# Astronomy 330

This class (Lecture 23):
Communication

Next Class:
Communication

**HW10 is due Wednesday. Will take longer than usual– not multiple choice.**

Music: *Aliens Exist*– Blink 182

# Online ICES

- ICES forms are available online, so far 33/100 students have completed it.
- I **appreciate** you filling them out!
- **Please** make sure to leave written comments. I find these comments the most useful, and typically that's where I make the most changes to the course.

# Question

Are you going to fill out an ICES form before the deadline?

a) Yes, I did it already.
b) Yes, sometime today
c) Yes, this weekend
d) Yes, I promise to do it before the deadline of May6th!
e) No, I don't want help you out (even after all you have done for me and my education) nor do I want to help out the large number of students who will come after me (I wish you a long life!). I prefer stagnation.

# Final

- In this classroom, Fri, May 7th, 0800-1100.
- Will consist of
  - 15 question on Exam 1 material.
  - 15 question on Exam 2 material.
  - 30 questions from new material (Lect 20+).
  - +4 extra credit questions
- A total of 105 points, i.e. 5 points of extra credit.
- Final Exam grade is based on all three sections.
- If Section 1/2 grade is higher than Exam 1/2 grade, then it will replace your Exam 1/2 grade.

# Final

- A normal-sized sheet of paper with notes on both sides is allowed.
- Exam 1and 2 and last year's final are posted on class website (not Compass).
- I will post a review sheet

# Final Paper

- Must turn in your draft and final paper by May 5th discussion class (at beginning of class).
- If you are happy with your draft grade, you don't have to turn in a final paper.

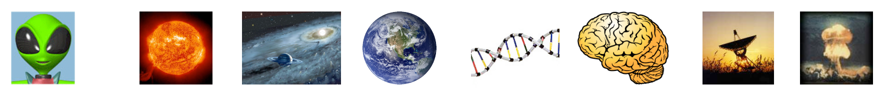
# Outline

- Important factors for detection– the detection haystack.
- SETI experiments.

# Drake Equation

Frank Drake

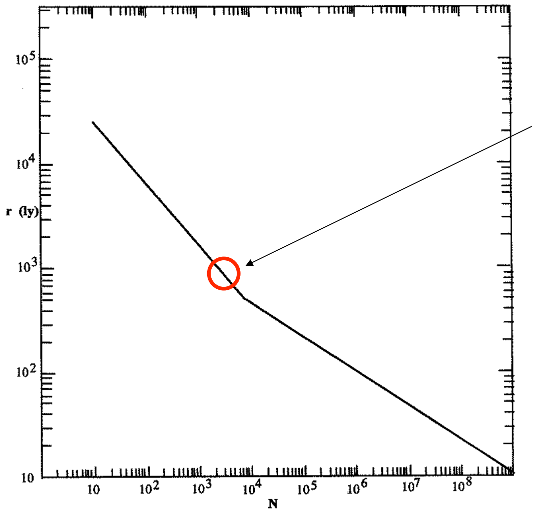
**That's 2,759 advanced civs!!!**



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

| $N$ | $R_*$ | $f_p$ | $n_e$ | $f_l$ | $f_i$ | $f_c$ | $L$ |
|---|---|---|---|---|---|---|---|
| # 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 |
| | 9 stars/ yr | 0.29 systems/ star | 1.03 x 0.22 = 0.23 planets/ system | 0.46 life/ planet | 0.3 intel./ life | .52 comm./ intel. | 65,000 yrs/ comm. |

# The Neighbors




We need to look at every star within ~850 lyrs for one detection!

Using N=2,759

# Problems…Problems

- Assume that an advanced civilization is broadcasting either in all directions or toward us.
- Where and when do we listen?
- Which frequency?
- Which channel?
- Which polarization?
- What is the code?

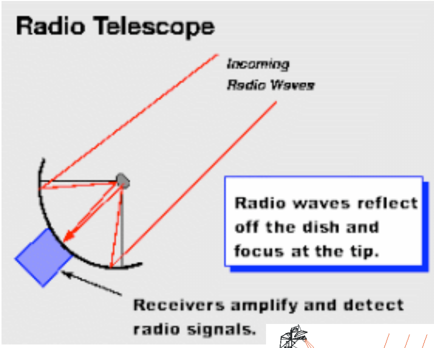
# Problems…Problems

- The problem is worse than searching for a needle in a haystack.
- We have to assume that they are constantly broadcasting, or the problem is impossible.
- Have to make the needle bigger!

http://nl.ijs.si/et/talks/esslli02/metadata_files/Haystack-FINALb.jpg

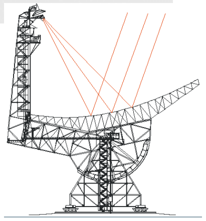
# Sky Dishes

- Radio telescopes are similar to optical telescopes, just different wavelength.
- Most radio telescopes are Parabolic Cassegrains.
- Radio telescopes measure the source intensity.
- The bigger the dish, the more sensitive.
- So a big dish is best, right?




http://www.nrao.edu/whatisra/radiotel.shtml

Unblocked Aperture



# Haystack: Sensitivity

- Sensitivity of a radio telescope:
- We have to detect a weak signal in the presence of noise.
- So, ideally look in a fixed direction for a long time– better sensitivity to weak signals.
- But it may be the wrong direction.
- And a big dish is best, right?

Channel size, time

$$S \propto D^2 \sqrt{\Delta \upsilon \times t}$$

Dish diameter

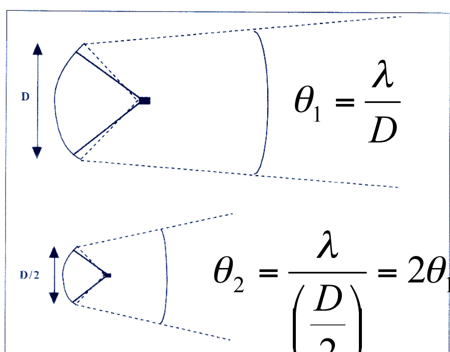
# Question

What makes a telescope more sensitive?

a) Double the size
b) Double the channel width
c) Double the observing time
d) Double the voltage
e) Double the trouble

# Haystack: Direction

- We can not *a priori* know which direction to look, so we must look in many directions.
- Tradeoff: The most sensitive radio telescope has the largest diameter but the smallest field of view.
- Beam size decreases as the diameter increases.
- The number of times you have to point to cover a certain area of the sky increases as diameter squared.



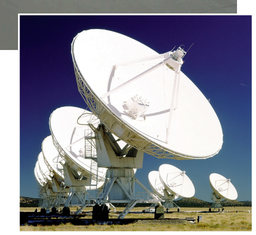

$$\theta_1 = \frac{\lambda}{D}$$

$$\theta_2 = \frac{\lambda}{\left(\frac{D}{2}\right)} = 2\theta_1$$

θ is in radians.

# Dish Decision

- If ET signals are a few strong signals, we can use a small telescope and listen for a short time in any direction. The small diameter dish covers more area.
- If ET signal is many weak signals, we can use a bigger telescope and observe in a single direction for a long time. A weak signal requires a big dish.



http://www.noao.edu/staff/mighell/sacpeak/jpina/VLA%20in%20dish%204.jpg

# Question

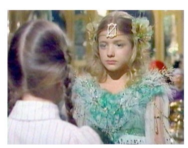
In any SETI experiment, it is best

a) To use the biggest radio telescope available.
b) To use a big radio telescope and sit on one star for a long time.
c) To use a combination of small and large telescopes.
d) To look for UFOs directly.

# Haystack: Frequency

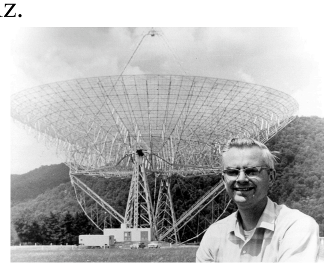
- Would the signal be concentrated in a small range of freqs?
- What size should a channel be?
- Could argue that the best choice is around 1 Hz.
- Then in the 1-10 GHz band there are $9 \times 10^9$ channels!
- With modern electronics we can survey large numbers of channels, but not that many.
- What's the history of SETI?

# Project Ozma



http://www.angelfire.com/pa/maryanne/images/ozma.jpg

- The first look for ET radio signals by Frank Drake in 1960.
- Used a 26 meter telescope in W.V. using the H atom frequency band of 1.42 GHz.
- Targeted search of 2 nearby stars (11 lyrs) that are the same age as our Sun
- 200 hours over 3 months.
- A single 100 Hz channel scanned 400 kHz.
- 1 false alarm due to a secret military experiment.
- Nothing else detected



http://216.120.234.103/setiprime/setiprime/images/images-2003.html


# Ozma II

- Ben Zuckerman and Pat Palmer used the 91m telescope in W.V. to survey the 670 nearest "suitable" stars.
- Targeted Search of stars with low mass and binaries that allowed stable planet orbits.
- Also observed at 1.42 GHz with 192 channels of 4 kHz and 192 channels of 52 kHz.
- Could have detected a 40 MW transmitter on a 100m telescope.
- Observed for 500 hours.
- No detection at a sensitivity 10 times better than Ozma

# Ohio State Survey

- In 1973 by F. Dixon and D. Cole.
- Used Ohio State radio telescope for a continuous survey of sky.
- Not steerable– sort of like Arecibo, so cuts a swath through the sky: A Sky Survey
- Searched overhead for signals.


http://www.bigear.org

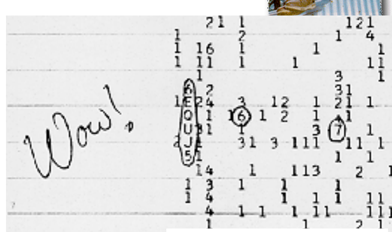
# Ohio State

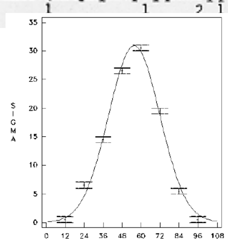
- 1.42 GHz with 50 channels of 10 kHz.
- Modest sensitivity— 100 times worse than Ozma II
- But not just looking at stars.
- Could only detect extremely strong transmissions.
- Land was sold to a golf course development.


http://www.bigear.org

# The Wow Signal

- Aug. 15, 1977, Jerry Ehman was looking through the data when he recorded the Wow! signal.
- A major signal in the telescope– 30σ detection!
- Stayed around for >72 seconds.
- Unlikely to be noise, but never seen again.
- "Even if it were intelligent beings sending a signal, they'd do it far more than once."
- Used in X-Files

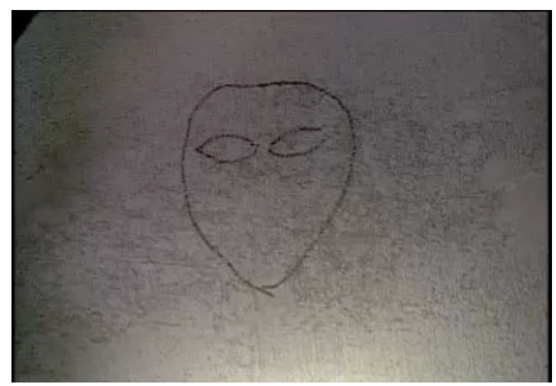



http://www.bigear.org/wow.htm

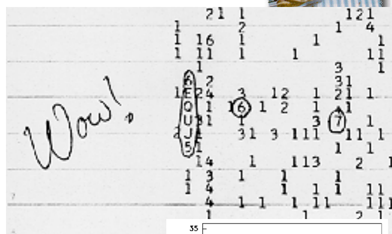
Gray & Marvel 2001, ApJ 546, 1171

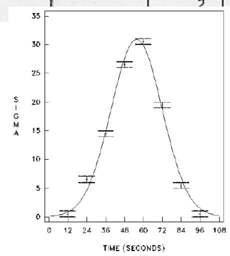
# Wow! in pop culture



# The Wow Signal: Facts

- Narrowband signal: < 10 kHz wide (one channel only)
- Signal observed in only one (of two) horns
- Signal observed only once ("Big Ear" or other observatories)
- Within each 10-second observing interval, the average signal strength remained constant.
- For the entire observing interval of 6 data points lasting 72 seconds, the average signal strength remained constant (because the 6 data values follow the antenna pattern to better than a 99% accuracy).
- Modulation (signal strength variation) on a time scale less than 10 seconds could not be measured.



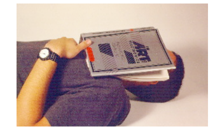




http://www.bigear.org/Wow30th/wow30th.htm#otheranal

http://www.bigear.org/wow.htm

Gray & Marvel 2001, ApJ 546, 1171

# Paul Horowitz Searches 1.42 GHz



- Paul Horowitz moved from a small number of channels to many many many channels.
- 1983 Sentinel: 128,000 channels covering 6 kHz each
- 1985 META: 8 million channels with 400 kHz bandwidth.
- 1993: Horowitz and Sagan reported 8 unexplained signals that did not repeat.
- 1995 BETA: Nearly a billion channels ($2.5 \times 10^8$) covering 2 GHz, 10 kHz channels. Windstorm blew the telescope over in late 1990s.
- Overall, Paul has found 37 signals that did not repeat, and did not have any other known source.

# The NASA Search

The most ambitious search was planned by NASA on the 500th anniversary of the *Discovery* of America– Oct 12, 1992.

Christopher Columbus
(1451 – 1506)

http://www.teslasociety.com/exposition2.jpg
http://www.sailtexas.com/columbusships.html

# The NASA Plan

- 2 prong approach using both Targeted Search and Sky Survey
- Sky Survey:
  - NASA's 34 m tracking telescopes in CA and Australia.
  - 6 year plan covering 1-10 GHz with 16 million channels of 20 Hz each and 30 different settings.
  - Would only detect very strong signals.
- Targeted Search:
  - Cover 800 suitable stars within 75 lyrs.
  - 16 million channels with 1 Hz bandwidth
  - 1-3 GHz range and very good sensitivity!

# The NASA Search

- “In 1993, Nevada Senator Richard Bryan successfully introduced an amendment that 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.”

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

# The NASA Search

- “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

# The SETI Institute

- An independent institute that was working with NASA on their SETI project.
- Once NASA cut funding, they went ahead with a more modest version of the Targeted Search– Project Phoenix.
- Now funded by private donors.
- Initially a search of 200 stars within 150 ly younger than 3 x $10^9$ yrs using an Australian 63 m telescope for 5 minutes on each target.
- Scanned 28 million channels each 1 Hz wide, used multiple settings to scan 1.2 to 13.0 GHz

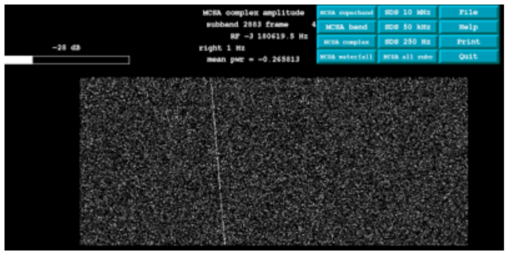
http://www.seti.org/seti/our_projects/project_phoenix/oveview/overview.html

# Project Phoenix

- Just finished up in 2004. (http://www.seti.org/seti/projects/project-phoenix/faq.php).
- About 2-3 weeks a year of telescope time to scan a total of 800 stars (out to 240 lyrs) for a total of 11,000 hours.
- Best survey to date, but no ET signals.

# Project Phoenix

- Proof of concept was shown by tracking the Pioneer 10 spacecraft (launched in 1973) that is 6 billion miles away and broadcasting with a few Watts of power.
- The signal was detected.
- As the Earth and object are moving, there is a small Doppler shift in the frequency of the light received over time.

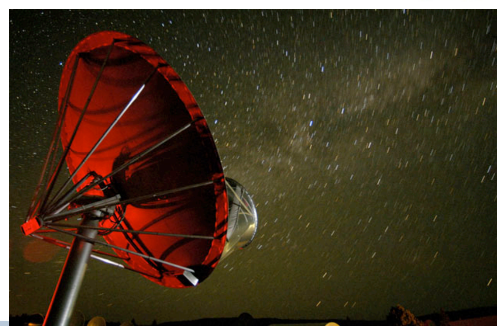



# Allen Telescope Array

- At the BIMA site, UC Berkeley and the SETI Institute, with majority of funding from Paul Allen, are building the ATA.
- 350 antennas that are 6.1 m in diameter, planned.
- Area comparison: Arecibo (70,650 $m^2$) & ATA (10,200 $m^2$) but still > 100 m single dish.

# Allen Telescope Array

- And small dishes– larger field of view.
- But LOTS of them.. planned
- With advanced electronics it will cover 1-10 GHz with many channels.
- Can image a few stars per field.



# Allen Telescope Array

- 100% SETI (with science on for the ride)
- Will increase search to 100,000 or 1 Million stars.
- Current status is 42 dishes.
- Is now observing!
- http://www.seti.org/ata/

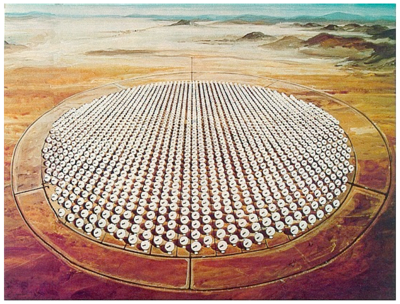
# Allen Telescope Array

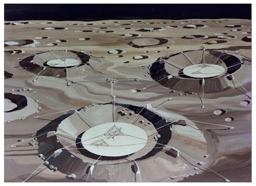
See the telescope in action:

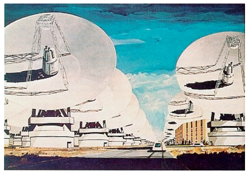
http://atacam.seti.org/maincam-index.html

# The Future?

- Cyclops – 1000 telescopes each 100 m in diameter.
- Resembles a giant eye.
- Could detect leakage transmission at 100 ly.
- Could detect a 1000 MW transmission at 1000 lyrs.
- Bucco Bucks– $50B and 10-20 yrs to build.







http://www.astrosurf.com/lombry/ovni-bioastronomie-et.htm

# End All

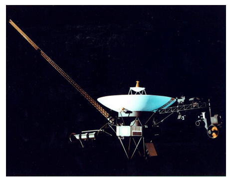
- The modern SETI searches are really expanding the frequency range in which we search, but we are still sensitivity limited.
- In any SETI experiment, what does a null result mean?

# 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…”
- Human colonization of the Galaxy has to start somewhere. Our own backyard!

# Interstellar Travel

- The distances are freaky huge!
- Nearest star is 4.3 ly away or around 4 x $10^{13}$ km!
- **40,000,000,000,000 km! 40 TRILLION km!!!**
  - **Voyager (our fastest spacecraft to date) would take** 100,000 years



# Humans Spreading Out

If we assume that no life is found in our solar system, we have multiple options.

- Seed other planets with genetically engineered life or terraform the planet for terrestrial life.
- Colonize the planets or asteroids.
- Send robots to exploit solar system resources.

# GELFs

Spider genes being injected into a goat egg. Goat produces spider silk protein in milk– Biosteel.

http://science.howstuffworks.com/designer-children3.htm

http://www.nexiabiotech.com

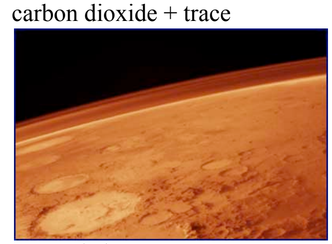
- Genetic engineering techniques might allow us to develop organisms suitable for life on Mars, in the clouds of Venus, or the upper atmosphere of Jupiter.
- But the most likely organism would be those that are part of a larger plan to transform an environment into one suitable for human colonization.
- Terraforming– forming a planet or moon into something like the Earth conditions.

# Terraforming Mars

- Mostly envision Mars for terraforming.
- Comparison:

Mars:
- 95.3% carbon dioxide
- 2.7% nitrogen
- 1.6% argon
- 0.2% oxygen

Earth:
- 78.1% nitrogen
- 20.9% oxygen
- 0.1% carbon dioxide + trace



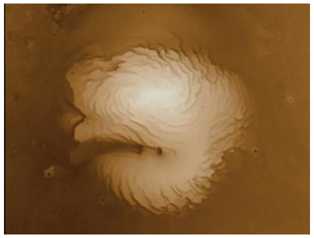
- Why terraform?
  - In 1-2 x $10^9$ yrs, Earth will get hot.
  - Other economical possibilities.
- What are the essential ingredients?
  - Water, Oxygen, and Ozone.
- The bacteria that can build up oxygen need the water.

# Terraforming Mars: By Aliens?


- Sometime movies are full of errors.
- But what can you do?

# Wet Mars

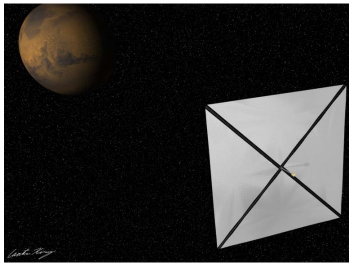
- There is clearly water on Mars frozen in the permanent ice caps or in icy deposits below the surface.
- Probably $10^{14}$ tons of ice in the caps, but how to melt it?
- Spread a layer of dark soil, which will sublimate the water to water vapor.
- Water vapor is a greenhouse gas, so eventually pressure and temperature goes up and liquid water can exist.
- Would take about 10,000 yrs to melt.



http://www.ucl.ac.uk/GeolSci/MITC/marsinfo/icecap.jpg

# Solar Mirror?

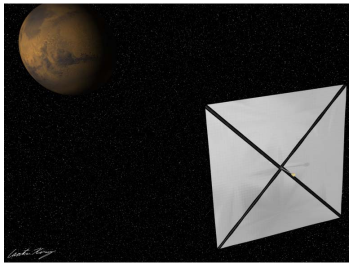
- Could build huge solar mirrors in space to add light to mars– size of Texas for 2% increase.
- Power needed to melt the icecap (remember only first step) is equivalent to 2500 yrs of the US energy output!



http://www.futurespace.de/gallery/pictures/sail-mars1.jpg

# Solar Mirror?

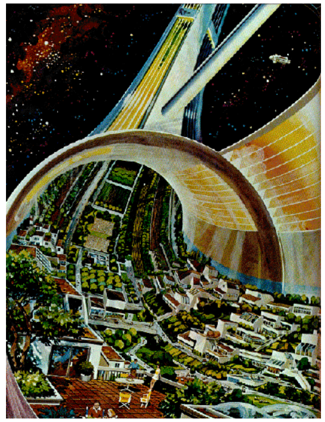
- A solar sail satellite (diameter of 125 km) above the pole should melt the icecap in 10 yrs.
- Other options: genetically engineered bacteria to add greenhouse gases, nanobots, etc.
- Bottom line, at this time it would be very costly and time consuming to terraform Mars.



http://www.futurespace.de/gallery/pictures/sail-mars1.jpg

# Space Colonies?

- Super-duper version of the Space Station.
- Collect materials from Moon, and make a large space structure.
- Artificial gravity from rotation– life could exist.
- But why?
- Hard to justify the expense.
- Maybe solar power collector– beaming microwaves back to Earth.



http://static.howstuffworks.com/gif/space-station-space-settlement.gif

# Dyson Spheres– Recap

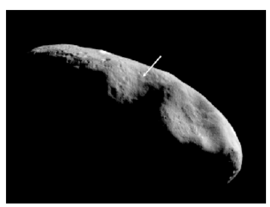
- Again, one could imagine a Dyson Sphere around the Sun to collect the sunlight.
- If other advanced civilizations built one, could we detect it?
- If at 1AU, the sphere would be about 300 K and emit in the IR.
- But if we detected it, we would think it was a star surrounded by dust-- a circumstellar disk of a young star or a blown out shell of dust from an old star.

http://www.homoexcelsior.com/omega.db/datum/megascale_engineering/dyson_sphere/



# Asteroid Living and…

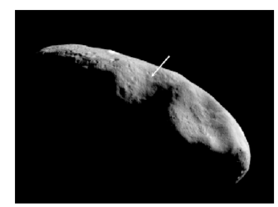
- Mining the Apollo (near Earth) asteroids for metals is a possible economical driver for life in space.
- But all of this requires moving machines, humans, or material around the solar system.
- Today, if there were piles of gold laying on the Moon, it would not be cost effective to go get it.



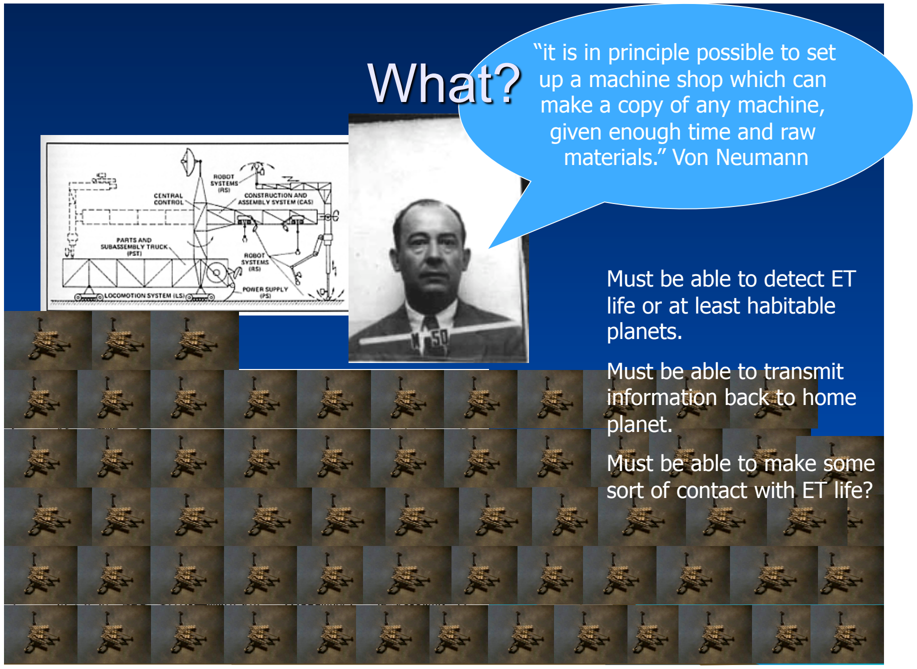
http://apollo-society.org/images/near_arrow_sm.jpg

# Asteroid Living and…

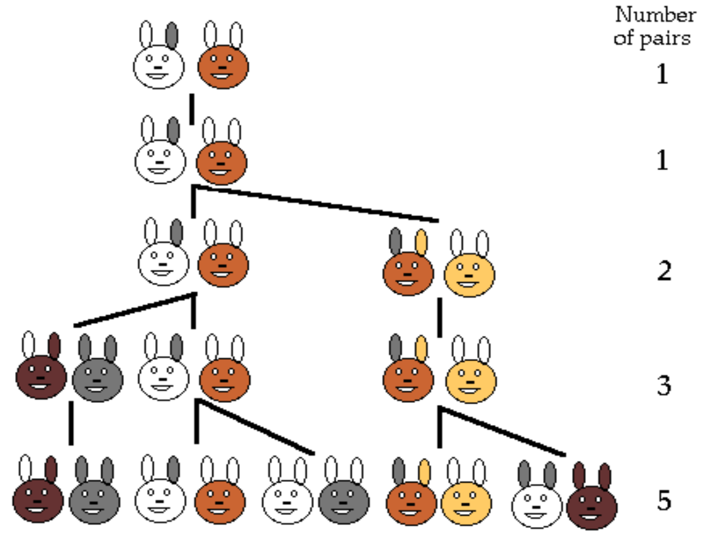
- But, remember to date human space travel has cost 10 times as much as remote "robot" travel.
- Probably devise ways to mine remotely.
- Efficient mining requires more and more intelligent robots.
- What if they get too smart?
- Still self-replicating space probes could be result of such advances.



http://apollo-society.org/images/near_arrow_sm.jpg




# Propagation Run Away



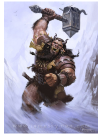

# Space Probed

- A single probe is constructed and dispatched to a nearby star system
- It surveys the system in an intelligent and exhaustive manner
- After which, the probe uses the energy and available raw materials of the system to reproduce itself .

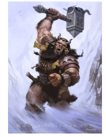
# Neumann Space Probed

- Dispatches its "children" onwards to repeat its mission in other star systems
- The parent probe is then able to choose whether it wants to stay in the system or not, depending on what it found
- Still need a way to get to other worlds.

http://www.biochem.wisc.edu/wickens/meetings.html



# BERSERKERS!!!!!!



- Self-Replicating Devices
- Openly hostile to life forms
- Out of control
- Probe ecosystem?
- Programmed to evolve?

# Energy into Propulsion

- For any type of space travel, we need an energy source to propel the vehicle.
- The basic idea is to convert some stored energy into *energy of motion* for the spacecraft
- Two ways basically:
  1. Process some sort of fuel
     - Carried onboard
     - Collected from space and processed
  2. Other, non-fuel-like energy source:
     - Solar (if near a star)
     - Gravity (using an astronomical body's gravity field to propel a ship)

# *We got a speed limit!*

- No matter what we do, we can not go faster than the speed of light!
- That naturally occurs when one demands that the speed of light *must* be the same regardless of who measures it.
- This is completely counter-intuitive!


http://www.rpi.edu/dept/phys/Dept2/APPhys1/optics/optics/node4.html

- Basis of Einstein's Theory of Special Relativity.

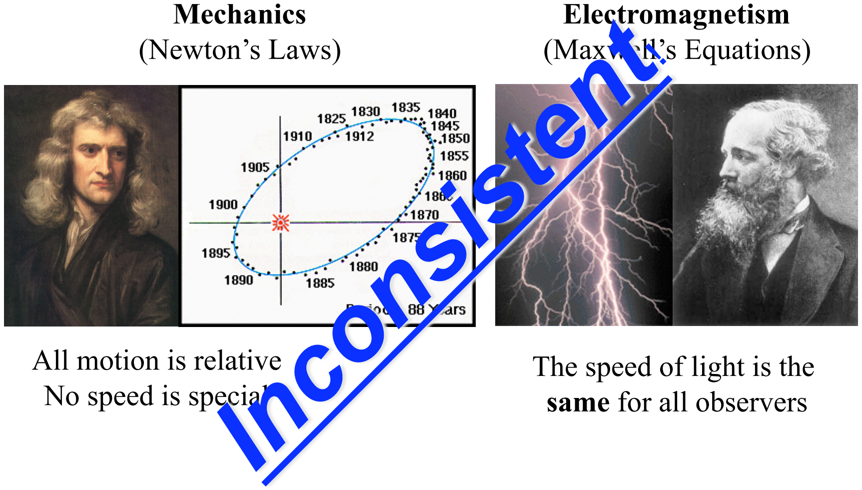
# *How Fast is Light?*


- The speed of light is $c = 3\times10^8$ m/s (186,000 miles per second)!
- How fast is that?
  - Around the Earth over 7 times in a second
  - From Earth to the Moon in under 2 seconds (it took the Apollo astronauts 3 days)
  - From the Sun to the Earth in a little over 8 minutes
  - From the Sun to Pluto in about 5½ hours
  - From the nearest star to Earth, about 4 years

## Two Threads of Thought in Physics up to 1900

**Mechanics**
(Newton's Laws)

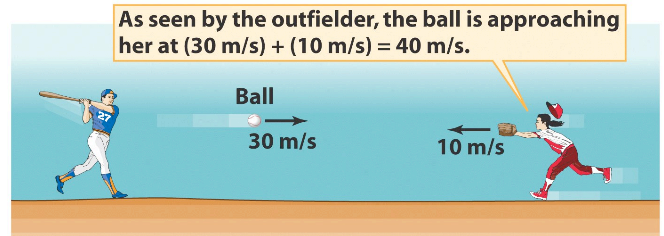
**Electromagnetism**
(Maxwell's Equations)




All motion is relative
No speed is special

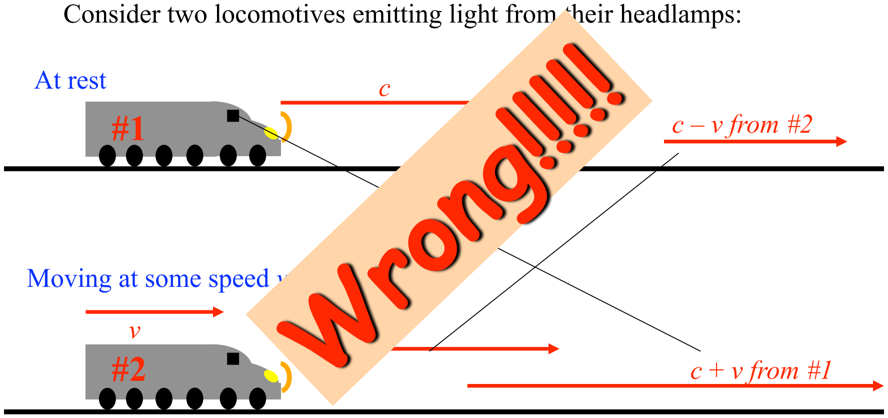
The speed of light is the **same** for all observers

## Why Newton and Maxwell Can't Both Be Right

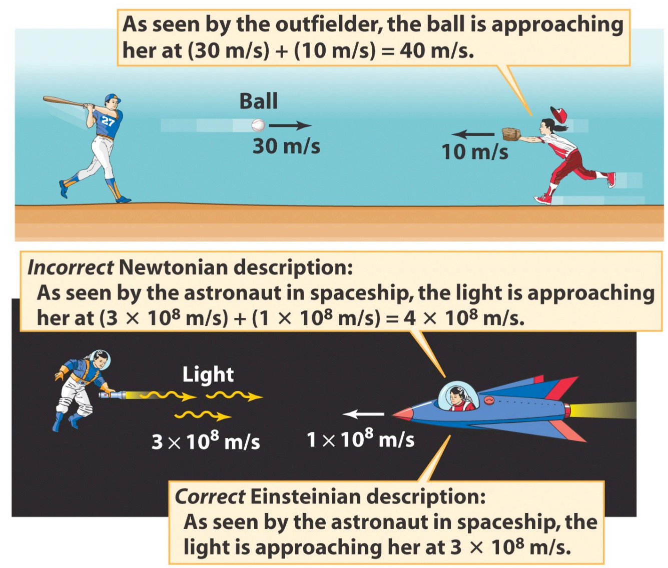



## Why Newton and Maxwell Can't Both Be Right

Consider two locomotives emitting light from their headlamps:




## Why Newton and Maxwell Can't Both Be Right



## Why Newton and Maxwell Can't Both Be Right

So the speed of light can't be the same for everyone if Newton – and our intuition – are right. But Maxwell says it is constant!

Something must happen. And what must happen for Newton and Maxwell to be both right, is that there is a modification of time and distance. Remember

$$speed = \frac{dist}{time}$$

Distance and time become relative to the observer.

## *Approaching the "c"*

- Time dilation – Moving clocks run slow.
- Length contraction – Moving objects contract along direction of motion.
- Mass increase – moving clocks get more massive

http://www.richard-seaman.com/Travel/Japan/Hiroshima/AtomicBombMuseum/IndividualArtifacts/

## *Question*

You are at the back of a jet traveling at 400 mph. You shine a laser toward your friend in first class. What speed does your friend measure for the laser light?

a) c+400 mph
b) c-400 mph
c) c
d) c/400 mph
e) $c/(c^2-400^2)$ mph

Where c is the speed of light.