

Life in the Outer Solar System

Jupiter



Big

$$R = 11R_{\oplus}$$

Massive

$$M = 300 M_{\oplus}$$

= 2.5 all the rest

Thick Atmosphere

Mostly H_2 , He

But also more complex molecules

Colors, storms

Like Miller - Urey

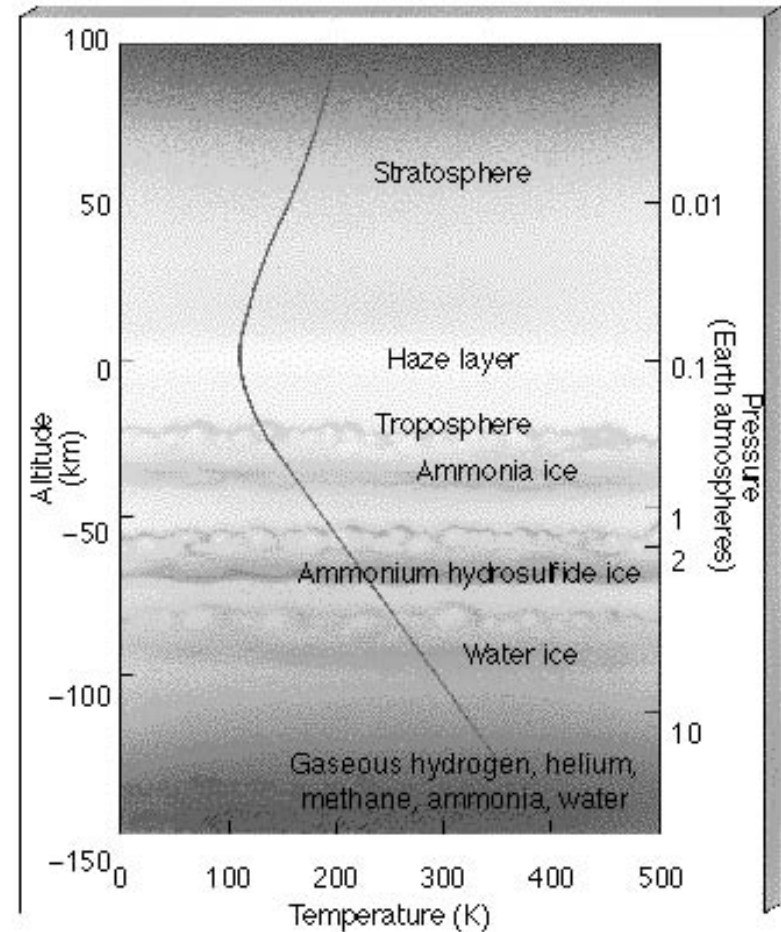
Life in Jupiter Atmosphere?

Sagan-Salpeter, etc.

Sinkers (Plankton)

Floaters (Fish)

Hunters (Fish)



Galileo Results on Jupiter

Reached Jupiter Dec. 1995 Sent probe into Jupiter's atmosphere at 100,000 mile/hour

Decelerated at 230 g Lasted for 57 min.

Found: Strong winds

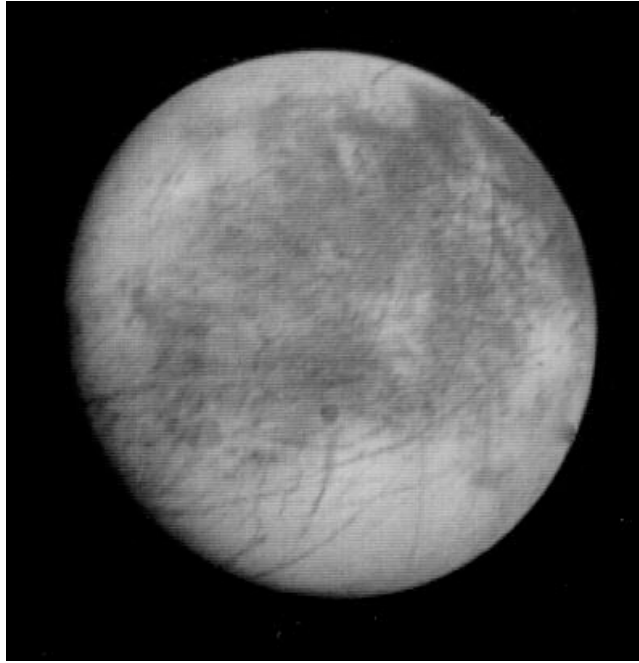
Turbulence, little lightning

Surprise: Little or no H₂O

May have entered in an unusual place (fewer clouds)

Life less likely?



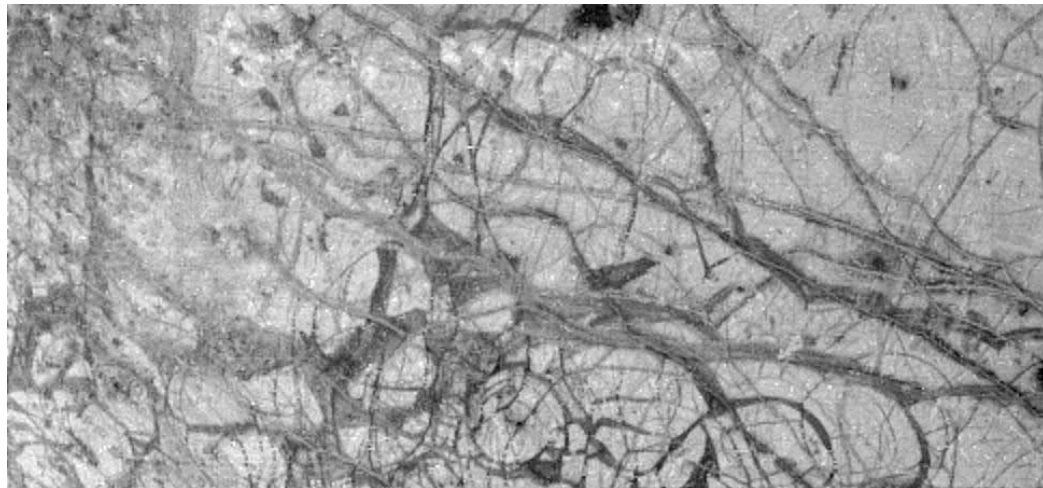


Europa (Moon of Jupiter)

Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

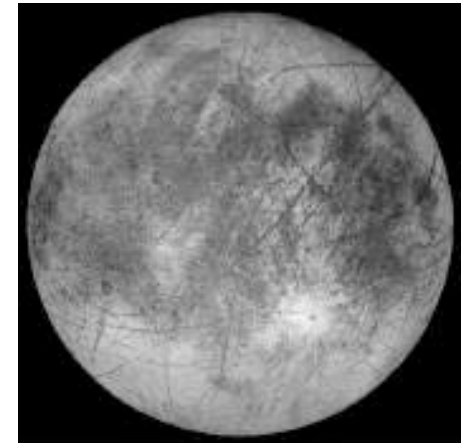


Close-up of "ice floes"

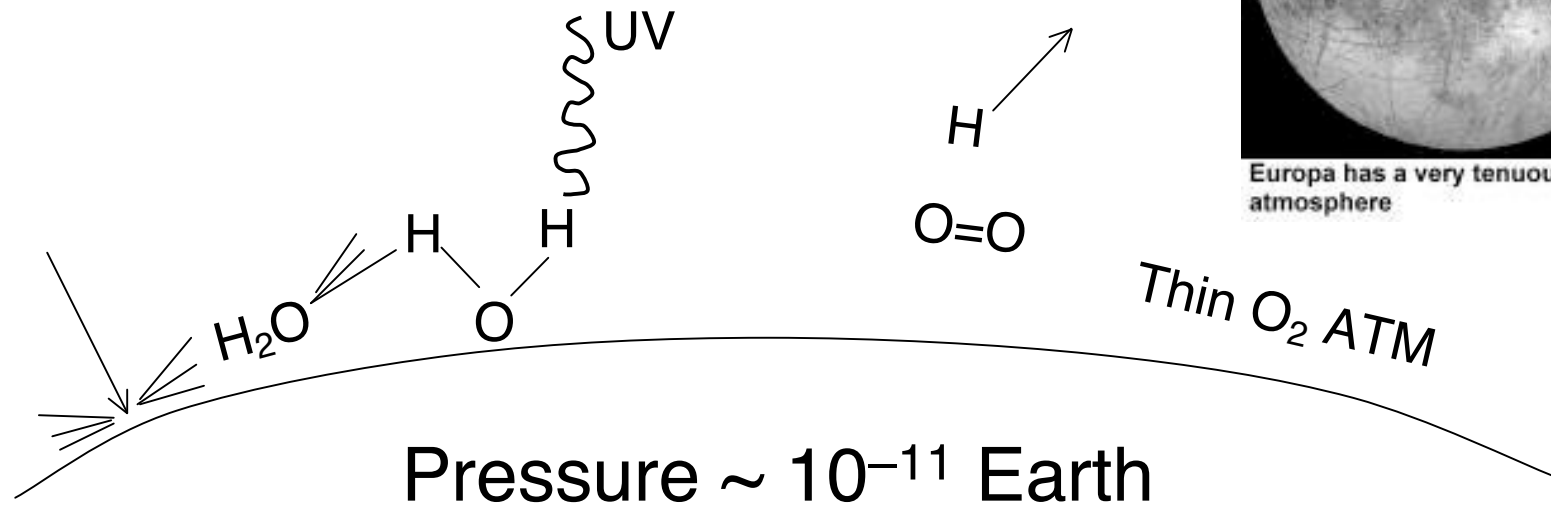
Galileo - Jupiter's Moons

<http://www.jpl.nasa.gov/galileo/index.html>

Europa has a (THIN!) atmosphere



Europa has a very tenuous atmosphere (NASA)

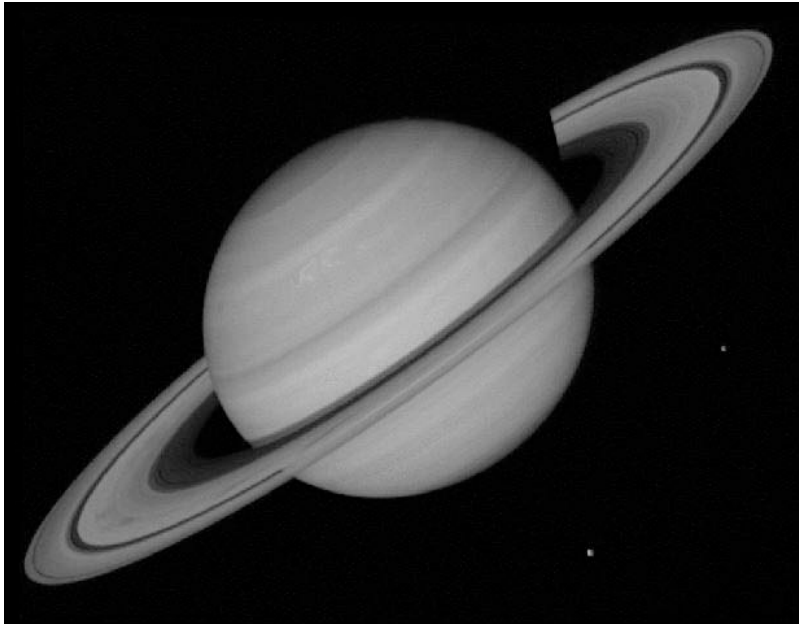


More evidence for resurfacing along cracks by

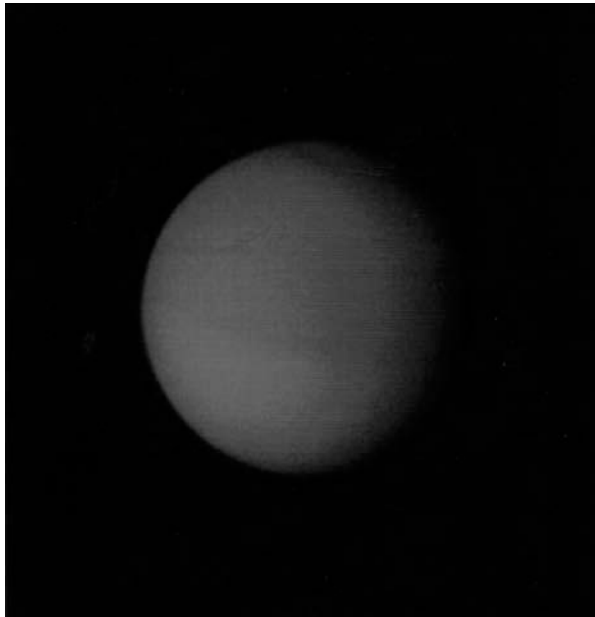
“ice geysers” \longrightarrow fluid ice or liquid water

Organic molecules on Callisto & Ganymede, maybe Europa?

Saturn



- Big ($9.4 R_{\oplus}$)
- Massive ($95 M_{\oplus}$)
- Year 29.5 years
- Day 0.43 days
- Composition similar to Jupiter



Titan

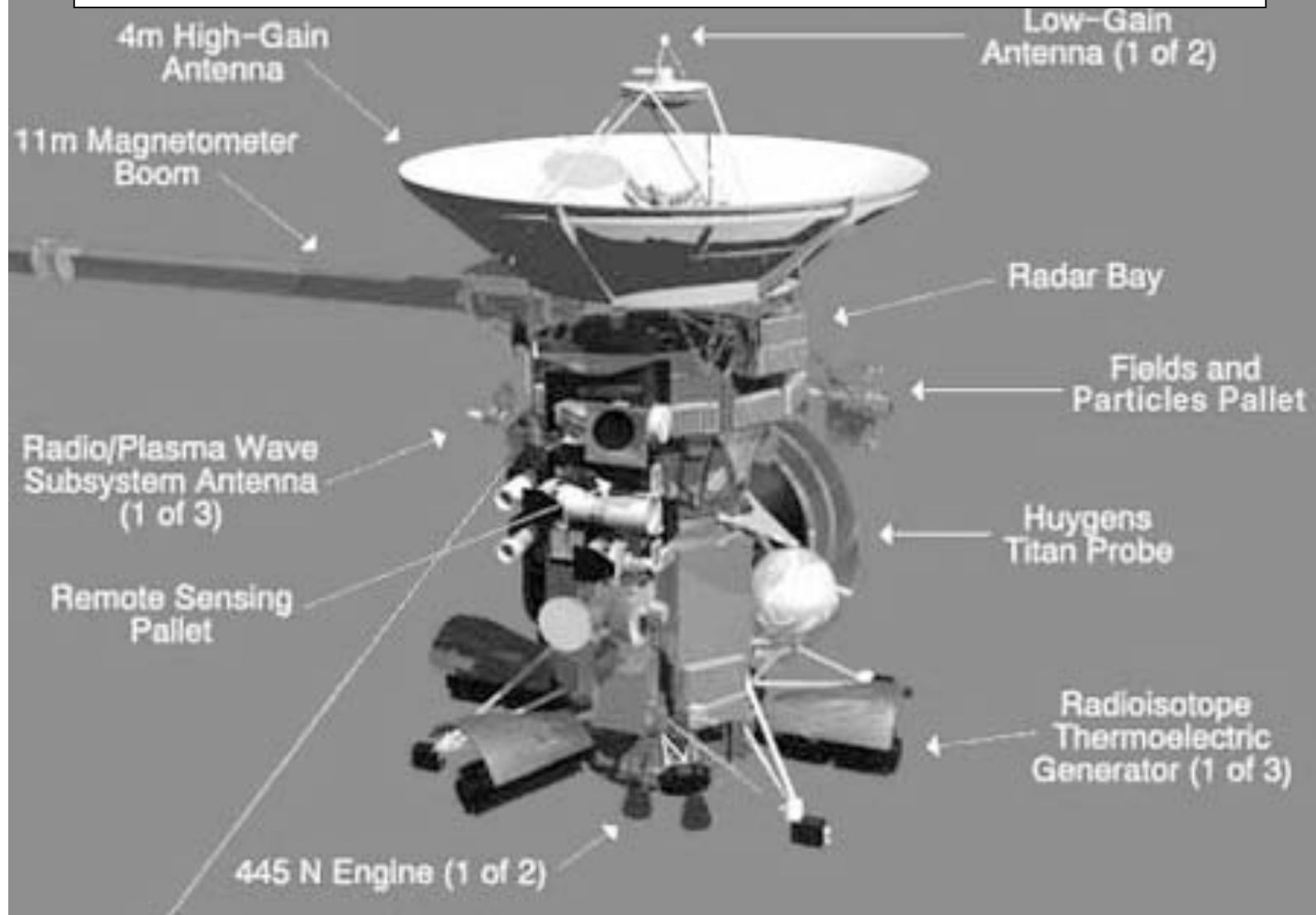
- Moon of Saturn
- Diameter ~ 0.4 Earth
- Atmospheric Pressure = $1.5 \times$ Earth
- 85% Nitrogen BUT
- Cold (~ 90 K)
- Reducing atmosphere
- Haze
- Lab for prebiotic chemistry

The Cassini-Huygens Mission

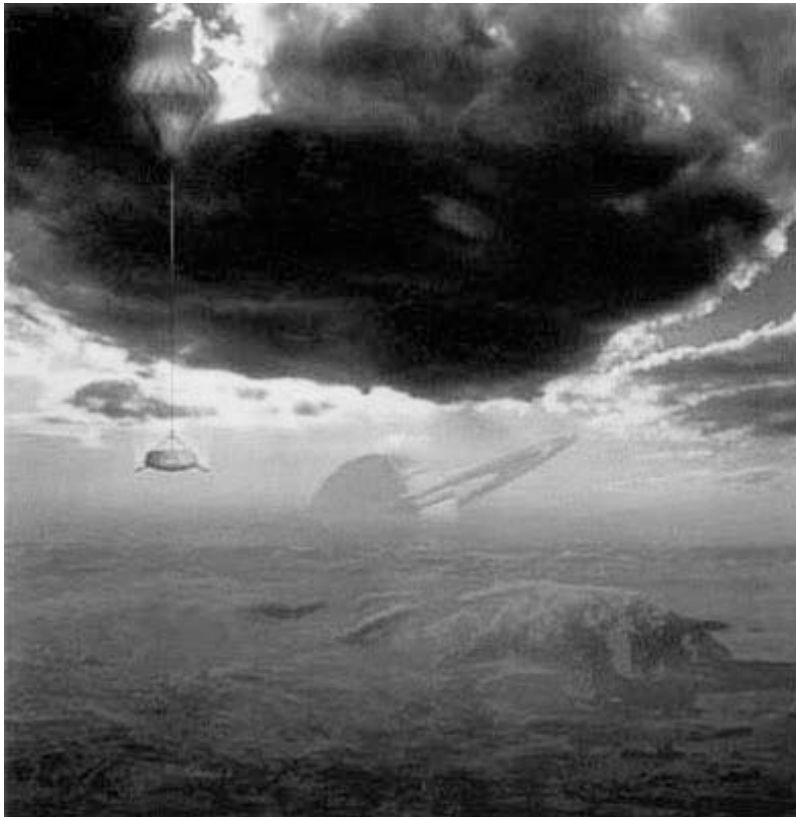


- Launched 10/13/97
- Arrived Saturn 7/2004
- Cassini studies
 - Saturn
 - Moons
- Huygens
 - Dropped onto Titan
 - Study atmosphere
 - Surface

CASSINI SPACECRAFT



Huygens Probe



- Released from Cassini
- Slowed by heat shield
- Parachute deploys
- Soft landing
- Sample gases in atm.
- Results so far:
 - High winds
 - 430 km/hr at 120 km

Titan Surface 10km up

- Mosaic of images
- Taken during descent
- Clearly shows features

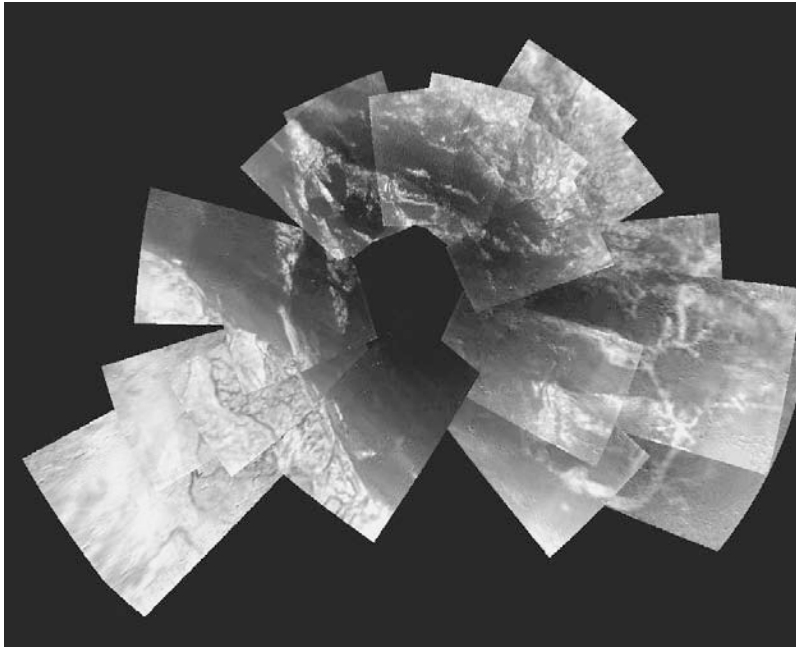


Photo: ESA

Titan

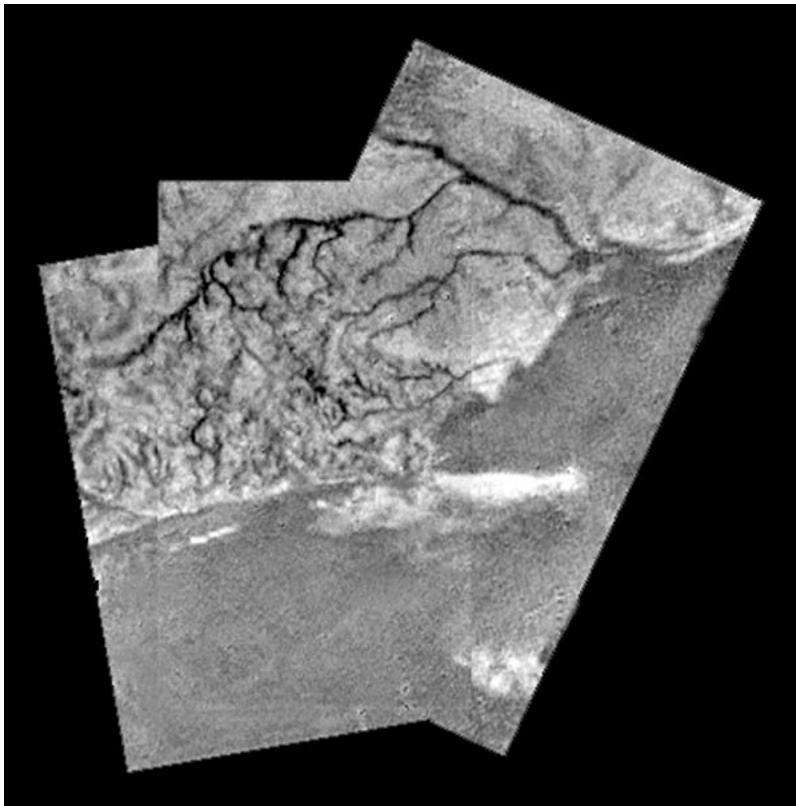
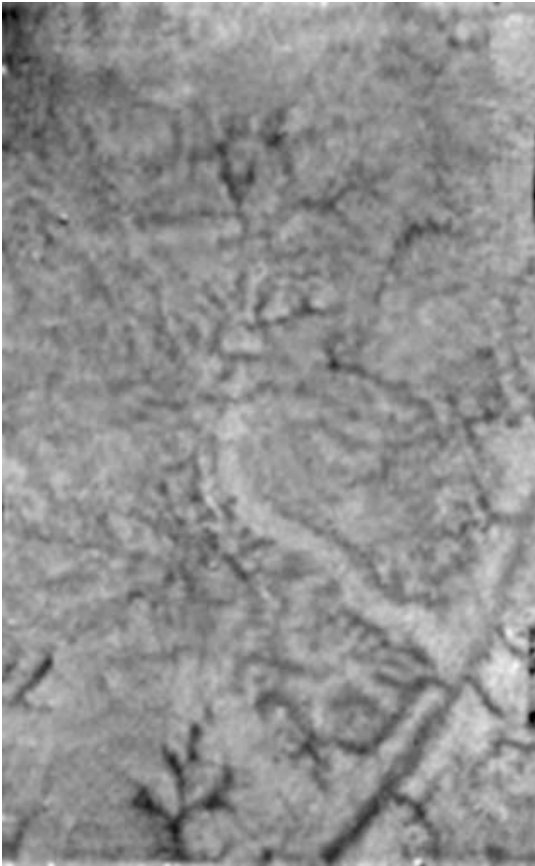


Photo: ESA

- River channel
- Coastline
- Liquid is present
- Methane (CH_4)

Water Rift and Methane Springs?



- Straight feature:
- Water ice extruded?
- Stubby channels:
- Methane springs?

Lakes at northern latitudes

- Radar mapping of northern latitudes (2006)
- Strong evidence for liquid lakes
- And big cloud of ethane (C_2H_6)
- Ethane raining (or snowing) into lakes

Lakes and Islands

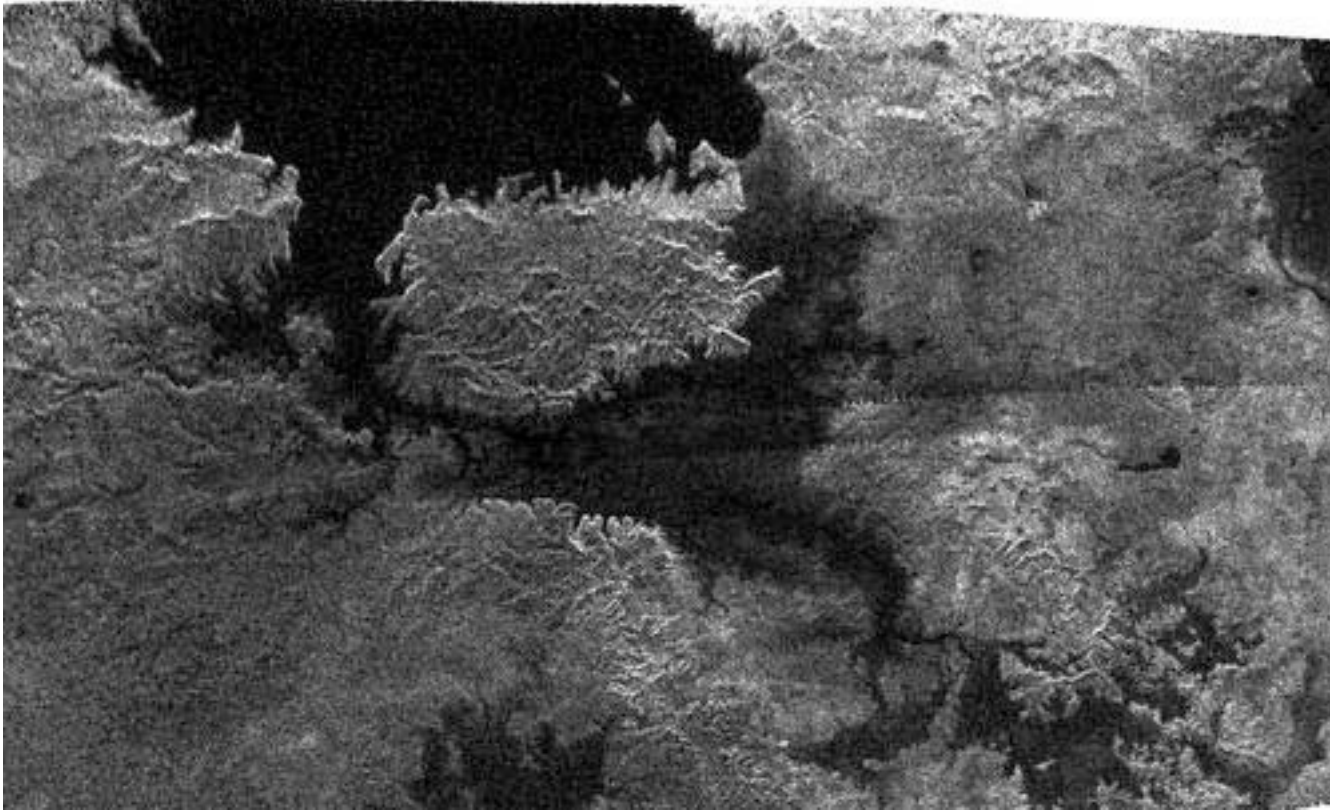


Image from Feb. 2007: based on radar.
Large lake and island (size of Big Island, Hawaii)
And smaller lakes

From the surface of Titan



- First view of surface
- “Rocks” of water ice
 - Pebble size (15 cm)
- Surface yielding
- Mixture of ices
 - Water
 - hydrocarbons

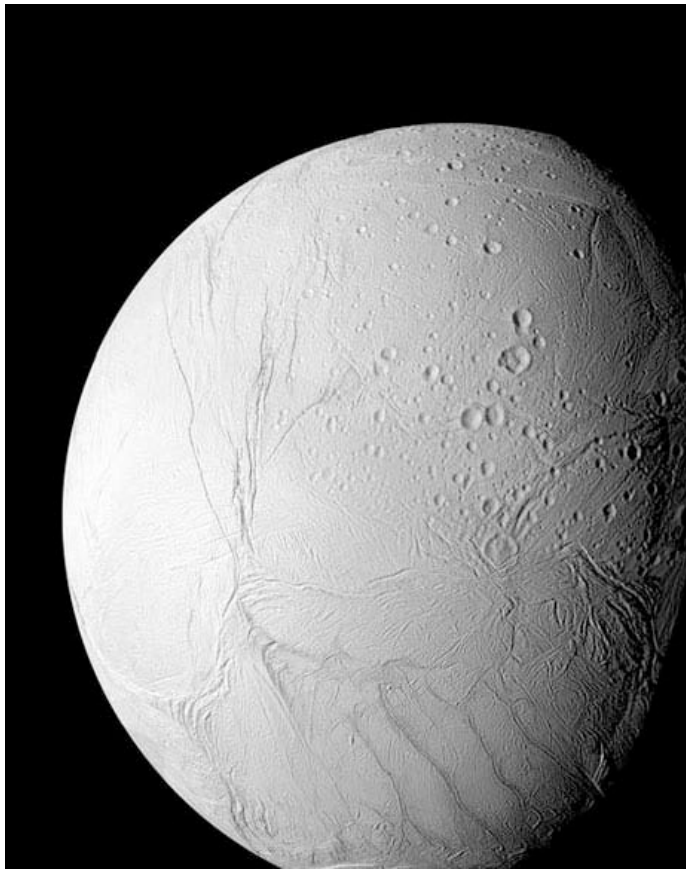
More Titan Results

- Hints of ammonia (NH_3)/water (H_2O) ocean
 - Under surface
 - Outgassing of NH_3 may supply N_2 atm.

Lots of stuff on websites

- <http://saturn.jpl.nasa.gov/home/index.cfm>
- <http://www.esa.int/SPECIALS/Cassini-Huygens/>

Enceladus



- Moon of Saturn
- Very shiny
- Part of surface old (craters)
- Part is new, with cracks
- Cassini saw ice geysers (2006)
- Subsurface liquid water
- Source of heat unclear

How to search for life

Have to decide what test indicates life

Hard to anticipate conditions (recall Viking results)

What about finding “protolife”?

National Academy report - how to search for life

1. Delivery by comets, meteorites e.g. Mars meteorites

2. Sample return - Mars possible

3. Experiments by landers -

Viking on Mars, ...

Future: Europa probe and return?

Titan?

Issues of contamination

4. Biomarkers

Presence of both O_2 and CH_4 in Earth atmosphere

indicative of life

How convincing?

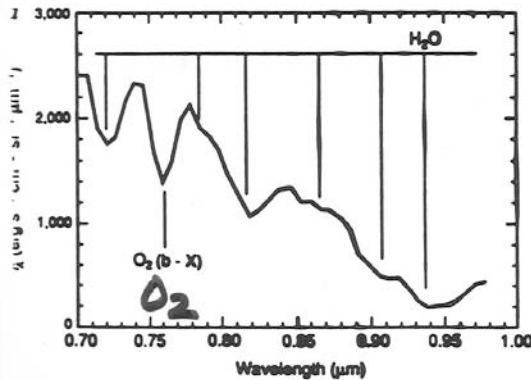
Detecting Life on Earth from Space

Galileo used during close Earth approach

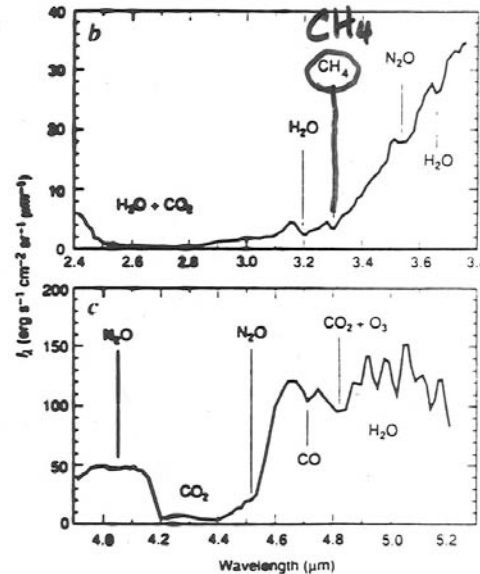
Photographs (1 km resolution) No clear signs of intelligent life

Spectrometers - evidence of life Lots of O₂

CH₄



1 a. Galileo long-wavelength-visible and near-infrared spectra of Earth over a relatively cloud-free region of the Pacific Ocean, north meo. The incidence and emission angles are 77° and 57° respectively. The (b'Σ_g⁺ - X³Σ_g⁻) O-O band of O₂ at 0.76 μm is evident, along a number of H₂O features. Using several cloud-free regions of 1g airmass, we estimate an O₂ vertical column density of 1.5 km² at ± 25%. b and c. Infrared spectra of the Earth in the 2.4-5.2 μm n. The strong ν₃ CO₂ band is seen at the 4.3 μm, and water vapour s are found, but not indicated, in the 3.0 μm region. The ν₃ band rous oxide, N₂O, is apparent at the edge of the CO₂ band near m, and N₂O combination bands are also seen near 4.0 μm. The



methane (0010) vibrational transition is evident at 3.31 μm. A cr estimate¹⁰ of the CH₄ and N₂O column abundances is, for both spec of the order of 1 cm-arnagate (≡ 1 cm path at STP).

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RADIO EMISSION: CLEAR EVIDENCE OF INTELLIGENT LIFE

TPF Concepts

TPF-I Infrared Interferometer (2020?)



TPF-C Visible light coronagraph (2014?)

Spectroscopy of atmosphere

