Exploring Ancient Skies

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An Encyclopedic Survey of Archaeoastronomy

Foreword by Anthony F. Aveni

With 392 Figures, 8 in Full Color, and 95 Tables

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Foreword

A third-millennium academic cliché worth repeating is that the questions we pose and the problems we now attempt to solve seem to have the effect of blurring the lines that demarcate the traditional disciplines. This is true not only among the sciences, in which universities now routinely offer interdepartmental courses in biophysics, neuropsychology, and astrogeology, but also across the traditional academic divisions of science, social science, and the humanities. The study of ancient astronomies is a perfect example of the latter case. Once partitioned into the traditional *history of astronomy*, which dealt exclusively with the underpinnings of Western scientific astronomy, and its upstart adopted child *archaeoastronomy*, which treated all other world cultures, it has now been subsumed by *cultural astronomy*, which, in addition, envelops the astronomical practices of living cultures.

The problems treated in *Exploring Ancient Skies* are as follows: What did ancient people see in the sky that mattered to them? How did they interpret what they saw? Precisely what knowledge did they acquire from looking at the sky, and to what ends did they employ this knowledge? In short, what were they up to and why?

You hold in your hand a weighty tome, the product of an enduring collaboration between a pair of seasoned veterans: one an observational astronomer of great expertise, and the other an archaeologist/epigrapher, well known among his Mesoamerican colleagues for his significant contributions to the problem of decipherment of ancient Maya script. What an ideal blend of expertise to produce a true interdisciplinary synthesis that treats the problems posed by these engaging and complex questions! *Exploring Ancient Skies* combines a deep and thorough treatment of relevant empirical naked-eye astronomy with sweeping cultural coverage from peoples of the Arctic to Oceania, from the unwritten astronomy encoded in ancient standing stones to what would become the platform on which Western astronomical tradition yet rests.

Daring in the presentation of some of its hypotheses and somewhat unorthodox in the treatment of certain long-standing problems, *Exploring Ancient Skies* may cause some scholars to bristle, for example, at the readings of certain pages of the Maya codices, the treatment of the calendar correlation problem, the universality of world ages, and the diffusion of astronomical ideas and concepts both north-south and east-west. But a foreword is not a review. Let any reader's reactions not diminish an appreciation of the way Kelley and Milone have delivered fresh knowledge and created a challenging synthetic approach that can only derive from years of experience in a variety of related fields.

Will *Exploring Ancient Skies* help solve our problems? Only time will tell. Seminal progress in the development of all fields of scholarship depends on our capacity to listen and to learn the lesson of history.

Hamilton, New York

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Preface

Exploring Ancient Skies: An Encyclopedic Survey of Archaeoastronomy brings the perspectives of the modern sciences to bear on the practices of pretelescopic astronomy in cultures around the world. In doing so, it traces the path of development of modern society and sheds light on the timeless questions: "Who are we?" and "How did we get here?"

Few previous works have attempted to cover the entire scientific, geographical, and historical spectrum of the subject, and for good reason. The present work has taken a quarter century to prepare as we have struggled to keep up with the voluminous and growing scholarship in this field. As we progress into the third millennium, it is time for such a comprehensive work on the broad spectrum of ancient astronomy to appear, even if, inevitably, incomplete.

This work is intended foremost as a textbook. It arose out of a need to develop a cogent body of scholarly materials and of practical knowledge for undergraduates in our course, Archaeoastronomy, at the University of Calgary, which we have taught, off and on, since 1976. The course has had no specific prerequisites, but has always been recommended for students beyond their first year of study. In most years, the class has been composed about equally of students with some background in archaeology or astronomy and those who have neither. In addition, *Exploring Ancient Skies* is intended to be a reasonably concise source and guide to a large and growing body of literature. A special feature is the somewhat more detailed chapter on Mesoamerica. There are several reasons for this: First, Mesoamerica is the only New World area from which we have written records; second, it is one of the few areas anywhere for which literary evidence is linked to astronomical alignments and to light and shadow phenomena; third, it has possibly the largest range of astronomically related phenomena recorded in literature, architecture, and building and site placements; and finally, it is an area that had been relatively neglected in most books on the treatment of ancient astronomy when we began, with the notable exception of Anthony F. Aveni's work. The abundance of scholarly material on the cultures of the Mediterranean precluded an exhaustive treatment by us, but because it provides antecedents of our present technological world, we have discussed what we feel to be the most representative and significant details. In dealing with areas and cultures that have already received a great deal of attention, we try to provide sufficient links to previous writings to convey the vitality of the scholarship and to encourage further examination.

The present text now represents more than 25 years of effort. Some areas in which we provide interpretation had been relatively unexplored when these sections were first drafted but have now been reached by the rising tide of scholarship. EFM originally wrote the first five chapters with the help of a Killam Resident Fellowship at the University of Calgary in the academic year 1988–1989, but we have revised them continually ever since. The bulk of the bibliography dates to about 1996, when we stopped trying to systematically update it in order to bring this extensive project to a close; yet critical references to work we knew about continued to be added through 2000.

We mentioned that we intend *Exploring Ancient Skies* to be a textbook. It is, however, not a standard textbook in certain ways because much interpretation is still, of necessity in this field, controversial, and judgments about content and value must be made. Nonetheless, the book must contain basic data on astronomical phenomena and must put archaeoastronomical materials in a cultural and archaeological context. The judgments that are made must be justified and hence must contain more scholarly apparatus than is usually presented in an introductory text. Relationship to mythology must be considered, but this makes both astronomers and mythologists uneasy. Many astronomers think that mythology, in and of itself, deals with "nonscientific" matters, and in the present context, it is probably related to the contemptible belief system of astrology. Mythologists may think that a "reductionist" bias is introduced, phrased in esoteric formulas that no proper humanist should have to consider. We have no doubt that our own presuppositions have entered in and influenced both what we write about and how we write about it. This can scarcely be avoided, but where we are conscious of it, we have tried to discuss alternative standpoints or interpretations. Having said this, we now review the details of the book's structure and indicate why we present the material that we have.

Pedagogically, there are two books here. Chapter 1 is a general introduction to the field and applies to both parts. Part I consists of Chapters 2 to 5, which emphasize the astronomy and are illustrated with examples of astronomical practices of other times and places. Part II consists of Chapters 6 to 14, which emphasize the varieties of pretelescopic astronomy as practiced by cultures around the world, with references to the fundamental principles of Part I. Chapter 15 underscores parallels and differences in astronomical thought among world cultures and offers possible explanations.

Abundant cross-references make it possible to skim the early chapters to see what is there, and to use them as technical resources for the cultural chapters. For general-interest readers, and for classes to be taught over only a single term, whose need for the underlying astronomical principles may not be paramount, a concentration on Part II may be a suitable approach. For anyone planning to do field work in archaeoastronomy, but who may have some acquaintance with archaeology, ethnology, or other closely allied fields, initial concentration on Chapters 1 to 5 may prove the more useful strategy. For physical science students, close study of the early chapters is essential; we believe they will provide the necessary physical underpinning for further work in most of the areas discussed in the second part. In Astronomy 301 at the University of Calgary, we have usually gone through all chapters in sequence, spending about one-third (or more) of a semester on the first five chapters and two-thirds (or less) on the culture areas. We have tried alternative procedures, but this procedure has been received best by the students, although it requires a strenuous pace. A year would be about right, but at the University of Calgary, we have never had that option. In this broadly interdisciplinary course, however, a wide mix and choice of questions on examinations can make the lives of students much easier than if they are required to master a fixed set of topics. The important point is that every student should master a significant corpus of material in order to do well. In the interest of fairness, what constitutes a significant corpus is a question that an instructor must weigh carefully.

Now we briefly review the contents of each chapter.

Chapter 1 defines the field and discusses its development, its significance, and its relationship to other disciplines.

Chapter 2 provides an overview of the naked-eye objects in the sky and of the phenomena with which they are connected. The basic motions of objects on the sky, the coordinate systems by which their locations are specified, and the means to transform from one coordinate system to another are treated in detail. Chapter 2 begins with an exposition of very basic positional astronomy; this is not the stuff of bestsellers, but it is the heart of practical astronomy, ancient or modern. Consequently, we provide more examples in the text here than in any other chapter. We go on to discuss each of the basic classes of astronomical objects and their motions.

Chapter 3 deals with the observation of these objects, providing the reader with the vocabulary to discuss the brightness and colors, and the variation in position due to precession and proper motion. The important corrections to altitude and azimuth measurements of objects due to refraction, dip, and parallax are described. We discuss the conditions affecting the light and color of astronomical objects, and how these can change for various intrinsic and extrinsic reasons. The effects of the Earth's atmosphere are among the extrinsic reasons. Aside from the obvious need to reduce and standardize astronomical data, such an exposition is needed to apply corrections in reverse to reveal what might have been seen in ancient contexts. The implicit basic question in this chapter is, "Was it visible?" We provide the principles with which such a question may be approached. Recent scholarship has indicated some promising directions for an even more quantitative approach to visibility, and we try to highlight the work in this area without committing to a rigid approach to observational questions.

Chapter 4 is given over to an exposition of time and its measurement, the historical and present-day units of time and time intervals, and the whole concept of scientific dating of artifacts and structures. Calendrics requires such an exposition. In particular, this material, along with that of §§2 and 3, should provide useful background on the astronomical dating of events and monuments.

Chapter 5 describes transient phenomena of the air and the sky, and explores the underlying physical principles. It deals with the characteristics of transient phenomena such as auroras and other upper and lower atmospheric phenomena, eclipses, comets, meteors and meteorites, novae, supernovae, and other variable stars. Here is where we treat such mysteries as the "missing Pleiad," the color of Sirius, the apparent deficiency of European records of observations of the supernova event of 1054 A.D., and the craters of Wabar. Additionally, the value of eclipses for historical dating and the use of ancient eclipse records to explore the deceleration of the Earth's rotation (and the acceleration of the Moon) are explored. This chapter completes the basic astronomical exposition.

Part II starts by defining the spacial and temporal roots of cultural interest in astronomy. Frequent cross-references throughout attempt to refer the reader back to fundamentals in the first five chapters, and from these chapters, to the cultural contexts in which they apply. Chapter 6 begins with what can be said about the Palaeolithic, goes through the Neolithic, and ends with the medicine wheels and similar constructs of North America.

Chapter 7 treats the antecedents of the modern Western world: Mesopotamia and Greece, and subsequent developments down to pretelescopic Europe. It emphasizes the background of Western astronomy and helps to explain the origins of the scientific method and, therefore, of our current understanding of the universe. We briefly discuss the attacks on the integrity of Claudius Ptolemy in the context of modern investigations of his work. The observations of particular cometary and eclipse observations are discussed (as they are in each cultural group in which records of such phenomena are recorded). We also discuss relevant cosmological aspects of the mystery religions, Judaism, Islam, and Christianity.

In Chapter 8, we begin with ancient Egypt, spring from there to the rest of Africa, and from there to native astronomy around the world. The Dogon "Sirius mystery" is described and discussed here.

Chapter 9 treats India and the cosmological aspects of Buddhism, Jainism, and Hinduism. The extent of the influences of these religions on other areas is discussed, as well as the migration of astronomical ideas between India and the Middle East. We also describe the cosmological aspects of other Near Eastern religions, such as Zoroastrianism.

Chapter 10 deals with China, Korea, and Japan and the development of astronomical ideas in the context of the Chinese sensibility to harmony in Heaven and on Earth. The continuing importance of early astronomical records from this region is emphasized.

Chapter 11 deals with the cultures of the Pacific, beginning with the Dream Time of Australia. The techniques used by the native navigators and their "voyaging stars" are highlighted, and the use of astronomy to understand the terms and legends of the islands is described.

The next three chapters cover the early astronomy of the Western Hemisphere. In Chapter 12, we discuss the extensive details known about Mesoamerica, to which we have already referred, but discuss new aspects of the relationships between the gods and the planets. Astronomy north of Mexico is discussed region by region in Chapter 13, and the burgeoning material of South America is treated in Chapter 14. Alignments of structures again appear as important topics in these discussions, as well as ethnoastronomy among many groups.

Finally, universal aspects are touched on in Chapter 15. Here, we deal with the ultimate purposes in the cultures of astronomy, and discuss the evidence for the independent development of ideas or, in some cases, the derived development through diffusion of ideas. We conclude with a summary of what we regard as the main purposes of ancient astronomy: astrology, navigation, calendar regulation, and that ultimate goal of so much of human activity—to know and to reach harmony with the forces that control the universe.

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Historical Perspectives

1.1. Perpectives of Ancient Astronomy

We deal in this book with the broad and burgeoning subject of pretelescopic astronomy. People around the world have been deeply interested in the sun, moon, and stars for millennia. Of central interest to historians are answers to the questions, "What did they know and when did they know it?" In this section, we discuss why we want to know the answers to these questions, and the means by which scholars have attempted to provide the answers.

What we know of ancient cultures stems from their writings, artifacts, representations, monuments, tombs, and even the organization of their cities. In one way or another, each of these cultural expressions demonstrates interest in an aspect of the heavens. The deciphering of Babylonian cuneiform and of Egyptian hieroglyphic writing and the decoding and interpretation of astronomical texts and tables are long-standing scholarly activities. The newer science of *archaeoastronomy* deals mainly with astronomical discoveries *outside* of the writings.

As a discipline, archaeoastronomy stems from the publication of J.N. Lockyer's *Dawn of Astronomy* in 1894. Working with little regard to the findings of archaeology, Lockyer attempted to date structures by purely astronomical criteria. With this approach, he at once illumined a fresh path for scientific exploration and incited such criticism that few dared to venture on that path again for more than half a century. The renaissance of the subject is more than a little due to the publication in 1968 of *Stonehenge Decoded* by Gerald Hawkins. This helped to draw popular attention to the astronomical practices of earlier cultures, and interest has continued to grow. As a science, where successful, it has had to be open to the contributions of many disciplines, as diverse as ancient poetry and quantitative mathematics.

An aspect of ancient astronomical study deals with trying to find solutions to astronomical and astrophysical problems from early data. Thus, the discovery that the bright star Sirius was once described as red, when it is now clearly white, may light up formerly obscure paths of stellar evolution. Early descriptions of the "seven sisters" may help us to find out something about long-term variability among the Pleiades star cluster, because the normal unaided human eye now detects only six stars. Records of ancient eclipses provide evidence of the length of the month (and the changing distance of the Moon) on the one hand, and of the length of the day (and the slowing of the Earth's rotation) on the other. Records of ancient supernovae provide dates of initial explosions, and thus ages, and when coupled with current measures of the angular sizes and rates of expansion, provide distances, and luminosities of these objects. Because supernovae are among the brightest single stars known, they provide "standard candles" for the determination of distances to remote galaxies, thus, aiding the determination of the size and age of the universe.

A branch of ancient astronomy, called "astroarchaeology" by Hawkins, deals with the application of astronomy to archaeological problems. The term has not achieved wide currency, but the aspect of archaeoastronomy it represents has not been ignored. The astronomical dating of structures (or complexes of structures) that may have incorporated astronomical alignments is an example of such application. The success of any such enterprise, depends, therefore, on the genuine astronomical intent of the builders. This question is still moot in many cases, but in others, the evidence for intent appears to be strong.

Most contemporary practitioners of archaeoastronomy seem to be interested in the subject for itself, in order to understand the astronomical activities of ancient cultures. Investigations of the use to which astronomy is put in the religious and social contexts of particular groups has produced still another area of contemporary study: *ethnoastronomy*.

It is difficult enough to work in a field such as the history of mathematical astronomy, as exemplified by the prolific work of the late great scholar Otto Neugebauer, in which the scholarly materials required to understand completely the ideas and workings of a culture are still undiscovered in the debris of destroyed cities or in caches of forgotten caves. It is even more difficult to recover ancient astronomy practices from the remnants of cultures that were systematically destroyed, as in post-Columbian Mesoamerica, or from cultures for which no written material at all is known, as in Stone Age Britain. Mesoamerican scholars and astronomers have long had mutual interest in studying eclipses and calendars, among other phenomena in which the Mayans and other peoples of the region had remarkably strong interest. Multidisciplinary scholars such as Anthony Aveni have done much to demonstrate astronomical alignments at Mesoamerican and South American sites. The study of megalithic Britain by the survey-engineer Alexander Thom and his son Archibald has helped to reveal the capabilities of the megalith builders. More recent archaeoastronomy has been characterized by close scrutiny of the uncertainties in the observational data and a strong emphasis on the limitations of measurements in the field due to various effects, such as parallax shifts, or the bending and dimming effects of the Earth's atmosphere, or the intrinsic motions of the stars. Much greater attention also is being paid to the archaeological and cultural contexts of the cultures. Measurements of great accuracy, investigations of the precision and accuracy of those measurements, and attention to context are in large part what distinguishes archaeoastronomy from Lockyer's (1894/1973) early efforts. If we know, for example, that a certain group of people was interested in the " dark constellations" of the Milky Way, we should not limit our study of potential astronomical alignments of their geoglyphs or structures to the brightest objects in the sky or even to the brightest stars. As it continues to mature, archaeoastronomy can be regarded as an increasingly important component of ancient astronomy.

Whatever the emphasis, the end result of attention to detail of any of these approaches is a richer appreciation of the cultures that provide the data and of the advance of the arts and sciences that are needed to complete the study. In the present work, we try to consider evidence from all the approaches to ancient astronomy.

Aside from purely scholarly reasons for studying the subject, to seek an understanding of ancient astronomy is to encounter deep well-springs of religion, life-energizing forces of sex and eroticism, and, frequently, cosmic aspects of games and sports. In discovering the astronomy of the ancients, we also discover much about their cultures and their intellectual capabilities, accomplishments, and limitations, and in discovering these things, we discover much about ourselves.

1.2. Archaeological, Anthropological, and Historical Contexts

People behave in ways that reflect cultural patterns, including belief systems. These may include naive or sophisticated ideas of the real or imagined influences of astronomical events on human affairs. The regulation of daily and seasonal activities by the relative positions of earth and sun is an obvious reality, conditioning a great deal of human behavior. Likewise, the movements of the moon affect the tides, which are a major factor in the lives of coastal dwellers throughout the world, and the changing phases that produce dark nights or moonlit nights have affected most of humankind until very recently. In many cultures, people postulate a tremendous range of astrological effects and partially pattern their behavior to conform to or to modify the postulated influences. To the extent that this behavioral response to the astronomical environment involves structural patterns or objects that may be recognized or recovered archaeologically, we are dealing with *archaeoastronomy*. The structural patterns may take the form of alignments and layouts of tombs, monuments, buildings, or cities, in cosmological patterns that may also be incorporated in calendrical tables or in other artifacts.

Where belief in the importance of astronomical influences on human affairs was important, people made more precise observations, and it is now often possible to find and recognize observational instruments and structures. A less direct, but culturally more important, process is the patterning of many facets of life because of presumed associations or causal connections between astronomy and daily life. An example of such a patterning is the development of the astrologically based 7-day week. Human behavior may be governed by a belief that life on earth is a model of celestial happenings, or that individual or collective behavior is determined by celestial happenings. The cosmological pattern of a particular group was normally constructed in terms of human activities and beliefs so that the stars and planets, individually or in groups, may be identified as humans, animals, deities, souls of the dead, artifacts, or natural phenomena. The relative movements of the heavenly bodies were often thought of as interrelationships comparable to human activities, and humans frequently responded appropriately by prayers, offerings, ceremonial drunkenness, ritual abstinence, and so on. The alignment of burials is one practice that can be recognized archaeologically and may throw some light on cosmological beliefs and astronomical interests, although it is seldom of high astronomical precision. Temples are frequently regarded as partial models of the universe constructed to embody cosmological beliefs. Alignments to the rising of the sun at specified days of the year, or to the heliacal rising of some star are apt to be the most obvious astronomical features, but they may be much less important in the local cosmology. Where alignments are found, their purpose was often to cause some particular effect. In Mesoamerica, Motolinia (quoted by Long 1948) said that the sun was supposed to rise at the vernal equinox, at a certain festival, between the two temples of the great pyramid in Tenochtitlan and that Montezuma wanted to pull down the temples because the line was not quite straight. Wriggling serpents at the corners of the temple of Kukulcan at Chichen Itza are observed in a spectacular hierophany of light and shade at the equinoxes.

The widespread interest in astronomy among the peoples of the historic world has its roots in ancient times. There is some evidence for calendar keeping in the Palaeolithic, perhaps as far back as 50,000 years or more, and in the Megalithic, such evidence is strong. In the fifth millennium

B.C., we find evidence for archaeologically recognizable cultures in which astronomy played an important role.

In Alberta, on the western Canadian prairie, we find the earliest of the large rings and cairns of stone known as medicine wheels. Later constructs are found both east and south of Alberta. Interpretation of these "wheels" has been diverse: memorials to dead leaders, markers for trails, religious or ceremonial, or astronomical markers.

Wheels showing at least some structural similarity continued to be built into the last century, and some seem to be aligned on the equinoxes and solstices. One of the most notable of the recent structures is the Big Horn Medicine Wheel in Wyoming. Jack Eddy's (1974) study suggested that the spokes were aligned on particular prominent stars, the first rising of which before sunrise would provide calendar markers. At Moose Mountain in Saskatchewan, a similar wheel seems to show spoke alignments to the same stars, but at an earlier date, in accord with the precession of the equinoxes. If these two wheels, separated by nearly 2000 years represent a common tradition, it is surprising that other wheels resembling these two more closely are not (at present) known.

In Europe, a somewhat similar tradition is assigned to the megalithic cultures. Here, the consistency of some alignments created by placing large stones in lines or circles or making tomb chambers is considerable. Few scholars dispute alignments on the solstices and equinoxes, but competent scholars disagree on the extent to which lunar and stellar alignments are deliberately incorporated into these structures. The distribution of monuments of the megalithic culture seems to be suggestive of sea-farers, but this is far from certain. One of the earliest structures anywhere in the world that shows a solstitial alignment is the *Brugh-na-boinne* (Newgrange) in Ireland. This site is alleged in Irish mythology of a much later time to be the burial place of *Aongus mac nOg* (Aongus, the ever young), usually identified as a sun god. Many later cultures identify the winter solstice as the point of the annual death and rebirth of the Sun. A shaft of sunlight penetrates into the inner chamber of Brugh-na-boinne at winter solstice sunrise, in fitting tribute to such a belief. The best-known megalithic monument is undoubtedly Stonehenge, in southern England. Hawkins (1963, 1965a) has argued that a series of holes associated with the monument was used to predict eclipses, and certainly someone with a modern knowledge of eclipses could have used Stonehenge for such a purpose. Indeed, Schlosser, Schmidt-Kaler, and Milone (1991/1994) have included this exercise among their astronomical laboratory challenges. Of all the megalithic monuments, that which most suggests a working observatory is an array of stones in northern Scotland called *Hill a' Many Stanes*. Here, the stones are small enough to be easily moved and so could have been adjusted to achieve a precision alignment. The Thoms have argued that the site was used to study movements of the Moon. No serious attempts have been made to relate these megalithic monuments to later or modern myths or stories, although there seem to be some folk-beliefs and practices of possible relevance.

A third tradition that began about the same time is that of Mesopotamia. Here, urban civilization and writing appear for the first time. This gives us direct evidence of gods and myths. We know that the Mesopotamian gods of later periods were directly identified with the planets. Recorded myths let us see the interaction of gods in a heavenly framework, which strongly suggests the creation of constellations as a sort of geographic backdrop for the movements of the gods. Although Mesopotamian scholars have been reluctant to regard the earliest myths as astronomically patterned, recent work by Hostetter (1982), Adamson (1988), and Tuman (1984) generically support such a view. Adamson (1988) presents evidence that the goddess Inanna or *Ishtar* was associated with the planet Venus in the earliest texts. Hostetter (1982) presents a convincing argument that the entire structure of the early myth is astronomical. Tuman (1984) argues that deity and symbolic representations corresponding to planets and constellations arise substantially earlier than has usually been believed.

The Mesopotamian system of constellations, planetary gods, and accompanying myths spread to the Greeks probably before 1400 B.C. and later reached the Romans, with substantial modifications in both cultures. Eventually, a further modified system dominated the Mediterranean and then spread north and west throughout Europe (see Figure 1.1). A late Babylonian form, somewhat modified by Egyptian ideas and mythology, spread into India in the early centuries A.D., where it came into contact with a local Indian tradition. A mixed set of astronomical practices intimately tied to cosmology still bears this Egypto-Babylonian imprint, as does much of the Greco-Babylonian technical astronomy, in much of southeast Asia. The astronomical content of the Hindu, Jain, and Buddhist religions of India resulted in the carrying of that astronomy into China, Korea, and Japan with Buddhism.

A tradition that started only slightly later than the Mesopotamian but that was markedly distinct was that of Egypt. Here, constellations were envisaged that depicted animals that lived on the fertile lands adjacent to the Nile and in the desert beyond. Mesopotamian boats, architecture, textiles, ceramics, other trade goods, and ideas stimulated changes and further developments in the Nile valley. A local writing system appeared. Curiously, the later Greeks claimed to derive great knowledge of technical astronomy from the Egyptians, a conclusion that currently available evidence certainly does not support. There is, however, much evidence for the use of astronomy at less technical levels. The great stone pyramids, which were funeral monuments, were aligned to the cardinal points, even if this alignment did not require tremendously sophisticated astronomy. The great temples dedicated to the Sun god have both texts and alignments to show astronomical associations. Egyptian culture was carried south to Meroe, in current day Sudan, where a temple was built with an entrance aligned on the winter solstice sunrise. In calendrical studies, the Egyptians put a great deal of emphasis on the heliacal rising of the star Sirius (which they called *Sopdet*) that was for a long period of time associated with the annual flooding of the Nile, upon which Egyptian agriculture depended.

The Egyptians recognized a series of stars (*decans* is the Greek term) whose first rising before dawn marked periods

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(a)

Figure 1.1. *The Northern and Southern Celestial Hemispheres* ((a) and (b), respectively) as rendered by the great Renaissance and Reformation artist Albrecht Dürer. Many representations of the sky by post-Renaissance Europe derive from Dürer's rendition of 1515, in which the star positions from Ptolemy's catalogue were set down by the Nürnberg mathematician Heinvogel. The positions were subsequently improved and more stars added, but the woodcut figures of Dürer essentially remained the same through the charts of Bayer (1603), Flamsteed (1729), and Argelander (1843). Note the lack of stars near the SCP. Black-and-white prints from the Rosenwald Collection, Photograph © 2001 Board of Trustees, National Gallery of Art, Washington [1954.12.233.(B-21421)/PR (Meder 260) and 1954.12.234.(B-21422)/PR]. Reproduced here with permission.

(b)

FIGURE 1.1. *Continued.*

of approximately ten days, so that there were 36 stars or asterisms in the series. As will be explained later, this leads directly to a concept of a 24-hour day, which had been developed in Egypt by about the XII dynasty (about 2000 B.C.). The series of decans was taken by Hellenistic astrologers and used in India, so that they became a regular feature of later astrology as practiced from Britain to the Malay peninsula, well into the Middle Ages. The 24-hour day also spread widely, and the Egyptian year of 365 days, without leap year adjustments, was called the "astronomers' year" by medieval Europeans, because of the relative ease with which periodicity calculations could be made with it.

Another major component in Eurasian astronomy and calendrics was the system of 28 asterisms known as the *lunar mansions*, because the Moon is among a different group of stars each night. Internal evidence suggests that the system may have originated about 2500 B.C. It is directly attested in India at about the 8th century B.C., and at about the same date in China, from which it traveled to Korea and Japan. It was supposed by the scholars of the *pan-Babylonismus* school to have originated in Mesopotamia, but there is no trace of such a system in Sumer, Babylon, or Assyria. The 28 asterisms were, however, known to the Arabs before the writing of the Koran, and a Greco-Coptic series is known from a manuscript of the 5th century A.D. It was spread through Jewish scholars into medieval Europe. The Arab version was spread wherever Islam penetrated, including mid-Africa. Finally, it will be argued that it is likely that elements of this system were incorporated in the ancient Mesoamerican calendar.

Now we begin with an exposition of the basic astronomy required to understand the perceptions and knowledge of the ancients. In Chapter 6, we again take up the cultural contexts of astronomy.

Part I
Astronomical Background