Physical Characterization Studies of Near-Earth Object Spacecraft Mission Targets

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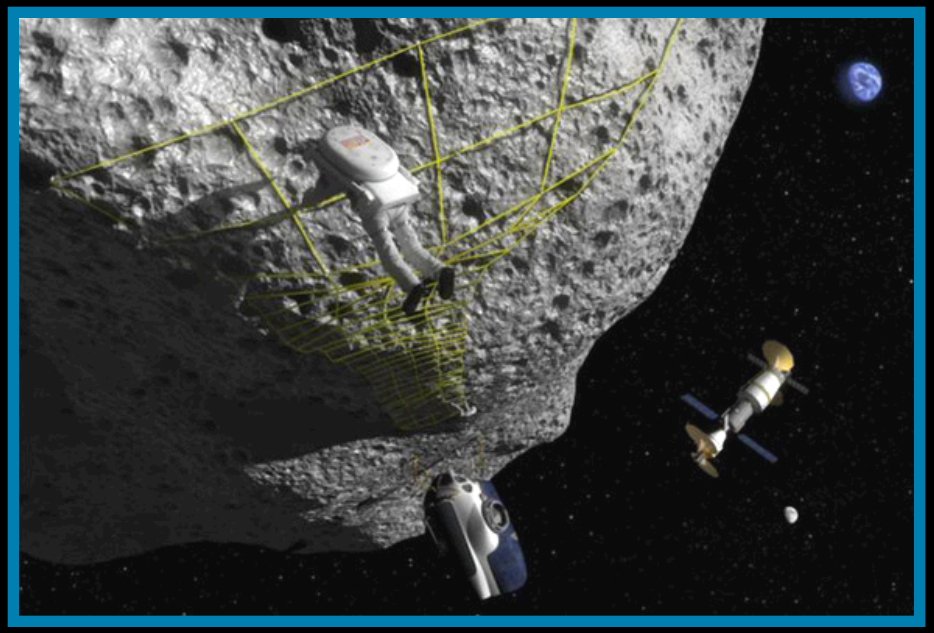
Astronauts to Visit an Asteroid by 2025



The official *National Space Policy of the United States of America* as of June 28, 2010, includes the goal of sending astronauts to an NEA in the 2025 timeframe.

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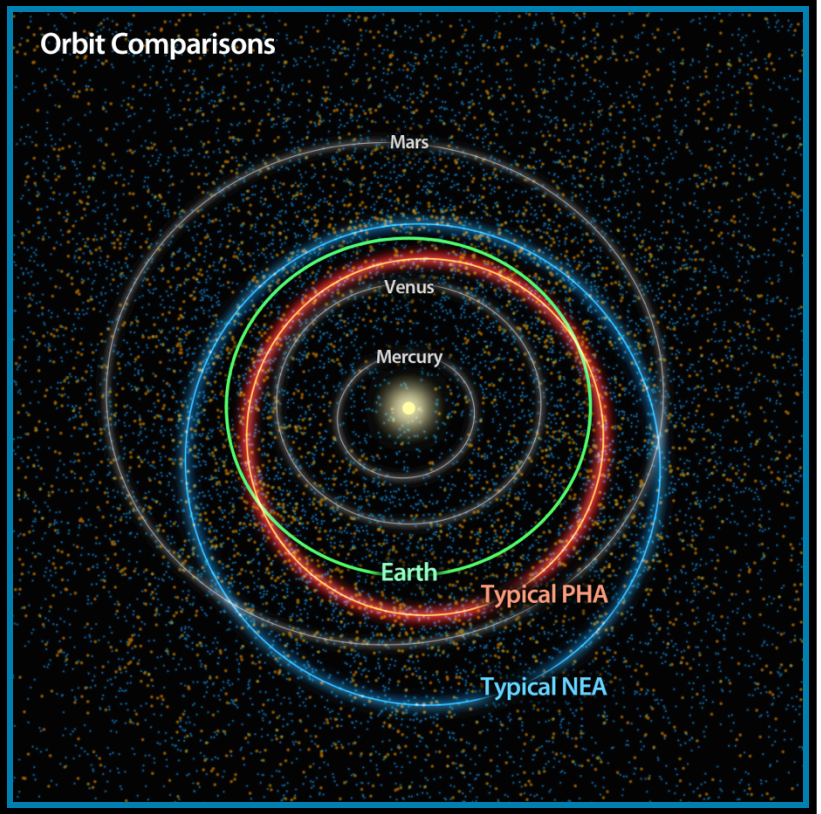
What is the Best Target?

A **Near-Earth Asteroid (NEA)** is an object that approaches the Sun to within 1.3 AU or less, bringing it to within 0.3 AU of the Earth's orbit. Estimates are that **more than a million NEAs larger than 40 m in diameter exist.**

NEAs proximity make them good targets for spacecraft missions.



Practical Concerns: Some **Potentially hazardous NEAs (PHAs)** are capable of colliding with our planet **(~1300 of these objects have been discovered).**

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MRO 2.4-meter Telescope

The MRO 2.4m Telescope is an effective follow-up facility for tracking and characterizing even the smallest asteroids.

Researchers at the 2.4-meter facility have capitalized on real-time opportunities to observe close-approaching, newly discovered NEAs to derive better orbits, calculate spin rates, and to determine composition.

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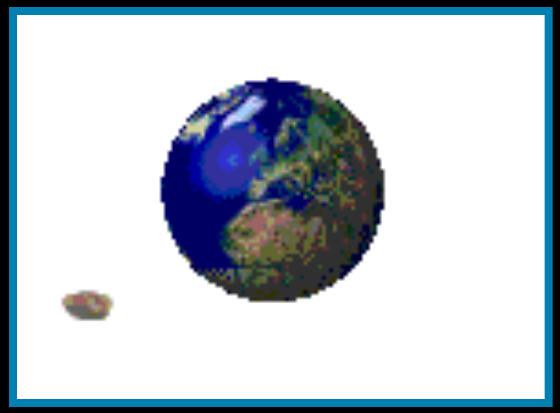
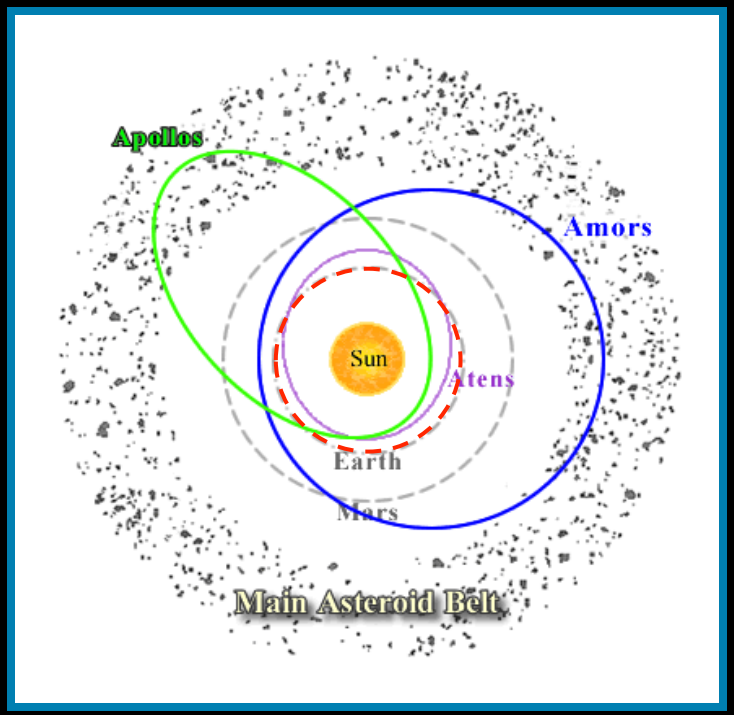
Target Characterization





At the first instant of discovery: we know rough orbits and absolute magnitudes. Need much more information: size, composition, and rotation rate.

Timing for asteroid follow-up and physical study is critical: when objects are first discovered they are in a prime location with respect to visibility from the Earth.

When they will once again be in that same location can be as long as decades.

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Human Spacecraft Mission Parameters

An artist's concept of NASA's Dawn spacecraft and the giant asteroid Vesta.

- **Minimal Delta-V (less than 12 km/s) for departure/return**
- **Roundtrip mission duration (less than a year)**
- **Asteroids preferred over comets: no active surface and less eccentric orbits**

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Target Selection: NHATS Table

Designation	*n*	Estimated Diameter (m)
2000 SG_{344}	3302638	27 - 85
1991 VG	2737751	5 - 16
2006 BZ_{147}	1674416	20 - 63
2001 FR_{85}	1618888	30 - 96
2008 EA_9	1597844	7 - 22
2010 VQ_{98}	1580174	6 - 18
2007 UN_{12}	1443703	4 - 14
2006 RH_{120}	1283817	3 - 10
2010 UE_{51}	1242487	5 - 17
2008 HU_4	1227757	6 - 17
2007 VU_6	1186902	12 - 38
2008 UA_{202}	1114827	3 - 10
2010 UJ	1082350	14 - 45
2011 BQ_{50}	1010896	5 - 16
2004 QA_{22}	1008597	6 - 20
2001 GP_2	980724	10 - 32
2009 HE_{60}	970582	18 - 56
2010 JR_{34}	960736	7 - 22
2009 BD	936904	5 - 16
2011 MD	936324	6 - 18
2010 TE_{55}	920319	6 - 20
2008 JL_{24}	904774	3 - 9
2011 BL_{45}	865199	9 - 28
2007 YF	791134	27 - 85
2010 JK_1	773964	32 - 100
2009 BF_2	205,531	11 – 51
2009 UD	431,711	7 – 29
2012 DW_{60}	113,217	9 – 40
2012 HM	15, 578	27 - 85

Adapted from Abell et al. 2012

Sample of currently known NEAs that are compliant as assessed by NASA's Human Space Flight Accessible Targets Study (NHATS).

The number of viable trajectories (*n*) is useful for assessing which NEAs are the most accessible.

Highlighted entries denote objects MRO 2.4m has studied.

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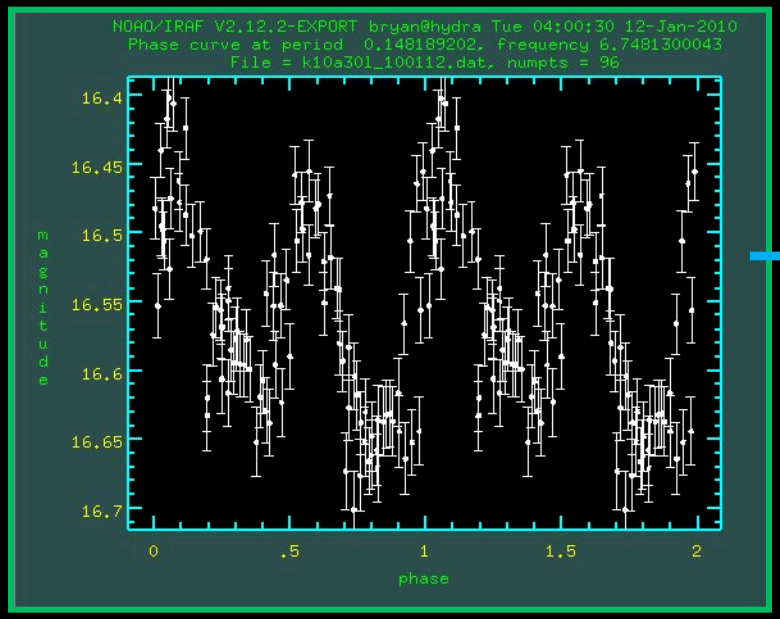
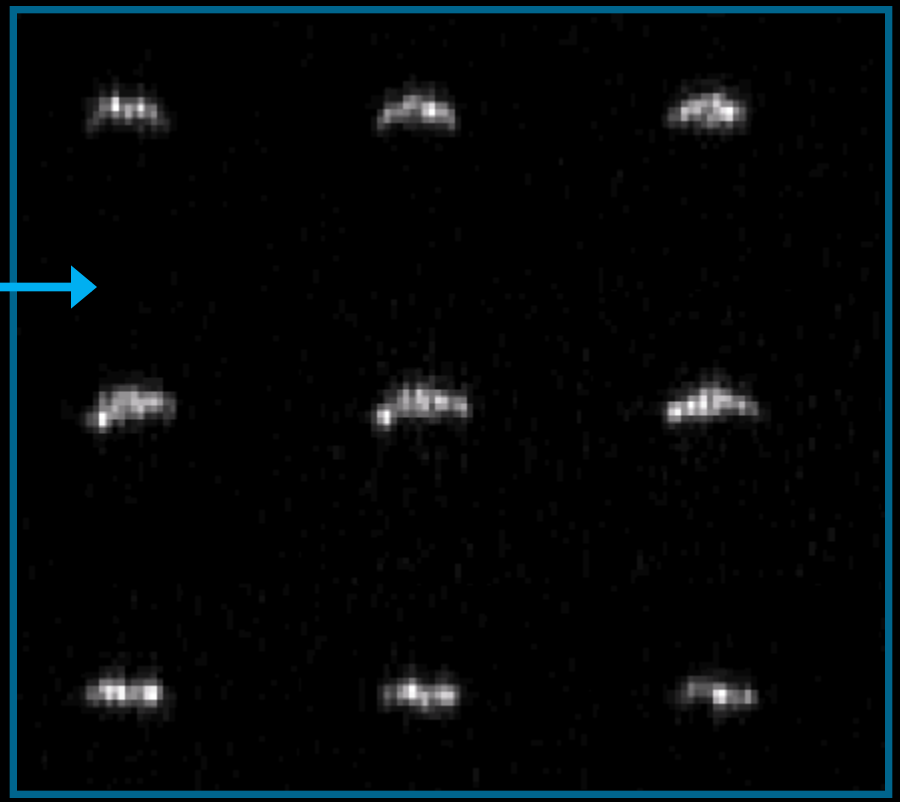
Optical/Radar Observational Synergy: Imaging

- **Imaging close-approaching asteroids: position (astrometry), spin rate, and composition from optical telescopes provides good preparation for radar work.**



Lightcurve of radar target 2010 AL_{30} exhibiting a spin rate of 8.9 minutes. The data were taken with the MRO 2.4m Telescope in January, 2010, and the asteroid's diameter is estimated to be 12 m.



Radar Doppler Images

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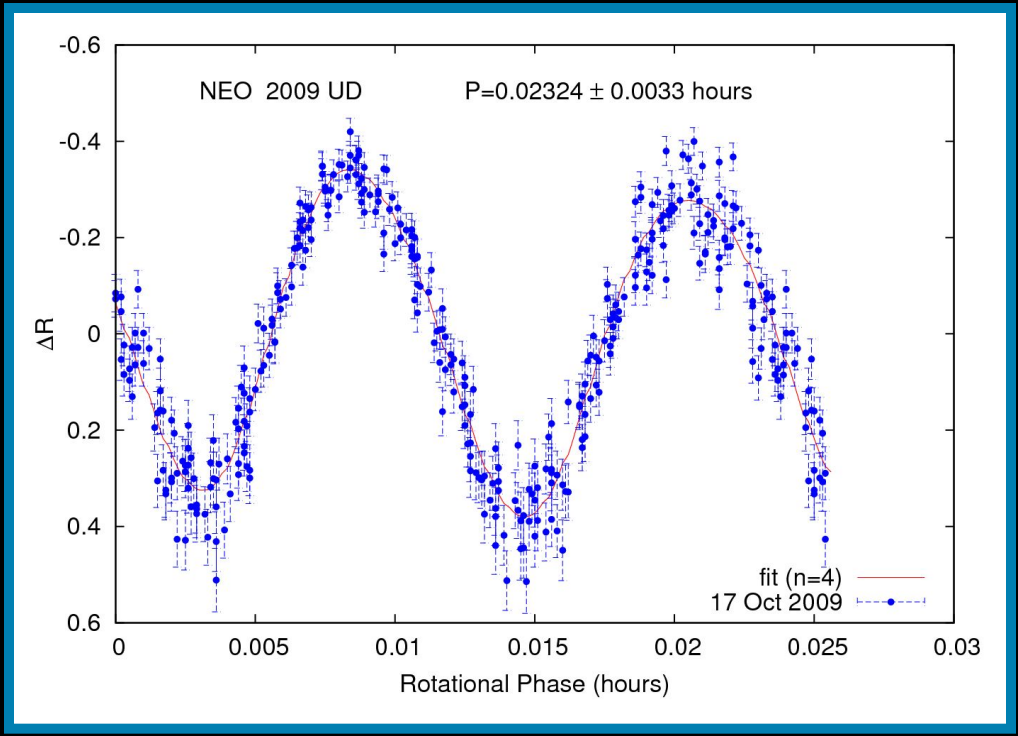
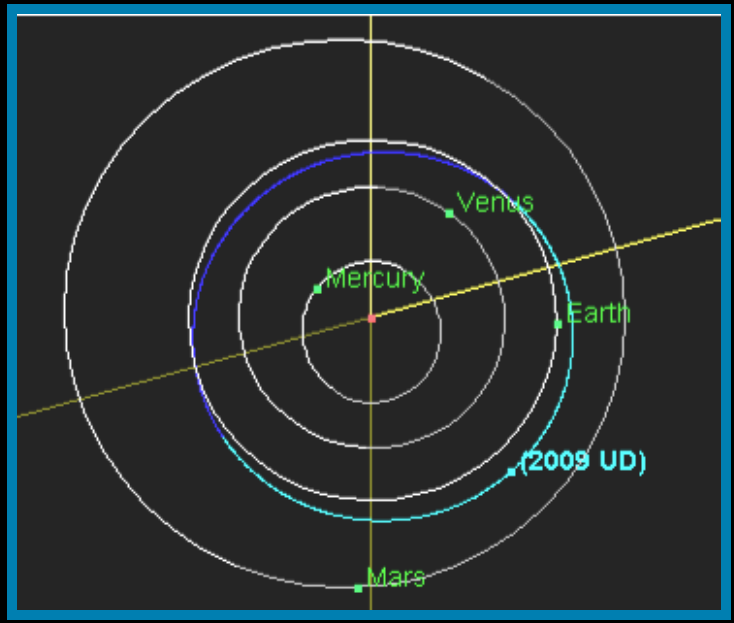
Rotation Rates: 2009 UD





Lightcurve (left) and orbit diagram (right) of close Earth-approaching asteroid 2009 UD; the asteroid's diameter is about 18 meters, and its rotation period was determined to be 0.023 hours. Data was collected for the lightcurve in October, 2009 using the MRO 2.4-meter telescope; the visual magnitude of the asteroid was V~18.

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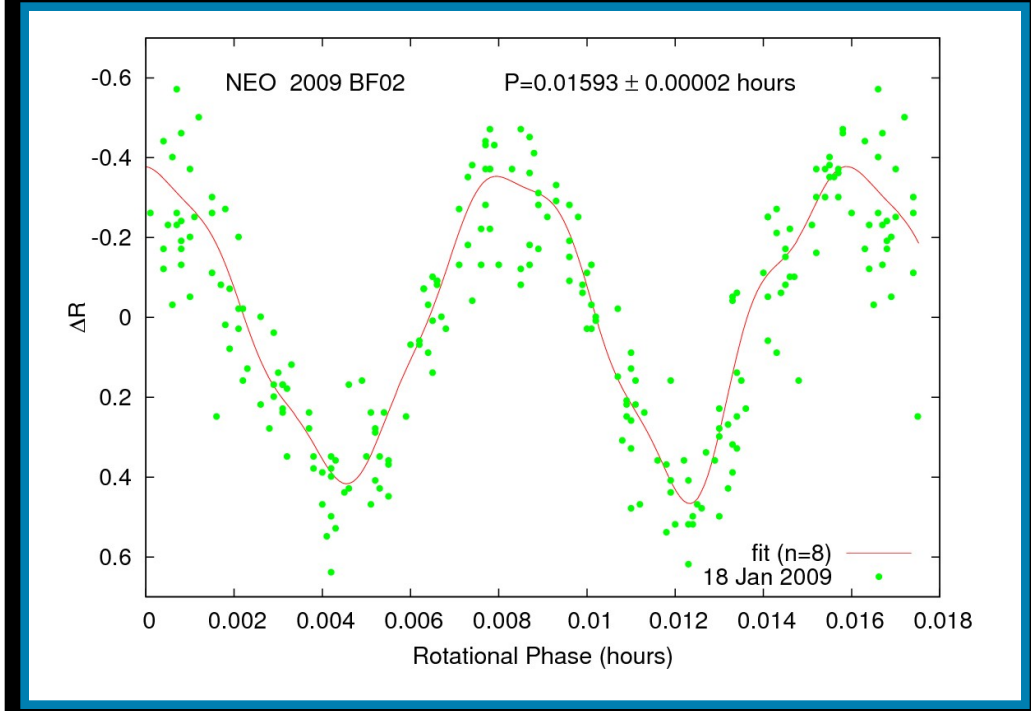
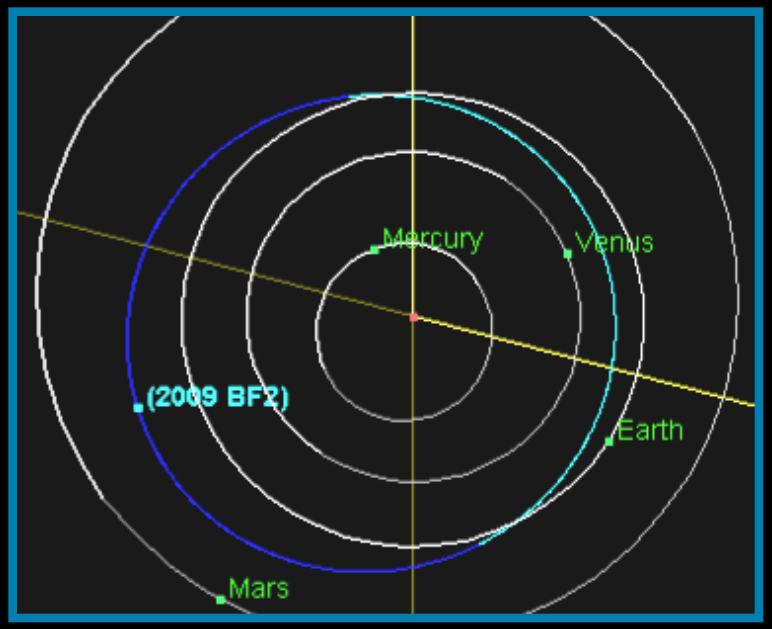
Rotation Rates: 2009 BF_2 (Tumbling?)





Lightcurve (left) and orbit diagram (right) of close Earth-approaching asteroid 2009 BF_2; the asteroid's diameter is about 27 meters, and its rotation period was determined to be 0.0159 hours. Data was collected for the lightcurve in January, 2009 using the MRO 2.4-meter telescope; the visual magnitude of the asteroid was V~18.5.

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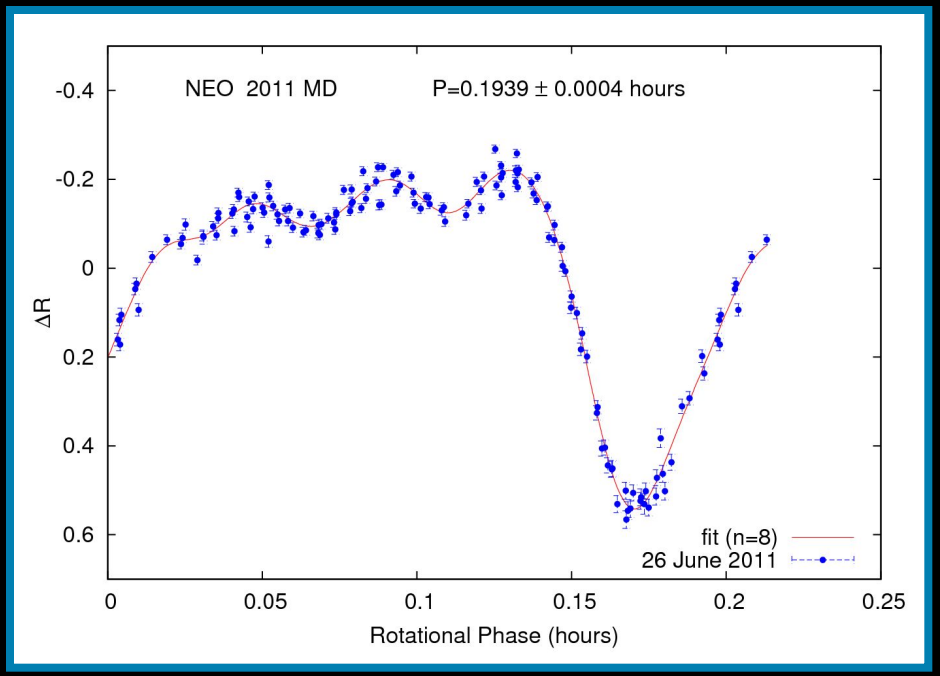
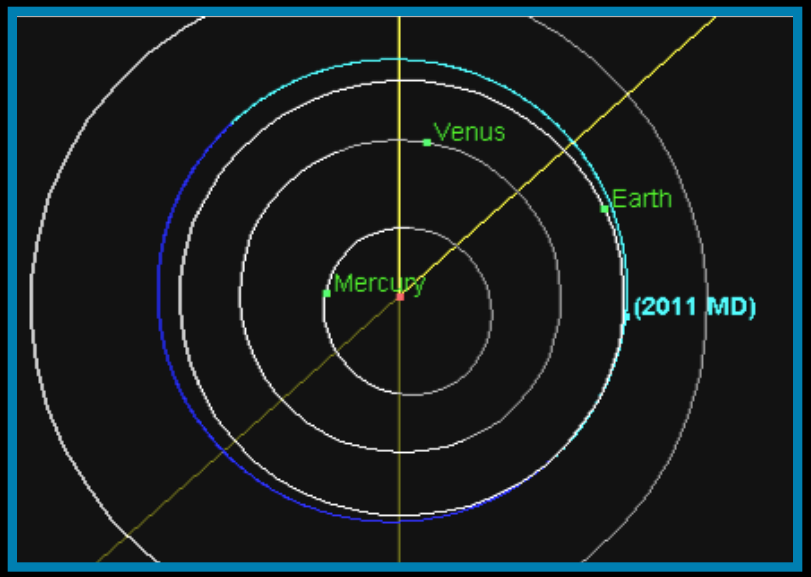
Rotation Rates: 2011 MD





Lightcurve (left) and orbit diagram (right) of close Earth-approaching asteroid 2011 MD; the asteroid's diameter is about 11 meters, and its rotation period was determined to be 0.194 hours. Data was collected for the lightcurve in June, 2011 using the MRO 2.4-meter telescope; the visual magnitude of the asteroid was V~17.

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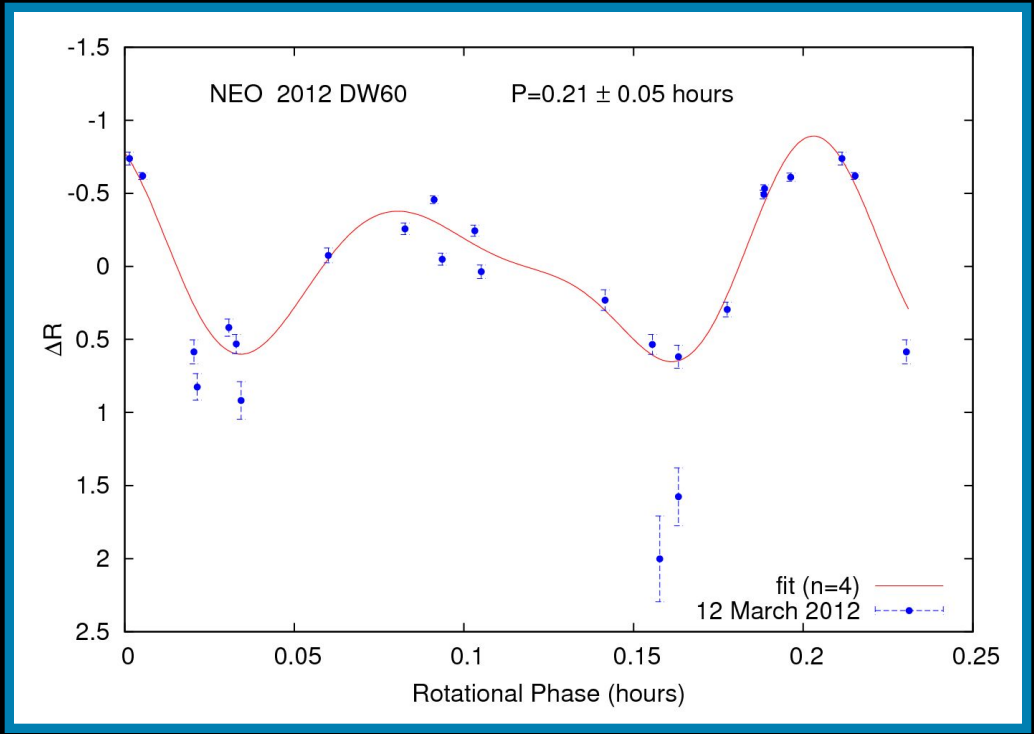
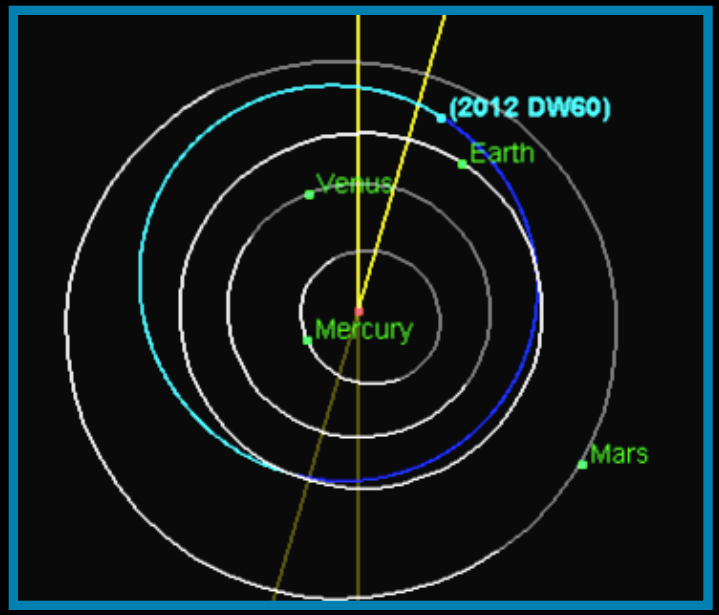
Rotation Rates: 2012 DW_{60} (Radar Target)





Lightcurve (left) and orbit diagram (right) of close Earth-approaching asteroid 2012 DW_{60} (also a radar target); the asteroid's diameter is about 18 meters, and its rotation period was determined to be 0.21 hours. Data was collected for the lightcurve in March, 2012 using the MRO 2.4-meter telescope; the visual magnitude of the asteroid was V~19.

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Fast Rotations Not Optimal

- Rapid rotation periods (minutes!) for small asteroids would likely mean solid, non-rubble pile internal structures; but without loose gravel or regolith (difficult to tether to).

- Fast spins would also mean that astronauts at a particular site of interest on the asteroid surface would tend to be carried away from their spacecraft. If the asteroid rotated quickly enough, astronauts might transition out of sight/communication of the spacecraft during any extra-vehicular activities (EVAs), making these operations difficult.

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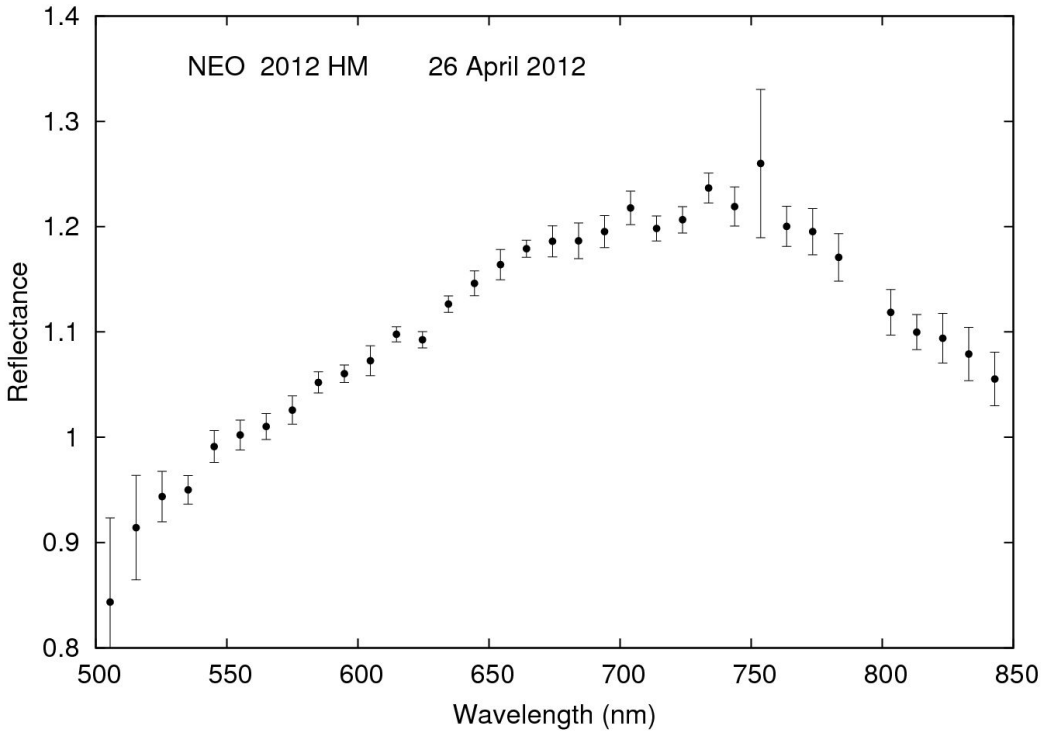
Spectra: Composition of 2012 HM



- **Composition helps constrain size (albedo) and surface conditions.**
- **Extension of SSA collaboration with Edwards AFB and JPL (Lee Johnson & David Conroy).**

Spectral characteristics (visible wavelengths) of potential mission target 2012 HM; the spectrum indicates that it is likely an S-type asteroid: characteristic steep slope shortward of 0.7 µm, and a small dip at 0.63 µm. This object was also extensively studied by radar groups.

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Asteroid Sample Return Missions:

NASA

Scheduled for launch in 2016, the OSIRIS-REx spacecraft mission will collect and send back the first samples ever taken of a carbon-rich near-Earth asteroid, 1999 RQ_{36} (diameter ~ 500 meters).

Asteroid 1999 RQ_{36} is also a potentially hazardous object, with a small probability (currently a 1-in-1000 chance) of impacting the Earth in the year 2182.

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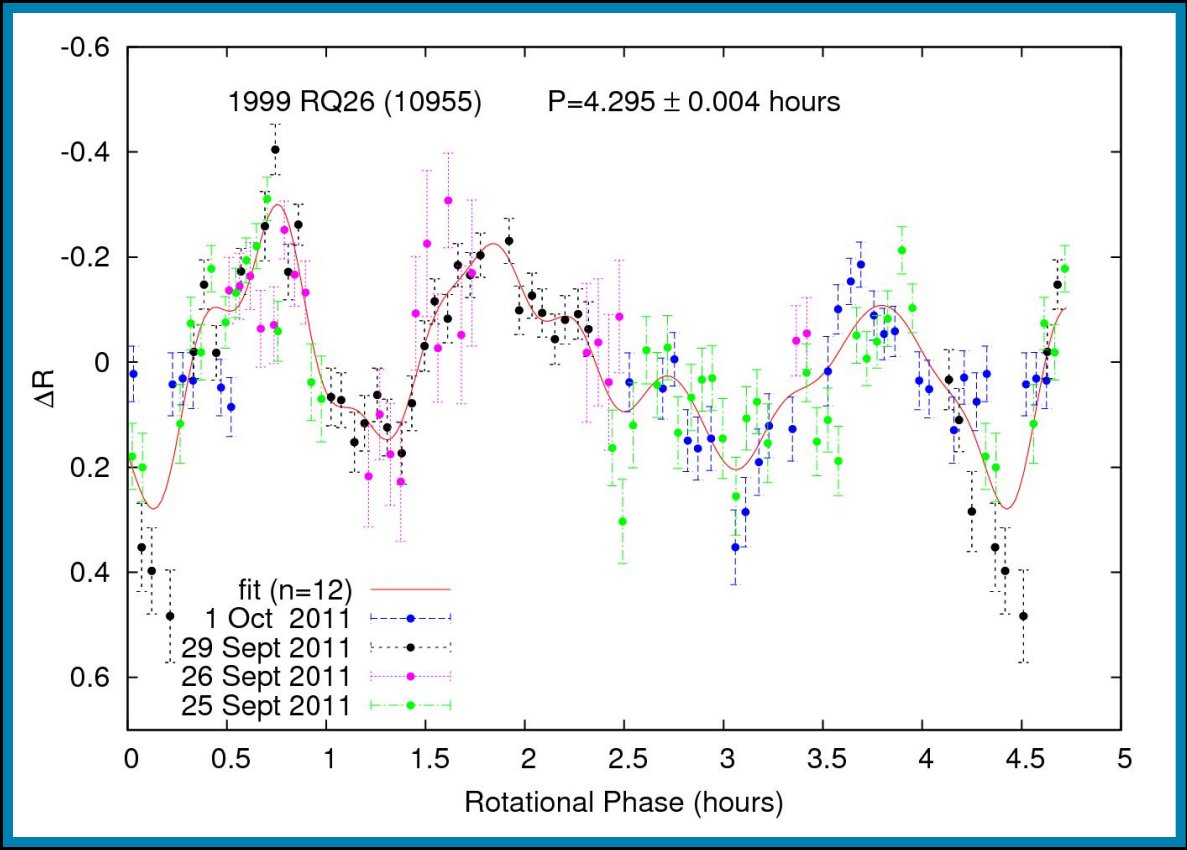
Rotation Rate: 1999 RQ_{36}



Lightcurve for PHA 1999 RQ_{36} acquired in September and October, 2011 using the MRO 2.4-meter telescope. The spin period is 4.295 hours. Approximate visual magnitude for the asteroid at the time the observations were taken was V~21.

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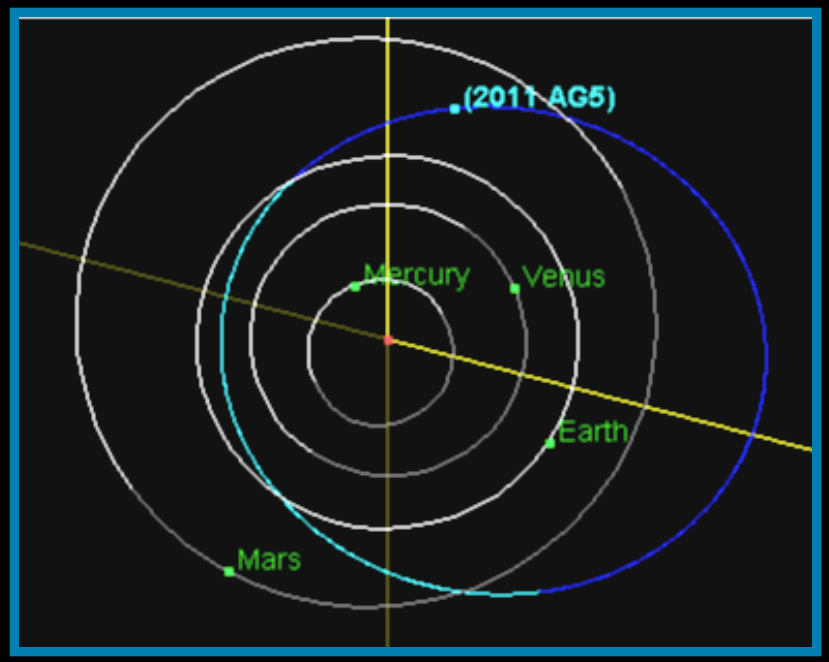
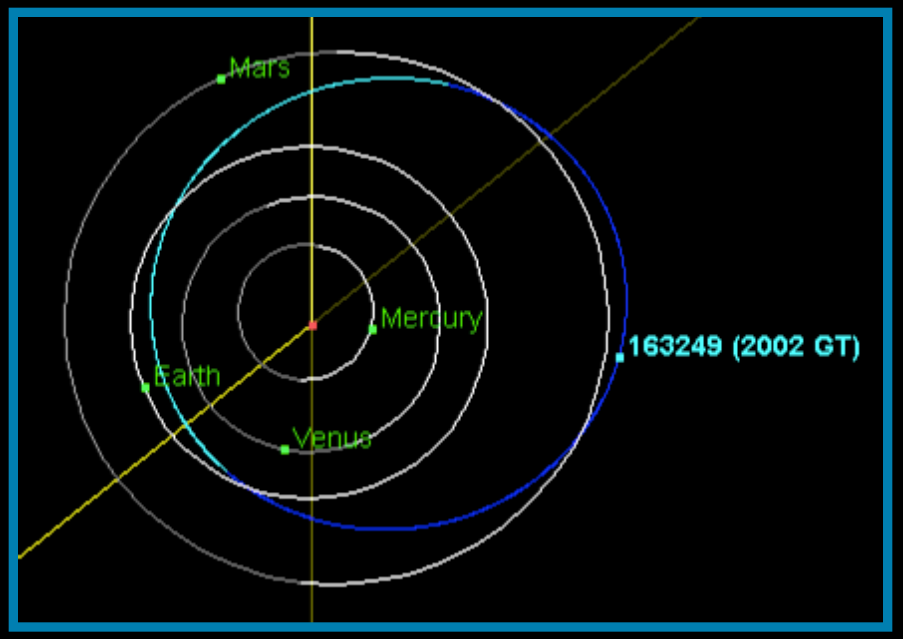
Other PHAs: 2011 AG_5 and 2002 GT

Ground-based observing campaigns are underway.



2011 AG_5 will make a keyhole pass in 2023; possible impact in 2040.



2002 GT is a January 2020 flyby target of the Deep Impact Spacecraft.

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Summary

- New NEAs are discovered every day. Very little is known about their physical properties.

- Selection of potential human spacecraft targets means characterization of newly discovered NEAs must be timely.

- Ground-based observations to determine the spin rate and composition of NEAs will help select targets for 2025.

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