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Muddled Math and its Implications for Early Chinese Manuscript Culture

Daniel Morgan, University of Chicago

American Oriental Society 221st Meeting, Chicago, March 12, 2011

My purpose in this presentation is to take my experience working with astronomy texts and discuss their implications for broader issues of early Chinese sociology of knowledge and manuscript culture that concern everyone.

Generally speaking, when scholars of language, philosophy, and literature approach early manuscripts they revel in the anomalous. This is because textual and graphic anomalies offer us new vistas into the history of the written language, the formation of the classical corpus, and how all of this was embedded in a culture of manuscripts and orality. On the other hand, when scholars of mathematics and mechanical divination arts like hemerology approach early manuscripts, their reaction to the anomalous is generally to bracket or correct it as the first order of business, after which the text *as it is actually written* disappears from discussion about the text. With these texts it is easy both to *make* and *justify* corrections because the anomalies they present are of a different sort than those of, say, poetry—they are, for the most part, *unambiguous mistakes* in numbers or *tiāngān dìzhī* within coherent formulae or patterns of distribution.¹

In this paper I attempt to apply the approach of the former to the materials of the latter, and tease a story from muddled math. My focus is the planetary astronomy of the second century BC silk manuscript *Wǔxīng zhān* recovered from Mǎwángduì tomb 3, which provides for **Jupiter**, **Saturn**, and

¹ Examples of eminent scholars: Liu Lexian 劉樂賢, *Jianbo shushu wenxian tanlun* 簡帛數術文獻探論; Cullen, *The Suàn shù shū* 筭數書 'Writings on reckoning': a translation of a Chinese mathematical collection of the second century BC, with explanatory commentary. Cullen has several dozen examples, mostly leaving numbers off, confusing 7 and 1.

Venus a planetary model and 70-year “ephemeris” from the first year of Qín Shǐhuáng's reign as king in 246 BC to the third year of Hàn Wéndì in 177 BC. For reasons I will touch upon in passing, *Wǔxīng zhān* appears to be a Hàn copy of a Qín Dynasty work.

On your handout I have provided for you a transcription and translation of the *Wǔxīng zhān* Venus model. At a glance, the number of brackets is a clear indication of the degree to which such texts can *and must* be corrected before meaningful discussion.

First a word of explanation. Up until the Sui, planetary models for inferior planets like Venus were comprised of three elements:

- **One**, a start-point, or “system origin”.
- **Two**, on page 2, a synodic period—that is, the time it takes for the object to reappear in the same position relative to the sun. Thus, for example, *Wǔxīng zhān* tells us that Venus makes 5 first morning risings in 8 years, for a synodic period of 584.4 days.
- **Three**, a model that divides each iteration of the synodic period into stages of angular velocity and visibility phenomena such as first risings and settings. This is best represented in table format, as I have provided on page 2. These models are predicated on two principles:
 - **One**, symmetry.
 - **Two**, a fixed angle from the sun at which risings and settings occur, which in early models is half a *cì*, or 15°. For convenience, I will call this the “zone of invisibility.” The consequence of this principle is that from rising to setting, the angular distance traveled by the planet must equal the angular distance traveled by the sun over the same period.²

Now that we understand the principles involved, let us see how they were violated. In Venus' seventh stage, the slow stretch before setting in the west, *Wǔxīng zhān* records a velocity of 40 *fēn*. This is impossible. It violates both the principle of symmetry and of the “zone of invisibility.” For the

² Teboul, *Les premières théories planétaires chinoises*.

model to work at all, the value must be 120. Before photographs of the manuscript were published, Hé Yòuqí argued that the graph for 40 was actually a compound of *bǎi niàn*, 120.³ However, if you turn to page 3, you can tell from the pixelated photograph at the top that the graph can only be 40. Thus, it appears to be a mistake.

Next, the velocity of stages 5, 6, and 7, when Venus is in the west, present a progression from fast to slow symmetrical to stages 1, 2, and 3, when Venus is in the east. However, the *durations* of 5, 6, and 7 do not—they are in the same order as 1, 2, and 3. This violates the principle of symmetry. It also violates the principle of the “zone of invisibility,” because whereas the total distance traveled by Venus in the east equals the distance traveled by the Sun in the same time—the Sun traveling one *dù* per day—in the west, Venus overshoots it. This too is clearly a mistake.

Lastly, the *Wǔxīng zhān* is silent on Mercury and Mars, but gives the start-points of Venus, Jupiter and Saturn all as a first morning rising with the Sun in Yíngshì on *lìchūn*, the first day of the first month of the first year of King Zhèng of Qín, later Qín Shǐhuáng—that is, approximately February 8th, 246 BC. Later descriptions of the Qín's Zhuānxū astronomical system confirm that its system origin was a five-planet conjunction at *lìchūn*. This conjunction was fudged. If you look at the table at the bottom half of the page you will see that:

- Mars was out of the picture entirely, half-way round the sky and having risen some nine months prior.
- Mercury was indeed nearby, but had already risen and set by system origin.
- The other planets were spread out over 38° and several different lodges, and their first morning risings were weeks apart.

The result of synchronizing the planetary models of Venus, Jupiter, and Saturn to this fudged

3 He Youqi 何幼琦, “Shi lun Wu xing zhan de shidai he neirong 試論《五星占》的時代和內容。”

start-point is miscalibration—the accuracy of the models *vis-à-vis* the planets is compromised by beginning several weeks too early or too late. The graphs on page 4 help visualize this. **PAUSE** The y-axis is right ascension in degrees, and the x-axis is time—the graph for Venus covering its first 8 years and 5 synodic periods, and the graphs for Jupiter and Saturn covering the entire 70-year period of the *Wǔxīng zhān* ephemerides. The gray lines represent true right ascension, the black, that calculated from the *Wǔxīng zhān*, and the faint line at the bottom, the difference between the two. The breaks in the lines represent periods of invisibility.

Now, for Venus, note how the *Wǔxīng zhān* starts considerably behind the true, a difference of up to several weeks. Saturn starts fairly accurately because its true first morning rising was only one week after system origin; its right ascension and periods of invisibility then fall out of sync over the course of 70 years. However, Jupiter, whose true first morning rising occurred 33 days prior to system origin, begins 20 to 40° off of true, and falls gradually *into* sync over the years.

So what's the story?

The story of the system origin is clear. A five-planet conjunction at the beginning of a dynasty was considered an auspicious omen, and many dynasties purport to have begun with one: not only the Qín, for example, but also the Zhōu and Hàn. Huáng Yīnóng has shown that the fabrication of celestial omens was something of a cottage industry such that the majority of five-planet conjunction records in Chinese history were fabricated to glorify good emperors, while actual conjunctions during the reigns of bad emperors went unrecorded.⁴ The *Wǔxīng zhān*, however, is the first instance I know of in which the data of mathematical astronomy is grounded in propaganda to the detriment of its accuracy.

4 Huang Yi-Long 黃一農, *Shehui tianwenxue shi shi jiang* 社會天文學史十講.

Following Hé Yòuqí, I argue that our system origin is a case of *misrepresentation*.

The two mistakes tell a different story.

First off, when we encounter mistakes in mathematical manuscripts it is crucial that we distinguish between issues of numeracy, literacy, expertise in subject matter, and care of copying, as well as the roles of author, owner, and copyist.

Numeracy, as Christopher Cullen has forcefully argued in several recent articles,⁵ was quite prevalent among the early elite, the most evident reason for which was the crucial role of accounting in the administration of a bureaucratic empire. Not only do the biographies of great men tell us as much, the majority of excavated writings from the period happen to be meticulous accounts of people, land, taxes, and goods, and laws and administrative code concerning accounting. On the other hand, Yabuuti Kiyosi, Cullen, and Chén Měidōng have shown that most of the work of mathematical astronomy was done outside the context of government service by highly numerate enthusiasts.⁶

Obviously, the Qín author was competent on all charges—when corrected, the *Wǔxīng zhān* Venus model works to predict the position and motion of Venus more accurately than any other system known in China until Lú Xīn's *Sāntǒng lì* more than two centuries later. We cannot know the relationship between the copyist and the owner—who was a young male relative of Lǐ Cāng 李蒼, Marquis of Dài—they could well be the same person, thus I will treat them separately, but not as mutually exclusive.⁷

5 Cullen, “Huo Rong's observation programme of AD 102 and the Han li solar table”; Cullen, “Actors, networks, and 'disturbing spectacles' in institutional science: 2nd century Chinese debates on astronomy”; Cullen, “People and numbers in early imperial China: locating ‘mathematics’ and ‘mathematicians’ in Chinese space”; Cullen, “Numbers, numeracy and the cosmos.”

6 Yabuuti Kiyosi 藪内清, *Chūgoku no temmon rekihō 中國の天文曆法*; Cullen, *Astronomy and mathematics in ancient China*; Cullen, “Actors, networks, and 'disturbing spectacles' in institutional science: 2nd century Chinese debates on astronomy”; Chen Meidong 陳美東, *Zhongguo gudai tianwenxue sixiang 中國古代天文學思想*.

7 In tomb 3 was a wooden placard records the internment of the occupant on —year 12, month 2, new moon at yisi (42),

If the aesthetic quality of his calligraphy is any reliable indicator, the copyist was clearly literate. Anyways, his mistakes involve only basic numbers—simple and common graphs which someone with even the barest level of literacy could not mistake. Rather than illiteracy, these mistakes appear to be the product of the copyist's **carelessness** and/or **inexpertise** with the subject matter. Substituting “40” for “120” is clearly a mistake. The visual similarity between “20” and “40”, as well as the fact that the mistake appears at the beginning of a new line suggest a process of **visual copying** from another manuscript rather than oral transmission.

Mistakes like these are endemic in mathematical texts. In many, if not the majority of, cases, it is evident that complex formulae were *calculated* correctly, but in *copying*, one or more numbers were omitted, reversed, or mistaken. For example, we all know that in the transcription of ancient texts into Hànclerical script, the numbers 7 and 10 were frequently confused. But even *within clerical script*, numbers continued to be a problem. In the *Suànshù shū* mathematics primer from Zhāngjiāshān, for example, and government accounting such as the Húběi river dyke surveys purchased by the Chinese University of Hong Kong, graphically similar numbers like ● **one**, and **two**, ● **two** and **three**, and even ● **one** and **seven** are frequently confused, and the numbers 1 and 100 are often dropped.⁸

The inversion of the durations of stages 5 and 7 suggests a similar explanation. It appears that in

day wuchen (5), which accords with Wendi 文帝 12 (-167). See Hunan sheng bowuguan 湖南省博物館 and Zhongguo kexueyuan kaogu yanjiusuo 中國科學院考古研究所, “Changsha Mawangdui er, san hao Han mu fajue jianbao 長沙馬王堆二、三號漢墓發覺簡報。”

8 *Suanshu shu* mistakes: s4 8 for 30; s5 ...; s23 1 left off; s27 1 left off; s41 2 for 1; s48 1 for 2; s48 7 for 8; s50 2 for 1; s68 1 for 7; s71 40 for 20; s76 2 for 5; s84 10 left off; s84 100 left off; s85 1 left off; s104 4 for 5; s108 5 left off; s127 7 for 1; s141 5 for 3; s141 6 for 9; s142 section left off; s150 1 left off; s155 7 for 1; s162 7 for 1; s173 之 for 5; s176 40 for 30; s178 9 for 7; s181 9 for 8. See Cullen, *The Suàn shù shū 筭數書 'Writings on reckoning': a translation of a Chinese mathematical collection of the second century BC, with explanatory commentary*. For the **river dyke surveys**, see Peng Hao 彭浩, “Hedi jian' jiaodu “河堤簡” 校讀”; Lander, “Han dynasty texts on the surveying of river dykes”; Chen Songchang 陳松長, *Xianggang Zhongwen daxue wenwuguan cang jiandu 香港中文大學文物館藏簡牘*. Lander argued that the numerical disarray in calculations of land-area therein was evidence of poor math skills amongst local officials. In discussion, I showed that even there, it was evident that most areas were calculated correctly, but that the occasional number was miscopied due to graphic similarity and carelessness. See also the issue of 古度 lodge extensions in Sun Zhanyu. (More?)

copying from another manuscript, the copyist grasped that there was some symmetry at play in the array of data, but confused the correct order, either because he skipped to the wrong line, or set out to correct the master copy with a weak understanding of the principles of the mathematical model.

As for the owner of *Wǔxīng zhān*, the fact that the ephemerides were filled out until nine years prior to his internment in the twelfth year of Hàn Wéndì suggests that he or someone he knew used and added to the manuscript decades after the text's authorship in the Qín. From his expansive tomb library, we can tell that the owner was irrefutably literate, and was a connoisseur of natural and occult knowledge. He does not, however, appear to have been an expert in astronomy. Unlike other manuscripts of his library, all on other subjects, the owner made no corrections to *Wǔxīng zhān*: he did not correct the wrong and inverted numbers; nor did he attempt by observation and recalculation to unanchor it from the propaganda of a despised dynasty and make it accurate for his day. **He simply used it as is.**

Stepping back, I think that the case of *Wǔxīng zhān* highlights an important double-function of manuscript culture in the transmission of technical knowledge. On the one hand, as Donald Harper has written about at length, manuscript culture facilitated the horizontal dissemination of technical knowledge, both within circles of specialists *and beyond*, to a larger audience of literate and numerate connoisseurs.⁹ On the other hand, manuscript culture also acted to *dilute* and *scramble* that knowledge, as well as, *vertically*, to transmit knowledge that had gone out of date, and out of fashion.

Furthermore, I think that the example of mathematical texts can be informative to the study of

⁹ Harper, *Early Chinese medical literature: the Mawangdui medical manuscripts*; Harper, “Warring States natural philosophy and occult thought.”

manuscripts on philosophy, literature, and other topics at the core of modern sinology. For example, technical literature is often intensely visual, featuring diagrams, illustrations, and tables, and instances of textual corruption are almost always at the level of layout, and simple data like numbers and *tiāngān dīzhī*. On the one hand, this is strong evidence for the prevalence of the written, rather than oral, transmission of knowledge. On the other hand, it also reminds us that reducing the issues of anomaly and textual corruption to the literacy of scribes is too simplistic. Instead, we should also consider problems independent of literacy, like inexpertise with subject matter, and carelessness in copying. If copyists were sloppy with government accounts and imperial edicts, as A. F. P. Hulsewé has shown, then why should philosophy or science have fared any better?¹⁰

Thank you.

10 Hulsewé, “Qin and Han Legal Manuscripts.”

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American Oriental Society 221st Meeting, Chicago 2011

Wuxing zhan 五星占 Venus model (lines 143-146):

秦始皇帝元年正月，大白出東方，【日】行百廿分，百日。行益【疾】，【日行一度】，【六】十日。行有（又）益疾，日行一度百八十七半[分]以從日，六十四日而復還日，晨入東方，凡二百廿四日。浸行百廿日，夕出西方。太白出西【方】，【日行一度百八十七半】，【百日】。行益徐，日行一度以待（待）之，六十日。行有（又）益徐，日行【卅】[百廿]分，六十四日而入西方，凡二百廿四日。伏十六日九十六分。【太白一復】爲日五【百八十四日九十六分日】。【凡出入東方各五】，【復】與營室晨出東方，爲八歲。

In the first month of the first year of Emperor Qin Shihuang (*r.* 246-210 BC) Venus emerges from the east. It travels 120 *fen* (out of 240) [per day] for 100 days; then, its movement [accelerates, and it travels 1 *du* per day for 6]0 days; then, its movement further accelerates, and it travels 1 *du* and 187½ (*fen*) per day, whereupon it charges toward the sun, catching up with it again in 64 days and setting in the morning to the east—224 days in all.

Then, it travels submerged for 120 days, and emerges at sunset from the west.

[Venus rises in the west traveling 1 *du* and 187 and a half *fen* per day for 100 days;] then, its movement decelerates, and it travels 1 *du* per day and waits for it (the sun) for 60 days; then, its movement further decelerates, and it travels (40) [120] *fen* per day for 64 days before setting in the west—224 days in all.

Then, it hides for 16 days and 96 *fen*.

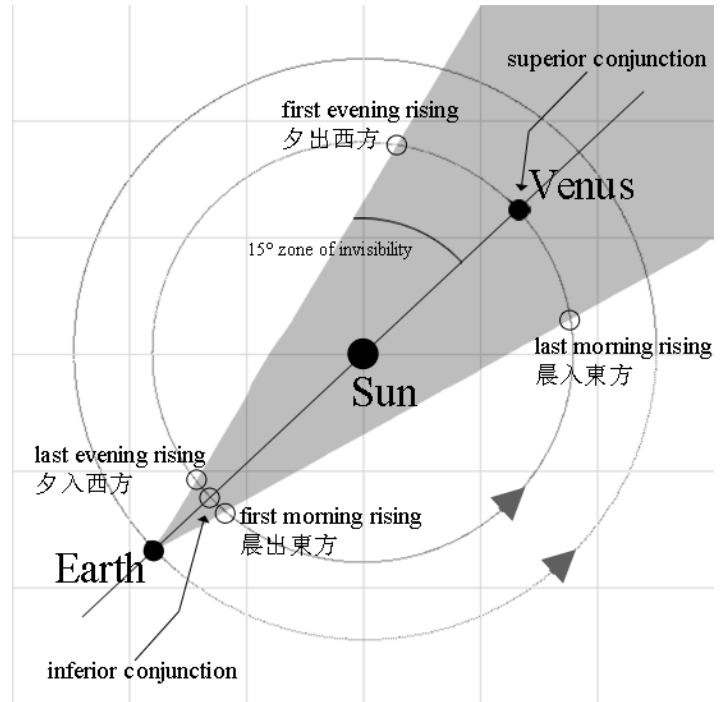
[One return of Venus] takes 5[84 days and 96 *fen* in days. In total it rises and sets in the east and west each five times, then again] emerges in the morning in the east with [the Sun in] *Yingshi*, constituting 8 years.

The three elements of early planetary astronomy (for inferior planets):

- System origin (*yuan* 元): all planets experience first morning rising with Sun in *Yingshi* (α Peg) on *lichun*, first day of the first month of the first year of Qin Shihuang (*ca.* February 2nd, 246 BC)
 - 曆記始於顛頊上元太始闕蒙攝提格之歲，畢陬之月，朔日己巳立春，七曜俱在營室五度。（《新唐書·曆三上》引《洪範傳》）
 - 顛頊曆術曰：“天元正月己巳朔旦立春，俱以日月起於天廟營室五度。”今月令孟春之月，日在營室。（《後漢書·律曆志中》李賢注引蔡邕）
 - 顛頊以今之孟春正月為元，其時正月朔旦立春，五星會于天廟，營室也。（《晉書·律曆志中》引董巴議）

- Synodic period: $584 \frac{96}{240}$ days

Synodic period:
The time it takes for the planet to reappear in the same position relative to the sun, e.g. from inferior conjunction to inferior conjunction, or first morning rising to first morning rising.



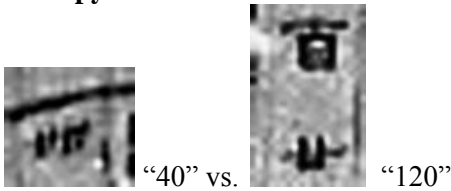
- (Angular) motion model (*xingdu* 行度):

	stage	mov.	ang. vel.	duration	arc
morning - east	1	slow	$\frac{120}{240} du/day$	100 days	50 <i>du</i>
	2	med	[1 <i>du/day</i>]	[6]0 days	60 <i>du</i>
	3	fast	$1 \frac{187.5}{240} du/day$	64 days	114 <i>du</i>
	4	submerged	-	120	-
evening - west	5	fast	$[1 \frac{187.5}{240} du/day]$	[100 days]	178.125 <i>du</i>
	6	med	1 <i>du/day</i>	60 days	60 <i>du</i>
	7	slow	$\frac{40}{240} du/day$	64 days	32 <i>du</i>
	8	hidden	-	$16 \frac{96}{240}$ days	-

The two principles of motion models:

- Symmetry
- Fixed 15° (半次) “zone of invisibility” from Sun determining risings and settings.

Miscopy



Misapprehension

morning visibility				
stage	mov.	vel. (du/day)	days	arc (du)
1	slow	$\frac{120}{240}$	100	50
2	med	[1]	[6]0	60
3	fast	$1 \frac{187.5}{240}$	64	114
TOTAL			224	224

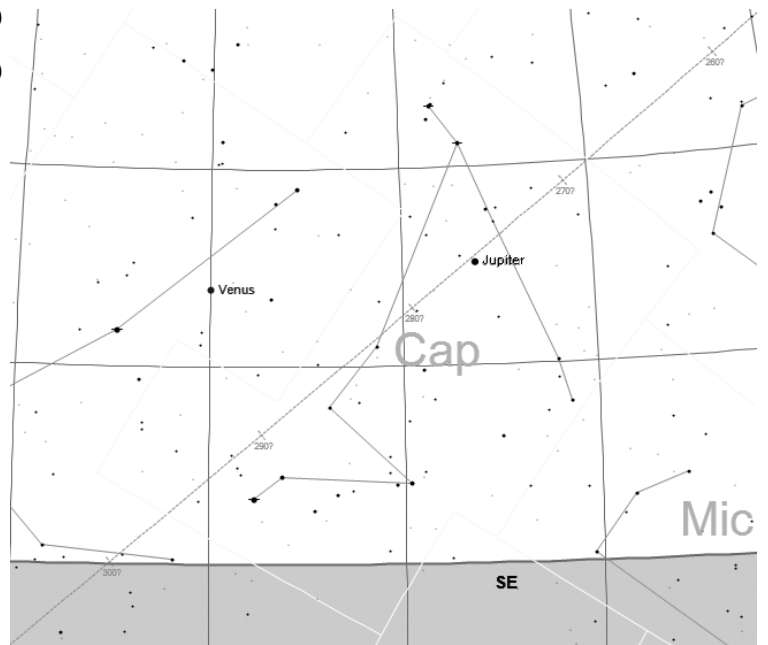
evening visibility				
stage	mov.	vel. (du/day)	days	arc (du)
5	fast	$\left[1 \frac{187.5}{240}\right]$	[100]	$178 \frac{30}{240}$
6	med	1	60	60
7	slow	$\frac{(40)[120]}{240}$	64	32
			224	$270 \frac{30}{240}$

Because the (mean) Sun travels 1 du per day, the total number of days equals the distance travelled by the Sun.

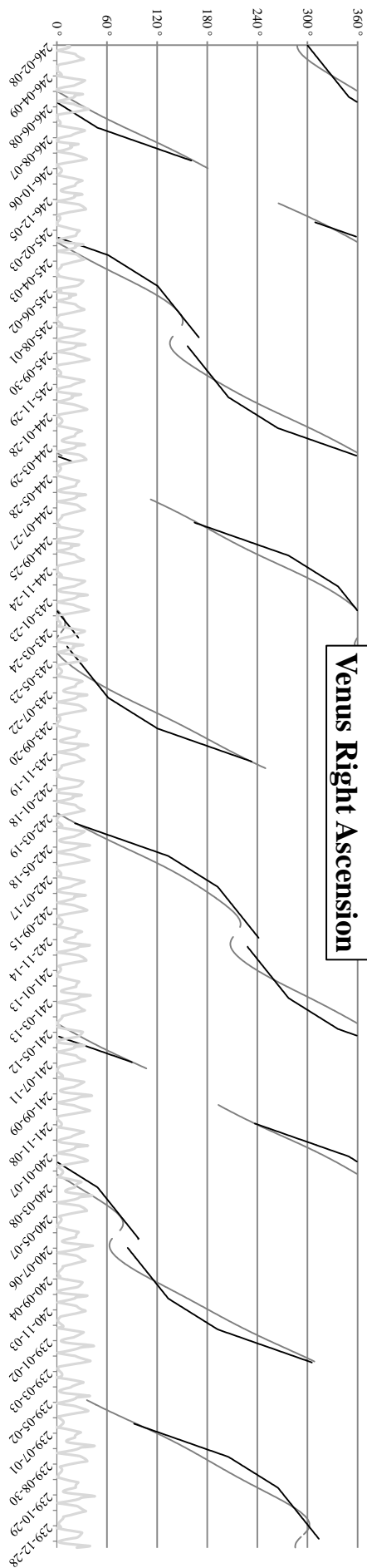
Misrepresentation

Planets at system origin (ca. 246-02-08)

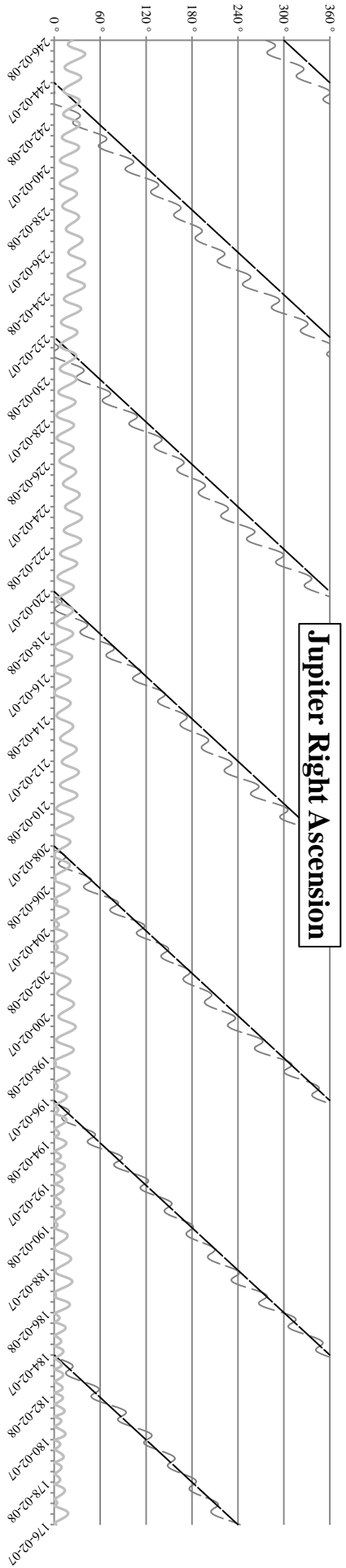
planet	RA	lodge	nearest first morning visibility (computed)
Mars	122°	七星	247-05-16 (278 days prior)
Mercury	315°	營室	set 246-1-23 (16 days prior)
Jupiter	277°	牽牛	246-01-06 (33 days prior)
Venus	288°	婺女	246-01-20 (19 days prior)
Saturn	301°	虛	246-02-15 (7 days later)



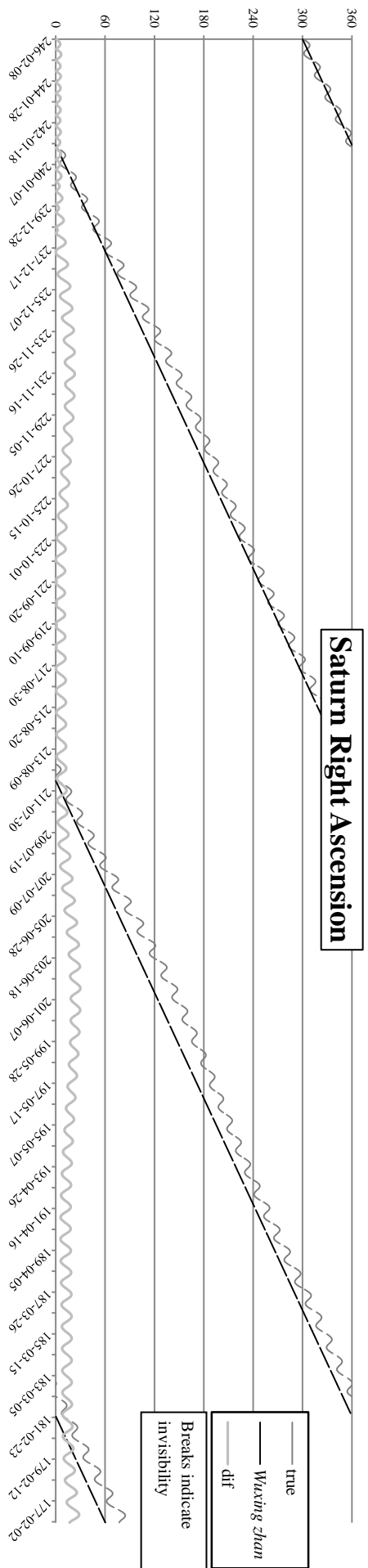
Dawn 246-02-08, system origin: Jupiter and Venus alone rise in the east.



Venus Right Ascension



Jupiter Right Ascension



Saturn Right Ascension

— true
 - - Waxing zhan
 - - dif
 Breaks indicate invisibility