Astronomy 330

<u>This class (Lecture 13):</u>
What is n_p?
Anna Dorn
Praneet Sahgal

<u>Next Class:</u>
Life on Earth
Mary Heaton
Alison Melko

HW 6 due next Thursday.

Music: *Chiron Beta Prime* – Jonathan Coulton

HW 2

- Nicholas Langhammer
  http://www.bibliotecapleyades.net/sociopolitica/esp_sociopol_washingtonDC01.htm
- Suharsh Sivakumar
  http://martiancoverup.com/

Presentations

- Anna Dorn
  The Science and Studies Behind UFOs
- Praneet Sahgal
  Terraforming

Outline

- Life on Titan?
- What type of stars are good for life?

Drake Equation

That's 16 planetary systems/year

Frank Drake

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

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	0.8 systems/star	planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

n_e

Complex term, so let's break it into two terms:

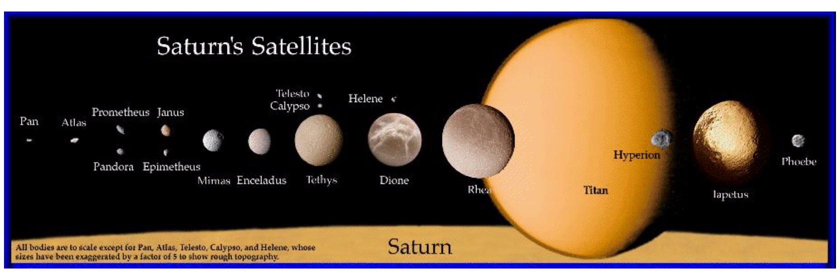
- n_p: number of planets suitable for life per planetary system
- f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

$$n_e = n_p \times f_s$$

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

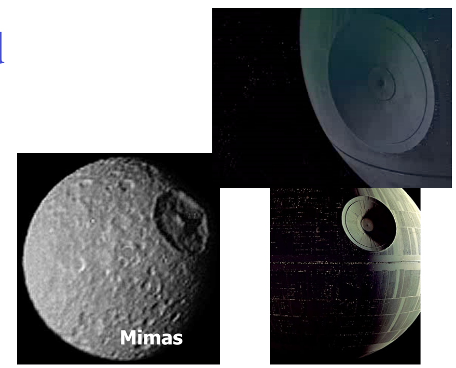
Saturn's Moons

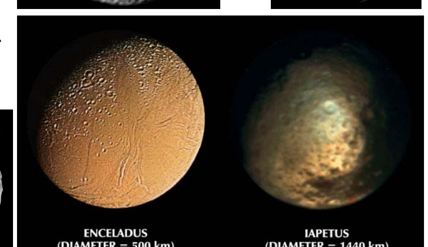
- Saturn has a large number of moons
  - At least 60
- Only Titan is comparable to Jupiter's Galilean moons
- Smaller moons are mostly ice, some rock

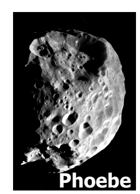


Saturn's Odd Moons

- **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

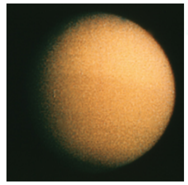




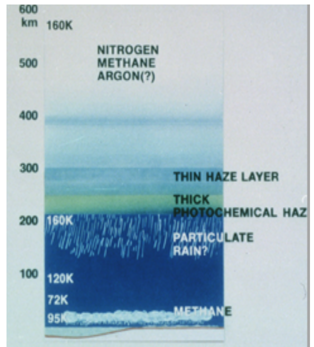


Titan

- 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!

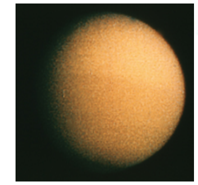


Titan's atmosphere

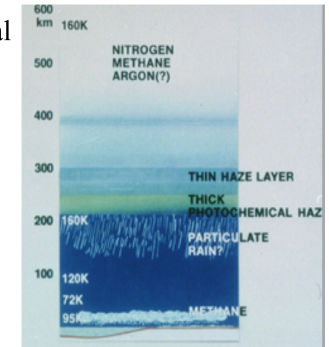


Titan

- 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

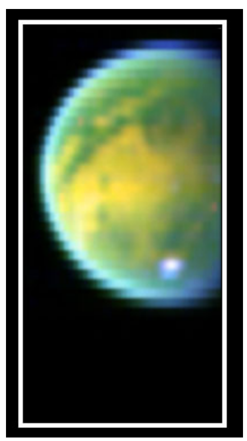


Titan's atmosphere



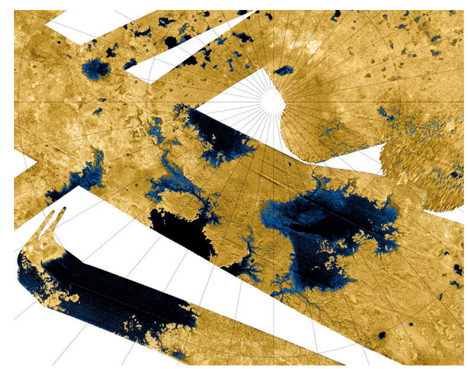
Piercing the Smog

- 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



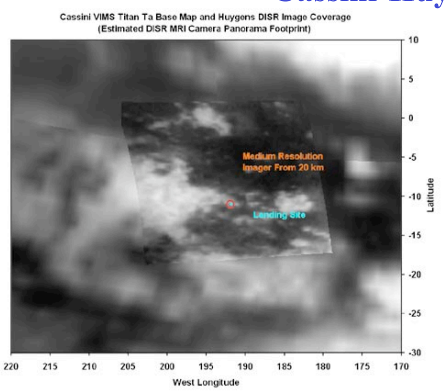
Surface Liquid

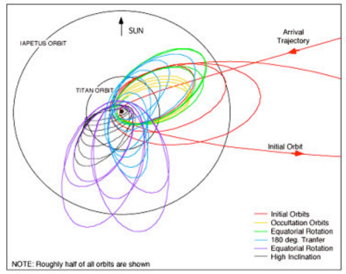
- Now confirmed to have liquid on surface.
- Only body besides the Earth.
- Too cold for water, so most likely filled with liquid ethane, methane, and dissolved nitrogen



http://photojournal.jpl.nasa.gov/catalog/?IDNumber=PIA10008

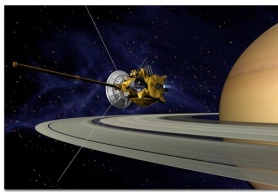
Cassini-Huygens

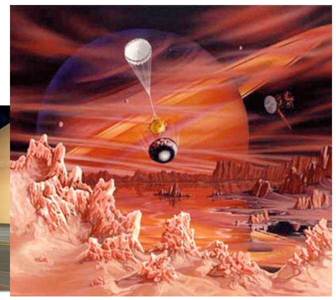




Arrival at Saturn
July 1, 2004

Huygens Probe
descent to Titan
Jan 14, 2005



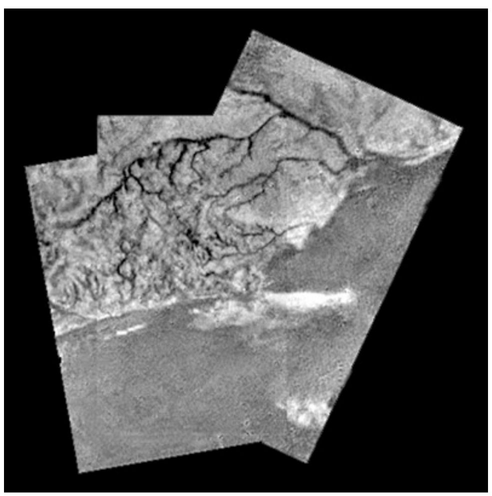


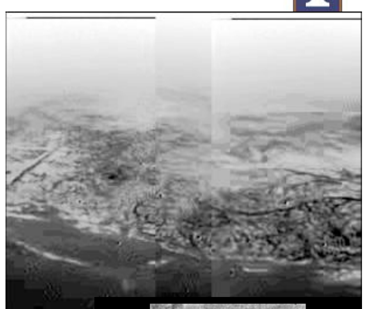
A Possible Landing

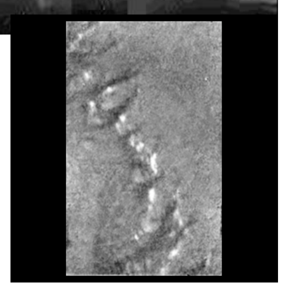
- The probe floating in the methane/ethane sea of Titan.
- Mountains in the distance.

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

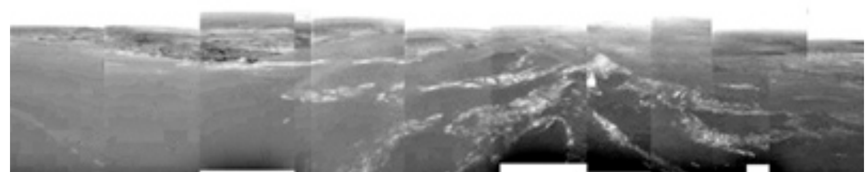
Mapping Titan

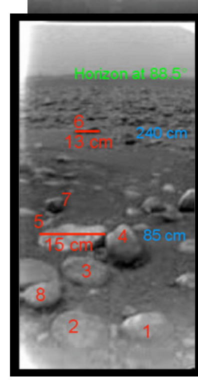


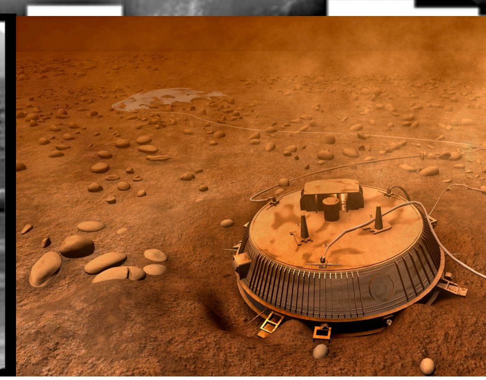


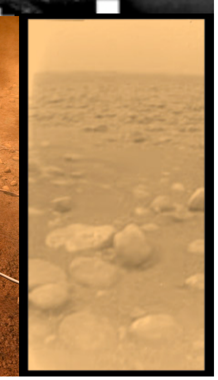


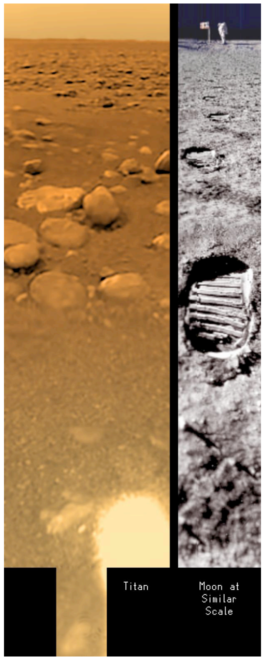
Mapping Titan



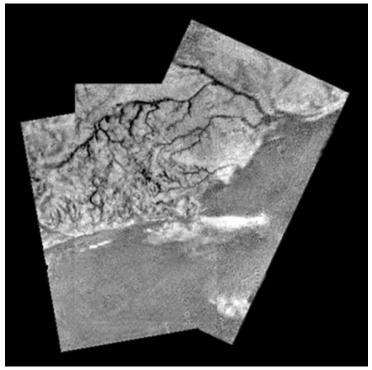








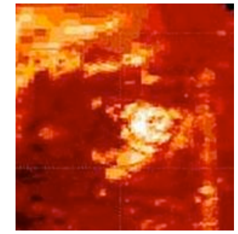
Mapping Titan



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– deep frozen.
- 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

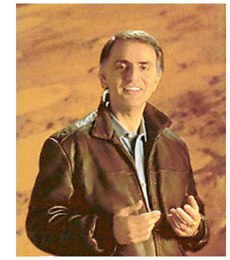
- ***No conclusive evidence exists for life in our solar system besides on Earth***
- But, possibilities exist for life
  - Venus’s clouds may have migrated life.
  - Mars may have some microbial history linked to water, and perhaps some subsurface life.
  - Jupiter’s reducing atmosphere may harbor sinkers.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

Question

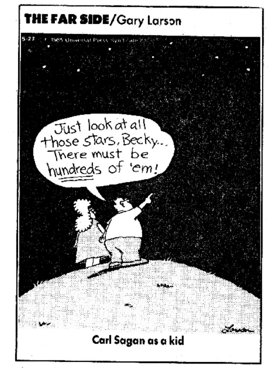
Why is Titan an interesting place to look for life?

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 friendly planets per planetary system (average)

- Can range from 0.01 (from Kepler) to >3 (Sagan).
  - 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.

$$n_e = n_p \times f_s$$

n_p: number of planets suitable for life per planetary system

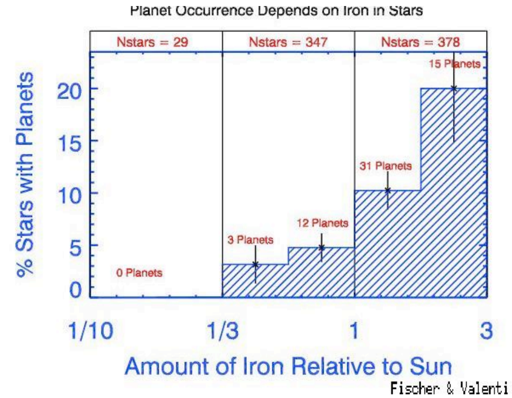
f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

We can list 5 situations that will have an effect on f_s.

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

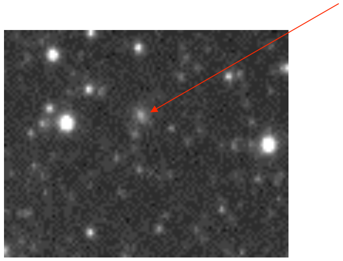
Differences of Stars to Life

1. **Metal rich stars**. Stars with heavy elements, probably more likely to have planets. Suggested in the current planet searches. About 90% of all stars have metals.



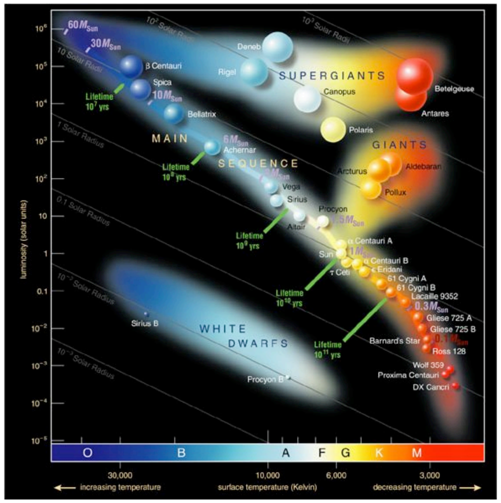
Differences of Stars to Life

2. **Main sequence stars**. Need the brightness to stay as constant as possible. Otherwise the temperature changes dramatically on the planets. This is 99% of all stars.



Differences of Stars to Life

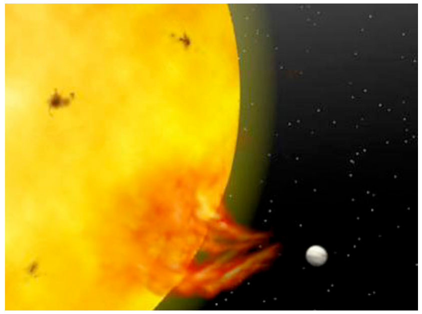
3. **Length of time on the main sequence**. We needed temperature stability for 5 billion years to get intelligence on Earth. This rules out stars more massive than 1.25 solar masses! 90% of all stars are less massive than that.



http://mjbs.org/hr.jpg

Differences of Stars to Life

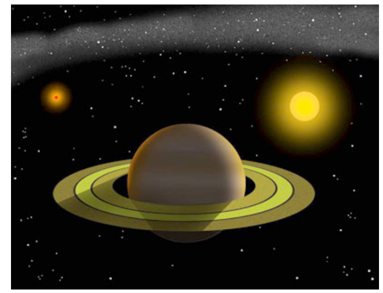
4. **Minimum mass of star**
For low-mass stars, any life bearing planet would have to be closer to the star– and closer to stellar effects (e.g. tidal locking and more flares from low mass stars). That limits us to a minimum of 0.5 solar masses. 25% of all stars are more massive than that.



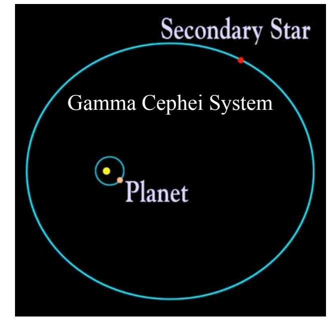
http://spaceflightnow.com/news/n0401/19planet/planet.jpg

Differences of Stars to Life

5. **Binarity**. Planets may form. But they may have odd orbits unless the 2 stars are far enough apart or the planet orbits the pair. Only 30% of all stars are single stars. 50% of all stars are single stars or wide binary stars.



http://spaceflightnow.com/news/n0210/11planet/



Adding it all up

Stellar Requirement	***Mass Limit***	***Fraction OK***	***Cumulative Fraction***
Heavy Elements	…	0.9	0.9
Main Sequence	…	0.99	0.891
Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
Not a Binary	…	0.30	0.267
Wide Binary Separation	…	0.50	

Adding it all up

Stellar Requirement	***Mass Limit***	***Fraction OK***	***Cumulative Fraction***
Heavy Elements	…	0.9	
Main Sequence	…	0.99	
Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
Not a Binary	…	0.30	
Wide Binary Separation	…	0.50	

Adding it all up

Stellar Requirement	*Mass Limit*	*Fraction OK*	*Cumulative Fraction*
✓ Heavy Elements	…	0.9	
✓ Main Sequence	…	0.99	
✓ Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
✓ Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
Not a Binary	…	0.30	
✓ Wide Binary Separation	…	0.50	

f_s: fraction of stars that life can exist around

Stellar Requirement	*Mass Limit*	*Fraction OK*	*Cumulative Fraction*
Heavy Elements	…	0.9	
Main Sequence	…	0.99	
Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
Not a Binary	…	0.30	
Wide Binary Separation	…	0.50	

Value can range from ~ 0.06 to ?