Dr. Á. Paula Granados C.

TAOS2

Detecting new objects beyond Neptune through occultations

TAOS2

- The Transneptunian Automated Occultation survey
  - Blind occultation survey to detect faint trans-Neptunian objects (TNOs)
  - International collaboration

Academia Sinica Institute of Astronomy and Astrophysics (ASIAA)

Taiwan

Universidad Nacional Autónoma de México (UNAM)

México

Center for Astrophysics | Harvard & Smithsonian (CfA)

USA

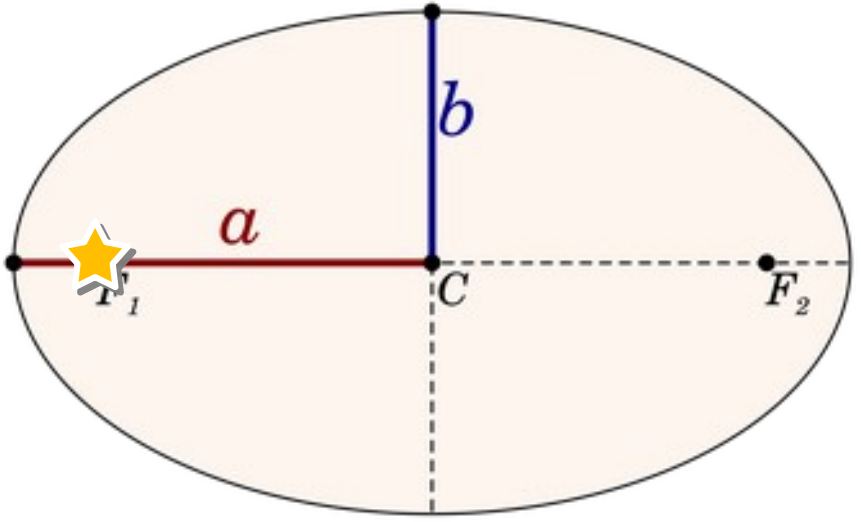
National Research Council Canada (CADC)

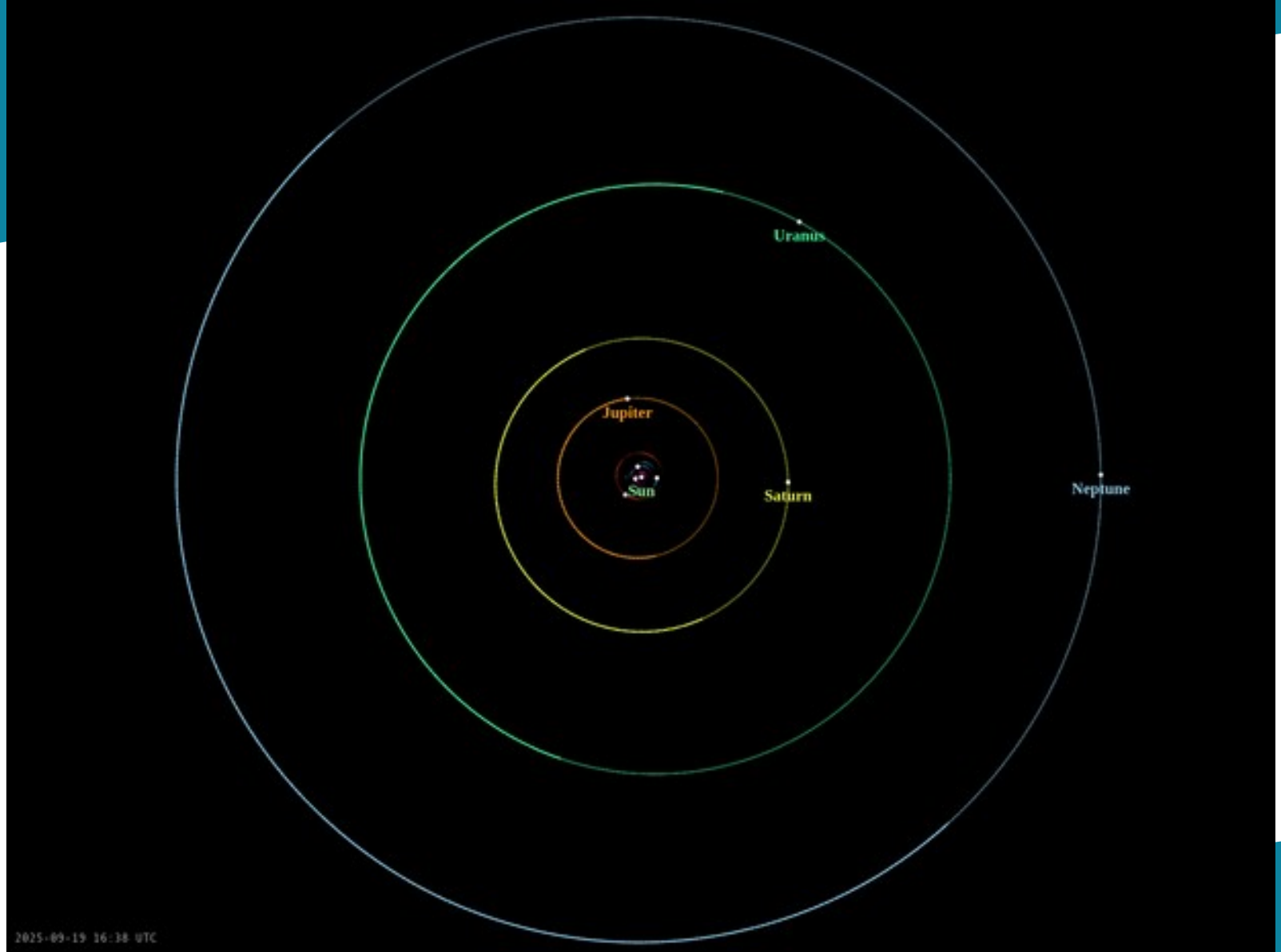
Canada

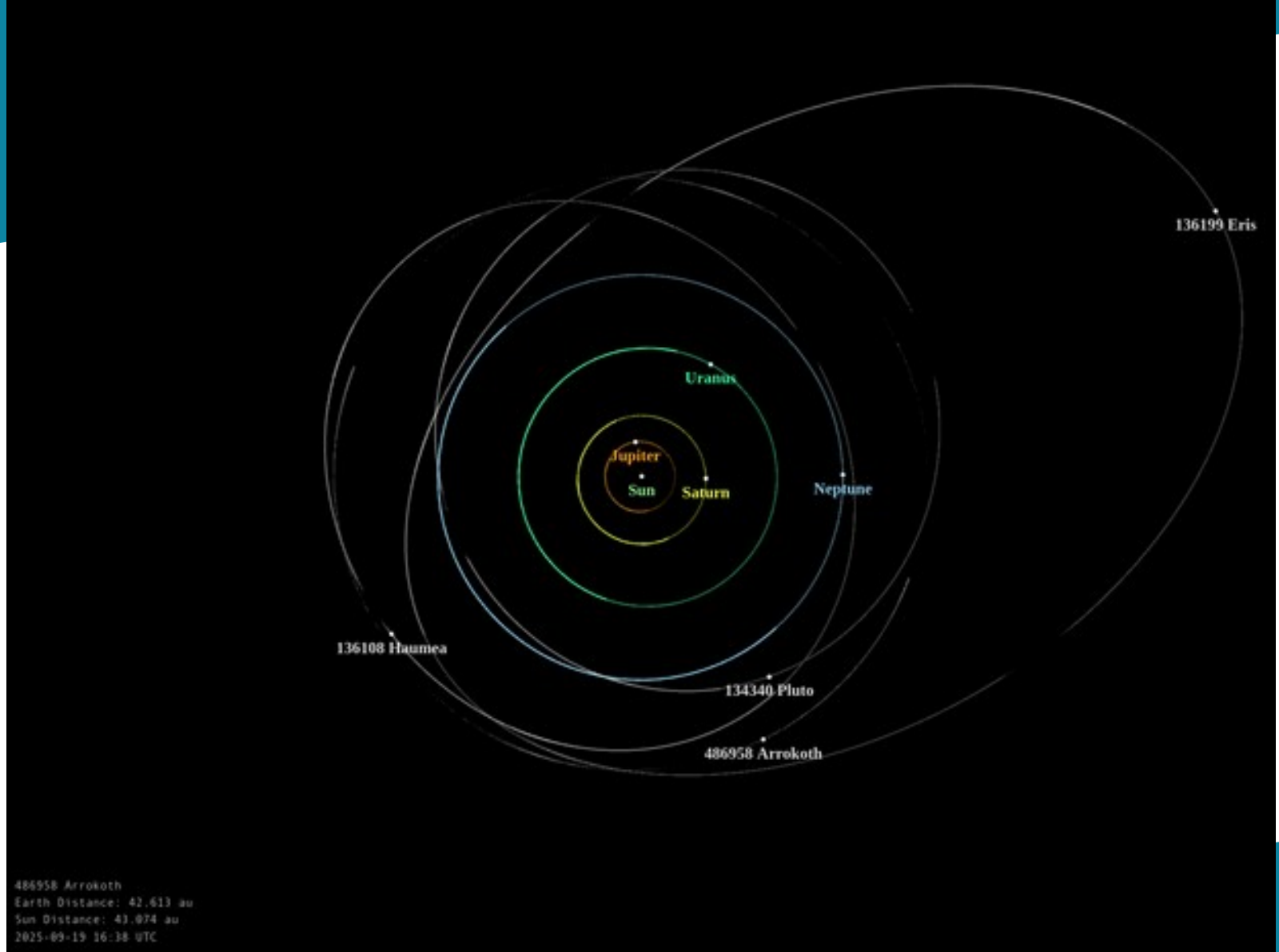
TNOs

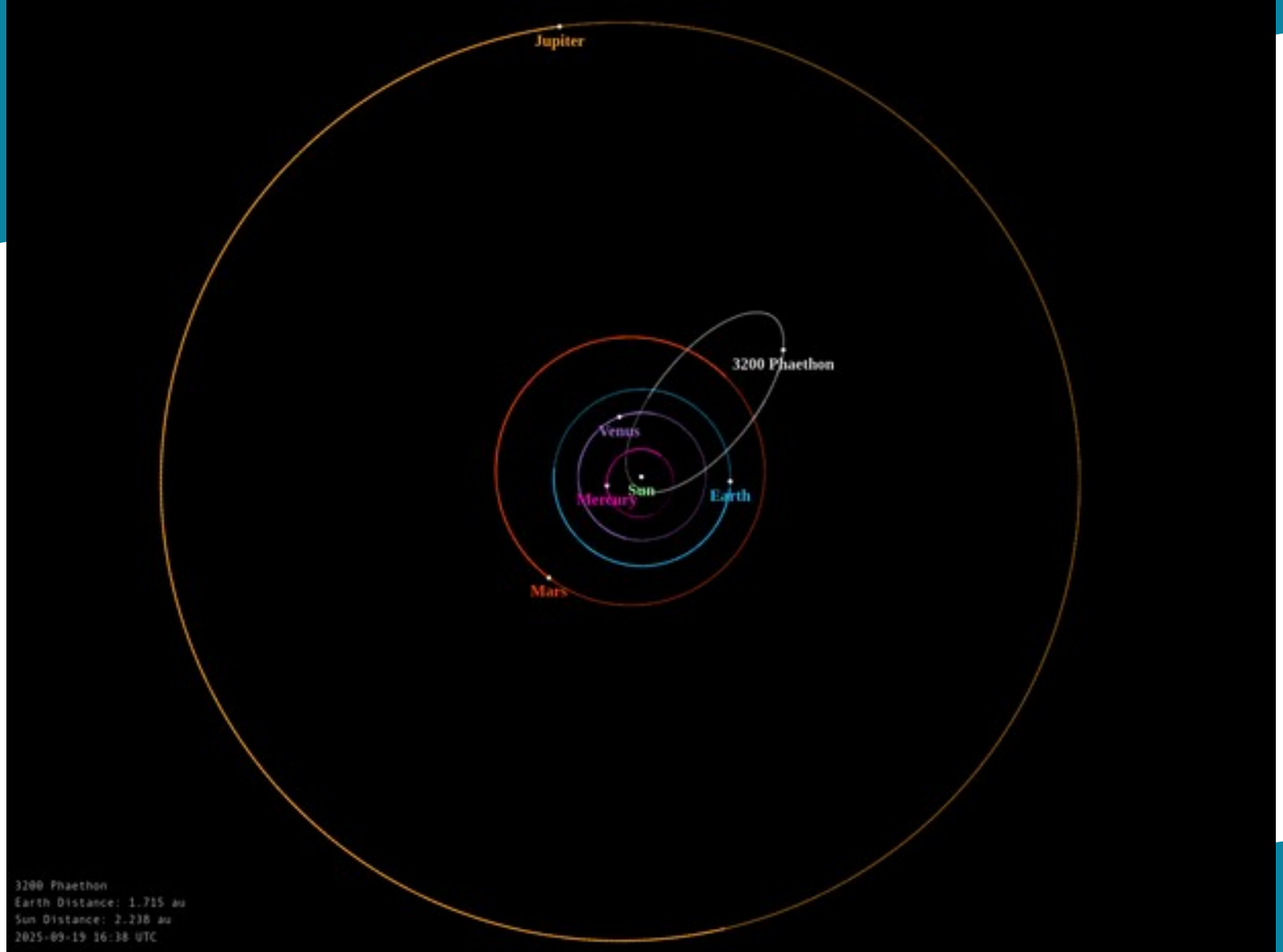
Trans-Neptunian Objects = objects beyond Neptune's orbit

- Orbits with semi-major axis: $a \geq a_{Neptune} = 30.1$ au
- Relics of the Solar System formation (planetesimal remnants)



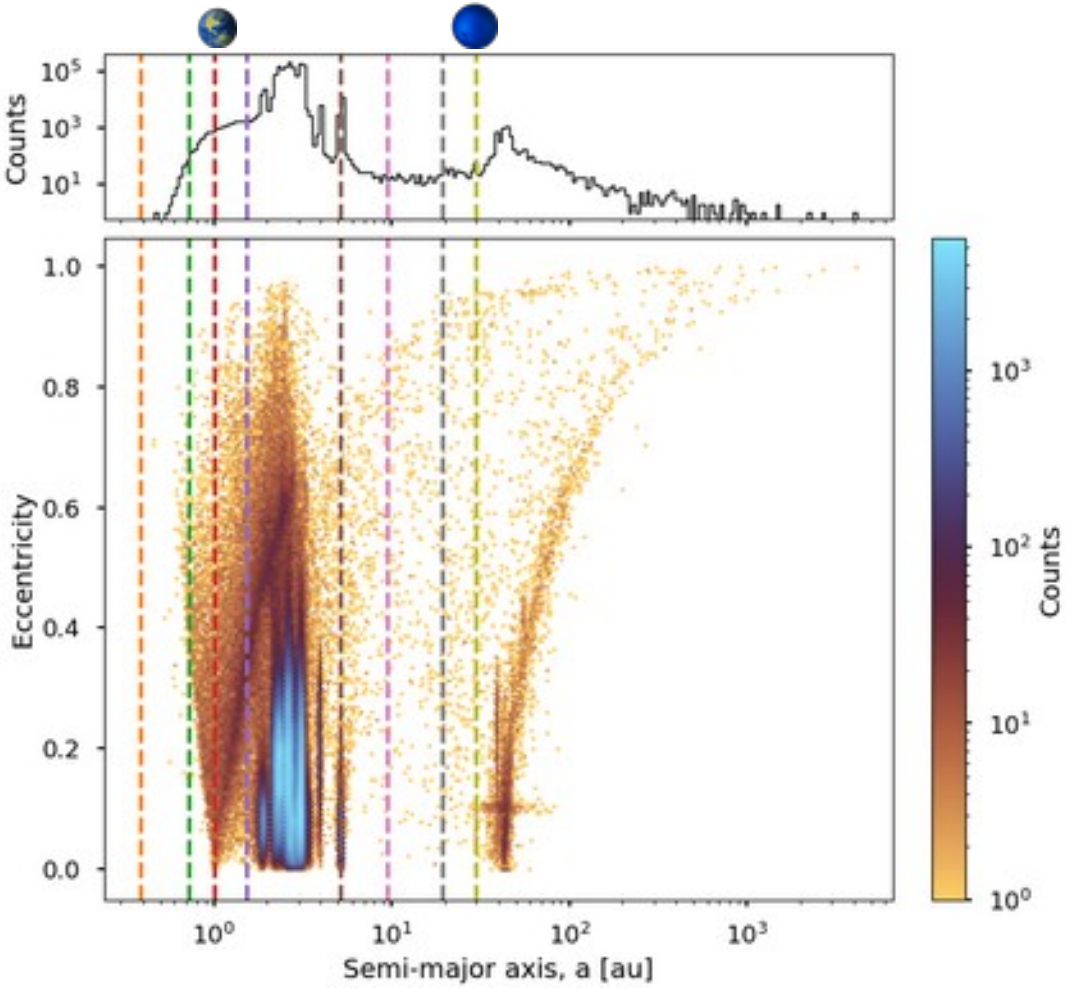

Uranus
Jupiter
Sun
Saturn
Neptune
2025-09-19 16:38 UTC


136199 Eris
Uranus
Jupiter
Sun
Saturn
Neptune
136108 Haumea
134340 Pluto
486958 Arrokoth
486958 Arrokoth
Earth Distance: 42.613 au
Sun Distance: 43.074 au
2025-09-19 16:38 UTC


Jupiter
3200 Phaethon
Venus
Sun
Mercury
Earth
Mars
3200 Phaethon
Earth Distance: 1.715 au
Sun Distance: 2.238 au
2025-09-19 16:38 UTC

Why TNOs?

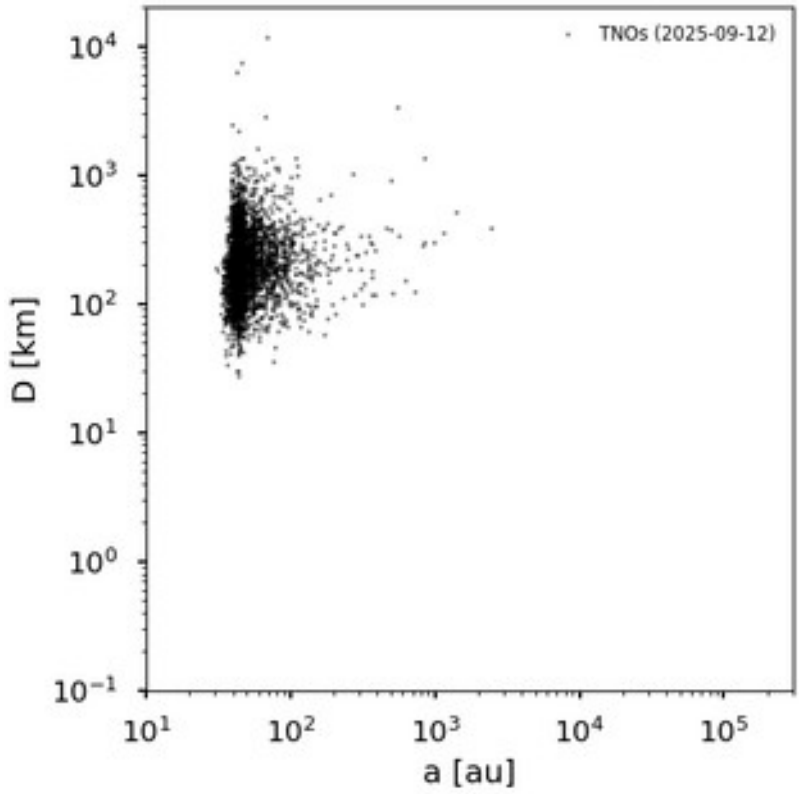
- Spatial distribution helps understand the dynamical evolution of the Solar System
- Size distribution - understand the collisional erosion of planetesimals
- Direct searches well-suited to objects with D≳30 km
  - Smallest TNO detected so far D ~ 22 km (assuming p=0.04)
- Much of the mass may be in smaller objects



TAOS2

- The Transneptunian Automated Occultation survey
  - Blind occultation survey to detect faint trans-Neptunian objects (TNOs)
  - International collaboration
  - **Main goal: measure the size distribution of TNOs with diameters between 0.2 to 30 km**

Occultations



- It is complicated to estimate the size of objects with direct imaging
- Usually an albedo needs to be assumed
- Albedos are usually unknown

Occultations

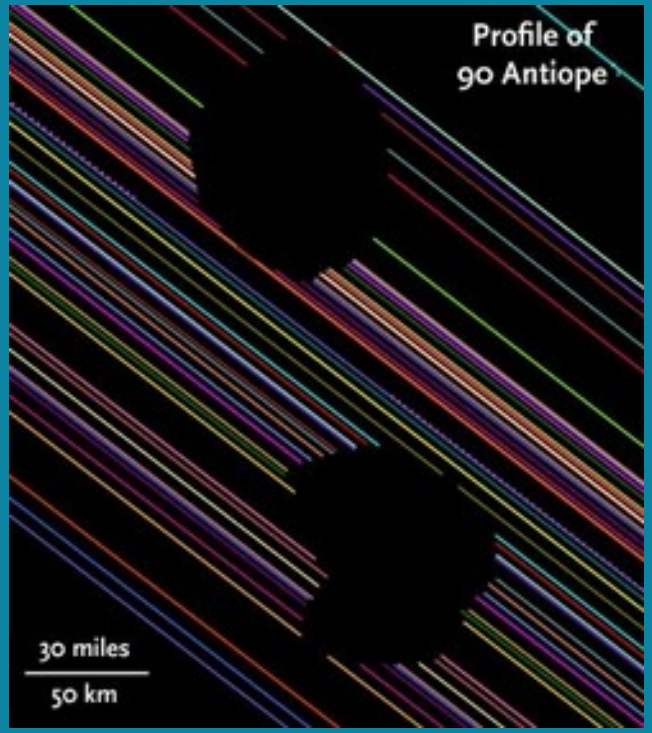
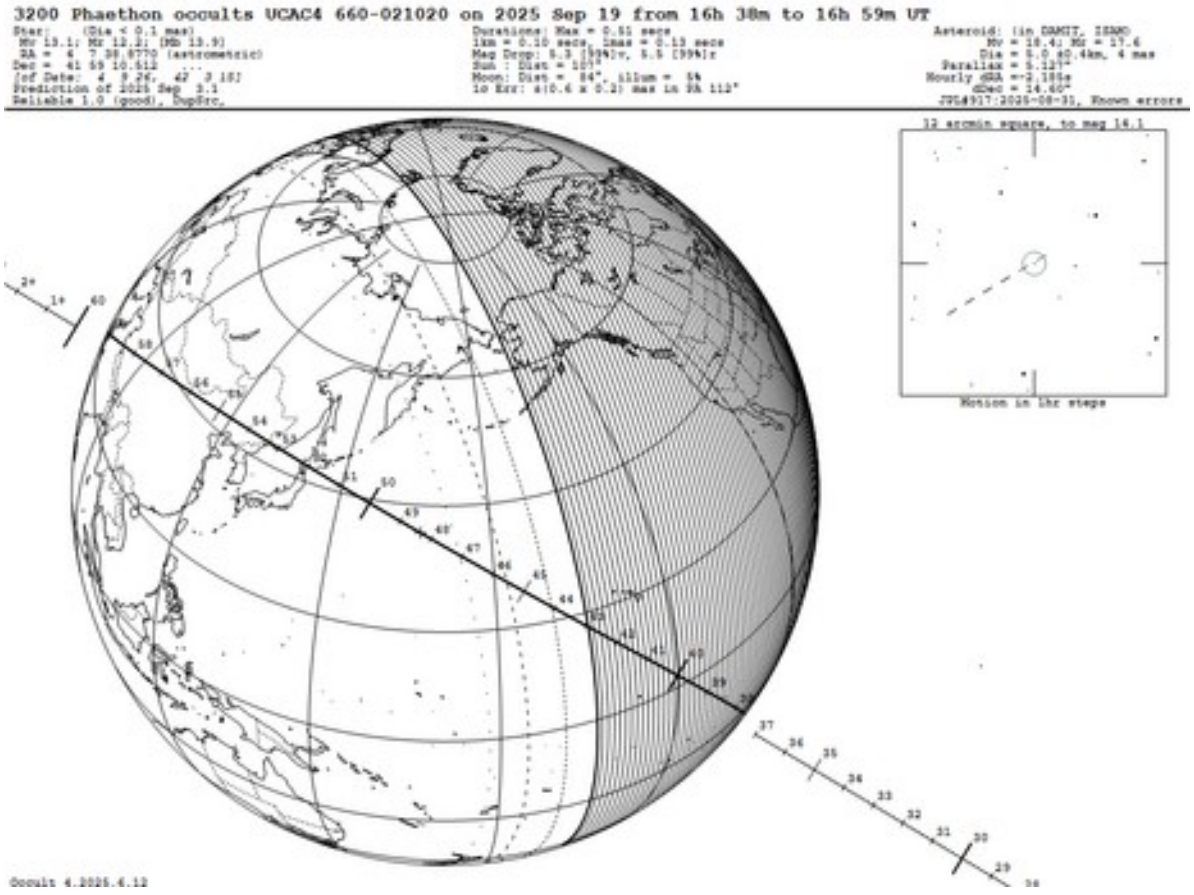


Image credit: IOTA

- Occultations allow us to indirectly study the size and shape of an object
- However, occultations look different when we consider kilometre-size TNOs
  - Strong diffraction features in projected shadows

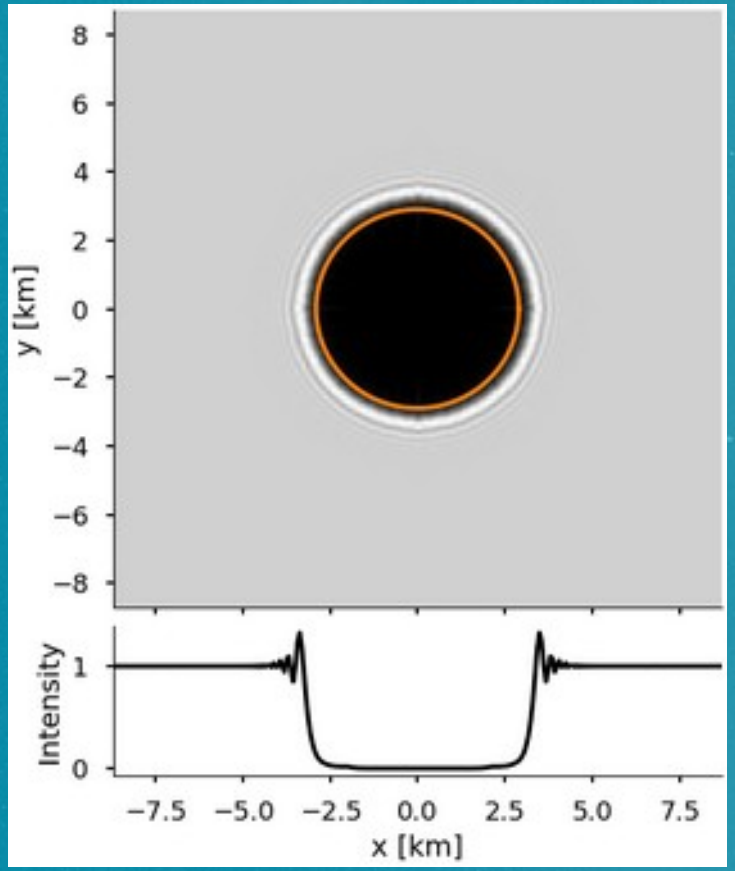
Today

- Foreground object:
  - (3200) Phaethon
- Background object:
  - star UCAC4 660-021020

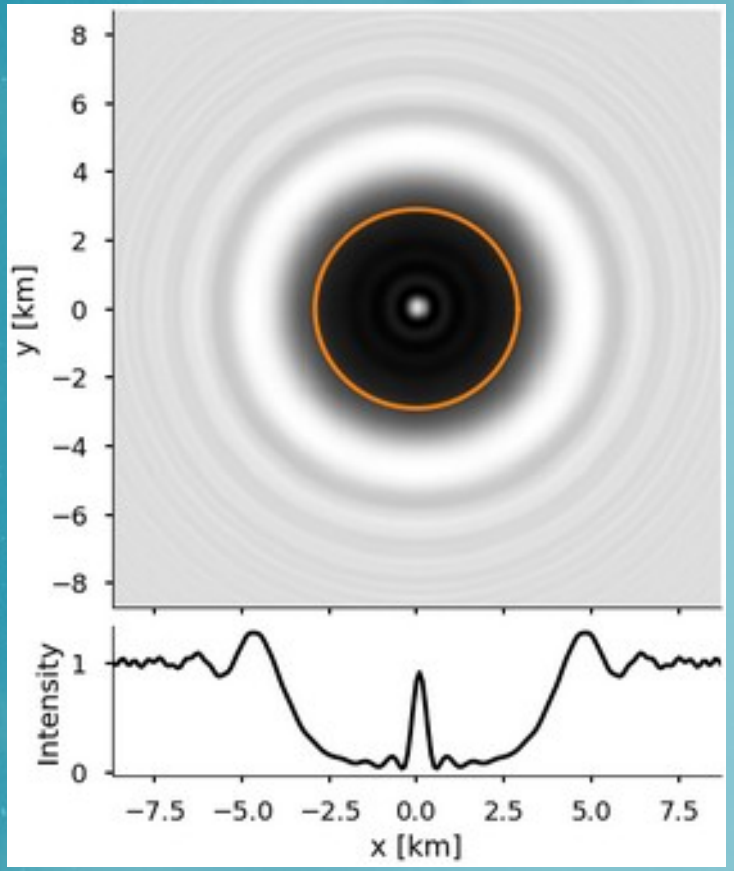


Shadow of Phaethon as…

An asteroid (Δ=1.715 au)

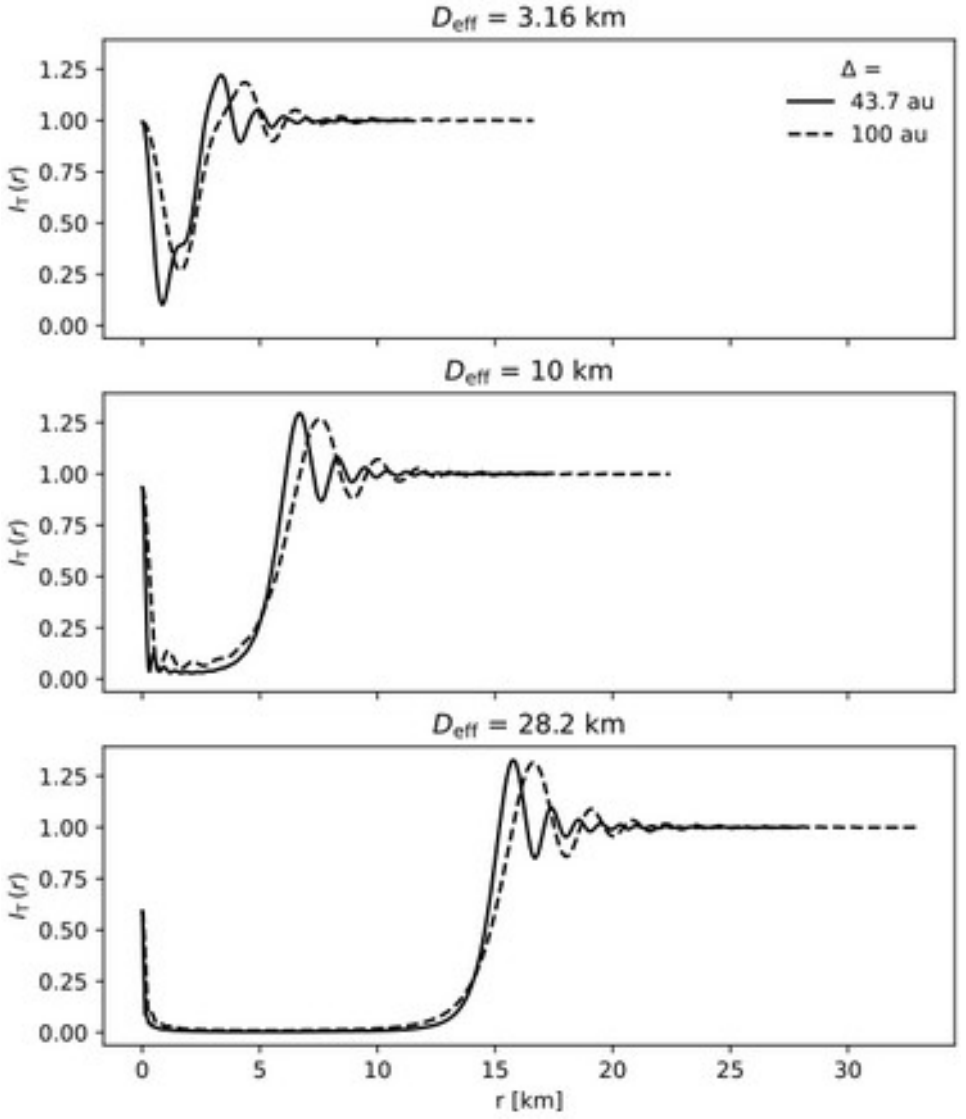


A TNO (Δ=43.7 au)



Diffraction features

- Depends on:
  - size of occulting object (TNO, asteroid, etc)
  - distance of object to observer, Δ
  - projected size of occulted object (star)

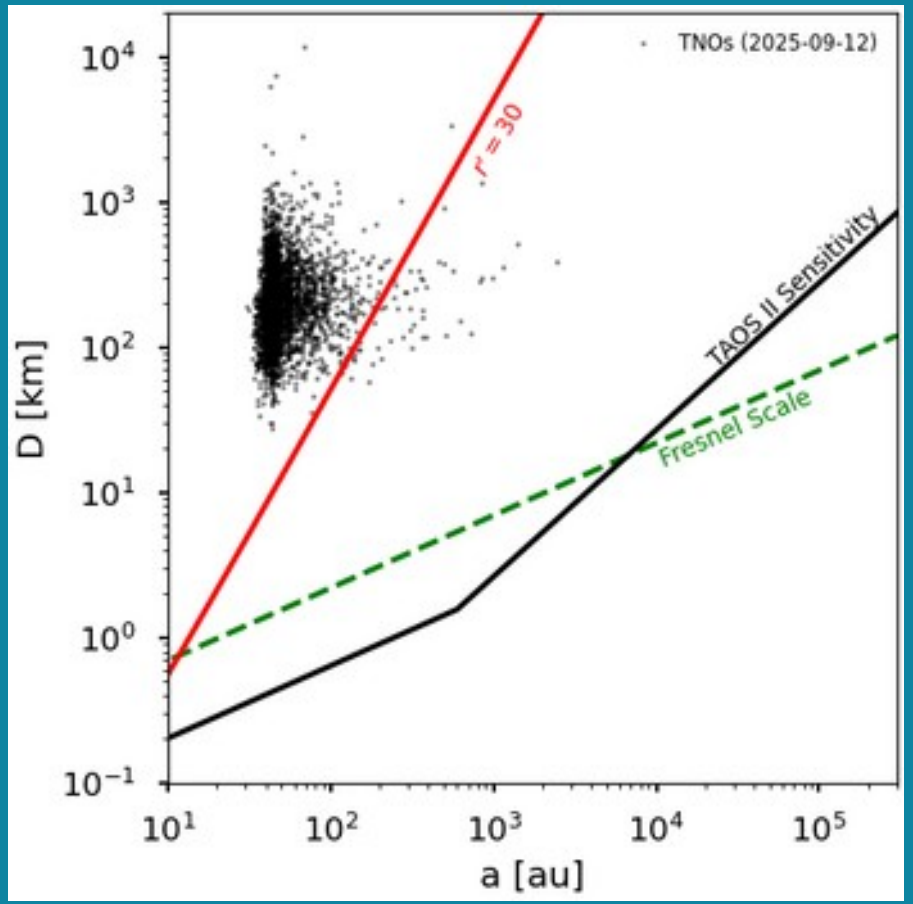


TAOS2

- The Transneptunian Automated Occultation survey
  - Blind occultation survey to detect faint trans-Neptunian objects (TNOs)
  - Main goal: measure the size distribution of TNOs with diameters between 0.2 to 30 km
  - Secondary goals:
    - Exoplanets
    - Supernovas
    - Variable stars

Why TAOS2?

- We know very little about small/faint TNOs
- Majority of TNOs discovered with direct imaging are larger than 30 km
- Direct searches are limited by the object's brightness



To have in mind

- TNOs move slower than asteroids
  - occultations by TNOs are less common than occultations by asteroids
- Occultation searches are limited by the Fresnel scale and angular diameter of the target stars
- The duration of occultations by TNOs is short
  - About 0.2 s

To succeed

- We need lots of data
  - Good site → many clear nights and good observing conditions
  - Monitor the brightness of 5000 to 10000 stars at the same time

Where is TAOS2 located?

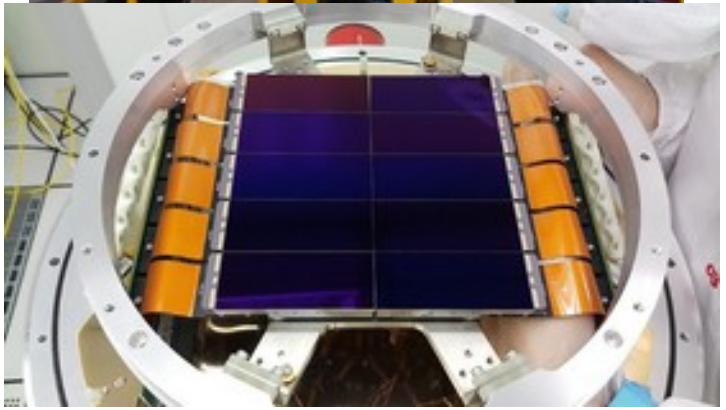
México's *National Astronomical Observatory*

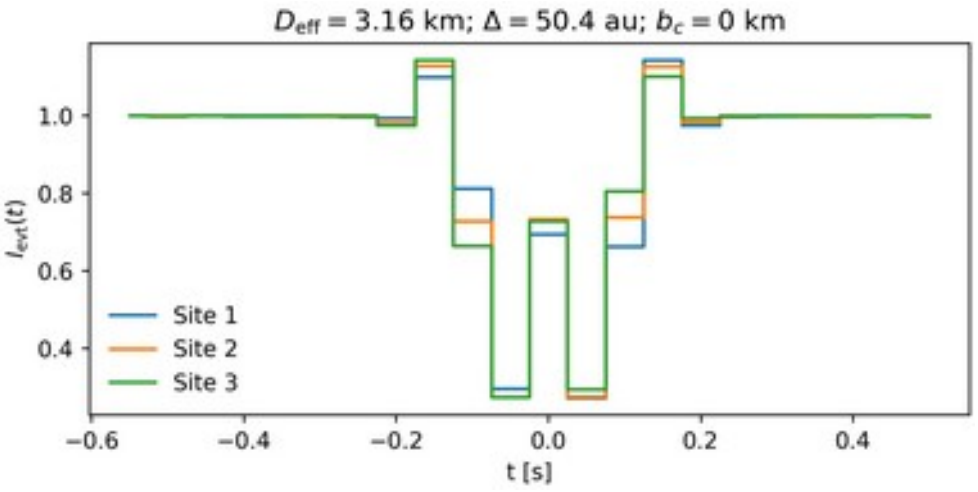
San Pedro Mártir, Baja California, México

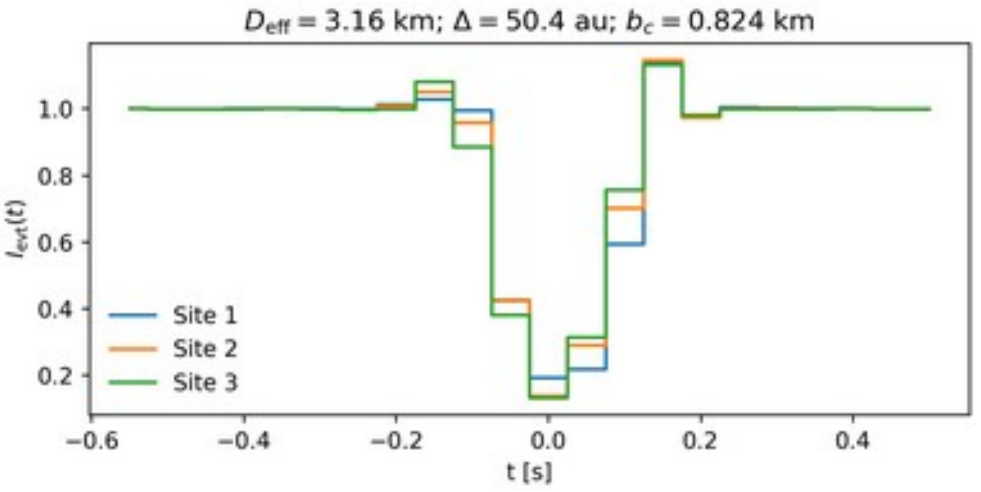
To succeed

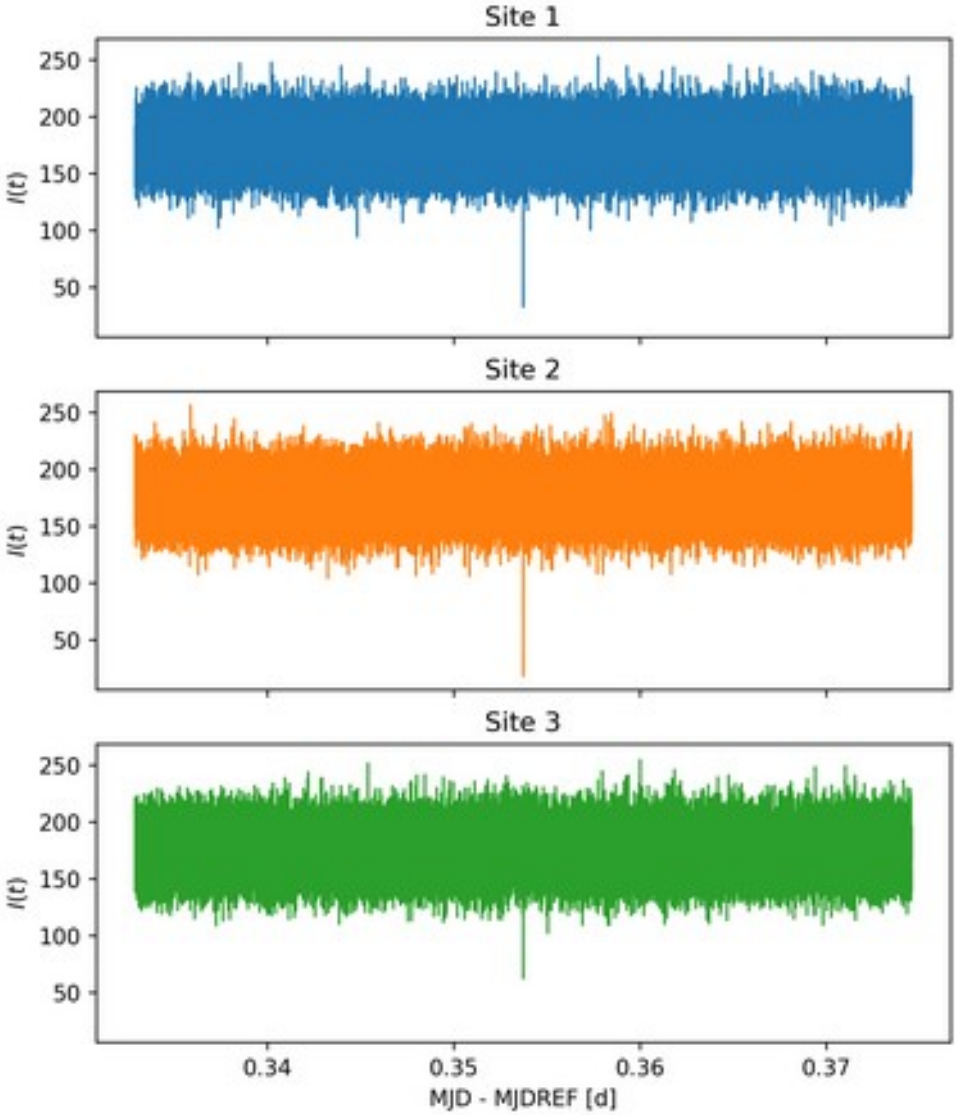
- We need lots of data
  - Good site → many clear nights and good observing conditions
  - Monitor the brightness of 5000 to 10000 stars at the same time
- Fast imaging to resolve the events
  - Observations with a cadence of 20 Hz
  - CMOS imagers
- Minimize false positive rate
  - tens to thousands of events per year ~10^{12} photometric measurements per year
  - require coincident detection in multiple telescopes (3 telescopes)
  - telescopes separated by more than 100 m (scintillation)

Layout




D_{eff} = 3.16 km; Δ = 50.4 au; b_c = 0 km
$I_{evt}(t)$
t [s]
Site 1
Site 2
Site 3


D_{eff} = 3.16 km; Δ = 50.4 au; b_c = 0.824 km
$I_{evt}(t)$
t [s]
Site 1
Site 2
Site 3



- No actual observational data has been shown in this presentation.
- We hope to show real data soon.
- There’s a lot of work still to be done.
- We are excited to get to know more about TNOs and their sizes.