Dynamical origin of two potentially hazardous asteroids

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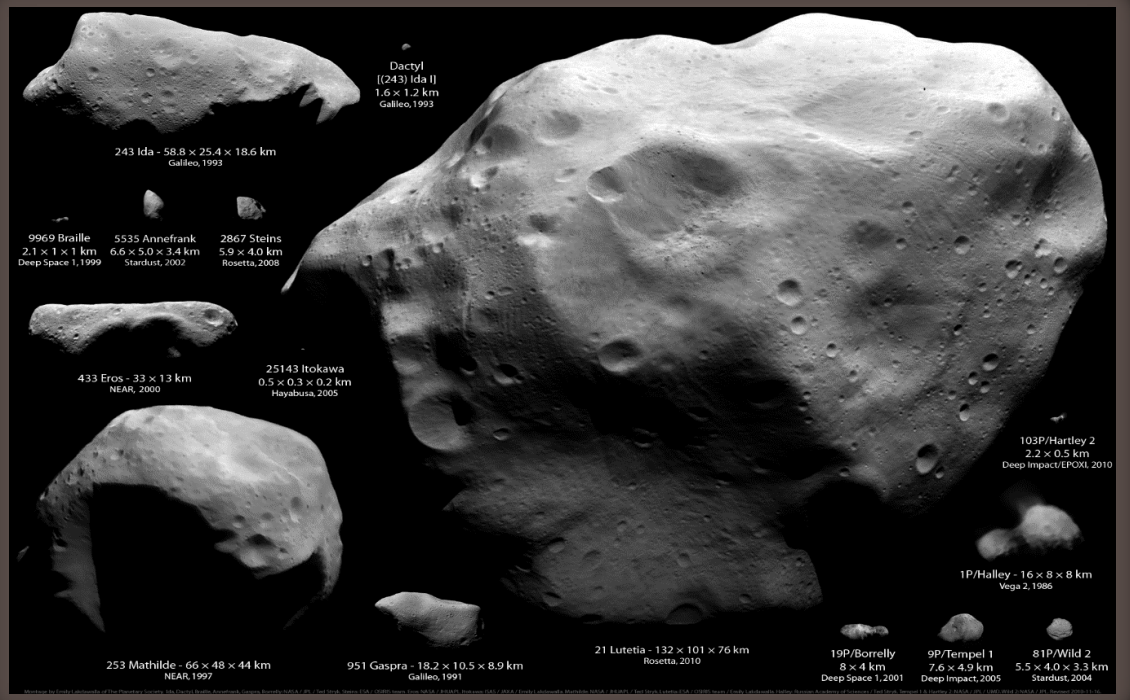
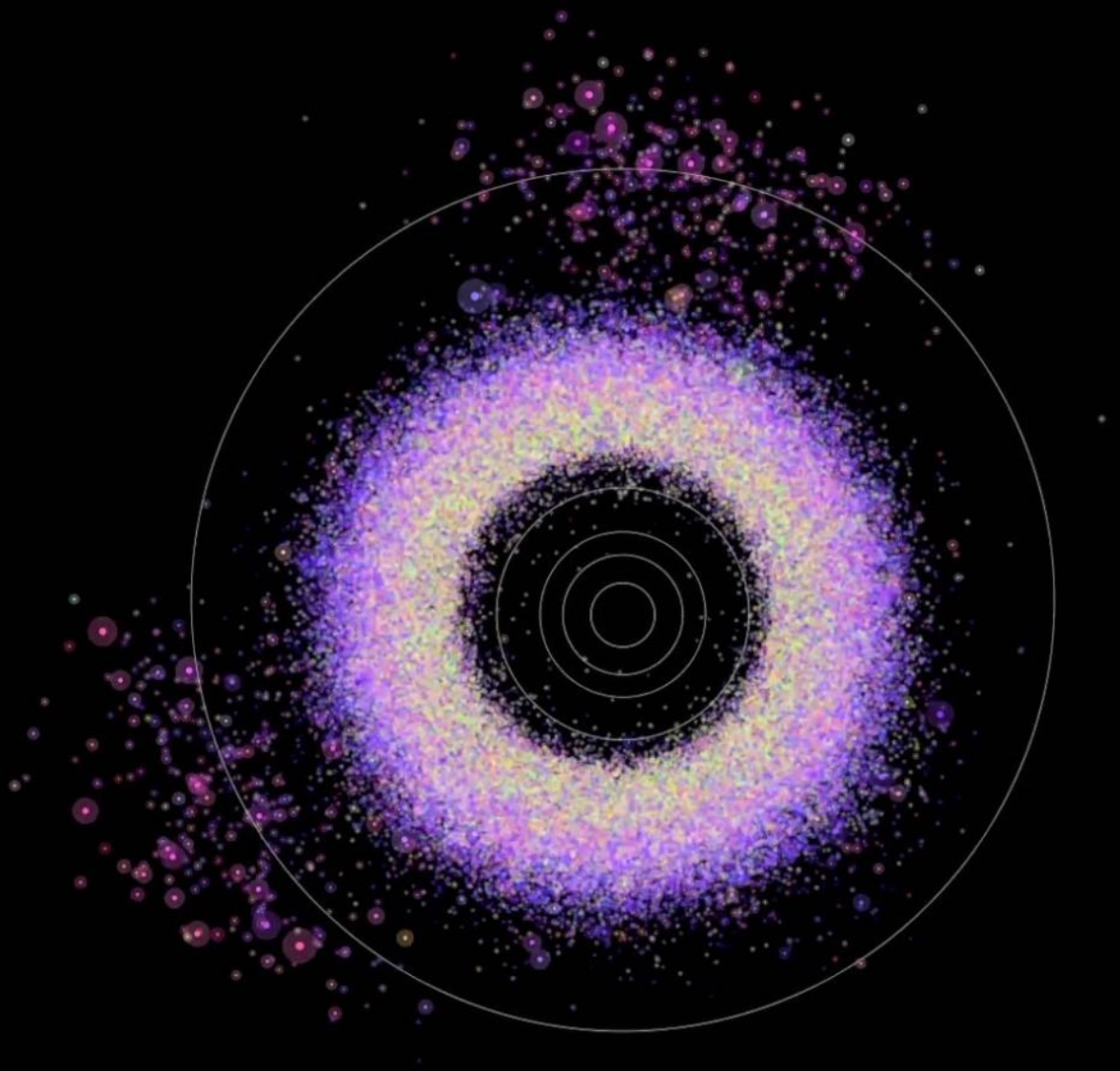
Petnica, 12. 05. 2019.

Asteroids

- Small rocky bodies orbiting aroun the Sun
- Building blocks of the Solar system
- Size: meters to 100s kilometers
- Composition: silicate, ice, metal, ...
- Everywhere in the Solar System

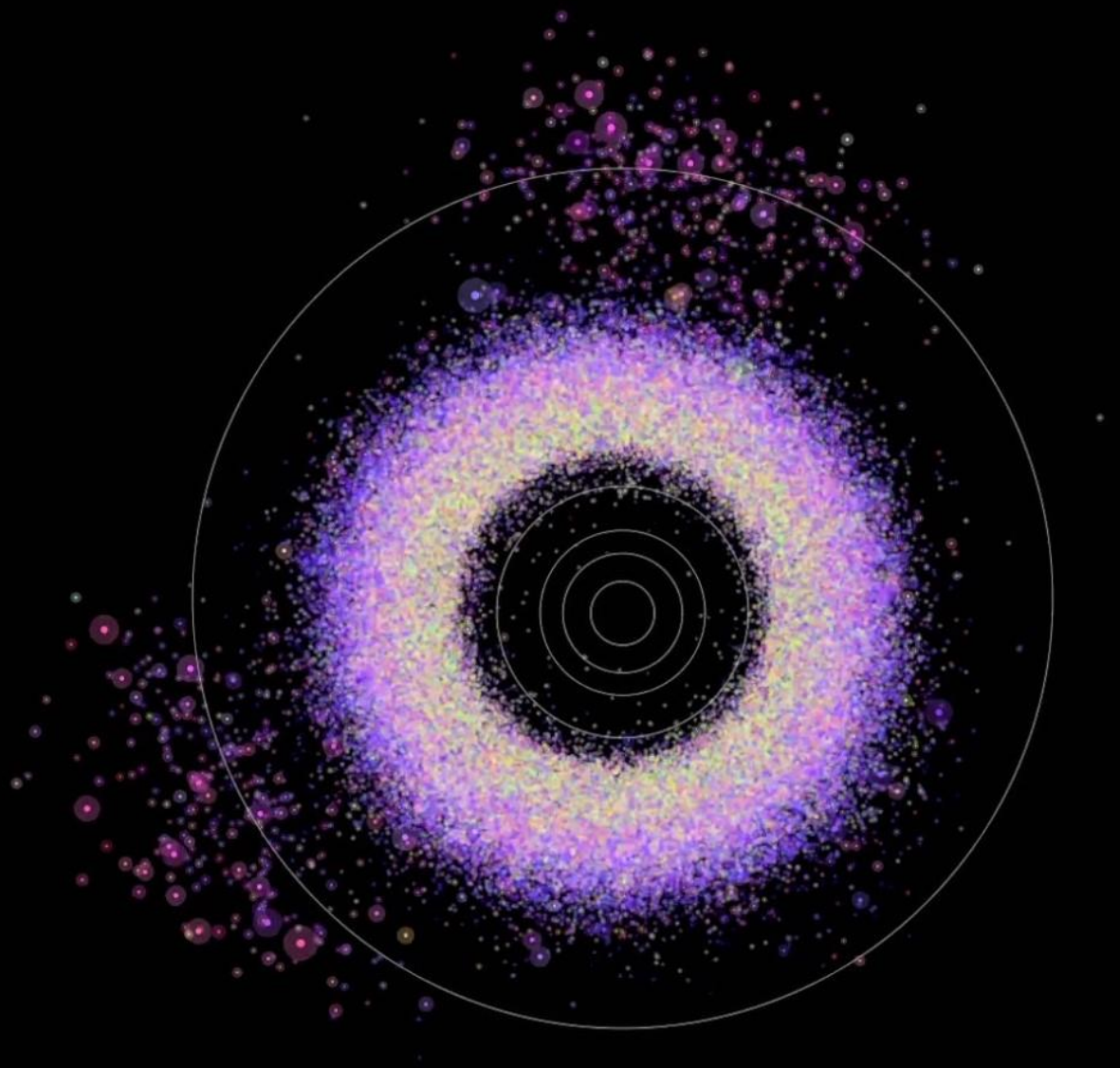


Asteroid belt



- **659 457 asteroids**

https://newton.spacedys.com/astdys2/



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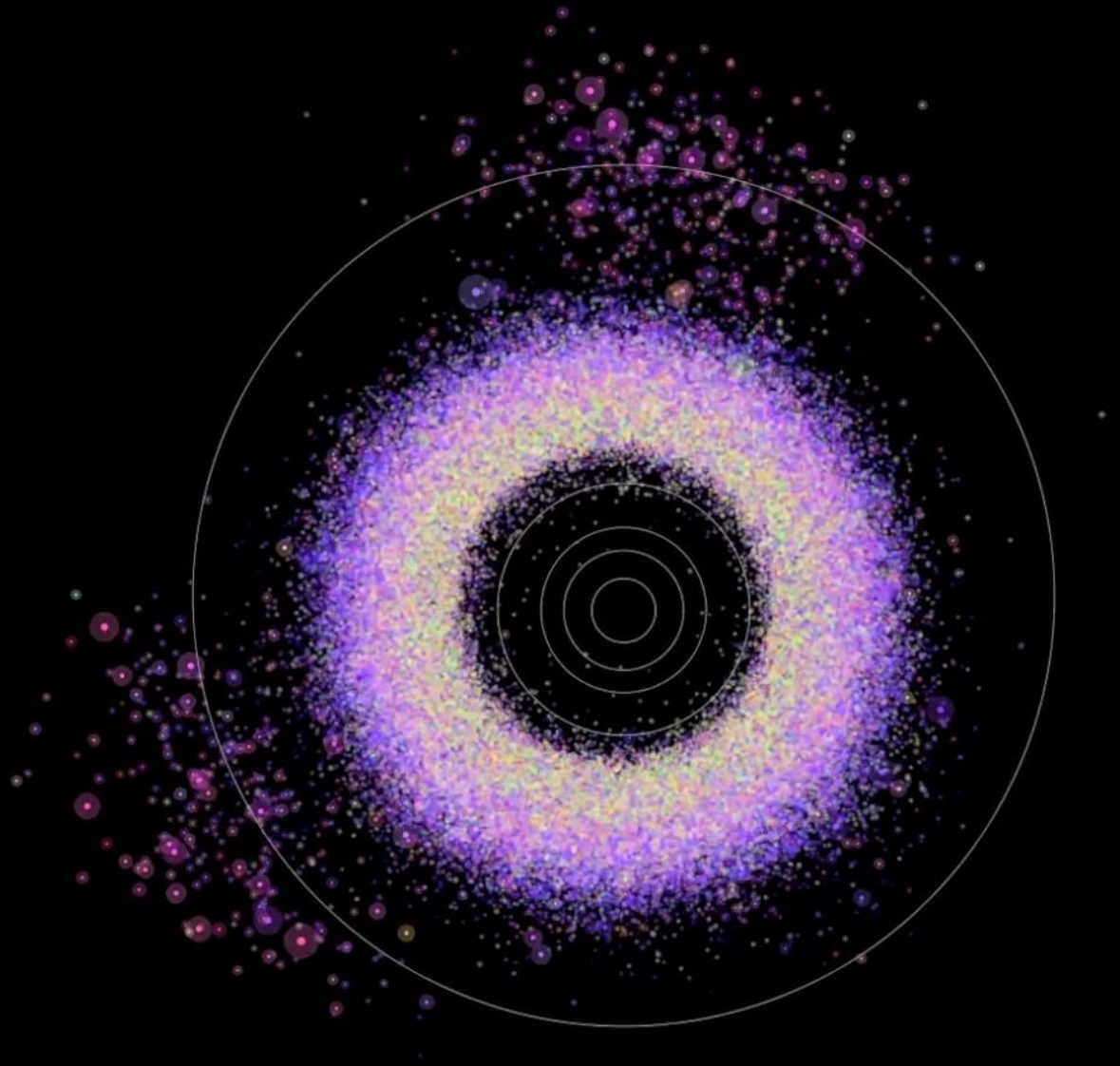
- **20 071 Near Eart Objects - NEOs**

https://newton.spacedys.com/neodys



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https://newton.spacedys.com/astdys2/

- **20 071 Near Eart Objects - NEOs**

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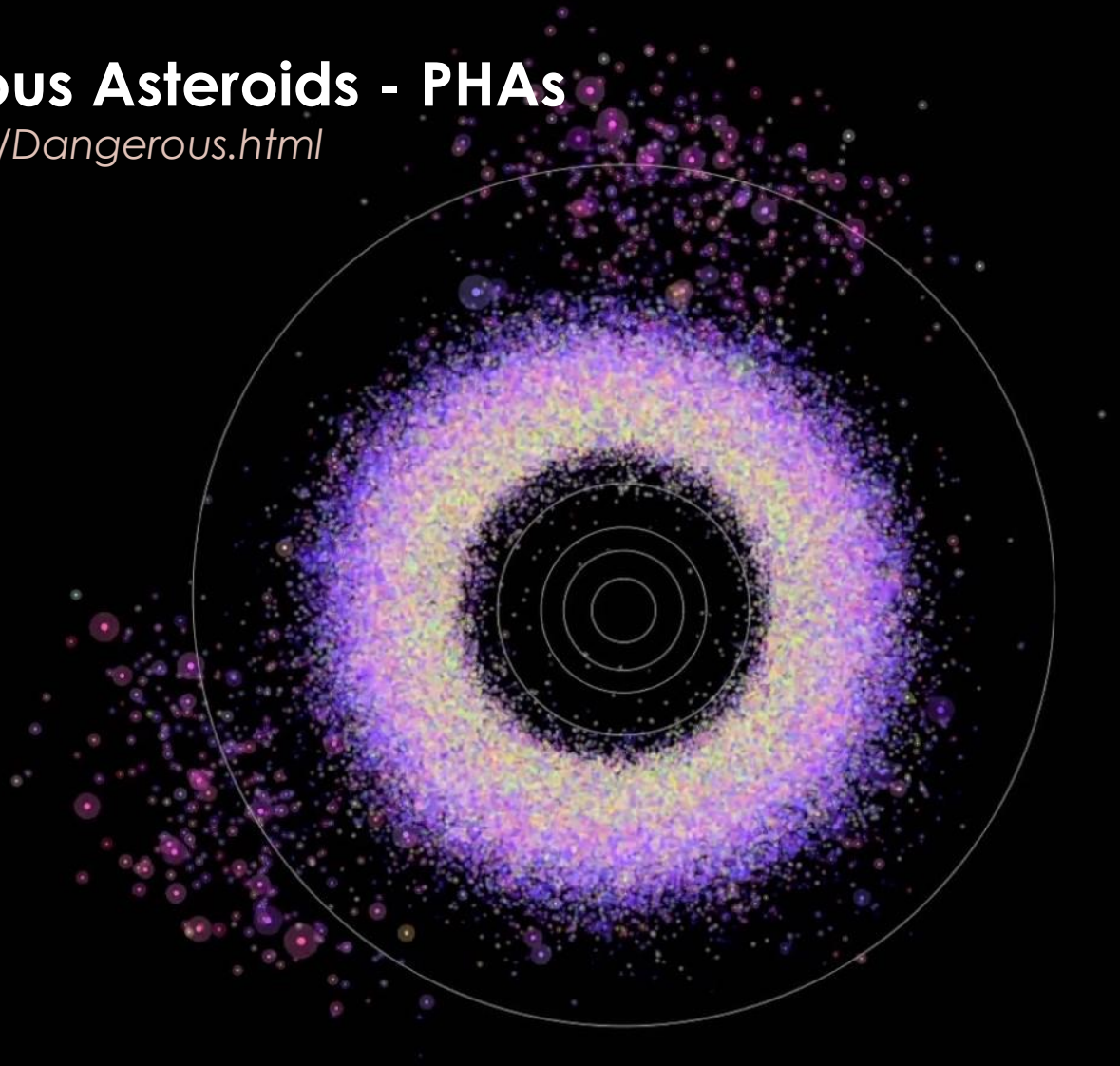
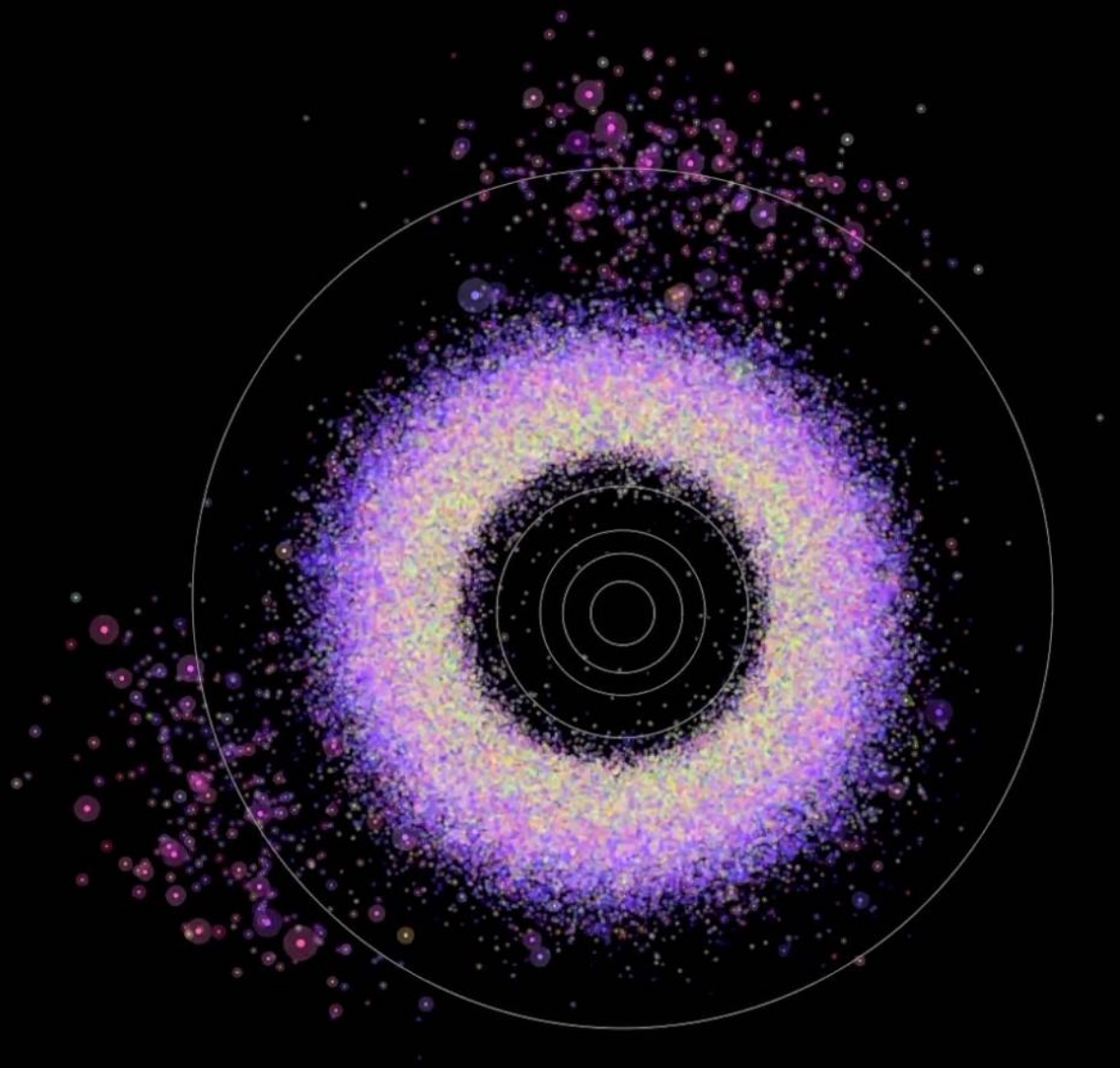
- **1971 Potentially Hazardous Asteroids - PHAs**

https://www.minorplanetcenter.net/iau/Dangerous.html

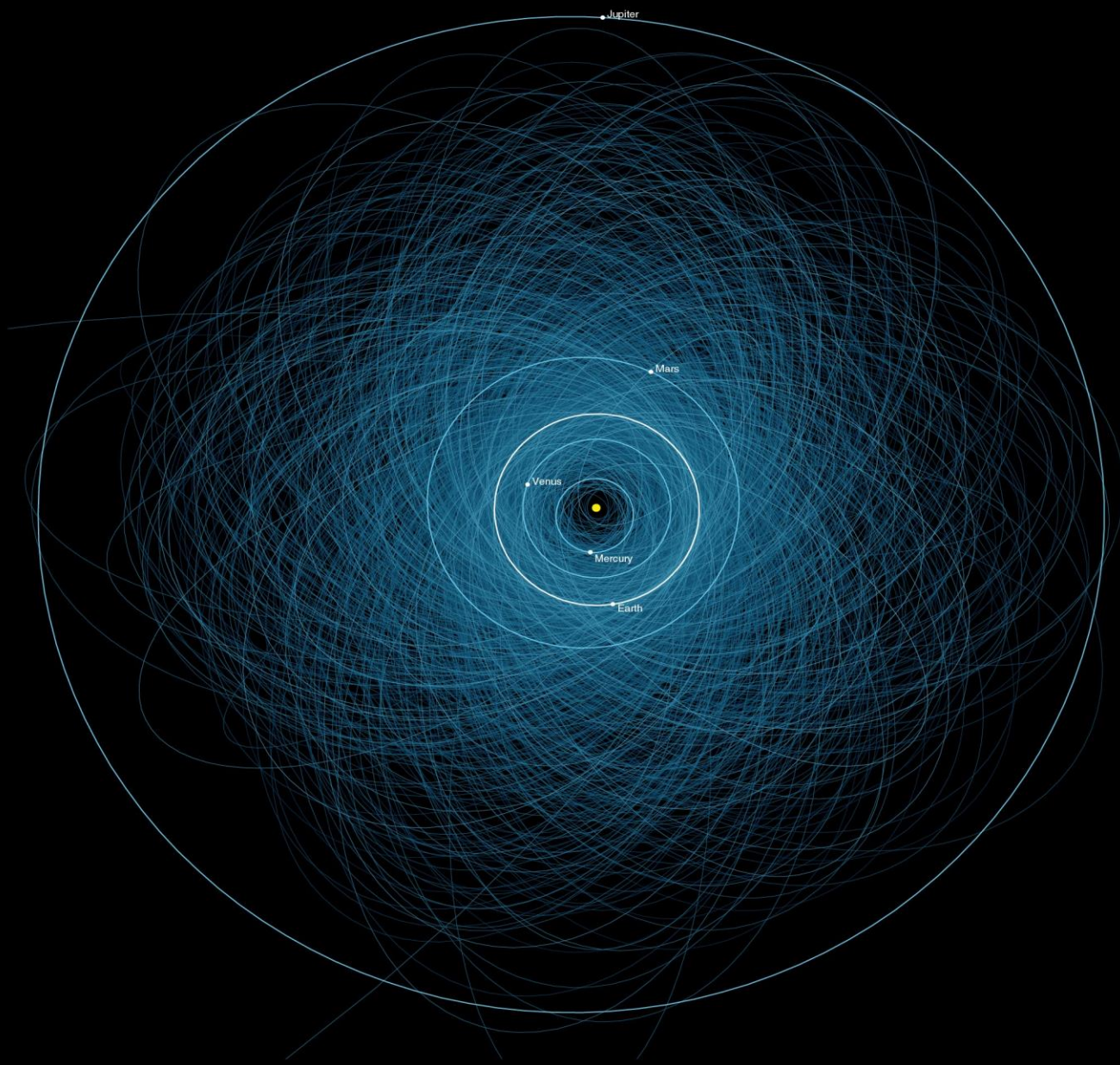


Potentially hazardous Asteroids - PHAs

- Minimum orbit intersection distance < **0.05 AU** or **7.5 mil km**
- Absolute magnitude **H < 22**



Orbits of potentially hazardous asteroids



1400 PHAs, early2013

Image credit: NASA/JPL-Caltech

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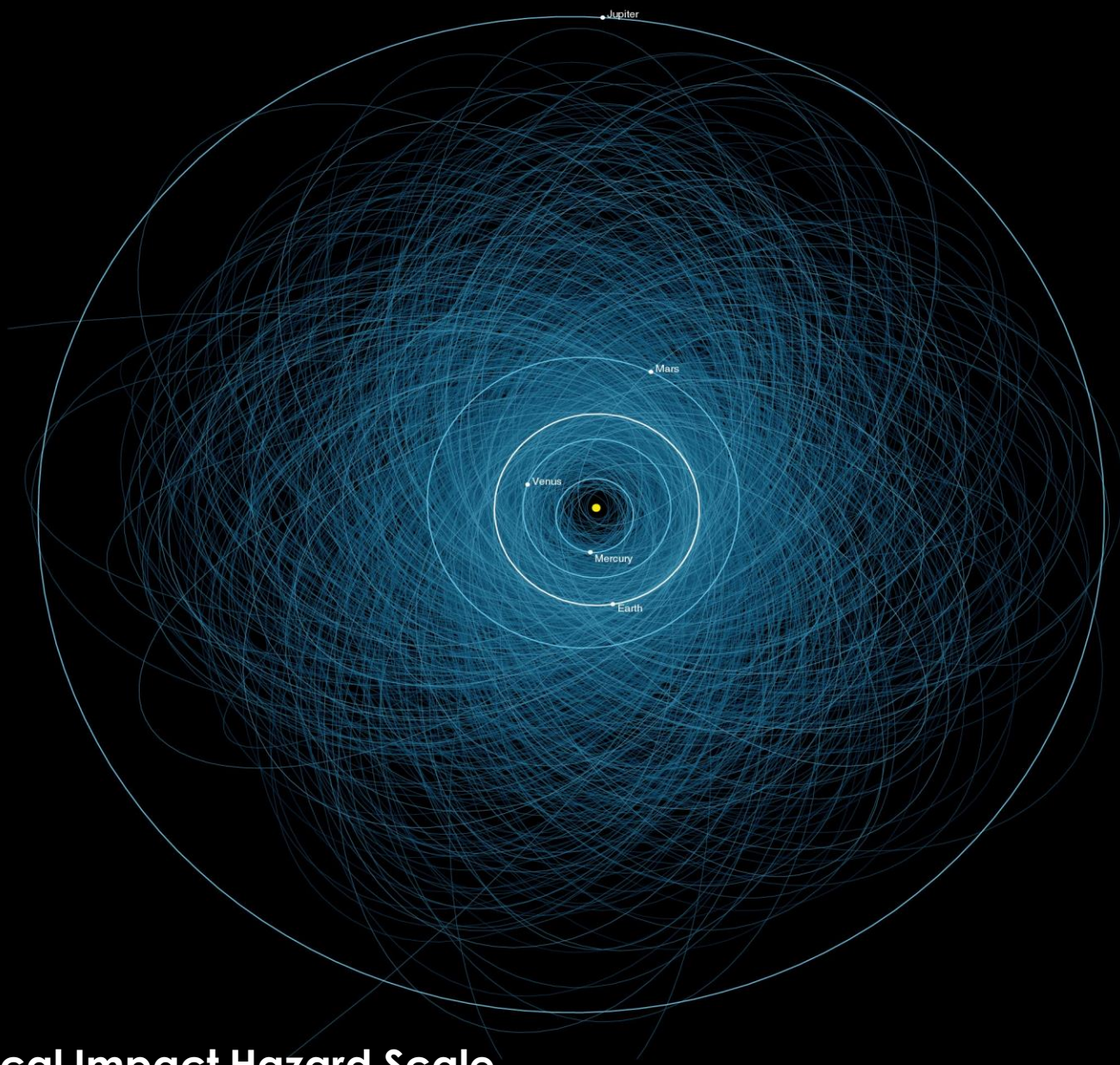


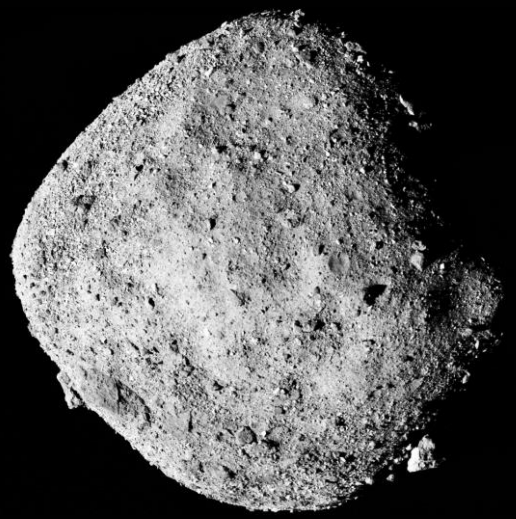
- **Torino scale**
- **Palermo Technical Impact Hazard Scale**

1400 PHAs, early2013

Image credit: NASA/JPL-Caltech

3200 Phaethon 5.8 km

101955 Bennu 500m



3200 Phaethon 5.8 km

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.The predicted encounters by Potentially Hazardous Asteroids (PHAs) to within 0.05 AU of the earth from the start of this year through 2178.

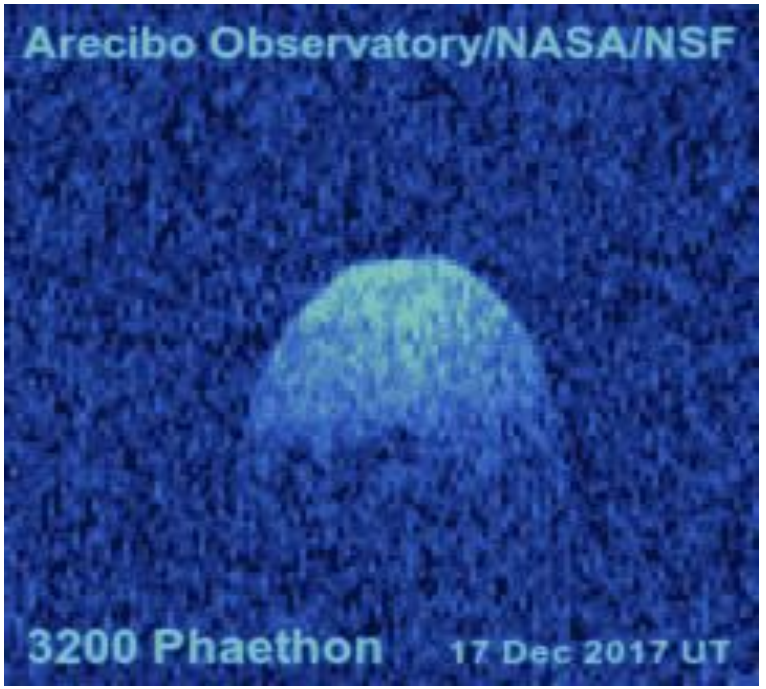
	date	distance
.(101955) Bennu	**2060** Sept.23.03	0.005006
.(101955) Bennu	**2135** Sept.26.20	0.008728
.(101955) Bennu	**2080** Sept.21.94	0.016501
.(101955) Bennu	**2148** Sept.28.78	0.032778
.(101955) Bennu	**2054** Sept.30.04	0.039300
.(3200) Phaethon	**2093** Dec. 14.46	0.019605

3200 Phaethon

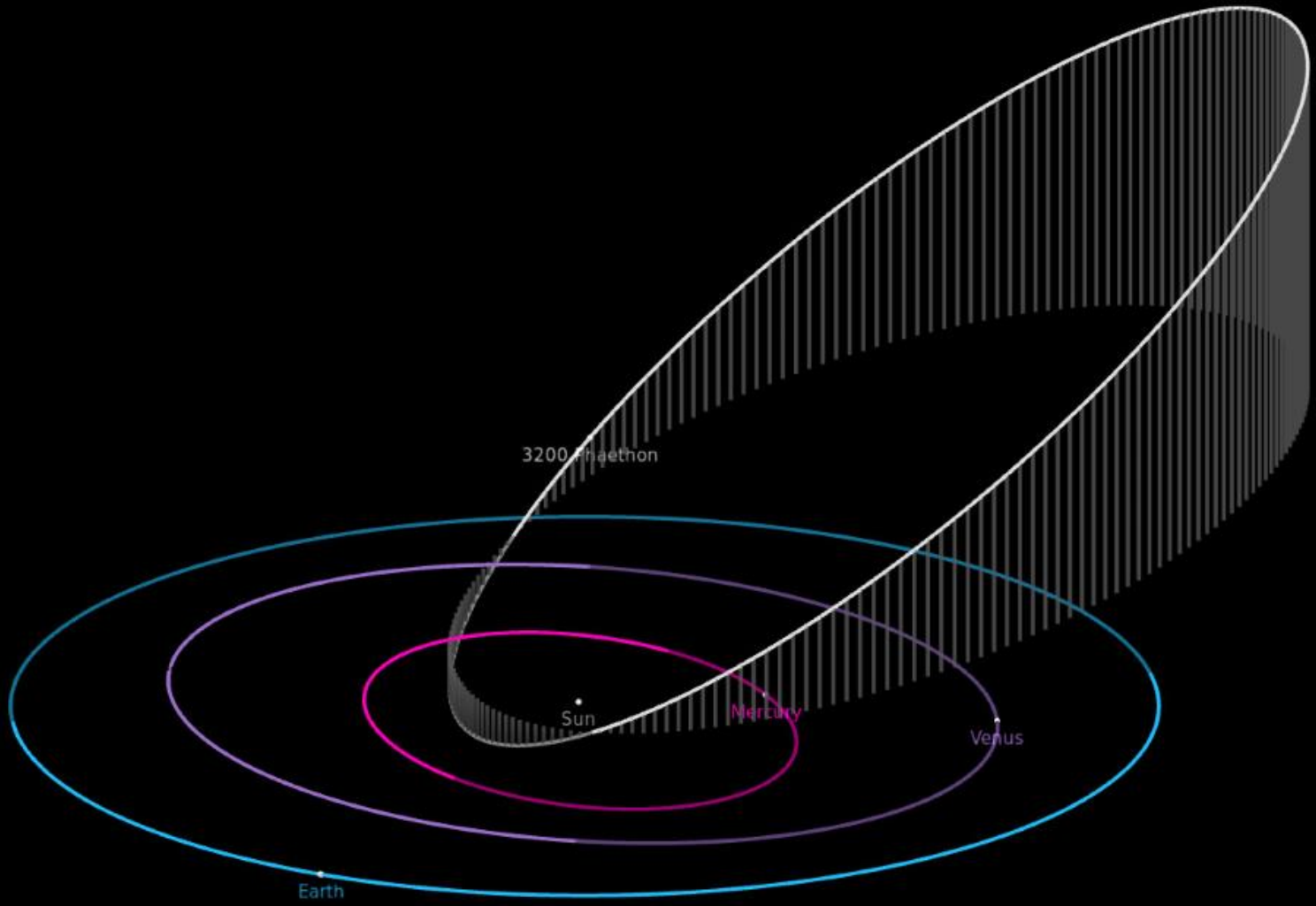
Time lapse photography of asteroid 3200 Phaethon- at maximum angular velocity, by amateur astronomer Ingvars Tomsons at Riga, Latvia, through a telescope (600/154 reflector CCD HEQ5). 100x20sec. frames series began 2017-12-15 18:47:13 UTC, ended 2017-12-15 19:24:50 UTC

3200 Phaethon

- Phaethon was the first asteroid to be discovered using images from a spacecraft while searching Infrared Astronomical Satellite (IRAS) data for moving objects.
- Discovered in October 11, 1983.
- Active asteroid

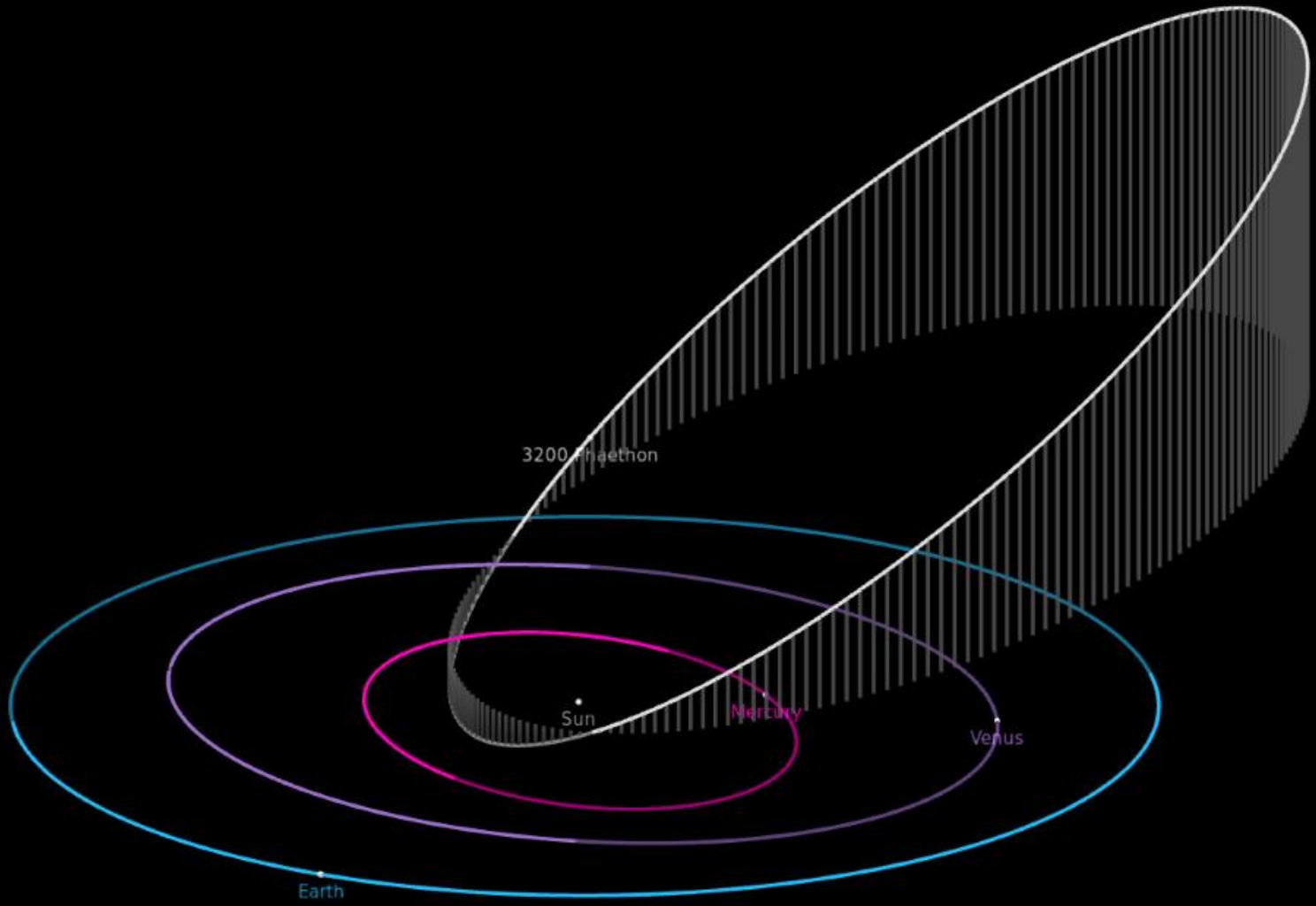


Phaethon is the parent body of the Geminids meteor shower of mid-December



Phaethons orbit

Semi-major axis **a = 1.27 AU**
Eccentricity **e = 0.89**
Perihelion **q = 0.14 AU** (20.9 million km)
Inclination **i = 22.25°**



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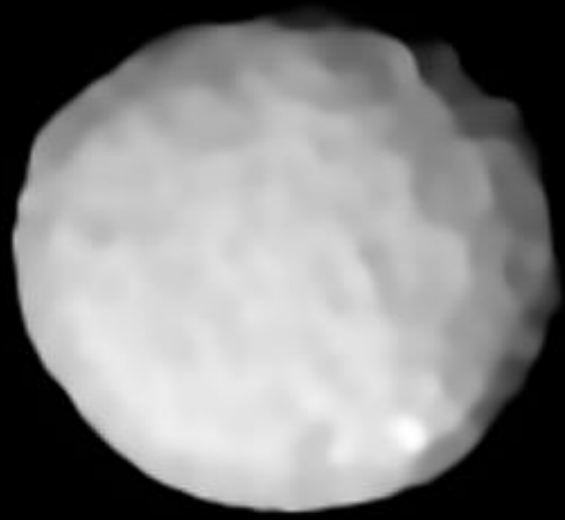
At perihel it heats up to almost 1000 K. 262 days later, Phaethon is 359 million km [223 million miles] away from the Sun, far beyond the orbit of Mars. There it cools down to very low temperatures. This constant periodical cooling and heating cycle cracks its mineralogical surface into small dusty particles. Each December, when Earth passes close to the orbit of Phaethon, the small grains swept from Phaethon by the radiation pressure (of sunlight) enter our atmosphere as the Geminids.

How Phaethon came close to Earth?

- Hypothesis that 3200 **Phaethon** was a fragment of the asteroid Pallas.
- 2 **Pallas** is the second largest (512 km) asteroid in the Solar system, at 2.77 AU
- Both Pallas and Phaethon are B type asteroids (they have similar surface composition).
- De León et al. A&A, 2010 ➔ **low probability (1%) for the transportation**



Dynamical origin of NEOs

- Lifetimes of *NEOs* < *10e7 yrs*
- *Hit Sun or some planet, escape from the Solar system*
- Objects are older than t > 10e7 yrs

→ →

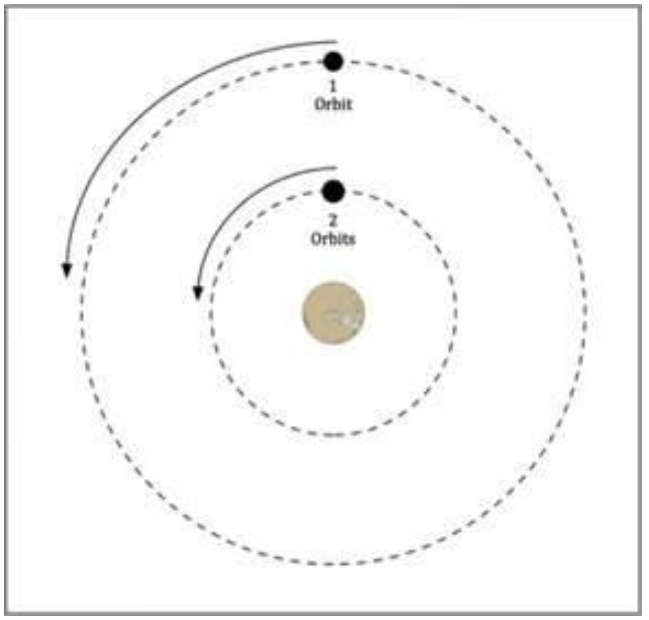
- Formed in other places of the Solar System
- Mechanism that drives bodies from the main belt to the NEO region
- Mechanism produced in **Resonances**

Mean-motion orbital resonances

- A *mean-motion resonance* occurs when two bodies have periods of revolution that are a simple integer ratio of each other.

$$mT_{planet} = nT_{asteroid}$$

$$m:n = T_{asteroid} : T_{planet}$$



Strongest MMRs: 5A:2J, 2A:1J, 3A:1J, 7A:3J

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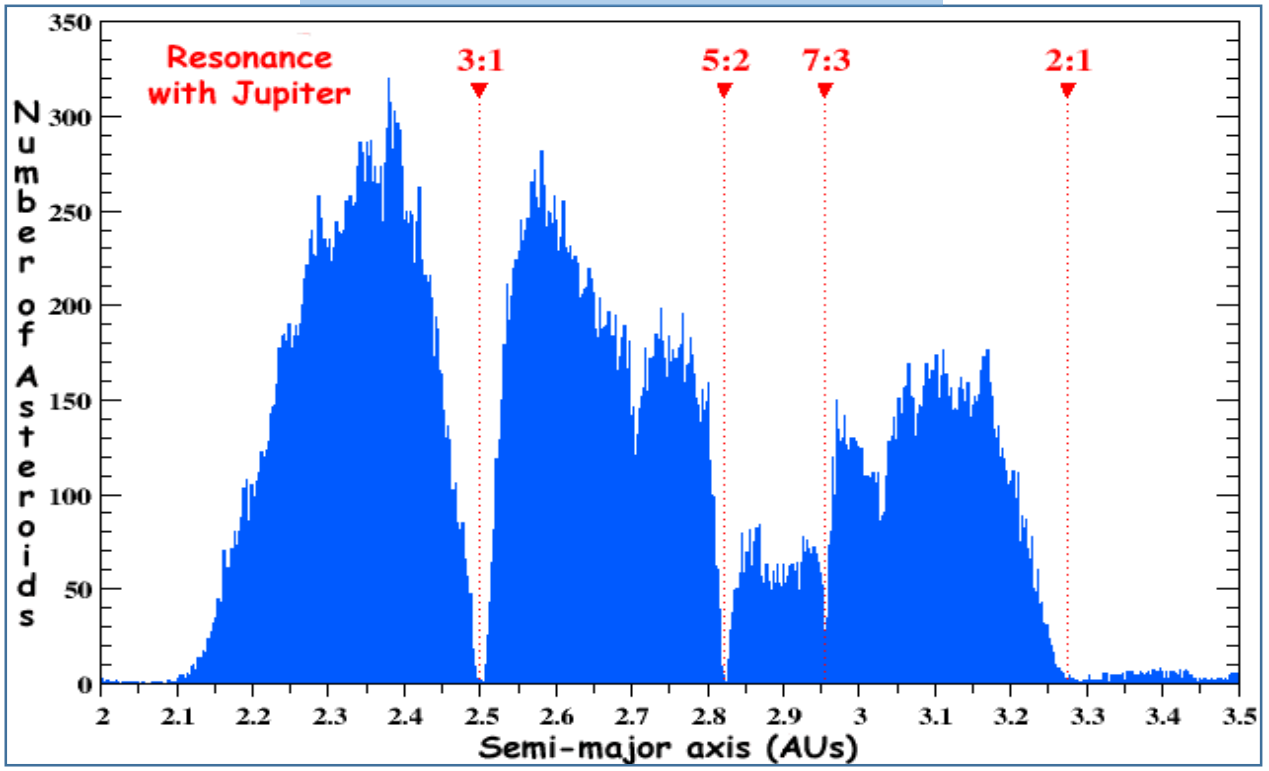

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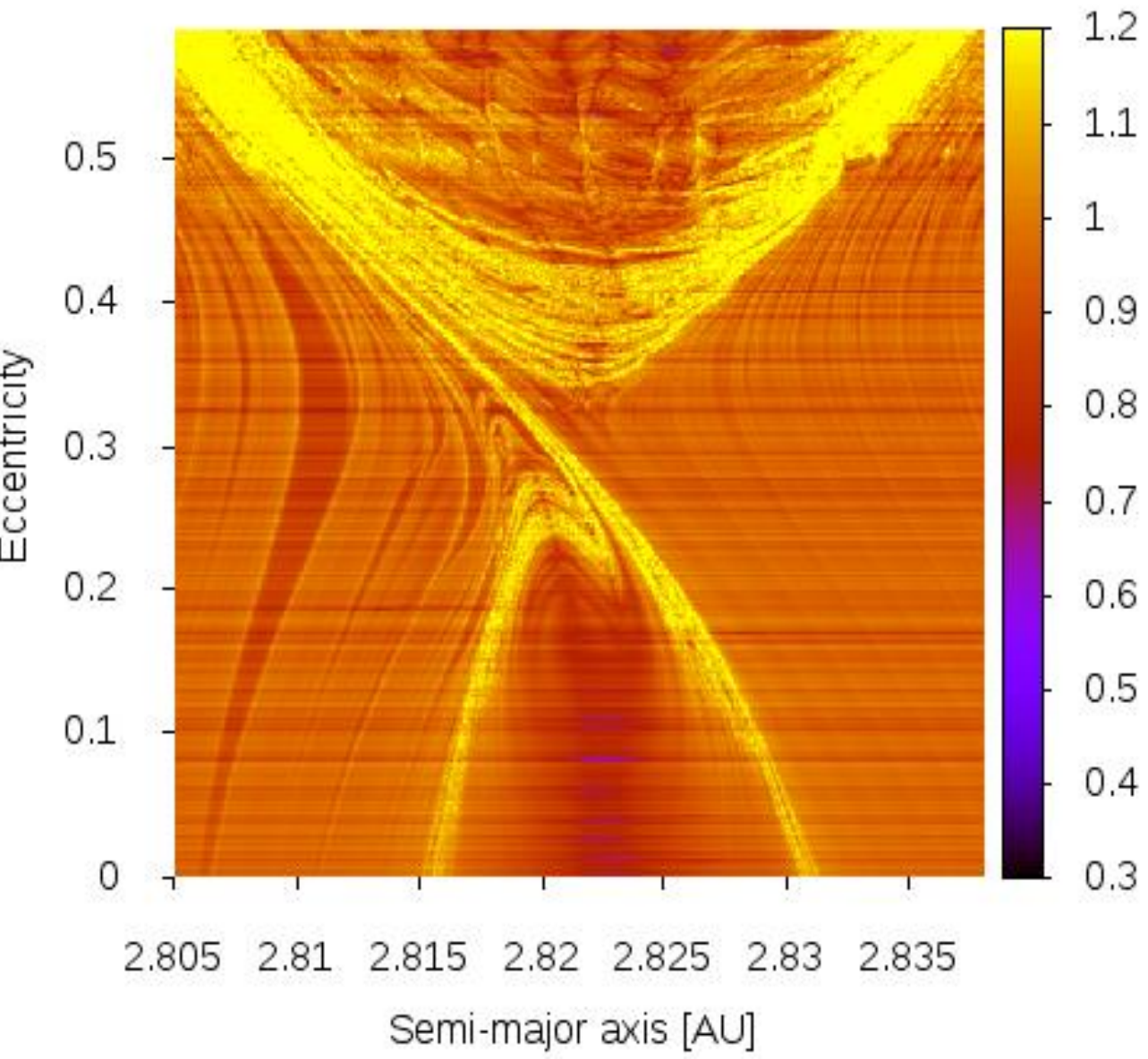
Map of the **5A:2J** Mean motion resonance computed in the orbital plane of 2 Pallas



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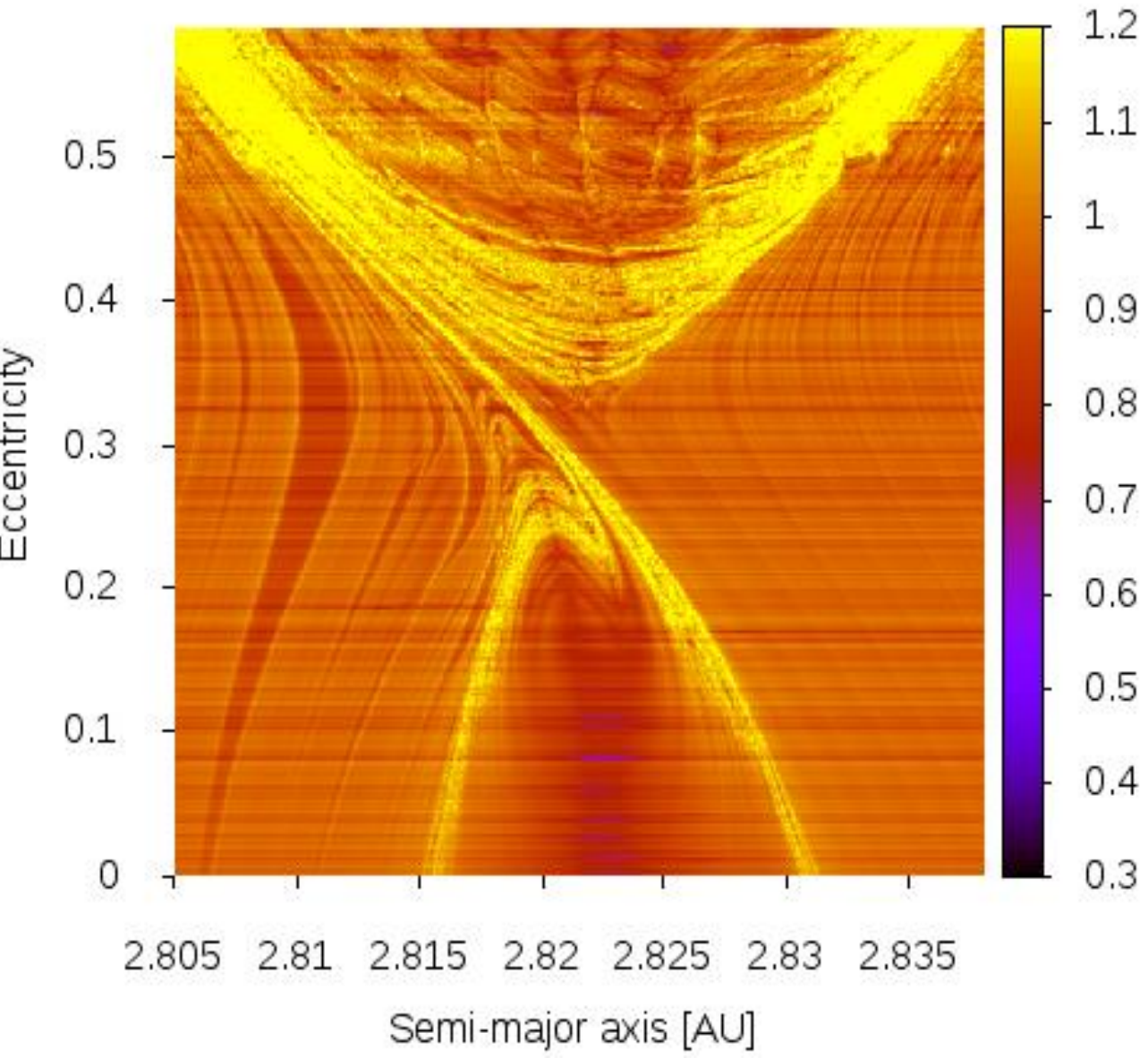

Real image calculated in the (a,e) orbital plane.

Fermi cluster.

Color - Stability

Yellow - chaotic
On the resonant border

Red and orange stable
out of the resonance and inside of the resonance

Pallas fragment injected into the resonance.

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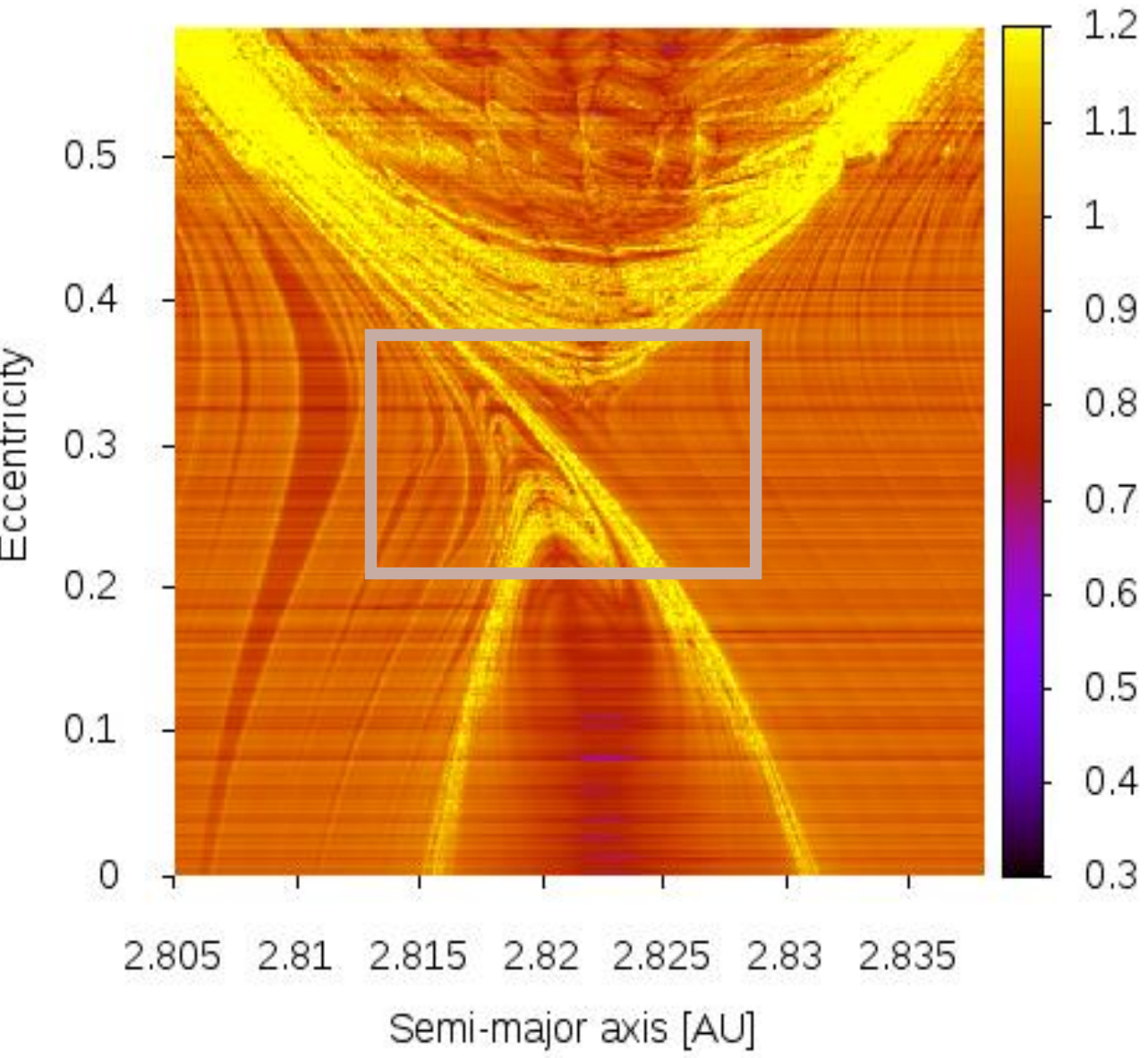

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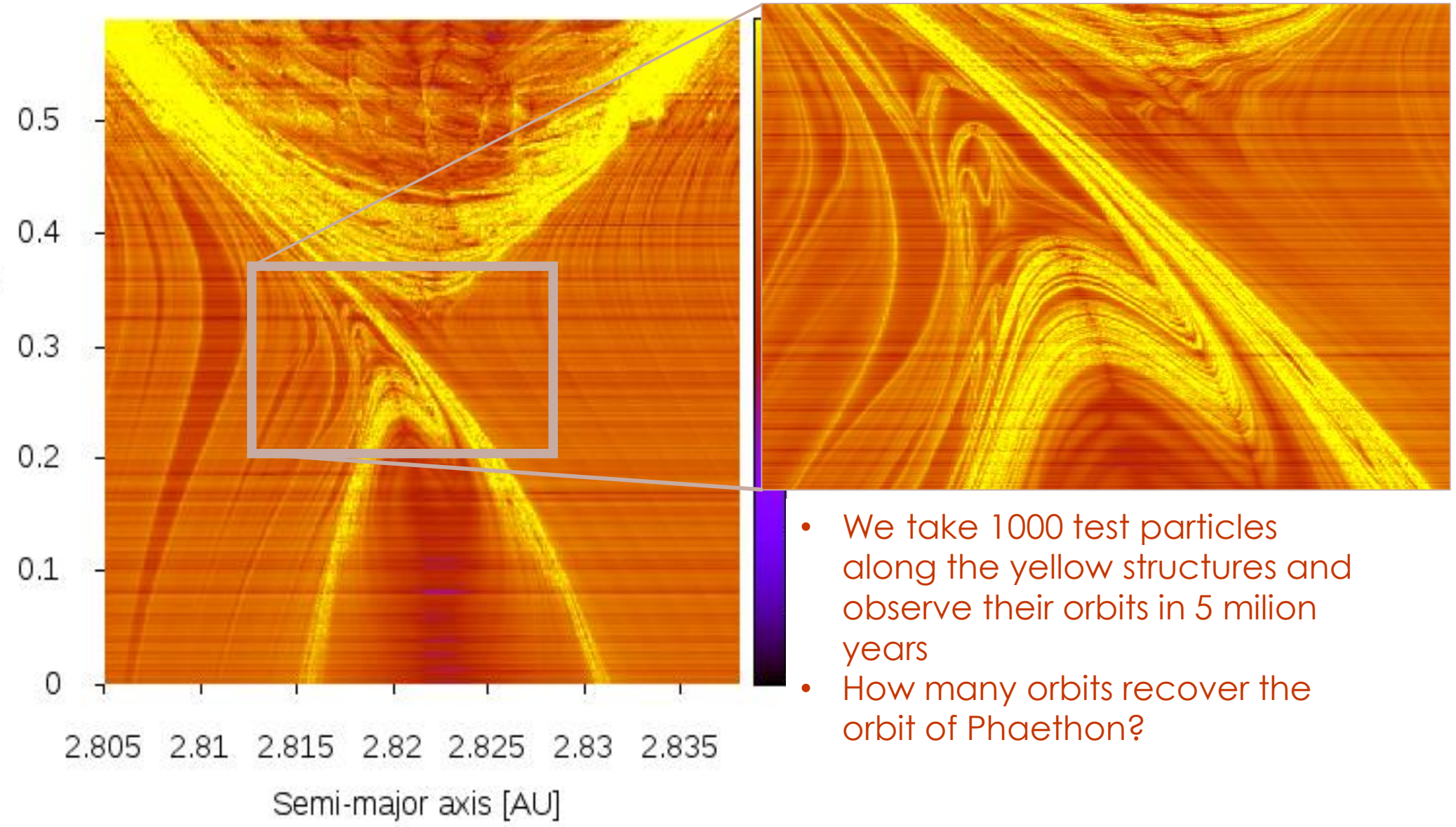

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- How many orbits recover the orbit of Phaethon?

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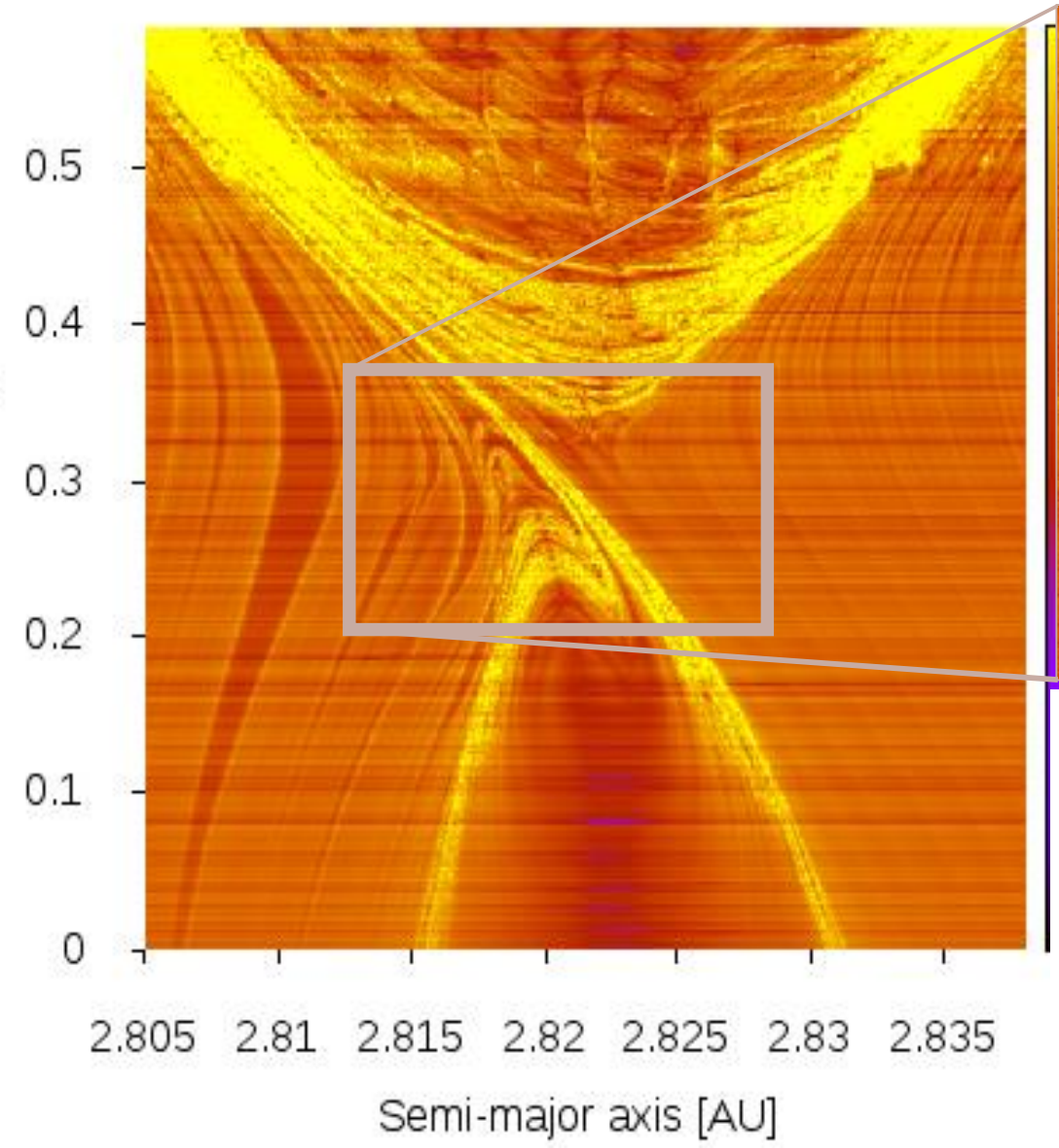

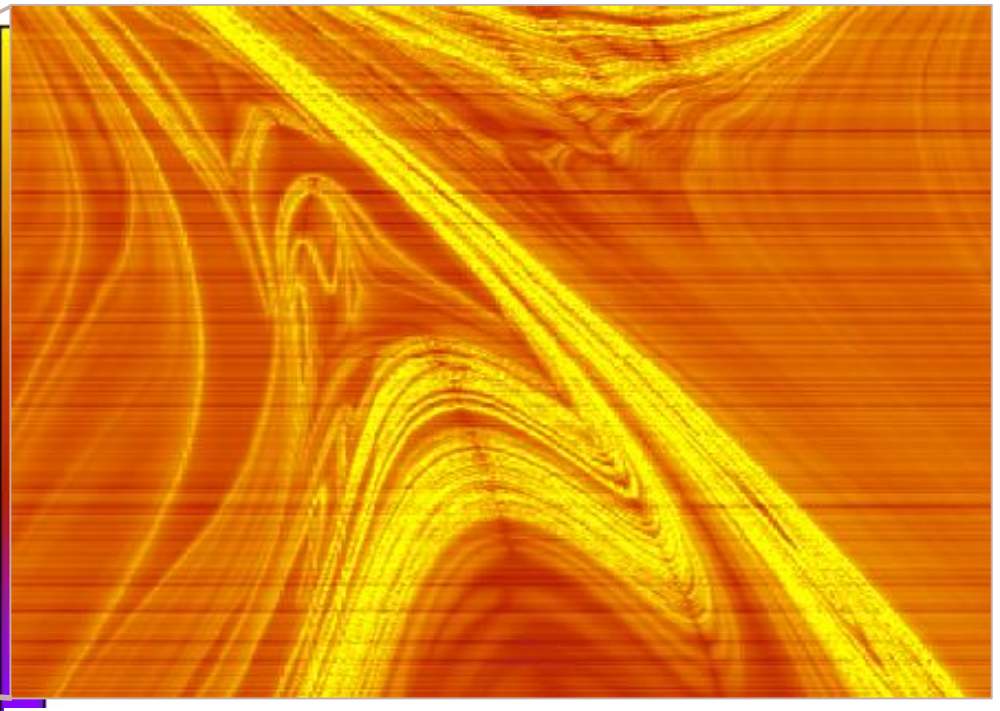

- **460 particles**
- **46% probability for Phaethon – Pallas connection**
- *De Leon et al, 2010 - **1%***

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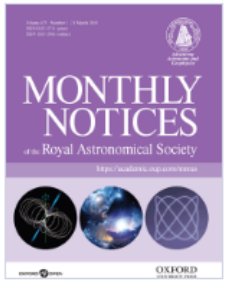

Volume 475, Issue 1
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The dynamical connection between Phaethon and Pallas

Nataša Todorović

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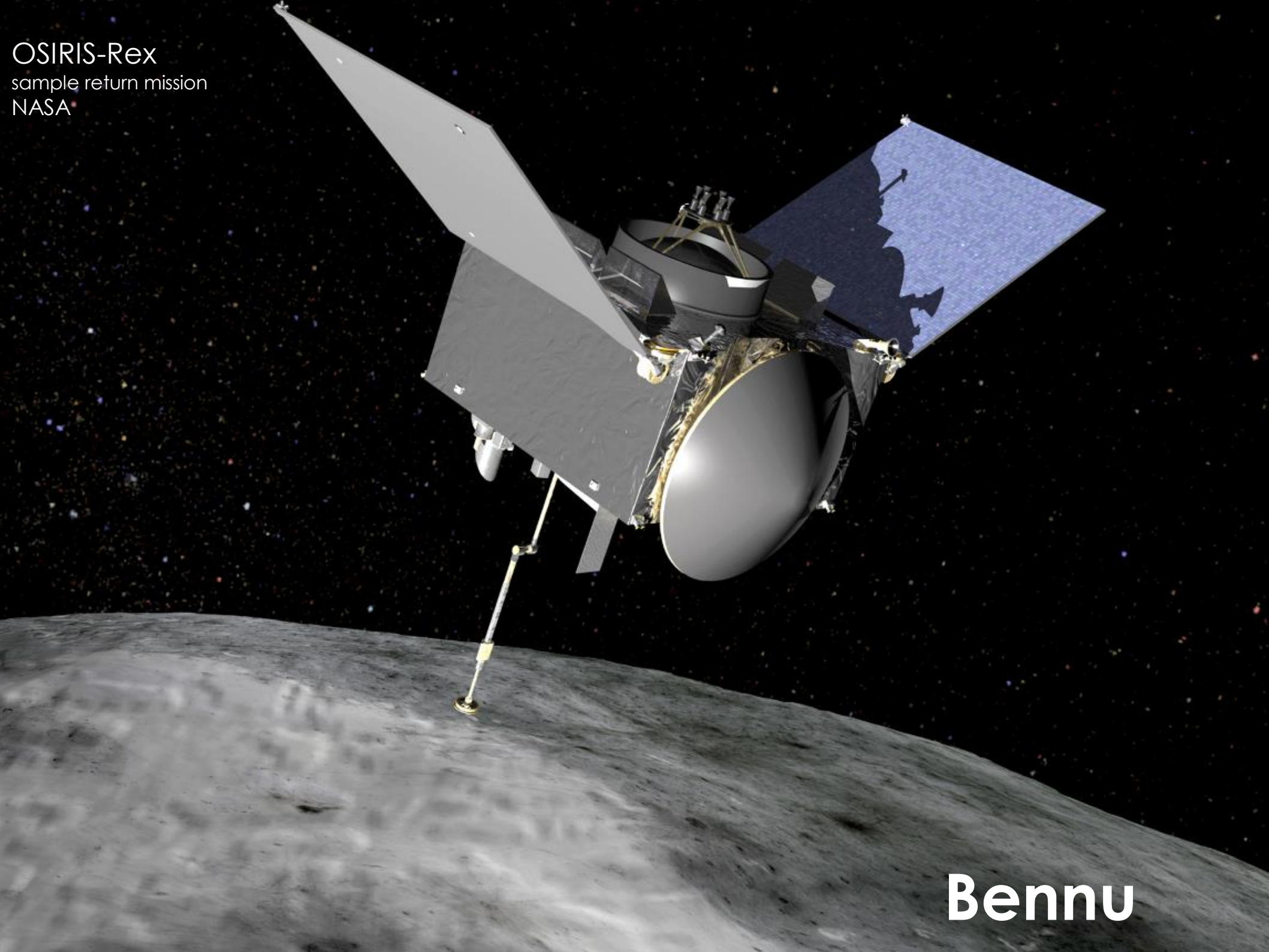
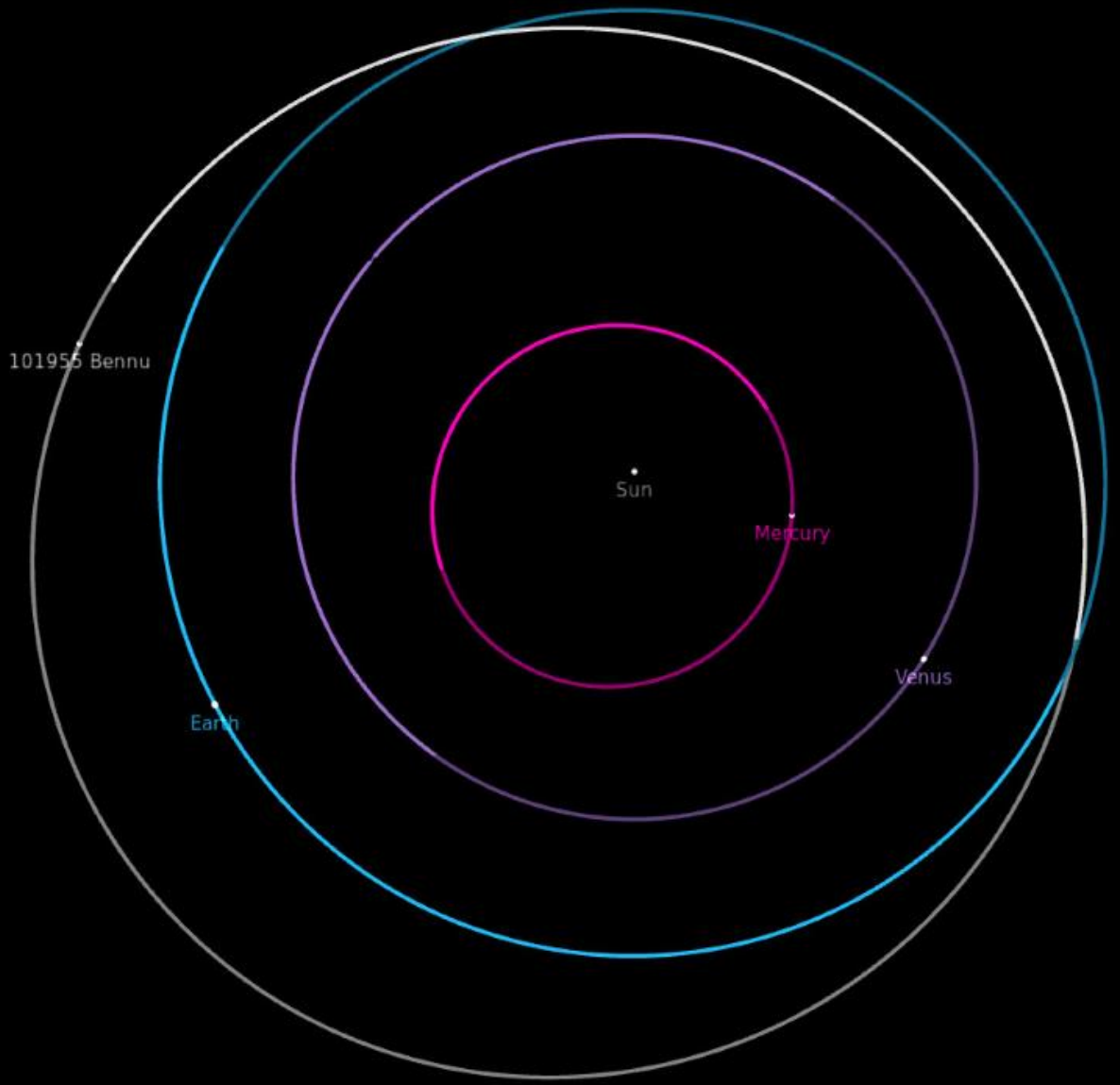
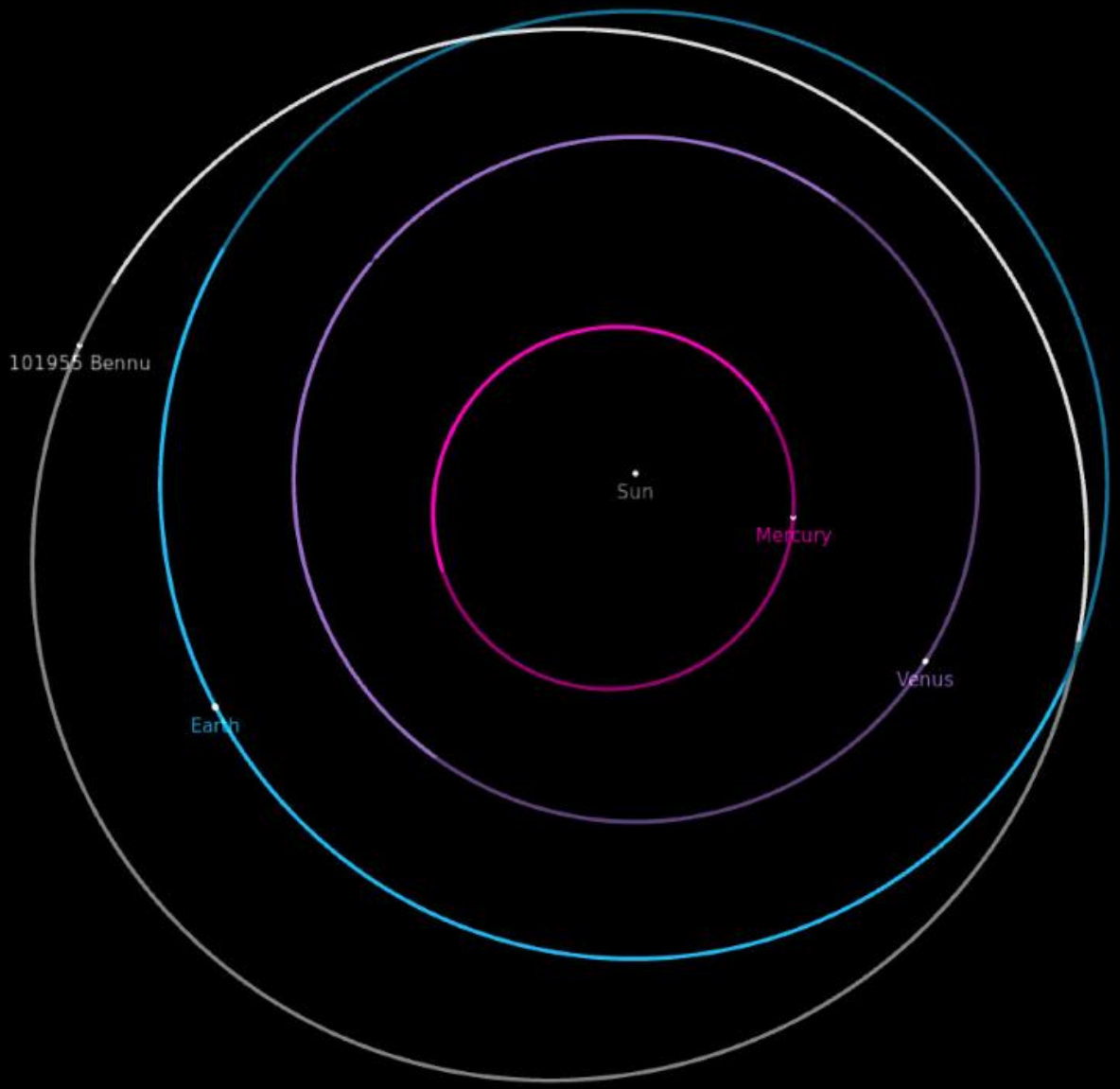
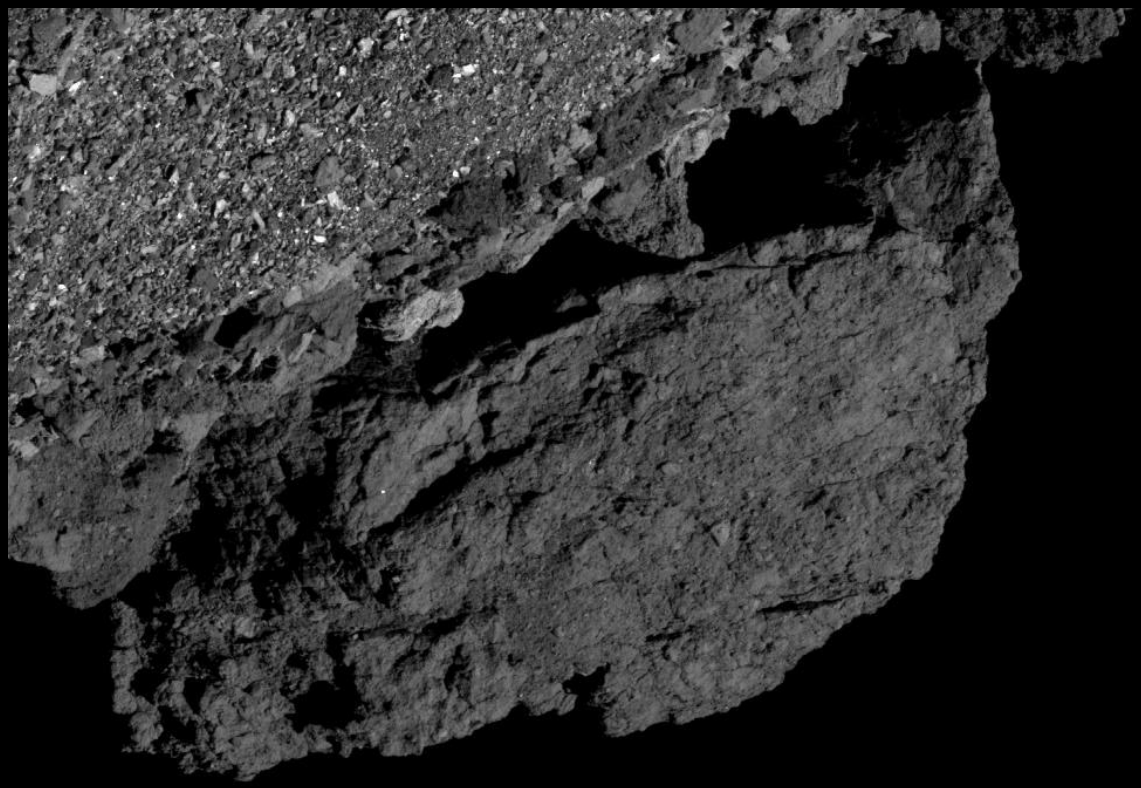
Published: 13 December 2017 **Article history** ▾


OSIRIS-Rex
sample return mission
NASA
Bennu


101955 Bennu
Sun
Mercury
Venus
Earth



.Between 2175-09-25.15 and 2199-09-25.11 **78 close approaches**



This image was taken by PolyCam on Mar. 29 as part of Flyby 4B. The brightest rock in the image -- a little up and to the right of the image's center -- is 4 ft (1.1 m) wide, which is about the size of a dining room table.

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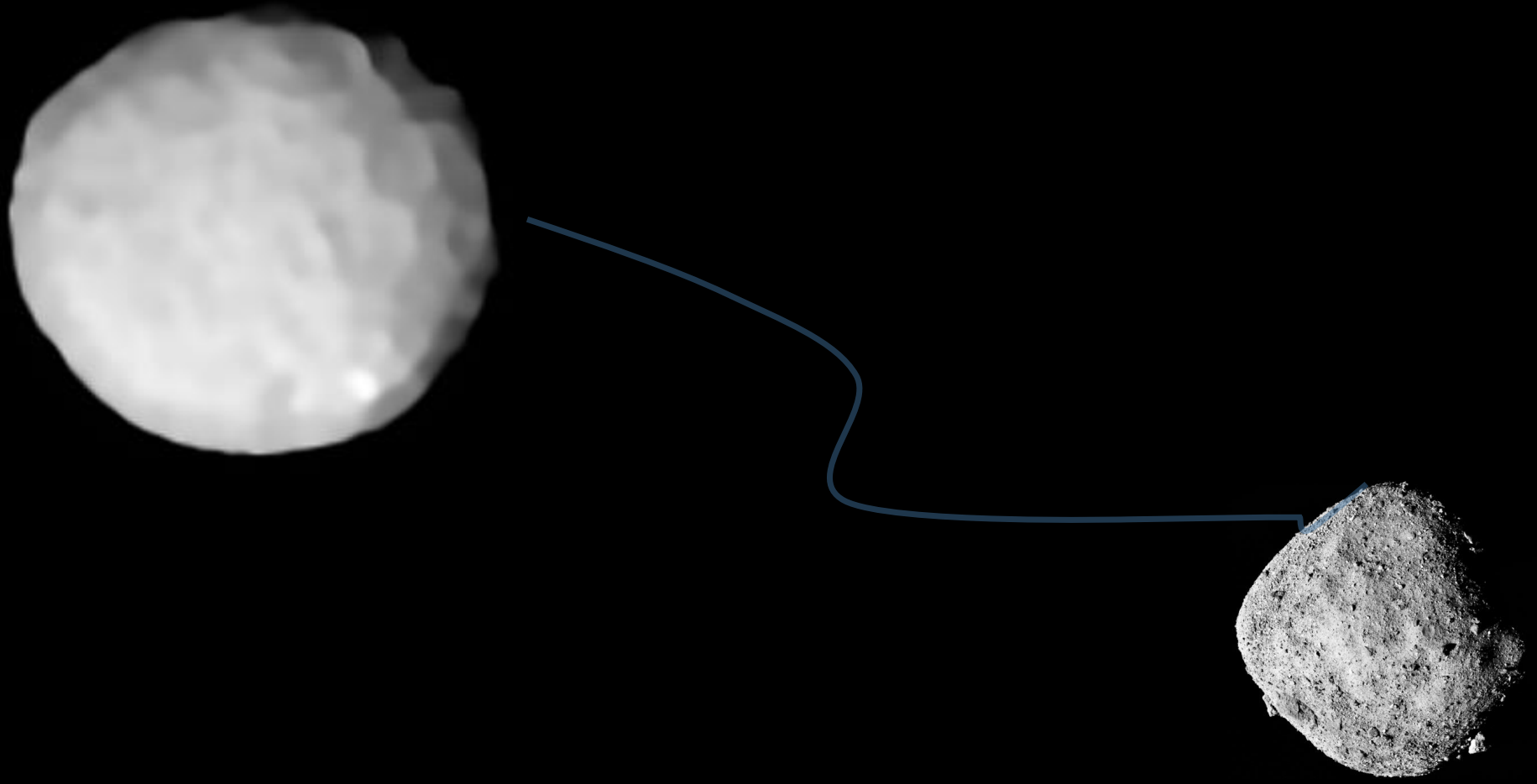
What is the probablity that Bennu arrived from the Pallas family via the 5:2 MMR?



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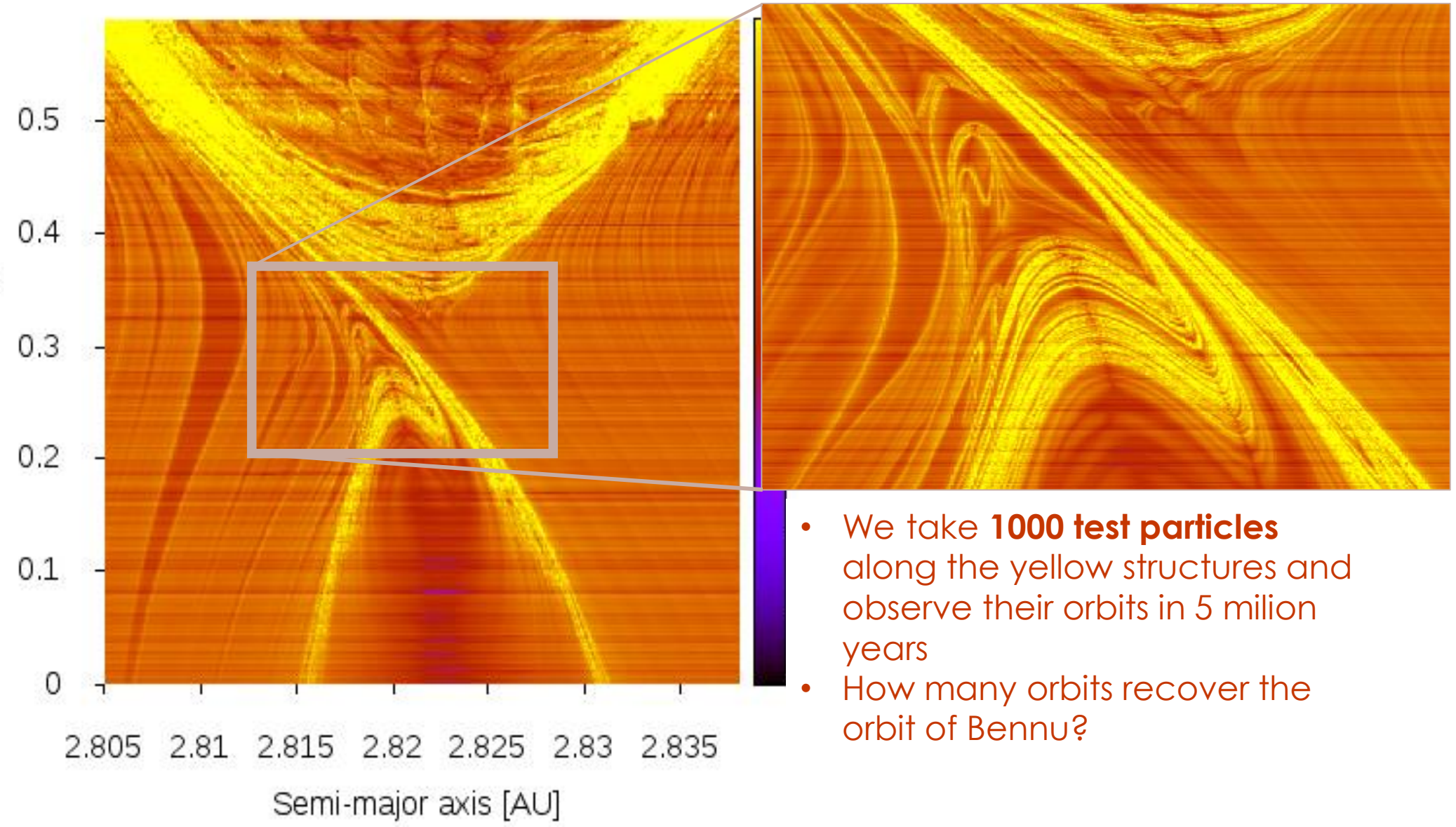

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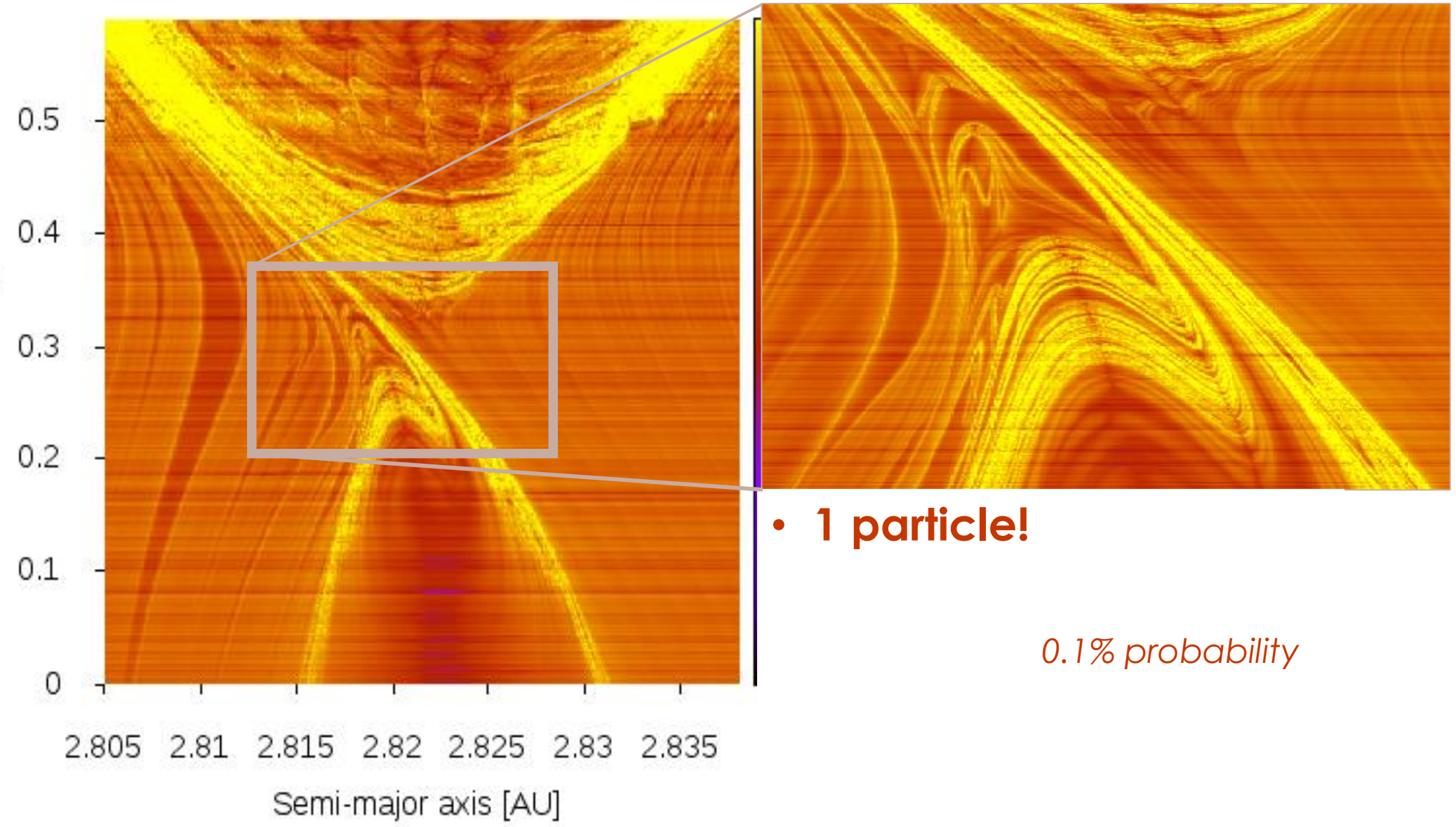

- **1 particle!**

0.1% probability

Conclusions

- Powerful and efficient mechanism bringing bodies from different parts of the Solar System near Earth.
- Delicate structure of the phase space revealing the sources of fast routes.
- It does not apply in all directions.

Хвала
Thank You

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