# The Japanese astronomy in the 7th and 8th centuries

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## 1. Introduction

In this short report, we compare the characters of the Japanese astronomies in the 7th and 8th centuries. We already analyzed the character of astronomy in 7th century in Tanikawa & Sôma[1] using the astronomical records in the Nihongi[2]. We review the result in section 2.1. It seems to the authors that the character of the Japanese astronomy in the 8th century has not fully been analyzed. Similar to the method used in ref.[1], we study the records in the Shoku-Nihongi[3] in the sense of independence from the Chinese records and whether records were based on observation or prediction. In this respect, we do not treat local phenomena such as meteors and meteorites nor atmospheric phenomea such as aurorae. We consider solar and lunar eclipses and comets in the 8th century.

## 2. Analysis of the records

### 2.1 Astronomy in the 7th century

Astronomical phenomena are recorded in the Nihongi published in AD 720 which describes the history of Japan from the ancient beginning. There are 31 astronomical records[4]. These are concentrated in the 7th century. The records start in AD 620. These are listed in Table I. Phenomena are 11 solar eclipses, 2 lunar eclipses, 7 comets, 4 meteors or meteor showers, 2 occultations, 2 aurorae, 1 meteorite, 1 planetary phenomenon, and 1 guest star.

There is one erroneous solar eclipse in AD 636. Some astronomer successfuly moved the date of eclipse to another year. So, the record may reflect the real solar eclipse. The tenth record '客星入月' is out of chinese rules of description and is doubtful because there was no known bright stars hidden by the moon. A planetary penomenon in AD 696 is the aporoach of Jupiter and Mars. However, the approach was not the closest. The closer approaches should have been observed on the nearby dates. It is strange why this date is chosen and recorded.

Among the remaining records, there are three records which were surely based on observation. One is the solar eclipse in AD 628. The record says '日有蝕盡之' which implies that the eclipse was total or at least almost total. The chinese record says simply '日有食之', that is, the eclipse was partial and not deep. The second is the occultation in AD 640. There is no Chinese record. The modern calculation shows that $\alpha$ tau was hidden by the moon. The third is the occultation in AD 681. Mars was hidden by the moon. This occulation was observable only in Japan.

Five out of seven records of comets treat the same comets with the Chinese records. Wording and the form of records are diffrent in Japanese and continental records. So, the records are judged not to be transported from China nor Korea. Most of the remaining records represent local phenomena. As a consequence of our conclusion that records of non-local phenomena are all based on observation, we deduce that these records of local phenomena are also based on observation.

The thirty volumes of the Nihongi have been classifed into groups $\alpha$ and $\beta$ and the final volume (H. Mori[5]). The astronomical records are in accord with this classification, that is, the records based on observation are seen only in the volumes of group $\beta$. The number of the records of solar eclipse is five. The number of observable solar eclipses is 15 during years of group $\beta$. the ratio of clear days to the total days is 2/5, which means roughly 6 eclipses should have been oberved. We have 5. We interpret that astromers always watched the sky.

Table 1. All the astronomical records in the *Nihongi.*

| | Op. # | Julian Calendar Year | Month | Day | 現象 | 日本年代 | Group | 中国記録 | Remarks O/P |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 620 | 12 | 30 | 赤気 | 推古 28.12.01 | $\beta$ | - | |
| 2 | 4374 | 628 | 4 | 10 | 日食 | 推古 36.03.02 | $\beta$ | ○ | O |
| 3 | | 634 | 8-9 | | 彗星 | 舒明 6.08 | $\beta$ | ○ | O |
| 4 | | 635 | 1-2 | | 彗星 | 舒明 7.01 | $\beta$ | - | |
| 5 | - | 636 | 2 | 12 | 日食 | 舒明 8.01.01 | $\beta$ | - | error |
| 6 | | 637 | 3 | 24 | 流星 | 舒明 9.02.23 | $\beta$ | - | |
| 7 | 4397 | 637 | 4 | 1 | 日食 | 舒明 9.03.02 | $\beta$ | ○ | |
| 8 | | 639 | 3 | 5 | 彗星 | 舒明 11.01.25 | $\beta$ | ○ | O |
| 9 | | 640 | 3 | 4 | 掩蔽 | 舒明 12.02.07 | $\beta$ | - | O($\alpha$Tau) |
| 10 | | 642 | 8 | 9 | 客星入月 | 皇極 1.07.09 | $\alpha$ | - | |
| 11 | 2863 | 643 | 6 | 8 | 月食 | 皇極 2.05.16 | $\alpha$ | - | P |
| 12 | | 664 | 4 | | 隕石 | 天智 3.03 | $\alpha$ | - | |
| 13 | | 676 | 8-9 | | 彗星 | 天武 4.07 | $\beta$ | ○ | O |
| 14 | 4508 | 680 | 11 | 27 | 日食 | 天武 8.11.01 | $\beta$ | ○ | O |
| 15 | 2922 | 680 | 12 | 12 | 月食† | 天武 8.11.16 | $\beta$ | ○ | |
| 16 | | 681 | 11 | 2 | 彗星 | 天武 9.09.16 | $\beta$ | ○ | O |
| 17 | | 681 | 11 | 3 | 掩蔽 | 天武 9.09.17 | $\beta$ | - | O(Mars) |
| 18 | 4510 | 681 | 11 | 16 | 日食 | 天武 9.10.01 | $\beta$ | ○ | |
| 19 | | 682 | 9 | 10 | 流星 | 天武 10.08.03 | $\beta$ | - | |
| 20 | | 682 | 9 | 18 | 白気 | 天武 10.08.11 | $\beta$ | - | |
| 21 | | 684 | 9 | 7 | 彗星 | 天武 12.07.23 | $\beta$ | ○ | O |
| 22 | | 684 | 12-1 | | 彗星 | 天武 12.11 | $\beta$ | - | |
| 23 | | 685 | 1 | 1 | 流星 | 天武 12.11.21 | $\beta$ | - | |
| 24 | | 685 | 1 | 3 | 流星雨 | 天武 12.11.23 | $\beta$ | - | |
| 25 | 4534 | 691 | 10 | 27 | 日食 | 持統 5.10.01 | | - | P |
| 26 | | 692 | 9 | 14 | 惑星現象 | 持統 6.07.28 | | - | 火・木 |
| 27 | 4537 | 693 | 4 | 11 | 日食 | 持統 7.03.01 | | - | P |
| 28 | 4538 | 693 | 10 | 5 | 日食 | 持統 7.09.01 | | ○ | 日入帯食 |
| 29 | 4539 | 694 | 3 | 31 | 日食 | 持統 8.03.01 | | - | P |
| 30 | 4541 | 694 | 9 | 24 | 日食 | 持統 8.09.01 | | - | P |
| 31 | 4545 | 696 | 8 | 4 | 日食 | 持統 10.07.01 | | - | P |

As for the 7th century, the authors arrive at an idea that there was an observational astronomy in Japan in the seventh century. Our conclusion is that the Japanese observational astronomy started in the seventh century.

## 2.2 Records of solar eclipses in the 8th century

Table 2. List of solar eclipses in *Shoku-Nihongi.*

| | Op. # | Julian Calendar Year | month | day | 日本年代 | 唐 記録 | 観測 可否 | 日本 記録 | 観測 可否 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4556 | 701 | 5 | 13 | 大寶 1.04.01 | - | - | ○ | - |
| 2 | 4561 | 702 | 9 | 26 | 大寶 2.09.01 | ○ | ◎ | ○ | ◎ |
| - | 4562 | 703 | 3 | 22 | - | ○ | ○ | - | ○ |
| 3 | 4564 | 704 | 3 | 10 | 慶雲 3.06.01 | - | - | ○ | - |
| 4 | 4571 | 706 | 7 | 15 | 慶雲 3.12.01 | - | - | ○ | - |
| 5 | 4572 | 707 | 1 | 9 | 慶雲 4.06.01 | - | - | ○ | - |
| 6 | 4573 | 707 | 7 | 4 | 慶雲 4.12.29 | ○ | ○ | ○ | ○ |
| 7 | 4574 | 707 | 12 | 29 | 慶雲 4.12.29 | ○ | ○ | ○ | ○ |
| 8 | 4576 | 708 | 12 | 17 | 和銅 1.11.01 | - | - | ○ | - |
| 9 | 4577 | 709 | 5 | 14 | 和銅 2.04.01 | - | - | ○ | - |
| 10 | 4578 | 709 | 11 | 6 | 和銅 2.10.01 | - | - | ○ | - |
| 11 | 4579 | 710 | 5 | 3 | 和銅 3.04.01 | - | - | ○ | - |
| 12 | 4580 | 710 | 10 | 27 | 和銅 3.10.01 | - | - | ○ | - |
| 13 | 4581 | 711 | 4 | 23 | 和銅 4.04.01 | - | - | ○ | - |
| 14 | - | 711 | 10 | 17 | 和銅 4.09.01 | - | - | ○ | - |
| - | 4585 | 712 | 10 | 5 | - | ○ | ○ | - | ○ |
| 15 | 4586 | 713 | 3 | 1 | 和銅 6.02.01 | - | - | ○ | - |
| 16 | 4588 | 714 | 2 | 19 | 和銅 7.02.01 | - | - | ○ | ○ |
| - | 4589 | 714 | 8 | 15 | - | - | ○ | - | ○ |
| 17 | 4591 | 715 | 8 | 4 | 靈龜 1.07.01 | ○ | ○ | ○ | ○ |
| 18 | 4592 | 715 | 12 | 31 | 靈龜 1.12.01 | - | - | ○ | - |
| 19 | 4596 | 716 | 12 | 19 | 靈龜 2. 閏 11.01 | - | - | ○ | - |
| 20 | 4598 | 717 | 12 | 8 | 養老 1.11.01 | - | - | ○ | - |
| 21 | 4599 | 718 | 6 | 3 | 養老 2.05.01 | ○? | - | ○ | - |
| 22 | 4601 | 719 | 5 | 24 | 養老 3.05.01 | ○ | ○ | ○ | - |
| 23 | 4605 | 720 | 10 | 6 | 養老 4.09.01 | - | - | ○ | - |
| - | 4607 | 721 | 9 | 26 | - | ○ | ○ | - | △ |
| 24 | 4608 | 722 | 3 | 22 | 養老 6.03.01 | - | △ | ○ | ○ |
| 25 | 4614 | 724 | 7 | 25 | 神龜 1.07.01 | ? | △ | ○ | - |
| - | 4615 | 725 | 1 | 19 | 玄宗開元 12. 閏 10.01 | ○ | - | - | ○ |
| 26 | 4617 | 726 | 1 | 8 | 神龜 2.12.01 | - | △ | ○ | - |
| 27 | 4620 | 727 | 5 | 25 | 神龜 4.05.01 | - | - | ○ | - |
| 28 | 4623 | 728 | 5 | 14 | 神龜 5.04.01 | - | △ | ○ | ○ |
| 29 | 4626 | 729 | 10 | 27 | 天平 1.10.01 | ○ | ◎ | ○ | ◎ |
| 30 | 4628 | 730 | 10 | 16 | 天平 2.09.01 | - | - | ○ | - |
| 31 | 4629 | 731 | 3 | 13 | 天平 3.02.01 | - | - | ○ | ○ |
| 32 | 4631 | 732 | 3 | 1 | 天平 4.02.01 | ○ | - | ○ | - |
| - | 4632 | 732 | 8 | 25 | 玄宗開元 20.08.01 | ○ | - | - | |
| 33 | 4634 | 733 | 8 | 14 | 天平 5.07.01 | ○ | ○ | ○ | - |
| 34 | 4639 | 734 | 12 | 30 | 天平 6.12.01 | ○ | ○ | ○ | ◎ |
| - | - | 735 | 11 | 19 | 玄宗開元 23.11.01 | ○ | - | - | - |
| 35 | 4641 | 735 | 12 | 19 | 天平 7. 閏 11.01 | ○ | ○ | ○ | - |
| 36 | 4642 | 736 | 6 | 14 | 天平 8.05.01 | - | - | ○ | ○ |
| 37 | 4644 | 737 | 6 | 3 | 天平 9.05.01 | - | - | ○ | - |

Chinese records are taken from [6]; Op. # are taken from [7].

Table 2. (continued). List of solar eclipses in *Shoku-Nihongi.*

| | Op. # | Julian Calendar Year | Month | Day | 日本年代 | 唐記録 | 観測可否 | 日本記録 | 観測可否 |
|---|---|---|---|---|---|---|---|---|---|
| 38 | 4648 | 738 | 10 | 18 | 天平 10.09.01 | ○ | - | ○ | - |
| 39 | 4650 | 739 | 10 | 7 | 天平 11.09.01 | - | - | ○ | - |
| - | 4651 | 740 | 4 | 1 | - | ○ | ○ | - | ○ |
| 40 | 4654 | 741 | 3 | 22 | 天平 13.03.01 | - | - | ○ | ○ |
| 41 | 4657 | 742 | 8 | 5 | 天平 14.07.01 | ○ | ○ | ○ | ○ |
| 42 | 4659 | 743 | 7 | 26 | 天平 15.07.01 | - | - | ○ | - |
| - | 4666 | 746 | 5 | 25 | - | ○ | ○ | - | ○ |
| 43 | 4669 | 747 | 11 | 7 | 天平 19.10.01 | - | - | ○ | - |
| 44 | 4672 | 749 | 3 | 23 | 天平勝寳 1.03.01 | - | ○ | ○ | - |
| 45 | 4677 | 751 | 8 | 26 | 天平勝寳 3.08.01 | - | - | ○ | - |
| 46 | 4682 | 753 | 1 | 9 | 天平勝寳 4.12.01 | - | - | ○ | - |
| - | 4685 | 754 | 6 | 25 | - | ◎ | ◎ | - | ◎ |
| 47 | 4690 | 756 | 10 | 28 | 天平勝寳 8.10.01 | ◎ | ○ | ○ | - |
| - | 4691 | 757 | 4 | 23 | - | - | - | - | ○ |
| 48 | 4696 | 759 | 4 | 2 | 天平寳字 3.03.01 | - | - | ○ | - |
| 49 | 4699 | 760 | 8 | 15 | 天平寳字 4.07.01 | - | - | ○ | - |
| 50 | 4701 | 761 | 8 | 5 | 天平寳字 5.07.01 | ◎ | ◎ | ○ | ○ |
| 51 | 4702 | 762 | 1 | 30 | 天平寳字 6.01.02 | - | ○ | ○ | ○ |
| - | 4704 | 763 | 1 | 19 | - | - | - | - | ○ |
| - | 4708 | 764 | 6 | 4 | - | - | △ | - | - |
| 52 | - | 765 | 10 | 19 | 天平神護 1.10.01 | - | - | ○ | - |
| 53 | 4713 | 766 | 11 | 7 | 天平神護 2.10.01 | - | ○ | ○ | - |
| 54 | 4714 | 767 | 4 | 3 | 神護景雲 1.03.01 | - | - | ○ | - |
| 55 | 4716 | 768 | 3 | 23 | 神護景雲 2.03.01 | ○ | ○ | ○ | ○ |
| 56 | 4717 | 768 | 9 | 16 | 神護景雲 2.08.01 | - | - | ○ | - |
| 57 | 4719 | 769 | 9 | 5 | 神護景雲 3.08.01 | - | ○ | ○ | ○ |
| 58 | 4723 | 770 | 8 | 25 | 寳龜 1.08.01 | - | - | ○ | - |
| 59 | 4726 | 772 | 1 | 10 | 寳龜 2.12.01 | - | - | ○ | - |
| 60 | 4727 | 772 | 7 | 5 | 寳龜 3.06.01 | - | - | ○ | - |
| 61 | 4729 | 773 | 6 | 25 | 寳龜 4.06.01 | - | - | ○ | ○ |
| 62 | 4734 | 775 | 10 | 29 | 寳龜 6.10.01 | ○ | ○ | ○ | - |
| 63 | 4735 | 776 | 4 | 23 | 寳龜 7.04.01 | - | - | ○ | ○ |
| 64 | 4738 | 777 | 4 | 12 | 寳龜 8.02.30 | - | - | ○ | - |
| 65 | 4741 | 778 | 8 | 27 | 寳龜 9.08.01 | - | - | ○ | - |
| - | 4742 | 779 | 2 | 21 | - | ○ | ○ | - | ○ |
| 66 | 4743 | 779 | 8 | 16 | 寳龜 10.07.01 | ○ | - | ○ | - |
| - | 4744 | 780 | 2 | 10 | - | ○ | ○ | - | - |
| 67 | 4753 | 783 | 11 | 29 | 延暦 2.11.01 | - | ○ | ○ | ○ |
| - | 4756 | 785 | 4 | 13 | - | - | - | - | △ |
| - | 4761 | 787 | 9 | 16 | - | ○ | ○ | - | △ |
| 68 | 4765 | 789 | 1 | 31 | 延暦 8.01.01 | ○ | ○ | ○ | ○ |
| - | 4767 | 790 | 1 | 20 | - | - | △ | - | ○ |
| 69 | 4770 | 791 | 7 | 6 | 延暦 10.06.01 | - | ○ | ○ | ○ |
| 70 | 4774 | 792 | 11 | 19 | 延暦 11.11.01 | ○ | ○ | ○ | ○ |
| 71 | 4776 | 793 | 11 | 8 | 延暦 12.10.01 | - | - | ○ | - |
| 72 | 4777 | 794 | 5 | 4 | 延暦 13.04.01 | - | ◎ | ○ | ○ |
| 73 | 4779 | 795 | 4 | 24 | 延暦 14.04.01 | - | - | ○ | ○ |
| 74 | 4782 | 796 | 9 | 6 | 延暦 15.08.01 | ○ | ○ | ○ | ○ |
| 74 | 4791 | 800 | 6 | 26 | 延暦 19.06.01 | - | ○ | ○ | ○ |

Chinese records of solar eclipses are obviously based on observation. This is because almost all records actually correspond to observable eclipses. In this period, the skill of prediction was not good as the correspondence in Table 2 shows. On the other hand, the Japanese records are obviously based on prediction. This is because the number of records is too large and the many of the predicted eclipses were not observable.

We can ask for the accuracy of prediction. During AD 701 and 737 年, 37 eclipses are predicted, while 11 were observable and 26 were not observable. There were 4.5 eclipses which were not recorded but were observable. Here weight 0.5 means that depending on the value of $\Delta T$ the corresponding eclipse may have been observable (denoted by △ in the tables). During AD 738 and 778 年, 28 eclipses are predicted, while 8 were observable and 20 were not observable. There were 6 eclipses which were not recorded but were observable. Finally, during AD 783 and 800, 9 eclipses were predicted, while 8 were obervable and 1 were not observable. There is 1 eclipse which was not recorded but was observable.

Our conclusions are

(1) Solar eclipses ware predicted in the 8th century.

(2) Predictions were not bad in the sense that eclipses which took place on the Earth were predicted.

(3) The skill of prediction suddenly increased in the *Enryaku* (延暦) reign period.

## 2.3 Other records in the 8th century

Table 3. the list of comets in *Shoku-Nihongi.*

| | Julian Calendar | | | 日本年代 | 記録 |
|---|---|---|---|---|---|
| | Year | Month | Day | | |
| 1 | 718 | 12 | 8 | 養老 2.11.12 | 彗星守月 |
| 2 | 722 | 7 | 3 | 養老 6.07.03 | 有客星見閣道邊凡五日 |
| 3 | 725 | 2 | 11 | 神龜 2.01.24 | 有星悖于華蓋 |
| 4 | 745 | 1 | 8 | 天平16.12.02 | 有星悖於將軍 |
| 5 | 770 | 6-8 | | 寶龜 1.06-07 | 彗星入於北斗 |
| | | 5 | 26 | 代宗大歷 5.04.27 | 有彗星于五車 (新唐書 · 代宗) |
| 6 | 773 | 1 | 20 | 寶龜 3.12.23 | 彗星見南方 |
| | | | 17 | 代宗大歷 7.12.20 | 長星出于參 (新唐書 · 代宗) |

In *Tangshu* (唐書), there are 14 records of comets in the 8th century. Among them, two records in AD 770 and AD 773 describe the same comets with Japanes records. Comet Halley was observed in China in AD 760. There is no corresponding record in Japan. Japanese records in AD 718, 722, 725, and 745 have no counterparts in *Tangshu.*

Our conclusion is that Japanese records of comets were based on observation.

Table 4. the list of Lunar eclipses in *Shoku-Nihongi*

| OP.# | Julian Calendar Year | Month | Day | 日本年代 | 記録 |
|---|---|---|---|---|---|
| 3085 | 785 | 10 | 22 | 延暦 4.09.15 | 竟夜月面黒，光消失空闇也 |

In China, there are 34 records of lunar eclipse. There is no records in AD 785. Japanese record of AD 785 is judged to be based on observation by its wording.

## 3 Conclusions

We conclude that

(1) Characters of Japanese astronomy in the 7th and 8th centuries are diffrent.

(2) In the most important item of astronomy, i.e., solar eclipse, records were based on observation in the 7th century, whereas these were based on prediction in the 8th century.

(3) Japanese astronomy did not evolve linearly.

We do not have convincing explanations on this diffrence of characters. Our understanding of general history of ancient Japan lacks some key ideas.

## References

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