

Istituto Nazionale di Astrofisica

Osservatorio astronomico di Brera

INAF ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Universo in fiore

Il Sistema Solare: origini e caratteristiche

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4 dicembre 2018

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1. Le leggi del moto dei pianeti
2. La struttura del Sistema Solare
3. La formazione del Sistema Solare
4. Un’occhiata al Sistema Solare

1

Le leggi del moto dei pianeti



Tycho Brahe
(1546-1601)

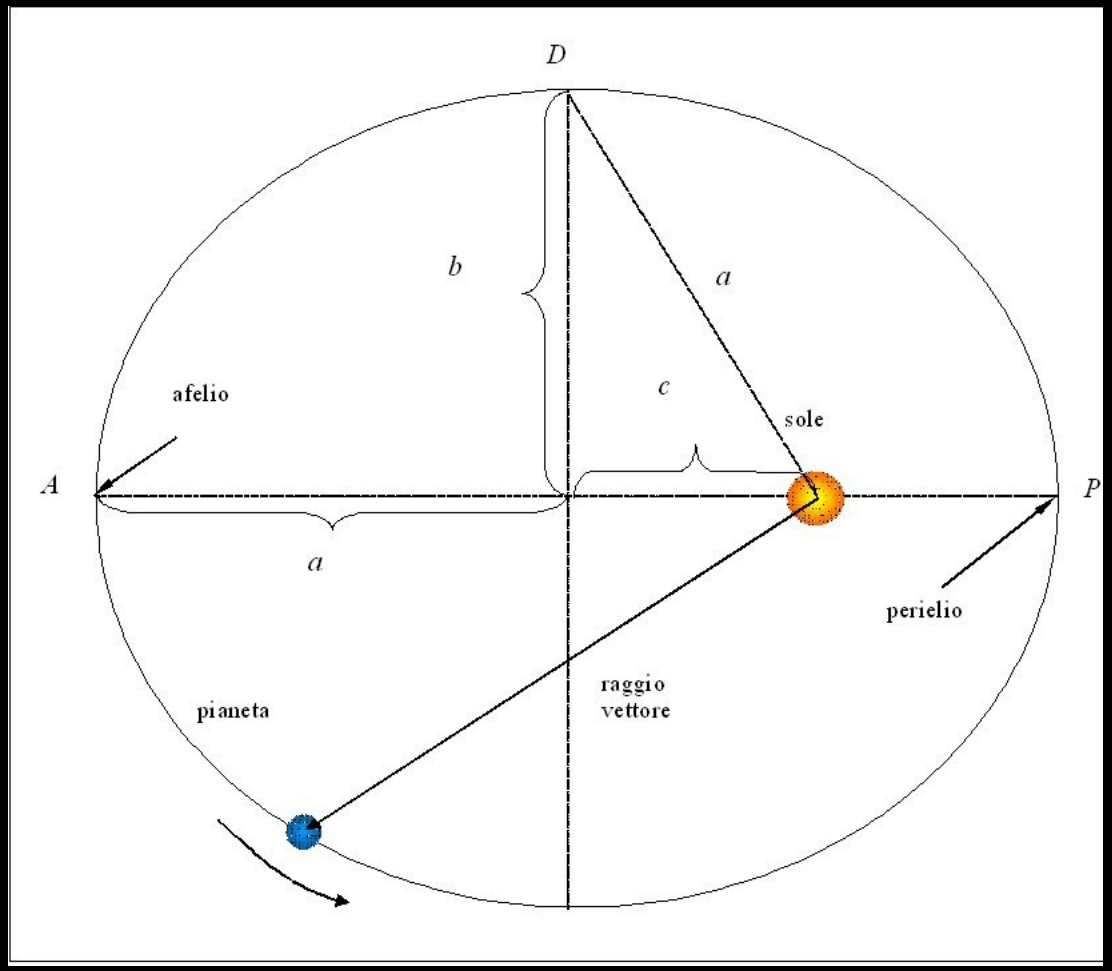


Johannes Kepler
(1571-1630)



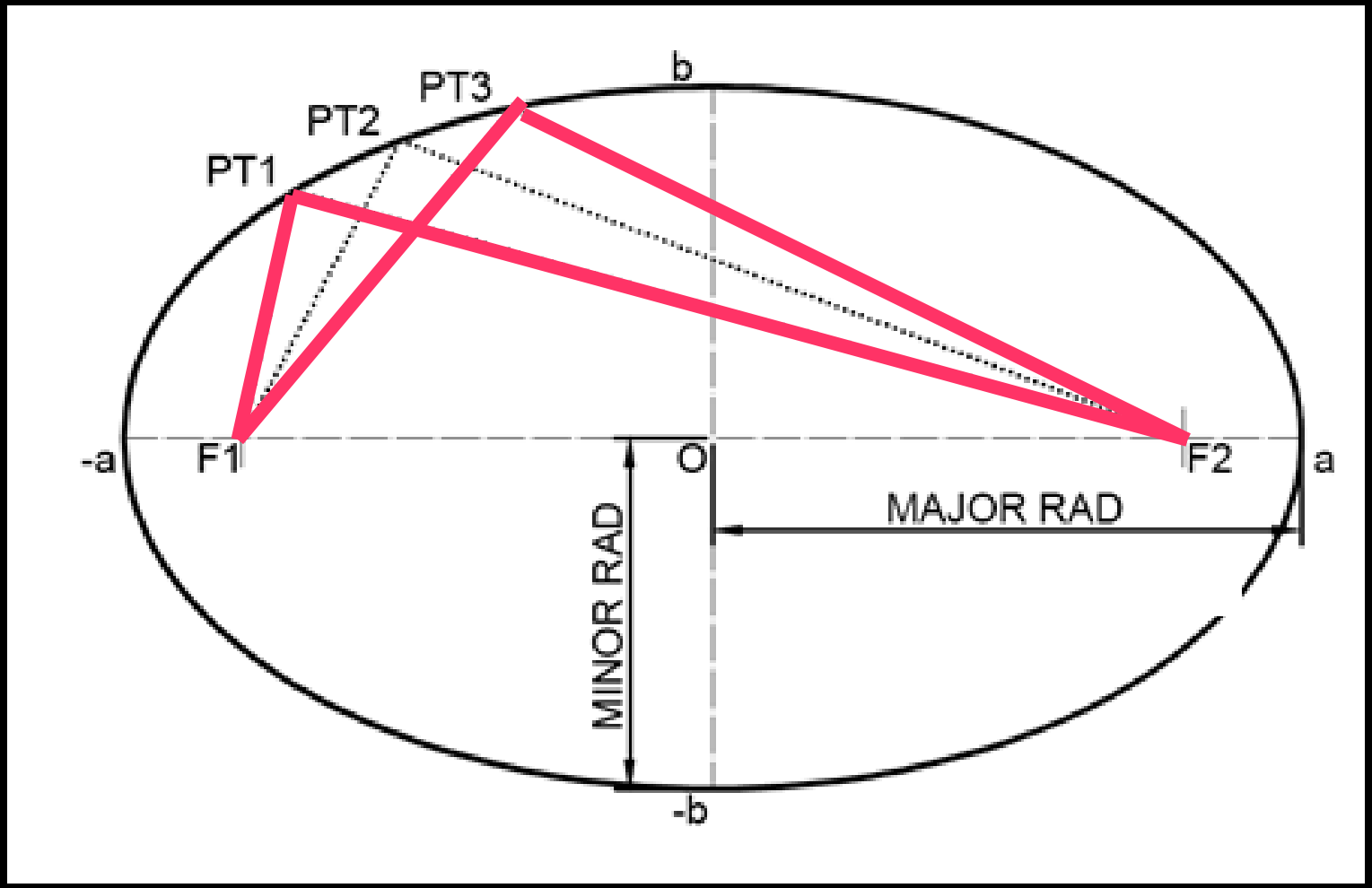
Il grande quadrante murale di Uraniborg

Prima legge di Keplero



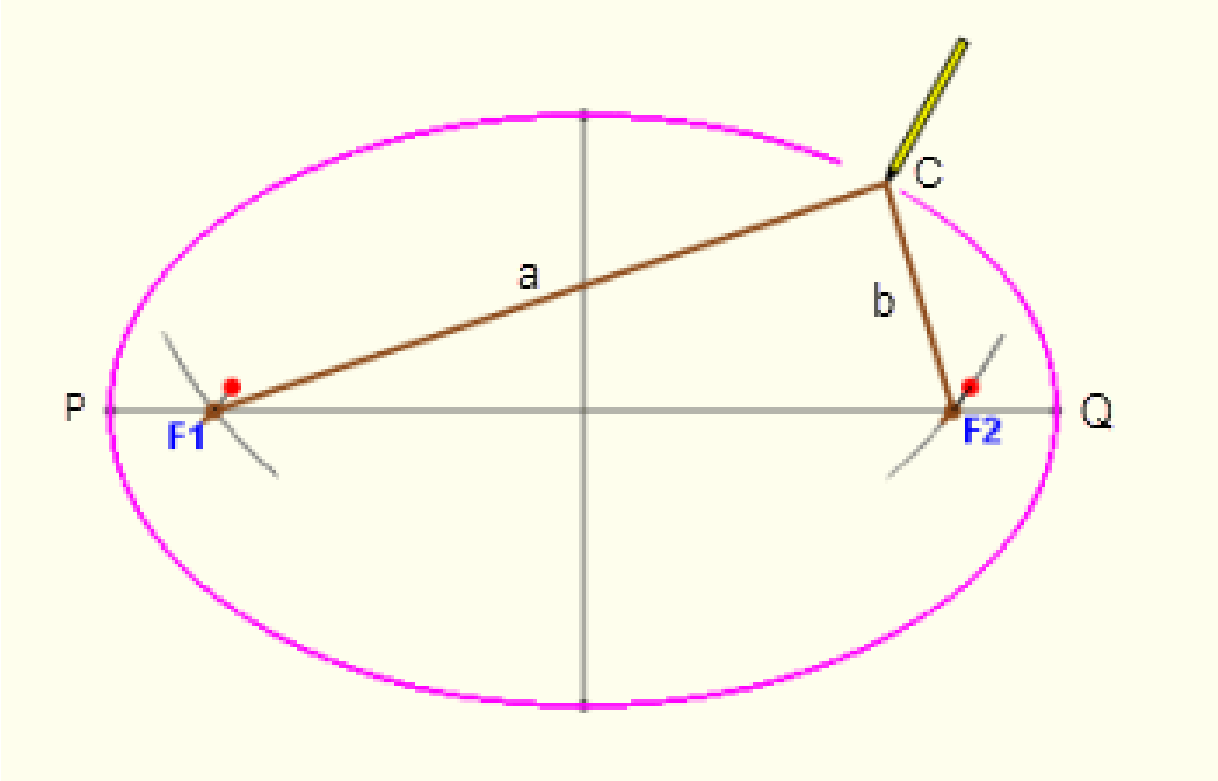
L'orbita di un pianeta è un'ellisse, di cui il sole occupa uno dei due fuochi

I fuochi di un’ellisse



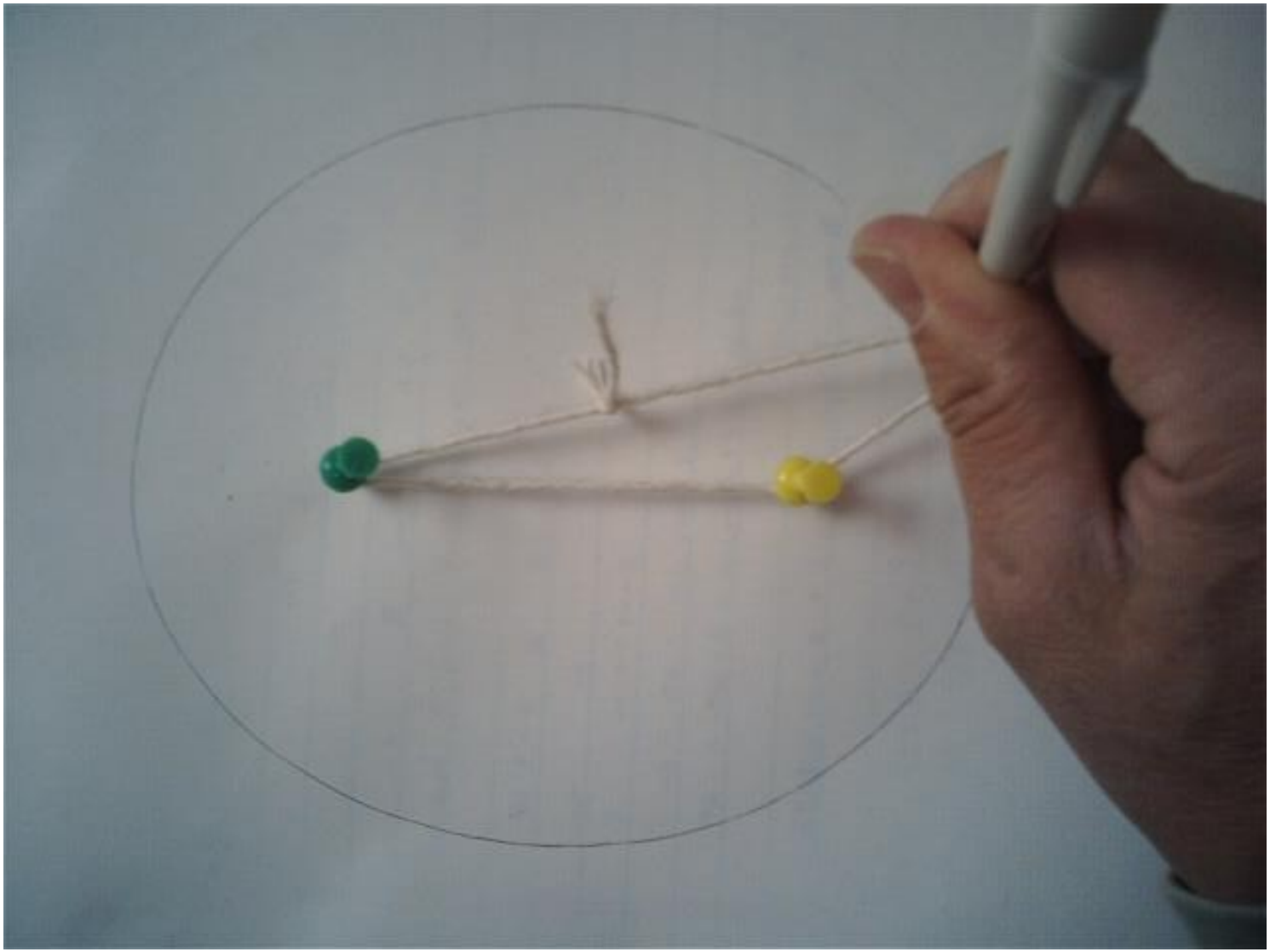
F1-PT1+PT1-F2 = F1-PT2+PT2-F2 = F1-PT3+PT3-F2

Definizione di ellisse

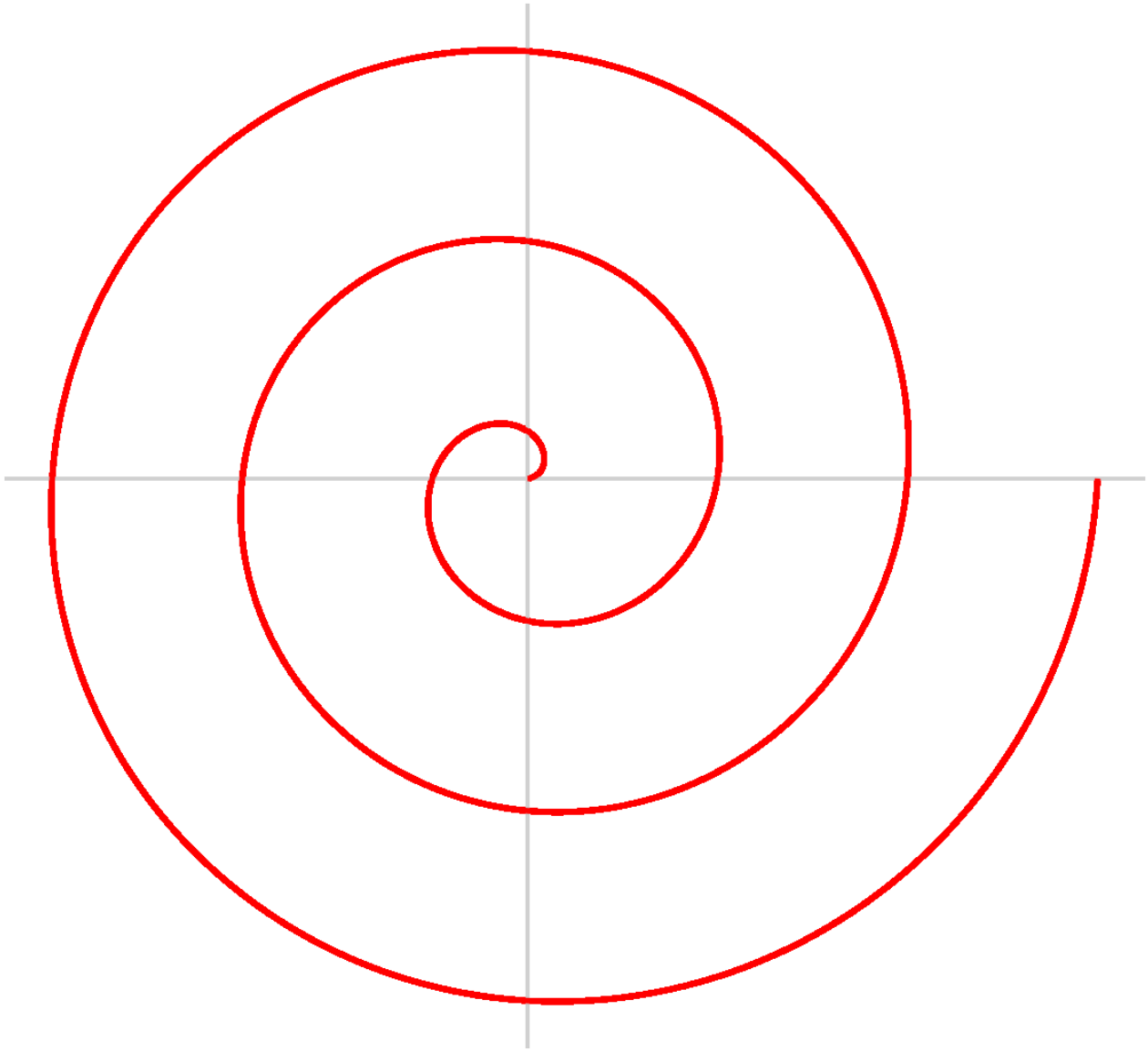


La costruzione “del giardiniere”

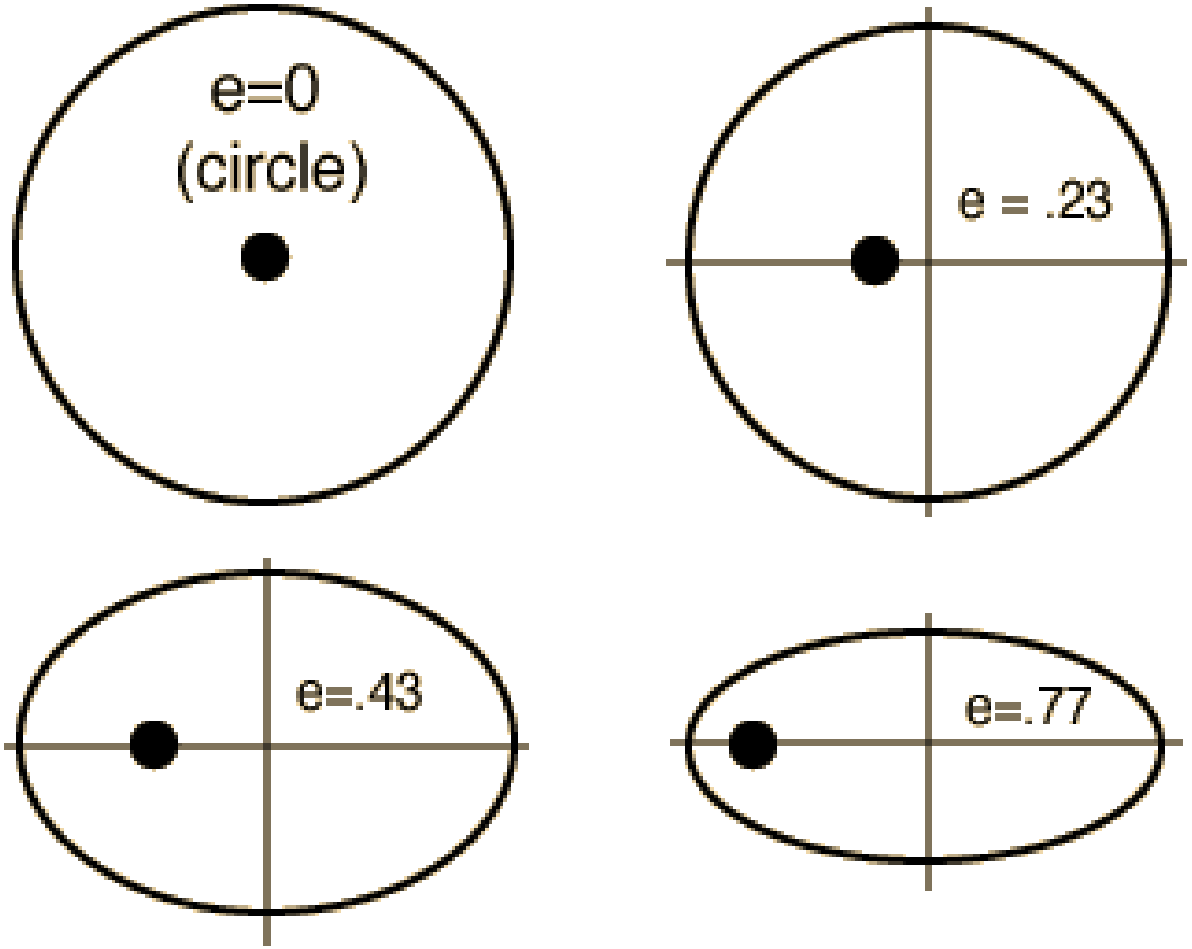
Definizione di ellisse

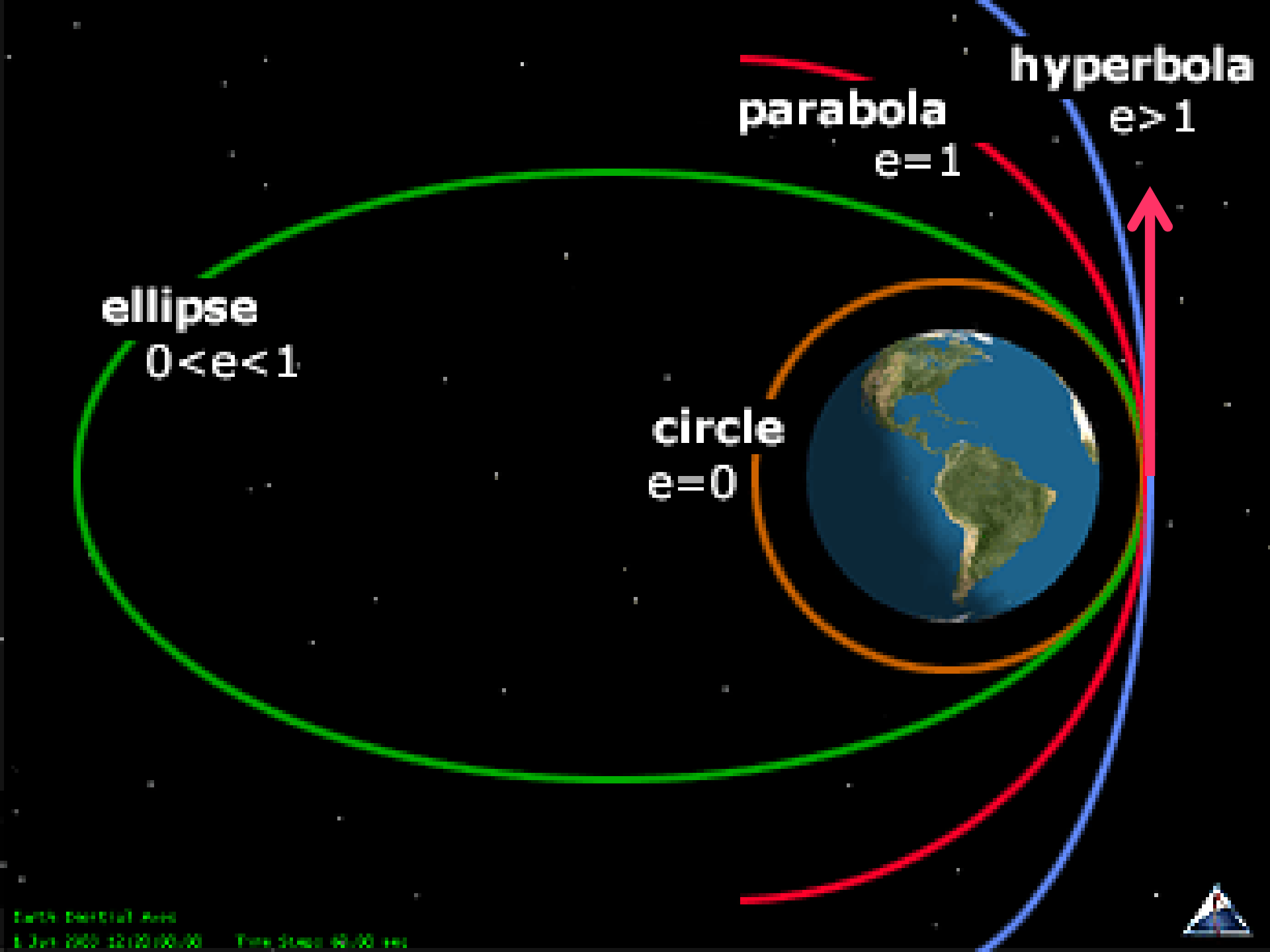


Esempio di traiettoria non chiusa

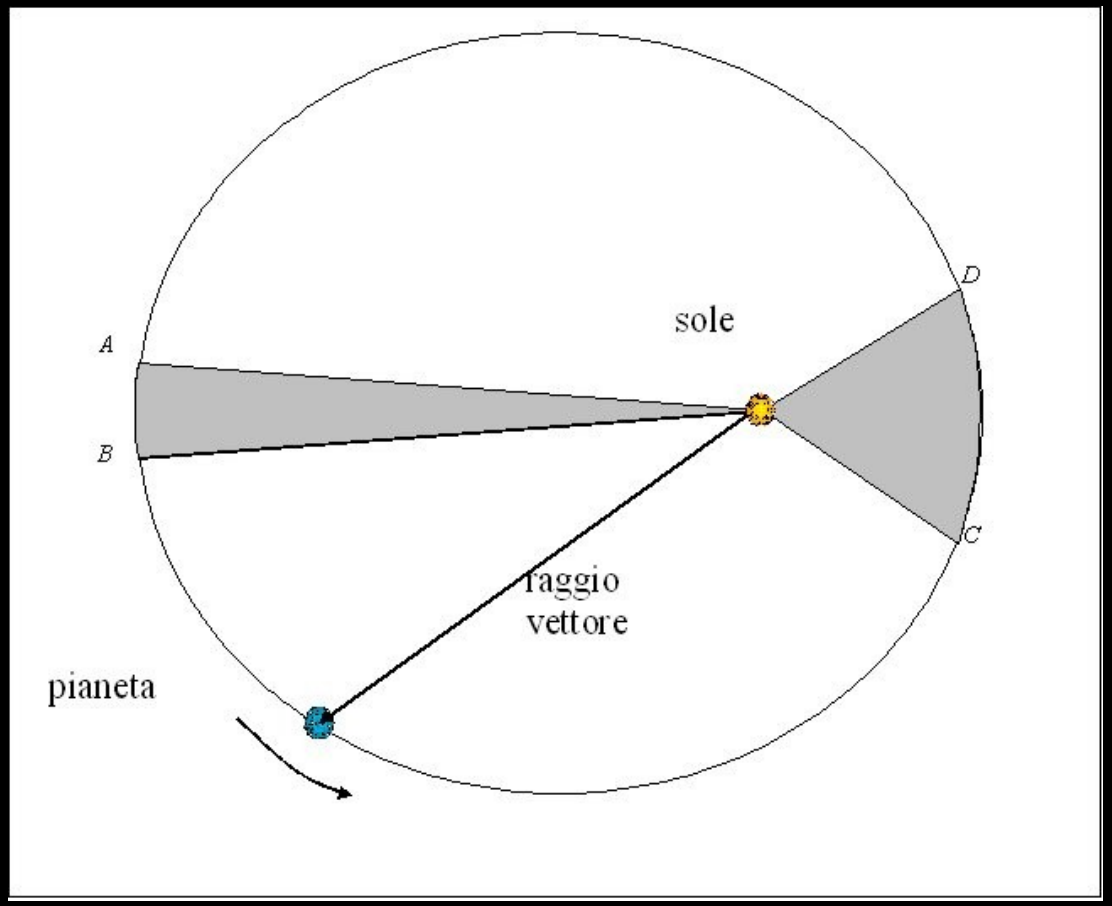


Eccentricità di un’ellisse




hyperbola
e>1
parabola
e=1
ellipse
0<e<1
circle
e=0

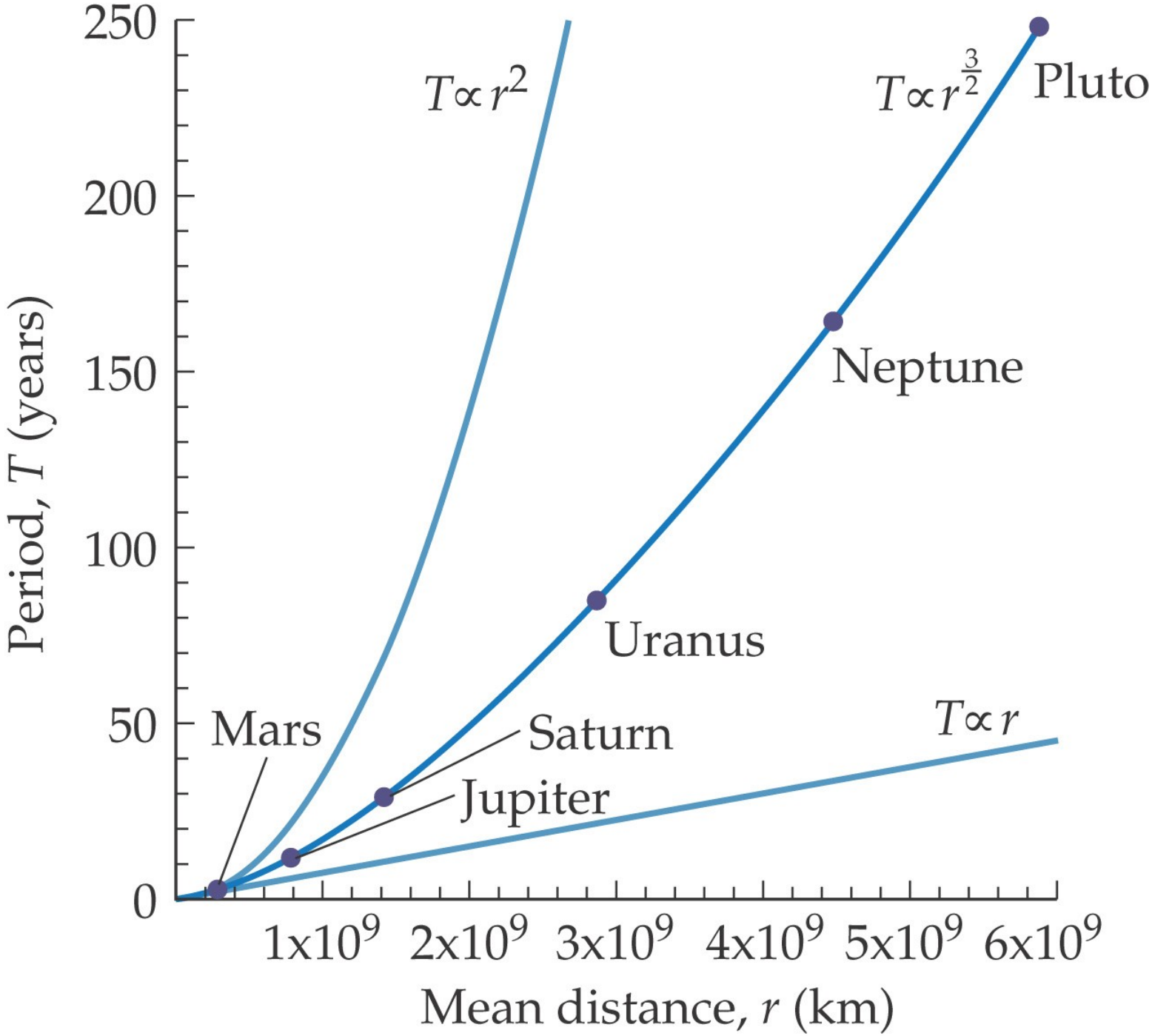
Seconda legge di Keplero



Il raggio vettore del pianeta descrive aree uguali in tempi uguali

Terza legge di Keplero

Pianeta	Distanza dal Sole (AU)	Periodo orbitale (anni)
Mercurio	0.387	0.241
Venere	0.723	0.615
Terra	1.000	1.000
Marte	1.52	1.88
Giove	5.20	11.9
Saturno	9.54	29.4
Urano	19.2	84.0
Nettuno	30.1	165


250
200
150
100
50
0
Period, T (years)
$T \propto r^2$
$T \propto r^{\frac{3}{2}}$
Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
$T \propto r$
1x10^9
2x10^9
3x10^9
4x10^9
5x10^9
6x10^9
Mean distance, r (km)

Galileo Galilei
(1564-1642)

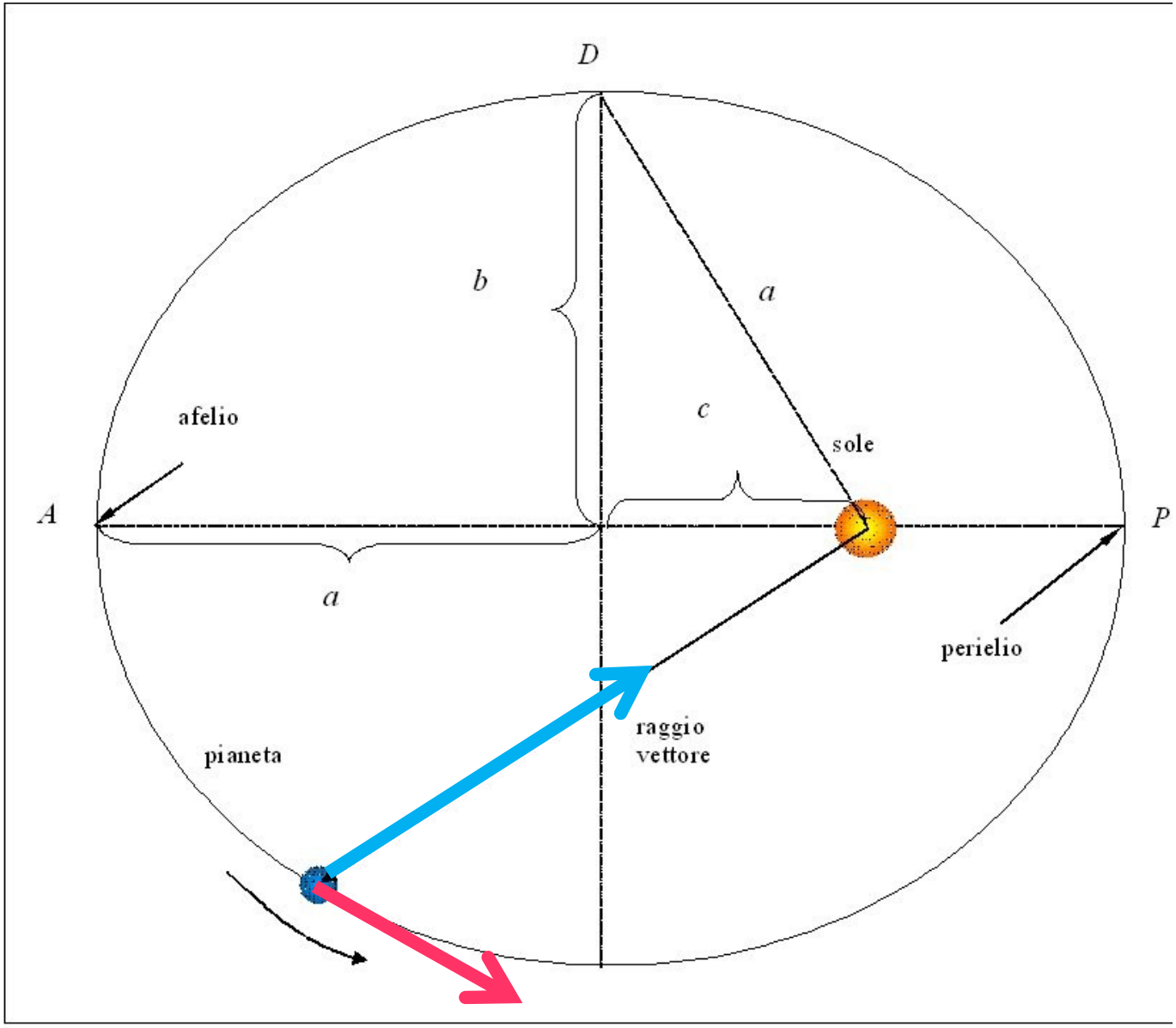


Isaac Newton
(1642-1727)



Legge di gravitazione universale di Newton

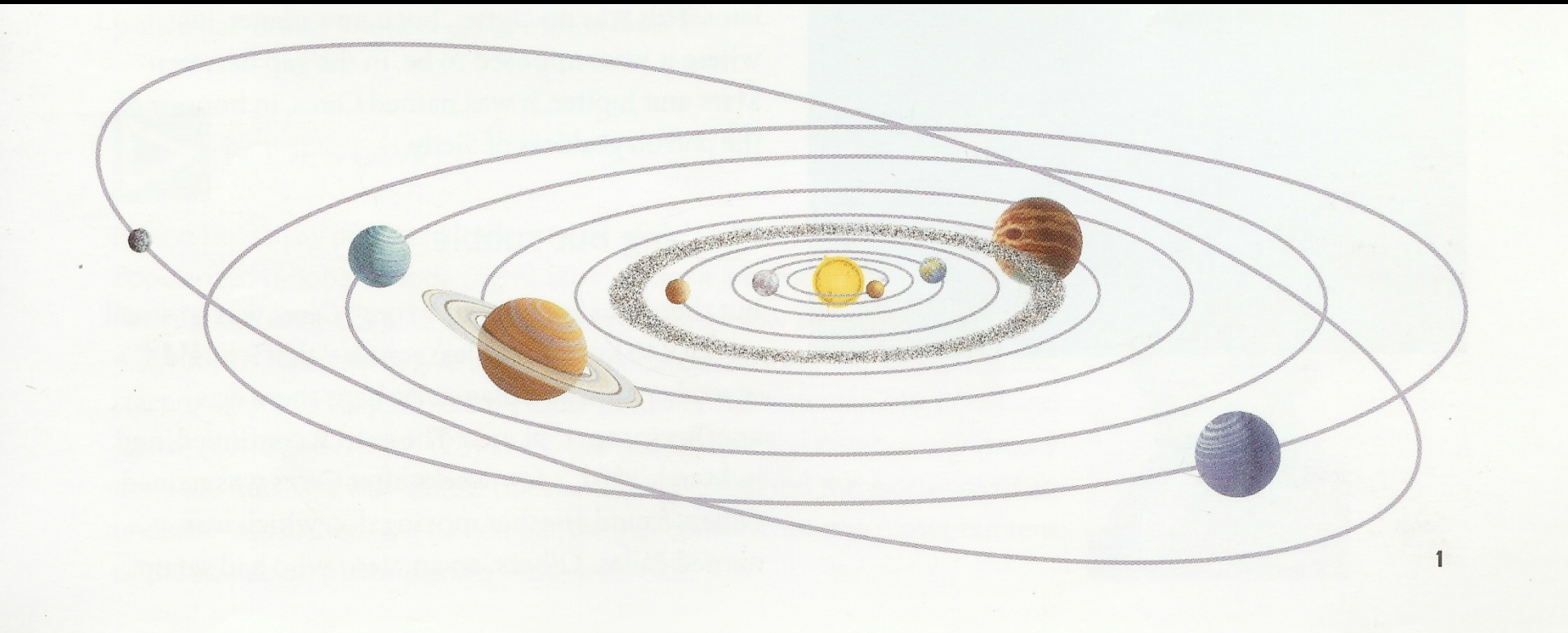
$$f = \frac{G m_1 m_2}{r^2}$$


D
b
a
c
afelio
sole
A
P
a
perielio
raggio
vettore
pianeta

2

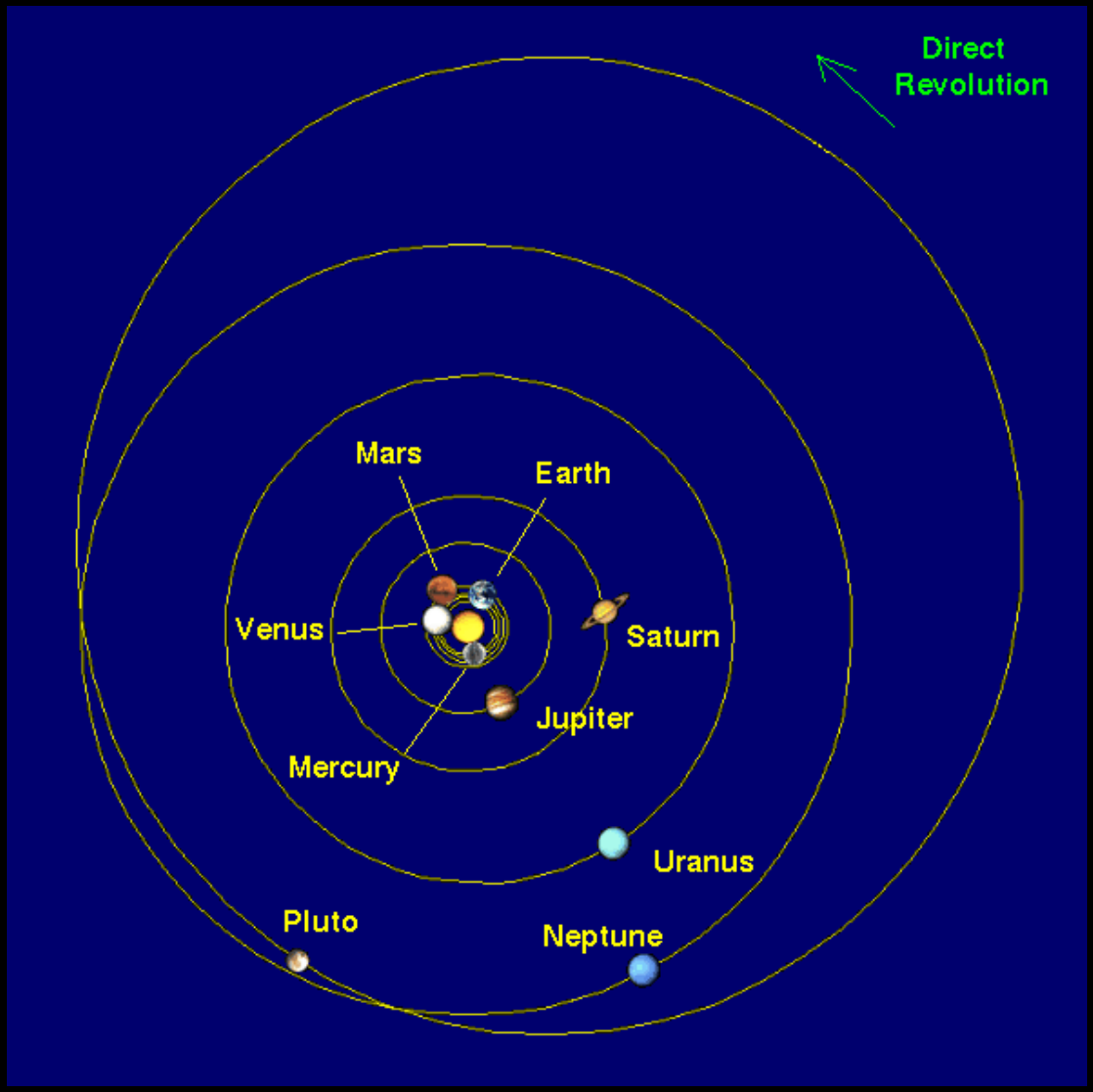
La struttura del Sistema Solare

Struttura del Sistema Solare

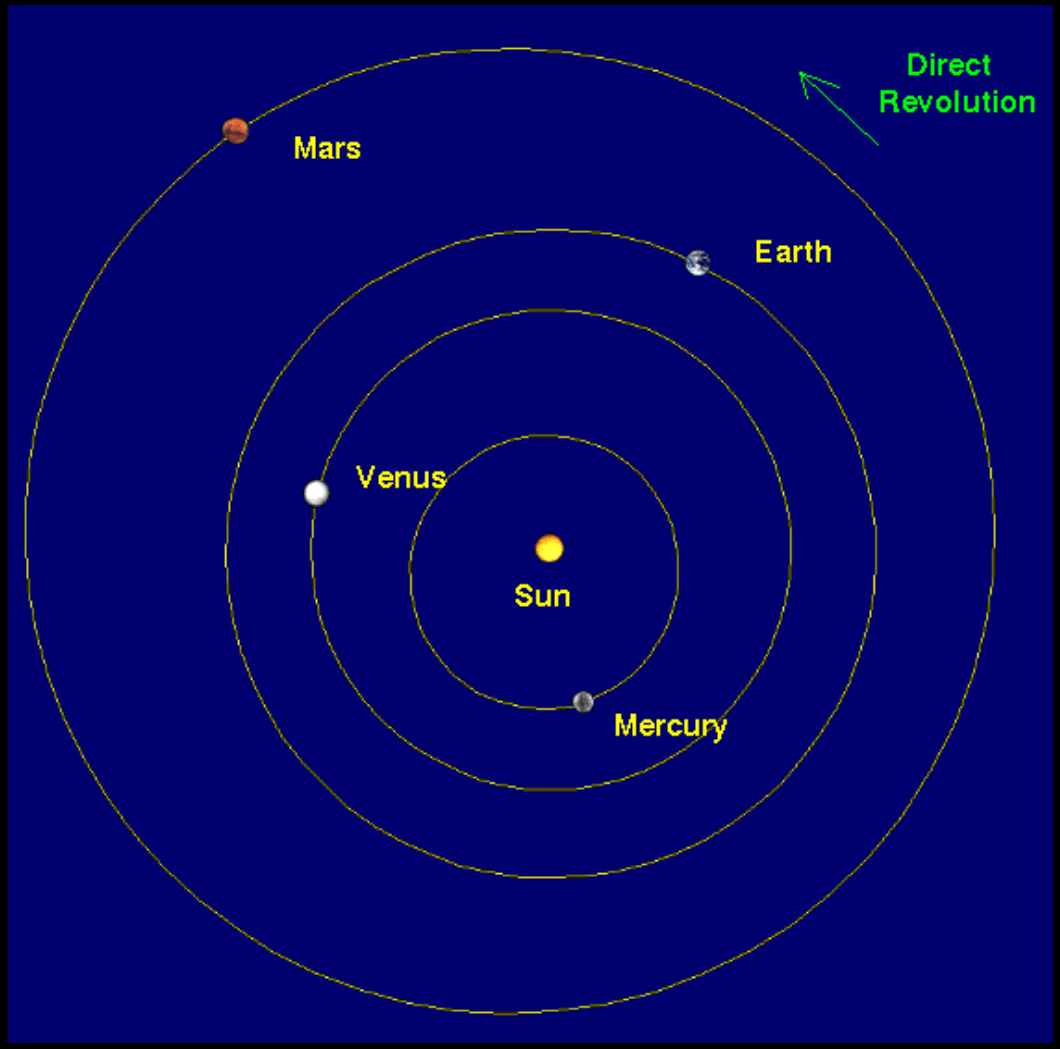


1

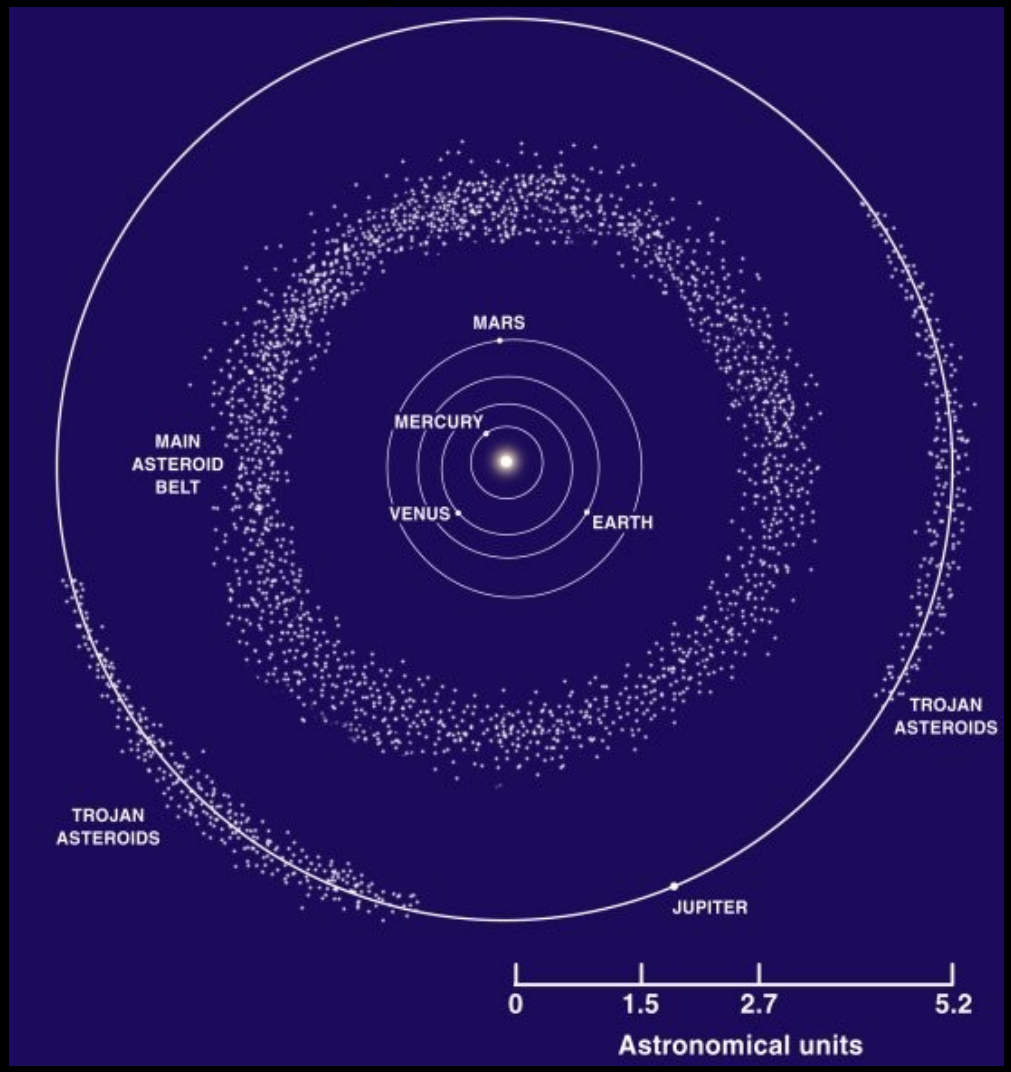
Struttura del Sistema Solare



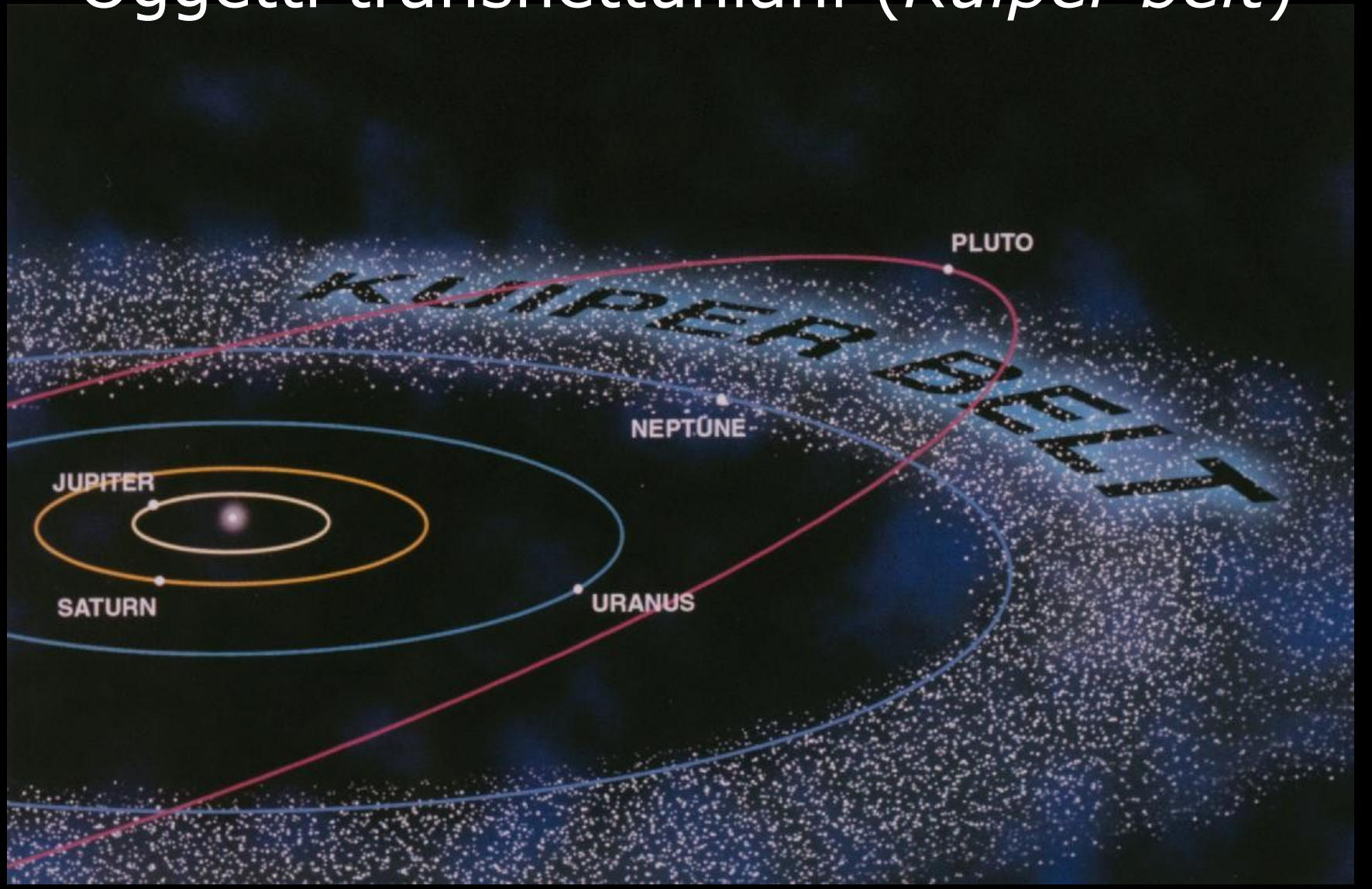
Il Sistema Solare interno



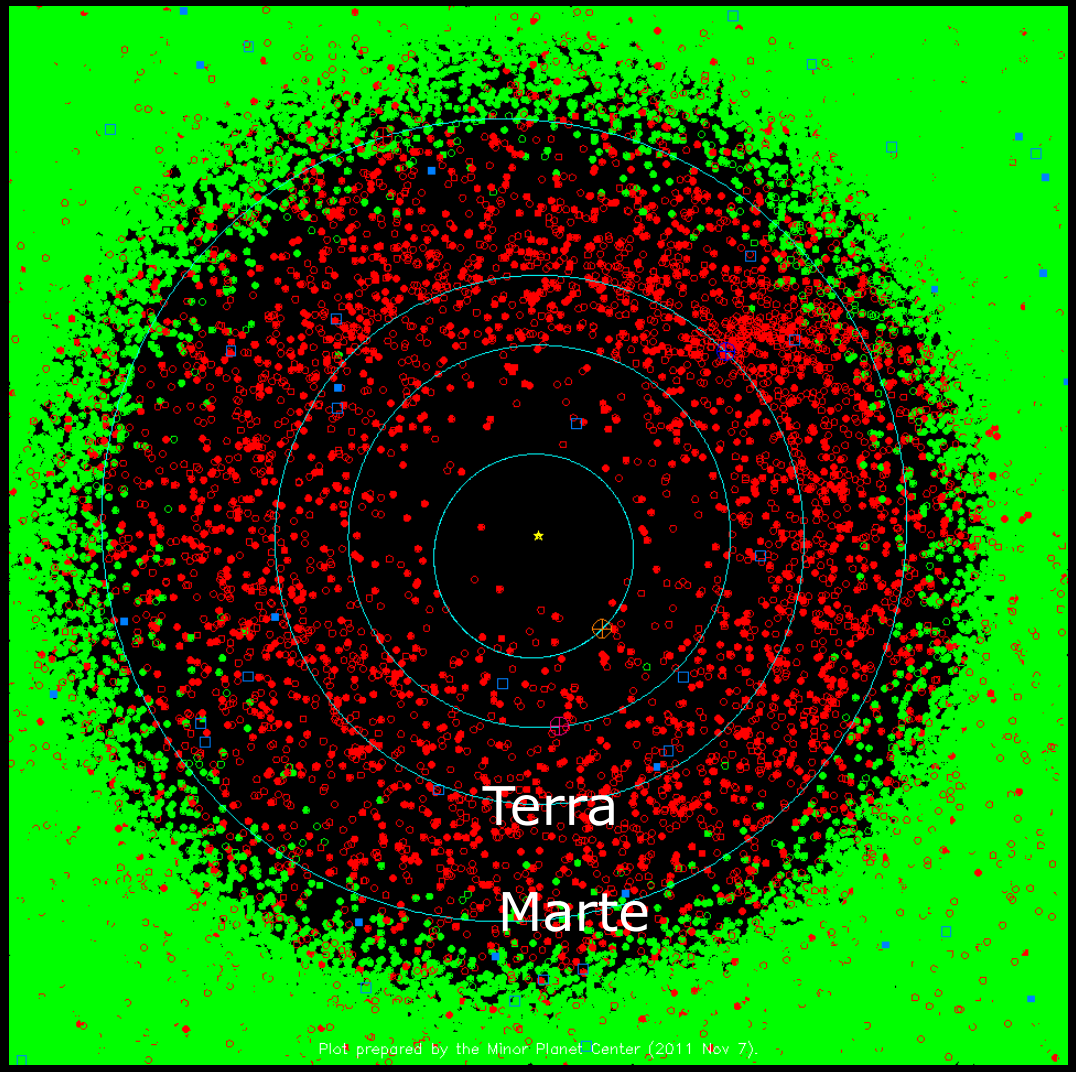
Asteroidi: fascia principale e Troiani



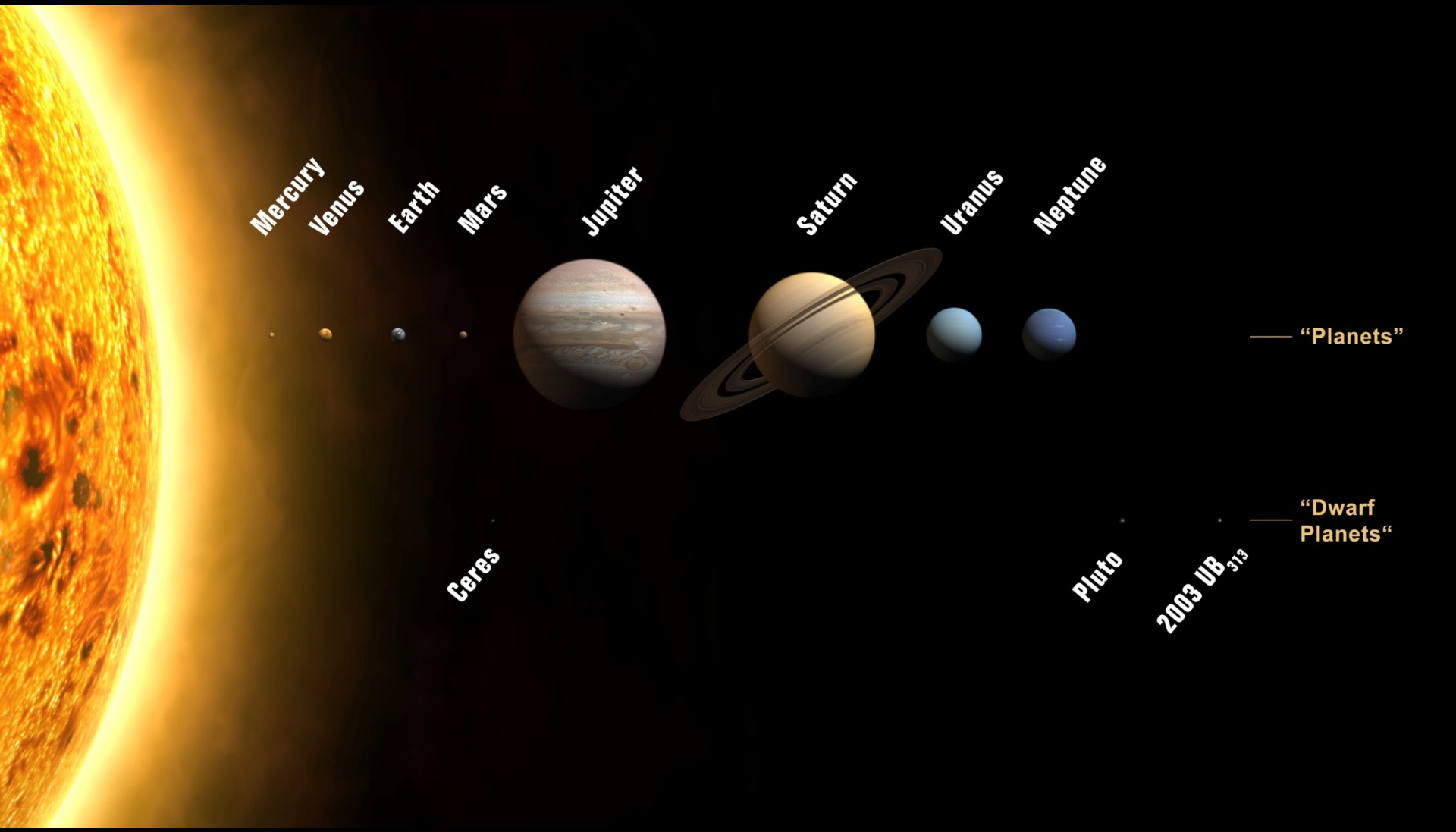
Oggetti transnettuniani (*Kuiper belt*)



Near Earth Asteroids (NEA)



Struttura del Sistema Solare



3

La formazione del Sistema Solare

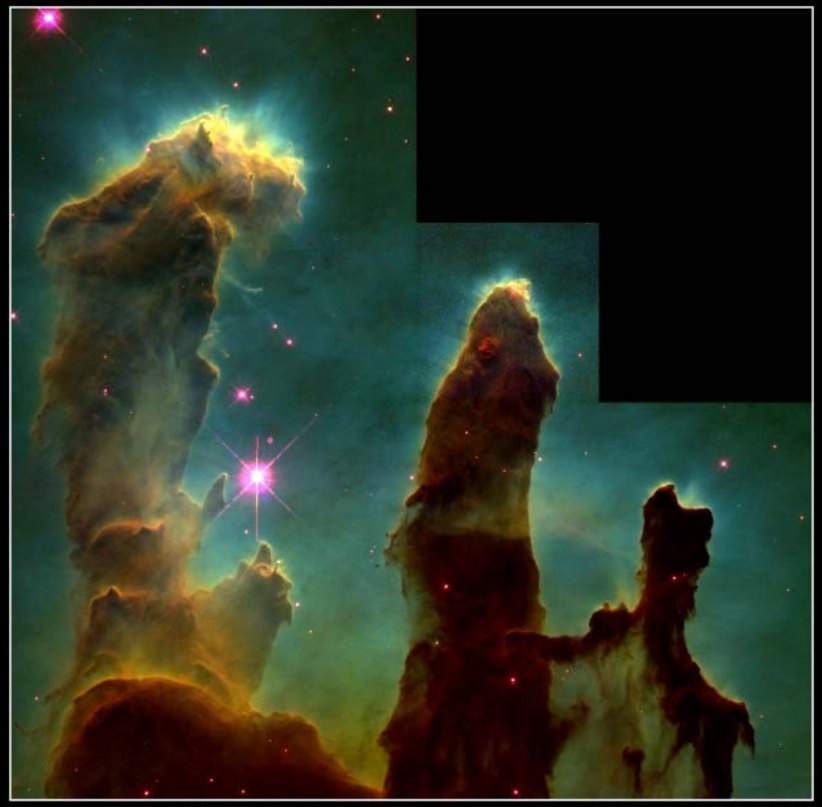




Nubi molecolari giganti



Nubi molecolari giganti

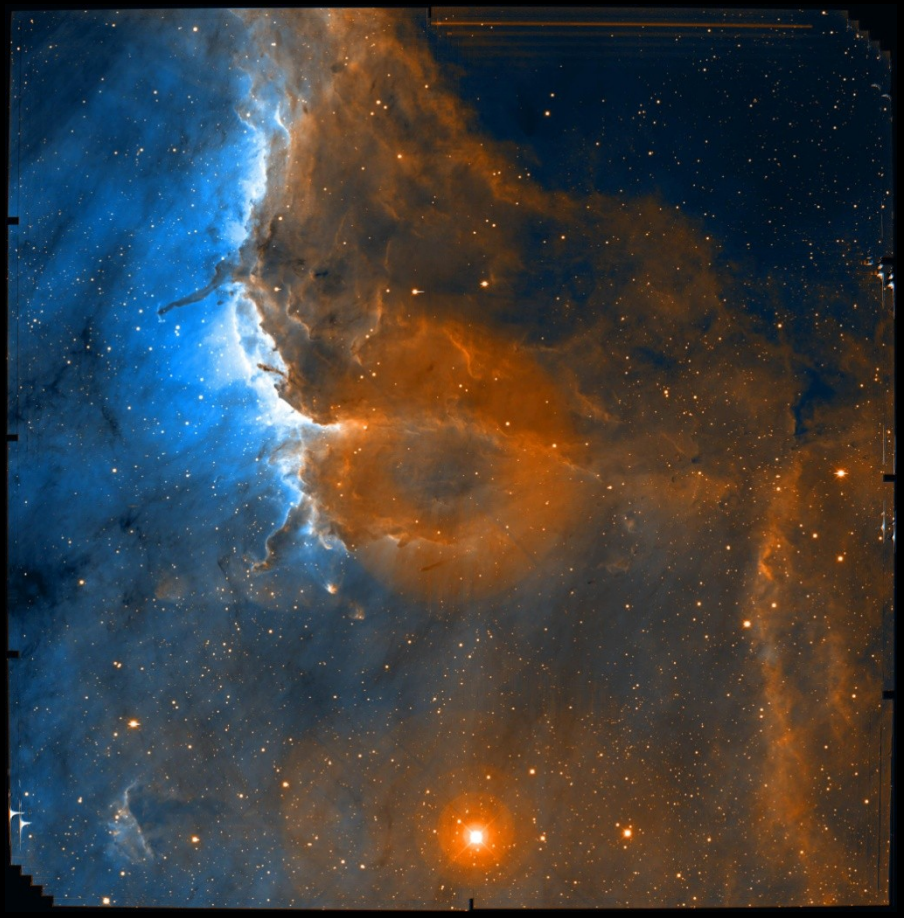


Gaseous Pillars · M16 HST · WFPC2

PRC95-44a · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA



Nubi molecolari giganti





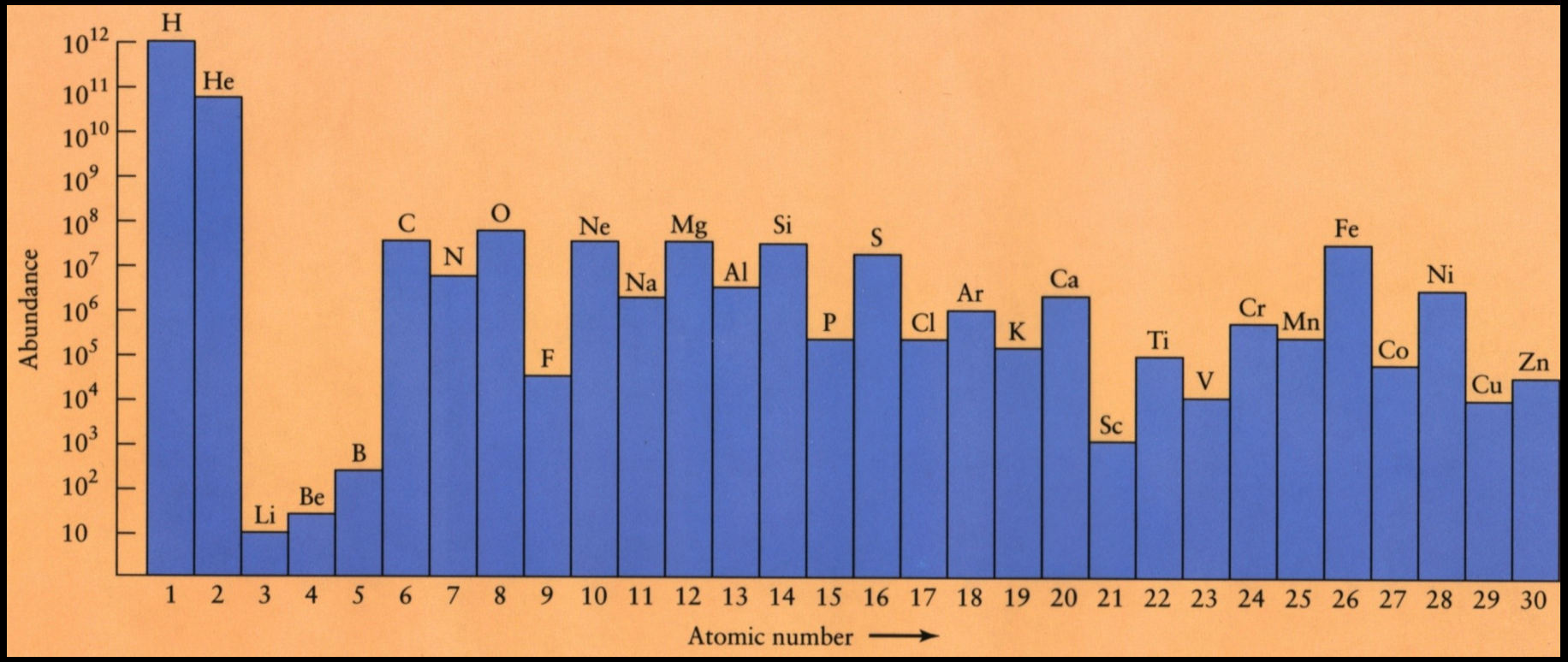
Abbondanza cosmica di elementi

Idrogeno (H): 74 %

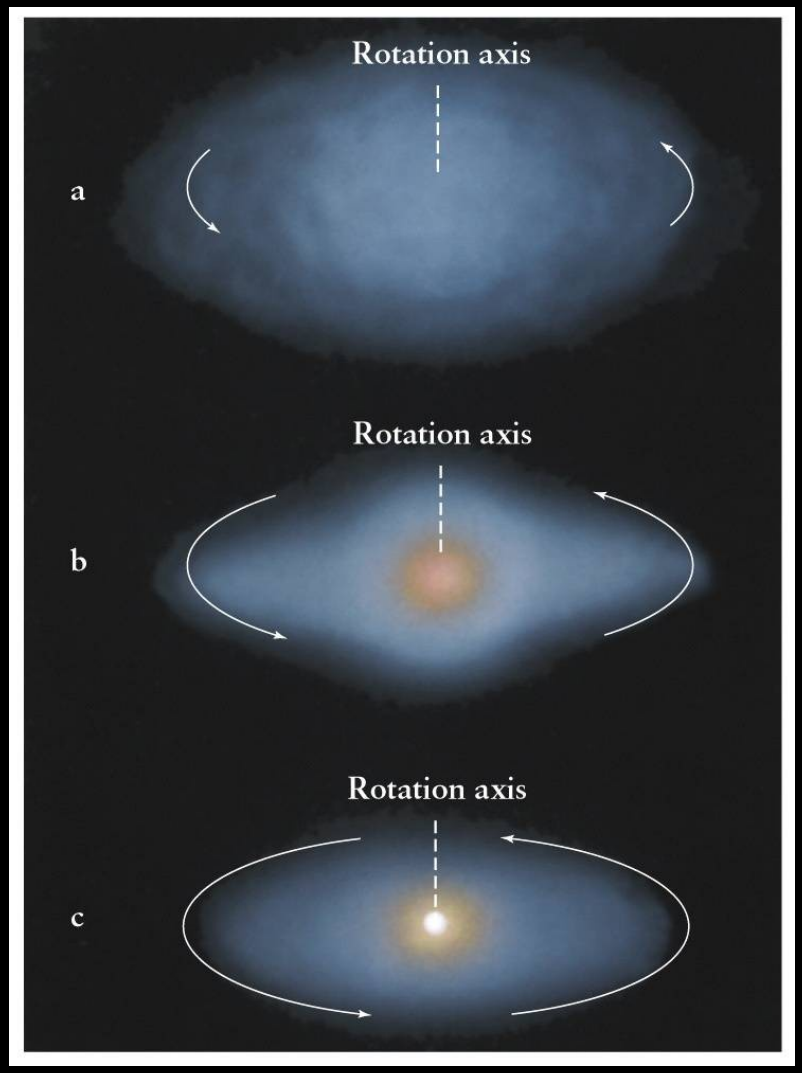
Elio (He): 24 %

altri elementi: 2 %

Abbondanza cosmica di elementi



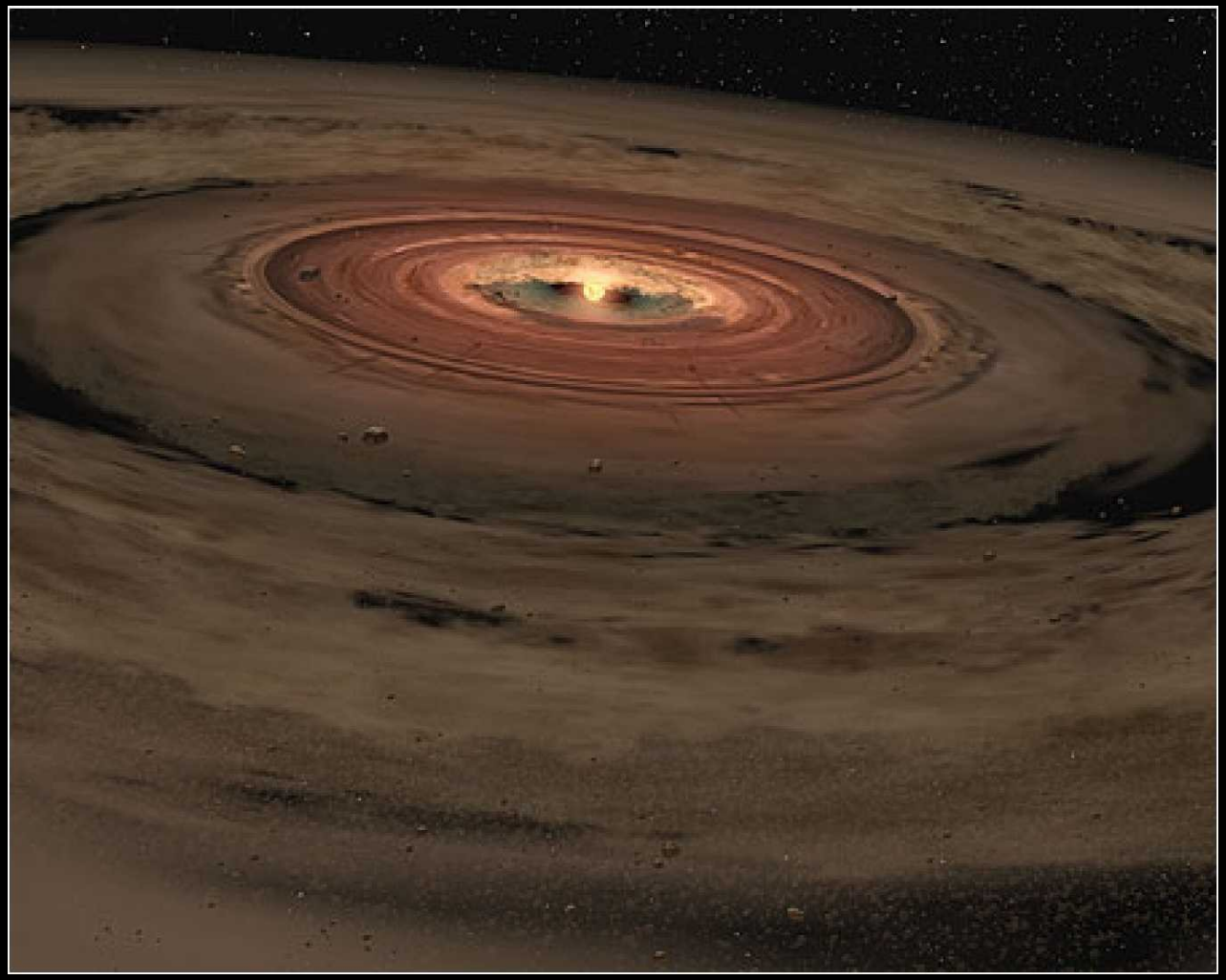
Contrazione della protonebulosa solare



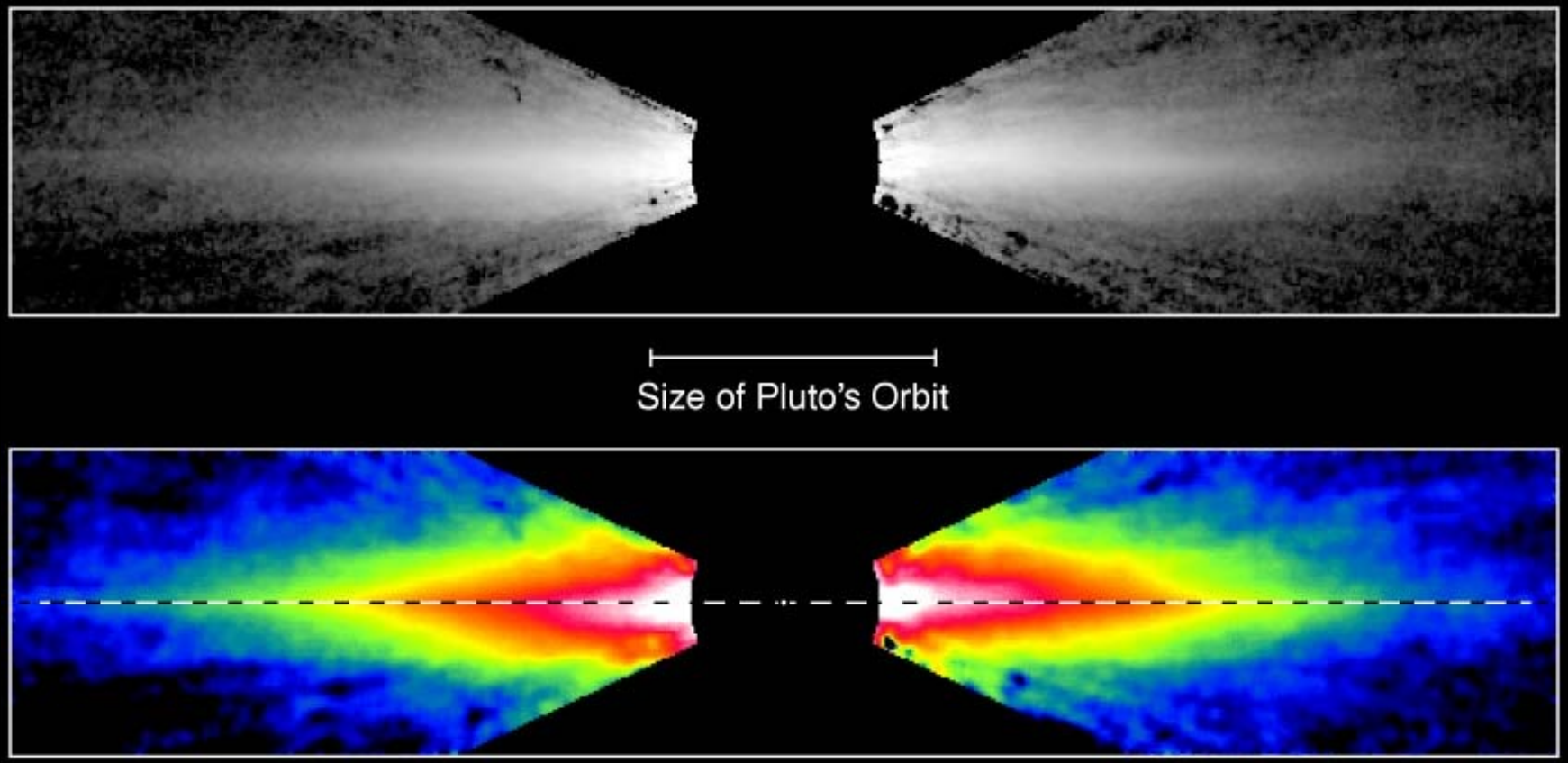
Formazione del disco protoplanetario



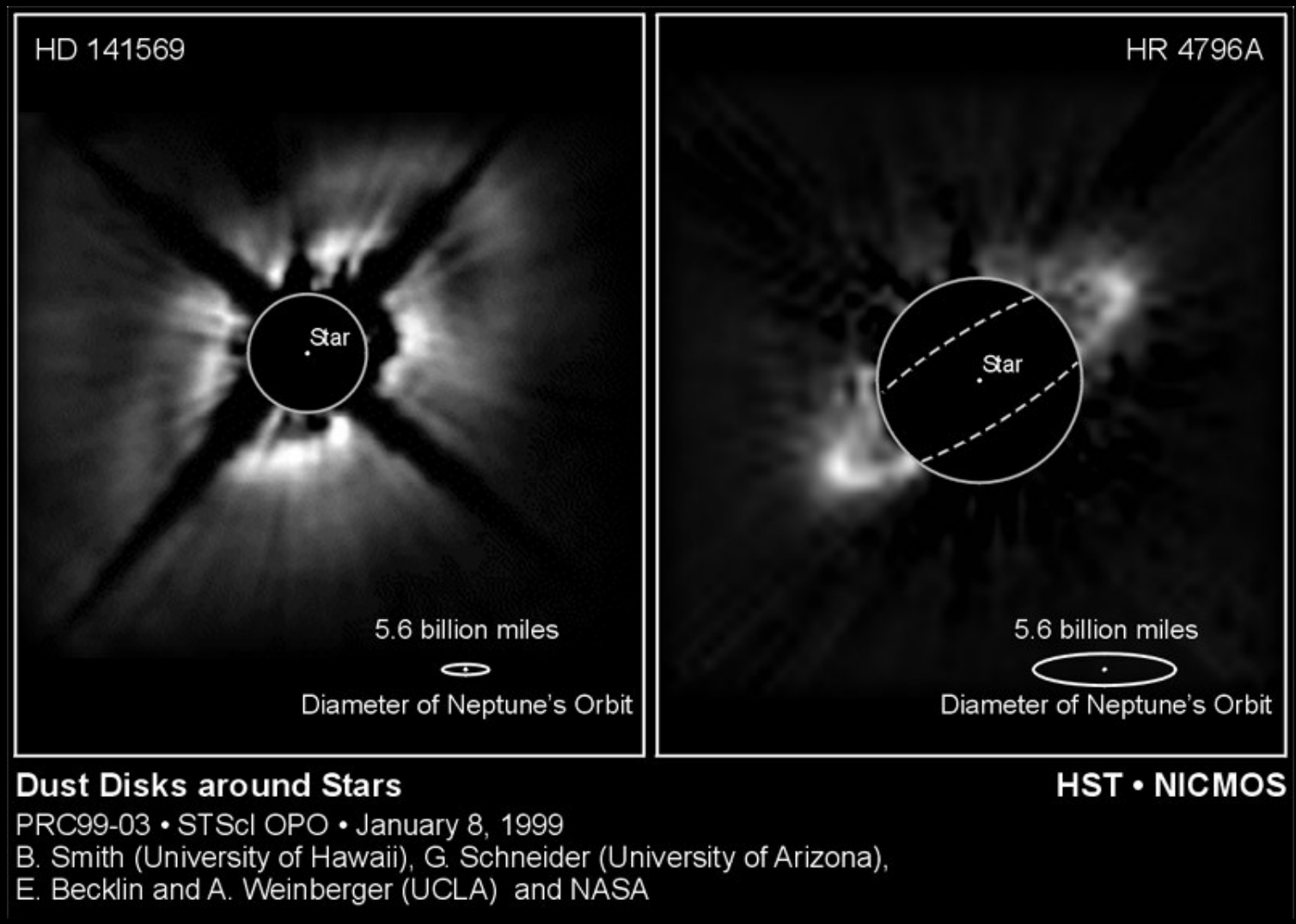
Accrezione dei planetesimi dal disco



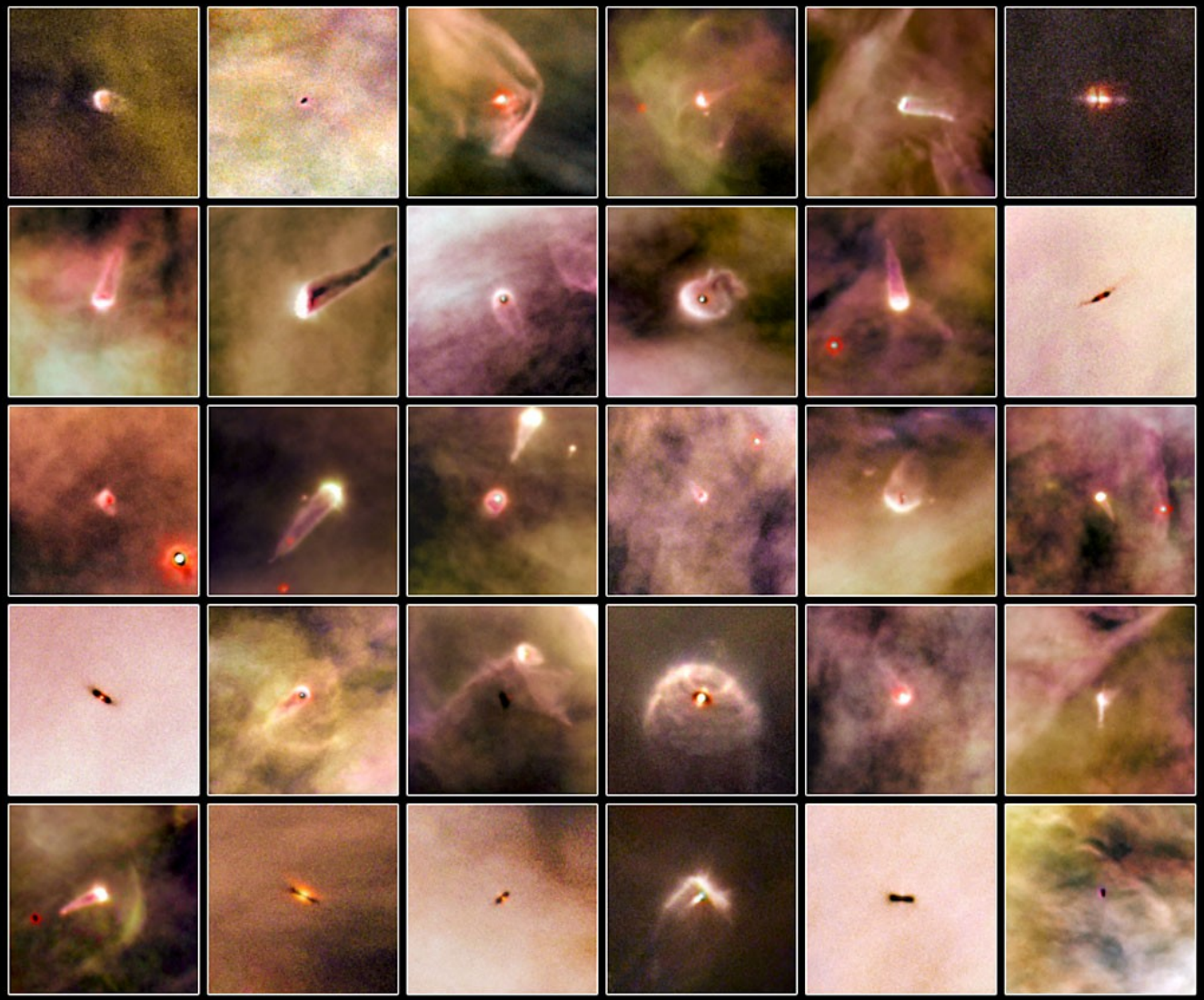
Dischi protoplanetari



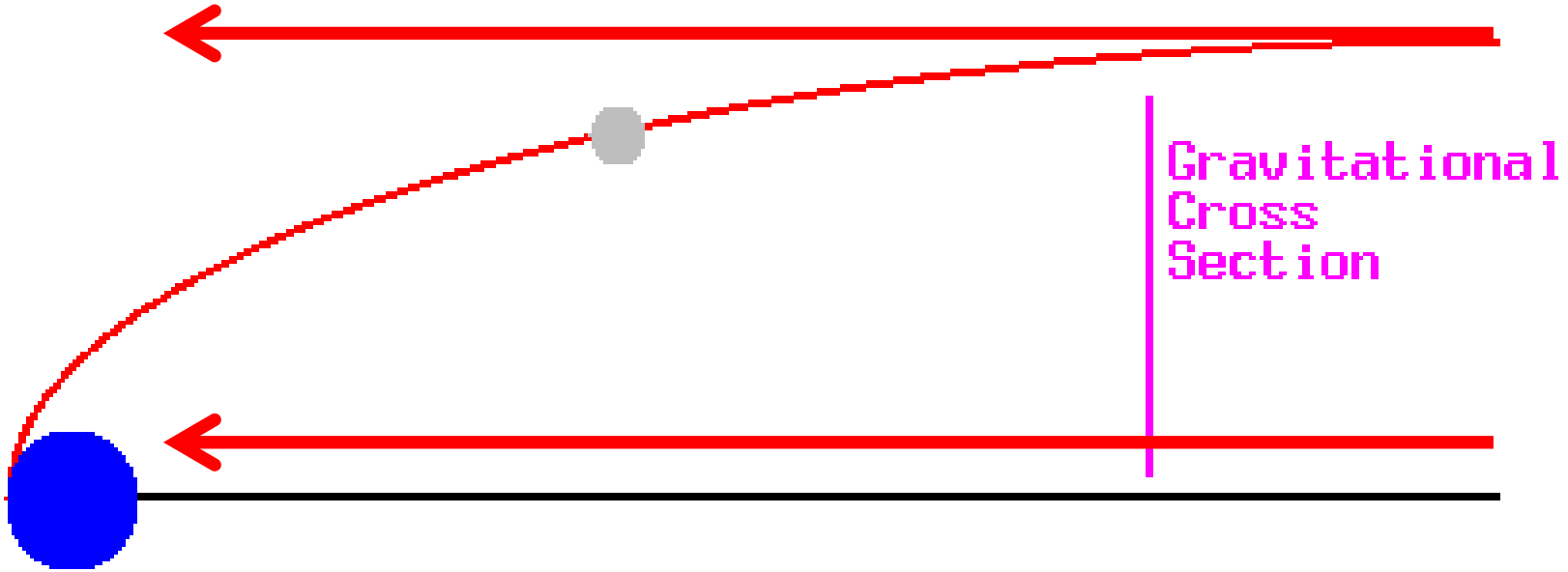
Dischi protoplanetari



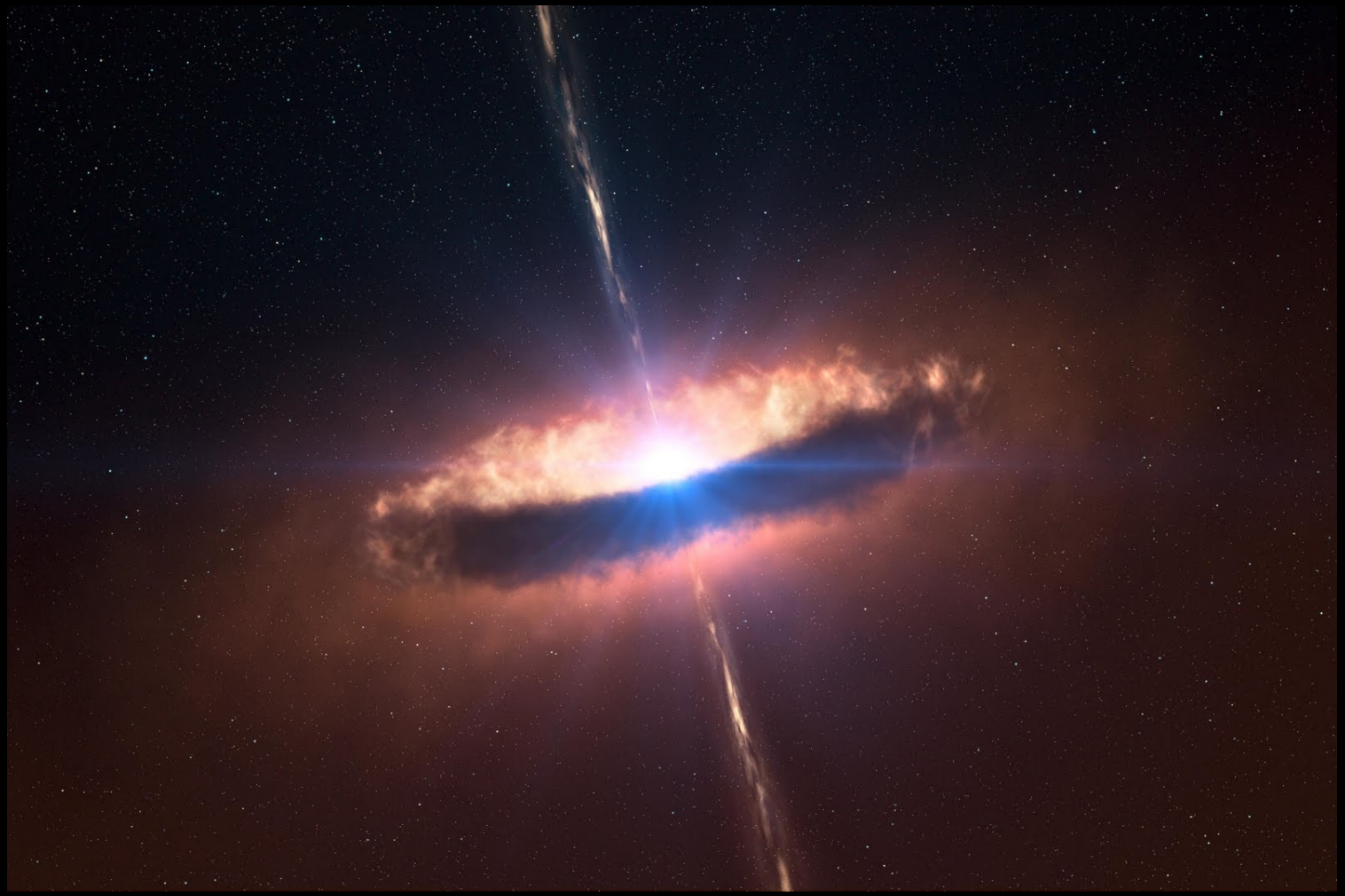
Dischi protoplanetari



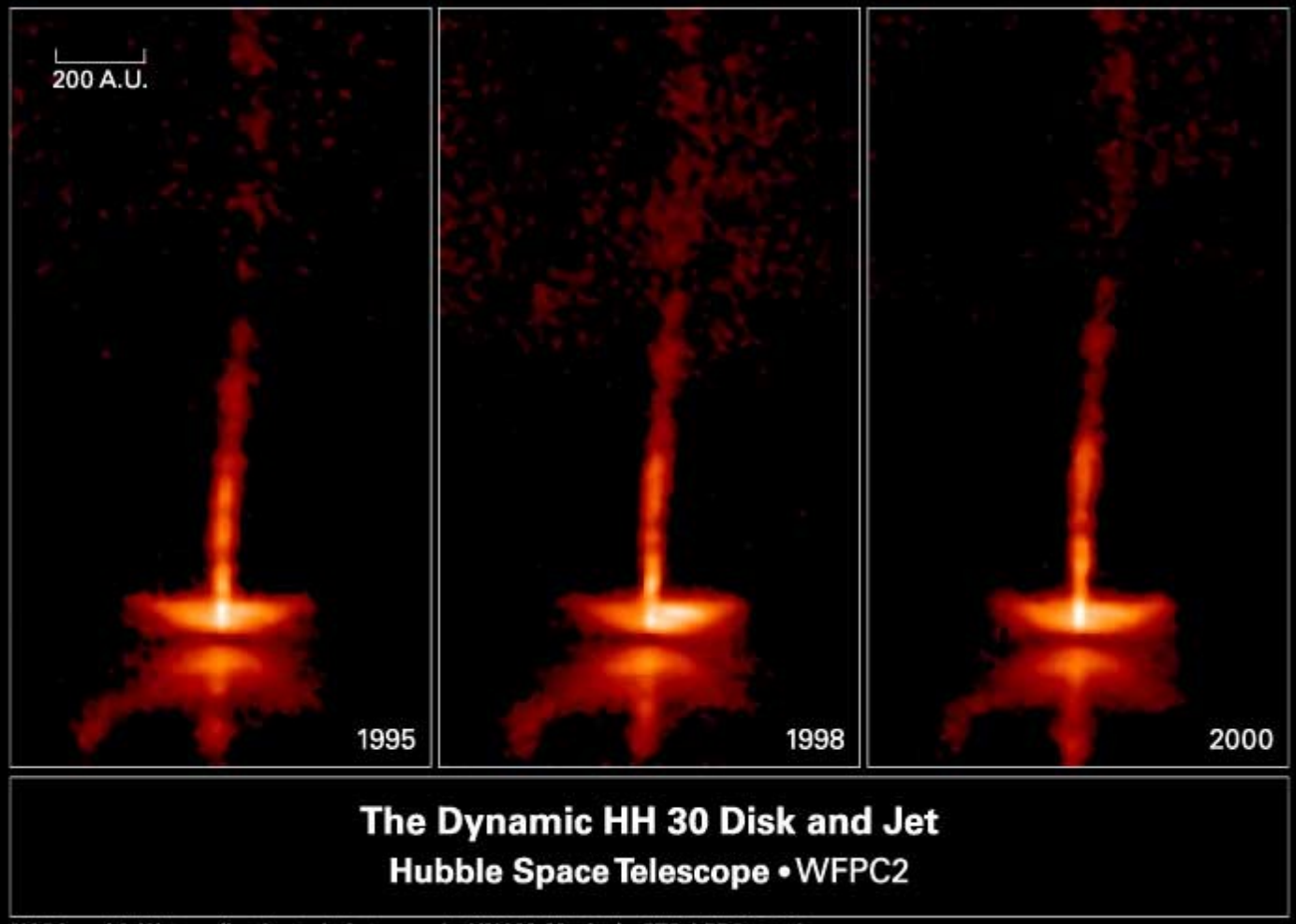
Accrezione gravitazionale



Il proto-Sole: una stella T Tauri



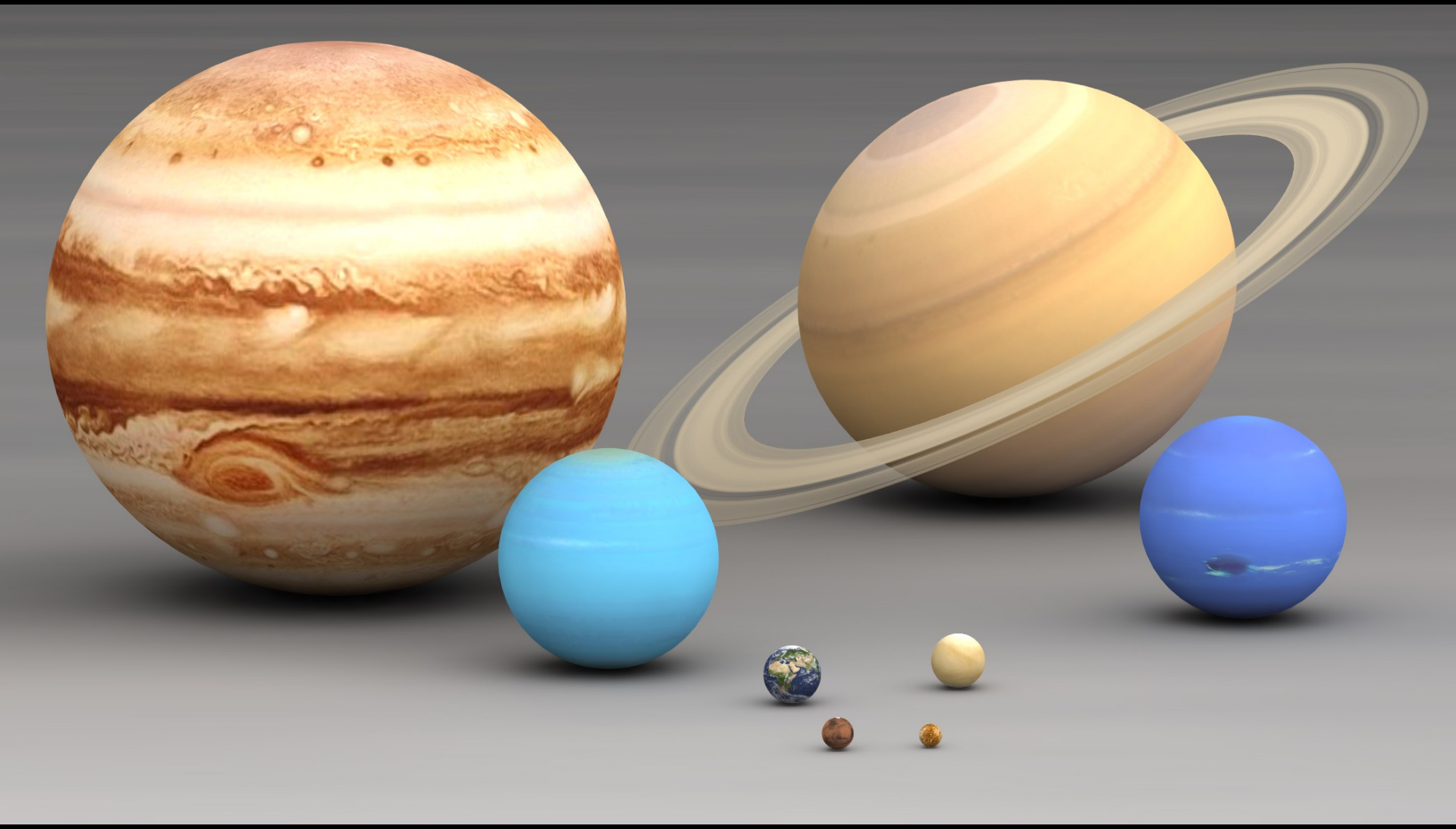
Stelle T Tauri



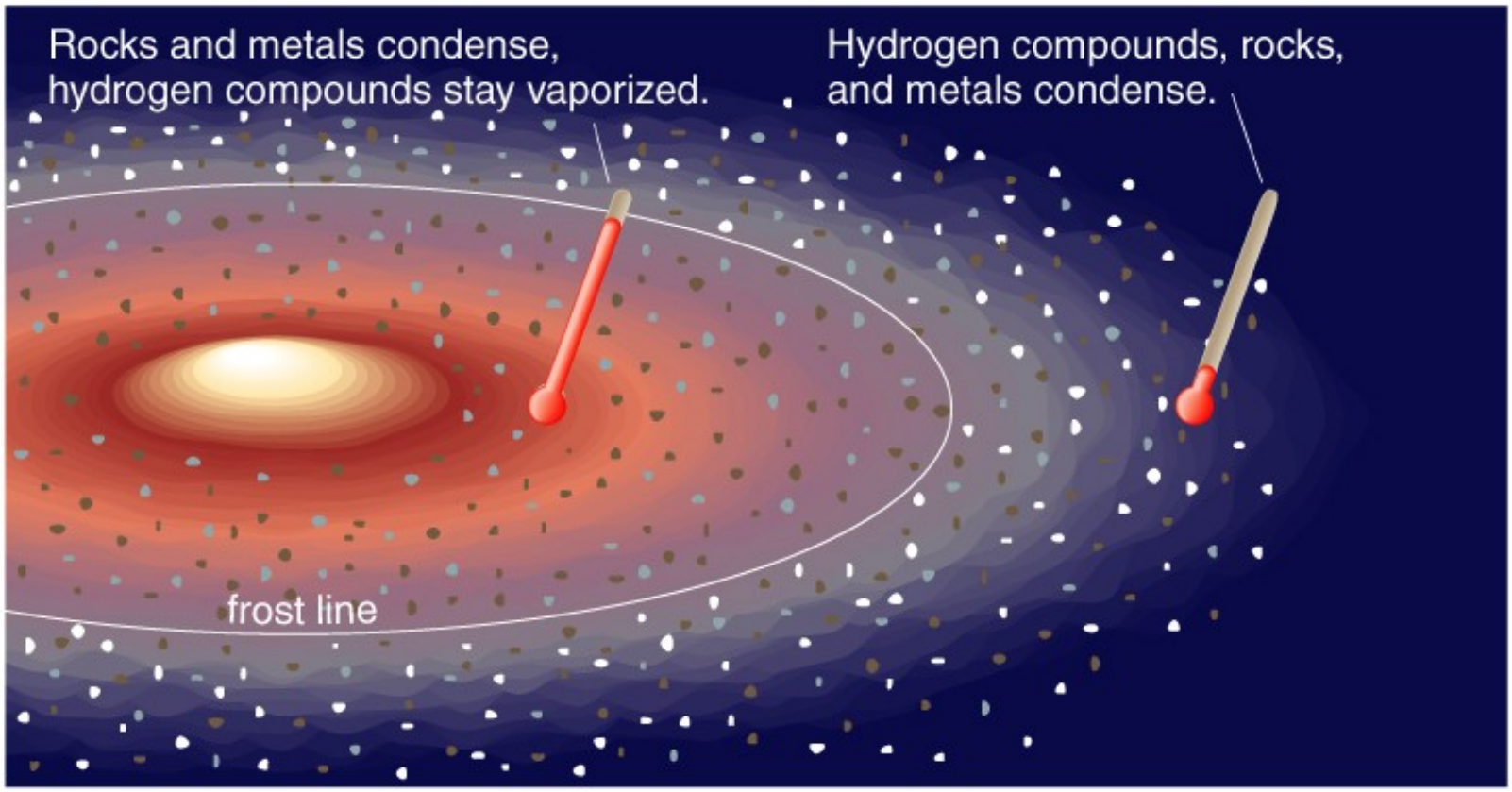
Accrezione dei protopianeti



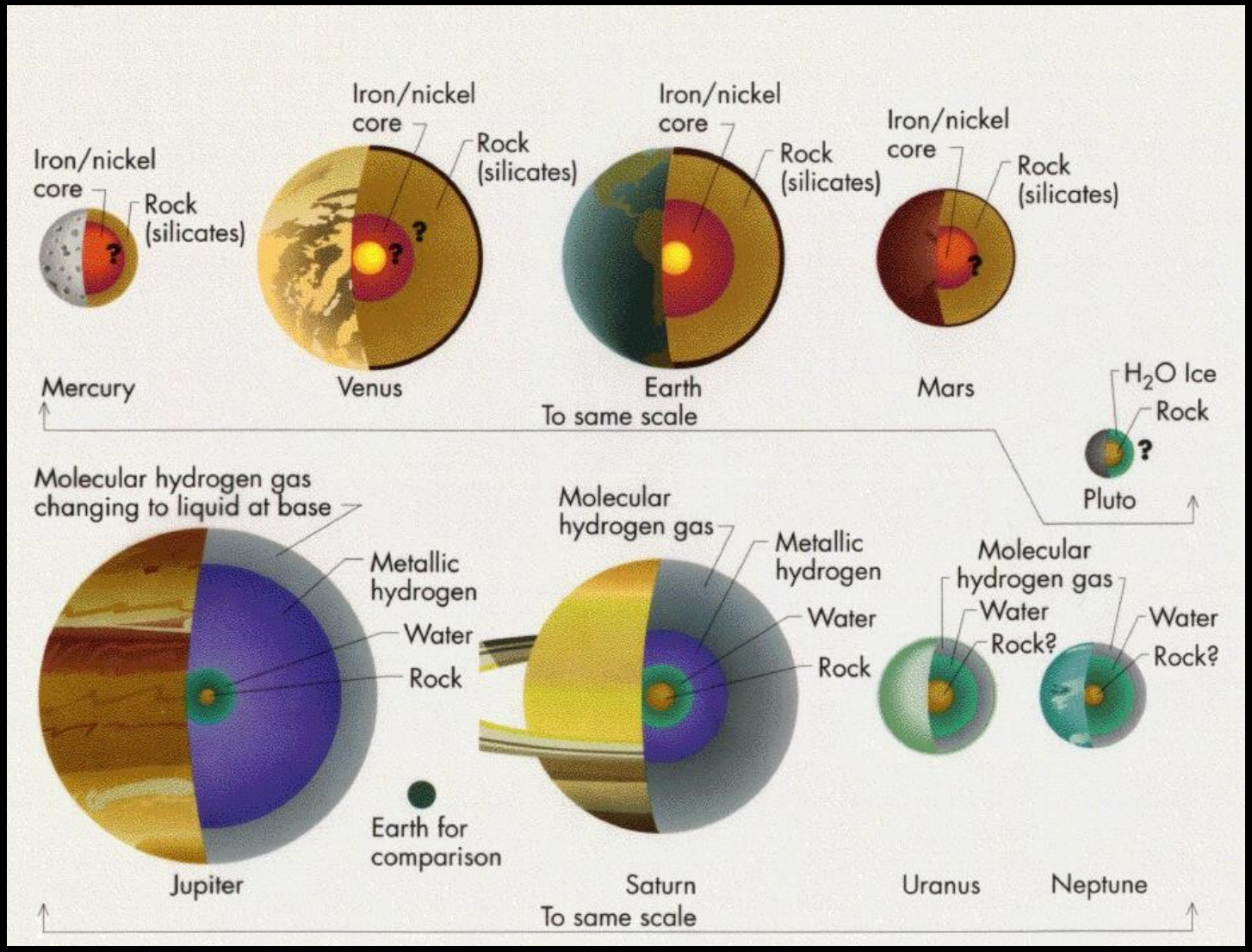
I pianeti in scala



Gradiente di temperatura



Differenze di composizione interna



pianeti “terrestri” (interni)

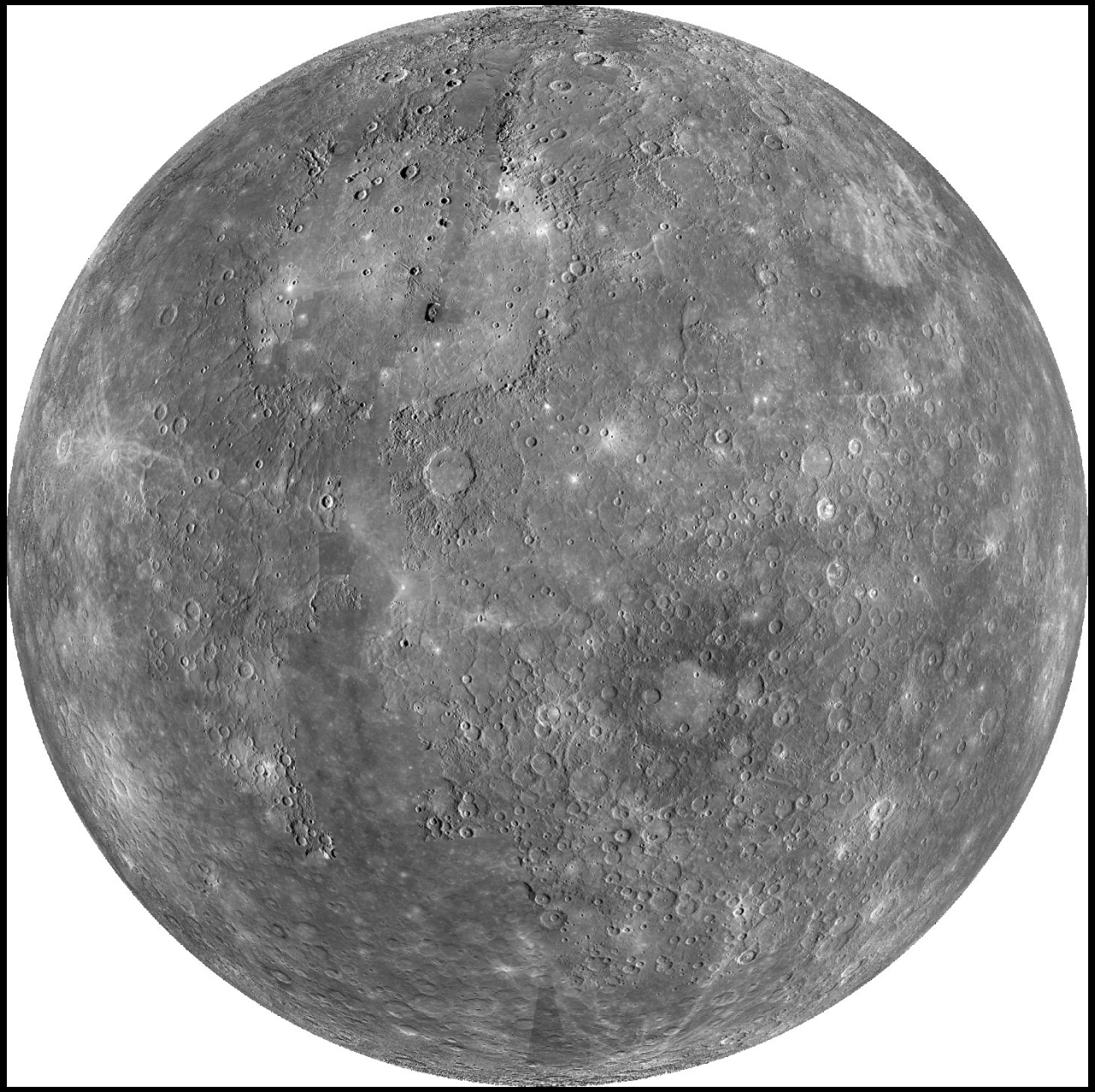
pianeti “giganti” (esterni)

4

Un’occhiata al Sistema Solare

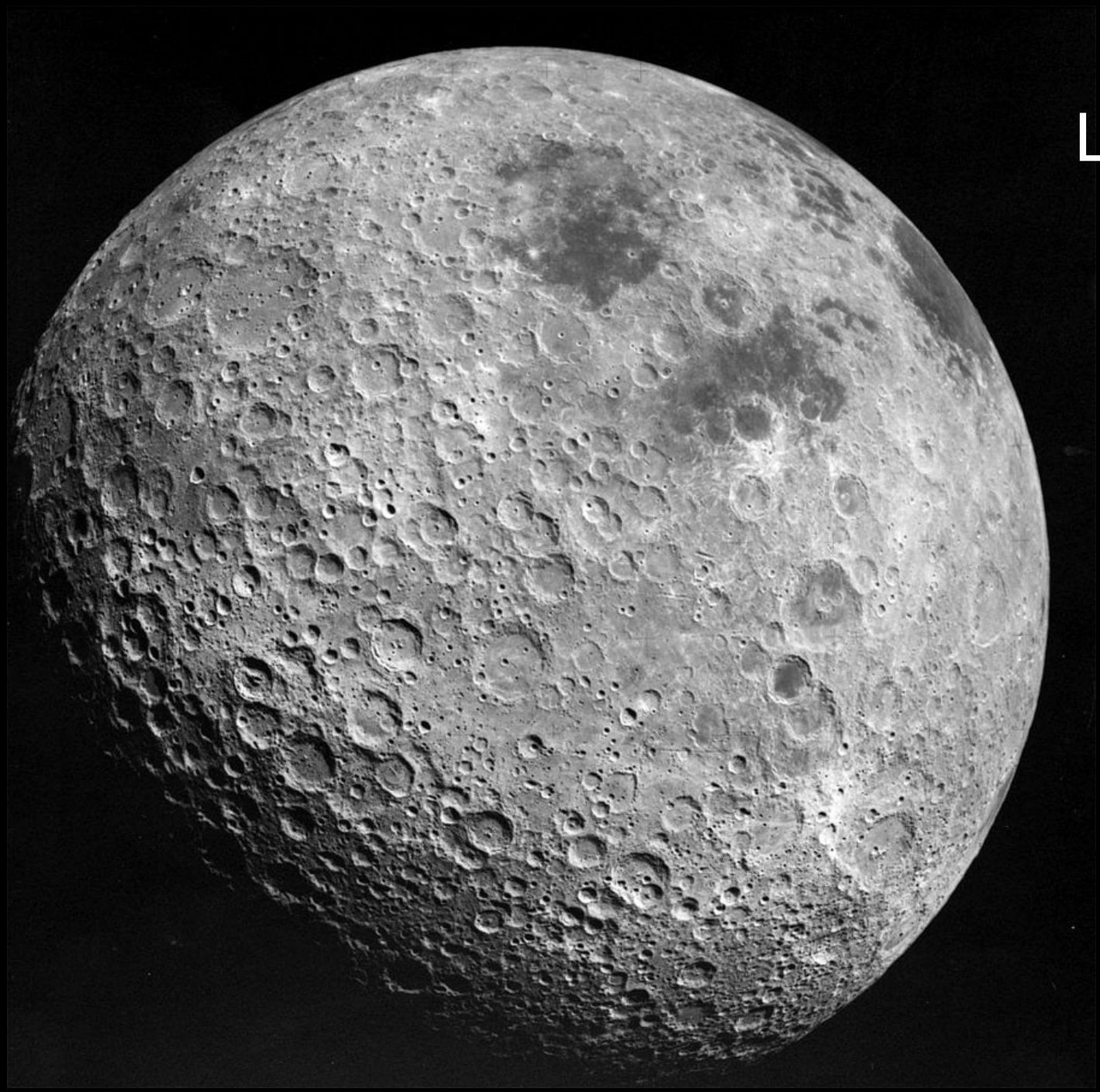
I pianeti del Sistema Solare

Pianeta	Distanza (AU)	Periodo orbitale	Diametro ($km \times 10^3$)	Densità (kg/cm^3)	Temperatura (°C)
Mercurio	0.39	88 d	4.88	5.4	167
Venere	0.72	225 d	12.1	5.2	464
Terra	1	365 d	12.76	5.5	15
Luna			3.47	3.3	-50
Marte	1.52	687 d	6.79	3.3	-20
Giove	5.20	12 y	143	1.3	-65
Saturno	9.54	29 y	121	0.7	-110
Urano	19.2	84 y	51	1.6	-195
Nettuno	30.1	165 y	50	1.8	-200



Mercurio

d = 0.39 AU
P_{orb} = 88 d
P_{rot} = 59 d
R = 2440 km

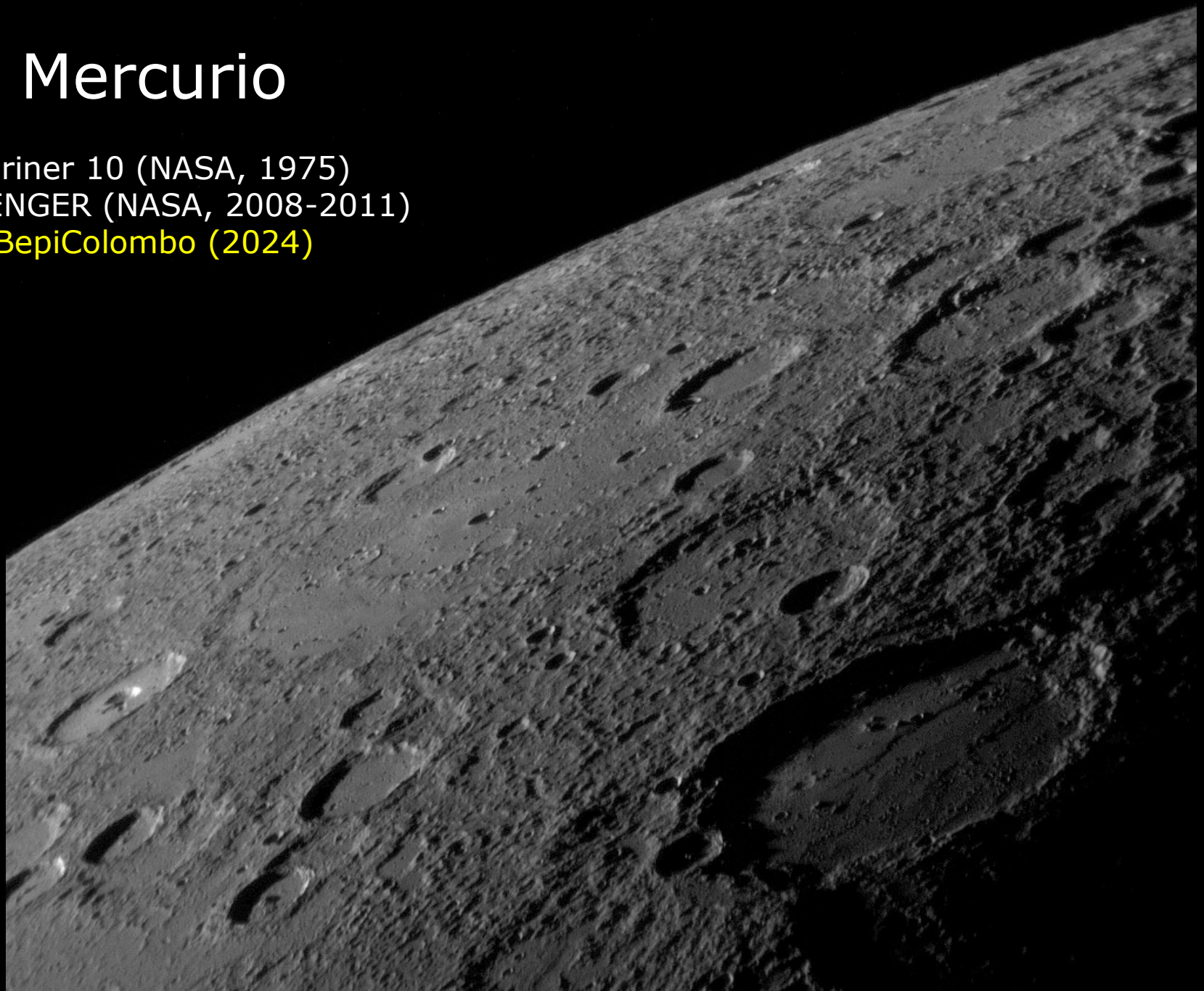


Luna

R = 1738 km

Mercurio

Mariner 10 (NASA, 1975)
MESSENGER (NASA, 2008-2011)
BepiColombo (2024)



Mercurio



Come si forma un cratere



Come si forma un cratere

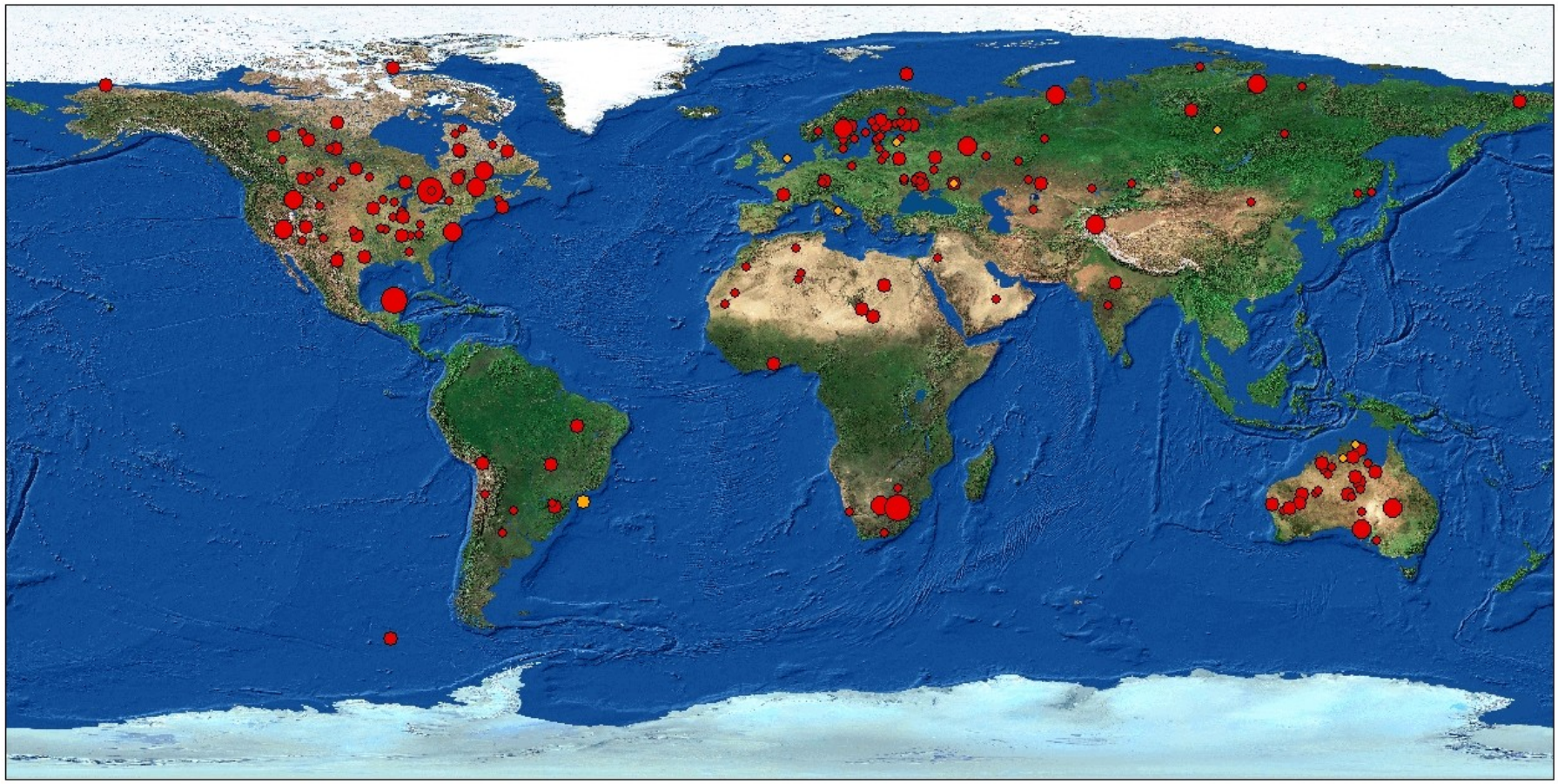


Come si forma un cratere



Come si forma un cratere





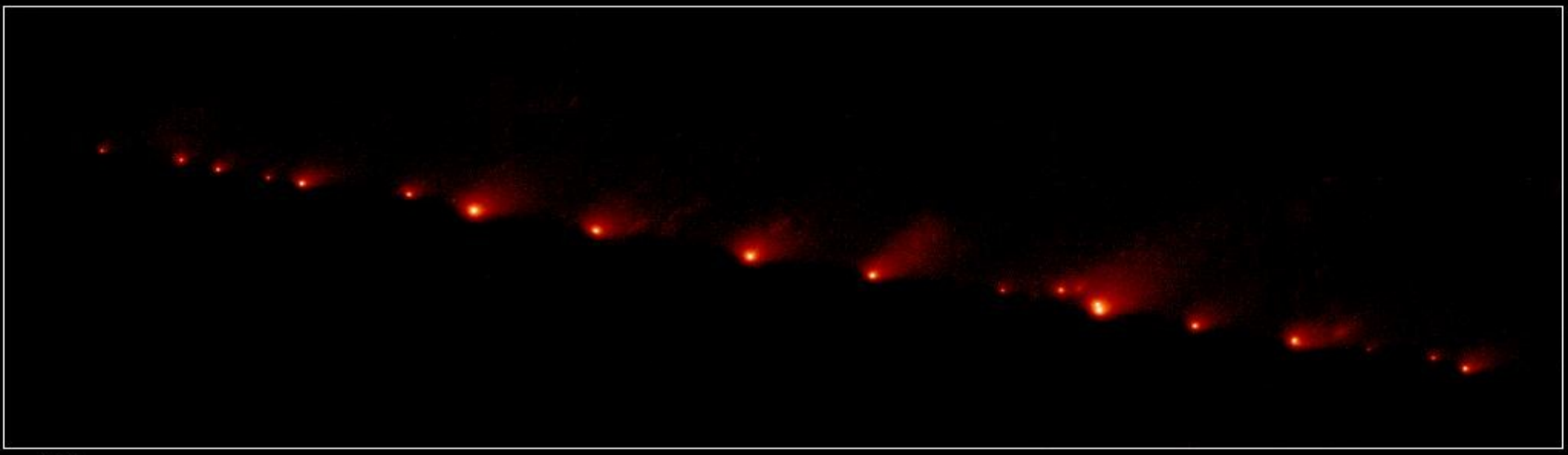
182 strutture da impatto confermate (10 m – 300 km)
+ altre 400/500 dubbie/da confermare


Barringer Meteor Crater (Arizona, USA)
diametro: 1200 m; età: 49.000 anni



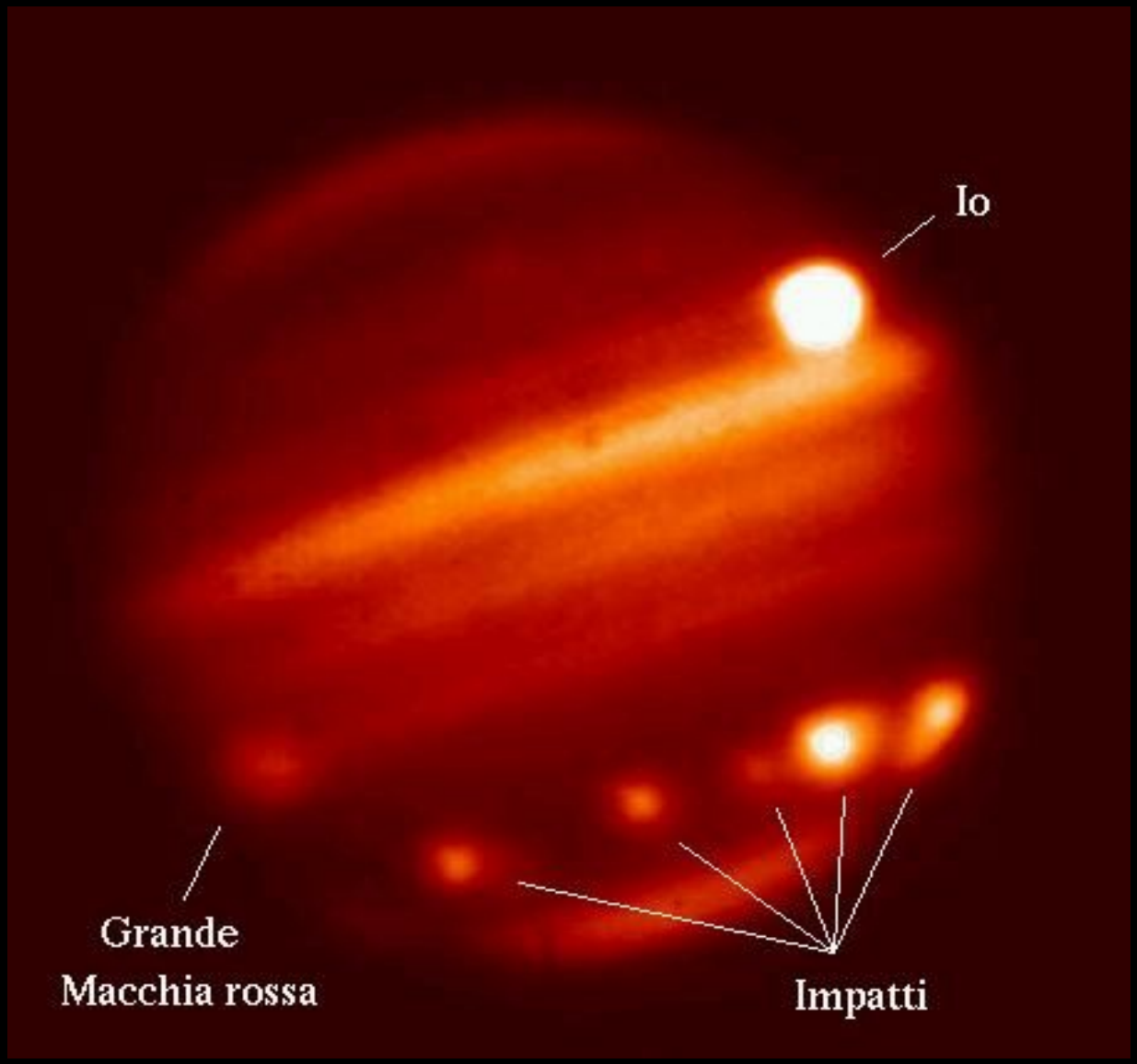
Barringer Meteor Crater (Arizona, USA)

Comet P/Shoemaker-Levy 9 (1993e) • May 1994



SPACE TELESCOPE SCIENCE INSTITUTE

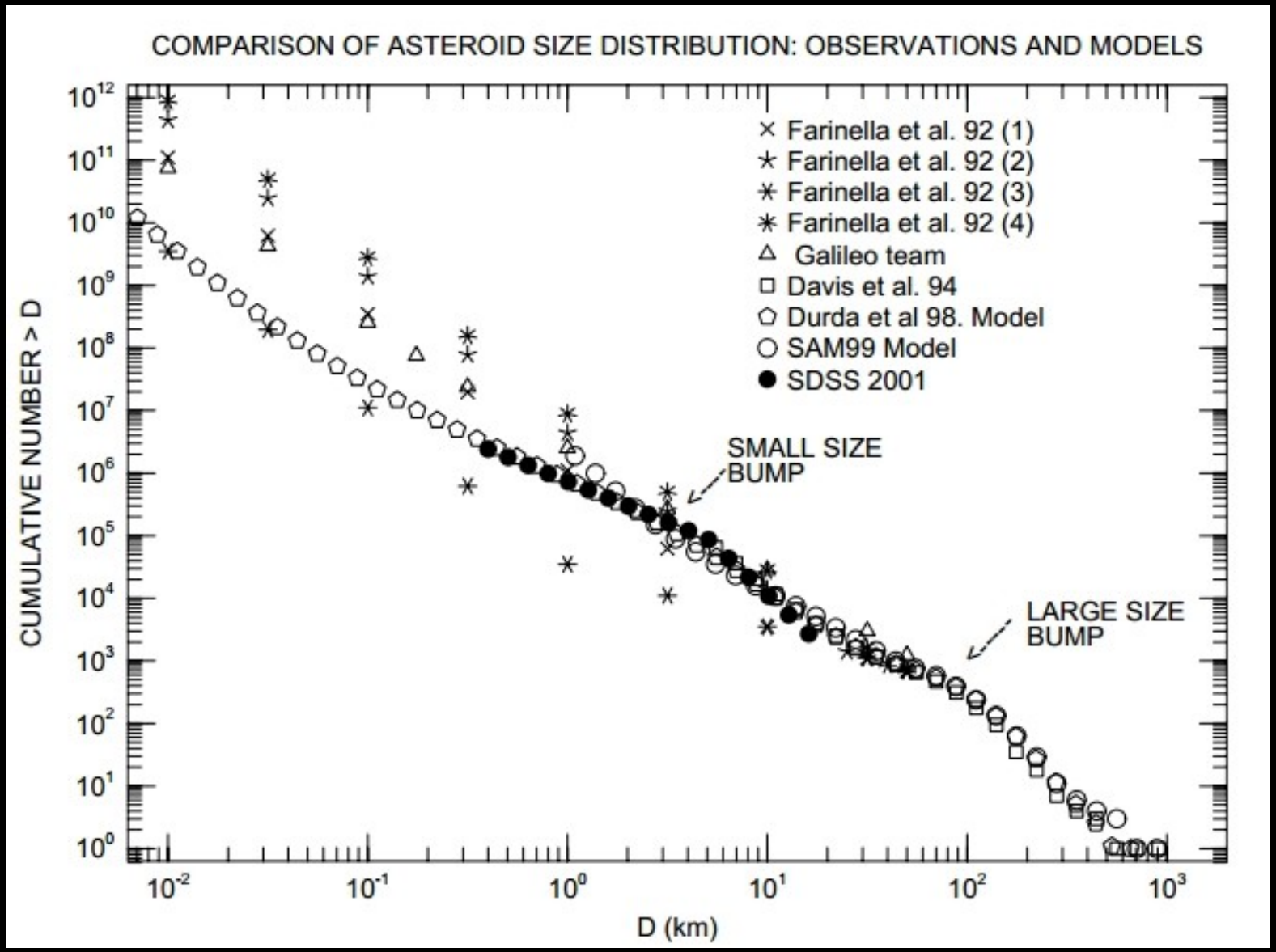
Hubble Space Telescope • Wide Field Planetary Camera 2



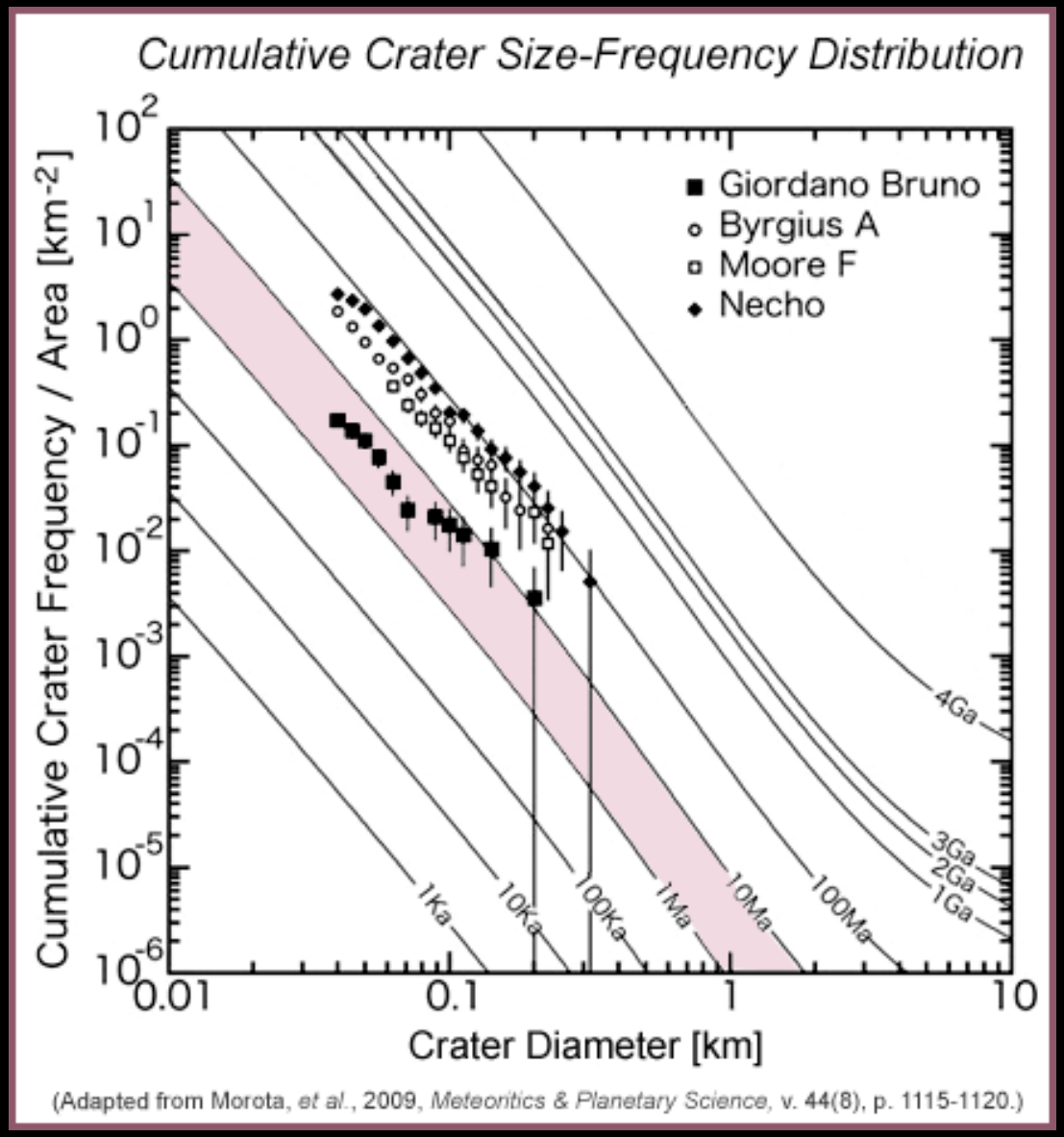
Impatto dei frammenti della cometa *Shoemaker-Levy 9* con il pianeta Giove



La (nostra) Luna



Conteggio di asteroidi in funzione delle dimensioni



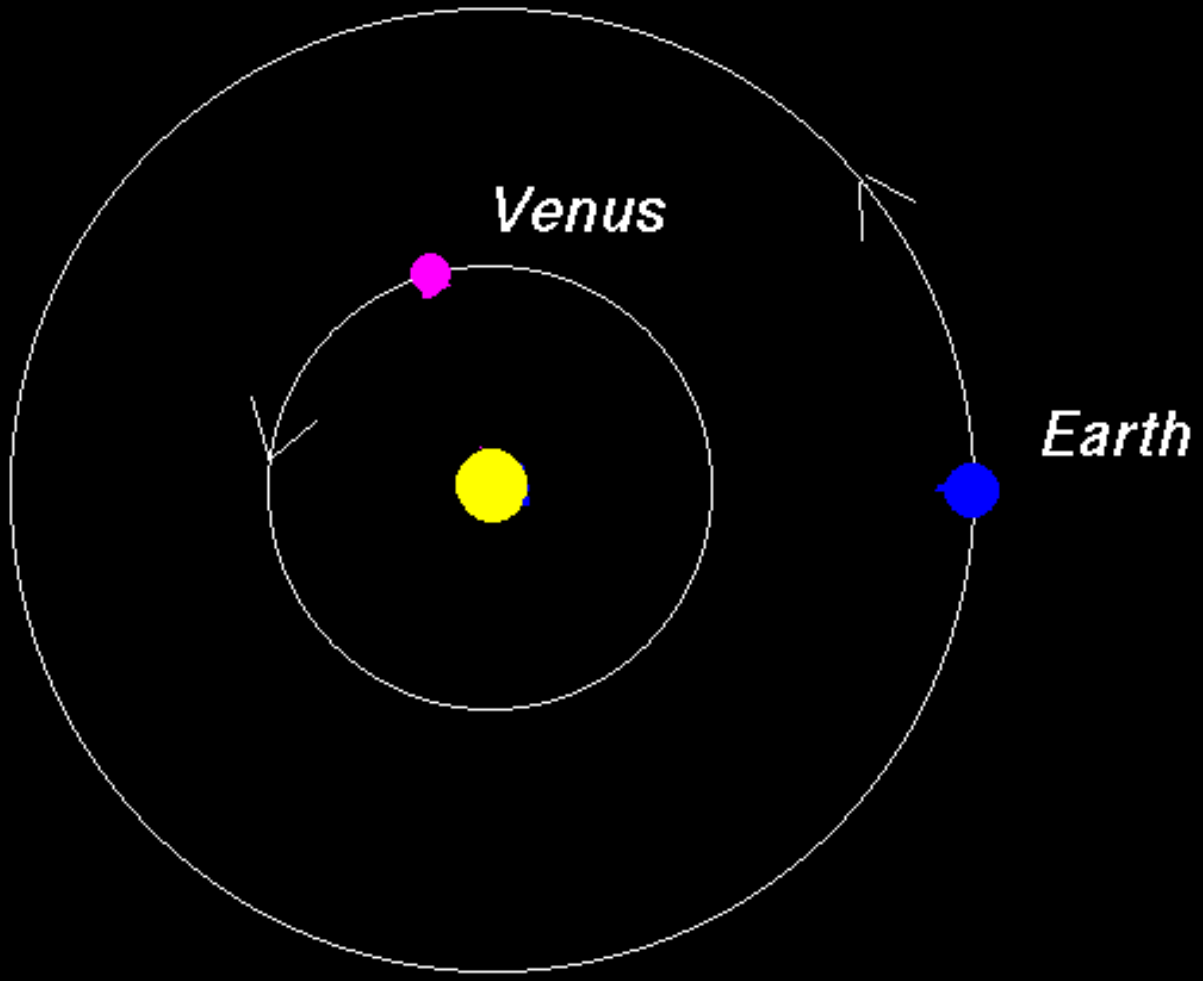
Conteggio di crateri lunari in funzione delle dimensioni

Le fasi dei pianeti interni



Venere

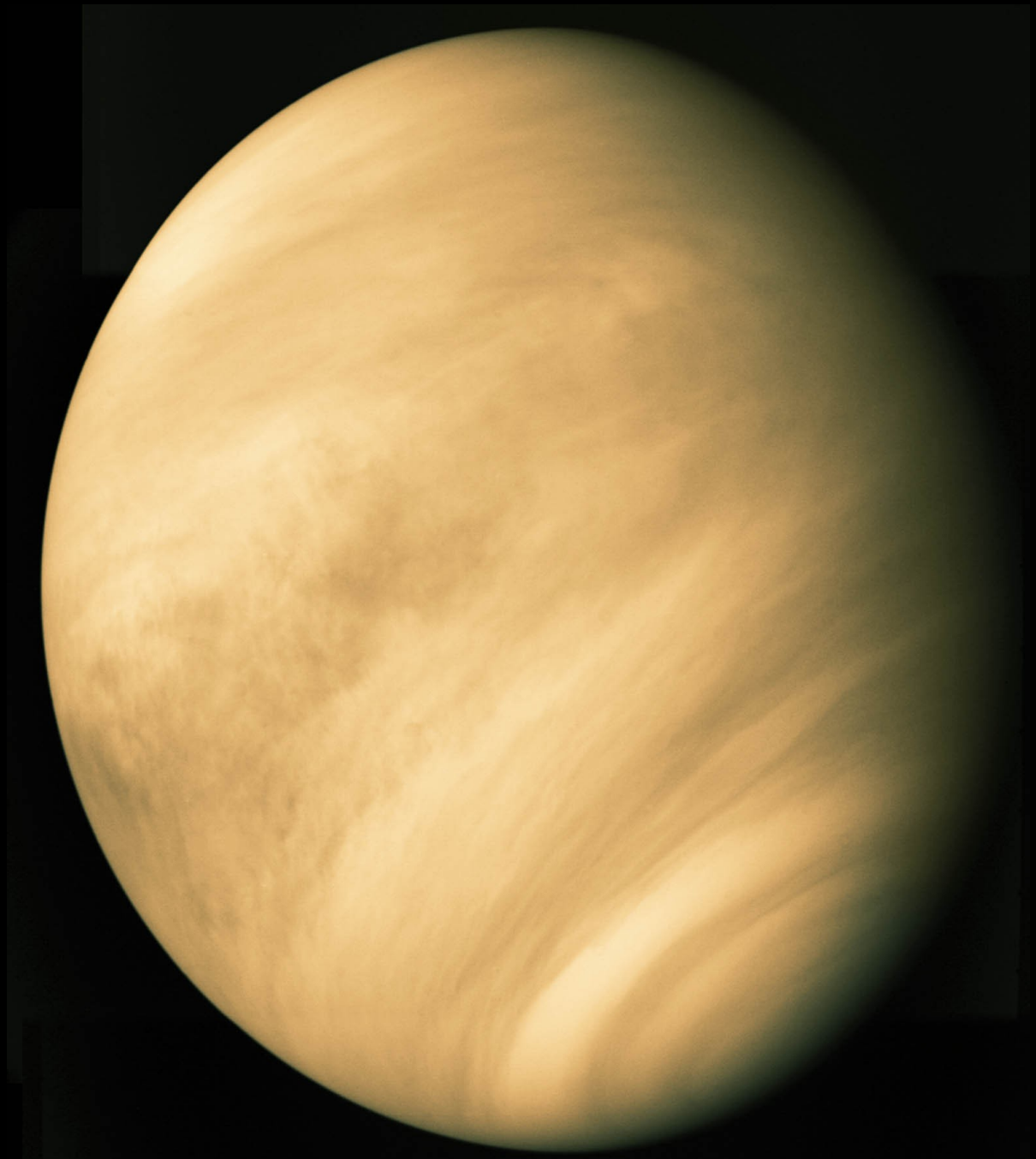
Le fasi dei pianeti interni



Le fasi dei pianeti interni



Venere



Mariner 10 Image of Venus

© Copyright Calvin J. Hamilton

Venere

d = 0.72 AU
P_{orb} = 225 d
P_{rot} = -243 d
R = 6052 km

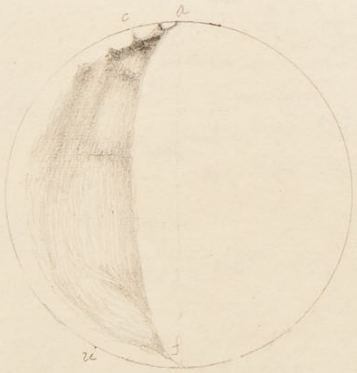


$15^h\,0^m$
$15\ 15^m$

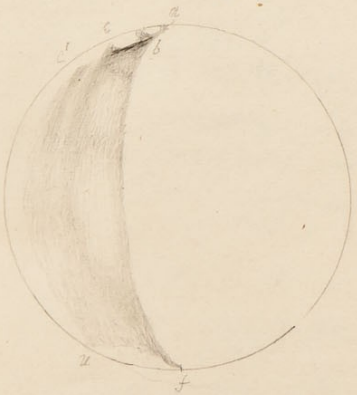
XIV 20 Lug 1895
Ocul B' vetro chiaro
Aria II un po' ondulata. Questo disegno rende bene la proporzione delle varie ombre.



XV 21 Lug 1895
Ocul B' vetro chiaro
(un po' velato)



XVI 25 Lug 1895
$10^h\,20^m \rightarrow 10^h\,35^m$
Ocul B' naturale
Aria I–II a momenti incupisce Cielo un po' velato
pare bene riuscito
Il bottone a appena si vede: la punta c: dei corni portata un po' a sinistra.



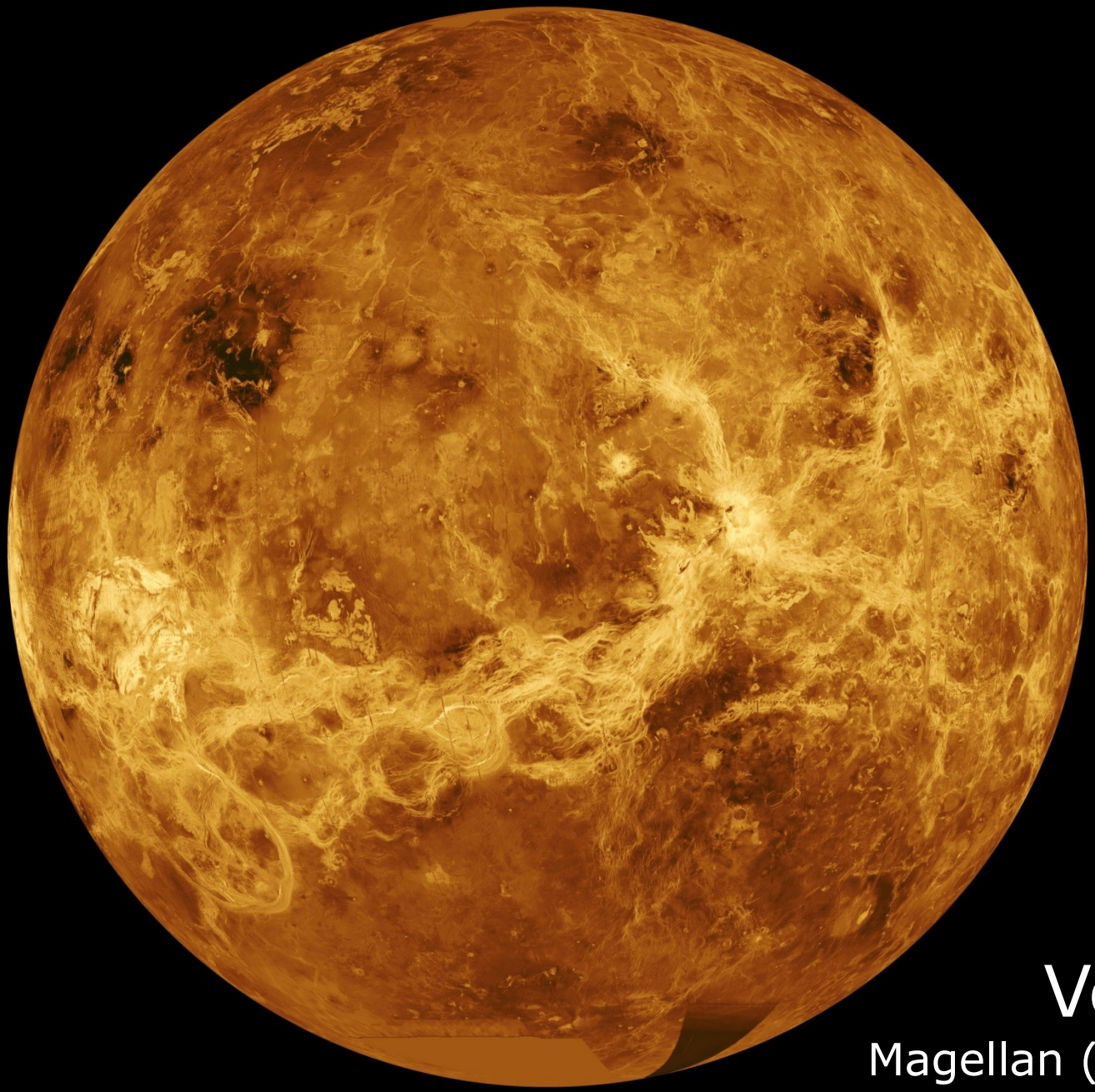
XVII 2 Agosto
$10^h\,40^m - 10^h\,55^m$
Ocul B' vetro I
Aria II tabacchi III e IV
Il quando in quando si vede luna. pare Cosmo.
Bottone a ben deciso

Venere vista da Schiaparelli



Venere

Venera 9 (URSS, 1975)

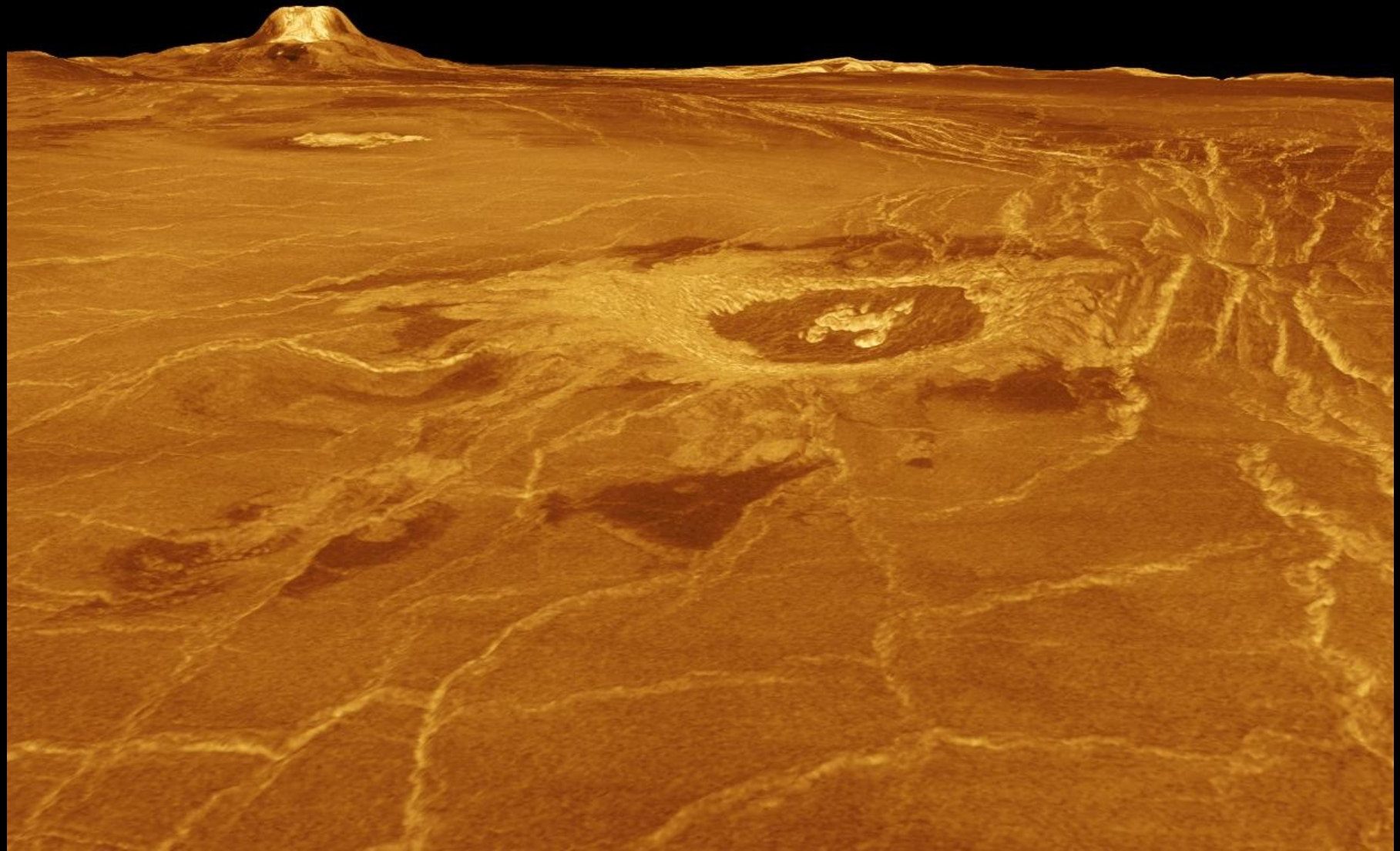


Venere

Magellan (NASA, 1990-94)

Venere

Magellan (NASA, 1990-94)



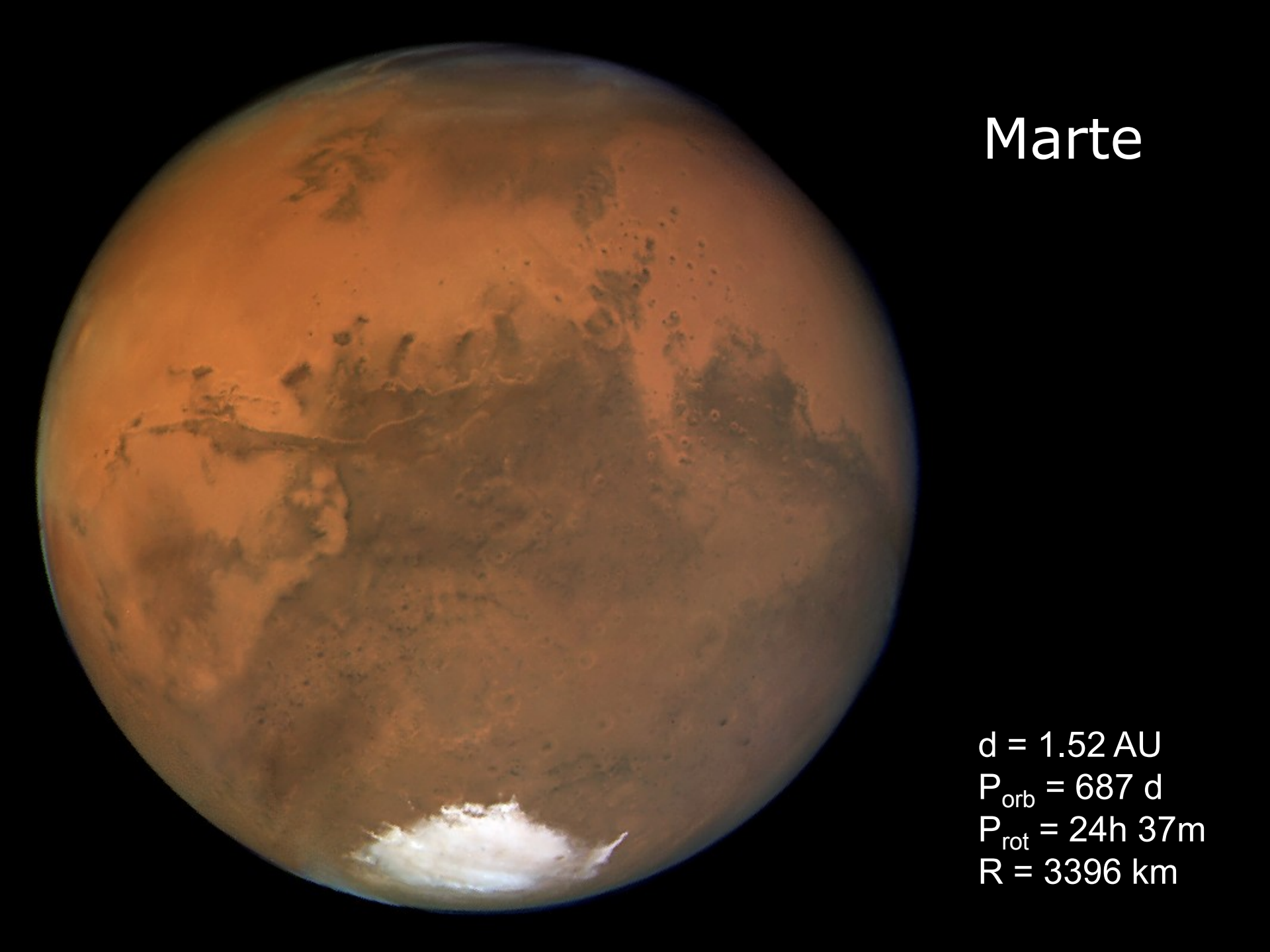


Terra

d = 1 AU

P_{orb} = 365.25 d

R = 6378 km



Marte

d = 1.52 AU
P_{orb} = 687 d
P_{rot} = 24h 37m
R = 3396 km

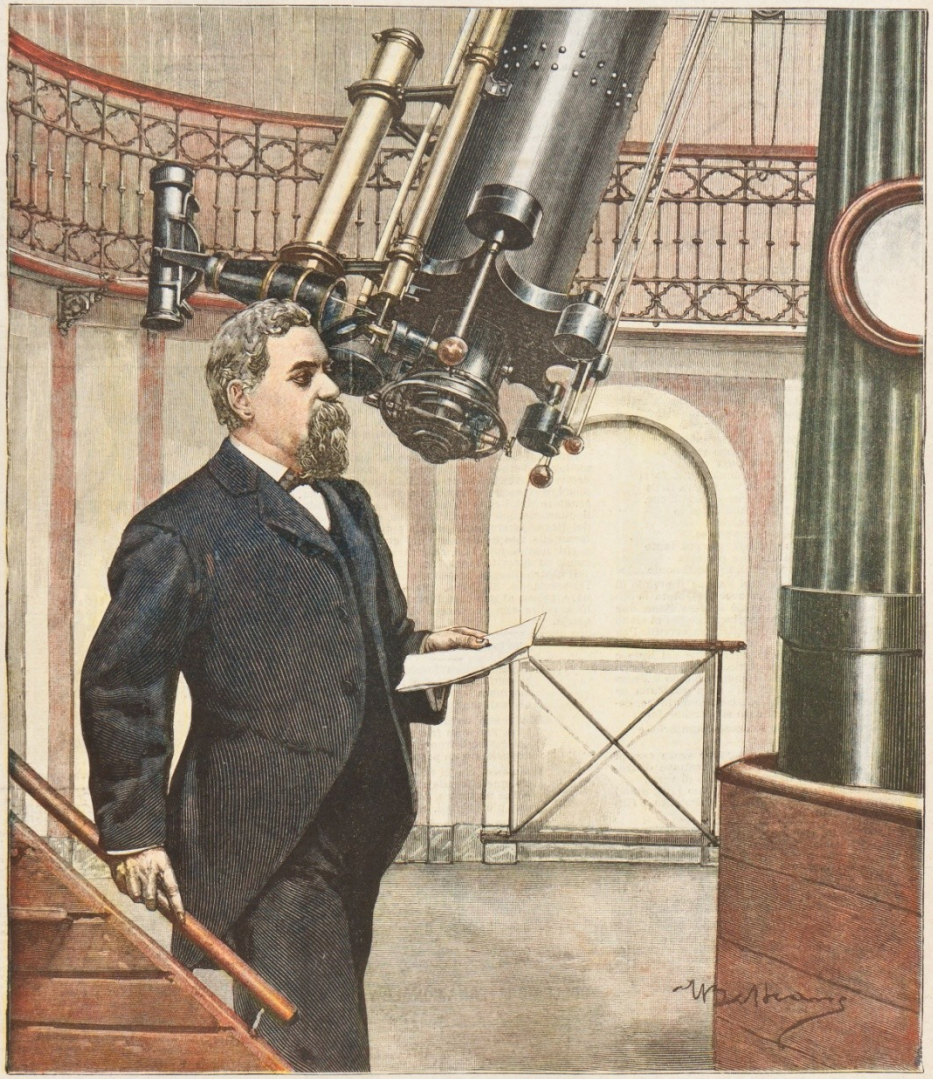
LA DOMENICA DEL CORRIERE

Anno . . . . . L. 5 — L. 8 —
Semestre . . . . . » 2 50 » 4 —

SI PUBBLICA A MILANO OGNI DOMENICA
Dono agli Abbonati del "Corriere della Sera,,

Uffici del giornale:
Via Pietro Verri, 14
MILANO

Anno II. — N. 43. 28 Ottobre 1900. Centesimi 10 il Numero.

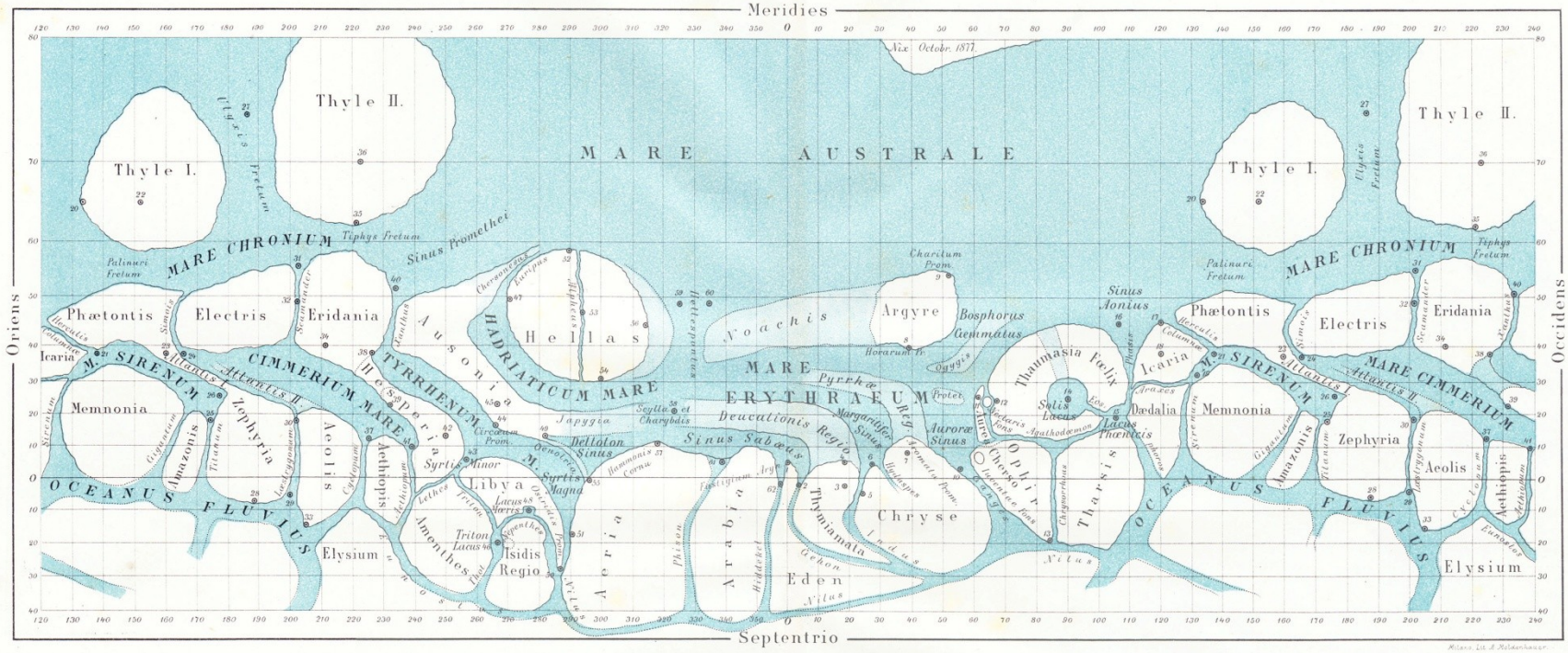


IL GRANDE ASTRONOMO SCHIAPARELLI NELL'OSSERVATORIO DI BRERA.

(Disegno di A. Beltrame, da [illegible] vero).

Giovanni Virginio Schiaparelli
(1835-1910)

Schiaparelli – Mappa di Marte (1877)



Tab. III

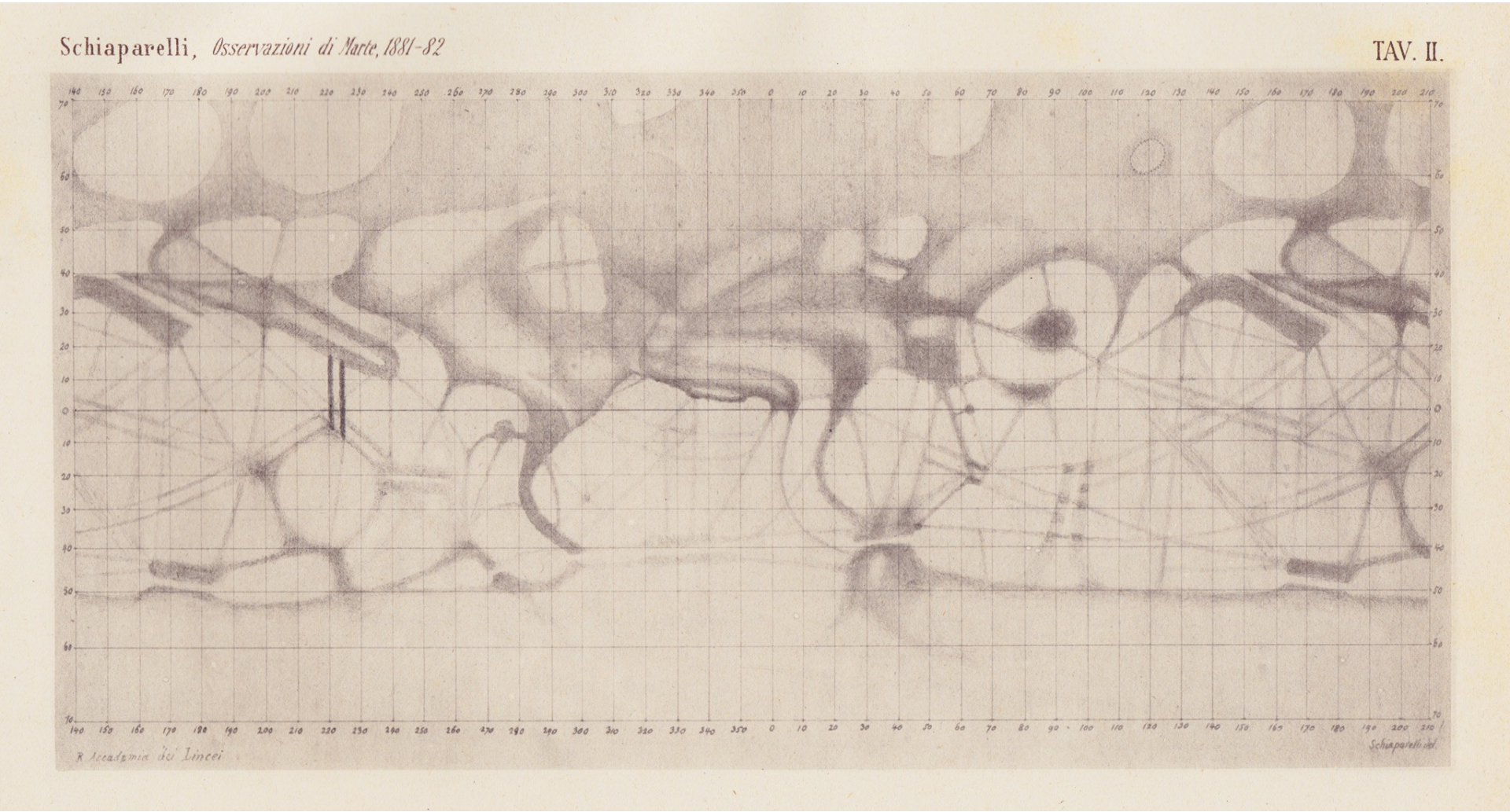
MAPPA AREOGRAPHICA

*Exhibens Planetæ Martis Chorographiam inter Polum Australem et Parallelum 40^um^*
Latitudinis Borealis:

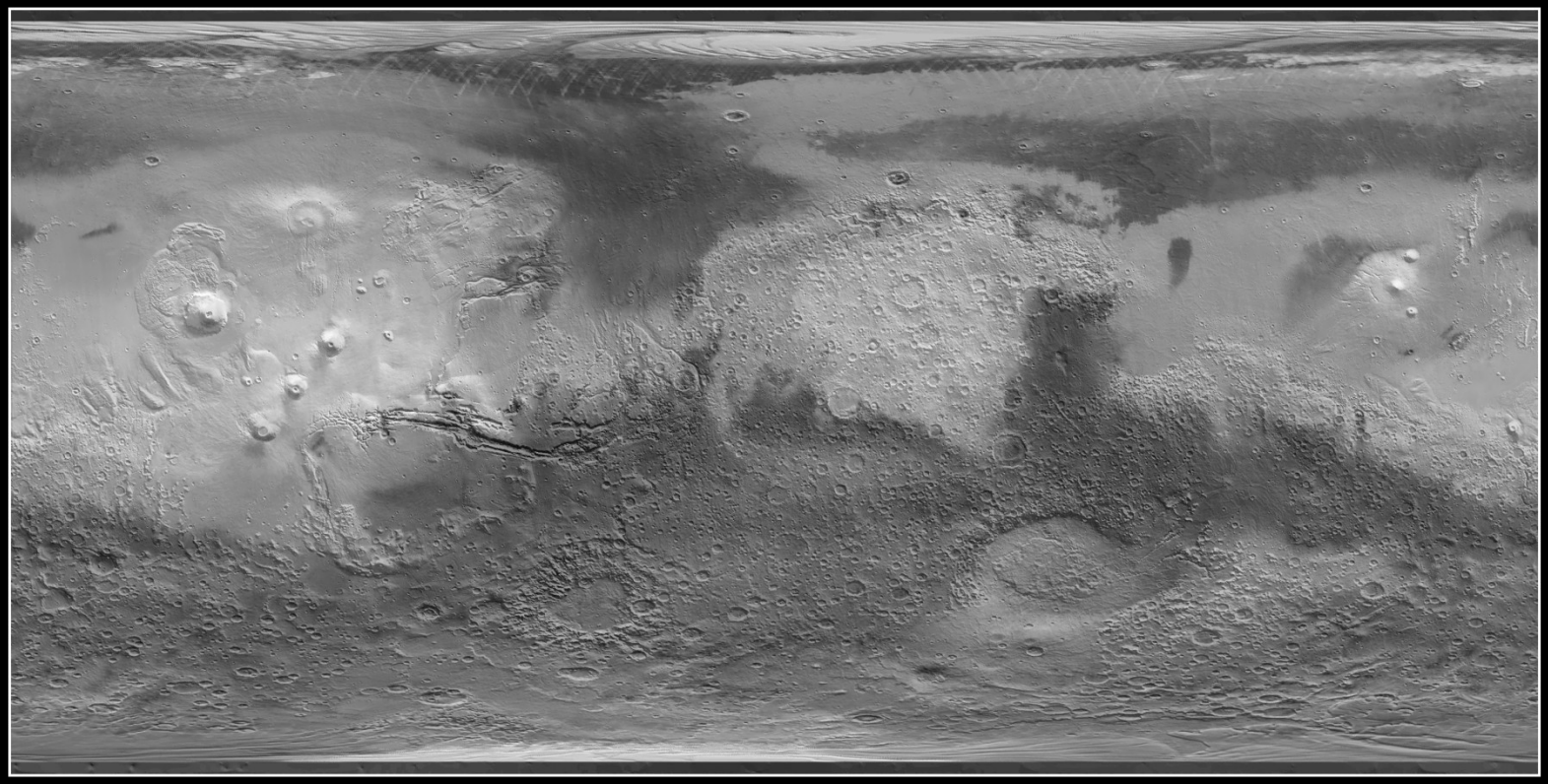
Ex propriis Observationibus atque Mensuris ope Tubi Merziani decempedalis
in Speculâ Braydensi Mediolani habitis
composuit, supputavit, atque delineavit **J.V. Schiaparelli**

1877 — 1878.

Schiaparelli – Mappa di Marte (1881)



TES Albedo



Mars Global Surveyor (1996-2006)

Pareidolia: il volto su Marte

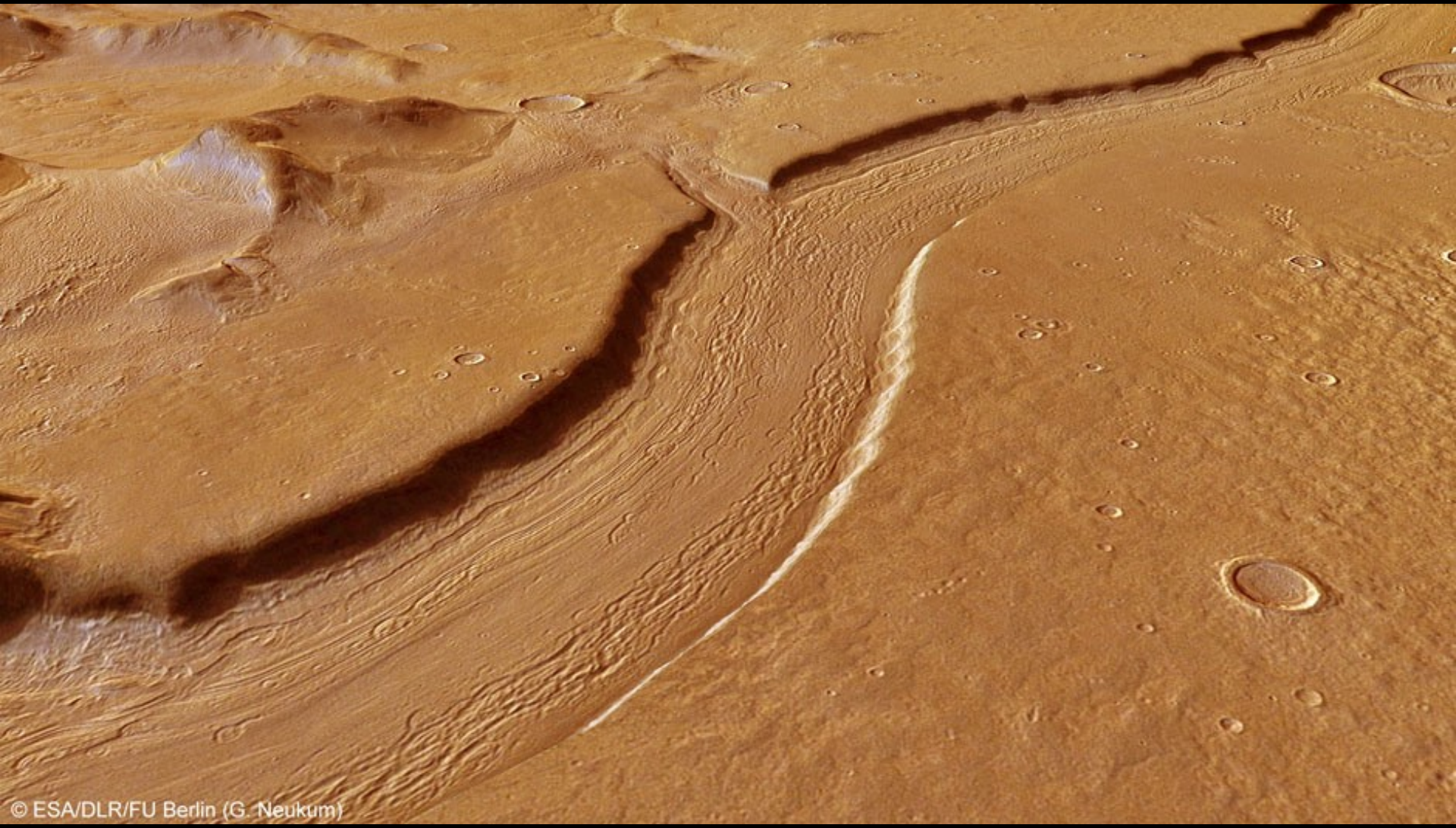


Pareidolia: il volto su Marte

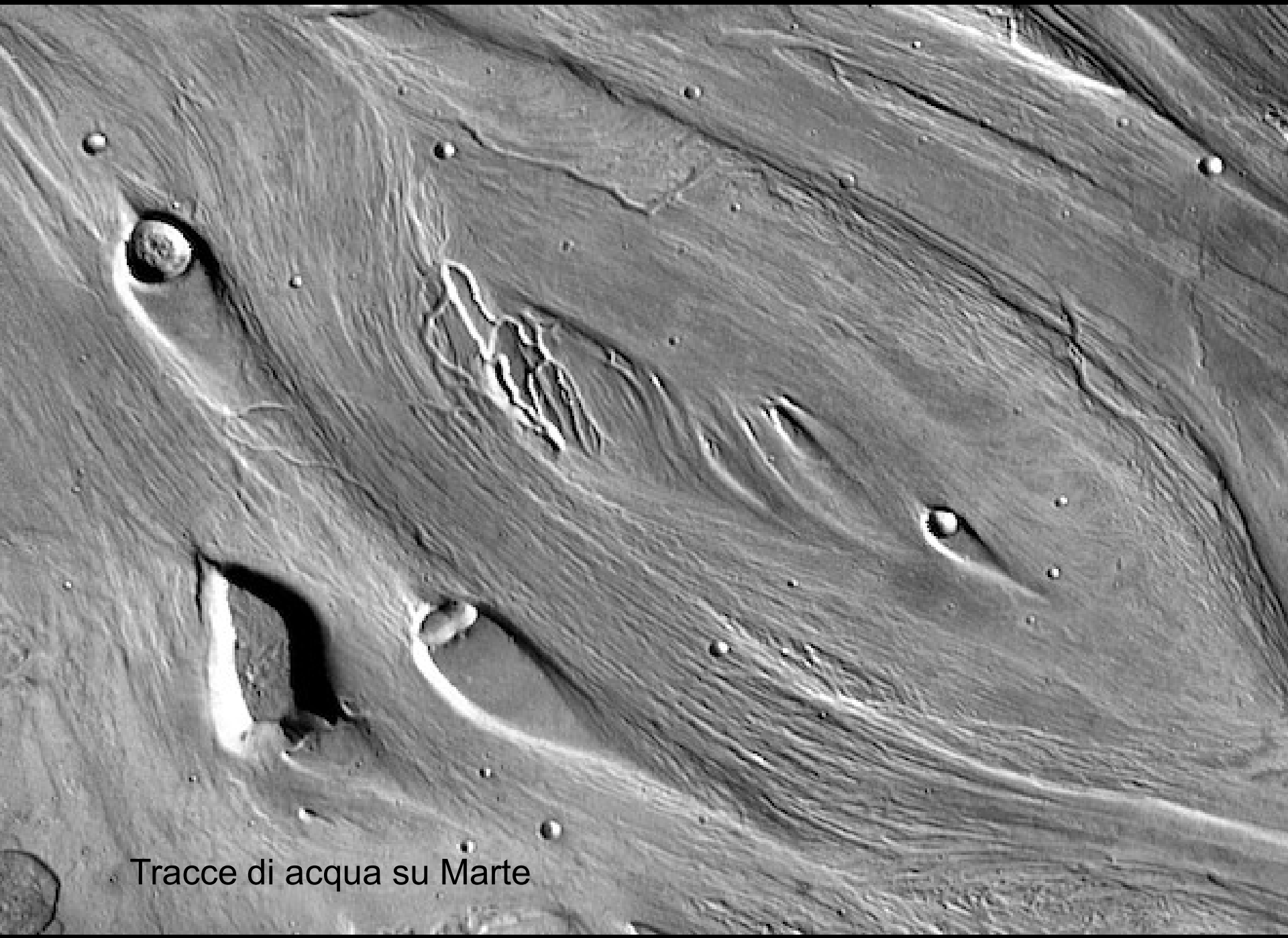




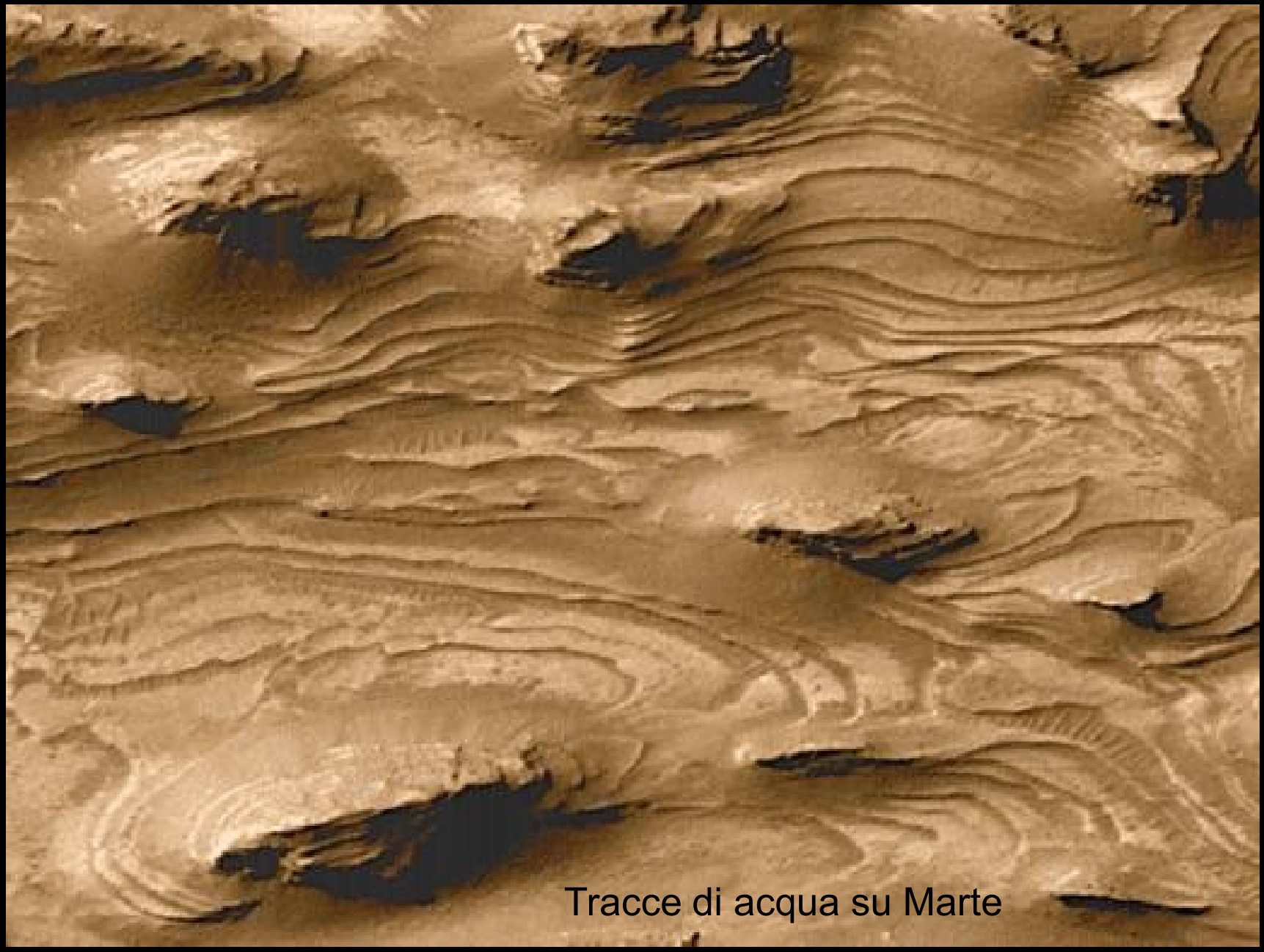
Tracce di acqua su Marte



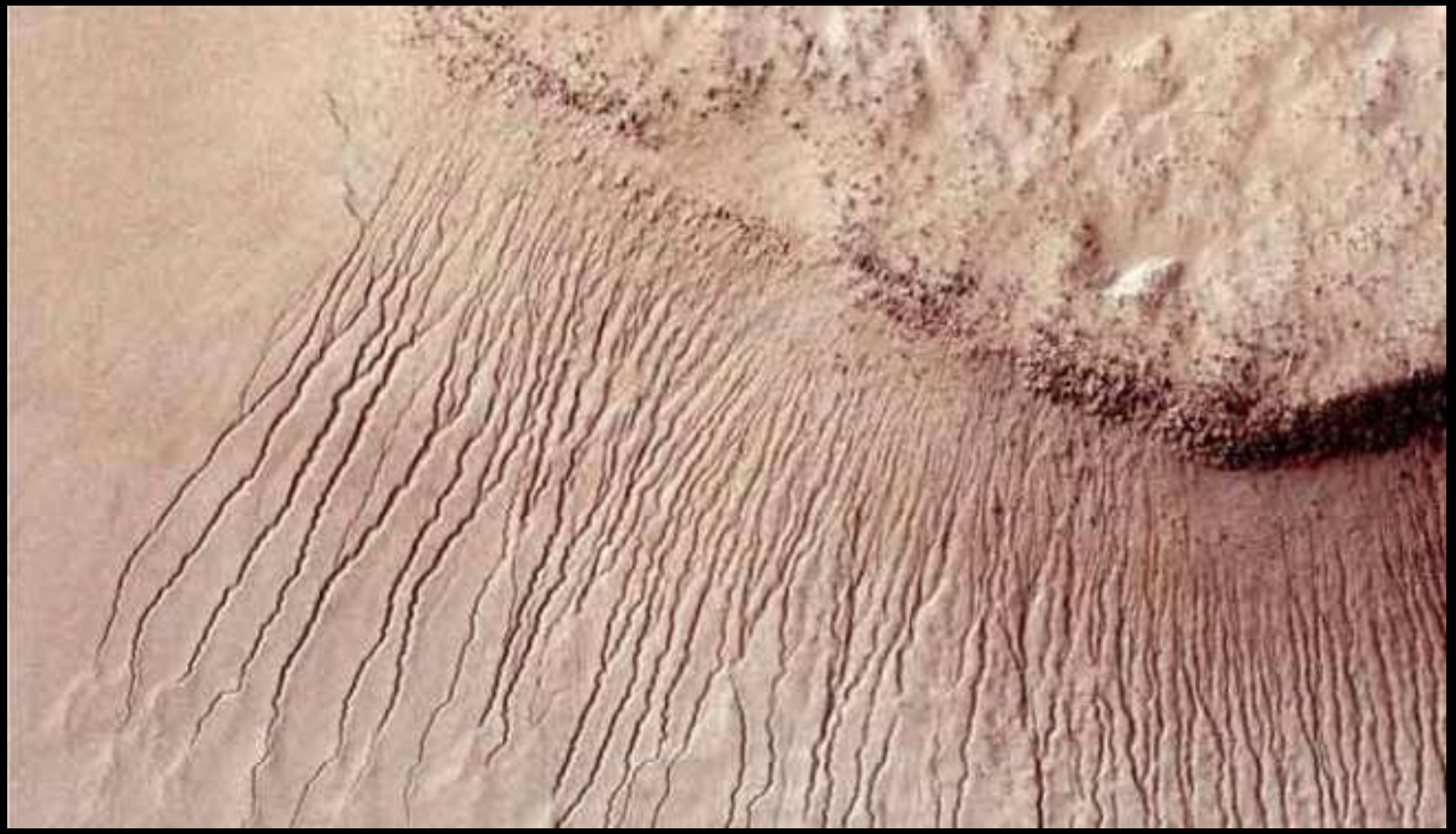
Tracce di acqua su Marte



Tracce di acqua su Marte

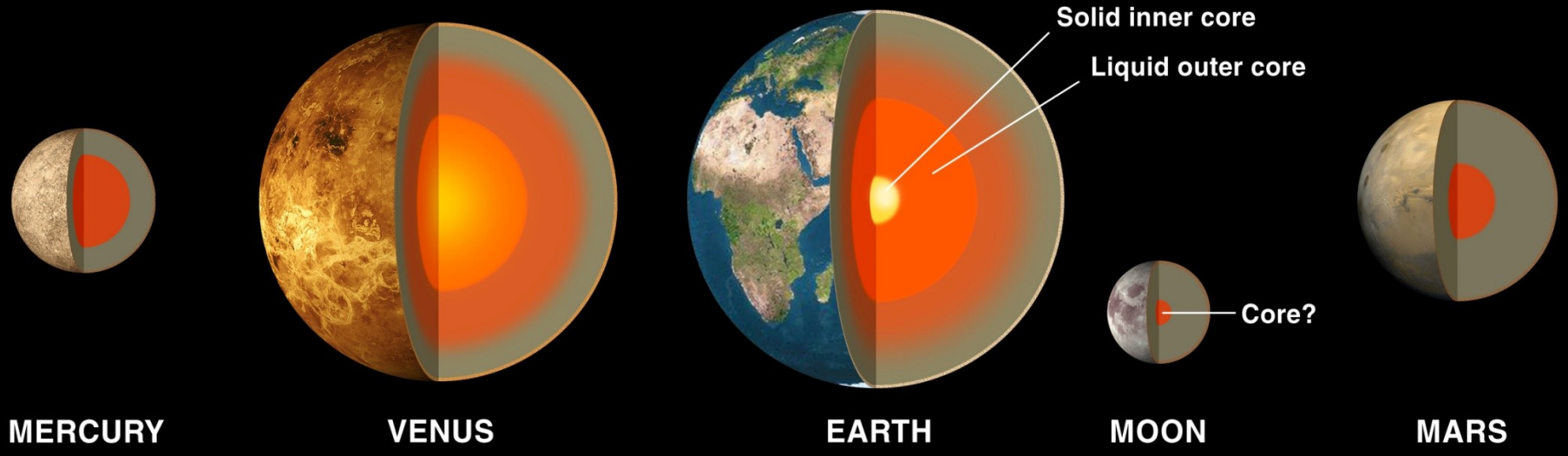


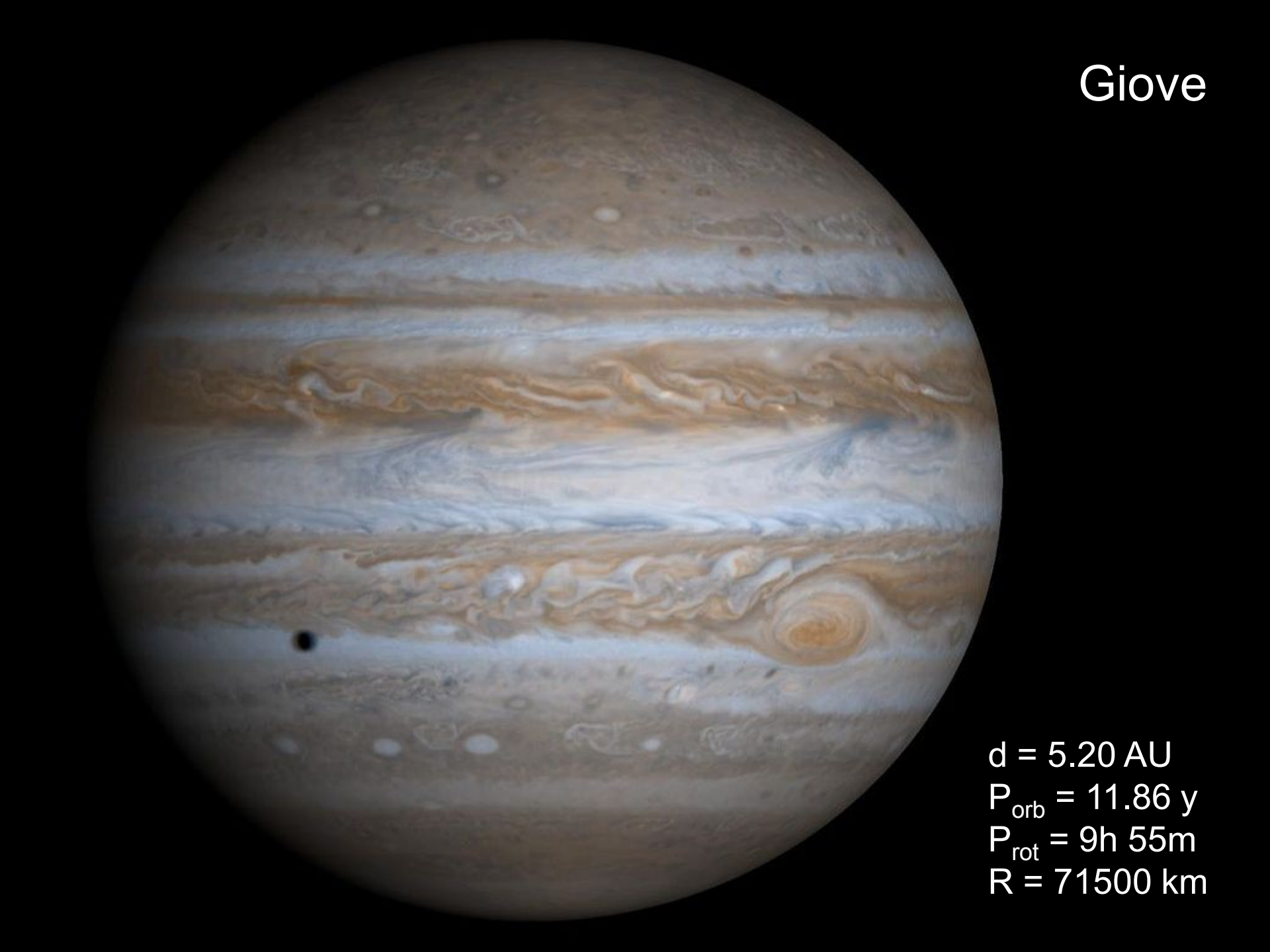
Tracce di acqua su Marte

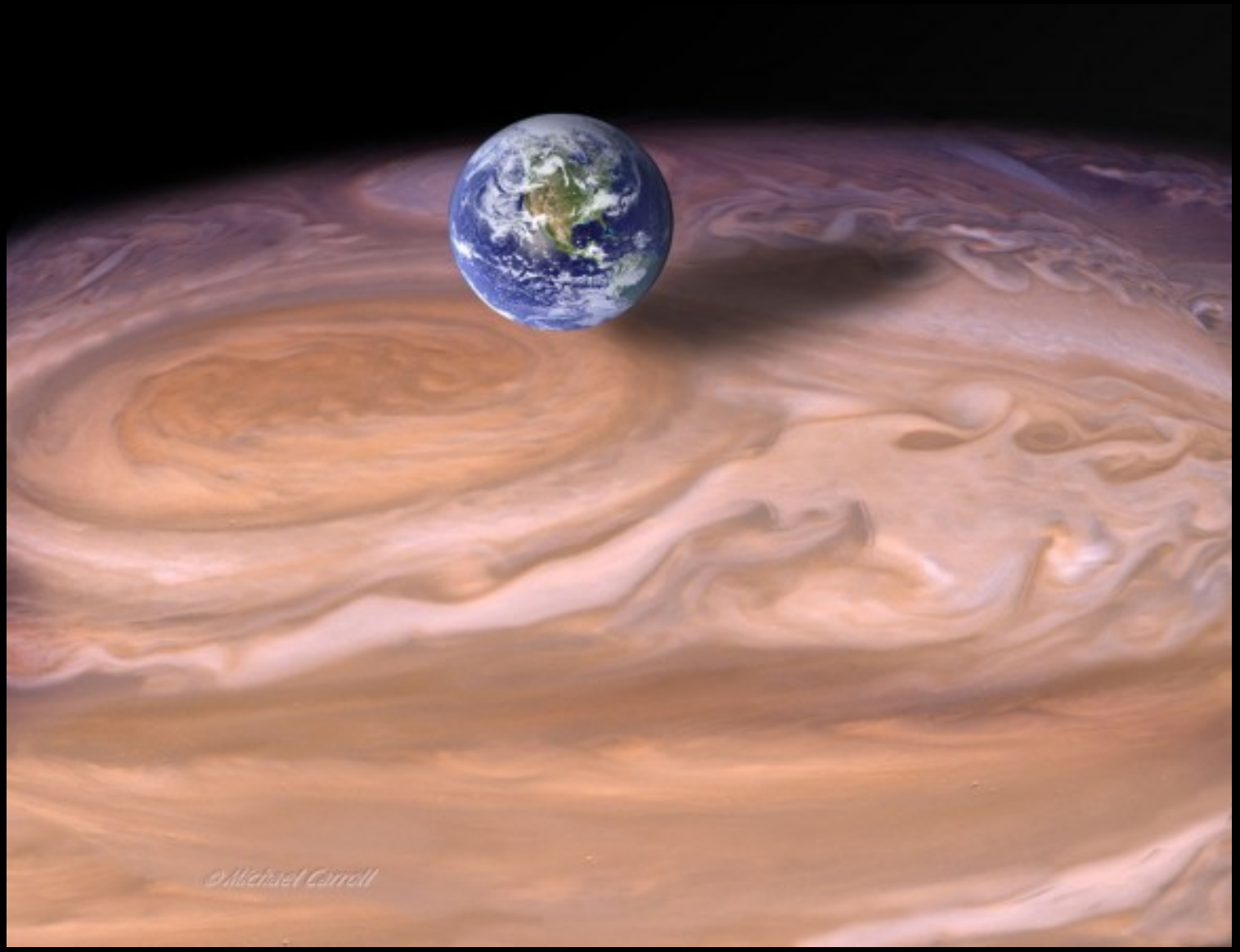


Tracce di acqua su Marte

Confronto tra i pianeti “terrestri”

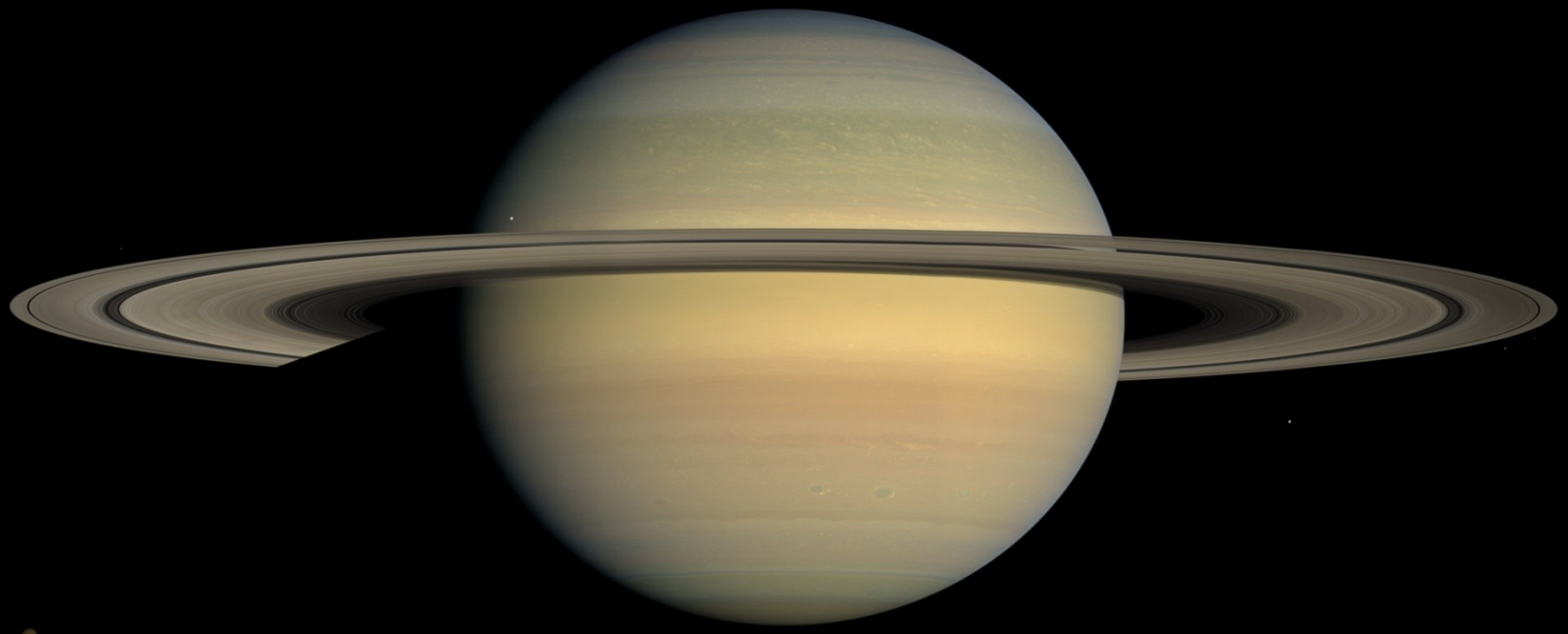



Giove
d = 5.20 AU
P_{orb} = 11.86 y
P_{rot} = 9h 55m
R = 71500 km



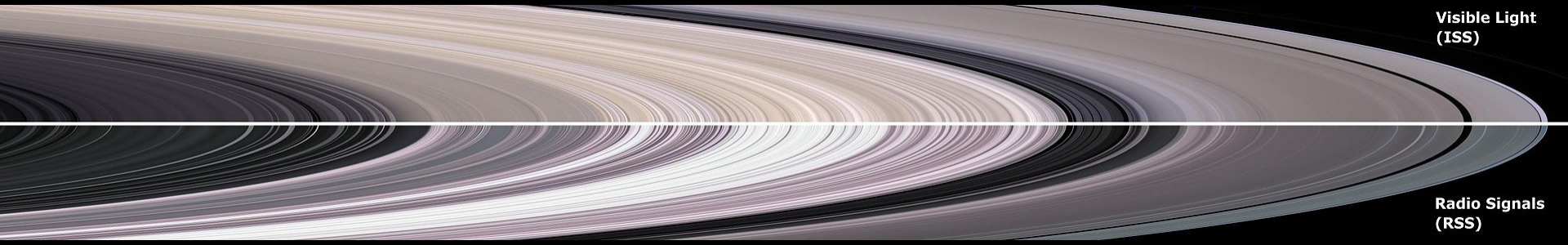
La Terra e la macchia rossa di Giove

Saturno

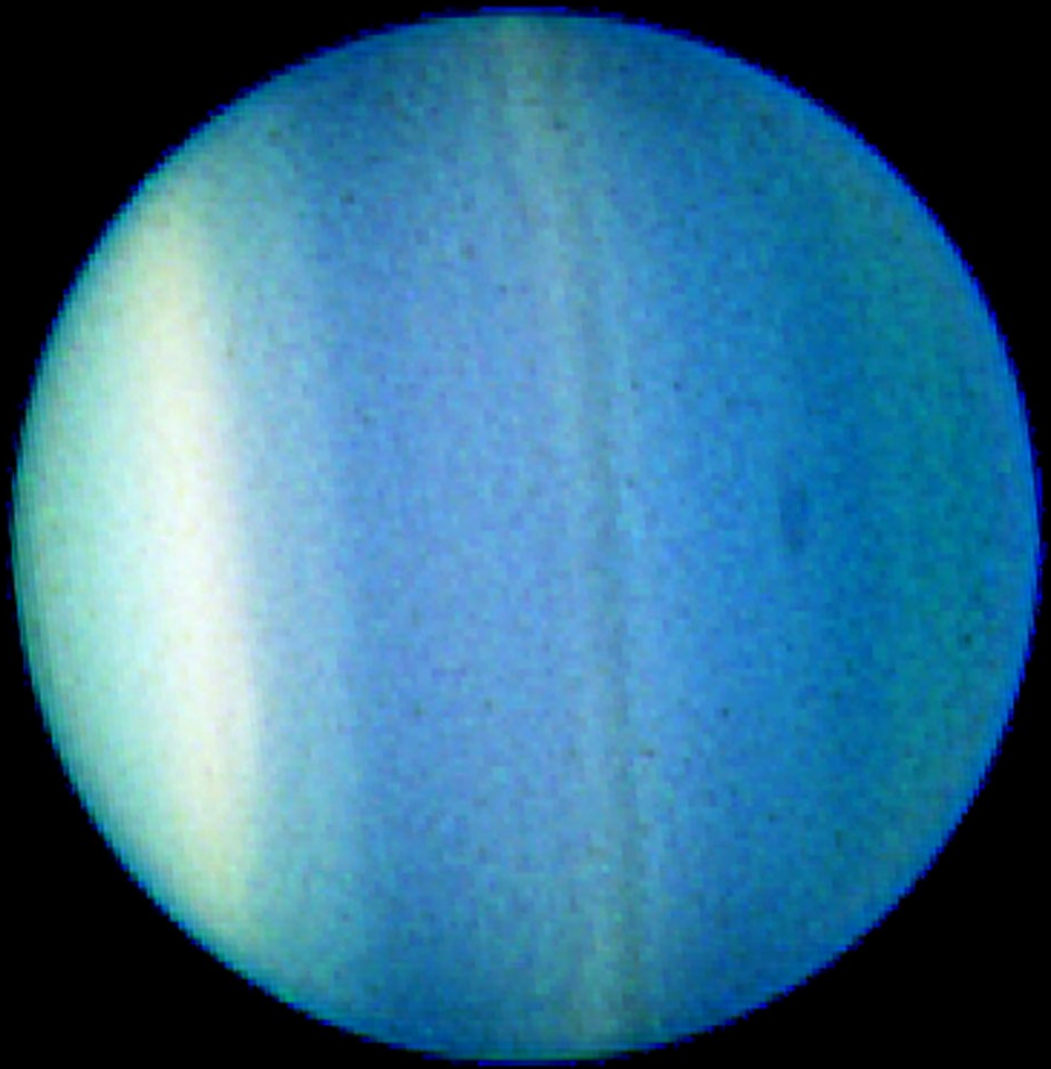


d = 9.58 AU
P_{orb} = 29.46 y
P_{rot} = 10h 33m
R = 60268 km

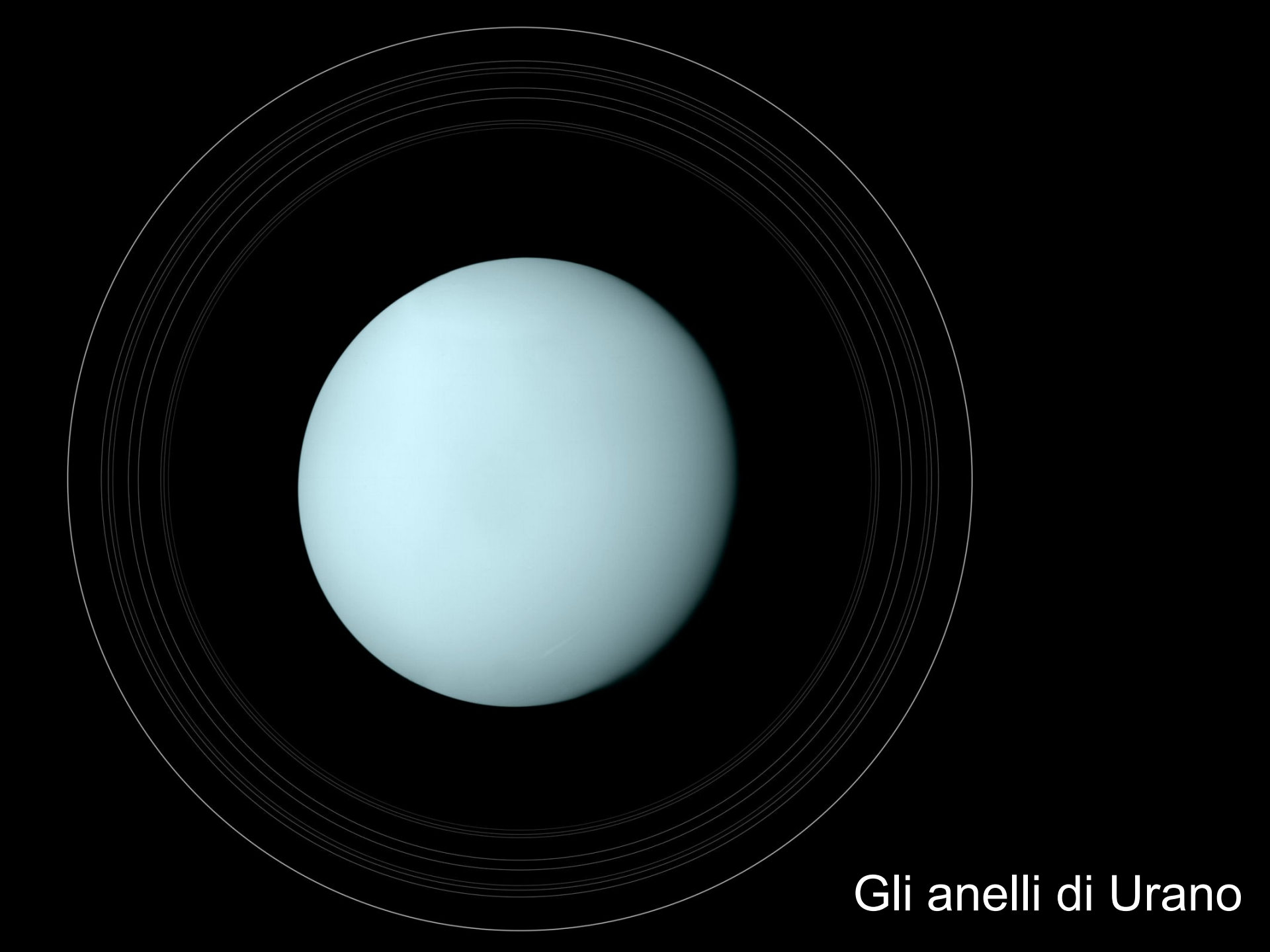
Gli anelli di Saturno



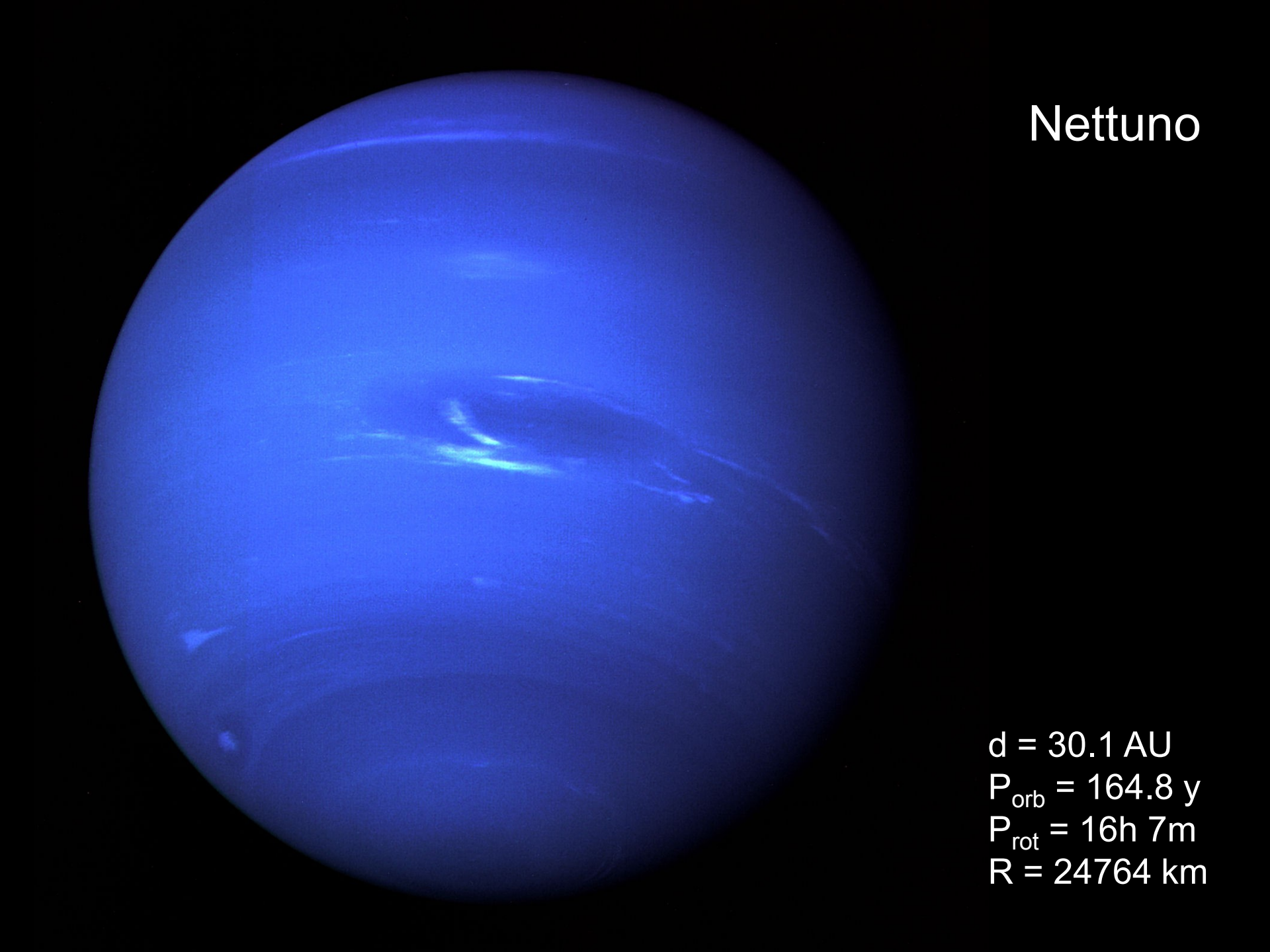
Urano



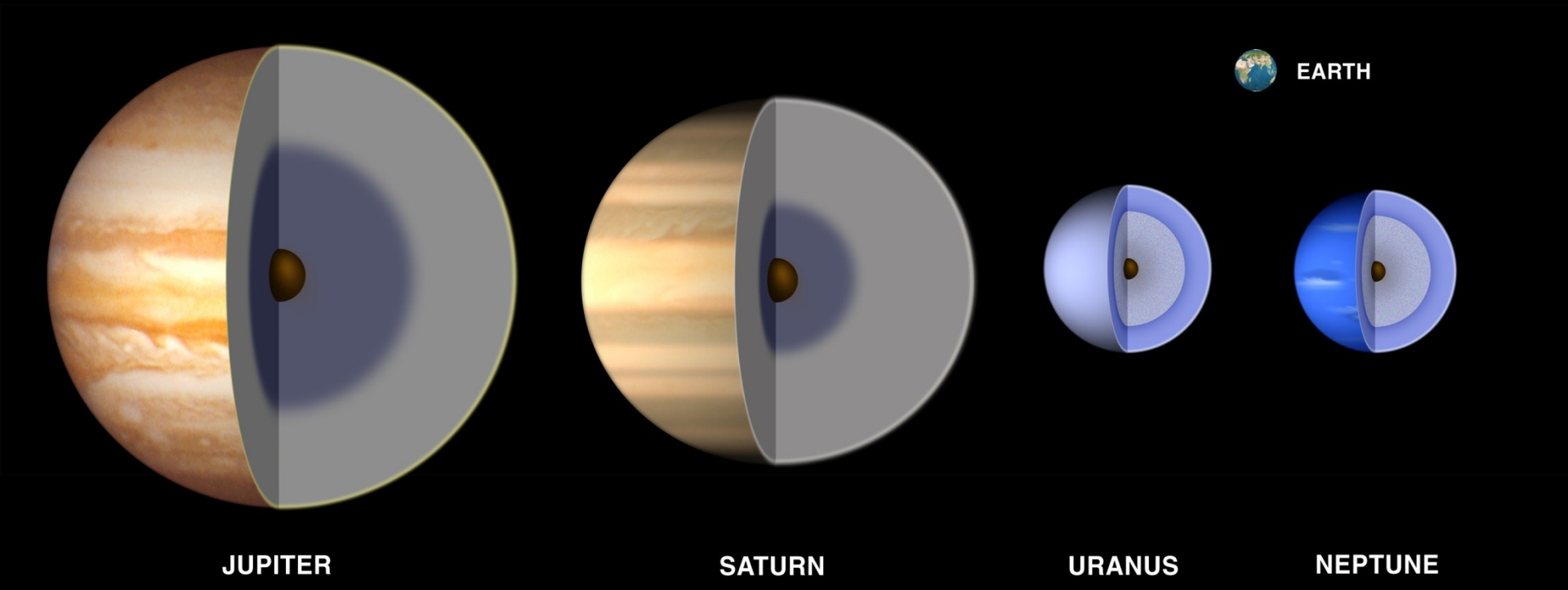
d = 19.20 AU
P_{orb} = 84.0 y
P_{rot} = 17h 14m
R = 25560 km



Gli anelli di Urano


Nettuno
d = 30.1 AU
P_{orb} = 164.8 y
P_{rot} = 16h 7m
R = 24764 km

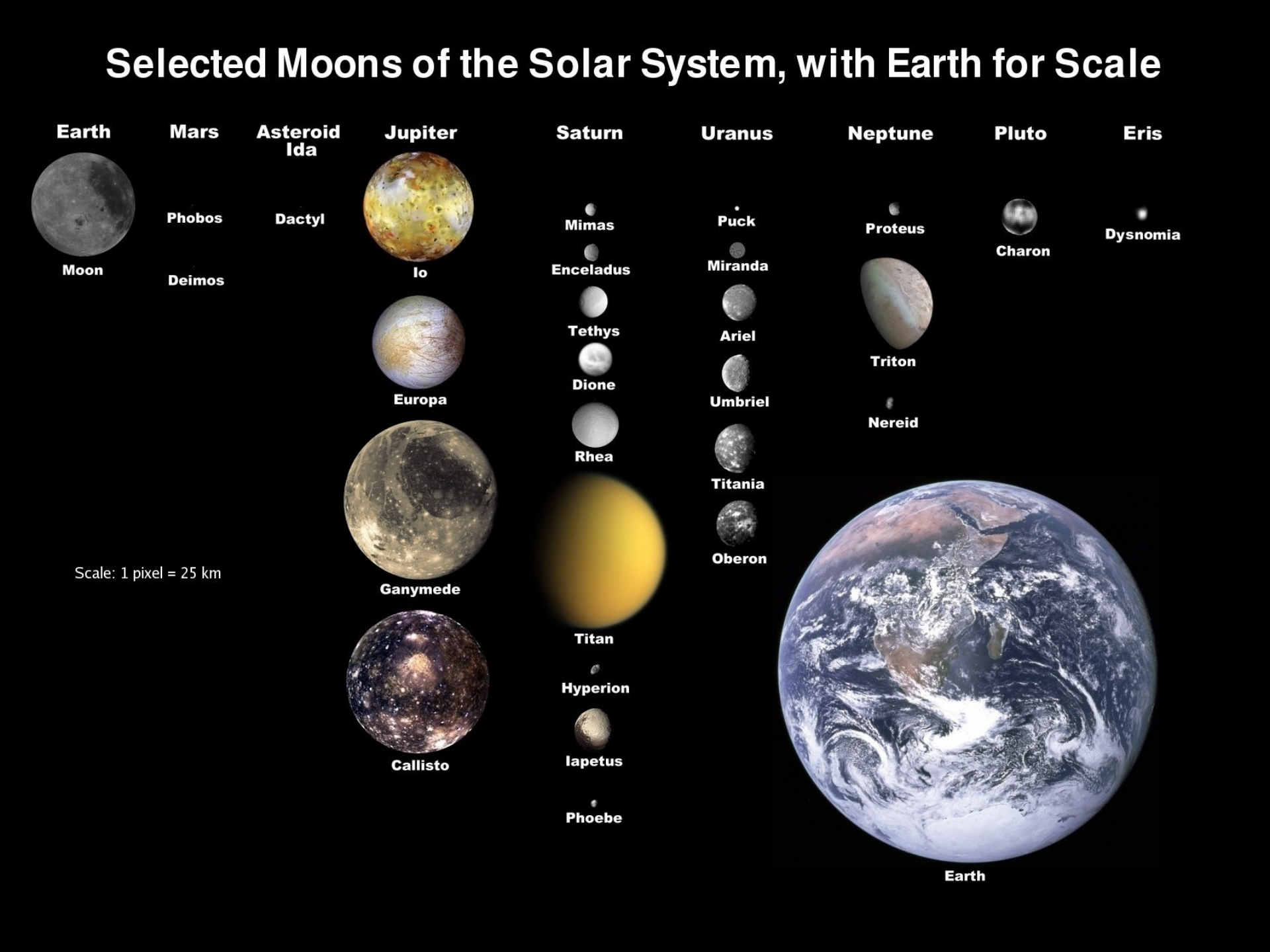
L’interno dei giganti gassosi



I satelliti nel Sistema Solare

Pianeta	Numero satelliti
Terra	1
Marte	2
Giove	67
Saturno	62
Urano	27
Nettuno	14

Selected Moons of the Solar System, with Earth for Scale



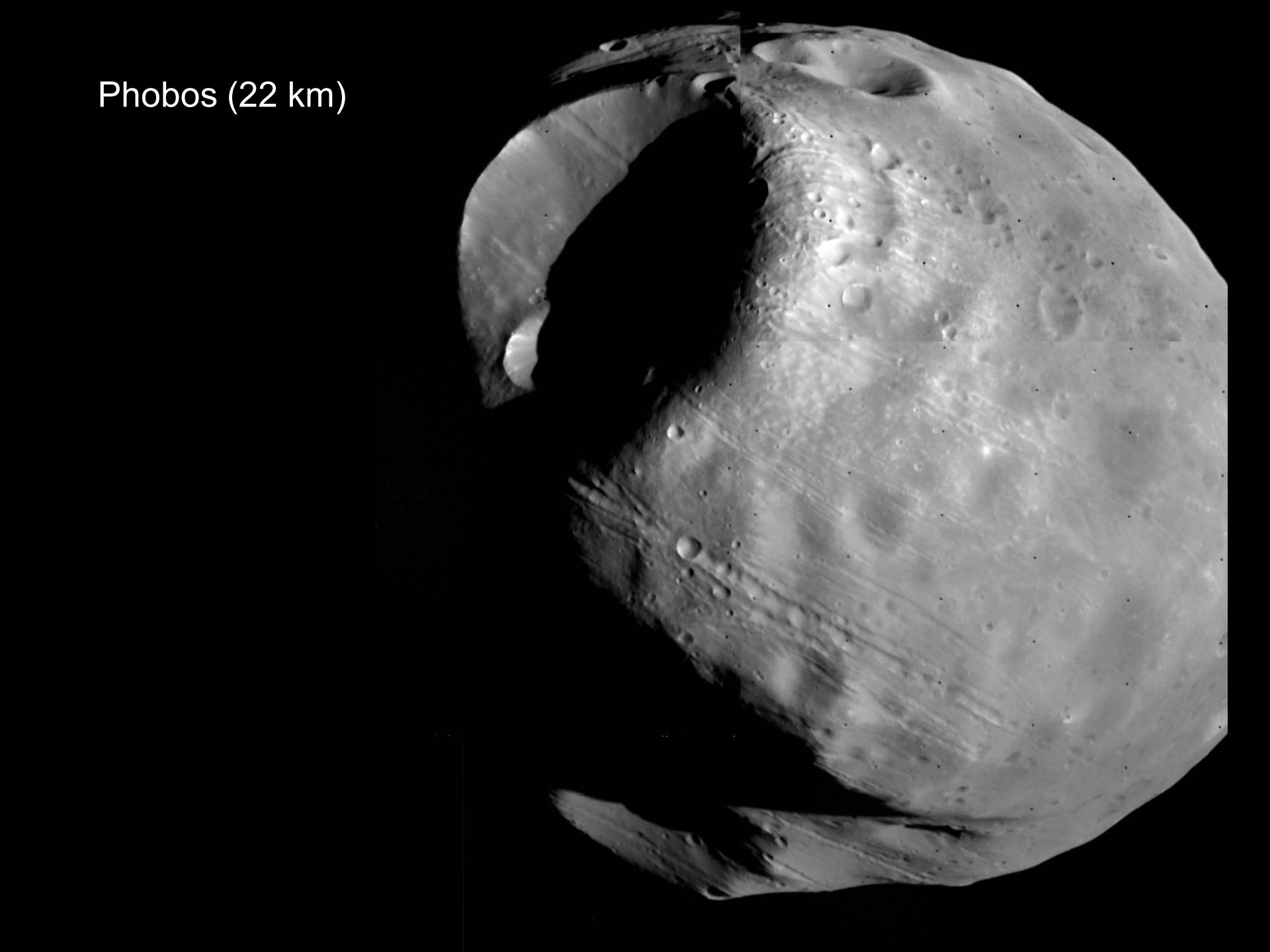
Phobos (22 km)



© ESA/DLR/FU Berlin (G. Neukum)

N - North pole

Phobos (22 km)



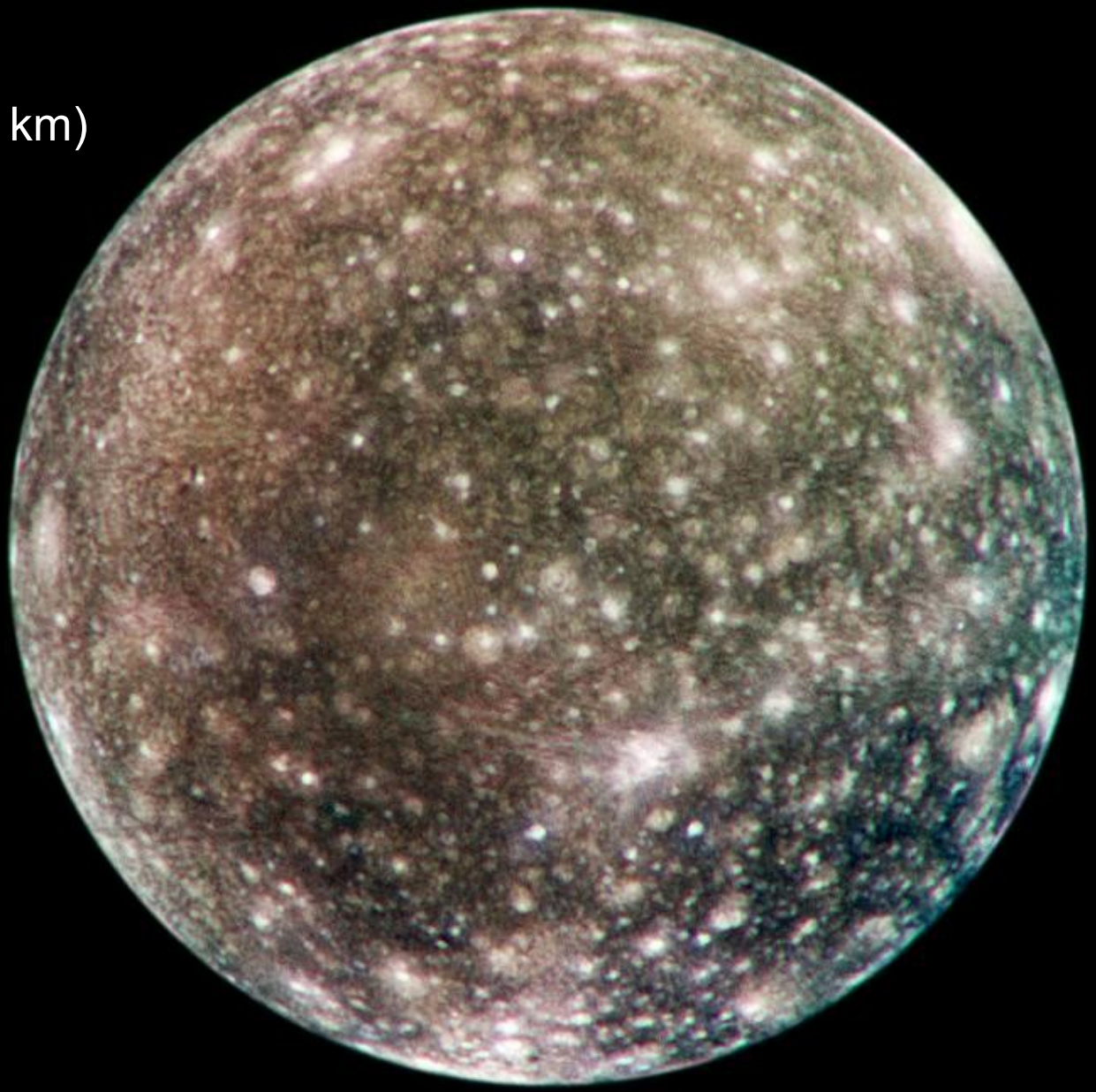
Satelliti principali di Giove (“medicei”)



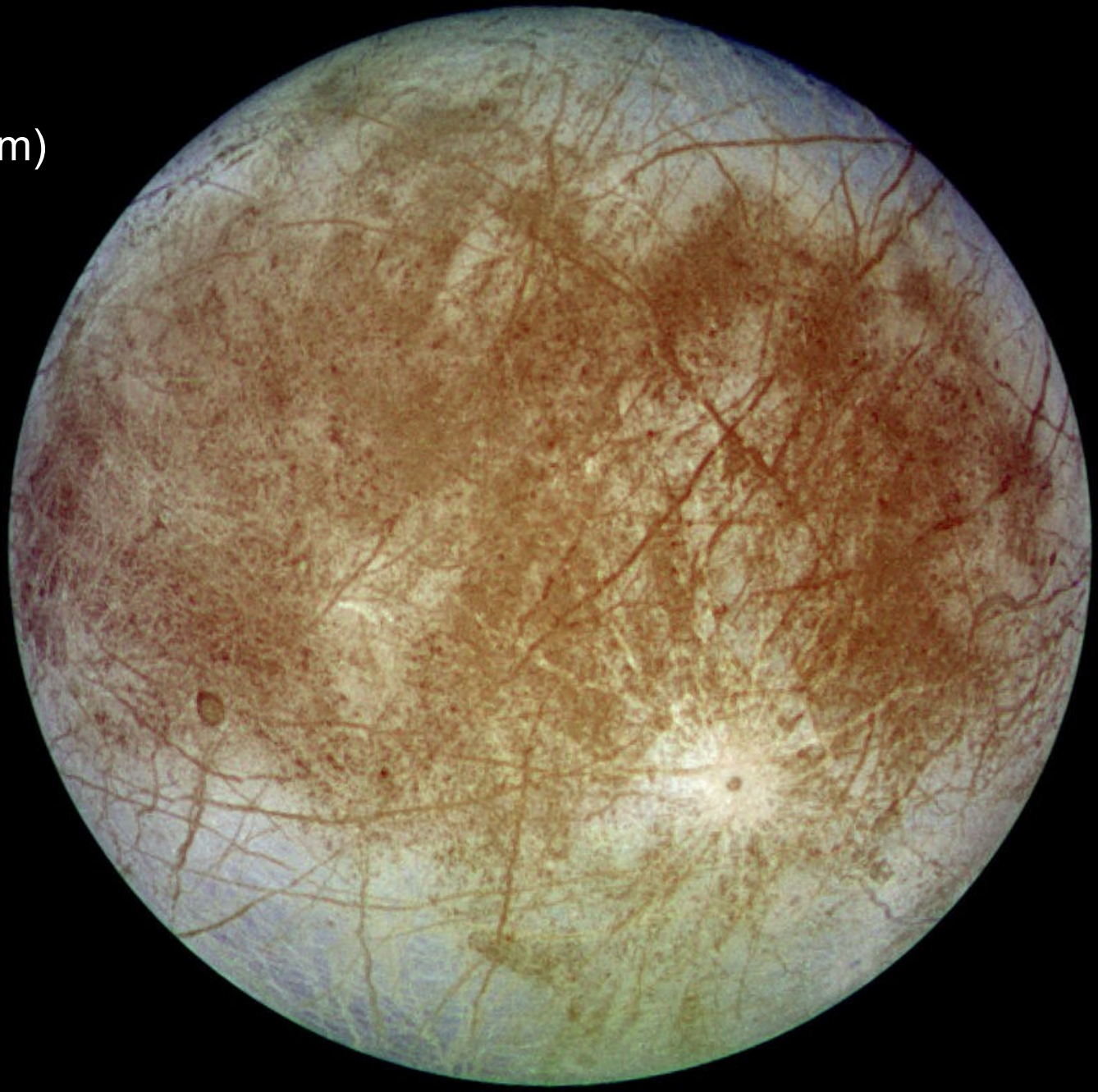
Ganimede (5270 km)



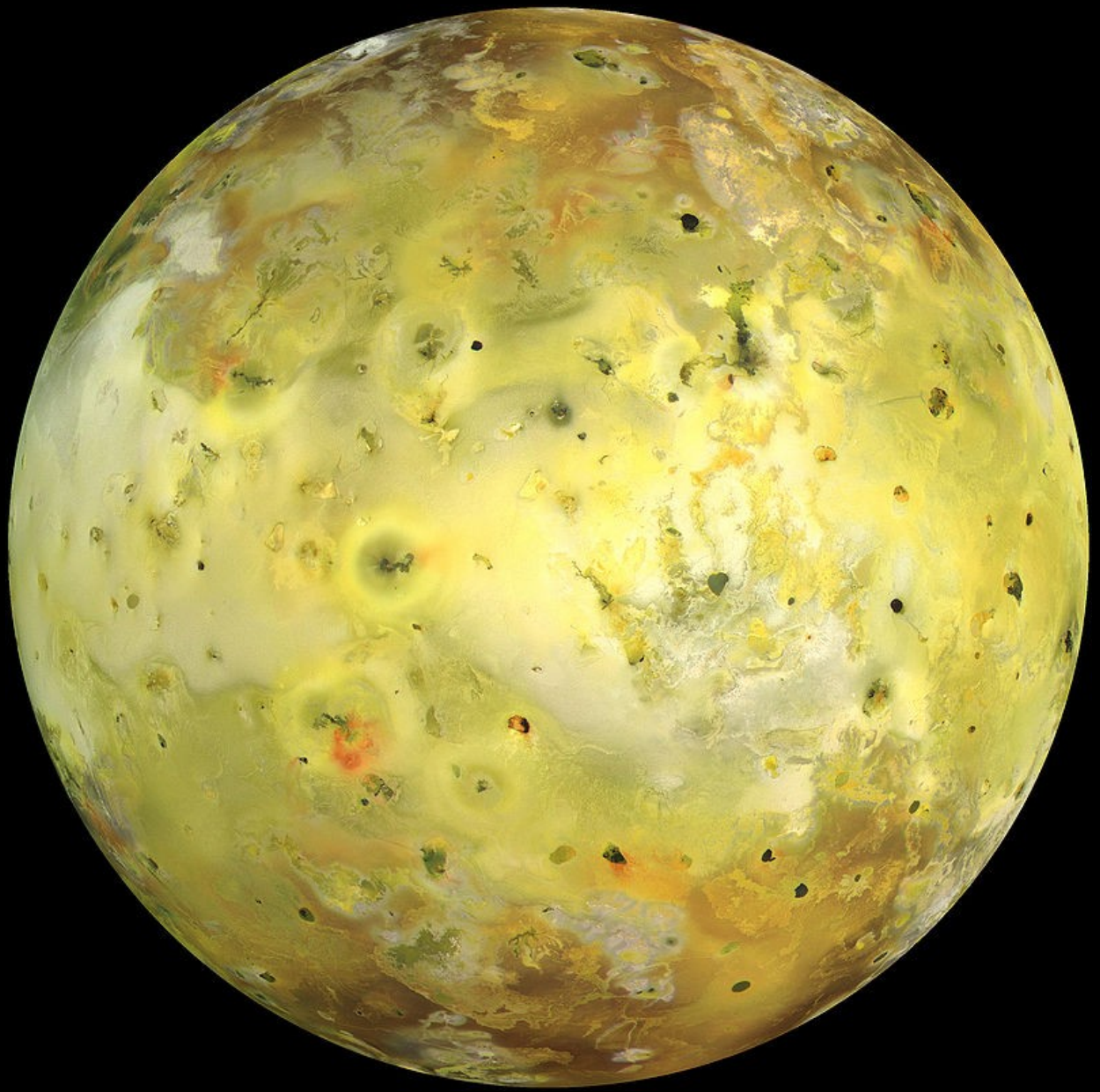
Callisto (4816 km)



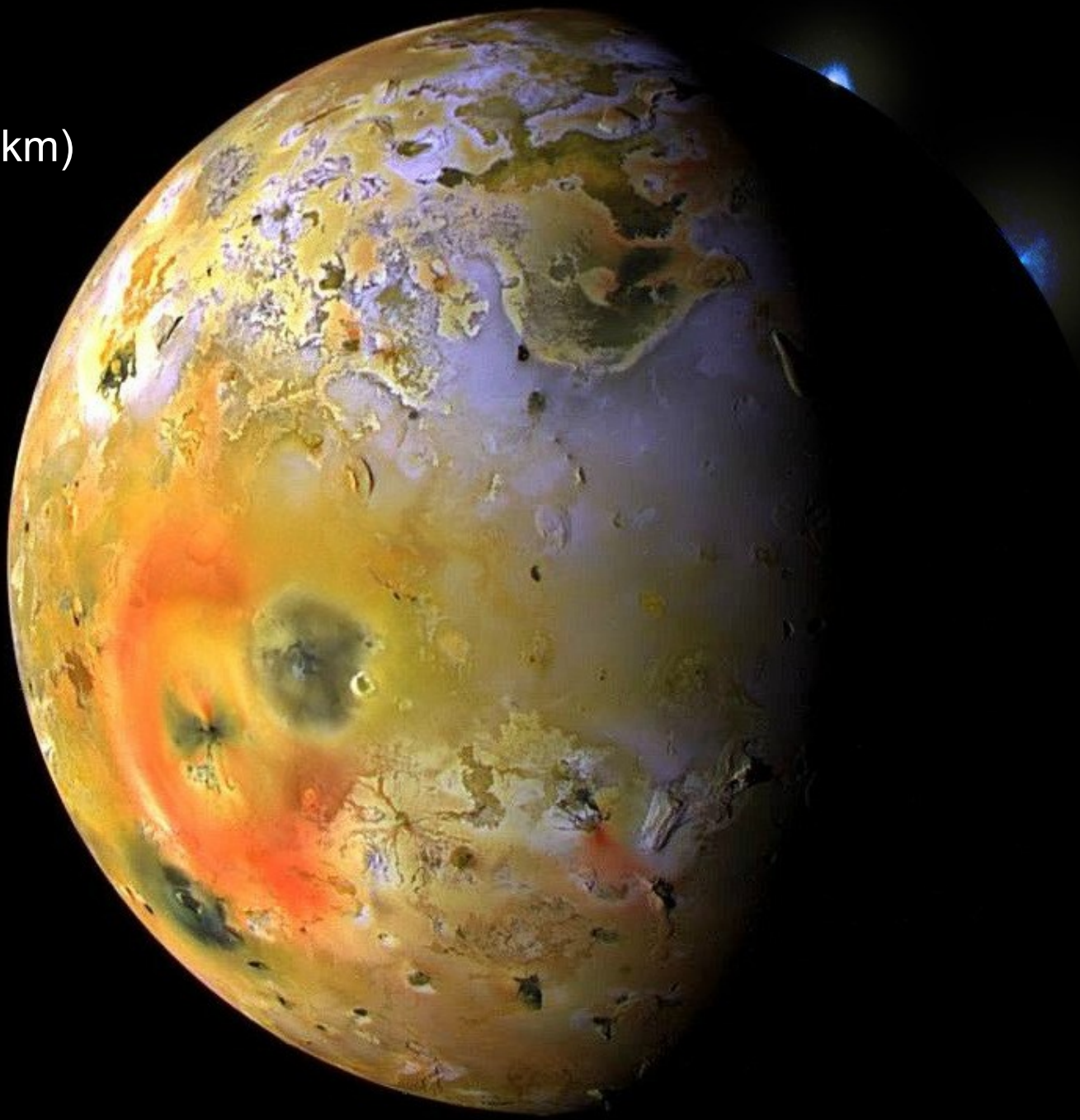
Europa (3120 km)

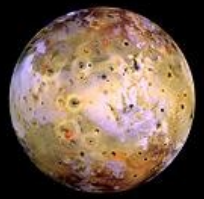


Io (3636 km)



Io (3636 km)





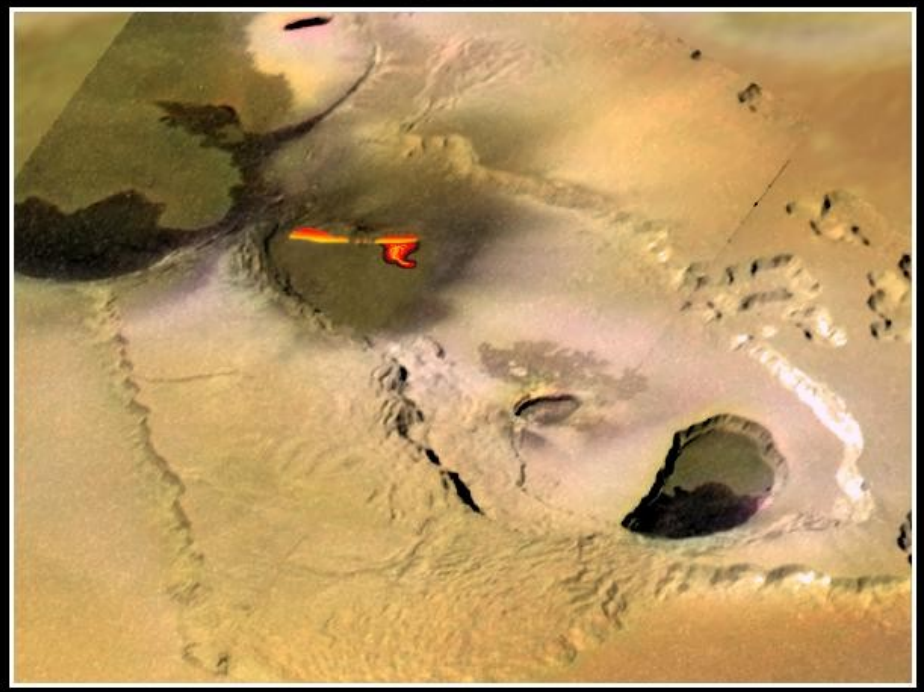
Io — Tvashtar Catena

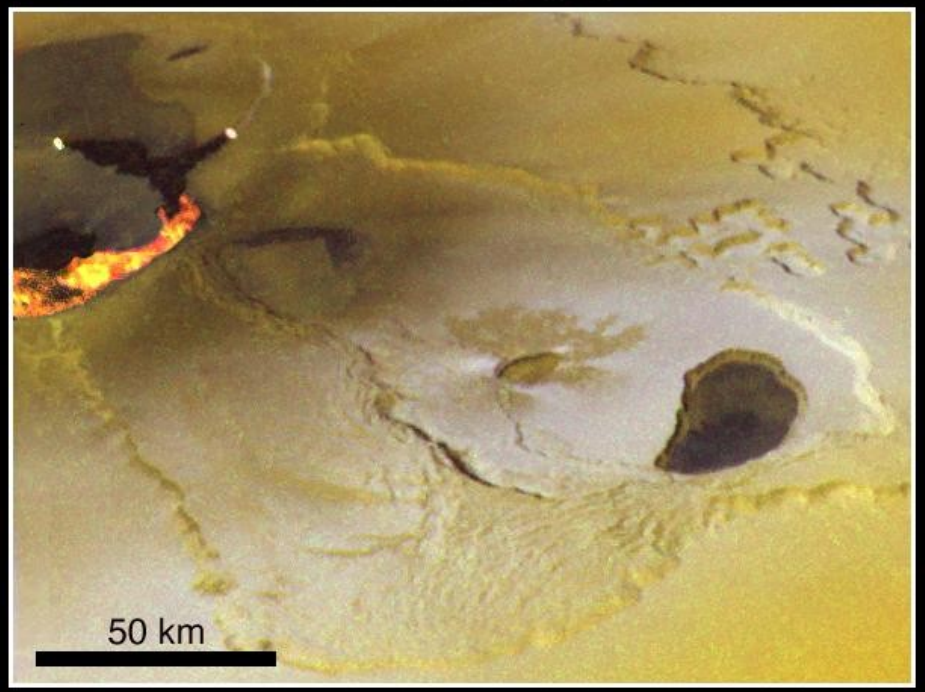
I25 (26 Nov 1999)

+ C21 low-resolution color
+ fire fountain sketch

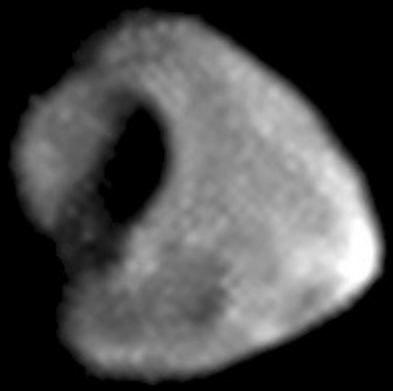
I27 (22 Feb 2000)

visible wavelength data
+ IR data of active lava flow

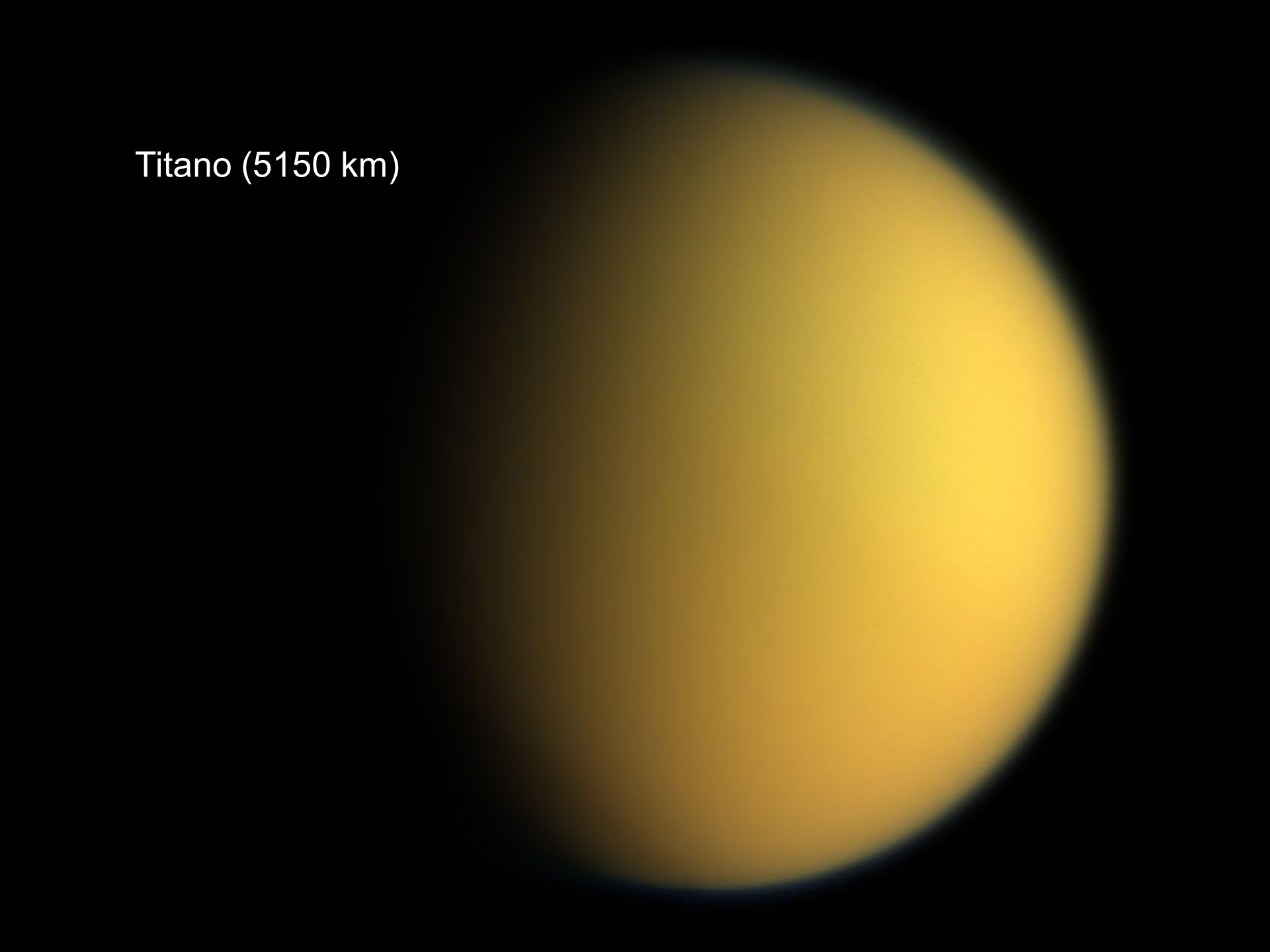


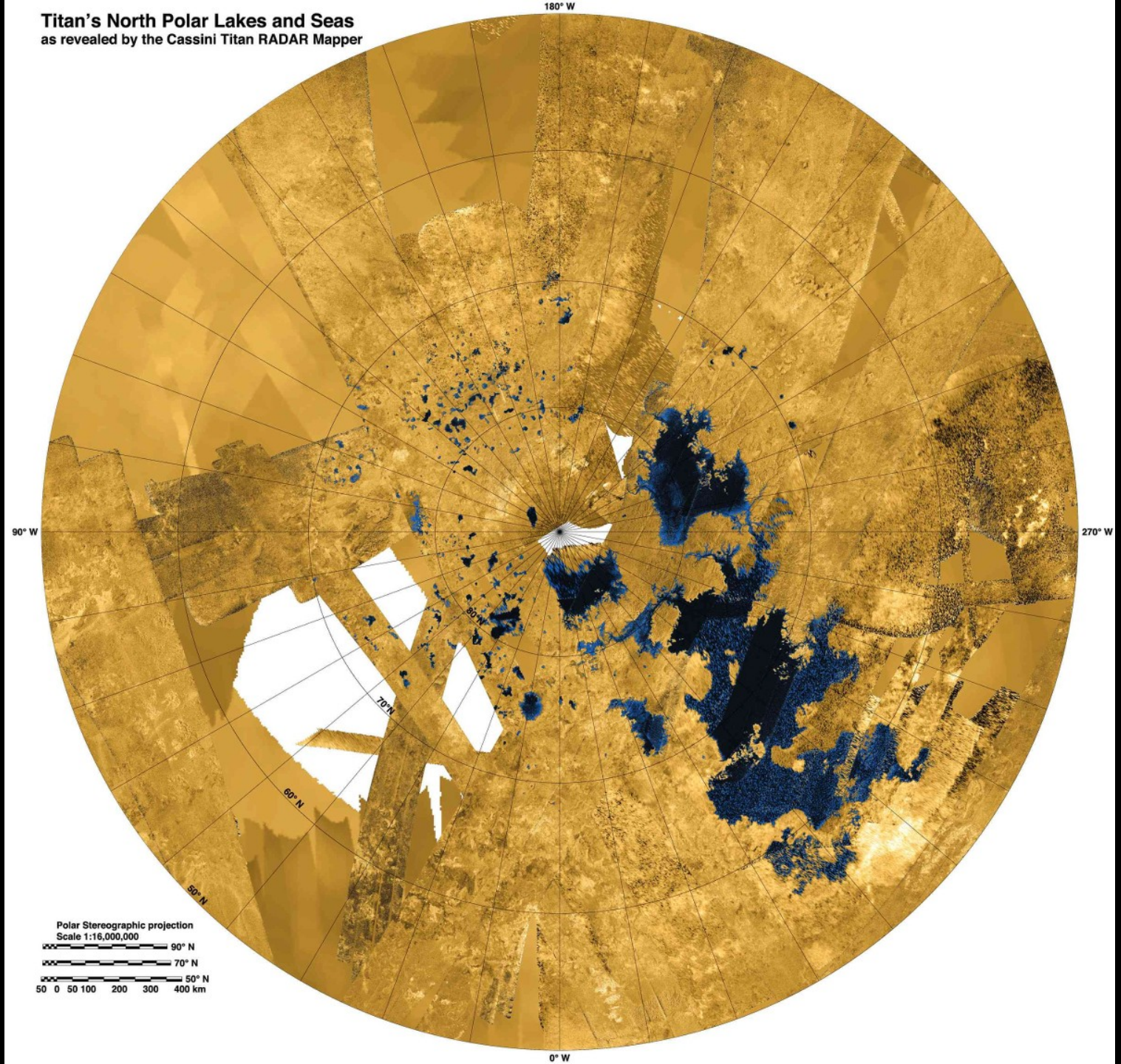


Thebe (100 km)

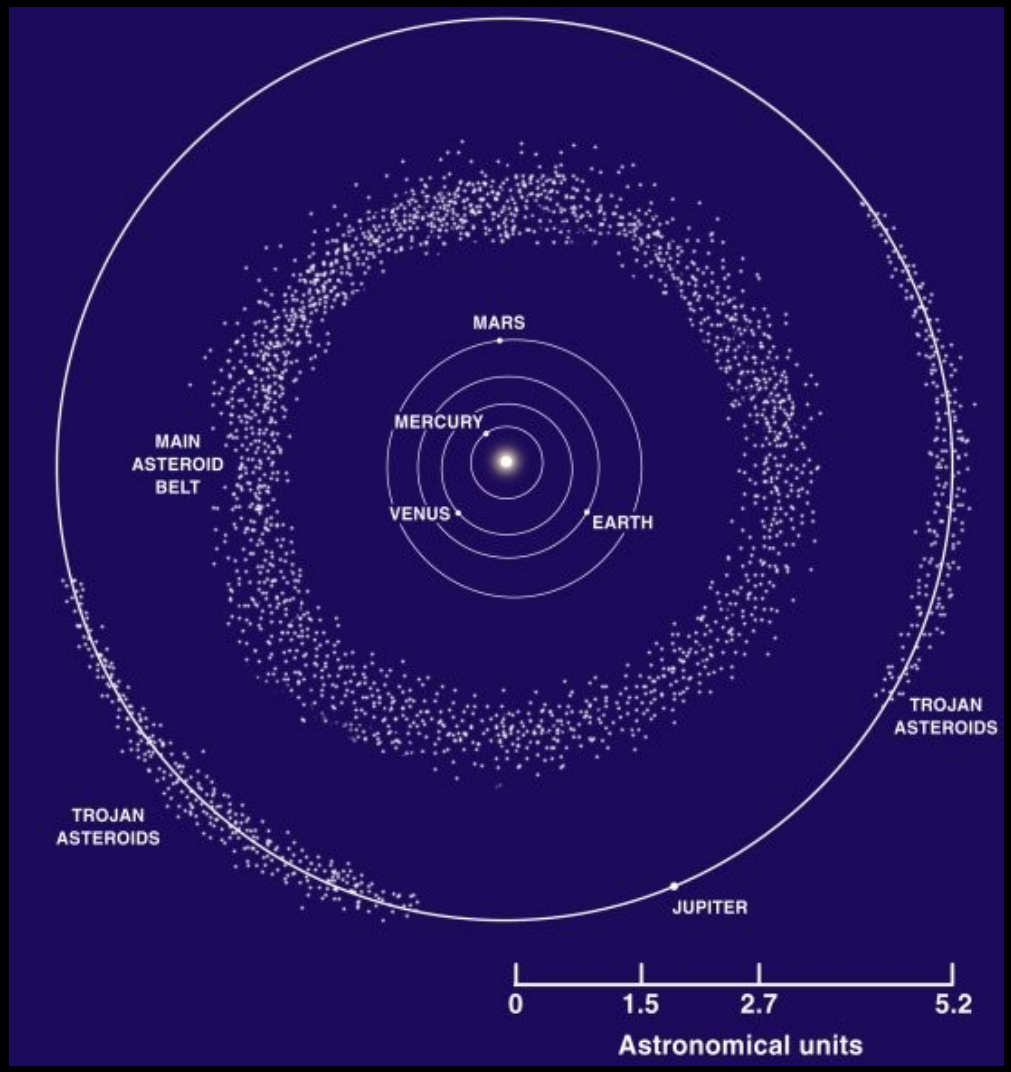


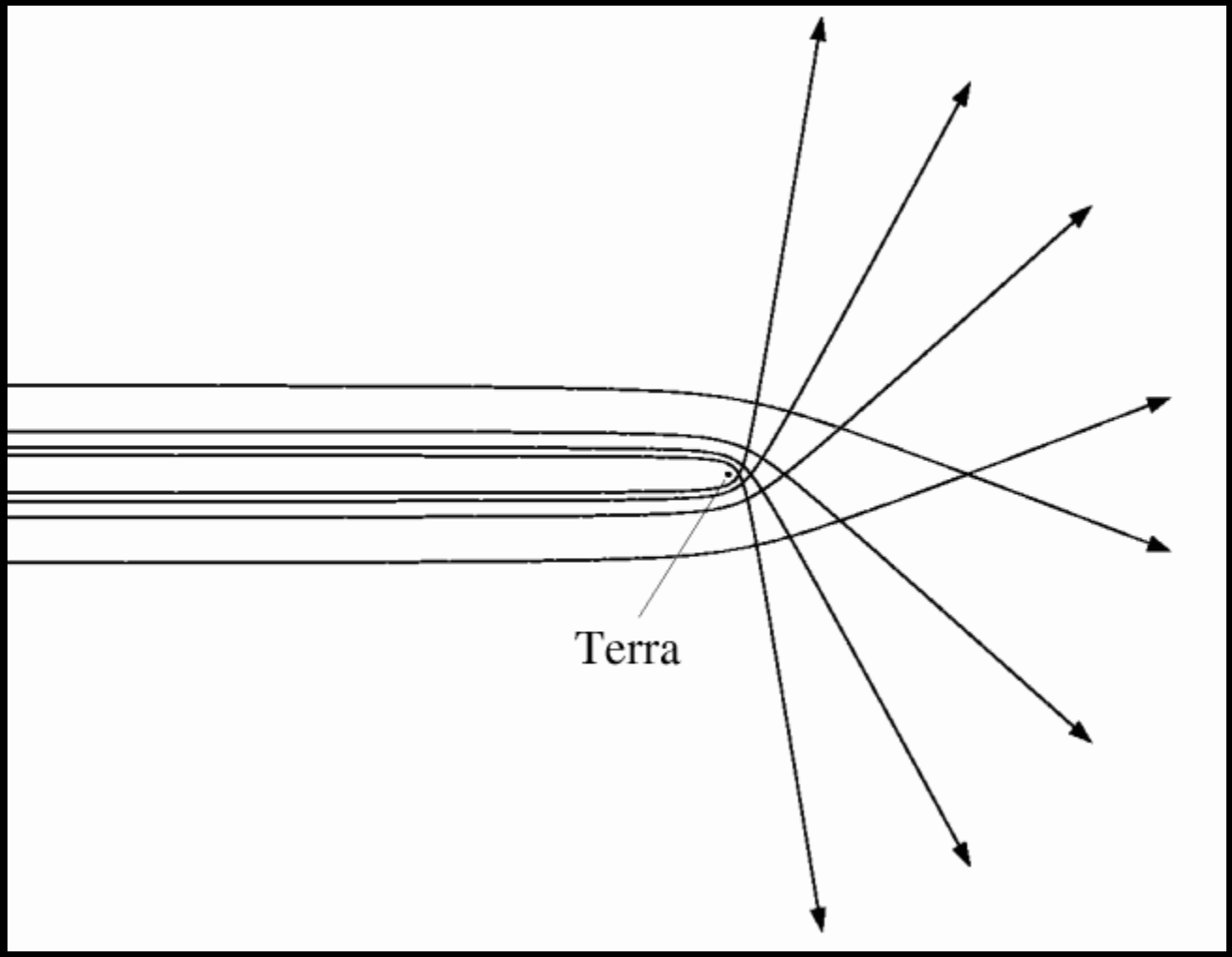
Titano (5150 km)




Titan's North Polar Lakes and Seas
as revealed by the Cassini Titan RADAR Mapper
180° W
90° W
270° W
0° W
80° N
70° N
60° N
50° N
Polar Stereographic projection
Scale 1:16,000,000
90° N
70° N
50° N
50 0 50 100 200 300 400 km

Asteroidi: fascia principale e Troiani





Deflessione prodotta da un incontro ravvicinato



Luna (3474 km)



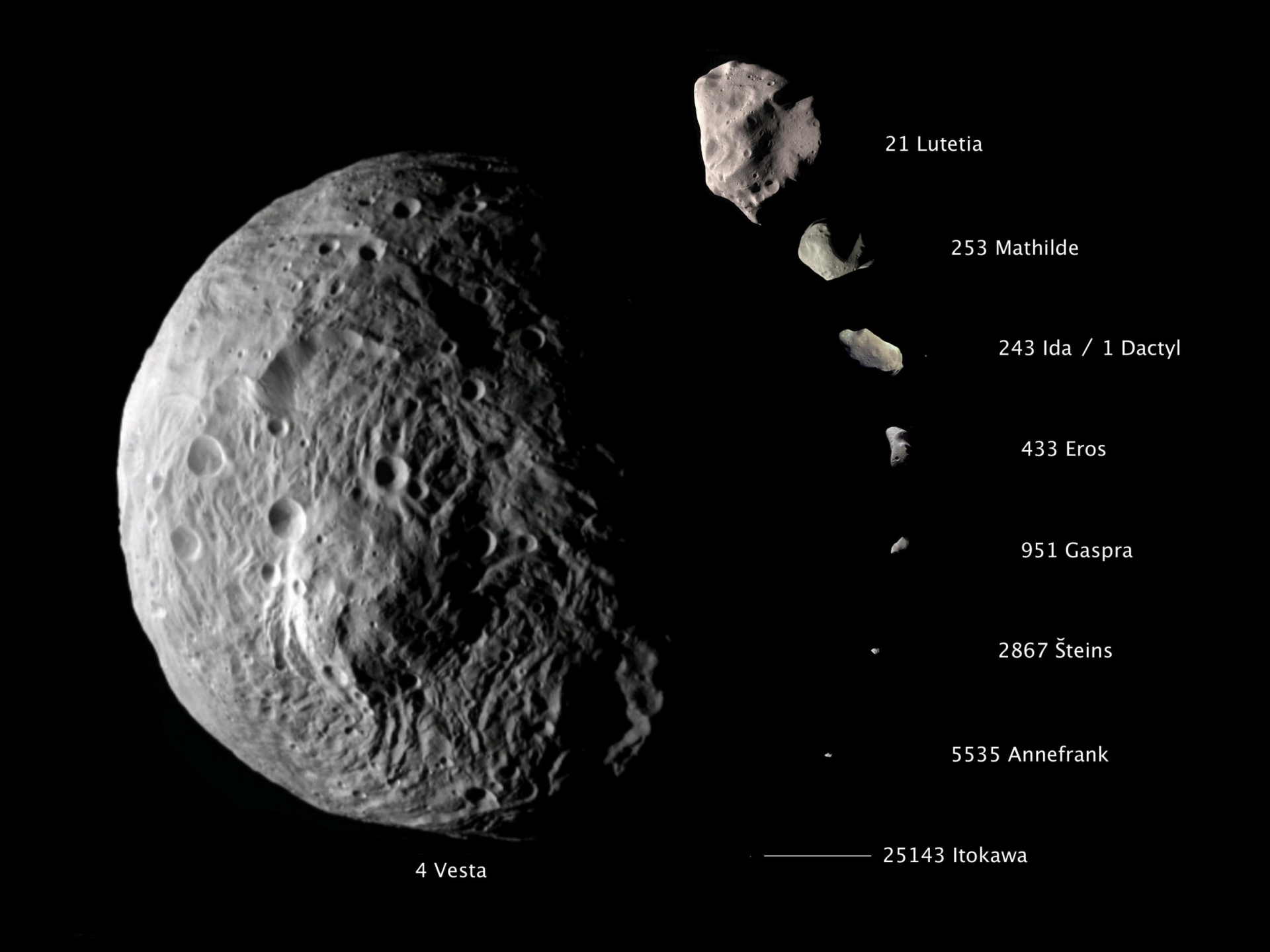
Cerere (975 km)



Vesta (530 km)



Terra (12742 km)


21 Lutetia
253 Mathilde
243 Ida / 1 Dactyl
433 Eros
951 Gaspra
2867 Šteins
5535 Annefrank
25143 Itokawa
4 Vesta



Cerere (Ø 975 km) ripreso dal Telescopio Spaziale Hubble (23/1/2004)

Vesta (Ø 530 km) ripreso dalla sonda Dawn (12/10/2011)





Ida (54×24×15 km) ripreso dalla sonda Galileo (agosto 1993)



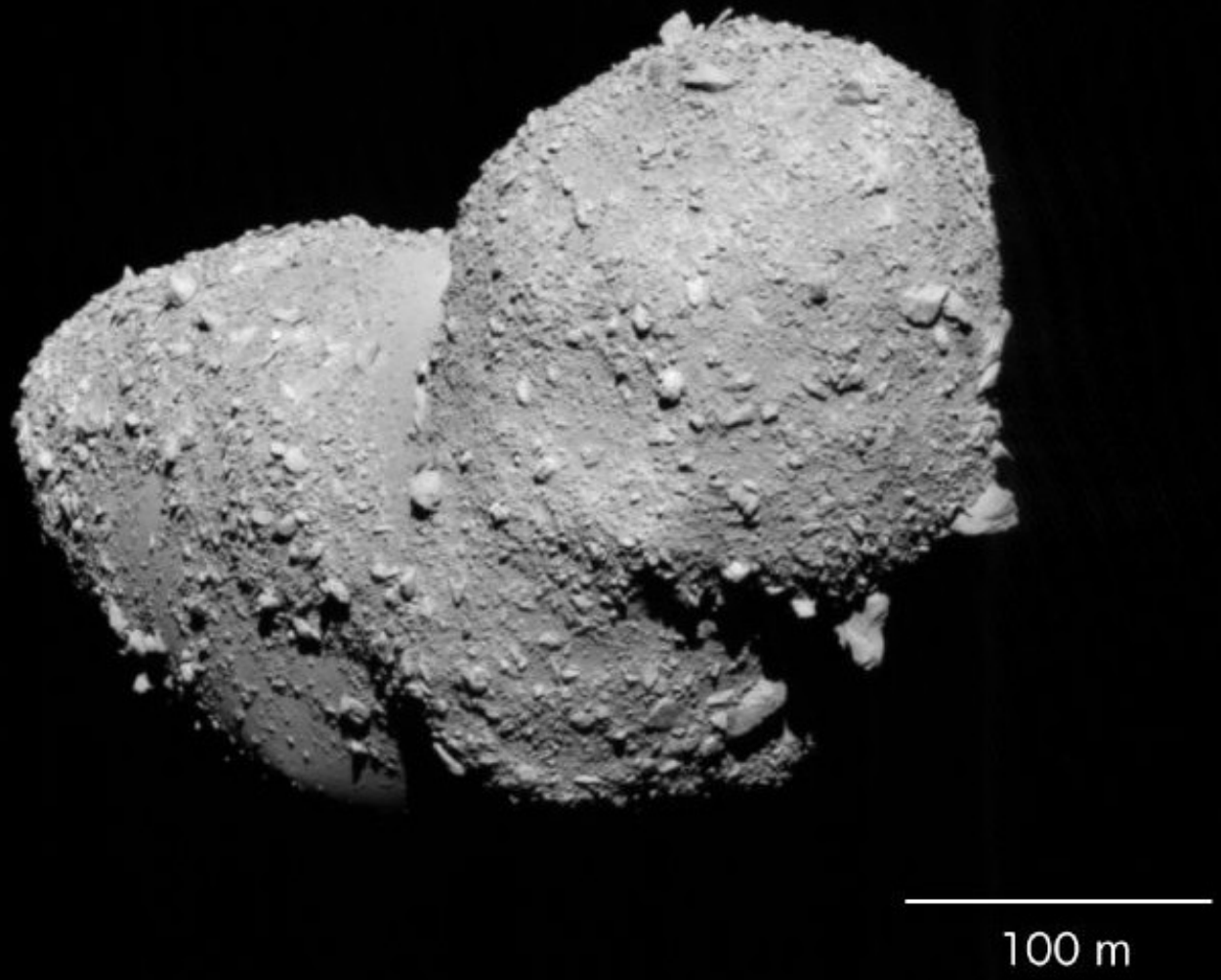
Aspetto dell'asteroide Ida in varie fasi della rotazione



Mathilde (Ø 53 km) ripreso dalla sonda NEAR (27/6/1997)



Eros (34×11 km) ripreso dalla sonda NEAR (12/2/2001)



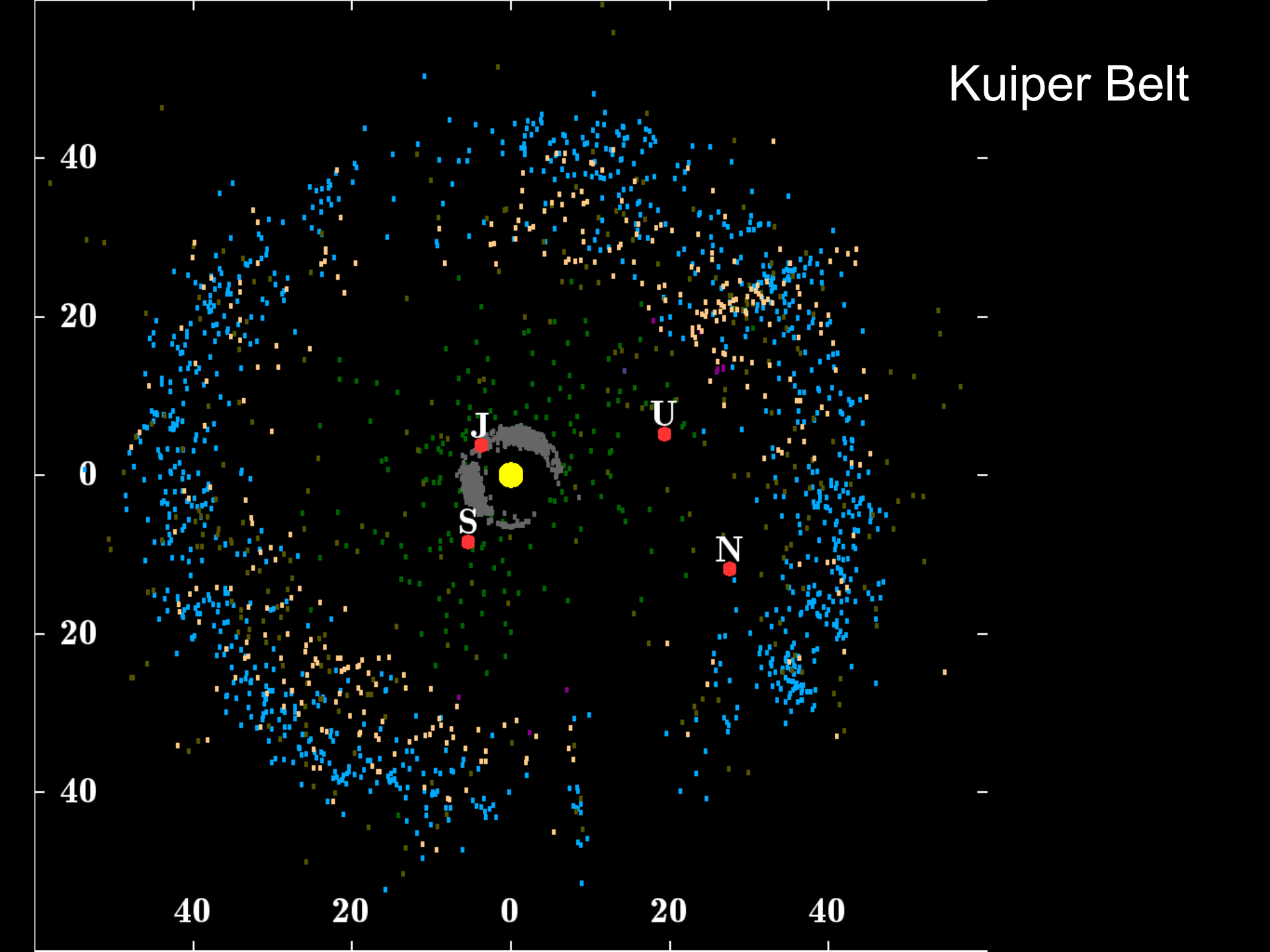
Itokawa (330 m) ripreso dalla sonda Hayabusa (ottobre 2005)

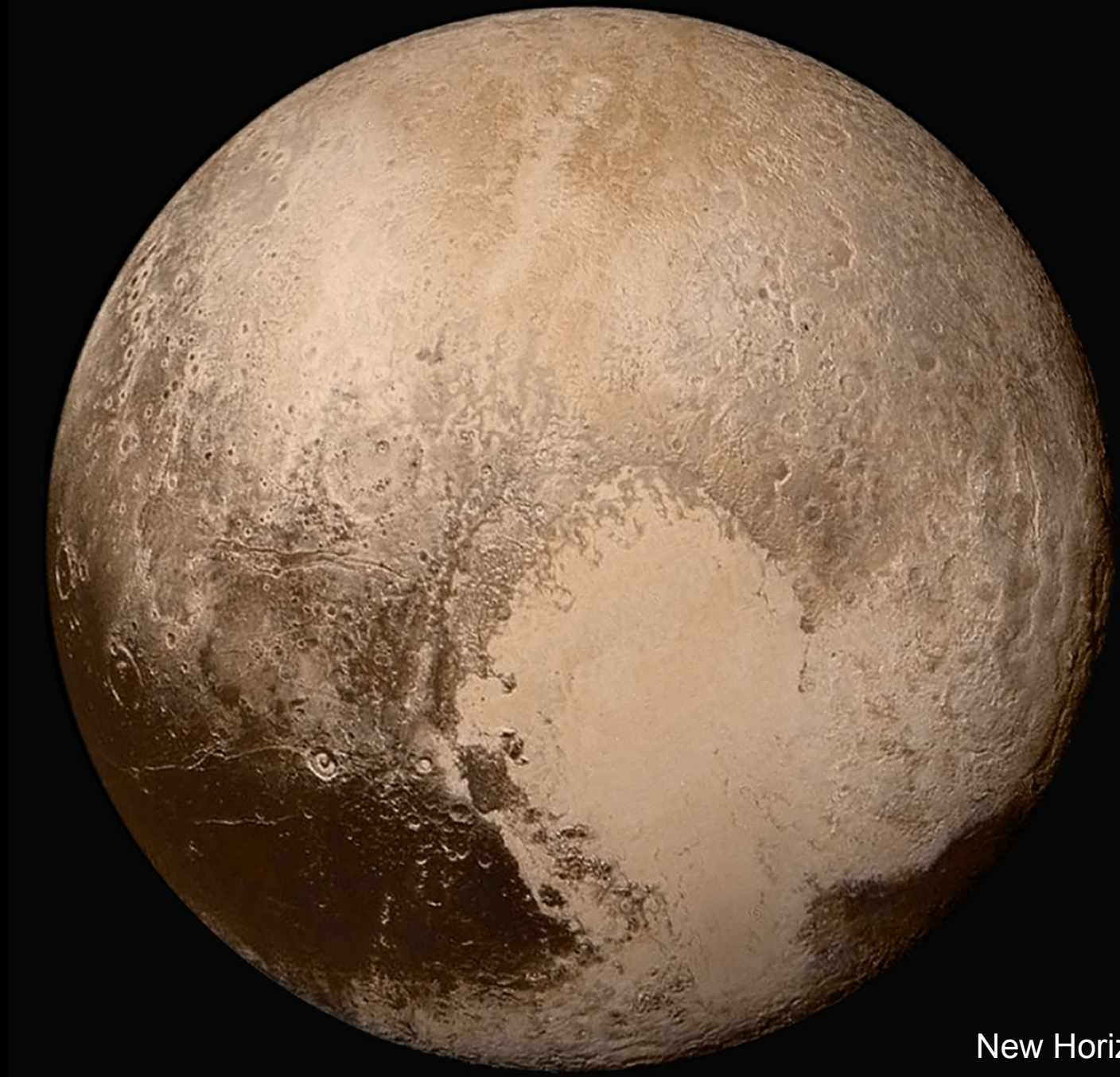
Quanti sono gli asteroidi?

Dipende dalle dimensioni:

1 :	diametro = 930 km (Cerere)
4 :	diametro > 400 km
30 :	diametro > 200 km
250 :	diametro > 100 km
1,000,000 ? :	diametro > 1 km

Numero di asteroidi “conosciuti”: circa 1.300.000

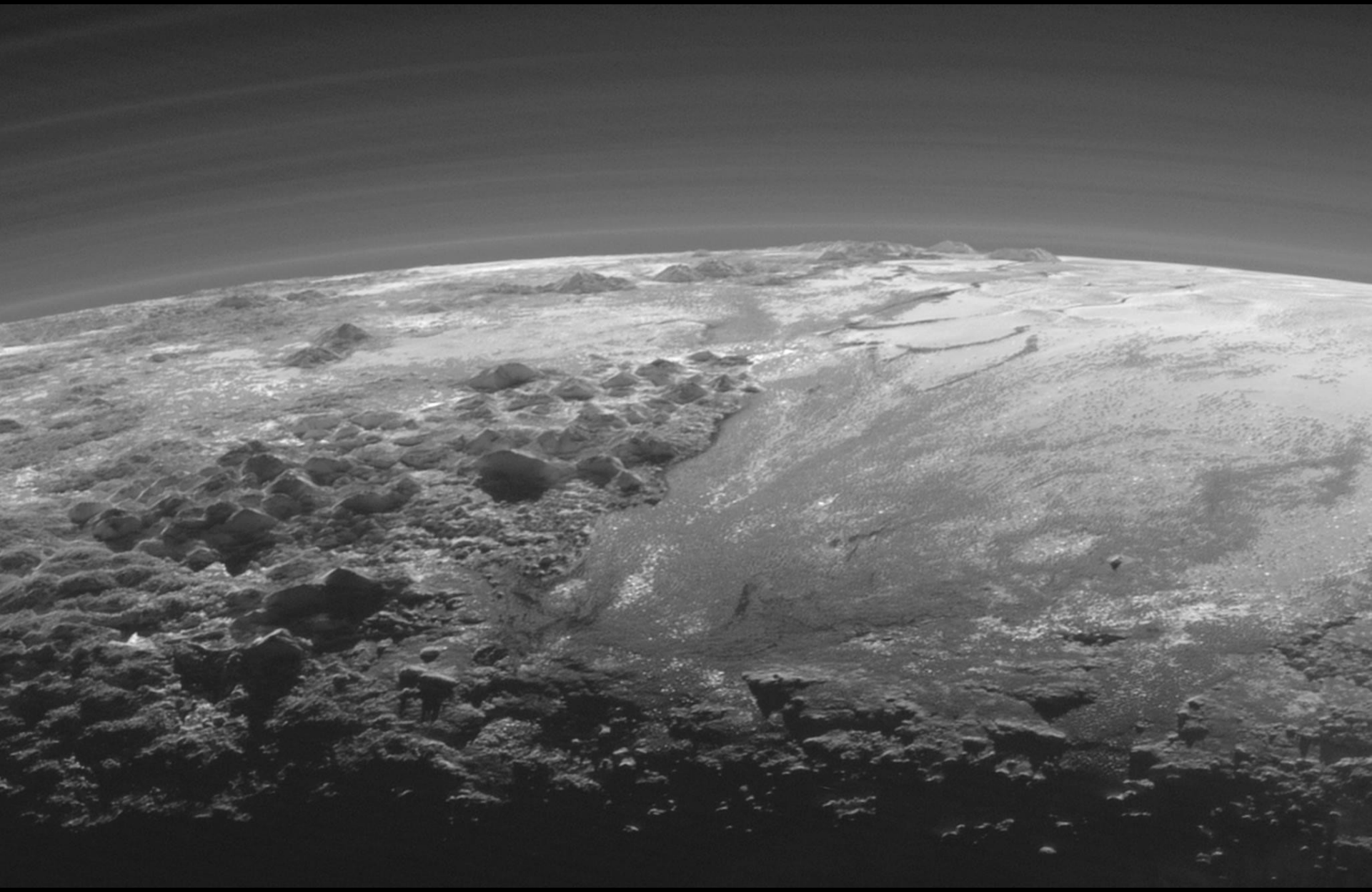

Kuiper Belt
40
20
0
20
40
40
20
0
20
40
J
U
S
N



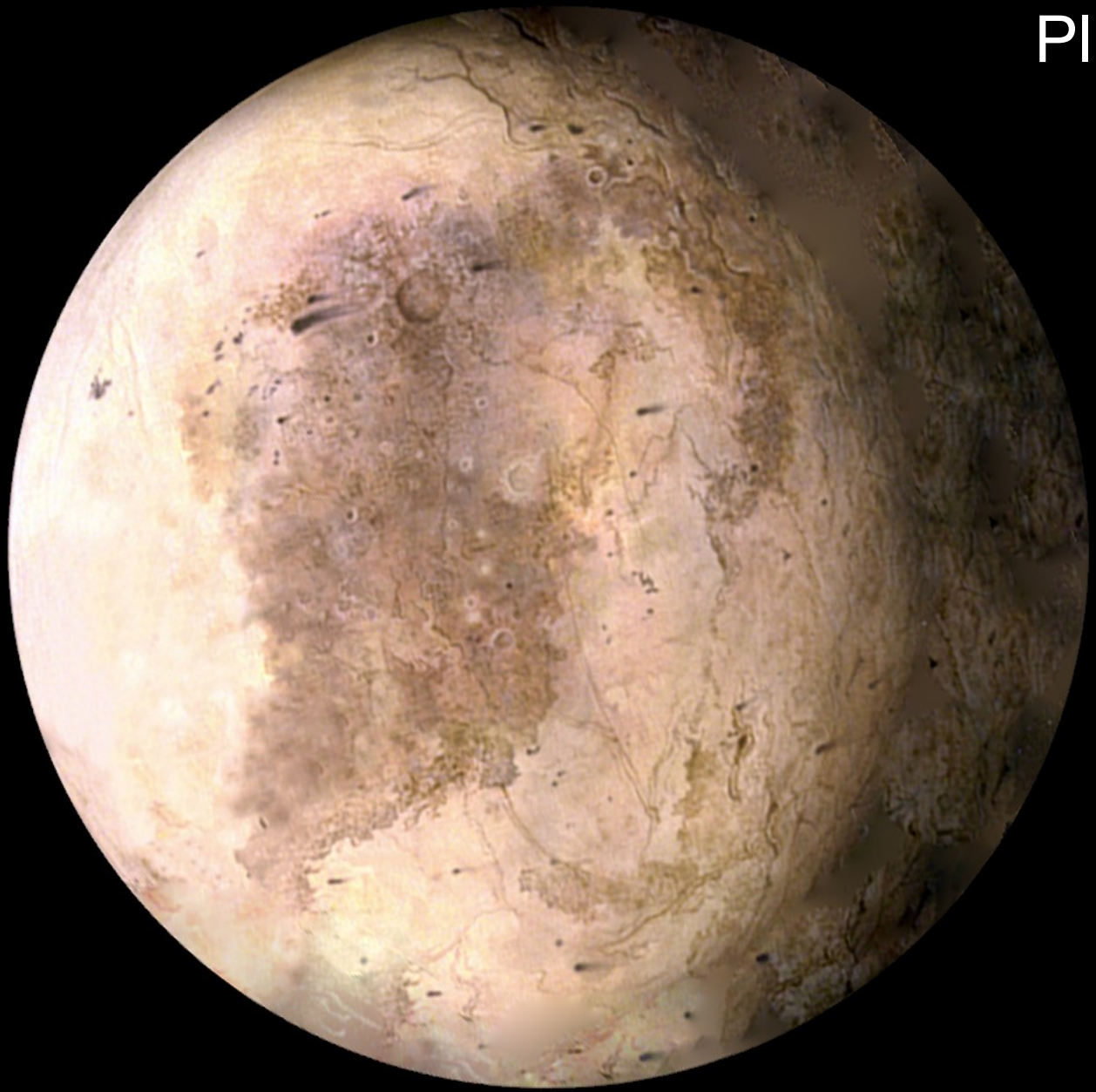
Plutone

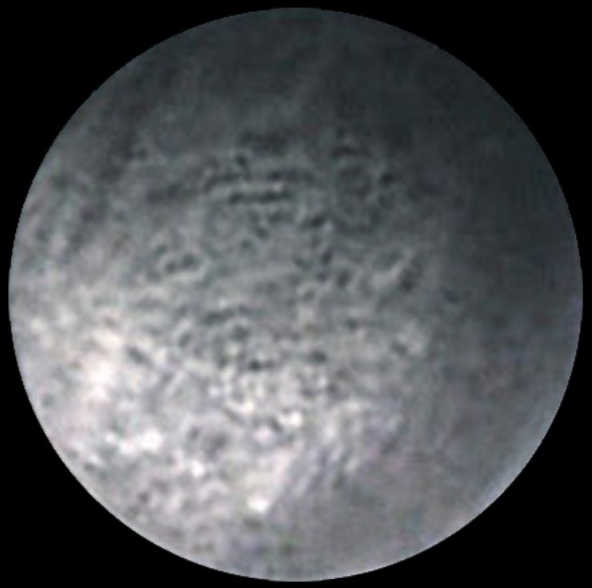
d = 39.5 AU
P_{orb} = 248 y
P_{rot} = 6.4 d
R = 1187 km

New Horizons (luglio 2015)



Plutone e Caronte






Nix
(~ 50 km)
Hydra
(~ 40 km)
enhanced color
black and white