

High-Precision Measurements for Brightness Variation of NII Nereid

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The origin of the second largest satellite of Neptune, Nereid, is still unclear. We performed photometric observations for Nereid to measure its rotation properties using Subaru/S-Cam. The obtained lightcurves show a rapid rotation with a period of 11.5 hr. We suggest that Nereid formed an external region and later was captured into the current orbit by Neptune.

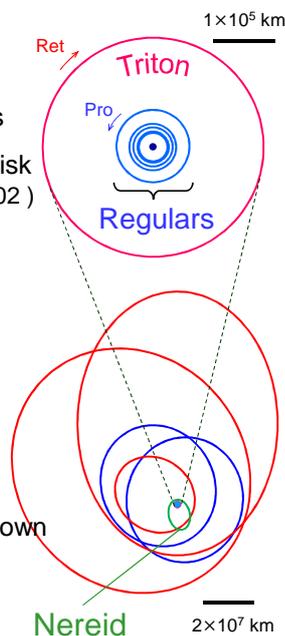
NASA/JPL-Caltech

Satellites of Giant Planets

Regular satellites

- Close to the host planet (semi-major axis < ~ 0.05 Hill radius)
- Circular, coplanar, prograde orbits
- Formed in the circumplanetary disk (e.g. Canup & Ward 2002)

Neptune's satellites



Irregular satellites

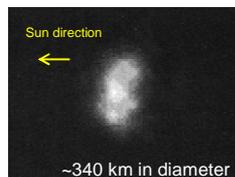
- Distant from the host planet
- Eccentric and/or inclined orbits
- Most have retrograde orbits
- Captured from external sources at an early epoch
- The source regions remain unknown
 - Vicinity of the host planets ?
 - Kuiper belt ?



Constraints for dynamical evolution of small bodies in the early Solar system

NII Nereid

- Second largest satellites of Neptune
- Prograde, eccentric ($e \sim 0.75$) orbit
- Apparent magnitude : $V \sim 19$ mag



Voyager 2's view of Nereid (Smith+1989)

Previous photometric observations

- Several observations with ~ 1 -m telescopes (e.g. Bus+1988)
 - large variations (0.1 – 1.5 mag) with unstable periods
- Grav+ (2003) with CTIO 4-m telescope
 - small variation (0.03 mag) with a short period (11.5 hr)

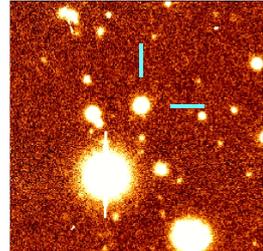
Theoretical studies

- Goldreich+ (1989) → Nereid formed as a regular satellite but was ejected outward by Triton
- Dobroovoskis (1995) → For the rotation period > 2 weeks, Nereid is likely in spin-orbit resonance or chaotic rotation

Is Nereid regular or irregular ?

Observations

- Date: Sep 1, 2, and 29, 2008
- Subaru telescope + Suprime-Cam
- 240-sec exposure with VR-band
- About 20 sequential shots in 2 hr
- Relative photometry using 10 stars with $V-R \sim 0.44$ mag
- Very low photometric uncertainty of ~ 0.002 mag



Nereid on a S-cam image

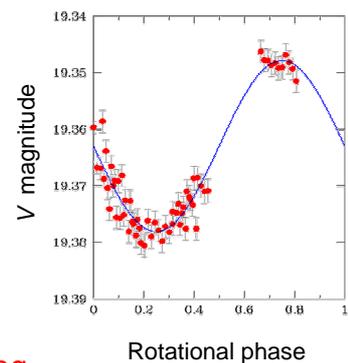
Lightcurves

Periodic analysis
(Lomb 1976; Scargle 1982)



Rotation period :
 11.5 ± 0.1 hr

Peak-to-peak amplitude :
 0.031 ± 0.001 mag



- Consistent with Grav+(2005)
- Rapid, constant rotation (unlikely in resonance/chaos)

Discussion

Two scenarios for Nereid's origin :

I. Formed in the circumplanetary disk

- Synchronous rotation due to tidal locking
 - Initial semi-major axis $\sim 2.7 R_{\text{Nep}}$ (currently at $224 R_{\text{Nep}}$)
 - Disagrees with orbit-mass relation of regular satellites
- Located at $4.4 R_{\text{Nep}}$ (agrees with the relation)
 - Required an impact of a body with ~ 60 km in diameter

II. Captured body from a heliocentric orbit

- The rotation state is usual for a irregular satellite
- Consistent with the size-spin relation of TNOs/Centaurs

Conclusion : Nereid has been an irregular satellite since it began to orbit around Neptune