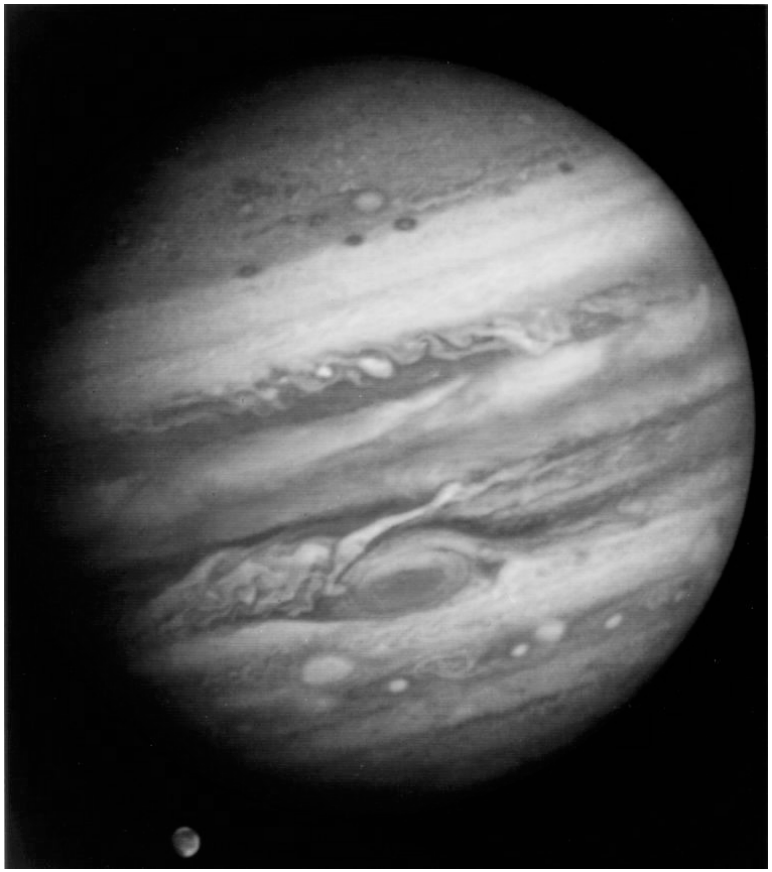
Life in the Outer Solar System

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

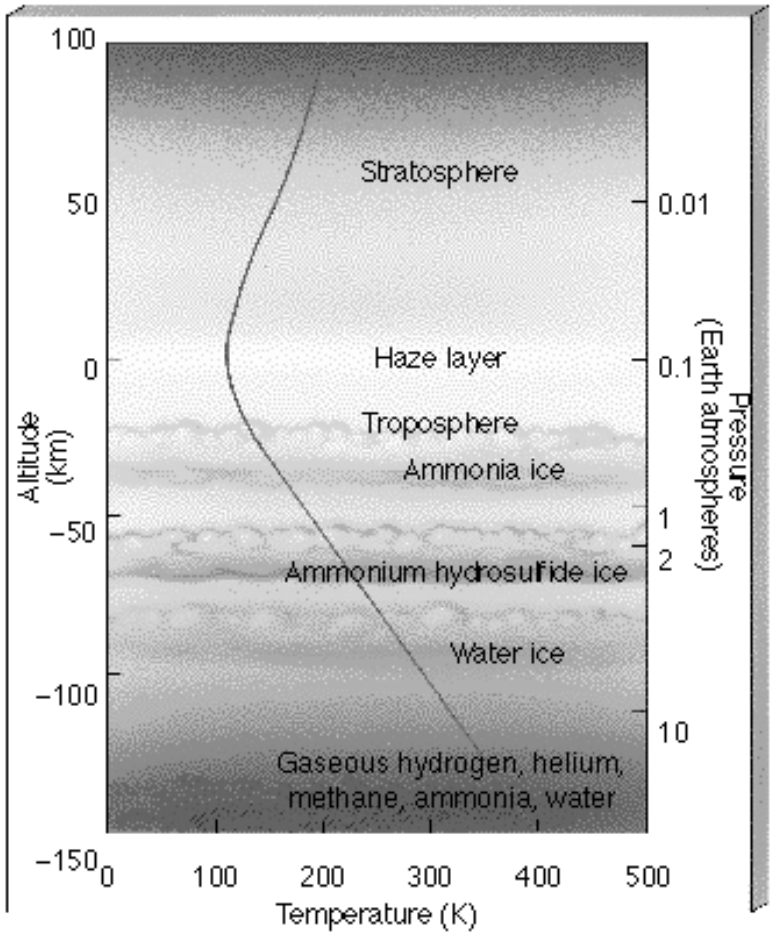
Colors, storms

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.

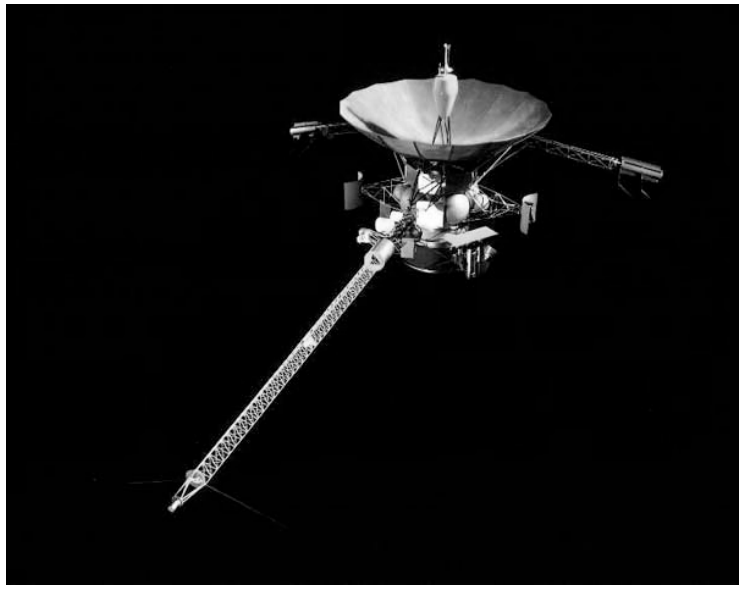
Found: Strong winds

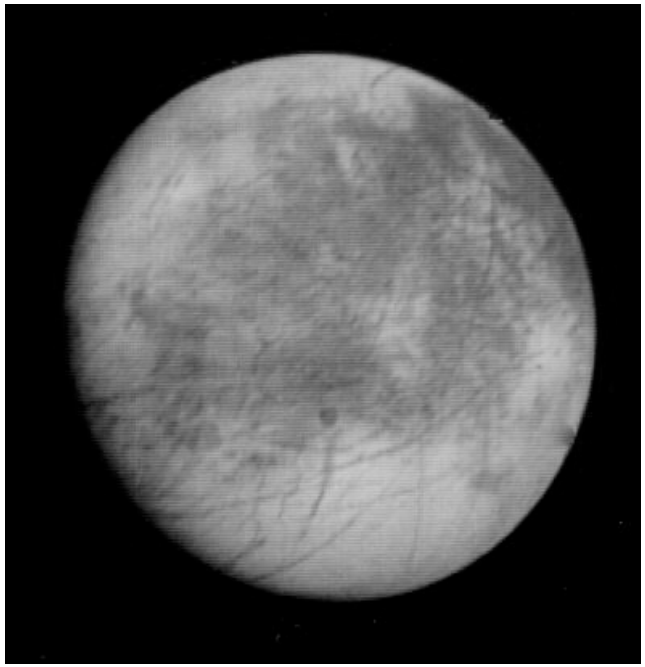
Turbulence, little lightning

Surprise: Little or no H_2O

May have entered in an unusual place (fewer clouds)

Life less likely?



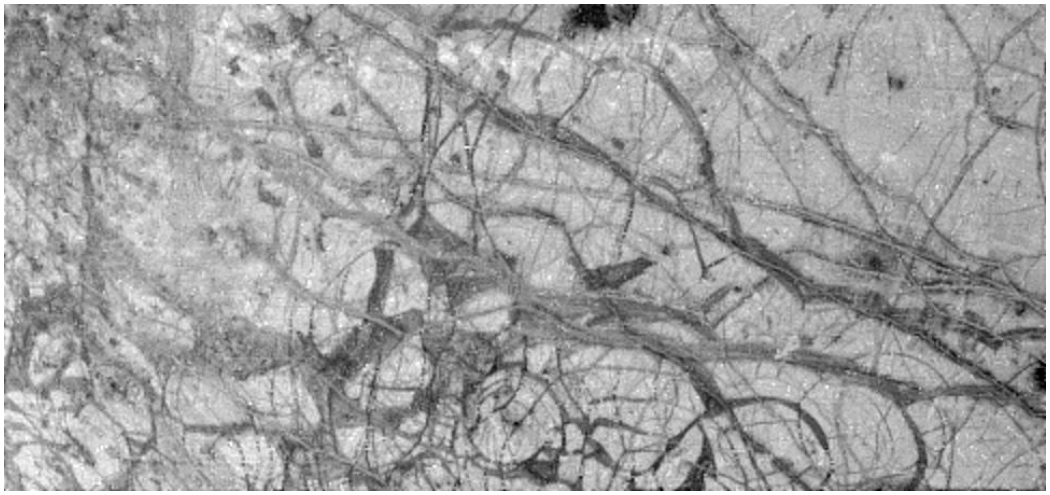


Europa (Moon of Jupiter)

Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

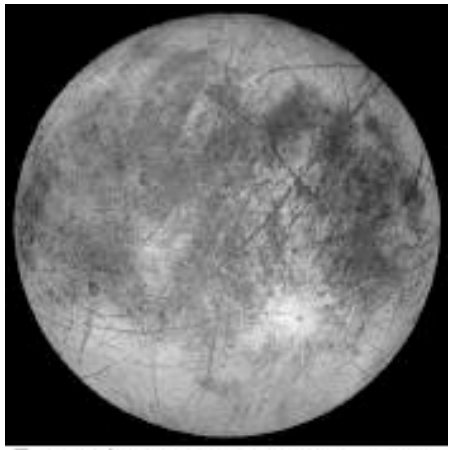


Close-up of “ice floes”

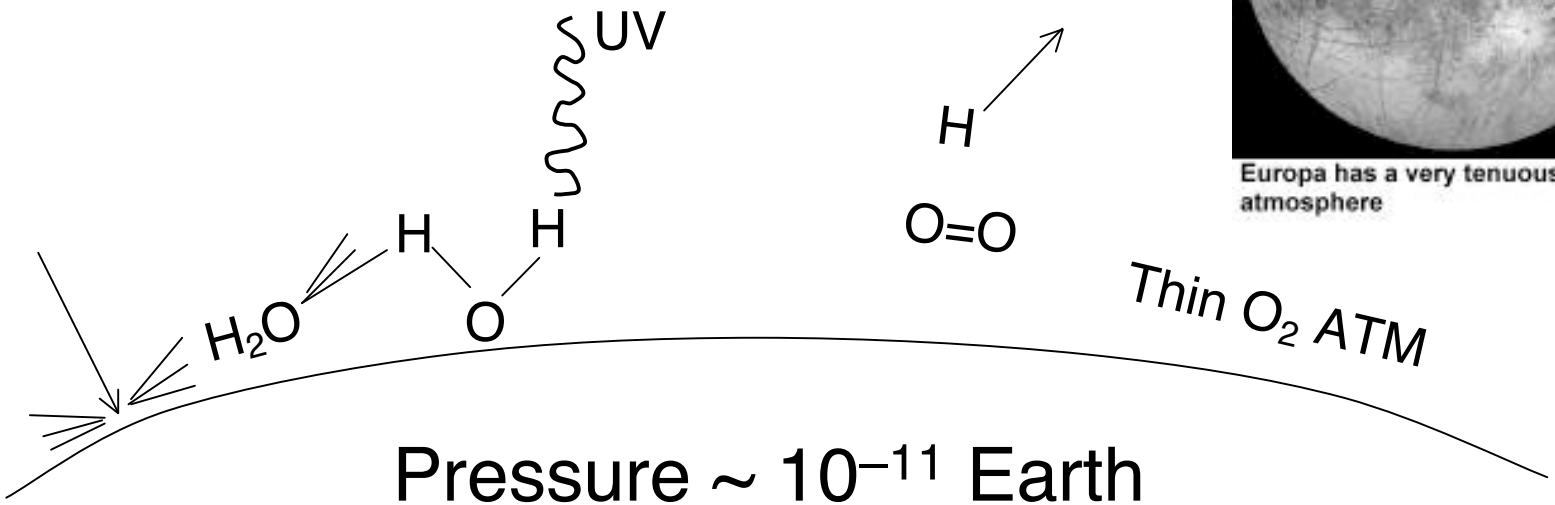
Galileo - Jupiter's Moons

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

Europa has a (THIN!) atmosphere



Europa has a very tenuous atmosphere (NASA)



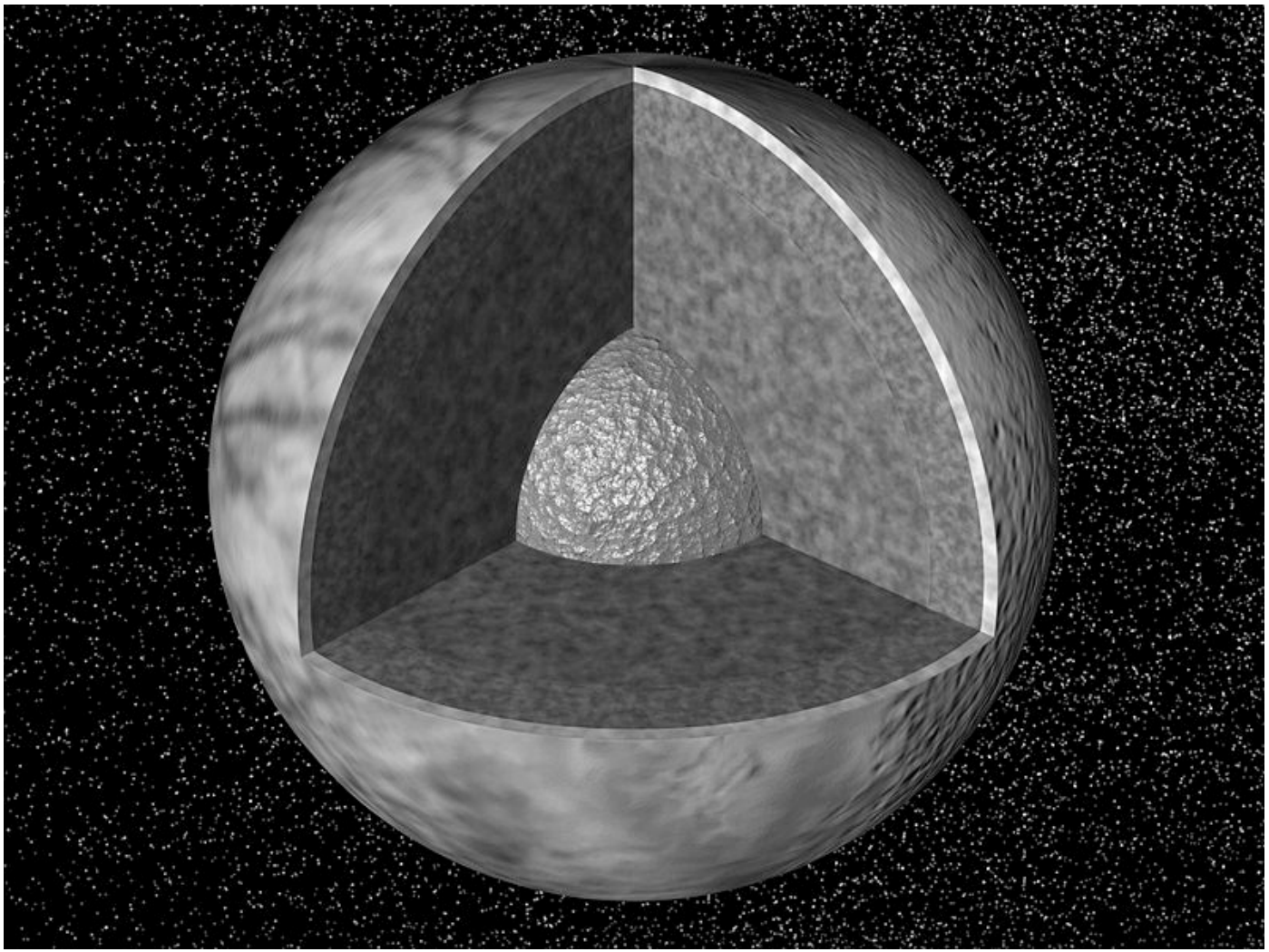
Pressure ~ 10^{-11} Earth

More evidence for resurfacing along cracks by

"ice geysers" ⟶ fluid ice or liquid water

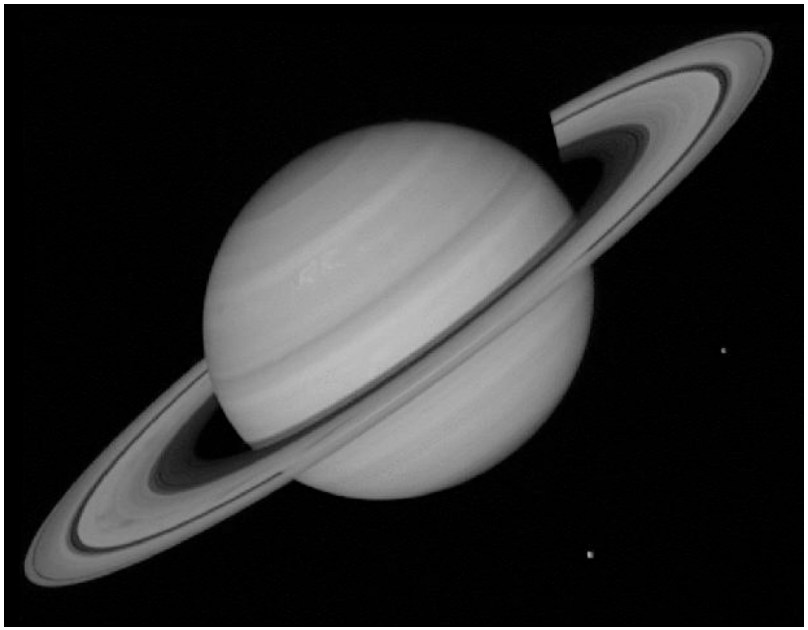
Organic molecules on Callisto & Ganymede, maybe Europa?

Model of Europa's Interior

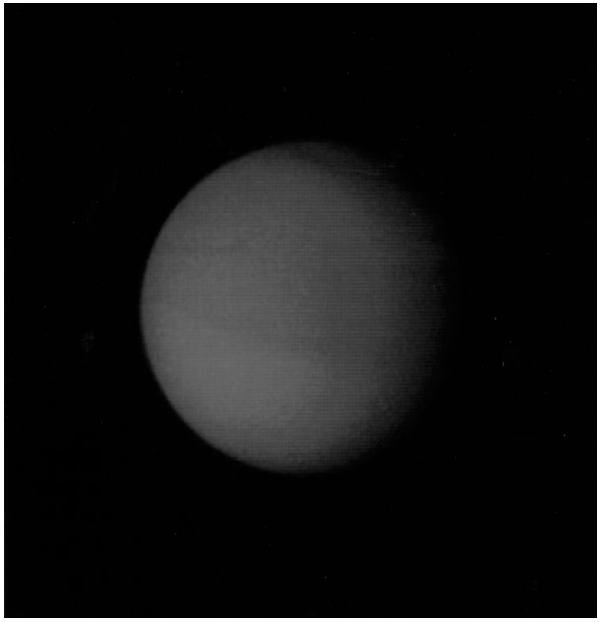


Ice crust may be a 10-30 km thick.
Ocean may be 90 km deep.

Saturn



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



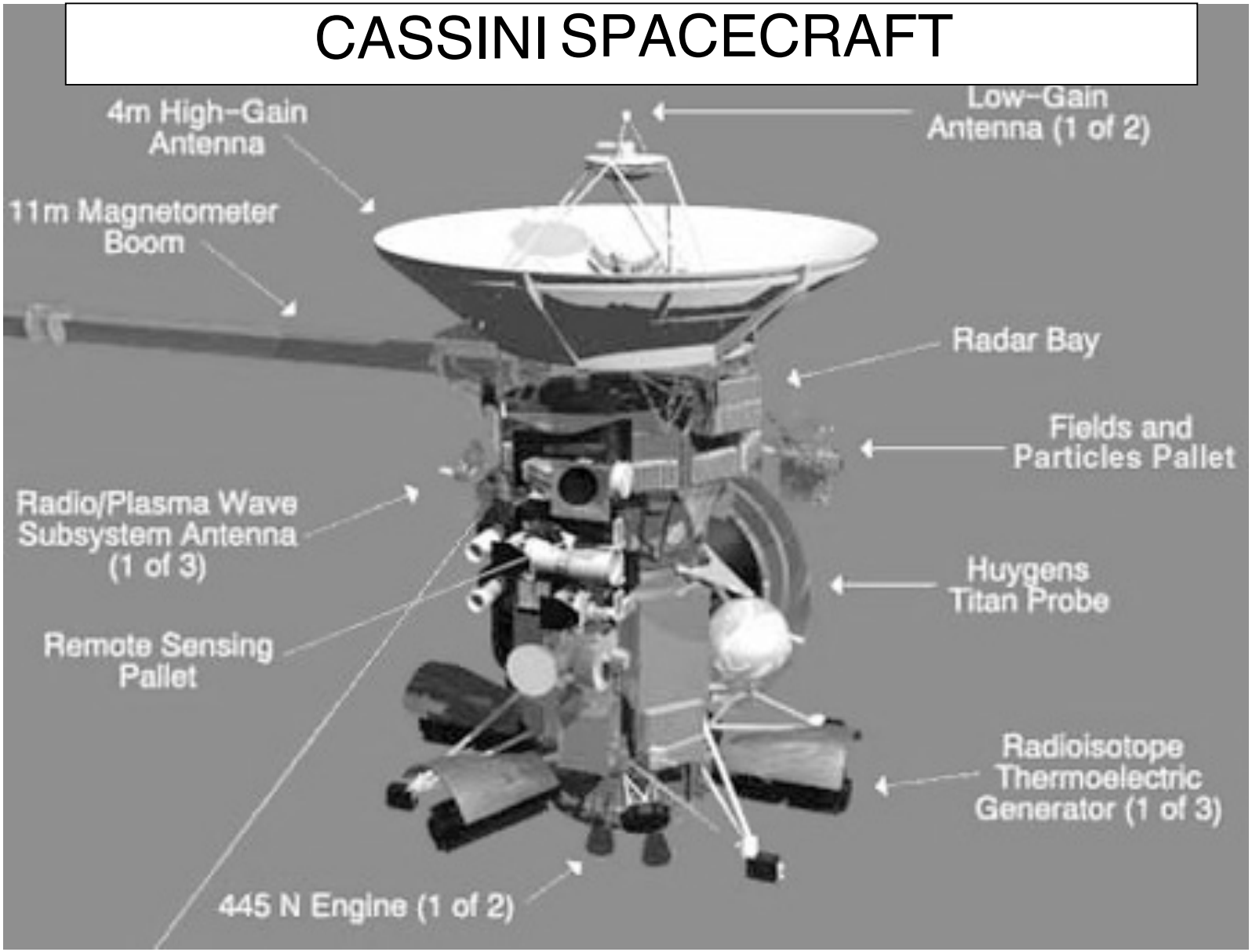
Titan

- Moon of Saturn
- Diameter ~0.4 Earth
- Atmospheric Pressure = 1.5 × 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

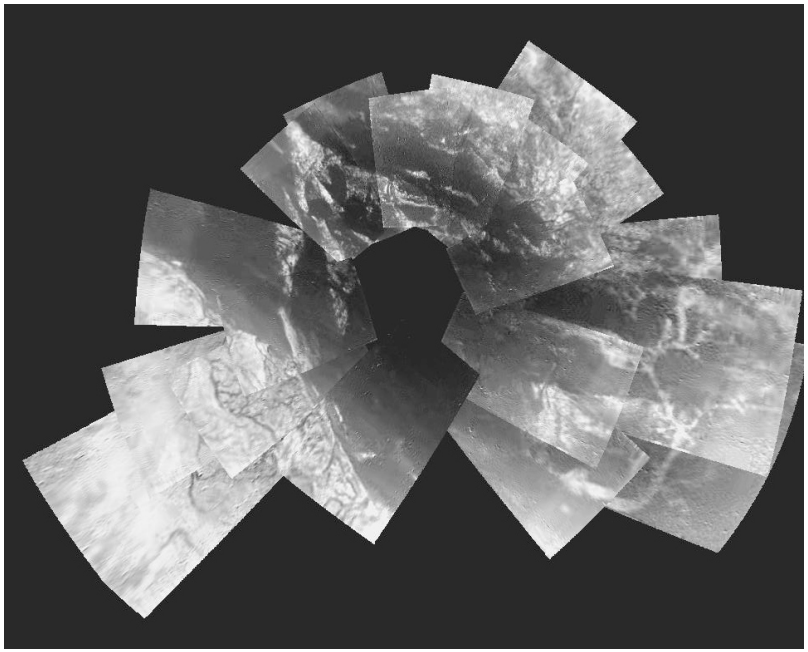


Photo: ESA

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

Titan

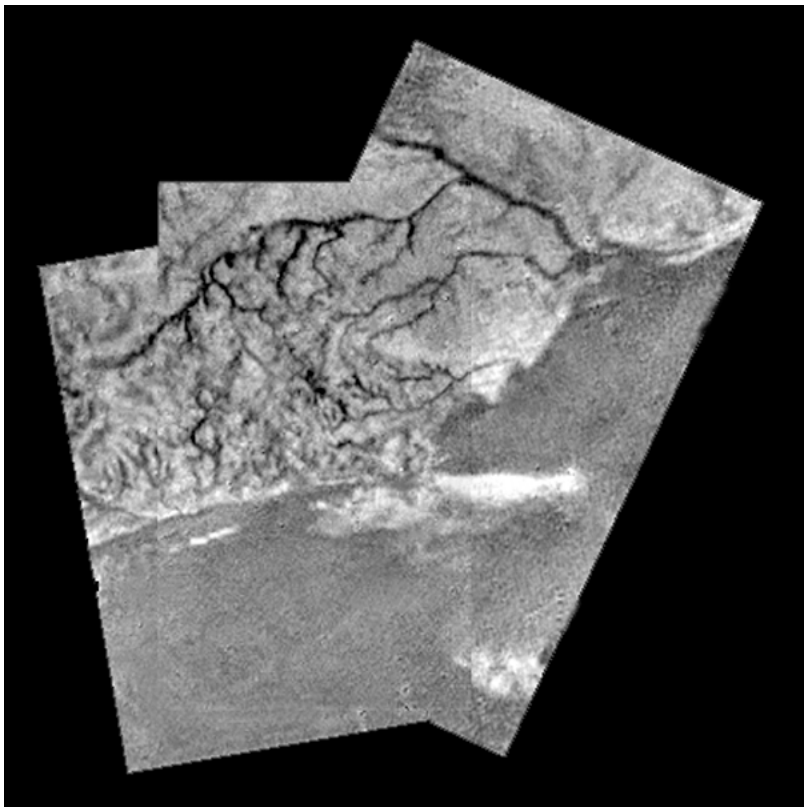
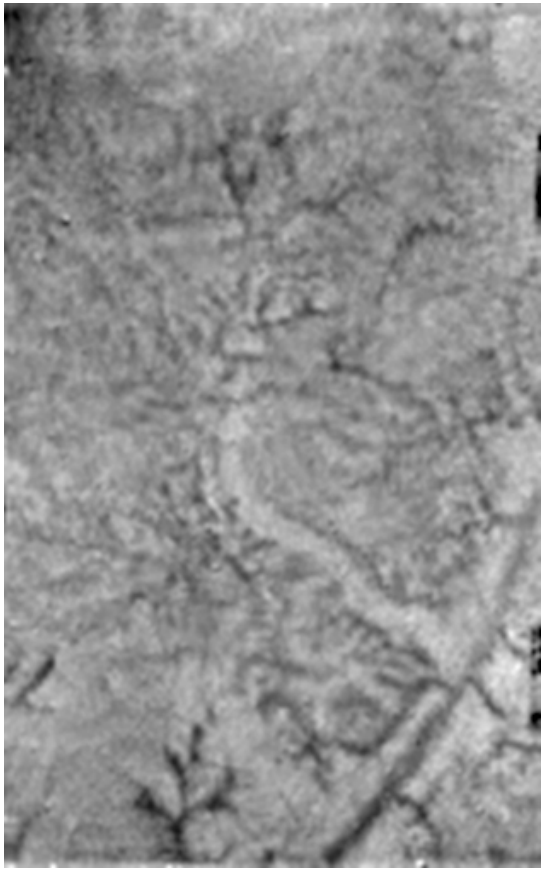


Photo: ESA

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

Water Rift and Methane Springs?



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

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

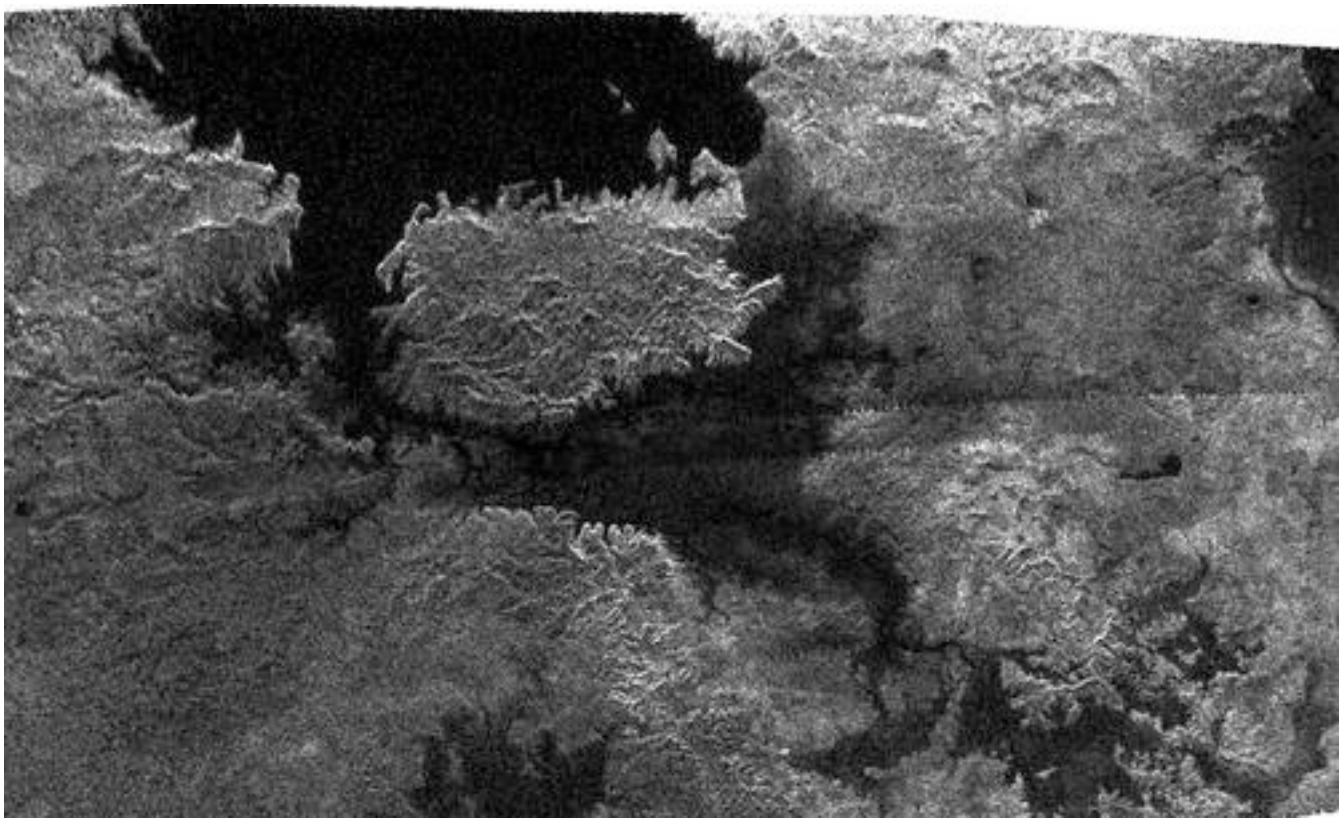


Image from Feb. 2007: based on radar.
Large lake and island (size of Big Island, Hawaii)
And smaller lakes

From the surface of Titan

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

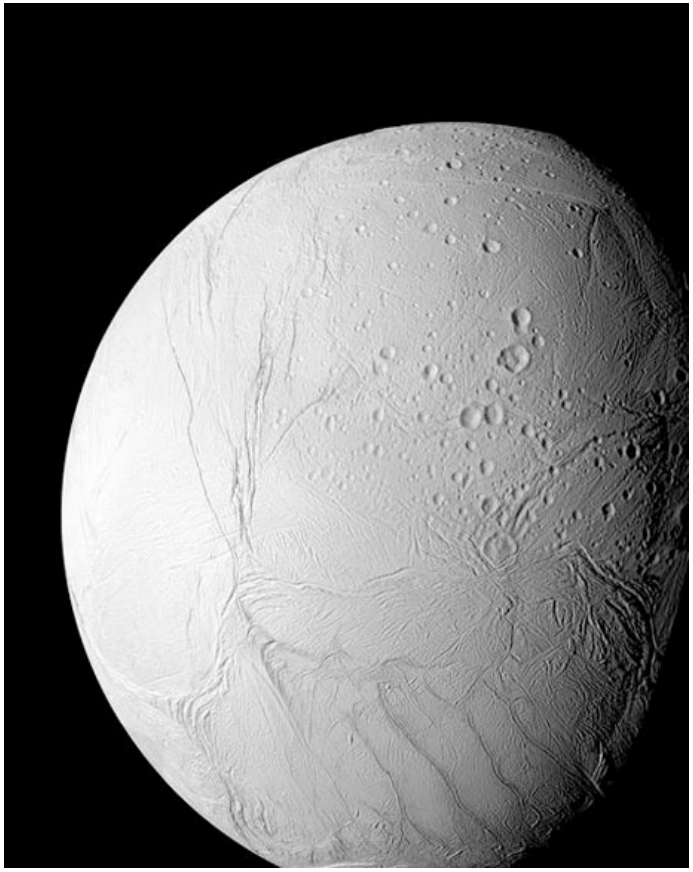
More Titan Results

- Hints of ammonia (NH_3)/water (H_2O) ocean
  - Under surface
  - Outgassing of NH_3 may supply N_2 atm.
- Mapping by radar reveals many lakes and seas of hydrocarbons
  - Total hydrocarbons on surface about 100 times total oil gas reserves on Earth (Feb. 08)

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?

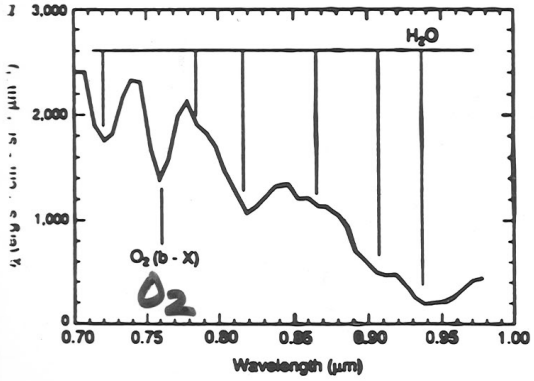
Detecting Life on Earth from Space

Galileo used during close Earth approach

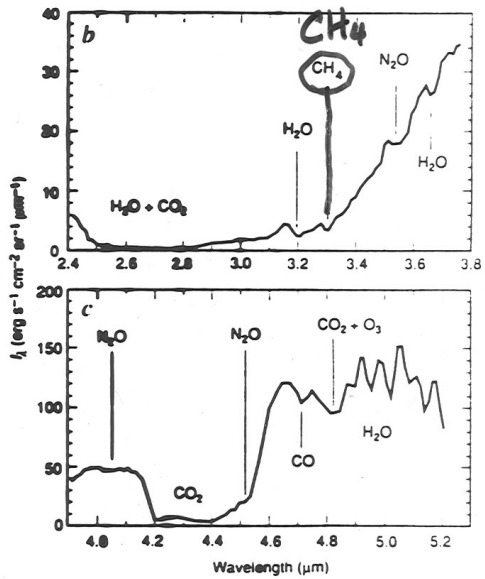
Photographs (1 km resolution) No clear signs of intelligent life

Spectrometers - evidence of life Lots of 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).

NATURE · VOL 365 · 21 OCTOBER 19

RADIO EMISSION: CLEAR EVIDENCE OF INTELLIGENT LIFE

TPF Concepts

TPF-I Infrared Interferometer (2020?)

TPF-C Visible light coronagraph (2014?)

Spectroscopy of atmosphere