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The background of the *Zhou bi*

I shall argue that the *Zhou bi* can best be understood as a product of the Han 漢 age. The Han dynasty lasted from 206 BC to AD 220, with a relatively brief interruption from AD 9 to 23, when a powerful courtier, Wang Mang 王莽, usurped the throne. He was the only ruler of his short-lived Xin 新 'New' dynasty. It is usual to call the first half of the dynasty 'Western Han' and the second half 'Eastern Han', since the capital shifted from Chang'an 長安 in the west to Loyang 洛陽 in the east after the Xin interregnum. The Han dynasty therefore spanned an interval as long as that which separates late twentieth century England from the time of Queen Elizabeth the First.

Given such a long period of time, it is clear that we must be cautious in generalising about Han culture. Of course the analogy with English history is a little misleading. The Chinese world of the second century BC was not separated from the world of the second century AD by anything comparable with the scientific and industrial revolutions, the rise and dissolution of the British Empire, and the world-wide military and social cataclysms of the twentieth century. Nevertheless the Han writers whose words have come down to us are clearly conscious of living in a world where social, political and intellectual change are continual, sometimes for the better and sometimes for the worse.

The most striking evidence of change for a Han historian was the contrast between his own age and that which had preceded it. The world in which he lived was a political unity bound together by ideological and administrative structures unprecedented in China. There had been previous kingdoms claiming rule over the whole country, such as the Shang 商 in the five centuries up to about 1025 BC, or the earlier centuries of the rule of the Zhou 周 who overthrew them. But after their capital fell to outside enemies in 771 BC the Zhou kings were no more than nominal rulers. The real power was in the hands of their vassals, the lords of the great feudal states, some comparable in size with modern European countries. By the time of Confucius around 500 BC warfare between the states was frequent, and it rose in a crescendo of scale and intensity until the western state of Qin 秦 destroyed all its rivals and set up a unified empire in 221 BC.

Rejecting the old Zhou system of feudal appanages, the first ruler of Qin extended the civil administrative system of his own state to the whole country, so that for the

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first time China was ruled by a non-hereditary bureaucracy. He was guided in this by a varied group of statesmen, who generally advocated a ruthless *realpolitik* in which the preservation of the ruler's power and the promotion of his interests came before all else. Chinese historians of later centuries, perhaps over-concerned to systematise the past, tended to see these men as representatives of a self-conscious ideological movement, which they labelled retrospectively as the *Fa jia* 法家 'School of Laws' or 'Legalists'. The first ruler of Qin saw his conquest in cosmic terms. The world was governed by the cyclical dominance of the Five Powers *wu de* 五德 of Earth, Wood, Metal, Fire, Water (later commonly referred to as the *wu xing* 五行 'five phases') and he believed that it was through the rise of Water that he had come to power. Lucid discussions of five phase theory will be found in Graham (1989) and Sivin (1987), and the details need not detain us here since the theory does not appear in the *Zhou bi*..

But the harsh rule of Qin was short-lived. The death of the first Qin emperor in 210 BC was followed by widespread rebellion, from which by 202 BC one of the many contenders emerged with sufficient clear advantage to proclaim himself emperor of a new dynasty, the Han. This was Liu Bang 劉邦, originally a petty official of peasant origins who is better known to history by his posthumous title Gao Zu 高祖 'The High Ancestor'.

The Han dynasty mostly continued the political and administrative structures of the Qin. In the field of ideas, however, the situation was different. The age of the so-called 'Warring States' from the fifth century BC to the rise of Qin had been the most varied and fruitful period of Chinese thought, and, unlike the Qin, the Han had the time and security to create a synthesis to serve its needs. The intellectual products of an age of semi-anarchy were transmuted into an ideology to underpin the new imperial state. By the first century BC the main lines of a new world-view had been laid down on the ostensible basis of the ancient texts preserved by the scholars known as *Ru* 儒. This is the group usually referred to by Westerners as 'Confucians', although it is doubtful how far Confucius would have recognised his own voice in the doctrines taught by the professors appointed to supervise the intellectual formation of imperial bureaucrats.

He would certainly not have recognised the elaborate cosmology which was created to underpin the moral and political orthodoxy of the centralised empire. This was the age when the ideas of Yin 陰 and Yang 陽 and the Five Phases, and of the Book of Change, *Yi Jing* 易經, were woven into complex schemes in which every phenomenon found a place in an ordered cosmos, at the centre of which the Chinese emperor had the duty of holding the proper balance between Heaven, Earth and Man. Since the appearance of the sky was one of the clearest and most striking expressions of cosmic order (or the lack of it), it is not surprising that an important department of the imperial bureaucracy was concerned with astronomy. It is within the context of the

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marked changes in astronomical theory and practice under the Han that we must try to understand the nature and origins of the *Zhou bi.*

What follows is an attempt to give the reader without specialist knowledge an outline understanding of the place of astronomy in the culture of the early imperial period. It is not intended as a complete introduction to early Chinese astronomy, and for the sake of brevity some points are therefore made in summary form.

More detailed information on the development of Chinese astronomy from early times up to the seventeenth century will be found in Needham (1959). Despite the criticisms of Cullen (1980) this remains the best general account of the topic in a European language, and its references to earlier studies are comprehensive. For the present purpose Needham's low estimate of the importance of calendrical astronomy in China is however a significant defect. Sivin (1969) is therefore an essential supplement for anyone who wants to get a detailed picture of how the users of the early astronomical systems actually did their calculations. Yabuuchi (1969) collects (although it does not synthesise) the researches of the twentieth century's greatest East Asian scholar in the field of Chinese astronomy. There are a number of general histories of Chinese astronomy in Chinese. Anon. (1987) is a convenient one-volume treatment whose authors are more scrupulous than is usual in giving references to original sources and the research literature.

The foundation charter

The Book of Genesis stands at the beginning of the sacred canon of the Judaeo-Christian tradition. In its first chapter we are told of God's creation of the natural order, and in particular of the creation of man. By contrast, in the earliest canonical account of the past in the Confucian tradition we are told with equal solemnity of the creation of the socio-political order by a human ruler. According to the first chapter of the *Shu jing* 書經 'Book of Documents', perhaps compiled around 400 BC, an important part of this process was the commission given to two hereditary lineages of star-clerks by the legendary Emperor Yao 堯 in remote antiquity:

> Thereupon he ordered Xi 羲 and He 和 to accord reverently with august Heaven, and its successive phenomena, with the sun, the moon and the stellar markers, and thus respectfully to bestow the seasons on the people.[7]

Xi and He each have two sons, who are dispatched to the four quarters of the earth with separate commissions to note the times of the summer and winter solstices, and of the spring and autumn equinoxes. Finally the Emperor turns back to the fathers:

[7] For text and a slightly different translation see Karlgren (1950), pp. 2 and 3.

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> O you Xi and He! The period is of three hundreds of days, and six tens of days, and six days. Use intercalary months to fix the four seasons correctly, and to complete the year.[8]

This document has sometimes been called the foundation charter of Chinese astronomy. Whatever its historical value, it certainly does give an early indication of the importance attached to calendrical astronomy by the pre-modern Chinese state. Until the end of imperial China all governments maintained a staff of astronomical specialists. While such officials were not at the top of the bureaucratic tree, no government felt it could manage without them. We must now say something about the functions that belonged to their office.

The role of astronomy

Calendrical astronomy

The essential task given to Xi and He is 'respectfully to bestow the seasons on the people'. They are to prepare a calendar, which will be promulgated with imperial authority. This task was a principal concern of the official astronomical establishment for all the centuries during which it is known to have existed. The basic need seems obvious enough. Clearly no government of any complexity can operate without some means of unambiguously designating in advance the days on which it expects to perform certain functions, or requires certain obligations to be fulfilled. But to the reader familiar only with the Gregorian system now used in most countries, the preparation of a calendar may seem a puzzlingly trivial task to absorb the energies of an important group of bureaucrats. In fact the problems encountered could be highly complex, and might demand ingenuity of a high order for their solution.

A modern Gregorian style calendar gives the days of the twelve months in numbered sequence, and indicates on which days of the seven day week they fall. Once the rules for the placing of leap years are understood, a calendar for any given year can easily be drawn up. The information required is simple: one must know the names of the months in order, and the numbers of days in each (allowing for the extra day for February in a leap year), and the names and order of the days of the week. Knowledge of the day of the week for any given day of a given month in a given year enables the two sequences to be matched up for all other dates.

As we shall see, the luni-solar nature of the ancient Chinese calendar makes the equivalent task much more difficult. The Chinese astronomers had to work with real months that followed lunations quite closely, as well as keeping a civil year of a whole number of months in step with the seasons. But in addition, from near the beginning

[8] Same reference.

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of the imperial age astronomers had other tasks imposed on them. It was expected that the motions of the visible planets should be tabulated in detail, and that lunar eclipses should be predicted. More difficult still, some advance warning of the possibility of solar eclipses was expected. To do all this, it was essential to have a complete system of mathematical astronomy in operation. Some of the details of such a system are discussed in the *Zhou bi*. But why was all this effort considered worthwhile?

The timekeeping function

It is likely that some Chinese astronomical specialists were mainly motivated by intellectual curiosity, or perhaps by a wish to rise in their careers as successful professionals. Such reasons do not explain why such specialists were felt to be an essential part of the state apparatus. One explanation frequently offered by both Chinese and Western authors runs along the following lines. China was an agrarian civilisation. Successful agriculture demands that such operations as sowing and harvesting are carried out at the proper time. Therefore it was essential for the Chinese government to provide the peasantry with an accurate calendar, and indeed to make constant efforts to improve its accuracy.

This explanation seems to me both misleading and inadequate. In the first place it is not much of a compliment to the Chinese peasant to suggest that without the help of the government he would not have known when conditions were appropriate for the work he had to do. Further, given the natural vagaries of the weather and variations in local conditions, it is likely that a peasant who sowed and reaped by the calendar would do rather worse than one who trusted to observation and experience. Then we have to face the fact that only a small part of the work of official astronomers related directly to the passage of the seasons at all: once the dates of solstices have been determined there is in principle nothing left to say on the topic. And even then, for agricultural purposes a few days' error about (say) the date of midsummer is neither here nor there. The elaborate attention paid to the movements of the moon and the planets is, according to the view criticised here, quite inexplicable.

The ritual function

Why then should Chinese astronomers have wanted precise answers to such questions as when a lunation began? It will help if we recall the Chinese emperor's role as the pivotal element linking the human microcosm and the natural macrocosm. He is responsible for the orderly functioning of both spheres. Visible disorder in nature is a sign of a malfunction in the human order, and may thus evoke direct criticism of the emperor's rule. In the natural order celestial portents drew the most attention, and it is therefore quite understandable that Chinese astronomers tried to reduce to rule as many astronomical phenomena as possible, with the ultimate aim of predicting everything

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predictable. If, for instance, the occurrence of a lunar eclipse could be predicted its significance as a portent was much reduced. More positively, the image of the emperor as successful preserver of the cosmic order was inevitably enhanced if his government was seen to comprehend the subtlest motions of the heavens.

Such motivations go some way towards explaining the astronomical preoccupations of the Chinese state. But once the astronomers had produced their detailed tabulations, did they answer any purpose beyond serving as imperial status symbols? Why should anyone care that the moment of winter solstice fell precisely when it did and not an hour or so later? In fact such data were seen as of the highest practical importance, both for the state and for the individual.

For the state, it was necessary that certain imperial rituals should be carried out at the proper times. Such rituals, often involving the emperor himself as celebrant were an essential contribution to the maintenance of cosmic order. If they were mistimed, they could fail to produce benefit or even do harm. If winter solstice fell a few minutes before midnight, but the astronomers predicted it an hour later, the emperor would be led to carry out his sacrificial ritual a whole day late. For the individual the consequences were similar. Almost all the activities of daily life, from taking a wife to closing a business deal, were conducted according to an elaborate divinatory scheme of lucky and unlucky days. Such schemes were an essential part of the calendar in the form most widely distributed. Commercially published almanacs giving this information are still bought in huge numbers by modern Chinese people. If the calendar is in error, bad fortune or even serious danger might be the result.

The role of portents

It appears, then, that a great deal of what we would nowadays characterise as scientific activity was supported by the Chinese state for motives that had little to do with modern science. For completeness I will mention a related aspect of ancient Chinese astronomical activity. This was the observation of transient phenomena such as comets, novae and meteor showers. None could be predicted, and all were therefore potentially ominous. As a result it fell to the official astronomers to take careful note of all such phenomena, and of the precise times and locations at which they occurred, with the aim of ensuring that their significance was correctly deduced and reported to the throne. Many such records have been preserved to the present day, and remain of the greatest value to modern astronomers. The *Zhou bi* does not however concern itself with this aspect of official astronomical activity. In this it follows a division between portent astrology *tian wen* 天文'celestial patterns' and mathematical astronomy *li fa* 曆法 'calendrical methods' which is basic to ancient literature dealing with the heavens.

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The problem of the calendar

Modern astronomical theory

Quite apart from the fact that the Chinese calendrical astronomer was expected to produce detailed predictions of a wide range of phenomena, it has already been mentioned that the basic nature of the Chinese calendar set him a more difficult task than running the Gregorian calendar demands. This was because the Chinese calendar was of the luni-solar type, which uses the moon as well as the sun as an important time-marker. In Europe the moon plays no role in the civil calendar at all, although it is still important in fixing the date of Easter in the calendar of the Christian church. The following sections introduce the problems of running a luni-solar calendar, so far as they are relevant to the concerns of the *Zhou bi*. I begin with a very short reminder of some basic astronomical facts, which may be skipped by those who do not need reminding. Fuller and very clear introductions to basic naked-eye astronomy, more or less from scratch, will be found in Kuhn (1957) and Dicks (1970).

On the modern view, the earth is an almost exact spheroid of radius 6400 km which rotates once daily on its axis. Once a year it completes a revolution round the sun. Its axis of daily rotation is tilted 23.5 degrees from the perpendicular to the plane of its orbit round the sun. During the course of a year the earth's tilted axis points in an almost unchanged direction in space, stabilised by the gyroscopic action of the spinning earth. Due to the effect of the sun's gravitational pull on the earth's slight equatorial bulge, over a longer period it becomes clear that this axis is in fact precessing conically like the axis of a child's top, so that it takes about 23 000 years to return to its original orientation.

As the earth moves in its orbit round the sun, the moon orbits round the earth. The combined gravitational influence of the earth and the sun make its motion relatively complex. Not only does its orbital speed vary, but the tilt of its orbital plane relative to that of the earth round the sun can vary by up to about six degrees either way. Hence all lunar phenomena seem much less regular than those involving the apparent motion of the sun alone.

Even the nearest stars are vast distances away compared to the radius of the earth's orbit. Over a period of many years their relative positions as seen by an observer on the earth therefore change very little. As a result they may be taken as an almost fixed reference system against which phenomena within the solar system can be measured. By the beginning of the Christian era astronomers in both East and West had come to think of the stars as fixed on the inner surface of a vast rotating celestial sphere with the human observer at (or very near) its centre. The points where the sphere's imaginary axis passes through it are the north and south celestial poles. In reality the apparent celestial axis is simply the projection outwards into space of the

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earth's axis. Likewise the celestial equator, a great circle midway between the poles, is the outwards projection of the earth's equator. Greek astronomers, who believed in a spherical earth, were aware of these correspondences, but since Chinese astronomers lived in a flat-earth universe the poles and the equator remained solely celestial concepts. A second great circle, the ecliptic, is inclined to the celestial equator at about 23 degrees. This circle is the apparent annual path of the sun around the celestial sphere against the background of the stars. In reality it is simply the outward projection of the plane of the earth's orbit around the sun.

Further technical details of the phenomena just outlined can be found in standard texts such as Smart (1979). For our present purpose we are only concerned with the apparent motions of the celestial bodies as seen by an observer on the earth. In common with the majority of pre-Copernican inhabitants of the earth, the ancient Chinese believed that they lived on a stationary body, and they therefore took the apparent motions of the sun, moon, stars and planets as real motions. Since the coming of artificial lighting even educated people are rarely as familiar with the changing appearance of the night sky as their ancestors would have been. Some necessary reminders are therefore given in the course of the following discussion so far as space will allow. The best detailed introduction to this topic is given in the opening chapters of Kuhn (1979).

Days and day cycles

The observer assumed in the *Zhou bi* is in a latitude close to that of the Yellow River basin, around 35 degrees north. For such an observer the earth's daily rotation causes the sun to appear to rise over his eastern horizon, climb to its highest position due south of him at the moment of noon, and then sink back over his western horizon. Because of the tilt of the earth's axis relative to its orbital plane (which is the plane of the ecliptic), the time the sun spends above the horizon and the maximum altitude it attains both vary markedly in the course of a year as the earth orbits the sun.

No human society living on the surface of our planet can avoid using this repeating cycle of light and darkness as its basic unit of time reckoning. The *Zhou bi* is no exception when it states that 'daylight and night make one day' (#K8).[9] There have however been differences of practice as to when the division between days was placed. While the current civil practice in the majority of countries begins a new day at midnight, the religious calendars of Judaism and Islam make the division at dusk. Whatever the earliest practice in China may have been, by the end of the first millennium BC the convention of starting a new day at midnight was firmly established.

The *Zhou bi* does not raise the question of whether or not the day is of constant

[9] As noted above, the reference here is to section K of the *Zhou bi*, paragraph 8, according to my own division of the text.

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length. The modern civil day is constant by definition, since it is taken to be precisely 24 hours, and each of these hours contains 3600 seconds defined by a standard atomic clock. A day defined by the cycle of the sun's apparent movement is by no means as simple. The combination of the earth's rotation on its axis with its orbital motion round the sun means that the time interval between successive noons as measured by a clock can vary by up to twenty minutes during the course of the year. For this reason time told by a sundial will not always be close to civil time as marked by a clock or watch. This fact will however prove to be of only minor importance in deciding how close the *Zhou bi*'s description of the phenomena comes to reality.

In the West, the artificial seven-day cycle of the week has long played an important role in structuring civil and religious time. In ancient China a ten-day period, the *xun* 旬, played an analogous role from at least as far back as the Shang dynasty. Each day was named using one of ten characters known as the *tian gan* 天干 'heavenly stems'. There is no consensus amongst scholars as to the original significance of these characters. By systematic pairing of the ten stems with another set of twelve cyclical characters (the *di zhi* 地支 'earthly branches') a longer cycle of sixty day-names was generated: see table 1. This sexagenary cycle was used for civil dating independent of months and years, and seems to have run unbroken up to the present from at least as far back as the beginning of the first millennium BC. During the Han dynasty it became customary to use the *gan zhi* 干支 cycle of sixty character pairs to designate a cycle of sixty years in addition to its continuing use for naming days.

Table 1. Stems and branches

	Stems	Branches
1	甲 *jia*	子 *zi*
2	乙 *yi*	丑 *chou*
3	丙 *bing*	寅 *yin*
4	丁 *ding*	卯 *mao*
5	戊 *wu*	辰 *chen*
6	己 *ji*	巳 *si*
7	庚 *geng*	午 *wu*
8	辛 *xin*	未 *wei*
9	壬 *ren*	申 *shen*
10	癸 *gui*	酉 *you*
11		戌 *xu*
12		亥 *hai*

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The first decade of the sexagenary cycle begins with the stem–branch pair *jiazi* 甲子 as #1, and ends with *guiyou* 癸酉 as #10. The next decade begins with #11, *jiaxu* 甲戌 and continues with an offset of two in the stems relative to the branches. This process is continued, the offset increasing by two each decade, until we reach *guihai* 癸亥 #60, and the cycle then repeats. All one needs to do to convert stem–branch pairs to sexagenary numbers is therefore to find the offset (remembering to count forwards through the cycle of branches until one comes level with the stem) and divide by two to find the tens, and then take the units from the number of the stem. For an example, the reader may like to verify that *bingchen* 丙辰 corresponds to #53.

The lunar cycle

There is no hard evidence to decide the question, but it seems probable that long before the sixty-day cycle came into use the lunar cycle already served as a medium term time unit. In the earliest records we have (Shang oracle bones of the late second millennium BC) both units are already used in parallel, as they were to be ever after. Before entering into calendrical matters, it may be helpful to give a brief reminder of the appearance of the lunar cycle for an observer on the earth.

Following a lunation

Figure 1 indicates the physical basis of the varying appearance of the moon during the course of a complete lunar cycle, or lunation. When the moon is at A, its illuminated side is turned away from the earth, so that the observer cannot see it. This is the moment of conjunction, or 'new moon'. The Chinese term is *shuo* 朔 'dark'. Since the moon's orbit is in general not in the same plane as the earth's orbit round the sun, the moon is rarely exactly aligned between the sun and an observer on the earth; when this does happen the result is an eclipse of the sun in that observer's locality. If the moon was visible at conjunction, it would be very close to the sun in the sky, and would rise and set at almost the same moment as the sun. On the day when the moon is at B an observer on the earth sees a half-illuminated moon. This phenomenon, is called *xian* 弦 as are crescents in general. The sightlines to the sun and the moon are at right angles. As a result the moon appears to lag about a quarter of a day behind the sun in the sky. It rises near noon, reaches its highest point ('culminates') close to sunset, and sets about six hours after the sun. At C the moon is opposite the sun, and its visible side is fully illuminated. The moon now rises at about the time of sunset, and culminates close to midnight. This is the time of full moon, *wang* 望. The rare case of an exact sun–earth–moon alignment at full moon leads to an eclipse of the moon, as that body moves through the shadow-cone cast by the earth. Unlike an eclipse of the sun, an eclipse of the moon is seen by everyone who can see the moon at that time. At D the moon once more appears half illuminated, and is once more

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