Space Research Institute Graz
Austrian Academy of Sciences

Exploring the Planets and Moons in our Solar System

Geysirs, volcanoes and icy worlds

Helmut O. Rucker

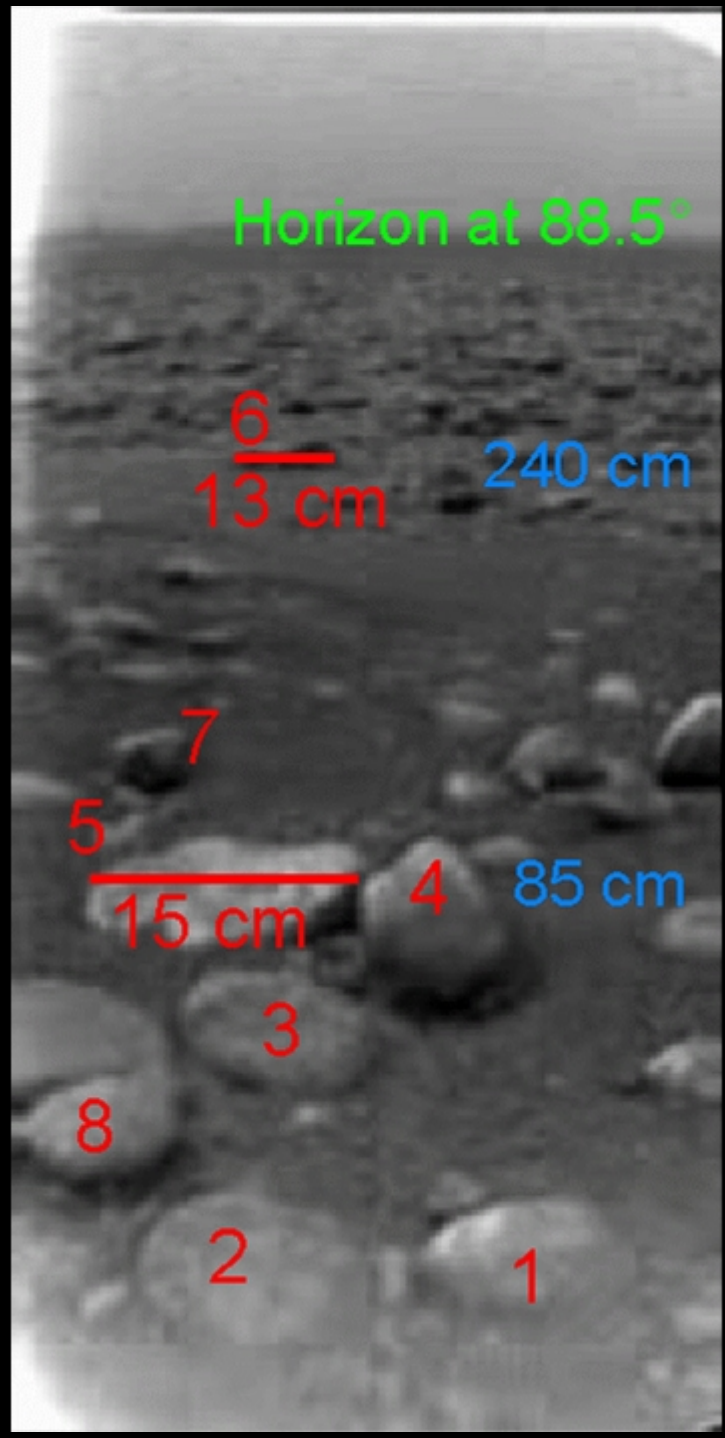
CERN, Geneve, June 2006

Titan,
the biggest moon of Saturn

(only marginally second to Ganymede,
the biggest moon in the solar system)

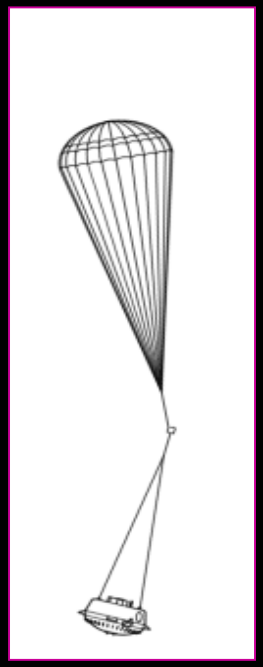
1655 discovered by Christiaan Huygens

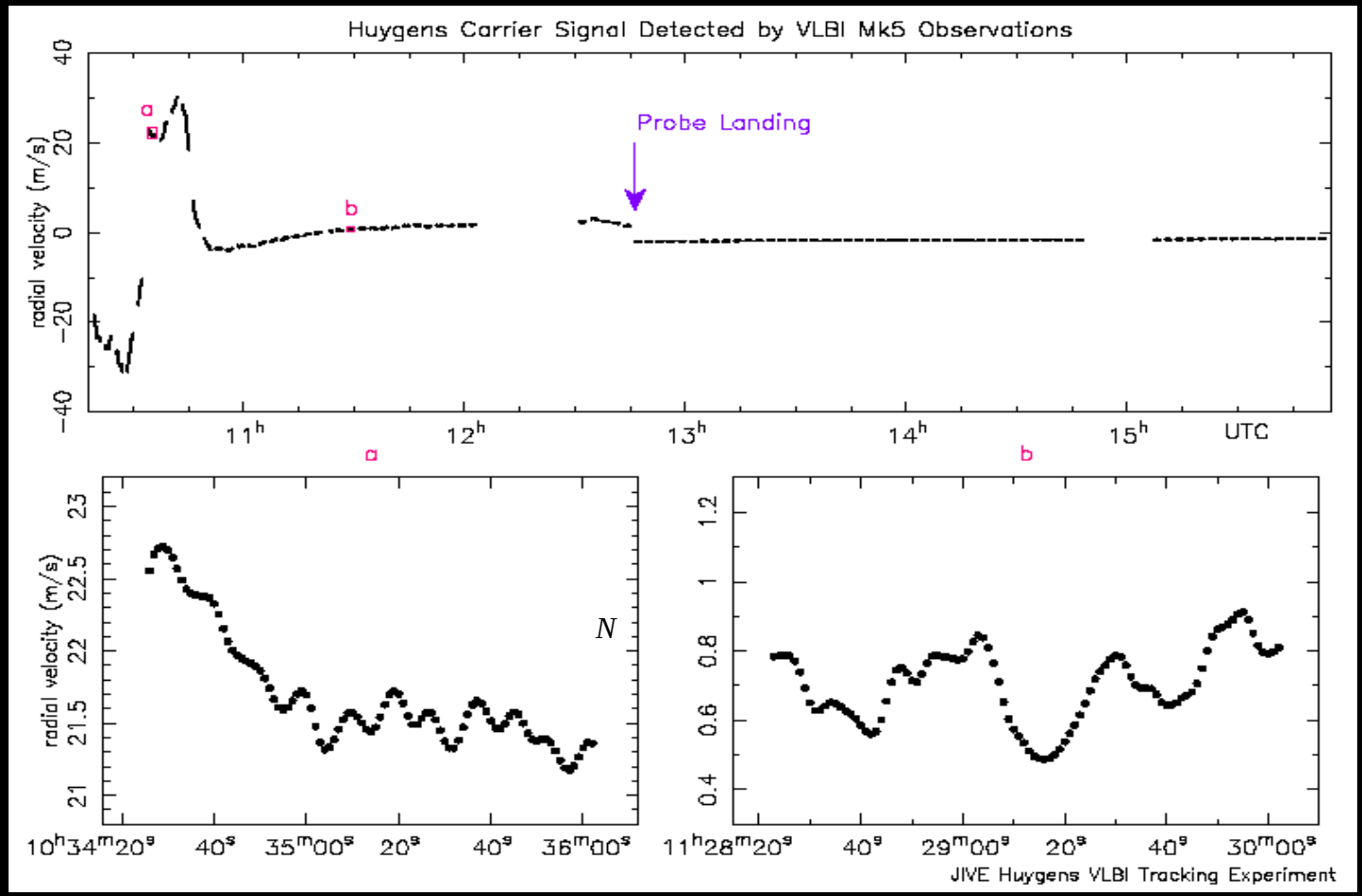
equatorial radius	2,575 km
distance to Saturn	~20 Rs
average density	1.88 g/cm^3
rotation period	15.94542 days
orbital period	15.94542 days
average surface temperature	-178°C
surface atmosphere pressure	1.5 bar



“VLBI tracking” of Huygens Probe, January 14, 2005

jive
JOINT INSTITUTE FOR VLBI IN EUROPE



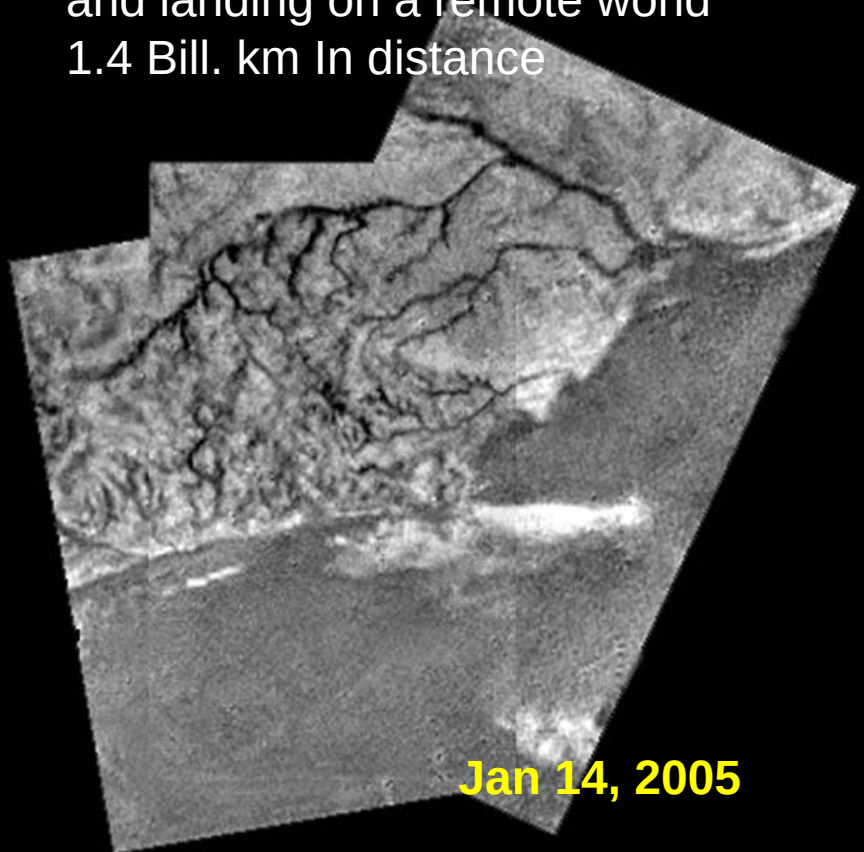


VLBI tracking January 14, 2005

Titan – atmosphere: $N_2 (\sim 96-98\%)$

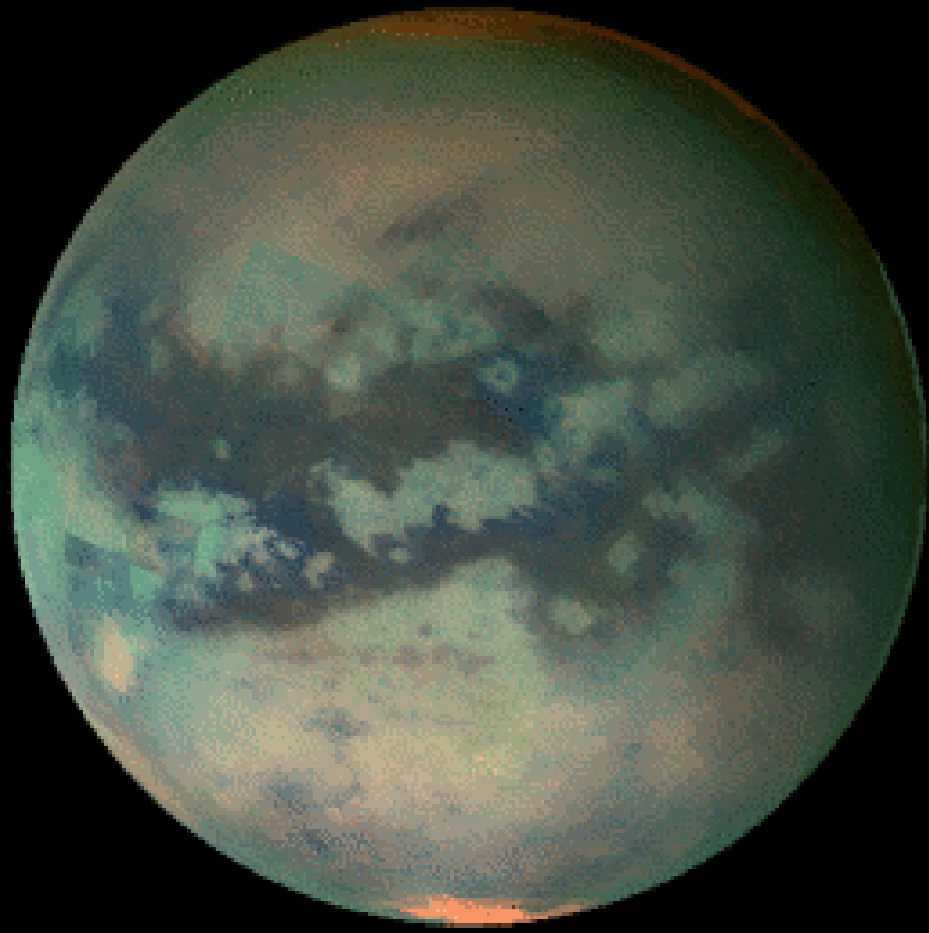
$CH_4 (\sim 2-4\%)$

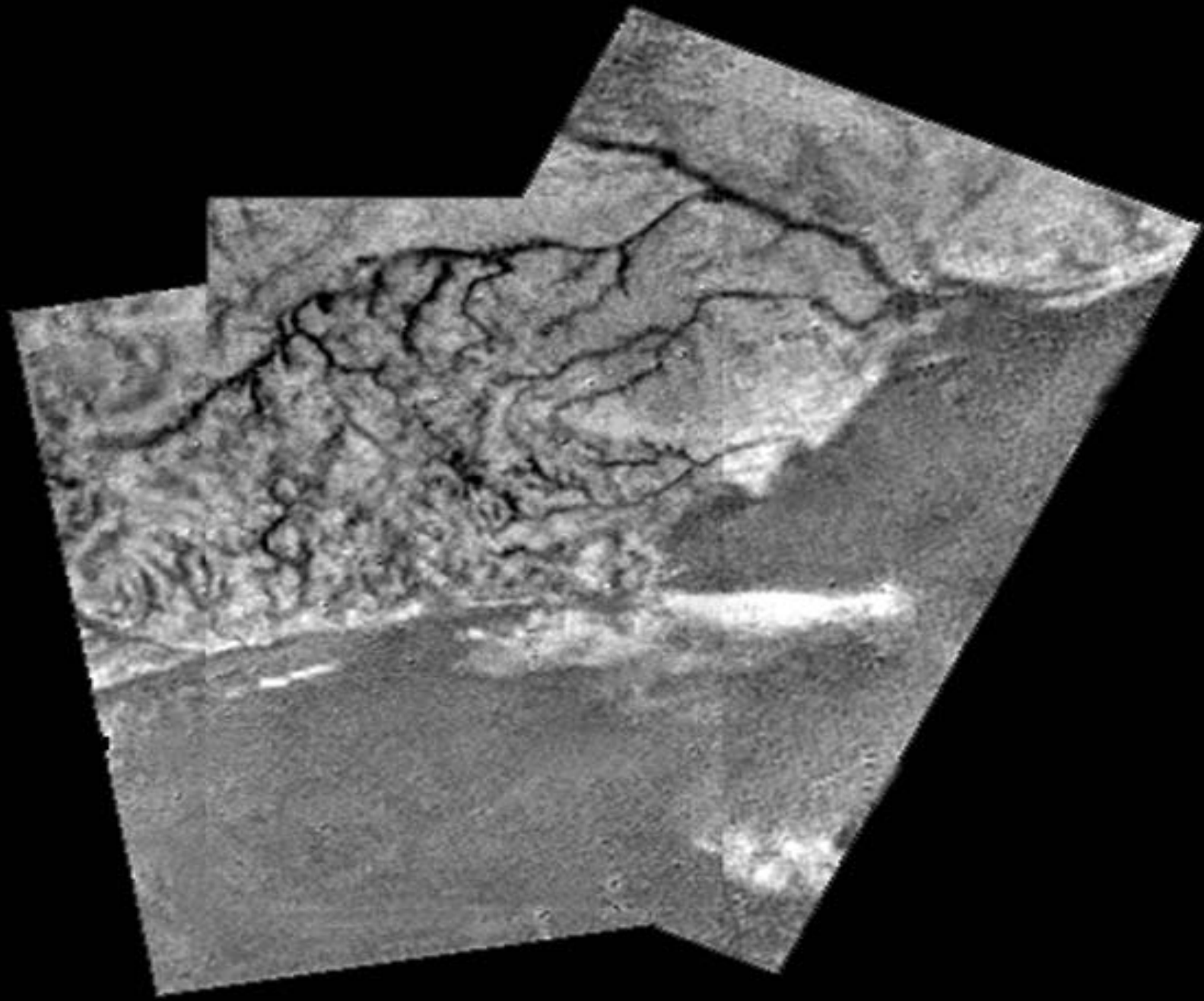
Christiaan Huygens
350 years between discovery
and landing on a remote world
1.4 Bill. km In distance



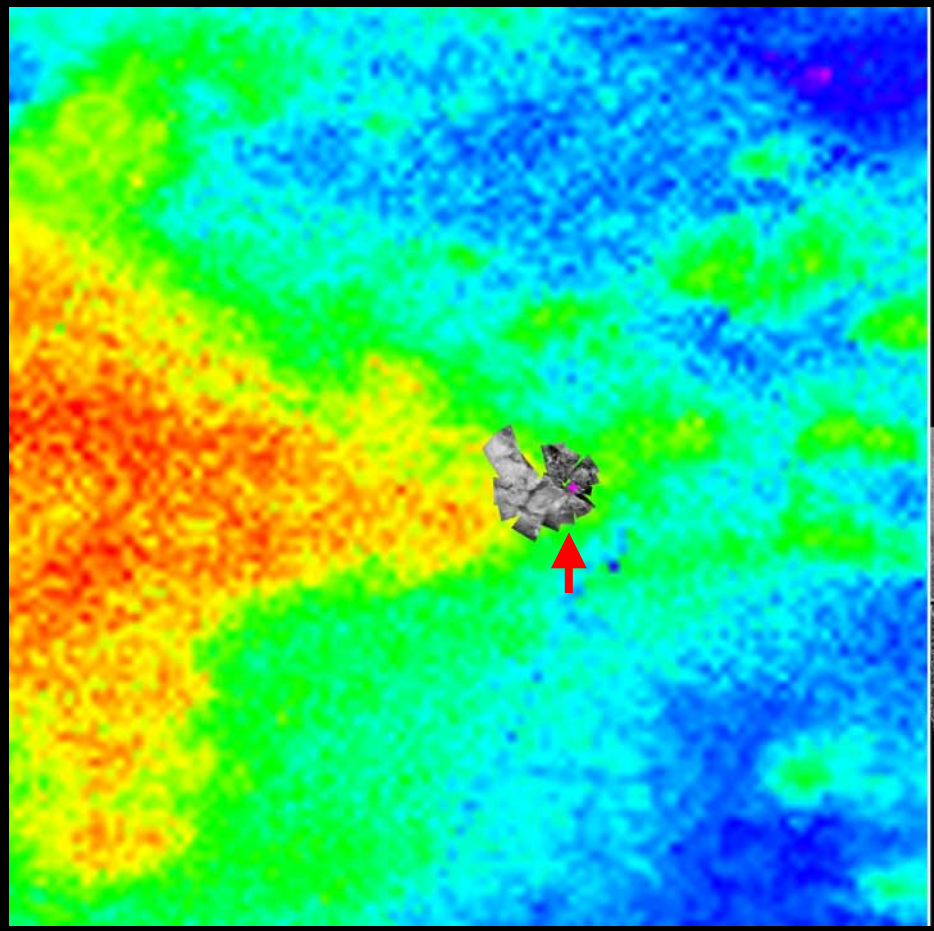
Jan 14, 2005

Titan in IR

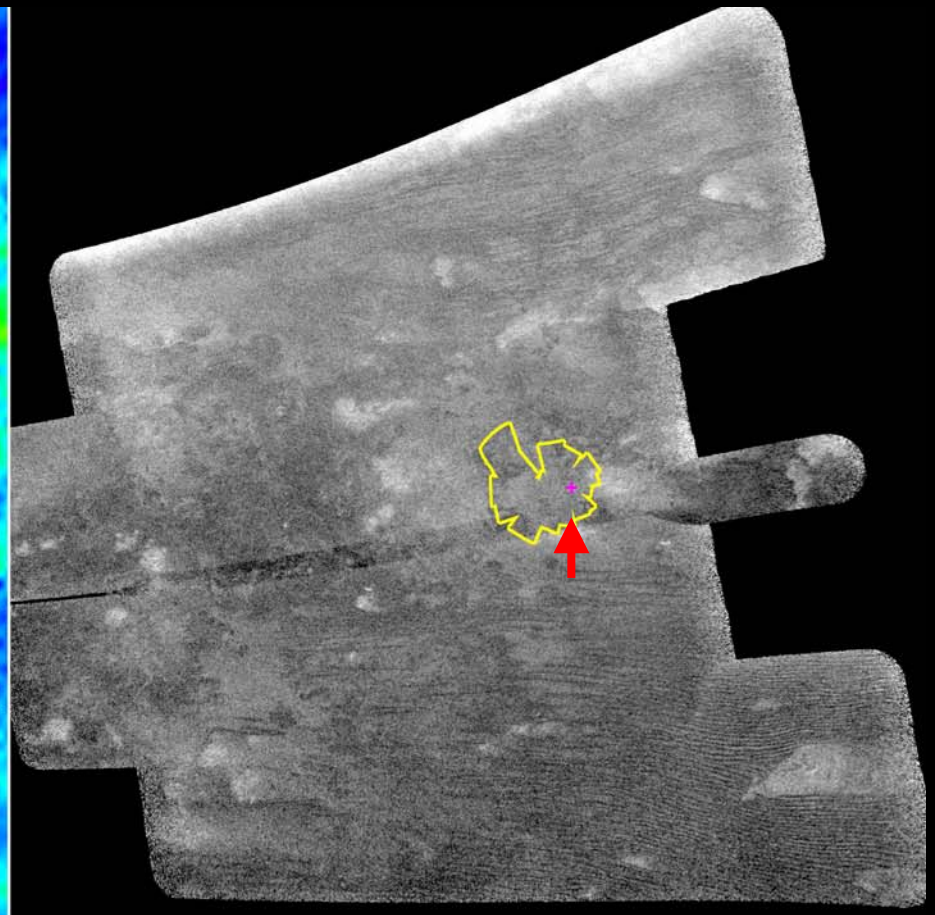




CASSINI imaging from Huygens landing site



Imaging and infrared



Synthetic aperture radar

Orange smog covers Titan`s surface, in thickness ~300 km

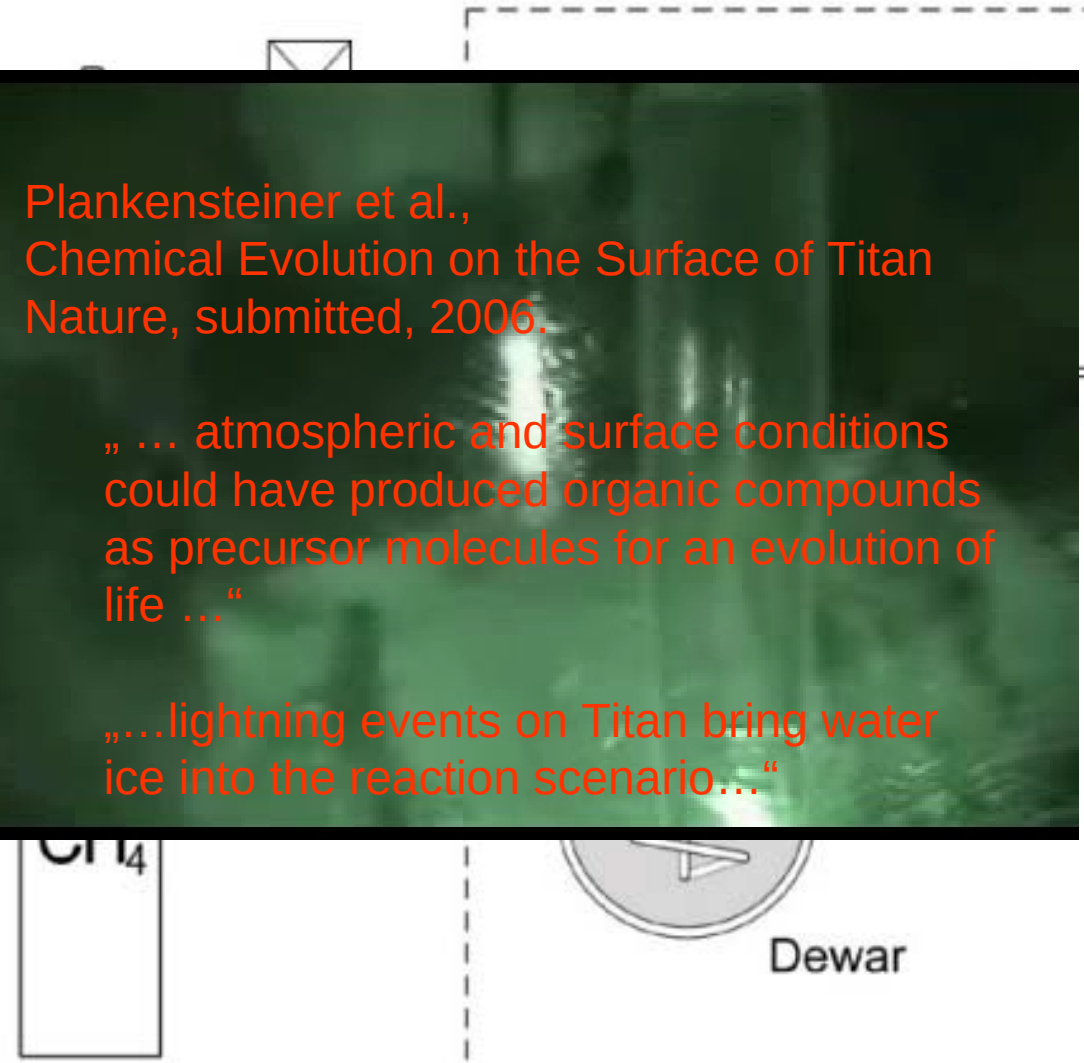
Molecule	Symbol	Amount
Major Constituents		*Percent*
Nitrogen	N_2	87-99
Argon	Ar	0-6
Methane	CH_4	1-6
Minor Constituents		*parts per million*
Hydrogen	H_2	2000
Hydrocarbons		
Ethane	C_2H_6	20
Acetylene	C_2H_2	4
Ethylene	C_2H_4	1
Propane	C_3H_8	1
Methylacetylene	C_3H_4	0.03
Diacetylene	C_4H_2	0.02
Nitrogen Compounds		
Hydrogen Cyanide	HCN	1
Cynaogen	C_2N_2	0.02
Cyanoacetylene	HC_3N	0.03
Acteonitrile	CH_3CN	0.003
Oxygen Compounds		
Carbon Monoxide	CO	50
Carbon Dioxide	CO_2	0.01

Univ. Innsbruck (Austria), Inst. f. Theoretical Chemistry:

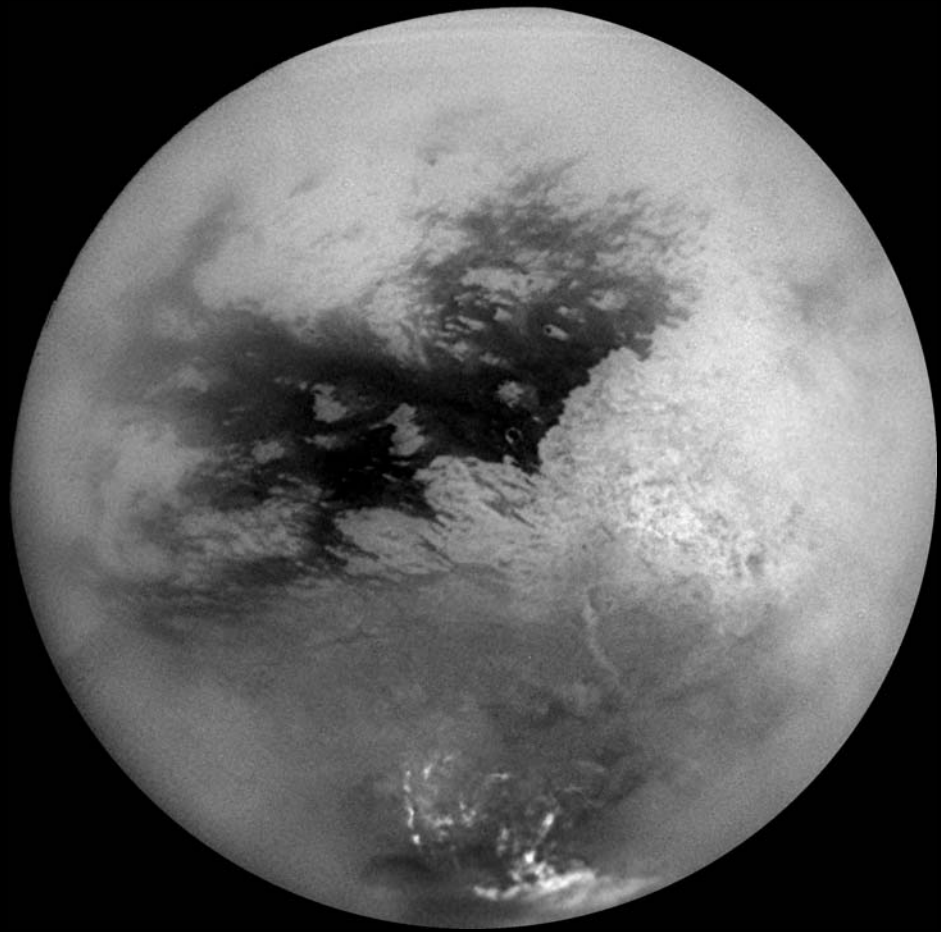
Plankensteiner et al.,
Chemical Evolution on the Surface of Titan
Nature, submitted, 2006.

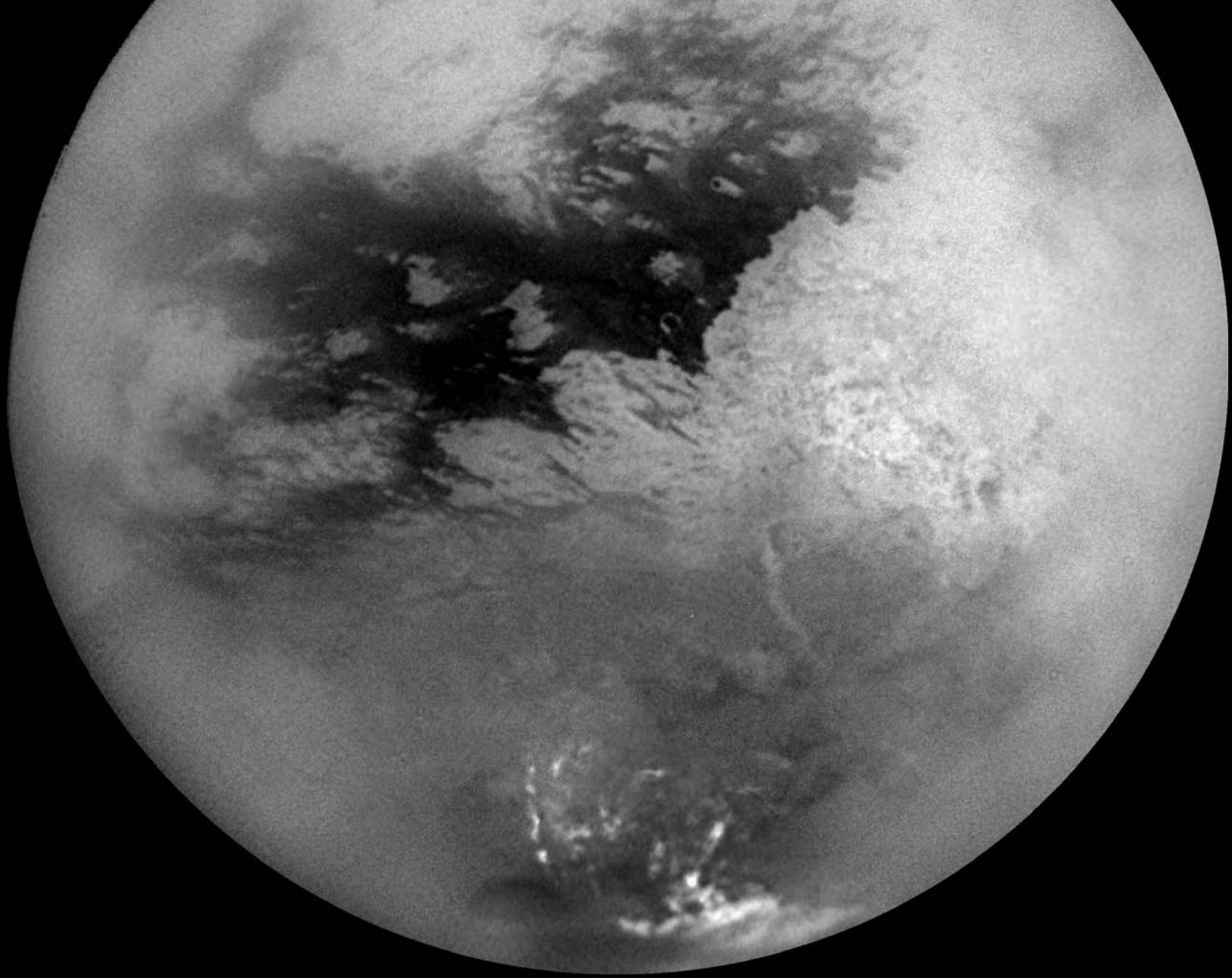
„ … atmospheric and surface conditions could have produced organic compounds as precursor molecules for an evolution of life …“

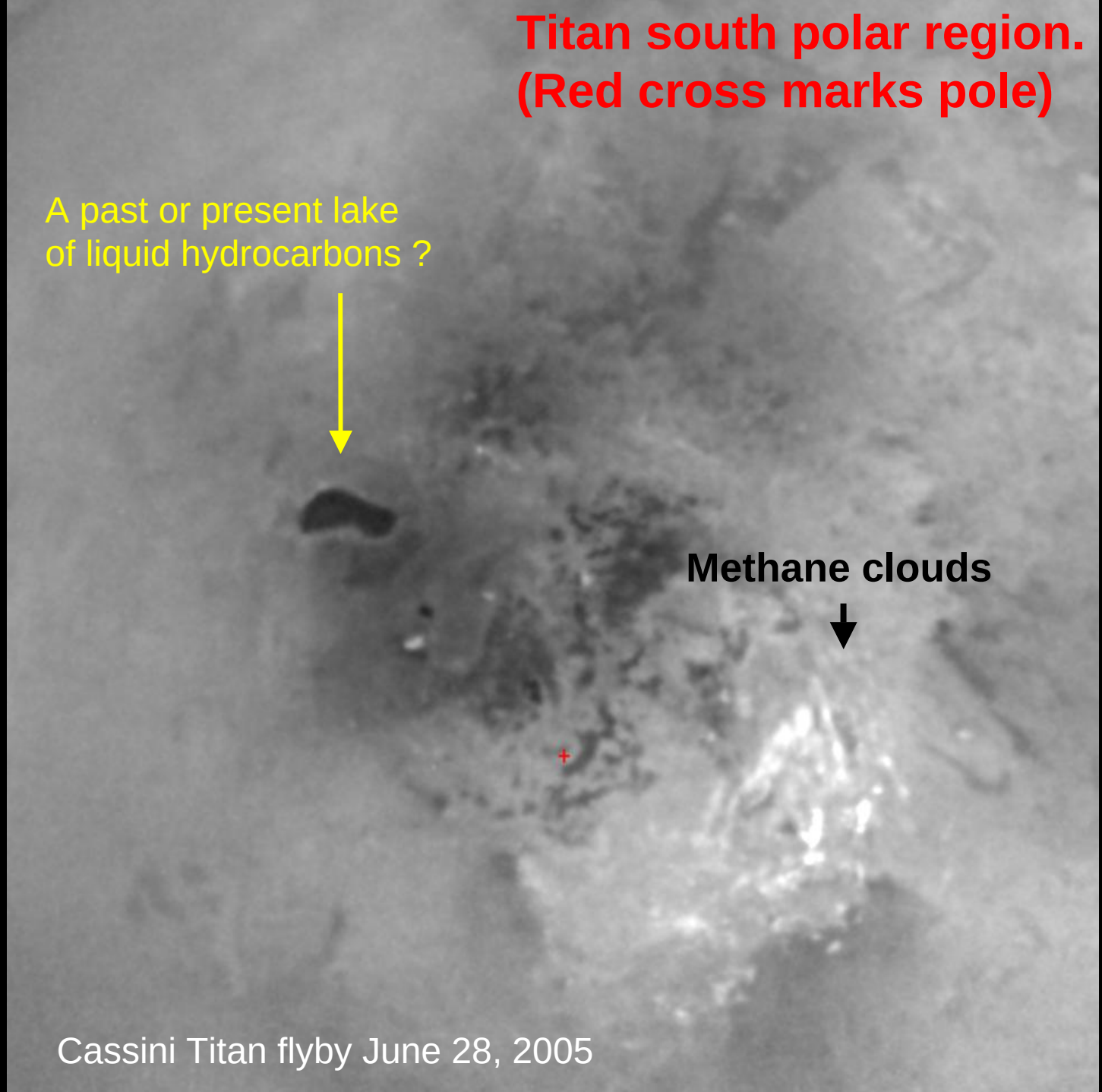
„…lightning events on Titan bring water ice into the reaction scenario…“



Composition of the interior rather unknown.
Likely a combination of rock and ice.
No magnetic field has been detected from Titan – suggesting that an iron core is not present.

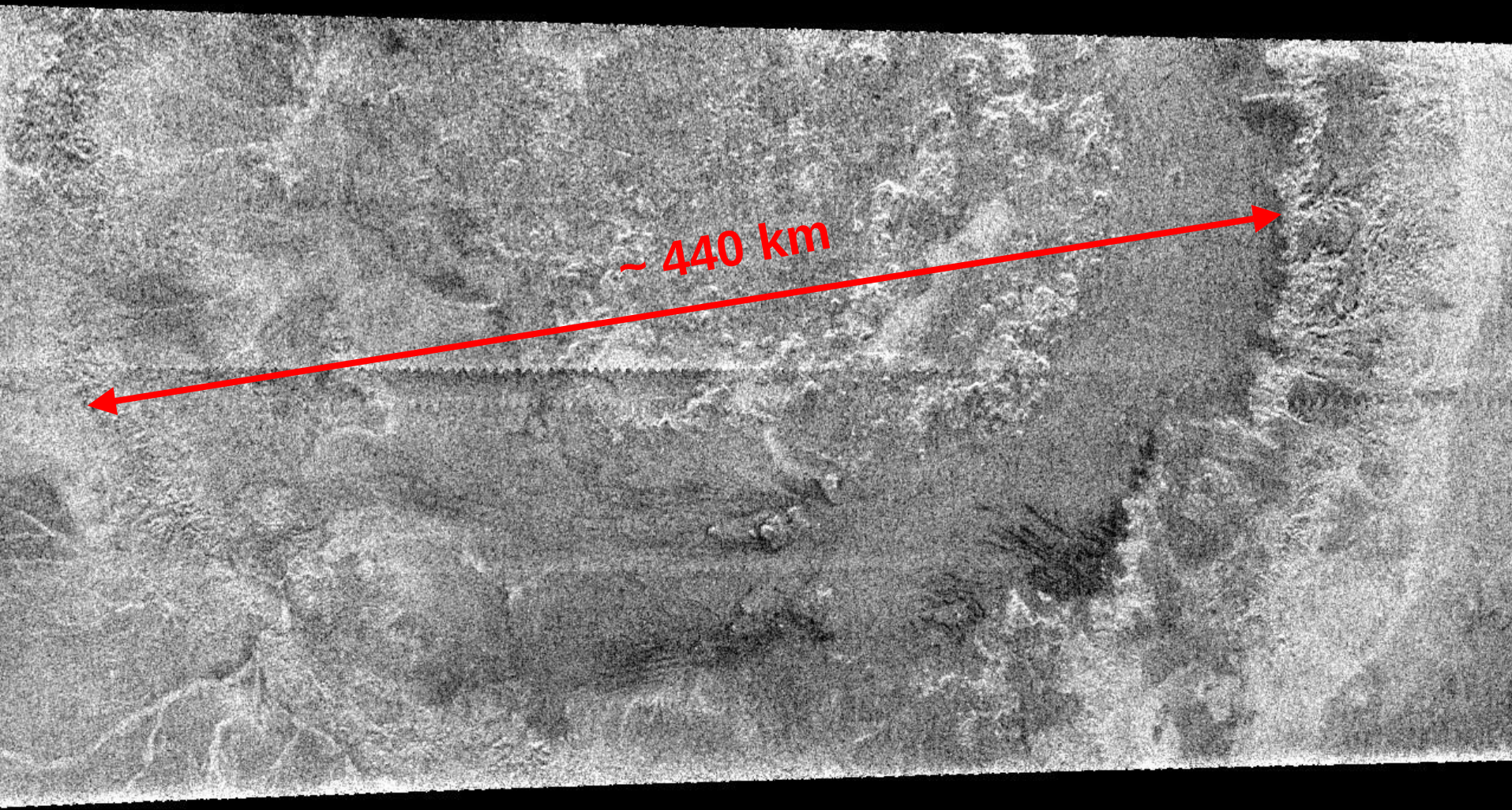





Titan south polar region.
(Red cross marks pole)
A past or present lake
of liquid hydrocarbons ?
Methane clouds
Cassini Titan flyby June 28, 2005

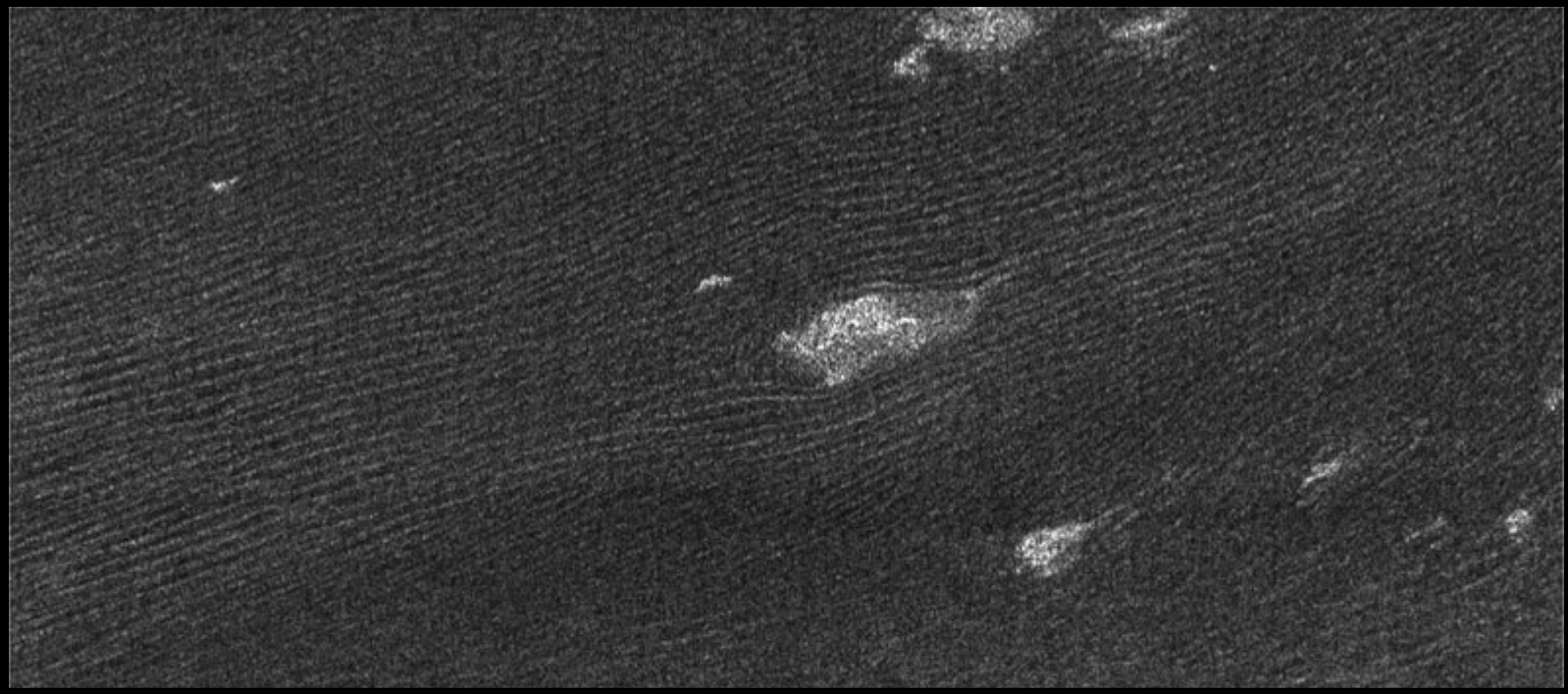
The hot spot hypothesis will be tested during a Titan flyby on 2 July 2006, when the visual and infrared spectrometer will take nighttime images of this area. If it is hot, it will glow at night.

First impact feature identified in radar images of Titan: Circus Maximus

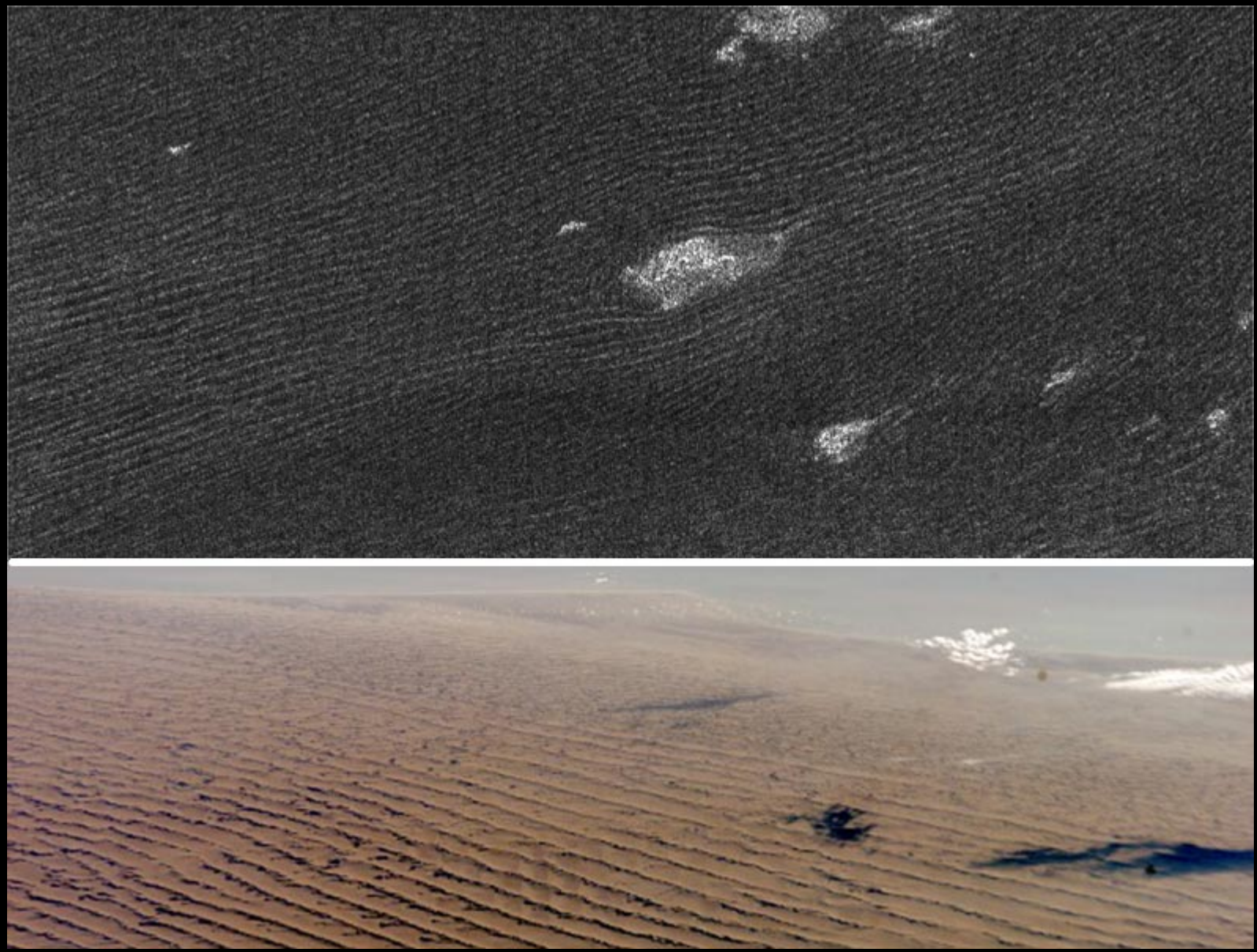


Xanadu is one of the most prominent features on Titan
and was first seen in ground-based observation

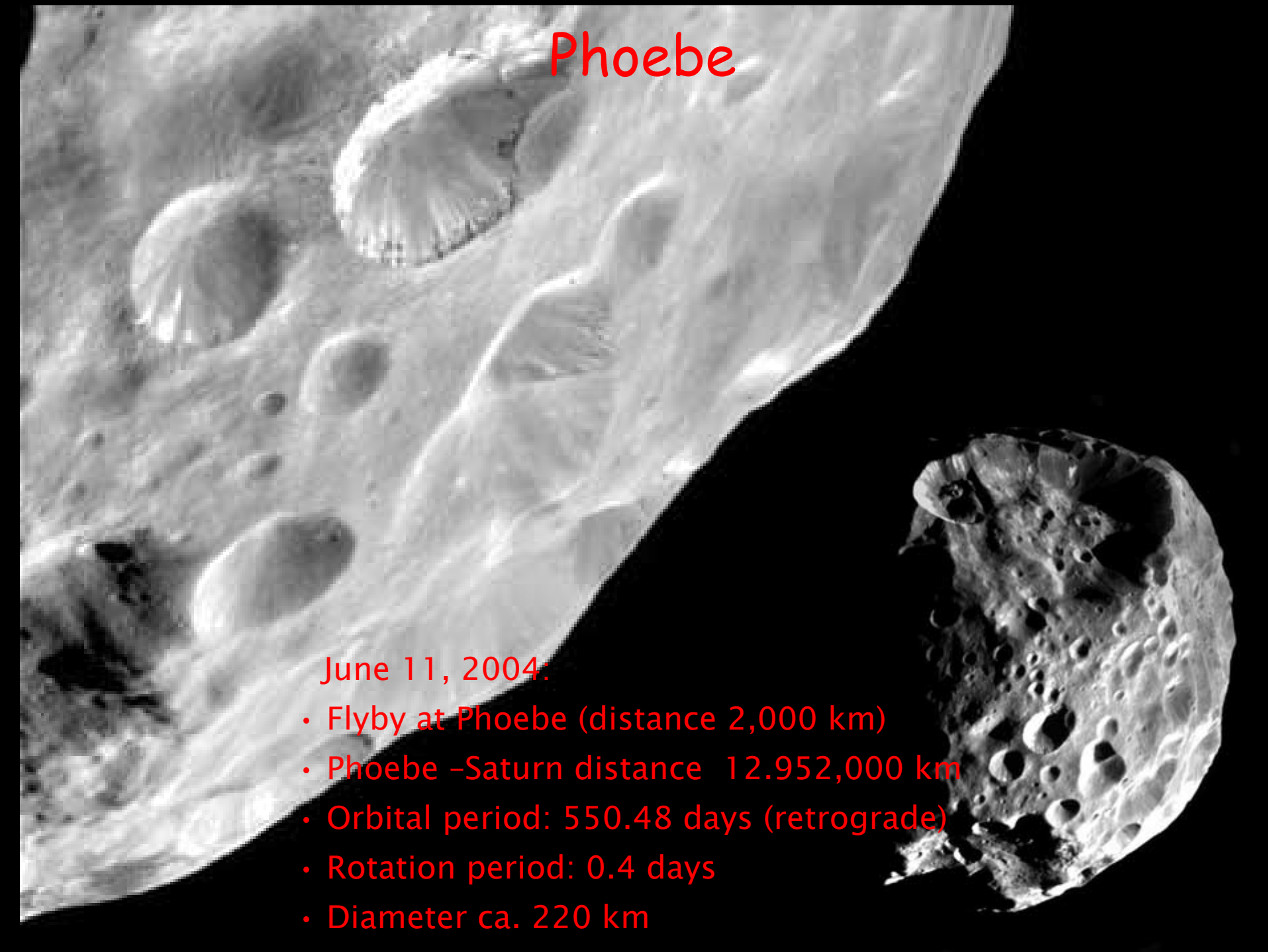
Synthetic Aperture Radar instrument (May 3, 2006)



Cassini radar sees sand dunes on Saturn's giant moon Titan (upper photo) that are sculpted like Namibian sand dunes on Earth (lower photo).

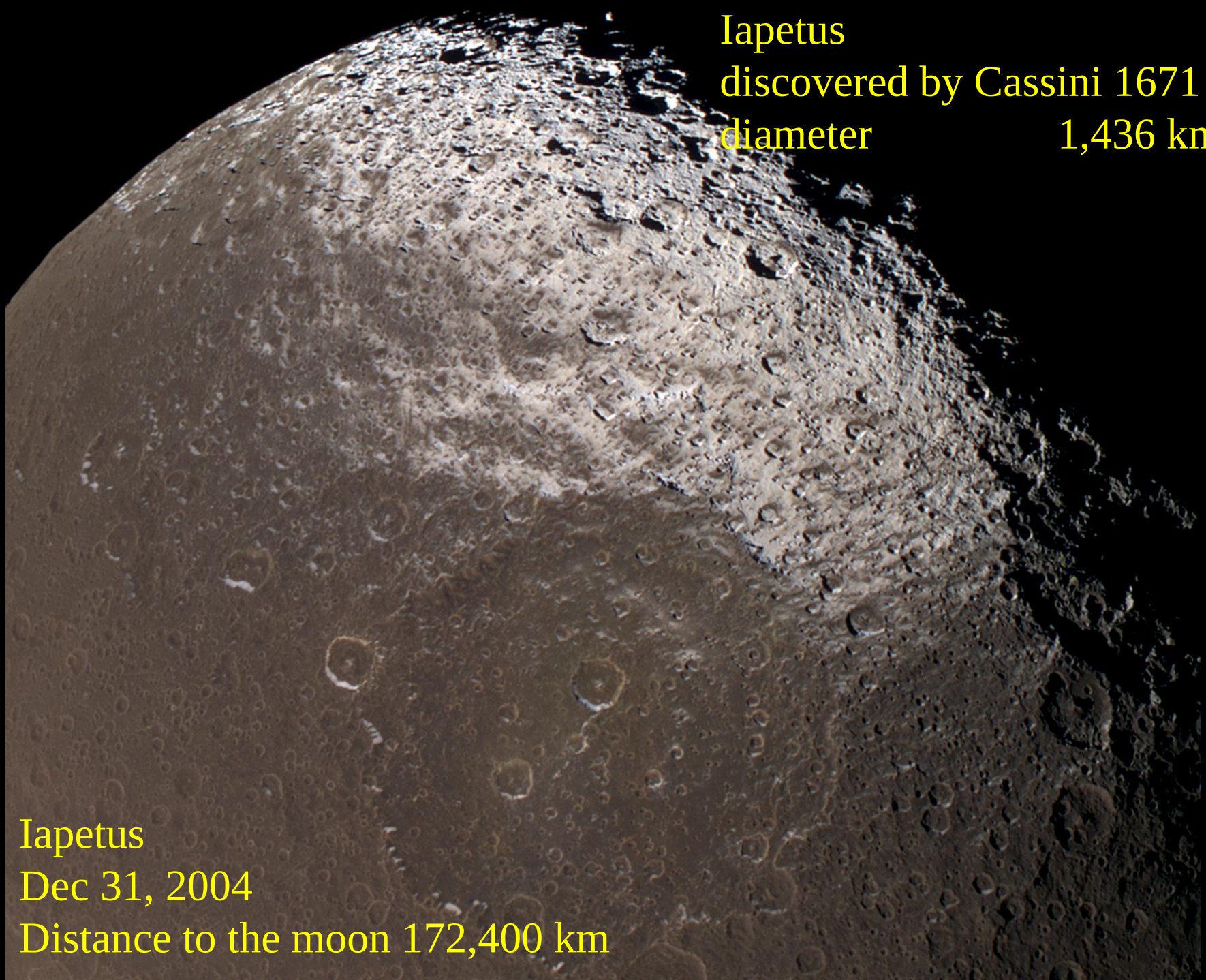


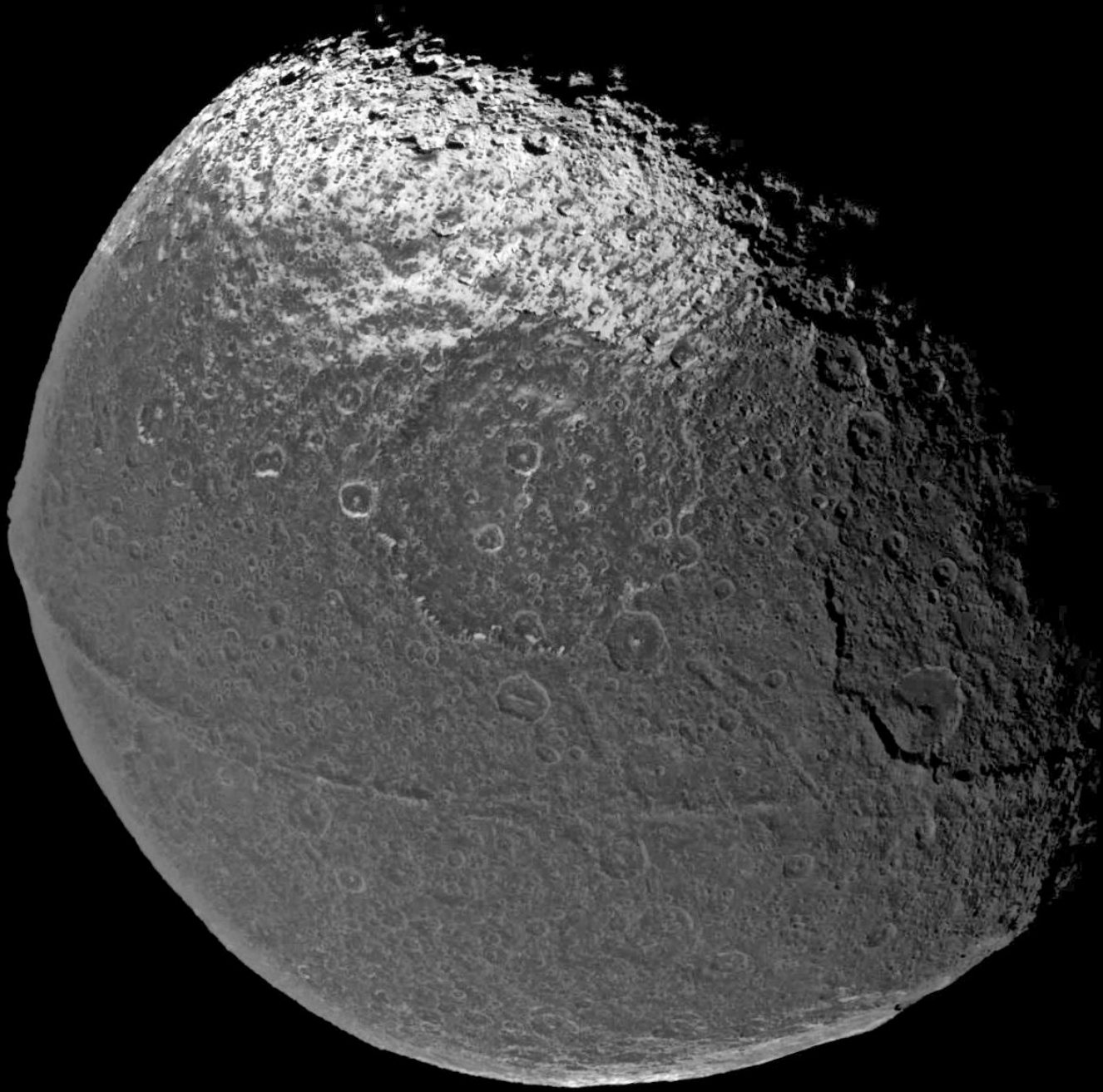
Phoebe

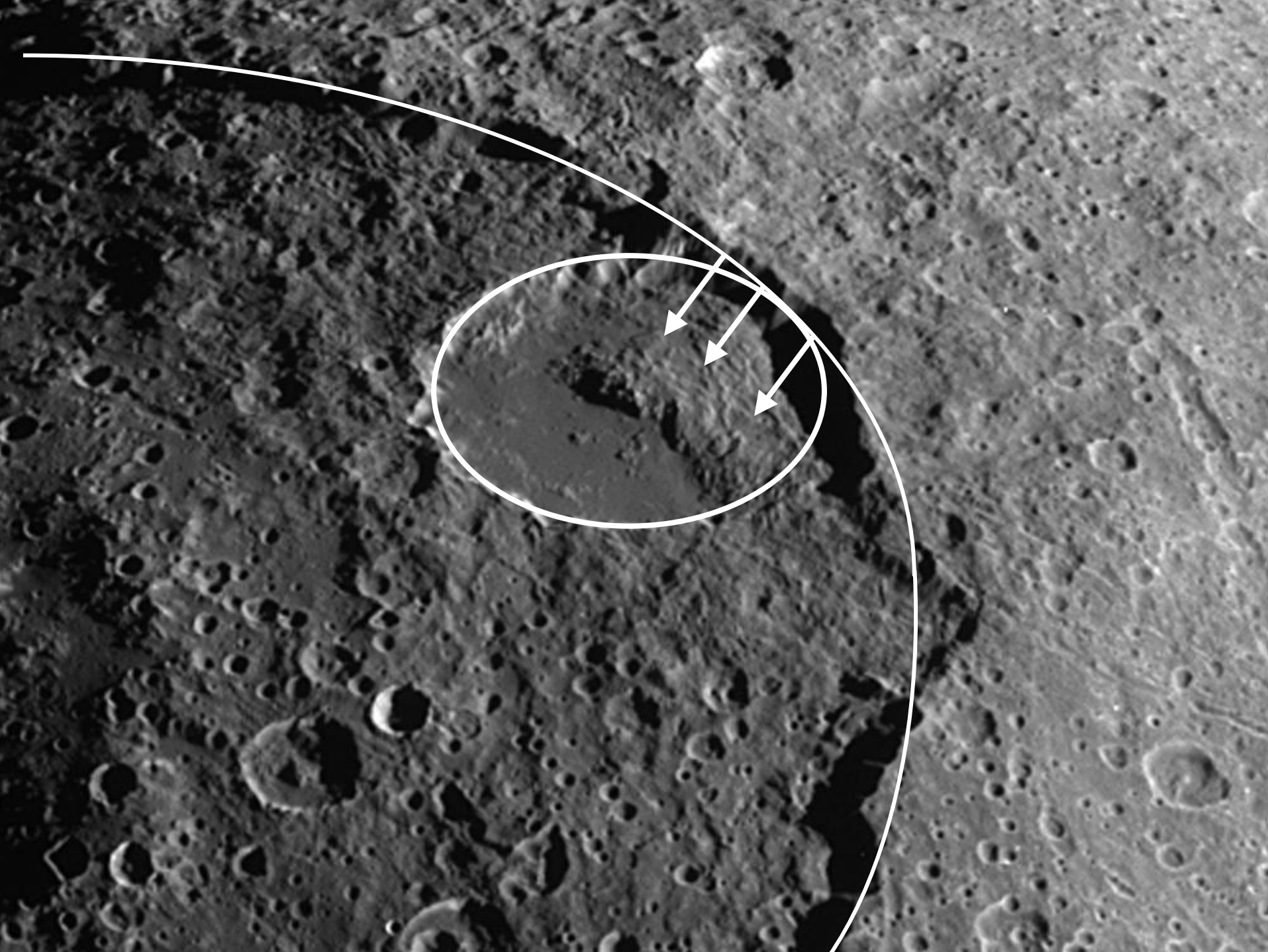


June 11, 2004:

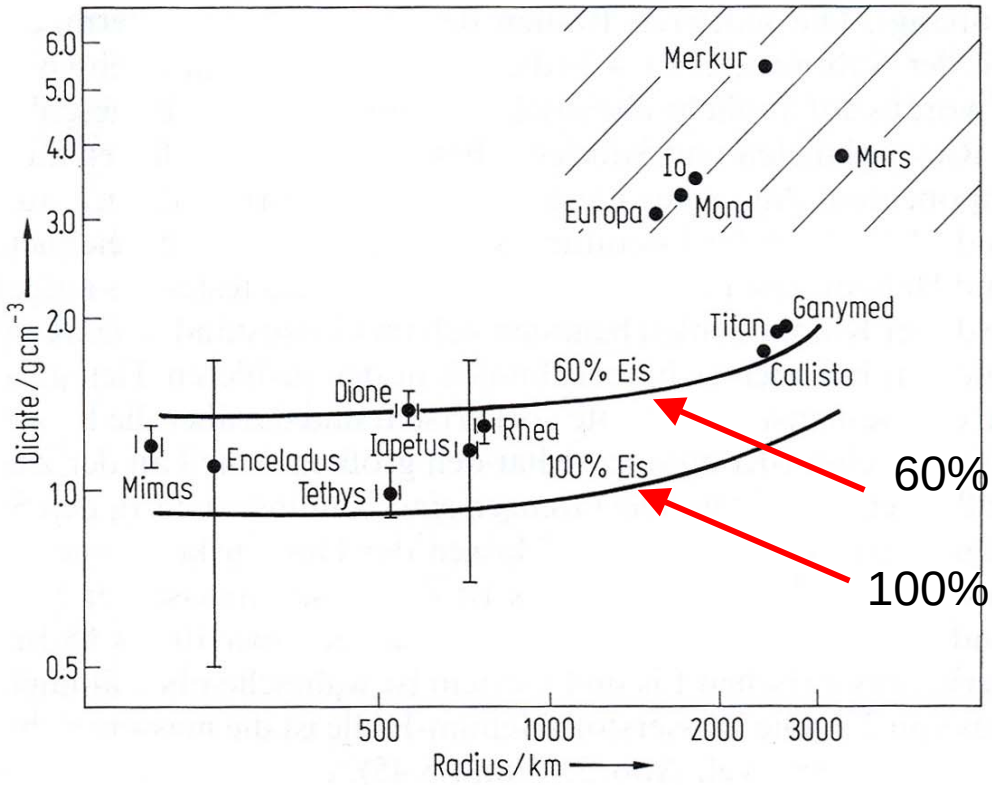
- Flyby at Phoebe (distance 2,000 km)
- Phoebe –Saturn distance 12.952,000 km
- Orbital period: 550.48 days (retrograde)
- Rotation period: 0.4 days
- Diameter ca. 220 km


Iapetus
discovered by Cassini 1671
diameter 1,436 km
Iapetus
Dec 31, 2004
Distance to the moon 172,400 km





Radius versus density



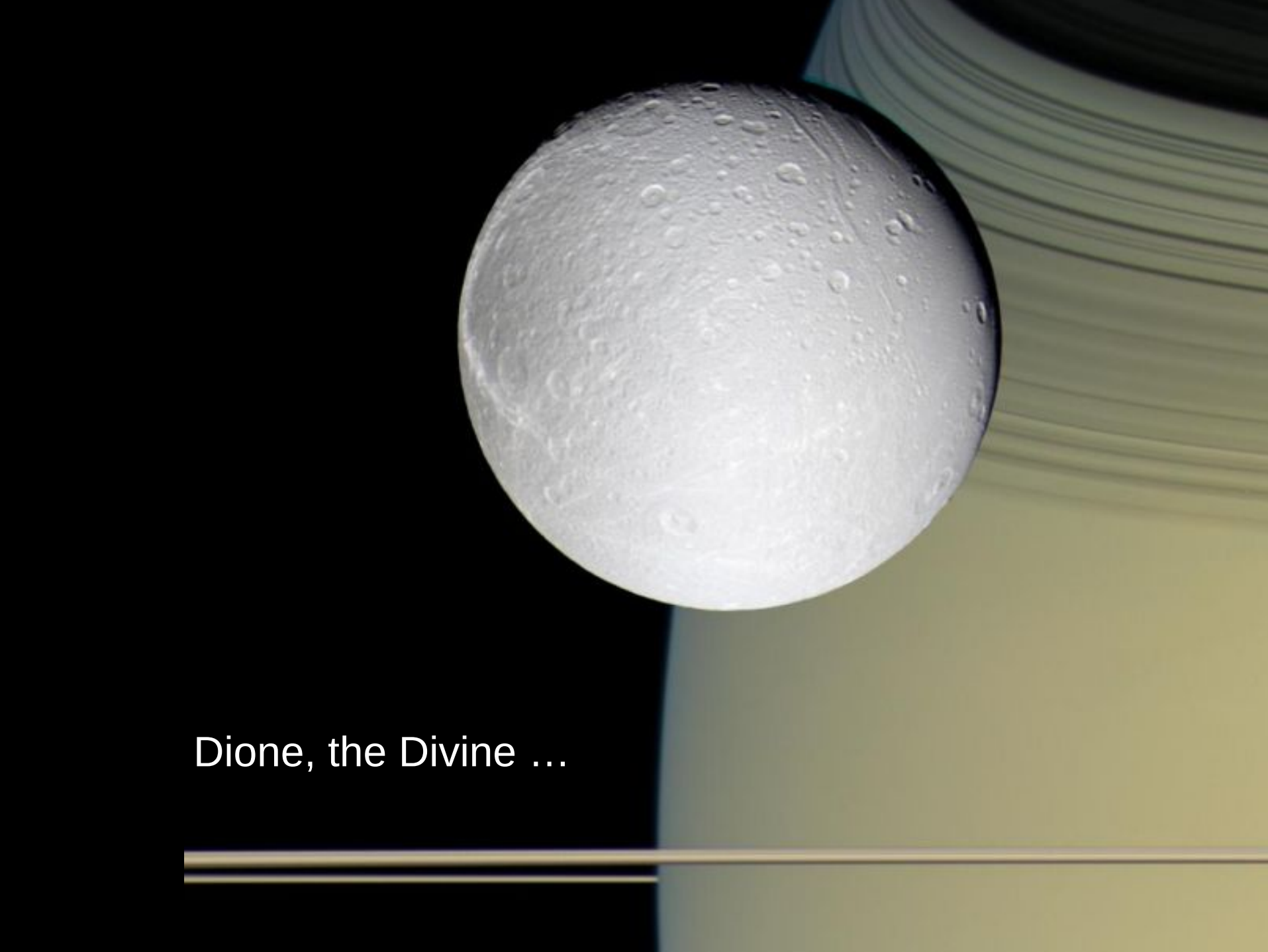
rock-, iron-bodies
(Mercury = own B-field)

rock-, ice-bodies

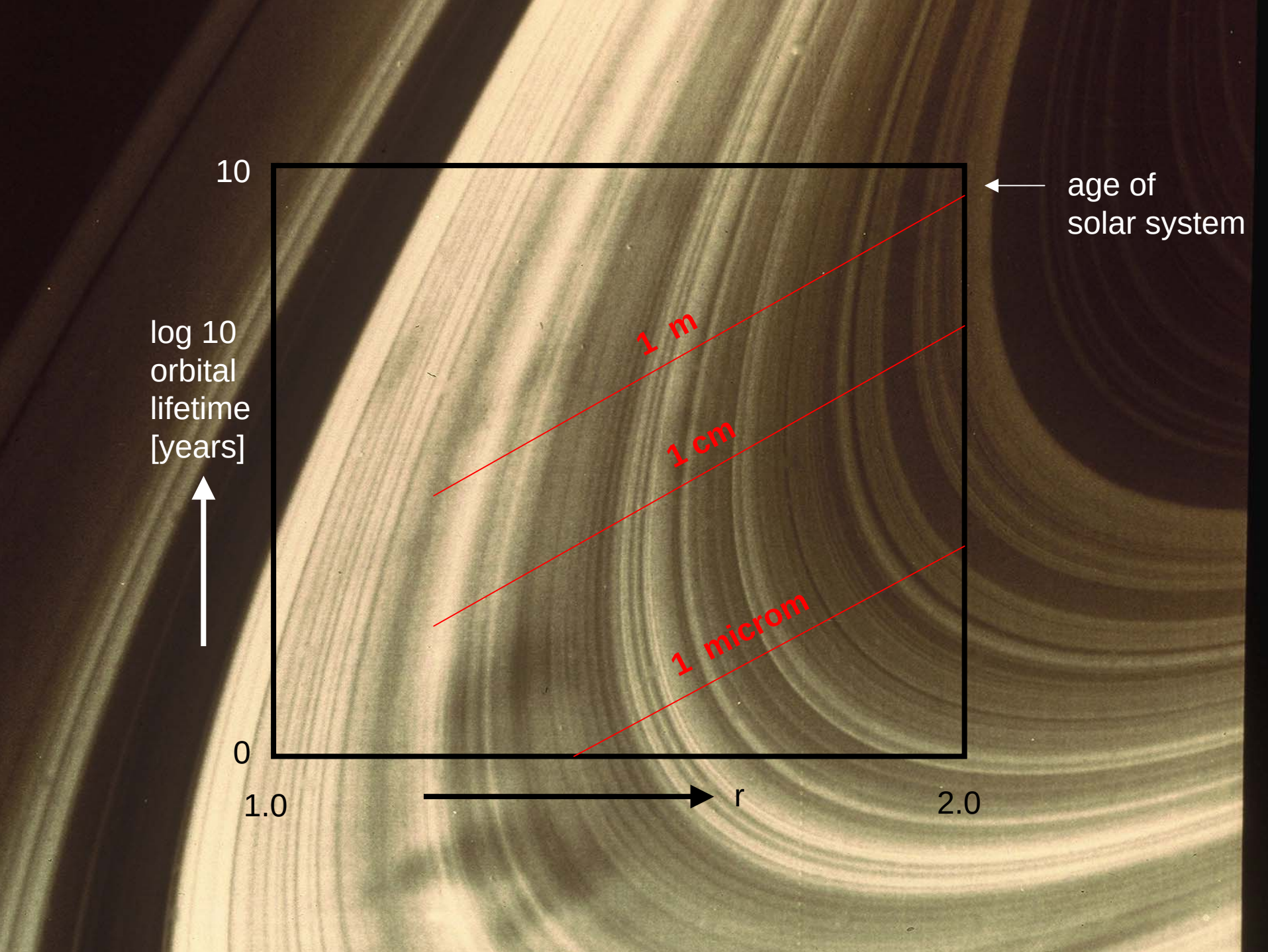
60% ice

100% ice

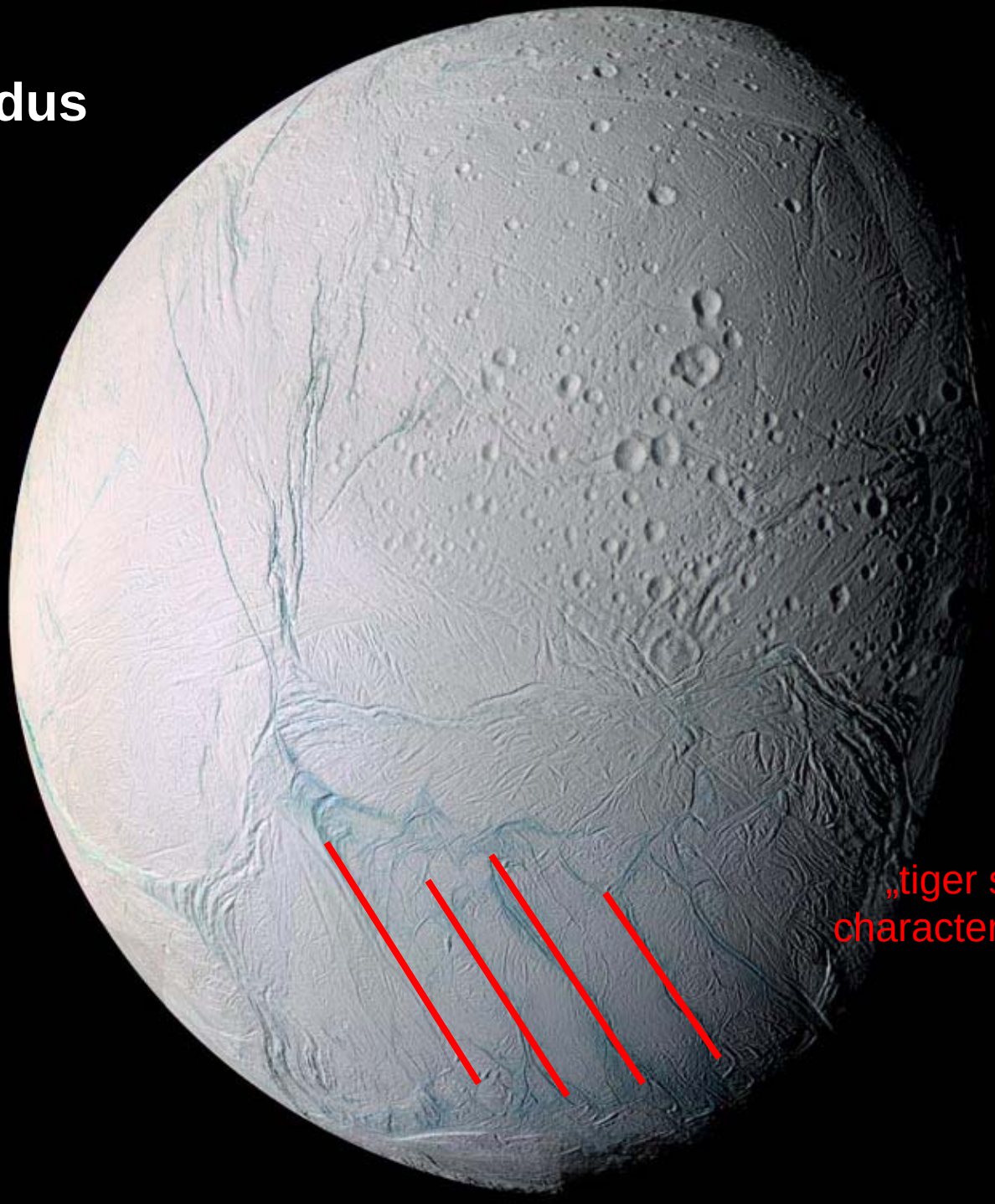
Abb. 5.6 Radius-Dichte-Beziehung für kleinere terrestrische Planeten und für Trabanten der Riesen- und Sub-Riesenplaneten nach [16]. Man erkennt deutlich wie sich die Gesteins-Eisenkörper (Europa, Io, Mars, Merkur, Mond) von den Eis-Gesteinskörper unterscheiden. Eingezeichnet sind weiterhin die Radius-Dichte-Beziehungen für Modellkörper, die aus reinem Wassereis und aus einem Gemisch von 0.6 Massenanteilen Wassereis und 0.4 Massenanteilen Gestein besteht. Der Anstieg dieser Kurven für größere Radien ist eine Folge der Kompression durch Eigengraviation.



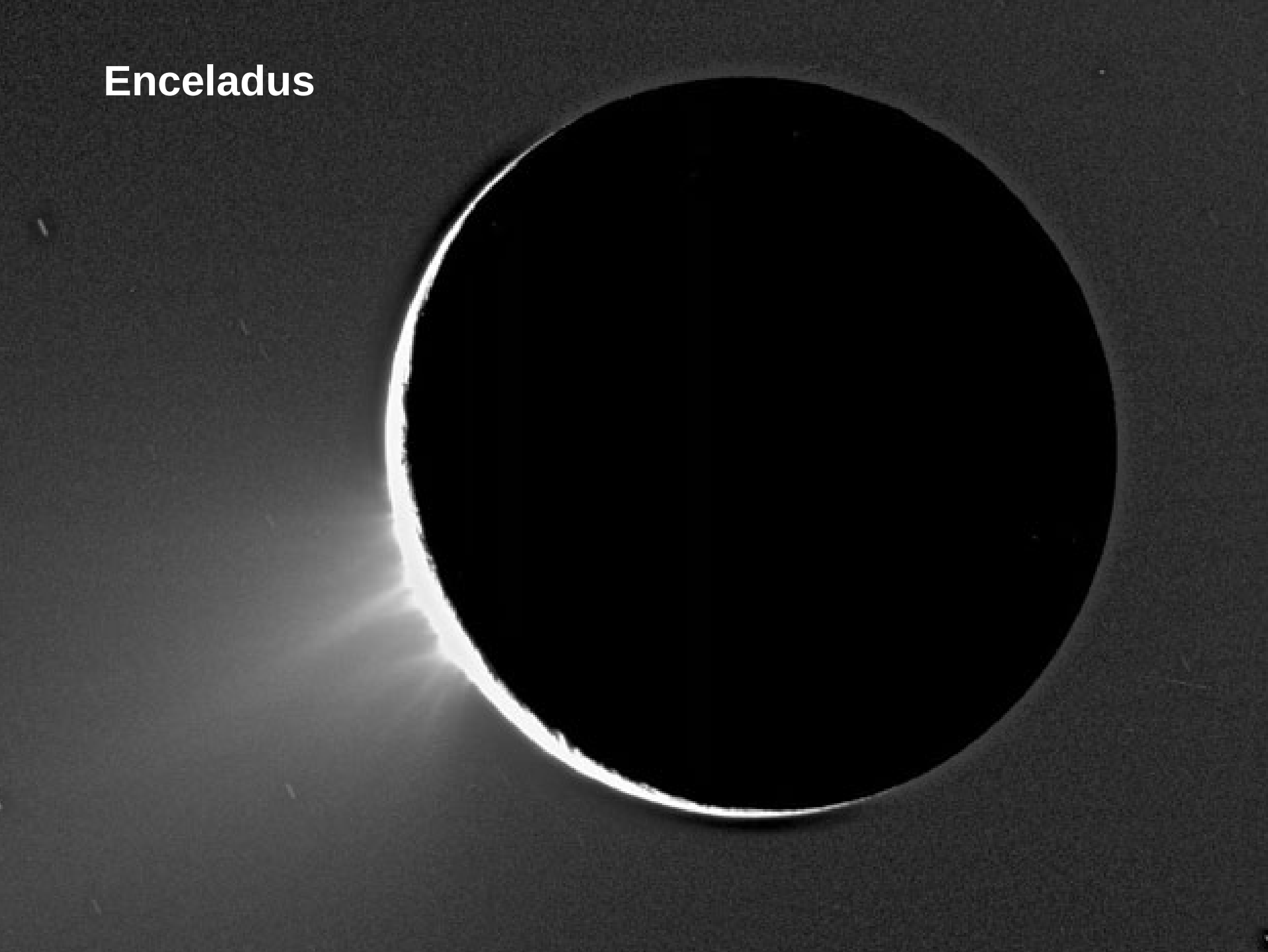
Dione, the Divine …

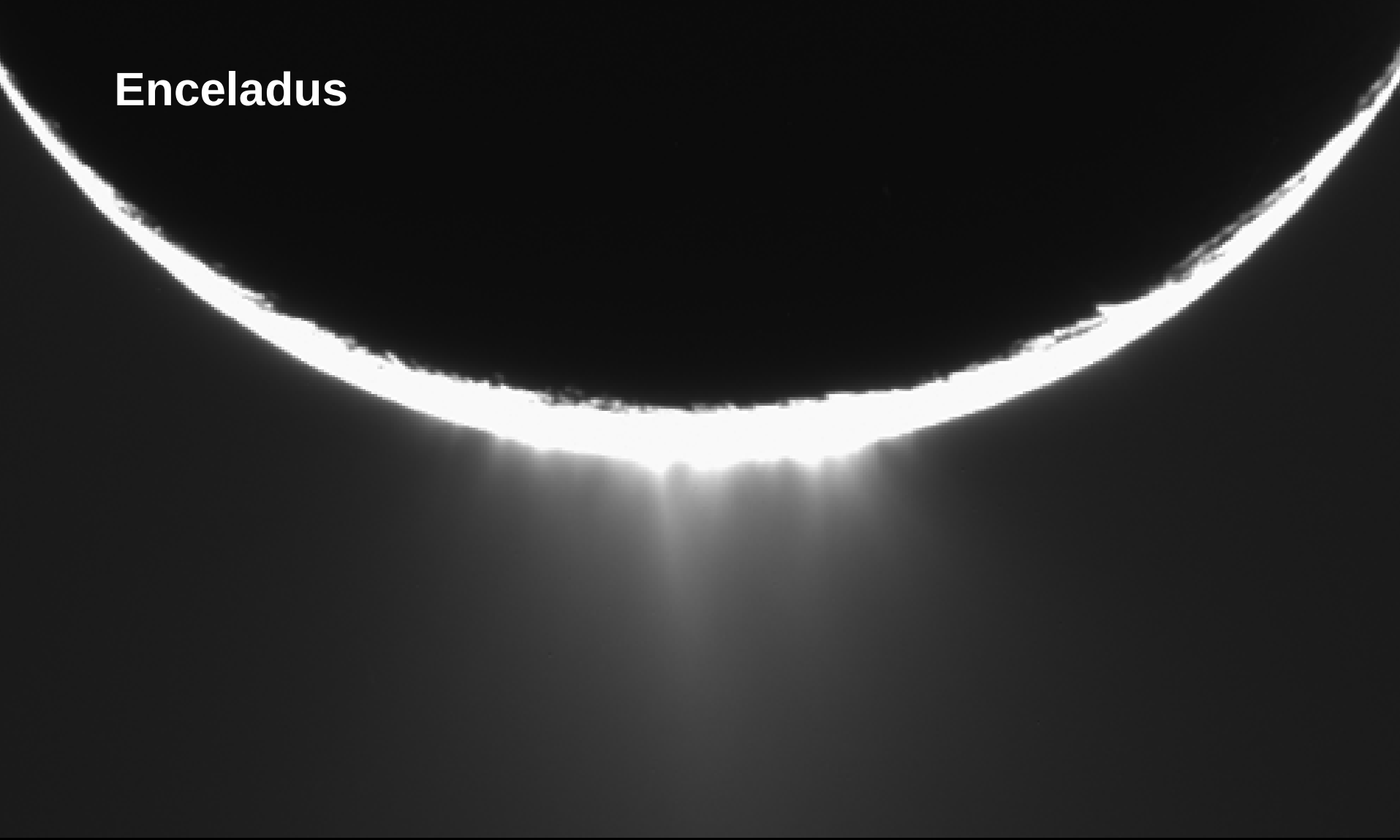

10
0
log 10
orbital
lifetime
[years]
1.0
r
2.0
age of
solar system
1 m
1 cm
1 microm

Enceladus



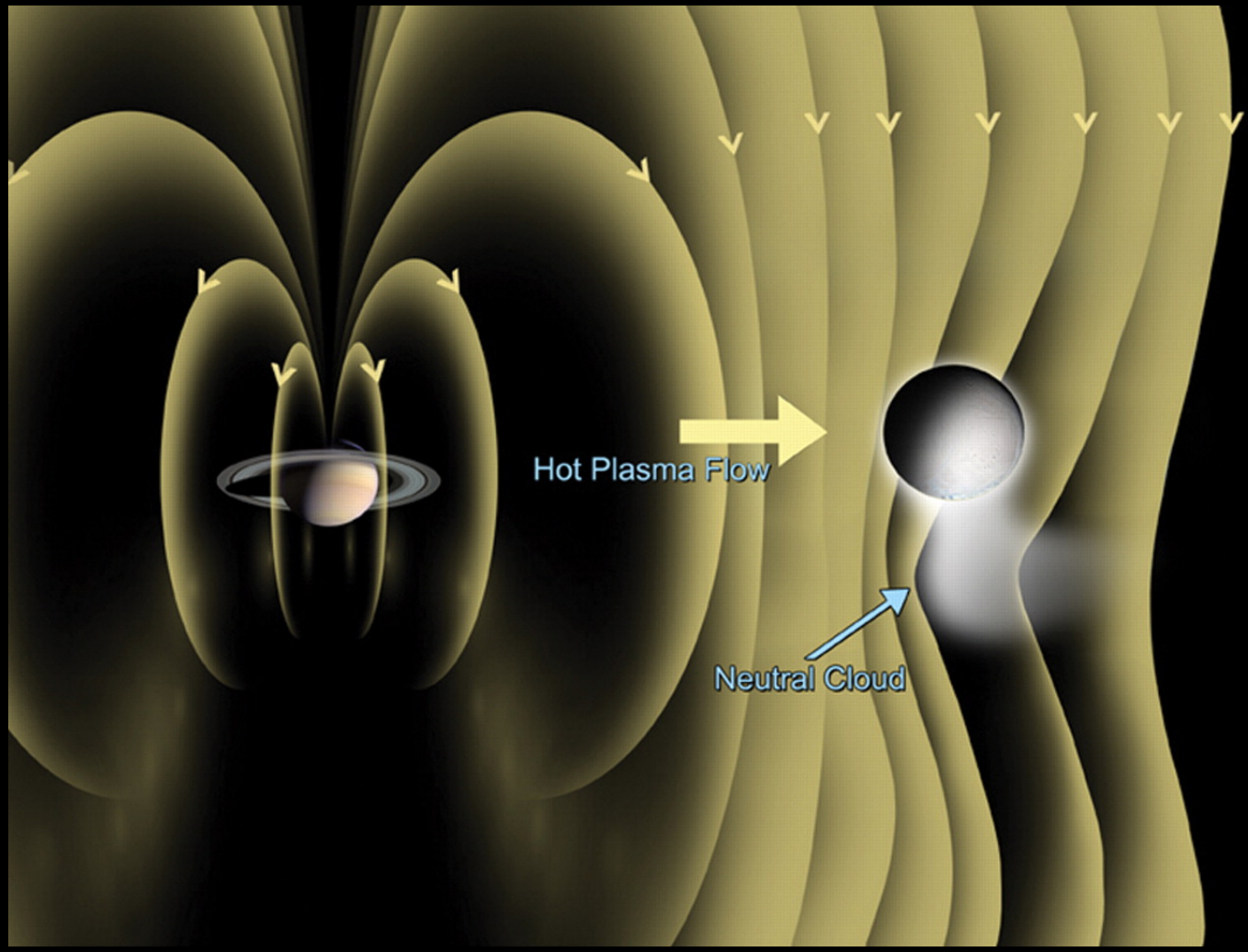
Enceladus





C. C. Porco et al., Science 311, 1303 - 1401 (2006)

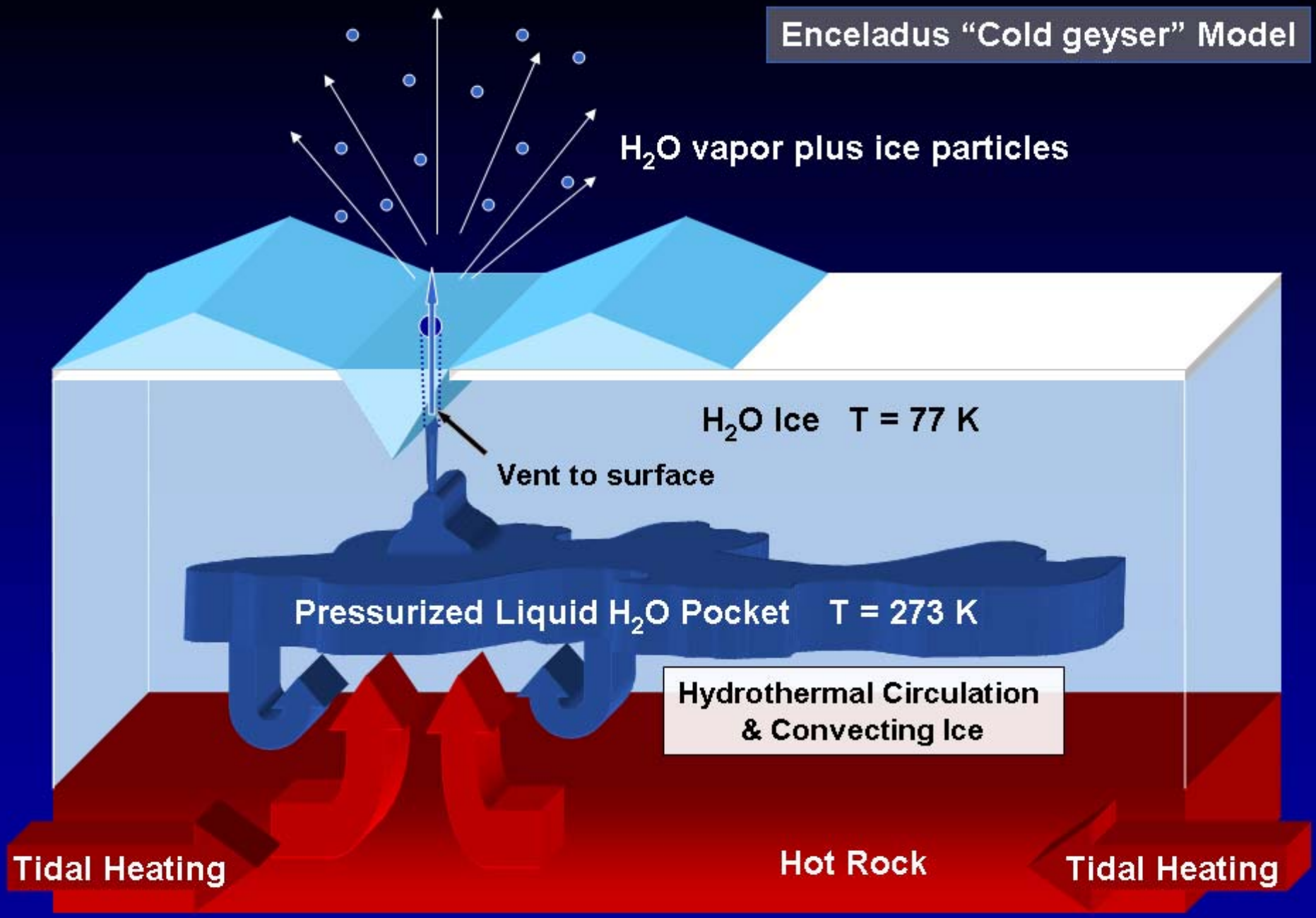
A schematic (Saturn and Enceladus not to scale) showing the corotating Saturn magnetic field and plasma being perturbed by the neutral cloud that is produced by a polar plume generated close to the south pole of Enceladus



M. K. Dougherty et al., Science 311, 1406 -1409 (2006)

Published by AAAS

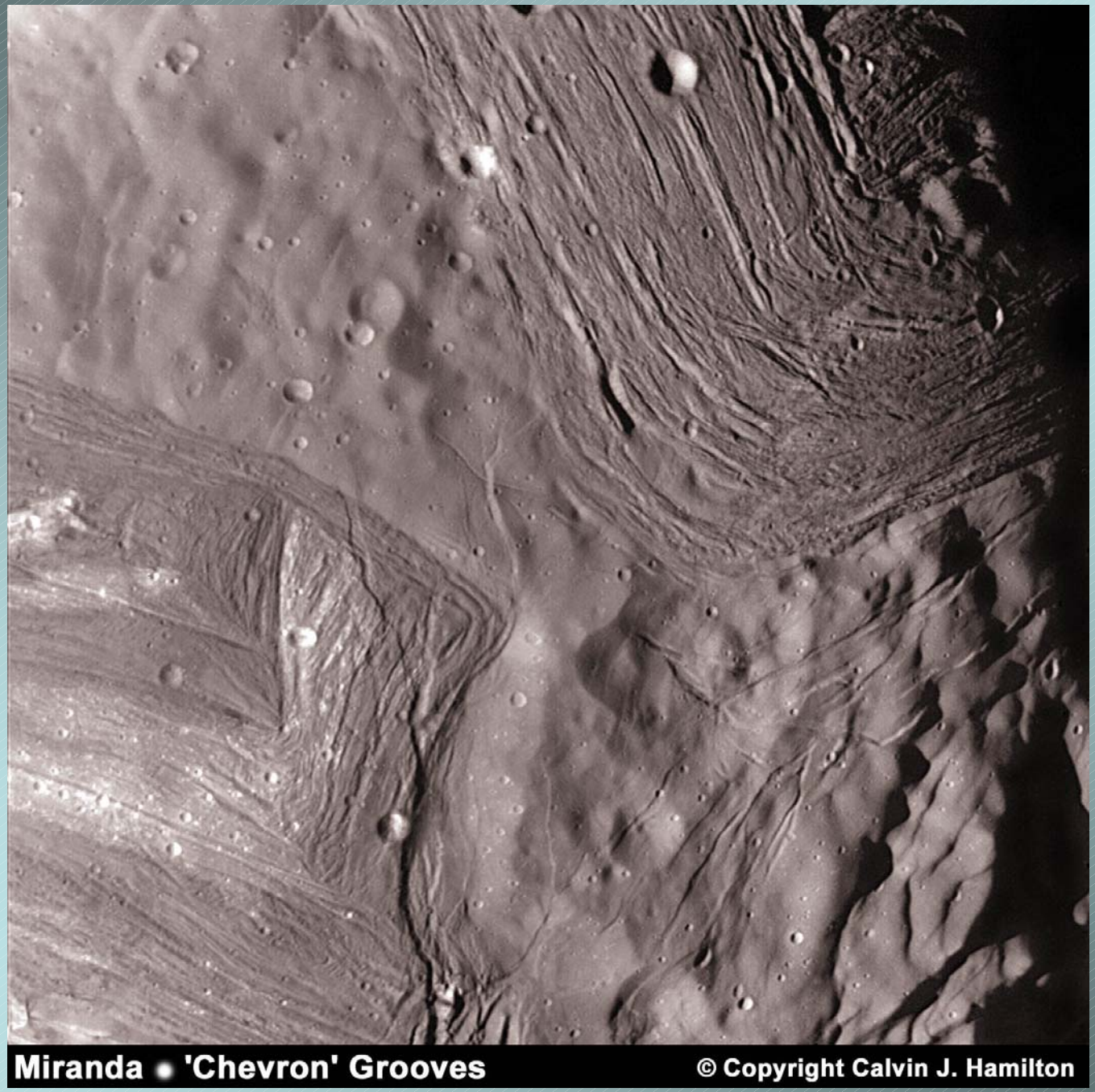
Courtesy Ingersoll



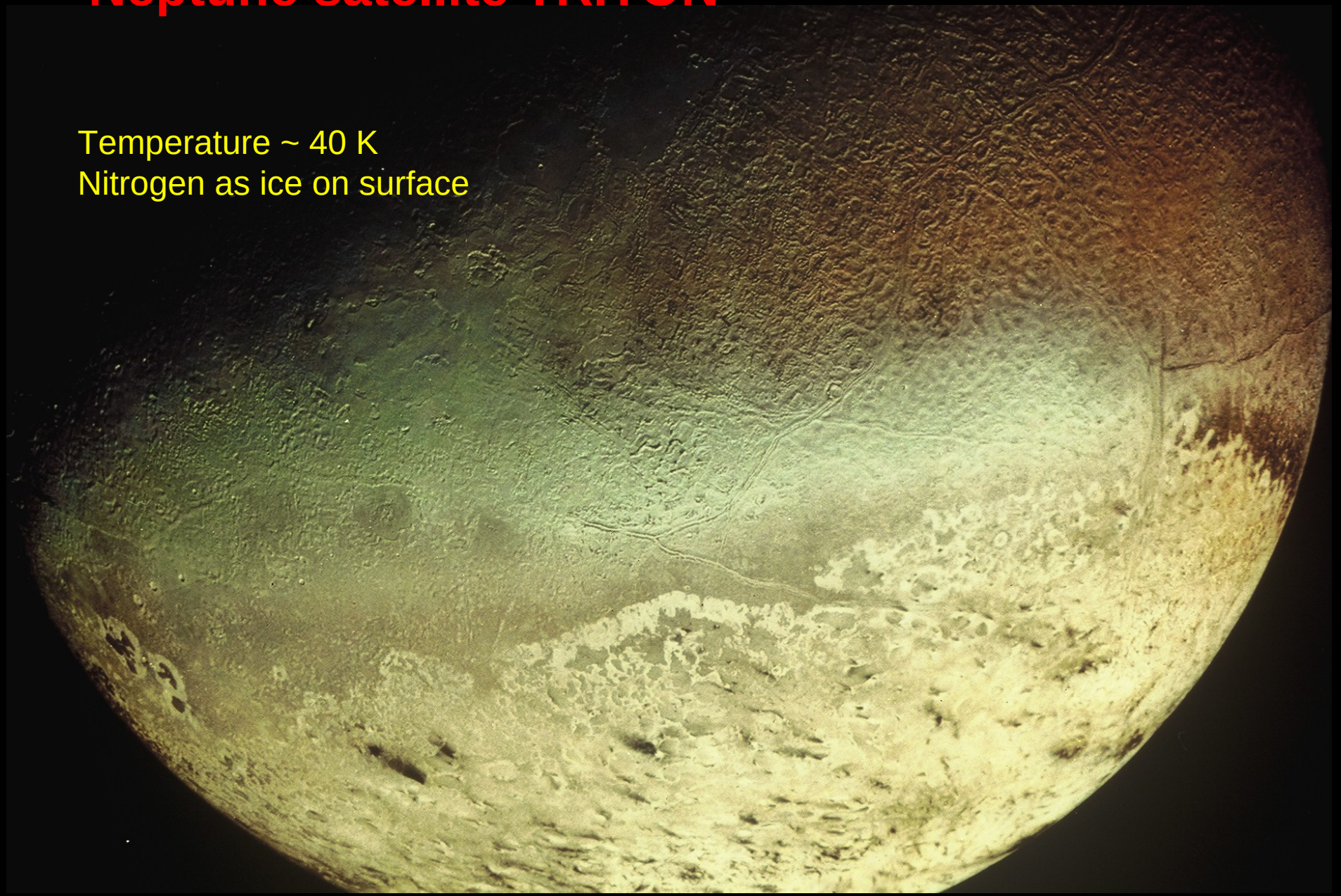
Courtesy Ingersoll

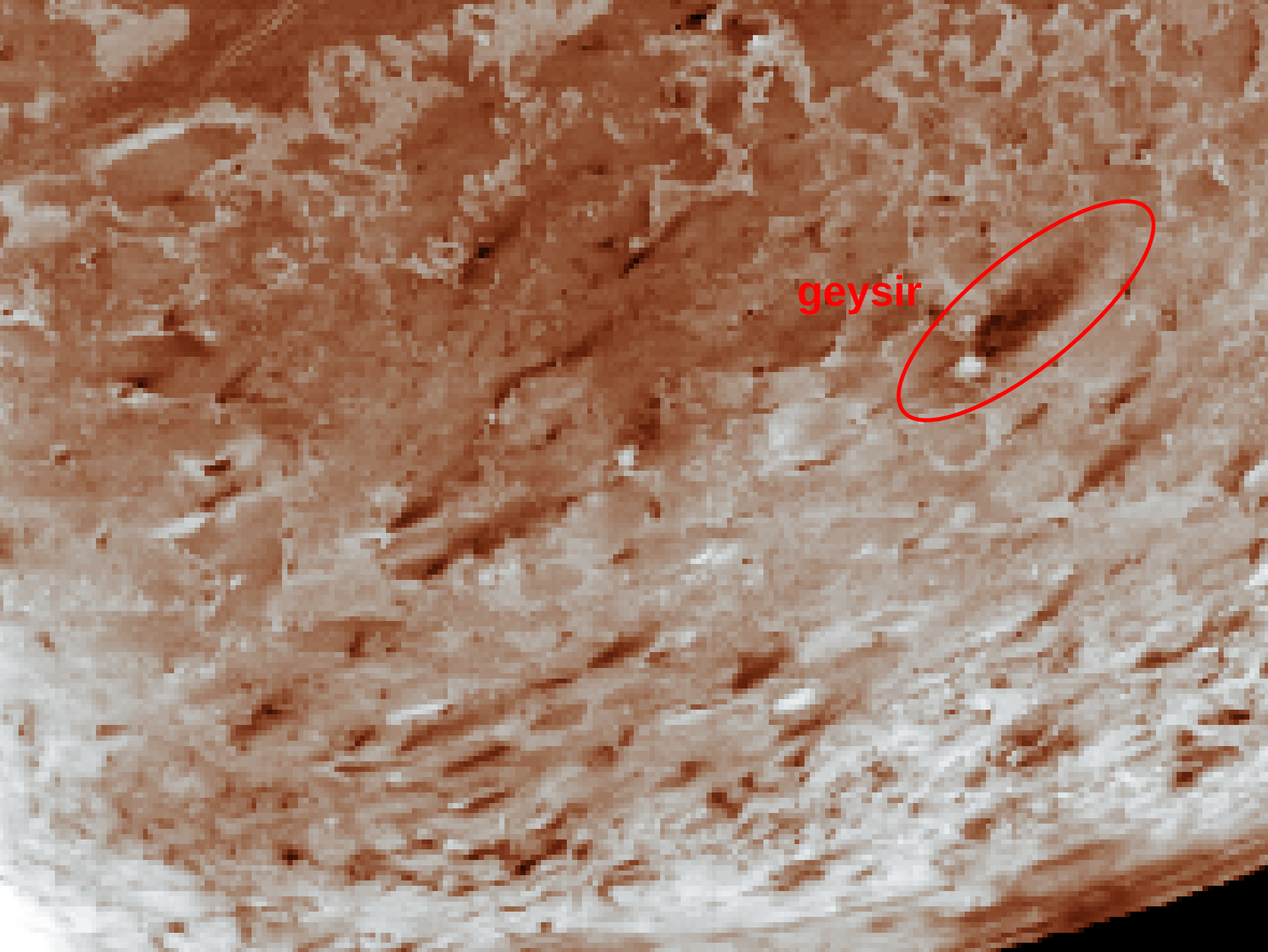
MIRANDA – Moon of Uranus

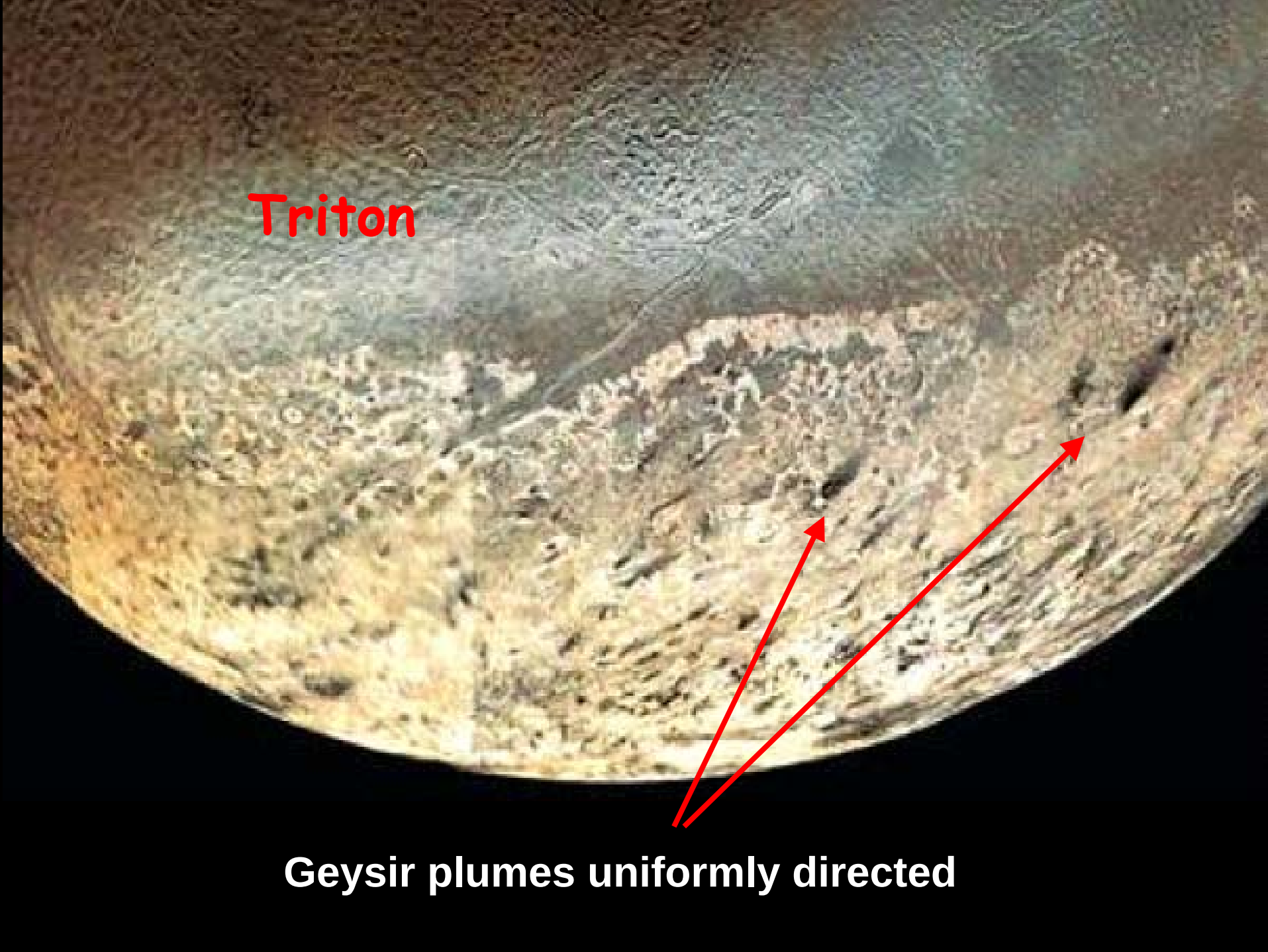
Miranda


Miranda • 'Chevron' Grooves
© Copyright Calvin J. Hamilton

Neptune satellite TRITON

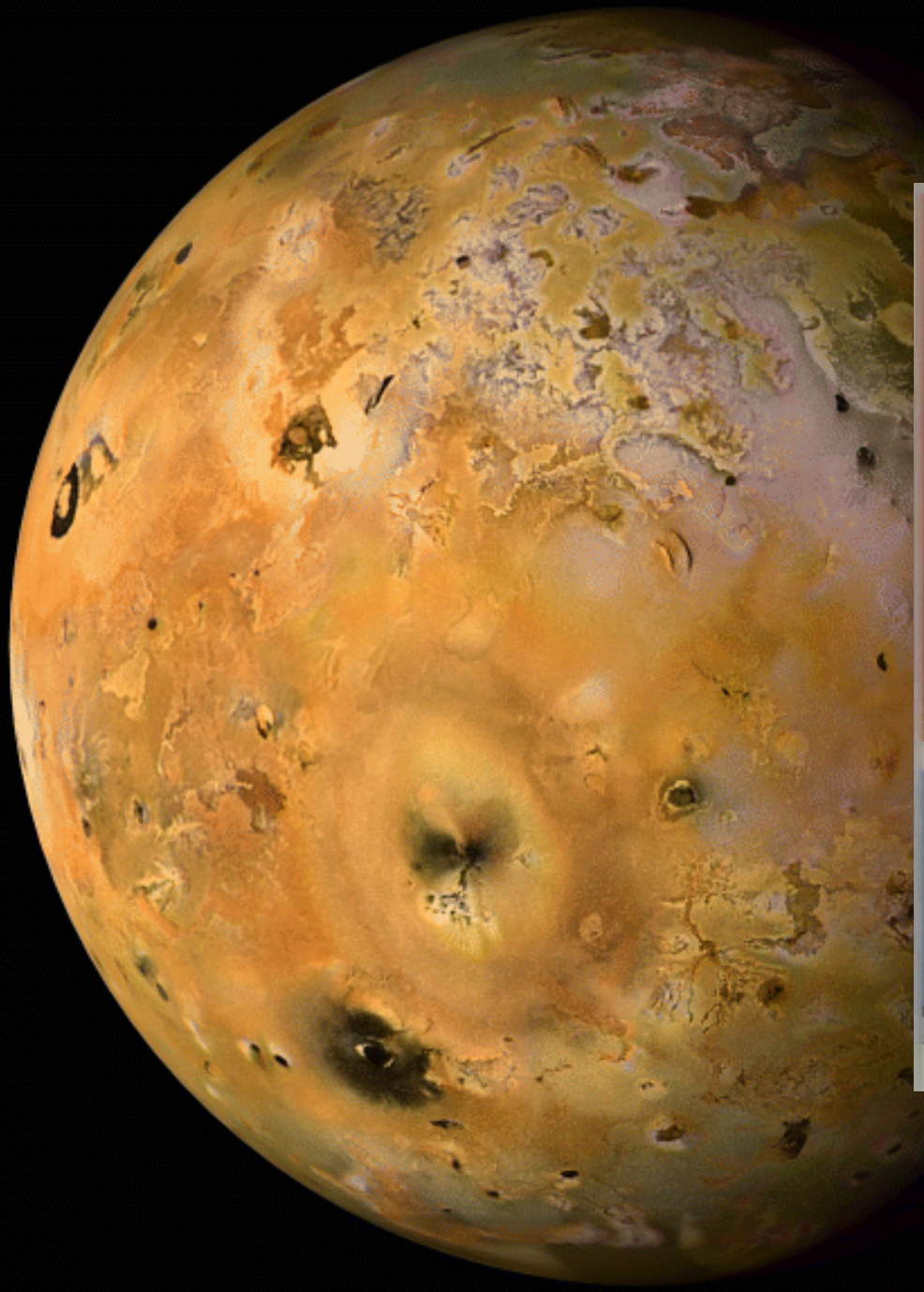


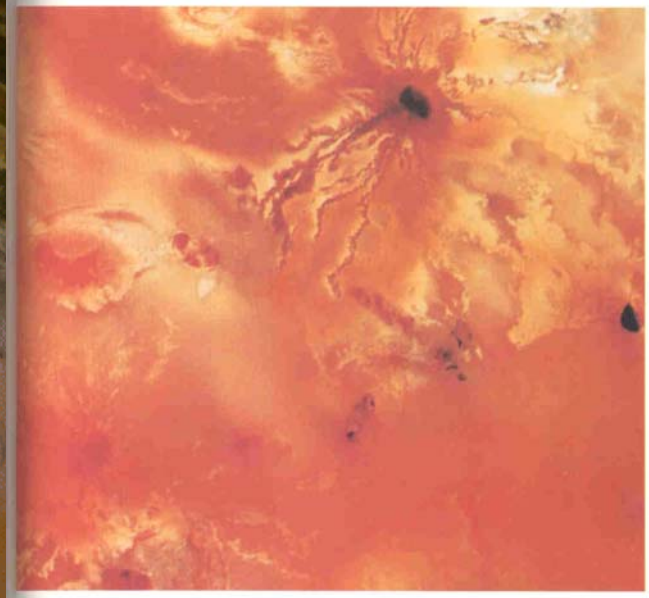

geysir


Triton
Geysir plumes uniformly directed

The Galilean Moons

Io Europa Ganymede Callisto





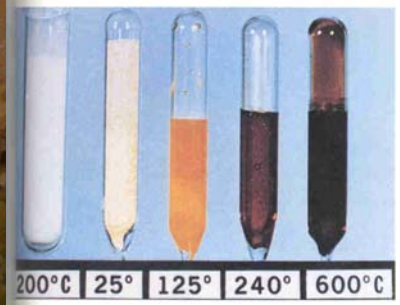


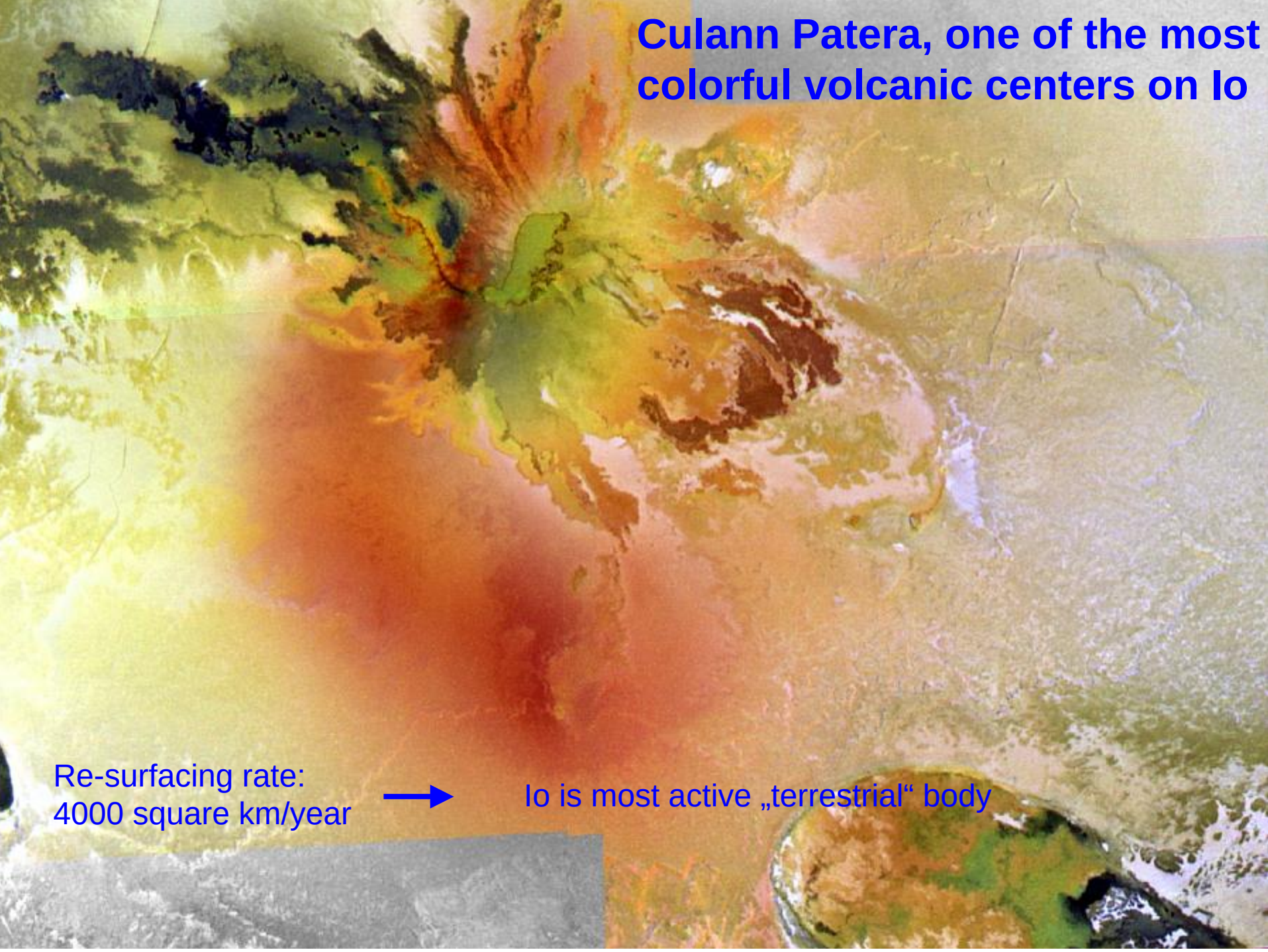
Plate 1a. *Above:* The colorful surface of Io near Ra Paterna, an equatorial volcanic feature at longitude 320°. Width of area shown is nearly 1000 km. Voyager 1 photograph: JPL P-21277C.

Plate 1b. *Left:* The color of elemental sulfur at various temperatures (see Chapter 7). Photograph courtesy of B. Meyer, Lawrence Berkeley Laboratory, University of California.

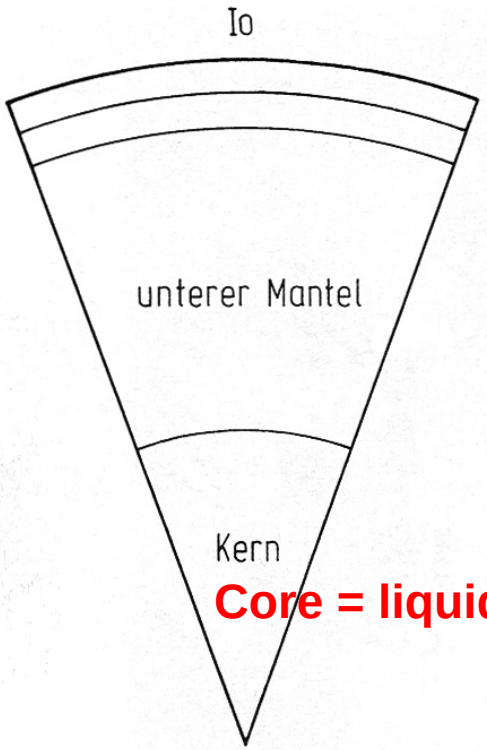
Potential V(r) of gravitational field

$$V(r) = G\frac{m_P}{r}\left(1 - \sum_{n=2}^{\infty}\left(\frac{R_P}{r}\right)^n J_n P_n(\cos\theta) + \sum_{n=2}^{\infty}\sum_{m=1}^{n} P_{nm}(\cos\theta)\left(\frac{R_P}{r}\right)^n (C_{nm}\cos m\lambda + S_{nm}\sin m\lambda)\right)$$

G … gravitational constant
mp.... mass
r…….distance from mass center
Rp….planetary radius
$J_n, C_{n,m}, S_{n,m}$ … coefficients to be determined
θ, λ ...planetocentric polar distance, longitude


Culann Patera, one of the most colorful volcanic centers on Io
Re-surfacing rate:
4000 square km/year
Io is most active „terrestrial“ body

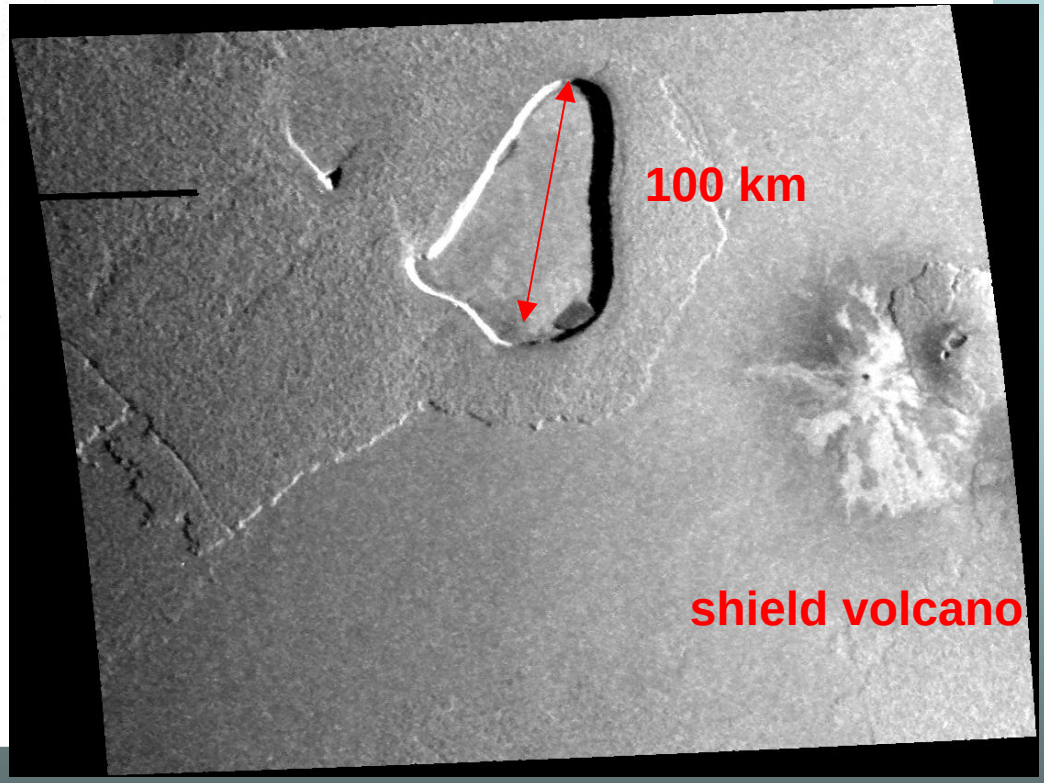
Interior of Io



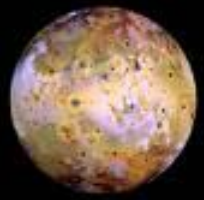
Lithosphere ~ 30 km

Core = liquid

central feature is a large volcanic depression



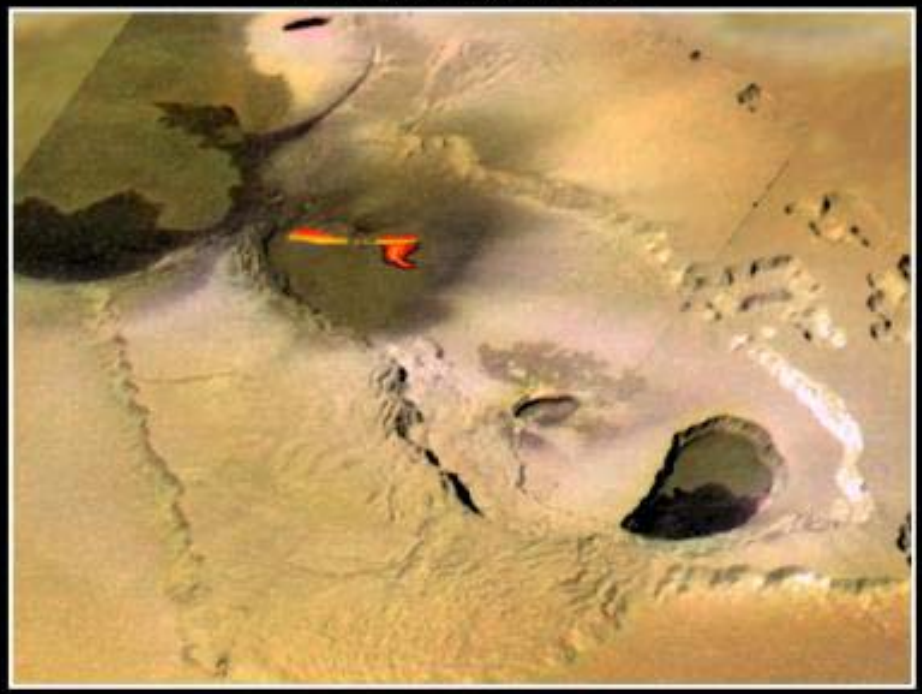
Active volcanism on Io



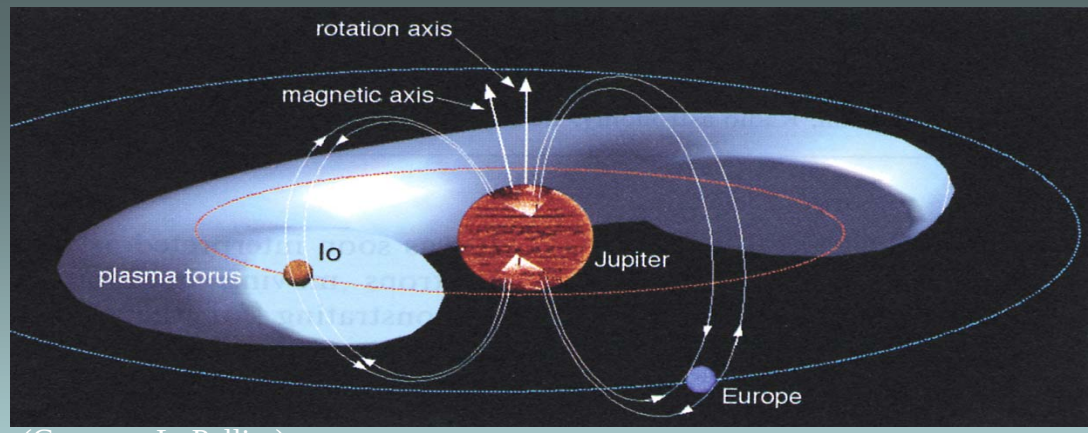
Io — Tvashtar Catena

I25 (26 Nov 1999)
+ C21 low-resolution color
+ fire fountain sketch

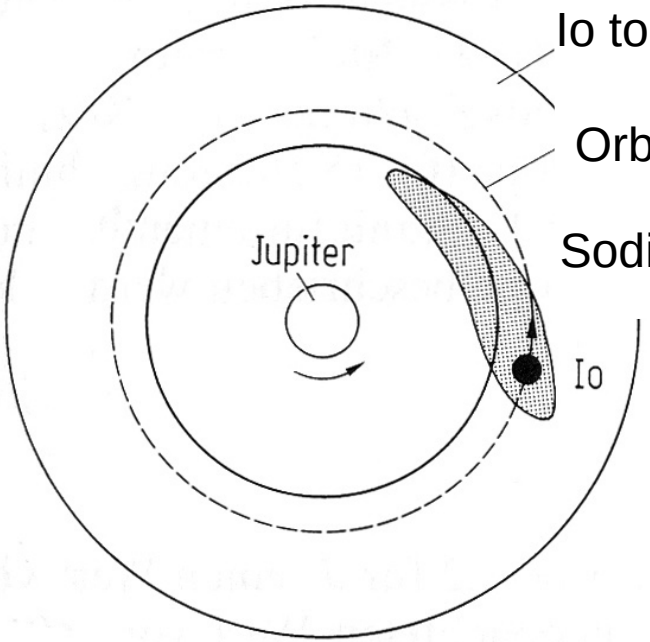
I27 (22 Feb 2000)
visible wavelength data
+ IR data of active lava flow



Io-Torus



(Courtesy L. Pallier)



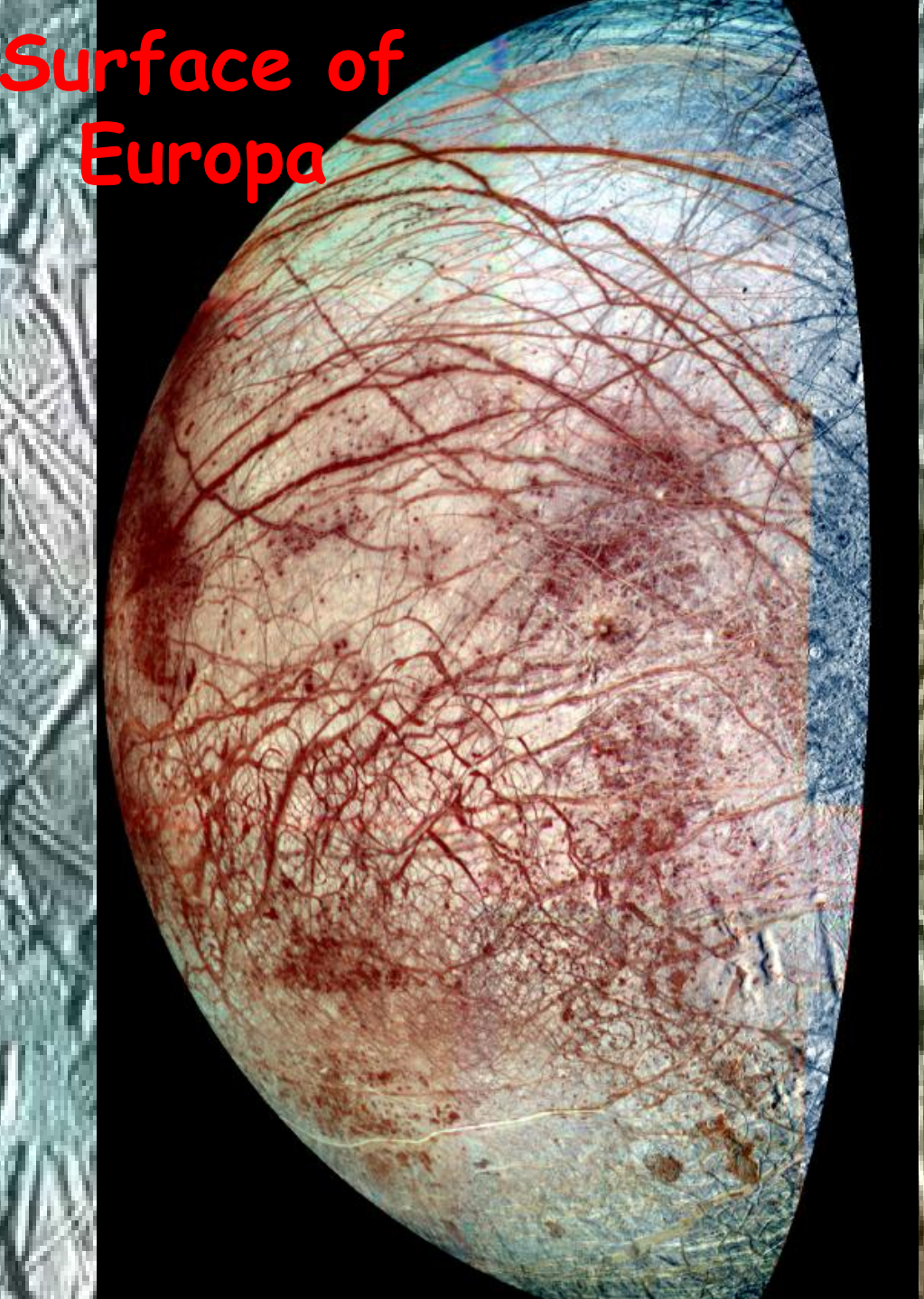
Voyager 1 observed 9 active volcanic geysirs.
Voyager 2 saw still 8 of them active:

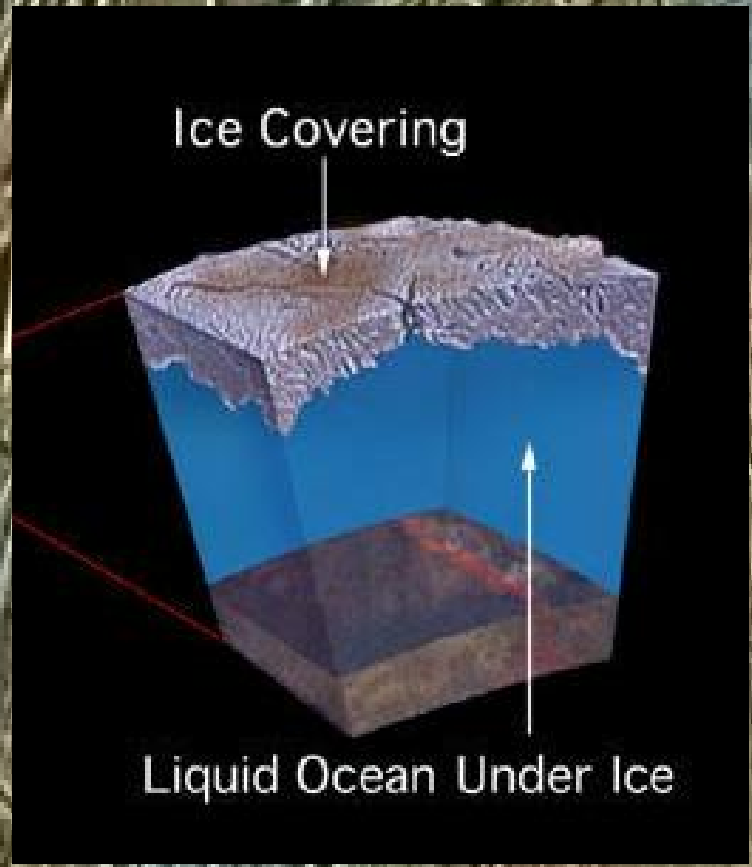
➔ Life time LT of geysirs
months < LT < years

Material ejection up to 200 km height,
ejection velocity ~ 0.5 km/s

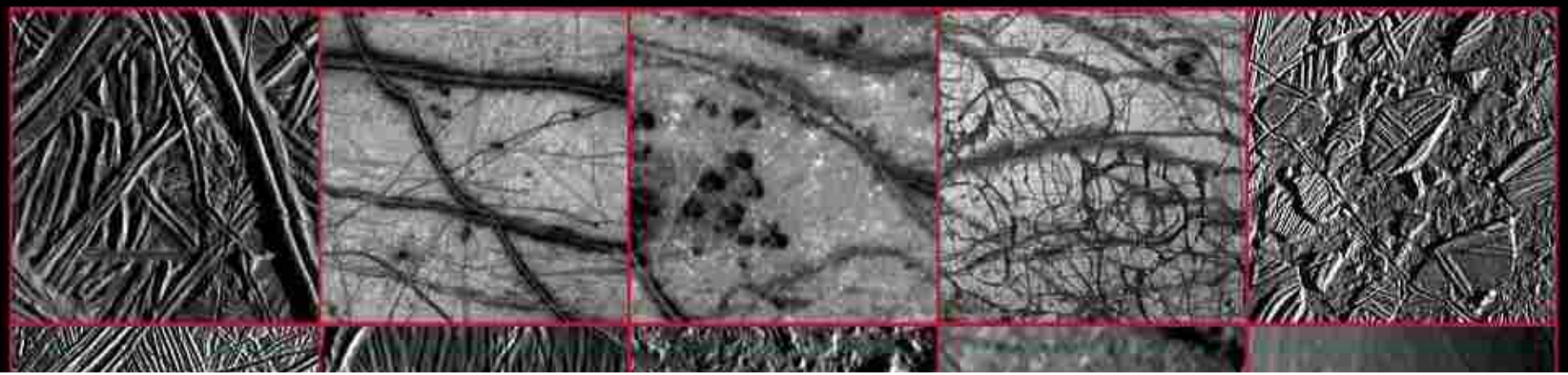
Ganymede

Surface of Europa

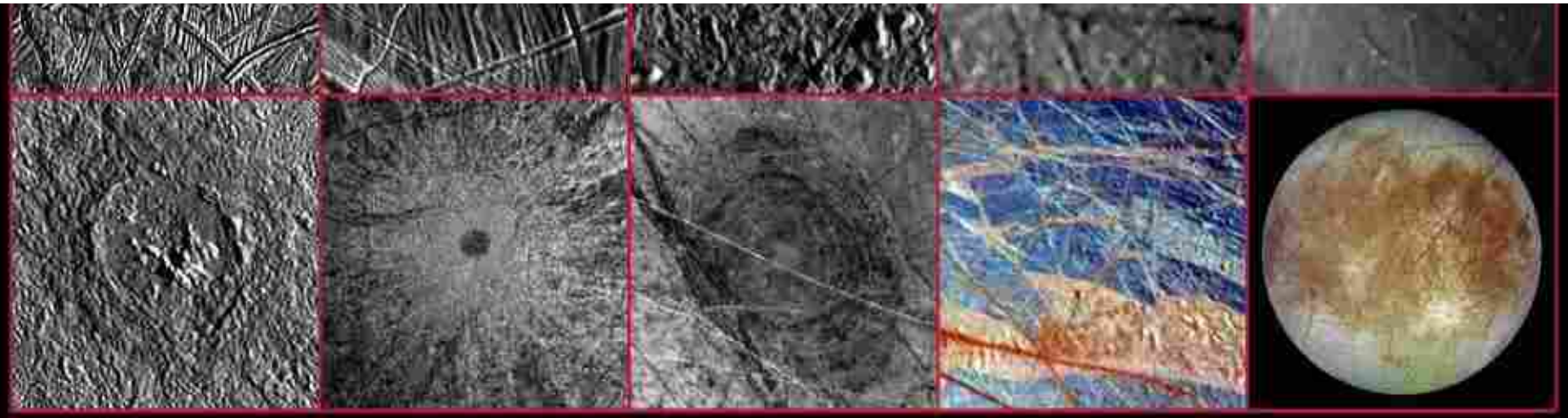




Europa



Probably the destination of an ESA-, NASA mission



Exploring the Planets and Moons in our Solar System

Thank you for your attention !