Two Aspects of Solar and Lunar Eclipse Records in Vietnamese Historical Sources

— An attempt to judge whether these records were based on observation or prediction —

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Abstract

An attempt was made to judge whether (briefly described) solar and lunar eclipse records in Vietnamese historical sources were based on observation or on prediction, by using statistical approaches. For this purpose, two aspects of these solar and lunar eclipse records were examined: (a) The "Eclipse-recorded (ER) ratio" and (b) Bimonthly distribution of eclipse records. The results are as follows: (1) The ER ratio of solar eclipse records in the *ĐNTL-CB* suggests that many of these records in Period D are those of eclipse prediction deduced by calendar calculation. (2) The bimonthly distribution of the number of solar and lunar eclipse records in the *VSL* and the *TT&TB* in Periods B and C was found to show a large scatter, making it difficult to determine whether the distribution would have any correlation to the seasonal variation of sky conditions (cloud coverage and sunshine time), which led to no definitive conclusion for these records.

1. Introduction

Some historical sources in Vietnam contain a considerable number records of astronomical phenomena, as those in China, Korea and Japan do. For example, Ho Peng-Yoke (1964) and Okazaki and Yokoo (1984) found astronomical records in *Đại Việt Sử Ký Toàn Thư* (*TT*, 大越史記全書, Complete Annals of Great Vietnam) and *Việt Sử Lược* (*VSL*, 越史略, Abridged Chronicles of Vietnam), respectively.

Recently, Okazaki (2019) examined 124 solar and 59 lunar eclipse records (including a few ones of predicted eclipses) ranging from the third century BCE to 1888 CE, which are found in *VSL*, *TT&TB* (the *TB* stands for *Đại Việt Sử Ký Tục Biên*, 大越史記續編, Sequel of Annals of Great Vietnam, which is practically the sequel of the *TT*) and *Đại Nam Thực Lục Chính Biên* (*ĐNTL-CB*, 大南寔録 正編, the Principal Records [or the Main Volumes] of Veritable Record [or True Record] of the Great South). Among these eclipse records, most of those before the 10th century are considered to have been copied from Chinese sources (e.g., Ho Peng-Yoke, 1964). Hence, we will not deal with any eclipse records before the 10th century.

Okazaki (2019) also studied another 29 solar eclipse records found in the *Đại Nam Thực Lục Tiền Biên* (*ĐNTL-TB*, 大南寔録 前編, the Prequel Records [or the Early Volumes] of Veritable Record [or True Record] of the Great South). The *ĐNTL-TB* is the annals of the Nguyễn lords, whose descendants established the Nguyễn dynasty later on, while the *ĐNTL-CB* is the annals of the dynasty. For a certain reason (see below), we will deal with the records in the *ĐNTL-CB* separately from the other ones in the next section and later.

Many of these eclipse records are so brief that each of them tells us nothing more than the occurrence of an eclipse and its date. Thus, we can hardly determine whether these eclipse records were based on observations or predictions. Some studies (e.g., Saito and Ozawa, 1992) claimed that many historical records of solar and lunar eclipse in East Asian countries would be based on predictions deduced by calendar calculation, while other studies (e.g., Zhang, 1993) suggested that most of these records would be of reliable eclipse observations.

As for the solar eclipse records in the *ĐNTL-TB*, Okazaki (2019) found that their reliability (for the reliability, see section 3.1) is extremely low (31%). Moreover, all the doubtful records in *serious error* fall within the period from the late 1660s to the early 1720s. Meanwhile, disorders in allocation of intercalary months in the *Vạn Toàn Calendar* used in the *ĐNTL-TB* are mostly concentrated in this period as well. Such a strong link between the low reliability of the records and the disorders in the calendar seems to suggest that most of the solar eclipse records were based on prediction.

In this note, we will attempt to judge whether eclipse records in other Vietnamese historical sources were based on observation or prediction by using statistical approaches. For this purpose, we will focus on two aspects of these solar and lunar eclipse records: (1) The "Eclipse-recorded (ER) ratio" and (2) Monthly distribution of eclipse records.

2. Vietnamese luni-solar calendars

Before proceeding to the main issue, we briefly mention Vietnamese luni-solar calendars from the early 10th century through the late 19th century for the later discussion. Hoàng (1982) pointed out that some definite differences existed between the Vietnamese and the Chinese luni-solar calendars since as early as the late eleventh century. He also suggested that Vietnamese court astronomers calculated their own country's calendar by themselves using a Chinese calendar-making method since the late eleventh century. Subsequently, Lê (2007) restored the Vietnamese luni-solar calendar up to 1544 based on old calendar materials and published conversion tables between the Julian/Gregorian and the Vietnamese luni-solar calendars. We used his table to convert the dates of solar eclipse records in Vietnamese historical sources in and after 1544. For those before 1544, we had no choice to use a conversion table for Chinese luni-solar calendar. For recent reviews on the history of the Vietnamese luni-solar calendar, see Lê and Nguyễn (2017), Okazaki (2017) and Lê and Phạm (2019).

For later discussion, we divide here the time covered by the historical sources into four periods (Periods A, B, C and D) by calendar-making method used in Vietnam as follows:

Period A: Before 1080
The Chinese calendar was directly used.

Period B: 1081 – 1300
Not the same as the Chinese calendar in the same period. Calculated by Vietnamese astronomers

Period C: 1301 – 1812
Calculated by Vietnamese astronomers using the same method as Chinese *Shoushi* (授時) / *Datong* (大統) method.

Period D: 1812 –
Calculated by Vietnamese astronomers using *Hiệp Kỷ* method equivalent to Chinese Shixian (時憲).

3. Examination of "Eclipse-recorded (ER) ratio" for solar eclipse records

3.1 Reliability and ER ratio

Firstly, we introduce a measure, called here "reliability", to evaluate historical eclipse records. By the "reliability" we mean the ratio of the number of the records of the eclipses that

were observable in the capital of the Vietnamese dynasty to the number of all the eclipse records. To evaluate how an eclipse was seen in the capital on a described date, we used the simulation software program the *JavaScript Solar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.)

Fig. 1 shows the reliability of solar eclipse records in the *VSL*, *TT&TB* and *ĐNTL-CB* in Period B to D. We see from the figure that the reliability in Period D is higher than that in Periods B and C. However, we have to say that the increase by ~10% from Period C to D is not large enough to conclude that it is significant.

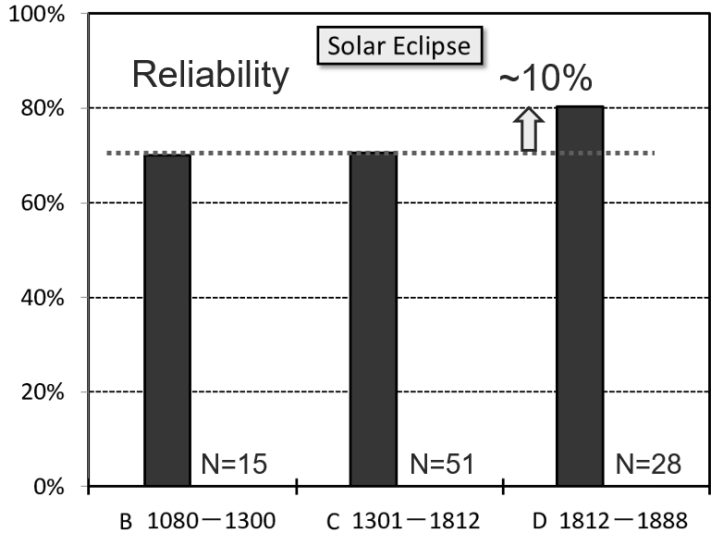

Fig. 1 Reliability of solar eclipse records found in the *VSL*, *TT&TB* and *ĐNTL-CB* in Period B to D. The number (*nn*) of records in each period is given in the form N=*nn*. See subsection 3.1.

Now, we introduce another measure, called here the "eclipse-recorded ratio (ER ratio)", which evaluate the ratio of the number of the (reliable) recorded eclipses to the number of all the eclipses occurred in the capital. We obtained the number of the latter in each Period by using *JavaScript Solar/Lunar Eclipse Explorer* (Espenak and O'Byrne, n.d., a/b).

Fig. 2 indicates the ER ratio of solar eclipse records in the *VSL*, *TT&TB* and *ĐNTL-CB* in Period B to D. The ER ratio (78%) in Period D is much larger than that (< 20%) in Periods B and C. We consider that this high ER ratio is connected with accuracy improvement due to the introduction of the *Hiệp Kỷ* calendar.

3.2 Extremely high ER ratio in Period D

As mentioned in the last subsection, the ER ratio (78%) of solar eclipse records in Period D is much larger than that (< 20%) in Periods B and C. If many of the eclipse records were based on predictions, no wonder that more accurate calendar calculations, which leads to more accurate eclipse calculations, resulted in an increase in the ER ratio. If many of the eclipse records were based on observations, accurate predictions should have led court astronomers to notice solar eclipses much more often so that the ER ratio increased, too. Thus, both of these seem acceptable to explain the high ER ratio in Period D.

However, if most of these eclipse records were based on observations and if the climate in Huế, the capital of the Nguyễn dynasty, has not varied significantly since the early nineteenth century, the high ER ratio (78%) should be unacceptable. This is because an annually averaged percentage of sunshine time in Huế, which can be roughly regarded as an upper limit of the ER ratio for solar eclipses, is estimated to be merely $\sim 41 \pm 4\%$ from the climate data provided by

the General Statistics Office of Vietnam (http://www.gso.gov.vn/default_en.aspx?tabid=773). Therefore, we may conclude that a large fraction of the records in Period D would be based on prediction.

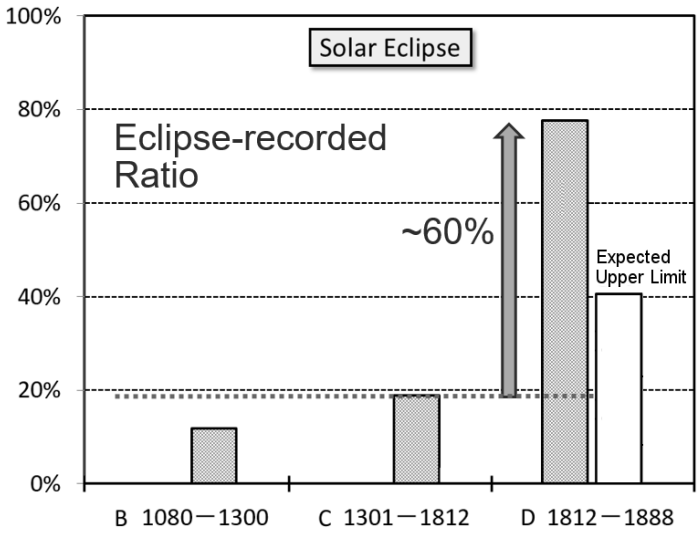

Fig. 2 ER ratio of solar eclipse records found in the *VSL*, *TT&TB* and *ĐNTL-CB* in Period B to D. In Period D, an expected upper limit of the ER ratio, which was estimated from an annually averaged percentage of sunshine time in Huế (based on the data by the General Statistics Office of Vietnam), is also given. See subsection 3.2.

4. Examination of monthly distribution of solar and lunar eclipse records

Now, we turn to solar and lunar eclipse records in Periods B and C. We will attempt to judge whether they were based on observation or prediction by examining their monthly distribution. For this purpose, we use 85 reliable briefly described records (44 solar and 41 lunar eclipses). Since the number of records in each month is not large enough, we have to examine a bimonthly distribution rather than a monthly one.

Fig. 3 displays the bimonthly distribution of the number of (briefly described) solar and lunar eclipse records in Periods B and C. It is seen from the figure that the number of the eclipse records shows a variation with a range of 12 to 18. Although the variation may reflect statistical fluctuation due to a small number of records in each record, we should see whether it would include any seasonal variation of sky condition. If many of these records were based on observation and if such a seasonal variation of was large enough, in the bimonthly distribution, we may expect some correlation between the number of eclipse records and sky condition parameters. Since the capitol, where the observation was made, was present Hanoi almost during Periods B and C, we compare them with modern climate data in Hanoi. Thus, we assume that climate condition has not varied significantly for last 1000 years.

Firstly, as a sky condition parameter, we employ cloud coverage, i.e. the average percentage of the sky covered by clouds. Its seasonal variation can be obtained, for example, by calculating the data for Hanoi presented by Weather Spark (https://weatherspark.com/y/118181/Average-Weather-in-Huế-Vietnam-Year-Round), which were based on NASA's MERRA-2 (The Modern-Era Retrospective analysis for Research and Applications, Version 2). We defined here the expected observation probability to be 100% minus (bimonthly averaged) cloud coverage (%). In Fig.3, full circles connected by solid line segments represent the bimonthly variation of the expected observation probability based on cloud coverage.

Secondarily, we adopt the bimonthly variation of sunshine time in Hanoi, which can be obtained by averaging the data given by the General Statistics Office of Vietnam (see above). We simply defined here the expected observation probability to be the percentage of (bimonthly averaged) sunshine time. It is noted that sunshine time is meaningful only in the daytime so that it should be compared with the number of solar eclipse records only. In the figure, open circles connected by broken line segments indicate the bimonthly variation of the expected observation probability based on sunshine time.

As shown in Fig.3, it is difficult to determine whether the distribution of the number of the eclipse records would have any correlation to the seasonal variation of cloud coverage or sunshine time. Thus, as for (briefly described) solar and lunar eclipse records in the *VSL* and the *TT&TB* in Periods B and C, we deduced no definitive conclusion of whether they were based on observation or prediction.

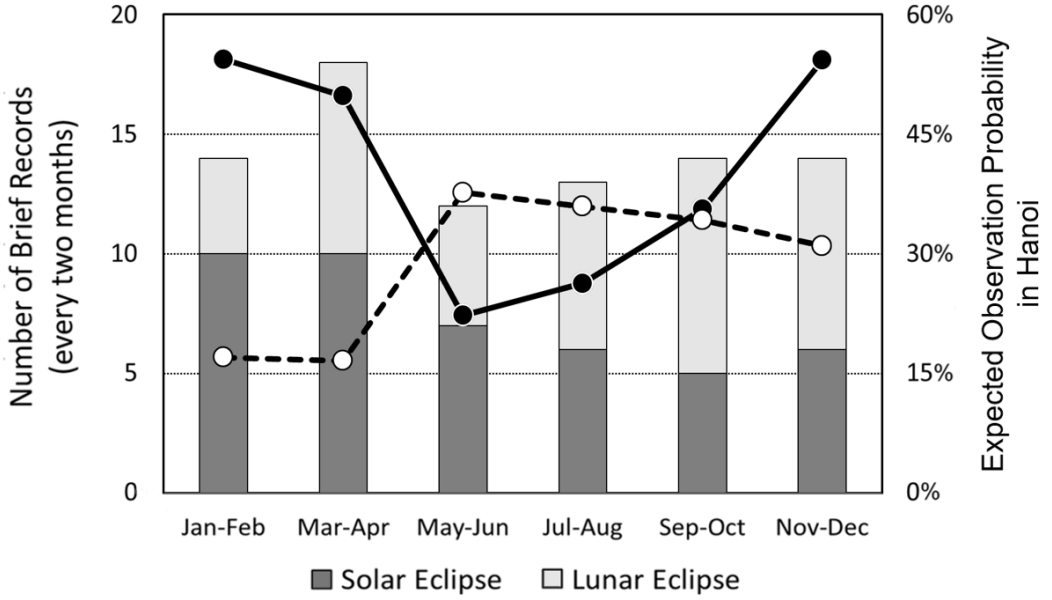

Fig. 3 The bimonthly distribution (vertical bars) of the number of solar and lunar eclipse records in the *VSL* and the *TT&TB* in Periods B and C. Full circles with solid line segments and open circles with broken line segments represent the bimonthly variation of the expected observation probability based on cloud coverage and on sunshine time, respectively. See section 4.

5. Summary

We attempted to judge whether (briefly described) solar and lunar eclipse records in Vietnamese historical sources were based on observation or on prediction. We examined two aspects of these solar and lunar eclipse records: (a) The "Eclipse-recorded (ER) ratio" and (b) Bimonthly distribution of eclipse records.

Our conclusions are summarized as follows:

(1) The results of our examination of the ER ratio of solar eclipse records in the *ĐNTL-CB* in Period D suggests that many of them were based on prediction deduced by calendar calculation.

(2) The bimonthly distribution of the number of solar and lunar eclipse records in the *VSL* and the *TT&TB* in Periods B and C was so scattered that we could not determine whether the distribution would have any clear correlation to seasonal variation of cloud coverage or sunshine time. Thus, we reached no definitive conclusion for these records.

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