The planetary visibility tables in the second-century BC manuscript Wu xing zhan

Daniel Patrick Morgan

EASTM XX(20xx): xx-xx

The Planetary Visibility Tables in the Second-Century BC Manuscript *Wu xing zhan* 五星占[1]

Daniel Patrick Morgan

[Daniel P. Morgan is a Ph.D. candidate at the University of Chicago's Department of East Asian Languages and Civilizations researching the history of astronomy in early imperial China. In 2011-2012 he received an Andrew W. Mellon Foundation fellowship to pursue dissertation research at the Needham Research Institute. Contact: dpmorgan@uchicago.edu]

* * *

Abstract: This article is a study of the planetary tables in the second-century BC manuscript *Wu xing zhan*. Products of computation in this and later texts are compared to what we know about contemporary bodies of planetary knowledge to highlight discrepancies between theory and practice, as well as pluralities of tradition, within the early imperial astral sciences. In particular, this study focuses on such tables' apparent use of a solar calendar (as distinct from the lunisolar civil calendar) for the purposes of planetary astronomy; it also attempts to explain anomalous features of the *Wu xing zhan*'s planetary tables in the context of early manuscript culture.

The subject of this article is the planetary visibility tables in the second-century BC manuscript *Wu xing zhan* 五星占 (Divination of the Five Stars [Planets]). The *Wu xing zhan* is a unique document. It is at once the earliest reliable treatise on the astral sciences in China and the only one to have come down to us from this era in manuscript form. It also furnishes us with one of the only examples of calculated planetary tables from the

[1] I am grateful to Professor Karine Chemla for inviting me to present an earlier version of this article at the "Histoire des tables numériques" seminar of the CNRS series *Histoire des sciences, Histoire du texte* (Université Paris Diderot, March 23, 2012), as well as for her invitation to publish it here, and for the many ideas that she sparked in my mind during our conversations in Paris. I am equally grateful to Professor Christopher Cullen and the Andrew W. Mellon Foundation for supporting my rewarding stay at the Needham Research Institute, were it not for which I would have made none of the discoveries presented here. I would also like to thank EASTM's anonymous referees for their many helpful comments and suggestions.

early and medieval period in China.[2] This study will focus on two aspects of these tables as they reflect upon what we know about the history of astronomy in China from traditional sources.

One is their status as products of practice. Almost everything that we know about mathematical astronomy in this period we know from manuals for state astronomical systems preserved in the dynastic histories, which Nathan Sivin describes as sets of "step-by-step instructions, worked out so that a minor functionary with limited mathematical skills could calculate the annual ephemeris."[3] If we are to construct a history of Chinese astronomy from these sources, we must take a number of hermeneutical considerations into account. As a purely functional technology, they obscure the 'scientific process' that went in to their creation—what it was, for example, that Liu Hong 劉洪 (c. AD 135-210) or Zhang Zixin 張子信 (fl. 526-576) were doing in the decades they spent perfecting their innovations.[4] Nor is a manual itself able to tell us how real people used it. Furthermore, we know from excavated calendars and historical records that what appear like inviolable 'canons' were in practice continuously modified and reconstituted.[5] The work of

[2] The manuscript itself is untitled, as is common of this period, leaving the editors assign it the descriptive title *Wu xing zhan*. In addition to the *Wu xing zhan*, there is another manuscript on planetary astronomy/astrology, the *Wu xing* 五星, that was recovered from Shuanggudui 雙古堆 tomb 1 (closed in 165 BC) in Fuyang, Anhui in 1977. Unfortunately, this manuscript was badly damaged during excavation and never published. For a description of the Shuanggudui *Wu xing*, see Hu Pingsheng 胡平生 (1998).

[3] Sivin (2009), p. 21. For other monumental studies of Chinese astronomical systems, see Nōda Chūryō 能田忠亮 and Yabuuti Kiyosi 藪内清 (1947); Liu Hongtao 劉洪濤 (2003); Zhang Peiyu 張培瑜, et al. (2008).

[4] Liu Hong is attributed with the first coherent model for lunar inequality and latitude in China, and Zhang Zixin, among other things, with the first models for solar and planetary inequality. Received sources describe them as spending 20 and 30 years on their respective systems (*Jin shu* 晉書, 17.499; *Sui shu* 隋書, 20.561). For their contributions to the history of Chinese astronomy, see Chen Meidong 陳美東 (2003), pp. 212–217, 298–303; Cullen (2002).

[5] Sivin (2009) and Martzloff (2009) use the term 'canon' to denote what I call here the 'system manual' instantiation of *li* 曆. In addition to the scholarship on calendars mentioned in the next line, an excellent case in point concerning the mutability of these 'canons' is the Han Quarter-remainder system (*Sifen li* 四分曆; *Hou Han shu* 後漢書, *zhi* 3, 3058-3081): adopted in AD 85, the emperor ordered a change of its calendrical parameters in the following year, and we know the solar table appended to it in the *Hou Han shu* to have derived from AD 173. On the history of the Quarter-remainder system, see Ōhashi Yukio 大橋由紀夫 (1982).

scholars like Zhang Peiyu 張培瑜 (2007), Huang Yi-long 黃一農 (1992), Deng Wenkuan 鄧文寬 (2002), Jean-Claude Martzloff (2009), and Alain Arrault (2002) has gone a long way to reveal the complexity of pre-print calendar culture in China and the ambiguities that existed between state manuals, practice, and *realia*. By comparison, the case of planetary tables is less studied because there are simply fewer materials available to us.

Another aspect of these tables that I intend to explore is how they reflect upon diversity within the astral sciences. The manuscript's technical contents are inconsistent—inconsistent with later tradition, astronomical reality, and even each other. I will attempt to explain a number of contradictions by demonstrating how the *Wu xing zhan* tables conflate discrete forms of planetary knowledge. I will also present evidence for the pre-modern Chinese use, for the sake of computational convenience, of a solar calendar—one distinct from the lunisolar civil calendar but whose exact features spring up here and in other pre-modern sources. The question at the heart of this article is ultimately why the *Wu xing zhan* is the way it is, and in the final section I offer several conjectures based on what we know about early Chinese manuscript culture and the *Wu xing zhan*'s own textual history.

The *Wu xing zhan* was discovered in 1973 in Changsha, Hunan amid the manuscript horde at Mawangdui 馬王堆 tomb 3—a Western Han tomb sealed in 168 BC belonging, it seems, to Li Xi 利豨, the second marquis of Dai 軑.[6] The manuscript is written on a piece of silk approximately one by one-half meter in size. The text, which amounts to 146 lines, is divided into eight units, each of which begins on a new line. The first five units are devoted to planetary omens for Jupiter, Mars, Saturn, Mercury, and Venus, respectively. Each section is prefaced with an introduction to the metaphysical and divine associations of each planet and a description of its normal behavior, followed by omen series typical of received literature. Occupying roughly the same amount of space, the last three sections are devoted to computation, providing for Jupiter, Saturn, and Venus 70-year visibility tables running from 246-177 BC and planetary models.

[6] Hunan sheng bowuguan 湖南省博物館 & Zhongguo kexueyuan kaogu yanjiusuo 中國科學院考古研究所 (1974). For the case for identifying the occupant of tomb 3 as Li Xi, see Chen Songchang 陳松長 (2003).

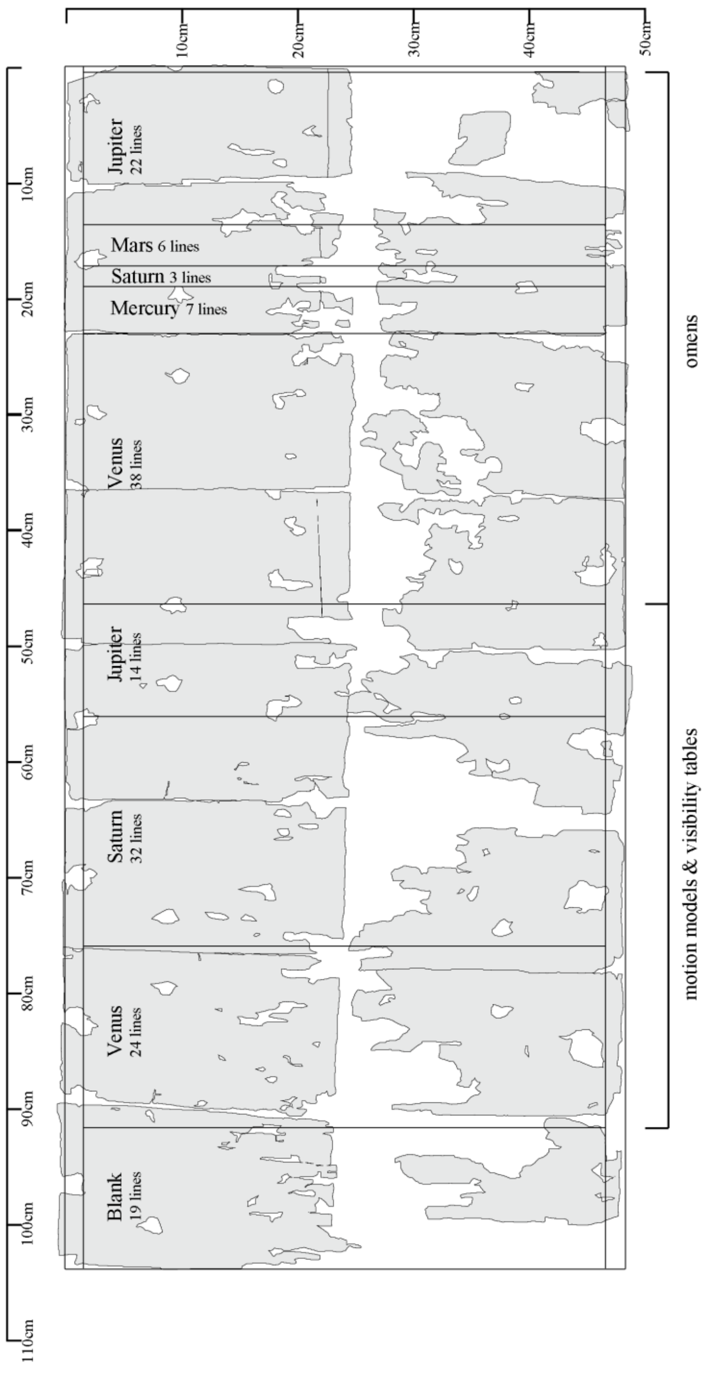


Figure 1. ***Wu xing zhan*** **textual units**

There are now several dozen articles and chapters on the *Wu xing zhan* and complete translations into Chinese, Japanese and English. Most of the scholarship thus far has been introductory or focused on the issue of the Jovian year-count, and is synthesized in Liu Lexian 劉樂賢 (2004). Since then, Takeda Tokimasa 武田時昌 and Christopher Cullen have resolved many of the text's remaining technical issues and raised stimulating new questions about its function and its place in the history of Chinese astronomy. The present study attempts to address some of these questions, building off of my own work on the textuality and hybridity of the *Wu xing zhan*.[7]

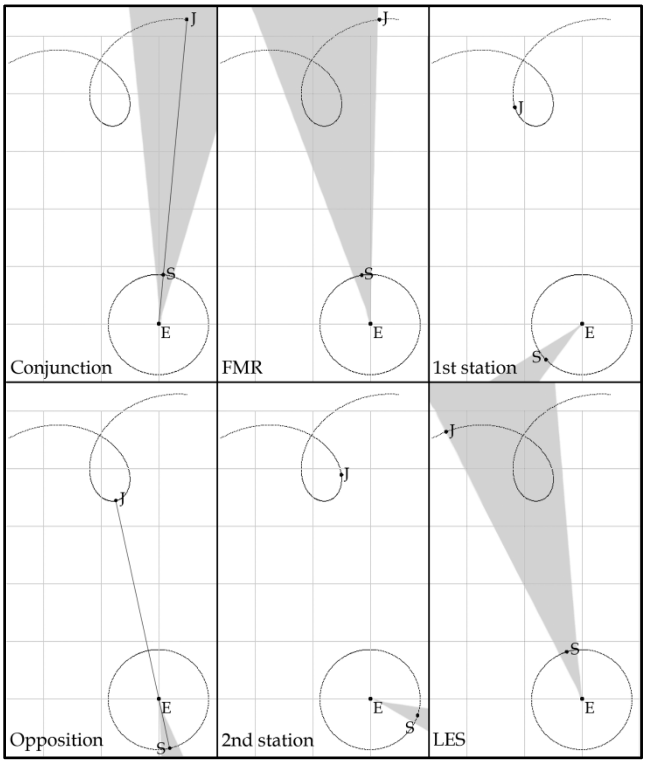
The Astral Sciences in Early Imperial China

Before coming to the tables, let us outline the phenomena with which they are concerned and the traditions of knowledge that they bring to bear upon them. Our first question is thus "what do planets do?"

The apparent motion of Jupiter is a good place to begin since 'the Year Star' (Suixing 歲星) invariably comes first in any list. Like Mars and Saturn, Jupiter is a superior planet, meaning that its orbit is larger than our own and that its apparent motion along the ecliptic is slower than that of the sun. When Jupiter is opposite the Sun in conjunction (*he* 合), it is 'hidden' (*fu* 伏) and nowhere to be seen. However, within a week or two the Sun moves far enough past the planet that the latter finally "emerges in the morning in the east" (*chen chu dongfang* 晨出東方) before being washed out by the break of dawn—it experiences first morning rising (FMR). For the next 12 to 13 weeks, it rises earlier and earlier each morning, traveling forward through the stars, all the while gradually slowing until it comes to a stop (*liu* 留)—first station. At this point it begins to accelerate backwards in retrograde (*nixing* 逆行), reaching opposition (*chong* 沖) about 7 weeks later. In another 7 weeks it slows and comes to another stop—second station—before again moving forward or 'prograde' (*shun* 順). For the next 12 to 13 weeks it gradually accelerates while the Sun catches back up with it, setting earlier and earlier each night until it is again drowned out by the brightness of the Sun and

[7] For translations, see Kawahara Hideki 川原秀城 & Miyajima Kazuhiko 宮島一彥 (1985); Zheng Huisheng 鄭慧生 (1995), pp. 181 – 217; Chen Jiujin 陳久金 (2001), pp. 102 – 147; Cullen (2011a). For scholarship relevant to the current study, see Yabuuti (1982), Takeda (2010), Cullen (2011b), and also Mo Zihan 墨子涵 (Daniel P. Morgan) (2011).

Figure 2. The synodic period of Jupiter



NOTE: This diagram illustrates the characteristic phenomena of Jupiter (J) over the course of one synodic period as viewed geocentrically from Earth (E). The grey area indicates the hypothetical 'angle of invisibility' around the sun (S). Individual diagrams were modified from *Alcyone Ephemeris* v3.2.

"enters in the evening in the west" (*xi ru xifang* 夕入西方)—i.e. experiences last evening setting (LES). The length of time it takes a planet to complete these actions and return to the same position *vis-à-vis* the Sun is its synodic period (*S*). This is distinct from, though proportionally related to, its sidereal period (*P*), which is the amount of time it takes to return to the same position among the stars. The apparent motion of Venus and Mercury, the inferior planets, is more complex, but the example of Jupiter is sufficient for our purposes here.[8]

[8] For a lucid explanation of each planet's characteristic phenomena and how early Chinese planetary models dealt with them, see Teboul (1983), esp. pp. 49–109.

The Chinese traditionally divided their astral sciences into two categories: *tianwen* 天文 'celestial patterns' and *li* 曆 'calendro-astronomy'. Generally speaking, *tianwen* generally deals with star cataloging, observation, and omenology, and *li* with predictive mathematical modeling. This distinction is fully manifest in the practices, professions, and textual genres of the Han as we know them from contemporary descriptions, bibliographies, and the titles and contents of extant works. As contemporary actors' categories these are a good place for any modern study to begin. Of course, while we can trace core practices like sky watching, omenology, and calendrics back to the earliest written records in China, it is still wise to exercise caution in extending these specific categories backwards in time or beyond the received tradition of elite literature.[9]

Li

The earliest *li* manual currently extant is Liu Xin's 劉歆 (c. 50 BC – AD 23) Triple Concordance system (*Santong li* 三統曆; *Han shu* 漢書, 21b.991-1011) of *circa* AD 5. The *Wu xing zhan* antedates the Triple Concordance system by almost two centuries, but comparison seems apt given the extent to which their computational models resemble one another in terms of style, approach, and theory. Planetary astronomy in early *li* system manuals is comprised of four elements. The first is the *shu* 數 'numbers' of the calendar and the planet's synodic period, the latter of which are derived from a ratio of FMR to years, i.e. a resonance period. The second is the *xingdu* 行度 'motion-degree' model, a formulaic

---

[9] The difference between *tianwen* and *li* genres is most clearly manifest in the respective eponymous treatises of the dynastic histories. Generally speaking, a *tianwen* text is a catalog of facts about Heaven (i.e. descriptions, measurements, and omens) organized spatially, topically, and, in the case of observational/divinatory records, chronologically; extant *li* texts, on the other hand, are either step-by-step calculational manuals or histories of the field. While most of this literature is now lost, the bibliographic treatises of the *Han shu* and *Sui shu* confirm the self-identification of early works with these genres from the prevalence of those including the words *li*, *tianwen*, and *zhan* 占 'divination' in their titles (*Han shu*, 30.1763 – 1767; *Sui shu*, 34.1018 – 1026). That *tianwen* and *li* embodied different practices and skill sets is further suggested by the bifurcation of the state astronomical office into the *li* specialists of the Grand Clerk (*taishi* 太史) and the *tianwen* specialists of the Numinous Terrace (*lingtai* 靈臺) observatory; see Deane (1989), esp. pp. 1 – 141; Chen Xiaozhong 陳曉中 & Zhang Shuli 張淑莉 (2008), esp. pp. 33 – 94. For an overview of *tianwen* and *li* practices recorded in Shang 商 (?-1046 BC) oracle bones, see Keightley (2000), pp. 17 – 53.

description of the planet's motion over the course of one synodic period based on two premises: symmetry and a fixed angle (in right ascension) from the Sun at which the planet appears and disappears—an 'angle of invisibility'. The third is the *li yuan* 曆元 'system origin', a point in time and space where all calendro-astronomical cycles coincide and from which subsequent iterations are counted. Lastly, the fourth is the *shu* 術 'methods' of calculation.[10] The one element absent from the *Wu xing zhan* is the 'methods'; otherwise, the difference between them comes down to complexity. Take for instance their respective motion-degree models:

> 秦始皇帝元年正月，①歲星日行廿分，十二日而行一度，終【歲行卅】度百五分，見三【百六十五日而夕入西方】，②伏卅日，三百九十五日而復出東方。【十二】歲一周天，廿四歲一與大【白】合營室。
>
> On Qin Shihuang 1-I-[1], ① Year Star was [in Hall_{13}], traveling $\frac{20}{240}$ *du* per day, traveling 1 *du* in 12 days, and [traveling 30] $\frac{105}{240}$ *du* [in a complete year]. It is visible for 3[65 days before entering in the evening in the west], where ② it hides for 30 days. In 395 days it emerges again in the east. [In 12] years it makes one circuit through Heaven, and every 24 years it goes into conjunction with Great [White] (Venus) in Hall_{13} (*Wu xing zhan*, section 6, lines 89-90).[11]

> 木，①晨始見，去日半次。順，日行十一分度二，百二十一日。②始留，二十五日而旋。③逆，日行七分度一，八十四日。④復留，二十四日三分而旋。⑤復順，日行十一分度二，百一十一日有百八十二萬八千三百六十二分而伏。凡見三百六十五日有百八十二萬八千三百六十五分，除逆，定行星三十度百六十六萬一千二百八十六分。凡見一歲，行一次而後伏。日行不盈十一分度一

[10] For more details, see Teboul (1983) and Liu Hongtao (2003). Note that the Triple Concordance system is atypical of the tradition that proceeds it in two regards: one, it builds slight asymmetries into each of its motion-degree models; two, subsequent systems count synodic periods from conjunction rather than FMR. See also note 38.

[11] Throughout, the transcription and line numbers are those of Liu Lexian (2004). Note that while the text of the *Wu xing zhan* is frequently defective due to physical damage, transcriptions like Liu Lexian's are often able to confidently reconstruct missing numbers and text through calculation and/or textual parallels with received literature.

。⑥伏三十三日三百三十三萬四千七百三十七分，行星三度百六十七萬三千四百五十一分。一見，三百九十八日五百一十六萬三千一百二分，行星三十三度三百三十三萬四千七百三十七分。通其率，故曰日行千七百二十八分度之百四十五。

Wood (Jupiter): ① First morning visibility at half a station (15°) from the sun. Prograde: travels $\frac{2}{11}$ *du* per day, 121 days. ② First station: 25 days, then circles back. ③ Retrograde: travels $\frac{1}{7}$ *du* per day, 84 days. ④ Second station: $24\frac{3}{7308711}$ days, then circles back. ⑤ Return to prograde: travels $\frac{2}{11}$ *du* per day, $111\frac{1828362}{7308711}$ days, then hides (LES). Visible for a total of $365\frac{1828365}{7308711}$ days, and, minus retrograde, travels a fixed $30\frac{1661286}{7308711}$ *du* through the stars. It is visible for a total of one year, in which time it travels one station (30°) before hiding at an [average] rate of less than $\frac{1}{11}$ *du* per day. ⑥ Hidden: $30\frac{3334737}{7308711}$ days, travels $3\frac{1673451}{7308711}$ *du*. One [first] appearance: $398\frac{5163102}{7308711}$ days, $33\frac{3334737}{7308711}$ *du* travel through the stars. Connect (average) its rates, and it can thus be said that it travels $\frac{145}{1728}$ *du* per day (Triple Concordance system, *Han shu*, 21b.998).

In contrast to the Triple Concordance system, which derives comparatively precise planetary periods (S = 398.71 days, P = 11.92 years) from large resonance periods (1583 FMR : 1728 years), the *Wu xing zhan* adopts simple values for each ($S = 365\frac{165}{240}$ days $= \frac{13}{12}$ year, P = 12 years). Moreover, the *Wu xing zhan*'s periods appear to have been arrived at independent of one another since they do not exhibit the proportional relationship befitting planets' sidereal and synodic periods. [12]

[12] An understanding of this proportional relationship is evident already in the Triple Concordance system, which derives the superior planets' synodic arcs Δα (the angular distance traveled in one synodic period) from the length of the year E (= the circumference of Heaven) and a synodic period expressed in terms of appearances A : years Y. In symbolic form:

$$\Delta\alpha = \frac{Y - A}{A} \times E$$

In modern terms, $\frac{1}{P} = \frac{1}{E} - \frac{1}{S}$, where P is the planet's sidereal period, S is its synodic period, and E is the earth's sidereal period. According to the the Triple Concordance's formula, for example, the *Wu xing zhan's* synodic period for

Furthermore, whereas the Triple Concordance system divides its motion-degree models into numerous stages to account for prograde, station, and retrograde motion, the *Wu xing zhan* gives the superior planets constant angular velocities derived from their sidereal periods (Jupiter's $\frac{20}{240}$ *du*/day = 365¼ *du* ÷ (12 years × 365¼ days)). As Takeda (2010, pp. 9–12) convincingly argues, the *Wu xing zhan* also appears to place visibility phenomena at 0° from the sun, which is absurd compared to the Triple Concordance system's 'half station' (15°)—an appropriate average for Jupiter.

The *Wu xing zhan*'s system origin is also a problem. Though the manuscript itself gives us only a date (Qin Shihuang 秦始皇 1-I-[1] or 246 BC February 3), parallels with later descriptions of the Qin Zhuanxu system (*Zhuanxu li* 顓頊曆) and clues within the text itself confirm that this system origin also posited the coincidence on this date of the Enthronement of Spring (*li chun* 立春) and the FMR of the five naked-eye planets 5 *du* into the lodge Hall_{13}.[13] It is important to remember that a system origin need not be perfectly accurate so long as functions to produce accurate results for the intended age. In fact, both the *Wu xing zhan* and Triple Concordance's system origins make obvious concessions to political symbolism.[14] The difference is that the *Wu xing zhan*'s is

---

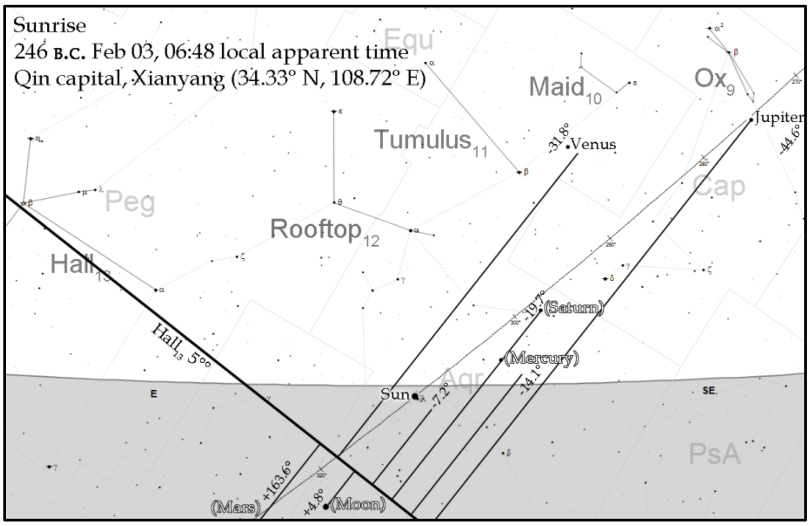
Jupiter would produce a sidereal period of 13 rather than 12 years. The results of this incongruence are evident in the discussion of the Jupiter table below.

[13] According to Liu Xiang's 劉向 (79-8 BC) *Hongfan zhuan* 洪範傳, "Calendrical records began with Zhuanxu, his high origin being the year Yanmeng-Shetige (year $\textit{jiayin}_1$), month Bi-Zou (month I), the day of the new moon, $\textit{jisi}_6$, the Enthronement of Spring, with the seven luminaries all at the fifth *du* of Hall_{13}" 曆記始於顓頊，上元太始閼蒙攝提格之歲，畢陬之月，朔日己巳立春，七曜俱在營室五度 (cited in *Xin Tang shu* 新唐書, 27a.602–603). Cai Yong 蔡邕 (AD 133-192), Liu Hong, and Dong Ba 董巴 (fl. third century AD) provide similar descriptions of the Qin 秦 (221-206 BC) Zhuanxu system (*Hou Han shu*, *zhi* 2, 3039 [commentary], 3042–3043; *Jin shu*, 17.502). While the exact date of the Zhuanxu system origin, which scholars place in 366 BC does not coincide with the *Wu xing zhan*, these and other coincidences are sufficient to attribute the astronomical contents of the *Wu xing zhan* to the Qin Dynasty; see Mo Zihan (2011), pp. 121-122. The system origin date, Qin Shihuang 1-I-1, corresponds to 246 BC February 3 of the proleptic Julian calendar based on the reconstructions of the Qin calendar in Zhang Peiyu (2007) and Li Zhonglin 李忠林 (2010).

[14] Cullen (2007) provides insightful analysis of the requirements for a system origin's accuracy and functionality. On the politics and political significance of the Triple Concordance/Grand Inception (*Taichu li* 太初曆, 104 BC) system origin, see Cullen (1991). In the case of the *Wu xing zhan* and Zhuanxu system origin, a five-planet convergence on the first day of the first month of the first year of the

dramatically more inaccurate: at system origin the planets were spread out over half the sky (none of them in $Hall_{13}$), and half of them were invisible, their FMR having likely occurred several weeks apart (fig. 3).

Figure 3. Eastern horizon at *Wu xing zhan* system origin

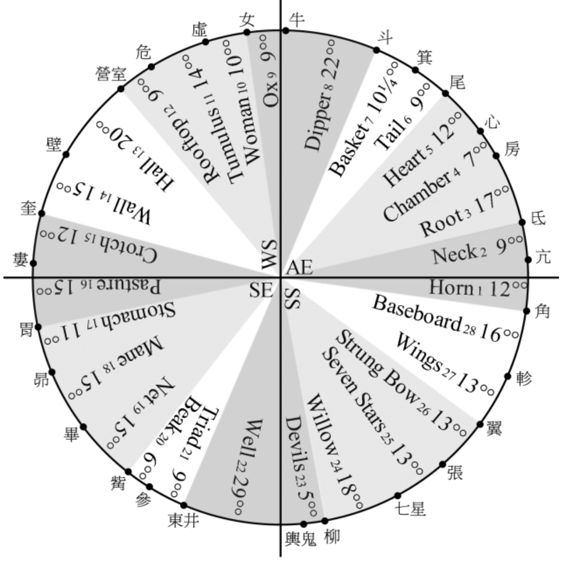


NOTE: Figure produced by *Alcyone Ephemeris* v3.2 and modified by the author to show the Chinese lodge system. Distances from $Hall_{13}$ 5°° (taking η Pegasi as $Hall_{13}$ 0°°) are given in degrees of right ascension (RA). Parentheses indicate bodies not yet visible at dawn.

---

first emperor of Qin in $Hall_{13}$ (also known as Tianmiao 天廟 "the Celestial Temple," which is associated with the north and the virtue water, the symbols of the Qin) is as unambiguous an affirmation of its Heavenly Mandate as is possible. The *Kaiyuan zhanjing* for example quotes a *He tu* 河圖 to the effect that, "if the chronogram essence (: Mercury : water : black) commands the five essences (planets) to converge in [one of] the seven lodges of the north, then the Black Emperor (: water : Qin) will arise by virtue of clear peace, quiet purity, and penetrating perspicacity" 辰精帥五精聚于北方七宿，黒帝以清平、靜潔、通明起 (*Kaiyuan zhanjing*, 19.3b).

Figure 4. The 28 lodges of the 'ancient degree' system



NOTE: the celestial coordinate system illustrated here is polar-equatorial, with 365.25°° = 360°, and the vertical and horizontal lines representing the solstitial (S) and equinoctial (E) colures, respectively. The 2- and 3-lodge zones indicated in differing shades are the 12 Jovian stations (below). On the *gu du* 古度 'ancient-degree' system current in the third and early second centuries BC, see Pan Nai 潘鼐 (2009), pp. 29-41 and Sun Zhanyu 孫占宇 (2011).

Tianwen

Next to the *Wu xing zhan*, the earliest reliable self-described works of *tianwen* are the *Huainanzi* 淮南子 (139 BC) "Tianwen xun" 天文訓 and the *Shiji* 史記 (91 BC) "Tianguan shu" 天官書 treatises. Equally valuable are later compendia like the *Kaiyuan zhanjing* 開元占經 (AD 729), which preserve numerous quotations from omen literature dating to the centuries before and after the aforementioned works. Planetary models are one of the places that the spheres of *tianwen* and *li* literature overlap. Both genres value quantitative knowledge, but they deploy it to contrary ends: *li* manuals, to the end of prediction (and retrodiction), and *tianwen* omen series, as normative bases for the identification and interpretation of celestial anomalies. Distinct in function, *tianwen*- and *li*-literature planetary models tend to take distinct forms. In general, *tianwen* models are simpler and more conservative than contemporary *li* models, and many are embedded in the idiom of observational astronomy, concerning themselves with altitude, angular measures of 'inches' (*cun* 寸) and 'feet' (*chi* 尺), and so on. The most distinctive feature of early *tianwen* planetary models, however, is the intellectual influence of hemerology (calendar divination).[15]

As we now know from an increasing number of excavated 'daybooks' (*rishu* 日書), hemerology appears to have enjoyed massive popularity in the early imperial period. Hemerology features a wide variety of schemes for determining the auspiciousness of times and directions for performing everyday activities, the more complex of which involve calendar deities and mantic functions moving through schemata arranged around the *tiangan dizhi* 天干地支 'heavenly branches and earthly stems,' e.g. the chord-hook diagram common to *shipan* 式盤 diviner's boards. The clearest example of how hemerology and early planetary astronomy bled together is Taiyin 太陰. Taiyin is a terrestrial deity that moves clockwise through the twelve branches at the rate of one per year, mirroring Jupiter's roughly 12-year sidereal period. Once referred to as 'Counter-Jupiter,' it is actually Taiyin that determines the planet's position, month of FMR, and the progression of the twelve so-called 'Jovian years.' The *Wu xing zhan*, with ample parallels to early sources like the *Huainanzi* and *Shiji*, offers us the following descriptions:

> 歲處一國，是司歲。①歲星以正月與營宮晨【出東方，其名為攝提格。②其明歲以二月與東壁晨出東方，其名】為單閼。③其明歲三月與胃晨出東方，其名為執徐。④其明歲以四月與畢晨【出】東方，其名為大荒【落。⑤其明歲以五月與東井晨出東方，其名為敦牂。⑥其明歲以六月與柳】晨出東方，其名為汁給。⑦其明歲以七月與張晨出東方，其名為芮堇。⑧其明歲【以】八月與軫晨出東方，其【名為作噩】。⑨【其明歲以九月與亢晨出東方，其名為閹茂】。⑩其明歲以十月與心晨出【東方】，其名為大淵獻。⑪其明歲以十一月與斗晨出東方，其名為困敦。⑫其明歲以十二月與虛【晨出東方，其名為赤奮若。⑬其明歲與營室晨】出東方，復為攝提【格，十二歲】而周。皆出三百六十五日而夕入西方，伏卅日而晨出東方，凡三百九十五日百五分【日而復出東方】。

[15] An excellent sampling of such *tianwen* planetary models can be found in *juan* 23, 30, 38, 45, and 53 of the *Kaiyuan zhanjing*. On the use of linear measures in Chinese observational astronomy, see Wang Yumin 王玉民 (2008). On hemerology, see Kalinowski (1986) and Liu Lexian (2002). The following discussion of the hemerological mechanics of *tianwen* planetary models is developed from Mo Zihan (2011).

[Jupiter] occupies one state per year, this is why it officiates the year. ① In month I, Year Star [emerges] in the morning [in the east] with Hall$_{13}$, [and its name is Shetige. ② In month II of the next year, it emerges in the morning in the east with Eastern Wall$_{14}$, and its name] is Chanye. ③ In month III of the next year it emerges in the morning in the east with Stomach$_{17}$, and its name is Zhixu. ④ In month IV of the next year it [emerges] in the morning in the east with Net$_{19}$, and its name is Dahuang[luo. ⑤ In month V of the next year it emerges in the morning in the east with Eastern Well$_{22}$, and its name is Dunzang. ⑥ In month VI of the next year] it emerges in the morning in the east with [Willow$_{24}$], and its name is Zhiji. ⑦ In month VII of the next year it emerges in the morning in the east with Strung Bow$_{26}$, and its name is Ruijian. ⑧ [In] month VIII of the next year it emerges in the morning in the east with Baseboard$_{28}$, and its [name is Zuoe. ⑨ In month IX of the next year it emerges in the morning in the east with Neck$_{2}$, and its name is Yanmao.] ⑩ In month X of the next year it emerges in the morning [in the east] with Heart$_{5}$, and its name is Dayuanxian. ⑪ In month XI of the next year it emerges in the morning in the east with Dipper$_{8}$, and its name is Qundun. ⑫ In month XII of the next year [it emerges in the morning in the east] with Tumulus$_{11}$, [and its name is Chifenruo. ⑬ The next year] it emerges [in the morning] in the east [with Hall$_{13}$], and is again Sheti[ge. In 12 years] it makes its circuit. It always emerges for 365 days before entering in the evening in the west and hides for 30 days before emerging in the morning in the east. In a total of 395 1[6]5/240 [days it reemerges in the east] (*Wu xing zhan*, section 1, lines 1-5).[16]

歲星與大陰相應也，大陰居維辰一，歲星居維宿星二，大陰居中辰一，歲星居中宿星【三】。□□□□□□□□□□□□□□□□□□□□□【歲】星居尾箕，大陰左徙，會於陰陽之界，皆十二歲而周於天地。

The Year Star and Taiyin correspond. When Taiyin occupies a corner (hook) chronogram (earthly branch), Year Star occupies the two corner lodges, and when Taiyin occupies a center (chord) chronogram, Year Star

[16] For the correction of the text's "395 105/240 days" to "395 165/240 days," see Mo Zihan (2011), pp. 126–129.

> occupies the three center lodges. ... [Year Star] occupies Tail$_6$ and Basket$_7$. Taiyin shifts left (clockwise) and they meet at the boundaries of *yin* and *yang*, circling Heaven and Earth, respectively, in 12 years (*Wu xing zhan*, section 1, lines 42-43).[17]

All of this makes perfect sense in the mechanics of hemerology, where we might expect Jupiter (and its visibility phenomena) to cycle incrementally forward through chronograms, years, and months like proper calendar deities, but these mechanics contradict contemporary astronomical knowledge in two regards. First, when the Jovian cycle repeats, FMR skips from 12-XII to 1-I (i.e. 13-I, exactly one month later) rather than 14-I (a full 13 months later, as we would expect), because this 12-year sidereal period is incompatible with a 13-month synodic period. The fact that Jupiter's mean sidereal period is actually 11.86 years further complicates matters, and the Triple Concordance system—which compensates by having the planet "exceed a chronogram" (*chao chen* 超辰) every 144 years—witnesses the first and last attempt to salvage the Jovian year count in *li* literature.

Second, while hemerological systems treat the 28 lodges that constitute the Chinese celestial coordinate system as even counters, they are in actuality zones of uneven width (compare fig. 4 and fig. 5). In the 'ancient degree' system used by the *Wu xing zhan*, for example, the Taiyin model has Jupiter travel two- and three-lodge zones varying from 15 to 44 *du* in equal durations of time (365¼ *du* = 360°). Likewise, the omenological portion of the *Wu xing zhan* parallels early *tianwen* models in positing that Mercury appears four times a year at the solstices and equinoxes at stark odds with its mean synodic period of 115.88 days (cf. the Triple Concordance's 115.91 days).[18] It also parallels models that describe Saturn as traveling one lodge per year for 28 years, though in the computational portion of the text it later attributes the planet a sidereal period of 30 years (cf. its actual mean sidereal period of 29.49 years):

> 實填州星，歲□□□□□□□□□□□既已處之，有（又）【西】東去之，其國凶。

[17] I have not corrected the names of the Jovian years to accord with received parallels as does Liu Lexian (2004), pp. 30-32. Note that received sources combine the Jovian year-count and Taiyin model (also known as Taisui 太歲 and Suiyin 歲陰); for parallels see *Erya zhushu* 爾雅注疏, 5.17b-18a; *Han shu*, 26.1289-1290; *Huainan honglie jijie* 淮南鴻烈集解, 3.117-120; *Kaiyuan zhanjing*, 23.2b – 10a; Shiji, 27.1313-1316. Important studies of the Jovian/Taiyin year-count include Wang Shengli 王勝利 (1989) and Tao Lei 陶磊 (2003), pp. 73-97.

[18] Teboul attempts to explain these models in (1983), pp. 134–137, 143–145.

> Verily, the star that quells provinces (Saturn), each year... If it has already dwelt there but leaves to the [west] or east, that state is ill-fortuned (*Wu xing zhan*, section 3, line 51)

> 歲填一宿，其所居國吉。...又西東去，其國失土。...歲行十三度百十二分度之五，日行二十八分度之一，二十八歲周天。
>
> Each year [Saturn] quells one lodge. The state in which it dwells is fortuned. ... If it leaves to the west or east, that state will lose earth (territory). ... It travels 13 $\frac{5}{112}$ *du* per year—$\frac{1}{28}$ *du* per day—and completes one circuit of Heaven in 28 years (*Shiji*, 27.1319-1320).[19]

Compare these to the computational model following the Saturn table:

> 秦始皇帝元年正月，填星在營室，日行八分，卅日而行一度，終歲行【十二度卌二分】，【見三百四十五】日，伏卅二日，凡見三百七十七日而復出東方，卅歲一周于天，廿歲與歲星合爲大陰之紀。
>
> Qin Shihuang 1-I-[1], Quellor Star is in Hall$_{13}$. It travels $\frac{8}{240}$ *du* per day, traveling 1 *du* in 30 days, and $\left[12\,\frac{42}{240}\right]$ in one complete year. [It is visible for 345] days and hidden for 32 days. In total, it emerges again in the east 377 days after [first] appearing. In 30 years it makes one circuit around Heaven, and in 20 years it goes once into conjunction with Year Star for a Taiyin era (*Wu xing zhan*, section 7, lines 121-122).

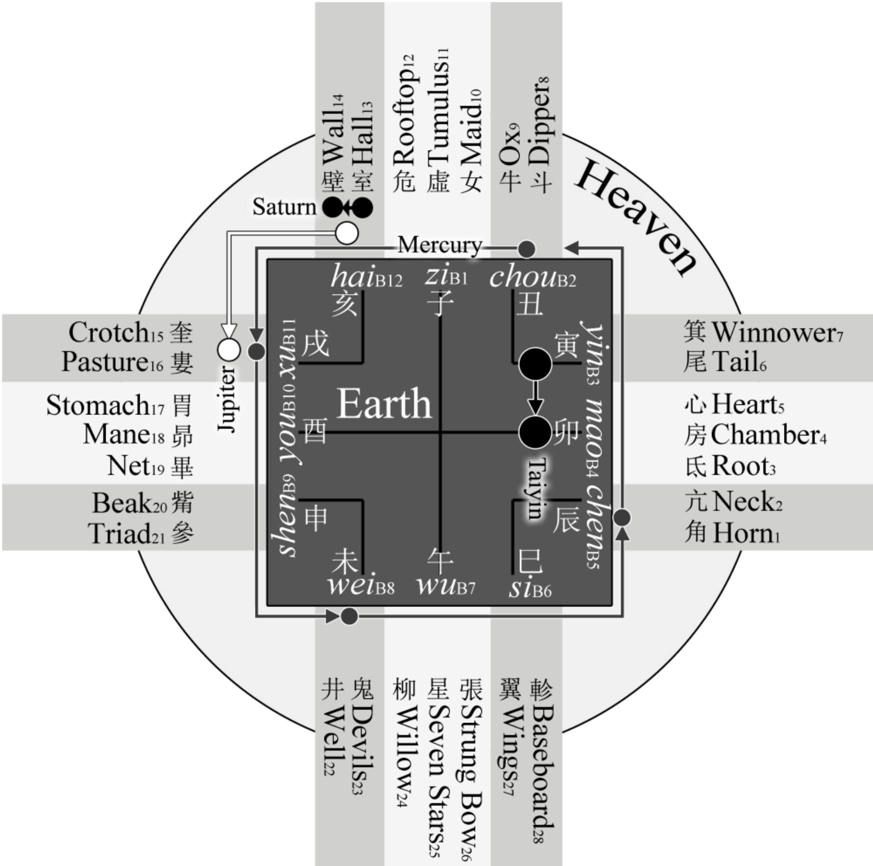
* * *

The *Wu xing zhan* contains what later actors would categorize as distinct bodies of planetary knowledge: *li*-like mathematical models, which count out cycles to a precision of 1/240 of a day and *du*, and *tianwen*-like omenological models, which use cruder measures like years, months, and lodges, and which are bound up in the mechanics of hemerology in a way that conflicts with the logic of mathematical models. When compared to the motion-degree models of later *li* literature the models in the *Wu xing zhan*'s computational sections look less like coherent systems than independent pieces of observational and theoretical knowledge that have been cobbled together. Nonetheless, the fact that they occur in the

---

[19] For parallel descriptions, see also *Huainan honglie jijie*, 3.90; *Kaiyuan zhanjing*, 38.2b–5b.

Figure 5. Hemerological planetary models on a chord-hook diagram (year 1 of 60)



same manuscript with, but clearly segregated from, hemerological *tianwen* models suggests that something like the *tianwen*/*li* distinction does go back to the time of the *Wu xing zhan*.

The Tables

When discussing the *Wu xing zhan* tables, it is best to work backwards from Venus. Due to the complexity inherent in the planet's apparent behavior (and the text's model thereof), the table for Venus is more complex than those for Jupiter and Saturn and, thus, provides an important point of reference concerning the tables that precede it. The computational portion of the *Wu xing zhan*, it will be remembered, is silent on Mars and Mercury. The case of Mars is easy to understand: earlier on, the manuscript complains that "[its advancing and retreating] are without constancy and cannot be taken as [a standard]" 【進退】無恒，不可為【極】 (section 2, line 45). Surprisingly, the *Wu xing zhan* is rather more sanguine about the prospects of modeling Mercury—a planet whose apparent behavior is, to make things worse, as difficult to see as it is to model—but since it attributes the planet with an idealized seasonal pattern (above), the same from year to (solar) year, a year-by-year table would seem unnecessary.

On the Venus table (lines 123-142), each column describes the 'month' (*yue* 月) of a visibility phenomenon, the lodge in (*yu* 與, lit. 'with') which the planet/sun rise, and the period between this and the next phenomenon. Every other column or so are also numbers marked with *yu* 余 'remainder' and *qu* 取 'take' and the year in which said phenomenon occurs. The years are counted in reign periods, and those above 10 are abbreviated, such that years 11, 21, and 31 revert to 1. These years run (right to left) across several rows, each row (top to bottom) representing Venus' resonance period of 5 FMR : 8 years, such that the planet's visibility phenomena are shown to repeat exactly in each subsequent eight-year period. The number of days between each phenomenon is an exact match to the (*li*-like) motion-degree model following the table in lines 143-146. It is clear, therefore, that this table is the product of calculation rather than observation.[20]

First, let us consider the lodge-positions. Because the mean sun travels 1 *du*/day, and because the sun and planet are at the same position at 'emergence' and 'entry', the number of *du* traveled over each period necessarily equals the number of days elapsed. Thus, if we count out from a system origin with the sun and planets 5 *du* into Hall_{13} (as we can assume the compiler might have done), we should be able at assess whether and how the planet's lodge-positions were calculated. Doing so, Mo Zihan (2011, pp. 125-126, 132-134) shows that each and every position on the Venus table accords with calculation performed in this manner

[20] Initially declared "records of actually observed astronomical phenomena" (Liu Yunyou 劉雲友 [1978], p. 33), historians of astronomy now agree that the *Wu xing zhan* tables were computed. In reality, the planets' visibility phenomena are rather more capricious, dependent as they are on a host of geometric, atmospheric, and subjective variables. For an example of the later *li* tradition's attempt to address some of these variables, see Sivin (2009), pp. 516-550.

Table 1. *Wu xing zhan* Jupiter table (lines 77-88)

	Resonance period ← 1	← 2	← 3	← 4	← 5	← 6
FMR with Hall$_{13}$	QSH 1	3 234	5 222	[7] 210	9 198	[2] 186
… Eastern Wall$_{14}$	2 245	4 233	6 221	[8] 209	[10] 197	[3] 185
… Pasture$_{16}$	3 244	5 232	7 220	[9] 208	1 196	[4] 184
… Net$_{19}$	4 243	6 231	8 219	[40] 207	2 195	[5] 183
… Eastern Well$_{22}$	5 242	7 230	9 218	Han 1	XHui 1	[6] 182
… Willow$_{24}$	6 241	8 229	30 217	2 205	2 193	[7] 181
… Strung Bow$_{26}$	7 240	9 228	1 216	[3] 204	[3] 192	[8] 180
… Baseboard$_{28}$	8 239	20 227	2 215	[4] 203	4 191	[1] 179
… Neck$_{2}$	9 238	1 226	3 214	5 202	5 190	2 178
… Heart$_{5}$	10 237	2 225	4 213	6 201	6 189	3 177
… Dipper$_{8}$	1 236	3 224	5 212	7 200	7 188	
… Serving Maid$_{10}$	2 235	4 223	6 211	8 199	Rgncy	

NOTE: These tables abbreviate “emerge in the morning in the east” to FMR (first morning rising), “enter in the morning in the east” to LMR (last morning rising), “emerge in the evening in the west” to FES (first evening setting), and “enter in the evening in the west” to LES (last evening setting). Where present, the ‘remainder’ and ‘take’ numbers are marked +/−, respectively. Reign periods: QSH = Qin Shihuang 秦始皇 (r. 246/221-210 BC); RoC = Rise of Chu 楚; XHui = Han Xiaohuidi 漢孝惠帝 (r. 192-188 BC); GE/Rgncy = Regency of Empress Lü 呂. Note that the table reverts to 1 in 179 BC at the beginning of Han Wendi’s 文帝 reign (r. 179-157 BC). Underlining indicates contradiction.

Table 2. ***Wu xing zhan*** **Saturn table (lines 91-120)**

FMR with	Hall$_{13}$	1 QSH		1	216	2	186
""	Hall$_{13}$	2	245	2	215	3	185
""	E. Wall$_{14}$	3	244	3	214	4	184
""	[Crotch$_{15}$]	4	243	4	213	5	183
""	Pasture$_{16}$	5	242	5	212	6	182
""	Stomach$_{17}$	6	241	6	211	7	181
""	Mane$_{18}$	7	240	7	210	8	180
""	Net$_{19}$	8	239	8 RoC		1	179
""	Beak$_{20}$	9	238	9	208	2	178
""	Attack$_{21}$	10	237	40	207	3	177
""	E. Well$_{22}$	1	236	Han 1			
""	[E.] Well$_{22}$	2	235	2	205		
""	Demons$_{23}$	3	234	3	204		
""	Willow$_{24}$	4	233	4	203		
""	Seven Stars$_{25}$	5	232	5	202		
""	Strung bow$_{26}$	6	231	6	201		
""	Wings$_{27}$	7	230	7	200		
""	Baseboard$_{28}$	8	229	8	199		
""	Horn$_{1}$	9	228	9	198		
""	Neck$_{2}$	20	227	10	197		
""	Root$_{3}$	1	226	1	196		
""	Chamber$_{4}$	2	225	2	195		
""	Heart$_{5}$	3	224	XHui 1			
""	Tail$_{6}$	4	223	2	193		
""	Basket$_{7}$	5	222	3	192		
""	Dipper$_{8}$	6	221	4	191		
""	Led Ox$_{9}$	7	220	5	190		
""	Serv. Maid$_{10}$	8	219	6	189		
""	Tumulus$_{11}$	9	218	7	188		
""	Rooftop$_{12}$	30	217	GE 1			

Table 3. *Wu xing zhan* Venus table (lines 123-142)

I, FMR with Hall$_{13}$. In 224d LMR with Horn$_{1}$ in VIII.		[Qin 1]	[9] 238	[7] 230	5 222	3 214	Han 1	9 198	5 190	6 182
Travels submerged for 120d and FES with Tumulus$_{11}$ in XII.	-21									
FES with Tumulus$_{11}$. In 224d LES with Wings$_{27}$ in VIII.		[2] 245	[10] 237	[8] 229	6 221	4 213	2 205	10 197	6 189	7 181
Hides for 16d and 96 parts and FMR with Baseboard$_{28}$.										
FMR with Baseboard$_{28}$ in VIII. In 224d LMR with Mane$_{18}$ in III.	+78									
Travels submerged for 120d and FES with... in <u>IX</u>.		3 244	[1] 236	9 228	7 220	5 212	3 204	1 196	7 188	8 180
FES with Wings$_{27}$ in <u>VIII</u>. In 224d LES with Pasture$_{16}$ in II.	+57									
Hides for 16d and 96 parts and FMR with Mane$_{18}$ in III.		4 243	[2] 235	20 227	8 219	6 211	4 203	2 195	GE 1	1 179
FMR with Mane$_{18}$ in III. In 224d LMR with Basket$_{7}$ in XI.										
Travels submerged for 120d and [FE]S with Pasture$_{16}$ in III.	+52									
FES with Pasture$_{16}$… In 224d LES with Heart$_{5}$ in X.		5 242	[3] 234	[1] 226	9 218	7 210	5 202	Hui 1	2 186	2 178
… for 16d and <u>90</u> (96) parts and FMR with Basket$_{7}$ in XI.	-73									
FMR with Basket$_{7}$ in XI. In 224d LMR with Willow$_{24}$ in VI.		6 241	[4] 233	[2] 225	[30] 217	[8] 209	6 201	2 193	3 185	3 177
Travels submerged for 120d and FES with Heart$_{5}$ in IX.	-94									
FES with Heart$_{5}$ in IX. In 224d LES with Well$_{22}$ in V.		7 240	[5] 232	[3] 224	[1] 216	[9] 208	[7] 200	3 192	4 184	
Hides for 16d and 96 parts and FMR with Devils$_{23}$ in <u>IX</u>.										
FMR with Devils$_{23}$ in <u>VI</u>. In 224d LMR with Western Wall$_{13}$ in I.	+5									
Travels submerged for 120d and FES with Well$_{22}$ in V.		8 239	[6] 231	[4] 223	[2] 215	[40] 207	[8] 199	4 191	5 183	
FES with Well$_{22}$ in X. In 224d LES with Tumulus$_{11}$ in XII.										
...6d and 96 parts and FMR with Eastern Wall (Hall$_{13}$) in I.										

against the 'ancient degree' lodge system. Thus, the lodge-positions were not only calculated, they were calculated correctly—correctly, that is, in terms of internal consistency.

The dates are a more complicated matter. Features of the *Wu xing zhan* tables are inconsistent with the civil calendar. First, the civil calendar of the time began on month X (Oct/Nov) not, as the tables do, on month I (Jan/Feb). Second, the civil calendar was lunisolar, fixing the *nian* 年 'civil year' of 12 or 13 lunar months (of 354/355 and 384/385 days, respectively) to the *sui* 歲 'solar/agricultural year' of 365¼ days by means of a 19-year intercalation scheme (19 years = 19 × 12 + 7 lunations = 235 lunations).[21] The tables, however, make no mention of intercalary months; nor are the 12, 30-, and 8-*sui* patterns of repetition around which they are compiled compatible with a 19-year intercalation scheme.

The *yue* 'month'-dates of the Venus are, as Cullen (2011b) details, an even bigger problem. First, because Venus' 8-year cycle does not fit neatly into a 19-year intercalation scheme, the planet's phenomena could not possibly be expected to reoccur in the same civil months every cycle—mismatched with the sequence of big, small, and intercalary months, the regular sequence of visibility phenomena would slide forward and backward through the months. What is more, in 10 out of 20 entries the difference in month-dates (assuming a lunation of ≈29.5 days) falls short of the corresponding number of days elapsed between phenomena—a shortfall for which no one 8-year stretch of intercalation in effect between 246-177 BC can effectively compensate. Lastly, two of the month-dates are simply impossible, and two (which appear twice) are contradictory.[22]

---

[21] On *sui* and *nian*, see note 34.

[22] Cullen (2011b) introduces these problems and attempts to explain them by reading these *yue* as civil months and attempting to find an optimal intercalary scheme for a single 8-year window:

> Trial and error shows that the best results are produced if an intercalation is inserted after the 9th months of year 3 and year 6 of the 8-year sequence. In that case, leaving on one side the two impossible months already mentioned, it is found that 15 out of the remaining 18 months can be predicted by using the stated intervals between events and assuming that the first event falls at the start of month 1… But as already mentioned, the pattern of intercalations in subsequent 8-year cycles must be different (p. 247-8).

Archeology has now provided us calendars and dates sufficient for Zhang Peiyu (2007) and Li Zhonglin (2010) to reconstruct the civil calendar of the 70-year

Reading the *Wu xing zhan* tables in civil time is problematic, so let us set aside for a moment our sense, in Chinese studies, of the inevitability of the civil calendar. Yabuuti (1982, p. 6) urges us to consider the possibility that these are "solar calendars" and that "the *yue* here is not that of the lunisolar calendar but refers instead to solar months"—that is to say a year of 365¼ days (a *sui* in astronomical terms) divided into twelve $30\frac{21}{48}$-day solar 'months' counted from the nodal *qi* Enthronement of Spring.

This is certainly true of the year. A 365¼-day year neatly coincides with the value that the text gives for Venus' synodic period ($8 \times 365\frac{1}{4} = 5 \times 584\frac{96}{240} = 2922$ days), such that "it takes eight years [in total for it to emerge from and enter the east five times each and re]emerge in the morning in the east with Hall$_{13}$" 【凡出入東方各五，復】與營室晨出東方，爲八歲 (lines 145-146). Furthermore, inspection reveals that the 'remainder' and 'take' numbers (which come before each new year) indicate the number of days, plus-or-minus, from the first day of the year *as counted in 365¼-day units* from year 1, month I, day 1 of each 8-year period.[23]

---

period of the *Wu xing zhan* tables with a reasonable degree of certainty. According to their reconstructions, none of the 8-year windows beginning from 246 BC match the optimal pattern that Cullen offers. The closest that Zhang and Li's reconstructions come are in the windows 206-199 BC, 198-191 BC, 190-183 BC (all with intercalary month IX^2 in year 2, year 5, and year 8), and 182-175 BC (intercalary month IX^2 in year 3, year 5, and year 8), which accommodate 14 out of the 20 month-dates (other windows accommodate between 7 to 12).

[23] The *Wu xing zhan*'s motion-degree model has Venus alternate between periods of 224, 120, 224, and 16.4 days for a synodic period of 584.4 days. If, as I have marked on Table 3, we take the 'remainder' and 'take' numbers to be the positive and negative discrepancy in days between said phenomena and the beginning of the next year, respectively, then we find the following:

Year	±	Explanation of ± Day-Numbers
1	−21	$224 + 120 = 344 = 365 - 21$
2	+78	$344 + (224 + 16.4 + 224) = 808.4 = (365 + 365.4) + 78$
3	+57	$808.4 + (120 + 224) = 1152.4 = (2 \times 365 + 365.4) + 57$
4	+52	$1152.4 + (16.4 + 224 + 120) = 1512.8 = (2 \times 365 + 2 \times 365.4) + 52$
5	−73	$1512.8 + (224 + 16.4) = 1753.2 = (2 \times 365 + 3 \times 365.4) - 73$
6	−94	$1753.2 + (224 + 120) = 2097.2 = (3 \times 365 + 3 \times 365.4) - 94$
7	+5	$2097.2 + (224 + 16.4 + 224) = 2561.6 = (3 \times 365 + 4 \times 365.4) + 5$
8		$2561.6 + (120 + 224 + 16.4) = 2922 = (3 \times 365 + 5 \times 365.4) = \mathbf{8 \times 365.25}$

Though he maintains that the *Wu xing zhan* tables are necessarily plotted onto the lunisolar civil calendar, Cullen too concludes from these numbers that that "each

A solar year, as Yabuuti (1982) suggests, would seem to imply solar 'months'. The *concept* is not without precedent, indeed the 1/12–*sui* solar 'month' is at the heart of Liu Xin's (*li*) planetary methods as well as, it seems, the *Wu xing zhan* Jupiter table (below).[24] True, it is atypical for *yue* 'moon/month' to refer to such a solar 'month' (Liu Xin, for example, uses the term *zhong* 中 'medial-[*qi*]') but neither is it unprecedented, as we will see later in this article. Either way, the debate surrounding the "Xia xiao zheng" 夏小正 10-*yue* calendar preserved in the *Da Dai Liji* 大戴禮記 raises the very real possibility that, at around the time of the *Wu xing zhan*, the term *yue* could indeed refer to solar periods abstracted from the ≈29.5-day lunation.[25] So, does Yabuuti's solar calendar solve the problem of the Venus table month-dates? Yes and no. It certainly facilitates the neat repetition of the planet's 8-*sui* cycle of visibility phenomena (as well as the other tables' 12- and 30-*sui* cycles). However, such an arrangement is still inconsistent with 7 of the Venus table's 20 month-dates per cycle, faring only moderately better than the civil calendar over the same 70-year period.[26] In the end, whatever sort of calendar its compiler intended, these problems and the presence of impossible and contradictory month-dates suggest that the *dates* of Venus table way well have suffered miscalculation or corruption.

Now that we have an idea of the calendrical idiosyncrasies present in the Venus table, let us return to the superior planets. The latters' visibility tables are considerably simpler, omitting LES, month-dates, days elapsed, as well as 'take' and 'remainder' numbers. In the Jupiter table (lines 77-88), each column describes a *synodic* phenomenon, but the table itself is arranged around the planet's 12-*sui* *sidereal* period. Like the hemerological *tianwen* models of the omen section, the table thus confuses the relationship between the two, having synodic phenomena repeat every 13th rather than 14th year in a way that is inconsistent with

year apparently being (sic.) reckoned as 365 days"; see Cullen (2011a), pp. 244-245.

[24] For a detailed explanation of Liu Xin's planetary methods and his use of the *zhong* 中 solar month, see Liu Hongtao (2003), pp. 15-22, 37-49.

[25] For the case that the "Xia xiao zheng" is a solar calendar divided into 10 solar 'months' roughly 36 days in length, see Chen Jiujin (2001), pp. 310-333.

[26] Namely, assuming 1/12-*sui* solar 'months' beginning at 1-I-1, LES1 falls 20 days into 2-VII rather than 2-VIII; FES2 falls 15 days into 3-VII rather than 3-VIII; LMR3 falls 23 days into 5-X rather than 5-XI; FES3 falls 21 days into 5-II rather than 5-III; FMR4 falls 18 days into 6-X rather than 6-XI; LMR4 falls 29 days into 6-V rather than 6-VI; and FMR5 falls 24 days into 7-V rather than 7-VI. Between 246-175 BC this accommodates a total of 117 out of 180 month-dates, whereas the civil calendar accommodates 107 over the same period.

the mathematical model that immediately follows it (lines 89-90). In fact, given the periodicities with which the text ascribes it, the planet's sidereal and synodic periods would coincide only after 156 solar years (that is 12 × 13 *sui*), which would not permit a compact, repeating table like that for Venus.

That said, the table's compiler did not simply repeat the above *tianwen* models. Period *tianwen* texts like the *Huainanzi* and *Shiji* have the calendar deity Taiyin/Taisui determine the time and place of Jupiter's FMR in the idealized space of a chord-hook diagram; however, both here and in the Jovian year list in lines 2-5 the lodges of FMR correspond not to the Taiyin/Taisui scheme but the ancient-degree *richan* 日躔 'solar steps'—the lodge-position of the sun at 1/12-*sui* intervals through the solar year—as recorded in era daybooks. Mo Zihan (2011: 126-129) argues that the coincidence of the successive lodge-positions along Jupiter's 13-'month' (1 1/12-*sui*) synodic period with the successive lodge-positions of the sun at 1/12-*sui* intervals through the solar year is further evidence that the *Wu xing zhan* tables are operating on solar time.[27]

Other than being organized around a 30-year sidereal period, the Saturn table (lines 91-120) is identical to that for Jupiter, and it too is at odds with the motion-degree model that follows (lines 121-122). Like the case of Jupiter, the compiler takes recourse to the *tianwen* model, moving Saturn one lodge per year despite the unevenness of the lodges and the skill with which he was able to compute them in the case of Venus. In a concession to the 30-year period of the mathematical model, however, he repeats 2 of the 28 lodges, choosing two of the largest ones. Here we have an interesting paradox: the compiler treats the lodges as all the same until it comes time to plug a gap, at which point he relies on his knowledge of how they are not all the same.

---

[27] Kalinowski (1996) demonstrates that the lodge-positions that third- and second-century BC daybooks attach to each *yue* of the year are part of a hemerological (and thus non-astronomical) day-count, but notes that "the choice of the twelve new-moon lodges was closely related to observations of the sun's sidereal positions in the course of the year" (p. 78)—i.e. the solar steps. For an excellent study of the solar steps as seen in excavated and transmitted literature, as well as a demonstration that the daybook *yue*-lodges correspond to the 'ancient-degree' solar steps, see Wu Jiabi 武家璧 (2003), pp. 265–272. For Takeda's argument that the *Wu xing zhan* places visibility phenomena at 0° from the sun, see above.

Table 4. Comparison of *Wu xing zhan* Jupiter FMR with 'ancient-degree' solar steps

Mo.	Solar steps	*Wu xing zhan*		
		Table	Year-count	Taiyin sys
I	13	13	13	13, 14
II	15	14	...	15, 16
III	17	16	17	17, 18, 19
IV	19	19	19	20, 21
V	22	22	...	22, 23
VI	24	24	...	24, 25, 26
VII	26	26	26	27, 28
VIII	28	28	28	1, 2
IX	3	2	...	3, 4, 5
X	5	5	5	6, 7
XI	8	8	8	8, 9
XII	10	10	11	10, 11, 12

NOTE: Lodges are given in numbers; for reference, see Figure 5. The 'Solar steps' column gives the 'ancient-degree' solar steps found in third- and second-century BC daybooks (source: Wu Jiabi 武家璧 [2003], p. 277, Table 12). Grey indicates a match between the 'ancient-degree' solar step and the 'monthly' FMR. Note that the solar step for month II is actually right on the border of lodges 14 and 15, making the *Wu xing zhan* Jupiter table a near match in this instance.

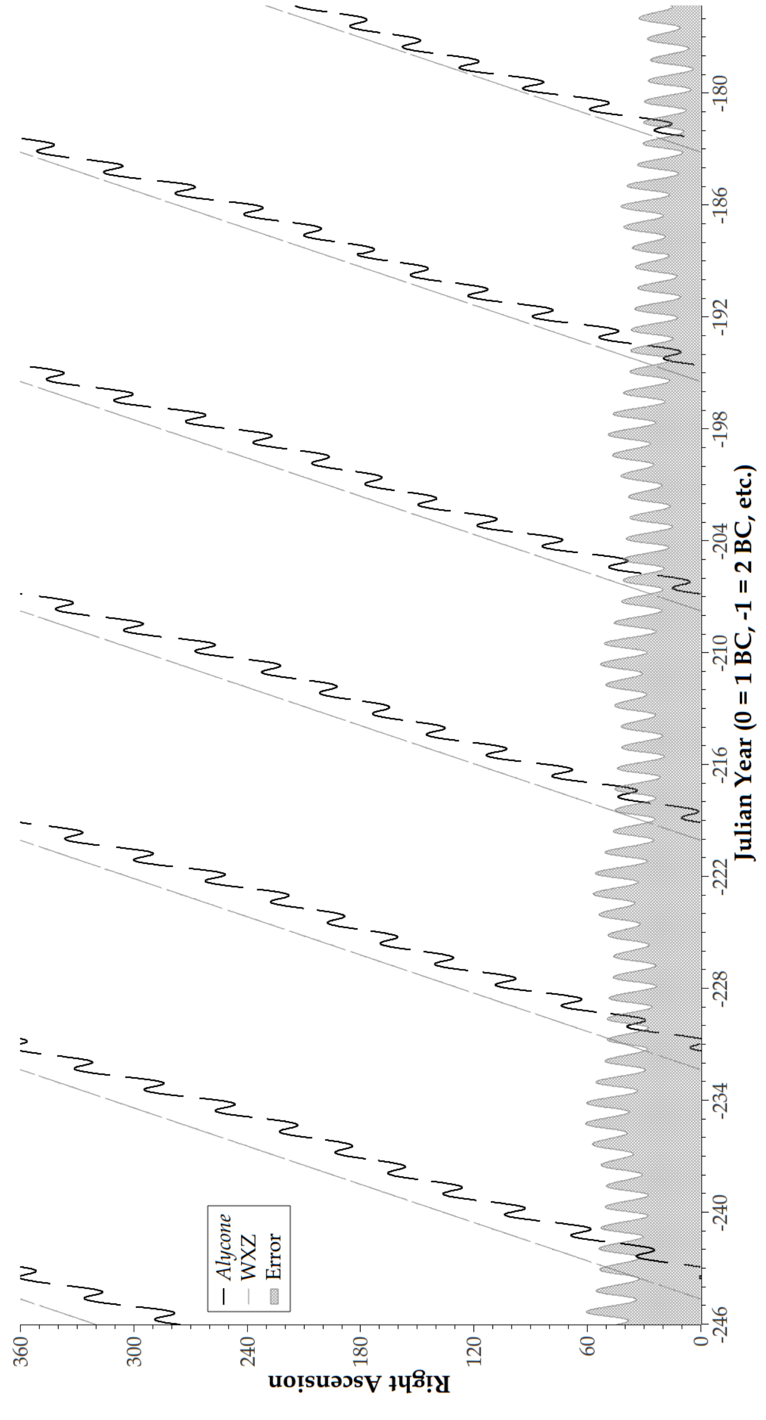
Accuracy

The Jupiter and Saturn tables are theoretically incoherent, but are they empirically inaccurate? Any answer to this question is bound to be unsatisfactory to the savvy historian of science given its subjectivity and the impossibility of retrodicting visibility phenomena—visibility itself being determined in part by atmospheric, physiological, and subjective factors. In addition, whether or not the text's hypothetical user considered it accurate depends upon if he consulted it as a solar or civil calendar or, indeed, if he consulted it at all. With these caveats in mind, Cullen (2011b) assesses the accuracy of predicted visibility phenomena against apparent phenomena retrodicted via computer program for the tables, concluding that the tables are off a large percentage of the time when read as civil calendars. Here I would like to plot the planets' calculated *positions* to illustrate a different set of issues.

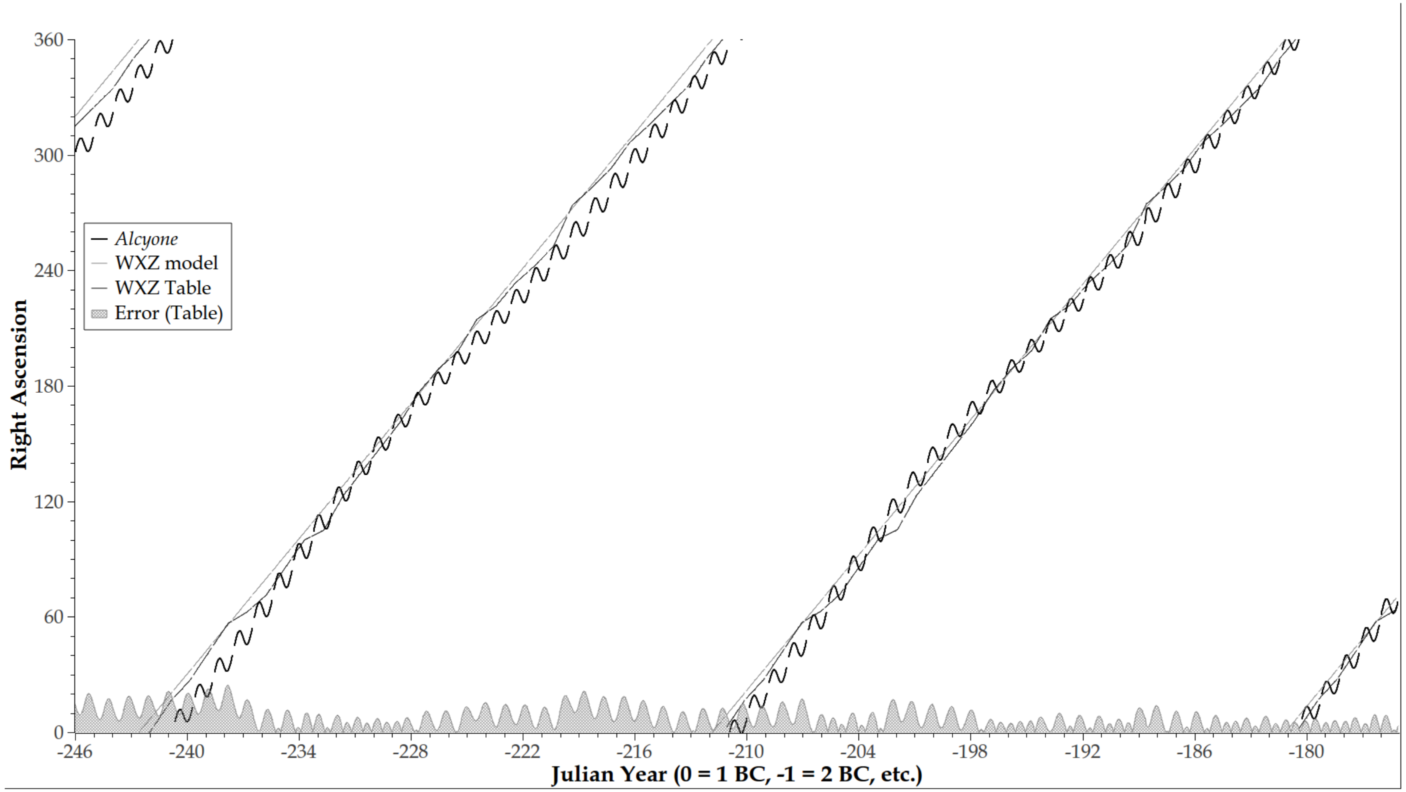
On Graphs 1 & 2 I have charted Jupiter and Saturn's right ascension over time as calculated from system origin (assuming Yabuuti's solar calendar) according to the parameters of the *Wu xing zhan* visibility tables and motion-degree models, and I compare these to results retrodicted from *Alcyone Ephemeris* v3.2.[28] Graph 1 illustrates what we might expect: the *Wu xing zhan* table/model's linear trajectory fails to capture the complexity of the planet's actual motions, and it begins and continues grossly out of sync. What is surprising is that the periods of invisibility (the line breaks) are aligned more or less throughout. This is a curious result of how the planet's synodic period resets every 12 years, as the extra solar month (or 12 missing solar months) effectively compensates

[28] My methodology is as follows. (1) For system origin, I chose 246 BC Feb 3 00:00 (JD 163 1604.5), corresponding to Qin Shihuang 1-I-1 00:00 on the *civil calendar*. This date is somewhat tentative, since we cannot know whether the calendar (civil or otherwise) placed the Enthronement of Spring on new moon or sometime nearer to true Enthronement of Spring (Feb 8, or winter solstice [247 BC Dec 25] + 3 × 365¼ ÷ 24 days)—given the errors involved, however, the effect of shifting system origin as far back as Feb 8 is negligible. (2) For the 'Alcyone' line, I used *Alcyone Ephemeris* to calculate the RA of each planet at three-day intervals from system origin; then, using *Planetary, Lunar, and Stellar Visibility* v3.1, I calculated the *rough* periods of invisibility, which I removed from the 'Alcyone' line (leaving only punctuated periods of visibility). (3) For the Jupiter graph '*Wu xing zhan*' line, I multiplied the motion-degree model's constant angular velocity (1/12 *du* per day) by the number of days elapsed since system origin to determine *du* travelled from Hall.$_{13}$ 5°°, *modulo* 365.25°° for full circuits of heaven; from this, I derived the planet's RA by converting from *du* to degrees, then adding the degrees travelled from Hall.$_{13}$ 5°° to the precession-corrected RA of the Hall.$_{13}$ guide star (+5°°), for which I selected η Pegasi according to Cullen (2011b), p. 227, Table 1, *modulo* 360°; lastly, I used the table's 1 *sui* : 1/12 *sui* sequence of visibility and invisibility to remove periods of invisibility. (4) The Saturn graph 'WXZ model' line is calculated in the same way, with the exception that it uses the motion-degree model's sequence of 345 days of invisibility followed by 32 days of invisibility. (5) The Saturn graph 'WXZ table' line is calculated by assuming the planet travels one lodge per *sui* at a constant rate averaged from the width of each lodge as given in the 'ancient-degree' system. (6) The 'Error' line represents the absolute value of the difference of the '*Wu xing zhan*' and 'Alcyone' lines.

Graph 1. ***Wu xing zhan*** **Jupiter table vs.** ***Alcyone Ephemeris*** **v3.2 computed RA**



Graph 2. ***Wu xing zhan*** **Saturn table vs.** ***Alcyone Ephemeris*** **v3.2 computed RA**



for the short 395.69-day synodic period.[29] Graph 2 illustrates much the same for Saturn, the exception being that Saturn, which began 24.9° closer to the idealized system origin, does essentially fall into sync over 70 years. What is surprising here is that the linear motion-degree model (avg. error 9.55°) is so crude that the table's hybrid one-lodge-per-year model (avg. error 7.35°) actually outperforms it. At this level of sophistication, the (*tianwen*-like) hemerological models seem to outperform the (*li*-like) mathematical models across the board, which leaves us to wonder whether the *tianwen*/*li* distinction might have been more fluid *in practice* than transmitted literature has led us to believe.

* * *

In conclusion, the *Wu xing zhan* planetary visibility tables appear to be arranged around a solar time frame distinct from the lunisolar civil calendar. In the Venus table, the allotment of lodges in which visibility phenomena occur demonstrate the compiler's understanding of contemporary astronomical knowledge like lodge-widths and his ability to do simple calendro-astronomical calculations; on the other hand, the month-dates are a mess and appear to either contradict this or suggest textual corruption. Furthermore, the Jupiter and Saturn tables are an amalgam of contradictory knowledge from the omenological and computational sections of the text. What makes this curious is the fact that we never see *tianwen* and *li* models adjoined, let alone *conjoined*, in the received tradition. What makes it even more curious is the fact that the tables' contravention of generic boundaries and theoretical incoherence appear to produce negligible if not positive effects for accuracy. In the end, the *Wu xing zhan* tables look nothing like what later *li* manuals instruct the user to compute, leaving us to wonder just how inchoate or atypical of later planetary tables they may be.

Later Planetary Tables

History, unfortunately, has left us little by way of comparison. Two examples of computed planetary tables survive from the early imperial period, both from completely different times and completely different

---

[29] The mean synodic period of Jupiter is actually 398.88 days. At this rate, it should take around 4388 days for 11 synodic periods to elapse, some 35 days longer than the *Wu xing zhan* (13/12 year × 11 years × 365¼ days ≈ 4353 days). Like an intercalary month added at the end of the year, the extra solar month reduces this discrepancy to less than 5 days in 12 years.

contexts. Yet, as different as they are, these tables exhibit a number of interesting commonalities with the *Wu xing zhan* that merit our attention.

Recorded in the *Jin shu* 晉書, the first appears in a calendro-astronomical debate of *circa* AD 226. The topic of debate is the accuracy of Han Yi's 韓翊 recently submitted Yellow Inception system (*Huangchu li* 黃初曆) *vis-à-vis* Liu Hong's famous Supernal Emblem system (*Qianxiang li* 乾象曆) of several decades earlier. Inserted somewhat arbitrarily into the text of the debate is a list, each line of which reads:

> 【星】以【年月日干支日】【晨/夕】【見/伏】；黃初【月日干支日】【見/伏】，【先/後】【幾】日；乾象【月日干支日】【見/伏】，【先/後】【幾】日。
>
> [Planet] [appeared/hid] in the [morning/evening] on [date]. Yellow Inception had it [appear/hide] on [date], [x] days [prior/after]. Supernal Emblem had it [appear/hide] on [date], [x] days [prior/after] (*Jin shu*, 17.500-502).

The form and function of this data are obviously distinct from the *Wu xing zhan* tables, though it may have been compiled from something similar. To begin with, this is more a *list* than a table (though I have reproduced it in table form in Table 5 for the sake of convenience). Furthermore, it compares dates in the civil calendar as we might expect.

Here, two points deserve special mention. First, Mars is absent, and for good reason. The behavior of 'the Sparkling Deluder' (Yinghuo 熒惑) is highly variable and difficult to model, which is probably why the *Wu xing zhan* does not even try. Echoing the *Wu xing zhan*—"[its advancing and retreating] are without constancy and cannot be taken as [a standard]"—Li Yexing 李業興 complains as late as AD 539 that "the [planet] Mars sometimes fails to accord with its [predicted] *du* since the essence of its appearance/disappearance is inherently inconstant" 熒惑一星，伏見體自無常，或不應度 (*Wei shu* 魏書, 107B.2698). In the third century AD, *li* planetary astronomy was ill-equipped to handle this variability, and so it makes sense that the Yellow Inception and Supernal Emblem systems would not be held accountable to this. Of course, the matter-of-fact models of *li* manuals tell us nothing of actors' *confidence* in said models. In the same vein, though *li* system manuals detail procedures for calculating the position and behavior of a planet at any given time, here, like in the *Wu xing zhan*, we see that the emphasis is still on first and last visibilities. That *visibility* is used as a criterion for judging a system's accuracy is noteworthy, since this is something equally beyond the third-century astronomer's ability to predict with any great accuracy, what with the atmospheric and subjective factors involved and his lack of anything more sophisticated than a fixed 'angle of invisibility' along the equator or ecliptic to determine visibility.[30]

Table 5: *Jin shu* Yellow Inception debate planetary system test results

1	2	3		4	5	6	7
no.	**Phenomena**	**Observed**		**Supernal Emblem**		**Yellow Inception**	
				Prediction	error	Prediction	error
Jupiter							
1	FMR	222	Jun 20	Jun 13	-9^{d}	Jun 11	-7^{d}
Saturn							
2	FMR	221	Dec 27	Dec 22	-5^{d}	Dec 19	-8^{d}
3	LES	222	Dec 02	Dec 02	$+0^{d}$	Nov 28	-4^{d}
4	FMR	223	Jan 11	Jan 04	-7^{d}	Jan 01	-10^{d}
Venus							
5	LMR	222	Aug 09	Jul 21	-19^{d}	Jul 18	-23^{d}
6	FES	222	Nov 02	Oct 11	-23^{d}	Oct 08	-25^{d}
Mercury							
7	FMR	221	Dec 18	Dec 14	-4^{d}	Dec 13	-5^{d}
8	LMR	222	Jan 13	Jan 15	$+2^{d}$	Jan 14	$+1^{d}$
9	FES	222	Jun 14	Jun 14	$+0^{d}$	Jun 13	-1^{d}
10	LES	222	Jul 09	Jul 16	$+7^{d}$	Jul 15	$+6^{d}$
11	FMR	222	Aug 19	Aug 03	-16^{d}	Aug 02	-17^{d}
12	LMR	222	Aug 31	Sep 04	$+4^{d}$	Sep 03	$+3^{d}$
13	LMR	223	Jan 03	Dec 29	-5^{d}	Dec 28	-6^{d}
14	FES	223	Feb 16	Jan 31	-16^{d}	Jan 31	-16^{d}

NOTE: Column 1 gives the number of each phenomenon; note that the text states that there are 15. Column 2 gives the type of phenomena: FMR for 'morning appearance' 晨見 (first morning rising), LES for 'hiding' 伏 (last evening setting), and for the inferior planets, LMR for 'morning hiding' 晨伏 (last morning rising), and FES for 'evening appearance' 夕見 (first evening setting). Column 3 gives the reported date of observation, converted to the Julian calendar. Columns 4 and 6 give the reported predictions of the Supernal Emblem and Yellow Inception systems. Columns 5 and 7 give the reported error from the observational results in Column 3.

The second set of computed planetary tables comes from the *Qiyao rangzai jue* 七曜攘災決 (*T* no. 1308). Preserved in the Japanese Taishō 大正 Buddhist canon, the text claims to have been "written and collated by the

[30] For discussion of the limitations of indigenous Chinese planetary models and methods later developed to adjust for seasonal variations in visibility, see Sivin (2009), pp. 32–33, 102–106, 516–550.

Brahmin monk of west India, Koṅta" 西天竺國婆羅門僧金俱吒撰集之 (*T* no. 1308, 426:b22) in the ninth century AD, shortly after which it was taken to Japan. Rather than the state-centered judicial astrology typical of *tianwen* literature, the *Qiyao rangzai jue* deals with horoscopy. It describes the nature and functions of the Seven Luminaries (sun, moon, and planets), Rāhu, and Ketu (here, the moon's ascending node and apogee, respectively), as well as how to counteract their untoward effects on personal fortune through apotropaic rituals. In the middle of the text we find motion-degree models and tables for the five planets. As we have them now, the latter are arranged around resonance periods that have been assigned to Japanese reign periods from the eleventh to twelfth centuries, though it stands to reason that the details of the tables themselves may have existed prior to that time. Each column of the tables represents a year, and each row a *yue* 'month', but it is difficult to understand where each row breaks in the Taishō edition because of the way that the text has been arranged for printing. Table 6 is thus provided according to Yano Michio's 矢野道雄 study of another Japanese manuscript edition of AD 1122.[31]

Unlike the *Wu xing zhan*, these tables detail the planet's position and/or behavior in each month and the specific date of each characteristic phenomena—first and last appearances, first and second station, and prograde and retrograde motion—which makes sense in the context of horoscopy where the question is the planet's position at any given time. Like the *Wu xing zhan*, however, the tables are arranged around the planet's resonance period, allowing the calendar years to repeat around it, each column of the Jupiter table being assigned to two sexagenary years in the Japanese calendar 83 years apart. The main difference in this arrangement then is that the *Qiyao rangzai jue* uses longer resonance periods befitting a proportional relationship between the planet's sidereal and synodic periods, i.e. 83 years = $76S = 7P$ for Jupiter. Also like the *Wu xing zhan*, the tables are compiled according to models that are significantly simpler than contemporary *li* (or *li*-like) ones. What is more, as in the *Wu xing zhan*, for these tables to repeat exactly over a given number of years the civil calendar will not do. Instead, the *Qiyao rangzai jue* explicitly employs a solar calendar, the details of which it describes later in the text:

[31] Yano (1986). Equally important is Niu Weixing 鈕衛星 & Jiang Xiaoyuan 江曉原 (1997). For studies of the other horoscopic materials in the Taishō canon, see Yabuuti (1961) and Niu Weixing (2004).

Table 6. *Qiyao rangzai jue* Jupiter table (excerpt)

	長承元壬子 1132 / 己丑 1049	辛亥 1131 / 戊子 1048	庚戌 1130 / 丁亥 1047	己酉 1129 / 丙戌 1046	戊申 1128 / 乙酉 1045	丁未 1127 / 寛德元甲申 1044	丙午 1126 / 癸未 1043	
8	7	6	5	4	3	2	1	yr/mo
	24th appear L_{12} 12°°	L_9 L_{10}	L_8	L_6	3rd stop L_3 1°°	Retreat	Retreat L_{26}	I
	L_{12}	L_{10}	L_8	4th stop L_6 6°°	Retreat L_2	Retreat L_{28}	22nd rtrt-stop L_{26} 8°°	II
	L_{13}	L_{11}	6th stop L_8 12°°	Retreat	L_2	22nd rtrt-stop L_{28} 1°°	Stop L_{26}	III
	L_{13}	14th L_{11} 4°°	Retreat	Retreat L_6	21st L_2 0°°	Stop	Stop L_{26}	IV
	27th stop L_{13} 14°°	L_{11}	Retreat	22nd stop L_4 5°°	Garrison L_2	Stop	L_{26}	V
⋮	Stop	L_{10}	24th rtrt-stop L_8 1°°	Garrison L_5	Garrison L_2	Stop	L_{27}	VI
	Retreat L_{13}	28th rtrt-stop L_{10} 5°°	Garrison L_8	L_5 L_6	L_2	Stop	9th hide L_{27} 8°°	VII
	L_{13}	Stop	L_8	L_6	L_3	10th hide L_{28} 19°°	11th appear L_{27} 12°°	VIII
	5th retreat L_{13} 3°°	L_{10} L_{11}	L_8	L_6	9th hide L_3 8°°	10th appear L_1	L_{27}	IX
	L_{13}	L_{11}	L_8	10th hide L_6 14°°	11th appear L_3 12°°	L_1	L_{28}	X
	L_{13}	L_{12}	13th hide L_8 20°°	13th appear L_7 3°°	L_4	L_2	L_{28}	XI
	L_{13}	16th hide L_{12} 3°°	17th appear L_9 4°°	L_7 L_8	L_5	L_2	4th stop L_{28} 12°°	XII

每年十二月皆以月節為正。其伏見入月日數各從節數之。假令三月十日者。當數清明後十日是也…推之考驗。往古及今。年所留宿度。若應符契分毫無差也。

> The 12 months (*yue*) of every year are all based on the nodal *qi* of the [civil] months. The number of days into each month of hiding, appearance, etc. are each counted from the nodal *qi*. Suppose that we have III-10: one should count 10 days after Pure and Bright (the nodal *qi* of month III). … Calculate it and examine the results: back to antiquity and up to today the lodge-degrees where [the planets] linger each year, like matching tallies, do not differ by a fraction of a hair's breadth (*T* no. 1308, 448: b7-c4).

The *qi* 氣 refer to the 24 divisions of the solar year, which alternate between 12 'nodal' and 'medial' *qi*. It turns out that this is *exactly the same calendar* as that that which Yabuuti (1982) argues to be the basis of the *Wu xing zhan* tables: a solar year of 365¼ days divided into 12 solar months and beginning on the nodal *qi* Enthronement of Spring.

Of course, it behooves us to question what connection a Buddhist horoscopy text necessarily has to indigenous traditions. In this case, the connection is unmistakable. Certain of the planets' resonance periods do coincide with Indian-language precedents, but the features of the text's planetary astronomy are wholly consistent with Chinese practices: the sky is divided into 365¼ *du*; the text uses 28 lodges of uneven size, whose widths it sets in accordance with Chinese 'polar-ecliptical' coordinates; the motion-degree models are consistent in style and approach with the Chinese variety; and so too is the calendar, beginning halfway between winter solstice and spring equinox and being based on the 24 *qi* rather than the position of the Sun in the Western zodiac.[32] From this it seems

[32] In contrast, the Indian-language tradition of calendro-astronomy divides the sky into 360° and 27 or 28 *evenly-sized* nakshatras, and it begins the solar year in Mesha, in March/April, which it divides by the zodiac rather than *qi* (though this does produce similar fortnightly periods). On this tradition, see Pingree (1978). For the identification of the lodge-widths reflected in the *Qiyao rangzai jue* solar-step table with Chinese 'polar-ecliptical' coordinates, see Yano (1986), pp. 29–30; Niu & Jiang (1997), pp. 243-244. While the *Qiyao rangzai jue*'s motion-degree models are typical of the Chinese tradition of *li*, similar models appear in other civilizations as well. For example, Alexander Jones has brought to my attention a Venus model in the second-century AD Greek papyrus 4135 from Oxyrhynchus that looks remarkably similar to the *Wu xing zhan*'s and that has clear parallels in Babylonian and Indian traditions (Jones, 1999 vol. 1, pp. 81-84; vol. 2, pp. 10-13). Lastly, Clemency Montelle has also drawn my attention to parallels between the

reasonable to attribute those features coinciding with the *Wu xing zhan* tables to Chinese tradition as well, be they the source of the *Qiyao rangzai jue* astronomy or indigenous conventions to which foreign knowledge was adapted.

The Chinese Solar Calendar?

Through many vicissitudes, the lunisolar civil calendar continued to enjoy official status until the Republic of China adopted the Gregorian calendar on January 1, 1912. The *Qiyao rangzai jue*, however, was not the last mention of our Enthronement of Spring solar calendar in pre-modern times. The idea appears again in Shen Gua's 沈括 (AD 1031-1095) *Mengxi bitan* 夢溪筆談 of AD 1088. Shen complains that the use of the lunar month makes the civil calendar needlessly complex and injurious to agricultural timing. He proposes the following solution:

> 今為術莫若用十二氣為一年，更不用十二月，直以立春之日為孟春之一日，驚蟄為仲春之一日，大盡三十一日，小盡三十日。歲歲齊盡，永無閏餘。十二月常一大一小相閒，縱有兩小相併，一歲不過一次。如此，則四時之氣常正，歲政不相陵奪， 日月五星亦自從之，不須改舊法。唯月之盈虧，事雖有繫之者，如海、胎育之類，不預歲時，寒暑之節，寓之曆閒可也。... 今此曆論，尤當取怪怒攻罵，然異時必有用予之說者。
>
> If today we were going come up with a new method, none would compare to using the 12 *qi* as a civil year rather than 12 lunar months, and directly taking the day of the Enthronement of Spring as the first day of the first 'month' (*yue*) of spring and Excited Insects as the first day of the second 'month' of spring. Big [months] would run 31 days and little [months] 30 days, each and every year being the same length, eternally free of the intercalary remainder. 12 'months' would always alternate between big and small, and even if there were two small ones together, this would happen at most once per year. In this way, the *qi* of the four seasons would always be correct, the agricultural and civil year would not conflict, the sun, moon, and planets would also naturally accord with it without

---

Qiyao rangzai jue's resonance periods for Jupiter (83 years = 76*S* = 7*P*), Mars (79 years = 37*S* = 42*P*), and Saturn (59 years = 57*S* = 2*P*) with texts of the Indian Brāhmapakṣa tradition in Pingree (1970), p. 104.

> having to change old methods. Though it is connected with things like tides and gestation, the waxing and waning of the moon alone has no relationship to the year and the rhythm of cold and hot, and thus noting it in the calendar would be fine. ... I expect this discourse of mine on *li* (the calendar) should meet special condemnation, but at some other time my idea will definitely see use (*Mengxi bitan jiaozheng* 夢溪筆談校證, entry 545).

Whatever originality he claims for his idea, it is identical in every detail to the calendar underlying the *Wu xing zhan* and *Qiyao rangzai jue* tables. In fact, Shen Gua himself seems to hint at an old astronomical precedent for this—"the sun, moon, and planets would also naturally accord with it without having to change old methods"—but can we imply from this the idea of a practical tradition of table-making (on which transmitted *li* literature is silent, no less) connecting sources centuries and centuries apart?[33]

Let us say that the exact same solar calendar was independently introduced some three different times over the early imperial period—this would, at the very least, indicate to us that it was a perennially good idea. The *Wu xing zhan* and *Qiyao rangzai jue* make the functional advantage of such a calendar abundantly clear: it allows for compact repeating planetary tables such that, in the *Qiyao rangzai jue*'s words, "back to antiquity and up to today the lodge-degrees where [the planets] linger each year, like matching tallies, do not differ by a fraction of a hair's breadth" (*T* no. 1308, 448: c3-4).

But were the necessary ideas for such a calendar in place by the third or second century BC? The concept of the solar year, with its obvious importance for seasons and agriculture, is evident in intercalation practices going back to the earliest written records in China. In the pre-Qin classics we already see a lexical distinction between *nian* (the lunisolar civil year) and *sui* (the solar/agricultural year) that trickles down into the language of the astral sciences. In the 'Yao dian' 堯典 chapter of the *Book of Documents*, for example, the ancient sage king Yao 堯 commands the Xi-He 羲和 brothers, "a period of 366 days, use intercalary months to fix the four seasons and complete the *sui*" 朞三百有六旬有六日，以閏月定四時成歲 (*Shangshu zhushu* 尚書注疏, 2.21b) and the *Rites of Zhou* describes the duty of the Grand Clerk as being to "set

[33] Of course, here a useful parallel might be drawn with the popular transmission of hemerological knowledge over the same period, see for example Kalinowski (1996) and Harper (2010).

straight the *sui* and the *nian* (via intercalation) to order affairs" 正歲年以序事 (*Zhouli zhushu* 周禮注疏, 26.401b).[34]

From there, it is not difficult to imagine that someone at the time of the *Wu xing zhan* was *able* to divide the *sui* by twelve, but was this common practice? The first complete inventory of the 24 *qi* occurs only in the *Huainanzi* (3.98-102), almost thirty years after the sealing of Mawangdui tomb 3. Of course, numerous *qi* names appear in works as early as the *Zuo zhuan* 左傳, *Guanzi* 管子 and *Lü shi chunqiu* 呂氏春秋 (239 BC), and complete inventories occur also in the "Zhou yue" 周月 and "Shi xun" 試訓 chapters of the *Yi Zhou shu* 逸周書 (which, like the *Zuo zhuan* and *Guanzi*, scholars tend to date vaguely to the fourth or third centuries BC). Historians of astronomy, however, generally reject the *Yi Zhou shu* chapters, because text critics have labeled them Han fabrications, and, coming around full circle, text critics like Huang Peirong 黃沛榮 label them fabrications because they contain complete inventories of the 24 *qi*.[35] Whatever our faith in the preeminence of the *Huainanzi*, the presence of the 'ancient-degree' solar steps in daybooks excavated from the third and second centuries BC now provides us with unequivocal precedence for the division of the solar year by twelve.[36]

What makes a connection between the *Wu xing zhan* and *Qiyao rangzai jue* tables conceivable (although by no means conclusive) is the fact that *a* solar calendar is, by definition, intrinsic to the lunisolar calendar and, thus, the practice of *li*. Wolfram Eberhard's description, now more than a half century old, is still quite apt:

> It can easily be shown that the Chinese were capable of developing a pure solar calendar. If an astronomer intends to make any astronomical calculation, for example, to calculate the date of the next new moon or

[34] On the distinction between *sui* and *nian* in the language of mathematical astronomy, see Qu Anjing 曲安京 (2008), pp. 66–67. Note that *in non-astronomical contexts* this distinction is not an absolute one, e.g. the *Jiuzhang suanshu* 九章算術 gives the length of a *sui* as 354 days (*Huijiao Jiuzhang suanshu* 匯校九章算術, 3.115), and the *Erya* 爾雅 identifies these terms as synonyms: "a *zai* (year) is a *sui*; the Xia called it *sui*, the Shang called it *si*, the Zhou called it *nian*, and Tang Yu called it *zai*" 載，歲也，夏曰歲，商曰祀，周曰年，唐虞曰載 (*Erya zhushu*, 5.18b).

[35] Huang Peirong 黃沛榮 (1976), pp. 265-278, 282-283; cf. Huang Huaixin 黃懷信 (1992), pp. 111-115. Whatever the authenticity of the "Zhou yue" and "Shi xun" chapters, it is worth noting that other *Yi Zhou shu* materials previously considered suspect have appeared in the fourth-century BC Tsinghua University manuscripts, dispelling any lingering doubts about those particular chapters.

[36] On the solar steps, see note 27.

> the next eclipse of the moon or sun, he has to start from the movement of the sun. An examination of the formula which the Han astronomers used for their calculations shows that they developed a pure solar calendar system for their calculations and then converted it into the "civil" calendar of a luni-solar character. If the function of Chinese astronomy had been to provide a tool for the farmer, this "astronomical" calendar would have been the ideal tool, because the seasons were fixed in this calendar. The fact that the Chinese retained the luni-solar calendar until the twentieth century indicates that their interests were different. We must assume that they followed an old tradition which had fixed the popular festivals and observances of a religious cult by the phases of the moon (1957, p. 63).

The Chinese astronomer was no slave to the civil calendar. Not only did astronomers vie to reform it throughout the ages, the very procedures of *li* literature required that, to do any astronomical calculation whatsoever, one must compute a calendar as one goes along. Simple and repetitive, solar time is eminently suited to this purpose—it is for much the same reason that Greek astronomers came to adopt the 365-day Egyptian calendar for use in calculation.[37] More to the point, solar time determines solar position, which, in the Chinese motion-degree model, determines planetary position. It is for this reason that the Triple Concordance system manual instructs the user to perform parallel calculations in solar and lunar time, the sole purpose of the latter (which invariably comes second) being to put a civil date on an astronomical event.[38] What is odd about the *Wu xing zhan* and *Qiyao rangzai jue* tables, therefore, is not that have solar time as their bases but that, unlike the *Jin shu* list, they omit the final steps of calculation.

[37] See Neugebauer (1942).

[38] Note that the Quarter-remainder and subsequent systems simplify the parallel solar and lunar 'methods' of the Triple Concordance system by moving from the initial solar calculations—the number of synodic periods elapsed from high origin to the year previous that in question and the number of day/*du* past winter solstice the previous conjunction fell—to the calculation of months and binome days, bypassing medial *qi* and solar stations. For a comparison of these methods, see Liu Hongtao (2003), pp. 37–49, 97–100.

The *Wu xing zhan* as Manuscript

If the *Wu xing zhan* planetary tables are indeed solar calendars, it would seem that they would only be of use to someone able to recognize them as such and convert their dates to the civil calendar. However, the fact that both the *Qiyao rangzai jue* and Shen Gua feel the need to provide detailed instructions for such conversion suggests that this may not have been common or self-evident knowledge. We cannot assume *ipso facto* that the *Wu xing zhan*'s owner understood its contents. If anything, the tables are so inaccurate, due to the limitations of the system origin and planetary models, that it would make little practical difference whether one consulted them as solar or civil calendars. Whether or not the compiler of the tables knew what he was doing remains a mystery, but what we know for certain is that the copyist did not: the manuscript is beautifully copied but rife with numerical corruption, corruption that is obvious and goes uncorrected.[39]

So, what use could the manuscript and its tables have been to anyone? Cullen suggests that the latter might function within the context of the omenological half of the text to set parameters of normal behavior through which to interpret observed phenomena:

> We need to recall what David Brown has written in the context of ancient Mesopotamian astronomy: one of the advantages of schematic depictions of celestial motions is that they automatically generate portents through their divergence from what is actually observed. A celestial diviner who had constructed something like the Venus table in the *Wu xing zhan* may well have felt a double satisfaction: on the one hand he had uncovered the ideal reality of what Venus ought to do, but on the other hand he also had the ability to interpret for his clients what it meant when Venus did not act as it should have done. Regard (and reward) for his professional competence was thus assured on two fronts (2011b, pp. 248–249).

I agree that this may well have been the case at some point in the text's history, but I suspect that the Mawangdui manuscript as we have it was not for use—that is, at least, not its computational sections. I say this for several reasons. At the time, it was customary to avoid the personal names of the rulers of the current dynasty, alive and dead, and to replace

---

[39] For a discussion of numerical corruption in the *Wu xing zhan*, see Mo Zihan (2011).

these words with equivalents. The *Wu xing zhan* avoids the name of Han Gaozu 高祖 (Bang 邦) but not that of Qin Shihuang (Zheng 政) or Han Wendi 文帝 (Heng 恒), before and after him. Assuming the rigorous application of such taboos, this suggests that the manuscript as we have it was copied between 206 and 180 BC, just about the time that the tables come to an end.[40] There is more than enough space left in the tables to fill them out to the manuscript's date of interment in 168 BC—so much, in fact, that one could fill the Saturn table out to AD 84—but it seems that its owner was not interested in doing so. This brings us to an important point: *this is not a forward-looking table, nor could one hope to plot a forward-looking table in regnal years.* The *Qiyao rangzai jue* avoids this problem by using the sexagenary year-count, which, unlike the rule of men, continues uninterrupted into the infinite future. The *Wu xing zhan*'s tables, in other words, were historical tables for who knows what purpose.

Donald Harper has argued at length that the abundant medical literature found also in Mawangdui tomb 3 reflects a culture of connoisseurship among the elite of the time, who not only sought to patronize and keep experts on retainer but to consume texts.[41] I suspect that we can also attribute the *Wu xing zhan*'s presence in this tomb to these factors—as just one more example of how, in the burgeoning manuscript culture of the time, expert knowledge began to circulate beyond expert circles and find its way into unlikely hands. At the same time that it facilitated this flow of information, however, manuscript culture also opened it to innovation and corruption at the popular level. It is in this context, I believe, that we can reconcile the way that the manuscript combines and hybridizes contradictory planetary models with what we know of the received tradition's efforts to segregate them.

Conclusion

The goal of this article has been to explore the question of diversity within the scientific culture of a single time and place. Looking at calculated planetary tables allows us to reflect upon discrepancies between *manuals* and *practice* in early imperial mathematical astronomy.

First, it is striking that both sets of planetary ephemerides extant from the period are organized around the same solar calendar. While this is at

---

[40] Of course, it is important not to take these practices for granted. Chen Yuan 陳垣 (1997, pp. 64–66) notes numerous examples where the personal names of emperors were not avoided in the Han.

[41] See for example Harper (1998), pp. 42–67.

odds with the lunisolar civil calendar that received system manuals instruct the user to produce, we know astronomers to have implicitly used such a calendar in their calculations because of the centrality of solar time to planetary models and computational procedure. The *Wu xing zhan* and *Qiyao rangzai jue* tables are simply evidence that they may have done so *explicitly* as well, if for the added benefit of textual compactness.

Second, the *Wu xing zhan* tables and *Jin shu* list note only planets' first and last visibilities, the latter taking these as the sole criterion for judging system accuracy. With the exception of Buddhist horoscopy texts, this hints at a distinct emphasis in astronomical practice that is impossible to glean from manuals, which devote equal attention to all a planet's characteristic phenomena and the computation of daily positions. This emphasis seems somewhat curious given the inability of period models to account for the complexities of visibility. On the other hand, both texts' de-emphasis of Mars betrays an appropriate lack of confidence concerning actors' ability to model this planet that too is impossible to glean from manuals.

Third, both the *Wu xing zhan* and *Qiyao rangzai jue* tables are calculated according to numbers and models that are radically simpler than those of contemporaneous *li* mathematical astronomy. Here again we see the plurality of traditions within the Chinese astral sciences: there is the state of the art and there is working knowledge, there is planetary astronomy and there is planetary hemerology. While the received tradition firmly segregates this knowledge into the categories *tianwen* and *li*, the *Wu xing zhan* hints that *in practice* the boundaries between them may have been somewhat porous. Lastly, these distinctions may also reflect a divide between expert and amateur, or elite and popular, traditions of the astral sciences within a manuscript culture, as technical knowledge began to circulate independently of experts and through the hands of dilettantes like Li Xi.

References

Primary Sources

Erya zhushu 爾雅注疏 (*Erya* Dictionary with Commentary and Subcommentary), compiled by Xing Bing 邢昺 et al., 999; reprint from *Wenyuange Siku quanshu* 文淵閣四庫全書, 1782;

edition Taibei: Taiwan shangwu yinshuguan, 1983-1986.

Han shu 漢書 (History of the [Former] Han [Dynasty]), Ban Gu 班固, 111; edition Beijing: Zhonghua shuju, 1962.

Hou Han shu 後漢書 (History of the Later Han [Dynasty]), Fan Ye 范曄 (398-445); edition Beijing: Zhonghua shuju, 1965.

Huainan honglie jijie 淮南鴻烈集解 (Extensive Collected Explanations of [Matters] from Huainan), Liu An 劉安 et al., 139 BC; edition Beijing: Zhonghua shuju, 1989 (2 vols.).

Huijiao Jiuzhang suanshu (zengfu ban) 匯校九章算術（增補版） (The Collated *Jiuzhang suanshu* [Expanded Edition]), anonymous, compiled probably in the Han (206 BC – 220 AD); critical reprint with annotations by Guo Shuchun 郭書春; edition Shenyang: Liaoning jiaoyu chubanshe, 2004 (2 vols.).

Jin shu 晉書 (History of the Jin [Dynasty]), Fang Xuanling 房玄齡 (chief ed.), 648; edition Beijing: Zhonghua shuju, 1974.

Kaiyuan zhanjing 開元占經 (The Divination Classic of the Kaiyuan Reign), Gautama Siddhārtha, 729; reprint from *Wenyuange Siku quanshu* 文淵閣四庫全書, 1782; edition Taibei: Taiwan shangwu yinshuguan, 1983-1986.

Mengxi bitan jiaozheng 夢溪筆談校證 (*Dream Stream Brush Talks* Collated and Verified), Shen Gua 沈括 (1031-1095); critical reprint with annotations, Shanghai: Shanghai guji chubanshe, 1987.

Qiyao rangzai jue 七曜攘災決 (Formulae for Averting Disaster by the Seven Luminaries), Koṅta 金俱吒, ninth century; reprinted in Takakusu Junjirō 高楠順次郎 and Watanabe Kaigkoku 渡邊海旭 (eds.), *Taishō shinshū daizō-kyō* 大正新脩大藏經, Tōkyō: Taishō issaikyō kankō-kai, 1924-1934, *T.* no. 1308.

Shangshu zhushu 尚書注疏 (*Book of Documents* with Commentary and Subcommentary), compiled by Kong Yingda 孔穎達, 653; reprint from *Wenyuange Siku quanshu* 文淵閣四庫全書, 1782; edition Taibei: Taiwan shangwu yinshuguan, 1983-1986.

Shiji 史記 (The Grand Clerk's Records), Sima Qian 司馬遷, 109/91 BC; edition Beijing: Zhonghua shuju, 1982.

Sui shu 隨書 (History of the Sui [Dynasty]), Wei Zheng 魏徵 et al., 636; edition Beijing: Zhonghua shuju, 1973.

Wei shu 魏書 (History of the [Northern] Wei [Dynasty]), Wei Shou 魏收, 554; edition Beijing: Zhonghua shuju, 1974.

Xin Tang shu 新唐書 (New History of the Tang [Dynasty]), Ouyang Xiu 歐陽修 and Song Qi 宋祁, 1060; edition Beijing: Zhonghua shuju, 1975.

Zhouli zhushu 周禮注疏 (*Rites of Zhou* with Commentary and Subcommentary), compiled by Jia Gongyan 賈公彥, 999; reprint from *Wenyuange Siku quanshu* 文淵閣四庫全書, 1782; edition Taibei: Taiwan shangwu yinshuguan, 1983-1986.

Secondary Sources

Arrault, Alain (2002), "Les premiers calendriers chinois du IIe siècle avant notre ère au Xe siècle," in Jacques Le Goff, Jean Lefort, & Perinne Mane (eds.), *Les Calendriers: Leurs enjeux dans l'espace et dans le temps: colloque de Cerisy, du 1er au 8 juillet 2000*, Paris: Somogy, pp. 169–191.

Chen Jiujin 陳久金 (2001), *Boshu ji gudian tianwen shiliao zhu xi yu yanjiu* 帛書及古典天文史料注析與研究 (Commentarial Analysis and Researches on Sources for the History of Astronomy in Silk Manuscripts and the Classics), Taibei: Wan juan lou.

Chen Meidong 陳美東 (2003), *Zhongguo kexue jishu shi: tianwenxue juan* 中國科學技術史：天文學卷 (History of Chinese Science and Technology: Astronomy Volume), Beijing: Kexue chubanshe.

Chen Songchang 陳松長 (2003), "Mawangdui san hao mu de zai renshi" 馬王堆三號墓的再認識 (A Reappraisal of Mawangdui Tomb 3), *Wenwu* 文物 2003.8: 56–59, 66.

Chen Xiaozhong 陳曉中, and Zhang Shuli 張淑莉 (2008), *Zhongguo gudai tianwen jigou yu tianwen jiaoyu* 中國古代天文機構與天文教育 (Astronomical Organizations and Astronomical Education in Ancient China), Beijing: Zhongguo kexue jishu chubanshe.

Chen Yuan 陳垣 (1997), *Shi hui juli* 史諱舉例 (Examples of Taboo Words in History), Shanghai: Shanghai shudian chubanshe.

Cullen, Christopher (1991), "Motivations for Scientific Change in Ancient China: Emperor Wu and the Grand Inception Astronomical Reforms of 104 BC," *Journal for the History of Astronomy* 24.3: 185–203.

______ (2002), "The First Complete Chinese Theory of the Moon: the Innovations of Liu Hong c. A.D. 200," *Journal for the History of Astronomy* 33: 21–39.

______ (2007), "Huo Rong's Observation Programme of AD 102 and the *Han li* Solar Table," *Journal for the History of Astronomy* 38.1: 75–98.

______ (2011a), "*Wu xing zhan* 五星占 'Prognostics of the Five Planets'," *SCIAMVS* 12: 193–249.

______ (2011b), "Understanding the Planets in Ancient China: Prediction and Divination in the *Wu xing zhan*," *Early Science and Medicine* 16: 218–251.

Deane, Thatcher E. (1989), "The Chinese Imperial Astronomical Bureau: Form and Function of the Ming Dynasty Qintianjian from 1365 to 1627," Ph.D. diss., University of Washington, Seattle.

Deng Wenkuan 鄧文寬 (2002), *Dunhuang Tulufan tianwen lifa yanjiu* 敦煌吐魯番天文曆法研究 (Researches on the Astral Sciences at Dunhuang and Turpan), Lanzhou: Gansu jiaoyu chubanshe.

Eberhard, Wolfram (1957), "The Political Function of Astronomy and Astronomers in Han China," in John Fairbank (ed.), *Chinese Thought and Institutions*, Chicago: University of Chicago Press, pp. 37–70.

Harper, Donald (1998), *Early Chinese Medical Literature: the Mawangdui Medical Manuscripts*, London: Kegan Paul International.

______ (2010), "The Textual Form of Knowledge: Occult Miscellanies in Ancient and Medieval Chinese Manuscripts, Fourth Century B.C. to Tenth Century A.D.," in *Looking at It from Asia: The Processes That Shaped the Sources of History of Science*, ed. Robert S. Cohen, Jürgen Renn, and Kostas Gavroglu, Dordrecht: Springer, pp. 37–80.

Hu Pingsheng 胡平生 (1998), "Fuyang Shuanggudui Han jian shushu shu jianlun" 阜陽雙古堆漢簡數術書簡論 (Overview of the Han-Slip Numbers and Techniques Books from Shuanggudui, Fuyang*), Chutu wenxian yanjiu* 出土文獻研究 4: 12–30.

Huang Huaixin 黃懷信 (1992), Yi Zhou shu *yuanliu kaobian* 『逸周書』源流考辨 (An Investigation on the Origin and Development of the *Yi Zhou shu*), Xi'an: Xibei daxue chubanshe.

Huang Peirong 黃沛榮 (1976), "Zhoushu yanjiu" 周書研究 (Researches on the [Yi] Zhou shu), Ph.D. diss., Guoli Taiwan daxue.

Huang Yi-long 黃一農 (1992), "Zhongguo shi libiao shuorun dingzheng juyu" 中國史曆表朔閏訂正舉隅 (Inductive Examples of Corrections to the New Moons and Intercalary Months of Calendric Tables for Chinese History), *Hanxue yanjiu* 漢學研究 10.2: 279–306.

Hunan sheng bowuguan 湖南省博物館, and Zhongguo kexueyuan kaogu yanjiusuo 中國科學院考古研究所 (1974), "Changsha Mawangdui er, san hao Han mu fajue jianbao" 長沙馬王堆二、三號漢墓發掘簡報 (Simplified Report on the Excavation of the Han Tombs 2 and 3 at Mawangdui, Changsha), *Wenwu* 文物 1974.7: 39–48, 63.

Jones, Alexander (1999), *Astronomical Papyri from Oxyrhynchus*, Philadelphia: American Philosophical Society.

Kalinowski, Marc (1986), "Les traités de Shuihudi et l'hémérologie chinoise a la fin des Royaumes-Combattants," *T'oung Pao* 2d ser., 72, no. 4/5: 175–228.

______ (1996), "The Use of the Twenty-eight *Xiu* as a Day-count in Early China," *Chinese Science* 13: 55–81.

Kawahara Hideki 川原秀城, and Miyajima Kazuhiko 宮島一彦 (1985), "Go sei sen" 五星占 (*Wu xing zhan*), in Yamada Keiji 山田慶兒 (ed.), *Shinhatsugen Chūgoku kagakushi shiryō no kenkyū* 新發見中國科學史史料の研究 (Researches on Newly Discovered Sources for the History of Chinese Science and Technology), Kyōto: Kyōto daigaku jinbun kagaku kenkyūjo, pp. 1–44.

Keightley, David (2000), *The Ancestral Landscape: Time, Space, and Community in Late Shang China, ca. 1200-1045 B.C.*, Berkeley: Institute for East Asian Studies, University of California, Berkeley.

Li Zhonglin 李忠林 (2010), "Zhoujiatai Qin jian lipu xinian yu Qin shiqi lifa" 周家臺秦簡曆譜係年與秦時期曆法 (The Date of the Zhoujiatai Calendar and the Calendrics of the Qin Period), *Lishi yanjiu* 歷史研究 2010.6: 36–53.

Liu Hongtao 劉洪濤 (2003), *Gudai lifa jisuanfa* 古代曆法計算法 (The Calculational Methods of Ancient Calendro-Astronomy), Tianjin: Nankai daxue chubanshe.

Liu Lexian 劉樂賢 (2002), *Jianbo shushu wenxian tanlun* 簡帛數術文獻探論, Wuhan: Hubei jiaoyu chubanshe.

______ (2004), *Mawangdui tianwen shu kaoshi* 馬王堆天文書考釋 (Study and Exegesis of the Mawangdui Astronomical Books), Guangzhou: Zhongshan daxue chubanshe.

Liu Yunyou 劉雲友 (Xi Zezong 席澤宗) (1974), "Zhongguo tianwen shi shang de yi ge zhongyao faxian—Mawangdui Han mu boshu zhong de *Wuxing zhan*" 中國天文史上的一個重要發現—馬王堆漢墓帛書中的『五星占』, *Wenwu* 文物 1974.11: 28-36.

Martzloff, Jean-Claude (2009), *Le calendrier chinois: structure et calculs, 104 av. JC-1644: indétermination céleste et réforme permanente: la construction chinoise officielle du temps quotidien discret à partir d'un temps mathématique caché, linéaire et continu*, Paris: Champion.

Mo Zihan 墨子涵 (Daniel P. Morgan) (2011), "Cong Zhoujiatai Rishu yu Mawangdui Wuxing zhan tan rishu yu Qin Han tianwenxue de huxiang yingxiang" 從周家臺『日書』與馬王堆『五星占』談日書與秦漢天文學的互相影響 (A Discussion of the Mutual Influence between Daybooks and Qin-Han Astronomy from the Zhoujiatai Daybook and the Mawangdui Wu xing zhan), *Jianbo* 簡帛 6: 113–137.

Neugebauer, Otto (1942), "The Origin of the Egyptian Calendar," *Journal of Near Eastern studies* 1.4: 396–403.

Niu Weixing 鈕衛星 (2004), *Xi wang Fantian: Hanyi Fojing zhong de tianwenxue yuanliu* 西望梵天：漢譯佛經的天文學源流 (Gazing Westward at Brahma Heaven: the Origin and Development of Astronomy in Buddhist Sūtras Translated into Chinese), Shanghai: Shanghai jiaotong daxue chubanshe.

Niu Weixing 鈕衛星, and Jiang Xiaoyuan 江曉原 (1997), "Qiyao rangzai jue Muxing libiao yanjiu" 『七曜攘災訣』木星曆表研究 (Researches on the Calendro-Astronomical Table for Jupiter in the Qiyao rangzai jue), *Zhongguo kexueyuan Shanghai tianwentai niankan* 中國科學院上海天文台年刊 18: 241–249.

Nōda Chūryō 能田忠亮, and Yabuuti Kiyosi 藪内清 (1947), *Kansho ritsurekishi no kenkyū* 漢書律暦志の研究 (Researches on the *Han shu* "Lü li zhi"), Tōkyō: Zenkoku shobō.

Ōhashi Yukio 大橋由紀夫 (1982), "Kōkan Sibunreki no seiritsu katei" 後漢四分暦の成立過程 (The Process of Establishing the Latter Han Quarter-Remainder System), *Sūgakushi kenkyū* 數學史研究 93: 1–27.

Pan Nai 潘鼐 (2009), *Zhongguo hengxing guance shi* 中國恆星觀測史 (The History of Fixed-Star Observation in China) (2d ed.), Shanghai: Xuelin chubanshe.

Pingree, David (1970), "On the Classification of Indian Planetary Tables," *Journal for the History of Astronomy* i: 95–108.

______ (1978), "History of Mathematical Astronomy in India," *Dictionary of Scientific Biography*, New York: Charles Scribner's Sons, vol. 15, pp. 533-633.

Qu Anjing 曲安京 (2008), *Zhongguo shuli tianwenxue* 中國數理天文學 (Chinese Mathematical Astronomy), Beijing: Kexue chubanshe.

Sivin, Nathan (2009), *Granting the Seasons: the Chinese Astronomical Reform of 1280, with a Study of its Many Dimensions and a Translation of its Records*, New York: Springer.

Sun Zhanyu 孫占宇 (2011), "Fangmatan Qin jian rishu 'Xing du' pian chutan" 放馬灘秦簡日書「星度」篇初探 (A Foray into the Fangmatan Qin-slip Daybook 'Star degrees' Section), *Kaogu* 考古 (Archeology) 2011.4: 70-79.

Takeda Tokimasa 武田時昌 (2010), "Taihaku kōdo kō: Chūgoku kodai no wakusei undōron" 太白行度考—中国古代の惑星運動論 (A Study of Motion-Degree Models for Venus: the Planetary Theories of Ancient China), *Tōhō gakuhō* 東方學報 85: 1–44.

Tao Lei 陶磊 (2003), Huainanzi Tianwen *yanjiu—cong shushu de jiaodu* 『淮南子·天文』研究——從數術的角度 (Researches on Huainanzi "Tianwen": from the Perspective of Numbers and Techniques), Jinan: Qi Lu shushe.

Teboul, Michel (1983), *Les premières théories planétaires chinoises*, Paris: Collège de France.

Wang Shengli 王勝利 (1989), "Xingsui jinian guanjian" 星歲紀年管見 (Humble Opinions on the Stellar and Jovian Year-Count), in

Zhongguo tianwenxue shi wenji bianji zu 中國天文學史文集編輯組 (ed.), *Zhongguo tianwenxue shi wenji* 中國天文學史文集 (Collected Essays on the History of Chinese Astronomy) Vol. 5, Beijing: Kexue chubanshe, pp. 239–245.

Wang Yumin 王玉民 (2008), *Yi chi liang tian—Zhongguo gudai mushi chidu tianxiang jilu de lianghua yu guisuan* 以尺量天—中國古代目視尺度天象記錄的量化與歸算 (Measuring Heaven with a Ruler: the Quantification and Deduction of the Naked-Eye Measurements of Astronomical Records), Jinan: Shandong jiaoyu chubanshe.

Wu Jiabi 武家璧 (2003), "Cong chutu wenwu kan Zhanguo shiqi de tianwen lifa chenjiu" 從出土文物看戰國時期的天文曆法成就 (A Look at Achievements in the Astral Sciences of the Warring States Period from Excavated Antiquities), in Beijing daxue Zhongguo kaoguxue yanjiu zhongxin 北京大學中國考古學研究中心, and Beijing daxue gudai wenming yanjiu zhongxin 北京大學古代文明研究中心 (eds.), *Gudai wenming* 古代文明 (Ancient Civilization) Vol. 2, Beijing: Wenwu chubanshe, pp. 252–294.

Yabuuti Kiyosi 藪内清 (1961), "Tō ni okeru seihō temmongaku ni kansuru ni, san no mondai" 唐代における西方天文學に關する二、三の問題 (Two or Three Problems Relating to Western Astronomy in the Tang Dyansty), in Tsukamoto Hakushi shōju kinenkai 塚本博士頌壽記念會 (ed.), *Bukkyō shigaku ronshū: Tsukamoto Hakushi shōju kinen* 佛教史學論集：塚本博士頌壽記念 (Collected Essays on the History of Buddhism: Festschrift for Dr. Tsukamoto), Kyōto: Tsukamoto Hakushi shōju kinenkai, pp. 883-894.

______ (1982), "Baōtai san go bo shutsudo no Gosei sen ni tsuite" 馬王堆三號墓出土の「五星占」について (On the Wu xing zhan excavated from Mawangdui Tomb 3), in Ono Katsutoshi 小野勝年 (ed.), *Tōhōgaku ronshū: Ono Katsutoshi Hakushi shōju kinen* 東方學論集：小野勝年博士頌壽記念 (Collected Essays on Oriental Studies: Festschrift for Dr. Ono Katsutoshi), Kyōto: Ryūkoku daigaku tōyō shigaku kenkyūkai, pp. 1-12),

Yano Michio 矢野道雄 (1986), "The *Ch'i-yao jang-tsai chüeh* and its Ephemerides," *Centaurus* 29.1: 28–35.

Zhang Peiyu 張培瑜 (2007), "Genju xinchu liri jiandu shilun Qin he Han chu de lifa" 根据新出曆日簡牘試論秦和漢初的曆法 (An Attempt to Discuss the Calendrics of the Qin and Early Han According to

Newly Excavated Calendars on Slips and Boards), *Zhongyuan wenwu* 中原文物 2007.5: 62–77.

Zhang Peiyu 張培瑜, Chen Meidong 陳美東, Bo Shuren 薄樹人, and Hu Tiezhu 胡鐵珠 (2008), *Zhongguo gudai lifa* 中國古代曆法 (Ancient Chinese Calendro-Astronomy), Beijing: Zhongguo kexue jishu chubanshe.

Zheng Huisheng 鄭慧生 (1995), *Gudai tianwen lifa yanjiu* 古代天文曆法研究 (Researches on the Ancient Astral Sciences), Kaifeng: Henan daxue chubanshe.