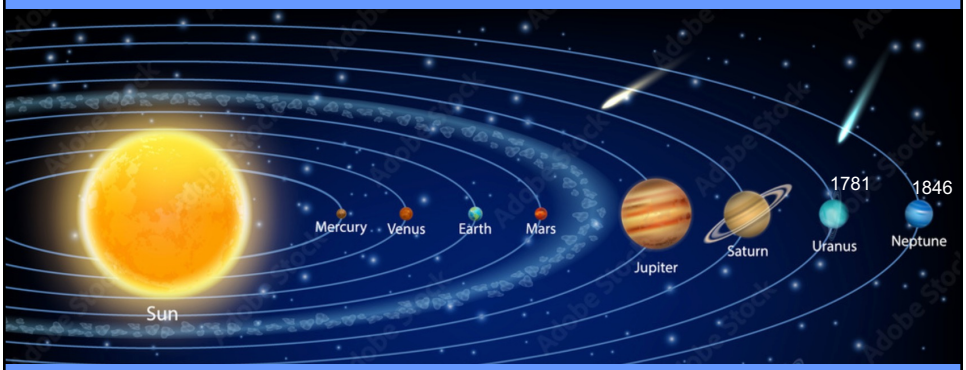
Modern Revolutionary Ideas in Solar System Science

The Asteroid Belt
The Oort Cloud
Centaurs
The Kuiper Belt
The Status of Pluto
Ocean Worlds
Interstellar Comets (just passing through)

1

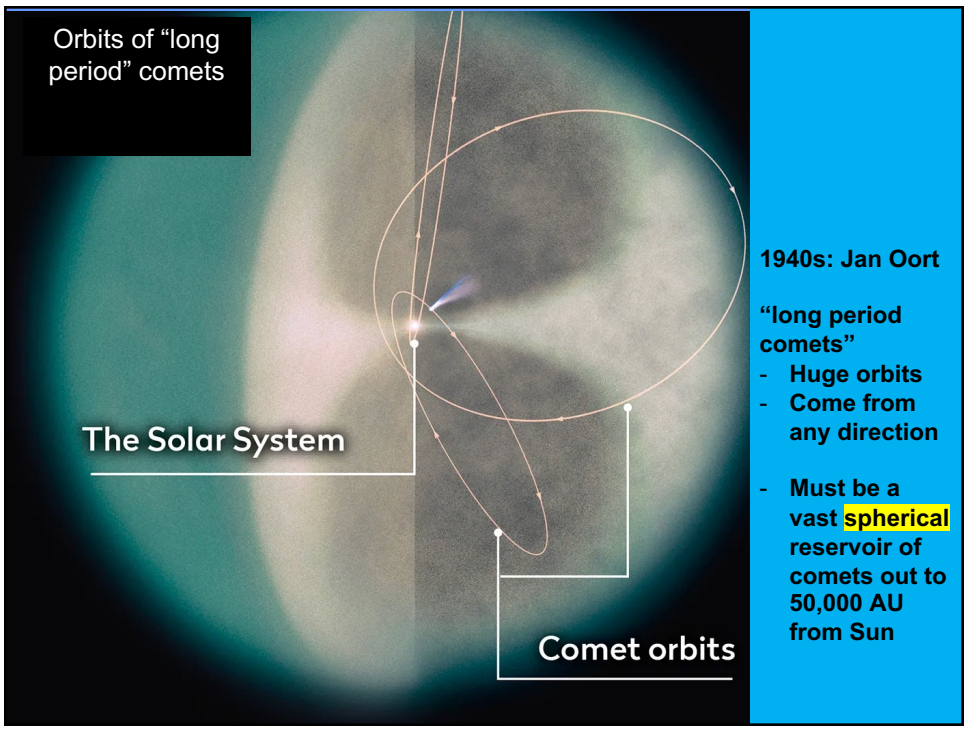
Asteroid Belt

new part of the solar system, discovered in early 19th century

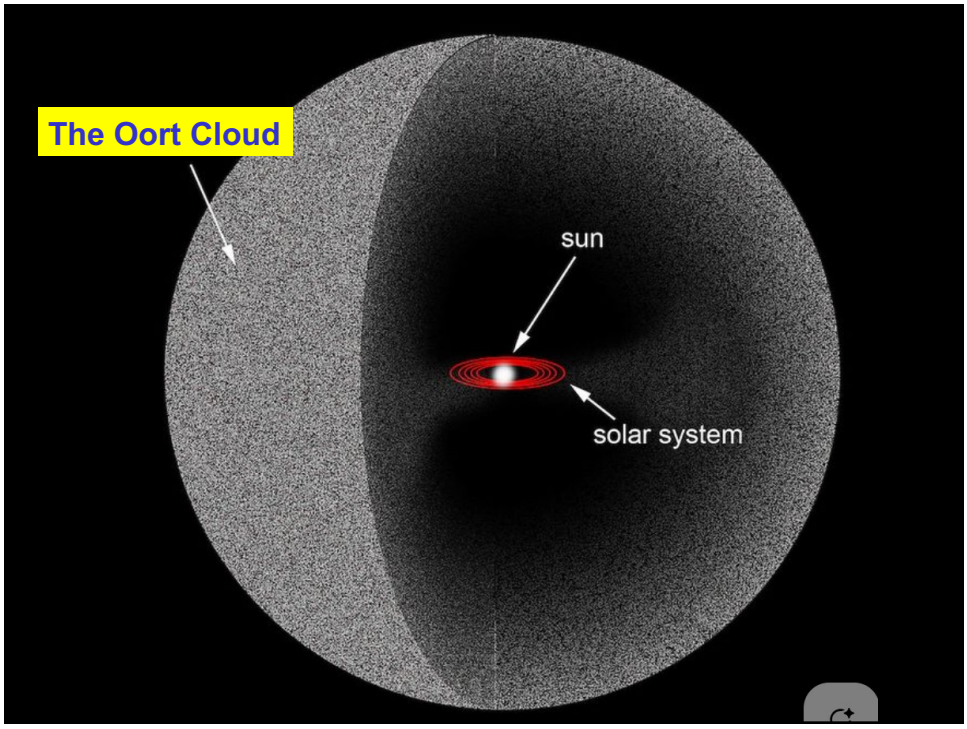


1801: Ceres … Giuseppe Piazzi → the "missing planet" in between Mars and Jupiter
1802: Pallas … Heinrich Olbers — More planets?
1804: Juno … Karl Harding
1807: Vesta … Heinrich Olbers → "asteroids" (star-like objects)
1845: Astraea … Karl Ludwig Hencke
1840s: 5 more
1850s: 47 more → The asteroid belt
1860s: 52 more
1870s: 102 more

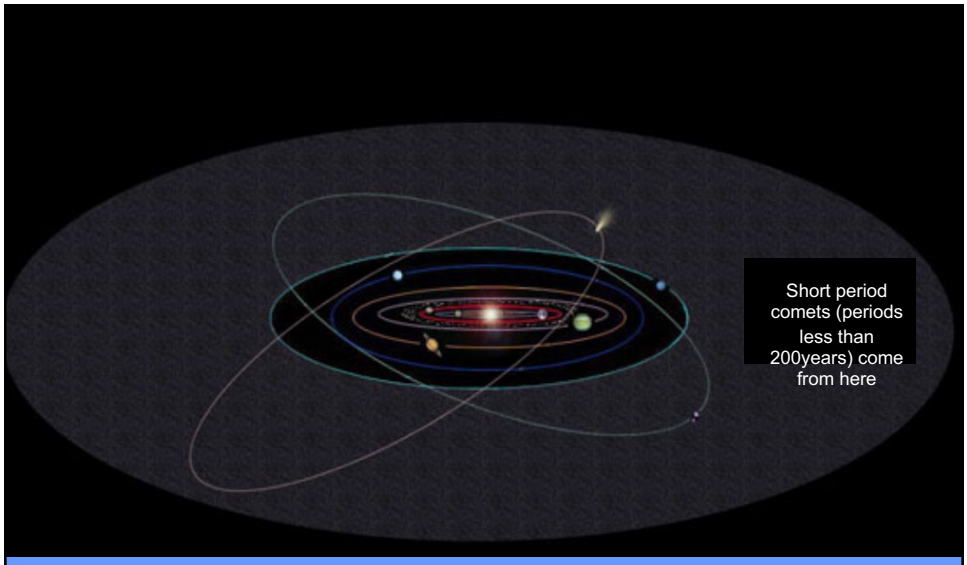
2


Orbits of “long period” comets
The Solar System
Comet orbits
1940s: Jan Oort
“long period comets”
- Huge orbits
- Come from any direction
- Must be a vast spherical reservoir of comets out to 50,000 AU from Sun

3


The Oort Cloud
sun
solar system

4



1940s: Essex Edgeworth and Gerard Kuiper
… predicted reservoir of short-period comets beyond Pluto

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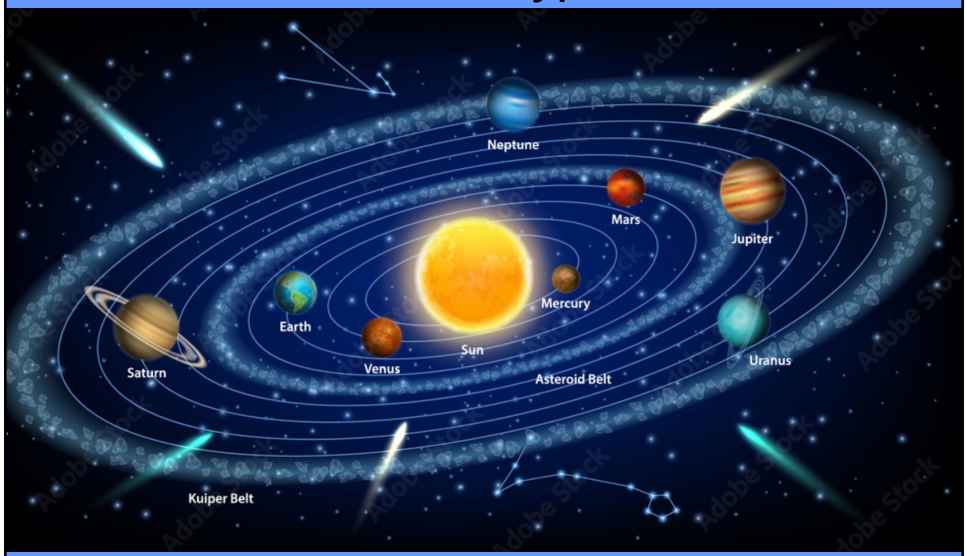
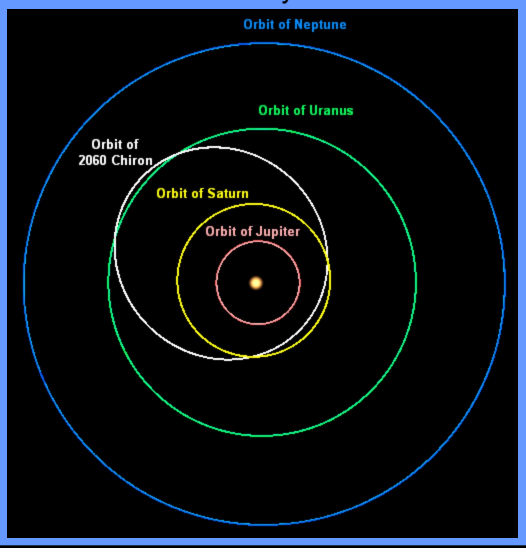
The Kuiper Belt … *hypothesized*

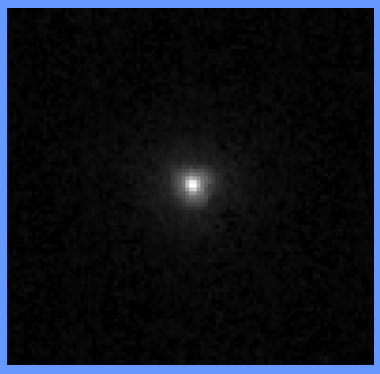


1970s: Julio Fernandez
… must be a flattened disk of objects in between Neptune and Oort Cloud

6

Chiron … discovered in 1977 by Charles Kowal
… big (200 km) comet-like object
… crosses orbits of Saturn and Uranus: **unstable orbit!**
… must have come from another part of the solar system and been kicked out of previous orbit

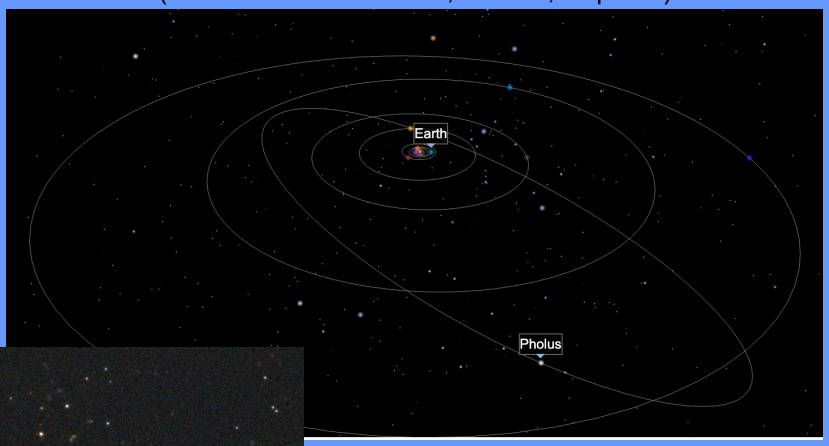




CENTAURS
objects scattered out of Kuiper Belt

7

Pholus … discovered in 1992 by David Rabinowitz
… big (200 km) comet-like object
… unstable (crosses orbits of Saturn, Uranus, Neptune)



Another centaur!
If two centaurs exist, then the Kuiper Belt must exist … but not yet found

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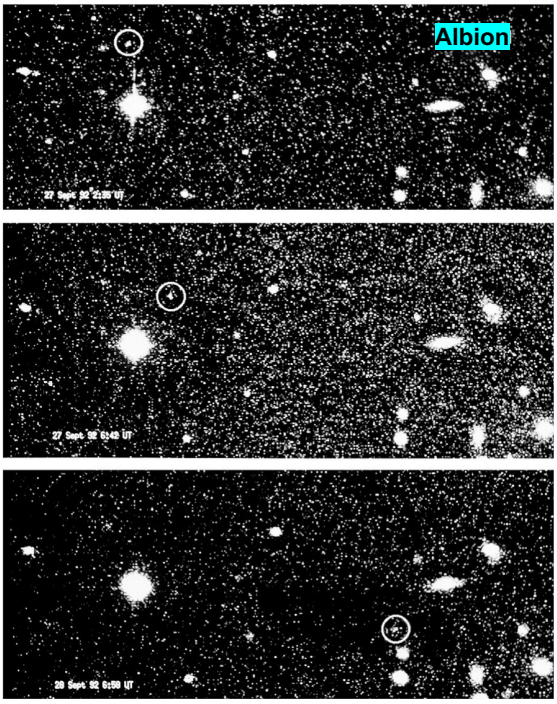
August 1992 … David Jewitt and Jane Luu found Albion (diameter 280 km; a = 44 AU)

First known object in Kuiper Belt!

Eary discovery images of Albion --- the object in the circle moves, while all the background stars stay in the same places



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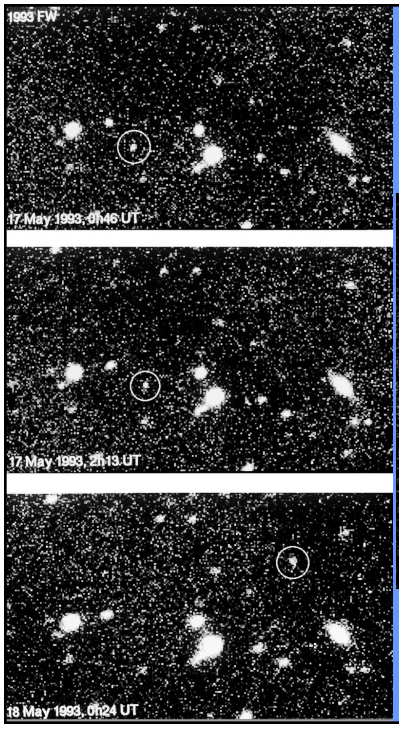
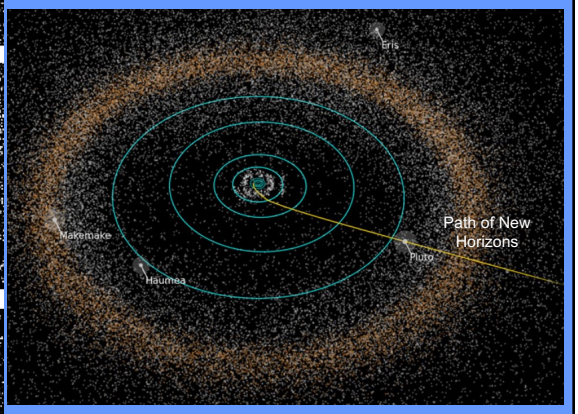


← Sept 1993: discovery of 1993 FW

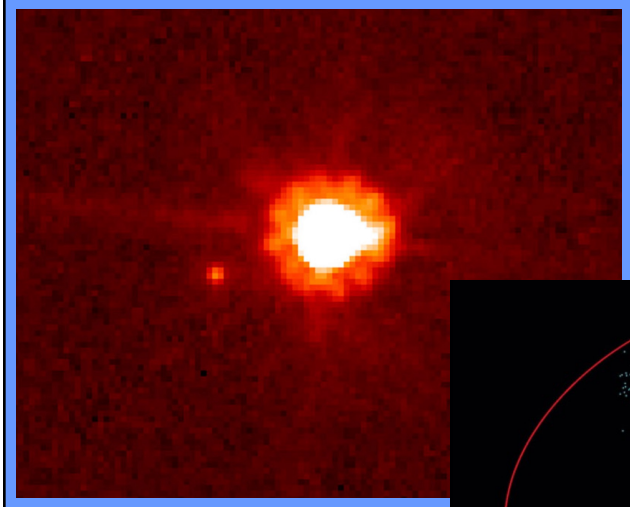
KUIPER BELT FOUND!

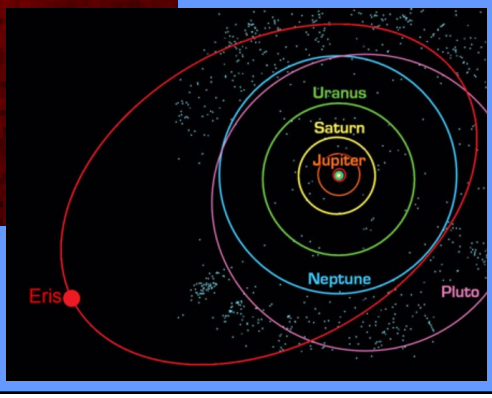


Map of locations of known KBOs

10

Eris and its moon Dysnonia (HST image 2006)





Discovered in 2005

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Largest known trans-Neptunian objects (TNOs)

KB Object	Diameter	Orbit semi-major axis
2002 TC_{302}	>500 km	55.3 AU
Varuna	~700 km	43.1 AU
Ixion	~710 km	39,.7 AU
Aya	~700-800 km	47.2 AU
Sedna	~900 km	506 AU
Orcus	~900 km	39.174 AU
Quaoar	~1100 km	43.3 AU
Haumea	1200-1500 km	43 AU
Makemake	~1600 km	45.6 AU
Eris	2326 km	67.9 AU
Pluto	2377 km	39.482 AU

Is Pluto different from other KBOs? Are they all planets?

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RESOLUTION 5A

The IAU therefore resolves that planets and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

(1) A "planet" is a celestial body that
- *a. is in orbit around the Sun,*
- *b. has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and*
- *c. has cleared the neighbourhood around its orbit.*

(2) A "dwarf planet" is a celestial body that
- *a. is in orbit around the Sun,*
- *b. has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,*
- *c. has not cleared the neighbourhood around its orbit, and*
- *d. is not a satellite.*

(3) All other objects, except satellites, orbiting the Sun shall be referred to collectively as "Small Solar System Bodies."

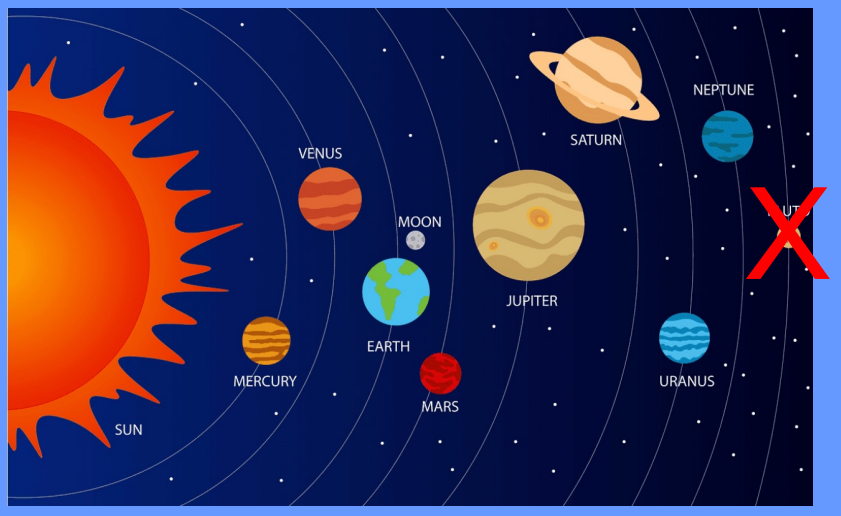
RESOLUTION 6A

The IAU further resolves:

Pluto is a "dwarf planet" by the above definition and is recognized as the prototype of a new category of trans-Neptunian objects.
The words "dwarf planets" should be used with inverted commas.

13

The Sun and planets: post-2006



Credit: https://www.funkidslive.com/learn/top-10-facts/top-10-facts-about-the-solar-system/

14

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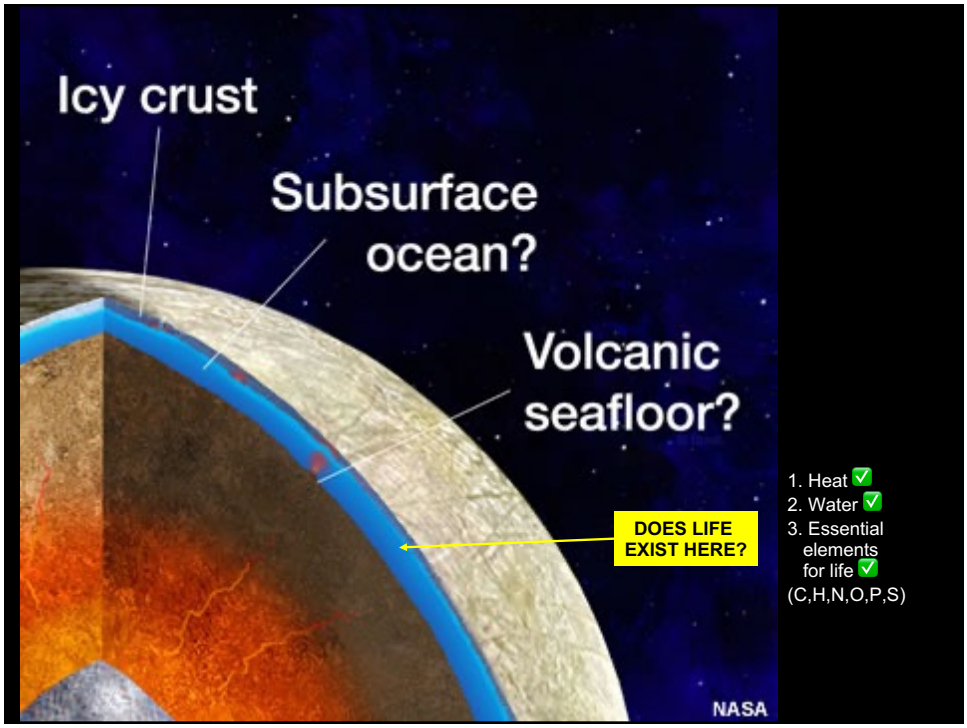
15

16


Icy crust
Subsurface ocean?
Volcanic seafloor?
DOES LIFE EXIST HERE?
1. Heat ✅
2. Water ✅
3. Essential elements for life ✅
(C,H,N,O,P,S)
NASA

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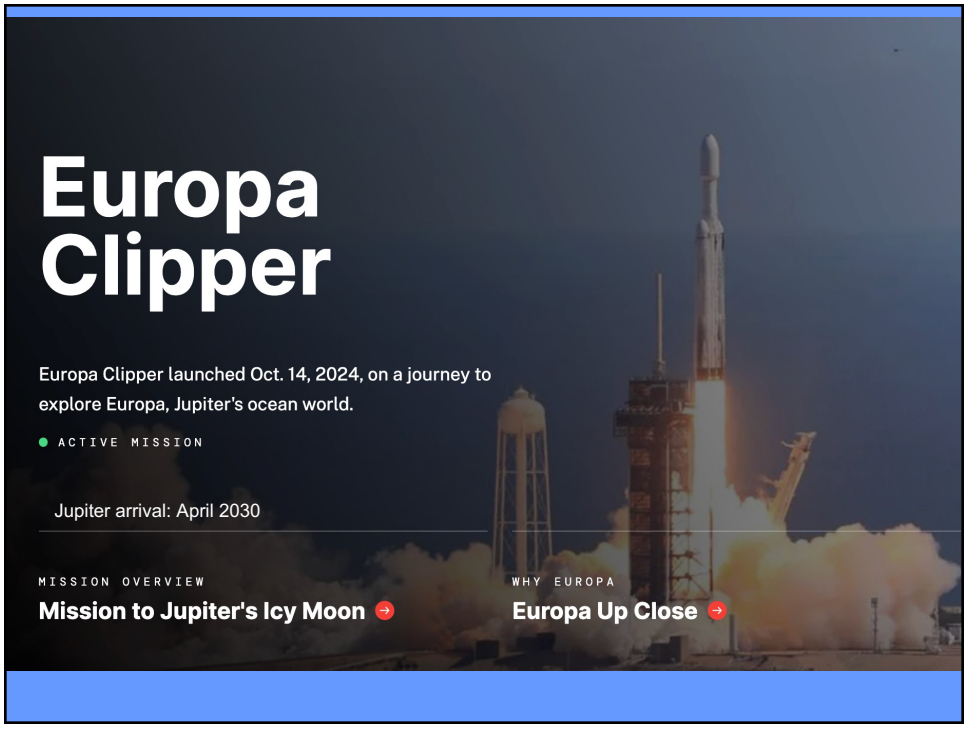
Europa Clipper
Europa Clipper launched Oct. 14, 2024, on a journey to explore Europa, Jupiter's ocean world.
ACTIVE MISSION
Jupiter arrival: April 2030
MISSION OVERVIEW
Mission to Jupiter's Icy Moon
WHY EUROPA
Europa Up Close

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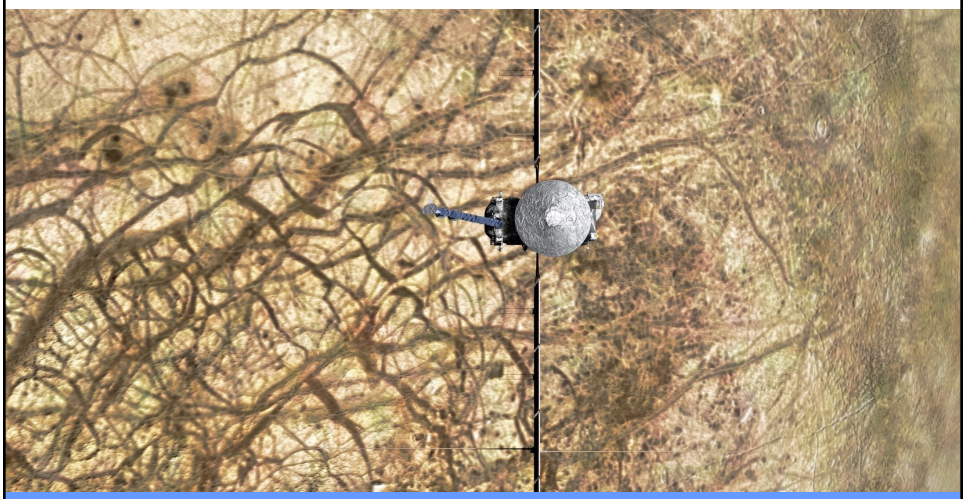
What Will Europa Clipper Do?

Europa Clipper's three main science objectives are to understand the nature of the ice shell and the ocean beneath it, along with the moon's composition and geology. The mission's detailed exploration of Europa will help scientists better understand the astrobiological potential for habitable worlds beyond our planet.



Main goal: determine if there are subsurface regions that could support life

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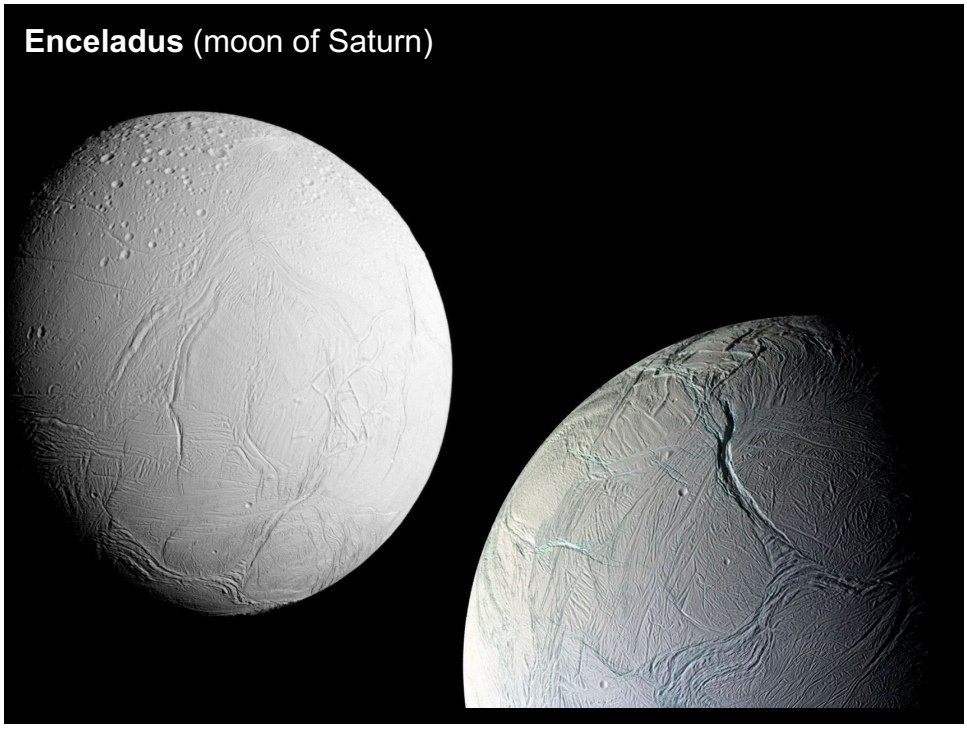

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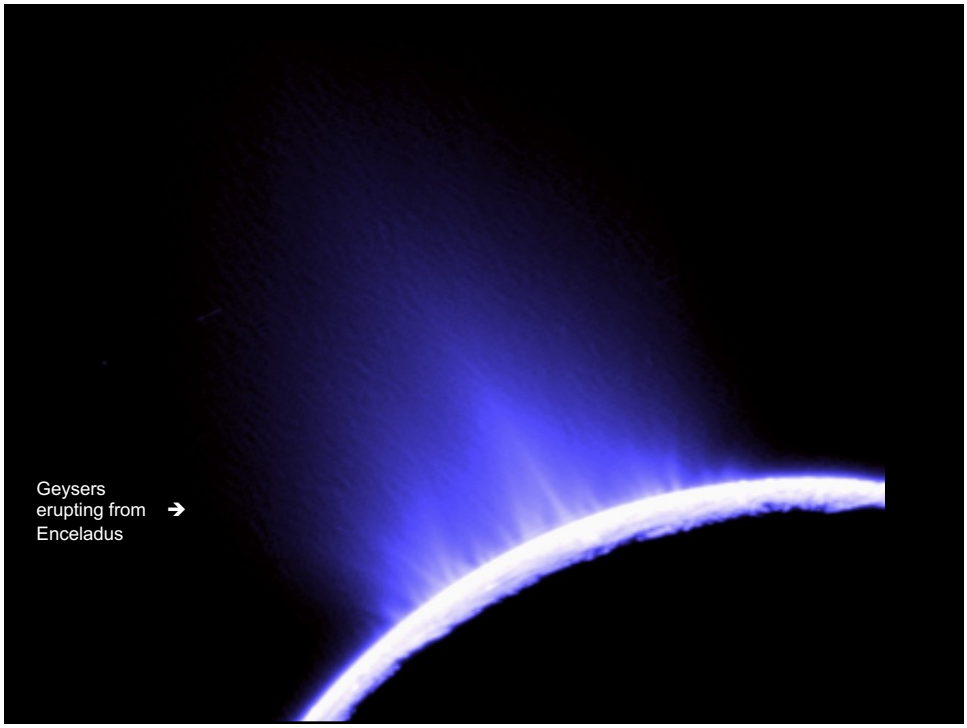
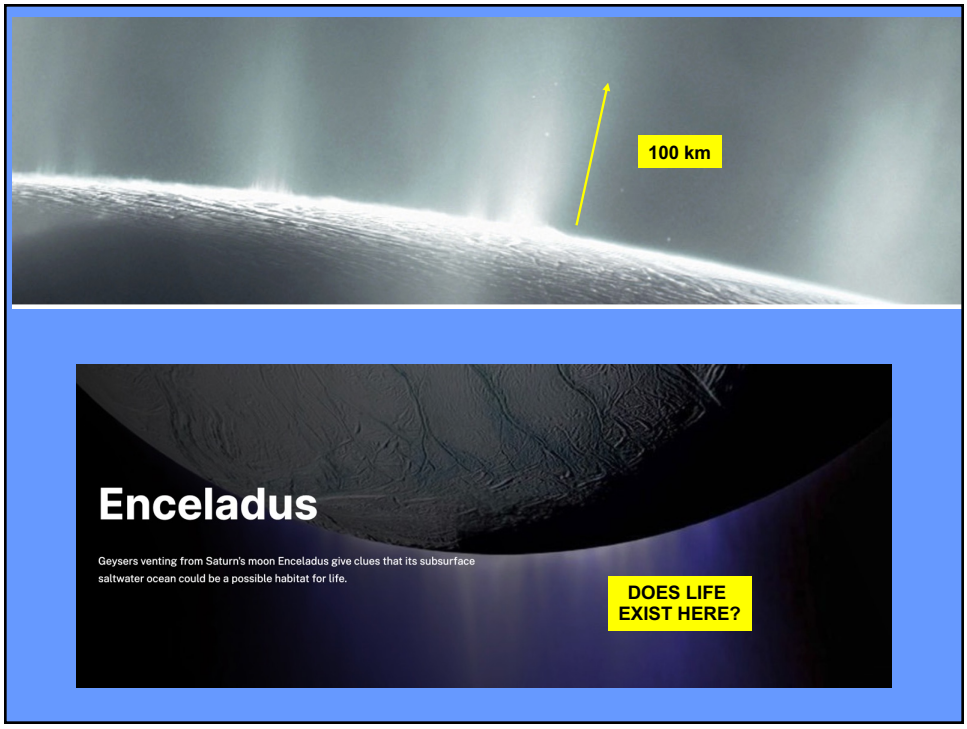

Geysers
erupting from
Enceladus

21


100 km
Enceladus
Geysers venting from Saturn's moon Enceladus give clues that its subsurface saltwater ocean could be a possible habitat for life.
DOES LIFE EXIST HERE?

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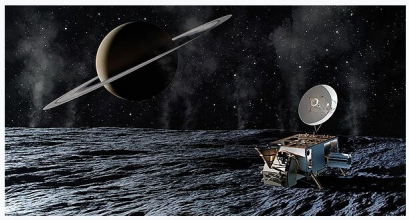
NASA mission concept

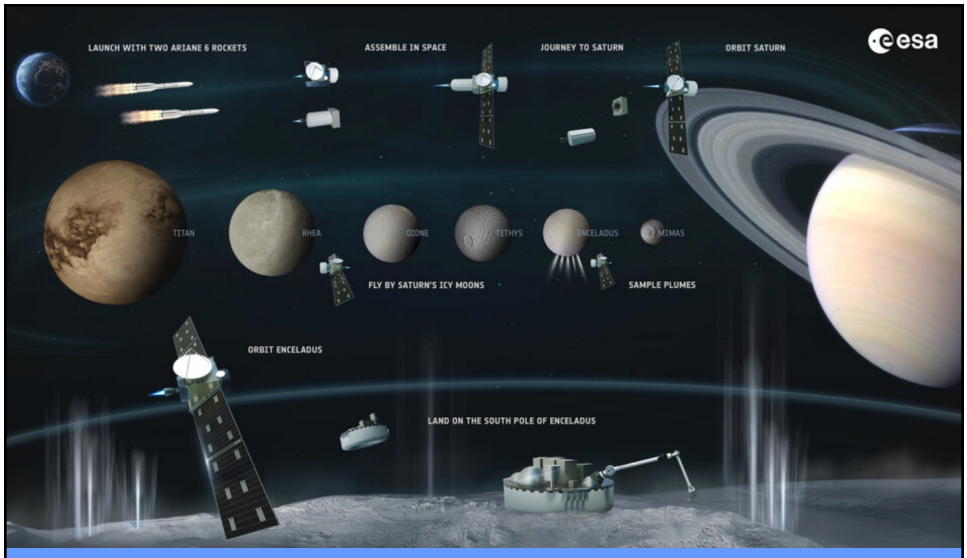
Enceladus Orbilander



Artist's impression of the Enceladus Orbilander

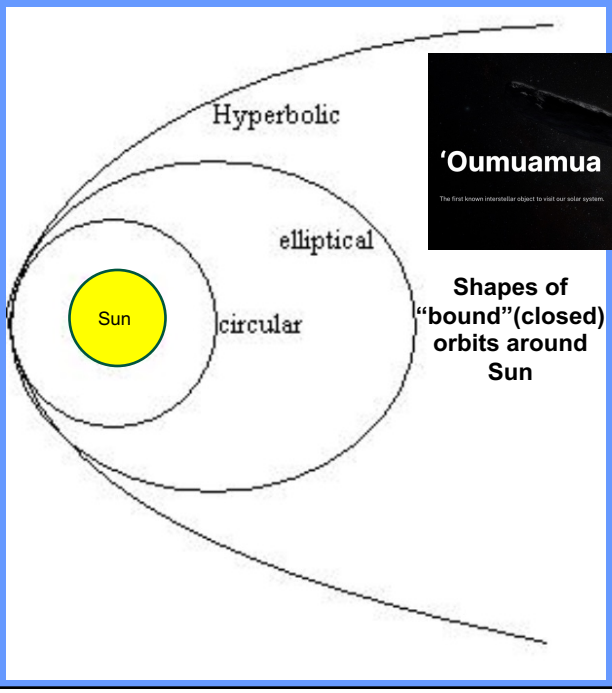
The **Enceladus Orbilander** is a proposed NASA Flagship mission to Saturn's moon Enceladus. The Enceladus Orbilander would spend a year and a half orbiting Enceladus and sampling its water plumes, which stretch into space, before landing on the surface for a two-year mission to study materials for evidence of life.[1] The mission, with an estimated cost of $4.9 billion, could launch in the late 2030s on a Space Launch System or Falcon Heavy with a landing in the early 2050s. It was proposed in the 2023–2032 Planetary Science Decadal Survey as the second highest priority Flagship mission, after the Uranus Orbiter and Probe.[2][3]

23



ESA mission concept for 2040s

24



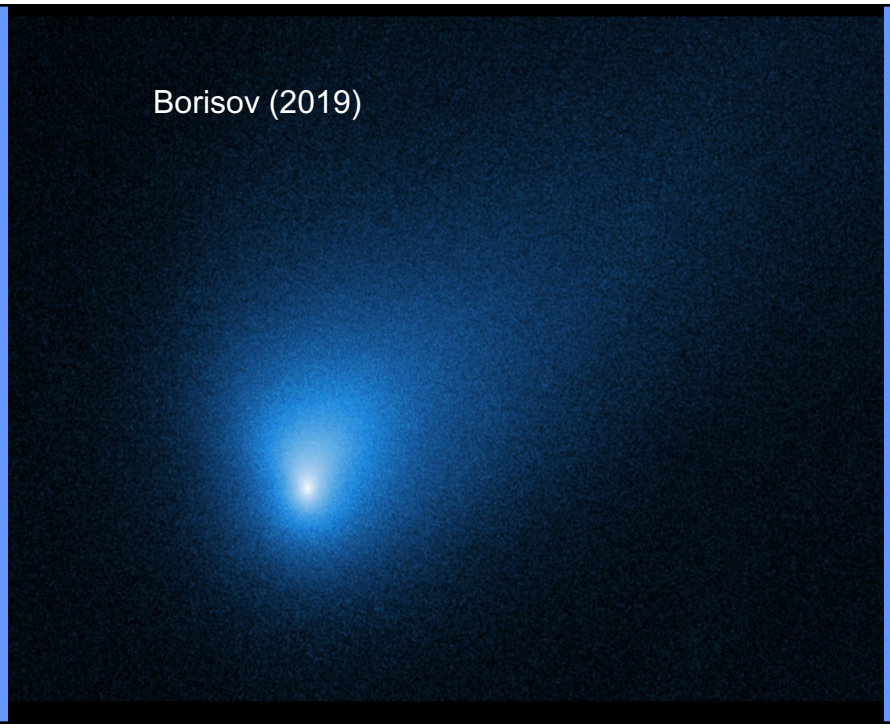
Shapes of "bound"(closed) orbits around Sun

"hyperbolic orbit"

shapes of "unbound" (not closed) orbits

- comes from interstellar space
- must return to interstellar space

25



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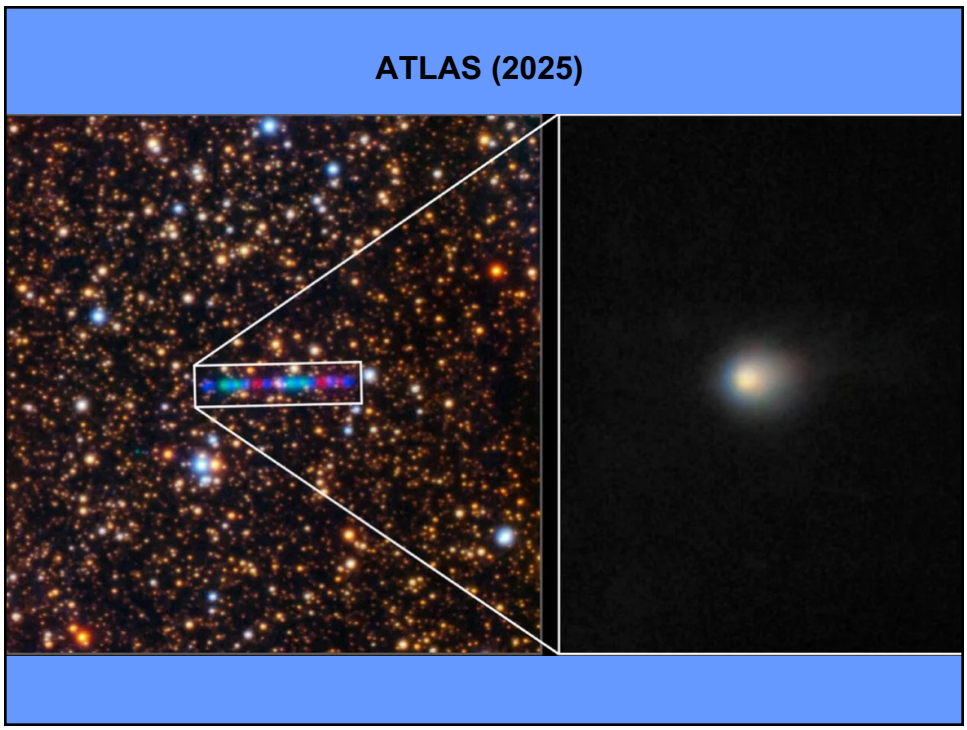

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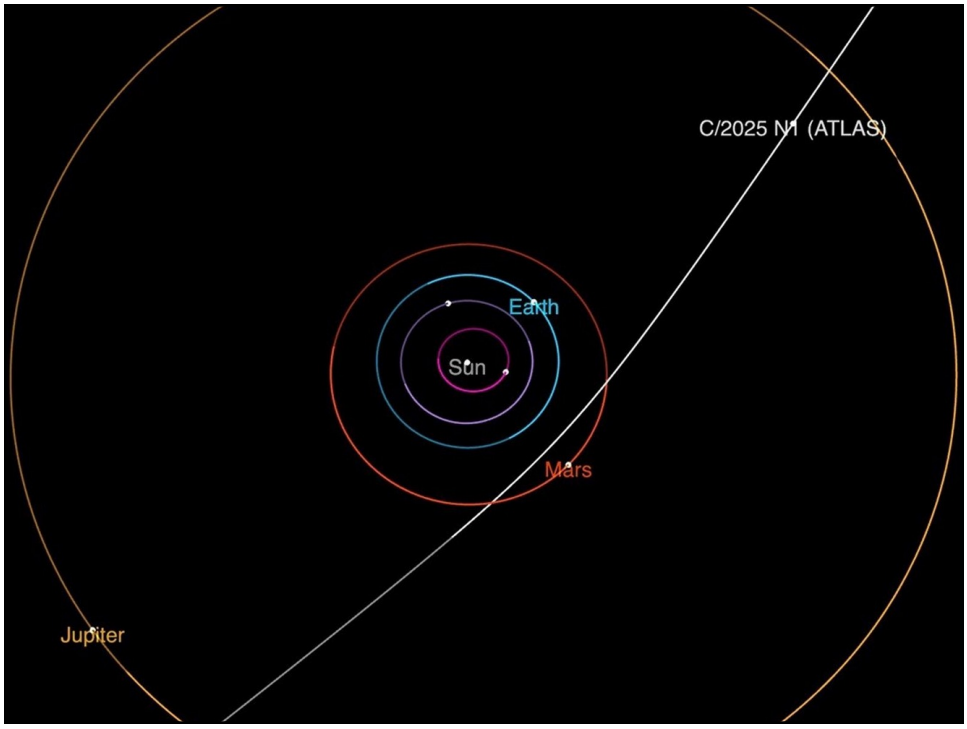

28

NOT YOUR GRANDPARENT'S SOLAR SYSTEM!

The **Asteroid Belt** (disk shaped; from Mars to Jupiter)
The **Kuiper Belt** (donut shaped; just beyond Neptune)
The **Oort Cloud** (spherical; halfway to next star)

Centaurs (kicked out of KB; e.g., Chiron, Pholus)
Pluto (a dwarf planet or a "dwarf planet")
KBOs (in Kuiper Belt; e.g., Eris, Makemake)

Ocean Worlds (e.g., Europa, Enceladus)
Interstellar Comets (just passing through)

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