SDSU: Astr 310: Astrobiology Prof. Welsh

# Astrobiology: The *BIG* Picture

## Speed of light: c

finite; 3 x $10^5$ km/s in a vacuum; nothing can go faster.

## Space is big....really, really big!

Distances to stars are ENORMOUS!
Even at the speed of light, it takes years, decades, centuries to travel to the stars. Would take tens or hundreds of millennia to travel the galaxy at the speed of light. But in fact, we can't even come close to reaching the speed of light. It is hopeless with current technology.

## Universe is not infinitely old

started ~13 billion years ago: Big Bang
Since it is not infinite, we can't expect it to be filled with advanced civilizations.
Big bang was the start of it all: not just matter, but also space and time
Only H and He were made in any substantial amount. The big bang theory is based on a lot of evidence: Hubble's law, cosmic microwave background, abundance of elements.

## "We are all made of star stuff"

Stars are not all the same: some are bigger and hotter
Stars are born, age and die; Massive stars burn-out quicker
Stars are powered by thermonuclear fusion
Fusion created all the elements besides H, He
When stars die, they release much of their mass back into space

We live in the **Solar System,** way out from the center of our spiral galaxy.
Sun is a typical star (G-type), 5 billion yrs old. The solar system contains the Sun, planets, moons, comets, asteroids, plus smaller bodies. There are 4 terrestrial planets, 4 Jovian planets + Pluto (just a Kuiper belt object?)

Small planets cannot hold onto their original atmospheres (H, He, $CH_4$, $NH_3$,); but big planets can.

Terrestrial atmospheres evolve:
Lose their initial H, He (+ $CH_4$, $NH_3$)
Left with mostly $CO_2$ and $N_2$
For example, the greenhouse effect on Venus; loss of atmosphere on Mars
Water removed $CO_2$ from the Earth's atmosphere

*Life* on Earth greatly altered the atmosphere: "polluted" the air with oxygen, a highly reactive, toxic gas

## Life in the Solar System?

Venus is *hell* - but its cloud tops might be interesting.
Mars may have had lots of water in the past, so it is a very likely candidate.
Europa: liquid water underneath an ice layer?A prime candidate.
Titan: thick smog of organic material (but too cold for liquid water).

Note: comets & meteors can contain a lot of water and organic compounds

## Earth: Formation and Geology

Radioactive decay keeps the inner temperature high.
Crust gets recycled (plate tectonics); almost no rocks older than 3.5 billion years
Heavy meteorite bombardment until ~4 billion years ago. We still get clobbered on occasion: Chixculub meteor wiped out the dinosaurs 65 million years ago

## Life (as we know it):

Requires liquid water, organic molecules, and a source of energy.
Carbon is special because it can form complex molecules.
Water is special for many reasons.
Life builds complex molecules from simpler ones (polymers out of monomers)

### Some important monomers:

- sugars
- amino acids (only 20 used; builds proteins)
- nucleotides (ATGC in DNA + U in RNA)

### All terrestrial life is very similar:

- All life uses ATP as the energy molecule
- Specific handedness (enantiomers) of molecules
- DNA and the same genetic code (codons-to-amino acids)

Implies a common origin for terrestrial life.

## Extremophiles

some like it hot....some like it cold (or salty, acidic, alkali, under pressure, etc.)
some like it in the pot 9 *doses of gamma rays* old...
....bacteria are incredibly hardy, especially in the spore state.

It has been, and always will be, the *Age of the Bacteria*

Most extremophiles are in the domain **archaea.**
Other domains are **bacteria and eukarya.**

**Bacteria and archaea are *prokaryotes*** (no organelles). ***Eukaryotes*** are much more complex; some organelles might have originally been prokaryotes (endosymbiosis)

## Origin of Life on Earth

Organic molecules are common and easy to make in a reducing environment (Urey + Miller experiment), but harder to make in a non-reducing atmosphere.

> It appears that Earth life started as soon as it could have, about 4 bya; probably used RNA, not DNA at first.

Life may have started numerous times, which implies that if the conditions are right, life will arise.

*But the conditions may be very, very hard to get right (Rare Earth)*

## Extrasolar Planets

~102 of them (as of 2002)
Mostly "hot Jupiters" (gas giants close to their host stars)
All discovered via the Doppler effect. Other techniques are astrometry, transits and gravitational microlensing.
One transiting system known (HD209458); transits tell us the radius of the planet.
Planets are common: a*t least 5% of sun-like stars have planets!*
Many more will be found in the next few years.

## SETI:

Search for extraterrestrial intelligence is based mostly in the radio because radio waves do not get absorbed by interstellar gas and dust.
Drake Equation: way to think about how many ET civilizations there are in the galaxy.

## Critical Thinking

Occam's Razor: simpler is better"
Science is a *process*, not a *subject*
A scientific hypothesis must be falsifiable
Pseudoscience is pseudo thinking!

> Be skeptical of the outrageous: "extraordinary claims require extraordinary evidence"

The mind is exceptionally complex. We do not understand many things about the mind: e.g. false memories; belief in weird things (demons, astrology, superstition)

UFOs are simply unidentified flying objects. They exist...
...but it doesn't mean ETs are routinely abducting us!
Rigorous, credible evidence of ET visitors does not exist.
UFOs probably tell us more about ourselves than ET!