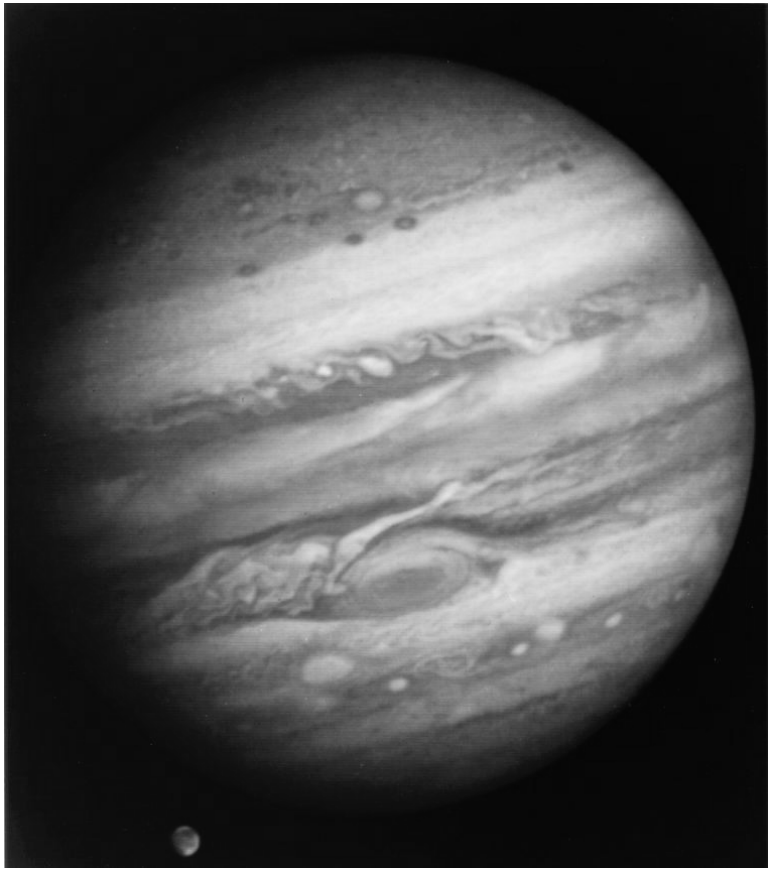
Life in the Outer Solar System

Jupiter



Big $R = 11R_{\oplus}$

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

$= 2.5$ all the rest

Mostly H_2, He Thick Atmosphere

But also more complex molecules

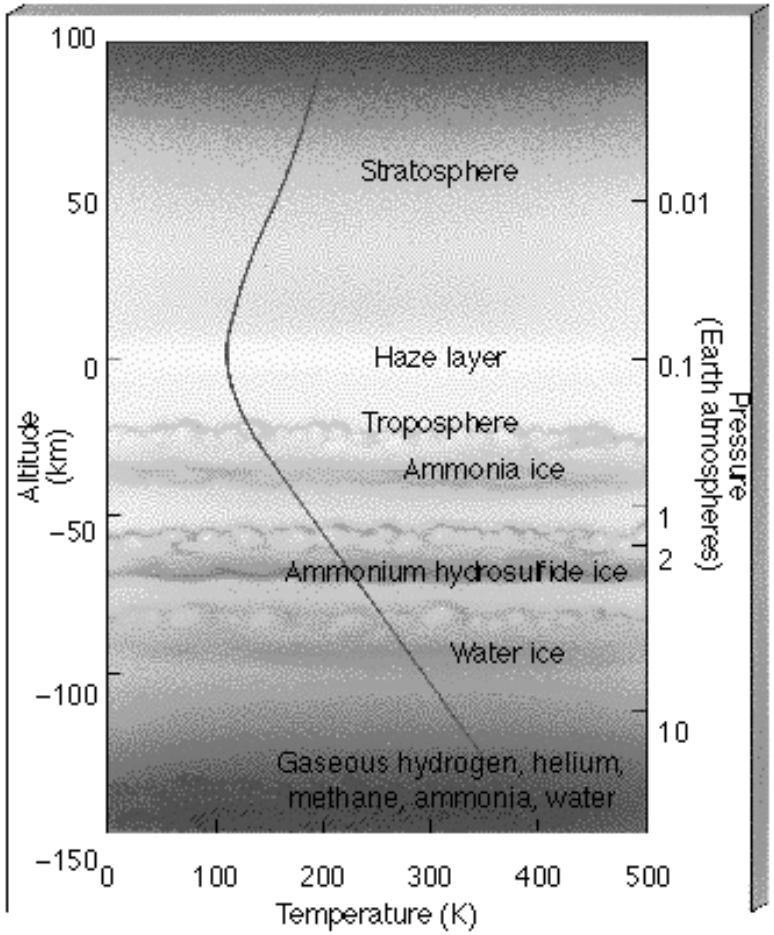
Colors, storms

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.

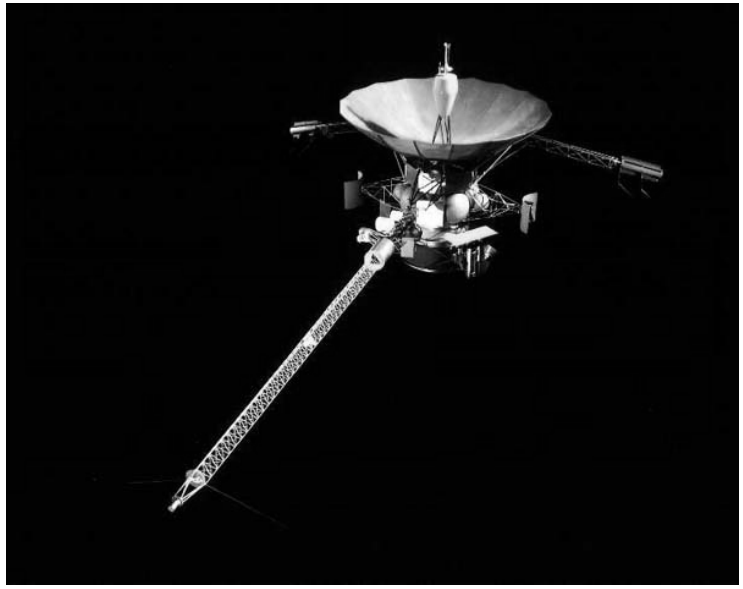
Found: Strong winds

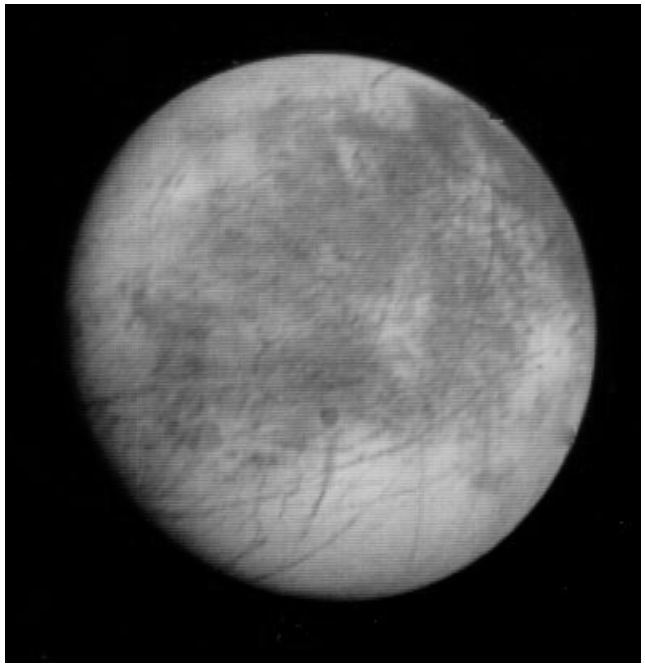
Turbulence, little lightning

Surprise: Little or no H_2O

May have entered in an unusual place (fewer clouds)

Life less likely?



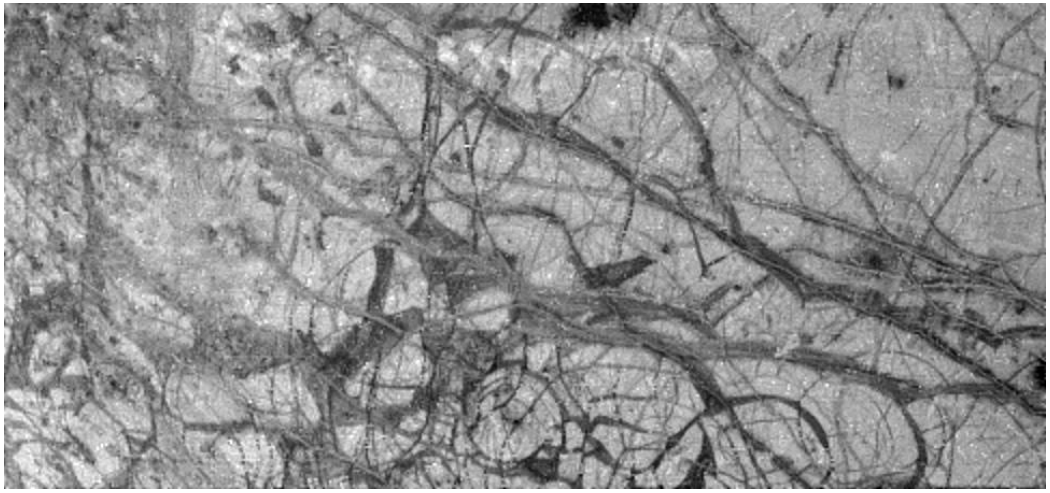


Europa (Moon of Jupiter)

Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

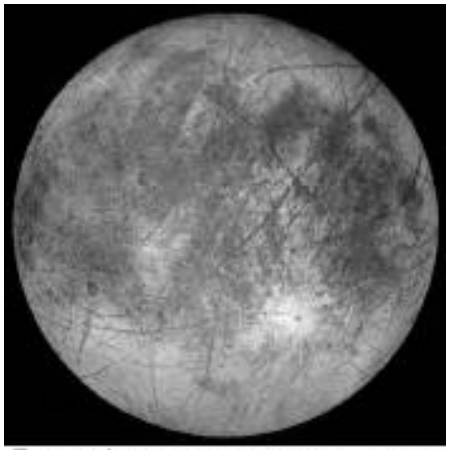


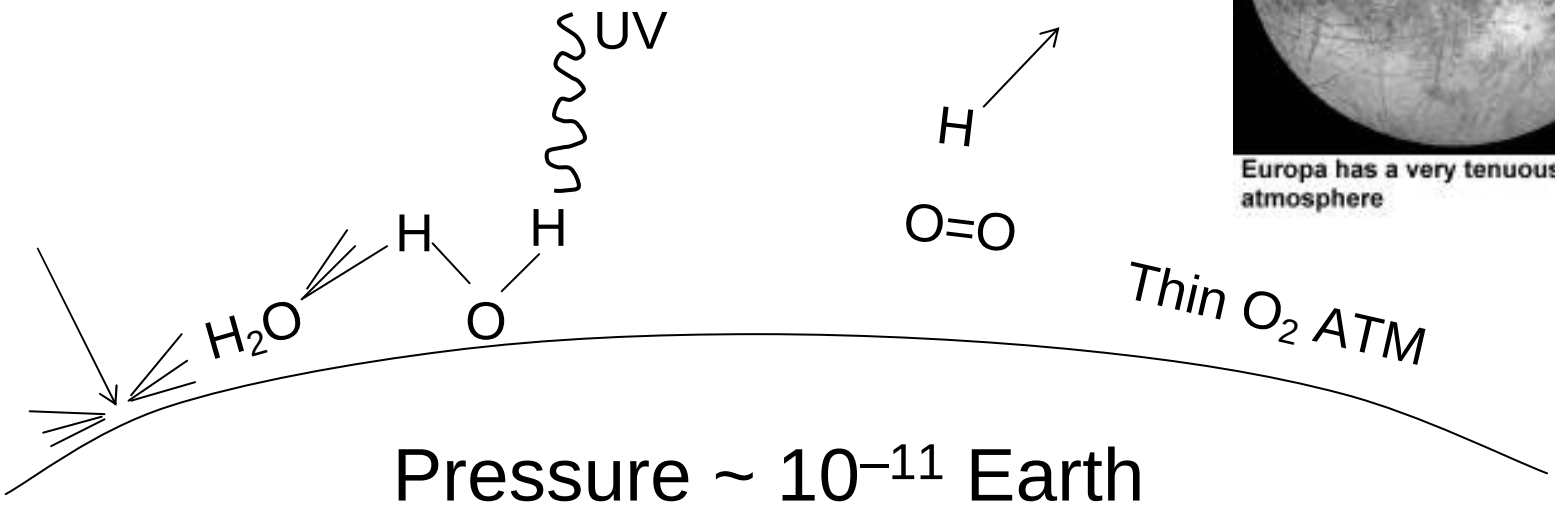
Close-up of “ice floes”

Galileo - Jupiter's Moons

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

Europa has a (THIN!) atmosphere





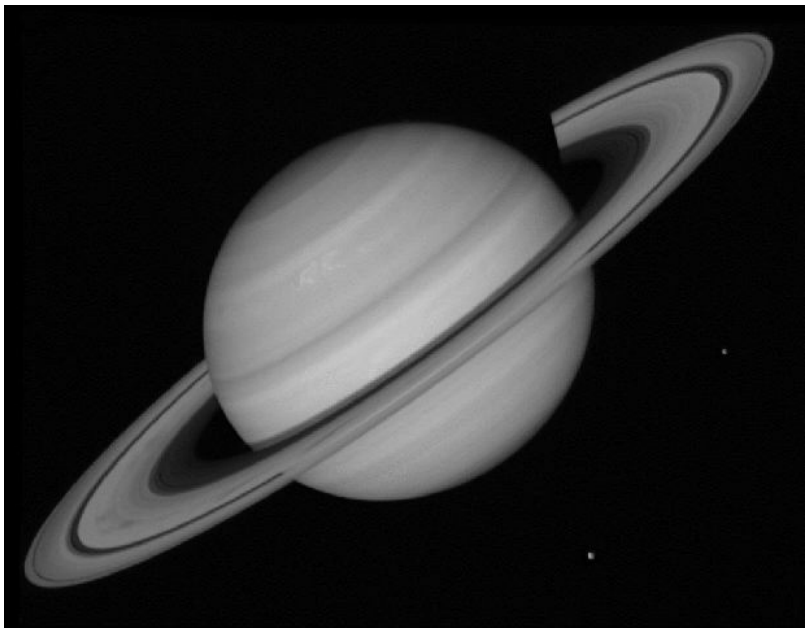
Pressure ~ 10^{-11} Earth

More evidence for resurfacing along cracks by

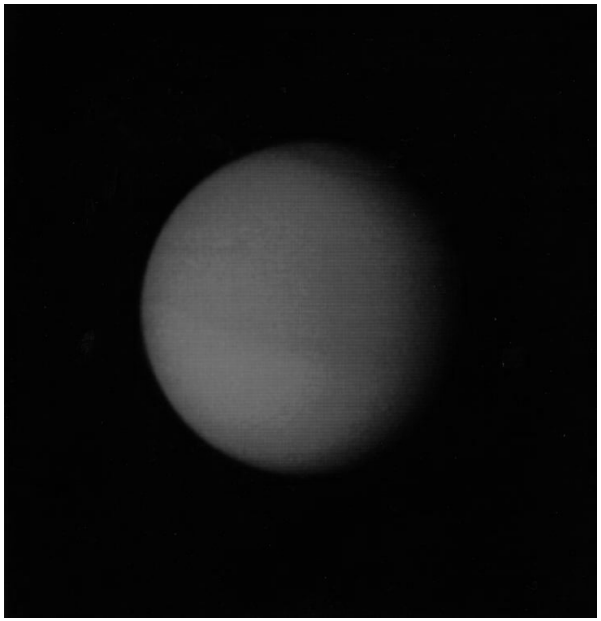
"ice geysers" ⟶ fluid ice or liquid water

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



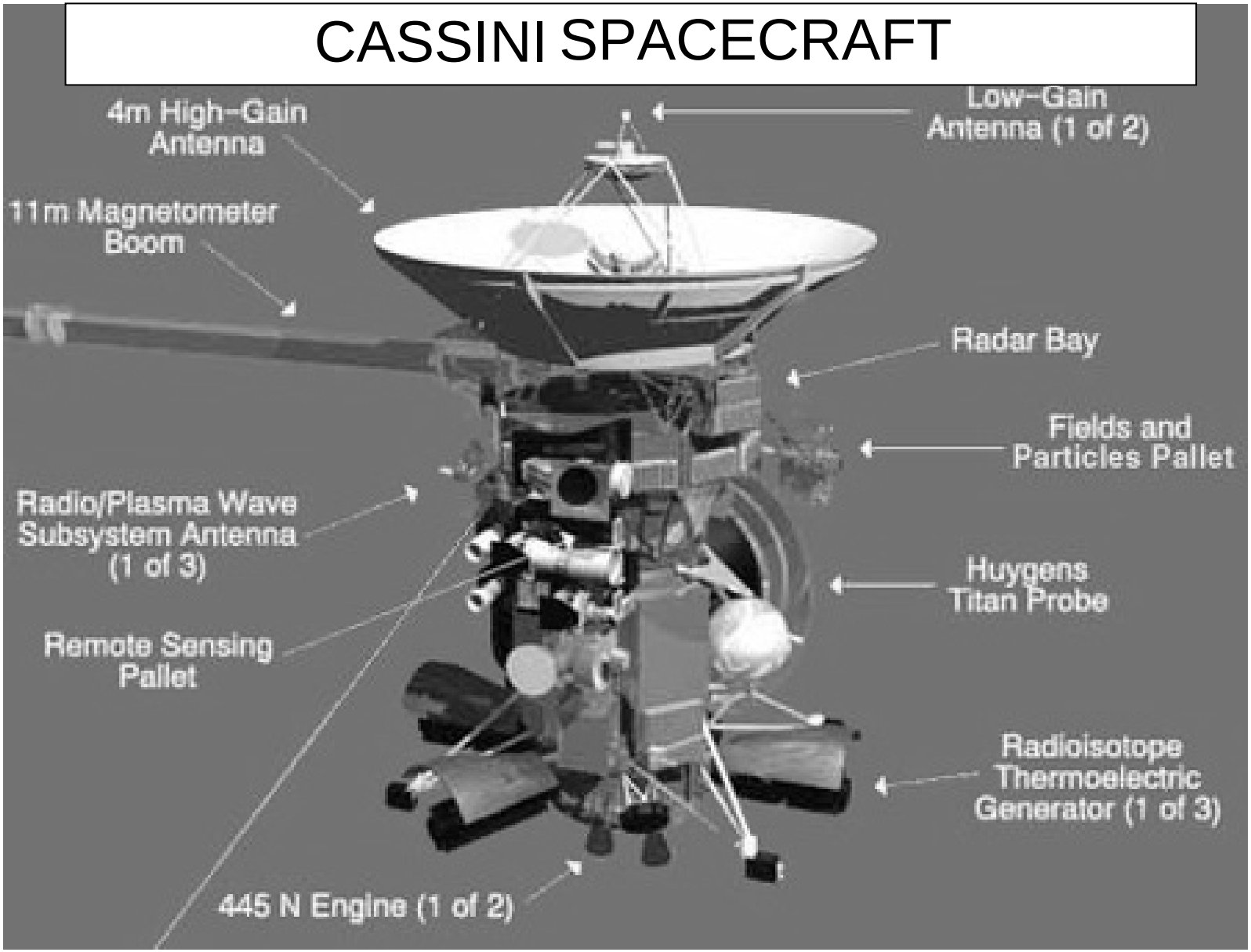
Titan

- 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



2005 Saturn Tour Highlights:

- **Jan. 14, 2005:** The European Space Agency's Huygens probe descends through Titan's cloudy atmosphere, touching down on the surface about two and half hours later. Cassini will send the data back to Earth.
- **Feb. 15, 2005:** Cassini makes another pass by Titan. In 2005, the spacecraft will have six chances to study Titan at altitudes ranging from 1,025 kilometers (637 miles) to 60,000 kilometers (37,290 miles).
- **Mar. 9, 2005:** Cassini flies within 500 kilometers (311 miles) of icy Enceladus. Cassini will visit Enceladus five times in 2005.
- **Sep. 26, 2005:** Cassini studies Hyperion at a range of 1,010 kilometers (628 miles), the closest approach ever to the tiny moon. It will be Cassini's only visit to the moon during the primary mission.
- **Oct. 11, 2005:** Cassini turns its instruments on Dione from a distance of 500 kilometers (311 miles).
- **Nov. 26, 2005:** Cassini passes within 500 kilometers (311 miles) of Rhea.

Huygens Probe

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

Titan Surface 10km up

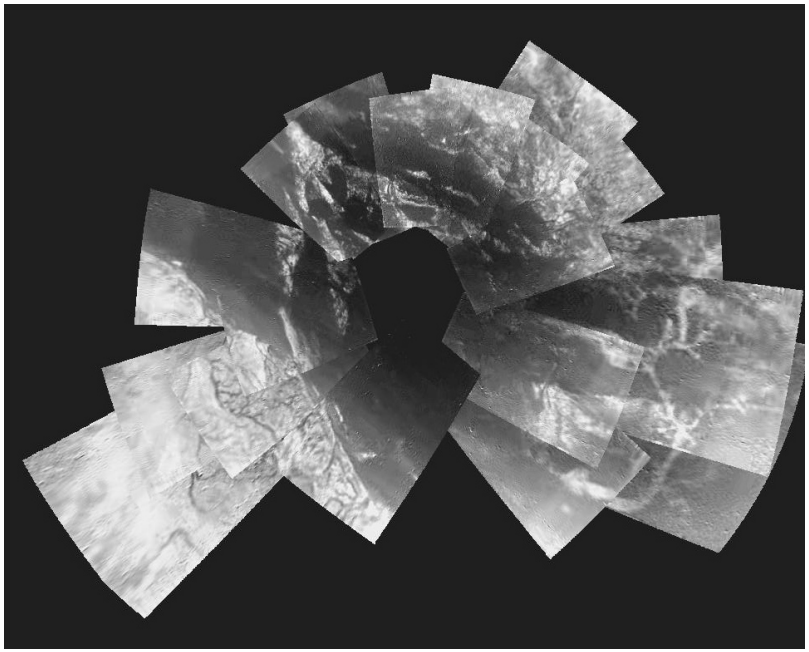


Photo: ESA

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

Titan

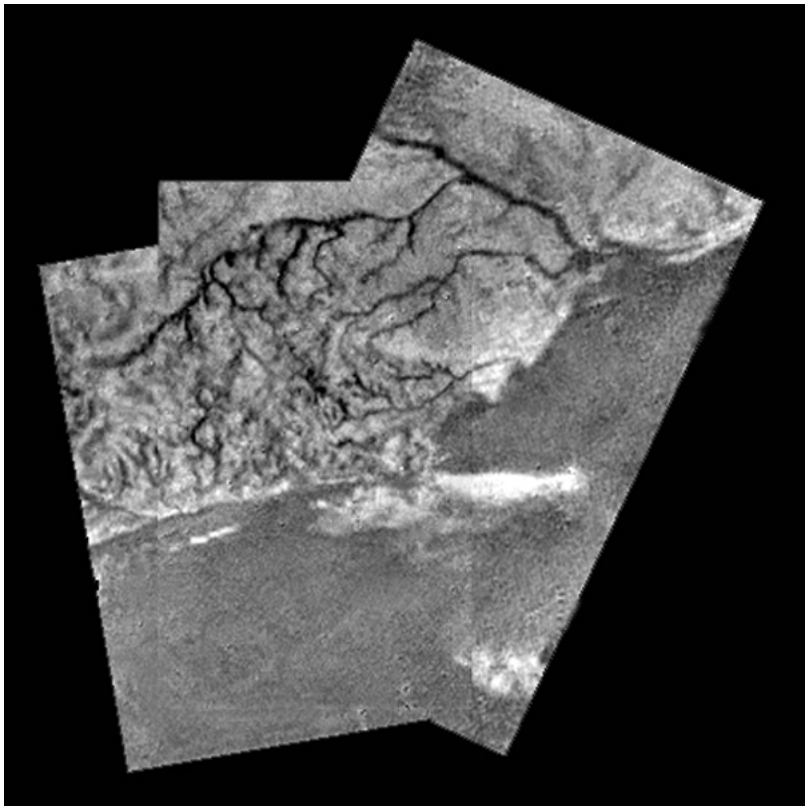
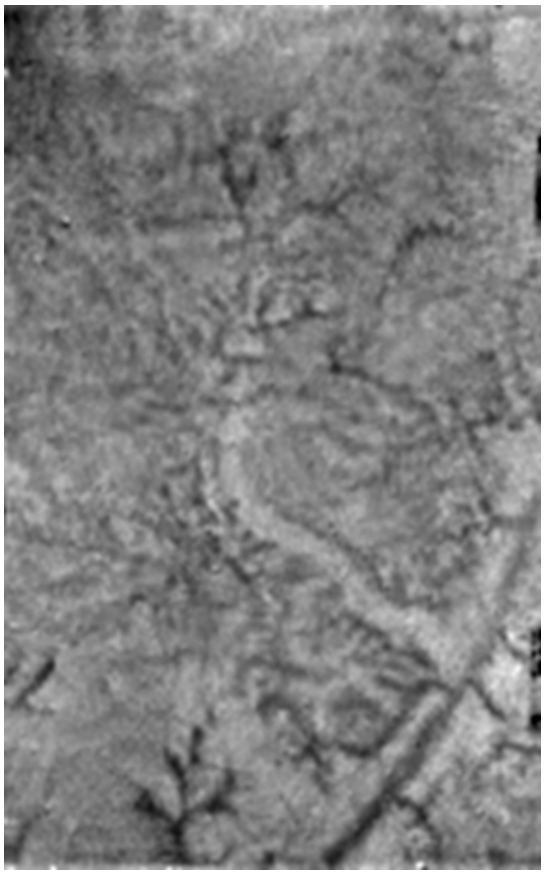


Photo: ESA

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

Water Rift and Methane Springs?



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

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.

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?

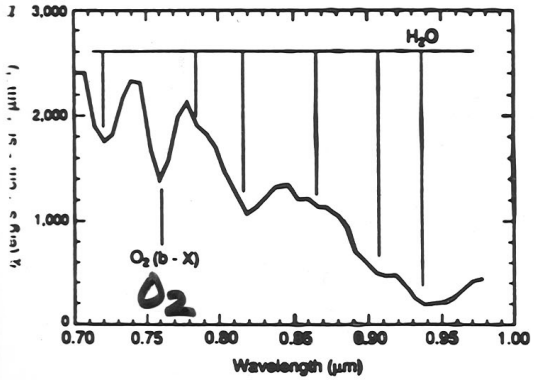
Detecting Life on Earth from Space

Galileo used during close Earth approach

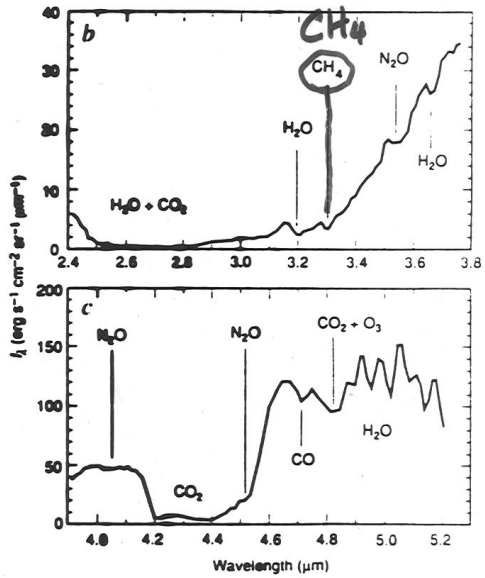
Photographs (1 km resolution) No clear signs of intelligent life

Spectrometers - evidence of life Lots of O_2

CH4



1 a, Galileo long-wavelength-visible and near-infrared spectra of arth over a relatively cloud-free region of the Pacific Ocean, north meo. The incidence and emission angles are 77° and 57° respec-. The ($b'\Sigma_u^+ - X^3\Sigma_g^-$) 0–0 band of O_2 at 0.76 μm is evident, along a number of H_2O features. Using several cloud-free regions of ng airmass, we estimate an O_2 vertical column density of 1.5 km-at ± 25%. *b* and *c*, Infrared spectra of the Earth in the 2.4–5.2 μm n. The strong υ_3 CO_2 band is seen at the 4.3 μm, and water vapour s are found, but not indicated, in the 3.0 μm region. The υ_3 band rous oxide, N_2O, is apparent at the edge of the CO_2 band near m, and N_2O combination bands are also seen near 4.0 μm. The



methane (0010) vibrational transition is evident at 3.31 μm. A cr estimate[10] of the CH_4 and N_2O column abundances is, for both spec of the order of 1 cm-amagate (≡ 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