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ECLIPSE OBSERVATIONS MADE BY JESUIT ASTRONOMERS IN CHINA: A RECONSIDERATION

YUNLI SHI, University of Science and Technology of China

1. *Introduction*

In the *Qing-chao Wen-xian Tong-kao* (*Comprehensive study of civilization of the Qing Dynasty*, hereafter: *QCWXTK*) completed in A.D. 1785, there is a record of nearly one hundred and eighty observations of both solar and lunar eclipses visible from Beijing (116°.92E, 39°.92N) between A.D. 1644 and 1785, when the official Astronomical Bureau of China was technically dominated by several Jesuit astronomers. For each eclipse, the record summarizes the date of the event, the position of the sun or moon at the maximum phase, the times of the different phases, as well as the magnitude of the maximum obscuration.[1] These observations were first incorporated by A. Wylie in his table of "Eclipses recorded in Chinese works",[2] and then by the Beijing Observatory in the *Union table of the records of celestial phenomena from ancient China*.[3] In addition, when studying the timing system in the observations of solar eclipses in ancient China, Chen Jiu-jin also extracted the summaries of the solar eclipses from these observations and reduced the times to hours and minutes.[4] A few years ago, F. R. Stephenson and L. J. Fatoohi published two papers studying these observations.[5] After a systematic analysis of the errors in the times and estimates of magnitude of these observations, they concluded with a remark that "the eclipse observations made in China by Jesuit astronomers during the seventeenth and eighteenth centuries were of surprisingly poor quality", for two reasons:

(1) For the magnitudes, the standard errors of measurement are 0.05 for the solar eclipses up to about 1750 and 0.07 for the lunar eclipses up to about 1745, which is a typical performance of the unaided eye. After this period, the standard errors for solar and lunar eclipses both drop to 0.03, which is commensurable with the use of a small telescope.

(2) A clepsydra was still the main timing device in these eclipse observations. Up to about 1750 (for solar eclipses) and 1745 (for lunar eclipses), timing errors were considerable — typically amounting to a quarter of an hour. This is no better than the achievements of Chinese astronomers several centuries earlier. The later Jesuit observations, although substantially improved, were impaired by systematic clock errors of about 0.1^h.

This conclusion is indeed "surprising" if we consider the following facts:

(1) With the help of Jesuit astronomers, a telescope had been used by the official observatory of China in observations of eclipses since 1631.[6] In fact, right between

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the lines of the observations in the *QCWXTK*, one can find a short passage which tells the story of Emperor Kang-xi who once used a telescope to observe a solar eclipse in his palace by projecting the image of the sun onto a sheet of paper.[7] We cannot imagine that the Jesuit astronomers, who were largely responsible for introducing the telescope into China, had no telescope at their own disposal and that they failed to instal one at the official observatory which was then largely under their control. In fact, they were equipped with still more modern instruments than a telescope. For example, already in 1717 they had applied a micrometer in their eclipse observations.[8] And before 1750, they even had been donated a transit instrument by a Portuguese physician.[9]

(2) Due to the influence of European astronomy, astronomers at the official observatory of China had been well aware of the importance of the timing in an eclipse observation at least since 1628, and they understood some practical techniques of time calibration. In fact, they did not rely on a clepsydra as constantly as we imagined. On the contrary, during an eclipse observation, they usually measured times directly either from the apparent positions of the sun and the moon or from the transits of certain fixed stars.[10] In addition, a considerable number of mechanical clocks were brought to China by Jesuit astronomers after 1583 and they had become quite popular.[11] In 1718, a pendulum clock had already become the main timing device in various astronomical observations made by Jesuit astronomers in China, who also knew clearly how to make a *horologium correctum* for an astronomical observation.[12]

Bearing these two facts in mind, one would feel very reluctant to accept Stephenson and Fatoohi's conclusion, especially with regard to the observations before 1745 and 1750. However, their analysis is established on a solid basis of modern astronomy. Therefore, there should be other origins for the existence of such unreasonably large errors revealed by them. The most likely origin lies in the observations themselves, and therefore we will reexamine the original data of these observations to test their reliability. First we will re-analyse the original text in the *QCWXTK* concerning these observations, and then check the data against observational records extant in the archives of the Qing Dynasty and the astronomical reports sent back by Jesuit astronomers from China to Europe. Finally, we will compare them with eclipse predictions released by the Astronomical Bureau of the Qing Dynasty, to see if they have any sort of connection.

2. *Re-analysis of the Original Text*

When reading carefully through the original text in the *QCWXTK*, one can easily notice the following questionable points relating to these observations:

(1) There are all together 48 solar and 131 lunar eclipses summarized in the text. These include nearly all eclipses greater than 0.1 in magnitude and visible from

Beijing between 1644 and 1785. The summaries are all astonishingly complete, describing the course of every eclipse from the beginning to the end, without any interruption or omission. Only one solar eclipse, that of 1647 Jan. 17, was described as being obscured by cloud and rain. This seems to imply that the other 178 eclipses all took place under perfect weather conditions, without interference from cloud, fog, rain or snow.

(2) In the text, we can find one such complete summary of the solar eclipse that occurred on 1719 Feb. 19, the first day of the year *Kang-xi* 58. However, what follows is an edict of Emperor Kang-xi, which reads: "The solar eclipse on the New Year's Day of this year was not observed [from Beijing] because of the heavy clouds and slight snow. But it should have been seen from some other provinces where the sky was unclouded."[13] This indicates that the preceding summary is in fact an unobserved result.

(3) There are 4 solar and 10 lunar eclipses that are recorded explicitly as occurring around the horizon as seen from Beijing. But, strangely, for 9 of these 14 eclipses (namely the solar eclipses on 1731 Dec. 29 and 1763 Oct. 7, and the lunar eclipses on 1753 Oct. 12, 1754 Oct. 1, 1755 Sept. 20, 1759 Jan. 13, 1780 May 18, 1783 Mar. 19, and 1783 Sept. 11), the text describes either the times of the first contacts before the sun or the moon rose above the horizon, or the moments of the last contacts after they set below the horizon. To give a general idea of what is going on in these nine summaries, here are two examples from the book, expressing the times directly with hours and minutes, with the sun on the meridian at 12.00^h:

> The year *Yong-zheng* 9, month 12, day *geng-yin* (1731 Sept. 12). The sun was eclipsed at zero degree and 26 minutes in the lunar lodge *dou* to the extent of 9 *fen* 11 *miao*. <u>The beginning of loss was at $6^h\ 53^m$.</u> The sun rose from the horizon at $7^h\ 25^m$ with an obscuration of 6 fen 40 miao. It underwent maximum obscuration at $7^h\ 49^m$ and was restored to fullness at $9^h\ 5^m$.
>
> The year *Qina-long* 48, month 2, day *wu-yin* (1783 Sept. 11). The moon was eclipsed at 7 degrees and 37 minutes in the lunar lodge *yi* to the extent of 17 *fen* 46 *miao*. The beginning of loss was at $3^h\ 22^m$. The moon underwent maximum obscuration at $4^h\ 23^m$, set below the horizon at $6^h\ 2^m$ with an obscuration of 10 *fen* 24 *miao*, <u>began to recover brightness at $6^h\ 5^m$, and was restored to fullness at $7^h\ 5^m$</u>.

Obviously, it is impossible for anyone to observe the underlined phenomena in these two paragraphs.

(4) By checking all observations in the text with the rising and setting times of the sun and the moon calculated with modern algorithms kindly made available by Professor Peter J. Huber, we found that even more eclipses had in fact occurred, between 1644 and 1739, around the horizon as seen from Beijing. But for each of these eclipses, the text still gives a complete description of the whole process from

the beginning to the end, without any word as to their eclipsed rising or setting, as if they had all taken place above the horizon. Tables 1 and 2 list the times of the three major phases of these eclipses as recorded in the *QCWXTK*, together with the actual rising and setting times of the sun or the moon on the corresponding days computed with modern algorithms. The unit of time is local time in hours, while the date is in the Gregorian calendar. The items marked with asterisks must in fact have occurred below the horizon.

These four points cast a heavy shadow of suspicion on the reliability of these observations. But before any conclusion can be drawn, it is necessary for us to check them with some eclipse observations from other sources.

TABLE 1. Solar eclipses recorded in the *QCWXTK* that actually occurred close to the horizon.

No.	Date	First Contact	Middle	Last Contact	Sun Rise	Sun Set
1	1657/6/11	3.317*	5.150	6.067	4.51	19.48
2	1665/1/16	15.350	16.617	17.767*	7.15	16.86
3	1695/12/6	15.717	16.850*	17.950*	7.26	16.73
4	1706/5/12	18.350	19.217*	20.050*	4.85	19.14
5	1708/9/14	16.867	17.080	18.650*	5.27	18.26
6	1712/7/3	3.667*	4.517*	5.417	4.53	19.47
7	1715/5/3	18.183	19.033*	19.850*	5.01	18.98

TABLE 2. Lunar eclipses recorded in the *QCWXTK* that actually occurred close to the horizon.

No.	Date	First Contact	Middle	Last Contact	Moon Rise	Moon Set
1	1648/6/5	18.800*	19.983	21.183	19.30	4.97
2	1650/5/15	2.267	3.750	5.233*	18.68	4.84
3	1653/9/7	16.767*	18.667	20.567	18.33	6.26
4	1660/4/25	15.150*	17.133*	19.117	18.85	4.92
5	1663/8/18	2.100	3.933	5.917*	18.47	5.33
6	1671/3/25	17.150*	19.200	21.267	18.07	6.03
7	1674/7/17	2.433	4.317	6.217*	19.08	4.75
8	1679/4/25	5.183	6.550*	7.900*	19.32	5.25
9	1681/3/4	17.433*	19.067	20.700	17.62	6.57
10	1682/2/21	4.933	6.833	8.750*	17.96	6.57
11	1685/12/10	4.333	6.417	8.500*	16.89	7.44
12	1686/6/6	17.167*	18.817*	20.467	19.45	4.93
13	1686/11/29	5.650	7.117	8.583*	16.90	7.35
14	1688/10/9	17.317*	18.850	20.383	17.67	7.00
15	1690/3/24	4.600	5.933*	7.267*	17.59	5.84
16	1693/7/17	16.633*	18.567*	20.483	19.27	5.26
17	1695/5/28	17.533*	18.867*	20.200	19.37	5.05
18	1699/9/9	16.683*	18.367	20.067	18.25	6.21
19	1701/2/22	5.983	7.250*	8.500*	17.95	6.61
20	1707/10/11	16.767*	18.717	20.667	17.61	7.01
21	1708/9/29	3.700	5.067	6.433*	17.63	6.22
22	1710/2/13	5.067	6.700	8.333*	17.84	6.81
23	1710/8/9	16.005*	17.767*	19.500	19.00	4.49
24	1715/5/18	18.717*	20.317	21.917	19.07	5.15
25	1719/8/29	3.150	4.450	5.767*	18.37	5.49
26	1732/12/1	3.900	5.817	8.750*	16.19	7.39
27	1735/4/7	17.217*	18.700	20.167	18.40	5.84

3. *Check Against Observations from Other Sources*

In ancient China, an eclipse of the sun and the moon was believed to be a portent of the utmost gravity. Whenever an eclipse occurred, a special ceremony was to be held to save the sun or the moon from loss. Up to the Qing Dynasty, the Astronomical Bureau was required to organize an observation during the ceremony, and to record the whole process with words and a scheme depicting the shape of the eclipse during maximum phase. Then they had to submit to the throne an observational report together with an astrological explanation.[14] Some of these reports are still extant in the astronomical archives of the Qing Dynasty, and have been edited and published by Bo Shu-ren.[15] In these reports, we can find 32 solar and 82 lunar eclipses observed at Beijing between 1681 and 1785. However, more than 44% of them are recorded as either totally or partially unobserved either because of the weather or because of the rising or setting of the eclipsed body, while another 16% list data different from those for observations of the same date recorded in the *QCWXTK*. Besides, contrary to the observations in the *QCWXTK*, none of the observational reports in the astronomical archives presents the magnitude and the exact celestial position of the eclipse. These differences show that the observations in the *QCWXTK* were not transcribed from these reports.

It might be thought that we now should be able to analyse the accuracy of these observational reports and thus to establish the calibre of the Astronomical Bureau of the Qing Dynasty in eclipse observation. However, it turns out that it would be wholly unwise to take this step, because the credibility of these observational reports is also questionable, even if they supply us with some genuinely observed information such as weather conditions and the rising or setting of the eclipsed body.

For example, there was a solar eclipse on 1704 December 27 that was visible from Beijing. According to the prediction of the Astronomical Bureau, the times of the three major phases of this eclipse would be 12.933, 14.250 and 15.367 hours respectively (the unit of time being the same as that in Table 1). During the occurrence of the eclipse, the Emperor Kang-xi, who was very versed in astronomy, conducted an independent observation with the instruments installed in his palace, and measured totally different values for the times of the three phases, namely 12.433, 13.783 and 15.250 hours respectively.[16] But when we check the observational reports in the astronomical archives, the values given are exactly the same as those in the prediction quoted above. Comparison of all data that were said in these reports actually to have been measured (including the data of these partially observed eclipses) with the corresponding data in the extant eclipse predictions of the Astronomical Bureau of the Qing Dynasty (see the next section) shows that they are identical. Obviously, this level of compatibility between predictions and observations is too perfect to be true.

In ancient China, an emperor would severely condemn, and even punish, the astronomical officers who made apparent mistakes in an eclipse prediction. Up

TABLE 3. Solar eclipses reported by Hallerstein.

No.	Date	Magnitude	First Contact	Middle	Last Contact
1	1719/2/19	—	14.642	—	—
2	1720/8/4	0.725	10.717	12.217	13.700
3	1721/7/24	—	17.350	—	—
4	1730/7/15	0.842	—	12.850	14.453
5	1731/12/29	—	—	—	8.600
6	1735/10/16	0.833	7.783	8.963	10.292
7	1742/7/3	0.700	—	7.533	8.550
8	1746/3/22	0.745	9.246	10.817	12.433
9	1751/5/25	0.487	6.698	7.550	8.435
		0.487	6.708	7.558	8.434

to the Qing Dynasty, these officers faced one further hazard — the tables used in astronomical calculations were either adopted by the order of an emperor, or even "royally edited" by such emperors as Kang-xi and Qian-long. If someone found a table was inaccurate in the eclipse prediction, he was challenging the authority of the relevant emperor, unless he could find a good excuse for the inaccuracy. Therefore, when Kang-xi himself found the discrepancy between predictions and observations, he was far from pleased, and delivered the following edict to the Astronomical Bureau:

> There is no possibility that the new method [i.e. the new tables first re-adopted at his order and later "royally re-edited" by him] can cause any mistake. It is likely that the mistake stemmed from a mis-transcription or was committed by the computers who truncated fractions too much in their calculation. Make a thorough investigation and submit a report to me.

A few days later, the mandarin chief and several other officers of the bureau pleaded with him for punishment, because they had found that it was their computation that proved to be inexact.[17] In this kind of situation, the Astronomical Bureau would certainly prefer that the observational results entirely conformed to the predictions!

Although the Astronomical Bureau of the Qing Dynasty was technically dominated by Jesuit astronomers from 1644 to the late eighteenth century, with only a brief period of suspension between 1666 and 1668, their role in these eclipse observations is quite obscure. But it is very clear that in 1717, when Ignatius Kögler became the technical chief of the bureau, he began to organize more systematic astronomical observations independent of the regular observations of the bureau. After he died in 1746, Augustin Hallerstein inherited his position in the bureau together with the whole bundle of the observational reports accumulated since 1717, and carried on the observations until 1752. A few of these observations were published in *Philosophical transactions*[18] and *Observations mathématiques, astronomiques, géographiques, chronologiques et physiques*,[19] but they were all included by Hallerstein in a book.[20] The observations range from solar and lunar eclipses to the lunar and planetary occultation of fixed stars. In addition, we can also

TABLE 4. Lunar eclipses reported by Hallerstein.

No.	Date	Magnitude	First Contact	Middle	Last Contact
1	1717/9/21	0.637	0.417	1.842	3.267
2	1718/3/16	Total	21.785	23.557	1.328
3	1718/9/10	Total	1.708	—	—
4	1719/8/30	—	—	—	—
5	1721/1/13	0.600	21.200	22.683	0.167
6	1722/1/2	Total	20.317	22.283	0.250
7	1722/12/22	—	—	—	—
8	1725/10/22	Total	0.725	No record	4.358
9	1726/4/16	—	—	—	22.258
10	1728/8/19	0.650	23.033	0.517	2.000
11	1729/2/14	Total	2.642	No record	6.294
12	1730/7/29	—	—	—	—
13	1731/11/13	0.412	18.300	19.450	20.683
14	1732/6/8	Total	—	—	23.750
15	1732/12/2	Total	Total	3.750	3.742
16	1733/5/29	0.700	1.367	3.258	—
17	1733/11/21	0.742	19.250	20.863	22.075
18	1735/4/7	—	—	—	19.983
19	1737/3/16	0.450	22.708	23.626	1.217
		0.457	22.711	23.641	1.217
20	1738/1/25	0.683	5.408	6.833	—
21	1739//7/20	—	—	—	—
22	1740/1/14	Total	4.000	—	—
23	1741/1/2	Under	6.086	Under	Under
24	1742/5/19	—	—	—	—
25	1742/11/12	0.575	18.833	20.100	21.367
		0.575	18.800	20.061	21.328
26	1744/10/21	No record	19.100	No record	21.814
27	1750/6/20	Total	2.967	Under	Under

find in the book a discussion of instruments such as the pendulum clock, telescope and micrometer that were used in these observations.

Nine solar and 27 lunar eclipses visible from Beijing were covered by the observations recorded in Hallerstein's book. Tables 3 and 4 list the measured times and magnitudes of these eclipses, using the same calendar and time unit as in Table 1 and expressing the magnitude as a decimal fraction of the solar or lunar diameter. Some eclipses in these two tables have two groups of data, because they were measured simultaneously at the royal observatory and at the Jesuit College in Beijing. Dashes indicate that observations were not possible because of the weather, while those labelled "Under" were not observed because the sun or moon was below the horizon, according to Hallerstein's report. From these two tables, we find that these observations provide totally different data as compared with those in the *QCWXTK*. In addition, a considerable number of these observations were affected by bad weather, whereas all the corresponding observations in the *QCWXTK* are very complete, without any hint of such difficulties.

To give a general assessment of the accuracy of these (genuine) Jesuit observations, we reduce the calculated results of the solar eclipses occurring between 1717 and 1752 from Tables 1 and 2 in Stephenson and Fatoohi's first paper,

TABLE 5. Errors in the solar eclipse data reported by Hallerstein.

No.	Date	Magnitude	First Contact	Middle	Last Contact
1	1719/2/19	—	–0.056	—	—
2	1720/8/4	–0.011	0.026	–0.008	–0.017
3	1721/7/24	—	0.020	—	—
4	1730/7/15	–0.004	—	0.000	–0.151
5	1731/12/29	—	—	—	–0.002
6	1735/10/16	0.008	0.087	0.094	0.124
7	1742/7/3	–0.002	—	0.023	0.039
8	1746/3/22	–0.007	–0.037	–0.015	0.003
9	1751/5/25	0.010	–0.015	0.007	–0.007
	1751/5/25	0.010	–0.005	0.015	–0.008
Standard Errors		0.007	0.035	0.023	0.044
Systematic Errors		0.000	+0.003	0.017	–0.019

and compare them with Hallerstein's data. The new errors (measured – calculated) are listed in Table 5, and this shows that both the standard and systematic errors of the magnitude and times are much smaller than Stephenson and Fatoohi's original results. This provides us with further evidence that the observations in the *QCWXTK* have no connection with the genuine Jesuit observations, because we cannot imagine that the same observers of the same phenomena could have obtained two groups of entirely different data with such very different accuracy.

4. *Comparison with Other Predictions from the Same Era*

No reasonable explanation can be given for the facts we uncovered in the last two sections, especially the completeness in the descriptions of eclipses that were in fact partially or even totally unobservable, unless at least some of these summaries describe predicted rather than observed results. As long ago as 1981, Bo Shu-ren compared the eclipses in the *QCWXTK* with the observational reports collected from the extant astronomical archives of the Qing Dynasty. He noticed that in the *QCWXTK* complete data are listed for a considerable number of the eclipses that were recorded as partially or even totally unobserved in the observational reports, and he pointed out that these data might have been transcribed directly from predictions.[21] But to confirm this inference, we need to compare these observations with the eclipse predictions of the Astronomical Bureau of the Qing Dynasty.

The Qing government began a systematic prediction of solar and lunar eclipses at least from 1644, when the new empire moved its capital from Sheng-yang to Beijing and took over the Astronomical Bureau from the Ming Dynasty. According to the ordinance of this Dynasty, the Calendar Officers of the Astronomical Bureau were to pre-calculate, at the end of every year, any eclipse that would be visible in China in the upcoming year, and to present a detailed prediction in the ephemeris for that year. Then, five months before a predicted eclipse, they were to submit to the throne another prediction. This prediction would list the position of the sun or the moon at the maximum phase, as well as the magnitude and times of the eclipse contacts as seen from Beijing and every province where the eclipse would be visible.[22] This prediction would be released formally through the Minister of Rite to the provinces involved. If the eclipse was observable from Seoul, a prediction would also be delivered to the King of Korea. Before about 1736, the prediction was made with the table based on the Tychonic system. Afterwards, however, a set of tables based on the first and second laws of Kepler and Newtonian lunar theory was employed.[23]

These predictions are now available in two sources. One is the astronomical archives of the Qing Dynasty,[24] while the other is the China-related diplomatic documents of the Chosŏn Korea.[25] Unfortunately, however, all predictions before 1721 seem to have been totally lost. Therefore, for the era covered by the *QCWXTK*, we have been able to collect only the predictions for 18 solar and 54 lunar eclipses visible from Beijing between 1721 and 1785. Checking these predictions against the corresponding observations in the *QCWXTK*, we find that, except for one

TABLE 6. Disagreement between certain 'observations' and predictions.

Date	Items	Observations	Predictions
Solar Eclipse			
1730/7/15*	Magnitude	0.937	0.937
	First Contact	11.017	10.950
	Middle	12.767	No record
	Last Contact	14.500	14.433
Lunar Eclipse			
1725/10/22	Magnitude	1.847	1.852
	First Contact	1.150	1.033
	Middle	3.100	No record
	Last Contact	5.033	4.950
1731/11/13	Magnitude	0.537	0.420
	First Contact	18.250	18.317
	Middle	19.667	No record
	Last Contact	21.083	20.467
1732/6/8*	Magnitude	1.550	1.508
	First Contact	19.883	20.083
	Middle	21.883	No record
	Last Contact	23.867	23.783
1732/12/2*	Magnitude	1.790	1.758
	First Contact	3.900	3.850
	Middle	5.817	No record
	Last Contact	8.750	7.450
1733/11/21	Magnitude	0.717	0.733
	First Contact	19.600	19.333
	Middle	21.100	No record
	Last Contact	22.583	22.133
1735/4/7*	Magnitude	0.617	0.538
	First Contact	17.217	17.433
	Middle	18.700	No record
	Last Contact	20.167	20.050

solar and six lunar eclipses, they provide exactly the same data for the position of the sun or moon at the maximum phase, as well as for the magnitude and times of each eclipse. This means that at least 80% of the 'observations' after 1721 in the *QCWXTK* actually obtained their data from predictions, rather than from genuine observations.

The inconsistent observations and predictions are tabulated in Table 6, where the 'observations' are taken from the *QCWXTK* while the 'predictions' have been assembled by us. The units and calendar are the same as those used in the previous tables. So far as these 'observations' are concerned, their disagreement with the corresponding predictions do not mean that they were certainly observed, because at least the four asterisked eclipses have proved to be partially unobservable from Beijing (see Table 4, no. 4, and Table 5, nos. 14, 15 and 18). It is very likely that they were taken from some other source of eclipse prediction different from the regular prediction of the Astronomical Bureau of the Qing Dynasty. For example, in 1730, Ignatius Kögler suggested that Emperor Yong-zheng adopt a set of much more exact European tables in the official calculation of the eclipse. Although the emperor granted the suggestion, the translation of the new table was not completed until about 1736, when the Astronomical Bureau was able to put it into practical application.[26] During this long period of transition, it is possible that both the old and the new tables were used in parallel in eclipse prediction, to compare their accuracy, and therefore for a number of years there may have been two predictions for each projected eclipse. It is very possible that the discordant observations and predictions in Table 6 reflect the co-usage of the two sets of tables during these years.

5. *Concluding Discussion*

Through the analysis of the foregoing three sections, we are now in a position to say that an absolute majority of the eclipses recorded in the *QCWXTK* are predicted results rather than observational reports. For the modern user of these data, it might be another "crime" in the history of astronomy. But before bringing this kind of accusation, we should pause to consider the special cultural background of the eclipse observation and recording in ancient China.

It is well known that ancient Chinese astronomers have bequeathed to us the longest and most substantial series of eclipse observations in the world. But few realize that after the tenth century A.D., when Chinese astronomers had developed a systematic method of eclipse prediction and thus were able to forecast this kind of ominous phenomenon with satisfactory precision, predictive results often sneak into the observed records in certain historical works. A considerable amount of this kind of spurious observation can be easily detected by checking against other available records of the same eclipse. For example, according to the *Astronomical annals of the new history of the Five Kingdoms*, "there was a solar eclipse" on day 24, month 2, year of *tian-chen* 3 (i.e. 928 Feb. 24). In the *Late Tang annals of the old history of the Five Kingdoms*, however, we find the following description of the same eclipse: "The officials concerned reported that there would be a solar eclipse. But it was not in fact observed because of clouds."[27] According to the author's rough survey of the records in the *Union table of the records of celestial phenomena from ancient China*, there are at least 21 solar eclipses of this kind recorded in the *Standard history of the Liao, Song and Jin Dynasties* that can be similarly identified.[28]

The reason why these historians recorded predicted eclipses together with observed ones was by no means to mislead. On the contrary, they were conscientiously fulfilling their duty not to neglect any important omens concerning which they could acquire information. In some of their minds, if a predicted eclipse was not eventually observed for whatever reason, it might be a good omen, and so they should record it as a predicted but unobserved eclipse. Others however might think that a predicted eclipse would definitely have taken place, whether or not it was observed from the capital city. They would record the eclipse according to the prediction.

As to the authors of the *QCWXTK*, they had even more reasons to use predictions in the bulk of their book. First of all, they were writing a history of their contemporary dynasty, and it was therefore too early to get access to confidential documents related to the security of the country. As we have mentioned above (see the beginning of Section 3), the Astronomical Bureau of the Qing Dynasty would have controlled many of the observational reports of eclipses since they were ordered to write such a report for each observed eclipse. However, the report always came accompanied by an astrological interpretation, which concentrated mainly on the fate of an emperor or other important members of the aristocracy, and therefore was among the highest secrets of the empire.

The authors of the *QCWXTK* were trying to do something different from the traditional recording of eclipses in an historical work. They were attempting to record all possible eclipses visible from Beijing in the most detailed and systematic way possible — unlike other histories, which used to give only very brief and incomplete accounts of eclipses. But the reality is that the authors of the *QCWXTK* had no access to the highest imperial secrets. Under such circumstances, the authors of the book could appeal to no other sources than the predictions, which not only included all the necessary information about every eclipse, but were purely 'scientific' and therefore very easily obtained.

Bearing in mind this complex background, we must be very wary when using astronomical data from ancient Chinese sources.

Since the majority of Stephenson and Fatoohi's data come from the eclipse predictions made by the Astronomical Bureau, their analysis actually reflects the error pattern of these predictions in a broad sense. It gives rise to another interesting question, namely, what is responsible for this pattern of error distribution? This relates in turn to two other questions: (1) Which European tables were adapted by Jesuit astronomers in their astronomical activites in China? And (2), how did they resolve such problems as the difference between the geographical longitudes of

Beijing and Europe when they tried to adapt these European tables for application in China? These will be our topic of further research.

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