Astronomy 230

Section 1– MWF 1400-1450
106 B1 Eng Hall

This Class (Lecture 20):

Life in the Solar System

Midterm Friday!!!!

Next Class:

Midterm

Music: *Great Big White World* – Marilyn Manson

Midterm

- 1 hour exam in this 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 I

- What are the five biological attributes of life, and what do they mean?
- Compare the chemical composition of life to the chemical composition of: a) the crust of the Earth; b) Earth's oceans; and c) the Sun.
- What is the Drake Equation, and what do the terms mean?
- What is the origin and use of the four main biological elements H, O, N, and C?
- Describe the Early Universe. Why do we believe in the Big Bang?
- What are the properties of a first generation star? In particular, describe which heavy elements they made and how they did it.
- What are the properties of a second generation star? In particular, describe which heavy elements they made and how they did it.
- What does the presence of complex molecules in interstellar space tell us?
- Describe the techniques that astronomers use to search for planets around stars?

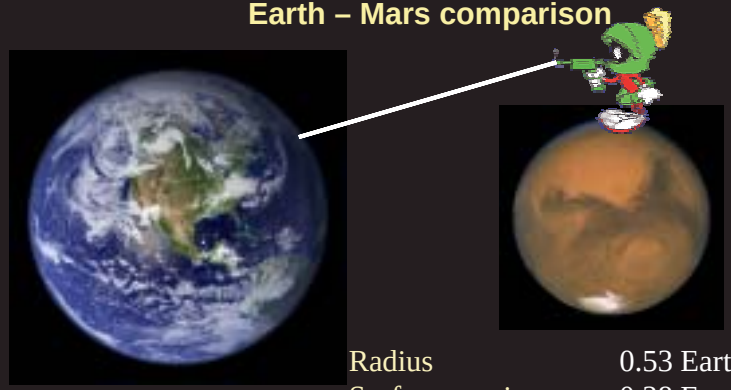
Review I

- Describe the processes for forming a star and its planets.
- The planets and the Sun formed from the same interstellar cloud. Discuss reasons why the chemical abundances of the inner planets are different than the outer planets.
- What determines if a planet is in the Habitable Zone?
- Discuss DNA and RNA. How do they function to assemble proteins that carry the genetic code?
- What was the Miller-Urey experiment and why is it thought to be important for life? Include the role of a reducing atmosphere in your discussion.
- What is one possible scenario for the synthesis of polymers on the early Earth? Include the probability of getting 200 of the 20 relevant amino acids in the correct order for constructing a protein.

Outline

- Mars
  - Martian microbes?
- Jupiter
  - Big planet with possibly interesting chemistry.
  - Floaters?
- IO
- Europa
  - Liquid water under a sheet of ice?
- Titan
  - Ethane or Methane oceans

Earth – Mars comparison



Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Average Temp	-63 C
Max Temp	20 C
Year	687 Earth days
Length of Day	24 hours 39 minutes
Atmosphere	CO_2 95%

The Search for Mars Life

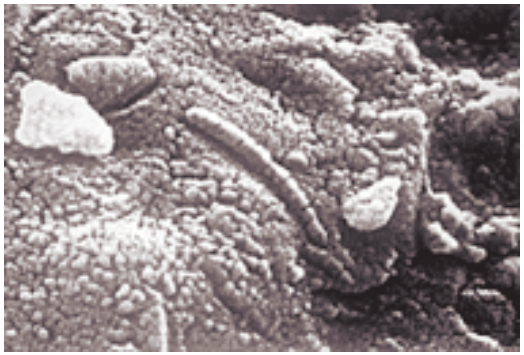
- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.

Martians?

- In August 1996, evidence for microbial life was found in a Martian meteorite.
  - ALH84001: Found in Antarctica, composition suggests it was knocked from Mars
  - About 14 such Mars rocks have been found on Earth
- David McKay *et al.* suggested that there was fossil evidence for bacteria in the meteorite.

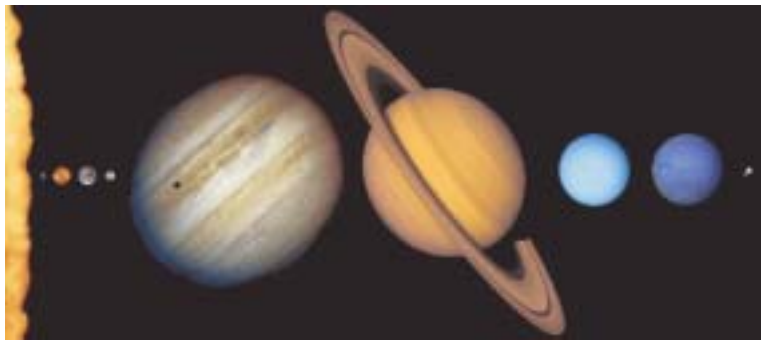
Martian Microbe Fossils?

- Microscopic shapes that resemble living and fossil bacteria on Earth– nanobacteria.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end, not impelling enough. Non-biological processes can probably produce the observed features



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

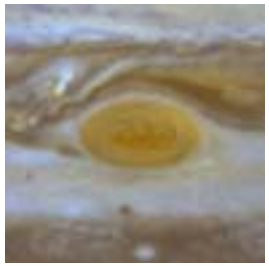
Biggest and most massive planet, has the largest gravity, has the largest number of moons (>61), yet has the shortest day in Solar System. Radiates more energy than it absorbs.

Radius	11.2 Earth
Cloud-top gravity	2.5 Earth
Mass	318 Earth
(more than 2.5 times the rest combined)	
Distance from Sun	5.2 AU
Year	11.88 Earth years
Solar day	9 hours 55 minutes

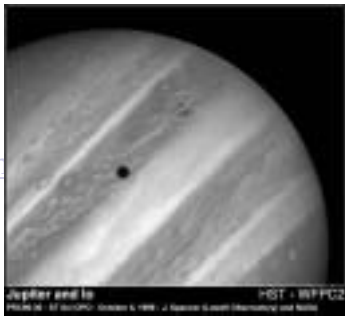
Causes a bulge at the equator.

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.

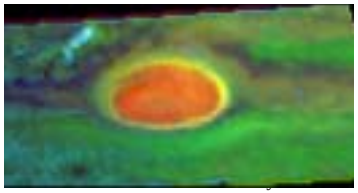


http://www.solarviews.com/raw/jup/vjupitr2.m



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.

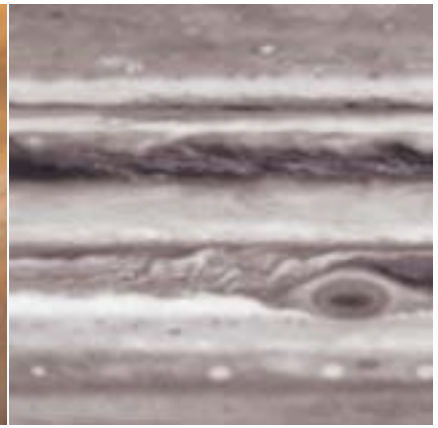


Icy ammonia (light blue) discovered by Galileo

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 not 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 a proposed ecology.
- They also posited "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.

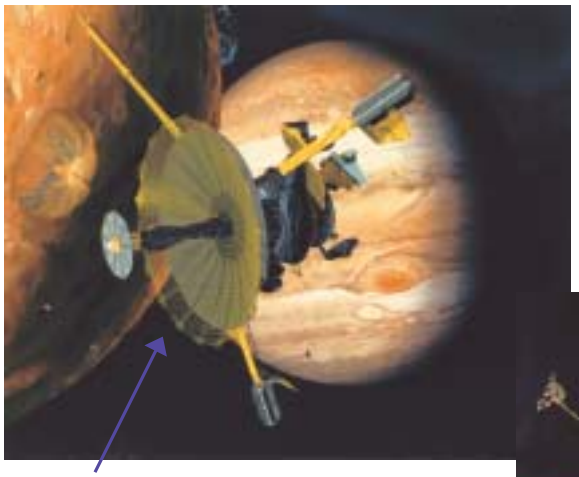
http://www.firaxis.com/smac/nativelife.cfm

Floating Life

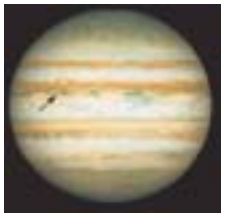
- Maybe similar to whales–mixture between jellyfish and birds?
- Big bags of hyrdrogen gas.
- Of course, this is all speculative, and there is no way to detect such life.
- Science fiction from scientists really.

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

The Galileo Spacecraft (1989 – 2003)



How the main antenna *should* have looked



First atmospheric probe

Probing the Atmosphere

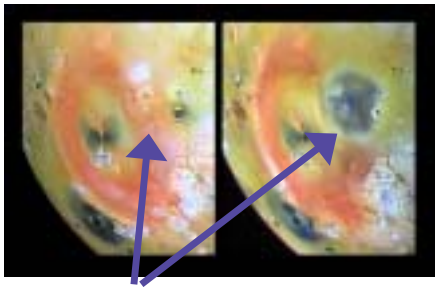
- The probe lasted for 57 minutes before it was destroyed by temperature and pressure.
- Found a lot of turbulence, strong winds (330 mph), very little water ice, and no lightning.
- Did not encounter the layers of clouds that was expected.
- The probe entered the least cloudy region of Jupiter.
- Did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

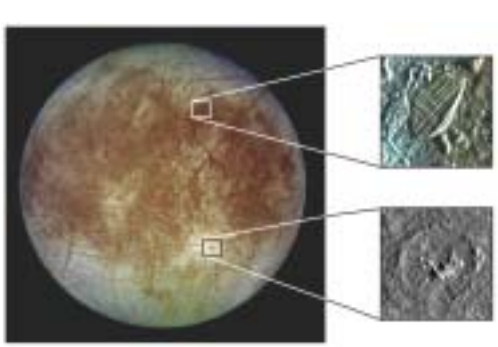
- Innermost Galilean moon – the “pizza moon”
- The most volcanically active body in the solar system.
- Sulfur/sulfur dioxide on surface; silicate lava flows?
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter’s tides
- Atmospheric gases ripped off by Jupiter’s magnetic field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

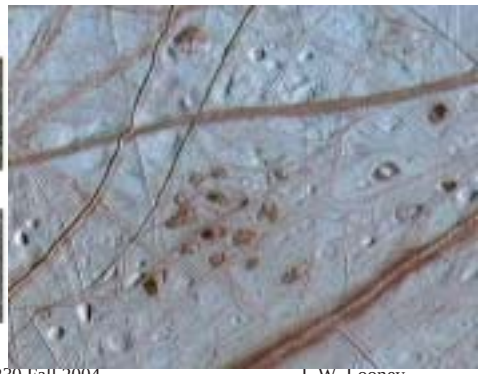


Pillan Patera eruption
Before & after

Europa

- Slightly smaller than 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?

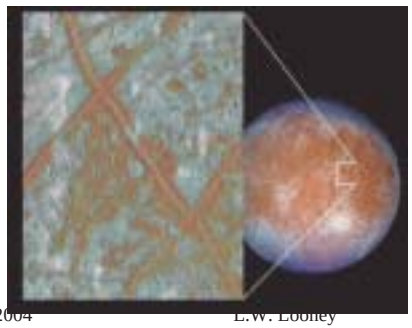




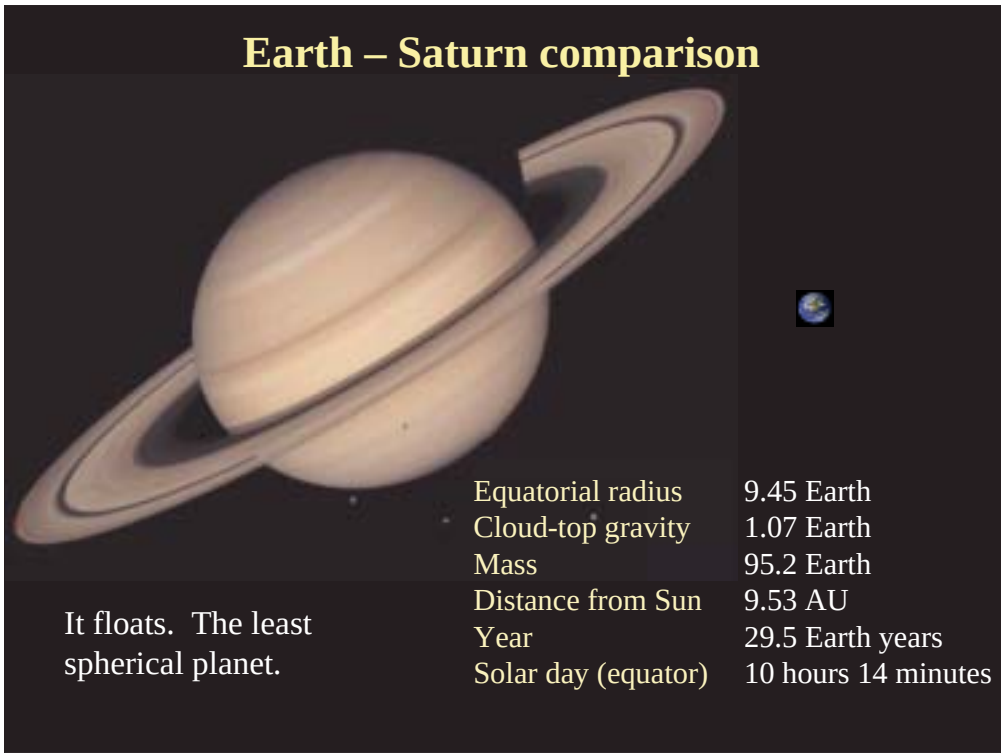
Galileo

Europa

- Few impact craters indicate recent resurfacing.
- Life would have to be below the surface, around hydrothermal vents.
- Like Io, it probably has strong tidal forces.
- Very encouraging, as early life on Earth, might have been formed around such vents.
- We don’t how thick the ice is yet.
- To be continued.
- 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

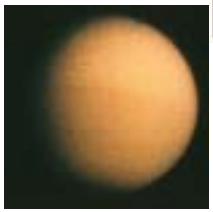
- The Lord of the Rings
- Broad atmosphere banding is similar to Jupiter
- At least 30 moons, of which only 7 are spherical
- http://www.solarviews.com/raw/sat/vsaturn1.mpg

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

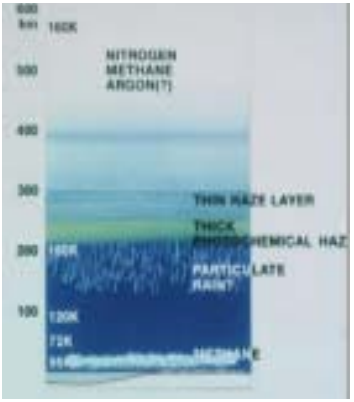
L.W. Looney

Titan



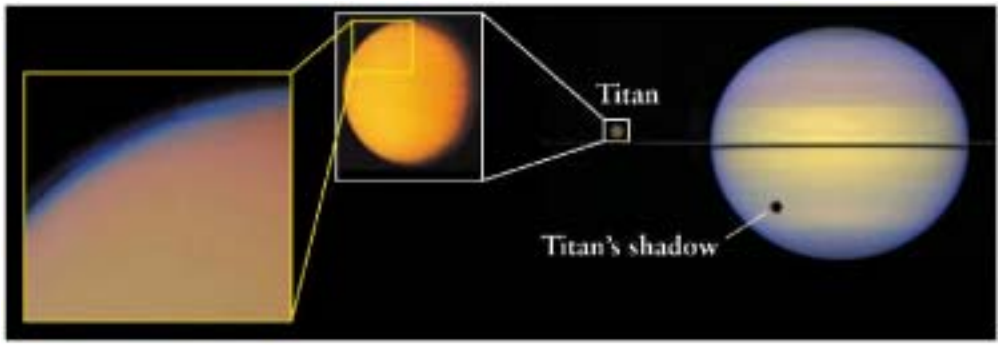
Titan's atmosphere

- 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 F).

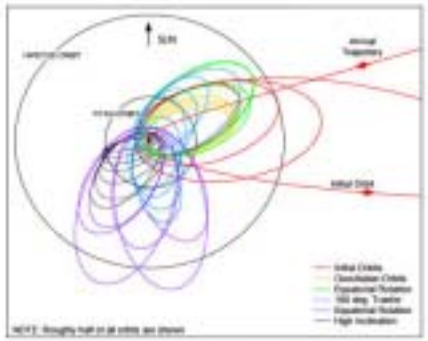


Titan

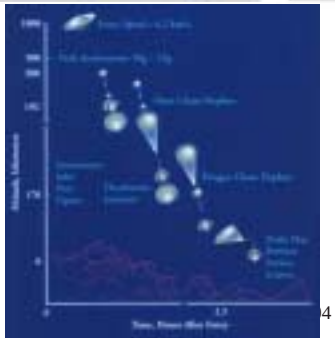
- N_2 came from ammonia (NH_3) – common in outer solar system
- Second most abundant component is methane (natural gas)
  - One option is UV + methane → hydrocarbons (e.g., ethane)
  - Then, ethane condenses and rains down on Titan's surface
- So, it might have liquid ethane or methane lakes/oceans?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



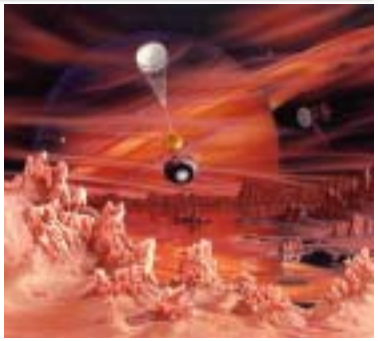
Cassini-Huygens



Arrival at Saturn
July 1, 2004



Huygens Probe descent to Titan
November 4, 2004



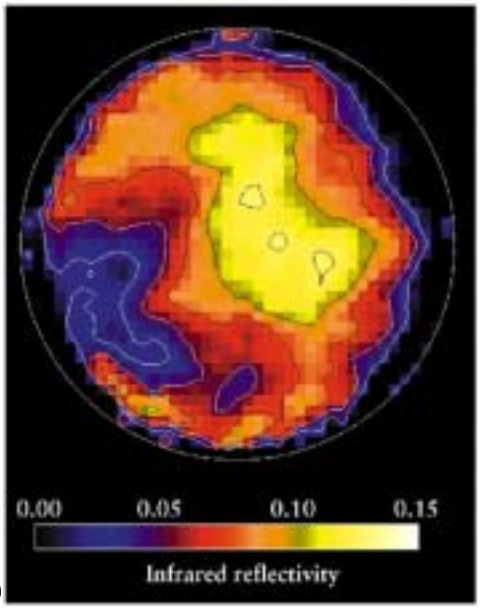
A Possible View– In the IR

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

http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/imagegallery/work/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 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.

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 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.
- 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