101955 (1999 RQ36)

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radar astronomy



The basics:

A radar transmitter transmits radio waves at a known frequency for a certain time interval.

The waves hit the object, bounce off of it, and return to the telescope. The receiver, now moved into the focus of the telescope, detects the weak echo.

- Transmitted wave
- Echo from distant object

asteroid images

Direction of radar

- Delay Doppler images map a 3D object into a 2D image
 - **Circles**: Represent lines of constant range
 - Lines: Represent lines of constant Doppler shift



- Observed in 1999 at high SNR for three days at Arecibo. Also observed at Goldstone.
- Re-observed in 2005 to measure oblateness.
 - Higher resolution due to instrument improvement, but lower SNR.
 - Better sky coverage (about 90 degrees) and complete visible lightcurve allows a pole solution.
- Potential OSIRIS mission target.





- Ellipsoidal model to constrain pole.
- Fixed rotation period to 4.2 h from lightcurve.
- Ellipsoidal model gives a too-large size d=700m (it's not an ellipsoid).



Radar Image Synthetic Radar Image Synthetic Sky Image



adar	Synthetic	Synthetic
nage	Radar Image	Sky Image

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It



• 15-degree grid, 5-degree grid near best solutions.



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- A spherical harmonic solution gives a better flavor of the shape,
 - Size somewhat smaller (d \sim 560 m)
 - "bulging can" shape

- Ellipsoidal model to constrain pole.
- Fixed rotation period to 4.2 h from lightcurve.
- Ellipsoidal model gives a too-large size d=700m (it's not an ellipsoid).
- Harmonic model gives a more "reasonable" 560m diameter, and allows (prefers) obliquity near 180°, the YORP extreme spin Slivan state.

- Polarization Ratio μ_C is a measure of wavelength-scale roughness
 - Roughness vs. polarization not well calibrated
- 1999 RQ36 $\mu_C = 0.18$
 - on the low end of typical for NEAs
 - Itokawa and Eros both $\mu_C \sim 0.27$
 - 1999 KW4 (binary) $\mu_C \sim 0.45$
 - suggesting "smooth"



- Sequence of ratio images doesn't show features that follow from frame to frame (noise).
- Full shape model will allow summing mode data for higher SNR.



- Somewhat oblate rounded object
 - Probably rubble pile structure
 - Previously spun up?
 - Did it lose a satellite?
 - Is it spinning up now?
- No clear signs of surface roughness variation.





Release 051101-2 ISAS/JAXA



- High-resolution radar imaging only possible for nearby objects (< 0.1 AU).
- Ranging of NEAs to ~0.3 AU.
- Typical radar targets are smaller than likely to be visited by spacecraft.
- Radar highest range resolution ~10 m.
- Radar lowest range resolution ~ target radius.
- Radar SNR typically of order 10 per pixel.
- Many more objects can be observed.
- Much lower cost.

asteroid images

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asteroid images

- One important piece of information we obtain from the Delay-Doppler images is the *size of the asteroid*
 - The extent of the asteroid in range represents its radius



- The frequency resolution is selected <u>after</u> the data has been collected by adjusting the FFT length
- The range resolution is limited by the hardware and SNR
 - Common sampling rate for image = 0.1µs (or 15 m)

- Object V dispersion Spin and shape
- Object D depth

Size and shape

- Excellent imaging at Arecibo, Goldstone and bi-static to GBT
- Binary, primary 1.5 km Prot=2.3 hrs
- IR spectrum from IRTF shows it is S-type, expected density 2.5 g/cm³





- Funding from NSF for astronomy is uncertain (75% astronomy, 5% planetary radar, 20% aeronomy)
- NASA and NSF are talking about how to continue the planetary radar program
- We are painting the telescope and planning for 20+ yrs of operations
- Community pressure has been helpful and effective (keep up the good work!)

