Existing and Expected Near-Earth Object Follow-up Capabilities

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(NM Tech/Magdalena Ridge Observatory)

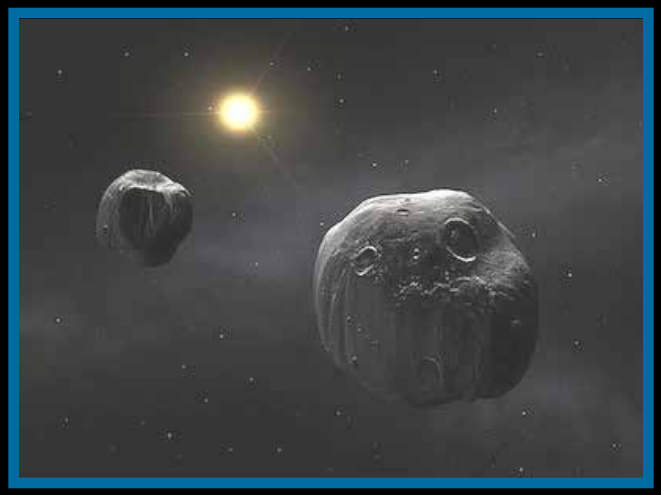
NEO Spaceguard Program

- **Discovery Telescopes: find NEOs**
- **Follow-up Telescopes: acquire astrometric positions**
- ***Minor Planet Center:* coordinates all observational data in real time**
- **NASA-JPL NEO Program Office: calculates orbits and assesses risk**

Follow-Up in Support of Discovery

- Follow-up astrometry provides the extended arc 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.
- Need continual follow-up on existing NEOs (especially PHAs and VIs) to update orbits. Without targeted follow-up, new discoveries can be lost. Characterization is also important.

Target Characterization



- After discovery, more information to characterize the 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 critical: 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.

IAU Minor Planet Center

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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 04:00 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. 00.5 UT.   R.A. = 12 07.1, Decl. = -45 43, V = 18.3] Added Apr. 0.03 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
P106CRm  97 1 [2013 Apr. 07.3 UT.   R.A. = 11 24.8, Decl. = -12 35, V = 20.4] Updated Apr. 8.83 UT
P106CRp  93 2 [2013 Apr. 07.3 UT.   R.A. = 11 05.5, Decl. = -15 16, V = 21.1] Updated Apr. 8.83 UT
P106CRn  97 2 [2013 Apr. 07.3 UT.   R.A. = 11 40.9, Decl. = -17 42, V = 21.1] Updated Apr. 8.65 UT
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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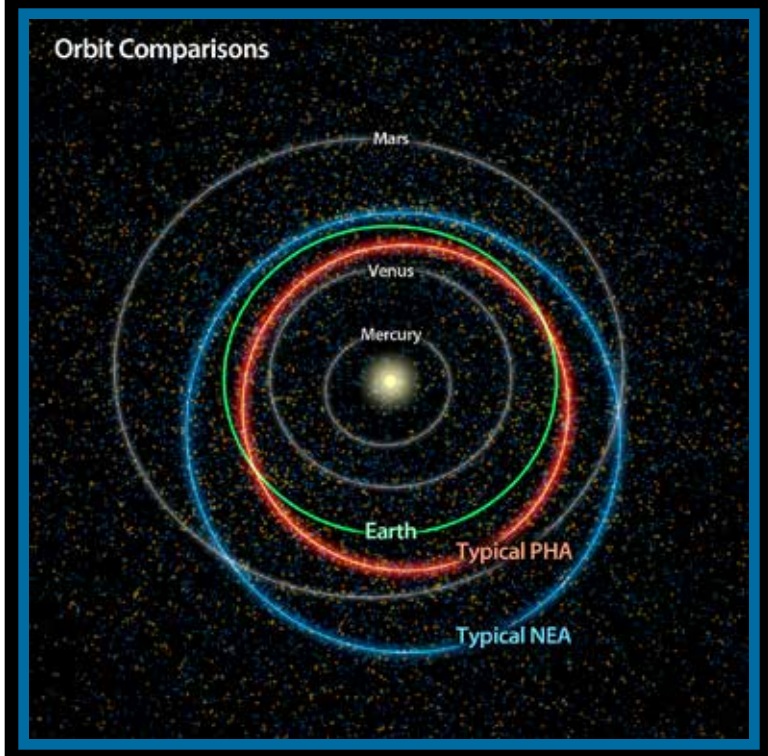
Funded NEO Follow-Up Programs



- **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”…

Astronomical Research Institute

(Robert Holmes, H21, Westfield, Illinois)

ARI coordinates follow-up using amateurs and students

24-inch Telescope

30-inch Telescope

32-inch Telescope

Limiting magnitude V~23

Also working at CTIO (807) in Southern Hemisphere using 0.41m Skynet telescopes in time-swap (1 oper., 2 students).

ARO Future Enhancements: 1.3m Telescope

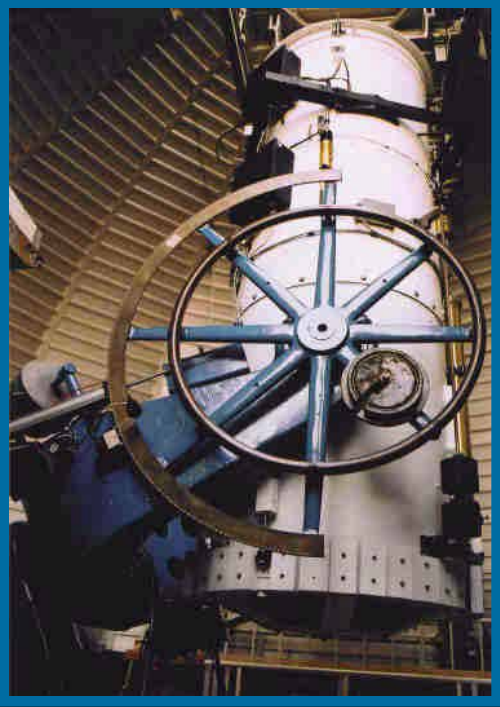
- New 1.3m telescope under construction
- On-sky testing with uncoated mirror for final adjustments
- Mirror now at coating facility
- Commissioning slated to start May 2013

Spacewatch

(Robert McMillan, 291, Kitt Peak, AZ)

Some discovery of Near-Earth Objects; primarily follow-up

1.8m Telescope



0.9m Telescope

Limiting Magnitude:

0.9 m Telescope: V~20-21
1.8 m Telescope: V~23.3

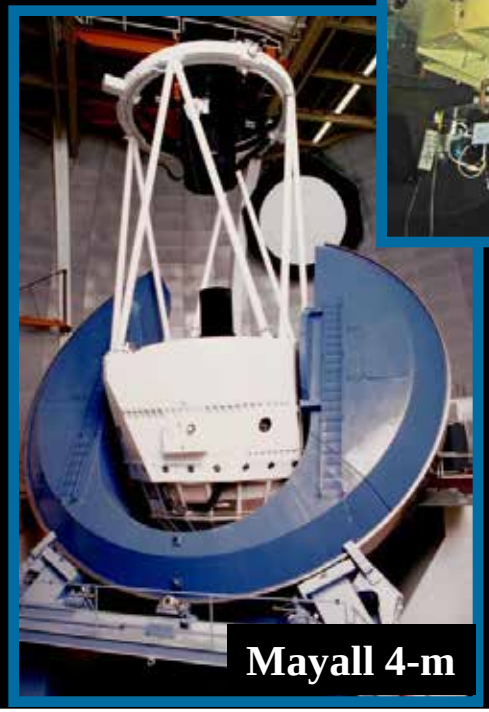
Spacewatch: Enhancements

- Improved productivity and astrometric accuracy in October 2011 with a better CCD

- Since 2010, regularly awarded time (~24 nights/yr) on the Kitt Peak's Bok 2.3-m (astrometric and BVRIz follow-up) and the Mayall 4-m (~5 nights/yr) for follow-up of faint NEOs and Virtual Impactors (VIs)

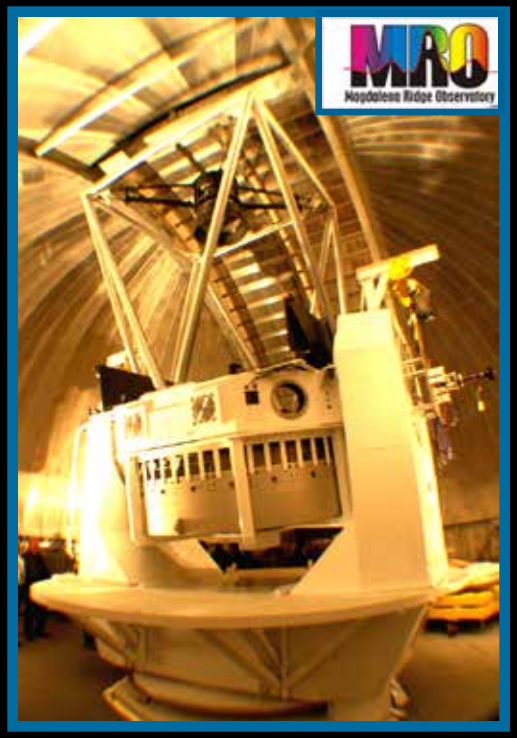
- Potential to make all images available for community access via an online database


Bok 2.3-m

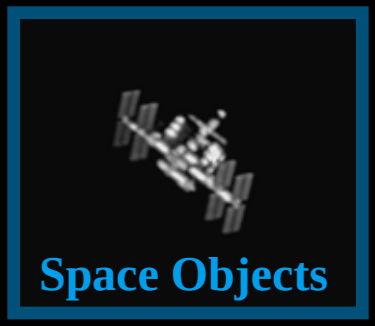

Mayall 4-m

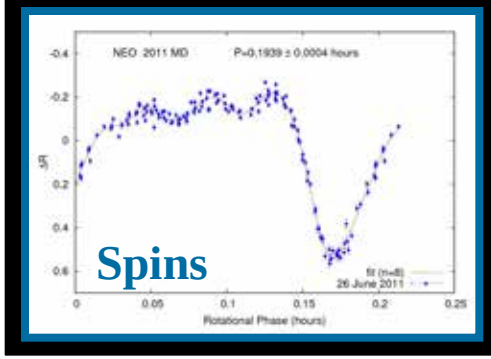
Magdalena Ridge Observatory 2.4m Telescope

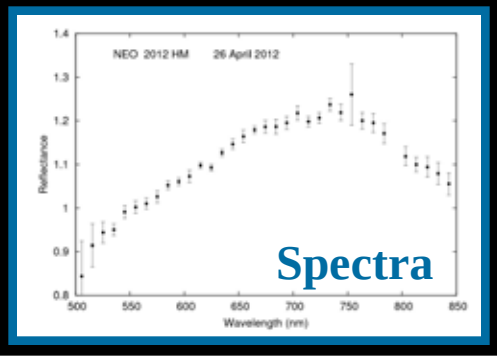
(Eileen and Bill Ryan, Socorro, NM



Limiting Magnitude V~24.5





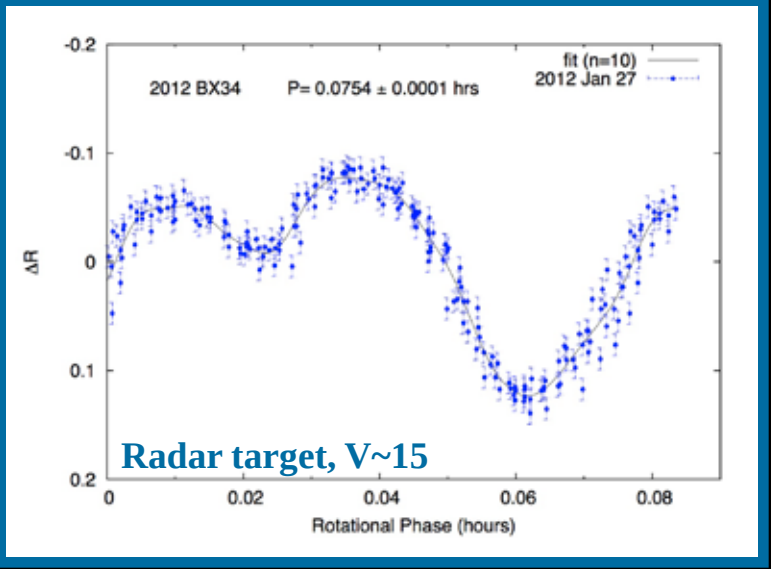


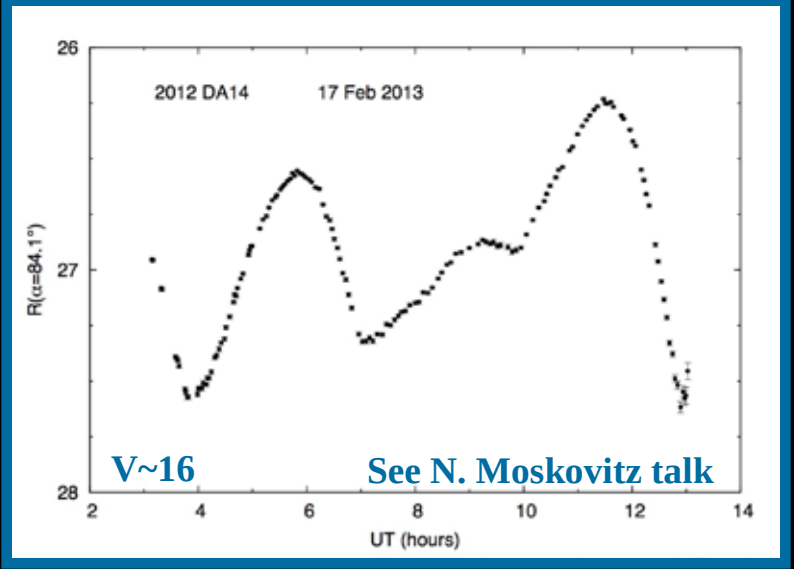
- **Follow-up on even the smallest asteroids**

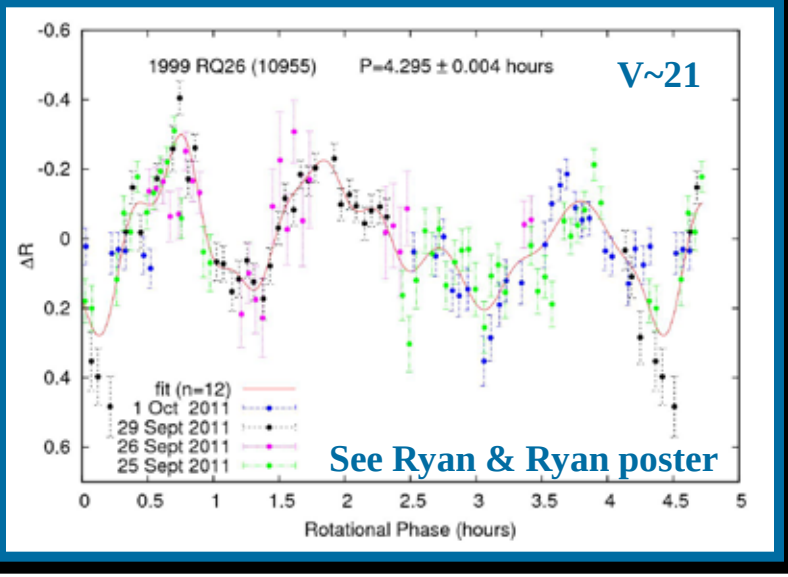
~7 nights per month

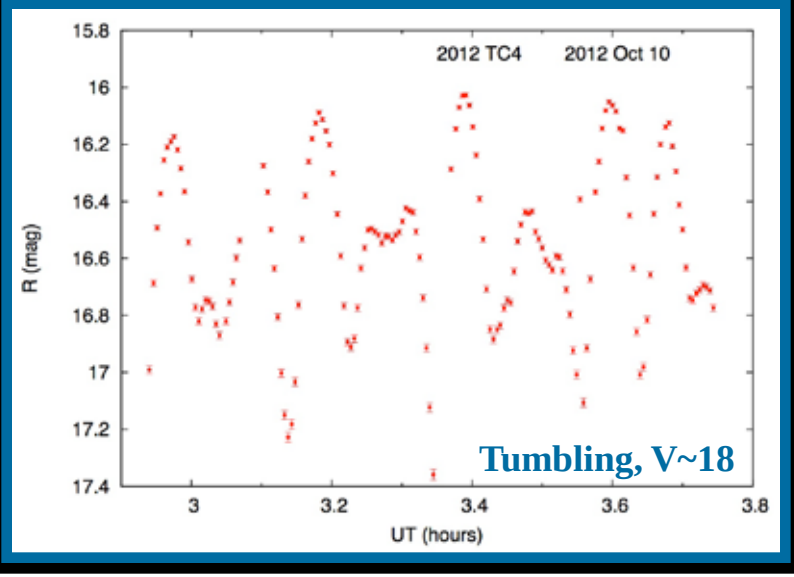
- **Capitalizes on real-time opportunities to observe close-approaching, NEAs to calculate spin rates, and determine composition.**
- **Coordinates with Radar**
- **Characterizes Potential Spacecraft targets**

MRO 2.4m Telescope: Characterization of Flybys/Spacecraft Targets









NASA-JPL Table Mountain Observatory

(Paul Weisman, Michael Hicks, Wrightwood, CA)

- **Confirmation and Recovery of Near-Earth Objects**
- **Physical Characterization of Spacecraft mission targets**
- **Asteroid Retrieval Studies (ARM)**
- **Physical characterization of NEOs in support of Goldstone and Arecibo radar studies**

0.6-m Telescope

0.4-m Telescope

Future Enhancements: More staff and refurbishment of a dome for 1-m telescope on loan from Lowell Observatory (Fall. 2013).

University of Hawaii 2.2-m

(Dave Tholen, 568, Mauna Kea, HI)

Astrometry and characterization of faint Near-Earth Objects

CFHT 3.6-m, Subaru 8.2-m, and Keck 10-m also used

Catalina Sky Survey

(Steve Larsen, G96/G84, Mt. Lemmon, AZ)

- **Upgrades complete to Mt. Lemmon 1.5-m reflector to support deeper survey, follow-up, and physical characterization programs.**

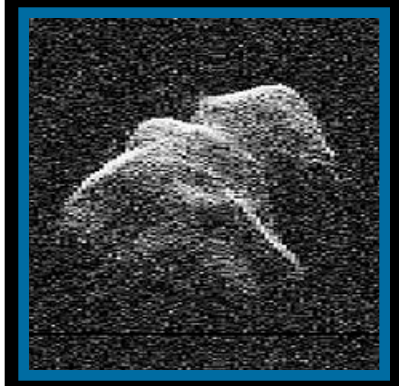
- **Transitioning to using refurbished 1-m telescope on Mt. Lemmon for astrometric follow-up in the next few months; verified that astrometry is good and have an MPC code.**

- **For Southern hemisphere astrometric follow-up and characterization, working with the LCOGT. Telescopes are being used at McDonald Observatory, Cerro Tololo, South Africa (Sutherland), and Siding Spring Observatory (with Tim Lister, LCOGT).**

Radar Observations

(Lance Benner, Mike Nolan, Goldstone/Arecibo)

Radar delivers precise orbit determination & shape modeling



1996 Goldstone radar image of Toutatis

- **New ranging system at Goldstone increased precision for tiny NEAs to 7.5 meters. (Can achieve 3.75 meters for ranging astrometry for objects less than ~10 m in diameter).**

- **More radar tracking due to increased funding. In 2012, 67 NEAs observed at Arecibo and 26 at Goldstone. Expected to observe 50-60 NEAs combined in 2013.**

See Lance Benner's talk on Tuesday

Notable "Self-funded" Contributions

*(*Peter Birtwhistle, *J95, Great Shefford, England)*

The Great Shefford Observatory is a private facility located in West Berkshire, England, about 60 miles west of central London.

0.4-m Telescope

About <u>400</u> MPECs in 2012 (over 160 nights) in a cloudy country!

Limiting magnitude V~20-21

Crowd Sourcing Follow-up: Legion of Self-funded NEO Supporters

- 926 Tenagra II Observatory. Observers P. R. Holvorcem, M. Schwartz. Measurer P. R. Holvorcem. 0.81-m f/7 Ritchey-Chretien + CCD.
- 950 La Palma. Observers O. Vaduvescu, T. Badescu, D. Lacatus, A. Paraschiv, M. Popescu, O. Suciu, A. Tudorica. Measurers M. Popescu, D. Lacatus. 2.5-m f/3.3 reflector + CCD.
- 954 Teide Observatory. Observer N. D. Diaz. 0.26-m f/11.6 reflector + CCD.
- A13 Observatoire Naef, Marly - Observer P. Kocher
- A24 New Millennium Observatory Mozzate - Observer E. Cozzi
- A50 Andrushivka Astronomical Observatory. Observers Y. Ivashchenko, O. Gerashchenko, P. Kyrylenko. 0.6-m reflector + CCD.
- A74 Bergen-Enkheim Observatory - Observer U. Suessenberger.
- A81 Balzaretto Observatory, Rome. Observer L. Francond in him and him and
- A99 Osservatorio del Monte Baldo. Observer C. Flavio. Measurer M. Claudio. 0.4-m reflector + CCD.
- B03 Alter Satzberg, Vienna - Observer M. Pietschnig.
- B04 OAVdA, Saint-Barthelemy. Observer A. Carbognani. 0.81-m f/7.9 reflector + CCD.
- B15 Inastars Observatory, Potsdam (since 2006). Observer B. Thinius. 0.36-m f/5.8 Schmidt-Cassegrain + CCD
- B18 Terskol Observers M. Andreev, A. Sergeev. Measurer M. Andreev. 0.6-m f/12.8 reflector + CCD.
- B28 Mandi Observatory, Pagnacco. Observer p. corelli. 0.45-m f/4.5 reflector + CCD.
- B33 Libbiano Observatory, Peccioli - Observers P. Bacci, R. Emilio
- B42 Vitebsk. Observer V. Nevski. 0.3-m f/5.0 reflector + CCD.
- B49 Paus Observatory, Sabadell. Observer J. Camarasa. 0.25-m f/4 Newtonian reflector + CCD.
- B86 Sternwarte Hagen. Observer M. Klein. 0.50-m f/3.0 Deltagraph + CCD.
- B90 Malina River Observatory, Povoletto. Observers G. Sostero, E. Guido, V. Gonano, L. Donato. 0.25-m f/10 reflector + CCD.
- B96 Brixiis Observatory, Kruibeke. Observer B. E. 0.4-m f/3.8 astrograph + CCD.
- C32 Ka-Dar Observatory, TAU Station, Nizhny Arkhyz. Observer V. Gerke. Measurers A. Novichonok, D. Chestnov. 0.40-m f/8 Ritchey-Chretien + CCD.
- C44 A. Volta Observatory, Lanzo d'Intelvi. Observer F. Tozzi. 0.40-m f/3.5 reflector + CCD.
- C47 Nonndorf. Observer G. Dangl. 0.25-m f/4.8 reflector + CCD.
- C81 Dolomites Astronomical Observatory. Observers R. Holmes, T. Linder, M. Maturi. Measurers R. Holmes, T. Linder. 0.41-m f/11 Ritchey-Chretien + CCD.
- C92 Valdicerro Observatory, Loreto. Observer M. Caimmi. 0.24-m f/6. Schmidt-Cassegrain + CCD.
- C93 Bellavista Observatory, L'Aquila. Observer P. Berardi. 0.24-m f/6.5 Schmidt-Cassegrain + CCD.
- D90 RAS Observatory, Moorook - Observers C. Jacques, E. Pimentel. Measure: C. Jacques.
- D96 Tzec Maun Observatory, Moorook. Observers P. Concari, S. Foglia, G. Galli, M. Tombelli. 0.18-m f/2.8 Newtonian reflector +

…Etc.

Some International Contributors…

300 Bisei Spaceguard Center- BATTeRS. 1.0-m

926 Tenagra II Observatory. 0.81-m

950 La Palma. Observers 2.5-m

J04 ESA Optical Ground Station, Tenerife 1.0-m

586 Pic du Midi. Observers M. Birlan, F. Colas, M. Popescu, A. Nedelcu (EURONEAR). 1.05-m

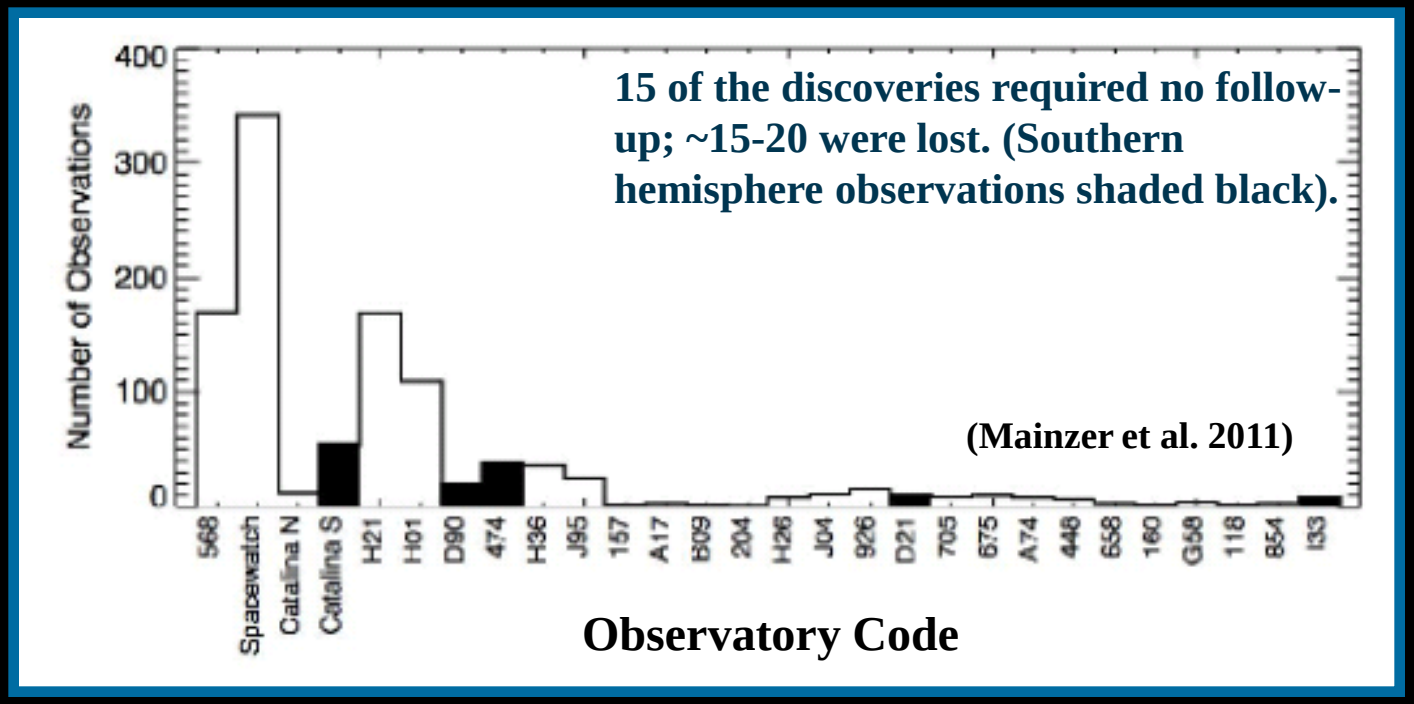
F65 Haleakala-Faulkes Telescope North. Observer R. Miles, 2.0-m

E10 Siding Spring-Faulkes Telescope South. Observer R. Miles, 2.0-m

246 The Klet Observatory. Observer M. Tichy, 1.06-m

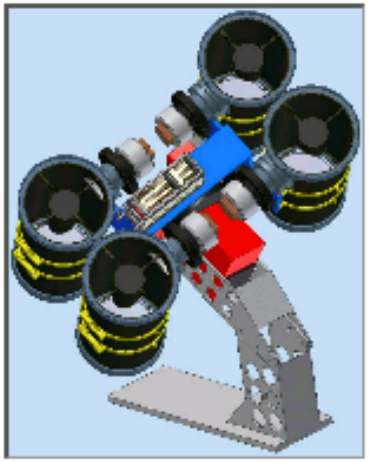
Follow-up Support to Space-based Assets

The *NEOWISE* portion of the Wide-Field Infrared Survey Explorer (WISE) project surveyed the NEO population at thermal infrared wavelengths ranging from 3 to 22 um, and discovered about 135 new NEOs.



Visible follow-up observations within ~2 weeks of the original observations were essential for orbit determination.

Support to New Ground-based Survey: ATLAS



An early ATLAS design concept.

- **ATLAS (Asteroid Terrestrial-impact Last Alert System Project, operational in 2015) will warn of an impending asteroid impact with the Earth.**
- **Once ATLAS detects a hazardous asteroid/comet it will immediately alert professional and amateur follow-up telescopes.**
- **Combined observations will predict the impact time/location with great precision, (as with 2008 TC_3).**

See John Tonry's talk later this session

Expected Future Directions

Self-follow-up planned, but for short-warning, potentially hazardous discoveries, traditional ground-based follow-up and characterization may be valuable.

- **Support for potential spaced-based initiatives like NEOCam, currently funded for technology development, or the Sentinel Space Telescope (see talks by Amy Mainzer and Ed Lu later this session)**
- **Support for groundbased initiatives like LSST and SST**