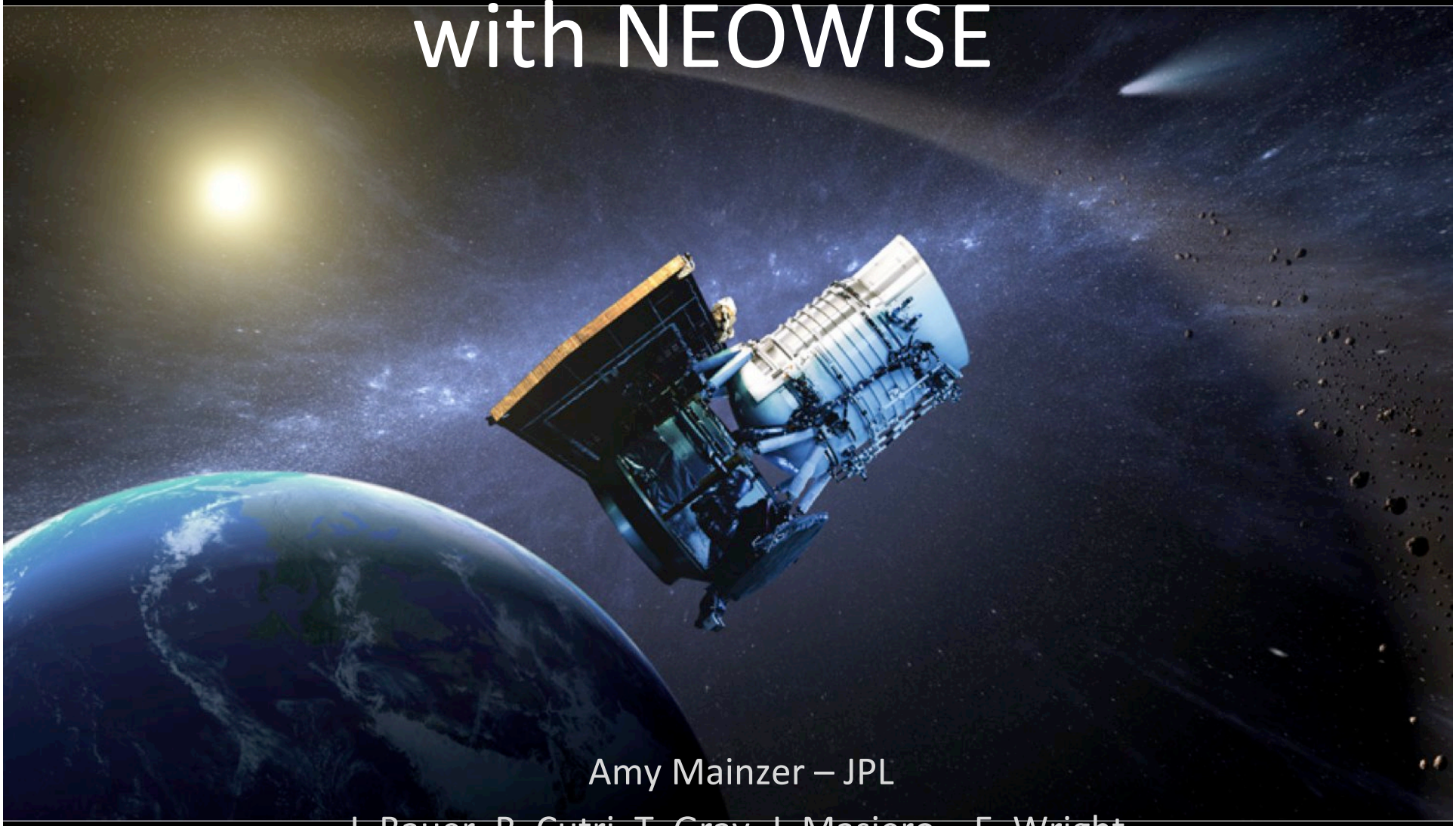
Exploring the Near-Earth Objects with NEOWISE



Amy Mainzer – JPL

J. Bauer, R. Cutri, T. Grav, J. Masiero, , E. Wright,

P. Eisenhardt, C. Nugent, R. Stevenson, S. Sonnett, B. Fabinsky

NEOWISE Science Team

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

Big Questions

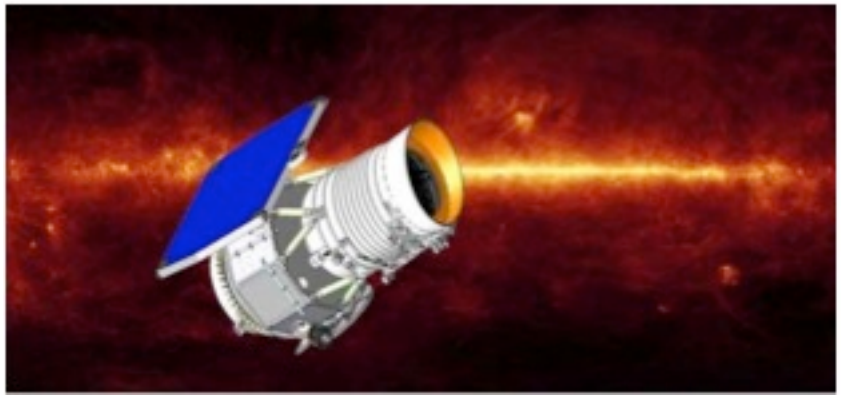
- How often do asteroids & comets impact Earth, and with what energy?
- What is the distribution of their physical properties, such as sizes, albedos, regolith, & rotational states?
- What can we infer about their origins & subsequent collisional and dynamical evolution?

Near-Earth Objects

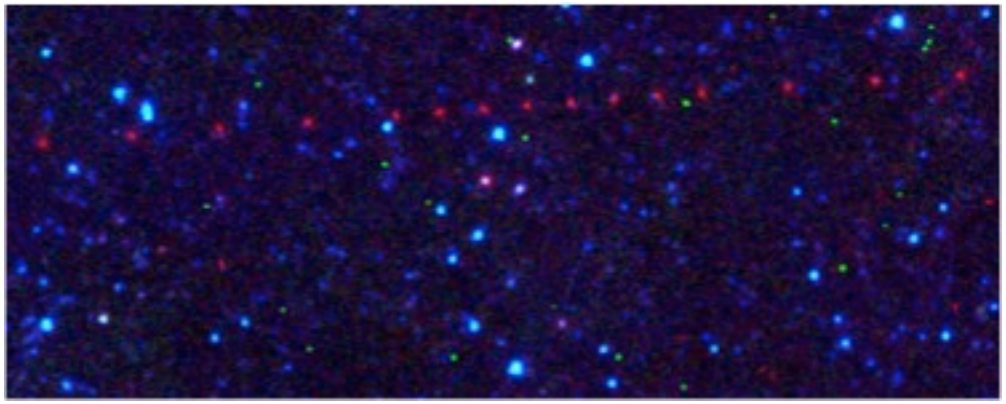
- ~11,000 known today
- Physical properties known for ~2000:
  - Spectra, diameter, albedos, shapes, rotational states
  - Radar observations for hundreds
    - Sizes, shapes, improved orbits, radar albedos
- But for the rest, only orbit & absolute magnitudes are known

NEOWISE = Near-Earth Objects + WISE

Wide-field Infrared Survey Explorer (WISE)



Tracklet: a moving asteroid in multiple detections



WISE

- 40 cm telescope in Sun-synchronous orbit
- All-sky survey
- PI: Ned Wright (UCLA)
- Four channels: 3.4, 4.6, 12 and 22 μm
- Launched in Dec 2009; operated through February 2011

NEOWISE

- Developed enhanced WISE Moving Object Processing System (WMOPS)
- Processed WISE data to detect asteroids
- All data from prime mission released
- Observed >158,000 minor planets
- > 34,000 new asteroids and comets discovered

Why Study Asteroids with WISE?

- Unbiased sample: IR ~insensitive to albedo (p_V)
- Infrared → diameter errors ±10%
  - Visible light →diameter errors ±200-300%
- Space-based survey has consistent biases that are easier to model accurately
  - No weather, no seeing, no daytime
- Representative sample

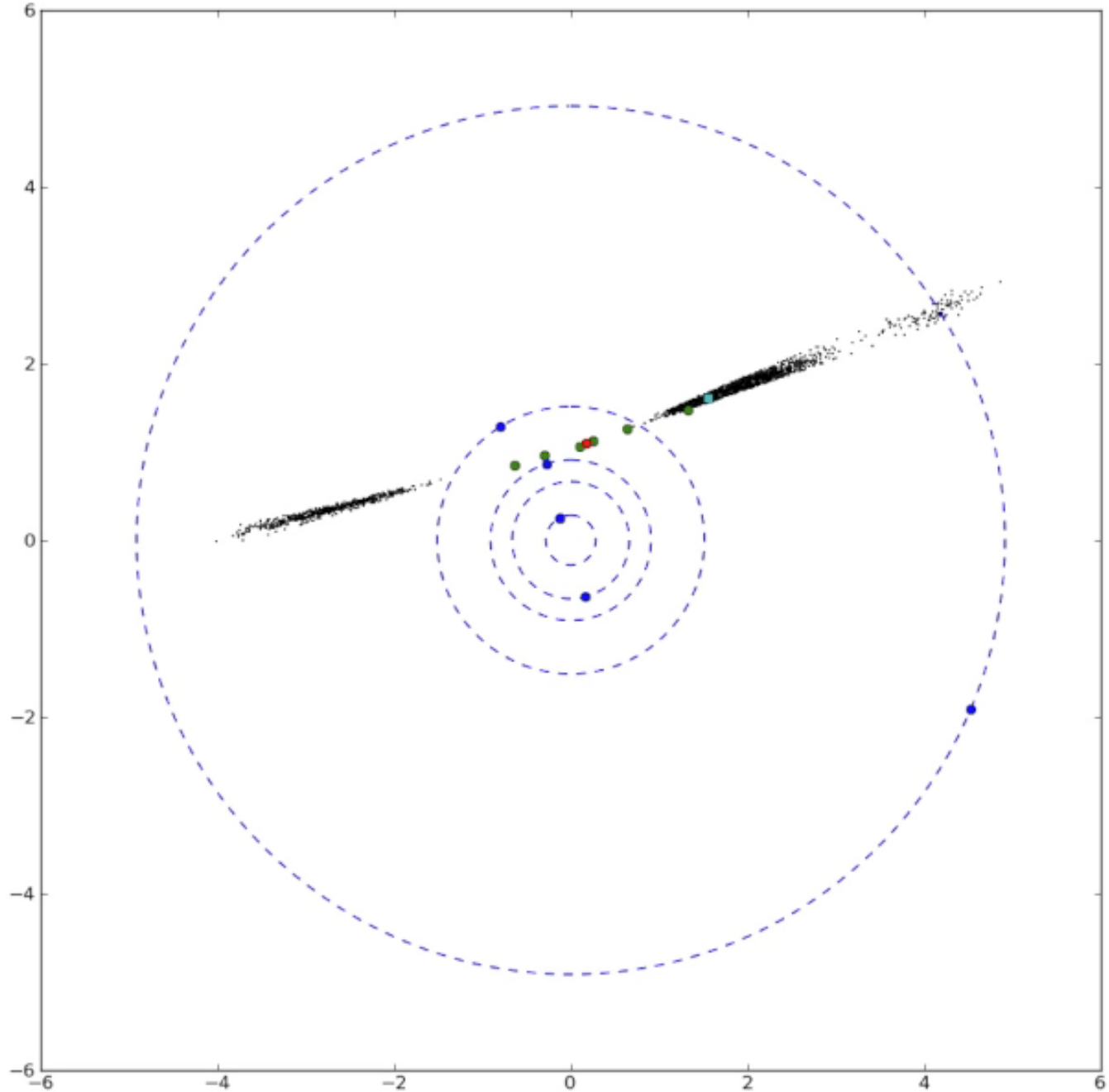
New NEOs

Known NEOs

New Comets

Known Comets

- >158,000 total asteroids observed
- ~34,000 new discoveries
- ~700 NEOs
- 135 NEO discovered
- ~150 comets



NEOWISE Science

- Populations studies – numbers, orbits, sizes, albedos, taxonomic classification vs. physical properties
  - NEOs, MBAs, Trojans, Hildas, Cybeles, Centaurs, comets (long & short period)
- Dynamical studies of asteroid families & collisional history
- Detailed thermophysical studies
- Comets: sizes, CO/CO_2 abundances, dust size distribution & composition, evolution & activity vs. distance, Main Belt comets
- Zodiacal dust trails
- Weird objects – Earth Trojans, horseshoes, etc.

Constraining Populations with NEOWISE

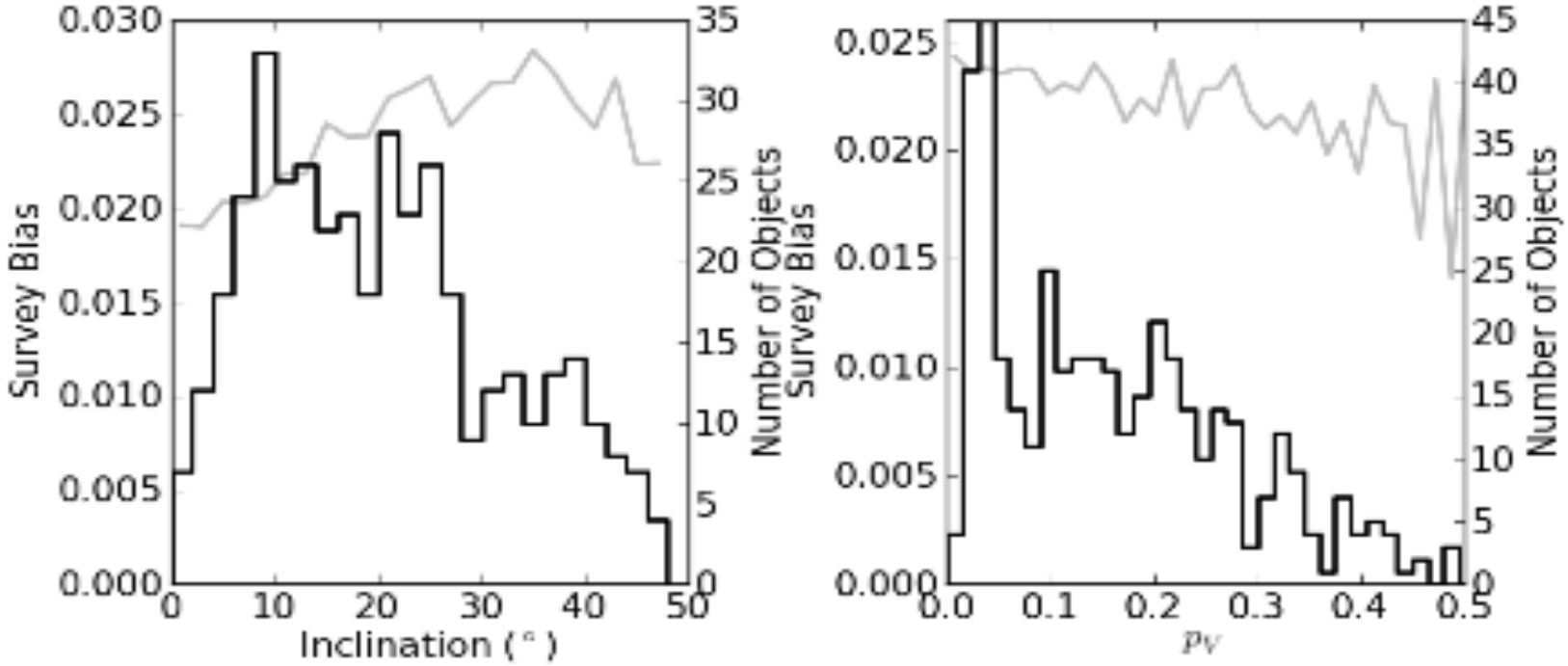
- NEOWISE: repeatable, no variations in seeing or weather, all-sky coverage

- By determining the survey biases and dividing them out, we can generalize NEOWISE sample to entire population
  - c.f. analytical method of Jedicke & Metcalfe (1998)
  - But we do this numerically following Spahr (1998)

$$N_T(a, e, i, p_V, p_{IR}, \eta, D > 100m) = \sum_{D=0.1km}^{10km} \frac{N_o(a, e, i, p_V, p_{IR}, D)}{P_N(a, e, i, p_V, p_{IR}, \eta, D)}$$

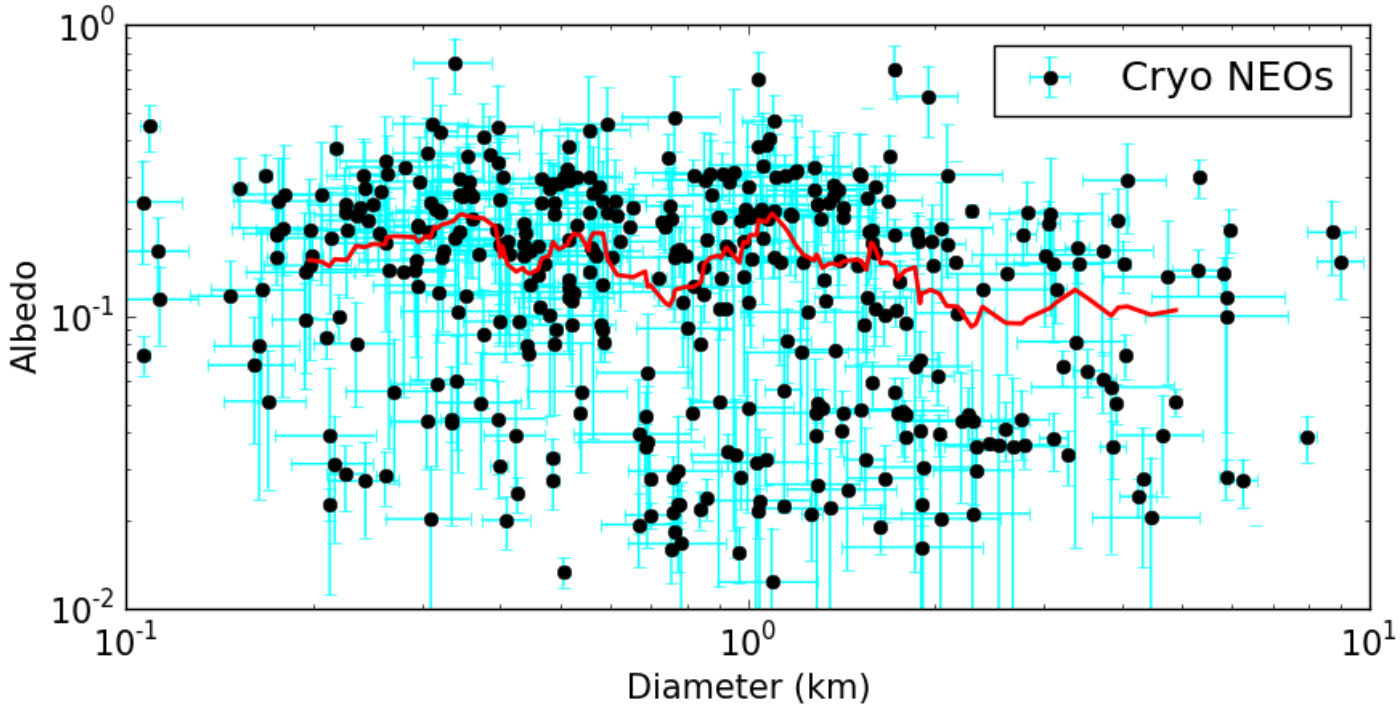
- Where N_T is total larger than 100 m, N_o is the observed sample, and P_N are the survey biases as a function of orbital elements & physical properties

Survey Biases



- NEOWISE is ~unbiased w.r.t. albedo and inclination

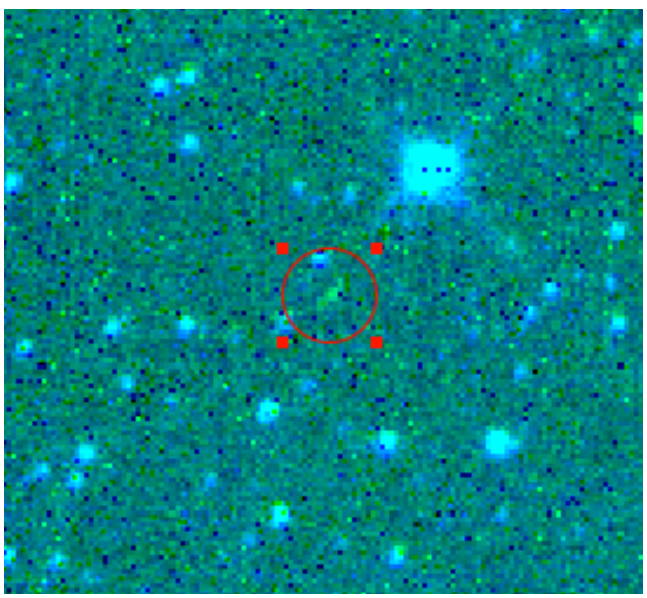
NEO Albedo vs. Diameter

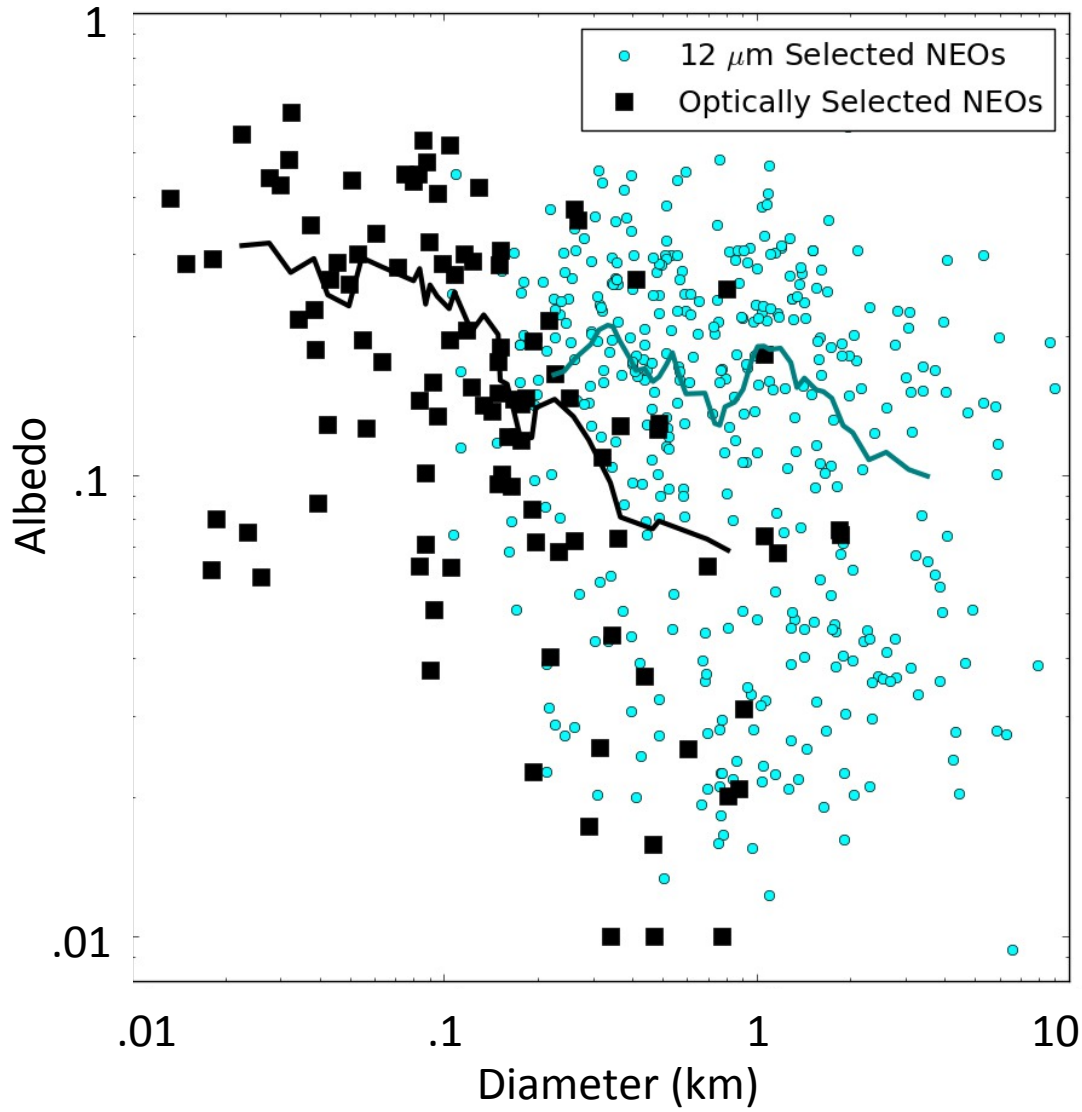


- ~430 NEOs
- No significant change in albedo vs. diameter
  - Albedo is constant all the way down to small sizes
- Contrary to previous studies that are biased against small, low albedo objects

NEOWISE Detections of Small NEOs

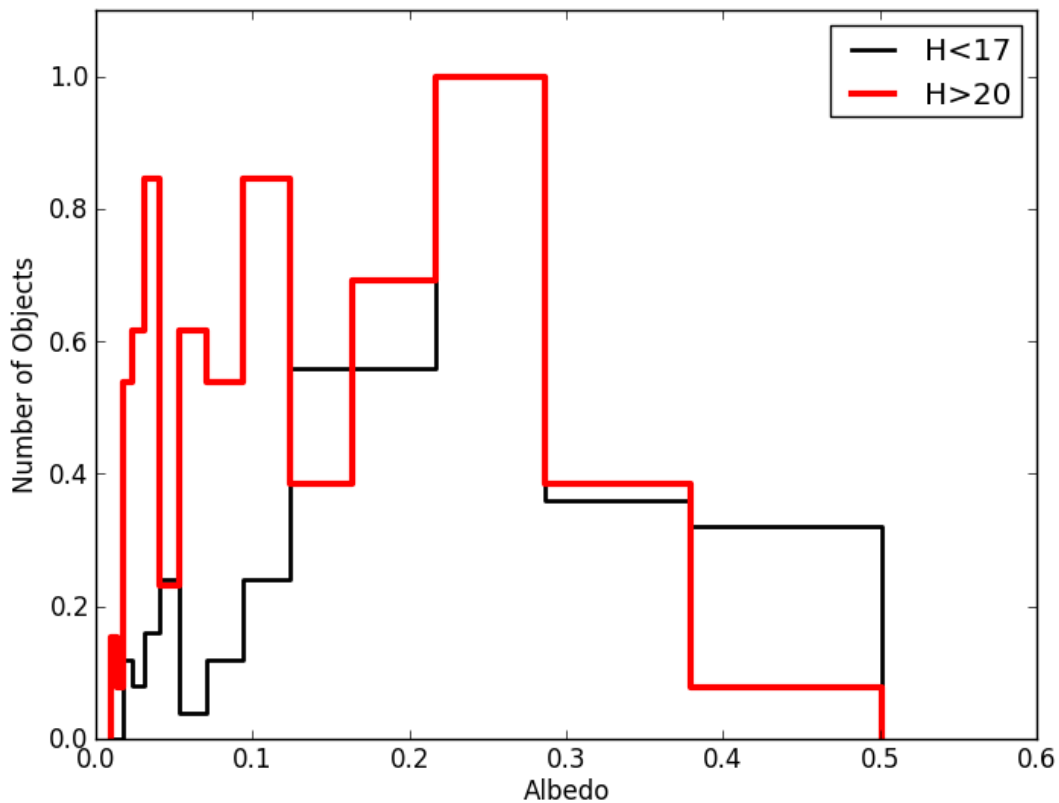
- Smallest NEOs detected by NEOWISE are 8m in diameter



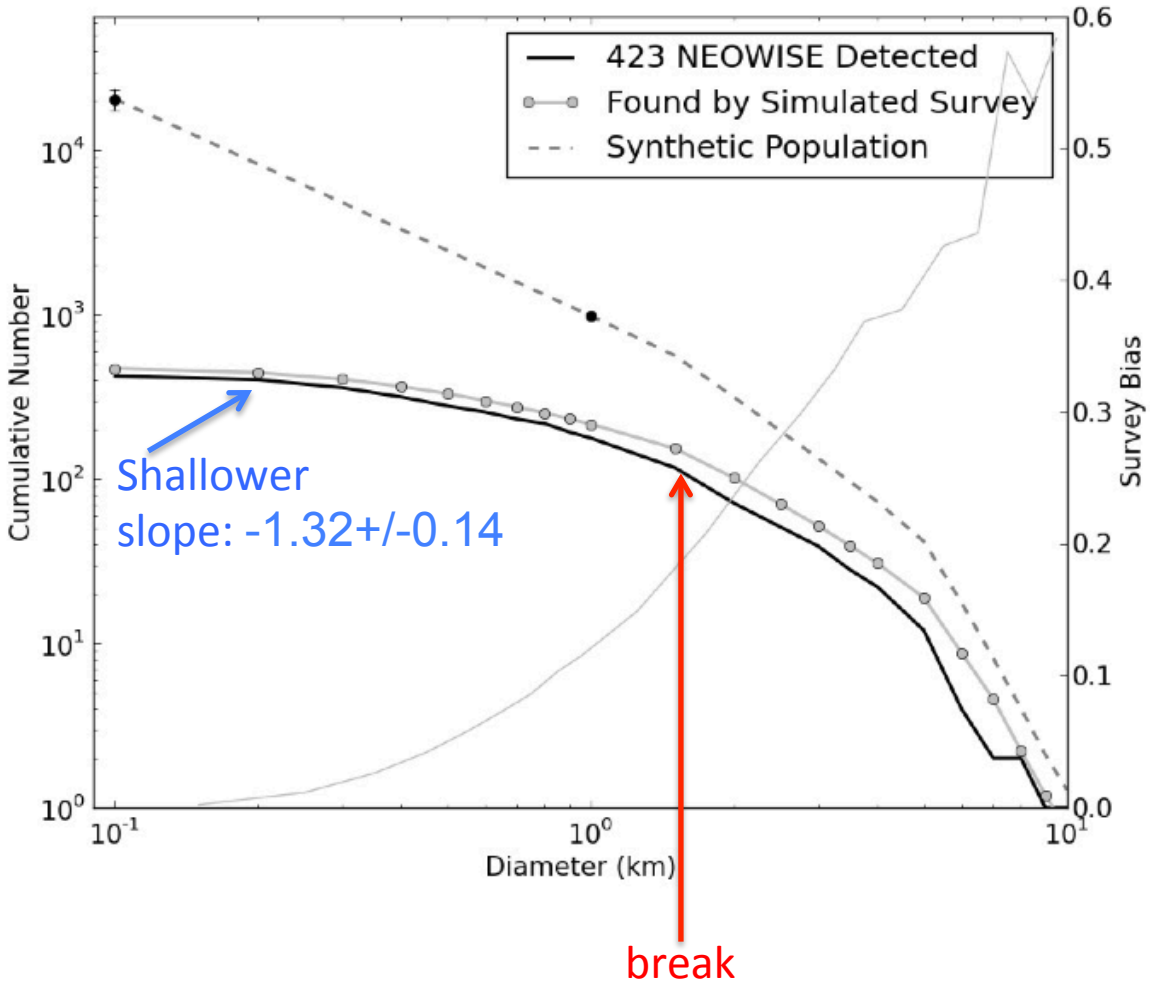


Albedo vs. H

- Not appropriate to use NEOWISE albedo distribution for low H objects to predict total numbers
  - Bright objects much more likely to have high albedo

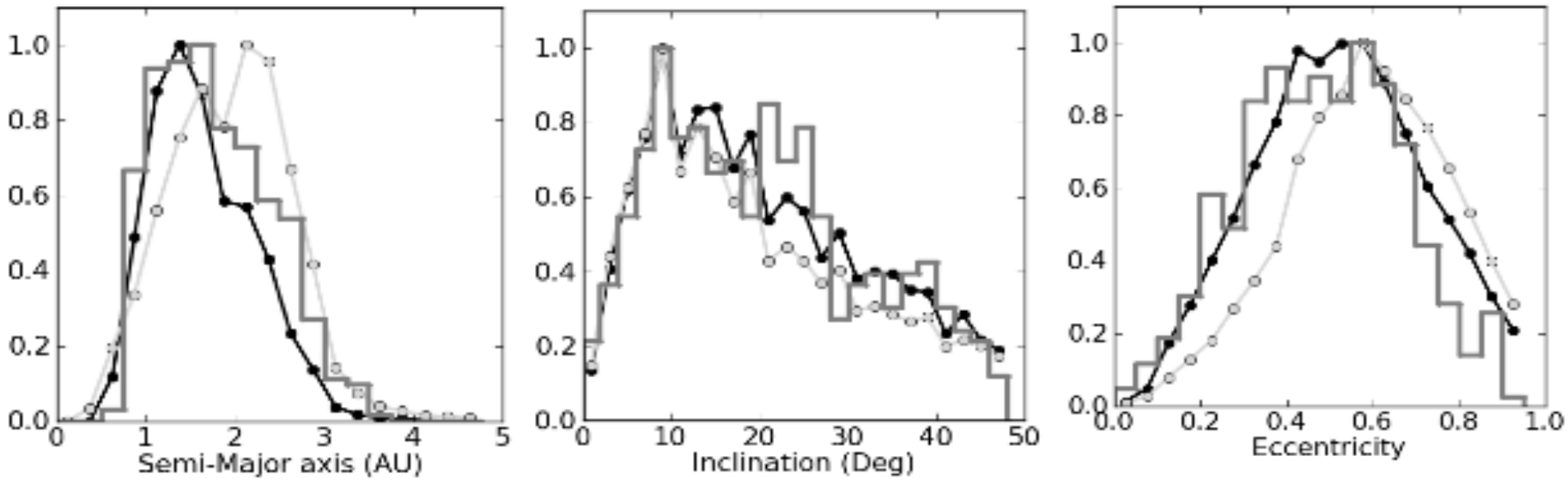


Near-Earth Asteroid Numbers & Sizes



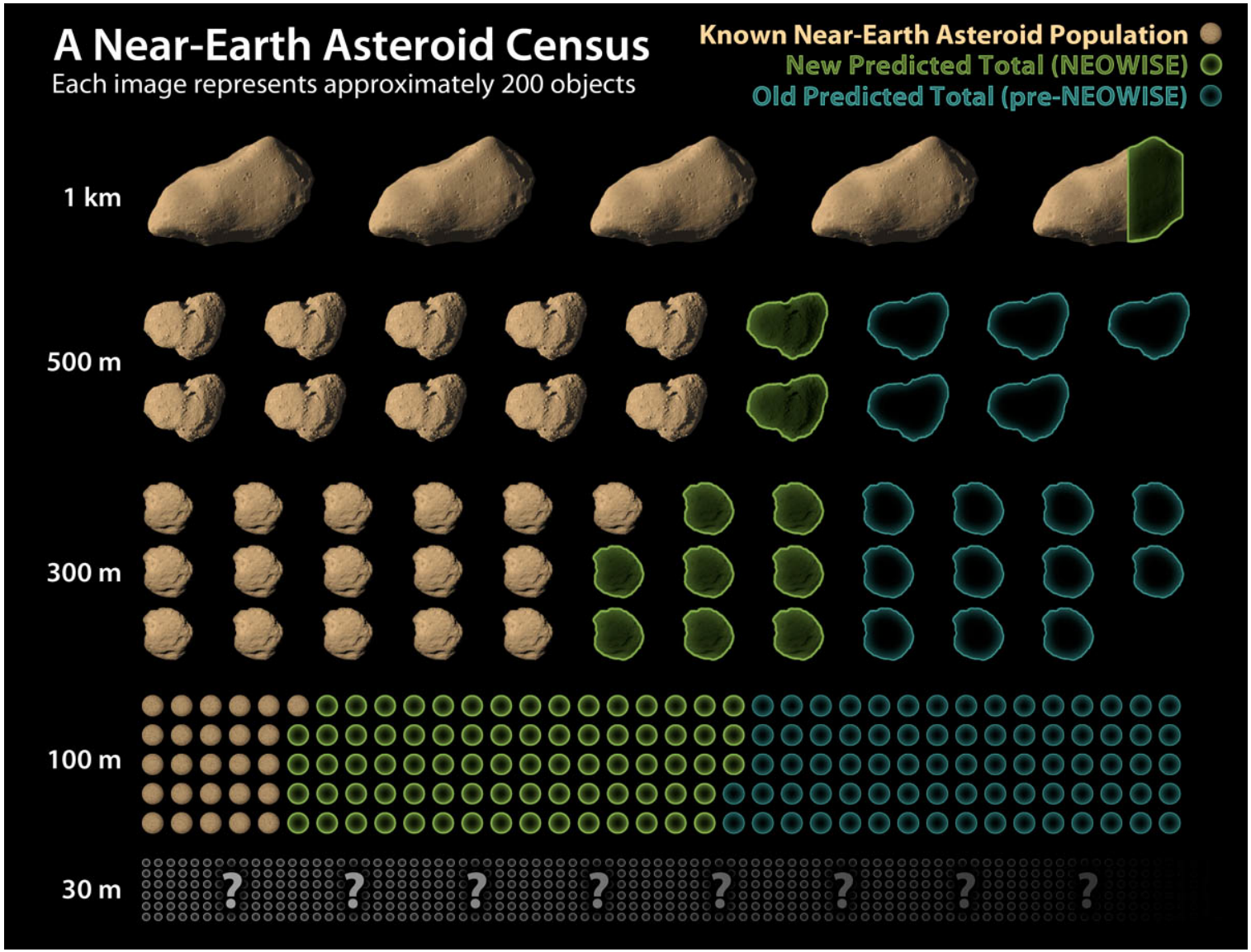
- Use well-known sensitivity & uniformity of four band survey to compute total numbers from observed sample
- 20,500+/-3000 @ 100m vs. prior estimates of 36,000 – 100,000
- Mainzer et al. 2011 ApJ 743, 156

Orbital Elements of NEAs

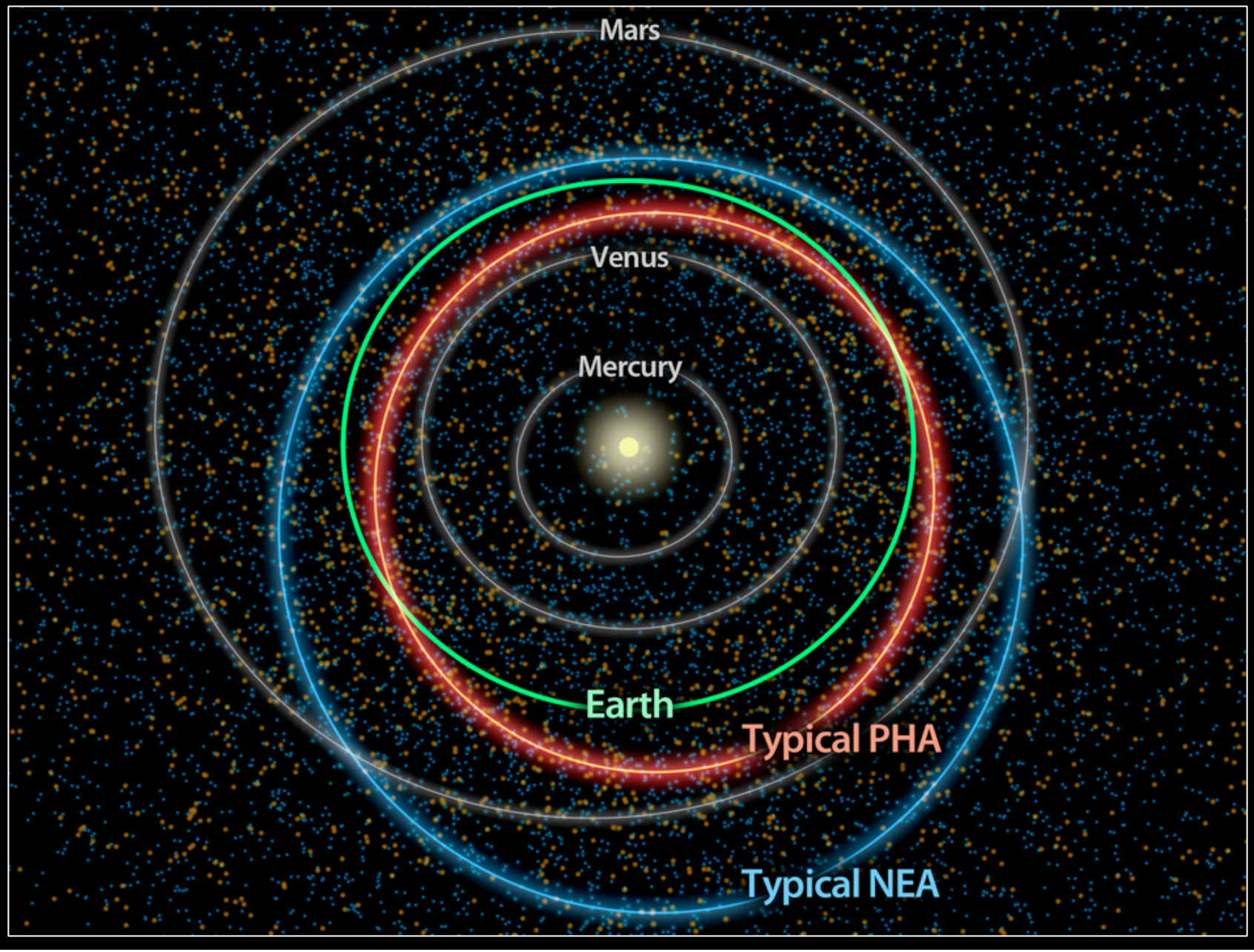


- Orbital element model of Bottke et al. (2002) pretty good match to NEAs as a whole
- But not the end of the story…

New Estimate of Numbers of NEAs

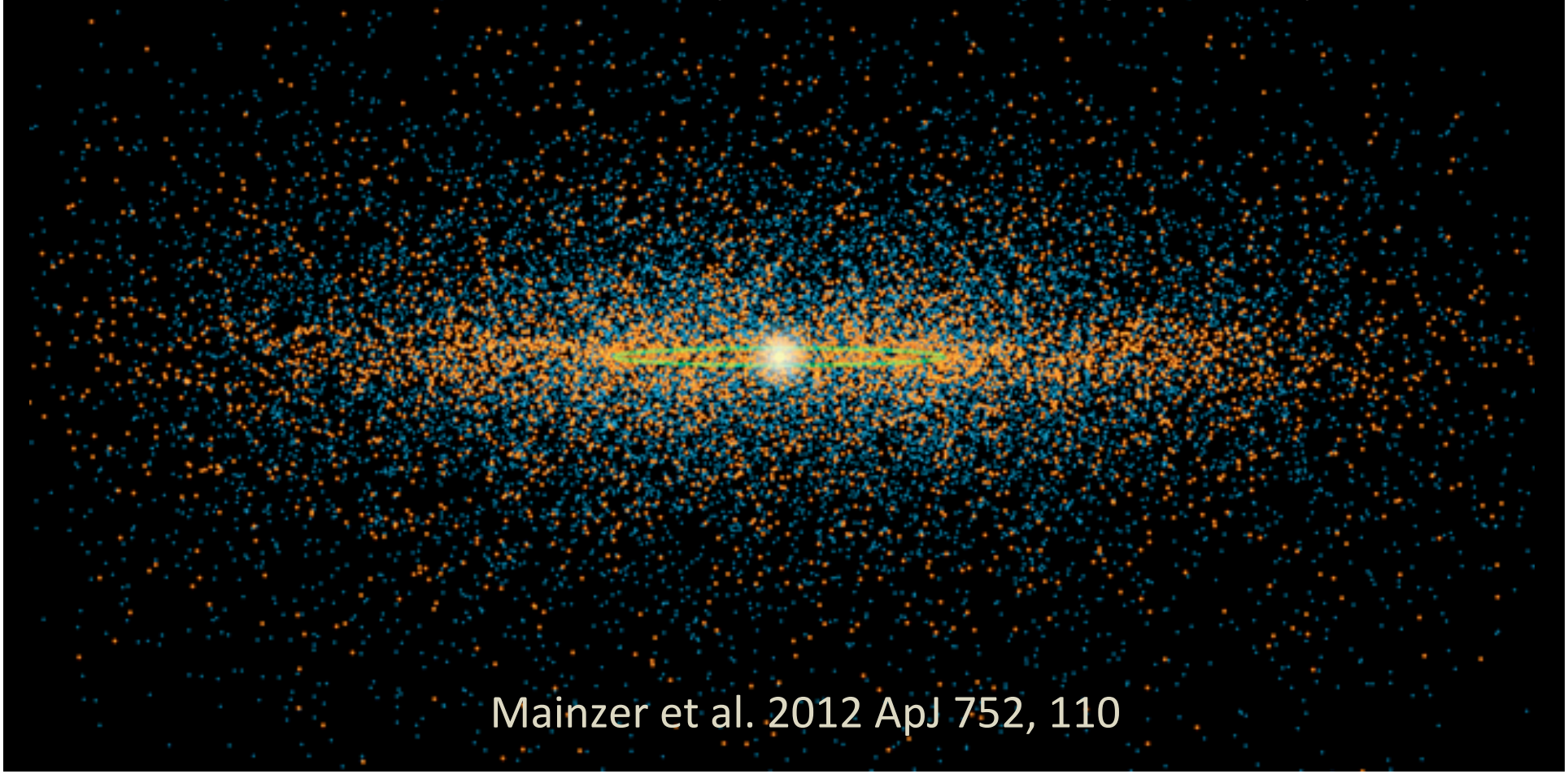


Potentially Hazardous Asteroids



Potentially Hazardous Asteroids

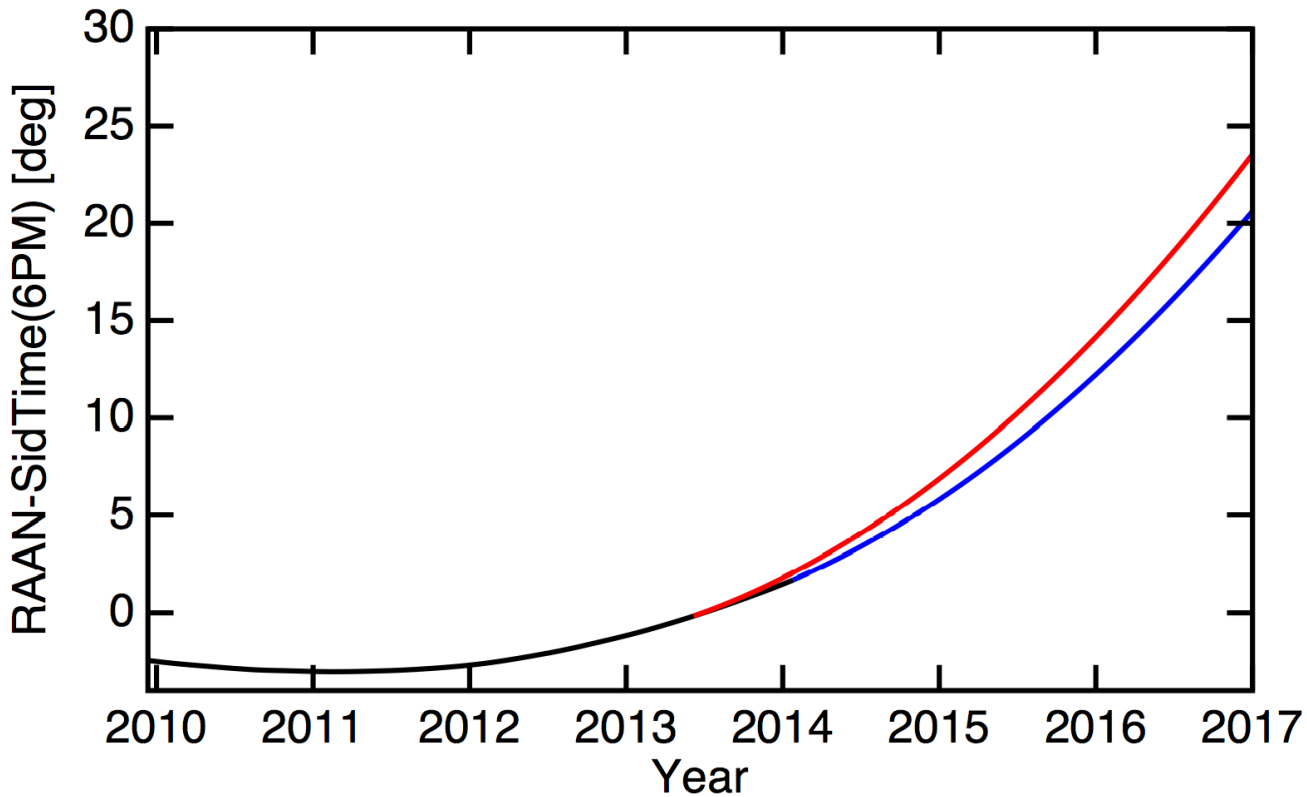
- 4700 ± 1500 PHAs larger than 100 m
- 2x more PHAs in low inclination orbits
  - More hazard, but more potential low Δv targets for exploration



Mainzer et al. 2012 ApJ 752, 110

Restarting NEOWISE

- Have restarted NEOWISE & resumed survey using bands W1 and W2 only (3.4 & 4.6 μm)
- No consumables now, but limited lifetime due to orbit precession
- Orbital plane drift rate depends on solar activity

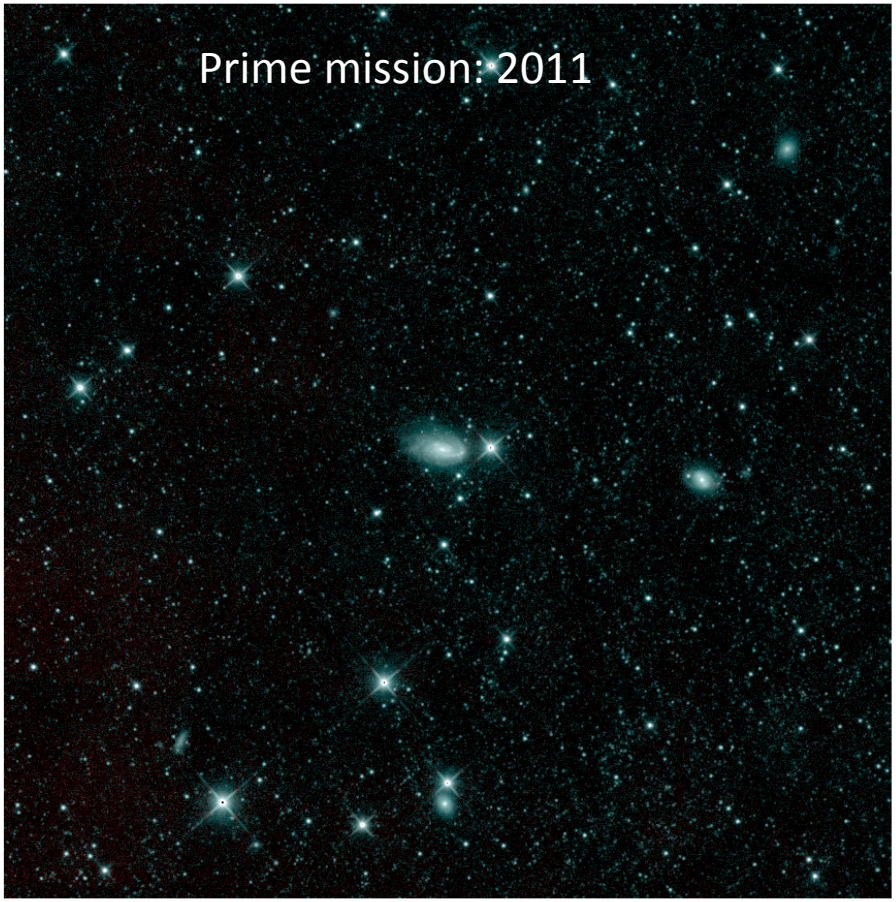


NEOWISE Reactivation Expected Science Return

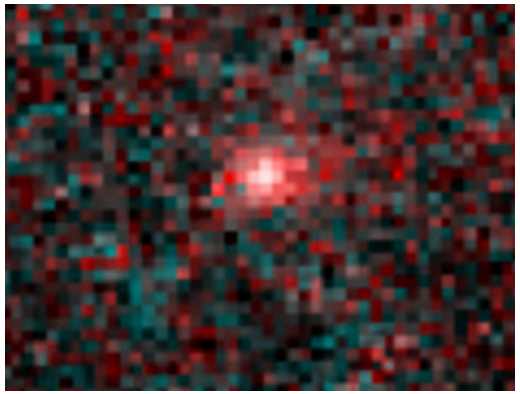
- Only ~1000-2000 NEOs have any sort of physical properties measured beyond H & orbit out of ~11,000 known to date
- Detect & characterize ~2000 near-Earth objects (NEOs) over 3 year survey at 3.4 & 4.6 μm
  - Derive diameters to ±25%, albedos to ±50%
  - Tens of thousands of Main Belt asteroids + comets
- Set additional constraints on subpopulations of NEOs, including Earth Trojans and potentially hazardous asteroids
- Data delivery policies same as prime mission

Instrument Performance

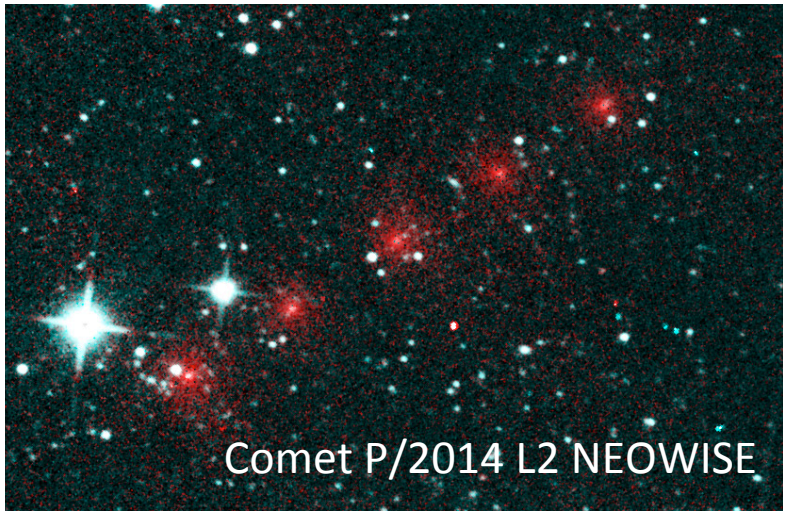
- Image quality, photometric accuracy, astrometry, sensitivity all unaffected bv 32 month hibernation

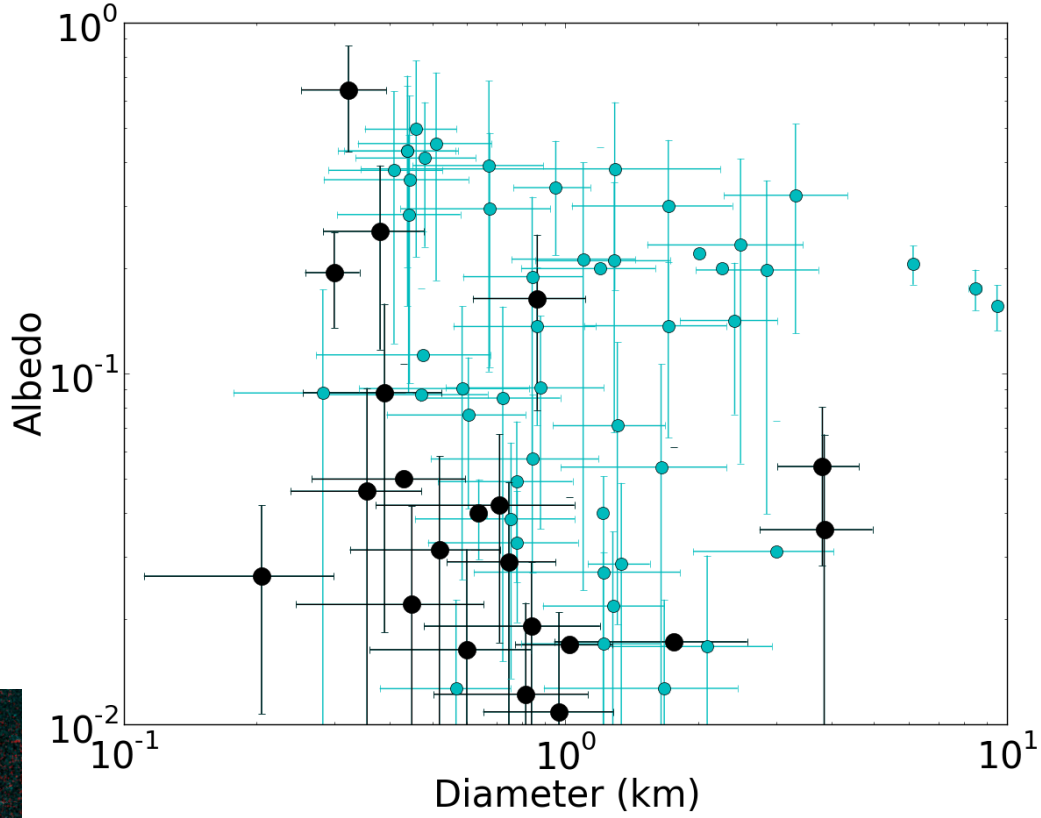


Preliminary Results



Comet C/2014 C3 NEOWISE





- Three new comets
- NEO discoveries are large, dark; 25% potentially hazardous asteroids

Data Access

- All NEOWISE data from Prime Mission have been publicly released & are available through NASA's Infrared Science Archive (IRSA):
  - Diameters & albedos in team papers (heading to PDS)
  - irsa.ipac.caltech.edu

- First NEOWISE Restart data release March 2015; annually thereafter
  - neowise.ipac.caltech.edu

Conclusions

- IR space telescopes provide an effective means to rapidly determine the numbers, orbital elements, & physical properties of asteroid & comet populations

- NEOWISE data being used by community: >100 refereed publications to date

- NEOWISE Restart will return ~double the number of NEO physical properties known, + tens of thousands of Main Belt asteroids