Exploring Hazy Titan with Cassini-Huygens

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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

- $\lambda < 1300$ Å
  - Short UV
- $\lambda > 2000$ Å
  - Long UV

- Nitrogen
- HCN
- Ethane
- Acetylene
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
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.

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/N2 > 10% (1%): Titan’s atmosphere came in as N2
  • Ar/N2 << 1%: NH3 is the source of the atmosphere: 2NH3 → N2+3H2

**THE PRESENCE OF AMMONIA ANSWERS QUESTION 1**
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
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$_2$O 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
Water and ammonia

Atmospheric UV-driven chemistry

- Amino Acids
- Impact / volcanic melt of icy crust
- HCN oligomers
- Purines, Pyrimidines
- Sugars
- Hydrocarbons (C-H), Nitriles (H-C-N)

Ammonia-water melts last 103 years in crater bottoms (O'Brien et al., 2004)
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?