1. Correlation with the opposition in Europe and Asia is weaker or non-existent. The conjunction seems, in Europe, at least, to corroborate Kepler's observation that it marks warmer temperatures.

Northeastern Stations Composite: Daily temperature data from ten stations in Northeastern US were averaged and an anomaly from the mean was calculated for 1971-2000 (Figure 28). Standard deviation from the mean is 3.87. The stations are Farmington ME, Groton CT, Amherst MA, Hanover NH, New Brunswick NJ, Cooperstown NY, West Point NY, Franklin PA, State College PA, Burlington VT. A graph of the Sun-Saturn oppositions during the period appears below. Temperatures during much of the period are below normal with the low on day -1 which is preceded by a rapid drop of nearly 3 degrees from a high on day -5.

Figure 28. Northeastern Stations Sun-Saturn Opposition Composite.



2.8 Testing Sun-Saturn aspects: Southern Hemisphere

The limited land mass of the southern hemisphere at latitudes near or greater than 40 degrees presents two problems in the analysis of weather data required for this study. The first is that the regions of this category, the southern tip of South America and New Zealand's South Island, have relatively limited daily weather datasets and many of these are not complete. The second is that nearly all the stations are near the coast and the climate is therefore maritime and not continental. In spite of these constraints, data was obtained from the Online Climate Data Directory of the

NOAA Satellite and Information Service for six southern hemisphere stations, three in New Zealand, two in Argentina and one in Chile (Figures 29.a-f).[141]

Christchurch, NZ 43S32 172E37. Temperatures were somewhat lower on day -2 but climbed afterwards then dropped steeply on day 6.

Invercargill, NZ 46S26 168E23. Varing temperatures for the period with the lowest on day +7.

Nelson, NZ 41S18 173E16. Similar to the other two coastal New Zealand station records, not suggestive on any Sun-Saturn effect on day 0.

Neuquen Aero., AR 38S57 68W08. This inland location shows higher temperatures surrounding day 0.

Rio Gallegos Aero., AR 51S37 69W17. A temperature peak at day +1 is immediately followed by a 2 degree C drop sustained through day +6.

Puerto Montt, CH 41S25 73W05. Temperatures drop to a low on day 0, then a further drop on day 7.

Figures 29.a-f. Southern Hemisphere Sun-Saturn Oppositions.

Figure 29.a

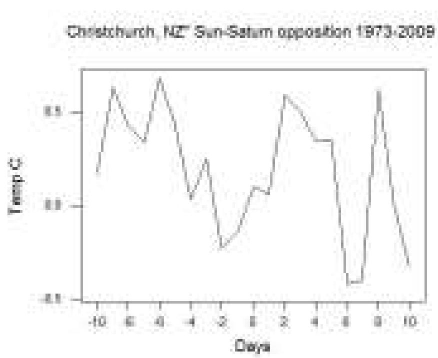
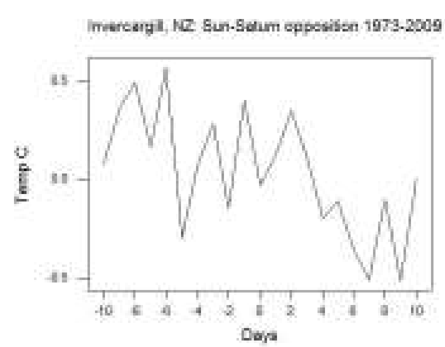


Figure 29.b



[141] NOAA Satellite and Information Service. National Environmental Satellite, Data, and Information Service. http://www7.ncdc.noaa.gov/CDO/cdosubqueryrouter.cmd

Figure 29.c

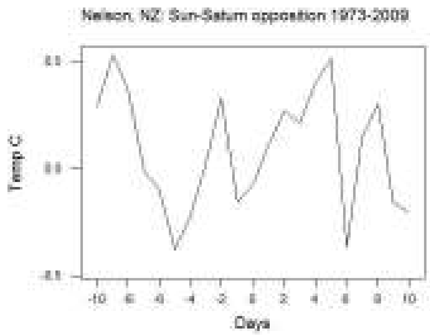


Figure 29.d

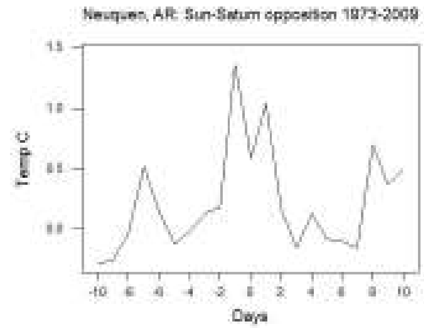


Figure 29.e

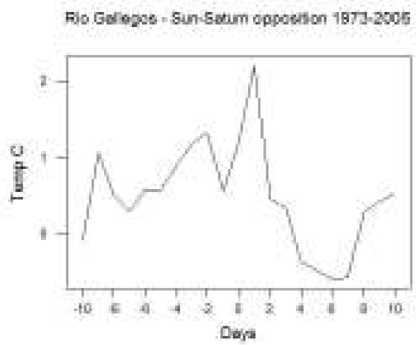
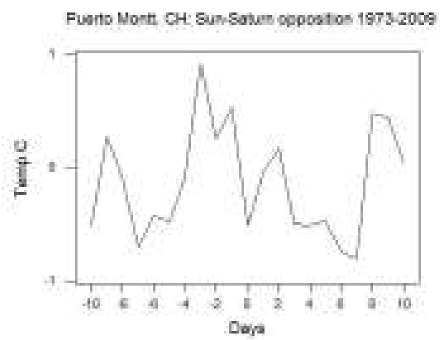


Figure 29.f



A composite of the three South American stations (Figure 30.a) shows a nearly 1.5 degree temperature drop following day +1. This is not found in the composite of the New Zealand stations (Figure 30.b). The graph of all six southern hemisphere stations (Figure 30.c) combined shows a temperature drop of about 1 degree C beginning on day +1 and reaching a low on day +6. This graph represents 220 years of station reports for the Sun-Saturn opposition and it appears to register a cooling trend lasting for several days following the alignment, this being most obvious in the South American data alone. During the period under investigation, 1973-2009, the planet Saturn was near perigee and at opposition to the Sun only once, on July 2nd, 1989. A composite graph of this opposition from all six stations (Figure 30.d) shows an approximately 4 degree drop in temperature starting on day -3 followed by a 3 degree rise, a 3 degree fall and a another 3 degree rise all centered around day 0.

Figures 30.a-d. Composites of Southern Hemisphere Stations.

Figure 30.a

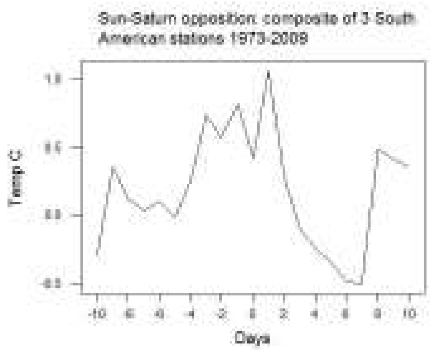


Figure 30.b

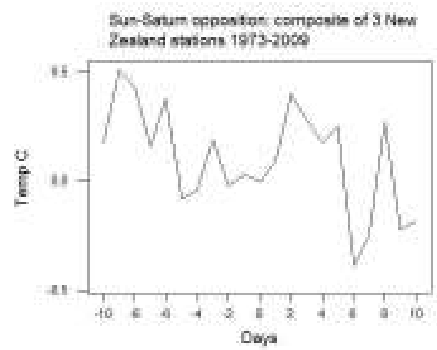


Figure 30.c

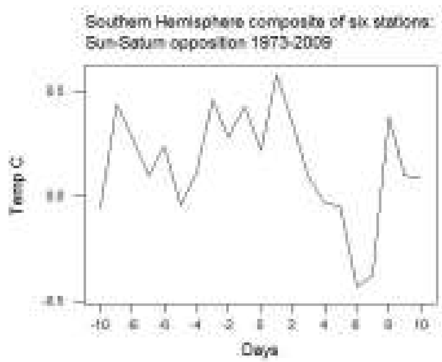
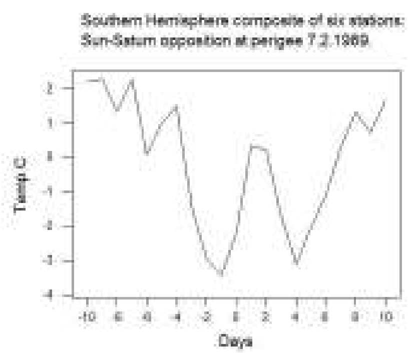


Figure 30.d



Of the six Southern Hemisphere stations analyzed, only Neuquen is located inland away from the coast and is less subject to maritime weather conditions. A graph for the Saturn perigee appears as Figure 31.a. The temperature drop centered around day 0 is more than two standard deviations (SD for entire Neuquen dataset = 3.19) and is therefore significant. A graph of all oppositions in the dataset for Neuquen (Figure 31.b) is inconsistent with those for the same events in the Northeastern datsets. Here the temperature rises centered on day 0, an indication of heating in this case, and temperature instability. Northern Hemisphere data for the opposition event at perigee on 7.2.1989, including Northeastern North America, Central England and Prague, all show temperature declines prior to and at day 0, but a rise occurs during the following days.

Figures 31.a-b. Neuquen Sun-Saturn Oppositions.

Figure 31.a

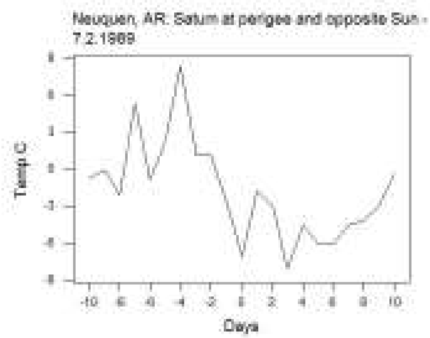
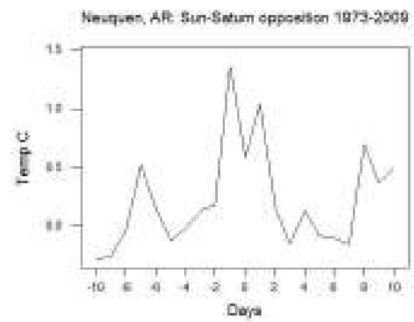


Figure 31.b



2.9 Discussion and Conclusions

The many tests and accompanying graphs presented in this study document a wide-ranging investigation into the possibility that there is substance to at least one component of traditional astrometeorology. This component, the geocentric aspects of the Sun and Saturn, was studied in detail within the range of the many datasets obtained. The opposition aspect of Sun and Saturn, in particular, has been a focus of the study as this syzygy occurs when the Earth is closest to Saturn in its annual orbit around the Sun and Saturn's gravitational effects are therefore stronger than when in other positions. In total, this study uncovers a possible signal from Saturn in the daily temperature databases that is consistent with the hypothesis that any such effects should occur when (1) Saturn is nearest to Earth, (2) involved with other bodies, and (3) near zero degrees declination or aligned with the equinoxes and therefore at right angles to the poles. In the first case, as already noted, the geocentric Sun-Saturn opposition locates Saturn closer to Earth than at other parts of its orbit. However, the eccentricity of Saturn's orbit, and that of the Earth's, puts Earth at aphelion and Saturn at perigee only occasionally. The most recent occurrence of this event is graphed in Figures 2.a and 31.a where a statistically significant temperature drop occurred in certain Northern and Southern Hemisphere data. Sun-Saturn oppositions located near to other bodies, such as the Moon, were also tested and similar results were found as shown in Figure 2.b and 15.b, 15.c, 16.a and 16.b. What was found was that day 0 was typically located on or near the low of the ten preceding and following days, or much of the entire 21-day period was below the mean.

As this study finds that proximity of Saturn to the Earth, and also positioning at right angles to the poles, correlates with a stronger temperature signal, it is hypothesized that an atmospheric tide is the mechanism behind the phenomena. Gravitational tides from the Moon are known and there is both a gravitational and thermal tide from the Sun that moves the atmosphere. It follows that a tidal force on the atmosphere causes a bulging near the equator and compression at the poles, which then forces cold polar air southward. This movement of polar air masses to the south is conditioned by land mass, more of which exists in the Northern Hemisphere, and tests of Sun-Saturn alignments appear to be more pronounced and consistent in some locations and not so in others. Maritime conditions tend to distort the pattern and as shown in certain Northern Hemisphere datasets and especially those in the Southern Hemisphere where there is little land mass.

The gravitational force of solar system bodies on the atmosphere can be calculated. Using the formula $F = G\, m_1 m_2 / d^2$, the gravitational forces expressed in Newtons between the Sun, Moon and Saturn, and the estimated mass of the Earth's atmosphere, are listed in the table below.

Table 5. Gravitational Forces on the Earth's Atmosphere.

Object	Mass in kilograms	avg. distance from Earth
Earth's atmosphere	5×10^{18}	
Moon	7.36×10^{22}	3.84×10^{8} meters
Sun	1.99×10^{30}	1.5×10^{11} meters
Saturn	5.6851×10^{26}	1.427×10^{12} meters

Sun and Earth's atmosphere = 3×10^{16} N
Moon and Earth's atmosphere = 1.65×10^{14} N
Saturn and Earth's atmosphere = 9.3×10^{10} N
Saturn at apogee = 6.89×10^{10}
Saturn at perigee = 1.33×10^{11}

It can be seen that the actual gravitational force of the planet Saturn on the Earth's atmosphere is weaker by four and six orders of magnitude compared to that of the Moon and Sun, respectively, even when the planet is at perigee. Many of the tests done in this study were of alignments occurring near the equinoxes where tidal forces would presumably lower the height of polar air, bringing colder air toward lower latitudes (see diagram below) and two tests of 500 mb height confirmed that the temperature signal is also found well above the surface. If there is such a tidal effect from this alignment to the Earth's atmosphere, then some amplification of the signal by resonance such as that proposed by Seymour may be occurring. Tides in the Sun's atmosphere driven by planetary gravitational fields have been proposed and it is possible that the tests performed in this study may be evidence of a similar terrestrial effect.[142] If there is a gravitational factor behind the cooling trend at the time of Sun-Saturn oppositions, then it follows that a similar trend may also occur at the time of the full Moon. Several tests in regions where Sun-Saturn oppositions showed a strong correlation with a cold trend did not show a similar response to full Moons, however. This may be due to the rapid motion of the Moon and that the opposition alignment with the Sun is relatively brief in comparison with the Sun-Saturn opposition.

Summary of observations:

1. The hypothesis that any effects should occur when Saturn is nearest to Earth, involved with other bodies, or aligned with the equinoxes and therefore at right angles to the poles appears to be supported.

2. In the case of the opposition in northeastern US, the effect appears to occur on day -1. Traditional astrometeorological rules sometimes stress that forming aspects (applying) are more pronounced than those that are separating.

3. Involvement with other bodies, such as the Moon, was tested and similar results were found In all cases some indication that day 0 was either a focal point of a low or much of the period was below the mean.

4. Many of the tests of alignments occurring near the equinoxes appear to document a cooling trend focused on or near day 0. It is at the equinoxes, zero declination, where tidal forces would presumably lower the height of polar air, bringing colder air toward lower latitudes. Two tests of 500 mb height replicated the pattern on the ground.

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[142] Seymour, Willmott, and Turner (1992).

5. The correlations, excepting the cases where two or more conditions in the hypothesis are met, are not statistically significant using the standard deviation from the mean. However, they are visible in the "noise" in a way that is consistent with the hypothesis.

The tests performed in this study were designed to isolate a single component of a complex methodology. The opinion of those who have worked with astrometeorology, including Kepler and Goad, is that this cannot be done – meteorological correlates with planets are thought to be a result of many interactive factors. Further testing will need to take this system-like situation into account if anything practical is to be accomplished in studies of astrometeorology. The evidence for a tidal effect from Saturn produced in this study is therefore intriguing but not conclusive. In addition to the complexity of the system being measured, there is much noise in the actual data itself. The methodology developed here, that is the use of a focal point day (aspect day 0), allows the aspect under study to be separated from the changing planetary context in which it occurs, and in many cases a consistent signal, albeit weak, is detected. Control samples do not reveal such a regular signal. Should it be conclusively found that there is indeed a planetary effect on the Earth's atmosphere through further correlative studies, or by direct measurement of an atmospheric tide, the implications are substantial for the meteorological establishments. In addition, there may be applications to climatology as outlined in Section IV.

This study of a possible effect on the Earth's weather from an outer planet raises a number of issues, especially the centuries-old dismissal of the Western astrometeorological tradition. Geoscientists and historians, should examine astrometeorological treatises from both a practical and historical perspective. The subject matter itself may be placed in the same category as orbital variations, solar cycles and cosmic ray flux levels – geocosmic influences on the Earth system.

The findings of this study may be of use in modern meteorology. Knowledge of Sun-Saturn alignments, in combination with modern meteorological data, could improve forecasting, both short and long range. Further studies of other traditional astrometeorological techniques may broaden this approach. Satellite data would also be useful for further studies as would longer datasets and cross-comparisons in tracking air mass movements, presumably by tidal effects. Longer range datasets would also allow for investigating recurrent alignments of planets, especially conjunctions and oppositions of the larger planets, which may turn out to be modulating factors in climate studies.

CHAPTER 3

THE DECLINE AND MARGINALIZATION OF ASTROLOGY

In Section I the history of natural astrology, specifically astrometeorology, was traced from its origins in Mesopotamia to the 17th century efforts of Kepler and Goad to reform and test it using the methodologies of the new experimental science. The effort to modernize astrology in general failed both technically and socially and the subject was soon abandoned by those who developed the new scientific methods. By the end of the 17th century even astrometeorology was practiced by very few in the experimental science community, although it survived in the popular almanacs. The causes behind this transition were complex and natural astrology's decline was interwoven with the fate of judicial astrology – most practitioners of astrometeorology did not limit their interests to that branch of the subject alone. For this reason, Section III considers the decline and marginalization of all branches of astrology and far more attention will be given to judicial astrology and the response it generated in society than was given in Section I. When the term "astrology" is used in this section, it will therefore refer to the following branches of astrology: natural (weather, agricultural), judicial (natal, horary, elections, etc.), and medical. Also, those who developed and practiced what eventually came to be called science will be referred to in this section as either natural philosophers, which is what they called themselves, or experimental scientists.

What was it that happened between 1500 and 1700 that resulted in the near extinguishing of a subject that, while always controversial to some extent, has an impressive historical pedigree? There was, of course, the rise of formalized experimental science which came to exclude astrology. Conflicts with organized religion were continuous and discouraging. Economic and social factors, including the rapid growth of capitalism, climate change and resource depletion, and the rise of a middle class, shaped the period in many ways and changed the type of knowledge valued. My approach, primarily a review of secondary literature, is to organize the historical material relevant to understanding this transition into general categories – intellectual, religious, economic and social. This should provide a stable foundation on which an understanding of a multi-level situation like the decline of astrology might be placed.

History is a complex process, no less complex than that displayed in a geological section that reveals deposition, intrusion, folding and faulting, and also indications of missing pieces. Like the geological section, understanding the downfall of astrology requires an analysis of primary data followed by informed speculation where data is scarce, distorted or nonexistent. Unlike most geological data which can quantified, historical data requires interpretation. An understanding of history beyond a mere collection of facts and dates may be enhanced though the use of a broad perspective or framework that places both solid and missing data in an arrangement that appears meaningful. This approach can also be misleading though and, in the final analysis, a long list of uncontradicted facts are what validates an explanation – or explanations. If nothing else, this section of the thesis offers several ways of thinking about the problem which, hopefully, are informative without being overly general. I begin with the perspective that views the scientific revolution as a triumph over a static past, a turning point on the way to modern times.

3.1 The Progressive Explanation

The view of the scientific revolution as a singular progressive historical event is a common interpretation propagated by both those who lived during the 17th century and also by many modern historians.[143] The event is seen as a major turning point in European history – the shift to modernity after two earlier historical periods that are generally called ancient and medieval. This perspective was also held by many of the founders of modern science themselves and they expressed it by the use of the word "new" in titles of publications such as those by Bacon (*New Organon, New Atlantis*), Kepler (*New Astronomy*) and Galileo (*Two New Sciences*). For them, the scientific revolution was a time of rejection of ancient authorities and the birthing of an entirely new world view. An explanation of the decline of astrology is neatly found in this progressive explanation – the authorities that supported the astrological world view were found to be wrong, and their downfall took astrology with them.[144] The story goes like this:

The Aristotelian model of the universe had provided a causal explanation for astrological planetary effects in (1) the notion of distinct crystalline spheres, each containing specific celestial

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143 Butterfield, *The Origins of Modern Science 1300-1800,* (1957), in particular, has articulated the view that the scientific revolution destroyed astrology, though it is also found in Thorndike, (1923) and Thomas, (1971), among others.

144 For a summary account of the downfall of Aristotle and Ptolemy see Butterfield (1957) 67-88, and Thomas (1971) 349-350, 643.

phenomena, including the planets used in astrology, and (2) in the idea of motion having a "natural" direction towards the Earth's center.[145] Assuming a loosely interpreted Aristotelian view, it would seem logical that if the planets exerted any powers, these would naturally move down through the spheres in some manner and ultimately be felt on Earth. But during the Renaissance natural events and observations with instruments exposed problems with Aristotle's model. To many observers the comet of 1577 appeared to cut through the supposed solid spheres of the celestial realm. The novae of 1572 and 1604, along with Galileo's reports of sunspots, were further blows to another traditional Aristotelian tenet, the idea of a perfect and changeless universe. Also, the sharp distinction between the superiority of the stars and planets and the gross physical sublunary world was undermined when Kepler showed that the same laws applied to both regions. The above events conspired toward the distrust of Aristotle and his eventual downfall as an authority on cosmology. One could then argue that the failure to find another causal explanation for astrology led to its own collapse.[146]

In 1543 a heliocentric model of the cosmos was published by Nicolas Copernicus (1473-1543) that contradicted the geocentric model articulated by Ptolemy, the greatest astronomer of the ancient world. During the next 150 years, Ptolemy's astronomical system, set out in his major work the *Almagest*, lost credibility as physical and mathematical evidence, especially from Galileo and Kepler, for the heliocentric model accumulated. Ptolemy, who was also an astrological authority for his highly regarded text book of astrology, the *Tetrabiblos*, became the other great ancient authority to fail and, again, one could argue that astrology failed with him as the timing of the decline of both was more or less coincident. There is thus a common assumption that the Copernican Revolution had a great part in the fall of astrology as the one rose in status at the same time the other declined.[147]

There are, however, two problems here. First, the above account of astrology's decline doesn't consider the nature of astrology itself as a discipline shaped and driven by experience and not theory.[148] Causal explanations were not necessary to make forecasts or answer questions and few

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[145] Aristotle, *Metaphysics*, Book VII, and On Generation and Corruption, 336b.

[146] Kepler did argue for another explanation, one of harmonics and resonance, but this assumed the Earth was a living entity and that notion, described ahead, was discarded in the 17th century.

[147] J.V. Field (1984) 225, has argued that this factor in the decline cannot be underestimated.

[148] In this sense astrology was not a branch of natural philosophy, nor was it astronomy, which was regarded as a branch of mathematics. Astrology is so unique that it should be placed in its own category. Kepler was unique as he could be considered to have been identified with all three subjects throughout his entire career.

astrologers cared to say anything more than that astrology worked by occult forces. Heliocentricity was not something attacked by astrologers. In fact some very influential 16th century astrologers were open to, and even promoted, heliocentrism.[149] From the astrological point of view, heliocentricity, or any other solar system theory for that matter, was not a threatening theoretical problem. In astrology, there is far more concern with the exact location of a planet or body in the sky and far less with theories explaining why it is there when it is. If the Copernican model was able to produce better planetary tables, then so much the better. One could argue that it was the concern of astrologers for more accurate tables of planetary positions, part of a general reform movement in astrology, that actually drove the astronomical work that was central to the scientific revolution. It is true that much of this work was done by Tycho Brahe and Kepler, both of whom practiced astrology. It appears then that Ptolemy's astronomical model mattered little to those who actually did astrology and Aristotle's theory, while explanatory, was likewise unnecessary. Astrology is, for the most part, a practical discipline based on experience. While it relies on accurate sky mapping, few astrological authorities have offered explanations, proposed theories, described mechanisms, or speculated on its purpose, the later being left to the philosophers and theologians.

Second, consider the fact that some of the founders of experimental science, the same ones who were eager to overthrow Aristotle and Ptolemy, either practiced, endorsed, reformed or defended astrology during the 17th century. Copernicus certainly knew something about astrology as he was a physician and Rheticus, who brought the work of Copernicus into the world, was a respected astrologer.[150] Bacon called for a reform of the subject, what he called a "sane astrology," that focused for the most part on natural astrology. While he thought judicial astrology was full of superstition, he didn't abandon it entirely and advocated an experimental program that included the planetary aspects and orbital variations that in many ways was similar to what Kepler was doing.[151] Although he was a critic of judicial astrology, Galileo practiced the subject for his wealthy patrons, but he didn't write any books on it. As already noted, Tycho Brahe's effort to better chart the sky was a response to the inadequacy of existing tables available for making

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149 John Dee appears to have been interested in the heliocentric hypothesis as it was consistent with ideas of solar supremacy inherent in Hermeticism (which was also true for Copernicus himself). Dee's pupil, Thomas Digges, son of almanac maker Leonarde Digges, was an advocate for Copernicism as he plainly argued for it in his father's almanacs. See Digges, (1605). Most importantly, it was also regarded as an important methodology for calculating planetary positions, which is all that astrologers require from astronomy. Most astrologers were by nature pragmatists and the loss of a mechanism did not affect the practice of the subject in any significant way. See also Goad, (1686) 18.

150 See Kusuwawa, *The Transformation of Natural Philosophy,* (1995) 173 on Copernicus' credibility as an astrologer.

151 Bacon, (1970) 462-465.

horoscopes. Brahe made astrological reports for his patrons and published an astrological prognostication on the comet of 1577. We also know that Kepler was a serious astrologer who was consulted by highly-placed patrons, produced annual almanacs, wrote three books on the subject and included the subject in his major work, the *Harmonics of the World*. The fact that these men, who made truly significant contributions to the scientific revolution, either embraced, proposed reforms, or were open to parts of the subject, raises questions about exactly how and why the downfall took place.

During the 16th century astronomy and astrology, the two being linked for centuries, began to become more sharply distinguished from each other, although natural astrology was often included under astronomy. Even in the early 17th century astrology was still perceived by many as the complement to astronomy and was embraced by leading experimental scientists as we have already seen. But astronomy changed radically while astrology remained the same. The instrumentation (telescopes) and mathematical modeling (Kepler's laws) that developed during this century accelerated astronomical knowledge, but had no real effect on astrology which persisted in a practical form that had changed very little over the preceding centuries. There were attempts to reform astrology as a discipline, but in the end these were unsuccessful.[152] It appears that astrology was never disproven, it was either a subject that could not be easily modernized, or its functions and general domain became irrelevant to the new type of scientist in the 17th century – or both. Given the above, a case could then be made that astrology simply did not change with the times and failed to provide what was sought after, and as a result was left behind.

The progressive argument goes further. It takes the present as its reference point and assumes the criteria of modern scientific theory and the data produced by its own methods to be necessary and sufficient in accounting for the failure of astrology to become a science like astronomy, physics, chemistry, etc. From this modern perspective, it is then the lack of proof, along with the lack of a satisfactory mechanistic explanation, of exactly how the planets affect the Earth that caused the rejection of astrology by the evolving experimental scientific community during the 17th century. In other words, if the alleged planetary effects central to astrology were not measurable, then they must be false, a figment of the imagination of men for millennia. This view is reflected in the

[152] In the later part of the 17th century some attempts at creating a heliocentric astrology were attempted, but these failed. These attempts seem desperate, as if it was a case of too little, too late, but they were not adopted by other astrologers probably for the reason that they didn't work very well in practice. Childrey, *Indago Astrologica,* (1652) and Hunt, *Demonstration of Astrology,* (1696) are examples.

histories written on the subject.[153] After four decades of careful investigation on my part, and that of many others, this doesn't seem to be the case at all, but there exists a bias or a tacit assumption on the part of many scientists and science popularizers in regard to the validity of astrology that, I would argue, distorts any real discussion. This assumption crosses academic boundaries. The mere fact that for many years, and even today, historians of science have regarded astrology in the 20th century has having nothing of value in the assembly of a historical analysis of the subject, reflects the underlying reality that the progressive explanation lives on to a large extent and that reputations trump truth (what else is new?), as few will take on the job of assessing the situation fairly.[154] If the patient is declared dead, then its continuing existence is a problem and ignoring it may be a good option.

3.2 Renaissance Naturalism

The term "scientific revolution" could be used to describe a progression of changing interests and goals among the makers of knowledge in regard to the various Renaissance philosophies of nature (here collectively referred to as Renaissance naturalism) and the mechanical philosophies of the 16th and 17th centuries.[155] This revolution, in which Renaissance naturalism was trumped by mechanical philosophy, is often located in time between the major publications of Copernicus and Newton (1543 to 1686), which is again, more or less, the period during which astrology declined. It would appear that a discussion of these philosophies of nature is necessary in order to better understand the problem raised and discussed in this section. A number of reasons have been proposed to explain the transition between world views. Again, science historians most

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[153] Many influential historians and science writers have dismissed astrology as either irrelevant or so wrong-headed that it can hardly be taken seriously. Dampier, *A History of Science,* (1943) 89, states that astrology was a dangerous foe to modern science and the subject is not even mentioned in Crombie, *Medieval and Early Modern Science, Volume II,* (1959) and Burtt, *The Metaphysical Foundations of Modern Science,* (1954). Butterfield (1957) 47, offers a backhanded putdown of the subject and Shumaker, *The Occult Sciences in the Renaissance,* (1972) 54, rejects it outright. In the latter's discussion, p. 13 ff., astrology is presented as dishonest and impossible, which, as presented, it seems to be in the context of reductionist, scientific materialism. In reaching this conclusion Shumaker refers to a particular weak, and certainly inadequate, collection of modern sources. But this scarcely scrapes the surface of this deep-seated bias. See Valerie Vaughan's introductory chapter to Kepler's *Tertius Interveniens,* (2007) in which she savagely exposes many other presumably respectable scholars and science writers who have made bold but ignorant pronouncements on the subject of astrology.

[154] In 1990 I approached a history of science professor at the University of Massachusetts and inquired as to the possibility of developing a graduate program for myself focusing on the history of astrology. He immediately dismissed the suggestion and said it would be the "kiss of death" to his career and mine.

[155] Shapin, *The Scientific Revolution,* (1996) argues that there really isn't such a thing as a scientific revolution, just a range of stories, each focusing on its particular interests. Regarding Renaissance naturalism, that term refers to a wide group of related philosophies of nature including Neoplatonism, Hermeticism, Cabalism, etc. to be distinguished from Scholastic philosophy and mechanical philosophies.

often cite Copernicus as a powerful force for change, because his ideas eventually led to the overthrowing of the Ptolemaic model of the solar system and the worldviews associated with astrology. But, as previously noted, heliocentrism, which Copernicus himself saw as consistent with Hermeticism, meant little to practicing astrologers. The situation appears to have been more complex.

The historical change called the scientific revolution is sometimes divided into two stages. In the late 15th and 16th centuries natural philosophy (which ,since the 12th and 13th centuries, was based almost entirely on Aristotle's writings) became influenced by a revival of Neoplatonism, Hermeticism and other similar philosophies from the ancient Greek and Latin world. Many texts, never before seen in Western Europe, were translated and studied by humanists and, to a large extent, these texts presented the world of nature as a self-sufficient living organism animated by a world soul. This view, in sharp contrast with the prevailing Christian ideas on nature, even had its own kind of evidence, coming mostly from astrology. The Stoic concept of sympathy, central to astrology, alchemy, and natural magic, described the interconnectedness of the world through the doctrine of signatures, a kind of symbolic taxonomy in which a host of widely differing objects, organisms and processes operated within distinctive domains. The domains were designated by the planets, Sun and Moon, and the workings of astrology throughout all of nature, i.e. weather, agriculture, medicine, and human life, in the context of these domains was sufficient proof of this ancient world view for many intellectuals of the time. These metaphysical holistic and organic views that were held by well-known Renaissance intellectuals like Cardano, Dee and Bruno, form the basis of what is generally referred to as Renaissance Naturalism.[156]

Renaissance naturalism could be said to have been a loose composite of several holistic philosophies, all of which had roots in the ancient Greek, Hellenistic and Latin worlds.[157] These ancient views of nature took for granted that the world, in fact the entire universe, is one enormous organic entity, the "anima mundi," composed of many parts that communicate with

[156] It is important to understand that astrology was immediately relevant to alchemy and natural magic as it informed and structured their activities in the way that mathematics today informs and structures physics, astronomy, chemistry, and other sciences. Thorndike, "The True Place of Astrology in the History of Science," in *Isis,* (1955) goes as far as saying astrology was the first universal law, one that applied mathematics to natural phenomena and was only replaced by Newton's laws.
[157] I define holism as any philosophy that conceptualizes individual parts as existing within the context of a larger whole, or the theory that regards natural phenomena not as assemblages of discrete units, but as components of larger systems (wholes) that give rise to emergent properties (not necessarily vitalistic) that are not predicted by the units. Organic and systems theories are holistic, as is Neoplatonism. See Smuts, *Holism and Evolution,* (1926).

each other. This animistic view underlies nearly all of Greek philosophy especially that of the pre-Socratics, Plato, and the Stoics, and even more the later syncretic philosophies Hermeticism and Neoplatonism. All of these were powerful influences on Renaissance thinking and it was in the context of these holistic worldviews that astrology became so accepted. The following is a brief survey of these views beginning with the first philosopher-scientists.

The pre-Socratic Ionian philosophers, Thales, Anaximander, and Anaximenes lived during the 6th century BCE and were clearly the first proto-scientists. They not only investigated the world systematically, but they offered explanations for the phenomena they observed. Their tool was the intellect and their results were theories about nature that later philosophers referred to. These early natural philosophers, called hylozoists or animists, regarded the world as an organism, specifically an animal, a view that was not radical for the time as it was a fundamental belief in ancient Greek culture.[158]

Plato (429-347 B.C.) is best known for his theory of forms which stated that nature is constantly striving towards ideal structures that exist in a realm somewhere behind appearances. Plato's philosophy is known as rationalism, in reference to the mind as the means by which reality is apprehended. Plato didn't reject the ancient Greek notions of a living cosmos. His writings, particularly in the dialogue Timaeus, the only dialogue known to the Medieval world, described the world in holistic terms, as a living entity with intelligence.[159] His notion of the world soul, or anima mundi, had a great influence on thinkers for millennia.

Stoicism, founded in 300 B.C. in Greece by Zeno (c. 336-263 B.C.), was a widely-embraced philosophical tradition that evolved into a rigorous intellectual system by appropriating a range of ideas, many drawn from other philosophical knowledge traditions. It had a wide influence for at least 500 years and it evolved over this period, synthesizing and extending its doctrines and adapting and contributing to intellectual developments in the Greek and Roman worlds. It appealed to the educated in all classes and occupied a respectable position in Roman society. The Stoics taught that the cosmos, that is the orderly, physical universe, was a living, intelligent being, not unlike an organism. In the context of astrology and four element theory, the animating principle behind nature was associated with the element fire, thought to be the vital force of the

158 Collingwood, *The Idea of Nature*, (1960) 32, 95.
159 Plato, *Collected Works*, (1961), *Timaeus*: 30.d

universe. Stoic natural philosophy was not at all like rationalism and differed from Plato's view of ideal, transcendent forms. It was more a materialistic vitalism or "cosmobiology." The Stoics saw nature as more than simply the sum of many disconnected parts and they developed concepts like “sympathy” to explain the interconnectedness of phenomena – this being the rationale for astrology, a subject most Stoics embraced. Unfortunately, Stoic natural philosophy was not compatible with Christian views on nature and, due to the exercising of the Church's power of censorship, few Stoic writings have survived.[160]

Hermeticism was a mixture of Platonic, Stoic, Babylonian, Jewish, Gnostic, and Persian ideas that arose in Greek Alexandria around the 2nd century B.C. It’s origin was attributed to the ancient Egyptian god Thoth, the god of time-measurement, astronomy, and all the arts and sciences that depended on writing including astrology, medicine and alchemy. The Greeks in Egypt used the name of their god of writing, Hermes, in reference to this tradition and the author was credited as Hermes Trismegistus (three times great Hermes). Some key concepts of Hermeticism include the use of astrology as a means of acting on the world, the anima mundi, and the Sun as the center of the cosmos. Hermeticism involved the seeking of knowledge through the use of alternatives to reason including the Jewish Cabala as a model of the universe and the intuitive recognition of resemblances and correspondences in nature – the sympathies of the Stoics and the basis of sympathetic magic – which gave the world an interconnectedness with living properties. In many respects Hermeticism was more than an eclectic philosophy, it was a kind of personal religion, a factor that put it in conflict with the Church. It called for an intuitive, mystical and imaginative approach through which an individual could seek illumination and ascend toward the divine source of existence without the aid of any religious tradition or institution. Further, man could become like God through knowledge. Hermeticism had a particularly strong influence on Renaissance thought. Because of its reputation as being of immense antiquity, Marsilio Ficino was ordered by Cosmo de’ Medici to translate the Hermetic Corpus before he began work on the dialogues of Plato.[161]

Neoplatonism, built on Plato’s Timaeus and further developed by Plotinus and others, was the last school of ancient pagan philosophy and one that was sometimes blended with Christianity. The central doctrine was monotheistic, the idea of emanation from the one source, God, which

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[160] See Hahm (1977) 136 ff. and also Sandbach (1975).

[161] See Thorndike (1923) Vol. I, 287 ff., Yates Giordano Bruno *and the Hermetic Tradition*, (1964) 20 ff.

then gives rise to all cosmic forms. The cosmos itself was seen as an organic unity in which each part has a sympathetic relation to the rest, a view supported by the doctrine of correspondences thought to be clearly demonstrated by the efficacy of astrology. In Neoplatonism matter and spirit are not quite separate realms, and the cosmos is seen as being inhabited by a hierarchy of spirits that are passed by the soul along its ascent to God, the One. As with Hermeticism, notions of unity through interconnectedness of the cosmos supported magical ideas such as the possibility of divination, the power of colors, letters, and numbers and the influence of the imagination on the body.[162]

The cosmologies of the ancient world cited above had many similarities, especially in regard to the living Earth, or anima mundi, and in regard to the role of astrology in structuring the flow of time and linking natural phenomena. Together, especially Neoplatonism and Hermeticism in various proportions, they informed Renaissance naturalism and offered an alternate source of spiritual authority – and also spiritual autonomy. Christian metaphysics, if one could say there is such a thing, did not offer this level of philosophical organization and Christianity by itself did not contain enough natural philosophy to sustain a coherent view of nature. Aristotelianism had filled this gap.

Aristotle (384-322), Plato's successor, was well known to the medieval world (more so after the 12th and 13th centuries) when his philosophy was synthesized with Christian ideas by Albertus Magnus, Thomas Aquinas and others to form the core of Scholasticism and medieval theology. Aristotle thought that nature has a tendency to change in very definite ways and that inherent in nature are processes of becoming and stages of development, i.e. the growth of a seed into a mature plant. Therefore something internal to an organism, that is something animating, must be directing such changes. This view has teleological implications and, further, implies some kind of non-material causes. For Aristotle, this something inside would be the soul, for lack of a better word, which wants and desires to attain a definite form. The form is thus the goal, implying a certain direction and purpose, and this view then leads to a theory of final causes. It was this Aristotelian teleological view that was a target of attacks by Bacon, Descartes and others.[163]

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[162] Plotinus, *Enneads*, V1.ii: 63, in Gregory, *The Neoplatonists: A Reader,* (1991). It should also be noted that the "New Age" movement of the past three decades, which promotes positive thinking, dreamwork, symbolism, ritual and various kinds of natural healing is essentially a resurfacing of Hermeticism and Neoplatonism in addition to some Eastern religious ideas.

[163] Collingwood, (1960) 93, See also Copleston, *A History of Philosophy, Volume I, Parts I and II Greece and Rome,* (1962) and Osler, *Rethinking the Scientific Revolution,* (2000).

By the Middle Ages, European intellectuals had come to embrace a synthesis of Aristotelian and Christian ideas. This synthesis, originally based on a limited number of Christian and Aristotelian texts, was disrupted from the 12th through the 15th centuries when copies of previously unknown Greek and Roman manuscripts entered Europe from Arab lands. These introduced what was described above – Platonism, Neoplatonism, Stoicism and Hermeticism, and most of Aristotle, all of which either located or accommodated astrology within its system, and all of which promoted a view of the Earth as a living entity. A key work that articulated a version of this general world view was the supposed writings of the ancient Egyptian god Thoth or "Hermes Trismegistus," the *Corpus Hermeticum*. This text influenced many Renaissance intellectuals and natural philosophers including Marsilio Ficino, John Dee, Giordano Bruno, and William Gilbert, whose doctrine of magnets presented a quasi-mechanistic view that the world was alive.

By the middle of the 16th century the influx of ancient writings had become so influential that many leading thinkers had become fully grounded in an astrologically-structured holistic worldview and few challenged the notion that the Earth was a living entity. Individuals drew from the several ancient philosophies and it is difficult to say whether someone like Bruno was a Hermeticist, a Neoplatonist, a Stoic or, more probably, a mixture of all of them as the doctrines tend to overlap to a large extent.[164] These rediscovered philosophies share much in common, and most importantly, they were holistic in outlook. They taught understanding through a subjective, wide-angle kind of knowledge. Taken loosely together as Renaissance naturalism they constituted a major intellectual force that opposed Christian monotheistic thought – like it did a thousand years before as found in the writings of Augustine. These opposing views, Christian and ancient holism, are extremely difficult to reconcile, though exactly that problem seemed to be the agenda of people like Dee and Bruno. But neither they nor others were successful as institutionalized religion, which was deeply entrenched in the culture, had more social power.

The French historian/philosopher Michel Foucault described the general mind-set of Renaissance naturalism as one built on an episteme of resemblances, an episteme being a world view, the epistemological field in which knowledge conditions history. Inside the system, knowledge consists of knowing how things were related, similar or analogous. The perceived connections between things, in various types of similarity within the episteme, he view as a closed-loop, an all-constraining preconceptual grid that had to be broken out of in order for the modern world to

[164] Yates (1964) 250-251.

come into being.[165] Foucault has been criticized for basing his socio-archaeological model on the assumption that Neoplatonic/Hermetic thought was typical of the Renaissance, which it may not have been. It can be argued that Aristotelianism was a more dominant influence and that the continuation of scholasticism made it impossible to separate philosophical and religious issues.[166] But it is true that many of the early experimental scientists were familiar with Neoplatonic/Hermetic thinking. Building a historical argument for the scientific revolution entirely on a change of mindset as modeled by Foucault has some merit, but my impression of Foucault is that of an extreme rationalist unable to actually enter the world of Renaissance naturalism and therefore limited in his ability to map it, and he only confuses the matter (though perhaps he reads better in the French). Further, the presumed constraints of the episteme of resemblances, which I associate with the concepts of sympathy and the doctrine of signatures, was probably not as limiting as Foucault makes it out to be. There were probably many people who could successfully navigate more than one world – as there are today.

Frances Yates argued that Renaissance naturalism encouraged a manipulative orientation toward the world. An extension of the concept of sympathy led to the notion that humans could use the "energies" of the planets to influence the things and processes under each planetary domain. It was this instrumental approach that lay at the heart of alchemy and natural magic, and also the branch of astrology called elections in which specific times were chosen for actions to be more effective. Within the framework of these activities a new kind of scientific practitioner arose – the Renaissance magus – a category that included personages like Ficino, Agrippa, Patrizi, Dee, Bruno, Campanella and Fludd, all of whom were among the most learned men of their time.[167] These men were deeply involved with metaphysical, philosophical, scientific and technical knowledge in the context of Neoplatonism and Hermeticism, had an experimental attitude toward their work and, through the use of sympathetic magic and the techniques of alchemy and astrology, they sought to control nature. In contrast with the elitist book learning of Scholasticism, the Renaissance magus intended to act on nature and was comfortable with the hands-on world of technology. In this sense, the role of the magus can be seen as a matrix for the modern scientist – a role in which practitioners use tools and equipment to measure and harness

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[165] Foucault, *The Order of Things,* (1970) 17 ff.
[166] See Maclean, "Foucault's Renaissance Episteme Reassessed: An Aristotelian Counterblast." *Journal of the History of Ideas,* (1998) who also argues that Foucault's episteme is not so all-constraining. See also Cassier, *The Individual and the Cosmos in Renaissance Philosophy,* (1963) 3.
[167] They also had many opponents, however, which underscores the point that not everyone at the time was in agreement with Renaissance Naturalism.

nature. Yates argued that science adopted the epistemological framework of the technical trades and the Hermetic/Neoplatonic traditions, both being active ways of addressing the natural world and controlling the environment, and the 16th century Renaissance magus was a prototype for the experimental scientist of the 17th century. This view makes sense when considering that alchemy is an activity that requires tools and apparatus, the prerequisites for laboratory work, and astrology requires accurate astronomical data, hence the quest for better models of solar system dynamics. Take away the Hermetic and Neoplatonic metaphysical philosophy behind alchemy and astrology and they both look very scientific.[168]

In the Hermetic/Neoplatonic traditions of Renaissance naturalism the components within the cosmic system were thought to communicate in some way with each other. It does appear that the forces or processes connecting (i.e. in communication) the parts of the Earth and cosmos became the targets for discovery for natural philosophers like Gilbert and Kepler. Both attempted to map out these connections through close observation, experiments and mathematical modeling. In doing so, both Gilbert and Kepler replaced the loosely defined vital energies of the anima mundi with more or less mechanical ones in their work, although they may not have intended to. For example, in the early 17th century Kepler saw the Earth as alive, the proof of this for him being the efficacy of astrology.[169] He argued that the planetary aspects, the angular separations between the planets viewed geocentrically, produced a kind of mathematical harmony to which the Earth resonated. It had to be alive if it could hear this harmony, and the fact that weather patterns and human behavior corresponded with the changing aspects was proof enough for him. In seeking to describe this phenomena, Kepler uncovered the mathematical order of the planetary orbits, which he regarded as a sign of intelligence behind nature (intelligent design). This discovery ultimately led in Newton's work to a mechanical view of planetary motions that caused nothing on the Earth.[170] In this way also, Renaissance naturalism stimulated the careful investigation of nature that was such a central part of experimental science.

In the first decades of the 17th century, at about the same time that Kepler was working on the orbits of the planets, the second phase of the scientific revolution began and the transition to a mechanical philosophy accelerated. Atomism was an ancient philosophy, not holistic like the

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[168] See Yates (1964) 155-156 and Berman, *Reenchantment of the World*, (1981) 99 ff.
[169] See Kepler's, *Harmonics of the World*, Book IV, and also *De Fundamentis.*
[170] With the exception of the tides, a topic traditionally considered astrological and debated for much of the 17th century.

others previously described, that played an important role at this time. First described by the Greek Democritus and elaborated on by the Romans Epicurus and Lucretius, atomism viewed the world as being composed of discrete material elemental particles in motion. Attention to this theory was given by Bacon and Galileo who leaned toward it as a way to explain elemental state changes (solid to liquid to gas) and how the senses are impacted by objects. Gassendi (1592-1655) was more forthright in restoring atomism and did so in a way that was complimentary to Christianity. Atomism is a view with an ancient pedigree that reduces nature to minute pieces of matter in motion that works well with a mechanical explanation of phenomena.

In England, Francis Bacon (1561-1626) laid out a program for doing practical science that rejected Aristotle. In his criticism of Aristotle's empiricism he argued that the method did not express any real, useful insight into things as it uses artificial constructs of logic. However, in line with Aristotle's empiricism in which sense data is crucial to understanding, Bacon argued that nature must subjected to an experimental method, quantified, and be forced to give up its secrets. For Bacon, nature is there to be mastered and used, a view that conveniently facilitates capitalism, an economic system that grew along with experimental science.

At more or less the same time in France, Rene Descartes (1596-1650) argued that nature was just a machine, separate from humans, that exists to be measured and used. Descartes was a rationalist, in the tradition of Plato, who saw mind as the tool that led to truth and apprehension of reality. In his view, the mind must be skeptical so that it can first eliminate uncertain beliefs and thus be capable of finding truth. Then, having arrived in the realm of the mind where truth resides, Descartes argued that mathematics, as taught by Plato (and Pythagoras), is the most solid platform on which to build a philosophy of nature as it allows for a kind of certainty not found in other approaches to knowledge. This practice of placing data in a mathematical context continues to be a central tenet of modern science. But while Descartes built his case for the creation of a mathematically-structured mechanical philosophy, he became stuck at the problem of mind and how it related to the objective world. His legacy of dualism is modern science's problem also. In mechanical philosophy the mind is separate from the world, in contrast to Hermeticism, Neoplatonism, etc., in which mind connects and participates with the world.

In Italy, Galileo's (1564-1642) experiments with motion pushed further the conclusion that truth in nature is to be found in mathematical facts, that is the "Book of Nature" could be de-coded by mathematics. Galileo, more than anyone else, put mathematics and experiment into one package. With his gravity-physics experiments in which motion is quantified by mathematical formulae, Galileo established the archetype of the modern scientific method, at least for the "hard" sciences. In experiments he showed that quantity could be measured and that nature could be mastered by taking parts of it out of context and placing it in a study situation. Galileo brought Bacon and Descartes together in a philosophical view of nature that is manipulative, technical, reductionist and one in which quantity trumps quality.

Bacon, Descartes and Galileo had no time for holistic systems that delivered only subjective knowledge, and by the end of the 17th century the astrological and magical traditions central to Renaissance holism had been abandoned, defeated or replaced.[171] During the 18th century nearly all leading natural philosophers came to adopt a reductionist-mechanistic view of nature which had proven itself with its predictive power and was better able to adapt itself to Christianity. The reductionist approach to nature was applicable to disciplines like astronomy, physics, ballistics, and chemistry. Other disciplines, like biology and botany, were more Baconian and concerned with accurate and organized documentation. Astrology, which cannot be easily reduced to units, could not be quantified mathematically, and any documentation of its effects were subjective and qualitative. I would argue that these problems, inherent in astrology at that time and as a subject in and of itself, are reasons why it could not be a part of the fundamental reorganization of perspective and method among makers of knowledge during what is called the scientific revolution. Astrology only made sense within the context of Renaissance Naturalism and its fall was coincident with the rejection of holistic philosophies. The question of how and why this occurred is next viewed from a sociological and anthropological perspective.

3.3 Holism vs. Reductionism

By the end of the 17th century the philosophy, the doctrines, and the methods of experimental science were, more or less, in place and natural magic, alchemy and astrology had lost explanatory power – the critical stages of the scientific revolution had occurred. While it would be another century before the experimental program would begin to have an impact on the world

[171] Another factor in the decline of natural magic, at least, and the rise of mechanical philosophy may have been the rise of artificial magic, the creation of automata – wonderful moving devices made by engineers that were both amazing and tangible. See Grafton, *Magic and Technology in Early Modern Europe,* (2002).

outside that of intellectuals, and yet another before it became accepted by the majority, an enormous change had transpired in a relatively short time. Generally speaking, the leading thinkers of the Western world, the makers of knowledge, had shifted from a view of the world in which nature was perceived to be alive, to a view that saw nature as a machine, and also one to be exploited. The larger part of this shift occurred in the period between 1600 and 1650, though change was in the works at least a century before that and the new approach continued to be refined right into the 19th century.

In the discussion so far, the reasons given behind the scientific revolution have been conceptual, a case of a mental change of perspective, at least among those who made knowledge. E.A. Burtt approached the problem in this way by describing the fundamental intellectual developments of the period, they being the key to understanding this kind of historical change.[172] The definition of reality had shifted from that of an interconnected living Earth to a universe of material atoms, and causality from sympathy to bodies in motion. Mind, formerly the means by which humans could interact with the cosmos, became separate from nature and not a subject for scientific study – it was left to philosophy, and dualism had to be accepted.

I think there is some value in moving to very broad frames of reference when considering ideas as historical artifacts.[173] A useful way to understand what happened during the scientific revolution is with a taxonomy of philosophical world views. Those of Plato and Aristotle have already been mentioned, the first two having deep connections with Scholastic philosophy and both having been a source of debate for centuries. But there are ways other than reference to a specific a philosopher to organize philosophical perspectives and various taxonomies of conceptual approaches to nature and existence have been proposed. Groups of thinkers, or even portions of an individual thinker's philosophy have been included in categories such as Idealism (Plato, Descartes, Spinoza), Naturalism (Thales, Democritus, Hobbes), Realism (Aristotle, Aquinas, Locke), Pragmatism (Heraclitus, Bacon, James), Existentialism (Kierkegaard, Sarte) and language analysis (Wittgenstein).[174] Another such system has been proposed by Stephen Pepper who organizes world views into four other general categories: Formism (Plato, Aristotle), Mechanism

[172] Burtt, (1954).
[173] Generalizations are models, not territory, and given the impossibility of knowing anything for sure, they have their uses as long as one does not become too attached to them.
[174] This is the format of Butler, *Four Philosophies*, (1951).

(Democritus, Galileo, Hobbes), Contextualism (James, Bergson) and Organicism (Schelling, Hegel).[175]

In Pepper's model of world hypotheses mechanism and organicism are the fundamental integrative world views and both strive to establish a plan or baseline for reality. Each tend to combine with formism and contexualism, respectively, ultimately reducing all constructive philosophical thought to two general approaches.[176] Pepper describes organicism as a view in which events are best understood in the context of a process. It is a view that emphasizes an organic whole which transcends contradictions in the parts much like the fundamental notions of systems theories. He describes mechanism as the view of the world as a machine where the parts are more important than the whole. Another perspective on such a fundamental dichotomy in world view may be found in the profound differences in thinking between Western European and East Asian peoples. In *The Geography of Thought*, Nisbett presents considerable, historical, sociological and psychological evidence that East Asian thought tends to be field dependent, that is things are perceived in their context, and is essentially holistic. In a social sense, this would emphasize the collective. In contrast, Western European thought tends to be field independent, essentially reductionist and individualist.[177] It appears that Nisbett and Pepper make a case for, in the broadest view, organicism/holism/collective and mechanism/reductionism/individual as the most generalized perspectives that offer descriptions of reality.[178] In regard to the historical theme of this section, consider that the efforts of men like Dee and Bruno were directed towards a reconciliation of scientific and magical world views. Their perceived failure to do so could be

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[175] Pepper, *World Hypotheses*, (1942).
[176] One may argue that doing so discounts many important details, and that may be so. I would argue that to understand world views, one must have a world view that is so broad that it incorporates nearly everything, which, I think, is what thinkers like Pepper and Foucalt have attempted. What is interesting here, is the "reduction" to an either-or situation. This is something that seems to come up in other areas of thought, i.e. the individual vs. the collective, or in political persuasion, i.e. conservative vs. liberal. Such generalized dichotomies (remembering that these are really extreme points along a continuum) may be the product of human brain evolution which has shaped perception – something along the lines of what Kant suggested.
[177] See Nisbett, *The Geography of Thought*, (2004).
[178] Smuts (1926) established the modern definition of holism and contrasted it with mechanism in *Holism and Evolution*. See also Rudhyar, *The Astrology of Personality*, (1936) 46 ff. The connection I see here begins with organicism being defined by Pepper as the "integrative organic process" and holism being a description of a key quality of evolution where an increase of unity occurs as parts are blended. This is a process Lynn Margulis sees as natural on all biological levels. I admit that the application of holistic thinking in my attempt to unify and blend various perspectives into one broad view, which could not be done from a reductionist perspective, is likely to be perceived as resting on questionable foundations and vulnerable to criticism. It is, however, merely intended to be a model or tool appropriate to the problem at hand.

considered evidence of the mutual incompatibility of reductionist and holistic philosophies, at least in terms of what was possible at that time.

3.4 Participating and Non-participating Consciousness

The shift from ancient to experimental science appears to parallel a change in the fundamental conscious orientation of certain types of knowledge makers. The natural philosophers of the ancient world and the Renaissance could be seen as people who functioned within a particular type of consciousness in which humans participate with the world. This, what might be called participatory consciousness, is a state in which a person is not objectified from the environment, but actually joins with it in multiple ways.[179] Participation is self and not-self identified at the moment of experience, mundane examples being moments of artistic creativity, feeling God in nature, and intense love-making. The major "sciences" of the ancient world and the Renaissance, astrology (the branch called elections), alchemy, and natural magic were participatory activities. For example, the astrological practitioner of electional astrology observes both self and nature (the planets) as two ends of an ongoing holistic cosmic process that could be consciously entered and even modulated to some extent using an enlightened free-will. This procedure allows a practitioner to choose precise times to enter the timestream (flow of time) that, based on experience, are thought to be more propitious in achieving specific goals than if entering it at other times. During the Renaissance, the timing of an event like a coronation, the start of a journey or the staging a wedding were frequently based on the configurations of the planets calculated for a future moment. In contrast, non-participatory consciousness, which characterizes the dualism of modern science, separates self and not-self (nature). The scientist observes nature at a distance by breaking it into parts that can be isolated and manipulated. It is possible for a single individual to embrace both perspectives, Kepler and Elias Ashmole, alchemist, astrologer and founding member of the Royal Society, being historic examples.

Morris Berman's anthropological approach to understanding the historical dynamics of the scientific revolution is to view it as a shift from participatory consciousness to non-participatory consciousness focusing on the leading figures of the period and their views.[180] Descartes is often singled out as a crucial contributor, a father of modern science, in part because he so

[179] See Berman, (1981) 69-114. Owen Barfield originally used the term "participating consciousness."
[180] Ibid.

enthusiastically attacked medieval philosophy and argued for a new foundation in scientific thinking. But Bacon is also important. For Bacon, nature is external, but it must be pushed around and shaken in order for knowledge to be generated. With Descartes and Bacon we see different types of non-participatory consciousness. In Cartesian dualism the mind is a tool and everything out there in the world can only be known for certain through the use of mathematics. For Bacon, nature must be manipulated, that is taken out of its natural context, in order to be known. The important point is that, in both cases, humans are clearly separate from nature.

What appears to have happened in the early 17th century was the realization that rationalism and empiricism (Plato and Aristotle, Descartes and Bacon) are not really incompatible paths and that these views of could be synthesized into an objective and reductionist philosophy. In Galileo this all comes together in his mathematical modeling of motion through carefully designed experiments in which natural behaviors are isolated. One result of this shift is that asking "how" becomes the goal of science and "why" is no longer asked. A second result is that teleology is completely denied and the world, i.e. the Book of Nature, becomes an object for humans to study and use. This approach was actually more compatible with religion as it eliminated the need to interpret nature. Understanding "how" does not say anything about God's intentions, which are to be found in the Bible itself, it is just a way of measuring (and initially appreciating, later using) God's creation.[181] A few decades after Galileo's work, Newton launched a fully-articulated philosophy of nature based on this synthesis of rationalism and empiricism. Weak points in his natural philosophy, such as a precise definition of gravity, he handled by stating that a force like gravity need not be explained if it can be measured. Again, "how" trumps "why." Newton's scientific model became the dominant view for the next two and one-half centuries and was not significantly challenged until the advent of 20th century relativity and quantum mechanics.

The rejection of participating consciousness in Western culture has deep roots that are traceable to the Jews and the Greeks. In Judaism, Yahweh is a god that is not in nature; he is a portable god not linked to any specific sacred site. Knowledge is therefore divorced from place and is something attained though a mind that is separate from nature. This is very different from the pagan view of sacred places and multiple gods and goddesses, and not at all supportive of a living world. In the Greek tradition, especially in Plato, reason and personal identity, the ideal forms and tangible objects in the world also suggests a separation of mind from nature. Contrast this with

[181] Bono, *The Word of God and the Languages of Man. Vol. 1: Ficino to Descartes*, (1995) 193-198.

Hermeticism in which the union of subject and object is the basis of knowledge, or Neoplatonism in which spirit and matter are not so easily distinguished from each other. The great dualistic paradox at the heart of modern science from the 17th century comes down to the relation between the objective and subjective.

It has been an assumption of practitioners of science in modern times that science is value-free and operates on the world in a way that is completely detached from morals. But this assumption is as questionable as the concept of objectivity itself. Scientific detachment leads to positions that are evaluative in their own right.[182] A natural philosophy (science) that is presumed to be objective has this position as a subjective bias, and therefore it does establish values, in this case values that are not holistic, humanistic, or compassionate. The modern scientific judgment of alternate realities and previous world views are examples of this hidden value system in science. When holistic subjects like astrology are judged by modern objectivist terms, they will inevitably appear to be impossible and therefore dismissed without discussion and, it is hoped, cease to exist so that a kind of unity may be achieved.

3.5 Religion and Astrology

Relations between astrology and Christianity were never comfortable. Augustine (354-430) attacked the fatalistic doctrines of judicial astrology arguing that they eliminate the need for God. While he accepted the influence of the Sun and Moon on nature, he didn't see this as necessarily leading to a rule of the stars over human will.[183] The Dominicans Albertus and Aquinas both accepted astrological effects on nature, including the weather, but were critical, though not completely dismissive, of judicial astrology.[184] Both men ascribed precise astrological predictions made by astrologers that were accurate to the workings of demons or the Devil, however. The issue here was really about an exterior/interior distinction. Natural astrology, and also medical astrology which concerns the physical body, could be accepted, but any influence on the inner life that wasn't coming from God was a problem for theologians and clerical authorities that wished to maintain Church control over interior or psychic space. In this regard, a distinction developed

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[182] Shapin (1996) 164.
[183] Augustine, *Confessions,* Book Fifth: 142-151.
[184] This was especially true of Albertus. See Thorndike, *History of Magic and Experimental Sciences*, (1923), vol 2: 585.

by Christian thinkers was that of the planets as signs versus causes. Planets as signs could be understood as having been placed there by God, and this is stated clearly in Genesis. But if the planets were causes, then there was less room for God in a person's life and religion itself could be seen as just one type of social process modulated by the ongoing cycling of planets. But even if the planets were regarded only as signs, predictions made by astrologers could be seen as interference and were open to condemnation and labeling as magic by religious authorities. For astrology this is a lose-lose situation and for religion it is a territorial issue. Guinard argues that confusion between astrology proper and astromancy (astral magic), which has served to sustain a negative reputation among the religious, has been propagated by the enemies of astrology for centuries.[185]

Tensions between religious authorities and practicing astrologers were particularly high from the late 15th century onward, the case of Simon de Phares and the arguments of Pico della Mirandola, both discussed below, illustrate this situation. The founders of the Protestant Reformation were not sympathetic to astrology, though certain individuals were able to reconcile differences.[186] Although the many Protestant sects battled amongst themselves regarding fine points of doctrine, reason was generally regarded as faulty while faith, exercised through the use of the will, was seen as the direct route to God. Martin Luther in particular was anti-intellectual and dismissed Aristotle as a thinker of any real value to a Christian, this distinction marking a clear separation of theology from philosophy.[187] In this atmosphere, astrology was at best highly suspect. The Catholic position became an outright rejection of judicial astrology; in 1586 Sixtus V issued a papal Bull against it. In spite of this authoritative pronouncement, astrology was still so generally accepted that some who were clergy, including Pope Paul III, personally used astrology in its various forms. Another example is Pope Urban VIII who, in an attempt to evade what he believed were dangerous occult influences, was not above requesting the astrological aid of Tommaso Campenalla, himself both a practicing Catholic and intensely interested in natural magic and astrology. This same pope also condemned judicial astrology again in another papal bull in 1631.[188]

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185 See Guinard, *The Manifesto*, (2002) for a discussion on the moral aspects of the conflict over astrology from ancient times through the 17th century.

186 Kepler, who identified himself as a Luthern astrologer, was both deeply Protestant and astrological.

187 Kusukawa, *The Transformation of Natural Philosophy,* (1995) 35

188 See Walker, *Spiritual and Demonic Magic from Ficino to Campanella,* (1958) 205 ff., and Yates, (1964) 375.

In spite of a few references in the Bible, such as God creating lights in the firmament for signs, and the three astrologers following a star to find Jesus, Christianity has consistently viewed astrology as a competitor.[189] Judicial astrology claims to offer not only explanations for individual fortune and the possible meaning of a life, it also offers a way to control or modify the flow of personal time and the path of destiny.[190] Further, an astrologically-informed personal philosophy is a program that eliminates the need for both religious authority and prayer. In response to this perceived usurping of their position, religious thinkers and ecclesiastical authorities have for centuries attacked astrology using mostly versions of the same two arguments. One is that it is not man's place to pry into God's secrets and the other is that the planets cannot over-ride human free-will. Both arguments have a very long history. In regard to the first, St. Paul, in Romans 11:20 (Revised Standard Version) makes a statement about humility – "do not become proud, but stand in awe." There was a persistent tendency to distort this passage into "don't know high things." Although the following passages in Romans continue the theme of warnings against the "intellectual curiosity of heretics," this phrase, *Non altum sapere*, was taken out of context and quoted often as a warning against the illicit knowledge of "higher things."[191] What we have here is the notion that it is forbidden to know divine secrets, a position that preserves existing social and political hierarchies and condemns subversive thinkers.

In regard to the free-will issue, attacks on astrology from religious convictions were intense and sustained and they have to be seen as a major factor in the decline of all forms of astrology, including astrometeorology, itself a case of guilt by association. Judicial astrology had been attacked in Roman times by the Stoic Carneades, by Sextus Empiricus and most importantly by Saint Augustine.[192] But the greatest attack, probably in the entire history of astrology, came from the brilliant humanist Giovanni Pico della Mirandola (1463-1497). Pico, a Renaissance scholar, was originally favorable toward Hermetic and astrological thought but near the end of his life and, apparently driven by religious motives and his position on human dignity, changed his mind about these things and wrote a scathing criticism of astrology.[193] Later writers ascribed this

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[189] Genesis 14, Matthew 2. Magi is often translated as astrologer.

[190] I use the present tense here because the situation is virtually unchanged today – astrology is popular in Western society and still regularly attacked by religious fundamentalists.

[191] See Ginzberg, "Clues, Myths and the Historical Method." In *The High and the Low: The Theme of Forbidden Knowledge in the Sixteenth and Seventeenth Centuries,* (1986) 61, and Thomas, (1971) 358-359.

[192] Carneades was unusual in that the majority of Stoics were strong advocates of astrology. Sextus Empiricus, in *Against the Professors*, Book V, Against the Astrologers (1949) 323-371, argued mostly from the standpoint that measuring the motions of the sky. was impossible. Augustine used arguments of twins and, like Sextus Empiricus, the impossibility of exactly measuring the moving sky.

[193] See Garin, (1976) 83-99, Walker, (1958) 54-59, and Allen, (1964) 19-34.

reversal to the influence of the fanatical religious reformer Savonarola (who also attacked the subject just a few years later) and also to a prediction of his early death by at least one, and possibly three, astrologers.[194]

Pico's attack on astrology, published posthumously in 1497, was comprehensive, twice the size of all his previous writings combined. Titled *Disputationes Adversus Astrologiam*, this work was a long list of arguments against astrology from which, for the next century and a half at least, opponents of astrology borrowed as needed. In the first section, Pico pointed to a select group of ancient authorities that condemned it. He then argued that astrology is uncertain and not useful, and that many of the components of the astrological system, the zodiac and houses, for example, are not of substance. The first 10 sections of the *Disputantiones* describe traditional judicial astrological doctrines and criticize astrology as a science, the last two describe the ways of astrologers and criticize it as an art – all followed by rejection. Pico argued that man has the free-will to change from brute to angel and that he is not controlled by outside forces like planets. He stated, along the lines of Nicolas Cusa (1401-1464), that man contains the whole universe within, but that man has a separate mind, and because of this nothing can control him. He stated that events ordained by God are not effected via the planets, God directs men rather through angels and, further, that prying into God's ways is anyway wrong – astrology interferes with both free-will and God's plan. Here are the same two arguments again, based on unprovable metaphysical and religious concepts, not developed philosophical reasons. The unstated implication in all of it is that astrology may work on some levels – but it is bad for you so stay away from it.

For the most part, Pico's anti-astrology arguments were not entirely original. Thorndike wrote that Pico's presentation is rambling and he is not orderly in his arguments, making them less effective.[195] Walker and Allen suggest that Pico drew much of his material from an unpublished manuscript written by Marsilio Ficino, translator of ancient manuscripts for the academy of Cosmo de Medici.[196] Like Pico, Ficino was strongly influenced by Hermeticism, one of the most urgently translated subjects of this period, and his writings reflect this influence and the conflicts between it and Christian notions. In Ficino's book *De Vita Coelitus Comparanada* (How Life Should Be Arranged According to the Heavens), he wrote about astrology, describing the virtues

[194] Schumacher, (1972) 17, Allen, (1961) 18-35. Pico did die young.
[195] Thorndike, (1923) Vol. IV, 529.
[196] Walker, (1958) 57, Allen, (1961) 4-18.

of the planets, relations with the organs of the body, herbs, amulets, etc. as a knowledgeable physician. However, Ficino was full of what appear to be contradictions and, while he argued against judicial astrology, he also read horoscopes and made predictions. The real problem, and it is the same problem raised by astrology for millennia, is in regard to human free-will. Ficino believed the planets may be signs, but not causes, and at best they only influence matter. But the human mind, or rational soul, however, is free from planetary powers and only God can influence it – free choice is God's great gift to man.[197] Allen considers Pico's attack on astrology essentially a defense of free-will and therefore consistent with Pico's views on the dignity of Man.[198]

It is here, with Ficino and Pico, that the clash between Christianity and astrology became complicated and full of apparent contradictions regarding how much of the later could the former tolerate. Ficino, who translated the Hermetic corpus, was caught between world views. He was completely convinced that astrology "worked" but exactly how was the problem, and he struggled to find a way that was consistent with Hermetic and Neoplatonic explanations and also compatible with Christian doctrines. His defense led him to quote Aquinas, who thought that certain natural substances were able to carry astrological influences, herbs and gems being examples. But Aquinas, like Augustine, also thought that such things could be taken too far and under certain circumstances may attract demons and the Devil.[199] Ficino argued that an individual who is pure and receptive is capable of benefiting from the use of astrological natural magic, but his critics argued that in such situations one was only opening themselves up to bad spirits. Walker summarized the problem as one that required the sorting out of "good" and "bad" astrology, not the complete rejection of the later, and it appears that subtle distinctions such as these, and arguments over who was qualified to make them, continued to be the case for the next century, at least.

To some extent natural astrology fares much better in Pico's *Disputationes Adversus Astrologiam*. While Pico stated that the stars are signs and causes of nothing, he admitted the Sun influences inferior things, but only through light, heat and motion. He thought that the Moon has a similar force as Sun, but less so, which is moisturizing, though the Moon has nothing to do with the tides. He attacked Galen's critical days, but thought that sailors and farmers should pay

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[197] Allen, *The Star-Crossed Renaissance,* (1961) 22.
[198] Ibid.
[199] Walker, (1958) 43.

attention to the phases of the Moon.[200] Cassier argued that Pico's attack on astrology is also a revolution in knowledge in which Pico distinguishes mathematical-physical causality from astrological causality. Pico's rejection of judicial astrology and the acceptance of only tangible forces therefore marks a step in the direction of a modern science of nature and some of his ideas can be found in Kepler's astrological reforms.[201]

Astrologers, a diverse group that included some of the most enlightened and respected men of the age, responded immediately to these broadsides against astrology and offered both apologies and proposals towards the reform of the subject. Giovanni Pontano, one of the greatest poets of his time, a scholar with political interests and insights into social psychology, and also a friend of Pico, argued that Pico's attack was full of errors. Pontano saw astrological influences as factors built into a person's corporeal body that required conscious attention, and the way around these embedded behaviors was to use astrology. Only in this way could one effectively express free-will.[202]

Pico's arguments against astrology should also be seen in the context of the social world he moved in. Astrological practitioners during the last decades of the 15th century in Italy and France produced a steady stream of prognostications propelled by the advent of printing. Conjunctions, such as that of Jupiter and Saturn in 1484, were a focus of published predictions and they drew public attention. Any distinction between prophecy, which could be described as imagination, and prognostication, a careful analysis of astrological data, was blurred. This lack of distinction in effect leveled the playing field between mathematicians who worked out forecasts and anyone who came up with a compelling vision of the future. Pico's arguments may be, as Vanden Brocke suggests, a response to this situation and should be read as a call to reform – he was motivated by the negative social impacts of judicial astrology.[203] This view is supported by the fact that Kepler, perhaps the greatest of astrology's reformers, was to a large extent, in agreement with certain points made by Pico, as were many other leading astrologers.[204] Pico's was only one reaction

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[200] The critical days were based on the quarters of the Moon and were used by doctors well into the 17th century. It was thought that every 7 days from the time a person took to bed due to illness the condition they had would reach some kind of critical point.

[201] See Cassier *The Individual and the Cosmos in Renaissance Philosophy*, (1963).

[202] Allen, (1961) 39.

[203] See Vanden Broecke, (2003).

[204] Rabin, "Kepler's Attitude Toward Pico and the Anti-astrology Polemic." *Renaissance Quarterly,* (1997) 64.

against judicial astrology at this time, another is the near contemporaneous case of Simon de Phares.

In 1490, the physician and perhaps too successful astrologer Simon de Phares was consulted at Lyon by the king of France, Charles VIII, who testified publicly as to his expertise. Simon was quickly condemned and imprisoned by the archiepiscopal court and was forbidden to practice, and was then moved to Paris. While the king was away in Italy and elsewhere, the law court had his books, a collection of about 200, confiscated and submitted to the theologians of the university for inspection. It took until 1494 before they reported on his library and officially condemned eleven books, most of which were standard works on the subject, including some on astrometeorology. Their condemnation was mostly of divinatory astrology, the astrology of precise predictions – a more general astrology they granted was allowable. Thorndike's appraisal of this condemnation was that it was inconsistent and suggestive more of politics than any real theological concern.[205] Simon was handed over to the bishop and the inquisition and exactly what happened to him afterwards is unknown, except that he published a historical defense of astrology in 1498 in which he attacked the "ignorant detractors" of the subject. Apparently, Simon's case was not a serious deterrent to the practice of astrology but it was an example of the power of religious censorship and perhaps an example of power politics between church and state. The arrest of Simon de Phares and the broadside of Pico della Mirandola focused the deep conflicts between astrology and religion and stimulated a reevaluation of the subject on the larger social level, but also among astrologers who began to split into two groups – the reformers and the traditionalists.

Protestant leaders in European countries who attacked astrology drew from Pico's great work. Jean Calvin wrote an anti-astrology book, translated into English in 1563, in which he condemned astrology for tempting men to know more than they should. He did not attack natural astrology, which he accepted as a study of how God works through nature, and he thought that humans should regard natural calamities indicated by the stars as God's punishment. The Protestant humanist Thomas Erastus, using the Bible literally as an authoritative scientific text, attacked all of natural magic and in the process argued against any astrological influence at all. The first English attack on astrology came from the Puritan William Fulke, author of a work titled *Antiprognosticon*, published in 1560. Fulke's attack was only against judicial astrology and, like

[205] Thorndike (1923), Vol. IV: 529-540.

Calvin's work, consisted of basically all the standard arguments propagated by Pico. However, he introduced these into England for the first time and they were consistent with the fundamental beliefs of Puritanism. Other attacks on astrology in post-Reformation England, directed towards judicial astrology and focused on the free-will issue, came from anti-Roman Catholic Puritans. Very few attacks came from those without connections to religion and there were really no religious opponents of natural astrology by itself in England.[206]

The conflict between the perceived fatalism of astrology and human free-will could be reduced to the problem of where humans stand in regard to nature. Pico, the champion of the freedom and dignity of Man, had to separate Man from nature to be consistent. If man is part of nature, as is the ontological position of Renaissance naturalism, then he is subjected to the forces of nature including planetary action at a distance. Destroying astrology, which is itself a general conception of reality and nature, is one way to underscore the liberty of Man (and certainly simplify the debate). Astrology was thus a critical issue in one of the great themes of the Renaissance. Garin places this intellectual conflict, with a focus on astrology, as a major theme in the Renaissance.

By forcing a debate on astrology, he [Pico] invited a close discussion on astronomy, or rather on the physical universe and on man, on nature and on destiny. This discussion is placed alongside the debate on the soul and on immortality, initiated by Ficino and Pomponazzi, and that on human society and on the state which was dramatically expressed by Machiavelli. They are three explosive themes.....the focal points of the philosophical "revolution" of the modern age: the order of world: the concept of the self: the res publica, the state.[207]

The rise of Renaissance naturalism and its associations with astrology, and also the advent of printing technology which allowed individual astrologers to speak to the public, moved it more directly into competition with organized religion. The attacks on astrology from religion throughout the 16th and 17th centuries had an impact on the legitimacy of the field that can be seen in the introductions to astrological publications where references to God Almighty abound and readers are assured the author is a Christian. William Lilly's *Christian Astrology,* which is just a text book on the subject and has nothing to do with religion, implies by its title the existence of religion-minded censors, though the astrologers of mid 17th century England considered themselves God-fearing interpreters of cosmic messages and astrology itself a divine kind of knowledge. Of a dozen or so books authored by astrologers from 17th century England that I

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[206] Allen, (1961) 148, Thomas, (1971) 367.
[207] Garin, (1976) 93.

examined, none were even remotely atheistic. A 1642 publication titled *Astrology Theologized* even makes the case that astrology, while basically the most powerful philosophical knowledge available to man, is not enough. Theology must be its companion.[208]

3.6 Astrology in the 15th and 16th Centuries

Astrology, natural and judicial, was a part of late Medieval and Renaissance academic culture. It was discussed thoroughly by Albertus, Aquinas and Bacon in the 13th century who each found ways to reconcile most of its doctrines with Aristolelian Christianity. By the 15th century astrology was being taught at the universities. The university at Louvain (Belgium) was founded in 1425 and five years later hired Joannes Vesalius (great-grandfather of the anatomist) who was a doctor and astrologer, these professions overlapping widely.[209] Vesalius produced annual almanacs, which consisted of astronomical data, tables of the best times for medical procedures, and astrological predictions for the year ahead. This academic astrological publication format evolved into more specialized annual prognostications which enabled individual astrologers, including Johannes Laet who worked in the region but had no professional connection to the university, to distinguish themselves and acquire patrons in high stations. With printing technology came the problems of publicity and information management. Previously, prognostications about notable persons, like the king or Pope, might be private, but with printing, astrologers were put into competition with each other.[210] A flurry of exaggerated predictions could upset the public and arose the wrath of the authorities, civil and religious, and this phenomena occurred frequently during the Renaissance. In the 16th century annual prognostications from university astrologers, however, moved towards a refinement of the subject. These practitioners used more detailed data, often restricted themselves to making only weather predictions, and they paid more attention to theory.[211]

At the university of Louvain, astrology was taught in the context of lessons in astronomy or mathematics, but this raised some problems from the university theologians regarding the prediction of the future. Potential conflict was kept in check by referring to astrological

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208 Valentine Weigelius, *Astrology Theologized.* (1642).
209 See Vanden Brocke, (2003) 29-53, for a history of Louvain astrology.
210 The effects of printing on almanac production might be compared to the rise of the internet which has brought with it lower standards and uncontrolled amateur publishing.
211 Vanden Broecke, (2003) 188.

predictions as "future contingents" which did not negate the possibility of God's actions.[212] Astrology was also taught at the university in Bologna where annual astrological prognostications were made by professors who taught in the arts and medicine.[213] Novara , Petramellarius and Vitalis all taught at Bolgna between 1483 and 1554 and Novara is said to have had Copernicus as a student. Lactantius Benatius was the sole astrology instructor between 1554 and 1572 when the chair of astrology became vacant. In general, there was a trend among university astrologers to favor Ptolmaic theory and practice, which would be the purist position, to that of the Arab astrologers who were known for their emphasis on conjunctions.

A strong supporter of astrology in the Renaissance was Martin Luther's advocate and organizer Philip Schwarzerde, better known as Melanchthon, who promoted a moderate and rational astrology as part of a revitalized German natural philosophy.[214] Like many other supporters of astrology he regarded natural astrology as an obvious phenomena, and good evidence of God in nature. He saw astrology as an important part of his reform of knowledge, a project coincident with the reform of religion, and he established a natural philosophy program in 1545 at Wittenberg that included astrology and influenced many students including, Michael Maestlin, who taught Kepler.[215] Rheticus, the student and promoter of Copernicus, was hired by Melanchthon and taught astrology and astronomy there. Melanchthon was also a friend of the notable astrologer Schoener (1477-1547), who included astrometeorology in his book *Opusculum Astrologicum*, and himself noted that droughts and heavy rainfalls corollated with eclipses and conjunctions. [216]

One of the most learned Renaissance scholars, Girilalmo Cardano (1501-1574), practiced and confidently promoted a traditional astrology. Cardano annotated Ptolemy, wrote a defense of astrology and collected horoscopes in an effort to put the subject on more secure foundations. This method of gathering case studies was one that many other astrologers continued over the next century and a half in Europe and England. Cardano was critical of certain parts of astrology and was well aware of its limitations, though he also cited the weakness of the human intellect as a factor in wrong prognostications. He was an internationally known figure and his books were

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[212] See Vanden Brocke, (2003) 49-53.
[213] See Thorndike, (1923) Vol. V: 234-251.
[214] Kusukawa, (1995). See also Schoener, *Opusculum Astrologicum,* trans. Hand (1994) iii, and Allen (1961) 63.
[215] Kepler referred to himself as a Luthern astrologer, something explained by this connection and highlighted in the title of Field's (1984) monograph on Kepler. See also Kusukawa (1995) 170 ff.
[216] Schoener, (1995) 9.

widely distributed and influential. In addition to being a master astrologer, Cardano was one of the creators of modern algebra and probability theory, and was also a medical doctor.[217]

Jean Bodin (1530-1596) was an early social scientist who initiated many modern ideas in matters of law, political economy and government theory. He linked the cosmic order to the terrestrial political order, as was done in ancient Mesopotamia, through a kind of astrological numerology which he thought would lead to better government. In his method of cyclical historical analysis, he referred to planetary movements as the framework on which history moved. Bodin had a plan for reforming astrology that included the comparison of chronologies of events with planetary cycles and eclipses which would then allow for translation into specific patterns organized by number. He didn't actually do this, however, it was just a suggestion.[218]

Tycho Brahe (1546-1601) was an astrological reformer who became the leading collector of accurate astronomical data in his time. Using only sophisticated sighting devices, he mapped the stars and the planetary motions in great detail, allowing Kepler to solve the problem of the planetary orbits which put the heliocentric hypothesis on strong foundations. Brahe wrote astrological forecasts for his high-ranking patrons and he regarded the subject as generally reliable and worth improving through greater astronomical accuracy. In delineating the astrological effects of the comet of 1577, he offered practical information and called for a rational exercise of free-will informed by astrological interpretations of the comet's significance.[219]

3.7 Experimental Science and Capitalism

By the end of the 16th and into the early 17th century, the Renaissance natural magic of Ficino and Agrippa (who wrote a survey of Renaissance magic in 1533) which was infused, if not integrated, by astrology, had become perceived as a serious threat to religion. A number of highly visible and enthusiastic advocates of this astrologically-informed world view were attacked, or like Bruno, burned at the stake.[220] It was in this social environment that Marin Mersenne (1588-1648), of the Order of the Minimes in France and a devout Christian, came to lead a major attack on

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[217] See Grafton, *Cardano's Cosmos*, (1999).
[218] Campion, "Astrological Historiography in the Renaissance," in Kitson, ed. *History and Astrology*, (1989) 89-136.
[219] Christianson, "Tycho Brahe's German Treatise on the Comet of 1577." *Isis,* (1986) 130.
[220] Yates (1964) 130 ff. Grafton, in *Defenders of the Text*, (1991) 145, calls this period "some of the worst mapped and most forbidding territory known to intellectual history."

Renaissance natural magic, Neoplatonism, and the other holistic and animistic philosophies of nature, portraying them as the chief enemies of both Christianity and true science.[221]

In 1623 Mersenne published a work called *Quaestiones celeberrimae in Genesim.* Using Bible text as the basis of his attack on Renaissance naturalism, he completely discarded astrology, sympathy, microcosm-macrocosm and condemned the doctrine of the anima mundi. Mersenne, a major supporter of mechanical philosophy, strongly rejected the notion of matter being alive. He also had some influential friends, including Descartes and Gassendi among others, and for many years he worked tirelessly networking with those sympathetic to his cause through correspondence and regular conferences.[222] Mersenne's attack came at the same time that the Rosicrucians, an underground brotherhood essentially Hermetic in outlook, appeared to be growing and also when Robert Fludd (1574-1637) attempted to prop up Renaissance naturalism and revitalize, or at least sustain, the world view of the Renaissance magus. Fludd, in a 1617 publication, essentially reconstructed the Renaissance outlook of the previous century, hoping to give it new life by combining Ficinian Hermeticism with Cabalism, and keeping it vaguely Christian by the addition of a hierarchy of angels.

Much of the prestige of Hermeticism came from its alleged antiquity, one that challenged the precedence of the Judeo-Christian tradition and revelation. This ancient prestige was undermined by Isaac Casaubon who, in 1614, dated the Hermetic writings to post-Christian times. Using style, vocabulary, and mentions of events and authors as proof, Casaubon argued that the writings were forgeries and the contents were basically derived from Platonism. This revelation shattered the authority of Renaissance naturalism, lowering the social position of the Renaissance magus, and it gave Mersenne a major weapon in his attack. A debate between Mersenne and Fludd focused the clash between these rival world views, and it was well-publicized and closely followed by intellectuals in Europe. Kepler joined the debate. On the one hand he defended astrology, while the other he attacked Fludd's Pythagorean numerology in his major work *Harmonies of the World*, himself arguing for a quantitative use of mathematics. In the 1630's Gassendi, also weighed in with a Christianized version of a revived atomism and argued that only measurable

221 Yates (1964) 432 ff.
222 See Yates (1964) 432 ff., Berman (1981) 109-111, Butterfield (1957) 83-88, and Bono (1995) 256 ff.

things were real.[223] This period, from 1615 to 1630, may be the focal point of the larger "paradigm" shift. Renaissance holism was defeated publicly, but was not completely dead – it went underground. Fludd was a Rosicrucian, the secret society originating in Germany probably about this time, that was a discrete form of Hermeticism. Like Freemasonry, it has preserved elements of Renaissance naturalism to the present day.[224]

Puritanism was another factor involved in the rise of experimental science. In spite of the fact that there were as many as 180 Puritan sects, they all shared some central religious and ethical convictions and differences were in the details. Calvinism, perhaps the classic type of Puritanism, promoted the view that the world was evil but humans could remake it through hard, practical work. Calvinism thus favored utilitarianism, a value that was shared with experimental science, making the later congenial to Puritan tastes.[225] The practical study of nature was then an exercise in the appreciation of the works of God and, further, success in the world by doing good works was evidence of being one of God's elect, and not well-placed planets in one's horoscope. Contrast this with Catholicism in which the material world was generally perceived as evil, and salvation involved retirement from the world. In Puritanism, strong emotions were to be controlled and avoided, while reason and education were promoted. This formula clearly favored experimental science with its disciplined hands-on approach to problem solving and its practical goals.

The most compelling evidence for the connection between Protestantism and experimental science is in regard to the composition of the Royal Society whose founding members were strongly religious, and mostly Puritan. In 1663, 42 of the 68 members were Puritan, a ratio much higher than found in the English population. Protestantism continued to produce scientists. By 1869 Europe was populated by 140 million Catholics as opposed to 44 million Protestants, but there were many more Protestant scientists of note than those practicing the Catholic faith.[226] Experimental science and the Puritan religion had no quarrel during the formative stages of the scientific revolution, and the early experimental scientists of the Royal Society were most anxious

223 Gassendi, in his book *Vanity of Judiciary Astrology*, argued that Ptolemy's Tetrabiblos was a fake, though that association has not been held up by subsequent scholarship. See Bowden (1975) 5, and Rosen, "Kepler's attitude toward astrology and mysticism," in Vickers, ed. *Occult and Scientific Mentalities in the Renaissance*, (1984) 256.
224 Yates (1964) 404 ff.
225 Merton, *Science, Technology and Society in Seventeenth-Century England,* (1970) 80.
226 Merton (1970) 114, 128.

to show, through their new methodology, the existence and glory of God as revealed through the study of his creation, nature.

Historians have drawn connections between the scientific revolution and the rise in Italy of capitalism. Although the origins of capitalism could be located as early as the 10th and 11th centuries, settlements during Medieval times were, for the most part, self-sufficient and commerce was limited.[227] After recovery from the plague of the 14th century, however, there was an increase in economic operations that led to the commercial revolution of the Renaissance, a time of long voyages and improvements in technology to facilitate commerce. For the rising bourgeoisie the new experimental science and the practical, technological offshoots it produced offered money and prestige, and it generated a general faith in progress. The rising population density of the times, in addition to climate change (the Little Ice Age – a factor that should not be underestimated in terms of political and cultural history), produced an energy crisis in the form of timber depletion that created a need for solutions to problems experimental science, not astrology, alchemy or natural magic, could solve.[228] The 17th century push to industrialization in England involved coal mining, a topic addressed by the Royal Society, and pumps like those described by Boyle and Hooke became urgently needed. Puritanism was then a religious doctrine compatible with both science and capitalism, areas of activity open to those in all social classes, and the aspiring middle class was very interested in opportunities to move up the socio-economic ladder.[229]

During the period under study, a general congruence between science and capitalism developed. The need for improvements in mining, navigation, etc., and the erosion of the gap between scholar and craftsman epitomized by Galileo and foreshadowed by the tool-using Renaissance magus, accelerated technological progress. Technology, like that used by alchemists or cathedral builders, had long existed but had no theoretical basis until Bacon. Then, in the 17th century, with a theory of natural science and expanding commercial activity driven by growth, climate change and resource depletion, the stage was set for intellectual activities that were compatible with capitalism. The new experimental science community, dominated by ambitious middle class Protestants, found a social identity with material rewards. Alchemists or astrologers could not fill

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[227] Cipolla, *Before the Industrial Revolution: European Society and Economy, 1000-1700*, (1994) 197.
[228] Ibid. 246
[229] Ibid. 138 ff., 214.

this opening. In alchemy one asks why a mining activity is conducted, and no sharp distinctions are made between mental and material events in the process of doing a transformation – the attitude is not driven by anything like a profit motive. In the competitive capitalistic mindset, the need for capital accumulation drives a need to know practical things, i.e. how to extract metals from a mine or how to navigate around the world. The demand for solutions to material problems replaced the alchemist or astrologer with someone more practical – the scientific engineer, the cartographer and the maker of navigational instruments.

3.8 Social Factors

During the 16th century some astrologers worked at the highest levels of politics as advisors to royalty.[230] Famous examples were Luca Gaurico in Italy, Michel Nostradamus in France and John Dee in England. In Italy, in the papal court, astrology was routinely used, though the subject became increasingly restrained by the 17th century. Predictions of the success or failure of important personages made by these advisors, sometimes right and sometimes wrong, were perceived to be a problem, depending on what side of the prediction one might have been. An astrological prediction of the early death of a royal heir, or defeat in an impending battle, was not welcome in all quarters, and such predictions could easily become politically destabilizing. In political turf wars of any kind, a clever advisor to a ruler may appear to be an asset, but only if that ruler continues to dominate. In such a situation the astrologer has two options. One is to make unbiased predictions – which, if these are negative to the ruler, could lead to the loss of a job. The other is to predict success for the leader, which may or may not occur. Either way, the astrologer will eventually encounter some awkward situations and, given the general lack of introspection found among political leaders, advice and forecasts that were more than superficial would fall on deaf ears. Decades of astrological advice to leaders during the Renaissance proved to have a neutral influence at best and were counterproductive at worst and the reputation of astrology suffered. Advisory politics as a social factor in the decline of astrology cannot be overemphasized.

[230] See Baignet, Campion, and Harvey, Mundane Astrology, (1984) 61-68, for a review of politics and astrology during the Renaissance.

John Dee, advisor to Elizabeth I, wrote that there were three enemies of astrology; those who gave it too much credit, those who granted it too little and, worst of all, the vulgar practitioner who gave it a bad name.[231] In the debate on astrology, one point both sides agreed on was the despicability of charlatans. Dee's sentiment was shared by serious astrologers like Cardano, Brahe and Kepler and the most vicious attacks on astrology from its enemies generally focused on those who made outrageous claims for judicial astrology. These people undermined the credibility of the subject itself and surely contributed greatly to its downfall. Printing opened the floodgates of astrological opinion which had previously been restrained, more accurately contained, by the patronage system. With the advent of printing technology, an individual astrologer's predictions could be published and widely circulated in an annual almanac or as a separate prognostication. Through their publications, astrologers routinely criticized each other in regard to method as well as the accuracy of their specific predictions, each claiming to have the best product.

Competition among astrologers, on all levels of society, became a fact of the profession and often those making the most extreme forecasts sold the most almanacs. In this way astrologers were easy targets for ridicule and mistrust by the thinking classes and to a lesser extent by the public. One example of this trend was the conjunction of 1524. An unusual series of conjunctions in the water sign Pisces, including that of the slow moving planets Jupiter and Saturn, caught the attention of astrologers some years before it occurred. A large number of publications appeared forecasting various disasters, many stating a flood like that of Noah would occur in that year. Thorndike devotes 45 pages to this event, and his report demonstrates wide differences and a serious lack of cooperation among astrologers.[232] While a number of these writers predicted only a very wet year, which it turned out to be in certain regions, many predicted much worse and these forecasts were perceived in retrospect as not only wrong, but disturbing to the populace as many were motivated to take drastic precautions. Another similar example were predictions of trouble for the year 1588 by some English astrologers, which were proven wrong when it turned out to be one of the best years for that country's government – the defeat of the Spanish Armada. Massive failures, at least in regard to public perception, like these did much to undermine the credibility of astrology, yet the abundance of this sort of fear-mongering astrological literature was persistent. Kepler expressed his concern for this situation, which he saw as a kind of vicious circle where

[231] Allen, (1961) 182.
[232] Thorndike (1923) Vol. II: 178 ff.

strong almanac sales encouraged astrologers to dramatize predictions more than they probably should, giving the public an unbalanced literary diet.[233]

The decline and marginalization of astrology accelerated during the second half of the 17th century as the various holistic beliefs and practices of Renaissance Naturalism, previously overlooked or tolerated to some extent by the Church and the intelligentsia, were attacked and driven underground. In France astrology was officially excluded from the Academy of Science in 1666 and court patronage of astrologers ended. However, elements of natural astrology were appropriated by natural philosophy, and almanacs with weather predictions continued to be published, but not without censorship and controversy. According to Guinard, what changed at this time, in France at least, was not any refinement of anti-astrology argument but a change in the status of anti-astrology opinion.

Astrology was not displaced by a convincing argument of philosophical or scientific nature, it was simply rejected on the basis of the enforcement of a consensus among an established body of intellectuals – a consensus which has never been achieved since that time – and primarily by scientific academies, religious orders (above all the Jesuits) and the literary salons – which is to say, by people whose interest was served not by liberty of thought but rather by the success of their own ideas, the preservation of social position, and above all by imposing direction on the ideas of others.[234]

This view of the decline of astrology in mid-17th century France differs from what Thomas, Capp, and others have suggested, that astrology was beaten into the corner by hostile clerical authorities, suffered from a lack of interest by scientists, was destroyed by a new vision of nature, and was useless to the needs of modern urbanization. These reasons have already been discussed and, collectively, they do seem to have made conditions difficult for astrology throughout Europe. But what I find compelling about Guinard's explanation is its implied socio-biological view of the process of history. People make history out of individual self-interest and group needs for dominance, i.e. social position, and fashion, whether in clothing or in ideas, is often the means by which such is achieved. Ideas that challenge the status quo, in this case astrology, are purposely obscured. Guinard makes another point, that the above conventional explanations for the decline of astrology do not account for two important historical facts conveniently left out by those who frame these arguments, these being first the continuity of astrology among the middle and lower classes and then the spectacular rebirth of the subject at the end of the 19th and

[233] Kepler, (2007) 55, 176.
[234] Guinard, (2002) 80.

throughout the 20th century.[235] This revival, being a very real social phenomena, suggests that reasons for the decline of astrology may be located in the dynamics of emotional-territorial maneuvering within human primate pecking orders at crucial turning points in history. History is not necessarily a rational process, but one more likely driven by dominant humans forcefully promoting their personal agendas.

In England, the 17th century was broken up by civil war. Discontent over increased taxes and duties, and exercises of absolute power by the king (including dissolving Parliament), harsh treatment of Puritans, and Catholic-friendly attitudes led to a rebellion and civil war in 1642. The Puritan leader Oliver Cromwell organized an army and defeated the royal forces of Charles I, and in 1649 executed him. Cromwell ruled until 1658 but was hated for his Puritanical standards. With two years of his death, royalty was re-established, though in 1688 Parliament took back control of government. Until 1641 astrological publications and their contents were regulated by the Company of Stationers and religious and university censors. The breakdown in political and ecclesiastical restrictions after 1642, as well as cheap printing, led to an explosion of publications peaking in the 1650's. During this time of little or no censorship hundreds of almanacs and textbooks dealing with astrology appeared and it secrets were open to inspection by the public. The most famous astrologer of the time was William Lilly, a moderate Parliamentarian, who was known for his correct predictions of Royalist military defeats that he issued in almanacs or as separate prognostications. In the 1640's, sales of William Lilly's almanacs were selling in the range of 30,000 a year and sales of almanacs in general are estimated to have reached 400,000 a year by the 1660's. This uncontrolled rash of astrological publications was generally perceived as connected to radical politics and astrology thus became identified with Parliamentary revolution, regicide and radical sects, associations which had historical consequences when order was restored.[236]

Astrology in England was at its peak of popularity and influence during the civil war and afterwards. In his role as popular prophet, Lilly was seen as a spokesman for the radical elements of popular culture, yet his friends included some advanced astronomers, an indication of the fluid

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[235] Anyone interested in measuring the success of this rebirth will not find much about it in academic publications, but astrology's widespread influence will register in a study of early radio broadcasts, book sales, newspaper and magazine columns, and internet websites as well as in the formation of a number of relatively large organizations, some international.

[236] For accounts of Lilly and other Civil War astrologers see Thomas, (1971) 288-289, Capp, (1979) 39, 182, and Curry, (1989) 19 ff.

boundaries between the subject of astrology and society itself at the time. Elias Ashmole, one of the founding members of the Royal society, and a royalist conservative, was his close friend and a fellow astrologer. Still, astrology was far from considered completely socially acceptable. Lilly's astrological textbook, *Christian Astrology*, in which he outlined in ordinary English how judicial and horary astrology were practiced, says much about the cultural environment at the time as well as his wit and social survival skills. Nicolas Culpeper, a medical astrologer and younger contemporary of Lilly, published the first English translation of the London College of Physicians Dispensary, which was formerly in Latin. By doing this, Culpeper, in a personal campaign against the monopolization of medical practice by the Royal College of Physicians, had opened medical secrets to the public. This was not authorized by the doctors, who were furious.

Almanacs full of astrology and political predictions had become wildly successfully and widely distributed, and the power of astrology to incite the people had become obvious to many. When order was reestablished the government moved to censor almanac content again, and by the post Restoration a line had been drawn, but not between astrology and reason. Nor was it one within the broad subject of astrology itself, not between judicial and natural astrology – it was a social and intellectual distinction. In England this split, which occurred around 1660, did not separate rich and poor, or aristocracy and commoners, it was more a case of respectable astrology (nobility, gentry, rising middle class) as opposed to vulgar astrology (country folk and laborers). In perhaps the best account of the social status of astrology in 17^{th} century England, Patrick Curry argues that to understand its fate, it should be divided into three categories; popular astrology, interpretive judicial astrology, and high cosmological astrology.

Popular astrology included the astral beliefs and practices of the rural and semi-literate laborers and also the urban artisans and working class. This astrology, consisting of lunar wisdom and weather lore, offered to the masses both an explanation of natural phenomena and a means of making predictions. Some astrological medicine was part of this mixture and it offered to the public home remedies and healing methods. In addition the local wise "cunning" man or woman would typically use this kind of astrology in their practice. Farmers almanacs and other secular publications provided current tables to the phases of the Moon and planet's places which kept this kind of astrology alive and well.[237]

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[237] Curry, (1989) 95 ff.

Judicial astrology, a more complex interpretive and technical astrology that focused on the lives of individuals, their problems and decision-making, appealed to the better educated. Its practitioners were informed, but not at the cutting edge of science, as it was basically applied math and interpretation based on experience, not a theoretical study. Members of this community included almanac makers, antiquarians, and physicians that were mostly middle class and living near London. Several astrologers of this general category actually attempted to reform the subject more or less in line with experimental science. John Gadbury (1627-1704), a royalist and Lilly's competitor, published in 1658 his anecdotal evidence for the subject, a collection of 153 natal horoscopes, the largest collection published in England to that date, which he analyzed in great detail.

High philosophical and cosmological astrology, which was essentially the purer elements of natural astrology, was speculative and overlapped with physics, at least in regard to the presumed influences of the planets and the mechanics of the solar system. Although there was a deep distrust of astrology by the elite, due in part to the uncontrolled explosion of astrological political predictions following the Civil War, the Royal Society did include a few astrologers. If astrological ideas were discussed, however, they were probably redescribed in terms of experimental science. One astrological reformer, Joshua Childrey (1623-1670) might be placed in this category. He was, like Goad, inspired by Bacon and worked closely with the Royal Society in regard to the improvement of meteorology. His work on tides was important as he kept records of observations and noted the role of wind and the effects of lunar perigee. In astrology he argued for the importance of aspects that were coincident in both geocentric and heliocentric perspectives, these being the conjunction and opposition.[238] About the same time as Childrey, Robert Hooke advocated correlations between the phase of the moon and weather records.

To an extent certain components of astrology were appropriated by the official scientific community. The effect of the Moon on the tides and Newton's redefinition of action at a distance as gravity could be seen as natural astrology without the name. Cometography, the official discussion on comets and their effects on the Earth and its inhabitants that took place among members of the Royal Society, is another example of the appropriation of astrological methods

[238] Childrey, (1652). See also Bowden (1975) 164-175.

without using the word astrology.[239] Astrology also offered a system of historical explanation and the concept of historical periods grew out of astrological interpretations of long planetary cycles. This approach is found in Newton's *Chronology of Ancient Kingdoms* in which he attempted to date Biblical kingdoms and events by the slow precession of the equinoxes. When Newton did it, it wasn't astrology. The idea of authorized prophets, rather than an uncontrolled stream of enthusiastic and questionable people all calling themselves astrologers, was more appealing to this group of new natural philosophers who were concerned with maintaining a strong and respectable social position. So astrology were not disproved, it was banished from high and respectable society and kept at a safe distance by those in control – or it was renamed.

In general, there was a state of permanent crisis in European politics, society and culture during the 16th and 17th centuries. During periods such as this one, when "paradigms" shift and institutions are attacked, skepticism flourishes and solutions to the problem of what is proper knowledge, that which will stabilize society, becomes urgent. Reliable ways to solve fundamental problems affecting society are required, and the arts or sciences that are best able to deliver become the preferred remedies. This a sociological phenomenon – the process of validating solutions occurs on the social level, not by evidence alone. Shapin argues that no practice, including experimental science, has rejected testimony and authority as the basis for truth, even though science claims to only seek direct individual experience.[240] If this were the case, astrology, or at least a high version of it, may have survived as a kind of study, like botany, that involves classification and does not easily lend itself to mathematical modeling. But with the religious attacks and the taint of charlatans, among other things, no form of astrology had a chance – its reputation was irreversibly tarnished. Knowledge is ultimately a form of faith and a sense of collective truth. One knows something to be true because one trusts someone else who, presumably, has the proper knowledge and has a good reputation. People-knowledge precedes thing-knowledge and social-knowledge leads to natural-knowledge. The claims of science in regard to objectivity, and in regard to trusting only personal experience, are only claims. We are primates, and social maneuvering driven by deep territorial and tribal instincts is the means by which we come to accept those things that we regard as truth.

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[239] Schaffer, "Newton's Comets and the Transformation of Astrology," in Curry, ed. *Astrology, Science and Society: Historical Essays,* (1979) 219.
[240] Shapin (1996) 123.

Indicators of reliable truth-tellers in 17th C England were birth station, wealth and behavior. According to Shapin, a gentlemanly culture of honor was transferred to the new domain of experimental philosophy, and the financially unburdened Robert Boyle became the greatest model for the 17th century experimental scientist, a new kind of respectable identity in English culture. Boyle was a master of scientific credibility, a Christian gentleman and scholar virtuoso – a careful and purposeful assembly of cultural elements that defined respectability and truth in his world.[241] Yet Boyle was known to have had an interest in astrology, consulted judicial astrologers and even proposed a mechanistic explanation for its effects that involved magnetism, air pressure and other unknown forces, referred to as determinate effluvia, that acted on substances.[242] However, the model experimental scientist he was living or portraying (probably both), made sure that this interest was handled with care and kept within in a scientific context. So astrology, for Boyle and a number of other early members of the Royal Society who favored the subject, was something to be discreet about, not a badge to wear under any circumstances lest they be associated with uncontrolled political prophecy produced by charlatans.[243]

The perception and establishment of borders and boundaries among people is a fundamental social process related to tribalism, ranking and pecking order, and it can be seen to operate on many levels throughout history.[244] In the case of astrology, during the 17th century, in England, a boundary layer formed between its practitioners and those who were holding the high ground, i.e. the well-respected men in society who identified themselves with experimental science. This separation may be in part be due to the failure of astrology's symbolic language, i.e. the doctrine of signatures and the many symbols for planets and signs, etc., to be translated into the evolving language and conceptual categories of natural philosophy. Geneva argues that astrology's language was meant to conceal, and in an environment of demystification it could not survive.[245] Bacon and others advocated for a universal language that would reflect nature accurately and become a medium for scientific discourse, and a committee was established in the Royal Society

[241] See Shapin, *A Social History of Truth,* (1994).
[242] Bowden, (1975) 202-209.
[243] It is also true that a number of members also spoke out against the subject. See Shapin, (1996).
[244] From an evolutionary psychology perspective, all of human history is about groups bonding and maneuvering for status. In this case, one group, the experimental scientists, sanctified their exclusive activities and thus were able to get past the dominant censoring group, the religious authorities, while the astrologers remained outsiders. Tribalism is quite possibly a kind of social immune system which had a critical role in pre-historic times but now operates as both a binding and excluding social force.
[245] See Geneva, (1995) 271 ff. This argument makes better sense if applied to alchemy, but astrology's symbolic language was, to a large extent, part of the public dialogue as shown by its frequency in the writings of Chaucer and Shakespeare.

to work on this matter. Astrological language, being symbolic, found itself in a situation within which it could not operate, and interest in it declined among the elite intellectuals of the time.

A contrast between medicine and astrology during this period further illustrates how the differences between these two social activities led to one achieving acceptance, the other rejection in the context of the social conditions of the time. At the beginning of the century there was much overlapping between astrology and medicine and both were often practiced by the same person. Regulation was minimal, though more focused in several regulatory organizations in the case of medicine. By the end of the century the status of medical doctors had gone up and that of astrologers had gone down, and not necessarily because one was more effective in getting cures than the other. The medicine of the time, blood letting, leeches, etc. was quite primitive and the knowledge of astrologers in regard to herbal cures or other non-invasive actions was considerable in some cases. What seems more to be the case is that medicine, a classifying and labeling activity not using a symbolic language, was intrinsically more compatible with the methods of experimental science, and it had a regulatory organization, the Royal College of Physicians, that became dominant and was able to define the subject in terms that suited the trends of the times – experimental science, technology and capitalism. There is a social factor at work here as well. Doctors classify patient symptoms in the context of a model and then they dispense or act on the situation in some way. This gives doctors a certain power that is not found in the case of the astrologer who responds to whatever question the client has. The doctors also operated in a collegial way, the astrologers individually responded to patrons. Further, astrologers also did not use models that were scientific, at least relative to the times, and they had no real regulating entity. Competition between astrologers for clients and almanac sales was yet another factor that worked against the profession.[246] In the end, the doctors were far more successful than the astrologers in defining boundaries and they protected themselves collectively. The downfall and marginalization of astrology was not simply a case of effectiveness in actual practice, but more a case of better socially-defined boundaries and the power of one organization to hold its ground.[247]

[246] There was an astrologers society which met for feasts for several years but this appears to have been more of a trade association than a scientific society. Curry, (1989) 40.
[247] See Wright, "Astrology and Science in Seventeenth Century England," in *Social Studies of Science,* (1975).

3.9 Summary

Astrology, both judicial and natural, normally practiced by the same person, became less influential during the 17th century and was completely marginalized in respected society by the 18th for a number of reasons. From the progressive perspective of experimental science, the reductionist world view that replaced Renaissance naturalism, it had lost its previously authoritative "scientific" foundations with the collapse of Ptolemy and Aristotle. Astrology found itself without a rationale and was isolated, becoming a separate discipline mostly unrelated to other acceptable fields of inquiry. I've argued that the decline of holistic perspectives in general and the rise of reductionism left astrology without a world view that could accommodate it. Astrology was never disproven and continued to be a practice, but it fell out of favor among the theoretically motivated, fashion-conscious intellectual leadership.

Something to consider is that astrology always had strange relations to other fields of knowledge. It depended on astronomy, which itself was considered a branch of mathematics, and until the 17th century most astrologers were also astronomers. Neither of these subjects was considered natural philosophy. Astrology, although it was based on experience over centuries, was also not natural history. Neither was it medicine, although it informed that subject, and many people practiced both. It had applications to agriculture and also to social science in that it mapped historical cycles. Generally speaking, astrology was a complex art-like practice based on mathematical principles that some individuals did well and others poorly, and with the rise of printing and the lack of regulation inconsistencies became apparent.

Much of 17th century experimental science was concerned with mechanics. As such, this was a challenge to astrology which as a subject deals with only influences. In traditional mechanics, connections are visible, can be touched, measured and modeled precisely using mathematics. With such precision, predictions either prove true or they don't. In traditional astrology, things were thought to change by a transfer of some occult influence which was not measurable and therefore had no units on which to apply mathematics. Attempts were made to provide a mechanistic explanation to astrological influence including one by Boyle mentioned above and one by Claude Gadrois (1642-1678), a follower of Descartes. Gadrois argued that there was a particle exchange between the planets and the Earth and, to account for the different qualities of the planets, that the planets differed in the density, size, speed and force of their particles.[248] Mechanistic particle theories did not catch on, presumably because they couldn't be measured. The technologies proposed to study astrology were either very new or undeveloped, i.e. the thermometer and barometer that Goad began to use, or impractical such as the mirrors of John Dee. Quantitative data was not generated. The only approach possible towards a scientific astrology then was through correlation, which collectors of nativities like Cardano and Gadbury attempted. Correlation, however, requires large numbers of precisely timed birth charts or, as in the case of Goad, quantitative data to begin with. After that, correlation requires statistical methodologies which were yet to be developed. In the 17th century correlation was too slow a process for the kind of results that a viable experimental science was expected to deliver.

Kepler thought that astrometeorology was too complicated and he complained that the subject was misused by believers and critics alike, so he stopped writing meteorological almanacs.[249] When John Goad attempted his monumental Baconian reform of meteorological astrology, he only found some correlations that amounted to a list, not data that could be quantified and reproduced. Without instrumentation for recording units, or statistics to deal with the complexities of a system, he was left with essentially anecdotal evidence for astrological weather rules.[250] In the final analysis, the attempts to reform astrology scientifically had failed. Reforms had been suggested by various astrologers, some of whom were respected natural philosophers, but there was no collective and coordinated effort. Mary Ellen Bowden recognized the impossibility of a scientific reform in astrology and wrote "On the whole, bad methods did not cause the failure of its revolution; the scientists concerned were simply attacking a problem that could not be solved."[251]

Judicial astrology endured a sustained attack from its religious and ecclesiastical opponents, although the debate never really went anywhere. Opponents perceived a denial of free-will, limits placed on God's power, and dealing with demons as major reasons to avoid astrology. Proponents of astrology admitted the importance of free-will and they argued that foreknowledge gained from

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[248] Bowden, (1975) 198-201.
[249] Kepler, *(2007)*, Theses 130, 131: 193-194.
[250] Experimental reproducibility has proven difficult with astrology – as it is with any system that can't be broken into parts. One exception has been the Gauquelin studies that correlate planetary diurnal cycles with profession and other personal characteristics, which though challenged many times, appear to be holding up. See Ertel and Irvng, *The Tenacious Mars Effect,* (1996).
[251] Bowden, (1975) 223.

astrology actually permitted a better use of it. The major theme of the Renaissance, the dignity and freedom of man as championed by Pico, could not accommodate astrology's notions of planetary influence on human destiny. The astrologers could see a way around this issue but it required psychological caveats that were too complex for most to understand, especially those not at all knowledgeable of astrology. The fact that astrology offered a world view that contained within itself the rise and fall of religions and the possibility of making a horoscope of Christ's birth put it on the firing line from Rome and from Protestant leaders. The two sides weren't all that far apart in regard to the charlatans, however, who were offensive to the respected and an embarrassment to the astrological community. The argument came down to a kind of standoff – the opponents admitted an astrological influence on nature, but in regard to humans, it was impossible to say exactly what it was. The astrologers, on the defensive, responded by saying there were flaws in the subject but these could be eventually removed by reforms, and with that accomplished it would evident to all what that influence on humans was.

Whether or not one accepts that astrology is a legitimate subject in and of itself, it is definitely a subject in the same league as philosophy, religion, sociology and evolutionary theory – all of them subjects that have extensive explanatory power. It could even be said that astrology was the earliest attempt at a universal law that was not specifically religious.[252] Like religion it filled an intellectual worldview and offered answers, but without all the ritual and priesthood. Recognizing this, the clergy, for the most part, viewed it as an unacceptable alternative to their program and they discouraged its use for centuries. Still, many associated with religion, such as Albertus, Aquinas, Melanchthon and Capanella, studied and practiced astrology.

In evaluating the "truth" of astrology, historians, while acknowledging its ubiquity in certain periods of the past, generally dismiss it directly, or indirectly. Thomas says repeated failures in almanacs showed that astrology was utterly incapable of providing accurate predictions – except, one supposes, for those that were accurate, like many of Lilly's and countless others before, during, and after the Renaissance. He says that astrologers covered their failed predictions using chants like "the stars incline, don't compel," and that it was also customary to make ambiguous predictions. Could more or less the same be said of weather forecasters and economists today? But the question remains, if the forecasts in almanacs, which were mostly weather and politics, were just guesses, why were astrological almanacs in demand? Thomas deals with this problem

[252] See Thomas, (1971) 324.

by stating that almanac astrology didn't work, but then he quickly puts natural astrology, which is the primary content of an almanac, aside and goes to judicial astrology for reasons. He says that to account for failures astrologers would typically fall back on exceptions like divine intervention, complain about censorship, point to mistakes they made in calculations, and make complaints about other bad astrologers.[253] This is a list of excuses, not an evaluation of a mapping technique for dynamical systems. It is also suggestive of astrometeorology's guilt by association problem.

The decline and marginalization of astrology in the 16th and 17th centuries was also a cultural process. The problems of theology, politics, economics, and the social conditions of the age demanded the attention of the best minds. There was certainly a brain-drain during this period away from practices such as astrology towards work that was more tangible and had the support of institutions, or conferred status in some way. Fewer and fewer talented individuals entered the field. Consider Kepler, a master astrologer who would rather solve the complex astronomical problems of his time than cater to wealthy self-indulgent patrons who were incapable of understanding the subtleties of their own horoscope and raising their level of self-knowledge. The job of doing astrology for patrons, basically that of a consulting psychotherapist, was not what a person of Kepler's caliber was seeking in a career. Still, astrology continued to be unquestioned in principle by Kepler and by most others of his time.

The creation of a new, respectable social identity exemplified by Robert Boyle was surely a factor in the decline of astrology. To be associated publicly with astrology, which implied political recklessness, enthusiasm and the vulgar classes, was to ask to be tainted. Although Lilly had exceptional social skills, astrologers as a group did not conduct themselves well during the English civil war and consequently set themselves up for marginalization by royalist factions which eventually returned to power. From another perspective, mid 17th century English astrologers further contributed to the lowering of their status by publishing works on astrology in the vernacular. Lilly, Ramesey and others published do-it-yourself books on astrology in English,

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[253] Thomas, (1971) 334. Thomas may have produced a generally good social history, but he is out of his league in this regard. It is indeed challenging to evaluate the predictive accuracy of consulting astrologers of centuries past, though maybe for historians, that's the wrong question. Will future historians pay any attention to the accuracy of 20th century forecasts of global warming by scientists? Many astrologers simply gave advice, and did not limit themselves to predictions. Their casebooks don't reveal what they told clients or what happened afterwards. We only have thousands of astrological charts which nearly all academic historians are incapable of reading. It is only fair to expect a writer of the history of geology, for example, to actually know something about the subject.

not Latin. A related example was Culpepper, an astrologer, who upset the medical profession by publishing the major medical text of the time and thus opening it to public inspection, which no doubt contributed to marginalization by those higher in the social ranks, i.e. doctors. Prior to the appearance of these works in English, skepticism of astrology, and other fields, was highly exceptional. When the public could see how things were really done, how astrologers actually worked with strange pagan symbols and made only estimates of possible outcomes of planetary configurations, the prestige and power of the practitioner fell under increasing scrutiny. Unrestrained individualists and charlatans accelerated the fall, and writers came to consistently portray the astrologer as a rogue. In regard to some of the political and predictive extremes found in the almanacs produced by so many unleashed astrologers, they had something to parody.

The decline of natural astrology followed, but lagged, the decline of judicial astrology. Astrometeorology was rarely attacked during the transition period and right up to Newton's time. Goad's book, published in 1686, was favorably reviewed and considered respectable by some in the Royal Society. There was not an abrupt, clean break between natural astrology and the interpretation of cosmic influences on the Earth by those within the Royal Society. It was more the case of the appropriation of method and some content by one group from another. From cometography to Hershel's observations on the correlation between grain prices and sunspot numbers, an interest in connections between celestial and terrestrial phenomena continued. Some scientific meteorology utilized astrological indicators, including the moon and the signs of the zodiac, up to the late 18th century.

From the early 19th century to the present day, astrological weather forecasting continued to exist as a separate tradition in the annual "farmers" almanacs published in England and America. The English almanac was successfully transplanted to the colonies. The first press in America opened in 1638 in Cambridge and the second document printed there was an "Almanac Calculated for New England" by Mr. Pierce, Mariner. The press was set up by Henry Dunster and it became the Harvard University Press. In 1686 Benjamin Harris in Boston came up with new format and style of almanac, which was considered heathenish by Puritans, and not much later John Tulley, from Saybrook, CT, who began his almanac with January, not March, made weather forecasts based on planets. He also presented the most ubiquitous feature of the popular almanac, the zodiac man (Man of the Signs).[254]

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[254] Sagendorph, (1970) 46-47.

Many other annual almanacs were published in the colonial period including Benjamin Franklin's *Poor Richard's Almanac* which continued the tradition of astrological weather forecasting. Franklin apparently employed others to do the astronomical calculations, which probably also included the forecasts based on planetary aspects, that made up much of his almanac's content. There is no question that astrology was behind the forecasts. For example, in his 1753 almanac, it is noted that the Sun is opposition Saturn on the 24th of June and the forecast noted between the 23rd and the 26th is "thunder, then cooler."[255] On December 29th of that year the Sun was conjunct Saturn and the forecast is "cold and cloudy." To a large extent the almanacs preserved astrometeorology, and other parts of astrology as well, which experienced a major resurgence during the 20th century in both England and America.

Natural astrology was preserved in other ways. A few English and American astrologers in the 19th century wrote on natural astrology, but more as a review of established methodology and less as an ongoing investigation.[256] An astrometeorological society was formed in London in 1860, but it lasted only two years. Within the small middle class community of English and American astrologers in the late 19th and 20th centuries, natural astrology came to be referred to as mundane astrology, and this category included the analysis of weather, earthquakes, storms, plagues, migrations, historical cycles, politics, market fluctuations, etc. The use of the time slice (horoscope), most often calculated at equinoxes, solstices and lunations, became the preferred technique and actual research aside from case studies was, for the most part, abandoned as it didn't pay and had no institutional support.

[255] Example of Poor Richard's almanac online at http://public.gettysburg.edu/~tshannon/his341/pra53jun.htm (accessed March 2010).
[256] See Pierce, (1890), as an example. He summarizes, more or less, Renaissance astrometeorology with occasional references to John Goad's observations.

CHAPTER 4

NATURAL ASTROLOGY AS GEOSCIENCE

The study of cosmic, i.e. solar system or extra-solar system, influences on the Earth system is here suggested to be essentially the same field of inquiry as that of natural astrology. Three major areas of current study in this regard are those concerned with orbital cycles, solar cycles and cycles of cosmic ray flux. In the first, orbital cycles, variations of the Earth's orbit, which are modulated by the gravitational tugs of the other planets, have become accepted drivers of climate and related geological processes such as sedimentation rates. Cycles of solar activity are a known source of climate regulation on shorter scales. It is not known how solar cycles originate but the orbits of the planets may play a role. The orbit of the solar system around the center of the galaxy causes it to pass through spiral arms which raise the level of cosmic ray flux entering the Earth system. It is thought by some that such changes influence climate and related geological and biological processes over very long periods.

The 20th century saw a revival of astrology. Popular astrology in newspapers and magazines has become ubiquitous. Professional astrology, benefiting from progress in psychology and computer software, is now quite sophisticated and used by people on all levels of society. Innovations in technique, some based partly on Kepler's ideas, have added extended methodologies. Professional organizations are now found throughout the developed world, and older traditions, such as Vedic astrology from India, have made inroads into Western astrological culture. Progress in natural astrology, often referred to as mundane astrology and focused more on forecasting social and economic trends, has occurred as well, though the public hears little about it except in regard to economic and stock market forecasting.

Astrology was both utilized and tested in the 20th century by scientists. For much of his life Carl Jung was interested in the subject and he drew from it when developing his theory of personality types. The four functions, intuition, sensation, thinking and feeling correspond neatly with the astrological elements fire, earth, air and water. These form the basis of the Meyers-Briggs personality assessment which has become widely recognized and respected. Jung also proposed a non-mechanism to explain the workings of astrology and certain other phenomena which he called synchronicity. He conducted several studies on astrology, but abandoned this line of inquiry and theory when hearing of the work done by John Nelson and others who were proposing physical mechanisms.

Nelson, who for many years lectured at astrology conferences, developed in the 1940's and 50's a methodology for predicting solar storms (for RCA) using elements of classical astrological methodology. He thought that when planets were aligned in specific angles (the aspects) heliocentrically, their gravitational forces on the Sun were a cause of solar storms, flares, and sunspots. Another astrological hypothesis of the time involved magnetism. Beginning in the 1930's, electrical engineer and astrologer Edward Johndro proposed that it was the Earth's magnetic field, modulated by planetary aspects, that caused the astrological effect. In the 1960's astrologer Donald Bradley, who used the pseudonym Garth Allen when he wrote for astrological publications, found a lunar-cycle/rainfall correlation that was in line with John Goad's observations 300 years earlier (it was published in *Science*). German judge and scientist Theodor Landscheit, who defended astrology from the 1970's until his death in 2004, correlated climate patterns with the movement of the solar system's barycenter, which itself is modulated by planetary cycles. He viewed the Sun and planets together as an intricate "organism" regulated by complex feedback loops. The Sun, making the planets revolve around itself, is in turn influenced by the planets which make it revolve around the center of mass (barycenter) of the entire system. These complex movements stimulate solar activity which influences the Earth's atmosphere via the solar wind. Landscheidt's work is related to that of scientists Rhodes Fairbridge and John Sanders who have also stressed the importance of planetary patterns in determining the Sun's motion with respect to the barycenter and the corresponding "effects" on the Earth. During the 1980's and 90's English astronomer Percy Seymour argued that planetary alignments affect the magnetic properties of the Sun, and also may directly affect the Earth's magnetic field. In this regard he has suggested that very small gravitational forces can produce very large effects on magnetic fields and has proposed a theory of *magneto-tidal resonance*.

The argument of my thesis is essentially that natural astrology has a long history, was a contributing factor in the scientific revolution, with the right approach can be investigated scientifically, and it still exists. Further, I argue that the subject holds a "space" of its own – while it incorporates material and methodologies from astronomy, meteorology, geology, and many related sub-disciplines, it organizes geocosmic studies into one category instead of many. The subject matter of this field are dynamic natural systems and dissipative structures such as magnetic fields (solar and terrestrial), the atmosphere (weather and climate) and the biosphere (biological cycles), all of which lend themselves to a non-linear scientific approach. Such subject matter is not easily quantified using classical reductionist scientific methodologies and should be examined in the light of emerging scientific paradigms – systems, chaos and complexity. Again, this is surely one reason for the decline of astrology during the rise of Newtonian science – the subject is inherently too complex for reductionist investigation.

If one defines natural astrology as the study of correlations between astronomical forcing and processes on, but not limited to, the Earth system, it appears to me that a kind of natural astrology exists within the scientific community. In today's geoscience and climatology, correlations between the orbital cycles of the Earth and various geological and climatological phenomena have relatively recently become accepted as a primary mechanism for climate change and also as a means of establishing a chronology. This was not always the case as seen in the next section. Tidal forces have long explained marine and atmospheric phenomena and are now seen as a force that keeps planetary moons like Europa, Io and Enceladus geologically active. Also, correlations between solar cycles and geophysical phenomena are likewise considered legitimate study areas. I argue that these topics are examples of a modern natural astrology.

4.1 Orbital Forcing

Astronomical cycles, specifically the regular variations of the Earth's orbit around the Sun, were correlated with global climate history by Sir John Herschel in 1830, Joseph Alphonse Adhemar in 1842 (*Revolutions of the Sea*), and more importantly, by James Croll in 1875 (*Climate and Time*). Today orbital cycles are primarily associated with Milutin Milankovitch (1879-1958) who further developed these ideas over the course of his lifetime in *Mathematical Theory of Heat Phenomena Produced by Solar Radiation* in 1920 and *Canon of Insolation of the Earth and its Application to the Problem of Ice Ages* in 1941. He demonstrated mathematically that the three key orbital cycles, precession, obliquity, and eccentricity, modulate the amount of insolation (INcoming SOLar radiATION) the Earth receives over long periods of time. These three cycles are often called Milankovitch cycles.

Precession is the cycle (s) of the gradual change in the direction of the Earth's axis. The gravitational torques exerted by the Sun and Moon on the bulge of the Earth at its equator cause the axis to wobble like a top. This motion is called *axial precession* and it creates a cycle of about 26 k.y. (26,000 years) during which time the north pole traces a circle in space. This cycle was used by several ancient civilizations to structure their history.[257] *Elliptical precession* occurs as the elliptical orbit of the Earth rotates around one focus. The two effects result in the equinoxes and solstices shifting slowly around the Earth's orbit coincident with changes in the location of the Earth at seasonal markers. Due to torques from other planets, notably Jupiter and Venus, there are variations in this cycle that create periods of about 19, 22, and 24 k.y. These cycles are used in insolation calculations.

Obliquity is the effect of the Earth's axial tilt. It is currently tilted from the vertical to the plane of its orbit by 23.45 degrees. This tilt varies from a minimum of about 21.8 degrees to a maximum of 24.4 degrees within a cycle of approximately 41 k.y. It is the tilt of the axis that produces the seasons and it follows that when the angle of the axis is lower the contrast between the seasons will be less. Changes in obliquity have only a minor effect on solar radiation at low latitudes, but this increases in the higher latitudes. The effect is strongest at the poles, weaker at the equator and modulates insolation in both north and south hemispheres equally.

Eccentricity involves the actual orbit of the Earth around the Sun which varies from nearly circular to elliptical over periods that are generally averaged at approximately 100,000 years. There is a second eccentricity cycle of about 413 k.y. that also appears to be reflected in some long-term climate cycles. When the orbit is most elliptical (about 6 million miles farther from the Sun at aphelion) the variations between the season are amplified. This cycle also modulates the precession cycle.

Milankovitch theorized that the total summer radiation received in the northern latitudes (near 65 degrees north – where ice sheets have formed previously) is the key factor in the development of an ice age. The fact that there is more land mass in the northern hemisphere than there is the southern hemisphere accounts for a stronger response to lower insolation there. Precession

257 Precession of the equinoxes, as this cycle is generally called, was known in Hellenistic times and probably before, and is probably the basis of the Maya Long Count. It is also the motion that the astrological ages, i.e. Age of Aquarius, is based on.

effects, which Milankovitch calculated should have the strongest effect on insolation because they regulate where the equinoxes are relative to the aphelion and perihelion, accentuate the seasons. According Milankovitch's model, when summer in the northern hemisphere coincides with aphelion, obliquity is at minimum, and eccentricity is high, insolation is very low and conditions are most conducive to glaciation. The triggering of an ice age is thus thought to occur during times of cool summers, a response to low insolation levels, which allows for an accumulation of ice and snow from year to year in the higher latitudes. Eventually this builds into an ice sheet that reflects solar radiation back into space, which accelerates the cooling of the Earth (positive feedback).

It is important to emphasize that Milankovitch's modeling of insolation driving glaciations is based primarily on precession, but does include a weaker obliquity signal. This is logical as the calculated variations in insolation for the three cycles are 8-13% for precession, 5% for obliquity, and 0.2% for eccentricity. Of the three cycles, eccentricity produces the least amount of change in insolation and was believed to have the least effect on climate. Eccentricity, an orbital modulation driven by perturbations from Jupiter and Venus, consists of three periods of 95, 125, and 400 k.y. that are apparent in spectra derived from climate records. It is not a simple 100 k.y. cycle. However, both marine and ice core $\delta^{18}O$ global proxy data show the strongest correlations to a basic 100 k.y. cycle with obliquity and precession apparently being weaker signals This is the reverse of what would be expected and, further, this has only been the case for the previous million years. Prior, the 41 k.y. cycle predominated. In spite of these anomalies, many geoscientists and climatologists have embraced orbital forcing and accept the dominant 100 k.y. cycle as a solution to the mystery of global climate change. Orbital forcing is in the textbooks.

The Earth's axis and its orbit are known to be further perturbed by the gravitational forces of the other planets. These perturbations also produce cycles in insolation. When the solar system is viewed downward, assuming the plane of the Earth's orbit as a fixed reference plane, the orbits of the other planets (their shapes) are regarded as factors that exert what are called "*g*" frequencies. This is something like a longitudinal effect. Differences in the planetary orbits on the vertical level (parallel to the plane of the Earth's orbit) are called "*s*" frequencies, these being similar in principle to latitude or declination. Climatic frequencies are then produced by the combinations of the individual g and s frequencies as well as the precessional constant p. The limits of precision allow the g and s frequencies to drift over long periods of time making it difficult to produce isolation curves for more than about 20 million years into the past or future. At 200 million years there can be as much as a 40% error. The 404 k.y. cycle, however, appears to be very stable and has been found in the geological records (Newark basin and other Triassic-Jurassic basin cyclical records). These may serve as a means of focusing the celestial mechanics of orbital variables in the remote past.

The actual beginning of the Pleistocene, the period of the ice ages, was first suggested by Lyell in 1893 to be the point in the geological record in which 90-95% of the fossils found were of organisms alive in the present. It was later suggested that this era be dated by evidence of a cold climate. In 1948 the first appearance of cold-water species found in a specific southern Italian sediment marked the beginning of the period. Later it was found that this point coincided with the Olduvai Normal Event, a magnetic pole reversal, at 1.8 m.y. Traditionally, four ices ages during this period were documented in North American and six or seven in Europe.

In the 1950's Milankovitch's theory on orbital forcing was rejected by most geologists due to the advent of radiocarbon dating and the results it produced in regard to the Pleistocene. It was discovered that there had been warm climate intervals as recent as 25,000 years ago and other ice fluctuations over 80,000 years that were at variance with Milankovitch cycles. In the 1960's, however, the analysis of deep sea cores produced evidence that sea level fluctuations appeared to occur in a 21,000 year cycle. Then, using sediment cores from the Indian Ocean, Hays et al. (1976) showed that there was a fairly consistent phase relationship between insolation, sea surface temperature and ice volume. They also found that the 100 k.y. cycle was far more prominent that had been expected. The 100 k.y. cycle has apparently been consistent for the previous 700 k.y., but before that time climate cycles of about 40 k.y. (obliquity) appear to dominate. There have been two approaches to this problem: One seeks an explanation in orbital forcing by the technically stronger 19 k.y. and 23 k.y. precessional frequencies which affect the terminations of glacial episodes. The second proposes that ice-volume fluctuations are modulated, not driven, by orbital forcing in a highly complex system.

It appears that different components of the Earth system can be modulated by differing orbital cycles. The Oligocene marked the start of a generalized cooling, with glaciers forming in Antarctica and an increase in ice sheets that led to a fall in sea level. This cooling caused the tropics to diminish while cooler woodlands and grasslands expanded. The overall cooling trend was to continue through the Miocene, culminating in the ice ages of the Pleistocene. Palike, et al., used benthic foraminifera stable isotope ^{13}C data from Ocean Drilling Program leg 199, site 1218, equatorial Pacific, at a 4.8 km water depth, to quantify the rhythms of the carbon cycle during the period.[258] The analyzed data show two large-scale glaciation events at the Eocene-Oligocene and Oligocene-Miocene boundaries and other distinct trends in their division of the Oligocene into four parts of roughly 2.5 m.y. each. Persistent throughout the entire epoch is a cycle of benthic delta ^{13}C which becomes entrained to a long, and very weak, 405 k.y. eccentricity cycle. In addition there are also glacial intervals found in the data of ~1.2 m.y. synchronized to an obliquity amplitude cycle. Two climate models constructed to simulate the data from the core show that the onset of glaciations during the Oligocene are independent of the exact timing of CO_2 reduction and are triggered by astronomical forcing only when CO_2 levels are close to threshold values. They also find a ~20 k.y. lag of ^{13}C in the 405 k.y. cycle and suggest that the power of this cycle is due to the long residence time of carbon in the oceans which causes it to respond more strongly to longer orbital forcing periods. Palike et al. conclude that, considering the weakness of the 405-k.y. eccentricity cycle, the Earth-system is very sensitive to orbital variations. Apparently very weak signals from the solar system can drive large systems on the Earth.

Orbital cycles have been found in sedimentation patterns in the Mediterranean. The Messianian Salinity Crisis, which began about 6 million years ago in the late Miocene, was a period when the Mediterranean evaporated and filled at the precessional rhythm. As many as 55 precession induced sedimentary cycles have been found. At precession maxima, which corresponds to a dry climate, gypsum beds were deposited, and at precession minima, a wetter climate, sapropelitic marls are found.[259] In the late Triassic strata of the Newark rift basin in New Jersey, lake level cycles have been found to correlate with orbital cycles.[260] The Newark Basic Coring Project retrieved cores covering a period of about 32 million years in the late Triassic and Jurassic, a time when the region was located in the tropics. The cores revealed the cycles of precipitation and evaporation that were controlled by Milankovitch cycles, specifically precession and ellipticity. No obliquity signal was found, though that signal works primarily in northern latitudes. The time-

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[258] Palike, et al., "The Heartbeat of the Oligocene Climate System," *Science,* (2006).

[259] Krijgsman, W. et al. "Astrochronology for the Messinian Sorbas basin (SE Spain) and orbital (precessional) forcing for evaporite cyclicity," *Sedimentary Geology,* (2001).

[260] Olsen, P. E. and D.V. Kent, "Long-period Milankovitch cycles from the Late Triassic and Early Jurassic of eastern North America and their implications for the calibration of the early Mesozoic time scale and the long-term behavior of the planets," *Philosophical Transactions of the Royal Society* of *London A,* (1999).

scale produced from these records was used by Olsen and Kent as a template for magnetic field polarity reversal stratigraphy. The astronomical tuning of the geomagnetic time scale was based on the 404 k.y. ellipticity cycle which is modulated by the gravitational forces of Venus and Jupiter which are stable over long periods. A long period of ellipticity, 1.75 m.y., was found in the cores and is thought to correspond with a more recent period of 2.5 m.y., the difference being the chaotic behavior of the Mars-Earth orbital relationship over the past 200 m.y. Apparently, the solar system exerts an influence on Earth's climate through these orbital variations.

4.2 The Sun, Solar Cycles and Earth

The Sun is considered to be a second generation (G2) star in the main sequence that is about 4.5 billion years old. Like other stars, the Sun generates energy as a result of a chain of nuclear reactions in its core. It is nuclear fusion of hydrogen atoms into helium, driven by gravitational pressures within the Sun, that produces solar energy. The temperature of the Sun's core is 15×10^6 K. The visible outer layer of the Sun, called the photosphere, has a temperature of 5,700 K. Some of the heat produced in the Sun's core is radiated from the photosphere into space, where a small portion is encountered by the Earth in its orbit around the Sun. About 70% of this solar radiation is absorbed, heating the Earth and fueling the biosphere.

The Sun is a dynamic system operating in a fluid state. This fluid nature is shown in its axial rotation which is 25 days at its equator and 30 days at its poles, with an average rotation of 27 days. The Sun has an axial polar dipole magnetic field though other dipole fields emerge along the equator and generate the interplanetary magnetic field. It is thought that the naturally-occurring magnetic fields of the Sun experience extreme distortions due to this uneven rotation, and that the magnetic field lines twist, creating a constantly evolving magnetic field – the solar dynamo. In the process magnetically charged sunspots form on its surface, these being large regions that are about 1,500 K cooler than the surface. Sunspots reduce the radiated energy from the region they occupy by 0.1%.

The Earth is bathed in a flux of both cosmic rays and the solar wind. The solar wind is a stream of charged gas particles, mostly hydrogen, that are lost from the Sun. Because the Sun rotates, the solar wind radiates out from the Sun like streams of water from a rotating lawn sprinkler. The number of sunspots on the Sun at any given time is a good indication of the power of the solar wind as sunspots indicate higher solar activity. The solar wind also carries with it magnetic fields that spiral out into the solar system, creating what is called the Interplanetary Magnetic Field (IMF). If the Earth or another planet is in the way of one of these spiraling waves of magnetically charged solar wind, it gets blasted.[261] The charged particles of the solar wind contact the Earth's magnetic field, bending it like the bow of a ship bends the water in front of it. When the solar wind is particularly active, i.e. after a solar flare occurs, its collision with the Earth's magnetic field intensifies generating aurorae near the poles. At the high point of a sunspot cycle, when the Sun's magnetic field is very active, the push of the solar wind on the Earth's magnetic field is stronger than during the low point of the solar cycle. A weak solar wind allows a higher flux of cosmic rays to enter the Earth's upper atmosphere, and a high flux of cosmic rays produces higher levels of certain isotopes, i.e. those of Carbon and Beryllium, which are used as insolation proxies.

The total omni-directional energy output of the Sun is called its solar luminosity. The amount of energy that the Earth intercepts (assuming a surface perpendicular to the solar beam at the top of the atmosphere) is called the solar constant, which has been established to be ~1366 W/m^2. This figure, thought to be constant within a narrow range, is the total radiant power at one astronomical unit, the average distance of the Earth from the Sun. There is some fluctuation of the energy reaching the Earth, however, and this appears to be related to the 11-year sunspot cycle, but it is considered to be very small, about 0.1%. This fluctuation raises two issues; how it is generated and does it have an effect on Earth's climate and biosphere? Before these are addressed, a history and overview of the nature of the solar cycle is appropriate.

A roughly 11-year solar cycle is evident in the numbers of sunspots counted on the Sun over a period of time. Heinrich Schwabe (1789-1875) is generally credited with discovering this cycle and it is now often referred to as the Schwabe cycle. Schwabe was an amateur astronomer who systematically observed the Sun through a telescope from 1826 to 1868 in hopes of spotting a solar transit of Vulcan, a hypothetical inter-Mercurial planet. He never found Vulcan but he recorded a succession of sunspots and thus created a data base. In 1843 announced that he had discovered a cycle of 10 years during which time sunspots increased and then decreased in number. Rudolf Wolf (1816-1893) refined this discovery. He noticed that sunspot cycles varied

[261] This may be the proper term as an early definition of "blasted" implies a force emanating from the stars. The term was used by astrologers to describe astrological effects.

from as short as 8 years to as long as 17 years, though the average was about 11.1 years. Wolf worked in Zurich, Switzerland and established an index of sunspots which is now called either the Wolf or Zurich index. The formula for this index is somewhat complicated because it was designed to account for the different qualities of telescopes used by observers. Wolf also examined older records of sunspots and pushed the index back as far as 1700, effectively creating the first multi-century solar activity data base.

Another important 19th century figure in the history of solar science is Richard Carrington (1826-1875). In addition to his observation of a solar flare and noting a connection to magnetic field disturbances on the Earth, he also discovered that the Sun has differential rotation and that sunspots form at higher solar latitudes and move toward the equator as the cycle progresses. This phenomenon was graphically illustrated by E. Walter Maunder (1851-1928) in 1904 and it has since become known as the Maunder butterfly diagram, because of its resemblance to butterfly wings. In the early 20th century George Ellery Hale (1868-1938) recognized that sunspots were actually gigantic magnetic storms on the surface of the Sun, and not dark clouds. He also noticed that an increase of the Sun's polar and dipole magnetic field occurred at times when solar activity was at a minimum. Maximum solar activity apparently occurs when the differential rotation of the Sun pulls the magnetic field into coils, these interlocking with previous magnetic fields and creating an evolving magnetic field. When these coiled magnetic field lines penetrate the surface of the Sun, sunspots are formed, a phenomena that explains why sunspots are magnetically charged. The magnetic polarity of sunspots shift from positive to negative at each 11-year cycle. A complete pattern of reversal then takes 22-years, which is thought to be the proper length of the solar cycle. This cycle is now commonly referred to as the Hale cycle.

Exactly what causes the Sun to produce a solar cycle of sunspot numbers and magnetic field changes, is not completely understood. Textbooks either ignore this question or they will briefly explain it in terms of differential rotation.[262] This model, originally proposed in 1961 and often called the solar dynamo model, suggests that the faster equatorial rotation of the Sun, which

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[262] A look at two major introductory astronomy college textbooks and two books about the Sun are evidence of this statement. Arny, *Explorations: An Introduction to Astronomy,* (1998) offers only a simplified description of the differential rotation model and Zelik, *Astronomy: The Evolving Universe,* (2002) completely ignores the issue. Lang, *The Cambridge Encyclopedia of the Sun*, (2001), in a moderately technical book dedicated entirely to the Sun, offers one page on this matter. Phillips, *Guide to the Sun,* (1992), in a similar book, goes into some detail in regard to the dynamo model (p. 67-72) but also doesn't mention the planetary hypothesis. In contrast, Seymour, *Dark Matters,* (2008) discusses the dynamo model and its weaknesses, and the planetary model in some detail (p. 114-129).

distorts or "winds up" its magnetic fields, is the cause of the solar cycle. At the start of the cycle the Sun's magnetic lines of force are parallel to longitudinal lines running from pole to pole – a poloidal field. As the solar equator moves faster than the polar regions, these magnetic field lines distort eventually becoming parallel to the equator – a toroidal field. After about three years these lines have been pulled around the Sun about five times creating a spiral pattern. From these windings it is hypothesized that subsurface bands develop kinks and emerge from below the photosphere becoming pairs of sunspots. Eventually, these migrate and dissipate and produce a polarity reversal when the poloidal field is reestablished. The cyclicity is then something that apparently emerges out of the Sun's rotation.

The alternate model to explain the cause of sunspot cycles involves planetary gravitational forcing. Paul D. Jose analyzed the movements of the center of mass of the solar system (barycenter) and found that its eccentric paths in and out of the body of the Sun followed a 178.7-year period (which is close to a recognized solar cycle noted in the literature).[263] He argued that this is driven by the angular momentum of the solar system in total, and that the larger planets, Jupiter, Saturn, Uranus and Neptune, contribute greatly to the effect. Jose plotted the movement of the center of mass relative to the Sun's surface and also the Sun's motion around it and correlated this data with the Wolf sunspot index. He concluded that sunspots may be generated by the gravitational torque of the planets on the Sun which stirs convection currents below the surface. These convection currents then play a role in moving magnetic fields that lead to sunspot formation. Critics of planetary forcing of the solar cycle point to the fact that there were few sunspots during the Maunder Minimum of the late 16th and early 17th centuries, but the planets were presumably still orbiting the Sun in those years.[264]

Rhodes Fairbridge, and also climatological mavericks Niroma and Landscheidt, are among those that have incorporated planetary forcing in climate studies.[265] Niroma argues that the orbit of Jupiter modulates the solar cycle and, using the Wolf index, shows that sunspots increase when Jupiter is at aphelion, but decrease when the planet is at perihelion. Jupiter does orbit the Sun every 11.86 years, a figure very close to the Schwabe cycle. Landscheidt developed a unique

263 Jose, (1965).
264 Eddy, "The Maunder Minimum," *Science,* (1976).
265 See Mackey, "Rhodes Fairbridge and the idea that the solar system regulates the Earth's climate," *Journal of Coastal Research*, (2007), Landscheidt, *Sun-Earth-Man*, (1988) and Niroma, *One possible explanation for the cyclicity in the Sun,* (2005).

method of forecasting solar events and he noted that Jupiter's gravitational torque on the Sun, combined with that of the Earth, is reflected in a correspondence between heliocentric conjunctions of Earth and Jupiter and the rotational velocity of the Sun. Landscheidt, who made climate predictions, practiced a kind of heliocentric natural astrology. More recent work on planetary forcing of the solar cycle by Wilson, et.al., suggests there is a spin-orbit coupling between the Sun's rotation and the Jovian planets.[266] Changes in the Sun's equatorial rotation rate are affected by shifts in the center of mass of the solar system (barycenter) and that this connection is modulated by the ~20-year synodic period of Jupiter and Saturn. One finding is that alignments (syzygy) of Jupiter and Saturn occurring after solar maximum establish a trend where the Wolf sunspot number remains above 80. This pattern is then sustained for a period that is roughly the length of the Gleissburg cycle after which time a collapse of the pattern occurs when the syzygy occurs before maximum. The authors argue that it is a resonance lock between planets and Sun that is broken when the cycles drift apart after about 90 years, or four Hale cycles. In spite of this work, the theory of planetary modulation of the solar magnetic field is currently not of interest to the majority of solar cycle researchers but it remains a viable alternative.

The crucial issues in determining whether or not the Sun plays an active role in climate change are the nature, variability, and amplitude of the Sun's energy output, and these are dependent on accurate measurements of the solar constant. Much effort has been spent on measuring the solar energy reaching the Earth and past results were not very clear or decisive. One of the more productive projects was carried out by Charles Greeley Abbot (1872-1973) who ran the Smithsonian Astrophysical Observatory from 1902 to 1957. During this time he carefully measured solar brightness using many delicate instruments and his records remains to this date a useful dataset of solar variability. Greeley had found that sunspots will, on the short term, decrease solar irradiance (called sunspot blocking), but that on the long term, the active Sun at sunspot maximum is brighter.

In the 1970's and 1980's satellite measurements of the Sun refined the dataset on solar irradiance. It was found that solar irradiance changed over the course of the 11-year cycle with an amplitude of 0.1% on a yearly basis. On a daily basis, however, the change could be as much as 0.5%. Another finding was that faculae, the bright portions of the Sun surrounding sunspots, make up

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266 Wilson, et.al., (2008)

for sunspot blocking, so Greeley was correct, the Sun at sunspot maxima was actually putting out more energy. It is known that the solar spectral peak is at 0.5 microns, the center of the visible spectrum. But the Sun also radiates energy in other wavelengths. Solar radiation of short wavelengths show significantly greater variation, > 10%, than do those of visible light over the course of the solar cycle amounting to as much as 2.1 W/m^2. Critics of a solar influence on climate point out that short wavelengths < 0.3 don't reach the Earth's surface, they are absorbed in the atmosphere. However, they do heat the stratosphere which may affect climate indirectly.

Variations of solar irradiance at all wavelengths are carried by photons. The nuclear chain reactions taking place in the Sun also produces neutrinos that, like photons, carry energy away from the solar core. These massless particles are identified as a flux with a period some early studies found to be near that of the solar cycle. It is thought by some that the solar neutrino flux accounts for an amplitude of 1 W/m^2 over the course of the solar cycle, though this assumption and the value is questionable.[267] However, if there is a correlation, and this figure is combined with the short wavelength variation, then there is a 3.1 W/m^2 change in solar energy, a figure that amounts to 0.227% of the solar constant. Critics of a solar effect on climate change say even this is still not enough to account for changes in the various components of climate.

One possible amplifying mechanism for solar irradiance considers a previously mentioned effect on the upper atmosphere. During sunspot maxima, sunspots decrease the solar output at all wavelengths. But along with more sunspots comes more faculae, bright photosphere regions surrounding sunspots. These faculae radiate strongly in the blue and ultra-violet (UV) portions of the spectrum and account for a net increase of UV radiation reaching the Earth's atmosphere during times of solar activity. UV radiation accounts for 20% of the total solar energy reaching the Earth. These faculae, located near the Sun's equator where sunspots migrate and are most concentrated, radiate at oblique heliographic angles, another factor that marginally affects the solar constant. Since faculae are mostly located in the central regions of the Sun, their radiation is highest in the direction of the plane of the solar system (the Sun has a low axial tilt) and will therefore intercept the Earth's orbit. All of this amounts to saying that UV radiation increases are substantially higher than other wavelengths over the course of the solar cycle and that these may

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[267] Sturrock, "Combined Analysis of Solar Neutrino and Solar Irradiance Data: Further Evidence for Variability of the Solar Neutrino Flux and Its Implications Concerning the Solar Core," in *Solar Physics* (2009), and Walther, "Absence of Correlation between the Solar Neutrino Flux and the Sunspot Number," in *Physical Review Letters,* (1997).

have some affect on the upper atmosphere, which in turn, affects the lower atmosphere and consequently climate. Shades of Aristotle's concentric spheres of influence.

Is solar variability found in other stars, and if so, at what amplitude? Stars other than the Sun are now known to display strong cycles of variability in energy output. In fact, most stars display variability to a much greater extent than does the Sun, leading some scientists to speculate that our Sun is atypical. Younger stars are more active than older stars and the variability cycles observed typically ranges from 7 to 20 years. Solar-type stars display variations of up to 0.6%. With instrument data extending only a century or two into the past, and human historic records extending not more than a few thousand, it is difficult to say whether or not the Sun displays over time the range of variability now known to exist in other stars.

In summary, a good case can be made for solar irradiance being variable, but not with a particularly high amplitude except in the UV range. Many solar variability cycles have been described or proposed and several have been correlated with climate data. One is the 27-day rotation of the Sun thought to produce a variability when one hemisphere of the Sun contains sunspots and other doesn't. Rotation would then alternate two different sides of the Sun each with a different radiative value, specifically in the higher wave lengths. This cycle is so close to that of the lunar cycle that correlations of data displaying a 27-day periodicity are difficult to ascribe to a specific mechanism, solar or lunar. Best known of the solar cycles is the Schwabe 11-year cycle of sunspots. Individual Schwabe cycles vary, however, with some expressing more sunspot blocking and others expressing more facular emission. Schwabe cycles also alternate with reversed polarity as described earlier. The Hale 22-year double sunspot cycle includes this magnetic field change which amounts to one full solar reversal cycle. Magnetic field reversals in the solar cycle are thought by some to affect the Earth's magnetic field, which in turn influences the upper atmosphere in terms of electrical charge.

The 11-year Schwabe solar cycle actually ranges from as few as 8 years to as much as 17 years. The Gleissberg cycle of 80-90 years groups Schwabe cycles together according to a lengthening or shortening trend and appears to be more of a wave than a pulse. It is also considered one of the more significant solar cycles and it shows up in isotopic proxies such as ^{14}C, ^{10}Be and ^{18}O records, though it also shows that the solar cycle is not a true periodicity. This cycle was first noticed by Wolf in 1853 (he claimed it was 83 years) but was rediscovered by several other scientists since then. In the 1930's Wolfgang Gleissberg published a large number of papers on the subject and this cycle has since become associated with him. Interestingly, solar cycle length has been shown to correlate with temperatures. A connection between globally averaged sea surface temperatures and Wolf's long-term solar activity record has been reported.[268] In this climate model study the 80 to 90-year Gleissberg period was the dominant cycle of sea surface temperatures, and that the necessary change in the solar constant to produce this long-term effect, according to the model, was under 1%. The Seuss cycle of about 180-208 years has been found in sunspot counts and in isotopic cosmogenic proxies in ice core data. It has been linked to the 179-year barycenter cycle and a recurrence cycle of Jupiter and Saturn by Landscheidt and others.

In 1976 John A. Eddy published a landmark paper that drew attention to a period of low solar activity in the late 17th century and early 18th century which he named the Maunder Minimum. During this entire period the number of sunspots observed was not more than the number observed in a single active year since that time. Using a combination of historical evidence and ^{14}C records he argued that solar activity was extremely low between 1645 and 1715 and that during this period Europe, at least, experienced a cold climate. Eddy argued that sunspots must have been scarce because, when they were sighted during that time by the astronomers of the day, they were regarded as special discoveries. He also drew from records of aurorae and observations of the Sun's corona during eclipses (they were both absent) and ^{14}C records from tree rings which during that period are very high, suggesting an inactive Sun and consequently a higher cosmic ray flux.[269]

A chart in Eddy's paper, based on deviations in ^{14}C concentrations in tree rings, illustrates solar activity patterns since about 1050 A.D. The chart shows a rise in ^{14}C levels not only at the Maunder Minimum, but also between 1460 and 1550, a period Eddy called the Sporer Minimum (named for Gustave Sporer, a sunspot science pioneer). The chart also shows very low ^{14}C levels between 1100 and 1250, a warm period that Eddy refers to as the Grand Maximum, also known as the Medieval Maximum. Since the publication of this paper, the Maunder Minimum has become regarded as a solid fixture in the climatic past although more recent climate reconstructions have shown that the period immediately before was even colder. It has been

268 Reid, "Influence of solar variability on global sea surface temperatures," in *Nature,* (1987).
269 Eddy, "The Maunder Minimum," *Science,* (1976).

suggested that a correspondence between solar activity and solar irradiance is not consistent and that in some cases it lags temperature which moves ahead of it.[270]

Beginning in the early twentieth century several studies noted a correlation between air temperatures and solar cycle lengths. In 1991 a major paper reiterating the same idea drew attention to the Gleissberg cycle and the Northern Hemisphere record of Hansen and Lebedoff, and Jones, a data base considered to be the most reliable global temperature record available at the time.[271] The authors, Friis-Christensen and Lassen, first correlated the record with the 11-year solar cycle but found that the temperature record actually led the solar cycle, negating a cause and effect relation. They then determined the solar cycle lengths which, when filtered and fit into the 80 to 90-year Gleissberg cycle envelope, corresponded neatly to the temperature records, removing the solar lag. A correspondence with sea ice volume near Iceland was presented as further evidence of a solar-climate link that they suggest amounted to an increase in the solar constant of about 1%, much higher than the 0.15% normally given.

Additional solar indices have been noted. Hoyt in 1979 drew attention to the ratio between the sizes of the umbra and penumbra of sunspots and showed that this ratio appears to correlate with solar irradiance changes. The thought here is that if convective velocities in the Sun increase, then pressures on the photosphere surrounding the sunspots increases causing the photosphere to decrease. This allows for a brighter Sun. In 1987 Ribes argued that solar radius variations caused changes in solar luminosity and in 1993 Hoyt and Schatten analyzed the sunspot decay rates and found that these correlate with solar irradiance changes.[272]

Correlations between the various solar cycles and climate have been made since the early days of sunspot observation. Historically, proponents of a correlation have differed as to whether or not sunspot maxima coincided with higher or lower temperatures. By the 1960's, this long history of a lack of consensus led to the entire field of solar-climate research falling into disrepute. The major problem seems to have been that sunspot cycle maxima did correspond to higher

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270 Hoyt and Schatten, (1997) 183.
271 Friis-Christensen and Lassen, "Length of the Solar Cycle: An Indicator of Solar Activity Closely Associated with Climate," *Science,* (1991).
272 See Hoyt and Schatten, (1997) 187-191.

temperatures between 1720 and 1800, but it correlated with lower temperatures between 1600 and 1720 and 1880 to 1920. The correlation reversal that occurred in the 1920's was one during which a number of Sun-climate relationships changed or broke down completely. These reversals of correspondence are now called sign changes.

Since the 1960's a number of investigators have used a variety of proxies in their search for climate records that correlate with the solar cycle. D.J. Schove documented sightings of aurorae, ^{14}C flux rates, and varve periodicities extending back 10 k.y. In this evidence he found an 11-year cycle in weather. Robert Curie used world temperatures and applied a new method of calculating spectral peaks in the data. He found a 10.7-year cycle with an amplitude of 0.27 C, and also cyclic variations in U.S. temperatures with peaks at 10.4 and 18.84 years. In the Eastern U.S. temperatures were in phase with the solar cycle but in the Western part of the country they were 180 degrees out of phase.[273] Clearly, the subject is compounded by not only changes in phase, but by differences in region and blurring with the lunar nodal cycle.

The solar cycle appears to correlate with more climate data than just temperatures. Correlative evidence for a link between the solar cycle and precipitation has been described, but it has also proven inconclusive. Again, there is a long history of studies of this nature, but as soon as one apparent correlation has been found and a paper has been published, the next study disproves it. The most central problem has to do with the fact that rainfall varies spatially and any given region's annual rainfall may not accurately reflect the larger pattern. Another problem is that cyclic variations in records for precipitation show both an 11 and an 18.5-year cycle. This later figure is presumed to represent a response to the lunar 18.5-year nodal cycle during which time the lunar orbit modulates its tidal effect. It is thought that this cycle has some effect on the surface area of the oceans, the amount of surface area available for heating. Drought cycles have been found in tree rings and many of these show a roughly 20-year cycle which some believe to be a reflection of the 22-year Hale cycle. Others have argued that this could also be a reflection of the lunar 18.5-year cycle – or both.

A mechanism to explain cyclic patterns in rainfall driven by solar activity involves the expansion and contraction of the Hadley cell. An increase in solar irradiance would theoretically expand and

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273 See Hoyt and Schatten, (1997) for these and other correlations between climate and the solar cycle.

intensify the ITCZ near the equator where the highest levels of incoming solar radiation are received. This expansion would move the descending limb of the cell north and south of the equator, moving the desert regions poleward. It is thought that a 0.15% increase in solar irradiance would result in about the same percentage increase in precipitation. As the world precipitation average is 100 cm per year, this amounts to an increase of 0.15 cm per year – but distributed differently over the globe in patterns that reflects the solar cycle. This has yet to be demonstrated conclusively.

Storm frequencies are another weather variable that appear to reflect the solar cycle. The thought behind this connection is that higher levels of solar irradiance produce higher sea surface temperatures and that this leads to the production of more cyclones. Both higher and lower frequencies of storms at solar maxima have been noted and apparently both the phase and the actual location of the study is again crucial. The annual number of cyclones does appear to follow an 11.3-year pattern, but there is also a peak at 51.2 years, the later thought to correlate with a solar activity peak that occurs at 52.7 years (yet another cyclicity). Thunderstorm frequencies also appear to follow the solar cycle and a mechanism has been proposed to explain this. Low levels of solar activity will result in a thinner and weaker solar wind, allowing more cosmic rays to enter the Earth's atmosphere. Increased cosmic ray bombardment causes changes in the electrical charge of the ionosphere and consequently variations in the global electrical circuit, thus affecting thunderstorms with electrical discharges.

Further evidence of possible solar effects on climate may be seen in population cycles of various organisms. Many studies have shown an 11-year cycle in insect populations, often high just before sunspot maximum. Reasons given for this include increased heating and/or precipitation (depending on species and region) and also increase solar UV radiation which is thought to stimulate activity. Locusts, a plague species, have been correlated with the sunspot cycle with populations waxing between minimum to maximum and declining between maximum to minimum. Tent caterpillar populations in New Jersey also show a roughly 11-year cycle that peaks about two years ahead of sunspot maximum. Interestingly, recent satellite data has shown that the Sun brightens at about this point in the solar cycle. Tree rings, which are a highly regarded climate proxy of both temperature and precipitation, reveal a weak 11-year cycle, but its appearance is inconsistent, leading to a general distrust of this connection.[274]

[274] See Hoyt and Schatten, (1997).

There are many problems in simply defining a solar-climate relationship. Exactly what is being sampled, i.e. temperature, pressure, wind, humidity, precipitation, etc. can make an enormous difference. The length of the sample will shape the results. Using 30-year norms may not show a long term increase or decrease of what is being measured – such records are simply not long enough. There are also difficulties in taking accurate measurements. Instruments need to be calibrated and properly located, and there are choices to make in regard to sorting the data in terms of mean, highs, and lows. One major problem today is discriminating between natural and anthropogenically-driven changes. These need to be separated, but this if often very difficult, if not impossible. In some cases measuring only extreme weather events, events of eminence, yields clear results and yet reflects only very small variations in the solar constant. Amplifying mechanisms, some of which have already been described, have been suggested and sought for. The solar-climate relationship is not a clear-cut situation. Much depends on how questions are formulated and the actual tolerances of the climate system. Given the complexities and uncertainties of the solar-climate relationship, climate modeling, which is completely dependent on the program established by the operator, has its limits.

Today there is not a consensus on a solar cycles and how they may affect the Earth. Some argue for the Sun being the predominant influence on Earth's climate. There are many websites dedicated to showing that the greenhouse effect is a deception, and most of them support this claim with papers arguing for a dominant solar influence on climate. Typical arguments posted on these websites point to the temperature trends that correlate strongly with the sunspot cycle and also to the period of the Medieval Warming and the Little Ice Age that correlate with sunspot minimums. Those against a predominant solar influence on climate argue that the solar constant varies by only about 0.1%, not enough to make much of a difference. However, others say that this variation is not realistic, it is more like a 0.5 to 1.0% change. Those against also argue that a simple doubling of the CO_2 content in the atmosphere will warm the Earth by 2 to 6 degrees, something that would require a 2% increase in the solar constant, and this is not seen in the ground or satellite data. Again, if the variability of the solar constant is as small as it appears to be, and that this is somehow driving climate in certain ways, then there must be some kind of amplifying mechanism at work. Some of these have already been mentioned.

Today, most mainstream climate researchers would agree that solar variability is an important factor in climate change and that it must be incorporated into climate models. But most also agree that it is not enough of a force to explain the warming that is occurring - but the increase of greenhouse gases is apparently enough. The current thinking is that as greenhouse gas levels rise, solar variability will play less and less a role in climate change. This means that anthropogenic forcing has trumped the Sun and that other biotic or natural mechanisms will be unable to modulate these human-induced extremes. We are living through an experiment.

4.3 UV and Cosmic Ray Flux

Solar cycles (sunspot numbers) have been correlated with weather and climate change for over two centuries. Variations in total solar irradiance over the course of the Schwabe 11.1-year cycle are only about 0.1%, and climatologists have sought amplifying mechanisms that link this very small change with measurable atmospheric data. The solar wind, a flux of charged particles, is strongest at sunspot maximum fortifying the Earth's magnetic field and shielding it from cosmic rays (CR). CR emanate from supernova remnants in the spiral arms which are also areas of star formation and abundant interstellar clouds. When the Sun is calm, more CR enter the Earth's atmosphere possibly affecting tropospheric cloud formation by serving as cloud condensation nucleii. Increased low altitude cloud cover (LACC), stimulated by higher CR flux (CRF), then ith increases global albedo and leads to cooling.

CRF as an amplifying mechanism for solar variability posits an inverse relationship between climate and solar cycle maximum. Svensmark and Friis-Christensen argue that changes in the distribution and total amount of clouds would change climate and that this factor is solar driven.[275] While an increase in high altitude clouds leads to warming and an increase in low altitude clouds leads to cooling, an increase in total clouds is thought to lead to overall cooling of the Earth. During sunspot minimum, when the solar wind is at its lowest levels, cosmic rays reach the atmosphere with greater frequency and, as has already been mentioned, this changes the isotopic ratios of certain elements that are used as climate proxies by paleoclimatologists. If cosmic rays also affected sulfate aerosol formation and cloud nucleation, then this would amount to an amplifying mechanism for small changes in the solar constant. Therefore cosmic ray

[275] Svensmark and Friis-Christensen, "Variations of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships," in *Journal of Atmospheric and Solar-Terrestrial Physics,* (1997),

intensity should be inversely proportional to the sunspot cycle. Svensmark and Friis-Christensen, using a limited satellite dataset of ocean clouds between 1983 and 1990, showed that the percentage of cloud cover follows the cosmic ray flux variations for that period. They claim these results indicate a direct connection between the two factors and recommend this external forcing factor to climate modelers. As for a mechanism Svensmark and Friis-Christensen cite several possibilities. One suggests that the charge of cosmic rays on aerosols modulates cloud formation. A second has to do with atmospheric transparency, a change in the optical properties of the atmosphere, that is caused by the ionizing effects of cosmic rays and leads to changes in cloud cover. This model has critics and uncertainties. One problem is that there are gaps in the correspondence between CRF and global total cloud cover after 1991 or to low cloud cover after 1994.[276] This model has also generated controversy among global warming advocates, including the International Panel on Climate Change.

CRF variations, which ranges from 25% to 135% of the current values, or a variation range of 7-35% for low altitude clouds operating over much longer time frames, may modulate very long cycles. Correlations have been proposed between estimated rates of galactic CRF and climate change, tectonic activity, glaciations and extinction events. Astrophysicist Nir Shaviv proposes that very long climate cycles, driven by variations in galactic cosmic ray flux, occur as the solar system orbits the center of the galaxy.[277] The community of climate scientists has not embraced this hypothesis and has been critical of the databases used to make the case for such cycles. Support has been stronger among astronomers and physicists.

The density of CR sources is not uniform in the galaxy – they are concentrated in the spiral arms and emanate from supernova remnants. The spiral arms themselves are not material, they are density waves that can have a destabilizing and cosmic ray generating effect on stars. The arms are transient, may last under 1 billion years, and vary according to distance from the galactic center where conditions are more complex. There appear to be two dominant arms, but four in the range that our solar system orbits. In Shaviv's hypothesis, CRF entering the Earth system is higher when the solar system passes through the spiral arms, causing long periods of cooling due

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[276] See Laut, "Solar activity and terrestrial climate: an analysis of some purported conclusions" in *Journal of Atmospheric and Solar-Terrestrial Physics*, (2003), for a review of problems with the hypothesis that cosmic ray flux is a driver of climate.

[277] See Shaviv, "Cosmic Ray Diffusion from the Galactic Spiral Arms, Iron Meteorites and a possible Climatic Connection," in *Physical Review Letters* (2002), and "The Spiral Structure of the Milk.y. Way, Cosmic-Rays and Ice-Age Epochs on Earth," in *New Astronomy*, (2003).

to enhanced low altitude cloud formation. The solar system orbits the galactic center in a 240-m.y. cycle, passing through all four arms (which are also moving but more slowly) in a 704 m.y. cycle. Galactic Arm passages (the solar system is presently in the Orion armlet), taking into consideration both motions, are estimated to occur every ~150 m.y. As the solar system enters a galactic arm acceleration occurs, followed by deacceleration while in the arm. The moving spiral arms leave behind a wake of slowly diffusing CR making CRF higher just after solar system crossing of arm than before its passage.

The actual timing of spiral arm passages is not known with precision. Shaviv bases his dating of spiral arm passages and consequent increases in CRF on a combination of density wave theory, observations, and meteorite exposure dating. In this later method, meteorites are dated from their break with the parent body using tracks of CR on their newly formed surfaces. Shaviv uses a sample of 80 iron-nickel meteorites from which he selects 50 and plots a histogram of Fe-Ni exposure age distribution.[278] The method uses K and other isotopes and analyzes ratios between them which presumably provides an indication of epochs in CRF. A periodicity of 143 +/– 10 m.y. emerges from this method, though it has been criticized as problematic. The solar system also oscillates above and below the Galactic Plane in cycle of ~32 m.y., or 64 m.y. for a complete sine wave-like cycle. A major flux of CR is produced in the north crossing of the Galactic Plane which is the direction toward which the galaxy is moving in the local super cluster. Sepkowski's fossil diversity data, sea level and Large Igneous Province periodicities of ~62 m.y. are close to this figure.[279]

In Earth's glacial history ice ages occur on two time scales, 10^4 and 10^8, the first generated by orbital variations, the second possibly by galactic arm passages. A reconstruction of Phanerozoic temperatures using oxygen isotopes in calcitic shells, ice rafted debris and other glacial deposits, as paleoclimate data, suggests a broad correspondence between higher CR flux and glacial or cool episodes, the later which display a cycle of 135 +/– 10 m.y.[280] From the geological record, ice age or cool epochs during the Phanerozoic are: 446 – end Ordivician, 310 +/- 20 – later Carboniferous, 160 +/- 10 – mid Mesozoic cooling, 20 +/- 10 - Neogene. These periods are spaced at intervals of roughly 135, 150, and 140 m.y., close to estimates of spiral arm passage.

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278 Shaviv, (2002).

279 Medvedev and Melott. "Do Extragalactic Cosmic Rays Induce Cycles in Fossil Diversity?" In *The Astronomical Journal,* (2007).

280 Shaviv, (2003).

Recent scientific papers continue to speculate on possible effects of CRF during spiral arm passage. Proposals include variations of solar activity and the lowering of solar system shielding (interplanetary magnetic field) leading to global cooling and climate change via low altitude cloud cover, geomagnetism disruptions, and field reversals. For the Earth itself, acceleration into the arm has been proposed as a cause of change in spin rate, true polar wander, tectonic activity, and geomagnetic field changes. Also, perturbation of Oort Cloud during passages may occur leading to more frequent bollide impacts and large igneous province formation. Possible effects of CRF on the biosphere include direct radiation which cause mutations via muons formed by CR, increases of atmospheric oxides of N by increased lightning causing damage to ozone shield, and solar UV (290-320 nm) causing cancers and phytoplankton damage.[281]

[281] Gillman and Erenler. "The galactic cycle of extinction," in *International Journal of Astrobiology,* (2008).

APPENDIX A

OUTER PLANET HELIOCENTRIC AND GEOCENTRIC ALIGNMENTS MODULATE A 1500-YEAR CLIMATE CYCLE

ABSTRACT

An ~1500-year periodicity has been reported in paleoclimate proxy data and claims have been made that this rhythm persists through glacial and interglacial periods. It is not thought to be driven by orbital variations. Many questions concerning the reality of this periodicity have been raised. It has been suggested that the periodicity is driven by solar cycles, though solar cycles longer than 200 years are not well-documented. An argument is made here that outer planet conjunction cycles, specifically a regularly repeating triple conjunction of Saturn, Uranus and Pluto of 1542 years, may be the source of the ~1500-year signal in the paleoclimate records, as well as others, and that such conjunctions may either modulate solar activity, which in turns affects Earth's climate, or influence climate directly through tidal forcing of the Earth's atmosphere.

In the ancient tradition of natural astrology climatic changes have been associated with the cycles of Jupiter and Saturn, the two outermost planets known prior to the discovery of Uranus in 1781. The ~20-year synodic cycle of Jupiter and Saturn was considered the primary rhythm of smaller weather cycles while the recurrence cycles of 60 and 800-year events were used to map out larger historical periods.[282] There are two schools of thought today regarding planetary influence on climate. The first argues that the tidal forces of the outer planets modulate solar activity which consequently affects the Earth system in various ways. The second argues that the outer planets modulate the Earth system directly, an approach which requires no modification of the traditional geocentric modeling techniques of natural astrology. These two approaches will be examined in the context of a mysterious ~1500-year periodicity which has found in many paleoclimate datasets. The first step in this analysis will be to consider the data supporting or contradicting the existence of a ~1500-year periodicity in the paleoclimate record. Following that a case will be made for how the planetary modulation hypothesis, heliocentric and geocentric, may be a subtle forcing mechanism on climate that produces an ~1500-year periodicity in the paleoclimate record.

[282] Recurrence cycles occur when the individual cycles of two planets mesh, for example two cycles of Saturn and five cycles of Jupiter are equivalent to about 60 years.

A.1 The 1500-year Climate Cycle

Located in a range much longer than the Schwabe and Hale solar cycles, and much shorter than the shortest orbital cycle, precession, millennial scale cycles in glacial advances and retreats were first reported in 1973.[283] Over twenty years later data from marine cores also suggested cycles in this range. In a 1997 paper in *Science* Gerard Bond et al. reported on a pattern of sediment grains found in marine cores extracted from the North Atlantic. The deposition of three types of grains occurred in a pattern with peaks at 1400, 2800, 4200, 5900, 8100, 9400, 10300 and 11100 B.P., all of these in the Holocene. According to Bond, the implication of this record is that a millennial-scale climate periodicity of cold North Atlantic climate has been operating in cycles with lengths of 1400, 1400, 1700, 2200, 1300, 630, and 1070 years, about 1400 years being the average of these figures.

Bond et al. examined marine cores from the Irminger Sea – Denmark Strait area and also from the North Atlantic due west of Ireland (VM 28-14 and VM 29-191 – see Figure 1), core sites that are 1000 km apart. Concentrations of three climate proxies were initially used in the investigation: lithic grains, fresh volcanic glass, and hematite-stained grains thought to have been sourced from red beds from East Greenland. The location of the drill sites indicated that these grains were not deposited by ocean currents after being carried great distances, but that they were dropped in place. Bond hypothesized that the sediment layers containing the highest grain numbers correlated with periods when drift ice came as far south as the coring sites. Such increases in ice rafted debris (IRD) would then logically correlate with colder temperatures in the North Atlantic, making them a proxy of a cold sea surface temperatures. Further, IRD derived from the east coast of Greenland indicates a break in the pattern of northern ice discharge which normally occurs on the west coast of Greenland and enters the Atlantic from the Labrador Sea.

Sequences of foraminifera found in the cores also revealed alternating climate changes in a pattern similar to that delineated by the lithic grains. During cold episodes, increases in the planktonic foraminifera *Globigerina quinqueloba* and *Neogloboquadrina pachyderma*, both cold water species, are abundant. Decreases in warm water foraminferan species are also evidence of cooling. Based on this data, Bond et al. argued that the immediate cause of these ice rafting

[283] Denton and Karlen, "Holocene Climatic Variations – Their Pattern and Possible Cause," in *Quaternary Research*, (1973).

events was surface cooling, not greater than 2 degrees C, and that these sediments may also be evidence of a change in the North Atlantic circulation.

Bond et al. concluded that the marine core records reflect an approximately 1500-year climate cycle in the North Atlantic that it has been in operation not only during the Holocene, but also throughout the previous glaciation. This continuity implies a forcing agent that apparently persists independent of glacial or interglacial climate periodicities, which are driven by orbital parameters, i.e. Milankovitch cycles. The Holocene component of the cycle, according to Bond, averages 1374 years (+/– 502 years). The glacial component, which is argued to be the same as the Dansgaard-Oeschger rapid climate change events (sudden warmings followed by slow coolings – see below) that punctuated the last glaciation, averages 1470 years (+/– 532 years). Further, Bond et al. argued that the Little Ice Age (LIA– approximately 1550-1850) was not an isolated cooling event. It may have been related to a previous event several hundred years earlier, a period of rapid warming called the Medieval Warming Event, or the Medieval Climate Anomaly (approximately 500-1200). From this perspective, the LIA constitutes the cooling phase of a rapid climate change event that began with a warming. The primary difference between the ~1500-year climate cycles in the Holocene and the previous glaciation is then only one of amplitude. Both Holocene and glacial 1500-year cycles may therefore be responses to the same forcing mechanism.

In summary, Bond et al. argued that the climate of the North Atlantic during Holocene was not as stable as had been thought, but that it had undergone a number of climate reorganizations on millennial time scales. The paper also suggested that rapid climate change events have occurred during historical times and they may, should it turn out that the ~1500 year cycle is a true climate periodicity, serve as an index into the direction of natural, non anthropogenically-forced, climate change today. The case for the reality of this ~1500-year climate cycle in the North Atlantic is complex and is ultimately based on interpretations of several key climatological concepts and climate records. In the following section of this paper I will define these concepts and records and attempt to explain the argument.

Oxygen isotope records found in the Greenland Ice Sheet Project (GISP2) ice core, and also other Greenland ice cores, revealed a series of abrupt warmings and coolings called rapid climate change events during the previous glaciation (~117 k.y. to ~15 k.y. B.P.). The ratio of ^{18}O to ^{16}O

in ice cores is used as a proxy of the temperature when the snow, which eventually became the ice in the core, fell in on the Greenland summit. As the heavier isotope ^{18}O precipitates more readily in cooler temperatures, and with distance from its source (the ocean), the ratio of ^{18}O to ^{16}O will then decrease. The oxygen isotope ratio in the Greenland ice core may therefore be used as an indicator of Greenland's ancient climate, specifically air temperature. Other Greenland ice core proxies include dust content, ice accumulation rates and concentrations of methane.

The rapid transitions between cold and warm periods during the previous glacial were first described by climatologists W. Dansgaard and H. Oeschger.[284] Dansgaard-Oeschger (D-O) events, as they are now called, are characterized by abrupt warmings of ~10 degrees. Climate records suggest these occurred very rapidly, possibly within a few decades. Warmings were followed by an unstable climate plateau during which a slow, gradual cooling occurred. Towards the end of the period were rapid coolings leading to a return to glacial conditions. These D-O periods are also referred to as interstadials, departures from the overall cooling trend (that is now understood to be driven by orbital factors), of millennial scale length, about 500 to 2000 years. (Stadials are the normal cooler climate from which the interstadials depart.) D-O events are recorded in the ice core oxygen isotope ratios and in other climate proxy records as roughly rectangular-shaped departure from the general climate trends, the horizontal temperature plateau between rapid warmings and coolings reflecting the temporary stability of the change. They do not show in climate records as a series of sharp peaks and valleys. In other words, the changes appear to describe relatively rapid shifts from one stable climatic condition to another.

At least twenty D-O events have been registered in the GISP2 ice core record. The recurrence time of D-O events do not appear to reflect a particularly stable cycle, however. In general, over the past 90 thousand years (k.y.) recurrences appear to range from between 1 to 12 k.y., but this variability is reduced between 25-60 k.y. B.P. when the spacing ranged from between 1 to 5 k.y. Between 12 and 50 k.y. B.P. the spacing is closer to 1500 years, though some of the periods in this section of the core are longer multiples of this figure, i.e. 3000 and 4500 yr.[285] D-O events, or any significant temperature fluctuations are not well documented in the GISP2 ice core for the Holocene (with the exception of the Younger Dryas and the 8,200 year cooling). In an earlier

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[284] S.J. Johnson, et al., "Irregular glacial interstadials recorded in a new Greenland ice core," in *Nature,* (1992) and Dansgaard, et al., "Evidence for general instability of past climate from a 250-k.y. ice-core record," in *Nature,* (1993).
[285] Schultz, "On the 1470-year pacing of Dansgaard-Oeschger warm events," in *Paleoceanography,* (2002).

paper, Bond presented evidence of parallel temperature shifts shown in marine sediments from the North Atlantic that match the ice record of D-O events.[286] This replication suggests a strong atmosphere-ocean coupling.

D-O periods (rapid warming followed by slow cooling) are deviations within a larger trend. During a glacial period, the gradual cooling in the later part of the D-O cycle does not return to temperature levels at the onset of the rapid warming – further cooling occurs. Eventually, after several repetitions of these departures from the base line, a terminal cooling and a major ice rafting event occurs during which large amounts of ice are discharged from the Laurentide Ice Sheet and float southward through the Hudson Strait into the Labrador Sea. These large discharges of icebergs, referred to as ice armadas, are called Heinrich events. They are recorded in marine sediments by layers of coarse lithic particles and are also shown in cores by the interruption of microfossil sedimentation, a reflection of species relocation brought about by temperature changes.[287] It is thought that Heinrich events follow a roughly 10 k.y. cycle and are a response to changes in insolation brought about by the 20 k.y. precession cycle.[288] However, the spacing between Heinrich events decreased during the course of the previous glacial period to about 6 k.y. A grouping of successive D-O cycles, each terminating with a Heinrich event is now termed a Bond cycle. Bond cycles are not only recorded in North Atlantic sea cores, but are also found in mountain glacier advances and retreats in the southern hemisphere and in Florida pollen records. The conclusion of a Bond cycle, the coldest phase of several D-O cycles, correlates with a Heinrich event and is then followed by a rapid warming. It has been suggested that these warming and cooling cycles are responses to a regular oscillation of the North Atlantic circulation.

A.2 The North Atlantic Circulation

The formation of North Atlantic Deep Water (NADW) occurs in several places, but mostly north of Iceland in the Norwegian Sea where water of high salinity accumulates in deep ocean basins. Due to the higher density of this water, it flows southward into the Atlantic as a bottom current

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286 Bond et al., "Correlations between climate records from North Atlantic sediments and Greenland ice," in *Nature,* (1993).
287 Bond and Lotti, "Iceberg Discharges into the North Atlantic on Millennial Time Scales During the Last Glaciation," in *Science,* (1995).
288 Broecker, "Massive iceberg discharges as triggers for global climate change," in *Nature,* (1994).

and eventually works it way to the southern hemisphere and beyond. The movement of cold, dense saline waters southward draws surface waters north, these being the warmer waters of the northern Gulf Stream, which become the North Atlantic current. The movements of surface and bottom currents, density-driven from the Icelandic seas, is called thermohaline circulation (THC) and it is thought to account for the relatively warm temperatures experienced in Europe today. The flow rates of ocean circulation in this region have been shown to vary on a millennial length scales that correlate with well-documented climatic conditions in Europe.[289]

Thermohaline circulation in the North Atlantic is thought to alternate between at least two modes distinguished by the latitude of warm water penetration. During warm periods such as the present, icebergs remain in northerly waters. During the very cold climates of the D-O events, icebergs calved from the eastern coast of Greenland drift south into the Icelandic seas. Melt of these icebergs potentially freshens the ocean and weakens the density-driven circulation, a condition that would lead to further cooling. After several of these episodes an even colder Heinrich event occurs during which icebergs drift south from the Labrador Strait into the North Atlantic. The difference in latitude as indicated by IRD and the nature or lack of foram shells found in marine cores between these two extremes is about five degrees. It is thought that the collapse of the ice sheet (the source of icebergs) following a Heinrich event ultimately reduces the volume of ice in the ocean, allowing salinity to build up again and thus restart thermohaline circulation.[290]

The fresh water generated by ice-melt not only alters the formation of NADW but is apparently capable of stopping it altogether, a condition of THC called the drop dead mode. The cycle of iceberg discharges and consequent lowering of salinity in the North Atlantic is thought to be an internal oscillation of mutual responses to climate changes in an ice sheet-ocean-atmosphere coupled system. Mode-shifting oscillations within this climate system, thought to be driven by natural interactions based on energy transfers, are interpreted as stochastic resonance, cycle-like effects that inevitably occur when one part of the system crosses a threshold.[291] Significant climate shifts suggesting an alternating ocean current pattern in the North Atlantic may then be what are documented in the GISP2 ice core record as well as other regional proxy data, including

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289 Bianchi and McCave, "Holocene Periodicity in North Atlantic Climate and Deep-Ocean Flow South of Iceland," *Nature,* (1999).
290 Bond and Lotti, (1995).
291 Ganopolski and Rahmstorf. "Abrupt Glacial Climate changes due to Stochastic Resonance," in *Physical Review Letters,* (2002).

glacial advances in the Alps. This shift has an effect on global climate as well and simultaneous responses are found in climate records far from this region. This transition is even recorded in Antarctic ice cores, but only weakly.

There are several ways of conceptualizing the behavior of the climate in the North Atlantic. First, it could be seen as oscillations around a single state of equilibrium with variations in the strength of the ocean-atmosphere coupling. Or, it could be viewed at a situation in which transitions between two stable climate states occur from time to time. It has also been argued that the North Atlantic operates in three modes, and that it jumps back and forth between each. In the modern mode, characterized by a warm North Atlantic climate, deep water forms in the Nordic seas and in the North Atlantic. A second mode occurs when deep water is no longer formed in the Nordic seas, but only in the North Atlantic. This is the condition operative during glacial periods. A third mode is when both locations fail to form deep water, this being the time of the Heinrich events and also the Younger Dryas, times of rapid freshening of the North Atlantic.[292]

A.3 Mechanisms

There are several positions taken by those who are attempting to unravel the mystery of the D-O events and ascertain the reality of a Holocene ~1500-year cycle. One argues that the oscillations as described above are a product of a natural internal rhythm of oceanic circulation, an ocean-atmosphere coupling.[293] One interpretation is the oceans' bipolar seesaw where the salt-conveyor moves dense salt out of the North Atlantic at a rate that is faster than it can be replaced. This leads to lower salinity and consequently lower density, and eventually the conveyor is shut down. When this happens the Gulf Stream weakens and the Antarctic seas begin to exert an influence on global ocean circulation. Eventually, salt levels in the North Atlantic begin to rise, the water becomes denser, and the conveyor starts up again. This internal cycle operates on time scales in the millennial range and its effects on the regional climate is what has been recorded in the proxy data.

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292 Alley et al. "Making Sense of Millennial-Scale Climate Change," in *Mechanisms of global Climate Change at Millennial Time Scales,* (1999).
293 Broecker, "Glaciers That Speak in Tongues," in *Natural History,* (2001), and Debret et al. "The origin of the 1500-year climate cycles in Holocene North-Atlantic records," in *Climate of the Past,* (2007).

A global climate model has shown that D-O events, and consequently the breakdown of THC, can be triggered by small amplitude inputs of fresh water into the North Atlantic.[294] The freshwater-forcing in this model doesn't need to be very strong because the North Atlantic ocean-atmosphere system needs only to have a specific threshold to be exceeded before it jumps to a new state. The response time to a freshwater forcing may be several hundred years for the event itself, and another similar or even longer period must pass before the system returns to the point at which it can be triggered again. The likely interval range for this internal oscillation is from 1000 to 2500 yr. Further, a lower noise level, that is forcing factor, may cause the system to skip a beat but respond at the 3000 and 4500 yr periods that have been noted by Bond et al. Ganopolski and Rahmstorf conclude that the North Atlantic is the location of an excitable system that can respond to very weak periodic forcing.

A second argument for an internal rhythm is based entirely on ice sheet dynamics.[295] In this view, it is the surging ice sheets, the result of ice build-up, that drives a periodic calving of icebergs that freshens the North Atlantic and shuts down THC during Heinrich events and terminal phases of D-O events. Ice sheet response to atmospheric changes (as shown in ice core records) implies an input of forcing that would apply primarily to the ice sheet surface, not the glacier bed where the action takes place. How this process actually works is not clear. Whatever the case, the supposed internal forcing apparently follows the same schedule as South American mountain glaciers which move at the same time.[296] This fact suggests that ice sheet dynamics are a response to some other kind of forcing that also influences the southern hemisphere, so they may not be internally driven after all. Also, ice sheet internal dynamics would suggest an irregular rhythm of climate change, probably not a response to a regular ~1500-year periodicity.

The periodic nature of the ~1500-year cycle does suggest a third position, one in which some sort of external forcing is the mechanism that drives the system. Bond argued that the driver could be solar irradiance which is far more likely to produce a regular cycle length than one resulting from factors internal to the system.[297] Evidence for solar forcing, determined from isotopic records of

[294] Ganopolski and Rahmstorf, (2002).
[295] Van Kreveld et al., "Potential links between surging ice sheets, circulation changes, and the Dansgaard-Oeschger cycles in the Irminger Sea, 60-18 k.y." *Paleoceanography* ,(2000), and Calov et al., "Large-scale instaabilities of the Laurentide ice sheet simulated in a fully coupled climate-system model," *Geophysical Research Letters.* (2002).
[296] Bond and Lotti, (1995).
[297] Bond et al., "A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates," *Science,* (1997 and Bond et al., "Persistent Solar Influence on North Atlantic Climate During the Holocene," *Science,* (2001).

^{10}Be from Greenland ice cores and ^{14}C from tree rings, do show sudden large amplitude increases consistent with solar minima, times when a weak solar wind is less effective in deflecting cosmic rays that generate the isotopes. Higher levels of these isotopes in climate records also correlate with increases in drift ice and therefore colder temperatures. It is thought that solar-induced climate signals could be amplified by shifts in THC, causing major climate change in the North Atlantic as well as elsewhere.

Critics of a solar influence on climate argue that solar irradiance variability is too small to cause changes in climate. It has been shown, however, that a solar irradiance variation of 0.1%, which is within the observed range measured by satellites, is enough to produce a change in stratospheric ozone.[298] Although the solar spectral peak is at 0.5 microns, the center of the visible spectrum, the Sun also radiates energy in other wavelengths. Solar radiation of short wavelengths show significantly greater variation, > 10%, than do those of visible light over the course of the solar cycle, amounting to as much as 2.1 W/m^2 of variability. Short wavelengths < 0.3 don't even reach the Earth's surface, they are absorbed in the atmosphere. However, they do heat the stratosphere which may affect climate indirectly. Climate modeling experiments using this range of solar irradiance have also shown that solar variability, higher in the UV wavelengths, may modify the normal photochemical change rates in the stratosphere and therefore affect ozone.[299]

Solar radiation reaching the troposphere may therefore be modulated by changes in ozone concentration in the stratosphere occurring in response to the solar cycle. Modeling experiments have shown that these small modulations are capable of moving mid-latitude storm tracks toward the poles, changing surface atmospheric pressure, and shifting the descending limb of the Hadley cell northward (Haigh, 1996). Modeling also showed that changing stratospheric ozone as a variable generated more atmospheric change than did solar irradiance alone as a variable. While the mechanism implied by the modeling experiments is not clear, it does explain how a very small shift in solar irradiance may be followed by a natural amplifying mechanism. Another modeling experiment showed similar effects from small variations of solar irradiance.[300] In this study, UV radiation from the Sun was absorbed by stratospheric ozone which then acted as an amplifier, modifying zonal winds, altering long wave propagation, and also equator-to-pole energy

[298] Bond et al. (2001).
[299] Haigh, "The Impact of Solar Variability on Climate," *Science,* (1996).
[300] Shindell et al., Solar cycle Variability, Ozone, and Climate. *Science,* (1999).

transport. It was noted, however, that the decrease of ozone since the 1970's may have compromised the stratosphere's ability to affect climate today.

In a more recent paper, Bond compared the IRD records with nuclide production rate in ^{14}C for tree rings and ^{10}Be in ice cores.[301] The correlations produced show synchronous changes in both nuclide records and also a strong linkage between IRD and solar minima. Their paper suggests that the solar impact on climate was nearly global and they point to records that show synchronous changes of ^{18}O in stalagmites from Oman, ocean upwelling records in West Africa, and drought episodes in the Yucatan peninsula, among others. The cooling of the North Atlantic also correlated with reduced monsoonal activity and rainfall in low latitudes. The nine millennial length cycles in the Holocene reported by Bond et al. appear to be reproduced in other regions and mark a ~1500-year cycle. Bond et al. conclude that if this is the case, neither internally forced North Atlantic atmosphere-ice-ocean oscillations or orbital-forcing are likely candidates as drivers of this cycle. The solar cycle alone is all that is required. They hypothesize that reduced solar irradiance at times of solar minima somehow modulate stratospheric ozone which leads to cooling in high northern latitudes, a southward shift of the jet stream and a reduction in Hadley cell circulation. An immediate problem with this hypothesis is that solar cycles longer than 200 years have not been demonstrated with a high degree of certainty.[302]

External forcing is not limited to solar variability. Tidal forcing has also been suggested as a climate change mechanism and an ~1800-year tidal cycle has been proposed to be driving millennial-length cycles. The tides are not constant. When combined with the gravity of the Sun at full and new Moon, tides are greater. Tides are also higher when the Moon is at perigee, the part of its orbit nearest to the Earth. The combination of the soli-lunar synodic month that produces full and new Moons (29.5 days), and the perigee cycle or anomalistic month (27.6 days), yields a period of about 412 days or 1.13 years. When the Moon is on the ecliptic, i.e. when it is on its node (the crossing point of the lunar orbit and the Earth's orbit), lunar gravitational-forcing increases. This 27.2-day period resonates with the above cycle every 2.99 years. A fourth factor is the coincidence of all of the above with Earth's perihelion, which increases the solar gravitational component. All four conditions combined produce a period of

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301 Bond et al., (2001).
302 Hoyt and Schatten, (1997).

~1800 years. Other minor lunar orbital factors cause this figure to vary from about 1700 to 2000 years.

Keeling and Whorf argue that strong tidal forcing may be related to IRD events.[303] The mechanism proposed for this tidal cycle involves very high tides followed by a cooling of sea surface temperatures due to vertical mixing. Tidal mixing in general is significant, greater than wind-driven mixing, and when very strong tides occur the vertical mixing could well decrease sea surface temperatures by bringing colder deep waters to the surface. This may lead to large scale changes in winds, precipitation and other climate factors. Extreme tides such as those occurring every 1800 years may be 30% stronger than normal tides and, besides causing deep ocean mixing, they may be strong enough to break up ice shelves. Their interpretation of Bond's marine records show broad peaks of IRD at bands of 1800 and 4670 years and that cold periods closely match an 1800-year cycle. Their dating of these cooling events driven by tidal-forcing does not match Bond's IRD dating. Compare 525, 2348, 4239, 5921 and 7744 with Bond's 1400, 2800, 4200, 5900, and 8100 before present (BP). Only one date, about 5900 BP, is close. However, Keeling and Whorf argue that the time-scales established in the marine cores used by Bond et al. are not consistent and they note that the sediments of Elk Lake, in the north-central United Sates, which are of high resolution, show dust spikes at intervals of 1800 years which they relate to IRD events during cold climates. Tidal forcing may play a role in climate change but it does not appear to correlate closely with Bond's data, assuming that this data is solid.

A.4 Resolution of the Proxy Data

The first major problem to overcome is assessing the measurability of a ~1500-year climate cycle. Most available proxy data is not well-resolved is therefore not very useful for analyzing millennial length cycles. Ice core and speleothem data are better resolved and studies have analyzed spectral patterns in samples. In the cases noted below, signals of ~1500 years, or multiples of that figure have been found. It has been argued that spectra in this range found in climate data is an alias of the annual cycle, a product of sampling at regular integer multiples of

303 Keeling and Whorf, "The 1,800-year oceanic tidal cycle: A possible cause of rapid climate change," *Proceedings of the National Academ.y. of Sciences,* (2000).

the year.[304] A critique of this argument is that it arrives at a similar conclusion for the 21,000-year precession cycle, which has a basis in measurable orbital parameters.

A time-frequency analysis of GISP2 ^{18}O ice core doesn't show the constant 1500-year signal proposed by Bond et al. over all of the last 100 k.y., but there is good correspondence with the timing of some of the accepted Dansgaard-Oeschger events.[305] A 1500-year spectral peak is apparently a reflection of only D-O events 5, 6, and 7, (31-36 k.y. BP), though the cycle does work as a template for other D-O events recorded in the core between 13-46 k.y. BP, within a range of 20%. The spacing is more regular between 45 and 50 k.y. BP, but between 46 and 80 there are no significant 1500-year periods at all – this frequency is not distinguishable from random events. In other words, one portion of the record does show a close correlation with the ~1500-year cycle and its precision at this point is enough to dominate the other less precise cycles in a spectral analysis.

If one considers the spacing between midpoints between D-O events from 80 k.y. BP it is apparent that the ~1500-year signal applies most accurately to those events between 28 and 42 k.y. B. P. During the remainder of the period, D-O occurrences do fall into resonance with this period, i.e. at ~3000 yr. and 4500 yr., but the timing is otherwise not particularly constant. The increase in spacing towards the previous interglacial and the Holocene suggest that this cycle may not even occur during an interglacial – its increase equaling the duration of an interglacial.[306] Only two out of eight Holocene Warming events are consistent with the more specific 1470-year template.[307] In contradiction to this finding, a stalagmite from Germany, however, appears to show a 1450-year spectral peak in the Holocene from 6000 BP to the present[308]. Bond et al.'s contention that the ~1500-year cycle is a continuous feature and that Holocene warmings and coolings are a muted ~1500-year D-O cycle is here both questioned and supported.

One atmosphere-sea ice-ocean climate model has shown an oscillation in the meridional turnover of Atlantic THC of between 1600 to 2000 yr. of length.[309] Other climate models also predict an

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304 Wunsch, "On sharp spectral lines in the climate record and the millenial peak," *Paleoceanography,* (2000).
305 Schulz, "On the 1470-year pacing of Dansgaard-Oeschger warm events," *Paleoceanography,* (2002).
306 Schulz, (2002).
307 Schulz and Paul, "Holocene climate variability on centennial-to-millennial time scales: 1. Climate records from the North-Atlantic realm," In Wefer et al., eds., *Climate development and history of the North Atlantic Realm,* (2003).
308 Niggeman et al., "Sub-Milankovitch climatic cycles in Holocene stalagmites from Sauerland, Germany," *Earth and Planetary Science Letters.* (2002).
309 Schulz, (2002).

increasing oscillation that strays far from this periodicity length. However, the five documented Heinrich events that occurred between 15 and 47 k.y. BP closely match the 1470-year template. The general stability of this ~1500-year cycle, as shown in the various paleoclimate records, does suggest some sort of astronomical forcing and consequently a periodic decoupling in the formation of rate of NADW formation. The quantum nature of the D-O events is interesting. The records show a skipping of up to five cycles which suggests stochastic resonance – a nonlinear system that exhibits threshold behavior in which regularly-spaced though weak signals can push conditions into an altogether different mode, but not necessarily every time they occur.[310]

Another sampling of the GISP2 ice core back to about 51 k.y. BP was done using higher resolution data sets.[311] A 50 k.y. band with lines spaced at 1470 years apart and D-O events were found. Eleven of thirteen D-O events fall within 10% of the period, the other 2 within 20%. If this periodicity is regular, it could be distorted by earlier or later triggers. The cycle is not one that accumulates errors, though there is always the possibility of dating errors. Rahmstorf suggests the precision of this cycle points to some kind of orbital cycle, not a solar cycle (sunspot cycle) which has a much higher variability.

The case for a ~1500-year cycle as proposed by Bond et al. is based largely on what they believe to be a good correspondence between drift ice proxies and solar-forcing proxies during the Holocene. In their view, the D-O events continue their pacing through the Holocene, though they are muted. They argue that the LIA was the most recent phase of one of these cycles and that the Earth could expect to warm up over the next centuries. If the high point of the Medieval Climate Warming (or Anomaly) in about the 9th century marked the commencement of a 1500-year cycle, then the next warming should occur by the 25rd century. One of the major problems with this conclusion is that the marine core data used in Bond's 1997 paper does not show a strict periodicity in North Atlantic coolings during the Holocene, making interpretations on the nature of the cycle tentative at best. Schultz, who has evaluated the GISP2 climate data in detail, argues that only two out of eight Holocene warming events actually fit the 1500-year template and that this specific periodicity only works for the early Holocene. He notes that the fluctuations of the

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310 Ganopolski and Rahmstorf, (2002).
311 Rahmstorf, "Timing of abrupt climate change: A precise clock," *Geophysical Research Letters,* (2003).

D-O warming events during glaciation are far more coherent in terms of ^{18}O records and closer to a 1500-year cycle than the faint pulses of the Holocene.[312]

A.5 The Case for Solar Forcing

If the ~1500-year cycle involves a linkage between atmosphere-ice connections, fresh water injections and reduced NADW, a problem remains as to what role, if any, solar activity plays in all of this. Those who argue that internal ice-sheet dynamics drive the ~1500-year oscillation point out that while it appears periodic, it is really quite variable, especially in the Holocene.[313] They note that ice cores in Greenland do not record a 1500-year signal in ^{10}Be, which would be expected if there were significant periods of solar minima, but they do record shorter solar cycles. With no clear evidence for solar-forcing at millennial time scales they argue that it seems reasonable to accept that some sort of internal mechanism is probably operative and they propose that increases of IRD from multiple sources reflects a normal response of ice sheets to cooling. Further, they argue that D-O oscillations appear to have decreased or even stopped during times of changing orbital-forcings when the system is passing through the gap between two modes of response to orbital variables.

Bond et al. (1995) agree that D-O events, coupled with Heinrich events, are forced by the internal oscillating dynamics of ice sheets. But these events are thought to be responses to, not causes of, atmospheric climate change that they suspect is solar-forced. Assuming the North Atlantic climate system is sensitive to subtle changes of solar irradiance, very little modulation may be needed to push it into a different mode of operation. Low solar irradiance is therefore a negative forcing mechanism that leads to colder air temperatures over Greenland, ice build-up, and consequently the launching of iceberg armadas. This, in turn, results in cooler ocean surface temperatures and reduced NADW formation which amplifies the existing cold. So for Bond et al., internal ice sheet dynamics are an amplifier of low solar irradiance. Increased solar irradiance would presumably reverse the direction of climate change.

The Bond et al. argument that the ~1500-year cycle is a pervasive feature of the climate system in the North Atlantic, and beyond, does have some support, but it remains very unsettled. In the

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312 Schulz, (2002).
313 Alley et al., (1999).

Holocene it appears to be a quasi-periodic cycle, not a true periodicity, and this raises many questions about possible astronomical forcings which are generally assumed to be quite regular. The two most likely candidates for solar astronomical forcing are Milankovitch cycles, which are not thought to operate on the millennial time scale, and the known sunspot cycles, all of which are too short. Longer resonances of shorter cycles have been proposed as a source of the 1500-year cycle. The orbit of the Sun around the barycenter, a resonance period of the orbits of Jupiter and Saturn, occurs every 179 years. There are eight distinctive forms this orbit takes which then produces a longer cycle of about 1432 years.[314] Combinations of the DeVries-Seuss cycle of about 210 years and the Gleissburg cycle of 87 years are also proposed as the solar-forcing factors; 7 x 210 = 1470 and 17 x 87 = 1470, but explanations as to exactly how multiples of short cycles should act as triggers of climate change are highly speculative.[315]

The larger and more immediate problem with the ~1500-year cycle, however, is in regard to its intermediate length. Millennial scale cycles such as this one fall into in a problematic range in regard to paleoclimate data – they require lengthy, but also high-resolution records. In contrast, longer orbital cycles do not require precise resolution and decadal-scale cycles are short enough to show in more recent historical records which are on an annual or even shorter basis. Ultimately, to solve the mystery of this enigmatic cycle more work will be needed in resolving the climate record of the Holocene. Still, Bond et al. have raised many important issues regarding the ancient climate of the North Atlantic and have complicated the debate on global warming.

A.6 A Planetary-modulated Solar Activity Hypothesis

It is possible that a punctuated solar influence on terrestrial climate drives several millennial-length climate cycles, including a ~1500-year cycle, and that this solar influence shows correspondences with conjunctions or other alignments of the outer planets. One possible mechanism posits gravitational effects of the outer planets on the Sun that stimulate solar activity (including eruptions, i.e. flares and coronal mass ejections) which are then registered on the Earth as disruptions to the magnetosphere and upper atmosphere. This solar activity should also be registered as a temporary increase of the solar constant. A pulse of direct radiative heating could

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[314] In 178 years six orbits of Saturn equals fifteen of Jupiter, very near the figure for the orbit of the Sun around the barycenter of the solar system. See Mackey, (2007).

[315] Braun et al., "Possible solar origin of the 1,470-year glacial climate cycle demonstrated in a coupled model," *Nature,* (2005).

cause a displacement of the upper atmosphere shifting air masses toward the poles causing retreat in the polar front and increased ice melt in the Arctic. The timing of such a blast is probably important and may be more effective when occurring at the northern hemisphere vernal equinox.[316] At the same time, higher levels of UV radiation in the stratosphere may increase O_3 production creating a greenhouse effect. Once initiated by a sudden burst of solar activity and sustained by stratospheric UV, ice sheet or sea ice melt is accelerated and icebergs enter the northern seas and inject fresh water which lowers salinity and consequently slows THC. The time interval between the pulse of solar activity and lowered salinity may be as short as a decade or two. The consequent slowdown or stoppage of THC then results in a colder North Atlantic climate and within decades this change begins to be registered in other parts of the world.

Certain aspects of this hypothesis require explanation. The mechanism that results in increased solar activity begins with the gravitational tugs and torques on the Sun that are exerted by the planets when they form heliocentric conjunctions or oppositions. Torque that is capable of rapidly accelerating solar activity is possibly related to the movement of the center of mass of the solar system (barycenter), which is not permanently located in the center of the Sun. Torque on the angular momentum of the Sun as it orbits about this center of mass may modulate both subsurface and surface activity, i.e. sunspots and solar eruptions, which consequently increases solar irradiance.[317] Both the planets and the Sun orbit around this barycenter in a series of small circles over a period of 178.7 years[318]. This figure appears to be close to a recognized solar cycle called the Seuss cycle and it is also very close to the 181–year cycle length found in the oxygen isotope record of the Camp Century Greenland ice core.[319] It is also nearly equivalent to the orbital recurrence period of six Saturn cycles and 15 Jupiter cycles – 177.92 years.

Another way in which planetary alignments may increase solar activity is through their ability to raise tides on the surface (chromosphere) of the Sun. The tidal influence of a single planet is very slight but combinations of planets exerting gravitational pulls from the same direction act in resonance, theoretically creating much higher tides than the addition of their gravitational effects would allow. This, coupled with the slow solar rotation, could result in a sustained disturbance to

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316 Shindell, Whither Arctic Climate? *Science,* (2003).
317 Landscheidt, "Long-Range Forecasts of Solar Cycles and Climate Change," in Rampino et al., eds., *Climate: History, Periodicity, and Predictability*, (1987).
318 Jose, (1965), Fairbridge and Sanders, "The Sun's Orbit, A.D. 750-2050: Basis for New Perspectives on Planetary Dynamics and Earth-Moon Linkage," in Rampino et al., *Climate: History, Periodicity, and Predictability,* (1987).
319 Dansgaard, A New Greenland Deep Ice Core. *Science,* (1982).

the solar surface. A theory of magneto-tidal resonance has been proposed and modeling experiments have demonstrated that solar tides are greatly amplified when planets are aligned.[320] According to satellite data, solar irradiance varies by about 0.1 % over the course of the 11-year solar cycle. It may, however, vary to a greater degree over longer cycles, during periods of solar eruptions, and during unusual peak periods that have not, so far, been registered by instruments in the historical period. Of the various mechanisms described that link climate change to solar activity (or lack of it), a good candidate considers that increased solar activity heats the Earth directly through radiative input. There are several ways that this can be accomplished. During the peak of the sunspot cycle, strong solar winds may increase tropospheric vorticity in the Northern Hemisphere, effectively moving warm air poleward.[321] Solar flares may also distort the magnetosphere and modulate electric currents in the ionosphere, which may also enhance vorticity and modulate storm tracks. Further, as increases in solar irradiance are much higher in the UV spectrum, stratospheric production of O_3 will increase, and this will increase the greenhouse effect when the gas is at middle altitudes between the troposphere and stratosphere. Modeling studies have shown that a small increase in UV could cause substantial stratospheric heating that then impacts the troposphere resulting in an extension of the Hadley cells that forces the subtropical jet streams poleward, especially in summer. Stratospheric heating may also affect the troposphere through the modulation of large scale atmospheric waves which are capable of modulating weather patterns over long intervals.[322]

In general, a short but strong pulse of direct radiative heating may force the polar front northward causing ice sheet melting in high latitudes on Greenland and possibly the movement of Arctic ice southward. Alternatively, a pulse of solar activity may distort the magnetosphere, forcing warmer air toward the poles. The resulting iceberg release may then reduce the formation of NADW and slow, or even stop, THC. Thus, a decrease of density-driven ocean currents in the North Atlantic acts as a climate amplifier of a discrete pulse of direct solar radiative input.

I propose that planetary alignments of the heavy Jovian planets modulate the ~1500 year cycle by producing pulses, either heliocentrically or geocentrically, as regularly occurring intervals. When conditions in the climate system approach a threshold, such a pulse will be sufficient to move the

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[320] Seymour, (1992).
[321] Prikryl, Muldrew, and Sofko. The influence of solar wind on extratropical cyclones – Part 2: A link mediated by auroral atmospheric gravity waves? *Annales Geophysicae,* (2009).
[322] Haigh, (1996).

system to a new stage. Over time, the interval of the regularly occurring planetary alignment will be found in the climate record making it appear that there is a precise cycle underlying certain aspects of climate change. Heliocentric alignments may modulate insolation producing trends as described above. Geocentric tidal tugs from outer planets may modulate weather systems in higher latitudes through sustained atmospheric tides which may, in turn, force existing stable climatic patterns across thresholds leading to climate change. The tidal modulation of the Earth's atmosphere by outer planets in alignments with the Sun and Moon, should also be stronger when planets are located near the equinoxes. In this positioning, the tidal forces would be at 90 degrees to the poles and therefore the atmosphere would tend to bulge near the equatorial regions and flatten near the poles. This subtle flattening near the poles could cause cold air masses to migrate south more frequently, or in greater volume, than under normal conditions. During a conjunction of three or four planets, an event that can last for months, bi-weekly alignments with the Moon by conjunction and opposition may act as short term amplifiers producing a stronger effect on the Earth system than would be otherwise.

Conjunctions involving all four outer planets (Jupiter, Saturn, Uranus, Neptune), such as those of 2867-2869 and 644 BP, last several years and, when joined by the Sun and Moon, may disrupt weather patterns for extended periods. This would essentially be an amplification of the study material presented previously in this document, i.e. the Sun-Saturn alignments, and the causal mechanism may be atmospheric tidal modulation via minor, but threshold crossing, gravitational tugs from the planets. Only with high resolution climate records could planetary configurations be shown to produce significant coolings in climate, though they should not necessarily be regarded as the sole cause of the cooling, they may be an amplifier of an existing trend driven by larger cycles such as orbital modulation of insolation. The falsification of this geocentric hypothesis presents more complex problems than that of the planetary solar modulation hypothesis and will not be taken further in this paper.

If the solar signal is driven by periodic planetary alignments, certain frequencies should be prominent in climate records. The question is then – does the paleoclimate record contains many signals resulting from planet-modulated solar activity, a few of which will emerge as dominant in a spectral signal because of their high degree of regularity and synchronicity with other cycles? The 179-year cycle of the Sun around the center of mass of the solar system, which corresponds very closely to six cycles of Saturn and fifteen of Jupiter, may be the foundation for the ~200-year rhythm found in climate records, though it is not clear why that particular resonance, 6/15, becomes so powerful. Other longer cycles may be based on multiples of this cycle (eight of these cycles equals 1430 years) or possibly other known solar cycles. In a spectral analysis certain regularly recurring combinations should emerge if the hypothesis has any basis, including an ~1500-year cycle generated in response to the gravitational forces focused by conjunctions of Saturn, Uranus and Neptune which occur at precise 1542-year intervals. Thus the ~1500-year signal may be a combination of both the eight repeats of the 179-year barycenter cycle and the Saturn, Uranus, Neptune cycle. Combining 1430 and 1542 gives an average period of 1486 years, very close to the figures derived from the spectral studies of Bond and Schulz. Another possibility, though more remote if one considers gravity the force involved with planetary modulation of the Sun or Earth, is the recurrence cycle of Neptune and Pluto. This 492-year period contains two revolutions of Pluto and three of Neptune. Three of these amounts to a 1476-year period and have been associated with Huntington's Migration Cycle and Petry's Culture Cycle.[323]

The regularly-spaced conjunctions of Saturn, Uranus and Neptune fall into several series, not all of which contribute to a single steady rhythm detectable in paleoclimate data. Further, conjunctions of all four outer planets may produce a strong enough pulse of solar activity to shift climate in one region or another into a different state and distort any existing regular rhythm. So while an ~1500 year beat is driven by conjunctions of Saturn, Uranus and Neptune, other alignments will have their own effects which, depending on the climate conditions at the time, may or may not be amplified. An investigation of conjunctions of Saturn, Uranus and Neptune for the period 7,000 B.P. to the present has shown that these alignments come in three separate series. (Table 1.) One of these three is an approximate match to Bond's Holocene IRD peak periods, which are themselves matched with ^{10}Be records from the GISP timescale. These are 1400, 2800, 4200, 5900, 8100, 9400, 10300 and 11100 B.P. One series of conjunctions of Saturn, Uranus and Neptune, Series B in Table 1, occurred at 1324, 2867, 4410, and 5952 B.P., all very close to Bond's data.

323 Devore, *Encyclopedia of Astrology*, (1962).

In Table 1 below, the first column lists the years during which triple conjunctions of Saturn, Uranus and Neptune occurred. The second column gives the total number of degrees of zodiacal longitude between planetary combination which reflects the exactness of the conjunction. The third column gives the mean heliocentric longitude of the conjunction as a locator and the fourth column gives the number of years between conjunctions.

Table 6: Saturn-Uranus-Neptune Conjunctions.

Series A

Year BP	Minimum Orb	Mean Helio long.	Years From Previous
644	1.3	223	1543
2187	7.5	63.8	1540
3727	2.2	282	1544
5271	0.9	128.8	1542
6813	4.2	333.7	

Saturn-Uranus-Neptune Conjunctions: Series B

+49	7.5	277.4	1372
1324	5.2	165.6	1543
2867	3.6	15.7	1543
4410	14.6	227	1542
5952	7.4	73.3	

(Bond et al. IRD data: 1400, 2800, 4200, 5900, 8100, 9400, 10300 and 11100 B.P)

Saturn-Uranus-Neptune Conjunctions: Series C

2006	12.5	112.5	
3548	14.1	322.9	1542
5092	20.3	174.3	1544
6634	13	16.5	1542

Isolated Saturn-Uranus-Neptune Conjunctions. Not in above series.

6133	14.3	26.8

Table 7: Jupiter-Saturn-Uranus-Neptune Conjunctions.

Year BP	Minimum Orb	Mean Helio long.	Years From Previous
464	23	217.5	179
644	8.9	244	2225
2869	22.5	2.2	179
3048	12.5	326.7	179
3227	23.2	289.9	319
3546	20.3	329.2	1547
5093	24.8	167.4	179
5272	5.9	123.2	179
5451	20.5	82.6	498
5949	33.5	93.1	

(Source of data: Solar Fire 5.1 software published by Astrolabe Software, Inc. Brewster, Massachusetts)

Correlations between large planetary conjunctions and climate change timing as shown in various proxy data are interesting, though they prove nothing. A conjunction of Saturn, Uranus, Neptune, and Jupiter in 2867-2869 BP (see Table 2) correlates with one of Bond's IRD peaks recorded in marine cores. Other climate records offer further confirmation of a climate shift about 2.8 k.y. BP to colder conditions. For example, between 2.8 k.y. BP and 2.4 k.y. BP, after a long warm period, the Mediterranean region apparently became cool and wet. In Switzerland, the highest lake levels recorded in varves occurred at this time. In Western Europe the climate became very warm around 3.1 k.y. BP, followed by a steep drop in temperature beginning around 2.8 k.y. BP. Climate in Poland was very cold between 2.8 and 2.4 k.y. BP[324]. In 1306 AD (644 BP) a similar conjunction of the same four planets occurred. Prior to this date was a long warm period called the Medieval Optimum and afterward the beginning of the LIA which some now date to about 1350. A high-resolution speleothem record from Oman indicates that the climate in that region began to seriously deteriorate by 1320, leading to a change in the monsoon pattern that the authors believe was reflective of the LIA in the North Atlantic region[325]. It is hypothesized that

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324 Issar, (2003).

325 Fleitmann et al., "Palaeoclimatic interpretation of high-resolution oxygen isotope profiles derived from annually laminated speleothems from Southern Oman Quaternary," *Science Reviews,* (2004).

this rare close conjunction in 1306 produced a several year-long pulse of solar activity, or disrupted weather patterns by geocentric tidal forcing, that pushed the North Atlantic climate regime across a threshold.

If it is that solar activity, modulated by planetary cycles, is the driver of the ~1500 year cycle, then the following scenario may apply. First, solar activity modulated by outer planet alignments occurs in strong, punctuated bursts that initially causes Northern Hemisphere heating and ice sheet or sea ice melting. The consequent lowering of North Atlantic salinity then operates as an amplifying mechanism, and this pushes the region's climate across a threshold where it remains for several centuries. Some of these episodes occur at approximately 1500-year intervals because one specific type of outer planet conjunction cycle (Saturn, Uranus, Neptune) is equal to exactly 1542 years. The severity of such a pulse of solar activity followed by a cooling is probably relative to the climate conditions operative at the time, which are driven in the larger sense by insolation. If the climate system in general is more sensitive during cold periods, this may explain why D-O events, which occurred during a glacial period, are more pronounced than weak Holocene warming and cooling events.

The vast majority of research on millennial-scale climate changes analyzes the data for cyclicity with peaks at specific frequencies. It may be the case that the climate system is responding to disturbances, either via the sun or directly, that represent regular intervals that are found between the conjunctions that in themselves are cyclic. In Tables 1 and 2 it is apparent that there are in fact several series of Saturn-Uranus-Neptune conjunctions. While the spacing between conjunctions within a series is almost always 1542 years, the spacing between conjunctions in general establishes another set of figures. Periods of 680 and 180 years are the most common intervals between these outer planet conjunctions. The later figure is clearly the Gleissburg cycle and this is found in many climate proxies. The 680-year period may be reflected in an approximately 700-year cycle of drought in the Great Plains and also in a 725-year climate cycle from central Africa that is similar to sea-surface salinity records from the northern Indian Ocean.[326]

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[326] Schwalb et al., "Centennial Drought Cyclicity in the Great Plains, USA: A Dominant Climate Pattern over the Past 4000 Years," EGS - AGU - EUG Joint Assembly, (2003); Russell et al., "A 725 yr cycle in the climate of central Africa during the late Holocene," *Geology,* (2003).

A.7 Weakening or Falsification of the Hypotheses

In the solar modulation hypothesis, major planetary conjunctions are thought to produce a short, pulse-like forcing factor from the Sun that begins as heating and quickly becomes cooling in the North Atlantic region. Second, the consistent 1542-year pulse of Saturn, Uranus and Neptune conjunctions (possibly amplified by the 1430-year 8th harmonic of the 179-year solar cycle which incorporates Jupiter) is the driver of the spectral signal found at this frequency by several researchers.

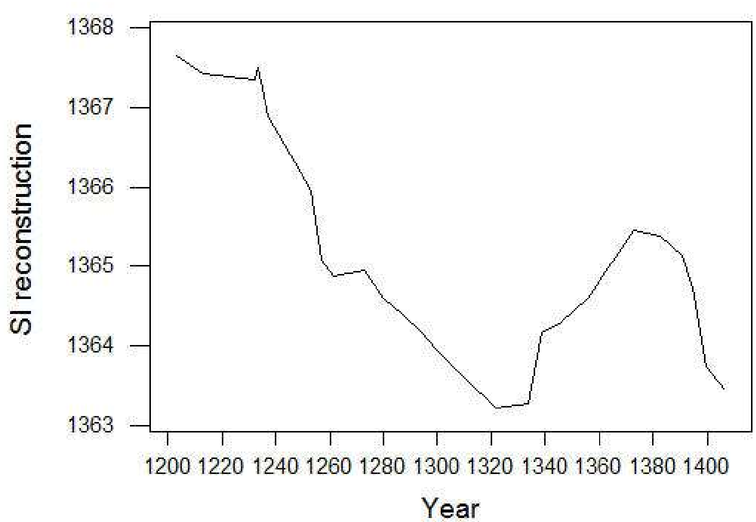
The hypothesis can be falsified by demonstrating a lack of correlation between outer planet conjunctions and high resolution paleoclimate data.[327] One possible test would be to correlate planetary conjunctions and the series of D-O events between 12 and 50 k.y. B.P. where the spacing between climate shifts is more consistent and the resolution of the proxy data is reasonably good, but this cannot be done without longer range computations.[328] Bond's data during the Holocene is not a strict periodicity (eg. 8100, 9400, 10300 and 11100 B.P. are separated by 1300, 900, and 800 years) and the precise 1542-year pulse of the Saturn, Uranus and Neptune conjunctions could not match these dates sequentially. Bond's data is probably accurate to the century, at best. But if the dating of climate changes is confidently resolved to within 50 years, and no major outer planet conjunctions are calculated to have occurred near these dates, the hypothesis would be falsified. Ultimately, very high resolution paleoclimate data over several millennia would be needed to thoroughly test the hypothesis and should rapid climate change not be found in such records within a decade or two following a major conjunction of planets, there would be no correlation as proposed.

The hypothesis is also weakened if rapid climate change is found when no major conjunctions of planets have previously occurred, though climate change can't be limited only to planetary conjunctions. The hypothesis merely states that planetary cycles have the power to entrain climate to a certain extent, and only when the climate system is near a threshold. Further, the proposed amplifying mechanisms of the solar modulation hypothesis may be shown to be incapable of responding rapidly, within decades, as proposed. The hypothesis predicts that as solar activity

[327] The software (Solar Fire 5.1 by Astrolabe) used to track outer planet conjunctions extends only to 7000 B.P. and correlating climate data with conjunctions beyond this rage requires additional computational methods.
[328] Shultz, (2002).

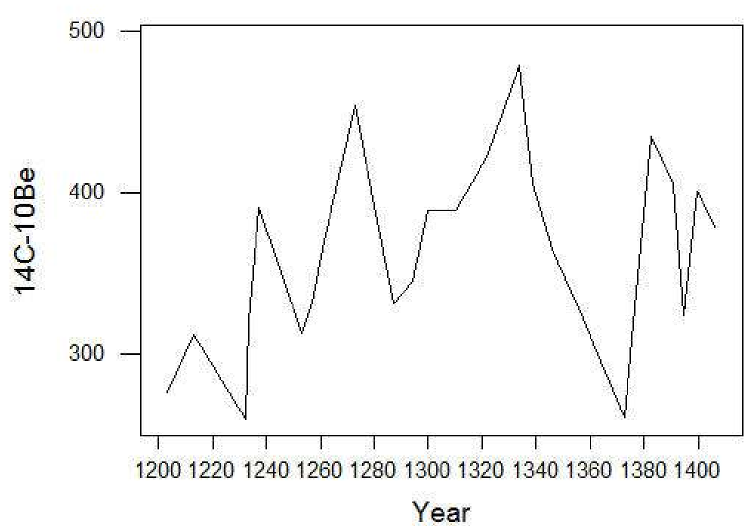
increases, due to planetary tidal effects on the Sun, there should be a sudden drop in C^{14} levels at the time of a conjunction as the enhanced solar wind blocks normal cosmic ray flux. This flux rate change should be discernable in tree ring records from the North Atlantic region and in reconstructed solar irradiance databases. Although annual resolution will be required, the complete absence of a change in solar irradiance proxies such as ^{14}C and ^{10}Be will weaken or even falsify the hypothesis. A graph of reconstructed dataset of solar irradiance based on radiocarbon data for the 13th and 14th centuries, which spans the 1306 conjunction of the four Jovian planets, appears below as Figure 32. The reconstructed solar irradiance shows a steep decline beginning about 1230 and leveling off between 1320 and 1330 before rising again. The reconstructed data is not yearly, so it is has a range of a decade, and also a lag time of about a decade needs to be taken into consideration. This data suggests that solar activity actually declined in the half century or more leading up to ~1320 (less a decade or more considering the lag time taken for cosmogenic nuclides to be taken up by trees or embedded in ice cores) and then began to rise, steeply at first.

Figure 32. Solar Irradiance Reconstruction 1200-1400.



Below, Figure 33, is a graph of cosmogenic nuclide production (^{10}Be and ^{14}C) from an ice core at the South Pole.[329] This data shows a rise in cosmogenic nuclide production peaking around 1330 followed by a sudden decline, which suggests a quiet Sun suddenly heating up. Resolution is decadal and a lag time of a decade or more must be taken into consideration.

Figure 33. Cosmogenic Nuclide Production 1200-1400.



The graph below, Figure 34, extends the reconstructed solar irradiance graph to 1200 years, from 800 to 2000. What this suggests is that solar activity was minimal during the early decades of the 14th century, was followed by a sudden rise but then remained lower than the period between approximately 1100 to 1250, the Medieval Maximum. The overall low trend between 1450 and 1850 has not been adequately explained, but it could be attributed to lower insolation values driven by orbital factors. The solar modulation hypothesis, however, predicts that a sharp rises in solar irradiance in the larger context of insolation changes should be marked by major outer planet conjunctions, or other tight alignments involving 90 or 180 degrees. If so, this graph suggests there should be conjunctions or close alignments preceding (considering lag time) the following years: 1060, 1460, 1540, 1690 and 1830.

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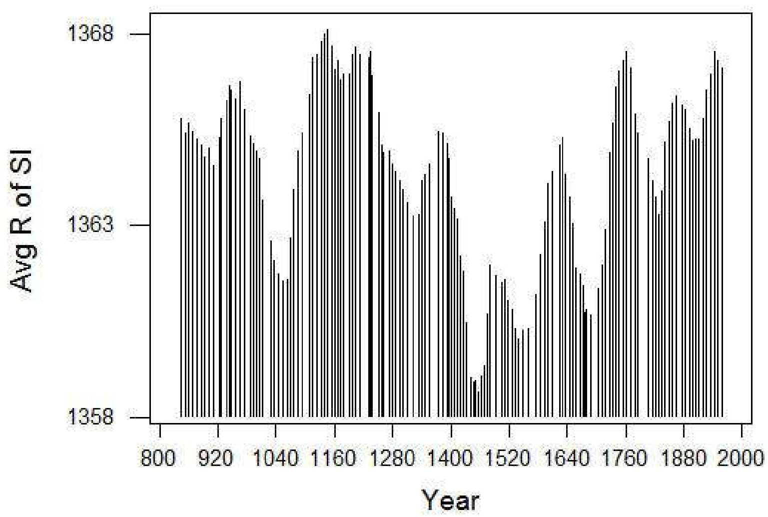
329 Raisbeck et al., "10Be and 2H in polar ice cores as a probe of the solar variability's influence on climate," *Philosophical Transactions of the Royal Society of London A,* (1990).

Figure 34. Reconstructed Solar Irradiance 800-2000.



In December of 1046 Jupiter and Saturn were in conjunction with Neptune and Uranus at 90 degrees from them. The configuration was particularly close, all planets within 3 degrees, and it occurred near the winter solstice and the equinoxes. In October of 1443 Jupiter, Uranus and Saturn conjoined near the winter solstice to within 10 degrees while at 90 degrees to Neptune near the equinox. In January of 1524 Jupiter, Neptune and Saturn were conjoined with a span of only one degree and twenty minutes of arc. In 1665 all four outer planets were spaced within a 45 degree arc. In October of 1671 Saturn and Uranus were in conjunction simultaneously opposed to Jupiter, all of this with three degrees of arc. In 1804 all four outer planets were spaced within a 42 degree arc. In November of 1821 Uranus and Neptune were conjunct near the winter solstice point at the same time that Jupiter and Saturn were conjunction near the vernal equinox. This suggests that, if there really is an effect from the planetary alignments, that the lag time is about fifteen years.

A close examination of the most recent major outer planet conjunction may prove useful in moving toward an understanding of this hypothetical mechanism of climate modulation. During 1988-1989, a Saturn, Uranus, Neptune conjunction formed, with the minimum orb occurring in the spring of 1989. One of the largest coronal mass ejections occurred in March of that year. The average solar constant for the year was not unusual and this period marked the height of the current solar cycle, i.e. more sunspots were forming and the Sun was consequently more active. In late 1989 to early 1990 Jupiter opposed this conjunction making this a relatively rare outer planet configuration. Below, Figure 35, is a graph of solar irradiance from satellite data for the years 1987-1991. Daily solar irradiance was averaged for each quarter of the 5-year period and plotted against the calendar.

Figure 35. Solar Irradiance from Satellite Data 1987-1991.

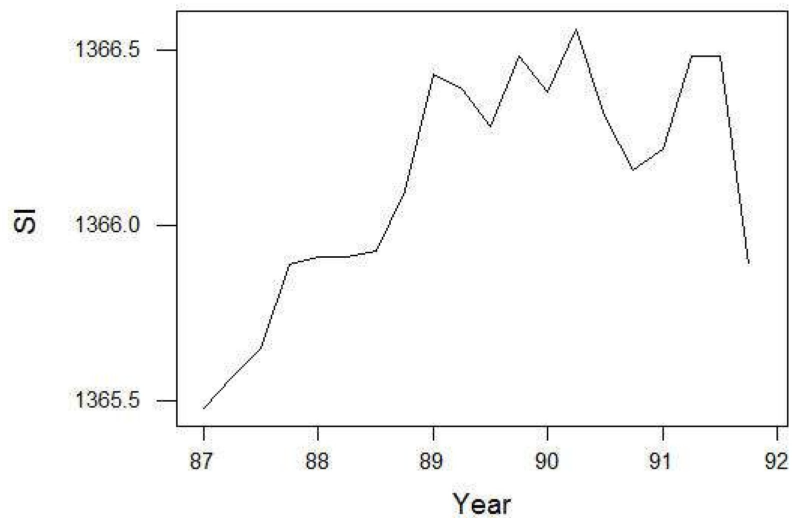
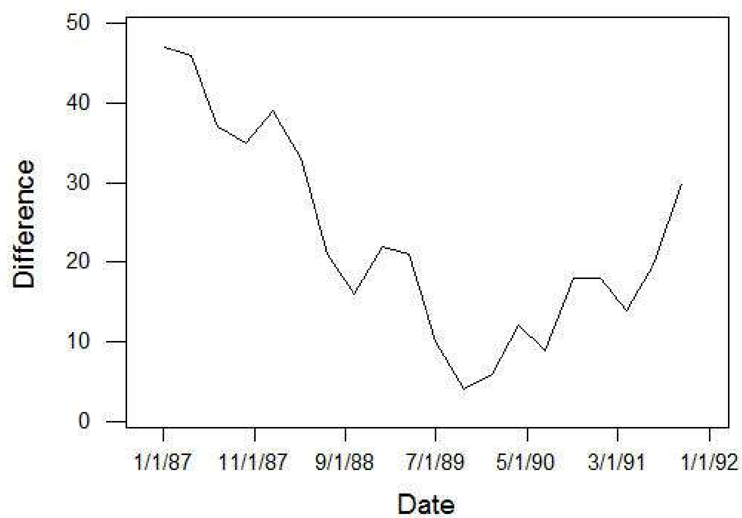


Figure 36 depicts the sum of the heliocentric angular differences between the four outer planets Jupiter, Saturn, Uranus and Neptune for the five years 1987 to 1991. The data was calculated as follows. Because the configuration formed in 1989-1990 was a conjunction of Saturn, Uranus and Neptune with Jupiter in opposition 189 degrees away, the second harmonic of the angles was used which brings Jupiter into the same range as the other three. This was done by locating all bodies (in this case only Jupiter) moving between the vernal equinox and the autumnal equinox (first degrees of tropical signs Aries and Libra) as they normally would be, from 0 degrees to 180 degrees. Planets moving between the autumnal equinox to the vernal equinox were likewise located between 0 and 180 degrees. This procedure allows an opposition between planets to appear numerically as if it were a conjunction. After adjusting the degrees of longitudes of the four planets, the difference in degree between each pair were calculated for the first day of each quarter of the five year period. There are six differences: Jupiter-Saturn, Jupiter-Uranus, Jupiter-Neptune, Saturn-Uranus, Saturn-Neptune, Uranus-Neptune. The differences in degrees of longitude for each quarter were then averaged to yield the figures in the graph below which reaches the lowest value, the point at which all four bodies came closest to each other, in late 1989. Note that this graph presents the difference in degrees on the first day of each quarter while the above graph of solar irradiance presents an average of daily data for each quarter.

Figure 36. Sum of angular differences between Outer Planets 1987-1991.



The above data does not falsify the planetary solar modulation hypothesis nor does it prove it. It is only suggestive that the hypothesis should be further tested. A study of the possible effects of Saturn-Uranus-Neptune conjunctions on climate sufficient to cause an ~1500-year periodicity to appear in the paleoclimate record requires highly resolved data. A paleoclimate dataset with annual resolution would, however, be the ideal solution to the problem of falsifying the hypothesis. As for the mechanism, as mentioned there have been proposals, notably the magneto-tidal resonance theory of Percy Seymour.

With correlations and a possible mechanism for planetary effects on the Sun or directly on the Earth's atmosphere, the final problem is the chain of mechanisms between solar activity and climate modulation. For example, the hypothesis assumes that increased solar activity drives a warming of polar regions, at least in the northern hemisphere. Should highly resolved climate data show that the opposite occurs, that is planetary conjunctions lower solar activity, this aspect of the hypothesis would need serious revision. Perhaps Svenmark's cosmic ray and low cloud cover cooling mechanism may play a role, or it may be the case that direct geocentric alignments correlate with cooling. Each portion of the hypothesis offers opportunities for study. Ultimately, it is the establishment of high resolution paleoclimate data that will be most effective in falsification or validation.

APPENDIX B

LIFE RESPONDS TO AND INTERNALIZES GEOPHYSICAL AND ASTRONOMICAL CYCLES

The life cycles of organisms occur in the constantly changing temporal environment created by the geophysical and astronomical cycles of the Earth, Moon, and Sun. Life has sensed and adapted to this environment for possibly 3.8 billion years and has utilized these geophysical/astronomical influences as a structural framework around which many crucial internal life functions organize themselves. Adaptation to these environmental constraints insures fitness and survival. Biological rhythms based on geo-celestial cycles can alert the organism in advance to coming changes in the environment – they are guidance mechanisms cued by sensory information that allows for better environmental navigation serving feeding, mating, movement, germination, flowering, and growth needs. Organisms have evolved sensory mechanisms that register the day and seasonal cycles, tidal cycles and other lunar rhythms, the Earth's magnetic field, and the solar cycle. This paper reviews the chronobiological properties of life organized by these environmental entrainment factors.

B.1 Environmental Periodicities and Biological Rhythms

The primary geophysical periodicity that nearly all organisms respond and adapt to is the rotation of the Earth relative to the Sun, i.e. the solar day of 24 hours. Another related period is the tidal or lunar day of 24.8 hours that denotes the rotation of the Earth relative to the position of the Moon. During the course of one 24-hour rotation of the Earth, the Moon advances in its orbit by about 13 degrees of celestial longitude, requiring an additional 0.8 hours of Earth rotation to complete. Another lunar period is the synodic cycle, or the cycle from new Moon to new Moon, of about 29.5 days. Half of this, 14.77 days, which spans the period from new to full Moon, is called the semilunar period. The solar year of 365.24 days, which marks one orbit of the Earth around the Sun, is a period during which the ratio of light and darkness vary in a cycle, creating the seasons. This annual cycle is most pronounced in high latitudes. Cycles longer than a year that are driven by solar activity are the 1.3-year cycle of the solar wind, the Schwabe cycle of 11.1 years and the Hale cycle of 22 years.

Biological rhythms as a property of living things were recognized by early natural philosophers. In his description of the Mediterranean sea urchin, Aristotle mentions that the size of its ovaries vary according to the lunar cycle. The study of biological rhythms in modern times began when French astronomer Jean Jacques d'Ortous de Mairan observed in 1729 that the cycle of daily leaf movements of a species of heliotrope persisted in continual darkness. In 1880 Darwin published his observations of leaf movements in his book *The Power of Movement in Plants*. Research on efficient tobacco propagation led to the discovery in 1920 that plant flowering at specific times in the year was influenced by the cycle of the day/night ratio within the annual cycle. This property is called photoperiodism. In 1936 the German scientist Erwin Bünning published a hypothesis concerning biological rhythms in which he stated that the timing mechanisms of photoperiodism were the same mechanisms behind daily leaf movements. He argued that the timing mechanism behind both of these rhythms was a roughly 24-hour endogenous, or internal, biological clock.

The nature of the mechanism of biological rhythms has been debated for many years. In opposition to Bünning, an argument was made for the "clock" being a sensory response to any number of environmental signals, it being essentially exogenous and driven by an external *zietgeber* (time giver). Laboratory data, including studies conducted at the south pole (with hamsters, *drosphila* and *neurospora)* and in space (with *neurospora*), pointed to an endogenous oscillator that is self-sustaining without any obvious environmental cues. It is now understood that biological rhythms, for the most part, are environmentally-independent, driven by complex internal molecular processes, not by external forcing. However, these rhythms are entrained by environmental cues, thus external signals are essential for their operation in nature.

The alternation of the light-dark cycle, the fundamental geophysical period caused by the rotation of our planet, is the most important environmental signal for organisms that live near the Earth's surface. This signal is experienced as a repeating pattern of light and dark that occurs as the Earth faces toward or away from the Sun during the course of a solar day. Biological rhythms of approximately 24 hours have been found to be a general feature of the physiological organization of organisms from all five kingdoms of life including prokaryotes, protoctista, plants, fungi and animals. These rhythms have been studied extensively and are referred to as circadian (circa=about, dian=day) rhythms.

True circadian rhythms are defined by three main characteristics. First is the persistence of a *period* of about 24 hours in constant light or dark conditions. Persistence of the rhythm and deviance from exactly 24 hours, the period, is species specific. Some organisms have rhythms that will continue without external signals for only several complete cycles, others can "free-run" for weeks or months. Secondly, circadian rhythms will persist throughout a wide range of temperatures allowing an organism to maintain a stable rhythm regardless of temperature variations throughout the day or year. Third, circadian rhythms can be entrained by light/dark (L:D) cues, by sharply changing temperature cues of >10 C, and in some cases by other environmental signals including food availability, social cues, electromagnetic field strength and atmospheric pressure.

Circadian rhythms in an organism will establish a *phase* relationship between subjective day and external day (or the reverse in nocturnal organisms) by responding to an external environmental signal. Some organisms establish the phase of their circadian period by the onset of light, others by the onset of darkness. Studies have shown that circadian rhythms can be modulated, i.e. phase shifted, by the presence of certain environmental signals such as light pulses at points in the diurnal cycle other than the normal onset of light or darkness. It is this ability to phase shift that accounts for the ongoing adaptation to the changing day:night ratio of the seasons. This means of adapting would not be possible with a period of exactly 24 hours, but is facilitated by a period that only approximates this figure.

Progress in the study of biological rhythms has accelerated in recent years. It was long thought that circadian rhythms would only be found in eukaryotes but in the late 1980's they were discovered in cyanobacteria. The mechanism behind circadian rhythms was a matter of speculation until the 1990's when a molecular model for the circadian oscillator was developed. In this model, a photo-receptor in the cell recognizes alterations of light and dark. This information is then fed to an oscillator that is essentially a negative feedback loop in protein production within the cell. This oscillator is capable of being reset by the photo-receptor should photic information reach it at critical points in its cycling. Finally, chemical messengers relay this information to other parts of the organism.

B.2 Circadian Rhythms in Prokaryotes

Until the late 1980s it was assumed that circadian rhythms existed only in eukaryotes, although evidence for rhythms in *E. coli* was reported in the 1960s.[330] The assumption was that since circadian systems appear to control the cell-division cycle, then prokaryotes, which divide in

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[330] Halberg, et al., Transdisciplinary unifying implications of circadian findings in the 1950s. *Journal of Circadian Rhythms,* (2003).

periods of less than one day, could not have circadian cycles because cell division in periods of less than 24 hours would cause an uncoupling of any circadian clock. However, circadian rhythms found in the marine cyanobacteria *Synechococcus* have made this assumption obsolete.

The cyanobacteria *Synechococcus* is now known to exhibit several circadian cycles. Daily oscillations in nitrogenase activity reflect the need to separate nitrogen fixation from photosynthesis. Because the nitrogenase enzyme complex is highly sensitive to oxygen and becomes inactive in its presence, this problem is solved in filamentous cyanobacteria by specialized cells called heterocysts that separate these functions spatially. *Synechococcus,* a coccoid bacterium*,* separates these processes by divisions in time. *Synechococcus* strains also exhibit other circadian rhythms including nitrogenase mRNA abundance changes, amino-acid uptake, protein synthesis, light/dark entrainment, and the cell division cycle.

In the early 1990s, the genes specific to the clock mechanism of *Synechococcus* were isolated. In one study a new strain of *Synechococcus* was created carrying luciferase genes that confer observable luminescence and thus report on gene expression.[331] This strain was then subjected to chemical mutagenesis and aberrant luminescence rhythms ranging from 16 to 60 hours were isolated. Rescue experiments on these populations led to the identification of a cluster of three clock specific genes that produced the rhythms. These genes, named *kai* A,B, and C (kai = cycle in Japanese), were found to be necessary in combination for the daily cycle to persist. The deletion of one or all of them causes arrhymicity. These genes were also found to be unique to prokaryotes and not similar to known clock genes found in the previously mapped *Drosophila* (fruit fly), *Neurospora* (bread mold) and mouse clocks. Although they are not found in eukaryotes, two of them are present in Archaea genome databases.

A study using sequential genomic data from 70 complete prokaryote genomes proposed an evolutionary history of the kai ABC gene cluster.[332] Using 16s rRNA gene sequences for comparative phylogenetic analysis, homologs of kai C were found in almost all major taxa of Archea (in which circadian rhythms have not yet been found), fewer were found in Eubacteria. It

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331 Kondo et al., "Circadian Clock Mutants of Cyanobacteria," *Science,* (1994); Ishiura, et al., "Expression of a Gene Cluster kaiABC as a Circadian Feedback Process in Cyanobacteria," *Science,* (1998).
332 Dvornyk et al., "Origin and evolution of circadian clock genes in prokaryotes," *Proceedings of the National Academ.y. of Sciences,* (2003). See also Johnson and Golden, "Circadian programs in cyanobacteria: adaptiveness and mechanism," *Annual Review of Microbiology,* (1999).

appears that Kai C, the oldest of the three genes, may have evolved as early as 3,800 million years ago with the earliest cyanobacteria. The kai BC grouping evolved sometime between 3,500 and 2,300 million years ago during the time that the atmosphere became oxygenated. The authors of the paper suggest that kai B probably originated in cyanobacteria and was then laterally transferred to other Eubacteria and Archea. Kai A, however, was found only in cyanobacteria indicating a more recent origin. The kai ABC cluster was probably in place by about 1,000 million years ago and is characteristic of cyanobacteria.

B.3 Circadian Rhythms in Protoctista

Circadian rhythms have been found in many single-celled protoctists including diatoms, *Euglena, Chlamydomonas, and Acetabularia*. One of the first eukaryotic organisms to be studied for its circadian rhythms was *Gonyaulax polyedra*, a dinoflagellate single-celled alga.[333] It has a circadian rhythm of bioluminescence that persists in constant light (L:L) as well as circadian cycles of photosynthesis and cell division – cell-division does not control the clock, the clock controls the cell cycle. All the rhythms of *Gonyaulax* are entrainable by either the natural day/night sequence or by single short light pulses, the latter are capable of phase-shifting the rhythm if applied at the proper time. Cell-division appears to be keyed to the ending of the night phase and light cues presented then will reset the clock. The circadian rhythm of photosynthesis, on the other hand, seems to be keyed to maximum light at midday with entrainment sensitivity at the beginning of the light phase (dawn). *Gonyaulax* also has at least two separate oscillators each receptive to different wavelengths of light. The cycle of bioluminescence is sensitive to blue wavelengths and the cycle of swimming behavior or aggregation is sensitive to red wavelengths.

In the ciliate *Paramecium micronucleatum*, the circadian clock drives mating type cycles. Reproduction in *Paramecium* is of three types; Autogamy (self-fertilization), binary fission, and conjugation which occurs between complimentary mating types that change sex according to an entrainable circadian rhythm. In a series of experiments, the sexual reactivity of *P. micronucleatum* was studied in considerable detail.[334] It was found that the mating type cycle is endogenous and that cells can be entrained even while dividing and also that the phase of the

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333 Sweeney, *Rhythmic Phenomena in Plants,* (1987).

334 Barnett, "A circadian Rhythm of Mating Type Reversals in Paramecium multimicronucleatum, Syngen 2, and its Genetic Control," *Journal of Cellular Physiology,* (1966).

previous entrainment is inherited even in dim L:L or D:D. *P. micronucleatum,* a ciliate with several nucleii, transmits the ability to cycle through an allele which must be present, but the genetic control of the circadian rhythm does not seem to be located in the macronucleus.

Acetabularia is a single celled alga, 5 cm high with a "cup" about 1 cm in diameter. It is generally found in shallow, sheltered waters attached to rocks and other shallow substrates in the vicinity of tropical coral reefs. It is of interest because it illustrates the location problem of the circadian oscillator. It was found that removing the organism's nucleus did not terminate circadian rhythm, but if it was retained, it did have an influence – though exactly how much is not clear. The problem of locating exactly the circadian mechanism is still not completely resolved by the current molecular model. Other findings of this study was a circaseptan rhythm (about one week) observed in the amplitude of the fundamental circadian rhythm.[335]

B.4 Circadian Rhythms in Other Eukaryotes

Circadian rhythms exist in most, if not all eukaryotic organisms and serve multiple important functions. They have been studied extensively in a number of model laboratory organisms (i.e. *Drosophila, Neurospora*, *Arabadopsis* (mustard plant), *Mesocricetus* (hamster) and it has been found that a wide variety of eukaryotes use the same molecules to control their circadian rhythms within the transcription-translation oscillator model.

In the molecular model, clock-controlled genes are instrumental in producing the overt rhythms that regulate cell activities and allow the organism to maintain homeostasis within its environment. The central feature of this model is a transcription-translation negative feedback loop. As translation in the cell proceeds, the protein gene product of a specific gene or genes accumulates in the cytoplasm. The accumulation of this protein eventually acts to inhibit further transcriptions of its own gene or genes. When the gene product declines to a certain level, translation begins again. The circadian oscillator thus uses negative feedback loops within the cell in making adjustments to the day-night cycle. *Neurospora* and *Drosophila* were the laboratory organisms from which this molecular model was developed.

335 Sweeney and Haxo, "Persistence of a photosynthetic rhythm in enucleated Acetabularia," *Science,* (1961), Woolum, "A Re-Examination of the Role of the Nucleus in Generating the Circadian Rhythm in Acetabularia," *Journal of Biological Rhythms,* (1991).

There does not seem to be a close connection between the clocks of eukaryotes and those of prokaryotes. It does appear that the general oscillator-protein-feedback arrangement of the circadian system has been conserved, but it seems to have evolved independently, perhaps many times. For example, the cyanobacterial oscillating mechanism is similar in general principles to those in eukaryotic systems, but the proteins are completely different, suggesting an independent evolution.

Photoreception in animals is primarily through the retina, though many species also utilize extraretinal photoreceptors in the brain or closely connected to it. The anatomical location of the circadian oscillator itself varies widely among animals. In gastropods it is found in the eyes, in some crustaceans it is located in the eyestalks, in insects in the brain, and in other organisms in the brains and abdominal ganglia. In reptiles and birds it is located in the pineal gland and in mammals in the hypothalamus. The genetic mechanisms for circadian biological clocks in animals are fundamentally the same, which suggests a common ancestral clock, and it appears that mammals and insects share at least some clock parts.

The circadian system in vertebrates consists of photoreceptors, usually eyes, for photon reception, the pineal organ, and the suprachiasmatic nucelus (SCN) which is located in the hypothalamus. It is thought that this particular circadian system is highly conserved and was established with the origins of vertebrates 500 million years ago. The SCN, the central pacemaker located in the hypothalamus, produces circadian rhythms by gene product negative feedback loops in specialized cells which then relay information via neural and endocrine pathways to the rest of the organism, including other peripheral clocks. The SCN controls the rhythmic release of melatonin which carries the rhythmic signal via the bloodstream to the rest of the body. The processing of light by vertebrates for the circadian oscillator differs significantly from the processing of light for vision and appears to involve brightness (photon count) receptors that are separate from rods and cones. For example, the mammalian eye has parallel pathways for vision and brightness, the later has dedicated photo receptor cells that comprise about 1 % of the total ganglion cells in the retina.

B.5 Photoperiodism

The seasonal progression of day-length is related to the Earth's orbit around the Sun. Day-length is modulated over the course of the year by the tilt of the Earth's axis producing a day of 12:12 at the equator, but up to 0:24 in latitudes over 66 degrees. The annual cycle of day-length challenges the ability of organisms to adapt to a continuously changing L:D ratio, particularly in the higher latitudes where the effect is so extreme. Organisms have evolved adaptive timing mechanisms to solve this problem, allowing them to adjust to seasonal opportunities for feeding, reproduction, growth, molt, migration, and hibernation. Circannual rhythms also provide information on distance and direction that are crucial to migratory behaviors and, in mid to high latitudes, timing information for animals that den for the winter. In general, photoperiodism is more robust and tightly organized in long-distance migrating species than in tropical species where there are slight annual cues. It is thought that continuous entrainment of the circadian oscillator by constant phase resetting is able to account for an organism's adaptation to changing day lengths.

There are two types of seasonal adaptation in animals. Many long-lived species have been shown to possess an endogenous free-running (environment-independent) period of 12 months. The adaptations are therefore self-sustaining under constant conditions such as L:L or D:D, and free-running periods been shown to persist for up to 12 cycles in birds, and 7 in mammals. These true circannual rhythms are also found in sheep, deer, bats, and starlings (a long-living bird), among others. The second type of seasonal rhythm is endogenous with exogenous components. Cues are needed to keep the endogenous rhythm synchronized with local seasonality. This type is common in shorter-lived species such as mice, hamsters and many birds and reptiles. In such species no localized oscillating center or anatomical feature for this rhythm has been found.

Plants, where photoperiodism was first scientifically studied, use photoperiod timing for growth, adjustments to seasonal changes, the induction of flowering and germination time for seeds at the appropriate time of year. Plants clearly measure day-length, but the molecular mechanism is not completely known. Vascular plants sense seasons by discriminating day from night, measuring time passage of the night interval and integrating this information in changes of growth, germination, and flowering. It appears that the circadian clock of the plant reads the day-length changes by comparing phase shifts, that is measures the changing day:night ratio against the endogenous circadian rhythm. Light occurring earlier in the circadian cycle, during the night portion, will phase shift the cycle to adjust for the changing ratio of light and dark. Photoperiodism in *Arabadopsis*, specifically clock-driven leaf movements, was studied for variations in period, phase and amplitude.[336] Variations of plant free-running periods ranging from 22-28.5 hours were positively correlated with latitude (day-length). Free-running periods longer than 24 hours were found to enhance the ability of the plant to track dawn, which allows for more rapid phase-shifting, that is adjusting to changing day-length, and therefore better latitudinal and seasonal adaptation. Correlations between phase and latitude and phase and day-length were not found to be significant.

B.6 Tidal and Lunar Rhythms

The Moon is a major component of Earth's rhythmic cosmic environment. The gravitational pull of the Moon on the Earth produces a daily tidal cycle of 24.8 hours that consists of two tides spaced about 12.4 hours apart. High tide occurs on the side of the Earth facing the Moon, but it also occurs simultaneously on the opposite side of the Earth. The shape of coastlines and the location of land masses distorts the timing of local daily tides making tidal schedules highly irregular. The selection pressure for a species to evolve a tidal clock, allowing it to anticipate the substantial changes in the coastal environment as the tide changes, is high, but local conditions require unique adjustments. Perhaps for this reason free-running tidal rhythms in many marine organisms are generally not as precise as circadian rhythms.

The periodicities of the day and the year, both based on Earth-Sun relationships, are relatively simple. Lunar cycles are far more complex, inexact, and multi-faceted. Perhaps the most identifiable of several lunar cycles is the synodic cycle of 29.5 days. This period is defined in days from alignments between the Moon and the Sun, i.e. new Moon (Sun-Moon-Earth) or full Moon (Sun-Earth-Moon). The combined gravitational forces of Sun and Moon at these two alignments correlate with the highest tides, the Sun's gravitational contribution being about 45%. The distance between the Moon and the Earth also varies by about 13% over a cycle of 27.5 days, called the anomalistic month. At perigee the Moon's gravitational force is stronger and the coincidence of perigee with a full or new Moon produces the highest tides. At present, the Moon orbits the Earth every 27.5 days at a mean distance of 382,000 kilometers. This period and

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336 Todd, et al. "Enhanced Fitness Conferred by Naturally Occurring Variantion in the Circadian Clock," *Science,* (2003).

distance has increased substantially during Earth history and semi-monthly tidal estimates from 2 billion-year old fossil stromatolites suggest that the lunar month was then ~25.6 days in a year of 880 days.[337]

Tidal and lunar periodicities are prominent features of many marine organisms and a few have been studied extensively.[338] Some of the most studied tidal organisms are the several species of the fiddler crab, *Uca*. These arthropods live in burrows and feed as the tide ebbs and so are subjected to repetitious fluctuations of light, temperature, and tidal submergence. It has been found that they have a 24-hour circadian cycle of shell color – darker at dawn, lighter at dusk. However, their running activity retains a tidal periodicity of ~24.8 hours, 50 minutes later each day. Further, in *Uca pugilator*, the reproductive rhythm is semilunar as their larvae are released at new or full Moon at the hour of high tide. It appears that more than one clock is operating in this organism.

Tidal rhythms in marine organisms such as *Uca* are known to vary widely among individuals and studies of groups of the same organism tend to distort data. One view on how tidal rhythms are maintained suggests that a circadian clock with a long free-running period is able to adjust itself, i.e. phase shift, by entrainment to changes in the environment, including such factors as hydrostatic pressure, temperature, water agitation, etc. This view is supported by the rapid shifting of certain organisms (eg. *Euglena obtusa*, diatoms) in the lab from a 24.8-hour tidal rhythm to a 24 hour L:D cycle. A second view, called the circa lunidian clock hypothesis, proposes that two coupled clocks run simultaneously within the organism, each one tracking a separate 12.4 hour period.[339] Evidence for multiple clocks include the finding that the two tidal periods of each day appear to be scanned at different rates.

Lunar rhythms are also found in marine protoctista. Many species of planktonic foraminifera have a reproductive cycle that is characterized by the alteration of two generations, haploid and diploid, with different modes of reproduction. Reproduction in these planktonic forams occurs in two primary stages that in some species may take two years to complete the necessary sequences.

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337 Mohr, "Measured Periodicities of the Biwabik (Precambrian) Stromatolites and their Geophysical Signficance," in Rosenberg and Runcorn, eds. *Growth Rhythms and the History of the Earth's Rotation,* (1975).
338 Brown et al., *The Biological Clock: Two Views,* (1970); Palmer, *Biological Rhythms and Clocks of Intertidal Animals,* (1995).
339 Palmer, (1995).

The cyclic reproductive process can be described as follows: Beginning at meiosis, haploid agametes are created and grow, becoming the sexually reproducing gamont generation with a single nucleus. The gamont, when fully grown, undergoes mitosis producing hundreds of thousands of flagellated, free-swimming haploid gametes. These gametes then leave the test or shell of the foraminifer, meet with others of its kind, and fuse – beginning the diploid phase of the life cycle. Reproduction in the ocean requires a large number of gametes, about 300-400 thousand. Gamete releases in the ocean require consolidation in time and space and precise synchronization in order to secure gametic fusions and the continuation of the species. Some species appear to coordinate these processes with the lunar synodic cycle.

In a study, samples of three species of foraminifera were collected every two days for 47 days, at the same time and depth each day.[340] It was found that the number of all species was at minimum 3-5 days after the full Moon. It was also found that the numbers of *Globigerinoides sasculifer* and *Globigerinoides ruber* were at maximum 9 days before the full Moon, but those of *Globigerinella siphonifera* were at maximum 3 days before full Moon. Apparently, each species has its preferred phase of surface activity relative to the full Moon. Laboratory studies suggest an exogenous component to this lunar reproductive rhythm. The lunar cycle continued in the lab for a related species, *H. pelagica*, with no moonlight and there was 85% gametogenesis at 3-7 days after the full Moon. It was also found that these forams count light/dark cycles, but the timing of gametogenesis can be altered by keeping them in L:L and D:D periods. *G. sacculifer*, *G. ruber* and *G. siphonifera* did not synchronize in the lab but reproductive timing was affected by culture conditions (i.e. food, light, population size, etc.). The question arises as to whether culture conditions actually override an endogenous rhythm, or is it that the organism requires an external *zeitgeber*. The cycle of moonlight is a possibility, but this varies and is unreliable due to weather conditions. Other possible signals include fluctuations of the magnetic field and changes in lunar gravitational strength (perigee).

One of the more curious studies that have raised the endogenous/exogenous issue in lunar rhythms involved a study of oysters transported from New Haven to Evanston, IL.[341] Their shells were wired and the frequency of opening and closing was recorded. The oysters were in the lab in

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340 Bjima et al., "Lunar and Semi-lunar Reproductive Cycles in some Spinose Planktonic Foraminifers," *Journal of Foraminiferal Research,* (1990).
341 Brown et al., (1970).

a pan of water that was not agitated. At first, maximum activity occurred at high tide for New Haven, but after 2 weeks the rhythm phase-shifted 3 hours later in lunar day, where it then stabilized. One explanation proposed was that the organisms were responding to tides in the atmosphere that register as subtle changes in barometric pressure. Contrary to this finding, mussels collected in Massachusetts and taken to California maintained their east coast tidal rhythm and did not adjust to west coast tidal rhythms until they were exposed to these tides.[342]

An outstanding example of a relatively precise response to the lunar synodic cycle is the reproductive behavior of the Palolo worms of the south Pacific. The terminal body segments of this marine polychaete are genetic capsules that are released at dawn, synchronous with the October or November third quarter Moon. Like the release of haploid gametes by planktonic foraminifera, the Palolo worms require precise daily timing, but also timing relative to the seasons. Records of spawning show that the worms, by following the third quarter Moons in either October or November, accurately track the 18-year Metonic cycle where a specific phase of the Moon occurs on the same date after exactly 18 years. Even more remarkable is the lunar synchronized reproduction of at least 107 species of coral along 500 kilometers of the Great Barrier Reef in the western Pacific. Nearly all release gametes 3 to 6 days following the full Moon in October or November, and about four hours after sunset.[343]

At present there is no known mechanism by which lunar influence is entrained in genetic processes. Light is certainly a factor in many organisms. Studies of juvenile salmon show grouping occurring at full Moon and movement at new Moon – a strategy that limits predation. Different degrees of lunar illumination will influence the vertical migration of zooplankton. At crucial developmental stages, zooplankton populations are vulnerable to higher levels of moonlight, which encourages predation. Since the phase of the Moon is not the same at a constant point in the seasonal cycle, predation will eventually select organisms, in this case the zooplankton, that can entrain to the lunar cycle. Fish, feeding on these smaller organisms, will then be entraining on the cycle as well.

The Moon's influence on the environment is not limited to variations in nocturnal illumination. The atmosphere displays lunar periodicities as the upper layers are affected by the Moon's gravity

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342 Sweeney, (1987).
343 Endres and Schad, *Moon Rhythms in Nature,* (1997).

and this modulates air pressure. Magnetic field data shows adjustments to the Moon's phases and other possible tidal triggers include temperature changes, turbulence, water pressure and salinity changes. Few studies have been done that compare the response of organisms to the various influences of the Moon mentioned above and the subject is still, in many respects, in its infancy.

B.7 The Geomagnetic Field and Life

The Earth is shielded from a steady rain of charged particles and cosmic rays by its own self-generated magnetic field. The field itself, called the magnetosphere, is comet shaped as a result of the constant force of the solar wind, a stream of hot electrons and protons emanating from the Sun. The sunward side of the field, the magnetopause, is compressed to a depth of about 11 Earth radii. The magnetotail, on opposite side away from the Sun, has the form of an elongated tail that may extend as much as 1000 Earth radii.

The magnetic field not only establishes an Earth-encircling electro-magnetic dipole framework, but it also exhibits fluctuations and periodicities. Geomagnetic micropulsations (caused by lightning storms, particle bombardment, etc.) which last less than 1 second to a few minutes occur constantly. Longer periodicities reflected in magnetic field variations include responses to the Earth's rotation (24 hours) and the lunar day (24.8 hours), the synodic month (29.5 days), solar rotation (~27 days), the solar year (365 days), variations in the solar wind (1.3 years), and the sunspot cycle (11 and 22 years on average).

At present it is known that the Earth's magnetic field is utilized by certain organisms for its directional and temporal information content. The most studied use of the magnetic field is in regard to navigation. This is accomplished by either direct contact to the field or as a response to weak electric fields induced by the geomagnetic field. The ability to "read" the geomagnetic field requires remarkable discrimination, but it is accomplished by bacteria which derive selective advantages from this response.

Magnetotactic bacteria are a diverse group of motile, mainly aquatic, anaerobic or microaerobic gram-negative prokaryotes that were first recognized at the University of Massachusetts.[344] They

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[344] Blakemore, Magnetotactic Bacteria, *Science,* (1975)

are motile by means of flagella and use this ability to remain aligned with the Earth's magnetic field. At the latitude of Cape Cod, the vertical component of the field is more evident than the horizontal. Magnetotactic bacteria have a negative response to atmospheric levels of oxygen and seek anoxic regions, using the north-sloping direction of the Earth's magnetic field as a guide to vertical motility. Their response and alignment to magnetic fields is possible due to a chain or chains of small, biologically-produced crystals of magnetite inside the body of the bacteria. These particles are called magnetosomes.

Magnetosomes are intracellular, single crystals of magnetite (Fe_3O_4) synthesized by the organism from materials found in their environment. Magnetite is the mineral that forms lodestone and is known to form inorganically only at high temperatures and pressures. In local environments with high hydrogen sulfide concentrations, sulfur is used with iron to produce magnetic greigite (Fe_3S_4). Magnetosomes are an example of biologically controlled mineralization, specifically an organic matrix-mediated process. They are made entirely by the cell within a coating called the magnetosome membrane, which regulates the deposition of the particle and controls its position in the cell relative to the other particles. In terms of size, all magnetosomes fall with the 35-100 nanometer range, the optimal size for reading the Earth's magnetic field. This size is just big enough for internal polarization but small enough to avoid multiple regions of polarization. Magnetosomes are arranged in one or more chains of about twenty particles that behave as a single magnetic dipole.

Other organisms known for their navigating abilities have been found to contain magnetite crystals in their bodies. These include pigeons, which are able to navigate using the Sun, topography or the magnetic field. Honeybees have magnetite in their abdomens. Other animals with magnetite include tuna, trout, blue marlins, green turtles, whales, dolphins, and possibly humans. It has been suggested that magnetic sensory systems evolved early in life history, are completely separate from other sensory mechanisms, and have increased in sensitivity over time.[345]

[345] Kirschvink et al., Magnetite-based Magnetoreception. *Current Opinion in Neurobiology,* (2001).

B.8 Solar Cycles and Life

Sunspots are visible evidence of both solar rotation and of a larger cycle of solar magnetism that affects the Earth's magnetic field. Solar activity varies over time, intensifying at sunspot maxima and decreasing at minima. The numbers and groups of sunspots change daily and their positions on the Sun's surface changes over time and sunspot counts are a way to track the solar cycle. The most recognized solar cycle is the Schwabe cycle of ~11 years during which the number of sunspots increases and decreases. The Hale cycle of ~22 years accounts for the magnetic reversals that occur between Schwabe cycles.

Many correlations have been reported that link biological and solar activity. Well-documented rhythms of about 10 years, close to the Schwabe cycle, include crop yields, fish catches, and boreal forest mammal population changes.[346] Insect populations show very close correlations with the Schwabe cycle and as such are regarded as sensitive climate monitors. Tent caterpillar populations peak predictably about two years before the peak of solar activity and other insect populations appear to do the same. It has been suggested that these population increases are due to the increased warmth and ultraviolet radiation that also follows the solar cycle.

At least one unicellular organism appears to show a response to a solar cycle. *Acetabularia,* its circadian cycle described above, has rhythms found in the geomagnetic Kp and aa indices, and also in the solar magnetic field. In a database covering 14 years of *Acetabularia* circadian cycle research, the prominence of a 1.3-year cycle, found in the rhythms of the solar wind cycle has been reported.[347] It is thought that entrainment to climate cycles that are driven by the solar cycle occurs in some species, more so in regions in which such climate fluctuations are more pronounced. These adjustments, which may correlate with increasing and then decreasing food supplies, then influences other species population levels.

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346 Hoyt and Schatten, (1997).

347 Halberg, *Solar wind's mimicry can override seasons in unicells and humans*. Unpublished paper received from the author. (2004).

B.9 Discussion

In 1960 it was stated that "circadian rhythms are inherent in and pervade the living system to an extent that they are fundamental features of its organization.[348] Biological clocks that match environmental periods are a nearly ubiquitous characteristic of life, but there are wide variations between species and even between individuals. In some species one clock, or clock system, controls all life functions, in some multiple clocks may be coupled, and in others are found master clocks that drive slave oscillators.

For organisms in the lab, biological clocks have not been shown to be essential for life. The lack or malfunctioning of a clock in nature is another matter. Clocks are generally assumed to confer fitness, though only a few studies have shown this to be so. It is thought that a lack of rhythm will cause an organism to be active at the wrong times of day, and that errors would be made in mating timing, resulting in fewer offspring. One of the best studies showing the fitness of circadian rhythms in cyanobacteria was previously described.[349] Another study involved the day-active antelope squirrel.[350] The SCN of a number of these animals was lesioned which induced arrhythmia causing them to be active at night. During the study, a feral cat managed to enter the research enclosure and proceeded to remove 60% of the lesioned animals, but only 29% of those with an intact SCN. A second study using chipmunks was conducted in a completely natural setting. Again, the SCN was lesioned in a number of chipmunks which didn't seem to create any serious problems for two years of stable food conditions. However, after two years of abundant acorns, the population of chipmunks increased and so did their predators. By the end of the summer season more SCN lesioned animals were killed by weasels than those without.

The endogenous vs. exogenous debate appears to be less a case of one or the other and more a case of complementation. The current molecular model of the circadian oscillator has established a solid foundation for the endogenous source of circadian rhythm, although there are exceptions. Similar models for lunar rhythms have yet to be described. The endogenous oscillator is a system separate from the environment and studies have shown that the free-running period of an

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348 Pittendrigh, "Cicadian Rhythms and the Circadian Organization of Living Systems," *Cold Spring Harbor Symposium on Quantitative Biology,* (1960).
349 Ouyang, et al., "Resonating circadian clocks enhance fitness in cyanobacteria," *Proceedings of the National Academ.y. of Science,s* (1998).
350 DeCoursey et al., "A circadian pacemaker in free-living chipmunks: essential for survival?" *Journal of Comparative Physiology,* (2000).

organism is almost never exactly 24 hours, but usually very close to it. This apparently allows for better tracking of environmental signals, more accurate adjustments, i.e. phase-shifting, and hence better fitness. However, the endogenous oscillator requires sensory input and external triggers to set the phase. Any number of sensory mechanisms may be involved in phase setting, although light is the primary trigger for the circadian system. Other periodic environmental entrainment signals include food availability, social cues, hydrostatic pressure, agitation, and temperature change. It may be that magnetic field variations and the solar wind are also triggers, suggesting that life has deep links to a broader definition of the environment. The study of biological rhythms is a study of how life has adapted to and internalized its environment, using the natural geophysical and astronomical periods as a framework around which the many complex processes of life have evolved.

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