Forward-Scattering Enhancement of Comet Brightness. II. The Light Curve of C/2006 P1 (McNaught)

Joseph N. Marcus *

St. Louis, MO, U.S.A.

Abstract. Like the great daylight comet C/1927 X1, comet C/2006 P1 (McNaught) underwent a remarkable brightness surge at small scattering angles (θ), becoming widely visible near the sun in broad daylight during the interval 2007 Jan. 12-15 UT, when it was as bright as total visual magnitude $m_1 \approx -6$. The enhancement, which had been forecasted (Marcus 2007b, 2007c), was due to forward-scattering of sunlight by the comet's dust grains. To characterize the surge, I first establish the comet's "baseline" brightness in the standard power-law formula $m_1 = m_0 + 5 \log \Delta + 2.5n \log r$ (Δ = geocentric distance and r = heliocentric distance), using binocular and naked-eye m_1 observations as tabulated in the *ICQ* that were made when the comet was *not* in forward-scattering geometry ($\theta > 90°$). I find that the solutions $m_0 = 5.71$ and $n = 4.59$ for pre-perihelion, and $m_0 = 3.83$ and $n = 3.61$ for post-perihelion, fit the observations well and provide continuity at perihelion ($q = 0.171$ AU) on Jan. 12.80 TT. Next, I apply the novel compound Henyey-Greenstein comet-dust light-scattering model developed in Paper I (Marcus 2007a) to analyze the excursion of the brightness from this baseline, as interpolated into the period Jan. 10.0-21.7 UT, when the comet was in forward-scattering geometry ($\theta < 90°$). I show that the model successfully accounts for the comet's brightness surge in the timing of the peak ($\approx$ Jan. 14.3 UT at $\theta_{\rm min} = 31^\circ\!.1$), its maximum amplitude (-2.1 ± 0.8 magnitudes, near the forecast of -2.4 magnitudes), and its shape — both for the data in aggregate and, in particular, for series by individual observers. I conclude that this model can be used to accurately predict and analyze the brightness of a comet in forward-scattering geometry.

1. Introduction

Comet C/2006 P1 (McNaught) was a "great" comet in nearly every sense (Bortle 1997). Although it did not come very close to the earth ($\Delta_{\rm min} = 0.817$ AU on 2007 Jan. 15.5 UT) and suffered from poor solar elongation during its northern-hemisphere apparition, the comet did venture close to the sun ($q = 0.171$ AU on 2007 Jan. 12.80 TT), where it could become bright. Moreover, it was *intrinsically* bright, as measured by its "absolute magnitude" (defined below). After passing perihelion, it dazzled southern-hemisphere observers in later January with its mammoth dust tail — resplendently bright, long, broad, and replete with seemingly innumerable striae, which were widely photographed. But C/2006 P1 fulfilled another criterion of "greatness" that has been widely overlooked (Marcus 1997): it passed in a direction between the earth and the sun. In this special geometry, forward-scattering of sunlight by its dust grains enhanced its brightness by a *further* two magnitudes, as I shall document here. That remarkable surge catapulted the comet into visibility throughout the world in broad daylight (Fig. 1) as close as $5^\circ\!.5$ from the sun, even by naked eye if the sun were suitably shielded by the hand or a building.

In the first paper, I reviewed forward-scattering in comets and developed a model to forecast and analyze it, based upon five comets that have been well-characterized photometrically in forward-scattering geometry (Marcus 2007a). The model, utilizing a compound Henyey-Greenstein function for dust scattering, derives from equations 8, 14, and 15 of Paper I. In full form it is given by

$$\Phi(\theta) = \frac{\delta_{90}}{1+\delta_{90}}\left[k\left(\frac{1+g_f^2}{1+g_f^2-2g_f\cos\theta}\right)^{3/2} + (1-k)\left(\frac{1+g_b^2}{1+g_b^2-2g_b\cos\theta}\right)^{3/2} + \frac{1}{\delta_{90}}\right], \qquad (1)$$

where $\Phi(\theta)$ is the scattering (or "phase") function of comet brightness, θ (= 180° − phase angle) is the scattering angle, $0 \le g_f < 1$ and $-1 < g_b \le 0$ are the forward-scattering and back-scattering asymmetry factors, $0 \le k \le 1$ is the partitioning coefficient between forward and backward scattering, and δ_{90} is the dust-to-gas light ratio in the coma as viewed at $\theta = 90°$. The model is applicable for all θ ($0° \le \theta \le 180°$) and is "normalized" — that is, $\Phi(\theta) = 1$, at 90°. In Paper I, I presented the light curves of five comets for which there are good photometric data in forward-scattering geometry. I found that the data for these five comets are well fit by parameter values $g_f = 0.9$, $g_b = -0.6$, $k = 0.95$, and $\delta_{90} = 1$ for a "usual" comet or $\delta_{90} = 10$ for a "dusty" one. I shall apply these values here in the study of comet C/2006 P1. The *magnitude* of $\Phi(\theta)$,

$$m_{\Phi(\theta)} = -2.5 \log \Phi(\theta), \qquad (2)$$

* e-mail address jnmarcus@sbcglobal.net

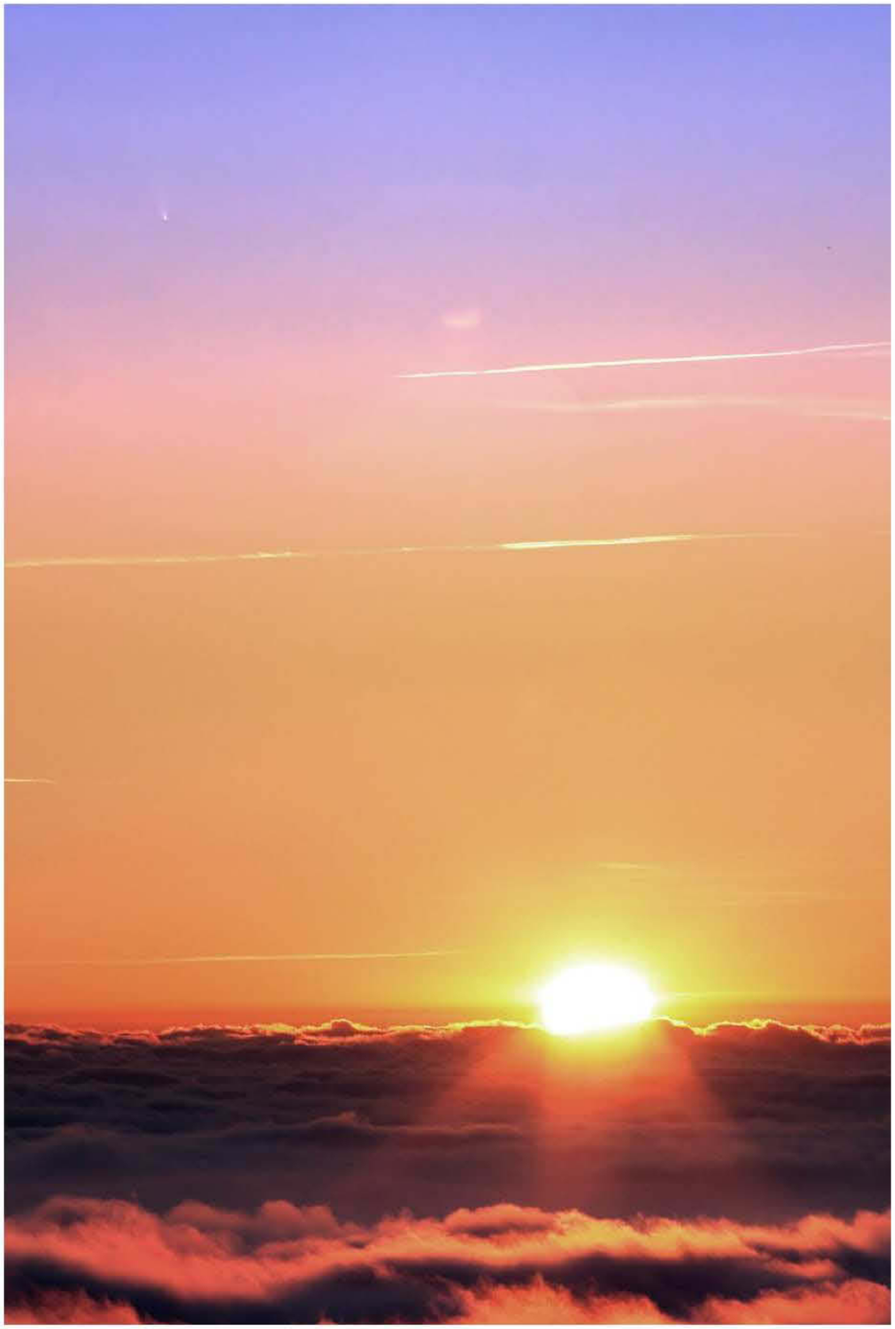

Figure 1. Comet C/2006 P1 (McNaught) in broad daylight on 2007 Jan. 13.66 UT, when the scattering angle, θ, was 34°.7 (1/250-sec exposure by Mauro Zorzenon from Monte Matajur, Italy, with a Canon 300D camera and zoom lens set at 112 mm. Copyright ©2007 by Mauro Zorzenon and Cristina Scauri, and reproduced here with permission). Minimum scattering angle was reached 16 hours later on Jan. 14.27 ($\theta_{\rm min}$ = 31°.1). The comet, at the upper left, is visible because its brightness has been boosted some two magnitudes due to forward-scattering of sunlight by its dust grains. In a like manner, water droplets along the edges of the cloud deck beneath the setting sun are forward-scattering sunlight toward the observer.

◇ ◇ ◇

[text continued from page 119]

appears as a term in the standard power law for cometary brightness,

$$m_1 = m_0 + 5 \log \Delta + 2.5n \log r + m_{\Phi(\theta)}, \tag{3}$$

where m_1 is the total visual magnitude of the coma (but see Section 5.3.1), Δ and r are the comet-earth and comet-sun

Table 1. Comet C/2006 P1 (McNaught) Ephemeris and Predicted Brightness Enhancement in Forward-Scattering Geometry[§]

Date (2006-7 UT)	Δ (AU)	r (AU)	ε (°)	ρ (°)	θ (°)	$m_{\Phi(\theta)}$[¶]
Aug. 03.0	2.468	3.119	121.4	101.3	163.9	−0.1
Aug. 23.0	2.523	2.845	98.0	105.7	159.4	0.0
Sep. 12.0	2.589	2.559	77.1	107.2	157.5	0.0
Oct. 02.0	2.614	2.256	58.4	105.4	157.8	0.0
Oct. 22.0	2.560	1.934	41.8	99.2	160.0	0.0
Nov. 11.0	2.399	1.586	27.3	85.7	163.3	−0.1
Dec. 01.0	2.110	1.199	16.6	56.7	163.4	−0.1
Dec. 21.0	1.666	0.751	14.1	10.4	161.4	−0.1
Jan. 02.0	1.293	0.431	15.3	357.2	143.0	0.2
Jan. 04.0	1.218	0.373	15.2	357.5	136.2	0.2
Jan. 06.0	1.138	0.314	14.9	359.1	126.7	0.2
Jan. 08.0	1.053	0.257	14.0	2.6	112.5	0.2
Jan. 10.0	0.963	0.206	12.1	9.5	90.5	0.0
Jan. 11.0	0.920	0.186	10.6	15.7	75.4	−0.2
Jan. 12.0	0.881	0.174	8.6	25.9	58.2	−0.7
Jan. 12.5	0.863	0.171	7.6	33.7	49.4	−1.1
Jan. 13.0	0.849	0.171	6.6	44.5	41.4	−1.6
Jan. 13.5	0.837	0.173	5.8	59.4	35.1	−2.0
Jan. 14.0	0.828	0.178	5.4	78.0	31.6	−2.3
Jan. 14.5	0.821	0.185	5.6	97.7	31.5	−2.3
Jan. 15.0	0.818	0.193	6.4	114.7	34.3	−2.1
Jan. 15.5	0.817	0.203	7.4	127.4	38.8	−1.7
Jan. 16.0	0.818	0.215	8.7	136.6	44.1	−1.4
Jan. 16.5	0.821	0.227	10.1	143.2	49.5	−1.1
Jan. 17.0	0.826	0.240	11.5	148.2	54.9	−0.9
Jan. 18.0	0.839	0.268	14.2	155.1	64.6	−0.5
Jan. 19.0	0.856	0.296	16.7	159.5	73.0	−0.3
Jan. 20.0	0.875	0.326	19.0	162.7	80.2	−0.1
Jan. 22.0	0.917	0.384	23.0	167.1	91.7	0.0
Jan. 24.0	0.962	0.442	26.2	169.9	100.3	0.1
Jan. 26.0	1.008	0.499	29.0	172.0	107.1	0.2
Jan. 28.0	1.052	0.554	31.3	173.6	112.4	0.2
Jan. 30.0	1.096	0.608	33.4	174.9	116.8	0.2
Feb. 09.0	1.290	0.857	41.6	179.3	130.1	0.2
Mar. 01.0	1.572	1.288	54.8	183.7	141.0	0.2
Mar. 21.0	1.755	1.665	68.1	185.3	146.3	0.1
Apr. 10.0	1.886	2.007	89.1	184.9	150.4	0.1
Apr. 30.0	2.011	2.324	94.9	182.3	154.4	0.1
May 20.0	2.170	2.623	105.1	177.2	158.1	0.0
Jun. 09.0	2.395	2.906	110.2	170.3	160.9	0.0
Jun. 29.0	2.697	3.177	109.0	163.7	162.4	−0.1
Jul. 19.0	3.069	3.438	102.6	159.7	163.2	−0.1

[§]See text (Sec. 2) for explanation of the columns.
[¶]Computed with the compound Henyey-Greenstein scattering model as given in Equations 1 and 2, using parameter values $g_f = 0.9$, $g_b = -0.6$, $k = 0.95$, and $\square_{90} = 1$.

[text continued from bottom of page 120]

distances, m_0 is the "absolute magnitude" of the comet as it would be seen at $\Delta = 1$ AU $= r$, and n is the power-law index by which m_1 varies with log r. Normally the $m_{\Phi(\theta)}$ term can be safely ignored in brightness analyses. However, in forward-scattering geometry, $m_{\Phi(\theta)}$ becomes extremely important and can overwhelm the other terms, approaching a value of -8 (!) as θ approaches 0° (see Fig. 15 of Paper I). Comet C/2006 P1 did not reach such extremely small scattering angles ($\theta_{\rm min}$ was 31°.1 on Jan. 14.3 UT), and so its magnitude surge — although considerable — was very much less than this.

While Paper I was under editorial review and revision, comet C/2006 P1 was discovered on 2006 Aug. 7 by Robert H. McNaught at Siding Spring, Australia (Green 2006). During the remainder of 2006 and the first days of 2007, it brightened briskly on its way to perihelion. Recognizing that the comet would reach small scattering angles, I applied the model as given in equation 3 to forecast the $\approx$ 2-magnitude surge noted above (Marcus 2007b). A detailed version of this forecast was posted on the Internet (Marcus 2007c) and is shown in Table 1 as $m_{\Phi(\theta)}$. In this paper, I formally analyze the brightness estimates of C/2006 P1 and demonstrate that the surge closely followed this forecast model.

2. The Apparition

Table 1 illustrates the geometric circumstances of the apparition, with 0.5-day spacing when the comet was at $\theta \leq 60°$. The ephemeris is based on orbital elements from *MPC* 59042. The columns provide the decimal date, Δ, r, elongation (ϵ), heliocentric position angle (ρ) measured counterclockwise from north on the sky, and scattering angle (θ). As paired coordinates, ϵ and ρ give a more direct sense of the apparition's geometry than do conventional right ascensions and declinations. Note, after 2006 October, the poor elongations throughout the comet's entire northern-hemisphere apparition, when $270° \leq \rho \leq 360°$ and $0° \leq \rho \leq 90°$.

I restrict this brief summary of the apparition to the comet's visual magnitudes, m_1, as currently tabulated in the *ICQ*. Coma and tail observations generally are not a focus of this study. The first estimate was on 2006 Aug. 25.48 UT (Seargent, $m_1 = 13.9$, 25.4-cm reflector, 114×). Observers put the comet at 14th to 13th magnitude in September, and 12th to 11th magnitude in October, as viewed in telescopes. The first binocular sighting was by Seargent on Oct. 11.41 UT (25×, 10-cm objectives, $m_1 = 11.1$). In mid-November the comet was 9th magnitude. After Nov. 18, there was a six-week hiatus of observations, as the elongation sank from 23° then to 14°-17° throughout December (Table 1). C/2006 P1 was next estimated on Dec. 29.28 UT, when Granslo (in Sweden) gave $m_1 = 3.9$ in a 25-cm reflector. Despite elongations in January that decreased from 15° to 7° at perihelion, the comet was brilliant enough to be viewed in bright twilight, particularly from high northern latitudes, at very low altitude, often at just 1° or 2°, as its heliocentric distance decreased and its magnitude brightened from $m_1 \approx 2$ at the beginning of January to ≈ -2 to -3 by Jan. 10. The extreme circumstances necessitated large corrections for atmospheric extinction, which likely led to uncertainties of $\pm$ 0.5 to $\pm$ 1 magnitude in the m_1 estimates in this period (see Sec. 5.3).

The comet was first estimated in broad daylight as having $m_1 = -2.5$ on Jan. 10.83 UT (R. Keen, Mt. Thorodin, CO, USA, 7.6-cm reflector). As the comet surged in brightness, most estimates during Jan. 12-15 UT were in daylight by naked eye or binoculars, with six observers putting the comet as bright as -6 between Jan. 13.56 and 15.17, and one observer giving $m_1 = -7$ on Jan. 14.82. This extreme brightness — no comet since C/1965 S1 (Ikeya-Seki) had been so bright (Green 2007) — should have led to an independent uncertainty in m_1 estimations of $\pm$ 0.5 to 1 (or greater) magnitude, owing to the lack of comparably bright comparison objects (Sec. 5.3); Venus, the brightest, was $\approx$ 2 magnitudes fainter at the time, at $m_V = -3.9$. As we shall see in Sec. 3.3.1, the daylight observations center upon the time of minimum scattering angle on Jan. 14.3 UT, rather than upon the time of perihelion on Jan. 12.8, as would be more conventionally expected.

After the comet passed south of the sun ($90° \leq \rho \leq 270°$) on Jan. 14 UT and attained comparatively greater elongations in later January (Table 1), the head could only be viewed from the southern hemisphere, although the tail was so long and arched that some of its striae were visible from mid-northern latitudes (see, *e.g.*, photos on pp. 71 and 73 of the April *ICQ*). The greater elongations meant that — in principle, at least — uncertainties in the m_1 estimates from extinction corrections would be smaller. The comet declined from 0th to 2nd magnitude in late January, from 3rd to 5th magnitude through February, from 5th to 8th magnitude in March, 8th to 9th magnitude in April, and 9th to 10th magnitude in May. Seargent continued to dominate the threshold observations (that is, the first or last to be made in a given instrument size), with the last naked-eye sighting on Mar. 9.42 UT ($m_1 = 6.4$) and the last binocular one on June 12.42 ($m_1 = 10.3$, 25×, 10-cm objectives). The last tabulated telescopic sighting was by Robledo on July 6.98 ($m_1 = 12.6$, 25-cm reflector).

3. Analysis

Our strategy is to first establish the *baseline* brightness of C/2006 P1, when the comet was *not* in forward-scattering geometry, taken here as $\theta > 90°$. Next I interpolate the solution into the forward-scattering interval ($\theta \leq 90°$). Any departure of the observations from the interpolated baseline should then represent the effect of forward-scattering.

3.1. The Observations

Total visual magnitude (m_1) estimates were taken from tabulations in the *ICQ* from 2007 and late 2006 (**28**, 168;

29, 32-33, 82-87, and 109). Because our intention is to construct a purely visual light curve, CCD observations (which are tabulated separately in the *ICQ*) were not utilized, although two are selectively examined in Section 4 for the purpose of correlation. In all, 425 visual m_1 estimates by 60 observers were available for analysis. Of these, 55 were near-simultaneous duplicates or triplicates by the same observer spanning a 0.01-day or, in three instances, a 0.02-day interval. In order not to give undue weight to these observers, only the observation made in the smallest instrument or by naked eye was retained, leaving a total of 370 m_1 estimates for consideration. Most estimates made in January and February were at low altitude and were corrected by the observer for extinction, generally with the *ICQ* extinction tables (Green 1992). No attempt was made to correct for magnification artifact, or "aperture effect" (Morris 1973), in which the contrast gradient of the outer coma, attenuated by magnification, falls below visual contrast threshold, effectively "shrinking" the visible coma, and leading to an underestimation of its brightness. This potential artifact should not be a significant problem in the C/2006 P1 light curve, for the far majority (84%) of the 370 m_1 estimates were at low magnifications in binoculars ($N = 183$) or by naked eye ($N = 126$), and the coma was condensed for observations at all but the largest heliocentric distances.

3.2. The Baseline Photometric Solutions

Figure 2 plots the observations as heliocentric magnitude ($H_1 = m_1 - 5 \log \Delta$), which is the comet's magnitude as seen at 1 AU from the earth, *vs.* the logarithm of the heliocentric distance. We see that H_1 is roughly linear with $\log r$ during both pre-perihelion (open symbols) and post-perihelion (closed symbols), with the exception of a spike just after perihelion at $\theta_{\rm min}$ ($\log r \approx -0.75$). This spike is the forward-scattering event. We also see that the post-perihelion brightness is systematically greater than the pre-perihelion brightness.

◇ ◇ ◇

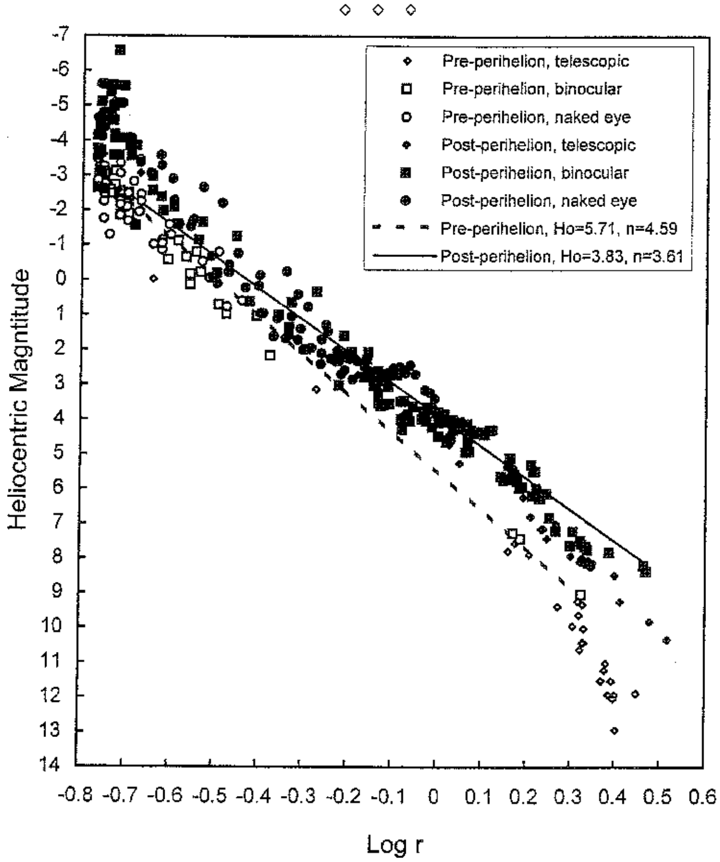

Figure 2. The heliocentric magnitude, $H_1 = m_1 - 5 \log \Delta$, of C/2006 P1 plotted against the logarithm of its heliocentric distance, r (AU). Perihelion ($q = 0.171$ AU) was on 2007 Jan. 12.80 TT. The lines, joined at perihelion ($\log q = -0.767$), represent the "baseline" brightness solution based on naked-eye and binocular m_1 estimates made at $\theta > 90°$ (see text). The brightness excess at $\log r < -0.5$ post-perihelion is due to forward-scattering of sunlight by the comet's dust grains.

◇ ◇ ◇

To obtain the baseline photometric parameters, I excluded observations made in forward-scattering geometry, which I operationally define here as $\theta \leq 90°$, corresponding to the interval 2007 Jan. 10.0-21.7 UT (see Table 1). I then applied a correction for the scattering function to the observations *not* made in forward-scattering geometry, using equations 2 and 3 with $\delta_{90} = 1$. This correction is small, just a few tenths of a magnitude or less (Table 1), and has little effect on the analysis. It is applied for the sake of consistency so that scattering effects will have been modeled for the *entire* data span, not just the forward-scattering portion. In order to minimize any underestimation of m_1 due to magnification artifact (see above), only binocular and naked-eye observations were used for the analysis. Least-squares linear regression on equation 3 then yields the following photometric solution for the "baseline" brightness: pre-perihelion, $0.324 \geq \log r \geq -0.686$, $m_0 = 5.53 \pm 0.20$, $n = 4.52 \pm 0.14$, $\sigma = \pm 0.50$, $N = 33$; post-perihelion, $-0.423 \leq \log r \leq 0.47$, $m_0 = 3.87 \pm 0.04$, $n = 3.61 \pm 0.07$, $\sigma = \pm 0.48$, $N = 83$. The error limits on m_0 and n are standard deviations; σ is the standard deviation of the observations about the regression line, a measure of the dispersion in the data set; and N is the number of observations utilized in the regression. Gratifyingly, pre- and post-perihelion solutions are nearly convergent at perihelion ($q = 0.171$ AU), yielding heliocentric magnitude values of $H_1(q) = -3.16$ and -3.06, respectively. On the assumption that this very slight discontinuity is not real, we "tweak" the parameters, within their standard-deviation error limits, to produce an intermediate common value $H_1(q) = -3.10$ at perihelion, by setting $m_0 = 5.71$ and $n = 4.59$ pre-perihelion, and $m_0 = 3.83$ post-perihelion (with $n = 3.61$ remaining the same). I adopt these adjusted photometric parameters as my "baseline" brightness solutions, which are shown respectively as the dashed and solid lines in Fig. 2. Joined at perihelion ($\log q = -0.767$), they provide the requisite continuous baseline during the forward-scattering interval.

3.3. The Forward-Scattering Brightness Surge

Figure 3 plots the observations against the time from perihelion, $t - T$. The "baseline"-brightness solution, $H_1 = m_0 + 2.5 \log r$ (dotted line), has been interpolated into the interval of forward-scattering geometry ($\theta \leq 90°$, -2.8 days $\leq t - T \leq 8.9$ days). Also shown is the compound Henyey-Greenstein forward-scattering model, $H_1(\theta) = H_1 + m_{\Phi(\theta)}$, for two dust-to-gas ratios, $\delta_{90} = 1$ (heavy solid line) and $\delta_{90} = 10$ (thin solid line). Note that the brightness does not peak at perihelion, as one would expect in the ordinary baseline model. Instead, there is a significant brightness excursion peaking near the time of the minimum scattering angle. The observations appear to follow the forward-scattering model curves better than the baseline brightness curve.

◇ ◇ ◇

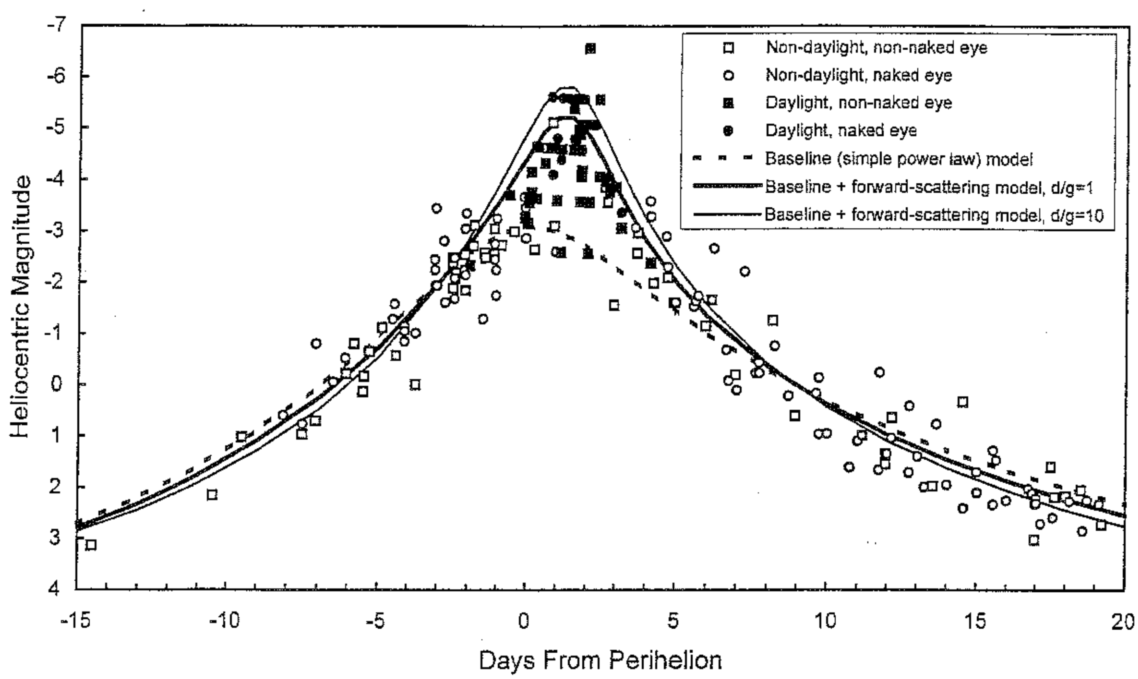

Figure 3. Heliocentric magnitude of C/2006 P1 plotted against the time from perihelion (T = 2007 Jan. 12.80 TT). The dashed line is the baseline power-law brightness solution. The solid lines show the compound-Henyey-Greenstein-function dust-scattering-model solutions for two dust-to-gas ratios, $\delta_{90} = 1$ and $\delta_{90} = 10$. Daylight visibility (closed symbols) occurred in forward-scattering geometry and centers on the time of minimum scattering angle at $t - T = 1.5$ days (see text). The brightness surge closely follows the compound HG dust-scattering models.

◇ ◇ ◇

3.3.1. The Timing of the Surge with Respect to the Daylight Observations

Qualitatively, the peak in heliocentric brightness appears to coincide with the time of minimum scattering angle in Figures 3 and 4. We can also get a semi-quantitative idea of the time of the maximum brightness by considering the daylight observations as a proxy for the period of maximum brightness of the comet. These are shown as filled symbols in

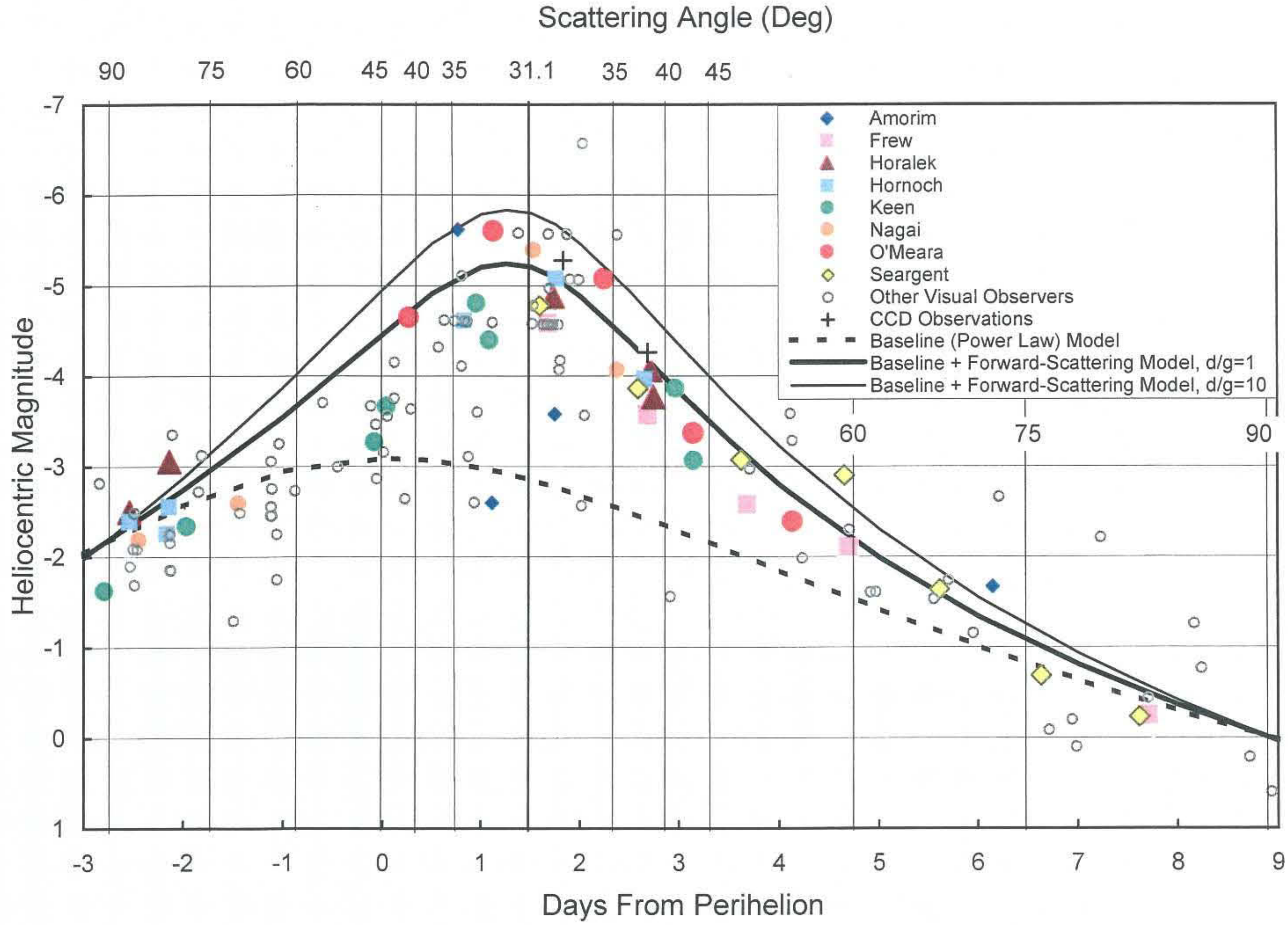

Figure 4. A closer view of the heliocentric magnitude of C/2006 P1 in forward-scattering geometry plotted against $t - T$ and the scattering angle. The minimum scattering angle is 31°.1. Observers with four or more estimates, at least one of which falls within moderate forward-scattering geometry ($\theta \leq 40°$), are represented by separate symbols. With so many observations, there is inevitable overlap of some symbols on the plot (estimates by Horalek and Hornoch at $t - T = -2.5$ days; Frew, Horalek, Hornoch, and Seargent at 1.5 to 1.7 days; Frew, Horalek, Hornoch, and Seargent at +2.6 to 2.7 days; and Frew and Seargent at 7.6 to 7.7 days). Note how closely seven of these eight observers follow the scattering models.

◇ ◇ ◇

[text continued from page 124]

Fig. 3. In all, fifty-six m_1 estimates were made in broad daylight between Jan. 10.83 and 16.94 UT: ten with telescopes, thirty with binoculars, and sixteen by naked eye. At peak brightness, six observers put the comet as bright as $m_1 = -6$, and one other gave $m_1 = -7$ (these correspond to heliocentric magnitudes $H_1 = -5.6$ and -6.6 in Figs. 3 and 4). Fifty-three of the 56 daylight estimates were made between Jan. 12.71 ($\theta = 46°.8$) and 15.94 ($\theta = 43°.4$), representing 80% of the 66 observations in that interval. The mean time of binocular and naked-eye daylight observations was Jan. 14.24, very close to the time of $\theta_{\min}$ on Jan. 14.27. This near-coincidence demonstrates the remarkably tight correlation of daylight visibility to the scattering angle.

3.3.2. The Shape of the Surge

The observations in aggregate seem to follow the shapes of the Henyey-Greenstein cometary scattering models in Figures 3 and 4. We can better see this effect if we consider series by the most prolific individual observers — specifically, those who had four or more observations in the forward-scattering interval, with at least one made at $\theta \leq 40°$. Eight observers fulfill these criteria: Alexandre Amorim, Brazil; David J. Frew, Perth, Australia; Petr Horalek, Czech Republic; Kamil Hornoch, Czech Republic and Austria; Richard A. Keen, Mt. Thorodin, Colorado, U.S.A.; Yoshimi Nagai, Gunma, Japan; Stephen J. O'Meara, Hawaii; and David A. J. Seargent, Cowra, New South Wales, Australia. Their observations are plotted separately in Figure 4. Note that the series by all-but-one of the observers follow the slopes of the HG scattering models closely. In particular, those of Hornoch, Keen, and O'Meara, which span across the time of θ_{min}, individually follow the shape of the "hump" centered on θ_{min}. In comparison with the "baseline" model, Keen's and Hornoch's follow the pre-θ_{min} HG models' steeper upslopes, and O'Meara's follow their steeper post-θ_{min} downslopes. The estimates of Horalek, Hornoch, and Nagai are within 0.5 magnitude or less of the HG model curves on the early upslopes and early downslopes. Seargent's and Frew's observations are in near-perfect concordance, and follow the downslopes of the HG models exquisitely well, beginning from θ_{min}. Only Amorim's estimates are difficult to characterize owing to their large (3-magnitude) dispersion over a one-day interval at the time of θ_{min} (Fig. 4). With this one series excepted, the close adherences of the series estimates of the other seven observers to the scattering model shapes are remarkable.

3.3.3. The Amplitude of the Surge

We can determine the maximum amplitude of the forward-scattering brightness enhancement from the $O - C$ ("observed" minus "computed") residuals of the m_1 estimates with respect to the computed "baseline" solution near the time of θ_{min} on Jan. 14.3 (Figures 3 and 4). To do this, we form a "normal point" of the 24 observations that span a one-day interval centered on Jan. 14.3. From these, I derive a mean value of $O - C = -2.0 \pm 0.8$ (σ) magnitudes. This excursion is close to that predicted by the compound-HG model (Table 1), which gives -2.3 magnitudes as averaged over the interval Jan. 13.8-14.8 and a maximum of -2.4 magnitudes on Jan. 14.3. From these considerations, we can infer that the maximum $O - C$ value on Jan. 14.3 would also be about 0.1 magnitude greater than the average — *i.e.*, -2.1 ± 0.8 (σ) magnitudes. In this same interval, a "normal point" formed of the eight observations by the seven selected observers in Sec. 3.3.2 gives a similar mean $O - C = -2.1 \pm 0.4$ (σ) magnitudes, or an inferred maximum $O - C = -2.2 \pm 0.4$ (σ) magnitudes.

4. Comparison with Selected CCD Photometry

CCD photometry can deliver high-precision estimates of cometary magnitudes, but the methods of reducing and analyzing the observations must be specified carefully in order for comparison with visual m_1 estimates to be meaningful. In this section, we look at the two CCD studies of C/2006 P1 in broad daylight that have reached formal publication.

Hornoch *et al.* (2007), observing from the Czech Republic, used a 6.3-cm Maksutov-Cassegrain telescope and an SBIG ST-7 CCD camera with no bandpass filter to obtain magnitudes on 2007 Jan. 15.479 with a variety of circular apertures, ranging from $0'.5$ to $6'$, centered on the central condensation of the coma (tabulated in 2007 in *ICQ* **29**, 88). Their assumed magnitude of -3.9 for the comparison object, Venus, was a visual magnitude. At the time of their measurement, Hornoch visually estimated the coma diameter as $3'$ in 8-cm binoculars at 10× (see *ICQ* **29**, 33). For this diameter, the authors obtained unfiltered mag -4.6 ± 0.15. To compare this unfiltered magnitude with visual m_1 estimates, it is necessary to apply color corrections, because the ST-7 CCD chip is red-sensitive (see spectral response at `http://www.sbig.com/sbwhtmls/ST7ME.htm`). I make the following assumptions for the photometry of dusty comets with this particular chip: (1) $V - R = +0.4$ (Sostero 2007a); (2) the R band and this unfiltered passband are photometrically are nearly equivalent (Sostero 2007b); and (3) the V band and human photopic passbands are nearly equivalent (see, *e.g.*, Cox 2000, Tables 5.22 and 7.5). For Venus, I adopt $V - R = +0.5$ (Mallama *et al.* 2006). Because the spectra of Venus and dusty comets each are approximately solar, I assume that for Venus, the R band and the unfiltered passbands are likewise nearly photometrically equivalent (Sostero 2007b). With the foregoing considerations, the equivalent visual magnitude of the comet is then $m_1 = -4.6 - 0.5 + 0.4 = -4.7$.

Miles (2007), observing from Dorset, England, used a 6-cm refractor and a Starlight Xpress SXV-H9 CCD camera with a standard V-band filter to obtain $m_V = -5.01 \pm 0.15$ on Jan. 14.624 for a $1'.5$-aperture diaphragm, the largest of several that he employed (tabulated in *ICQ* **29**, 88). Miles does not report a visual coma diameter, but near that time, on Jan. 14.54, Hornoch had estimated it in daylight as $3'$ in 8-cm binoculars at 10× (*ICQ* **29**, 33). To convert this magnitude to the equivalent for a $3'$-aperture diaphragm, I assume that the coma signal is mostly sunlight scattered by dust, and that the dust is under uniform steady-state outflow from the nucleus. Under these circumstances, the coma brightness should scale directly with the diaphragm size (Gehrz and Ney 1992). This would produce a theoretical correction of $\Delta m_V = -2.5 \log (3'/1'.5) = -0.75$ magnitude, which is encouragingly close to the measured -0.6-magnitude difference that Hornoch *et al.* (2007) obtained between $3'$- and $1'.5$-diaphragm sizes in their own study. Accordingly, I apply a -0.7-magnitude correction to the Miles (2007) datum to obtain an equivalent visual $m_1 = m_V = -5.01 - 0.7 = -5.71$.

Converting to heliocentric magnitudes (see Sec. 3), the Miles (2007) and Hornoch *et al.* (2007) data respectively yield $H_1 = -5.28$ at $t - T = +1.8$ days (when $\theta = 31^\circ.9$), and $H_1 = -4.26$ at $t - T = +2.7$ days (when $\theta = 38^\circ.6$). These two CCD data points are plotted in Fig. 4 as crosses. Note that they are congruent with the visual m_1 estimates, and fall quite close to the scattering-model curves.

5. Discussion

5.1. The Baseline Brightness

At $m_0 = 5.53$ and $n = 4.52$ pre-perihelion, and $m_0 = 3.87$ and $n = 3.61$ post-perihelion, comet C/2006 P1 was an intrinsically bright comet, intermediate to C/1975 V1 (West) post-perihelion ($m_0 = 4.6$, $n = 3.6$; Meisel and Morris 1982), and 1P/Halley post-perihelion ($m_0 = 3.4$, $n = 3.0$) at its most recent return (Green and Morris 1987). The C/2006 P1 light curve is reasonably linear over a wide range of log r, although beyond $\log r \gtrsim 0.2$, there is an apparent steepening of the slopes for both pre- and post-perihelion (Fig. 1). These latter m_1 estimates, however, were made in telescopes at higher magnifications, and could be prone to underestimation due to "magnification artifact", or "aperture effect" (Morris 1973). Although I made no attempt to "correct" these higher magnification estimates (Sec. 3.1), had they been adjusted by, say, the formula $-1.25 \log (M/10)$ that was used in the analysis of the light curve of 96P/Machholz in Paper I (M = magnification, $M \geq 10$; Marcus 2007a), then these telescopic estimates of C/2006 P1 would have fallen closer to the regression lines in Fig. 1. Because the far majority of the m_1 observations of C/2006 P1 were by naked eye or binoculars at low magnification, and *only* these observations were used in the regression analysis, we can be assured that the photometric solutions derived in Sec. 3 are not significantly affected by magnification artifact. The solutions presented here for the baseline brightness by naked eye and binoculars therefore can be regarded as definitive for $\log r \lesssim 0.2$. For $\log r \gtrsim 0.2$, the comet's photometric behavior perhaps would be better characterized by (yet-unpublished) CCD studies.

Like comets C/1975 V1 and 1P, comet C/2006 P1 was slightly brighter after perihelion than before (Fig. 1). Such asymmetry often leads to a mathematical discontinuity in brightness when the separate pre- and post-perihelion solutions are projected to perihelion. Fortunately, the pre- and post-perihelion solutions for C/2006 P1 give heliocentric magnitudes at perihelion that differ by only 0.1 magnitude. It took very little adjustment of the photometric parameters in Sec. 3.2 to bring the solutions to exact convergence at perihelion on Jan. 12.80 TT. This made it possible to interpolate a continuous baseline light curve into the forward-scattering interval of Jan. 10.0-21.7, when $\theta \leq 90°$. This is important, for a continuous baseline is required to realistically analyze excursions due to forward-scattering.

5.2. The Forward-Scattering Brightness Surge

Using the interpolated baseline brightness power law as a reference, I next characterized the brightness behavior of C/2006 P1 in forward-scattering geometry. I demonstrated that the comet underwent a significant, broad-based brightness surge. Because the surge correlated so exquisitely to the scattering angle, θ, we can conclude with good confidence that it was the result of forward-scattering of sunlight by the fine dust particles in the comet's coma. In its amplitude (−2.1 magnitudes), time of peak ($\approx$ Jan. 14.3 UT), and shape, the brightness enhancement closely followed the prediction (Marcus 2007b, 2007c; Table 1) based upon the compound Henyey-Greenstein cometary light-scattering model introduced in Paper I (Marcus 2007a). Comet C/2006 P1's brightness behavior therefore can be considered to be a validation of this model.

C/2006 P1 owed its widespread naked-eye visibility in broad daylight to the forward-scattering enhancement of its brightness. Without this boost, the comet would have remained at a baseline m_1 of "only" mag −3 to −3.5, and would not have shone at the mag −5 to −6 reported near the time of minimum scattering angle on Jan. 14. At just 6° off the limb of the sun, without forward-scattering enhancement of its brightness, the comet might have been barely visible in daylight in telescopes, but not by naked eye.

The brightness surge is the most problematic portion of the C/2006 P1 light curve. Had we not accounted for it with a proper model, we would have obtained anomalous photometric parameters that would have overestimated n in equation 3 for post-perihelion. Any light curve that is intended to be a proxy for the true activity of the comet, rather than just a superficial phenomenological description of the brightness, *must* be corrected for the effect of forward-scattering in some way. Our model provides a proper correction for scattering effects in the m_1 estimates as $m_{\Phi(\theta)}$ in Table 1.

5.3. Precision and Accuracy of the Visual m_1 Estimates

5.3.1. The Extenuating Viewing Circumstances and Errors in the Estimates

The magnitudes of C/2006 P1 were estimated in difficult circumstances of low altitude and/or bright twilight or daylight. These extenuating conditions are reflected in the rather high standard deviations of ± 0.5 magnitude in the observations in the non-forward-scattering ($\theta > 90°$) portion of the light curve (Sec. 3.2), and ± 0.8 magnitude in the forward-scattering ($\theta \leq 90°$) portion (Sec. 3.3.3). Much of the ± 0.5-magnitude dispersion must be due to uncertainty in extinction corrections used for the estimates made at very low altitudes. The higher ± 0.8-magnitude dispersion likely reflects the relatively greater importance of the lack of a comparably bright comparison object when the comet was at its brightest at $m_1 \approx -6$ (the next brightest comparison object, Venus, was then at $m_V = -3.9$), as well as potential difficulties in observing in daylight circumstances near the glare of the sun. On the other hand, the comet was generally at higher altitude during the daylight observations, comparable with Mercury and Venus, so that uncertainty from atmospheric extinction was effectively negligible then. A third source of potential error was any truncation of the fainter outer coma by the very bright daylight sky background near the sun. This difference could lead to a *systematic* underestimation of m_1 for observations made in broad daylight and, to a lesser degree, in bright twilight. No such loss should occur for the sharply defined disks of Venus or Mercury. Indeed, coma diameters tabulated in the *ICQ* for the height of the comet's daylight visibility over Jan. 13-15 are very variable, ranging from 0'.5 to 5'. Some of this variance is no doubt due to the intrinsic imprecision expected with the small magnifications used via naked eye and low-power binoculars. However, to the extent that the smaller estimates are more severely truncated by increased sky-background brightness from haze (like comet dust, the haze particles also forward-scatter sunlight), then the m_1 brightnesses will also be underestimated. This would mean that the brighter daylight estimates plotted in Figures 3 and 4 are closer to the truth. Indeed, the somewhat-brighter CCD estimates (Fig. 4) seem to imply as much. A fourth source of potential error would be the inclusion of the bright proximal tail in the m_1 estimate, which ordinarily is regarded as pertaining only to the coma (for the less dusty and bright comets, at least). This would lead to a systematic overestimation of the coma brightness and of the scattering function, as was pointed out in Sec. 4.3 of Paper I (Marcus 2007a).

5.3.2. The Reality of the Surge

This statistical dispersion (or "noise") in the estimates, however, was not so high as to mask the significantly larger, systematic signal in the data set due to forward-scattering. At magnitude -2.1 ± 0.8 (σ), the amplitude of the surge was some 2.6 times (= 2.1/0.8) greater than the standard deviation of the observations taken in aggregate. If instead the -2.2 ± 0.4 standard-deviation value for the more prolific observers is considered (Secs. 3.3.2, 3.3.3), then the surge was some 5.5 times (=2.2/0.4) greater. The reality of the surge above the baseline brightness cannot seriously be doubted.

5.3.3. Correlation To CCD Magnitudes

Even if the surge confidently rises above the "noise level" of the baseline light curve, the precision and accuracy of the visual m_1 estimates still is a matter of legitimate concern. In this respect, the CCD photometric data in the two published studies analyzed in Sec. 4 are reassuring. When carefully reduced to correspond to the visually observed coma size and corrected for color differences, the CCD magnitudes are consonant with the visual m_1 magnitudes of the more prolific observers in Fig. 4, and conform remarkably well with the HG-scattering-model curves (Figures 3 and 4). Still, this concordance does not exclude the possibility of systematic bias in the visual m_1 data set. For example, the bright daylight sky might have truncated the coma size relative to what could have been perceived on a darker background, leading to a systematic underestimation of the magnitudes during daylight. This possibility could be assessed independently with photometry from satellite observations, which would essentially be unaffected by sky background. Grynko (2005) did this for comets 96P/Machholz and C/2004 F4 (Bradfield) when they were in forward-scattering geometry in the *SOHO* C3-coronograph field, but these data have their own potential problems (Marcus 2007a). At this writing, however, photometric data on C/2006 P1 from the *SOHO* (or from *SECCHI*) satellites have not been presented in the literature.

5.4. Limitations of the Method

Following equation 19 of Paper I (Marcus 2007a), I extracted the scattering function, $\Phi(\theta) = I(\theta, r, t)/I(90°, r_0, t_0)$, for C/2006 P1 solely from its visible light curve, $I(\theta, r, t)$, using heliocentric distance, r, and scattering angle, θ, but not time, t, as regression variables in equations 1-3 of this paper. An intrinsic limitation of this "visible light curve" method is that it does not easily deal with potential confounding brightness variations that depend on time, such as bursts in dust production, or with uncertainty in the secular variation of heliocentric magnitude with log r (the value of n in equation 3). Given its very tight correlation with the scattering angle (Figures 3 and 4), it is highly unlikely that that the brightness surge of C/2006 P1 could have been due in any significant way to a dust burst, but the possibility cannot be ultimately excluded using this method. Indeed, minor dust bursts — manifested as small spikes in the light curve and corresponding synchronic bands in the dust tail — complicated Grynko's (2005) photometric derivation of the forward-scattering behavior of C/2004 F4 (Bradfield) in the *SOHO*-satellite C3-coronograph field (Marcus 2007a). In the case of C/2006 P1, I defer assessment of the possibility of small outbursts to dust dynamicists who are more experienced at "reading" dust tail structures than am I.

In contrast to the "visible light curve" method, the "gold standard" method of simultaneous visible/infrared photometry for deriving $\Phi(\theta)$ does not suffer from dependence on t or r. The "visible/infrared method" utilizes two different measures of dust — the flux of sunlight that it scatters, $f_s(\theta)$, and the flux of sunlight that it absorbs and immediately re-radiates as heat, f_t (Gehrz 1997, Marcus 2007a). Because $f_s(\theta)$ is dependent upon the scattering angle, but f_t is not, their ratio, $R(\theta) = f_s(\theta)/f_t$, leads directly to the scattering function, $\Phi(\theta) = R(\theta)/R(90°)$ (equations 20 and 21 of Paper I). Because time-dependent dust bursts or r-dependent secular changes in dust production affect both $f_s(\theta)$ and f_t *in the same way*, their *ratio*, and the scattering function that derives from this ratio, are independent of r and t. Through this virtue, the "visible/infrared method" escapes the confounding vagaries and uncertainties to which the "visible light curve" method — which relies on scattered-sunlight measurements alone — is prone. The scattering functions for comets C/1927 X1, C/1975 V1, and C/1980 Y1 were obtained by the "visible/infrared method" (see Paper I). Unfortunately, I am currently unaware that any simultaneous visible/infrared photometry of C/2006 P1 was taken in daylight when this comet was in forward-scattering geometry.

5.5. Comparison of C/2006 P1 with the Great Daylight Comet C/1927 X1

In many respects, comet C/2006 P1 is remarkably similar to the great daylight comet C/1927 X1 (Skjellerup-Maristany), which also ventured into forward-scattering geometry and experienced pronounced brightness enhancement as a result (Marcus and Seargent 1986; Marcus 1997; Marcus 2007a). In orbital characteristics, the eccentricities of the two comets were each very close to 1, and their perihelion distances were nearly identical ($q = 0.176$ AU for C/1927 X1). Each was in forward-scattering geometry at perihelion and suffered poor elongation through much of its apparition. In physical characteristics, each sported a strong dust tail visible in daylight, and their absolute magnitudes were comparable, with $m_0 \approx 5.5$ for C/1927 X1 (Marcus 2007d). On 1927 Dec. 16.8 UT, the Slipher brothers at Lowell Observatory (Flagstaff, Arizona) observed C/1927 X1 at a scattering angle near $\theta = 30°$, comparable to $\theta_{\rm min} = 31°$ for C/2006 P1. They recorded that "the experienced observer saw it readily during the day by merely extending the hand to shadow the eyes from the sun, which was only about five degrees southwest of the comet" (Slipher and Slipher 1928). The comet was still visible to them in daylight by naked eye on the next day at $\theta \approx 45°$. The similarity of the daylight visibilities of comets C/2006 P1 and C/1927 X1 at comparable θ, ϵ, Δ, and r is qualitative evidence that the two comets were of comparable intrinsic brightness.

However, unlike C/2006 P1, comet C/1927 X1 ventured much more deeply into forward-scattering geometry, reaching $\theta_{\rm min} = 6^\circ\!.5$ on 1927 Dec. 15.4 UT (Marcus 2007a). Twelve hours later, on Dec. 15.92, at $\theta = 11^\circ\!.7$, this comet blazed so brightly that it was *casually* discovered in daylight by a lady in a hiking party high in the clear air of the Sierra Madre mountains, with the sun shadowed by a peak (Goodhue 1928). Had C/2006 P1 reached this small scattering angle, the HG scattering model (Marcus 2007a) predicts a brightness enhancement of $m_{\Phi(\theta)} = -6.8$ due to forward-scattering. With a baseline brightness of $m_1 \approx -3.4$ at perihelion, C/2006 P1 would have become as bright as $m_1 \approx -3.4 - 6.8 = -10.2$! At this brightness, C/2006 P1, too, would have been casually discoverable by novices in broad daylight just several degrees off the limb of the sun.

6. Conclusions

From this study of the visual m_1 magnitude estimates published in the *ICQ*, I conclude:

1) C/2006 P1 (McNaught) was an intrisically bright comet, somewhat brighter after perihelion than before. For $\log r \lesssim 0.2$, the light curve is well fitted by the photometric parameters $m_0 = 5.71$, $n = 4.59$ for the pre-perihelion span, and $m_0 = 3.83$, $n = 3.61$ for the post-perihelion span.
2) The comet underwent a major surge in brightness due to forward-scattering of sunlight by small dust grains.
3) The comet's widespread visibility in broad daylight in binoculars and by naked eye was due to the forward-scattering enhancement of its brightness.
4) In its amplitude, timing, and shape, the surge closely followed the cometary scattering model presented in Paper I (Marcus 2007a). In particular, series of observations by individuals in the forward-scattering interval, as well as the two analyzed CCD magnitudes, follow the model shape very closely.
5) Closely following predictions (Marcus 2007b, 2007c), the light curve of C/2006 P1 validates my cometary light-scattering model. The model (Marcus 2007a) can be used to accurately analyze and predict the light curves of comets in forward-scattering geometry.

Acknowledgements. It is a privilege to have worked with the *ICQ* database of cometary photometric observations, and to acknowledge this invaluable resource in cometary astronomy. I am grateful to the many observers who made this study possible by contributing their observations of C/2006 P1 to this archive. Giovanni Sostero (Remanzacco, Udine, Italy) and Richard Miles (Dorset, U.K.) kindly read the manuscript and provided valuable guidance on the reduction of the CCD photometry. I also thank Brian G. Marsden (Smithsonian Astrophysical Observatory) for his comments on the manuscript. Above all, I thank the Editor for his many suggestions for improvement of not only this, Paper II, but also Paper I (*ICQ* **29**, 39) in this series on forward-scattering and comet brightness.

REFERENCES

Bortle, J. E. (1997). "Great Comets in History", *Sky Telesc.* **93**(1), 44.

Cox, A. N. (2000), ed. *Allen's Astrophysical Quantities*, 4th edition (New York: Springer-Verlag).

Gehrz, R. D. (1997). "Infrared Observations of Comets", *ICQ* **19**, 55.

Gehrz, R. D.; and E. P. Ney (1992). "0.7 to 23 μm Photometric Observations of P/Halley 1986 III and Six Recent Bright Comets", *Icarus* **100**, 162.

Goodhue, J. E. (1928). "Skjellerup's Comet Discovered Anew", *Pop. Astron.* **36**, 135.

Green, D. W. E. (1992). "Magnitude Corrections for Atmospheric Extinction", *ICQ* **14**, 55.

Green, D. W. E., ed. (2006). "Comet C/2006 P1 (McNaught)", *IAU Circular* 8737, 2006 Aug. 8.

Green, D. W. E., ed. (2007). "Observations of Comet C/2006 P1", *ICQ* **29**, 66-82.

Green, D. W. E.; and C. S. Morris (1987). "The Visual Brightness Behavior of P/Halley During 1981-1987", *Astron. Astrophys.* **187**, 560.

Grynko, Y. (2005). "Light Scattering by Cometary Dust Particles with Sizes Large Compared to the Wavelength of Light", Ph.D. dissertation, University of Göttingen (World Wide Web URL `http://www.mps.mpg.de/solar-system-school/alumni/grynko.pdf`), 2005 April (*Note*: URL address changed from that given in Marcus 2007a).

Hornoch K.; J. Srba; and E. Brezina (2007). "Daylight Photometry of C/2006 P1", *ICQ* **29**, 6.

Mallama, A.; D. Wang; and R. A. Howard (2006). "Venus Phase Function and Forward Scattering from H_2SO_4", *Icarus* **182**, 10.

Marcus, J. N. (1997). "Great Comet Geometry", *Sky Telesc.* **93**(4), 8.

Marcus, J. N. (2007a). "Forward-Scattering Enhancement of Comet Brightness. I. Background and Model", *ICQ* **29**, 39.

Marcus, J. N. (2007b). "C/2006 P1 (McNaught)", *IAU Circular* 8793, 2007 Jan. 11.

Marcus, J. N. (2007c). "Updated Brightness Forecast for Comet C/2006 P1 (McNaught) in Daylight with Predicted Forward-Scattering Brightness Boost", Astrosite Groningen (`http://shopplaza.nl/astro`), Jan. 2.

Marcus, J. N. (2007d). "The First Infrared Observations of a Comet: Carl Lampland's Radiometry of C/1927 X1", in preparation.

Marcus, J. N.; and D. A. J. Seargent (1986). "Dust Forward Scatter Brightness Enhancement in Previous Apparitions of Halley's Comet", in *Proc. 20th ESLAB Symposium on the Exploration of Halley's Comet*, ESA SP-250, ed. by B. Battrick, E. J. Rolfe, and R. Reinhard (Noordwijk: ESA/ESTEC), Vol. 3, 359-362.

Meisel, D. D.; and C. S. Morris (1982). "Comet Head Photometry: Past, Present, and Future", in *Comets*, ed. by L. Wilkening (Tucson: University of Arizona Press).
Miles, R. (2007). "Daytime Photometry of Comet McNaught", *J. Brit. Astron. Assoc.* **117**, 92-93.
Morris, C. S. (1973). "On Aperture Corrections for Comet Magnitude Estimates", *Publ. Astron. Soc. Pacif.* **85**, 470-473.
Slipher, V. M.; and E. C. Slipher (1928). "Daylight Observations of Skjellerup's Comet at the Lowell Observatory", *Pop. Astron.* **36**, 300.
Sostero, G. (2007a). "Updated Lightcurve of C/2006P1", Comets-ml e-mail discussion group, message no. 11539 (`http://tech.groups.yahoo.com/group/comets-ml/message/11539`)
Sostero, G. (2007b). Personal e-mail communications, 2007 May 2 and Nov. 28.

Φ Φ Φ

Photometry of Deep-Sky Objects

All of the new data below are from Jose Carvajal Martinez (Madrid, Spain). The previous batch of photometry of *ICQ*-recommended deep-sky objects appeared in the April 2006 issue, pp. 45-47. We encourage other regular comet photometrists to contribute both visual and CCD magnitudes of the recommended deep-sky objects; additional information is given in *ICQ* **20**, 98; **16**, 129; and **26**, 3.

See also the *ICQ* website: `http://www.cfa.harvard.edu/icq/icqproject.html`.

◇ ◇ ◇

Visual Data

NGC 221

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 12 10.84       M  8.2  S    32    L  5    76     1.5     7/                  MAR02
```

NGC 936

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 12 10.89       S 10.8  S    32    L  5    76     0.75    2/                  MAR02
```

NGC 1068

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 12 10.89       M  9.2  S    32    L  5    76     1.5     5/                  MAR02
```

NGC 1952

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 12 10.90       S  7.2  S    32    L  5    76     4       0                   MAR02
```

NGC 2068

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 12 10.91       M  7.3  S    32    L  5    76     4       0                   MAR02
```

NGC 6356

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 07 28.90       M  8.8  TI   10.5  M 14    57     2.5     4/                  MAR02
```

NGC 6712

```
DATE (UT)        N MM MAG.  RF   AP.   T F/   PWR    COMA     DC    TAIL    PA    OBS.
2006 07 28.91       M  8.9  TI   10.5  M 14    57     3       3                   MAR02
2006 10 14.82       M  8.9  TI   32    L  5    76     4       3/                  MAR02
```