NEO Follow-up Astrometry and Characterization

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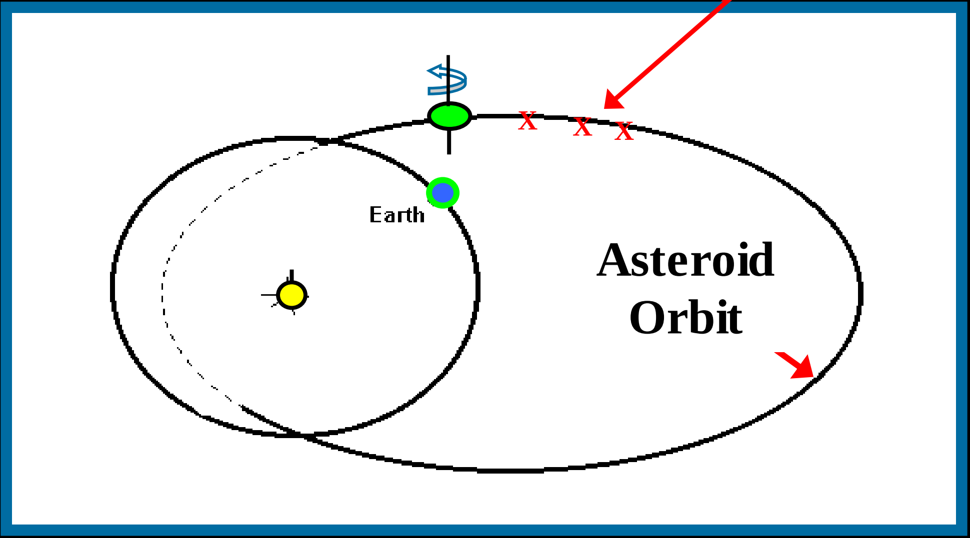
Follow-Up in Support of Discovery

- Follow-up astrometry provides the <u>extended arc</u> necessary (discovery arc is too short) on subsequent nights to determine orbits and assess whether the new discovery is an NEO. Follow-up is needed **at least until recovery at the next apparition is assured.**
- Follow-up telescopes allow discovery telescopes to focus on **surveying.**

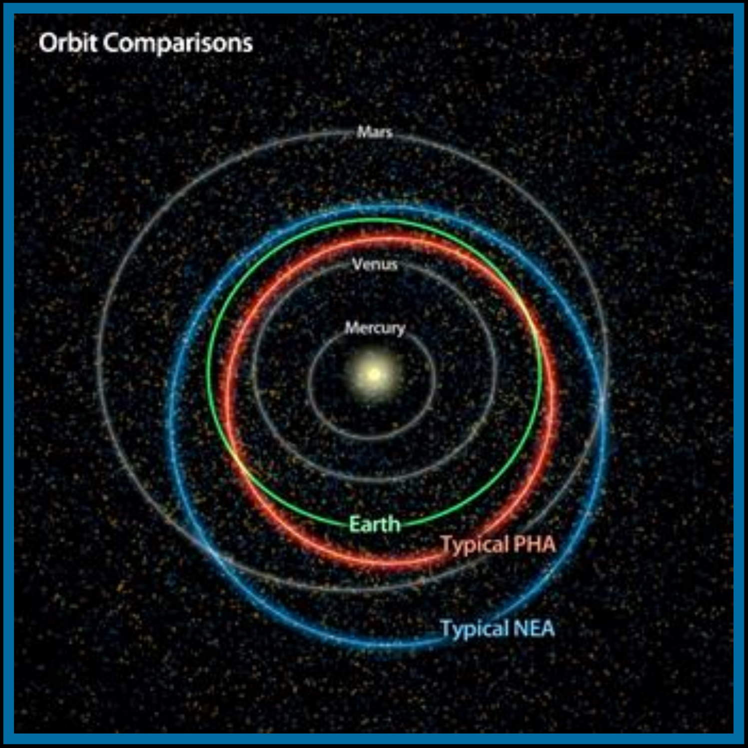


Follow-up Telescopes can also acquire physical characterization information:

<u>Spin Rate</u>
<u>Material Composition</u>

This information is useful for science and hazard application.

Funded Astrometric Follow-Up Programs



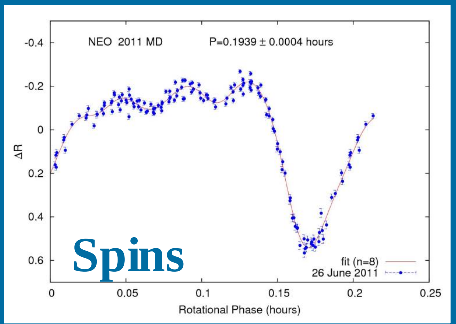
- Astronomical Research Institute
- Spacewatch
- Magdalena Ridge Observatory
- Dave Tholen via UH 80”, CFHT 3.6-m, Subaru, & Keck
- JPL’s Table Mountain Observatory

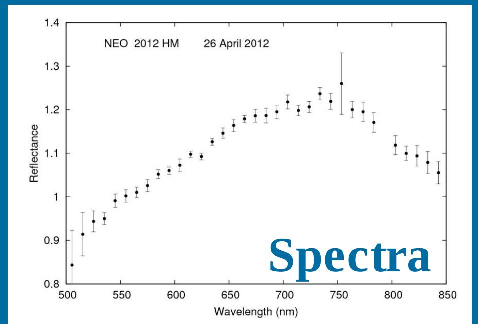
Plus numerous self-funded “amateurs”…

Magdalena Ridge Observatory 2.4m Telescope

(Eileen and Bill Ryan, Socorro, NM)

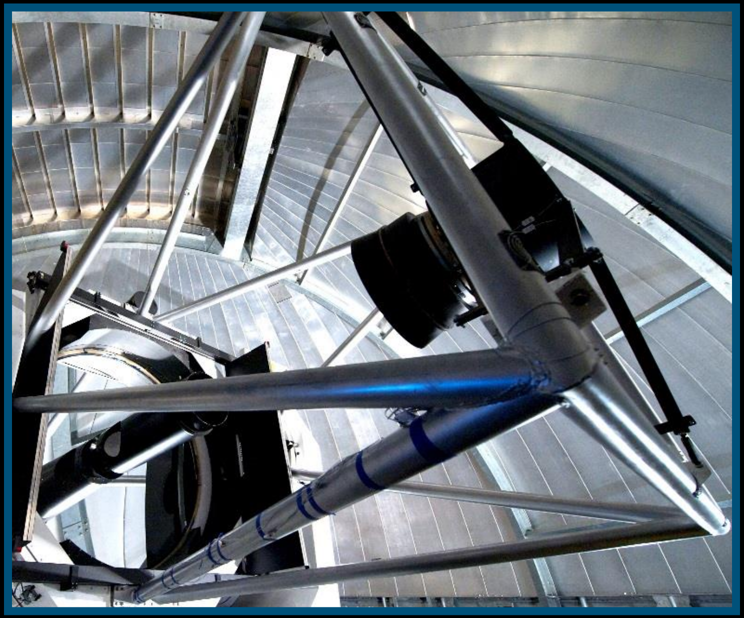
Limiting Magnitude V~24.5





- The MRO 2.4-meter is part of NASA Spaceguard, and does follow-up on even the smallest asteroids ~9 nights per month.
- Capitalizes on real-time opportunities to observe close-approaching, NEAs to calculate spin rates, and roughly determine composition.
- Coordinates with Radar.
- Characterizes potential spacecraft targets.

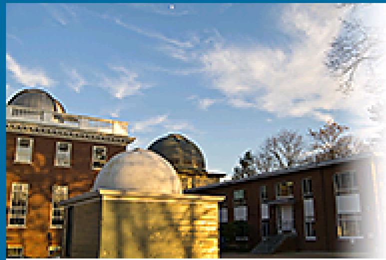
Instrumentation/Software Needed



- **Telescope and CCD Camera**
- **Data Reduction Software:**

Examples

- **Astrometrica** using the USNO-B 1.0 star catalogue– (quick look)
- **wcsTools** combined with IRAF scripts for analysis (in-depth analysis)



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Real-Time Target Selection

NEOCP Blog

Real time reporting of NEOCP follo

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H01 – PTFm35 found

Posted by neotech on 2013/04/06 at 04:09 UTC

2 (of 4 planned) images acquired – Bill

Category: Follow Up | Leave a comment

807: Targeting PTFp60 and P106xI4

Posted by Tyler on 2013/04/06 at 04:08 UTC

T. Linder

Category: Follow Up | Leave a comment

807: Recovered UG87D20 and P106xGx

Posted by Tyler on 2013/04/06 at 04:06 UTC

T. Linder

Category: Follow Up | Leave a comment

291 waiting for wind to decrease Apr 6

Posted by Spacewatch on 2013/04/06 at 04:04 UTC

291' s dome is back in operation but winds too high to open as yet Apr 6.

Category: Follow Up | Leave a comment

The NEO Confirmation Page

Please ensure you are familiar with the notes at the bottom of this page.

Problems? Comments?

Get ephemerides | Reset form

See this list in R.A. order

Select object(s) from the current list of objects needing confirmation (NEO prob, class, discovery date, rough current position and magnitude given):

All objects with V = -30 to 30, with Decl. between -90° and +90°, with an NEO probability of 0 % to 100 %

or just the objects selected below: Deselect All | Select All

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UG5D12E  70 2 [2013 Apr. 08.5 UT.   R.A. = 12 07.1, Decl. = -45 43, V = 18.3] Added Apr. 8.83 UT [
UG5D766 100 1 [2013 Apr. 08.7 UT.   R.A. = 20 26.3, Decl. = -37 50, V = 16.8] Added Apr. 8.80 UT [
P106E7B  90 2 [2013 Apr. 08.3 UT.   R.A. = 12 35.2, Decl. = -13 29, V = 20.0] Added Apr. 8.76 UT [
P106E7A  92 2 [2013 Apr. 08.4 UT.   R.A. = 12 45.3, Decl. = -11 35, V = 20.5] Added Apr. 8.76 UT [
P106E7D  61 3 [2013 Apr. 08.3 UT.   R.A. = 12 56.1, Decl. = -13 59, V = 20.7] Added Apr. 8.76 UT [
P106E7E  65 3 [2013 Apr. 08.3 UT.   R.A. = 12 23.2, Decl. = -05 37, V = 21.2] Added Apr. 8.76 UT [
P106E7y 100 1 [2013 Apr. 08.4 UT.   R.A. = 12 41.7, Decl. = -14 17, V = 19.6] Added Apr. 8.72 UT [
GG35B02 100 1 [2013 Apr. 07.2 UT.   R.A. = 13 02.0, Decl. = -15 59, V = 20.0] Added Apr. 8.43 UT
P106E7w 100 1 [2013 Apr. 07.3 UT.   R.A. = 11 21.6, Decl. = -16 09, V = 20.4] Added Apr. 8.39 UT *
P106E7x 100 1 [2013 Apr. 07.3 UT.   R.A. = 12 04.0, Decl. = -11 35, V = 20.1] Added Apr. 8.39 UT *
P106E7v 100 1 [2013 Apr. 07.3 UT.   R.A. = 10 56.3, Decl. = -05 14, V = 20.1] Added Apr. 8.39 UT *
P106CRE  66 2 [2013 Apr. 07.3 UT.   R.A. = 11 26.1, Decl. = -09 16, V = 20.0] Updated Apr. 8.20 UT
P106CRI  39 3 [2013 Apr. 07.3 UT.   R.A. = 11 14.6, Decl. = -15 09, V = 21.2] Updated Apr. 8.04 UT
P106CRo  90 2 [2013 Apr. 07.3 UT.   R.A. = 11 21.6, Decl. = -13 06, V = 21.1] Updated Apr. 8.83 UT
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P106CRl 100 1 [2013 Apr. 07.2 UT.   R.A. = 05 27.6, Decl. = +31 13, V = 21.3] Updated Apr. 8.29 UT
UG8B6CE  69 2 [2013 Apr. 07.3 UT.   R.A. = 13 14.9, Decl. = -03 08, V = 20.9] Updated Apr. 8.35 UT
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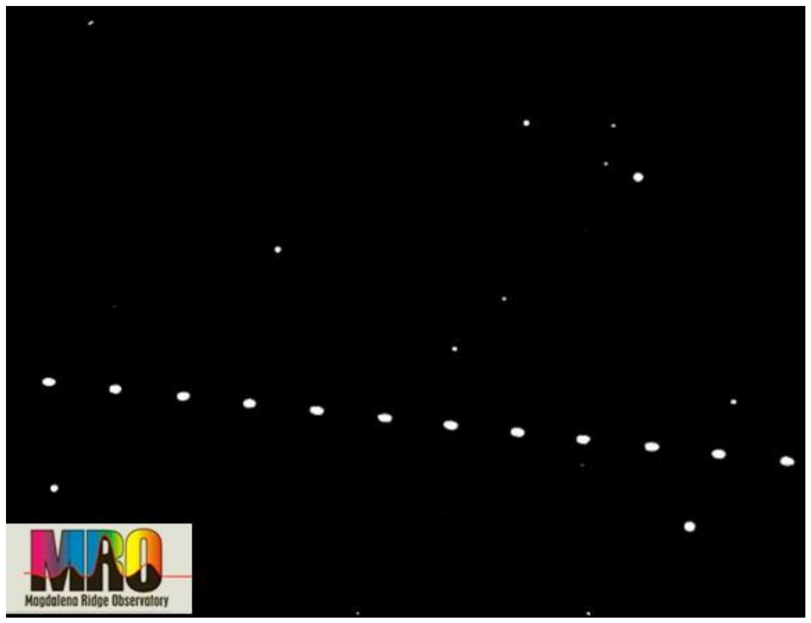
Astrometry: Tracking Challenges

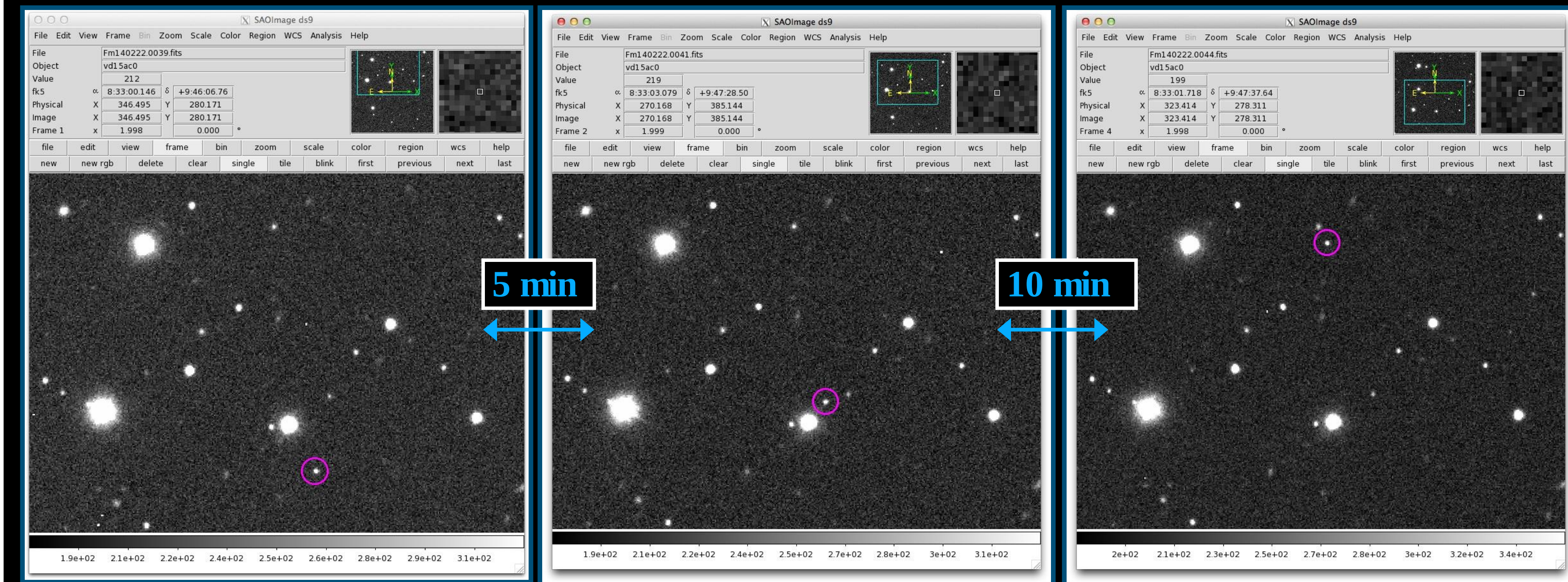


Time composite of asteroid 2005 YU 55

- Fast moving objects can pass through more than one CCD frame.
- Tracking on the object for too long of an exposure to increase S/N can cause field stars to become overly elongated. Image Stacking is an option.
- Enough reference stars need to be in the image to determine an accurate position.

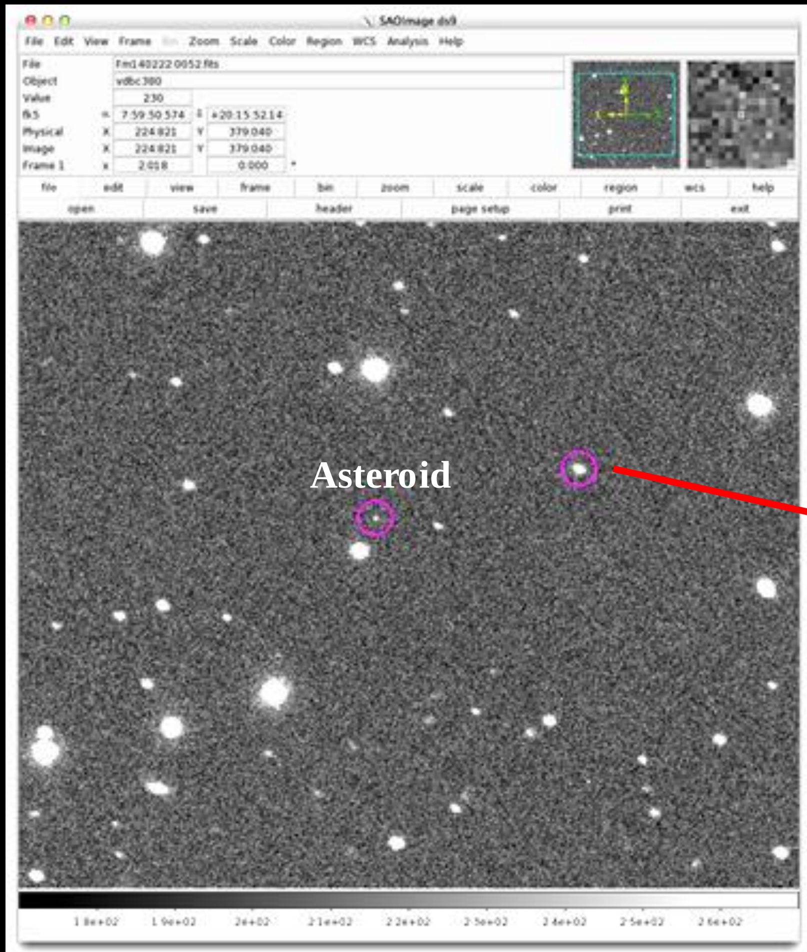
Astrometry: Techniques

Once you've identified the moving object (asteroid) on an image, you can calculate its coordinates by measuring its position with respect to reference stars.

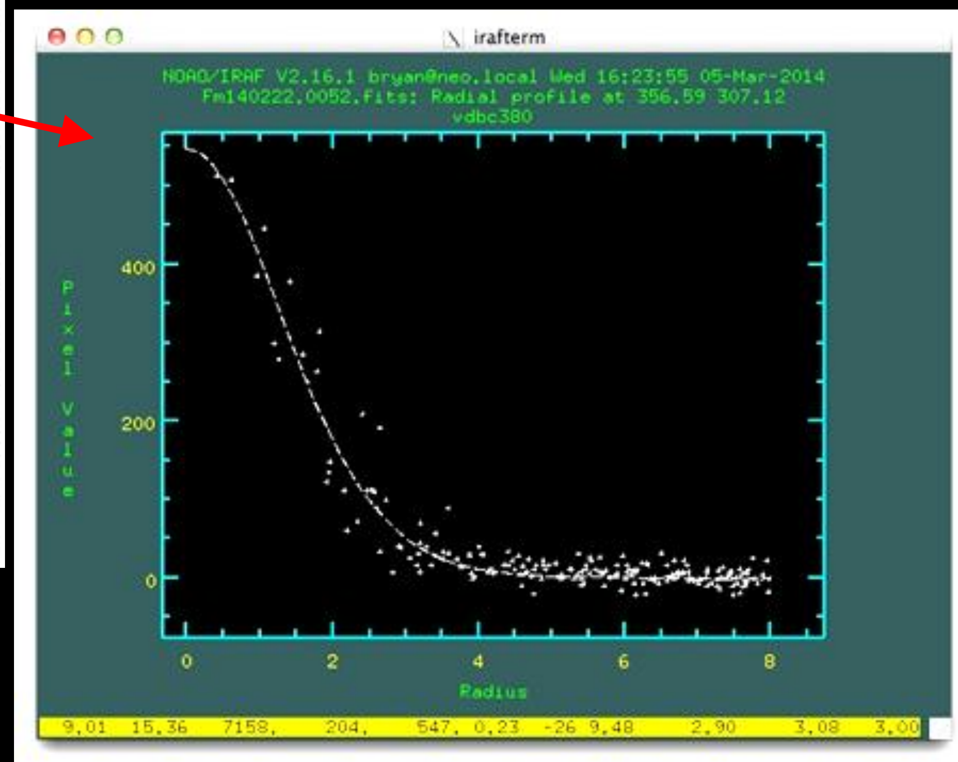


"Easy" asteroid 2014 DO_7 , visible magnitude V~20, exposure time=12 sec, speed= 5.8"/minute (relatively slow). Time elapsed ~ 15 minutes. Usually add a fourth image to the sequence before finalizing.

Astrometry: Faster-Moving Objects



Allowed field stars to elongate slightly to boost signal to the target. Analysis of sample field star shows still a good profile for centroiding.



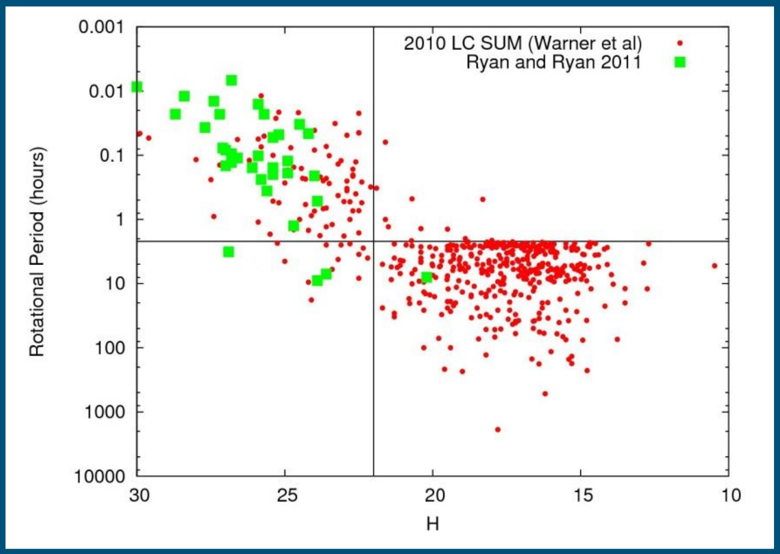
Faster-moving asteroid 2014 DF_{10}, visible magnitude V~21, exposure time=10 sec, speed= 8.1”/minute.

Target Characterization

- After discovery, more information to characterize the NEO population is needed: size, composition, & rotation rate; this information is also useful for selecting human spacecraft mission targets (maybe asteroid retrieval?).

- Timing for asteroid follow-up and physical study is <u>critical</u>: when objects are first discovered they are in a prime location with respect to visibility (i.e., brightness) from the Earth. Access to larger telescopes on short notice is advantageous (rapid response).

Lightcurves Reveal Spin Rate and Shape

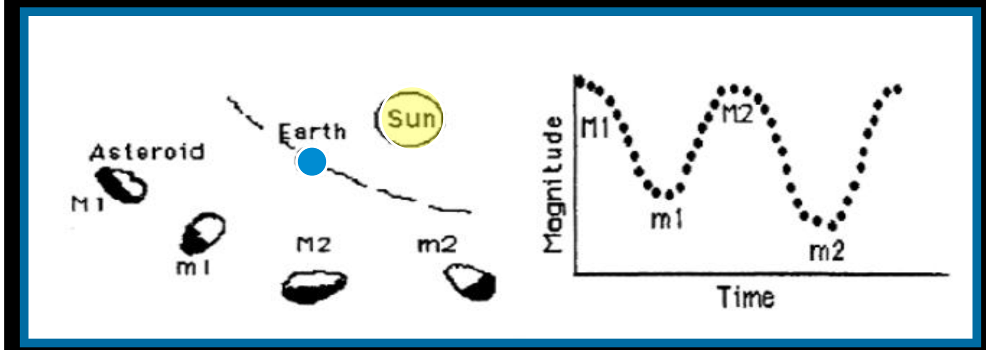


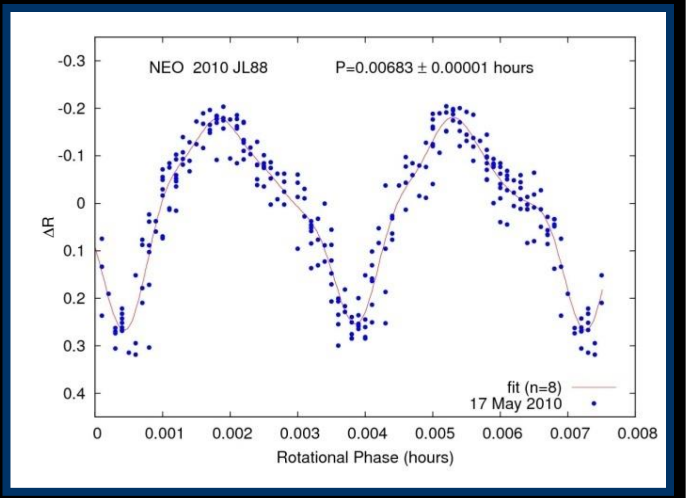
Spin rate as a function of asteroid diameter.

- There is limited data on physical properties such as rotation rate for the very smallest (< 500 m in diameter) Near-Earth Asteroids (NEAs) being discovered.
- Data are needed to better understand the spin rate distribution for the NEA population as a function of size, and to test current theories of the relationship between spin limits and overall strength.
- Lightcurve amplitudes can infer shape and degree of internal fracture (i.e., rubble pile objects would tend to exhibit different axial ratios than monolithic fragments created via impact events.

Target Characterization: Spin Rates

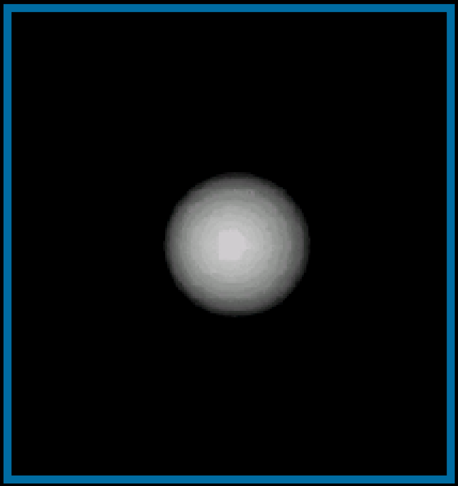
Data collection can be optimized for close-approaches (“Flybys”) to improve signal-to-noise in shorter exposures.

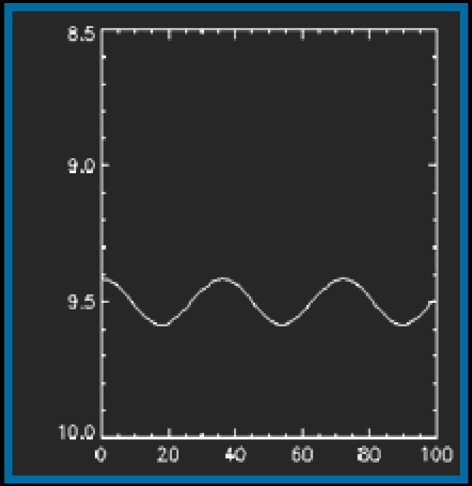




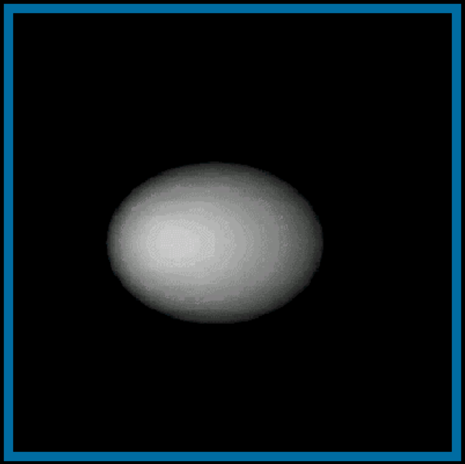
The lightcurve for NEA 2010 JL$_{88}$ (H=26.8, diameter ~19 m), taken with the MRO 2.4m telescope when the object had a visible magnitude of V~16.5. This object is spinning at a rate of 24.5 seconds, which is the fastest NEO rotation rate currently observed.

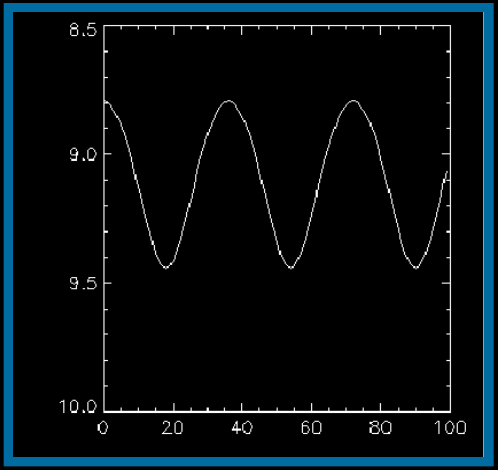
Lightcurve Amplitude





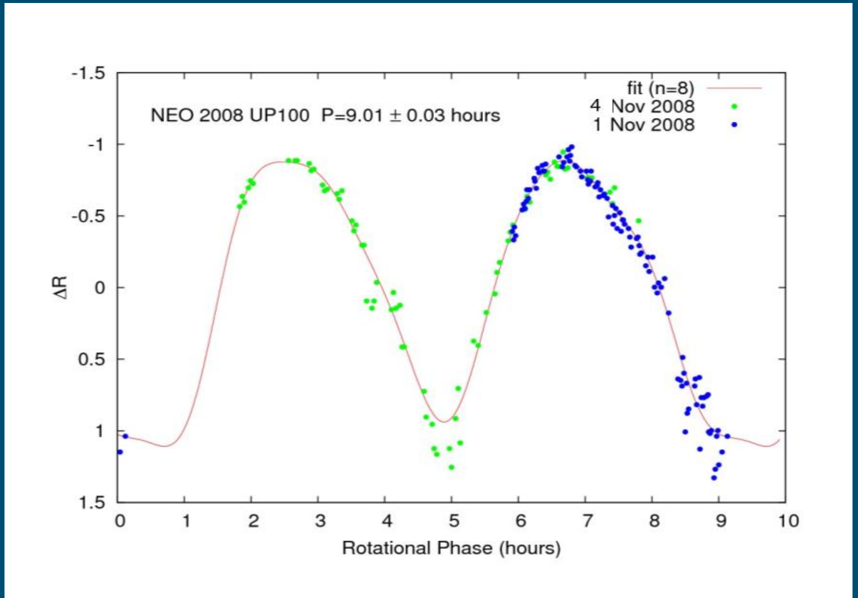
Lightcurve for a **roughly spherically-shaped** asteroid. Relative magnitudes are shown on the y-axis, and elapsed time on the x-axis. The amplitude is ~0.2 magnitudes (peak-to-trough).

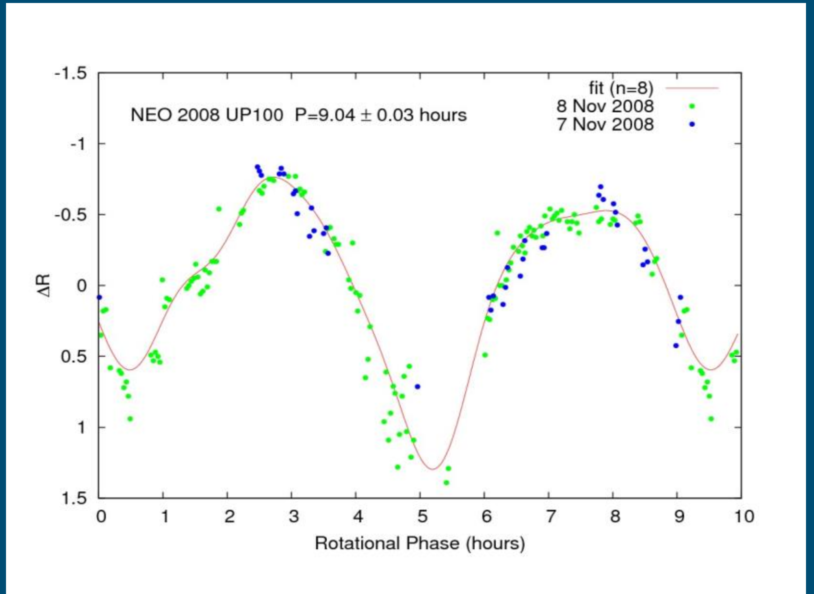




Lightcurve for a **triaxial ellipsoidal-shaped** asteroid. The amplitude is about 0.65 magnitudes (peak-to-trough variation), much larger than for a more spherical object.

Large Amplitude Variation

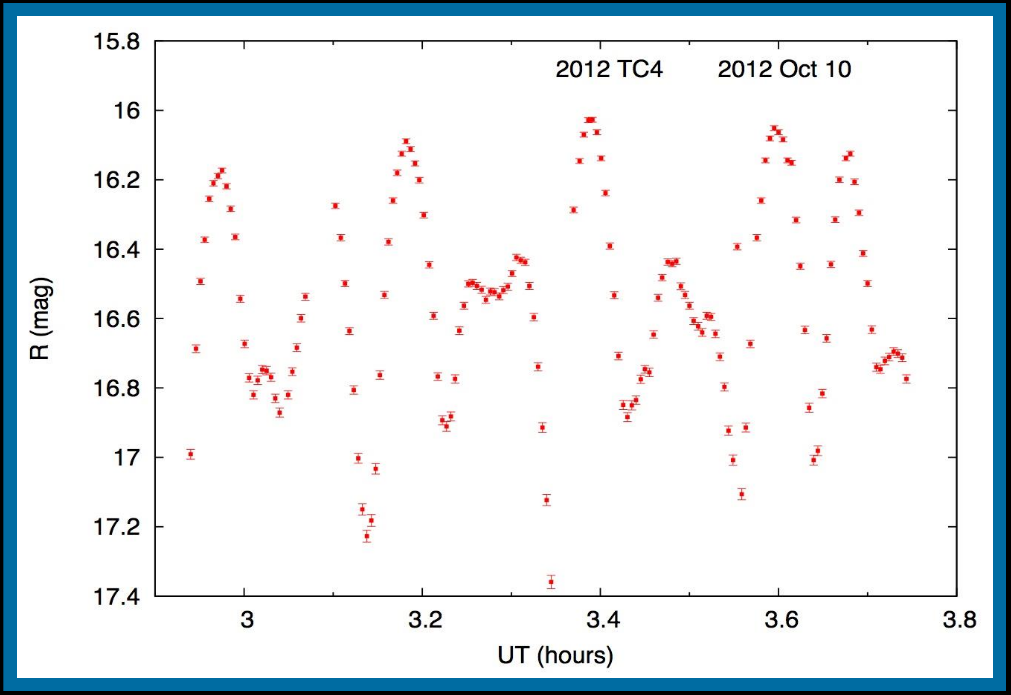




NEO 2008 UP$_{100}$ (H=23.9; diameter ~50 – 100 m) during 4 nights in Nov. 2008. Solar phase angle was 29 - 39° for Nov. 1-4 and 21 - 23° degrees for Nov. 7-8. A large amplitude of ~2 magnitudes is still evident at the lower phase angle. Rotation rate is 9 hours.

Recent modeling of rubble pile structures by Harris et al. (2009) indicates that this amplitude borders on or exceeds the elongation limit of a slowly rotating strengthless object, implying that this asteroid may have a non-negligible material strength.

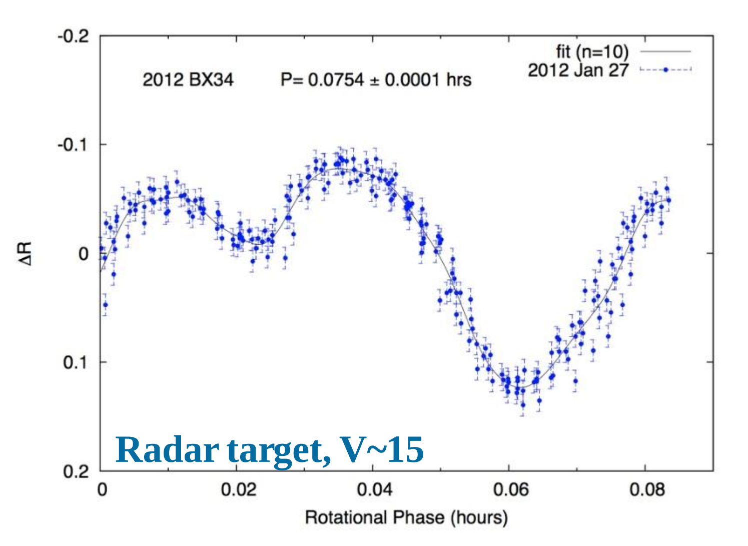
Challenges:

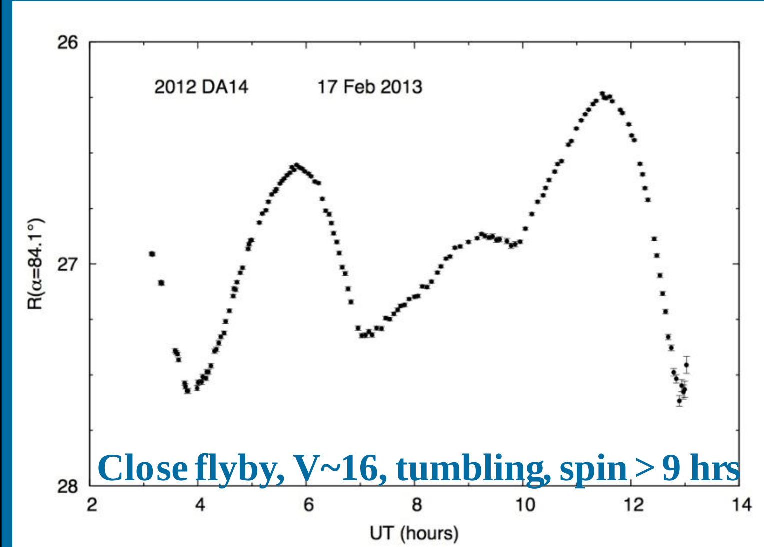


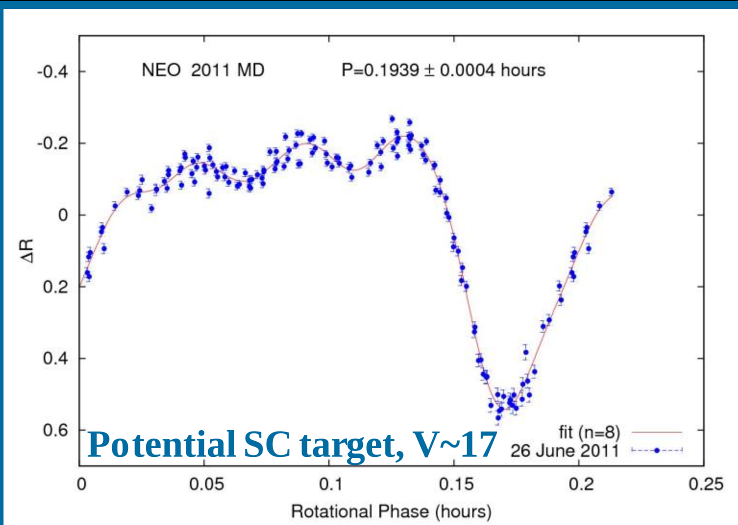
Lightcurve of a tumbling asteroid from a dataset of about ~60 lightcurves of NEAs collected at the Magdalena Ridge Observatory's (MRO) 2.4-meter telescope reduced for rotation rates.

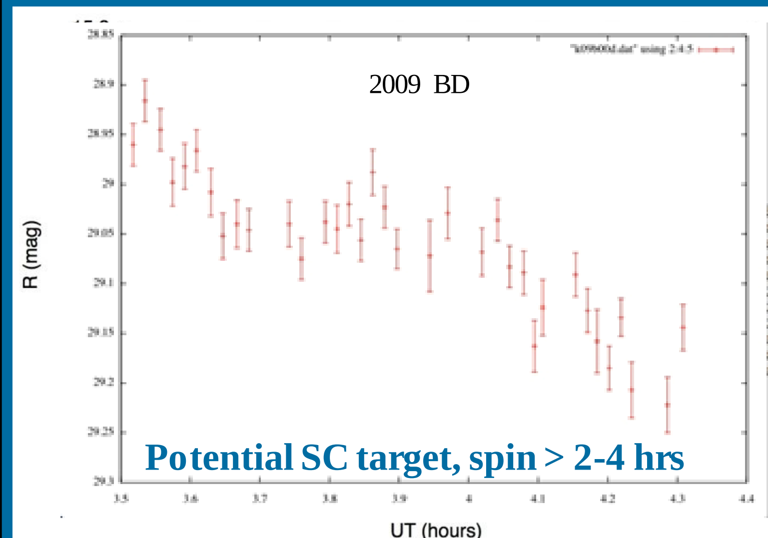
- Faint Targets
- Fast-moving asteroids
- Short spin rates (minutes)
- Long spin rates (many hours)
- Asteroids that are tumbling

MRO 2.4m Telescope: Characterization of Flybys

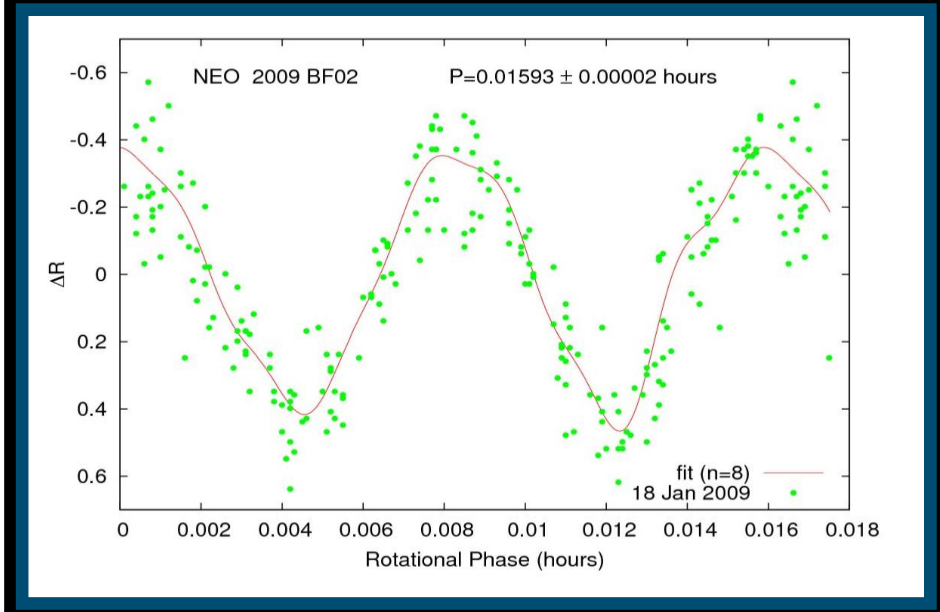


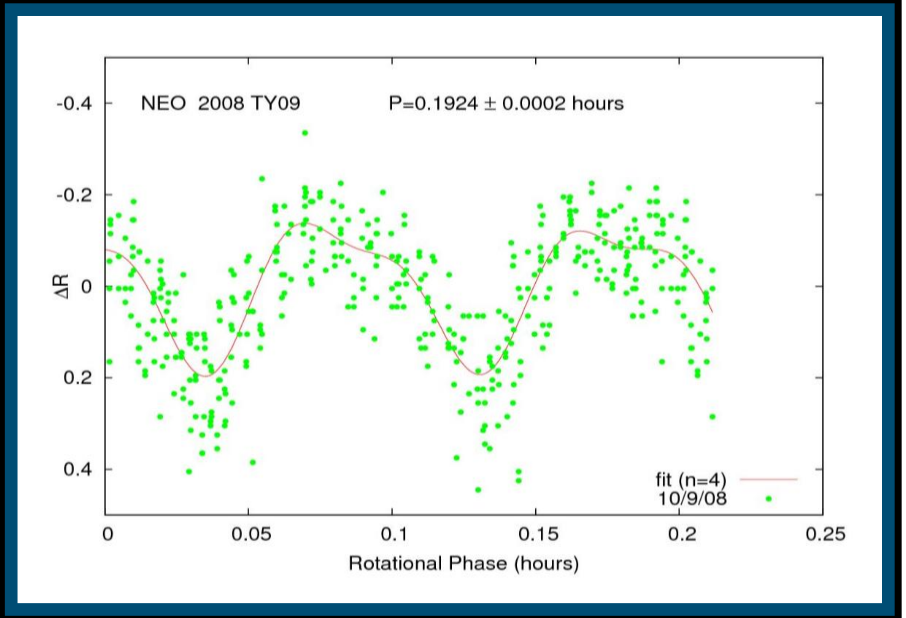






Fast, Small Diameter Rotators



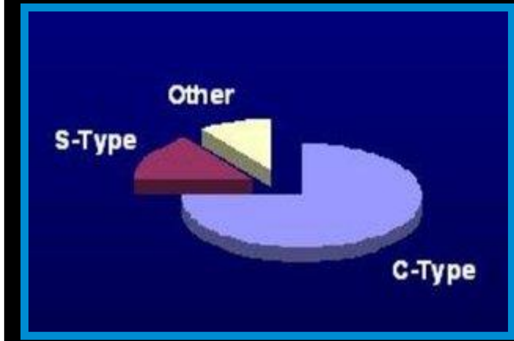


Size=20-50 m; V~18.3; motion 19"/min

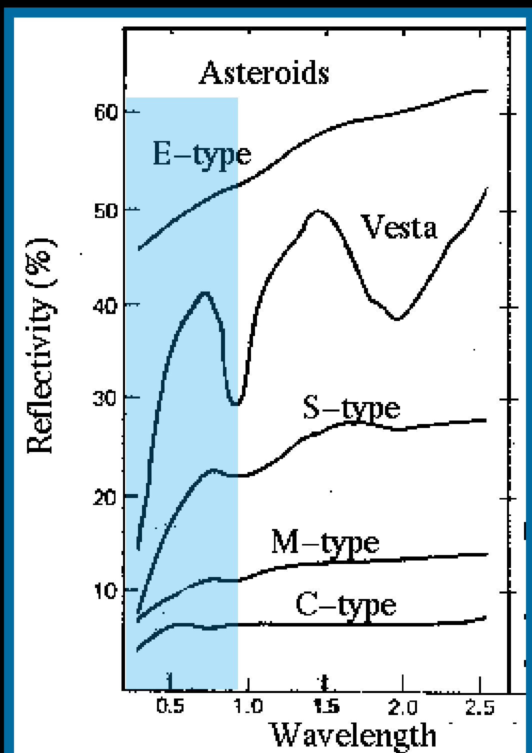
Size=25-75 m; V~19.5; motion 10.42"/min

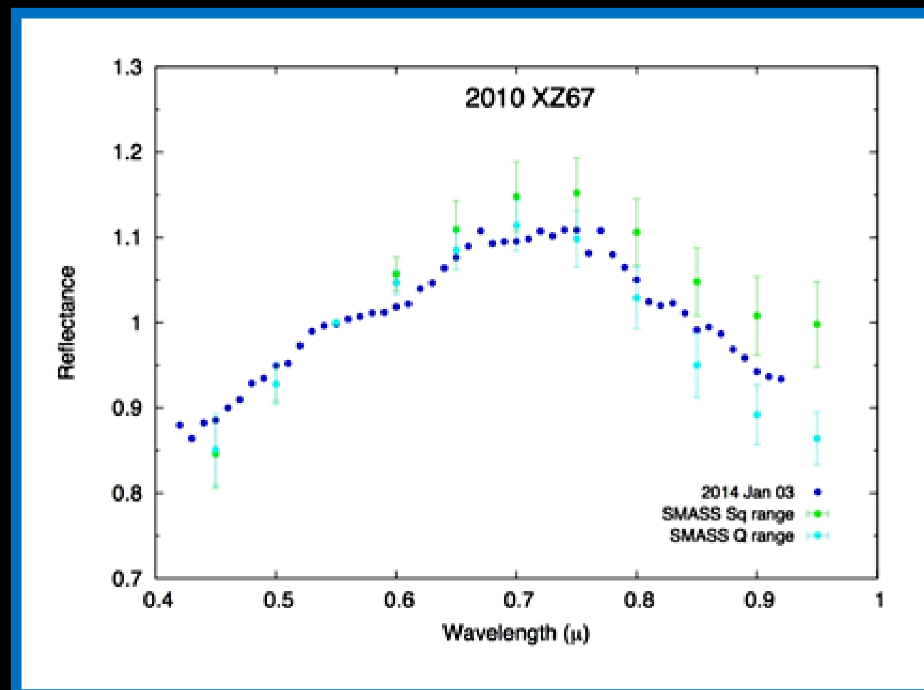
The lightcurve for NEO 2009 BF_2 is shown on the left. It's 57 sec rotational period and is *indicative* of a monolithic body. On the right is the lightcurve for NEA 2008 TY_{09}, which has a period of 11.5 min.

Target Characterization: Visible Spectra



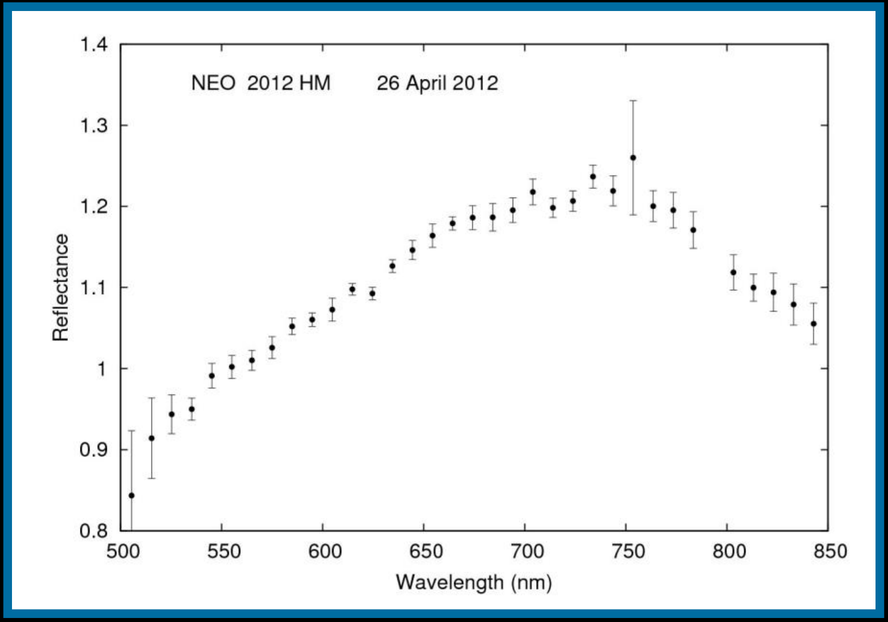
Asteroids are varied mixtures of metals (M-type), carbon (C-type) and silicon (S-type) compounds. We do a <u>first-order match</u> of telescope-acquired spectra to known materials. Composition helps constrain size (albedo).

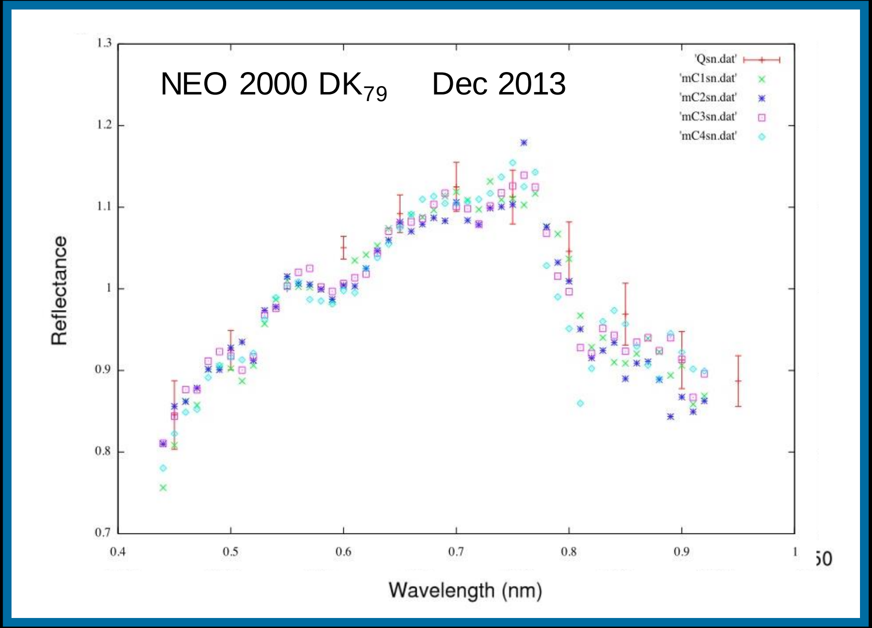




Visible spectrum of asteroid 2010 XZ_{67} (dark blue symbols) indicating an Sq-Q-type composition (silicate/metallic). Comparison spectra are shown (green & light blue symbols).

Target Characterization: Visible Spectra





Spectral characteristics (visible wavelengths) of NHATS list target 2012 HM (left); 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. Spectrum of asteroid 2000 DK$_{79}$ (right) indicating an Sq-Q-type composition (silicates/metals). These objects were also extensively studied by radar groups.

Summary: Rapid, Real-time Follow-up of NEOs

- **Follow-up Astrometry: allows accurate orbits to be calculated & assessment of hazard to be made.**

- **Spin Rates: reveal how fast an asteroid is rotating, whether it's tumbling, & shape characteristics**

- **Spectra: Rough composition determination helps constrain size (albedo, i.e., dark or bright) and identifies interesting potential spacecraft targets**