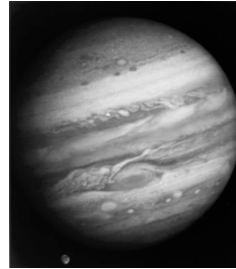


Life in the Outer Solar System

Jupiter

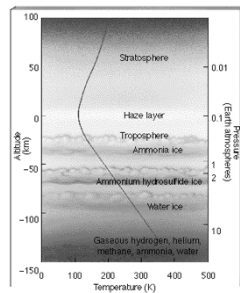


Big $R = 11R_{\oplus}$
 Massive $M = 300 M_{\oplus}$
 $= 2.5$ all the rest
 Thick Atmosphere
 Mostly H_2 , He
 But also more complex molecules
 Colors, storms
 Like Miller - Urey

Life in Jupiter Atmosphere?

Sagan-Salpeter, etc.

Sinkers (Plankton)
 Floaters (Fish)
 Hunters (Fish)



Galileo Results on Jupiter

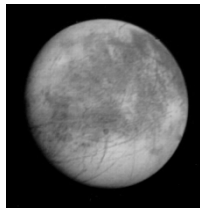
Reached Jupiter Dec. 1995 Sent probe into Jupiter's atmosphere at 100,000 mile/hour
 Decelerated at 230 g Lasted for 57 min.

Found: Strong winds
 Turbulence, little lightning

Surprise: Little or no H_2O
 May have entered in an unusual place (fewer clouds)

Life less likely?



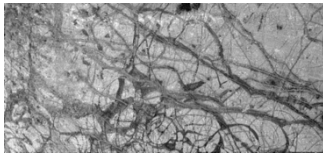


Europa (Moon of Jupiter)

Surface: Fractured Ice

Subsurface Oceans?

(Heated from Inside)

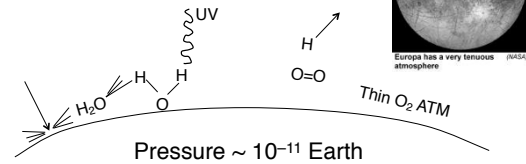


Close-up of "ice floes"

Galileo - Jupiter's Moons

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

Europa has a (THIN!) atmosphere

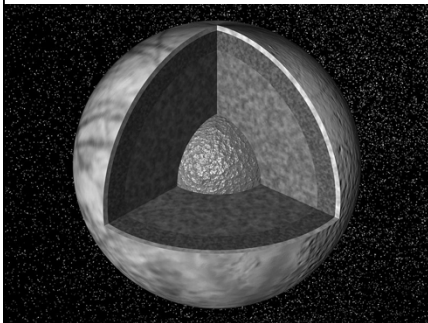


More evidence for resurfacing along cracks by

"ice geysers" \longrightarrow fluid ice or liquid water

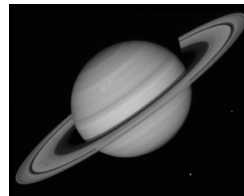
Organic molecules on Callisto & Ganymede, maybe Europa?

Model of Europa's Interior

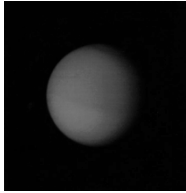


Ice crust may be 10-30 km thick.
Ocean may be 90 km deep.

Saturn



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



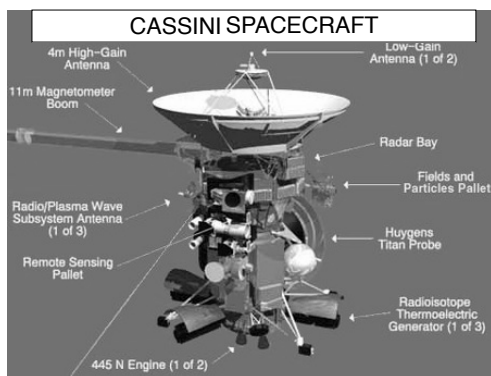
Titan

- Moon of Saturn
- Diameter ~ 0.4 Earth
- Atmospheric Pressure = $1.5 \times$ 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



Huygens Probe



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

Titan Surface 10km up

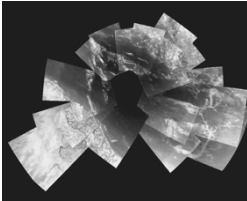


Photo: ESA

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

Titan

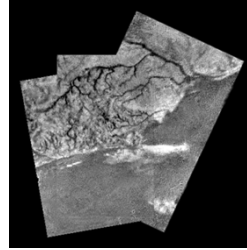
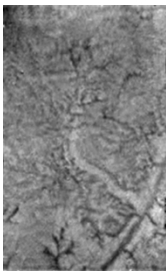


Photo: ESA

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

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

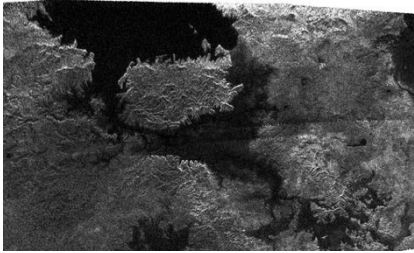


Image from Feb. 2007: based on radar.
Large lake and island (size of Big Island, Hawaii)
And smaller lakes

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 (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 and gas reserves on Earth (Feb. 08)

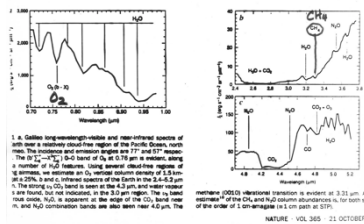
Lots of stuff on websites

- <http://saturn.jpl.nasa.gov/home/index.cfm>
- <http://www.esa.int/SPECIALS/Cassini-Huygens/>
- Periodic flybys of Titan
 - One scheduled for Mar. 27, 2009.

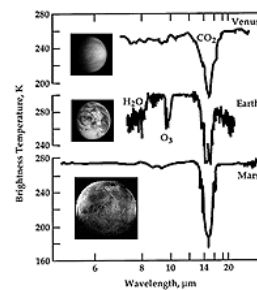
- ## How to search for life

National Academy report - how to search for life

- ## Detecting Life on Earth from Space

$$\text{CH}_4$$


Spectroscopy of atmosphere



6