Target-of-Opportunity Characterization of Sub-200 meter Near-Earth Asteroids

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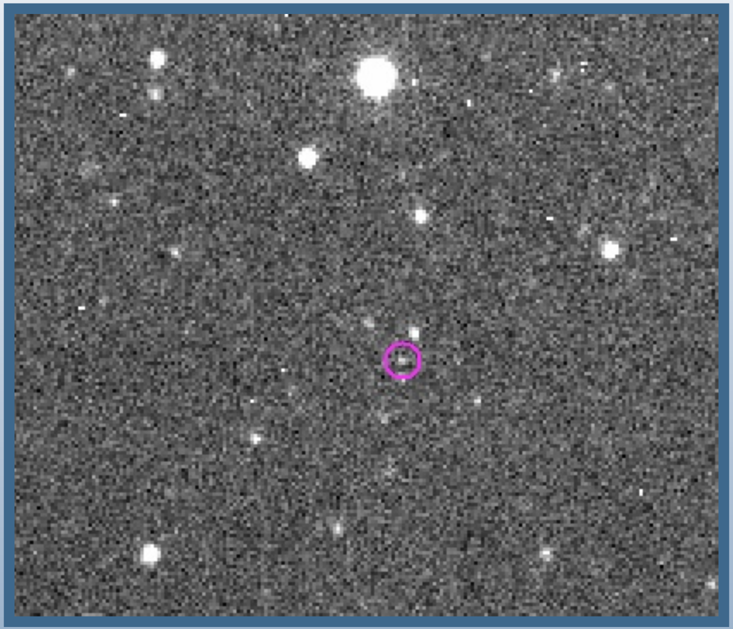
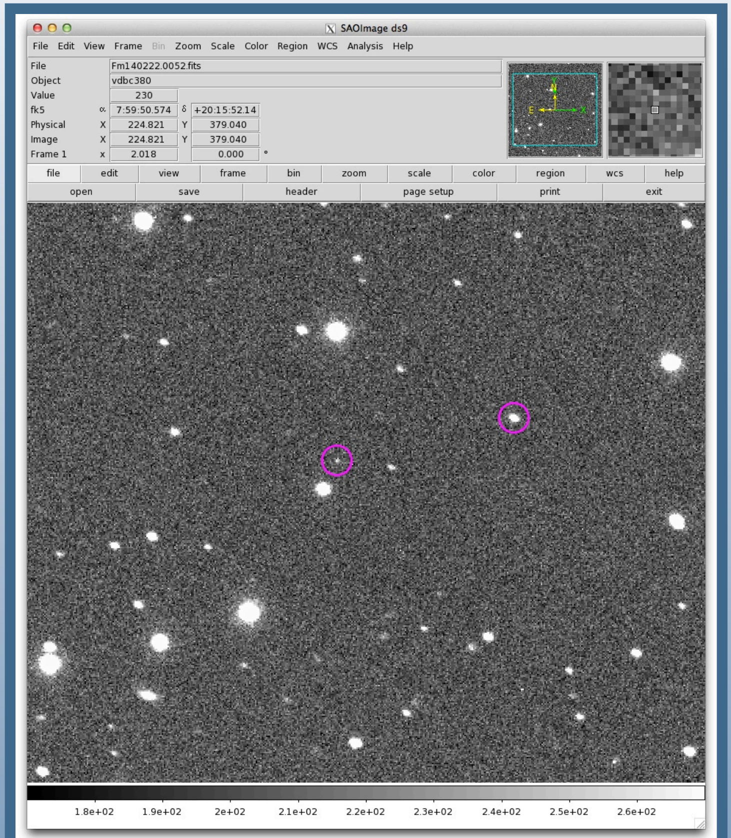
NEO Astrometric Follow Up



Single 240-second exposure of V~24.1 target 2012 QK_{24}



10-sec exposure of V~21.1 target 2014 DF_{10} moving at ~8.5”/min

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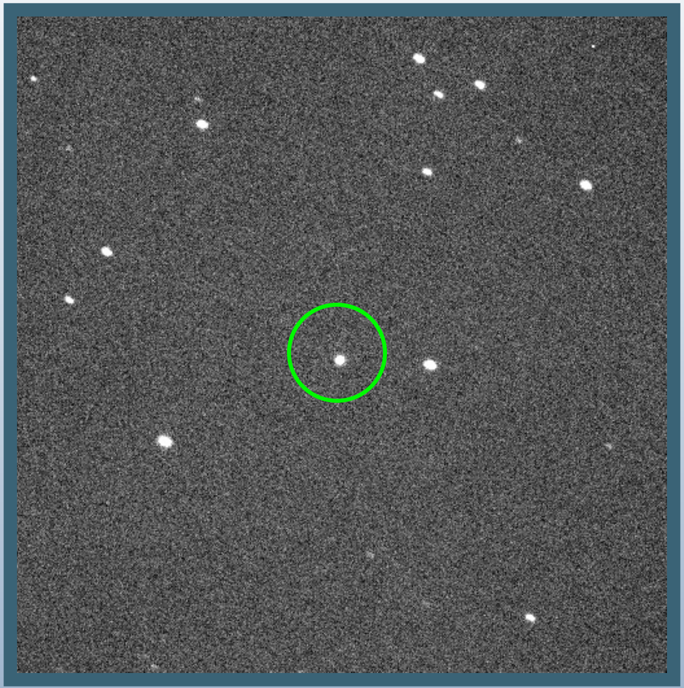
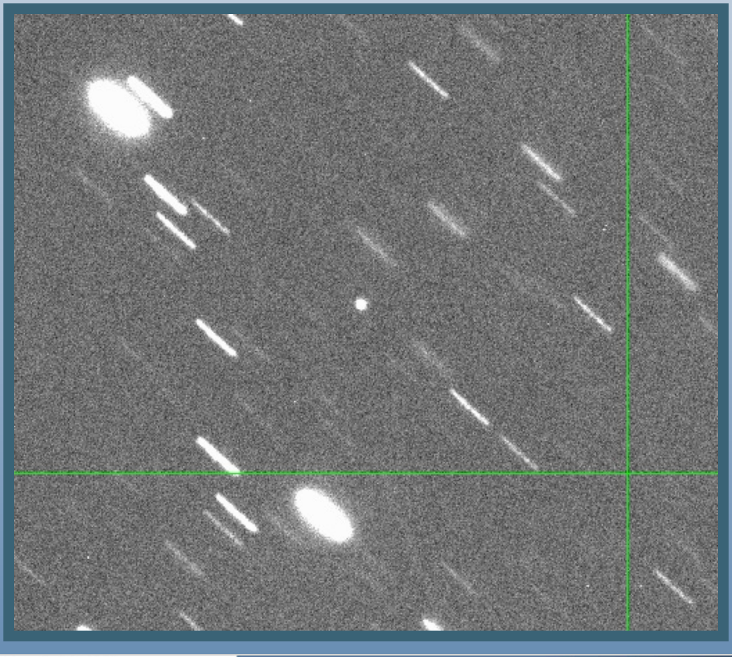
Extending to Characterization



Astrometry: 2014 JR_{24} (7 May 2014):

½-second images of bright (V~15.6) target moving at 300 "/minute



Photometry: 2015 FP_{35} (24 March 2015):

30-second images of V~18 target moving ~40 "/minute

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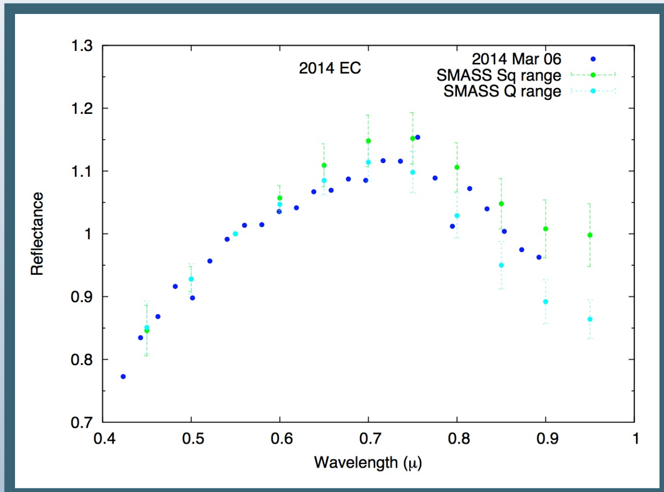
New Spectroscopic Capabilities

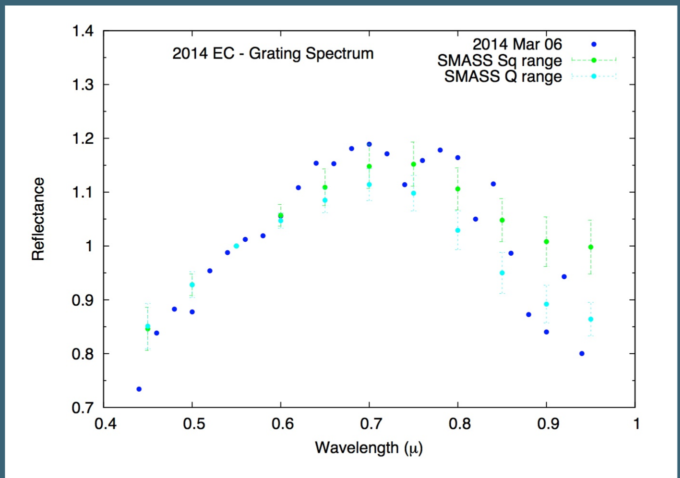
Magdalena Ridge Optical Spectroscopy System (MOSS)

- Dual-use R~250 spectrometer
- Permanently mounted at the second Nasmyth port
- Current Magnitude limit V~18-19



Slitless Grating

- Filter Wheel Mounted
- Current Magnitude limit V~17-18



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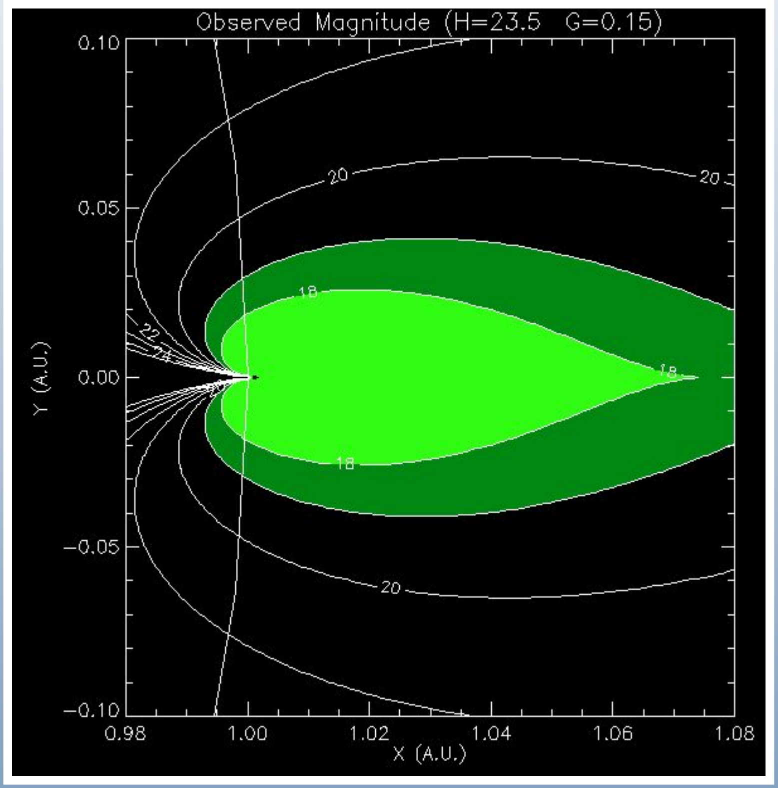
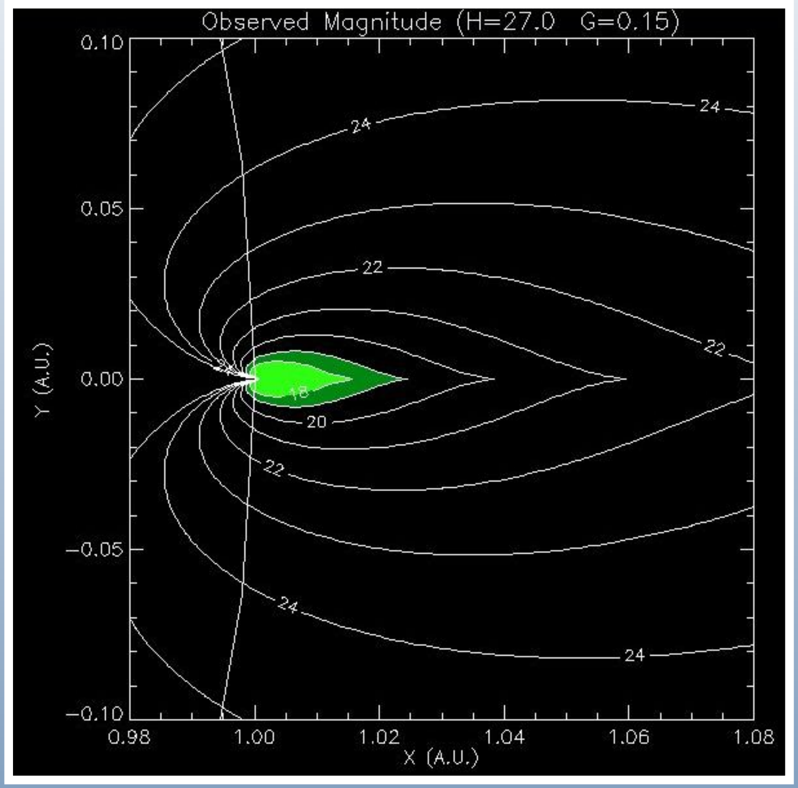
Targets of Opportunity





5 - 20 km/sec ~ 0.003-0.011 A.U. per day

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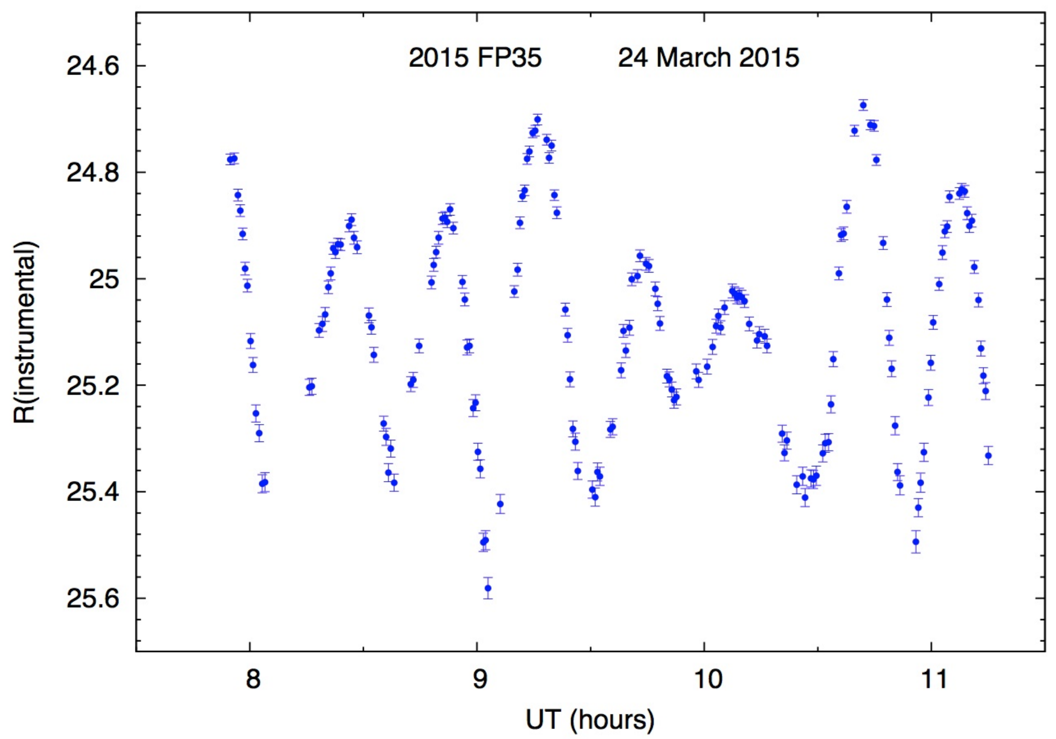
Observation Timeframe: Several Days



The lightcurve for **2015 FP$_{35}$** (H~24.3) exhibits tumbling behavior with a primary periodicity of ~1 hour.

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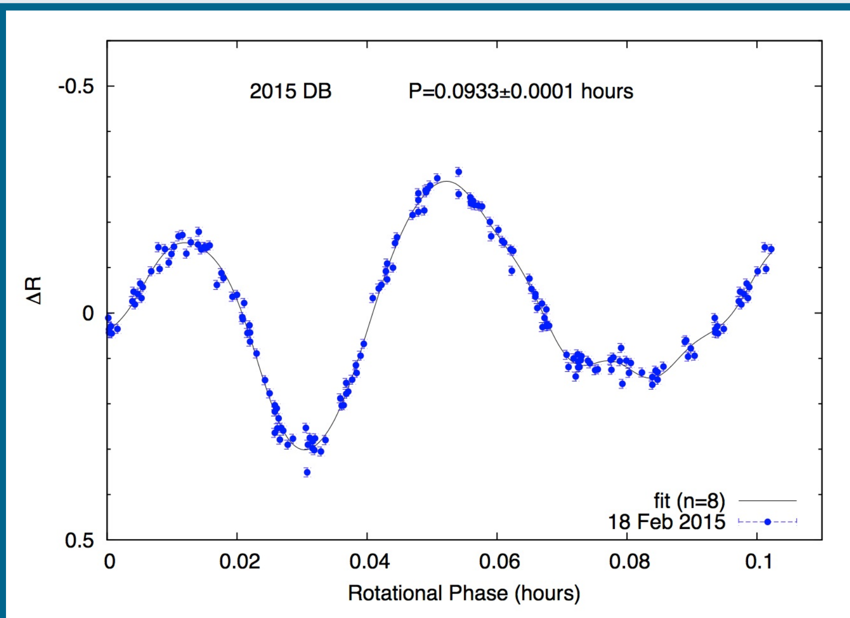
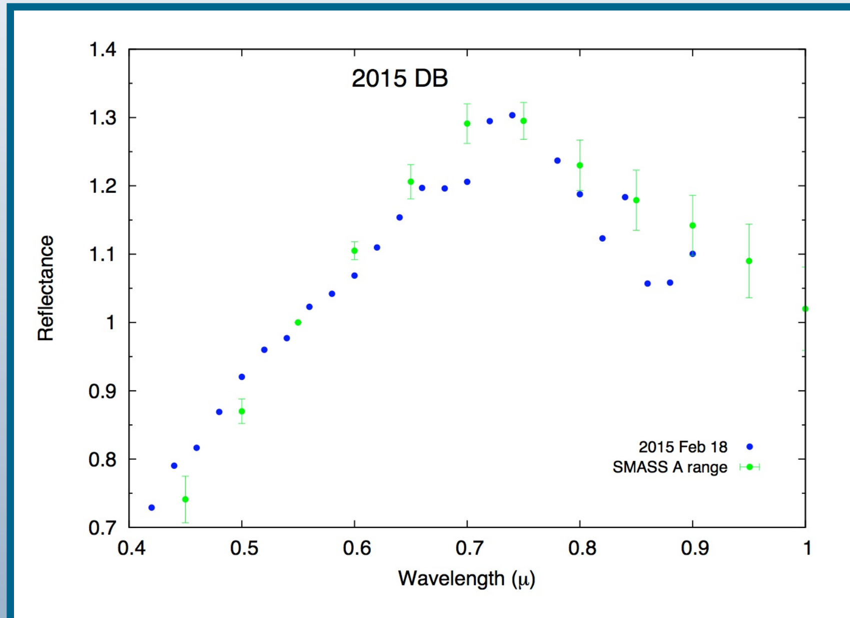
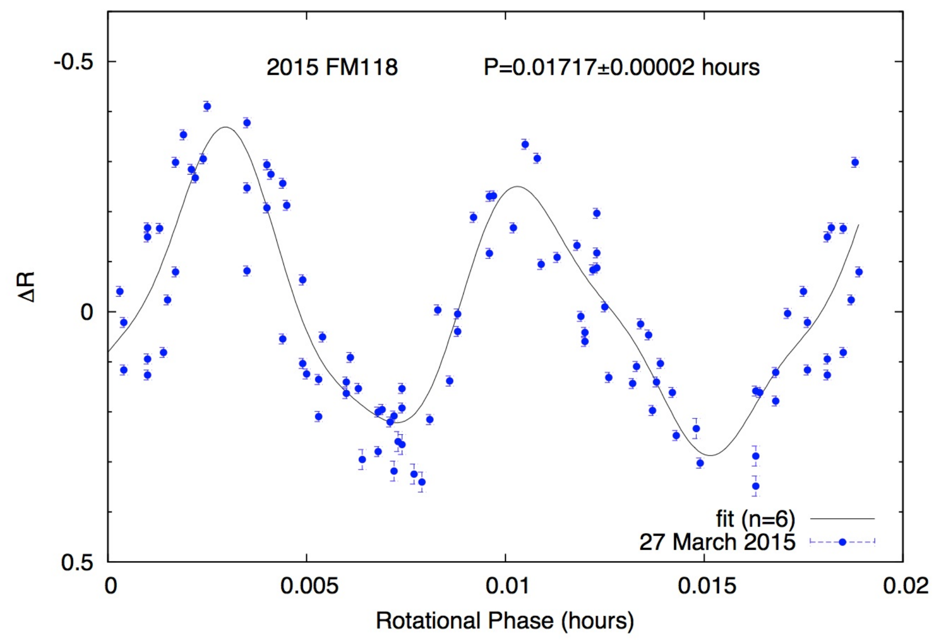
Observation Timeframe: 1-2 Days





Lightcurve (left) for **2015 DB** (H~27.7) which only stayed in the characterization zone for about 2 days. A visible grating-derived spectra is shown on the right, with SMASS A-type ranges overplotted. The spectra is derived from twenty 60 second exposures summed and calibrated with a solar standard.

Observation Timeframe: Immediate!



Asteroid **2015 FM$_{118}$** (H~28.7) was moving at approximately 80 arc-seconds per minute through a crowded star field, which made a slitless grating spectra difficult to impossible to obtain. However, a lightcurve was acquired yielding the approximately 61 second rotation period.

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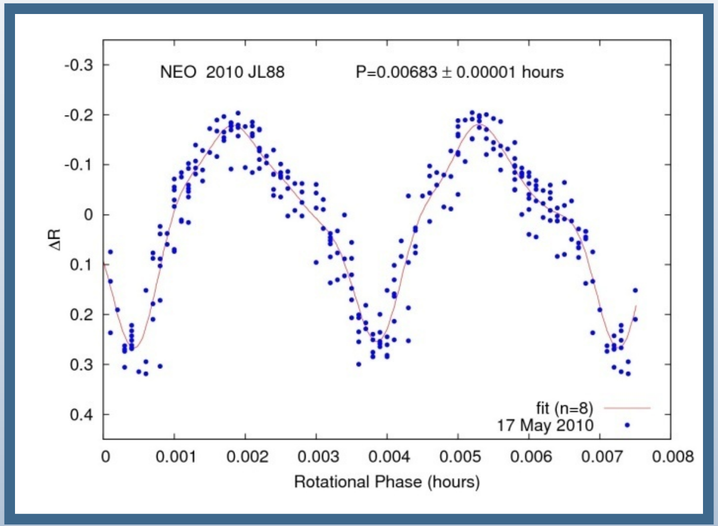
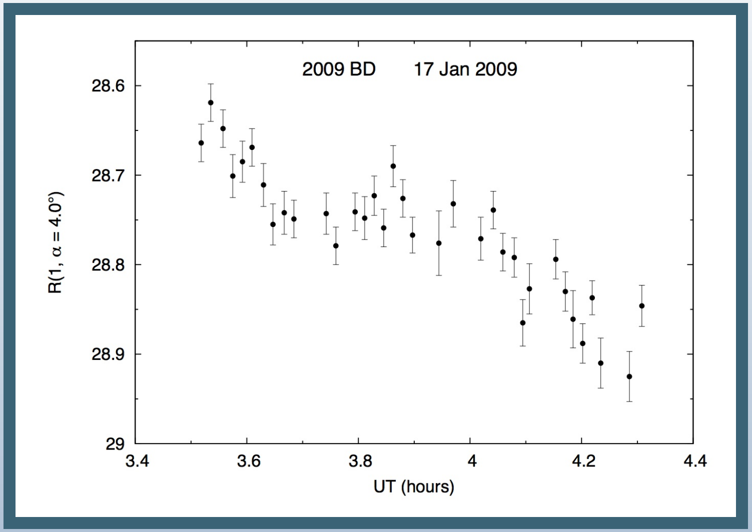
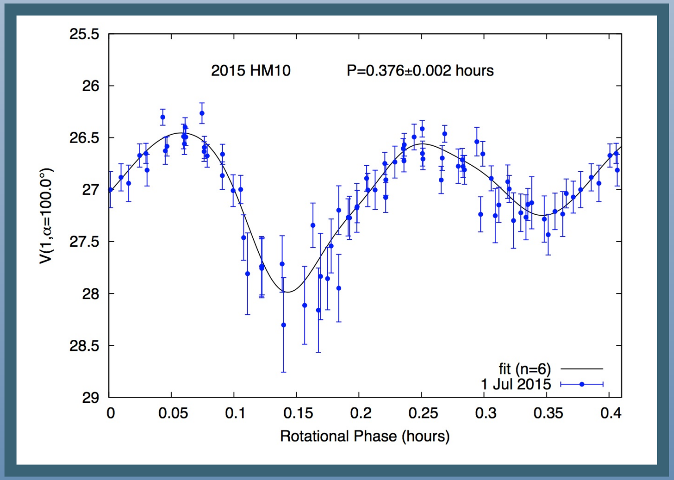
Interesting Results



2010 JL_{88} : H~26.8 (~12 - 25 meters)



2009 BD: H~28.1 (~8 – 15 meters)



2015 HM_{10}: H~23.6 (~50 – 100 meters)

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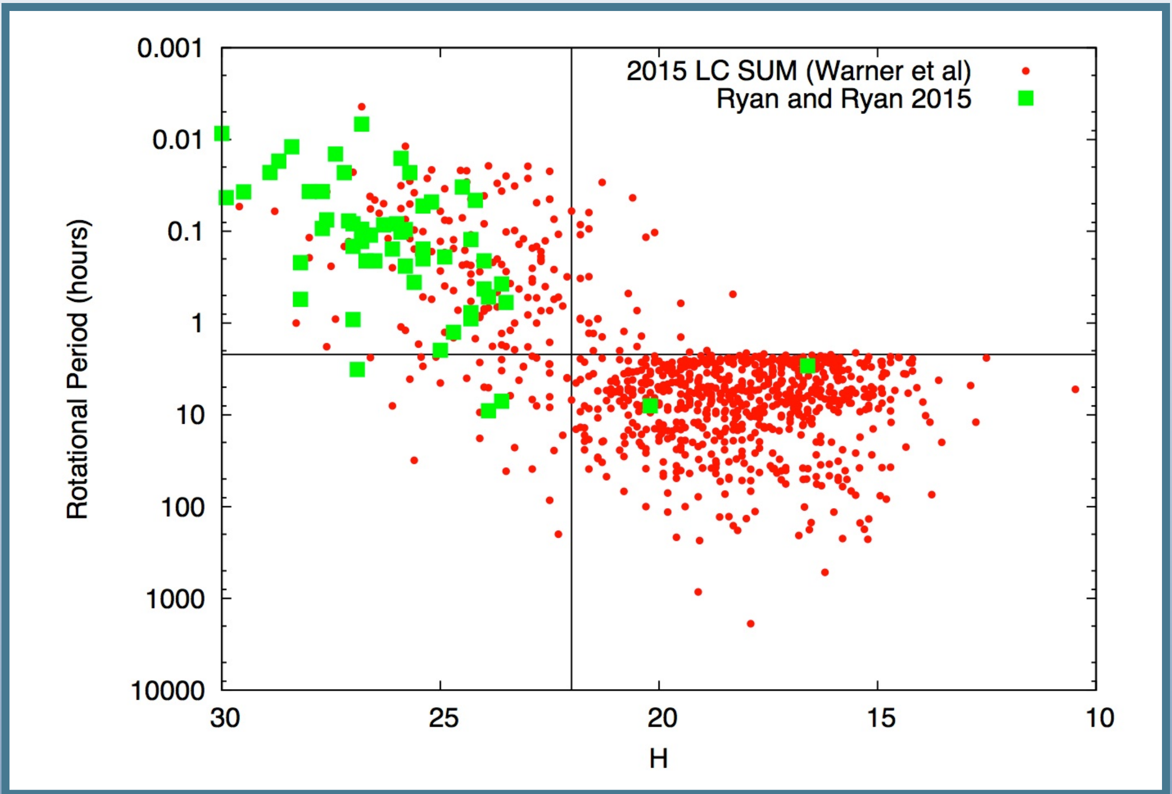
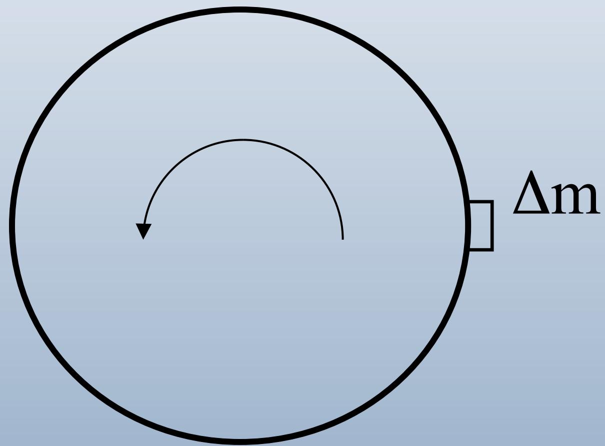
Spin Rate *vs.* Size



A plot of rotation period *vs.* absolute magnitude (H) where the red circles are NEAs from (Warner et al. 2015) and the green squares are new data acquired via this current work.

(Naive) Rubble Pile Rotation Barrier



$$F_{gravitational} > F_{centripetal}$$

$$\Rightarrow \text{Period} > \sqrt{\frac{3\pi}{G}\frac{1}{\rho}} = \frac{3.3\,\text{hours}}{\sqrt{\rho}}$$

$$\Rightarrow \text{Period} > 2.2\,\text{hours for } \rho \approx 2.2 - 2.3\ {}^{g}\!/_{cm^3}$$

Pravec and Harris (2000) – But . . . .

not really that simple!! (Holsapple 2003)

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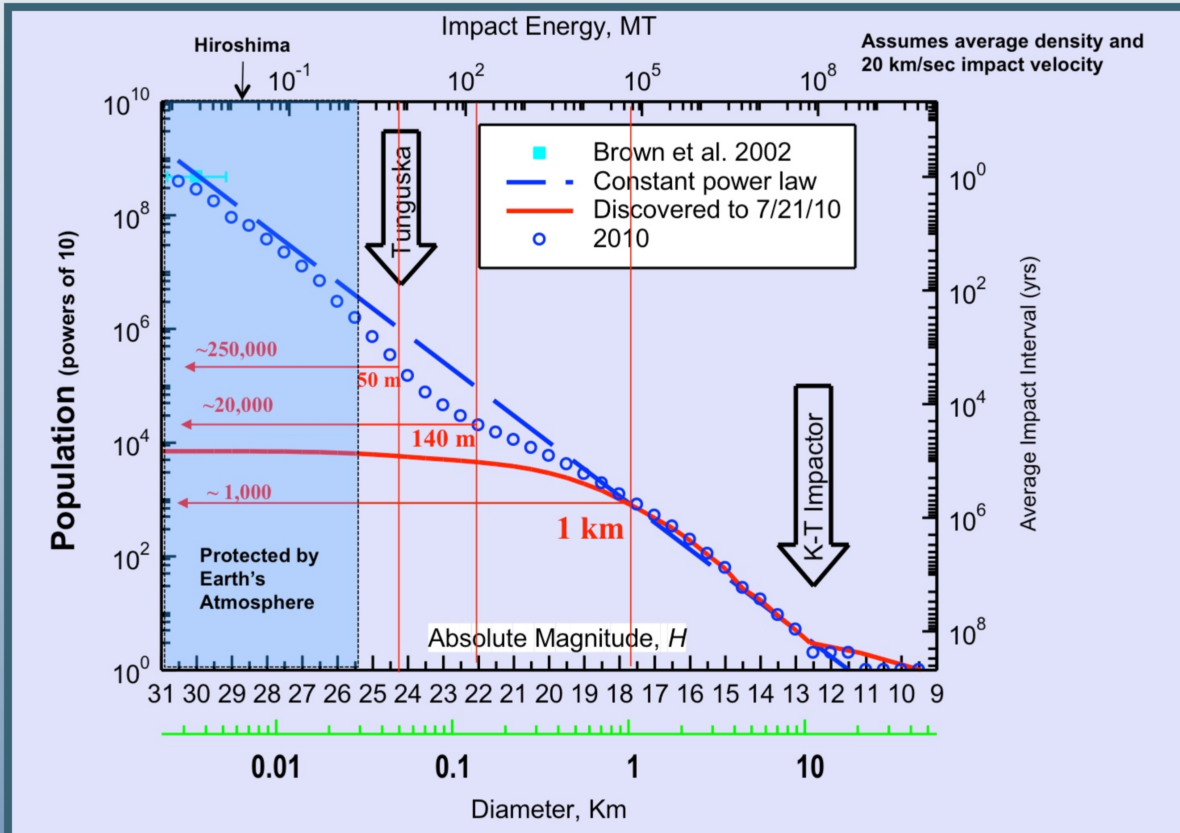
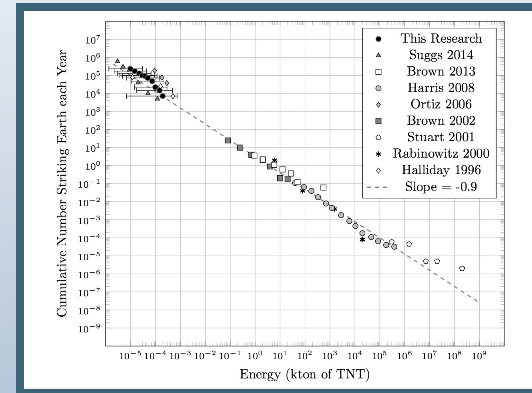
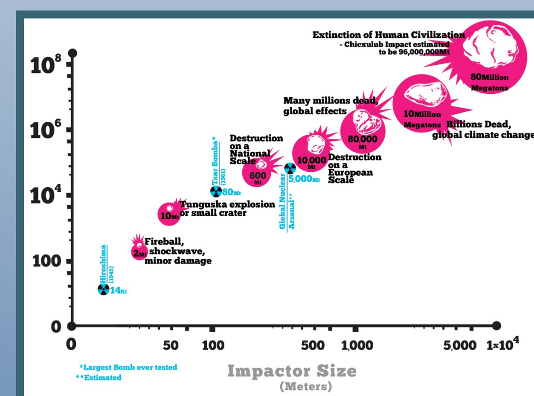
Significance to Hazard Mitigation



Harris, 2010



Rembold and E. Ryan, 2015



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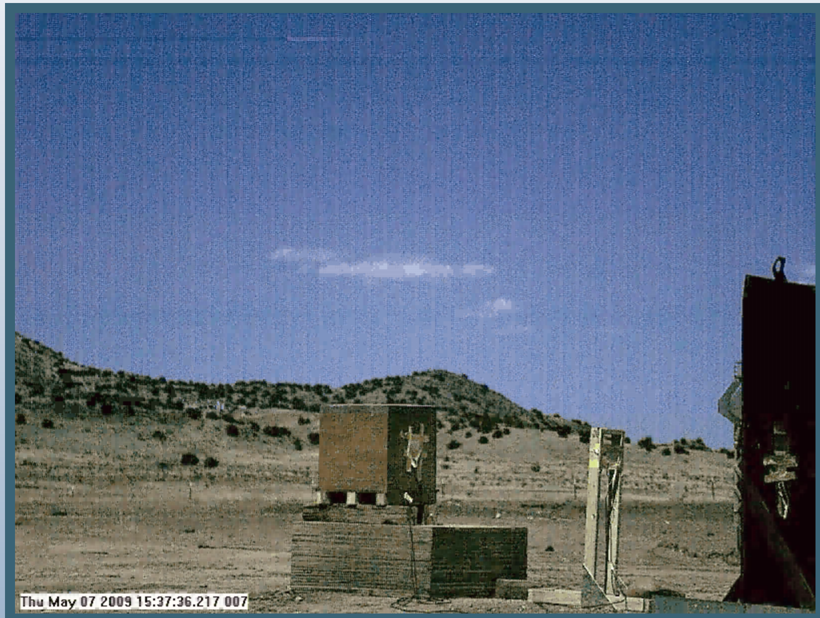
Small Asteroid Impacts are *Real* Threat

Carancas, Peru (2007) ~3 m impactor
(Tancredi et al., *ACM* 2008)

- 2008 TC3 Sudan (2008) ~4-5 m
- 2014 AA Atlantic?? (2014) ~1-3 m
- Tunguska, Siberia (1908) ~50 m
- *Chelyabinsk* (2013) ~20 m

Other Perspectives: Impact Experiments



E. Ryan and Love (2015), HVIS 2015

EMRTC October 2015

- **Examine initial size, rotations, and tumbling behavior of monolithic asteroidal material from fragmentation ejecta**
- **Validate Numerical Codes**

Observational Goals and Summary

Utilize target-of-opportunity scenarios to better characterize sub-200 meter asteroids during close approaches

Spin Rates:

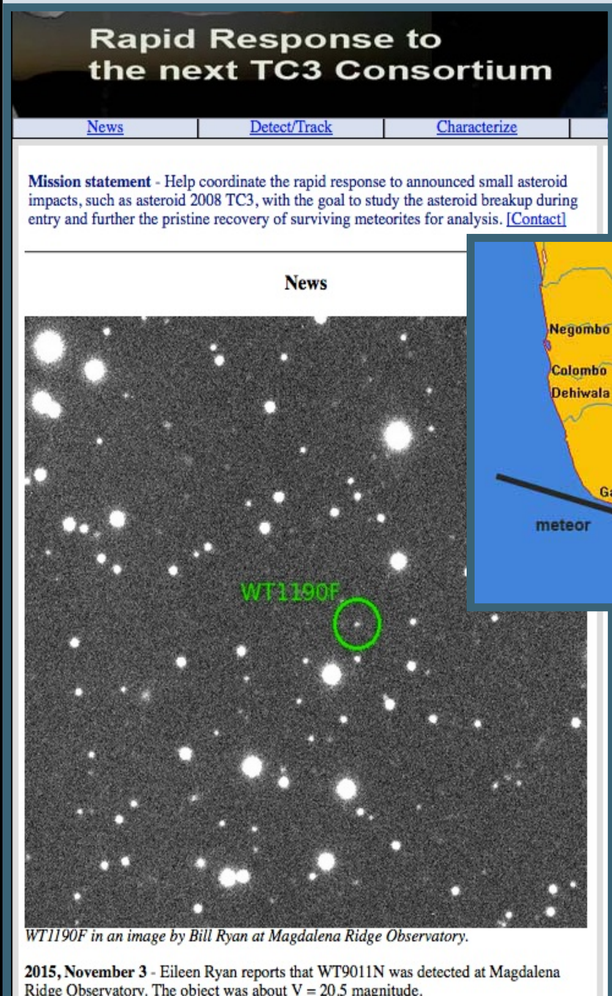
- **Not all small asteroids are fast rotators – current sample may be observationally biased. Therefore, to fully understand the structural constraints imposed by observed spin rates, effort must be made to ensure completeness of the sample (especially slower rotators)**

- **Compare observed spin rate characteristics with impact experiments. How much of observed spins in monolithic objects can be attributed as primordial? How much requires a 'spin up'.**

Spectra:

- **Better sample composition of the small NEA population**
- **Provides inputs and constraints to dynamical evolution models**
- **Composition, along with lightcurves, can provide hints to the (ranges of) material strengths of small asteroids.**

Asteroid Impact Scenario: WT1190F



Rapid Response to the next TC3 Consortium

News | Detect/Track | Characterize

Mission statement - Help coordinate the rapid response to announced small asteroid impacts, such as asteroid 2008 TC3, with the goal to study the asteroid breakup during entry and further the pristine recovery of surviving meteorites for analysis. [Contact]

News

WT1190F

WT1190F in an image by Bill Ryan at Magdalena Ridge Observatory.

2015, November 3 - Eileen Ryan reports that WT9011N was detected at Magdalena Ridge Observatory. The object was about V = 20.5 magnitude.

Practice mission:

- MRO is a research team member of the **Rapid Response Consortium (RRC)** providing astrometric and characterization data for (future) asteroids impacting the Earth.

- **WT1190** is likely a spent rocket body (~1 meter in size) that will impact the Earth over the Indian Ocean near Sri Lanka on **Nov 13, 2015.** MRO astrometric data is helping to constrain the region of impact.

- The **United Arab Emirates** together with the **RRC** is sponsoring an airborne observing campaign to study the entry of space debris object WT1190F. **The European Space Agency** is also conducting a ground based observational campaign.