1979PASJ...31..257H

Publ. Astron. Soc. Japan 31, 257–270 (1979)

Orbits of Ancient and Medieval Comets

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(Received 1978 August 25; revised 1978 December 1)

Abstract

New orbital elements are presented for thirty-eight ancient and medieval bright comets. Some possible identifications of them with short-period comets are suggested. The perihelion passages of Comet Halley and possible members of the sun-grazing comet group are discussed. The distributions of orbital elements of the older bright comets show that these comets are in the same population as the long-period comets observed since 1800.

Key words: Comet Halley; Cometary orbits; Periodic comets; Sun-grazing comet group.

1. *Introduction*

Since Halley (1705) published twenty-four parabolic orbits of older comets observed between 1337 and 1698, some authors have calculated cometary orbits from observations recorded in Chinese and European history. The observations used in their orbit calculations are collected by Pingré (1783, 1784), Biot (1846), Williams (1871), and others. Recently Ho (1962) compiled the most complete catalog of cometary observations recorded in ancient and medieval China together with Korean and Japanese observations.

Kiang (1972) studied the orbit of Comet Halley over the interval 240 BC–1910 AD and re-examined all available sources recorded before 1456, to improve its predicted perihelion times. Yeomans (1977a) also studied the motion of Comet Halley back to 837 AD, when the comet approached the earth to within 0.04 AU. Kiang (1972) estimated its perihelion time in 837 AD and gave small residuals for Chinese observations in that year except those on April 9 and April 11. However, according to the original sources, Kiang's (1972) perihelion time is likely to be improved to give smaller residuals and consistent results.

Although two to three more significant figures are given for the orbital elements of older comets, they are not always reliable, because older records do not provide cometary positions accurate enough for computing reliable orbits. These circumstances are easily understood, when two or more orbits are calculated for one comet by different computers, such as in the case of Comet 1337 given in Galle's (1894) catalog. Thus, it seems desirable to estimate the range of the error of those cometary orbits. Among the Chinese, Korean, and Japanese sources, there are more records of cometary observations useful enough to orbit determinations. Thus, the orbits already published need to be re-examined.

Kanda (1972) informed the author of his results on orbit determinations of older comets, and suggested that a thorough research be made on them. Besides orbit determinations, possible identifications with periodic comets and with members of sun-grazing comet are suggested in the present paper.

2. *Observations*

Older Chinese records of comets are found in the standard dynastic history and almost all of them are translated into European languages; and the most complete collections of them are compiled and translated into English by Ho (1962). Korean records are collected by Sekiguchi (1917a, b), and Japanese records are compiled by Kanda (1935, 1947). Most of them are also included in Ho's (1962) catalog. In the present study, in the case of Chinese observations, both the original records and Ho's (1962) catalog are consulted, in the case of Korean and Japanese observations, Sekiguchi's (1917a, b) and Kanda's (1935, 1947) works are used, respectively.

A general review of the identifications of Chinese star names and constellations has recently been made by Ohsaki (1976), and this is most useful to the present research. A brief introduction by Kiang (1972) to the Chinese star names and dating systems should be referred to by the readers. The Chinese systems of astronomy had been adopted in both the ancient Korean and Japanese astronomy.

3. *Determination of Orbits*

Throughout the present study, the star positions and the coordinates of the sun, and hence the comet positions, are referred to the mean equator and equinox at the beginning of the year in which the comet appeared. The comet positions on the horizontal coordinates system or their elongations from the sun were calculated to examine the records, if necessary. The sun's positions are taken from Tuckerman's (1962, 1964) tables, and they are transformed into the rectangular coordinates with Newcomb's (1895) elements of the sun and other constants. It should be noticed here that all orbital elements and related parameters presented in this paper are transformed and referred to the equinox of 1950.0.

When only three positions of a comet are available, Väisälä's (1939) method of the parabolic-orbit determination is used, and if more than three observations are given, an improved orbit is calculated from these observations. This is the case for Comet 1337, or Comet 1491 I. When two positions of a comet and its path without dates are given, an orbit which is most suitable for the older records is chosen, with some assumed geocentric distances which satisfy Lambert's equation for the parabola.

Table 1 presents the results of those orbit determinations. It also includes some re-determinations of formerly published orbits calculated by other authors, whose references are given in the last column of the table. By calculating some alternative orbits, for almost all comets, we can estimate the ranges of the errors of orbital elements, and they are attached to each value of elements with the double sign. It should be noticed that they are not the probable nor the mean errors. In the second column, the time of perihelion passage, T, is given in the old style, as well as the dates of observations in the eleventh column, and the universal time in decimals of a day is used. The coordinates of an aphelion point expressed in the solar-motion coordinates system (Hasegawa 1976), A and D, are shown in the seventh and the eighth columns. The absolute magnitude, H_0, in the ninth column is derived from the relations, $m-5\log\Delta-10\log r$, where Δ and r are the geocentric and the heliocentric distances of a comet at the time when its brightness, m, is assumed. It is so difficult to estimate the comet magnitude from older observations that the sixth magnitude is temporarily adopted, only when the fading out of the comet is clearly stated in the original sources. The angle, J, in the tenth column is the difference between the heliocentric longitudes of the earth and the comet when the comet is at its perihelion. This angle is used in a discussion on the Holetschek effect. In the eleventh column, the dates of observations used in the orbit determinations are given. In the twelfth, the sources of records are presented by the letters C, K, J, and E, which mean Chinese, Korean, Japanese, and European, respectively, and Ho, Ho's (1962) catalog with its record number in the parentheses; K, Kanda's (1935), and P, Pingré's (1783, 1784) with their page numbers, respectively. In the last column, references to the calculations by other authors and the indications of note are given.

Peirce (1846) calculated an orbit from the Chinese records on July 23, August 20 and 27 in the year −68, but this orbit seems to be improbable (Marsden 1973a), and the latter two observations are supposed to be identified with Periodic Comet Swift-Tuttle (see section 5). Burckhardt [quoted in Galle (1894)] calculated some orbits for comets which appeared in 240 and 565, but their positions are too uncertain to derive their orbits. For those comets which appeared in 868 and 1402, Kanda (1932) and Hind (1877) calculated uncertain orbits from indefinite records, respectively; however, we are not able to obtain the orbits of those five comets which appeared in −68, 240, 565, 868, and 1402. On the other hand, the orbits of Comets 1132, 1240, 1264, and 1299 have been calculated by other authors from well-determined cometary positions. Therefore, their improvements are not needed. We do not deal here with the comets that were well observed in Europe after the year 1433.

Although for each comet more than two positions and paths are recorded, it sometimes happens that the orbit cannot be determined. Those are the comets observed in 39, 838, 839, 1005, 1021, 1080, 1106, 1273, 1430, 1491 (January 17 and 22), and 1662. For the comets for which only two observations are available, Kanda (1972) calculated their optional orbits assuming geocentric distances at their first observations; these records should be left open to future investigations.

4. *Perihelion Passages of Comet Halley*

For each apparition of Comet Halley, several ephemerides are calculated from the orbital elements given in table 4 of Kiang's (1972) paper except for the perihelion times, which are chosen to make the best fit with the observations. The most reliable times of perihelion passage are presented in table 2 with the estimated range of errors. Each heading has the same meaning as in table 1. Brady and Carpenter (1971, 1972), Yeomans (1977a), and Chang (1978) also obtained nearly the same orbital elements as Kiang's (1972), and the differences among them do not give any appreciable deviations from the present results. Hence, the perihelion times given in table 2 are quite similar to Kiang's (1972) except for a few cases to which some comments are given in the notes attached to the table. Because of the large apparent motion of the comet, the perihelion time in 837 AD is determined precisely, within a range of 0.1 d. The cometary positions and their residuals are given in table 3. In his calculations, Kiang (1972) uses

Table 1.

Comet	Perihelion passage T(UT)	q (AU)	Mean ecliptic and equinox (1950.0)					H_0	J
			ω	Ω	i	A	D		
−146	Jun. 28$^{\mathrm{d}}$.0±0$^{\mathrm{d}}$.5	0.43±0.01	261° ±1°	329° ±1°	71° ±1°	162°	+28°	—	90°
390	Sep. 5 ±5	0.92±0.1	23 ±10	355 ±10	36 ±20	296	+ 7	—	351
400	Feb. 25 ±3	0.21±0.1	47 ±10	37 ±5	32 ±5	359	+24	—	100
442	Dec. 15 ±30	1.53±0.05	178 ±20	270 ±5	106 ±5	15	+44	2	15
539	Nov. 6 ±1	0.16±0.15	246 ±40	32 ±20	19 ±6	197	−27	—	150
568	Aug. 27.7±0.5	0.87±0.01	35 ±5	301 ±5	4 ±1	261	−11	5	20
574	Mar. 25 ±10	0.73±0.05	342 ±20	154 ±10	54 ±10	82	+30	—	63
770	June 5.8±1	0.58±0.10	88 ±10	110 ±5	117 ±2	335	−25	6	261
905	Apr. 26 ±1	0.20±0.2	50 ±25	69 ±15	140 ±15	316	− 1	—	210
961	Dec. 28 ±1	0.63±0.1	85 ±2	1 ±5	119 ±5	333	−69	3	197
1014	Apr. 6.0±0.5	0.56±0.02	84 ±3	173 ±1	117 ±5	7	−16	—	119
1018	Aug. 27 ±1	0.62±0.02	197 ±10	184 ±10	35 ±4	283	+26	8	334
1092	Feb. 22 ±5	0.77±0.05	62 ±10	113 ±2	124 ±5	351	− 1	3	105
1097	Sep. 22.3	0.302	298	351	41	209	− 5	5	22
1110	May 18.0±1	0.83±0.01	358 ±1	320 ±1	136.5±1	248	−20	5	294
1147	Jan. 28 ±2	0.12±0.01	300 ±7	281 ±6	110 ±10	210	+17	6	196
1230	Dec. 28.8±0.5	0.86±0.01	181 ±1	303 ±1	16 ±1	54	+32	—	351
1245	Apr. 1 ±1	0.50±0.01	87 ±2	179 ±1	20 ±5	191	−67	—	304
1293	Oct. 28 ±4	0.78±0.05	313 ±10	88 ±2	30 ±3	296	+54	—	6
1305	Jan. 19 ±5	0.65±0.1	56 ±5	105 ±5	99 ±5	7	− 8	—	44
1337	June 14.85	0.749	79.6	96.9	143.6	315	− 6	3	159
1345	Aug. 23 ±5	0.89±0.03	210 ±10	149 ±1	23 ±10	266	+13	—	349
1351	Nov. 19 ±5	1.01±0.1	165	263	7	343	+44	—	5
1362	Feb. 25 ±1	0.30±0.03	348 ±40	290 ±50	155 ±10	228	−30	6	230
1368	May 5 ±5	0.48±0.10	90 ±10	216 ±10	131 ±10	33	− 4	—	115
1376	July 31.7±1	0.55±0.10	81 ±10	300 ±5	76 ±10	338	−39	7	328
1385	Oct. 24	0.79	182	288	103	38	+42	—	300
1439	May 9 ±1	0.12±0.05	140 ±10	191 ±1	81 ±20	308	−18	—	241
1458	Nov. 7 ±1	0.49±0.20	258 ±15	116 ±5	69 ±10	212	+41	0	65
1462	Aug. 4 ±2	0.25±0.10	137 ±10	315 ±5	130 ±10	59	−14	—	161
1468	Oct. 7.3±1	0.85±0.01	91 ±5	106 ±3	138 ±1	316	−14	2	16
1491 I	Jan. 8.9	0.761	164.9	279.5	73.4	17	+31	6	29
1491 II	Jan. 22.7	0.85	316	165	9	57	+39	—	17
1499	Sep. 9 ±2	0.95±0.01	42 ±5	328 ±5	16 ±5	290	+ 6	10	352
1500	Apr. 30 ±5	1.11±0.10	352 ±10	304 ±5	99 ±5	186	−26	3	292
1506	Aug. 28.5	0.84	200	155	115	240	− 4	—	24
1539	May 12.6	0.961	174.5	54.4	18.6	137	−40	8	17
1557	Sep. 22	0.50	94	211	42	284	−57	6	69

1. According to the *Thien Wên Chih* (astronomical chapter), and after some trial calculations, August 22 is adopted for the date of the first observation.

2. This orbit fits also another record given in *Wei Shu* that the comet passed by Venus in three *chhih* at the end of November.

3. Hind (1848) uses a wrong date January 19 for January 9.

4. Kanda (1972) pointed out a probable identification with Periodic Comet Pons-Gambart (see section 5).

Orbital elements.

Observations	Sources	Remarks
Aug. 6, 7, 8, 11	C, Ho (32)	Kanda [quoted in Marsden (1973b)]
Aug. 22, Sep. 8, 17	C, K, Ho (178)	Note 1
Mar. 19, Apr. 10, path	C, K, Ho (183)	
Nov. 10, 443, Feb. 18, path	C, Ho (201)	
Nov. 17, 540, Jan. 30, path	C, Ho (221)	Burckhardt [quoted in Galle (1894)], Note 2
Sep. 3, 27, Oct. 16, Nov. 5	C, Ho (228)	Hind (1844), Laugier (1846)
Apr. 4, May 8, 23	C, Ho (229)	Hind (1844)
May 26, June 9, 19, July 9	C, K, J, Ho (279), K 479	Hind (1846), Laugier (1846)
May 18, 22, 26, June 12	C, J, E, Ho (321), K 485, P 352	
Jan. 28, Feb. 19, Apr. 2	C, Ho (342)	Hind (1846), Ravené (1897)
Feb. 27, Mar. 1, 7	C, J, Ho (359), K 495	
Aug. 2, 3, 4, Sep. 9, path	C, K, J, Ho (360, 362), K 495	
Jan. 8, 9, 30	C, Ho (389)	Hind (1848), Note 3
Oct. 6, 9, 16, 17, path	C, K, J, Ho (390), K 500	Burckhardt [quoted in Galle (1894)]
May 29, June 6, 11, path	C, K, J, Ho (393), K 505	Note 4
Jan. 6, Feb. 13, path	C, J, Ho (408), K 513	
Dec. 5, 15, 31, path	C, J, Ho (428), K 526	Note 5
Feb. 25, Mar. 30, path	J, Ho (435), K 537	
Nov. 25, Dec. 23, path	C, K, J, Ho (441), K 549	
Dec. 26, 30, 1304, path	K, J, Ho (448), K 553	
Jun. 26, July 6, 14, 27, Aug. 1, 7, 19	C, K, J, Ho (455), K 555	Halley (1705), Pingré (1783), Hind (1844), Laugier (1846), Note 6
July 31, Aug. 3, path	C, J, E, Ho (457), K 556, P 435	
Nov. 24, 27, 30	C, Ho (459)	Burckhardt [quoted in Galle (1894)]
Mar. 5, 17, Apr. 1, path	C, Ho (463)	Burckhardt [quotee in Galle (1894)] Van Biesbroeck (1916)
Apr. 7, 26, path	C, K, J, Ho (470), K 560	Note 7
June 22, July 12, Aug. 8, path	C, K, J, Ho (474), K 563	
Oct. 23, 30, Nov. 4	C, Ho (481)	Hind (1844, 1846)
Mar. 25, Apr. 2, 12	C, K, J, Ho (510), K 574	
Dec. 27, 1459, Jan. 12, path	C, K, Ho (521)	
June 29, July 16, path	C, Ho (524)	Hind [quoted in Chambers (1889)]
Sep. 22, Oct. 12, Nov. 12	C, K, J, Ho (526), K 580, Kanda (1947)	Laugier (1846), Vals (1846), Note 8
Jan. 8, 9, 10, 11, 22, 30	C, K, J, Ho (534), K 586	Hind (1846), Peirce (1846), Note 9
Jan. 20, Feb. 5, 12	K, Sekiguchi (1917)	
Aug. 16, 24, Sep. 6	C, K, Ho (537)	Hind (1861)
May 8, 31, July 10	C, K, J, Ho (538), K 588	Hind (1861)
July 31, Aug. 10, 14	C, J, Ho (540), K 589	Laugier (1846)
Apr. 20, May 17, 26	C, K, E, Ho (556), Apian (1540)	
Oct. 10, 27, 29	C, K, Ho (561), Sekiguchi (1917)	

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5. This has been regarded as Comet 1231, but because of mis-translations of the dates by Gaubil, Pingré's (1783) orbit has no credibility.

6. Probably identified with Comet 1468. See the discussion in the text.

7. Kanda (1972) gives a direct orbit, but, according to the record that the comet went out of sight (in the dusk) on April 26, 1368; a retrograde orbit seems to be reasonable.

8. Probably identified with Comet 1337. See the discussion in the text.

9. Most probably the parent comet of Quadrantids. See the discussion in the text.

Table 2. Perihelion times of Comet Halley before 1378.

Return	Observations	T(UT)	Sources	Remarks
−34…… −614	Aug.	Probably in Aug.	C, Ho (5)	1
−32…… −466		—	C, Ho (13)	
−29…… −239	May–June	Before June 20	C, Ho (19)	
−27…… − 86	Aug.-Sep.	After Aug. 26	C, Ho (47)	
−26…… − 11	Aug. 26, Sep. 2	Oct. 2±1	C, E, Ho (61), P 280	
−25…… 66	Feb. 20	Jan. 25±3	C, Ho (78)	
−24…… 141	Mar. 27, Apr. 16, 22, 23	Mar. 20.0±0.5	C, Ho (100)	
−23…… 218	Apr.-May	Apr. 8-13	C, Ho (122)	
−22…… 295	May	Apr. 27±5	C, Ho (156)	
−21…… 374	Mar. 4, Apr. 2	Feb. 15±1	C, Ho (175)	
−20…… 451	June 10, July 13, 22, Aug. 15	June 24±4	C, Ho (204)	2
−19…… 530	Aug. 29, Sep. 1-27	Sep. 24.7±0.3	C, E, Ho (217), P 315	
−18…… 607	Mar. 13, Apr. 4	Mar. 12±1	C, Ho (237)	
−17…… 684	Sep. 6, 7, Oct. 24	Oct. 2±4	C, J, Ho (258), K 477	3
−16…… 760	May 16-July 5 and later	June 5±4	C, Ho (273)	4
−15…… 837	Mar. 22-Apr. 28	Feb. 28.15±0.10	C, Ho (291)	5
−14…… 912	July 12, 14, 19-28	July 9.0±1.0	C, J, Ho (325), K 487	6
−13…… 989	Aug. 12, 13-Sep. 12	Sep. 9±1	C, K, J, Ho (349, 350), K 491	
−12…… 1066	Apr. 2, 24, 25, June 7	Mar. 23.4±0.4	C, K, J, E, Ho (380), K499, P373	
−11…… 1145	Apr. 28, May 14, June 9	Apr. 21.2±1	C, K, J, E, Ho (406), K 510, P 393	
−10…… 1222	Sep. 3, 10, 25	Oct. 1.0±1	C, K, J, Ho (425), K 525	
− 9…… 1301	Sep. 14, 16, 18-Oct. 30	Oct. 23.5±0.2	C, K, J, E, Ho (446), K 552, P 420	
− 8…… 1378	Sep. 26, Oct. 1, Nov. 10	Nov. 9.5±0.5	C, K, J, Ho (475), K 563	

1. Orbital elements used here are given by Chang (1978) as follows: $\omega=84^{\circ}.0$, $\Omega=25^{\circ}.3$, $i=163^{\circ}.5$ (1950.0), $a=17.758$ AU, and $q=0.578$ AU.

2. The astronomical chapter of *Wei Shu* gives July 22 and August 15 as the dates of the passage through in *Ti-Tso* and the trespassing against *Shang-Hsiang*, respectively. These dates are consistent also with Kiang's (1972) calculations.

3. The date August 31 given by Ho (1962) should be September 7.

4. Kiang (1972) takes July 9 for July 5 or later, but the apparent motion of the comet is so slow that T should be considered indefinite.

5. The dates given in Kiang (1972) are based on the assumption that each calendar dates begins at midnight, whereas we prefer the assumption that a day begins at dawn. These two assumptions imply a difference of one day in the case of an observation made between midnight and dawn.

6. It has been regarded that the Chinese observations in 912 do not belong to Comet Halley. However, after some trials, the fourth month in Chinese records is considered to be the intercalary one. Then they agree well with the Japanese records.

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Table 3. Observed and calculated positions of Comet Halley in 837 AD.

837 UT	α_{obs}*	α_{calc}*	$(O-C)_\alpha$	δ_{calc}*	Δ(AU)
Mar. 22.8	316°.4	317°.8	−1°.4	− 9°.3	0.69
Mar. 29.8	315.2	315.9	−0.7	−10.8	0.44
Apr. 5.8	310.8	311.0	−0.2	−15.8	0.18
Apr. 6.8	308.8	308.0	0.0	−17.8	0.14
Apr. 7.8	304.8	305.1	−0.3	−21.5	0.11
Apr. 8.8	299.9	297.0	+2.9	−28.3	0.07
Apr. 9.67	273.1	276.9	−3.8	−39.8	0.05
Apr. 10.67†	204.9	203.5	+1.4	−43.6	0.04
Apr. 13.5	147.7	150.1	−2.4	− 5.2	0.12
Apr. 28.5	140.8	141.6	−0.8	+ 5.1	0.68

* The mean equator and equinox of 837.0 are referred.

† The original date of April 11.67 UT should be changed to April 10.67 UT; otherwise, it gives very large residual and is inconsistent with all the other observations.

a date (April 14.6) for *Hsin Thang Shu*, where we have preferred to use April 13.5 UT from *Chiu Thang Shu*. According to the astronomical chapter of *Chiu Thang Shu*, the comet was at the seventh degree of the Chang on April 28, not at the tenth as Ho (1962) translated.

It is desirable that the orbital motion of Comet Halley and the nongravitational effects on it be investigated in the light of the present results, and Yeomans (1977b) is undertaking this interesting work.

5. *Suggestions of Possible Identifications with Periodic Comets*

Possible, but unconfirmed identifications with periodic comets are suggested as given in table 4; they are found by comparing observations with the search ephemerides calculated with the assumed perihelion times. Among seven identifications in table 4, Comet 1110 is the most probable one except for the established identity of Comet 1366 with Comet Tempel–Tuttle. In the fifth column, the mean periods obtained from the interval of two apparitions are given, and in the last column, the periods determined from the observations of last apparition are quoted. These references are given in Marsden's (1975) catalog. Although with alternative periods we can link the perihelion times of the supposed periodic comet appearing twice separated by long years, it may be difficult to make a definite confirmation of these identifications.

Besides periodic comets mentioned above, we may suspect two more possible identifications of Comet 1337 with Comet 1468 and Comet 1491 I with the parent comet of Quadrantid meteors. As for Comet 1337 and Comet 1468, the ephemerides calculated from the mean elements of the two comets, namely $q=0.80$ AU, $\omega=85°$, $\Omega=101°$, $i=141°$ (1950.0), are consistent with its two apparitions, if the perihelion passages are assumed to be 1337 June 14.5 and 1468 October 5.0 UT, respectively. These perihelion times do not differ largely from those given in table 1. It seems that Comet 1491 I may be the parent comet of Quadrantid meteors. The improved orbit determined with six observations gives $(O-C)$'s less than 1°. Perturbation calculations of the Quadrantid meteors by Hamid and Youssef (1963) give $\omega=165°$, $\Omega=284°$, $i=69°$ (1950.0), $q=0.6$ AU in 1550 AD.

Table 4. Possible identifications with periodic comets.

Comet	Observations	T(UT)	Mean period (yr)	Sources	Remarks
P/Swift-Tuttle (1862 III)......−68	Aug. 20, 27	Aug. 26±1$^{\mathrm{d}}$	120.6	C, Ho (54)	$P=120\pm2$ yr, Note 1
P/Mellish (1917 I) 193	Dec. 3, path	Dec. 13±5	143.6	C, Ho (114)	$P=145\pm0.6$ yr
Bennett (1970 II) 363	Sep., path	Sep. 15±10	1605	C, E, Ho (173), P 302	Note 2
Ryves (1931 IV) 423	Feb. 13, path	Jan. 29±5	503	C, Ho (197)	Note 3
P/Pons-Gambart (1827 II) 1110	May 29, June 6, 11, path	May 18±1	65.2	C, K, J, Ho (393), K 505	$P=63.8\pm10$ yr
P/Tempel-Tuttle (1866 I)......1366	Oct. 25, 26, 27, 28, 29	Oct. 18.46	33.3	C, K, J, Ho (468), K 560	$P=33$ yr, Note 4
P/deVico (1846 IV)...........1391	May 23, path	Mar. 20±2	75.8	C, K, Ho (483)	$P=75.7\pm3$ yr

1. The parent comet of Perseid meteors. This identification is already quoted by Marsden (1973a).
2. According to the value of total energy change given by Marsden et al. (1973), the original period becomes nearly 1579 yr.
3. Sitarski (1968) gives a period of 508 yr before its approach to Jupiter in 1930. On the other hand, Everhart and Raghavan (1970) gives $+0.010214\,\mathrm{AU}^{-1}$ for the changes of $1/a$ before its perihelion passage, then the original period becomes 704 yr.
4. The parent comet of Leonid meteors. Assuming $a=10.430$ AU given by Schubart [1968; quoted in Marsden (1968)], the following orbital elements are derived from observations in 1366: $T=$October 18.46 UT, $\omega=165^{\circ}.2$, $\Omega=225^{\circ}.4$, $i=150^{\circ}.5$ (1950.0), $q=0.9757$, and $e=0.9065$. It is noticed here that the inclination is not consistent with Schubart's (1968) value ($162^{\circ}.3$).

Table 5. Possible members of the sun-grazing comet group.

Observations	Constellations	T(UT)	Tail (in units of *chhih**) Length	Tail (in units of *chhih**) Width	Duration of apparition	Sources	Remarks
133 Feb. 8	Eri	Jan. $20\pm3^{\mathrm{d}}$	50	2	—$^{\mathrm{d}}$	C, Ho (99)	
191 Oct.	Vir	End of Sep. -Early Oct.	100	—	—	C, K, E, Ho (113), P 295	
252 Mar. 24	Cet, Ori	Mar. 17 ± 4	50-60	—	20	C, Ho (135)	
423 Feb. 13	Peg, And	Feb. 6 ± 3	20-30	—	20	C, E, Ho (197), P 312	
852 Mar.-Apr.	Eri, Ori	Mar. 7 ± 3	50	—	—	C, J, Ho (297), K 482	
943 Nov. 5	Hya	Oct. 28 ± 1	10	—	14	C, E, Ho (336), P 355	
1034 Sep. 20, 21, 28	Crt, Hya	Sep. 8 ± 5	20	0.5	22	C, K, J, E, Ho (368), K 496, P 370	
1106 Feb. 9-20	Cet, Eri	Jan. 30 ± 5	60	3	>30	C, K, J, E, Ho (391), K 501, P 389	1
1232 Oct. 17-Nov. 18	Crv, Hya	Oct. 13 ± 5	45	1	48	C, J, Ho (429), K 529	
1381 Nov. 7-Dec. 1	Lib, Hya	Oct. 31 ± 2	150-160	—	26	K, J, E, Ho (477), K 564, P 443	2

* The unit *chhih* corresponds to nearly $1\overset{\circ}{.}5$. See the discussion in the text.

1. Marsden (1967) also suggests this identification.
2. No records in Chinese sources.

Candidates for the identifications with Comet Encke and other bright periodic comets were extensively looked for, but no definite identifications could be found.

6. *The Sun-Grazing Comet Group*

From a set of mean orbital elements of the sun-grazing comet group, namely $\omega=86°$, $\Omega=7°$, $i=145°$ (1950.0), $q=0.0054$ AU, the perihelion times, T, given in the third column of table 5 are derived to fit the cometary paths of possible members of the group. The older records were selected with some criteria on the path or position of a comet, and on the tail description. The constellations in which these comets appeared, the durations of apparitions, as well as the tail length and its width are given in table 5. Generally, these comets are recorded in more than two countries and show remarkable appearances and long tails.

In the original records, as the unit of tail length, *chhih* is used. Kiang (1972) gives the *chhih*$=1.^{\circ}5\pm0.^{\circ}24$. From the discussion on the records of planetary trespassing, Watanabe (1953) derived the *chhih*/deg ratio to be about 1.5 in the case of greater than one *chhih*. In the present study, the value of 1.4 for the ratio is derived from the analysis on the records of Comet 1491 I, which give several comet distances from stars expressed in *chhih*.

The other entries of table 5 are the same as of table 1. The orbital elements of the comets in this group could not be determined from their own observations only.

7. *Discussion*

We now discuss distributions of the orbital elements and some other characteristics of the older comets. Except for a definite periodic comet (Comet 1110), we have 37 probable long-period comets in table 1. In addition, 21 comets observed before 1600 are contained in Marsden's (1975) catalog. We may call those 58 comets the older bright comets. The distributions of the parameters of those comets are shown in the figures herein, and in each figure, the distributions of the same parameter for long-period comets observed during 1800 and 1974 are presented for the sake of comparison. The eight members of sun-grazing comet group are excluded from them. Hence the number of long-period comets becomes 407, and their orbital elements are given in Marsden's (1975) catalog. For 256 long-period comets, including two members of the sun-grazing comet group, the other two parameters J and H_0, shown in figure 4, are given in table 1 of Everhart (1967). The graduations on the left side of all figures herein are for the histogram distributions of the older bright comets, and the ones on the right side are for the long-period comets shown by the solid lines.

Figure 1 shows that both the histogram distributions of the argument of the perihelion, ω, and the longitude of the node, Ω, of the older bright comets somewhat resemble those of the long-period comets, respectively. According to chi-square tests, there are no significant differences in these distributions between them. On the other hand, the distributions of inclination do not show any resemblance. The fact that a greater number of the older bright comets are in the region $i<40°$ than that of the long-period ones suggests that some short-period comets are included among these 58 older bright comets. The excess in the region $110°<i<120°$, as well as for the long-period comets in the region $120°<i<150°$, is also noticed. In spite of the exclusion of the sun-grazing comet

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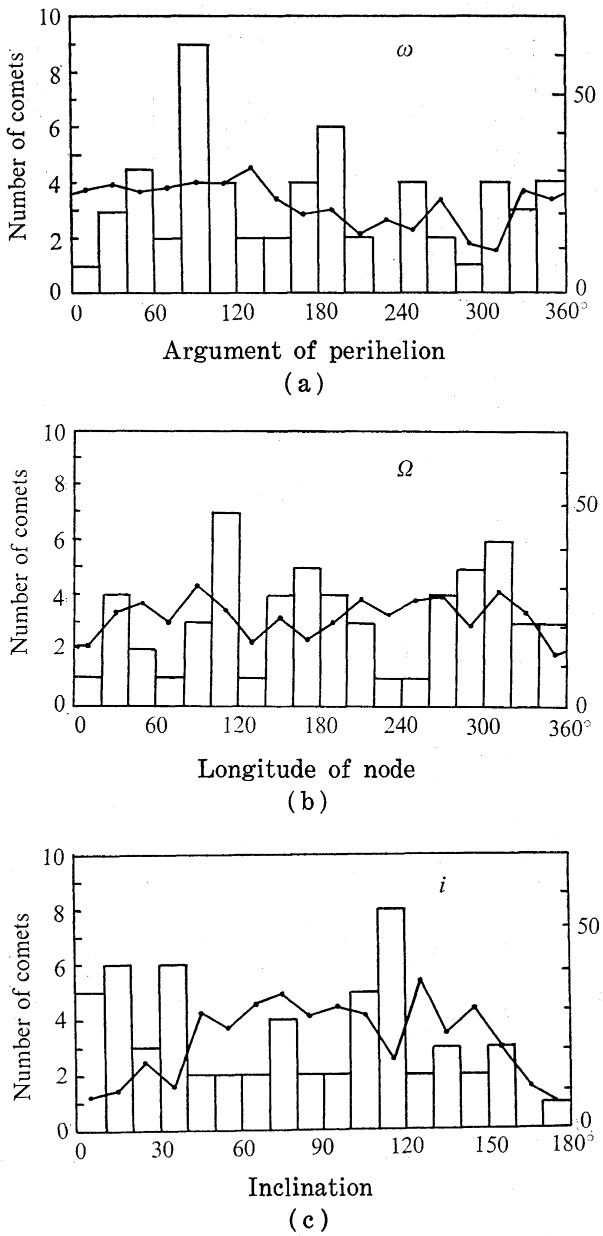
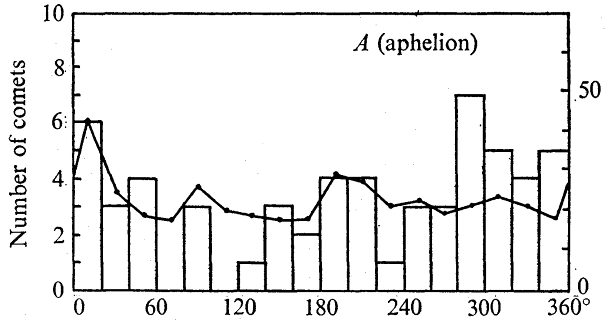


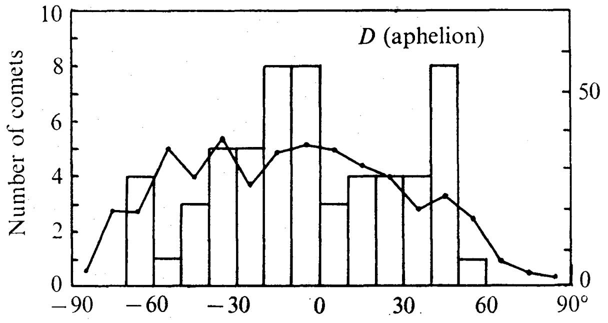
Fig. 1. (a) The histogram is the distribution of 58 older bright comets with respect to the arguments of the perihelion ω, and the left-side ordinate corresponds to this. The solid line is the same distribution for 407 long-period comets observed since 1800, and right-side ordinate corresponds to this. (b) Distribution of longitudes of ascending node Ω. (c) Distribution of inclinations of these comets.

group, the latter is pronounced and it has been discussed by Yabushita (1972). It is well known that the inclinations of the sun-grazing comets are nearly 144°.

In figure 2, the distributions of the longitude and latitude of the aphelion point expressed in the solar-motion coordinates system (Hasegawa 1976) are shown. The agreement between two kinds of distributions in both coordinates are good, except for the excesses of the older bright comets seen in the regions $280° < A < 320°$ and $+40° < D < +50°$. In these regions, there are four and two comets whose



Longitude of aphelion in the solar-motion coordinates system
(a)



Latitude of aphelion in the solar-motion coordinates system
(b)

Fig. 2. (a) The histogram is the distribtion of 58 older bright comets with respect to longitude (a) and latitude (b) of the aphelion in the solar-motion coordinates system (Hasegawa 1976). The left-side ordinate corresponds to this. The solid line is the same distribution for 407 long-period comets observed since 1800, and the right-side ordinate corresponds to this.

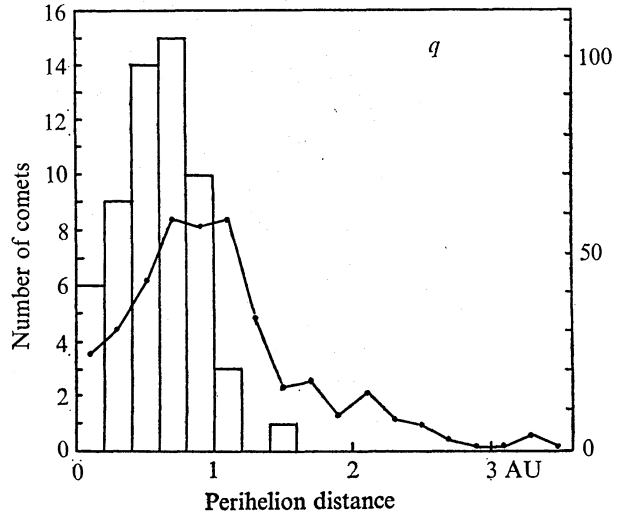


Fig. 3. Same as figures 1 and 2, but for the distribution of perihelion distance.

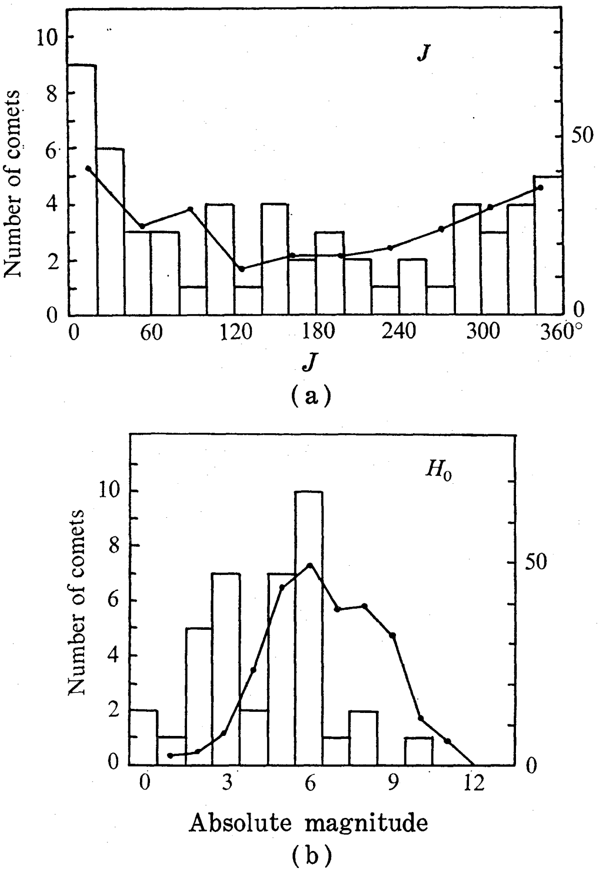


Fig. 4. (a) The histogram is the distribution of 58 older bright comets with respect to angle J between the earth's longitude and the comet's longitude at the time of its perihelion passage. The solid line is the same distribution of 256 long-period comets observed since 1840, and the right-side ordinate corresponds to this. (b) Distribution of absolute magnitude H_0.

inclinations are less than 30°, respectively. These comets with small inclination may be of short period.

As for the perihelion distance, a remarkable excess of the older bright comets may be noticed in the region $q<0.8$ AU as shown in figure 3; a similar excess is seen in the region $H_0<3$ in figure 4b. They may be the distinctive features of bright comets, though their distribution of J shown in figure 4a has no peculiarity compared with those of the long-period comets.

From these characteristics of the distributions of angular elements, we may draw a conclusion that long-period comets of the older bright comets belong to the same population as the long-period comets observed since 1800, but they have bright absolute magnitudes and small perihelion distances which enable them to show the remarkable appearances.

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