

# 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

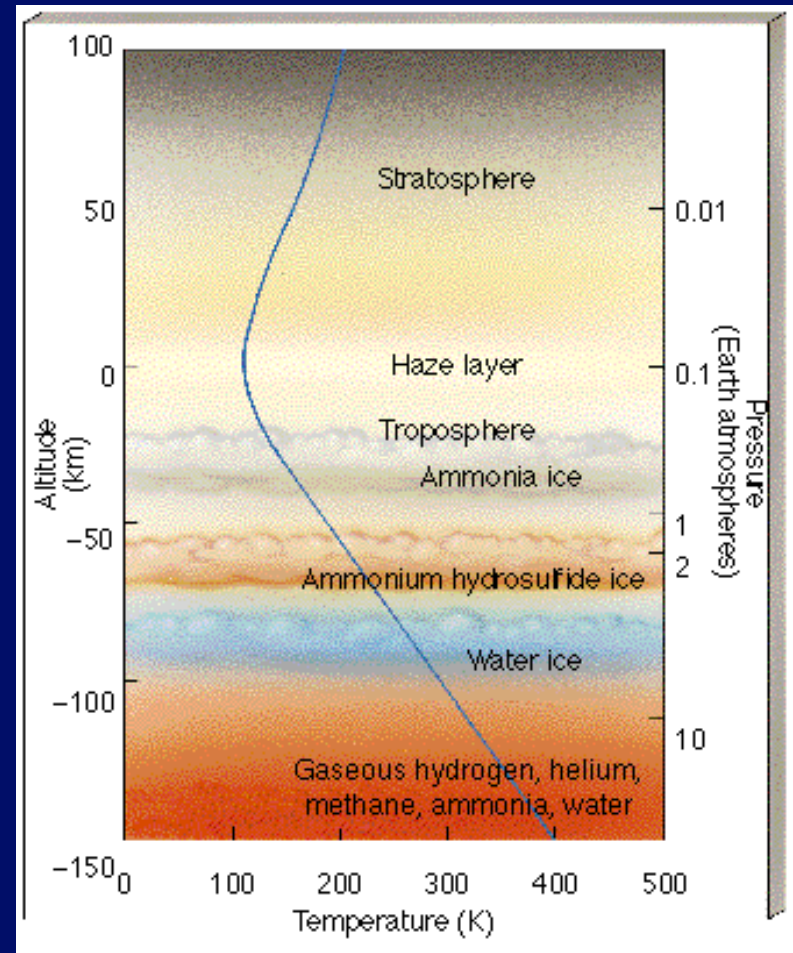
# Life in Jupiter Atmosphere?

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

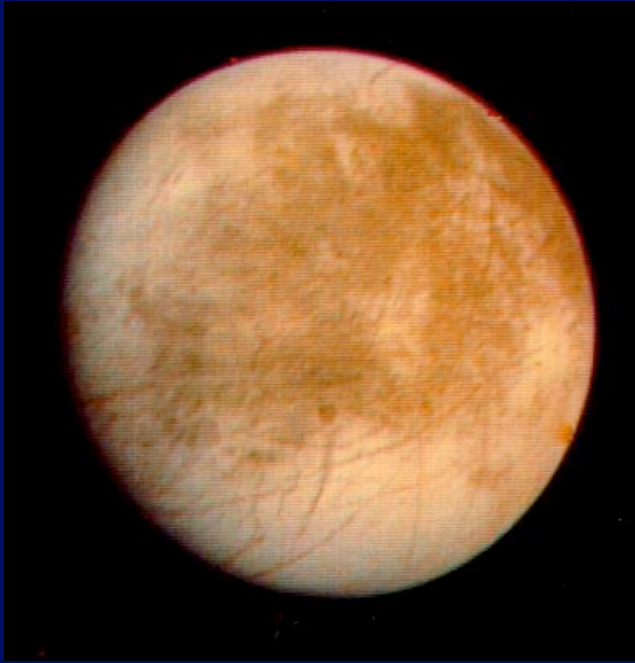
Surprise: Little or no H<sub>2</sub>O

May have entered in an unusual place (fewer clouds)

Life less likely?



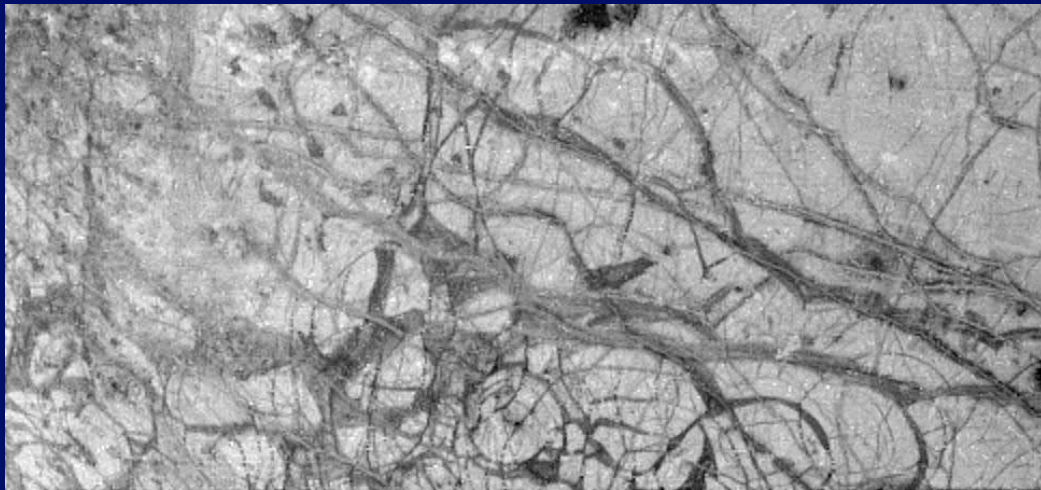
# Europa (Moon of Jupiter)



Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

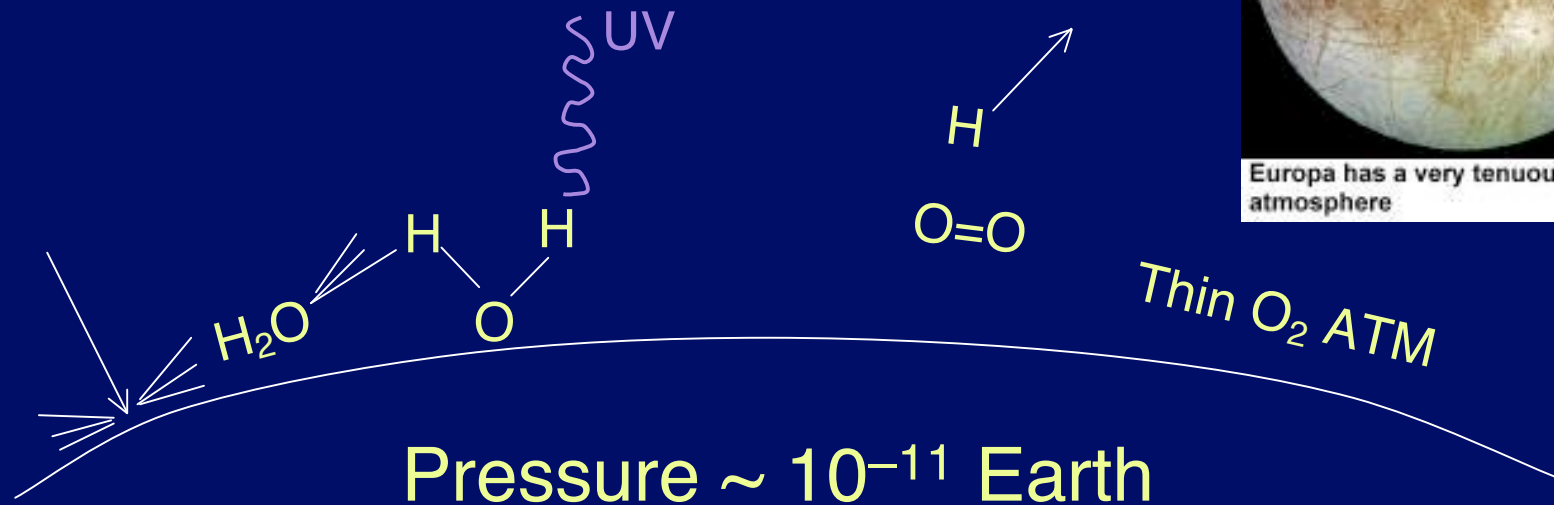


Close-up of "ice floes"

# Galileo - Jupiter's Moons

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

Europa has a (THIN!) atmosphere

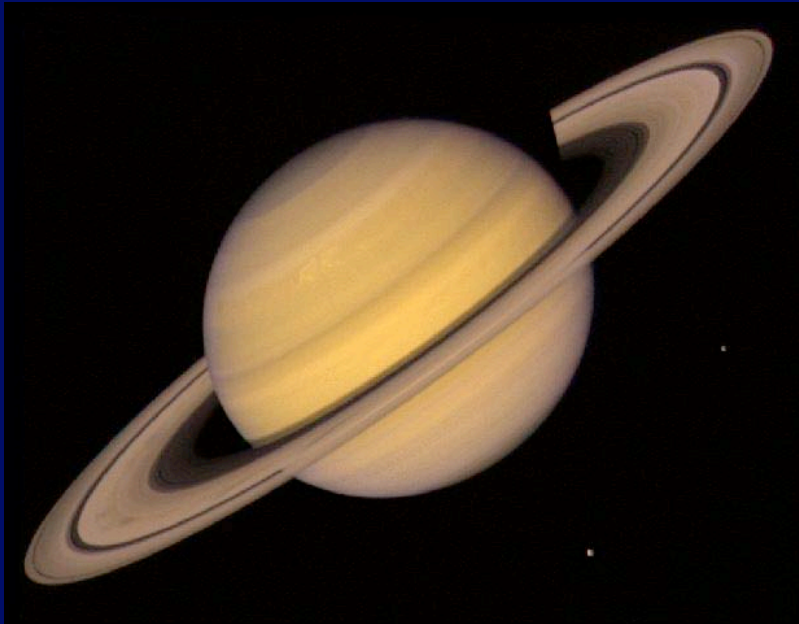


More evidence for resurfacing along cracks by

“ice geysers” → fluid ice or liquid water

Organic molecules on Callisto & Ganymede, maybe Europa?

# Saturn



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

# Titan



- Moon of Saturn
- Diameter  $\sim 0.4$  Earth
- Atmospheric Pressure =  $1.5 \times$  Earth
- 85% Nitrogen **BUT**
- Cold ( $\sim 90$  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

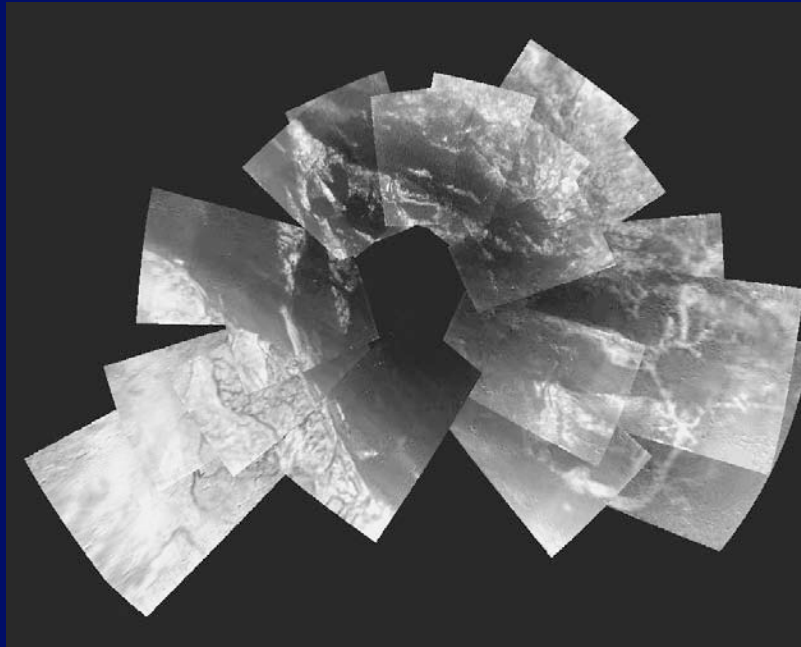
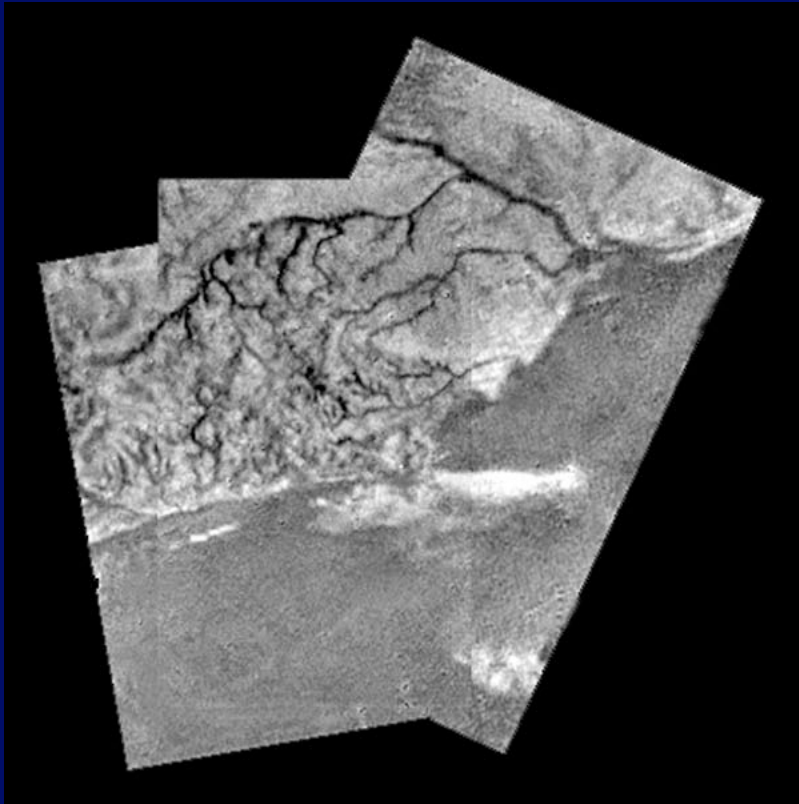


Photo: ESA

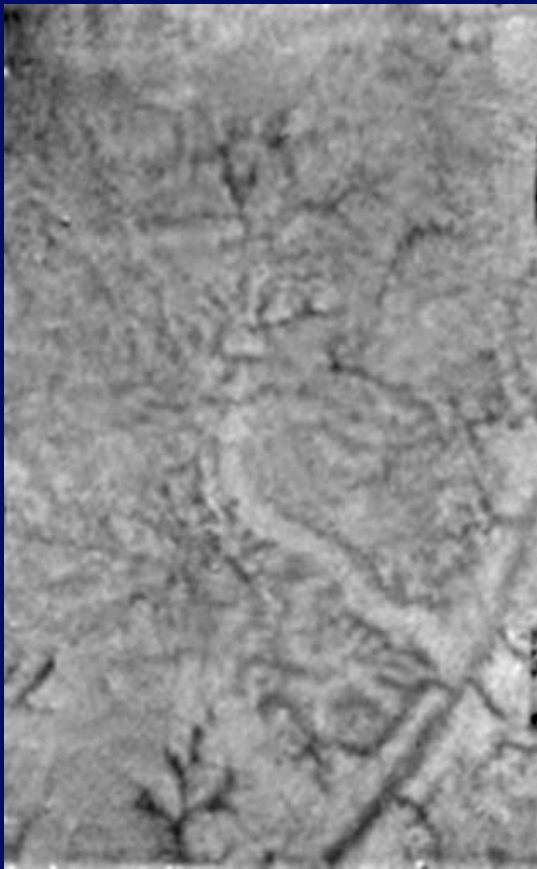
# Titan



- River channel
- Coastline
- Liquid is present
- Methane ( $\text{CH}_4$ )

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 ( $C_2H_6$ )
- Ethane raining (or snowing) into lakes

## Lakes and Islands

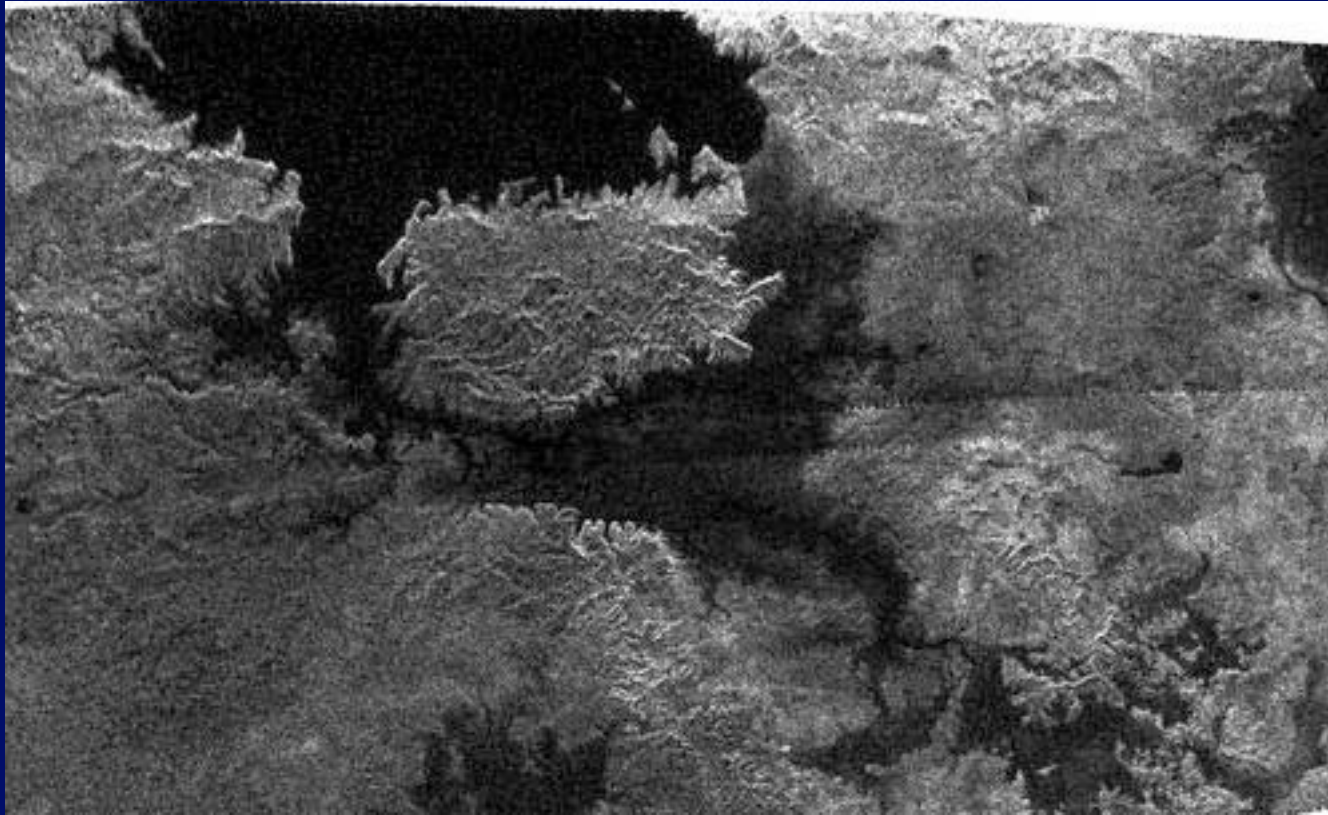
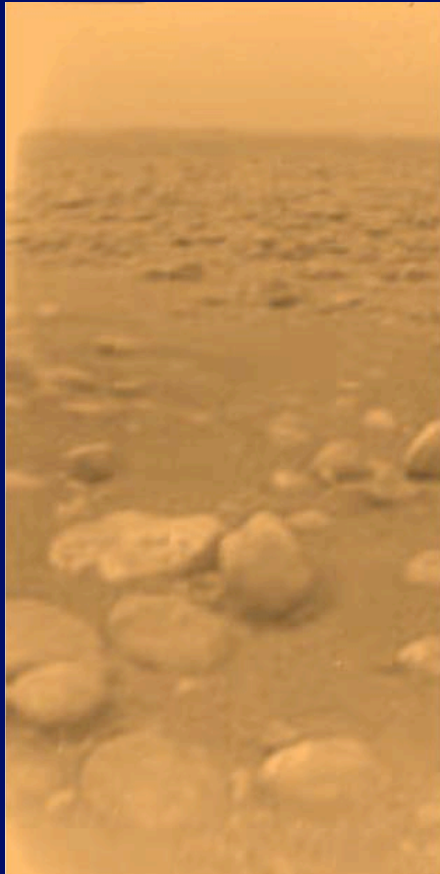


Image from Feb. 2007: based on radar.  
Large lake and island (size of Big Island, Hawaii)  
And smaller lakes



# From the surface of Titan



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

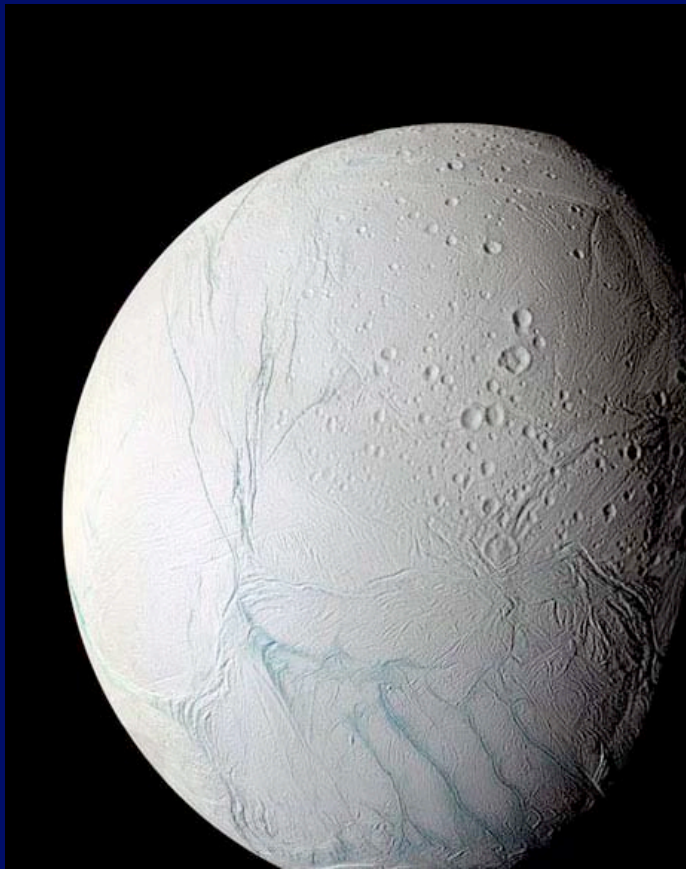
## More Titan Results

- Hints of ammonia ( $\text{NH}_3$ )/water ( $\text{H}_2\text{O}$ ) ocean
  - Under surface
  - Outgassing of  $\text{NH}_3$  may supply  $\text{N}_2$  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

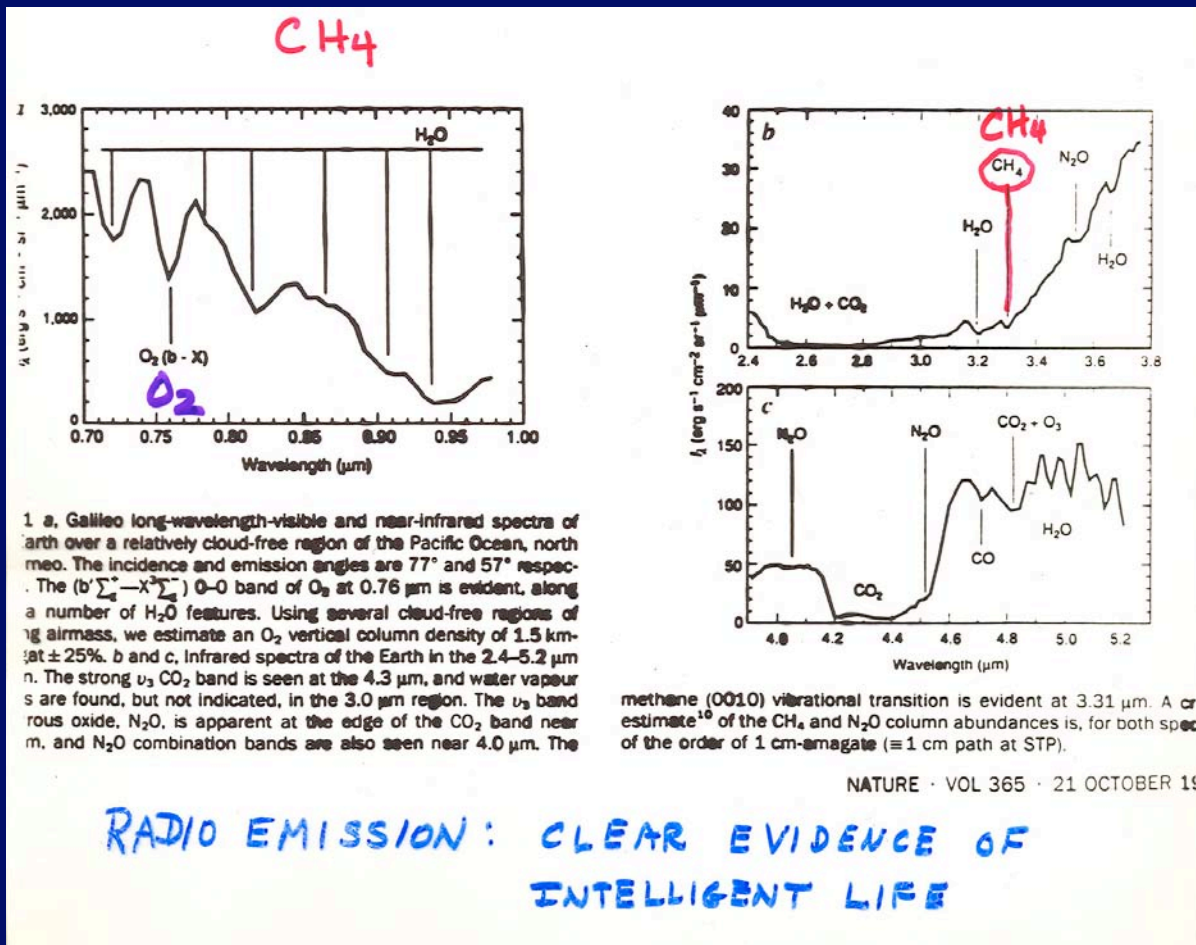
How convincing?

# Detecting Life on Earth from Space

Galileo used during close Earth approach

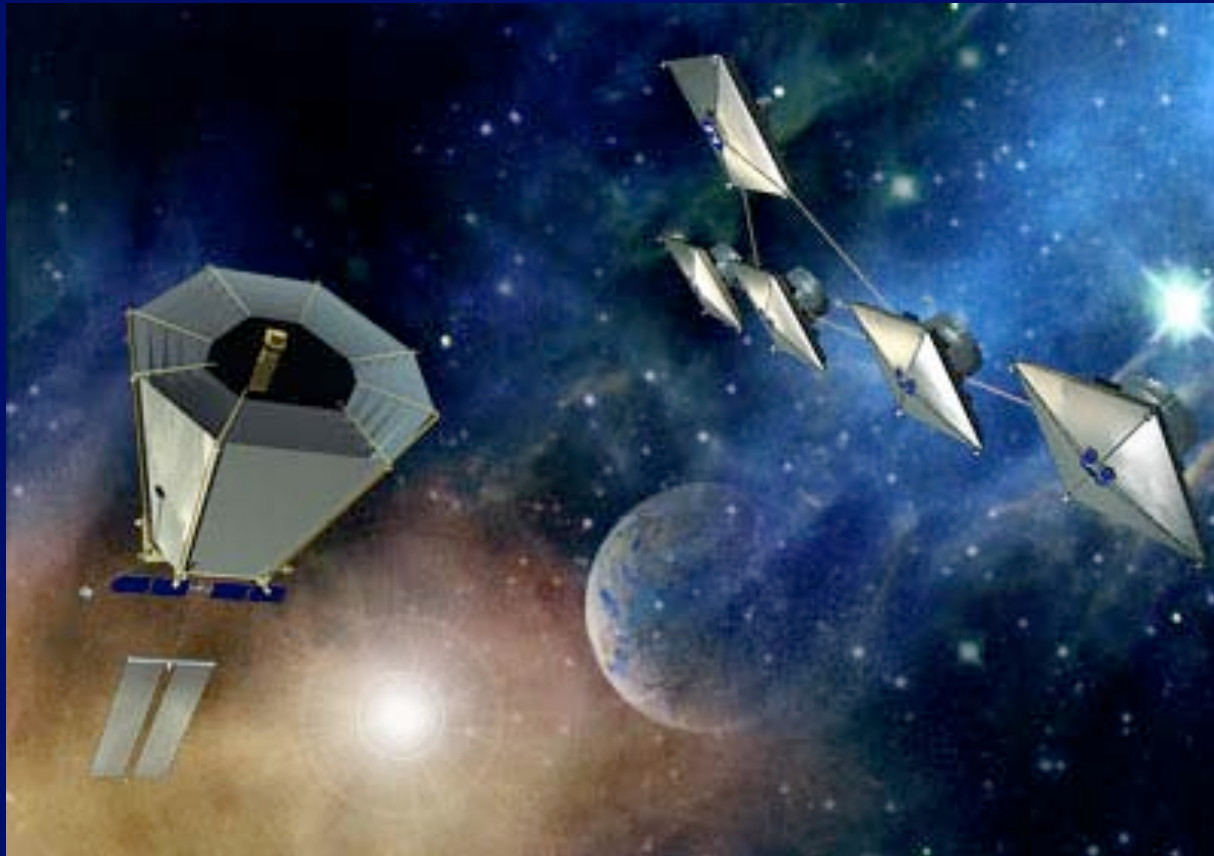
Photographs (1 km resolution) No clear signs of intelligent life

Spectrometers - evidence of life Lots of O<sub>2</sub>



# TPF Concepts

TPF-I Infrared Interferometer (2020?)



TPF-C Visible light coronagraph (2014?)

# Spectroscopy of atmosphere

