Science highlights from ZTF: Exotic Asteroids

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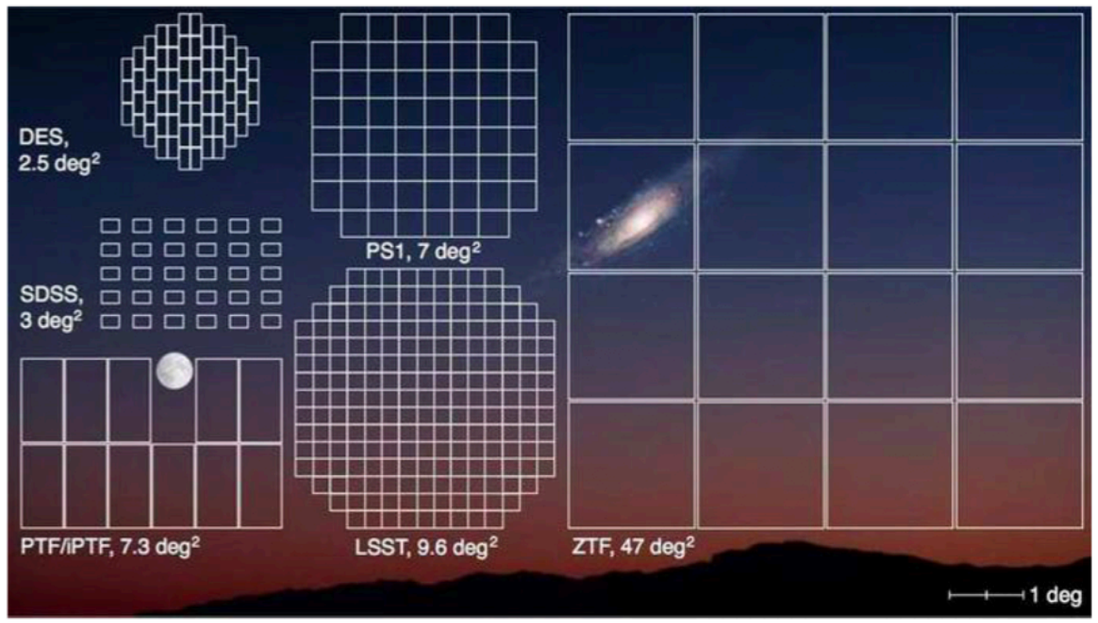
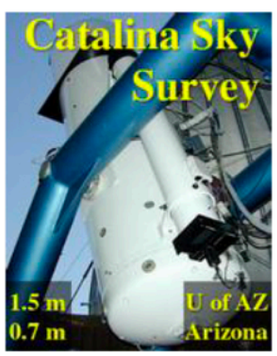
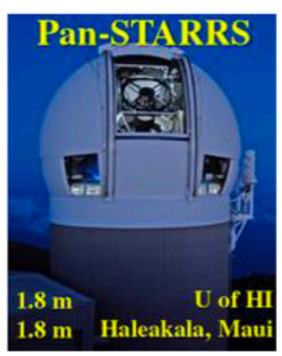
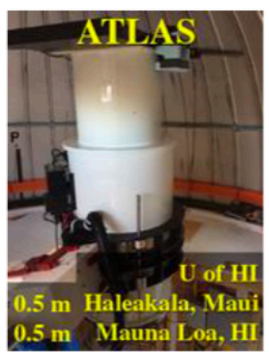
Celebrating ZTF-I & Soft Launch of ZTF-II 23 October, 2020

ZTF has an enormous field of view + moderate depth!









CSS 0.7-m

ATLAS 0.5-m (single system)

Surveys 3800 sq. deg/ h to r~20.5

NEO Discovery (Bolin, Helou, Kramer, Masci, Prince)

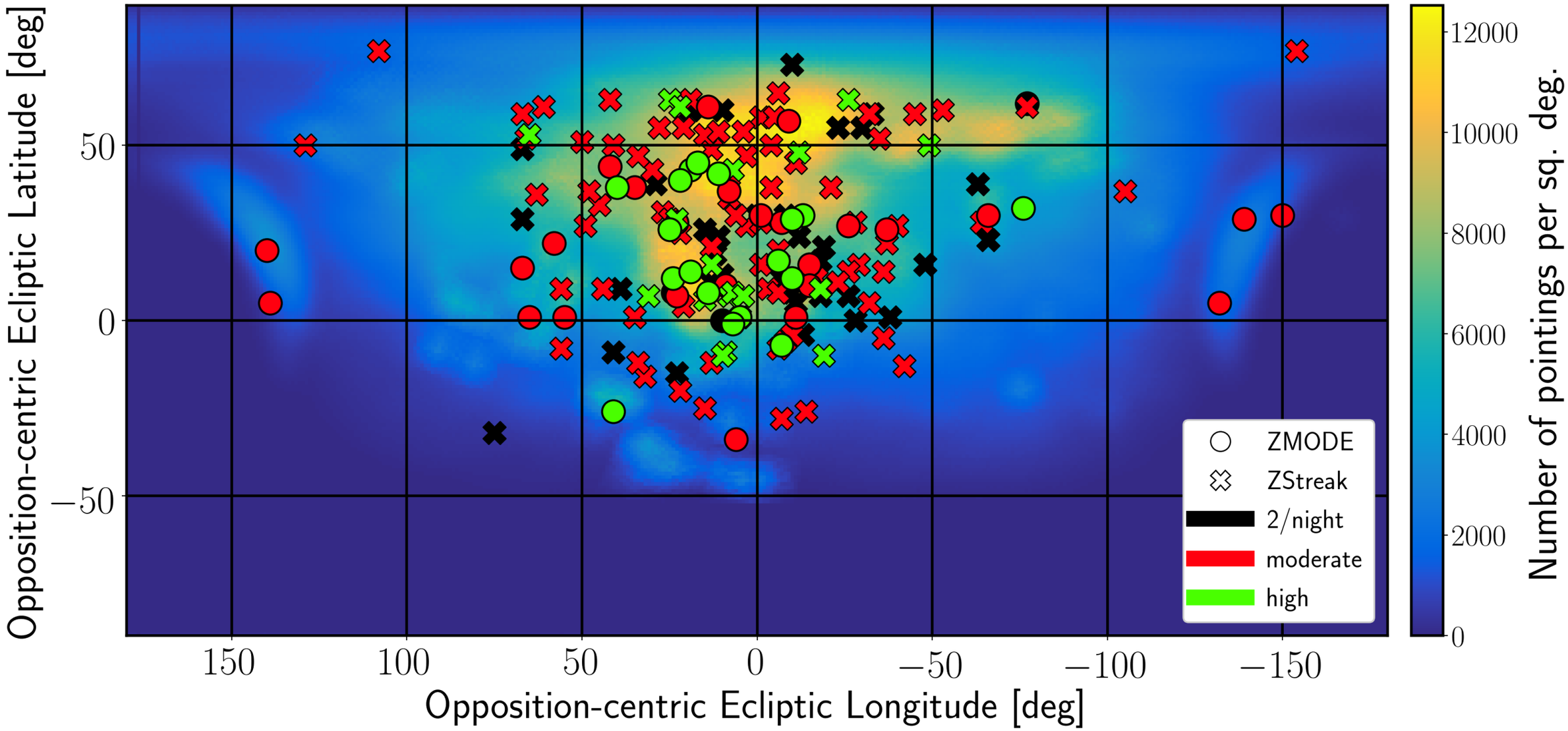
>180 NEOs discovered to date

- ZMODE: detection of point-like moving object
  - Main-belt asteroids; distant NEAs; comets

Masci et al. 2019

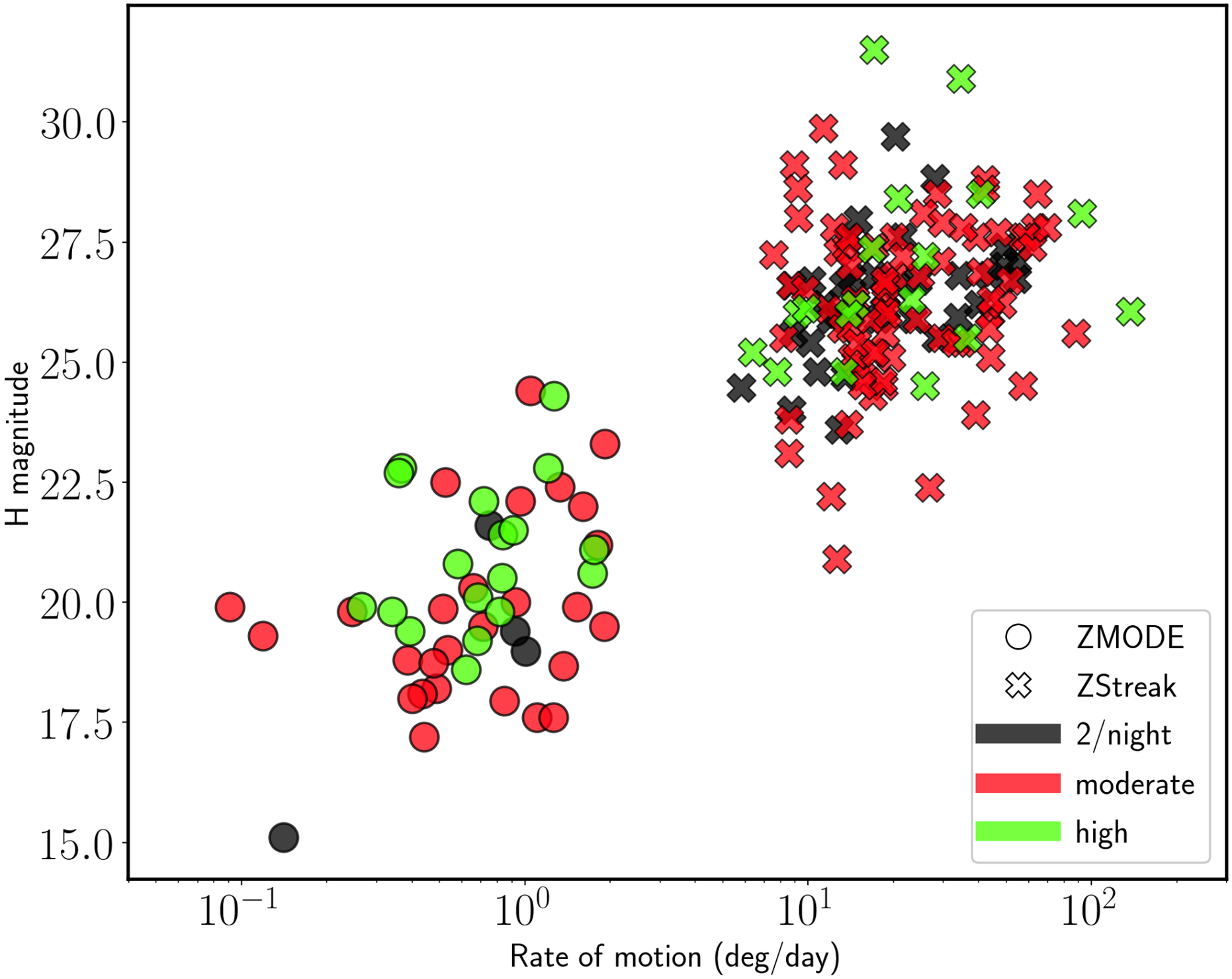
- ZSTREAK: detection of fast-moving objects (streaks)
  - Asteroids less than 0.01 au (~5 lunar distances) from the Earth
  - Also detect a lot of artificial satellites (a few dozens a night)
  - The new DeepStreaks algorithm reduced the false positive rate by 100x (thank you **Dima Duev** and **Ashish Mahabal**!)

Skyplane Distribution



Bolin et al. in prep

ZMODE/ZSTREAK Objects

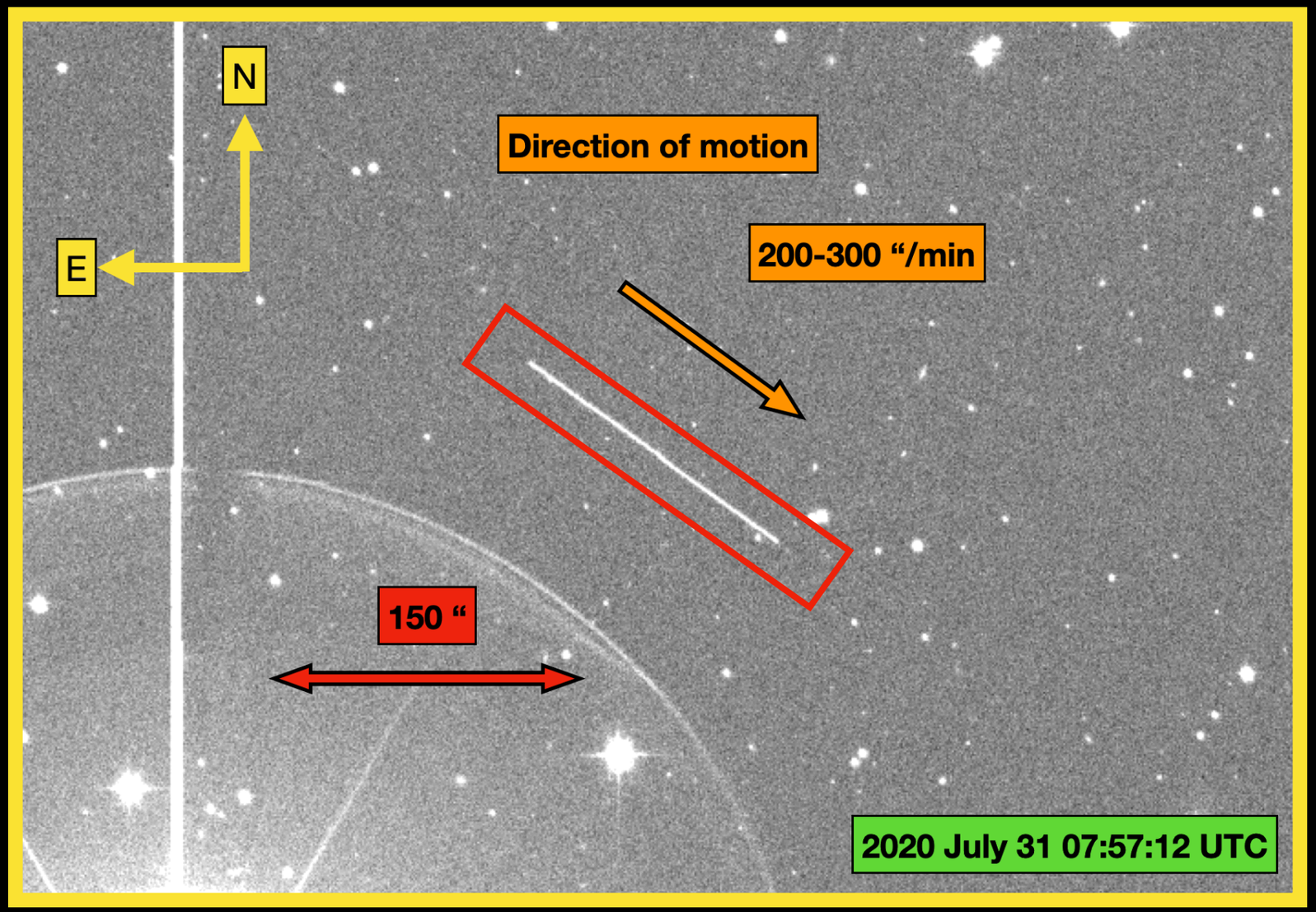


Objects moving as fast as ~130 deg/day

Bolin et al. in prep

Fast-moving asteroids

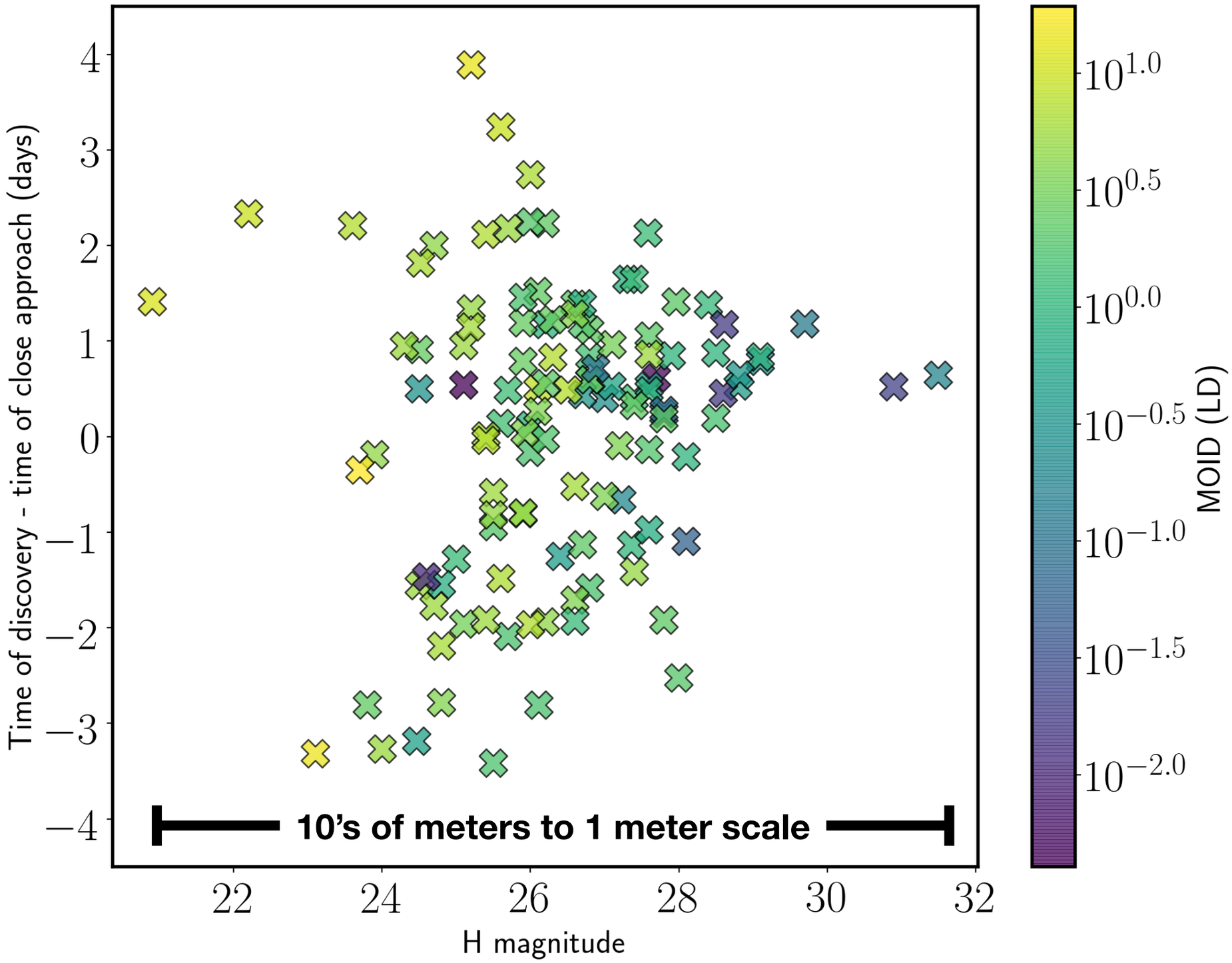
Bolin et al. 2020a, MPEC 2020-P04



2020 OQ6 motion > 130 deg/day!

Streaks are caused by asteroids and other objects moving fast enough to be streaked during the camera exposure. Notice how the moving streak object is elongated compared to the stationary background stars.

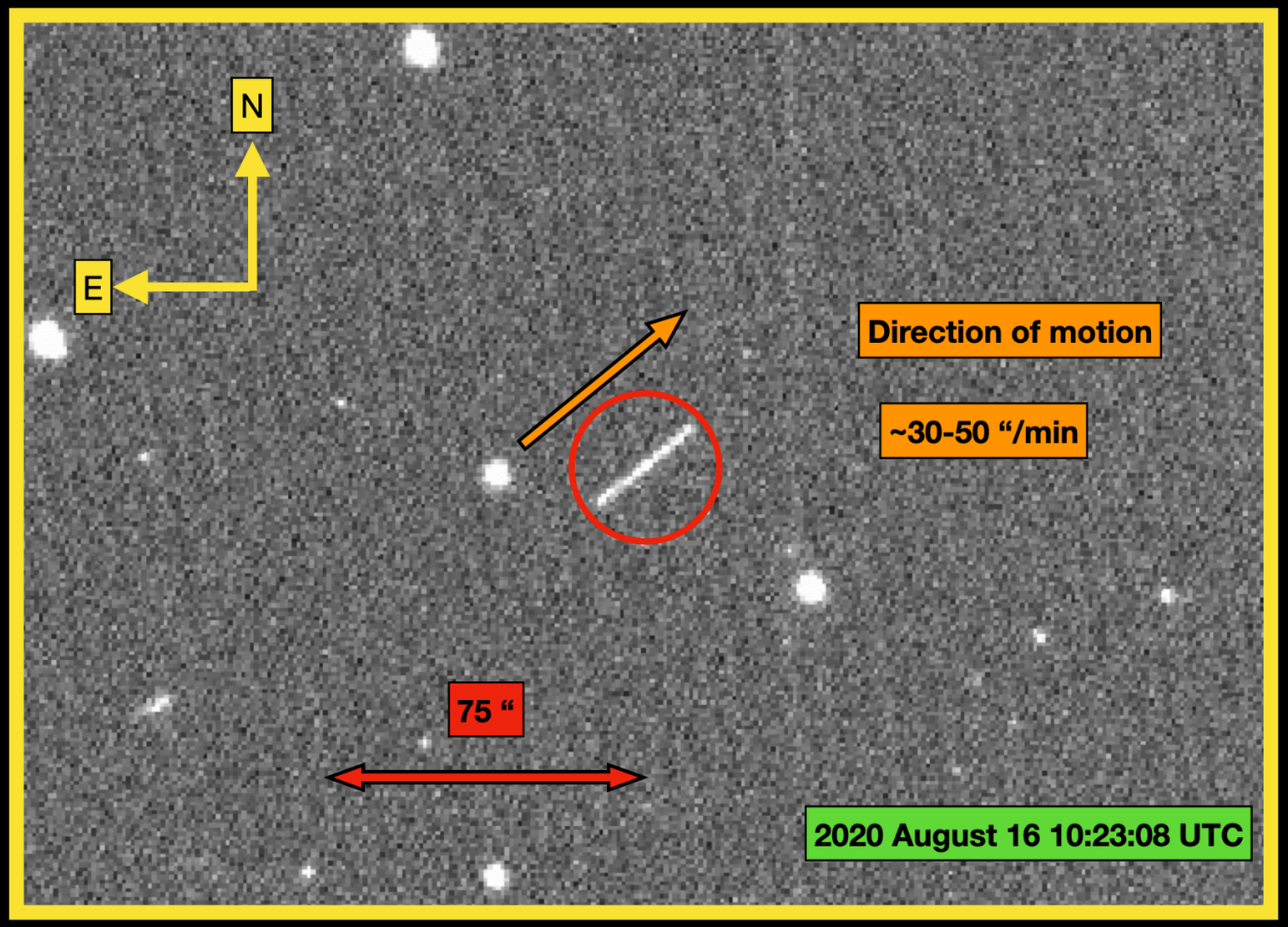
Close fly-by asteroids



Detect objects well inside the orbit of the moon

Bolin et al. in prep

2020 QG



Kunal Deshmukh (IITB)

Kritti Sharma (IITB)

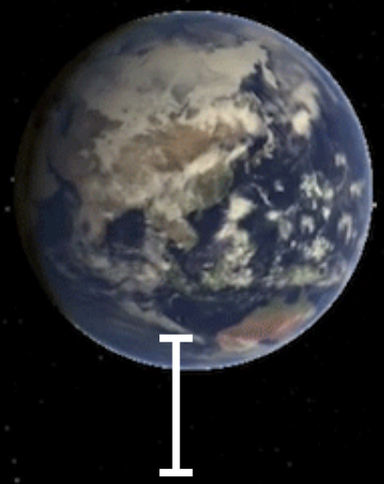
Chen-Yen Hsu (NCU)

Closest asteroid to fly-by the earth passing only 3,000 km above its surface

Discovered by student volunteers Kunal Deshmukh (IITB), Kritti Sharma (IITB), Chen-Yen Hsu (NCU)

Bolin et al. 2020b, MPEC 2020-Q51

2020 QG

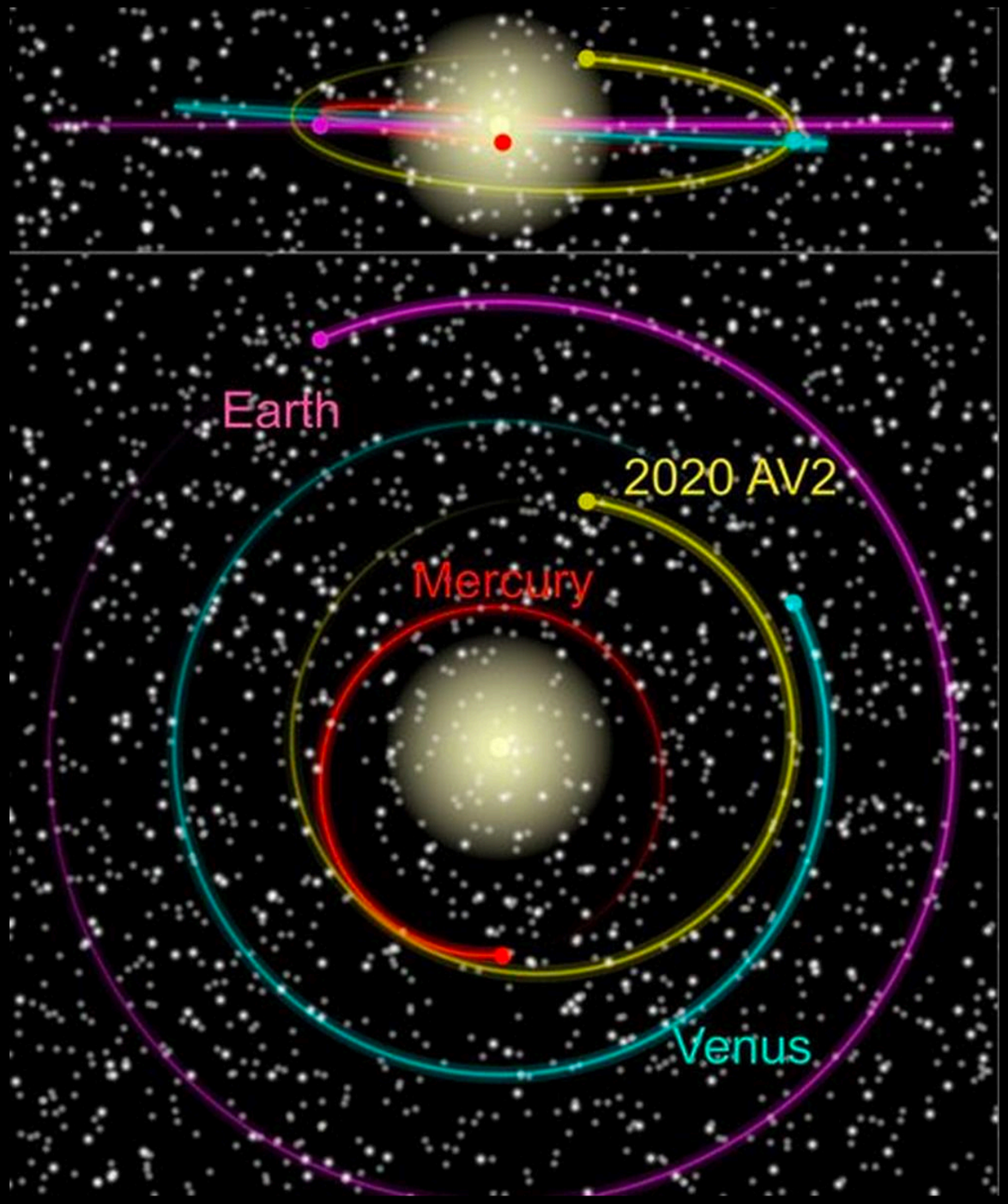


3,000 km

JPL/Farnocchia

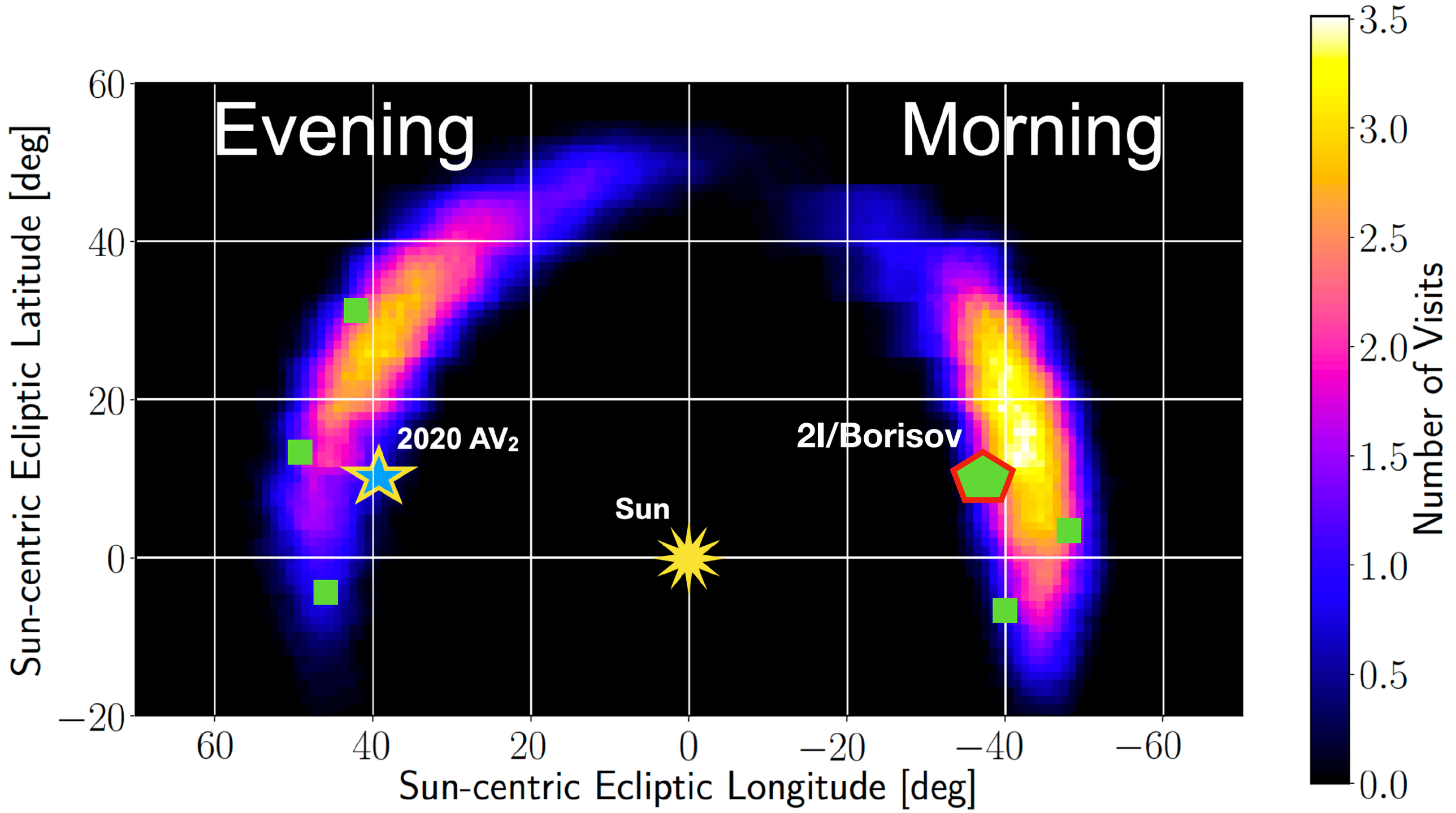
Closest asteroid to fly-by the earth passing only 3,000 km above its surface

Inner Earth/Inner Venus objects



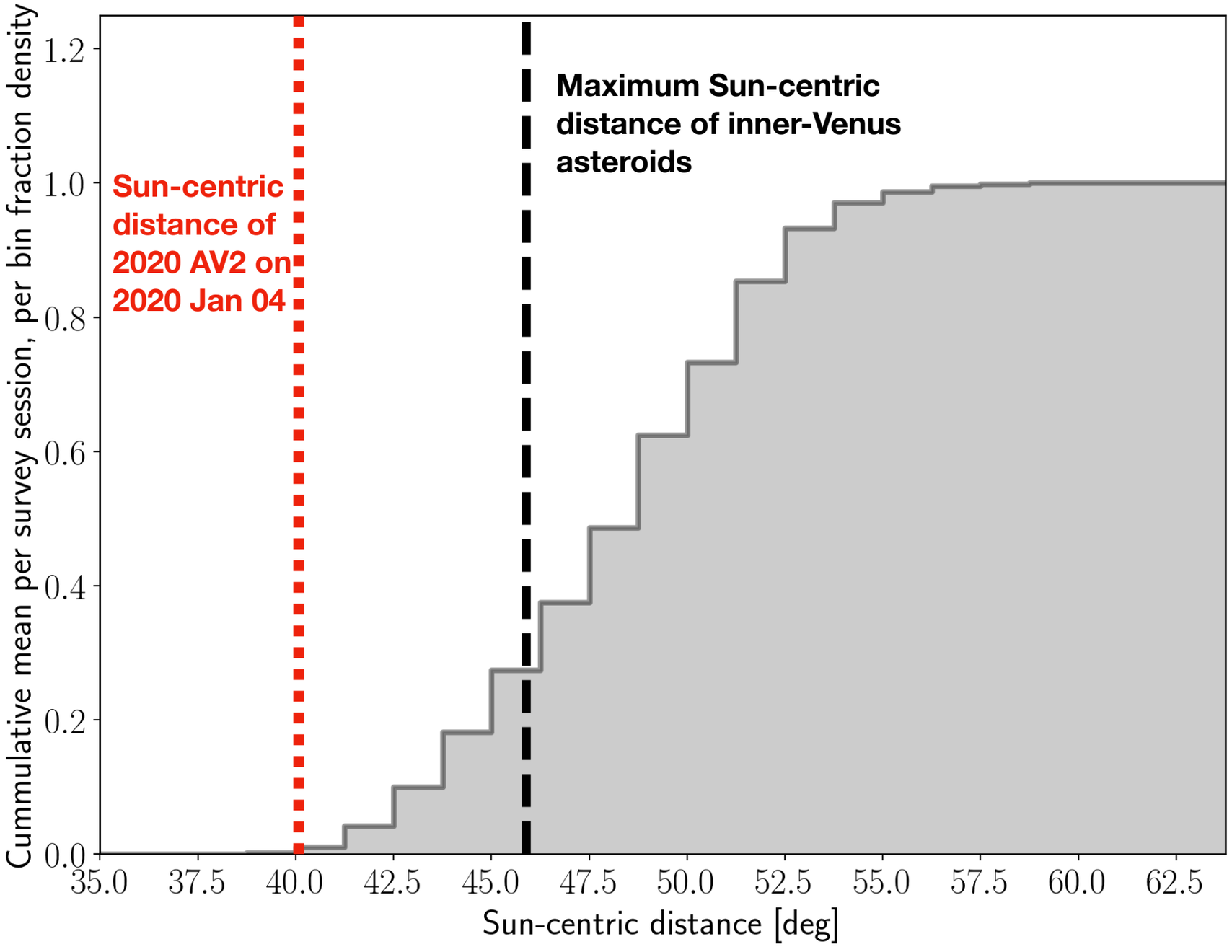
Bryce Bolin, Wing-Huen Ip, Frank Masci, and George Helou
Caltech/IPAC/NCU

Twilight survey



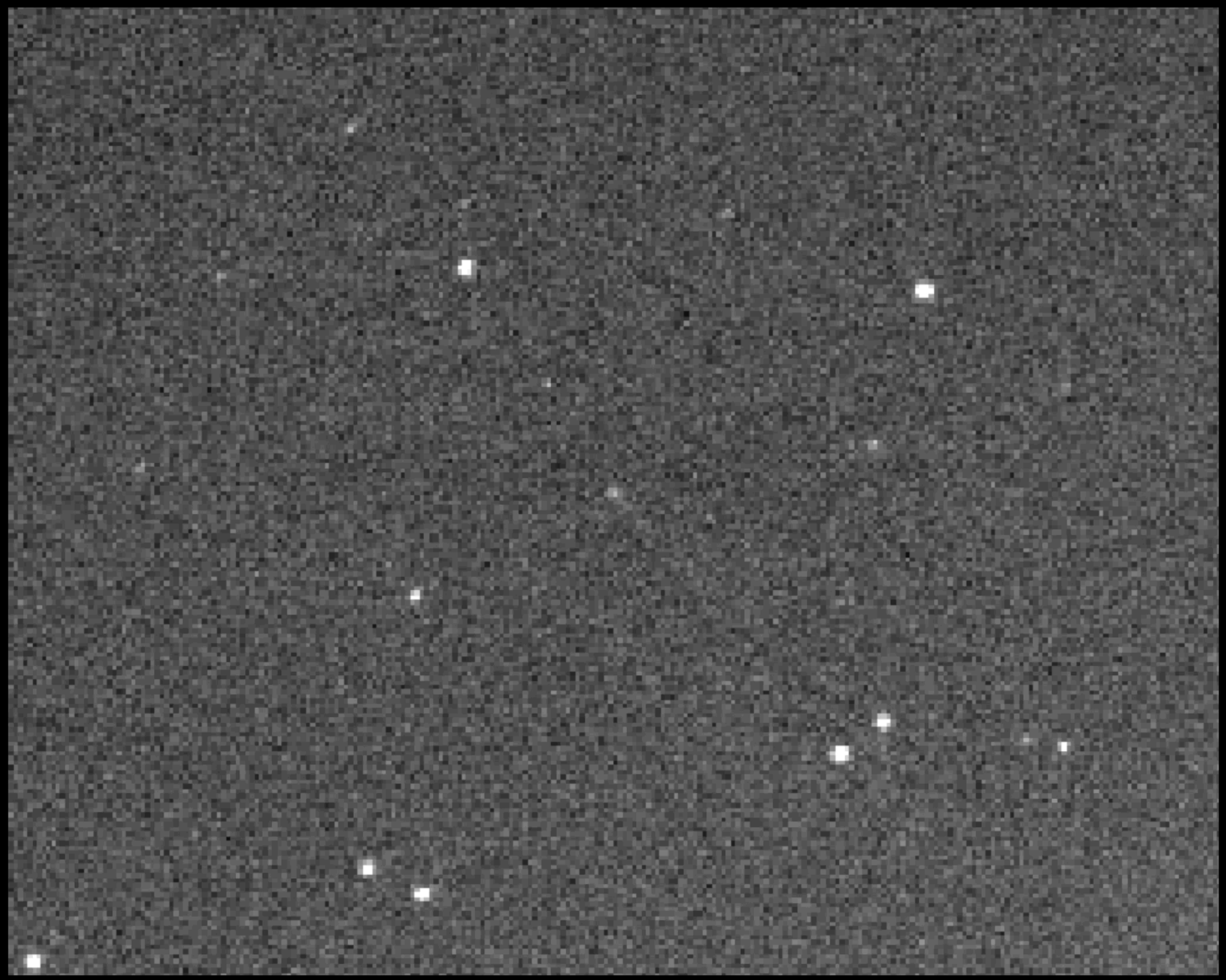
surveys sky ~18 deg. Twilight

TS Sun-centric distance



Allows survey of Sun-centric distances < 46 degrees where IVOs are located

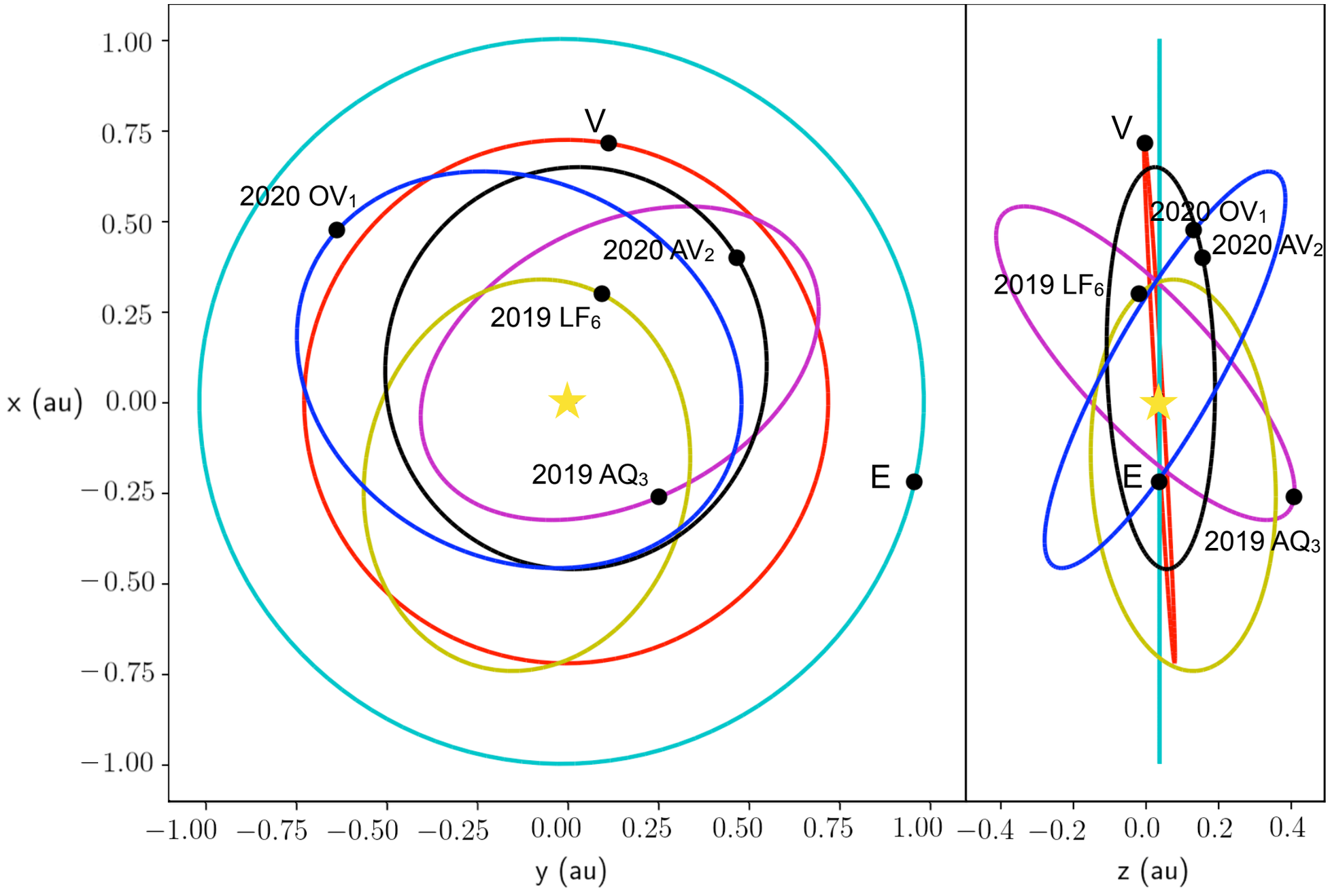
Discovery images



Discovered 2020 January 4, by ZTF, astrometric follow up by SEDM/KPED

Bolin et al. 2020c, MPEC 2020-O66; Ip, Bolin et al., under review

Inner-Earth/Inner-Venus objects

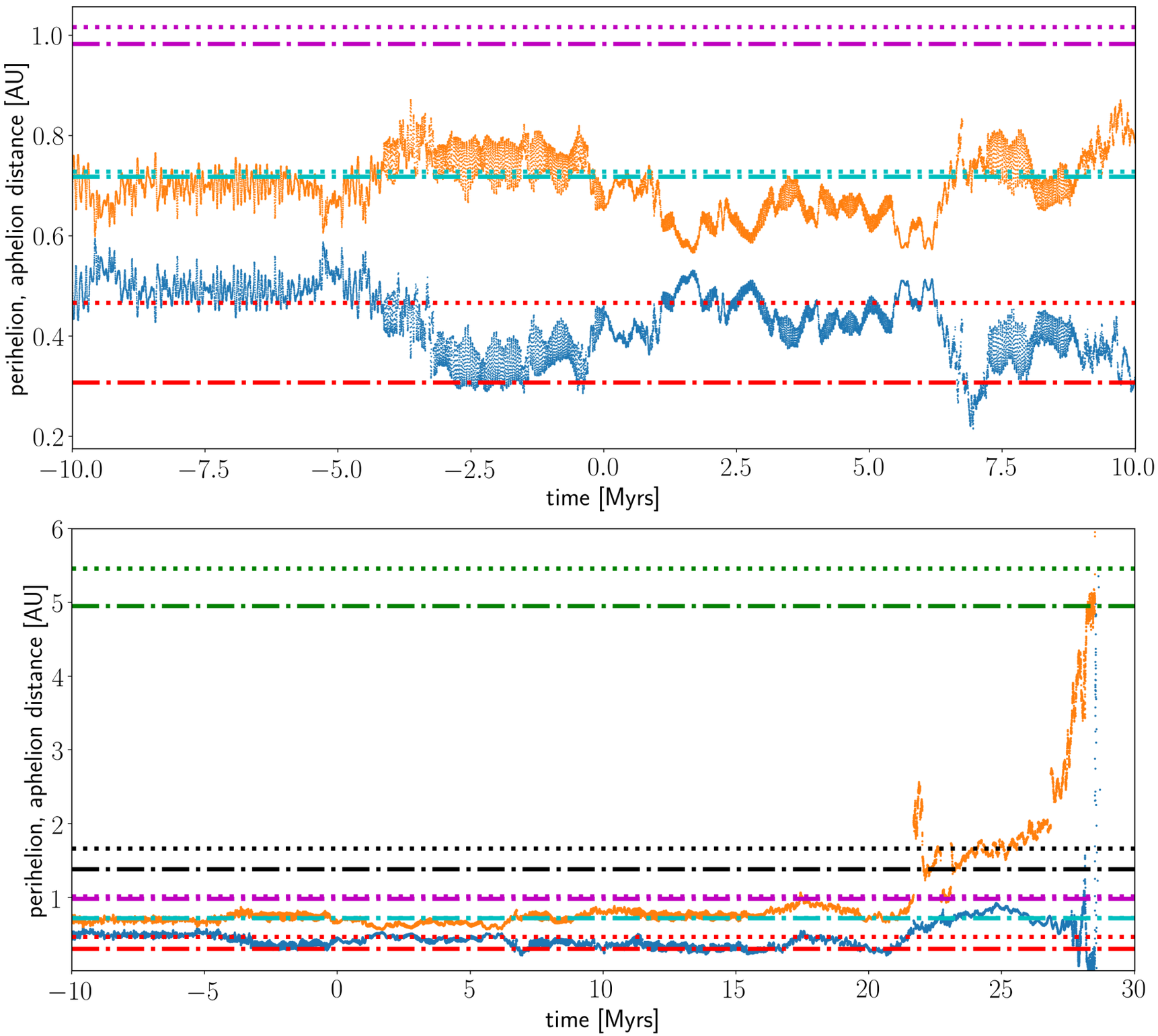


3 Atira/inner-Earth objets, 1 inner-Venus object

In 2020: inner-Venus object 2020 AV2 (Bolin et al. 2020c, MPEC 2020-A99) , Atira 2020 OV1 (Bolin et al. 2020d, MPEC 2020-O66)

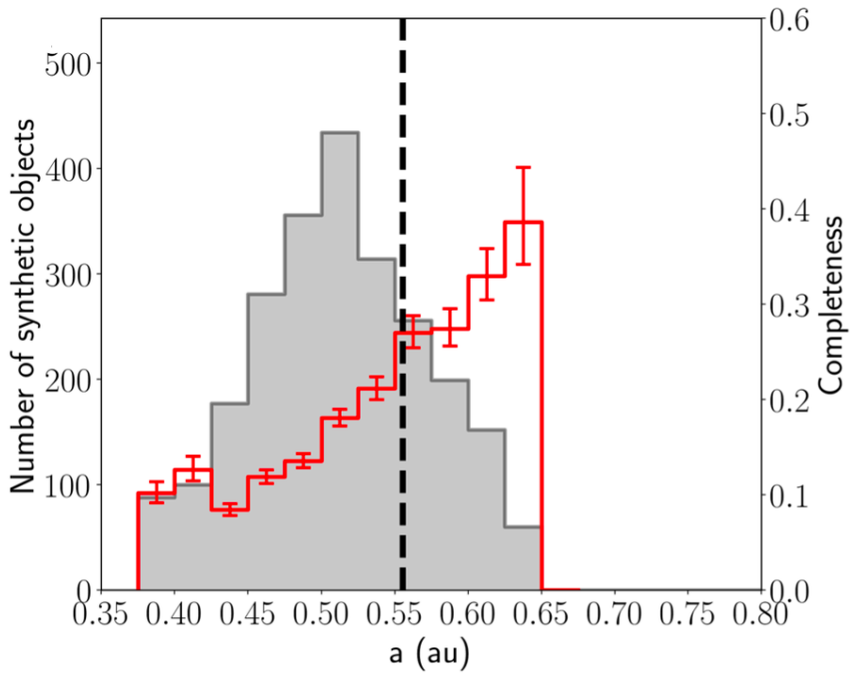
2020 AV2 presently the shortest orbital asteroid: 151.192 days

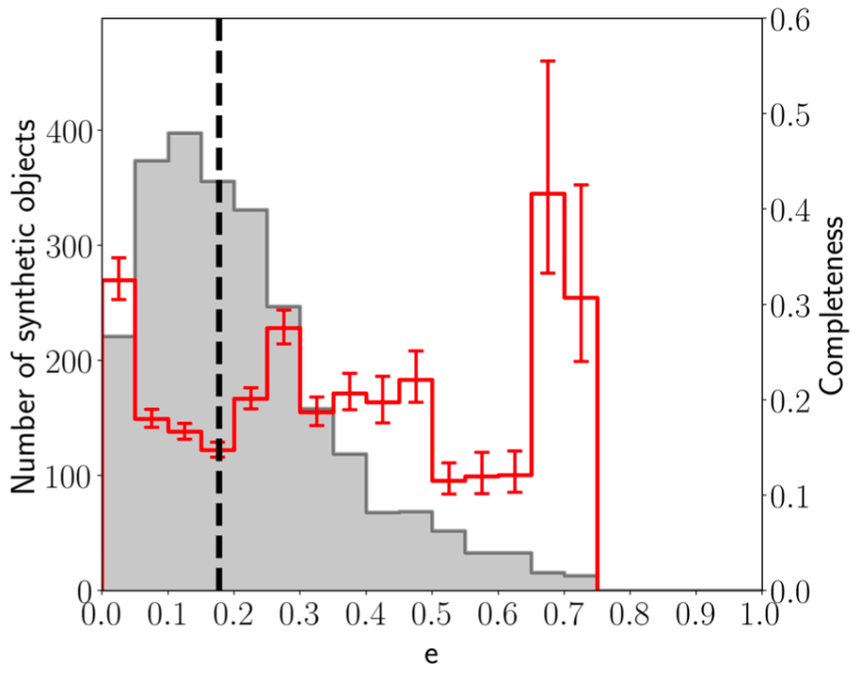
Orbital evolution

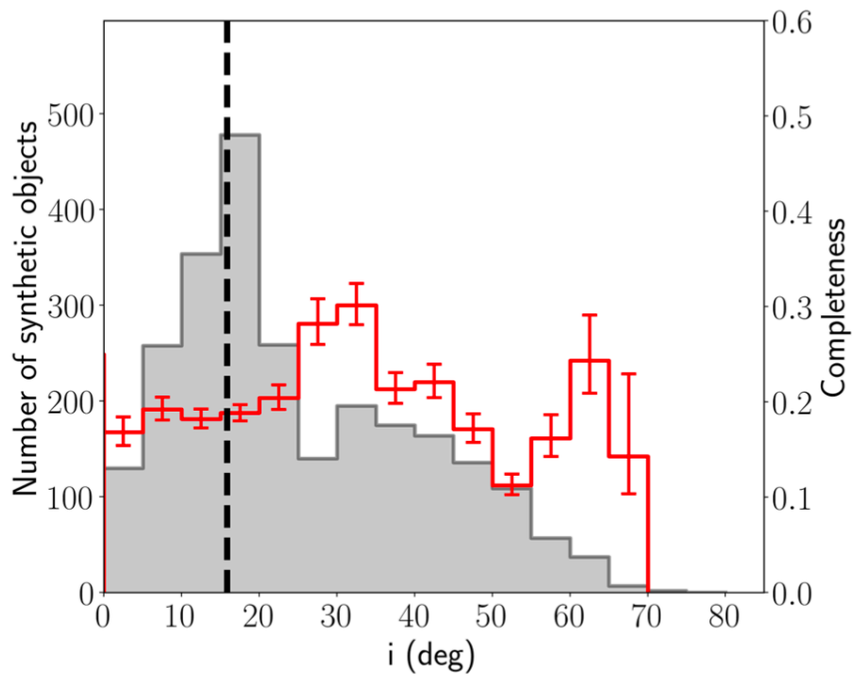


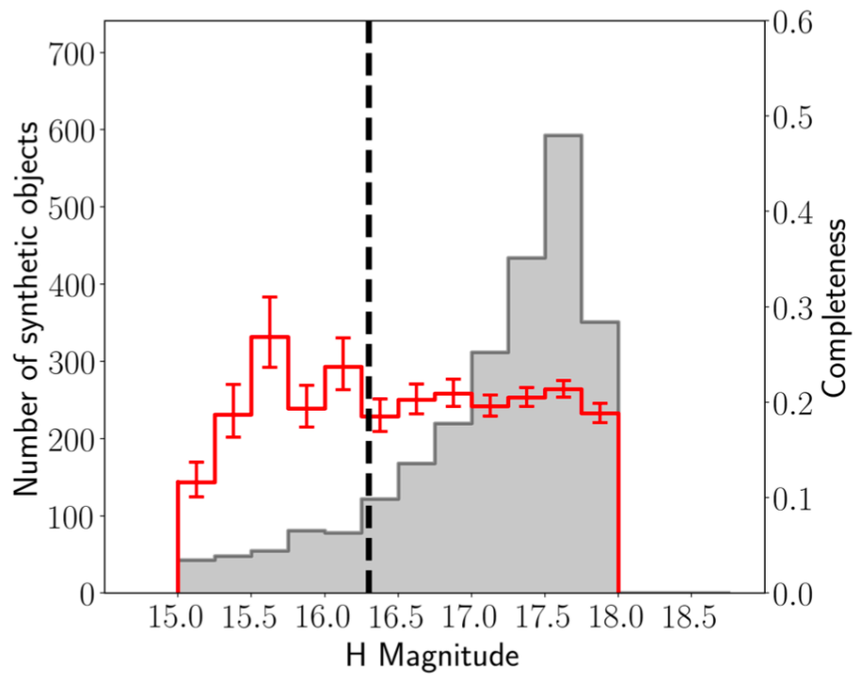
close encounters with terrestrial planets, lifetime 10-20 Myrs

Survey completeness









Combined Granvik et al. 2018 IEO model with ZTF Survey Simulation

~5% chance of detecting 2020 AV2

Interstellar Objects

Only two known ISOs: 1I/'Oumuamua and 2I/Borisov

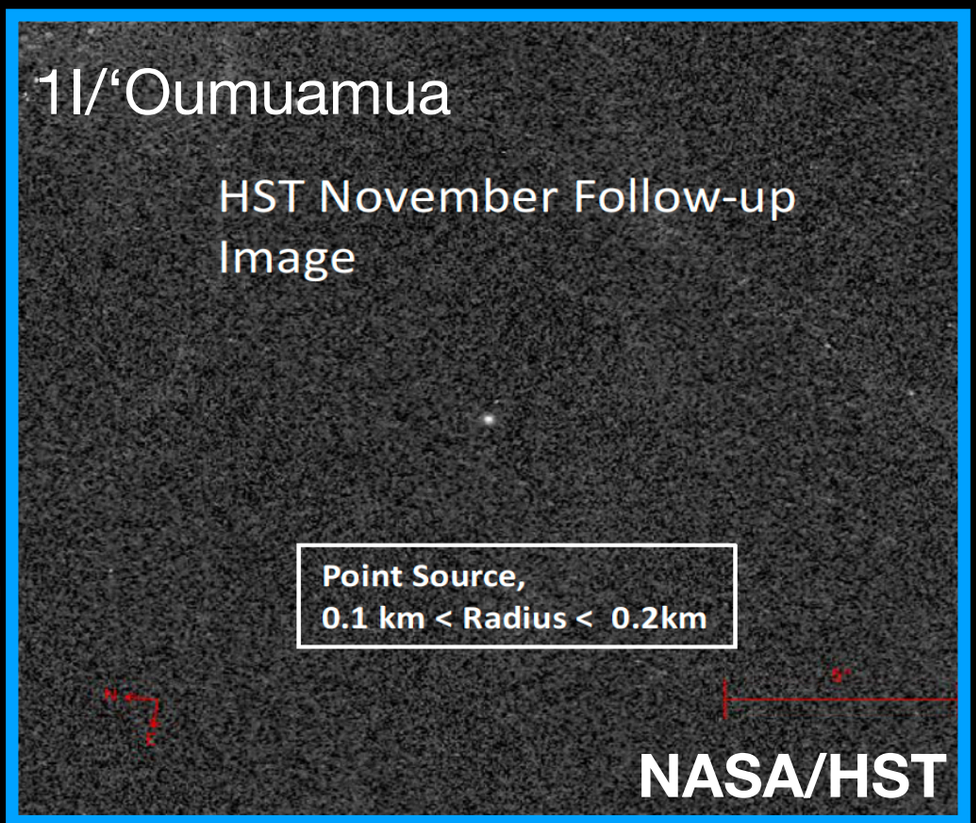
Eccentricity >1 !!!

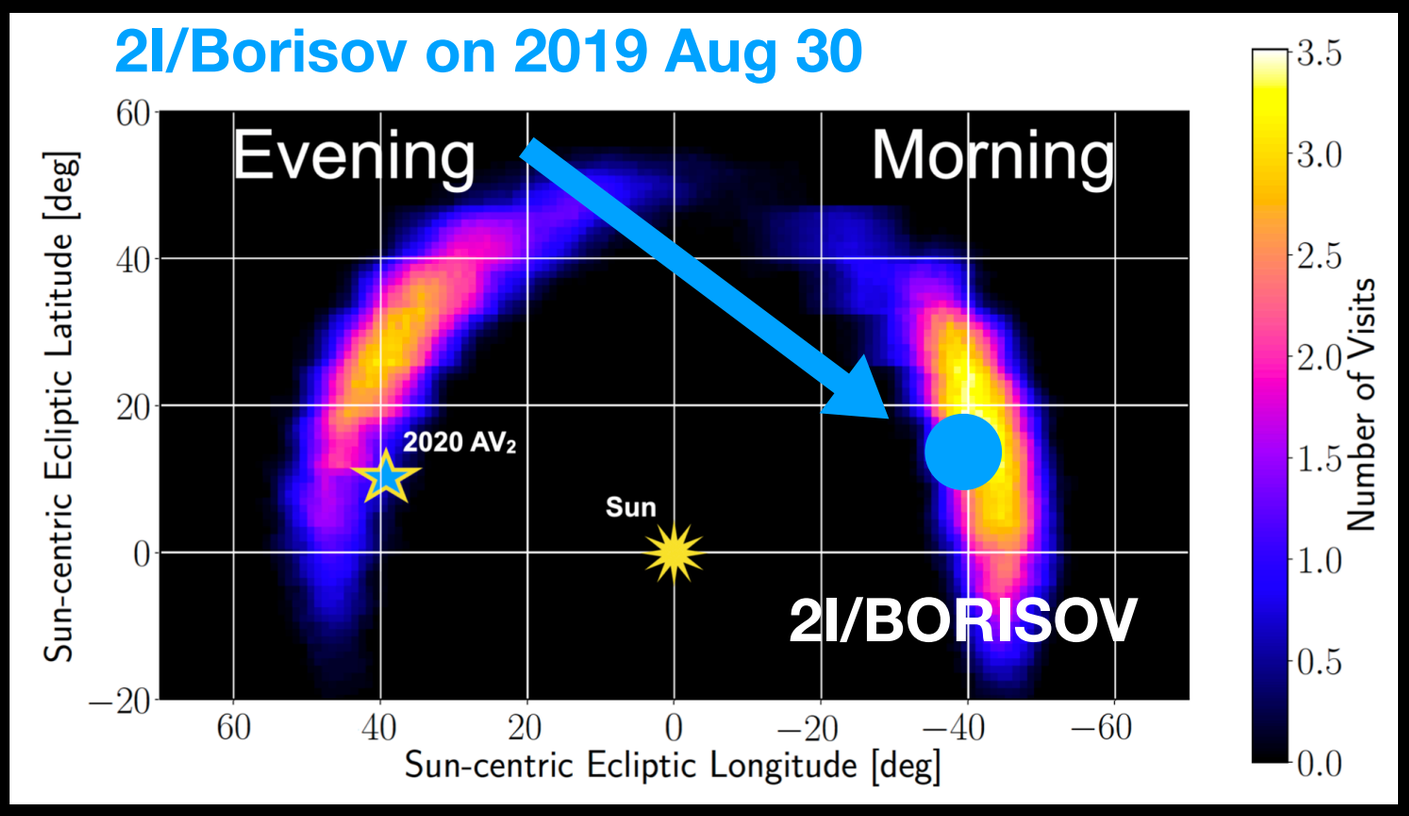
$e_{1I} = 1.20$, q = 0.25 au, $v_\infty = 26.3$ km/s

$e_{2I} = 3.35$, q = 2.0 au, $v_\infty = 32.5$ km/s

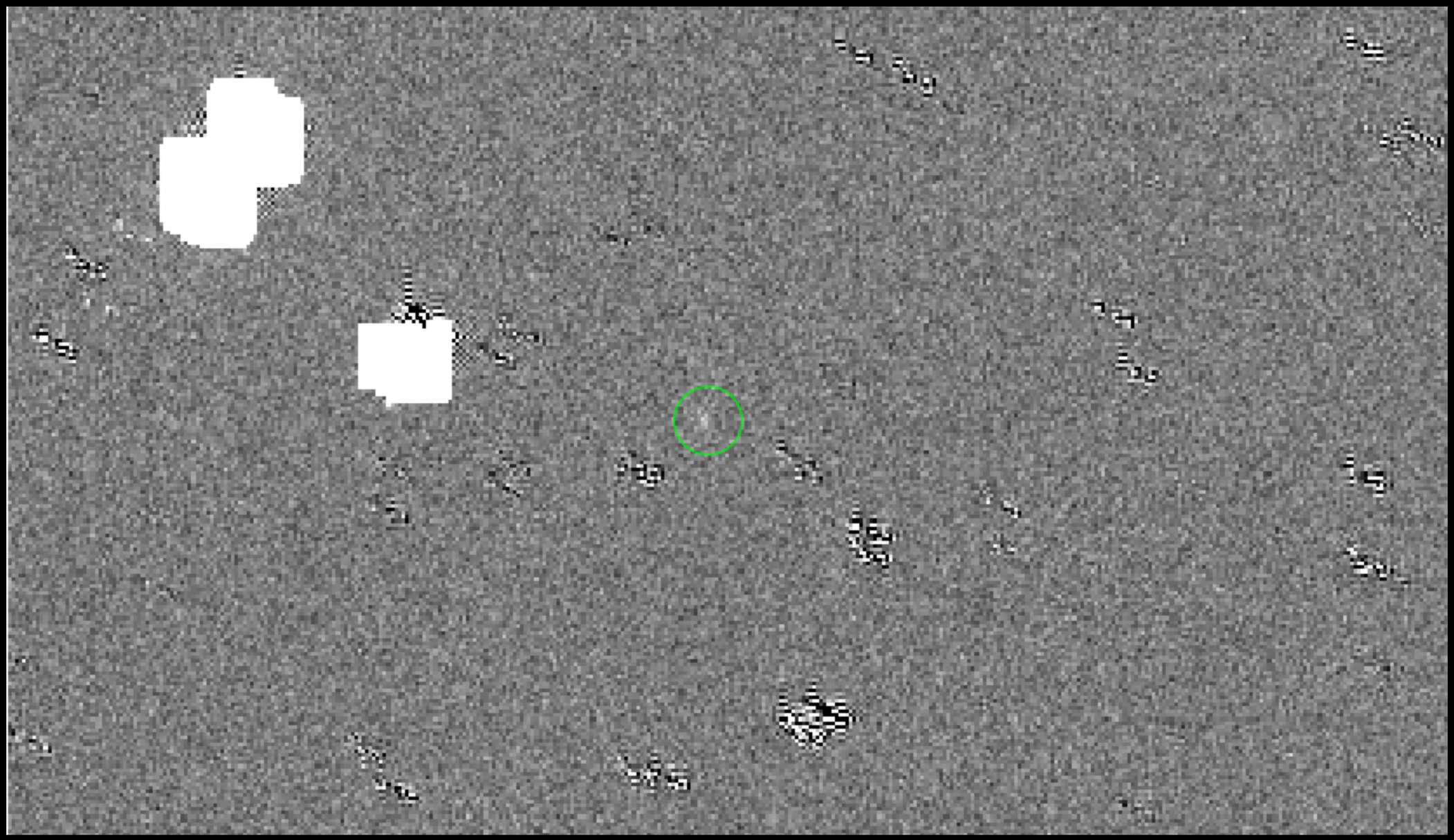
2I Discovered by G. Borisov on 2019 Aug 30

Found at V~18 in morning twilight





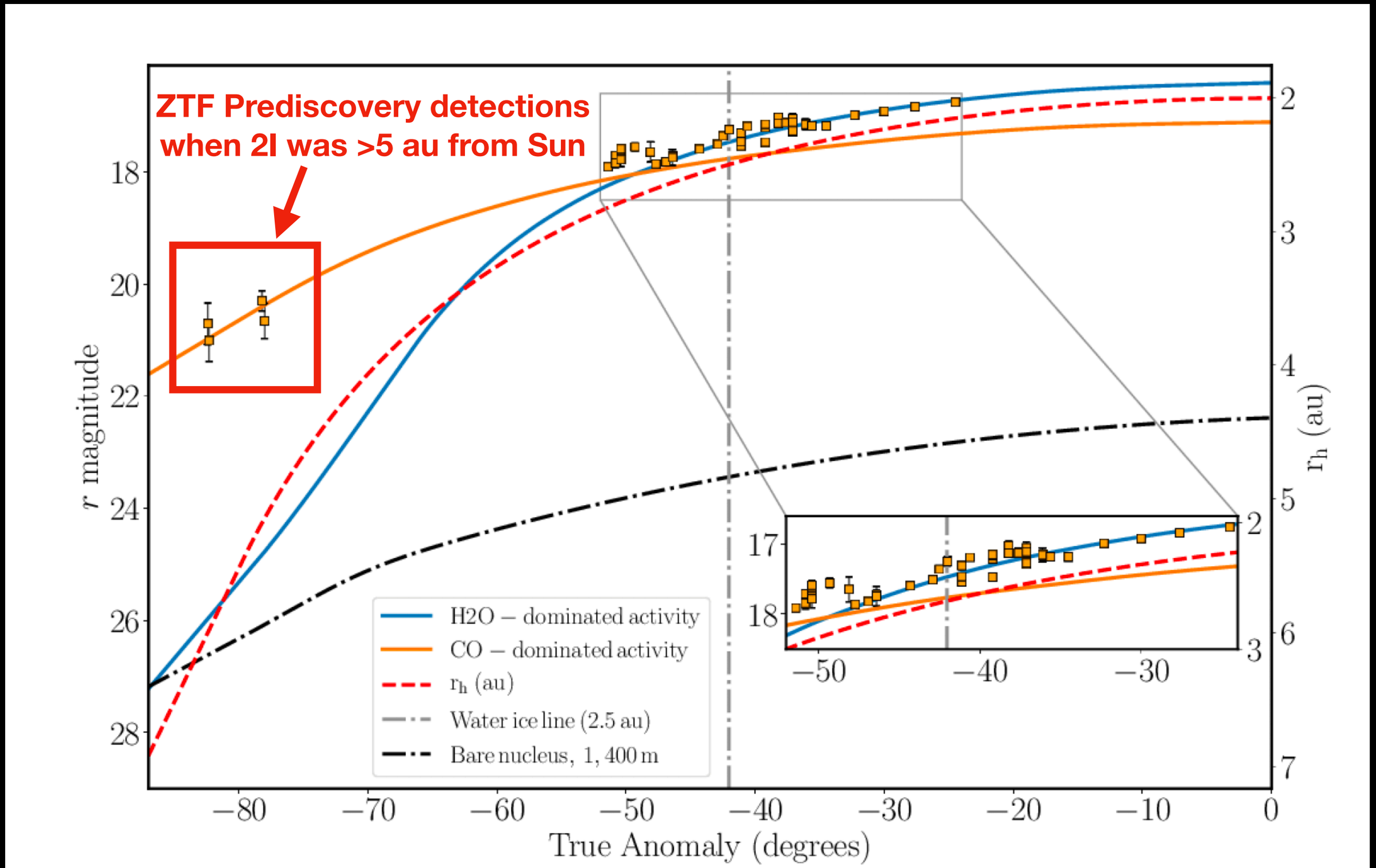
ZTF Pre-disovery data



2019-05-02 180 s r band stack,
more detections as far back as Dec 2018

Bolin et al. 2020e

Long-term Lightcurve



Brightness in pre-discovery images implies activity at >6 au, supervolatile (CO) activity

Recent turn on of H_2O

Bolin et al. 2020e

Summary

- **ZTF: Large étendue optical survey**
- **Two distinct modes of NEO detection: ZMODE and ZSTREAK**
- **Unique capability to identify fast-moving and close in objects (2020 OQ6, 2020 QG!)**
- **Capability of finding inner-Venus and inner-Earth objects (2020 AV2, 2020 OV1)**
- **Supports Solar System Science (Comets, Interstellar Objects)**