

A NEW INVESTIGATION OF THE ROTATION PERIOD AND SIZE OF 71 NIOBE

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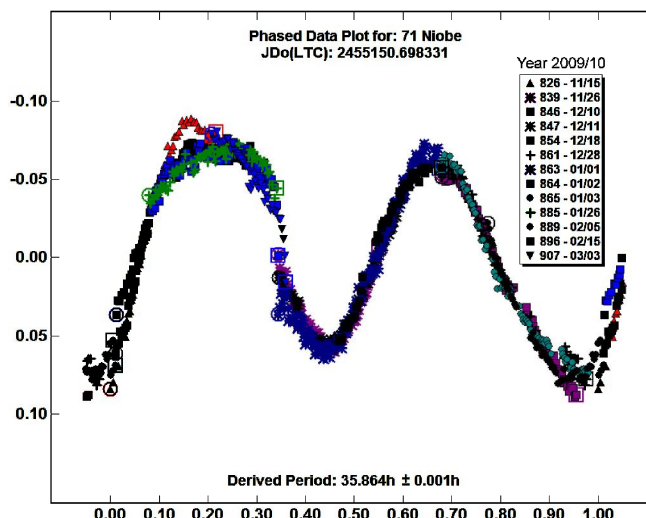
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New lightcurves of 71 Niobe show a synodic rotation period of 35.864 ± 0.001 hours, amplitude 0.15 ± 0.02 magnitudes. Six isolated occultation chords have lengths 13 – 76 kilometers. This makes a size significantly larger than the IRAS value of 87 km, and a rotation period near 72 hours allowed by the photometric data, extremely unlikely.

Among the lower numbered asteroids 71 Niobe has been one of the most difficult to obtain a secure rotation period because it is both long and highly Earth commensurate. Early investigations were hampered by a shortage of telescope time and produced only sparse data sets. These earlier period determinations include: Lustig and Dvorak (1975), 11.21 hours; Barucci and Fulchignoni (1984) were unable to find a period; Harris and Young (1989), 14.38 hours; Piironen et. al. (1998), 14.34 hours. Warner et. al. (2006) produced the first dense lightcurve which showed a period of 35.6 hours, amplitude 0.22 magnitudes. Sada and Warner (2007) extended the interval of the 2006 observations from two weeks to two months and improved the period to 35.81 hours. Shepard et. al. (2008) published radar observations of 71 Niobe from Arecibo in the same time frame as the lightcurves by Sada and Warner (2007). Assuming $P = 35.8$ h, the observed 2380 MHz radar echo Doppler bandwidth of $B = 75 \pm 15$ Hz indicates a maximum dimension (diameter along the major axis) of 97 ± 20 km if observed at an equatorial aspect (larger if observed at mid- or high latitudes). This is consistent with the IRAS survey diameter of 87.3 ± 1.7 km by Tedesco et. al. (1989). However, if the rotation period is doubled to the alternate 71.7 h, the diameter must double to 200 km (M. Shepard, personal communication).

A maximum elongation 2009 Dec. 31 at declination +44 degrees provided an opportunity for a new investigation at the Organ Mesa Observatory. Equipment consists of a 35 cm Meade LX200 GPS S-C, SBIG STL-1001E CCD, 60 s unguided exposures through a R filter, differential photometry only. Lightcurve analysis is by *MPO Canopus*. Because of the large number of data points they are binned for the lightcurve in sets of 5 with a maximum interval of 10 minutes between sets. With an expected period exactly 3/2 that of Earth, lightcurves obtained at intervals of 3 days or any multiple thereof should be identical except for variations caused by changing phase angle. The combination of long nights near the winter solstice and far northerly declination provided an opportunity to obtain single night lightcurves of nearly 12 hours duration at opposition. Except for very small gaps between the three segments, near 100% phase coverage of the lightcurve could be obtained on three consecutive nights from a single observatory. Sessions accomplishing this goal were performed 2010 Jan. 1, 2, 3, although observations were started 2009 Nov. 15 and continued until 2010 Mar. 3, on a total of 13 nights, to refine the period to 35.864 ± 0.001 hours, amplitude 0.15 ± 0.02 magnitudes.

A period near 71.73 hours, with likely 4 maxima and minima per cycle, is also allowed by the photometric data, with half of the lightcurve unobservable from any single location. Doubling the



rotation period also doubles the diameter obtained from the radar observations by Shepard et. al. (2008) to near 200 km, a severe conflict with the diameter as found by IRAS. Furthermore, 6 stellar occultations by 71 Niobe (asteroid occultation website 2010) have been observed in recent years. For five of these only a single chord was observed: 13 km 2004 Nov. 2; 54 km 2005 Feb. 10; 72 km 2005 Nov. 10; 76 km 2007 May 15; 69 km 2010 Jan. 19. For the sixth, 2009 Aug. 24, three positive chords of lengths 62 km, 21 km, 15 km, respectively, with 27 km across the occultation path between the largest and smallest occultation chords, were observed. These constrain the size to not much larger than 76 km diameter. For a spherical body in equatorial aspect, a chord length of $\frac{1}{2}$ diameter occurs at 60 degrees N or S latitude. This is in cross section $r \sin 60^\circ = 0.866 r$ from the equator, where r is the radius. For a chord at random distance from the equator the probability of a chord length $< r = \frac{1}{2}$ diameter is 0.134. This probability also holds for an ellipsoidal body, and approximately for a real asteroid so long as the shape is not bizarre. Nothing in any of the published lightcurves suggests a bizarre shape on a global scale. Of the 6 occultation events, all have chord length ≤ 76 km. The probability of a diameter 152 km is therefore $0.134^6 = 5.79 \times 10^{-6}$, and of a larger diameter is even smaller. This is strong evidence for a diameter not much larger than 76 km, and effectively rules out a 194 km diameter and from the radar measured bandwidth a rotation period near 72 hours.

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ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2009 AUGUST-NOVEMBER

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Photometric data for 24 asteroids were collected over 22 nights of observing during 2009 August through November at the Oakley Southern Sky Observatory. The asteroids were: 1654 Bojeva, 2013 Tucapel, 2216 Kerch, 2219 Mannucci, 3045 Alois, 3422 Reid, 3819 Robinson, 5832 Martaprincipe, 5914 Kathywhaler, 6066 Hendricks, 6734 Benzenberg, (7774) 1992 UU2, (9199) 1993 FO1, 10094 Ejikato, 11064 Dogen, 13123 Tyson, (13709) 1998 QE13, (14162) 1998 TV1, (19732) 1999 XF165, (20762) 2000 EE6, (27181) 1999 CX1, (29251) 1992 UH4, (29742) 1999 BQ12, and (55760) 1992 BL1.

Twenty-four asteroids were observed from the Oakley Southern Sky Observatory in New South Wales, Australia, near Coonabarabran on the nights of 2009 August 10-15, 17-18, and 26-27; October 7-9 and 20-24; and November 9-11, and 14. We were able to find lightcurves for 15 asteroids, none of which had previously published periods. We were unable to determine a period from our data on the remaining 9 asteroids.

Asteroids were selected based on their position in the sky about one hour after sunset. Throughout the selection, asteroids without previously published periods were given higher priority than asteroids with known periods. For the 22 nights of observing, a 0.5-m f/8.4 Ritchey-Chretien optical tube assembly mounted on a Paramount ME was used with a Santa Barbara Instrument Group STL-1001E CCD camera and a clear filter. The image scale was 1.2 arcseconds per pixel. Exposure times varied between 90 and 240 seconds. Calibration of the images was done using master twilight flats, darks, and bias frames. All calibration frames were

created using *CCDSOFT*. *MPO Canopus* was used to measure the processed images.

As far as we are aware, these are the first reported lightcurves for those 15 asteroids where we found a period and amplitude. No repeatable pattern was found for 1654 Bojeva, 2219 Mannucci, 3045 Alois, 3819 Robinson, 5832 Martaprincipe, 5914 Kathywhaler, 6734 Benzenberg, (13709) 1998 QE13, or (14162) 1998 TV1. Our data for these asteroids were so noisy that we feel comfortable publishing only the amplitudes. Results from the asteroids are listed in the table below.

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