Spacewatch Observations of Asteroids and Comets with Emphasis on Discoveries by WISE

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Abstract

- Targeted recoveries of objects discovered by WISE as well as those on impact risk pages, NEO Confirmation Page, PHAs, comets, etc.
- ~1900 tracklets of NEOs from Spacewatch each year.
- Recoveries of WISE discoveries preserve objects with long $P_{\text{syn}}$ from loss.
- Photometry to determine albedo at wavelength of peak of incident solar flux.
- Specialize in fainter objects to $V=23$.
- Examination for cometary features of objects with comet-like orbits & objects that WISE IR imagery showed as comets.
Why Targeted Followup is Needed

• Discovery arcs too short to define orbits.
• Objects can escape redetection by surveys:
  – Surveys busy covering other sky (revisits too infrequent).
  – Objects tend to get fainter after discovery.
• Followup observations need to outnumber discoveries 10-100.
• Sky density of detectable NEOs too sparse to rely on incidental redetections alone.
Why Followup is Needed (cont’d)

- 40% of PHAs observed on only 1 opposition.
- 18% of PHAs’ arcs <30\text{d}; 7 PHAs obs. < 3\text{d}.
- 20% of potential close approaches will be by objects observed on only 1 opposition.
- \text{1/3}rd of H≤22 VI’s on JPL risk page \textit{are lost} and half of those were discovered within last 3 years.
How “lost” can they get?

- (719) Albert discovered visually in 1911.
- “Big” Amor asteroid, diameter ~2 km.
- Favorable (perihelic) apparitions 30 yrs apart.
- Missed in 1941 due to inattention.
- Missed in 1971 due to large uncertainty.
- MPC recognized (719) as a rediscovery by Spacewatch in 2000.
1979 XB: A “Big” Lost “VI”!

- 4-day observed arc in 1979 December.
- $H \approx 18.5 \leftrightarrow$ Diameter 370-1200 m.
- Synodic period $\approx 1.4^\text{y}$.
- Possible close encounters in 2056 & 2086.
- Not rediscovered in $>3$ decades of modern surveying.
0.9-m Spacewatch Telescope

Hyperboloidal primary & refractive field corrector.
4-CCD Mosaic.
Bandpass $\approx 0.5$-$0.9$ $\mu$m;
$\lambda_{\text{eff}} \approx 0.7$ $\mu$m.
Began 2003 April.
23 nights per lunation.
Automated in 2005 May.
Patterns near opposition, WISE regions, & low elongation in east in morning.
1400 deg$^2$ per lunation.
$V$ mag limit $\approx 20.5$-$21.7$ depending on conditions.
Spacewatch CCD Mosaic on 0.9-m telescope.

Four EEV Grade-1, back-illuminated, antireflection-coated CCDs of 4608x2048 pixels each.
37 million pixels.
1 arcsec per pixel.
2.9 deg$^2$ covered.
Spacewatch 1.8-m Telescope: 0.6×0.6 deg FOV.
Same bandpass & scale as 0.9-meter.
Has reached V=23.3 by shift & stacking, typical $V_{\text{lim}} \approx 22.3$.
Mostly drift scanning for smoother background & responsivity.
Stacking @ asteroid rate.

Spacewatch 1.8-meter telescope scans.

← Target
Spacewatch Followup of WISE-observed objects as of 2010 Sep 1

- 226 out of 324 NEOs observed by WISE.
- 54 out of 115 NEOs discovered by WISE.
  - $V$ mags $\leq 22.9$
- 10 out of 17 PHAs discovered by WISE.
- 9 out of 16 comets discovered by WISE.
  - $T$ mags $\leq 22.1$
- 19 out of 33 Centaurs, SDOs, & other irregular objects discovered by WISE.
 Comet P/2002 LN13 = 2010 L2 (LINEAR) observed w/ Spacewatch 1.8-m on 2010 June 15.

Integration time in 3 co-added images = 418 sec. North up; East to left. Image size 23.5 12.6 arcmin. Tail ≥2.8 arcmin in p.a. 248 deg. Tmag=20.3. Discovered by LINEAR in 2002 as 2002 LN13. WISE discovered a tail on 2010 June 10 which was confirmed by these images.
Number of NEOs Observed per Year

The effects of the introduction of the 1.8-meter telescope in 2001, the mosaic of CCDs on the 0.9-meter telescope in 2003, the automation of the 0.9-m in 2005, and recent software enhancements are evident.
Numbers of Different PHAs Observed by Project
2003 Jan 1 - 2010 Aug 24:

- Spacewatch = COD 691 + COD 291 118
- Catalina = COD's 703, G96, E12, 693 & 413 113
- LINEAR = COD 704 90
- Holmes = COD's H21 + H55. 60
- Lowell = COD 699 (LONEOS) & 688 (1.8-m) 30
- NEAT (JPL) = COD's 644 + 675 + 566 + 608 26
- Faulkes = COD's F65 + E10 22
- Klet = COD's 046 & 246 19
- Mauna Kea = COD 568 19
- Mt. Hopkins/CfA = COD 696 19
- Mt. John, New Zealand = COD 474 18
- McDonald Obs. = COD 711 18
Observations of PHAs, by Observatory

V >= 21.5 Contributions to PHA Orbits 2006 Jan 1 - 2009 Feb 28

Positions Contributed

Spacewatch  H55  Catalina  568  H45  H01  246  474  J95  Others

Observatory
$>50^d$ arc-lengthening PHA Followup

![Graph showing PHA observations from 2006 Jan 1 to 2009 Feb 28. Observations extend the arc by more than 50 days. The graph compares Spacewatch, ARO, Catalina, Mauna Kea, Mt John, and Others in terms of the number of PHAs observed. Spacewatch has the highest number of observations, followed by ARO and others.]
Using Bigger Telescopes

• Target-of-Opportunity Mode $\rightarrow$ $V=24$.
  – KPNO 4-meter MOSAIC camera, FOV 35 35.
  – WIYN 3.5-meter MiniMo camera, FOV 9 9.
  – CTIO 4-meter Mosaic camera, FOV 35 35.
• Steward 2.3-m 90Prime camera, FOV $\sim$1 deg$^2$. 
Minor Planet 2010 OM101 observed with the WIYN 3.5-m f/6.3 telescope on 2010 Sep 9 UT.

High-e outer solar system object (trail) discovered Jul 28 by WISE showed no coma in 0.7 arcsec seeing while near perihelion. Observers A. L. Henry, M. A. Malkan, G. Will; Measurers A. Mendez, J. A. Larsen.
Distribution of Absolute Magnitudes of Small NEOs

- Spacewatch 0.9-m mosaic survey 2003-2010.
- Detections of known + previously unknown NEOs.
- De-biased for sky coverage & efficiency.
- Extended knowledge of dist’n to \( H \approx 28 \).
- Compare w/ dist’n of small craters on Moon.
Cumulative Absolute Magnitude of NEOs

Determined by de-biasing detections of NEOs with Spacewatch 0.9-m telescope and 2.9 deg² mosaic that surveyed the ecliptic from 2003 Apr -2010 June.
NEA Size Dist’n wrt Power Law extended to H=28

- Model Debiased Spacewatch (This Work)
- Harris (2008)
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