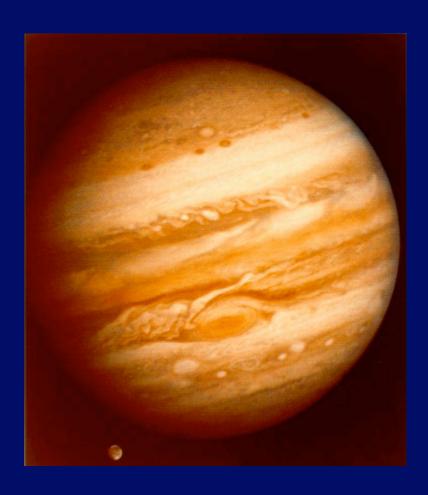
Life in the Outer Solar System

Jupiter



Big $R = 11R_{\oplus}$

Massive $M = 300 M_{\oplus}$

= 2.5 all the rest

Thick Atmosphere

Mostly H₂, He

But also more complex molecules

Colors, storms

Like Miller - Urey

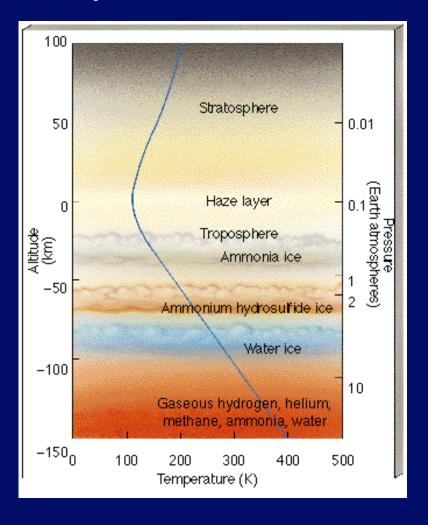
Life in Jupiter Atmosphere?

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?



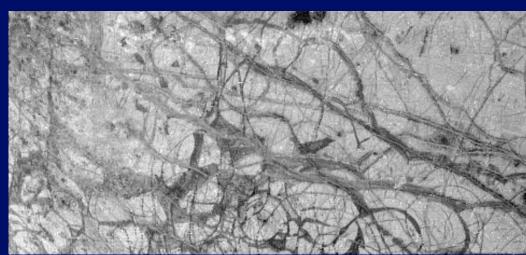


Europa (Moon of Jupiter)

Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

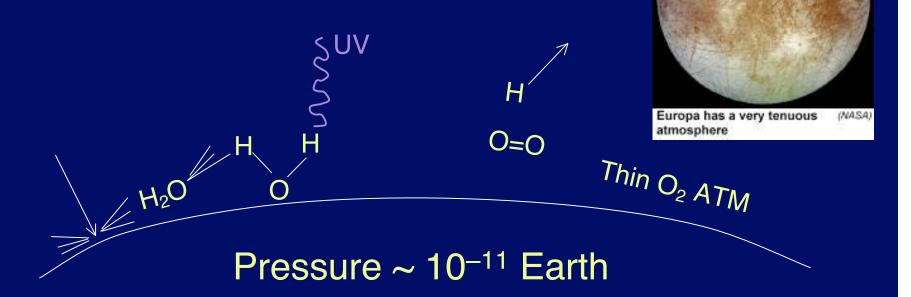


Close-up of "ice floes"

Galileo - Jupiter's Moons

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

Europa has a (THIN!) atmosphere



More evidence for resurfacing along cracks by

"ice geysers" ------- fluid ice or liquid water

Organic molecules on Callisto & Ganymede, maybe Europa?

Saturn



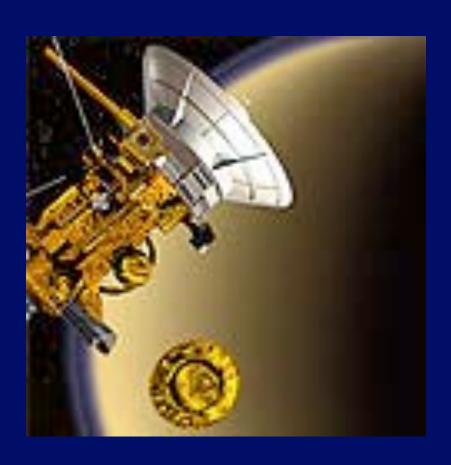
- Big (9.4 R⊕)
- Massive (95 M⊕)
- Year 29.5 years
- Day 0.43 days
- Composition similar to Jupiter



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

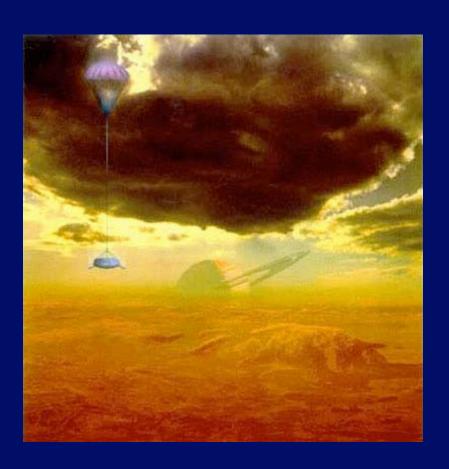
The Cassini-Huygens Mission



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

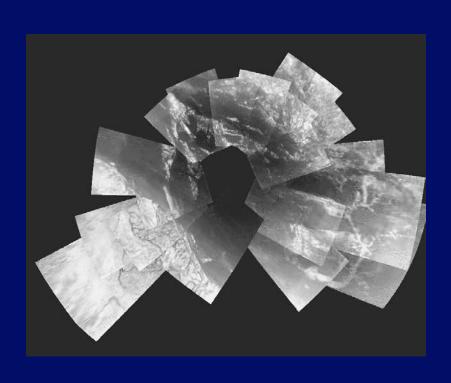


Huygens Probe



- 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

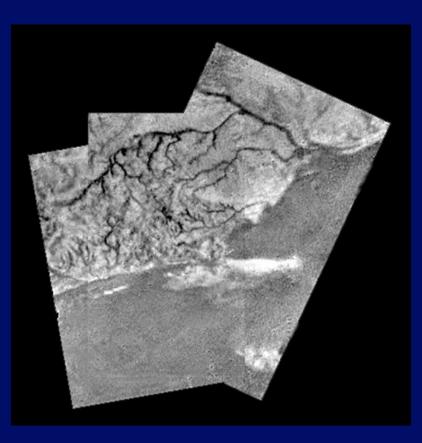
Titan Surface 10km up



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

Photo: ESA

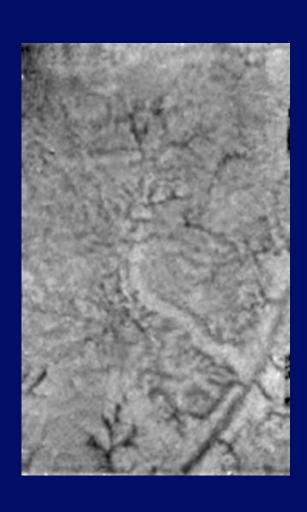
Titan



- River channel
- Coastline
- Liquid is present
- Methane (CH₄)

Photo: ESA

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 (C₂H₆)
- Ethane raining (or snowing) into lakes

Lakes and Islands

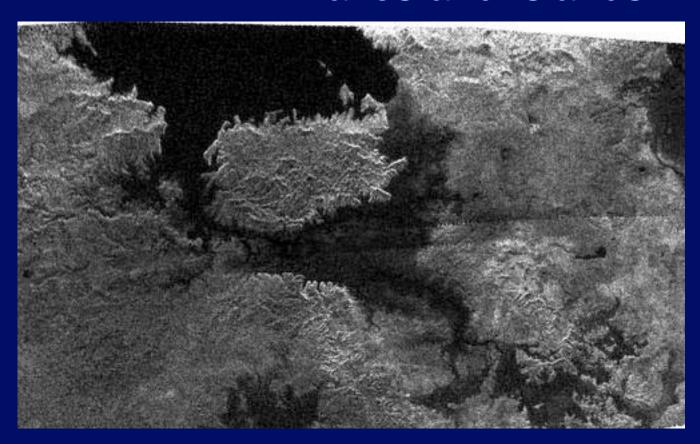


Image from Feb. 2007: based on radar. Large lake and island (size of Big Island, Hawaii) And smaller lakes

From the surface of Titan



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

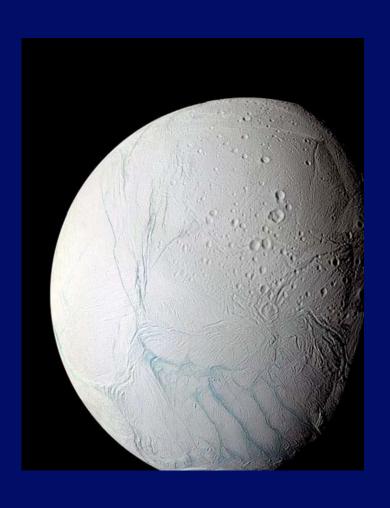
More Titan Results

- Hints of ammonia (NH₃)/water (H₂O) ocean
 - Under surface
 - Outgassing of NH₃ may supply N₂ 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?

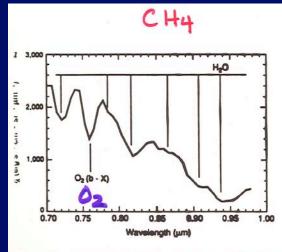
Issues of contamination

4. Biomarkers

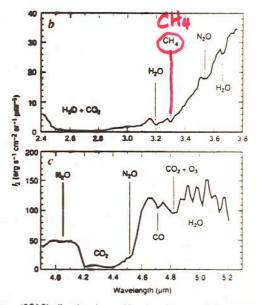
Presence of both O₂ and CH₄ in Earth atmosphere indicative of life How convincing?

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



1 a, Galileo long-wavelength-visible and near-infrared spectra of larth over a relatively cloud-free region of the Pacific Ocean, north meo. The incidence and emission angles are 77° and 57° respective. The (b' $\sum_{i=1}^{\infty} - X^3 \sum_{i=1}^{\infty}$) 0–0 band of O_0 at 0.76 μ m is evident, along a number of H_2O features. Using several cloud-free regions of a airmass, we estimate an O_2 vertical column density of 1.5 km-(at \pm 25%. b and c, infrared spectra of the Earth in the 2.4–5.2 μ m n. The strong v_3 CO $_2$ band is seen at the 4.3 μ m, and water vapour s are found, but not indicated, in the 3.0 μ m region. The v_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 μ m. The



methane (0010) vibrational transition is evident at 3.31 μ m. A cr estimate ¹⁰ of the CH₄ and N₂O column abundances is, for both spec of the order of 1 cm-amagate (\equiv 1 cm path at STP).

NATURE · VOL 365 · 21 OCTOBER 15

RADIO EMISSION: CLEAR EVIDENCE OF

TPF Concepts

TPF-I Infrared Interferometer (2020?)



TPF-C Visible light coronagraph (2014?)

Spectroscopy of atmosphere

