Recurrence of Super-Massive Explosions and Orbital Evolution of Comet 17P/Holmes: II. Search for Historical Records, and Outlook for Future Research

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Abstract. *Based on the results of Part I of this study, historical records are searched for possible observations of comet 17P/Holmes undergoing super-massive explosions. A major objective is to establish whether the two episodes of the 1892-1893 event and the megaburst of 2007 were accidental or diagnostic of a systematic long-term pattern. The comet's reference orbit (cf. Part I) has been integrated back in time to ~ 1000 BC, indicating that comet 17P repeatedly underwent close encounters with Jupiter, the result of which has been a gradual reduction of the orbital dimensions and period. A search ephemeris has been calculated and applied in comprehensively testing the historical records to determine — from the timing, the location in the sky, and the physical appearance of archived objects — pre-1892 instances of probable naked-eye detection of comet 17P during or shortly after a super-massive explosion. Attractive candidates include objects classified as dubious novae. A two-step search procedure has resulted in identifying four events as possible appearances of 17P: May 1621, August 1269, July-August 836, and September-October 305, this earliest one being the most promising instance. Forward integration of the reference orbit is used in part to probe the observing conditions during the comet's next return to perihelion in 2014.*

1. Introduction

Comet 17P/Holmes is the only comet known to have *repeatedly* undergone super-massive explosions, violent events of a relatively short duration (typically lasting a few days) but of global proportions on the scale of the nucleus, involving several km^2 of the surface. During each such event, a mass of 10^{13} to 10^{14} grams of microscopic dust is injected into the atmosphere and the comet becomes temporarily a naked-eye object, initially of starlike appearance, that develops into a round, sharply-bounded dust halo uniformly expanding at a subkilometer-per-second velocity for days, weeks, or even longer after the termination of an active phase. I introduced the term "super-massive explosions" (Sekanina 2008a) to distinguish these events from ordinary outbursts that involve dust masses not greater than 10^{12} grams, originate in fairly small areas of the nuclear surface, and occur frequently.

I have undertaken a comprehensive investigation of comet 17P/Holmes and have compared the properties of the two super-massive explosions that occurred 115 years apart — the two episodes of the 1892-1893 event and the megaburst of 2007 (Sekanina 2008b; 2009a). In Part I of this investigation (Sekanina 2009b, referred to hereafter as Paper 1), I studied extensively the comet's history of observation between the time of discovery in 1892 and the present time. I examined the possibility that additional super-massive explosions occurred between the two reported ones and the chances that they remained undetected, especially during the comet's seven missed returns to perihelion between 1913 and 1957. I concluded that there was no evidence — and a near-zero probability — of any such additional explosion taking place during the intervening 115 years. One can practically rule out recurring of super-massive explosions of comet 17P on a time scale much shorter than a century or so.

Next, I developed a comprehensive physical model for the super-massive explosions (Sekanina 2009c, referred to hereafter as Paper 2), adopting 17P as an example of comets whose nuclei are thought to consist of "layered" morphology, as illustrated by comet 9/Tempel in close-up images taken with the camera onboard the impactor of the Deep Impact mission (Thomas *et al.* 2007). A "super-massive explosion" is described in Paper 2 as a sudden release, from the nucleus, of a terrain layer tens of meters thick and several km^2 in areal extent that collapses upon liftoff into a cloud of mostly microscopic dust. The triggering mechanism is identified with an exothermic transformation of water ice from amorphous phase to cubic phase, a runaway, temperature-driven process activated by conduction of the solar energy from the surface into the interior of the nucleus. The water ice is stored in a reservoir beneath the layer, with superheated, highly volatile gases (such as carbon monoxide) trapped inside. The enormous momentum required for the layer's jettisoning is provided in part by the energy released by the phase change, but primarily by the superheated gases that escape from the ice upon its crystallization. The recurrence of super-massive explosions was employed in the proposed scenario for 17P in Paper 2 as a tool for modeling heat transfer in the interior of the nucleus, with the span of 115 years between the two events employed as a constraint for estimating an effective thermal conductivity of porous granular material that is thought to make up such terrain layers.

2. The Objectives, Orbital Motion of Comet 17P, and Error Propagation

From the nature of the proposed physical model, it was unequivocally concluded in Paper 2 that the recurrence time of super-massive explosions of comet 17P/Holmes may under no circumstances be understood as a strict periodicity. Besides, if the propensity of 17P (and apparently other comets as well; see Sekanina 2008a) for these violent events is rooted in continual removal of terrain layers, one by one, from the nucleus, then this process should proceed over very long periods of time, at least centuries or millennia, and records of the repeatedly exploding comet that temporarily becomes a naked-eye object may appear in old chronicles and annals.

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Table 1. Reference orbit JPL K077/21 for comet 17P/Holmes (equinox J2000.0).[a]

Osculation epoch (ET)	2007 May 20.0
Time of perihelion passage (ET)	2007 May 4.49672 ± 0.00011
Argument of perihelion (deg)	24.257660 ± 0.000047
Longitude of ascending node (deg)	326.867443 ± 0.000037
Orbit inclination (deg)	19.113149 ± 0.000005
Perihelion distance (AU)	2.05316182 ± 0.00000095
Orbit eccentricity	0.43243078 ± 0.00000026
Orbital period (yr)	6.88
Nongravitational parameters:	
Radial component A_1 (10^{-8} AU day^{-2})	+0.24754 ± 0.00488
Transverse component A_2 (10^{-8} AU day^{-2})	+0.03124 ± 0.00025
Orbital arc covered by observations	1964 Jul. 16—2009 Mar. 25
Length of time interval (days)	16,323
Number of linked apparitions	7
Number of observations	3581
Mean residual (arcsec)	±0.68

[a] See Mastrodemos (2009). The Ephemeris Time, ET, is a generic term used throughout this paper for a uniform time scale (see Sec. 3 for comments and conversion to the Universal Time, UT).

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The main objectives of this paper are a systematic search, in such historical sources, for possible records on comet 17P and its likely identification based on diagnostic data. The necessary prerequisite for this effort is the availability of reasonably accurate information on the orbital evolution of the comet over long periods of time. The arguments, in Paper 1, for choosing a reference JPL orbit K077/21 (Mastrodemos 2009) — derived by fitting nearly 3600 astrometric observations between 1964 and 2009 — as the best match to the comet's motion from 1892 on, now also support a decision to use this set of elements, reproduced in Table 1, as the basis for predicting the comet's orbital evolution over a more extended span of time. For an orbit of fairly stable dimensions and spatial orientation, a *nominal* error that, due to orbital integration, propagates in the time of perihelion passage t_π after n revolutions about the sun reckoned from the nearest apparition used in the orbit determination, can be estimated from

$$\epsilon_n(t_\pi) = \frac{1}{2} n(n+1)\langle P(t_\pi)\rangle \psi, \tag{1}$$

where $\langle P(t_\pi)\rangle = (t_\pi^\star - t_\pi)/n$ is the mean reference orbital period at the perihelion time t_π, $t_\pi^\star = 1964.87$ is the perihelion time in 1964 (the earliest return used in deriving the reference orbit), from which $\langle P\rangle$ for any t_π is reckoned, and ψ is a dimensionless factor numerically equal to an estimated relative error in the orbital period. From Sec. 4 and Table 2 of Paper 1 it follows that ψ in Eq. (1) can reliably be calibrated by the results for the 1899 apparition of comet 17P. The three best orbit determinations based on the observations including those from 1899 (Zwiers 1902, 1905; Koebcke 1948; Williams 1999) leave (as seen in column 3 of that table) the perihelion-time differences from the reference orbit of, respectively, 0.010, 0.010, and 0.006 day (in absolute value), or 0.009 day on the average. The number of revolutions back in time from 1964 to 1899 is $n = 9$ and the mean integrated orbital period in this time interval is $\langle P(1899)\rangle$ = 7.28 years = 2660 days, so that the error in the perihelion time (in days) propagated to the 1899 return is $\epsilon_9(1899)$ = $\pm\, 0.009 = \frac{1}{2} \times 9 \times 10 \times 2660 \times \psi$, or $\psi = \pm\, 0.75 \times 10^{-7}$. Equation (1) predicts that, on the assumption of a relatively stable orbit ($\langle P\rangle \simeq$ const.), the integration of the reference set of elements back in time leads to an estimated error in the perihelion time of ±0.4 day in AD 1500, ±2 days in AD 1000, ±7 days at the beginning of the Christian calendar, and ±17 days around 1000 BC, an extreme limit to which it is feasible to carry out the orbit integration, given the exceedingly incomplete and fragmentary statistics of earlier historical records.

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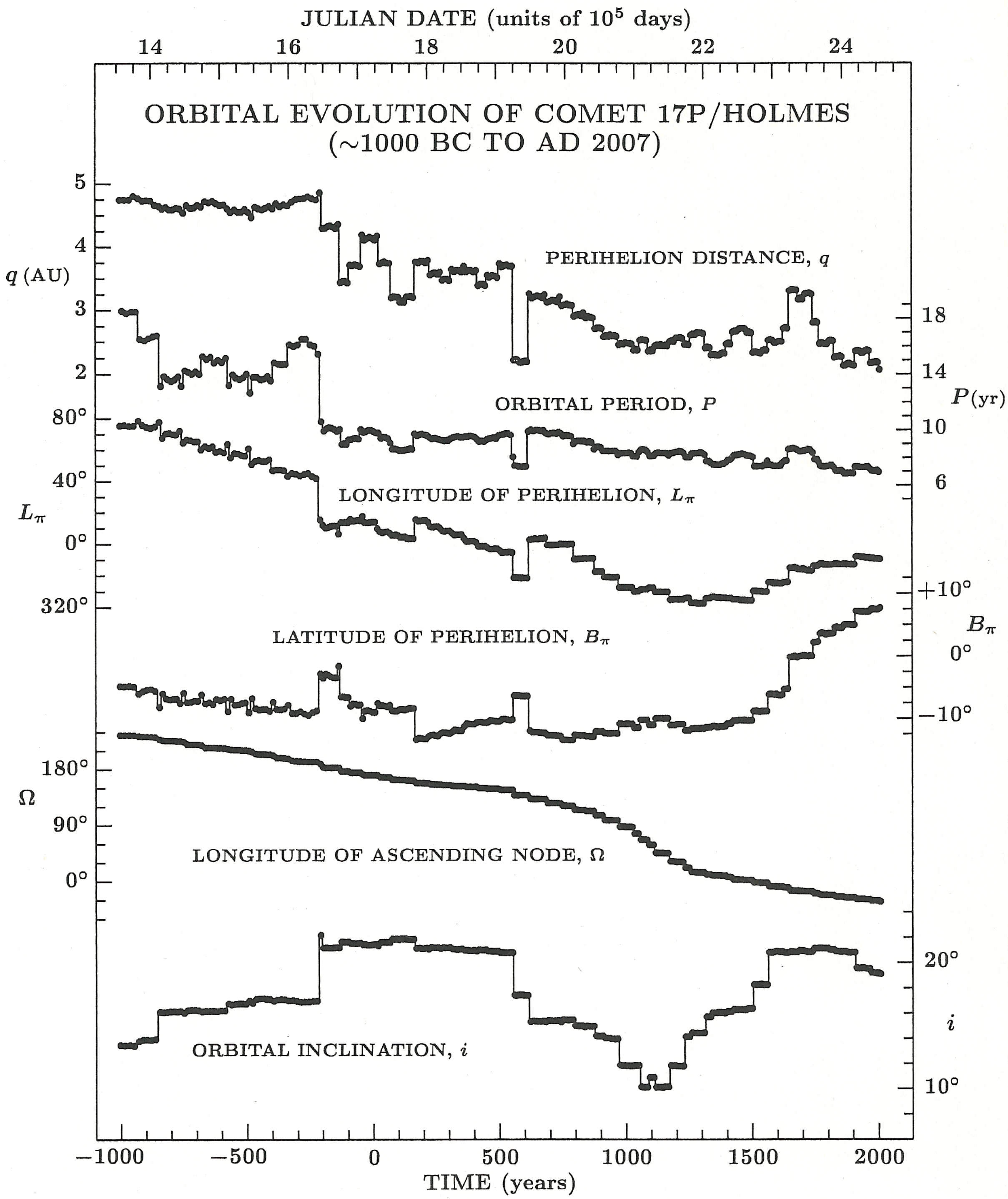

Figure 1. Orbital variations of comet 17P/Holmes calculated for the past three millennia from the reference orbit. Sudden major changes seen in the plots of six orbital parameters indicate instances of major perturbations by Jupiter. Rapid decreases in the orbital dimensions and period, the regression of the nodal line and the steplike variations in the inclination are clearly apparent.

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The actual integration of the reference set of elements shows a very complex orbital evolution of comet 17P/Holmes over the past three millenia, as seen from Figure 1. The main features are (i) numerous bumps on five of the six plotted parameters, indicating instances of major orbital perturbations by Jupiter; (ii) a striking reduction in the perihelion distance with time, from almost 5 AU near 1000 BC to about 2 AU today, implying an average rate of decrease of $\sim$ 1 AU per millennium; (iii) an equally dramatic shortening of the orbital period, especially a precipitous drop from 16.1

to 11.3 years near 215 BC; (iv) an unusually rapid motion of the line of apsides; and (v) two flat peaks in the inclination distribution, with a sharp minimum in between, around AD 1100.

The striking orbital changes displayed in Figure 1 have a major impact on the objectives of this paper (Sec. 3). The greater perihelion distance and longer orbital period in the distant past mean that heat transport through the interior of the nucleus must have proceeded much more slowly in those times, especially before AD 560. The bump between 1650 and 1740 could also cause an anomaly in the rate of super-massive explosions in that period of time. The changes in the orbital period and dimensions necessarily affect the rate of error propagation, and the times of perihelion passage calculated by orbital integration back in time are surely determined much less accurately than predicted by Eq. (1). The variable direction of the line of apsides is bound to contribute to an obliquity instability and thus to changes in the insolation regime, which is also affected by the steplike perturbations in the inclination and by the steady regression of the nodal line. These insolation variations over the surface of the nucleus ought to have an effect on the nongravitational parameters. A detailed search ephemeris (Sec. 3) will allow one to realistically estimate the influence of all these orbital changes on the comet's position in the sky as a function of the time from perihelion over many revolutions about the sun.

Table 2 summarizes the calculated changes in the perihelion distance and orbital period (reckoned from perihelion to next perihelion) of comet 17P/Holmes over the past nearly three millennia. Except in the angular elements, the comet's orbit was relatively stable for more than seven centuries, between the years 916 and 1644. With the exception of the returns 1652 to 1738, the perihelion distance is seen to have remained below 3 AU since the very end of the 8th century; it has stayed below 4 AU since AD 28. Also since this same time, the orbital period has remained below 10 years. Table 2 further shows that the mean reference period $\langle P \rangle$, affecting the error propagation in the perihelion time, has stayed below 10 years ever since the year −1004 (or 1005 BC) and has essentially been a steadily decreasing function of time.

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Table 2. Predicted variations in the perihelion distance and orbital period of comet 17P/Holmes between the returns 1892 and −1004.[a]

Returns to sun	Range of perihelion distances (AU)	Mean orbital period[b] (yr)	Mean reference period[c] (yr)	Number of returns[d] to sun
1829 to 1892	2.1 to 2.3	7.0	7.1	10
1747 to 1822	2.4 to 2.9	7.5	7.3	11
1652 to 1738	3.1 to 3.4	8.6	7.6	11
1628 to 1644	2.7 to 2.8	7.8	7.6	3
916 to 1620	2.2 to 2.7	8.1	7.9	88
799 to 908	2.7 to 3.0	9.1	8.0	13
622 to 790	3.0 to 3.3	9.8	8.2	18
560 to 612	2.1 to 2.3	7.4	8.2	8
171 to 552	3.3 to 3.8	9.5	8.5	41
75 to 162	3.1 to 3.3	8.7	8.5	11
28 to 66	3.7 to 3.8	9.5	8.5	5
−42 to 18	4.1 to 4.2	10.0	8.5	7
−126 to −52	3.4 to 3.8	9.3	8.6	9
−1004 to −136	4.2 to 4.9	14.5	9.7	61

[a] For comparison, for the 17 returns 1892 through 2007 the range of perihelion distances was 2.0 to 2.4 AU and the mean orbital and reference periods were both 7.2 years.
[b] From difference between perihelion times of the starting and ending returns.
[c] From difference between perihelion times of the starting return and the 1964 return.
[d] Including the starting and ending returns.

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Table 3 lists the nominal perihelion times between AD 1885 (the return immediately preceding the discovery apparition of 1892) and 1005 BC calculated by integrating the reference orbit back in time. There are 295 perihelion passages during this period of time. Both sudden orbital changes during close approaches to Jupiter and a lower orbital eccentricity necessarily lead to greater uncertainties in the perihelion times (as well as other elements) than predicted on a stable-orbit assumption. To account approximately for these inaccuracies, Eq. (1) has been modified to estimate an *effective* error propagating in the perihelion time,

$$\epsilon_n^*(t_\pi) = \frac{1}{2}(N+10)(N+11)\langle P(t_\pi)\rangle\,\psi^*, \qquad (2)$$

where n, the actual number of revolutions reckoned from the 1964 apparition, is expressed in terms of the return number, N (from Table 2), which has been augmented by 10 (the number of revolutions between 1964 and 1892), and the normalization constant is estimated at $\psi^* \simeq 10\psi = \pm 0.75 \times 10^{-6}$.

Table 3. Predicted perihelion times for comet 17P/Holmes between the years 1885 and −1004.[a]

Return No.	Perihelion time (ET)	Return No.	Perihelion time (ET)	Return No.	Perihelion time (ET)	Return No.	Perihelion time (ET)	Return No.	Perihelion time (ET)
1	1885 Jul. 19.80	60	1426 Sept. 17.54	119	942 Apr. 28.22	178	400 Jun. 3.96	237	−156 Apr. 11.99
2	1878 Aug. 24.36	61	1418 Sept. 9.75	120	933 Oct. 16.26	179	390 Oct. 31.09	238	−166 Jan. 25.70
3	1871 Oct. 13.48	62	1410 Oct. 24.27	121	925 Mar. 30.69	180	381 Mar. 12.98	239	−177 Oct. 27.36
4	1864 Dec. 3.96	63	1402 Dec. 10.73	122	916 Sept. 18.43	181	371 Aug. 15.85	240	−187 Aug. 27.80
5	1857 Dec. 11.31	64	1395 Mar. 20.84	123	908 Mar. 4.62	182	362 Jan. 18.41	241	−197 Aug. 19.13
6	1850 Nov. 9.13	65	1387 Aug. 12.97	124	899 May 14.38	183	352 Jul. 7.58	242	−208 Dec. 17.37
7	1843 Oct. 11.15	66	1380 Jan. 11.85	125	890 Jul. 6.54	184	342 Dec. 25.91	243	−223 Jun. 15.32
8	1836 Sept. 18.82	67	1372 Jun. 28.00	126	881 Sept. 11.94	185	333 May 23.76	244	−239 May 23.20
9	1829 Aug. 22.74	68	1364 Dec. 11.72	127	873 Jan. 4.55	186	323 Nov. 4.54	245	−255 Mar. 24.36
10	1822 May 6.72	69	1357 May 31.11	128	863 Nov. 9.23	187	314 May 7.07	246	−272 Aug. 23.04
11	1814 Nov. 19.42	70	1349 Nov. 13.33	129	854 Aug. 18.98	188	304 Dec. 4.24	247	−288 Jan. 22.01
12	1807 Jun. 7.43	71	1342 Apr. 19.90	130	845 Jun. 10.87	189	295 Aug. 25.11	248	−305 Nov. 29.03
13	1800 Jan. 10.70	72	1334 Aug. 3.66	131	836 Mar. 11.66	190	286 Apr. 25.18	249	−321 Nov. 16.56
14	1792 Aug. 25.87	73	1326 Oct. 13.96	132	826 Nov. 28.18	191	277 Jan. 14.06	250	−337 Sept. 23.72
15	1785 Apr. 16.30	74	1318 Dec. 21.50	133	817 Aug. 24.04	192	267 Sept. 15.51	251	−352 Dec. 7.32
16	1777 Nov. 29.52	75	1310 Sept. 20.42	134	808 May 10.91	193	258 Apr. 29.03	252	−366 Feb. 26.65
17	1770 Jul. 7.16	76	1302 May 7.39	135	799 Feb. 16.55	194	248 Nov. 20.46	253	−381 May 13.10
18	1762 Oct. 22.43	77	1293 Dec. 7.32	136	790 Jan. 20.86	195	239 May 30.34	254	−396 Jun. 20.56
19	1754 Nov. 29.15	78	1285 Jul. 19.71	137	780 Jun. 18.83	196	230 Jan. 4.36	255	−410 Nov. 10.92
20	1747 Jan. 4.24	79	1277 Mar. 11.05	138	770 Oct. 22.86	197	220 Jun. 25.63	256	−424 Dec. 6.80
21	1738 Aug. 19.40	80	1268 Oct. 24.54	139	761 Feb. 21.54	198	210 Oct. 26.68	257	−437 Mar. 12.52
22	1730 Jan. 23.89	81	1260 Jun. 19.23	140	751 Jul. 18.21	199	201 Feb. 8.21	258	−451 Jul. 4.94
23	1721 Jun. 12.98	82	1252 May 9.49	141	741 Sept. 26.20	200	191 May 2.07	259	−465 Aug. 24.43
24	1712 Nov. 20.17	83	1244 Apr. 13.86	142	731 Nov. 2.41	201	181 Aug. 7.80	260	−479 Oct. 13.57
25	1704 May 16.59	84	1236 Mar. 16.37	143	722 Jan. 19.53	202	171 Dec. 16.06	261	−491 Jan. 15.84
26	1695 Nov. 19.53	85	1227 Nov. 1.07	144	712 Mar. 13.83	203	162 Mar. 2.30	262	−506 Dec. 11.57
27	1687 May 28.05	86	1219 May 7.79	145	702 May 16.51	204	153 Jun. 21.17	263	−519 Feb. 11.12
28	1678 Oct. 30.50	87	1210 Oct. 29.32	146	692 Aug. 11.88	205	144 Sept. 28.29	264	−533 May 30.11
29	1670 Mar. 6.72	88	1202 May 4.67	147	682 Oct. 25.07	206	136 Jan. 26.22	265	−547 Aug. 7.22
30	1661 Jun. 18.12	89	1193 Nov. 27.22	148	672 Oct. 9.83	207	127 Jun. 13.25	266	−561 Jul. 25.89
31	1652 Oct. 14.53	90	1185 Jul. 5.58	149	662 Oct. 15.28	208	118 Nov. 8.00	267	−574 Apr. 12.60
32	1644 Feb. 26.74	91	1177 Feb. 13.44	150	652 Sept. 21.77	209	110 Apr. 5.12	268	−589 Jan. 15.43
33	1636 May 10.00	92	1168 Nov. 22.38	151	642 Sept. 3.93	210	101 Aug. 28.88	269	−604 Feb. 11.01
34	1628 Jul. 24.97	93	1160 Jul. 8.08	152	632 Sept. 13.36	211	92 Dec. 31.33	270	−619 Jan. 14.89
35	1620 Nov. 25.25	94	1152 Feb. 12.32	153	622 Aug. 19.52	212	84 Apr. 15.07	271	−634 Feb. 25.34
36	1613 Jun. 9.12	95	1143 Sept. 22.30	154	612 Aug. 31.43	213	75 Aug. 10.40	272	−650 Nov. 4.56
37	1605 Dec. 28.16	96	1135 May 1.95	155	605 Mar. 24.38	214	66 Jul. 1.64	273	−665 Sept. 11.16
38	1598 Jul. 28.73	97	1126 Dec. 1.81	156	597 Oct. 20.83	215	57 Jan. 18.78	274	−680 May 5.53
39	1591 Feb. 17.11	98	1118 Jul. 10.43	157	590 May 29.11	216	47 Jul. 5.07	275	−694 Mar. 30.91
40	1583 Sept. 7.07	99	1110 Apr. 26.56	158	583 Jan. 3.50	217	37 Dec. 14.37	276	−709 Dec. 24.79
41	1576 Feb. 28.65	100	1102 Feb. 17.08	159	575 Aug. 4.33	218	28 Jun. 24.83	277	−723 Nov. 19.23
42	1568 Aug. 26.99	101	1093 Dec. 10.00	160	568 Feb. 14.89	219	18 Aug. 24.55	278	−737 Sept. 5.95
43	1560 Nov. 10.69	102	1085 Jun. 22.08	161	560 Aug. 21.93	220	8 Oct. 13.33	279	−751 May 12.40
44	1553 May 20.76	103	1076 Nov. 9.19	162	552 Jul. 14.87	221	−2 Oct. 28.28	280	−764 Feb. 20.24
45	1545 Dec. 1.17	104	1068 Mar. 14.11	163	542 Nov. 7.18	222	−12 Oct. 4.60	281	−778 Mar. 27.76
46	1538 Jul. 5.42	105	1059 Jul. 28.57	164	533 Jan. 27.21	223	−22 Sept. 15.44	282	−792 Jul. 19.93
47	1531 Feb. 8.75	106	1051 Feb. 2.61	165	523 Apr. 9.42	224	−32 Oct. 2.45	283	−806 Dec. 19.48
48	1523 Sept. 19.41	107	1042 Dec. 9.86	166	513 Jul. 14.61	225	−42 Nov. 14.10	284	−819 Mar. 31.84
49	1516 Apr. 21.32	108	1034 Oct. 17.30	167	503 Oct. 28.62	226	−52 Oct. 3.40	285	−833 May 1.81
50	1508 Nov. 16.43	109	1026 Aug. 12.20	168	494 Mar. 3.98	227	−61 May 10.41	286	−846 Feb. 7.07
51	1500 Oct. 22.26	110	1018 Mar. 22.23	169	484 Sept. 26.76	228	−71 Nov. 12.69	287	−863 Apr. 12.89
52	1492 Aug. 27.97	111	1009 Oct. 20.60	170	475 Mar. 26.84	229	−80 May 27.60	288	−880 Jul. 2.94
53	1484 Jun. 25.97	112	1001 May 24.16	171	465 Oct. 8.50	230	−89 Jan. 10.32	289	−897 Nov. 16.11
54	1476 Apr. 9.11	113	993 Jan. 1.05	172	456 May 10.37	231	−99 Aug. 20.56	290	−913 May 27.65
55	1468 Jan. 1.32	114	984 Aug. 4.89	173	447 Jan. 1.01	232	−108 Aug. 7.28	291	−930 Oct. 30.09
56	1459 Sept. 7.44	115	976 Mar. 18.28	174	437 Oct. 15.05	233	−117 Jul. 5.69	292	−948 Apr. 12.61
57	1451 May 27.91	116	967 Dec. 16.64	175	428 Jul. 8.79	234	−126 Jun. 25.00	293	−967 Sept. 27.86
58	1443 Mar. 1.59	117	959 Jun. 4.06	176	419 Apr. 24.43	235	−136 May 14.68	294	−985 Apr. 19.39
59	1434 Dec. 5.11	118	950 Nov. 14.08	177	409 Dec. 15.60	236	−146 May 22.42	295	−1004 Sept. 7.11

[a] The dates are in the Gregorian calendar after 1582 Oct. 15, in the Julian calendar before and on that day.

3. Search Ephemeris

A search for pre-1892, historical records of comet 17P/Holmes as a naked-eye object during, or immediately following, a super-massive explosion is a difficult undertaking. In order to increase a chance of success, favorable conditions for detecting potential candidate objects should be carefully examined in terms of (i) timing, (ii) location in the sky and quality of observing conditions, and (iii) appearance and apparent brightness.

The timing is determined by three constraints. The first is based on our experience with the two observed super-massive events, in 1892-1893 and 2007, which shows that the comet was a naked-eye object for a significant fraction of time between 150 and 240 days after perihelion, suggesting that the search for historical records should essentially be focused on this period of time at each of the returns listed in Table 3. A modest extension of this interval in either direction is advisable, as the two observed events may be expected to cover less than the whole range of possibilities.

The second timing constraint is provided by the list of perihelion times in Table 3, from which the critical post-perihelion interval is to be reckoned. Because of the errors steadily propagating in the perihelion times (Sec. 2), a third constraint enters the considerations. Rather than correcting the tabulated perihelion times t_π by including their errors $\epsilon_n^*(t_\pi)$, one can use the t_π values as listed in Table 3 and account for their errors by incorporating them in the critical period for super-massive explosions — that is, by replacing the nominal interval from 150 to 240 days after perihelion with an extended interval from $150 - |\epsilon_n^*(t_\pi)|$ to $240 + |\epsilon_n^*(t_\pi)|$ days after perihelion.

Because of the significant orbital perturbations of comet 17P/Holmes over the long periods of time, a meaningful search scenario requires that a range of orbital solutions be used to provide a basis for predicting locations of potential candidate objects as a function of time. For this purpose, I have selected the sets of orbital elements at four widely separated returns to the sun, which suggest a degree of scatter across the sky that one can expect over the relevant period of time. The selected orbits refer to the comet's perihelion returns 1591, 1219, 722, and −2 (*i.e.*, 3 BC), covering 16 centuries. The predicted sets of elements for these returns are listed in Table 4, which — like Figure 1 — shows major variations, both systematic with time (like in the perihelion distance) and essentially random (like in the inclination). The regression of the nodal line is seen to reach ∼ 180° in the course of the 16 centuries.

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Table 4. Selected sets of orbital elements predicted for comet 17P/Holmes at its returns 1591, 1219, 722, and −2 (equinox J2000.0).[a]

Osculation epoch (ET)[b]	1591 Feb. 10.0	1219 May 24.0	722 Feb. 2.0	−2 Oct. 21.0
Time of perihelion passage (ET)[b]	1591 Feb. 17.11	1219 May 7.79	722 Jan. 19.53	−2 Oct. 28.28
Argument of perihelion (deg)	342.42	293.31	235.11	204.90
Longitude of ascending node (deg)	351.27	30.97	125.14	170.73
Orbit inclination (deg)	20.89	11.80	15.42	21.47
Perihelion distance (AU)	2.4826	2.5666	3.1523	4.1373
Orbit eccentricity	0.3477	0.3844	0.3127	0.1092
Orbital period (yr)	7.43	8.51	9.82	10.01

[a] Based on the reference elements computed by N. Mastrodemos and presented in Table 1.

[b] The dates of the osculation epoch and perihelion passage are in the Gregorian calendar for the 1591 return, in the Julian calendar for the earlier returns.

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The appearance and apparent brightness of potential candidate objects are important in complementing the timing and positional information. As Chinese chronicles (followed by Korean and Japanese annals) are the most important sources of historical data, I briefly address the relevant terminology. For more extensive discourse of this subject, the reader is referred to Ho (1962). In the early phase of evolution of a super-massive explosion (up to about 24-48 hours after the onset), comet 17P appears as an essentially star-like and tailless object to the naked eye, so that useful information is provided by historic records that describe discoveries of suspected novae, which were called "guest stars" (*kho-hsing*) by the Chinese (Ho 1962). Of particular interest is a comment by Duerbeck (2009), who cautioned that some guest stars could not be novae because they were reported to move relative to stars. In his updated catalogue of pre-telescopic galactic novae and supernovae, Duerbeck (2009) assigned a class 4 or 5 to such dubious objects, and these are among the most promising candidates in my quest to identify explosions of comet 17P. On the other hand, the likelihood of such detections is generally low because of the short duration of the early phases of evolution of the comet's explosive events.

As the dimensions of the gradually expanding dust halo reach more than ∼10 arcminutes, giving the comet a distinctly disk-shaped (rather than star-like) appearance, the comet's perception may better fit a category that Chinese called "sparkling stars" (*po-hsing*), which according to a definition quoted by Ho (1962), send out their rays evenly in all directions. In still later stages of evolution, when the expanding comet begins to loose its near-perfect symmetry (while still remaining a naked-eye object), its appearance could possibly be classified even as a "broom star" (*hui-hsing* or *sao-hsing*), but descriptions in terms of a "tailed star" (*chhang-hsing*) rule unequivocally out any possibility of identity with comet 17P. And when an object's length is reported to be about 1 "foot" or more (1 foot $\simeq$ 1°.50 ± 0°.24 according to Kiang 1972), the identity with 17P is out of the question regardless of the category to which the object has been attributed.

To estimate the likelihood of comet 17P being observable with the naked eye at a given time and location of a potential candidate object, the search ephemeris includes an apparent visual magnitude H calculated from a standard formula

$$H = H_0 + 5\log(r \cdot \Delta), \tag{3}$$

where r and Δ are, respectively, the heliocentric and geocentric distances (in AU), while the intrinsic magnitude H_0 (at $r = \Delta = 1$ AU) is assumed to be equal to the peak intrinsic magnitude, $(H_0)_{\rm peak}$, of the megaburst of comet 17P in 2007, $H_0 = (H_0)_{\rm peak} = -0.5$ mag (Sekanina 2009a). A minor phase effect has been neglected.

Having addressed issues of the timing, location, appearance, and brightness, the task is now to provide an estimate for a realistic upper limit on the propagated error $\epsilon^*_{\rm lim}$ in the perihelion time and thus for a maximum range of the critical period of time (relative to the nominal perihelion time) to be investigated. For the four selected orbits listed in Table 4, the error propagating in the perihelion time is, as given by Eq. (2), equal to ±2.5 days in 1591, ±10 days in 1219, ±26 days in 722, and ±62 days in 3 BC (when $\langle P \rangle = 8.6$ years from Table 2, $N = 221$ from Table 3, and therefore $n = 231$). At earlier times, comet 17P would remain fainter than apparent magnitude 5 even during the most favorable returns and would not be a naked-eye object during less favorable returns. Based on the above assessment of the error propagating in the perihelion time, I adopt for its upper limit

$$\epsilon^*_{\rm lim} = \epsilon^*_{231}(-2) \simeq \pm 60 \;\; {\rm days}, \tag{4}$$

so that the proposed search should cover the time from 90 to 300 days after perihelion.

Absorbed in the error $\epsilon^*_n(t_\pi)$ is a small conversion factor between the Universal Time, UT, and the Ephemeris Time, ET. The purpose of ET — now more commonly known as Coordinate Time, CT, and identical, within a very small fraction of a second, with the Terrestrial Time, TT (which itself differs by 32.2 seconds from the atomic time, TAI) — is to remove the effects on UT of variations in the earth's rate of rotation (*i.e.*, in the length of the day), caused primarily by lunar and solar tides. Though minute, these irregularities are systematic and accumulate to a sizable temporal effect over very long periods of time. The correction, ΔT = ET − UT, which was +29 seconds in 1950 and +64 seconds in 2000, amounted to only several seconds between 1830 and 1900 but reached considerable positive values many centuries ago, over a time scale that is relevant to this work. Morrison and Stephenson (2004, 2005) have investigated this problem and provided an expression to approximate the difference between ET and UT during the past three millennia. With ΔT in hours, their formula yields for a year Y

$$\Delta T = -0.006 + 0.889(\Delta Y)^2, \tag{5}$$

where $\Delta Y = 10^{-3}\,(Y - 1820)$. Thus, the correction ΔT was +0.04 hr in 1591, +0.3 hr in 1219, about +1 hr in 722, and nearly +3 hr in 3 BC; it never exceeded 0.2 percent of the error $\epsilon^*_n(t_\pi)$. In the 7th century BC, the uncertainty in the derived correction ΔT has been estimated by Morrison and Stephenson (2005) at ±500 seconds or ±0.14 hour.

Because the error $\epsilon^*_n(t_\pi)$ is smaller than ±60 days for returns more recent than two millennia ago, the time interval from 90 to 300 days after perihelion, adopted universally in the search ephemeris below, is longer than that based on the two known super-massive explosions, thereby addressing the concern — mentioned near the beginning of this section — that the two observed events may not cover the whole possible range of explosion times. And if the comet's post-explosion fading should proceed very slowly, as in 2007-2008, the end time of the interval may still turn out to be rather conservative.

The search ephemeris for historical records of comet 17P/Holmes is presented in Table 5 with a 20-day step in the date. For each date, the comet's predicted right ascension (α), declination (δ), and apparent magnitude [defined by Eq. (3)] are derived at the four selected returns (1591, 1219, 722, and −2) and at eight post-perihelion times (90, 120, 150, 180, 210, 240, 270, and 300 days), taking in essence the perihelion time as a parameter. These data are listed only when the comet is more than 45° from the sun. For smaller elongations, at which the comet becomes increasingly more difficult to observe, the entries are replaced with dots.

Table 5 provides critical information that constrains and streamlines the search for historical records of comet 17P. It shows in the first place that *no observation made between mid-March and the end of April of any year could refer to this comet*. More detailed inspection shows that around the 13th century, the "forbidden" time zone began even earlier, in mid-February.

Second, in spite of the orbital instability of 17P seen from Figure 1, the area of the sky that the exploding comet passed through during the 16 centuries covered in Table 5 is greatly restricted. The limits of this region range from about $22^{\rm h}10^{\rm m}$ to $5^{\rm h}00^{\rm m}$ in right ascension and from about −21° to +43° in declination (eq. J2000.0). The equatorial coordinates predicted by the ephemeris are strongly correlated in the sense that declination always increases with increasing right ascension, so that the areal extent of the ephemeris positions is actually much smaller than indicated by the overall spans of the coordinates. In the order of increasing right ascension, the exploding comet may have at various returns passed through the following 11 constellations: Aquarius, Pegasus, Pisces, Andromeda, Triangulum, Cetus, Aries, Perseus, Eridanus, Taurus, and Orion.

Third, in the long run the apparent motion of comet 17P has a tendency to regress with time in right ascension and to advance with time in declination, even though neither trend is universally valid. As far as the brightness is concerned, the most favorable season is shown in Table 5 to be September to October throughout the 16 centuries covered, which corresponds typically to the perihelion times in January through June (6 months), depending on the orbital position of the super-massive explosion. Returns with such perihelion times were generally less common before 1892 than between

Table 5. Search ephemeris for comet 17P/Holmes at four selected returns to the Sun (equinox J2000.0).[a]

Date of obser-vation[b] (0^hET)	Re-turn to Sun	Time after perihelion: 90 days			120 days			150 days			180 days			210 days			240 days			270 days			300 days		
		α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H
		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°	
Jan. 1	1591	22 45	−5.3	3.9	23 05	−0.3	3.9	23 25	+4.7	3.9	23 45	+9.8	3.9	0 06	+14.9	4.0	0 27	+19.9	4.0	0 49	+24.6	4.1	1 12	+29.2	4.1
	1219		......			......		23 27	−8.4	4.3	23 48	−5.0	4.3	0 09	−1.6	4.4	0 29	+1.9	4.4	0 49	+5.2	4.5	1 08	+8.5	4.5
	722	0 28	−11.4	4.8	0 48	−10.0	4.8	1 09	−8.5	4.7	1 29	−6.9	4.7	1 50	−5.2	4.7	2 11	−3.4	4.8	2 31	−1.7	4.8	2 51	+0.1	4.8
	−2	1 02	−5.9	5.8	1 16	−5.8	5.8	1 30	−5.6	5.8	1 44	−5.5	5.8	1 58	−5.3	5.7	2 12	−5.1	5.7	2 26	−4.9	5.7	2 42	−4.7	5.7
21	1591		......		23 20	+0.8	4.1	23 39	+5.4	4.1	23 57	+10.0	4.2	0 16	+14.5	4.2	0 35	+18.8	4.2	0 55	+23.0	4.3	1 15	+27.0	4.4
	1219		......			......			......			......		0 21	0.0	4.5	0 39	+3.1	4.6	0 57	+6.1	4.7	1 15	+9.1	4.8
	722		......		0 57	−7.8	4.9	1 16	−6.4	4.9	1 35	−4.8	4.9	1 54	−3.3	4.9	2 13	−1.7	5.0	2 32	−0.1	5.0	2 50	+1.5	5.0
	−2	1 10	−4.3	6.0	1 23	−4.2	5.9	1 36	−4.0	5.9	1 49	−3.8	5.9	2 02	−3.6	5.9	2 15	−3.4	5.9	2 28	−3.2	5.9	2 41	−3.0	5.9
Feb. 10	1591		......			......			......			......		0 31	+15.0	4.4	0 49	+18.9	4.4	1 07	+22.6	4.5	1 26	+26.2	4.6
	1219		......			......			......			......			......			......			......			......	
	722		......			......			......			......		2 04	−1.3	5.1	2 21	+0.2	5.1	2 39	+1.7	5.2	2 56	+3.2	5.2
	−2		......			......			......			......			......		2 23	−1.7	6.0	2 35	−1 5	6.0	2 48	−1.3	6.0
Mar. 2	1591		......			......			......			......			......			......			......		1 41	+26.3	4.7
	1219		......			......			......			......			......			......			......			......	
	722		......			......			......			......			......			......			......			......	
	−2		......			......			......			......			......			......			......			......	
⋮	⋮		⋮			⋮			⋮			⋮			⋮			⋮			⋮			⋮	
May 1	1591		......			......			......			......			......			......			......			......	
	1219	0 37	−3.1	4.1		......			......			......			......			......			......			......	
	722		......			......			......			......			......			......			......			......	
	−2		......			......			......			......			......			......			......			......	
21	1591	0 57	+8.7	4.0		......			......			......			......			......			......			......	
	1219	0 50	−2.4	3.9	1 11	+1.3	4.1	1 30	+4.7	4.2	1 48	+7.8	4.4		......			......			......			......	
	722	2 16	+0.4	4.9		......			......			......			......			......			......			......	
	−2	2 28	+3.2	6.0	2 40	+3.4	6.0		......			......			......			......			......			......	
Jun. 10	1591	1 10	+10.3	3.8	1 29	+14.8	4.0	1 49	+18.8	4.1	2 07	+22.4	4.3		......			......			......			......	
	1219	0 59	−2.4	3.6	1 21	+1.7	3.8	1 42	+5.4	4.0	2 01	+8.7	4.2	2 19	+11.6	4.4	2 37	+14.2	4.6	2 53	+16.6	4.8	3 09	+18.7	4.9
	722	2 28	+0.5	4.7	2 47	+2.1	4.8	3 05	+3.5	4.9	3 23	+4.9	5.0	3 39	+6.3	5.1		......			......			......	
	−2	2 37	+3.3	5.8	2 51	+3.4	5.9	3 04	+3.6	5.9	3 16	+3.8	5.9	3 29	+4.0	6.0	3 42	+4.1	6.0	3 54	+4.3	6.0	4 06	+4.5	6.1
30	1591	1 18	+11.5	3.5	1 39	+16.4	3.7	2 00	+20.6	3.9	2 21	+24.3	4.1	2 41	+27.5	4.3	3 01	+30.2	4.5	3 20	+32.5	4.6		......	
	1219	0 59	−3.7	3.3	1 25	+1.1	3.5	1 48	+5.3	3.8	2 09	+8.9	4.0	2 29	+12.1	4.2	2 47	+15.0	4.4	3 05	+17.4	4.6	3 21	+19.6	4.8
	722	2 37	−0.2	4.5	2 57	+1.5	4.6	3 16	+3.1	4.7	3 34	+4.6	4.9	3 52	+6.1	5.0	4 09	+7.4	5.1	4 25	+8.6	5.2	4 40	+9.8	5.3
	−2	2 43	+2.8	5.7	2 57	+3.0	5.7	3 11	+3.2	5.7	3 25	+3.3	5.8	3 38	+3.5	5.8	3 51	+3.7	5.9	4 04	+3.9	5.9	4 17	+4.0	5.9

Table 5. Search ephemeris for comet 17P/Holmes at four selected returns to the Sun (equinox J2000.0).[a]

Date of observation[b] (0^hET)	Return to Sun	Time after perihelion: 90 days			120 days			150 days			180 days			210 days			240 days			270 days			300 days		
		α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H	α_{2000}	δ_{2000}	H
		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°		h m	°	
Jan. 1	1591	22 45	−5.3	3.9	23 05	−0.3	3.9	23 25	+4.7	3.9	23 45	+9.8	3.9	0 06	+14.9	4.0	0 27	+19.9	4.0	0 49	+24.6	4.1	1 12	+29.2	4.1
	1219		......			......		23 27	−8.4	4.3	23 48	−5.0	4.3	0 09	−1.6	4.4	0 29	+1.9	4.4	0 49	+5.2	4.5	1 08	+8.5	4.5
	722	0 28	−11.4	4.8	0 48	−10.0	4.8	1 09	−8.5	4.7	1 29	−6.9	4.7	1 50	−5.2	4.7	2 11	−3.4	4.8	2 31	−1.7	4.8	2 51	+0.1	4.8
	−2	1 02	−5.9	5.8	1 16	−5.8	5.8	1 30	−5.6	5.8	1 44	−5.5	5.8	1 58	−5.3	5.7	2 12	−5.1	5.7	2 26	−4.9	5.7	2 42	−4.7	5.7
21	1591		......		23 20	+0.8	4.1	23 39	+5.4	4.1	23 57	+10.0	4.2	0 16	+14.5	4.2	0 35	+18.8	4.2	0 55	+23.0	4.3	1 15	+27.0	4.4
	1219		......			......			......			......		0 21	0.0	4.5	0 39	+3.1	4.6	0 57	+6.1	4.7	1 15	+9.1	4.8
	722		......		0 57	−7.8	4.9	1 16	−6.4	4.9	1 35	−4.8	4.9	1 54	−3.3	4.9	2 13	−1.7	5.0	2 32	−0.1	5.0	2 50	+1.5	5.0
	−2	1 10	−4.3	6.0	1 23	−4.2	5.9	1 36	−4.0	5.9	1 49	−3.8	5.9	2 02	−3.6	5.9	2 15	−3.4	5.9	2 28	−3.2	5.9	2 41	−3.0	5.9
Feb. 10	1591		......			......			......			......		0 31	+15.0	4.4	0 49	+18.9	4.4	1 07	+22.6	4.5	1 26	+26.2	4.6
	1219		......			......			......			......			......			......			......			......	
	722		......			......			......			......		2 04	−1.3	5.1	2 21	+0.2	5.1	2 39	+1.7	5.2	2 56	+3.2	5.2
	−2		......			......			......			......			......		2 23	−1.7	6.0	2 35	−1 5	6.0	2 48	−1.3	6.0
Mar. 2	1591		......			......			......			......			......			......			......		1 41	+26.3	4.7
	1219		......			......			......			......			......			......			......			......	
	722		......			......			......			......			......			......			......			......	
	−2		......			......			......			......			......			......			......			......	
⋮	⋮		⋮			⋮			⋮			⋮			⋮			⋮			⋮			⋮	
May 1	1591		......			......			......			......			......			......			......			......	
	1219	0 37	−3.1	4.1		......			......			......			......			......			......			......	
	722		......			......			......			......			......			......			......			......	
	−2		......			......			......			......			......			......			......			......	
21	1591	0 57	+8.7	4.0		......			......			......			......			......			......			......	
	1219	0 50	−2.4	3.9	1 11	+1.3	4.1	1 30	+4.7	4.2	1 48	+7.8	4.4		......			......			......			......	
	722	2 16	+0.4	4.9		......			......			......			......			......			......			......	
	−2	2 28	+3.2	6.0	2 40	+3.4	6.0		......			......			......			......			......			......	
Jun. 10	1591	1 10	+10.3	3.8	1 29	+14.8	4.0	1 49	+18.8	4.1	2 07	+22.4	4.3		......			......			......			......	
	1219	0 59	−2.4	3.6	1 21	+1.7	3.8	1 42	+5.4	4.0	2 01	+8.7	4.2	2 19	+11.6	4.4	2 37	+14.2	4.6	2 53	+16.6	4.8	3 09	+18.7	4.9
	722	2 28	+0.5	4.7	2 47	+2.1	4.8	3 05	+3.5	4.9	3 23	+4.9	5.0	3 39	+6.3	5.1		......			......			......	
	−2	2 37	+3.3	5.8	2 51	+3.4	5.9	3 04	+3.6	5.9	3 16	+3.8	5.9	3 29	+4.0	6.0	3 42	+4.1	6.0	3 54	+4.3	6.0	4 06	+4.5	6.1
30	1591	1 18	+11.5	3.5	1 39	+16.4	3.7	2 00	+20.6	3.9	2 21	+24.3	4.1	2 41	+27.5	4.3	3 01	+30.2	4.5	3 20	+32.5	4.6		......	
	1219	0 59	−3.7	3.3	1 25	+1.1	3.5	1 48	+5.3	3.8	2 09	+8.9	4.0	2 29	+12.1	4.2	2 47	+15.0	4.4	3 05	+17.4	4.6	3 21	+19.6	4.8
	722	2 37	−0.2	4.5	2 57	+1.5	4.6	3 16	+3.1	4.7	3 34	+4.6	4.9	3 52	+6.1	5.0	4 09	+7.4	5.1	4 25	+8.6	5.2	4 40	+9.8	5.3
	−2	2 43	+2.8	5.7	2 57	+3.0	5.7	3 11	+3.2	5.7	3 25	+3.3	5.8	3 38	+3.5	5.8	3 51	+3.7	5.9	4 04	+3.9	5.9	4 17	+4.0	5.9

[text continued from page 9]

1892 and 2007. Statistically, the probability is of course $6/12 = 0.50$, but in the 15th to 18th centuries, for example, the probability was only 0.43 (cf. Table 3), compared to 0.65 in 1892-2007 and 0.78 in 1950-2007 (cf. Table 1 of Paper 1). The high probabilities for recent returns were due to the comet's mean orbital period of almost exactly 7 years between 1972 and 2007.

And fourth, the perihelion distance, which has been steadily decreasing with time, is the reason for the comet's gradually increasing brightness (all else being equal) over the centuries, an effect that is strikingly apparent from Table 5. Indeed, except at times of favorable observing conditions, the comet's brightness some two millennia ago would barely exceed the naked-eye detection threshold of apparent magnitude 6 during a super-massive explosion comparable in power to the megaburst of 2007. This provides a major argument for discontinuing the search for historical records at earlier times.

4. Sources of Historical Records Employed in the Search

Original sources of historical records of comets can be divided into two broad categories by the geographical location of their origin: (i) Far-Eastern or Oriental, and (ii) European and Middle-Eastern. The first category consists of Chinese, Korean, Japanese, and Ryukyu sources (in the chronological order in which they began), the second category covers Babylonian, Greek, Roman, Arabian, Byzantine, and other regional sources, as well as more recent sources from individual European countries. There also are sources that do not fit either category (*e.g.*, from India), but these make up only a very small fraction of the total. As a rule, the oriental, especially Chinese, sources contain more accurate information and are generally considered more reliable than other sources.

Numerous compilations of historical records of both categories are available that summarize information from a great variety of original sources (old chronicles and annals) and are accessible in English. In this work I use the following compilations that update and correct the results of similar earlier efforts:

(i) Ho's (1962) catalogue of ancient and medieval observations of comets and novae from oriental sources, with 581 objects reported to have been observed between the 14th century BC and December 1600. This catalogue includes revised data from Tamura's (1958) work on Korean historical records of comets and from Williams' (1871) catalogue of ancient and medieval comets.

(ii) Hasegawa's (1980) catalogue of ancient and naked-eye comets, with more than 1000 entries between 2316 BC and AD 1700 from all recorded sources, and with additional 63 entries from the 18th century. This catalogue includes corrections to Pingré's (1783, 1784) and Baldet's (1949) classical works and also remarks on Ho's (1962) catalogue. Additions and corrections to Hasegawa's catalogue appear in Jansen (1991).

(iii) Chambers' (1889) catalogue of 539 comets between $\sim$ 1770 BC and AD 1889 with unknown orbits and a supplementary catalogue (Chambers 1909) with additional 25 comets between $\sim$ 1140 BC and 1905. The comet designations before Christ are systematically off by 1 year (*e.g.*, the bright comet in 5 BC, or in the year -4, is listed as occurring in 4 BC).

(iv) Kronk's (1999, 2003) cometographic volumes 1 (ancient-1799) and 2 (1800-1899), each of which provides two groups of potential candidates: comets with unknown orbits and uncertain objects. Although it is unlikely that another super-massive explosion of comet 17P occurred in the course of the 19th century, inspection of Kronk's second volume furnishes information that supports this premise.

(v) Duerbeck's (2009) list of 91 pre-telescopic galactic novae and supernovae, from the 14th century BC to AD 1604, which offers a convenient update to previous summaries of historical records of these objects, especially that by Stephenson (1976). As mentioned in Sec. 3, of interest as potential detections of comet 17P in an early phase of explosion development are the objects that Duerbeck (following Stephenson) classifies as dubious novae or supernovae, in part because of indications of their motion among stars.

(vi) Hsi's (1958) new catalogue of 90 ancient novae between $\sim$ 1400 BC and AD 1690, which is a thorough remake of Lundmark's (1921) list of 60 suspected novae between 134 BC and AD 1828. The value of these publications is in their longer temporal coverage, compared to Duerbeck's (2009) list, by incorporating more recent naked-eye (though no longer pre-telescopic) objects. Lundmark has also included meridian observations. Unlike Duerbeck and Lundmark, Hsi has assigned no grade to the events to indicate their likelihood of being novae, but he has admitted that some comets may still contaminate his catalogue.

5. Search for Pre-1892 Observations of Comet 17P/Holmes

With all necessary prerequisites completed, I now proceed with the search itself. The strategy is straightforward — identify all candidate objects from the six source compilations in Sec. 4 for which none of the following applies:

($1^\bullet$) The object has already been identified (*e.g.*, as a nova, Halley's comet, etc.).

($2^\bullet$) Only very crude information is available on the date of observation (with an uncertainty greater than $\pm$1 month).

($3^\bullet$) The date of observation is not between 90 and 300 days after perihelion of one of the returns listed in Table 3.

($4^\bullet$) The date of observation is at the wrong time of the year, comet 17P being then too close to the sun in the sky for detection (cf. Table 5).

($5^\bullet$) No diagnostic information is reported on the object's location in the sky.

($6^\bullet$) The object's location is outside the region of the sky predicted for comet 17P.

($7^\bullet$) The object's description (*e.g.*, the presence of a prominent tail) implies an appearance that is inconsistent with that of comet 17P during or shortly after a super-massive explosion.

Because of sensitive aspects of the application of test $(6^\bullet)$, the search has been conducted in two stages. The ephemeris from Table 5 has been employed in the first stage to identify select candidate objects that passed tests $(1^\bullet)$ to $(5^\bullet)$ and $(7^\bullet)$ and whose reported location did not manifestly meet a requirement for immediate rejection based on test $(6^\bullet)$. There were two categories of such select candidate objects: (a) those whose reported position was in one of the eleven constellations (or in one of the equivalent asterisms employed in the Chinese and other Far-Eastern sources) implied by the ephemeris (cf. Sec. 3); and (b) those for which the location was specified by only a general direction in the sky (north, northeast, *etc.*). All such select candidate objects advanced to the second stage of the search, where the status of each has been determined by more rigorous positional scrutiny, involving comparison of the reported location on the reported date (or in the course of the reported interval of time) with the predicted equatorial coordinates based on the adopted reference orbit.

In practical application of the first stage of the search, the top priority has been test $(1^\bullet)$, followed by $(2^\bullet)$. For an object that fails to pass either one of them, all other tests become irrelevant. Test $(3^\bullet)$ has been applied next, because it turns out that, as a filter, it is by far the most restrictive. Tests $(4^\bullet)$ through $(7^\bullet)$ have been applied only to objects that have passed the first three tests; relatively few additional objects have been rejected as a result. For example, when employed to examine Ho's (1962) catalogue, test $(1^\bullet)$ has eliminated $19\frac{1}{2}$ percent of all entries, which included novae and supernovae deemed probably real by Duerbeck (2009), 24 returns of comet 1P/Halley (cf. Yeomans and Kiang 1981; also, Marsden and Williams 2008), two returns of comet 109P/Swift-Tuttle (Marsden *et al.* 1993, Yau *et al.* 1994), one return of comet 55P/Tempel-Tuttle (cf. Hind 1872, Kanda 1933, Schubart 1966), and comets with known parabolic orbits between 147 BC and AD 1596 [derived by various authors, primarily by Hasegawa (1979), and compiled by Marsden and Williams 2008]. Test $(2^\bullet)$ has eliminated additional 7 percent of entries from Ho's catalogue, while test $(3^\bullet)$ has led to rejection of additional 68 percent of the total (or fully 93 percent of the remaining entries). Subsequent application of tests $(4^\bullet)$ through $(7^\bullet)$ has eliminated only 4 percent of the total. Only nine entries of Ho's (1962) catalogue, or $1\frac{1}{2}$ percent of the total, have passed all seven tests of the first stage of the search for 17P to become select objects.

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Table 6. Potential historical observations of comet 17P/Holmes during or shortly after a super-massive explosion. (Objects passing the first stage of search; a star in front of the date marks objects also passing the second stage.)

Date(s) of observation[a]	Return No.[b]	Days after perihelion	Location in sky[c]	Reported category[d]	Source(s)[e]	Reference(s)[f]
1661 Dec. 16–20	30	181–185	Aqu	guest	Kor	Ha(985)
*1621 May 22	35	178	E	red star	Chi	Ha(968), Hs(87), Kr
1419 Jun. 12	61	276	NE	object	Jap	Ha(805), Ho(496), Kr
*1269 Aug.	80	296 ± 15	E	comet	Sco	Ha(702), Ch(405), Kr
1220 Jan. 25	86	263	Peg	broom	Jap, Eur	Ha(671), Ho(422), Cs(13), Kr
1110 Dec. 24	99	242	E	comet	Eur	Ha(622)
1035 Jan. 15	108	90	Cet	star	Chi	Ha(574), Ho(369), Du, Kr
*836 Jul. 31 ±15	131	142 ± 15	E	spark	Kor	Ha(454), Ho(290), Kr
742 Jun.	141	262 ± 15	N	comet	Con	Ha(422)
400 Sept. 19 ±14	178	108 ± 14	E	spark	Kor	Ha(276), Ho(184), Kr
*305 Sept. 19 ±15	188	289 ± 15	Tau	spark	Chi	Ha(248), Ho(164), Hs(22), Ch(157), Kr
153 Nov. 18 ±15	204	150 ± 15	E, NE	broom	Kor	Ha(179), Ho(102), Kr
−136 Oct. 5 ±15	235	144 ± 15	NE	comet	Chi	Ha(88), Ho(37), Ch(44), Kr
−146 Oct. 26 ±15	236	157 ± 15	NW	comet	Chi	Ha(81), Ho(33), Ch(41), Kr

[a] First two dates are in the Gregorian calendar, the rest in the Julian calendar. For the second stage of search, see the text of Sec. 5.

[b] As defined in Table 3.

[c] Either abbreviation of a constellation (equivalent, for Far-Eastern sources, to an asterism that was referred to); or a general direction in the sky (N = north, NE = northeast, etc.).

[d] Abbreviated terms used in most Far-Eastern sources (cf. Sec. 3): guest = guest star (*kho-hsing*); spark = sparkling star (*po-hsing*); broom = broom star (*hui-hsing* or *sao-hsing*); or terms that describe broader categories, such as star, comet, or object.

[e] Oriental sources: Chi = China, Jap = Japan, Kor = Korea; other sources: Eur = Europe, Sco = Scotland, Con = Constantinople.

[f] Author of catalogue followed, where applicable, by object's catalogue number in parentheses: Du = Duerbeck (2009); Ha = Hasegawa (1980); Ho = Ho (1962); Ch = Chambers (1889); Cs = Chambers (1909); Hs = Hsi (1958); Kr = Kronk (1999).

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The described methodology of the first stage of search examination has been applied to the catalogues of historical records on transient celestial events (Sec. 4) and it has resulted in identifying a total of 14 select objects that could potentially be pre-1892 observations of comet 17P/Holmes during or shortly after a super-massive explosion. These objects are listed in Table 6 and are further tested in the second stage of the search in the following. One notes the somewhat-unexpected absence of events from the 18th century. Because all positional information in the historical sources is referred to the equinox of the date, it is this equinox — rather than the standard equinox of J2000 — that is used in the following accounts of the candidate objects.

1661 December 16-20. This object from a Korean source, listed only by Hasegawa (1980), is an attractive candidate for comet 17P/Holmes in the early phase of a super-massive explosion because it not only occurred at the right time in the generally correct area of the sky, but also because it was described as a *guest star* (*i.e.*, star-like and tailless) that changed its apparent position in 4 days. Amazingly, the year of its appearance is 231 years prior to the 1892-1893 event, almost exactly twice the time span between the 1892-1893 and 2007 explosions. Unfortunately, however, closer inspection shows some disconcerting discrepancies. As quoted by Hasegawa (1980), this was an evening object in Aquarius: on December 16 it was at 5° of the 10th lunar mansion,[1] implying $\alpha_{1661} = 20^h49^m$, and 102° from the pole, or $\delta_{1661} = -12°$. Four days later it moved to 1° of the 11th lunar mansion, implying $\alpha_{1661} = 21^h18^m$, and 97° from the pole, or $\delta_{1661} = -7°$. The ephemeris predicts comet 17P to have been in Pegasus, near the border with Pisces: at $\alpha_{1661} = 23^h16^m$ and $\delta_{1661} = +7\overset{\circ}{.}4$ on the first date and at $\alpha_{1661} = 23^h19^m$ and $\delta_{1661} = +7\overset{\circ}{.}7$ on the second date. An estimated error of ±1.7 days in the perihelion time would cause changes of only ± 1^m in right ascension and ± $0\overset{\circ}{.}2$ in declination. If having the same peak intrinsic brightness as in 2007, the comet is predicted to have been of apparent magnitude 4.8. The discrepancies of some 30°-35° in right ascension and 15°-20° in declination are one order of magnitude larger than errors with which positions of comets were determined in the 17th century [see, *e.g.*, the positions of comet 1668 recorded by P. G. Candone on a star chart and read by Kreutz (1901) more than 200 years later]. Thus, the object of 1661, which also moved much too fast, was obviously not comet 17P.

1621 May 22. This object would *à priori* have been a highly unlikely candidate for comet 17P, if the 1661 object — only 40 years later — had been positively identified. The late May date suggests a relatively small elongation from the sun, while the eastern location indicates a morning object. According to Williams (1871) this was a comet, but both Lundmark (1921) and Hsi (1958) listed it as a possible nova, although Lundmark considered it a very dubious one. It is in this sense that Hasegawa's (1980) term "uncertain object" is to be understood. Both Williams and Lundmark erroneously gave the Julian-calendar date of May 12. The search ephemeris places comet 17P ~ 35° from the sun, at $\alpha_{1621} = 1^h29^m$, $\delta_{1621} = +18\overset{\circ}{.}2$, about $1\overset{\circ}{.}3$ to the southwest of β Ari. With a close double star γ Ari, about $1\overset{\circ}{.}5$ to the south of β Ari, the comet and the two stars should have made up an eye-catching, tight, nearly equilateral triangle, which around 4 a.m. local time would have been fairly low above the eastern horizon. If observed shortly after a super-massive explosion comparable to the 2007 megaburst in terms of peak intrinsic brightness, comet 17P would have been of apparent magnitude 4.4, which compares with 2.6 for β Ari and 3.5 for a combined magnitude of γ^1 and γ^2 Ari (magnitudes 3.9 and 4.8, respectively). The reported reddish color may be an effect of the spectral contrast with the two stars (A5 for β Ari and A1 for γ^1 Ari) strengthened by a low altitude (the comet rose about 3 a.m., the sunrise was about 5 a.m. local time, with the moon still below the horizon). With only the soft positional constraint available, the circumstances for the 1621 object are consistent with those expected for comet 17P, even though the sighting must have occurred under less-than-ideal observing conditions.

1419 June 12. This object is difficult to interpret and it barely made this select list. The historical record is peculiar in two ways. One is the manner in which the event is described, as "an object like a (*chhang-hsing*) comet" (tailed star) — avoiding a more explicit wording that would result in the object's immediate rejection on the strength of test (7•). Because of the oblique way of conveying the object's appearance, I decided (with qualms) to retain this object on the select list. This could in fact be a bright fireball, but here the second peculiar detail comes into play: the object was observed from 23:00 to 1:00. Trains of even very prominent fireballs do not persist for two hours. Fortunately, the search ephemeris provides a straightforward solution, since the predicted position of comet 17P, $\alpha_{1419} = 2^h26^m$ and $\delta_{1419} = +21\overset{\circ}{.}4$, in the constellation Aries, shows that it would not have risen above the horizon until about 2 a.m. local time and it would then be located in the east rather than the northeast. Thus, the 1419 object was positively not comet 17P.

1269 August. This poorly constrained event is generally consistent with the predicted positional information on comet 17P from the search ephemeris. The only contentious point is the breadth of the observing period. While Hasegawa (1980) gives August, both Chambers (1889) and Kronk (1999) adopt August-September. Since August 1 was already 281 days after nominal perihelion, the end of September corresponds to 341 days after nominal perihelion. Following the 2007 megaburst, the last naked-eye observation of 17P was made 311 days after perihelion (cf. Paper 1) under superior conditions compared to those in 1269. The predicted equatorial coordinates for the August-September time slot are $\alpha_{1269} = 2^h12^m$ to 1^h56^m and $\delta_{1269} = +17\overset{\circ}{.}3$ to $+20\overset{\circ}{.}7$. The comet was in the constellation Aries, between 90° and 160° from the sun, and in the east in the early part of the night (10-11 p.m. local time). With the peak intrinsic brightness of the 2007 megaburst, the apparent magnitude is predicted to have been 4.0-4.2 in the two-month period, but this estimate does not include the fading that necessarily sets in sooner or later after the early phase of the super-massive explosion has terminated. The identity of this 1269 object with comet 17P is therefore possible, but given the insufficient details in the historic record, little convincing evidence can be offered.

1220 January 25. The first of apparently three independent comets that appeared in early 1220. There is a discrepancy between the location given by Hasegawa (1980), which is Pegasus, and Ho (1962), who refers to an asterism corresponding to an area in the northwestern portion of Andromeda, southwestern Cassiopeia, and northern Lacerta, containing among others the stars ι, κ, λ, and 7 And and α, β, 5, and 11 Lac. The search ephemeris places comet 17P at $\alpha_{1220} = 0^h15^m$ and $\delta_{1220} = +1\overset{\circ}{.}4$, in the constellation Pisces. The general area referred to by Ho (1962) and Kronk (1999) is some 40°-50° from the ephemeris position. This large discrepancy is also consistent with a difference in the direction of the object in the sky, to the northwest, while the ephemeris suggests the west-southwest. Hasegawa's (1980) claim that the comet of 1220 was also observed in Europe (specifically in England) is questionable, because Chambers (1909), to whom Hasegawa refers, mentions a "stupendous" comet in 1219, not 1220. Comet 17P is not involved in any case, which is not inconsistent with the "broom-star" (*hui-hsing*) appearance of the object reported by the Japanese.

[1] For more information on the lunar mansions in the Chinese uranography, see e.g. Kiang (1972).

1110 December 24. This object is listed only by Hasegawa (1980), who suspects that this may be a nova. Yet, it is included in none of the catalogues of novae — Duerbeck's (2009), Stephenson's (1976), Hsi's (1958), or Lundmark's (1921). The search ephemeris places comet 17P in the constellation Pisces, at $\alpha_{1110} = 0^{\rm h}35^{\rm m}$ and $\delta_{1110} = -0^\circ\!.3$, while the eastern sky was dominated by the constellations Gemini, Canis Minor, and Monoceros in the evening after sunset, by Virgo, Coma Berenices, and Leo around local midnight, and by Ophiuchus and Hercules in the morning before sunrise. The comet would have been in the southwestern sky in the evening and could not be identical with this 1110 object.

1035 January 15. Although Hasegawa (1980) places this object in the constellation Cetus, the position equivalent to the Chinese asterism *Wai-Phing* is in Pisces according to Ho (1962). Delimited by the stars α, δ, ϵ, ζ, μ, ν, and ξ Psc, this asterism occupies the intervals from $23^{\rm h}59^{\rm m}$ to $1^{\rm h}13^{\rm m}$ in right ascension and from $-2^\circ\!.1$ to $+2^\circ\!.6$ in declination (eq. 1035.0). Described in the Chinese annals as a star with "vaporous rays", this object is classified by both Stephenson (1976) and Duerbeck (2009) in the lowest category of novae, with a significant contamination by comets. Neither Lundmark (1921) nor Hsu (1958) list this object as a nova in their catalogues. The search ephemeris shows that comet 17P should have been in the constellation Aquarius, at $\alpha_{1035} = 22^{\rm h}33^{\rm m}$ and $\delta_{1035} = -18^\circ\!.7$, only 33° from the sun and more than 25° to the southwest from the nearest point of the reported area of the sky. The propagated error in the perihelion time is estimated at ±15 days, and if the perihelion occurred by this much earlier than predicted by the nominal orbit in Table 3, the comet's position would approach the observed position by about $13^{\rm m}\!.3$ in right ascension and by $1^\circ\!.3$ in declination and would not materially improve the situation. The error in the perihelion time of more than 100 days would be required to bring the discrepancy down to less than 5°. Such a large error in the perihelion time is unrealistic, and it appears certain that the 1035 object was not comet 17P.

836 July 31 ± 15 days. The poorly constrained location of this candidate object can be only crudely examined. The search ephemeris places comet 17P at $\alpha_{836} = 1^{\rm h}50^{\rm m}$ and $\delta_{836} = -6^\circ\!.1$ on July 17 and at $\alpha_{836} = 2^{\rm h}05^{\rm m}$ and $\delta_{836} = -7^\circ\!.2$ on August 15. Near the border of the constellations Cetus and Eridanus in mid-July, the comet then moved into Eridanus and remained more than 90° from the sun. A few hours after local midnight, it was gradually gaining elevation in the east-southeastern sky. In mid-August, it would be observable earlier and essentially in the southeast. Its apparent brightness, if observed soon after the onset of a super-massive explosion, would probably be near magnitude 4. Given the soft constraints, it is possible to argue for this object's identity with comet 17P, the second half of July being preferable to the first half of August. In July, the comet would have been only several degrees from o Cet (Mira), but the confusion with this pulsating star is unlikely, as Mira (together with Algol, δ Cep, and possibly other prominent variables in this part of the sky) was apparently known to ancient astronomers both in the Orient (*e.g.*, Gaspani 1998) and in Greece (*e.g.*, Wilk 1996).

742 June. Like the account of the 1110 object, this information, conveyed by Hasegawa (1980), comes from Pingré's (1783, 1784) catalogue. The predicted positions of comet 17P are in the constellation Taurus, at $\alpha_{742} = 2^{\rm h}44^{\rm m}$ and $\delta_{742} = +3^\circ\!.2$ at the very beginning of June and at $\alpha_{742} = 3^{\rm h}18^{\rm m}$ and $\delta_{742} = +5^\circ\!.2$ at the end. Only objects at declinations exceeding +50° could have appeared above the northern horizon at Constantinople. The comet should have shown up in the early morning sky in the east, and it could not be identical with the reported object.

400 September 19 ± 14 days. In this case the predicted positions of comet 17P are in the constellation Cetus, at $\alpha_{400} = 0^{\rm h}27^{\rm m}$ and $\delta_{400} = -19^\circ\!.5$ on September 5 and at $\alpha_{400} = 0^{\rm h}12^{\rm m}$ and $\delta_{400} = -22^\circ\!.6$ on October 3. These positions are inconsistent with the reported sighting in the east in the sense that in early September the comet was above the southeastern horizon, and in early October closer to the south than the east. In addition, at an estimated magnitude 4.5 or fainter, the comet would have been a difficult object to spot at its southern declination. When higher above the horizon before sunrise, the comet would be further to the south. It appears that the inaccurate description notwithstanding, the likelihood of the object being comet 17P is practically nil.

305 September 19 ± 15 days. In spite of the uncertainty in the observing time, this object is very intriguing. Three Chinese annals recorded (see Ho 1962) that during the period of time between September 5 and October 4, a sparkling star (*po-hsing*) appeared at the 18th lunar mansion and the 19th lunar mansion, with no mention of a tail. The text does not say explicitly whether the object was observed repeatedly, nor is it clear whether the order in which the two lunar mansions are listed implies the direction of motion. Since each lunar mansion covers a whole sector of the sky in the direction of increasing right ascension from the mansion's determinative star to the determinative star of the next mansion, no information is provided on the declination (or the polar distance).[2] If the object moved slowly and/or was observed just once or during a very short period of time, the right ascension of its location(s), based on the description in the historical records, was likely to be relatively near (within a few degrees of) the determinative star of the 19th mansion. The 18th lunar mansion is the Pleiades and its determinative star is 17 Tau ($\alpha_{305} = 2^{\rm h}08^{\rm m}$, $\delta_{305} = +17^\circ\!.3$), while the 19th lunar mansion is delimited by its determinative star ϵ Tau ($\alpha_{305} = 2^{\rm h}53^{\rm m}$, $\delta_{305} = +13^\circ\!.8$) and by α Tau. I adopt $\alpha_{305} = 2^{\rm h}50^{\rm m} \pm 20^{\rm m}$ as a working hypothesis for the object. As Kronk (1999) has noticed, the object would have been visible most of the night, under excellent conditions except for about a week or so around September 23, when the moon would have interfered. With the nominal perihelion time t_π = 304 December 4 (Table 3), the search ephemeris predicts for comet 17P $\alpha_{305} = 3^{\rm h}22^{\rm m}$ and $\delta_{305} = -7^\circ\!.1$ for September 5, $\alpha_{305} = 3^{\rm h}23^{\rm m}$ (maximum) and $\delta_{305} = -7^\circ\!.9$ for September 13, and $\alpha_{305} = 3^{\rm h}20^{\rm m}$ and $\delta_{305} = -10^\circ\!.1$ for October 4. This places the comet outside the object's right-ascension box by some 3° on the average. However, the propagated error in the perihelion time is estimated from Eq. (2) at ±46 days. Since the nominal time of appearance of this object is rather late, 289 ± 15 days after perihelion (Table 6), a preferred correction to the comet's passage through perihelion is positive, up to t_π + 46 days. If the comet reached perihelion at this time, on January 19, 305, the time of appearance would be reduced to more plausible 243 ± 15

[2]For a complete list of determinative stars in the Chinese uranography, see Kiang (1972).