Astronomy 330

This class (Lecture 23):
Lifetime

Next Class:
Communication

HW9 due Wednesday.

Music: *We Got the Neutron Bomb*– The Weirdos

Outline

- Lifetime of alien civilizations.
  - Could be a whole class (oh it is..)
  - Quick discussion
- What is L?

Drake Equation

Frank Drake

That's 4.2 Communicating life/century

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

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	0.52 comm./intel.	yrs/comm.

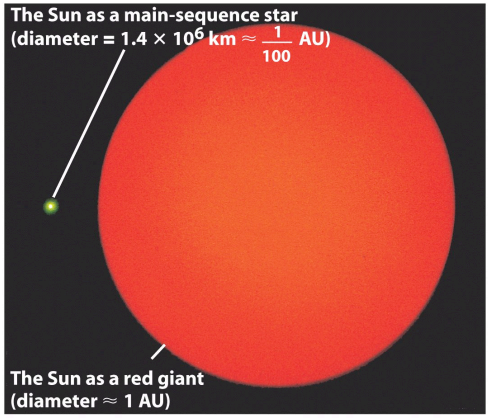
How much Gas do we have left?

- Even if we could save the Earth during this time of increased brightness, eventually the Sun runs out of fuel.
- Total energy available is easily calculated by mass of hydrogen in Sun and energy released by each hydrogen conversion.
- We only have about 6 billion years left!

http://skeptically.org/sitebuildercontent/sitebuilderpictures/.pond/suv-econ-gas-pump.jpg.w300h294.jpg

In 6-7 Billion years

- The Sun will expand to 100-250 times bigger than it is now!
- The same mass but now it's bigger.



The Sun today and as a red giant

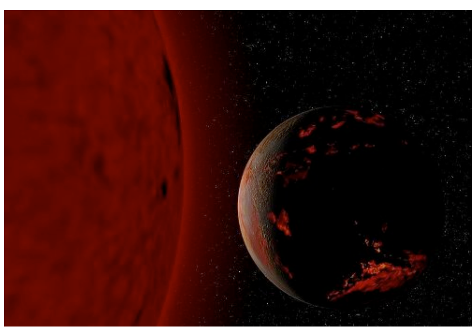
In 6-7 Billion years

- The surface gravity decreases and the Sun has more luminosity.
- The solar wind turns into a stellar wind, and it looses material as it expands, about 10^7 times more than now.
- It's blowing it all away!

http://www.astropix.com/wp/wp-content/uploads/2006/12/2006_02.JPG

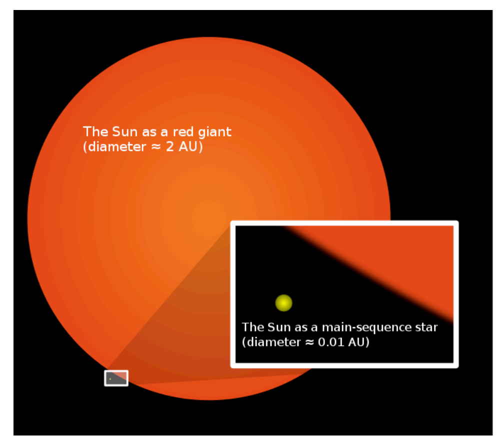
In 6-7 Billion years

- During the time it expands it loses a significant fraction of mass.
- So, the planets move outward.
- Planets race away as the Sun expands.
- Who wins?
- We aren't yet sure.



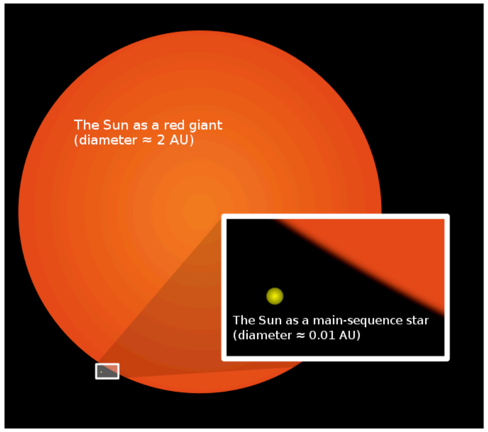
In 6-7 Billion years

- We use to think that the Sun would gobble the Earth.
  - Mercury gone
  - Venus probably gone
  - Earth?
- BUT even if not, with the Earth's oceans and atmosphere gone, crust still melts.
- Not good…



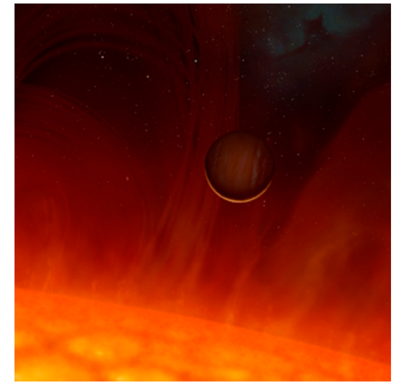
In 6-7 Billion years

- Mars?
  - For sure too hot.
- Jupiter's Moons?
  - Still too hot
  - Europa's water vaporizes
- Even the moons of Uranus and Neptune may be too hot.



Mitigation

- We would have to move the Earth out to Pluto or further!
- Probably not possible.
  - Interactions with Jupiter may eject us from Solar System
- Even then, Sun no longer in equilibrium, may oscillate in size or brightness.
- BUT, we got billions of years to figure it out!



http://www.sciam.com/media/inline/FA992809-E7F2-99DF-30B7058698177187_1.jpg

Natural Catastrophes

3. Stellar Evolution
   - Advanced civilization can likely find solutions.
   - Eventually, we would have to leave the Earth, move the Earth, or move to Mars.

http://www.boulder.swri.edu/~terrell/dtart_old.htm

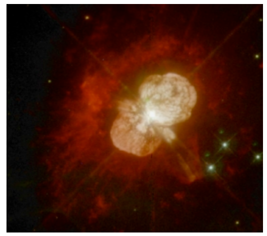
Question

In 6 billion years, our Sun will begin to turn into a red giant, on its way to a white dwarf. But never fear

a) An advanced civilization can stop the Sun from evolving.
b) We can always move to Venus.
c) An asteroid will probably hit and destroy the Sun first.
d) The Moon will be fine.
e) The Earth's oceans will evaporate long before then.

4. Natural Catastrophes

4. Killer Supernovae!
   - Death of a nearby massive star would be bad news.
   - Explosion within 30 ly would destroy ozone layer.
   - Right now, no candidates.
   - Unlikely to happen in time scales of less than 2 billion years.
   - A supernova event ~2 Myrs ago may account for an extinction event.



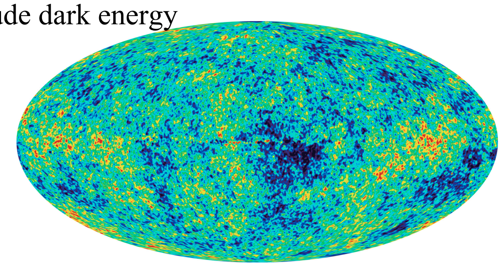
Question

A nearby killer supernova

a) is very scary, as we won't know about it.
b) would have to be very close, but it could destroy the ozone layer .
c) is any supernova in our Galaxy.
d) would not cause any real damage, no matter how close it was.
e) will evaporate the oceans.

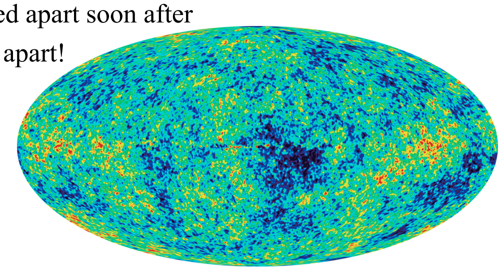
4. Natural Catastrophes

5. Ultimate limit to L!
   - Fate of the Universe.
   - A Big Crunch: 10^{12} years (a trillion years)
   - But, WMAP results from the cosmic microwave background suggest that we are in a flat universe.
   - Which does include dark energy



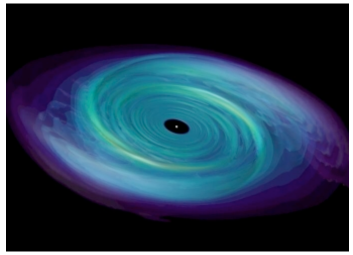
4. Natural Catastrophes

5. Ultimate limit to L!
   - The Big Rip?
     - If repulsive force increases– Brooklyn may expand too.
     - Gravity/E&M forces can not hold Galaxies rip apart
     - Could rip the MilkyWay apart in ~1 billion years
     - Earth gets ripped apart soon after
     - You get ripped apart!



4. Natural Catastrophes

5. Ultimate limit to L!
    - Big Rip seems unlikely
    - We'll know soon.
    - If we are just in a flat Universe, then it is a matter of energy.

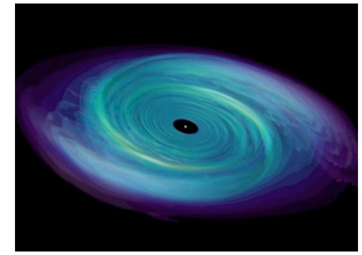


http://www.youtubeom/watch?v=oGVYG0ce1Ps

http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

4. Natural Catastrophes

5. Ultimate limit to L!
    - The end of the Universe… the death of the dark.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

Stelliferous Age: 10^8 to 10^{15} years

- Last stars to form will happen in a few hundred billion years.
- In about trillion years all Sun-like stars are gone from the Universe forever.
- Only stars left are low-mass red dwarfs (~0.1 solar masses), which can live for trillions of years

Stelliferous Age: 10^8 to 10^{15} years

- In 7-8 trillion years, in our Galaxy (Milkomeda), the last red dwarf stops fusing, becoming a white dwarf.
- These tiny white dwarfs will stay hot for quite some time.
- Wait another few trillion years and they fade.
- So when the Universe is 100 trillion years old, the Universe goes dark.

Really Dark

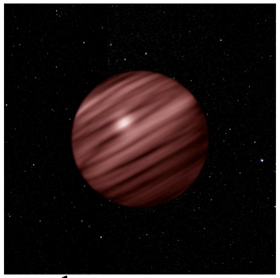
- If the Universe keeps expanding, it get worse for astronomers.
- The Galaxies we can see now, far away galaxies move out of our view.. Too far to see given the age of the Universe… out of our horizon.
  - The observable Universe is less and less
- The one giant elliptical galaxy (all that is left from our local group) is all that can be seen.
- The Universe appears empty!

Humans?

- We have 100 trillion years!
- Maybe longer, by smashing stars together to make fusion last longer.
- When the Universe is slightly older than 100 trillion years old, the human race is out of fuel, out of stars, and out of luck.
- But the Universe isn't done!

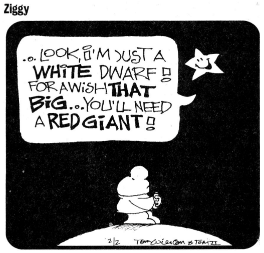
The Degenerate Era: 10^{15} to 10^{40} years

- Stellar corpses are all around the Galaxy.
- Every once in a while, a black hole will accrete a compact object, creating light again.
- Corpses may collide (remember we are talking 100 trillion years of time not the measly 13.7 billion of the Universe so far), and create new stars.
- Brown dwarfs, which did not have enough mass to fuse, can collide, making new stars.
- New life? Different Universe..



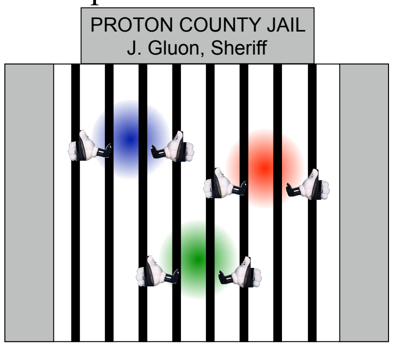
The Degenerate Era: 10^{15} to 10^{40} years

- But after a trillions, then quadrillions, and then quintillions of years, everything that can ever burn has happened.
- The Galaxy starts to lose weight.
  - Interactions with the stellar corpses, cause all the low-mass objects to be ejected from Galaxy.
  - High-mass objects fall to the center.
  - Supermassive Black Hole feeds!
- If the Earth still orbited the dead Sun (white dwarf) it is likely kicked out of the Sun and the Galaxy– a frozen dead planet in intergalactic space.



Proton Decay

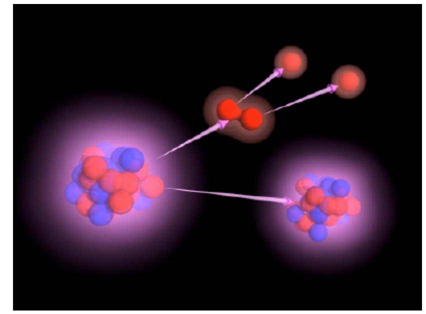
- Remember when quarks were imprisoned?
- We think that protons are radioactive.
- Except that they decay with a half-life of about 10^{37} years.
- Time is all that is left.



10^{31} years to life
Little chance of parole

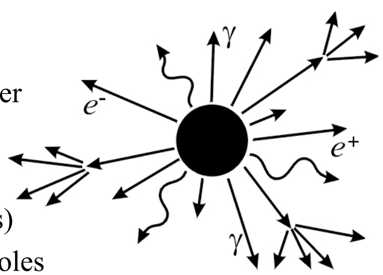
Proton Decay

- This proton decay creates heat again, feeble heat.
- What does non-proton life do?
- White dwarfs will evaporate
  - At -454 F, they are the hottest thing around!



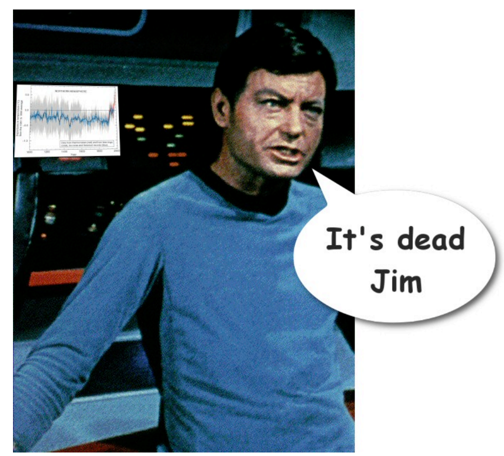
The Black Hole Era: 10^{40}-10^{92} years

- Black Holes survive.
  - Not made from matter, remember
- Galaxy is
  - The Supermassive Black Hole (1-10% of original Galaxy mass)
  - Trillions of stellar mass black holes
  - Lower mass stuff that was thrown out, so very far away.
- Hawking radiation is slow, but it will begin to evaporate the black holes
  - Slow, but lots and lots of time



The Dark Era: 10^{92}- Infinity

- 10^{92} is crazy!
- I mean really, really crazy!
- The weight of a single proton to the rest of the Universe is only 10^{79}!
- Still, at this point, the Universe is dead!
- Dead Jim!



The Dark Era: 10^{92}- Infinity

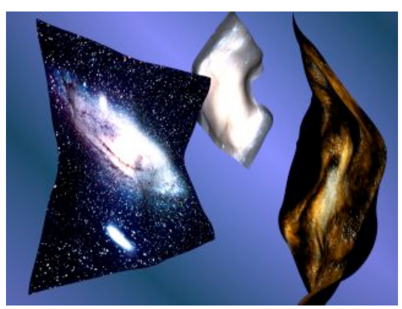
- Beyond this, two particles will once in a great while interact, but nothing will really happen.
- Universe is dead, randomized, and silent.
- Nothing really will ever happen again..
- Or will it?

The Dark Era: 10^{92}- Infinity

- Rebirth?
- We don’t know what caused the Big Bang.
- Maybe it happens again?
- Maybe it already has?

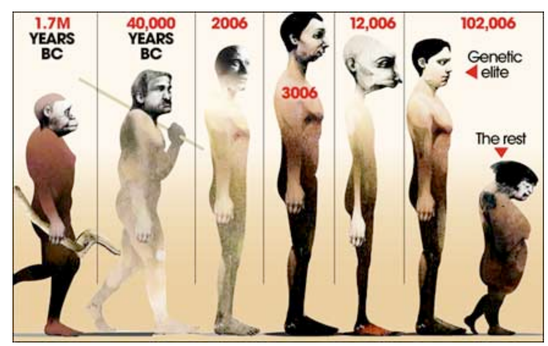
Branes, Branes!

- One idea is that the Universe has 11 dimensions
  - Our 4 dimensional Universe floats around in this space
  - Other universes float there too (called branes, short for membranes)
  - Sometimes they collide
  - Violently disturbed, energy/matter heat up, expanding space
  - Sounds familiar..



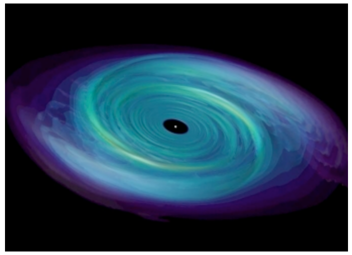
Mitigation

- Are you kidding me?
- If humans live this long, they won’t be anything we’d recognize as human.



4. Natural Catastrophes

5. Ultimate limit to L!
   - Bottom line is that the maximum age is speculative.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

Top 10 Ways Astronomy Can Kill Humans

1. Impacts
2. Sun Evolution/Coronal Mass Ejections
3. Supernovae
4. Gamma-Ray Bursts
5. Rogue Black holes
6. Rogue White Dwarfs
7. Galaxy Collisions
8. Cosmology
9. Quasars
10. Aliens

L-ing it

- We are talking about the amount of time that an advanced civilization (averaged over time) can communicate.
  – They may not want to for long periods of time
  – They may give up
  – They may be killed off
  – They may run out of resources
- Solving our energy problem (cheap energy) will give the largest lifetimes.

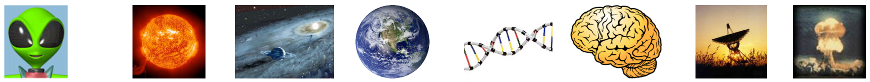
What is L?

- How long on **average** can an advanced civilization exist?
- Again, we only have a sample of 1 from which to discuss. What is our civilization's lifetime?
  – Short Term (100-1000 yrs)
    - Give up on communication due to budgets.
    - Depletion of resources.
    - Population.
    - War.
  – Long Term (10^5 to 5×10^9 yrs– age of galaxy is 10^{10} 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

That's 4.2/100 x ? advanced civs!!!


Frank Drake



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

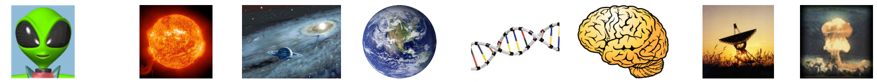
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	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.	? yrs/ comm.

Drake Equation For Optimist

$= 2.5 \times 10^{11}$

Communicating Civilizations

62.5% of all stars in our Galaxy.



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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	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
	50	**1**	**1**	**1**	**1**	**1**	**5 x 10^9**

Birthrate of 50/year!

Drake Equation For Pessimist

$= 7.5 \times 10^{-6}$

Communicating Civilizations

Must wait 10^7 years for one!

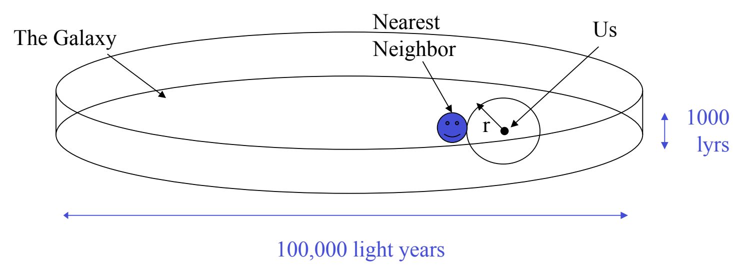
$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	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
	5	**0.1**	**0.15**	**0.01**	**0.01**	**0.01**	**100**

Birthrate of 7.5 x 10^{-8} / year!

Distance to Nearest Neighbor

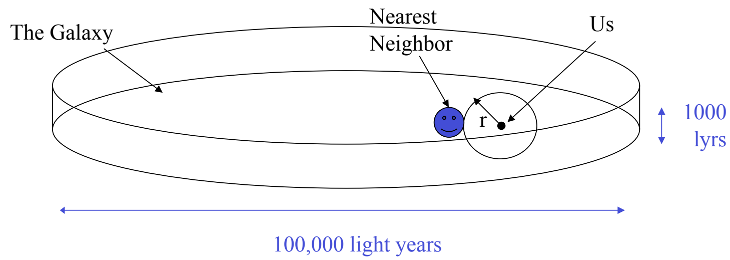
- Assume that the alien civilizations are uniformly scattered in our galaxy and N > 8000.
- We can then assume spherical volume to find ET, i.e. flatness of Galaxy not an issue.



Distance to Nearest Neighbor

- Assume N > 8000

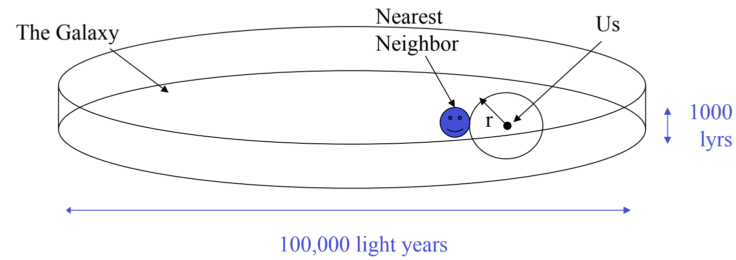
$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \text{alien volume } (\text{lyr}^3 / civ)$$



Distance to Nearest Neighbor

- Assume N > 8000

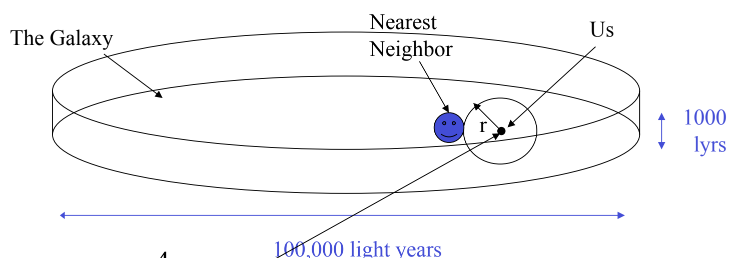
$$alien\ \text{volume} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{\text{N}}$$



Distance to Nearest Neighbor

- Assume N > 8000

$$alien\ \text{volume} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{\text{N}}$$

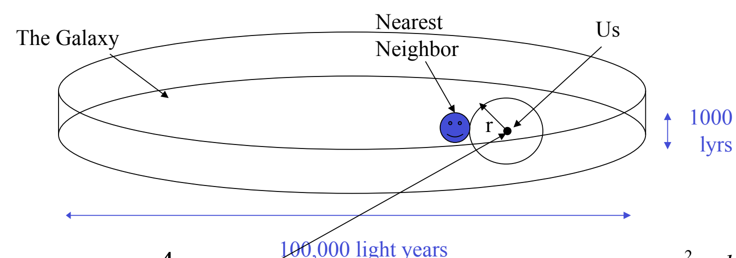


$$search\ volume = \frac{4}{3}\pi\, r^3$$

Distance to Nearest Neighbor

- Assume N > 8000

$$\frac{4}{3}\pi r^3 = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{N}$$



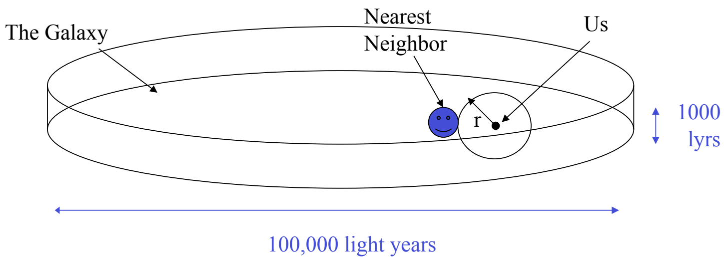
$$search\ volume = \frac{4}{3}\pi\, r^3$$

$$\text{alien volume} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N}$$

Distance to Nearest Neighbor

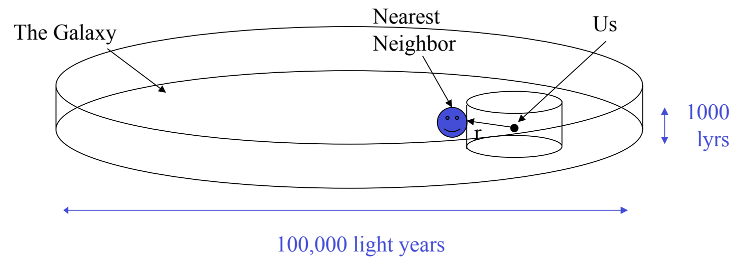
- Assume N > 8000

Then $r \approx \dfrac{12000\ ly}{N^{\frac{1}{3}}}$



Distance to Nearest Neighbor

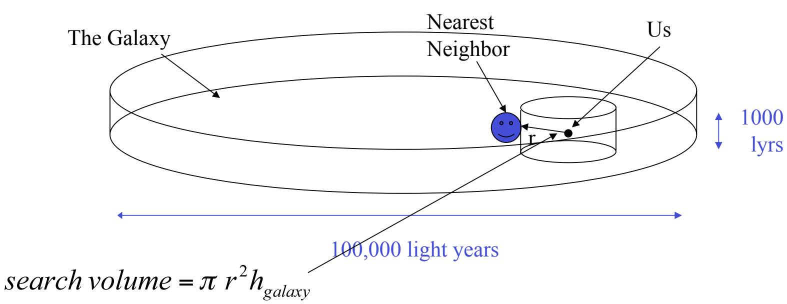
- Assume that the alien civilizations are uniformly scattered in our galaxy and N < 8000.
- Then, the flatness of Galaxy is an issue.



Distance to Nearest Neighbor

- Assume N < 8000

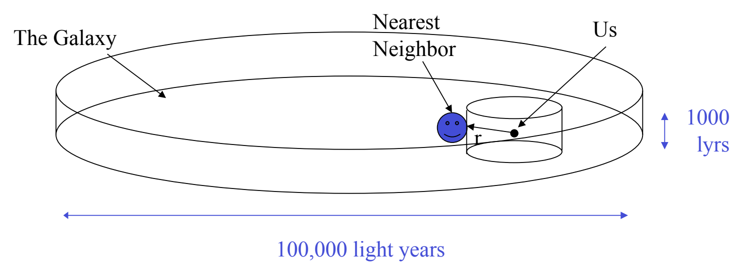
$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \text{alien volume}$$



Distance to Nearest Neighbor

- Assume N < 8000

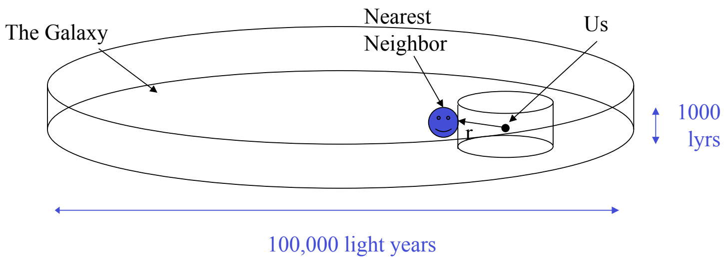
$$\pi r^2 h_{galaxy} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{N}$$



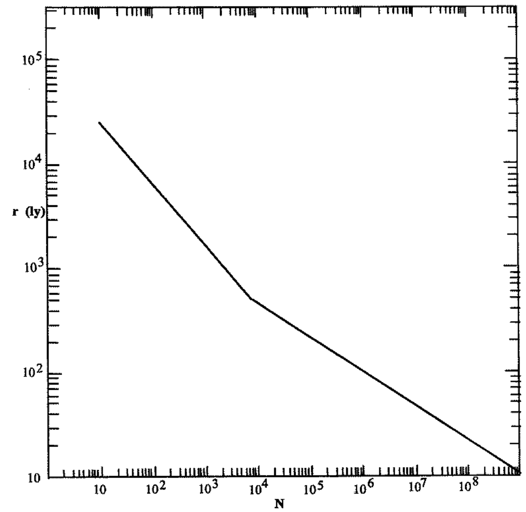
Distance to Nearest Neighbor

- Assume N < 8000

Then $r \approx \frac{50000\,ly}{N^{\frac{1}{2}}}$



The Neighbors



Interesting Points

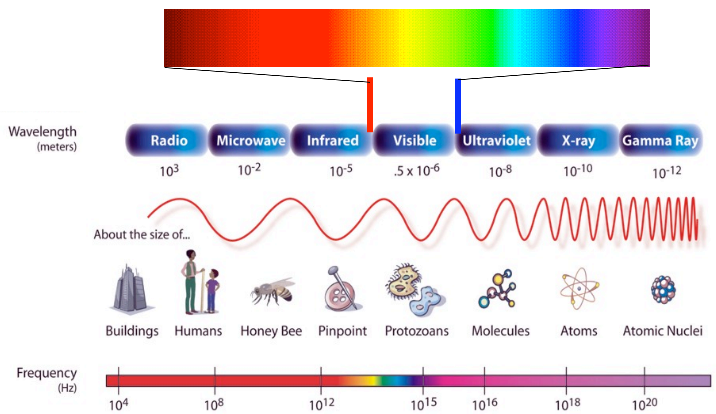
1. We assumed uniform density of civilizations.
   - Underweights the galactic center, but maybe that's okay– supernovae.
2. Distance away is the <u>average</u>.
   - Could be closer, but unlikely to be much closer.
3. Note that r is better defined than N.
   - R depends on $N^{1/2}$ or $N^{1/3}$.
   - If we are wrong in N by a factor of 100, then only off in r by factors of 10 or 4, respectively.
4. For communication, it may be that the distance there and back is longer than L.

How to Communicate?

- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive "lurker" civilization.
- Okay, so what will an advanced civilization use?
- Hard to figure out.. They are aliens!

Light me up

- Visible light is only a tiny portion of the full electromagnetic spectrum
- Red light has longer wavelength and lower frequency than blue light.
- Divisions between regions are from biology or technologies.



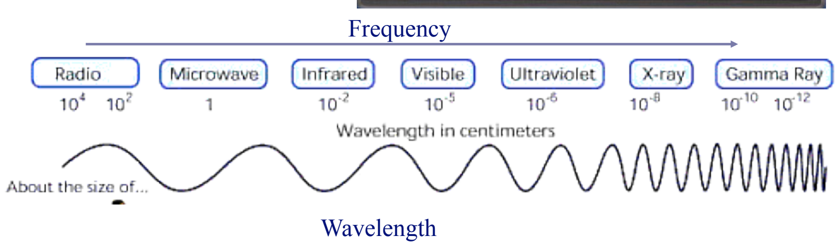
Question

I want to communicate with aliens at a distance of 100 light years. What is the fastest way to do that?

a) X-rays
b) Radio
c) Visible light
d) Gamma-rays
e) All of the above are light, so travel the same speed.

Frequency

- The frequency of light depends on its color.
- The unit is Hertz, equivalent to 1 cycle a second.
- For radio waves, we normally use larger units
  - 1 kHz = 1000 Hz
  - 1 MHz = 10^6 Hz
  - 1 GHz = 10^9 Hz



Question

Which of the following is the highest frequency?

a) 100 Hz
b) 100 kHz.
c) 100 MHz
d) 100 GHz

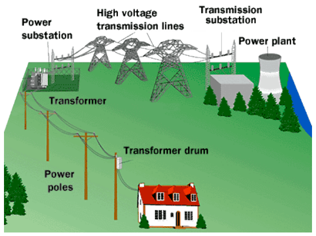
Question

Which of the following has the longest wavelength?

a) 100 Hz
b) 100 kHz.
c) 100 MHz
d) 100 GHz

What's the Frequency Kenneth?

- We can't broadcast over the whole range– too much power = expensive.
- So what kind of reasoning can we use to limit our search or any broadcasts?
- Keep in mind that ET must make the same decisions.
- May be very alien decisions.



http://http://science.howstuffworks.com/power.htm

What's the Frequency Kenneth?

- Want biggest bang for the buck.
- Interstellar dust is in the Galactic plane
- Attenuates light that is shorter than infrared wavelengths– a few microns.
- Or need very high frequency.
- Energy required for the photon increases with frequency.
- Argues for low frequency or long wavelength operation– radio.

http://www.beautydish.com/

Freq Show

- Keep in mind that radio stations fade as you get further away.
- In fact, light decreases in amplitude as the square of the distance traveled.
- And like your radio, there can be noise from competing stations or noise from the radio receivers.
- The Galaxy emits lots of emission at low frequencies.

http://www.micka.cz/f8.jpg

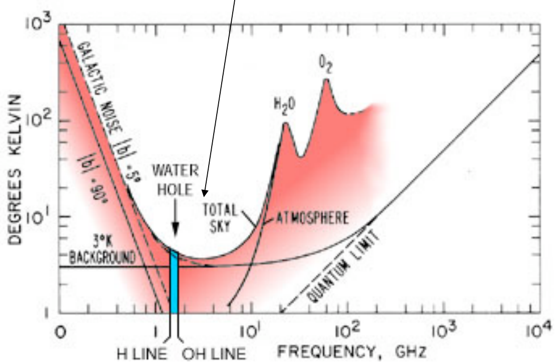
Freq-ing Out.

The best place to listen–in the “quiet” part of the spectrum

1. The galaxy emits lots of emission at low frequencies.
2. The Big Bang background noise–CMB.
3. Noise of receivers. The perfect receiver has a quantum limit of one photon noise.
4. The Earth’s atmosphere blocks many frequencies.

Wavelengths of 3 to 30 cm!

Frequencies of 1 to 10 GHz!



http://setiathome.ssl.berkeley.edu/about_seti/radio_search_2.html