SPACEWATCH®:
Do You Know Where Your Asteroids Are?

Dr. Melissa Brucker
Spacewatch Principal Investigator
Lunar & Planetary Laboratory
University of Arizona

Live from NOIRLab
March 10, 2021

Image from the Spacewatch allsky camera

Telescopes

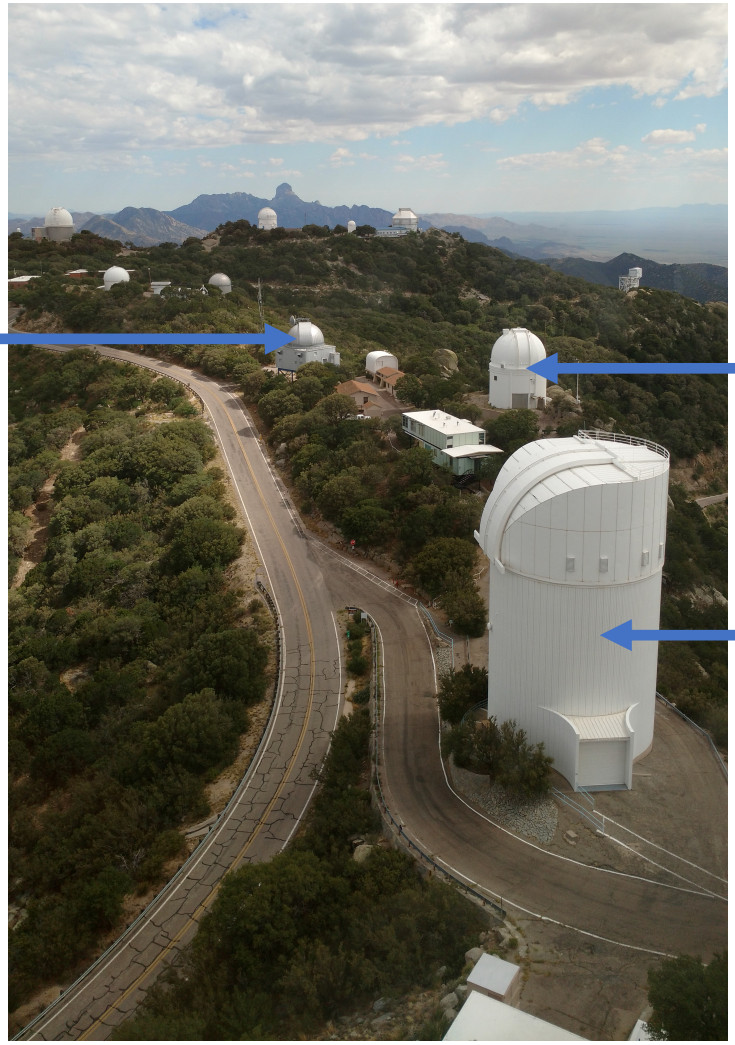
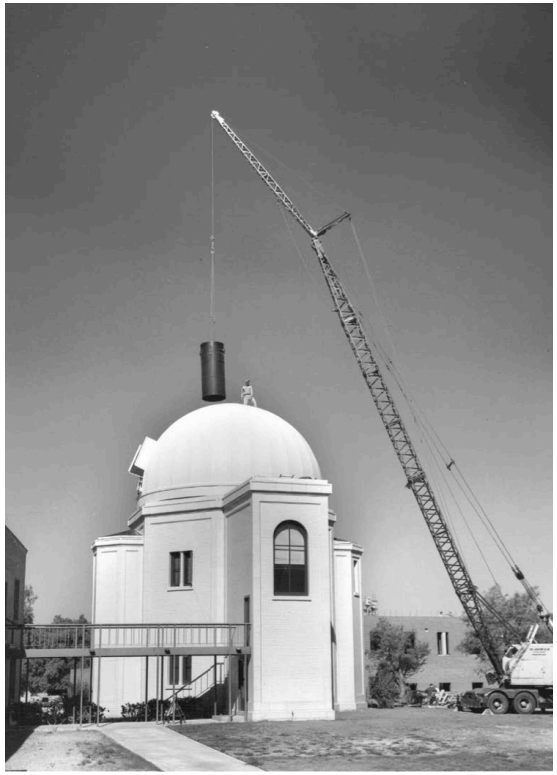
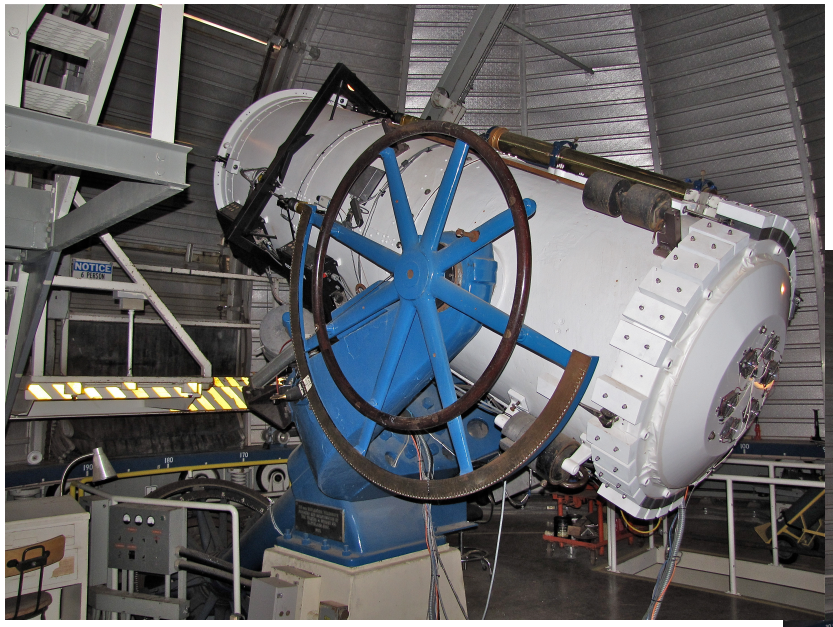


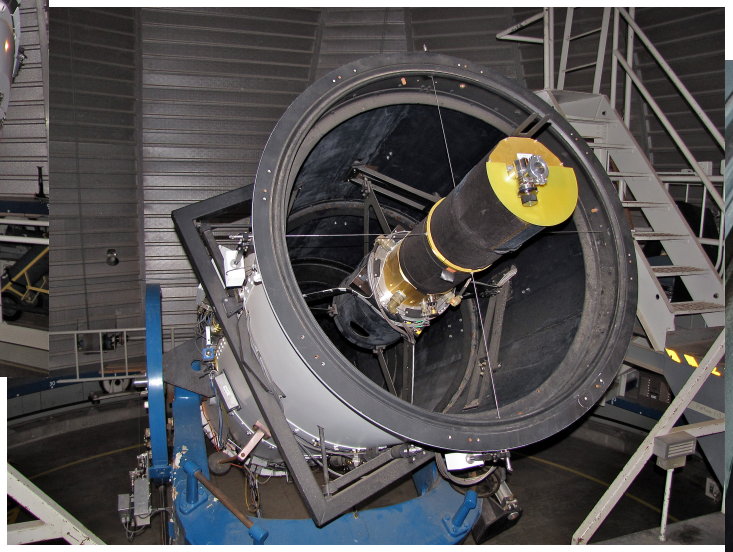
Photo: Melissa Brucker

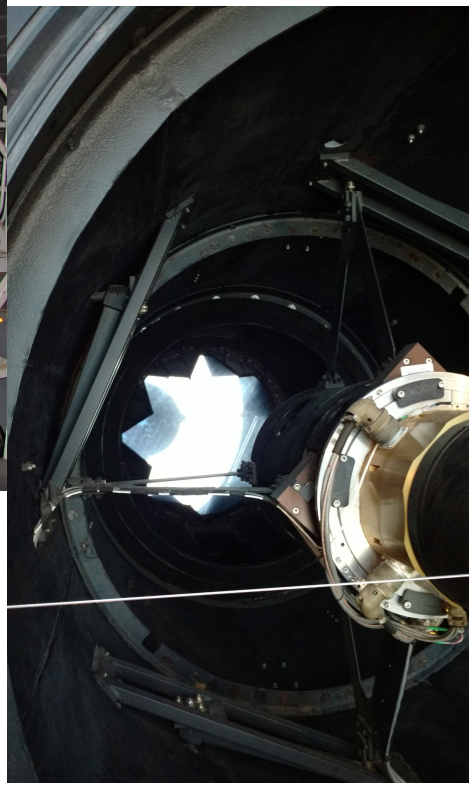
Steward Observatory 0.9m Telescope



Left: in the Warner and Swasey Factory, Cleveland, Ohio in 1921. Credit: A. E. Douglas courtesy of Roger E. Carpenter, MD. Right: leaving the UofA campus in 1962 to be installed on Kitt Peak. Image courtesy of University of Arizona Libraries, Special Collections







Spacewatch telescope body and mosaic camera as it is today.
Left and Center photos: Roger E. Carpenter, MD. Right photo: Melissa Brucker

LPL Spacewatch 1.8m Telescope

Photo: Jim Scotti

Secondary Mirror

Camera

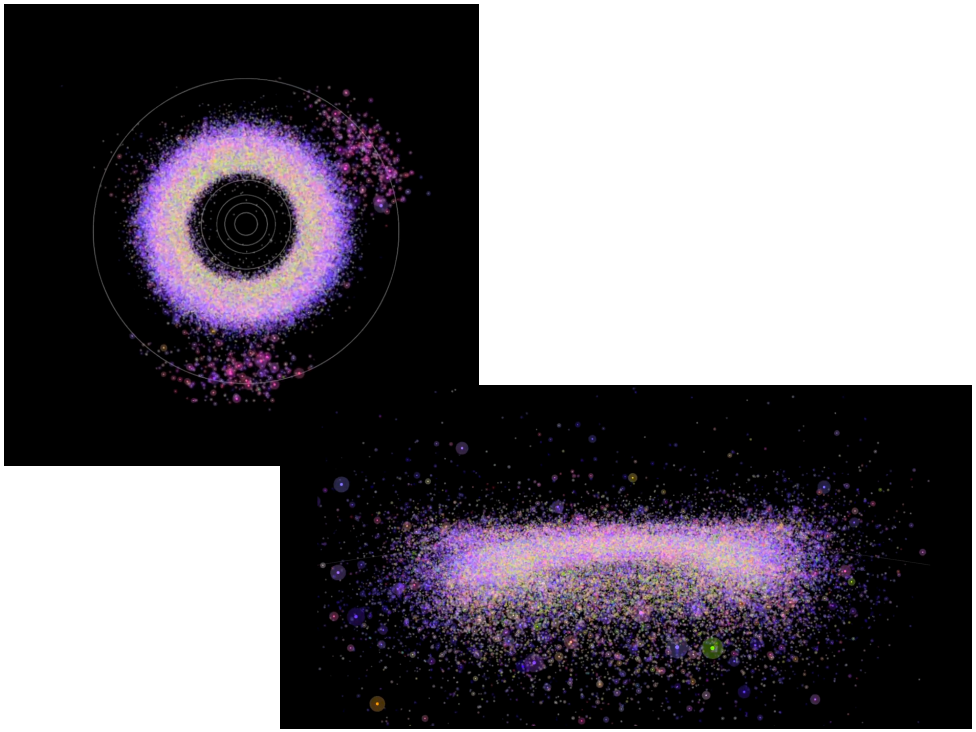
Primary Mirror Cover

Photo: Melissa Brucker

Spacewatch highlights

- Founded in 1980 by Prof. Tom Gehrels and Dr. Bob McMillan to explore populations of small solar system objects and investigate solar system evolution
- The first group to (as far as we know)
  - use CCDs to survey the sky for comets and asteroids
  - measure asteroid positions from CCD images (1984)
  - discover with a CCD a near-Earth asteroid (1989) and comet (1991)
  - develop automated software for detecting moving objects (1990)
- Discovered binary 65803 Didymos (1996 GT), the target of the AIDA mission (NASA's DART mission + ESA's Hera mission)
- Discovered 1998 KY26, the upcoming second target of JAXA's Hayabusa2 mission
- Made the most follow-up recoveries of WISE near-Earth asteroid discoveries during its cryogenic mission
- Participated in 3 IAWN campaigns, https://iawn.net/
  - 2012 TC4 in 2017, 66391 Moshup 1999 KW4 in 2019, 99942 Apophis 2004 MN4 currently

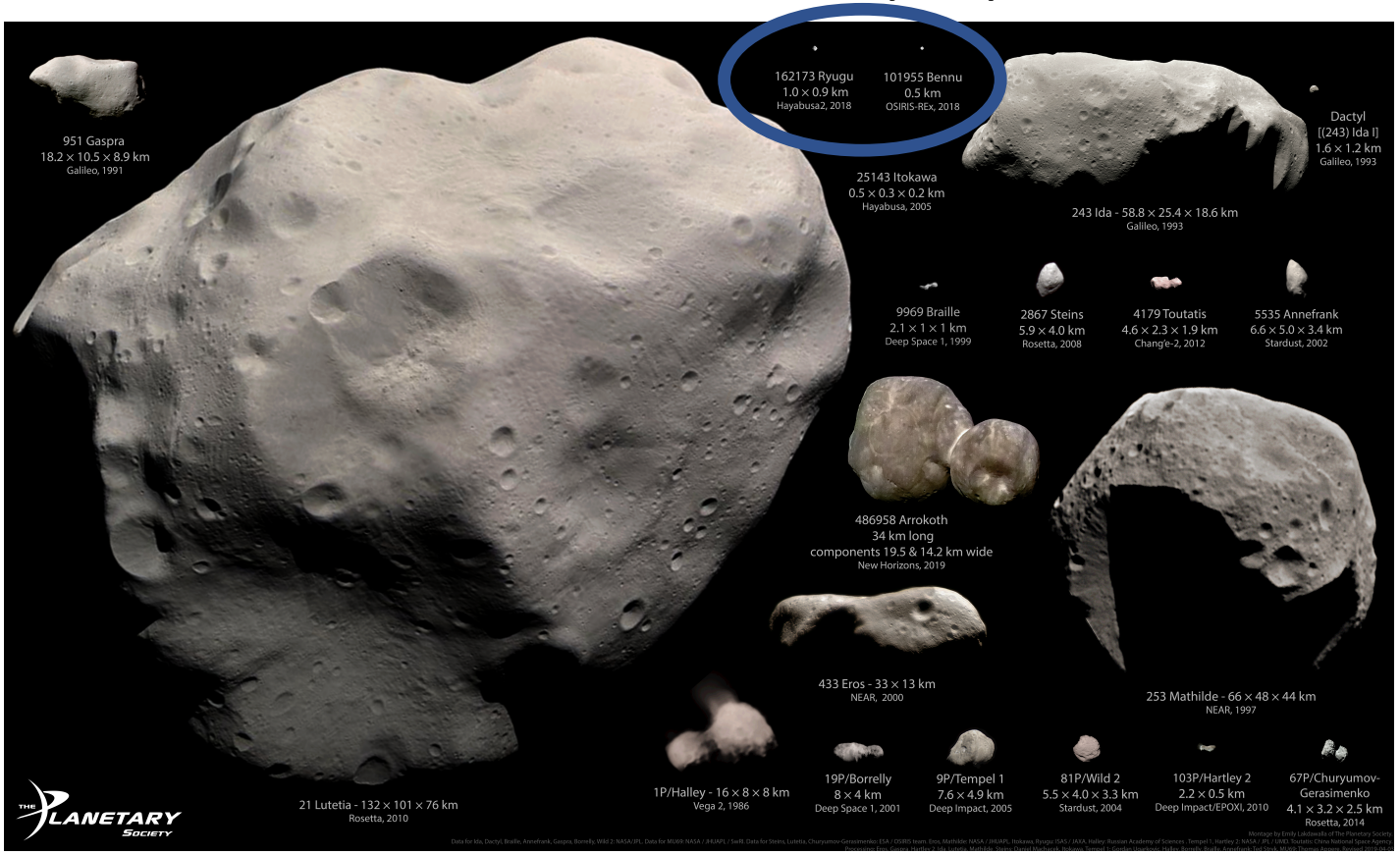
The Main Asteroid Belt



Left and Center: Alex Parker, data from SDSS, rendering at https://vimeo.com/alexhp
"Painted Stone: Asteroids in the Sloan Digital Sky Survey"

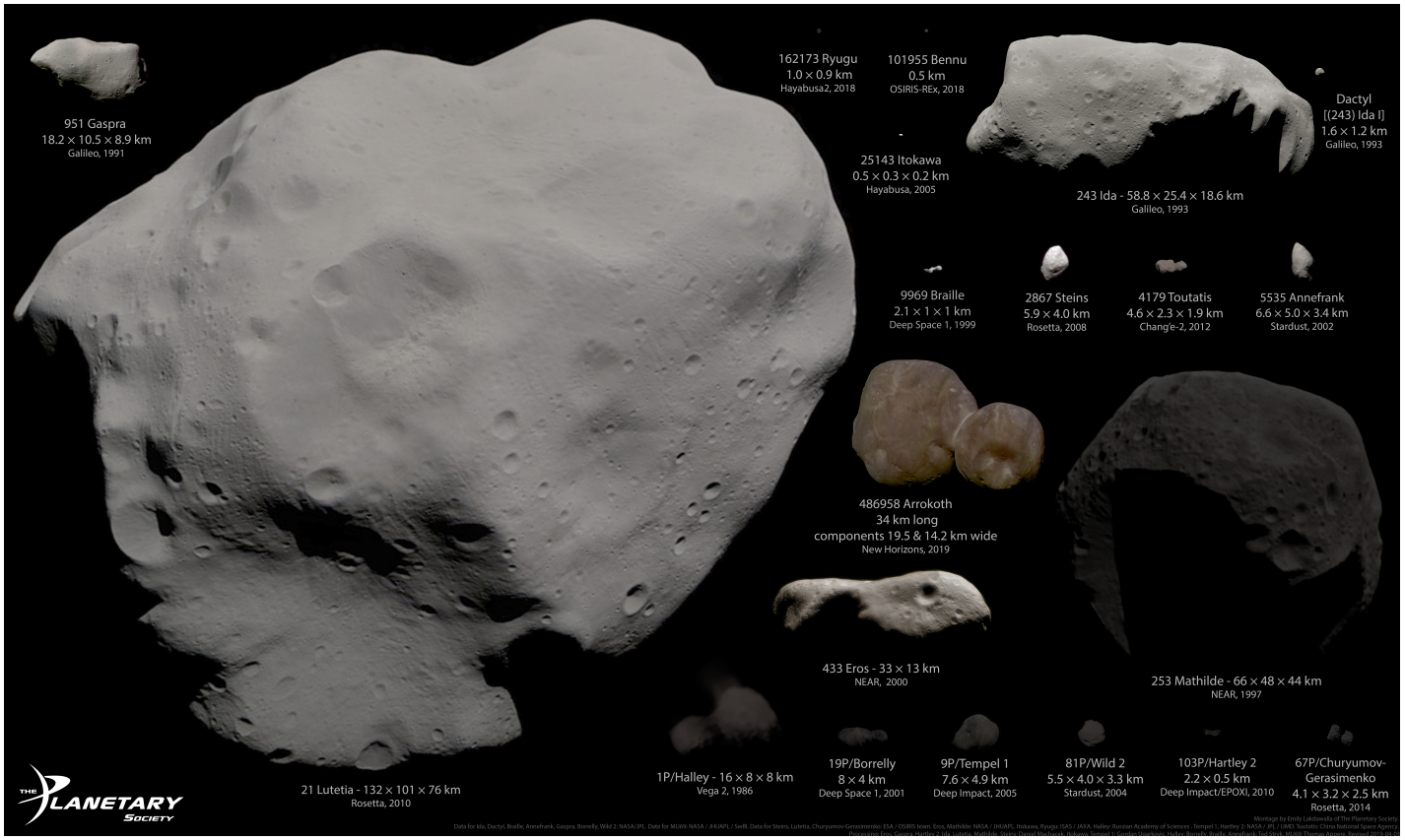
Right: Image grabbed from https://www.sciencefocus.com/space/how-do-spacecraft-avoid-asteroids-and-meteoroids/

Small Bodies Visited by Spacecraft



Montage by Emily Lakdawalla for The Planetary Society. Data from NASA / JPL / JHUAPL / SwRI / UMD / JAXA / ESA / OSIRIS team / Russian Academy of Sciences / China National Space Agency. Processed by Emily Lakdawalla, Daniel Machacek, Ted Stryk, Gordan Ugarkovic / Thomas Appéré. https://www.planetary.org/space-images/asteroids-and-comets-visited-2018

Small Bodies Visited by Spacecraft



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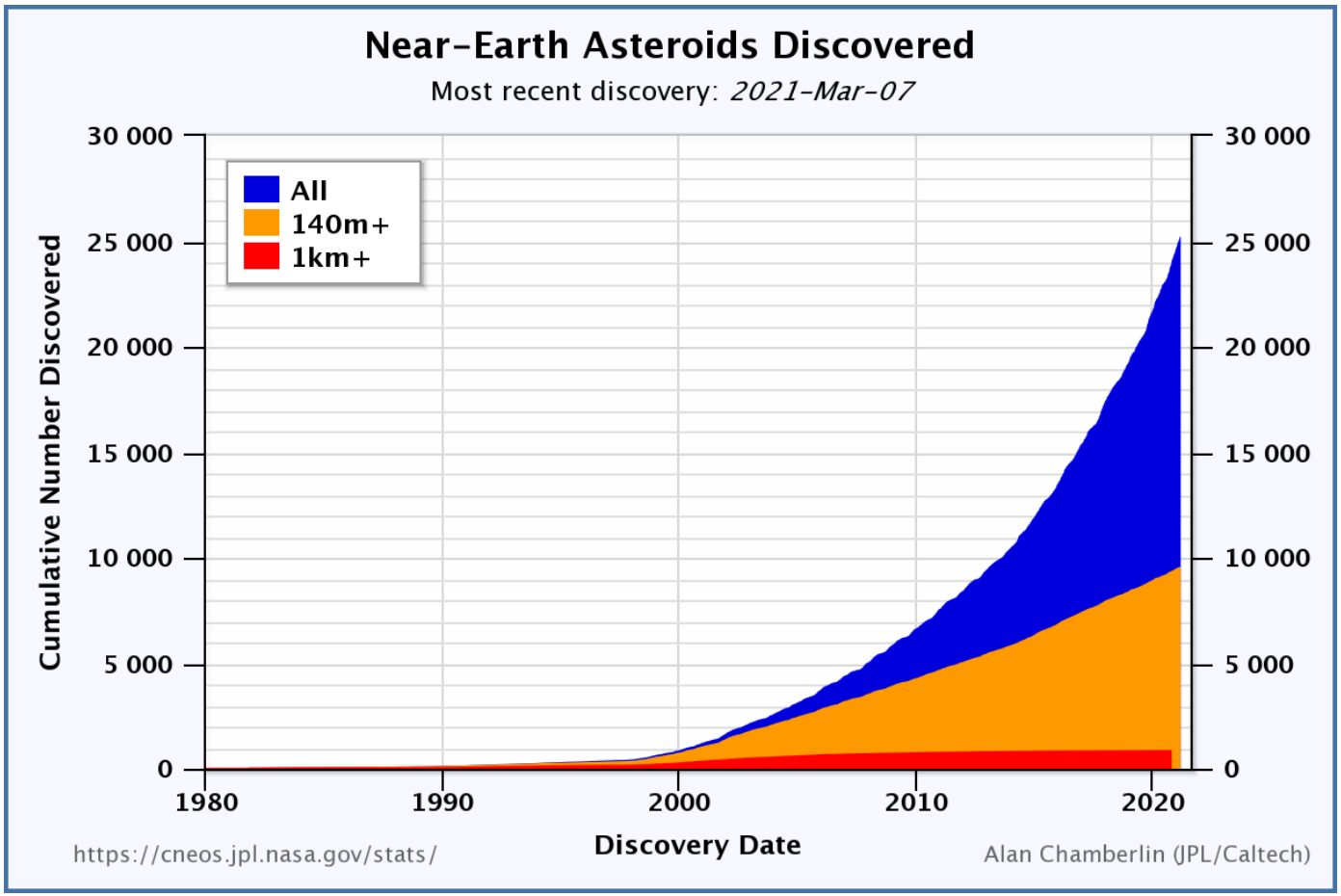
Near-Earth Objects (NEOs)

- asteroids (NEAs) or comets (NECs) with perihelia, q < 1.3 au
  - NECs must also have orbital periods, P < 200 yrs
  - Potentially Hazardous Objects/Asteroids (PHOs/PHAs)
    - absolute magnitude, H ≤ 22.0 (approximate size > 140m)
    - Minimum Orbit Intersection Distance with Earth, MOID ≤ 0.05 au [4,647,790mi]
  - Virtual Impactor (VI)
    - A NEO with a range of possible orbits such that the set of virtual asteroids contains at least one with a possibility of impacting Earth within 100 years.
      - the probability of impact is almost always very very low
    - more info: https://cneos.jpl.nasa.gov/sentry/intro.html
- 25,358 NEOs discovered as of March 8, 2021[1]
  - 1,043,048 total minor planets discovered

[1] https://www.minorplanetcenter.net

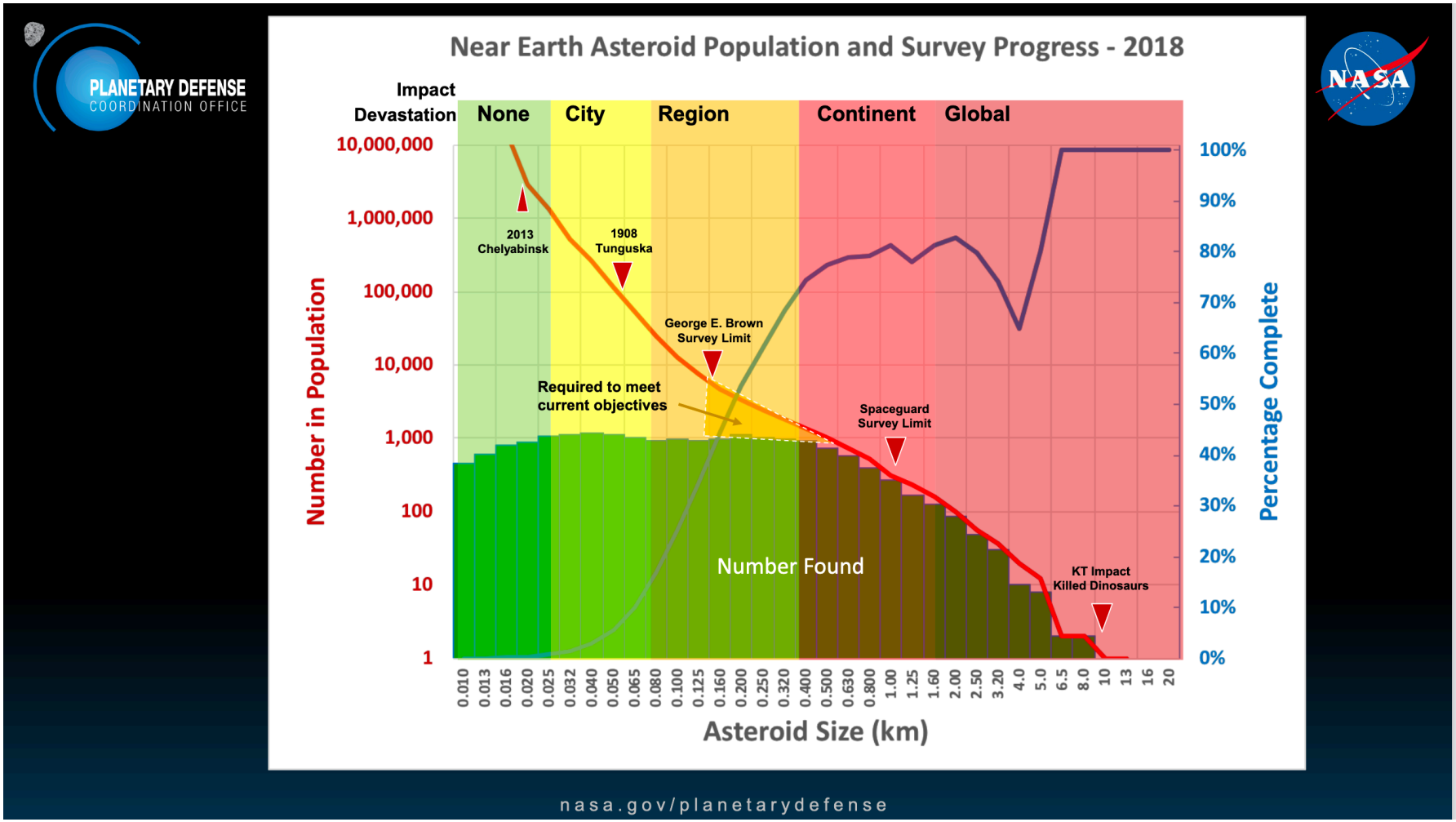


https://cneos.jpl.nasa.gov/stats/totals.html

NASA Planetary Defense

- NASA Authorization Act of 2005[1]
  - NASA "shall plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize" 90% of NEOs $\geq$ 140m by 2020
- Based on population models, the expected number of NEOs $\geq$ 140m is about 25,000[2]. This leads us to
  - about 13,600 NEOs between 140 m and 300 m to be discovered
  - about 1780 NEOs between 300 m and 1 km to be discovered
  - about 25 NEOs 1 km and larger to be discovered [97.3% found]
- With the only the current discovery surveys available, it will take about 30 years to meet the Congressional mandate given in 2005
  - solution: invest in new, larger telescopes for the purpose of NEO discovery

[1] https://www.congress.gov/109/plaws/publ155/PLAW-109publ155.pdf
[2] https://www.lpi.usra.edu/pac/presentations/1120/11-PDCOUpdate-Johnson-PACNov2020.pdf



https://www.lpi.usra.edu/sbag/meetings/jun2019/presentations/Fast.pdf
PDCO: https://www.nasa.gov/planetarydefense

NEO Close Approaches in 2020

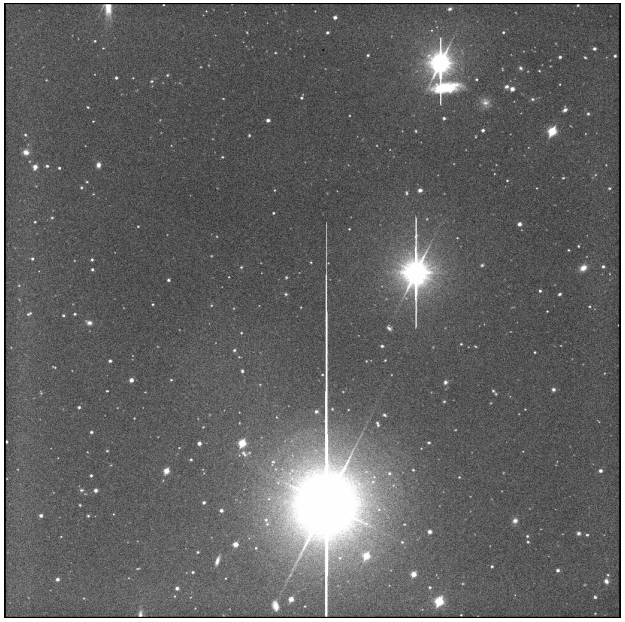
- 1425 passed closer 19.5x the average distance to the Moon

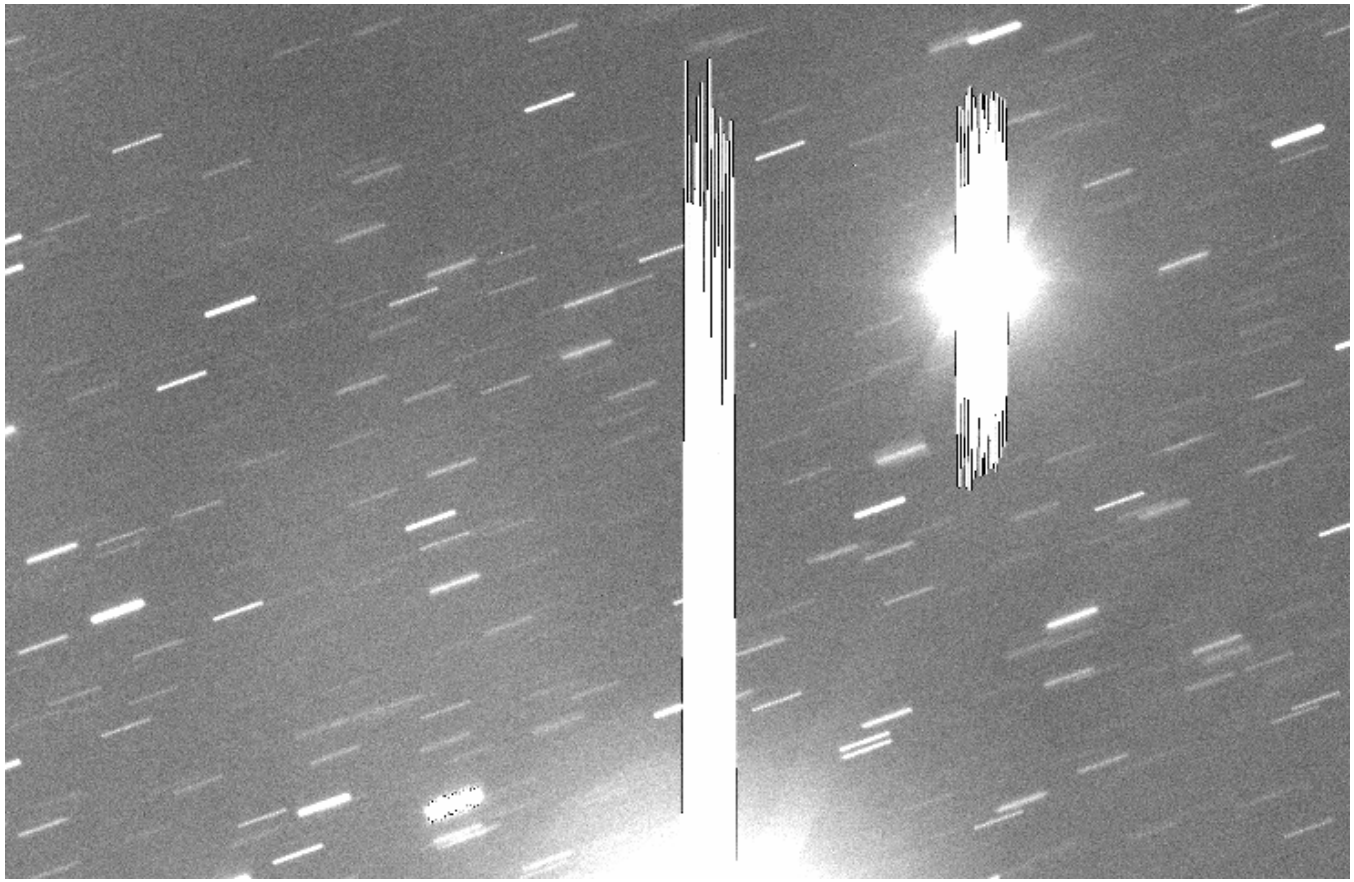
  1 LD = 238,803 mi, measured to the center of Earth

  - 873 passed closer than 10 LD
    - 106 passed closer than 1 LD
      - 9 passed approximately at or closer than the average distance of geosynchronous satellites (0.09 LD or 22,236 mi above Earth)
        - all 9 had estimated diameters < 12 m

https://cneos.jpl.nasa.gov/ca/

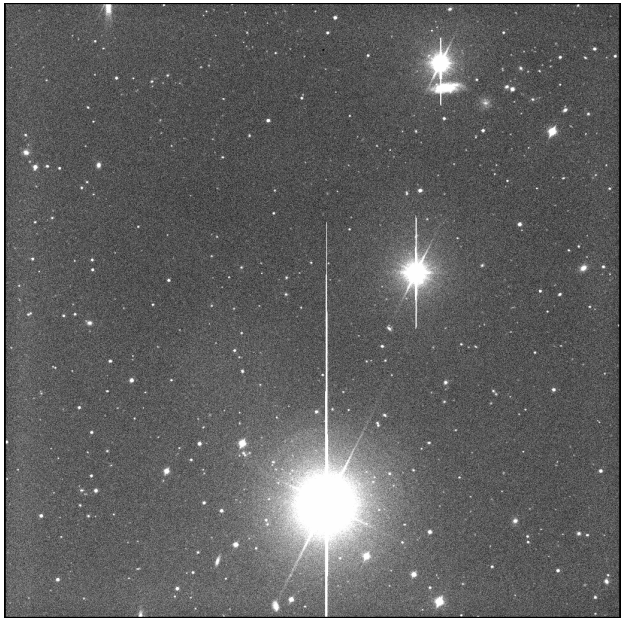
NEA 2008 DB with the 1.8m on March 3, 2021

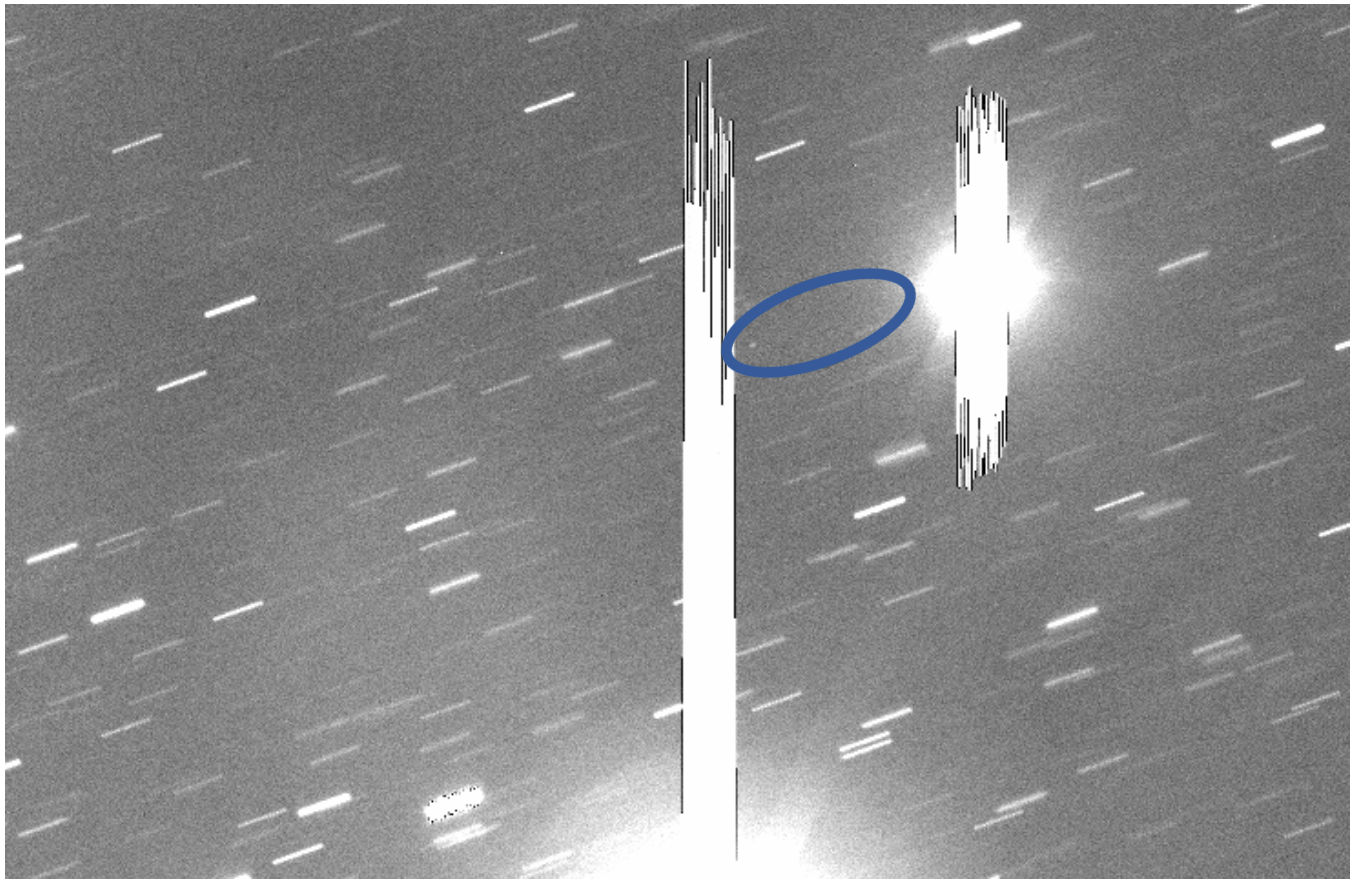




Left: single full image
Right: gif of three sets of images stacked at the asteroid's rate of motion, zoomed in on the target.

NEA 2008 DB with the 1.8m on March 3, 2021





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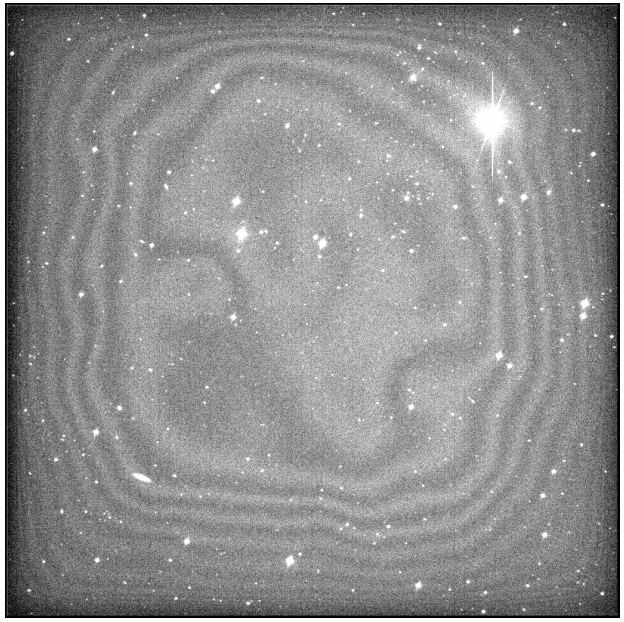
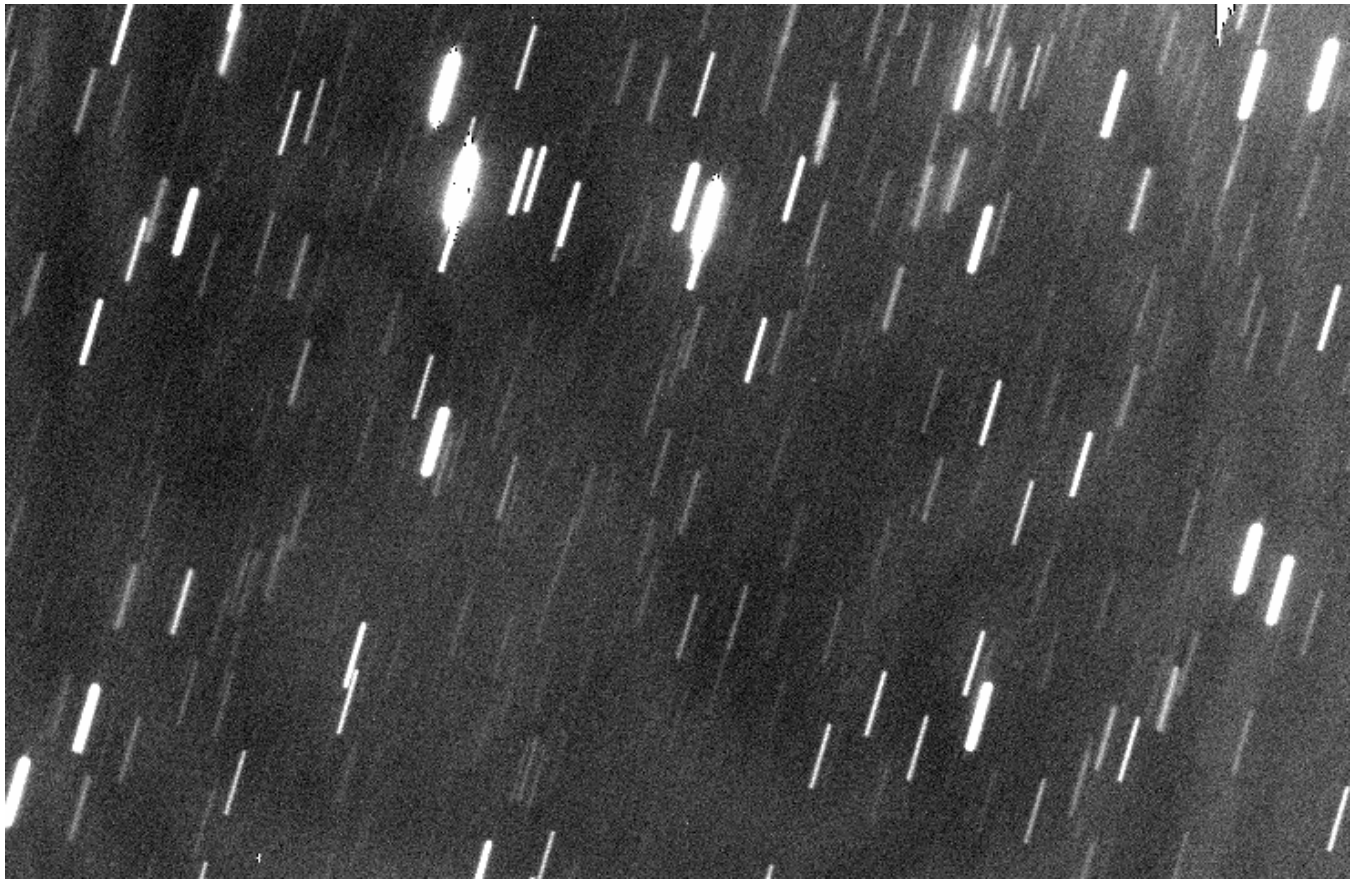
NEA 2021 CZ4 with the 1.8m on March 3, 2021





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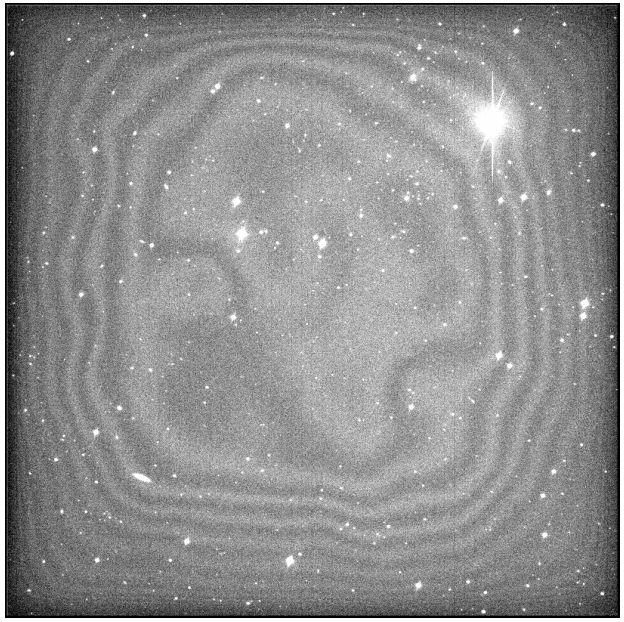

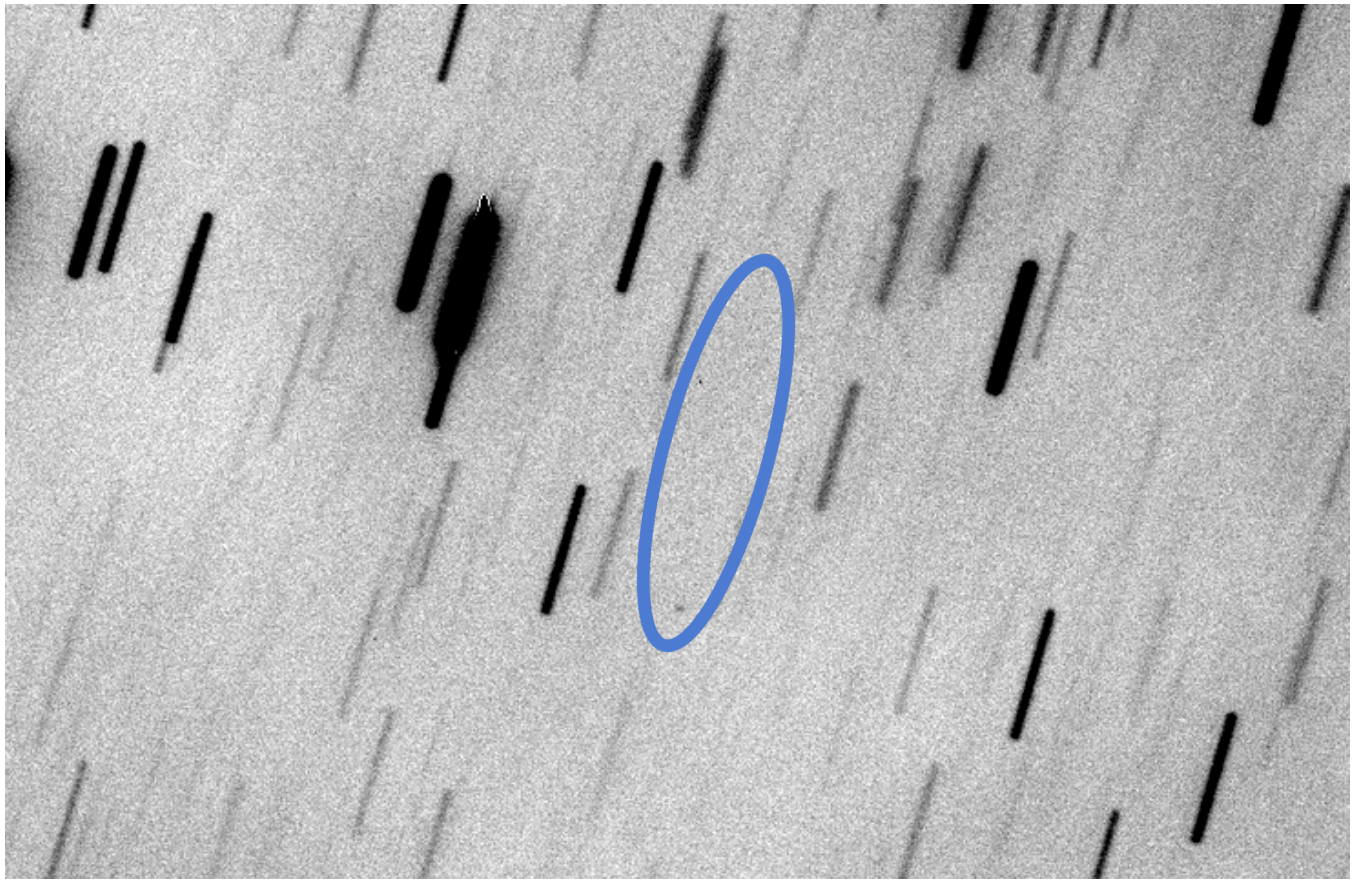

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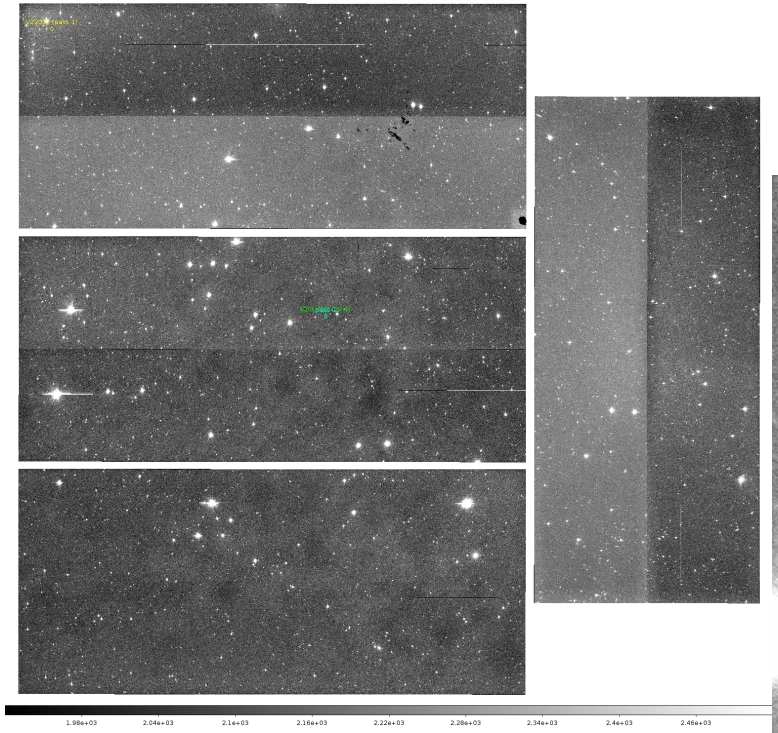
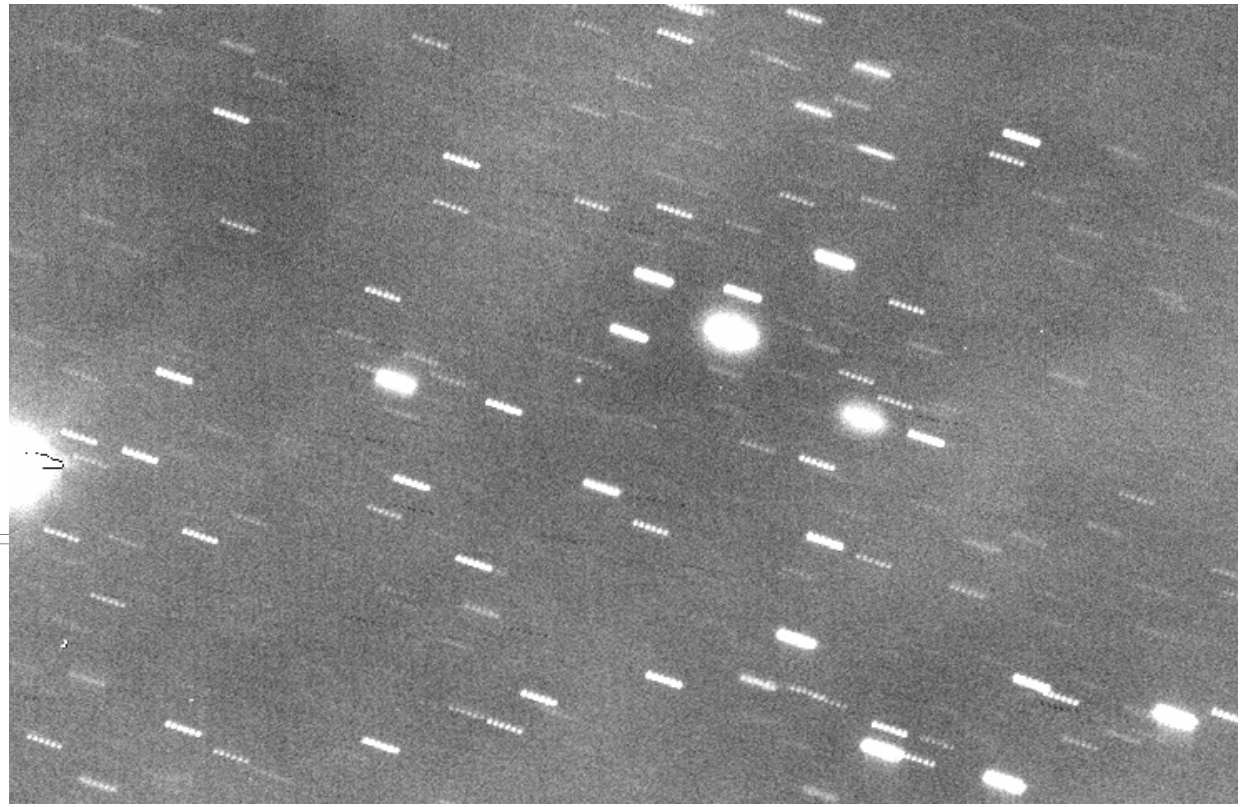
NEA 2020 UZ3 with the 0.9m on March 3, 2021





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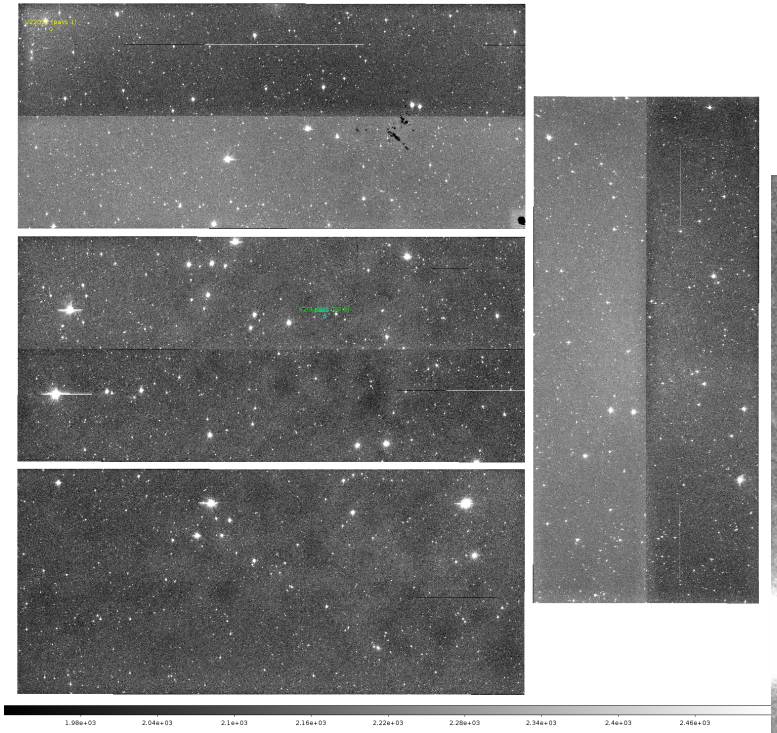

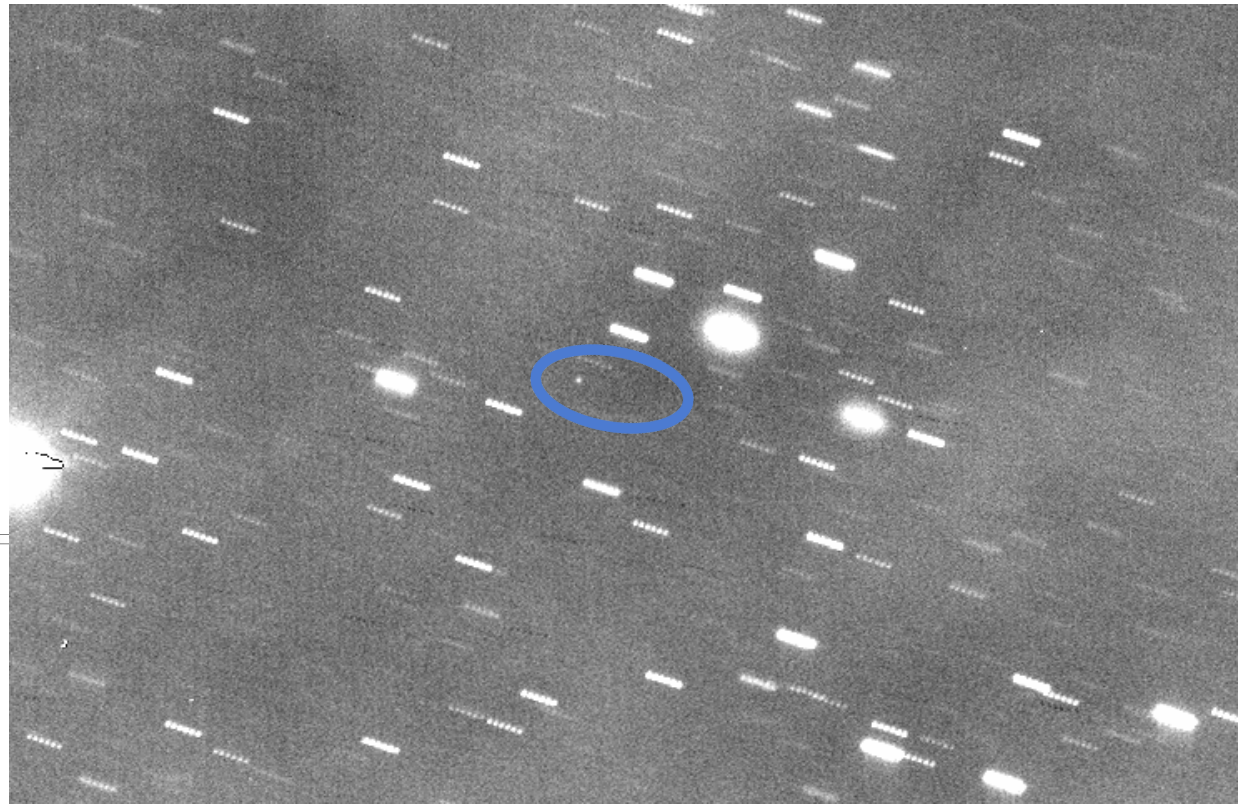

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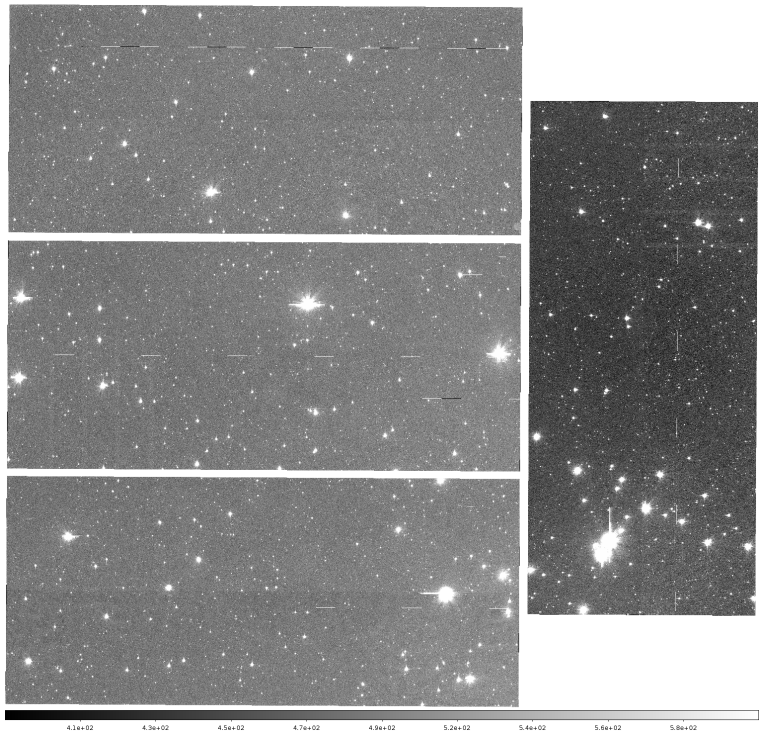
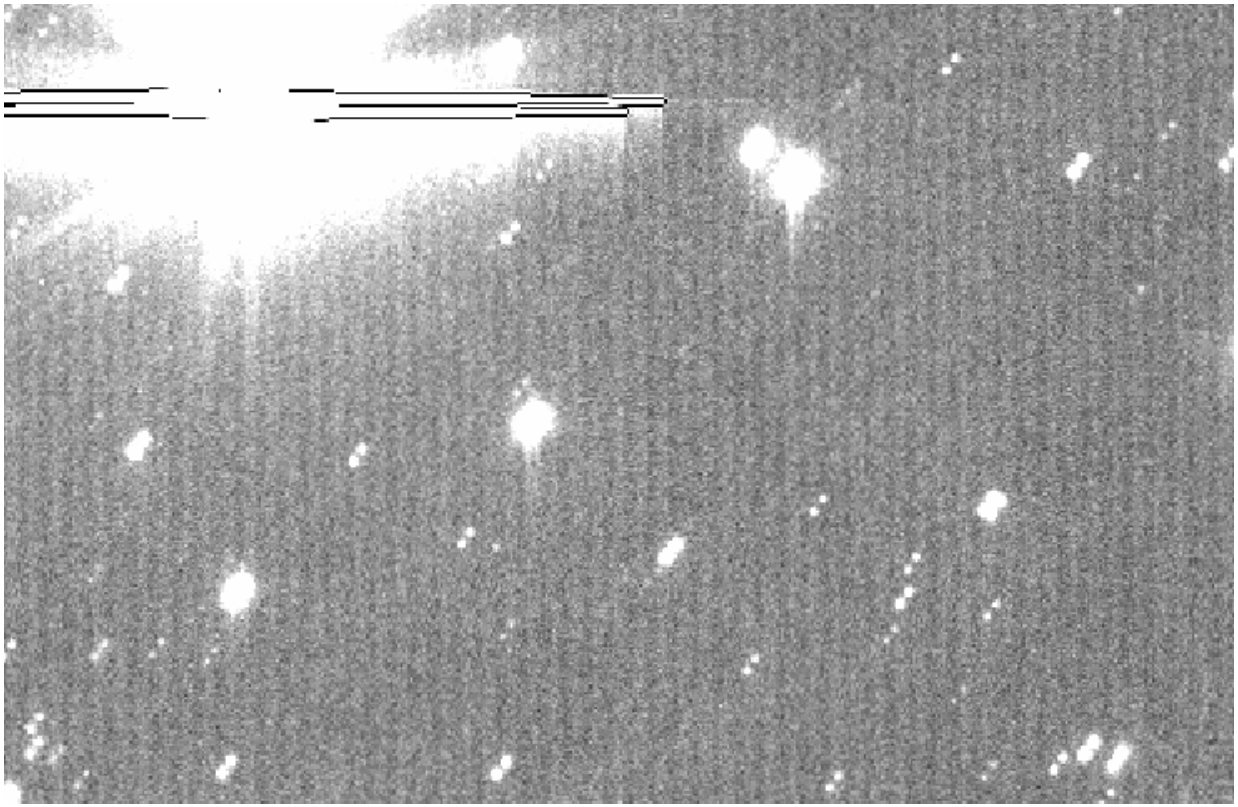
NEA 2021 CG3 with the 0.9m on March 3, 2021





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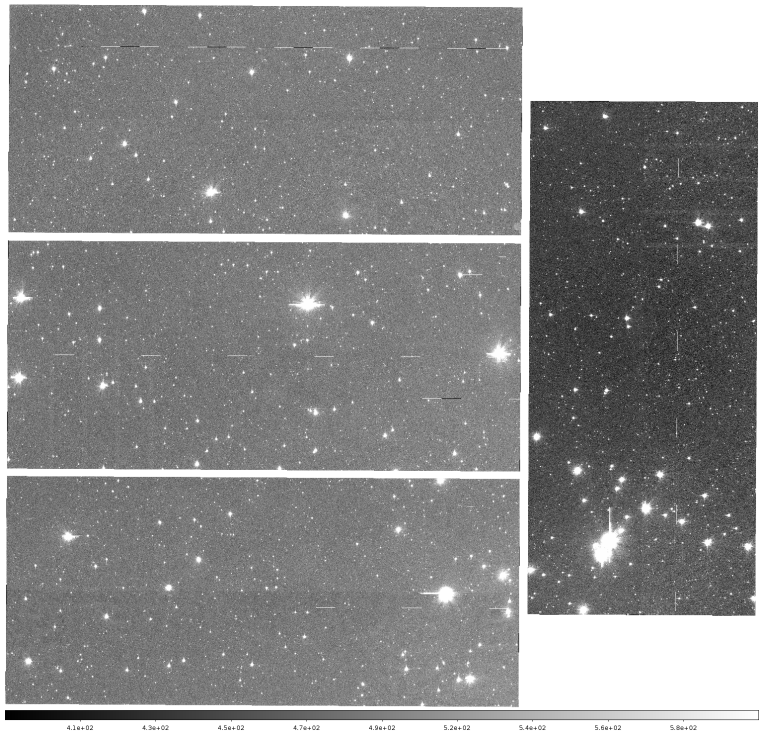

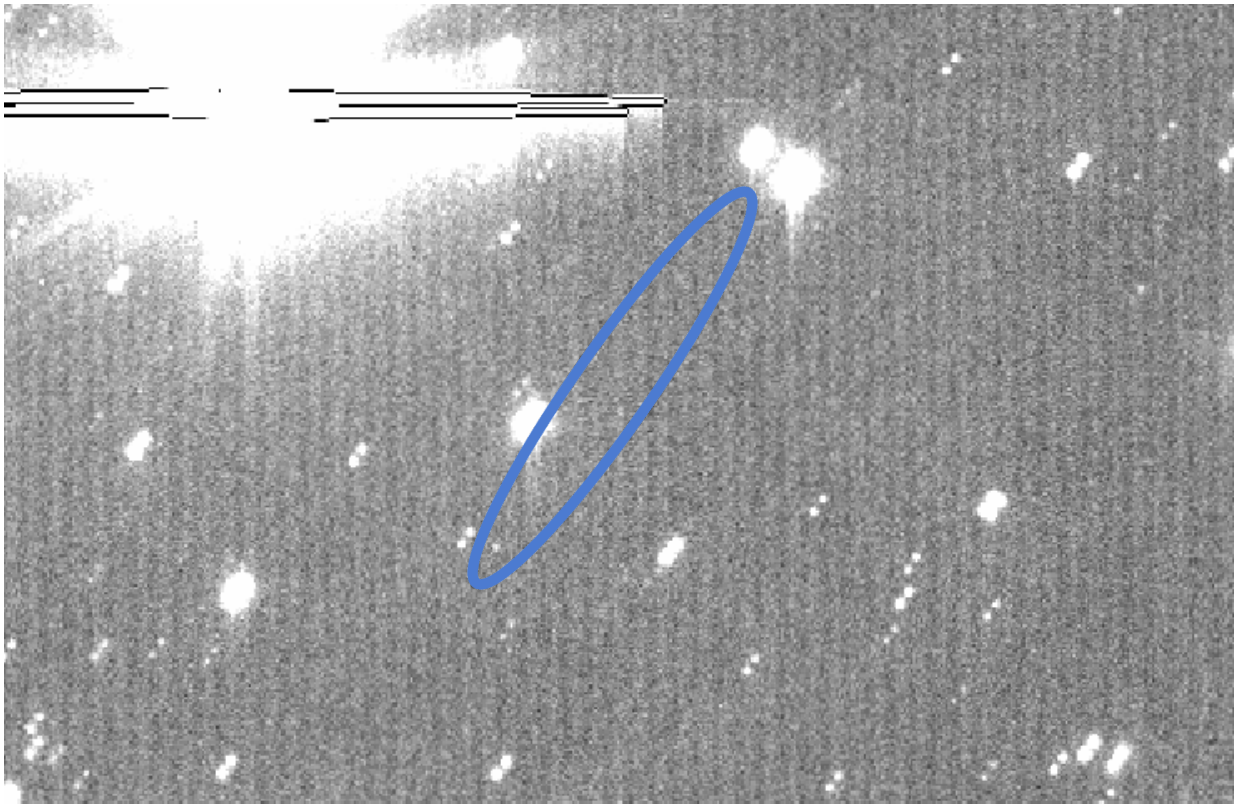

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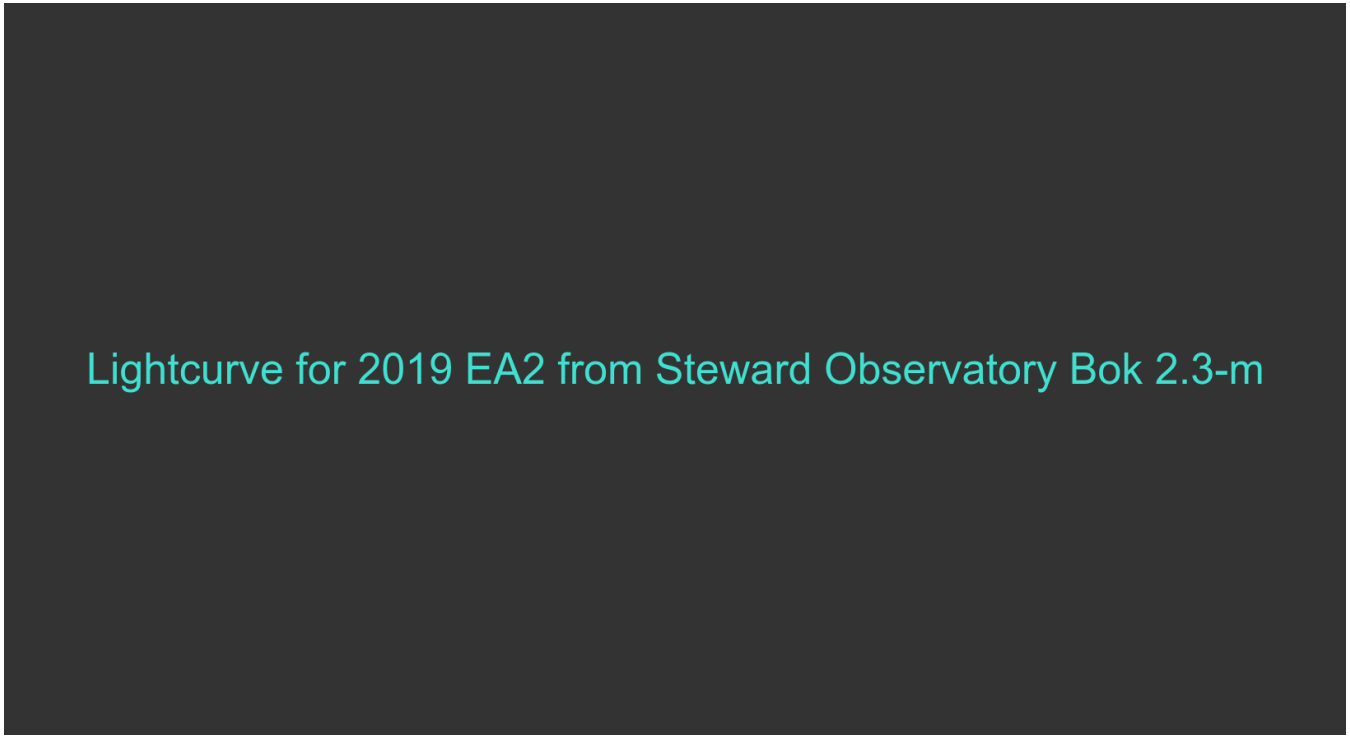
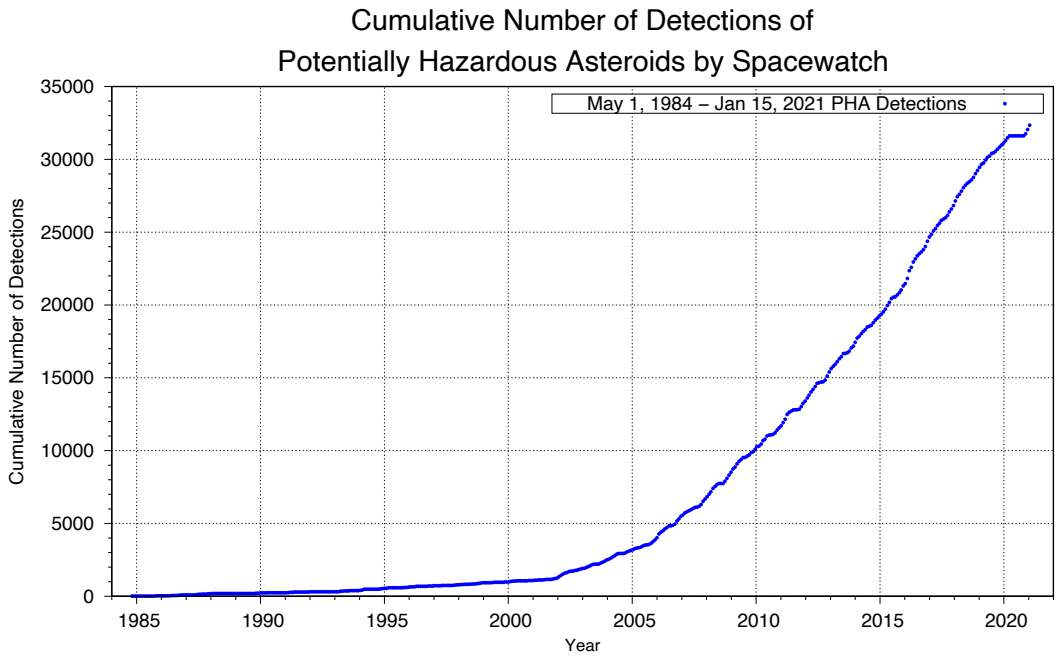
Lightcurves due to Asteroid Rotation



Data analysis and animation gif by Prof. Jeff Larsen, U.S. Naval Academy

Spacewatch astrometry productivity

- Number of NEO measurements in 2019:
  - 0.9m: 3900 1.8m: 3346 2.3m: 918
  - Number of PHA measurements in 2019:
    - 0.9m: 671 1.8m: 712 2.3m: 291



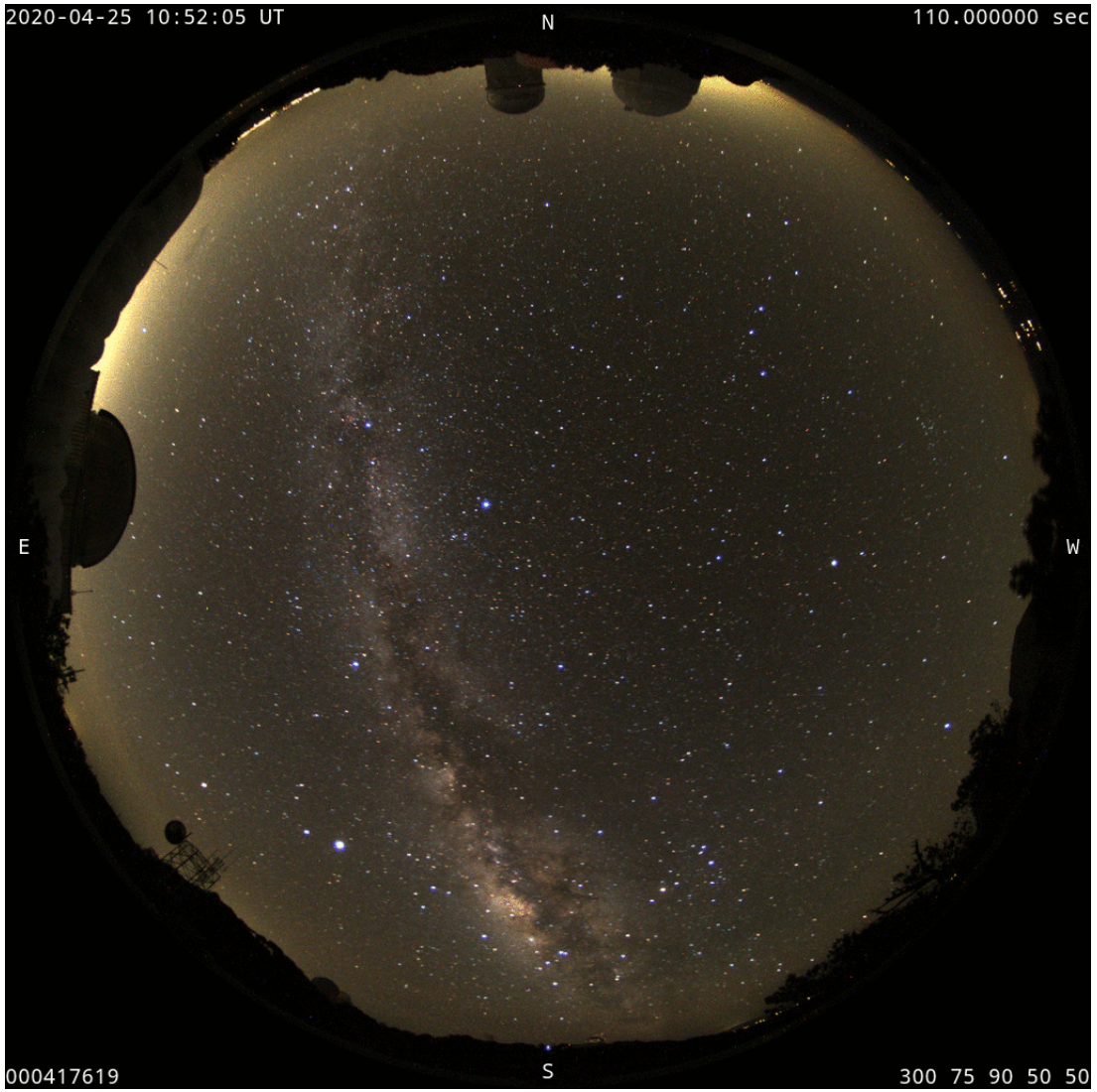
About 33,000 PHA measurements made between 1984 and 2021

We are honored to be permitted to conduct astronomical research on Iolkam Du'ag (Kitt Peak), a mountain with particular significance to the Tohono O'odham.

We appreciate the dedication of the Spacewatch researchers throughout the past 40 years.

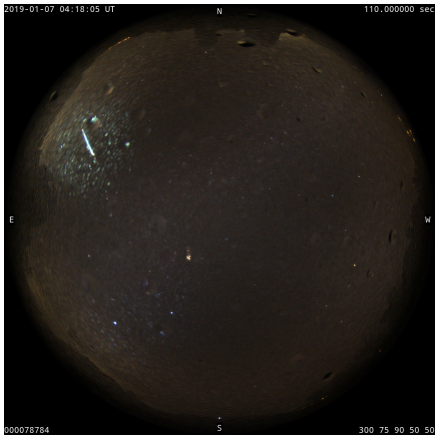
Spacewatch is supported by NASA/NEOO grants, the Lunar and Planetary Laboratory, Steward Observatory, Kitt Peak National Observatory, the Brinson Foundation of Chicago, IL, the estates of R. S. Vail and R. L. Waland, and other private donors. We rely on JPL and MPC for their web services.

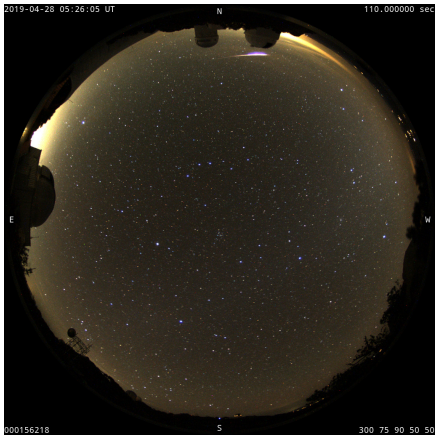
Extras

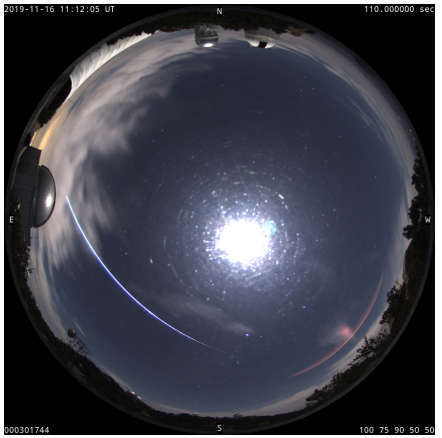


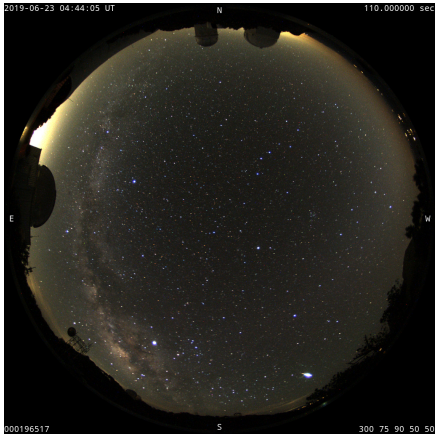
gif of meteor from the Spacewatch allsky camera

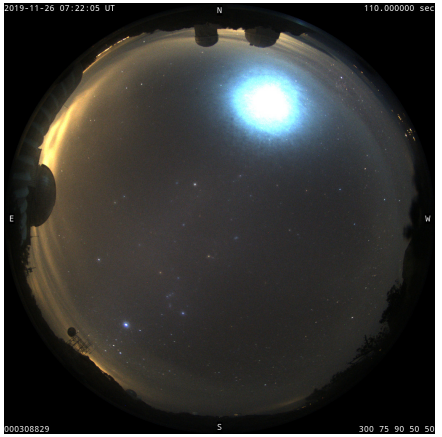
Meteors seen on the Spacewatch allsky camera



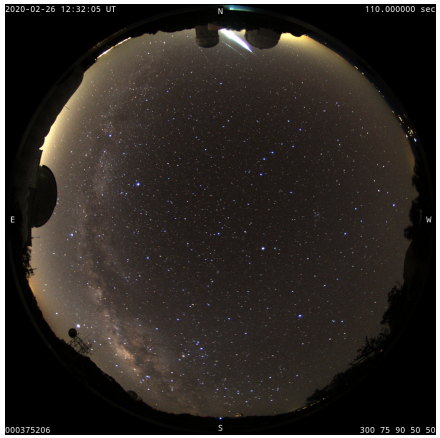


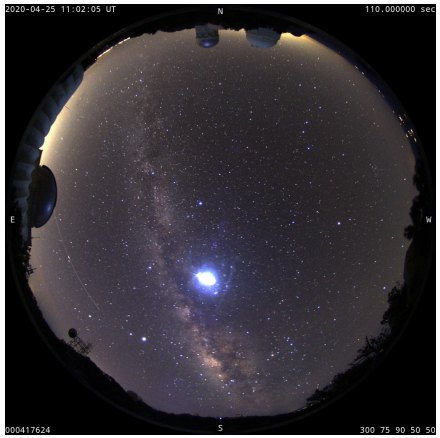


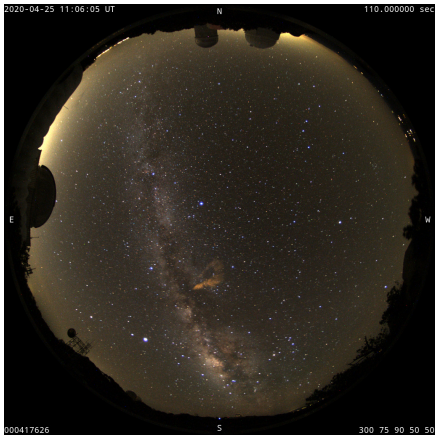


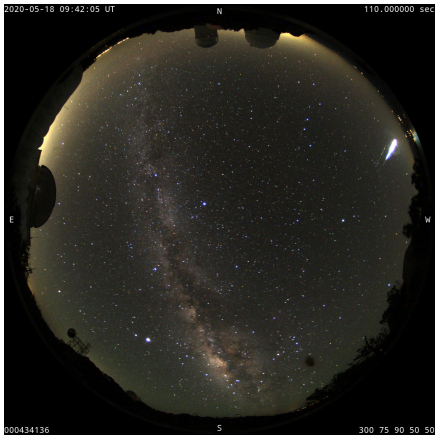


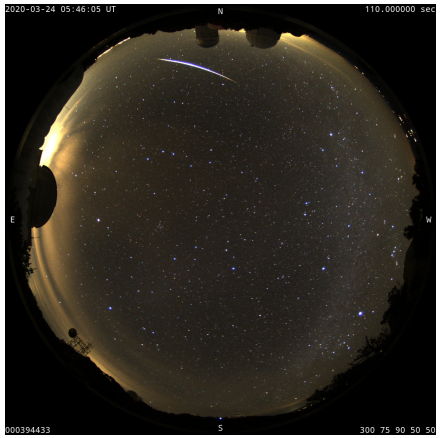
Meteors seen on the Spacewatch allsky camera

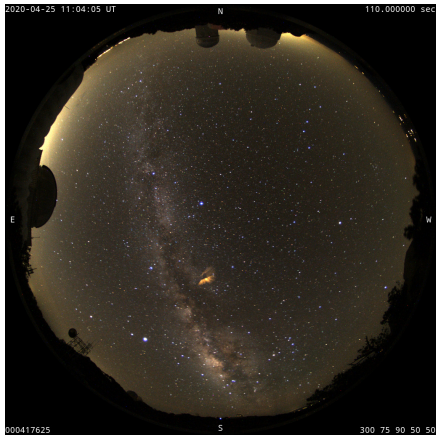


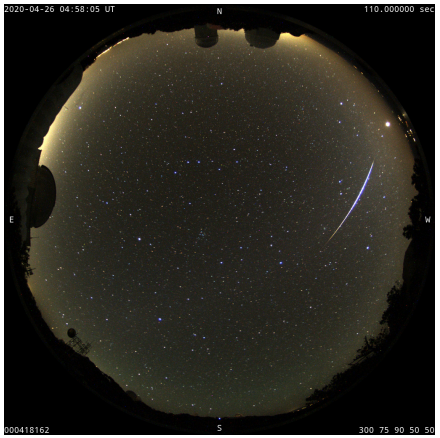


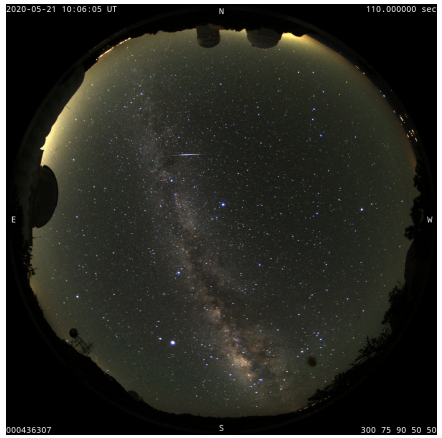












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