関西大学『社会学部紀要』第19巻第2号，1988，pp. 91-101. ISSN 0287-6817

Telescope and Observation in Late Ming China

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Abstract

It has, so far, been made clear that the first reference to the telescope and Galileo's astronomical discoveries in Chinese is in the T'ien Wên Lüeh of 1615, and that the first telescopic observation in China was carried out in 1631 when a solar eclipse occurred. Here our paper discusses the possibility that the telescope, introduced into China during the Ch'ung-chên astronomical reform inaugurated in 1629, was not the Galilean telescope but the Keplerian one. The fact can be reduced from the records of the partiality of the solar eclipse occurred in 1631 and of the position of Jupiter observed with the telescope. This has been overlooked by the authors who have dealt with the problem.

Key words: *Ch'ung-chên Li Shu, T'ien Wên Lüeh, Yüan Ching Shuo, Chiao Shih Li Chhi, Wu Wei Li Chih,* Hsü Kuang-ch'i, Li T'ien-ching, Solar Eclipse, Jupiter, Galilean Telescope, Keplerian Telescope

抄　録

中国にガリレオの望遠鏡による天文学上の諸発見（1610年）が紹介されたのは，1615年の『天問略』であったが，中国で最初に望遠鏡による天体観測がなされたのは1631年の部分日食であった。その後，木星などの位置観測も相ついでなされた。そのときの望遠鏡は，ケプラー式の天体望遠鏡であったことを史料の記録の分析によって明らかにしようと試みた。すなわち当時使用された望遠鑑はガリレオが用いたそれに比較すると視野が 30′ と大きく，それによってなされた木星の位置の観測結果や日食の食分の決定から帰納できる結論は，崇禎改暦の事業に利用された望遠鏡はケプラーが『ディオプトリス』(1611年）に論じたものに違いないということになる。

キーワード：崇禎暦書，天問略，遠鏡説，交食暦指，五緯暦指，徐光啓，李天経，日食，木星，望遠鏡観測。

The first reference to the telescope in Chinese is in the *T'ien Wên Lüeh* (Explicatio Sphaerae Coelestis[(a)]) by Emmanuel Diaz Jr. (Yang Ma-o[(b)]) of 1615, which explains Galileo's astronomical discoveries appeared in his *Sidereus Nuncius* published in 1610. Then, in 1618, Johannes Terrentius (Johann Schreck, Têng Yü-han[(c)]) arrived in China, and brought a telescope with him. The set was shown to the throne later in 1634. Adam Schall von Bell (T'ang Jo-wang[(d)]), with Li Tsu-pai[(e)], completed a Chinese treatise on the telescope, *Yüan Ching Shuo*[(f)], several years later in 1626.[1] This has explained the principle, the structure, and the usage of the telescope, as well as various astronomical discoveries with the instrument. In addition to Galileo's discoveries, it contains some other observational results, for example, the observation of the separation between Mizar and Alcor (ζ and 80 Ursa Majoris; *K'ai-yang*[(g)] and *Fu-hsing*[(h)], respectively).[2]

The telescope, as we have already made clar,[3] was made use of when the astronomical reform during the Ch'ung-chên[(i)] reign-period was inaugurated in 1629 under the supervision of Hsü Kuang-ch'i[(j)]. Here we should like to show how the telescope was used for various purposes at the reform.

I

As far as documents are concerned, the earliest opportunity for telescopic observation was the solar eclipse occurred on the 25th October, 1631.[4] This eclipse was a partial one. According to Oppolzer, this has been registered as Nr. 6736 in the part of solar eclipses.[5] Two sets of telescope were used at the Astronomical Bureau. One was put in the dark room (*mi-shi* [(k)]), and the other outside on the terrace. The result of the measurement of the magnitude of the partiality was 0.15 of the diameter, or one and a half per 10, of the solar disk, which was regarded as agreed with the revised calculation of 0.17 (see Fig. **1**).[6]

Here we should like to see how they observed the eclipse with the telescope. According to the *Chiao Shih Li Chih* completed in the following year, the telescope was covered with wrapping paper in the case that the eclipse was observed outside in the open air.[7] The projection plate was put in parallel with the lenses, in spite that we can find the long description of Kepler's method of elliptic projection just

(a) 天問略 (b) 陽瑪諾 (c) 鄧玉函 (d) 湯若望 (e) 李祖白
(f) 遠鏡説 (g) 開陽 (h) 輔星 (i) 崇禎 (j) 徐光啓 (k) 密室

1) Needham, J., *Science and Civilisation in China* 3 (Cambridge, 1959), pp. 444-445.
2) *Yüan Ching Shuo* (*Hsin Fa Suan Shu* edition, ch. 23), 5a.
3) Hashimoto, K., Kansai Daigaku *Shakai-gakubu Kiyou,* 18-1, 1986, 255-281.
4) D'Elia, P., *Galileo in China,* Harvard U. P., 1960, p. 42.
5) Cf. von Oppolzer, T. R., *Canon der Finsternisse,* Wien, 1887.
6) *Chiao Shih Li Chih,* ch. 7 (*HFSS,* ch. 70), 13a-14b.
7) *Ibid.* ch. 7, 13a.

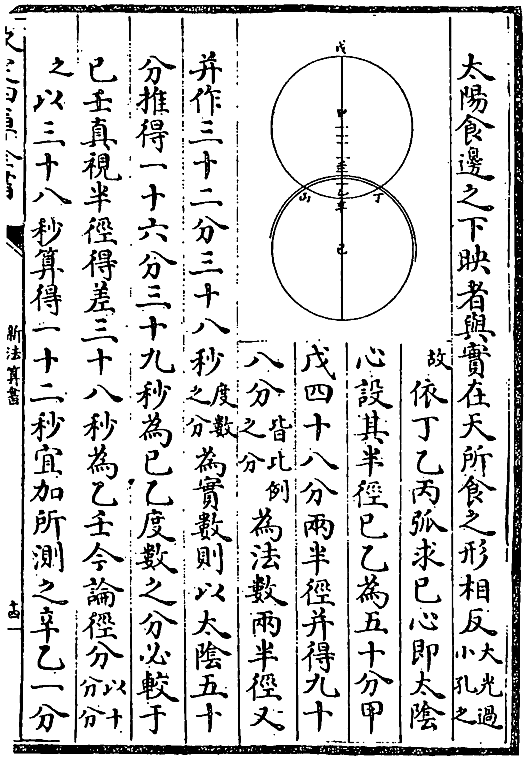

太陽食邊之下映者與實在天所食之形相反大光過小孔之故
依丁乙丙弧求巳心即太陰
心設其半徑巳乙為五十分甲
戊四十八分兩半徑并得九十
八分皆此例之分為法數兩半徑又
并作三十二分三十八秒之度分數為實數則以太陰五十
分推得一十六分三十九秒為巳乙度數之分必較于
巳壬真視半徑得差三十八秒為乙壬今論徑分以十分
之以三十八秒算得一十二秒宜加所測之辛乙一分
新法算書

Fig. 1

below in the other part of the *Treatise*.[1] The *Treatise* here also says as follows:[2]
"Now the shape of the (partially) eclipsed sun, which has been observed with the telescope, is like the figure *ting-i-ping-wu*[(a)] (see Fig. **1**). This is the image that the bottom of the sun's disk appeared to have been eclipsed and darkened on the telescopic projection. In reality, in the sky the shape of the eclipsed sun was quite opposite and upside down."

The last sentence suggests that the instrument was not the Galilean but the Keplerian telescope, and that the telescope, which had been brought to China, could have been the latter one. If so, the instrument for the observation of eclipse might have been the helioscope with the Keplerian telescope which had been used by Christopher Scheiner several years later after the publication of the *Dioptrice* by Kepler in 1611. We shall return to this question below in the end of the present paper.

After the death of Hsü Kuang-ch'i in 1633, the telescopic observation was frequently carried out as before. We can mention another example of the observation of a solar eclipse occurred on the 15th January, 1638. The director of the Astrono-

(a) 丁乙丙戊
1) *Chiao Shih Li Chih*, ch. 7 18b-20b.
2) *Ibid.*, 13b.

mical Bureau at that time was Li T'ien-ching[a] who had succeeded Hsü and was supervising J. Rho (Lo Ya-ku[b]) and Adam Schall von Bell to make use of the telescope for that purpose.[1]

II

Next we should like to examine the observation of planetary motions with the telescope. When Jupiter was retrograding and approaching to the Ssŭ-kuai, êrh[c] (1 Gem) in December, 1633. The change of the separation of Jupiter from the star was being measured day by day. Here we can see the change of the separation in the Figure **2**. According to the record, we can read as follows:[2]

"In the night on the *chia-chen*[d] day of the 16th of the 11th lunation in the *kuei-yü*[e] year in the Ch'ung-chên reign-period (i.e., 16th December, 1633, *Gregorian day*), we observed that Jupiter was about to eclipse the second star of the *Ssŭ-kuai* (1 Gem). Some one said that, although it looked like as if they were both joined together, the bodies of Jupiter and the star had actually not overlapped yet. The precise observation supported his assertion.

Now making use of the telescope, the minute numerical value of the mutual separation of the two celestial bodies could be measured. But the cloud sudddenly appeared and they disappeared. The time of that moment was in between the end

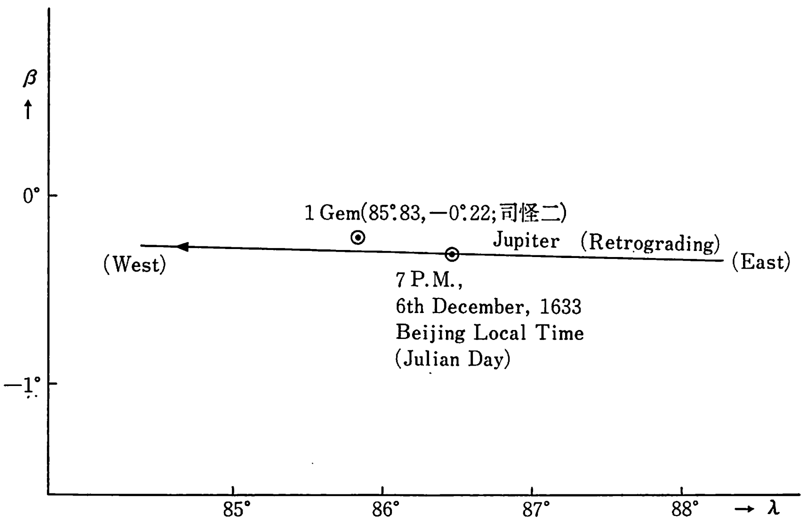


Fig. 2

(a) 李天経 (b) 羅雅谷 (c) 司怪二 (d) 甲辰 (e) 癸酉

1) *Chih Li Yüan Ch'i*, ch. 6 (*HFSS*, ch. 6), 18b-19a.

2) *Wu Wei Li Chih*, ch. 3 (*HFSS*, ch. 38), 28a.

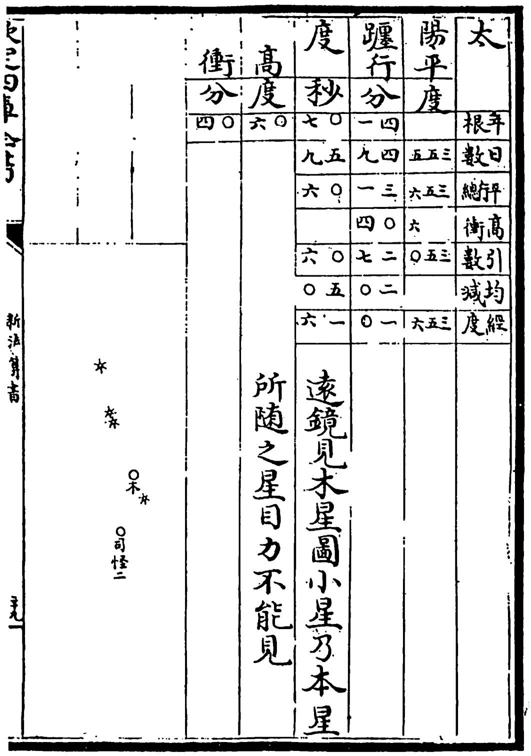


Fig. 3

of *shu*[a] and the beginning of *hai*[b] (21 hours)."

As for the theoretical calculation, they placed the time of the middle of *tzŭ*[c] (24 hours). As a result, they obtained 6 minutes as the minimum distance between them. The text goes on saying,

"Jupiter did not eclipsed the star yet. The bright light of Jupiter was, nevertheless, mixed up with the ray of the star. And they looked like one body as the effect of the mixture of the light of both of them. Again, with the telescope, it became clear that both Jupiter and the star did not overlap yet and were seen as two objects in the field of vision. And, since it was just before the conjunction, Jupiter was seen in the east and the star in the west, and both were located within 6 minutes distance."[1]

Here we should like to show the diagram from the *Wu Wei Li Chih*[d] (*Treatise on the Planetary Motions*) (Fig. **3**).[2]

According to our estimate, Jupiter was to come to the closest point from the

(a) 戌　(b) 亥　(c) 子　(d) 五緯曆指

1) *Op. cit.*, 29b.

2) *Wu Wei Li Chih*, ch. 3 (*HFSS*, ch. 38), 29a.

star, 1 Gem, during the night on the 8th December, 1633 (Julian calendar), and the separation between them was to be less than 6 minutes (see Fig. **2**), which does not contradict with the description in the text under consideration. Here the position of the star has been given there.[1)]

Although the date of the closest separation between the two objects is different to each other, the numerical value of distance is the same. Therefore, the observation and calculation can be evaluated as fairly good. We can conclude that it was made possible only by making use of the telescope.

Here we should like to show another example of the telescopic observation. It also concerns the motion of Jupiter now in vicinity of the *Chi-shih-ch'i*[(a)] (M44, Praesepe) in the middle of the *Kuei-shu*[(b)] (θ, η, γ, δ Cancri) of the 28 determinative stars system. Astronomers in Beijing pursued the motion of Jupiter from October in 1634 to June in the next year, during which the planet retrograded from the 10th October in 1634 to the 10th March in 1635. And Jupiter passed three times in vicinity of Praesepe in between. We can see in the Figure **4-a** the planetary orbit of how it was like at that time.

During the earlier stage of the Ch'ung-chên astronomical reform, it had been made clear that there are many (faint) stars in the oblong of the *Kuei-shu*, and, making use of the telescope, 36 stars had been recognized between the determinative (or standard) star (*chü-hsing* [(c)]; θ Cnc) and the north-east large star (*Tung-pei-ta-*

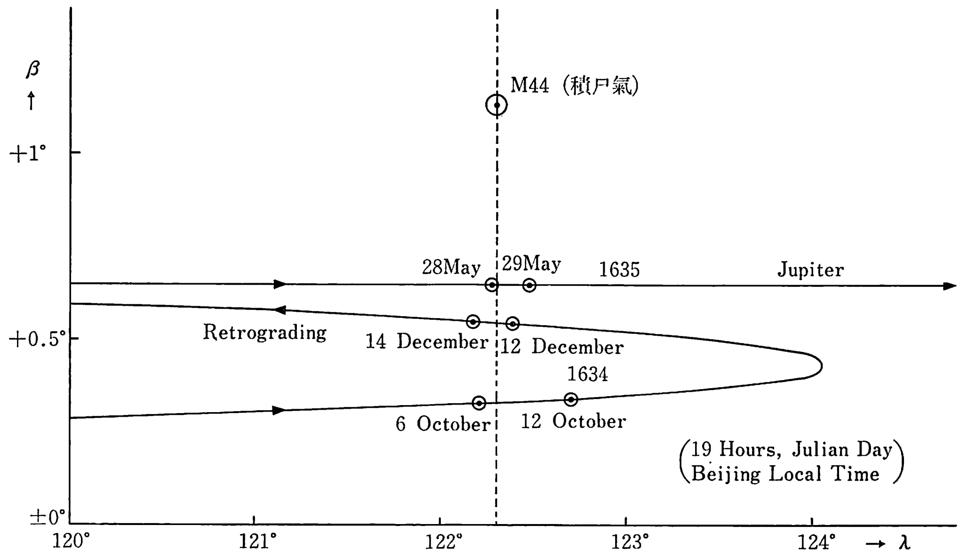


Fig. 4-a.

(a) 積尸氣　　(b) 鬼宿　　(c) 距星

1) *Wu Wei Li Chih*, ch. 3 28b.

hsing[a]; *r* Cnc).[1] The position of M44 had also determined for the epoch of the year, 1628.[2] (Here we have calculated the position independently from the Star Tables by P. Neugebauer[3]).

According to the document,[4]

"Jupiter was in the same degree and same minute with the *Chi-shih-ch'i* on the 22nd December as to right ascenssion, and on the 24th December, 1634, as to longitude, respectively. And the distance between Jupiter and the Praesepe was measured as 54/100 degree (=32′) and it was regarded as the intrusion (*fan* [b]) of Jupiter into the cluster.

Then, Jupiter was in the same degree and same minute with the Praesepe on the 7th June as to right ascenssion, and on the 8th June, 1635, as to longitude, respectively. The distance was 38/100 degree (=23′), and it was regarded as intrusion (*fan*)."

Before these observations, Jupiter was intensively observed. It was approaching to the Praeaepe at that time. As for the phenomenon, there remains a detailed memorial prepared by Li T'ien-ching, which was presented to the throne on the 7th November in 1634. His memorial first of all gives us an information about the telescope then available to the astronomers in Beijing.[5]

"Generally speaking, the tube (*k'uei-kuan* [c]) is capable of seeing the body of star, which is very faint and dark, and which is difficult for the naked eye to observe and distinguish. When two stars are located within half a degree, i. e., 30 minutes according to the new method, which is impossible to measure and distinguish by the naked eye by making use of ordinary instruments without the telescope, the tube can catch both of them within the same field of vision and can clearly distinguish them to each other. The field of vision allows more than half a degree (*pan-tu-ch'iang* [d]) which is the power of sight of the tube. In case two stars are separated to each other too much more than about half a degree, then they are not able to be seen in the same field at the same time."

It continues as follows:

"In the 25th night of the Leap month of the 8th month (16th October) and in the 1st night of the 9th month (22nd October, 1634), therefore, I, the subject of Your Magesty, together with the Superintendent and officials of the Ministry of Rites, was at the Bureau of Astronomy, and observed Jupiter to be seen in the *Kuei-hsiu* determinative asterism. We found it separated only by half a degree from the *Chi-*

(a) 東北大星 (b) 犯 (c) 窺管 (d) 半度強

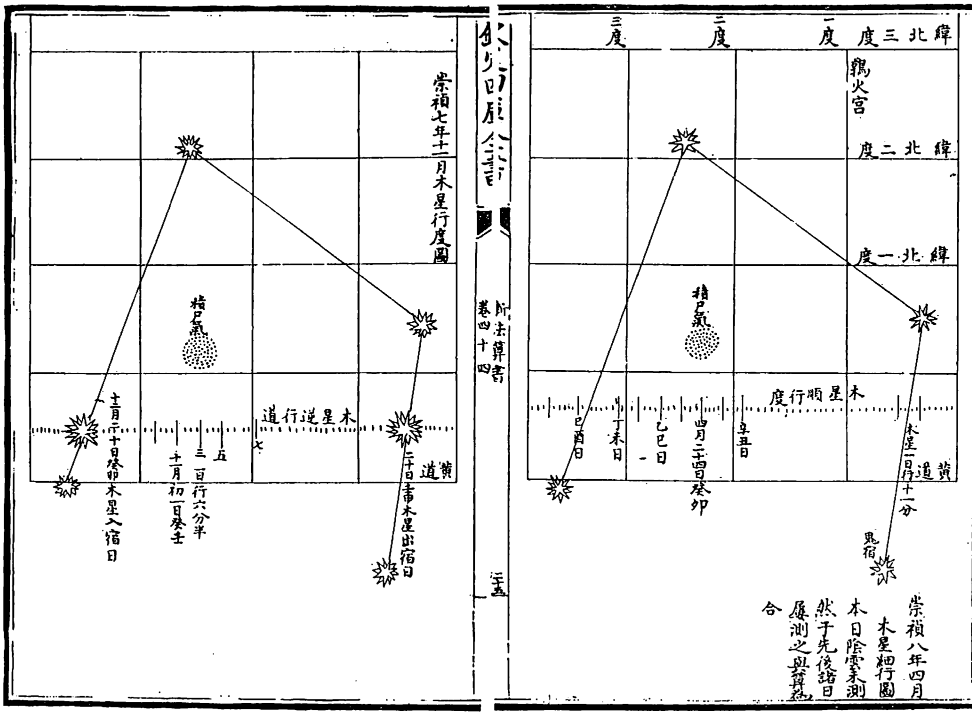
1) *Hêng Hsing Li Chih*, ch. 3 (*HFSS*, ch. 58), 36b.

2) *Hêng Hsing Piao*, ch. 1 (*HFSS*, ch. 59), 35a.

3) Neugebauer, P. V., *Sterntafeln*, Leipzig, 1912; Nr. 192.

4) *Wu Wei Li Chih*, ch. 9 (*HFSS*, ch. 44), 24a–25b. Also see Fig. **4–b**.

5) *Chih Li Yüan Ch'i*, ch. 3 (*HFSS*, ch. 3), 22b–24b.



(i) (ii)

Fig. 4-b. Jupiter and Praesepe (i) in December, 1634, and (ii) in June, 1635, (from the *Wu Wei Li Chih*, ch. 9).

shih-ch'i cluster. Because the light of Jupiter is big and bright and the body of cluster appears faint, it was impossible to measure (the mutual distance) if we did not rely on the sighting-tube (i.e., telescope). I, the subject, therefore, ordered people to use the telescope exclusively, so as for each of them to clearly observe that the cluster consists of several tens of small stars. And, in addition, I had them understood that, if they were able to see Jupiter together with the cluster in the same field of vision of the tube, then it was no other than their mutual transgression (*hsian-fan* [a])".

Now let us examine the statement by Li T'ien-ching above. According to our diagram (Fig. **4-a**), Jupiter was actually separated from the Praesepe by about 48 minutes when Li observed their mutual separation in October in 1634. And, if we take it into consideration that, as the statement above suggests, the field of vision of the telescope was about half a degree, it seems to be impossible that they were capable of obrerving Jupiter together with the cluster in the same field of vision. It is, nevertheless, quite obvious that they used the telescope to pursue the motion of the planet. And, it is quite safe to conclude that the next two consecutive approaches of Jupiter to the Praesepe must have been observed with the telescope although we

(a) 相犯

cannot find any mention of making use of it. Otherwise, they perhaps could not have measured the separation as 32′ for the second case and 23′ for the third, respectively. These observational determinations are remarkably good, because our diagram shows they were actually about 34′.8 and about 29′, respectively.

III

We have already suggested above that the telescope, which was used for the astronomical reform, could have been the Keplerian one. As is well known, Galileo's largest instrument had a field of only 7′ 15″, less than one quarter of the moon's diameter, and Kepler, set forth the astronomical telescope in his *Dioptrice* in 1611.[1] Although Kepler did actually not use the new telescope, Christopher Scheiner, a controversial Jesuit professor at Ingolstadt, did so about half a dozen years later. In fact, Scheiner's *Rosa Ursina* (1630) indicates free use of Kepler's telescope for some years previously, in just what size and power is uncertain.[1]

Here let us examine the the problem of the field of vision more in detail. According to Li T'ien-Ching's memorial cited above, the telescope was able to contain two stars in the field of vision at the same time, even if they were separated more than 30 minutes to each other.[2] And the field of vision is expressed as the *pan-tu-ch'iang*[a] in Li's memorial. He shows two examples in the same place in order to make clear of the meaning of the limit of the field. One is the separation of the three stars in the *Tsui-hsiu*[b], one of twenty-eight determinative asterism, that is, λ, φ_1, and φ_2 Ori-

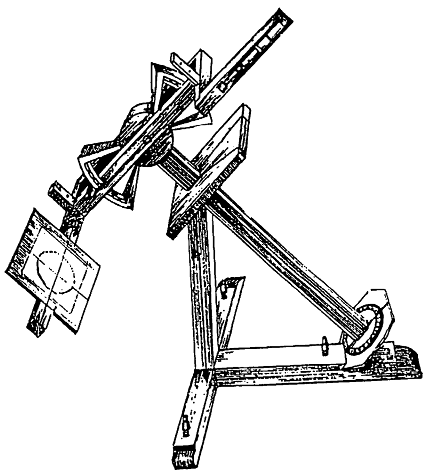
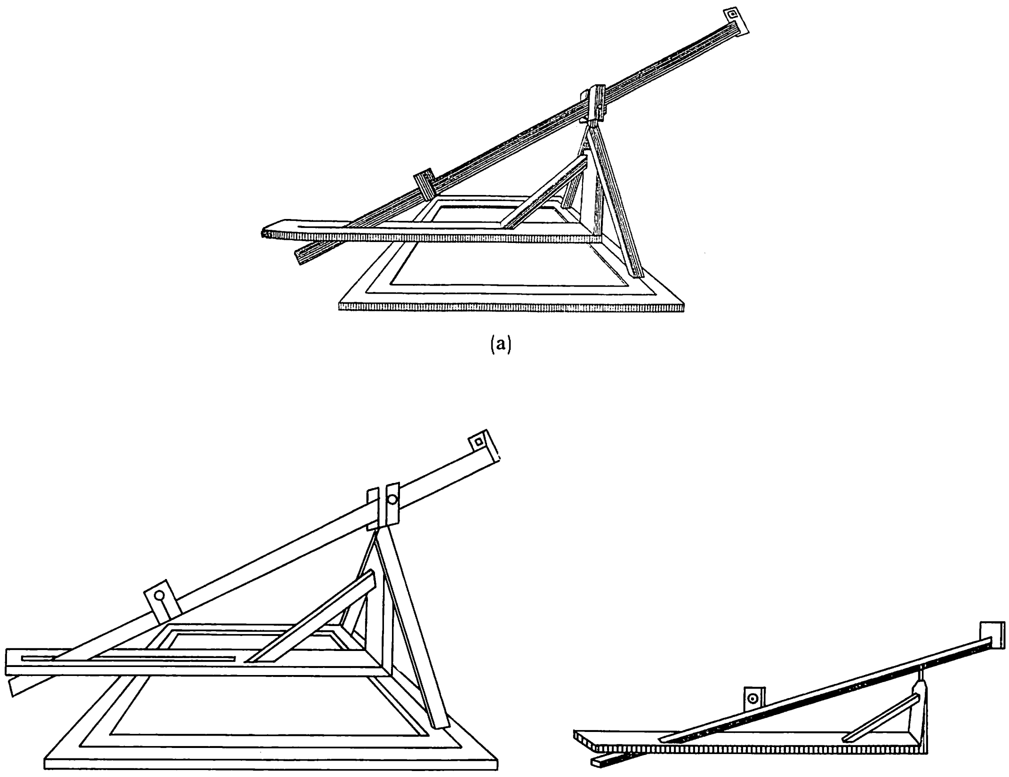


Fig. 5-a. Scheiner's helioscope (from H. C. King, *The History of the Telescope,* Dover ed., 1979, p. 42).

(a) 半度強 (b) 觜宿

1) Bell, L., *The Telescope* (1922), repr., New York, 1981, pp. 10-11.

2) See p. 91 above.



(a) (b) (c)

Fig. 5-b. Kepler's Instrument. (a) *Astronomia Pars Optica* (*Gesammelte Werke,* II, p. 289). (b) *Yüeh Li Li Chih,* ch. 3 (*Hsin Fa Suan Shu,* ch. 30), 5b. (c) *Chiao Shih Li Chih,* ch. 7 (*Hsin Fa Suan Shu,* ch. 70), 15b.

onis. The other is that of the two southern stars of the *Hsi-chu*[a] in the *Wu-ch'ê*[b] asterism, that is, ζ and η Aurigae. The separation of the former example is reportedly 37 minutes, and that of the latter is 44 minutes. In both cases, it can be evaluated remarkable precise. It is emphasized here that it was impossible to observe such stars in the same field of vision of the tube at the same time. Since these star-groups were not located in more or less the same declination to each other, it was not necessarily adequate to show the separations between them. But, at least we can understand by what means they tried to demonstrate the field of vision of their telescope(s). And it is particularly reasonable to have mentioned the separation between λ, φ_1, and φ_2 Orionis, because the declination of these stars was within 10° from the equator for that period of time.

Taking it into consideration that the field of the telescope was more or less the same with the disk of the sun, we should understand the meaning of it, expressed

(a) 西柱　　(b) 五車

as 'more than half a degree' (*pan-tu-chiang*), in this way.

Since the astronomers in China worked for the astronomical reform were dealing with the telescope with the field of about 30 minutes, it can safely be said that the instrument must have been the astronomical telescope. This does not contradict with our first example of the telescopic observation of the solar eclipse shown above, in the case of which the disk of the sun was projected onto the screen plate.

In this connection, we should like to see Scheiner's helioscope. He devised a crude parallactic mount (Fig. **5-a**), probably the first European to grasp the principle of the equatorial, which had long been anticipated by the Chinese instruments with sighting device.[2] The lower end carried a circle graduated into 24 hours divisions. Once the tube was pointed to the sun, the polar axis had only to be turned at a slow and constant rate to follow the disk across the sky.[3]

The Chinese device was, on the other hand, mounted the telescope on Kepler's original instrument for the observation of eclipses (see Fig. **5-b**).[4] This method, as matter of fact, has been explained in detail in the *Treatise on Eclipses* (*Chiao Shih Li Chih*[a]).[5] As far as the material source is concerned, it is quite reasonable to assume that the solar eclipse, occurred on the 25th October in 1631, might have been observed with the instrument explained in the *Treatise*. And the telescope was the Keplerian one.

(a) 交食曆指

1) Bell, *op. cit.*, see also King, H. C., *The History of the Telescope* (1955), repr., New York, 1979, p. 41.

2) Bell, *op. cit.*, p. 11.

3) King, *op. cit.*, p. 42.

4) Hashimoto, *op. cit.*

5) Ch. 7 (*Hsin Fa Suan Shau*, ch. 70), 1a-20b.