

LUCY



Surveying
the Diversity
of Trojans

Trojan Science and the Lucy Mission

Hal Levison

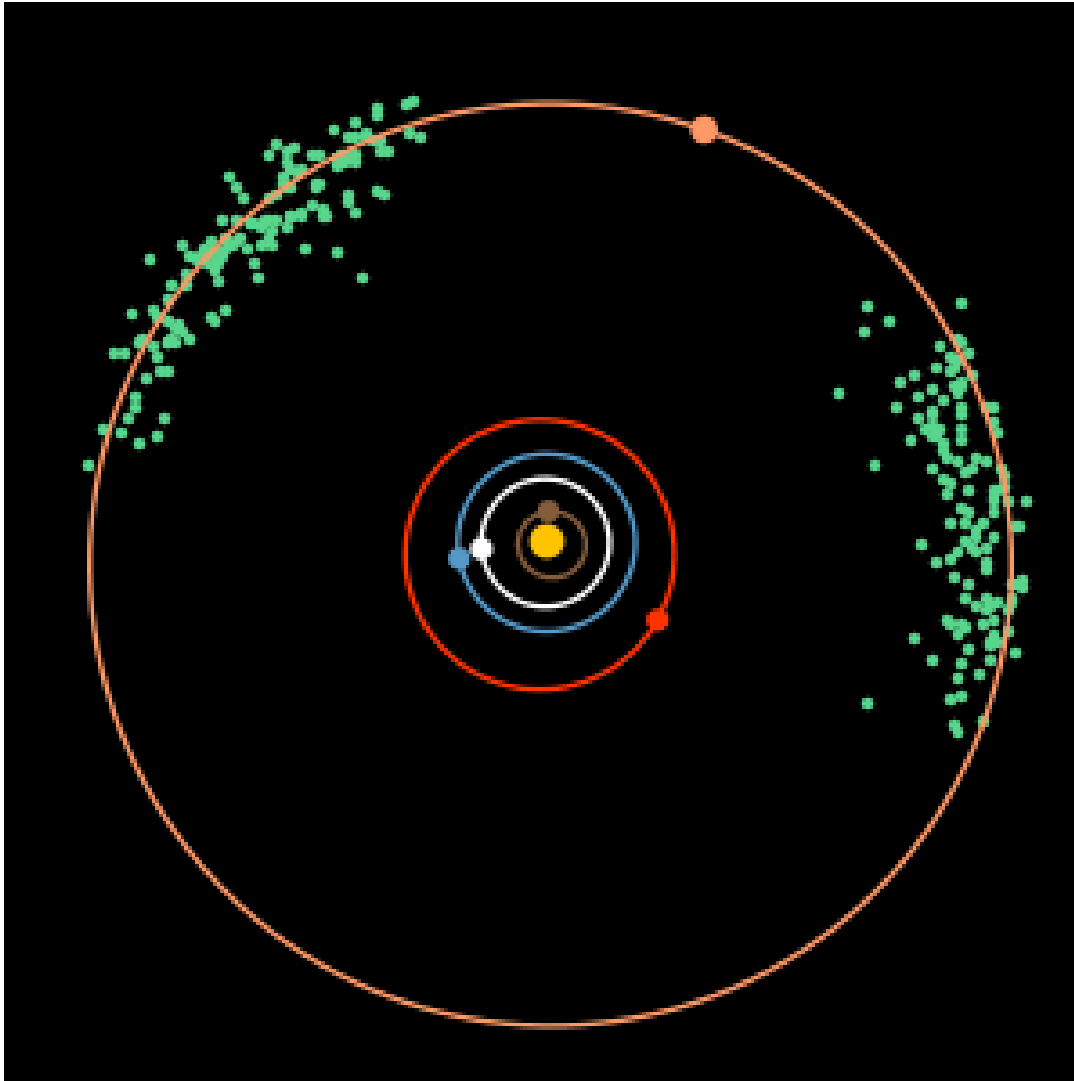
Southwest Research Institute

Lucy PI



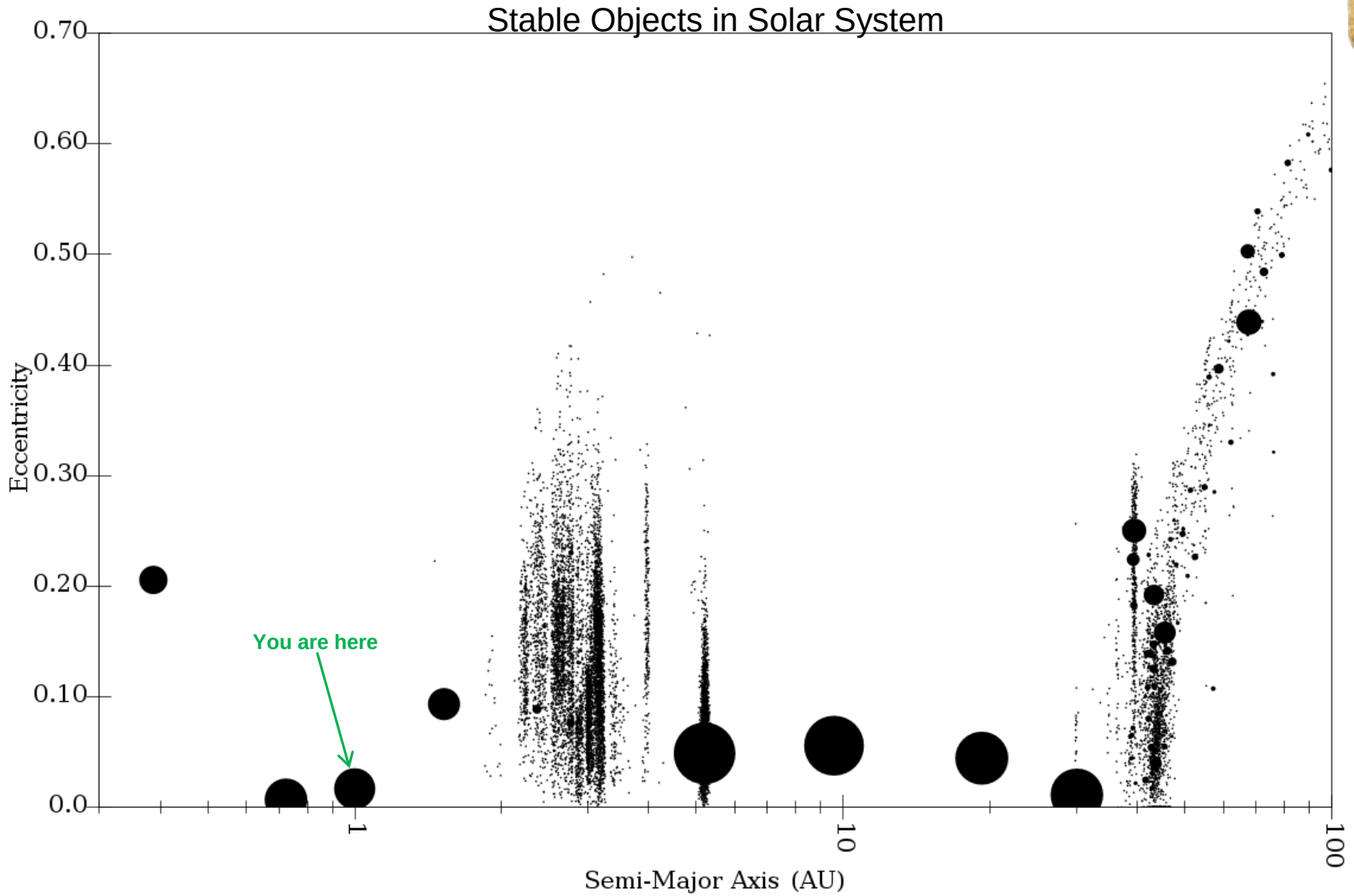


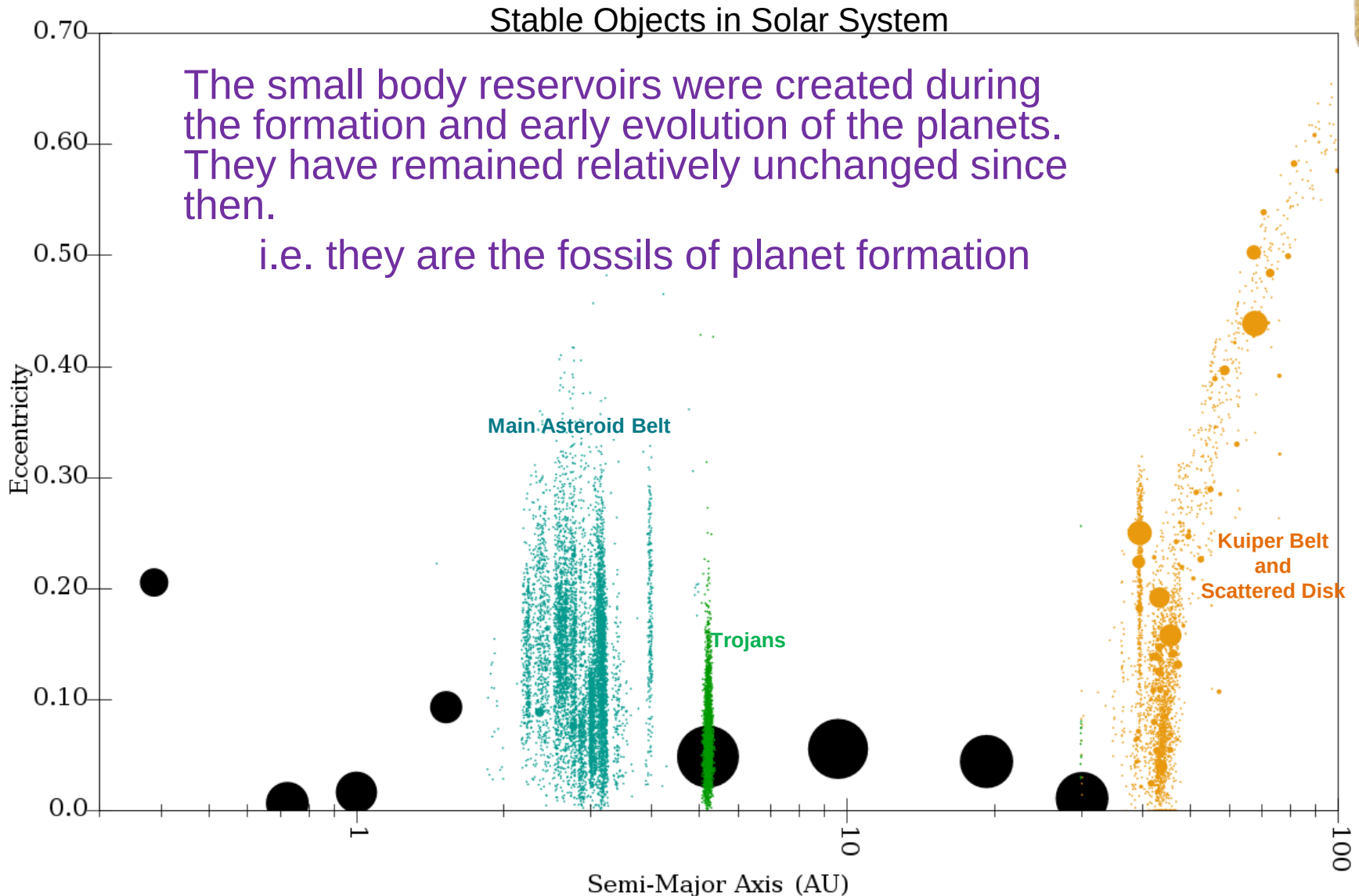
➤ Lucy is a Trojan tour

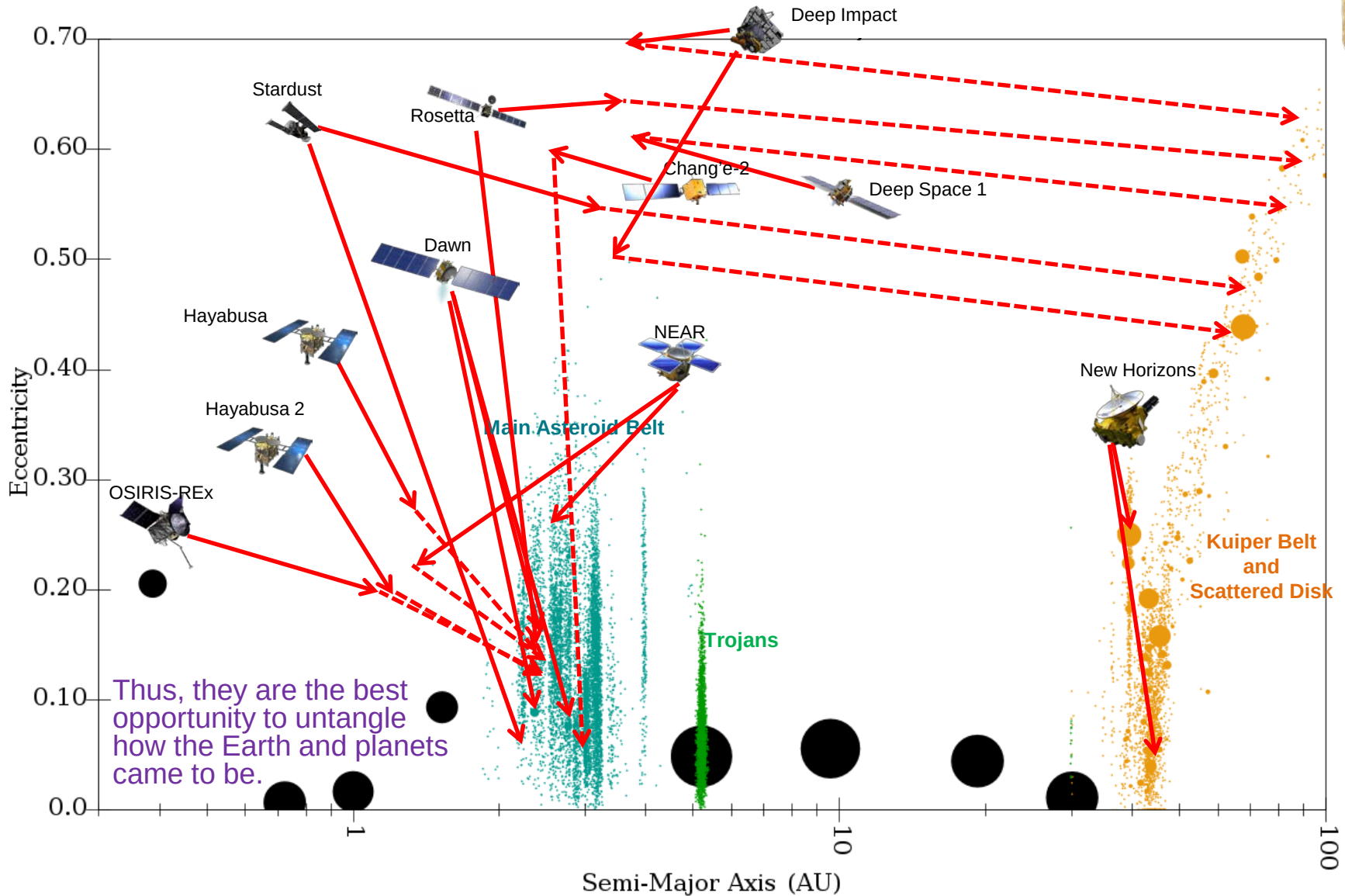


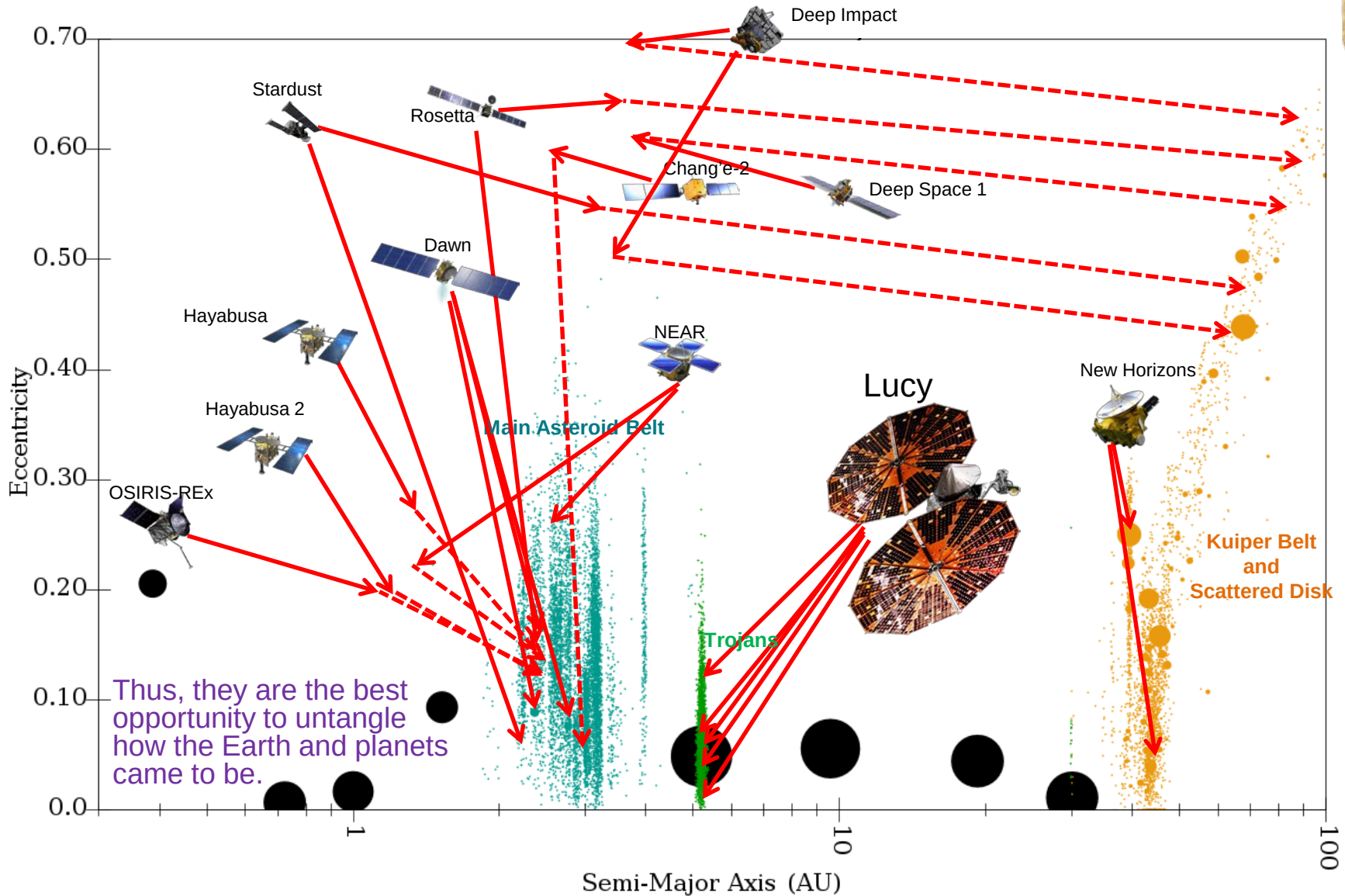
- 2021 launch
- MBA rehearsal in 2025
- 5 Trojan encounters from 2027-2033
 - Total of 7 objects





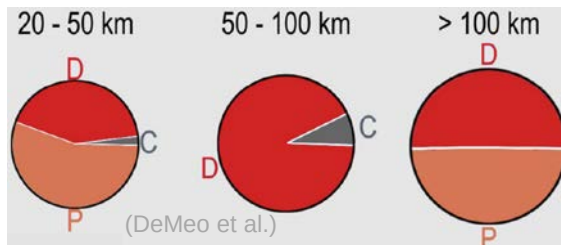
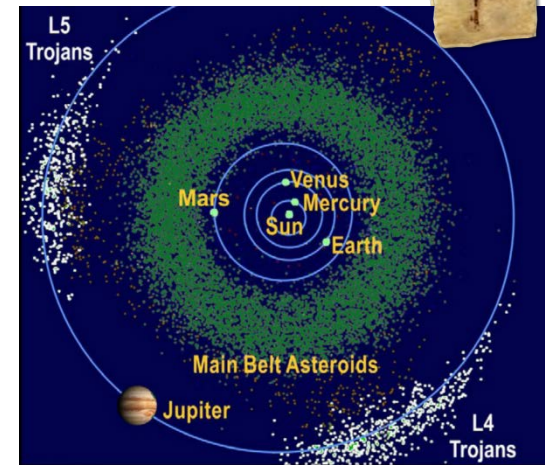




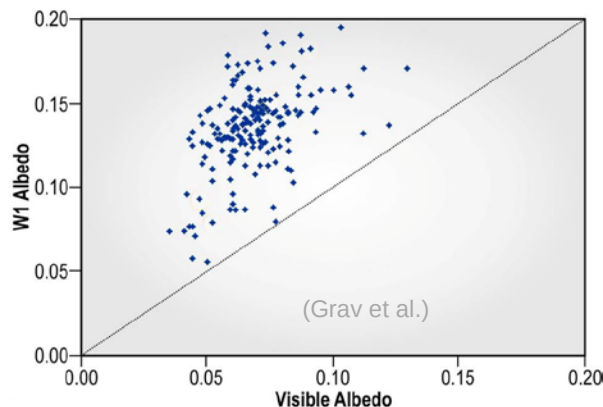




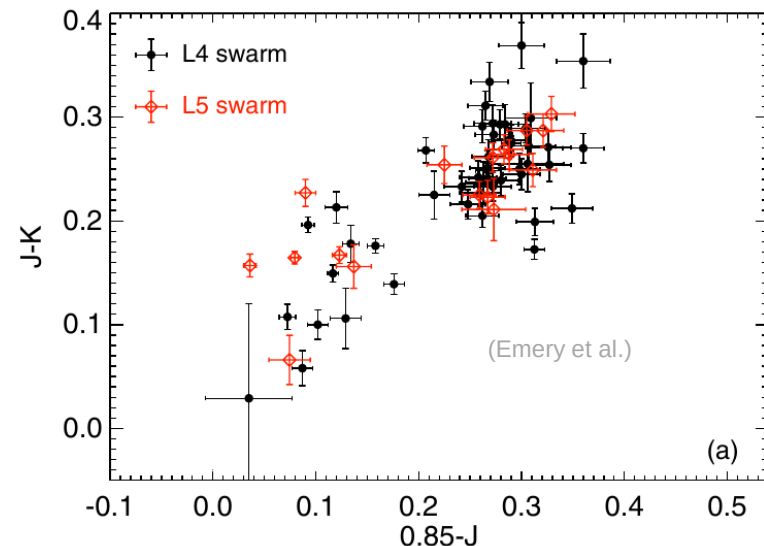
- To boldly go where no one has gone before
 - We have never seen one close up
- Trojans are remnants of giant planet formation
 - They should be low density and volatile rich below a desiccated surface layer with complex surface chemistry.
- **But**, they are not a homogeneous population
 - Contain C-, D-, and P-type spectral types



- Have visible albedos from ~4 - ~15%



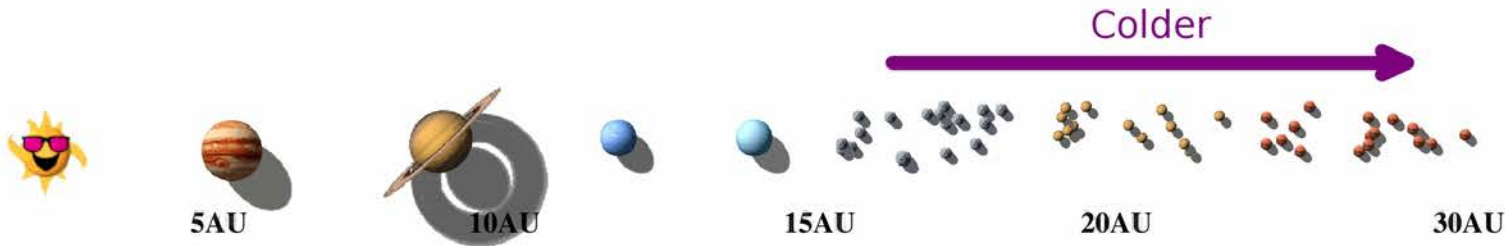
- Wide range of colors.





- Trojans have witnessed firsthand the history of the outer Solar System.
 - They likely formed at different locations.

Example: The Nice Model



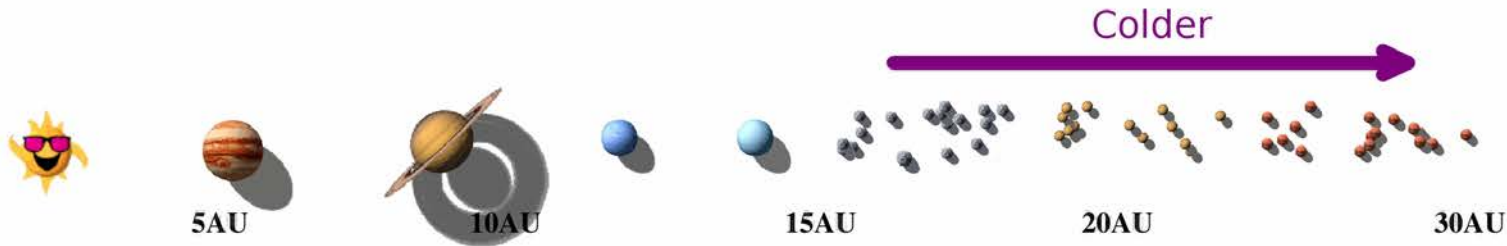
- They were mixed together by planet formation and migration.
- The same process led to their capture in the swarms.

So, Trojans likely harbor objects that formed throughout the outer Solar System. Thus, they present us with a **UNIQUE** opportunity to constrain planet formation and evolution models. **It is only by sampling their diversity that their true scientific potential can be realized.**



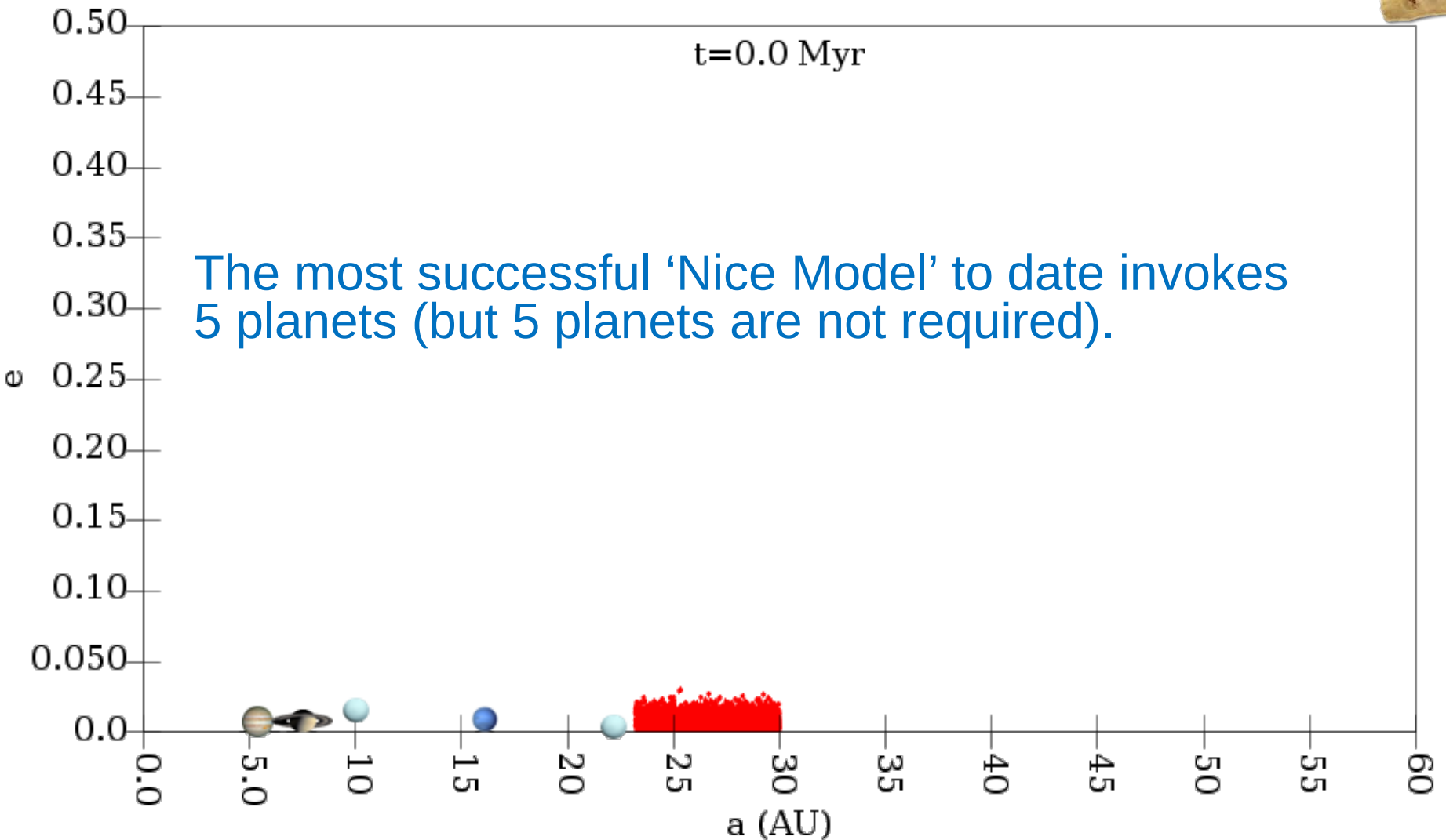
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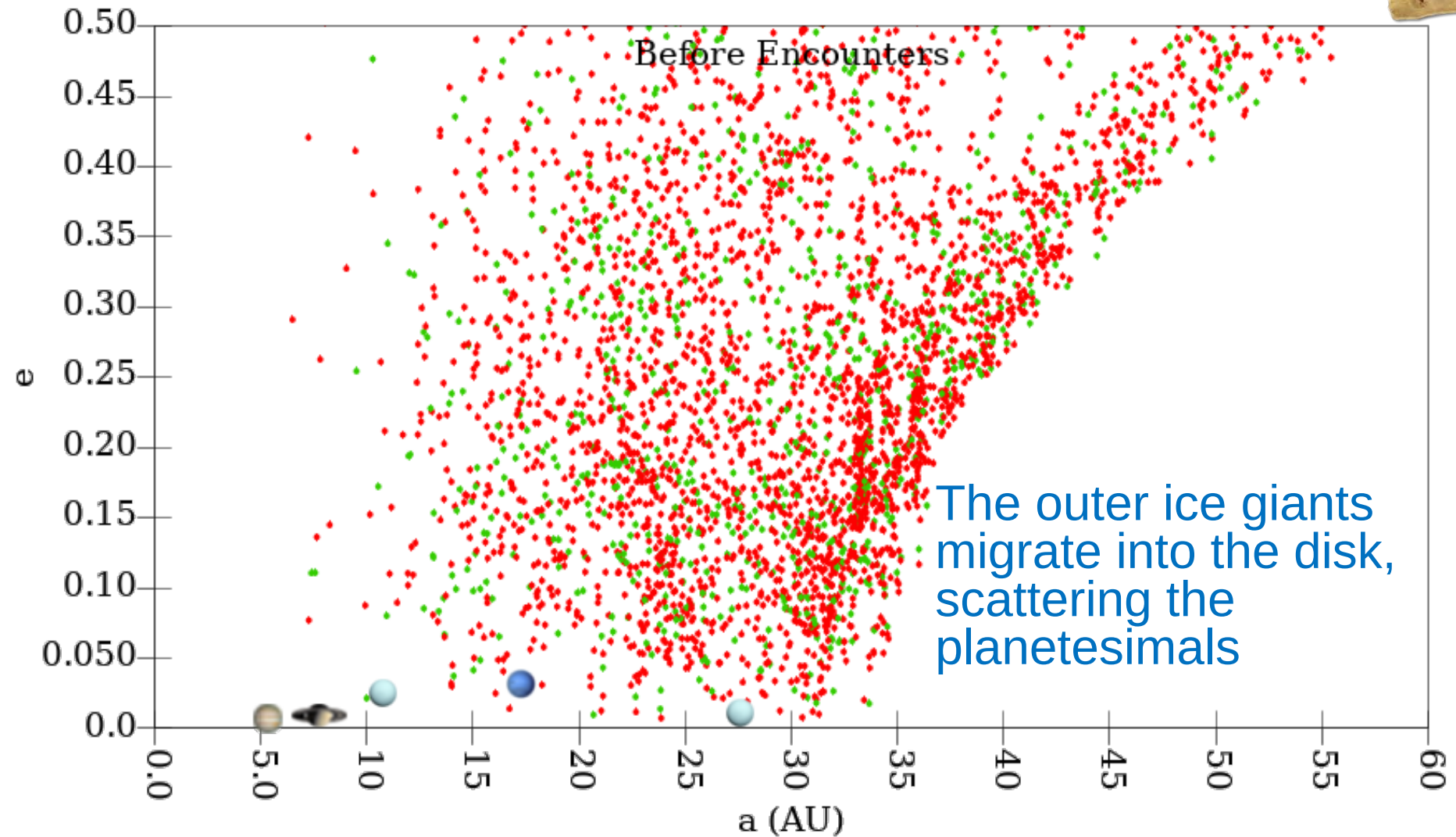
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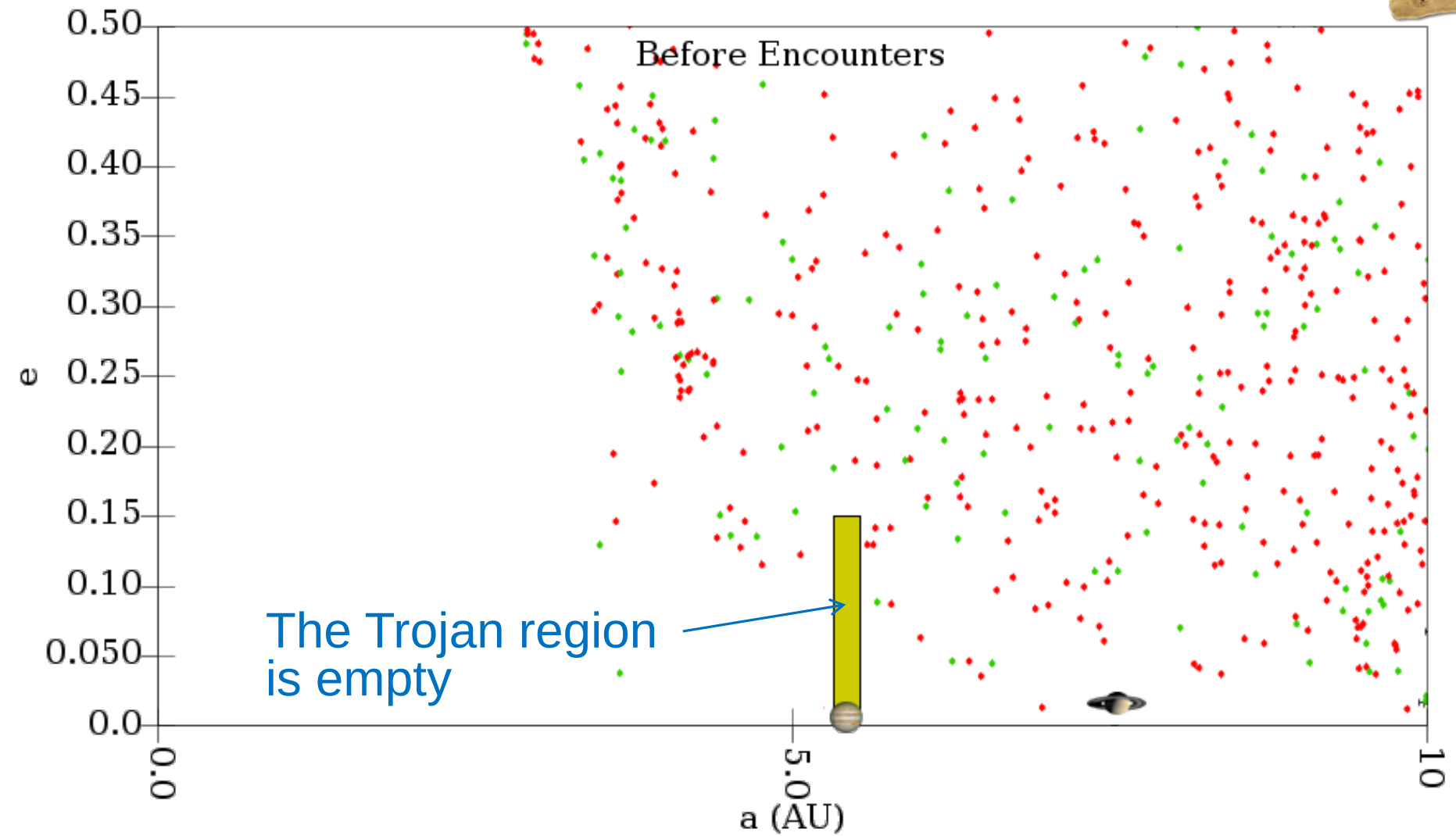


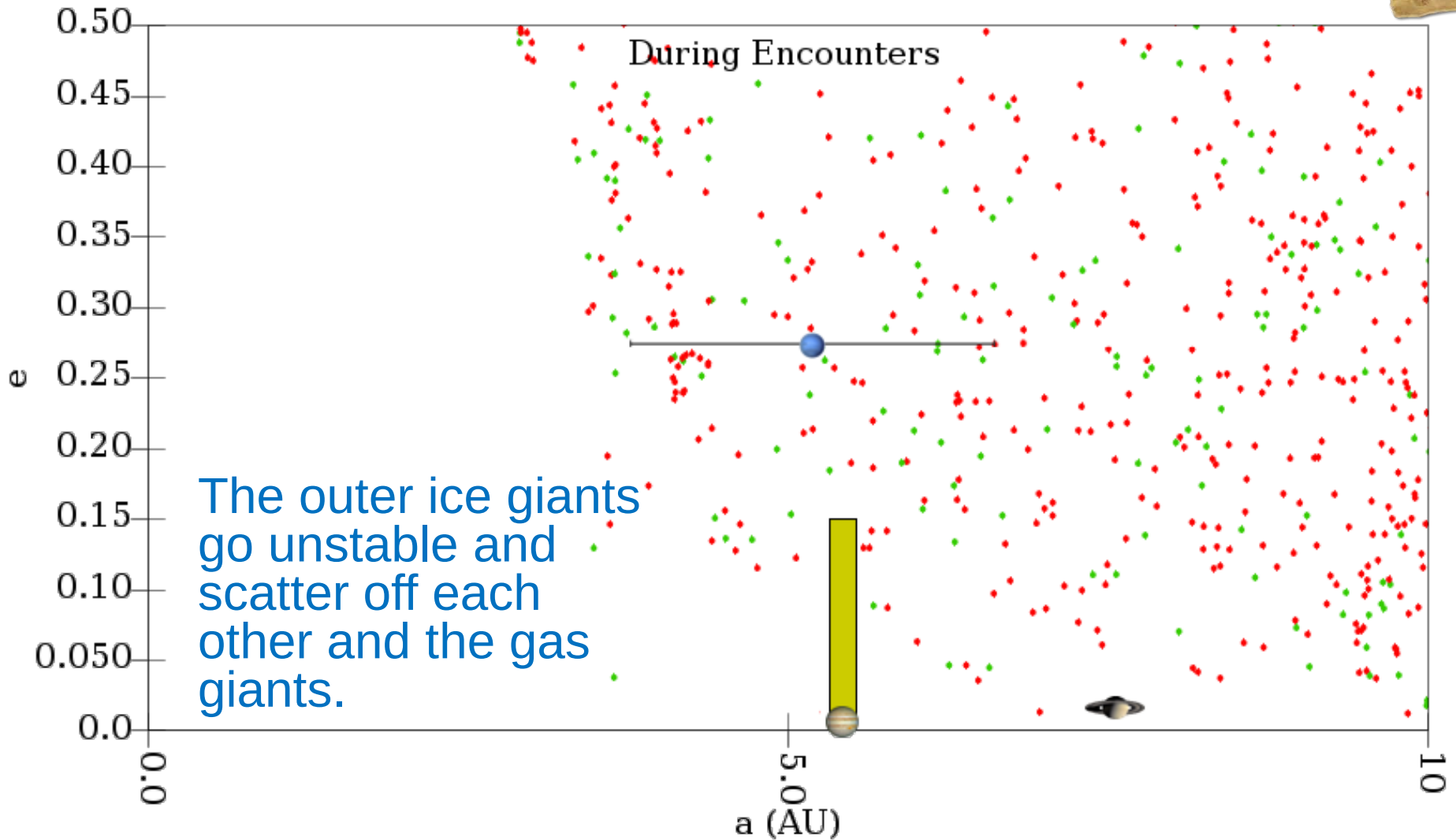
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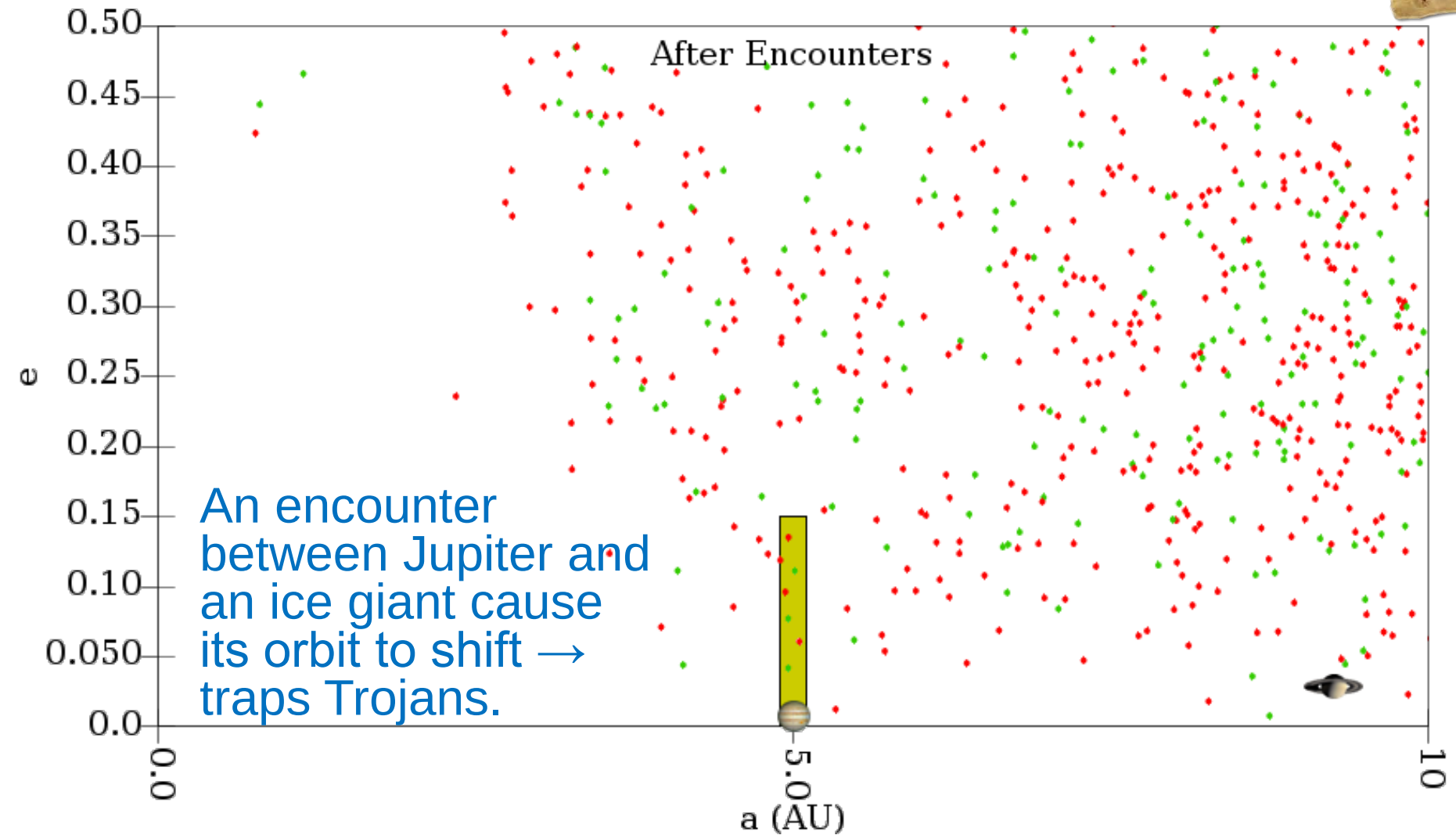
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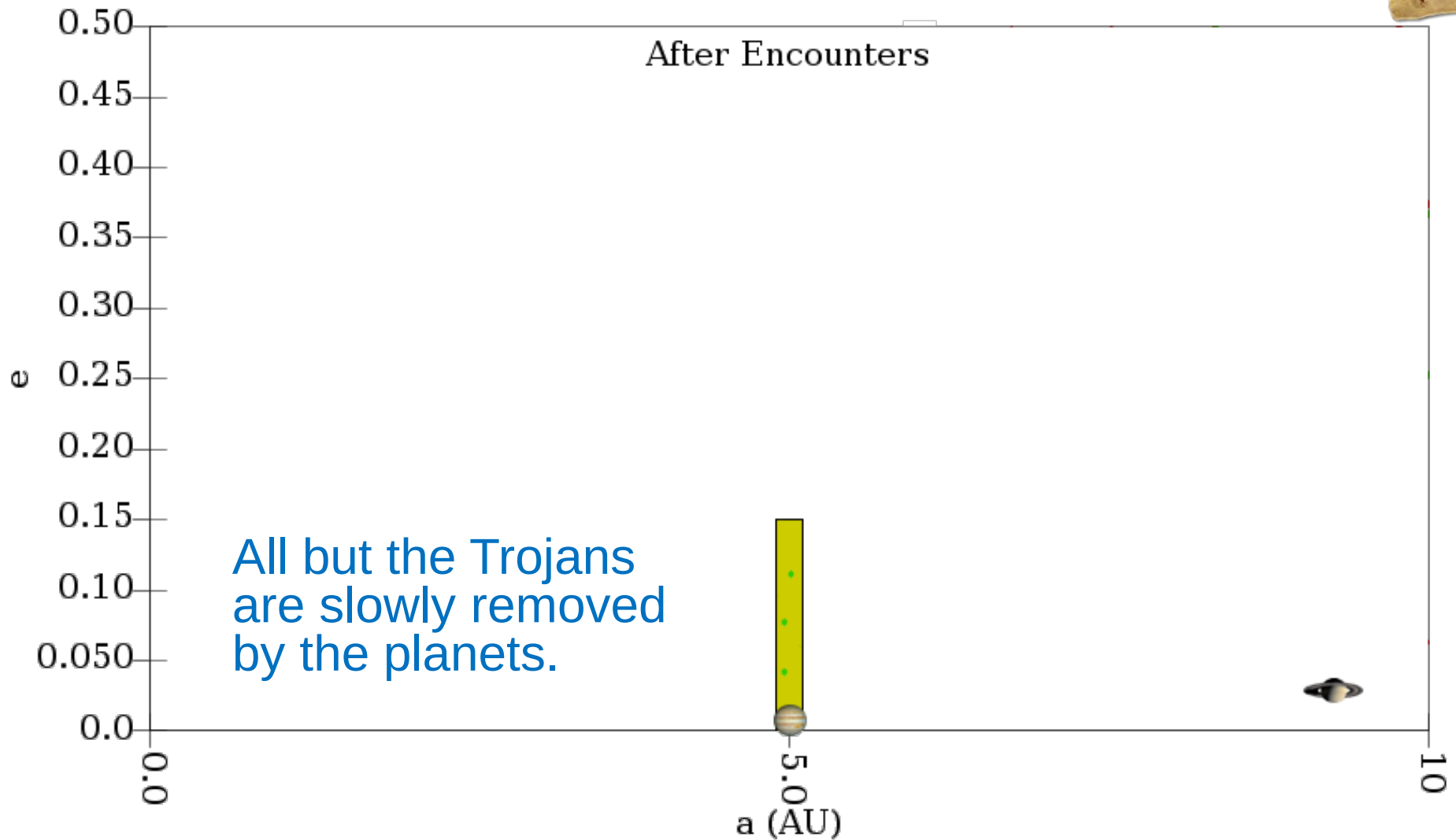


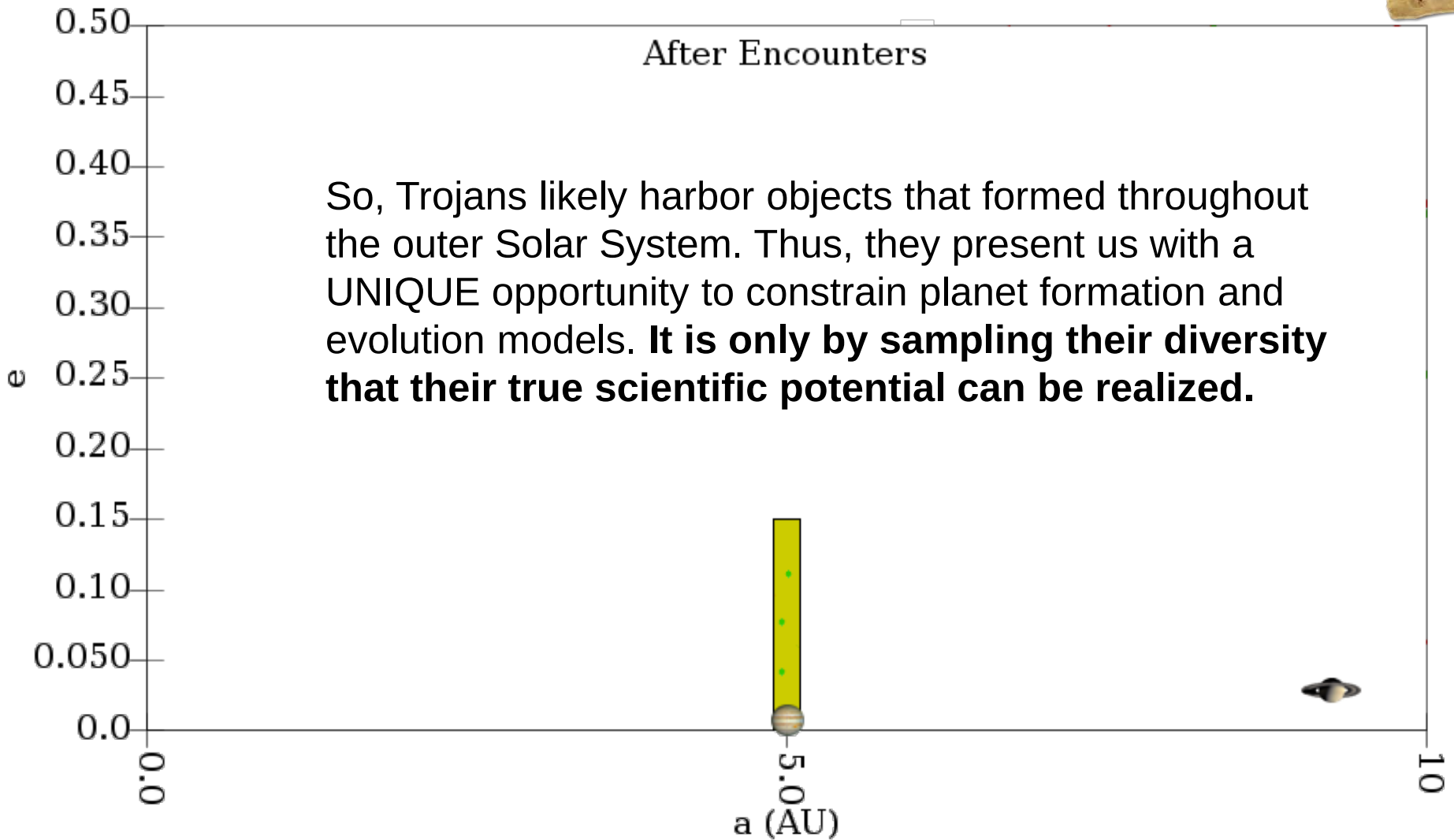




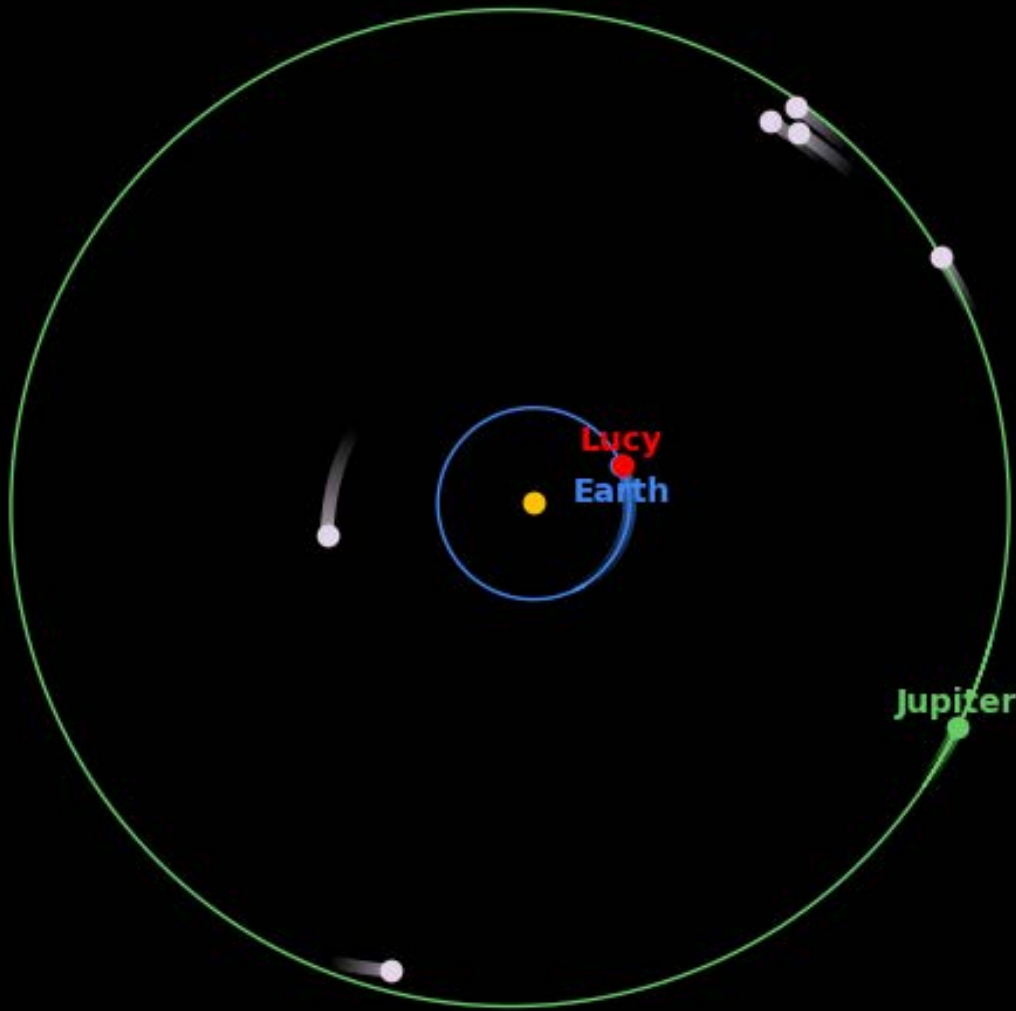






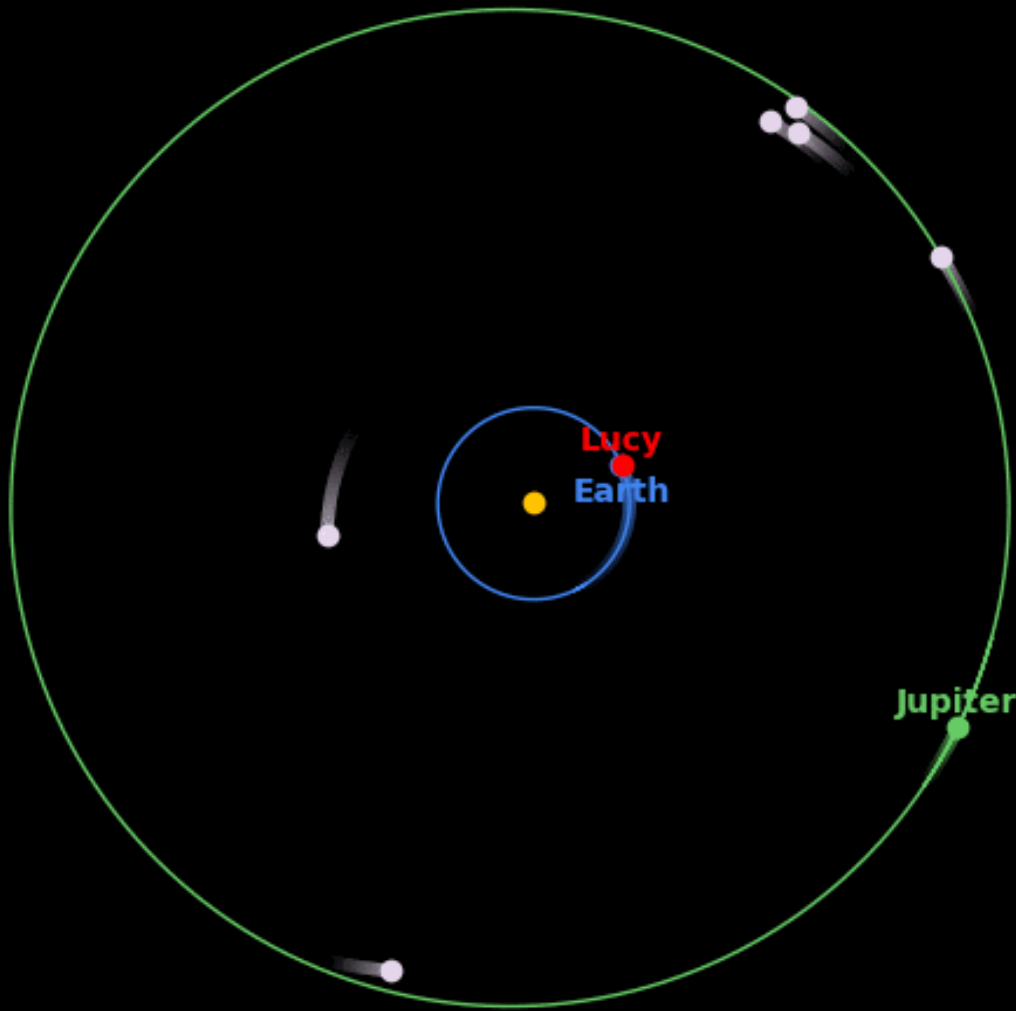


2021 OCT 17

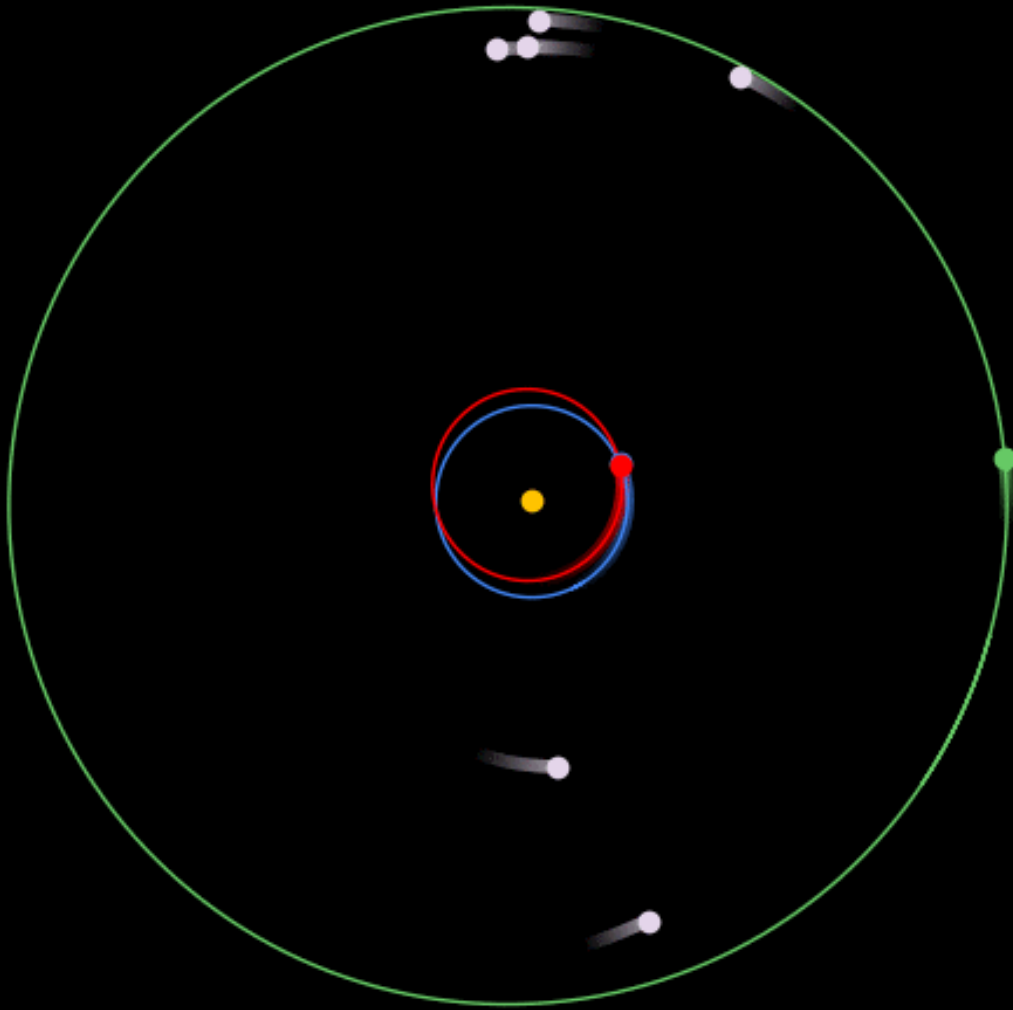


Lucy's unique trajectory is the key aspect of the mission

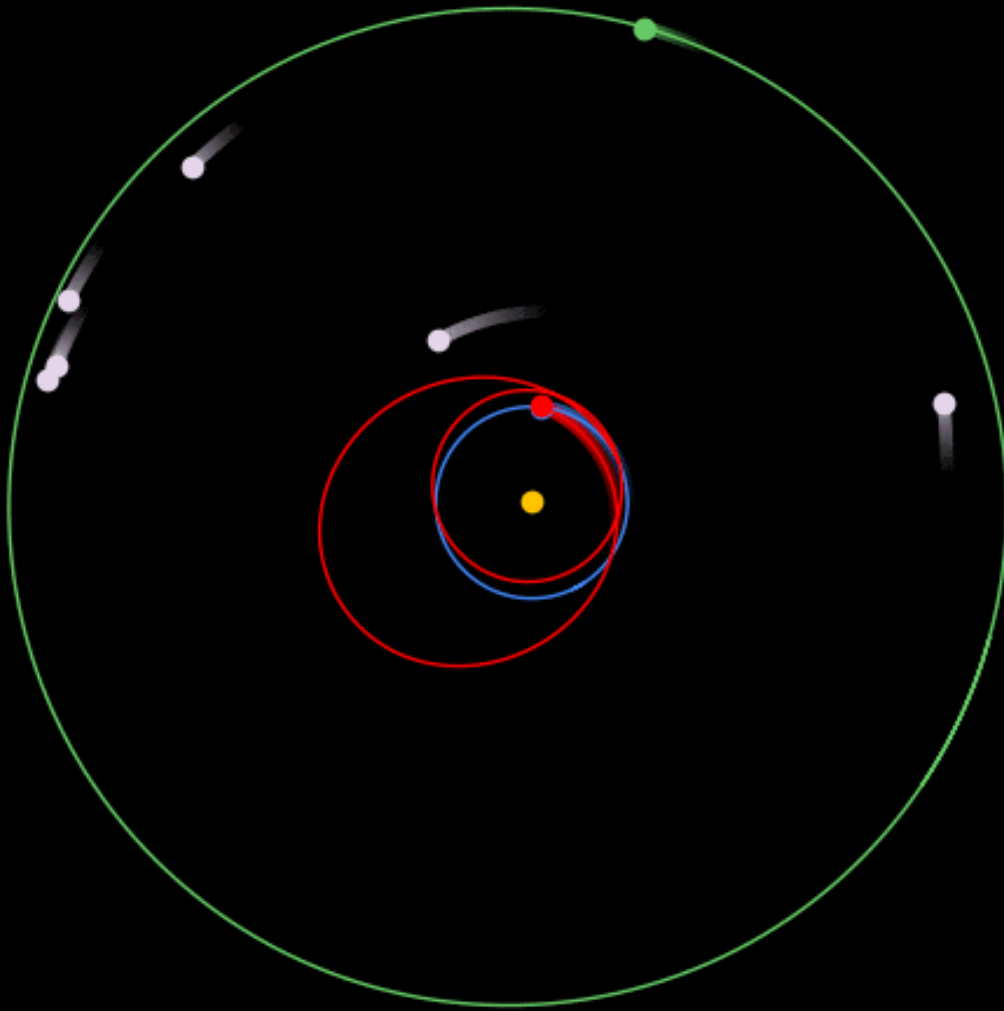
2021 OCT 17



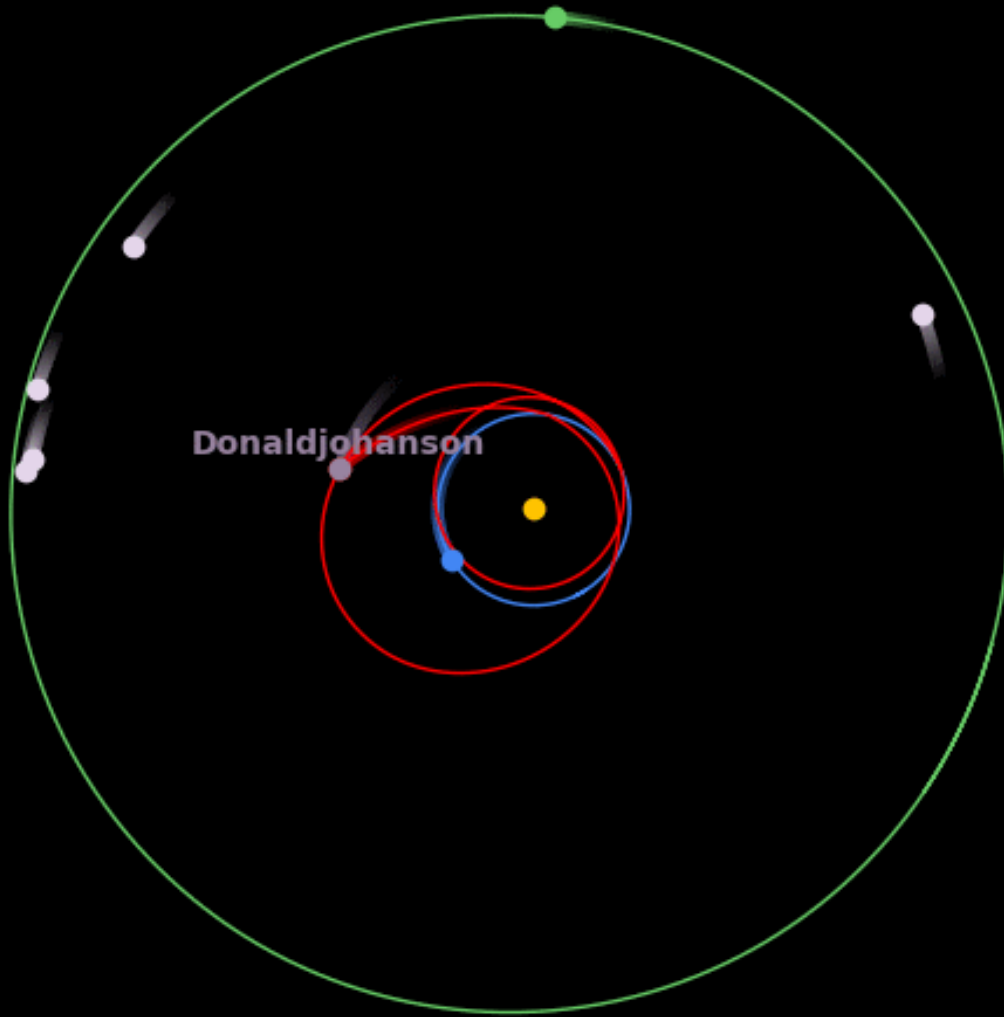
2022 OCT 16



2024 DEC 15

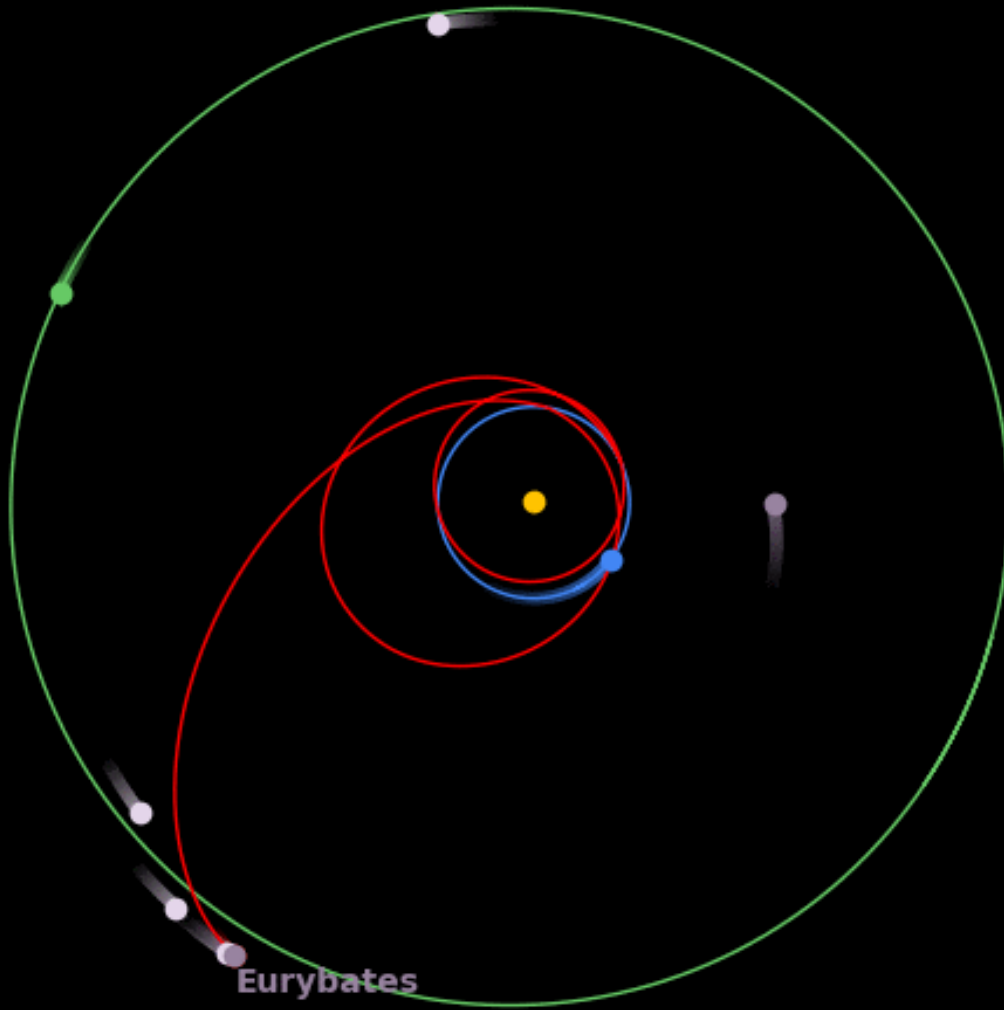


2025 APR 22

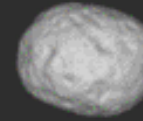


Lucy's unique trajectory is the key aspect of the mission

2027 AUG 16



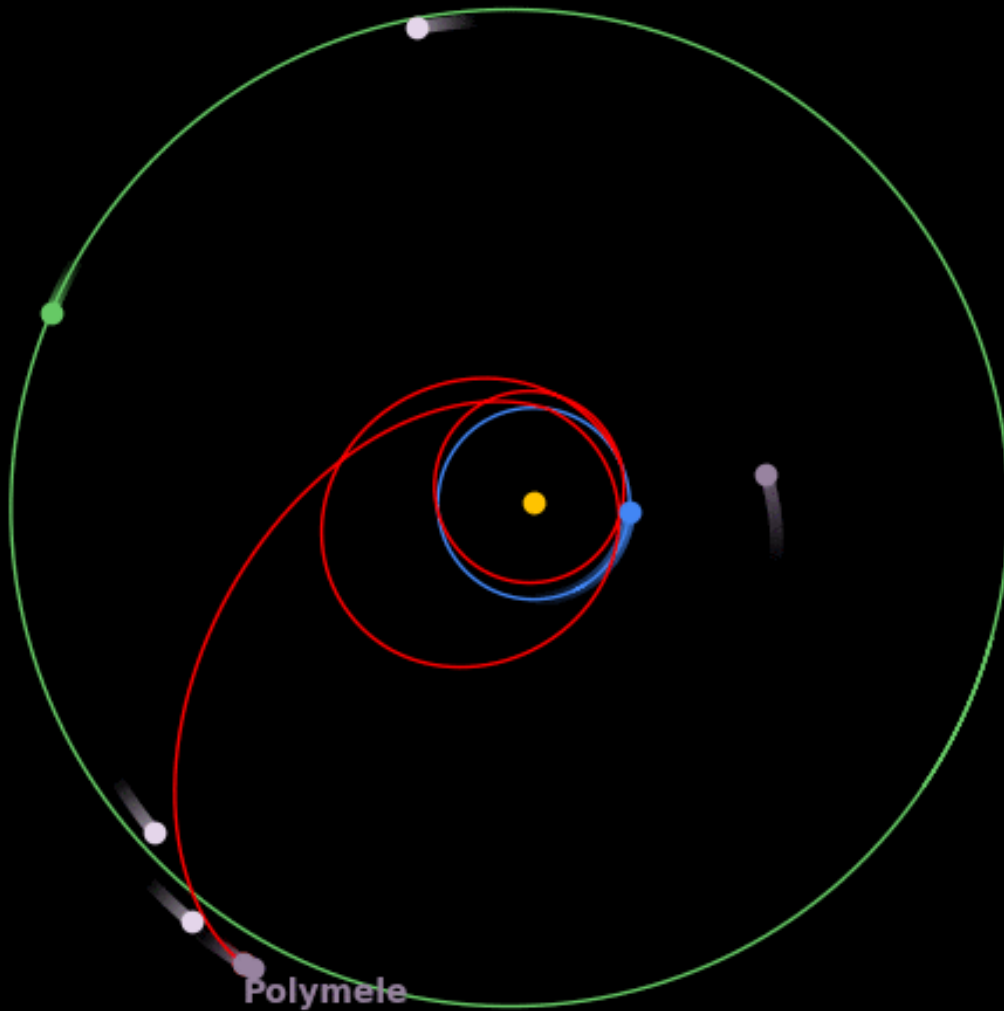
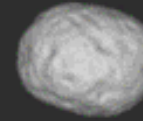
L₄:



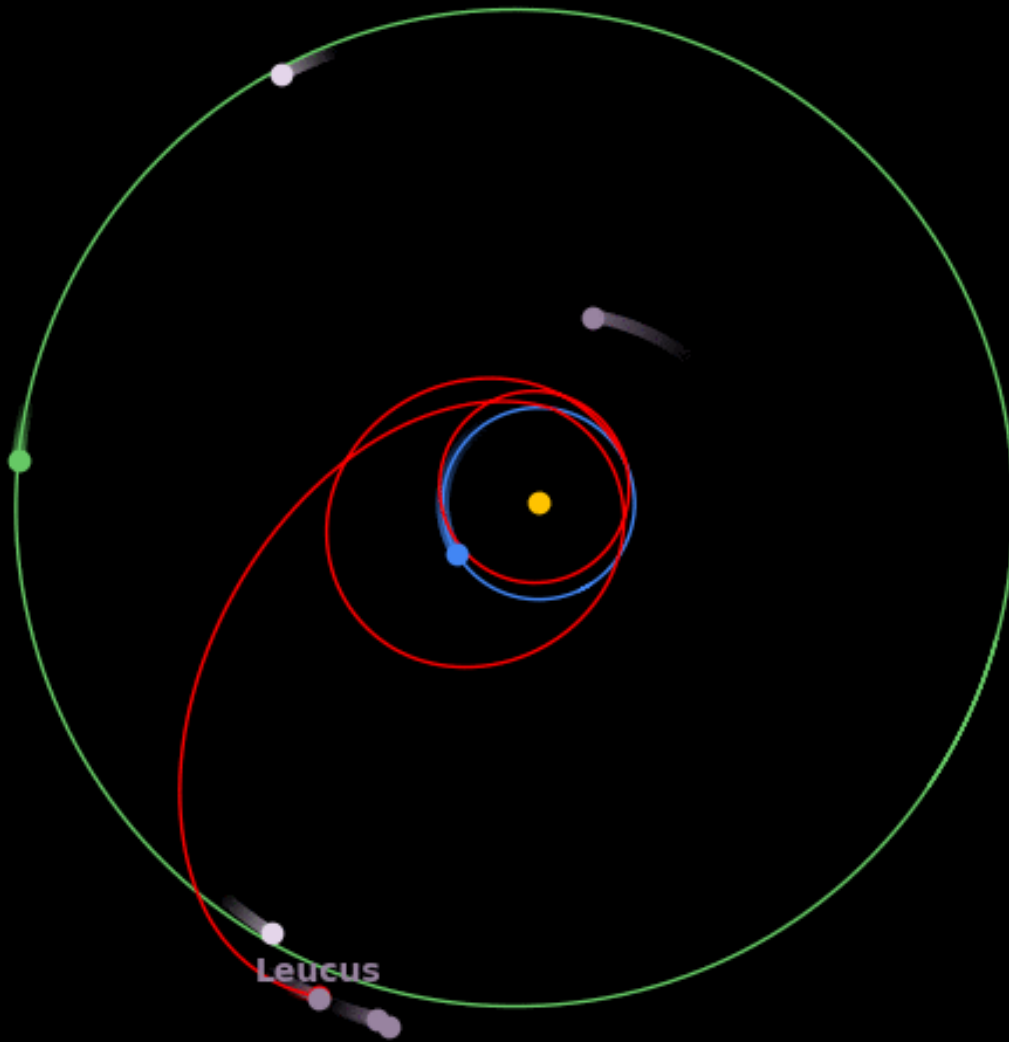
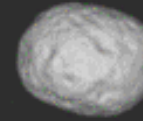
Eurybates+1 (C-type)



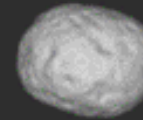
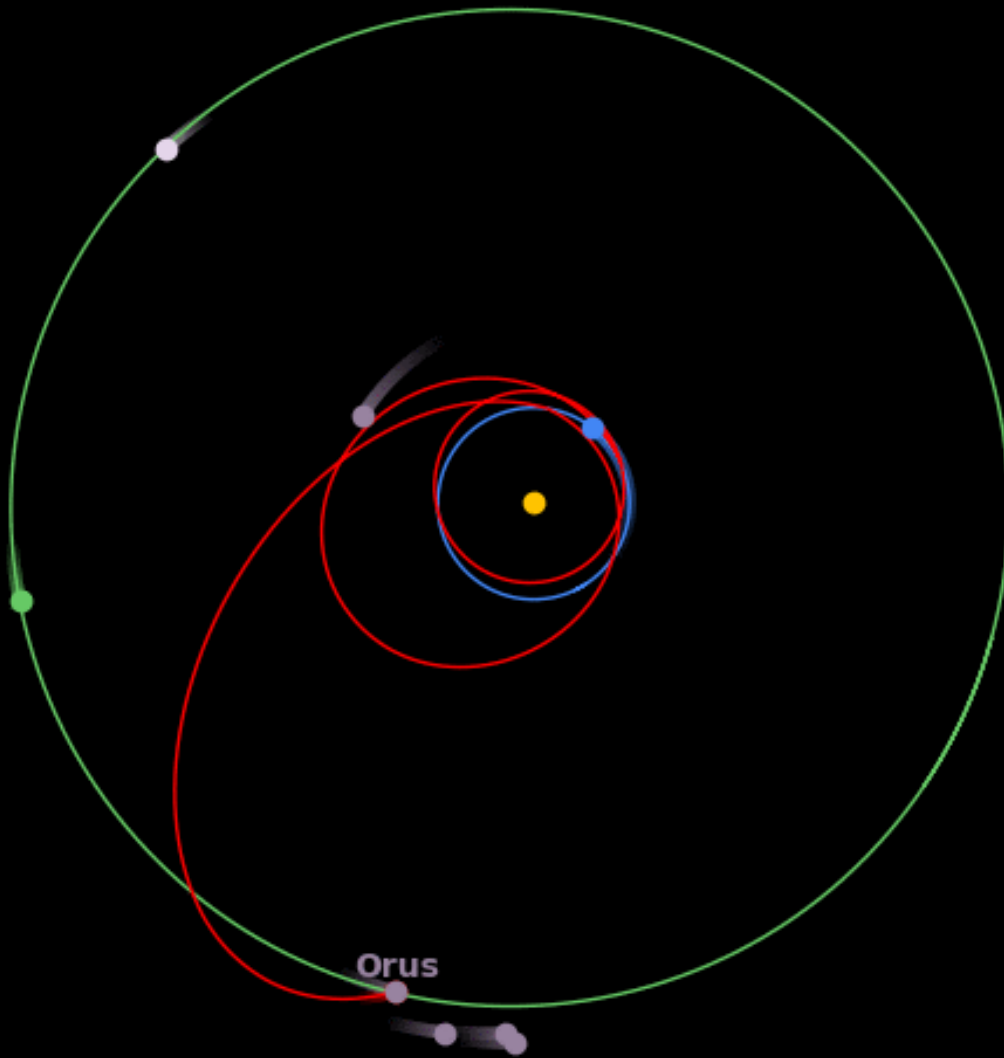
2027 SEP 17

 L_4 :**Eurybates+1 (C-type)****Polymele (P-type)**

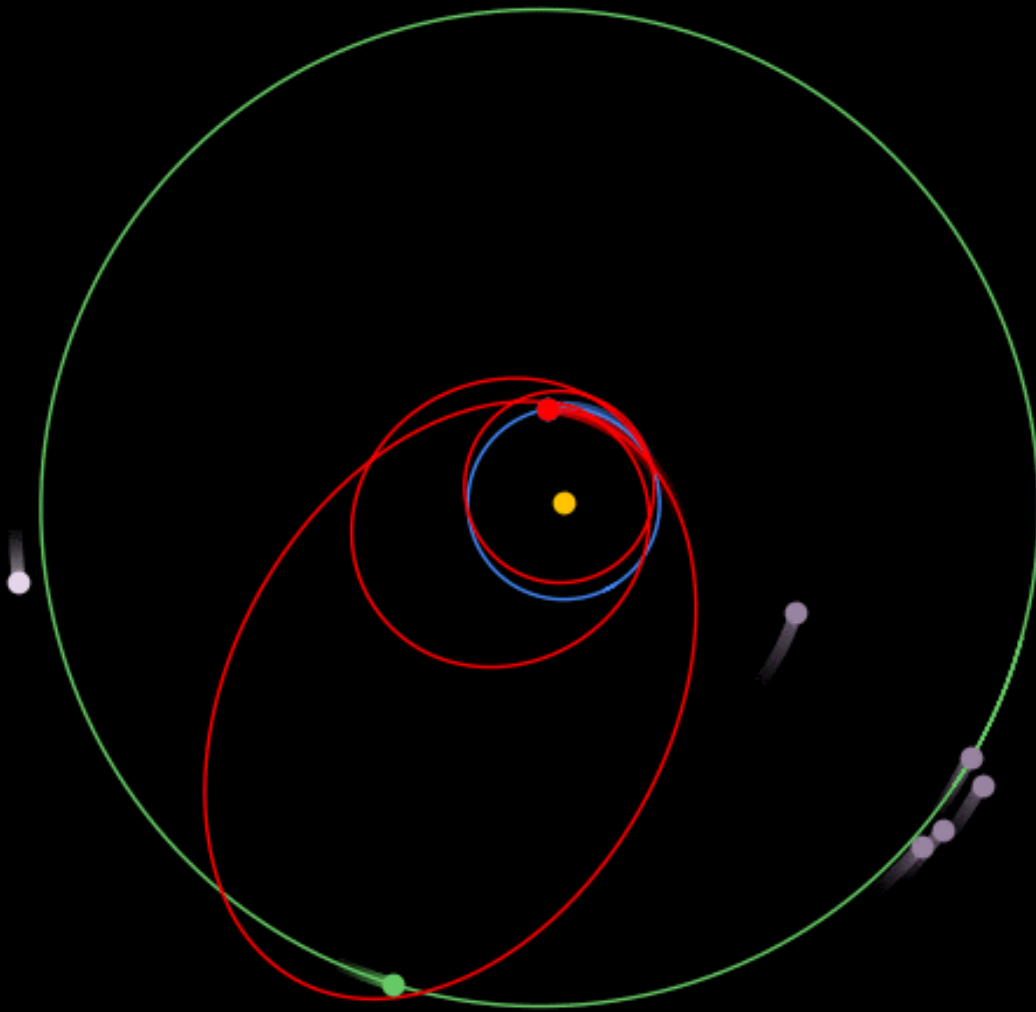
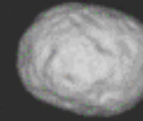
2028 APR 22

 L_4 :**Eurybates+1** (C-type)**Polymele** (P-type)**Leucus** (D-type)

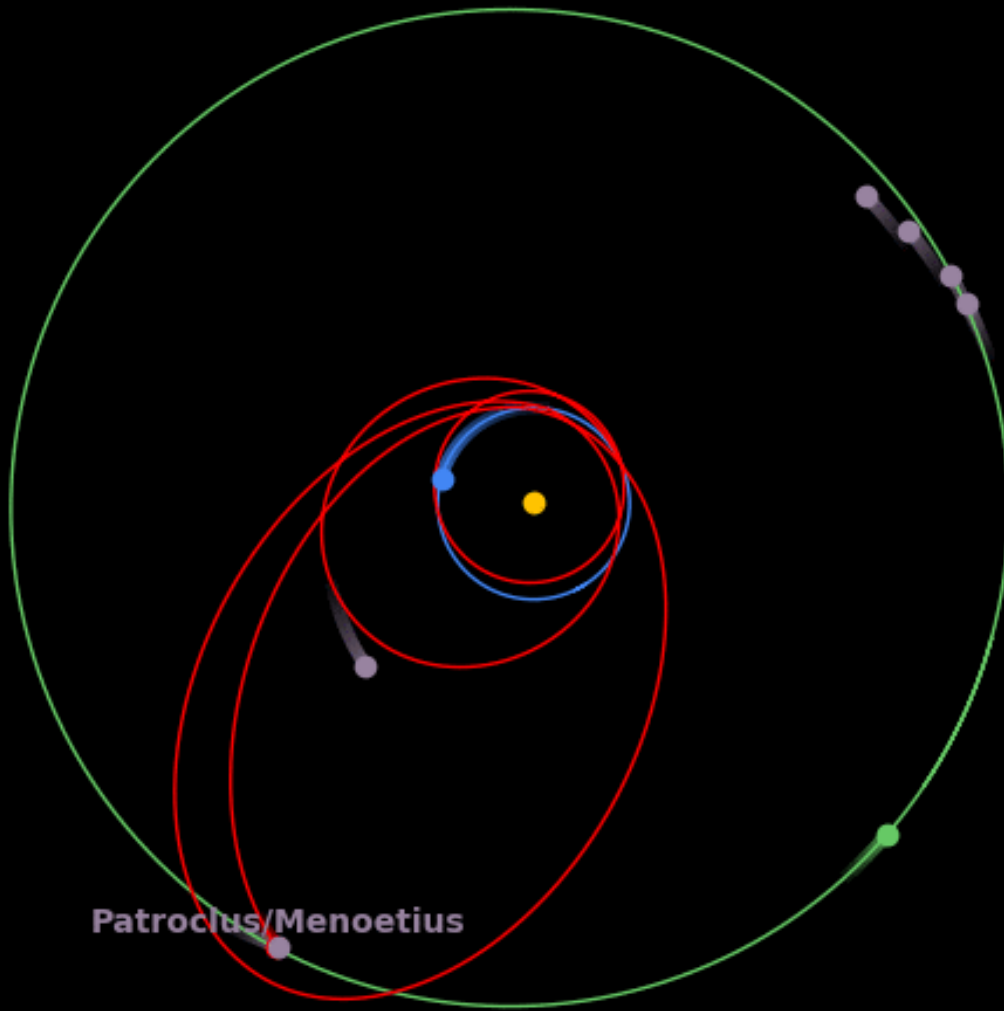
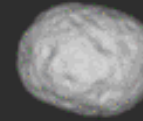
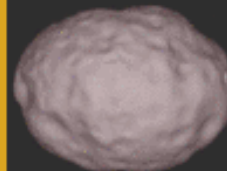
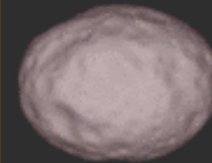
2028 NOV 13

 L_4 :**Eurybates+1** (C-type)**Polymele** (P-type)**Leucus** (D-type)**Orus** (D-type)

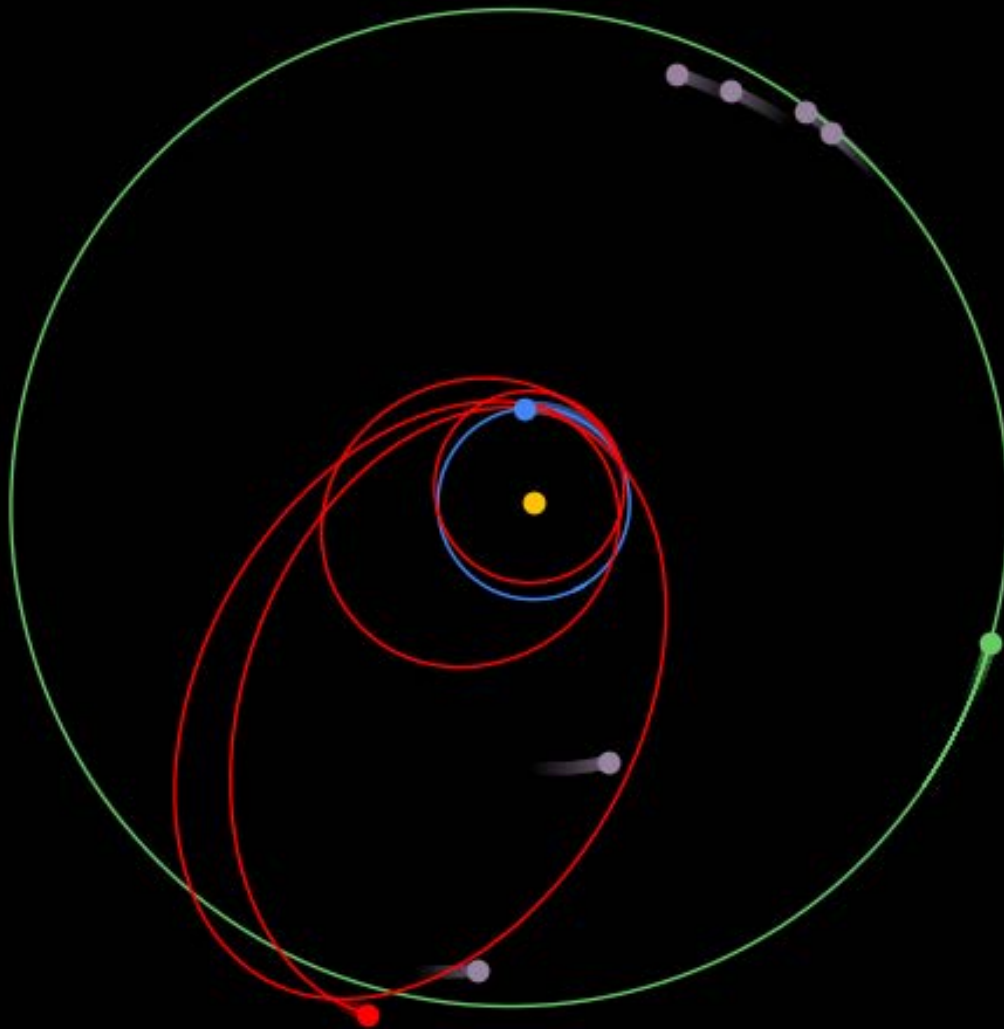
2030 DEC 31

 L_4 :**Eurybates+1** (C-type)**Polymele** (P-type)**Leucus** (D-type)**Orus** (D-type)

2033 MAR 06

 L_4 :**Eurybates+1** (C-type)**Polymele** (P-type)**Leucus** (D-type)**Orus** (D-type) L_5 :**Patroclus/Menoetius
binary
(P-type)**

2033 DEC 27



L_4 :



Eurybates+1 (C-type)



Polymele (P-type)



Leucus (D-type)



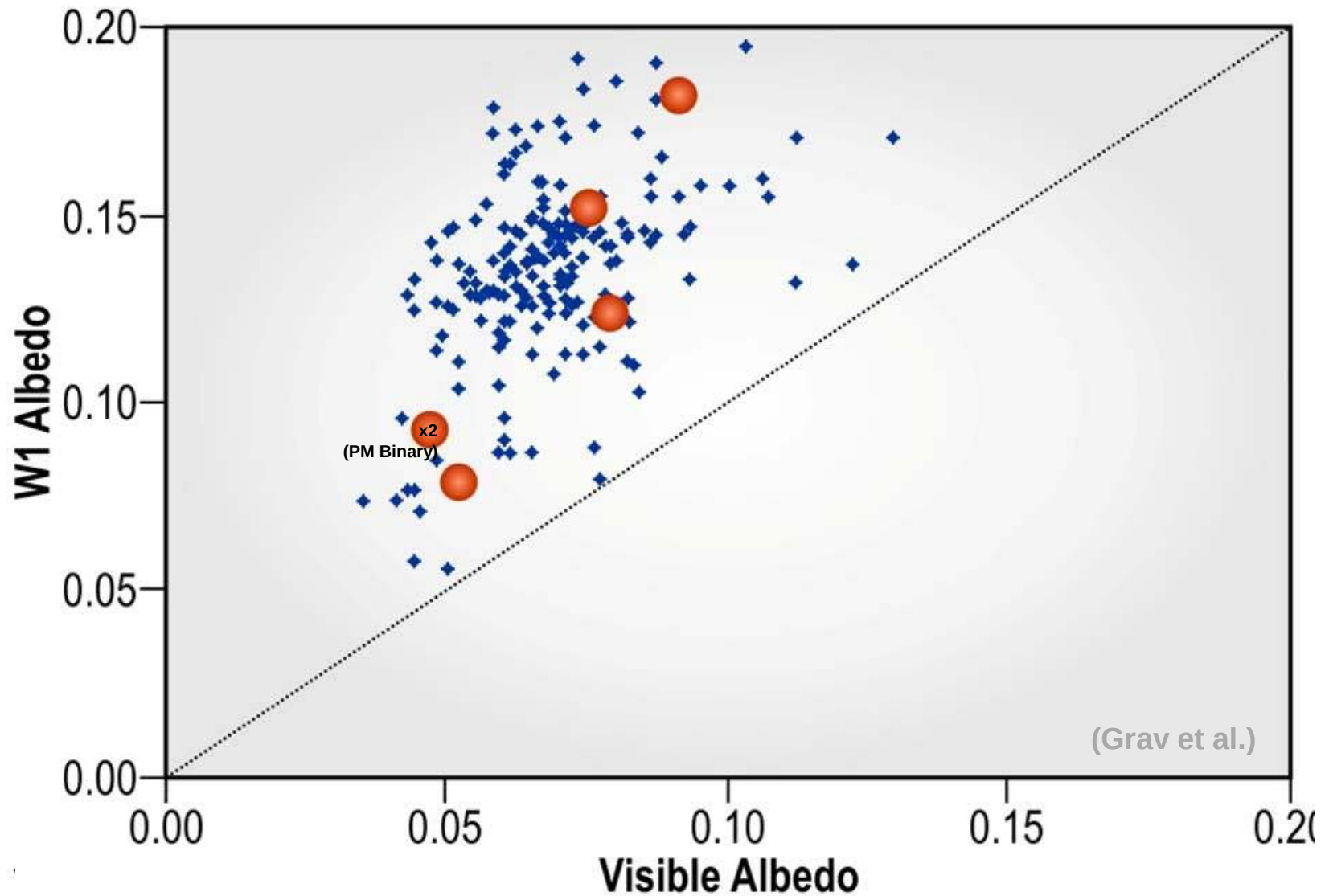
Orus (D-type)

L_5 :



**Patroclus/Menoetius
binary
(P-type)**







Eurybates

C-type
Aug. 2027



Polymele

P-type
Sept. 2027



Leucus

D-type
Apr. 2028



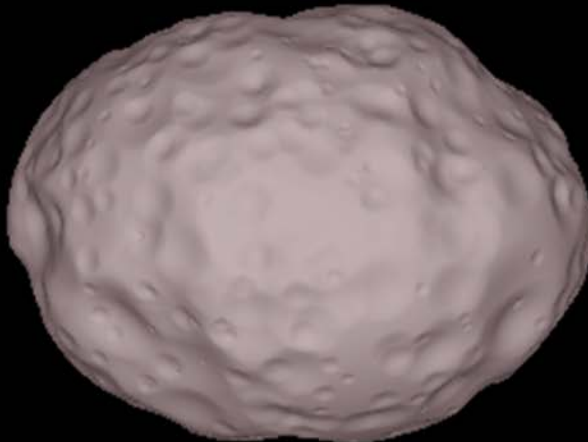
Orus

D-type
Nov. 2028



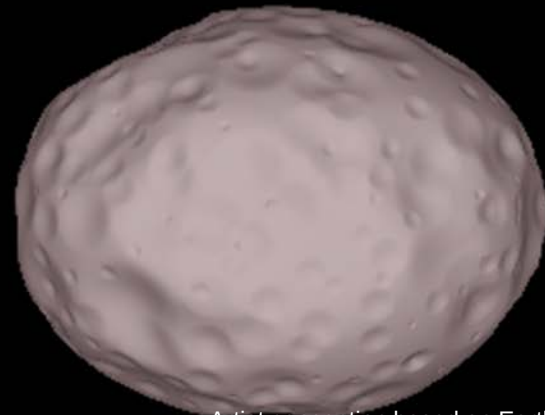
Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms



Eurybates

C-type
Aug. 2027



L_4 :

Polymele

P-type
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Leucus

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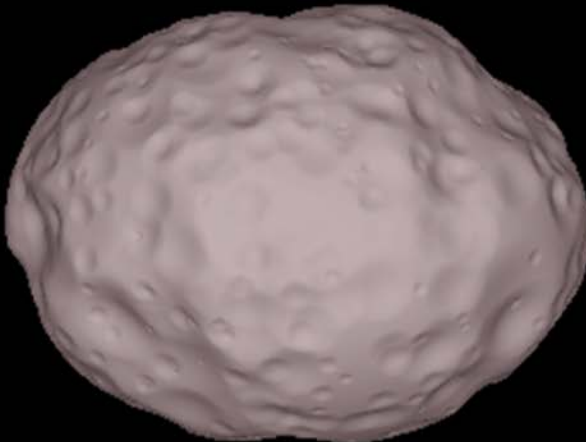
Orus

D-type
Nov. 2028



Patroclus

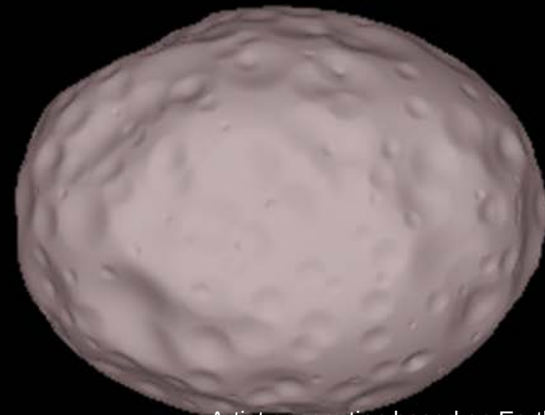
Binary & P-type



L_5 :

Menoetius

Binary & P-type



Mar. 2033

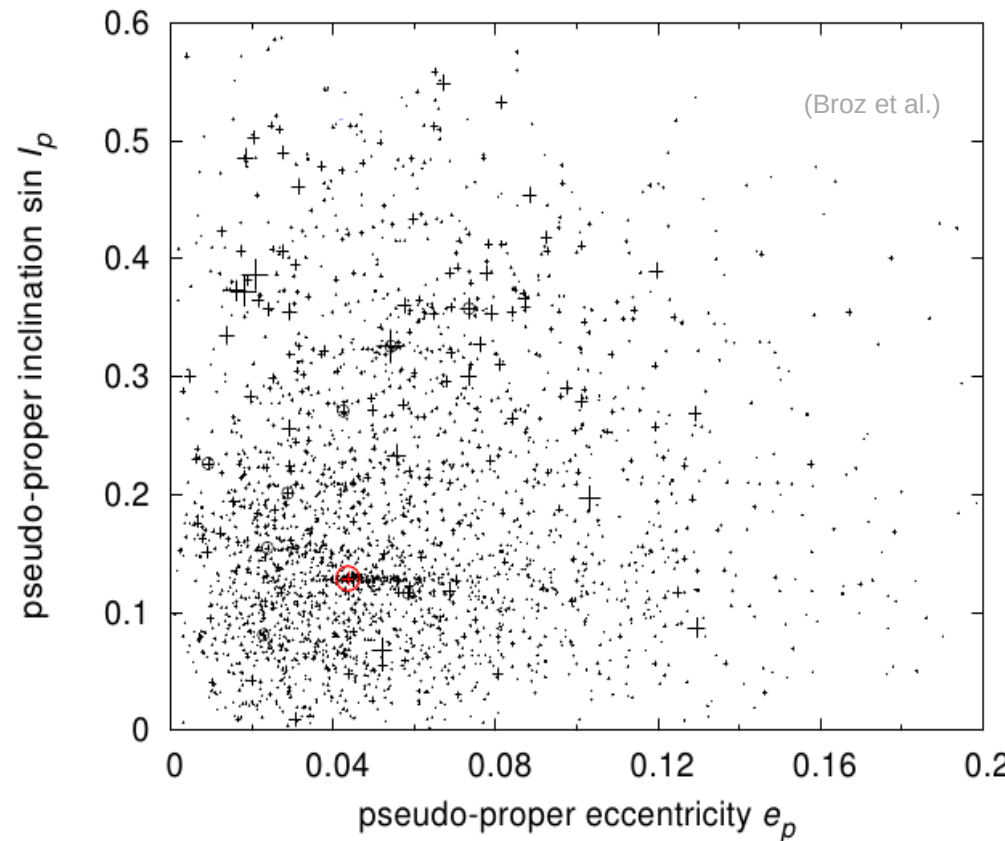
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All known spectral types — Both the L_4 and L_5 swarms



(3548) Eurybates is the largest remnant of the only disruptive collisional family in the Trojans.

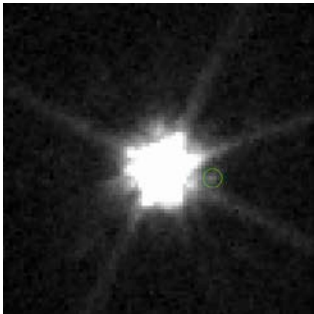
- We have never visited such a body before.
- This object will give unique insight into collisional processes.
- Eurybates is a C-type?!?
 - Rare in the Trojans
 - No D-type families in asteroid belt
 - Perhaps D's disintegrate when hit
 - Perhaps D's become C's when hit
 - Lucy will help understand this.



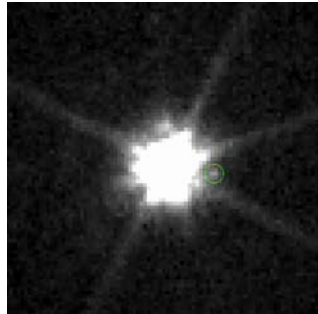


We discovered a small satellite in orbit about Eurybates with HST.

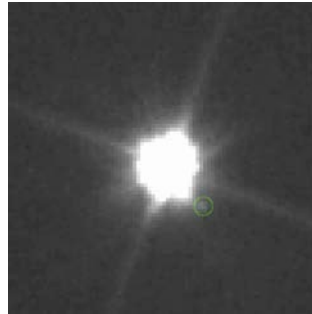
- Assuming same albedo as Eurybates, satellite diameter is ~ 800 m.



09:23 (UT) 12 Sep 2018

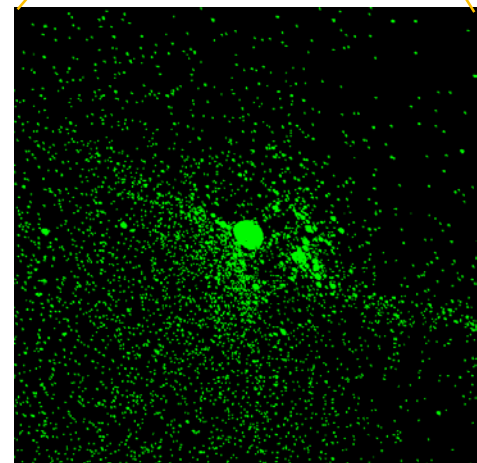
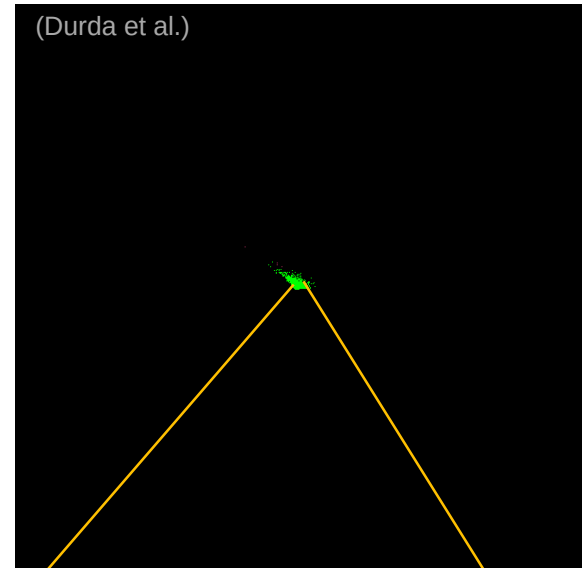


09:42 (UT) 14 Sep 2018



07:13 (UT) 03 Jan 2020

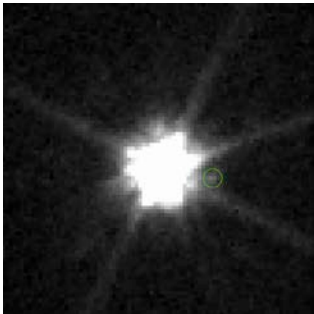
- No orbit yet.
 - Observed separations roughly 2000 km.
 - Physically reasonable orbits exist that fit data.
 - Periods $\sim 40 - \sim 200$ days.
 - More HST data is on its way.
- Perhaps it is not surprising that Eurybates has such a satellite.
 - They form in family-forming collisions.



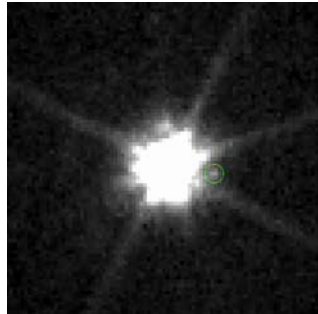


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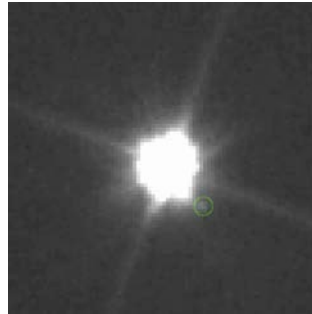
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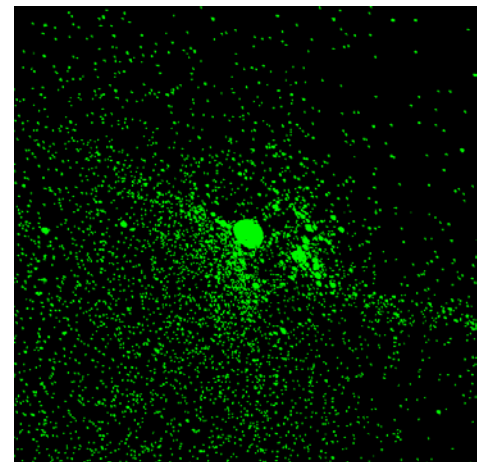
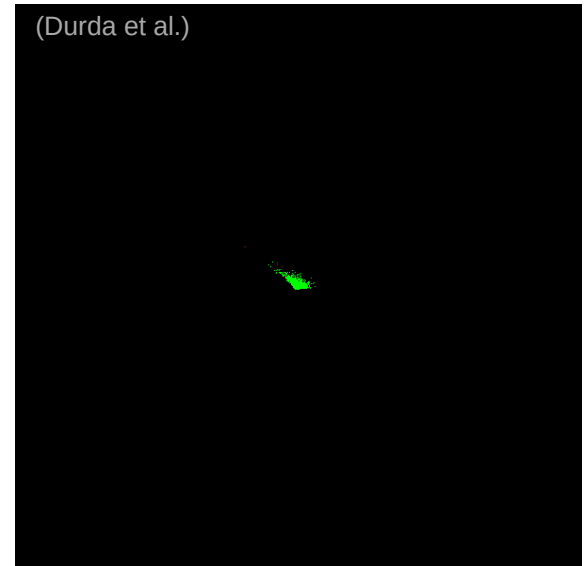


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Eurybates

C-type
Aug. 2027



Polymele

P-type
Sept. 2027



Leucus

D-type
Apr. 2028



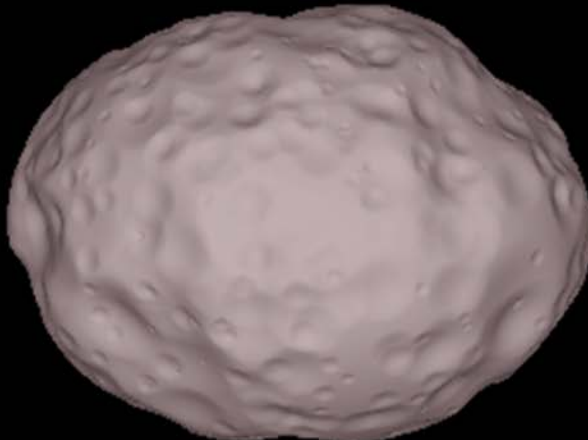
Orus

D-type
Nov. 2028



Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms — Disruptive collision remnant



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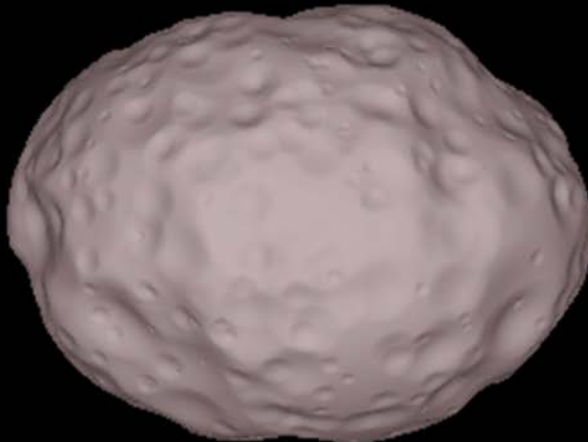
D-type
Nov. 2028



L₄:

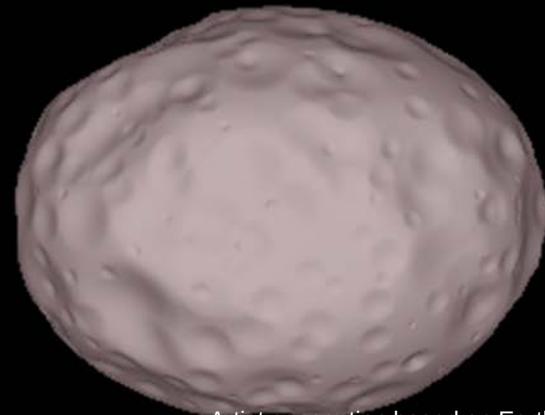
Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

L₅:

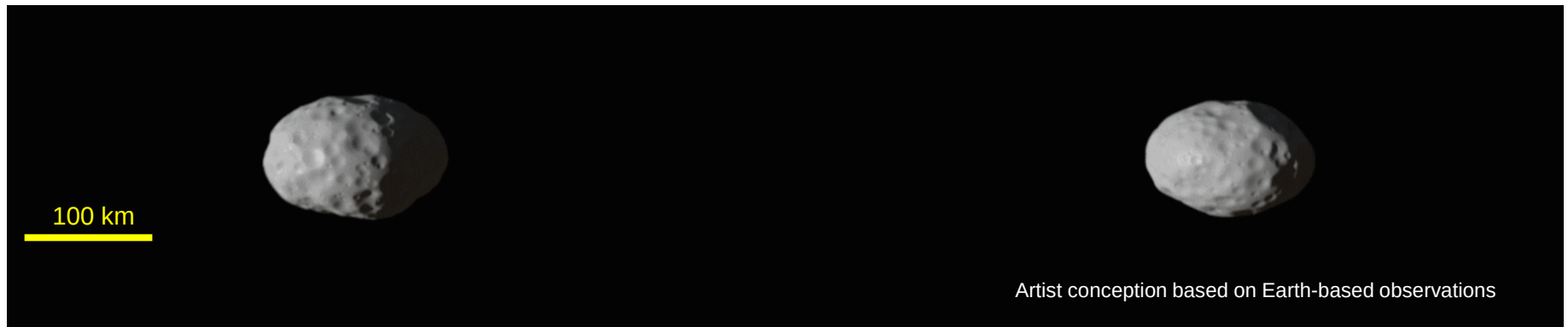
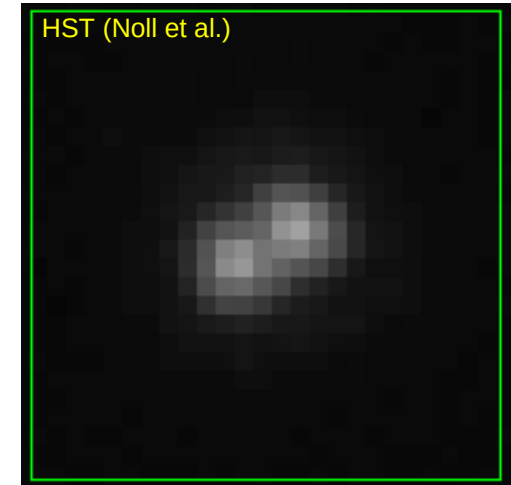
Artist conception based on Earth-based observations

All known spectral types — Both the L₄ and L₅ swarms — Disruptive collision remnant



A near-equal mass binary is within Lucy's reach!

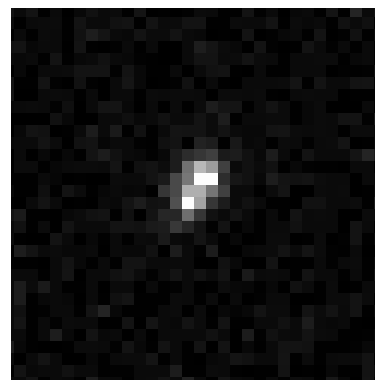
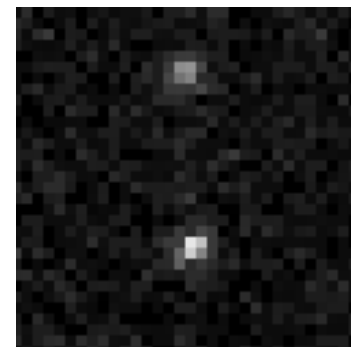
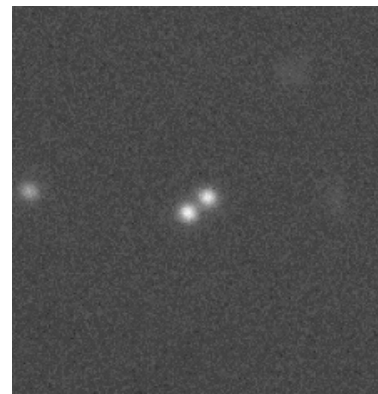
	(617) Patroclus and Menoetius
H	8.2
Size	127 x 117 x 98km 117 x 107 x 90 km
P rot	4.3 days
a (bin)	680 km
i (sun)	22 deg





Many Cold Classical KBOs are equal mass binaries

- o Most undisturbed population in the Solar System.
 - Most objects formed this way?
- o Their formation is a mystery.
 - Classical ideas don't work.
 - Most successful idea relies on pebble accretion.
- o (617) Patroclus is very similar.
 - It will give insight into how these things came to be.





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C-type
Aug. 2027



Polymele

P-type
Sept. 2027



Leucus

D-type
Apr. 2028



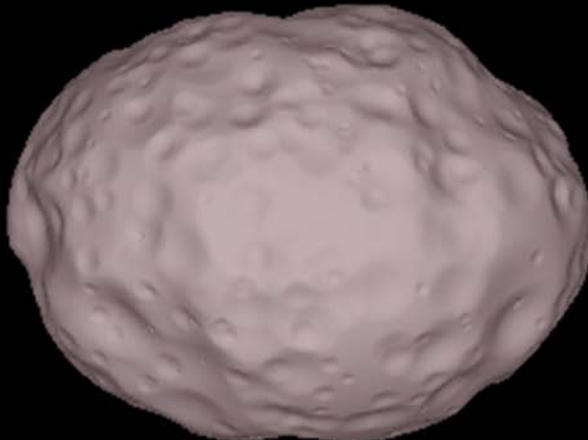
Orus

D-type
Nov. 2028



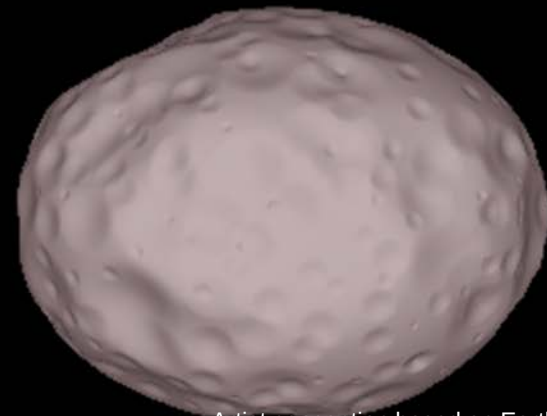
Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms — Disruptive collision remnant
near-equal mass (primordial?) binary



• Donald Johanson
MBA Rehearsal

Eurybates

C-type
Aug. 2027



Polymele

P-type
Sept. 2027



Leucus

D-type
Apr. 2028



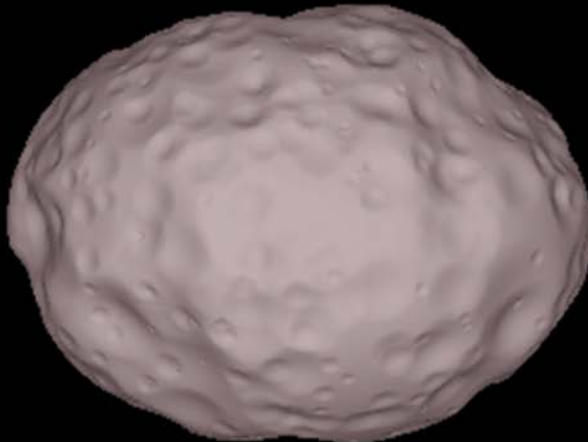
Orus

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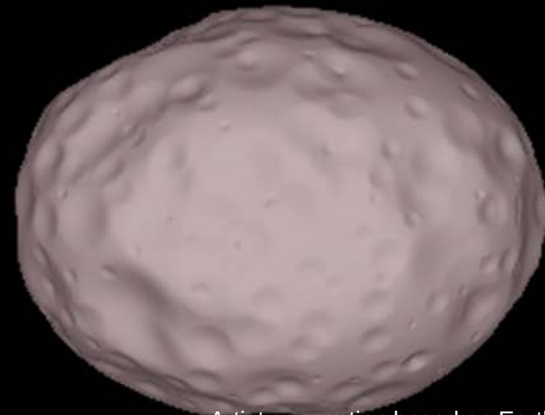
Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms — Disruptive collision remnant
near-equal mass (primordial?) binary — Ultra Slow Rotator

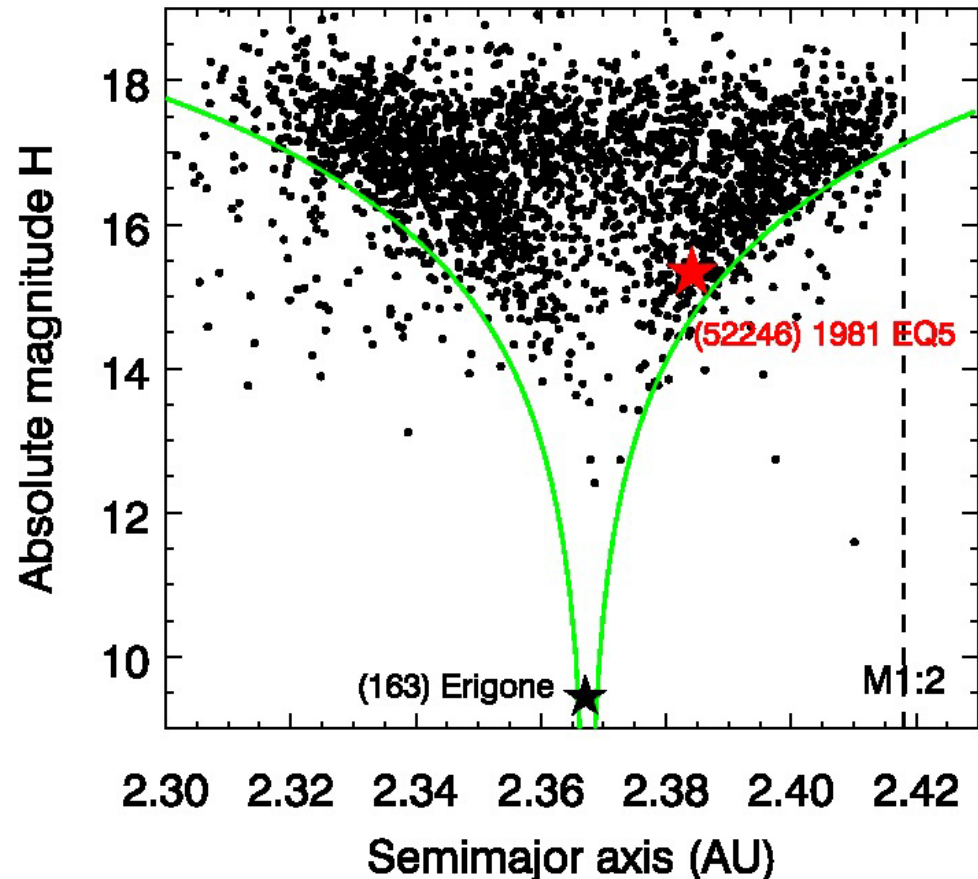
Lucy DonaldJohanson is Not Just Another Pretty Face



We will also visit a main belt asteroid, DonaldJohanson (1981 EQ5)

- Intended simply as a rehearsal.
- However, it is a member of the ~100Myr Erigone family.

- We will get to see a young surface.
- Fresh craters will help us understand collisional evolution of asteroid belt.
- It will constrain space weathering.
- Will help us understand the Yarkovsky forces.





• Donald Johanson
MBA Rehearsal

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Polymele

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Sept. 2027



Leucus

D-type
Apr. 2028



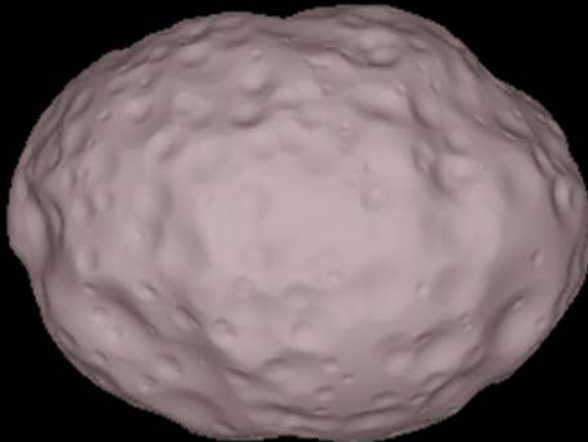
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D-type
Nov. 2028



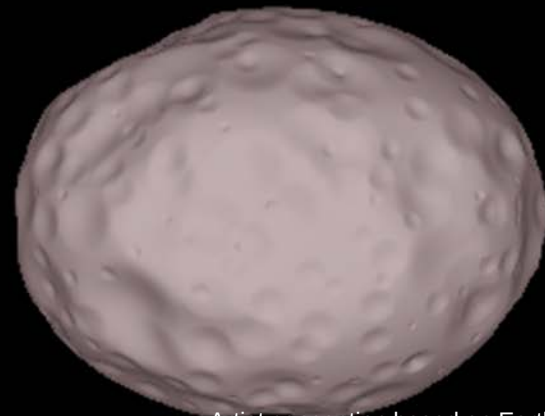
Patroclus

Binary & P-type



Menoetius

Binary & P-type



Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms — Disruptive collision remnant
near-equal mass (primordial?) binary — Ultra Slow Rotator



• Donald Johanson
MBA Rehearsal

Eurybates

C-type
Aug. 2027



Polymele

P-type
Sept. 2027



Leucus

D-type
Apr. 2028



Orus

D-type
Nov. 2028

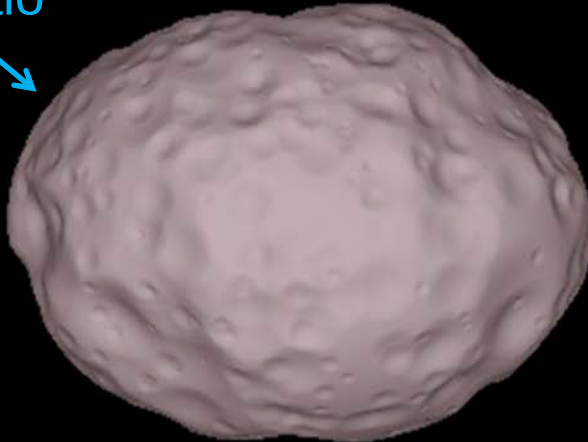


L_4 :

Roughly
160:1 ratio
in mass

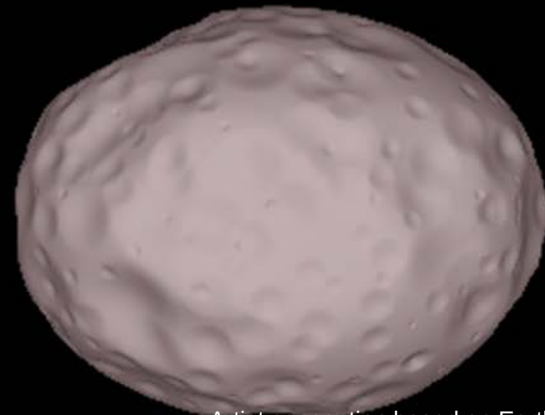
Patroclus

Binary & P-type



Menoetius

Binary & P-type



L_5 :

Mar. 2033

Artist conception based on Earth-based observations

All known spectral types — Both the L_4 and L_5 swarms — Disruptive collision remnant
near-equal mass (primordial?) binary — Ultra Slow Rotator



• Donald Johanson
MBA Rehearsal

Eurybates

C-type
Aug. 2027

Polymele

P-type
Sept. 2027

Leucus

D-type
Apr. 2028

Orus

D-type
Nov. 2028

L₄:

Largest
remnant of
disruptive
collision

Fragment

Patroclus

Binary & P-type

Primordial
Objects

Menoetius

Binary & P-type

L₅:

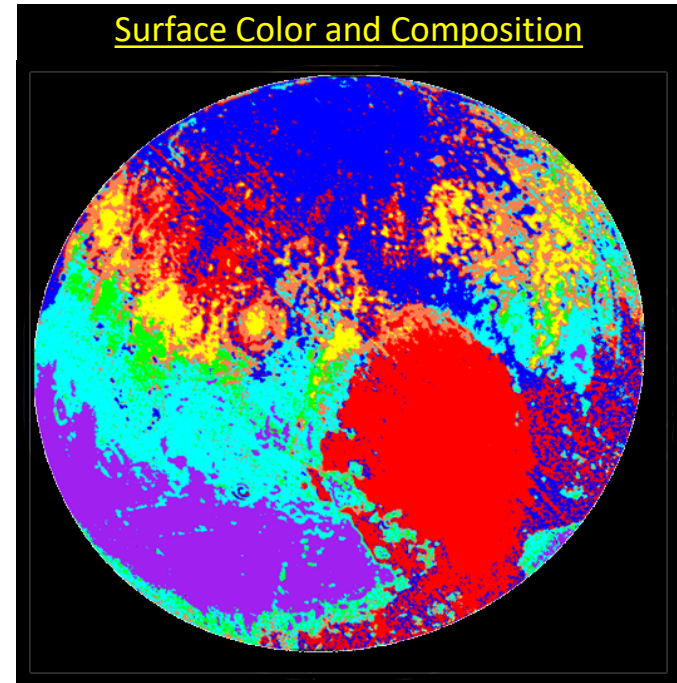
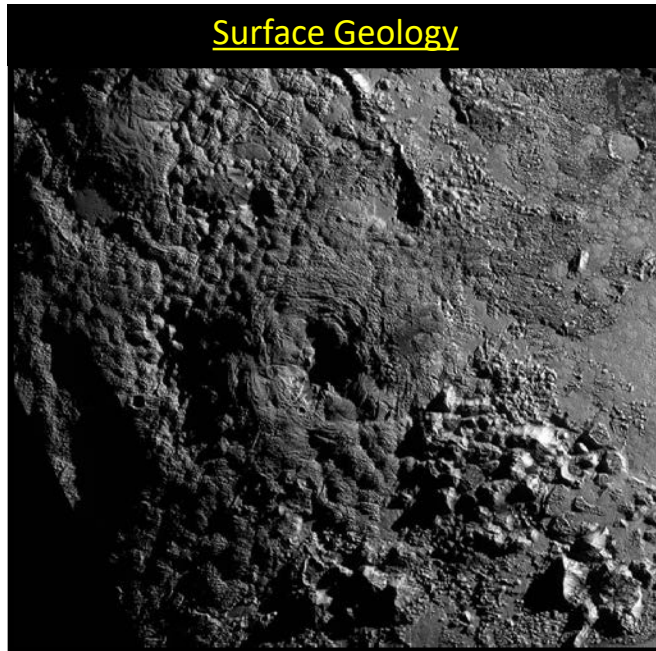
Mar. 2033

Artist conception based on Earth-based observations

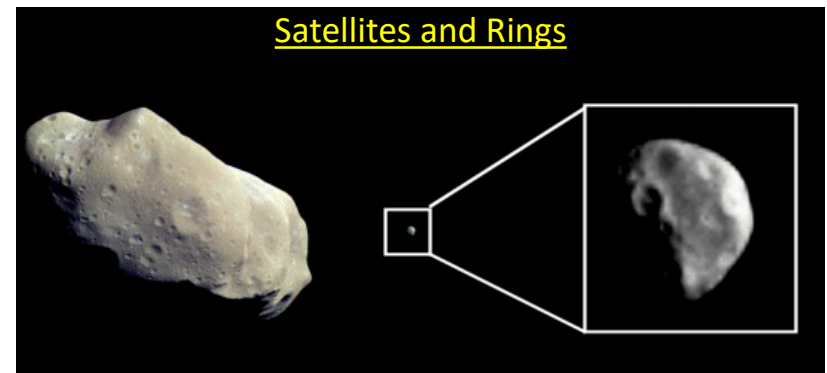
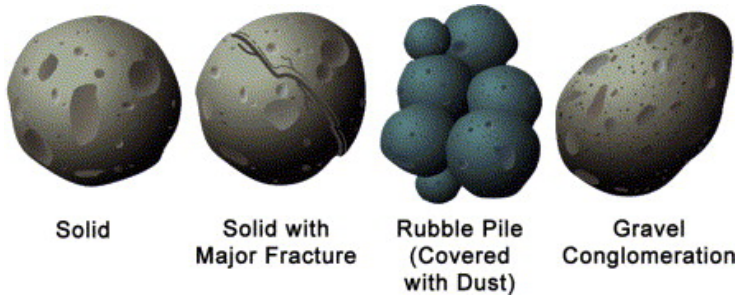
All known spectral types — Both the L₄ and L₅ swarms — Disruptive collision remnant
near-equal mass (primordial?) binary — Ultra Slow Rotator — Wide sample of sizes



➤ Lucy's remote sensing:



Interiors

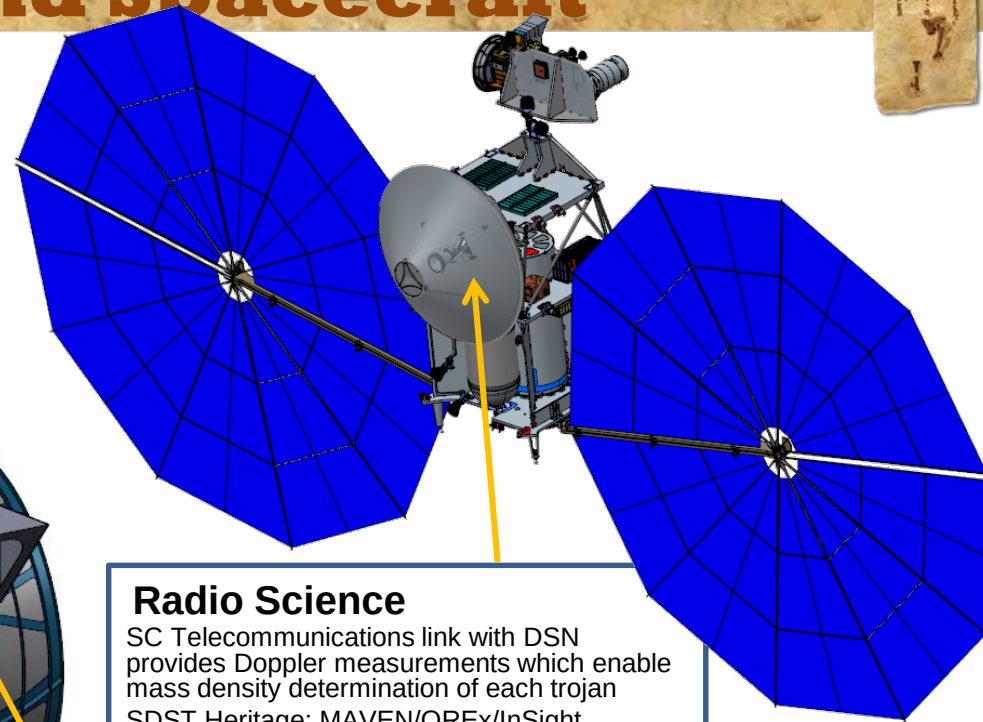
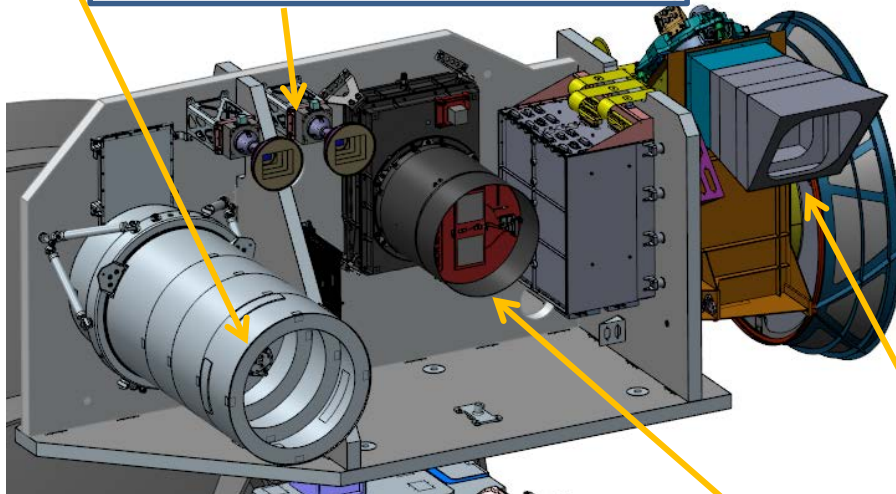


**L'LORRI**

Long Range Reconnaissance Imager (LORRI)
High spatial resolution visible imager
Heritage: NH

TTCam

Terminal Tracking Camera (TTCam)
Visible imager used for target centroiding
Supplier: Malin Space Systems

**Radio Science**

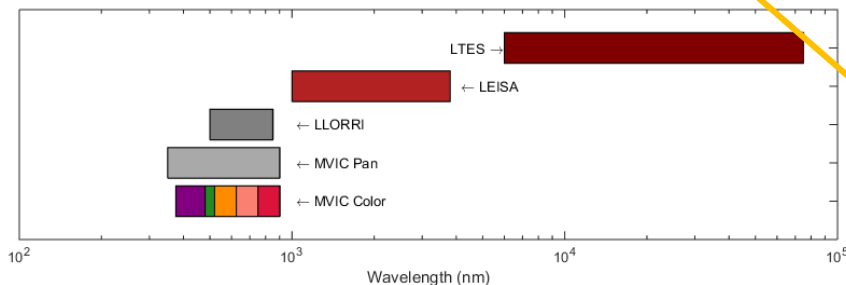
SC Telecommunications link with DSN
provides Doppler measurements which enable
mass density determination of each trojan
SDST Heritage: MAVEN/OREx/InSight

L'Ralph

Multi-spectral Visible Imaging Camera (MVIC)
Linear Etalon Imaging Spectral Array (LEISA)
Color visible imager (MVIC) and
infrared imaging spectrometer (LEISA)
Heritage: NH, O'REX

L'TES

Thermal Emission Spectrometer (TES)
Point FTIR spectrometer
Heritage: O'REX, MGS



Lucy Putting Lucy in Context – Main Belt Comparison



In the history of unmanned exploration, 8 MBAs have been studied

- This has revolutionized our view of this population



Lucy will study almost as many Trojans (6) – all within one Discovery mission.



"I Love Lucy" logo – Courtesy of CBS Broadcasting Inc.
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