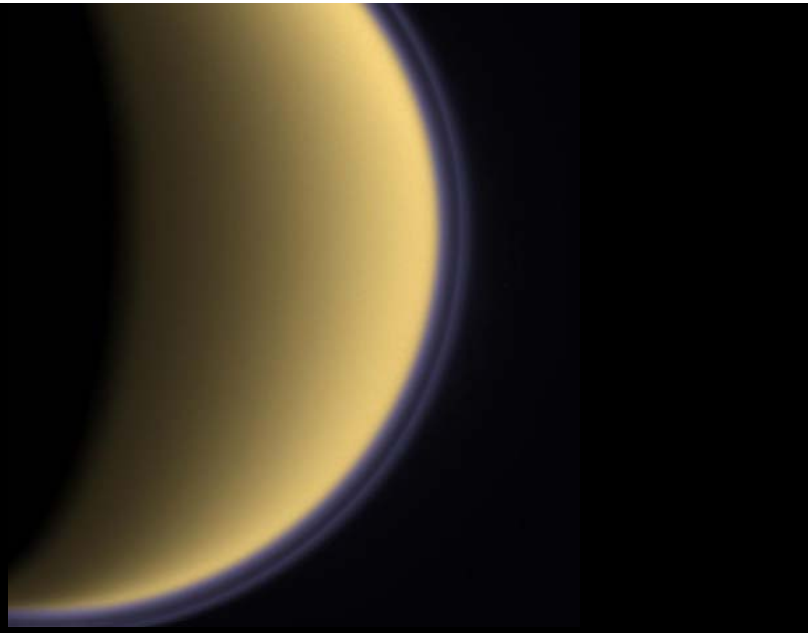
Exploring Hazy Titan with Cassini-Huygens

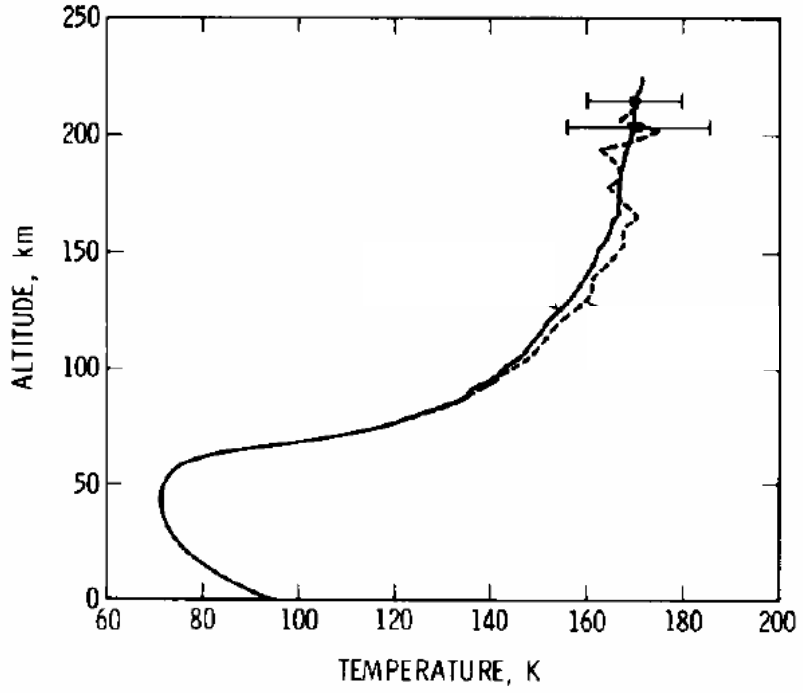
Jonathan I. Lunine
Interdisciplinary Scientist on Cassini/Huygens

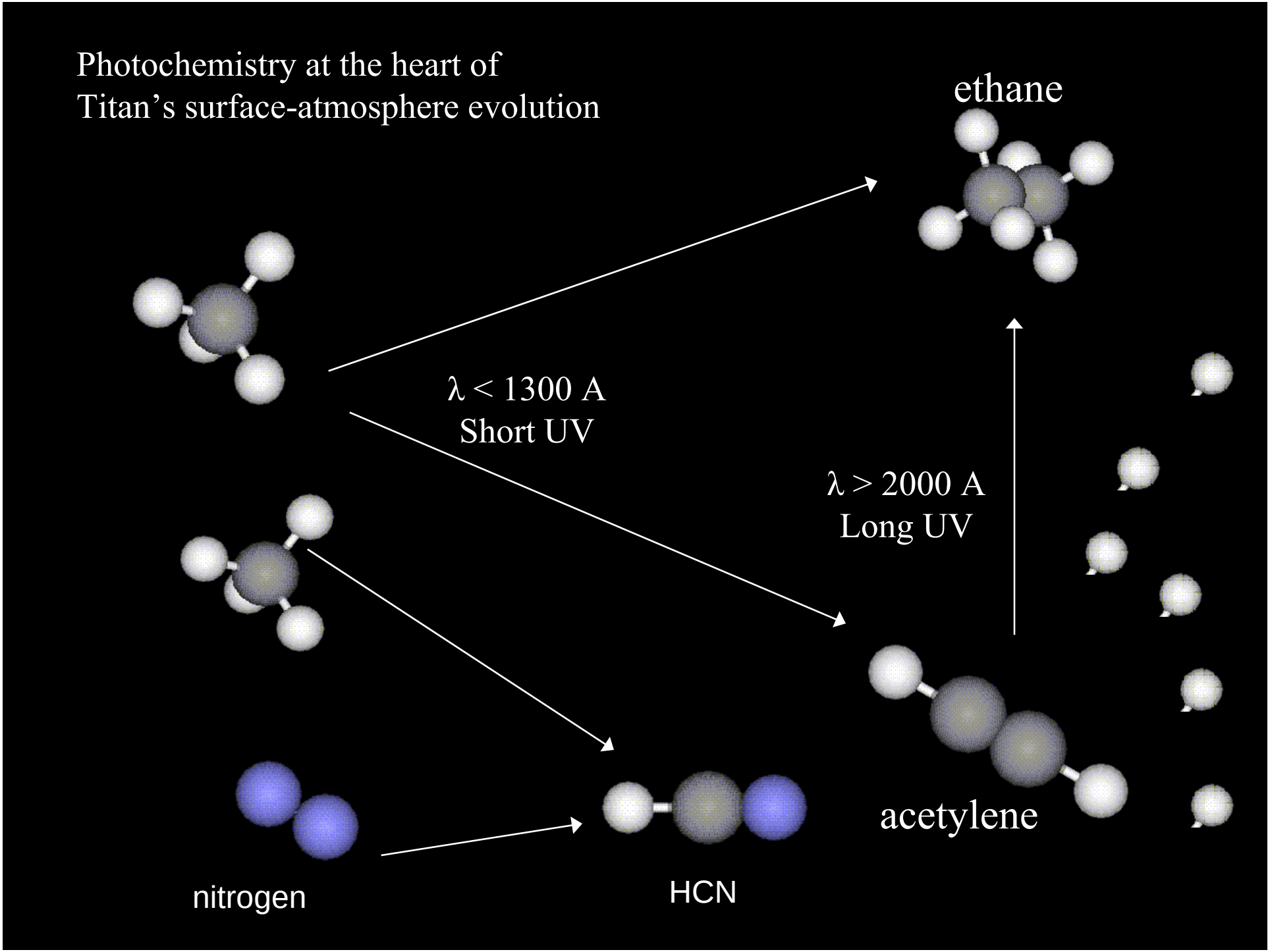
Binational Optics Symposium
Tucson AZ, USA
April 1, 2005

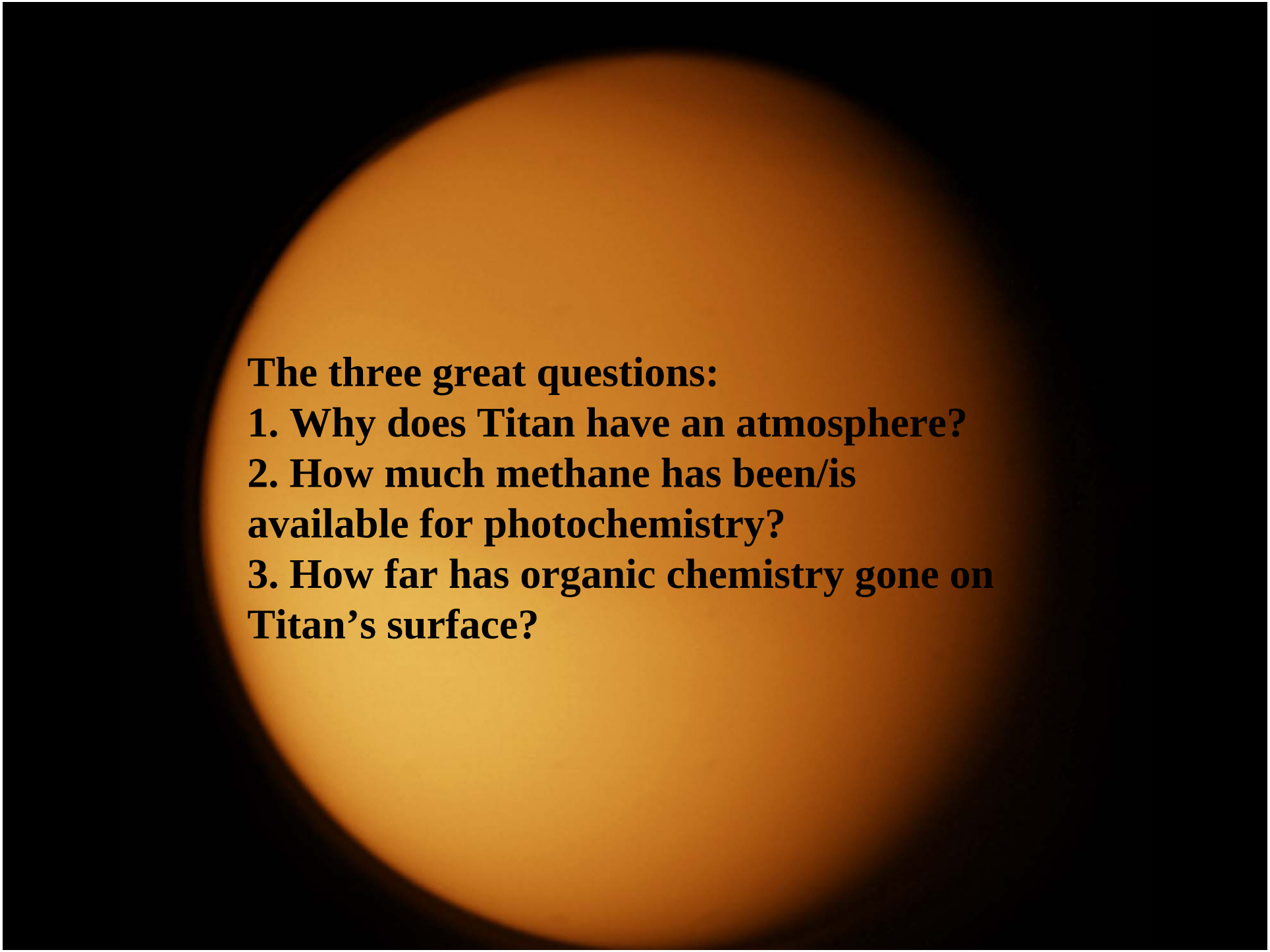
Titan is…



- …a natural satellite of Saturn.
- … same size, mass as Ganymede and Callisto
- … the second-densest atmosphere of the solid bodies of the solar system—nitrogen-methane composition → organic chemistry.
- Surface pressure 40% more than Earth. Temperature – minus 180 C
- Methane 5% near-surface, 1.8% in stratosphere.
- Target of 42 more Cassini flybys and the successful Huygens probe descent




Photochemistry at the heart of
Titan's surface-atmosphere evolution
ethane
λ < 1300 A
Short UV
λ > 2000 A
Long UV
acetylene
nitrogen
HCN

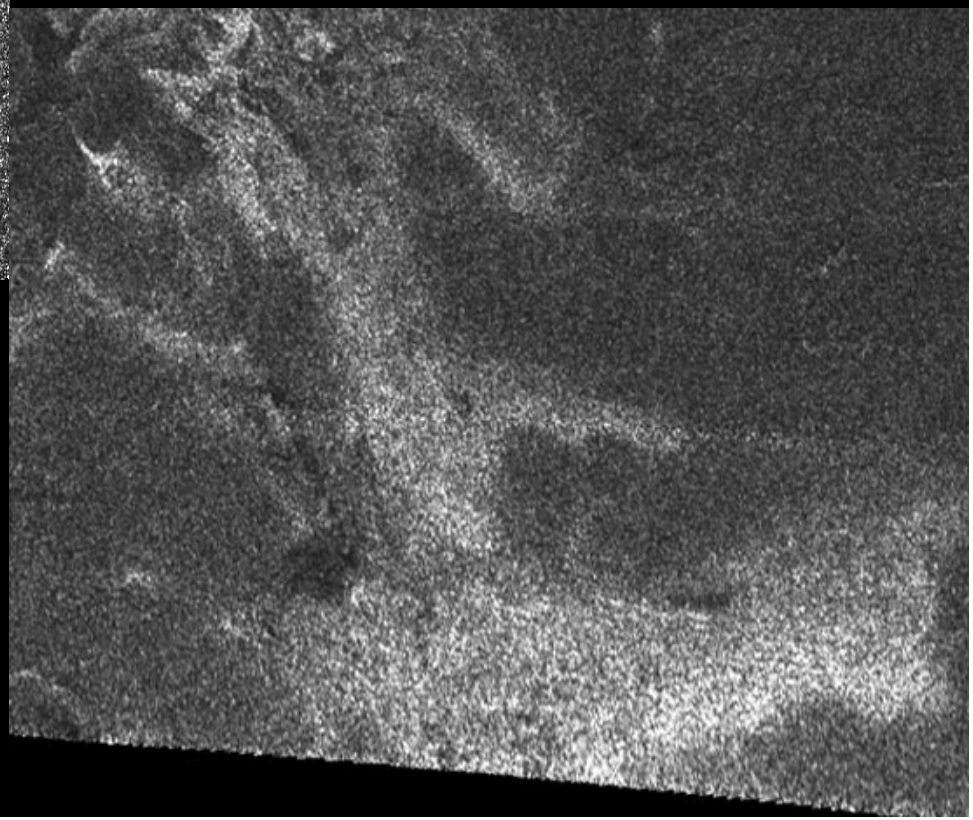

The three great questions:
1. Why does Titan have an atmosphere?
2. How much methane has been/is available for photochemistry?
3. How far has organic chemistry gone on Titan’s surface?

Cassini-Huygens:

A US-European collaboration: NASA/ESA/ASI

Volcanism

The feature below looks like a basalt flow, but cannot be lava—must be “cryo”-lava…water or water-ammonia.



Data from Ta (October 04)
Smallest features ~ 500 meters

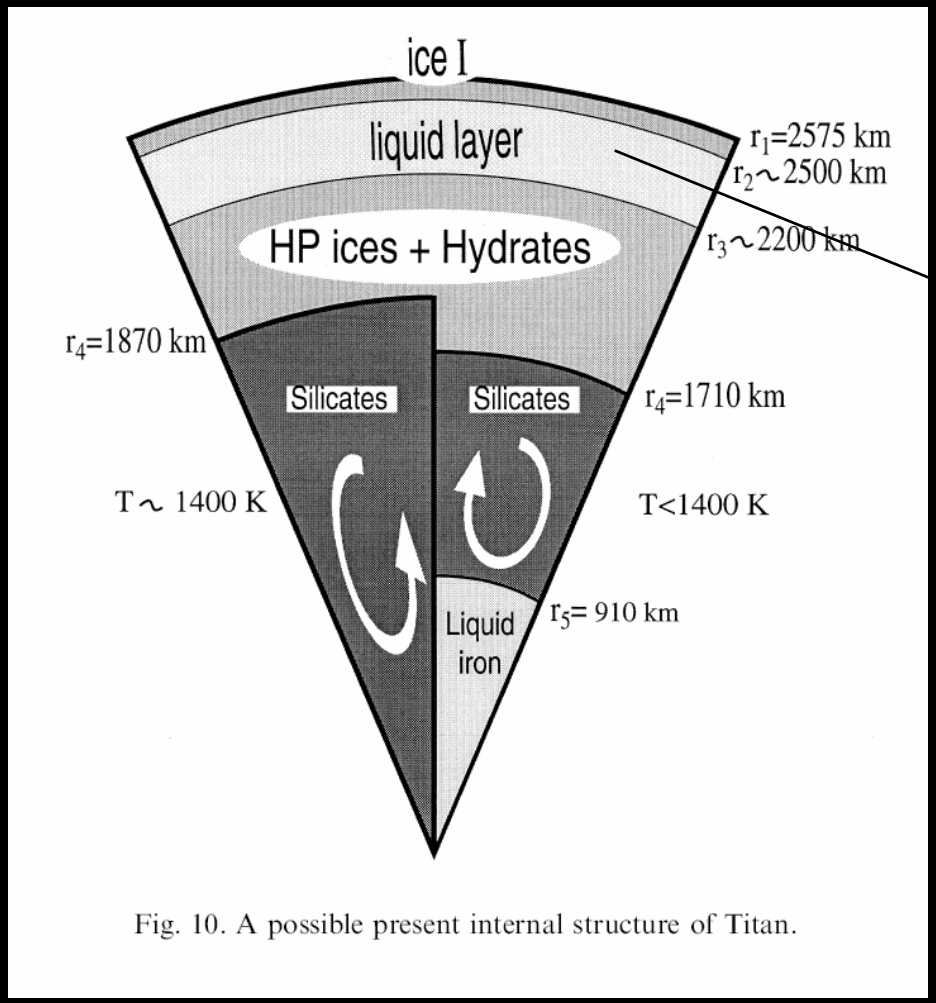
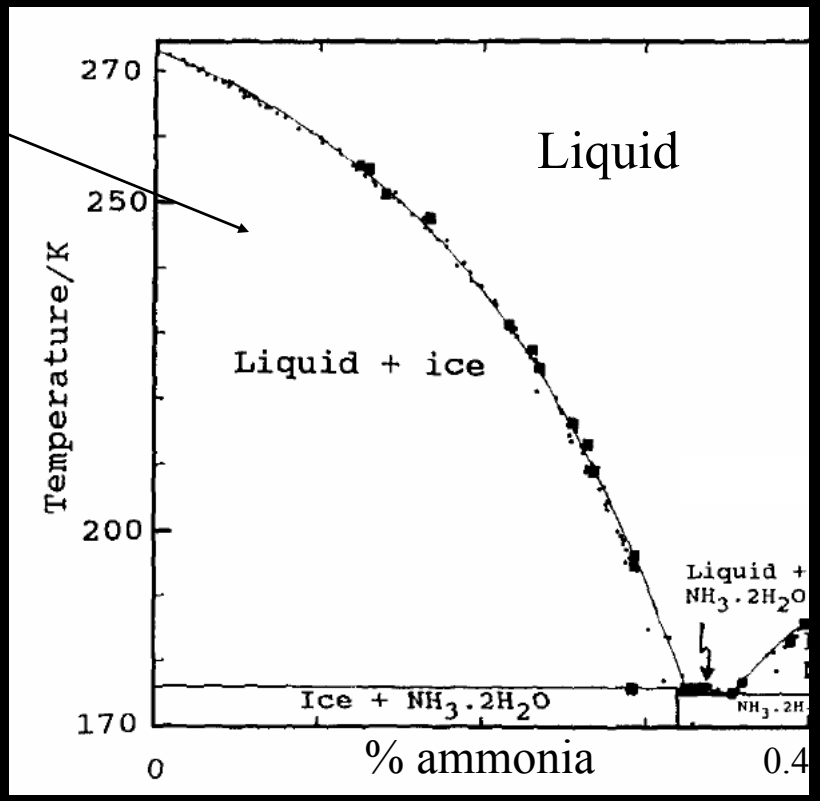
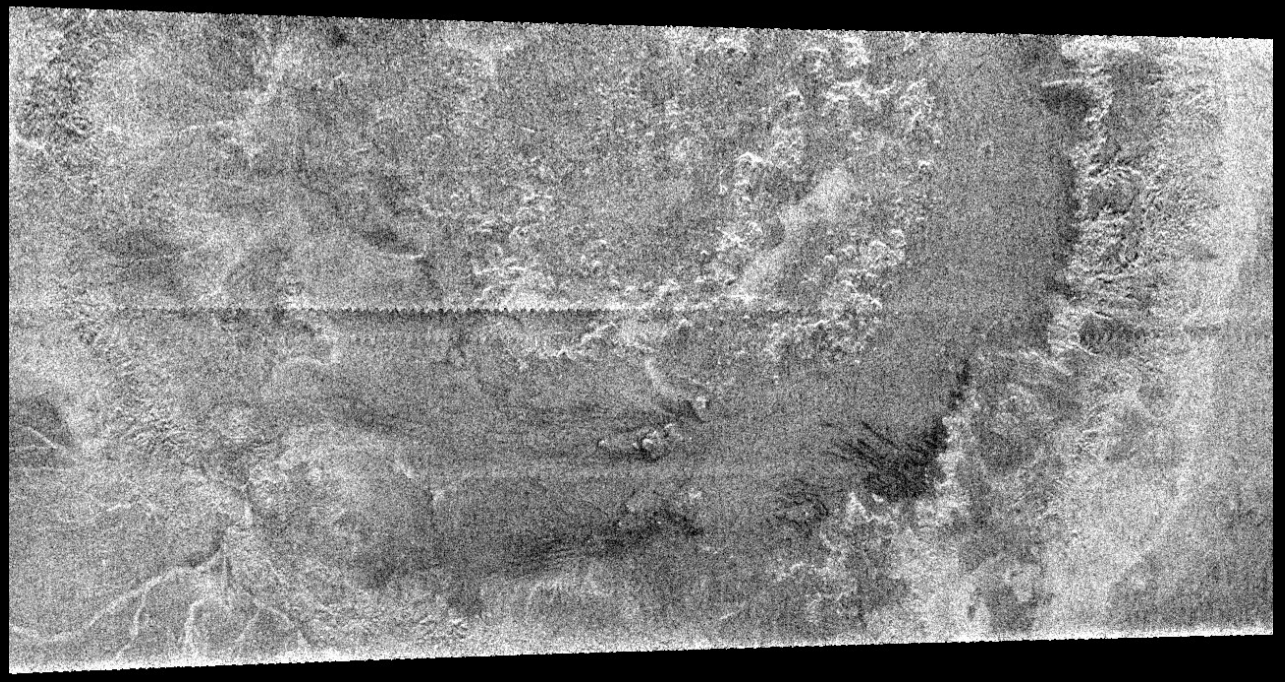


Fig. 10. A possible present internal structure of Titan.

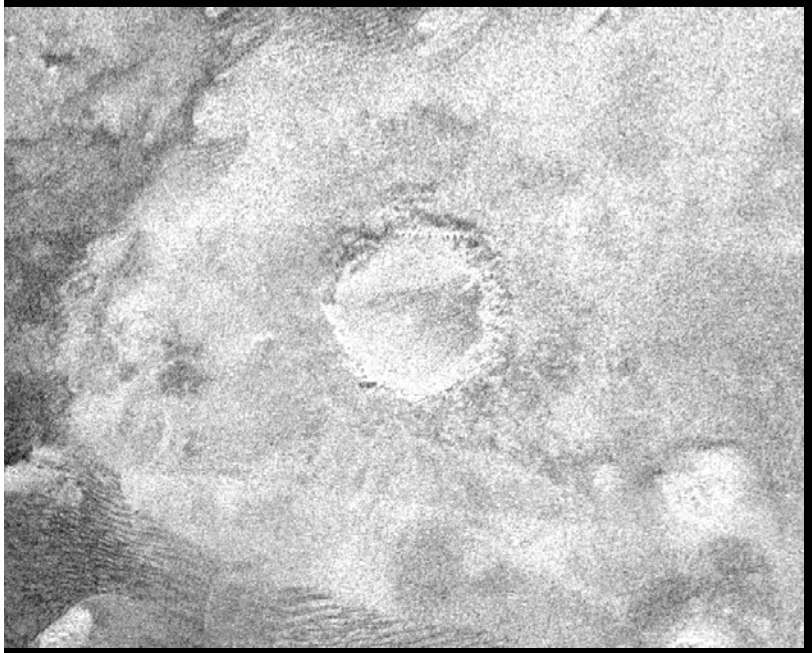


Ammonia lowers the melting point, density and mobility of liquid water

Impact craters are seen in the most recent radar data. But the surface is still lacking in craters relative to the other Saturnian satellites, Moon, Mars etc.



~450 km



~80 km

Heat flow on Titan is about 8% that on the Earth. With typical volcanic efficiency this implies a maximum cryovolcanic resurfacing rate 10 times the rate of deposition of hydrocarbons.

The evidence for ammonia as a key player in Titan's evolution

•Radar bright areas suggest internal activity and cryo-volcanism, implying both a liquid layer in the interior and an agent to lower the melting point, density and mobility of liquid water.

•There are few craters on the surface. Those < 10 km are not expected even on an ancient surface, but there is a dearth at all scales.

•Chemical evidence from two mass spectrometers on Cassini and Huygens: Non-radiogenic argon is not detected to at least 10 ppm by Orbiter INMS *and* Huygens GCMS. Owen (1982):

- •$Ar/N_2 > 10\%$ (1%): Titan's atmosphere came in as N_2
- •$Ar/N_2 << 1\%$: NH_3 is the source of the atmosphere: $2NH_3 \rightarrow N_2+3H_2$

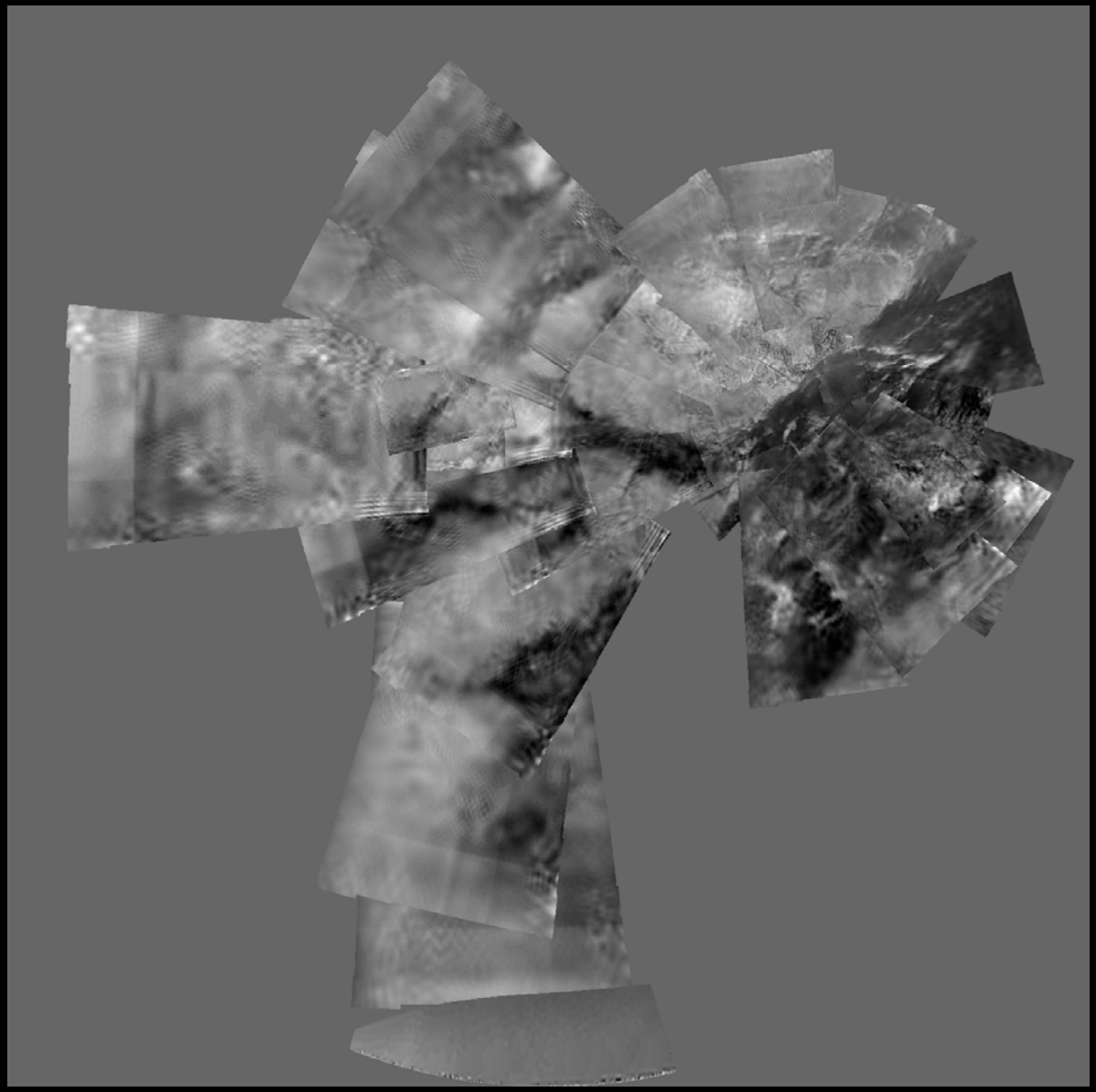
THE PRESENCE OF AMMONIA ANSWERS QUESTION 1

PROBE RELEASE December 24, 2004
PROBE DESCENT January 14, 2005

The probe was designed only for the atmospheric descent, with the possibility of another 3-30 minutes of transmission on the surface. The probe returned over 80 minutes of data on the surface.

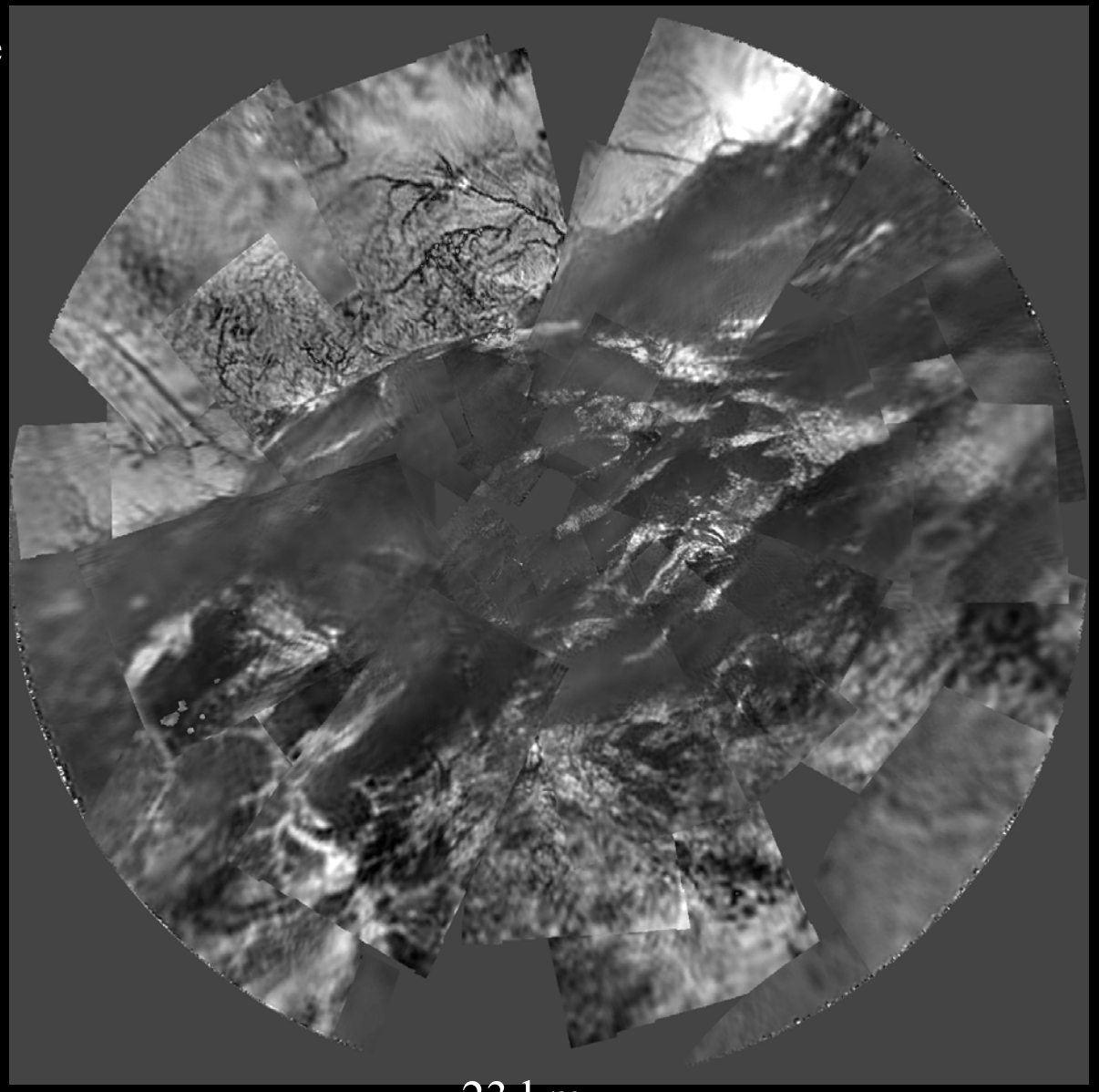
Descent Imager and Spectral Radiometer images during descent.

35 km altitude



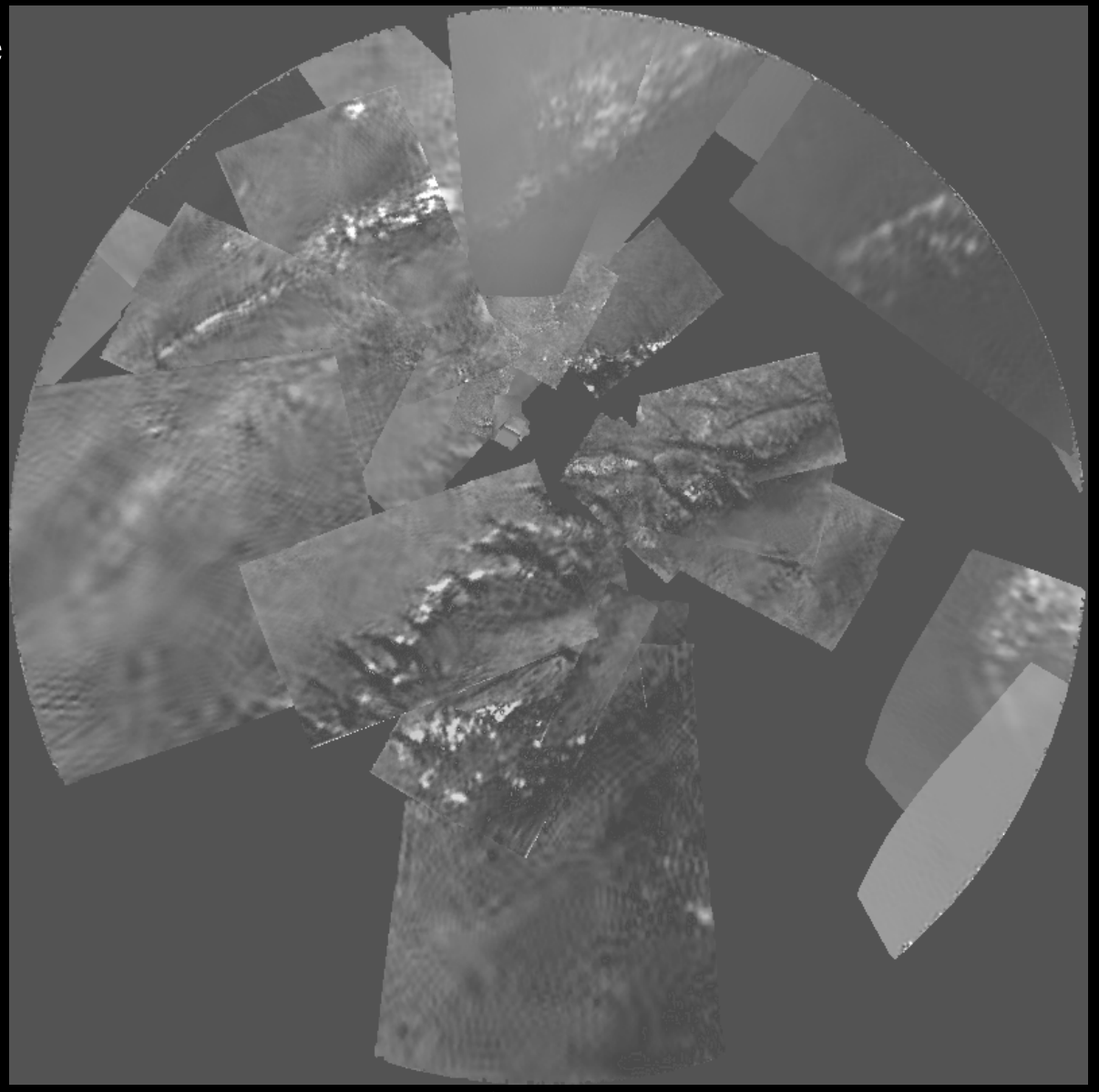
100 km

8 km altitude



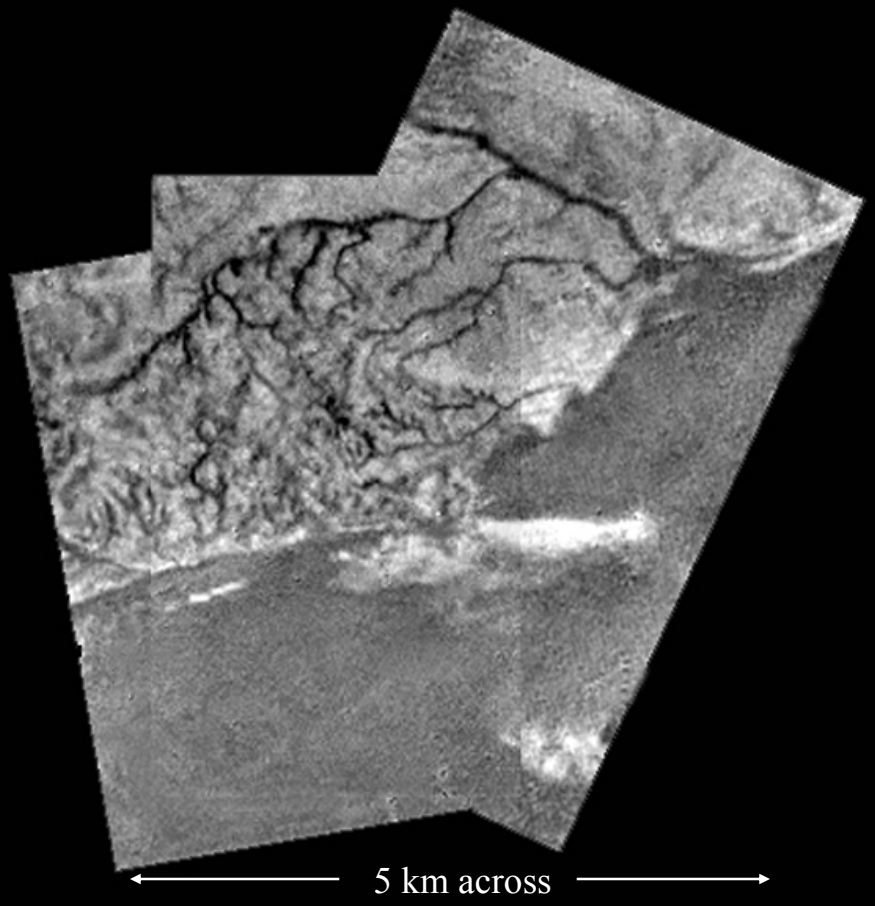
23 km

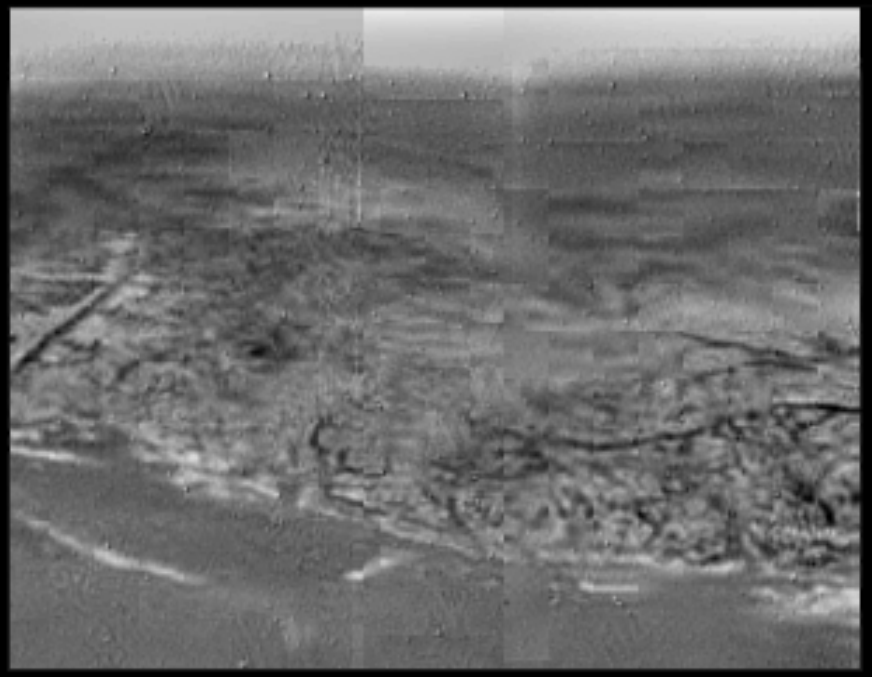
1 km altitude



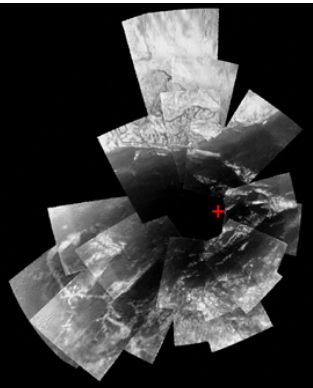
3 km

Haze and cloud scatter photons, reduce contrast and resolution

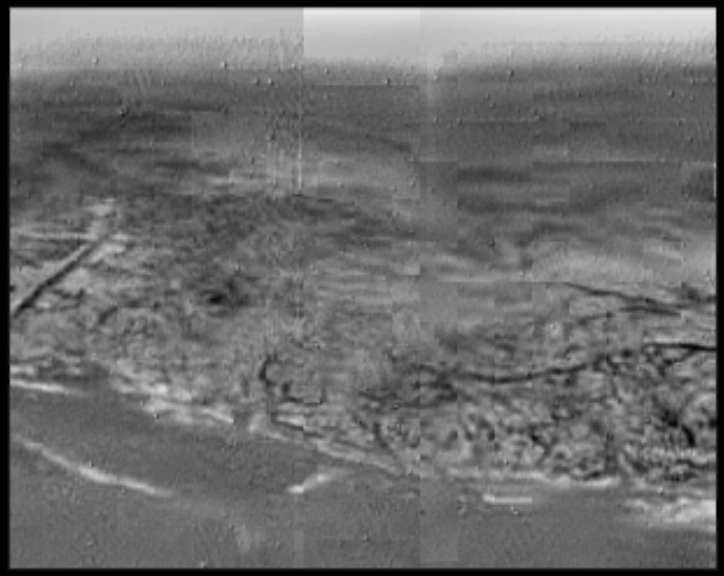


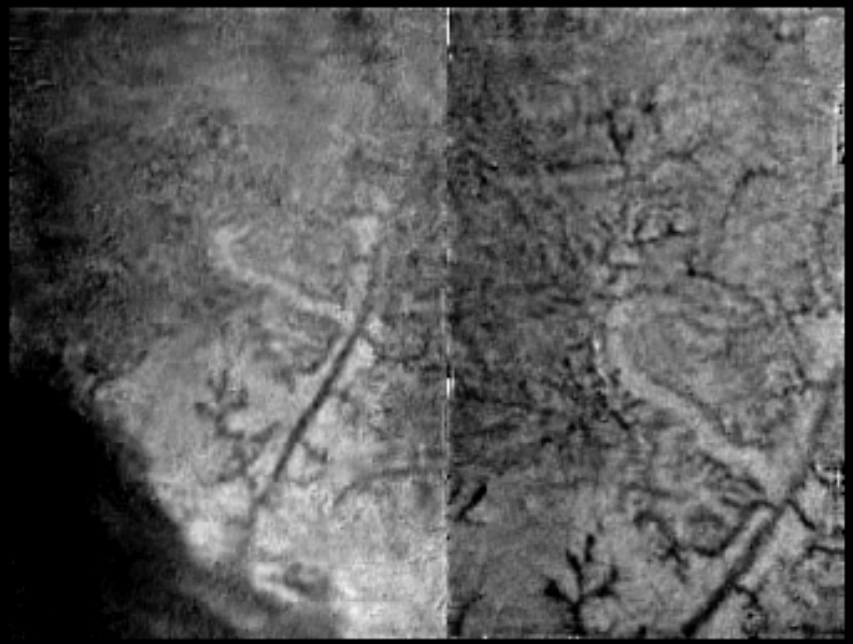


Complex, dendritic patterns carved by liquid methane and shaped by topography. Some of the patterns imply rainfall; others could be liquid methane liberated from subsurface. Structural patterns suggest tectonic control.



Different styles farther west. Evidence of NH_3-H_2O cryovolcanism? Stubby networks suggest spring sapping.

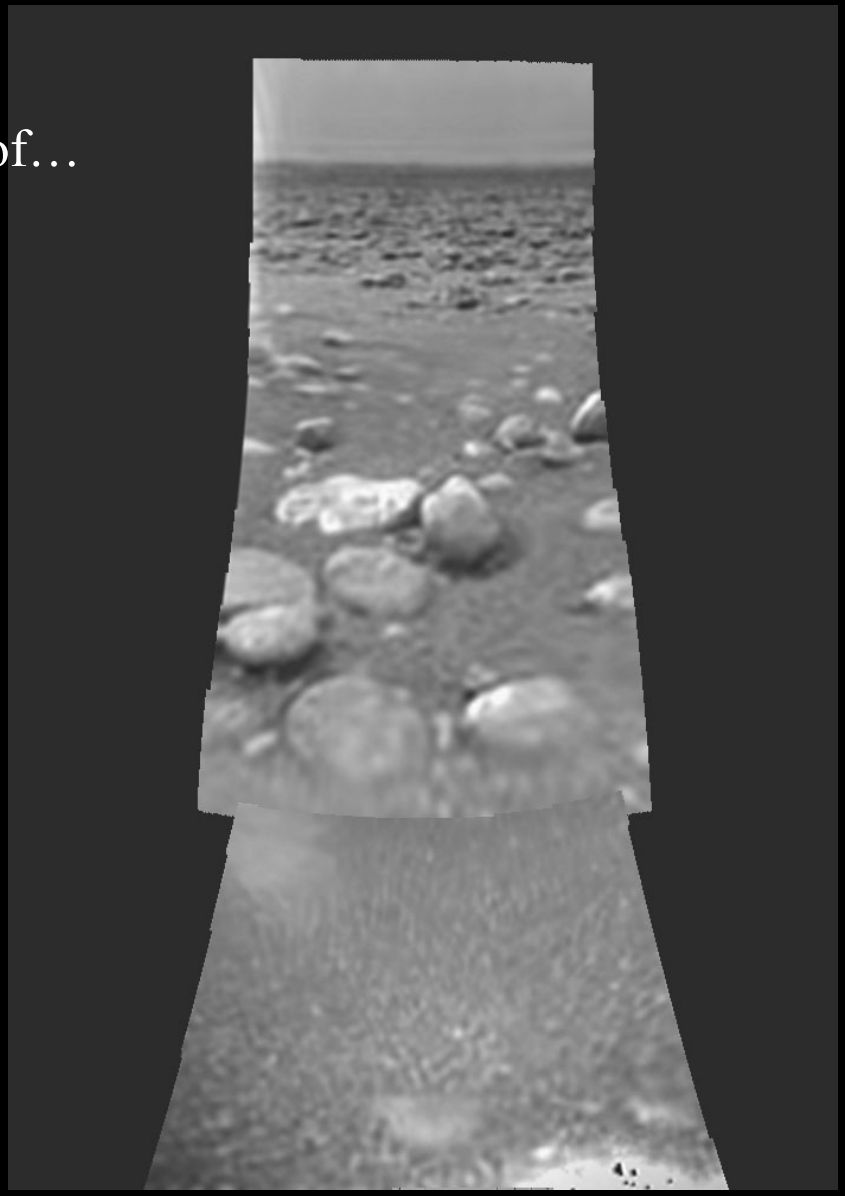




4x6 km wide frame

At the surface:

10-20 cm pebbles of…



Methane detected at surface

Other Possible Species:

^{40}Argon

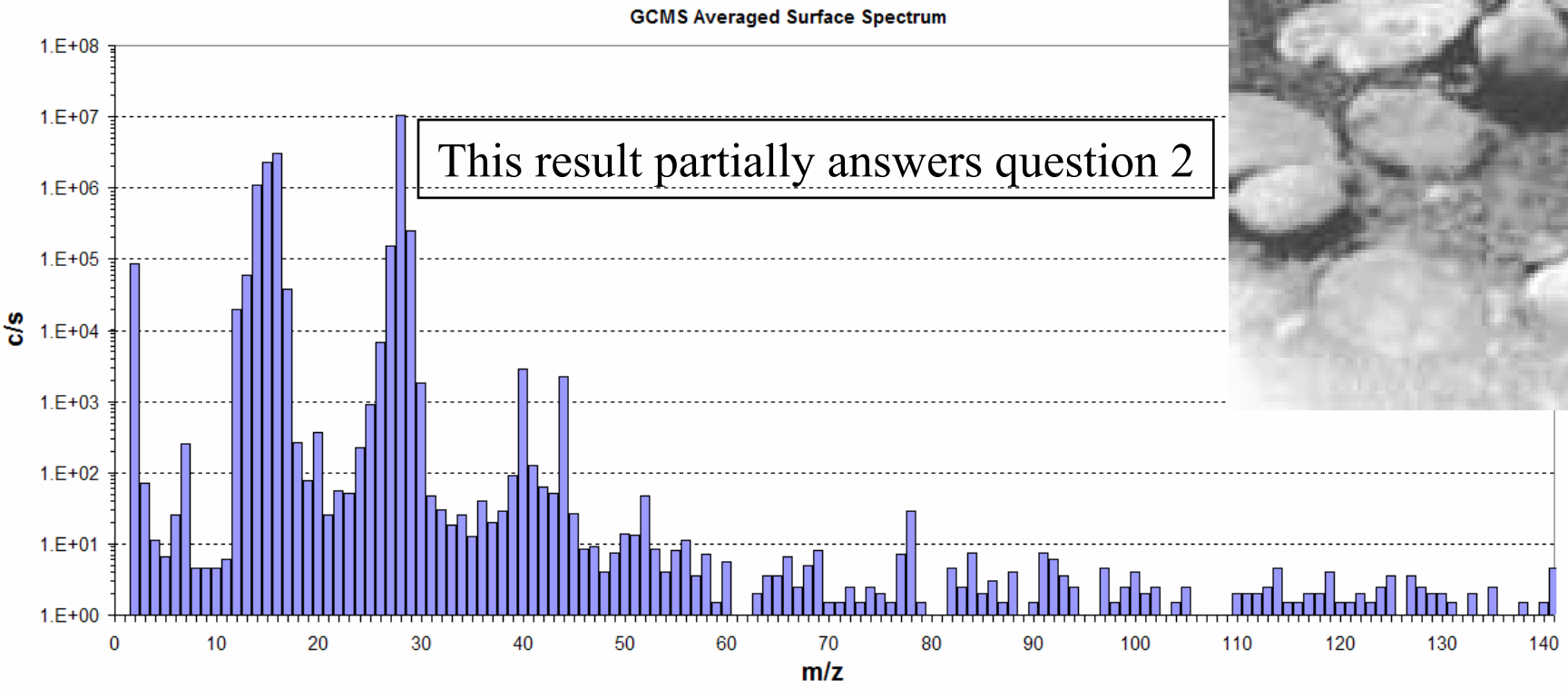
Ethane (C_2H_6)

Ethanedinitrile (C_2N_2)

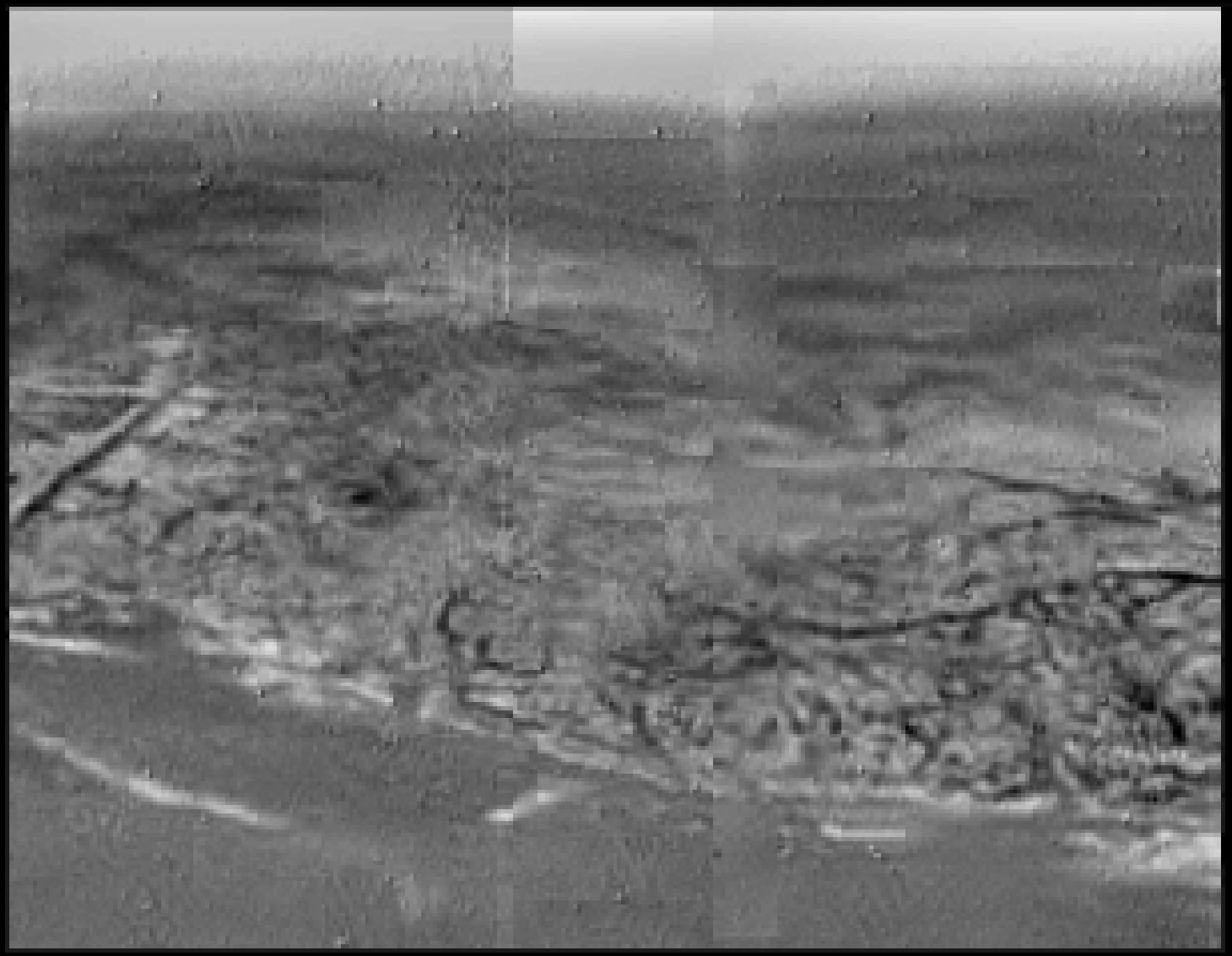
Acetylene (C_2H_2)

Carbon Dioxide (CO_2)

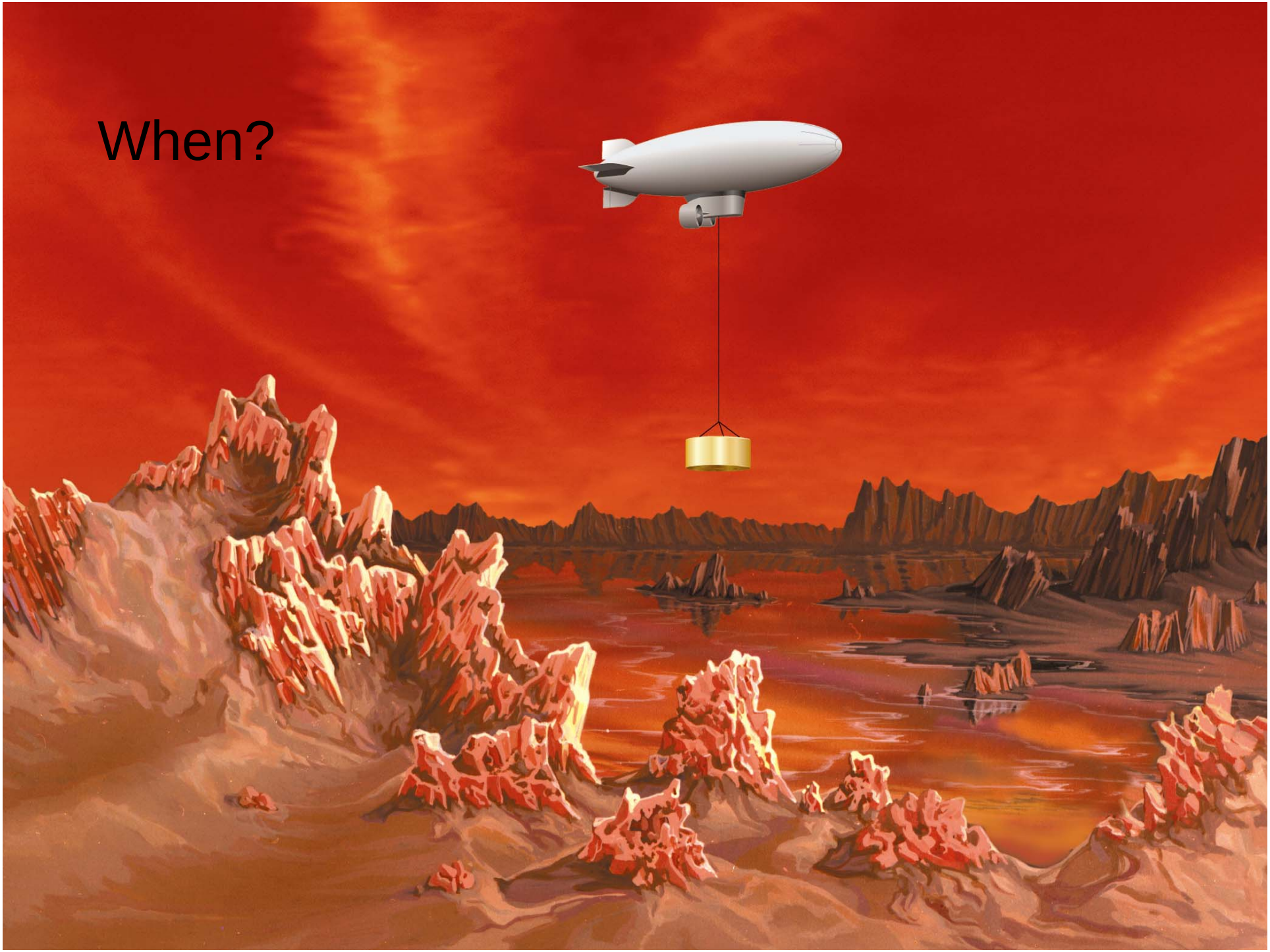
Benzene (C_6H_6)



This result partially answers question 2



When?



Will the moons of the giant planets be the final refuge for life as the Sun's main sequence time comes to an end?