Neptunian Moon Nereid's Rotation and Irregular Flaring

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Nereid is in several ways the weirdest of all the moons in our Solar System. It has a 360 day orbital period and the most eccentric orbit ($e = 0.75$). Nereid's extreme orbit is likely due to a unique origin as an almost-ejected inner moon (Schaefer et al. 2009). The central mystery of Nereid is that four different groups have seen large- (over 1 mag) amplitude irregular variations on time scales of hours to weeks, but these same groups have seen no fluctuations at other times. Four detailed models have been published to explain this wildly changing variability as due to (**A**) *a binary moon*, (**B**) *chaotic rotation*, (**C**) *forced precession*, and (**D**) *sporadic outgassing*, but none of these have any strong evidence. The trouble is that the large-amplitude variations have never been definitively observed with any reasonable time resolution, despite our monitoring of Nereid for 367 nights since 1987 (Schaefer et al. 1988; 2001; 2008)

A related mystery is the rotation period of Nereid. When *Voyager* passed by Neptune, it acquired only one very-distant picture of Nereid just 4 pixels across, not enough to determine accurately shape, size, or rotation period. Ground-based attempts to find a rotation period have resulted in claims to see a ~0.03 mag amplitude periodic modulation at 11.5 hours (Grav et al. 2003; Terai & Itoh 2013), while we see a ~0.045 mag modulation with a 5.5 hour period in a recent run at Siding Spring Observatory; all of these observed over only a handful of cycles.

We propose to use the K2 Field 3 campaign to get a light curve of Nereid to test the four models above. (**1**) If the K2 light curve has a rotational period of <14 days, then the *chaotic rotation* hypothesis is not physically possible. (**2**) However, if it is >14 days and shows rotational modulation with a significant period change across the 86-day duration, then the *chaotic rotation* hypothesis is proven. (**3**) If the K2 light curve demonstrates a rotational period of >3 days, then the *forced precession* hypothesis is disproven. (**4**) If the K2 light curve displays large-or-small sudden brightenings with 'exponential' declines, then this proves the *outgassing* hypothesis. Large events might be uncommon, but low-amplitude events could likely be frequent during the Field 3 campaign. (**5**) If the K2 light curve shows significant variations in the amplitude of the rotational modulation, then either the *chaotic rotation* or the *forced precession* hypothesis is correct. (**6**) If K2 sees periodic eclipses or transits, then this proves the *binary-moon* hypothesis.

This experiment is only possible for the K2 mission and for its Field 3 campaign. Nereid has a Kepler magnitude of near 19 around its stationary point. For the 30-minute cadence, this yields 2% photometry for each individual point. Our detailed simulations show that Fourier transforms can pull out the period confidently (at the >4-sigma level) from a 10-day interval for an amplitude of >0.008 mag.

We derive the correct J2000 pointing direction *from the Kepler spacecraft* with the definitive JPL *Horizons* program, with "@-227" for the observer's location (J. Giorgini, JPL, 2014, priv. comm.). Nereid "falls on silicon" (as determined by the *K2fov* program) from 15 Nov 2014 to 9 Feb 2015, all but 2 days of the Field 3 campaign. During this interval, Nereid travels 0.50° (about 450 pixels crossing half a single CCD chip) to its stationary position on 28 December 2014 and then closely retraces its pre-stationary path. Nereid is typically 3 arc-minutes away from Neptune, with its path largely overlapping with Neptune's path.

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