Astronomy 330

This class (Lecture 13):

Life in the Solar System
Maura Walsh
Carolyn Buesing

Next Class:

Origin of Life
Alesia Prakapenka
Anthony Salis

Midterm due next Thursday.

Music: *Life on Mars*– David Bowie

Take Home Midterm

- Will email it to everyone after class today.
  - 50%: 4 short (few paragraphs) essays
  - 50%: 1 large (~1-2 page) essay (with definition terms)
- Must be typed, not handwritten.
- Will cover material up to and including today.
- It is a closed notes exam (honor system!).
- You can make 1 page of notes that you use during the exam.

HW 2

- Michelle Boehm
  http://www.latest-ufo-sightings.net/
- Sonja Bromann
  http://www.proofofalienlife.com/

Presentations

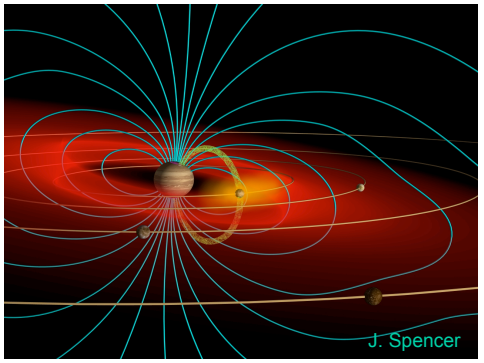
- Maura Walsh
  Space Food
- Carolyn Buesing
  Space Care

Outline

- What about life on Europa (Moon of Jupiter)?
- What about life on Titan (Moon of Saturn)?
- Need to consider the Star too..
  - Too big?
  - Too small?
  - Too binary?
  - Too hairy?

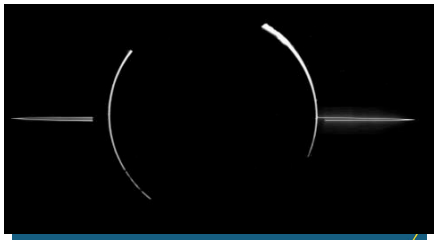
Jupiter's Magnetosphere

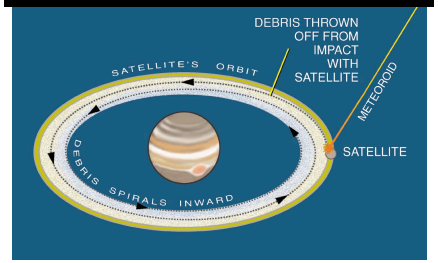
- Liquid metal hydrogen generates a magnetic field
  - 14x stronger than Earth's field
  - Over 4 million km across
- A ring of ionized particles surrounds Jupiter
  - Stripped from Jupiter's moon Io



Jupiter's Rings

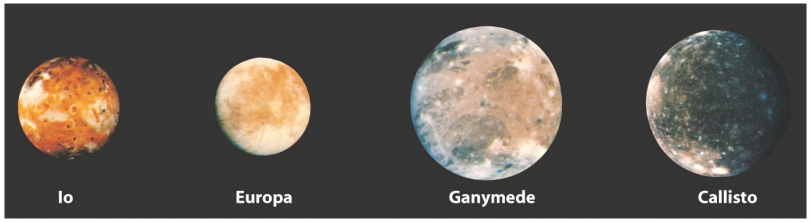
- Jupiter has rings!
- Discovered by the Voyagers
- Not prominent like Saturn's
- Dusty disk of debris, probably from meteoroid impacts with small moons





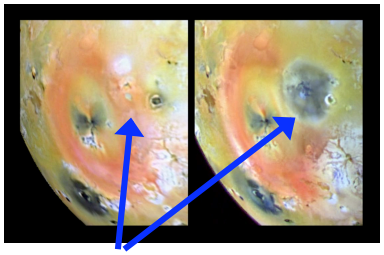
The Galilean Moons

- Io is active.
- Europa is now thought to be the best option for life.
- But, Ganymede and Callisto are contenders perhaps for ancient life.

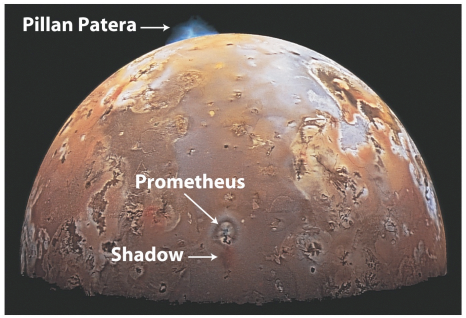


Io

- Innermost Galilean moon – the “pizza moon”
- The most volcanically active body in the solar system.
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter’s tides
- Atmospheric gases ripped off by Jupiter’s magnetic field – ion torus

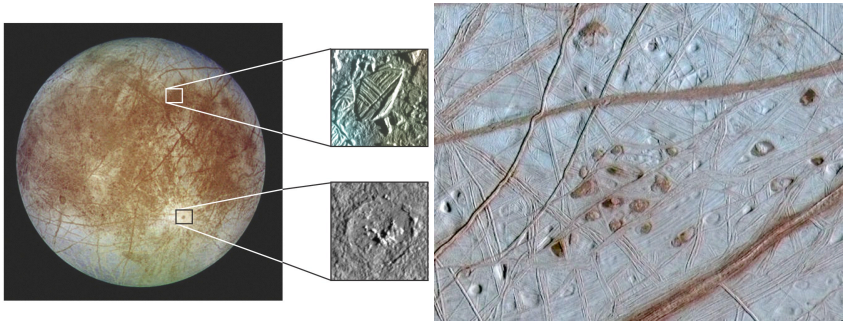


Pillan Patera eruption
Before & after



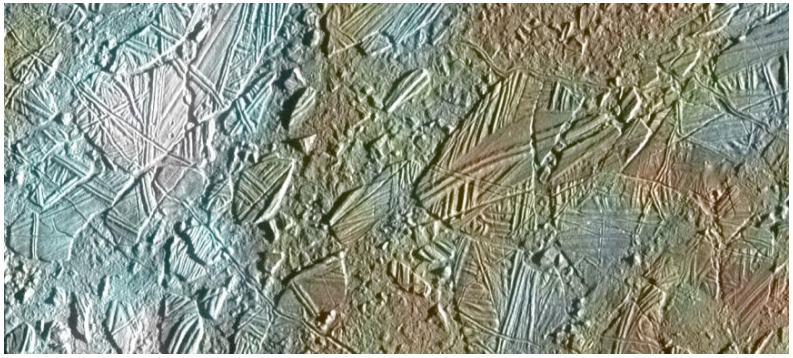
Europa

- Slightly smaller than our Moon.
- Icy crust 5 km thick. Can protect life against magnetic fields.
- Evidence for deep (50 km!) liquid water ocean beneath crust– remains liquid from tidal forces from Jupiter
- Cracks and fissures on surface – upwelling?



Galileo

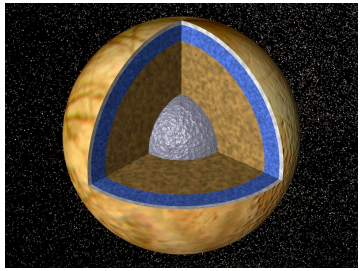
Europa



- Young surface – few craters
- Tidal forces pull and push the ice
  - Like Io, it probably has strong tidal forces.

Europa

- Life would have to be below the surface, around hydrothermal vents.
- Very encouraging, as early life on Earth, might have been formed around such vents.
- We don’t how thick the ice is yet.
- Future missions, will have to employ melting or smash and dive spacecraft.



Ganymede

- Largest of the Galilean Moons
- Partly ancient surface, partly younger surface
  - Younger surfaces about the age of the Moon's maria
- Compared to our Moon:
  - 50% larger
  - 100% more massive
  - 40% less dense
- Interior more differentiated than Callisto, probably has an iron core
- May have a water ocean under surface.

Callisto

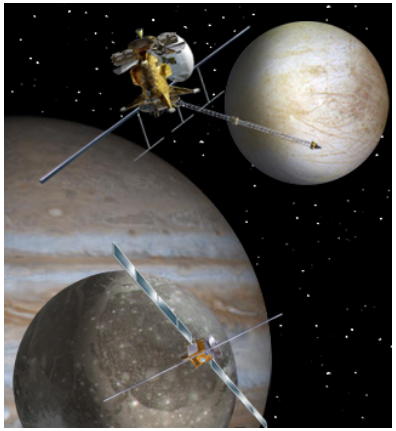
- Furthest of the Galilean Moons from Jupiter
- Ancient surface, covered with craters
- Compared to our Moon:
  - 40% larger
  - 50% more massive
  - 45% less dense
- Surface is made of "dirty ice"
- Interior is rocky, mixed with ice

Finding JIMO

- Jupiter Icy Moon Orbiter
  - To launch in 2017 or later
- Study Callisto, Ganymede, and Europa
  - Investigate makeup
  - Histories
  - Potential for sustaining life

Europa Jupiter System Mission

- Early planning stages of NASA/ESA/JAXA mission.
- Two or three orbiters
  - Launch date around 2020

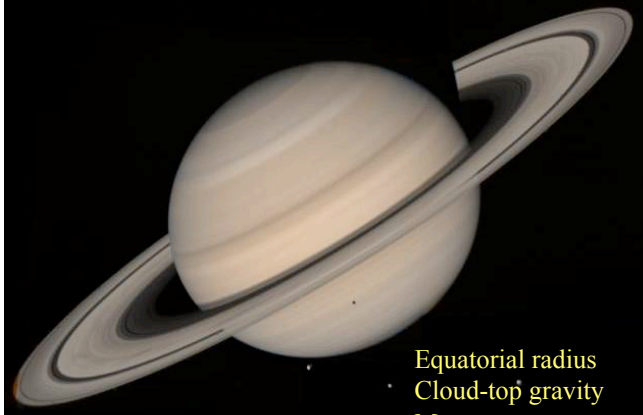


Question

The best place to look for life in the Jupiter system is

a) in the frozen oceans of Callisto.
b) in the frozen oceans of Ganymede.
c) in the upper atmospheres of Jupiter, floating life.
d) deep in the atmosphere of Jupiter, diamond bodied life to withstand the pressures.
e) under the ice on Europa.

Earth – Saturn comparison



It floats. The least spherical planet.

Equatorial radius	9.45 Earth
Cloud-top gravity	1.07 Earth
Mass	95.2 Earth
Distance from Sun	9.53 AU
Year	29.5 Earth years
Solar day (equator)	10 hours 14 minutes

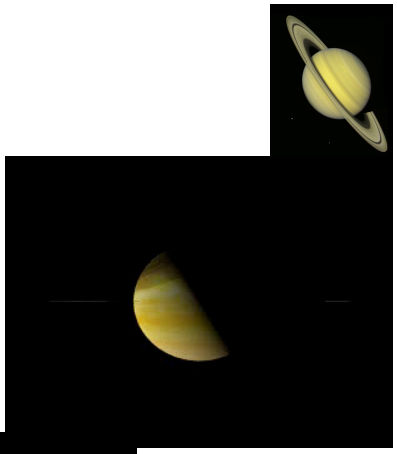
Jupiter-Saturn Comparison

Equatorial radius	0.84 Jupiter
Mass	0.30 Jupiter
Density	0.52 Jupiter

Almost as big as Jupiter, but
Much less massive!

Saturn

- Named for the father of the Roman gods
- Saturn is very similar to Jupiter
  - Large planet
    - Mostly liquid hydrogen
  - Has a mini-solar system
    - At least 60 moons
    - Most are small

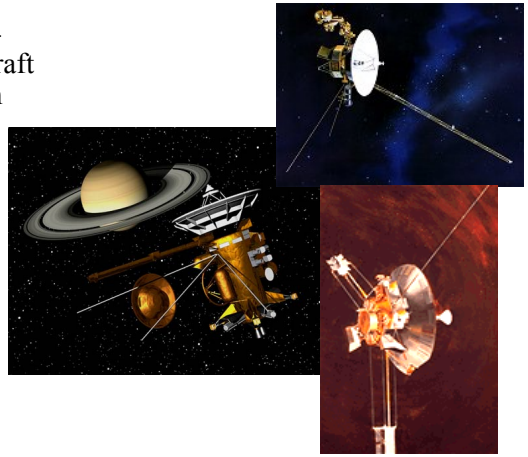


http://www.solarviews.com/cap/sat/saturn.htm

http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/images/saturn/images/PIA05380.jpg&type=image

Missions to Saturn

- There have been 4 unmanned spacecraft missions to Saturn
- Pioneer 11
  - Flyby 1979
- Voyager 1
  - Flyby 1980
- Voyager 2
  - Flyby 1981
- Cassini-Huygens
  - Arrived 2004

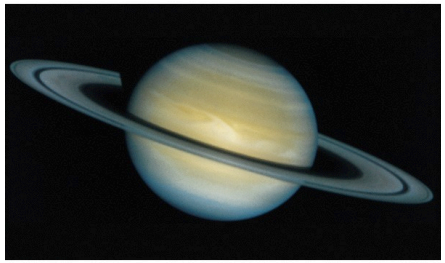


The Cassini Mission

- Launched on October 15th, 1997
- Arrived at Saturn on July 1st, 2004
- Orbiting Saturn, making flybys of the planet, its rings, and some of its moons
- Contains 12 scientific instruments
- Also carries the Huygens probe, which was dropped onto Titan, Saturn's largest moon on Jan 2005. Remember?

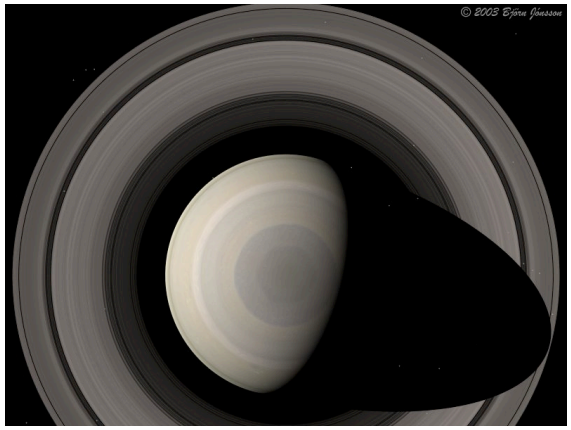
Saturn's Atmosphere

- Composition similar to Jupiter
  - Mostly hydrogen and helium
- Atmosphere more "spread out"
  - Less gravity
  - Contrast of cloud bands reduced
- Wind speeds fastest at the equator
  - 1000 km per hour!



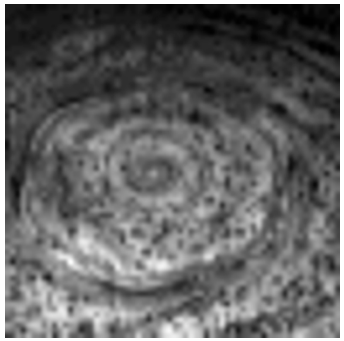
Driving Saturn's Weather

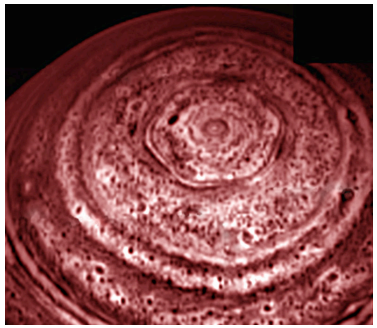
- As on Jupiter, Saturn's internal heat drives weather
  - Saturn radiates 80% more heat than it receives from the Sun
  - Like Jupiter, Saturn is still contracting!
  - As is contracts, heat is produced



Driving Saturn's Weather

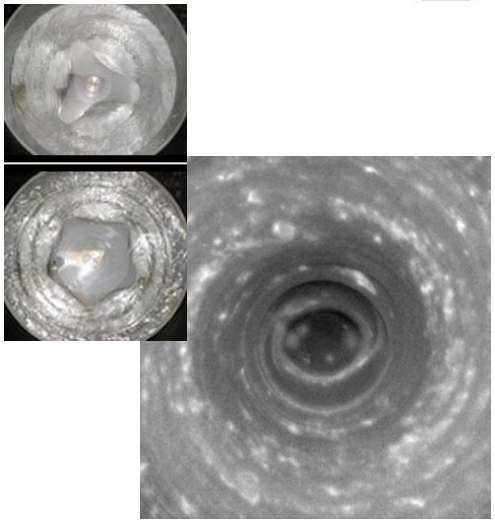
- As on Jupiter, storms are produced between cloud bands
  - No long lasting storm like the Great Red Spot, but hexagon cloud at pole has been stable for 20+ years.





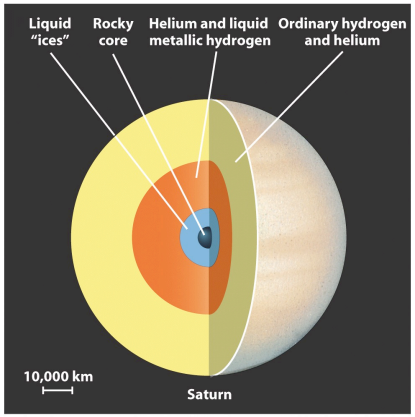
Driving Saturn's Weather

- Spinning water bucket experiments show similar features.
- Pseudoscience posit sound wave reflections.
- Saturn's South Pole also has an unusual structure.



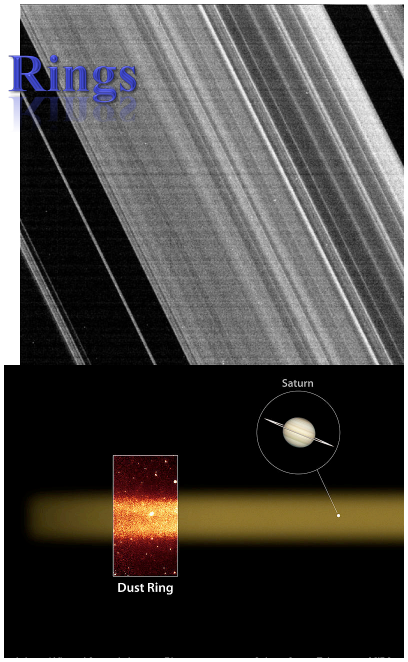
Saturn's Interior

- Similar structure to Jupiter's
  - But Saturn is less massive
  - The interior is less compressed
- Liquid metallic hydrogen creates a magnetic field
  - 30% weaker than Earth's



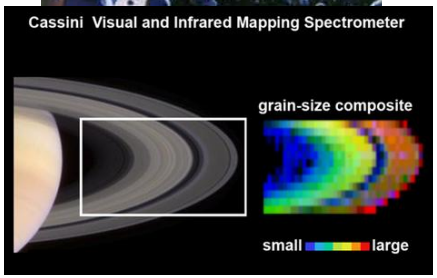
Saturn's Rings

- Two main rings
  - Several fainter rings
  - Each ring is divided into *ringlets*
- The rings are **thin**
  - Only a few tens of meters thick– razor thin!



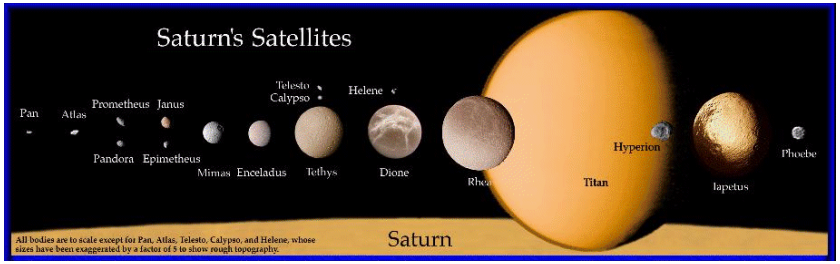
Makeup of the Rings

- The rings of Saturn are **not** solid rings
  - Made of icy rocks
  - 1cm to 10m across
- New Cassini data shows ring particle size varies with distance from Saturn
  - Note the gap is filled with small particles



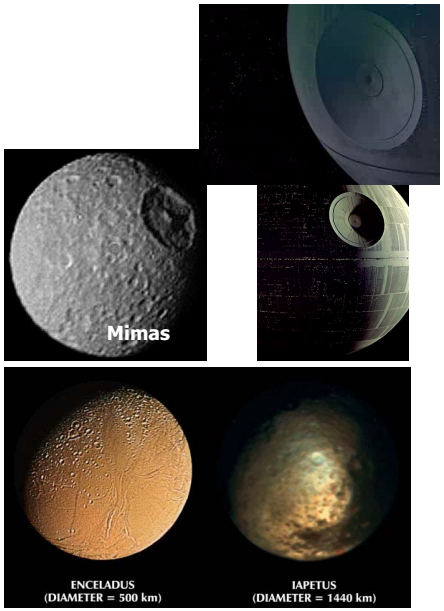
Saturn's Moons

- Saturn has a large number of moons
  - At least 60
- Only Titan is comparable to Jupiter's Galilean moons
- Smaller moons are mostly ice, some rock



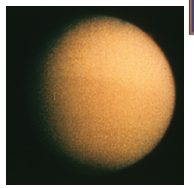
Saturn's Odd Moons

- **Mimas** - Crater two-thirds its own radius
- **Enceladus** - Fresh ice surface, water volcanoes?
- **Hyperion** – Irregularly shaped
- **Iapetus** - Half its surface is 10x darker than the other half
- **Phoebe** - Orbits Saturn backwards

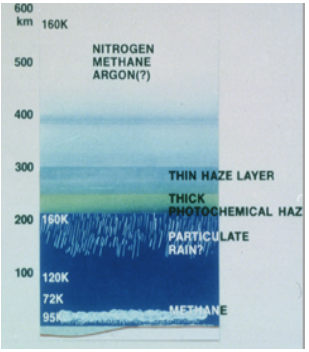


Titan

- Saturn's largest moon– bigger than Mercury.
- 2nd largest moon in the solar system after Ganymede.
- Discovered in 1655 by Christiaan Huygens
- Only moon to have a dense atmosphere
  - Dense nitrogen atmosphere
  - Small greenhouse effect
  - 98% nitrogen
    - –Only Earth is comparable
    - –Methane (something producing it)
  - Much like ancient Earth!

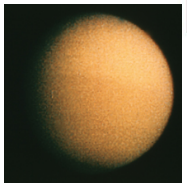


Titan's atmosphere

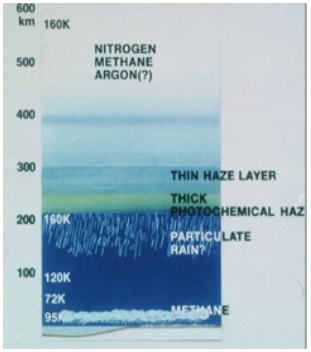


Titan

- Atmospheric pressure is 1.5 times Earth's
- Organic compounds – life?
  - Probably not – too cold: 95 K
  - May be a "deep freeze" of the chemical composition of ancient Earth

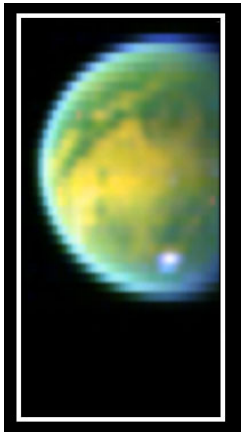


Titan's atmosphere



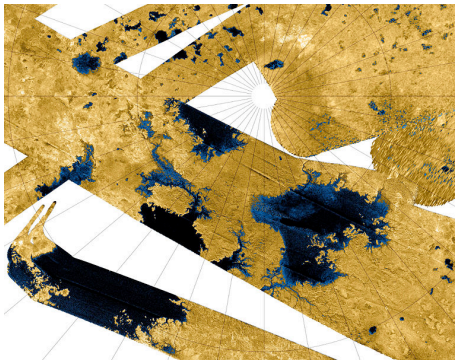
Piercing the Smog

- Cassini has special infrared cameras to see through Titan's smog
- Green areas are water ice
- Yellow-orange areas are hydrocarbon ice
- White area is a methane cloud over the south pole



Surface Liquid

- Now confirmed to have liquid on surface.
- Only body besides the Earth.
- Too cold for water, so most likely filled with liquid ethane, methane, and dissolved nitrogen



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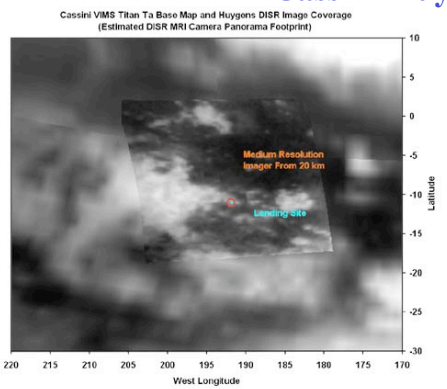
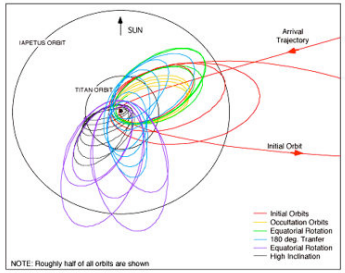
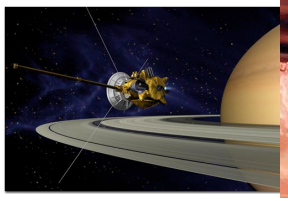
Cassini-Huygens





Arrival at Saturn
July 1, 2004

Huygens Probe
descent to Titan
Jan 14, 2005

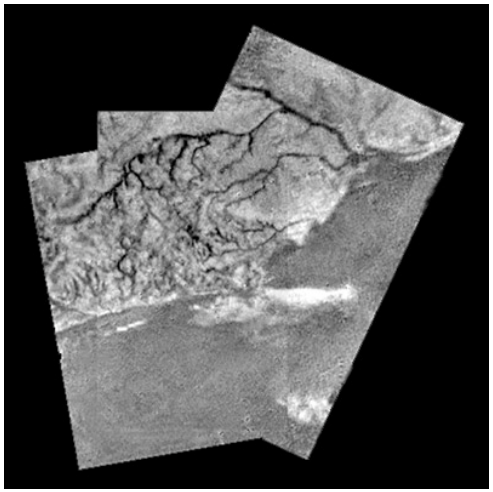


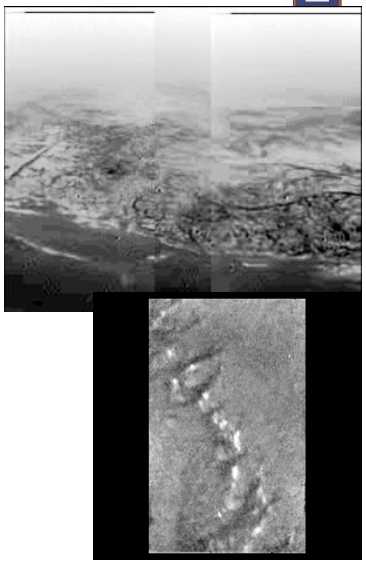
A Possible Landing

- The probe floating in the methane/ethane sea of Titan.
- Mountains in the distance.

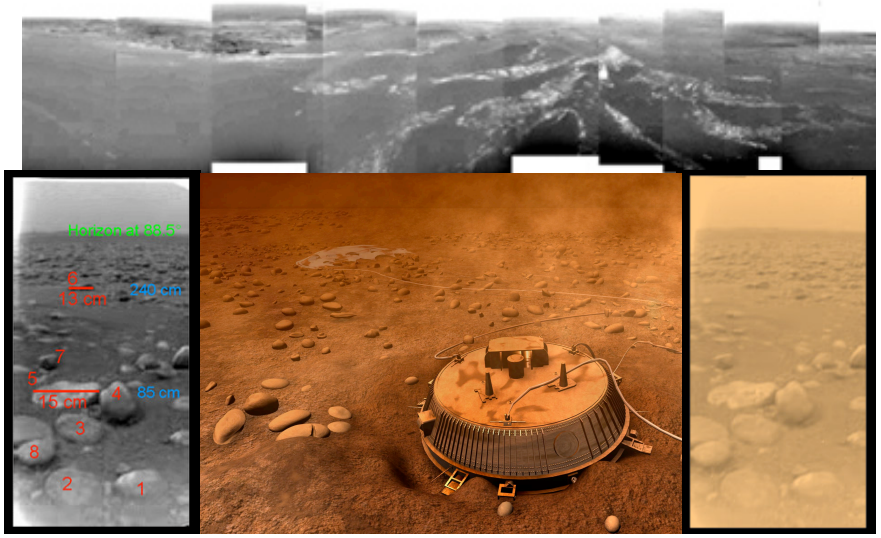
http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/images/artwork/images/

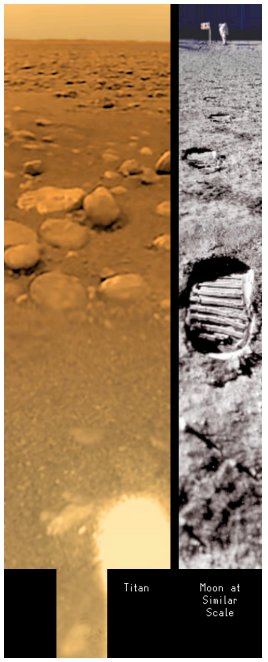
Mapping Titan



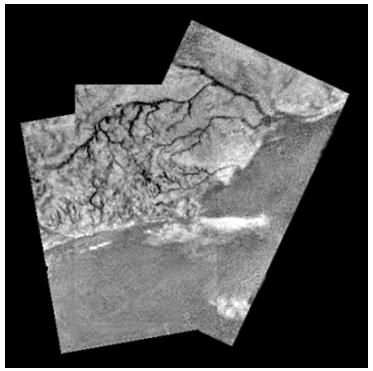


Mapping Titan





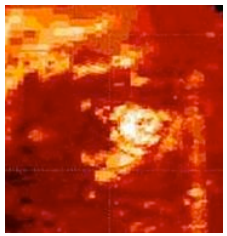
Mapping Titan



http://esamultimedia.esa.int/multimedia/esc/esaspacecast001.mp4

Cryovolcanoes

- Methane may come from volcanoes.
- Volcanoes heat up rock hard ice, spewing "lava" made up of water and ammonia.
- Two hot spots found in atmosphere, suggesting eruptions.
- Mountains found, suggesting some sort of plate tectonics.



Life on Titan

- Conditions much like the early Earth.
- Can organic chemistry work well in this environment?
- If found, would revolutionize our understanding of life.
- Some researchers suggest that panspermia from Earth is likely, so might find our cousins.
- Future missions will need to have biological component.

Conclusion

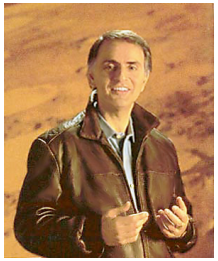
- ***No conclusive evidence exists for life in our solar system besides on Earth***
- But, possibilities exist for life
  - Venus's clouds may have migrated life.
  - Mars may have some microbial history linked to water, and perhaps some subsurface life.
  - Jupiter's reducing atmosphere may harbor sinkers.
  - Europa's sub-crustal oceans may harbor life, even fish-like life.
  - Titan is still very interesting
    - Thick atmosphere
    - Reducing chemistry

Question

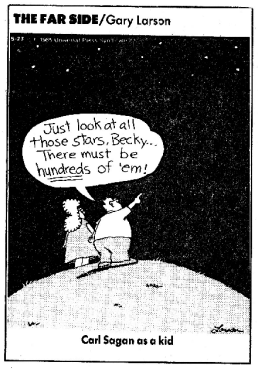
Why is Titan an interesting place to look for life?

a) It will revolutionize how we think about ET life.
b) It will create new life hybrids.
c) There is no chance of life there.
d) The life is in early state if at all.
e) Black beans.

Optimism?



- Carl Sagan argues for $n_p > 3$.
  - If Venus had less clouds (less greenhouse) it could have been cool enough for life.
  - If Mars had a thicker atmosphere it could have been warm enough for life.
  - If solvents other than water were used, maybe the moons of the outer planets?
  - Giant Jupiter-like planets close in?
  - Non-Earth life?



http://www.uranos.eu.org/biogr/sagane.html
http://spider.ipac.caltech.edu/staff/jarrett/sagan/sagan.html

Pessimism?

- We only considered temperature. What about:
  - Gravity?
  - Atmospheric pressure?
  - Size of the moon or planet?
  - Does life need a Moon-like moon? Does life need the tides? Does the Moon protect the Earth's rotation? Is a Jupiter needed?

- If we impose Earth chauvinism, we can easily reduce to $n_p \sim 0.1$

http://sagiru.tripod.com/Travel/Lost_in_the_Sahara/lost_in_the_sahara

n_p: number of life planets per planetary system (average)

- Can range from 0.01 to >3.
  - Is seismic activity necessary to recycle bioelements?
  - How important is the first atmosphere? Ozone?
  - Is a moon needed? A large Jupiter-like planet?
  - Is liquid water a requirement? Other solvents okay?
    - Not too hot, not too cold; not too much pressure, not too little– Goldilocks requirement?
  - Habitable Zone around the star.
  - Galactic Habitable Zone
  - Does atmosphere need feedback mechanism?
  - But in our solar system, maybe 5 nearly possible life planets.