



This Class (Lecture 21):

Extraterrestrial Life

HW8 due on Friday.

Nightlab report due in discussion class on April 12th.

Next Class:

The Milky Way

Nightlab makeup assignment available online (see assignments), also due on April 12th.

Music: *Who's There* – Smash Mouth

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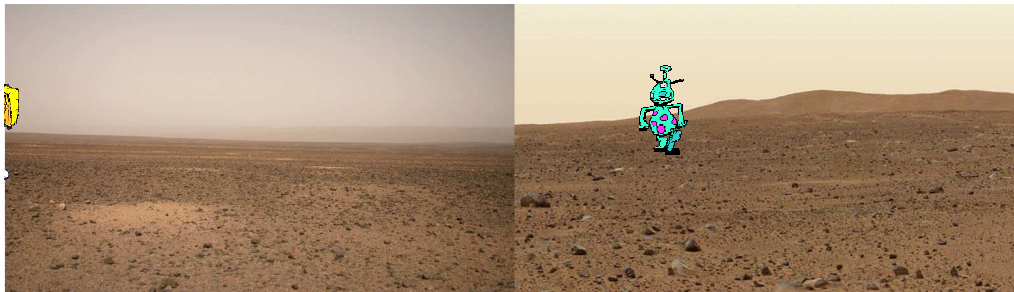


- Extraterrestrial life

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Which is Mars? Which is Earth?



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Are We Alone?



- It's a great time to think about this question!
- In 1995, we knew of 9 planets. Now, in 2006, we know of nearly 200 planets!
- In the near future, NASA missions may find life on Titan or Europa, evidence of life on Mars, or image Earth-like planets around nearby stars.
- Can we answer arguably the biggest astronomical question of all time: ***Are we alone?***
- We **can** address this question with scientific methods, but also perhaps with some philosophy and science fiction thrown in too.

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Other Questions



- Do you think extraterrestrial life exists?
- Do you believe that we have been visited by UFOs?
- Is that the same as ET life?

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The Universe: Some Facts to Help you Live in it



10 billion galaxies

100 billion stars in each galaxy

How many planets?

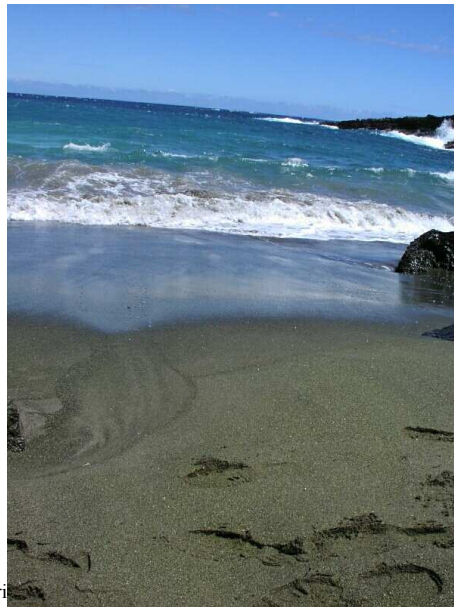
“Tell a man that there are 100 billion stars in our Galaxy and he'll believe you. Tell him a bench has wet paint and he has to touch it.”

<http://astron.berkeley.edu/~kalas/>

Numerically Challenged



- In the Universe, the number of stars is greater than the number of grains of sand on all of the beaches of the Earth.
- Each of these stars may have planets.
- Or only 0.0001%?
- Is it sensible to think that life only exists on Earth?



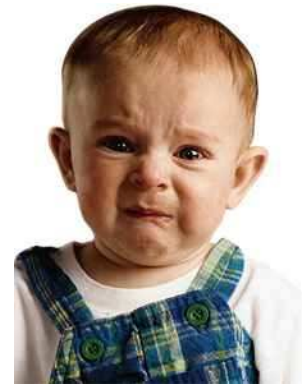
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Life?



- We are probably typical in many ways to the other planets around other stars, in other galaxies.
- One aspect of the study of extraterrestrial intelligent life is to determine if *life* is a typical phenomenon.



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Life?



- Our best guess is that most other galaxies have at least one planet with intelligent life on it
 - As the Milky Way has at least one planet with Intelligent Life.
- So, there ought at least 10 billion intelligent civilizations in the Universe!



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Aliens?



We have been bombarded by aliens in the media– all types.

No surprise that close to half of all Americans believe in aliens.

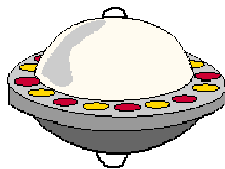
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Have we been visited by ETs?



“Extraordinary Claims Require Extraordinary Evidence”



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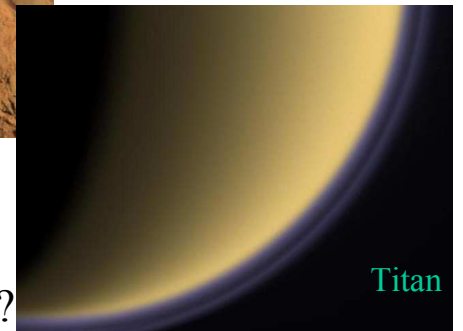
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Is There Anyone Out There?



Mars

Could there be life in a place like this?

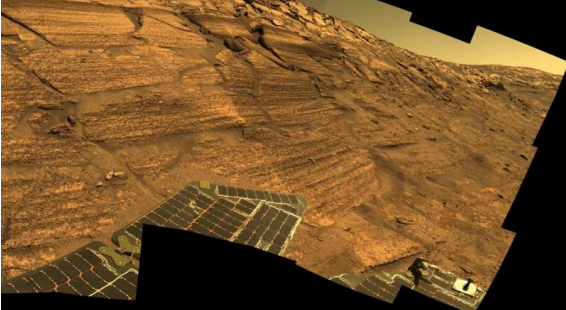
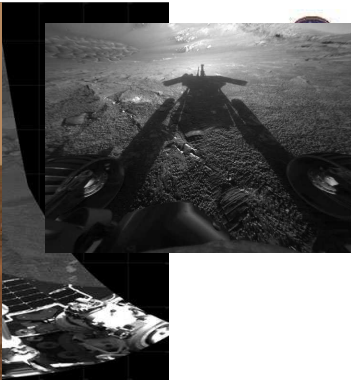
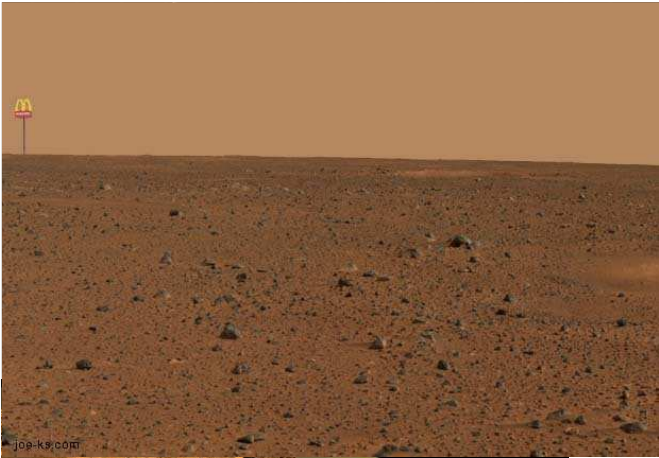


Titan

Or perhaps a place like this?

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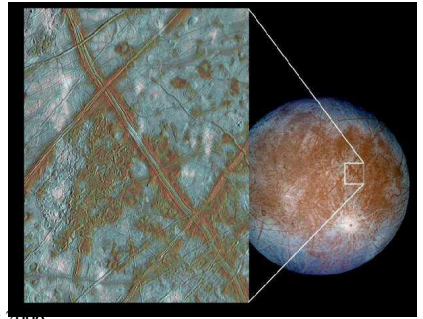
*Roving on Mars:
Spirit and Opportunity
find evidence of water*

http://antwrp.gsfc.nasa.gov/apod/image/0403/emptynest_opportunity_big.jpg
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Europa: Moon of Jupiter



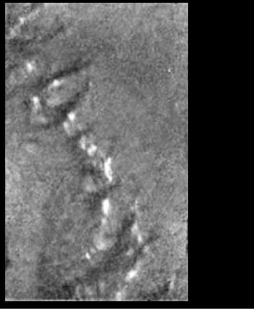
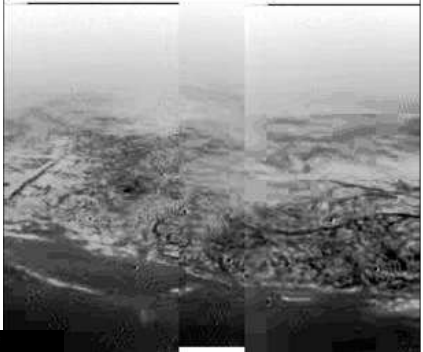
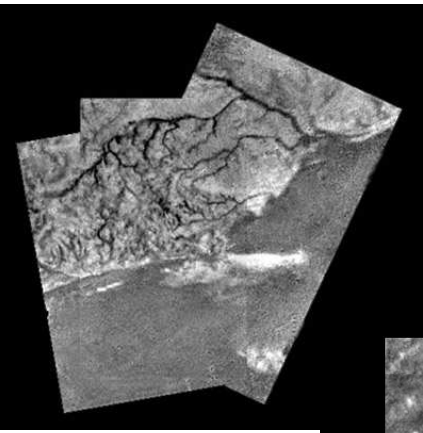
- Life would have to be below the surface, around hydrothermal vents.
- Similar to the first Earth life?
- We don't know how thick the ice is yet. To be continued.
- Future missions, will have to employ smash and dive spacecraft.



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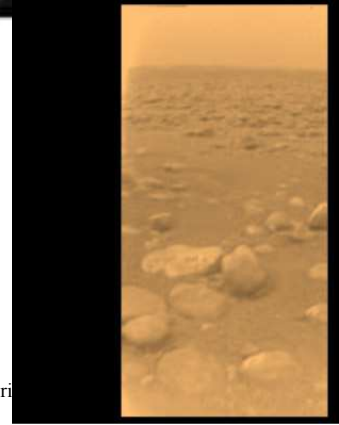
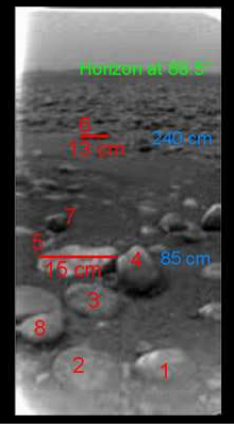
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Mapping Titan



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Mapping Titan

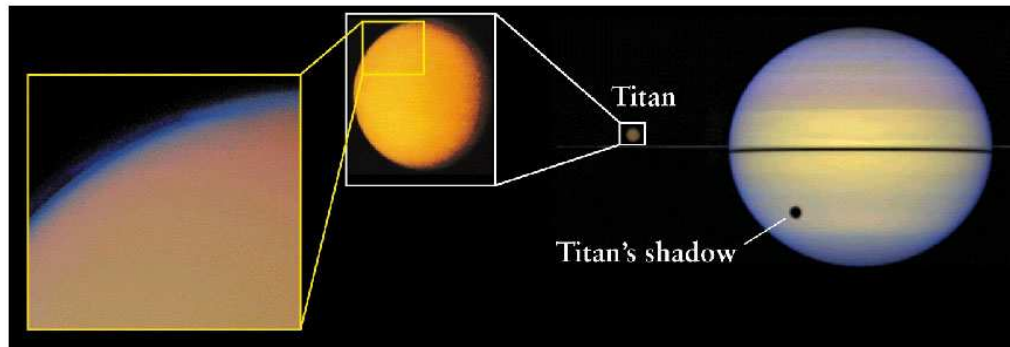


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Titan



- Second most abundant component is methane (natural gas)
 - Could create ethane in the upper atmosphere
 - 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
- If life exists here, then it will change our water-chauvinistic ideas.



Conclusions



- ***No conclusive evidence exists for life in our solar system besides on Earth***
- But, possibilities exist for life
 - Venus may have microbial life high in the atmosphere, fleeing the high temperature of the surface.
 - 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

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Life



If we took all the biomass of all the animals, and all the biomass of all the viruses, bacteria, protozoa, and fungi— who weighs more?

Around 90% of all biomass on the Earth is in the smallest and simplest lifeforms.



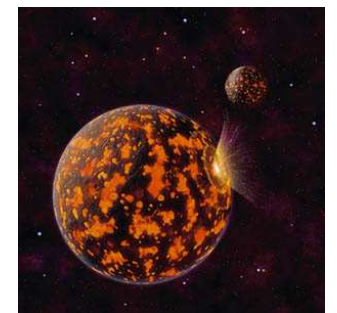
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How Old is Life?



- Earth's early geologic record (first 1/2 billion years) is GONE
 - Clues to early life formation are gone
 - Earth is about 5 billion years old
- But, we do have evidence for very early microbial life on Earth (about 4 billion yrs old).
- The heavy bombardment ended at about that time.
- First multi-celled life about 1 billion years ago



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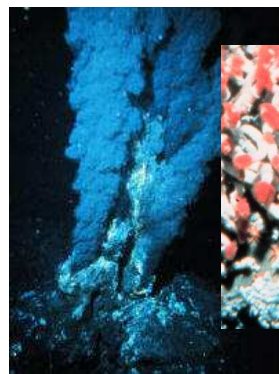
Not your Parent's ET-- Extremophiles



- These are microbes that live in the most extreme places on Earth.
- Temperature extremes
 - Boiling or freezing, 100⁰C to -1⁰C (212F to 30F)
- Chemical extremes
 - Vinegar or ammonia (<5 pH or >9 pH)
 - Highly salty, up to ten times sea water
- They are exciting, as they are the most likely candidate for extraterrestrial life.
- Probably dominated life on early Earth until *fairly recently*.

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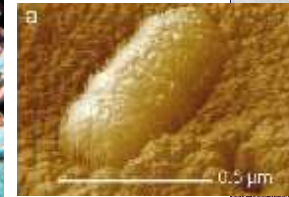
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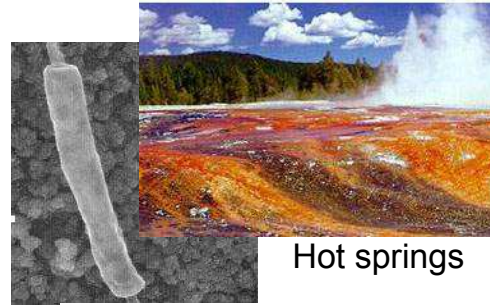
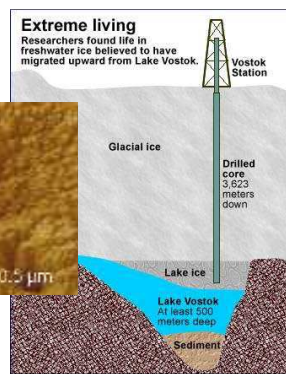
Hydrothermal vent



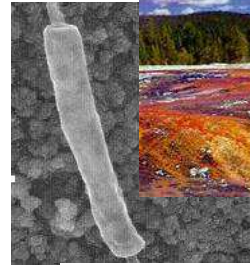
Tubeworms



Lake Vostok -
Antarctica



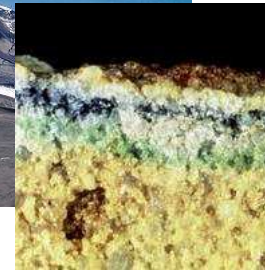
Hot springs



Thermophilic bacteria



Antarctic
dry valley



Cryptoendoliths

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Drake Equation

Frank Drake



$$N =$$

of advanced civilizations we can contact in our Galaxy today

Drake Equation

Frank Drake



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

of advanced civilizations we can contact in our Galaxy today

Star formation rate

stars/
yr

Fraction of stars with planets

systems/
star

of Earthlike planets per system

planets/
system

Fraction on which life arises

life/
planet

Fraction that evolve intelligence

intel./
life

Fraction that communicate

comm./
intel.

Lifetime of advanced civilizations

yrs/
comm.

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R_*



- There are perhaps tens to hundreds of billions of galaxies
 - Each with hundreds of billions of stars
 - Age of Universe is 13.7 billion years
- Probably best known number.



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f_p : Other Planets, Other Stars



47 Ursae Majoris System– 51 light years away (near the Big Dipper). 13 years of data has shown 2 planets– 1 Jupiter like and 1 Saturn like.



Wow! Among the most similar to our own system

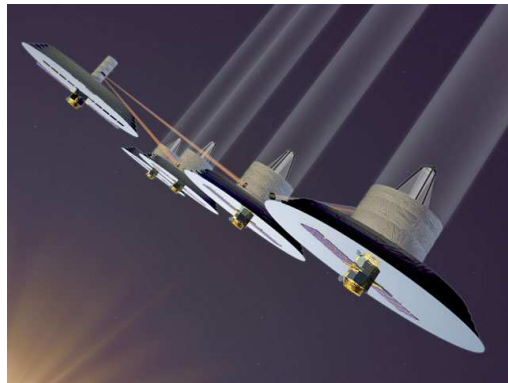
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Terrestrial Planet Finder Mission



- Survey nearby stars looking for terrestrial-size planets in the "habitable zone"
- Follow up brightest candidates looking for atmospheric signatures, habitability, or life itself
- Launch is anticipated between 2012-2015



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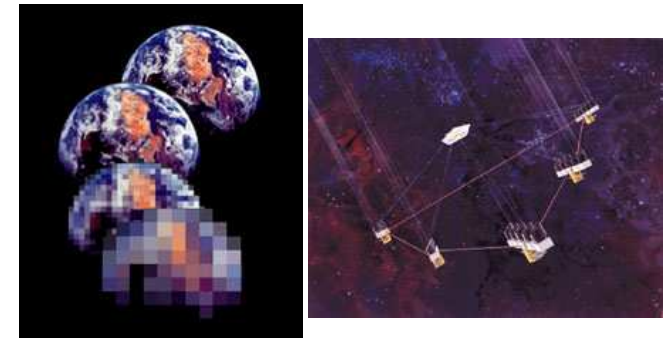
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Terrestrial Planet Imager



The goal of imaging an Earth-like planet.

5 platforms of 4 eight meter interferometer in space.



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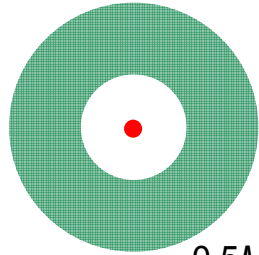
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<http://spider.ipac.caltech.edu/staff/jarrett/talks/LIU/origins/openhouse30.html>

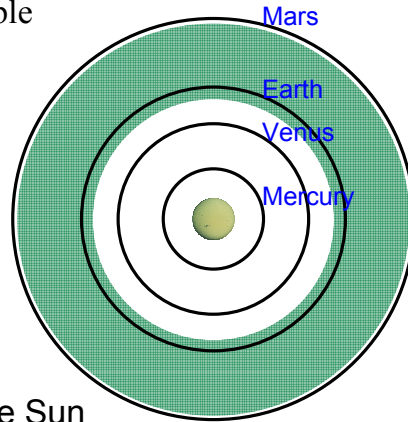
n_e : Habitable Zones— Are you in the Zone?



- Long living star
- Planets with stable orbits (thus stable temps)
- Liquid Water
- Protection from UV radiation



0.5 M_{Sun} star



The Sun

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f_i : Cosmic Imperative?

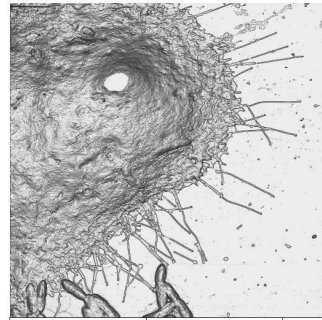


- Is life a cosmic imperative?
- Just like gas forms galaxies, and in galaxies stars and planets form, do chemicals on some planets form molecules that lead to life?

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All Made from the Same Stuff



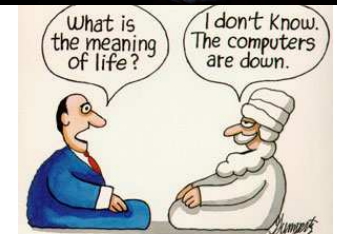
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What is the Earth made of?



- The makeup of the Earth is very different than our makeup (all life).
- **“We are star stuff!”**
- HONC are the elements of life.
 - Hydrogen– Big Bang
 - Oxygen– Fusion of 1st stars
 - Nitrogen– Fusion of 2nd stars
 - Carbon– Fusion of 1st stars



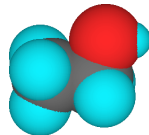
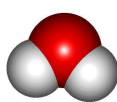
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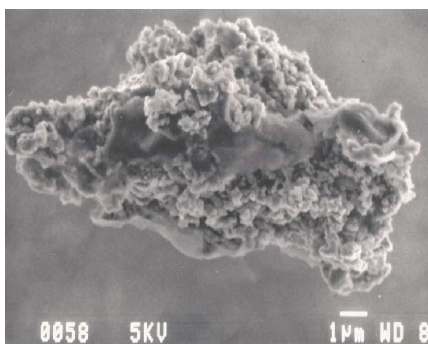
Molecules in Space!



- Molecules (e.g.)
 - Carbon monoxide (CO)
 - Water (H₂O)
 - Ammonia (NH₃)
 - Formaldehyde (H₂CO)
 - Glycine (NH₂CH₂COOH)?
 - Ethyl alcohol (CH₃CH₂OH)
 - Acetic Acid (CH₃COOH)
 - Urea [(NH₂)₂CO]
- Dust particles
 - Silicates, sometimes ice-coated
 - Soot molecules



Polycyclic aromatic hydrocarbons (PAH)



Dust particle (interplanetary)

Miller and Urey Experiment



- Testing chemistry on the early Earth– no oxygen.
- Can we make the important molecules of life easily?
- ALL 20 amino acids needed for life can form with water and an energy source under the right conditions.



http://physicalsciences.ucsd.edu/news_articles/miller-urey-resurrected051903.htm

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We are Left-Handed?



- Amino acids in non-biological situations are mixtures of both right and left handed molecules, but in life only left-handed molecules are used.
- Why? We don't know.
- Sugars in life are right-handed
- The opposite should have worked just as well, and this arrangement probably arose out of chance.
- An ET organism may be made of the same stuff, but if they are made of right-handed amino acids, they couldn't eat our food. Bummer.



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Making Oxygen: The First Air Pollution



- The early Earth had no oxygen.
- Cyanobacteria changed the world!
- Created first environmental disaster!
- From 3.5 to 1.8 Byrs ago, allowing more complicated life.



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Chain of Life



- 3.5 Byrs ago: **Bombardment of Earth stopped.**
- 3.8 Byrs ago: **First known fossils**
- 1 Byrs ago: **First multi-celled organisms.**
- 500 Myrs ago: **First boned creature— first fish.**
- 400 Myrs ago: **First amphibians.**
- 300 Myrs ago: **Many animals.**
- 200 Myrs ago: **Dinosaurs.**
- 100 Myrs ago: **Birds, mammals, flowering plants.**
- 65 Myrs ago: **Mass extinction— new chance for mammals.**
- 5 Myrs ago: **First humanoids.**

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f_i : Intelligence



- Intelligent life is a **very** recent development on Earth with the emergence of the primates, hominids, and H. sapiens.
- Everyone agrees that this particular evolution **will not occur** on other planets.
- But, will the characteristics of H. sapiens be common to human-like intelligence?
 - Manipulative organs— hands
 - Walking upright?
 - Is tool use and larger brains associated with walking upright?
 - Pair bonding?
 - Human brains quadruple in size after birth compared to other primates which double.

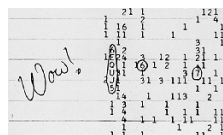
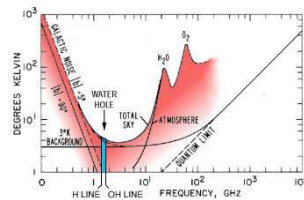
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f_c : Galactically Aware



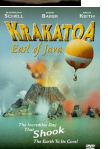
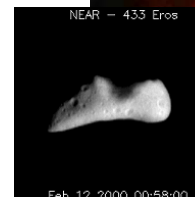
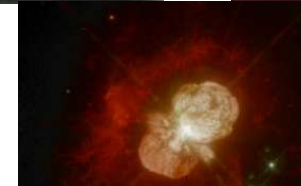
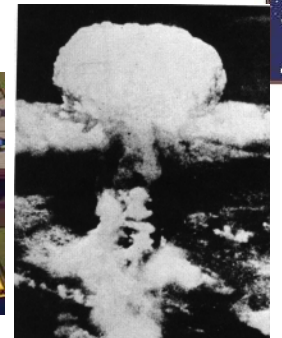
- Realization that extraterrestrial life is possible.
- The urge and technology to communicate.
- SETI problems
 - Where to look
 - What freq to look
 - What code to use
 - Etc...



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L: Lifetime



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What is L?



How long on **average** can an advanced civilization exist?

- Short Term (100-1000 yrs)
 - Give up on communication due to budgets.
 - Depletion of resources.
 - Population.
 - War.
- Long Term (100,000 to 5 Byrs– age of galaxy is 10 Byrs yrs and we took half of that to evolve)
 - Stellar Evolution.
- Don't forget the random volcano, asteroid, or supernova.
- Still in many cases an advanced civilization may be prepared for many of the issues!

Drake Equation For Optimist



= 40,000,000,000

Communicating Civilizations



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

# of advanced civilizations we can contact	Rate of formation of stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	20	1	1	1	1	1	2 Byrs

Birthrate of 50/year!

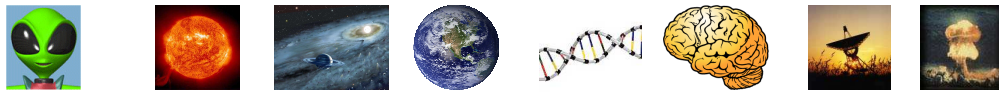
= 0.0000075

Communicating Civilizations

Drake Equation For Pessimist



Must wait 10,000,000 years!



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

# of advanced civilizations we can contact	Rate of formation of stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	5	0.1	0.15	0.01	0.01	0.01	100

Birthrate of 7.5×10^{-8} /year!

= 930,000

Communicating Civilizations

Drake Equation For Average



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

# of advanced civilizations we can contact	Rate of formation of stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	10	0.5	0.89	0.5	0.7	0.6	1 Byrs

Birthrate of 0.93/year!

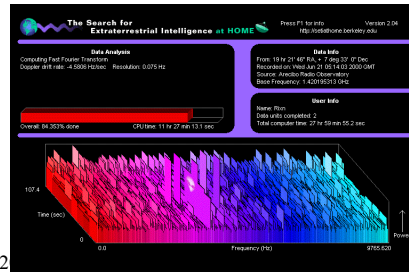
How to Communicate?



- If there, how do we go about detecting our neighbors?
- Are we seriously sending out messages now?
- No.
- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive “lurker” civilization.



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Allen Telescope Array



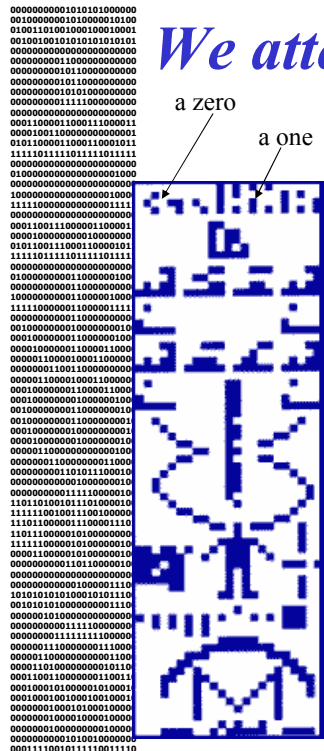
- UC Berkeley and the SETI Institute with majority of funding from Paul Allen are building the ATA.
- 350 antennas– each 6.1 m in diameter.
- With advanced electronics it will cover 1-10 GHz with many channels.
- Can image a few stars per field.
- 100% SETI time
- Will increase search to 100,000 or 1 Million stars.



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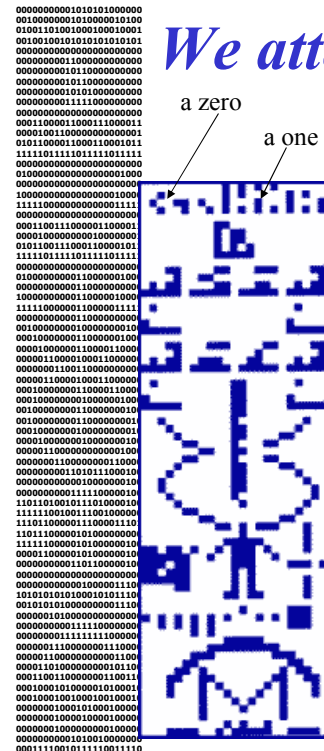
We attempted Contact



- The first real signal sent was in 1974 by the Arecibo telescope (20 trillion Watts of power).
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- Now, we wait.

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We attempted Contact



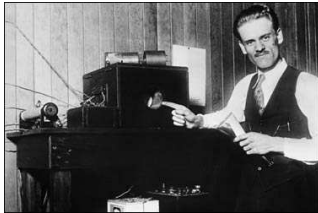
- ET should be able to arrange data into a picture.
- If they're looking, a SETI experiment will detect this.
- A few signals recently by companies, but arguably not taken seriously.

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Does ET Love Lucy?



- Another possibility is to look for unintentional leakage signals.
- Leakage, as it “leaks” from the planet’s ionosphere.
- We can not currently detect this, but maybe other civilizations can.
- What leakage do we have? TV, FM Radio, radar



<http://www.time.com/time/time100/scientist/profile/farnsworth.html>

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Contact



“If humans were the only life in the Universe it would be a terrible waste of space.”

Vega calls us back, but how can we be sure that we’re listening?

Our leakage radiation is actually decreasing with cable, fiber optics, direct satellite, etc. Civilizations may not spend much time in that phase.



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The NASA Search



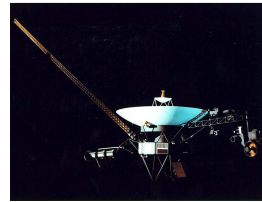
- The most ambitious search was planned by NASA on the 500th anniversary of the Discovery of America– Oct 12, 1992.
- “In 1993, Nevada Senator Richard Bryan eliminated all funding for the NASA SETI program. The cost of the program was less than 0.1% of NASA's annual budget, amounting to about a nickel per taxpayer per year. The Senator cited budget pressures as his reason for ending NASA’s involvement with SETI.”
- "The Great Martian Chase may finally come to an end. As of today millions have been spent and we have yet to bag a single little green fellow. Not a single Martian has said take me to your leader, and not a single flying saucer has applied for FAA approval."

<http://www.planetary.org/html/UPDATES/seti/history/History12.htm>
http://www.seti.org/about_us/faq.html

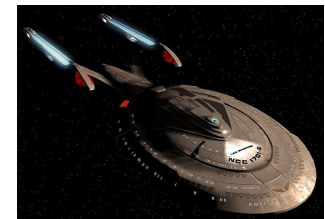
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Interstellar Travel



- But, what if all communication with ET fails?
 - Wrong frequencies.
 - Everyone is listening and no one is broadcasting.
 - We fail to recognize the signal.
- We can go visit them or the microbes. “To boldly go...”
- BUT, the distances are huge!
- Nearest star is 4.3 ly away or around 4×10^{13} km!
- **40,000,000,000,000 km! 40 TRILLION km!!!**
- Our fastest object, Voyager would take nearly 100,000 years



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Warp Drives



- Due to great distance between the stars and the speed limit of light, sci-fi had to resort to “Warp Drive” that allows faster-than-light speeds.
- Currently, this is **impossible**.
- It is speculation that requires a revolution in physics
 - It is science fiction!
- But, we have been surprised before...
- Unfortunately new physics usually adds constraints not removes them.



<http://www.filmjerk.com/images/warp.gif>

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ET's Spacecraft?



- We really don't know yet how to get to the stars realistically, so we don't know what advanced civilizations might use.
- But it is
 - Smarter
 - Cheaper
 - Still very informative and
 - Realisticto send an unmanned probe into stars first
 - Lighter payload!
- Self-replicating probes?

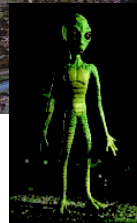
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Slow Long Haul Space Travel



- Spacecraft that we can envision easily would take a lifetime to get to the nearest star.
- Colonizing missions would have to be multi-generation missions.
- Space colonies with propulsion systems would slow down things, so maybe it would take 1000 yrs for each trip.
- How many of you would sign up today?



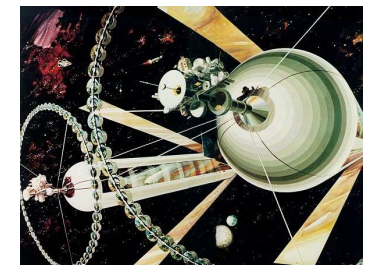
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1000 Years?



- So in 1000 years from now, we should be able to travel to other stars. But will we?
- It would be nuts to speculate on what will motivate our descendents (if any) 1000 years from now. But if interstellar travel really is easy and cheap, surely someone will give it a go?



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The Fermi Paradox

The Drake Equation - Even for a few hundred technical civilizations.

Only 150 million years (worst case) to colonize the Galaxy.

WHERE IS EVERYBODY?????

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Optimistic Aliens

Galaxy colonization the hard way— small hops. Every 500 years, a colonization craft makes it to the next suitable solar system— small delay.

Then, it only takes about 4 million years!

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Fact 2

- If ETI is abundant in our Galaxy, then we expect that, statistically, there exist or have existed ET civilizations that have achieved a technological capability greater than that which we now demonstrate— an advanced civilization!
 - It took us about 4.5 billion years on Earth, but it could easily be only 3.5 billion years somewhere else
 - An intelligent civilization can do a lot in a billion years

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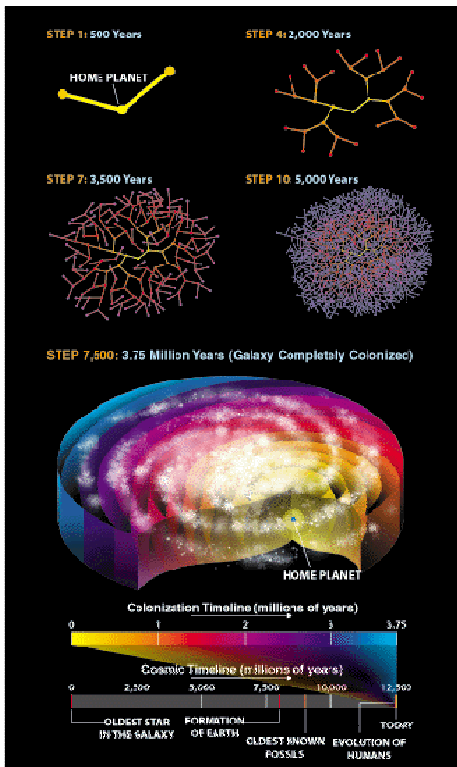


Fact 1

- It is possible that ETI life is abundant in our galaxy
 - With 100 billion stars and plenty of opportunities for life to develop.
 - Our average estimate for civilizations was high!
 - So, there are clearly arguments for common life.

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Fact 3



- The distances and times associated with interstellar travel are great, but as far as we know, it is conceivably possible that a civilization conduct significant interstellar exploration, especially with enough time.
 - At very least, a more advanced civilization could have sent out nanoprobes across the Galaxy.

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Fact 4



- It is possible therefore that an ET civilization has explored our region of the Galaxy, the Sun, and even our Earth at some point in its history
 - This is not pseudo-science but real logical consequences of abundant ETI.

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Fact 5



- We have no reason to believe that this has not happened
 - We also have no reason to believe that it has.
 - It is an open question.

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What are we left with?



- These are two distinct but still very significant claims
 - The Earth has been visited by ETs.
 - The Earth has not been visited by ETs.
- Neither of these statements has been validated.
- So, the only statement we can make is
 - We do not know whether or not the Earth has been visited by ETs.



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<http://www.egl.uwaterloo.ca/~csk/washington/graphics/logos/validated.gif>

The ET Visitor Hypothesis



- So far no reliable evidence exists for ET visitation
- But, the idea that we have been visited and traces exist somewhere is a valid **THEORY**
 - Maybe improbable but still valid
- *Don't expect people to believe your theory unless it is substantiated with reliable evidence*

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Give Me Real Evidence!



- Evidence:
 - A piece of a probe or spaceship
 - Some trace that can be uniquely linked to an ET probe
 - Biological material.
 - A reliable, logical calculation
- That is the same we require of ANY scientific investigation



http://www.biochem.wisc.edu/wickens/jpgs/2001_spac_odd.jpg

Astronomy 122 Spring 2006 <http://www.alien-ufos.com/images/ufos/miscufo4.jpg>

UFO Phenomenon

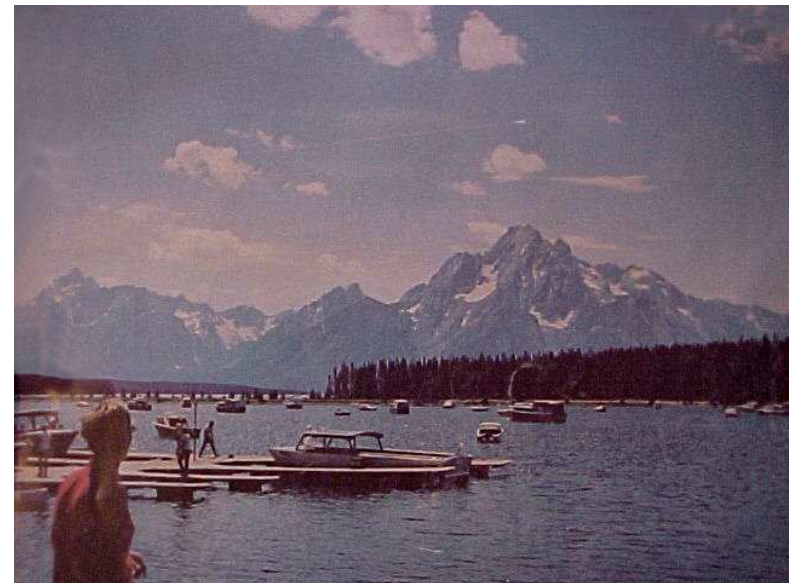


- Some argue that we have proof:
 - UFO sightings.
 - Strange historical accounts or grand technological accomplishments of humans in the past.
 - Alien abductions.
- This all falls into the realm of pseudo-science.
- There has never been any concrete evidence of extraterrestrials having anything to do with UFOs.
- UFOs could be so very many things. Why assume automatically that there is an otherworldly explanation? But those who want to believe will do so even despite evidence to the contrary.
- Occam's razor

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An Example: Meteor 1972



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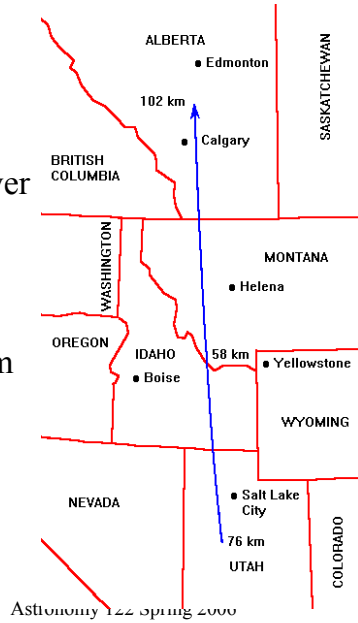
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<http://www.uwgb.edu/dutch/>

Yikes, a Near Miss



- A bus sized object entered atmosphere over Utah and exited over Canada
- Velocity of 15 km/sec
- Missed Earth by 58 km



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But...



- Event was completely unexpected
- Crossed relatively sparsely-inhabited region
- Only visible for a *total* of 101 seconds
- Visible for no more than 30 seconds at any one spot.



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But...



- Nonetheless, we have dozens of clear photographs of this event
- Still we have no comparable images of UFOs.
- And today digital cameras and camera phones should make unusual events even more seen.



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Problems?



The large number of sightings argues against alien spacecraft.

- Space is freaky big.
- There are extreme difficulties of interstellar space travel and the number of planets to explore.
- So, why would so many alien spacecraft be visiting the earth constantly?
 - There are other planets to check out.
 - What makes us so interesting?
 - We should not overestimate our significance.



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A



1965 - Soviets

Alien Abductions



- Alien abduction stories bare a resemblance to post traumatic stress disorder.
- Horrible memories re-manifest in dream-like states where the mind is highly susceptible to confabulation and fantasy.
- The stories often involve elements that sound like a condition called *sleep paralysis*.



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Your Call



- We have no reliable evidence to support actual ET contact.
- We have evidence that people historically make up stories about things they imagine to be linked to a light in the sky
 - So, what is the most logical explanation?

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Open Your Mind?



- Yes, as we have justified, it is possible that an ETI civilization has visited the Earth at some point in its history
- It is a legitimate scientific question to investigate this
- **We need legitimate scientific evidence in order to believe this theory**

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Bottom-line



- We have probably not been visited by aliens; there is **no** evidence.
- To me, alien reports are images of human psyche.
- But, our Drake equation estimate suggest that extraterrestrial life is common.
- So the Fermi Paradox: “Where are they?”
- I would argue that we keep trying to figure out the Universe, look at the concept of extraterrestrial life with a critical eye, fill in our gaps of knowledge, and the search is on.

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The History of the Universe in 200 Words or Less



Quantum fluctuation. Inflation. Expansion. Strong nuclear interaction. Particle-antiparticle annihilation. Deuterium and helium production. Density perturbations. Recombination. Blackbody radiation. Local contraction. Cluster formation. Reionization? Violent relaxation. Virialization. Biased galaxy formation? Turbulent fragmentation. Contraction. Ionization. Compression. Opaque hydrogen. Massive star formation. Deuterium ignition. Hydrogen fusion. Hydrogen depletion. Core contraction. Envelope expansion. Helium fusion. Carbon, oxygen, and silicon fusion. Iron production. Implosion. Supernova explosion. Metals injection. Star formation. Supernova explosions. Star formation. Condensation. Planetesimal accretion. Planetary differentiation. Crust solidification. Volatile gas expulsion. Water condensation. Water dissociation. Ozone production. Ultraviolet absorption. Photosynthetic unicellular organisms. Oxidation. Mutation. Natural selection and evolution. Respiration. Cell differentiation. Sexual reproduction. Fossilization. Land exploration. Dinosaur extinction. Mammal expansion. Glaciation. Homo sapiens manifestation. Animal domestication. Food surplus production. Civilization! Innovation. Exploration. Religion. Warring nations. Empire creation and destruction. Exploration. Colonization. Taxation without representation. Revolution. Constitution. Election. Expansion. Industrialization. Rebellion. Emancipation Proclamation. Invention. Mass production. Urbanization. Immigration. World conflagration. League of Nations. Suffrage extension. Depression. World conflagration. Fission explosions. United Nations. Space exploration. Assassinations. Lunar excursions. Resignation. Computerization. World Trade Organization. Terrorism. Internet expansion. Reunification. Dissolution. World-Wide Web creation. Composition. Extrapolation?

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