

Small Bodies in Our Solar System: Opportunity and Risk

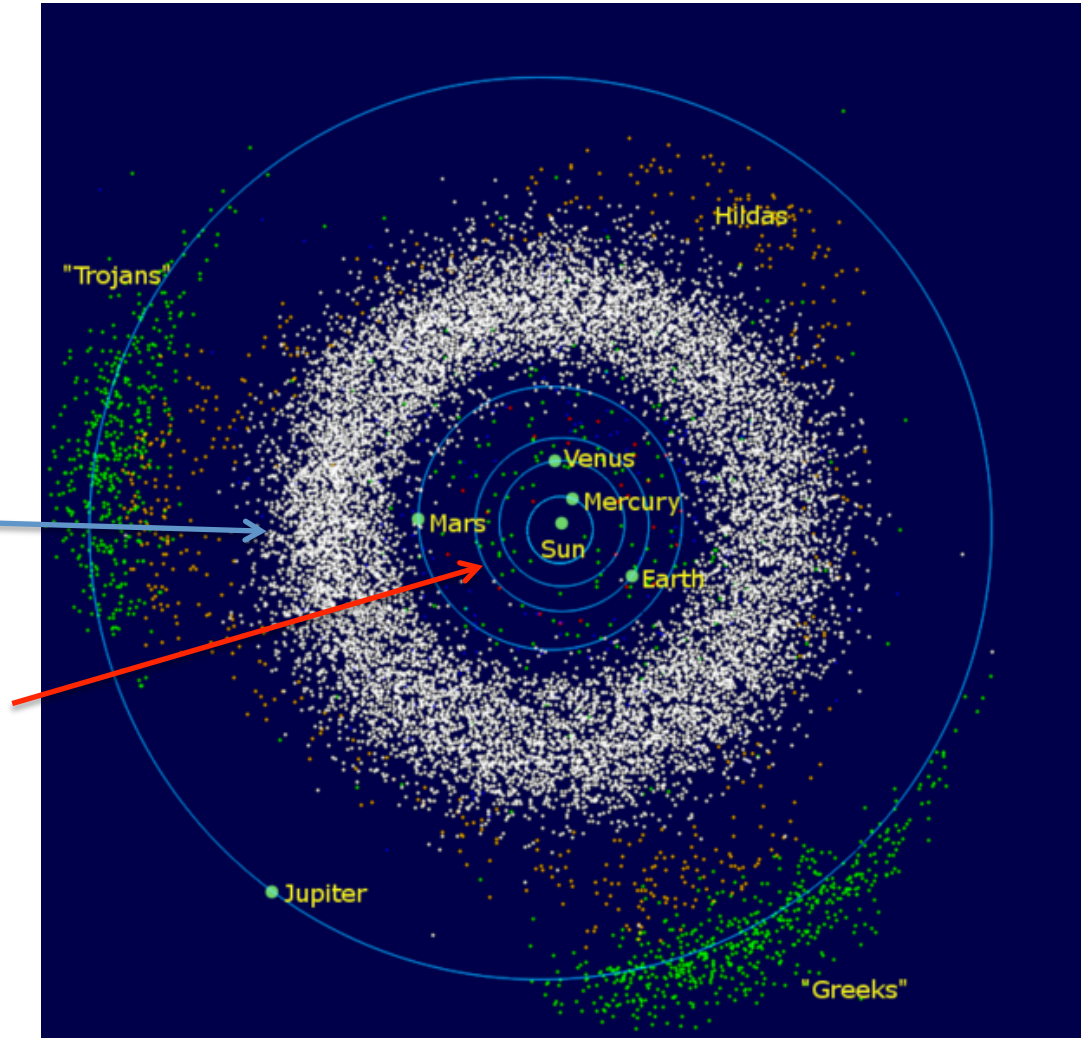
A composite image of space. In the foreground, a satellite with a large cylindrical instrument is oriented towards the viewer. To the left, the blue and white horizon of Earth is visible. In the upper left, a bright yellow sun glows. In the upper right, a comet with a long tail streaks across the dark sky. The background is filled with numerous small, dark asteroids of various sizes.


Amy Mainzer – JPL

J. Bauer, T. Grav, J. Masiero, R. Cutri, C. Nugent, S. Sonnett, R. Stevenson,
E. Wright

Asteroids

- Most asteroids live in the Main Asteroid Belt
- Main Belt Asteroids are ancient
 - Billions of years old, although heavily processed in some cases
 - ~700,000 known today
- Near-Earth Objects (NEOs) are extremely young - only few million years old
 - They either hit the Sun, hit a planet, or get scattered out of the region entirely
 - ~12,000 known today



A photograph capturing a bright fireball streaking across a hazy sky. The fireball is a large, glowing orange-yellow sphere with a long, thin white trail extending towards the upper right. The background shows a snowy landscape with a utility pole on the left and a road leading into the distance. The overall scene is dimly lit, suggesting a dawn or dusk setting.

**The Super Fireball
of February 15, 2013
over Chelyabinsk, Russia**



NEOWISE: An Enhancement to WISE



- The baseline WISE mission only identifies previously known solar system objects – NOT A DEDICATED ASTEROID MISSION
- NEOWISE
 - Funded by NASA Planetary Science
 - Created an archive of individual epoch images + a tool for accessing them
 - Permitted the discovery of new asteroids with WISE
 - Tracklets delivered to Minor Planet Center within 10 days
 - WISE Moving Object Pipeline (WMOPS) run 2x/week



NEOWISE Team



- PI: Amy Mainzer
- Deputy PI: James Bauer
- Roc Cutri - IPAC
- John Dailey - IPAC
- Tommy Grav - PSI
- Emily Kramer – JPL NPP
- Joe Masiero - JPL
- Carrie Nugent – IPAC
- Sarah Sonnett – JPL NPP
- Rachel Stevenson – JPL NPP
- Ned Wright - UCLA





Why Study Asteroids with WISE?



- Unbiased sample: IR ~insensitive to albedo (p_v)
- Infrared \rightarrow diameter errors $\pm 10\%$
- Space-based survey has consistent biases that are easier to model accurately
 - No weather, no seeing, no daytime
- We can use WISE/NEOWISE data to extrapolate the properties of observed samples to the entire population



Prime mission data:

New NEOs

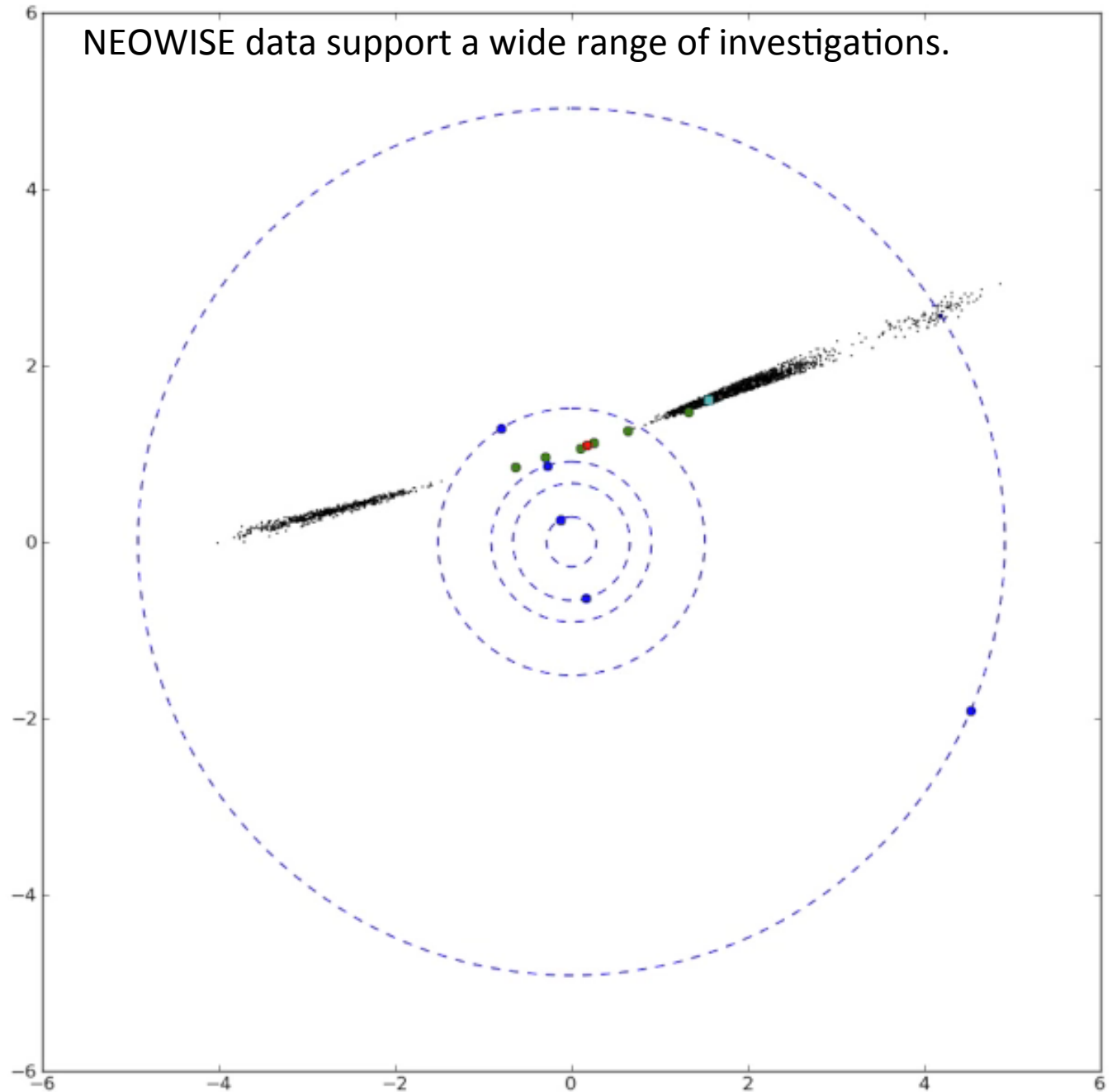
Known NEOs

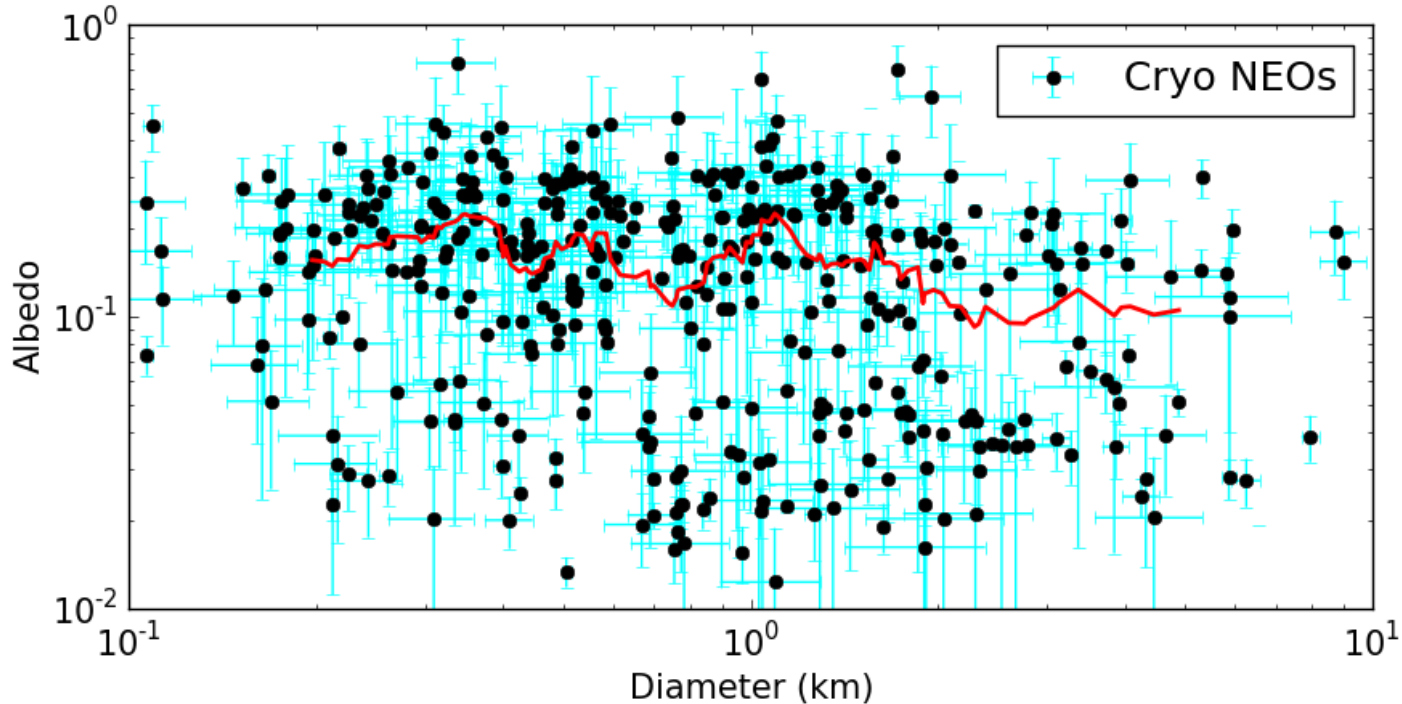
New Comets

Known Comets

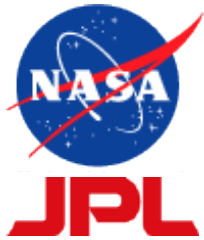
- >158,000 total asteroids observed
- ~34,000 new discoveries
- ~700 NEOs
- 135 NEO discovered
- ~160 comets

NEOWISE data support a wide range of investigations.





- ~430 NEOs
- No significant change in albedo vs. diameter
 - Albedo is constant all the way down to small sizes
- Contrary to previous studies that are biased against small, low albedo objects



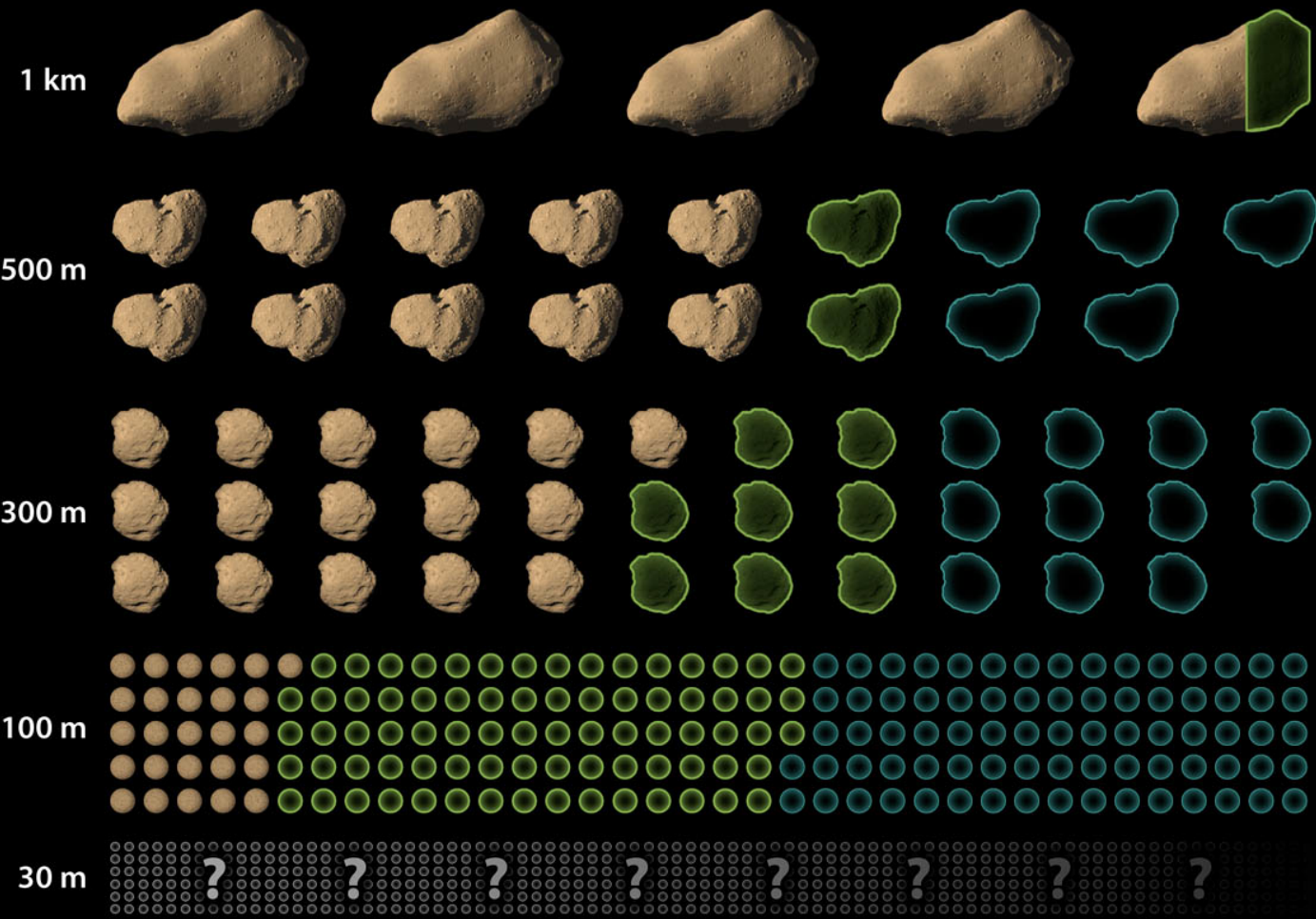
New Estimate of Numbers of NEAs



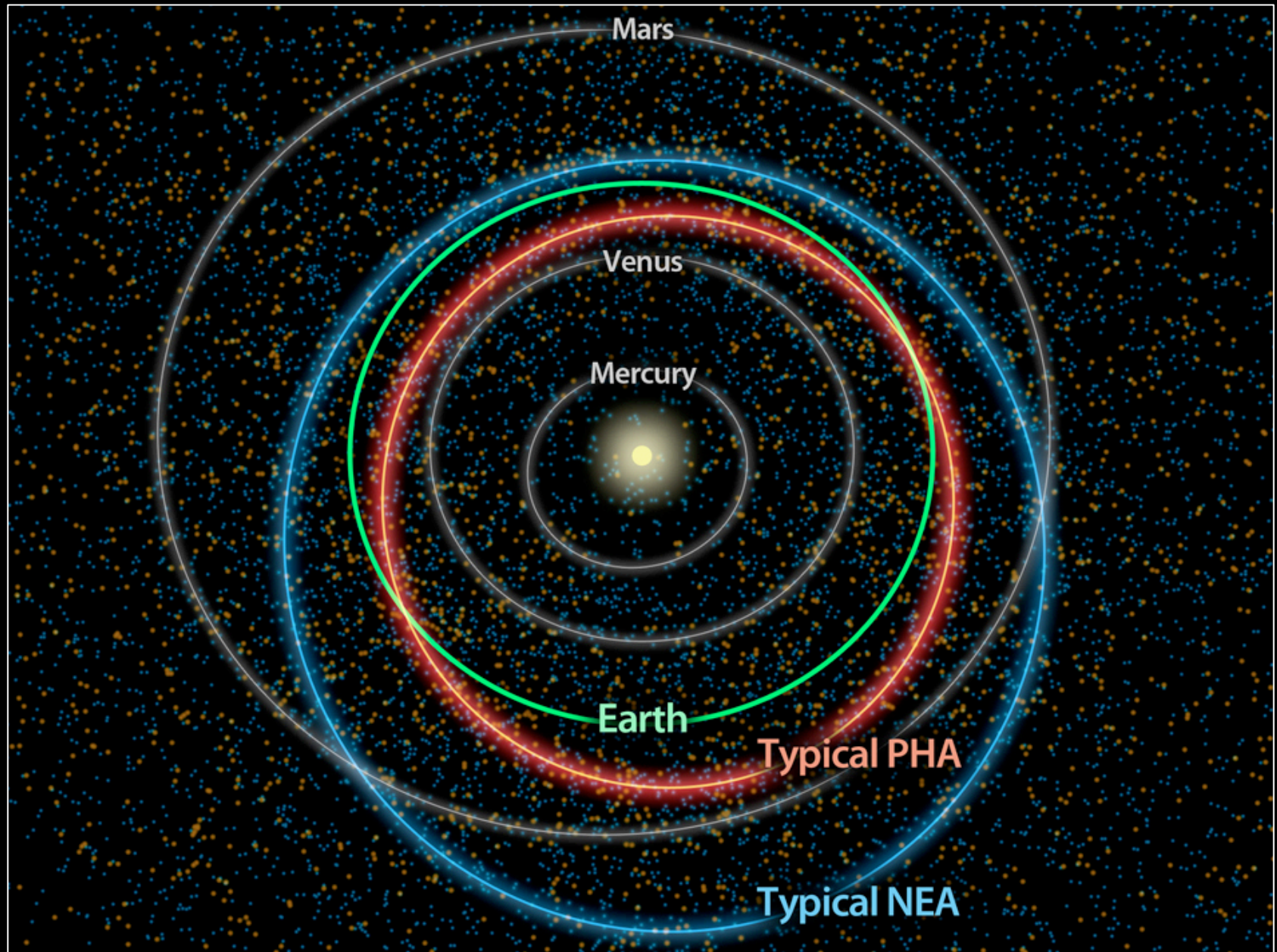
A Near-Earth Asteroid Census

Each image represents approximately 200 objects

Known Near-Earth Asteroid Population ●
New Predicted Total (NEOWISE) ●
Old Predicted Total (pre-NEOWISE) ●



Potentially Hazardous Asteroids

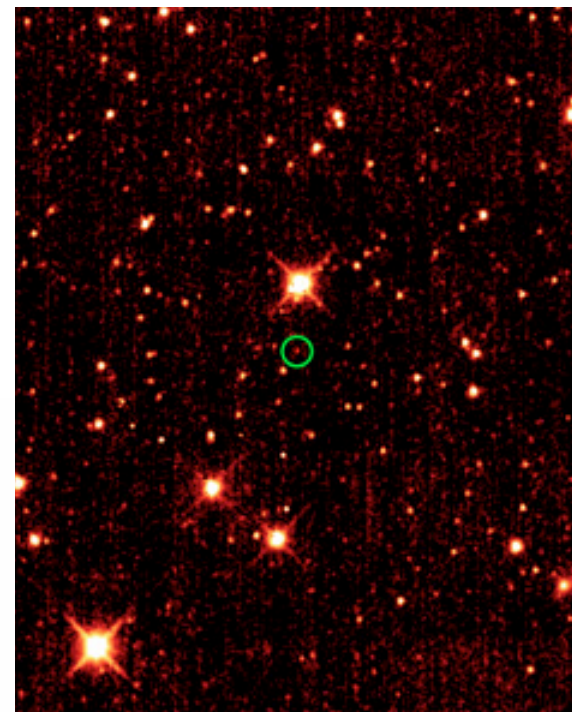
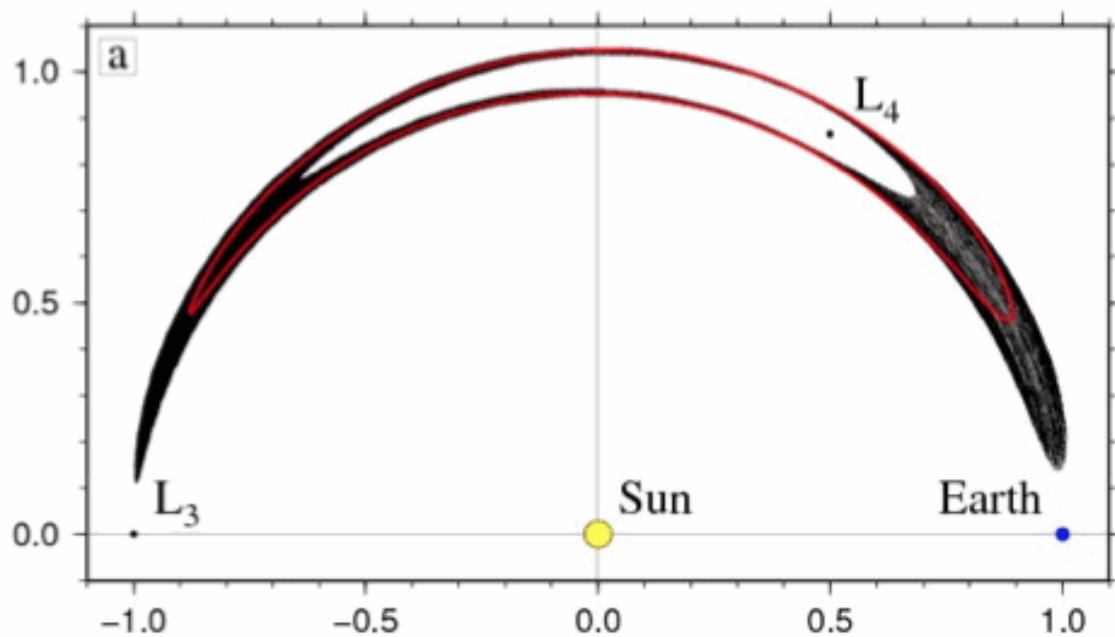


Potentially Hazardous Asteroids

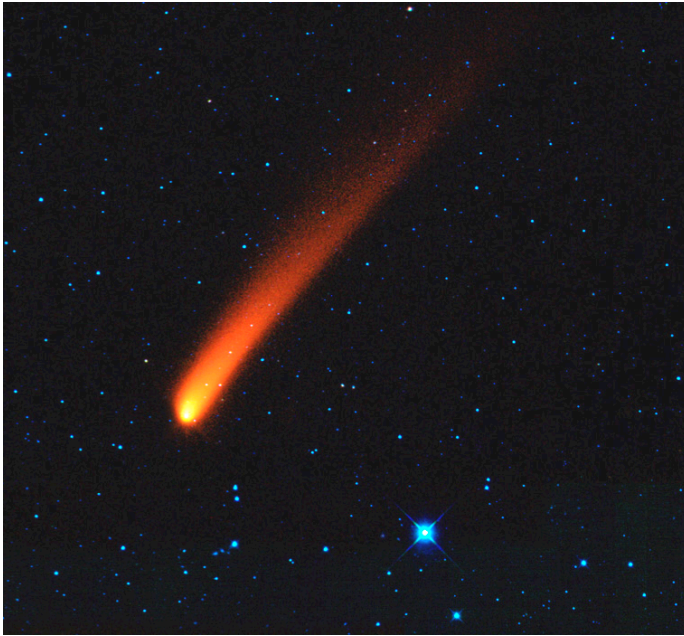
- 4700 ± 1500 PHAs larger than 100 m
- 2x more PHAs in low inclination orbits
 - More hazard, but more potential low Δv targets for exploration

Earth Co-orbitals

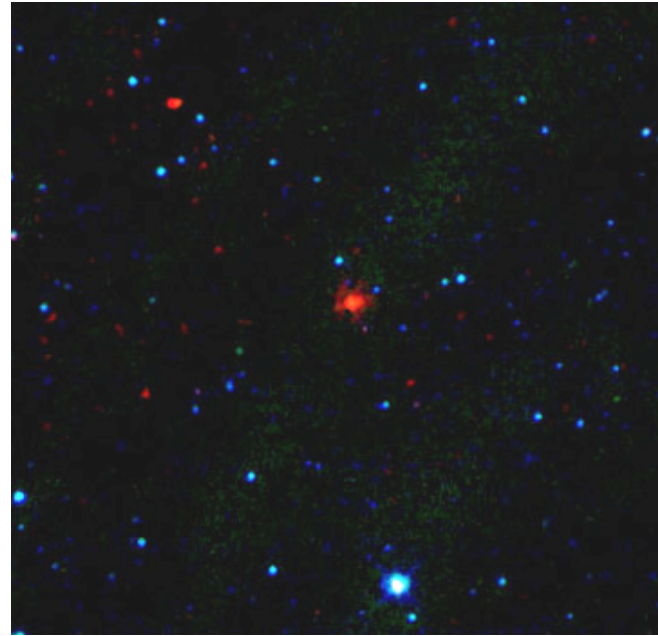
- 2010 TK7, first known Earth Trojan (Connors et al. 2010)
 - 380 ± 120 m diameter, $p_v = 6 \pm 5\%$



Preliminary Properties of Nuclei & Gas Production



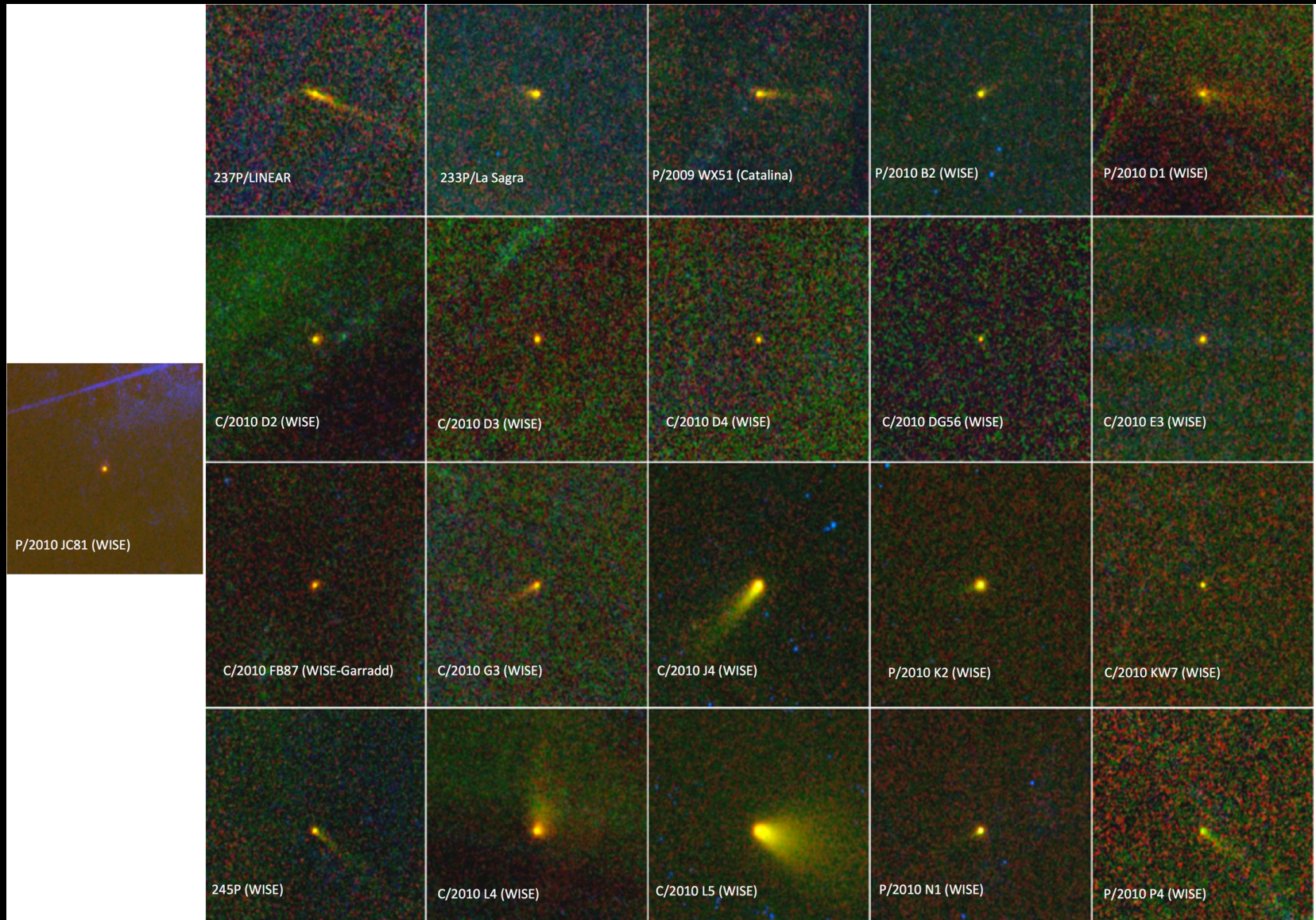
C/2007 Q3 Siding Spring



P/2010 B2 (WISE)

- Total sample 190 comets, including 24 new discoveries by NEOWISE
- Comet team: J. Bauer, A. Mainzer, T. Grav, Y. Fernandez, E. Kramer, C. Lisse, J. Masiero, K. Meech, R. Stevenson, R. Walker, P. Weissman

Characterizing comets with NEOWISE



21 comets that were discovered, or discovered to be active, by WISE



NEOWISE Data Use



- Total citation count using NEOWISE data & discoveries up to ~200 refereed publications
 - Total citation count for WISE >1100 refereed publications
- NEOWISE is a time-domain mid-infrared all-sky survey, so its science spans many areas of astrophysics & planetary science:
 - Asteroids
 - Meteoritics
 - Giant planet migration
 - Variable stars
 - Icy bodies in the outer solar system
 - Distance ladder determinations for cosmology
 - Human exploration
 - Supernovae
 - Pulsars
 - Exoplanets
 - Black hole accretion disks



Reactivating NEOWISE





First images received December 7, 2013



NEOWISE Reactivation Science Return



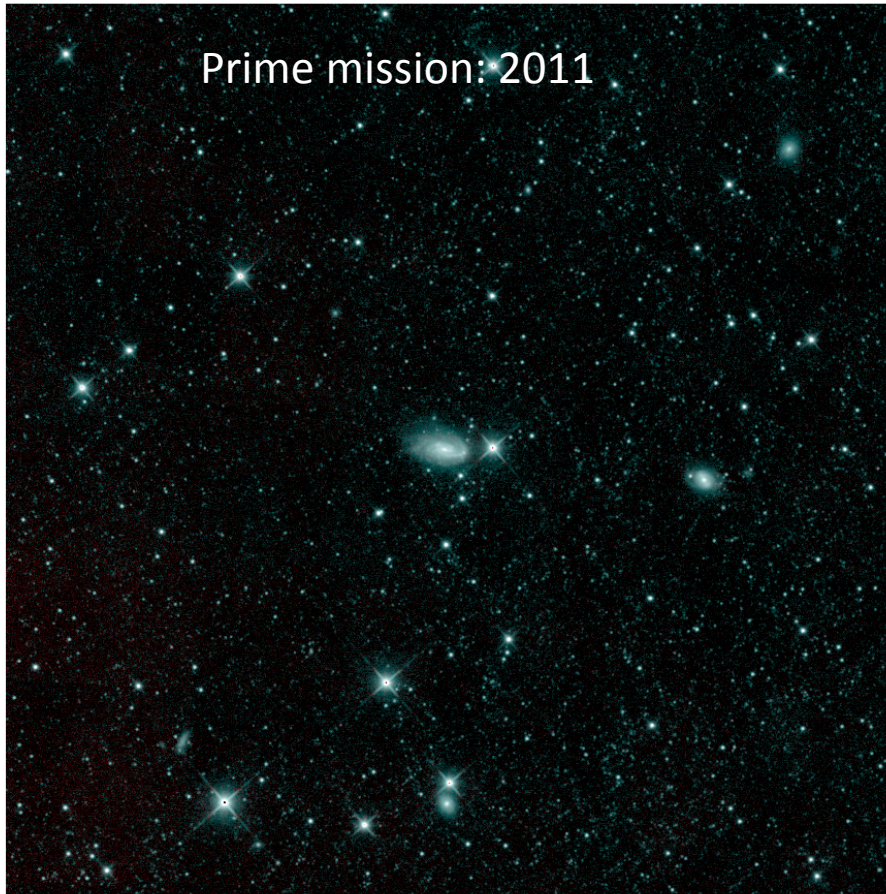
- Only ~1000-2000 NEOs have any sort of physical properties measured beyond H & orbit out of ~12,000 known to date
- Detect & characterize ~2000 near-Earth objects (NEOs) over 3 year survey at 3.4 & 4.6 μm
 - Derive diameters to $\pm 25\%$, albedos to $\pm 50\%$
 - Tens of thousands of Main Belt asteroids + comets
- Discover ~100 new NEOs (25% potentially hazardous)
- Set additional constraints on subpopulations of NEOs, including Earth Trojans and potentially hazardous asteroids



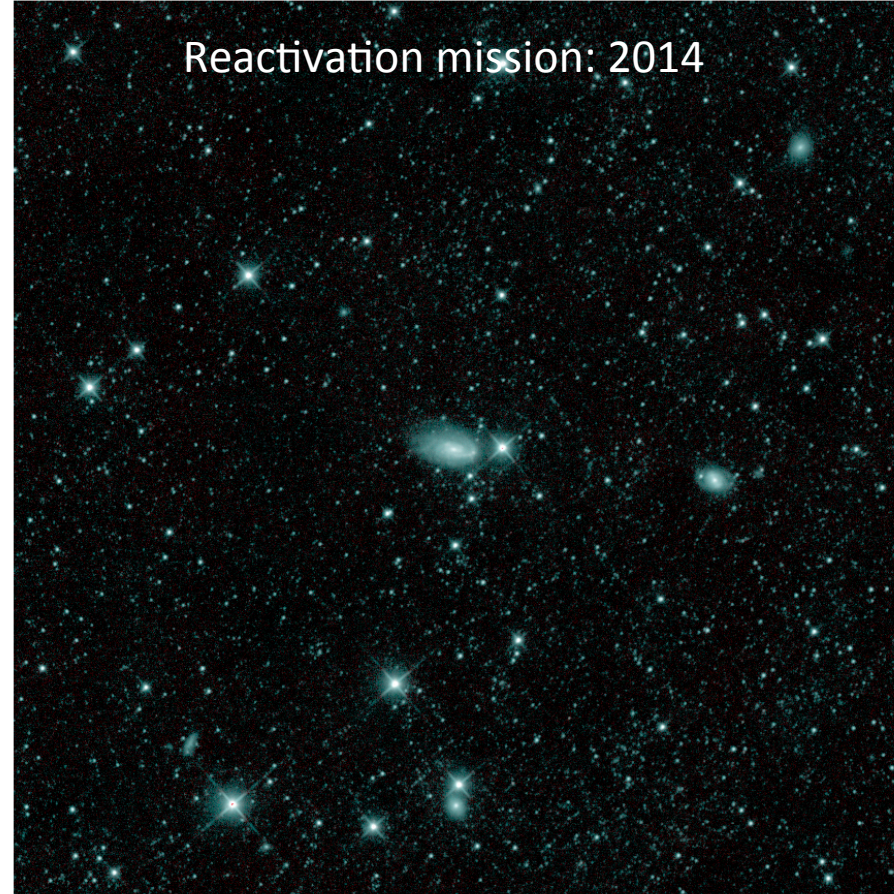
Instrument Performance

- Image quality, photometric accuracy, astrometry, sensitivity all unaffected by 32 month hibernation

Prime mission: 2011



Reactivation mission: 2014



First New NEO

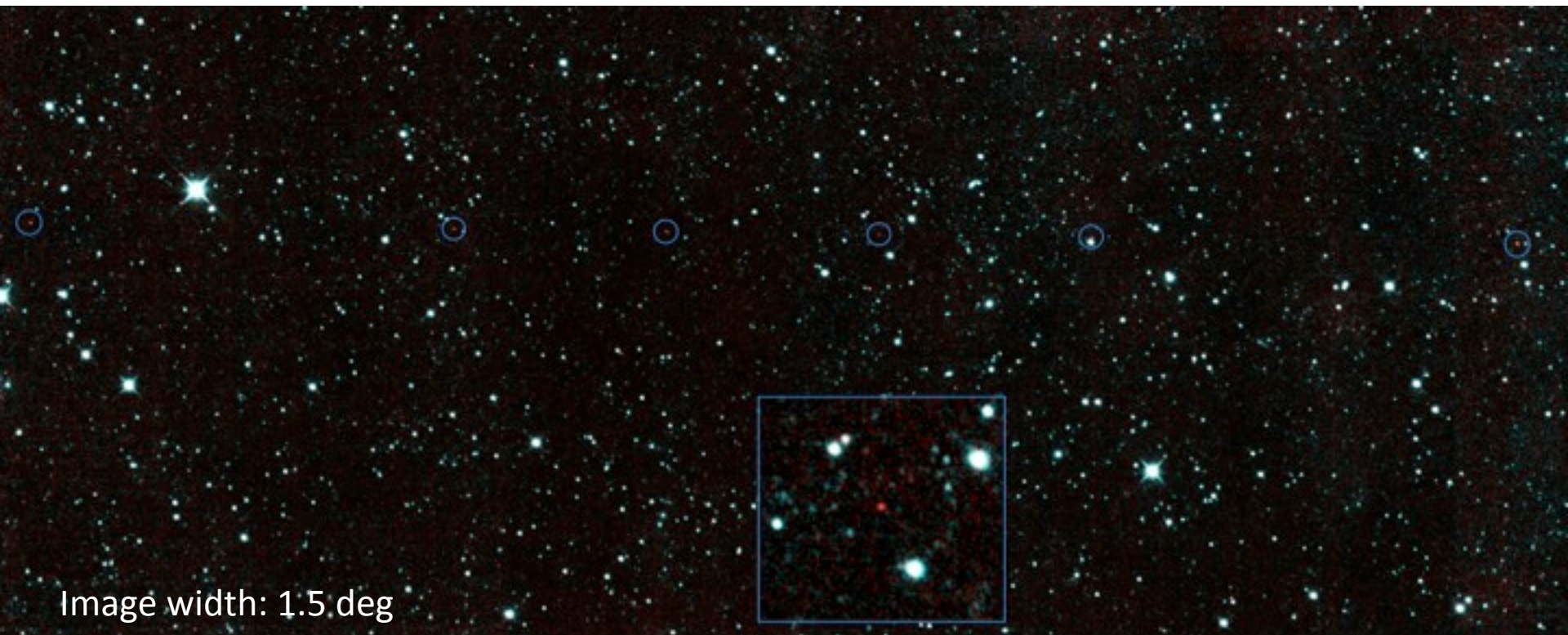
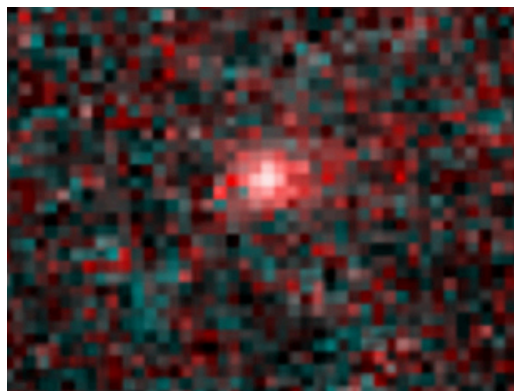


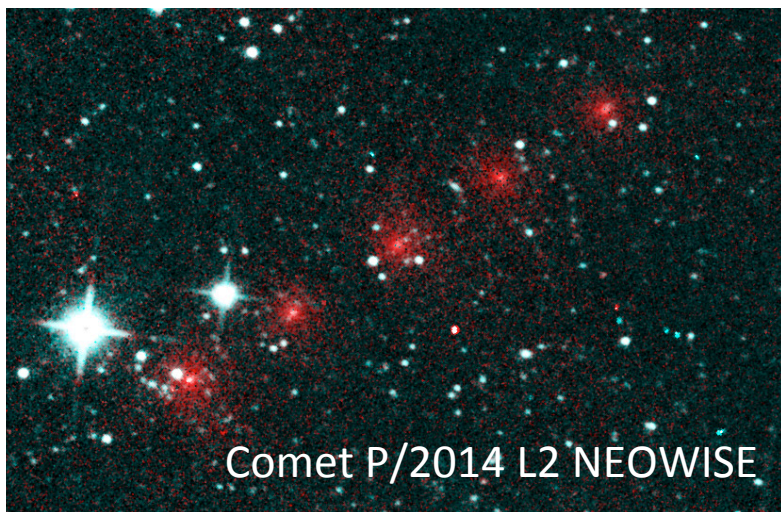
Image width: 1.5 deg

- 2013 YP139
- Prelim thermal fit: 650 ± 230 m, $p_v = 1-3\%$
- 6 detections in 0.4 days
- Velocity 3.2 deg/day
- Discovered Dec. 29, 2013, 6 days after survey start
- Follow-up: Spacewatch + Peter Birtwhistle (UK)

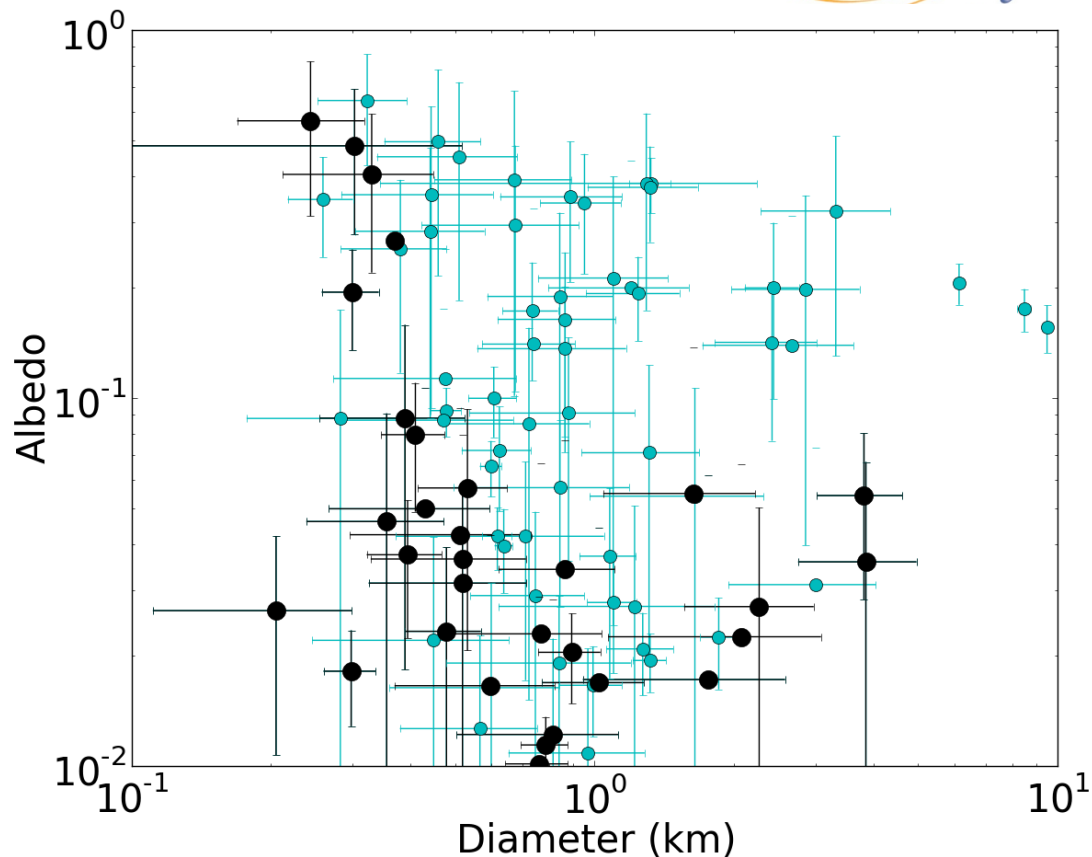
Preliminary Results



Comet C/2014 C3 NEOWISE

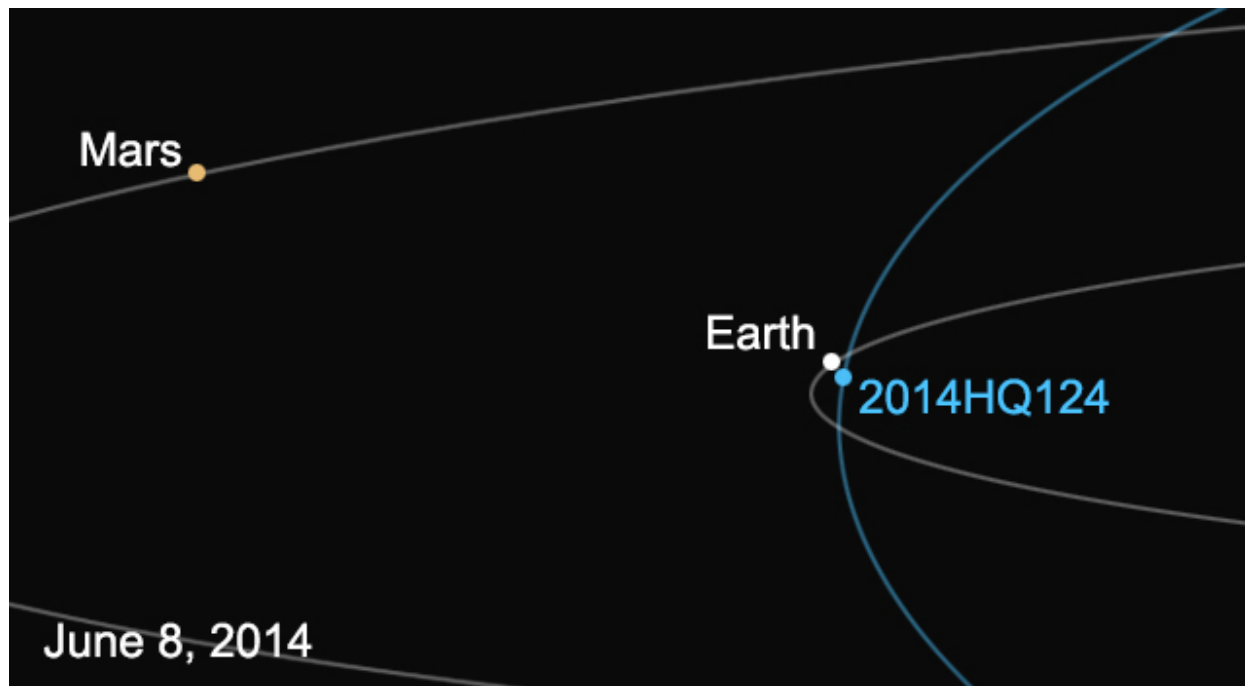
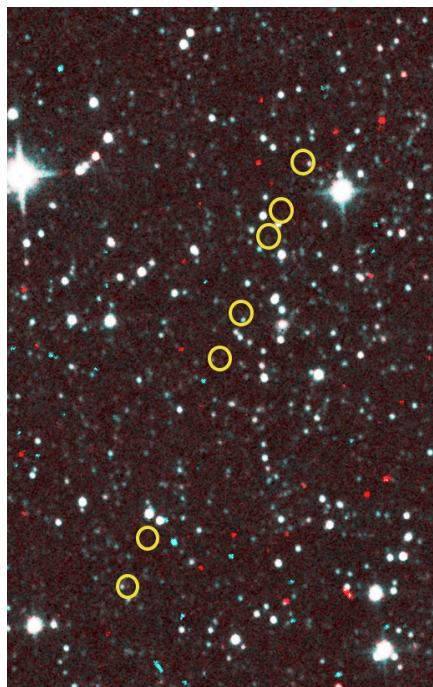


Comet P/2014 L2 NEOWISE



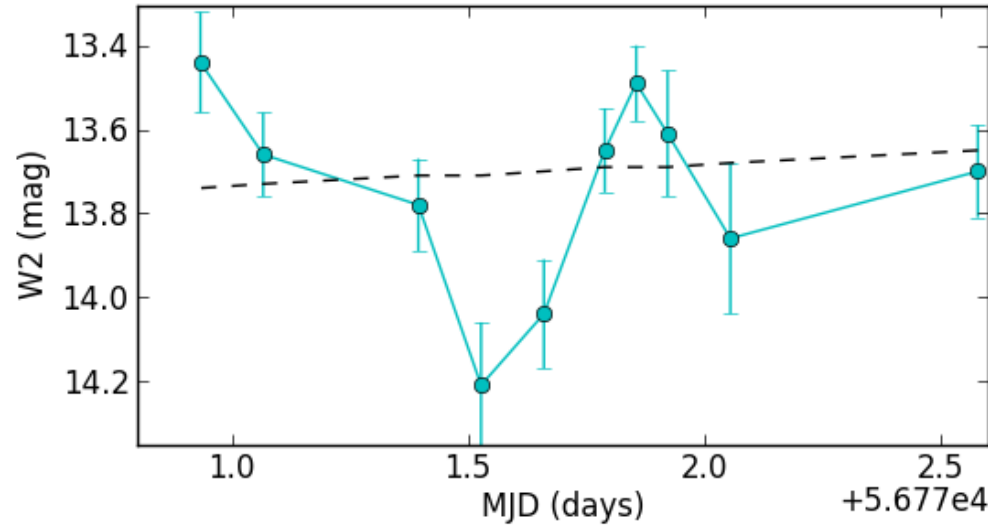
- Three new comets
- NEO discoveries are large, dark; ~25% potentially hazardous asteroid
- 267 NEOs observed to date

2014 HQ124

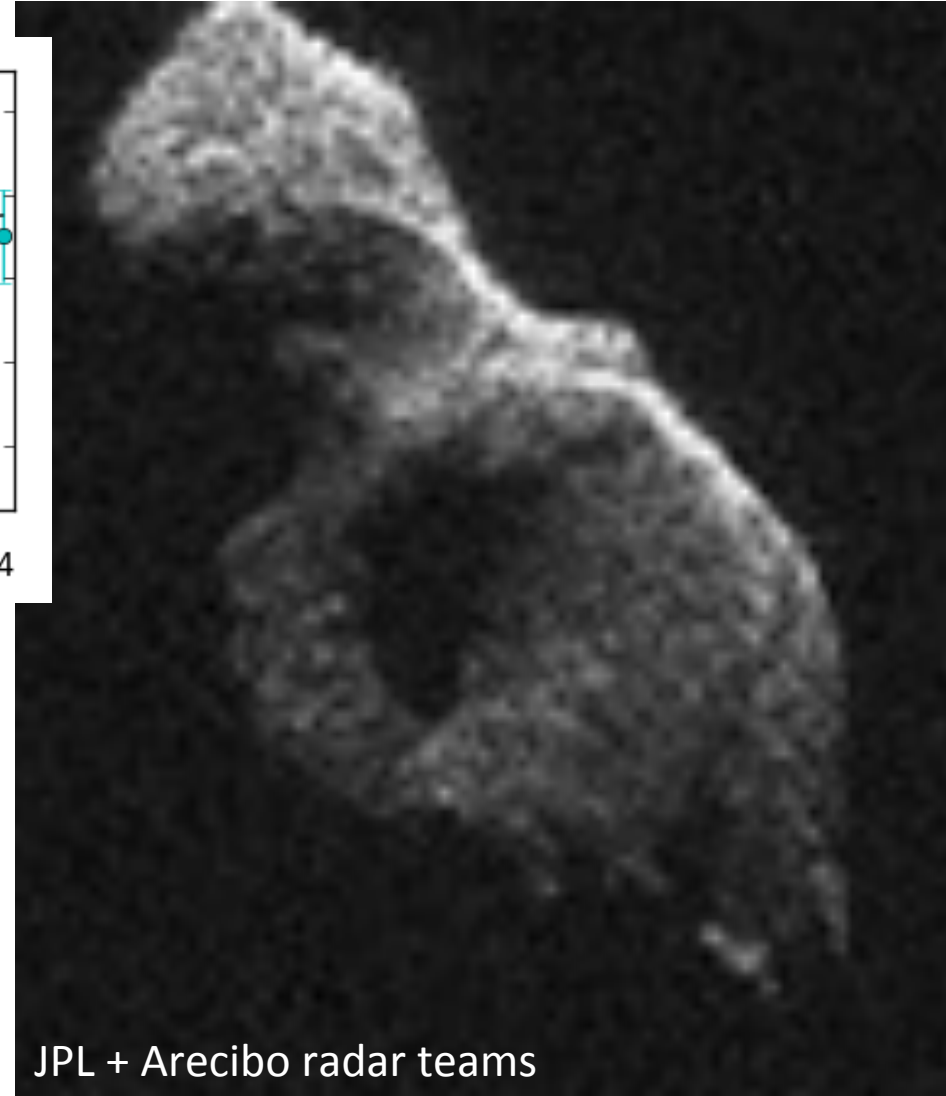


- Discovered at -72° declination on April 23, 2014
- ~ 3 lunar distance flyby on June 8, 2014

2014 HQ124



- Thermal fit: 330 ± 120 m effective spherical diameter
- Radar: 370 m along long axis



JPL + Arecibo radar teams



Thank You



Special thanks to the **Minor Planet Center**
and asteroid follow-up observers around the
world.