



Istituto Nazionale di Astrofisica

Osservatorio astronomico di Brera



Universo in fiore

Il Sistema Solare

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Sommario

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

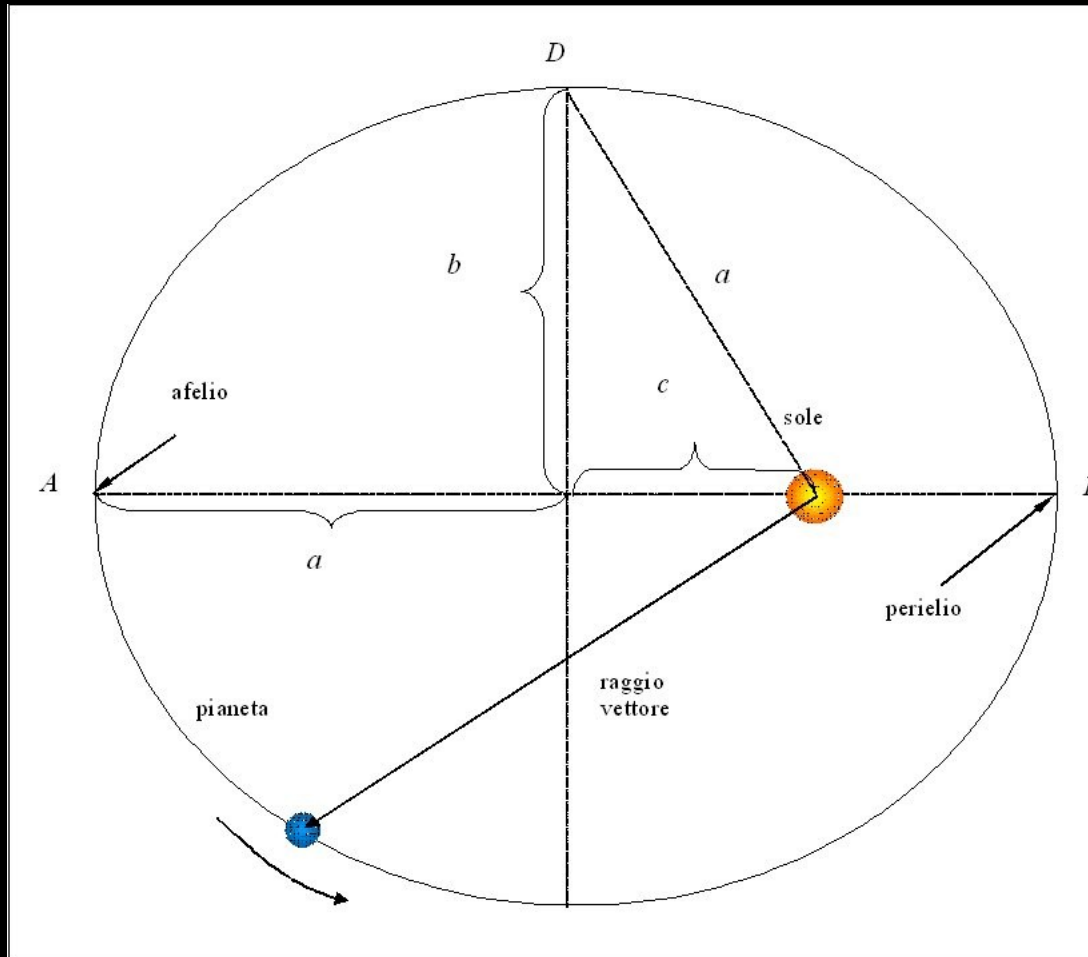


Tycho Brahe
(1546-1601)



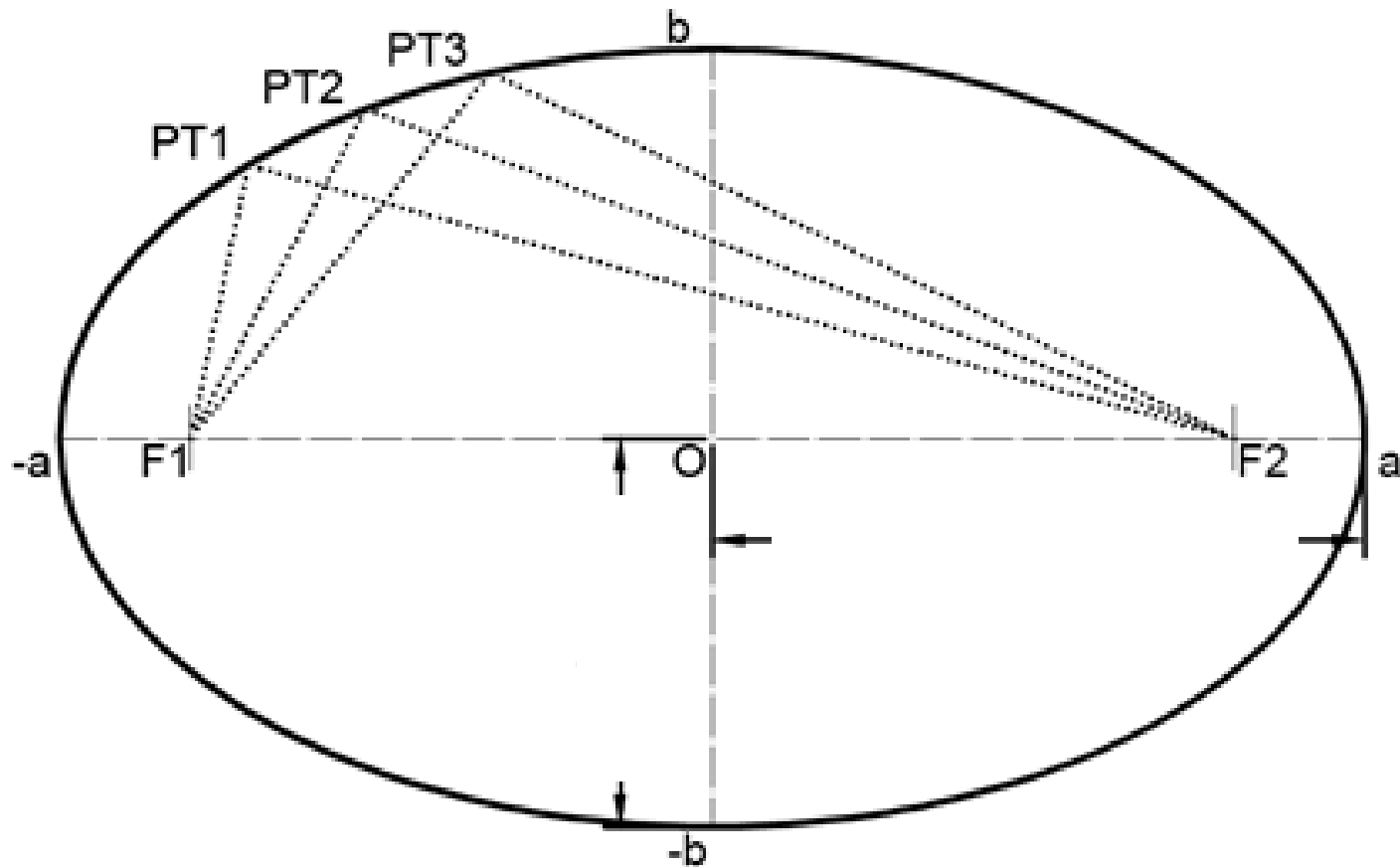
Johannes Kepler
(1571-1630)

Prima legge di Keplero

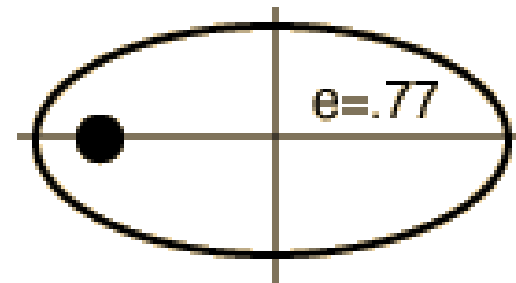
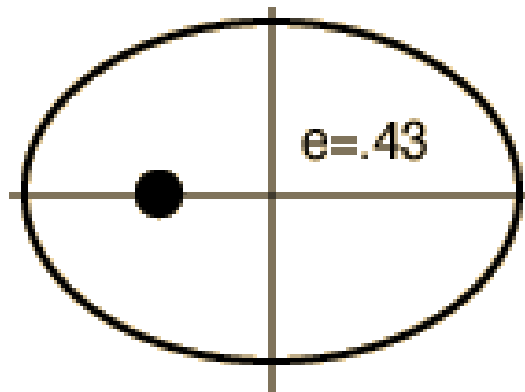
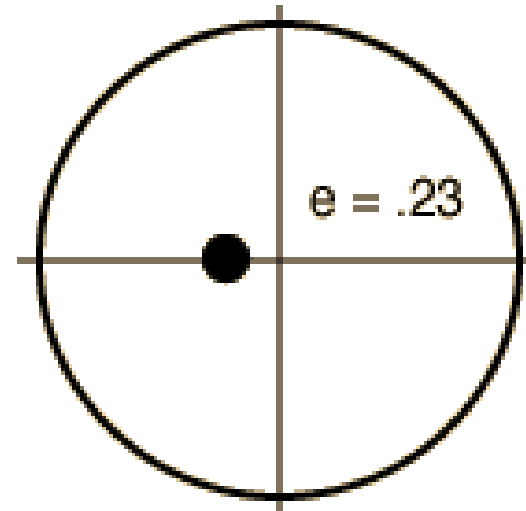
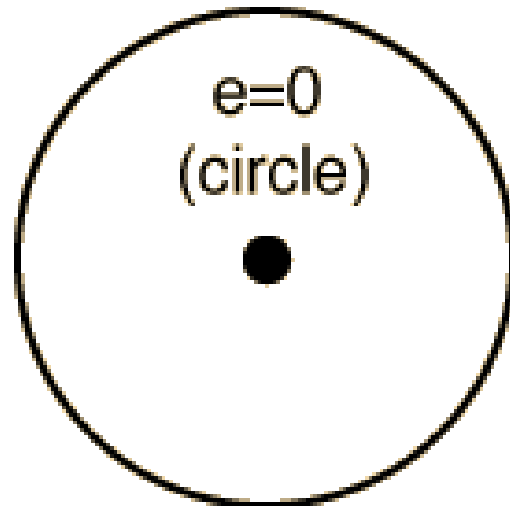


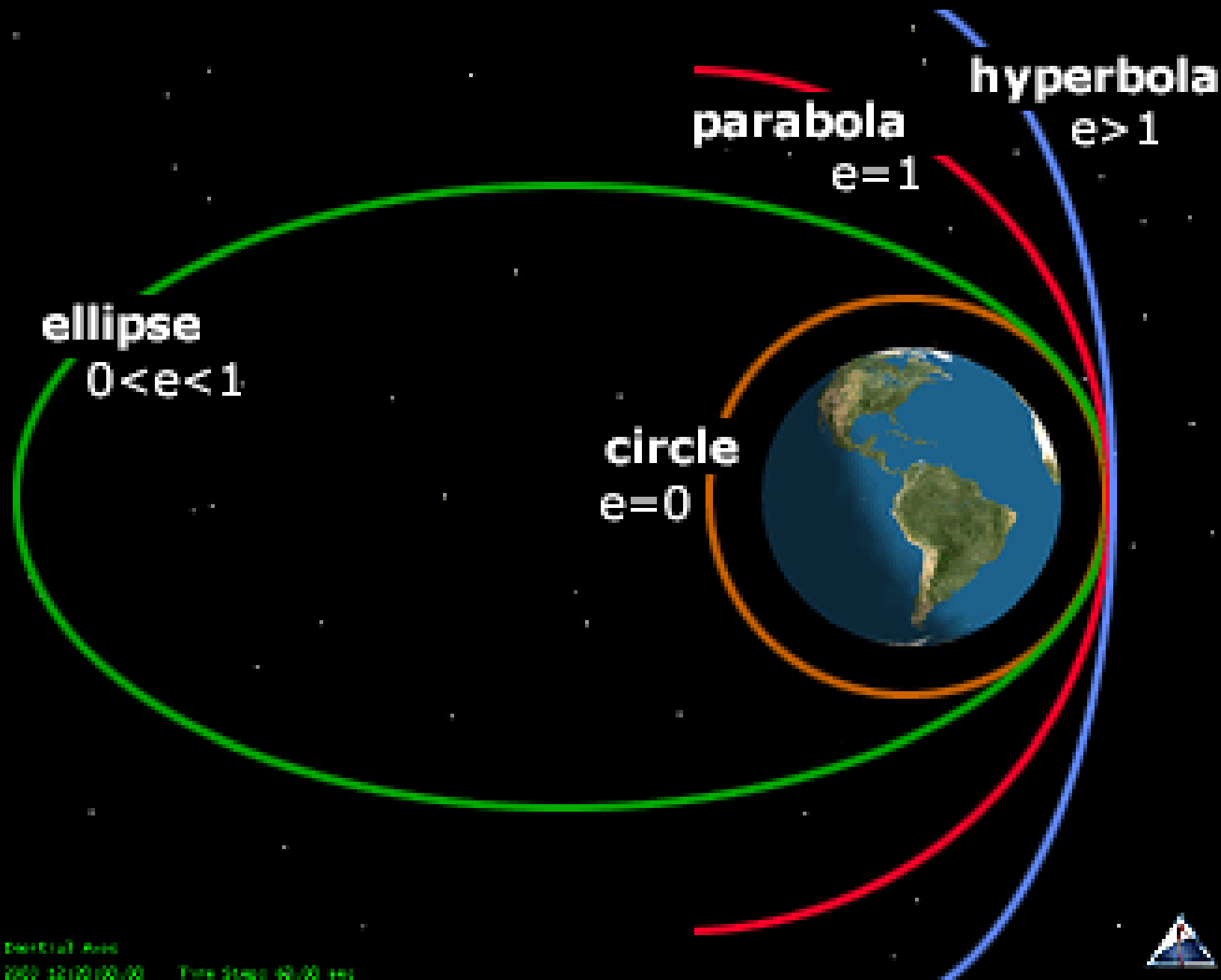
L'orbita di un pianeta è un'ellisse, di cui il sole occupa uno dei due fuochi

I fuochi di un'ellisse

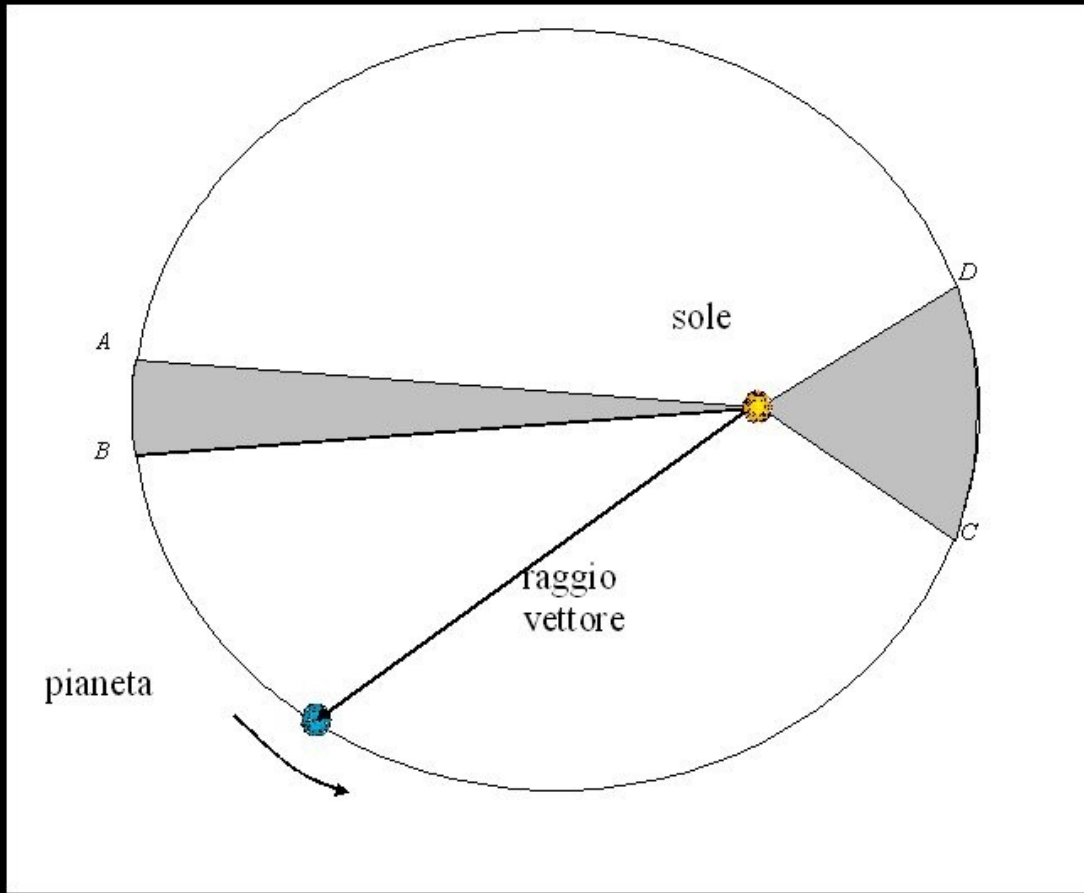


Eccentricità di un'ellisse





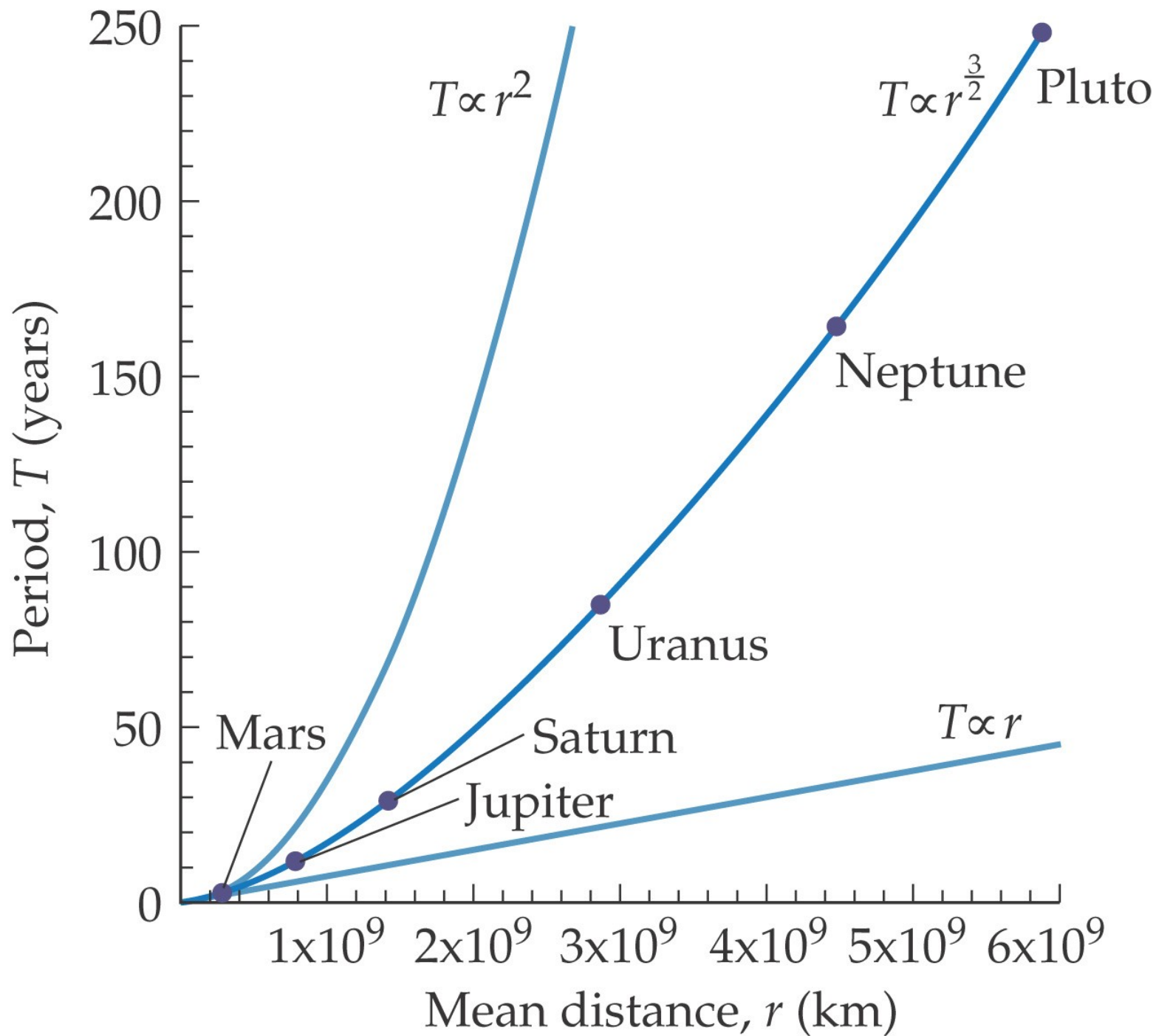
Seconda legge di Keplero



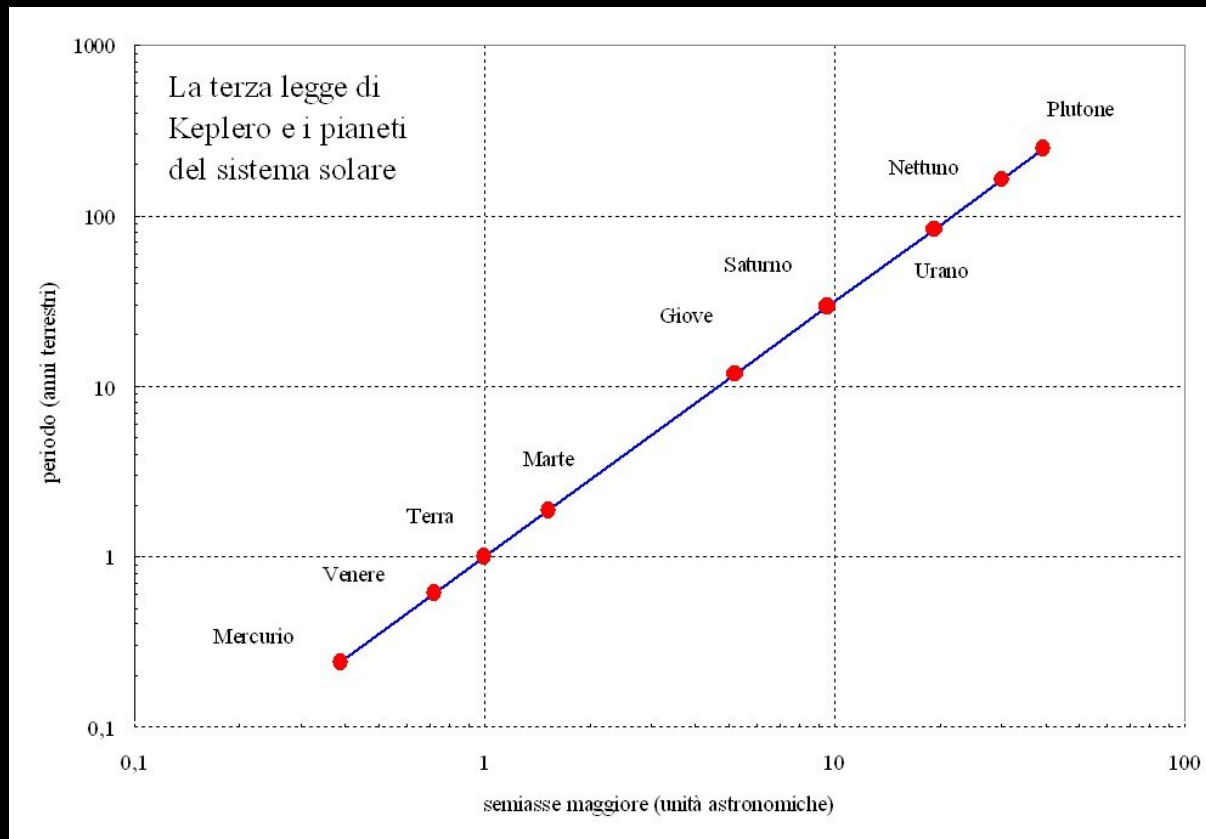
Il **raggio vettore** del pianeta descrive **aree** uguali in tempi uguali

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



Terza legge di Keplero



I quadrati dei periodi di rivoluzione sono direttamente proporzionali ai cubi dei semiassi maggiori delle loro orbite

$$\frac{P_1^2}{P_2^2} = \frac{R_1^3}{R_2^3}$$

Galileo Galilei
(1564-1642)

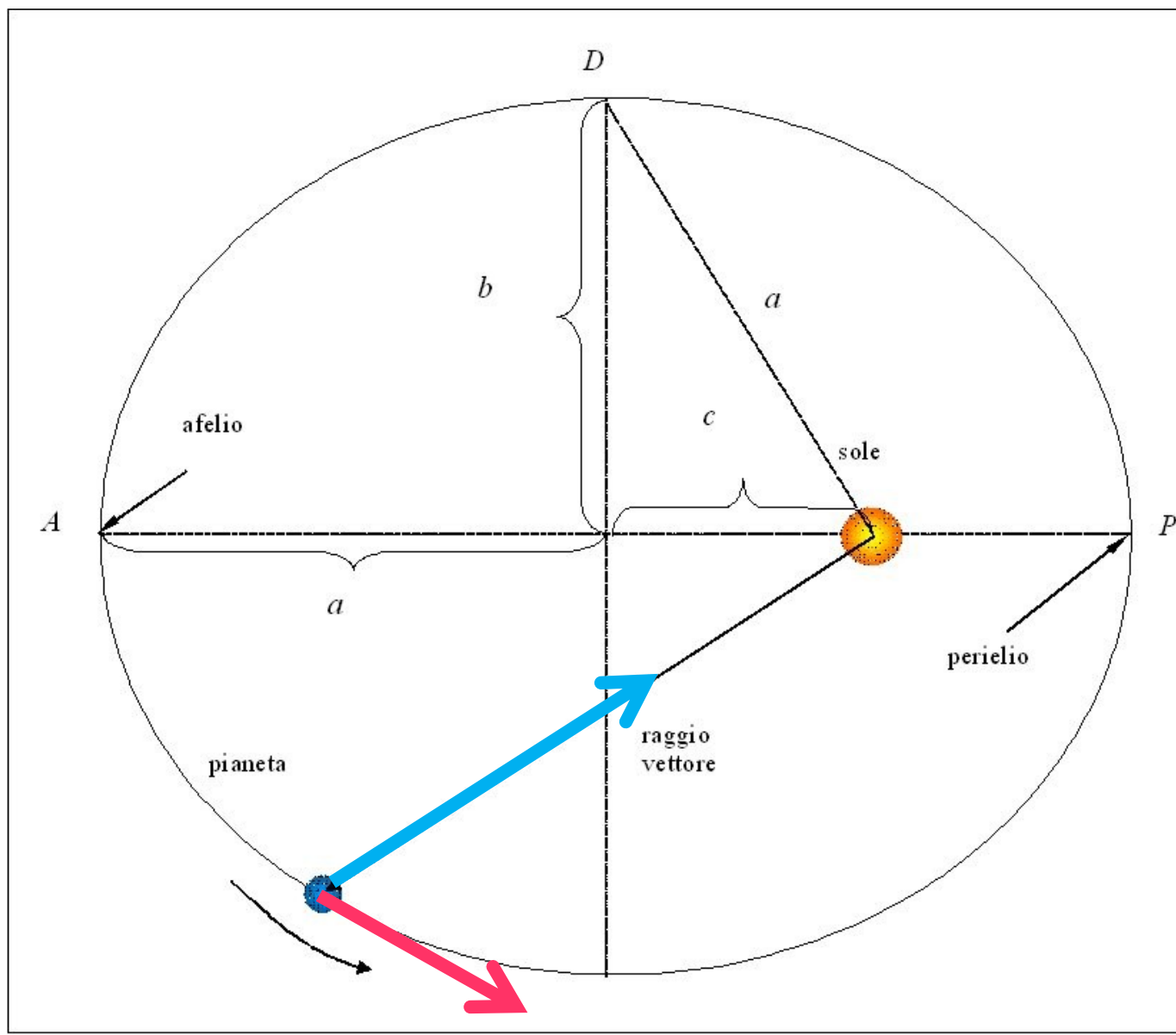


Isaac Newton
(1642-1727)



Legge di gravitazione universale di Newton

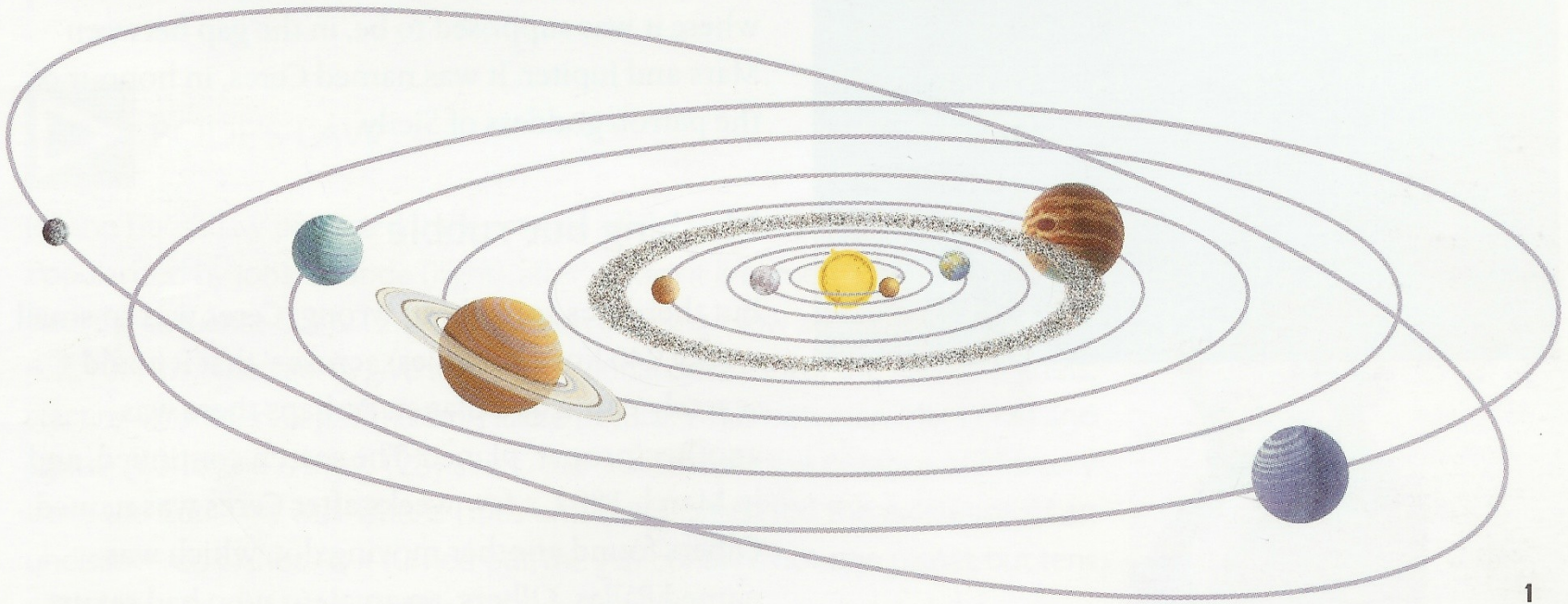
$$f = \frac{Gm_1m_2}{r^2}$$



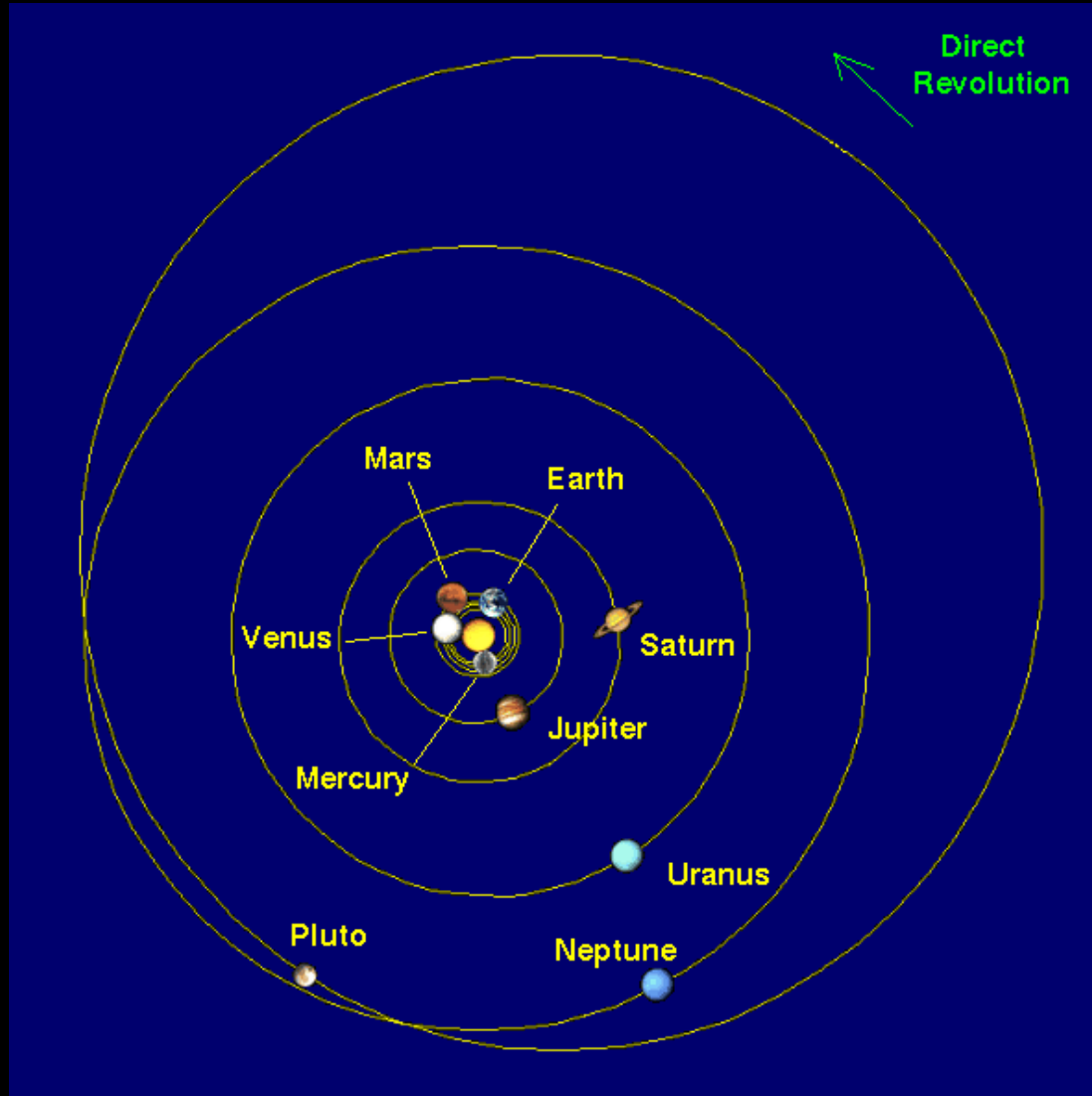
2

La struttura del Sistema Solare

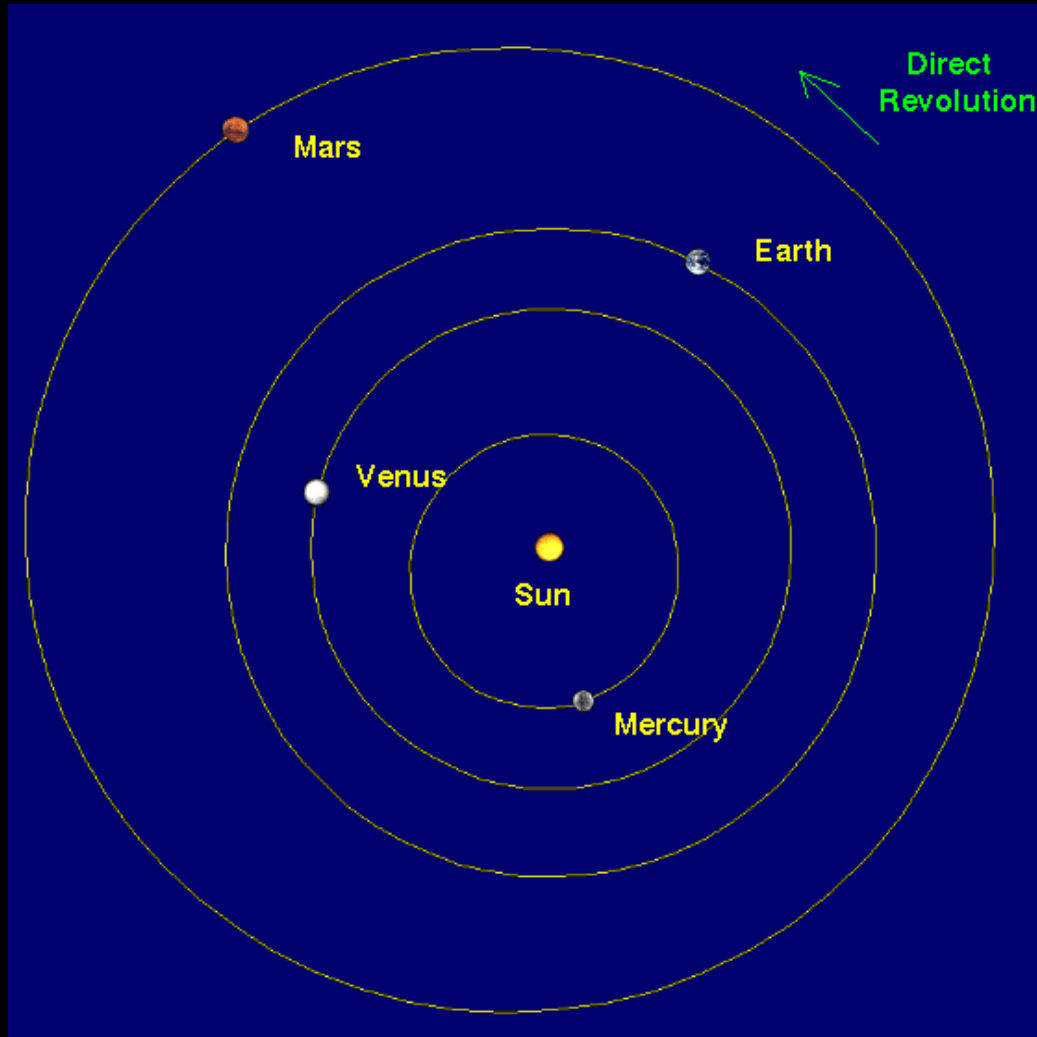
Struttura del Sistema Solare



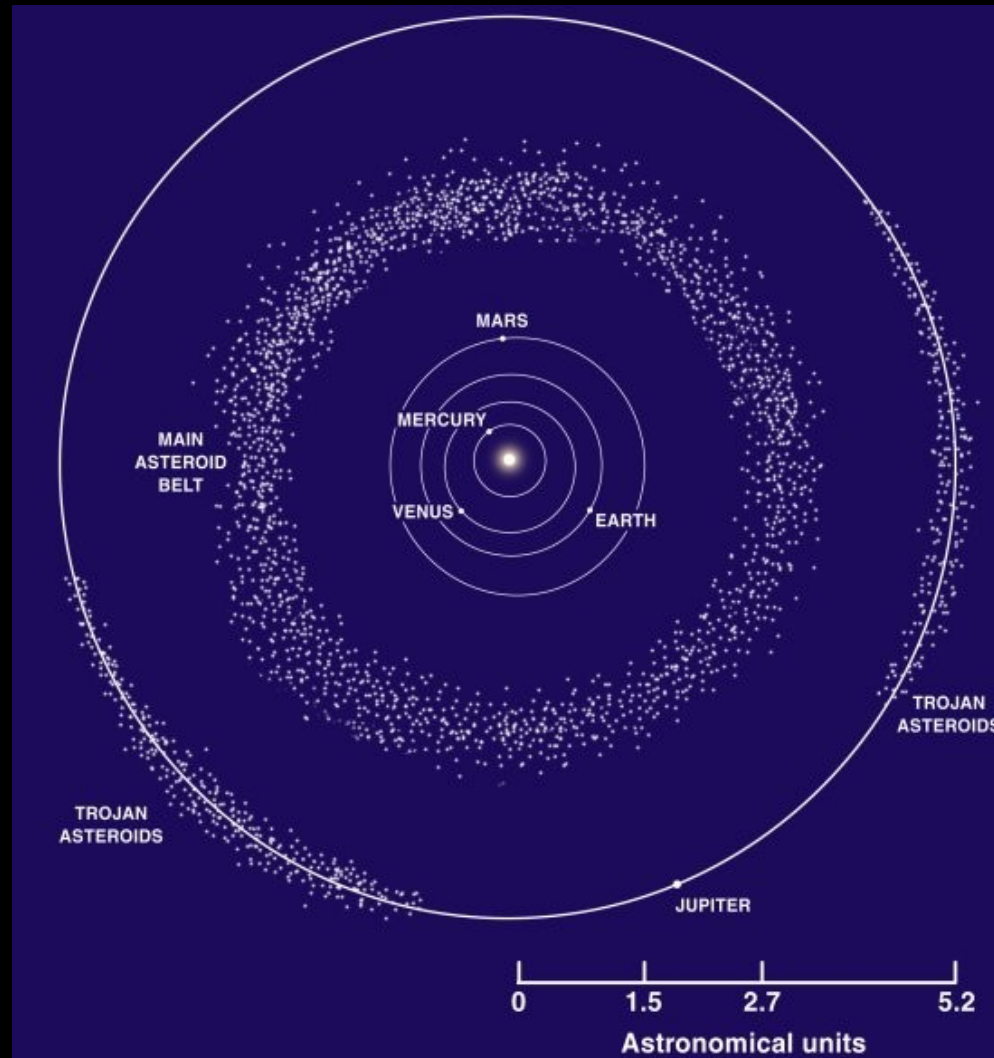
Struttura del Sistema Solare



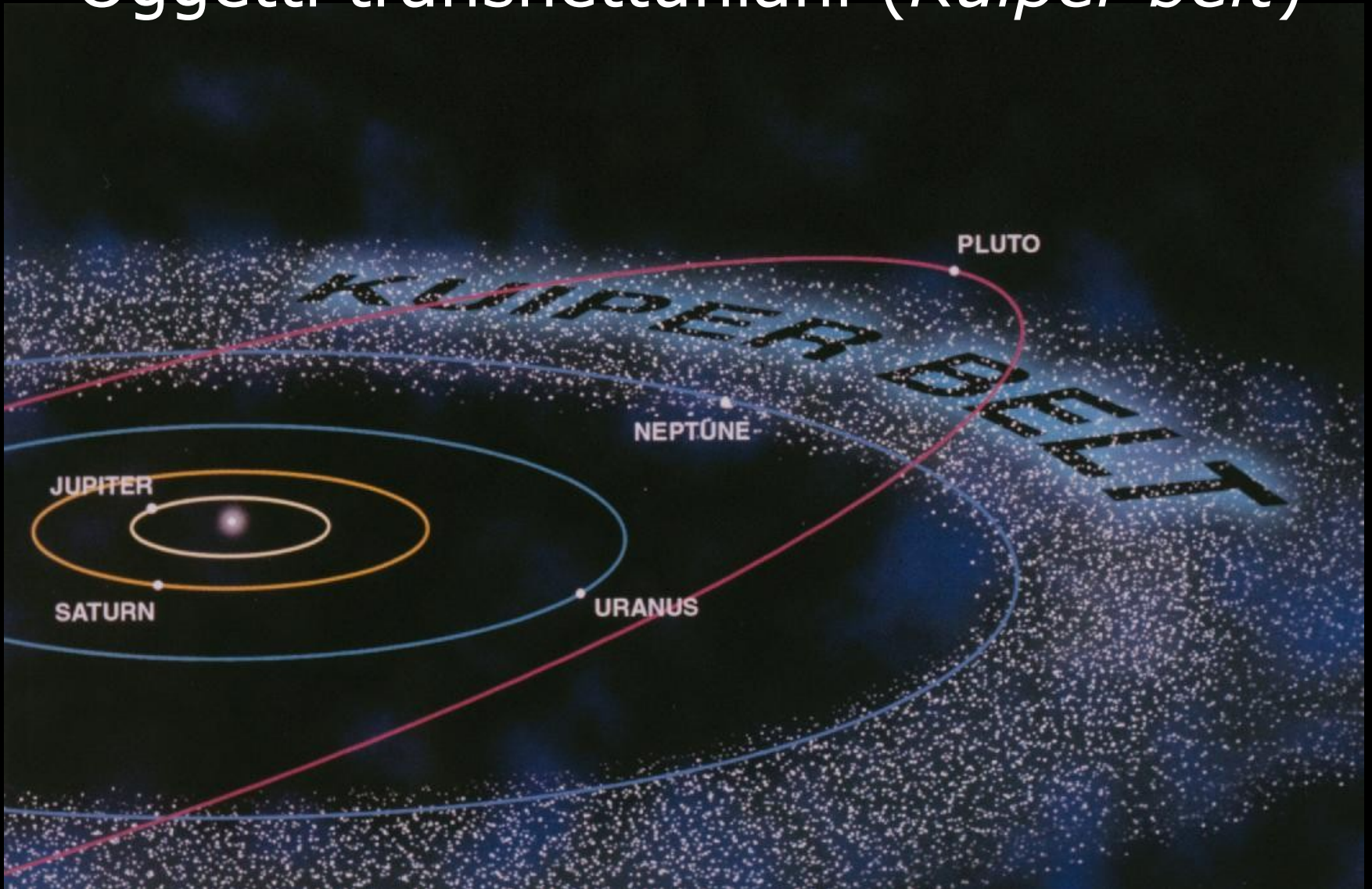
Il Sistema Solare interno



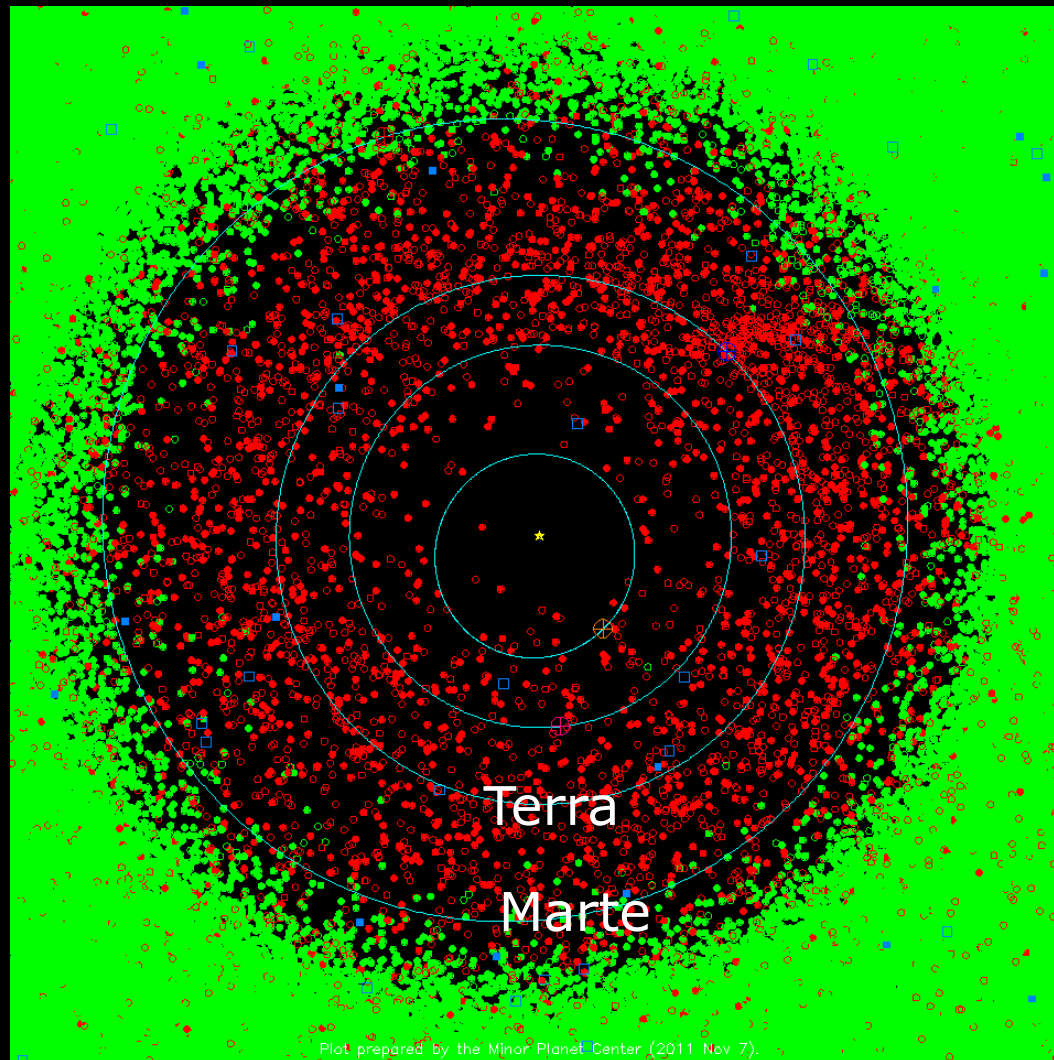
Asteroidi: fascia principale e Troiani



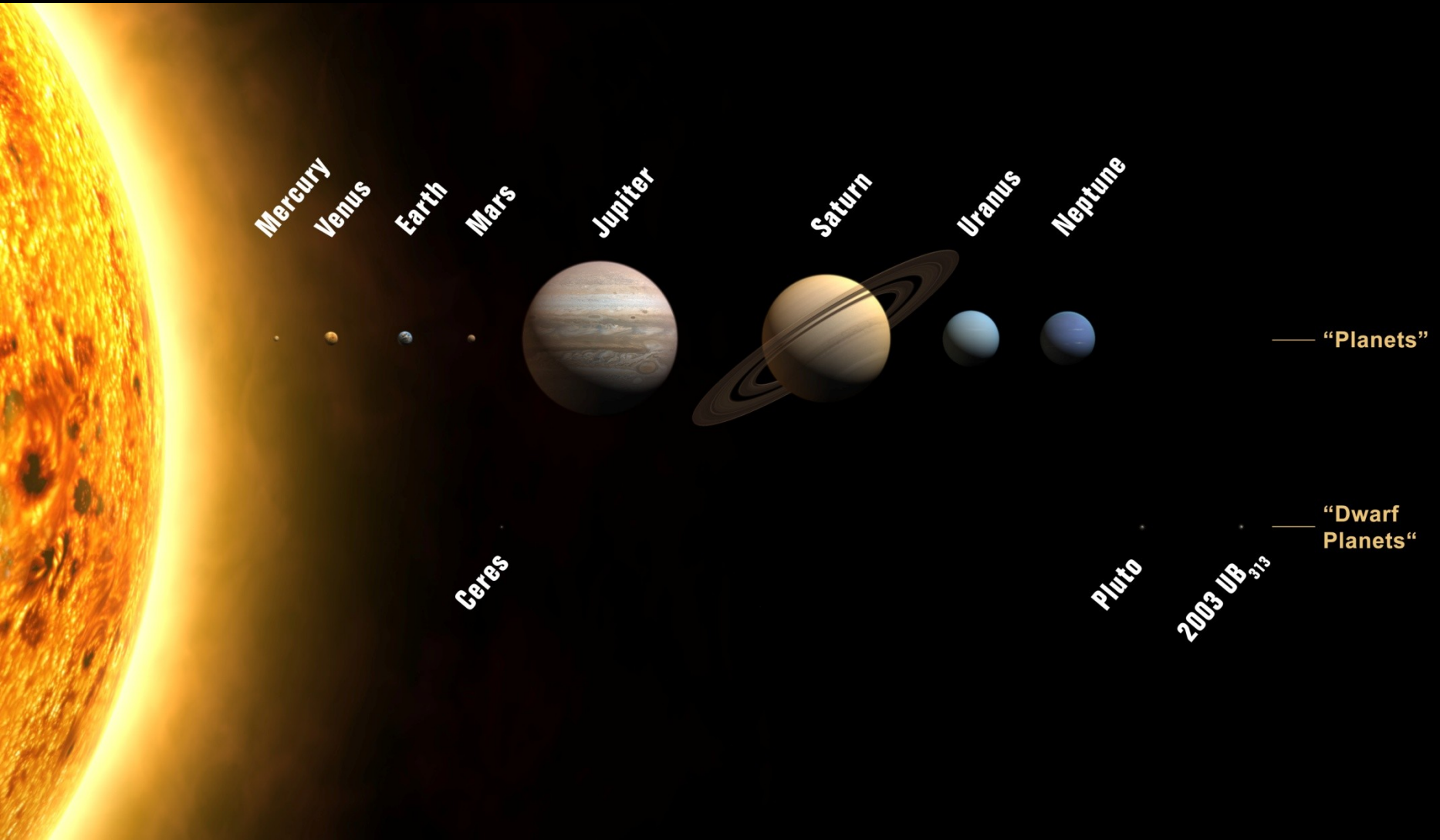
Oggetti transnettuniani (*Kuiper belt*)



Near Earth Asteroids (NEA)



Struttura del Sistema Solare



3

La formazione del Sistema Solare

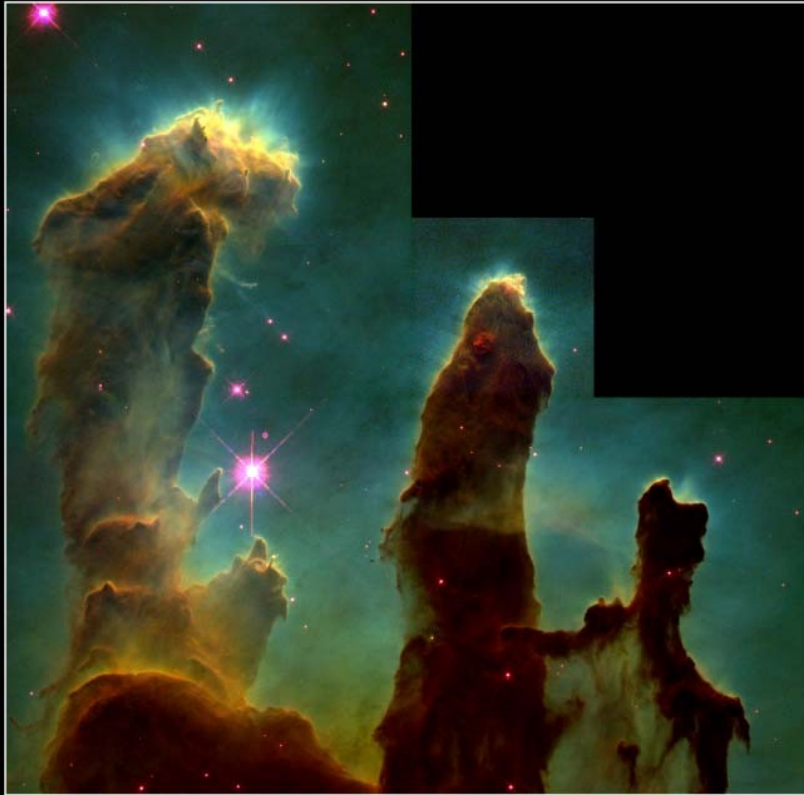




Nubi molecolari giganti



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



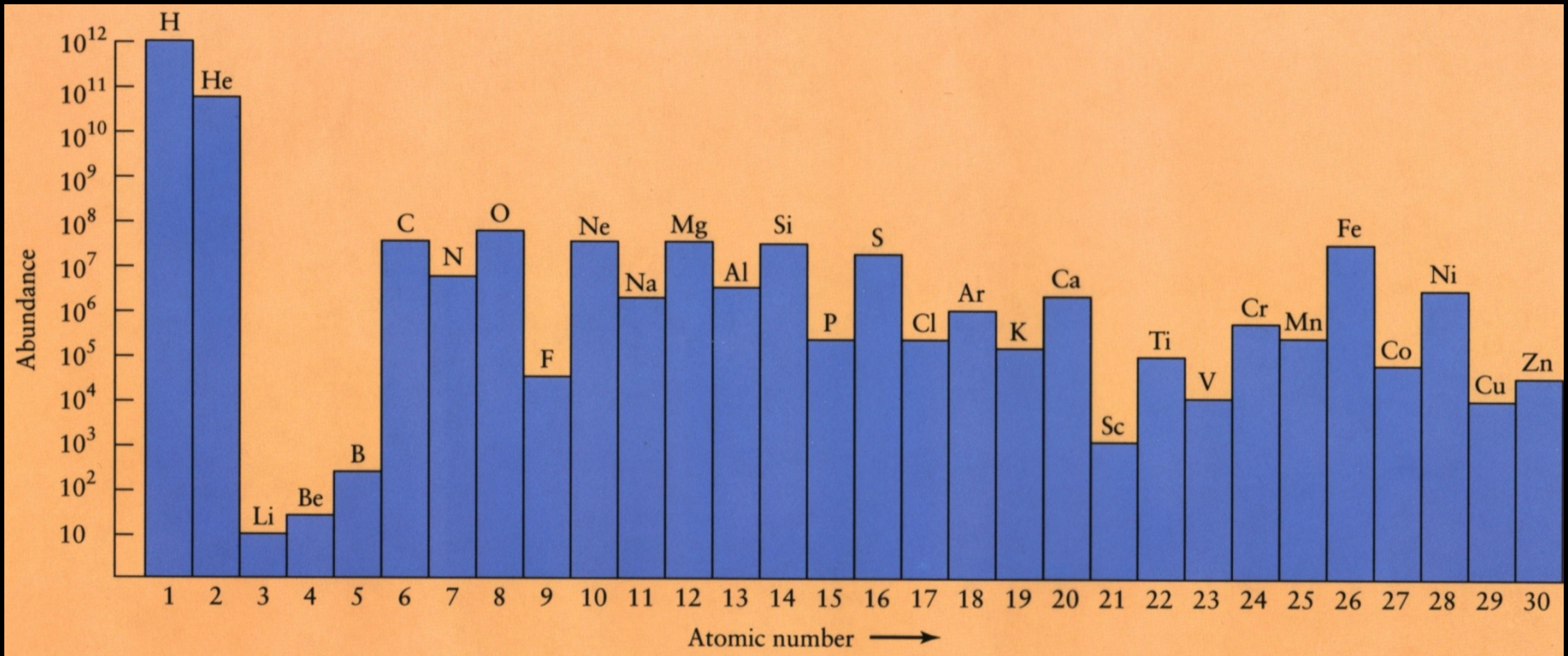
Abbondanza cosmica di elementi

Idrogeno (H): 74 %

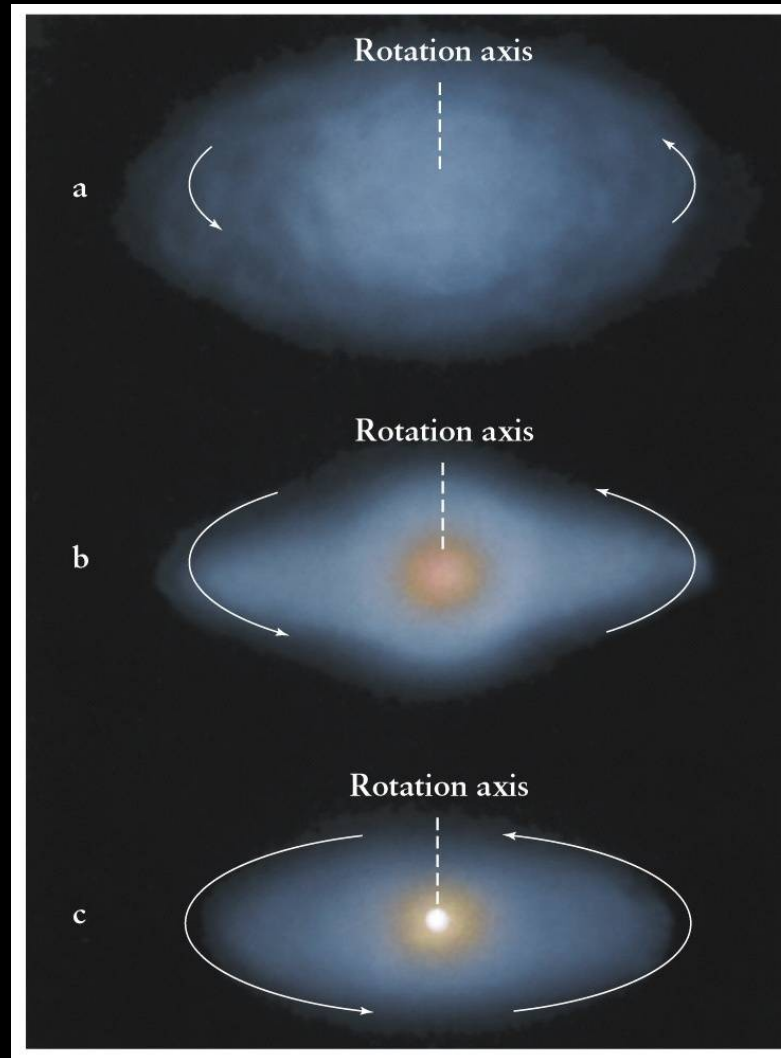
Elio (He): 24 %

altri elementi: 2 %

Abbondanza cosmica di elementi



Contrazione della protonebulosa solare

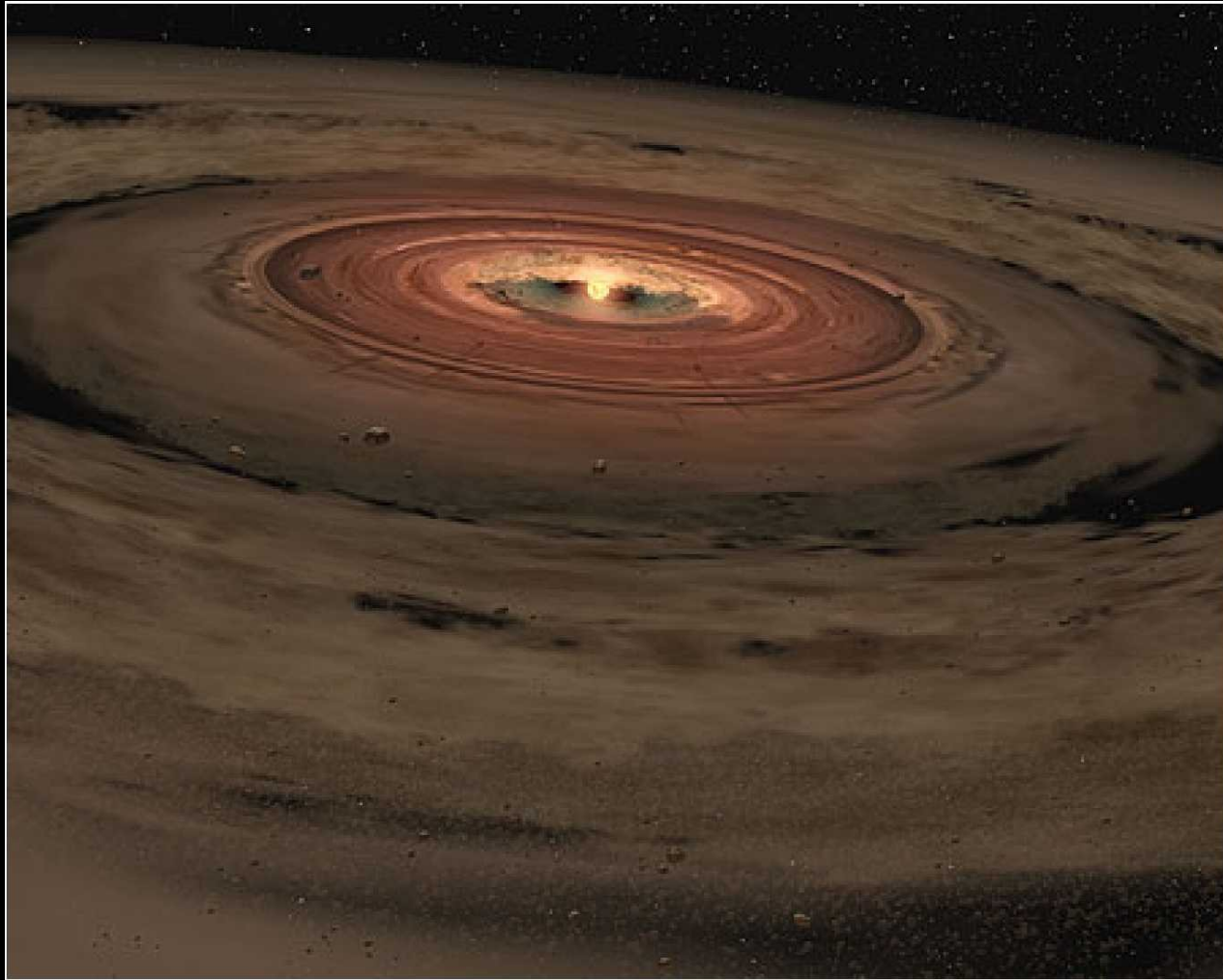


Formazione del disco protoplanetario

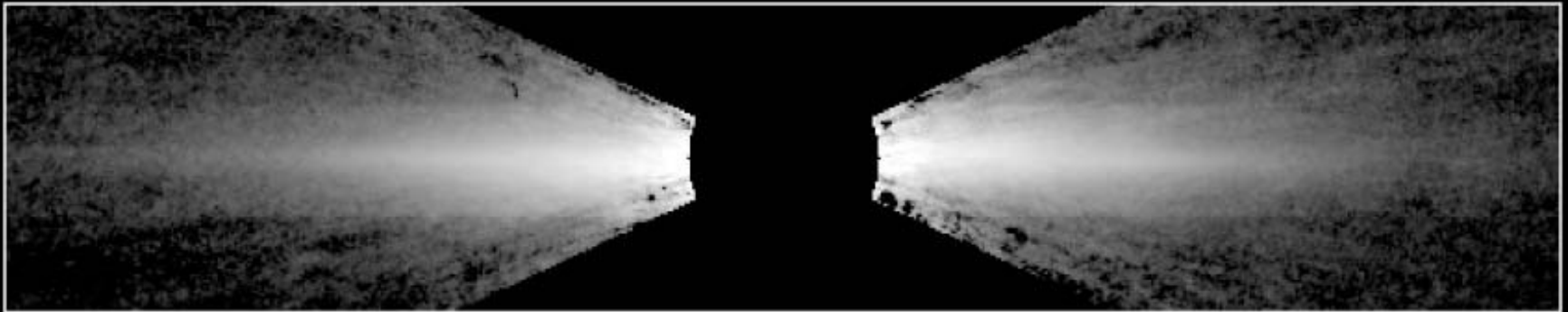


Yamato, F.

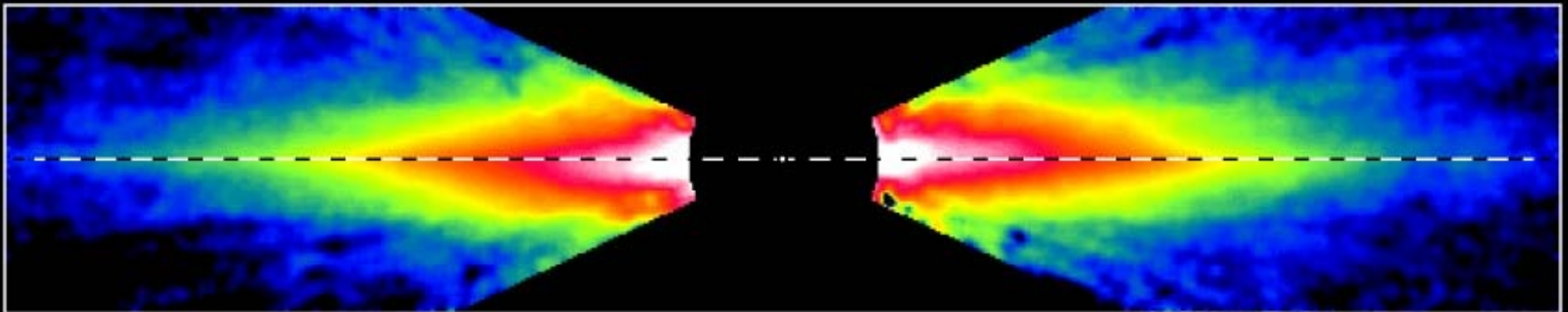
Accrezione dei planetesimi dal disco



Dischi protoplanetari



Size of Pluto's Orbit

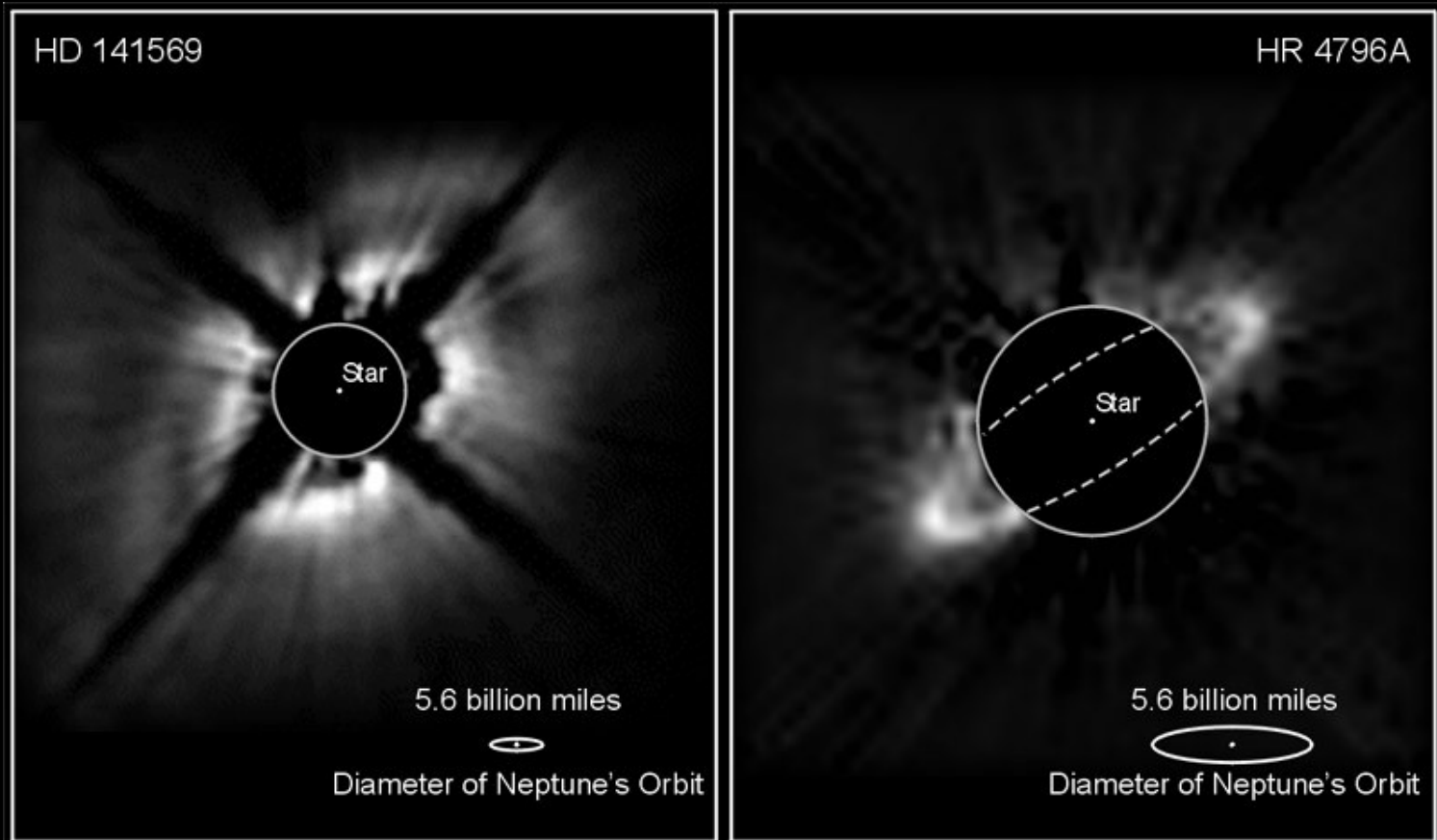


Warped Disk · Beta Pictoris

HST · WFPC2

PRC96-02 · ST ScI OPO · January 17, 1995 · C. Burrows and J. Krist (ST ScI), WFPC2 IDT, NASA

Dischi protoplanetari



Dust Disks around Stars

HST • NICMOS

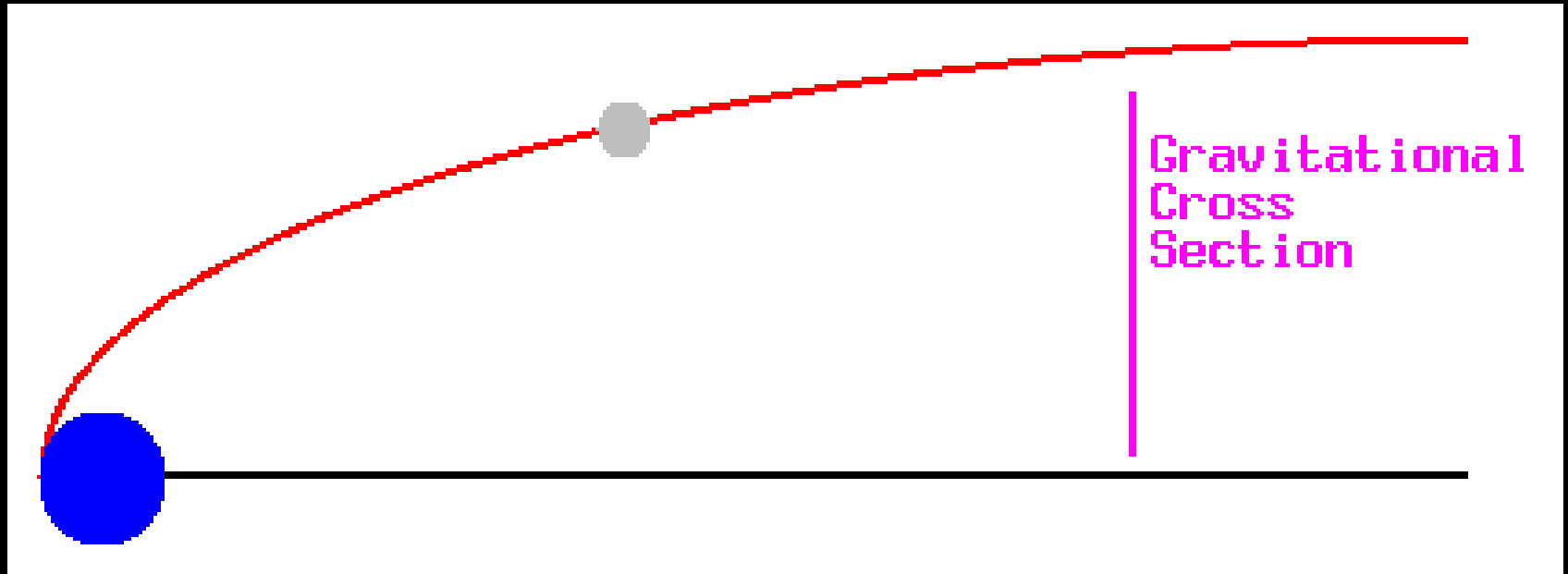
PRC99-03 • STScI OPO • January 8, 1999

B. Smith (University of Hawaii), G. Schneider (University of Arizona),
E. Becklin and A. Weinberger (UCLA) and NASA

Dischi protoplanetari



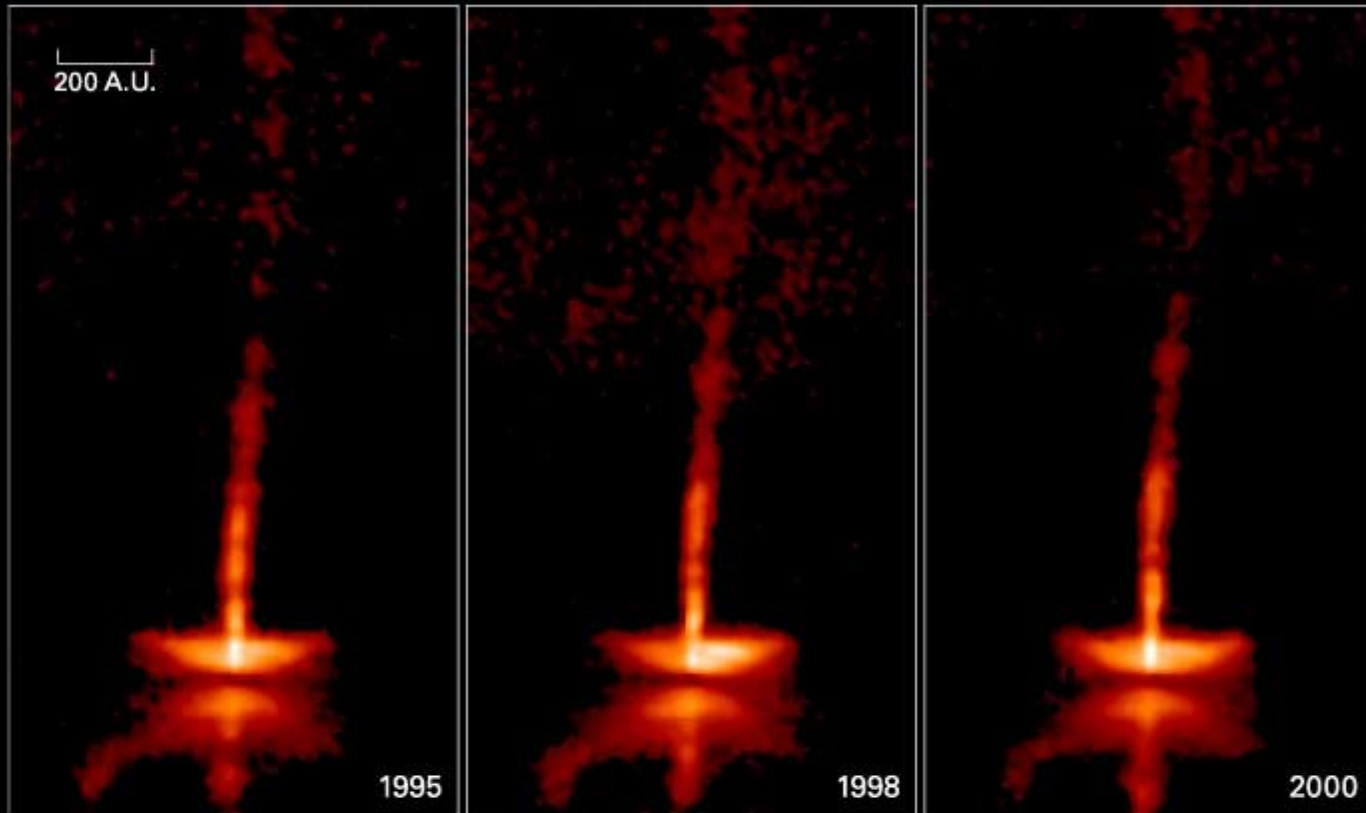
Accrezione gravitazionale



Il proto-Sole: una stella T Tauri



Stelle T Tauri



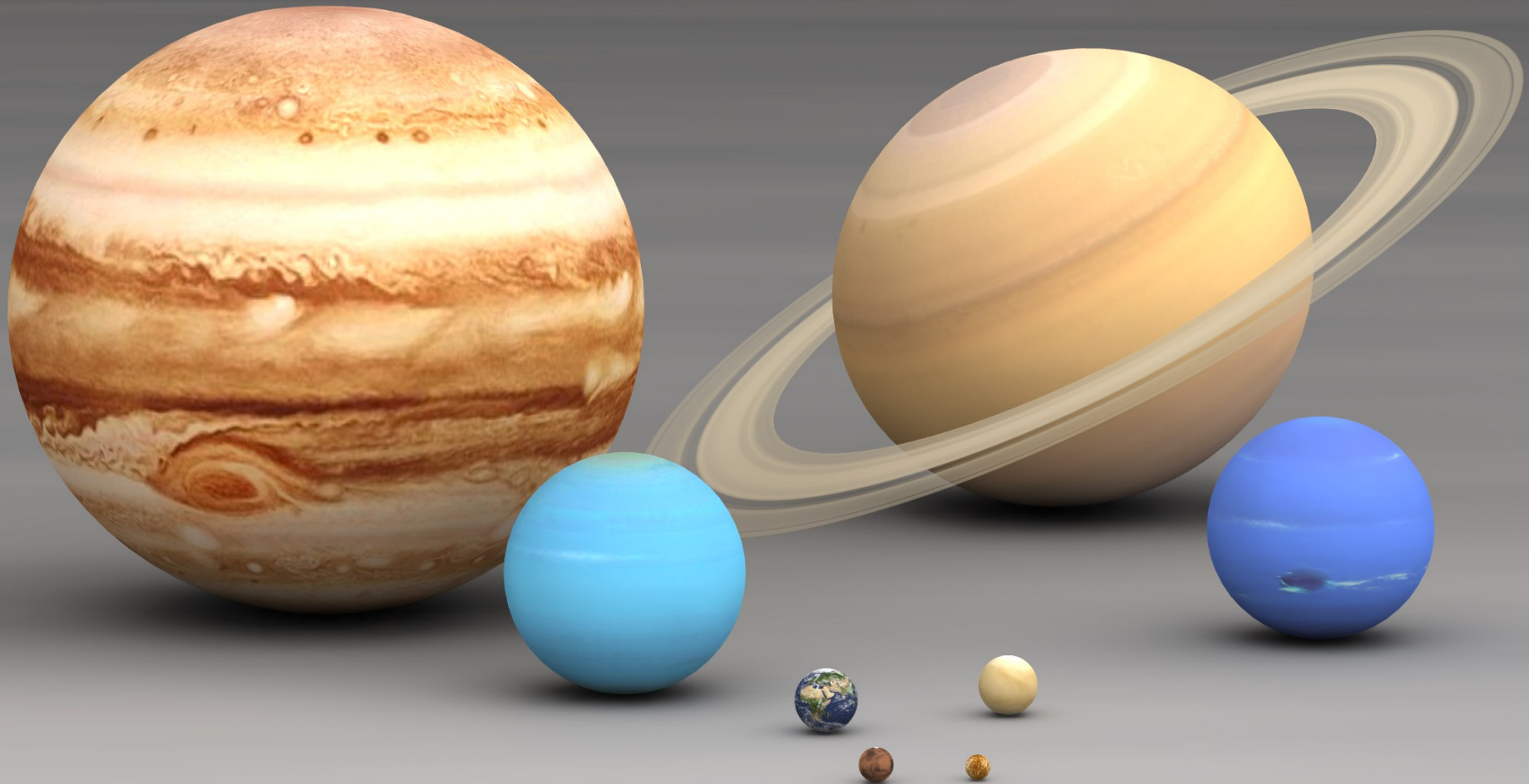
The Dynamic HH 30 Disk and Jet
Hubble Space Telescope • WFPC2

NASA and A. Watson (Instituto de Astronomía, UNAM, Mexico) • STScI-PRC00-32b

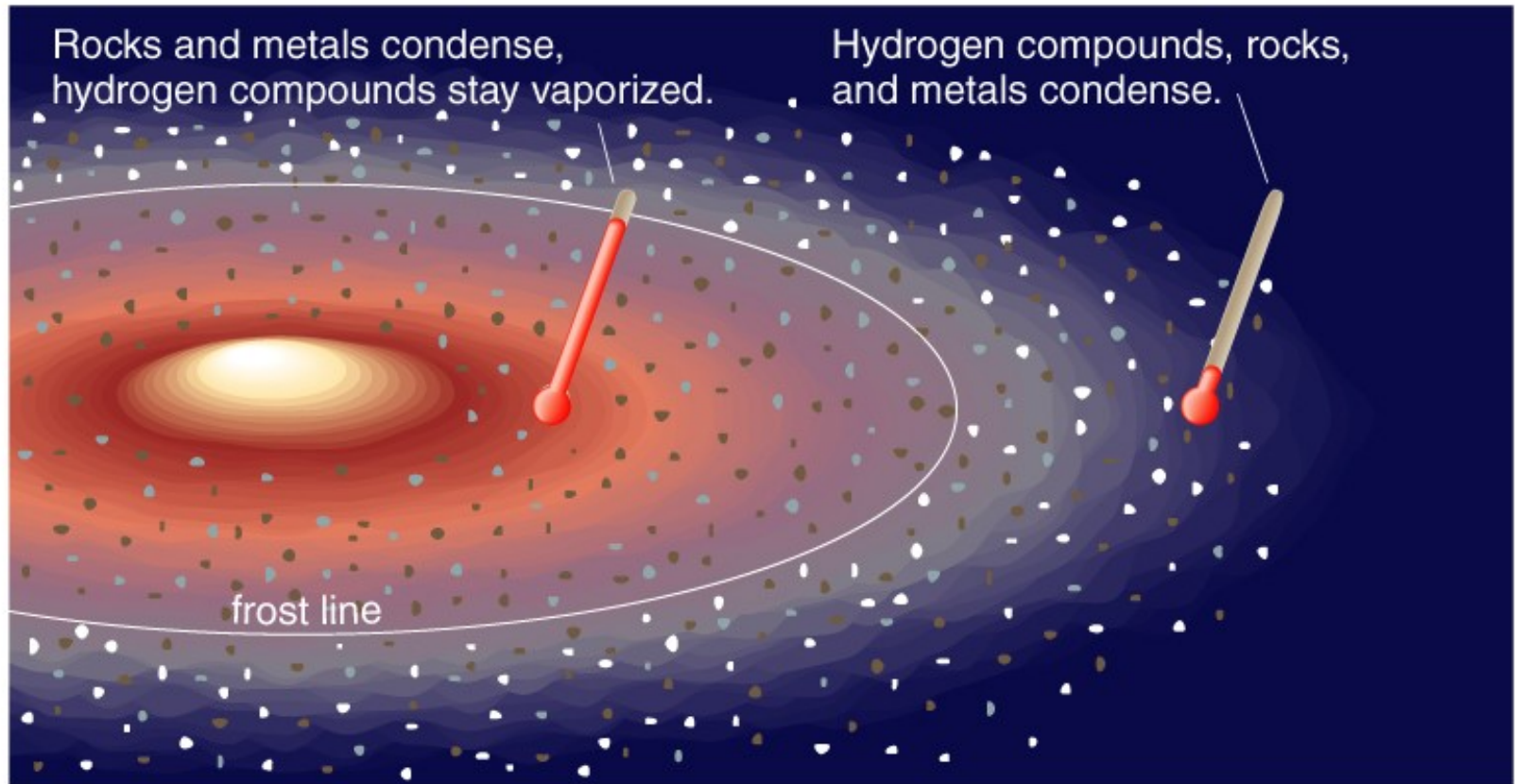
Accrezione dei protopianeti



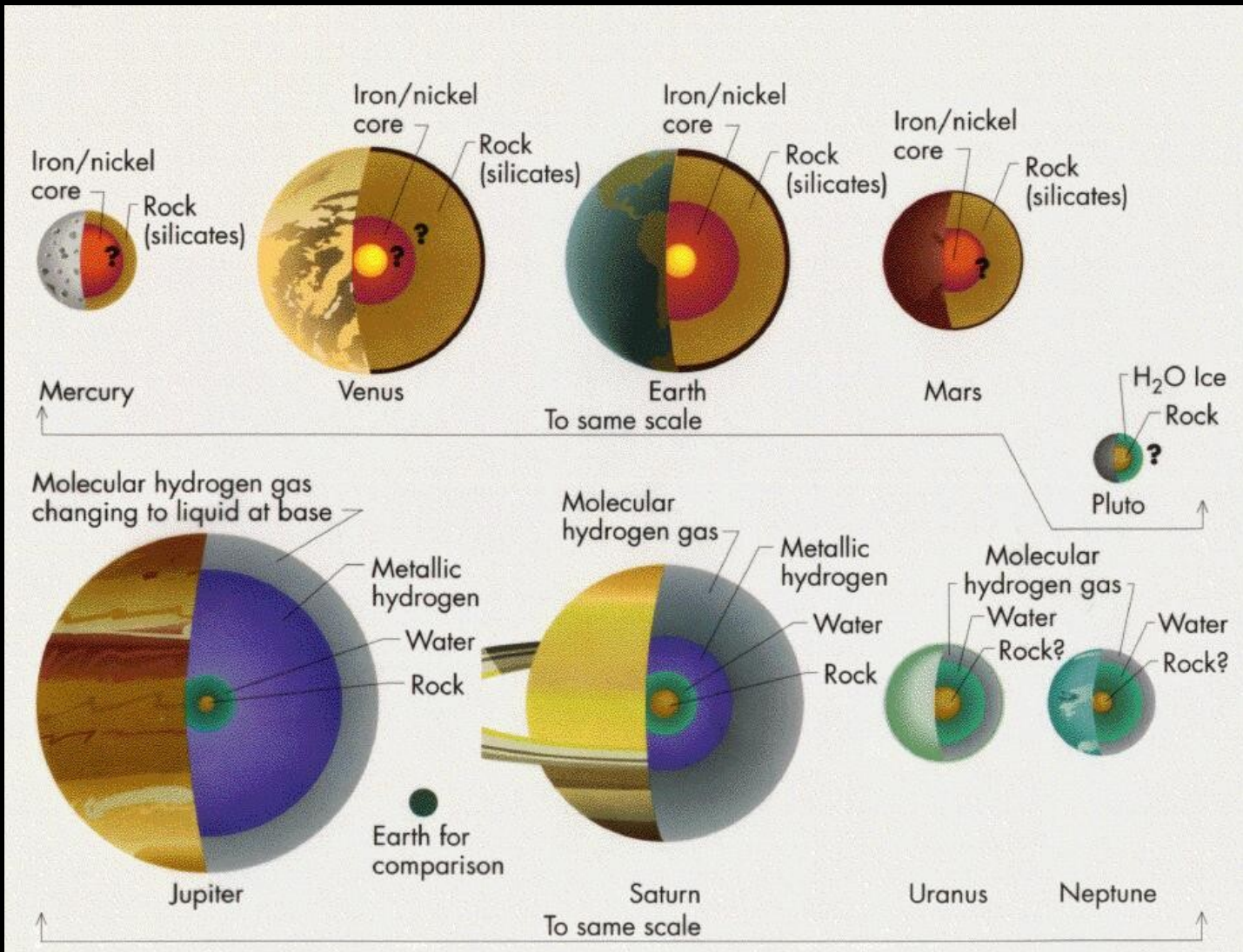
I pianeti in scala



Gradiente di temperatura



Differenze di composizione interna

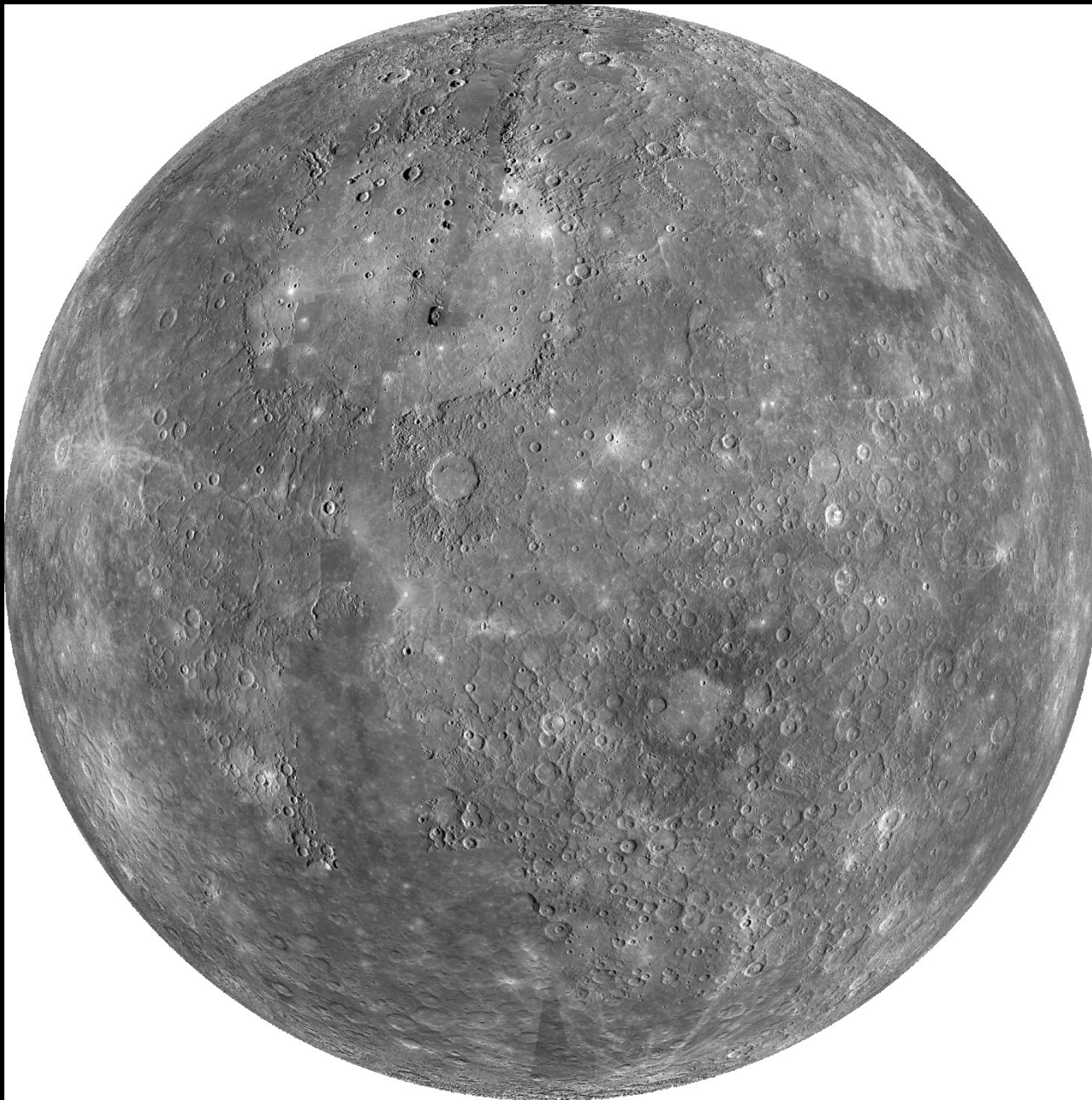


pianeti
"terrestri"
(interni)

pianeti
"giganti"
(esterni)

4

Un'occhiata al Sistema Solare



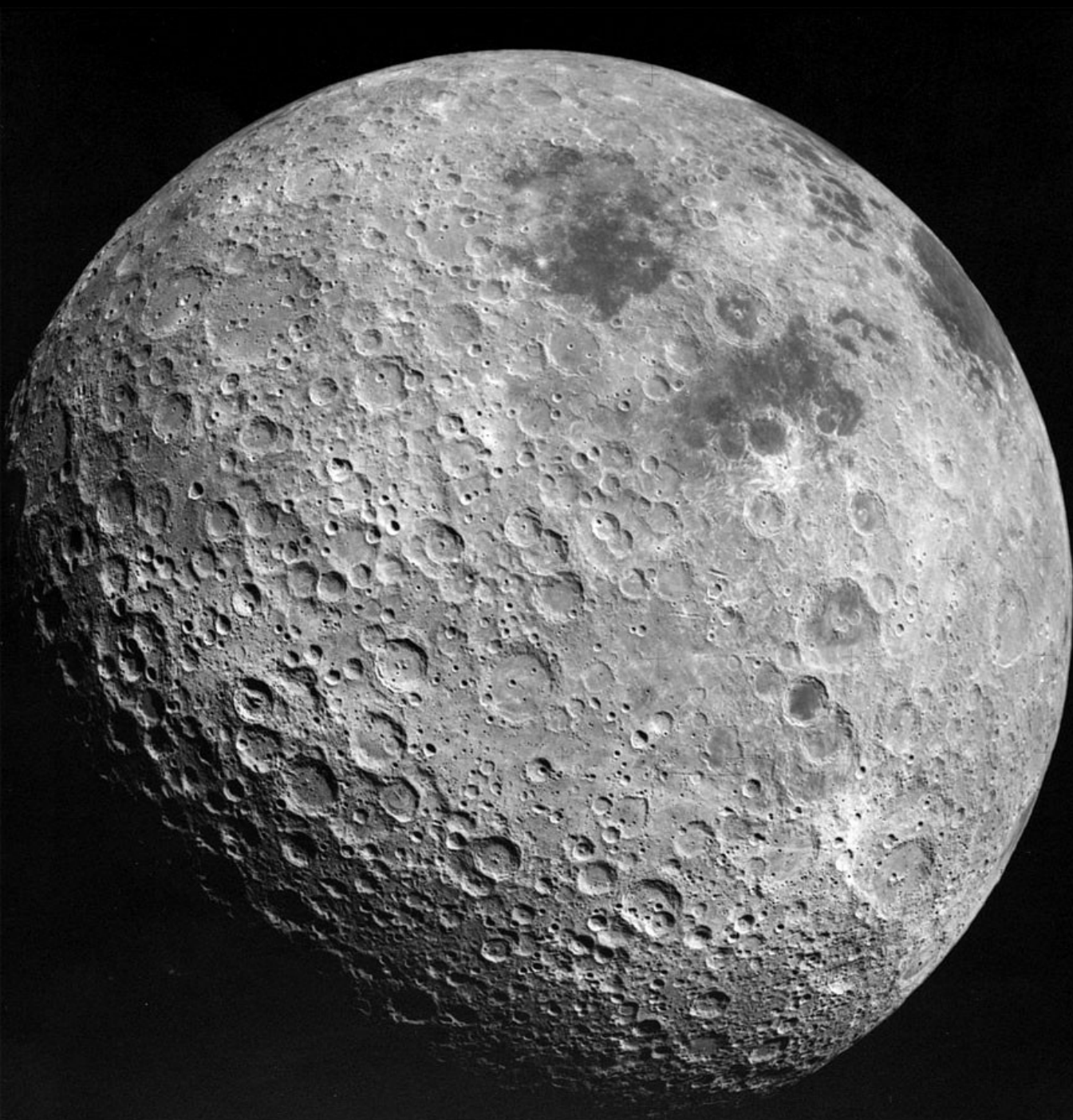
Mercurio

$d = 0.39 \text{ AU}$

$P_{\text{orb}} = 88 \text{ d}$

$P_{\text{rot}} = 59 \text{ d}$

$R = 2440 \text{ km}$



Luna

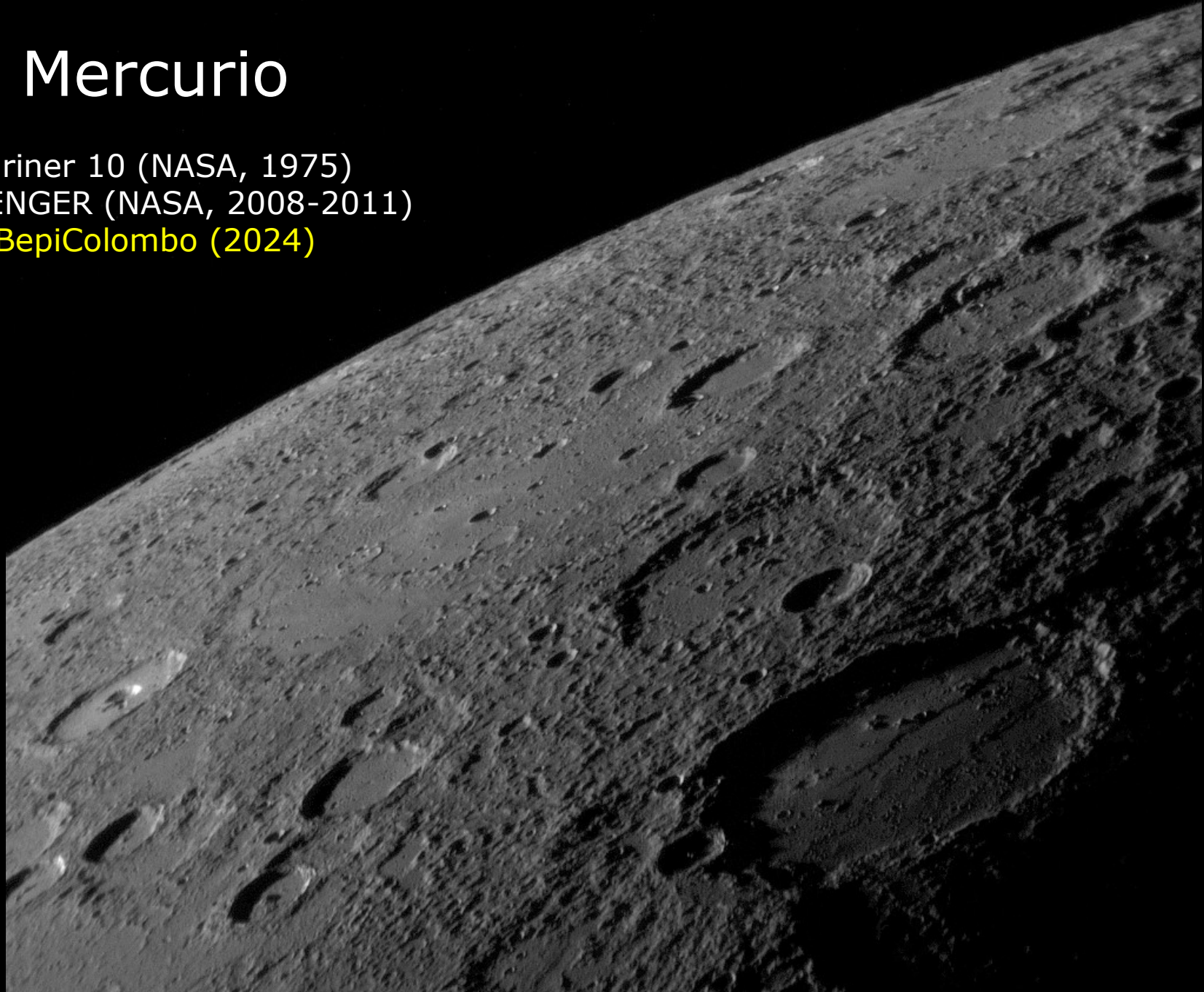
$R = 1738 \text{ km}$

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



Earth impact sites

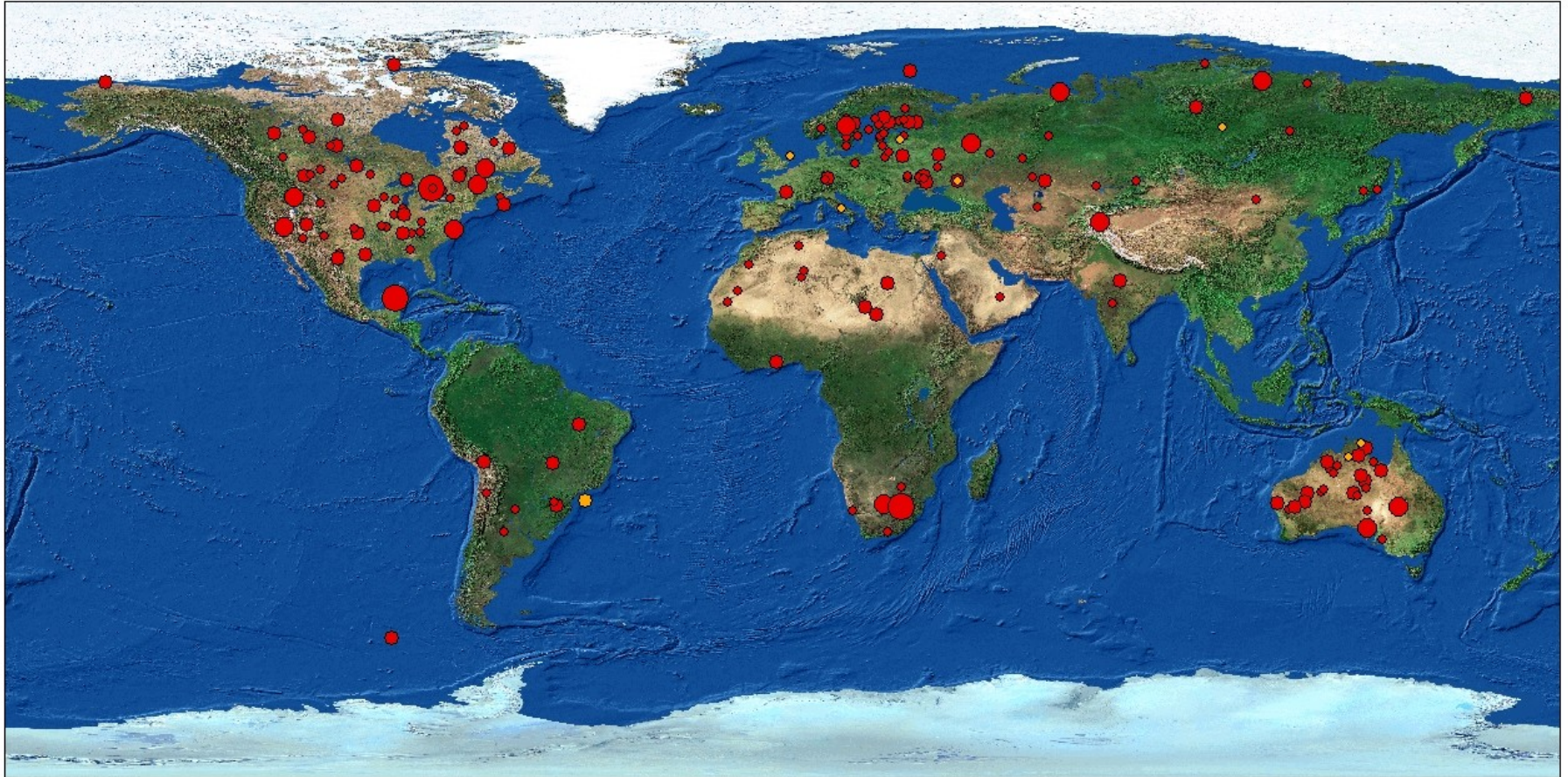
Design by David Rajmon using Impact database v.2010.1
and NASA Blue Marble topographic map - 15 May 2010.

Status:

- Confirmed with shock or chemical evidence
- Highly probable based on geological evidence

Diameter (km):

- <10
- 10 - 50
- 50 - 100
- 100 - 300



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



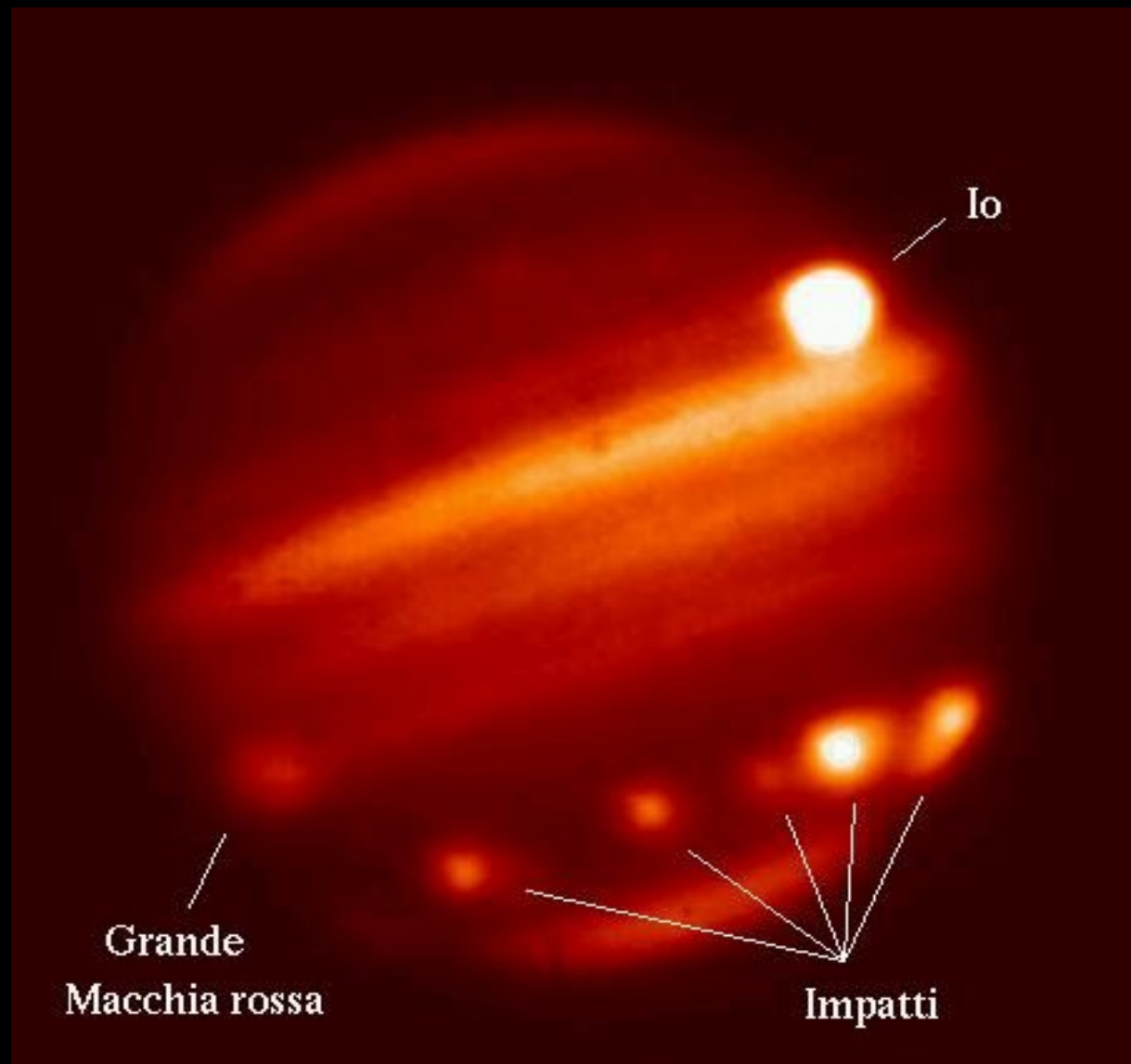


Barringer Meteor Crater (Arizona, USA)

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



Hubble Space Telescope • Wide Field Planetary Camera 2

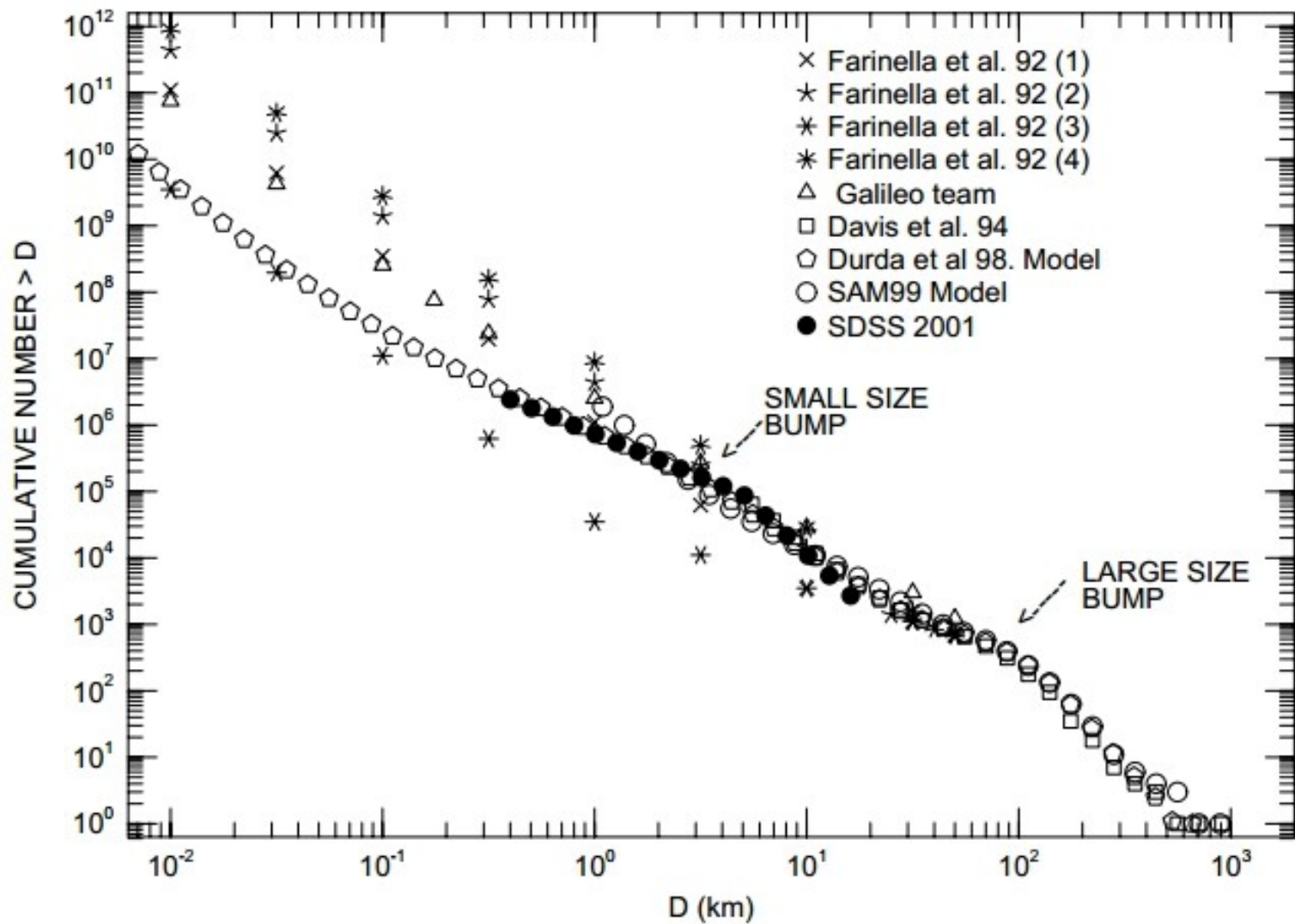


Impatto dei frammenti della cometa *Shoemaker-Levy 9* con il pianeta Giove

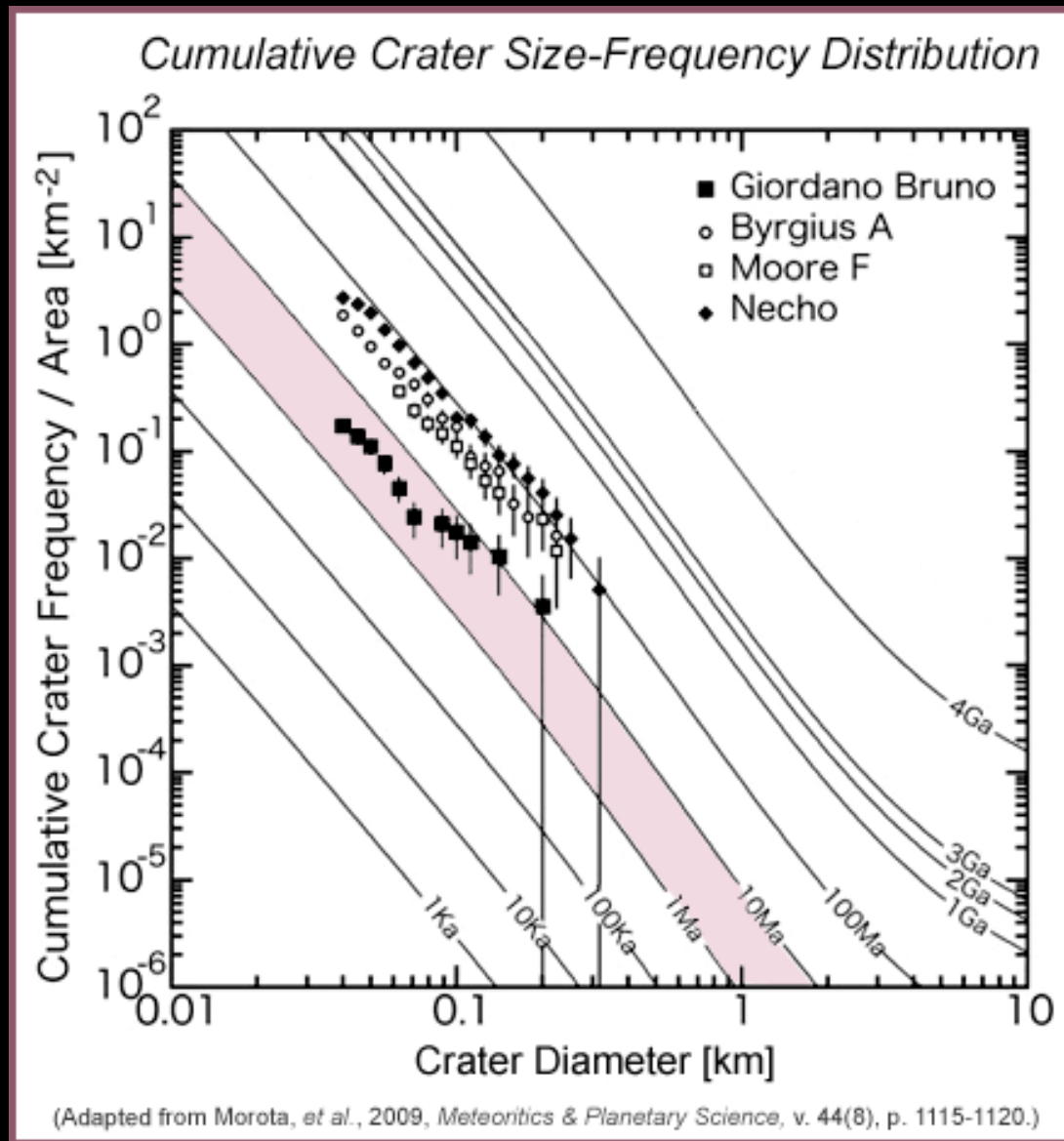


La (nostra) Luna

COMPARISON OF ASTEROID SIZE DISTRIBUTION: OBSERVATIONS AND MODELS

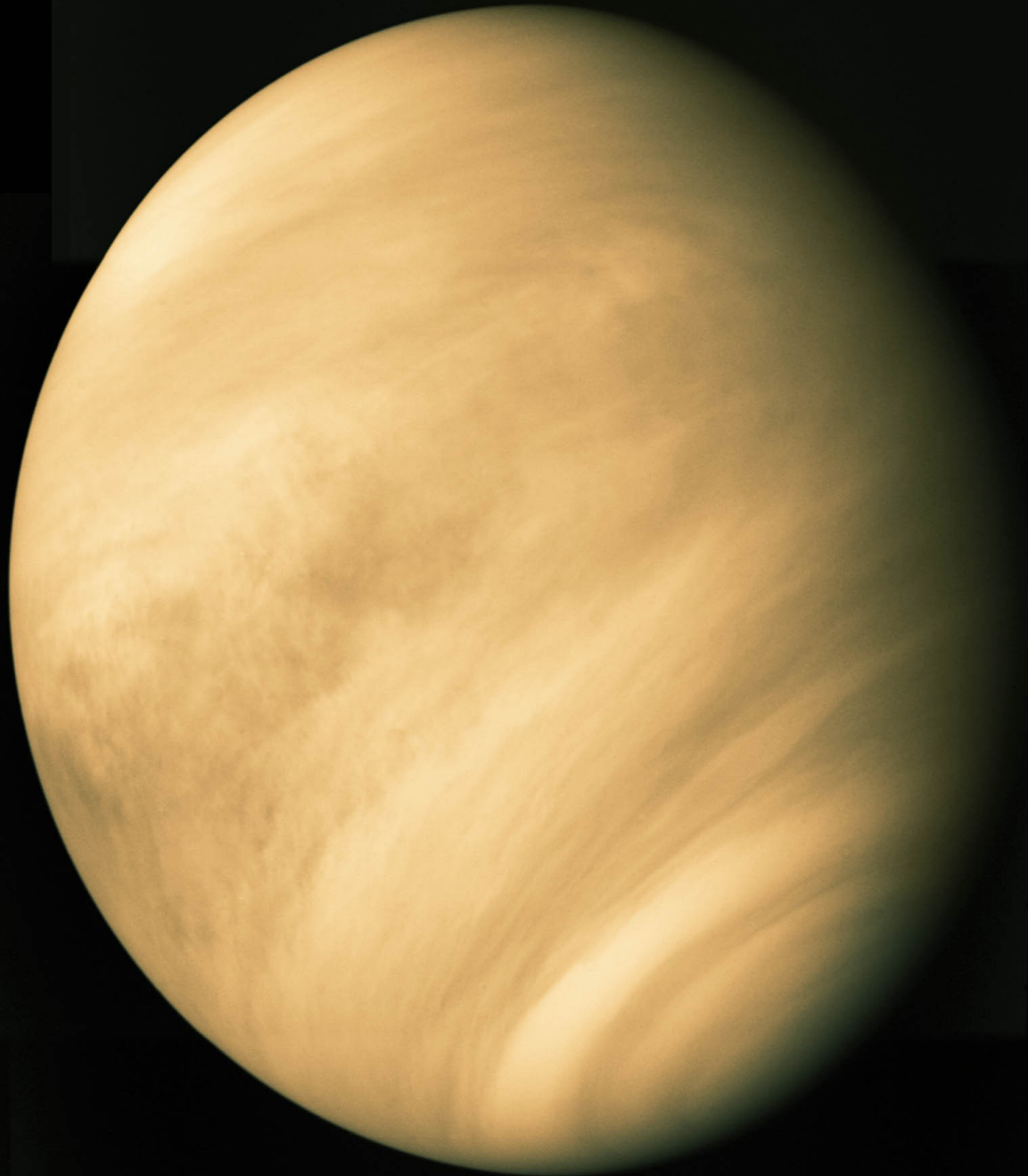


Conteggio di asteroidi in funzione delle dimensioni



Conteggio di crateri lunari in funzione delle dimensioni

Venere



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



15^h 0^m
15 15^m

XIV 20 lug 1895

Ocul B' vetro chiara

Ani II un po'
ondulata. questi
disegni rende bene
la proporzione delle
varie ombre.



XV 21 lug 1895

Ocul B' vetro chiara

(in completo)



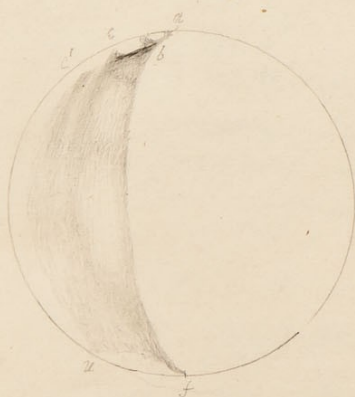
XVI 25 lug. 1895

10^h 20^m — 10^h 35^m

Ocul B' naturale

Ani I-II a moment
incognita bellezza con
culo un po' velato
pare bene riuscita

Il bottone a appena
si vede: la punta
c: dei ciferi probata un
No' a sinistra.



XVII 2 Agosto

10^h 40^m — 10^h 55^m

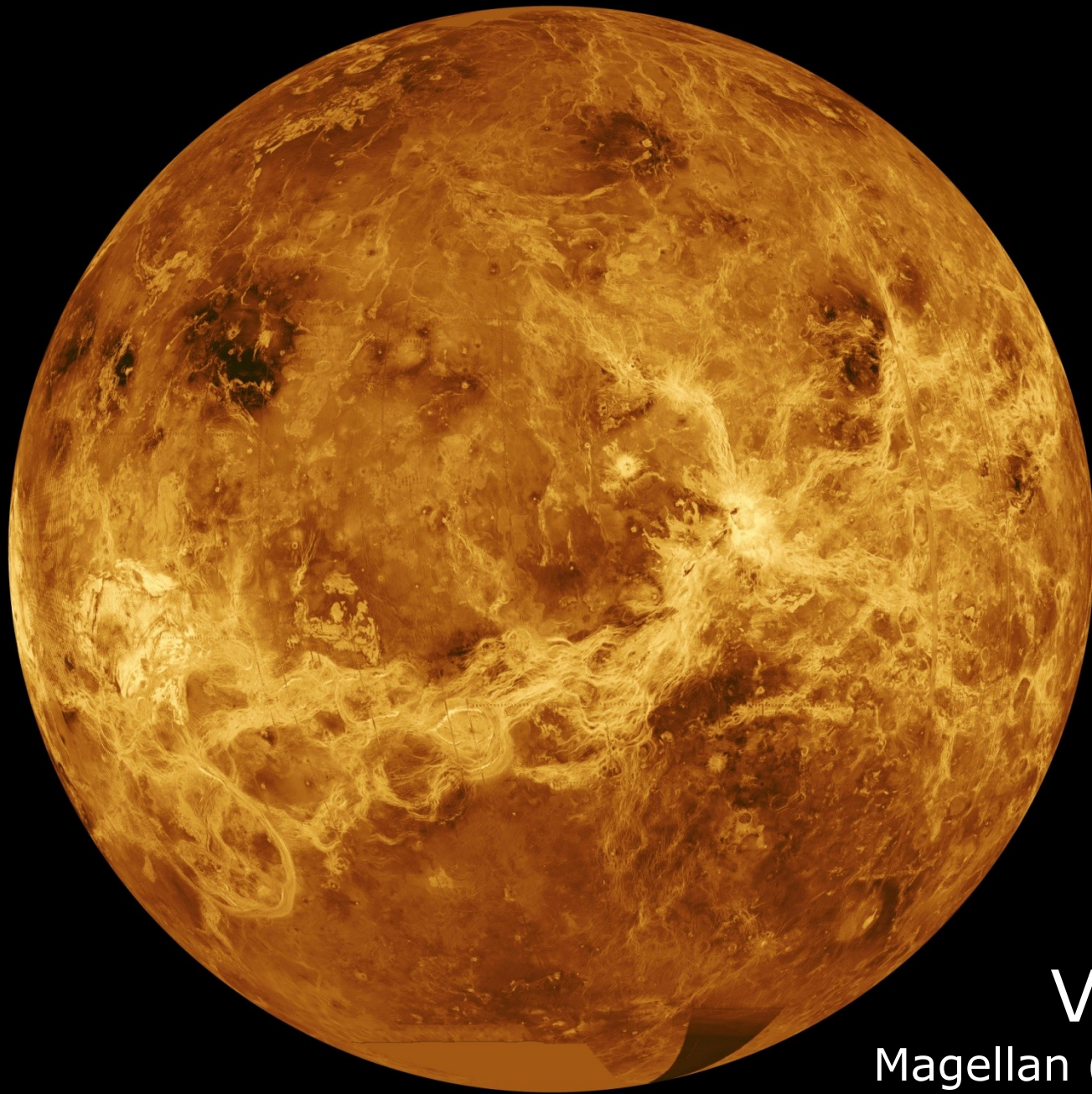
Ocul B' vetro I

Ani II, falce III e IV
il quando in quando si vede
bene. pare buono.
bottone a ben detto

Venere vista da Schiaparelli



Venere
Venera 9 (URSS, 1975)

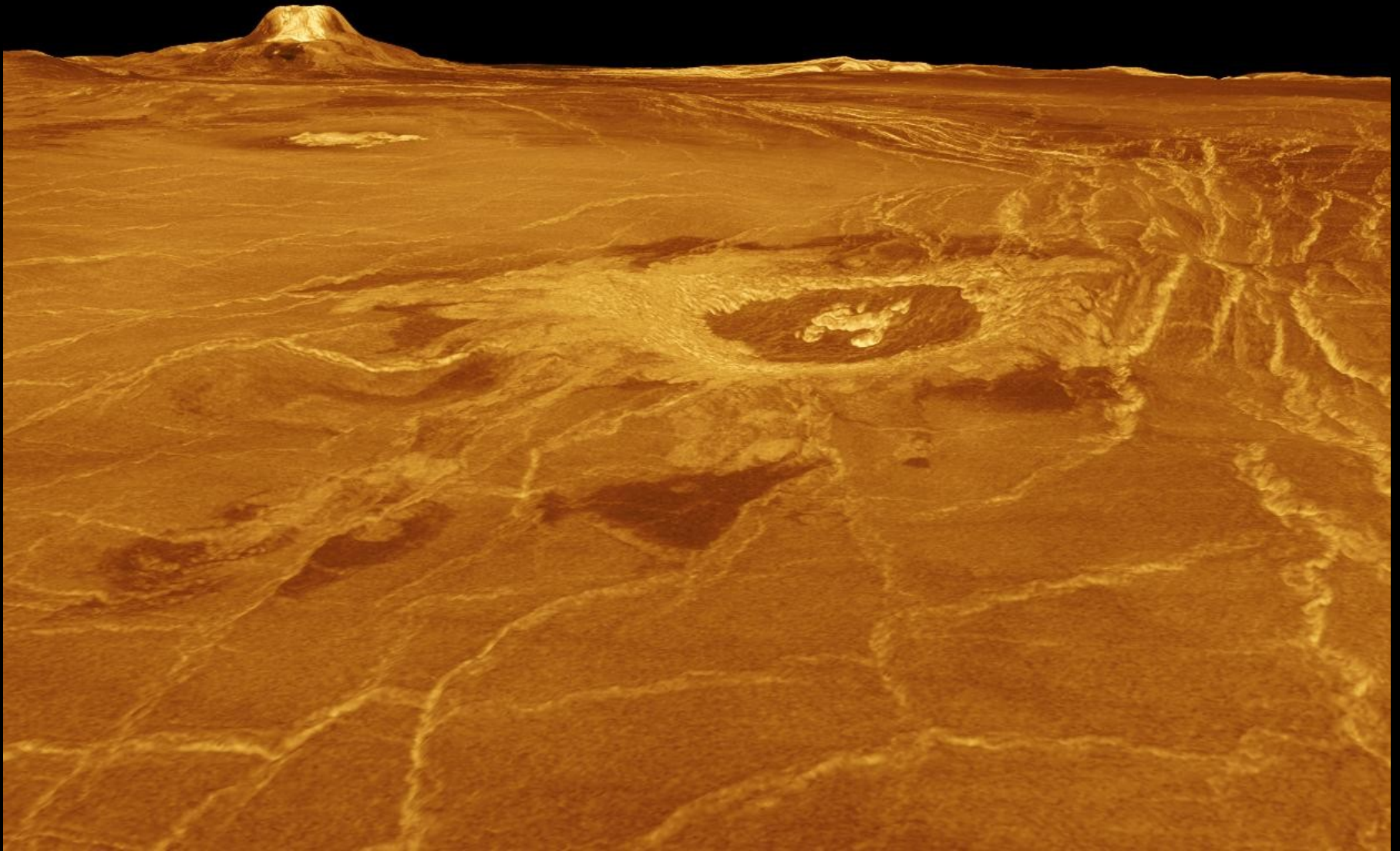


Venere

Magellan (NASA, 1990-94)

Venere

Magellan (NASA, 1990-94)



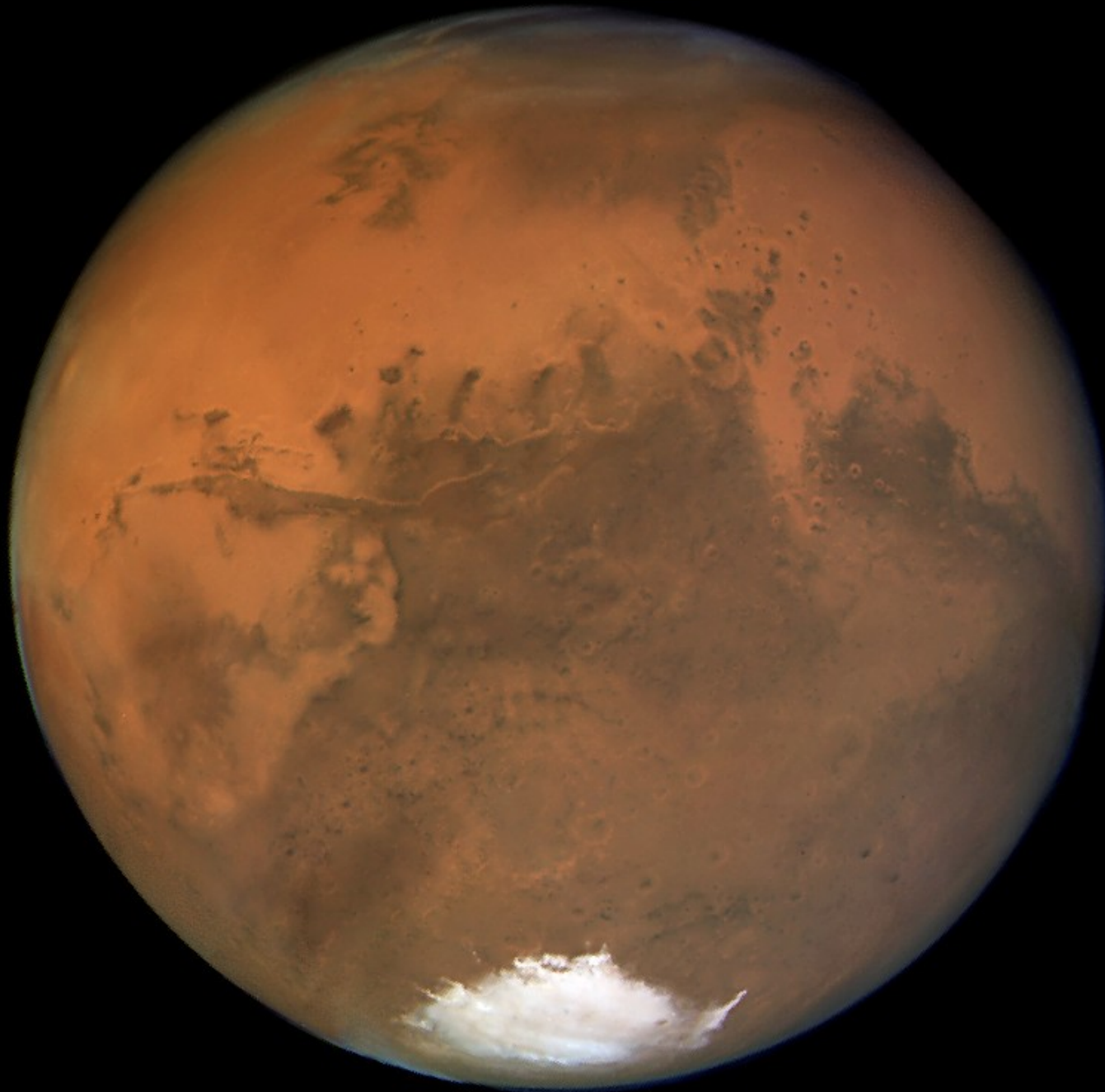


Terra

$d = 1 \text{ AU}$

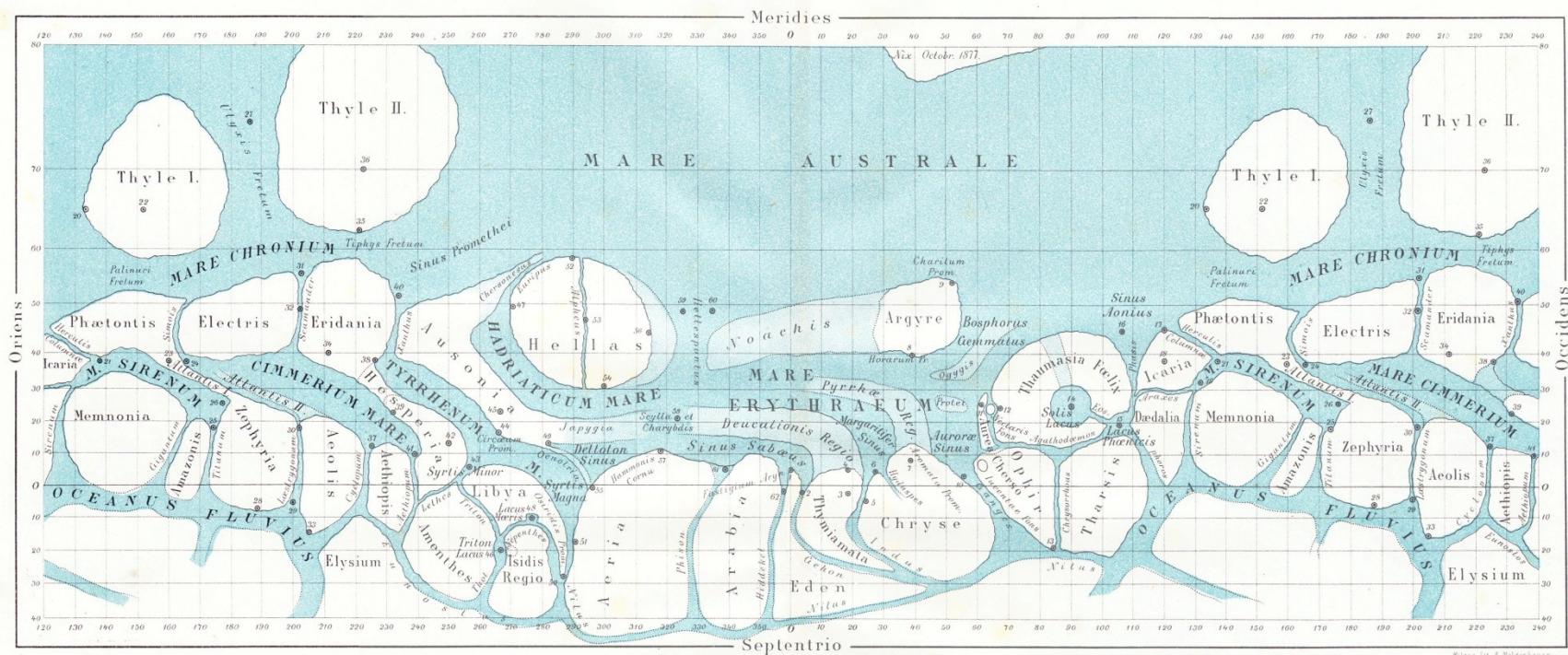
$P_{\text{orb}} = 365.25 \text{ d}$

$R = 6378 \text{ km}$



Marte

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



Tab. III

MAPPA AREOGRAPHICA

Exhibens Planetæ Martis Chorographiam inter Polum Australem et Parallelum 40^{am}

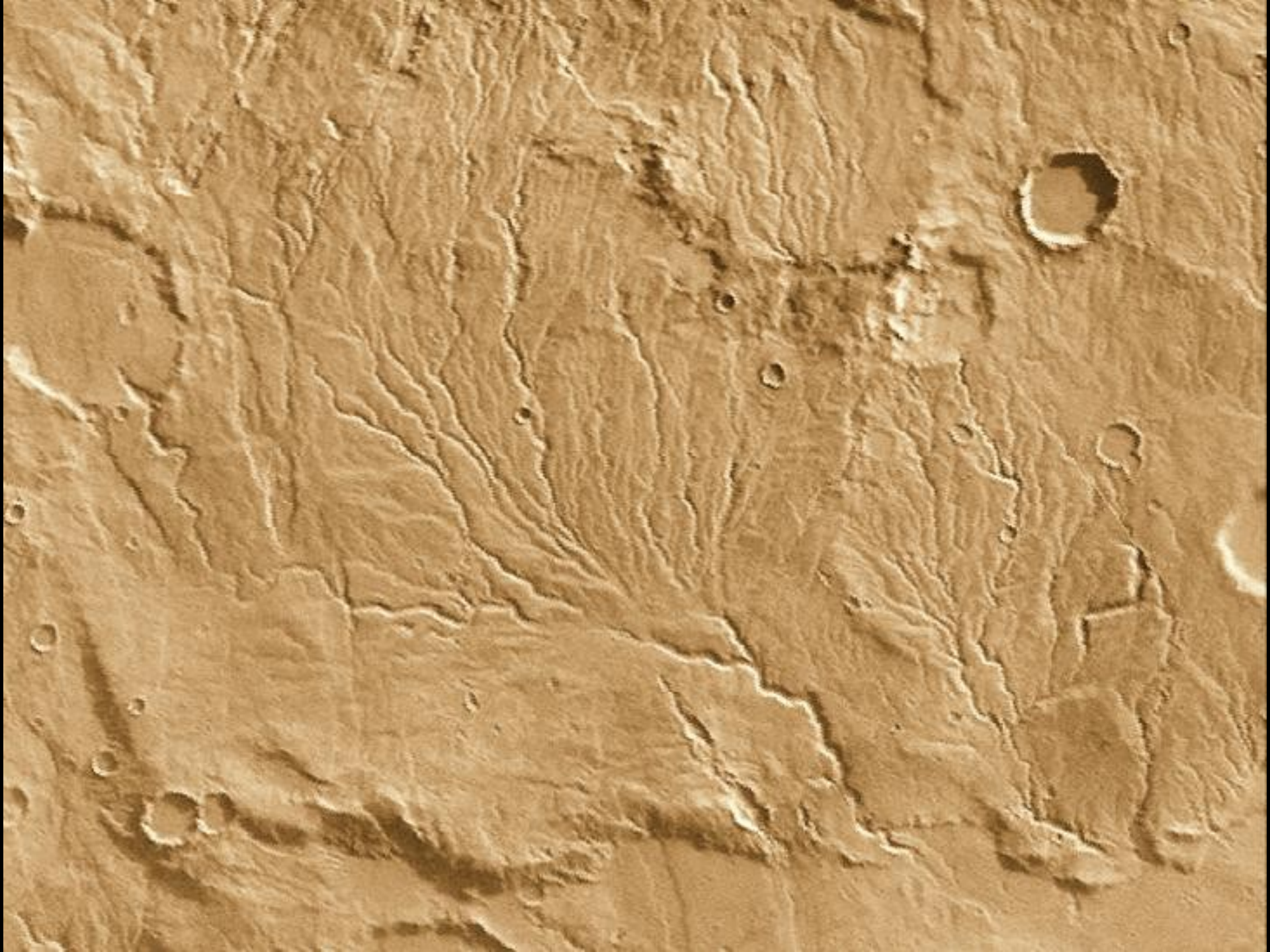
Latitudinis Borealis;

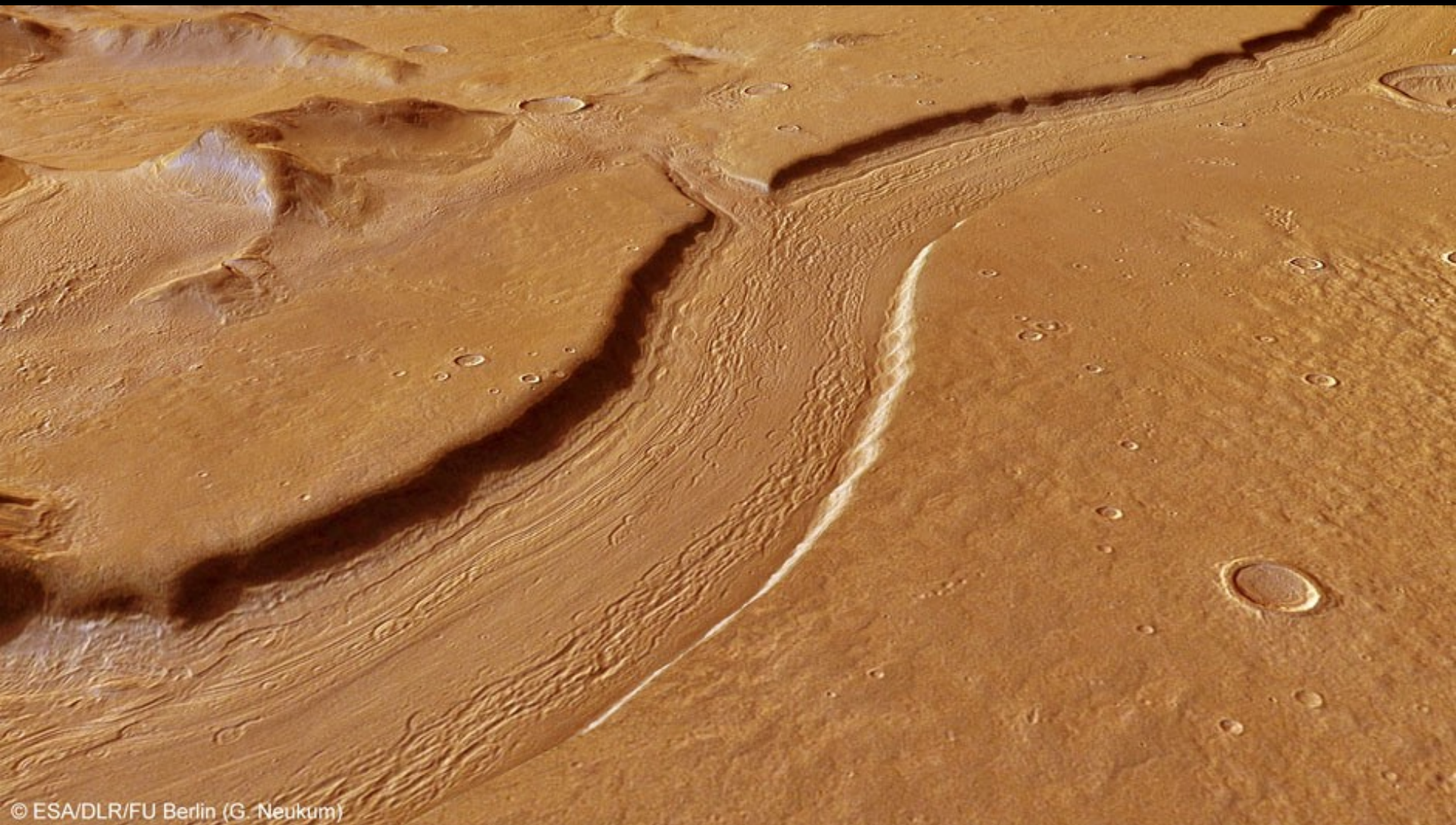
Ex propriis Observationibus atque Mensuris ope Tubi Merziani decempedalis

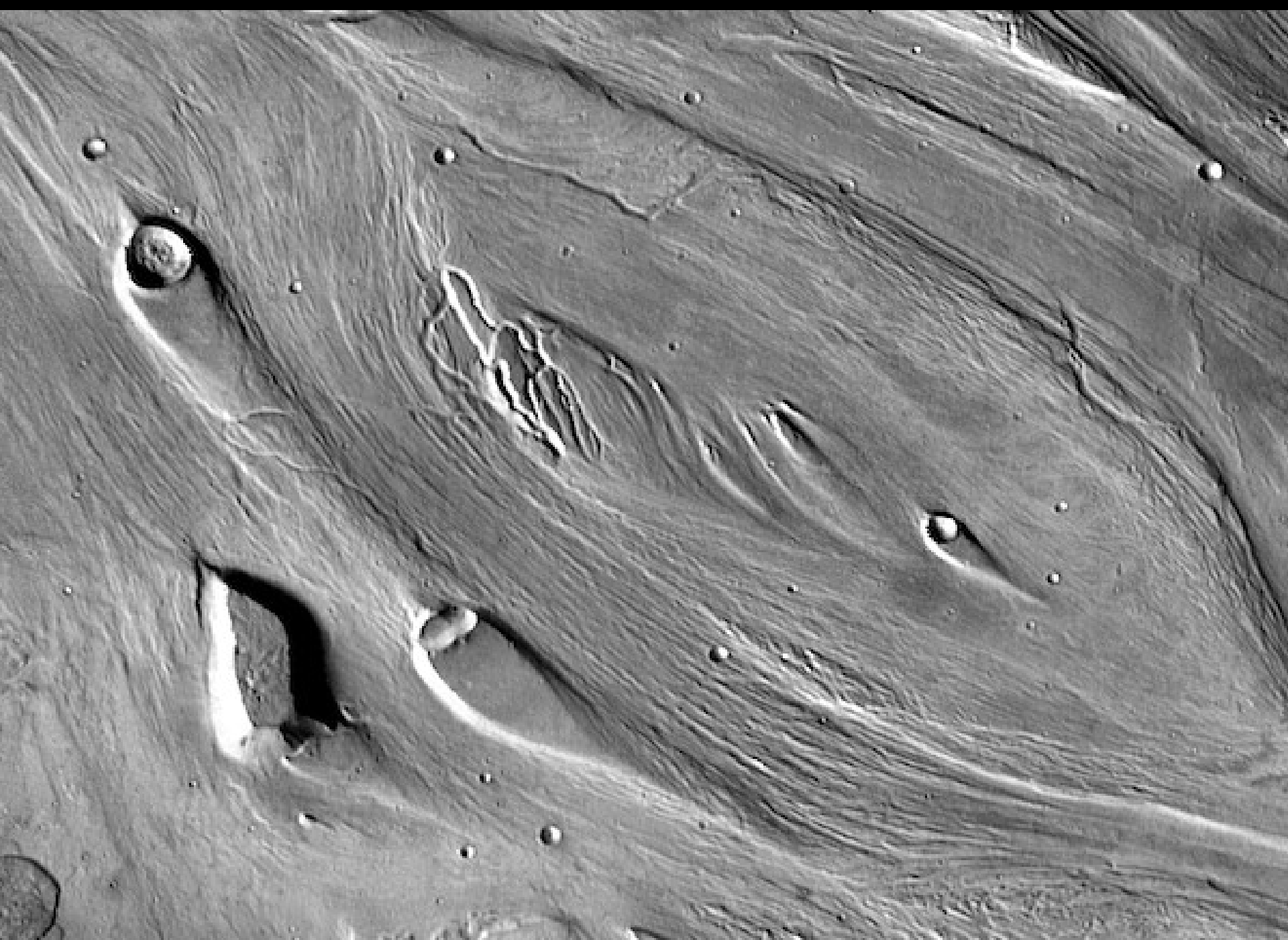
in Speculâ Braydenti Mediolani habitis

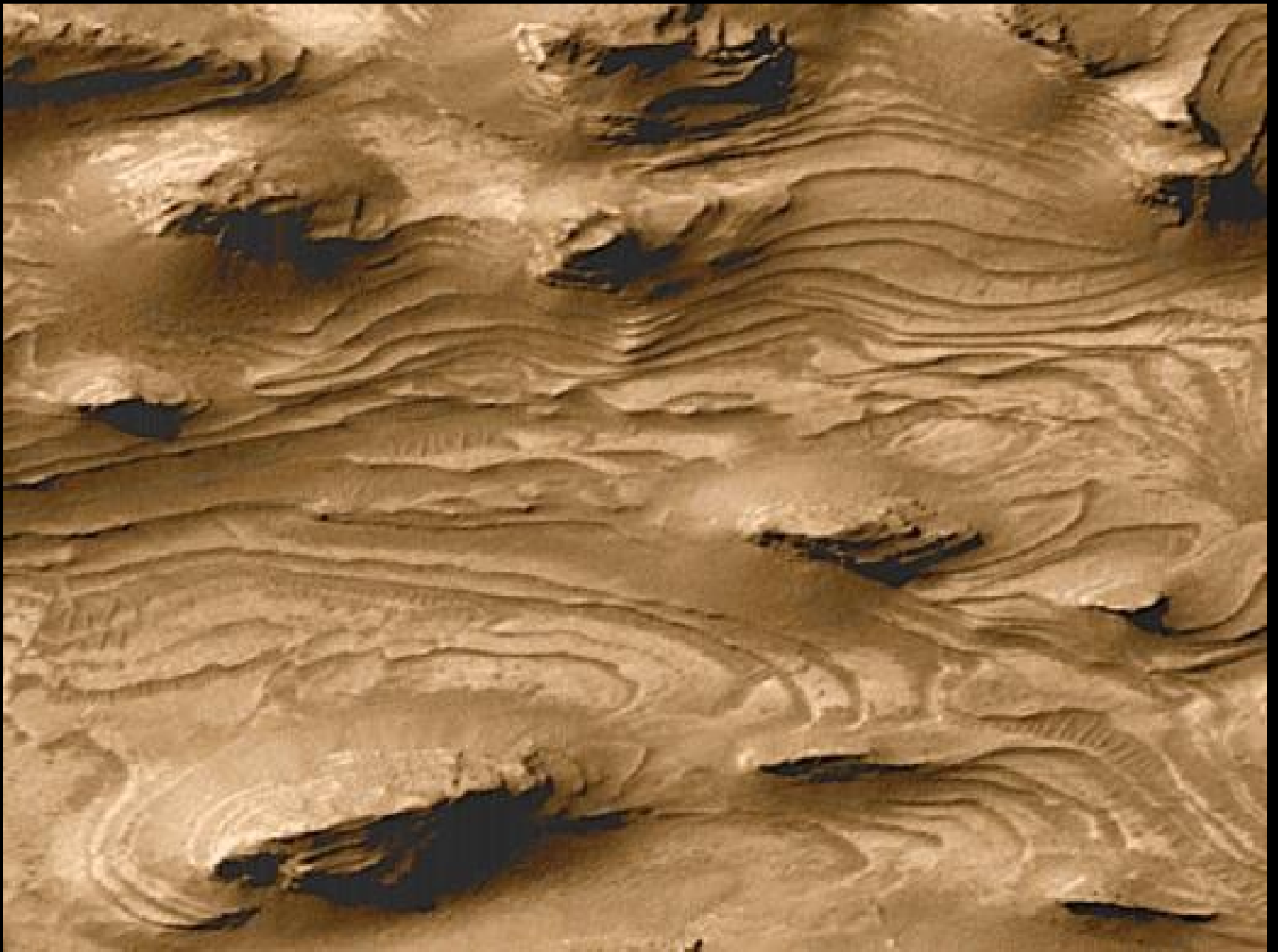
composuit, supputavit, atque delineavit J.V. Schiaparelli

1877 — 1878.



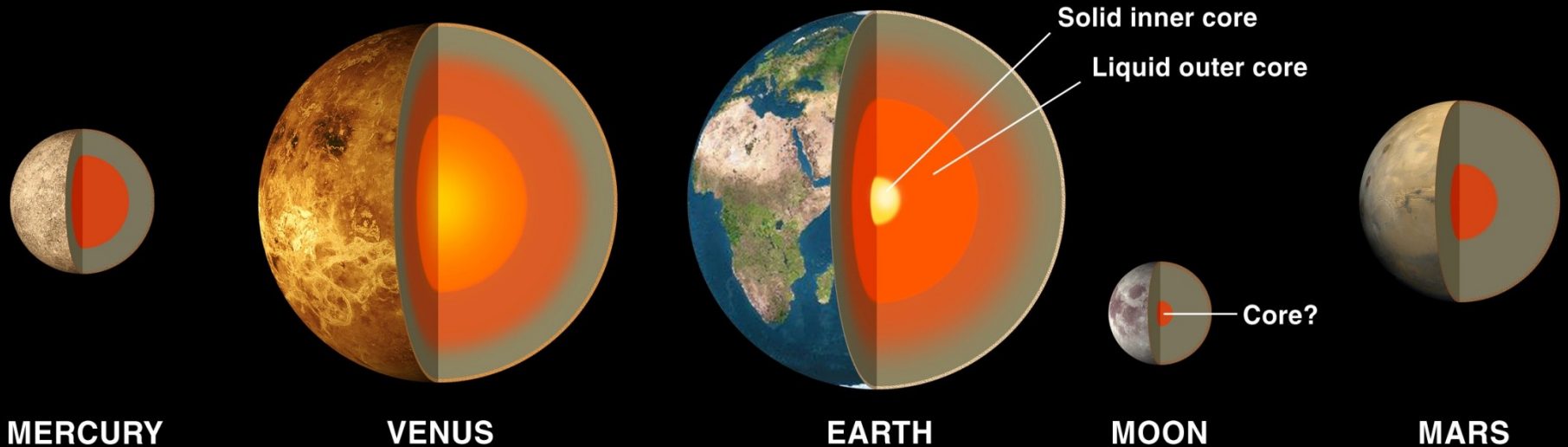




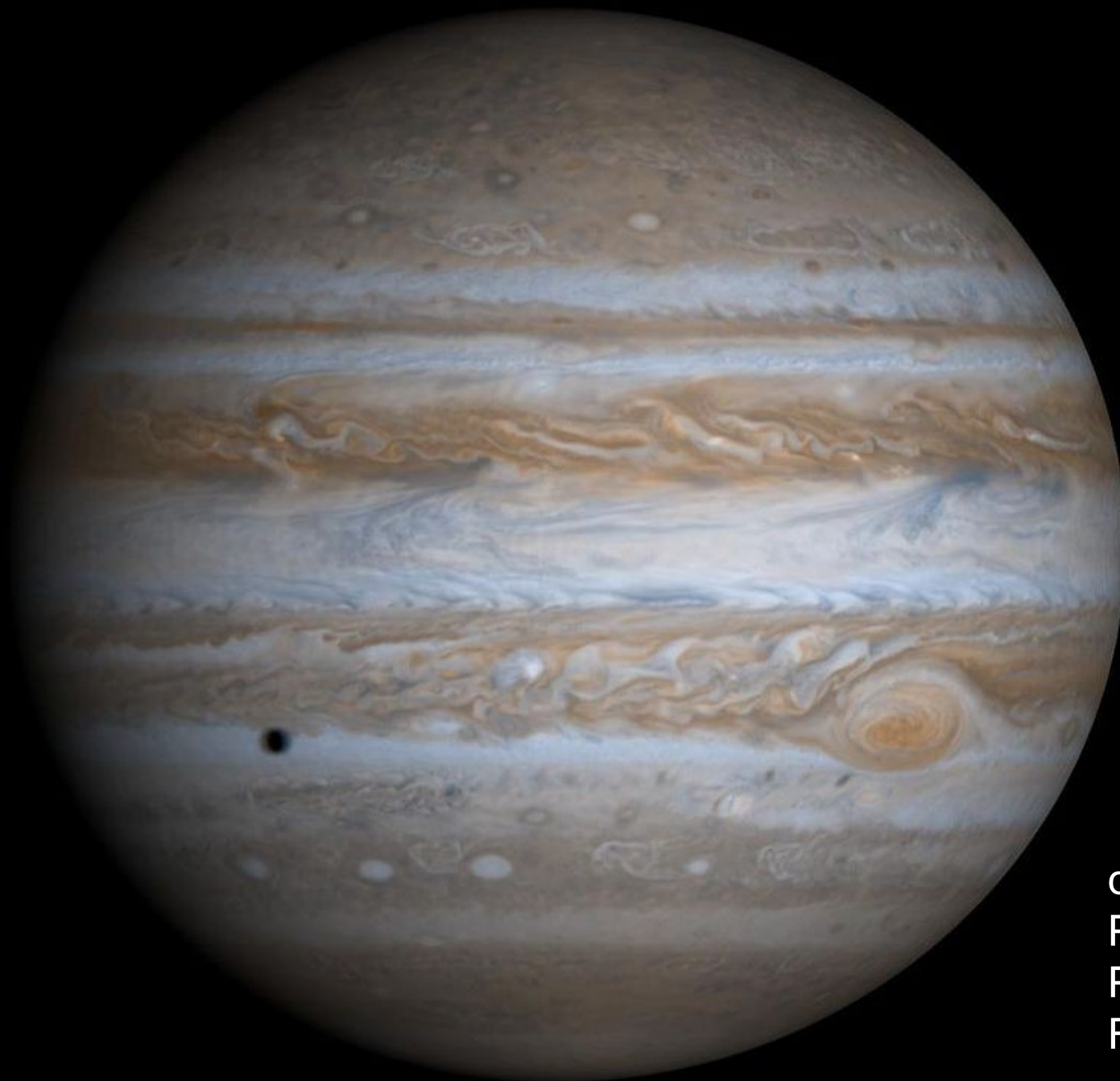




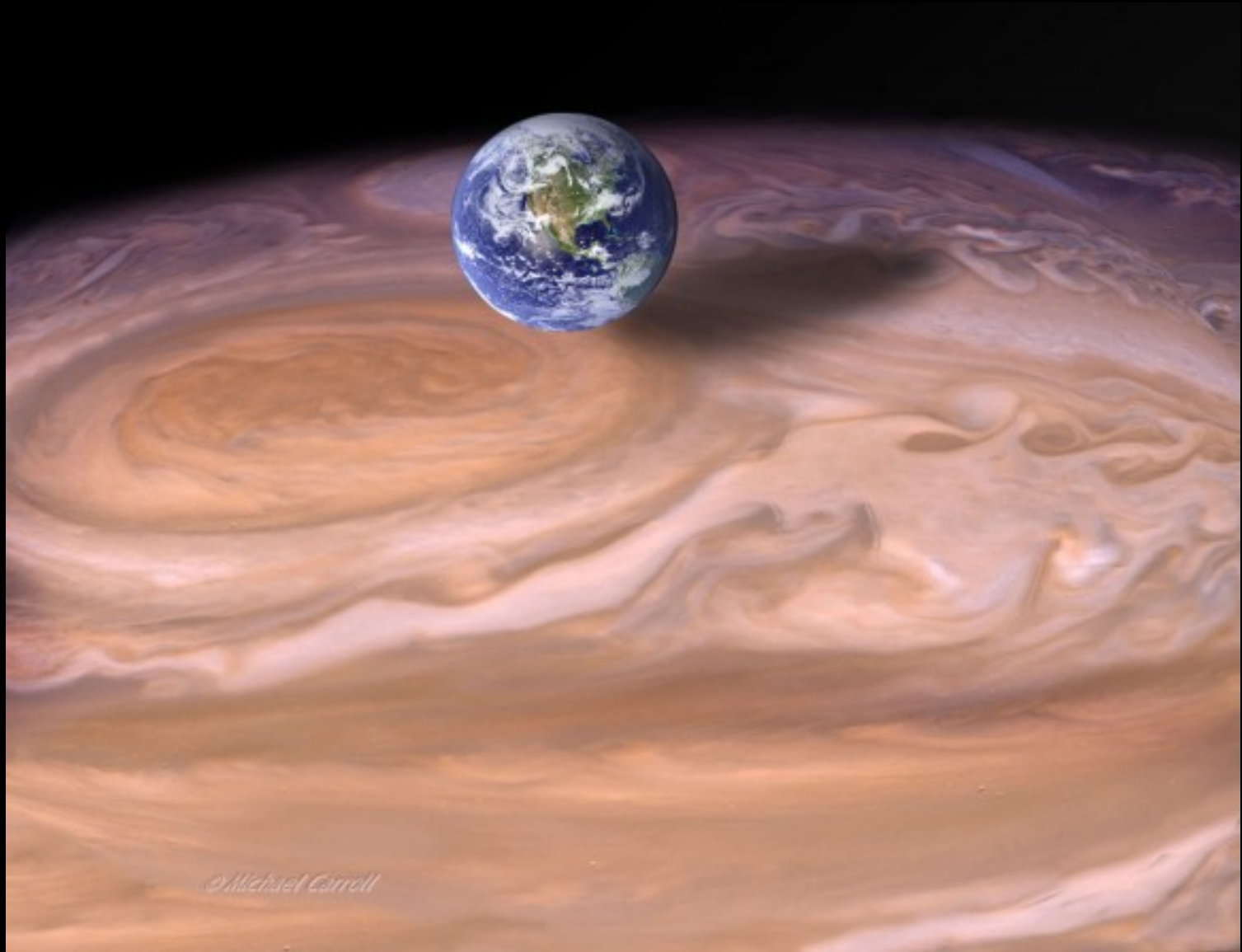
Confronto tra i pianeti "terrestri"



Giove

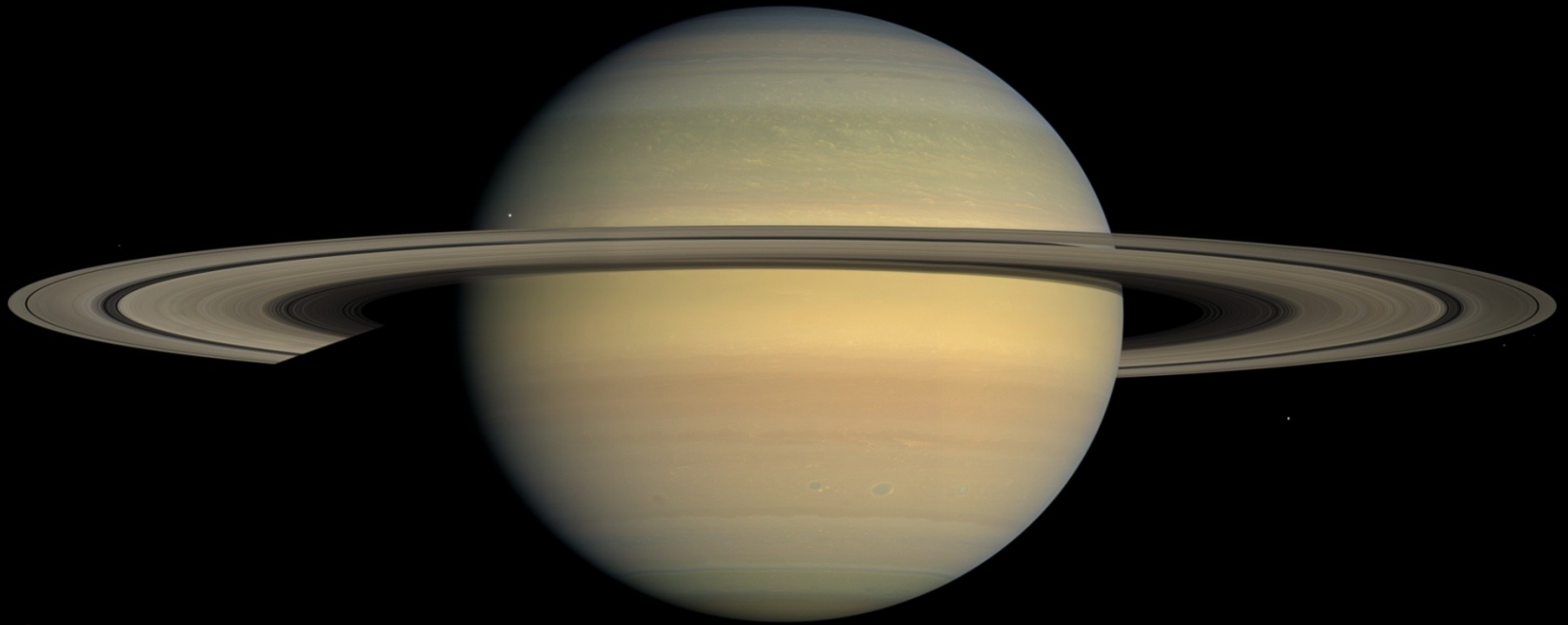


$d = 5.20 \text{ AU}$
 $P_{\text{orb}} = 11.86 \text{ y}$
 $P_{\text{rot}} = 9\text{h } 55\text{m}$
 $R = 71500 \text{ km}$



La Terra e la macchia rossa di Giove

Saturno



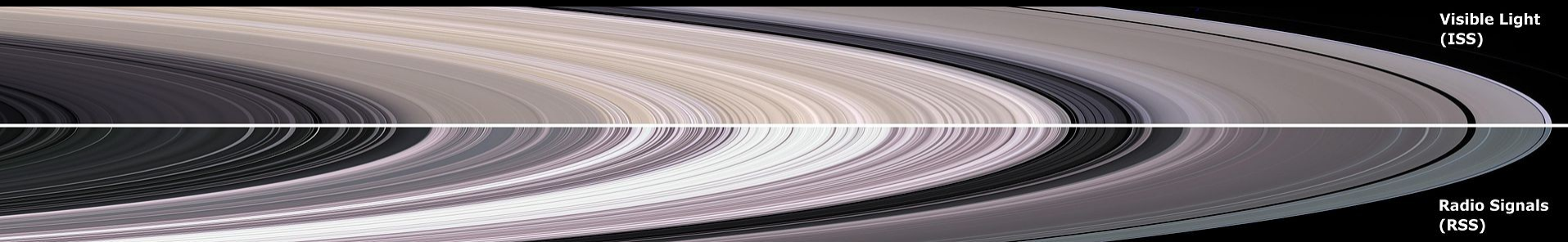
$d = 9.58 \text{ AU}$

$P_{\text{orb}} = 29.46 \text{ y}$

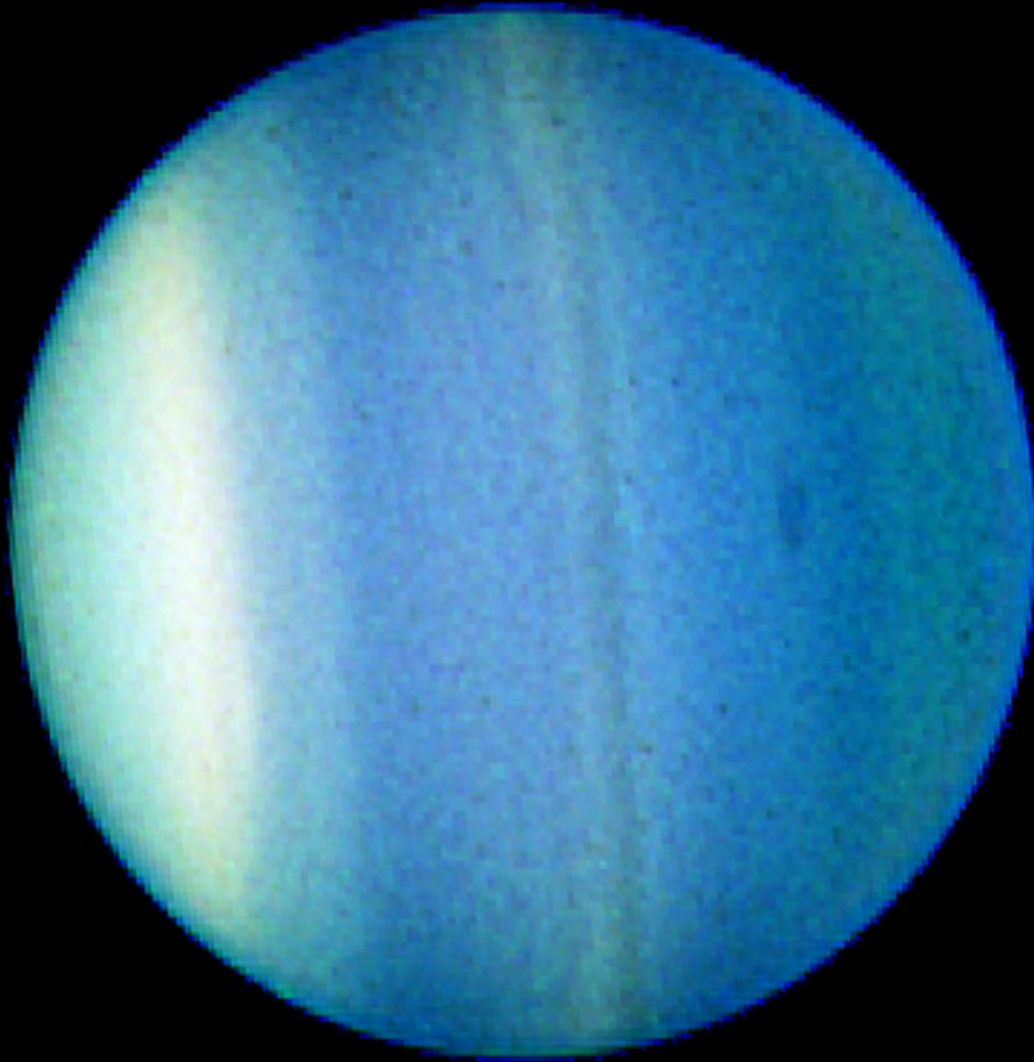
$P_{\text{rot}} = 10\text{h } 33\text{m}$

$R = 60268 \text{ km}$

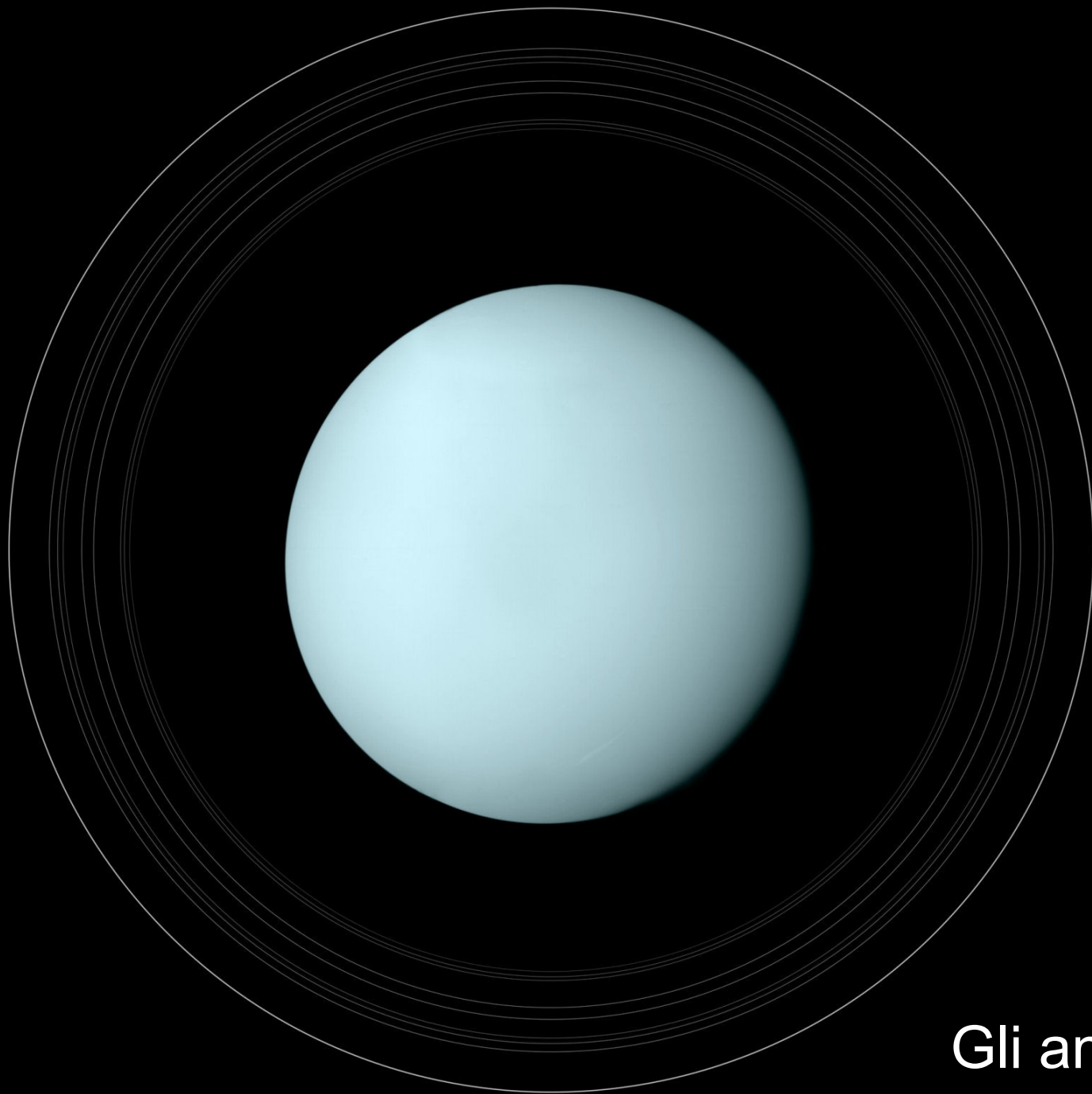
Gli anelli di Saturno



Urano

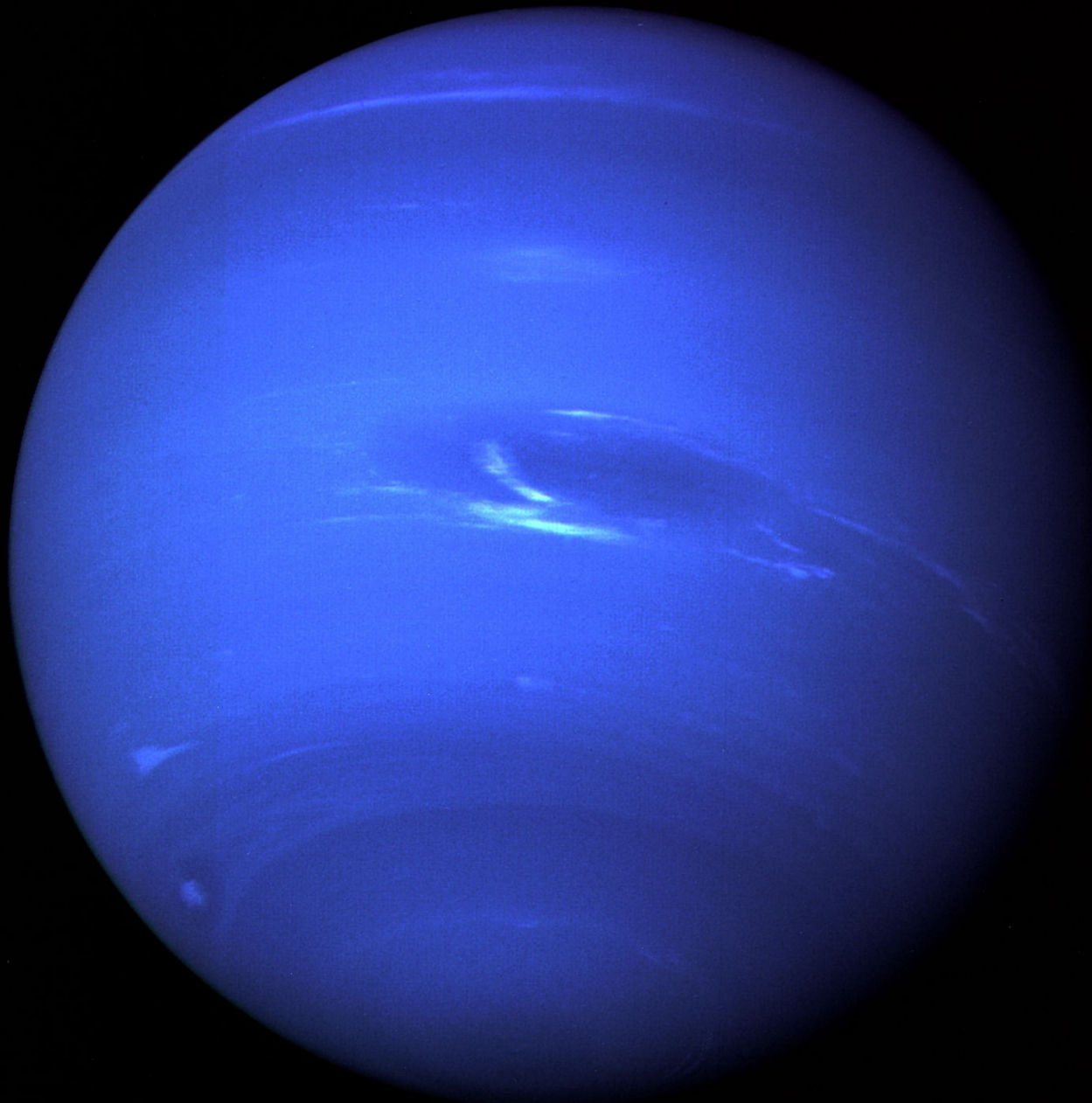


$d = 19.20 \text{ AU}$
 $P_{\text{orb}} = 84.0 \text{ y}$
 $P_{\text{rot}} = 17\text{h } 14\text{m}$
 $R = 25560 \text{ km}$



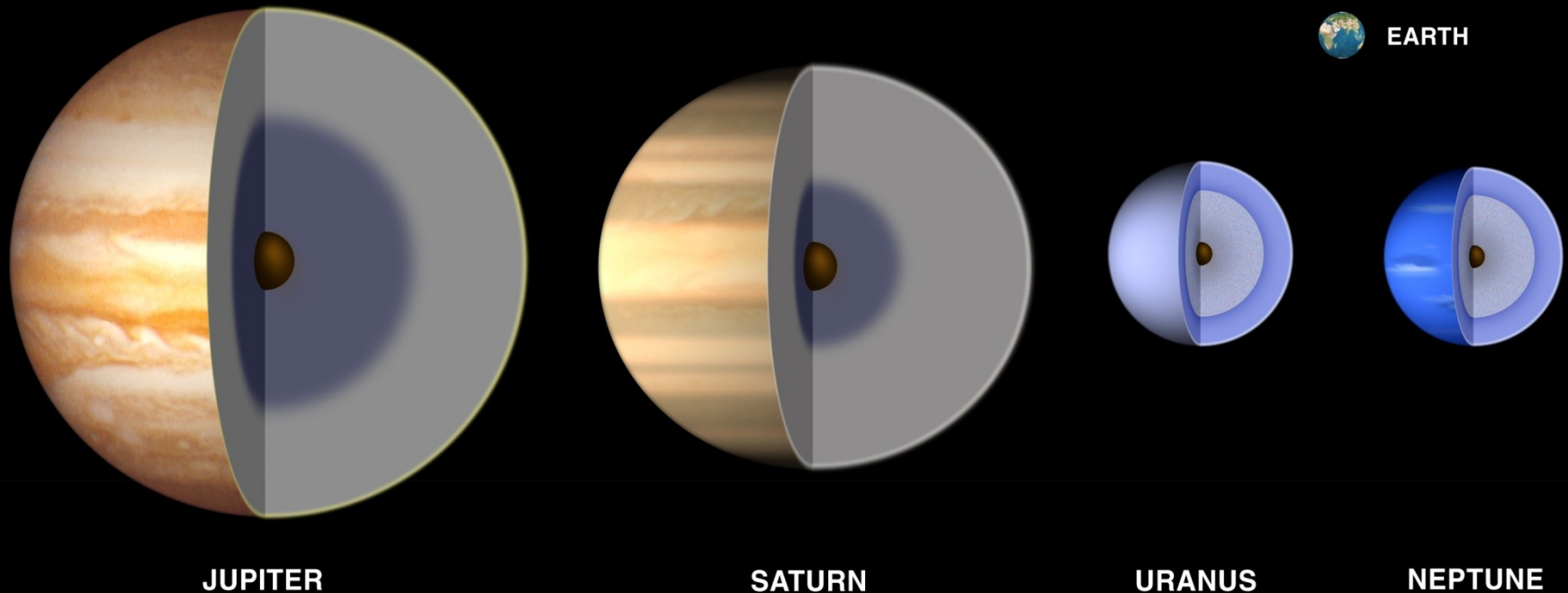
Gli anelli di Urano

Nettuno



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

L'interno dei giganti gassosi



■ Molecular hydrogen

■ Metallic hydrogen

■ Hydrogen, helium, methane gas

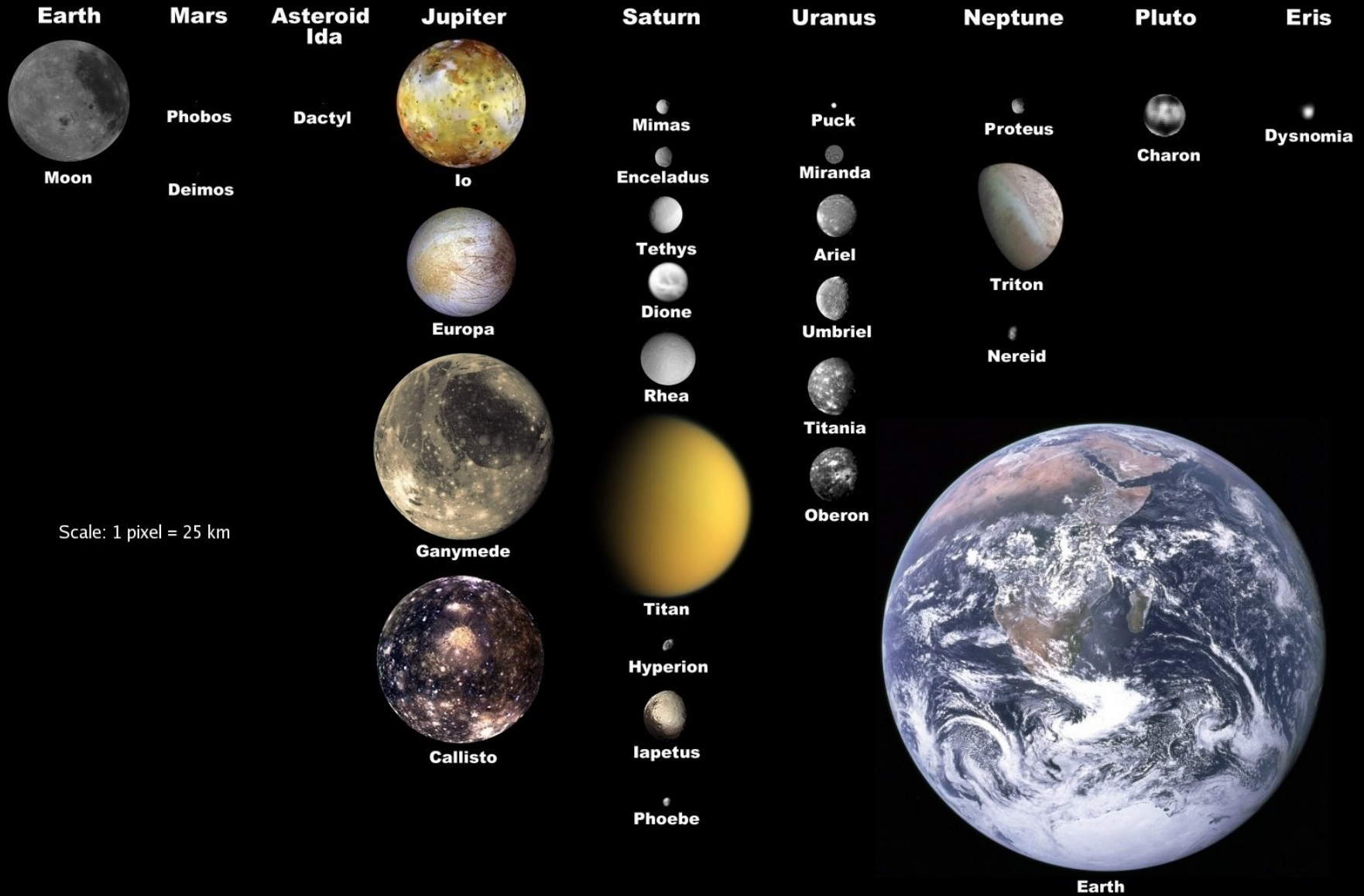
■ Mantle (water, ammonia, methane ices)

■ Core (rock, ice)

I satelliti nel Sistema Solare

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

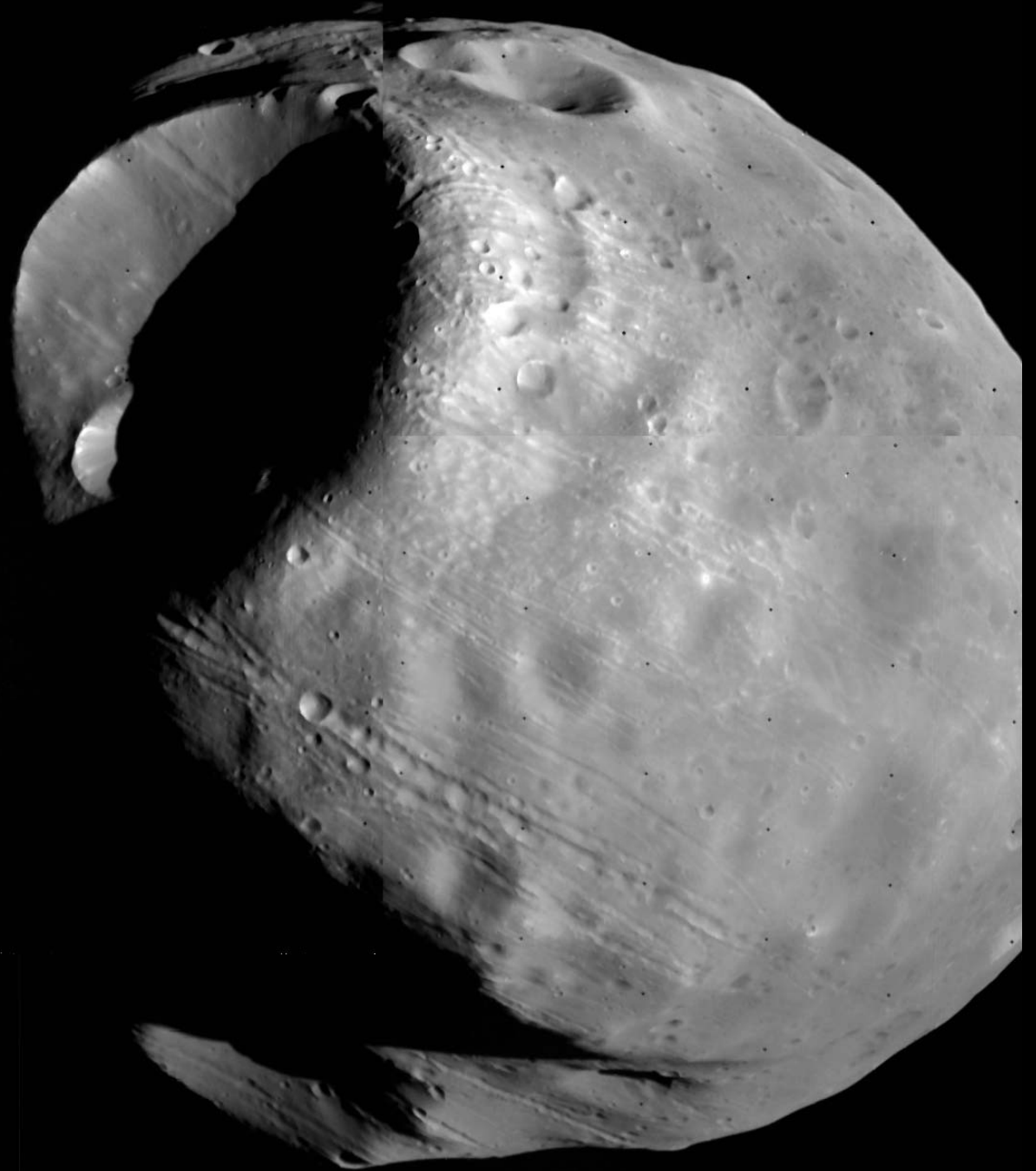
Selected Moons of the Solar System, with Earth for Scale



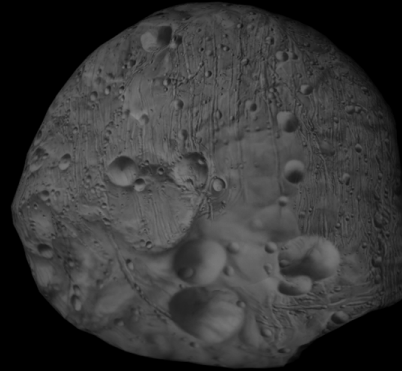
Phobos (22 km)



Phobos (22 km)



M1 - PHOBOS
ORTHOGRAPHIC VIEWS
1997



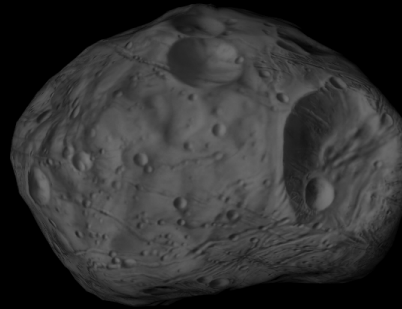
North



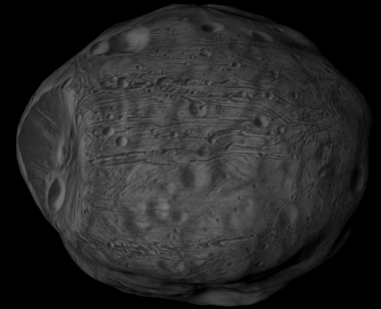
270°



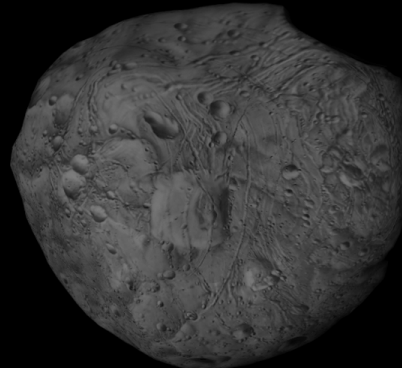
180°



90°

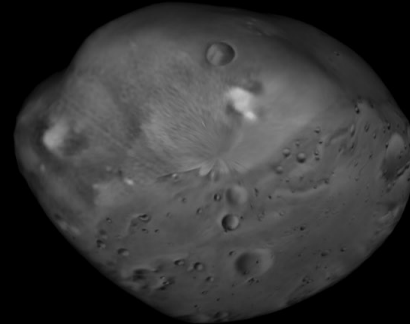


0°

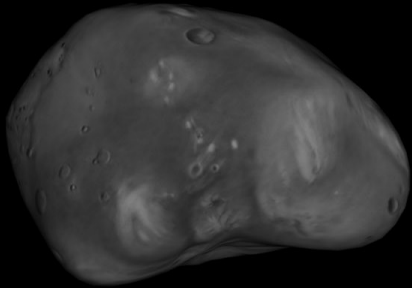


South

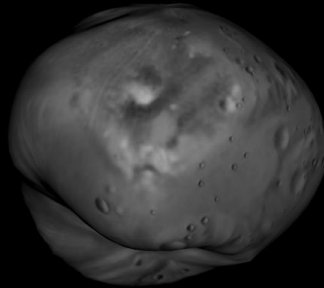
M2 - DEIMOS
ORTHOGRAPHIC VIEWS
1999



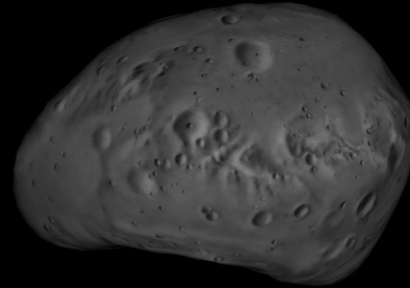
North



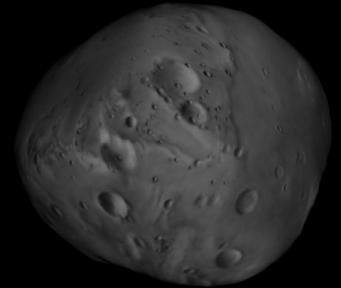
270°



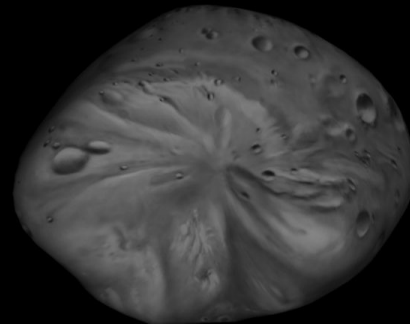
180°



90°



0°



South

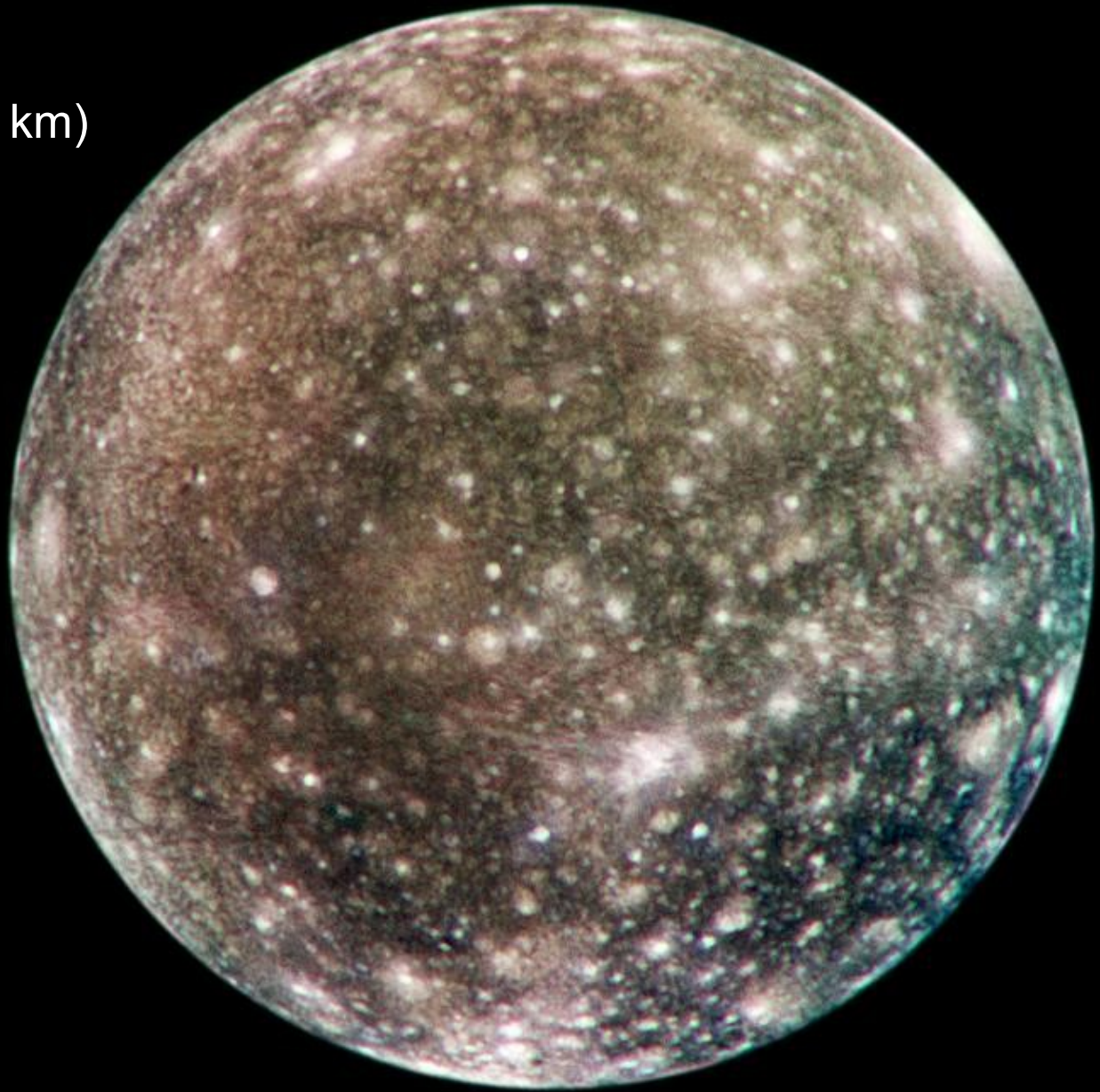
Satelliti principali di Giove (“medicei”)



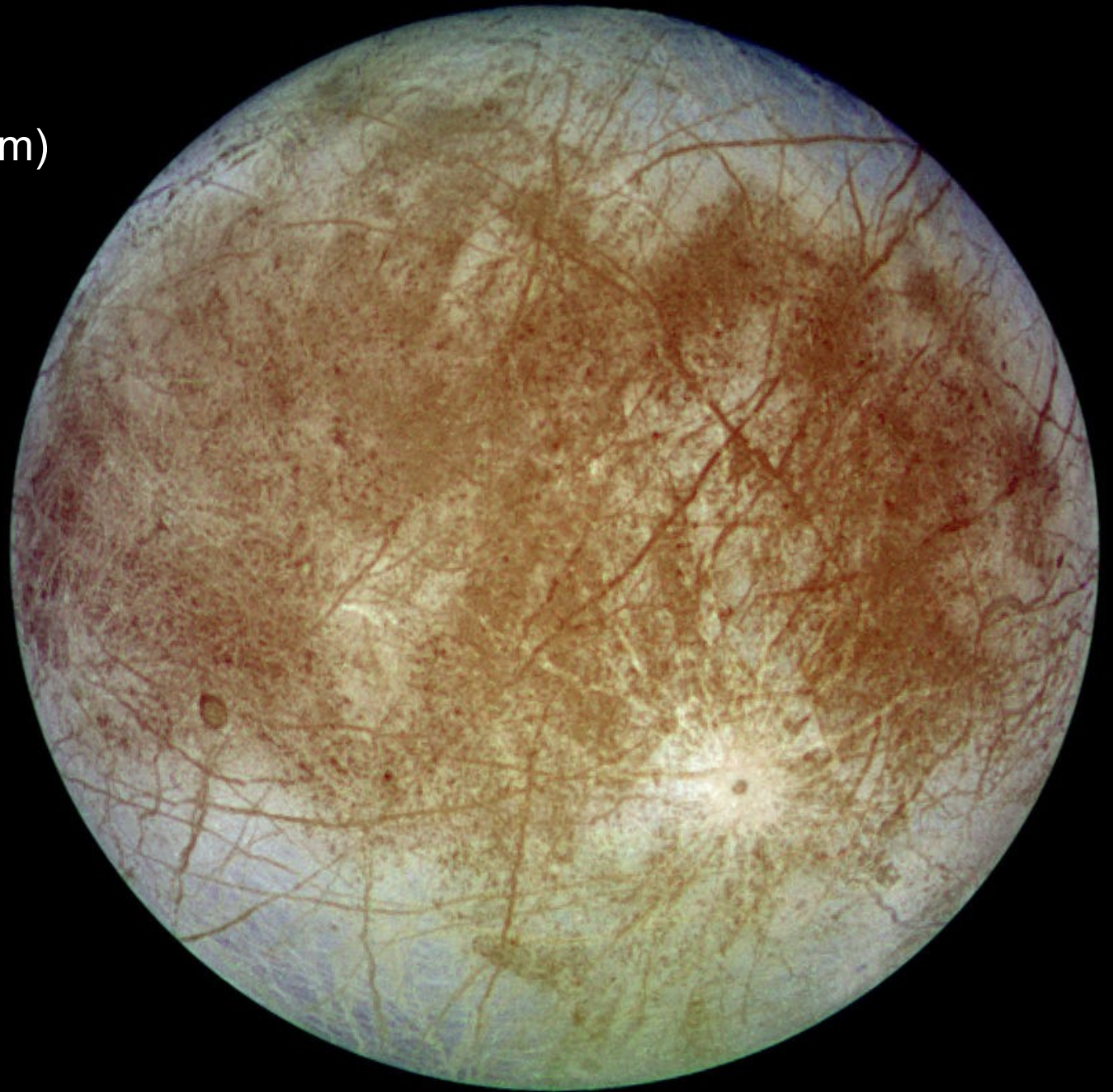
Ganimede (5270 km)



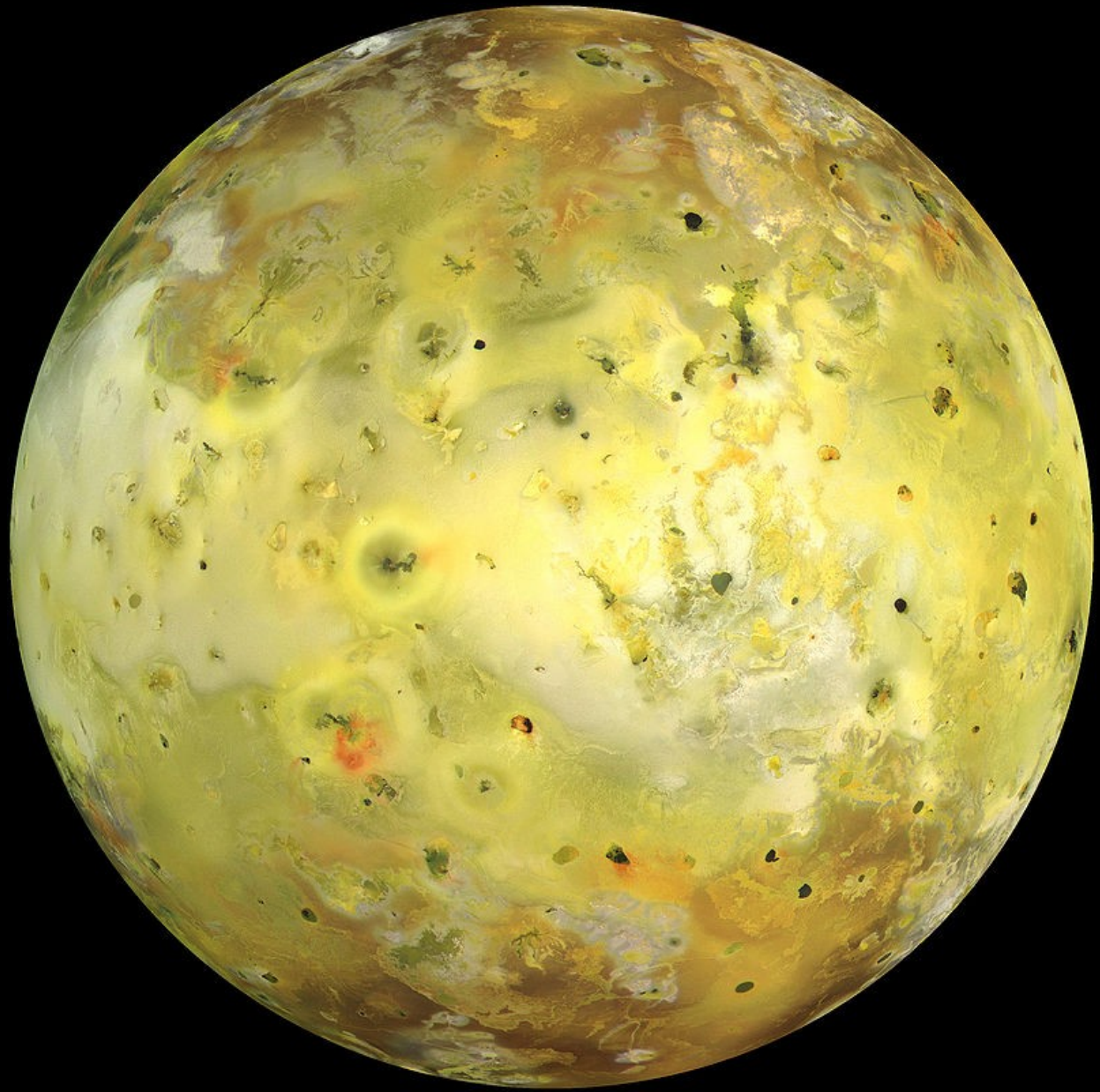
Callisto (4816 km)



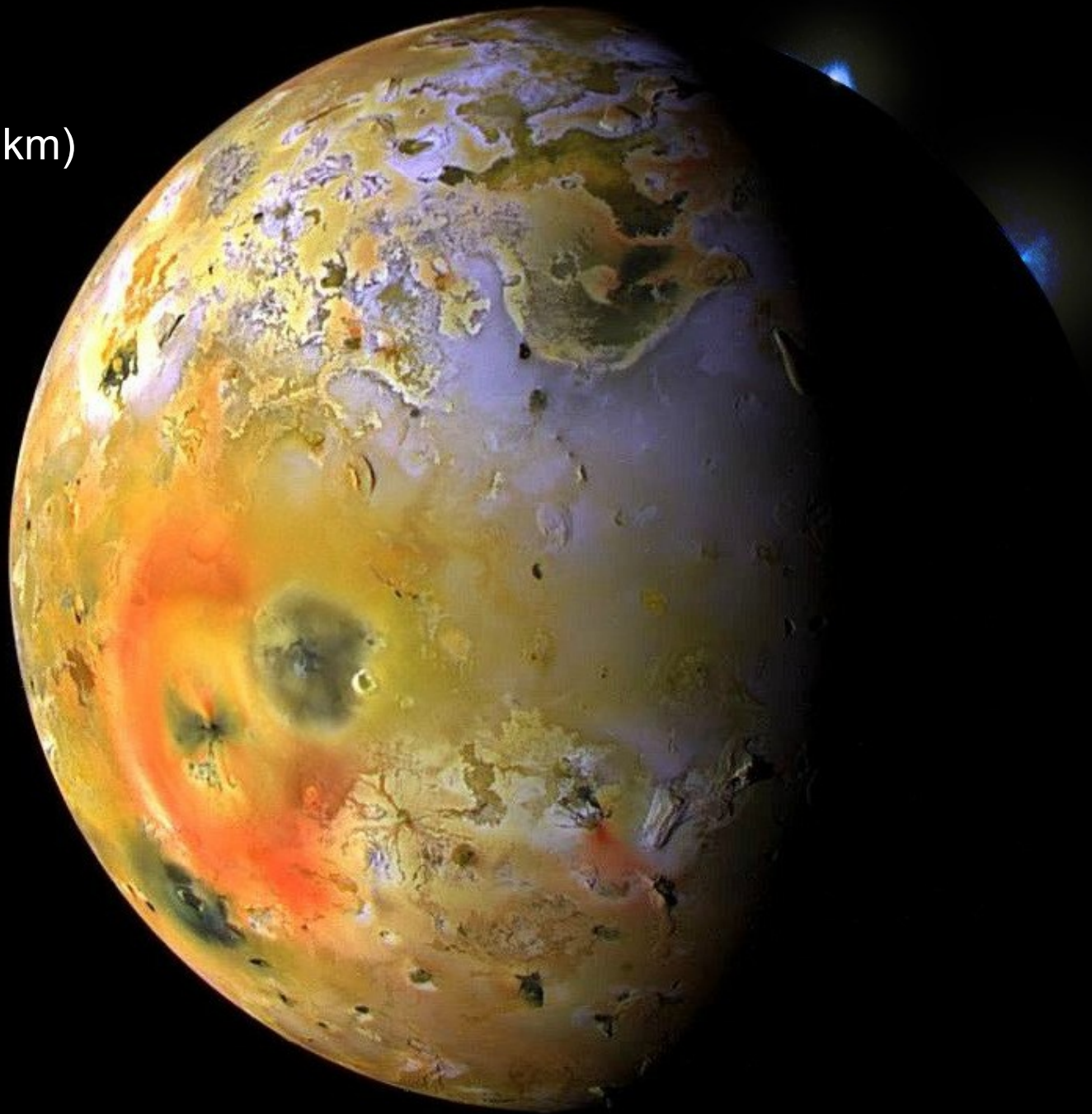
Europa (3120 km)

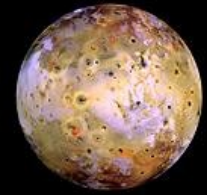


Io (3636 km)



Io (3636 km)

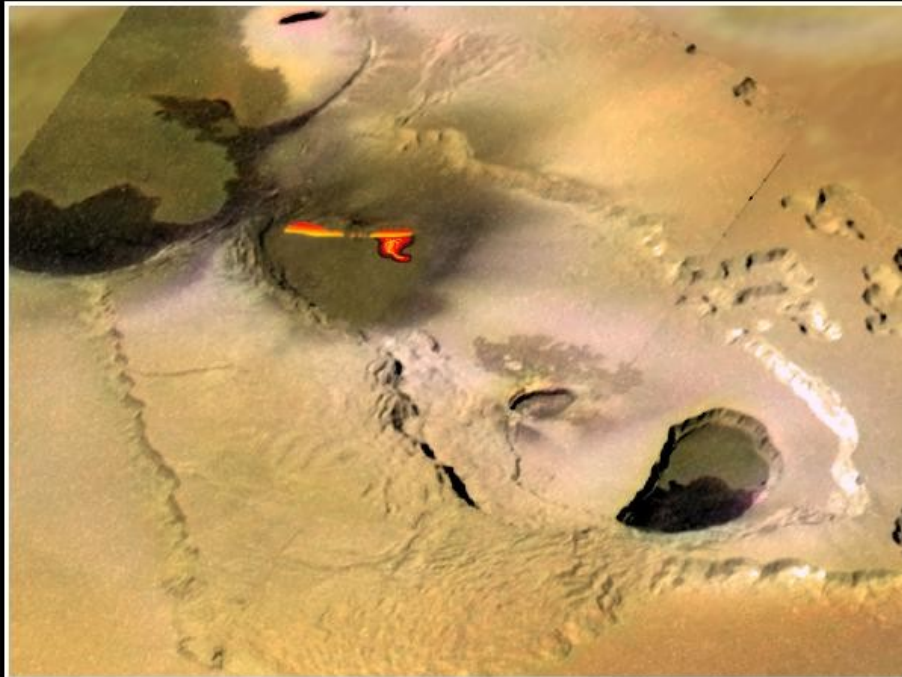




Io — Tvashtar Catena

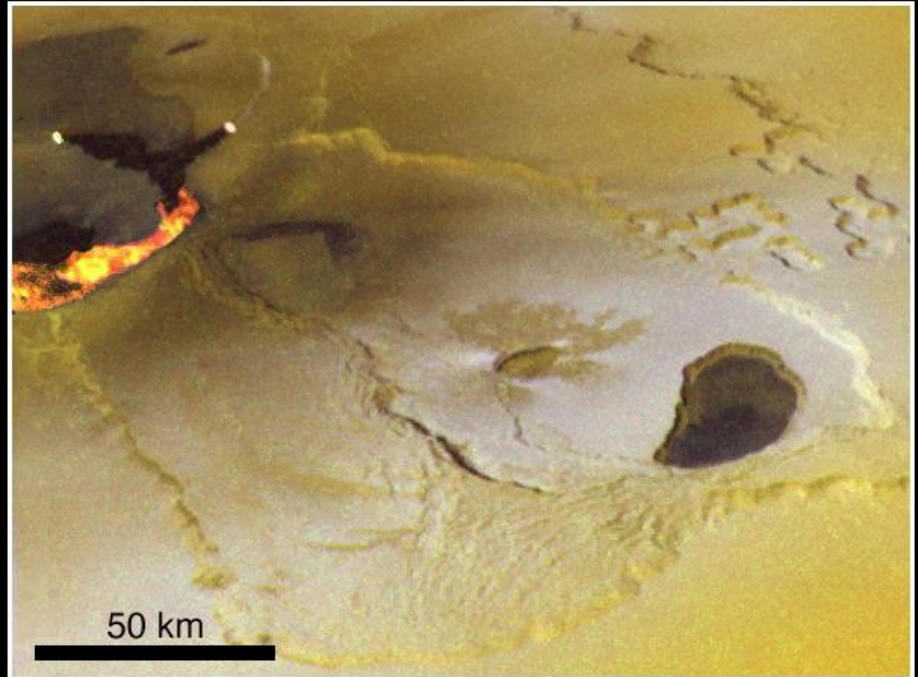
I25 (26 Nov 1999)

+ C21 low-resolution color
+ fire fountain sketch

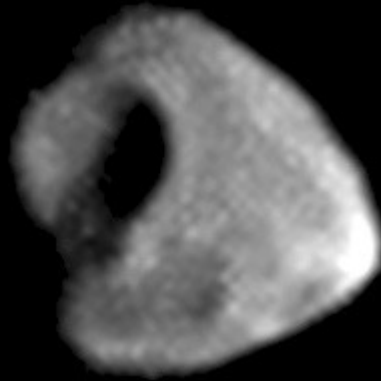


I27 (22 Feb 2000)

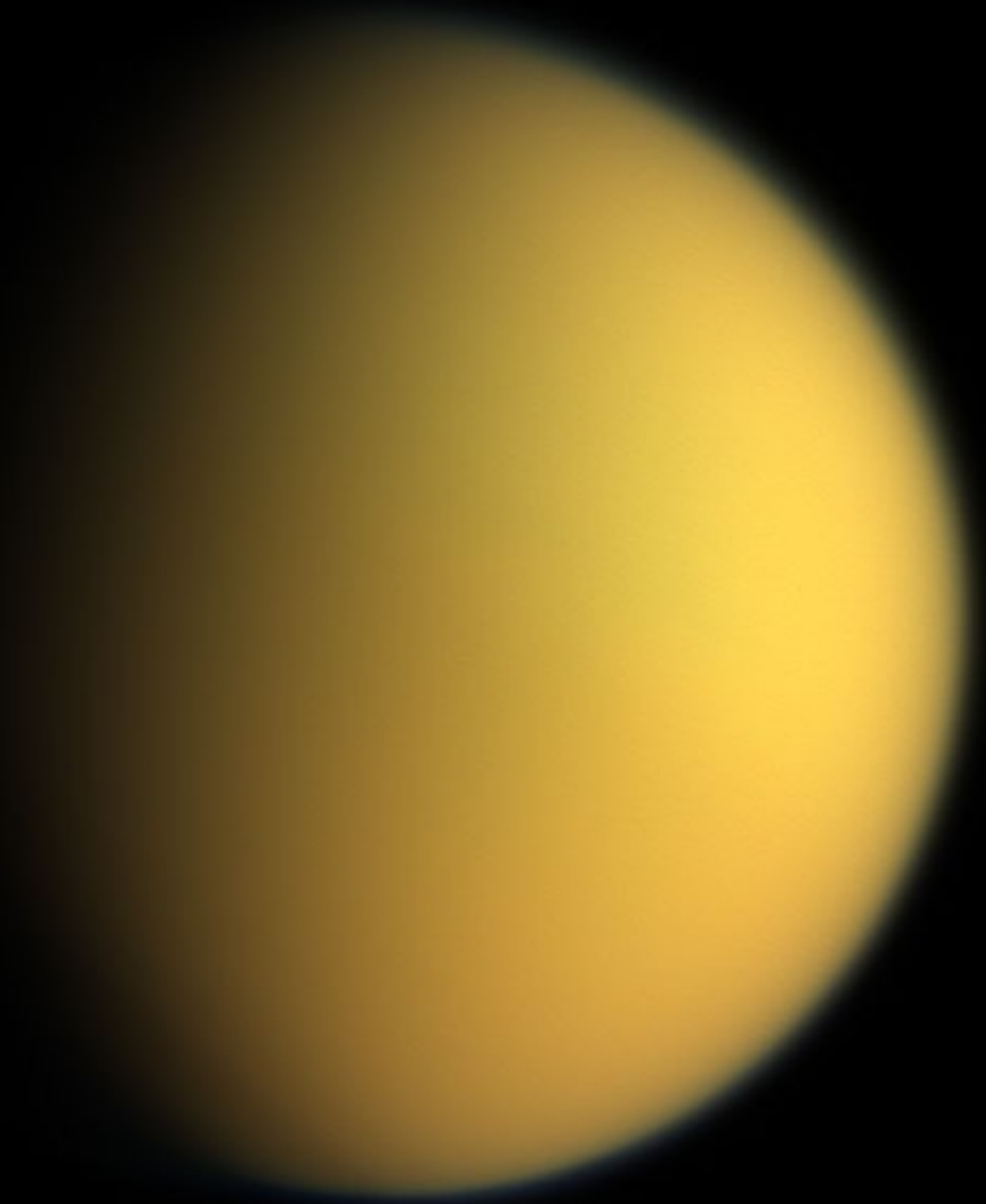
visible wavelength data
+ IR data of active lava flow



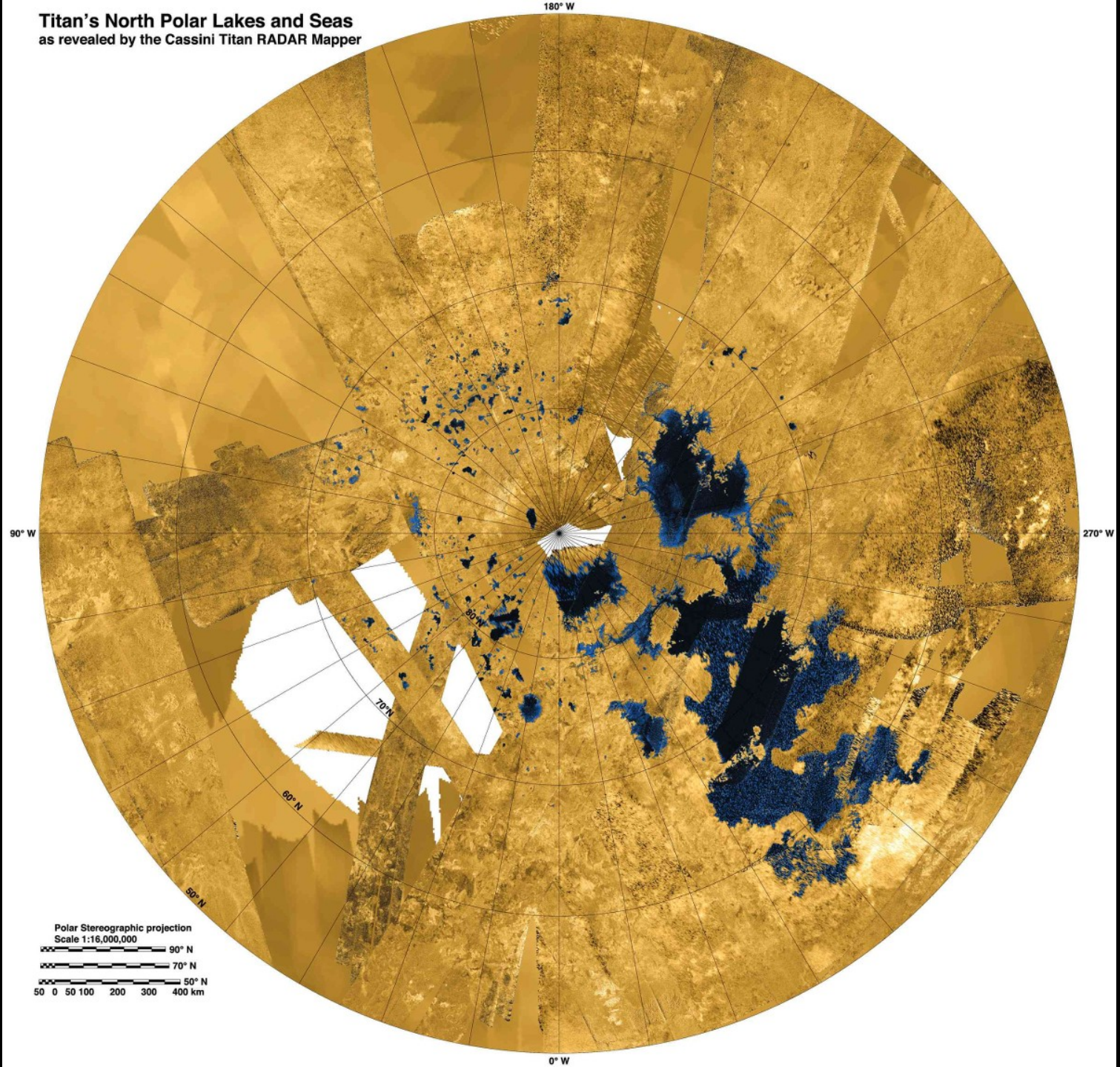
Thebe (100 km)



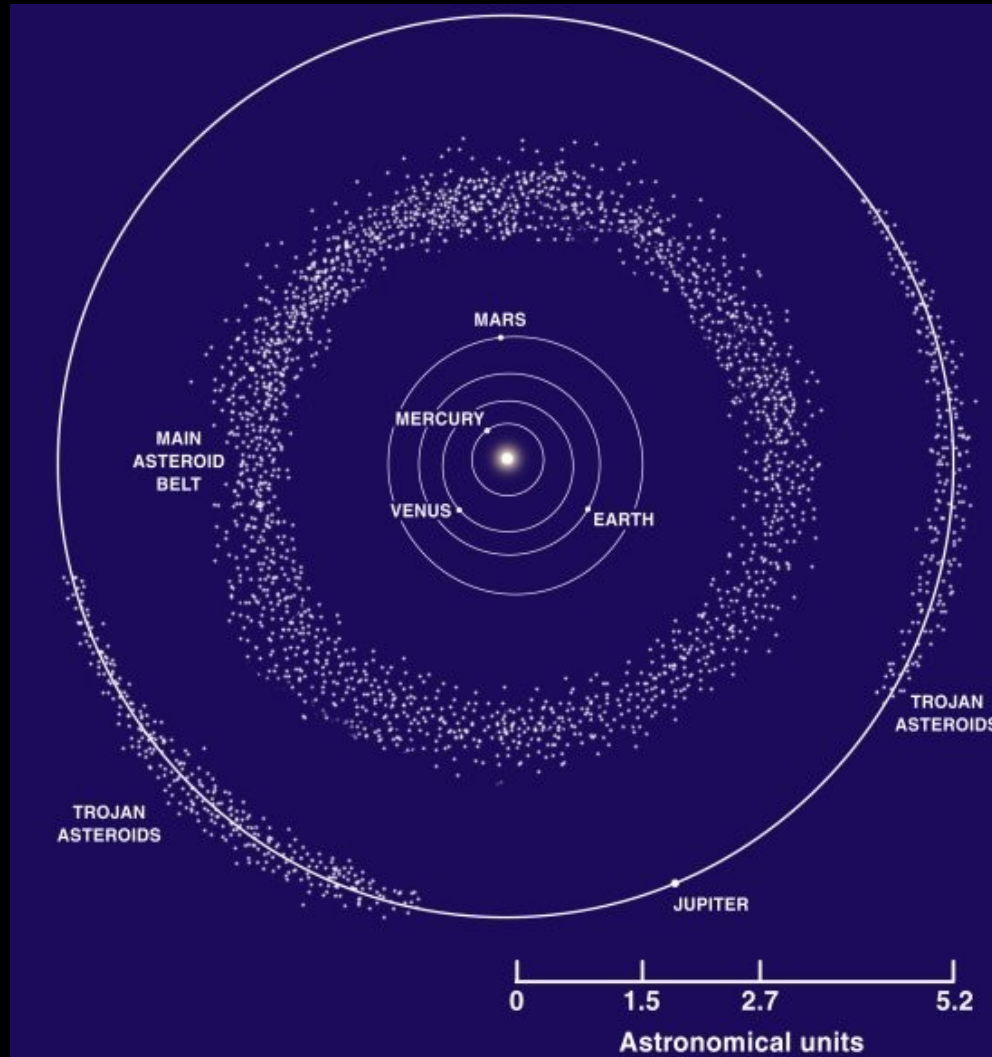
Titano (5150 km)

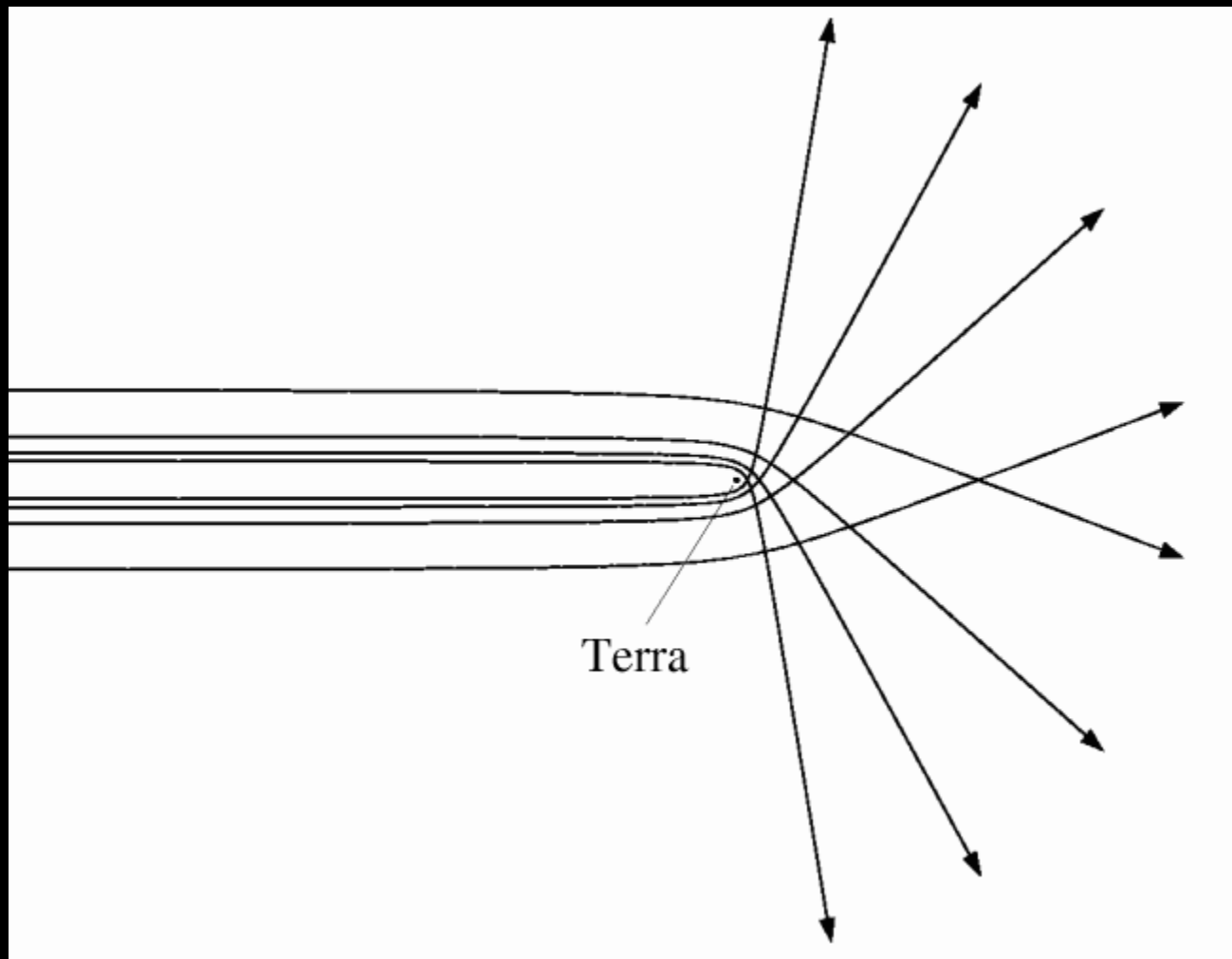


Titan's North Polar Lakes and Seas
as revealed by the Cassini Titan RADAR Mapper



Asteroidi: fascia principale e Troiani





Deflessione prodotta da un incontro ravvicinato



Luna (3474 km)



Cerere (975 km)



Vesta (530 km)



Terra (12742 km)



4 Vesta



21 Lutetia



253 Mathilde



243 Ida / 1 Dactyl



433 Eros



951 Gaspra



2867 Šteins

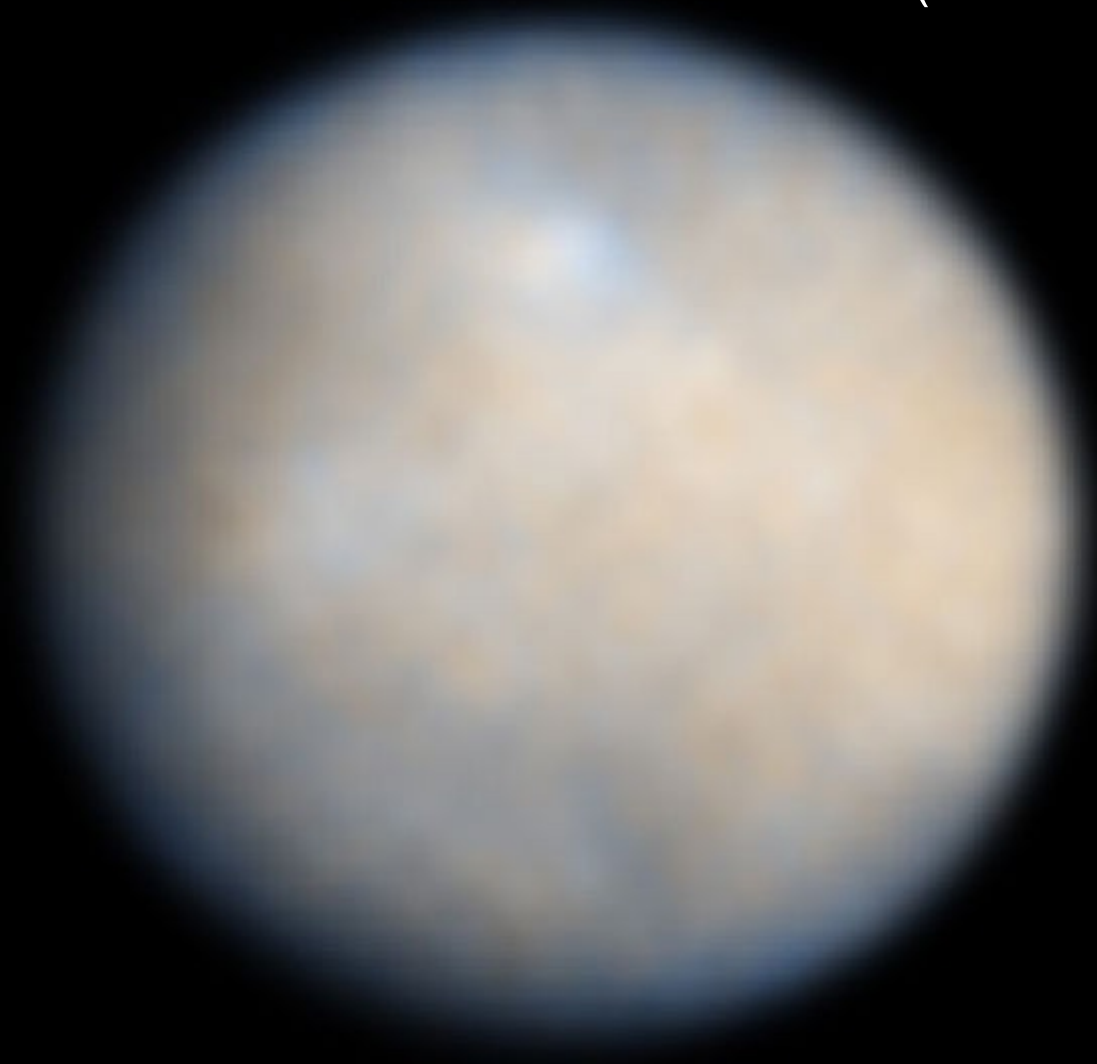


5535 Annefrank



25143 Itokawa

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



Vesta ($\varnothing$ 530 km) ripreso dalla
sonda Dawn (12/10/2011)





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



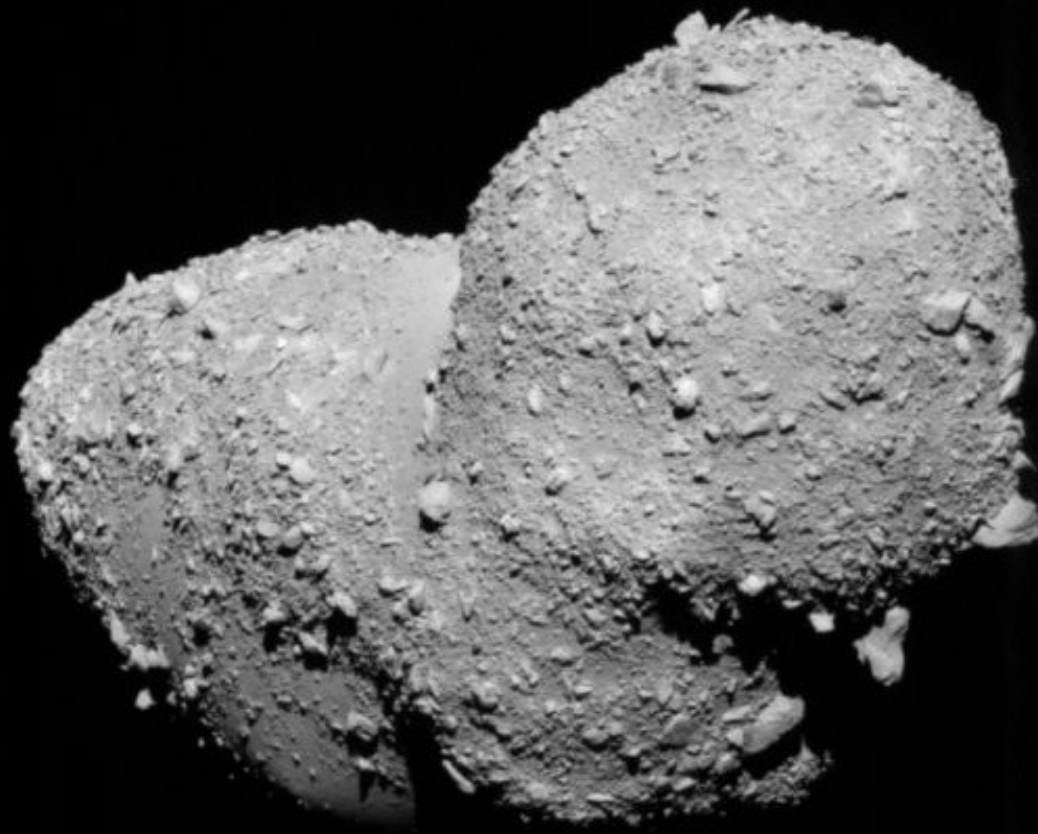
Aspetto dell'asteroide Ida in varie fasi della rotazione



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



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



100 m

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

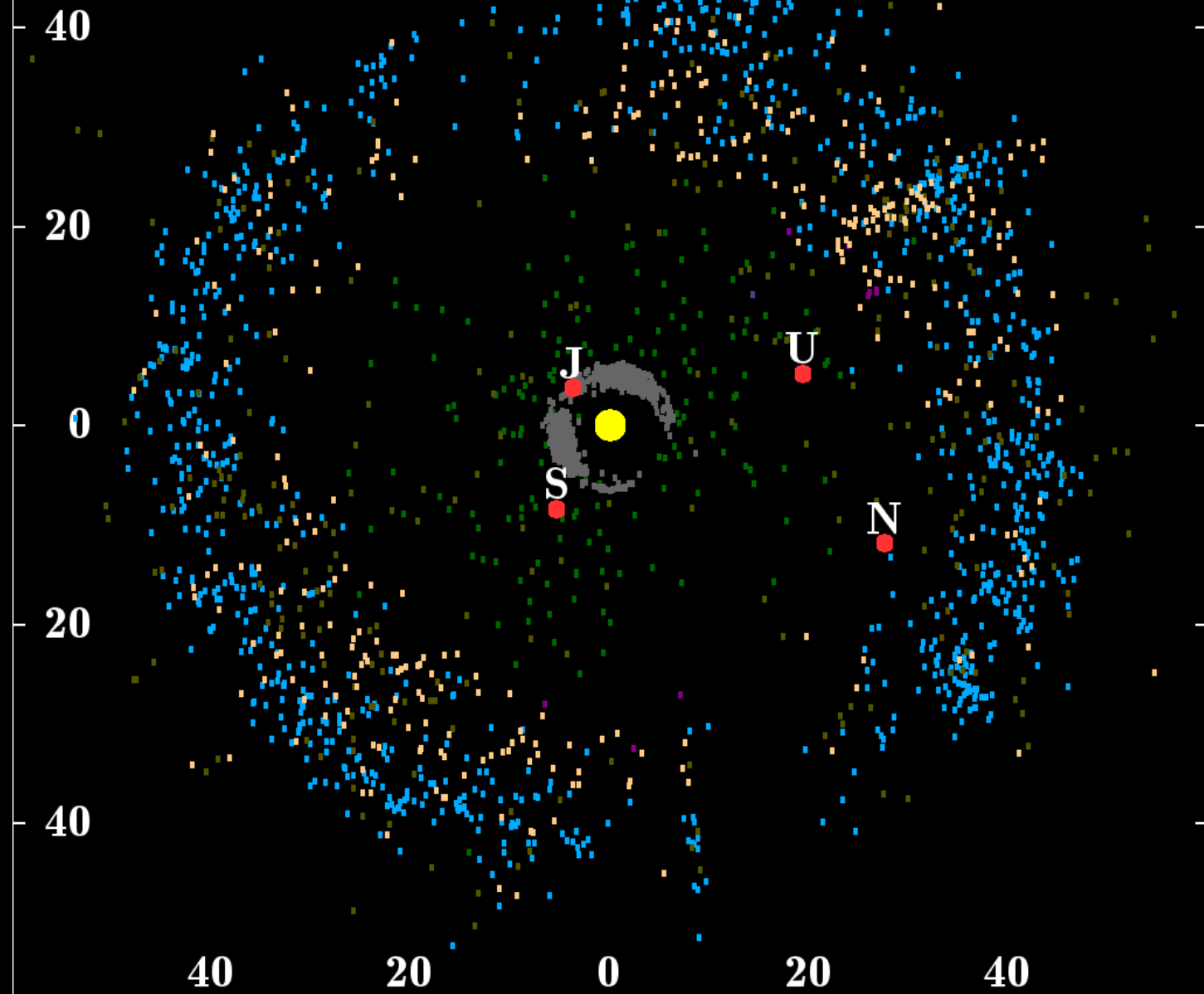
Quanti sono gli asteroidi?

Dipende dalle dimensioni:

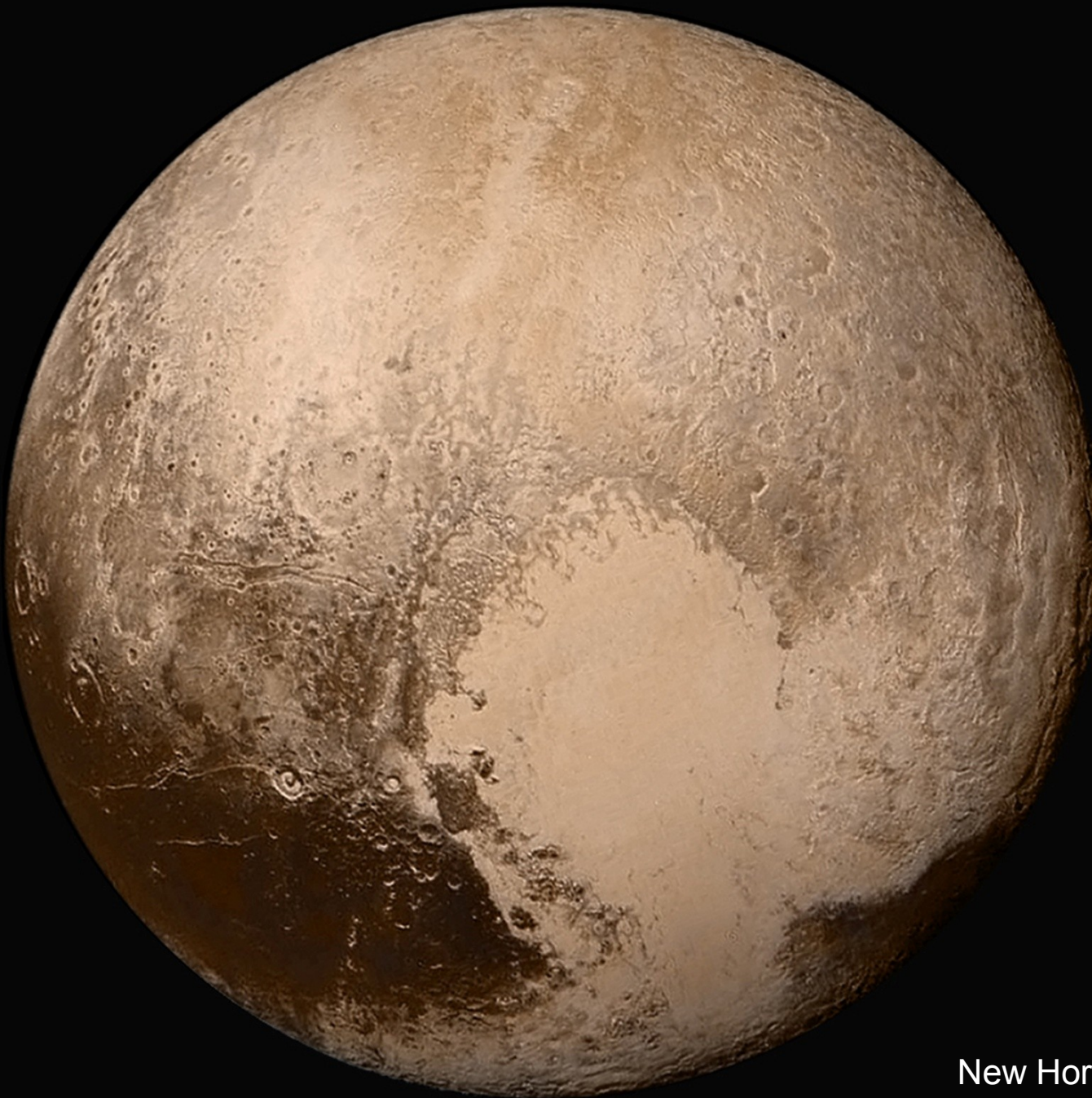
1	:	diametro = 930 km (Cerere)
4	:	diametro > 400 km
30	:	diametro > 200 km
250	:	diametro > 100 km
1,000,000 ?	:	diametro > 1 km

Numero di asteroidi “conosciuti”: circa 1.300.000

Kuiper Belt

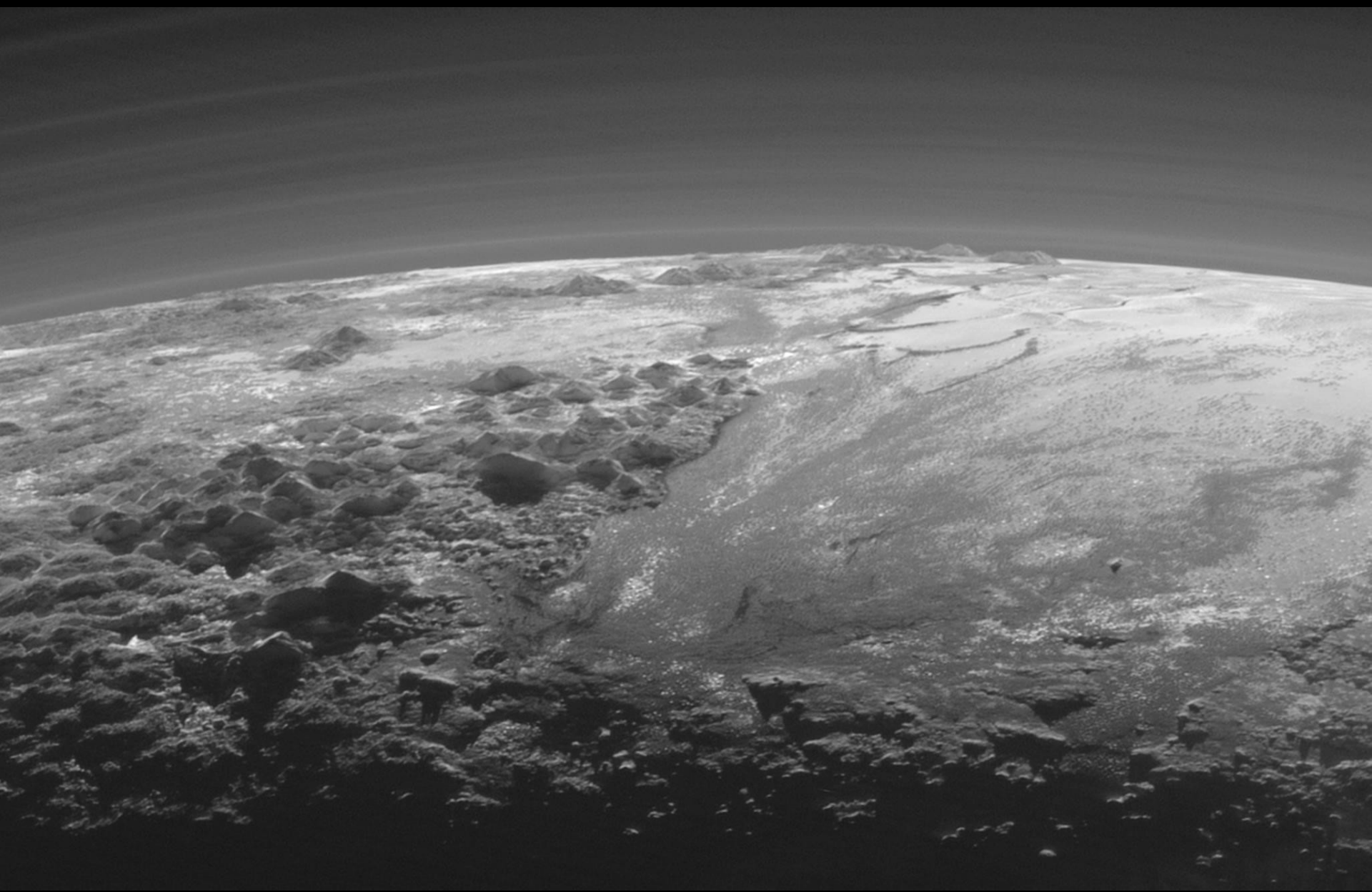


Plutone

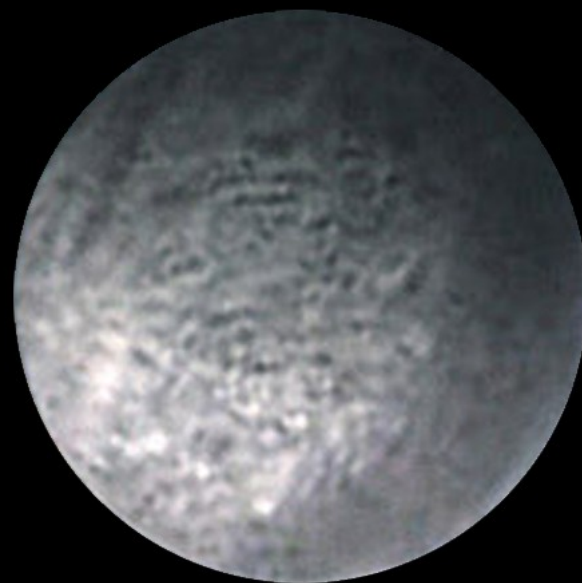
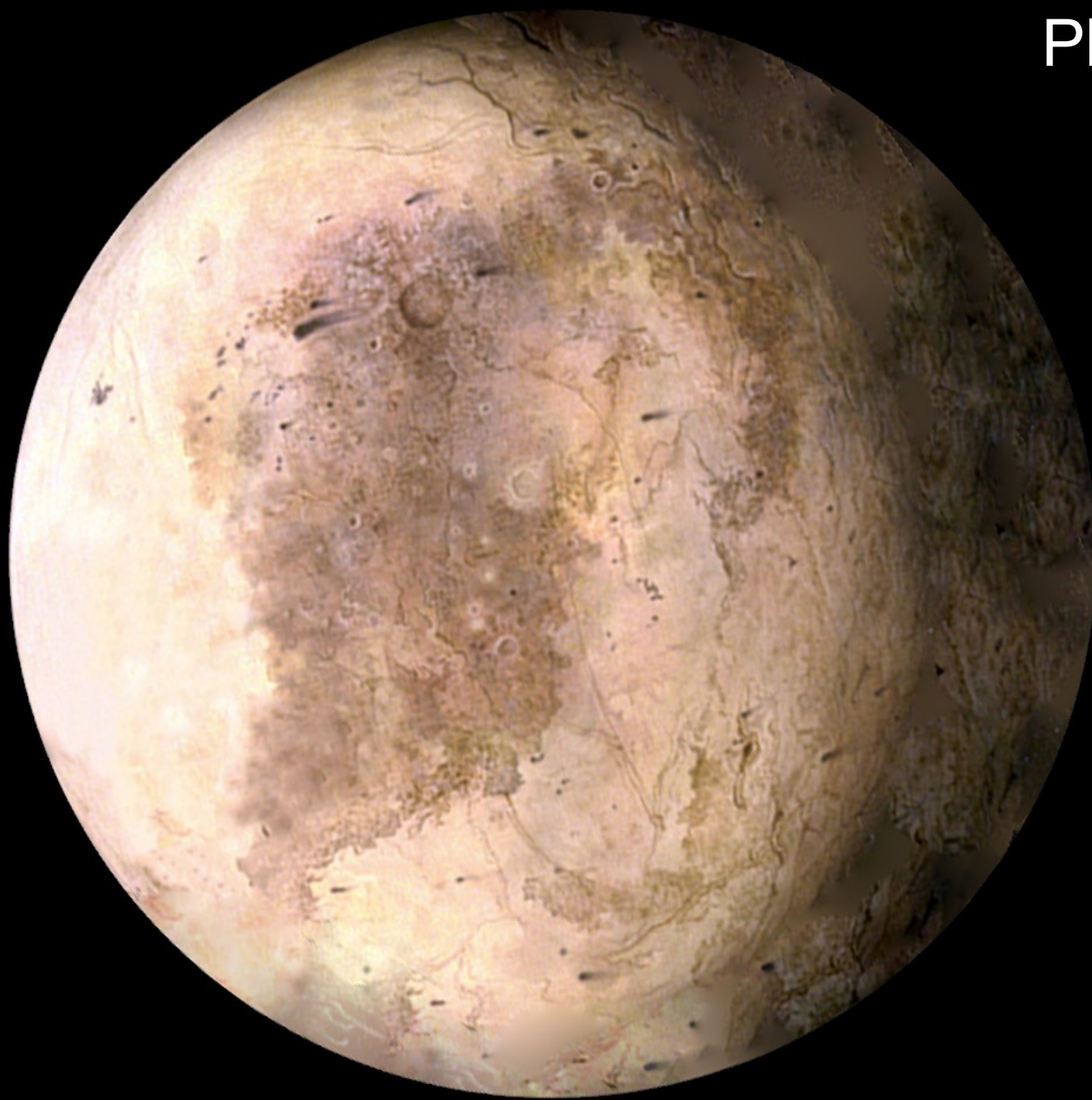


$d = 39.5 \text{ AU}$
 $P_{\text{orb}} = 248 \text{ y}$
 $P_{\text{rot}} = 6.4 \text{ d}$
 $R = 1187 \text{ km}$

New Horizons (luglio 2015)



Plutone e Caronte



Nix

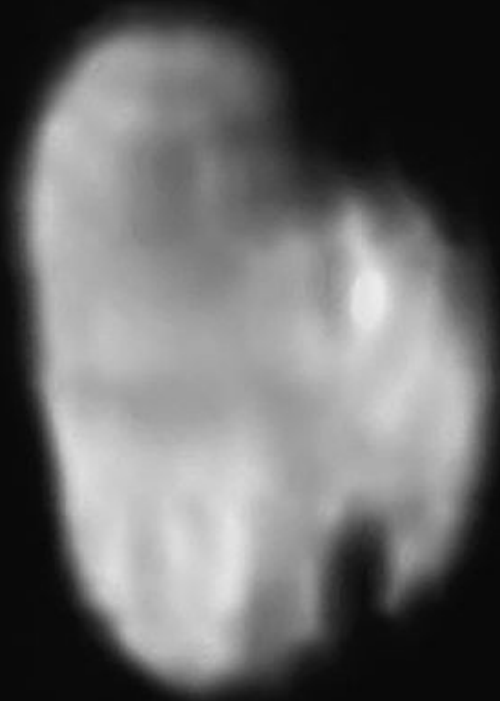
(~ 50 km)



enhanced color

Hydra

(~ 40 km)



black and white

The end