NEOWISE Views of Small Bodies

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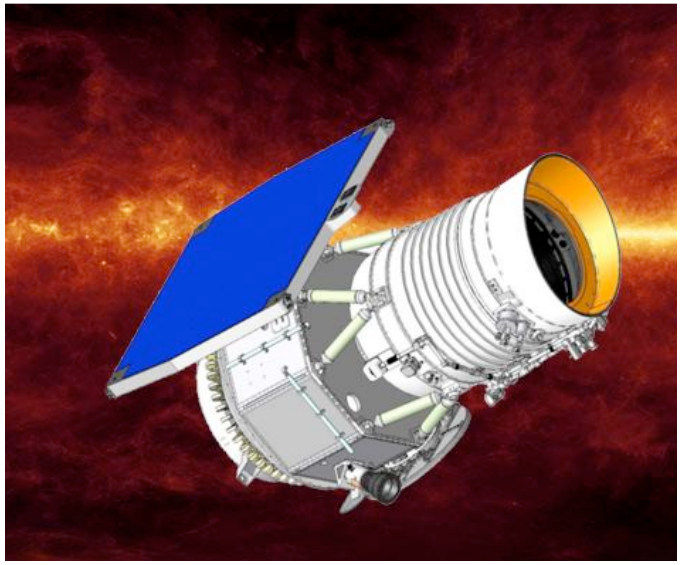
Mission Overview

Salient Features

- PI-led (PI: Amy Mainzer, JPL) mission under NEOO Program (Lindley Johnson, Program Exec)
- Uses WISE S/C that was brought out of hibernation in October 2013
- 3.4 and 4.6 μm bands (W1 and W2) at 75K
- Similar observing strategy to WISE/NEOWISE
  - Terminator-following pole-to-pole orbit
  - Surveys entire sky roughly every 6 months
- Science operations: 3 years starting 12/2013



Science

- Expand the NEOWISE survey of Near-Earth Objects (NEOs) at mid-infrared wavelengths using WISE W1 and W2 channels
- Obtain physical characterization (including diameters and albedos) of these NEOs and the thousands of other small bodies detected by NEOWISE

Prime Mission NEO Results

- Observations of ~430 NEOs from fully cryogenic mission (14 Jan 2010 – 5 Aug 2010) used to set constraints on population numbers, size distribution, albedos, orbital elements

- Results: 20,500±3000 near-Earth asteroids (no comets) >100 m;
  - shallow slope size distribution
  - ~25% survey completeness to date

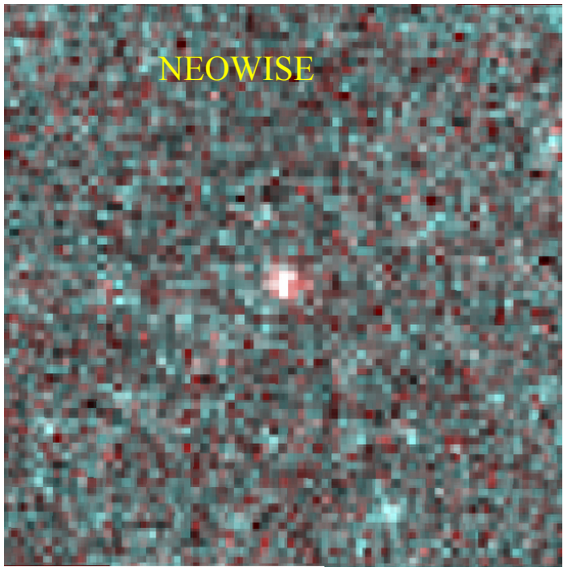
- Roughly 36% of NEOs are dark: p_V<0.1
  - Mainzer et al. 2011

NEO Results cont'd.

- 25% of NEOs detected by NEOWISE were potentially hazardous (PHAs; MOID<0.05 AU)
- For PHAs, there are 4700±1500 larger than 100m
- About 2x in low-inclination orbits compared to model prediction using Bottke et al. (2002) orbital elements
  - In good agreement with Greenstreet & Gladman (2013)
  - Mainzer et al. 2012

NEOWISE Restart

- Since the start of operations, NEOWISE has obtained **~350,000** infrared measurements of **16,569** solar system objects, including **419** NEOs, of which **68** are new discoveries
- Recent NEO discovery **2015 KL157** is a PHA with a MOID of 0.003AU (~1 lunar distance), diameter of 0.58km and V albedo of 0.05
- Fourth comet discovery: **2015 J3 (NEOWISE) –** Jupiter family



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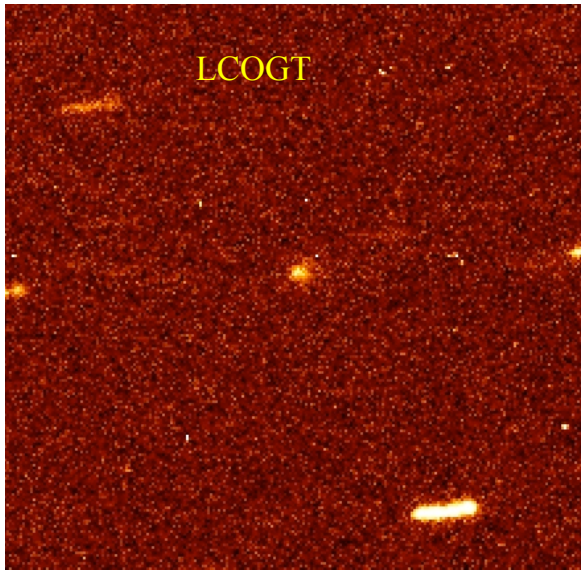

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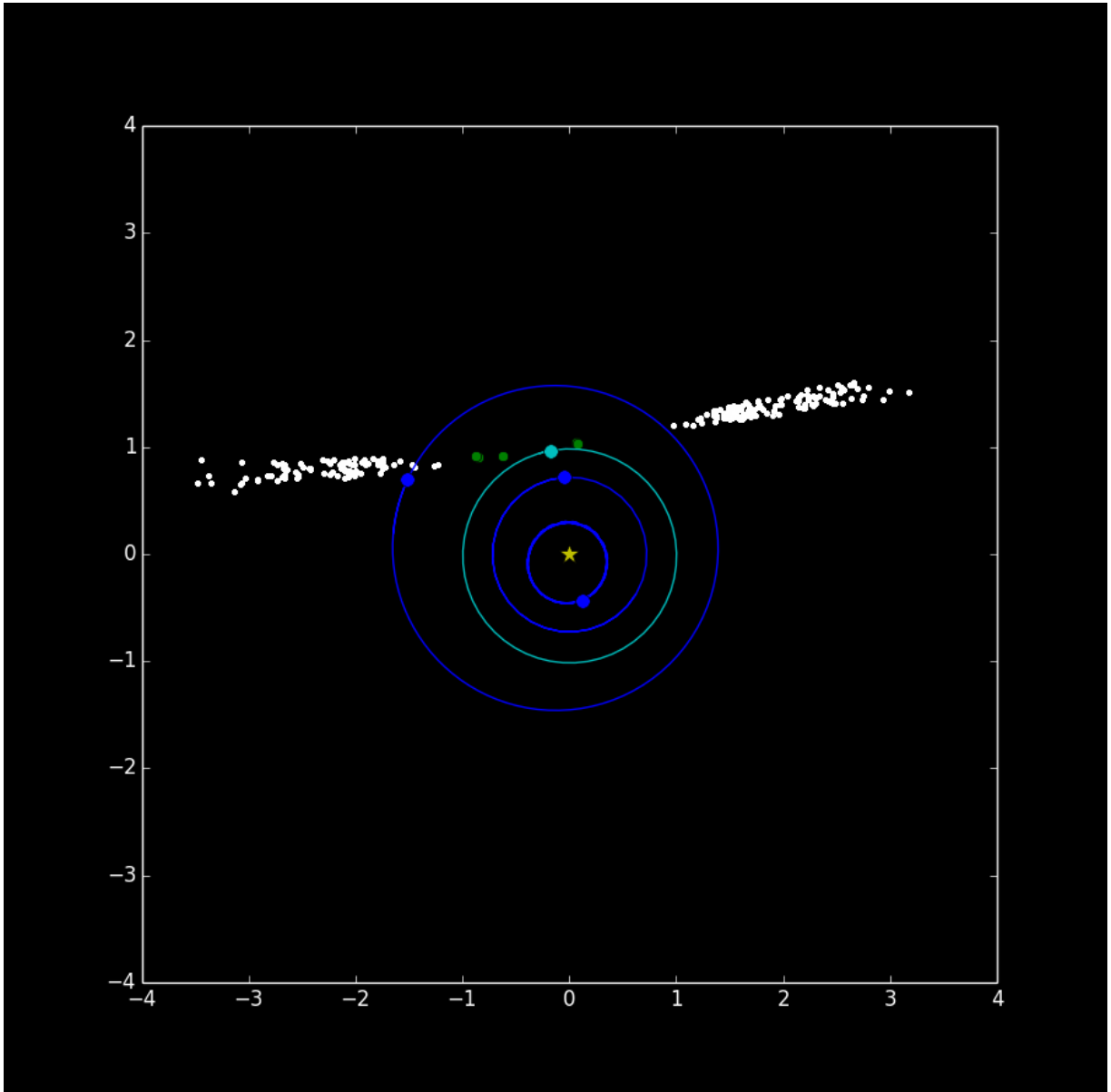
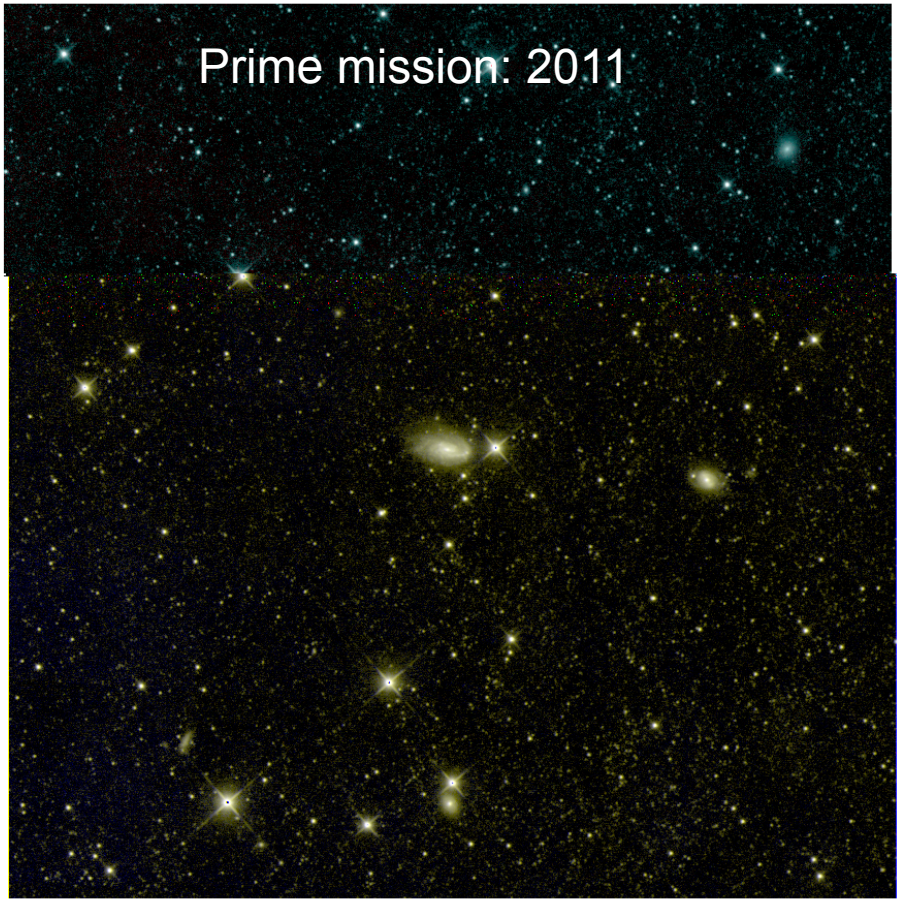
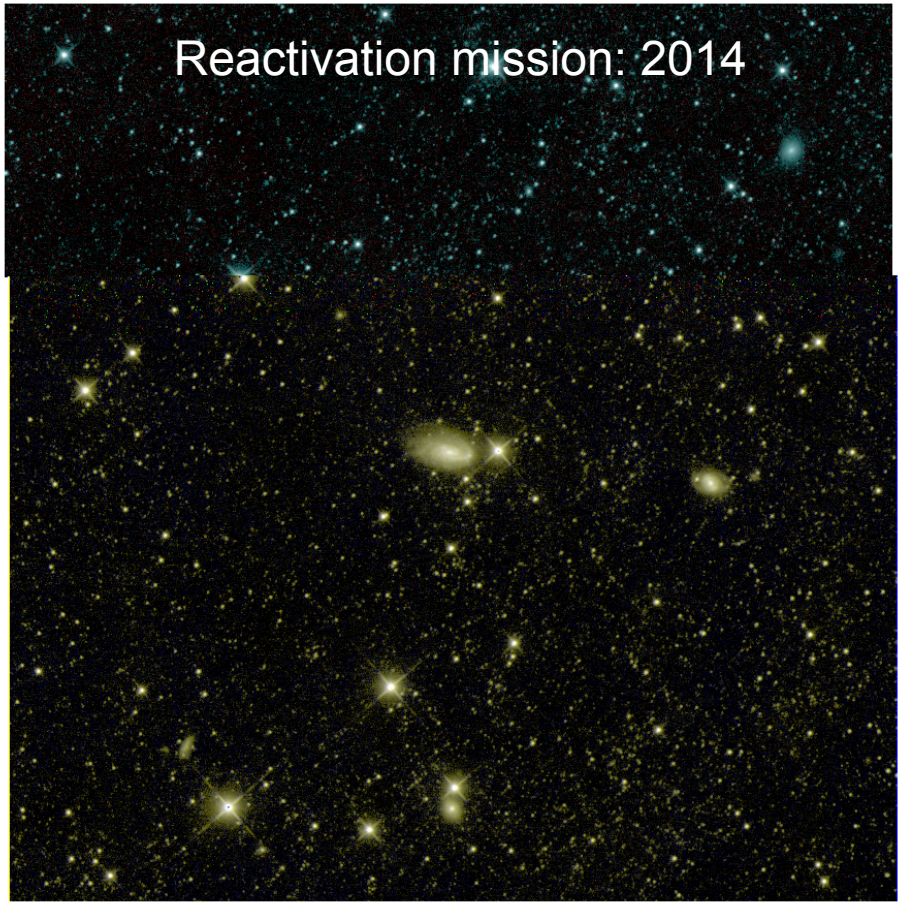
NEOWISE Year 1



Instrument Performance

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





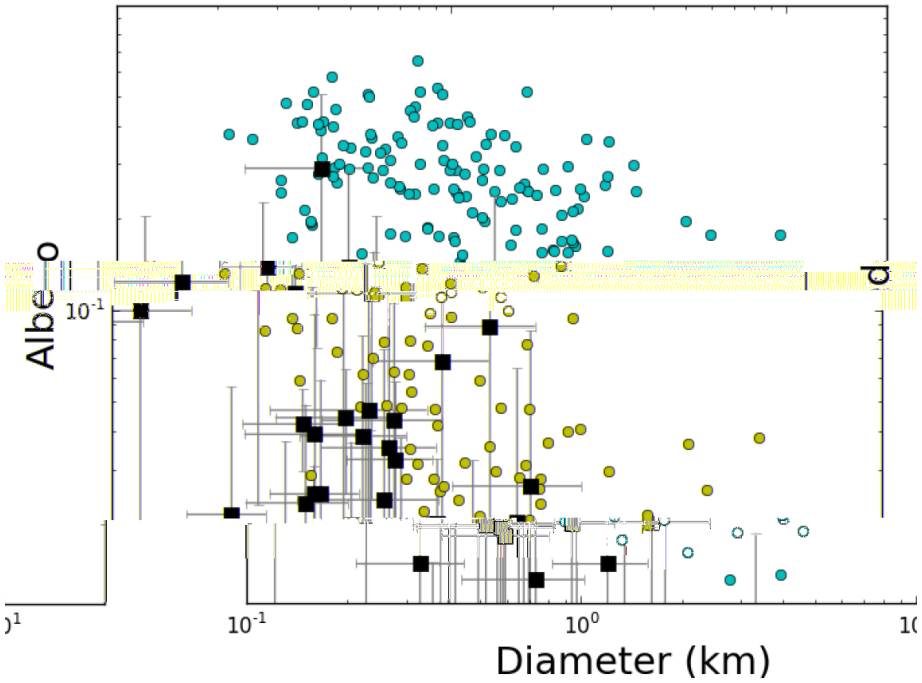
Single-exposure Source Database Characteristics

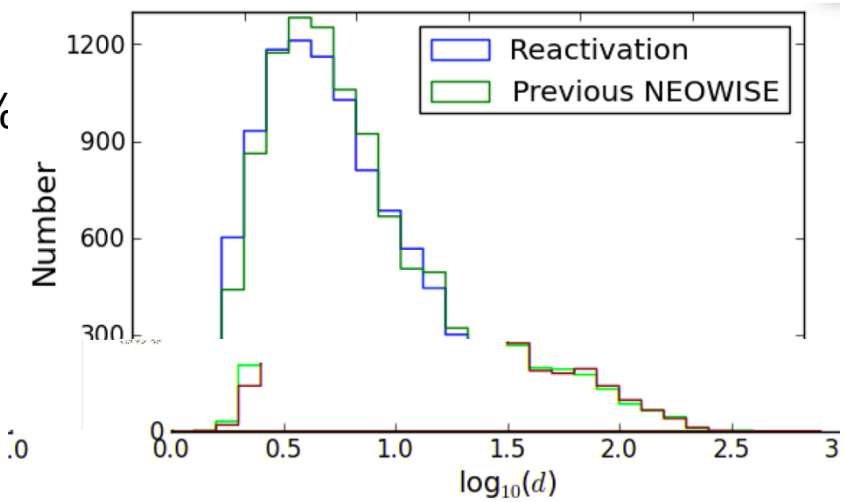
		W1	W2
Sensitivity (SNR=10)	**mag**	**15.0**	**13.7**
	microJy	300	565
Completeness (>90%)	**mag**	**15.8**	**14.4**
	microJy	150	300
Reliability (>95%)	**mag**	**15.0**	**13.5**
	microJy	300	680
Astometric Accuracy	70 mas (high SNR)		

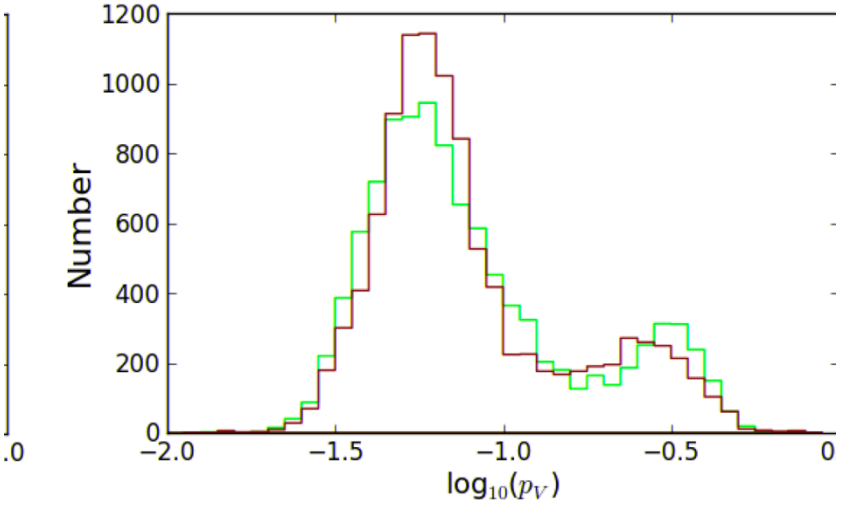
- Sensitivity nearly identical to prime mission

Diameters and Albedos for 9,309 Asteroids Detected During First Year

- Nugent et al. (2015 ApJ in press)
- Diameters accurate to ~20%, albedos to ~50%







- NEOWISE preferentially detects large NEOs
- NEO discoveries tend to be dark
- Nearly a quarter are PHAs

Diameters and albedos consistent with values from original NEOWISE mission

NEOWISE 2015 Data Release
March 26, 2015

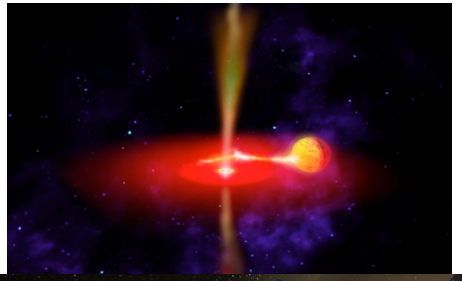
http://wise2.ipac.caltech.edu/docs/release/neowise

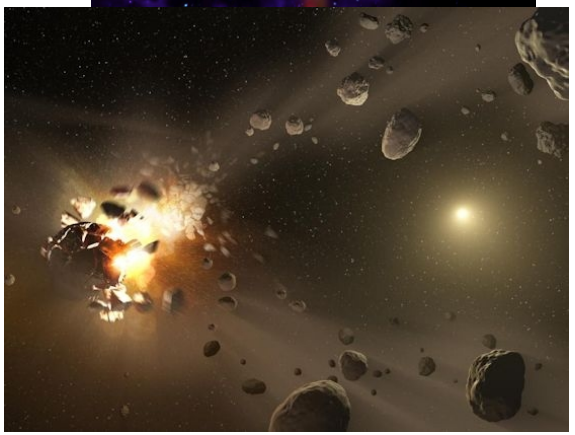
- **Single-exposure data** from the first year of the NEOWISE Reactivation Mission
- **2,497,867** calibrated 3.4 and 4.6 μm FITS images, uncertainty maps and bit masks
- **18,468,575,596** source extractions (positions and W1/W2 fluxes, ancillary information) from those images
- **Data access**:
  - Image and source database from the NASA/IPAC Infrared Science Archive (IRSA)
  - Moving Object tracklets from the IAU Minor Planet Center

NEOWISE Data Use

- Total citation count using NEOWISE data & discoveries: >200 refereed publications
  - Total citation count for WISE >1400 refereed publications

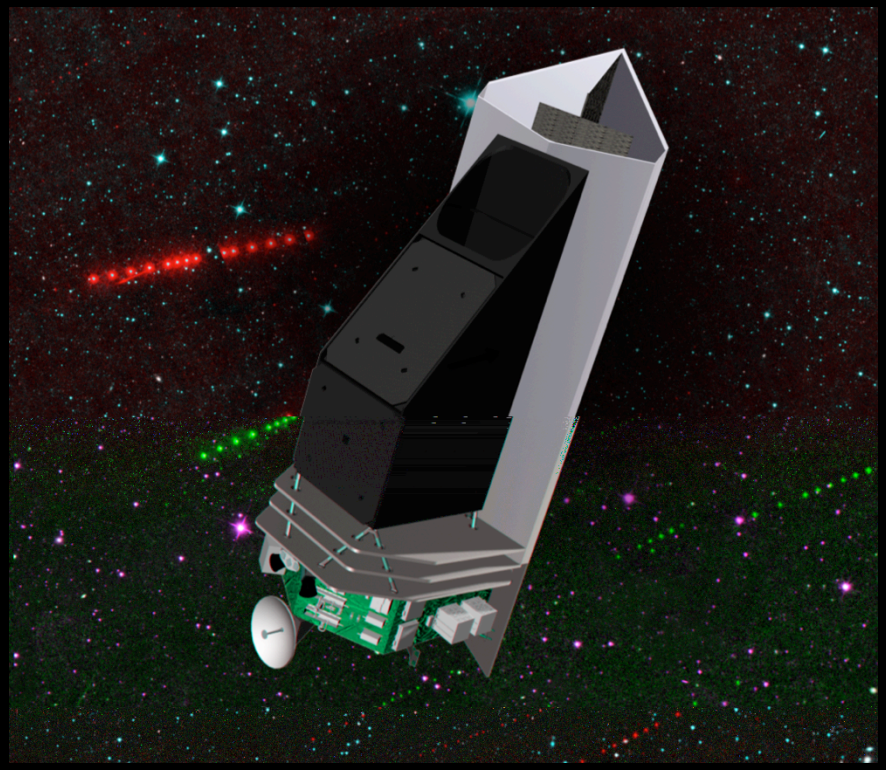
- NEOWISE is a multi-epoch mid-infrared all-sky survey, so its science spans many areas of astrophysics & planetary science:
  - Asteroids
  - Meteoritics
  - Giant planet migration
  - Variable stars
  - Icy bodies in the outer solar system
  - Distance ladder determinations for cosmology
  - Human exploration
  - Supernovae
  - Pulars
  - Exoplanets
  - Black hole accretion disks





NEOCAM

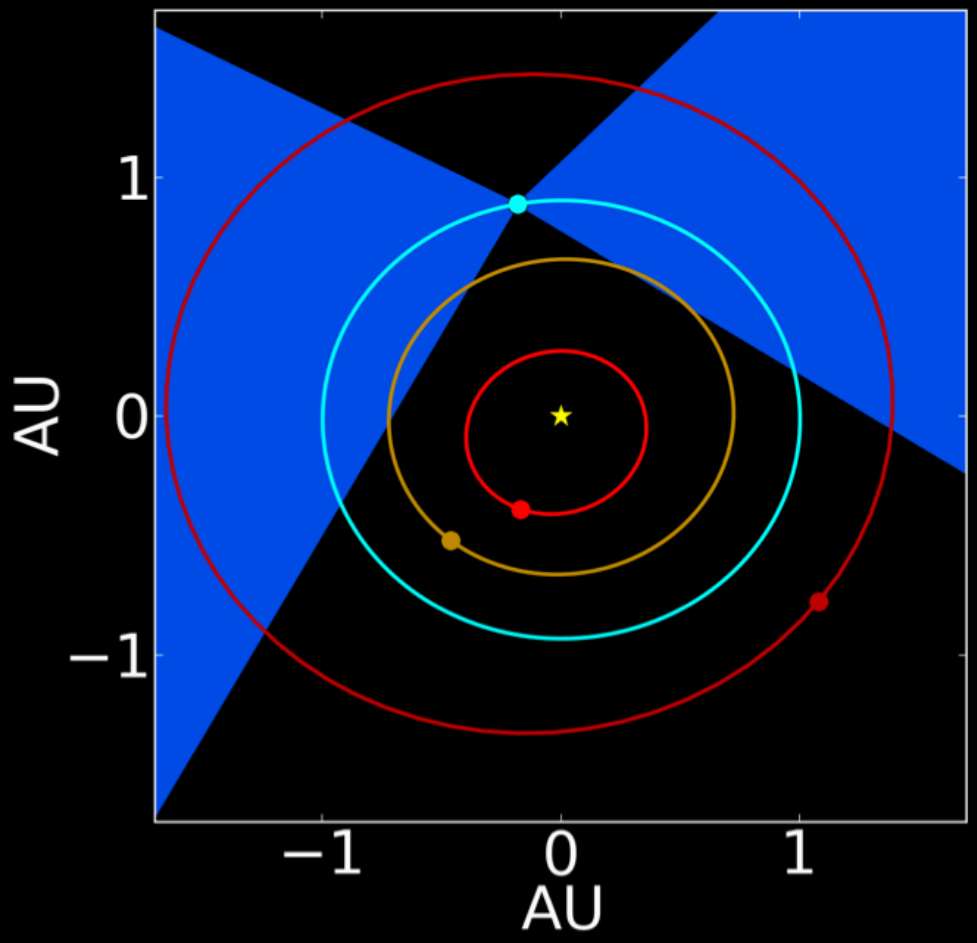
NEAR-EARTH OBJECT CAMERA



NEOCam is a dual-channel imager operating in a single step-and-stare survey mode. It includes:

- 50 cm telescope
- Two 16 megapixel HgCdTe focal planes at 4-5.4 and 6-10 μm simultaneously imaged
- Detectors passively cooled to 40K
- Sun-Earth L1 orbit
- First proposed 2005: Category II
- Awarded technology development funding in 2011 Discovery
- Step 2 Discovery (Phase A)

Orbit: Sun-Earth
L1 Lagrange Point



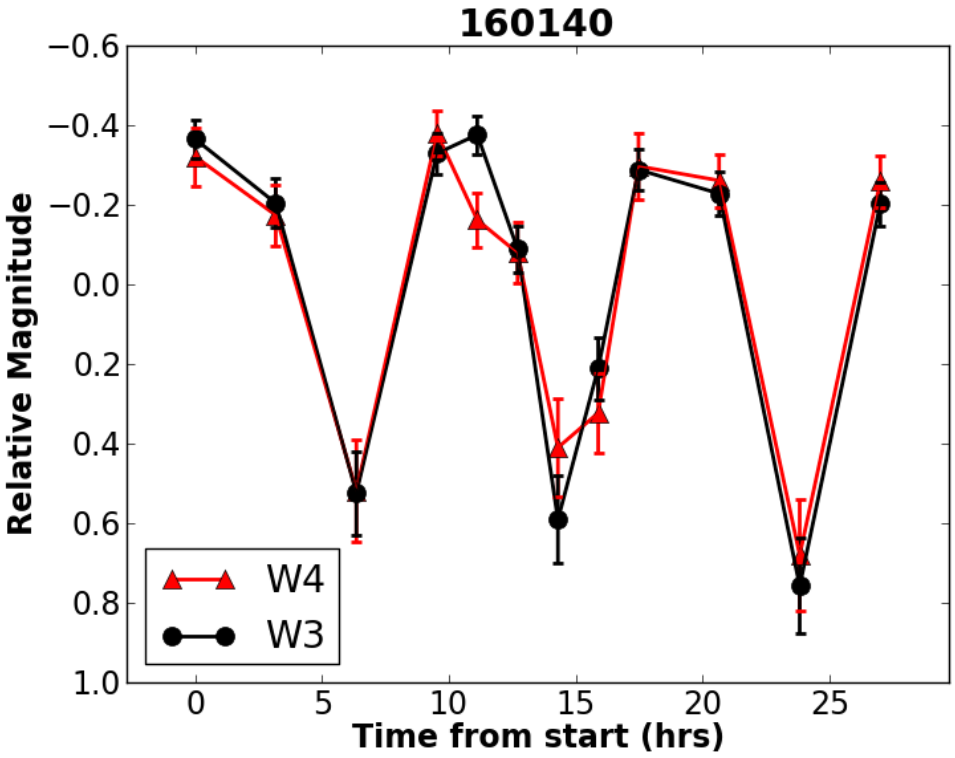
- Allows wide instantaneous viewing zones
- Close, constant distance from Earth allows full-frame images to be downlinked
- Thermal environment allows passive cooling to 40 K

NEOCam Science

- Planetary Defense
  - Detect millions of small bodies throughout the solar system, including 2/3 of PHAs >140m
  - Constrain impact probability for NEOs & comets of all sizes
- Origins & Evolution
  - Population studies: numbers, orbital distribution, physical properties
  - Origins of collisional families, NEOs
  - Identify and characterize rare populations: Earth Trojans, interior NEOs
  - Most comprehensive collection of comet orbit distributions, sizes, & CO/CO_2 abundances
- Finding New Destinations
  - Find the most accessible targets for future exploration

BACKUP

Example: Possible Binary Asteroids Identified by Large Amplitude Lightcurves

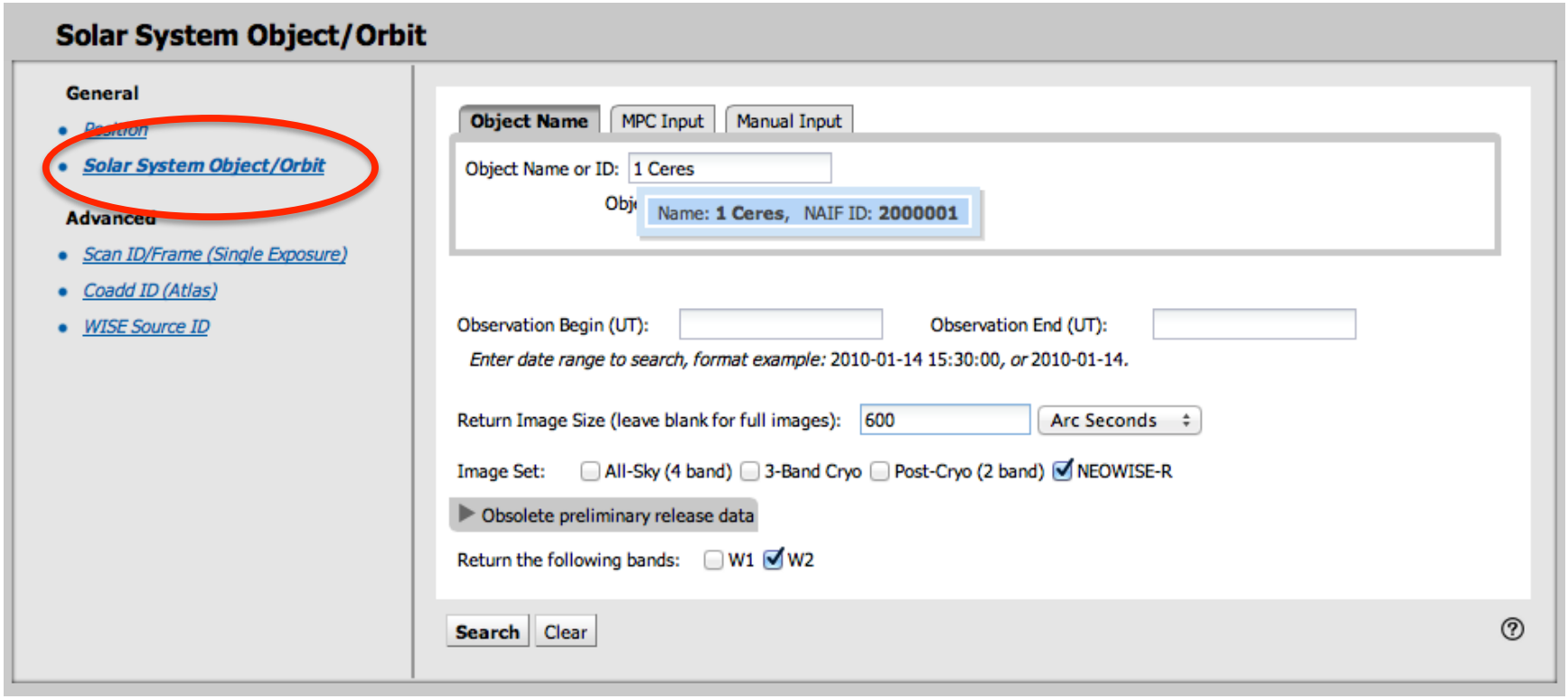


Sonnett et al. (2015)

- Close & contact binaries can sometimes be identified by their large brightness variations
- NEOWISE data record observations of asteroids every ~3 hours for ~30 hours
- 29 new binary candidates out of 953 Trojans (13-150 km)
- 48 new binary candidates out of 554 Hildas (4-36 km)

- Candidates are in need of follow-up to confirm binarity (follow-up underway)

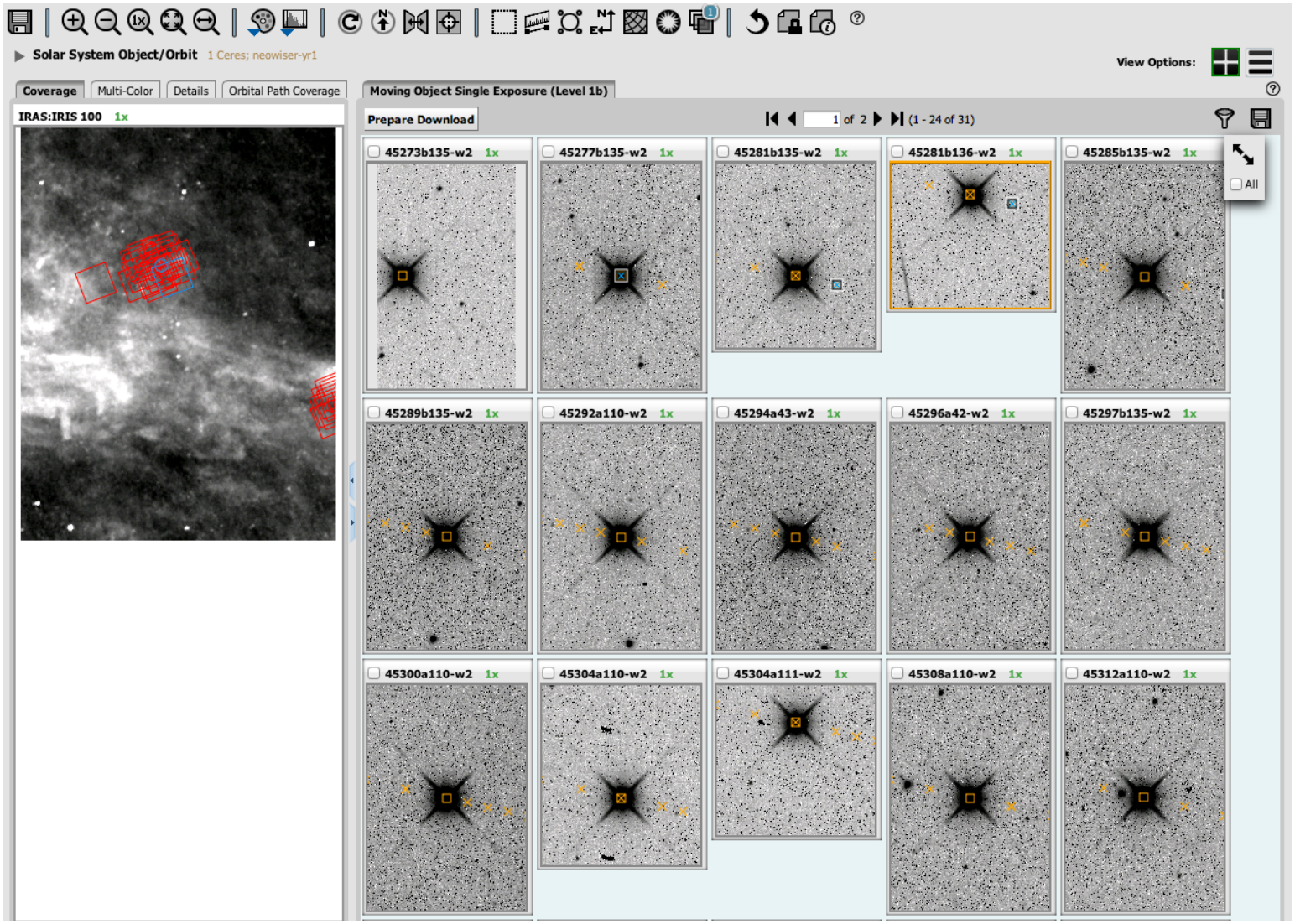
WISE/NEOWISE Image Server: Solar System Object Search



Search for Images that cover the position of Moving Objects at time of observation

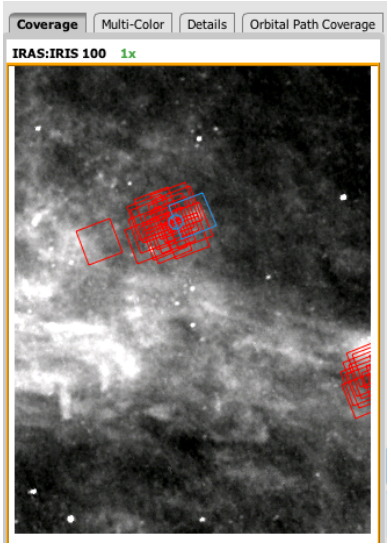
- Search by Object Name (Name resolution via JPL Horizons)
- Search using orbital elements with MPC format
- Search using manually input elements

Results of Solar System Search: Grid

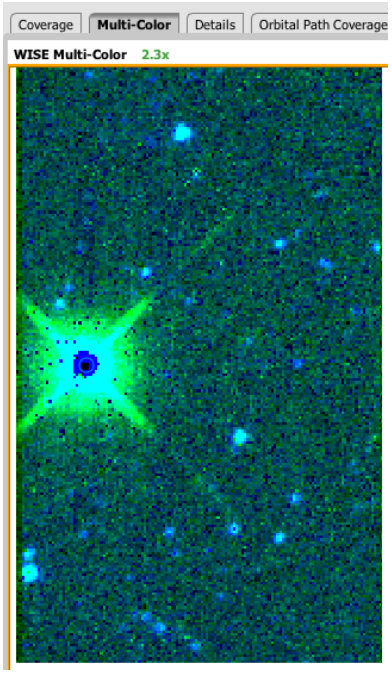


Results: left panel

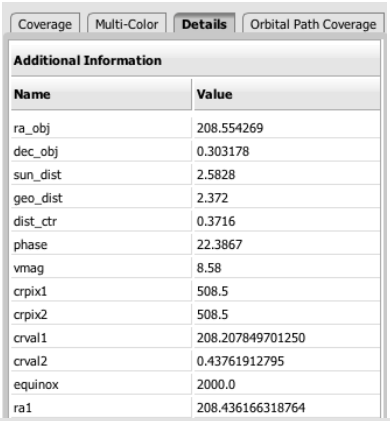
Coverage



Multi-Color

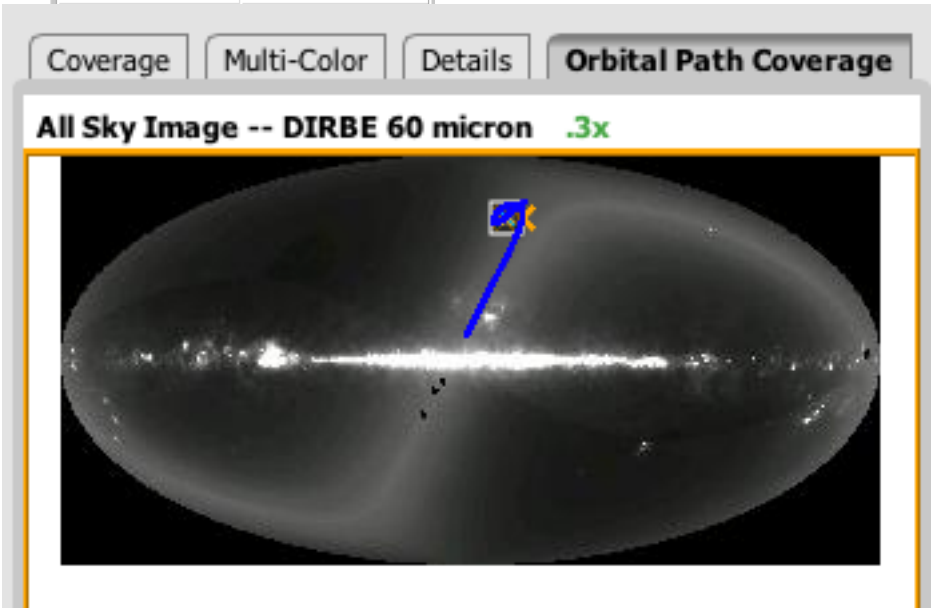


Details

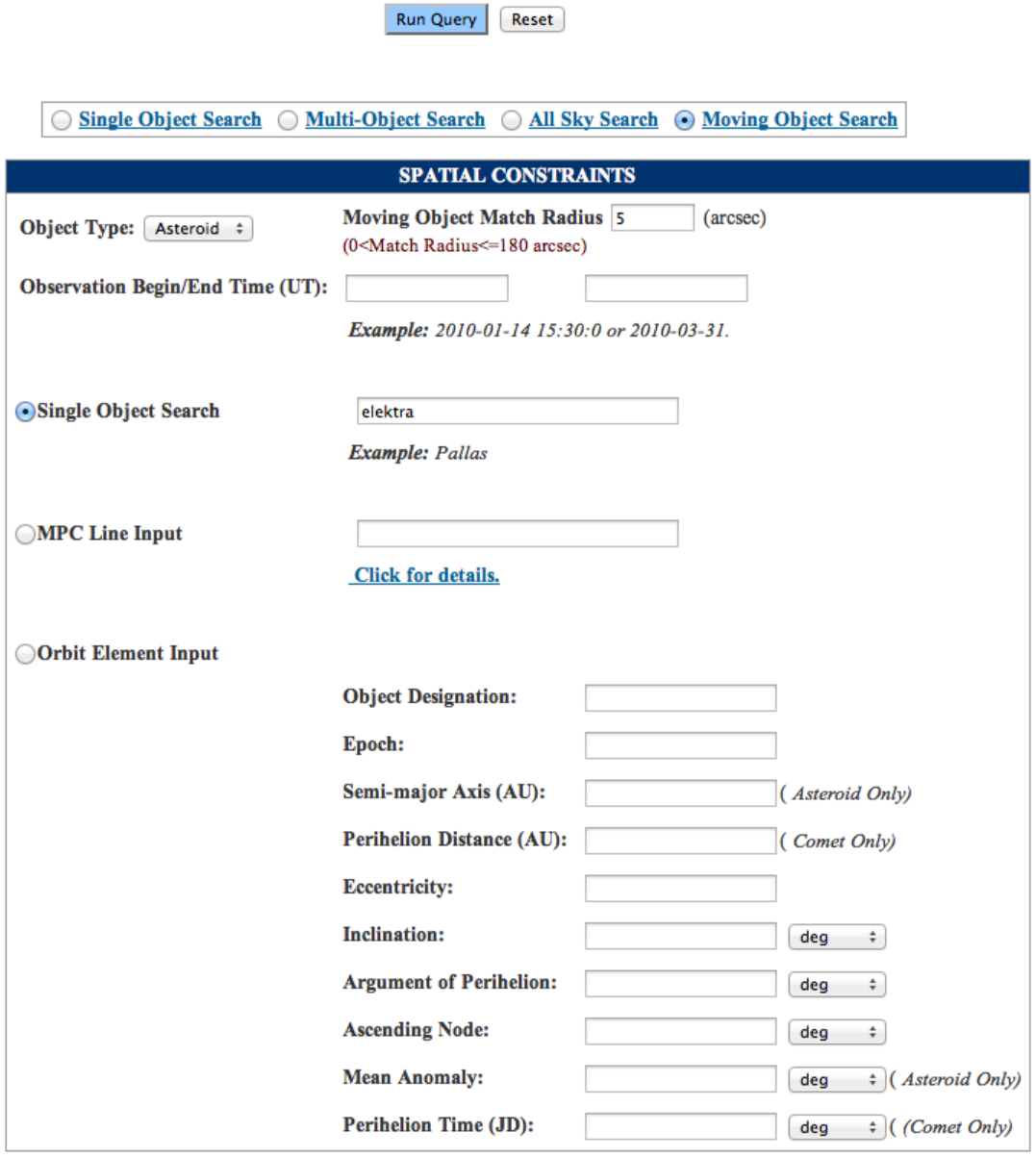


Name	Value
ra_obj	208.554269
dec_obj	0.303178
sun_dist	2.5828
geo_dist	2.372
dist_ctr	0.3716
phase	22.3867
vmag	8.58
crpix1	508.5
crpix2	508.5
crval1	208.207849701250
crval2	0.43761912795
equinox	2000.0
ra1	208.436166318764

Orbital Path Coverage



Catalog Query Engine: Solar System Object Search



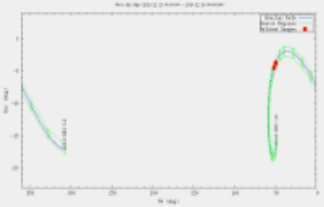
Search Source Database for Detections at predicted position of Moving Object at time of observation

- Search by Object Name (Name resolution via JPL Horizons)
- Search using orbital elements with MPC format
- Search using manually input elements

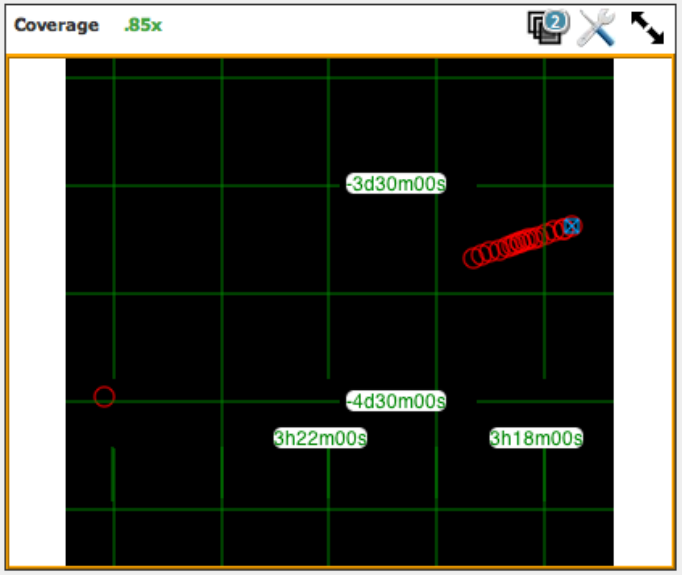
Catalog Search Result for NEOWISE-R Year 1 Single Exposure (L1b) Source Table

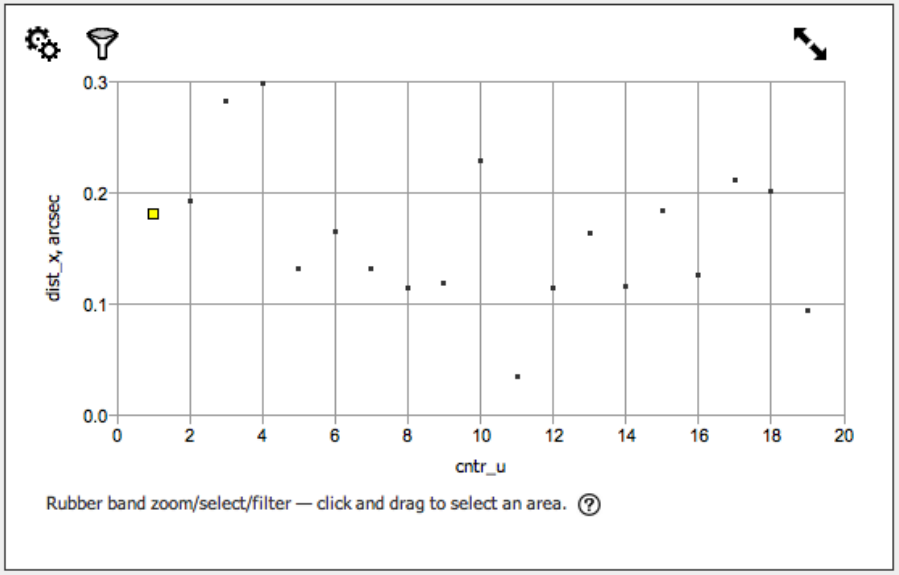
Moving Object		Observation Time	
Type	**Name**	**Begin**	**End**
Asteroid	130 Elektra	2013 12 13 00:00:00	2014 12 14 00:00:00
Designation	**Epoch (MJD)**	**Semi-major**	**Eccentricity**
130 Elektra	56639.00	3.123766383191	0.208587220463
Inclination (deg)	**Argument of Perihelion (deg)**	**Ascending Node (deg)**	**Mean Anomaly (deg)**
22.866505235768	235.628120738519	145.407982878680	317.995810613083

Matched Image List



All Sky Search Constraints: Yes **38 sources found.**





Result IPAC Table **Column Key**

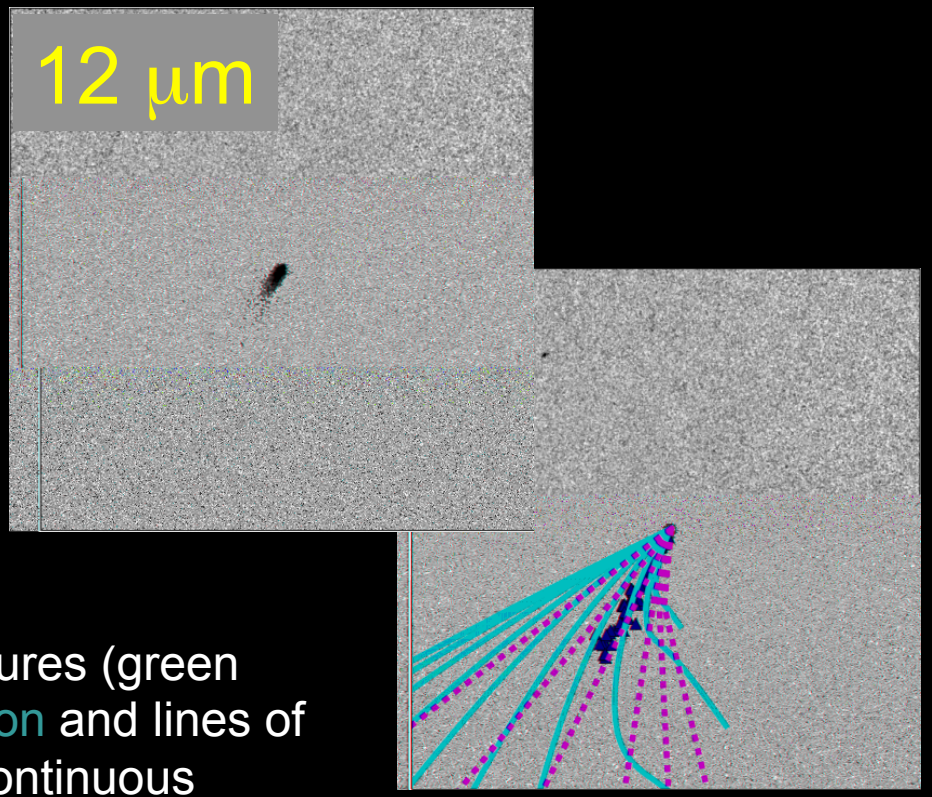
1 of 1 (1 - 19 of 19)

cntr_u	dist_x (arcsec)	pang_x (deg)	ra_u	dec_u	ra (deg)	dec (deg)	sigra (arcsec)	sigdec (arcsec)	sigradec (arcsec)	w1mpro (mag)	w1sig (ma
1	0.180826	40.666238	49.371581	-3.686568	49.3716138	-3.6865299	0.0276	0.0225	-0.0075	10.211	0.014
2	0.192727	16.236655	49.411816	-3.699347	49.4118310	-3.6992956	0.0274	0.0258	0.0039	10.293	0.018
3	0.281305	5.349284	49.411857	-3.699345	49.4118643	-3.6992672	0.0252	0.0226	0.0092	10.308	0.017
4	0.298546	5.108685	49.452031	-3.712170	49.4520384	-3.7120874	0.0266	0.0224	0.0080	10.080	0.016
5	0.130517	-13.854746	49.492144	-3.725041	49.4921353	-3.7250058	0.0262	0.0229	-0.0031	9.905	0.014
6	0.164148	19.429601	49.532194	-3.737959	49.5322092	-3.7379160	0.0252	0.0207	-0.0054	9.956	0.015

Cometary dust evolution

- NEOWISE data are particularly sensitive to large-grained dust (~mm) in cometary tails and comae.

- Kramer et al (2015): Evolution of emitted dust w/ gravitational & non-grav forces to characterize the outburst of comet C/2015 L5 (WISE) in 2010



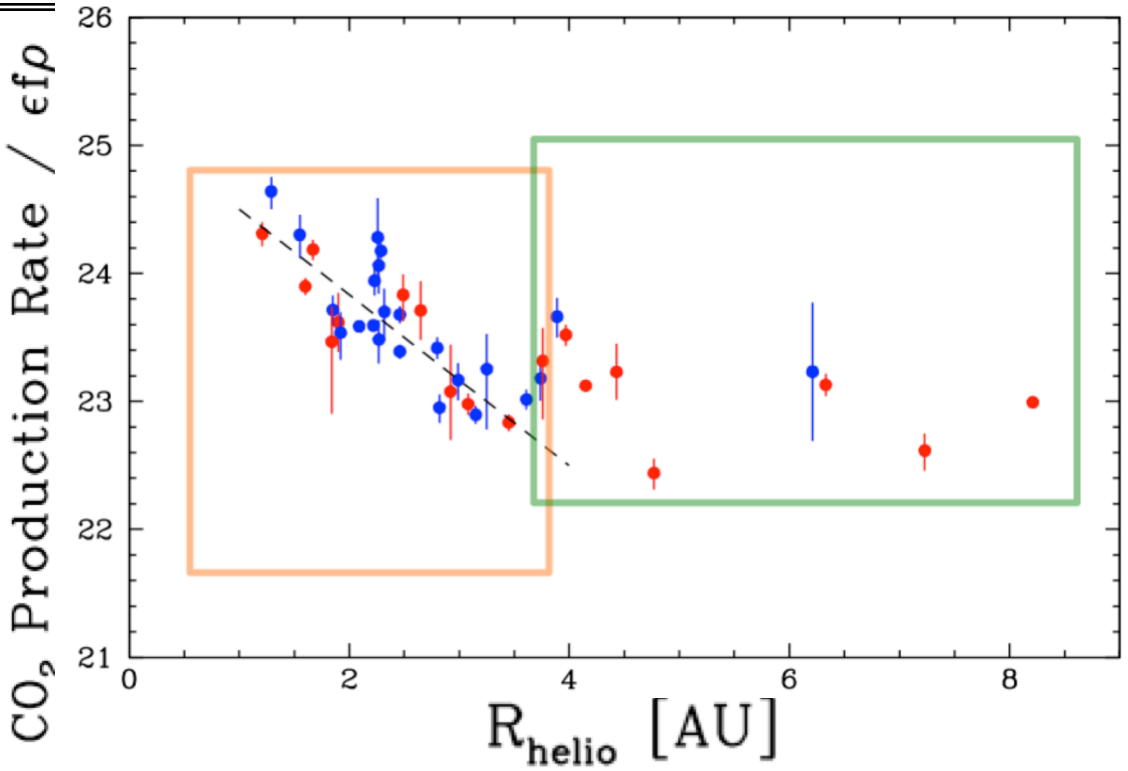
- Automated identification of tail features (green points), lines of unique time emission and lines of constant size particles assuming continuous emission.

- Activity on C/2015 L5 is most consistent with short, strong emission event within a few days of perihelion

- Tail particle sizes: 300 μm- 1 mm.

Properties of NEOWISE-Discovered Comets

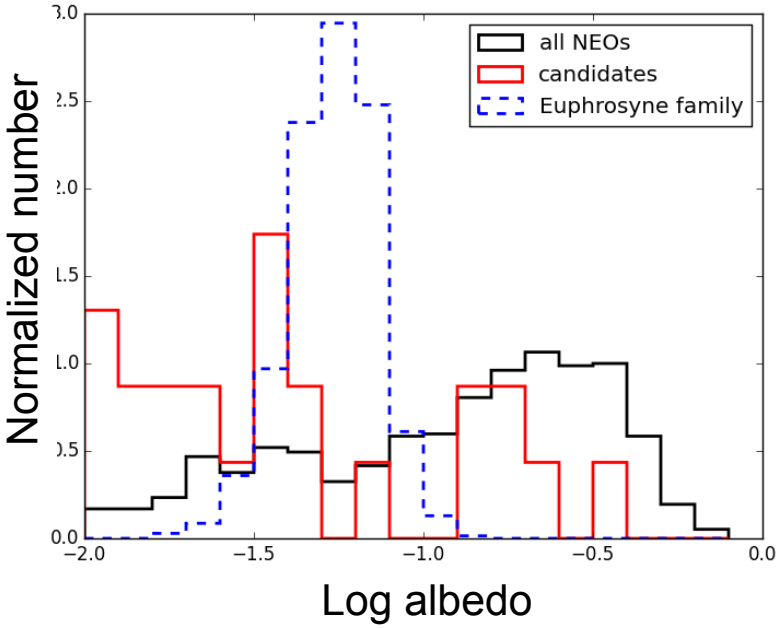
- 4.6 μm channel encompasses CO & CO_2 emission
  - Hard to observe from the ground
- Largest IR sample of comets to date, including long & short period comets
- CO_2 production rate measured for long-period & short-period comets.

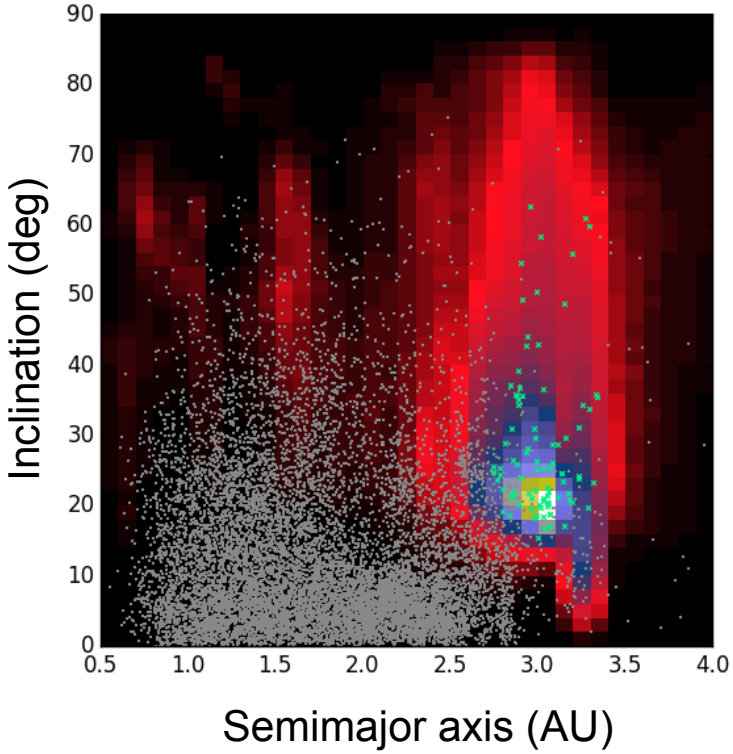


- Activity ~flat >4 AU; increases dramatically when the comets are closer to the Sun, indicating two distinct states of outgassing activity.
- Surprisingly, **no significant difference between the long- and short-period comets**, despite the common assumption that long-period comets are “fresh”!
- Bauer et al. (2015) ApJ accepted

Evolution of Euphrosyne Family Members into NEOs

- Using NEOWISE physical properties, Masiero et al. (2015) tracked the evolution of Euphrosyne family members from the Main Belt into NEO space.
- Family feeds an unusual region of the NEOs, meaning objects there have a high likelihood of having originated in this family: high inclination, dark





Probability density field (background colors) compared to all known NEOs (grey points). Known objects in the high-likelihood region are highlighted in green.

Conclusion

- NEOWISE is discovering & characterizing small bodies
  - Diameters accurate to ±20%, albedos to ±50%
  - Over 15,700 small bodies observed since restart
- Orbital precession will eventually force an end to the mission
- All data from prime mission (2010-2011) released; all data from Restart Year 1 released
- Data access: irsa.ipac.caltech.edu