THE EARLIEST EVIDENCE OF THE INTRODUCTION OF KEPLER'S LAWS TO CHINA AS IS OBSERVED IN THE *LIFA WENDA*

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Recently Catherine Jami and I have found the manuscript of the *Lifa wenda* (曆法問答 Dialogue on Astronomy) by Jean-Francois Foucquet (Fu Shengze 傅聖澤, 1665-1741) at British Library[1]. Together with the other, partial, but, otherwise identical, version, which she had located at the Vatican Apostolic Library[2], the manuscript, especially Book V, Part 1, from the British Library, gives us the detail of how Kepler's forst and second Laws was introduced into China as early as in the 1710's. This means that we can go back in the history of the introduction more than two decades earlier than the so far believed date.

On the other hand, when the *Chongzhen lishu* 崇禎曆書 had been compiled for several years from 1629, although Kepler's optical astronomy was extensively introduced, we cannot find the slightest evidence of the description of his Laws in it. Thus, the *Lifa wenda* can be regarded the earliest evidence, in which Kepler's Laws are openly discussed.

In connection with Kepler's Laws, Copernicanism was also discussed particularly concerning the instrumental model of the Solar System, that is the Orrery, manufactured by O. C. Rømer, which had been brought to China by the French Jesuit missionaries and presented to Kangxi Emperor as from the French King, Louis XIV[3]. On several pages of the manuscript, Copernicanism is referred to in connection with the explanation of planetary motions as well. The latter of the evidences shows that Copernicanism had been introduced into China almost half a century before M. Benoist did in his *Treatise on the Earth (Kunyu quantushuo* 坤輿全圖說 *)* in 1767[4]. Both of them can drastically change our understanding of the history of astronomy in China. First we should like to discuss the problem of the early introduction of Kepler's Laws.

Foucquet describes and introduces the discovery and development of the theory of elliptic orbits in the *Lifa wenda*, which must have been prepared probably between 1712 and 1716[5]. In Book V Part 1, he begins his discussion with repeatedly alluding to the recent sixty-years developement of the astronomical instruments and observational achievements in Europe[6], particularly after the establishment of the Paris Observatory and the telescope mounted with micrometer (*liang wei ge* 量微格[7]).

To begin with, Foucquet discusses the necessity of introducing the elliptical orbits in place of the combination of circular motions. Before the explanations of the problem of Martian motion, he particularly emphasises the shift of the perihelion of the orbit of Mercury in order to demonstrate the inadequacy of circular motions. Then he describes how the recent observational results show the discrepancy from the theoretical calculations.

Foucquet tried to show how recent telescopic observations had become precise by reporting Huygens's determination of Saturn's ring making use of his long telescopes from March 1655 to 1659[8]. In the manuscript, *Lifa wenda*, he explains the result with the heliocentric model of the

[1]Oriental and India Office Collections, OR Add. 16634.

[2]Borgia Cinese 319(1) and 319(2). Cf. Hashimoto, K. and Jami, C., "Kepler's Laws in China: A Missing Link?", *Historica Scientiarum*, vol. 6-3, 1997;171-185. In the paper, we have shown the table of the contents (cf. Table 1).

[3]Nissen, Andreas, *Ole Rømer*, Copenhagen, 1944;p.32.

[4]Yabuuti, Kiyosi, *Chugoku no Tenmon Rekiho*, Tokyo: Heibonsha. 1969,p.171.

[5]ARSI, Jap. Sin. II 154.

[6]*Lifa wenda* V-1-1. In the introduction of the Treatise on Lunar Motion, Foucquet first discussed this topic in detail in Chapter III-1.

[7]Book III Part 1, ff.72a-b.

[8]V-1, ff.3a-5b. The micrometer is described here.

J. Andersen (ed.), Highlights of Astronomy, Volume 11B, 736–738.

Solar System as Huygens did. Foucquet also tries to emphasise the importance of Cassini's telescopic observations of the surface of Jupiter, including a dark spot appeared which between 1690 and 1691[9].

Kepler had derived the elliptic orbit of Mars making use of Tycho's observations of opposition. We can observe four observational data reduced from Tycho's observations in the *Lifa wenda*[10]. We can find this data cited from the *Almagestum novum* in 1651 by the Bolognian Jesuit astronomer, G. B. Riccioli, of which had been made use by Boulliau. Based on these data, together with other observational results by various astronomers in Europe, Foucquet tries to emphasise the inevitability of the introduction of the non-circular motions of the planets.

Although Foucquet failed to give any illustrations to explain the geometrical orbit of planets in the manuscript, we can reconstruct what he means to describe, that is, the elliptic orbits in terms of Kepler's method. Following the explanation of Kepler's Laws, he discusses Boulliau's so-called revised method, Pagan's (Bagan 巴岡) simple method, and Riccioli's (Li-zhuo-li 利酌理) spiral orbit, successively.

Let us see his description of so-called Kepler's method (*Ke-bo-er zhi fa* 刻白爾之法), in place of the areas rule, in the manuscript itself. He writes as follows:

(After having studied the record of observations of Mars by Tycho Brahe)
'Kepler for the first time abandoned circular motions, and adopted the ellipse (*Dan-xing-xian* 蛋形線) for the orbit of Mars'[11].

Here he did not use the term *Tuo-yuan* 橢圓[12], which became the standard representation after the compilation of the *Shuli jingyun* 數理精蘊 in 1723. In order to explain the new method (*Xinfa* 新法), he describes the geometry of the ellipse, emphasising the importance of understanding the character of it. Foucquet constructs
He goes on to show that the ellipse has two focuses (*juguangjuhudian* 聚光聚火點, or abriged as *judian* 聚點), on the lower of which the Sun is located.

After that Foucquet explains the areas rule of Kepler[13]. He discusses how the planets move on the ellipse about the Sun. And, for the explanation, he makes use of Riccioli's representation, which we can read in the *Almagestum novum*. Riccioli tries to discuss the areas rule introduced by J. Kepler[14]. Obviously Foucquet must have been describing the method, as a whole, relying on the contents of explanation as well as the illustrations from Ricciolo's book.

He also alludes to the cause of the elliptical motion of planets like magnetic force, which Kepler used. But, he declines Kepler's analogy, and follows Descartes' physics of the cause of motion. By doing so, he starts to introduce Boulliau's method as well as Pagan's so-called simple method, which used the second focus as the equant. As the text suggests[15], he invented *cassinoid*, with the aim of obtaining a possible orbit for the planets in which the superior focus would serve as equant point, and introduced another kind of elliptical orbit[16]. As the fifth method he also explains Riccioli's spiral orbit of the Sun (or planets). We would just like to show this from the figure from Riccioli's original book. As a whole, we can repeatedly say that he is rather faithfully following the *Almagestum novum* by Riccioli.

However, we must point out that, the long discussion of Kepler's Laws notwithstanding, Foucquet eventually transcribed as the astronomical tables La Hire's *Tables* in 1702, instead. La Hire had produced the *Tables*, totally relying on his own observations made for a long time at the Paris Observatory after he succeded Jean Picard. It was, indeed, practical astronomy, which Foucquet

[9]V-1, 8b. Cf. The dark spot on Jupiter produced by the impact of Shoemaker-Levy 9 comet in 1995. As to Cassini's observation see I. Tabe et al., "Discovery of a Possible Impact Spot on Jupiter Recorded in 1690", *Pub. Astron. soc. Japan* **49**, pp.L1-L5 (1997)

[10]V-1, ff.36a-45b.

[11]V-1, f. 47b.

[12]In the preface to the treatise on planetary motions, we observe as the more term, *tuo-yuan*, has been used for the shape of orbits, oval or ellipse, other than circle (V-1, f. i). The term, *tuoyuan-xing*, with the hand radical for the character, *tuo*, has first appeared in the *Celiang quanyi* 測量全義, *quan* 6, in the *Chongzhen lishu*, where the conic sections are discussed. See the *Xinfa suanshu* 新法算書 edition, *quan* 92, p.9a, 1.2; Taibei reprint version, 1972.

[13]V-1, ff.50a.

[14]V-1, ff.51b-52b.

[15]V-1, ff.78a-83b.

[16]Cf. Wilson, 1989, p.183.

was trying to introduce in the manuscript, although he tried to explain even the physics of planetary motions.

In this connection it is also worthwhile to point out that he brought to China the achievements of determination of astronomical constants which were remarkably improved after the invention of the telescopes mounted with micrometer. To mention a few examples: The obliquity of ecliptic, Cassini's determination of horizontal parallax of the Sun as well as the refraction up to the zenith. Chinese astronomers had only known Tycho's refractions, which had been introduced several decades ago.

It seems likely that the Jesuit missionaries in China, who took care of the Imperial Astronomical Observatory in Beijing eventually follwed the Riccioli's choice for the adaption of Kepler's Laws. It was crucial for them to compile the *Lixiang kaocheng houbian* (曆象考成後編, Sequal to Astronomical Compendium) in 1742. This is until now believed to be the first, formal introduction of Kepler's theory of elliptic orbits, for which the German Jesuit missionary, Ignatius Koegler (Dai Jinxian 戴進賢), together with the Portugese missionary, Andreas Pereira, took responsibility to the compilation as the Astronomer Imperial (*Qintianjianzheng* 欽天監正) of the Qing dynasty.