Astronomy 230

Section 1– MWF 1400-1450

106 B6 Eng Hall

This Class (Lecture 17):

Life in the Solar System

Midterm is Friday!

The Exam will be in the Astronomy Building Classroom, room number 134.

Next Class:

Midterm.

Outline

- Midterm Discussion
- Jupiter
  - Big planet with possibly interesting chemistry.
  - Floaters?
- IO
- Europa
  - Liquid water under a sheet of ice?
- Titan
  - Do we need to redefine life?

Midterm

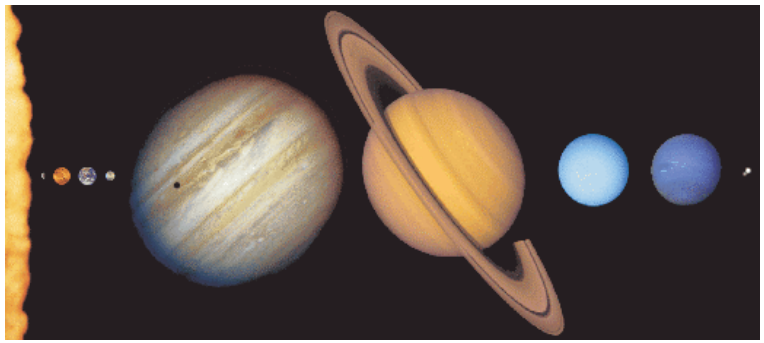
- 1 hour exam in Astronomy classroom.
- It will cover material up to, but not including, “Life in the Solar System”
- Will consist of 20 multiple choice/ true-false questions (worth 2 points each) and 2 essay questions (one worth 40 points and one worth 25 points) .
- A total of 105 points, so 5 extra credit points.
- You can bring a normal-sized sheet of paper with notes on both sides.

Review II

- How did the Earth probably acquire its moon?
- What will happen to our Sun?
- Why does our theory of the origin of the solar system and the current extrasolar planets not completely agree?
- What will happen to the Milkyway?
- What will happen to the Universe?
- Besides chemical processes, life could arguably use the nuclear strong force, the electromagnetic force, or gravitational force. Describe a life form based on one of these mechanisms for non-chemical life.
- Two theories exist to explain the transition of polymers to life. Discuss one of these theories.
- What is the closest star to the Earth?
- Stuff about killer supernovae.
- 3 questions from presentations.

Life in the Solar System

- Venus may have life in the clouds.
- Mars might still have life under the soil.
- But what about the outer solar system?
- It isn't in our definition of the habitable zone, but it still is interesting.
- We will focus on Jupiter, Io, Europa, and Titan in this class.



Earth – Jupiter comparison

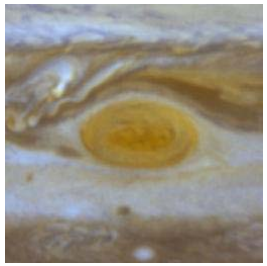
Biggest and most massive planet, has the largest gravity, has the largest number of moons (>61), yet has the shortest day in Solar System. Radiates more energy than it absorbs.

Radius	11.2 Earth
Cloud-top gravity	2.54 Earth
Mass	318 Earth
(more than 2.5 times the rest combined)	
Distance from Sun	5.20 AU
Year	11.88 Earth years
Solar day	9 hours 55 minutes

Causes a bulge at the equator.

Jupiter's Atmosphere

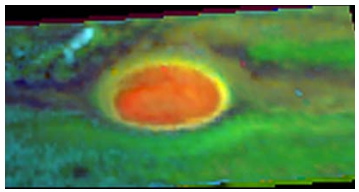
- Although mostly gas, by 20,000 km, the pressure is 3 million atmospheres!
- Due to an internal heat source, the temperature rises as one penetrates the atmosphere.
- The outer atmosphere is made of freezing clouds of ammonia, methane, and ice.
- The swirling patterns are evidence of great storms.



http://www.solarviews.com/raw/jup/vjupitr2.m

Jupiter's Atmosphere

- The atmosphere resembles the conditions of the Miller-Urey experiment.
- The red bands and spots may be biological molecules.
  - The Miller-Urey experiment produces amino acids and red polymers.
  - Carl Sagan suggested that the atmosphere might be an optical photochemistry, like photosynthesis but more effective. Not much evidence for such a statement.
- But, constant churning of the atmosphere probably makes development of complex life nearly impossible.

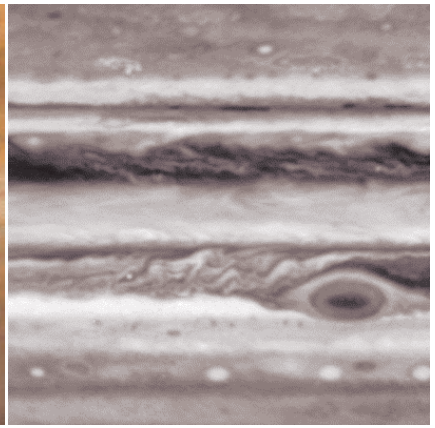


Icy ammonia (light blue) discovered by Galileo

The Great Red Spot

- A huge storm 25,000 km across – twice size of the Earth!
- First observed > 300 years ago!

Voyager 1 image



Cassini images

Floating Life

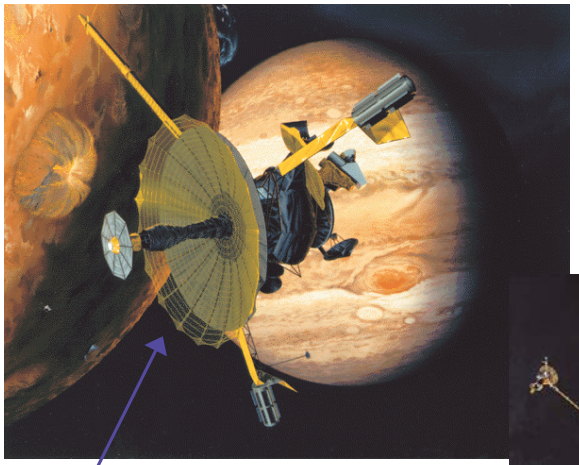
- Carl Sagan and Edwin Salpeter devised a scheme for life in the clouds of Jupiter.
- They argued that the atmosphere must be rich in organic chemistry, so why expect Earth-like life?
- The problem is that any life in the clouds that sank too far down would be destroyed by the temperature or pressure.
- 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.

Floating Life

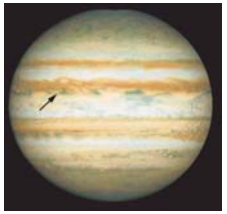
- The sinkers became the basis of an ecology.
- They also proposed “floaters”– large hydrogen balloon-like life that “swim” in the Jovian atmosphere.
- They could be huge creatures, as large as 1 to 2 km in diameter.
- Maybe similar to whales.
- Of course, this is all speculative, and there is no way to detect such life.
- Science fiction from scientists really.

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

The Galileo Spacecraft (1989 – 2003)



How the main antenna *should* have looked



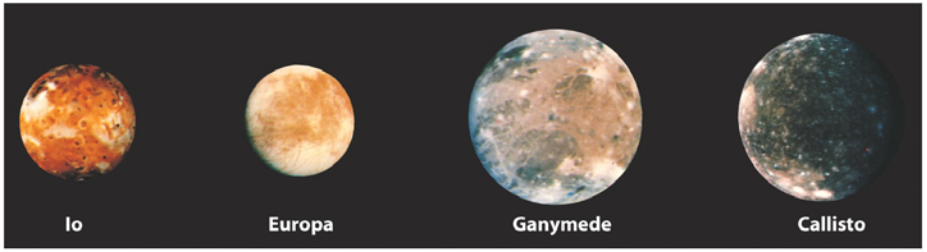
First atmospheric probe

Probing the Atmosphere

- The probe lasted for 57 minutes before it was destroyed by temperature and pressure.
- Found a lot of turbulence, strong winds (330 mph), very little water ice, and no lightning.
- Did not encounter the layers of clouds that was expected.
- The probe entered the least cloudy region of Jupiter.
- Did not rule out life, but did not support it.
- Later, the spacecraft Galileo was crashed into Jupiter.

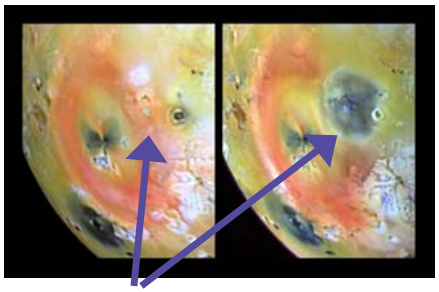
The Galilean Moons

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

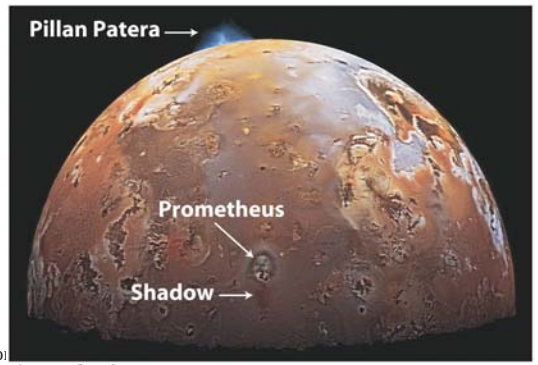


Io

- Innermost Galilean moon – the "pizza moon"
- The most volcanically active body in the solar system.
- Sulfur/sulfur dioxide on surface; silicate lava flows?
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter's tides
- Atmospheric gases ripped off by Jupiter's magnetic field – ion torus

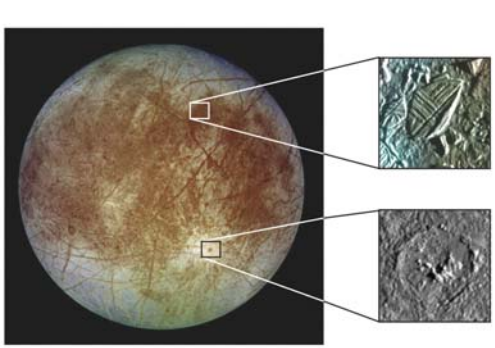


Pillan Patera eruption
Before & after



Europa

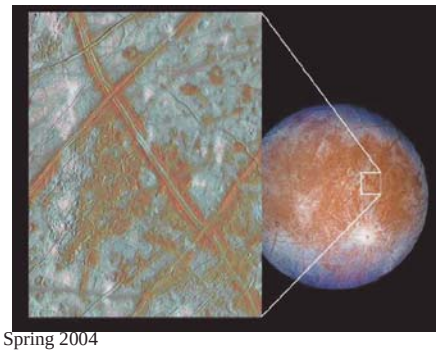
- Slightly smaller than the moon.
- Icy crust 5 km thick. Can protect life against magnetic fields.
- Evidence for deep (50 km!) liquid water ocean beneath crust– remains liquid from tidal forces from Jupiter
- Cracks and fissures on surface – upwelling?



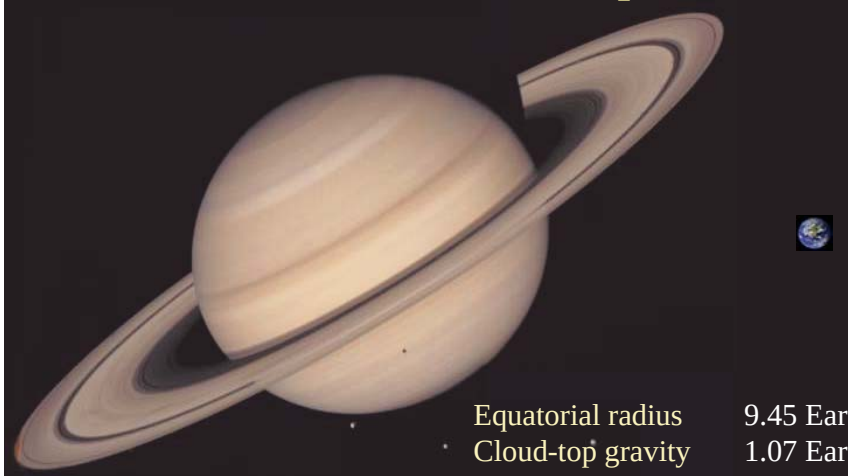
Galileo

Europa

- Few impact craters indicate recent resurfacing.
- Life would have to be below the surface, around hydrothermal vents.
- Future missions, will have to employ smash and dive spacecraft.



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

Saturn

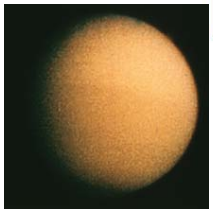
- The Lord of the Rings
- Broad atmosphere banding is similar to Jupiter
- At least 30 moons, of which only 7 are spherical
- http://www.solarviews.com/raw/sat/vsaturn1.mpg

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

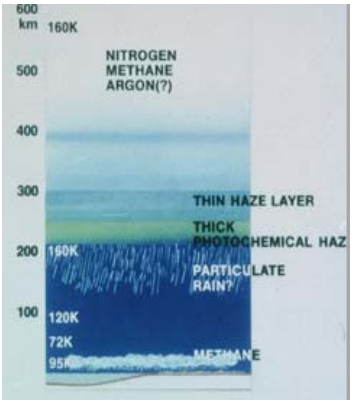
http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/images/saturn/images/PIA05380.jpg&type=image

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/methane atmosphere
  - Small greenhouse effect
  - 85% nitrogen
- Atmospheric pressure is 1.5 times Earth's
- Very cold! 85K (-308 K).

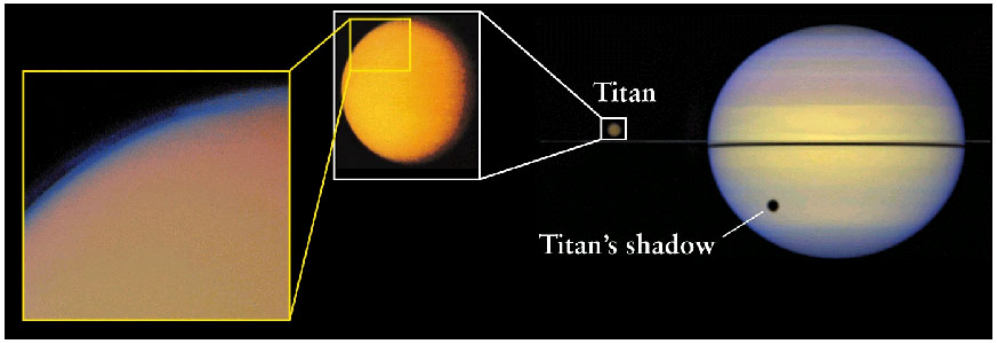


Titan's atmosphere

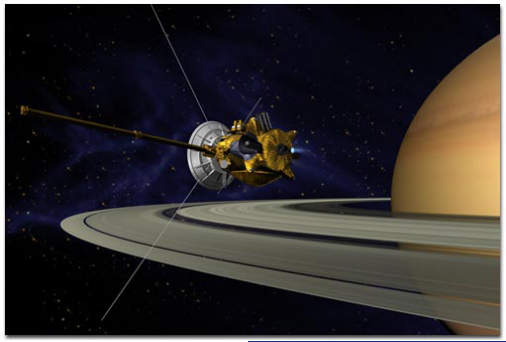


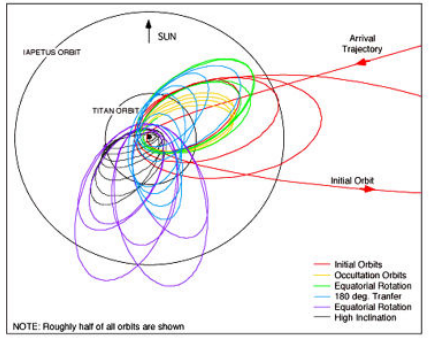
Titan

- N_2 came from ammonia (NH_3) – common in outer solar system
- Second most abundant component is methane (natural gas)
  - One option is UV + methane → hydrocarbons (e.g., ethane)
  - Then, ethane condenses and rains down on Titan's surface
- So, it might have liquid ethane or methane lakes/oceans?
- Many organic compounds in atmosphere– reducing atmosphere.
- If life exists here, then it will change our water–chauvinistic ideas.



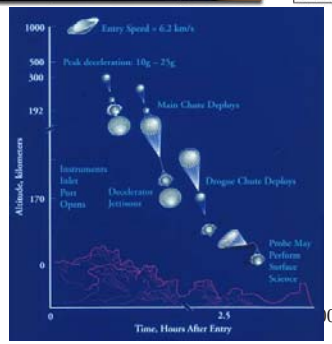
Cassini-Huygens





Arrival at Saturn
July 1, 2004

Huygens Probe descent to Titan
November 4, 2004



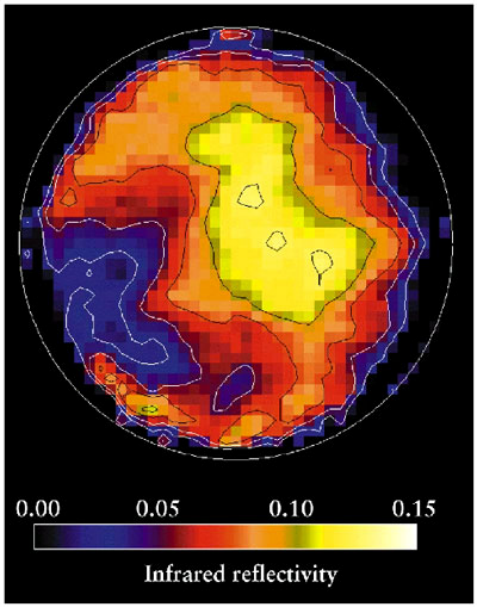
A Possible View– In the IR

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

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

Titan Continents

- IR can penetrate Titan's atmosphere
- The dark patches have lower reflectivity.
- Could be liquid hydrocarbon seas or large expanses of solid organic material.
- The bright yellow could be highly reflective "continents".



Conclusion

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

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 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.

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.
- 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 life 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.
- The Galileo spacecraft on its way out to Jupiter, turned and looked at the Earth.
- Spectrometers easily detected oxygen, methane, water, and other molecules indicative of life.
- An experiment to measure the light reflected off of the Moon detected oxygen, ozone, and water vapor. They attempted to look for the “red edge” a spectral feature of photosynthesis, but it was too difficult.
- Did they see signs of intelligent life? No. At a resolution of 1km no clear sign was seen.