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 α 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 α and β 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 β. The number of the records of solar eclipse is five. The number of observable solar eclipses is 15 during years of group β. 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	β	-	
2	4374	628	4	10	日食	推古 36.03.02	β	○	O
3		634	8-9		彗星	舒明 6.08	β	○	O
4		635	1-2		彗星	舒明 7.01	β	-	
5	-	636	2	12	日食	舒明 8.01.01	β	-	error
6		637	3	24	流星	舒明 9.02.23	β	-	
7	4397	637	4	1	日食	舒明 9.03.02	β	○	
8		639	3	5	彗星	舒明 11.01.25	β	○	O
9		640	3	4	掩蔽	舒明 12.02.07	β	-	O(αTau)
10		642	8	9	客星入月	皇極 1.07.09	α	-	
11	2863	643	6	8	月食	皇極 2.05.16	α	-	P
12		664	4		隕石	天智 3.03	α	-	
13		676	8-9		彗星	天武 4.07	β	○	O
14	4508	680	11	27	日食	天武 8.11.01	β	○	O
15	2922	680	12	12	月食†	天武 8.11.16	β	○	
16		681	11	2	彗星	天武 9.09.16	β	○	O
17		681	11	3	掩蔽	天武 9.09.17	β	-	O(Mars)
18	4510	681	11	16	日食	天武 9.10.01	β	○	
19		682	9	10	流星	天武 10.08.03	β	-	
20		682	9	18	白気	天武 10.08.11	β	-	
21		684	9	7	彗星	天武 12.07.23	β	○	O
22		684	12-1		彗星	天武 12.11	β	-	
23		685	1	1	流星	天武 12.11.21	β	-	
24		685	1	3	流星雨	天武 12.11.23	β	-	
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	大寳 1.04.01	-	-	○	-
2	4561	702	9	26	大寳 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	天平勝寶 1.03.01	-	○	○	-
45	4677	751	8	26	天平勝寶 3.08.01	-	-	○	-
46	4682	753	1	9	天平勝寶 4.12.01	-	-	○	-
-	4685	754	6	25	-	◎	◎	-	◎
47	4690	756	10	28	天平勝寶 8.10.01	◎	○	○	-
-	4691	757	4	23	-	-	-	-	○
48	4696	759	4	2	天平寶字 3.03.01	-	-	○	-
49	4699	760	8	15	天平寶字 4.07.01	-	-	○	-
50	4701	761	8	5	天平寶字 5.07.01	◎	◎	○	○
51	4702	762	1	30	天平寶字 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	寶龜 1.08.01	-	-	○	-
59	4726	772	1	10	寶龜 2.12.01	-	-	○	-
60	4727	772	7	5	寶龜 3.06.01	-	-	○	-
61	4729	773	6	25	寶龜 4.06.01	-	-	○	○
62	4734	775	10	29	寶龜 6.10.01	○	○	○	-
63	4735	776	4	23	寶龜 7.04.01	-	-	○	○
64	4738	777	4	12	寶龜 8.02.30	-	-	○	-
65	4741	778	8	27	寶龜 9.08.01	-	-	○	-
-	4742	779	2	21	-	○	○	-	○
66	4743	779	8	16	寶龜 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 ΔT 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 Year	Month	Day	日本年代	記録
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	代宗大歴 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	代宗大歴 7.12.20	長星出于参 (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.

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