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ASTRONOMICAL RECORDS IN THE *CH'UN-CH'IU* CHRONICLE

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Introduction

The ancient Chinese chronicle known as the *Ch'un-ch'iu* (or *Spring and autumn annals*), which covers the period from 722 to 481 B.C., cites many observations of astronomical phenomena. These are the earliest accurately datable celestial events in Chinese history. Principal among these are the reports of solar eclipses — the oldest extant series of such records from any part of the world. There are also several interesting references to comets and meteors.

Only incomplete surveys have so far been made of these intriguing data. In this paper we investigate the various astronomical records contained in the *Ch'un-ch'iu* in detail, paying particular regard to their reliability, dating accuracy and significance in the history of astronomy. Where appropriate, we have also attempted to provide an insight into contemporary official attitudes to celestial phenomena.

The Text

The *Ch'un-ch'iu* is by far the most detailed chronicle of ancient China that still survives.[1] It is a record of the feudal state of Lu, and its interaction with the other semi-independent states into which China was divided, over more than two centuries of the Eastern Chou Dynasty (770–256 B.C.). The chronicle itself covers the period from 722 to 481 B.C., while a brief supplement extends this interval down to 468 B.C.

In the *Ch'un-ch'iu* and its continuation, as many as 37 solar eclipses are recorded, while there are also four references to comets and two to meteors. However, no allusions to eclipses of the Moon or other lunar phenomena are found, while the planets are never mentioned. Throughout the text, accounts of celestial phenomena are cited alongside reports of mundane events (accessions and deaths of rulers, interstate wars, etc.), purely in chronological order; there is no special section devoted to astronomical records.

As the sole survivor of the ancient state chronicles of China,[2] the *Ch'un-ch'iu* almost certainly owes its preservation to its association with Confucius (K'ung Fu-tzŭ). Born in Lu in 551 B.C., Confucius spent much of his life there; he died in Lu in 479 B.C., not long after the end of the period covered by the chronicle. Although the compiler of the *Spring and autumn annals* is not named in the text, Mencius (Meng-tzŭ), the great Confucian philosopher (*c.* 371–289 B.C.), is

emphatic regarding Confucian authorship.[3] Down the centuries, the *Ch'un-ch'iu* has become so well known that it has given its name to the period of Chinese history it covers.

Although the *Spring and autumn annals* contains roughly 2,000 separate entries, the style of the chronicle is extremely terse. Few entries describing a single event exceed a dozen characters, while the total length of the whole text is only about 17,000 characters. Nevertheless, the chronicle has been venerated since ancient times. As one of the accepted Confucian Classics, the text has been studied and commented on by generations of scholars. Since the fourth century A.D., editions of the *Ch'un-ch'iu* have also included the text of its earliest known commentary, the *Tso-chuan*, on a year-by-year basis.[4] This work also contains a brief but important appendix which extends the period covered by the *Ch'un-ch'iu* by 13 years. The last entry in the chronicle itself occurs in the spring of the 14th year of 'Duke' Ai of Lu (481 B.C.). However, the supplement in the *Tso-chuan* continues down to the end of Ai's reign (his 27th year, i.e. 468 B.C.).

The *Tso-chuan* is more of an enlargement than a commentary. Although less consistent than the *Ch'un-ch'iu*, it is remarkable for the amount of extended narrative material it contains. From ancient times, the *Tso-chuan* was attributed to a contemporary of Confucius named Tso Ch'iu-ming, a chronicler of the state of Lu. However, there is now general agreement that the text was largely composed around 300 B.C., with later additions.[5] After about 550 B.C. the *Tso-chuan* cites many astronomical records that are not found in the *Ch'un-ch'iu*, but it makes no reference to several of the observations which the earlier work contains. In this paper we have restricted our attention to those celestial phenomena that are specifically recorded in the *Ch'un-ch'iu* and its brief continuation. Observations noted only in the commentary are not considered here.

No ancient copies of the *Ch'un-ch'iu* now survive, but it seems likely that the content of the chronicle has remained essentially unchanged since it was originally compiled. In particular, all of the eclipse records can be found copied verbatim in the *Han-shu* (*History of the Former Han Dynasty*, 206 B.C.–A.D. 9), composed between A.D. 58 and 76.[6] During the Later Han Dynasty (A.D. 25–220), existing texts of the *Spring and autumn annals* and other Confucian Classics were standardized and engravings of the entire works were cut on a series of about 45 stone tablets, each measuring approximately 1.8m by 0.9m. These stelae, each of which contained approximately 4500 characters, were placed outside the National Academy at the Later Han capital of Lo-yang.[7] This project commenced in A.D. 175 and took eight years to finish. No stele is now intact, but several hundred fragments are kept in public and private collections. The oldest complete copy of the *Spring and autumn annals* that still exists today dates from the T'ang Dynasty (A.D. 618–907). Between A.D. 837 and 841, the entire set of the Confucian classics was again engraved on large stone tablets, this time at the T'ang capital of Ch'ang-an (now Xi'an).[8] These stelae are now preserved in the Beilin Museum (or Museum of the Forest of Stelae) in Xi'an.[9]

TABLE 1. Dukes of Lu between 722 and 481 B.C.

Name of Duke	First Year of Reign	Length of Reign (years)
Yin	722 BC	11
Huan	711 BC	18
Chuang	693 BC	32
Men	661 BC	2
Hsi	659 BC	33
Wen	626 BC	18
Hsuan	608 BC	18
Cheng	590 BC	18
Hsiang	572 BC	31
Chao	541 BC	32
Ting	509 BC	15
Ai	494 BC	27

Calendrical Remarks

For each year of the period covered by the *Ch'un-ch'iu*, the text gives a brief summary of the major events occurring during that time. Years are numbered from the beginning of the reign of the current ruler or 'Duke' (*kung*) of Lu. For reference, we have given in Table 1 a complete list of the names of the Dukes of Lu during the Ch'un-ch'iu period, along with their dates of accession and length of each reign. It should be emphasised that the chronology of this period is so well established that in many cases the precise dates on the Julian Calendar of the accession and death of each ruler and other notable events can be determined.[10] By comparison, Chinese chronology prior to the Ch'un-ch'iu era is very vague, while even that in the subsequent Chan-kuo or Warring States Period (481 to 256 B.C.) is often problematical.

Within any particular year, entries in the *Spring and autumn annals* are grouped in conventionalized seasons (spring, summer, autumn and winter), each of duration three lunar months. It is the style of the chronicle never to omit a season, even if no event is recorded during that period.[11] For instance, in the 12th year of Duke Hsi (648 B.C.), we find the following entries: "It was autumn, the 7th month. In winter, the 12th month on day *ting-ch'ou*, Ch'u-chiu, Marquis of (the state of) Chen, died."

The calendar of the time was so regulated that the year began around — or possibly rather earlier than — the time of the winter solstice. Hence the four divisions of the year do not correspond well with the true seasons. Most years contained twelve lunar months so that the total length would be about 11 days short of the tropical year. In order to keep the beginning of the year close to the winter solstice, from time to time an intercalary 13th month was inserted. However, it is not definitely established whether at this early period intercalation followed a fixed rule — as it did in later times — or was more or less haphazard. The use of a luni-solar calendar (with a number of refinements) continued at all later periods in Chinese history.

TABLE 2. The sexagenary cycle in a tabulated form. The cyclic numbers are formed from the combination of two series of elements. The first series of elements is known as the celestial stems consisting of 10 elements, the second is known as the earthly branches consisting of 12 elements.

	TZU	CH'OU	YIN	MAO	CH'EN	SZU	WU	WEI	SHEN	YU	HSU	HAI
CHIA	CHIA-TZU 1		CHIA-YIN 51		CHIA-CH'EN 41		CHIA-WU 31		CHIA-SHEN 21		CHIA-HSU 11	
I		I-CH'OU 2		I-MAO 52		I-SZU 42		I-WEI 32		I-YU 22		I-HAI 12
PING	PING-TZU 13		PING-YIN 3		PING-CH'EN 53		PING-WU 43		PING-SHEN 33		PING-HSU 23	
TING		TING-CH'OU 14		TING-MAO 4		TING-SZU 54		TING-WEI 44		TING-YU 34		TING-HAI 24
WU	WU-TZU 25		WU-YIN 15		WU-CH'EN 5		WU-WU 55		WU-SHEN 45		WU-HSU 35	
CHI		CHI-CH'OU 26		CHI-MAO 16		CHI-SZU 6		CHI-WEI 56		CHI-YU 46		CHI-HAI 36
KENG	KENG-TZU 37		KENG-YIN 27		KENG-CH'EN 17		KENG-WU 7		KENG-SHEN 57		KENG-HSU 47	
HSIN		HSIN-CH'OU 38		HSIN-MAO 28		HSIN-SZU 18		HSIN-WEI 8		HSIN-YU 58		HSIN-HAI 48
JEN	JEN-TZU 49		JEN-YIN 39		JEN-CH'EN 29		JEN-WU 19		JEN-SHEN 9		JEN-HSU 59	
KUEI		KUEI-CH'OU 50		KUEI-MAO 40		KUEI-SZU 30		KUEI-WEI 20		KUEI-YU 10		KUEI-HAI 60

It is the usual practice of the *Ch'un-ch'iu* to describe the first month mentioned in each year as "the king's 1st [or 2nd or 3rd] month". This is done as a matter of respect for the Chou monarch. Although the various feudal states were semi-independent during the Ch'un-ch'iu period, the king still exercised nominal power. This authority essentially ceased during the Warring States Period, although the Chou Dynasty was not finally extinguished until 256 B.C.

The *Tso-chuan* notes that intercalary months were usually inaugurated with ceremonies at the Lu capital in which a sacrifice was offered and the Duke appeared at the temple of his ancestors. However, these ceremonies were not always properly observed. Thus in the intercalary month of the 6th year of Duke Wên (621 B.C.), the *Ch'un-ch'iu* records that the Duke "did not announce the month (in the usual way), although he still paid his respects at the ancestral temple".

For most events reported in the *Ch'un-ch'iu*, the lunar month is given, but in the case of more important occurrences the day of the sexagenary cycle is also frequently specified (as in the above example from 648 B.C.). This cycle, which is independent of any astronomical parameter, is first encountered in Chinese history on inscriptions of the Shang Dynasty (*c.* 16th to 11th century B.C.).[12] The full scheme, which has continued in use down to the present day, is shown in Table 2. Since the same cyclical day can recur only at intervals of approximately two months, accurate conversion of a date to the Julian Calendar is often possible even when there are doubts regarding the rules of intercalation that were adopted.

The earliest example of the usage of the 60-day cycle in the *Ch'un-ch'iu* is as follows:

> 2nd year (of Duke Yin), autumn, 8th month, day *keng-ch'en*, the Duke and (the tribe of) Yung made a pact.

The day *keng-ch'en* was the 17th day of the 60-day cycle. According to the recent chronological tables of Zhang Peiyu,[13] the equivalent Julian date was Jul 8 in 721 B.C. We have verified the accuracy of Zhang's conversion of the cyclical day number (subsequently abbreviated to CDN) to the Western calendar using a computer program. Exact dates in the above form are also given for most celestial phenomena, suggesting that these events were regarded as of special significance.

In the remainder of this paper, we shall first discuss the eclipse records in the *Spring and autumn annals* in depth, following this with an investigation of the other astronomical observations noted in the chronicle.

Solar Eclipse Records

The *Ch'un-ch'iu* registers 36 eclipses of the Sun — the earliest in 720 and the latest in 495 B.C. One further account, from 481 B.C., is noted at the very beginning of the supplement: only a few months after the last entry in the chronicle itself. The whole list is by far the earliest extant series of such observations from any part of the world. An Assyrian text, describing a solar

eclipse in 763 B.C., antedates the material in the *Spring and autumn annals* but this is no more than an isolated record.[14] Many ancient descriptions of *lunar* eclipses are preserved on the Late Babylonian clay tables which are now largely in the British Museum. However, although some of these extend as far back as the seventh century B.C., no *solar* eclipse observations from Babylon have survived from before the fourth century B.C.[15] (To judge from the available evidence, less than 10% of what was originally a vast Babylonian astronomical archive, possibly extending from about 750 B.C. to A.D. 100, has so far come to light.) Ancient Greek writings contain only scattered allusions to obscurations of the Sun — from about 650 B.C. onwards.[16]

In China itself, reports of solar eclipses are rare in the centuries both before and after the Ch'un-ch'iu period. Only sporadic references to these phenomena are found on the oracle bones of the Shang Dynasty,[17] while Szŭ-ma Ch'ien, the author of the first dynastic history — the *Shih-chi* (*Historical record*, compiled in the first century B.C.) — was able to uncover only nine accounts of solar obscurations from the whole of the Warring States Period.[18] Not until the Former Han Dynasty do we find a series of eclipse observations of comparable consistency to that recorded in the *Spring and autumn annals*.[19]

As noted above, there are no allusions to eclipses of the Moon in either the *Ch'un-ch'iu* or its supplement. Already by this period, it seems, solar obscurations were regarded as important omens, whereas their lunar counterparts were considered to be of minor significance. Such an attitude is exemplified in the *Shih-ching* (*Book of odes*), a collection of poems largely composed between the ninth and seventh centuries B.C. Here we find the following remark concerning two successive eclipses that occurred during the eighth century B.C.:

> That this Moon is eclipsed is but an ordinary matter; but that this Sun is eclipsed — wherein lies the evil?[20]

This is probably the reason why so few references to lunar eclipses are found in ancient Chinese history.[21]

Eclipses are invariably identified in the *Ch'un-ch'iu* by the term *jih-yu shih-chih*, whose original meaning was probably "the Sun was eaten". However, already by this period the expression had become a technical term, which may be better rendered by "the Sun was eclipsed". Essentially this same terminology continued in standard usage at all later periods in Chinese history. On three occasions (709, 601 and 549 B.C.), a total solar eclipse is described in the chronicle using the above expression — but with the addition of an extra character *chi*, signifying that the eclipse was complete. The full text thus reads: *jih-yu shih-chih chi* (i.e. "the Sun was totally eclipsed"). Other observational details (e.g. darkness or the appearance of stars) are never found in the *Spring and autumn annals*.

Since eclipses can be exactly dated by modern astronomical computations — independently of historical considerations — they are of major importance in chronology. Applications of eclipse records in this field of study include both calendrical research and the dating of individual historical events. Early in the present century, the solar eclipse reports in the *Spring and autumn annals* were

often the subject of investigations,[22] but apart from a paper by Zhang and his colleagues written some ten years ago,[23] little material on this theme has been published in recent decades.

The accounts of all but three of the 37 solar eclipses recorded in the *Ch'un-ch'iu* and its supplement include the day of the sexagenary cycle. Thus for tbe very earliest observation we find the following statement:

> In the third year (of Duke Yin), in spring, in the king's second month, on day *chi-szŭ* the Sun was eclipsed.

The day *chi-szŭ* was the 6th day of the cycle and according to the tables of Zhang Peiyu, the date corresponded to Feb 22 in 720 B.C. We have confirmed that the cyclical day is in accordance with this date. Computations show that on this same day there was an eclipse visible near sunrise in Eastern China.[24] The next event recorded in the chronicle, following the eclipse, notes the death of the Chou monarch, P'ing Wang, in the third month, day *kêng-hsü* (the 47th day of the cycle). The equivalent Julian date, i.e. Apr 4 in 720 B.C., can thus be accepted with considerable confidence. There are sufficient records of solar eclipses in the *Ch'un-ch'iu* to provide a firm chronological base for the whole of the period; observations are cited in the reign of nearly every Duke of Lu in the interval covered by the text.

In the above eclipse report from 720 B.C., the day of the lunar month is not given. Such an omission is fairly unusual; the exact day of the month — always the first day — is specified in 28 instances. The second eclipse record in the *Spring and autumn annals* is more typical in this regard:

> 3rd year (of Duke Wên), autumn, 7th month, day *jen-ch'en*, the first day of the month. The Sun was eclipsed and it was total.

The above date corresponds to Jul 17 in 709 B.C., the exact date of a total eclipse which we calculate to have been visible in China (see Figure 1). Although the *Ch'un-ch'iu* merely notes the occurrence of totality, the Five-Element Treatise of the *Han-shu* (chap. 27) adds the following details: "The eclipse threaded centrally through the Sun; above and below it was all yellow." Just possibly, there might be an allusion to the solar corona here. However, the source of the information in the *Han-shu* is obscure.

The fact that during the Ch'un-ch'iu period solar eclipses appear to have always occurred on the first day of a lunar month is especially noteworthy. (Later in Chinese history — especially from the third century A.D. onwards — this was usually the norm.) Hence already at this early stage, the month began with the day of true conjunction between the Moon and Sun: an unobservable event except at the time of a solar eclipse. This implies a calendar which had already advanced beyond the sighting of the crescent Moon in order to determine the start of a month.

Since the main focus of the *Spring and autumn annals* is on Lu affairs, it seems likely that most of the eclipse observations contained in the chronicle were made at the state capital, Ch'ü-fu. An alternative site is never specified. The Lu capital was located on the site of the modern city of the same name (latitude 35°.53 N,

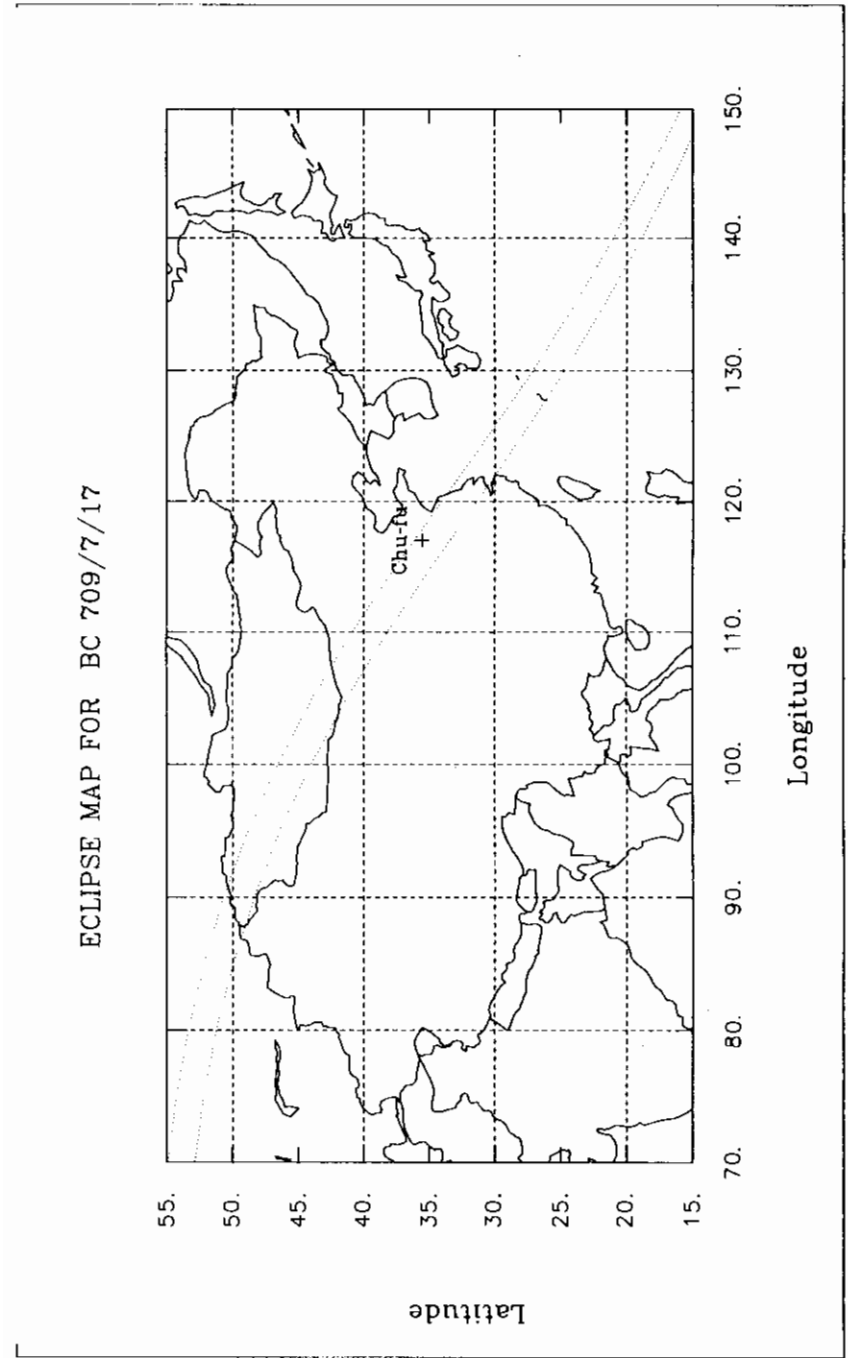

FIG. 1. A map showing the computed track of totality for the solar eclipse of Jul 17 in 709 B.C. (the modern political boundaries are depicted for reference).

longitude 117°.02 E). Even at this early period, individual states are known to have had official astronomers in the service of the ruler to interpret celestial omens.[25] However, it is not known what instruments were available at this period; the *Ch'un-ch'iu* is silent on this question, while the *Tso-chuan* mentions no more than the gnomon.

Eclipse ceremonies held at Ch'ü-fu on three separate occasions (in 669, 664, and 612 B.C.) are described in the *Ch'un-ch'iu*. The record in each case may be translated as follows:

> The Sun was eclipsed, drums were beaten and oxen were sacrificed at the temple.

It is not known whether similar rites were held at other eclipses. Interestingly, the *Tso-chuan*, in commenting on the eclipse ceremony in 669 B.C., states that this was irregular; such practices should have been confined to the first month and only offerings of silk should have been made.

Similar rites can be traced back to the Shang Dynasty when sacrifices were made to a variety of celestial bodies.[26] Even in relatively recent centuries it was the official custom to beat drums and gongs during an eclipse in an attempt to "save the Sun" (from the dragon that was imagined to be devouring it).[27] Yet already by the Ch'un-ch'iu period eclipses seem to have been recognised as natural phenomena, at least in certain quarters. The following extract from the *Tso-chuan*, recording a speech made in 597 B.C. in support of a defeated general who was in danger of execution, is particularly relevant in this context: "His defeat is like an eclipse of the Sun or Moon; does it harm the brightness (of those bodies)?" The general was reinstated!

All 37 eclipse records in the *Ch'un-ch'iu* and its supplement are summarised in Table 3. This gives column by column: (i) a reference number; (ii) the current Duke of Lu; (iii) the year of his reign in which the eclipse occurred; (iv) the lunar month; (v) the day of the month (where stated); (vi) the day of the sexagenary cycle (if given); (vii) the corresponding CDN (see Table 2); (viii) the equivalent date on the Julian Calendar; (ix) any additional remarks. Date reductions in column 8 are based on the tables of Zhang Peiyu[28] but whenever the day of the sexagenary cycle is specified in the text we have verified the accuracy of his reduction using a computer program. In two instances (645 and 549 B.C.) neither the day of the month nor the cyclical day is recorded. In converting both of these dates to the Julian calendar, we have assumed that the first day of the month is implied.

Computation of Past Solar Eclipses

In making calculations for the visibility of solar eclipses in the distant past, satisfactory allowance must be made for the gradual slowing down of the Earth's rotation due to tides and other causes. The mean epoch of the eclipses reported in the *Spring and autumn annals* is around 600 B.C. Although the length of the day at this period was only about 1/20 second shorter than at present,[29] almost one million days have elapsed since then. As a result, an imaginary clock

TABLE 3. Solar eclipses recorded in the *Ch'un-ch'iu* chronicle.

Ref	Ruler	Yr	Mh	Dy	Cyc day	CDN	BC date	Remarks
01	Yin	3	2	–	chi-szu	6	720/2/22	
02	Huan	3	7	1st	jen-ch'en	29	709/7/17	Recorded as total
03	Huan	17	10	1st	–	–	695/10/10	
04	Chuang	18	3	–	–	–	676/4/15	1st day assumed
05	Chuang	25	6	1st	hsin-wei	8	669/5/27	
06	Chuang	26	12	1st	kuei-hai	60	668/11/10	
07	Chuang	30	9	1st	keng-wu	7	664/8/28	
08	Hsi	5	9	1st	wu-shen	45	655/8/19	
09	Hsi	12	3		keng-wu	7	648/4/6	
10	Hsi	15	5	–	–	–	645/4/3	1st day assumed
11	Wen	1	2	–	kuei-hai	60	626/2/3	
12	Wen	15	6	1st	hsin-ch'ou	38	612/4/28	
13	Hsuan	8	7	–	chia-tzu	1	601/9/20	Recorded as total
14	Hsuan	10	4	–	ping-ch'en	53	599/3/6	
15	Hsuan	17	6	–	kuei-mao	40	592/5/15	
16	Cheng	16	6	1st	ping-yin	3	575/5/9	
17	Cheng	17	12	1st	ting-szu	54	574/10/22	
18	Hsiang	14	2	1st	i-wei	32	559/1/14	
19	Hsiang	15	8		ting-szu	54	558/5/31	
20	Hsiang	20	10	1st	ping-ch'en	53	553/8/31	
21	Hsiang	21	9	1st	keng-hsu	47	552/8/20	
22	Hsiang	21	10	1st	keng-ch'en	17	552/9/19	
23	Hsiang	23	2	1st	kuei-yu	10	550/1/5	
24	Hsiang	24	7	1st	chia-tzu	1	549/6/19	Recorded as total
25	Hsiang	24	8	1st	kuei-szu	30	549/7/18	
26	Hsiang	27	12	1st	i-hai	12	546/10/13	
27	Chao	7	4	1st	chia-ch'en	41	535/3/18	
28	Chao	15	6	1st	ting-szu	54	527/4/18	
29	Chao	17	6	1st	chia-hsu	11	525/8/22	
30	Chao	21	7	1st	jen-wu	19	521/6/10	
31	Chao	22	12	1st	kuei-yu	10	520/11/23	
32	Chao	24	5	1st	i-wei	32	518/4/9/	
33	Chao	31	12	1st	hsin-hai	48	511/11/14	
34	Ting	5	3	1st	hsin-hai	48	505/2/16	
35	Ting	12	11	1st	ping-yin	3	498/9/22	
36	Ting	15	8	1st	keng-ch'en	17	495/7/22	
37	Ai	14	5	1st	keng-shen	57	481/4/19	

that was regulated purely by the Earth's rotation from 600 B.C. to the present day would have lost some 6 hours relative to an ideal chronometer. Hence an eclipse calculation which ignored this effect would be seriously in error with regard to the visibility of the phenomenon on the Earth's surface.

The clock error (usually termed ΔT) arising from the gradual lengthening of the day cannot be deduced accurately on purely theoretical grounds. For any selected period before the development of telescopic astronomy, it is best derived from the analysis of roughly contemporaneous observations of eclipses.[30] The investigation of the solar eclipse records in the *Ch'un-ch'iu* is

TABLE 4. Calculated circumstances for solar eclipses contained in the *Ch'un-ch'iu* chronicle.

Ref	Yr	Mh	Dy	JD	CDN	LHR	Alt	Mag
01	720	2	22	1458496	6	7.0	5	0.44
02	709	7	17	1462659	29	15.6	42	1.06
03	695	10	10	1467857	7	15.9	22	0.55
04	676	4	15	1474619	49	17.7	8	0.70
05	669	5	27	1477218	8	10.2	62	0.90
06	668	11	10	1477750	60	10.5	35	0.74
07	664	8	28	1479137	7	15.5	37	0.85
08	655	8	19	1482415	45	14.8	47	0.93
09	648	4	6	1484837	7	17.9	4	0.27
10			No	Eclipse				
11	626	2	3	1492810	60	12.6	35	0.79
12	612	4	28	1498008	38	6.6	13	0.86
13	601	9	20	1502171	1	15.7	30	0.88
14	599	3	6	1502703	53	6.0	-5	0.69
15			No	Eclipse				
16	575	5	9	1511533	3	14.7	48	0.95
17	574	10	22	1512064	54	7.9	17	0.66
18	559	1	14	1517262	32	15.1	18	0.60
19	558	5	31	1517764	54	4.9	-1	0.37
20	553	8	31	Invisible	in	N. China		
21	552	8	20	1520037	47	14.5	51	0.70
22			No	Eclipse				
23	550	1	5	1520540	10	8.9	16	0.88
24	549	6	19	1521071	1	14.0	61	1.08
25			No	Eclipse				
26	546	10	13	1522282	12	7.3	12	0.92
27	535	3	18	1526091	41	14.4	39	0.36
28	527	4	18	1529044	54	12.0	63	0.88
29	525	8	21	1529900	10	17.5	15	0.84
30	521	6	10	1531289	19	10.3	65	0.61
31	520	11	23	1531820	10	11.6	35	0.60
32	518	4	9	1532322	32	8.2	29	0.58
33	511	11	14	1535098	48	10.1	31	0.58
34	505	2	16	1537018	48	15.0	25	0.39
35	498	9	22	1539793	3	11.5	57	0.88
36	495	7	22	1540827	17	11.8	76	0.52
37	481	4	19	1545847	57	0.8	61	0.84

Location of Chu-fu: Latitude 35°.53 N Longitude 117°.02 E

greatly facilitated by the many careful Babylonian timings of lunar eclipses which are available from much the same period. Most of these timings have been analysed as part of long-term studies of the Earth's rotation in the past, where the main emphasis is on geophysical interpretation.[31] In calculating the local circumstances for the *Ch'un-ch'iu* eclipses we have used the expression:

$$\Delta T = 32.5T^2 \text{ sec},$$

where T is the number of Julian centuries before the reference epoch of A.D. 1800. This equation was derived by Morrison and Stephenson[32] by fitting a parabola to the ΔT results deduced from a set of Babylonian eclipse timings. Over the period covered by the *Spring and autumn annals*, ΔT values yielded by the above formula agree closely with those obtained from a rather more complicated expression based on a study of both ancient and medieval observations.[33]

Our computations for all of the solar eclipses listed in Table 3 are shown in Table 4. In each case the assumed place of observation is Ch'ü-fu. This table gives in order: (i) a reference number corresponding to that in Table 3; (ii) the calculated Julian date of the eclipse for the longitudes of China; (iii) the Julian day number; (iv) the corresponding CDN; (v) the computed local time of greatest phase at Ch'ü-fu to the nearest 0.1 hour; (vi) the approximate altitude of the Sun at greatest phase; (vii) the eclipse magnitude or maximum proportion of the solar diameter covered. In particular, we estimate that errors in the magnitudes listed in column (vii) are unlikely to exceed 0.02 — more than sufficient precision for the present investigation.

Four of the entries in Table 4 (reference numbers 10, 15, 22 and 25) cannot be identified with calculated eclipses. Although the Moon and Sun were in conjunction on the stated dates, no eclipses occurred over the Earth's surface. As can be seen from Tables 3 and 4, both of the supposed eclipses of Sep 19 in 552 B.C. and Jul 18 in 549 B.C. are recorded exactly one month after real eclipses which were large at Ch'ü-fu. There is thus a possibility that these spurious reports might have arisen from accidental duplication of entries during editing. Alternatively, the observers may have been confused by atmospheric veilings of the Sun. On the two remaining occasions (645 and 592 B.C.), scribal errors are unlikely; no eclipses were visible in China for more than a year before or afterwards.[34] Possibly these false sightings might also relate to atmospheric phenomena.

We calculate that the recorded eclipse of B.C. 553 Aug 31 (ref. no. 20) would be visible in China but not at Ch'ü-fu itself. The penumbral shadow of the Moon would pass appreciably to the south of the Lu capital but in southern China a small fraction of the Sun would be obscured. News of the event could have been communicated to Ch'ü-fu from this region, but the text does not contain such information.

Of the 33 real eclipses (including that of 553 B.C.) cited in the *Spring and autumn annals* and its continuation, the day of the sexagenary cycle is recorded on as many as 31 occasions. The cyclical day proves to be *exactly* correct in all but one instance; the eclipse of 525 B.C. actually occurred on Aug 21 (CDN = 11) whereas the record implies the previous day (CDN = 10). For such an early chronicle, this degree of consistency is remarkable; it indicates considerable care, both on the part of the original scribes and of copyists down the centuries.

It will be noted that the computed solar altitudes at greatest phase in both 599 and 558 B.C. are negative; each eclipse occurred near sunrise. In particular, only the closing stages of the eclipse of 599 B.C. could have been observed at Ch'ü-fu, where the Sun would rise less than half covered (the result in Table 4 applies to

the invisible maximum phase). In all, six eclipses (including those of 599 and 558 B.C.) reached a calculated magnitude of less than 0.5. It may be inferred that on each occasion atmospheric circumstances could well have been favourable for viewing small magnitude eclipses. Apart from the advantage of low solar altitude (as was the case in 720, 648, 599 and 558 B.C.), five of these events (720, 648, 599, 535 and 505 B.C.) occurred in the spring when the glare of the Sun would be frequently reduced by dust storms.[35]

Most of the remaining 27 eclipses reached a calculated magnitude of more than 0.8 at Ch'ü-fu. Although these would be easier to observe than smaller phases, it should be emphasised that marked loss of daylight does not arise until practically the whole of the Sun is obscured. Among the very large eclipses, only two (in 709 and 549 B.C.) are calculated to have been total at Ch'ü-fu (see Figures 1 and 2). Hence the assertions in the *Ch'un-ch'iu* regarding totality on these two occasions are confirmed. However, we compute that less than 90% of the Sun would have been covered as seen from Ch'ü-fu in 601 B.C. — the only other instance when a total eclipse is registered in the chronicle. As is apparent from Figure 3, the calculated track of totality passed far to the south-west of Ch'ü-fu. Perhaps the record was communicated from another state (such as Ch'in in the far west of China or Ch'u in the extreme south of the country). However, there is nothing in the text to support such a contention.

General Statistical Considerations

Over the period of 241 years covered by the *Ch'un-ch'iu* itself, 31 solar eclipses which were visible at Ch'ü-fu are noted in the chronicle — an average of roughly one every 8 years.[36] After 575 B.C., the mean interval between successive observations fell to only four years. Comparison with the records from subsequent periods in Chinese history suggests that the Lu observers were remarkably diligent in watching for eclipses, especially in the later decades. For example, drawing on the observations made half a millennium later by the official astronomers at the imperial capital of Ch'ang-an, the *Han-shu* cites accounts of no more than 39 solar eclipses which were visible there over about 215 years.

In order the better to assess the efficiency of the Lu astronomers in detecting obscurations of the Sun, we have computed the local circumstances of all eclipses which should have been visible at Ch'ü-fu during the entire Ch'un-ch'iu period. Before discussing these results, some preliminary remarks regarding the frequency of eclipses seem necessary. If the lunar orbit was in the same plane as that of the Earth around the Sun (the ecliptic), an eclipse would take place every month at the time of conjunction between the Moon and Sun. In practice, the two orbits are inclined at an angle of about 5° to one another. Hence from the Earth's viewpoint, at most conjunctions the Moon passes either above or below the Sun and no eclipse is produced. According to the statistical estimate of von Oppolzer,[37] although roughly 1240 conjunctions occur in a typical century, the average number of solar eclipses visible on (at least some part of) the Earth's surface is approximately 240. Furthermore, since the Moon is considerably

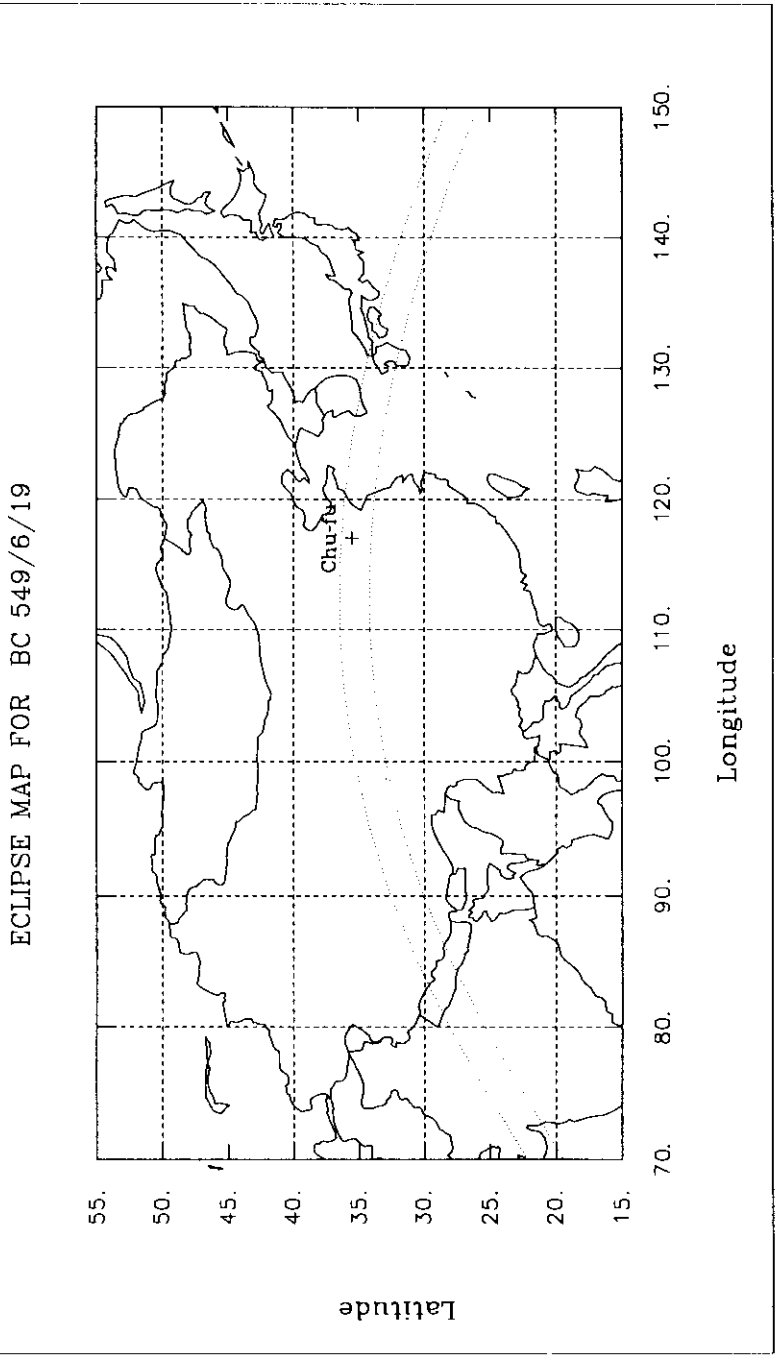

FIG. 2. A map similar to that of Fig. 1 showing the visibility of the total eclipse of Jun 19 in 549 B.C.

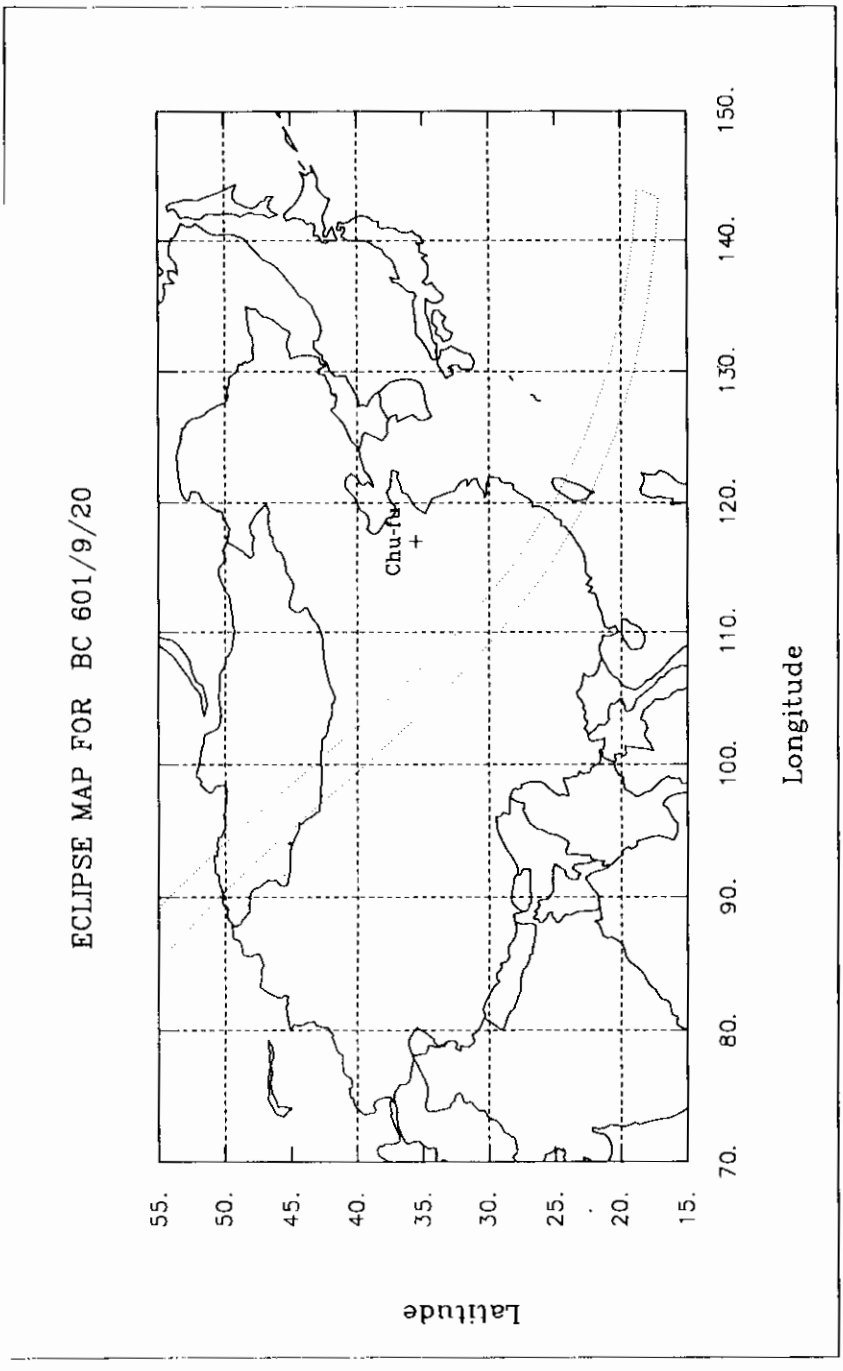

FIG. 3. A map showing the calculated track of totality on Sep 20 in 601 B.C.

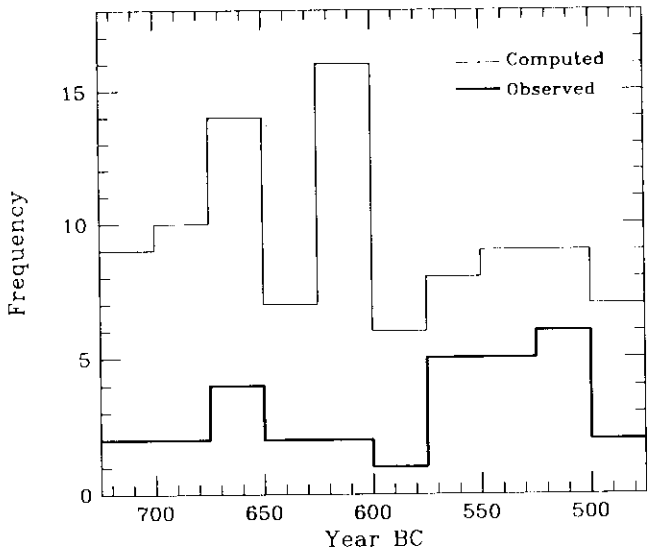

FIG. 4. Histograms comparing the frequency of observed and computed solar eclipses in the Ch'un-ch'iu period in 25-year intervals.

smaller than the Earth, during any particular eclipse no more than about 20% of the terrestrial surface encounters some part of the lunar shadow. As a result, as seen from any one location the Sun is obscured on only about 40 occasions during an average century. In contrast, the mean interval between *total* eclipses observable at any one site is roughly 300 years.

We compute that during the 241 years of the Ch'un-ch'iu period, 95 solar eclipses should have been observable from Ch'ü-fu. Hence the Lu astronomers attained an overall efficiency in detecting eclipses of about 33%. However, after 575 B.C. this figure was as high as 55% (18 out of a possible 33). The latter percentage represents a highly creditable performance. Of the obscurations of the Sun which were theoretically possible, some would be invisible owing to cloud, while others would probably pass unnoticed on account of their small magnitude; roughly half of the eclipses occurring during any selected period reach a magnitude of less than 0.5.

Figure 4 shows two histograms in which the frequency of observed and computed eclipses is compared at intervals of 25 years. (Since the actual date range is from 722 to 481 B.C., the first and last bins cover incomplete periods.) The large variations in the numbers of calculated eclipses from one 25-year period to the next is purely a statistical artefact, arising from the low frequencies involved. However, the increase in efficiency after about 575 B.C. is especially marked.

Figure 5 displays histograms similar to those in Figure 4, but only eclipses of calculated magnitude greater than 0.5 are represented. It is evident from this diagram that the Lu astronomers achieved a very high degree of success in

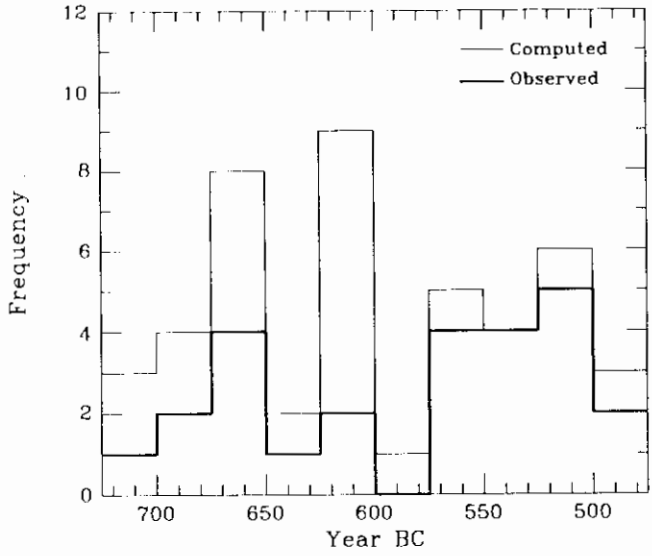

FIG. 5. Histograms similar to those in Fig. 4 but showing only eclipses with magnitudes greater than 0.5.

detecting larger magnitude eclipses after 575 B.C.; no less than 80% of all computed eclipses in this category were reported.

Other Astronomical Records

In comparison with solar eclipses, relatively little interest is shown in other celestial phenomena in the *Ch'un-ch'iu* or its supplement. As noted above, there are no references to the Moon or planets throughout the chronicle. However, the four allusions to comets and two to meteors deserve comment. The comets are stated to have appeared in the following years: 613, 525, 482 and 481 B.C. Both of the meteor accounts are earlier: 687 and 645 B.C. The meteor shower in 687 B.C. and the comet in 613 B.C. are probably the earliest reliable observations of such phenomena from anywhere in the world.

None of these six events is known to be recorded in the history of other civilizations. In this context, it should be emphasised that there are no references in Babylonian history to comets before the third century B.C. — probably due to the poor preservation of early texts.[38] In the remainder of the following section, we discuss the individual observations of meteors and comets recorded in the *Ch'un-ch'iu* in chronological order.

(i) Meteor shower in 687 B.C.

> 7th year (of Duke Chuang), summer, 4th month, day *hsin-mao*. At night the regular stars were not seen. At midnight stars fell like rain.

The above date is equivalent to Mar 23 in 687 B.C. The allusion to the lack of

visibility of the ordinary stars is problematical. The explanation provided by the *Tso-chuan* is that "the night was bright". Since the Moon would be only 5 days past new at the time, moonlight cannot have been responsible. Perhaps the meteor shower was so dense that the fixed stars could not be discerned. However, we can no more than speculate on the explanation.

An alleged reference to a much earlier display of meteors is found in the *Chu-shu Chi-nien* or *Bamboo annals* (a work not later than 300 B.C.). This relates to a supposed occasion when "stars fell like rain" in the 15th year of King Kuei, the last monarch of the Hsia Dynasty (sixteenth century B.C. or earlier). However, much of the material in the *Bamboo annals* is probably of questionable reliability,[39] while even the very existence of the Hsia Dynasty is in doubt.[40] In later Chinese history (from the first century B.C. onwards), "stars fell like rain" became the standard expression to describe a heavy shower of meteors.[41]

(ii) Fall of meteorites in 645 B.C.

> 16th year (of Duke Hsi), spring, in the king's first month, day *wu-shen*, the first day of the month, stones fell in Sung; there were five (of them).

This date corresponds to Dec 24 in 645 B.C. The state of Sung lay to the south-west of Lu and shared a common border with it.[42] The *Tso-chuan* asserts that the objects were falling stars. Meteorites provide the most viable explanation.

(iii) Comet in 613 B.C.

> 14th year (of Duke Wên), autumn, 7th month, a comet (*hsing-po*) entered the Northern Dipper (Pei-tou).

According to the tables of Zhang Peiyu, the 7th month extended from Jun 6 to Jul 5 in 613 B.C. Since there is no suggestion of rapid motion (which would indicate a meteor), the most likely interpretation of this phenomenon is a comet. The fact that only the month is recorded may indicate an extended period of visibility; approximate dates are also given for the other three *hsing-po* registered in the *Ch'un-ch'iu* and its supplement, in marked contrast to other celestial phenomena.

The *Tso-chuan* repeats the above statement but in the *Shih-chi* the same object is identified by the term *hui-hsing* ("broom star"). Later in Chinese history, *hsing-po* (literally "bushy star") seems to have become a standard term to describe a comet with a short tail, while *hui-hsing*, usually referred to a comet with a long tail. However, the *Ch'un-ch'iu* only ever uses *hsing-po*. At this early period, it seems probable that no distinction was made between comets of different appearance. It is unlikely that this account relates to Halley's Comet, as proposed by Chang.[43] The most precise computed date of the nearest apparition was three years beforehand, in 616 B.C.[44] Some other bright comet may well be described in the text; as records in later Chinese history reveal, bright comets occur fairly frequently, the average interval being perhaps five years or so.

Pei-tou (i.e. the Plough) is the only individual constellation mentioned in the

whole of the *Ch'un-ch'iu*, probably because of its readily recognisable configuration.

Following the appearance of the comet, the *Tso-chuan* quotes the official Chou astrologer as saying, "Within the next seven years, the rulers of Sung, Ch'i and Chin will all die through rebellion". This is one of the earliest known astrological interpretations of a celestial event in Chinese history. Such prognostications were precursors of the extremely comprehensive system of political astrology which was so prevalent in China from the Former Han to the fall of the last dynasty.

(iv) Comet in 525 B.C.

> 17th year (of Duke Chao), winter. There was a comet (*hsing-po*) at Ta-ch'en.

The *Tso-chuan* asserts that the comet was to the west of Ta-ch'en and reached the "Han River" (i.e. the Milky Way). Ta-ch'en was most probably another name for Ta-huo, one of the twelve *tz'ŭ* or "Jupiter stations"; it embraced parts of Libra and Scorpio. Here we have one of the earliest references to these twelve equal divisions of the sky based on the motion of Jupiter. The *tz'ŭ* were independent of the twelve signs of the occidental zodiac and had little in common with them.

The *Tso-chuan* comments on the astrological significance of the comet in the following words: "A broom (star) takes away the old and prepares for the new", a notion which was also widespread in later Chinese history. Neither this object nor the following two comets can possibly be identified with Comet Halley.

(v) Comet in 482 B.C.

> 13th year (of Duke Ai), winter, 11th month. There was a comet (*hsing-po*) in the eastern direction.

The tabular date of this event on the Julian Calendar is between Sep 26 and Oct 24 in 482 B.C. There are no comments regarding this occurrence in the *Tso-chuan*.

(vi) Comet in 481 B.C.

> 14th year (of Duke Ai), winter. There was a comet.

This entry is found only in the appendix to the *Ch'un-ch'iu*, which forms part of the *Tso-chuan*. It is possible that this statement is merely a repeat of that in the previous year — see (v) above.

Conclusions

The dates of nearly all of the solar eclipses recorded in the *Ch'un-ch'iu* prove to be in exact accord with those based on modern calculations. In addition, there is evidence that the Lu astronomers kept a systematic watch for obscurations of

the Sun, especially after about 575 B.C. Although only a few comets and meteors are noted in the chronicle, the observations are of considerable interest, especially in view of their antiquity. Above all, investigation of the astronomical records in the *Spring and autumn annals* provides impressive evidence in favour of the authenticity of this early Classic.

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2. Similar chronicles were kept in other feudal states, but most were presumably destroyed at the Burning of the Books. See B. Watson, *Early Chinese literature* (New York, 1962), 37.
3. Mencius, *Works*, chap. 9: Confucius was afraid, and made the "Spring and Autumn" .... Confucius said, "Yes! it is the 'Spring and Autumn' which will make men know me, and it is the 'Spring and Autumn' which will make men condemn me" (trans. by J. Legge, *The four books* (Shanghai, 1930), 676–7). Confucian authorship has been much disputed; see, for example, Watson, *op. cit.*, 38–40.
4. Two other ancient commentaries which are still accessible are the *Kung-yang*, which was officially copied from a manuscript in private hands during the second century B.C., and the *Ku-liang*, which was similarly copied about a century later.
5. Valuable historical comments are provided by: Watson, *op. cit.*, 40–66; and T. Pokora, in *Essays on the sources for Chinese history*, ed. by D. D. Leslie, C. Mackerras and Wang Gungwu (Canberra, 1973), 23–35.
6. *Han-shu* (chap. 27): "Treatise on the five elements" (*Wu-hsing Chih*).
7. Tsien Tsuen-hsuin, *Written on bamboo and silk* (Chicago, 1962), 73–79.
8. T. F. Carter, *The invention of printing in China and its spread westward* (New York, 1925), 212.
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18. *Shih-chi*, chap. 6.
19. *Han-shu*, chap. 27.
20. Translated by B. Karlgren, *The book of odes* (Stockholm, 1950), 137–8.
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22. See, for example: P. Hoang, *Catalogue des éclipses du soleil et de la lune* (Shanghai, 1927); W. Eberhard, R. Muller and R. Henseling, "Beitrage zur Astronomie der Hans-Zeit, II", *Sitzungsberichte der Preussischen Akademie der Wissenschaften, Philosophisch-Historische Klasse*, xxiii (1933), 937–79; Chu Wen-hsin, *Li-tai Jih-shih K'ao* (Shanghai, 1934), 14–22. The *Ch'un-ch'iu* eclipses form only a part of these surveys. In each case, the astronomical analysis is weak.
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25. *Shih-chi*, chap. 6, and chap. 27.
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27. A Jesuit account of the eclipse of A.D. 1610 as witnessed in Peking is given by P. Hoang. *Mélanges sur l'administration* (Shanghai, 1902), 91–93.
28. Zhang Peiyu, *op. cit.* (ref. 10).
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32. L. V. Morrison and F. R. Stephenson, "Secular and decade fluctuations in the Earth's rotation 700 B.C.–A.D. 1978", in *Sun and planetary systems*, ed. by W. Fricke and G. Teleki (Dordrecht, 1982), 173–8.
33. Stephenson and Morrison, *op. cit.* (ref. 29).
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(i) They suggest the 15th year of Duke Huan (697 B.C.) instead of the 15th year of Duke Hsi (645 B.C.) — assuming that the Duke's name is wrongly recorded. However, the characters for Hsiang and Hsu are quite dissimilar.
(ii) They propose reading the 7th year of Duke Hsüan (602 B.C.) instead of the 17th year of his reign (592 B.C.), while retaining the lunar month and cyclical day.
(iii) They tentatively suggest reading the 12th month of the 26th year of Duke Hsiang (547 B.C.), instead of the 10th month of the 21st year (552 B.C.), while retaining the cyclical day. On the basis of these amendments, they were able to identify three eclipses visible in China. However, we feel that their suggestions, especially in the case of (i) and (iii), are highly speculative.
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