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Relative photometry of the possible main-belt comet (596) Scheila after an outburst

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Abstract. In this paper we present results from photometric observations of (596) Scheila during its recent outburst. This one was the first time to observe the main-belt comet or a possible collision of two asteroids at the Skalnaté Pleso Observatory. The main aim of our observations was to determine whether and, if so, how much the rotational period and the amplitude were changed by the outburst or collision with respect to the published results by Warner in 2006.

Key words: asteroid – main-belt comet – photometry

1. Introduction

Main-belt asteroid (596) Scheila (1906 UA) was discovered by A. Kopff in 1906 from Heidelberg. Classified as a T-type, it is a large body with a diameter of 113 km and a visual geometric albedo of 0.038 (Tedesco *et al.*, 2002). With semimajor axis 2.928 AU, eccentricity 0.165, and inclination 14.7° it lies in the outer asteroid belt. Similarly, Scheila is a typical asteroid due to the value of the Tisserand parameter with respect to Jupiter, $T_J = 3.21$.

The observations taken with the 0.68-m Catalina Schmidt telescope between UT 2010 December 11.44 and 11.47 showed cometary activity (Larson, 2010). Archival Catalina observations showed that the activity was triggered before December 3, when Scheila appeared as a slightly diffuse object ($V = 13.2$ mag). With a main-belt orbit ($T_J > 3$) and a comet-like morphology, Scheila satisfies the definition of a main-belt comet (MBCs; Hsieh and Jewitt 2006). Scheila is now the seventh known example of this specific class of the objects in the Solar System. The currently known MBCs are 133P/Elst-Pizarro, 176P/LINEAR, 238P/2005 U1 (Read), P/2008 R1 (Garradd), P/2010 A2 (LINEAR), and P/2010 R2 (La Sagra) (see Fig. 1). As the largest one was a suitable candidate for first main-belt comet observations performed at the Skalnaté Pleso Observatory.

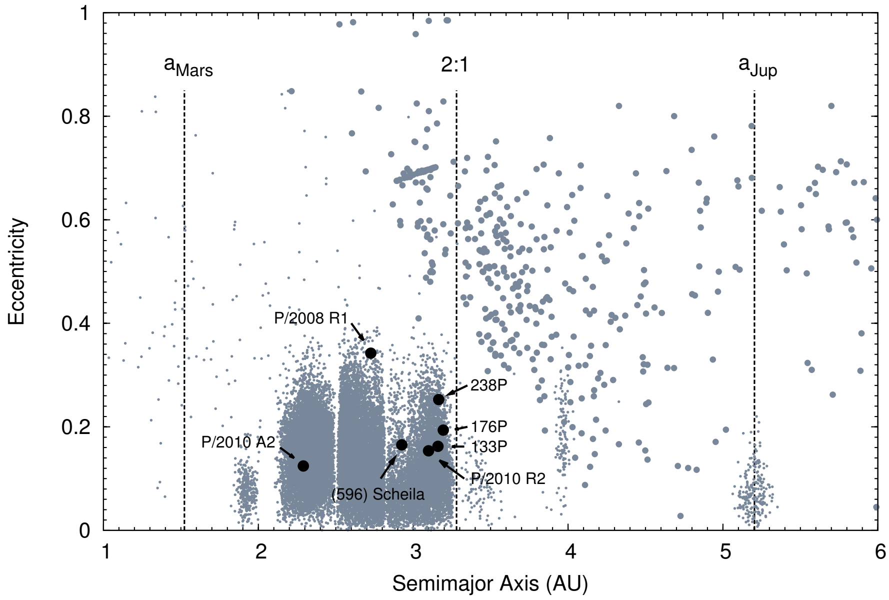

Figure 1. The semimajor axis vs. eccentricity plane with a distribution of the known MBCs (big black circles) and the corresponding distribution of asteroids (grey dots) and comets (bigger grey dots) for comparison. Dashed lines show the semimajor axes of the orbits of Mars, Jupiter and the location of the 2:1 mean-motion resonance with Jupiter.

2. Observations and results

The first photometrical result of Scheila was performed by Behrend (2006). He reported on his website (URL in references) a rotational period of 19.081 h. However, it was given a $U = 1$ rating as a result based on fragmentary a lightcurve and may be completely wrong. The data obtained at PDO (Warner, 2006) shows that the rotational period of 15.848 h is a more likely solution.

We performed photometric observations in 7 nights (see positions on the orbit in Fig. 3) between 2010 Dec. 15 and 2011 Jan. 9 with a 0.61-m f/4.3 reflector at the Skalnaté Pleso Observatory. Three-minute CCD frames were achieved by SBIG ST-10XME with 3×3 binning and resolution 1.6 arcsec/px (Fig. 2). We applied the standard calibration with dark and flatfield frames with IRAF tools. The period and amplitude analysis was performed following the procedure described by Harris *et al.* (1989). All result data in the composite lightcurve is relative and light-time corrected (total 362 points in the lightcurves).

The observational circumstances and aspect data for the asteroids on each observing night are listed in Table 1. The table gives the date of observation

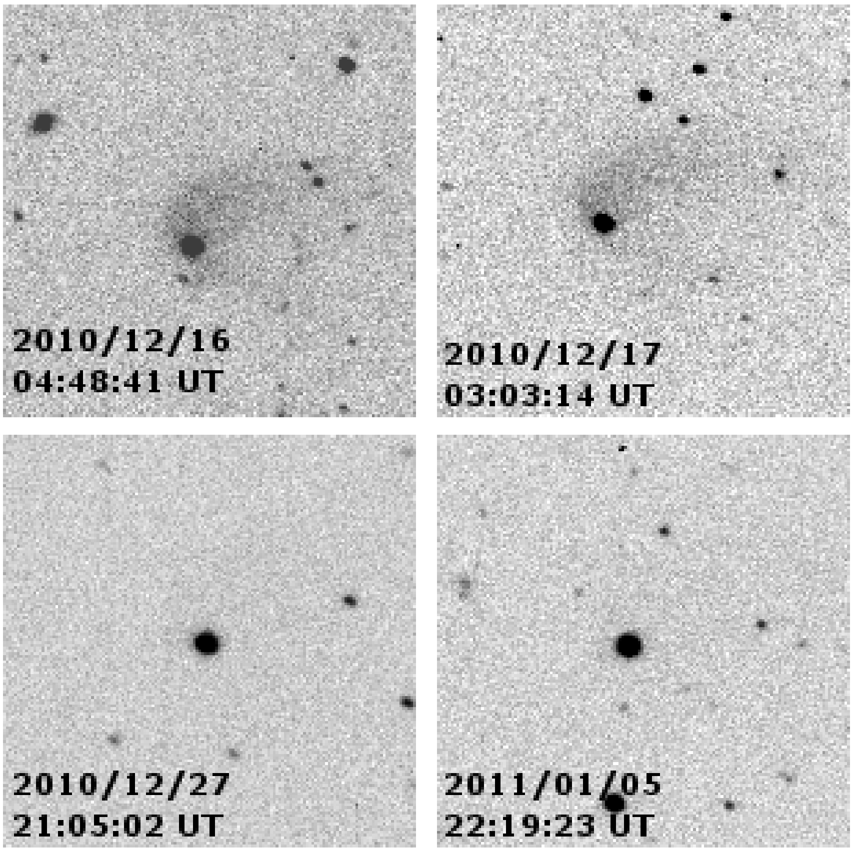

Figure 2. Three-minute R band images of (596) Scheila taken in four nights (times are on each of them). Images are cropped and slightly zoomed. North is top and east left.

given to the nearest tenth of a day to the midtime of the observational interval, the heliocentric and geocentric distances, the solar phase angle, and J2000.0 ecliptic coordinates of the phase angle bisector (PAB, that is the vector connecting the center of Scheila and the midpoint of the great circle arc between the sub-Earth and sub-solar points; for more information on the PAB, see Magnusson *et al.* (1989)).

We found a rotational period of 15.855 ± 0.002 h and a low amplitude of 0.08 mag using the 5th order Fourier fit on our 7 partial lightcurves (Fig. 4). These results are comparable with Warner's solution from 2006. In Fig. 5 it is shown a periodogram on which our and Warner's period is more probable than Behrend's incorrect 19-hr solution.

Table 1. The aspect data for (596) Scheila observed at the Skalnaté Pleso Observatory; r and Δ are the heliocentric and geocentric distances, respectively, α is the phase angle, and L_{PAB} and B_{PAB} are the ecliptic coordinates of the phase angle bisector. N_p stands for a number of the lightcurve points in each night and Coverage represents the time in hours how much of the rotational phase is covered.

Date [UT]	r [AU]	Δ [AU]	α [deg]	L_{PAB} [deg]	B_{PAB} [deg]	N_p	Coverage [h]
2010 12 15.0	3.104	2.496	16.0	133.8	13.7	47	5.1
2010 12 16.1	3.102	2.482	15.8	133.9	13.8	50	5.9
2010 12 17.1	3.101	2.469	15.7	133.9	13.9	45	5.4
2010 12 27.9	3.085	2.338	13.7	134.7	14.5	47	5.1
2011 01 04.0	3.074	2.263	12.1	135.0	15.0	88	9.0
2011 01 06.0	3.071	2.244	11.6	135.1	15.1	57	7.9
2011 01 09.9	3.065	2.209	10.7	135.1	15.3	28	3.9

From our observations we find that especially between 2010 Dec. 17 and Dec. 27 an apparent morphology of Scheila was changed (see Fig. 2). Before the significant fan tails are not visible on our CCD images. Unfortunately, we cannot descibe how rapidly the activity decreased and how the morphology changed within these 10 days.

3. Conclusion

Between 2010 and 2011 we performed observations in 7 nights at the Skalnaté Pleso Observatory to obtain a relative photometry of the possible main-belt comet (569) Scheila. The main aim of our observations was to determine whether and, if so, how much the rotational period was changed by an outburst with respect to the data published by Warner in 2006. We found that ours and a recent solution found by Warner (2006) are very similar, with no significant change.

Shortly after the discovery of significant and unexpected activity of the comet-like asteroid (596) Scheila Bodewits *et al.* (2011) and Jewitt *et al.* (2011) published possible reasons of the activity. Jewitt *et al.* (2011) considered a few mechanisms of that activity, but two of them cannot be applied to Scheila, as a result of its large size and slow rotation: (i) mass loss through a rotational instability is ruled out by the measured rotational period of ~ 15.8 h, which greatly exceeds the critical period at which the centripetal acceleration at the surface of a sphere equals the gravitational acceleration; (ii) the ejection of grains through

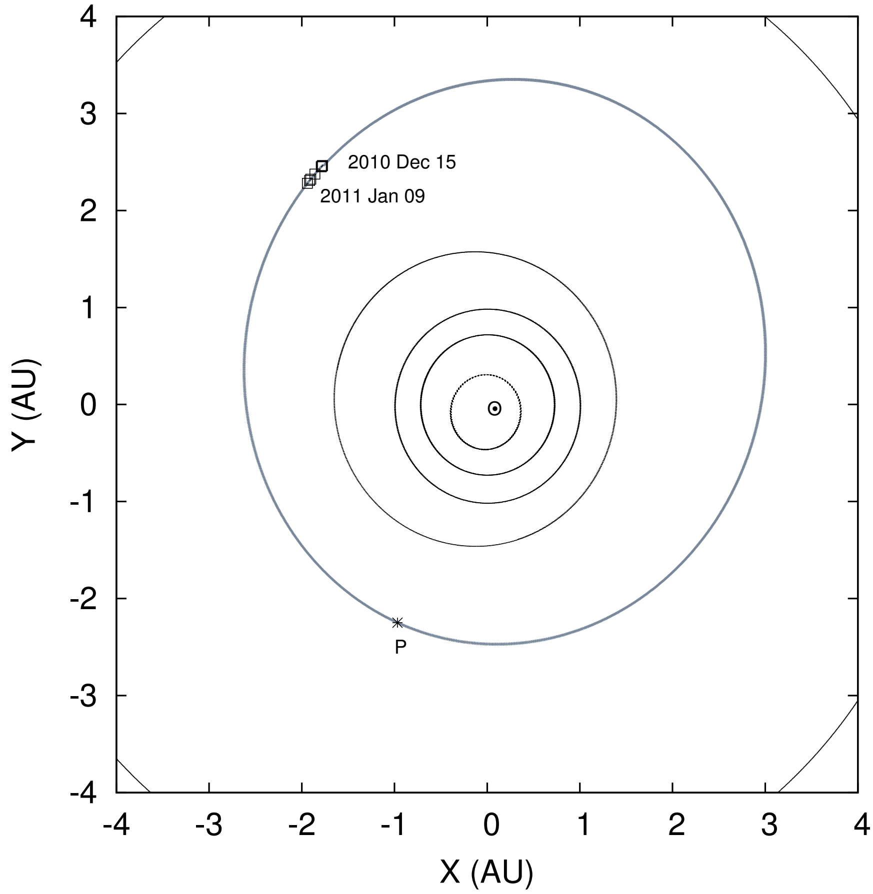

Figure 3. Plot of Scheila's orbit projected in the ecliptical plane. Small squares correspond to our observation dates from 2010 Dec. 15 to 2011 Jan. 09. P stands for the position of the perihelion of Scheila's orbit. The plot includes the orbits of the terrestrial planets and Jupiter for comparison.

electrostatic charging of the surface can be ruled out since the speeds generated electrostatically (typical speeds are $\sim 1\,\mathrm{m\,s^{-1}}$, but in the case of Scheila the escape speeds are $\sim 60\,\mathrm{m\,s^{-1}}$). The simplest explanation is that Scheila ejected material after being struck by another, much smaller asteroid. This is an explanation proposed elsewhere for the inner-belt MBC P/2010 A2 (Jewitt *et al.*, 2010). From images of (596) Scheila obtained by the *HST* it was found that the impact could be caused by a $\sim 35\,\mathrm{m}$ projectile. The resulting crater on Scheila would have a diameter $\sim 400\,\mathrm{m}$.

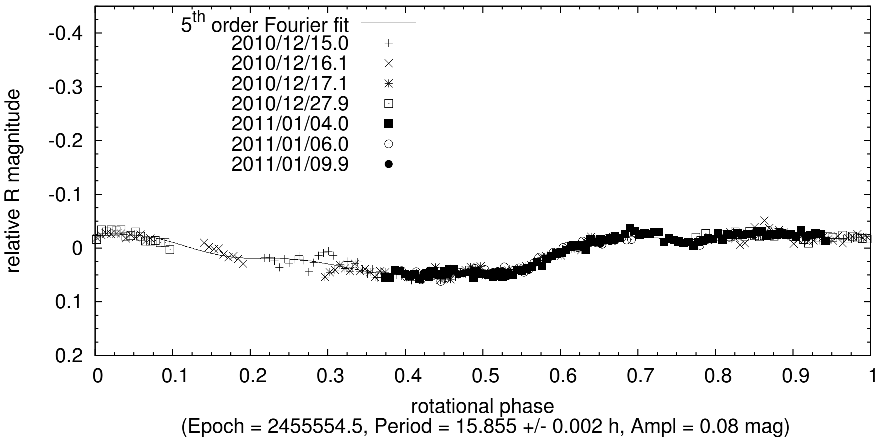

Figure 4. The composite lightcurve of Scheila from 7 nights.

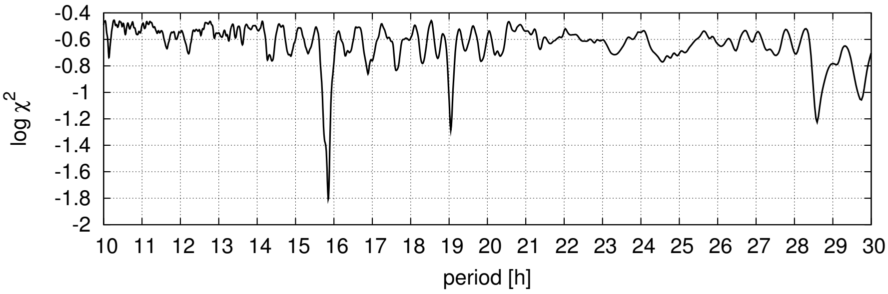

Figure 5. A plot of the sum of square residuals vs. period for Scheila.

Using optical and UV images and spectroscopy from *Swift* UVOT Bodewits *et al.* (2011) did not detect any of the gases that are typically associated with either hypervolatile activity thought responsible for cometary outbursts (CO^+, $CO_2{}^+$), or for any volatiles excavated with the dust (OH, NH, CN, ...). They estimate that 6×10^8 kg of dust (assuming 1 μm sized particles) was released with an ejection velocity of $57\,\mathrm{m\,s^{-1}}$ and they conclude that Scheila was impacted by another main-belt asteroid with a diameter of approx. 100 m.

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