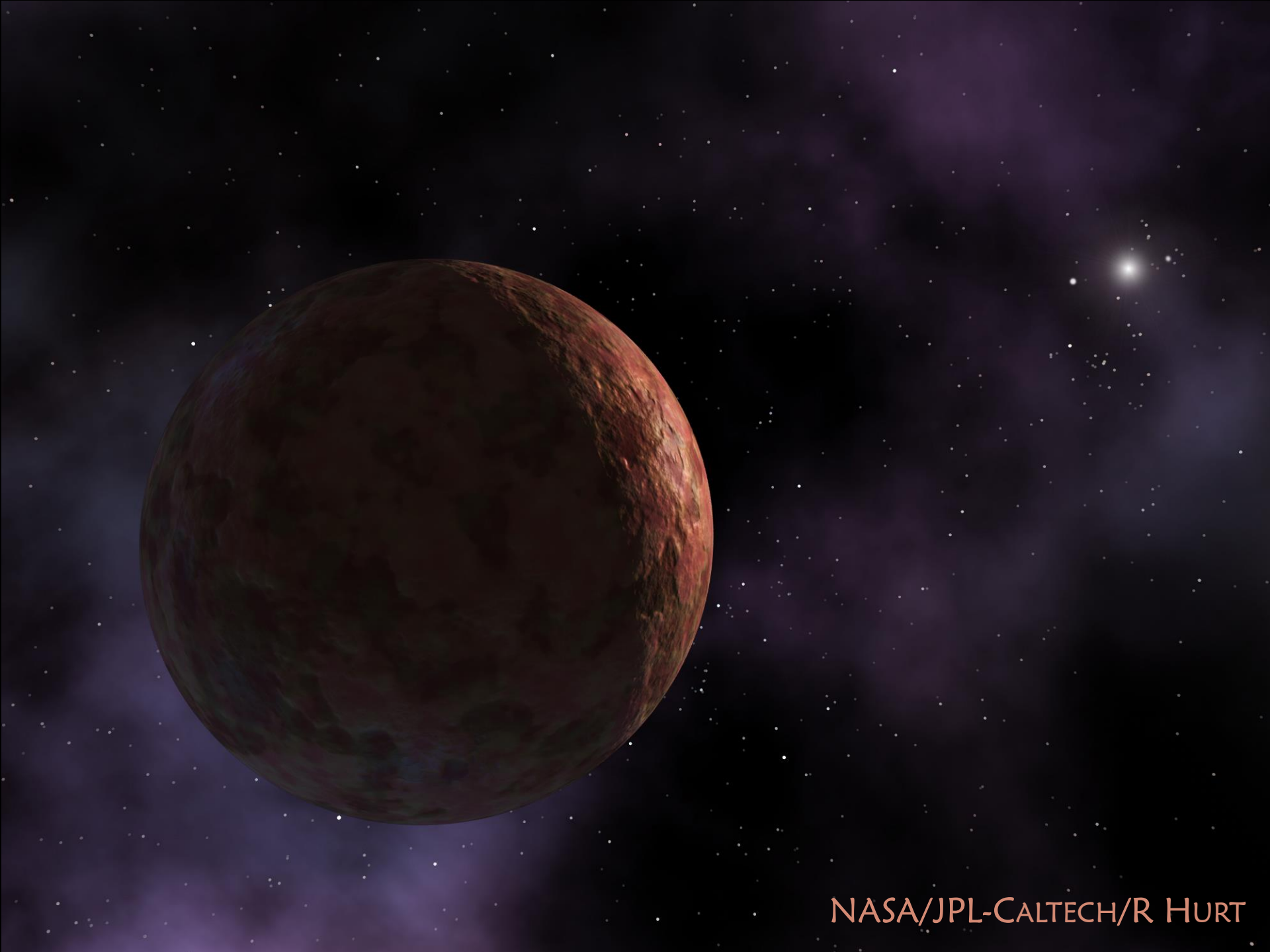
Small bodies of the Solar System

Carolin Crawford
Gresham Professor of Astronomy

NASA/NEAR

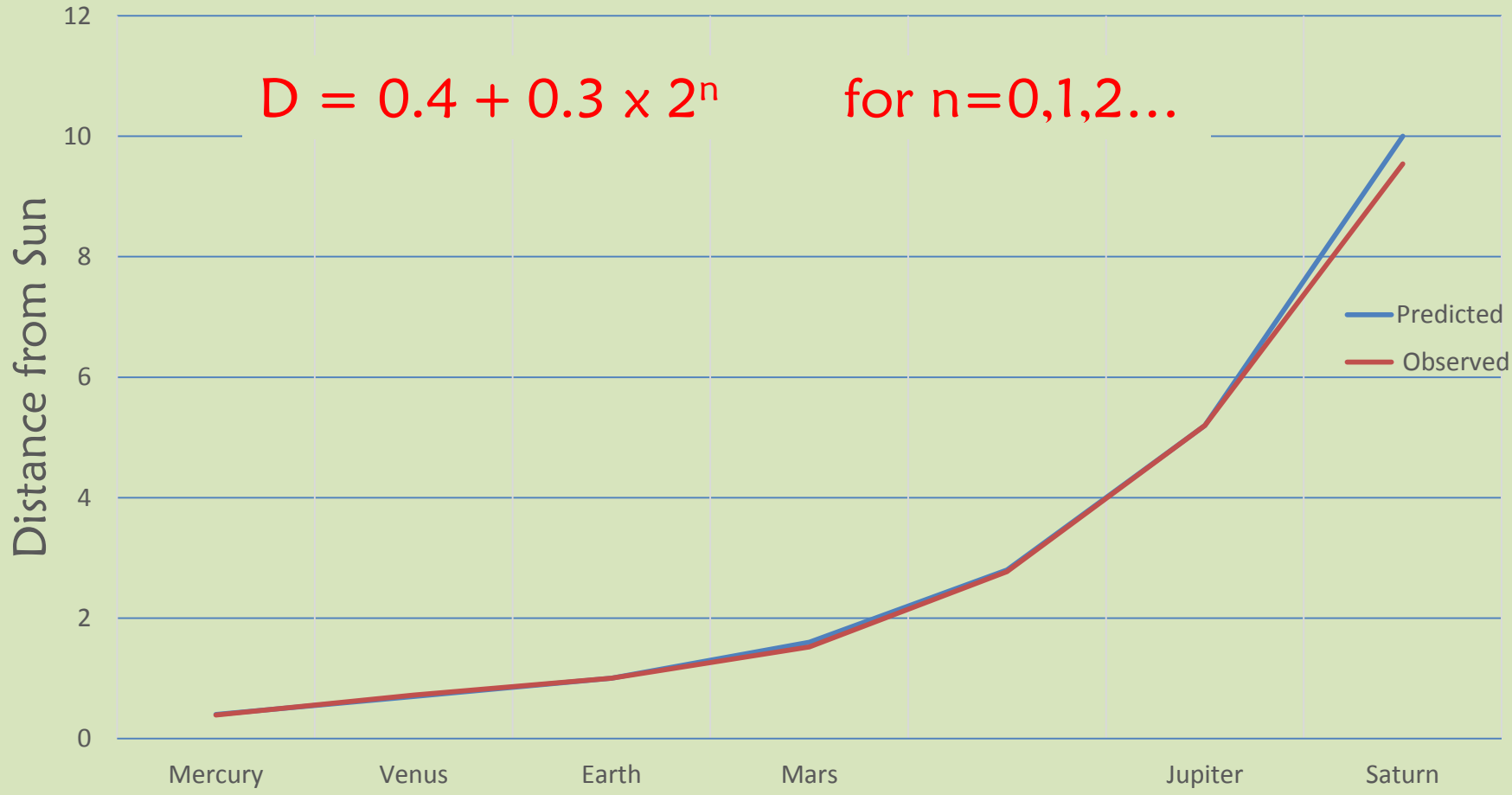
NASA/NEAR


NASA/JPL-Caltech/R Hurt

William Herschel

Titius-Bode Law

$D = 0.4 + 0.3 \times 2^n$ for n=0,1,2…



Titius-Bode Law

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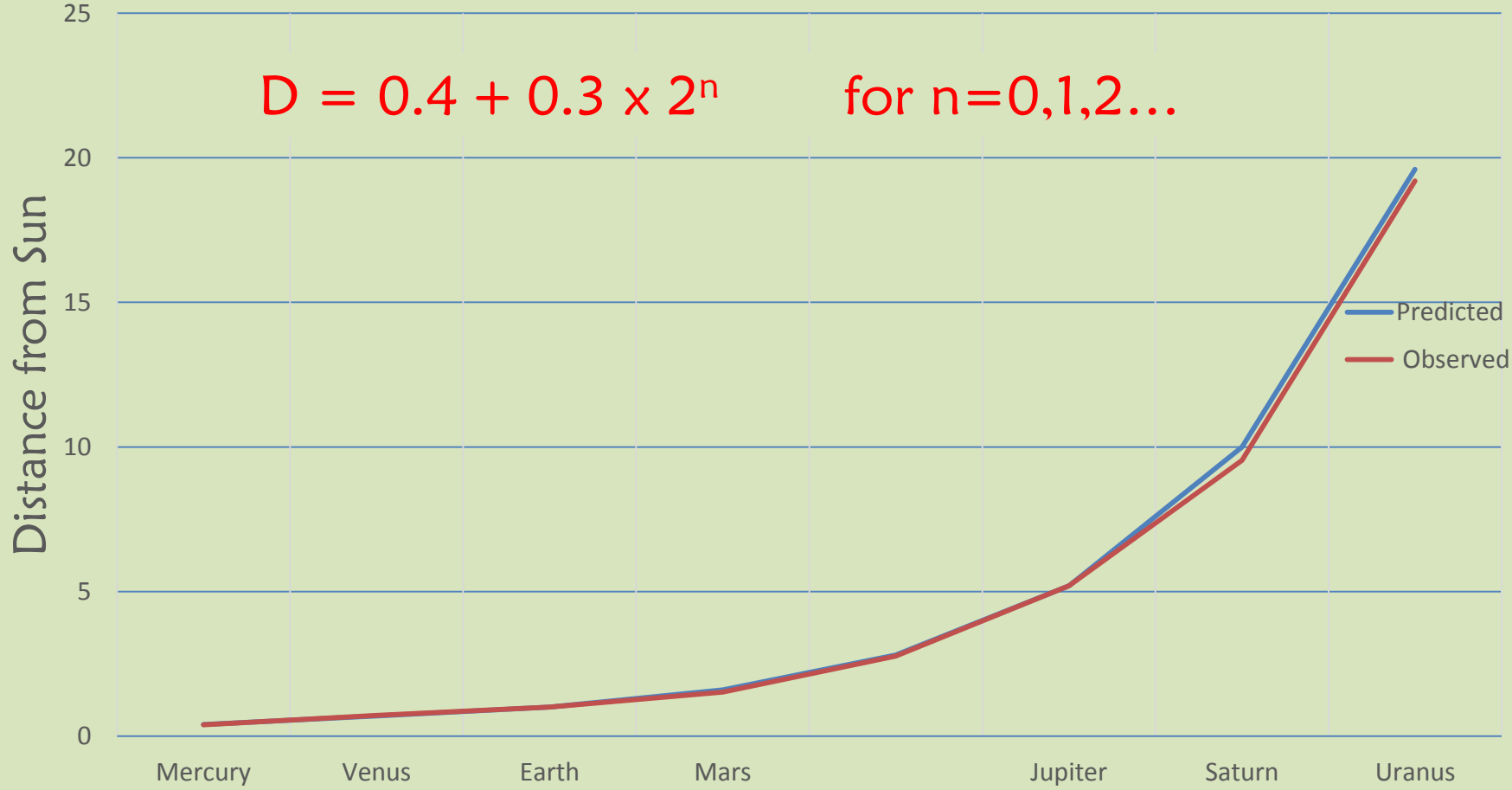


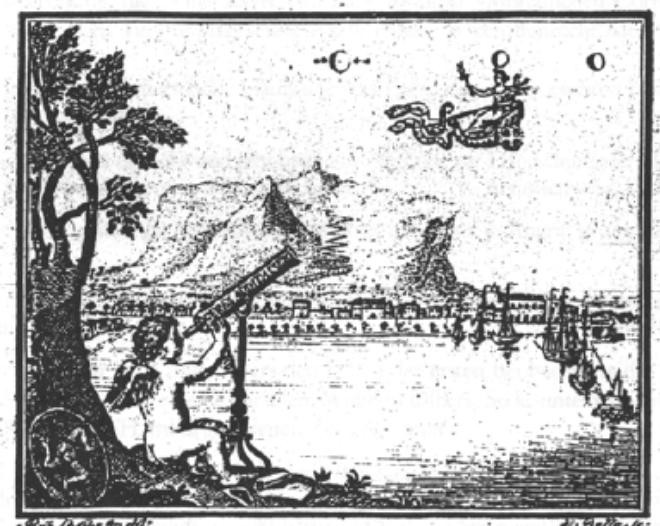
Giuseppe Piazzi

DELLA SCOPERTA

DEL NUOVO PIANETA

CERERE FERDINANDEA

OTTAVO TRA I PRIMARJ DEL NOSTRO SISTEMA SOLARE.



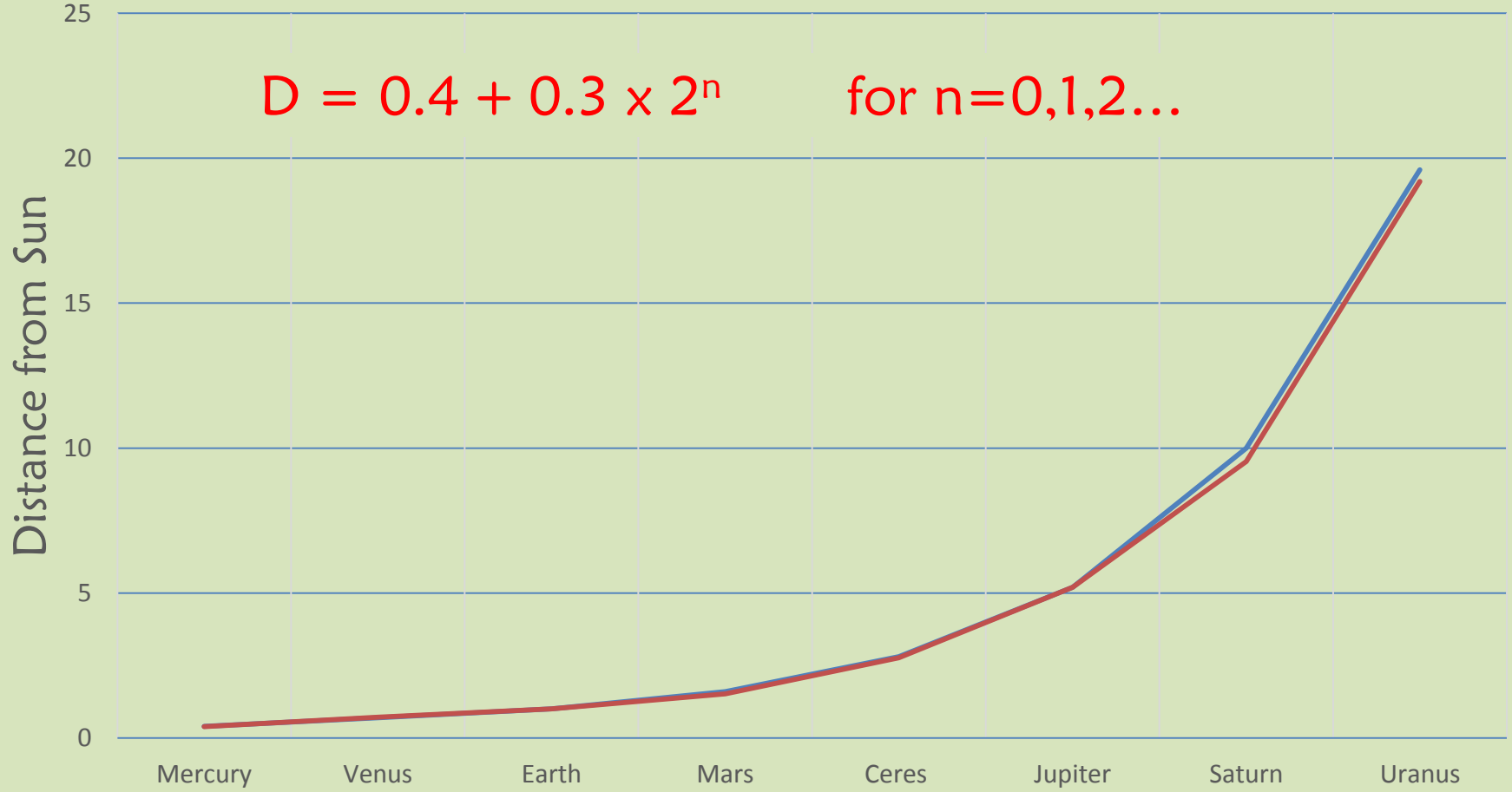
PALERMO

1802

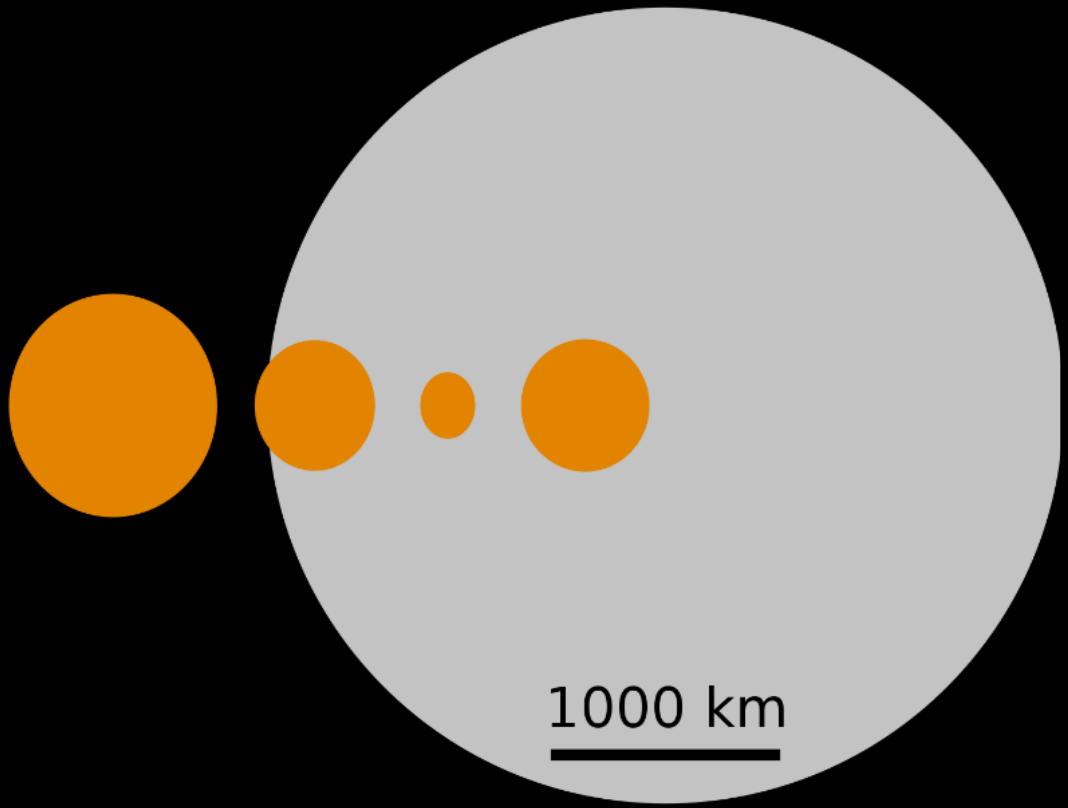
NELLA STAMPERIA REALE.

Titius-Bode Law

$D = 0.4 + 0.3 \times 2^n$ for n=0,1,2…



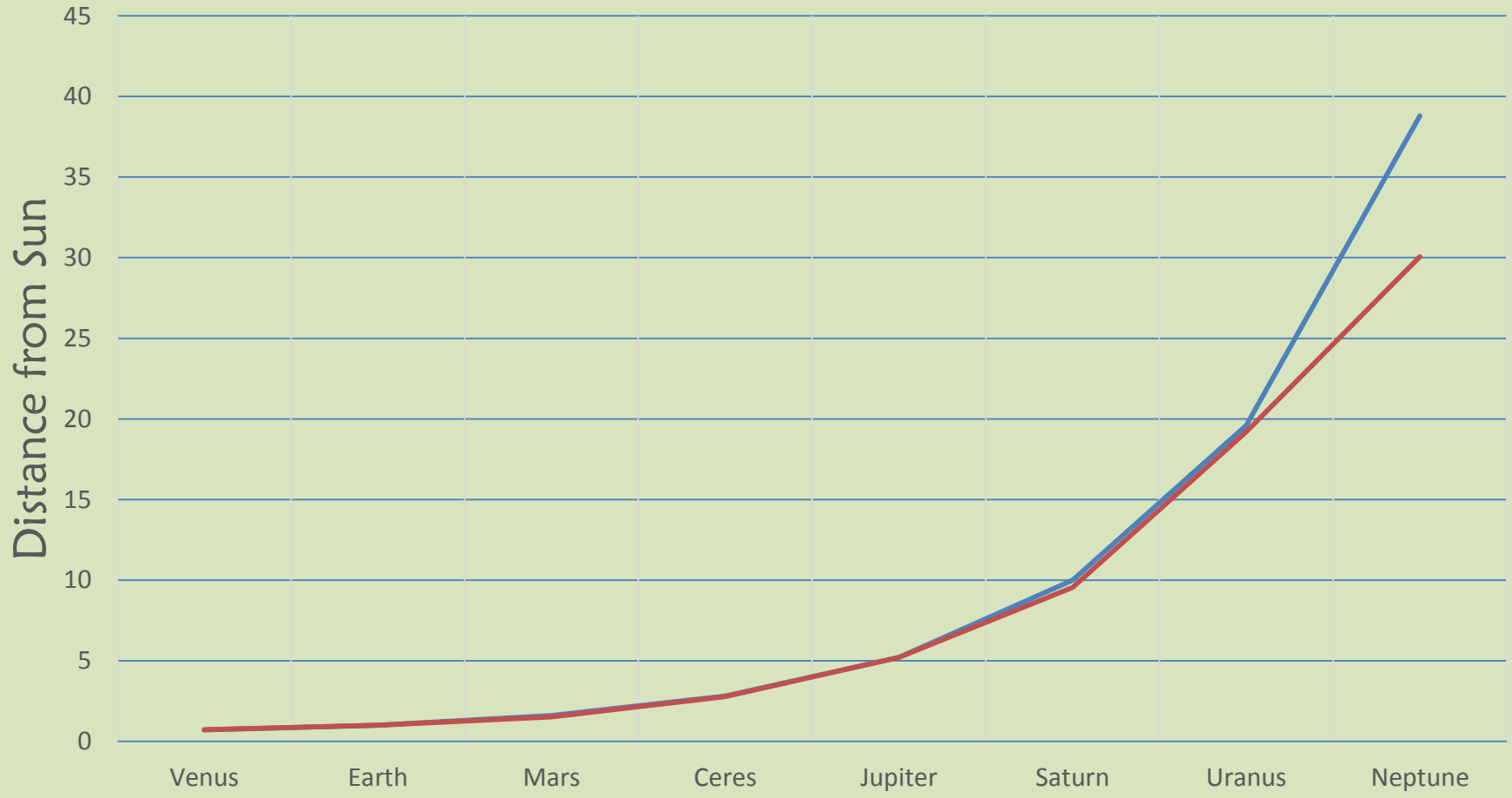
	Discovered
Ceres	1801



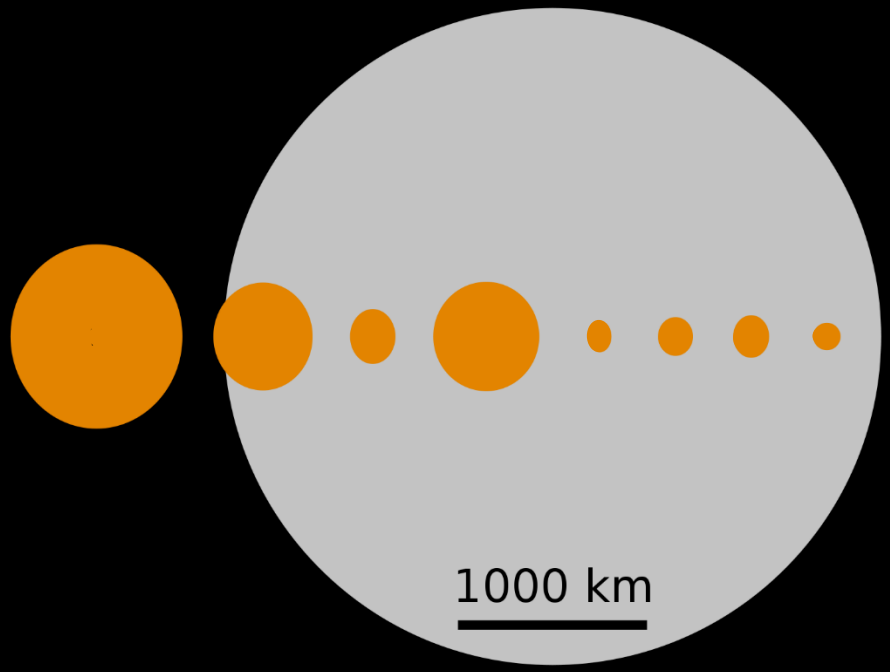
John Couch Adams

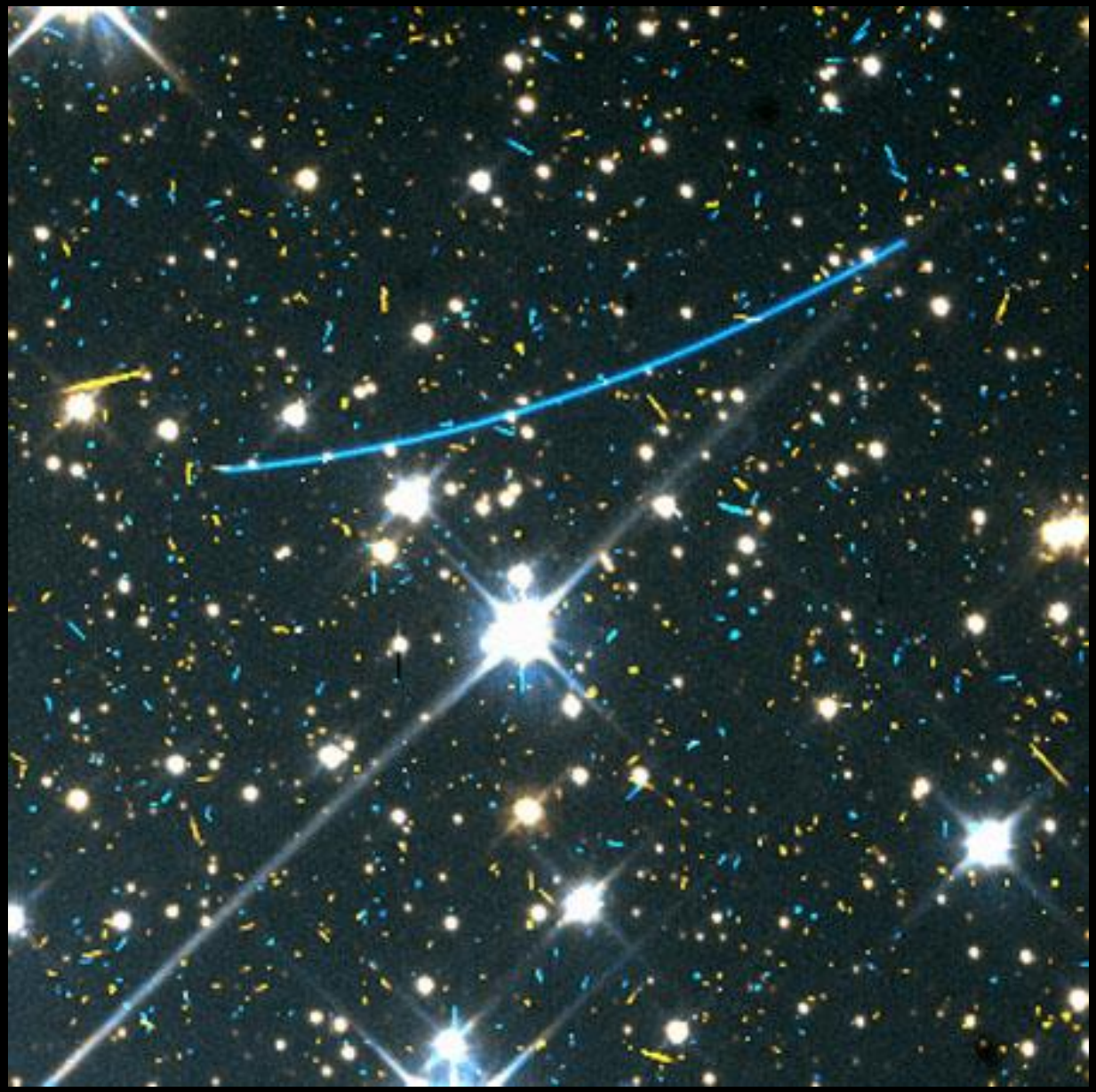
Urbain Leverrier

Titius-Bode Law



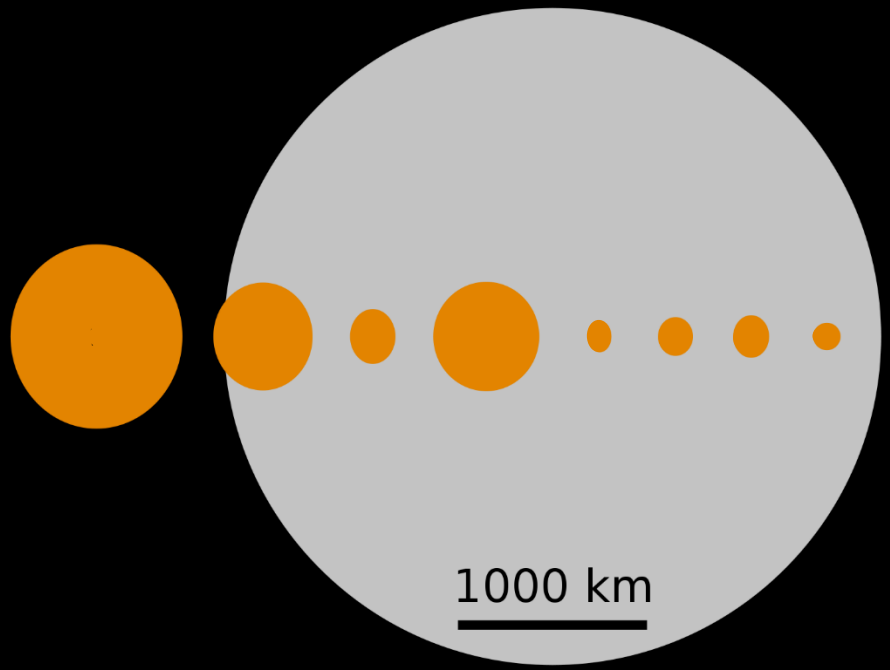
	Discovered	Distance (AU)	Diameter (km)
Ceres	1801	2.77	940
Pallas	1802	2.77	520
Juno	1804	2.67	230
Vesta	1807	2.36	530

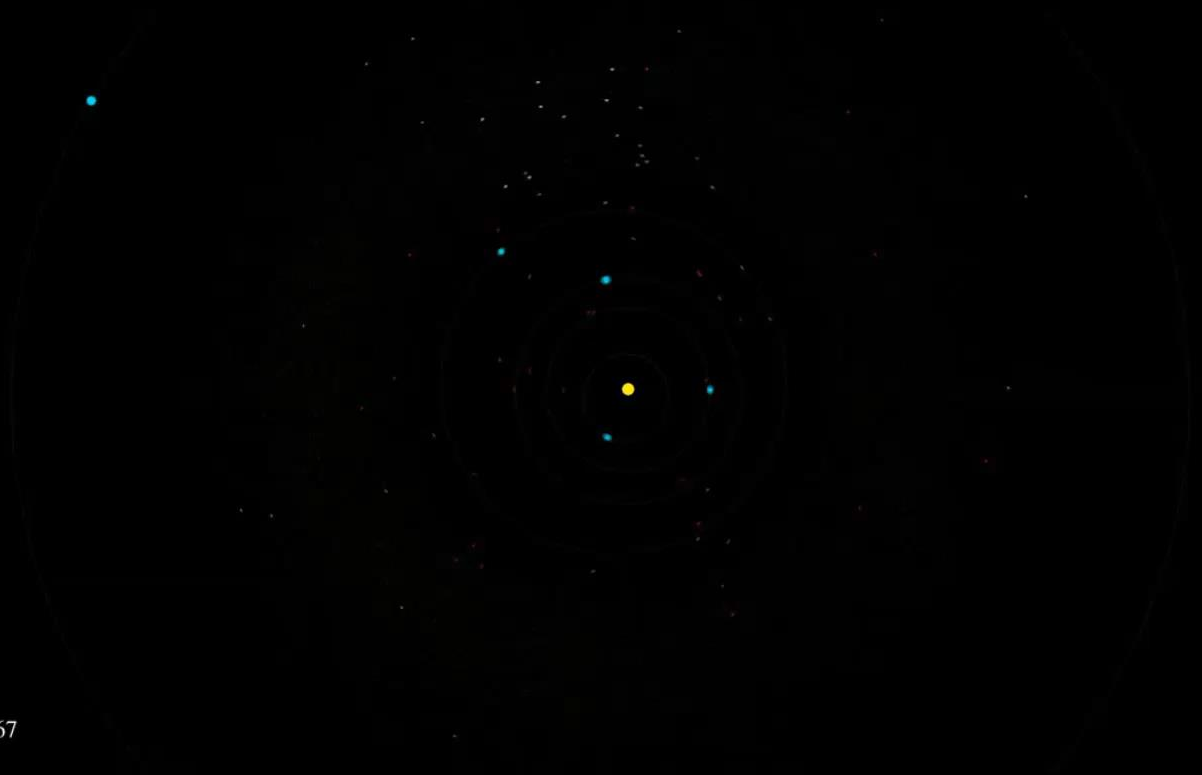




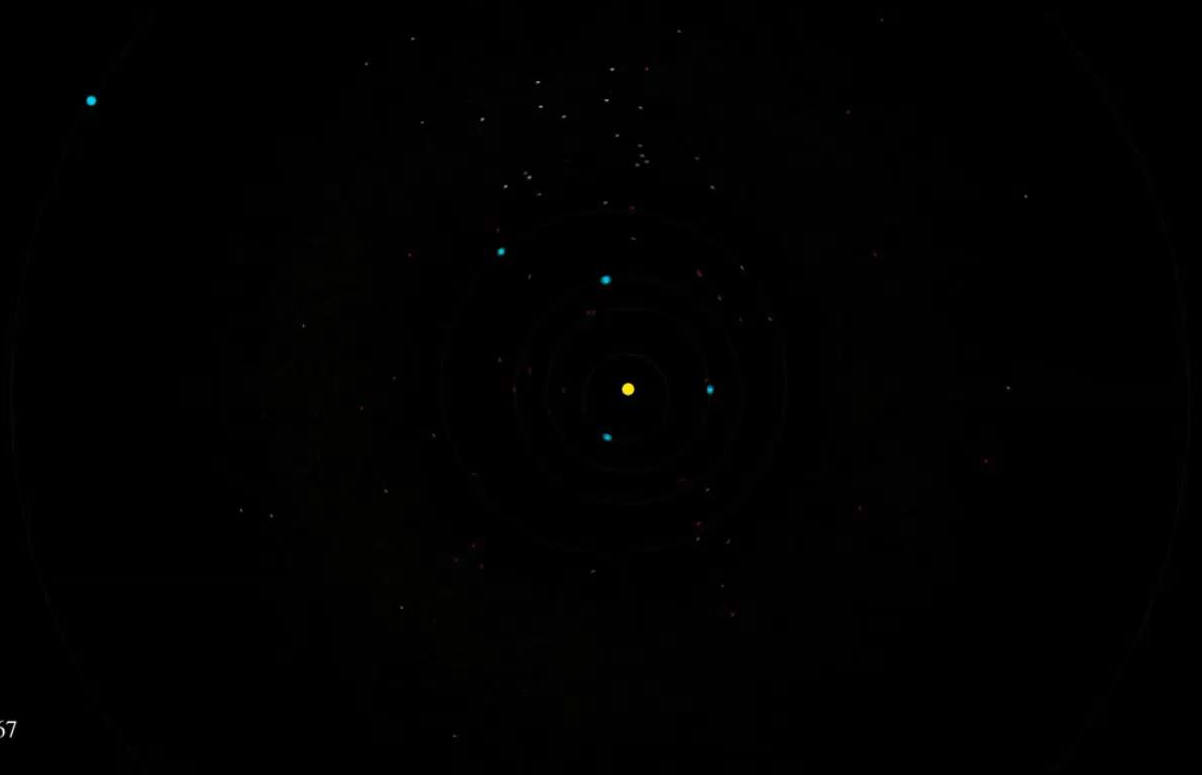
NASA/ R Evans & K Stapelfeldt, JPL

	Discovered	Distance (AU)	Diameter (km)
1 Ceres	1801	2.77	940
2 Pallas	1802	2.77	520
3 Juno	1804	2.67	230
4 Vesta	1807	2.36	530
5 Astraea	1845		
6 Hebe	1847		
7 Iris	1847		
8 Flora	1847		

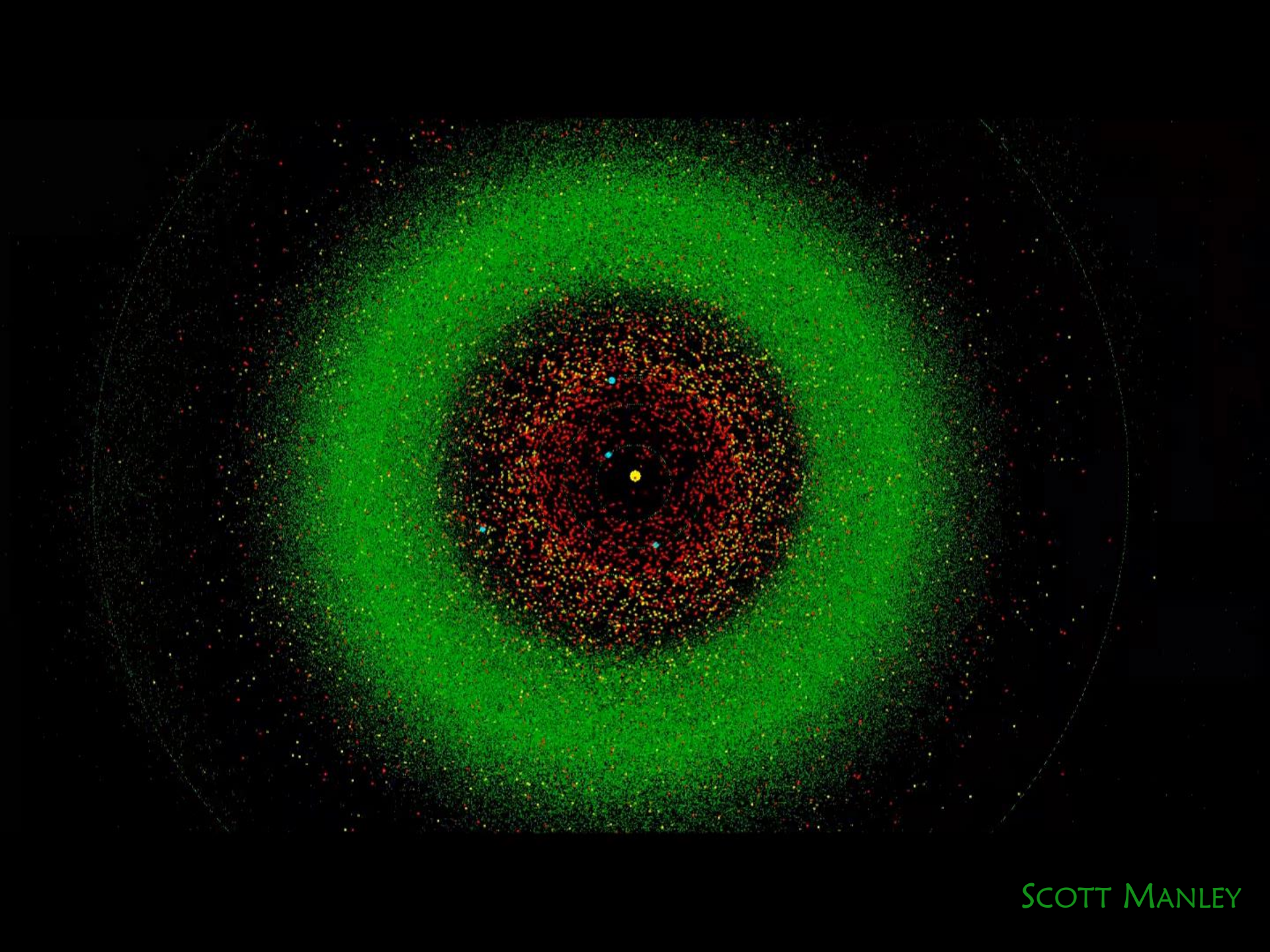




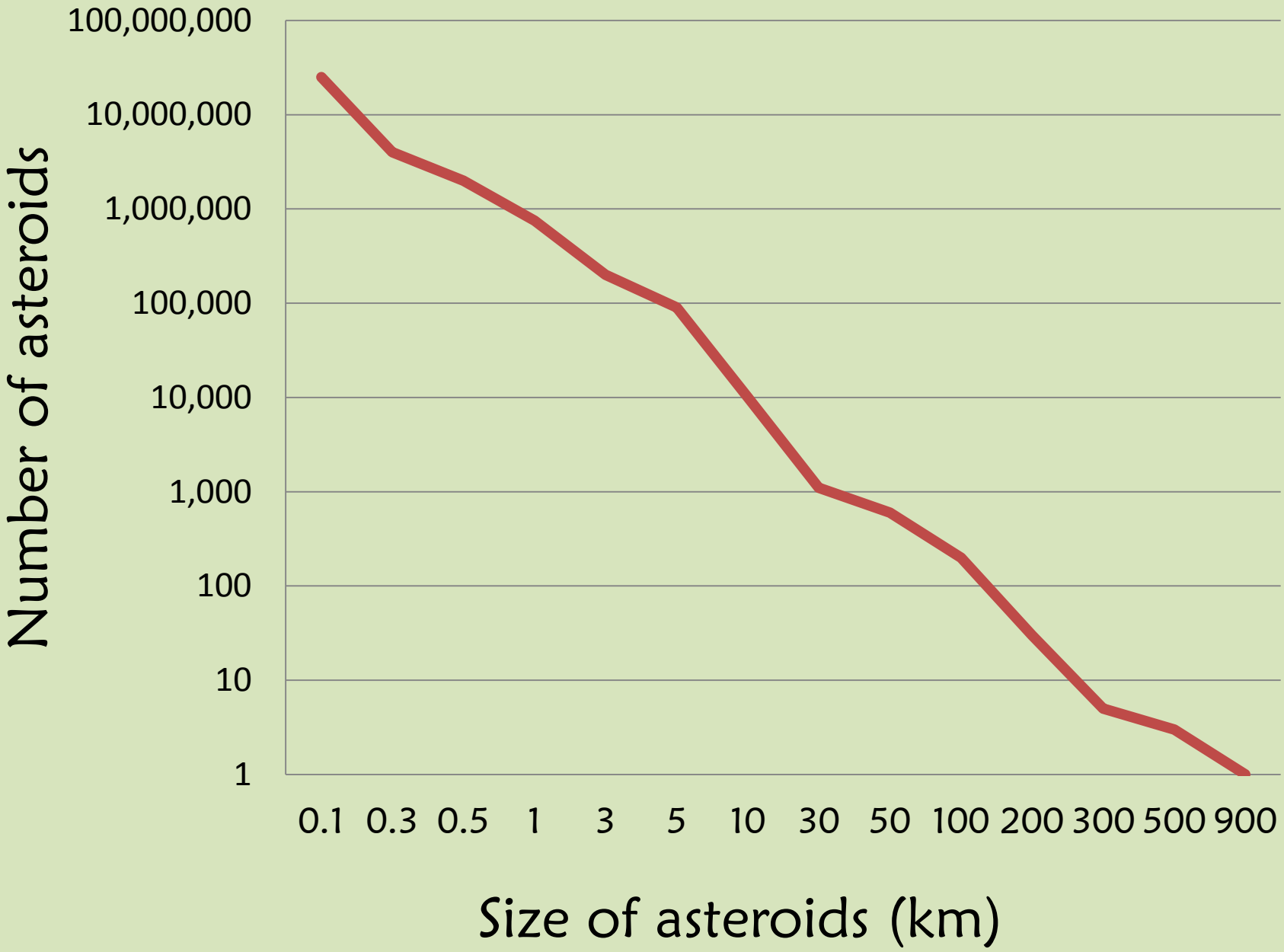
Scott Manley



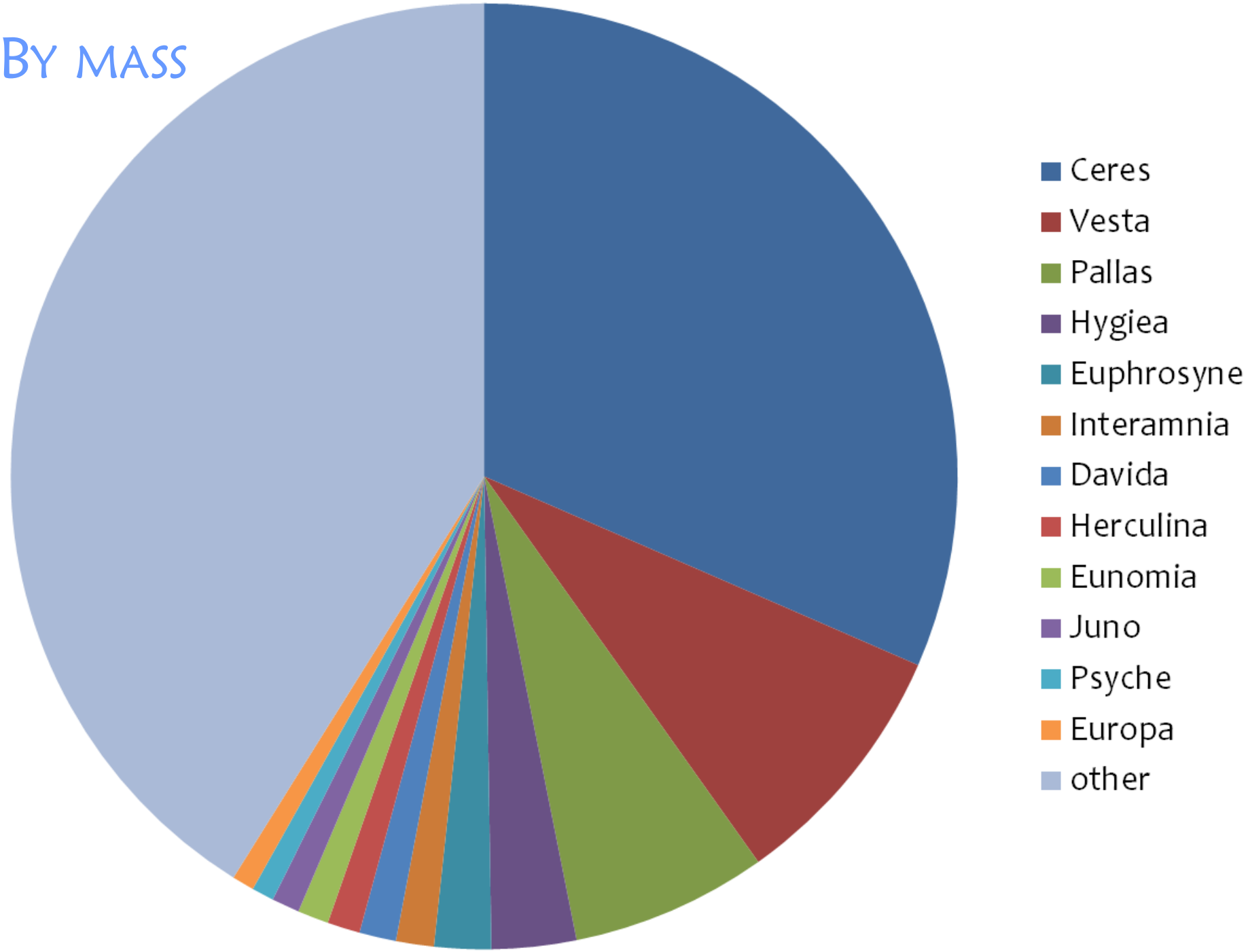
Scott Manley



Scott Manley

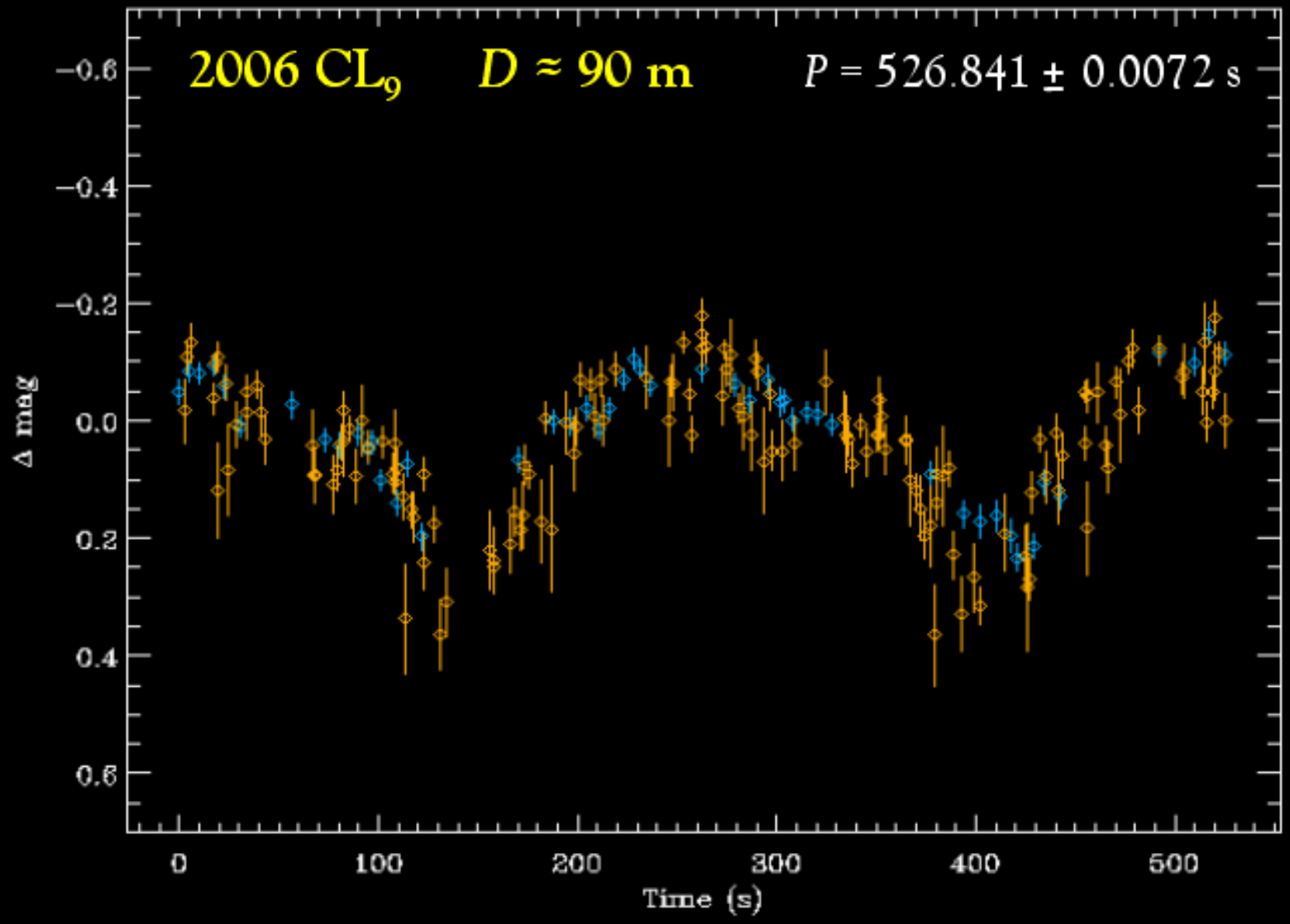

Number of asteroids
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.3
0.5
1
3
5
10
30
50
100
200
300
500
900
Size of asteroids (km)

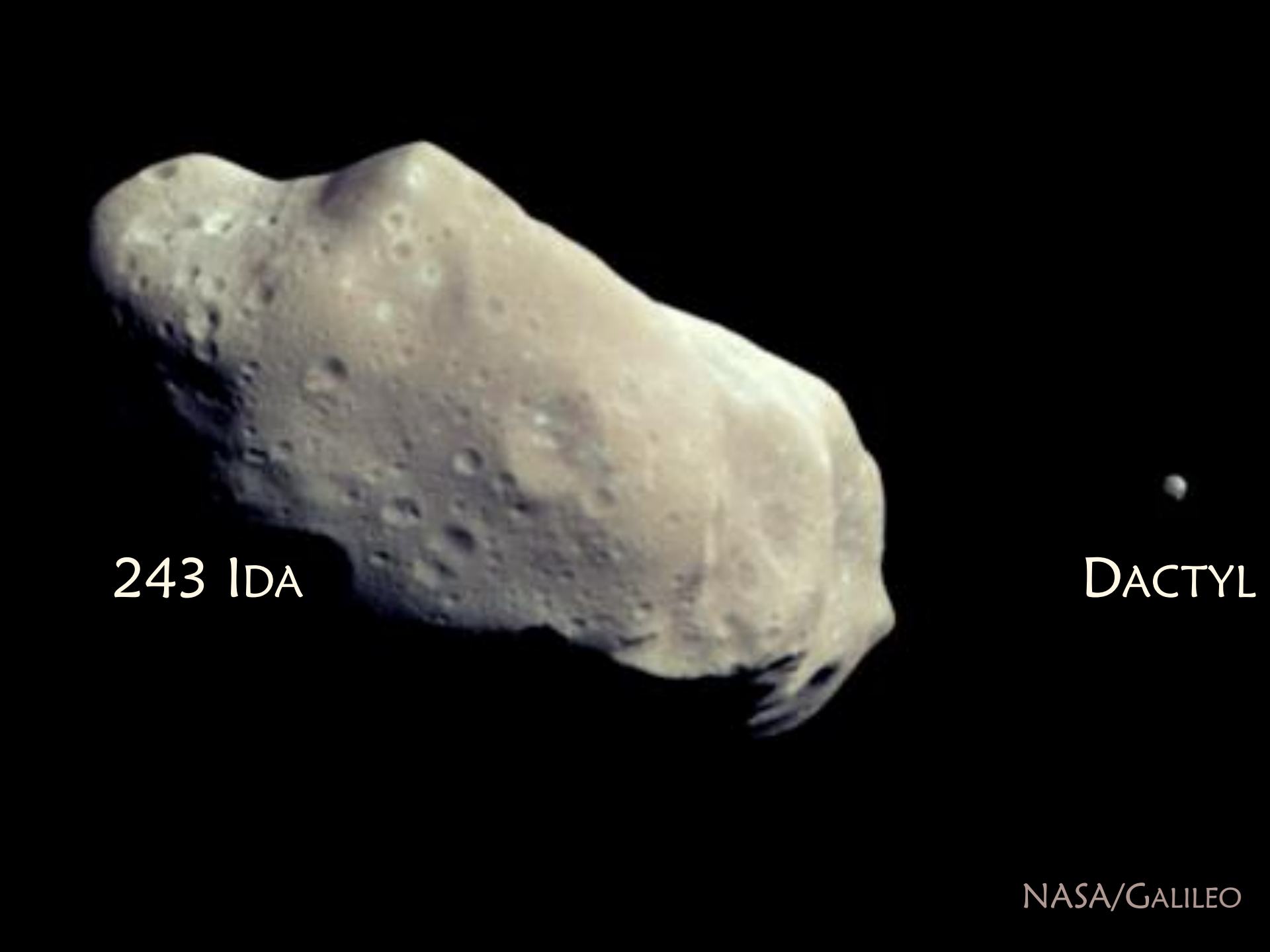
By mass


Ceres
Vesta
Pallas
Hygiea
Euphrosyne
Interamnia
Davida
Herculina
Eunomia
Juno
Psyche
Europa
other

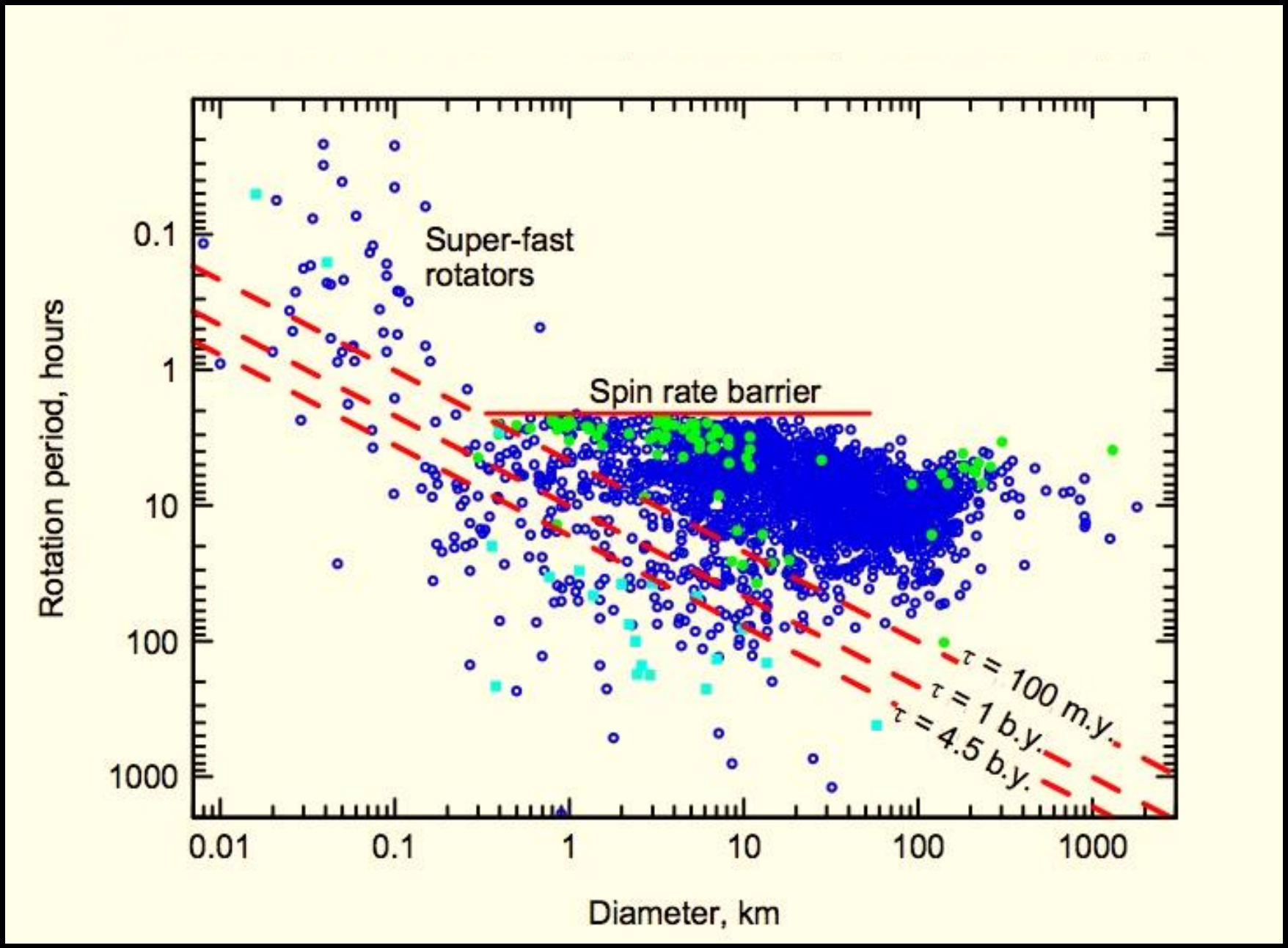
951 Gaspra

NASA/Galileo


2006 CL9
D ≈ 90 m
P = 526.841 ± 0.0072 s
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
Δ mag
0
100
200
300
400
500
Time (s)



NASA/Galileo


Super-fast
rotators
Spin rate barrier
τ = 100 m.y.
τ = 1 b.y.
τ = 4.5 b.y.
Rotation period, hours
0.1
1
10
100
1000
0.01
0.1
1
10
100
1000
Diameter, km

Alan Harris

25143 Itokawa

JAXA/Hayabusa


433 Eros
NASA/Near

75% C-type (carbon rich)

- dark
- outer asteroid belt
- water-rich clay-like minerals

75% C-type (carbon rich)

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15% S-type (silicate)

- iron, magnesium silicates
- bright
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433 Eros

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75% C-type (carbon rich)

- dark
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- water-rich clay-like minerals

15% S-type (silicate)

- iron, magnesium silicates
- bright
- inner asteroid belt

M-type (metallic)

- nickel-iron, some silicate
- inner to middle asteroid belt

21 Lutetia

ESA/Rosetta

75% C-type (carbon rich)

- dark
- outer asteroid belt
- water-rich clay-like minerals

15% S-type (silicate)

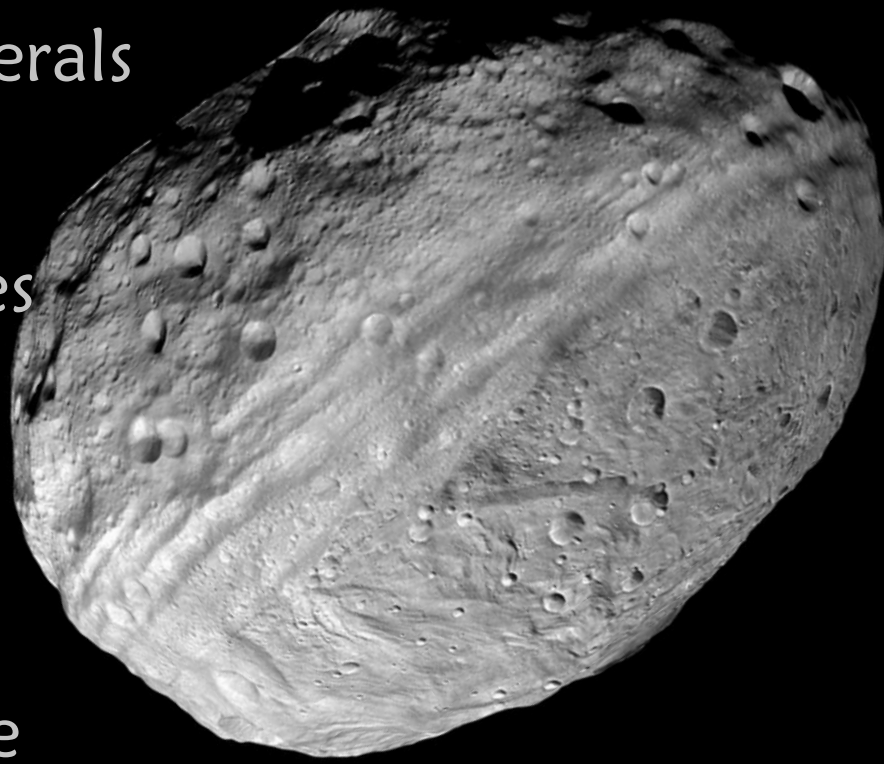
- iron, magnesium silicates
- bright
- inner asteroid belt

M-type (metallic)

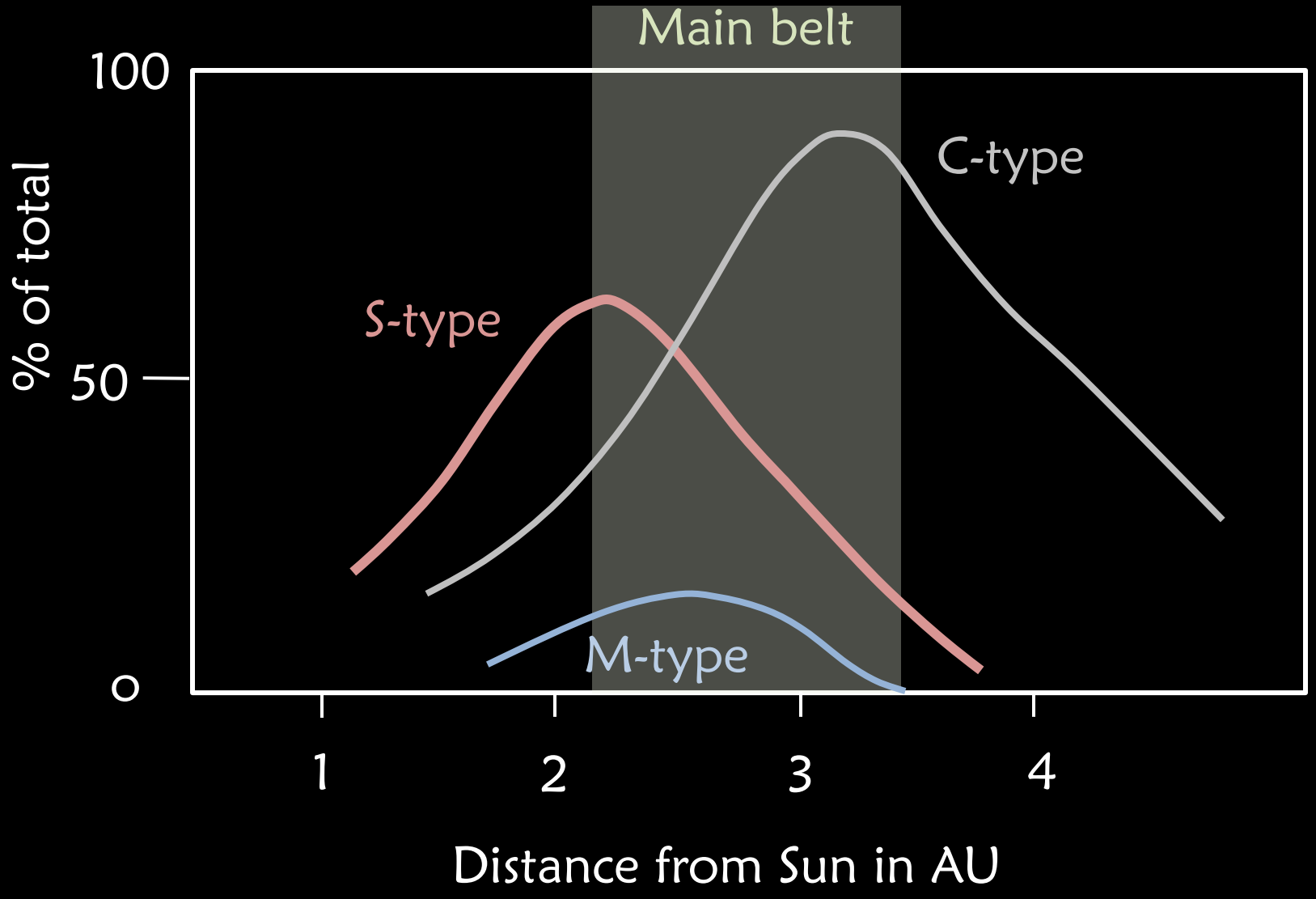
- nickel-iron, some silicate
- inner to middle asteroid belt

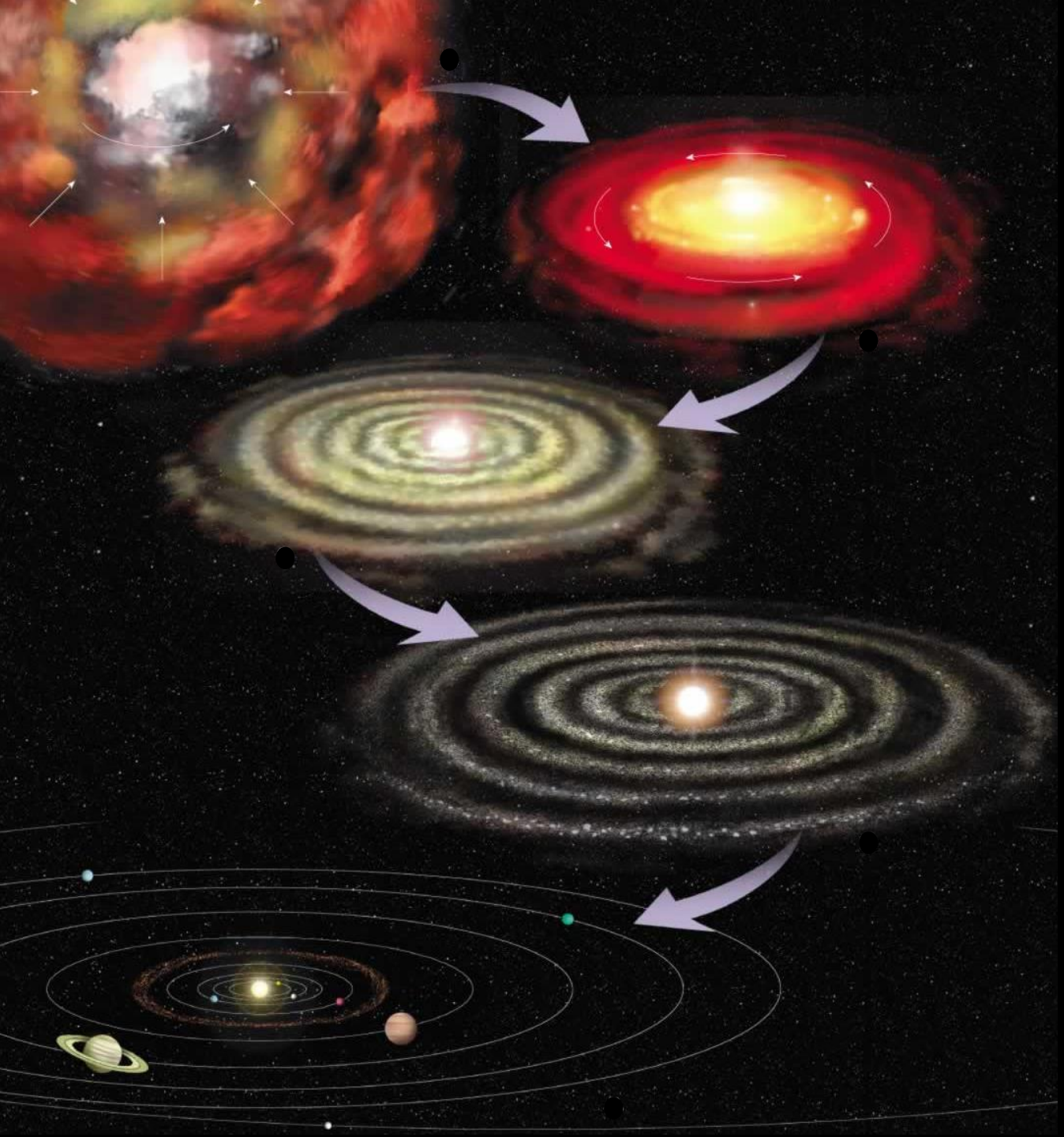
V-type (volcanic basalt)

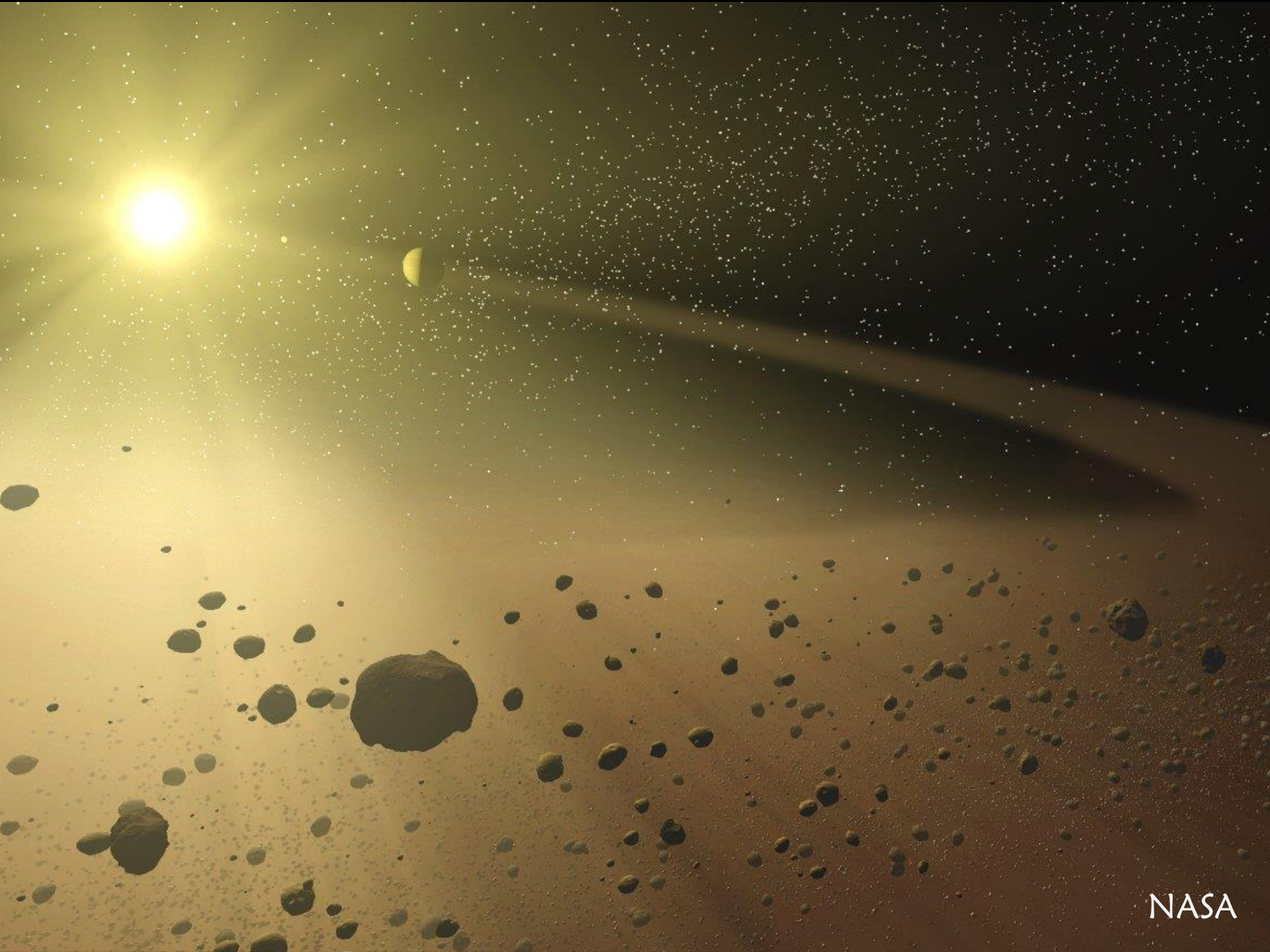
4 Vesta



NASA/Dawn


Main belt
100
% of total
50
0
C-type
S-type
M-type
1
2
3
4
Distance from Sun in AU

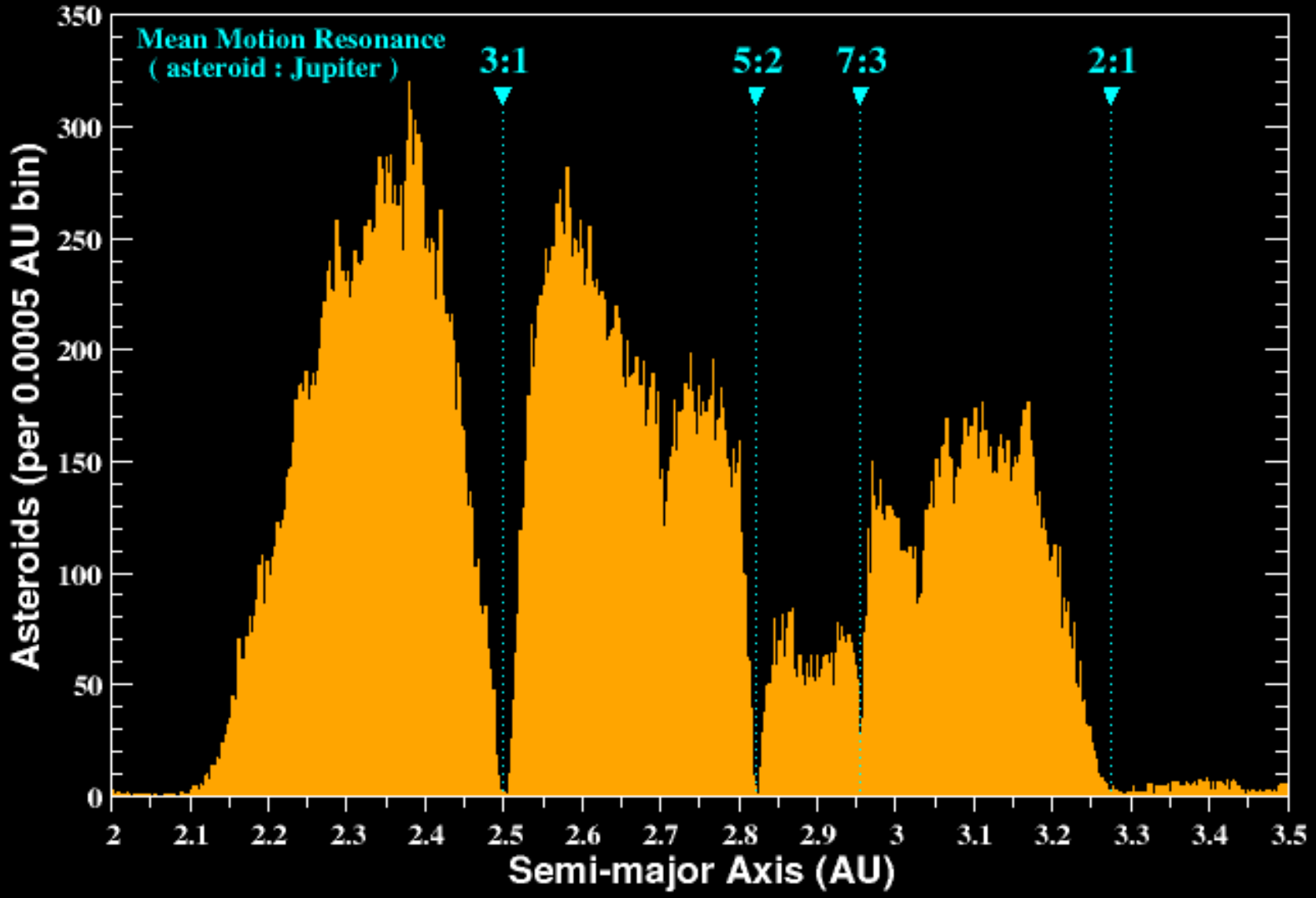



NASA

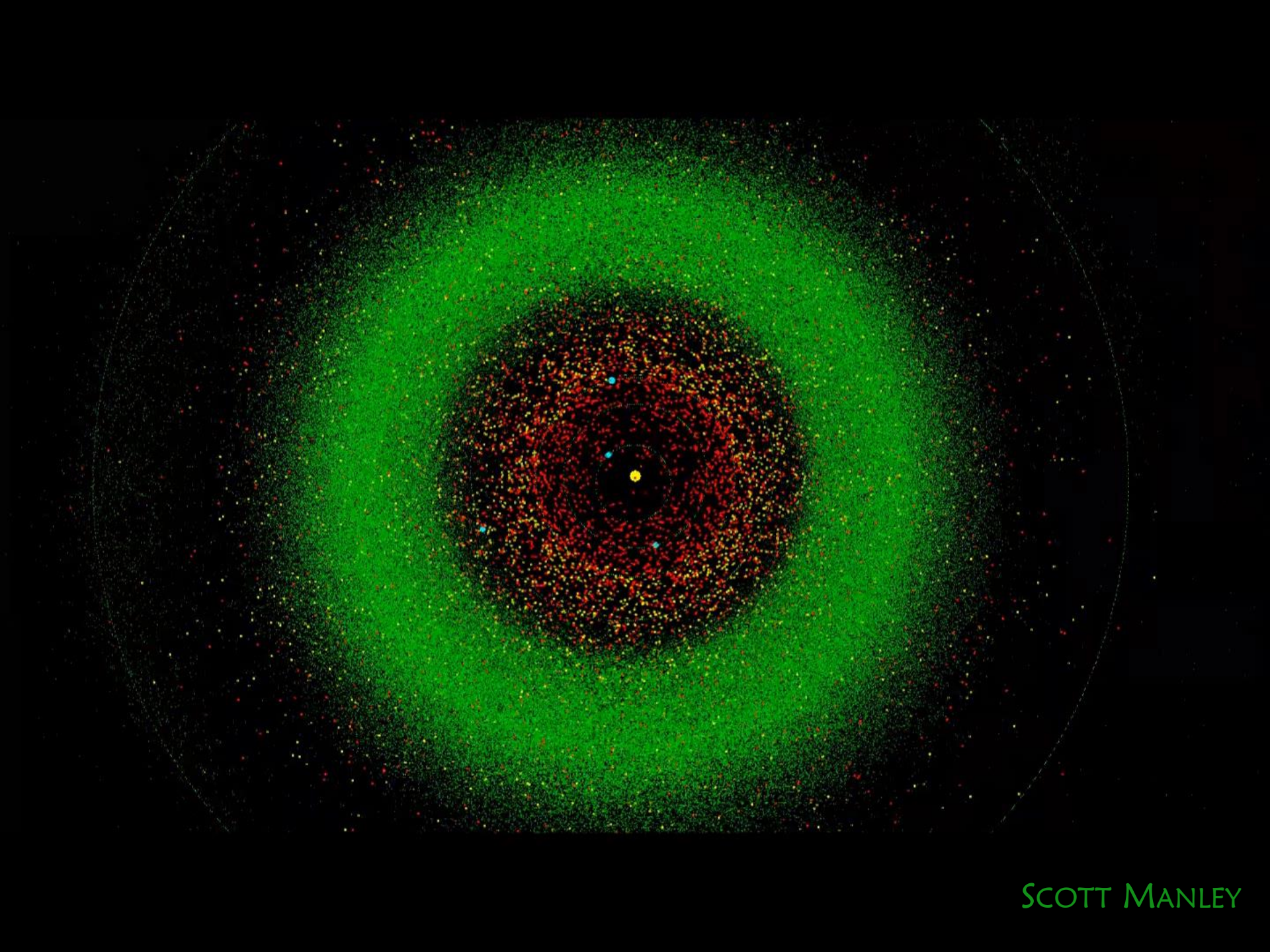

ADRIAN MANN

Asteroid Main-Belt Distribution

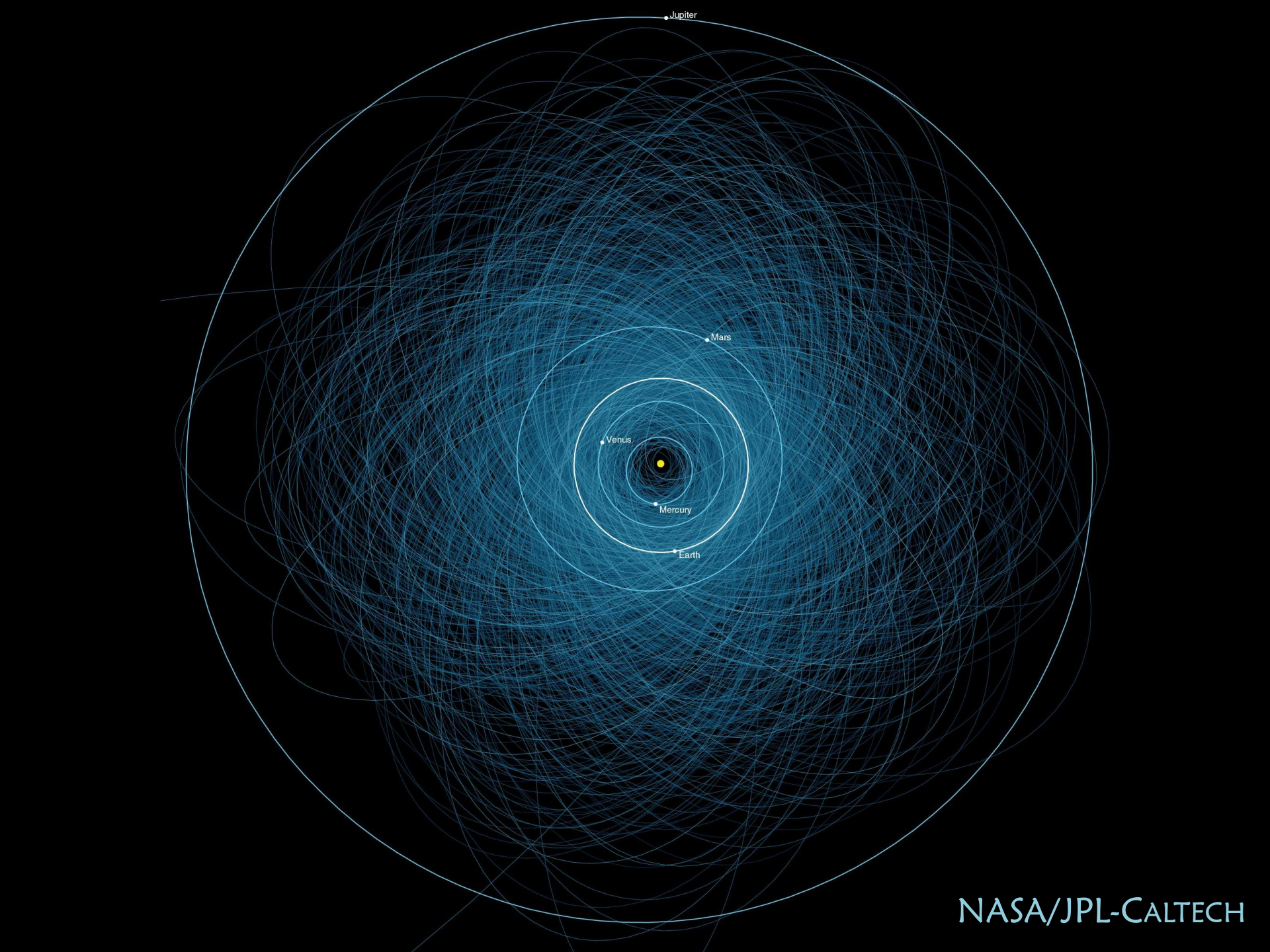
Kirkwood Gaps



A Chamberlain (JPL-Caltech)



Scott Manley


Jupiter
Mars
Venus
Mercury
Earth
NASA/JPL-Caltech

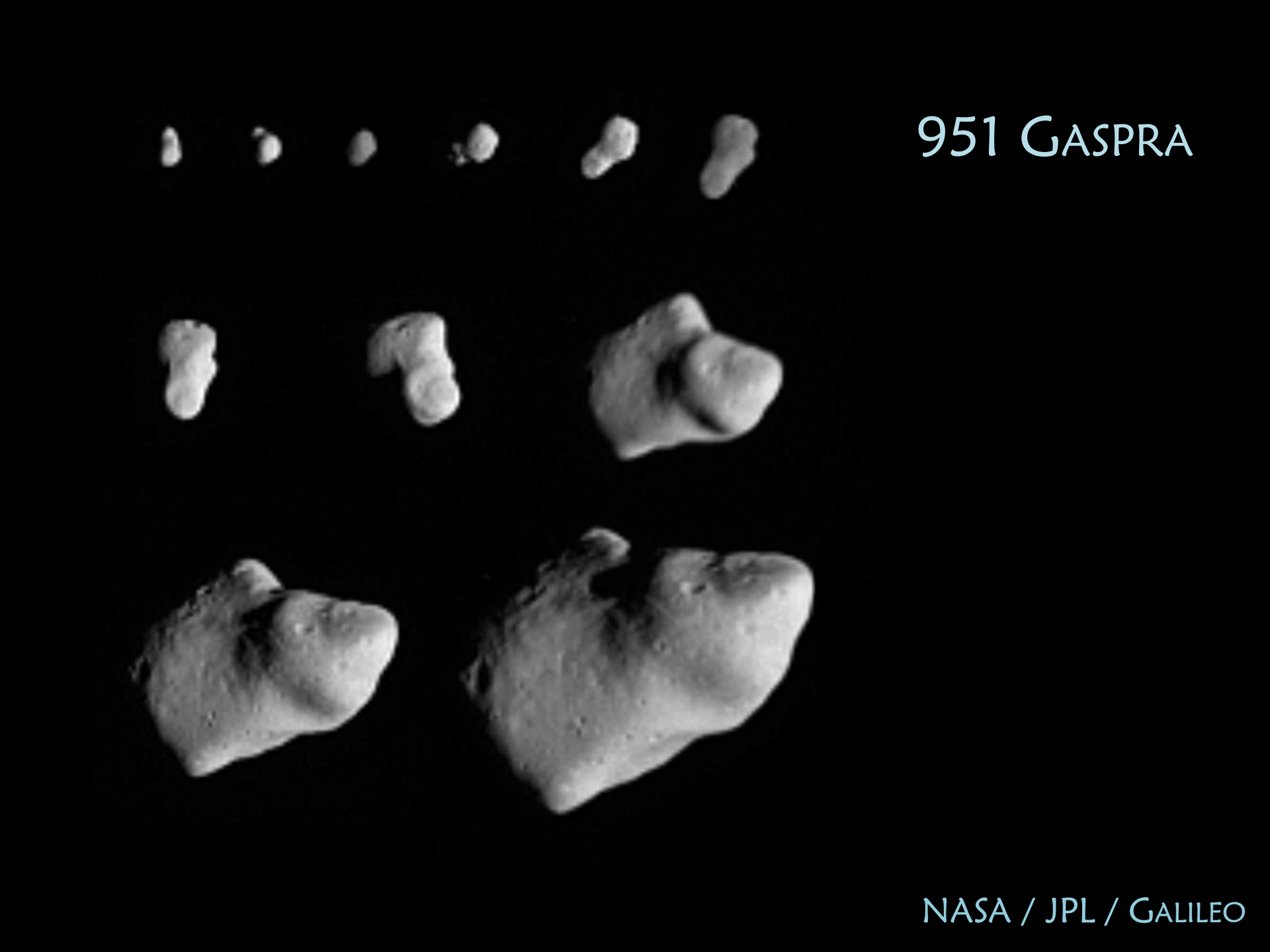
2012 DA14

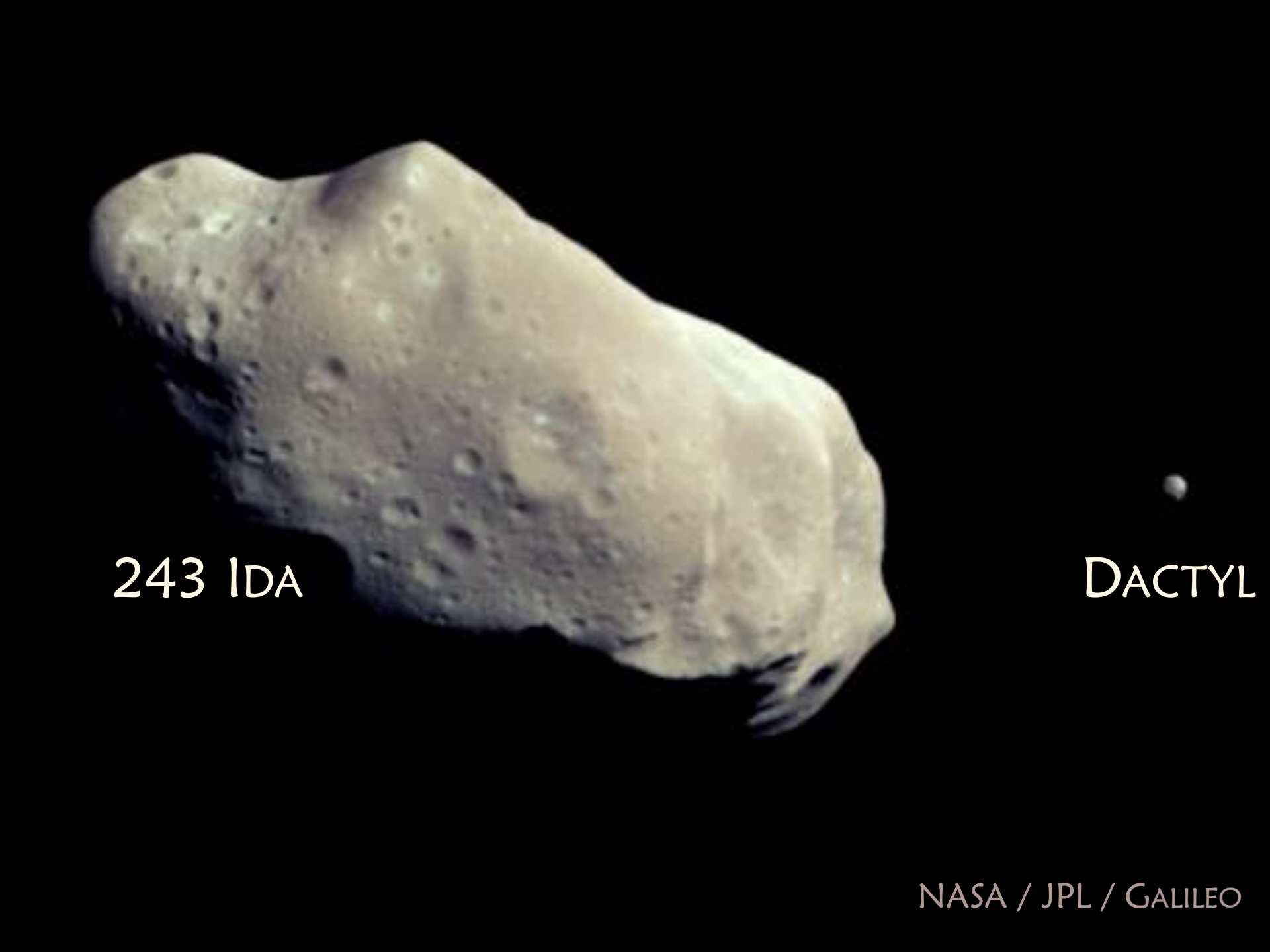
D Lopez, Teide Observatory

2014 HQ124

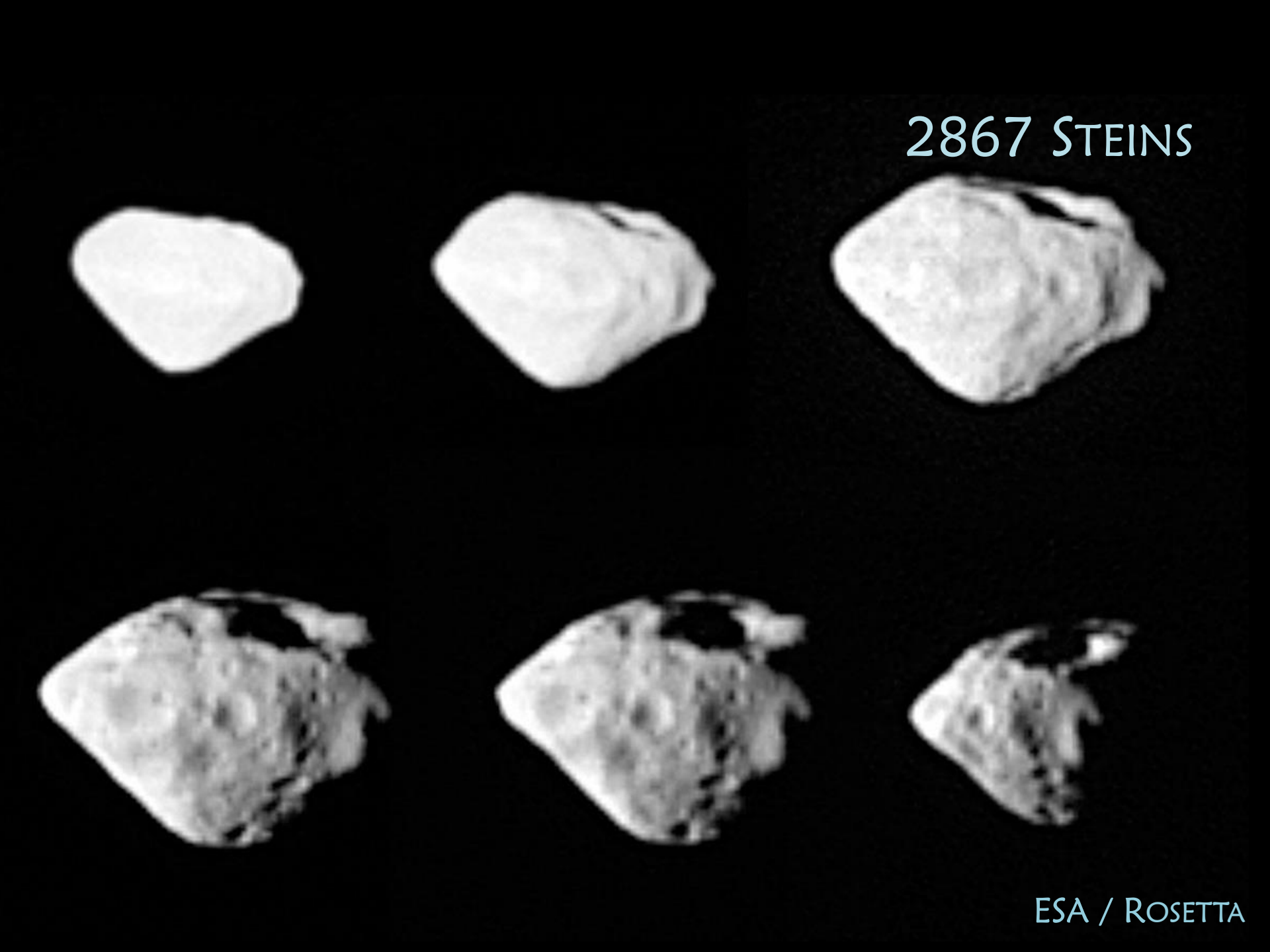
NASA / Goldstone

NASA / Goldstone


951 Gaspra
NASA / JPL / Galileo

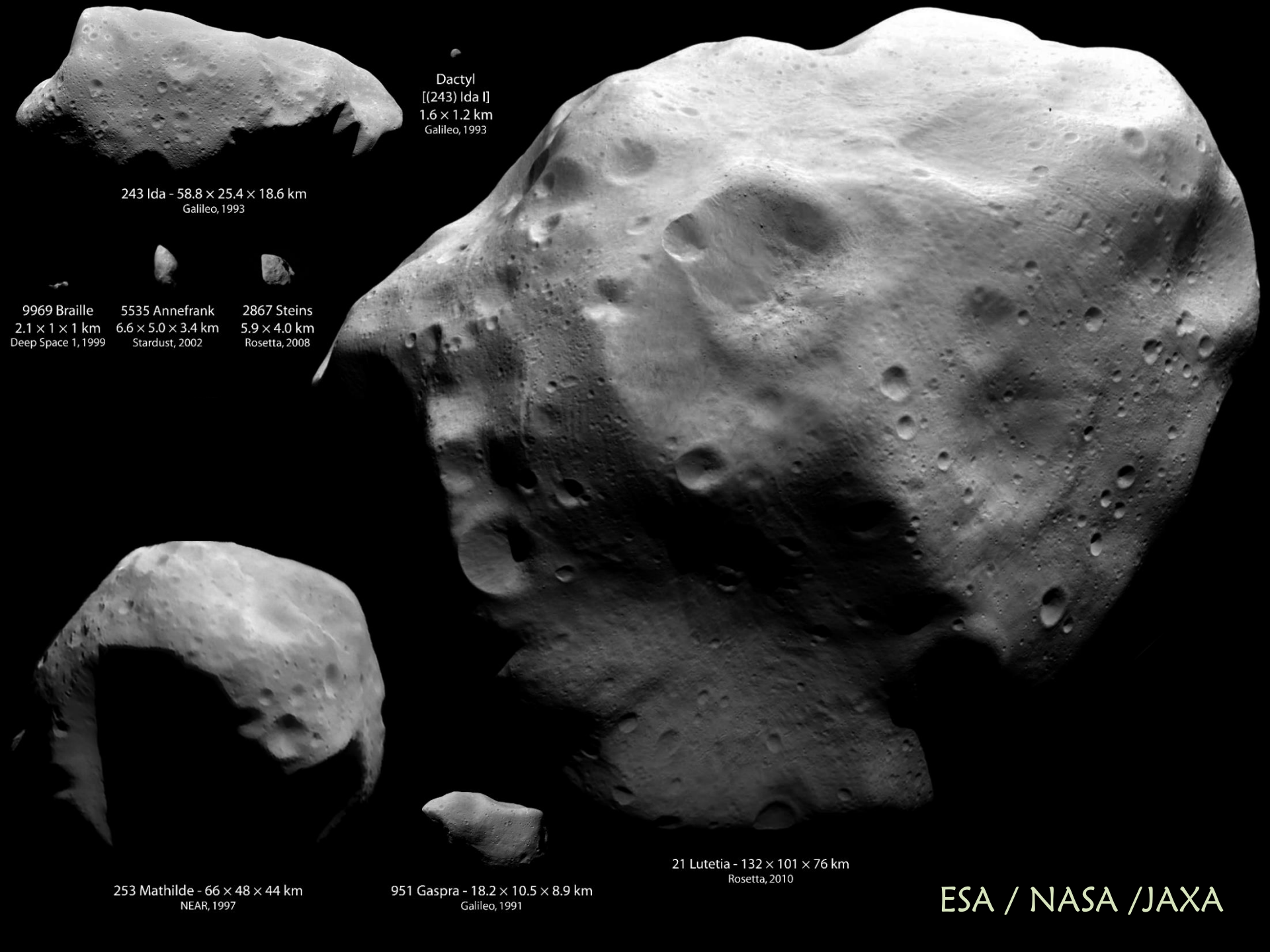


NASA / JPL / Galileo


2867 Steins
ESA / Rosetta

21 Lutetia

ESA / Rosetta


Dactyl
[(243) Ida I]
1.6 × 1.2 km
Galileo, 1993
243 Ida - 58.8 × 25.4 × 18.6 km
Galileo, 1993
9969 Braille
2.1 × 1 × 1 km
Deep Space 1, 1999
5535 Annefrank
6.6 × 5.0 × 3.4 km
Stardust, 2002
2867 Steins
5.9 × 4.0 km
Rosetta, 2008
253 Mathilde - 66 × 48 × 44 km
NEAR, 1997
951 Gaspra - 18.2 × 10.5 × 8.9 km
Galileo, 1991
21 Lutetia - 132 × 101 × 76 km
Rosetta, 2010
ESA / NASA /JAXA

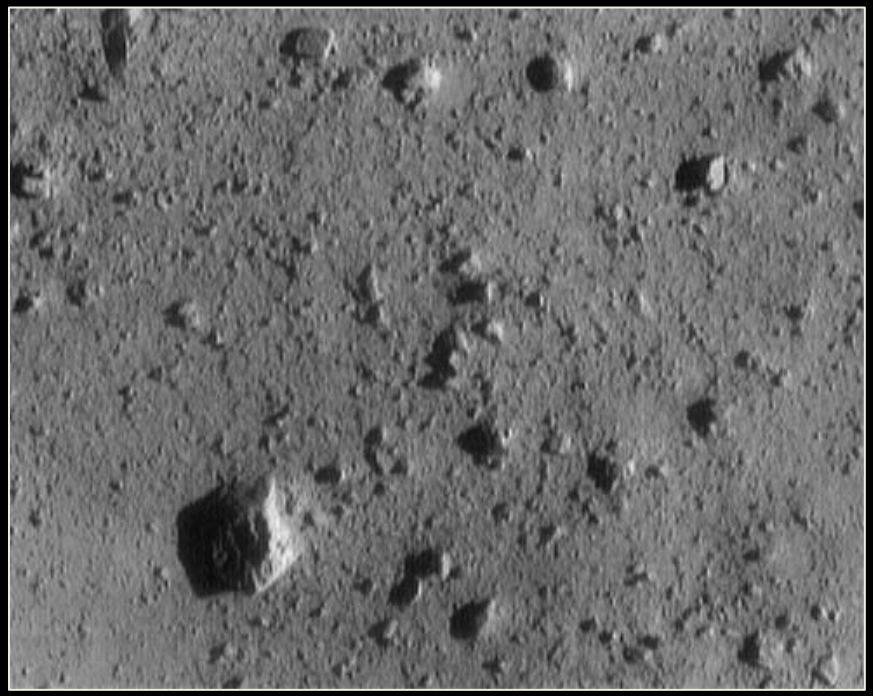

433 Eros
NASA/Near

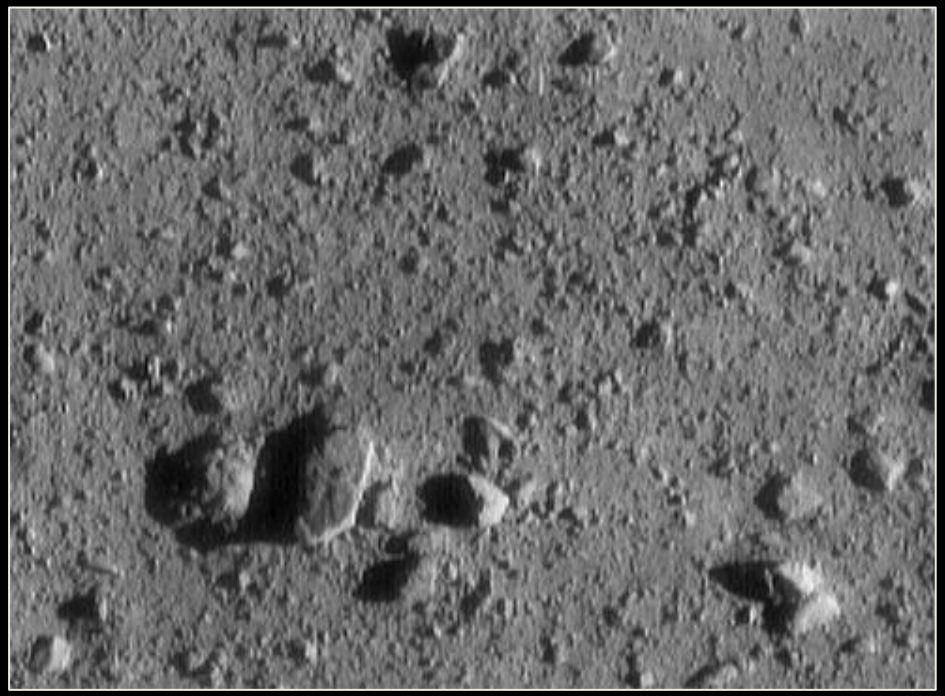
NASA/NEAR

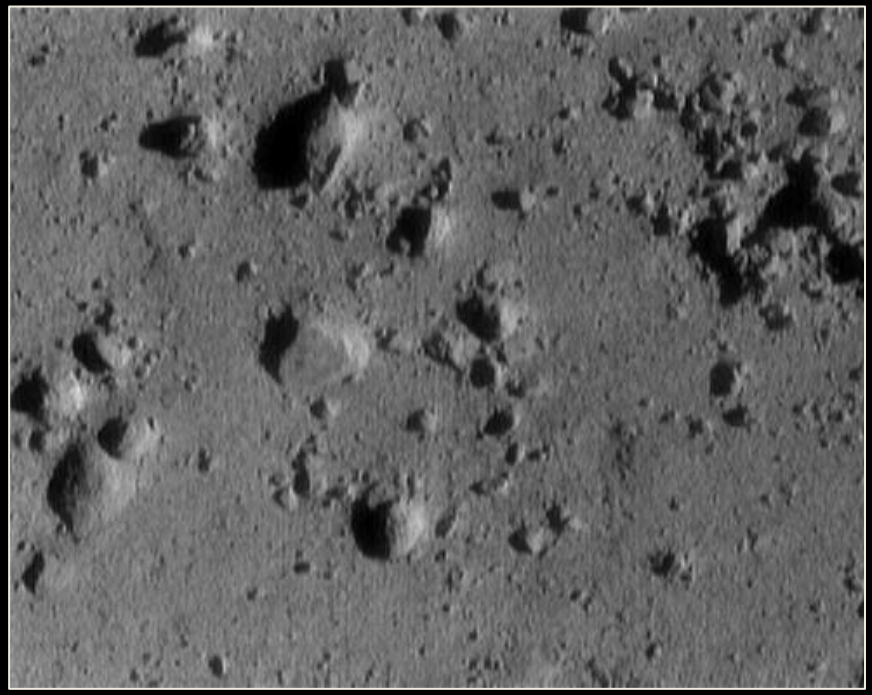
NASA/NEAR

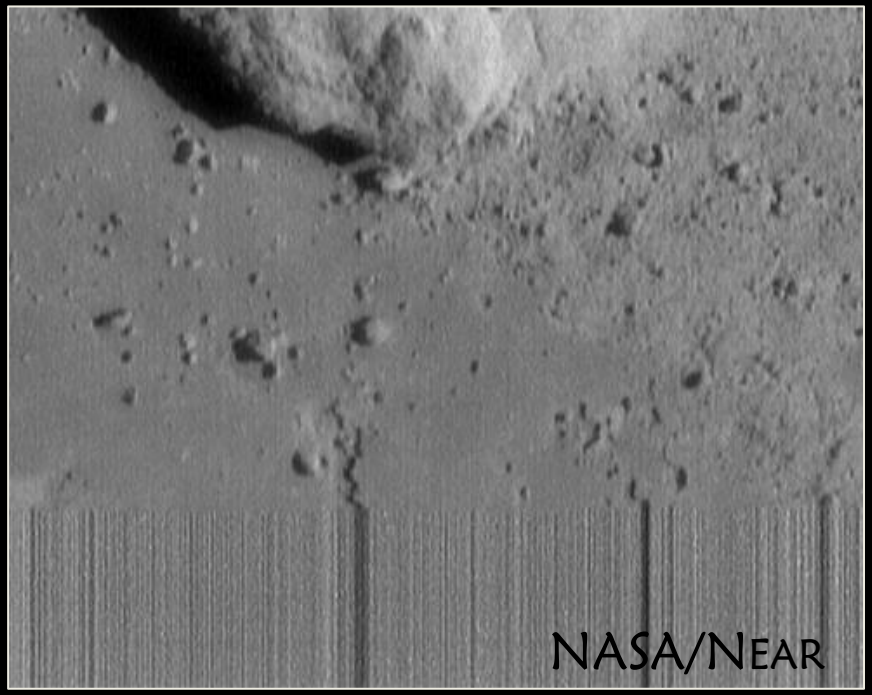

NASA/NEAR

NASA/Apollo

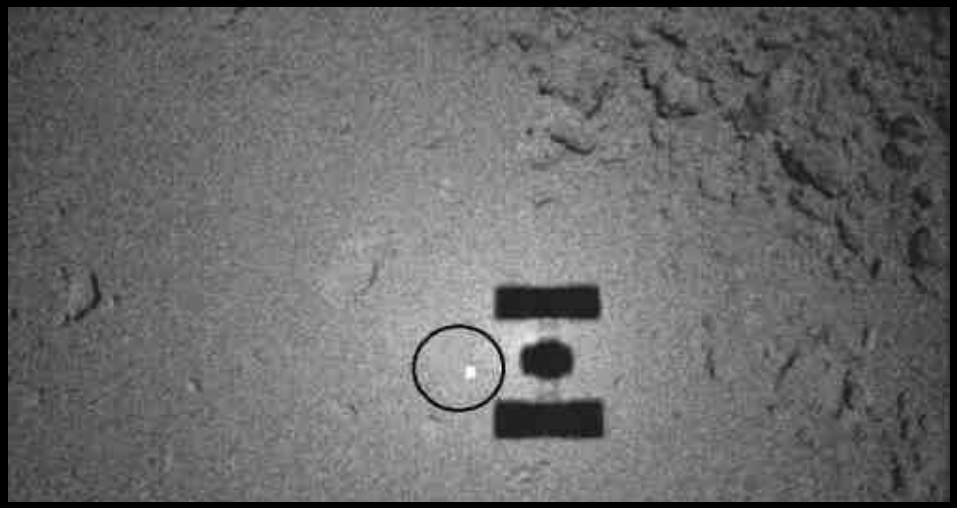







NASA/Near

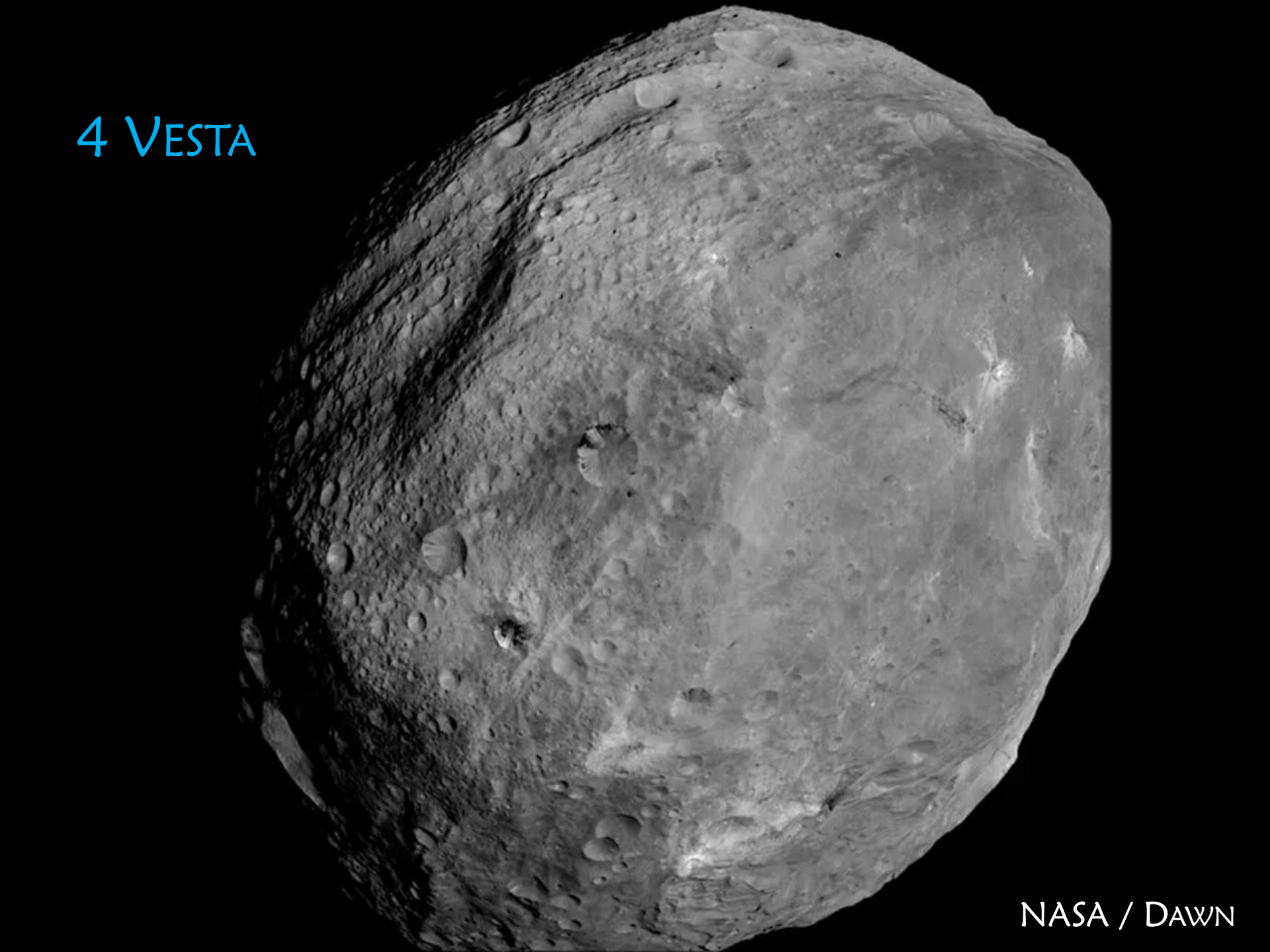
25143 Itokawa



JAXA/Hayabusa

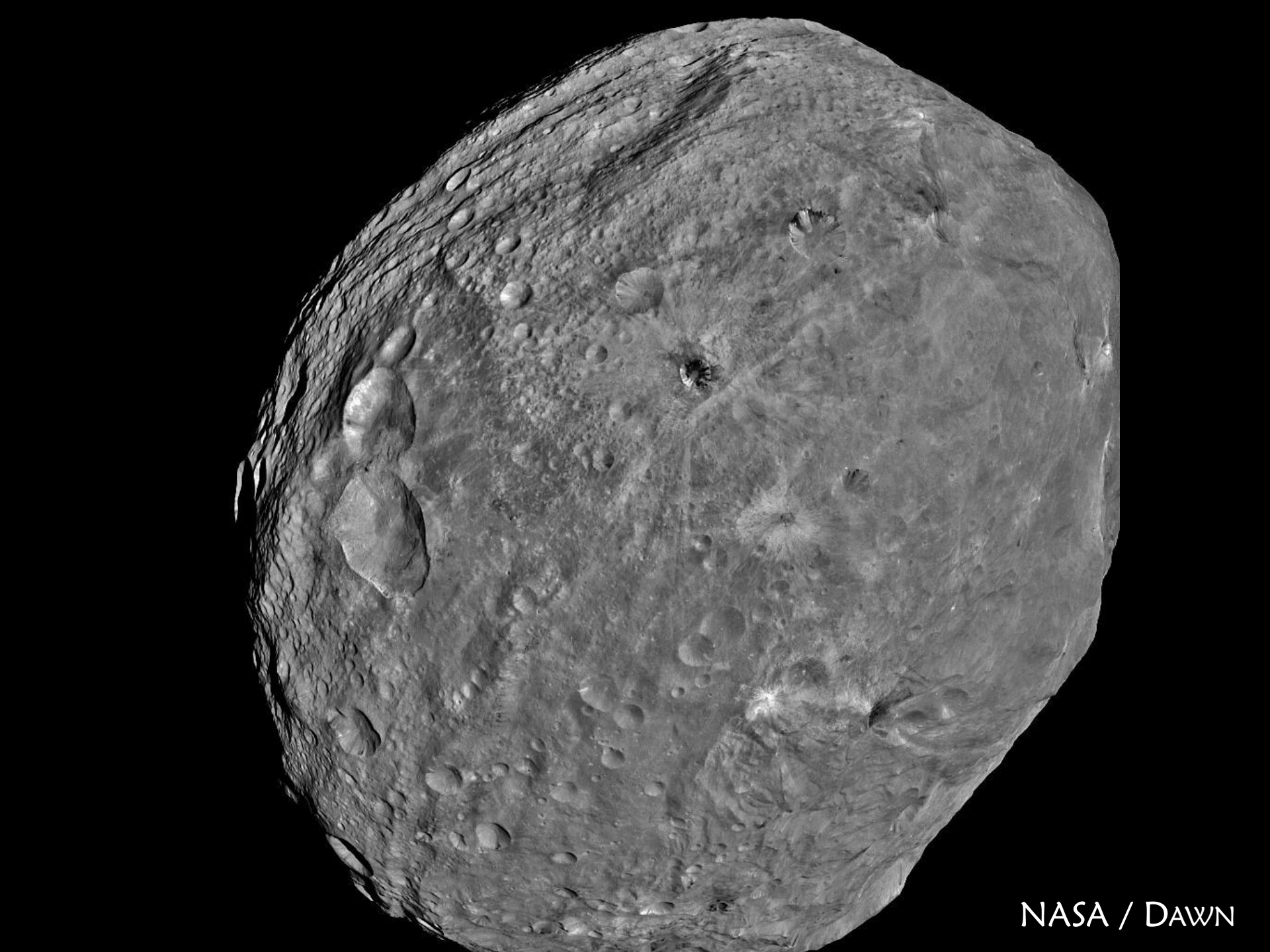

1 Ceres
4 Vesta

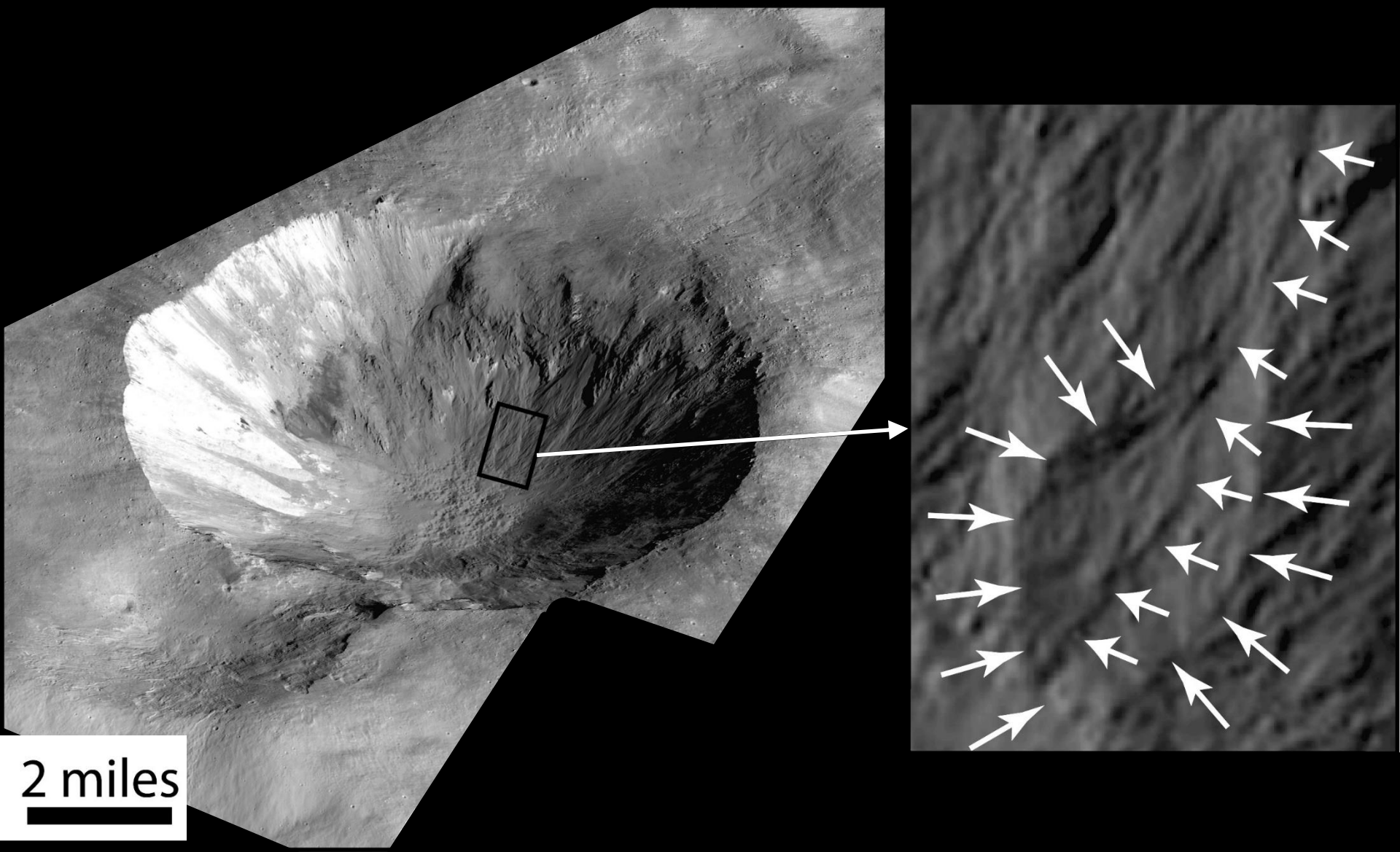
4 Vesta



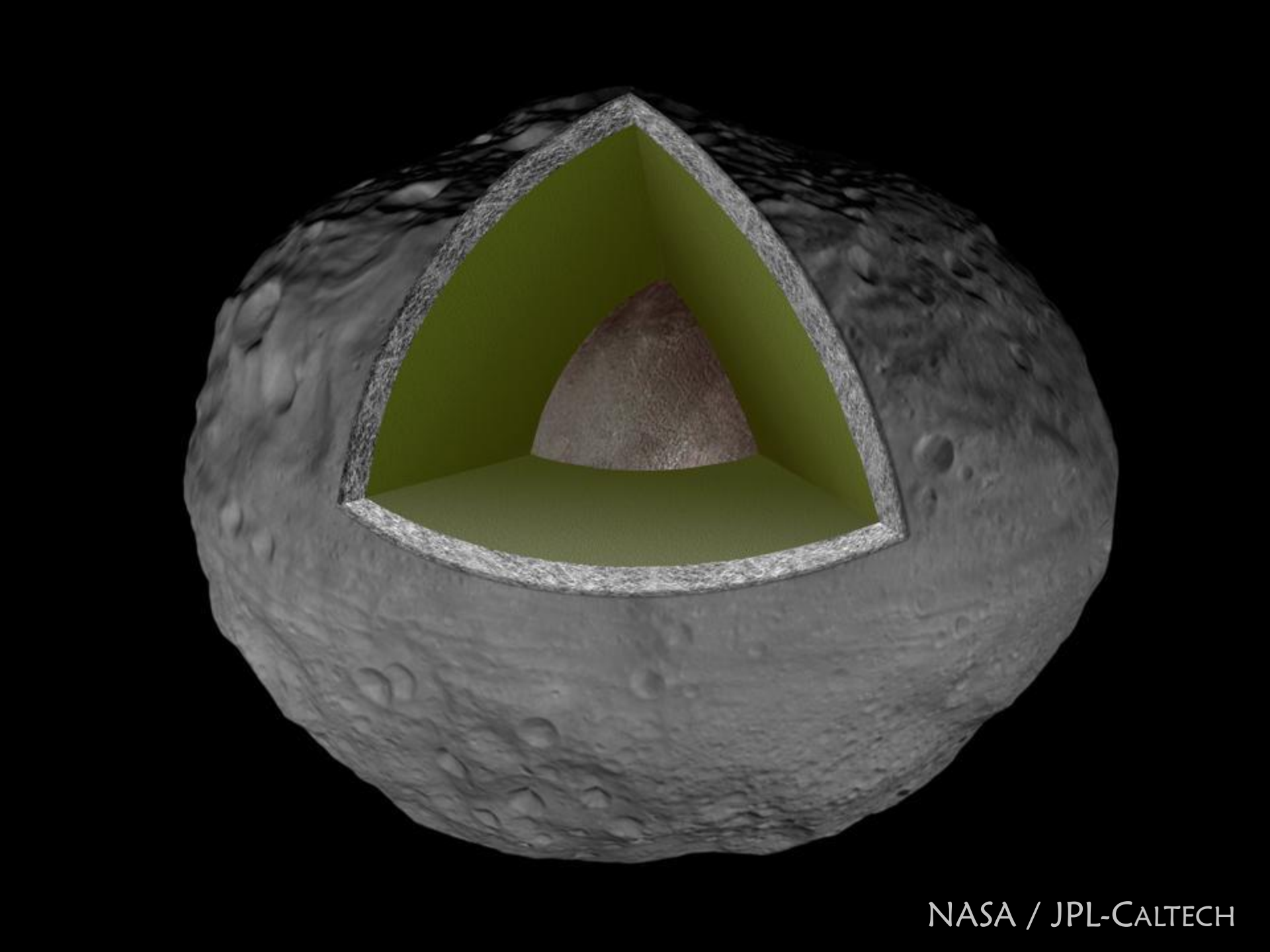
NASA / Dawn

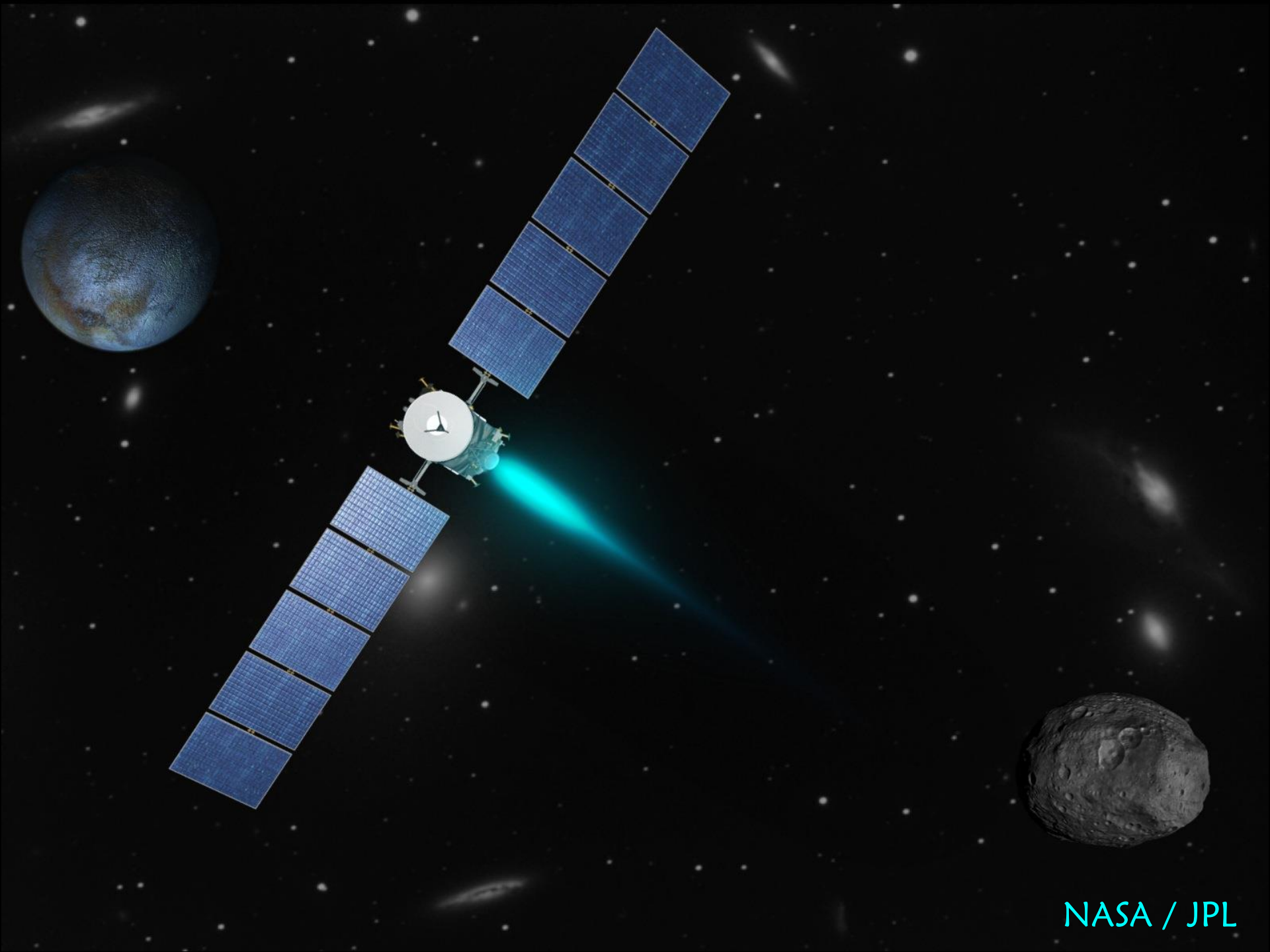

NASA / Dawn

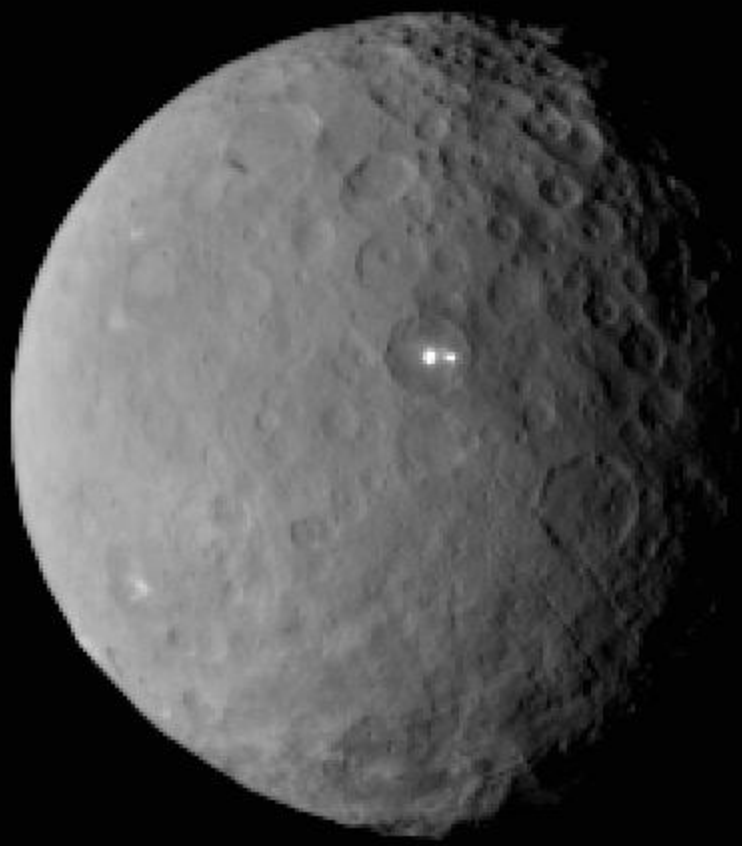

NASA / Dawn



NASA / Dawn

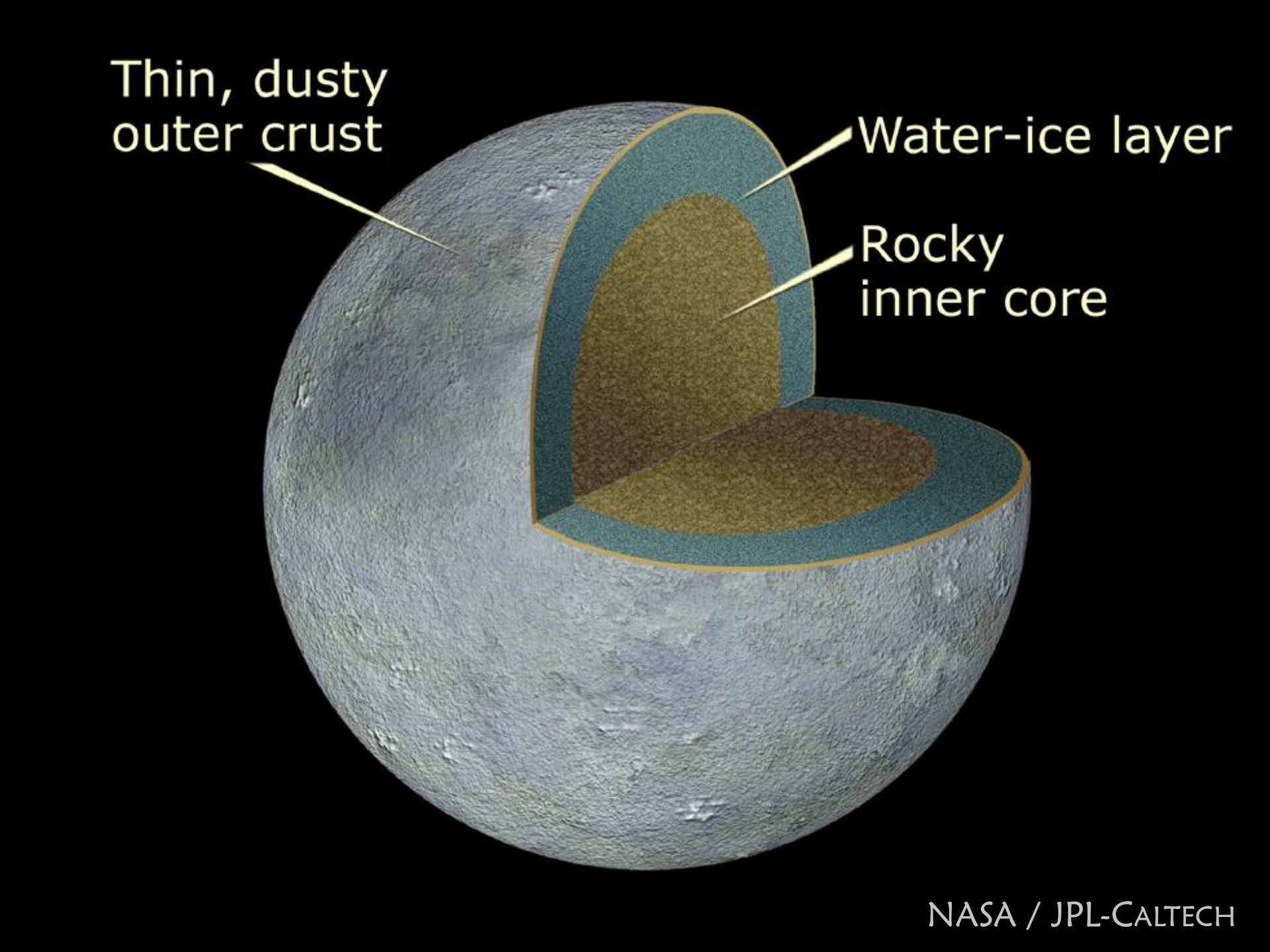

NASA / JPL-Caltech

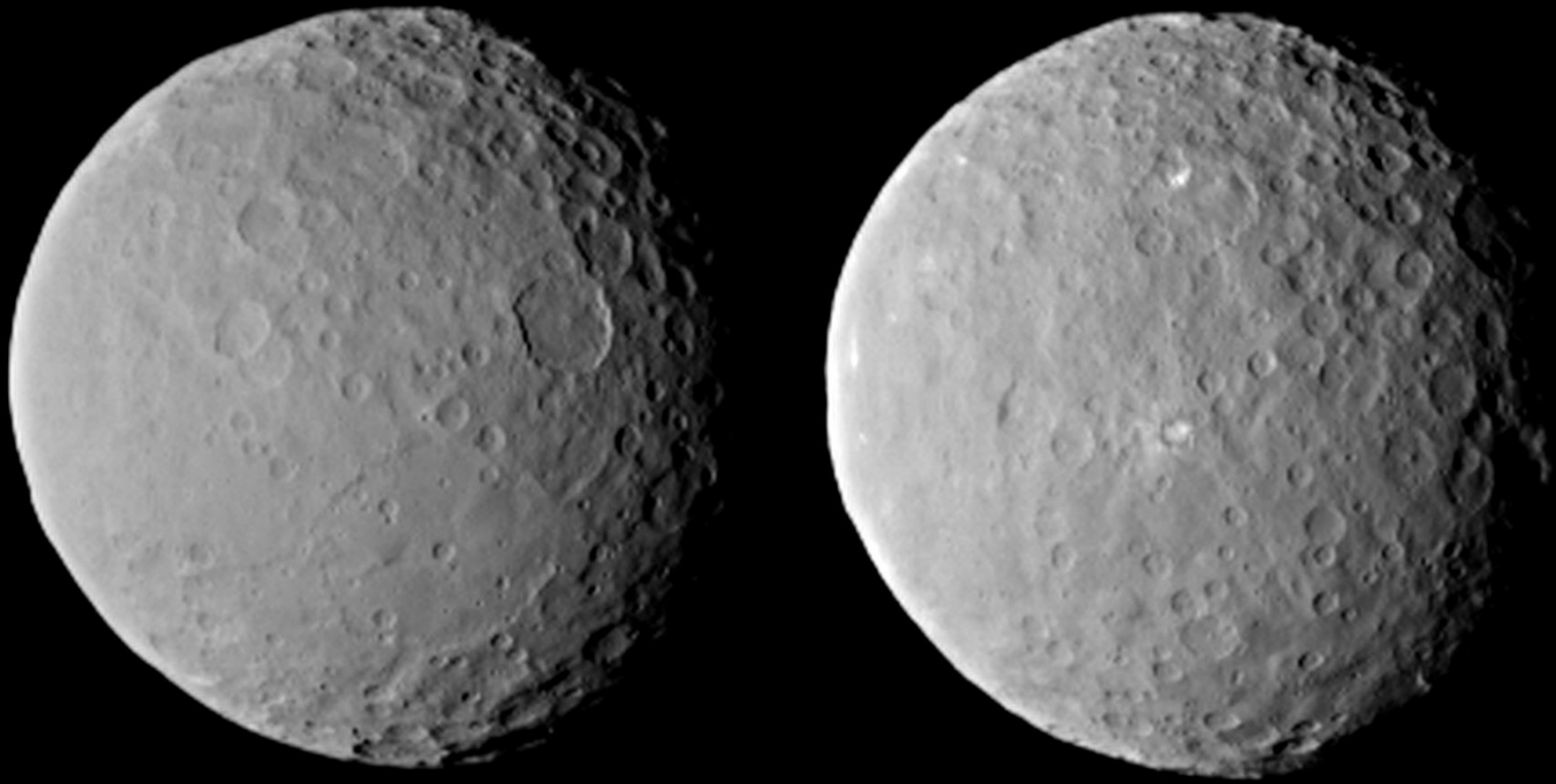

NASA / JPL



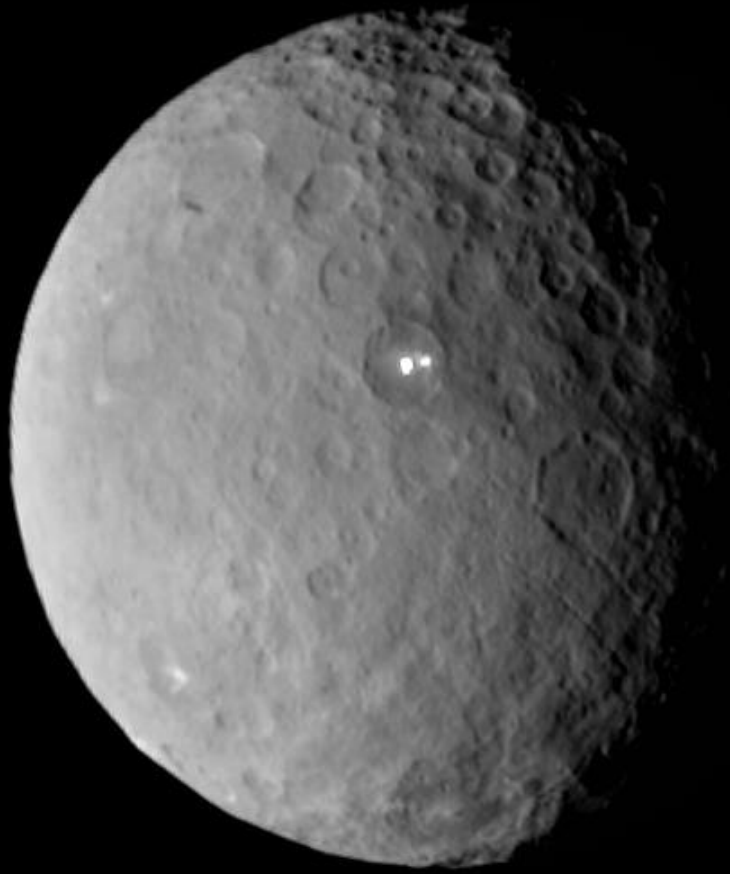
1 Ceres

NASA / Dawn


Thin, dusty
outer crust
Water-ice layer
Rocky
inner core
NASA / JPL-Caltech

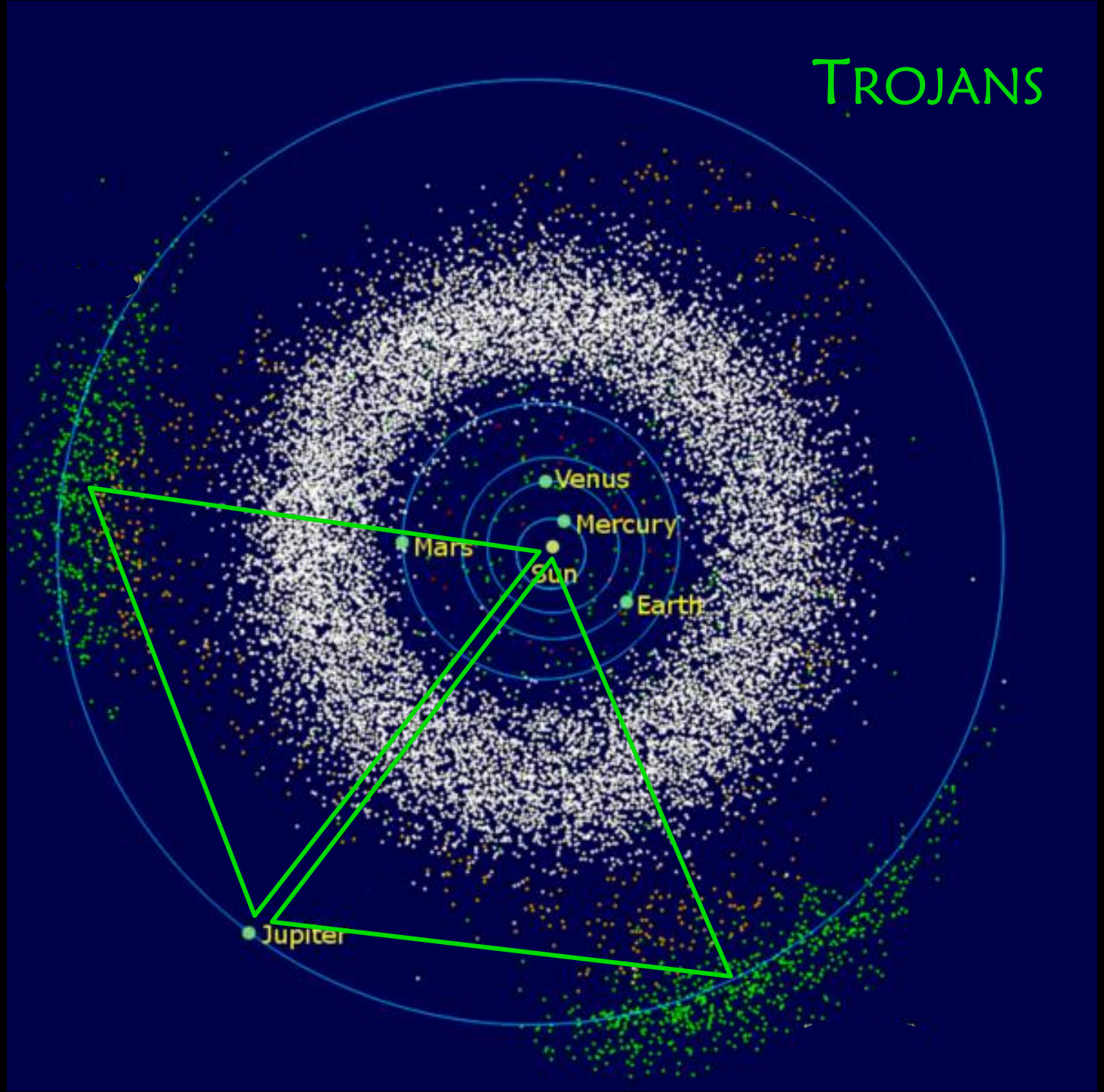


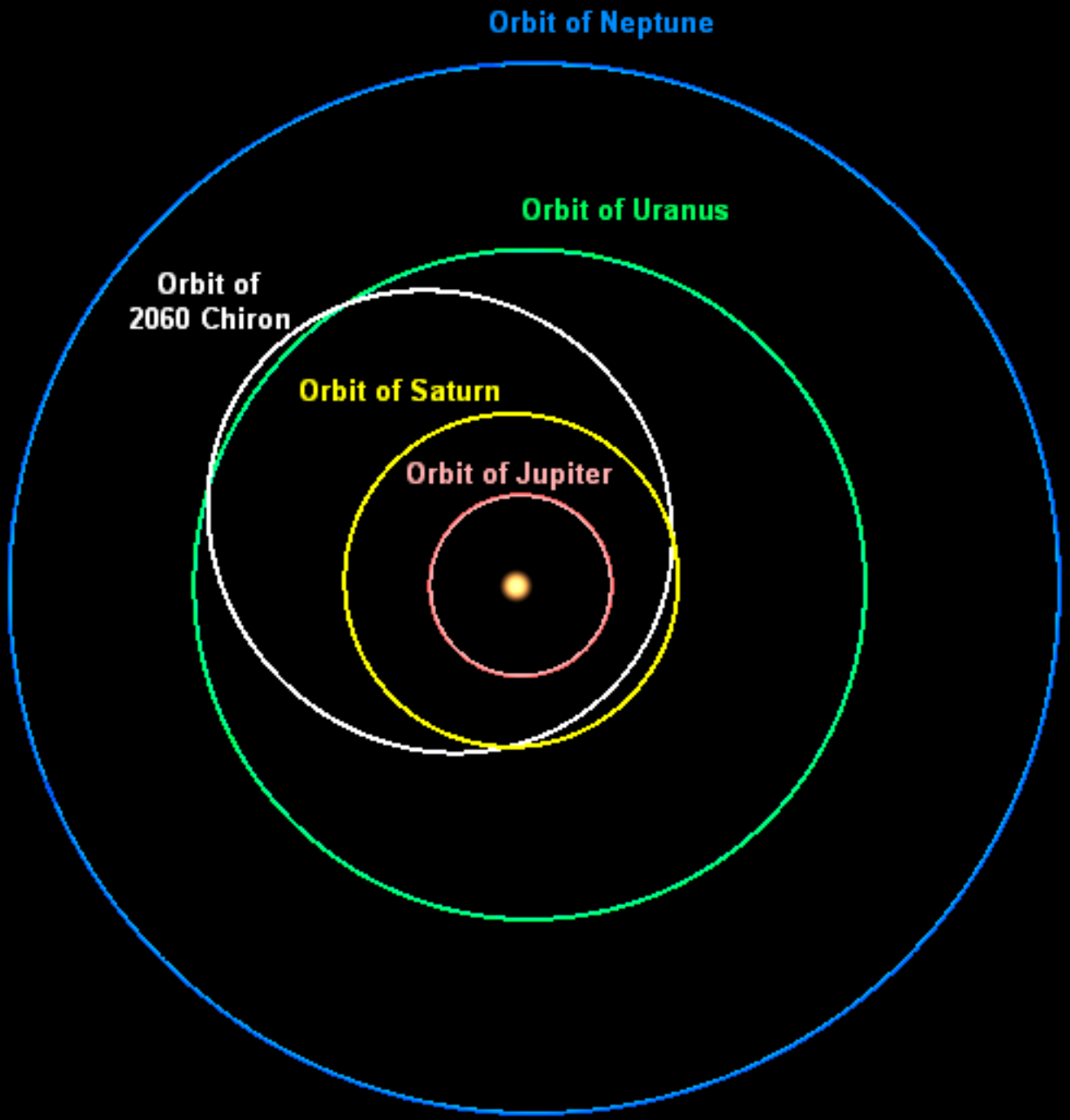
NASA / JPL



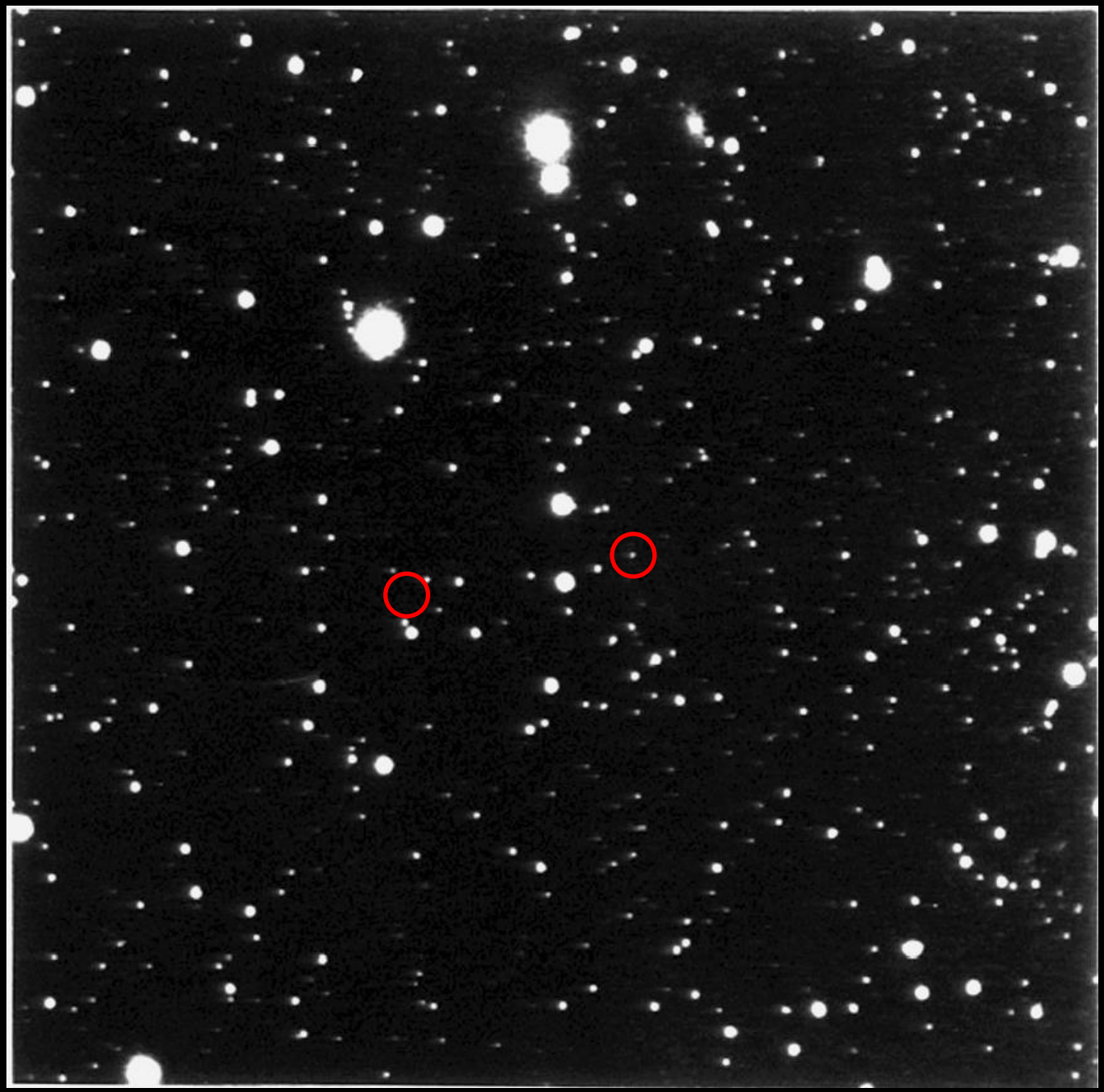
NASA / JPL

Trojans

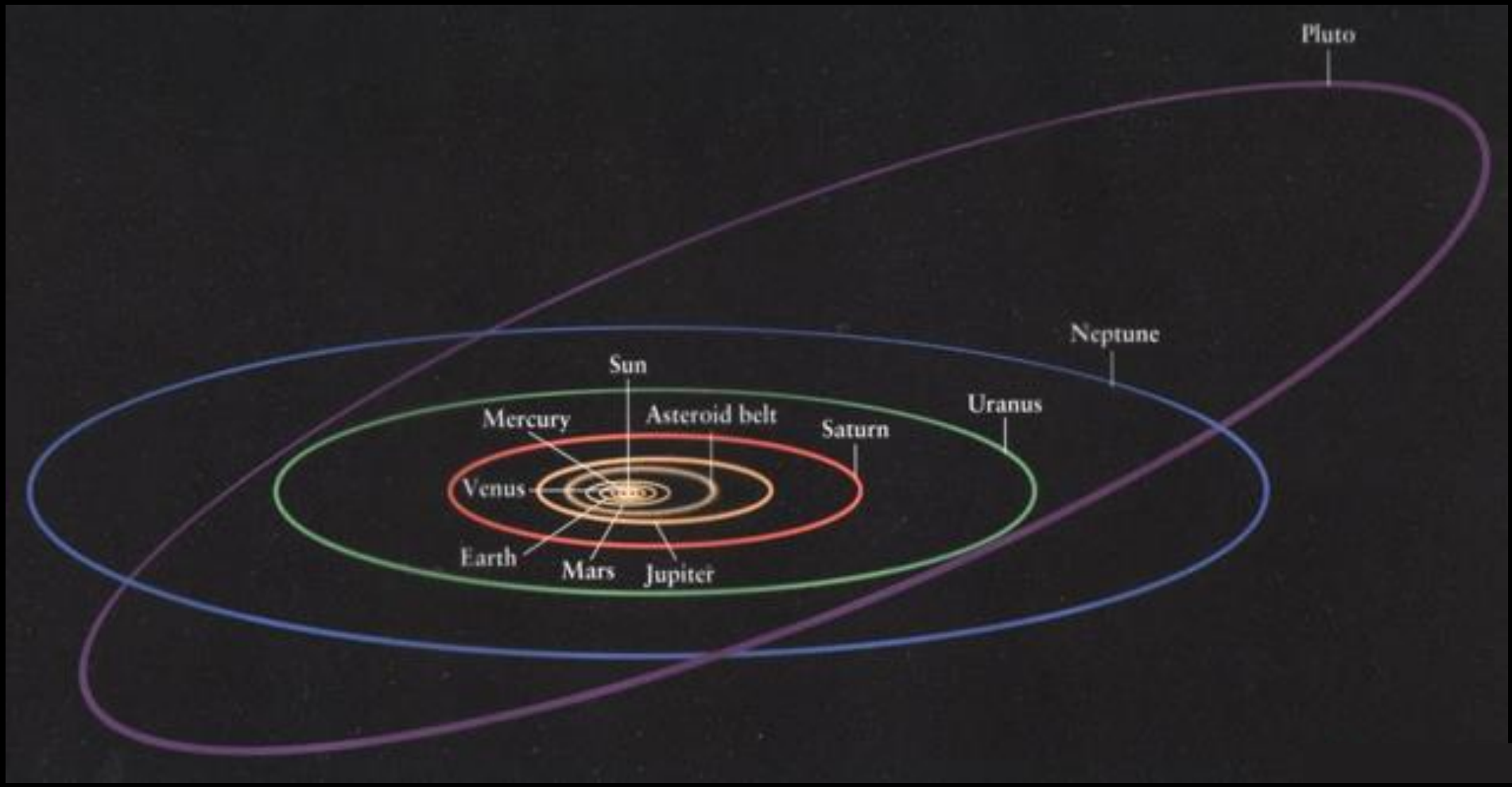


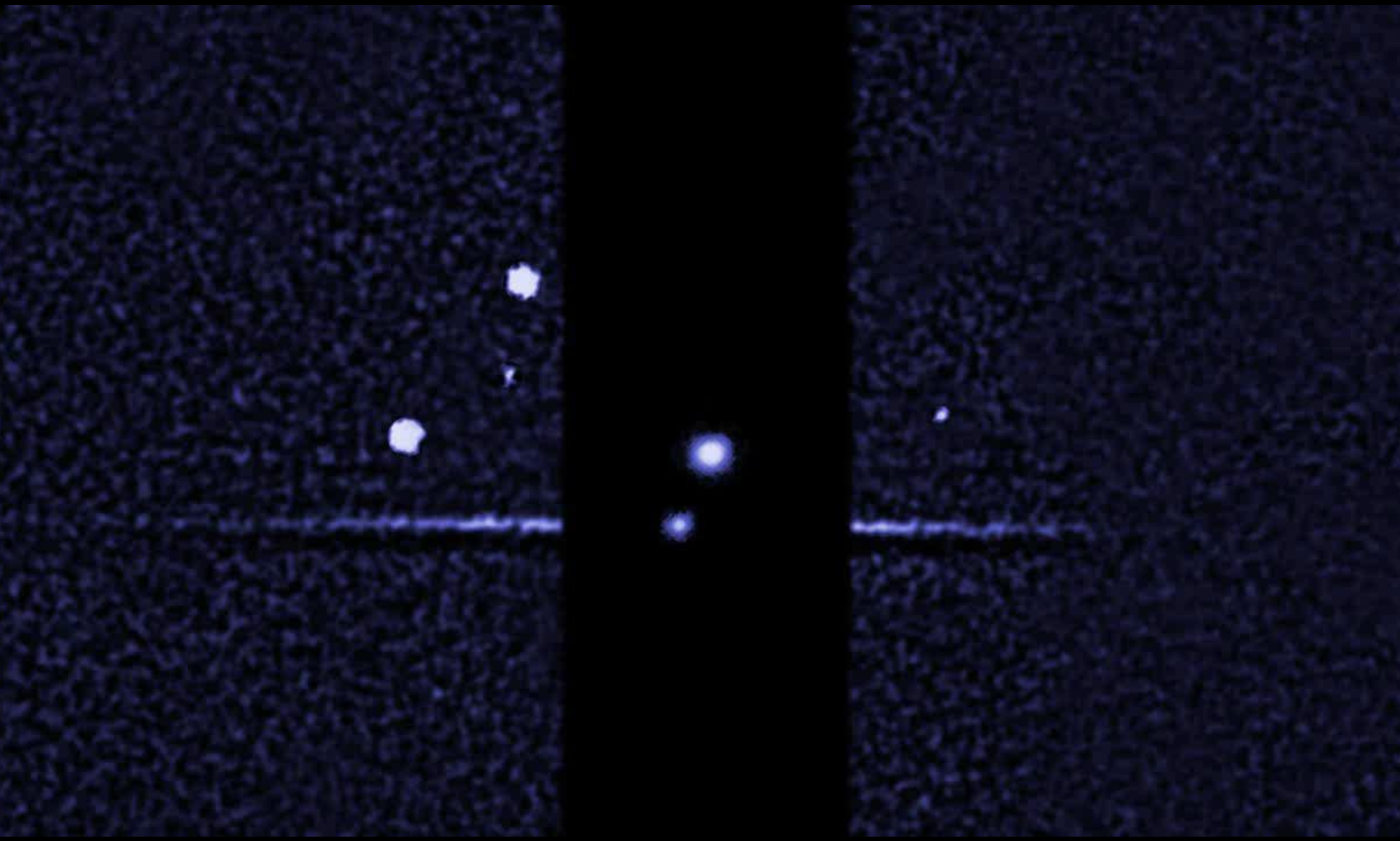

Orbit of Neptune
Orbit of Uranus
Orbit of
2060 Chiron
Orbit of Saturn
Orbit of Jupiter

Clyde Tombaugh

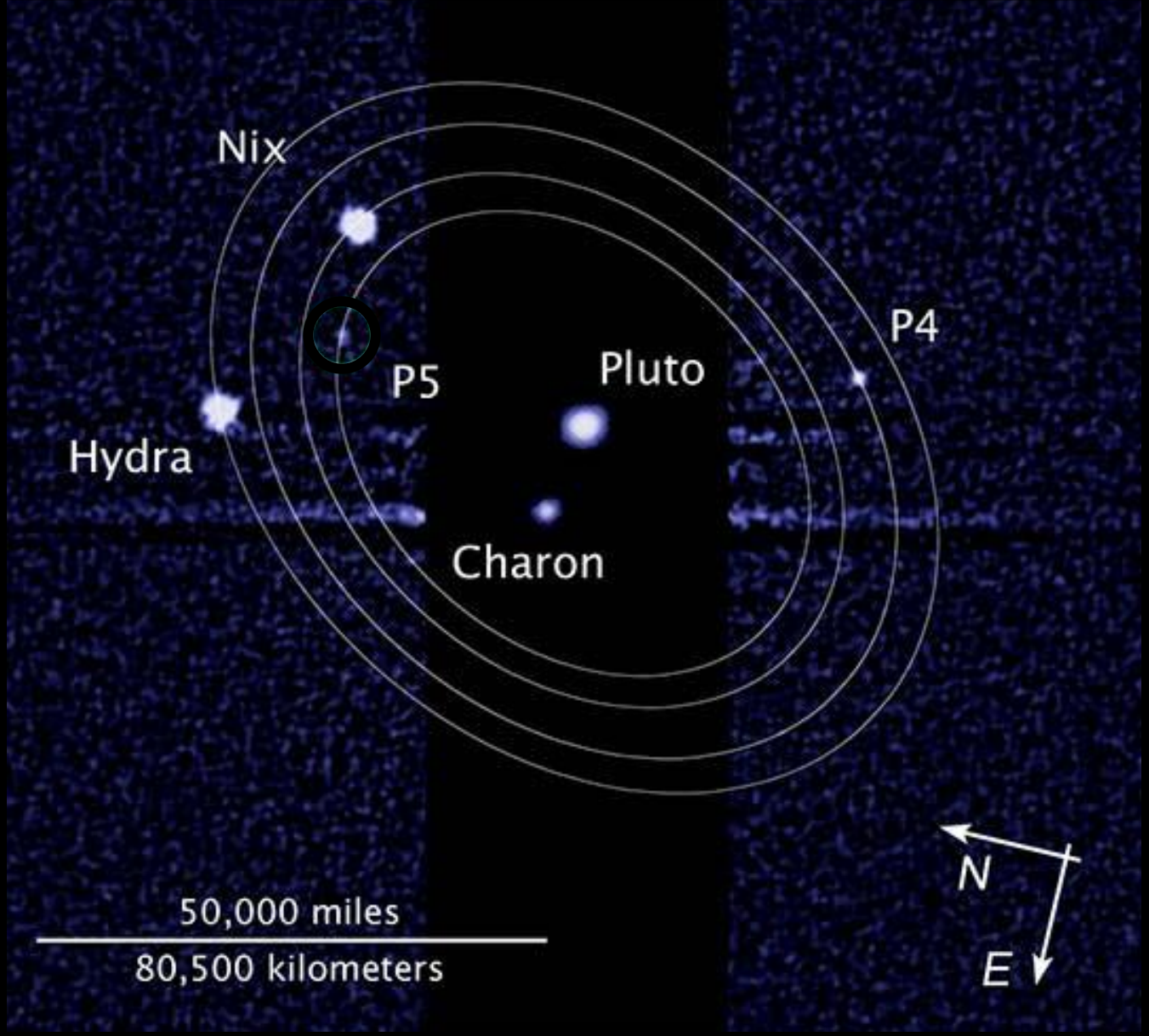


Lowell Observatory

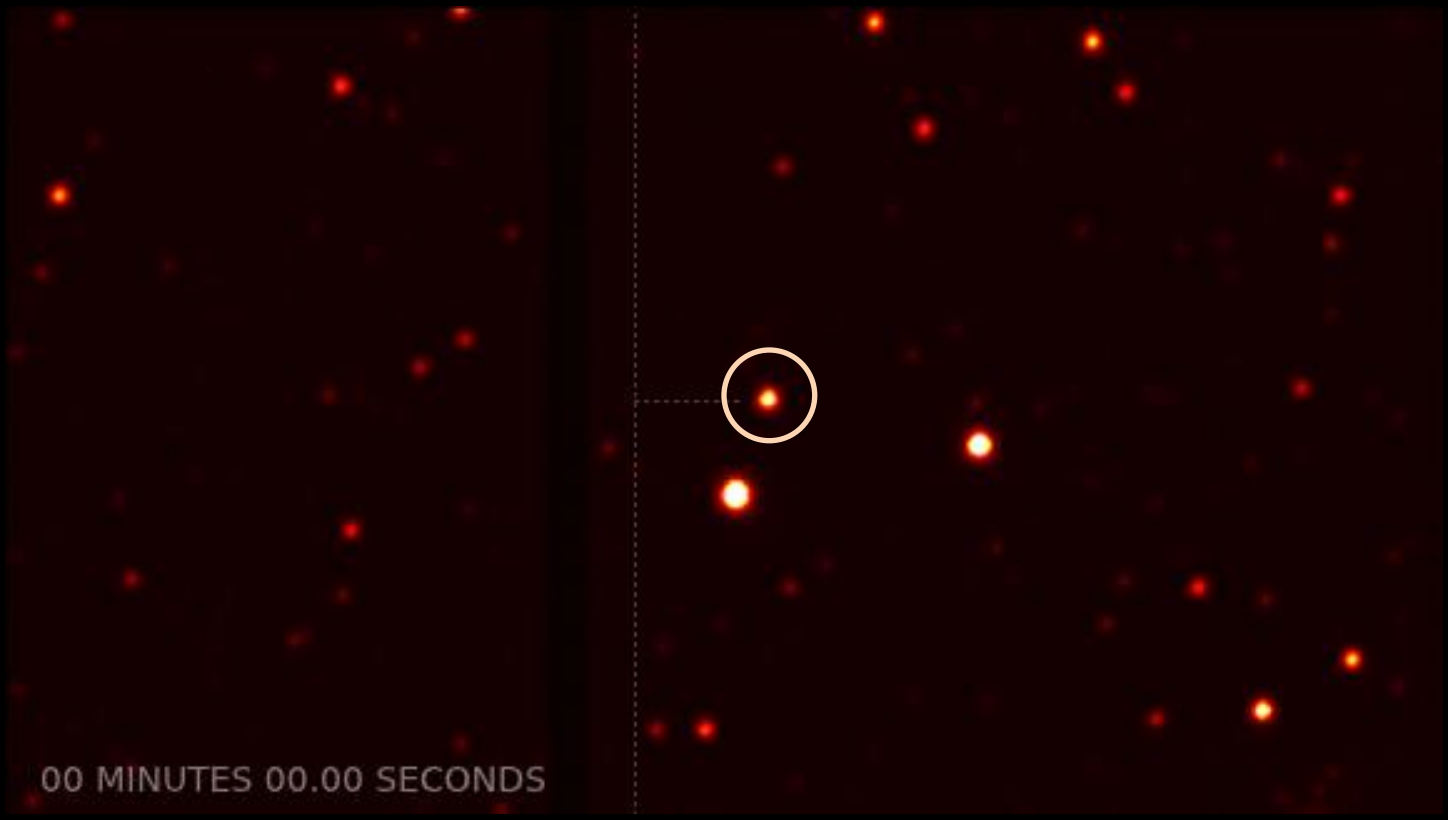

Pluto
Neptune
Sun
Uranus
Mercury
Asteroid belt
Saturn
Venus
Earth
Mars
Jupiter



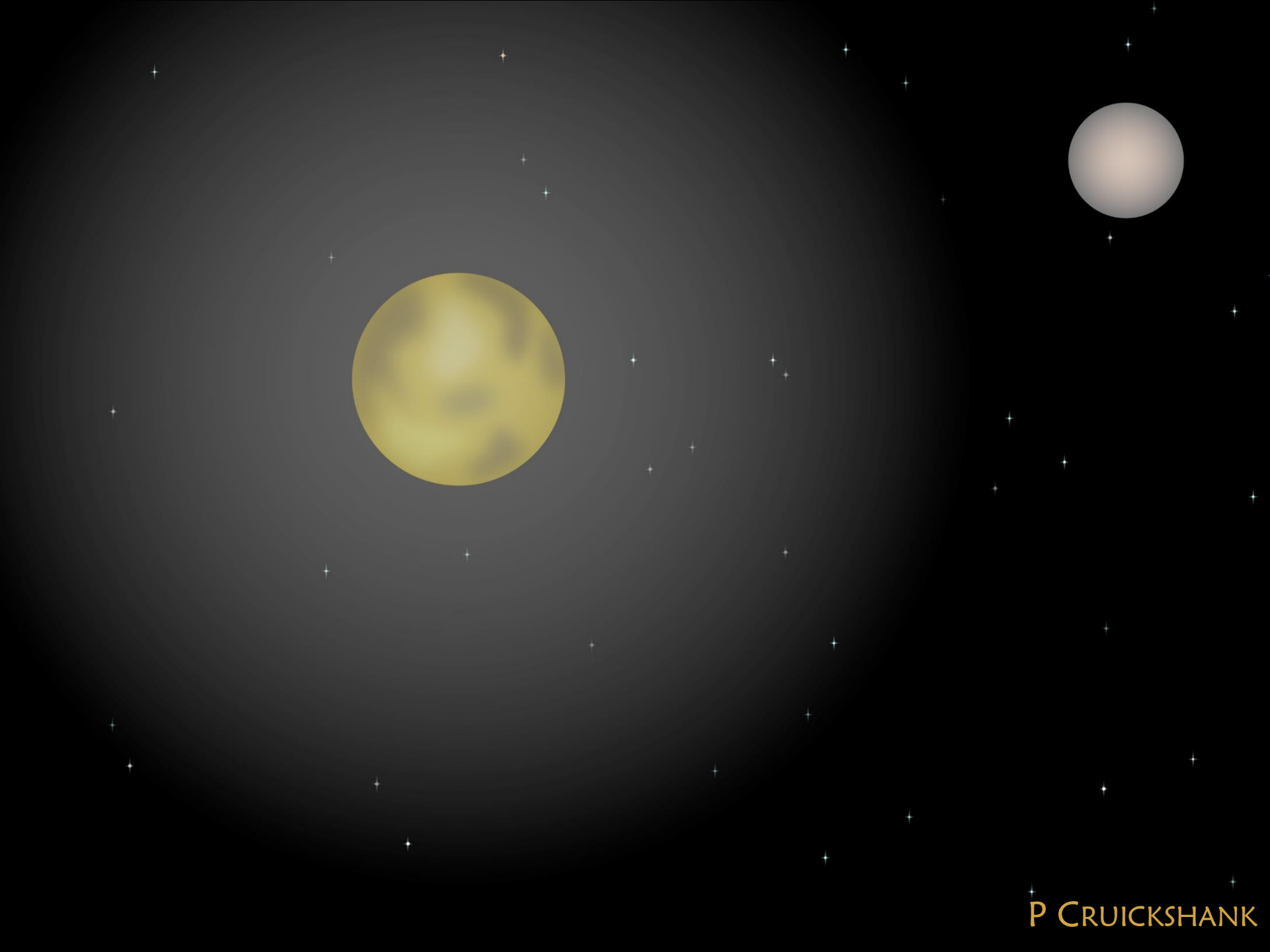
NASA / ESA / M Show

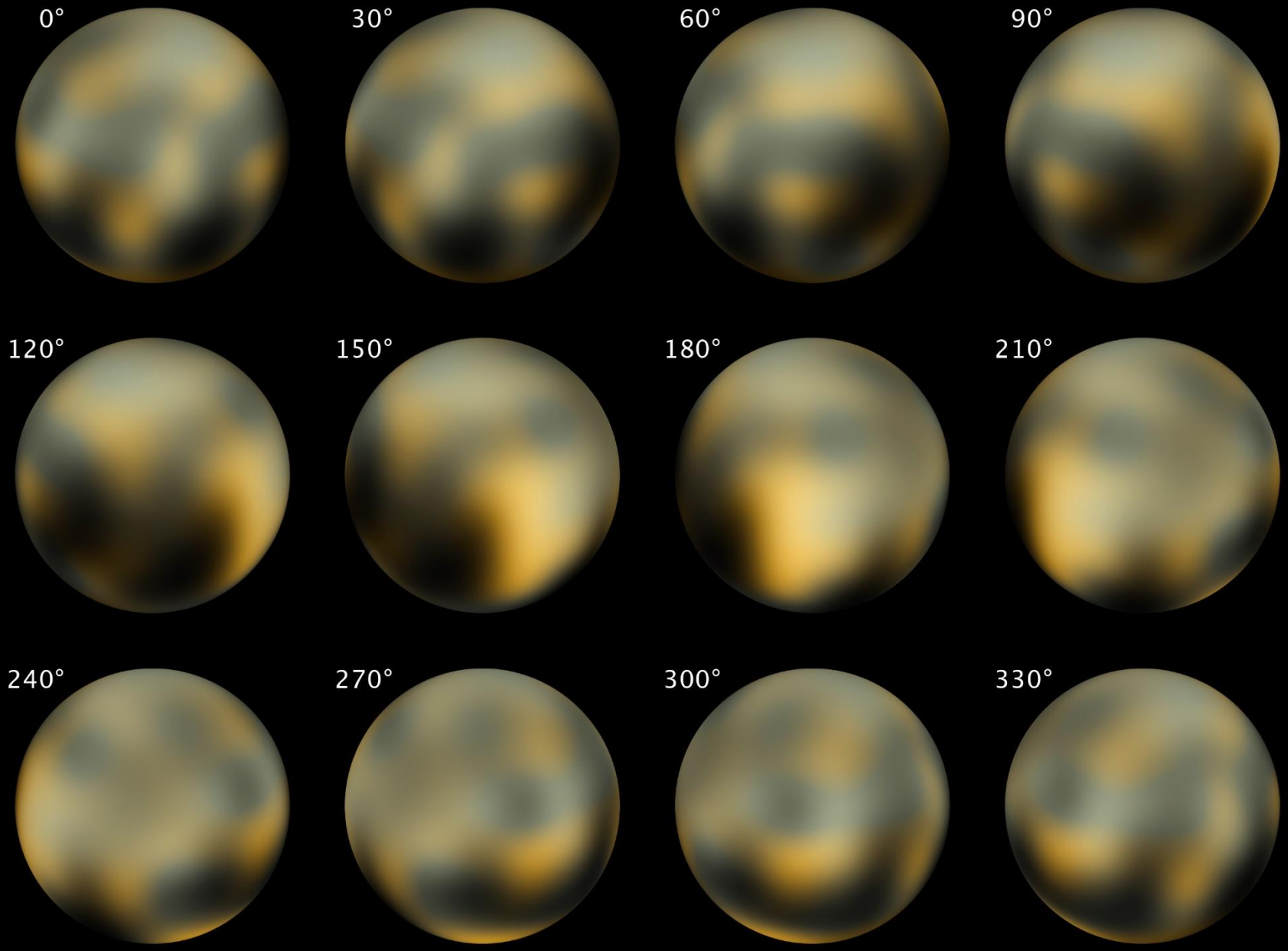


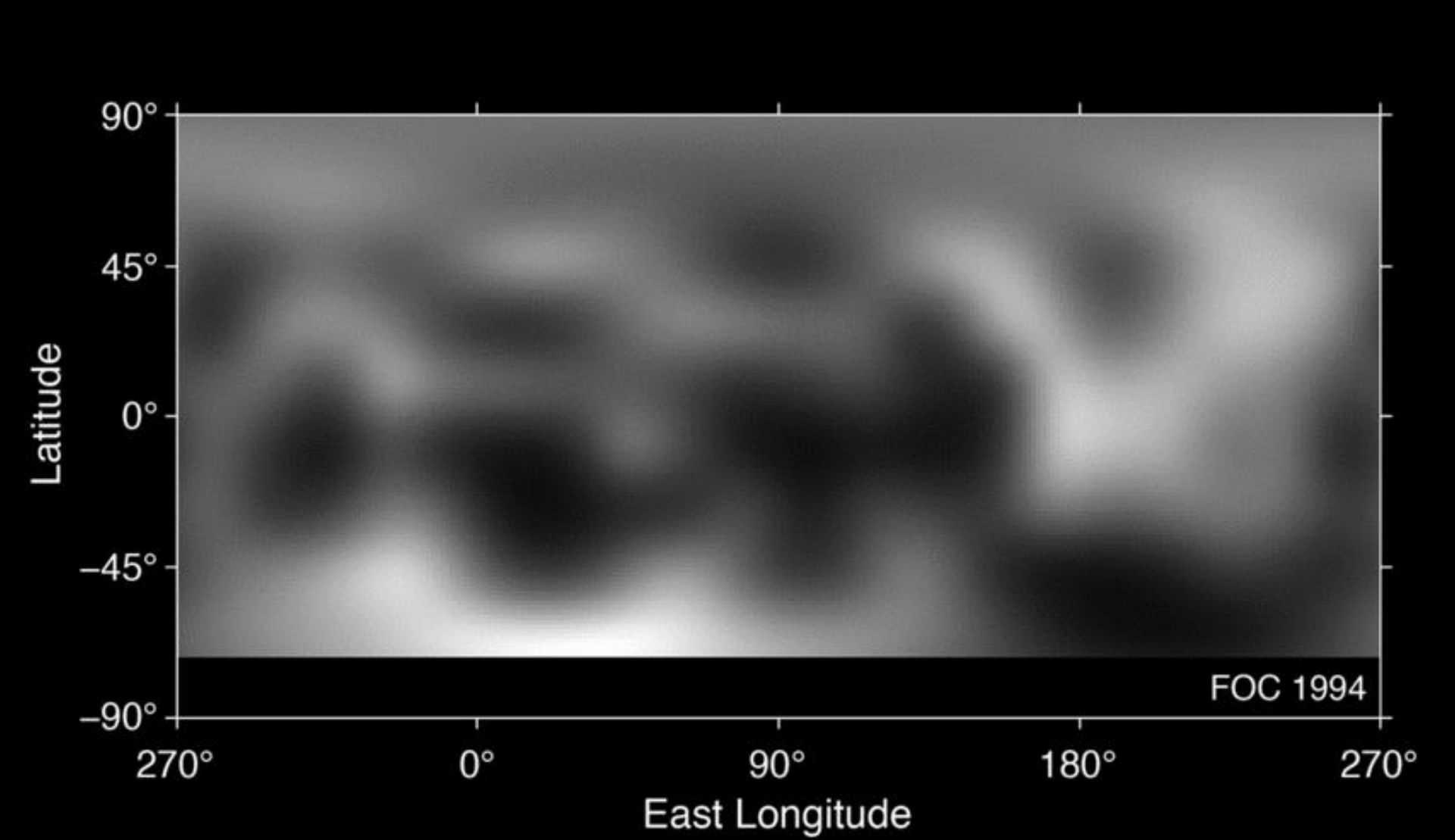
NASA / ESA / M Show



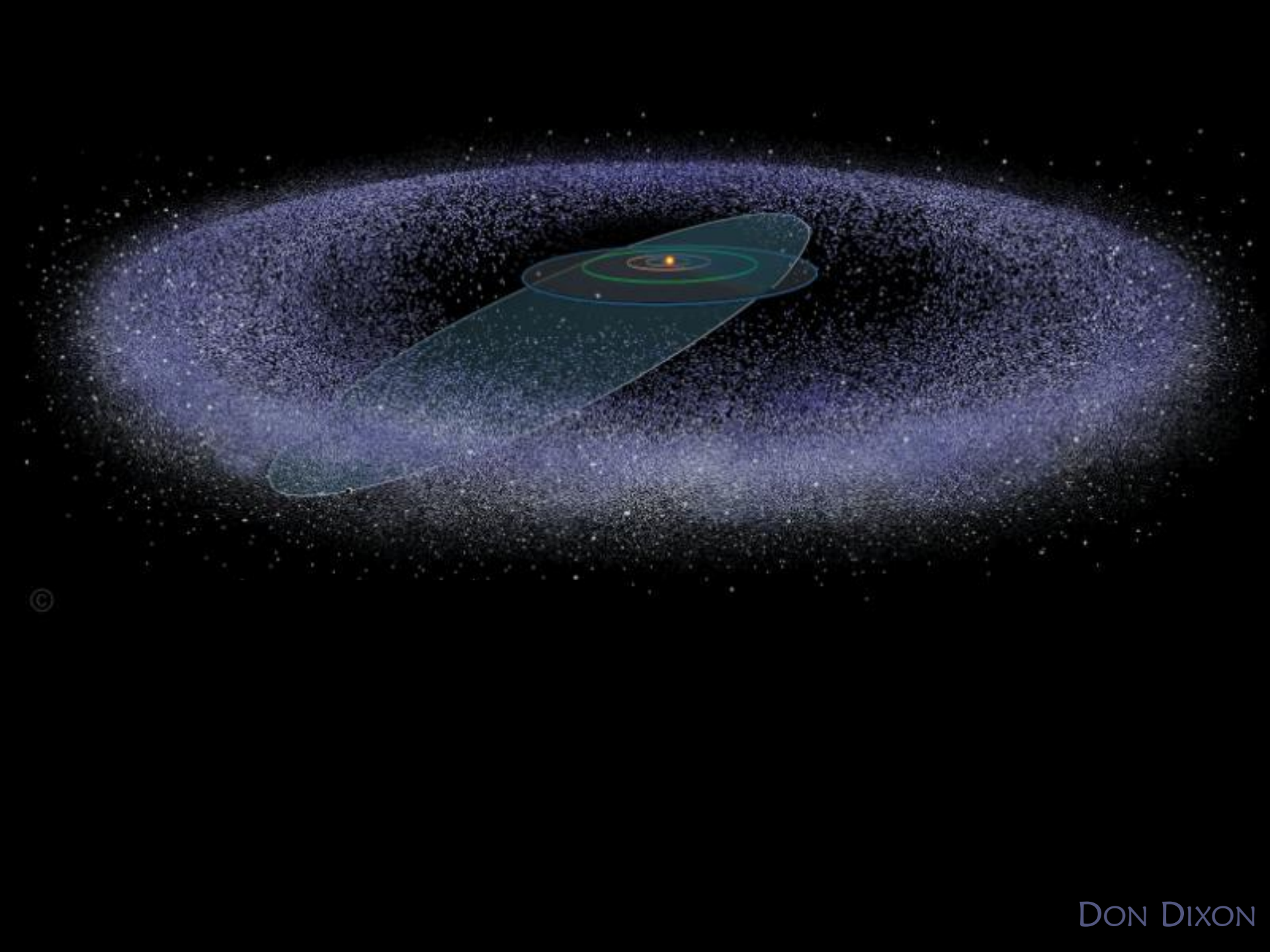
Alex Parker

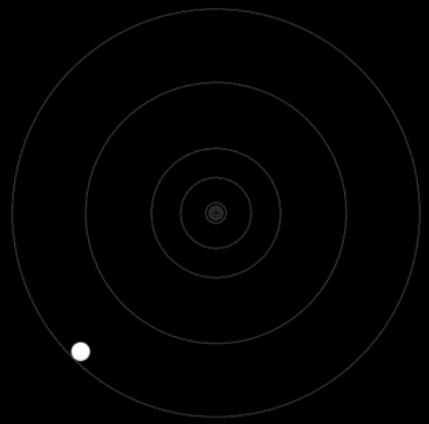

P Cruickshank


0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
NASA / HST



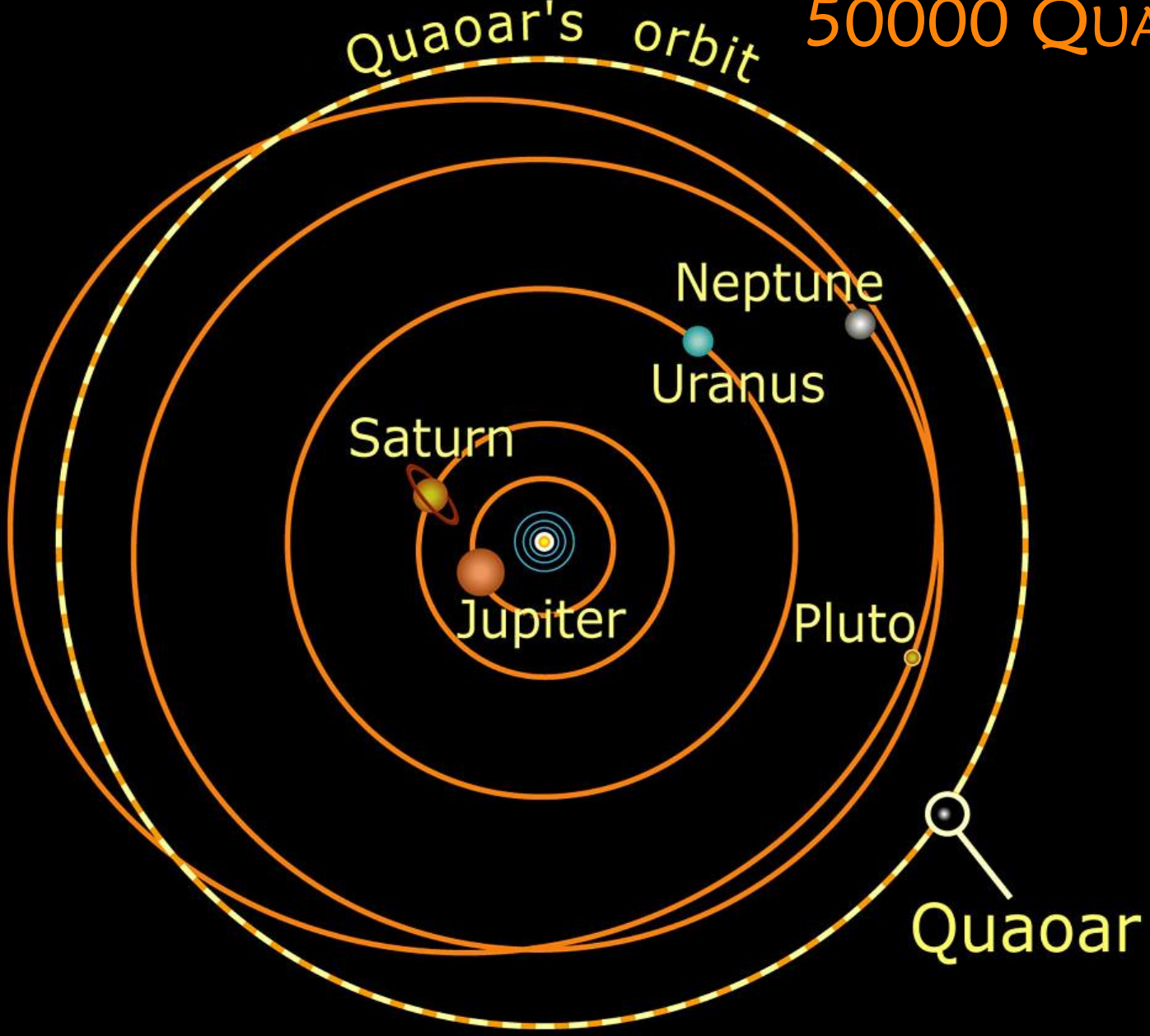
NASA / HST / M Buie (SwRI)


©
Don Dixon

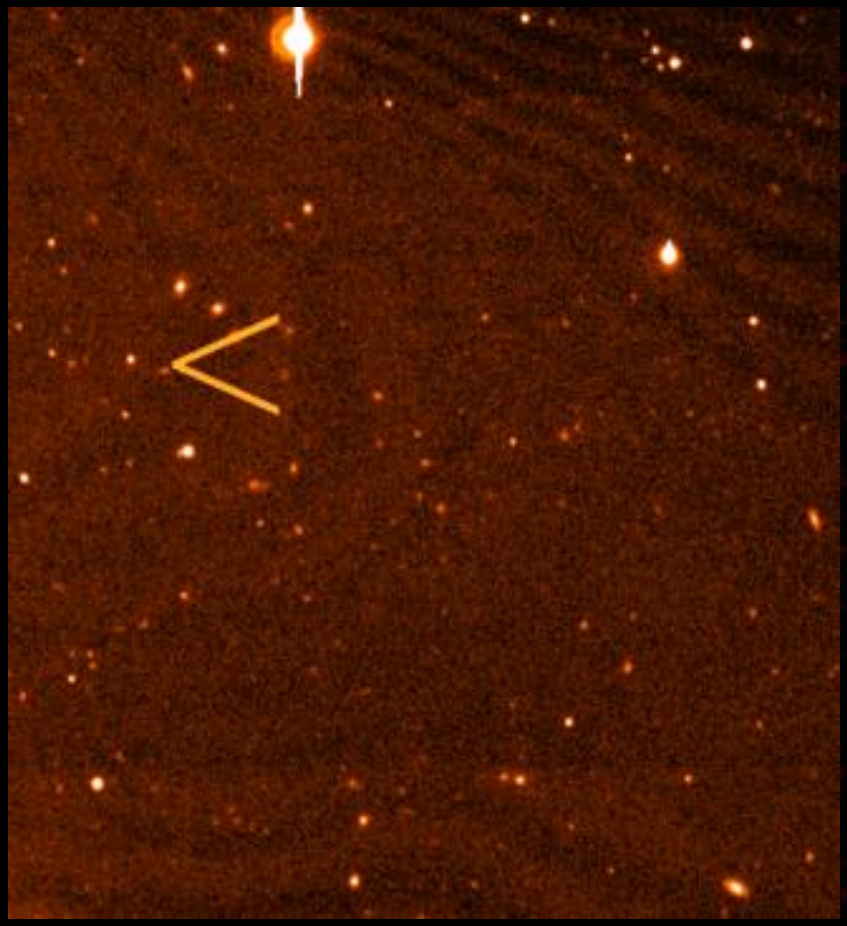


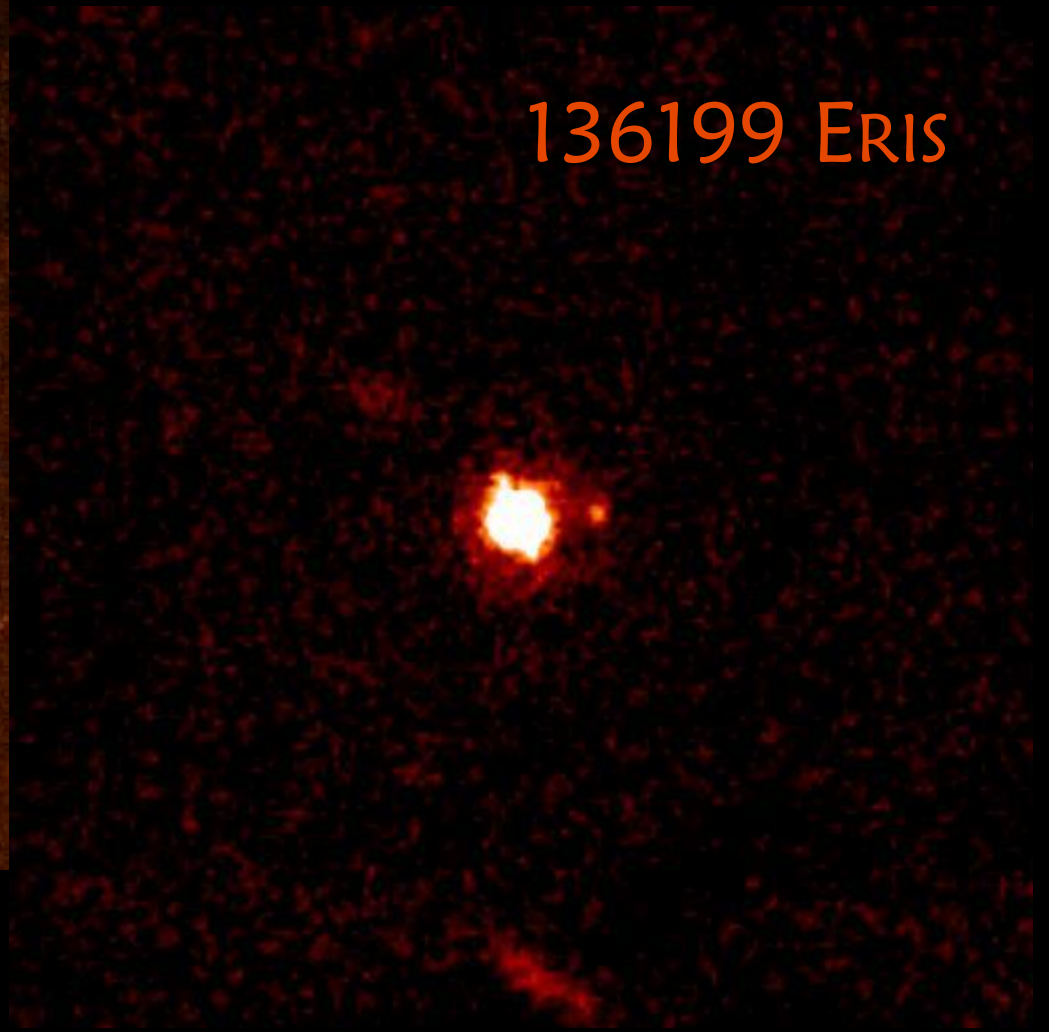
1990.0

50000 Quaoar



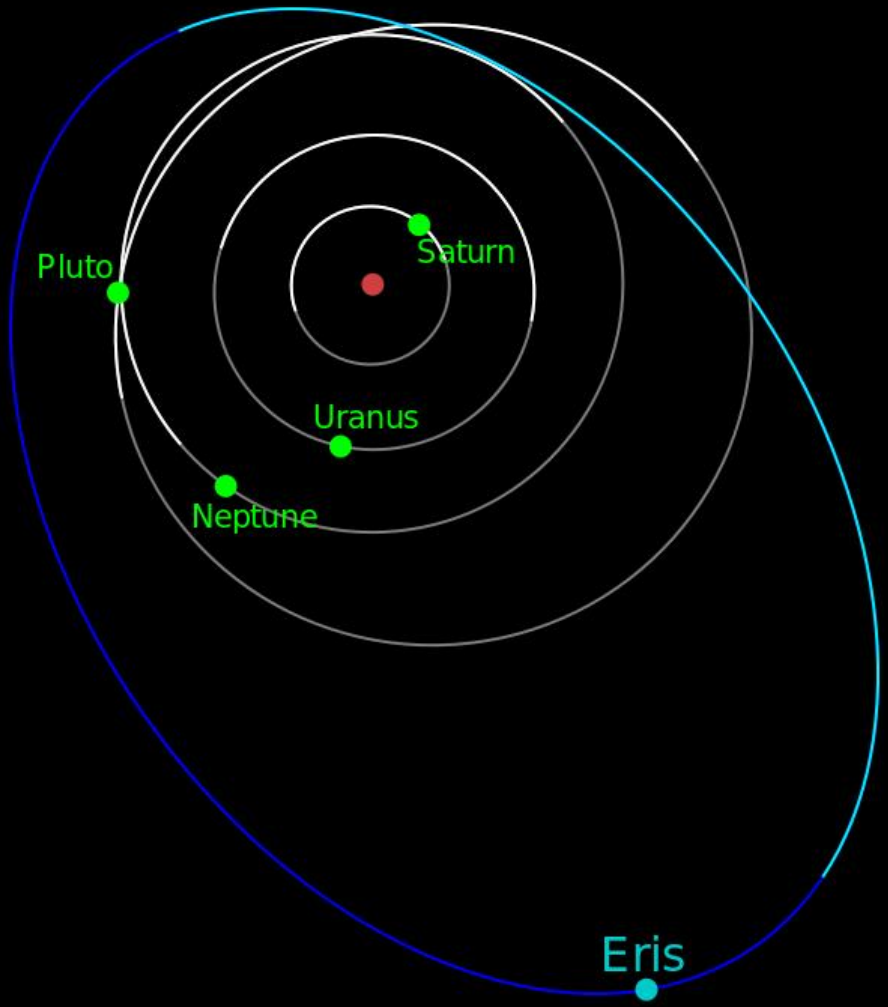
NASA/ESA & A Field (STScI)

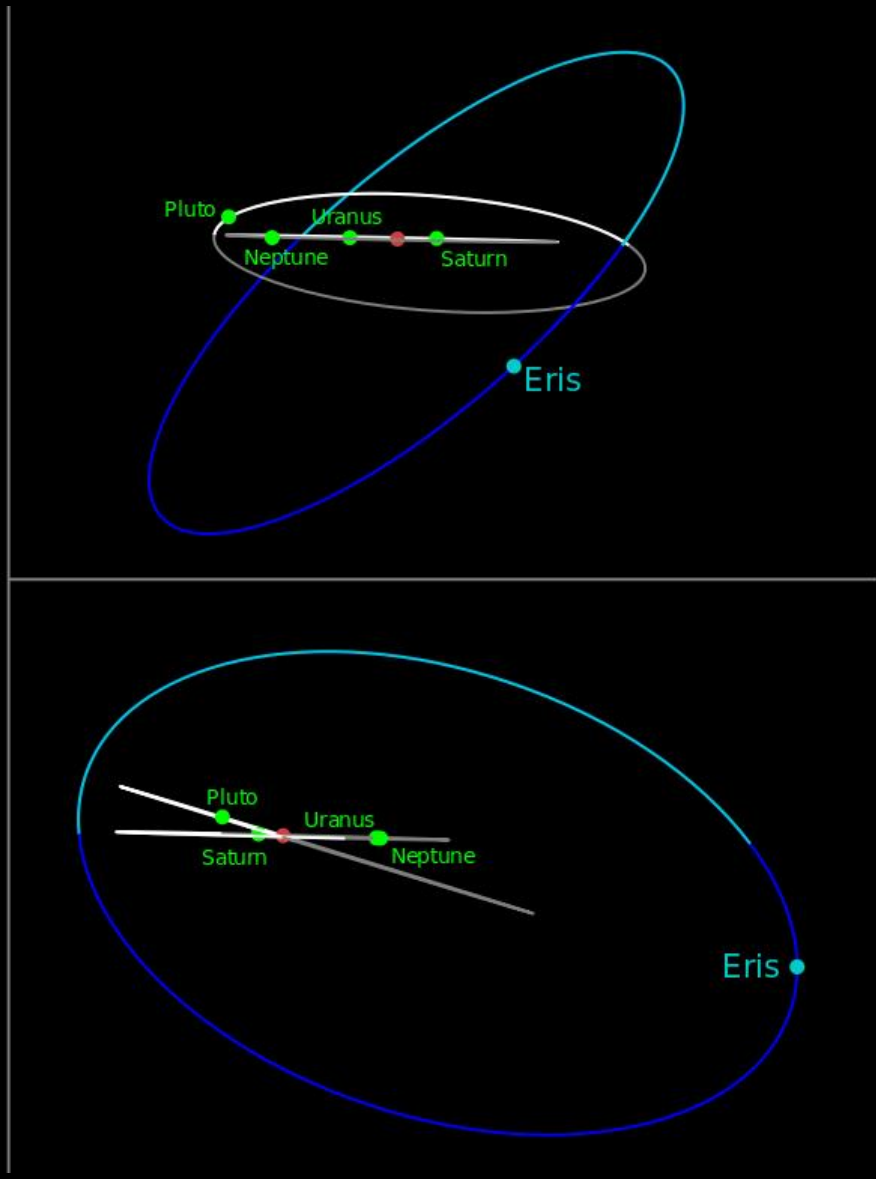




136199 Eris

M Brown et al

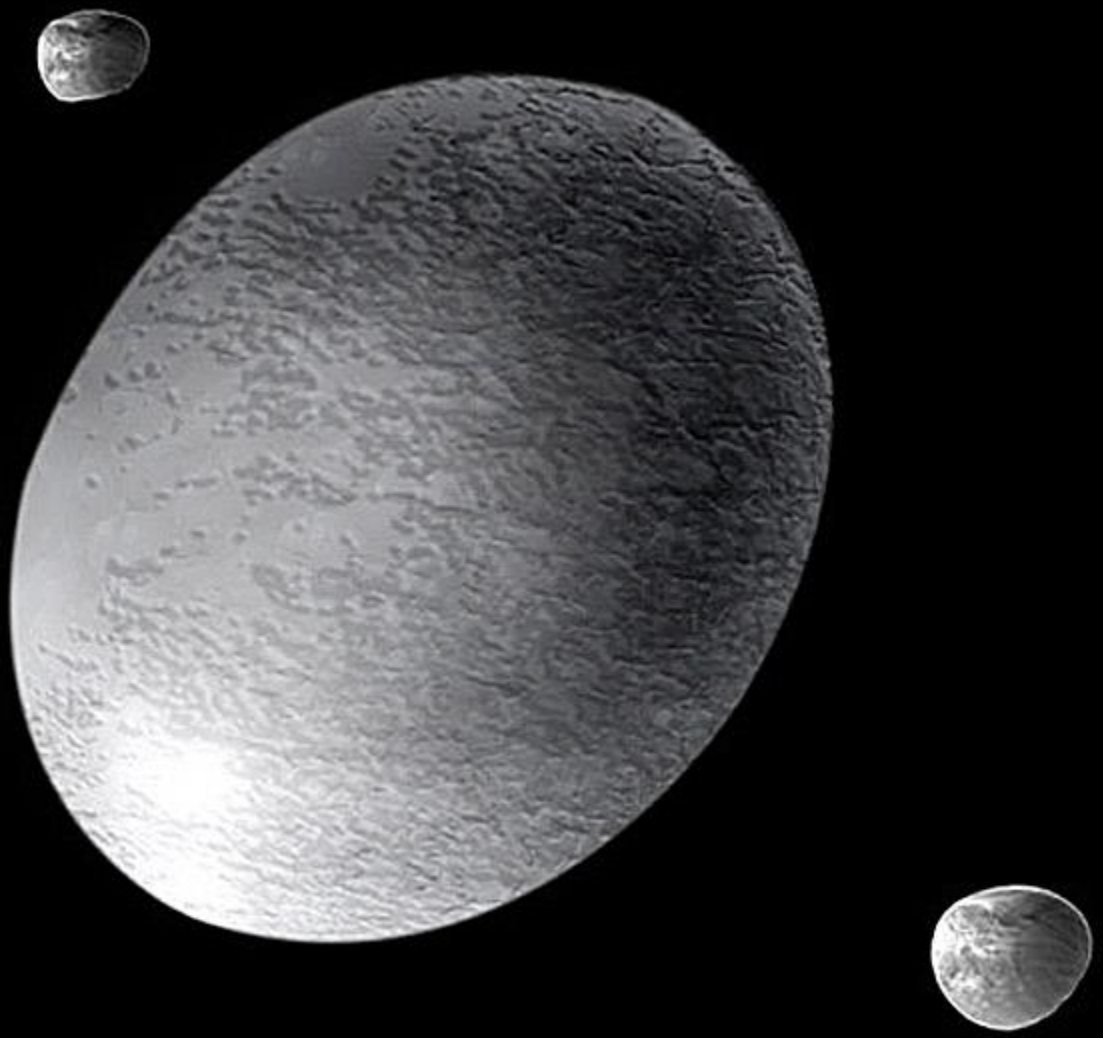

Pluto
Saturn
Uranus
Neptune
Eris


Pluto
Uranus
Neptune
Saturn
Eris
Pluto
Uranus
Saturn
Neptune
Eris


136199 Eris
R Hurt (IPAC)

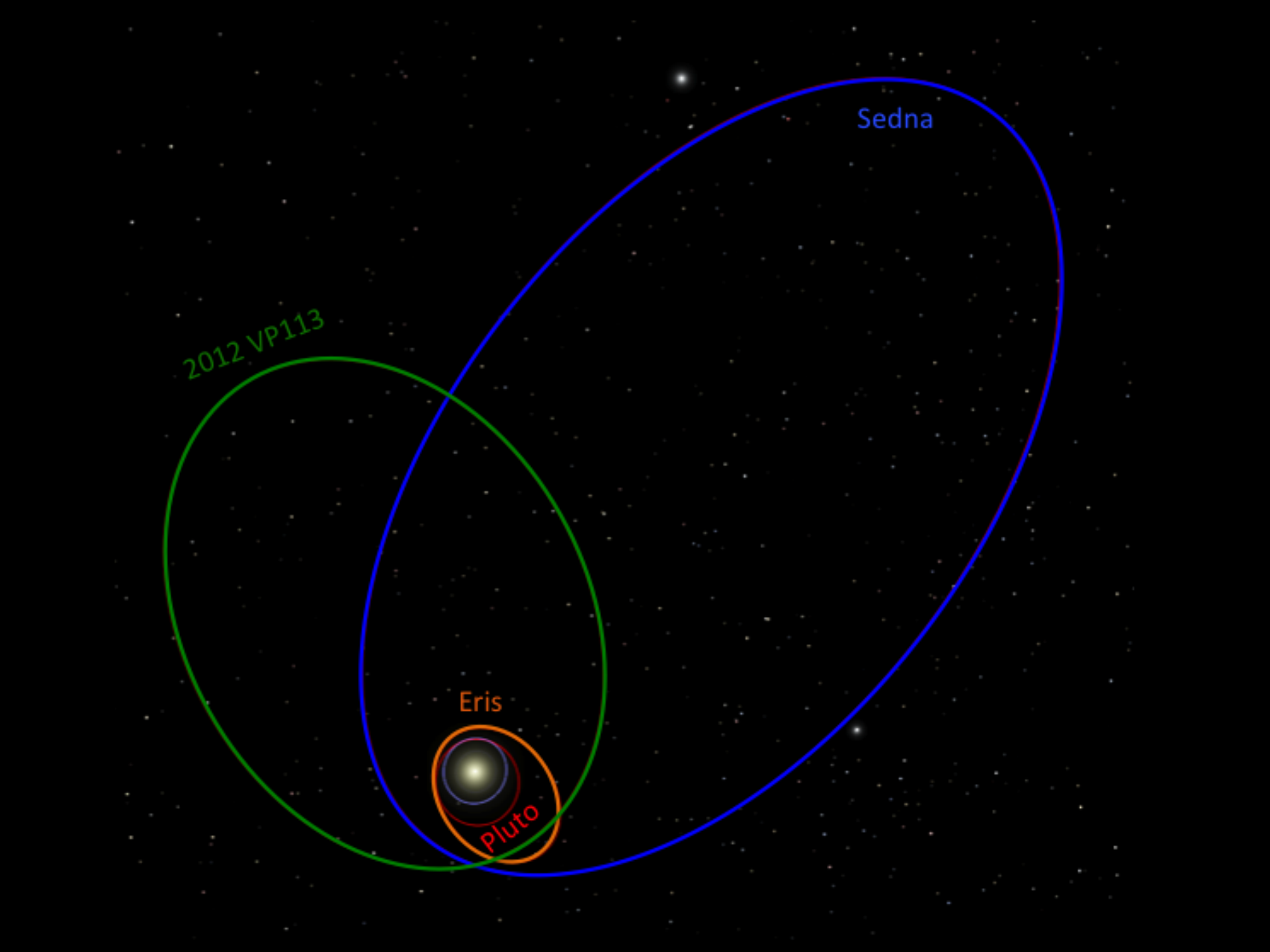

Dysnomia
Eris
Moon
Charon
Ceres
Earth
Pluto
NASA

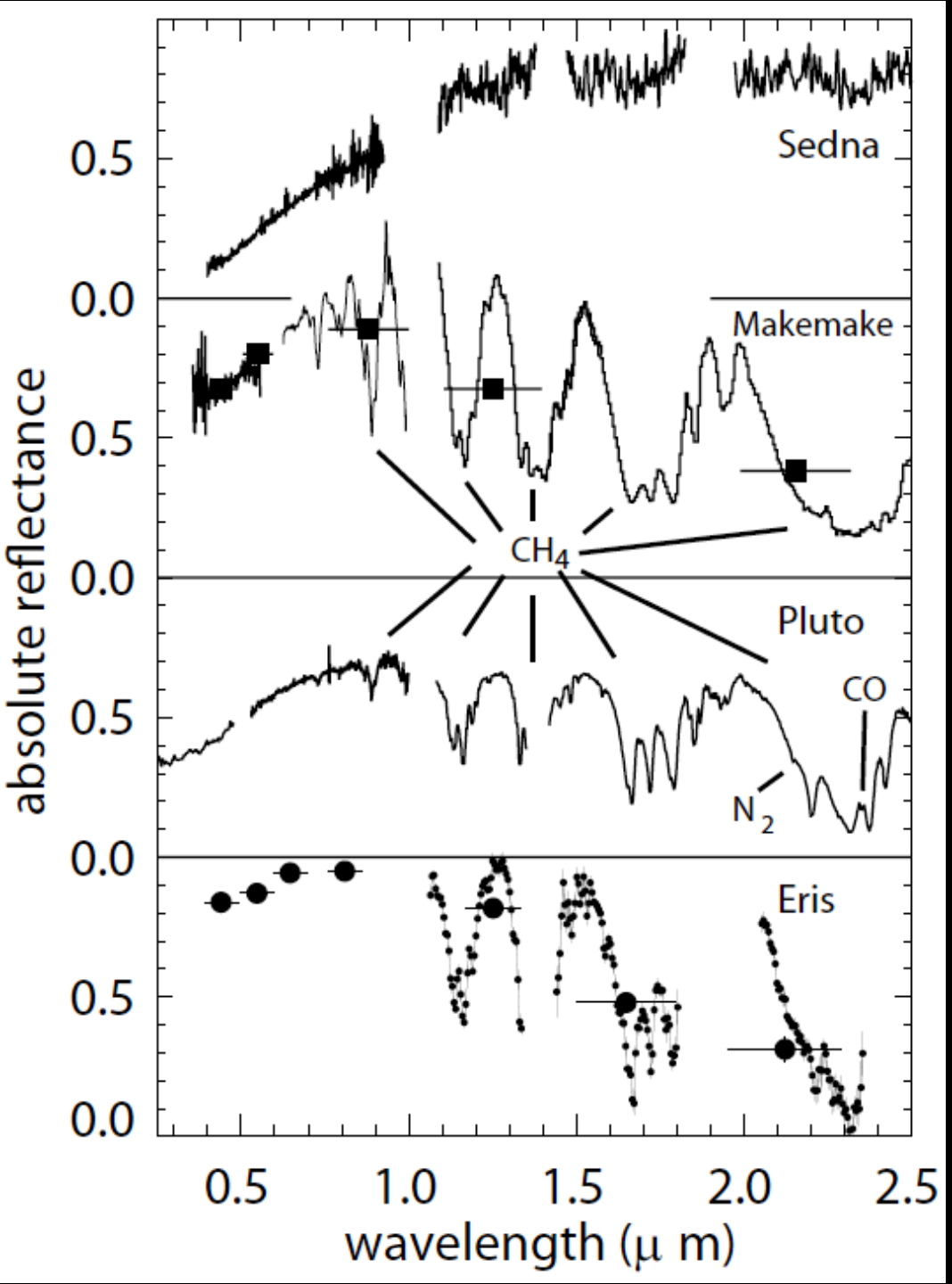
136108 Haumea



NASA


90377 Sedna
NASA / JPL-Caltech / R Hurt

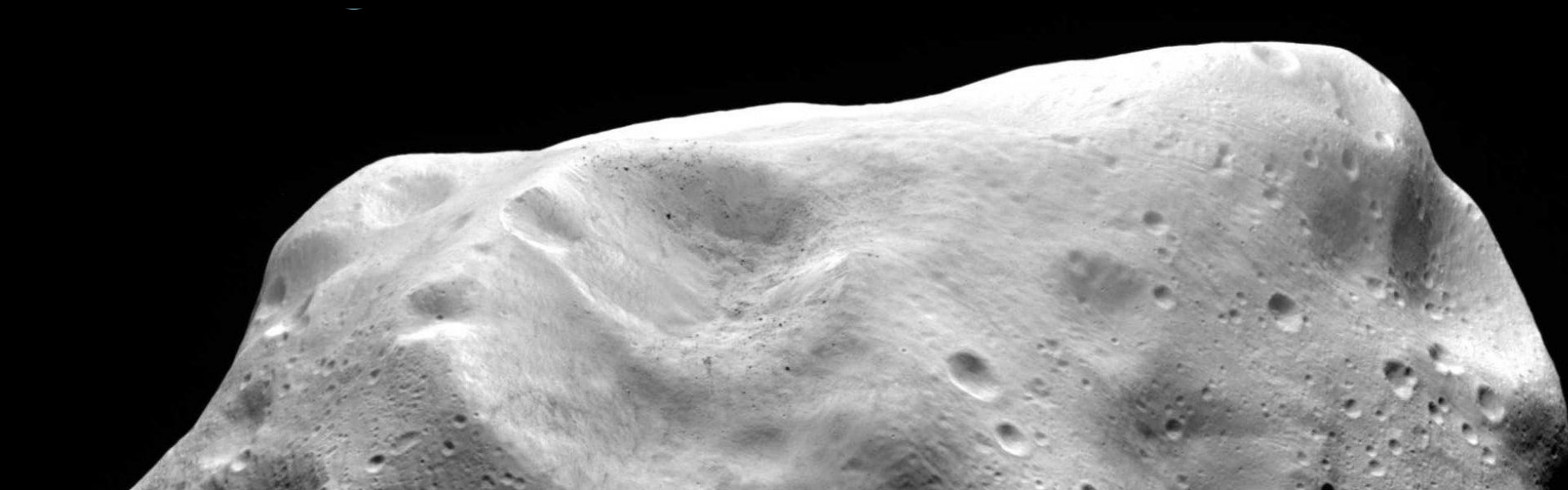

Sedna
2012 VP113
Eris
Pluto

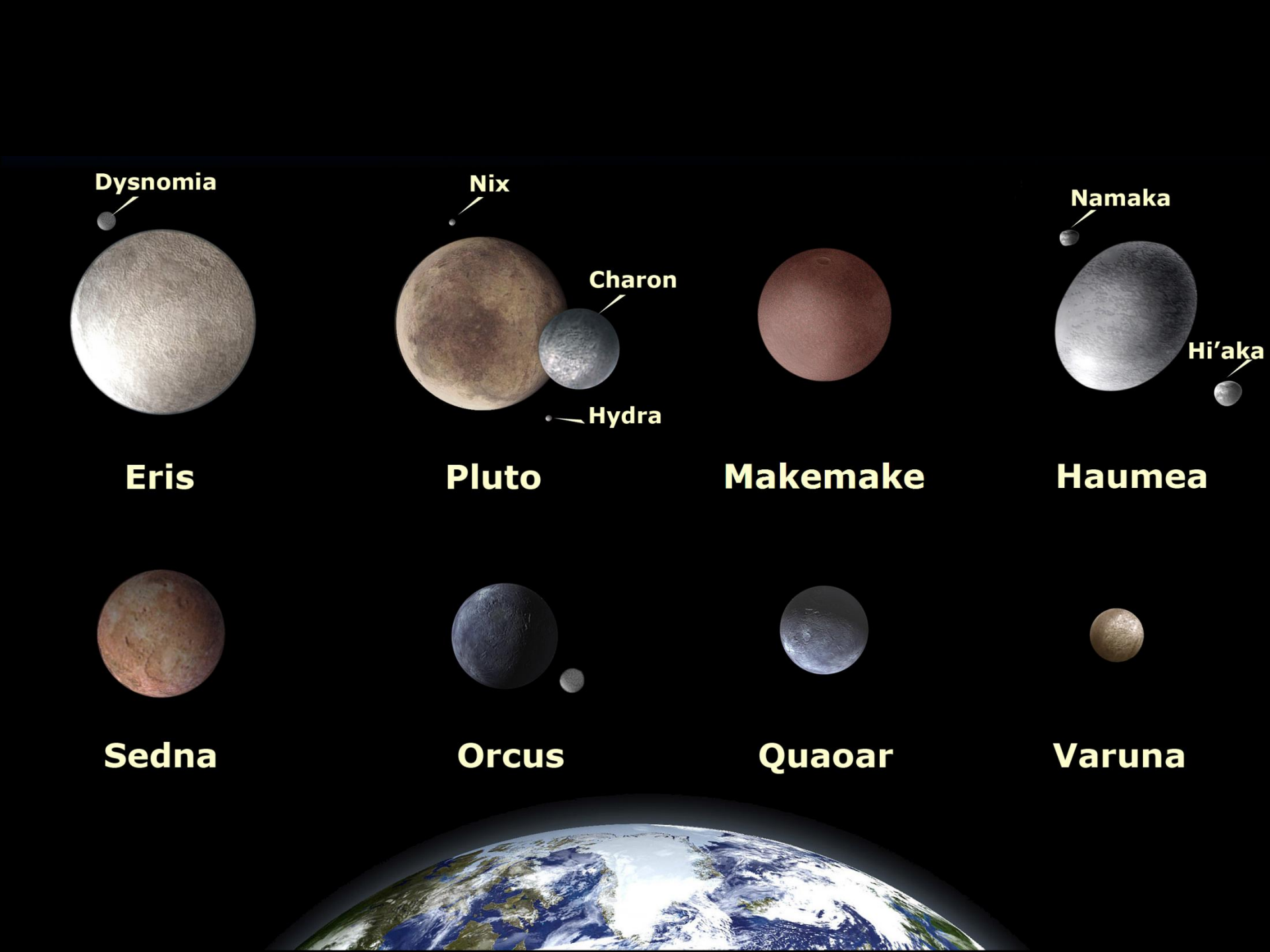

Sedna
Makemake
CH4
Pluto
CO
N2
Eris
absolute reflectance
0.5
0.0
0.5
0.0
0.5
0.0
0.5
0.0
0.5
1.0
1.5
2.0
2.5
wavelength (μ m)

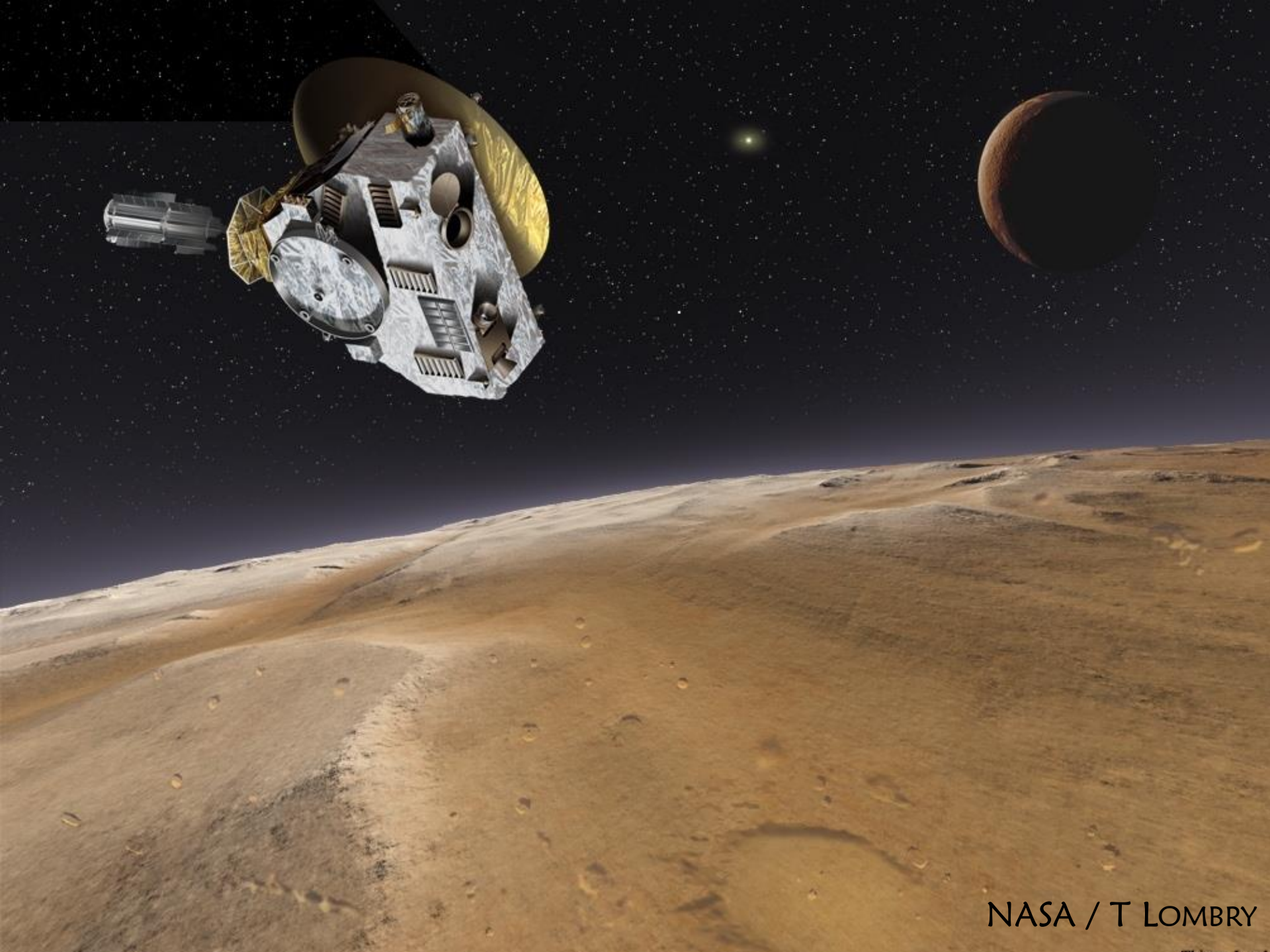
M Brown et al

Definition of a planet

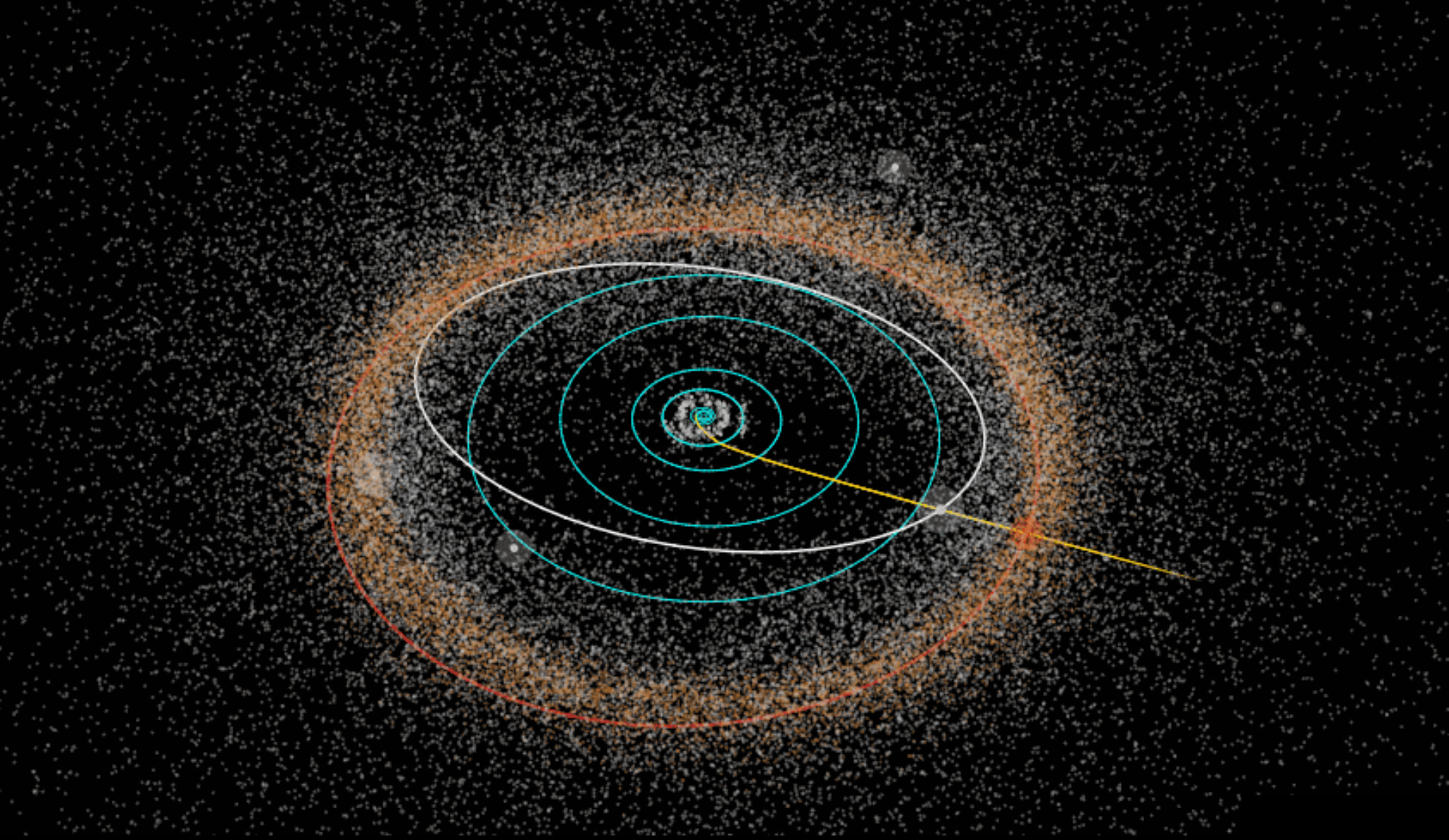
Anything in orbit about the Sun…



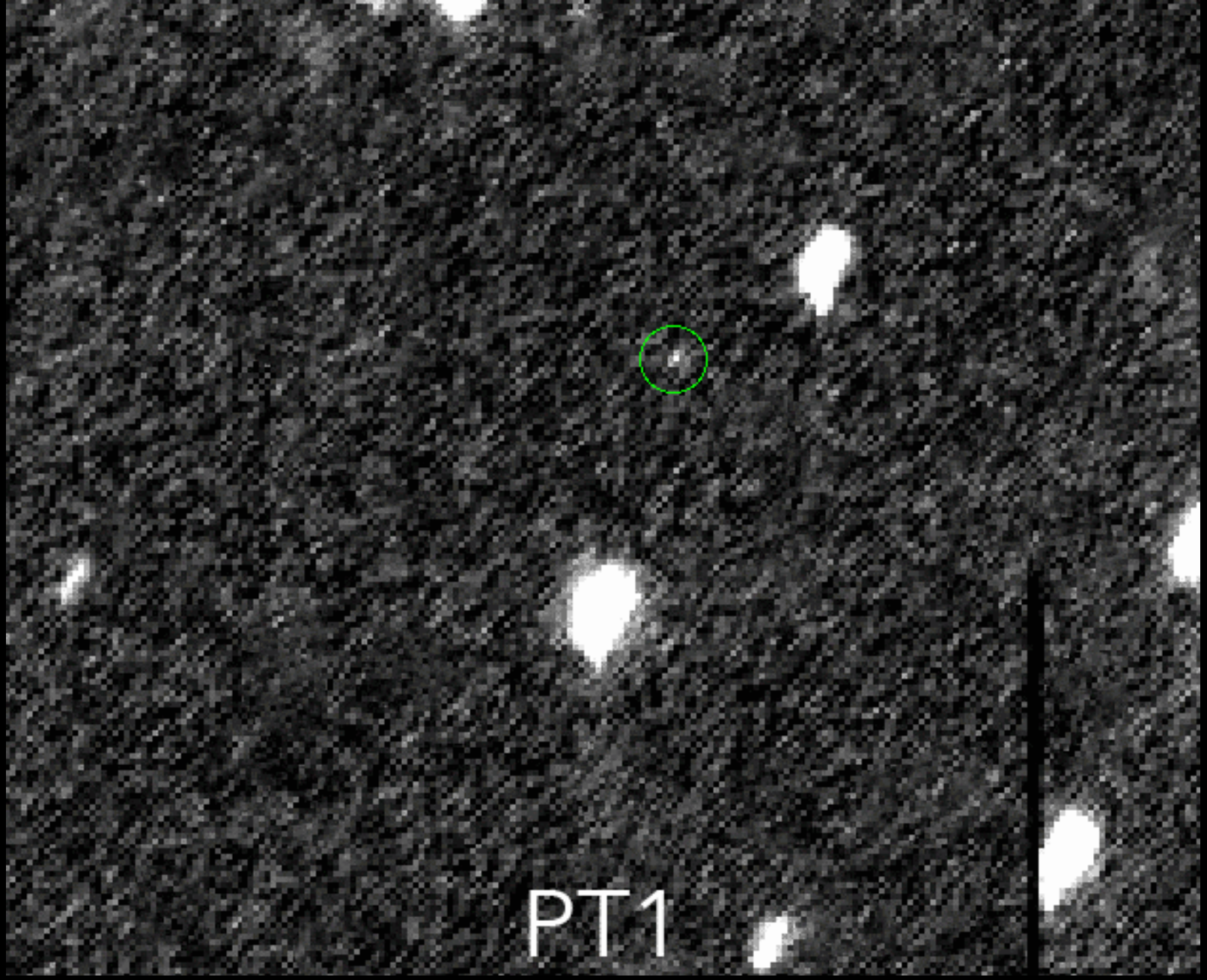

Dysnomia
Eris
Nix
Charon
Hydra
Pluto
Makemake
Namaka
Hi'aka
Haumea
Sedna
Orcus
Quaoar
Varuna


NASA / T Lombry

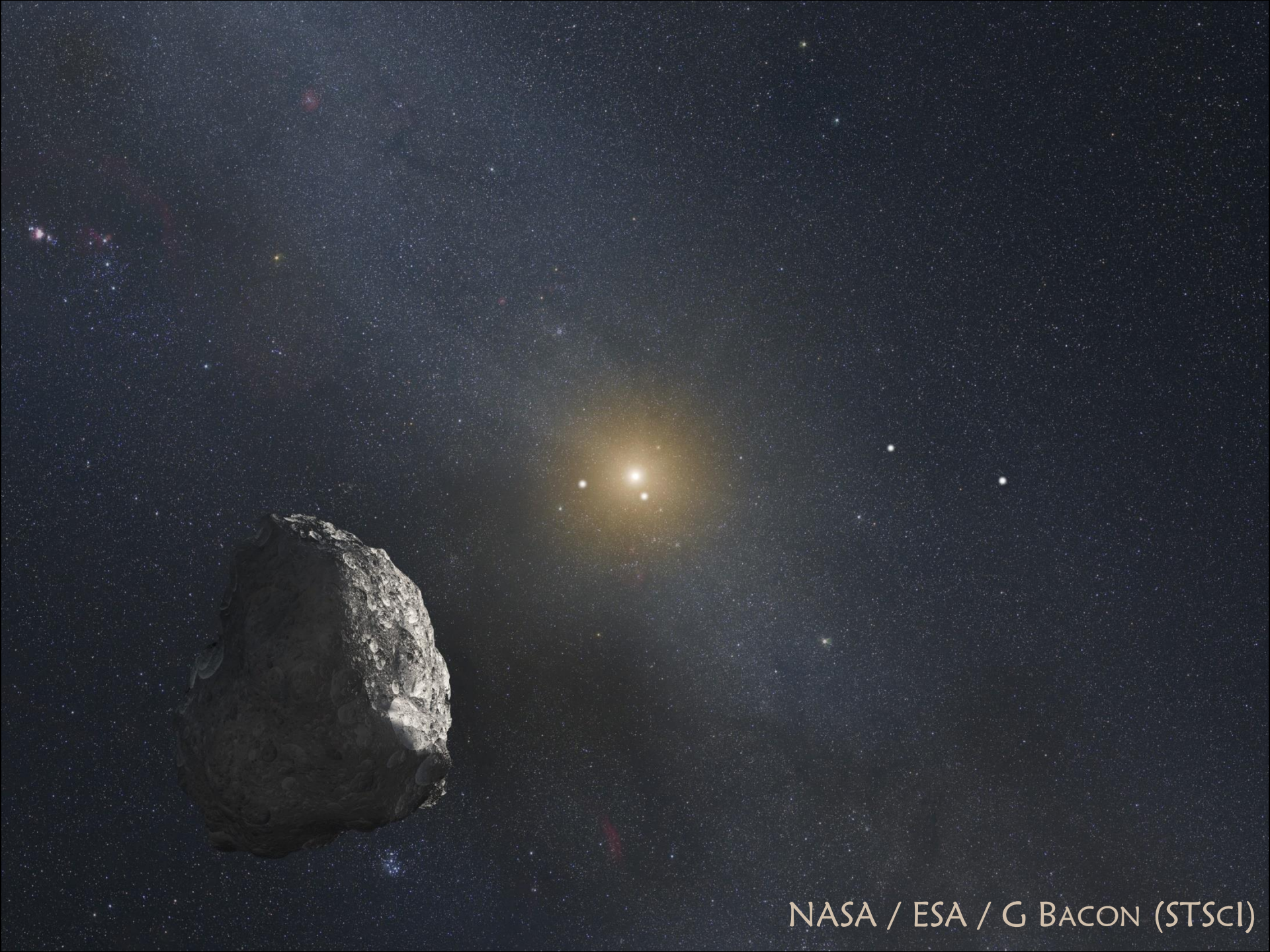
NASA/APL/SW Research Institute



Alex Parker



NASA/ESA/APL/SwRI/JHU


NASA / ESA / G Bacon (STScI)


The next big questions...
1st April 1pm