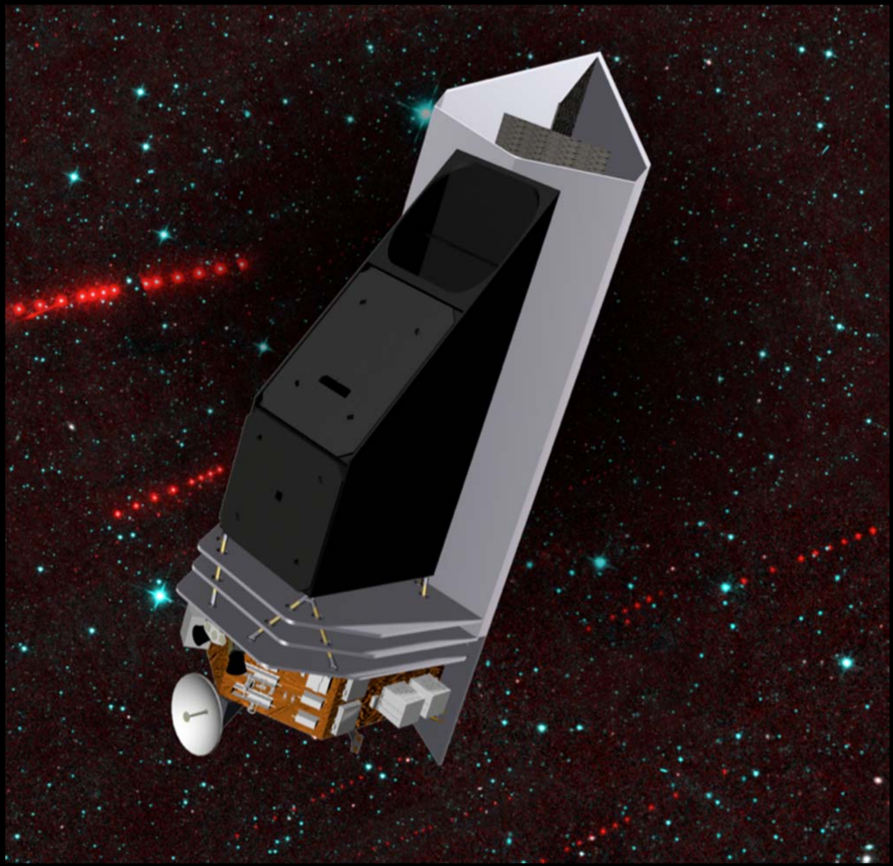
NEOCAM

NEAR-EARTH OBJECT CAMERA

A Comprehensive Survey of the Solar System



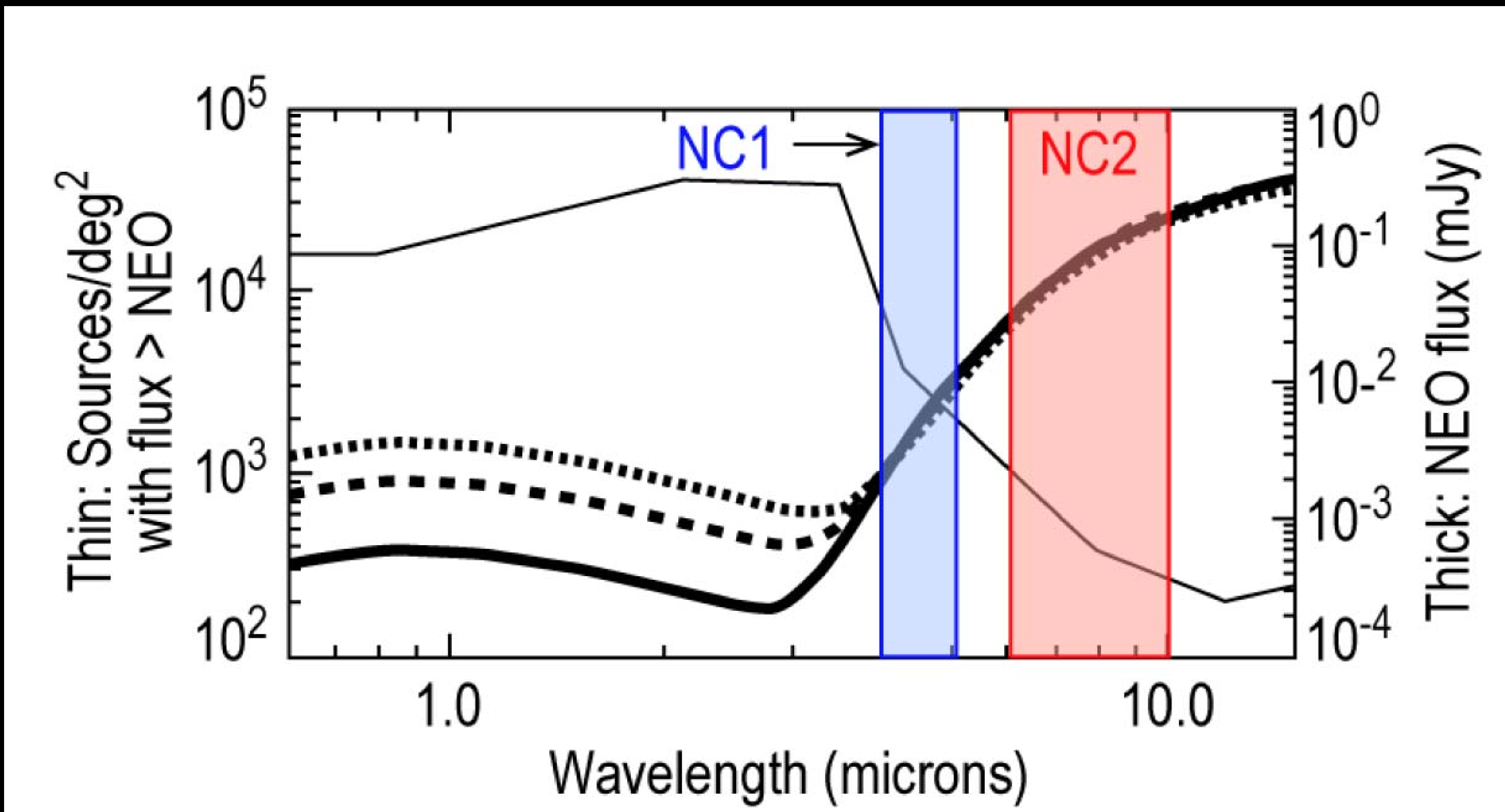
NEOCam is a dual-channel imager operating in a single step-and-stare survey mode.

- 50 cm telescope
- Two 16 megapixel HgCdTe focal planes at 4-5.4 & 6-10 ⌠m simultaneously imaged
- Detectors passively cooled to 40K
- Sun-Earth L1 orbit
- First proposed 2005: Category II
- Awarded technology development funding in 2011 Discovery
- Proposed to 2015 Discovery

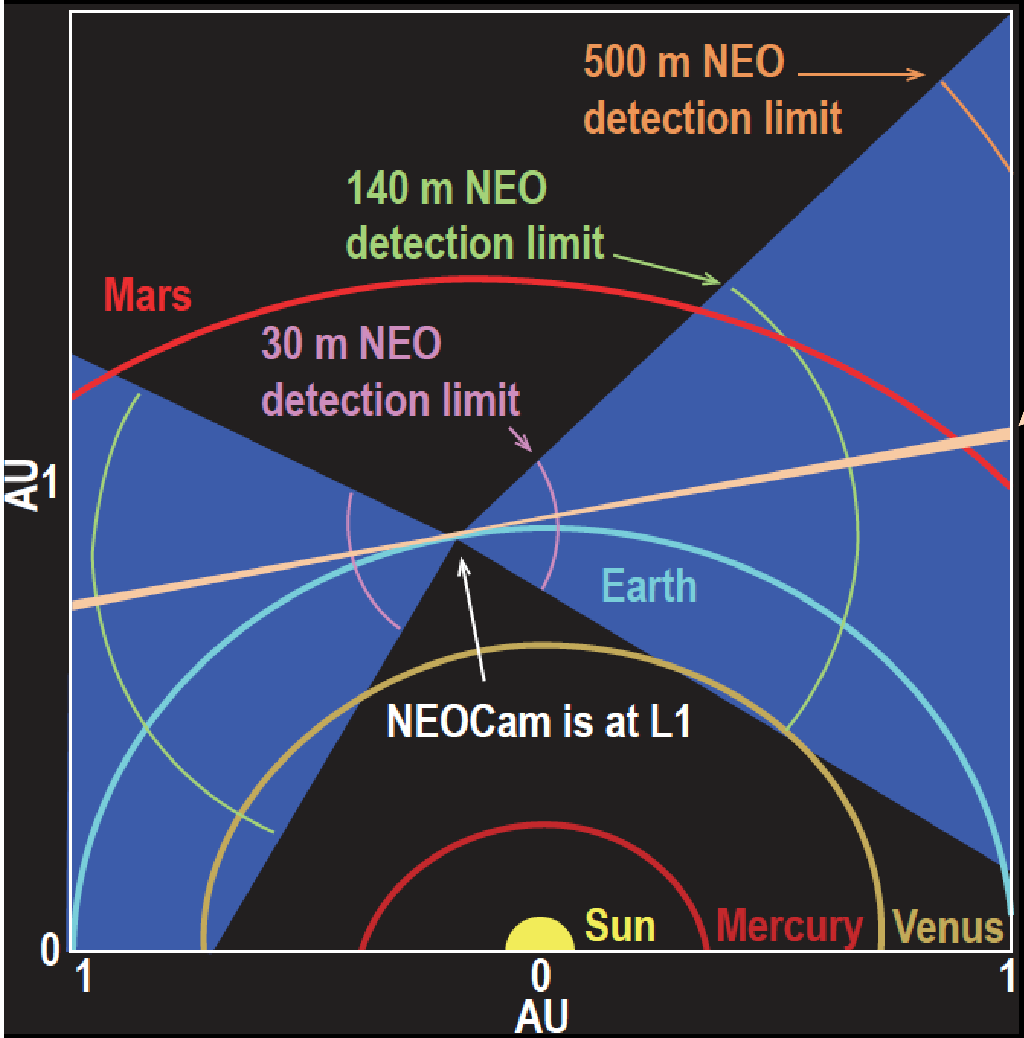
NEOCam Purpose

- NEOCam is an exploration mission designed to find, track, and characterize small bodies throughout our solar system
- It is optimized for NEO search and discovery, leveraging the experience from WISE/NEOWISE
- We expect to discover ~100,000 new NEOs & millions of MBAs, a significant improvement on the number known today

Optimized for NEOs & MBAs



Orbit: Sun-Earth L1 Lagrange Point

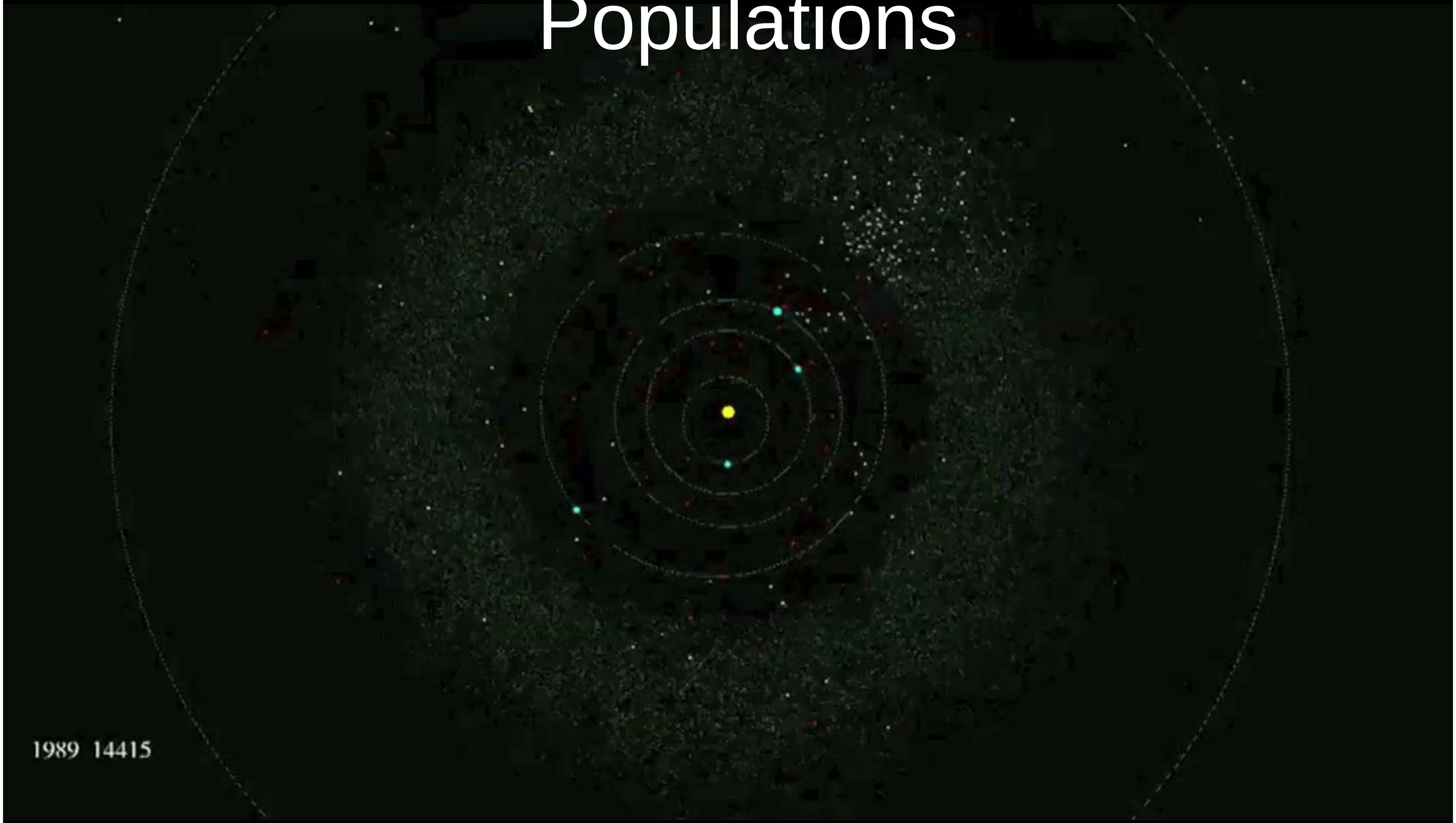


NEOCam Viewing Zones

NEOWISE Viewing Zone

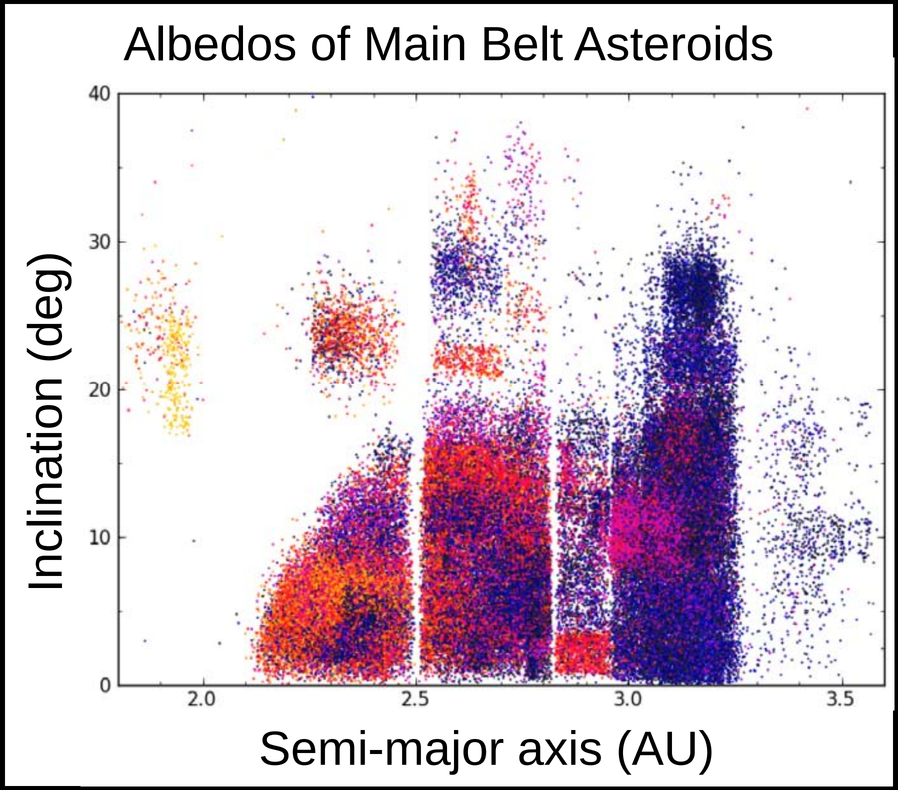
- Close, constant distance from Earth allows full-frame images to be downlinked
- Thermal environment allows passive cooling to 40 K
  - Key enabling technology

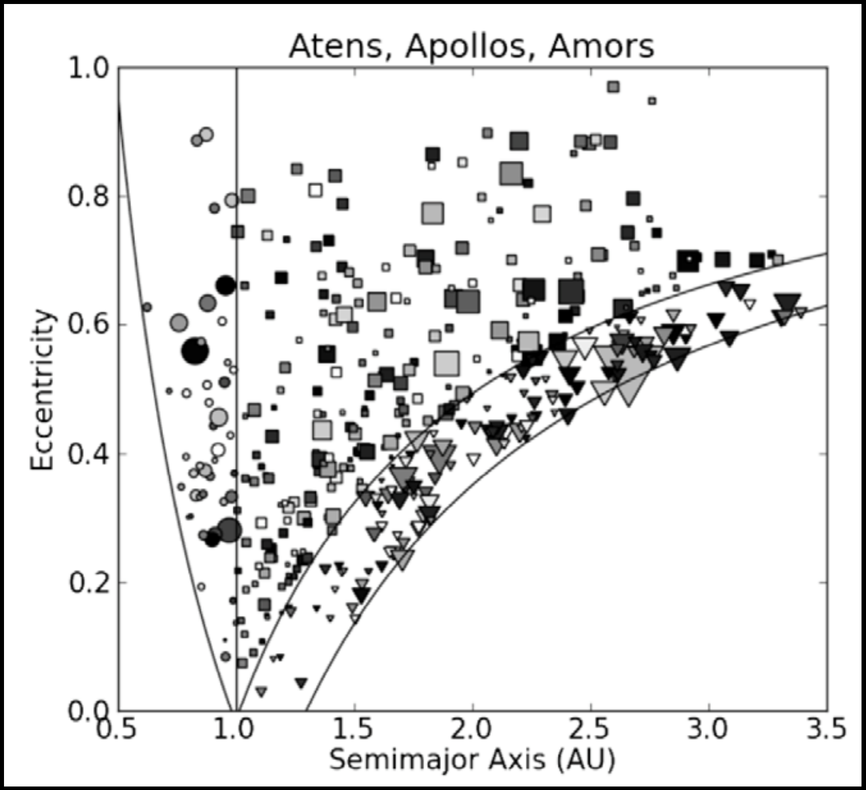
The Value of Studying Populations



Credit: Scott Manley/Armaugh Observatory

Surveys allow comparison of entire populations

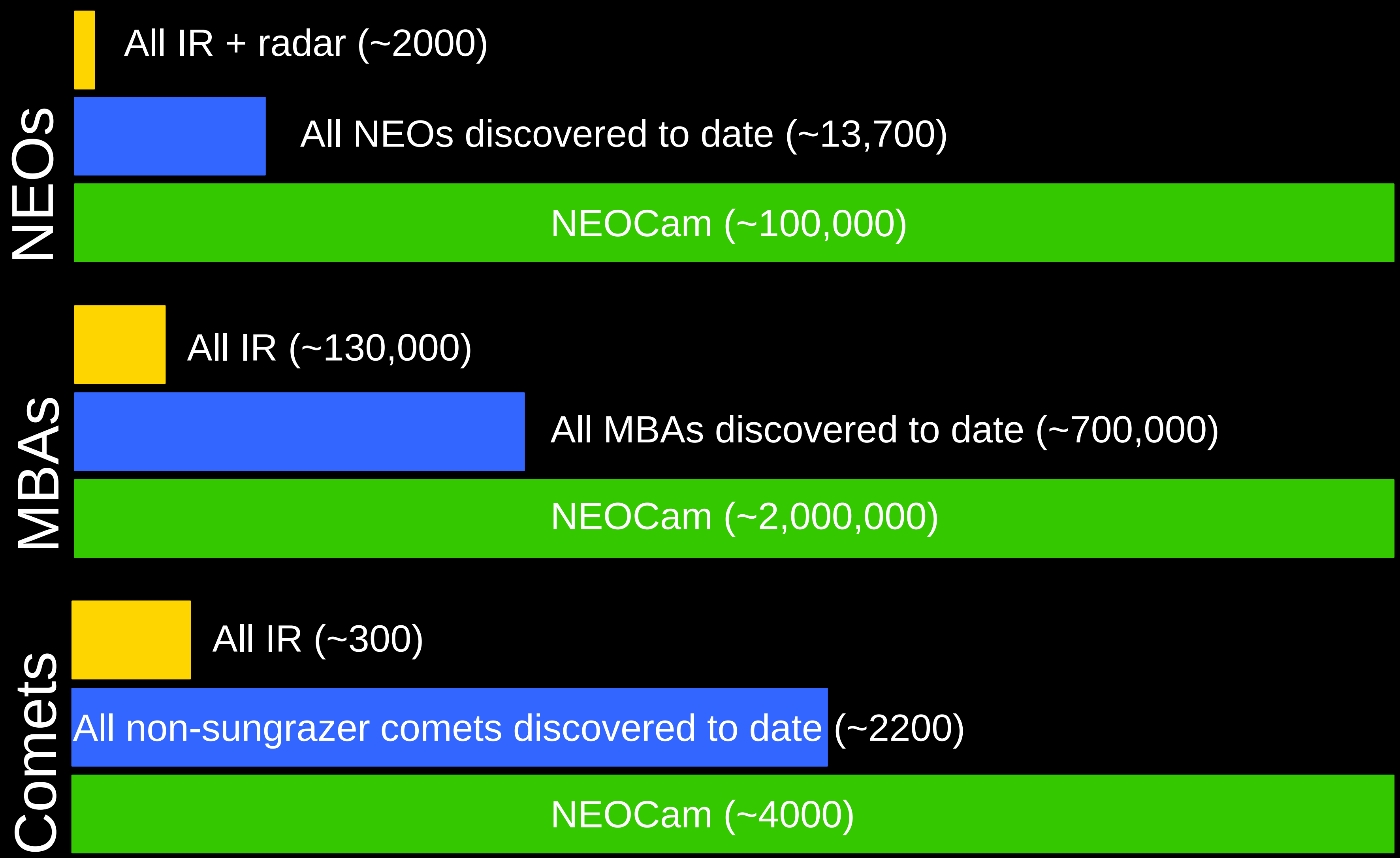




Surveys find the most unusual objects

First known Earth Trojan

NEOCam: A Powerful Method of Characterizing Populations



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
- Structure, Origins, & Evolution of Populations
  - Population studies: numbers, orbital distribution, physical properties of Main Belt Asteroids, Jovian Trojans, comets
  - 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

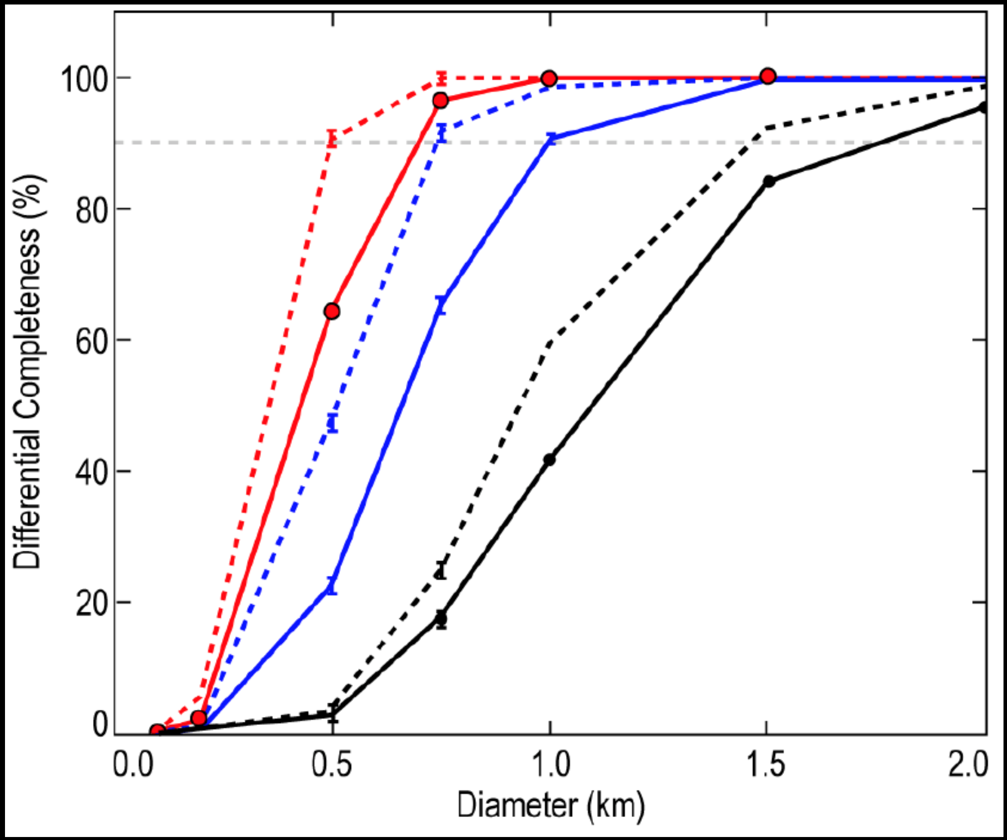
10 NEOCam Science Objectives

- Detect 2/3 of PHAs >140 m within 5 years
- Determine impact probability for
  - NEOs >20 m
  - Comets
- Identify sources of NEOs
- Identify asteroid collisional family members down to 1.5 km throughout asteroid belt
- Map distribution of low albedo material
- Determine sizes & orbital distribution of long & short period comets
- Constrain the population of Earth co-orbitals
- Identify low Δv NEOs

Constraining NEO Origins

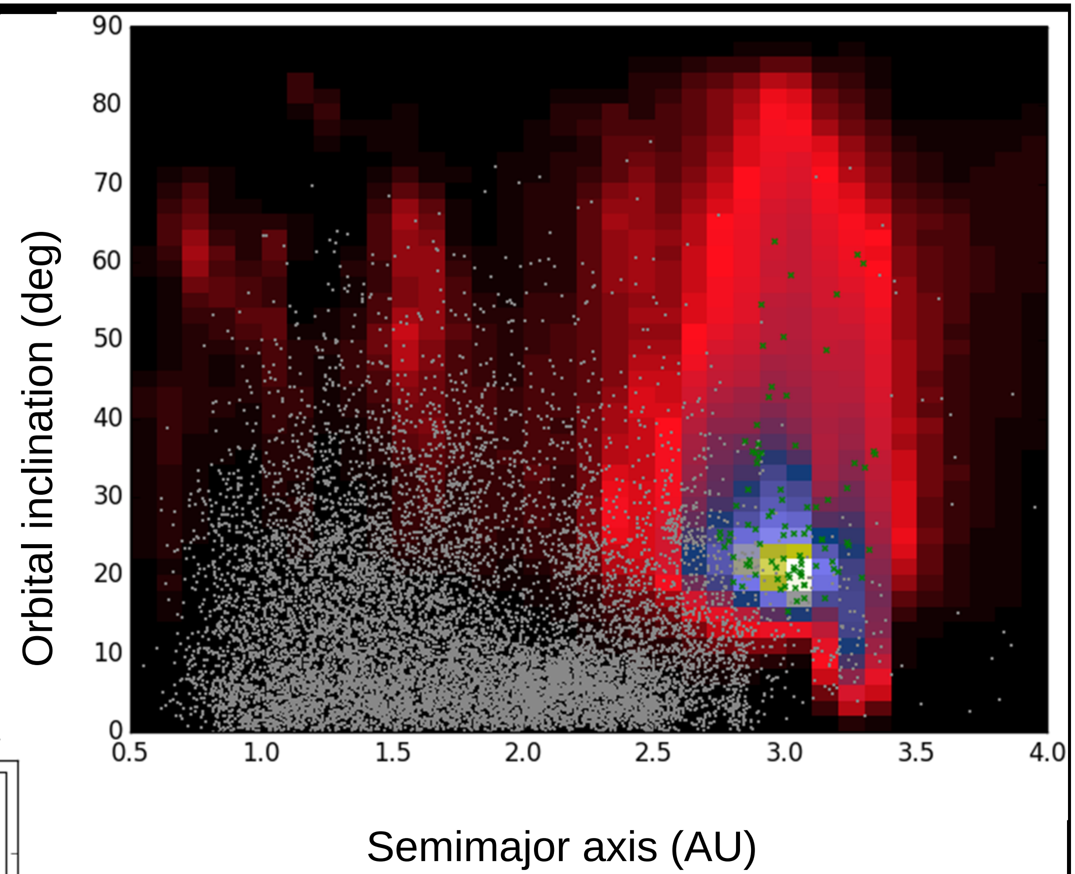
- Combining orbital parameters w/ diameter & albedo allows NEO origins to be probed

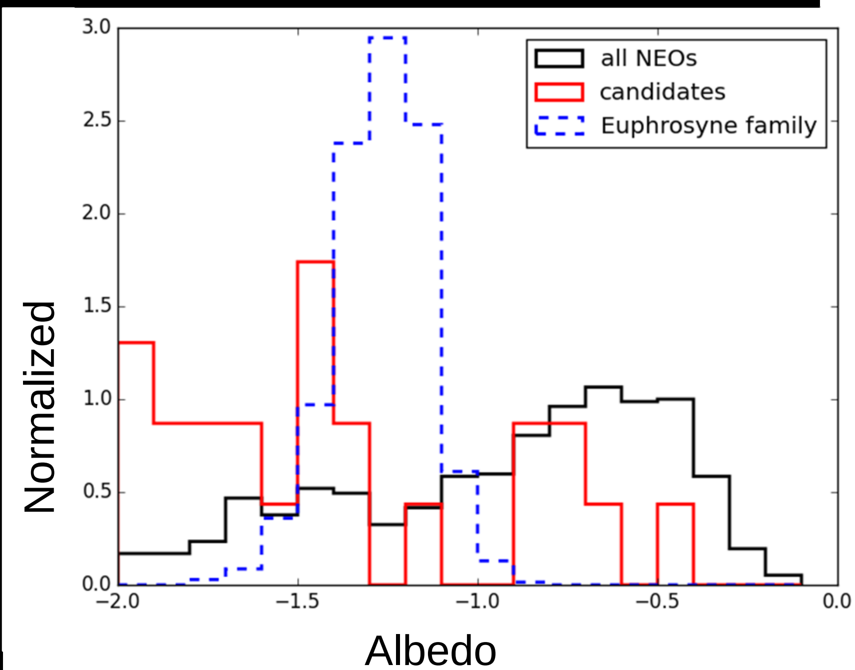
- NEOCam senses MBAs down to similar sizes as large NEOs



Link between Euphrosyne asteroid family & NEOs

- Euphrosyne-linked NEOs (red) have darker albedos than most NEOs (black), & span albedo of known family members (blue)
- Euphrosyne may represent an important source of primitive material to NEOs

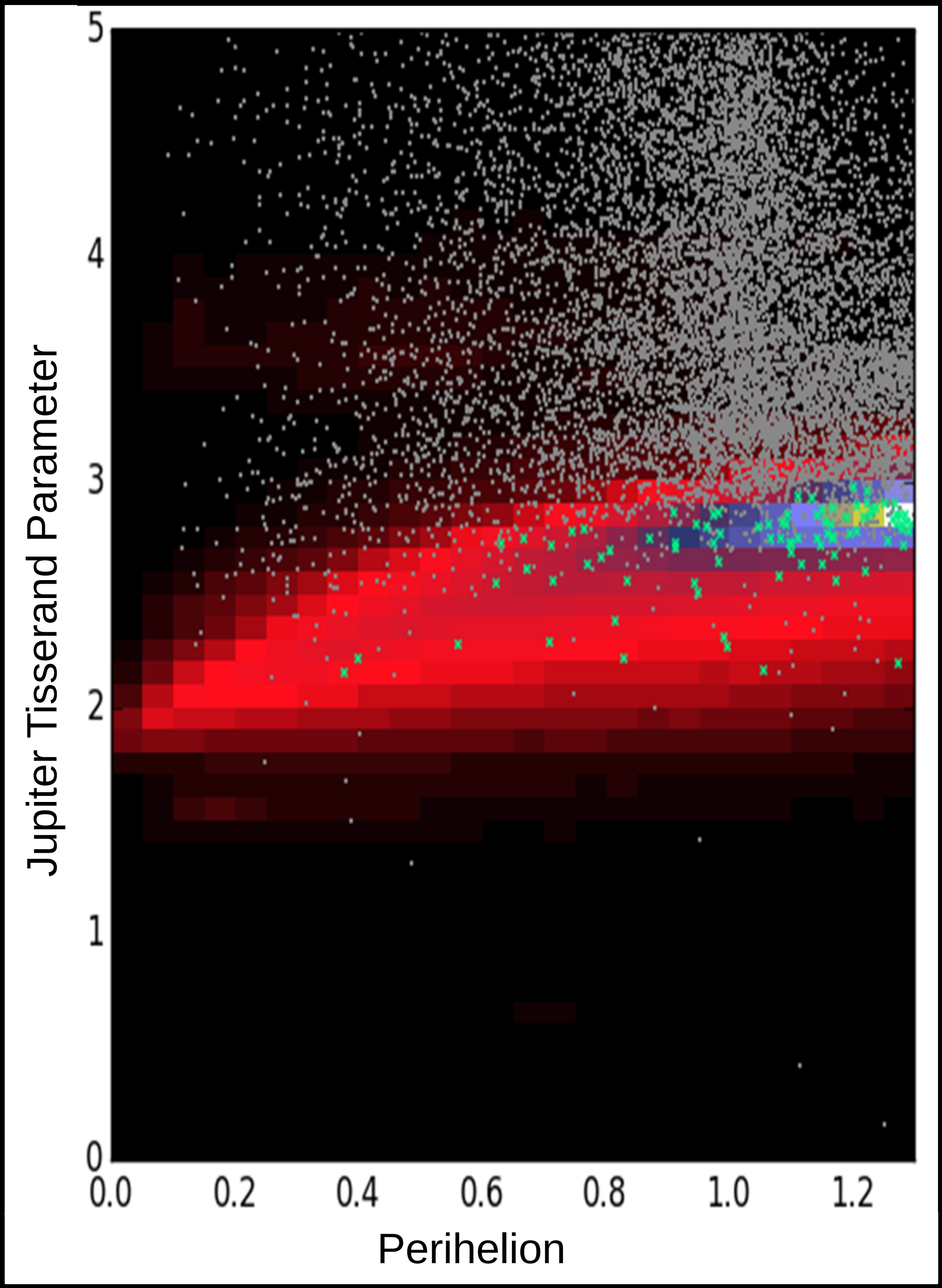




- Simulations show family members evolve onto high-I, high-e NEO orbits (background heatmap)
- Most known NEOs populate different region (grey points)
- Only 1% of NEOs in Euphrosyne-linked region (green points)

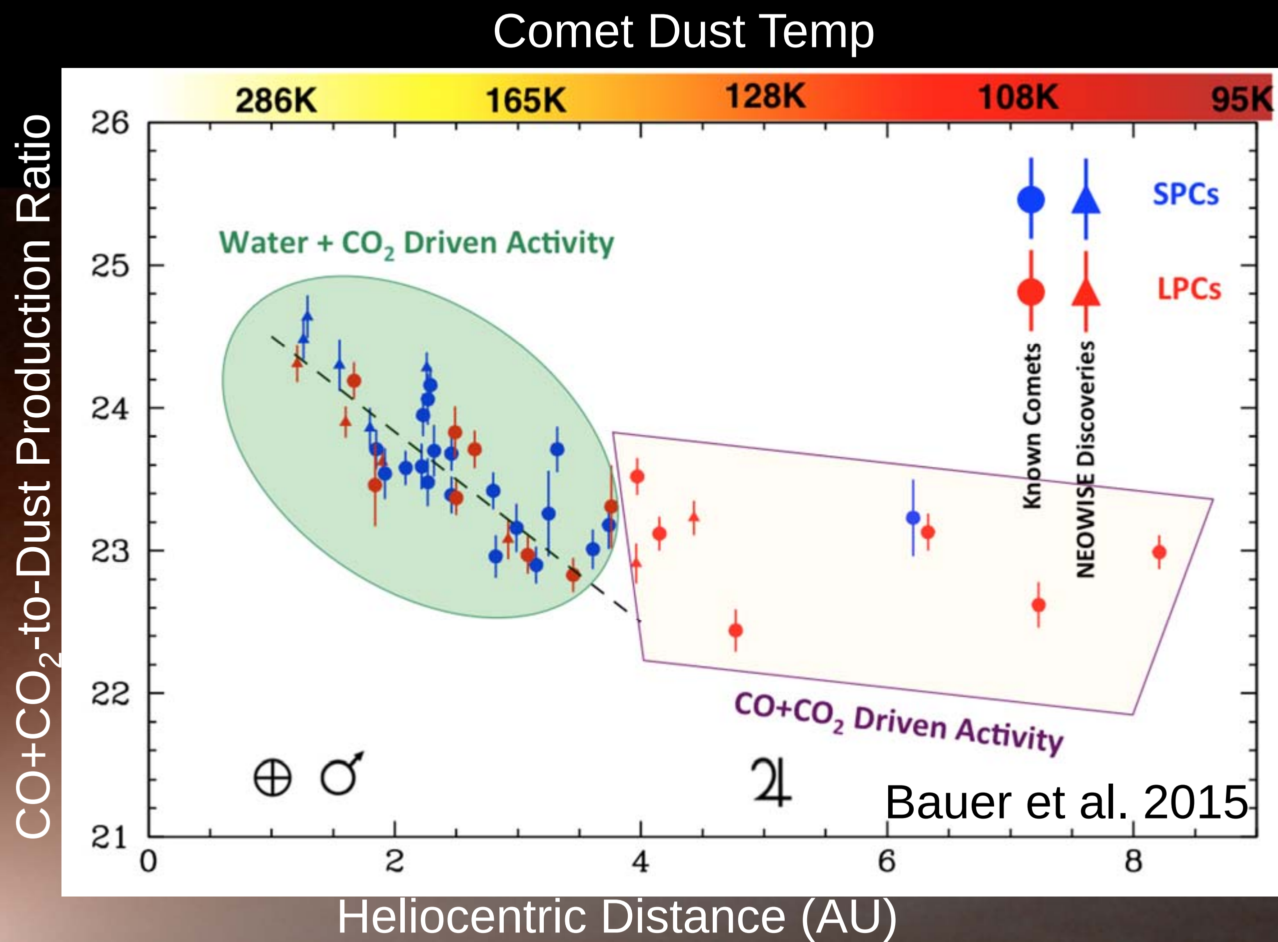
Link between Euphrosyne asteroid family & the NEOs

- Family members evolve onto orbits also similar to Jupiter Family Comets (e.g. T_J<3)
- Albedos of family members complete to ~6 km, while NEOs found in evolved region are 0.5-3 km in diameter.
- Complete survey of family to ~1.5 km will allow direct comparison of small family members to observed NEOs to confirm connection
- Albedos & diameters of JFCs will allow for distinction between objects that are extinct comets & objects that originated in (presumed) volatile-poor Euphrosyne family



Comet Volatile Abundances

- NC1 is centered on CO & CO_2 bands near 4 um
- Obtain $CO+CO_2$ ratios for many more objects than we can now, allowing us to break populations down by orbital parameters

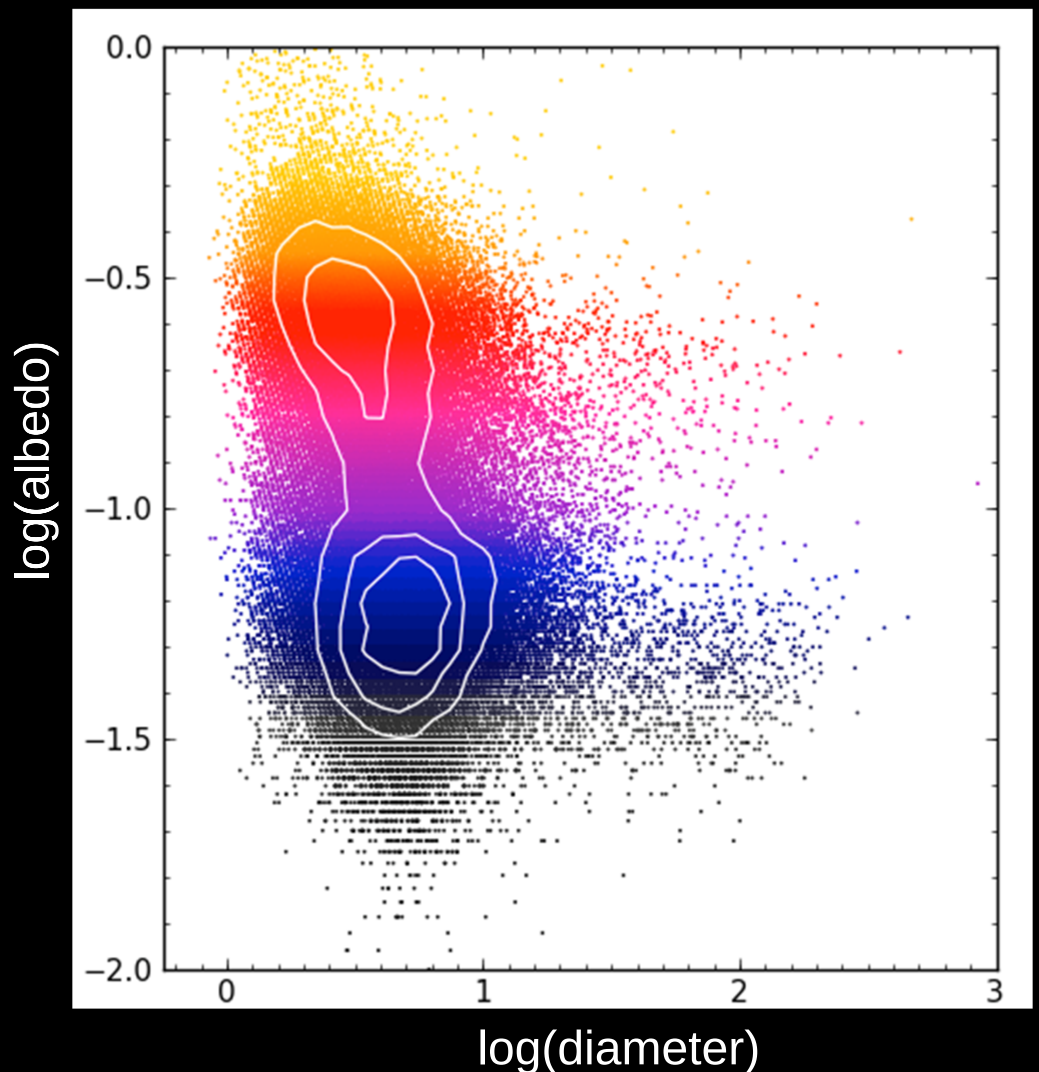


NEOWISE (prime):

- Short-period comets = 24
- Long-period comets = 12

NEOCam = ~700

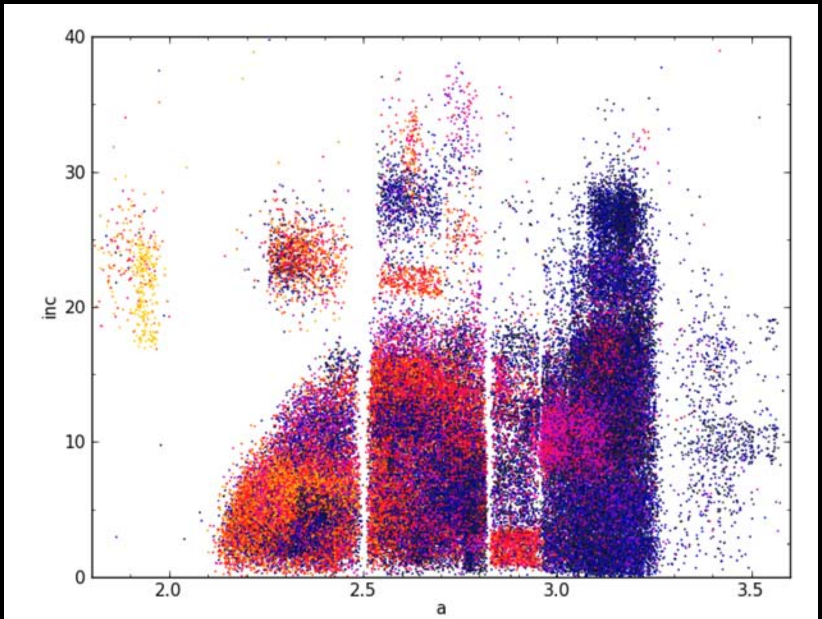
Census of Primitive Material in Inner Solar System



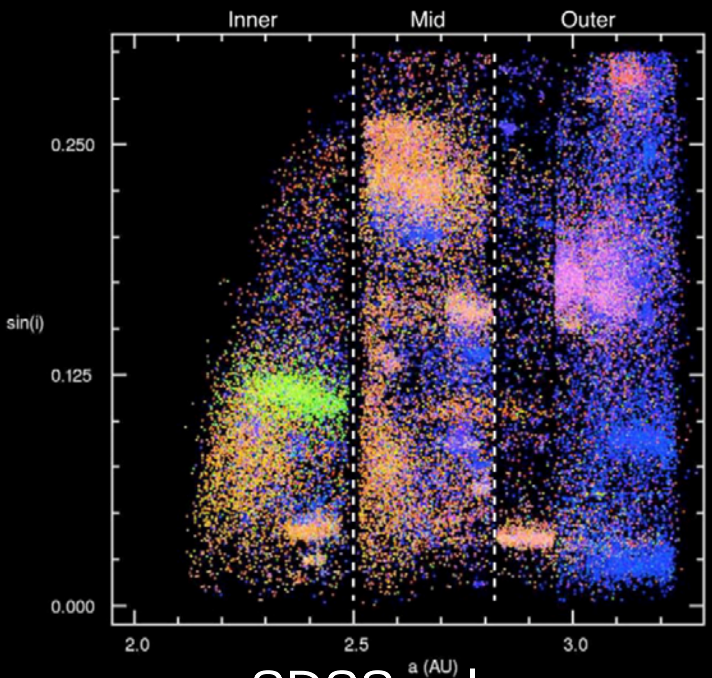
- Low albedo asteroids make up vast majority of Main Belt
- Composition includes
  - carbon,
  - hydrated silicates
  - sometimes water & volatiles (e.g. Themis, Ceres)
- Low albedo MBAs are key source of low albedo NEOs
  - May have delivered organics & volatiles to early Earth
- NEOCam: map low albedo component of inner solar system to sizes an order of magnitude smaller than NEOWISE

Synergy with LSST

- NEOCam & LSST together will provide a movie of the sky from near-UV through thermal IR wavelengths
- LSST adds colors & samples a complementary part of orbital element phase space from NEOCam

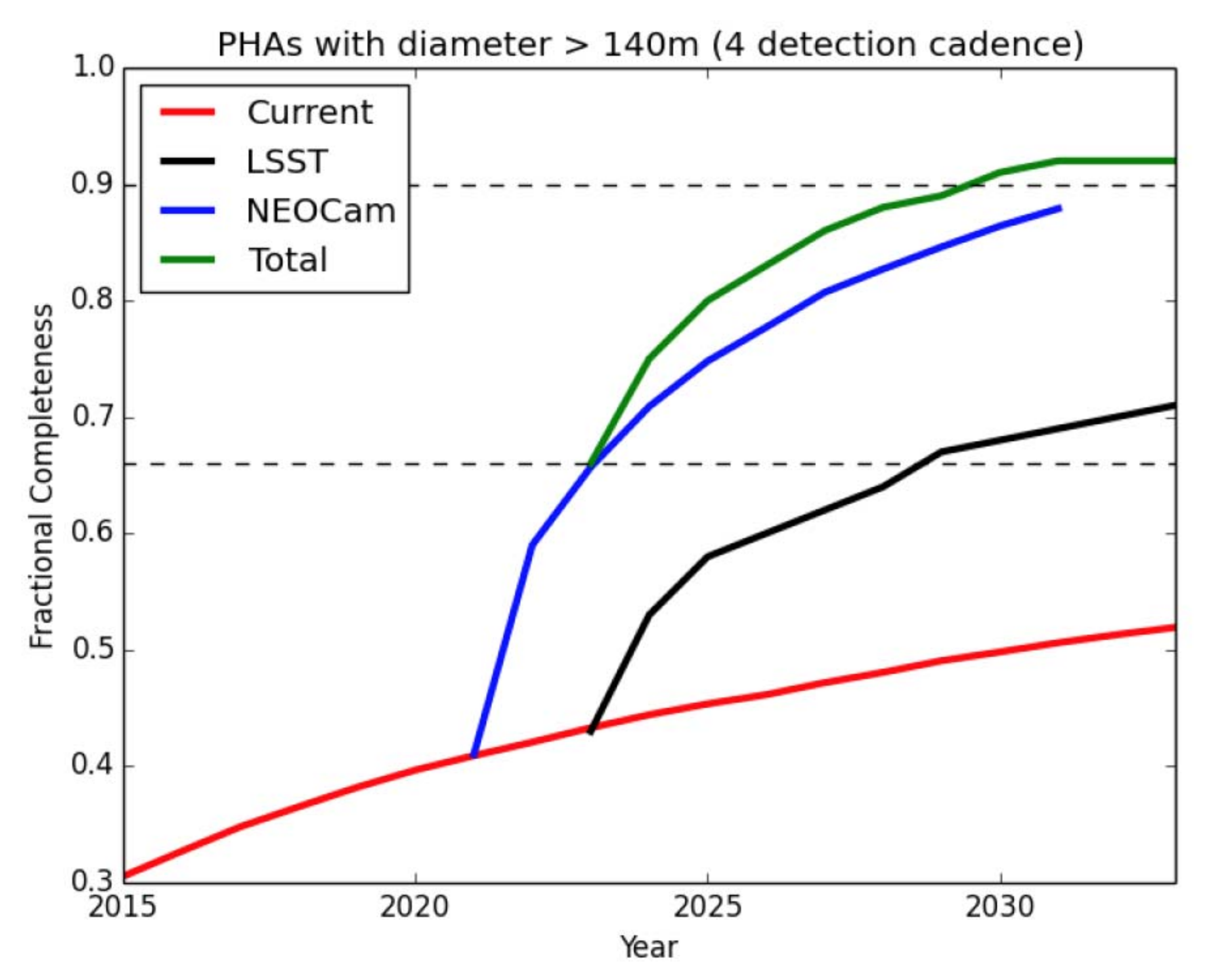


Albedos
Masiero et al. 2011



SDSS colors
Parker et al. 2008

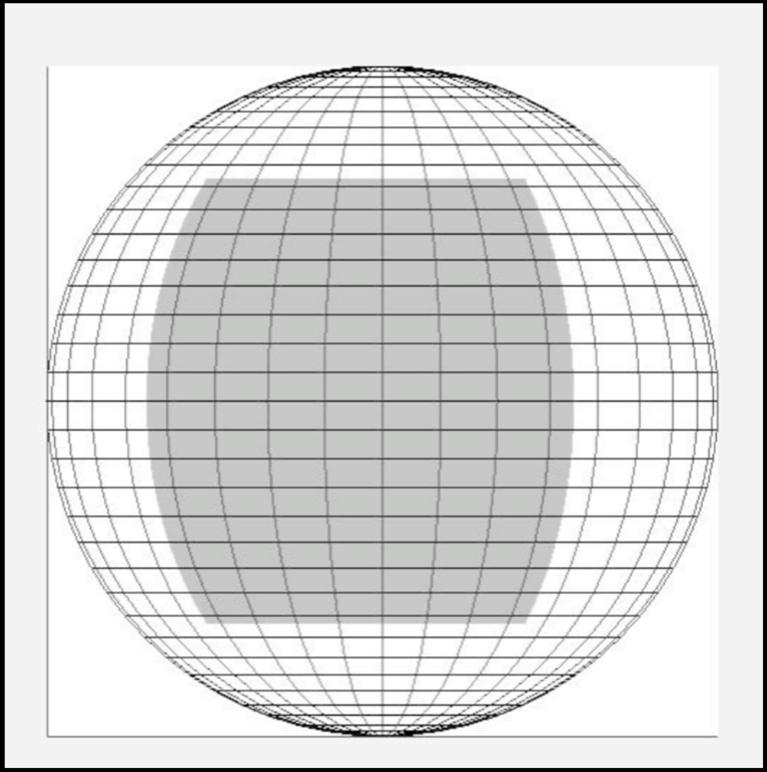
Potentially Hazardous NEAs >140 m

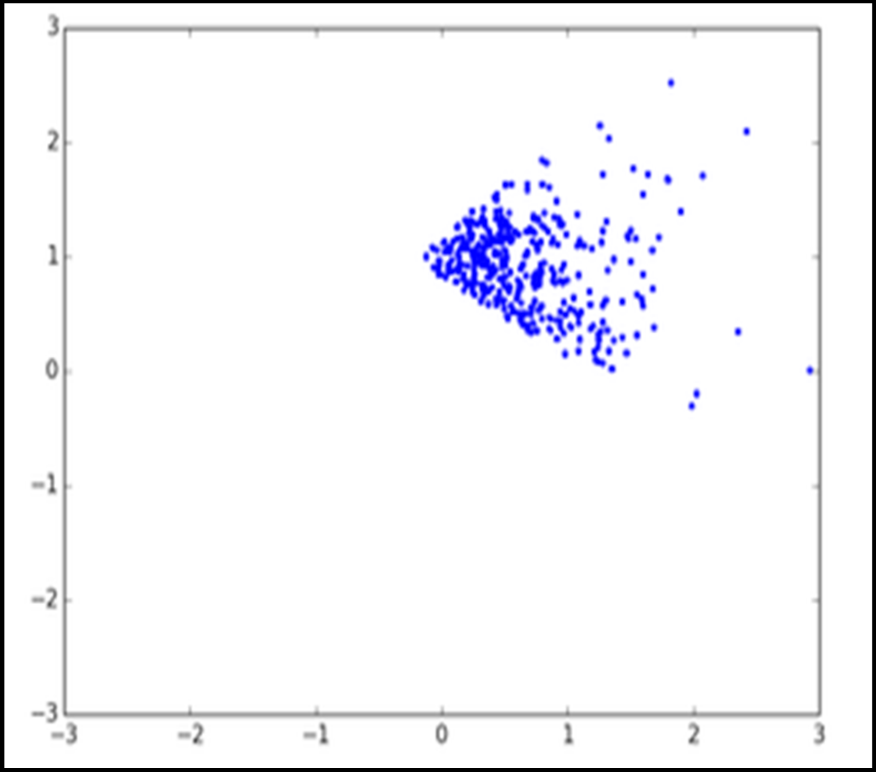


- The current surveys will take decades to find >90% of PHAs larger than 140 m, effectively relegating the task to another generation
- NEOCam is designed to find >2/3 of PHAs larger than 140 m in 5 years, and a total of ~100,000 NEOs of all sizes

Cadence

- NEOCam's cadence is optimized for NEO discovery
  - Designed for self follow up: no other observatories required to track asteroids
  - Target of Opportunity mode is supported



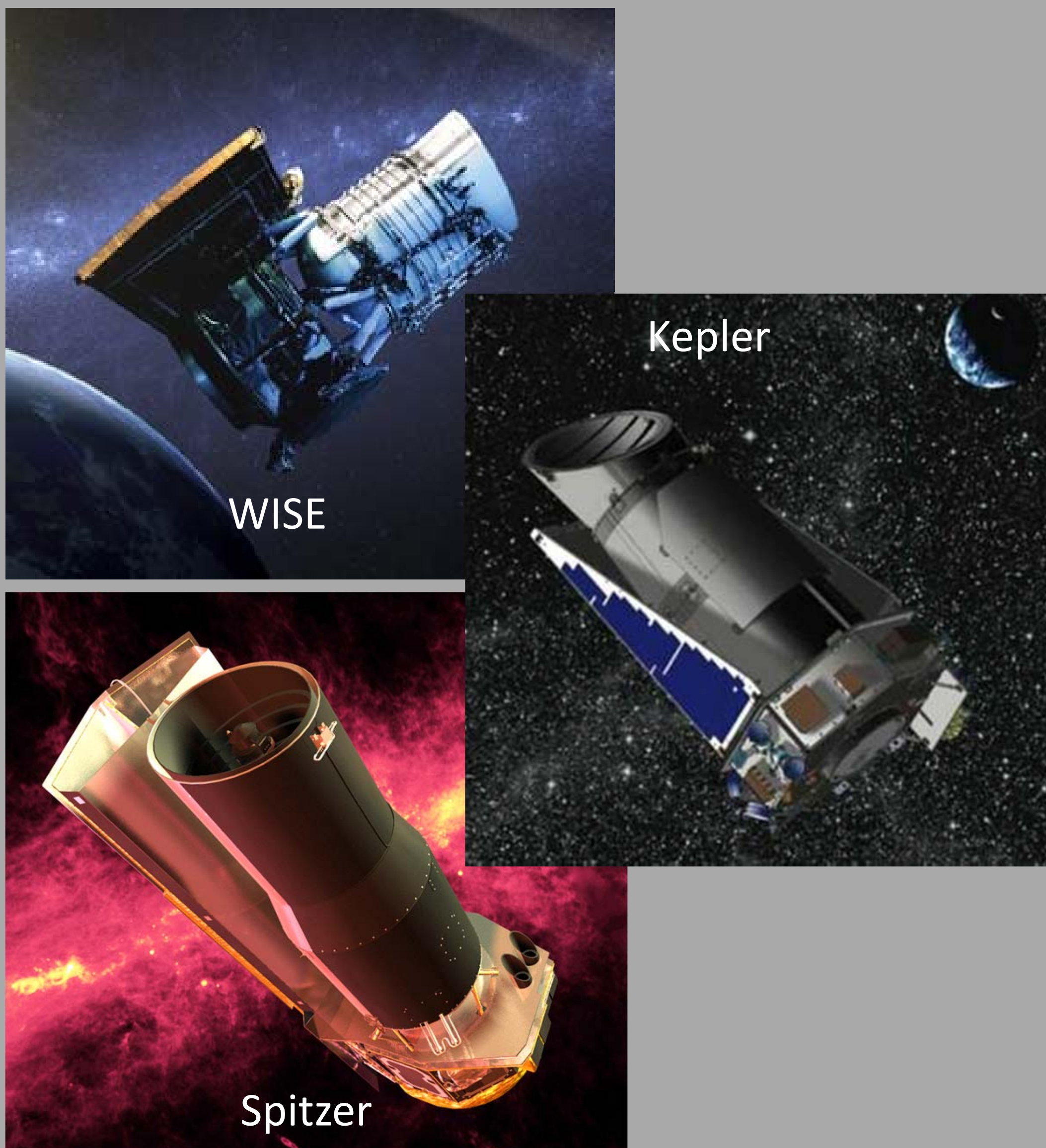


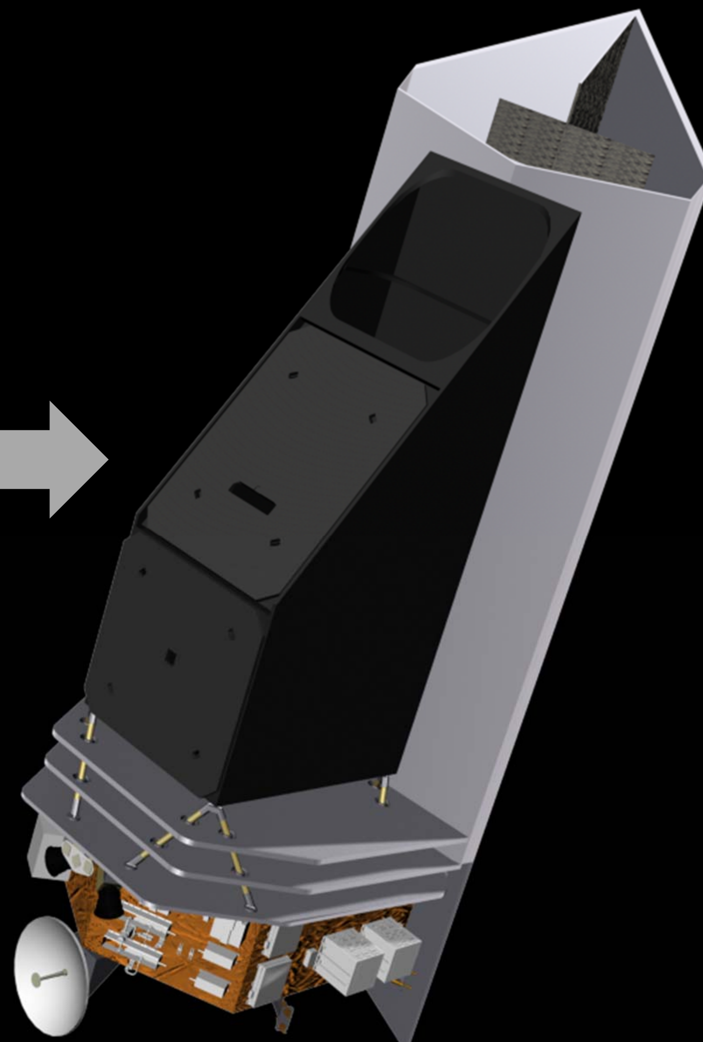
Data Access

- NEOCam returns science data quickly and constantly

Product	Frequency	Access Via
Moving object positions, times	Daily	MPC, IRSA
Images + source databases	2x per year	IRSA
Physical properties	2x per year	PDS, IRSA
Static sky image atlas	1x per year	IRSA

NEOCam Team Heritage





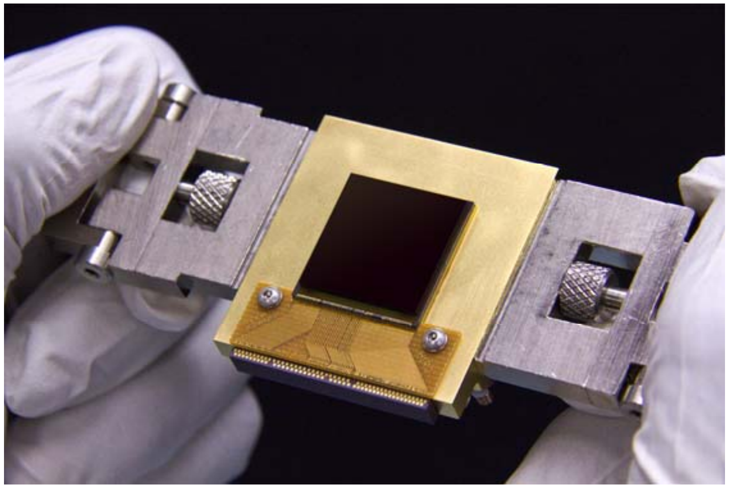
Conclusion

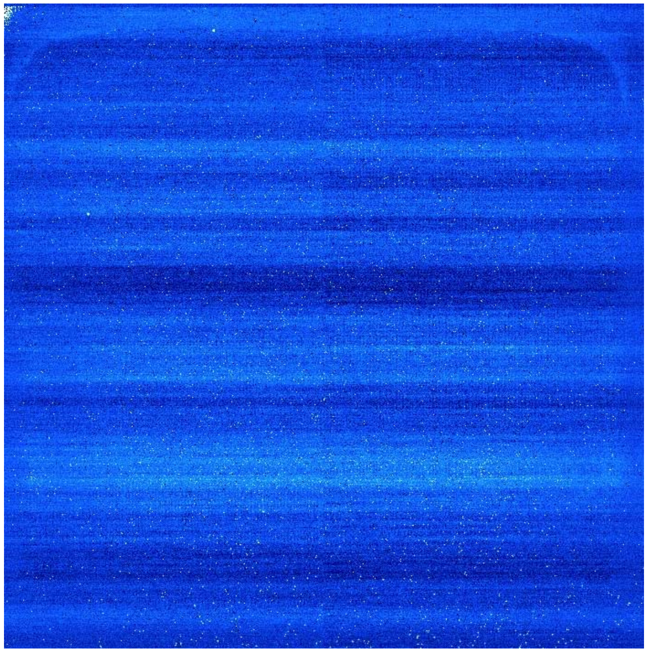
- NEOCam will become the world's premier survey for asteroids & comets, leaving a legacy for posterity

Detector Technology

- 2012: New detector arrays fabricated
  - All exceed NEOCam requirements

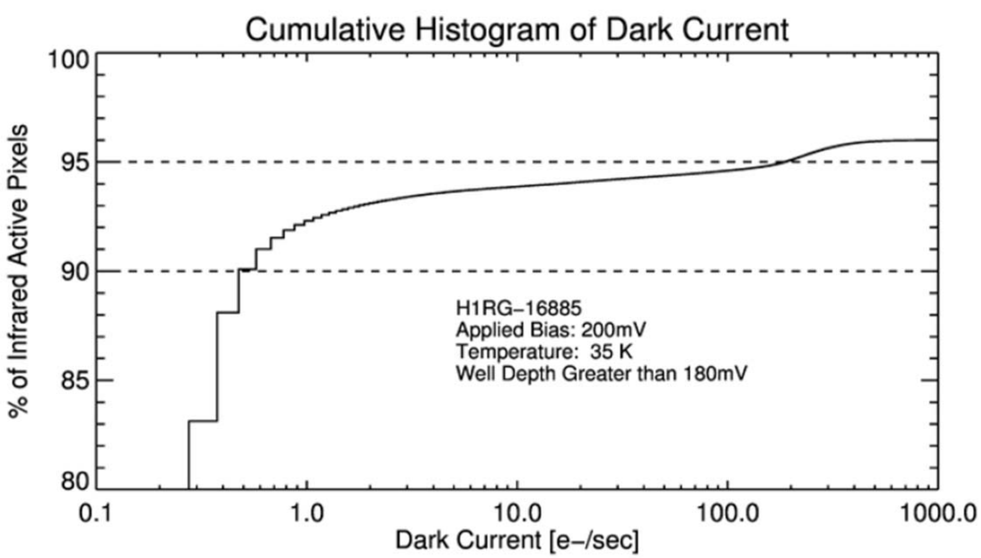
- 4 goals for NEOCam detector development:
  - Increase cutoff wavelength to ~10 μm: DONE
  - Increase % pixels meeting dark current spec to >=90%: DONE
  - Increase operability (well depth): DONE
  - Increase format from 512x512 to 1024x1024 pixels: DONE





Results

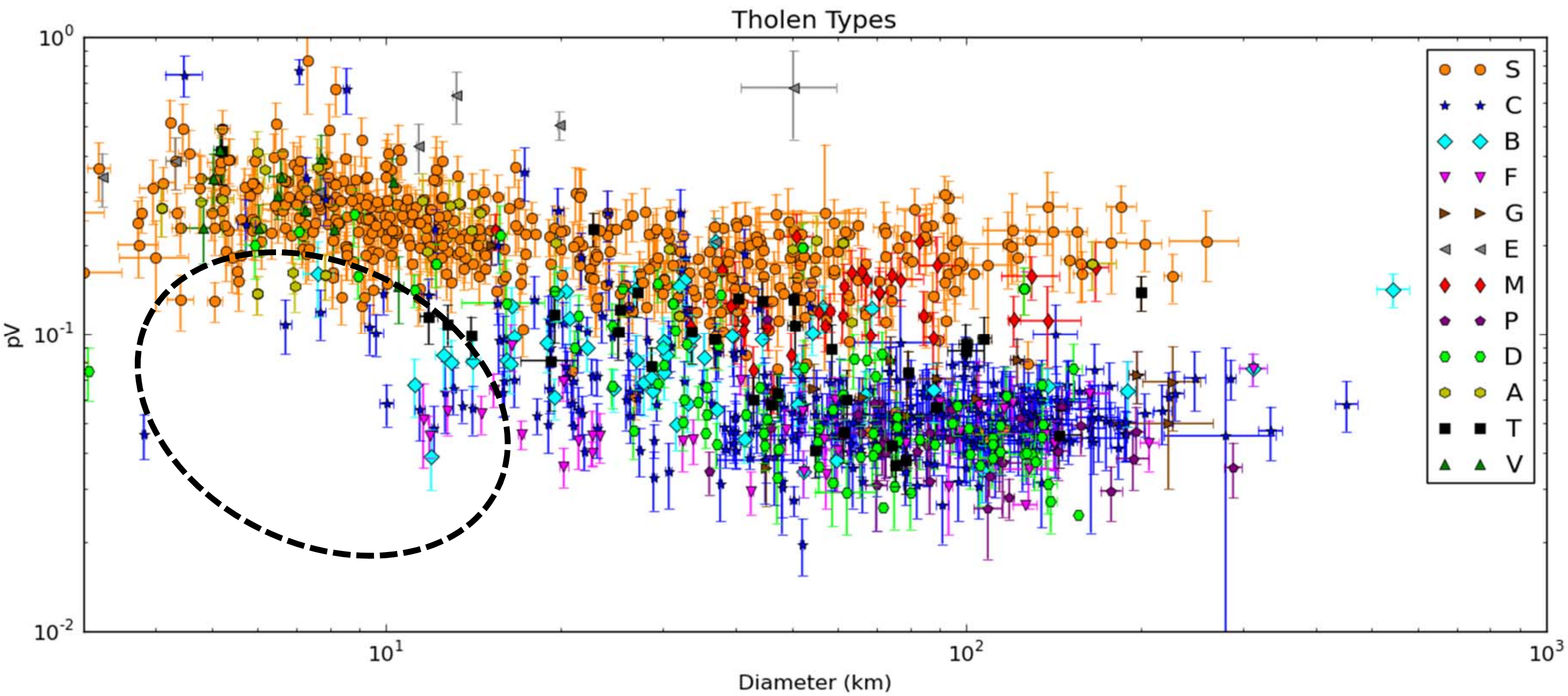
- Operability (defined as % pixels meeting well depth & dark current reqmts) >95% on all three arrays
- Cutoff wavelengths >10 μm for all three arrays
- McMurtry et al. 2013 Journal of Optical Engineering



Radiation test w/ 63 MeV protons

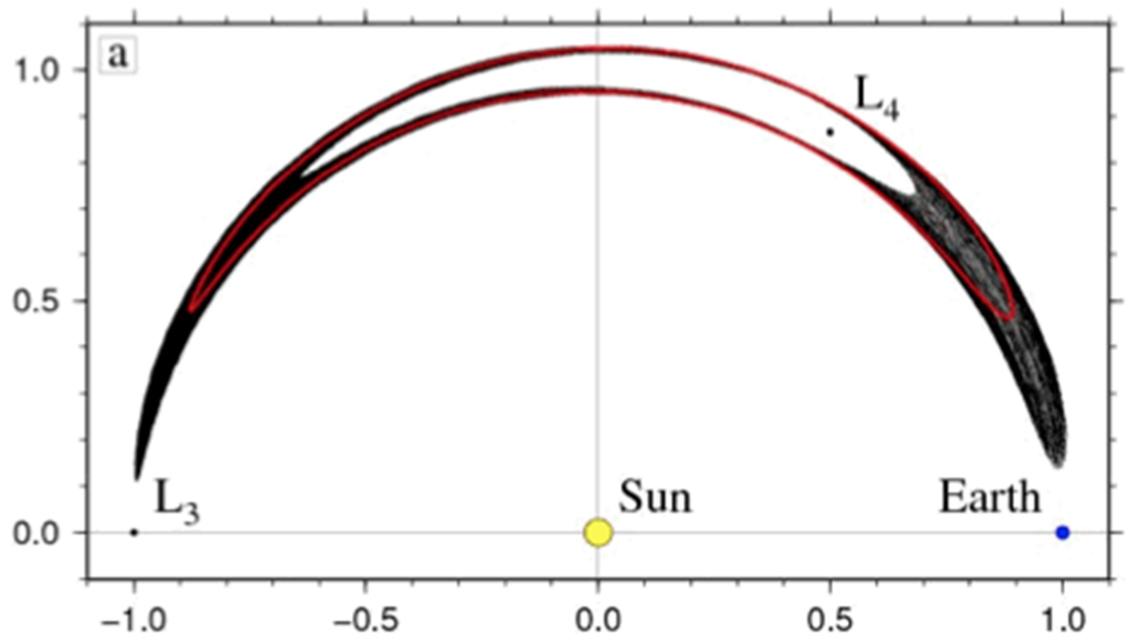
Taxonomy of Asteroids

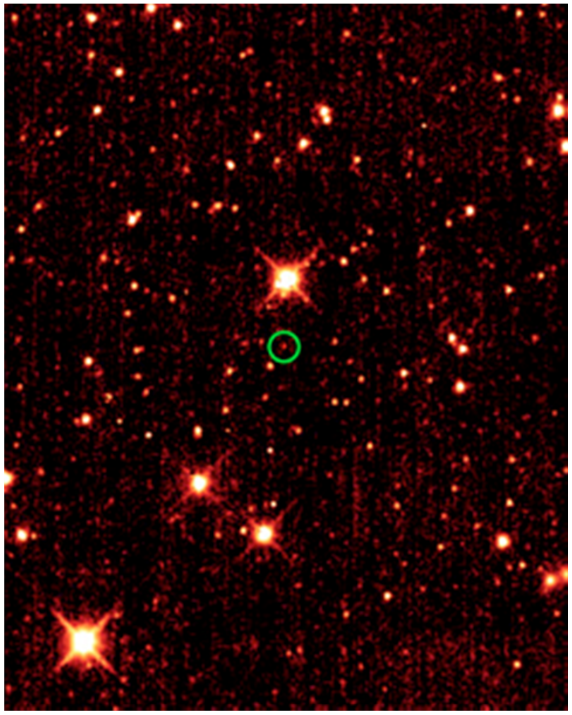
- Compare size and albedo to visible/near-infrared spectra from literature
- Two major taxonomic groupings:
  - S or "stony", C or "carbonaceous"
- Noticeable overrepresentation of S types
- Strong observational bias in visible surveys against small, low albedo objects
- Mainzer et al. 2011 ApJ 741, 90



Earth Co-orbitals

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

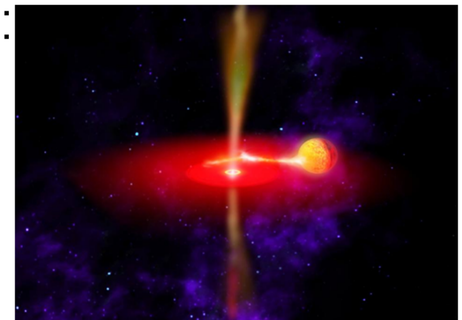


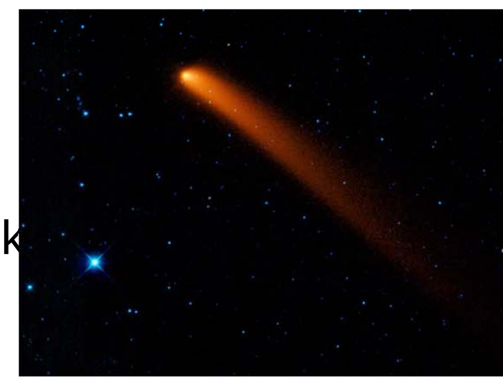


NEOWISE Data Use

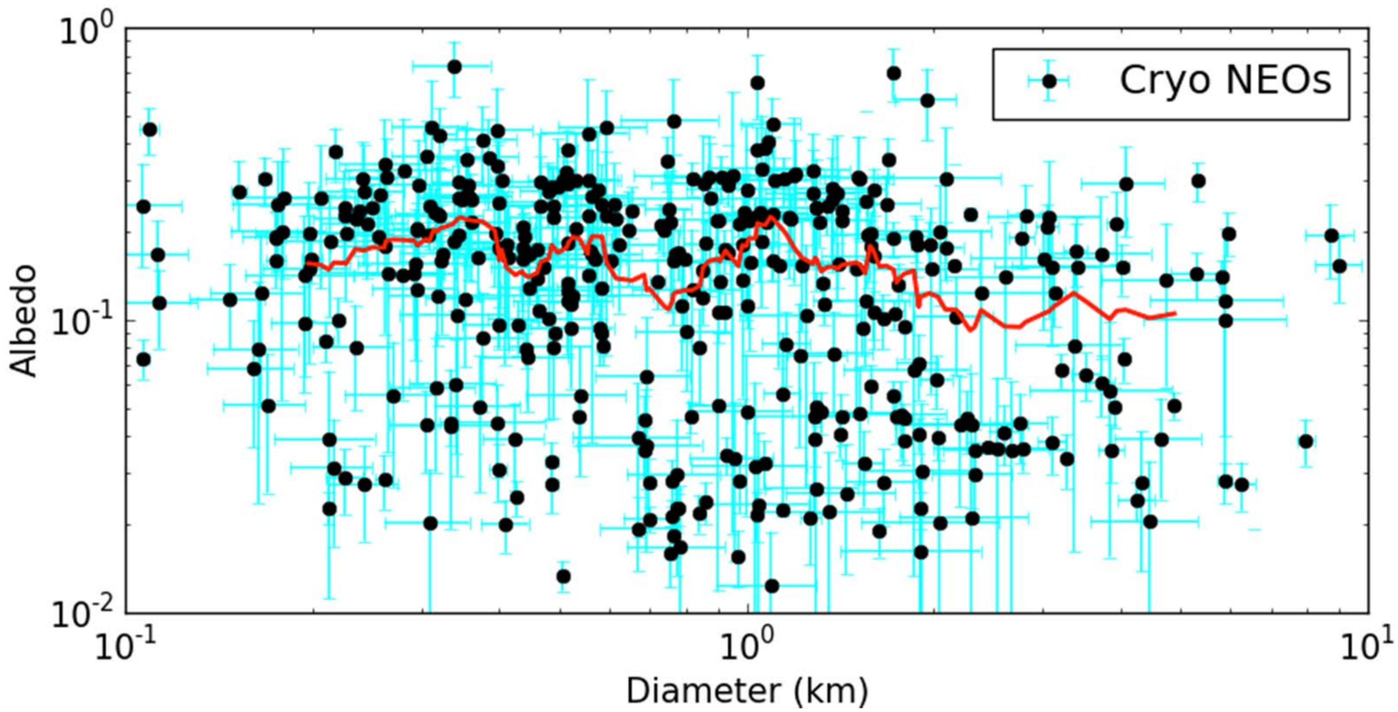
- Total citation count using NEOWISE data & discoveries up to ~100 refereed publications
  - Total citation count for WISE >600 refereed publications

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





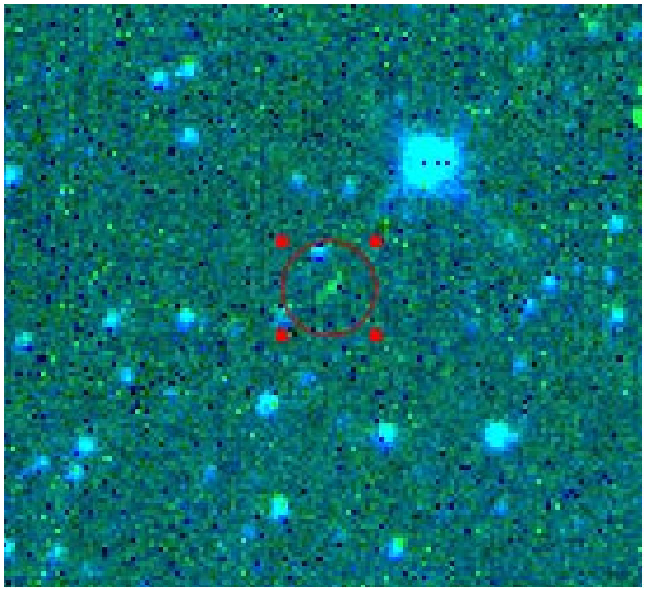
NEO Albedo vs. Diameter

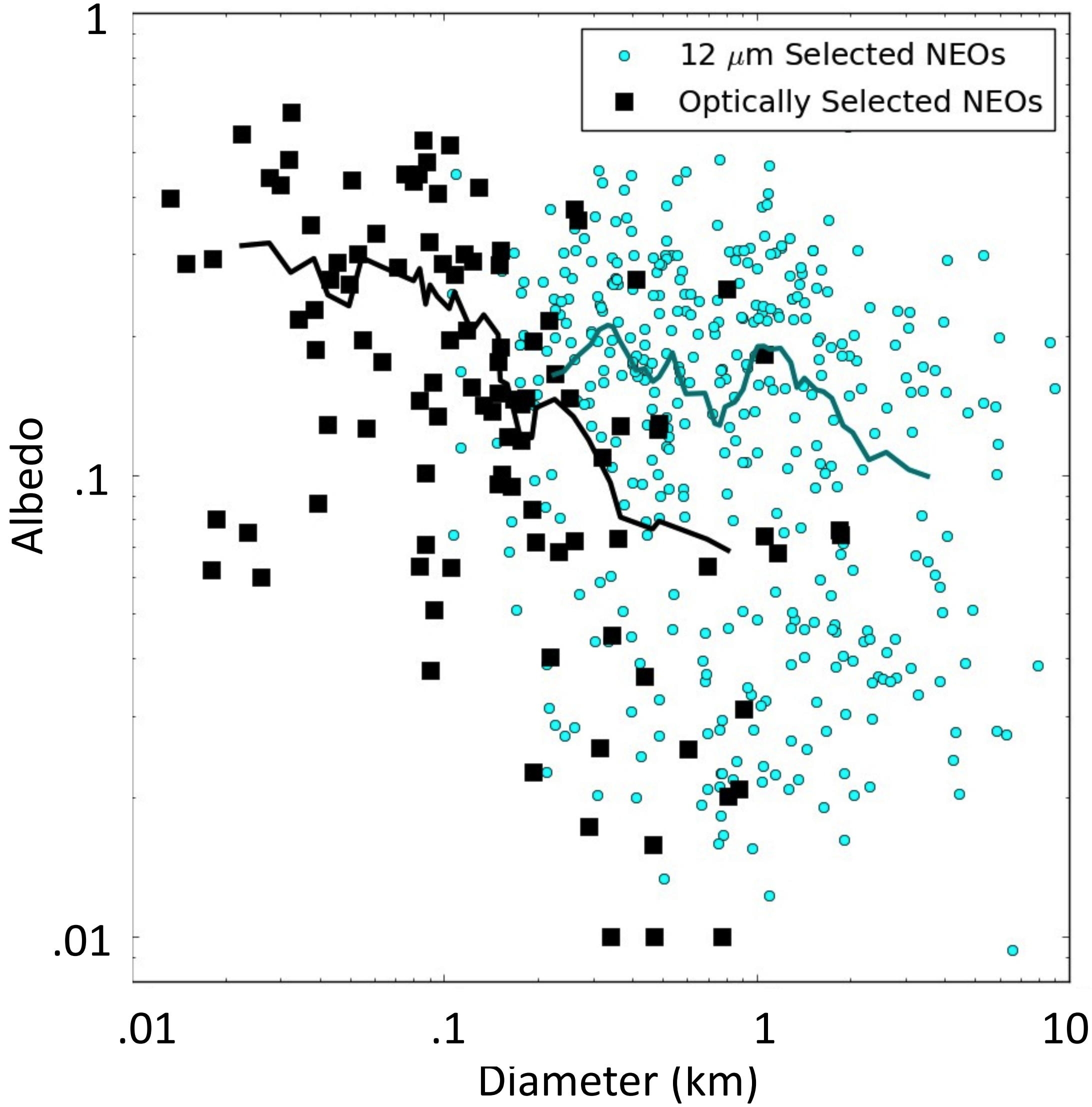


- ~430 NEOs
- No significant change in albedo vs. diameter
  - Albedo is constant all the way down to small sizes
- Contrary to previous studies that are biased against small, low albedo objects

NEOWISE Detections of Small NEOs

- Smallest NEOs detected by NEOWISE are 8m in diameter





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