days after perihelion. The search ephemeris then predicts for comet 17P $\alpha_{305} = 2^{\rm h}51^{\rm m}$ and $\delta_{305} = -9\overset{\circ}{.}7$ for September 5 and $\alpha_{305} = 2^{\rm h}46^{\rm m}$ and $\delta_{305} = -13\overset{\circ}{.}0$ for October 4. The comet's predicted right ascension is now in nearly perfect agreement with that of the object. It would remain within the error box even if the error in the perihelion time were only some +14 to +18 days (rather than +46 days), depending on the date of appearance. The comet's predicted position is actually in the constellation or Eridanus, fairly near the Taurus southern border. The region contains no prominent stars, the three brightest (ν, μ, and o^1 Eri) being near magnitude 4.0. If of a peak intrinsic brightness comparable to that of the 2007 megaburst, the comet might have apparent magnitude 4.5 to 4.8, depending on the date of appearance and the perihelion date, and would therefore be bright enough to attract observers' attention. I thus arrive at a conclusion that, the greater perihelion distance of $\sim$ 3.5 AU notwithstanding, the chances of comet 17P being identical with this object look rather promising.

153 November 18 ± 15 days. Reported by a single Korean source, this object was described as a "broom star" (*hui-hsing*), which during the month from November 4 to December 3 was seen first in the east and then in the northeast. The search ephemeris predicts comet 17P to move during this period of time through the constellation Cetus from $\alpha_{153} = 23^{\rm h}50^{\rm m}$ and $\delta_{153} = -23\overset{\circ}{.}5$ on November 4 to $\alpha_{153} = 23^{\rm h}55^{\rm m}$ and $\delta_{153} = -21\overset{\circ}{.}7$ on December 3. In the evening, the comet would be above the south-southeastern horizon in early November and above the southern horizon in early December. Thus, both its location in the sky and the direction of its motion during the month are inconsistent with those of the object, ruling out the identity. Shifting the perihelion time by as much as 50-60 days has no effect on this conclusion.

−136 October 5 ± 15 days. The positions of comet 17P predicted by the search ephemeris are $\alpha_{-136} = 23^{\rm h}34^{\rm m}$ and $\delta_{-136} = -12\overset{\circ}{.}3$ on September 21 and $\alpha_{-136} = 23^{\rm h}22^{\rm m}$ and $\delta_{-136} = -14\overset{\circ}{.}7$ on October 20. The comet was in the constellation Cetus. Because of the negative declination, the comet could not be observed, regardless of its brightness, above the northeastern horizon and could not be identical with the object. This conclusion is insensitive to the choice of perihelion time within limits predicted by Eq. (2).

−146 October 26 ± 15 days. This return of comet 17P is similar to that of −136. The comet's predicted coordinates are $\alpha_{-146} = 23^{\rm h}49^{\rm m}$ and $\delta_{-146} = -13\overset{\circ}{.}9$ on October 12 and $\alpha_{-146} = 23^{\rm h}40^{\rm m}$ and $\delta_{-146} = -15\overset{\circ}{.}2$ on November 10. The comet was again in the constellation Cetus, and because of the negative declination, it could not be detected above the northwestern horizon. The identity is again ruled out.

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Table 7. Sets of osculating orbital elements predicted for comet 17P/Holmes at its returns 1620, 1268, 836, and 304 (equinox J2000.0).[a]

Osculation epoch (ET)[b]	1620 Nov. 24.0	1268 Oct. 13.0	836 Mar. 15.0	304 Dec. 13.0
Time of perihelion passage (ET)[b]	1620 Nov. 25.25	1268 Oct. 24.54	836 Mar. 11.66	304 Dec. 4.24
Argument of perihelion (deg)	342.42	306.75	237.56	215.84
Longitude of ascending node (deg)	351.02	14.78	113.97	154.43
Orbit inclination (deg)	20.89	14.44	14.93	21.24
Perihelion distance (AU)	2.4956	2.6249	2.9565	3.4662
Orbit eccentricity	0.3452	0.3637	0.3350	0.2130
Orbital period (yr)	7.44	8.38	9.37	9.24

[a] Based on the reference elements presented in Table 1.

[b] The dates of the osculation epoch and perihelion passage are in the Gregorian calendar for the 1620 return, in the Julian calendar for the earlier returns.

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In summary, application of the two-stage search to historical records of transient objects suggests a pre-1892 detection of four possible super-massive explosions of comet 17P/Holmes. They are marked with the asterisks that precede the dates in Table 6 and extend as far back in time as the early 4th century. The reported locations in the sky of three of these candidate objects — dated 1621 May 22, August 1269, and July-August 836 — are not very well constrained, yet the identity of these objects with comet 17P cannot be ruled out. The fourth object, dated September 305, looks quite promising, the comet's large perihelion distance of $\sim$ 3.5 AU notwithstanding. The sets of osculating orbital elements of comet 17P for these four returns — with the nominal perihelion times in November 1620, October 1268, March 836, and December 304 — are presented in Table 7. Two potentially diagnostic properties of this sequence of events are: (i) the observations of all four objects were made between late May and the beginning of October, even though the search ephemeris in Table 5 shows that favorable conditions extend through the months October-January as well; and (ii) the dates make a chronological succession with the gaps between them steadily decreasing with time: 531 years between the earliest two, 433 years between the next two, 352 years between the last two, and 271-272 years between the last one and the 1892/93 event; in terms of the number of intervening revolutions about the sun, the gaps are 57 cycles between AD 304 and 836, 51 between 836 and 1268, 45 between 1268 and 1620, and 35 between 1620 and 1892. These numbers contrast with the 16 revolutions elapsed between 1892 and 2007. Allowing for missed events, the pre-1892 intervals must be regarded as upper limits to the recurrence time of super-massive explosions of comet 17P. The question to be addressed next is the dependence of the recurrence time on the perihelion distance and orbital dimensions in general from the standpoint of heat transport in the comet's nucleus.

6. Dependence of the Recurrence Time on Dimensions of the Orbit

An in-depth investigation of heat transfer into the interior of the nucleus of comet 17P/Holmes was conducted in Paper 2 for the average orbital dimensions between 1892 and 2007, characterized by a perihelion distance of 2.235 AU. The product of the modeling of heat transport was an effective thermal-conductivity coefficient $K_{\rm eff}$ of terrain layers that measures a heat-penetration rate needed to reach the point of runaway crystallization of gas-laden amorphous water ice in a reservoir located beneath each layer. Approximating the mean recurrence time of layer jettisoning (and of super-massive explosions), ν_0, a function of each layer's thickness and a critical temperature at its base (taken as 50 meters and 106°.3 K, respectively, in Paper 2), by the interval between the 1892-1893 event and the 2007 megaburst ($\nu_0 = 16$ revolutions or 115 years), I found in Paper 2 that consistent solutions to the equation of heat transfer required for $K_{\rm eff}$ a nominal value between 0.26 and 0.30 W m^{-1} K^{-1}, depending weakly on the variations, during the revolution about the sun, in the solar-radiation energy incident on the the comet's surface at a chosen point.

Because the comet's perihelion distance has systematically been decreasing with time over the past millenia (Figure 1) and was nearly 3.5 AU at the time of the first suspected detection of a super-massive explosion 17 centuries ago (Sec. 5), it is expected that the recurrence time in the past was longer than the 16 revolutions, because the amount of solar-radiation energy received by the comet per revolution varies as $q^{-\frac{1}{2}}$ with the perihelion distance, q. To determine how much longer and to gain an insight into the problem of variations with the perihelion distance, I have first introduced a dimensionless ratio x of the perihelion distance to the aphelion distance Q:

$$x = \frac{q}{Q} < 1, \tag{6}$$

which allows the eccentricity e and the osculating orbital period P to be expressed as

$$e = \frac{1-x}{1+x}, \tag{7a}$$

$$P = X(1+x)^{\frac{3}{2}}, \tag{7b}$$

where $X = 0.3536 Q^{\frac{3}{2}}$, Q is in AU, and P in tropical years. Next, I keep the aphelion distance constant at $Q = 5.5$ AU, an average that is suggested by the sets of orbital elements in Table 7. Then $X = 4.56$ years and the perihelion distance q is the only orbital element on which the heat-transfer solution depends.

The heat-transfer calculations have followed closely the methodology developed and extensively described in Sec. 9.1 of Paper 2, to which the reader is referred for details. Several perihelion distances have been selected, and for each an eccentricity has been calculated satisfying equation (7a). The equations of heat transfer have been integrated using $K_{\rm eff} = 0.3$ W m^{-1} K^{-1} in an isothermal approximation, which in Paper 2 was called a *standard scenario*, characterized for all points of the surface by the ratio of the cross-sectional area to the total surface area of a spherical nucleus. The prime result of the computer runs is a mean recurrence time for jettisoning layers *stacked on top of each other*, a quantity that can also be called a mean exposure lifespan $\mathcal{L}_{\rm layer}$ of layers exposed on the surface of comet 17P. For the given orbital dimensions and the chosen physical parameters governing the process of layer removal, $\mathcal{L}_{\rm layer}$ is a constant that is related to the recurrence time ν_0 by

$$\mathcal{L}_{\rm layer} = \frac{\pi D^2}{A_{\rm layer}} \nu_0, \tag{8}$$

where $D = 3.3$ km is the diameter of the nucleus of comet 17P (Lamy *et al.* 2000; Snodgrass *et al.* 2006) and $A_{\rm layer} \simeq 5$ km^2 is the base area of an average terrain layer (Belton *et al.* 2007). The mean recurrence time ν_0 of 16 revolutions (or 115 years) at $q = 2.235$ AU is equivalent to the mean exposure lifespan $\mathcal{L}_{\rm layer}$ of 110 revolutions (or ~ 790 years).

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Table 8. Mean exposure lifespan of 50-meter thick layer on surface of comet 17P/Holmes as function of perihelion distance (at constant aphelion distance of 5.5 AU).

Perihelion distance q (AU)	Orbital eccentricity e	Orbital period P (yr)	Mean exposure lifespan	
			rev.	yr
2.0	0.4667	7.26	95	690
2.5	0.3750	8.00	128	1024
3.0	0.2941	8.76	166	1454
3.5	0.2222	9.55	211	2014
4.0	0.1579	10.35	264	2733
4.5	0.1000	11.18	328	3667

The results of the heat-tranport calculations are summarized in Table 8. The mean exposure lifespan (in revolutions) can be fitted empirically to mean relative accuracy of about ±3 percent by

$$\mathcal{L}_{\rm layer} = 32.1 q^{1.52}, \tag{9}$$

with the residuals leaving a slight systematic trend. A better fit, to mean relative accuracy of ±0.5 percent, is achieved by

$$\mathcal{L}_{\rm layer} = 49 q^{0.7} \exp\left[1.97 (\log q)^2\right]. \tag{10}$$

Expressed as a function of the orbital period (in years), the exposure lifespan is

$$\mathcal{L}_{\rm layer} = 0.335 P^{20/7}, \tag{11}$$

to mean relative accuracy of ±1 percent. Because $\mathcal{L}_{\rm layer}$ varies rather strongly with q (or P) on time scales much shorter than is its value, predicted values of $\mathcal{L}_{\rm layer}$ as a function of time should strictly be computed by appropriately integrating one of the above expressions. However, estimates can readily be provided by approximately interpolating the tabulated values, especially because only crude averages are needed. The mean exposure lifespan between the beginning of the 4th century and the end of the 19th century is estimated at about 1300 years, so that the mean recurrence time, ν_0, which is, from Eq. (8), about 15 percent of the exposure lifespan $\mathcal{L}_{\rm layer}$, is just about 200 years. One could thus expect, statistically, that between the beginning of the 4th century and the end of the 19th century there would be some 8 super-massive explosions. If the findings of Sec. 5 are interpreted to indicate that the identity of 17P with the AD 305 object is probable to between 50 and 100 percent and with the other three objects to between 10 and 100 percent each, the overall detection probability of the conducted search is between 10 and 50 percent. Given the major odds against detection, this result appears by no means to be disappointingly low.

7. Comet 17P Not a Candidate for the Star of Bethlehem

The prediction of a perihelion passage of comet 17P in the year −2, or 3 BC, may instinctively invoke a thought that this return could provide a candidate for the Star of Bethlehem. This short section is meant to discourage any such intention, as this identity is effectively ruled out by two robust arguments: (i) there is no historical record of any transient object from around the critical period of time; and (ii) comet 17P should have had a perihelion distance of more than 4 AU at this return and it could hardly be brighter than apparent magnitude 6 in the aftermath of a super-massive explosion (cf. Table 5), becoming a celestial phenomenon that could not possibly attract the wise men's attention. As for the true identity of the Star of Bethlehem, one can either accept the hypothesis arguing that the comet — or, less probably, nova — in 5 BC was a plausible candidate,[3] consistent with a general consensus on the time of the birth of Christ (*e.g.*, Humphreys 1991), or relegate the story to the realm of myth (*e.g.*, Jenkins 2004).

8. The Future of Comet 17P/Holmes and Its Investigations

The reference orbit from Table 1 has next been integrated forward in time to ascertain the future motion of comet 17P until the early 22nd century. As seen from Table 9, the comet's orbit is predicted to remain fairly stable during this period of time, with only moderate perturbations due to an approach to Jupiter in April 2051. Relative to the respective average between 2014 and 2114, the perihelion distance will vary within ±0.10 AU, the orbital period within ±0.22 year, and the inclination within about $\pm 0^\circ\!.55$.

Comparison of these predicted sets of elements with Kinoshita's (2009) independently derived orbits shows an exceptionally good agreement. The differences in the perihelion time range from less than 2 minutes in 2014 to less than 25 minutes in 2106, the last entry on Kinoshita's list. The other elements likewise agree extremely closely: the angles to better than $5''$, the perihelion distance to within 1000 km, and the eccentricity to better than 2×10^{-6}. However, it should be kept in mind that the megaburst in 2007 may have introduced an unpredictable nongravitational perturbation of the comet's orbital motion, which could result in changes in the comet's future perihelion times that cannot be estimated and incorporated in current orbital integrations.

Because the recurrence time of super-massive explosions of comet 17P is by no means constant (Sec. 2), it is not possible to predict the time of the next event. However, from available evidence one would not expect it before the end of this century (Paper 1). During the period of time covered by the predicted orbital sets in Table 9, the primary long-term objective is to monitor the comet's activity — temporal variations in its dust and gas production throughout the orbit.

As I already observed in Sec. 8.1 of Paper 1, there is evidence from the light curve over the years 1899-2009 that it takes a long time for comet 17P to "recuperate" from a super-massive explosion and to gradually "settle down" to its normal, quiescent state. This long-term, secondary phase of the comet's post-explosion evolution, observed after the 1892-1893 explosive event and again following the 2007 megaburst, is not to be confused with the primary post-explosion phase, manifested by a more or less rapidly subsiding light curve within several weeks to a few months after the event's onset. The secondary phase begins after the termination of this primary phase and may extend over two revolutions about the sun after the super-massive explosion, as pointed out in greater detail below.

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[3] Although the Chinese historical source calls this object a broom star (*hui-hsing*; Ho 1962), Duerbeck (2009) — using the classification by Stephenson (1976) and despite that author's expressed doubts — regards it a possible nova or — because of the reported duration of more than 70 days — even a supernova. Hsi (1958) suggests that this may have been a radio point source, while Lundmark (1921) does not include this object in his catalogue of suspected novae. Both Pingré (1743) and Williams (1871) describe it as a comet.

Table 9. Predicted osculating orbital elements for comet 17P/Holmes at next 15 returns to the sun (eq. J2000.0).[a]

Epoch (ET)	2014 Apr. 13.0	2021 Mar. 7.0	2028 Jan. 30.0
Epoch JD	2456760.5	2459280.5	2461800.5
T (ET)	2014 Mar. 27.4738	2021 Feb. 19.7200	2028 Jan. 31.4694
ω (deg)	24.5135	24.4675	24.5076
Ω (deg)	326.7649	326.6204	326.5937
i (deg)	19.0916	19.0319	19.0034
q (AU)	2.056575	2.080676	2.091960
e	0.431860	0.427757	0.426093
P (yr)	6.89	6.93	6.96
Epoch (ET)	2034 Dec. 24.0	2041 Dec. 27.0	2048 Nov. 20.0
Epoch JD	2464320.5	2466880.5	2469400.5
T (ET)	2035 Jan. 10.6382	2041 Dec. 9.0864	2048 Nov. 5.2544
ω (deg)	24.4460	24.3815	24.5609
Ω (deg)	326.5924	326.4679	326.3944
i (deg)	19.0205	19.0254	19.0319
q (AU)	2.082353	2.064433	2.059149
e	0.427698	0.430680	0.431387
P (yr)	6.94	6.91	6.89
Epoch (ET)	2056 Jan. 3.0	2063 Mar. 27.0	2070 Jun. 18.0
Epoch JD	2472000.5	2474640.5	2477280.5
T (ET)	2056 Jan. 8.3780	2063 Apr. 3.4474	2070 Jun. 25.3446
ω (deg)	28.6202	28.7324	28.6662
Ω (deg)	324.8115	324.7526	324.7555
i (deg)	18.2047	18.1766	18.1884
q (AU)	2.206773	2.219302	2.208001
e	0.408898	0.407225	0.409404
P (yr)	7.21	7.24	7.23
Epoch (ET)	2077 Sept. 9.0	2084 Dec. 1.0	2092 Feb. 23.0
Epoch JD	2479920.5	2482560.5	2485200.5
T (ET)	2077 Sept. 3.3078	2084 Nov. 14.8211	2092 Feb. 17.7506
ω (deg)	28.4669	28.6877	29.3974
Ω (deg)	324.6396	324.5575	324.0757
i (deg)	18.1961	18.1988	18.0188
q (AU)	2.192518	2.187975	2.250282
e	0.411575	0.412169	0.402188
P (yr)	7.19	7.18	7.30
Epoch (ET)	2099 Jun. 26.0	2106 Oct. 28.0	2114 Jan. 19.0
Epoch JD	2487880.5	2490560.5	2493200.5
T (ET)	2099 Jun. 14.0892	2106 Oct. 8.6929	2114 Jan. 3.0399
ω (deg)	29.4689	29.4819	29.8260
Ω (deg)	324.0392	324.0167	323.4001
i (deg)	17.9933	18.0108	18.0198
q (AU)	2.261066	2.248957	2.181703
e	0.401007	0.402769	0.413907
P (yr)	7.33	7.31	7.18

[a] Based on the reference elements presented in Table 1.

The nature of the secondary post-explosion phase of elevated activity of comet 17P, which remains to be determined, is a major goal of the monitoring campaign proposed for 2010-2015 (Sekanina 2010). There are three basic scenarios that the comet may follow in this activity phase: (i) essentially continuous, or (ii) intermittent, or (iii) temporally restricted. These scenarios are diagnostic of the source and evolution of the ejecta that account for the elevated brightness in the extended post-explosion period of time. The continuously enhanced brightness could be an indication of large amounts of very slowly moving, sizable debris that lingers in the comet's atmosphere ever since the time of the super-massive explosion. Intermittent periods of brightening could be diagnostic of erratic, on-and-off surges of activity from isolated, unstable regions of the nucleus in an excited state. Finally, the elevated brightness that is restricted to only one or a few periods of time could be interpreted as an effect of steadily subsiding erosion of the affected regions of the nucleus, whose areal extent has been gradually (but possibly at variable rates) diminishing with time in the aftermath of the super-massive explosion.

In order for the light curve to be a meaningful measure of variations in the comet's activity, personal and instrumental magnitude corrections (sometimes also referred to as "aperture" corrections; see, *e.g.*, Marcus 1983) need to be applied to the magnitude determinations reported by individual observers to convert these brightness data to a standardized, common photometric system. This procedure is especially necessary when magnitude observations made with the naked eye or binolculars are to be linked with those made with the help of large-aperture telescopes. The issues of personal/instrumental corrections and the integration of corrected magnitudes into a resulting common light curve are addressed in detail in the Appendix.

As is apparent from the presented light curve, the available limited evidence for elevated activity of comet 17P/Holmes in the secondary phase of the post-explosion evolution consists of the following: (i) a moderate outburst, about 4 magnitudes in amplitude, which commenced on about 1899 July 4 or ~ 67 days after perihelion (Sekanina 2009a), as documented by the visual observations made by Perrine (1899, 1900) with the 91-cm refractor of the Lick Observatory and by Barnard (1932) with the 102-cm refractor of the Yerkes Observatory between 43 and 111 days after perihelion; (ii) the 1899/1900 gradually subsiding light curve between 135 and 268 days after perihelion, also based on Perrine's and Barnard's data, and indicating that the comet was in this period of time steadily brighter by nearly 4 magnitudes relative to the quiescent-phase light curve in 1986-2000 (Paper 1); (iii) the 1906 light curve, based on four photographic magnitudes between 167 and 268 days after perihelion obtained by M. Wolf and A. Kopff in Heidelberg (*e.g.*, Wolf 1906; see Paper 1 for the complete list of references) and closely following the 1899/1900 light curve; (iv) the "total" magnitude determinations from CCD imaging observations made by the Catalina Sky Survey group and elsewhere in late 2008 and early 2009, between 523 and 657 days after perihelion, and likewise showing the comet to be nearly 4 magnitudes brighter than in 1986-2000; and (v) a minor outburst, superimposed on this elevated light curve and reported by Miles (2009) to have occurred on 2009 January 4.7 ± 0.5 UT, 439 days after the onset of the megaburst and 611 days after perihelion, which had an amplitude of ~0.6 magnitude measured by the brightness of the inner coma and which may have been a continuation of three marginally detectable quasi-periodic brightenings during the primary phase of the post-explosion evolution, 40 to 140 days after the onset of the megaburst (Kidger 2008, Miles 2009).

With the personal/instrumental corrections applied, the apparent magnitudes $H(\Delta, r)$ have been reduced to a geocentric distance $\Delta = 1$ AU by an inverse-square power law, Δ^{-2}, to determine the *normalized* visual magnitudes H_Δ,

$$H_\Delta(r) = H(r, \Delta) - 5 \log \Delta, \tag{12}$$

neglecting a minor phase effect. The normalized magnitudes from the sets (ii), (iii), and (iv) are plotted against an inverse heliocentric distance $1/r$ in Figure 2, apparently satisfying an empirical law:

$$H_\Delta(r) = [20.4(\pm 0.2)] - [22.6(\pm 0.8)]\,(1/r), \tag{13}$$

where $1/r$ is in AU^{-1}. It should be remembered that this law is during the secondary phase of the post-explosion evolution supported by observations, at best, only in the time interval 135 to 657 days after perihelion, corresponding to a range of heliocentric distances between 2.3 and 4.3 AU.

The nucleus of comet 17P is known to be about 3.3 km in diameter (Lamy *et al.* 2000; Snodgrass *et al.* 2006), as photometrically derived on the assumptions of a geometric albedo of 4 percent and a phase slope of 0.035 mag/deg. The apparent visual magnitude of the nucleus, $h(r, \Delta)$, is then equal to:

$$h(r, \Delta) = 16.6 + 5 \log(r\Delta) + 0.035\beta, \tag{14}$$

where r and Δ are again in AU and β, in degrees, is the phase angle (angle earth-comet-sun). The difference,

$$H(r, \Delta) - h(r, \Delta) = 3.8 - 22.6(1/r) - 5 \log r - 0.035\beta, \tag{15}$$

is always negative and measures the degree of activity on the assumption of validity of Eq. (13). For example, $H - h = -8.5$ magnitudes at 135 days after perihelion (in 1899), -6.8 mag at 268 days after perihelion (in 1906), -5.5 mag 524 days after perihelion (in 2008), and -4.8 mag at 657 days after perihelion (in 2009). Compared with my conclusion that — in the secondary phase of the post-explosion evolution — the comet is nearly 4 magnitudes brighter than in the quiescent phase along much of the receding leg of the orbit, the above results show that in the quiescent phase the nucleus contributes almost one half of the comet's total light at a heliocentric distance of ~ 4.3 AU outbound.

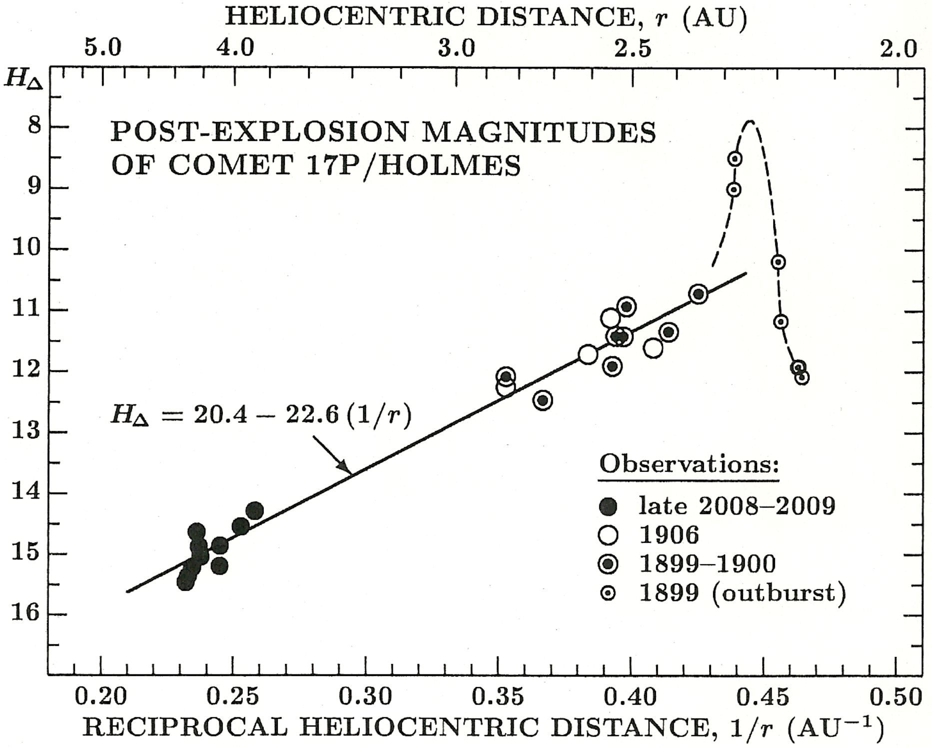

Figure 2. Normalized magnitude H_Δ (at 1 AU from the earth) from the periods of time following the super-massive explosions of comet 17P/Holmes plotted as a function of heliocentric distance. Linked are the post-perihelion brightness estimates from 1899-1900 and 1906 with the post-megaburst light curve from 2008 and 2009. The dashed curve connects the magnitudes shortly before and during the moderate outburst of 1899.

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[text continued from page 20]

Because of the shortcomings in our knowledge of the light curve of comet 17P (in the quiescent and post-explosion phases alike, especially along the pre-perihelion branch of the orbit), the apparent magnitude $H(r, \Delta)$ based on H_Δ from Eq. (13) does not offer a genuine parametric function of activity but only its proxy that has limited practical application. How much limited? Magnitudes H and h are likely to provide the upper and lower limits on the comet's apparent brightness during much of the investigated period of time and they allow one to judge the nature of activity variations during the secondary phase of the comet's post-explosion evolution (continuous, intermittent, or restricted regime) measured against a certain, however-imperfect standard.

In view of this opportunity, comet observers are encouraged to participate in the proposed monitoring program in 2010-2015. In order to assist such efforts, an ephemeris based on the reference orbit of comet 17P, extending over the six years — and accompanied by the magnitudes H and h — is presented in Table 10. With a 10-day step, the ephemeris covers the whole six-year interval except for times when the comet is at elongations of less than 45° from the sun. Columns 4 and 5, headed "Variation", provide the corrections that apply, respectively, to the right ascension and declination in columns 2 and 3 if the date of perihelion passage is one day later than predicted in Table 9. However, it is unlikely that this prediction is in error by more than a fraction of 1 hour. The total visual magnitude, H, computed from Eq. (12) after inserting for H_Δ from Eq. (13), and the visual magnitude of the nucleus, h, derived from Eq. (14), are listed, respectively, in columns 10 and 11. Both H and h can be converted to the Cousins R magnitudes using an average color index involving the Johnson V magnitude, $V\text{–}R = +0.41 \pm 0.07$, measured for the comet's nucleus by Snodgrass *et al.* (2006). A similar color results from Snodgrass *et al.*'s (2008) plot for the comet's expanding halo shortly after the megaburst of 2007. Adopting from Paper 1 that the visual magnitude of comet 17P is, on the average, 0.12 mag fainter than V, the R magnitudes corresponding to H and h in Table 10 are 0.53 mag brighter.

Table 10 shows that during 2010-2015, $H\text{–}h$ is predicted to vary between –4.2 mag in late February 2010, more than 6 months before aphelion, and –9.1 mag, after the 2014 perihelion. The comet's corrected total magnitude is expected to be (i) between h and H and closer to the former when the comet is in or near its quiescent phase; (ii) either between h and H or close to the latter in the phase of elevated activity; and (iii) brighter than H at times of strongly elevated activity, especially during outbursts.

Sufficiently powerful telescopes should detect the comet, except near its conjunctions with the sun, throughout the orbit, so there is no obstacle to monitoring the comet for light variations during the times listed in Table 10. Since the total brightness of 17P in the aphelion region and along the pre-perihelion branch of the orbit is unknown, any

Table 10. Ephemeris of comet 17P/Holmes for 2010-2015 (equinox J2000.0).

Date (0^hET)	α_{2000}	δ_{2000}	Variation		Δ	r	Phase	Elong.	H	h
	h m	° ′	m	′			°	°		
2010 Jan. 4	10 51.4	+4 51	−0.22	+2.9	4.418	4.996	9.7	121.0	19.1	23.7
14	10 48.5	+4 48	−0.23	+3.0	4.300	5.010	8.4	131.8	19.1	23.6
24	10 44.2	+4 52	−0.23	+3.1	4.201	5.022	6.8	143.0	19.0	23.5
Feb. 3	10 38.9	+5 04	−0.24	+3.1	4.128	5.035	4.9	154.3	19.0	23.4
13	10 32.8	+5 20	−0.25	+3.2	4.084	5.047	2.8	165.7	19.0	23.3
23	10 26.2	+5 41	−0.25	+3.2	4.071	5.058	0.9	175.6	19.0	23.2
Mar. 5	10 19.6	+6 02	−0.25	+3.2	4.091	5.069	2.0	169.6	19.0	23.3
15	10 13.5	+6 24	−0.25	+3.1	4.142	5.079	4.1	158.4	19.0	23.4
25	10 08.1	+6 43	−0.25	+3.0	4.222	5.089	6.1	147.2	19.1	23.5
Apr. 4	10 03.7	+6 58	−0.24	+3.0	4.329	5.099	7.8	136.3	19.1	23.6
14	10 00.6	+7 08	−0.23	+2.9	4.456	5.108	9.2	125.8	19.2	23.7
24	9 58.8	+7 12	−0.23	+2.8	4.601	5.116	10.2	115.6	19.3	23.8
May 4	9 58.3	+7 10	−0.22	+2.7	4.757	5.124	10.9	105.8	19.4	23.9
14	9 59.1	+7 02	−0.21	+2.6	4.920	5.132	11.3	96.4	19.5	24.0
24	10 01.1	+6 48	−0.20	+2.5	5.085	5.139	11.4	87.4	19.5	24.1
Jun. 3	10 04.1	+6 28	−0.19	+2.4	5.249	5.146	11.1	78.6	19.6	24.2
13	10 08.0	+6 03	−0.19	+2.3	5.407	5.152	10.7	70.2	19.7	24.2
23	10 12.8	+5 33	−0.18	+2.3	5.557	5.158	10.0	61.9	19.7	24.3
Jul. 3	10 18.2	+4 58	−0.18	+2.2	5.696	5.163	9.2	53.9	19.8	24.3
13	10 24.1	+4 19	−0.17	+2.2	5.820	5.167	8.2	46.1	19.9	24.3
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Nov. 10	11 47.5	−6 42	−0.17	+2.2	5.798	5.187	8.2	48.0	19.9	24.3
20	11 52.9	−7 39	−0.18	+2.2	5.667	5.185	9.1	56.3	19.8	24.3
30	11 57.5	−8 34	−0.18	+2.2	5.524	5.183	9.9	64.9	19.8	24.3
Dec. 10	12 01.3	−9 25	−0.19	+2.3	5.369	5.181	10.5	73.8	19.7	24.2
20	12 04.2	−10 13	−0.20	+2.4	5.207	5.178	10.9	82.9	19.6	24.2
30	12 06.0	−10 56	−0.20	+2.4	5.042	5.175	11.0	92.2	19.5	24.1
2011 Jan. 9	12 06.6	−11 33	−0.21	+2.5	4.878	5.171	10.7	101.9	19.5	24.0
19	12 05.9	−12 03	−0.22	+2.6	4.720	5.166	10.2	111.8	19.4	23.9
29	12 03.9	−12 26	−0.23	+2.7	4.572	5.162	9.3	122.0	19.3	23.8
Feb. 8	12 00.6	−12 39	−0.24	+2.8	4.440	5.156	8.1	132.4	19.3	23.7
18	11 56.1	−12 43	−0.24	+2.9	4.328	5.150	6.7	142.8	19.2	23.6
28	11 50.6	−12 37	−0.25	+3.0	4.242	5.144	5.0	153.1	19.1	23.5
Mar. 10	11 44.5	−12 22	−0.25	+3.0	4.184	5.138	3.4	162.1	19.1	23.4
20	11 38.1	−11 59	−0.25	+3.1	4.156	5.130	2.5	166.8	19.1	23.4
30	11 31.8	−11 30	−0.24	+3.1	4.159	5.123	3.3	163.0	19.1	23.4
Apr. 9	11 25.9	−10 57	−0.24	+3.1	4.193	5.115	4.9	154.4	19.1	23.5
19	11 21.0	−10 24	−0.23	+3.0	4.255	5.106	6.6	144.5	19.1	23.5
29	11 17.1	−9 53	−0.22	+3.0	4.342	5.097	8.1	134.3	19.2	23.6
May 9	11 14.5	−9 26	−0.22	+2.9	4.449	5.087	9.4	124.4	19.2	23.7

Table 10. (Continued.)

Date $(0^{\mathrm{h}}\mathrm{ET})$	α_{2000}	δ_{2000}	Variation		Δ	r	Phase	Elong.	H	h
	h m	° ′	m	′			°	°		
2011 May 19	11 13.1	−9 05	−0.21	+2.8	4.572	5.077	10.4	114.6	19.2	23.8
29	11 13.1	−8 51	−0.20	+2.7	4.706	5.067	11.1	105.2	19.3	23.9
Jun. 8	11 14.3	−8 44	−0.20	+2.6	4.846	5.056	11.5	96.1	19.4	24.0
18	11 16.6	−8 44	−0.19	+2.5	4.989	5.044	11.6	87.3	19.4	24.0
28	11 20.0	−8 53	−0.19	+2.5	5.130	5.032	11.4	78.8	19.5	24.1
Jul. 8	11 24.3	−9 09	−0.18	+2.4	5.266	5.020	11.0	70.6	19.5	24.1
18	11 29.5	−9 32	−0.18	+2.3	5.393	5.007	10.4	62.6	19.5	24.2
28	11 35.3	−10 01	−0.18	+2.3	5.510	4.993	9.6	54.8	19.6	24.2
Aug. 7	11 41.7	−10 36	−0.18	+2.2	5.613	4.979	8.6	47.2	19.6	24.2
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Dec. 5	13 16.4	−22 22	−0.25	+2.2	5.382	4.774	8.8	47.6	19.3	24.0
15	13 23.2	−23 30	−0.26	+2.2	5.241	4.753	9.8	55.5	19.2	24.0
25	13 29.3	−24 38	−0.28	+2.2	5.086	4.733	10.7	63.7	19.2	23.9
2012 Jan. 4	13 34.6	−25 43	−0.29	+2.3	4.920	4.711	11.5	72.1	19.1	23.9
14	13 38.9	−26 47	−0.31	+2.4	4.748	4.689	11.9	80.6	19.0	23.8
24	13 41.9	−27 48	−0.33	+2.5	4.572	4.667	12.2	89.4	18.9	23.7
Feb. 3	13 43.6	−28 44	−0.35	+2.6	4.396	4.644	12.1	98.5	18.7	23.6
13	13 43.8	−29 35	−0.37	+2.7	4.224	4.621	11.7	107.7	18.6	23.5
23	13 42.4	−30 19	−0.39	+2.8	4.061	4.597	11.0	117.1	18.5	23.4
Mar. 4	13 39.3	−30 54	−0.40	+3.0	3.911	4.573	10.0	126.6	18.4	23.2
14	13 34.6	−31 18	−0.41	+3.2	3.779	4.548	8.7	136.1	18.3	23.1
24	13 28.4	−31 29	−0.42	+3.3	3.669	4.522	7.3	145.1	18.2	23.0
Apr. 3	13 21.3	−31 26	−0.42	+3.5	3.584	4.497	5.8	152.9	18.1	22.9
13	13 13.5	−31 09	−0.42	+3.7	3.526	4.470	4.9	157.7	18.1	22.8
23	13 05.7	−30 39	−0.41	+3.8	3.498	4.443	5.0	157.5	18.0	22.8
May 3	12 58.5	−29 59	−0.40	+3.9	3.498	4.416	6.1	152.4	18.0	22.8
13	12 52.4	−29 12	−0.38	+3.9	3.525	4.388	7.7	144.7	18.0	22.8
23	12 47.7	−28 23	−0.36	+3.8	3.576	4.360	9.3	135.8	18.0	22.9
Jun. 2	12 44.6	−27 35	−0.34	+3.7	3.648	4.331	10.8	126.7	18.0	23.0
12	12 43.2	−26 52	−0.33	+3.6	3.737	4.302	12.1	117.5	18.0	23.1
22	12 43.5	−26 17	−0.32	+3.4	3.838	4.272	13.0	108.6	18.0	23.2
Jul. 2	12 45.5	−25 50	−0.31	+3.3	3.946	4.241	13.7	99.9	18.1	23.2
12	12 48.9	−25 33	−0.30	+3.1	4.059	4.210	14.0	91.5	18.1	23.3
22	12 53.8	−25 26	−0.30	+3.0	4.172	4.179	14.0	83.4	18.1	23.3
Aug. 1	12 59.8	−25 28	−0.30	+2.8	4.282	4.147	13.7	75.6	18.1	23.4
11	13 07.0	−25 40	−0.30	+2.7	4.386	4.115	13.2	68.0	18.1	23.4
21	13 15.2	−25 59	−0.31	+2.6	4.482	4.082	12.5	60.6	18.1	23.4
31	13 24.2	−26 26	−0.31	+2.5	4.568	4.048	11.6	53.5	18.1	23.4
Sept. 10	13 34.1	−27 00	−0.32	+2.4	4.640	4.015	10.5	46.5	18.1	23.4
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 10. (Continued.)

Date (0^hET)	α_{2000}	δ_{2000}	Variation		Δ	r	Phase	Elong.	H	h
	h m	° ′	m	′			°	°		
2013 Jan. 18	16 27.1	−38 17	−0.64	+0.6	4.101	3.532	12.1	48.9	17.1	22.9
28	16 41.4	−39 08	−0.69	+0.3	3.952	3.491	13.5	55.6	16.9	22.8
Feb. 7	16 55.3	−39 58	−0.74	0.0	3.793	3.451	14.7	62.5	16.7	22.7
17	17 08.6	−40 47	−0.79	−0.3	3.627	3.410	15.8	69.6	16.6	22.6
27	17 21.1	−41 37	−0.85	−0.6	3.455	3.369	16.6	76.8	16.4	22.5
Mar. 9	17 32.6	−42 26	−0.92	−1.0	3.279	3.327	17.3	84.1	16.2	22.4
19	17 42.8	−43 17	−0.99	−1.3	3.103	3.285	17.6	91.6	16.0	22.3
29	17 51.5	−44 09	−1.08	−1.7	2.929	3.243	17.7	99.3	15.8	22.1
Apr. 8	17 58.1	−45 03	−1.17	−2.0	2.759	3.200	17.4	107.2	15.5	22.0
18	18 02.4	−45 58	−1.28	−2.2	2.596	3.158	16.7	115.2	15.3	21.8
28	18 04.0	−46 53	−1.39	−2.4	2.445	3.115	15.6	123.5	15.1	21.6
May 8	18 02.5	−47 45	−1.51	−2.4	2.306	3.072	14.2	131.7	14.9	21.4
18	17 57.8	−48 30	−1.62	−2.2	2.185	3.029	12.5	139.8	14.6	21.2
28	17 49.9	−49 02	−1.72	−1.7	2.084	2.985	10.6	147.0	14.4	21.0
Jun. 7	17 39.4	−49 14	−1.79	−1.1	2.005	2.942	9.2	152.4	14.2	20.8
17	17 27.5	−49 02	−1.81	−0.3	1.950	2.899	8.8	154.2	14.1	20.7
27	17 15.5	−48 23	−1.77	+0.4	1.920	2.856	9.8	151.6	13.9	20.7
Jul. 7	17 05.0	−47 20	−1.70	+0.9	1.914	2.812	11.8	145.6	13.8	20.7
17	16 57.1	−45 59	−1.61	+1.1	1.931	2.769	14.3	137.9	13.7	20.8
27	16 52.6	−44 27	−1.50	+1.0	1.966	2.727	16.7	129.5	13.6	20.9
Aug. 6	16 51.7	−42 51	−1.40	+0.7	2.018	2.684	18.9	120.9	13.5	21.0
16	16 54.3	−41 16	−1.32	+0.2	2.082	2.642	20.7	112.6	13.4	21.1
26	17 00.0	−39 47	−1.24	−0.3	2.156	2.601	22.1	104.6	13.4	21.1
Sept. 5	17 08.6	−38 22	−1.18	−1.0	2.235	2.560	23.0	96.9	13.3	21.2
15	17 19.7	−37 03	−1.13	−1.6	2.317	2.520	23.5	89.6	13.3	21.3
25	17 32.8	−35 48	−1.09	−2.3	2.401	2.480	23.6	82.6	13.2	21.3
Oct. 5	17 47.8	−34 34	−1.06	−3.0	2.483	2.442	23.4	76.0	13.1	21.4
15	18 04.2	−33 21	−1.03	−3.7	2.563	2.404	22.9	69.6	13.0	21.4
25	18 21.9	−32 05	−1.01	−4.3	2.638	2.368	22.1	63.5	13.0	21.4
Nov. 4	18 40.6	−30 45	−0.99	−5.0	2.709	2.333	21.0	57.6	12.9	21.4
14	19 00.1	−29 19	−0.97	−5.6	2.774	2.299	19.8	51.9	12.8	21.3
24	19 20.2	−27 46	−0.95	−6.3	2.833	2.267	18.4	46.3	12.7	21.3
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2014 Jun. 22	2 28.8	+28 10	−1.05	−6.9	2.713	2.165	20.3	47.7	12.1	21.2
Jul. 2	2 48.9	+30 34	−1.08	−6.1	2.660	2.189	21.5	52.2	12.2	21.2
12	3 08.7	+32 50	−1.12	−5.2	2.603	2.217	22.6	56.8	12.3	21.2
22	3 28.1	+34 57	−1.16	−4.3	2.542	2.246	23.5	61.7	12.4	21.2
Aug. 1	3 47.0	+36 56	−1.20	−3.4	2.477	2.276	24.2	66.8	12.4	21.2
11	4 05.0	+38 47	−1.25	−2.4	2.408	2.309	24.7	72.2	12.5	21.2
21	4 21.8	+40 30	−1.29	−1.4	2.337	2.343	25.0	77.9	12.6	21.2

Table 10. (Continued.)

Date (0^hET)	α_{2000}	δ_{2000}	Variation		Δ	r	Phase	Elong.	H	h
	h m	° ′	m	′			°	°		
2014 Aug. 31	4 37.1	+42 08	−1.35	−0.5	2.263	2.379	25.0	83.9	12.7	21.2
Sept. 10	4 50.4	+43 40	−1.41	+0.4	2.188	2.415	24.6	90.4	12.7	21.1
20	5 01.3	+45 09	−1.48	+1.3	2.114	2.453	24.0	97.3	12.8	21.0
30	5 09.2	+46 33	−1.57	+2.0	2.042	2.492	22.9	104.7	12.9	21.0
Oct. 10	5 13.6	+47 52	−1.67	+2.5	1.975	2.532	21.4	112.5	13.0	20.9
20	5 14.0	+49 03	−1.79	+2.8	1.916	2.572	19.4	120.8	13.0	20.8
30	5 10.3	+50 01	−1.91	+2.7	1.869	2.613	17.1	129.2	13.1	20.7
Nov. 9	5 02.4	+50 40	−2.02	+2.3	1.838	2.655	14.6	137.6	13.2	20.6
19	4 51.4	+50 53	−2.10	+1.5	1.826	2.697	12.1	145.1	13.3	20.5
29	4 38.7	+50 36	−2.12	+0.4	1.837	2.739	10.2	150.5	13.5	20.5
Dec. 9	4 26.2	+49 48	−2.07	−0.6	1.873	2.782	9.5	152.1	13.6	20.6
19	4 15.5	+48 35	−1.96	−1.5	1.935	2.825	10.3	149.1	13.8	20.7
29	4 07.8	+47 06	−1.82	−2.1	2.022	2.868	11.9	142.9	14.0	20.9
2015 Jan. 8	4 03.6	+45 32	−1.67	−2.4	2.132	2.911	13.8	135.0	14.3	21.1
18	4 02.9	+43 59	−1.52	−2.4	2.261	2.955	15.5	126.5	14.5	21.3
28	4 05.3	+42 33	−1.38	−2.2	2.408	2.998	16.9	117.9	14.8	21.5
Feb. 7	4 10.5	+41 17	−1.26	−1.9	2.567	3.041	17.8	109.5	15.0	21.7
17	4 17.9	+40 11	−1.15	−1.5	2.735	3.084	18.3	101.3	15.3	21.9
27	4 27.1	+39 14	−1.06	−1.1	2.910	3.127	18.4	93.3	15.5	22.1
Mar. 9	4 37.8	+38 26	−0.98	−0.7	3.087	3.170	18.2	85.7	15.7	22.2
19	4 49.6	+37 44	−0.90	−0.3	3.264	3.213	17.7	78.2	15.9	22.4
29	5 02.4	+37 07	−0.84	+0.1	3.439	3.255	16.9	71.1	16.1	22.5
Apr. 8	5 16.0	+36 33	−0.78	+0.4	3.609	3.297	15.9	64.1	16.3	22.6
18	5 30.0	+36 01	−0.73	+0.7	3.773	3.339	14.7	57.3	16.5	22.6
28	5 44.4	+35 29	−0.68	+1.0	3.928	3.380	13.3	50.6	16.7	22.7
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Sept. 25	9 01.1	+25 22	−0.31	+3.1	4.501	3.955	11.4	51.4	18.0	23.3
Oct. 5	9 09.7	+24 44	−0.30	+3.2	4.410	3.989	12.4	59.1	18.0	23.3
15	9 17.2	+24 11	−0.30	+3.3	4.306	4.023	13.2	67.1	18.0	23.3
25	9 23.5	+23 42	−0.30	+3.4	4.193	4.057	13.7	75.4	17.9	23.3
Nov. 4	9 28.5	+23 19	−0.30	+3.5	4.073	4.090	14.0	84.0	17.9	23.2
14	9 32.0	+23 03	−0.30	+3.7	3.949	4.123	13.9	93.1	17.9	23.2
24	9 34.0	+22 54	−0.31	+3.8	3.826	4.155	13.4	102.6	17.9	23.1
Dec. 4	9 34.1	+22 52	−0.32	+3.9	3.708	4.187	12.6	112.6	17.8	23.0
14	9 32.5	+22 57	−0.34	+4.0	3.600	4.218	11.3	123.0	17.8	22.9
24	9 29.0	+23 08	−0.36	+4.1	3.507	4.249	9.6	133.9	17.8	22.8
2016 Jan. 3	9 23.7	+23 24	−0.38	+4.2	3.436	4.279	7.6	145.1	17.8	22.7

NOTE: Average extrapolated correction ΔT = ET − UT for the period of time 2010-2015 is expected to be about +66 seconds; see `http://tycho.usno.navy.mil/leapsec.html`.

such data from 2010-2013 and early 2014 will provide particularly valuable information. The results of the proposed monitoring campaign will also serve to test whether in mid-2014 — as in mid-1899 — the comet undergoes a moderate, early post-perihelion outburst, and whether its light curve during the second half of 2014 resembles that from 1899/1900 and 1906, and during the second half of 2015 that from late 2008 and early 2009.

9. Conclusions

The results of a search for historical records of naked-eye detections of super-massive explosions of comet 17P/Holmes suggest that the 1892-1893 and 2007 events were manifestations of a systematic, long-term pattern rather than isolated, unrelated flare-ups. Based on the properties of the 1892-1893 and 2007 explosions and dependent on the integration of the comet's motion back in time to about 1000 BC, the search was limited to 210-day long orbital arcs, from 90 days to 300 days after perihelion during each of the nearly 300 returns to the sun in the course of the three millennia. Because the perihelion distance and orbital period have been decreasing with time on account of the Jovian perturbations, the comet was in the past generally farther from the sun and the earth at the times of the expected super-massive explosions and therefore appearing somewhat fainter than in 2007. The search has suggested four possible sightings of comet 17P — in September 305, July-August 836, August 1269, and 1621 May 22. The most promising candidate is the object in AD 305, which was described in three Chinese historical chronicles as a sparkling star (*po-hsing*), for which no tail was mentioned and whose celestial position closely agrees with the ephemeris. The locations in the sky of the other three candidates were not pinpointed accurately enough to offer positive identifications. In each of the four cases, comet 17P should have reached about magnitude 4 for an explosion as powerful as the 2007 megaburst. Given that stronger explosions cannot be ruled out and that the likelihood of detection increases with increasing visual prominence, the comet may have been brighter than magnitude 4 during at least some of the recorded sightings. And given that the rate of conduction of the incident solar energy into the interior of the comet's nucleus depends on the orbital dimensions, the detection probability of the described search covering two millennia into the past is estimated at averaging between 10 and 50 percent. It is believed that the exploding comet 17P has never become a truly spectacular object and it certainly is not a plausible candidate for the Star of Bethlehem, even though one of its predicted returns to the sun occurred close to the conjectured time of the birth of Christ.

During the next 100 years, the orbit of comet 17P/Holmes will be subjected to no major variations. The most noticeable perturbations will result following an encounter with Jupiter in April 2051. Of greater interest is the physical behavior and the degree of activity of the comet following the megaburst of 2007. Since evidence from the apparitions 1899-1906 suggests that comet 17P was "settling down" very gradually after the super-massive explosion of 1892-1893, it is deemed desirable that — during the complete revolution about the sun, up to and including the year 2015 — the temporal variations in the comet's normalized integrated brightness be monitored to ascertain the extent to which 17P will mimic its post-explosion evolution more than 100 years before. An ephemeris and limited information on the light curve, based on the experience with the comet's behavior in 1899-1900, 1906, and late 2008 and early 2009, is hereinabove provided to facilitate such an observing campaign.

The history of super-massive explosions of comet 17P/Holmes as revealed by the results of the search for their observations over extended periods of time in the past (a) is consistent with the physical model proposed in Paper 2 for the mechanism of their formation; (b) strengthens the arguments that substantiate and underpin the vital importance of crystallization of gas-laden amorphous water ice in subsurface reservoirs as a trigger of these events; and (c) contributes to the understanding of the nature and evolution of the layered morphology in cometary nuclei. Finally, because the super-massive explosions represent a manifestation of nuclear fragmentation, as emphasized in Paper 2, their history in comet 17P shows the role they play in the process of comet aging and disintegration.

Appendix: Definitive Visual Light Curve of Comet 17P/Holmes 1892-2009

The work on the brightness of comet 17P undertaken in the previous papers of this series (Sekanina 2008b, 2009a, Paper 1) is here completed and the results summarized. The light curve of 17P is a plot of its integrated visual magnitude $H_\Delta(t)$ — defined as that recorded by an average observer and normalized to a geocentric distance $\Delta = 1$ AU by a Δ^{-2} power law — as a function of time t reckoned from the comet's nearest perihelion passage. The average observer has been defined by averaging the sampled naked-eye magnitudes reported by 52 participants to the *International Comet Quarterly* following the onset of the megaburst on 2007 October 23 (Sekanina 2009a). The common magnitude system established in this way has then been used to "calibrate" each observer's set of magnitudes by applying a constant personal magnitude correction. Subsequently, this common magnitude system has been extended to fainter magnitudes by linking the post-megaburst naked-eye brightness estimates with telescopic visual and CCD brightness data, reported as "total" magnitudes and made with the same instrumentation both before and after the 2007 event. Each visual and CCD telescopic observer with each instrument used in 2007-2009 has been assigned a personal/instrumental correction to convert the reported magnitude to the common system. This approach has further been extended to the apparitions 1986, 1993, and 2000 by comparing and calibrating the magnitudes reported by the same observers using the same instruments at more than one apparition.

All magnitudes of comet 17P reported from the apparitions 1964, 1970, and 1979 were referred to by the observers as "nuclear" (Paper 1) and they have not been considered here as input to the light curve. The comet was missed at its returns 1913-1957 and the only remaining pre-1986 brightness estimates are those from the apparitions 1892 (the discovery apparition), 1899, and 1906. The comet's naked-eye detections, including a few naked-eye magnitudes, reported by several observers in 1892 and 1893 have been used (Sekanina 2008b), as they are believed to be crudely compatible (to perhaps ±0.5 mag or so) with the 2007 naked-eye data, thus providing meaningful light-curve comparison on a time scale of more than 100 years. These results have also been employed to calibrate some telescopic visual-magnitude observations at the same apparition. The comet's brightness did not reach the naked-eye detection threshold in 1899-1900 and 1906, and the only possibility of approximately calibrating the magnitude observations available from these apparitions is by employing Barnard's (1932) data obtained with the 102-cm refractor of the Yerkes Observatory, whose magnitude correction was investigated in considerable detail by Marcus (1983). This correction was also used in Paper 1 to calibrate Perrine's (1899, 1900) visual-brightness estimates from 1899-1900 and Wolf's and Kopff's photographic-brightness estimates from 1906 (*e.g.*, Wolf 1906).

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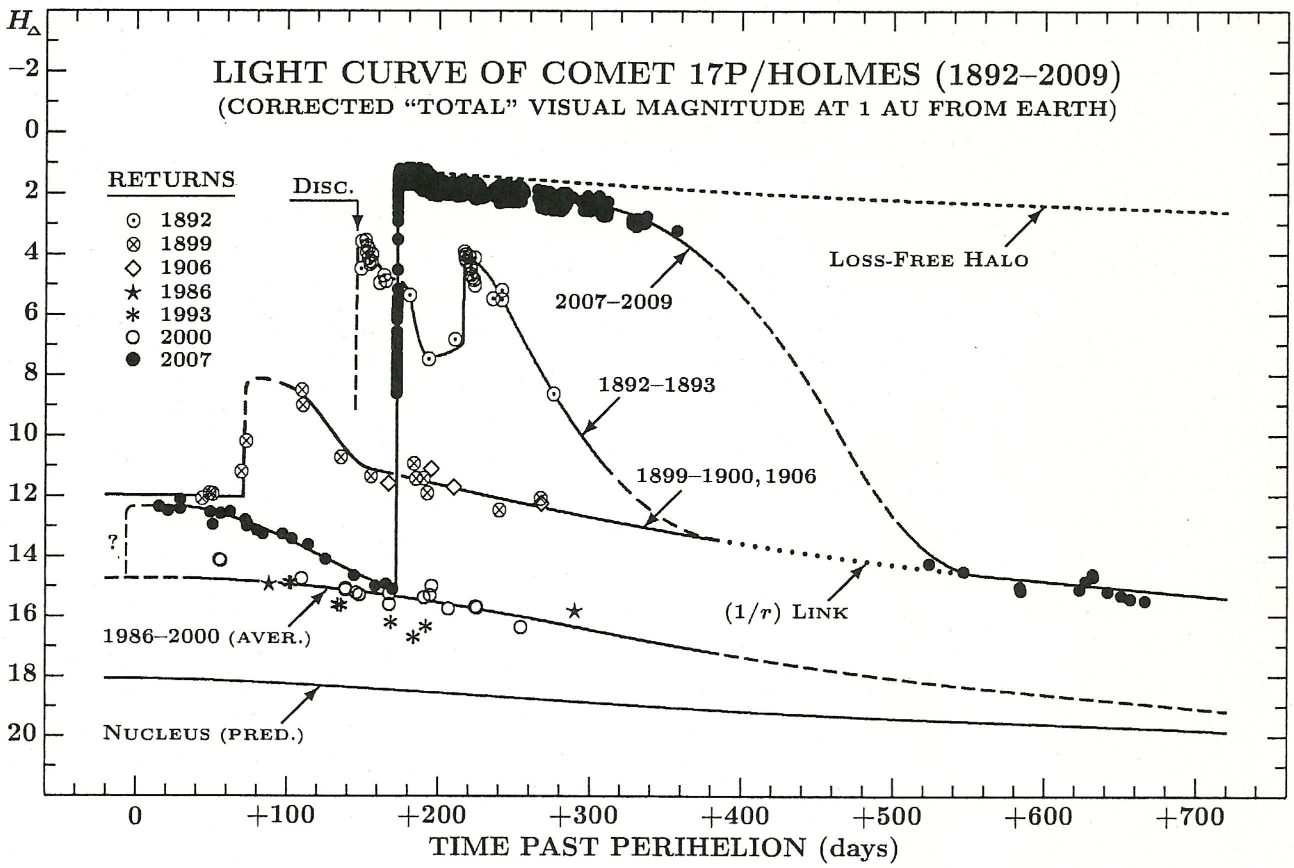

Figure A-1. The definitive visual light curve of comet 17P/Holmes at seven apparitions, based on 1610 data points from the period 1892 to 2009. The magnitudes H_Δ, normalized to a unit geocentric distance, have been corrected for personal and instrumental effects, with the corrections listed in Table A-1. The observations are represented by the apparition-specific symbols, with the discovery in 1892 marked and poorly determined light-curve segments depicted by long dashes. A hypothetical loss-free halo curve, shown with short dashes, applies to a case in which no dust particles injected into the atmosphere during the megaburst have escaped. The bottom curve is a predicted normalized magnitude of a spherical nucleus, at a zero phase angle, which is 3.3 km in diameter and whose geometric albedo is 4 percent. Highlighted as the $(1/r)$ link with the dotted curve is the assumed fit between the post-perihelion light curve for 1899-1900 and 1906 and the post-megaburst light curve in late 2008 and early 2009. A possible minor precursor outburst, before the comet was recovered in 2007, is indicated by a question mark.

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The definitive visual light curve of comet 17P/Holmes, the primary product of the described effort, is presented in Figure A-1. The plot illustrates the enormous variations in the normalized integrated brightness during and after the super-massive explosions in 1892 and 2007, as well as the apparently gradual "recuperation" after the two episodes of the 1892-1893 event, a process that may have taken at least two revolutions around the sun. There is a nearly constant difference of about 4 magnitudes along much of the post-perihelion branch of the orbit between the post-explosion apparitions 1899 and 1906 on the one hand and the quiescent apparitions 1986-2000 on the other hand. There is also an intriguing possibility that a relatively minor outburst, with an amplitude of ~ 2 magnitudes, took place before or very near the 2007 perihelion, just prior to the comet's recovery on May 13. If so, the brightness observations made over a period of about five months, before October 23, covered the subsiding branch of this early outburst — a precursor to the main event. The megaburst occurred at a time when the comet was just about to reach its 1986-2000 quiescent

Table A-1. Personal/instrumental magnitude corrections for observers of comet 17P/Holmes 1892-2009.

Return to sun	Observer(s) or observing project	Correction (mag)[a]	Observing technique	Instrument used	Location and/or country
1892	Backhouse, T. W.	−0.3	visual	naked eye[b]	Sunderland, U.K.
	Barnard, E. E.	0.0	visual	naked eye	Lick Observatory, Calif., U.S.A.
		−2.0	visual	8-cm refractor	"
	Coit, J. B.	0.0	visual	naked eye	Boston University, Mass., U.S.A.
	Holetschek, J.	−0.7	visual	4-cm comet seeker	Vienna Observatory, Austria
	Kammermann, A.	−1.7	visual	25-cm refractor	Geneva Observatory, Switzerland
	Kobold, H. A.	0.0	visual	naked eye	Strassburg Observatory, Germany
	Lovett, E. O.	0.0	visual	naked eye	Leander McCormick Observatory, Va., U.S.A.
	Updegraff, M.	0.0	visual	naked eye	Columbia Observatory, Mo., U.S.A.
1899	Barnard, E. E.	−3.0	visual	102-cm *f*/19 refractor	Yerkes Observatory, Wisc., U.S.A.
	Perrine, C. D.	−2.0	visual	91-cm *f*/19.3 refractor	Lick Observatory, Calif., U.S.A.
1906	Kopff, A.	−2.3	photogr.	41-cm *f*/5 refractor	Königstuhl Observatory, Heidelberg, Germany
	Wolf, M.	−2.3	photogr.	41-cm *f*/5 refractor	Königstuhl Observatory, Heidelberg, Germany
		−2.3	photogr.	72-cm *f*/4 reflector	"
1986	Gehrels, T.; Scotti, J. V.	−0.75	CCD	90-cm *f*/5.3 reflector[c]	Kitt Peak Observatory, Ariz., U.S.A.
	Gibson, J. B.	−0.75	CCD	150-cm *f*/8.75 reflector	Palomar Observatory, Calif., U.S.A.
1993	Nakamura, A.	−0.05	CCD	60-cm *f*/5.8 reflector	Kuma Kogen Observatory, Japan
	Scotti, J. V.	−0.75	CCD	90-cm *f*/5.3 reflector[c]	Kitt Peak Observatory, Ariz., U.S.A.
2000	Hotta, M.	−0.05	CCD	25-cm *f*/6 reflector	Konan Observatory, Japan
	Ikari, Y.	+0.25	CCD	25-cm *f*/6.3 reflector	Moriyama Observatory, Japan
	Jäger, M.	+1.0	photogr.	30-cm *f*/3.3 camera	near Vienna, Austria
	Kadota, K.	−0.3	CCD	18-cm *f*/5.5 reflector	Ageo Observatory, Japan
	Nakamura, A.	−0.05	CCD	60-cm *f*/5.8 reflector	Kuma Kogen Observatory, Japan
	Sugie, A.	−0.3	CCD	60-cm *f*/3.7 reflector	Dynic Astronomical Observatory, Japan
2007	Biver, N.	−0.22	visual	naked eye	France
		−0.27	visual	5-cm binoculars	"
	Bortle, J. E.	−0.18	visual	naked eye	Stormville, N.Y., U.S.A.
		−0.08	visual	2.5-cm binoculars	"
		−0.13	visual	5-cm *f*/4 monocular	"
		−0.20	visual	5-cm binoculars	"
	Bouma, R. J.	−0.01	visual	naked eye	The Netherlands
		+0.10	visual	2.8-cm *f*/2 refractor	"
		−0.10	visual	5-cm binoculars	"
	Brukhanov, I. S.	−0.45	visual	4-cm binoculars	Belarus
	Bus, E. P.	+0.12	visual	naked eye	The Netherlands
		+0.19	visual	3-cm binoculars	"
		+0.25	visual	4.4-cm binoculars	"
	Carvajal Martinez, J.	0.00	visual	naked eye	Spain
		0.00	visual	2-cm binoculars	"
	Catalina Sky Survey	+0.20	CCD	68-cm *f*/1.9 Schmidt	Catalina Mountains, Ariz., U.S.A.
	Cernis, K. T.	−0.15	visual	naked eye	Lithuania
		0.00	visual	5-cm binoculars	"
		−0.22	visual	5-cm *f*/4 refractor	"
	Comello, G.	−0.25	visual	naked eye	The Netherlands
		−0.42	visual	5-cm binoculars	"
	Creed, P. J.	0.00	visual	naked eye	Ohio, U.S.A.
	Dahle, H.	+0.10	visual	naked eye	Norway
	Diepvens, A.	−0.20	visual	5-cm binoculars	Belgium
	Dijk, E. van	0.00	visual	naked eye	The Netherlands
		+0.11	visual	2.8-cm *f*/2 refractor	"
		+0.10	visual	5-cm binoculars	"
		−0.10	visual	6-cm binoculars	"
	Giambersio, A.	−0.10	visual	naked eye	Italy
	Gilein, G.	−0.20	visual	naked eye	The Netherlands
	Gobet, F.	−0.54	visual	naked eye	Cestas, France
	Goiato, M. A. C.	−0.30	visual	5-cm binoculars	Brazil

Table A-1. (Continued.)

Return to sun	Observer(s) or observing project	Correction (mag)[a]	Observing technique	Instrument used	Location and/or country
2007	Gonzalez, J. J.	+0.25	visual	naked eye	Spain
		−0.10	visual	3-cm opera glass	"
		+0.33	visual	3-cm refractor	"
		−0.24	visual	10-cm binoculars	"
	Granslo, B. H.	+0.11	visual	naked eye	Norway
		0.00	visual	1.8-cm $f/4$ refractor	"
		0.00	visual	3-cm refractor	"
		−0.02	visual	5-cm binoculars	"
		−0.10	visual	5-cm $f/4$ refractor	"
	Green, D. W. E.	−0.01	visual	naked eye	near Cambridge, Mass., U.S.A.
		−0.08	visual	5-cm refractor	"
	Guido, E., *et al.*	0.0	CCD	25-cm $f/3.4$ reflector[d]	Remote Astron. Soc. Obs., N.M., U.S.A.
	Hale, A.	0.00	visual	naked eye	Cloudcroft, N.M., U.S.A.
	Hasubick, W.	−0.10	visual	naked eye	Germany
	Henríquez Santana, J. A.	+0.20	CCD	20-cm $f/9$ Cassegrain	Tenerife, Canary Islands, Spain
	Horálek, P.	+0.15	visual	naked eye	Czech Republic
	Hornoch, K.	+0.02	visual	naked eye	Lelekovice, Czech Republic
		0.00	visual	5-cm monocular	"
	Hsieh, H. H., *et al.*	0.00	CCD	SuperWASP-North[e]	La Palma, Canary Islands, Spain
	Ivanov, V. M.	−0.20	visual	naked eye	Russia
		−0.10	visual	3-cm $f/6$ refractor	"
	Kadota, K.	−0.30	CCD	25-cm $f/5.0$ reflector	Ageo Observatory, Japan
	Kammerer, A.	−0.40	visual	naked eye	Germany
		0.00	visual	6.3-cm binoculars	"
	Kanai, K.	−0.50	visual	naked eye	Isesaki, Japan
		−0.30	visual	3.5-cm binoculars	"
	Karhula, T.	−0.15	visual	naked eye	Virabo, Sweden
	King, B.	0.0	visual	naked eye	Duluth, Minn., U.S.A.
		0.0	visual	25-cm reflector	"
	Koukal, J.	−0.10	visual	naked eye	Czech Republic
		−0.05	visual	6-cm $f/6$ Maksutov	"
		−0.20	visual	6-cm $f/6$ reflector	"
	Labordena, C.	−0.08	visual	naked eye	Castellon, Spain
		+0.22	visual	3-cm binoculars	"
	Lehký, M.	−0.12	visual	naked eye	Hradec Králové, Czech Republic
		−0.10	visual	5-cm binoculars	"
	Maňák, R.	−0.05	visual	3-cm binoculars	Lipov, Czech Republic
	Meyer, M.	+0.05	visual	naked eye	Germany
		+0.05	visual	1.5-cm opera glass	"
		+0.05	visual	1.5-cm binoculars	"
		−0.20	visual	5-cm binoculars	"
	Mitsuma, S.	−0.10	visual	naked eye	Honjo, Japan
		−0.30	visual	3.5-cm binoculars	"
	Miyazaki, O.	−0.06	visual	naked eye	Ishioka, Japan
		−0.30	visual	2.1-cm binoculars	"
		−0.30	visual	3.2-cm binoculars	"
		−0.05	visual	5-cm binoculars	"
		−0.60	visual	5-cm refractor	"
	Morel, P.	−0.53	visual	2-cm binoculars	France
		−0.20	visual	8-cm binoculars	"
	Morris, C. S.	+0.17	visual	naked eye	Calif., U.S.A.
		+0.08	visual	5-cm binoculars	"
	Mount Lemmon Survey	−0.9	CCD	150-cm Cassegrain	Catalina Mountains, Ariz., U.S.A.
	Nagai, Y.	−0.10	visual	naked eye	Gunma, Japan
		−0.50	visual	1.8-cm refractor	"
		−0.50	visual	3.5-cm binoculars	"
		0.0	CCD	5.4-cm $f/6$ camera	"
	Nagashima, K.	−0.30	visual	5-cm binoculars	Nara, Japan
	Nagy, M.	−0.15	visual	naked eye	Csenger, Hungary
	Naves, R.; Campás, M.	+0.4	CCD	30-cm Schmidt-Cass.	Montcabre Observatory, Barcelona, Spain

Table A-1. (Continued.)

Return to sun	Observer(s) or observing project	Correction (mag)[a]	Observing technique	Instrument used	Location and/or country
2007	Nevski, V. S.	−0.03	visual	naked eye	Vitebsk, Belarus
		−1.5	CCD	30-cm $f/5$ reflector	"
	Novichonok, A. O.	−0.10	visual	naked eye	Russia
		−0.23	visual	5-cm binoculars	"
	Nowak, G. T.	−0.10	visual	naked eye	Vt., U.S.A.
	O'Meara, S.	+0.30	visual	5-cm monocular	Mass., U.S.A.
	Paradowski, M. L.	0.00	visual	naked eye	Poland
		−0.08	visual	2.4-cm binoculars	"
		+0.05	visual	2.4-cm refractor	"
		+0.15	visual	3.5-cm binoculars	"
		+0.15	visual	5-cm binoculars	"
		0.00	visual	6-cm binoculars	"
		−0.05	visual	6.7-cm $f/6$ refractor	"
		+0.16	visual	10-cm binoculars	"
		0.00	visual	20-cm $f/6$ reflector	"
	Pereira, A. J. S.	+0.01	visual	naked eye	Portugal
		−0.17	visual	2.2-cm $f/11$ refractor	"
	Pilz, U.	−0.40	visual	2.4-cm binoculars	Leipzig, Germany
	Rietveld, H.	0.00	visual	naked eye	The Netherlands
		+0.05	visual	3-cm binoculars	"
	Rinner, C.; Kugel, F.	−1.0	CCD	50-cm $f/3$ reflector	Chante-Perdrix Obs., Dauban, France
	Rzepka, Z.	−0.30	visual	6-cm binoculars	Lublin, Poland
		−0.40	visual	8-cm binoculars	"
	Sánta, G.	−0.15	visual	naked eye	Kisujszállás, Hungary
	Sárneczky, K.	−0.65	visual	naked eye	Budapest, Hungary
	Scarmato, T.	+0.35	visual	naked eye	Calabria, Italy
	Scholten, A. H.	+0.12	visual	naked eye	The Netherlands
		−0.05	visual	1.5-cm $f/3$ refractor	"
	Scotti, J. V.; Tubbiolo, A. F.	−0.75	CCD	90-cm $f/3$ reflector[c]	Kitt Peak, Ariz., U.S.A.
	Seargent, D. A. J.	−0.26	visual	naked eye	The Entrance, N.S.W., Australia
		−0.40	visual	2.5-cm binoculars	"
	Shurpakov, S. E.	0.00	visual	naked eye	Belarus
		−0.40	visual	3-cm $f/6$ refractor	"
		−0.25	CCD	8-cm $f/7$ refractor	"
	Skilbrei, O.	+0.30	visual	naked eye	Norway
	Souza, W. C. de	−0.30	visual	3-cm binoculars	Sao Paulo, Brazil
		−0.40	visual	4-cm opera glass	"
		−0.55	visual	5-cm binoculars	"
		−0.50	visual	8-cm binoculars	"
	Srba, J.	−0.2	CCD	14.5-cm $f/8$ reflector	Vsetín, Czech Republic
	Szabó, S.	−0.15	visual	4.2-cm binoculars	Sopron, Hungary
	Tóth, Z.	−0.15	visual	naked eye	Hungary
	Trigo-Rodríguez, J. M., *et al.*	+0.25	CCD	1.6-cm $f/3.5$ camera[f]	Spain
	Tsumura, M.	0.00	visual	naked eye	Wakayama, Japan
		0.00	visual	2-cm $f/5$ refractor	"
		−0.6	CCD	35-cm $f/14$ Cassegrain	"
	Wheeler, R. O.	−0.30	visual	naked eye	Okla., U.S.A.
	Yoshida, S.	+0.04	visual	naked eye	Kanagawa, Japan
		−0.20	visual	5-cm refractor	"
		−0.20	visual	6.6-cm refractor	"
	Yoshimoto, K.	−0.10	visual	naked eye	Yamaguchi, Japan
		−0.15	visual	3.5-cm binoculars	"
		−0.50	visual	5-cm refractor	"

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[a] This correction is added to the reported magnitude to convert the observer's apparent magnitude to the common system applied; the minus sign indicates the observer underestimated the brightness, and vice versa.

[b] Also field-glasses and 11-cm refractor.

[c] The magnitude correction for images taken with the participation of J. V. Scotti (1986, 1993, and 2007) is assumed to be the same, even though the instrument was reconfigured and a new primary mirror installed in 2002; see `http://spacewatch.lpl.arizona.edu/scopes.html`.

[d] And 30-cm $f/12$ reflector.

[e] SuperWASP is an extrasolar planet detection facility, consisting of two (northern and southern) robotic observatories operating continuously. Each consists of eight 11-cm $f/1.8$ cameras and 2048 × 2048 CCD detectors. For more information see `http://www.superwasp.org`.

[f] This camera is part of the Spanish Meteor and Fireball Network, consisting of a system of "fish-eye" all-sky lenses with CCD detectors.

state. Finally, the figure shows the surprising degree of correspondence between the comet's post-perihelion brightness in 1899-1900 and 1906 on the one hand and the "residual" post-megaburst brightness in late 2008 and early 2009. The empirical ($1/r$) link, referred to in Sec. 8 and used as a predictive tool in Table 10, is prominently depicted in Figure A-1.

The magnitude corrections applied to all selected observers and their instruments — the key information necessary for the construction of the light curve in Figure A-1 — are listed in Table A-1. Only consistent data sets have been selected. The light curve for late 2008 and early 2009 (500 to 700 days past perihelion) is dominated by the "total" magnitudes reported by the Catalina Sky Survey group and by K. Kadota (see Table A-1).

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