Life in the Universe

- This is a long lecture but mostly not “astronomy” and more “fun” topics. Only the astronomy, which planets and stars are best suited for life, will be on exams.
- 1 example of Life - Carbon-water based (on Earth)
- 1 example of “intelligence” → able to communicate with other “intelligent” life for about 80 years (us humans)
- Intelligence = able to use Radio to send/receive messages across space
- chemical building blocks (amino acids, water) plentiful in interstellar space
- Somehow about 1 billion years after Earth formed, bacteria appeared. All other life are probably descendants

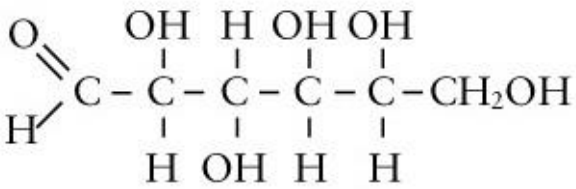
Life – Carbon+Water based?

"Ammonia! Ammonia!"

@R. Grossman 1962 New Yorker

Carbon vs Silicon? NO

Water vs other liquid or gas? Not sure but water seems to be the best medium



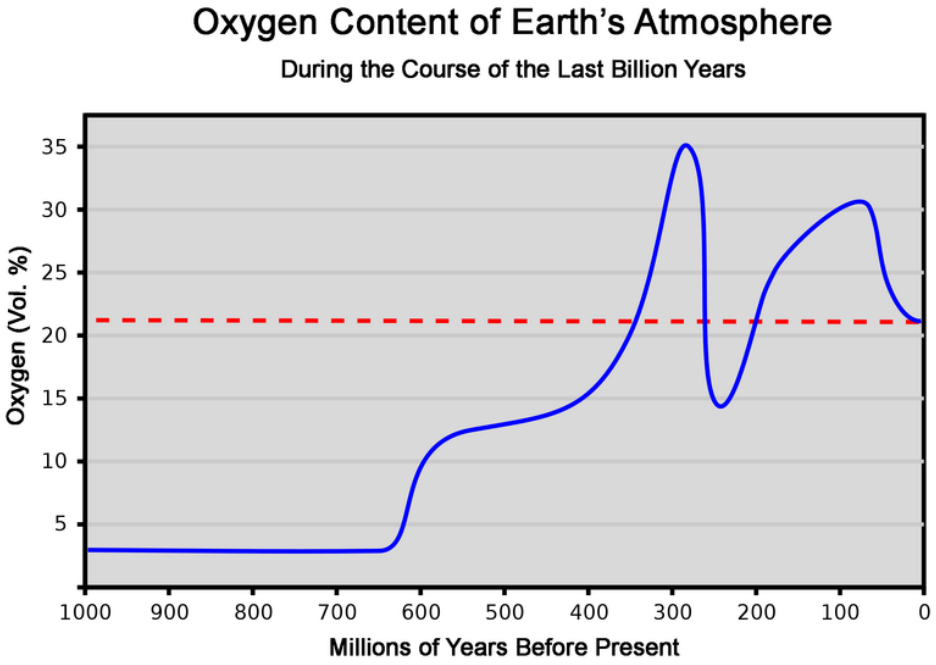
Glucose

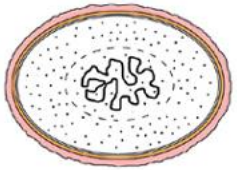
Carbon makes long chains but with H and OH not too tightly bound. Silicon makes rocks as tightly bound

Life on Earth

- 4.5 billion years ago Earth formed. About 1.5 billion years after that simple bacteria (prokaryote) appeared
- About 2 billion years after, complex life (eukaryote) appeared including algae which though photosynthesis started releasing oxygen
- atmosphere changed, probably keeping planet warm enough so end of periodic "iceball Earth"??

→ **Takes billions of years for complex life to develop. Lesson for PHYS 162 (don't need to know biology for this course)**





Prokaryotic Cell

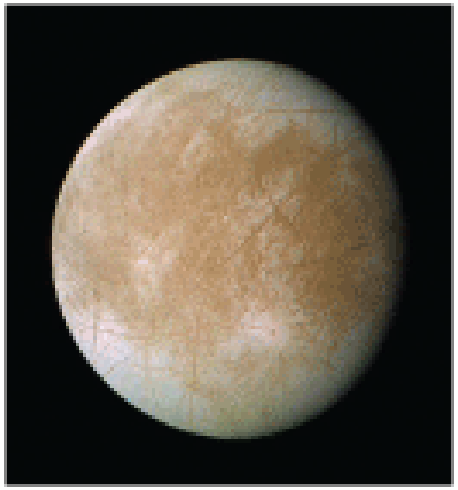
Animal (Eukaryotic) Cell

Other Life in Solar System?

- there is, or has been, liquid water on Mars and various moons of Jupiter (Europa, Ganymede, Callisto) and Saturn (Titan, Enceladus)→ look for signs of life.
- If ever find, is it of different origin then Earth's?
- more info about Mars then anywhere else: meteors from Mars and landings on the surface. No evidence yet

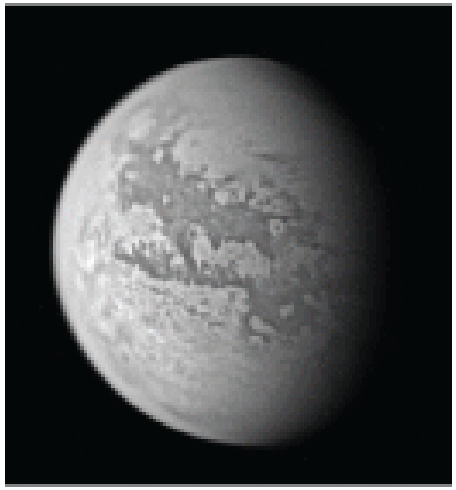
Best Bet: Moons of Jupiter and Saturn

● WATER ● ORGANICS ● NITROGEN ● ENERGY



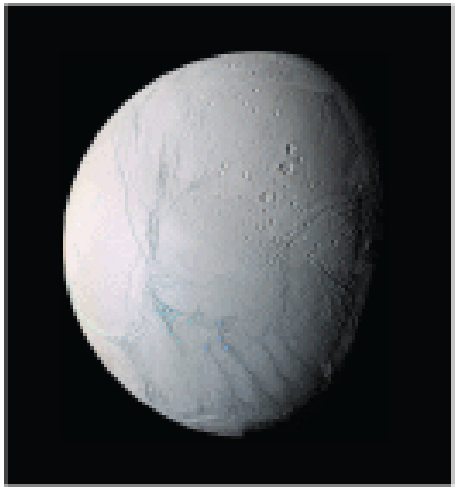
Europa ●

Water is abundant on Europa in the form of an ocean sloshing beneath the icy crust. Scientists don't yet know whether nitrogen or organics are present, but some think hydrothermal vents might erupt from the seafloor and power life.



Titan ● ● ●

The surface of Titan sits beneath a thick, nitrogen-containing atmosphere and is soaked in organic hydrocarbons, which could serve as an energy source. Whether a water ocean lurks deep underground is not yet known.



Enceladus ● ● ● ●

Water, organics and nitrogen pour into space from the satellite's geysers, which require an energy source for fuel. Still, scientists aren't sure whether liquid water has been around long enough for life to evolve on the tiny moon.

Life on Mars?

- landings on the surface have probably not shown any evidence (2019 article that is not yet published has title “Evidence of life on Mars?” which admits the evidence is pretty circumstantial and assumes it is Earth-based life which drifted to Mars).
- BUT 16 million years ago, an asteroid slammed into Mars, Mars rock thrown into space, drifted, and landed in Antarctica 13,000 years ago, analyzed starting in 1996
- tell from Mars by chemical and gas composition
- possible indications (tubelike objects, hydrocarbons) of bacteria fossils from 3.6 billion years ago
- no agreement among experts

Extra Terrestrial Intelligence

- is there intelligent life on other planets?

Drake equation (~1962, Frank Drake who later worked with Carl Sagan) estimates possibility in our galaxy. Carl Sagan and Joan Allen were speakers at 1995 NIU 100th anniversary event. DH was Sagan's escort for the day. DH suggested to Sagan to add the phrase "and possible infinite number of Universes" to Sagan's catchphrase of "billions and billions of stars in billions of galaxies". Sagan did at his NIU talk and those he gave before he died but did not give DH any credit.....DH also introduced Sagan to Joan Allen our NIU alumnus who has been nominated for an Academy award twice who sort of blew her off until he realized she was famous

- can we try to communicate?

SETI = Search for Extra Terrestrial Intelligence

For this course define intelligence as the ability to communicate by radio

Drake Equation $N = R * f_p n_e f_l f_i f_c L$

- N = number of "intelligent" civilizations in the Galaxy at any given time
- R* = rate at which solar type stars are formed
- f_p = fraction of stars which have planets
- n_e = number of planets suitable for life
- f_l = fraction of planets where life arises
- f_i = fraction of life that develops intelligence
- f_c = fraction of intelligent life that communicates by radio
- L = lifetime of communicating intelligence

First three (in red) are astronomy questions, rest (in green) biology, anthropology, sociology

Possible Stars + Planets

Stars can't be

- too large. Need lifetime more than 2 billion years and so stars like our Sun or smaller are stable main sequence stars for that amount of time or longer
- too small. habitable region is too close to star. See next slide on planets
- too old. Need heavy elements C,O,N which are formed in Red Giants or supernovas. The oldest stars are just Hydrogen and Helium
- in binary system. Planet's temperature varies as getting energy from 2 or 3 stars. Also can have complicated orbits for both the stars and the planets

Possible Stars + Planets

Planets can't be

too large or too small. want right atmosphere. Best guess is Earthlike

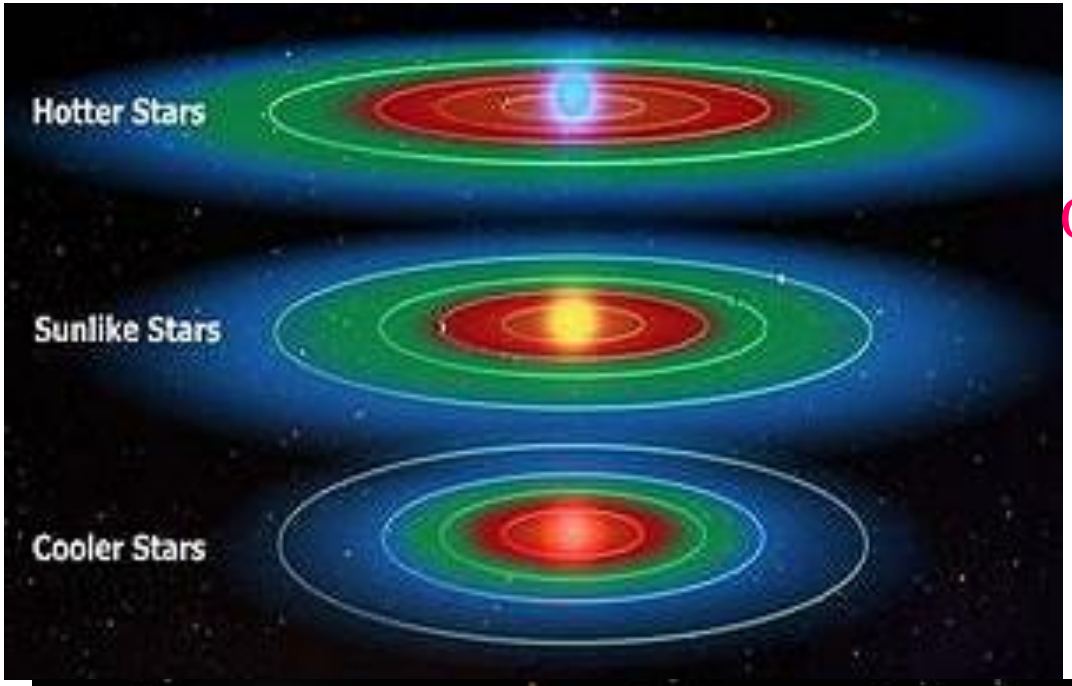
too hot or too cold. want temperature so liquid water

To close to their star: tidal forces tend to have one side of planet always facing its star. Solar flares from small stars are the same intensity as flares from our Sun. If planet is too close the flare would be destructive to any existing life

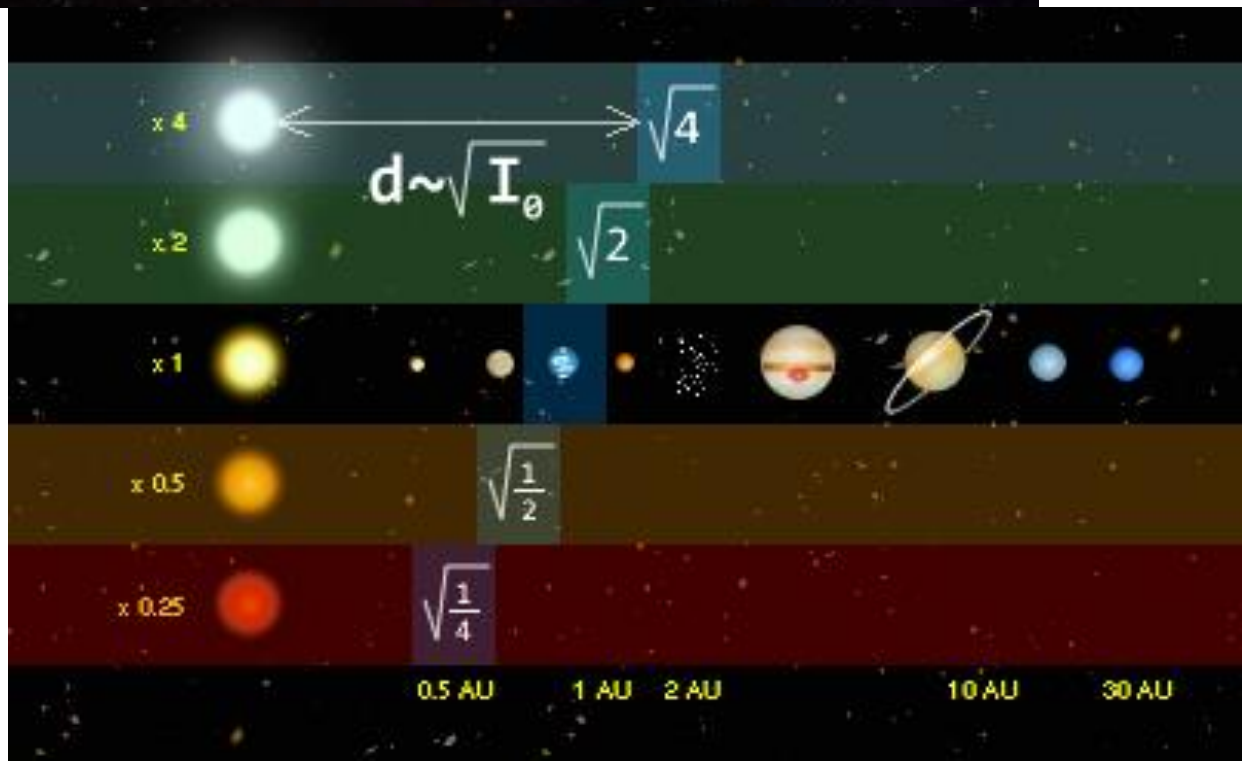
→ habitable zone about a star. Where water may be liquid if other conditions (size/atmosphere) are right

Habitable Zone:

further away if star more luminous, closer if less luminous



Green region

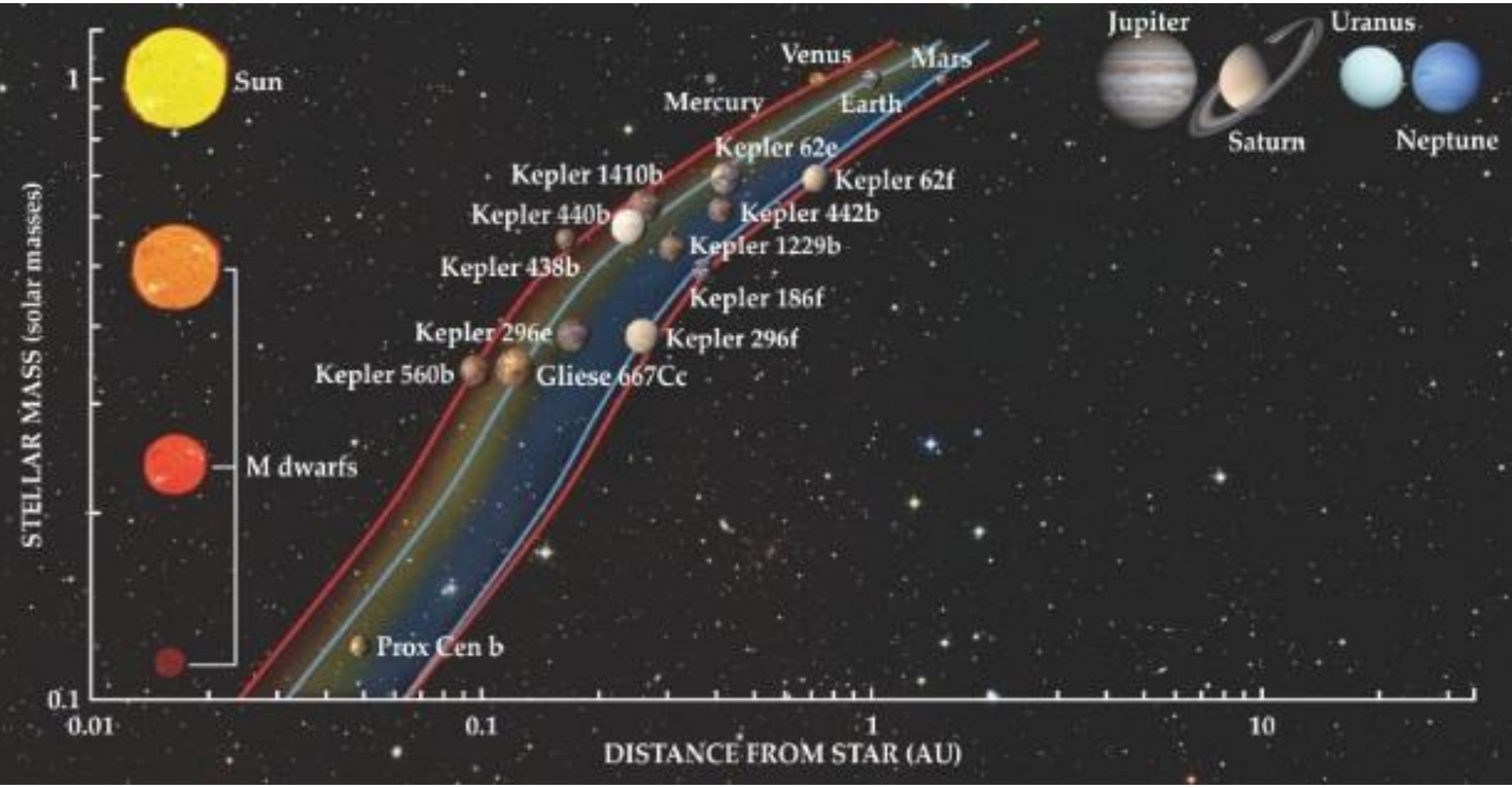


Hotter stars

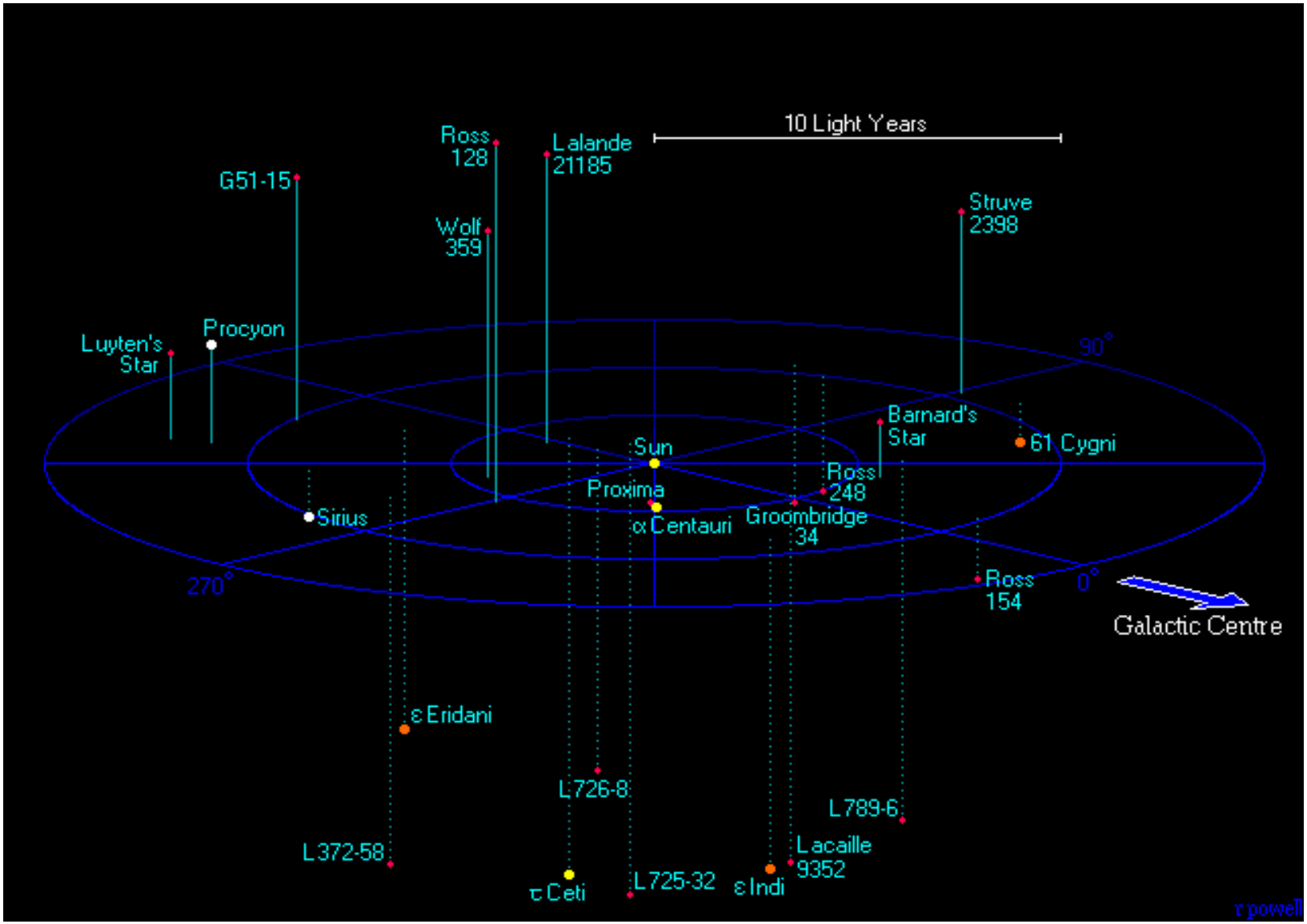
Our Solar System

Cooler stars

Habitable Zone – Some Exoplanets



Nearest Stars



Nearby Stars

- Most are smaller red stars with habitable zone very close to star

→ NOT good places for life to develop

gravitational pull → larger tidal forces → slow/stop planet spin

Stellar flares similar to Sun's → large radiation blasts on planet

- Stars similar to Sun (Procyon, Sirius, Alpha Centauri) are parts of binary systems or filled with debris (τ Ceti) or young (ε Eridani) or metal deficient (τ Ceti and ε Eridani)

→ NOT good places for life to develop

Binary systems: too much variation in energy received on planet and varying gravitational forces slow/stop planet's spin

→ No close-by star is probably a good place to visit ET. See link on course web page (plus preview of movie Battleship where aliens came from a nearby star….probably not)

Evolution of Intelligence+ Technology **not astronomy questions**

- Probability of evolution: simple to complicated to intelligent life?
- How probable is the development of technology?

  DH:NOT VERY Carl Sagan: VERY
- dolphins do not need technology
- How did humans evolve?

opposable thumb. Good for grasping, throwing (humans are the only animal capable of throwing an object, say a baseball, at 100 mph)

very good communication

physically slow and weak though with good endurance and so need to "do something" to survive → use tools

tools → technology (defined as "modern" tools such as radio) in some cultures but not in others. Why?

Length of Survival of "Intelligence"

- for human culture, anyone's guess. 100 to 100,000,000 years. Critical element in Drake equation and whether or not ET is still around should we receive a signal
- large asteroid: 1 of 5 previous mass extinctions on Earth. Gets all the headlines. Is the "astronomy" item
- Large volcano: 4 of 5 mass extinctions (Yellowstone next?). Some geologists believe the asteroid extinction was really due to another volcano extinction (Deccan in India).
- environmental catastrophes (global warming, ozone, insecticides)
- nuclear/biological war
- Plague including new viruses or bacteria

On assignment, your guess on what will destroy us

Length of Survival of "Intelligence"

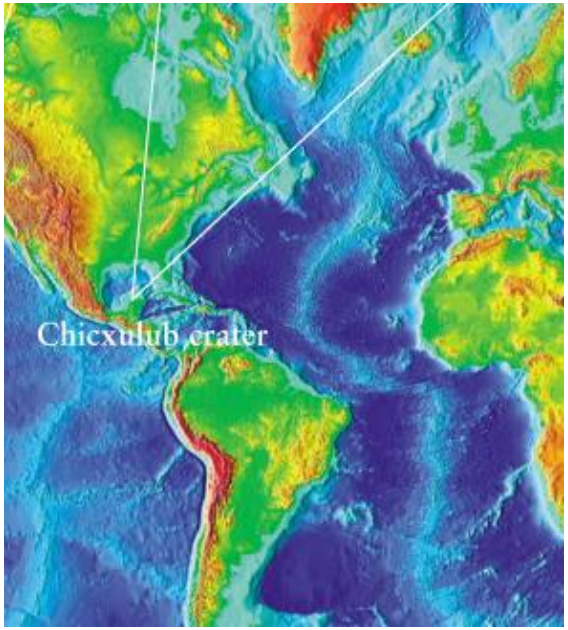
Most species are extinct

- In last 70 years we have almost destroyed ourselves
  - nuclear war (1962, 1982, still threat)
  - pesticides (similar to human hormones. reduce fertility, may still be problem, see link on web page)
  - destroy ozone layer (governments intervened)
  - climate change (governments unable/unwilling to intervene, still a problem)

  → Carter started clean technology
  → Reagan canceled Carter's programs
  → Bush/Obama increase use of renewables
  → Trump withdraws from Paris agreement, tries to increase coal use
  → ???civilization down the tubes based on a few hundred individuals making decisions (making money)?? (not based on good of all)

Asteroids, Comets and Meteors

Meteor crater in Arizona, from 50,000 years ago

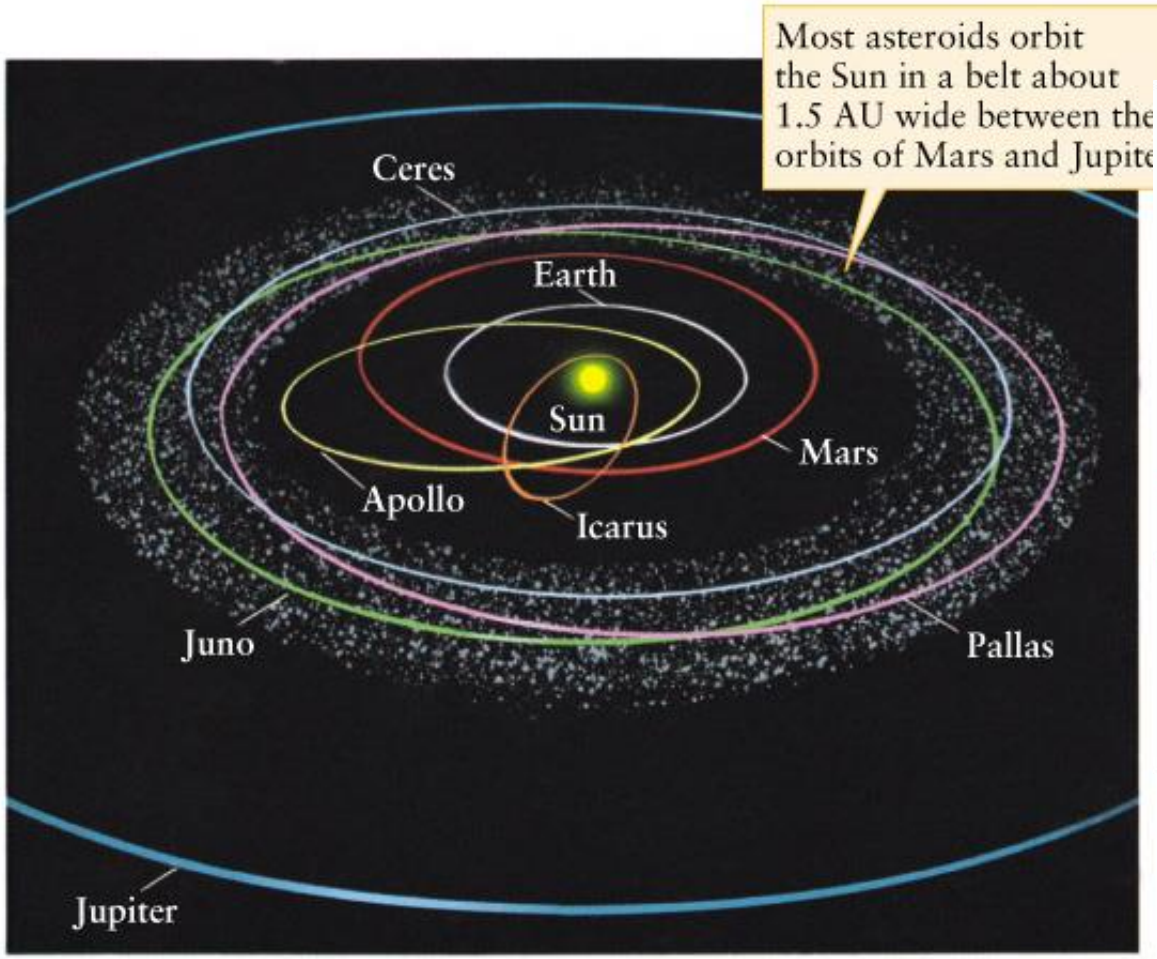


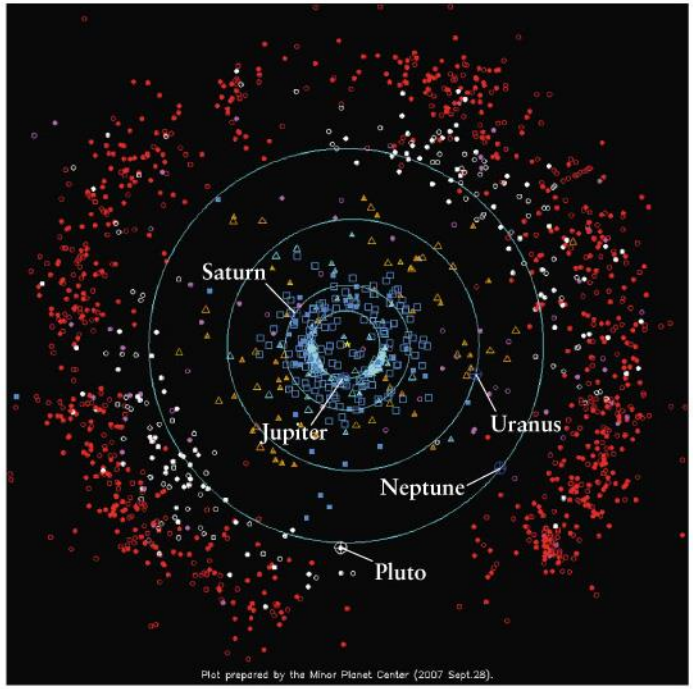
Meteor crater in Yucatan, from 65,000,000 years ago for extinction event, maybe end of dinosaurs

type	frequency	size	destructive force
Localized	1/200 yrs	100 m	300 kton
Regional	1/100,000 yrs	1 km	mag 12 earthquake
Global	1/20,000,000 yrs	10 km	extinction

19 mile wide crater under Antarctica ice from 800 m wide meteor which struck 1 million years ago discovered in 2018

Asteroids, Comets and Meteors

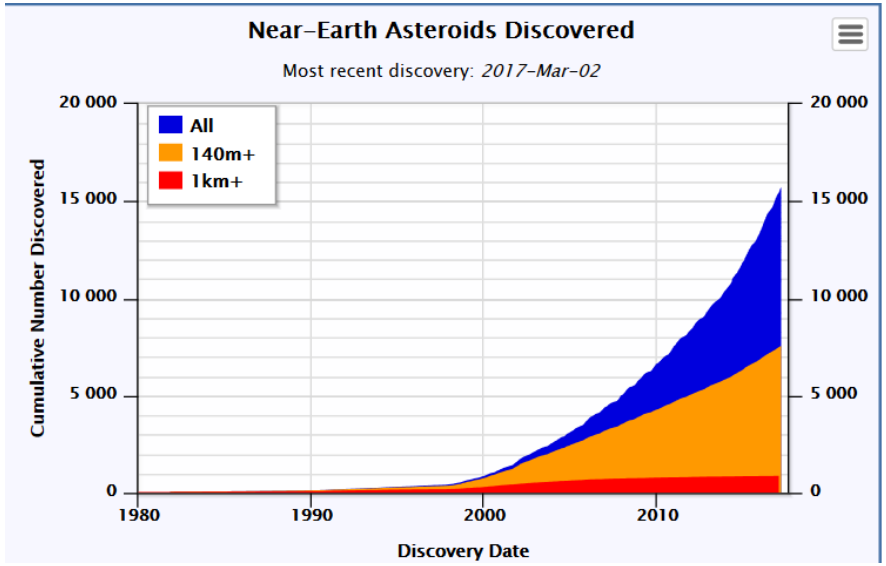


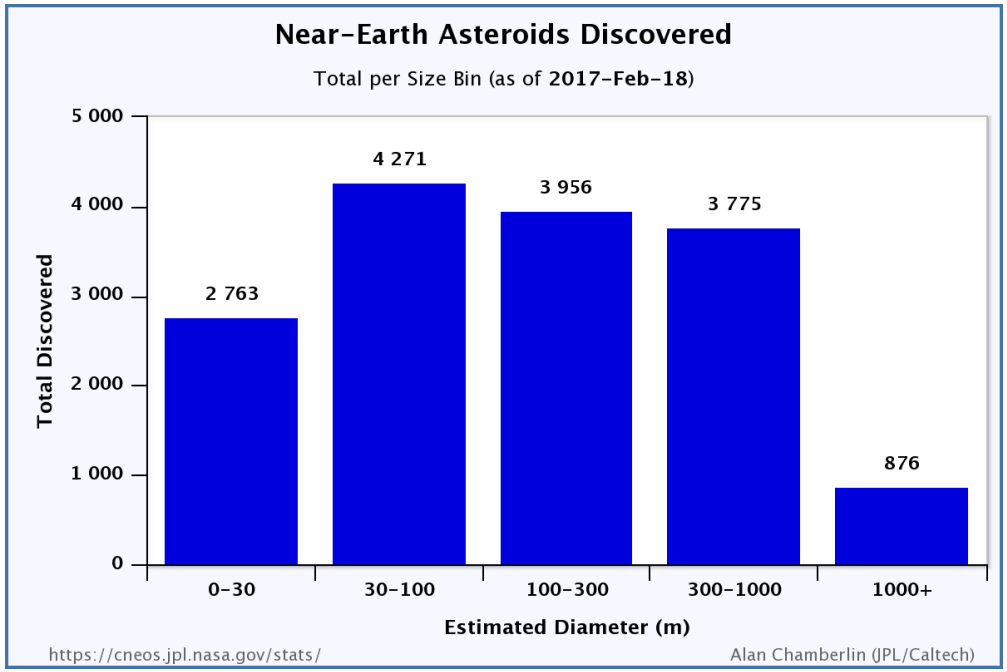


Some comets have very elliptical orbit and so can cross Earth's orbit

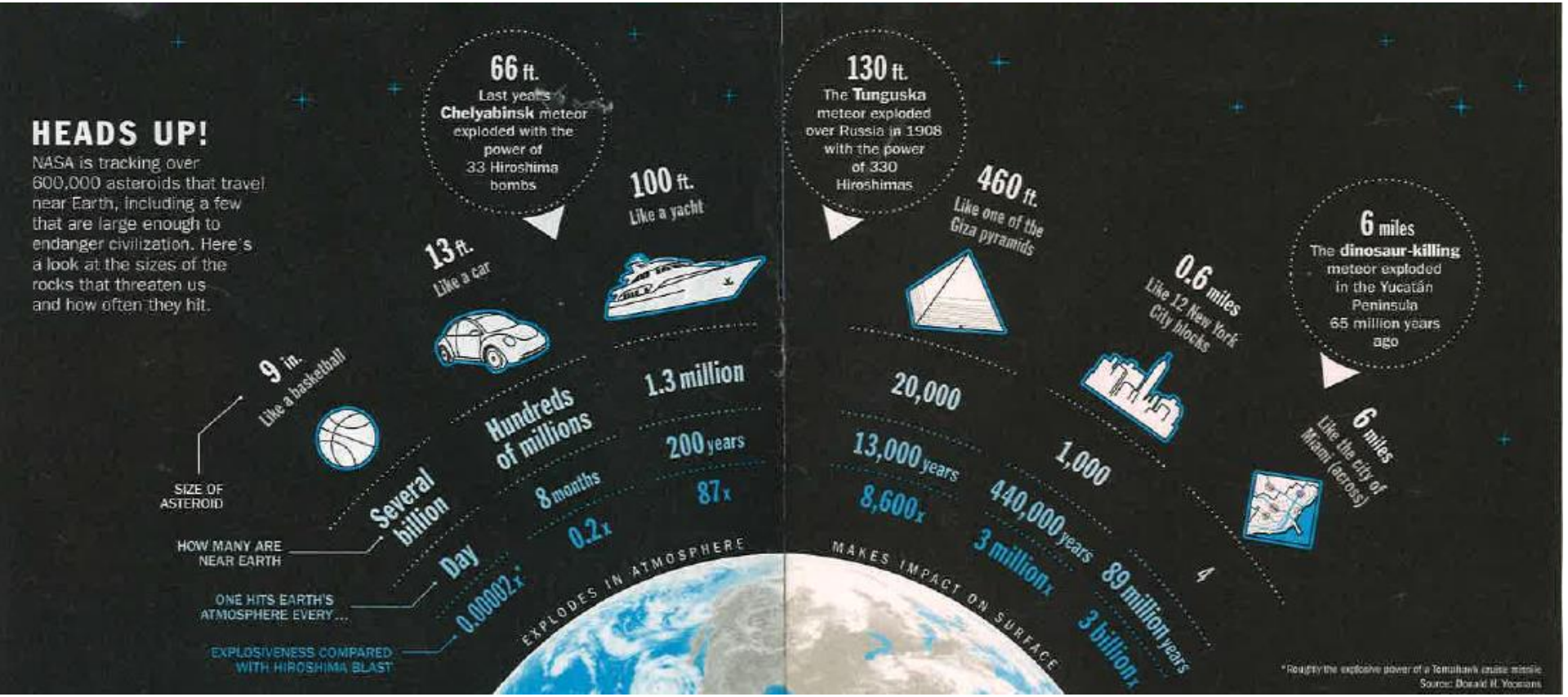
Can be bumped out of orbit in asteroid belt mostly by Jupiter

Near Earth Asteroid NEA

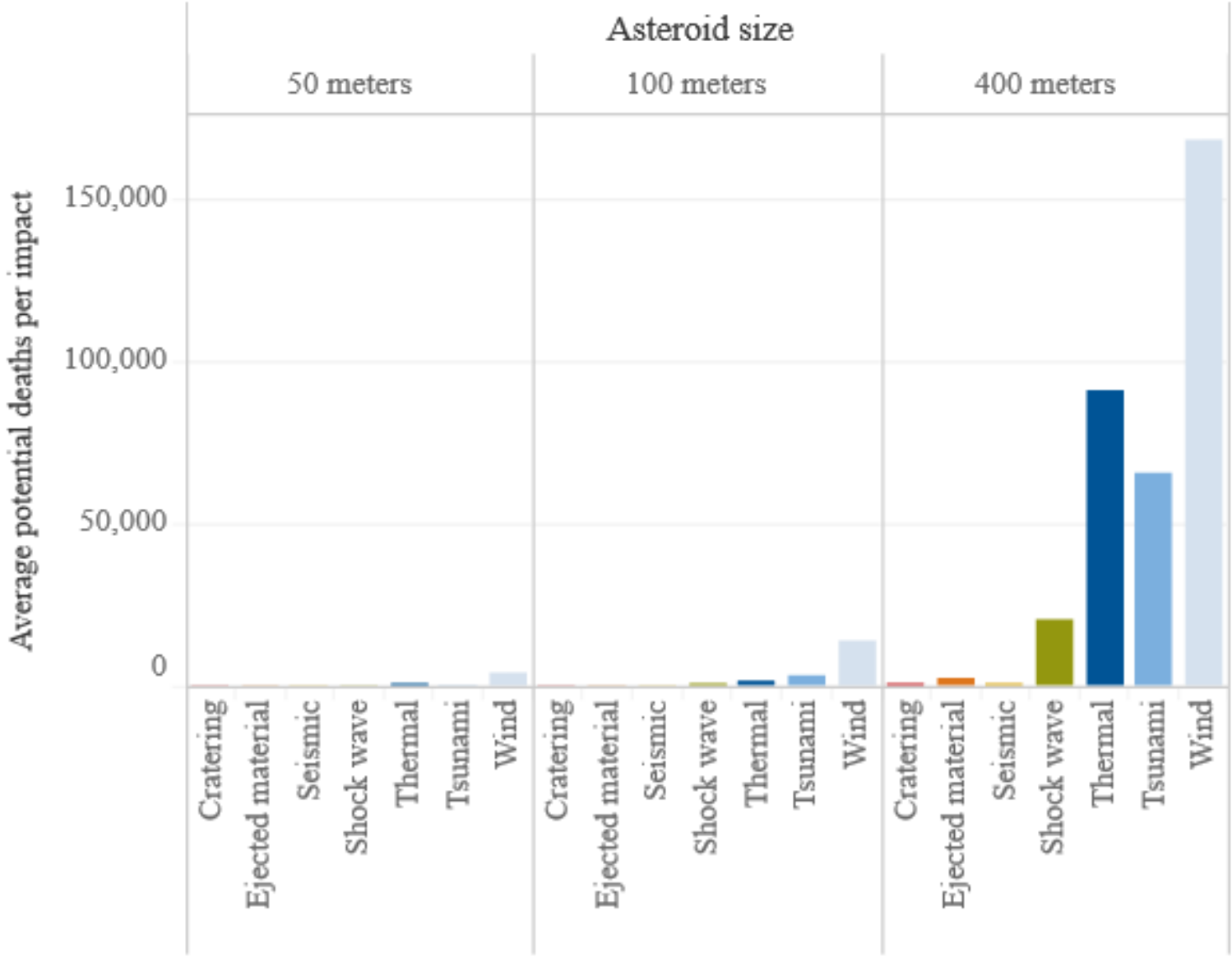




Look for and track all objects which pass close to Earth. ~1500 are “potentially hazardous”. Most new telescopes, like Dark Energy Survey, also look for and track nearby objects

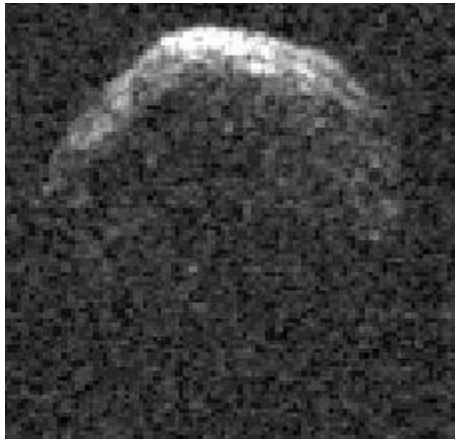

HEADS UP!
NASA is tracking over 600,000 asteroids that travel near Earth, including a few that are large enough to endanger civilization. Here's a look at the sizes of the rocks that threaten us and how often they hit.
9 in.
Like a basketball
13 ft.
Like a car
66 ft.
Last year's Chelyabinsk meteor exploded with the power of 33 Hiroshima bombs
100 ft.
Like a yacht
130 ft.
The Tunguska meteor exploded over Russia in 1908 with the power of 330 Hiroshimas
460 ft.
Like one of the Giza pyramids
0.6 miles
Like 12 New York City blocks
6 miles
The dinosaur-killing meteor exploded in the Yucatán Peninsula 65 million years ago
6 miles
Like the city of Miami (across)
SIZE OF ASTEROID
HOW MANY ARE NEAR EARTH
ONE HITS EARTH'S ATMOSPHERE EVERY...
EXPLOSIVENESS COMPARED WITH HIROSHIMA BLAST
Several billion
Hundreds of millions
1.3 million
20,000
1,000
4
Day
8 months
200 years
13,000 years
440,000 years
89 million years
0.00002x*
0.2x
87x
8,600x
3 millionx
3 billionx
EXPLODES IN ATMOSPHERE
MAKES IMPACT ON SURFACE
*Roughly the explosive power of a Tomahawk cruise missile
Source: Donald W. Yeomans

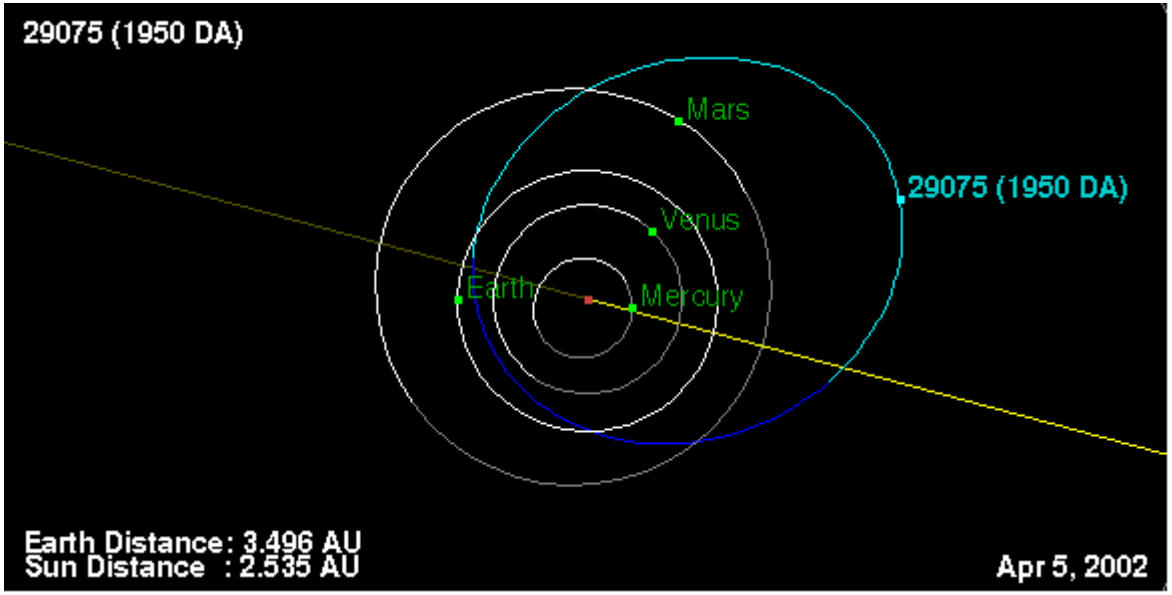
How Asteroids will Kill You



Near Earth Asteroids

(29075) 1950 DA is notable for having the highest known probability of impacting Earth (between 0 and 0.33%). Would happen on March 16, 2880. But orbit can change with time....





Nearby asteroids

Year	mass	size
2880	3 billion tons	1 km
2011 flyby	130 million tons	
2013 flyby	130,000 tons	45m

Drake Equation – guess at values – get number of CURRENT civilizations

$$N = R * f_p n_e f_l f_i f_c L$$

- R* = rate at which solar type stars are formed 1 per year
- f_p = fraction of stars which have planets 0.5 - 1
- n_e = number of planets suitable for life 0.01 - 0.1 ??
- f_l = fraction of planets where life arises 0.001 - 0.1 ?????
- f_i = fraction of life that develops intelligence 0.0001 - 0.5 ???????
- f_c = fraction of intelligent life that communicates 0.0001- 0.9 ??????
- L = lifetime of communicating intelligence 100 - 250,000 years ???
- N = # of "intelligent" civilizations currently in the Galaxy = 1000 (optimistic) OR = 1 (us possibly realistic).
  Guesses are mostly DH's (mine). In 50-100 years the number of suitable planets will probably be much better understood
- Communicate=receive/send radio signals
  SLIDE FOR ASSIGNMENT 7

Communicating with ET

- send a spaceship

too slow. velocity is at most .001 times light speed so more than 3000 years to nearest star. Movie Passengers

- send a radio/TV message (and listen for them)

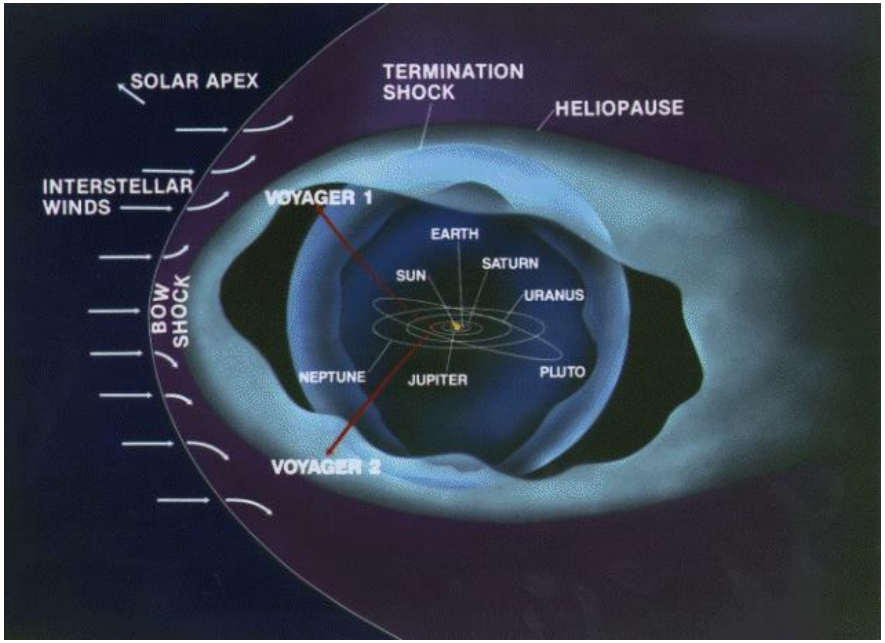
travels at speed of light over a wide area

What frequency?

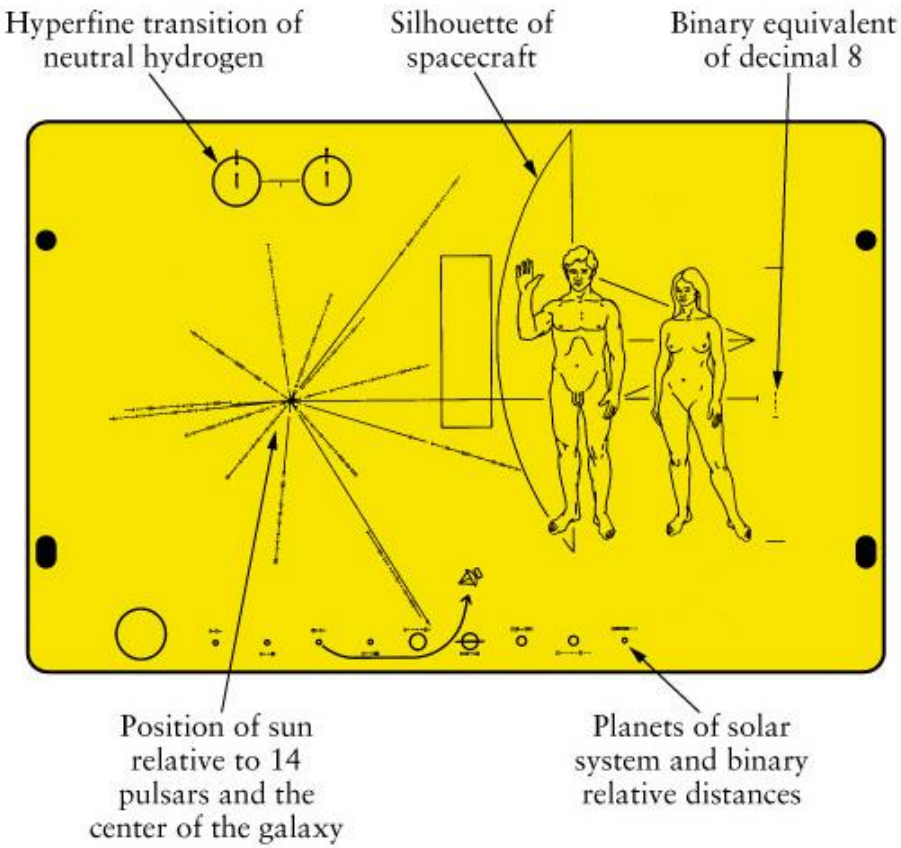
What message?

What direction? maybe in time have a list of found nearby Earth-like exoplanets (purpose of TESS project) and have studied their atmospheres with possible indications of life

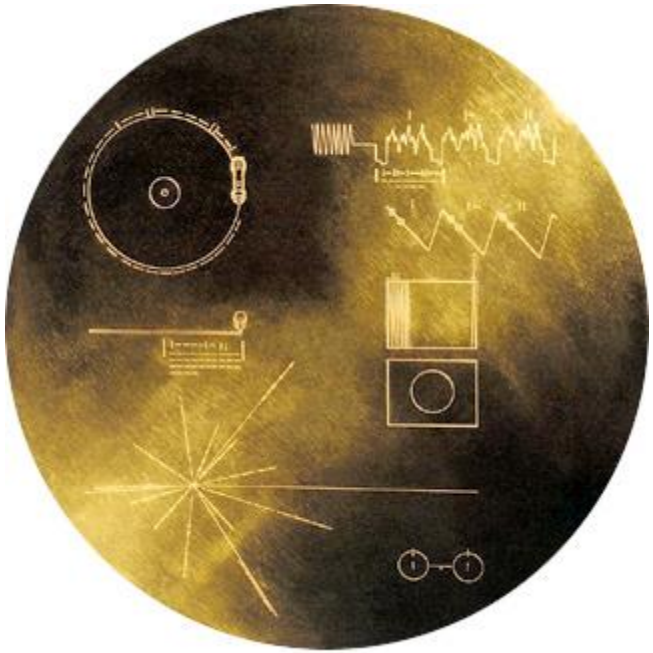
Communicating with ET: spacecraft



- Pioneer 10+11 and Voyager I+II launched in 1973+1977
- Now beyond Pluto. Can still communicate with the Voyager crafts at 117 AU from Sun
- contain plaques and records for ET to find



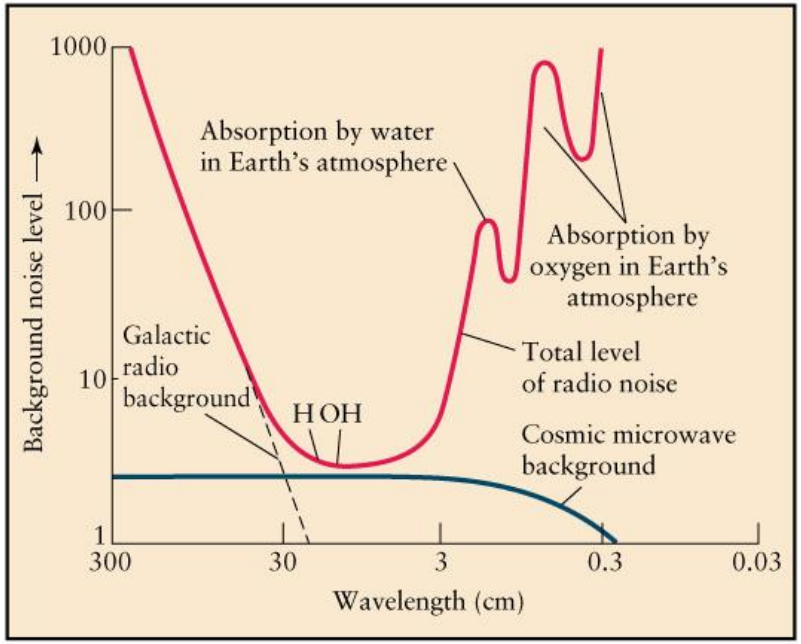
Pioneer plaque. Drake and Sagan design. Very controversial as humans are unclothed (!), not generic enough, and the male is dominant. Also our position is being given to the aliens and so they will be able to find us and attack us (not a joke)



- Voyager record includes “Hello” in many languages, Richard Nixon, and 90 minutes of music from Javanese to Bach to Chuck Berry. Sagan chaired committee. Also controversial as had “rock&roll”
- Old SNL joke. first message from aliens “send more Chuck Berry”

Communicating with ET: Radio

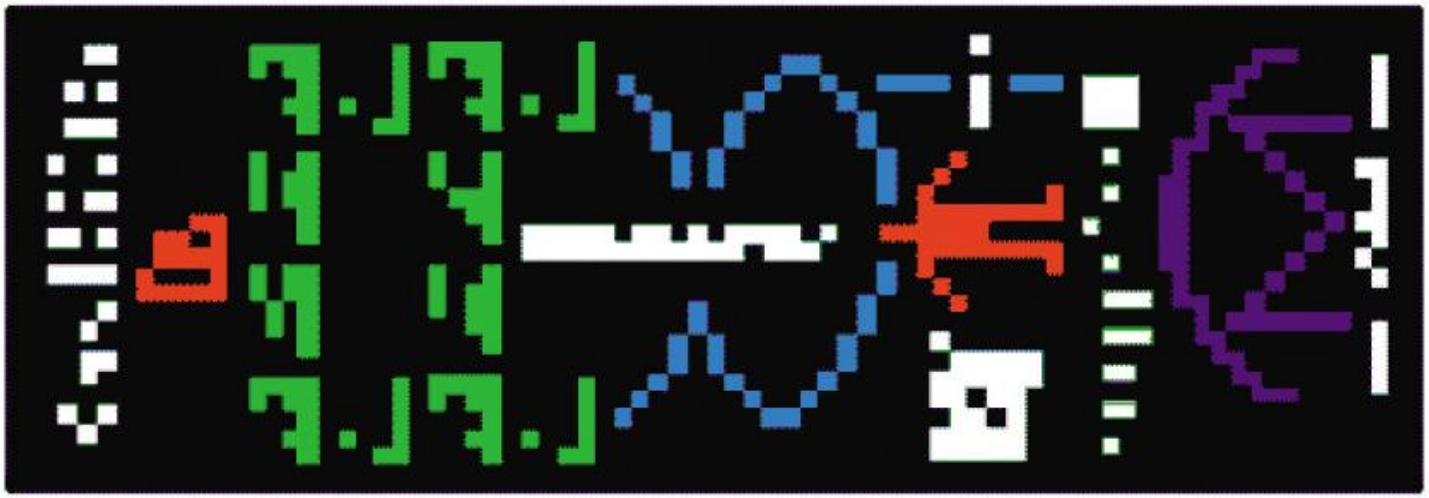
What frequency? Microwave is most quiet. One of water's frequencies? 21 cm often choice



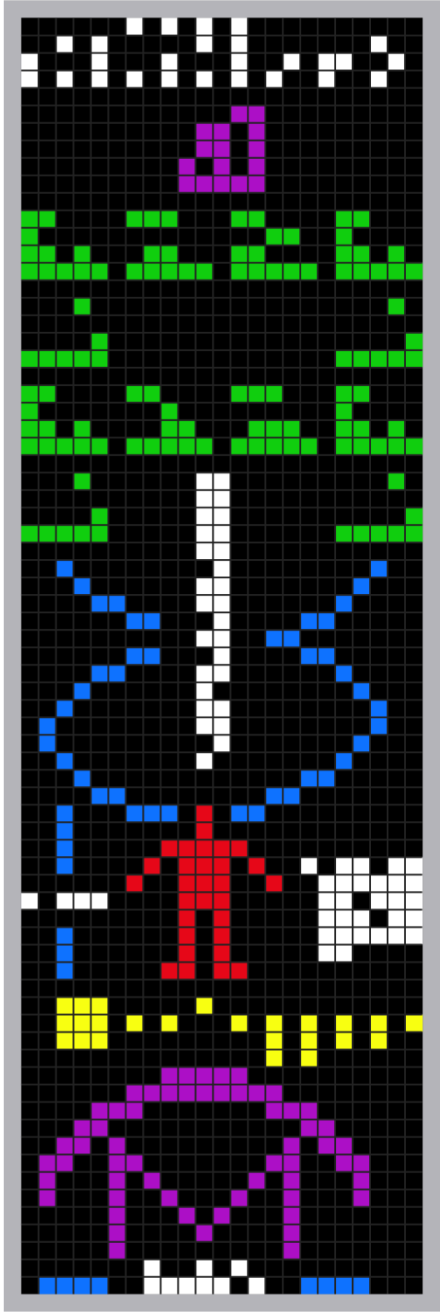
Humans have been sending out radio signals for about 80 years. As travel at the speed of light now 80 LYs away, and covers about 0.00001 (1 part in 100,000) of the Milky Way galaxy. If an alien civilization lasted less than about 100,000 years, if we detect any signal from them, they are probably still not broadcasting and not able to receive a reply from us.

Communicating with ET: Radio

What message? In SciFi humans and aliens can communicate (2016 movie Arrival). In reality we have “lost human languages” (Mayan, Egyptian without Rosetta Stone). In movie Contact (from Carl Sagan’s book). Signal sent in 1974 by Arecibo in Puerto Rico



23 columns by 73 rows = 1679 bits (either 0 or 1). 2 prime numbers. repeated pattern. No “color” just on or off for different bits. Aliens should recognize 2 odd numbers and pattern



numbers 1 to 10

elements H (1) C(6) N(7) O(8) P(15)

nucleotides (like phosphate and adenine)

DNA double helix including the number of base pairs in human genome (looks like antenna coming out of human's head)

human with height (left) and population (right)

9 planets plus Sun with Earth shifted

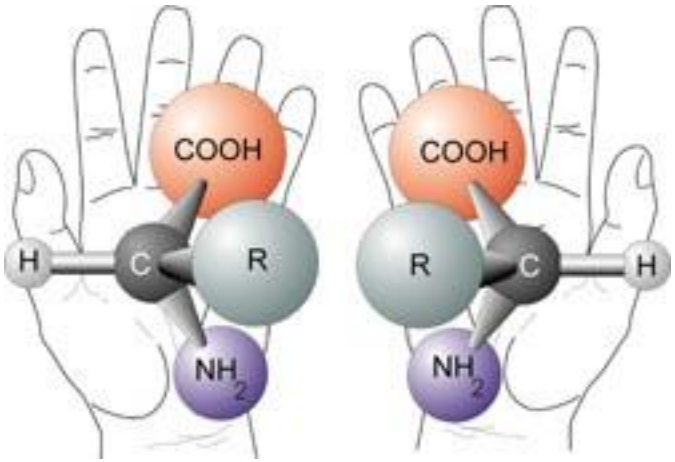
Arecibo telescope with diameter noted on bottom

Could we figure this out if not given the answer?

Extra Slides

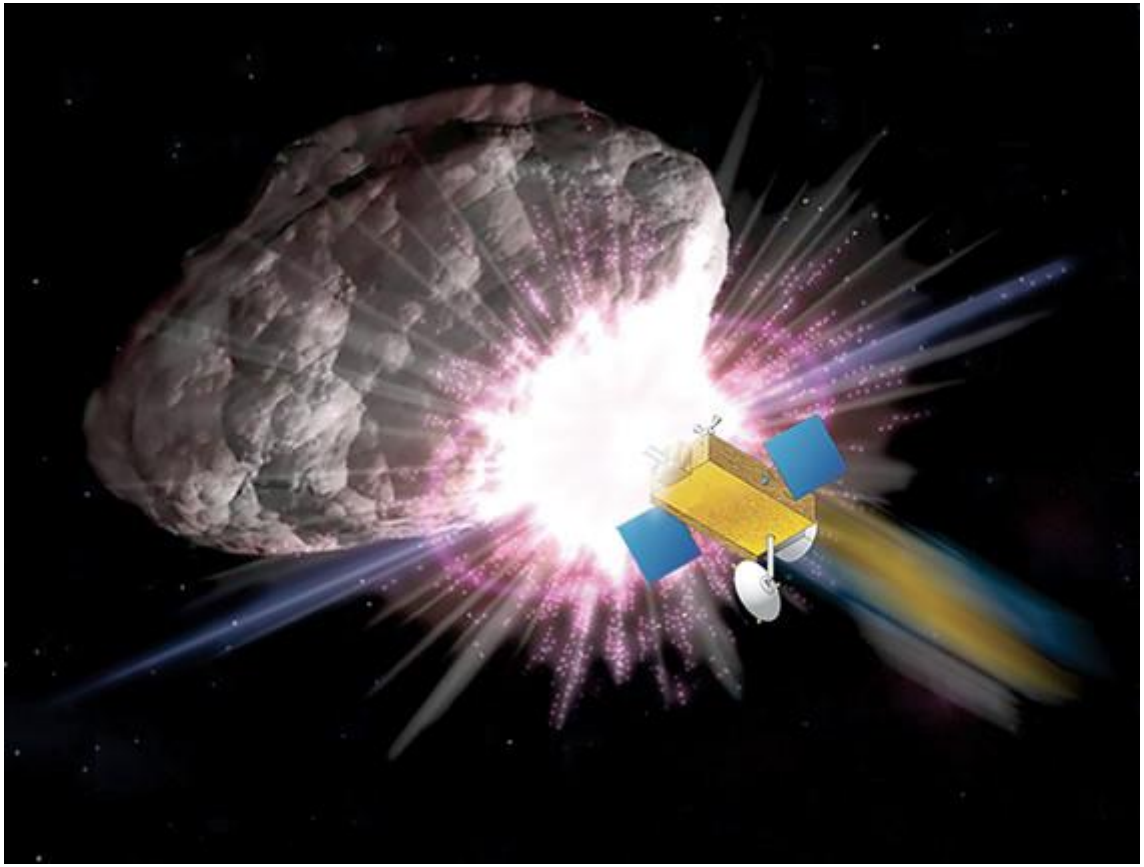
Life on Earth (don't need to know for this course)

- appears all current life descended from same ancestor
- all use DNA and RNA and amino acids
- all use ATP for storing/using energy
- amino acids come in both left-handed and right-handed versions. All Earth life uses left-handed exclusively

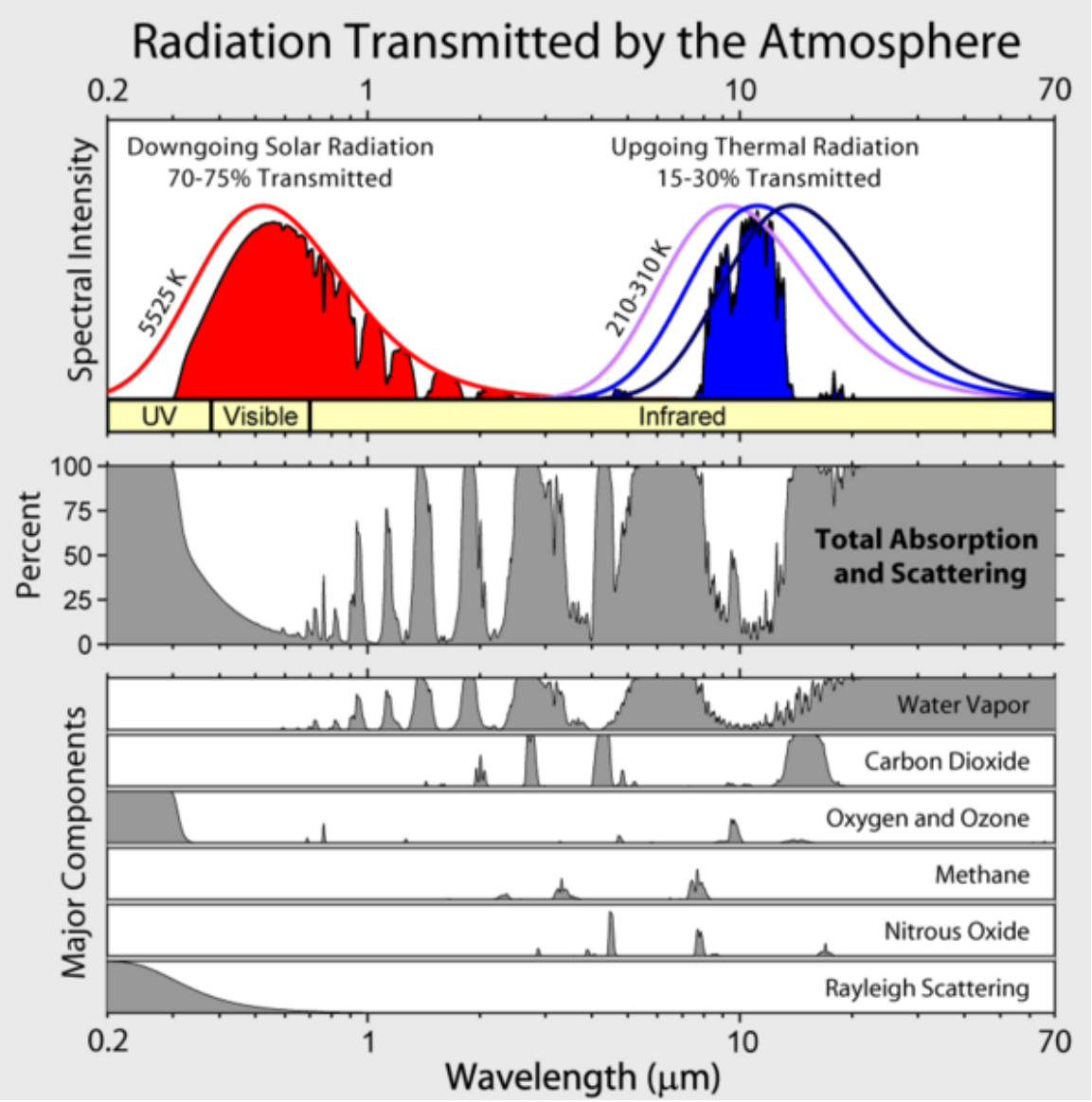


Near Earth Asteroids - Defense?

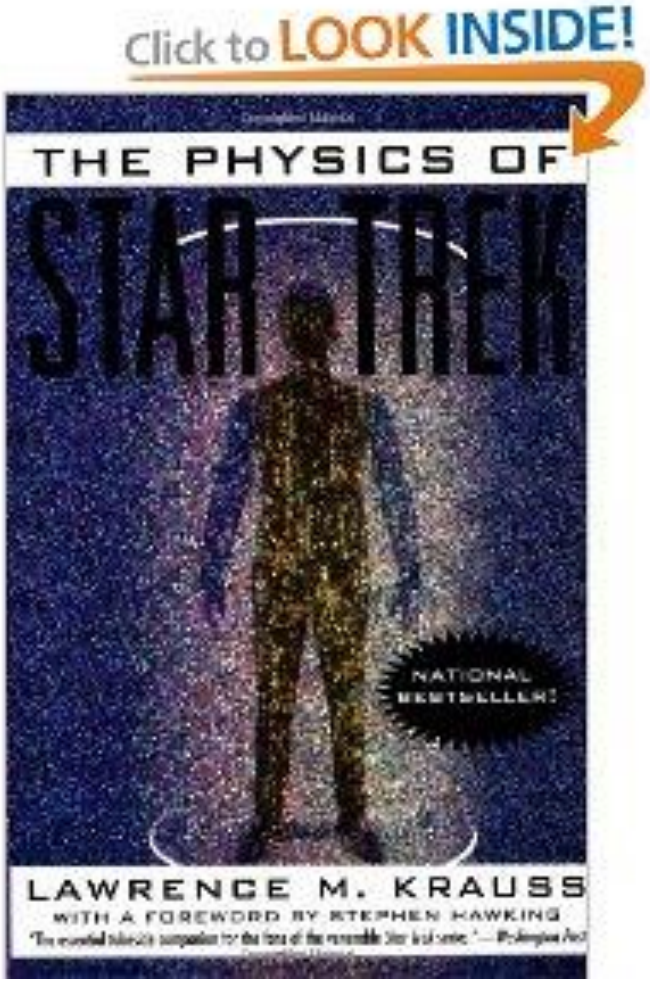
Ala movies: some research going in to how to destroy/deflect an asteroid if it looks like it will hit the Earth. See Physics Today article



Greenhouse Effect with Methane and Carbon Dioxide went over in detail earlier



Communicating with ET spacecraft



- covers why space travel will always be "slow"