

# The Case for a Large-Scale Occultation Network

**Malena Rice<sup>1</sup>** & Greg Laughlin

Advisor: Greg Laughlin

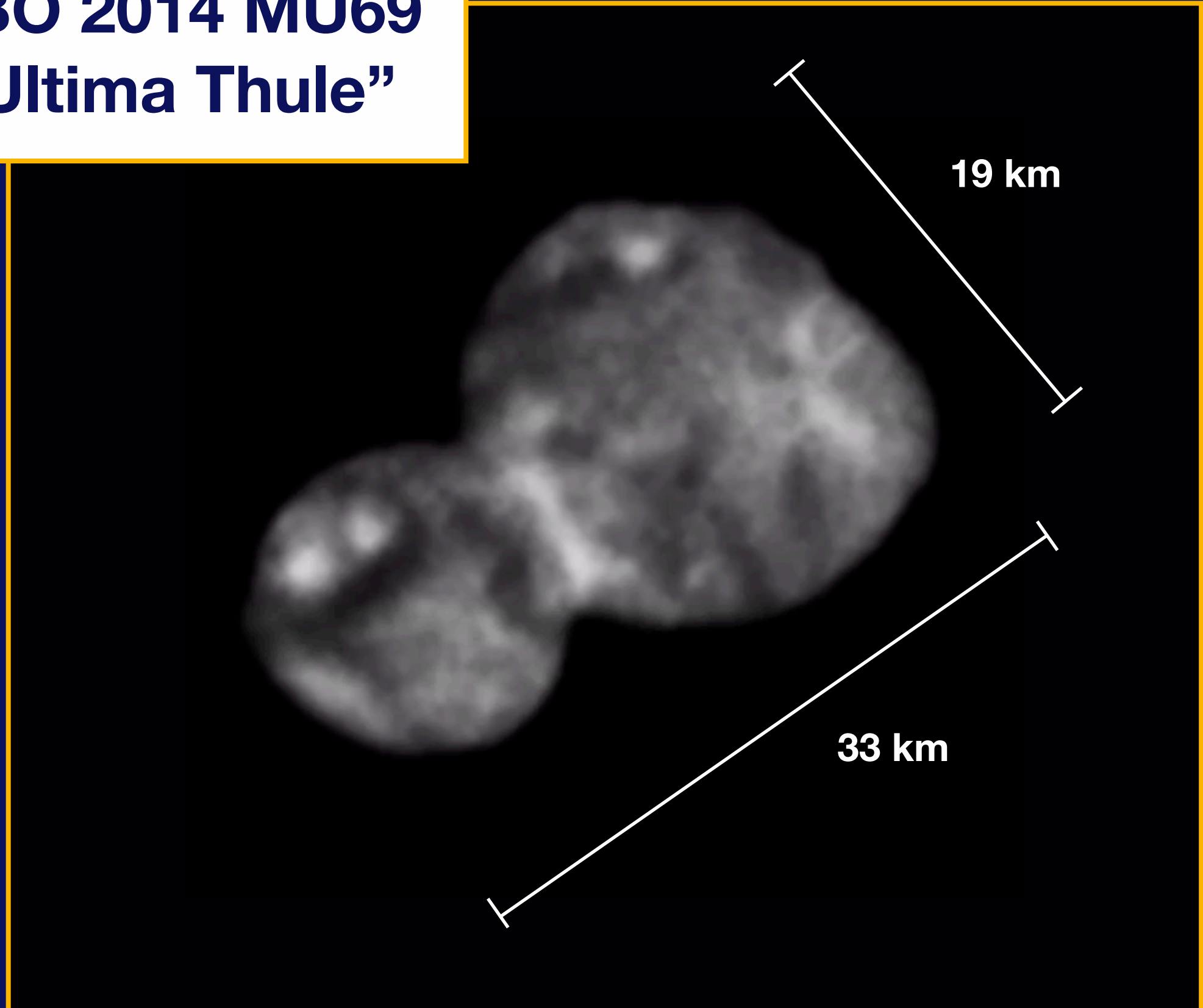
<sup>1</sup>NSF Graduate Research Fellow



**Great Barriers in Planet Formation Disc-ussion**  
**Monash University**  
**July 15, 2019**

**Yale**

# KBO 2014 MU69 “Ultima Thule”



Adapted from NASA / JHU-APL / SwRI

## **The New Horizons team hit its mark**

The prediction of New Horizons' closest approach to Ultima Thule was off by only 2 seconds. By contrast, for the spacecraft's flyby of Pluto in 2015, the prediction was off by about 80 seconds. Even though Ultima Thule is smaller and farther away, the navigators were able to plot a more precise course this time, because in 2017 and 2018, astronomers on the mission team were able to pin down Ultima Thule's location by observing the object passing in front of a few distant stars.

**Article by Kenneth Chang**

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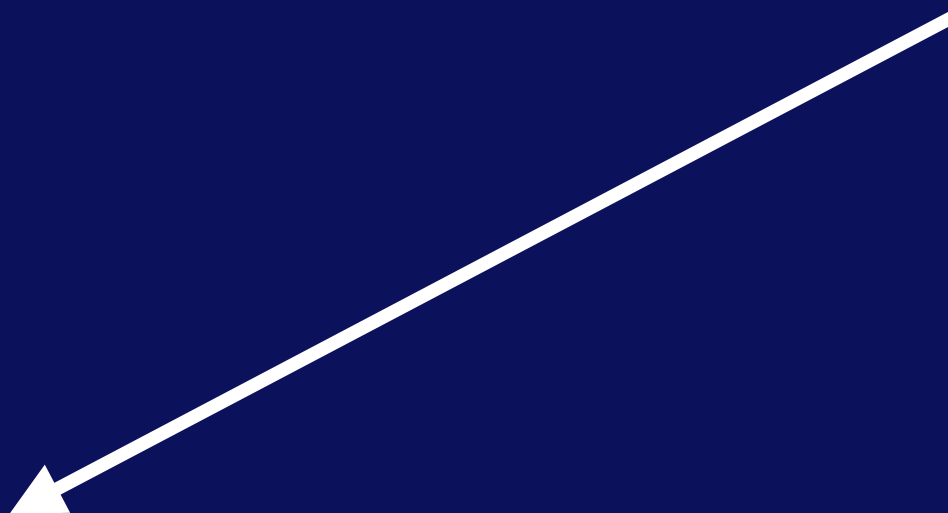
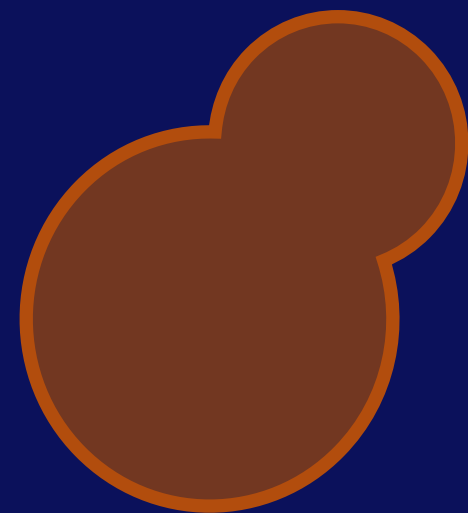
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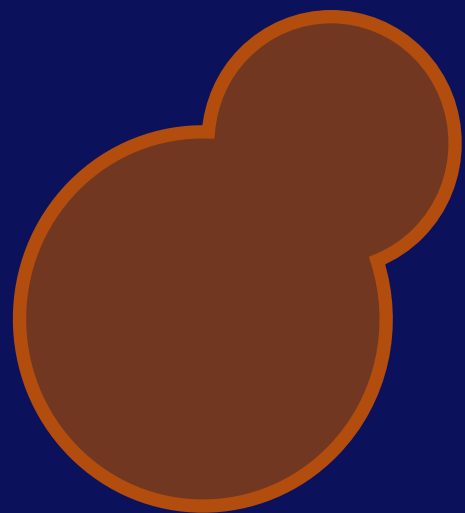
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- Multiple chords: rough 2D maps of the occulter



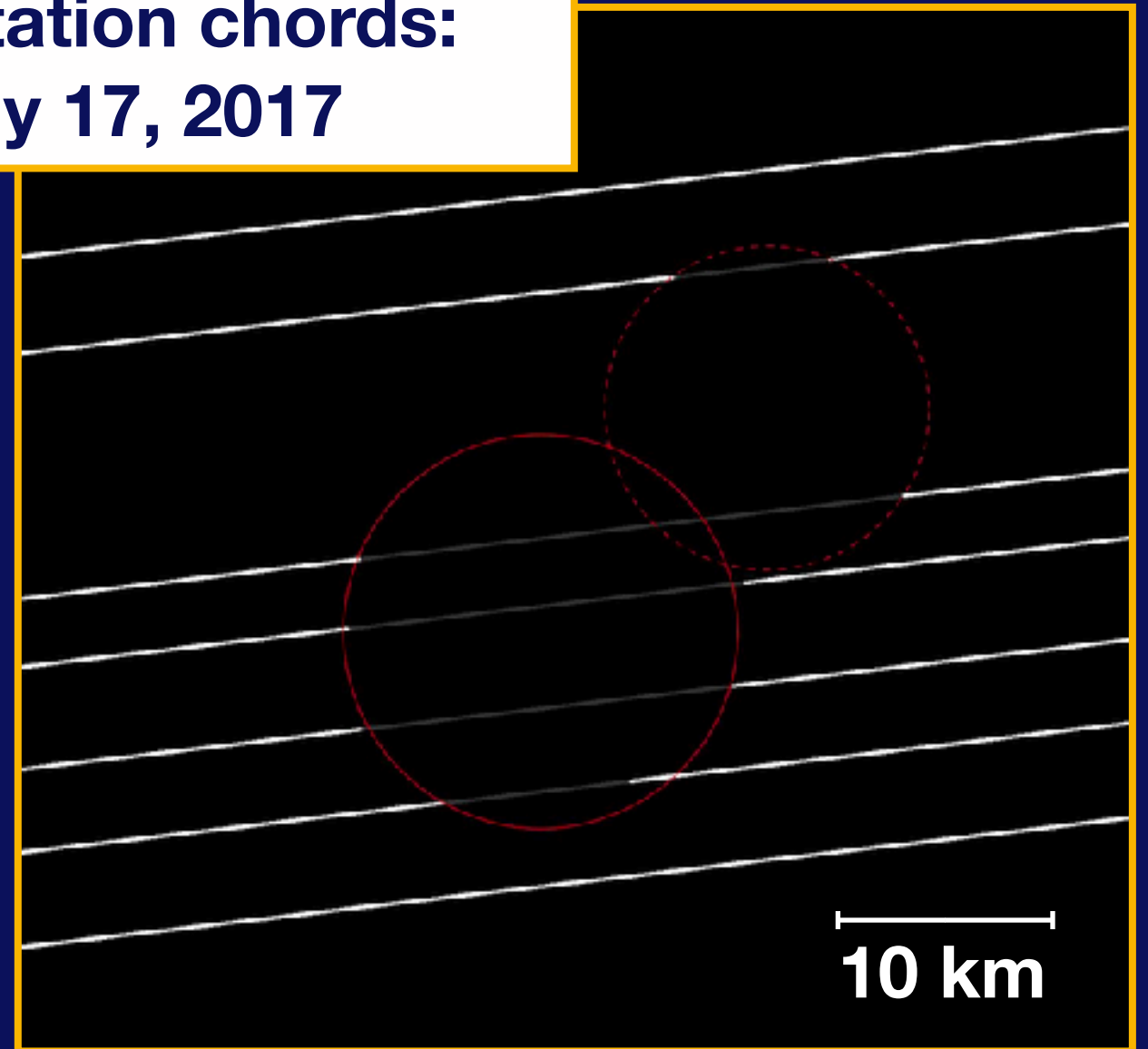
The Occultation  
'Picket Line'



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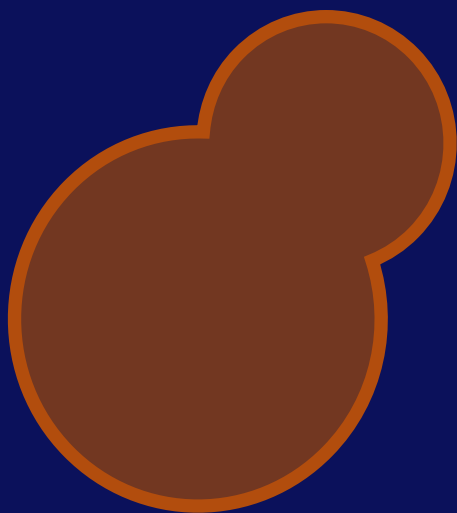


**Solid-body 2014 MU69  
occultation chords:  
July 17, 2017**

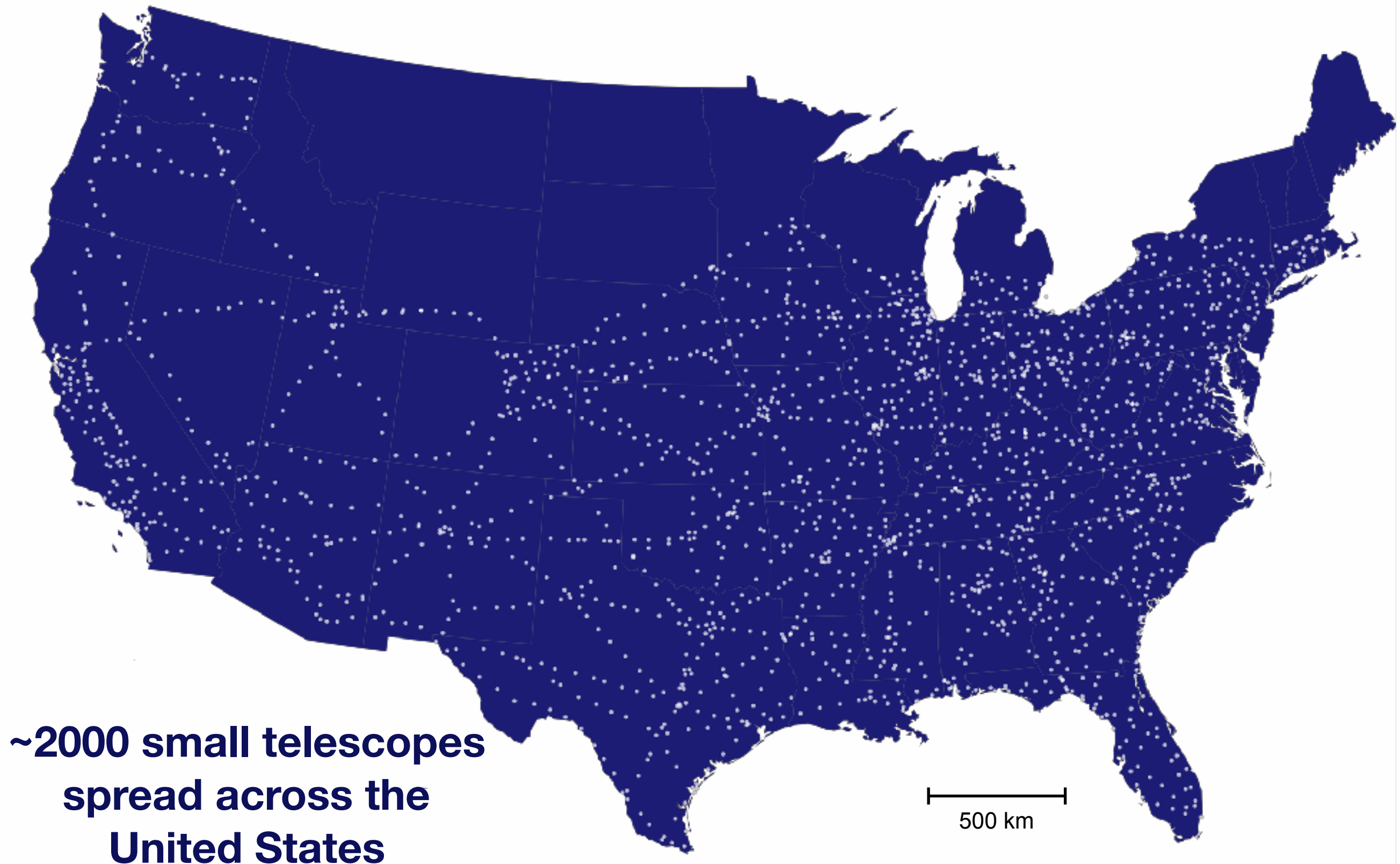


Adapted from NASA / JHU-APL / SwRI/ Alex Parker

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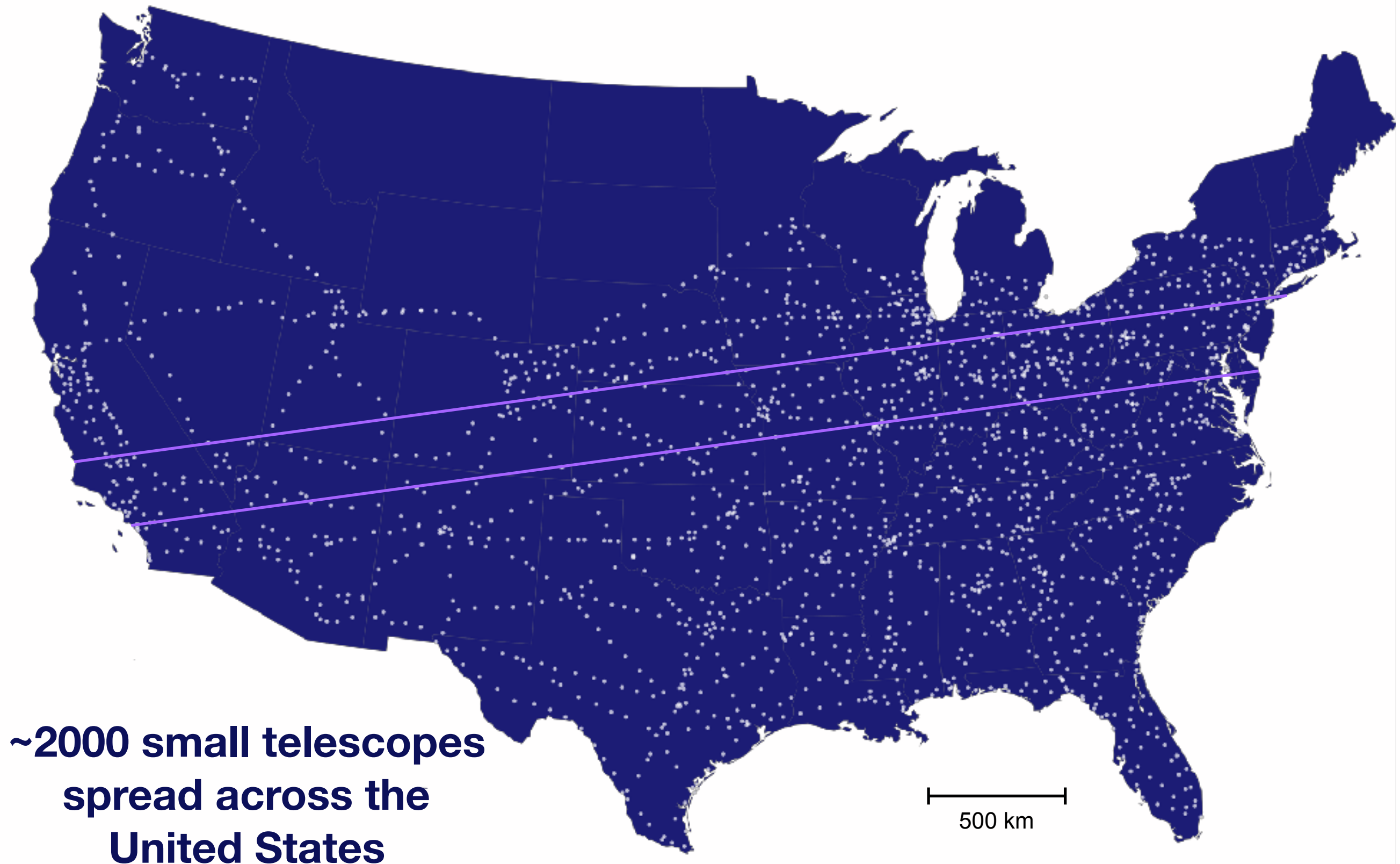
# The cISP Occultation Network



**~2000 small telescopes  
spread across the  
United States**

**Rice & Laughlin, 2019**

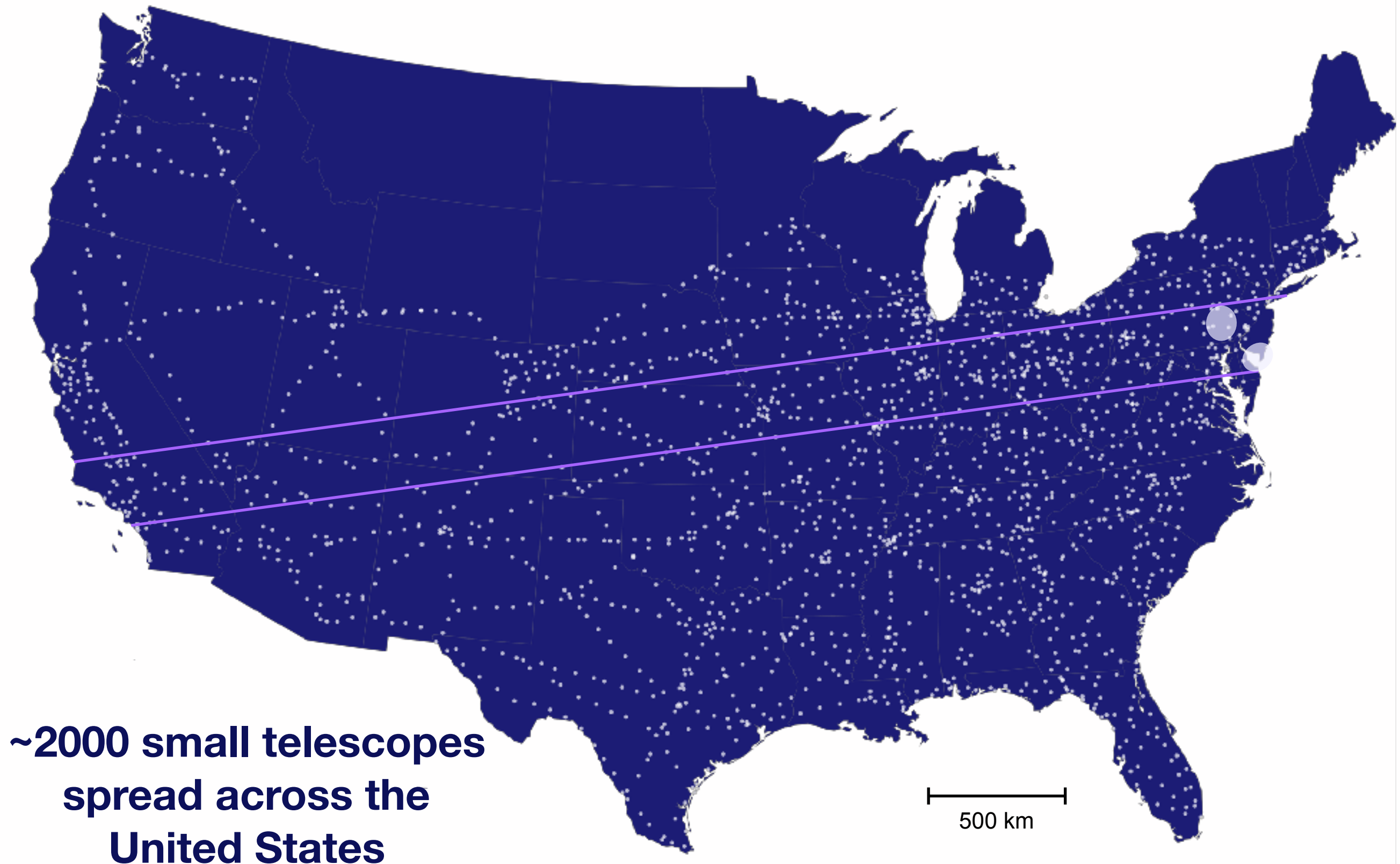
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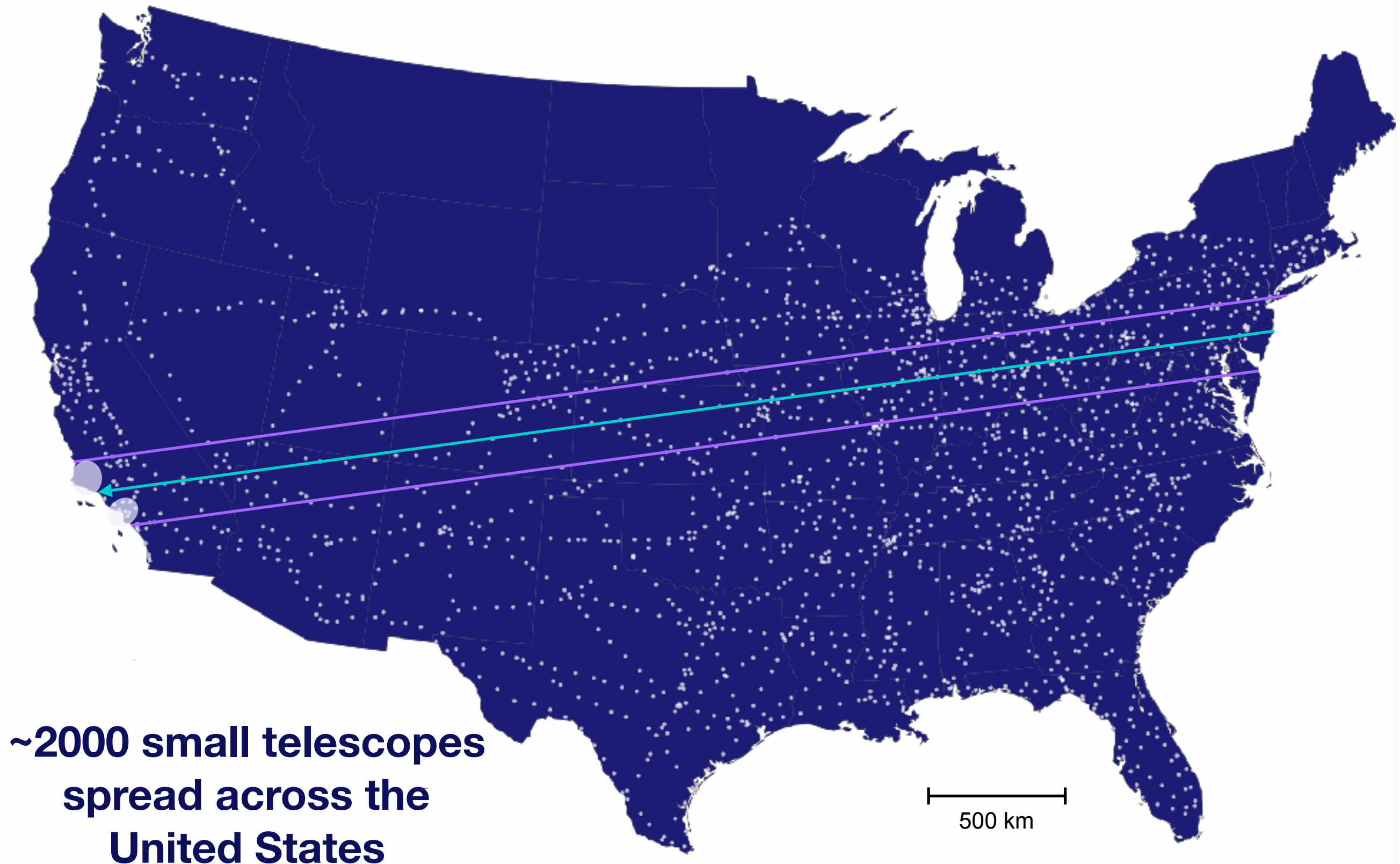


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**Gaia precision:** {  
At  $V=10$ ,  $\omega = 7 \mu\text{as}$   
At  $V=15$ ,  $\omega = 12\text{-}25 \mu\text{as}$   
At  $V=20$ ,  $\omega = 100\text{-}300 \mu\text{as}$

**At semimajor axis  $a = 5.2 \text{ AU}$ :**

- On average,  $\sim 7$  occultations per asteroid per year over the continental United States
- $dx \sim 75 \text{ m}$  for one occultation over a  $V=15$  Gaia star



# A Wide Range of Science Cases

- Direct asteroid size measurements
  - > Most asteroid radii currently determined using thermal modeling applied to images obtained from NEOWISE; requires several assumptions (spherical, non-rotating body, assumed albedo and temperature distribution)



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  - > The Trojan Color Conundrum (Jewitt et al. 2018)

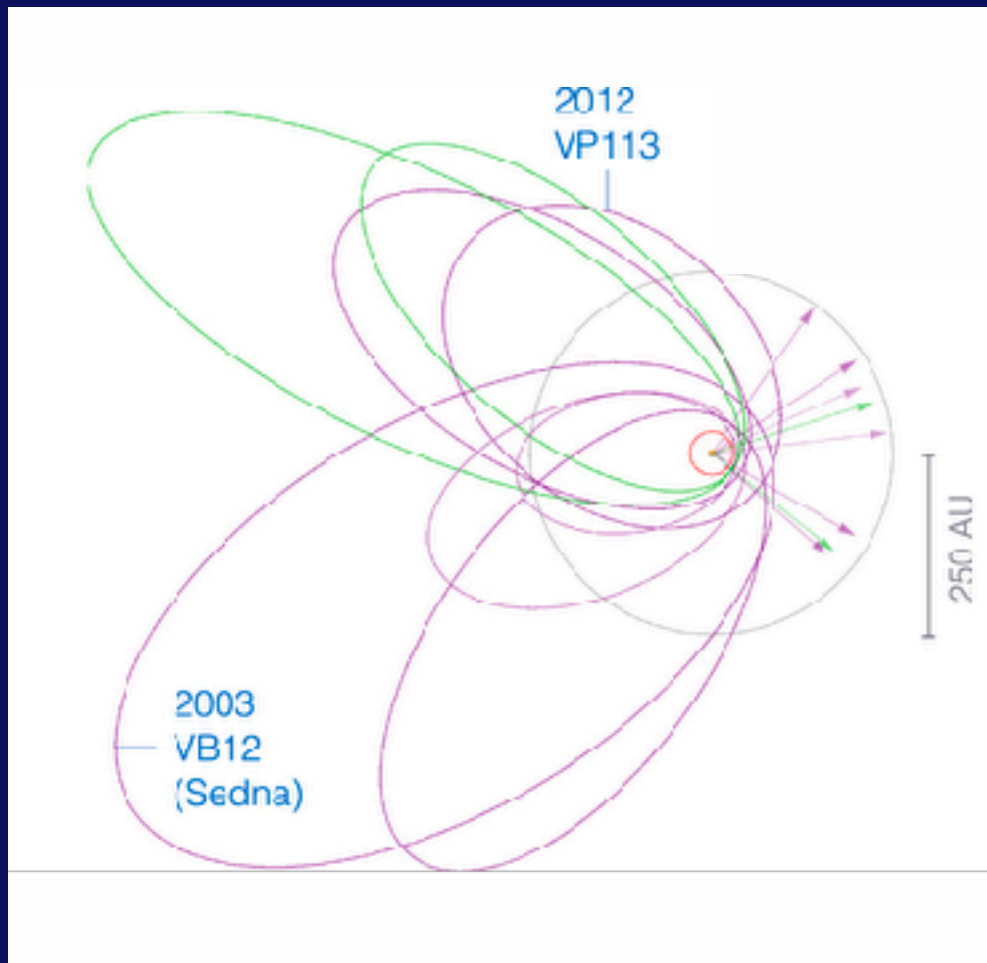
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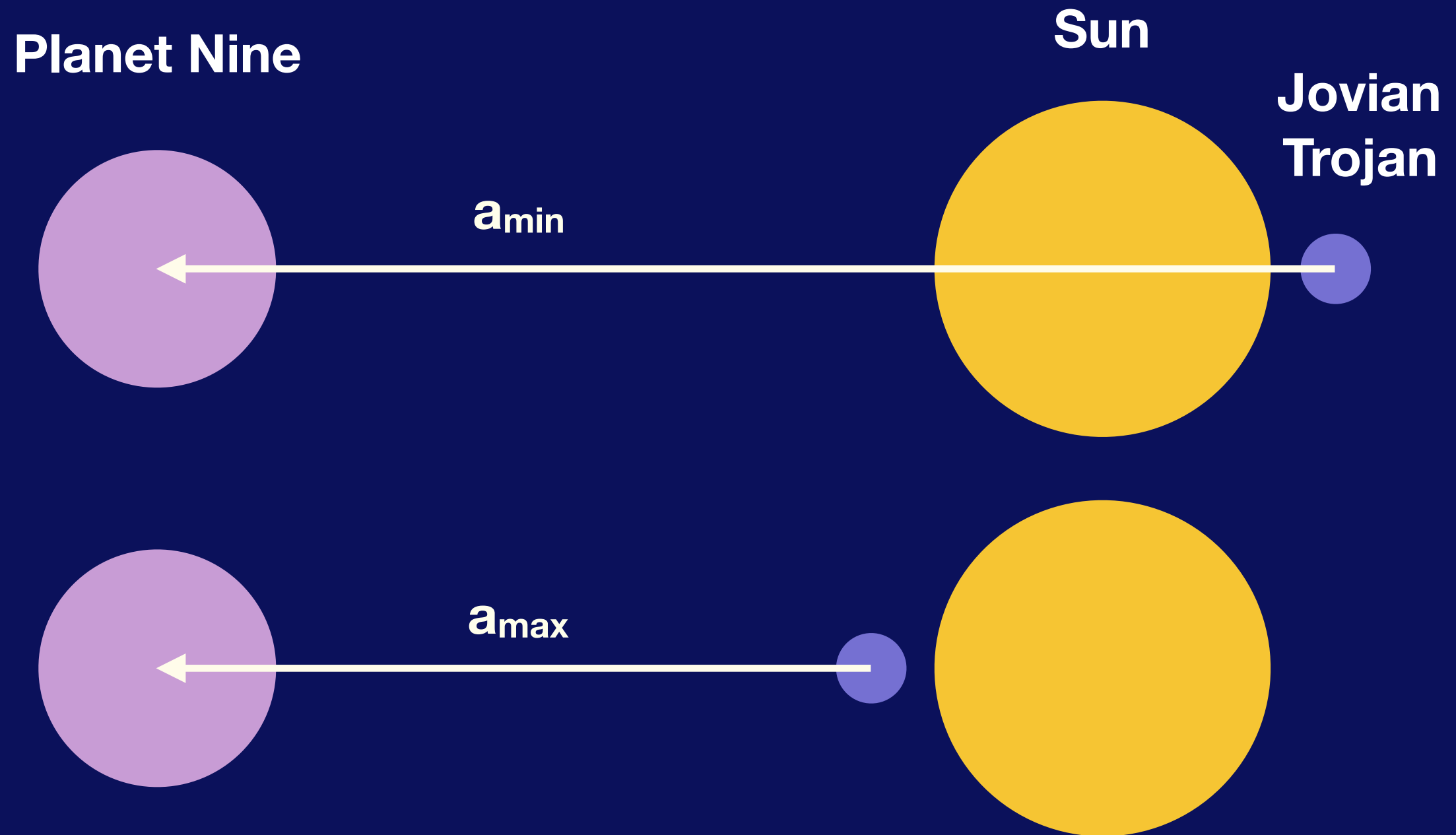
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- Synergies with upcoming NASA missions
  - > Lucy and Psyche missions
- Searching for undiscovered solar system bodies
  - > Planet Nine

# Planet Nine - A Brief Overview



Adapted from Batygin &  
Brown 2016

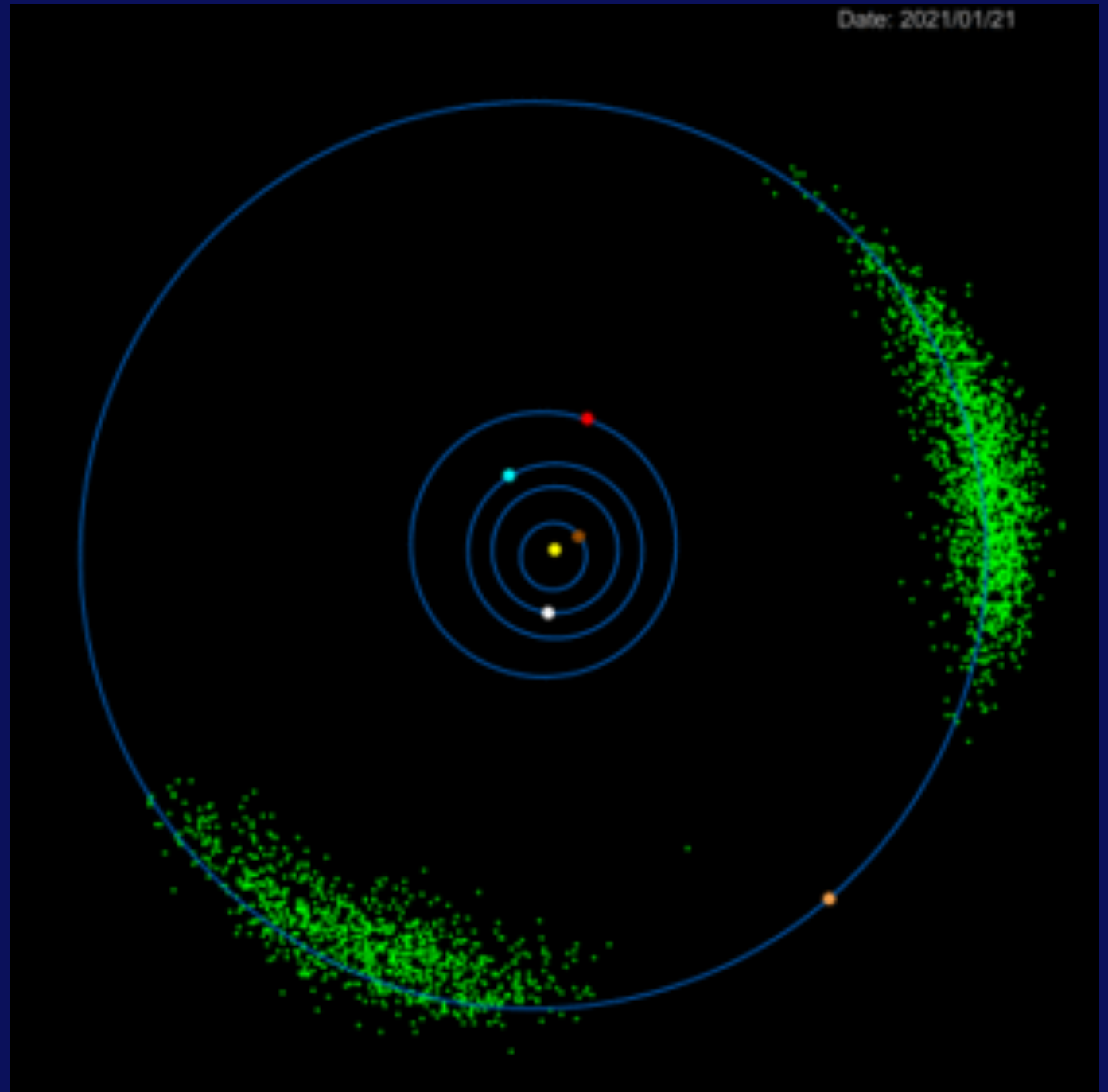
Parameter	Allowed Range
Semimajor axis	400-800 AU
Eccentricity	0.2-0.5
Inclination	15-25°
Mass	5-10M <sub>⊕</sub>



**$\sim 10^5$  Jovian Trojans with  $D \geq 2$  km**

(e.g. Jewitt et al. 2000, Yoshida & Nakamura 2005, Fernández et al. 2009)

**Planet  
Nine**



**Credits: NASA Lucy mission website/Astronomical  
Institute of CAS/Petr Scheirich**

**For Planet Nine,**

$$a = \frac{dGM}{r^3} \sim 3 \times 10^{-13} \text{ cm/s}^2$$

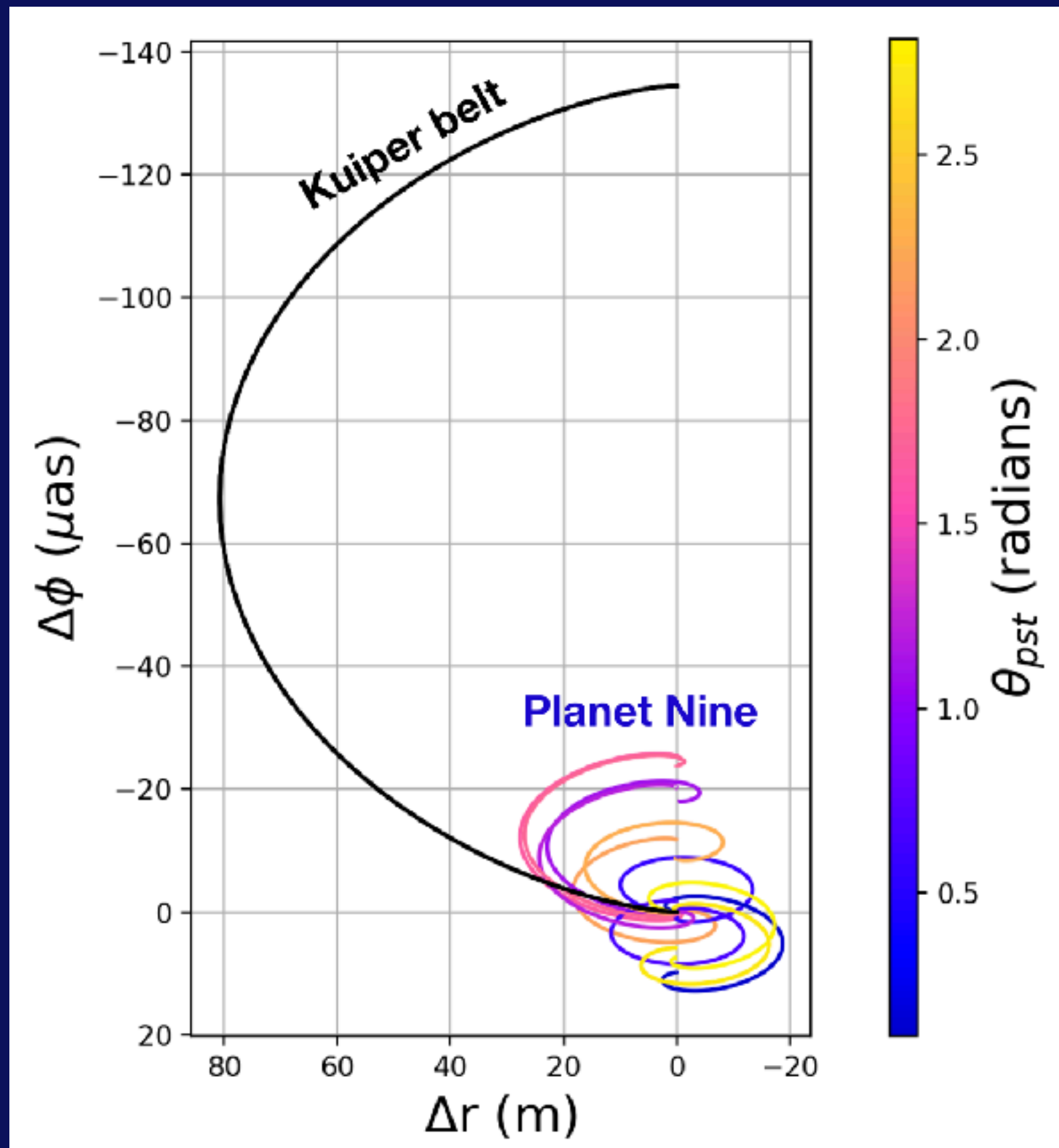
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**Over a 5-year time scale,**

$$\Delta x = \frac{1}{2}at^2 \sim 30 \text{ m}$$

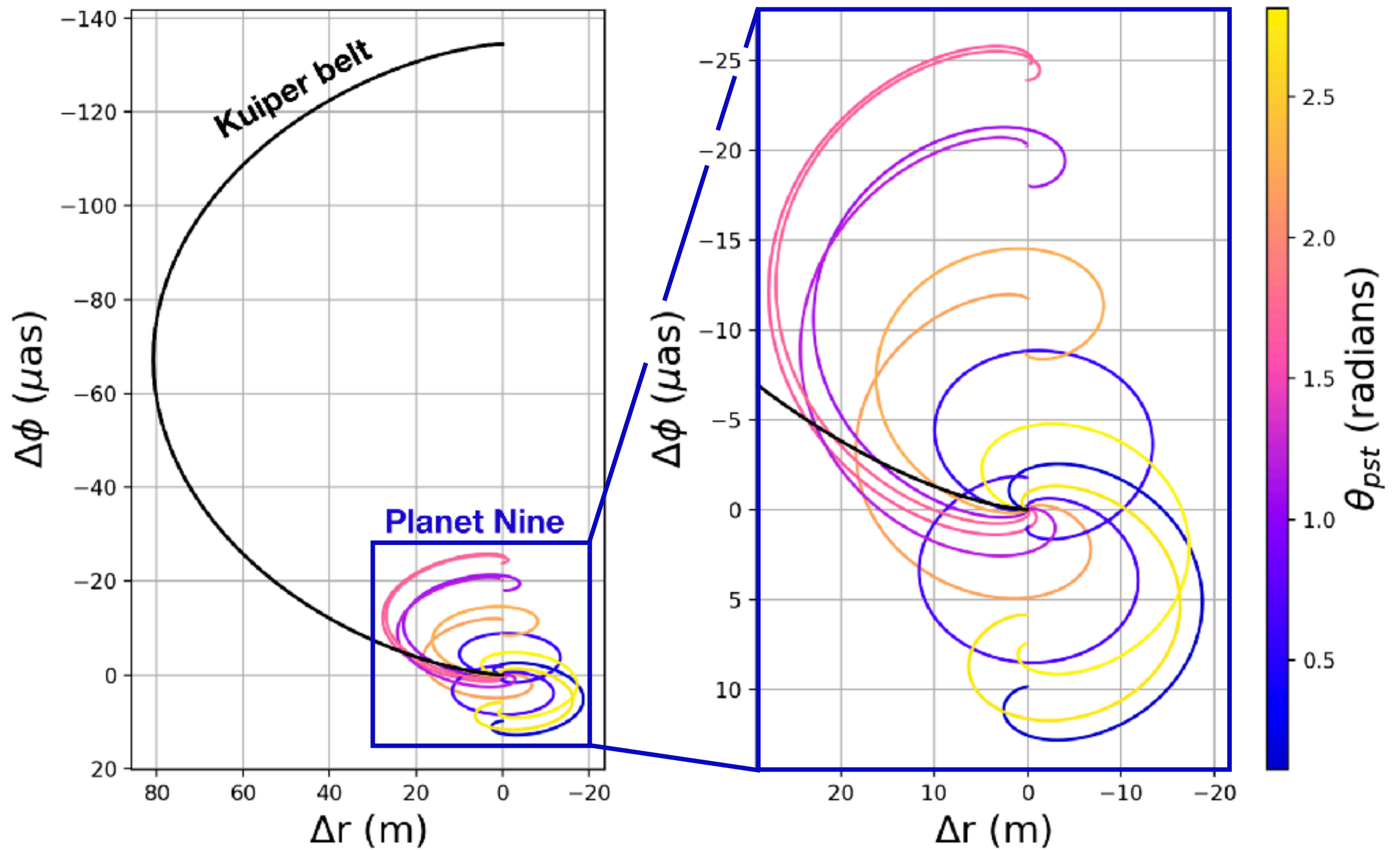
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**Same order of precision to which solar system  
ephemerides are currently predicted**



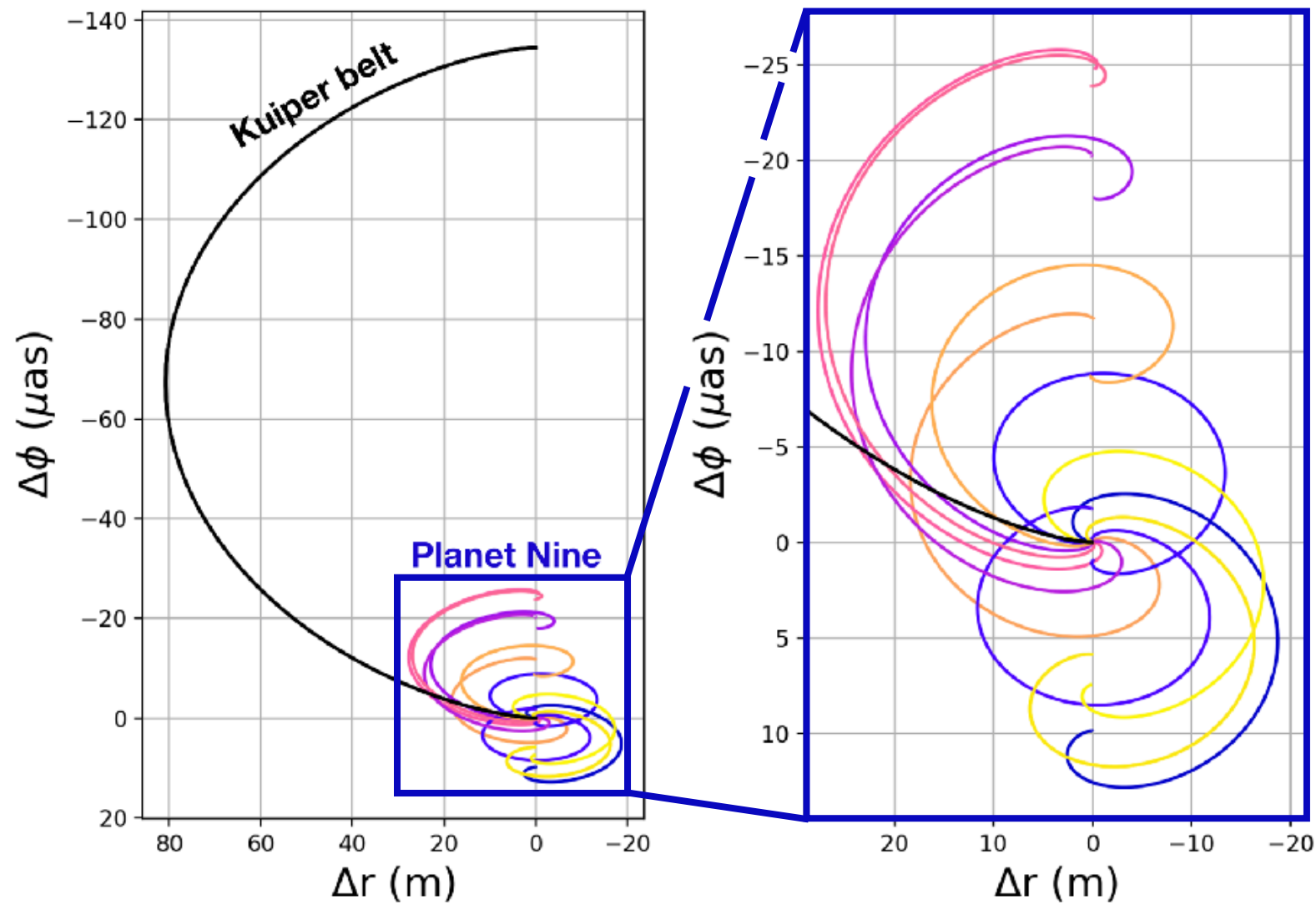
Rice & Laughlin, 2019



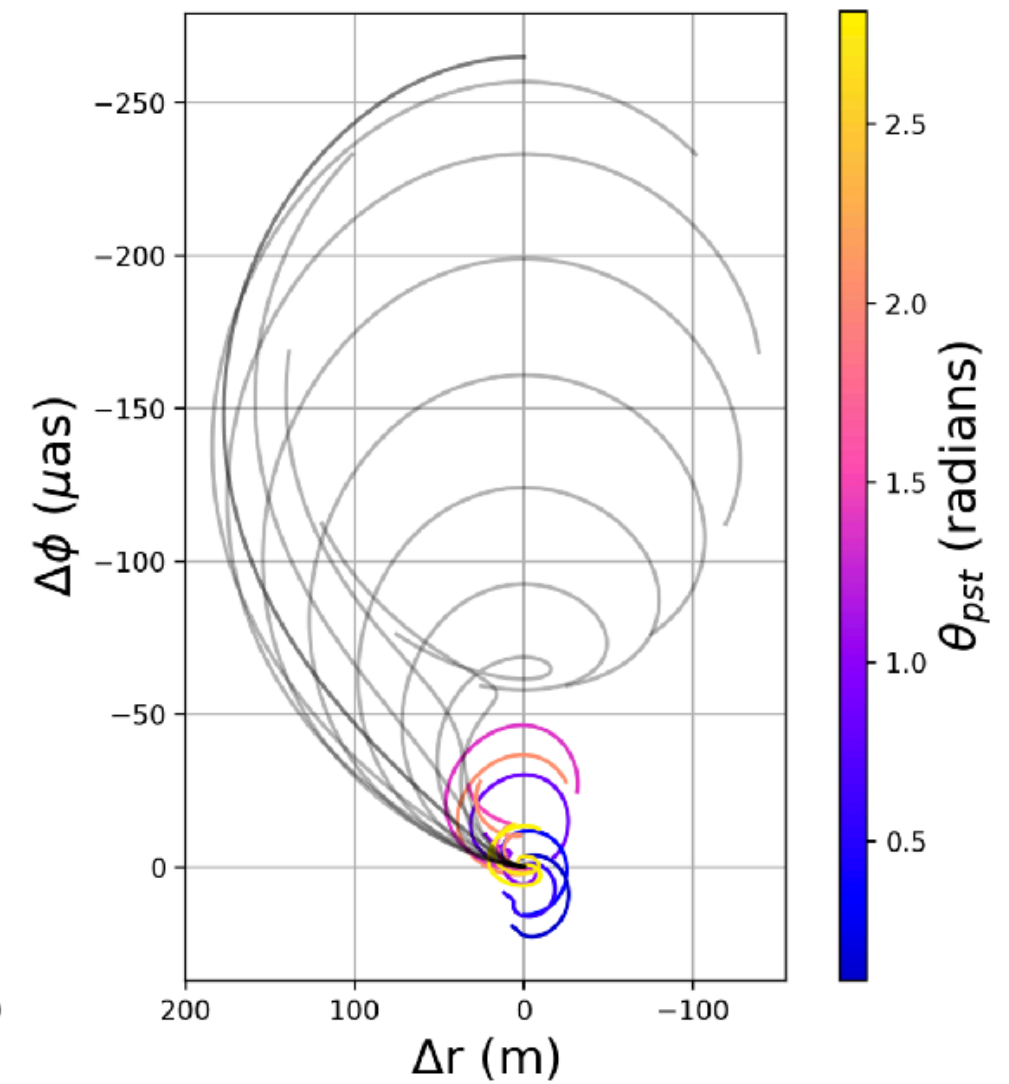


Rice & Laughlin, 2019

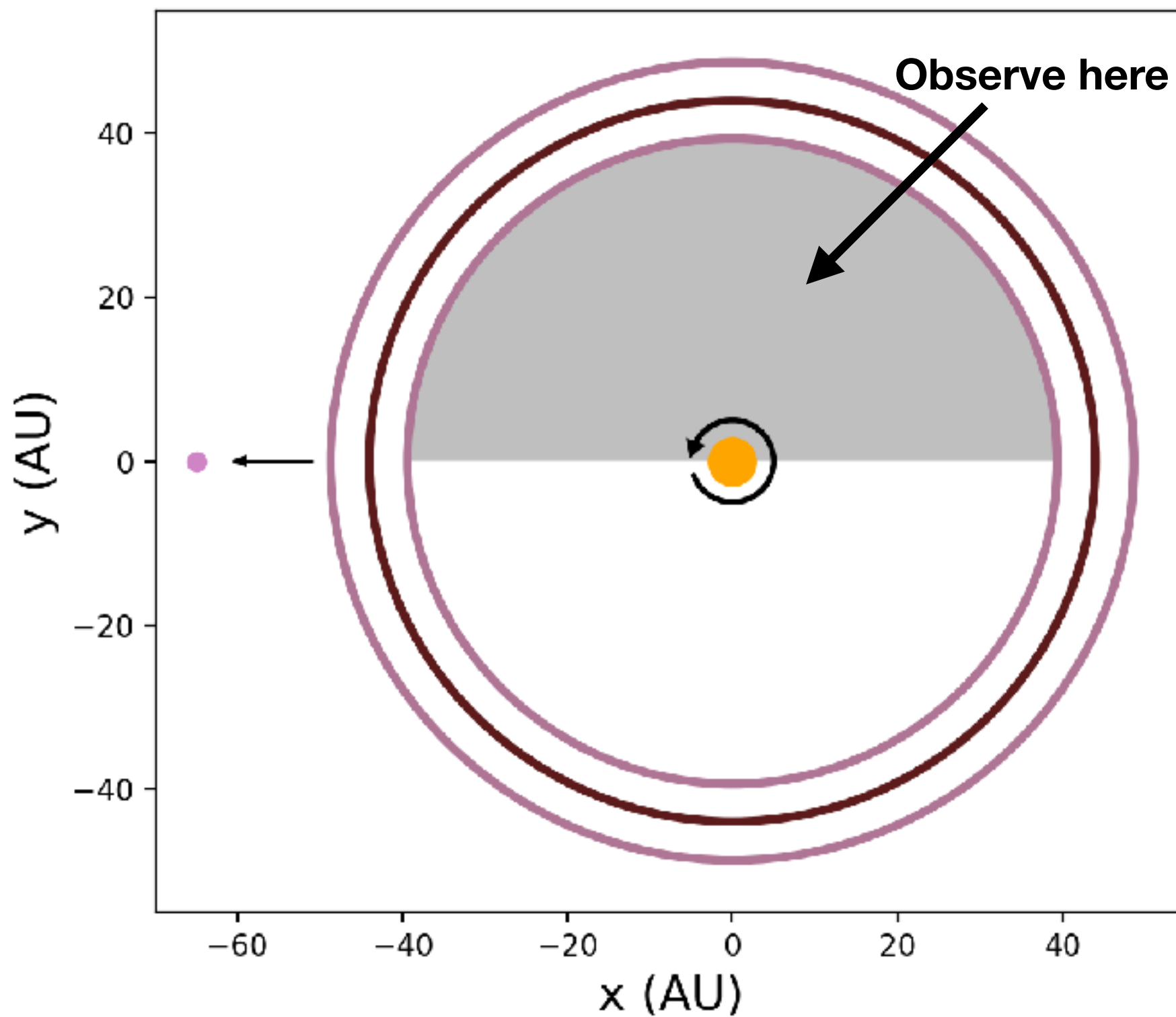
## Zero Trojan eccentricity



## Nonzero Trojan eccentricity



Rice & Laughlin, 2019



# cISP Network Overview

- cISP occultation network: ~2000 small telescopes across the continental United States.
- Detailed information about asteroid sizes, shapes, and positions.
- Tracking tidal perturbations of  $\sim 10^5$  Jovian Trojans with  $D \geq 2$  km can convincingly confirm the existence or non-existence of Planet Nine over  $t \sim 5$  years.
- Timely opportunity drawing from New Horizons, LSST, and Gaia.