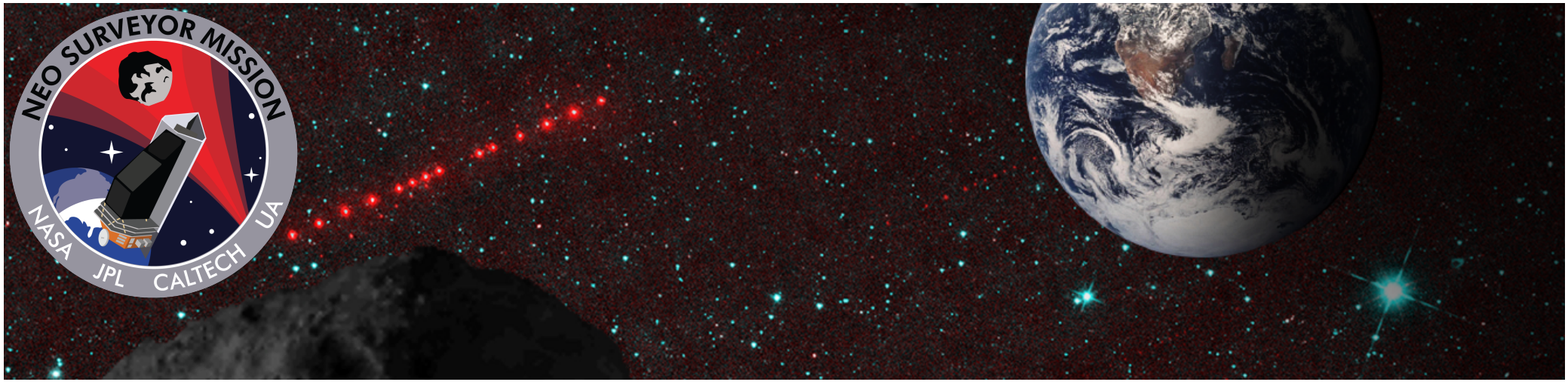


NEO Detection and The Future of Planetary Defense

NEO Surveyor Investigation Team

JPL · Ball · Space Dynamics Laboratory, Utah State University · ipac · Teledyne Scientific & Imaging, Everywhereyoulook™ · University of Rochester

NEOs: The Critical Questions

- **Need to know when impacts could occur and how bad they will be**
  - "If you can't measure it, you can't manage it, and you can't fix it." –Michael Bloomberg

- **When: Comes from finding objects & determining good orbits for them**

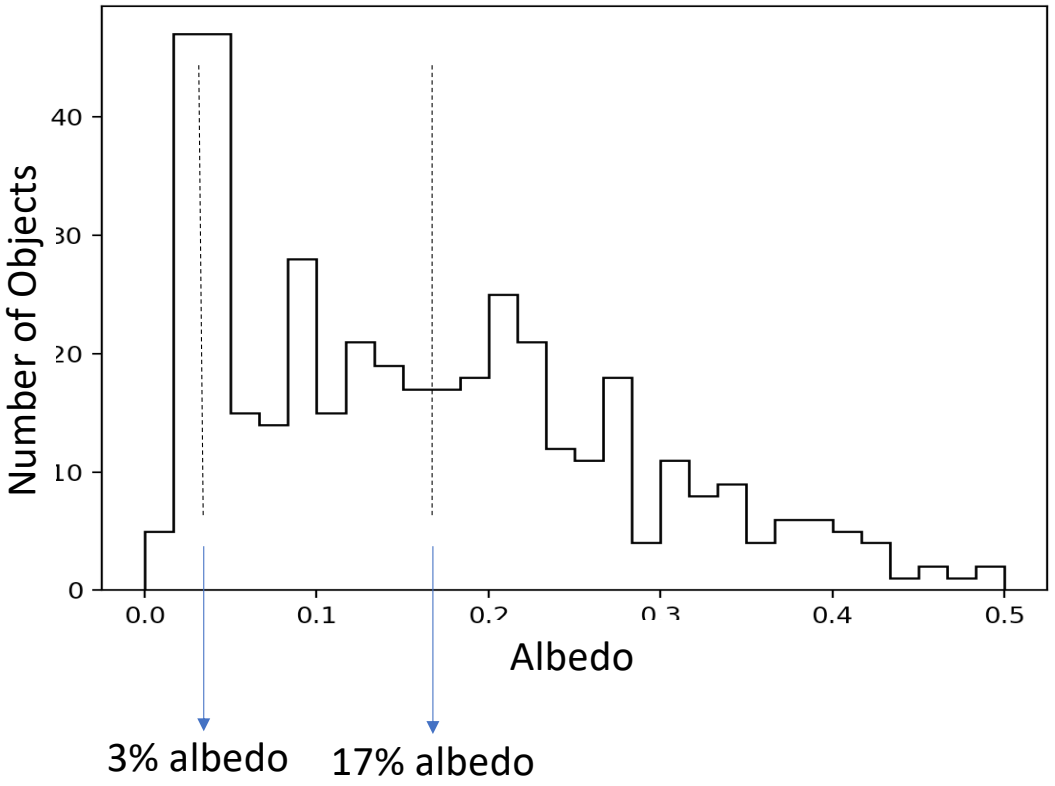
- **How bad: Comes from measuring the impact energy (KE)**
  - Impact energy scales as KE = ½ mass x velocity^2
  - **Velocity** comes from orbit
  - Mass = density x volume = density x diameter^3
  - Impact energy depends strongly on **diameter**

What We Have Learned About NEOs from NEOWISE

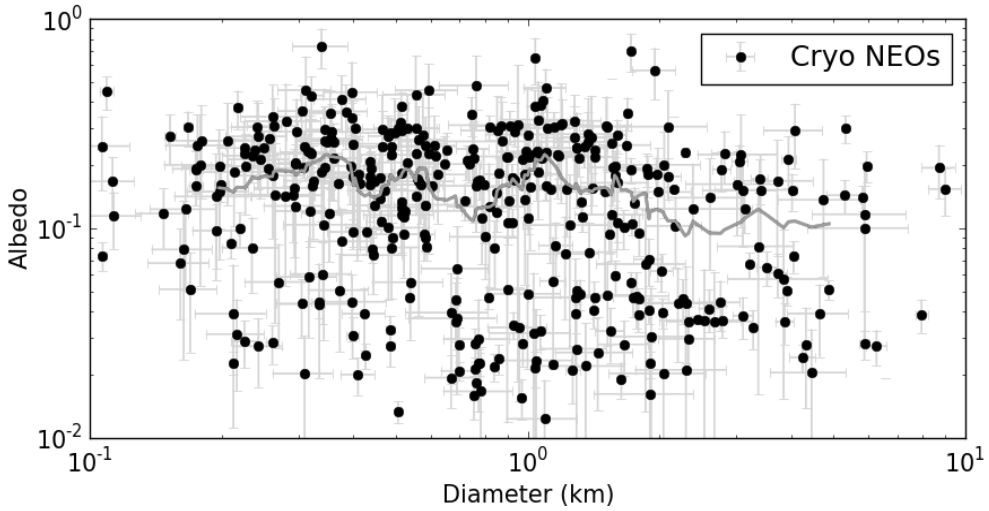
- Asteroid fluxes = $F_{reflected} + F_{emitted}$
- $F_{reflected} \sim A D^2$, $F_{emitted} \sim D^2 (1 - A) \sim D^2$
  - where A = Bond albedo and is usually <<1
  - NEO albedos vary widely: ~3-50%
- Infrared → diameter errors ~±10-20% for modest # of observations
  - With dense, multi-epoch observations, can get within 5% of ground truth e.g. Ryugu (e.g. Müller et al. 2017)
  - Visible light →diameter errors of factors of ~2
- IR is sensitive to both low and high albedo objects
- Space-based survey has consistent biases
  - No weather, no seeing, no daytime

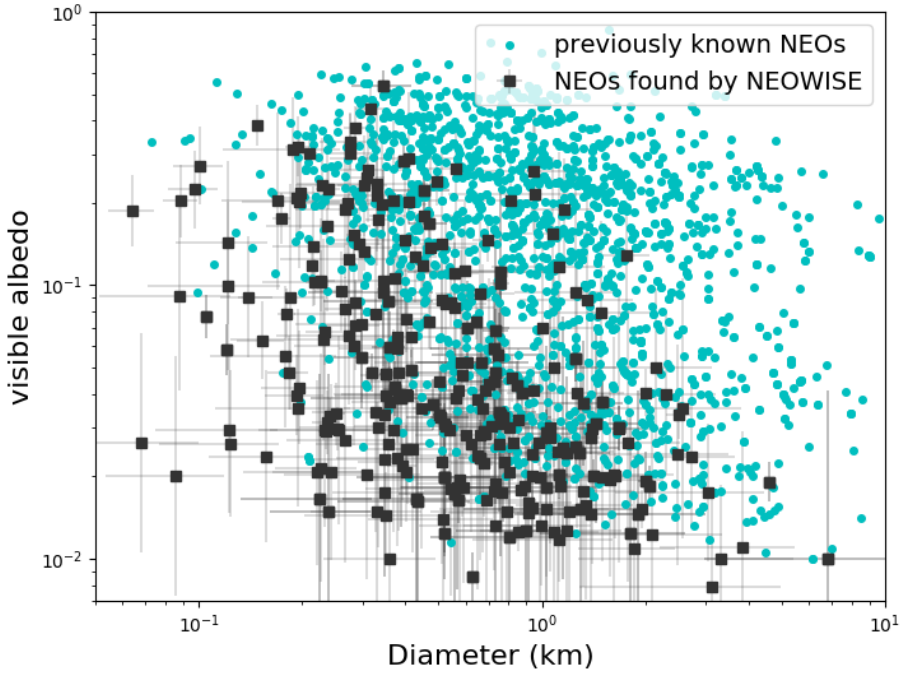
NEO Albedo Distribution

- **Approximately 30% of NEOs are very dark (3% albedo), and a population of less dark ones (17% albedo)**
  - Data from NEOWISE (Mainzer et al. 2011)
  - Data from Hayabusa 2 reveals that NEO Ryugu is extremely dark (few % albedo)
- **Wright et al. (2016) showed that H<22 mag is consequently not equivalent to 140 m: need to reach H<23 mag instead**
- **In order to reach 90% completeness, a system sensitive to dark NEOs as well as the bright ones is needed**



NEO Albedo Distribution



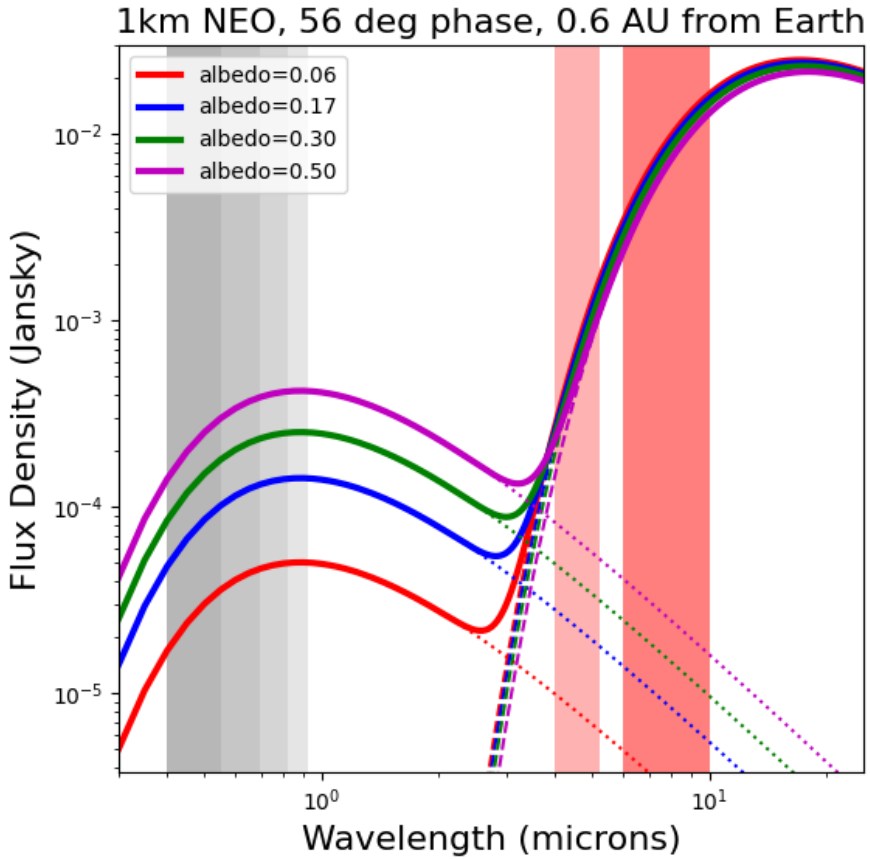


- **~430 NEOs selected based solely on 12um flux**
- **No significant change in albedo vs. diameter**
  - Albedo is constant all the way down to small sizes
- **Contrary to previous studies that are biased against small, low albedo objects**

- **Size vs visible albedo of asteroids observed (cyan circles) and discovered (black squares) by NEOWISE.**
- **NEOWISE discoveries are preferentially dark**

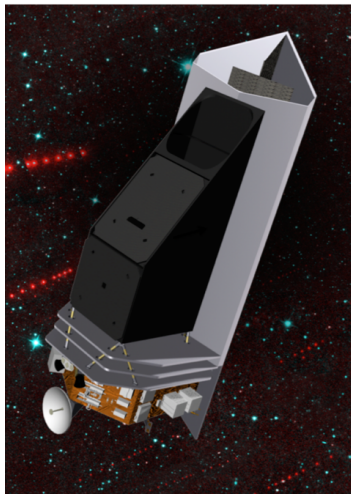
A New Mission: NEO Surveyor

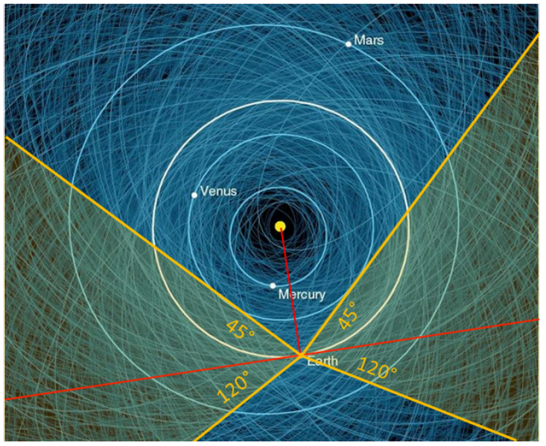
- **Mission Objectives:**
  - Find 2/3 of PHAs >140 m in 5 years (goal: 90%)
  - Produce diameters & compute albedos where visible data are available
  - Compute cumulative chance of impact over next century from PHAs >50 m and comets
  - Deliver tracklet data daily; images & extracted source lists every 6 months



Detecting NEOs

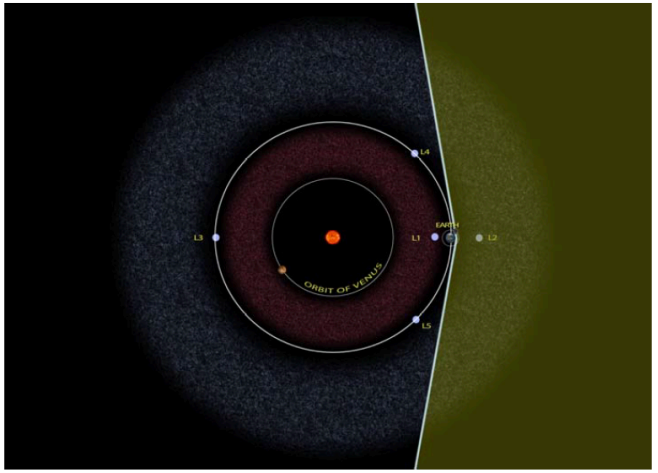
- **We observe the space where NEOs spend time**
  - 50 cm, passively cooled infrared telescope at the Earth-Sun L1 point
- **We survey repeatedly**
  - Mission lifetime – catch long synodic period objects
  - Survey redundancy – same area of sky many times
- **We survey thoroughly**
  - Pointing accuracy (to avoid gaps between fields)
  - Survey cadence optimized for NEO detection: no other science objectives
  - Survey design ensures highly reliable NEO tracklets
  - "Countable" tracklet: ≥ 4 linked observations, each pair of observations separated by < 12 hr
  - "Countable" object: ≥ 2 tracklets, ~ 12 days apart
  - Expect ~300k NEOs & millions of MBAs
- **We can target individual objects of interest**
  - Ability to rapidly respond to virtual impactors





Synergy Between Surveys

- Vera C. Rubin Observatory and NEO Surveyor cover complementary regions of near-Earth space as shown in the two images to the right
- Rubin's LSST survey (yellow region) is most sensitive to NEOs outside the Earth's orbit (blue points; Amors & Apollos)
- NEO Surveyor's area of regard (pink region) is most sensitive to NEOs along or inside the Earth's orbit (Apollos, Atens, Interior-to-Earth objects).
- Rubin Observatory will provide an excellent catalog of main belt asteroids, which are a significant source of confusion for NEO detection
- Combined, these two systems will provide regular monitoring of objects over the majority of their orbits, constraining physical properties (diameter, albedo, thermal inertia) that are needed for impact hazard assessment.



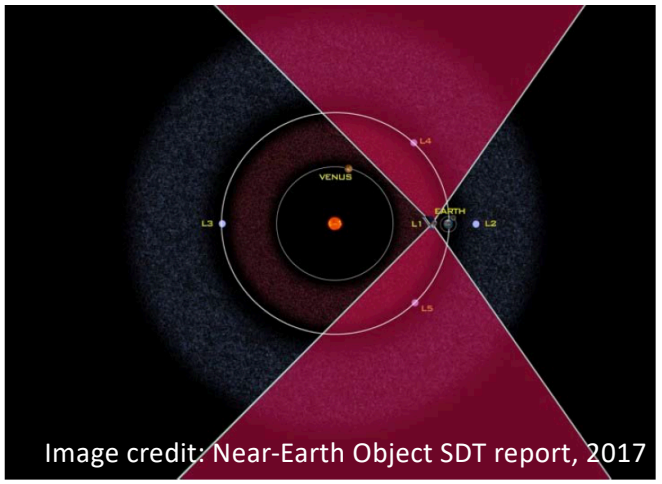
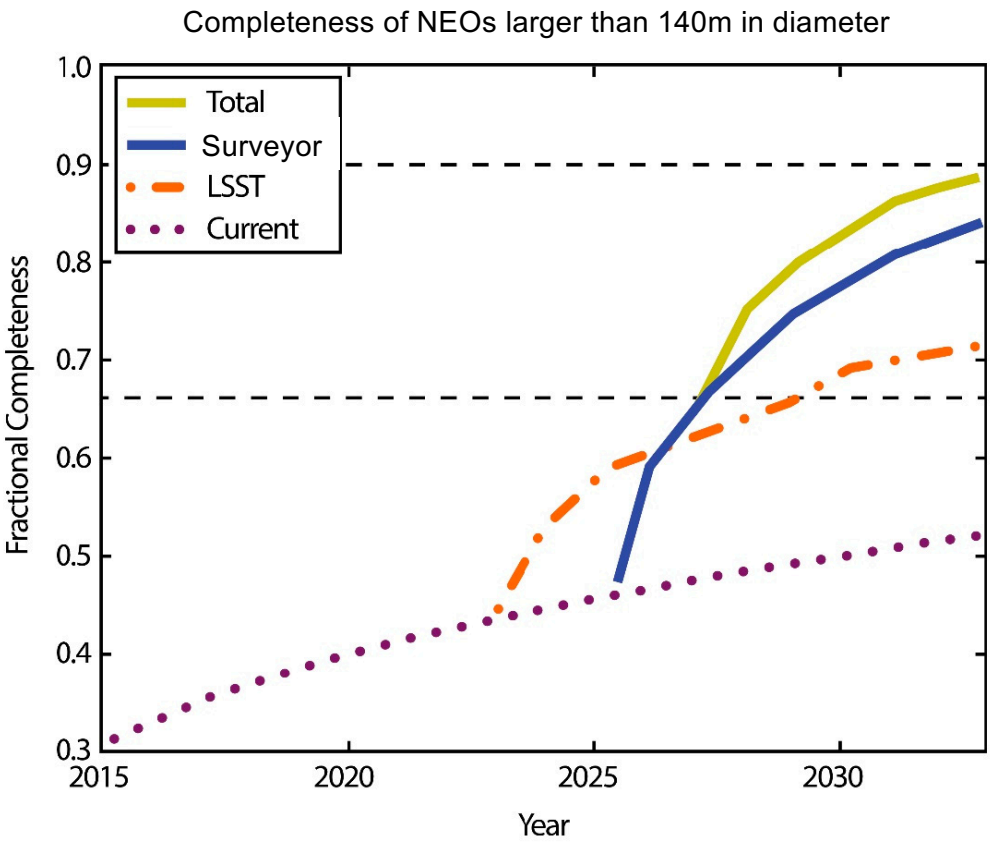


Image credit: Near-Earth Object SDT report, 2017

Synergy Between Surveys



- **Rubin Observatory is expected to begin surveying in late 2023**
- **NEO Surveyor currently on a schedule that would allow for a 2026 launch date with survey beginning 3 months later**
- **These two surveys will dramatically increase the state of knowledge of NEOs as shown in the plot to the left**
- **The NEO catalog will reach 90% completeness within 10 years of the launch of Surveyor, fulfilling the Congressional mandate to NASA**
- **See lightning talks by Grav, Lilly, Spahr, Surace, Wright**