PART ONE

The environment for medieval astronomies

CHAPTER ONE

Astronomies in cultures

> With regard to virtuous conduct in practical actions and character, [astronomy], above all things, could make men see clearly; from the constancy, order, symmetry and calm which are associated with the divine, it makes its followers lovers of this divine beauty, accustoming them and reforming their natures, as it were, to a similar spiritual state.
>
> Ptolemy, *Almagest*[1]

The lights in the heavens, the Sun and the Moon, the stars and the other planets, have enticed people to contemplate them from the beginnings of recorded history.[2] In the introduction to his great work of mathematical astronomy, the Hellenistic astronomer Claudius Ptolemy (ca. 100–ca. 175) put his finger on one of the timeless appeals of the heavens. The heavens display a constancy and an order, a symmetry and a calm, that stand as silent challenges to the transience and discord, the irregularity and turbulence, of the world in which we live. He spoke truly when he declared these characteristics to be divine.

Lest I mislead readers who may be unfamiliar with Ptolemy, his work, and its influence, he was not primarily concerned with the ethical symbolism and import of the orderly motions of the unchanging heavens. His *Almagest* was, from beginning to end, a work of mathematical astronomy, providing detailed geometrical models of the harmonious motions of the stars, Sun, Moon, and other planets. Yet the Latin West lost this mathematical astronomy in late antiquity. The only element of Ptolemy's astronomy that had any substantial influence through the early Middle Ages was that general concept, which he shared with philosophers and theologians, of the heavenly spheres as a model of order.[3]

For that reason this book, unlike Ptolemy's, is only peripherally concerned with the theoretical side of astronomy; we will touch on it briefly insofar as we need to know a bit of theory if we are to understand how astronomy was put into practice. Central to my discussion will be the practical aspects of astronomy

1. Ptolemy, *Almagest*, 1.1.
2. Apparent tallies of the waxing and waning of the Moon have been found on bones dating as early as the thirtieth millennium B.C.; Alexander Marshak, *The Roots of Civilization* (New York: McGraw-Hill, 1972). But see Francisco d'Erico, "Palaeolithic Lunar Calendars: A Case of Wishful Thinking," *Current Anthropology*, 30(1989):117–118, and Alexander Marshak, "On Wishful Thinking and the Lunar Calendar," *Current Anthropology*, 30(1989):491–500 (with a reply by d'Erico).
3. Taub, *Ptolemy's Universe*, esp. pp. 135–153.

in both the modern and the ancient senses: the uses of the regular motions of the heavens to reckon the passing of times and seasons, and the attempts to incorporate those celestial virtues of stability and order into human lives and societies.

Our concern with these practical uses to which an understanding of the heavens may be put leads to an approach which may disturb some students of mathematical astronomy. Practical astronomy is an art, not unlike the art of the potter, the smith, or the healer. As such, it can exist independently of any formal articulation of a mathematical astronomy or a philosophical cosmology. While modern technology depends upon modern science and cannot exist without it, even now the arts and crafts are only loosely tied to scientific theory. Thus we will more often find ourself discussing astronomical practices concerned with knowing how to determine a specific time, than with astronomical investigations concerned with finding how the heavens move.

Times and calendars

Studies of a broad range of societies have shown that the passage of the year commonly guides many human activities. The literature is filled with discussions of practical calendars that guide the annual cycle of planting and harvesting crops or of breeding and slaughtering livestock. This concern with observing natural phenomena in order to mark the turnings of the year came before the rise of settled agricultural communities and the development of writing. Even migratory bands of hunters and gatherers knew in detail the seasonal appearance of wild plants and animals as local vegetation bears its fruit and foliage and as birds, fish, and other animals migrate from place to place with the seasons. But, as social beings humans have more complex needs, and they must know the special times of gatherings to hunt, to trade, to negotiate, or to celebrate.[4]

This concern to mark special times does not require an astronomical calendar. The migrations of birds and other animals, the flowering of plants and the appearance of their fruit, all mark the arrival of special times. However, the orderly, cyclical recurrence of astronomical phenomena provides reliable, and widely used, indicators of the passing of the seasons; watching the Sun, Moon, and stars often goes hand in hand with watching other seasonal changes.[5] It is scarcely an exaggeration to say that astronomy, botany, and zoology are all natural human activities. These provide a range of observable regularities that can be used, and in fact have been used, to mark such special times.

I speak consciously of marking times, in the plural, rather than of measuring time, for the essence of a calendar lies in the demarcation of special days and

4. Hudson, "California's First Astronomers," esp. pp. 55–65.
5. For example, Hesiod, *Works and Days*, 383–90, 564–73; Malotki, *Hopi Time*, pp. 395–405; Tedlock, *Time and the Highland Maya*, pp. 185–190.

seasons that return in a recurring cycle, rather than in the measurement of an unending flow of undifferentiated moments of time. There is a temptation to dismiss this attention to special, distinct events, marked by "discontinuous time-indications," as a primitive antecedent of a "genuine system . . . of time-reckoning."[6] This misses the point; the determination of the arrival of the proper times for recurring practical, social, or ritual activities is a continuing human problem. What is central is that there is something, some activity, that sets these days apart from all others and makes them special. If we are to understand how medieval people used astronomy to punctuate the regular flow of the year, we must consider the simple astronomical phenomena they used to mark the return of significant days and to delimit the turning of the seasons.

The Sun is the most potent of heavenly beings, the source of warmth and light, the true fountainhead of life. Its risings and settings delimit the nights and days; its comings and goings mark the turning of the seasons. In diverse cultures and epochs religious thinkers and philosophers, hunters and farmers, have recognized its crucial importance. The annual changes of the Sun's motion separate seasons of growth from seasons of dormancy, seasons of planting from seasons of harvest, seasons when animals are abundant from seasons when they are absent. Making order of this central aspect of human experience – the changing of the seasons – drew the attention of observers to the heavens.

The Sun's annual journey is most clearly divided by its arrival at the limits of its travels – the southern limits which mark the onset of winter in the northern hemisphere and the northern limits which mark the onset of summer. Since the Sun is the source of heat and light, its travels not only provide a sign of the changing seasons but are often seen as causing them as well. Thus its journey is commonly at the heart of an observer's attention.[7]

We commonly note how the days become longer as we move towards summer and again become shorter as we turn towards winter. Usually, the longest day is taken as marking mid-summer and the shortest day, mid-winter. The day-to-day change, however, is quite small. At Mediterranean latitudes, the length of daylight changes by only six hours in the six months from June to December, an average change of only two minutes per day. The change becomes imperceptible at the extremes of the Sun's travels in June and December and so is even less suitable to mark the turning of the seasons. Thus, while the length of day indicates the general progress of the seasons, it cannot mark the seasons precisely without an accurate means of measuring time. It is not surprising then, that while many societies recognized the changing length of day and night and the complications

6. Nilsson, *Primitive Time-Reckoning*, pp. 8–10, 355–358.
7. Some peoples whose calendars were regulated by the stars came to consider the summer stars rather than the Sun as bringers of warm weather. Nilsson, *Primitive Time-Reckoning*, pp. 144–145.

that it raised for timekeeping, there are no examples of societies that measured this change as a way to determine the changes of the seasons.

A second common sign of the changing seasons is the changing height of the Sun at midday. We are used to feeling the noontime Sun beat down on our heads in summer, whereas we cast long shadows across the snow in winter. But it is hard to move from this general observation to precise determination of the end of one season and the beginning of the next.

We can most easily estimate the Sun's changing height in the sky by considering changes in its shadow. We do not need a standard unit of measure; all that is required is a marked stick or a careful pace. The precision with which these day-to-day changes in the shadow can be observed increases when larger objects cast the shadows or when more precise measuring rods are used.

As with the duration of daylight, the noontime height of the Sun changes most rapidly in spring and autumn, and more slowly in June and December, which makes such observations poorly suited for directly marking these turning points in the calendar. However, the changing length of shadows during the day was commonly used to mark the daily passage of time.

The third principal change in the Sun's motions during the year is the changing place of sunrise and sunset. This offers a handy way to find the current position of the Sun. Rather than watching the Sun at noon, we could equally well watch it rising or setting on the horizon. We would soon note that the Sun rises twice a year at any given point between the northern and southern extremes of its annual path along the horizon. Only a short step separates noting that the Sun rises or sets at a particular point on the day of a particular seasonal event from the identification of that point as a sign of that event. Besides such contingent seasonal events as planting and harvesting, the extremes, midpoints, and other regular divisions of the Sun's travel can mark special places on the horizon.

Note that just as a calendar is concerned with special days rather than with the measurement of duration in undifferentiated units of time, so is a solar horizon calendar concerned with special places rather than with the measurement of azimuth in quantifiable angular units. As we map special times onto special places, these special places can take on names and qualities appropriate to those events. If a place marks the time to plant beans it could become "bean planting mound"; the place of sunset when the blackbirds return could be called "blackbird's wing"; and the place where the Sun rests at the limits of his travels could be the "Sun's house."[8] When the Sun rises at a sacred time, and in most cultures the turnings of the seasons typify such sacred times, the place where he rises is thereby sanctified. The constant and regular return of the Sun to this landmark reinforces the sacred nature of the place and of the sacred moment in time.[9] Conversely, since

8. McCluskey, "Historical Archaeoastronomy," pp. 32–40, 47–48; Malotki, *Hopi Time*, pp. 427–441.
9. McCluskey, "Calendars and Symbolism."

these sacred places surround the central place from which the Sun is observed, that center, whether temple or village, also takes on something of the sacred and becomes, in a sense, the center of the world.[10]

Thus far, we have considered following the travels of the Sun against a terrestrial framework: a shadow on the ground or a marker on the horizon. But the Sun's seasonal travels through the heavens can also be mapped using the celestial landmarks provided by the stars in the sky.

People who watch the stars at dawn or in the evening twilight soon come to identify specific bright or conspicuously formed groups of stars. They then notice that different stars are visible at each season of the year. It is by something close to direct observation, to an intuitive process of association, that we connect the bright stars in Orion with winter.[11] The stars are not perceptibly warm, like the Sun. There is no obvious reason to associate them with the seasons; they just seem to be related. The seasonal appearance of these constellations, like the changing height of the noonday Sun, provide general signals for the changing of the seasons.

For more precise indications of the calendar we must connect the stars' regular seasonal cycle of appearances and disappearances more directly with the motions of the Sun. As with the Sun, the most conspicuous seasonal changes of a star's visibility, its first and last appearances, happen when the star is near the horizon. Most striking is the first seasonal appearance of a star or constellation, known technically as its heliacal rising, which occurs shortly before dawn and is thus, in some way, connected with the Sun. Similarly, the last seasonal appearance of a star, the achronical setting, occurs shortly after sunset.

With heliacal rising and achronical setting, we have two well-defined astronomical phenomena that closely connect observations of the stars with the Sun and are also sufficiently sharply defined to be suitable for setting the calendar. Unlike the length of daylight, the height of the Sun, or its position on the horizon, which are best observed when they change rapidly in spring or autumn, these phenomena can provide precise markers throughout the year. The rising or setting of an appropriate star can be observed equally well in spring or summer, in autumn or winter.

But despite the seasonal changes of visibility we see that each star, unlike the Sun, rises at the same point on the horizon throughout the year, moving only slightly in the lifetime of a single person. Here is a constancy, a changelessness, that makes the stars as constant and unchanging a reference frame as the mountains

10. In the terms of Mircea Eliade, when the celestial – the Sun – touches the earth at the horizon, such a hierophany reveals a sacred space, a sacred time, and the center of the world. See Eliade, *Sacred and the Profane*, pp. 20–76; *Cosmos and History*, pp. 12–21.

11. The further connection of those stars with the winter hunting season through the role of Orion as hunter suggests the kind of mythologizing by which such associations were preserved through the generations.

on the distant horizon from which they emerge and behind which they set. Furthermore, unlike horizon landmarks, the stars are not confined to a particular locality; their seasonal risings and settings are the same over a wide area.[12]

This relative movement of Sun and stars produces a sharply defined series of days on which stars are first seen. These events provide a sequence of benchmarks to define a solar calendar indirectly by observations of the stars, rather than directly by observation of the Sun.[13] Of course, from another perspective, we could say that the Sun is being observed indirectly against the framework of the stars.

While the Sun and stars provide clear paradigms of regularity, making order of the motions of the Moon and of the five planets requires greater effort. The phases of the Moon recur every twenty-nine or thirty days, but this period has no simple and obvious connection with the annual cycle on which a calendar is based. Nonetheless, since the lunar phases are easily seen, they were widely used to define a secondary unit of time, the lunar month.

Twelve such lunar months total some three hundred fifty-four days, about eleven days less than a solar year. If the series of lunar months are to be synchronized with the solar year a way must be found to decide when to insert a thirteenth month in the calendar. Some societies ignore this problem by using a purely lunar calendar, and others tolerate a communal ambiguity about what month it is (scarcely a decision at all). Some decide when to insert an intercalary month by observing the Sun or stars to determine when a particular solar date fell a month "late" in the lunar calendar, while others define a mathematically regular system of intercalation.[14]

Besides watching the changing shape of the Moon as it goes through its monthly cycle of phases, we can also watch the Moon as we do the Sun, noting the changing places where it rises and sets or its changing place among the stars. We will soon notice that the Moon's motion against the backdrop of the stars is limited to the same narrow band of constellations that rise and set near the Sun. Similarly, the Moon rises and sets over the same general range of landmarks as

12. Strictly speaking, the appearances of the stars are only constant over a band of constant latitude; they do change as we move north or south.

13. Such observations of the stars do not yield a true solar calendar, as stellar risings and settings recur with the period of the sidereal year (365.2564 days). The changes of the seasons recur with a period of one tropical year (365.2422 days). The difference is perceptible, adding up to a day in less than a century, and will cause problems to a well-regulated calendar. For most agricultural or ritual concerns, significant discrepancies will only arise after a number of centuries.

14. Turton and Ruggles, "Agreeing to Disagree"; Zeilik, "Ethnoastronomy II: Moon Watching"; Neugebauer, *HAMA*, pp. 296–297, 353–357, 584–585.

Theoretically a thirteenth month should be intercalated every 2.7154 years. Good approximations to this period are found by intercalating 3 months in 8 years (2.6667), 4 months in 11 years (2.75), and 7 months in 19 years (2.7143).

the Sun. In both cases, the Moon follows the same general path as the Sun, although it does wander north and south of the limits of the Sun's path.

At the simplest level, we can view these changing positions as distinctly analogous to those of the Sun, with the Moon returning to its former place along the horizon or among the stars every 27.3216 days.[15] Note that there is a difference of about 2.2 days between this 27 1/3-day sidereal month and the common lunar month (the synodic month) of 29 1/2 days. This means that if the Moon is full when it reaches its farthest north position along the horizon, or a specific place in the constellation Gemini, the next time it reaches that point it will be 2.2 days short of being full, the sixth time it will be 13 days short of being full, which makes it a new Moon, and the thirteenth time, which occurs about a year later, it will be a full Moon once again.[16]

But since the Moon wanders north and south of the Sun's path through the stars, at a more complex level we can concern ourselves with these variations of the Moon's travels. When does the Moon lie precisely on the Sun's path among the stars? When does the Moon reach its northern or southern limits? Where are these limits on the horizon? Where are they in the heavens? Can they be marked or identified in some way? Is there any regular pattern to these variations?

This kind of curiosity readily leads to several interesting, if not immediately practical, results. Eclipses of the Sun and Moon occur only when the Moon lies on the path that the Sun follows through the stars. If we have concerned ourselves with the paths of the Sun and Moon through the stars, we find that the eclipses occur at two points that move slowly along the Sun's path through the stars over 18.61 years.[17] If we have concerned ourselves with changing places of moonrise and moonset on the distant horizon, we find that the northernmost and southernmost points that the Moon reaches every 27 1/3 days are not fixed, but oscillate back and forth around the annual extreme places of sunrise and sunset with the same period of 18.61 years.[18]

The dramatic character of eclipses, and their association with particular points moving through the heavens, may suggest that those points manifest a malign

15. We can safely ignore the subtle distinction between the sidereal month, measured against the stars (27.32166 days at A.D. 500), and the tropical month, measured from the vernal equinox (27.32158 days at A.D. 500). The accumulated difference of one day in a millenium would have little impact on practical astronomical observations and calculations.
16. The Moon is full at its northernmost position at what is called the mid-winter full Moon, the full Moon of the winter solstice. The new Moon that appears at this same northern extreme six or seven sidereal months later is the mid-summer new Moon.
17. Similar eclipses in the same constellation must be separated by an integral number of years. The nearest integral value, nineteen years, is also a Metonic cycle which reconciles the lunar and solar calendars. The Babylonians, for one, were clearly aware that similar lunar eclipses, or their avoidance, recurred at the same position among the stars every nineteen years. Cuneiform Text, British Museum 41004, rev. 18–19; as cited in Moesgaard, "Full Moon Serpent," p. 51.
18. Thom, *Megalithic Sites in Britain*, pp. 20–23.

power to obscure the two great luminaries. It would take a somewhat greater level of abstraction to connect the ever-changing positions of extreme moonrise with eclipses and to grant a power to those landmarks. In some cultures, however, these vagaries of the inconstant Moon have been dismissed as irrational.

To summarize the range of possible lunar observations, we can observe the phases of the Moon or its position among the stars or on the horizon to establish a kind of auxiliary calendar. Among these options, it seems unnecessarily complex to relate the Moon with stars or horizon, rather than simply observe the Moon itself. In either case, such simple observations could lead to the further calendric problem of relating the solar year to the lunar month. Finally, long-term observations of the changing position of the Moon can point the way towards an understanding of eclipses.

Observations of the complex motions of the Moon and five planets among the stars or on the horizon, while significant to the development of theoretical astronomy and astrology, had little meaning for those astronomies concerned with the reckoning of time or the keeping of the calendar.[19] Their principal contribution to practical astronomy was in the sense of which Ptolemy spoke. Insofar as mathematical astronomers had demonstrated that the apparently erratic motions of the planets were subject to mathematical laws, this achievement extended the belief in the "constancy, order, symmetry and calm" of the celestial regions, an order that could be used to govern human activities.

19. For a detailed treatment of early theoretical astronomy, see Neugebauer, *HAMA*.

CHAPTER TWO

The heritage of astronomical practice

When – Zeus willing – counting from the winter solstice sixty days have passed,
then the star Arcturus leaves the sacred stream of Okeanos and first rises brilliant at eventide,
then the swallow, shrill voiced daughter of Pandion, flies up into the light when the new spring begins;
it is best to prune your vines before her arrival.

Hesiod, *Works and Days* (ca. VIII c. B.C.)[1]

In his *Works and Days*, Hesiod touches here on many of the methods and functions of early timekeeping: counting the passage of days, watching the Sun, stars, and birds for signs, and preserving a judicious concern for the gods and one's crops. Simple practices like these form an important part of the background to early medieval astronomies, yet the nature of their connection remains uncertain. In many cases we can establish direct connections between antique traditions and the Middle Ages; in others we can only point out the prior existence of these ideas and practices and ask whether, and to what extent, they influenced analogous elements of medieval astronomies.

Prehistoric solar horizon calendars

The earliest part of the astronomical heritage of the early Middle Ages is not announced with the eloquence of a Hesiod; it lies concealed in the crude stone monuments erected in the British Isles during the period from 4000 to 1000 B.C.[2] Most familiar of these megalithic structures, that is, structures made of large, roughly hewn, stone blocks, is Stonehenge. Almost everyone has heard, and most experts accept, that the axis of Stonehenge points towards the place where the

1. Hesiod, *Works and Days*, 564–570.
2. The seminal studies of British archaeoastronomy are the writings of Alexander Thom; on his work and its significance see Ruggles, *Records in Stone*. The best introduction to the issues in megalithic astronomy remains Heggie, *Megalithic Science*.