

# Recent studies on the models of solar orbit in the Qing dynasty, China, and natural philosophy

(清王朝時代の太陽軌道モデルについての最近の研究と、  
自然哲学)

Yukio Ôhashi (大橋由紀夫)

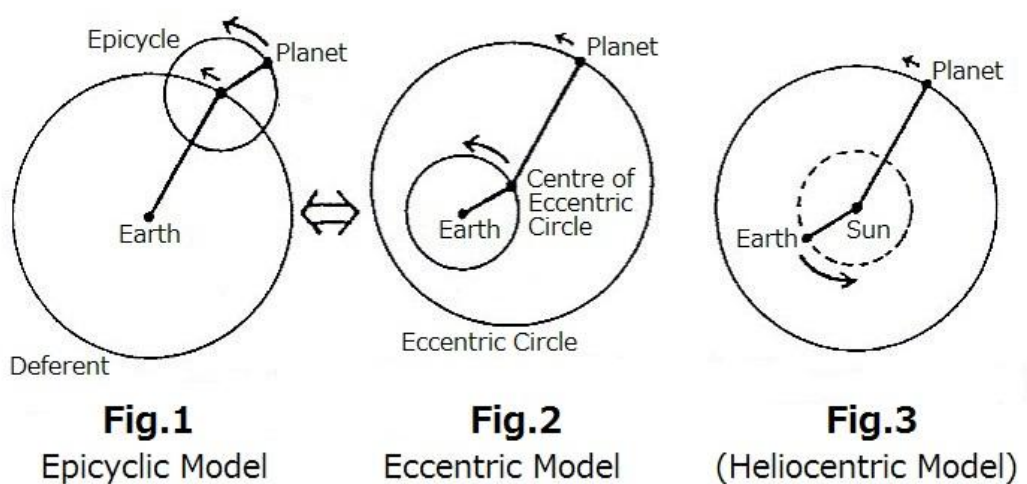
## I. Introduction

Western geometrical astronomy was introduced into China by Jesuit missionaries in the late Ming (明) dynasty and the early Qing (清) dynasty.

In the case of the solar orbit, it seems that there was certain Chinese originality. There are some recent studies on this topic.

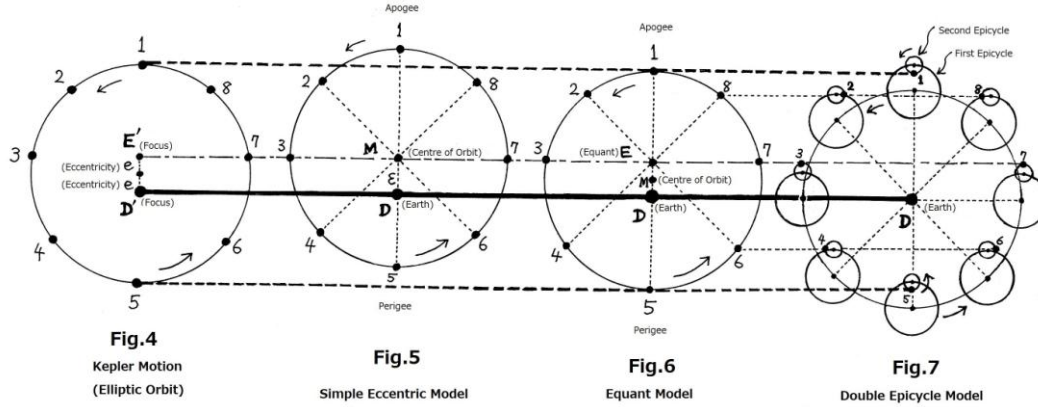
### (I.1) Western geometrical models

In ancient Greece, Apollonius (3<sup>rd</sup> century BC) used the epicyclic model for planetary orbits, and showed that it is equivalent to the eccentric model. (See Figs.1 and 2.)



Then, Hipparcus (2<sup>nd</sup> century BC) used the simple eccentric model for the solar orbit. (See Fig.5.) He also made a model of the lunar orbit, which is not discussed here.

Ptolemaeus (2<sup>nd</sup> century AD) newly used the “equant” model for the planetary orbits, and revised the model of the lunar orbit. However, the model of the solar orbit was the same as Hipparchus, that is the simple eccentric model. (See Fig.2.)



In the simple eccentric model (Hipparchus for solar orbit), the object revolves at a constant speed. (Fig.5.)

In the equant model (Ptolemaeus), the object revolves at a constant angular velocity around the equant “E”. (Fig.6.)

The double epicycle model was created by ibn ash-Shātīr (14<sup>th</sup> century AD). The object revolves at a constant speed on the small epicycle, and the small epicycle revolves at a constant speed on the large epicycle. The large epicycle revolves at a constant speed on the deferent. (Fig.7.) Its result is almost the same as the equant model.

### (I.2) Introduction of Western sciences into China, ----- Jesuit missionaries

Matteo Ricci (1552 – 1610) arrived at Beijing in 1601, and introduced Western sciences into China. Since then, several Jesuit missionaries visited China.

In China, some official astronomical works based on Western astronomy were composed as follows.

*Chongzhen-lishu* (Calendrical treatise in the name of Emperor Chongzhen) (崇禎曆書) (1631 – 34), where the simple eccentric model is used for the solar orbit.

*Xiyang-xinfā-lishu* (Calendrical treatise in Western new methodology) (西洋新法曆書) (1645), which is a re-edition of the *Chongzhen-lishu*. The *Xiyang-xinfā-lishu* (新法算書) was later renamed as *Xinfā-suanshu* (Mathematical treatise of new methodology).

*Lixiang-kaocheng* (Treatise of calendrical phenomena) (曆象考成) (1722), where the double epicycle model is used for the solar orbit.

*Lixiang-kaocheng-houbian* (Second part of the treatise of calendrical phenomena) (曆象考成後編) (1742), where Kepler’s elliptic orbit is used.

It should also be noted that there is one important non-official work composed in this period, the *Xiao'an-xinfa* (New method of Xiao'an) (曉庵新法) (1663) of Wang Xichan (王錫闡) (alias Xiao'an) (1628 – 1682). There are also non-official but very important works of Mei Wending (梅文鼎) (1633 – 1721), which were edited by his successors, and were very influential.

## II. Solar model in the *Lixiang-kaocheng*

In my Chinese paper [Ôhashi (2007)], I wrote that the double epicycle model of the solar orbit in the *Lixiang-kaocheng* may be a Chinese original device, because only the simple eccentric model was used in the geocentric system in Europe at that time. In a seminar in 2012, I presented the similar view in English [Ôhashi (2012)].

Recently, Chu Longfei and Shi Yunli also studied this topic, and expressed a similar view [Chu and Shi (2012) and Shi and Chu (2013)]. An anonymous referee of my paper [Ôhashi (2012)] informed me about these works.

Chu and Shi (2012) pointed out that the equant model for the orbit of the sun was tried (with certain uncertainty) to apply in the *Xiyang-xinfa-lishu* (1645). It is also mentioned in the *Xinfa-suanshu* (Vol.26). I think that this is certainly a Chinese new attempt to revise the theory of the orbit of the sun, and further research is needed.

Another important non-official work is the *Xiao'an-xinfa* (1663) of Wang Xichan (1628 – 1682). According to the interpretation of Miyajima (1991), it used the combination of an eccentric deferent and an epicycle for the sun, and according to the interpretation of Ning (2006), it used the “Double epicycle model” for the sun. The result of the both is the same. (As this text *Xiao'an-xinfa* does not have any figure, it is difficult to say which interpretation is correct.) This may be a forerunner of the *Lixiang-kaocheng*. Its relationship with the *Lixiang-kaocheng* should be investigated further.

And also, Shi and Chu (2013) pointed out that Mei Wending (1633 – 1721) suggested to use two epicycles for the sun in his *Lifa-yiwen* (Queries about calendrical science) (曆學疑問) (Vol.3). This may also be a forerunner of the further development, and more research is needed.

Then, the *Lixiang-kaocheng* clearly used the double epicycle model for the solar orbit with clear figures. (See Fig.8.) The *Lixiang-kaocheng* (Part I, Vol.4) explains the reason to introduce double epicycle as follows. Firstly, the observed solar longitude shortly after the solstices (i.e. around the apogee and perigee) is applied to the “Simple eccentric model”, and the longitude of the apogee and perigee is determined. Then, from the difference between the mean sun and the observed longitude of the sun when the mean sun is at the distance of right angle from the apogee, determine the eccentric

distance. And also, using the observed time of the equinoxes and “*lixia*” (立夏) (point of time when the solar longitude is  $45^\circ$ ), determine the longitude of the apogee and the eccentric distance. The *Lixiang-kaocheng* says that these results are not harmonious according to the “Simple eccentric model”, but are harmonious according to the “Double epicycle model”.

The “Double epicycle model” according to the *Lixiang-kaocheng* is as follows. There is a concentric deferent (“*bentian*”, 本天) whose centre is the earth. On the deferent is the first (larger) epicycle (“*benlun*”, 本輪), whose radius is three fourth of the eccentric distance of the “Simple eccentric model”. Its centre revolves along the deferent eastwards in a (tropical) year. On the first epicycle is the second (smaller) epicycle (“*junlun*”, 均輪), whose radius is one fourth of the eccentric distance of the “Simple eccentric model”. Its centre revolves along the first epicycle westwards in a year, but its speed is slightly slower than the speed of the centre of the first epicycle. (This difference is due to the secular variation of the longitude of the apogee.) The sun revolves eastwards on the second epicycle, and its speed is double of the speed of the centre of the second epicycle. Now it is clear that this is basically the same as the ordinary “Double epicycle model”. (See Fig.7.)

The “Double epicycle model” for the sun in the *Lixiang-kaocheng* (1722) is a special feature of this work. There is a possibility that the “Double epicycle model” for the planets was also applied to the sun when the *Lixiang-kaocheng* was edited in China. Although Keplerian elliptic orbit was introduced in the Sequel (*Lixiang-kaocheng-houbian*) to this work later, the “Double epicycle model” for the sun in the earlier *Lixiang-kaocheng* can also be considered to be a small improvement. The “Double epicycle model” for the sun in geocentric model is not found in Western standard works, and might be a Chinese device. Though the geocentric system is used here, this attempt to apply similar model to different heavenly bodies (the planets and the sun) is a kind of a step to the recognition of the universal laws of nature.

Why this device was produced in China? Was there a kind of natural philosophy behind this device? This point should be investigated further.

Chinese philosophy has a thought of a kind of “oneness”. This world was believed to have been born from the ultimate one (*taiji*, 太極, literally, the “great pole”). A Confucianist classic *Yijing* (易經, Book of Changes) says that “*Yi* (易, principle of changes) has the *taiji* (ultimate one), it produces *liangyi* (two principles, that is *yin* (negative side of the nature) and *yang* (positive side of the nature)), ---”. (易有太極, 是生兩儀, ---) [*Ekikyō* (1969), vol.2, p.241 (繫辭上傳).] And also, a Taoist classic *Laozi* (老子, also called *Daodejing* 道德經) says that “*Dao* (道, literally means “road”, that is the

fundamental principle of the world) produces “one” (existence), and the “one” produces “two” (heaven and earth) ---” [*Rōshi* (2008), p.203 (Chapter 42).]

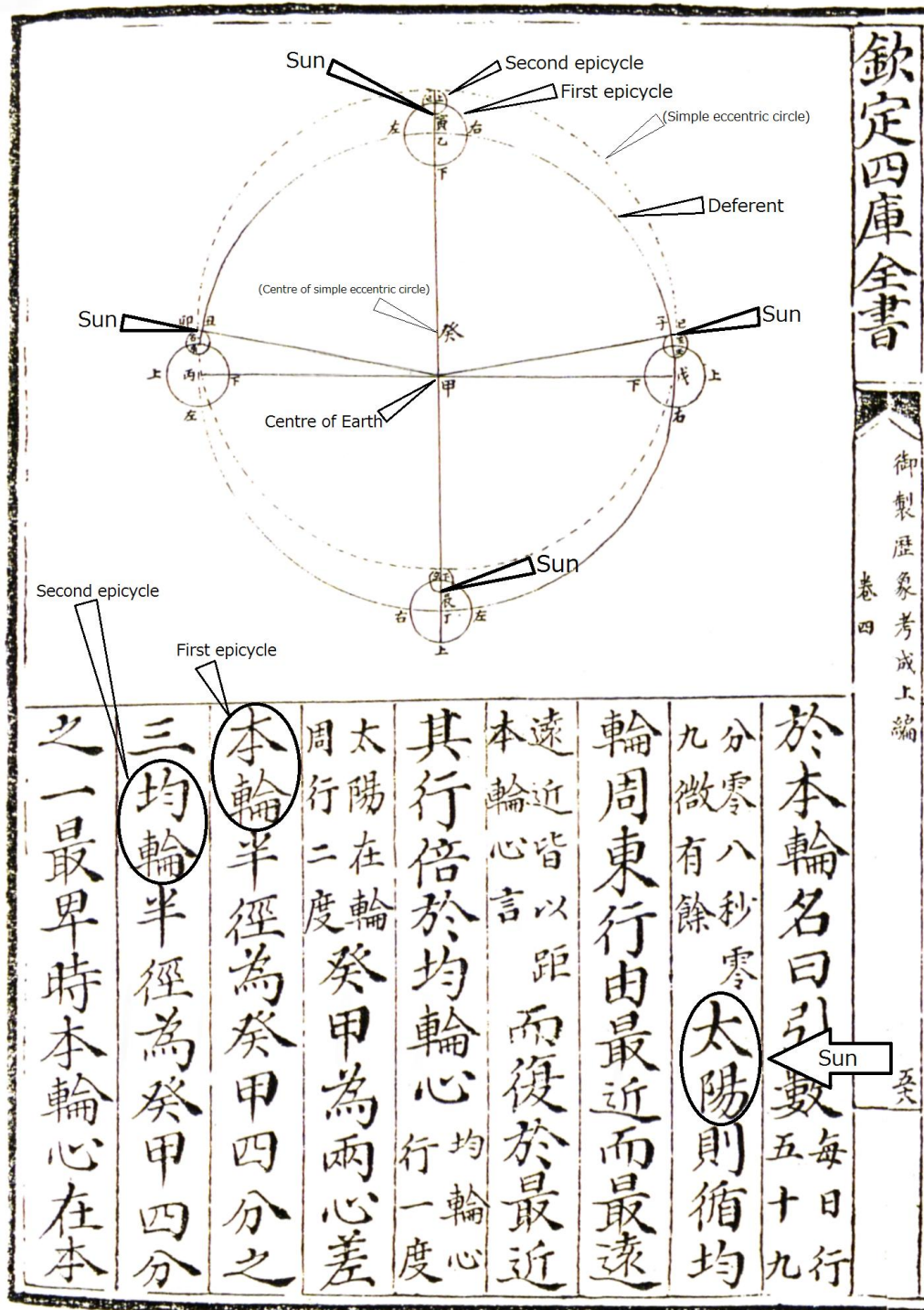


Fig.8, A page from the *Lixiang-kaocheng*

I do not say that the Chinese solar model was directly influenced by the Confucianism or Taoism, but we should consider that China had a thought that this world was originated in ultimate one. If so, there might have been a kind of thought of the uniformity of nature. This point should be investigated further.

### III. Conclusion

Eccentric models and epicycle models were used in Greek geometrical models for the orbits of the sun, moon and planets. These geometrical models were introduced into China by Jesuit missionaries in the early 17<sup>th</sup> century. Since then, several works on Western mathematical astronomy were composed in Chinese.

In the Greek model, a simple eccentric model was used for solar orbit, and it was introduced to China firstly. However, there is a Chinese work entitled *Lixiang-kaocheng*, composed in 1722, and a double epicycle model was used for the solar orbit there. It is almost equivalent to the “equant model”.

At that time, Kepler’s model had not been introduced to China. So, the double epicycle model for the solar orbit in China may be Chinese original device.

### References

Chu, Longfei and Shi, Yunli: “*Chongzhen-lishu* xilie lifa-zhong de taiyang yundong lilun” (The theory of Solar Motions in the *Chongzhen Lishu* Series) (in Chinese), *Ziran Kexue-shi Yanjiu* (*Studies in the History of Natural Sciences*), Vol.31, No.4, (2012), pp.410 – 427. (褚龙飞 石云里: “《崇祯历书》系列历法中的太阳运动理论”, 《自然科学史研究》, 2012, 31(4), 410-427)

*Ekikyō* (*Yijing*, Classical Chinese text with a Japanese translation), translated by Takada Shinji and Gotō Motomi, 2 vols, (Iwanami-bunko), Iwanami-shoten, Tokyo, 1969. (『易経』, 岩波文庫.)

Miyajima, Kazuhiko: “Ou Sekisen *Gyou’an Shinpou* no Taiyoukei moderu” (The model of the solar system in the *Xiao’an-xinfa* of Wang Xichan) (in Japanese), *Chūgoku Kodai Kagakushi-ron, Zokuhen*, Kyōto Daigaku Jinbunkagaku Kenkyūjo, Kyoto, 1991, pp.243 – 266. (宮島一彦: 王錫闡『曉庵新法』の太陽モデル, 『中国古代科学史論』, 京都大学人文科学研究所, 京都, 1991, pp. 243-266)

Ning, Xiaoyu: “*Xiao’an-xinfa* yu *Xinfa-suanshu* jisuan taiyang dixin huangjing fangfa de bijiao” (Comparison of the method to calculate geocentric solar longitude of the *Xiao’an-xinfa* and the *Xinfa-suanshu*) (in Chinese), *Zhongguo Keji Dianji Yanjiu – Di-san-jie Zhongguo keji dianjie guoji huiyi lunwenji* (*Studies on Ancient Chinese*

*Scientific and Technical Texts – Proceedings of the 3<sup>rd</sup> ISACBRST*, Daxiang Chubanshe, Zhengzhou, 2006, pp.201–209. (宁晓玉:《晓庵新法》太阳地心黄经的计算及其与《新法算书》的比较,《中国科技典籍研究 – 第三届中国科技典籍国际会议论文集》,大象出版社,郑州,2006, pp. 201–209)

Ôhashi, Yukio: “*Lixiang-kaocheng zhong de taiyang yundong-lun*” (On the Solar Motion in the *Lixiang-kaocheng*) (in Chinese), *Neimenggu Shifan Daxue Xuebao (Ziran Kexue Hanwen-ban)* (*Journal of Inner Mongolia Normal University (Natural Science Edition)*), Vol.36, No.6, 2007, pp.662 – 665. (大桥由纪夫:《历象考成》中的太阳运动,内蒙古师范大学学报(自然科学汉文版),2007, 36(6), pp. 662–665.)

Ôhashi, Yukio: Eccentric Model of the Solar Orbit in China (International Seminar on History of Mathematics, 2012, Ramjas College, University of Delhi, Delhi, India) (Its proceedings are forthcoming.)

*Rōshi* (*Laozi*, Classical Chinese text with a Japanese translation and commentary), translated and commented by Hachiya Kunio, (Iwanami-bunko), Iwanami-shoten, Tokyo, 2008. (『老子』, 岩波文庫.)

Shi, Yunli and Chu, Longfei: “Guanyu *Chongzhen-lishu* bianzuan guocheng-de xin-sikao” (On the new considerations in the process of editing the *Chongzhen-lishu*) (in Chinese), *Inter - cultural and Intra - cultural Perspectives on Scientific Exchanges in Seventeenth - and Eighteenth - Century East Asia, A Templeton International Workshop*, Seoul National University, 24 - 25 May 2013. (石云里 褚龙飞 “关于《崇祯历书》编纂过程的新思考 ——以日躔历和月离历的分析结果为例”.)

*Yingyin Wenyuange Siku-quanshu* (Photographic reproduction of the Complete library in four treasuries in the Wenyuange library) (in Classical Chinese), multivolumed reproduction, Taiwan Shangwu Yinshuguan, Taibei, 1983–86. (《景印·文淵閣四庫全書》, 臺灣商務印書館, 臺北.) The main text of the *Lixiang-gaocheng* is included in its vol.790.