Is there a ninth planet in the Solar System?

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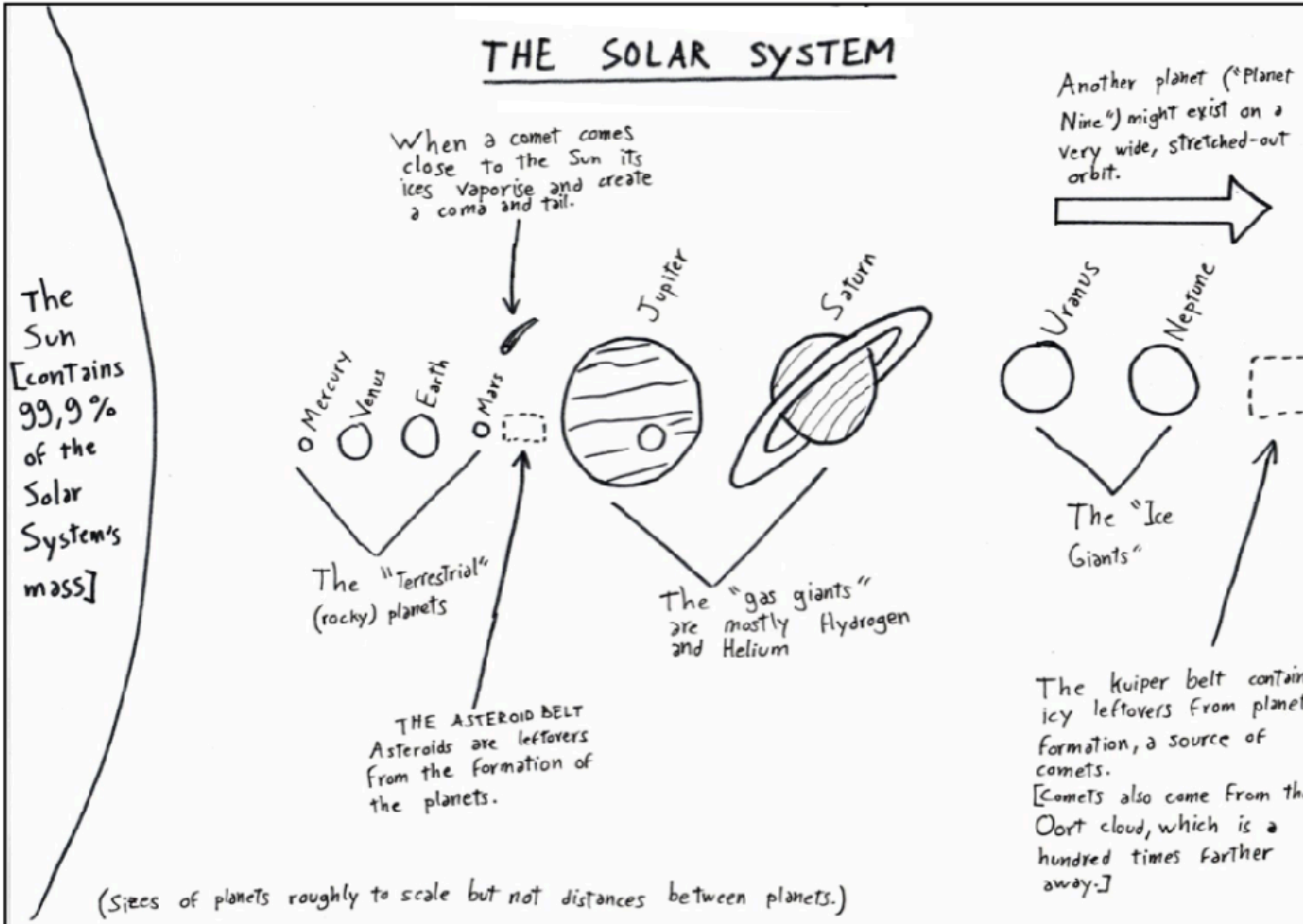
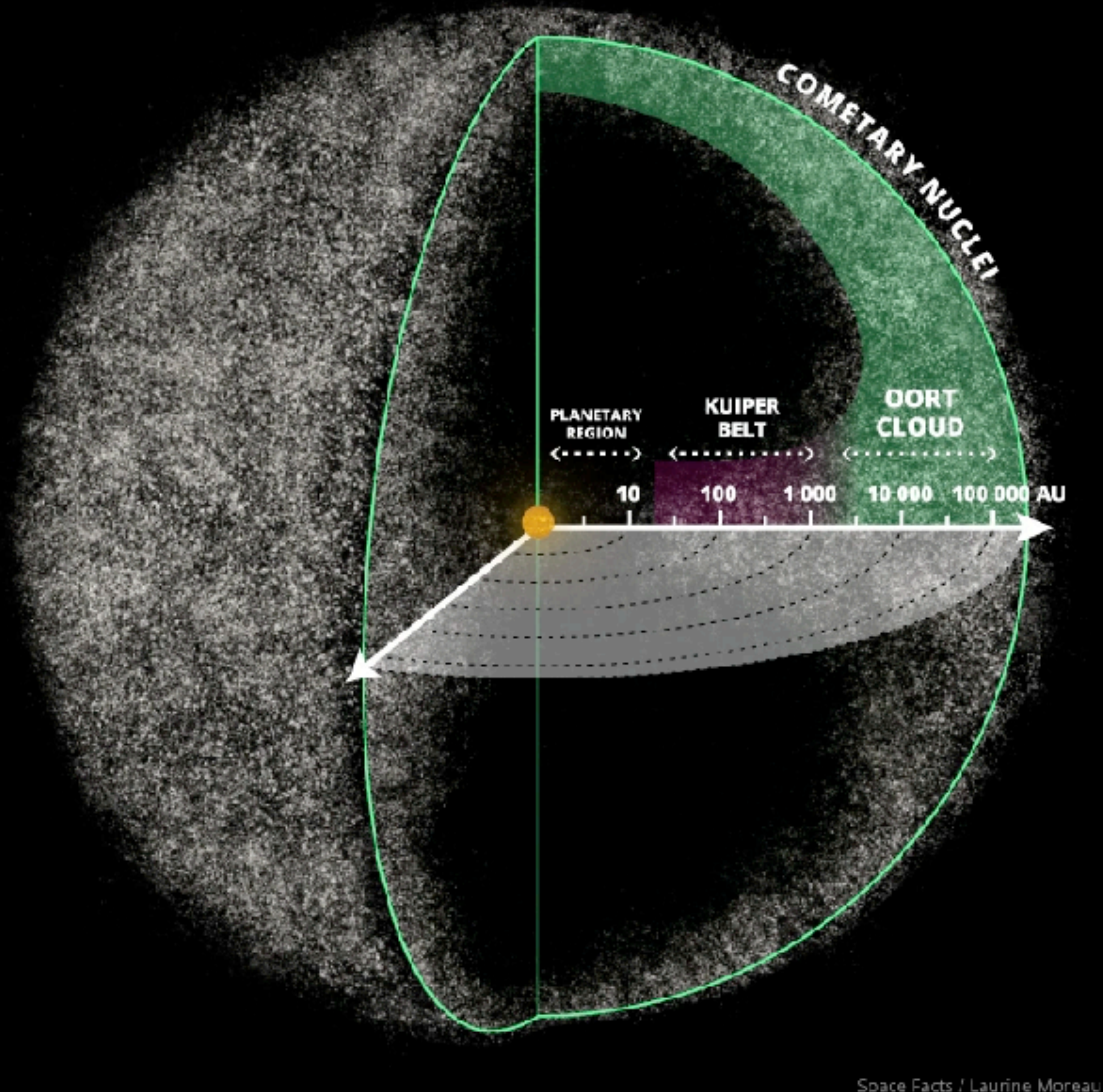


credit: Owen Raymond



For objects seen in reflected sunlight, brightness~R^4

Neptune's prediction

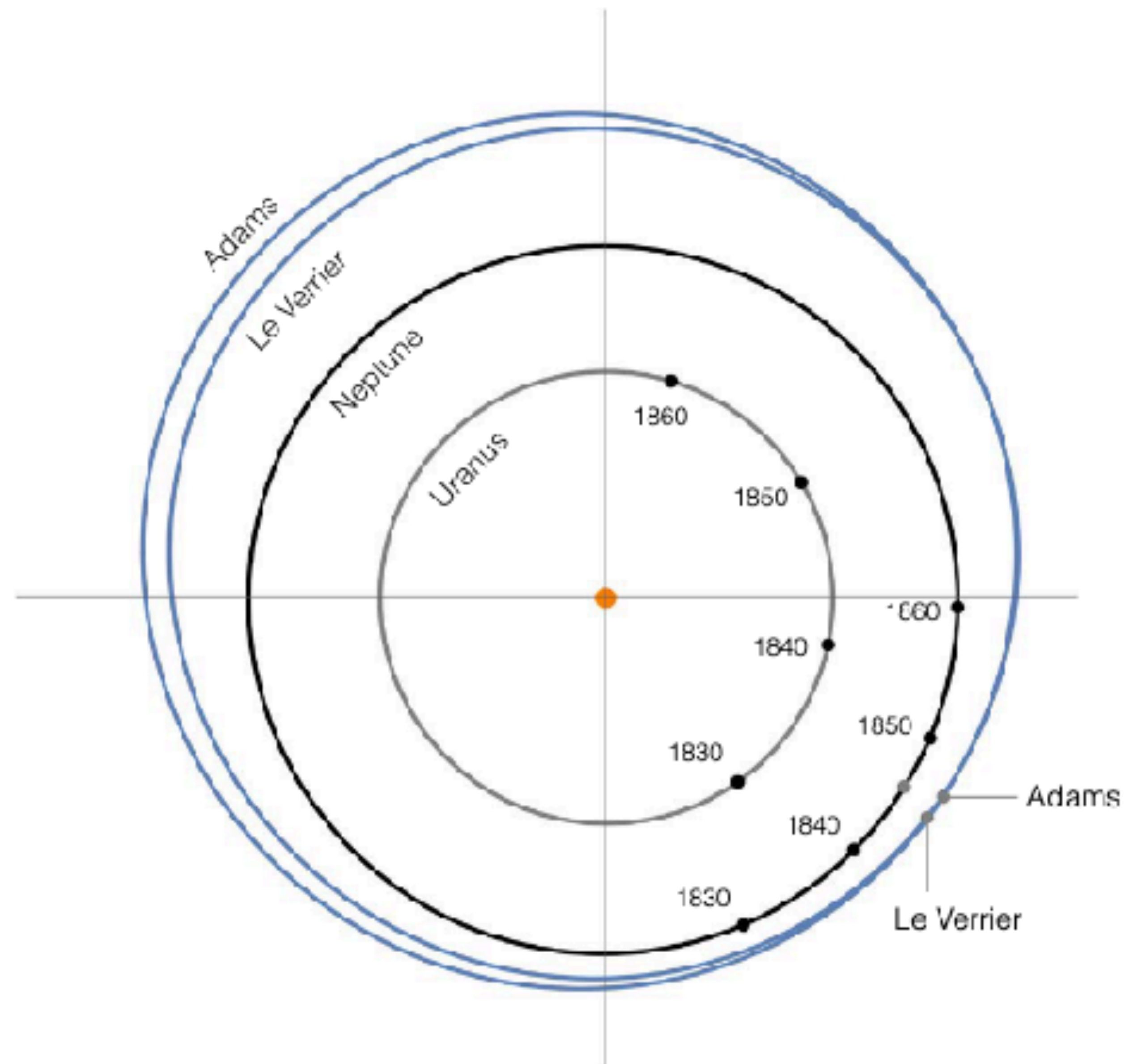
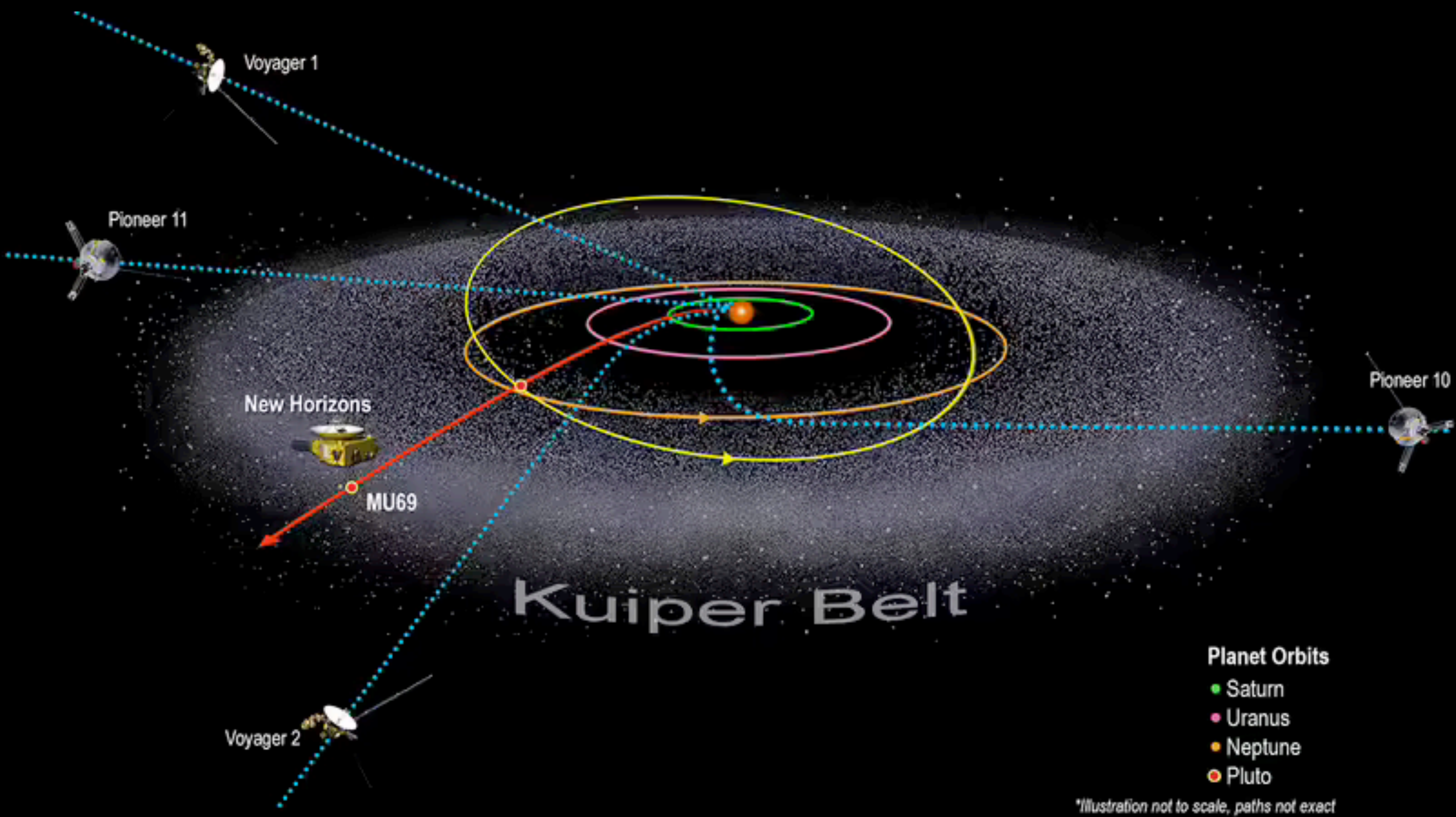


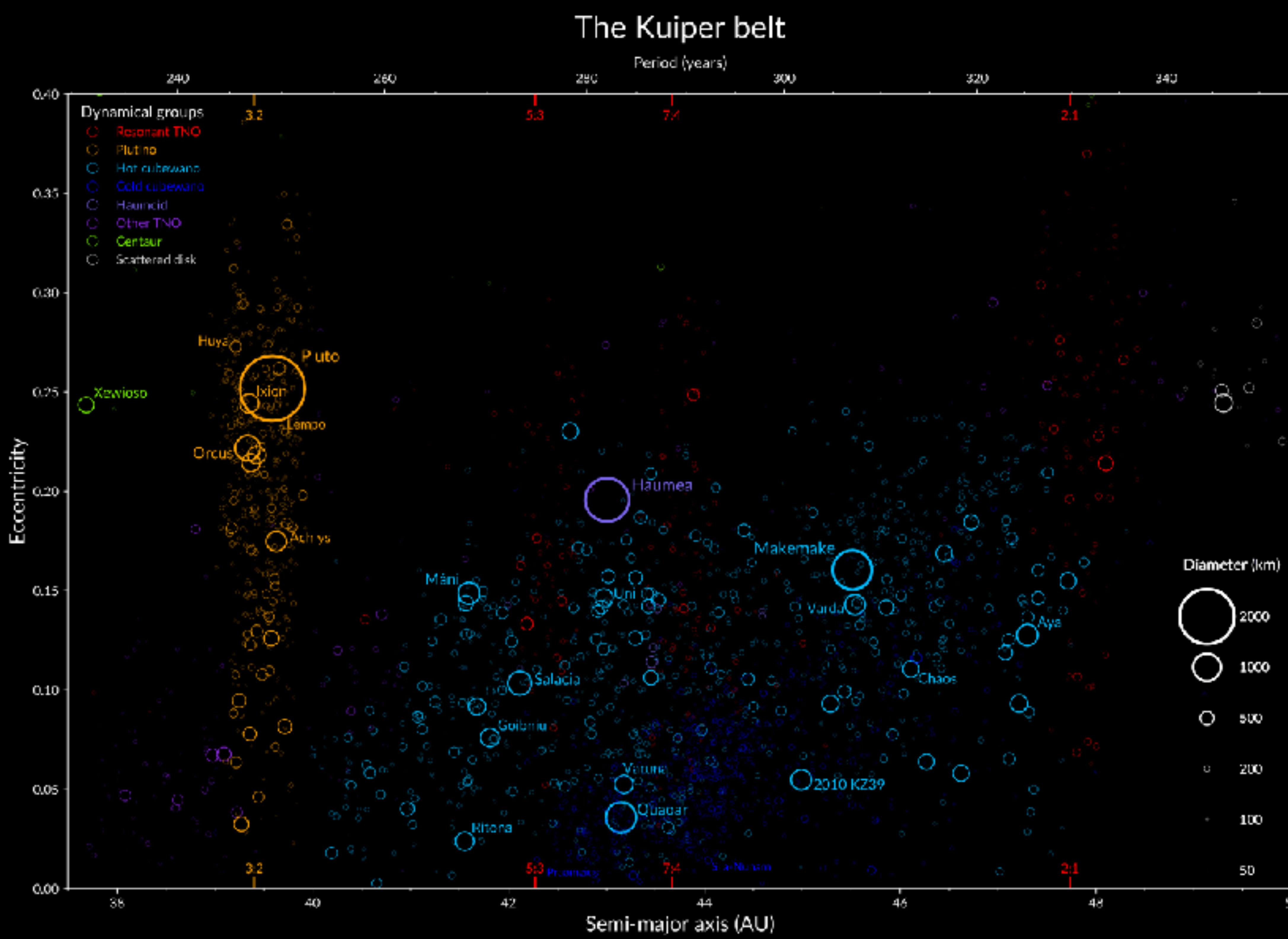
Figure 1: Predicted orbit of Neptune. This diagram shows the outer solar system viewed from the north ecliptic pole, including the orbits of Uranus (gray) and Neptune (black), as well as the predicted Neptunian orbits (purple) from Le Verrier (1846a) and Adams (1846). Note that although the predicted physical location of Neptune was in close agreement with the actual location of Neptune in 1846, the derived orbits are considerably wider and more eccentric than Neptune's true orbit.

Batygin et al (2019)

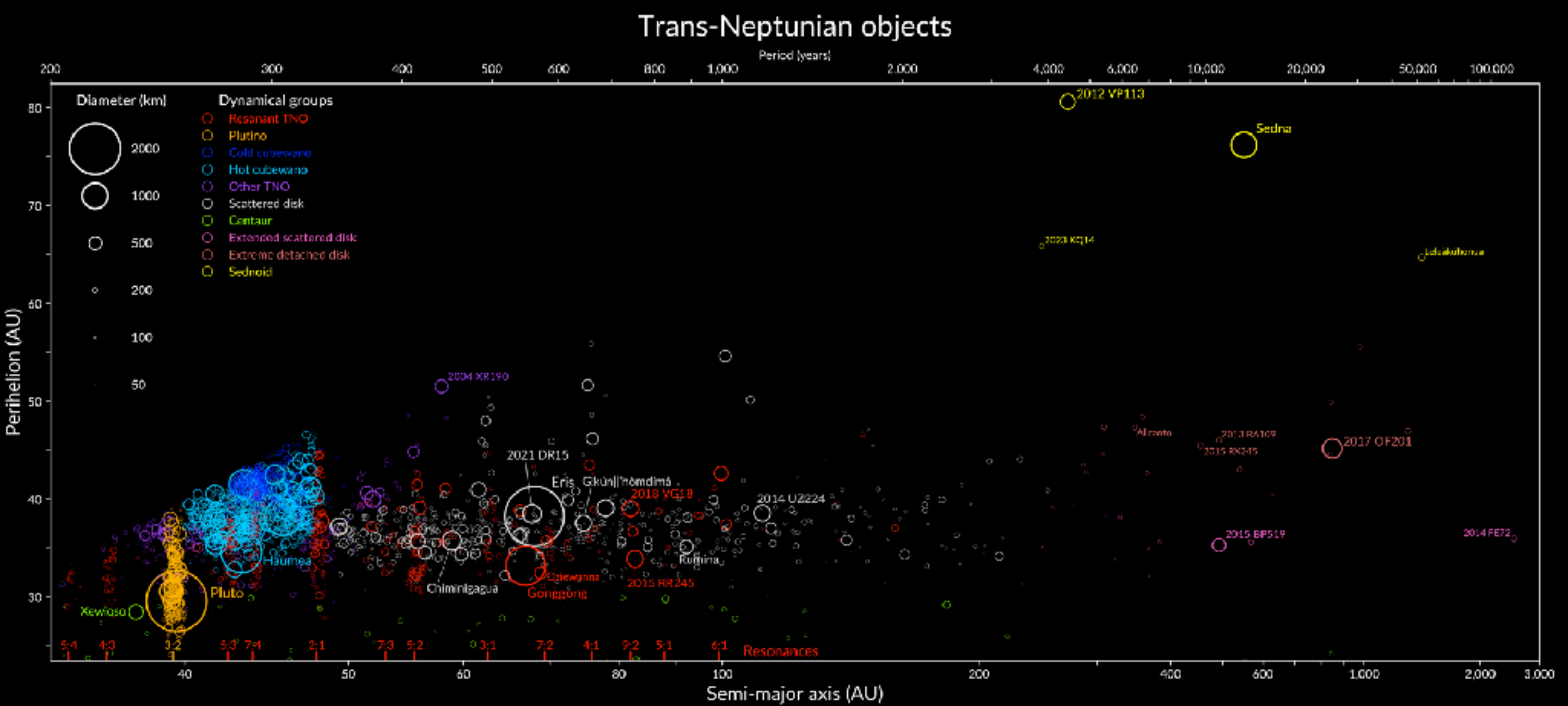


- **1st discovered Kuiper Belt Object: Pluto (1930)**
- **2nd: Charon (1978)**
- **3rd: 15760 Albion (1992)**
- **Currently ~4000 known KBOs (but Vera Rubin…)**

The Kuiper belt

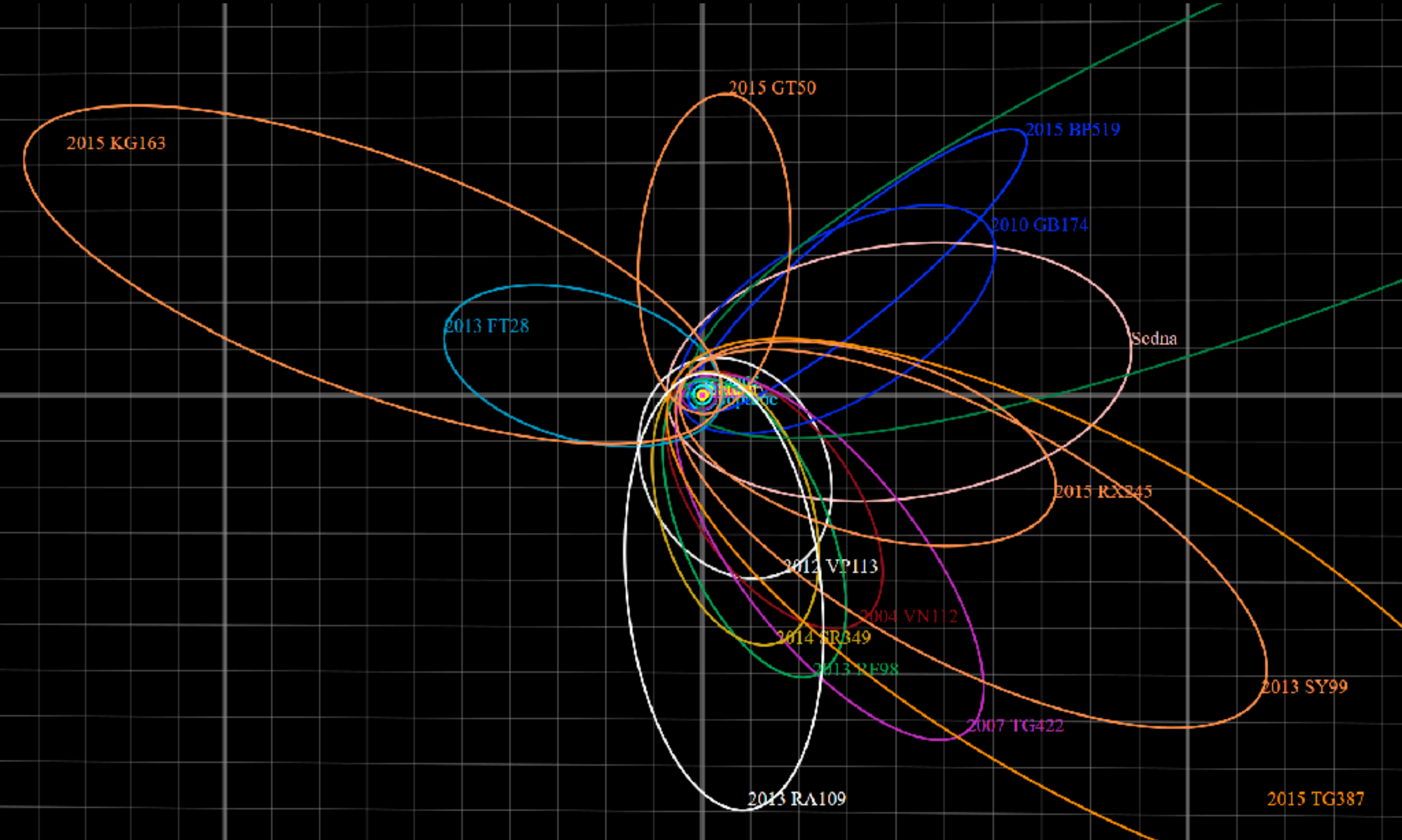


Trans-Neptunian Objects

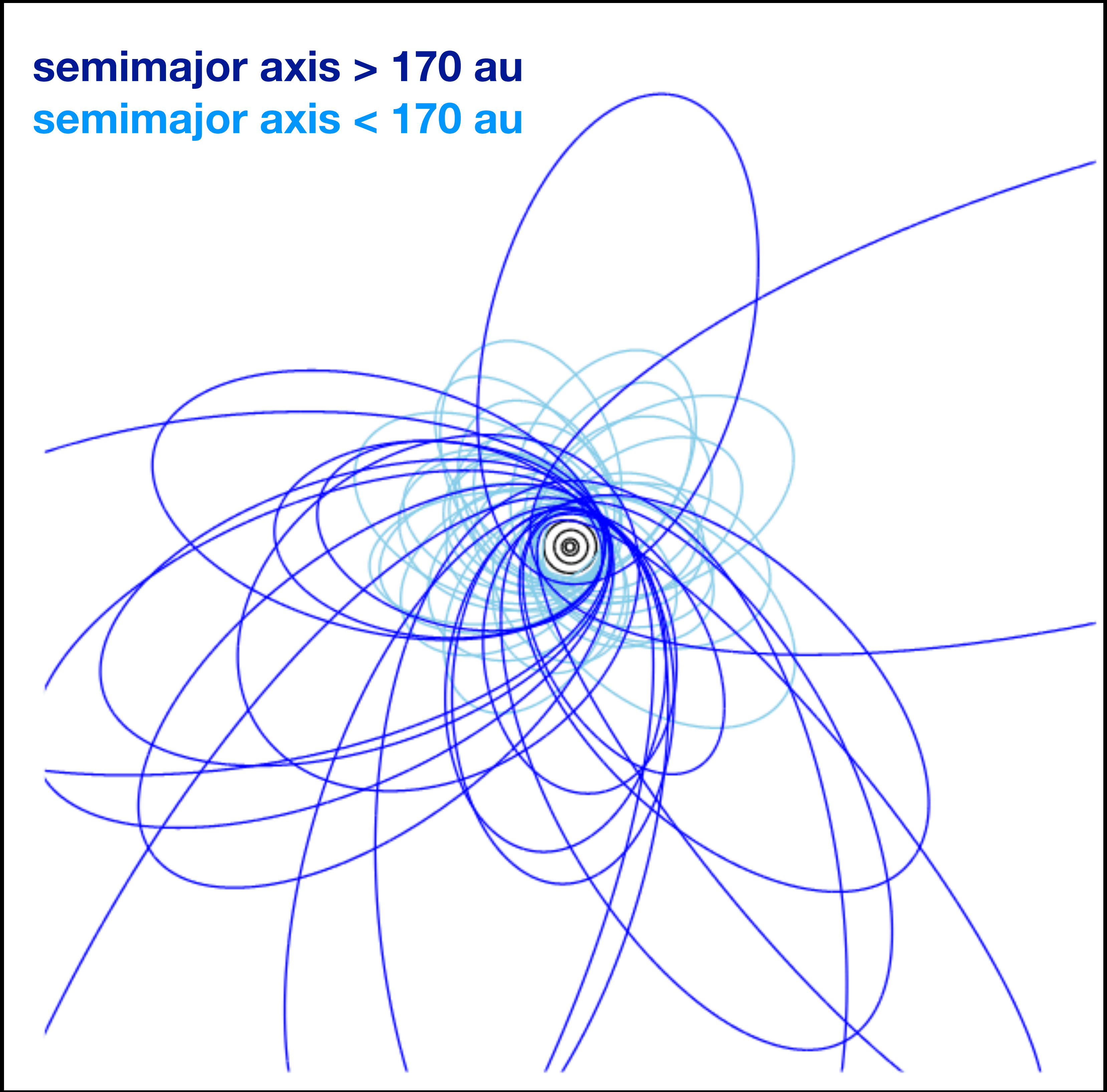


Extreme TNOs

(semimajor axis a > 250 au)

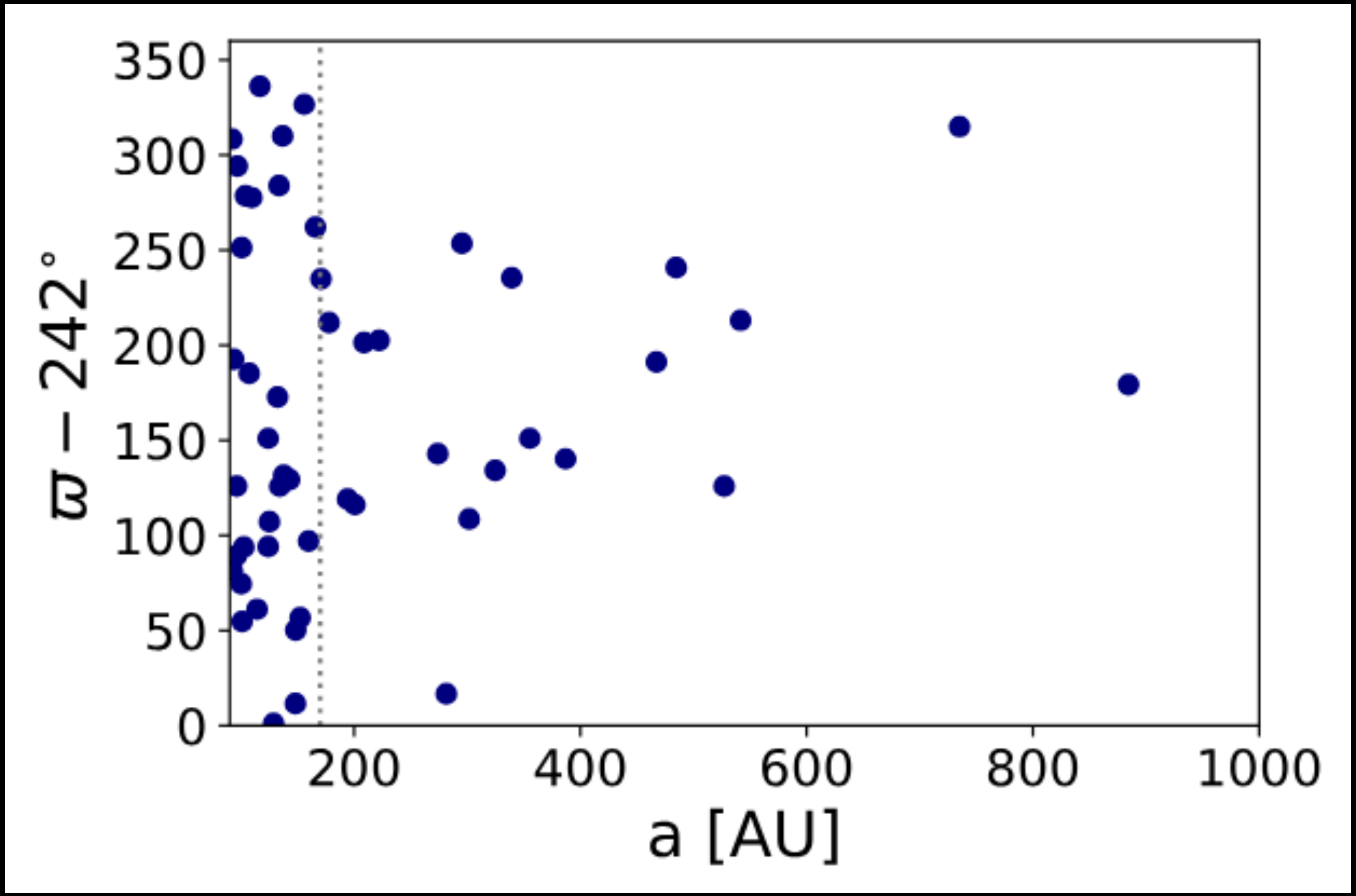


Extreme TNOs



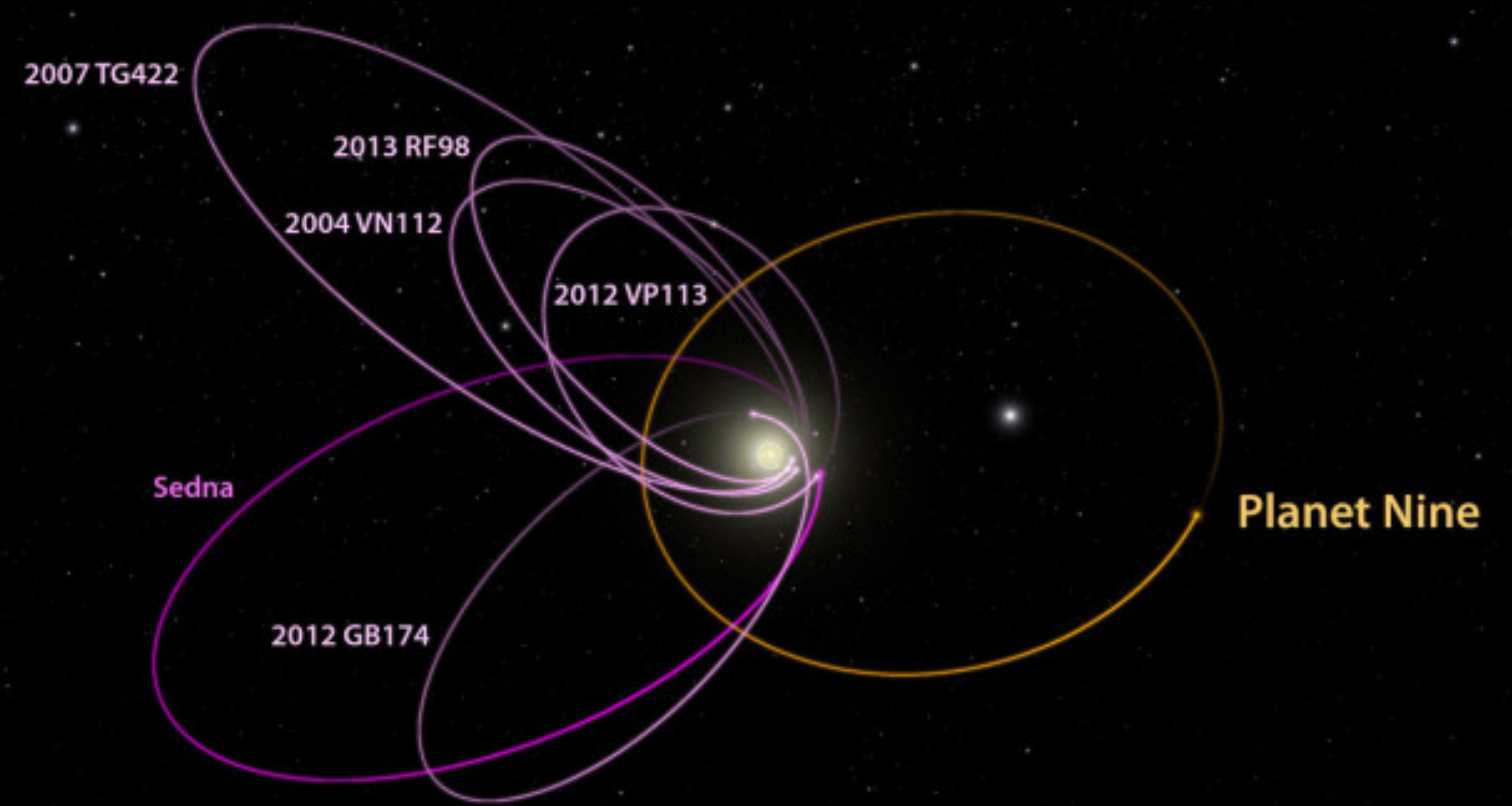
Siraj et al (2025)

Extreme TNOs



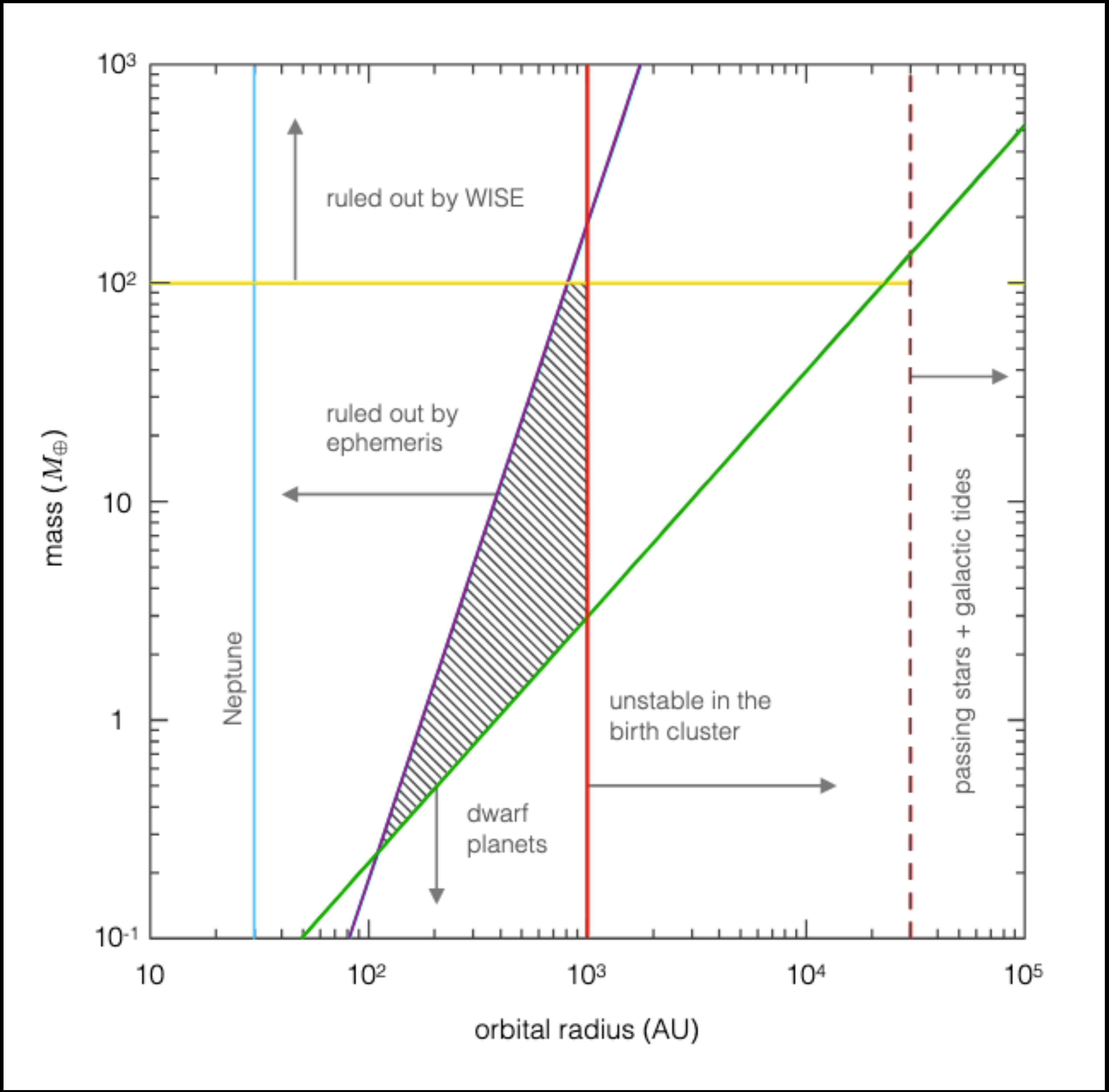
Siraj et al (2025)

The Planet 9 hypothesis



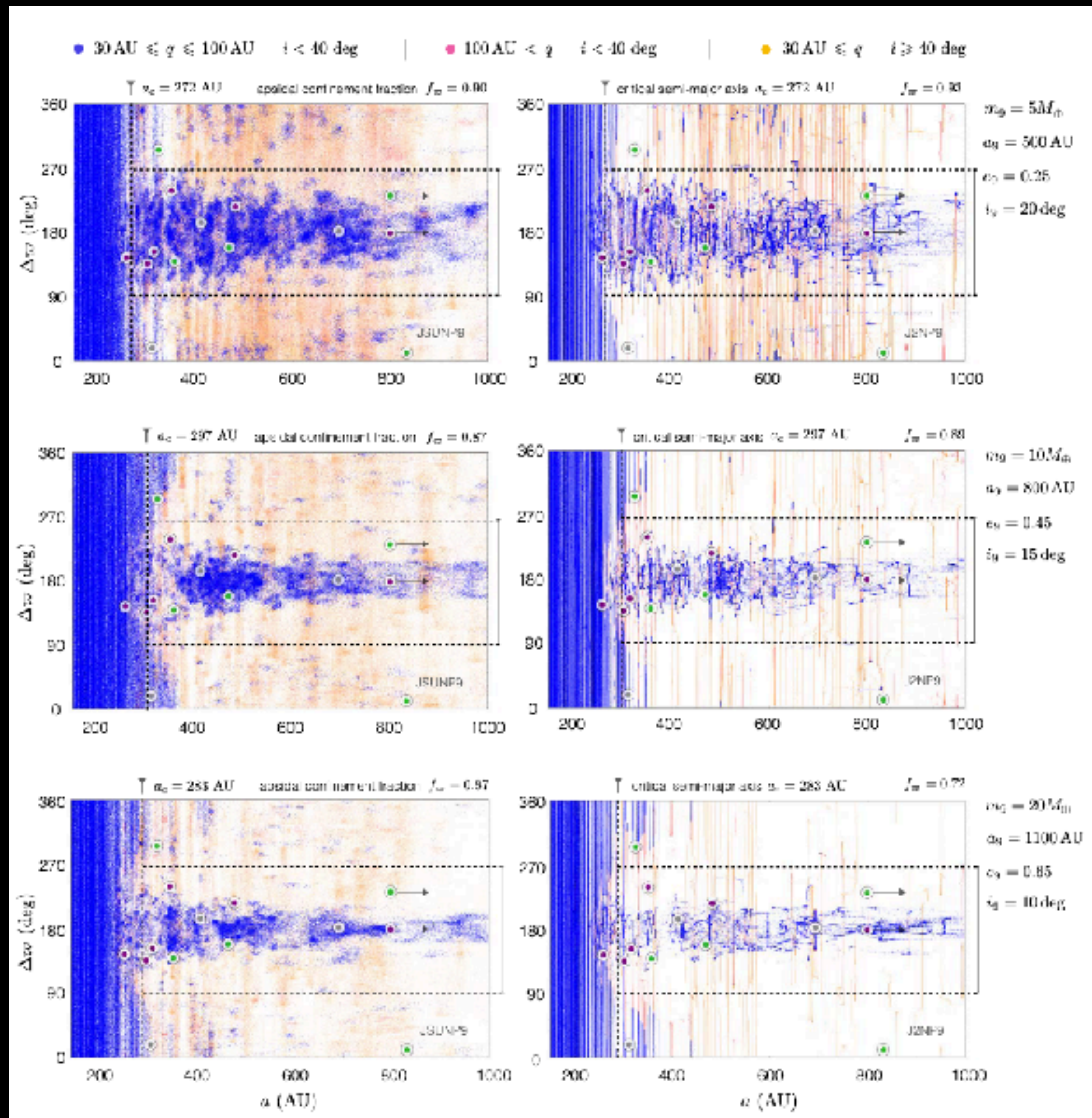
The farthest-out comets – their orbits align
A possible sign of a new … Planet Nine!
Its orbit would have to be wide and stretched out
To shepherd those comets and lead them about.

The Planet 9 hypothesis



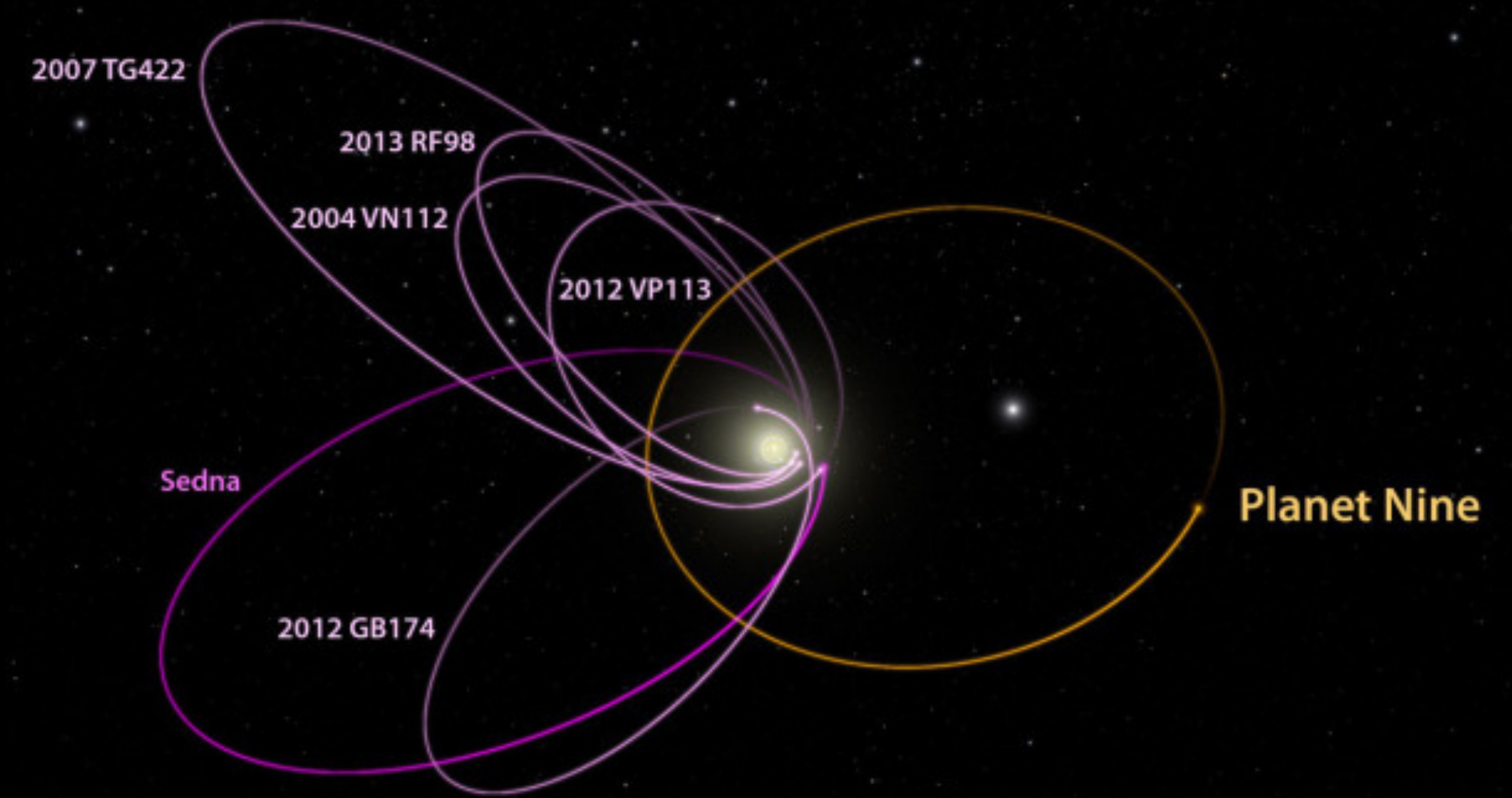
Batygin et al (2019)

The Planet 9 hypothesis



Batygin et al (2019)

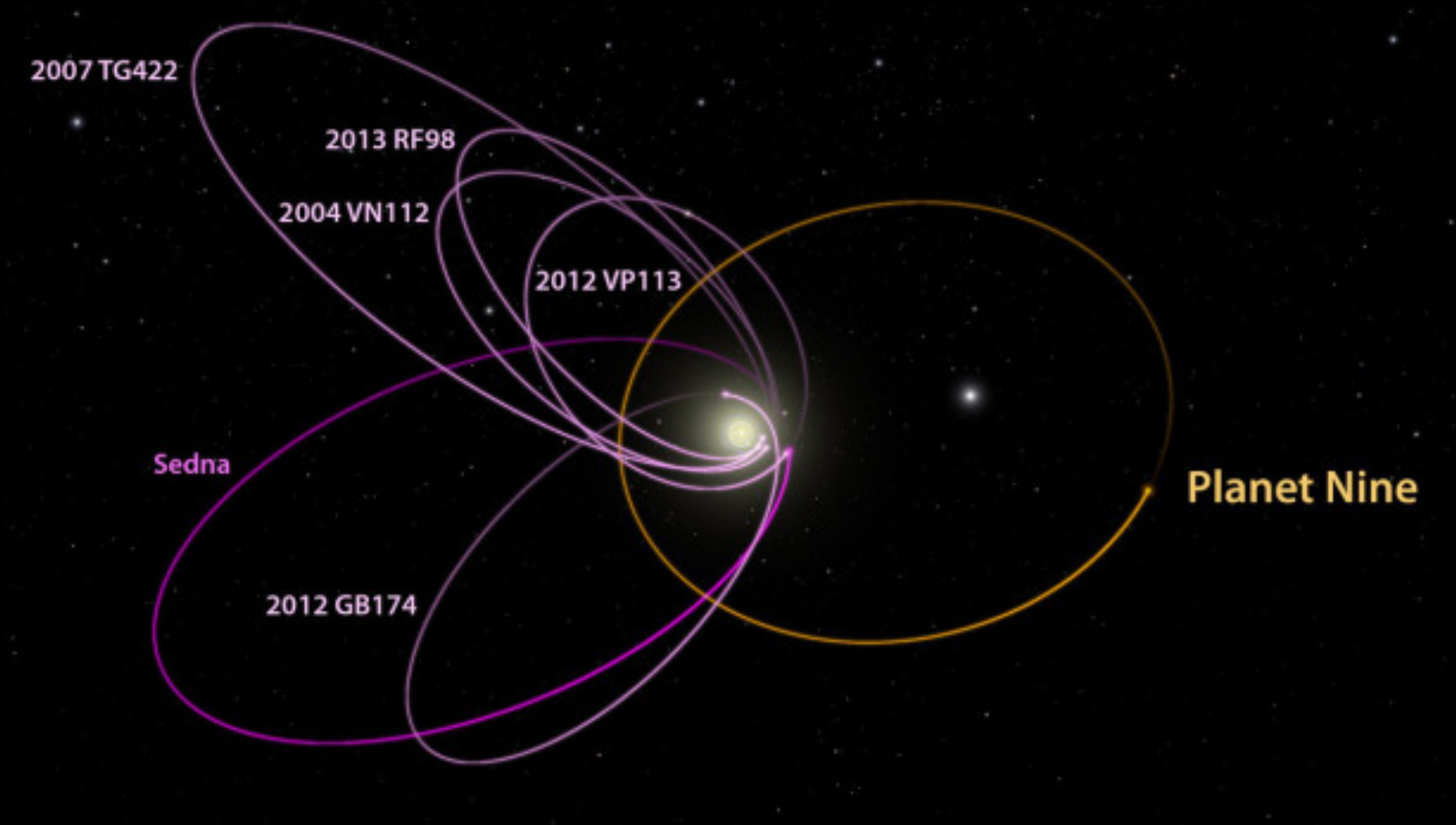
The Planet 9 hypothesis



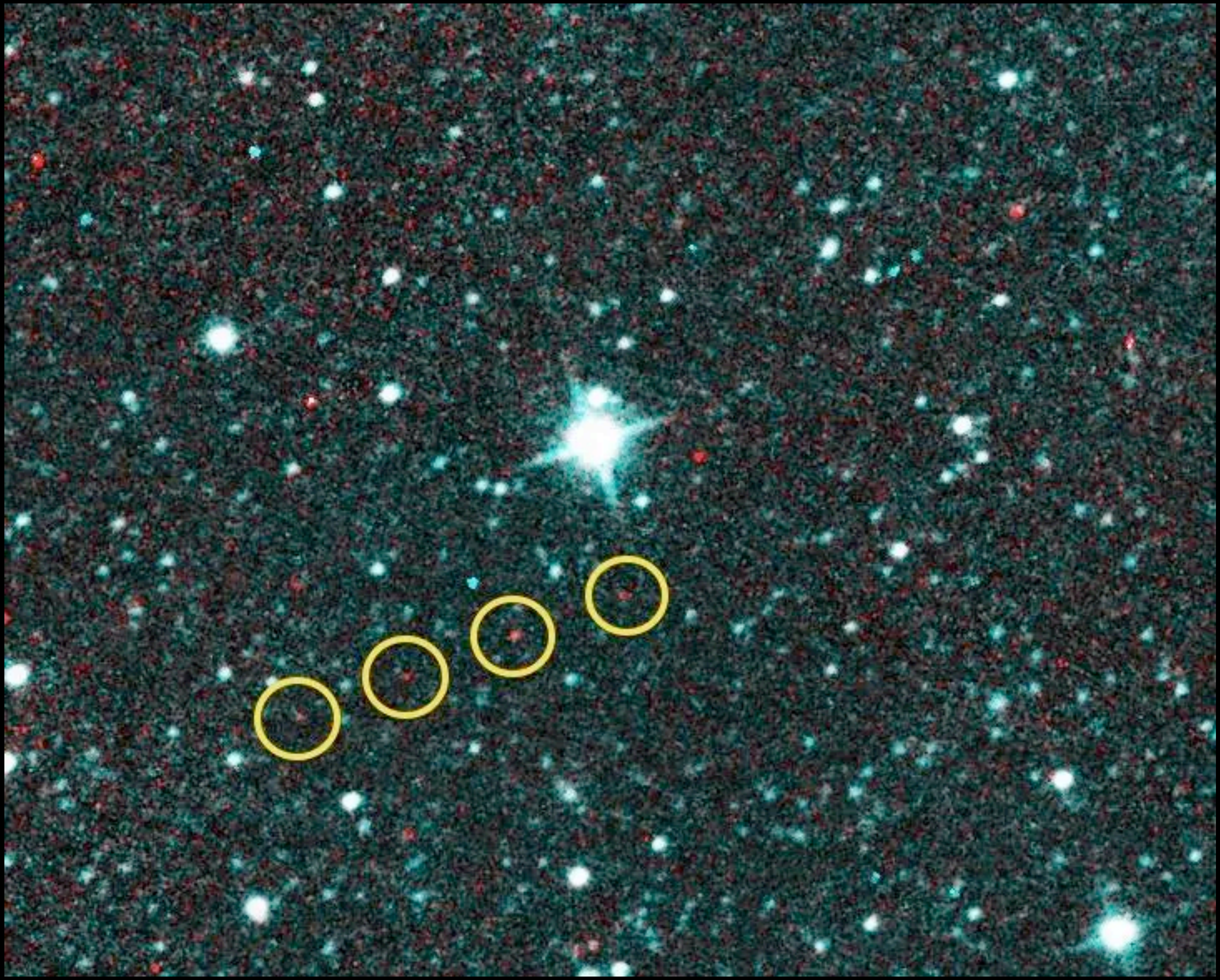
- Best fit: mass ~5 M_{Earth}, orbital distance ~300 au, eccentricity ~0.3, inclination ~7 deg (Batygin & Brown, 2016; Siraj et al 2025)

- Can also explain the Solar System obliquity and the population of low-inclination Neptune-crossing TNOs (e.g.Gomes et al 2016; Batygin et al 2024)

Is the alignment real?

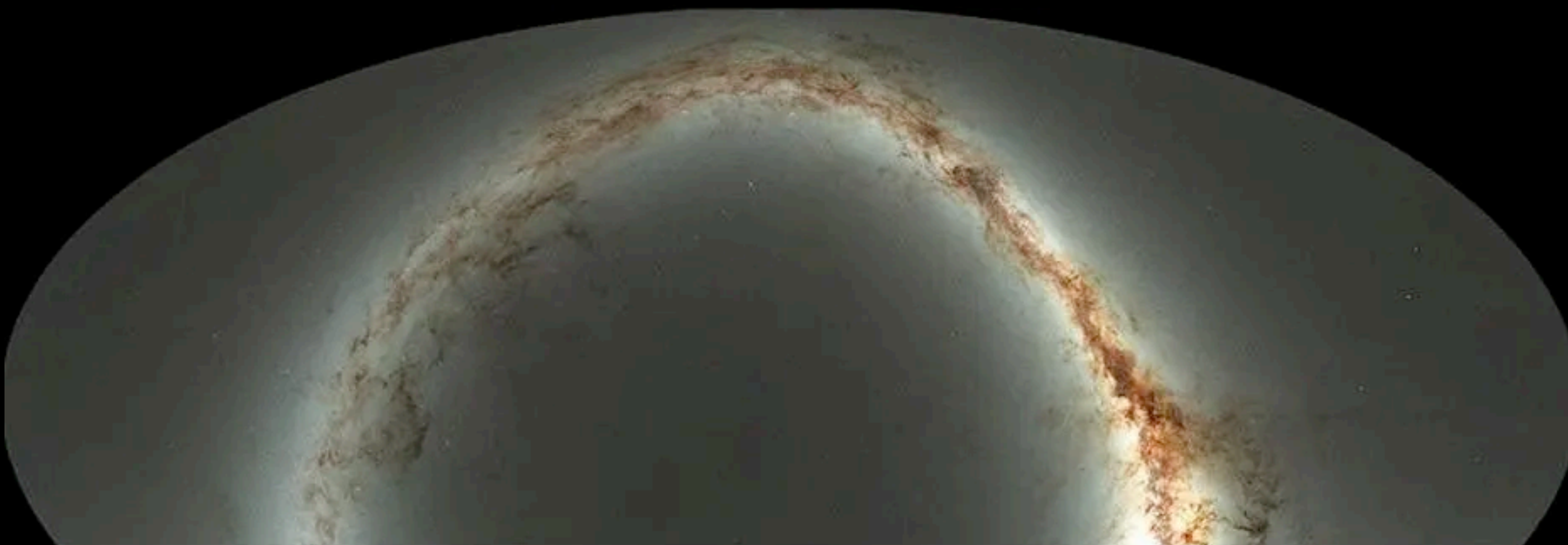


How TNOs are detected



NASA / JPL-Caltech, NEOWISE

The sky is not smooth



The Galactic disk: confusion

Avoiding the Galactic plane introduces bias

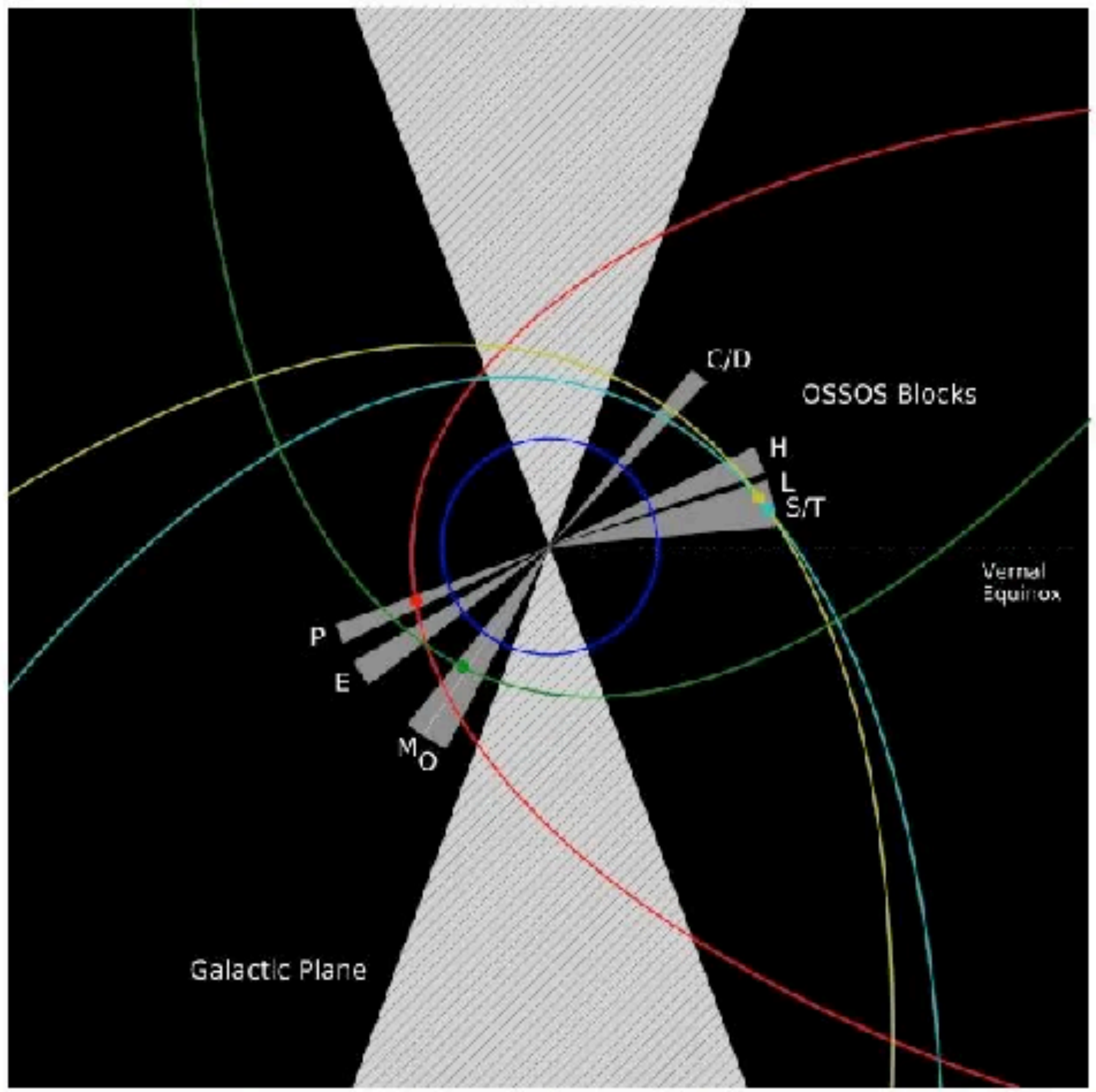
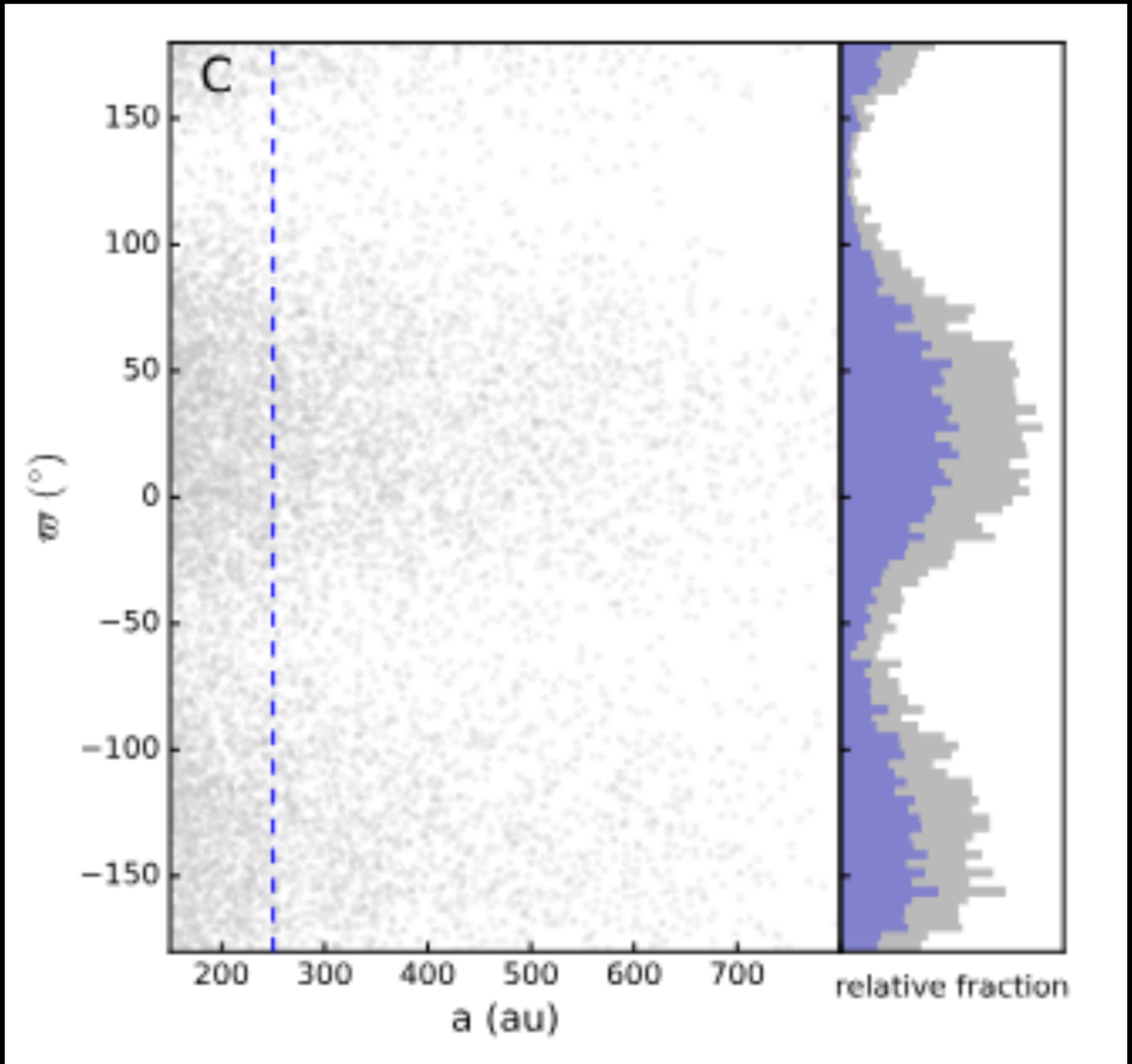


Figure 5. A top-down view of the Solar System including Neptune, a schematic for the OSSOS pointings and the four $a > 250$ au OSSOS TNOs. Neptune's orbit is plotted with a blue circle. The OSSOS TNOS are plotted in the following colours: o5p060 red, o5m52 green, o5s52 cyan, uo3l91 yellow. The discovery location of each TNO is indicated by a point of the appropriate colour. The eight OSSOS blocks (Bannister et al. 2016, Table 1) are plotted in grey and labelled (note that detection sensitivity continues radially beyond the wedge boundaries). The rough location of the galactic plane is plotted in hatched wedges. A dashed line indicates the direction of the vernal equinox, and therefore the upper right quadrant is the September to November opposition direction.

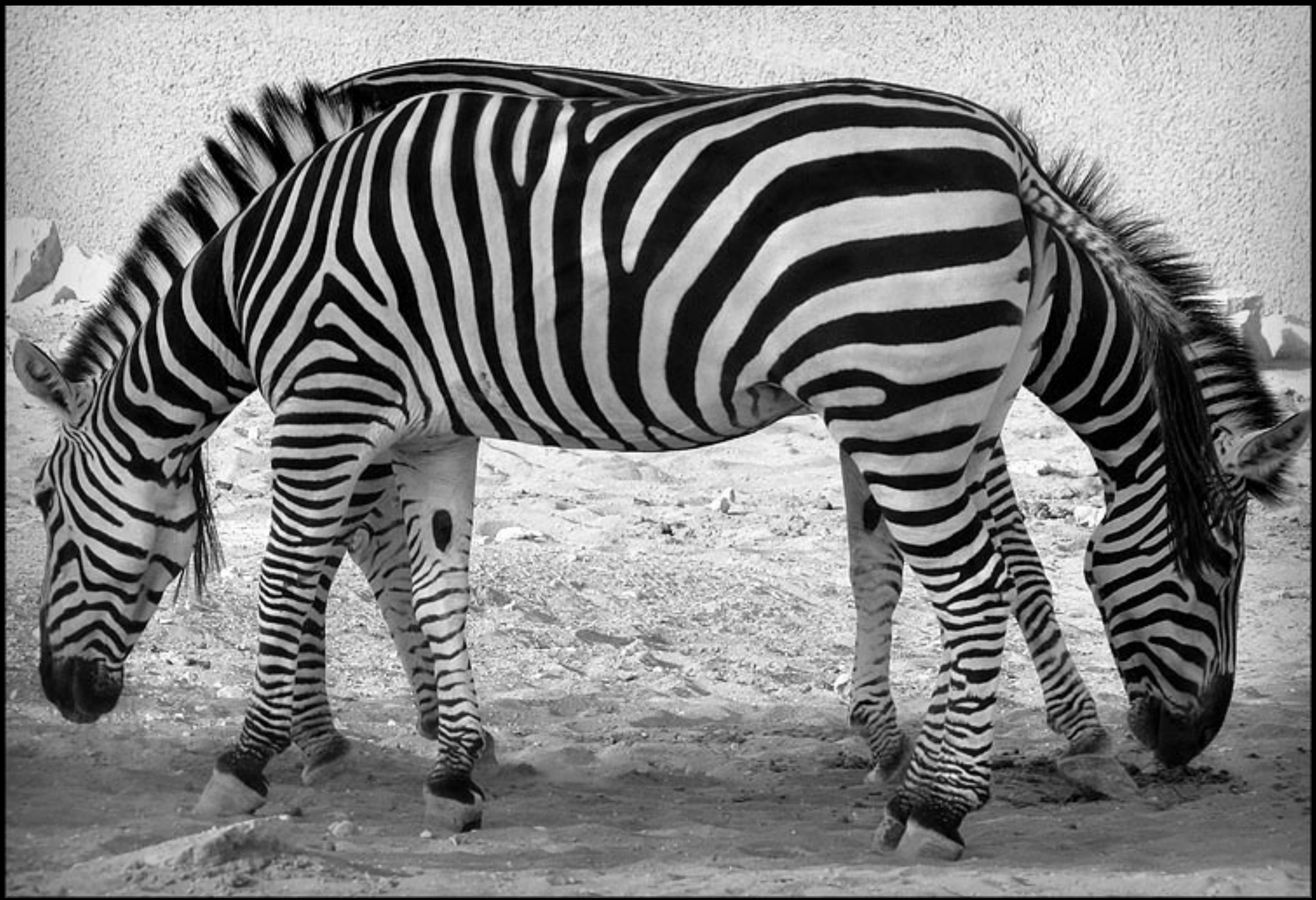
Shankman et al (2018)

Avoiding the Galactic plane introduces bias



Shankman et al (2018)

The origin of extreme wide-orbit planets is puzzling

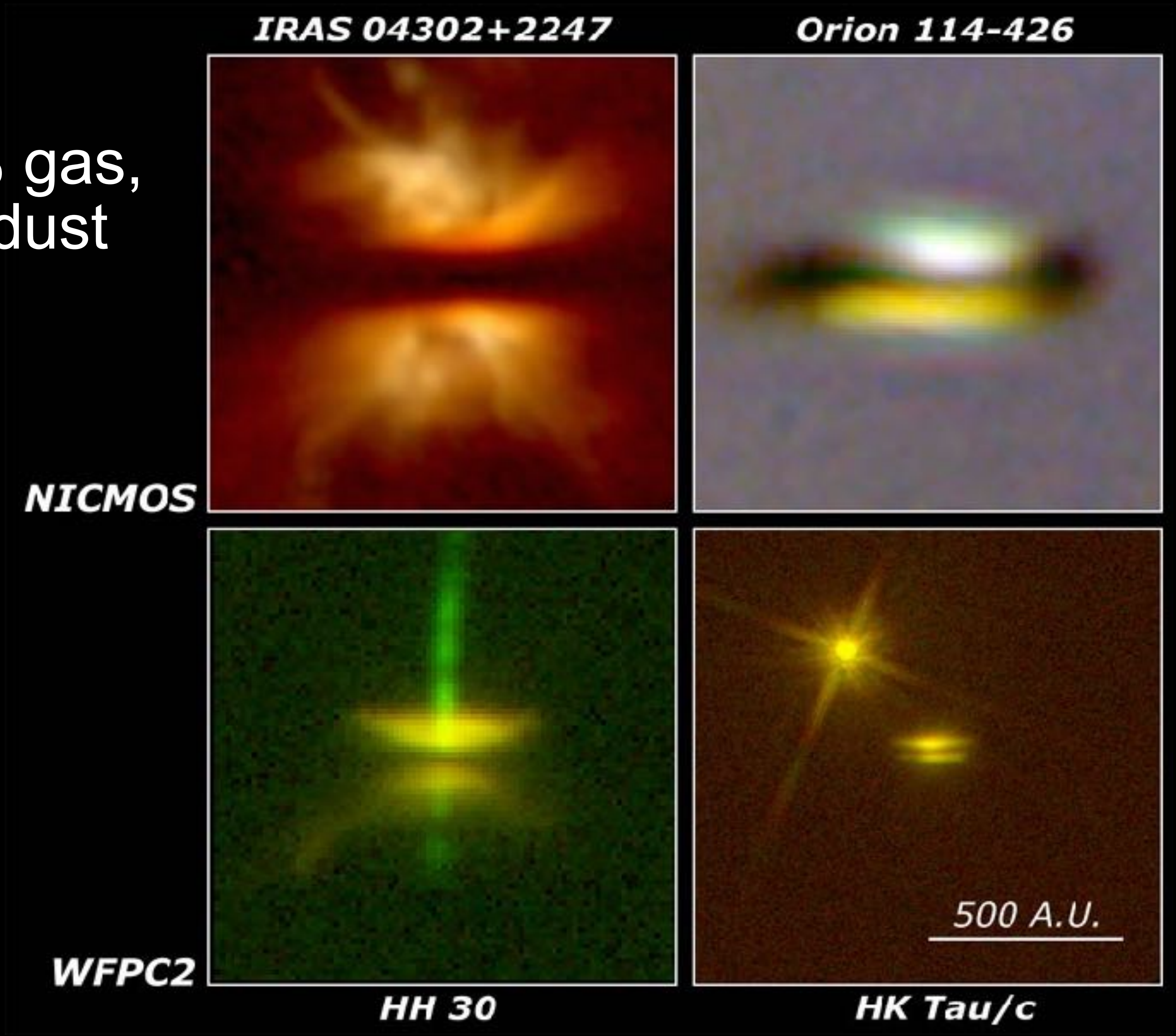


Planets form in disks

HL Tau's disk
(ALMA Partnership et al 2015)

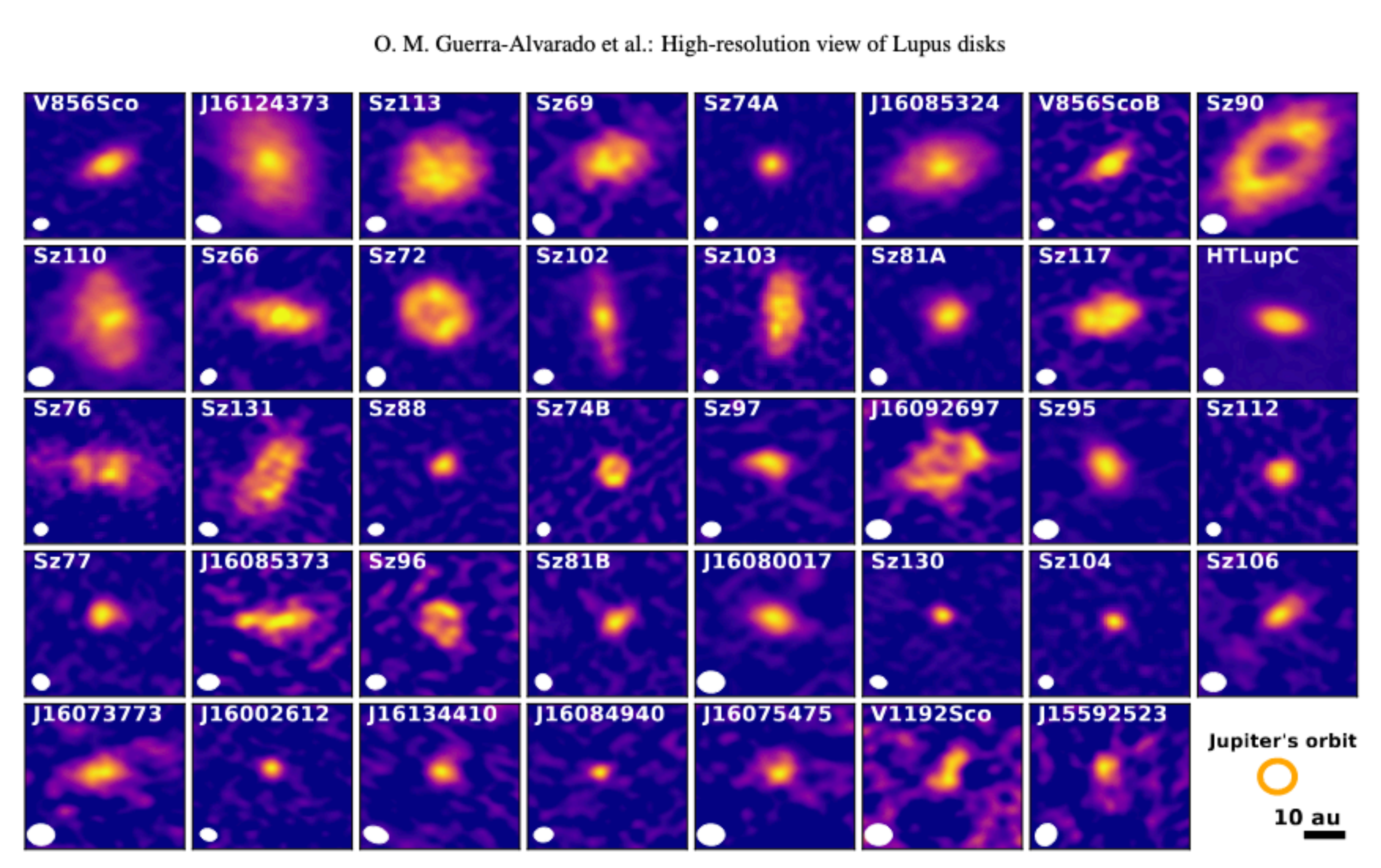
Disks around young stars: Hubble

- 99% gas, 1% dust



Planet-forming disks are typically 30-100 au

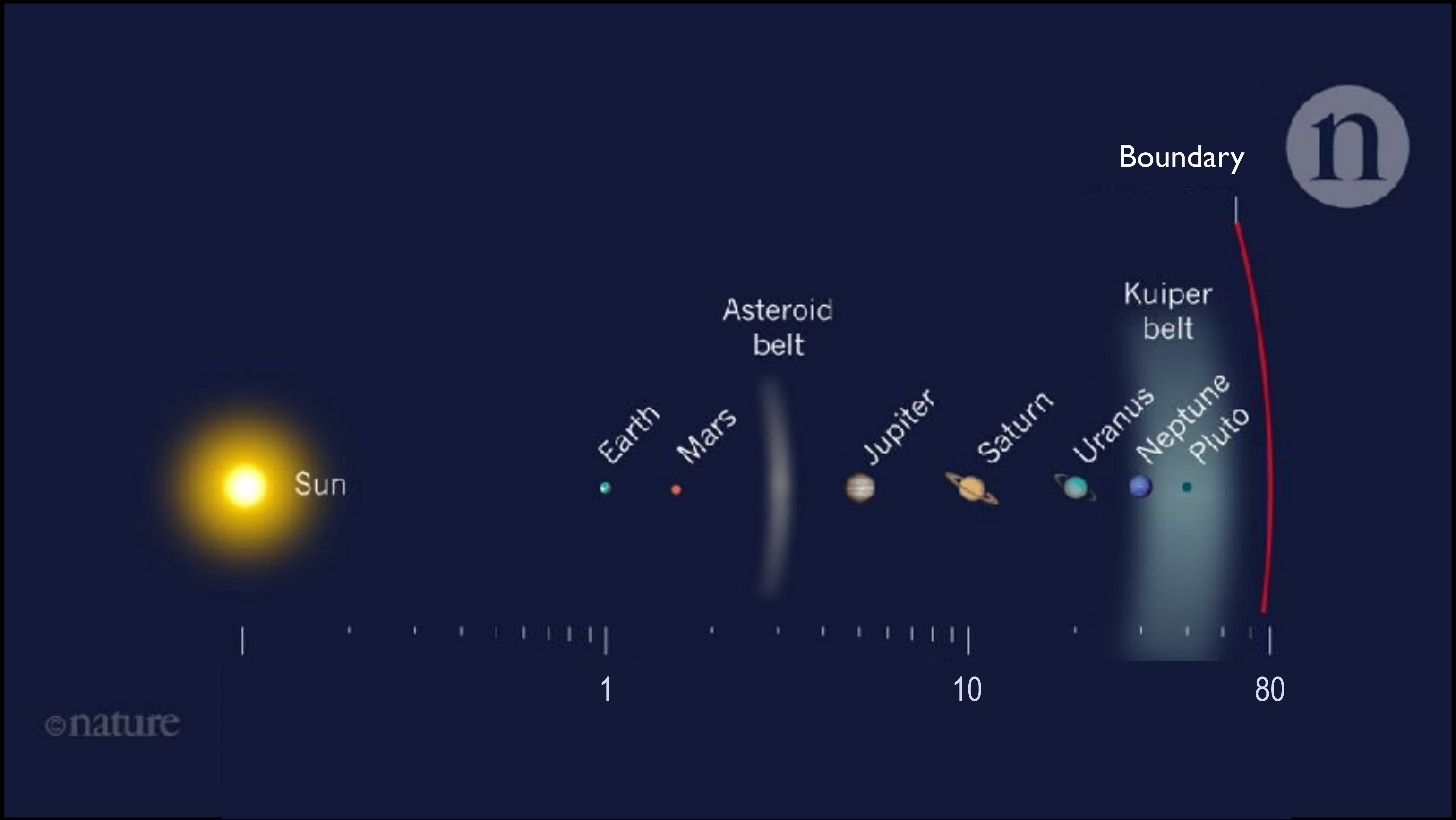
(e.g., Andrews et al 2018; Guerra-Alvarado et al 2025)



See also results by Gemini Planet Imager (GPI) Exoplanet Survey (Esposito et al 2020) and SPHERE (Beuzit et al 2019)

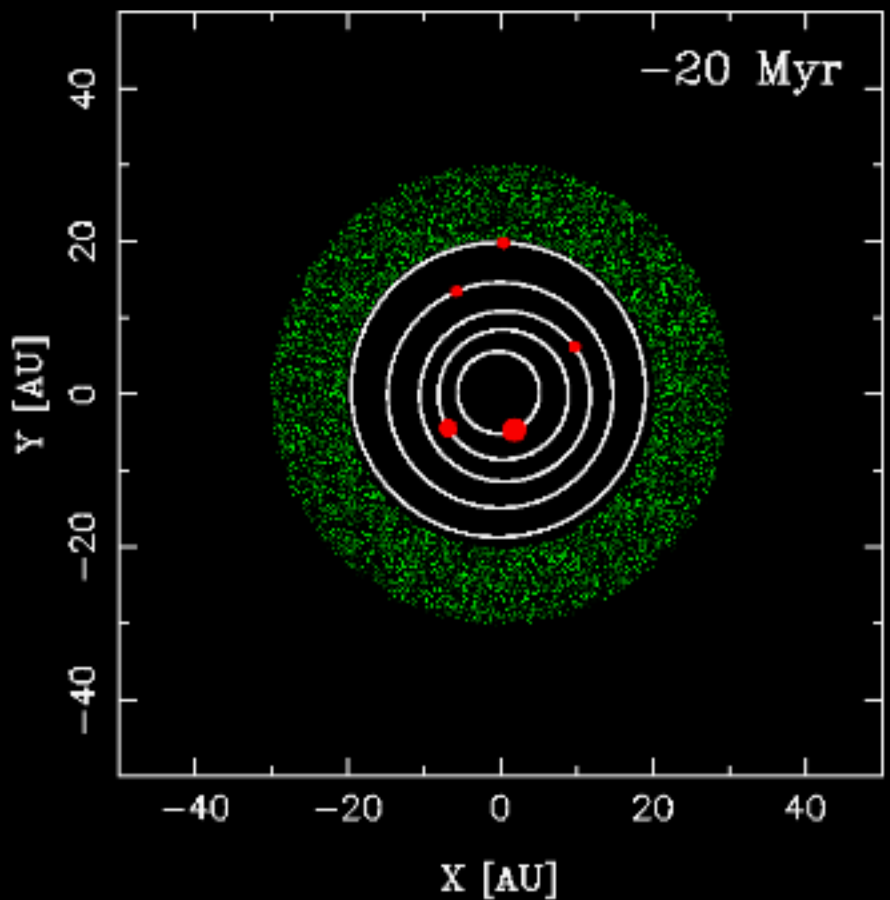
The Sun's disk was ~80 au

(due to deficit of high-inclination TNOs; Kretke et al 2012)



Kretke et al 2012

So, where could Planet 9 have come from?

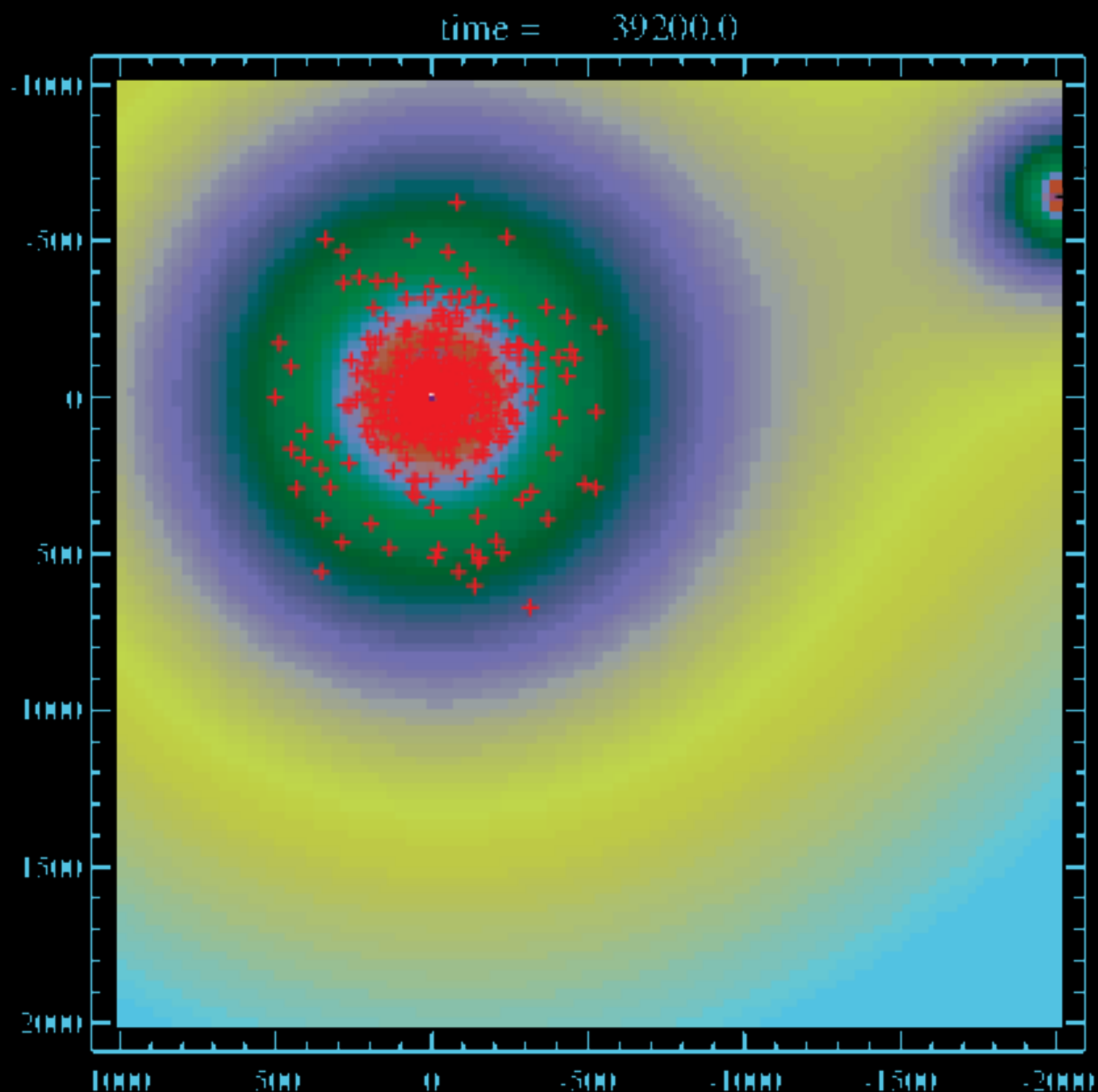


internal?

external?

Stars form in clusters that dissipate in a few to few tens of Myr

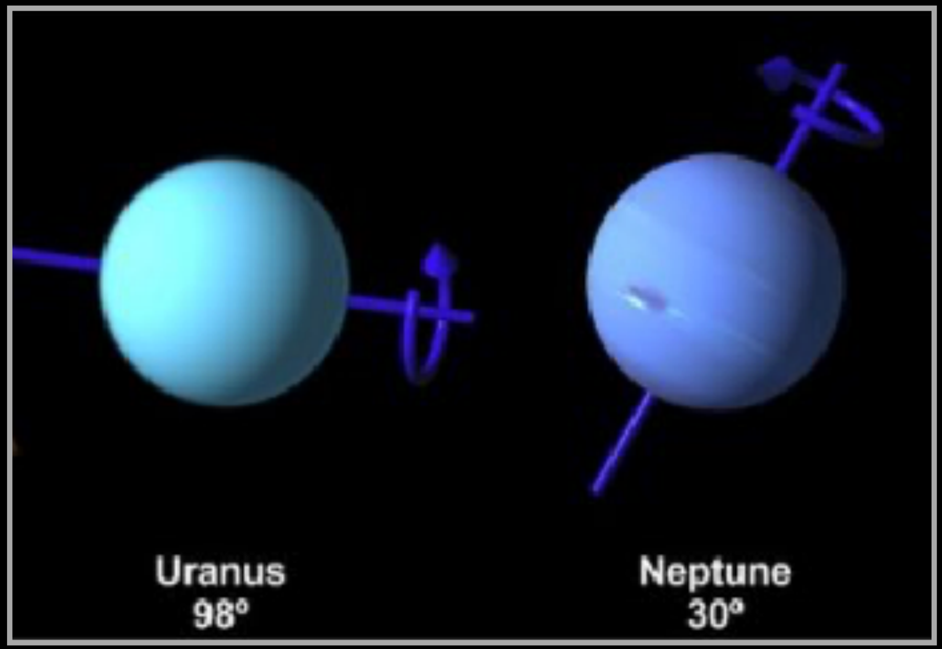
Capture of planet 9 from another star**



Mustill, Raymond, & Davies (2016)
also Li & Adams (2015)

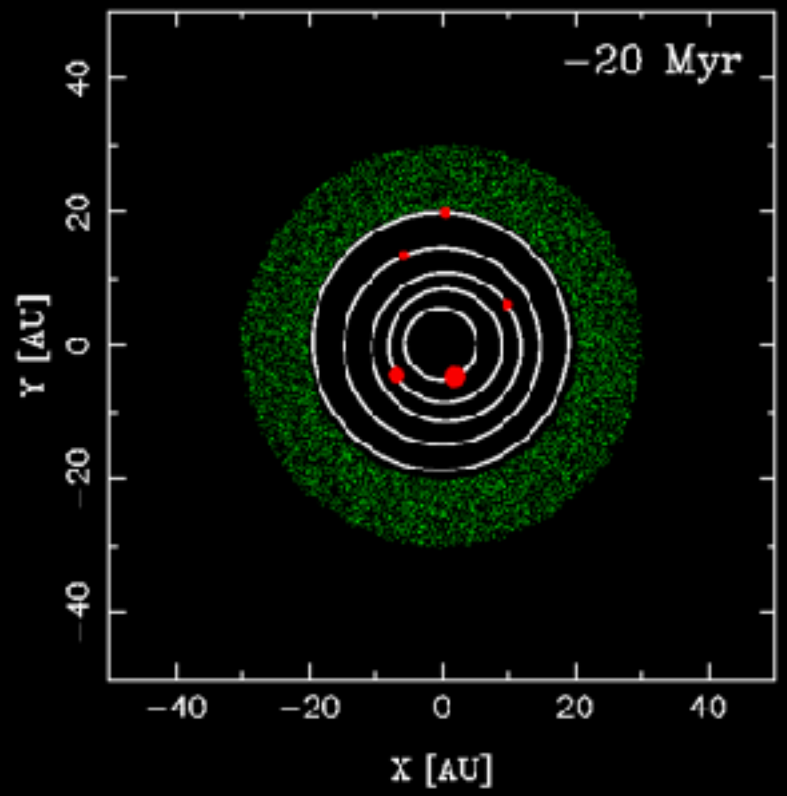
(Probability << 1%)**

The Solar System's dynamical instabilities



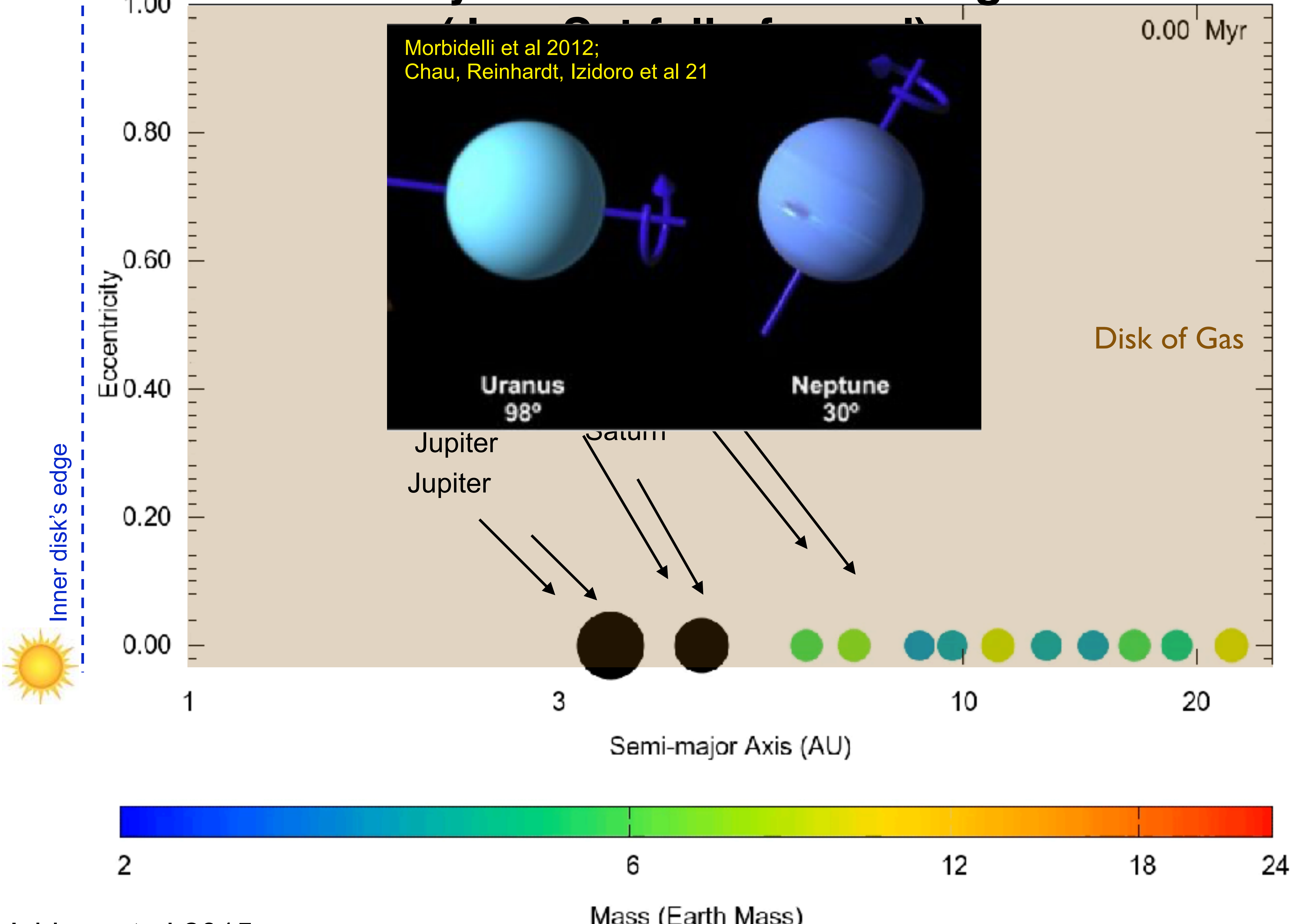
1. Accretion of the ice giants

credit: D. Nesvorny



2. The *giant planet dynamical instability*

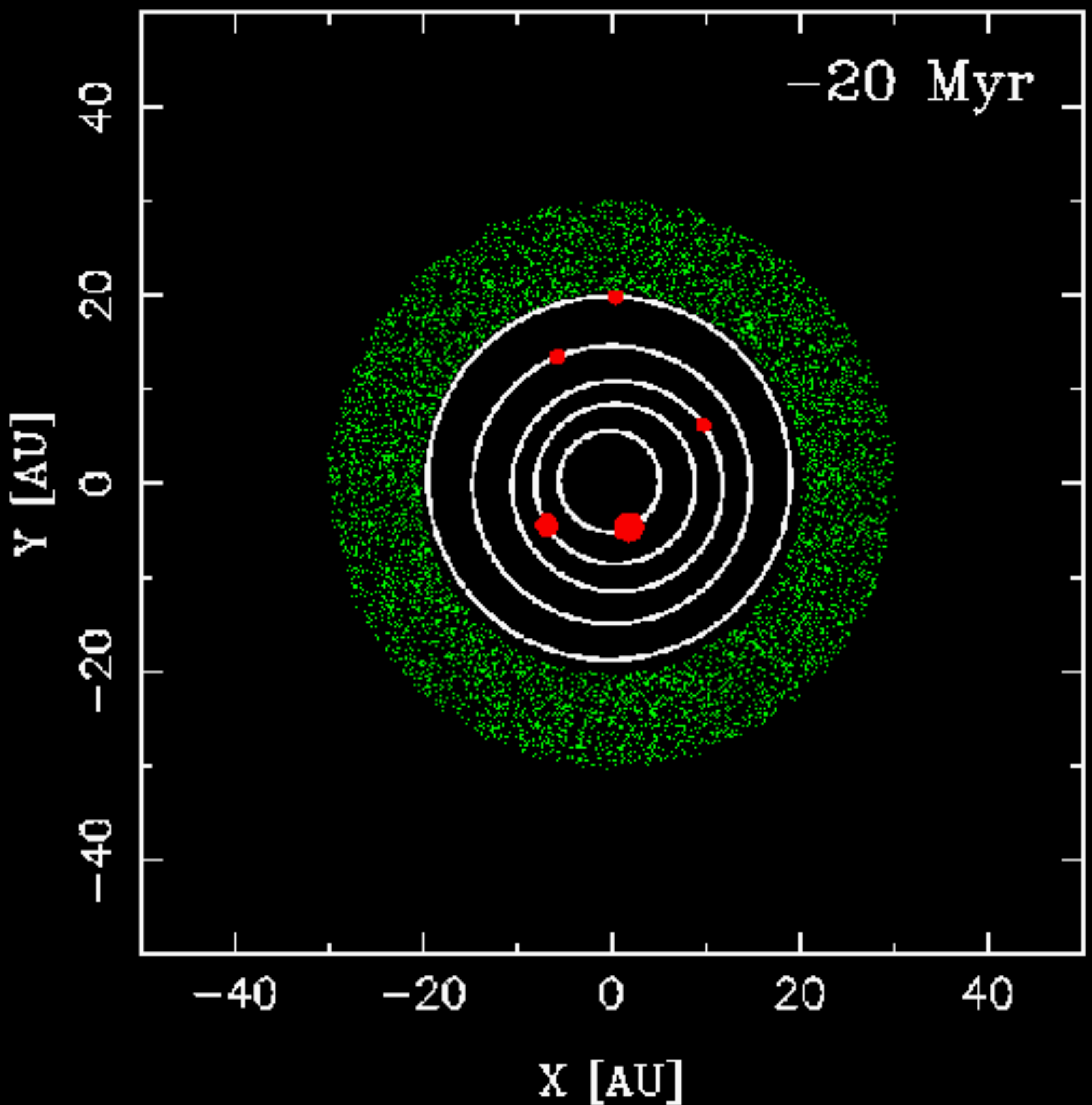
Instability 1: accretion of the ice giants



Izidoro et al 2015

slide courtesy A. Izidoro

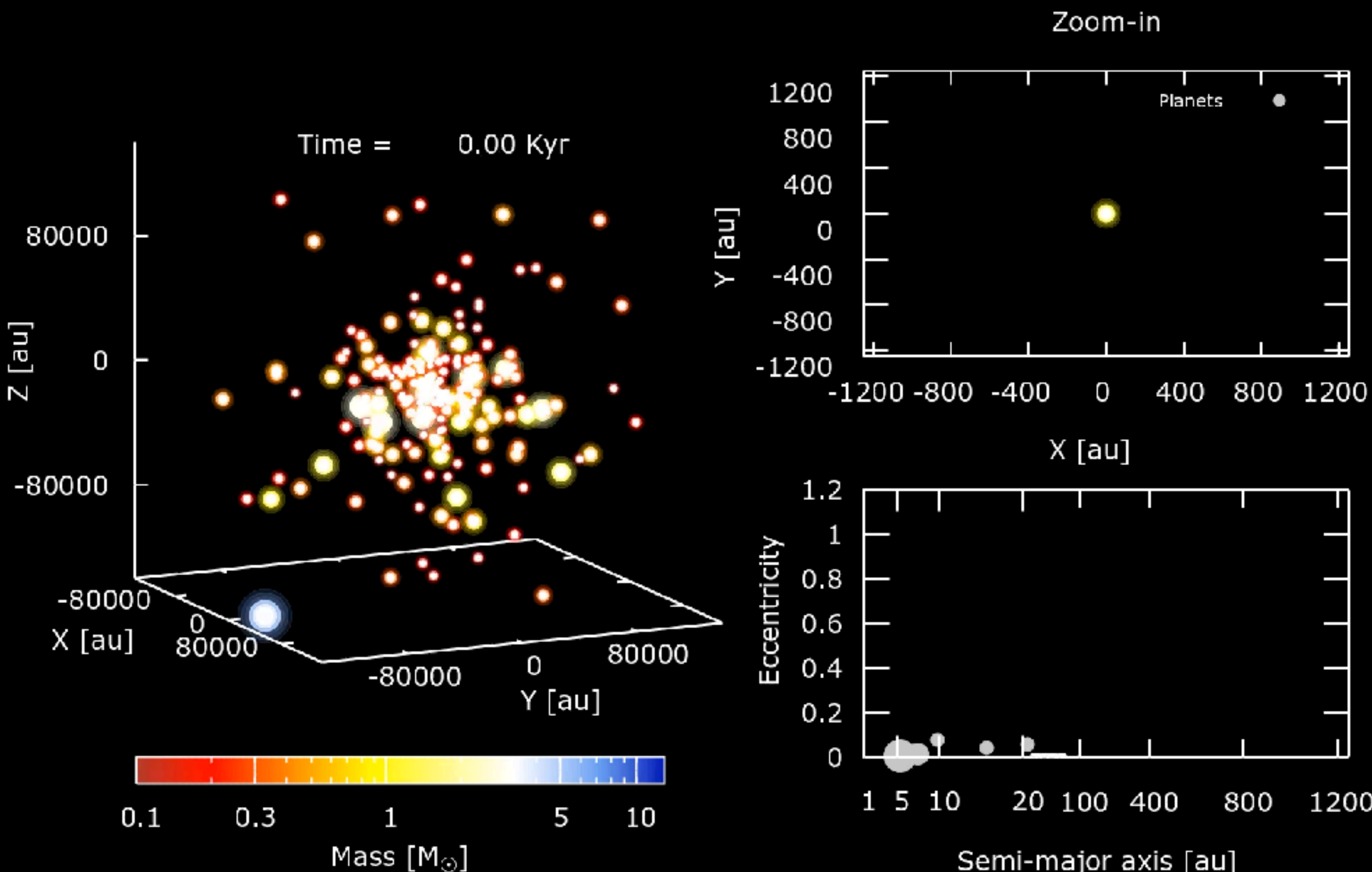
Instability 2: the *giant planet dynamical instability* ("Nice model")



Nesvorny (2011)

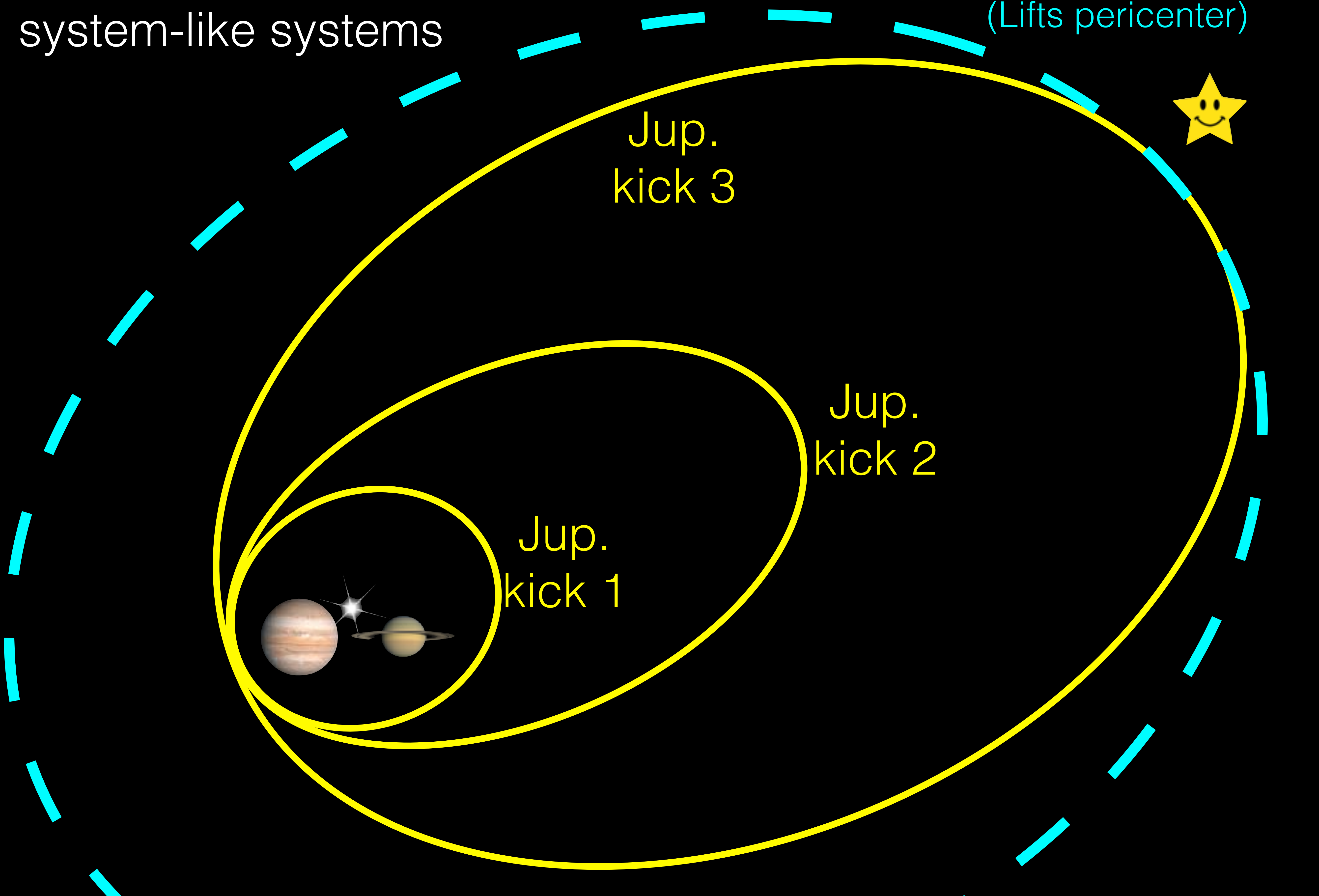
also Tsiganis et al (2005), Morbidelli et al (2007), Batygin & Brown (2012), Clement et al (2021)…

Giant planet dynamical instability during stellar cluster phase

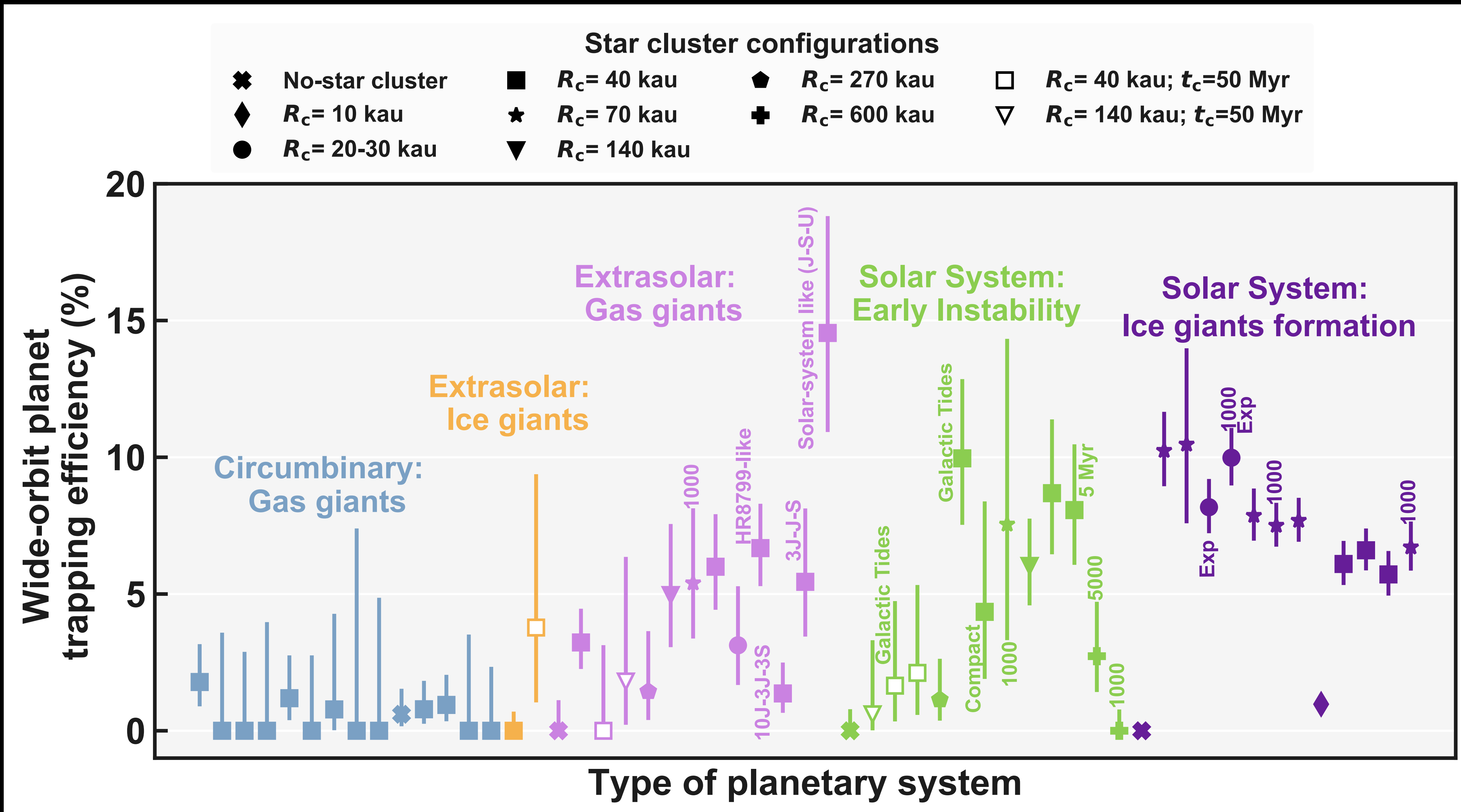


Izidoro et al (2025)

Gravitational scattering in solar system-like systems



Trapping Efficiency



Izidoro et al 2025

Assuming 5 planets ejected from the Solar System, binomial statistics imply a ~40% chance of capturing a wide-orbit planet


2025
NO SCHOOL TODAY
BULLIED FOR GOING GREEN
8 MAY 1945
CROWDS IN LONDON'S PICCADILLY CIRCUS CELEBRATE VICTORY IN EUROPE
ZOO NEW!
FRESH RULES ROAR IN!
HEROES IN A HALF SH
TRUMP IS BACK
LET US PLAY!
First News
TEACHERS! We've got everything you need to teach media and information literacy (MIL) across the curriculum!
KIDS LEAD THE WAY FOR EARTH DAY
SCHOOL 2. PUPILS PREPPED FOR THE AI AGE
READY TO RACE?
EVERY DROP COUNTS
SECOND HAND SEPTEMBER
VOTES AT
GOVERNMENT TO LOWER VOTING AGE ACROSS UK
NEWS KIDS CAN TRUST
NEWSPAPER OF THE YEAR

ARTICLE TYPE

A Search for Planet Nine with IRAS and AKARI Data

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Abstract

The outer solar system is theoretically predicted to harbour an undiscovered planet, often referred to as Planet Nine. Simulations suggest that its gravitational influence could explain the unusual clustering of minor bodies in the Kuiper Belt. However, no observational evidence for Planet Nine has been found so far, as its predicted orbit lies far beyond Neptune, where it reflects only a faint amount of Sunlight. This work aims to find Planet Nine candidates by taking advantage of two far-infrared all-sky surveys, which are IRAS and *AKARI*. The epochs of these two surveys were separated by 23 years, which is large enough to detect Planet Nine's ~ 3′/year orbital motion. We use a dedicated AKARI Far-Infrared point source list for the purpose of our Planet Nine search — AKARI-FIS Monthly Unconfirmed Source List (AKARI-MUSL), which includes sources detected repeatedly only in hours timescale, but not after months. AKARI-MUSL is more advantageous than the AKARI Bright Source Catalogue (AKARI-BSC) for detecting moving and faint objects like Planet Nine with a twice-deeper flux detection limit. We search for objects that moved slowly between IRAS and *AKARI* detections given in the catalogues. First, we estimated the expected flux and orbital motion of Planet Nine by assuming its mass, distance, and effective temperature to ensure it can be detected by IRAS and *AKARI*, then applied the positional and flux selection criteria to narrow down the number of sources from the catalogues. Next, we produced all possible candidate pairs including one IRAS source and one *AKARI* source whose angular separations were limited between 42′ and 69.6′, corresponding to the heliocentric distance range of 500 – 700 AU and the mass range of 7 – 17$M_\oplus$. There are 13 candidate pairs obtained after the selection criteria. After image inspection, we found one good candidate, of which the IRAS source is absent from the same coordinate in the *AKARI* image after 23 years and vice versa. However, *AKARI* and IRAS detections are not enough to determine the full orbit of this candidate. This issue leads to the need for follow-up observations, which will determine the Keplerian motion of our Planet Nine candidate.

Batygin says he would still cheer on the discovery: "I would be the first person to say, 'That is not Planet Nine—that is Planet 8.5.'"

Article

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Discovery and dynamics of a Sedna-like object with a perihelion of 66 au

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Check for up

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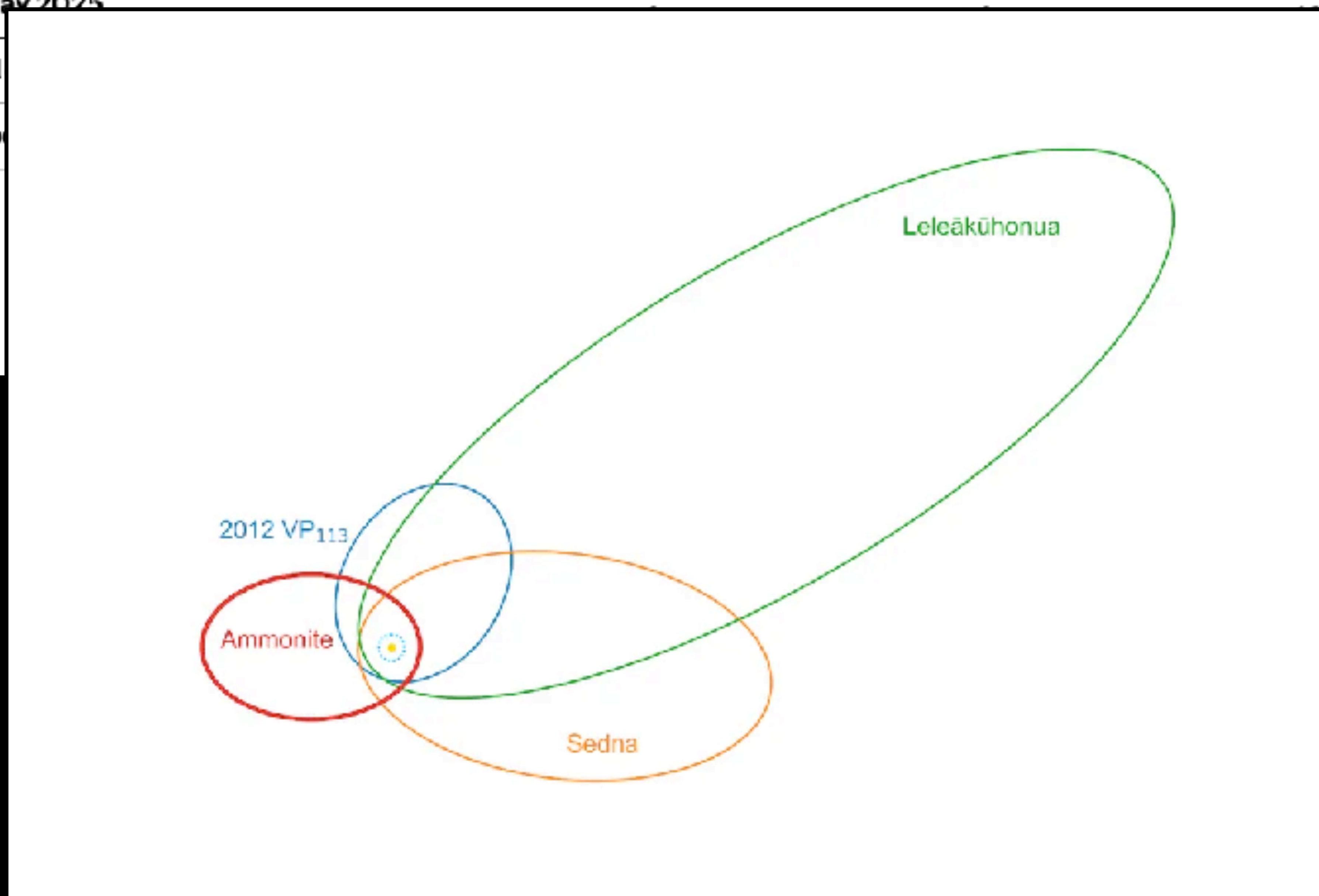
Ashton[1],

10,

kawa[23],



Vera Rubin Telescope (LSST)

Vera Rubin

Best known for discovering dark matter using Galactic rotation curves

Vera Rubin first light

(June 24 2025)

Telescope

- Etendue (AΩ): 319 m^2 deg^2
- Field of View (FOV): 3.5 deg (9.6 deg^2)
- Primary mirror diameter: 8.4 m
- Mean effective aperture: 6.49 m (area weighted over FOV)
- Final f-ratio: f/1.233
- Camera weight: 6,746 lbs (3,060 kg)
- Mirror (M1+M3 glass mirror only) weight: 35,900 lbs (16,284 kg)
- Expected median slew time between visits: 4.8 s

Data volume

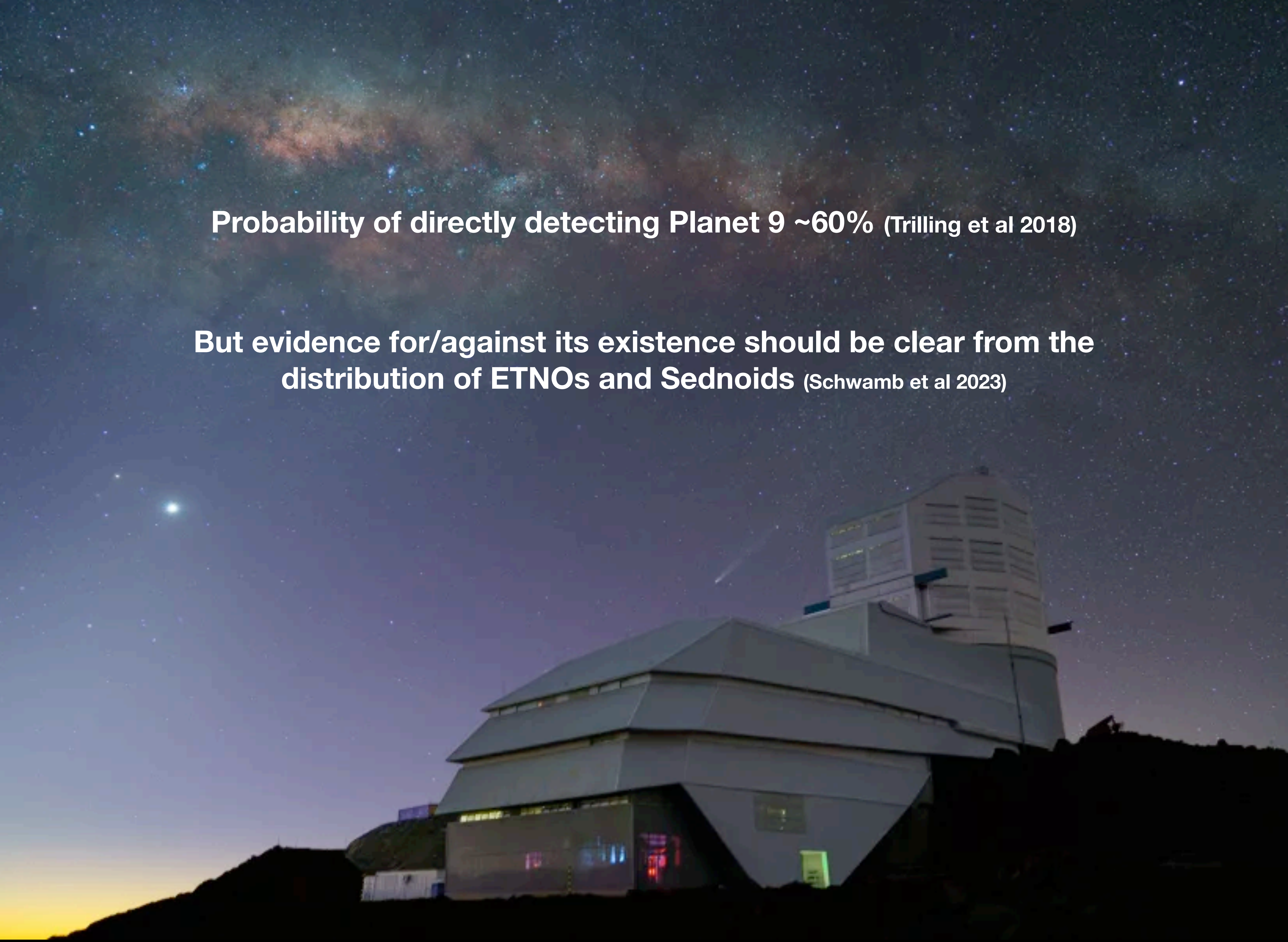
- Nightly data size: 10 TB/night
- Real-time alert latency: 60 s
- Alerts per visit: ~10,000
- Alerts per night: ~10 million
- Number of data releases: 11
- Final database size (DR11): 15 PB
- Final number of objects (DR11):
  - 20B galaxies
  - 17B resolved stars
  - 6M orbits of solar system bodies

Survey

- Survey duration: 10 years
- Fiducial number of visits per pointing (main survey): 800
- Fiducial main survey area: 18,000 deg^2
- Estimated total covered area (including special programs): 25,000 deg^2
- Standard visit exposures (expected): 30 s
- Time to take a single exposure: 34 s
- Median (Mean) visit time (normal survey mode): 36 s (41 s)

Probability of directly detecting Planet 9 ~60% (Trilling et al 2018)

But evidence for/against its existence should be clear from the distribution of ETNOs and Sednoids (Schwamb et al 2023)



More information

- *Very wide-orbit planets from dynamical instabilities during the stellar birth cluster phase (Izidoro et al 2025, Nat. Ast.)*
- planetplanet.net