Astronomy 330

This class (Lecture 16):
Life in the Outer Planets

Next Class:

Biological Evolution

HW 6 due March 31st

No Discussion class tomorrow

Music: *Spaceboy* – Smashing Pumpkins

Outline

- Life on Europa?
- Life on Titan?
- What is f_l?

Drake Equation

Frank Drake

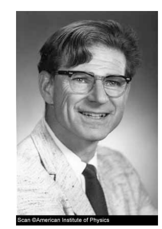
That's 0.36 Life-liking systems/year

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	20 stars/yr	0.12 systems/star	1.25 x 0.12 = 0.15 planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

Life?

- Carl Sagan and Edwin Salpeter devised a scheme for life in the clouds of Jupiter.
- They argued that the atmosphere must be rich in organic chemistry, so why not expect Earth-like life?



http://tierra.rediris.es/merge/Carl_Sagan/192a.jpg
http://www.aip.org/history/esva/catalog/images/salpeter_edwin_a3.jpg

Floating Life

- The problem is that any life in the clouds that sank too far down would be destroyed by the temperature or pressure.
- They proposed a simple life form like oceanic plankton called "sinkers".
- Small (0.1 cm) life that grew and fell, but then replicated by "splitting-up" and getting circulated back into the upper atmosphere.

http://www.wackerbaits.com/sf/media/bellsinker.jpg
http://www.mantapacific.org/mantapacific/information/images/plankton.jpg

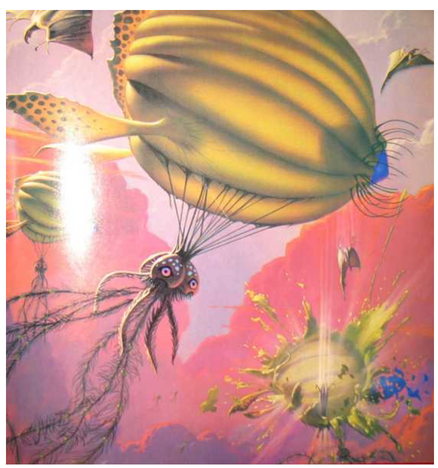
Floating Life

- The sinkers became the basis of a proposed ecology.
- They also posited "floaters"– large hydrogen balloon-like life that "swim" in the Jovian atmosphere.

http://www.firaxis.com/smac/nativelife.cfm

Floating Life

- They could be huge creatures, as large as 1 to 2 km in diameter.
- Maybe similar to whales– mixture between jellyfish and birds?
- Big bags of hydrogen gas.



http://img.photobucket.com/albums/v154/superminyme/National%20Geographic%20Picture%20Atlas%20of%20Our%20Universe/Pg4JupiterPic.jpg

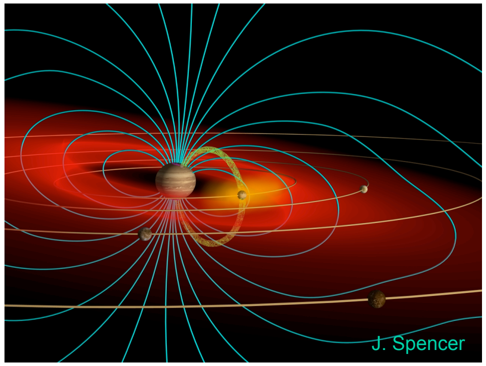
Floating Life

- Maybe there are also "hunters" that fed on the floaters?
- Of course, this is all speculative, and there is no way to detect such life.
- Science fiction from scientists really.

http://www.epilogue.net/cgi/database/art/list.pl?gallery=3126

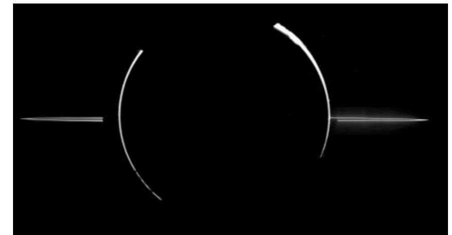
Jupiter's Magnetosphere

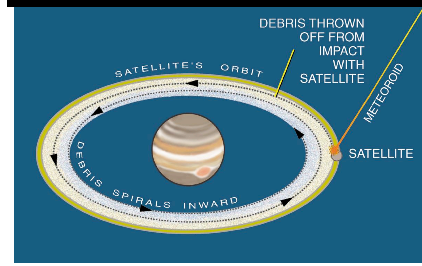
- Liquid metal hydrogen generates a magnetic field
  - 14x stronger than Earth's field
  - Over 4 million km across
- A ring of ionized particles surrounds Jupiter
  - Stripped from Jupiter's moon Io



Jupiter's Rings

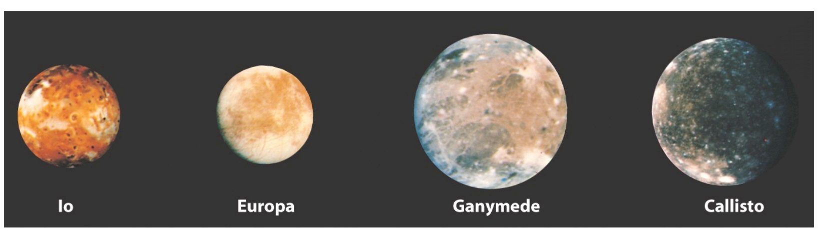
- Jupiter has rings!
- Discovered by the Voyagers
- Not prominent like Saturn's
- Dusty disk of debris, probably from meteoroid impacts with small moons





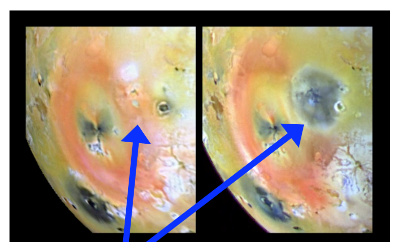
The Galilean Moons

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

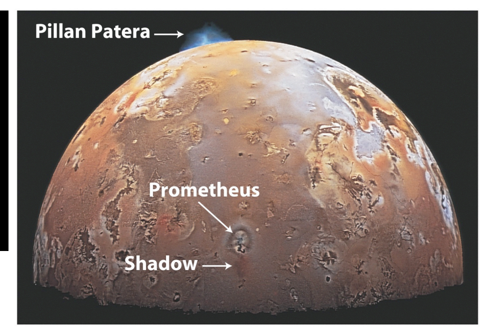


Io

- 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

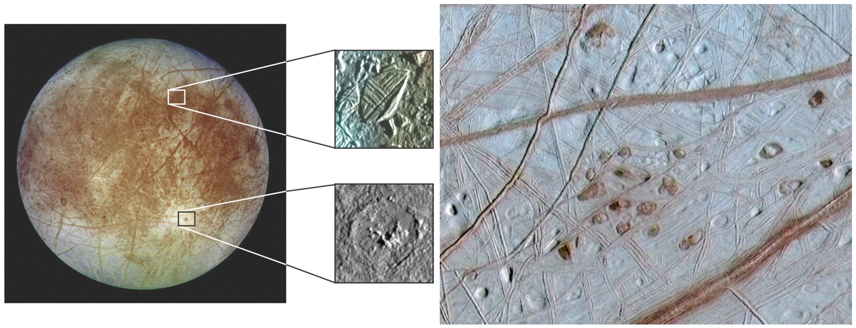


Pillan Patera eruption
Before & after



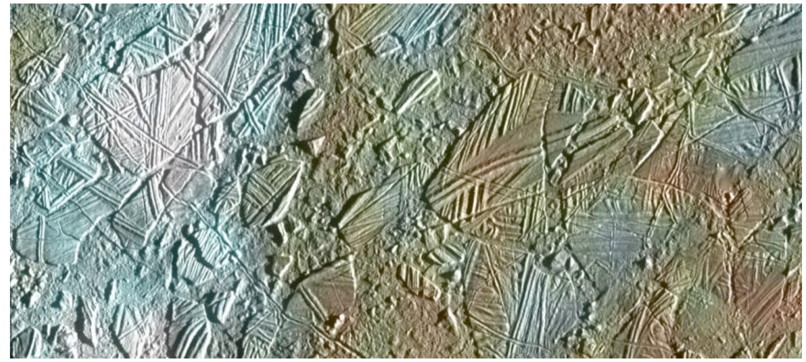
Europa

- 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

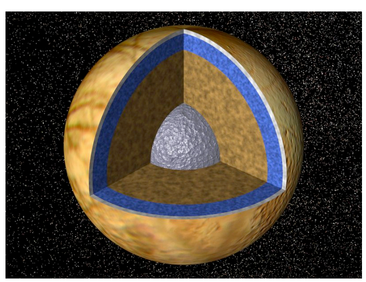
Europa



- 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

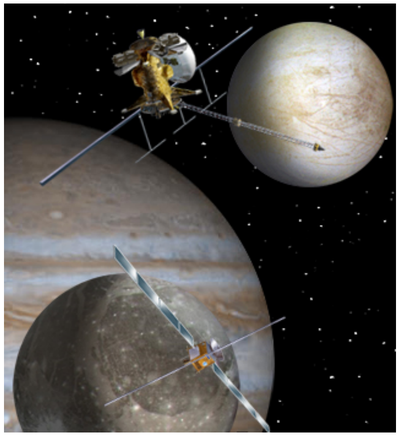
- Furthest of the Galilean Moons from Jupiter
- Ancient surface, covered with craters
- Compared to our Moon:
  - 40% larger
  - 50% more massive
  - 45% less dense
- Surface is made of “dirty ice”
- Interior is rocky, mixed with ice

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

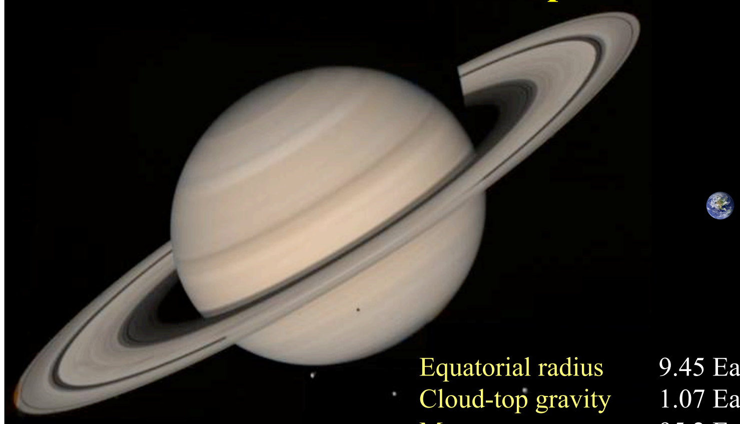


Question

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



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

It floats. The least spherical planet.

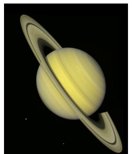
Jupiter-Saturn Comparison

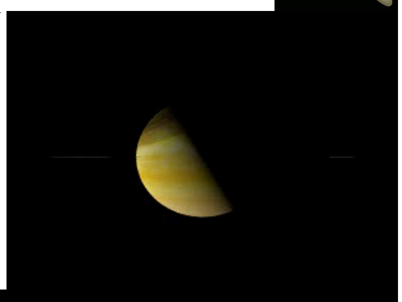
Equatorial radius	0.84 Jupiter
Mass	0.30 Jupiter
Density	0.52 Jupiter

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



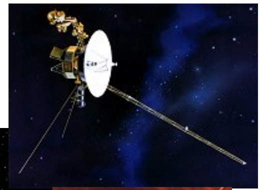


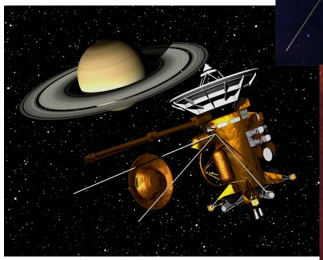
http://www.solarviews.com/cap/sat/saturn.htm

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

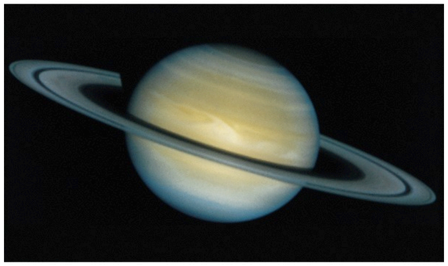




The Cassini Mission

- 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?

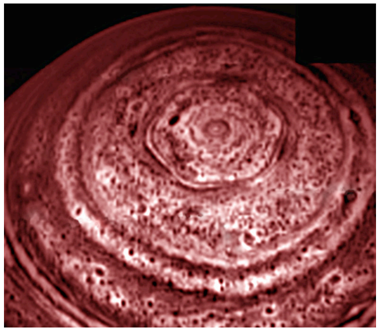
Saturn's Atmosphere



- 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

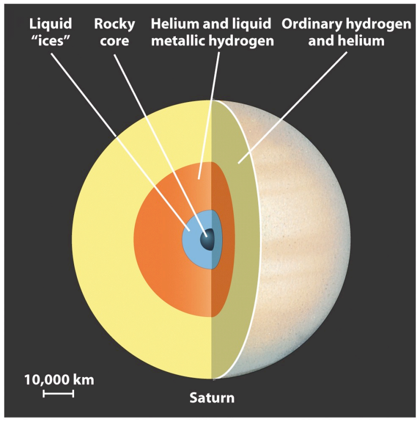
- As on Jupiter, Saturn's internal heat drives weather
  - Saturn radiates 80% more heat than it receives from the Sun
  - Like Jupiter, Saturn is still contracting!
  - As is contracts, heat is produced



- 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.

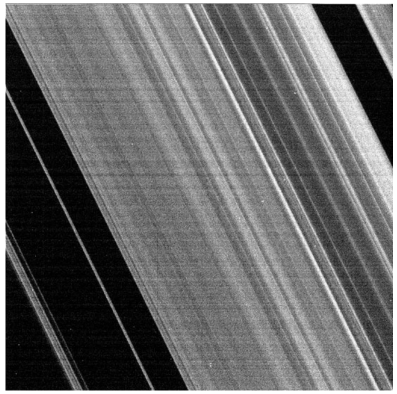
Saturn's Interior

- 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



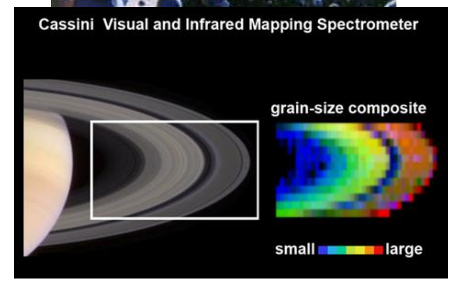
Saturn's Rings

- 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!



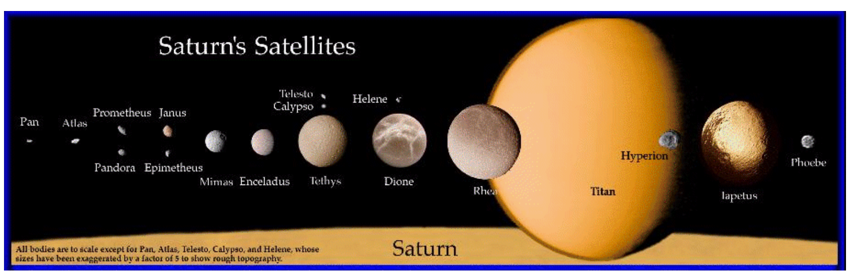
Makeup of the Rings

- 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



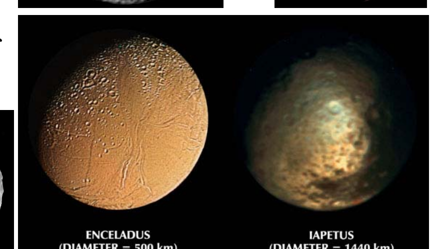
Saturn's Moons

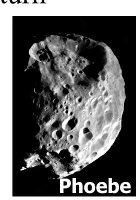
- Saturn has a large number of moons
  - At least 60
- Only Titan is comparable to Jupiter's Galilean moons
- Smaller moons are mostly ice, some rock



Saturn's Odd Moons

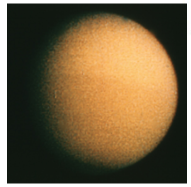
- **Mimas** - Crater two-thirds its own radius
- **Enceladus** - Fresh ice surface, water volcanoes?
- **Hyperion** – Irregularly shaped
- **Iapetus** - Half its surface is 10x darker than the other half
- **Phoebe** - Orbits Saturn backwards



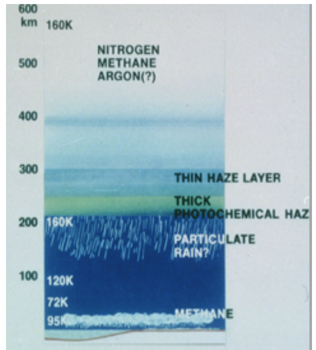


Titan

- 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!

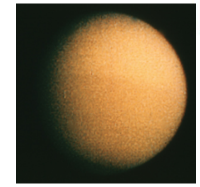


Titan's atmosphere

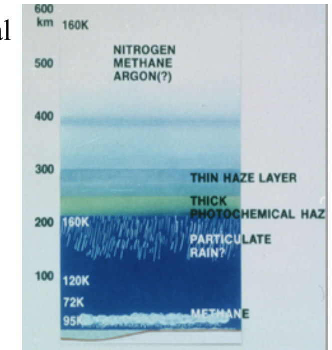


Titan

- 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

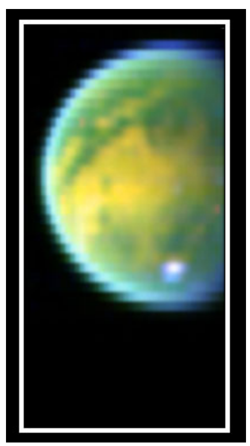


Titan's atmosphere



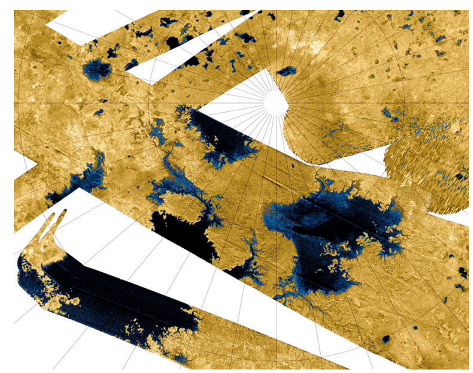
Piercing the Smog

- 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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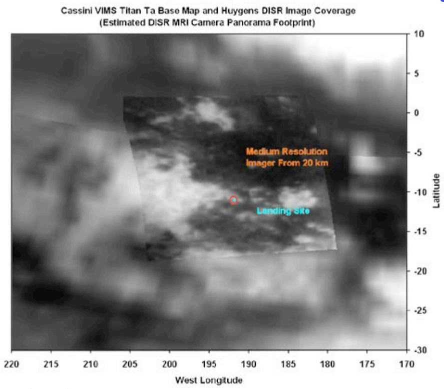
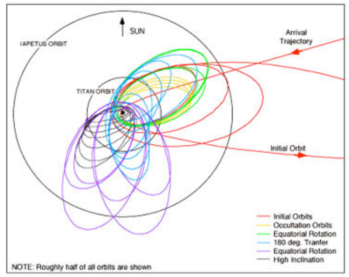
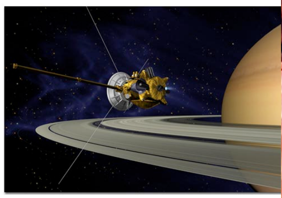
Cassini-Huygens

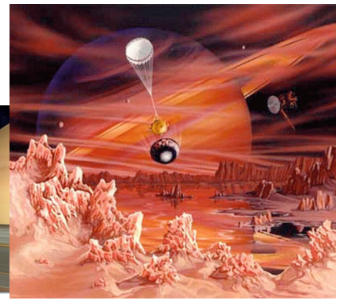




Arrival at Saturn
July 1, 2004

Huygens Probe
descent to Titan
Jan 14, 2005



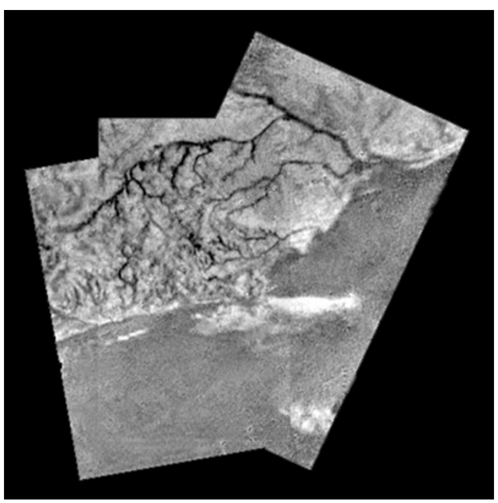


A Possible Landing

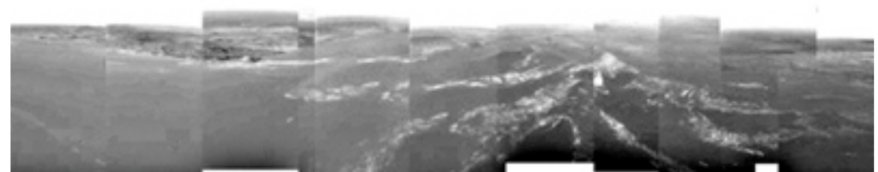
- The probe floating in the methane/ethane sea of Titan.
- Mountains in the distance.

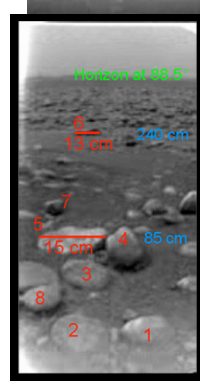
http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/images/artwork/images/

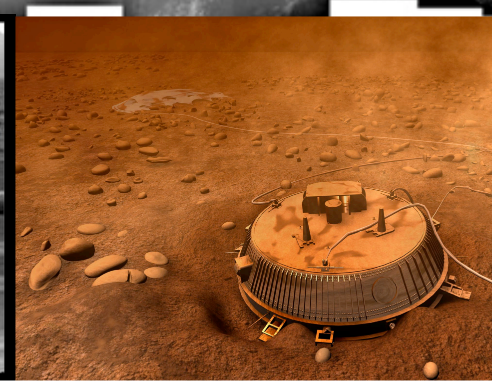
Mapping Titan

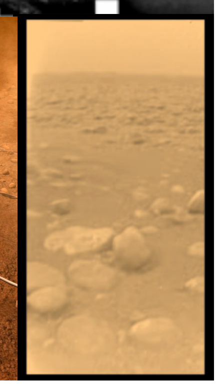


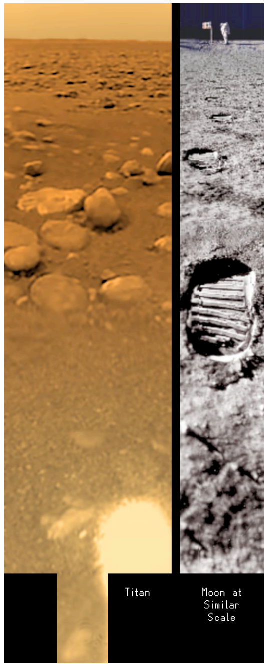
Mapping Titan



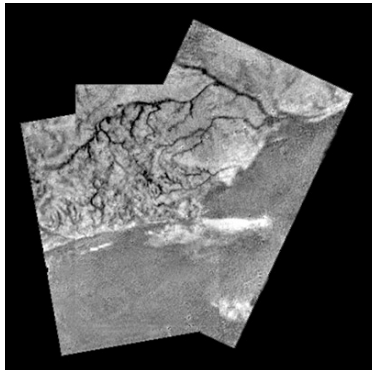








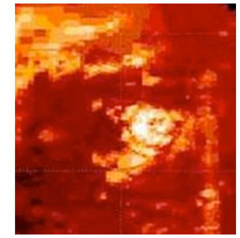
Mapping Titan



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

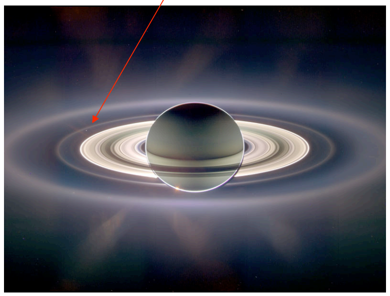
Question

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.

No Intelligent Life

- We might find evidence of some sort of life in the next decade, but very unlikely to find complexity needed for intelligent and communicative life.
- Apparently in our system, Earth's conditions are necessary.
- Other planets may have microbial forms of life, and maybe complex fish-like organisms, but we don't expect communicative beings.



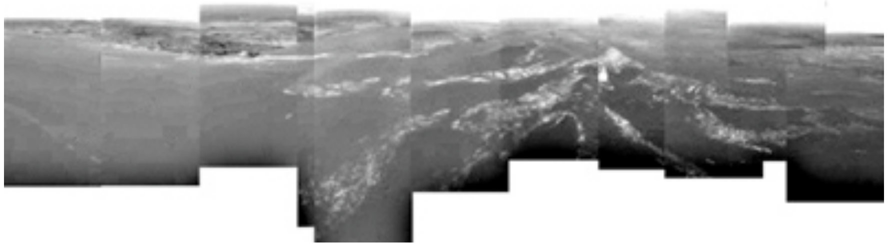
http://antwrp.gsfc.nasa.gov/apod/ap061016.html

How to search for life?

- How do we search for life in our Solar System and beyond?
- What test will indicate life exclusively?
- Remember the Viking problems on Mars.
  - Need flexibility to test interpretations.
- But, it is difficult to anticipate fully the planet conditions.

How to search for life?

- Is is apparent that future missions need to land as near as possible to sites of subsurface water or other solvents.
- On Titan, what are the important tests for determining biological signatures of non-water life?
- What if the life is still in the protolife stage? Can we detect that?
- The boundary between chemical and biological processes is difficult to distinguish.



Decision Trees– Search for Life

- Wait for it to come to us via meteorites or comets.
- Robotic one-way investigations– Mars rovers.
- Fetch and return with samples.

http://www.ibiblio.org/wm/paint/auth/friedrich/tree.jpg

Problems

- In the last 2 cases, we have the problem of contamination by Earth life.
- Organisms can live in Mars-like conditions on Earth.
- If some Earth life survives the space journey, it could colonize Mars, possibly destroy any Martian life. Think of Kudzu.
- Current missions must be sterilized.

http://www.hope.edu/academic/biology/faculty/evans/images/Angiosperms/CoreEudicots/EurosidsI/Fabaceae/Kudzu.JPG

Biomarkers: How to look for extrasolar life.

- We need to decide how to search for biomarkers or chemical signatures of life.
- On Earth, methane and oxygen are indicators. They normally react. Something is keeping it out of equilibrium. Sort of like Venus disequilibrium.
- The Galileo spacecraft on its way out to Jupiter, turned and looked at the Earth.
- Did it detect life?

Biomarkers: Looking at Earth.

- Strong "red edge" from reflected light. Absorption from photosynthesis.
- Strong O_2. Keeping oxygen rich atmosphere requires some process. It should slowly combine with rocks.
- Strong methane. Should oxidize. Replenished by life.
- Strange radio emissions that could be intelligent life.

http://epod.usra.edu/archive/epodviewer.php3?oid=56256

Biomarkers: Looking at Earth.

- Recently, researchers have looked at the Earthshine from the moon.
- They agree with Galileo result.
  There is life on Earth.
  - Water
  - Oxygen
  - Tentative detection of "red edge"

http://epod.usra.edu/archive/epodviewer.php3?oid=56256

Summing Up

- Existence of organic molecules in space implies that amino acid complexity is common.
- Fact: On Earth polymers arose and evolved to life.
- Life it seems evolves naturally through a number of intermediate steps if conditions are right and $\mathbf{f_l = 1}$
- But how often are the conditions right?
- Nonetheless, even with only a vague notion of how life on Earth evolved, it seems that there are possible pathways that take the mysterious polymerization to transition to life steps.
- Still a number of questions:

Summing for f_l

- Is life a natural occurring consequence of the laws of nature?
- Will each planet from n_e outgas and produce water?
- Will it have a reducing atmosphere?
- Will it have the right energy sources to produce life's monomers?
- Monomers from space?
- Will polymerization occur?
- Are tides necessary to wash polymers back into liquid water?
- Will basic life occur? Protolife or life?
- Alternative life?
- Maybe the conditions that produced life on Earth are unusual or maybe common.
- That means f_l can range from small numbers 0.0001 to 1.