

**(29606) 1998 QN94:
A BINARY ASTEROID IN A
SELF-SYNCHRONOUS ORBIT**

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We report that asteroid (29606) 1998 QN94 is a binary asteroid. The primary lightcurve has a period of 2.8965 ± 0.0001 h and an amplitude 0.17 mag. The orbital period of the secondary matches what we deduce as its own rotation period: 19.666 ± 0.004 h.

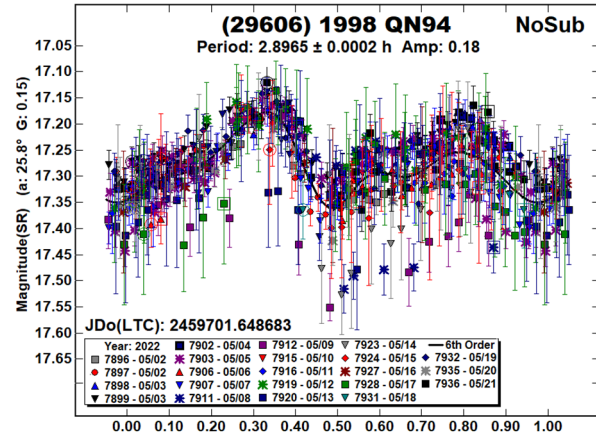
Observations of this member of the Phocaea dynamical family (Nesvorný, 2015; Nesvorný et al., 2015) were made at the Center for Solar System Studies in 2022 May. Either a 0.35-m *f*/10 Schmidt-Cassegrain and FLI Microline CCD camera or a 0.4-m *f*/10 Ritchey-Chretien and FLI Proline CCD camera was used to acquire images. Both cameras use a KAF-1001E chip, which has a $1024 \times 1024 \times 24\mu\text{m}$ array of pixels.

All lightcurve observations were unfiltered since a clear filter can cause a 0.1–0.3 mag loss. The exposure duration ranged from 180 to 360 seconds, depending on the asteroid’s brightness and sky motion.

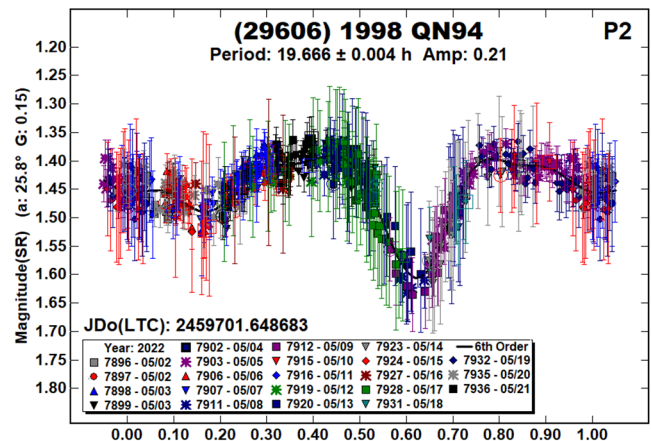
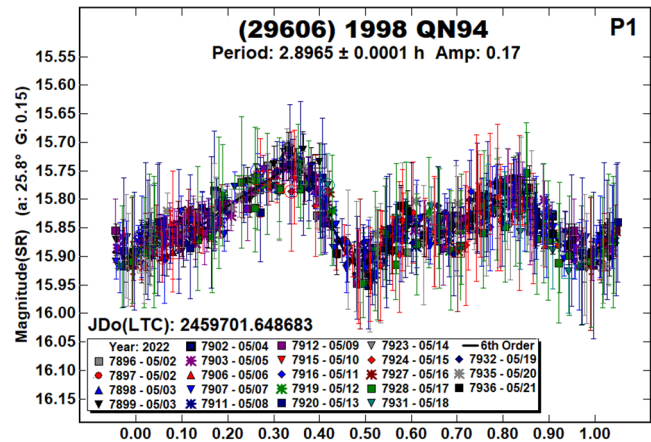
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. To reduce the number of adjusted nightly zero points and their amounts, the analysis of the data used the ATLAS catalog r' (SR) magnitudes (Tonry et al., 2018). The rare zero-point adjustments of $\geq \pm 0.03$ mag may be related in part to using unfiltered observations, poor centroiding of the reference stars, not correcting for second-order extinction, or selecting a star that is an unresolved pair.

The Y-axis values are ATLAS SR “sky” (catalog) magnitudes. The two values in the parentheses are the phase angle (α) and the value of G used to normalize the data to the comparison stars used in the earliest session. This, in effect, corrected all the observations to seem to have been made at a single fixed date/time and phase angle, leaving any variations due only to the asteroid’s rotation and/or albedo changes. The X-axis shows rotational phase from -0.05 to 1.05. If the plot includes the amplitude, e.g., “Amp: 0.65”, this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

No previous periods were found in the asteroid lightcurve database (Warner et al., 2009). Quickly it became apparent that there were deviations from the Fourier curve suggestive of a binary asteroid. Because of interference from high winds and a near Full Moon, the error bars for several sessions were larger than desired. The plot labeled “NoSub” shows the raw plot with suggestions of a secondary frequency in several sessions.



A search for a secondary frequency was done using the dual-period search feature in *MPO Canopus*. A primary period of 2.8965 ± 0.0001 h (Plot “P1”) and a secondary period of 19.666 ± 0.004 h (Plot “P2”) were found.



Number	Name	2022 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp/DsDp
29606	1998 QN94	05/02-05/21	25.9, 30.1	192	26	2.8965	0.0001	0.17	0.01	PHO
						19.666	0.004	0.21	0.02	≥ 0.29

Table II. Observing circumstances. The first line gives the primary or dominant period for the system. The additional line gives the secondary period(s). The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude (see Harris et al., 1984).

After 21 May, the lightcurve started to evolve as, over the course of observations, the phase angle increased from 26° to 30° . On the last night of observations, the mutual event (deep minimum) at phase 0.65 disappeared, leaving just the secondary lightcurve from the elongation of the satellite.

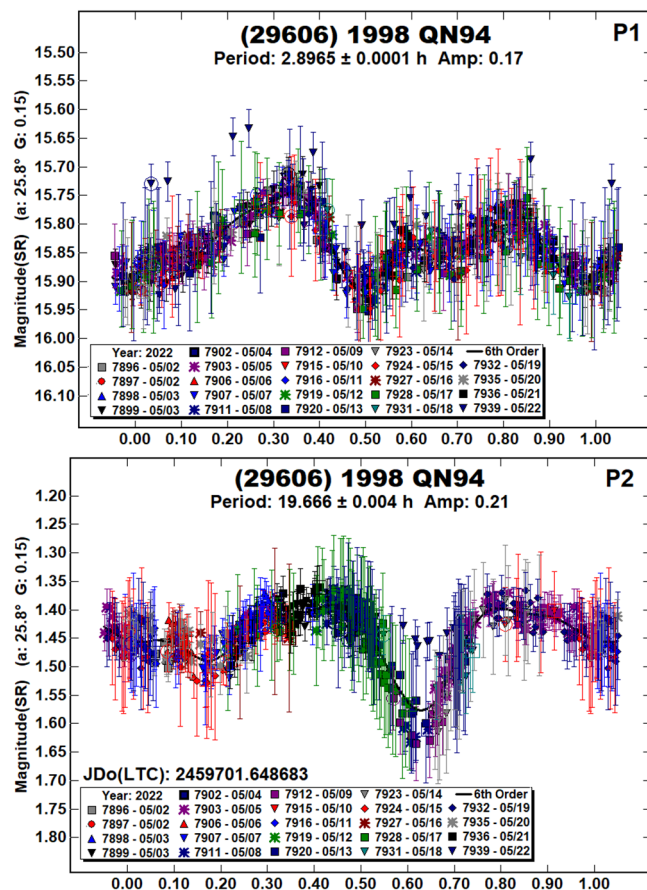
Looking ahead, the 2026 July ($16.9, +22^\circ$) is the next good chance for observations. However, the asteroid will be embedded in the galactic bulge at that time.

Acknowledgements

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References

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This lightcurve evolution, producing both mutual events, which eventually vanished, and what we deduce as the secondary's own rotation, allows us to determine both the secondary's orbital period and the secondary's rotational period. These values appear to be synchronous, i.e., the satellite's orbital period matches its 19.666 ± 0.004 h rotation. The satellite-to-primary effective diameter ratio is $Ds/Dp \geq 0.29 \pm 0.03$.