

# Announcements

- Remember to set clicker channel to 44
- Astronomy tutorial: Tuesday 3-5, 7-9 pm in 310 VAN
- Office hours: Tuesday 1–3 pm, Wednesday 10-11 am, in 702 VAN
- The first exam is Wednesday, Sept. 21.

An object is moving toward us at a great speed. Therefore, the light it emits is Doppler shifted to

- A) Redder, longer wavelengths
- B) Redder, shorter wavelengths
- C) Bluer, longer wavelengths
- D) Bluer, shorter wavelengths

The lowest mass extrasolar planets detected via Doppler shifts have been found by looking at red and brown dwarf stars. This is because

- A) Low mass stars have low mass planets
- B) The dim stars make it easier to see their accompanying planets
- C) Giant planets would destroy the small stars
- D) Low mass stars experience a bigger wobble due to the gravitational pull of the planet

# Life Beyond Earth

- What is life?
- Where might we find life?
- History of life on Earth

# What is Life?

- What are the essential characteristics of life?

# What is Life?

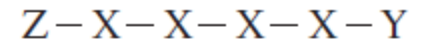
Essential elements are:

- Life reproduces itself
- Life is able to adapt and pass changes to new generations

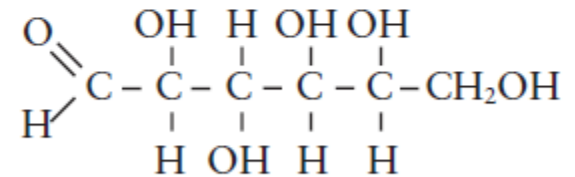
This seems to require a genetic code which can store information about how to grow new organism and is passed from generation to generation

# Organic molecules

- Life on Earth is based on 'organic' molecules – those containing carbon atoms
- A carbon atom can bond with four other atoms making it possible to form complex molecules
- Complex molecules appear necessary to store the information needed for a genetic code
- Life on Earth uses DNA, a carbon-based molecule, to store the genetic code



Linear molecule



Glucose



# Organic molecules

- Organic molecules are found on meteorites dating back to the origin of the solar system.
- Organic molecules are common in interstellar space.
- 99% of organic molecules consist of carbon, hydrogen, oxygen, and nitrogen – these atoms are very common throughout the Universe





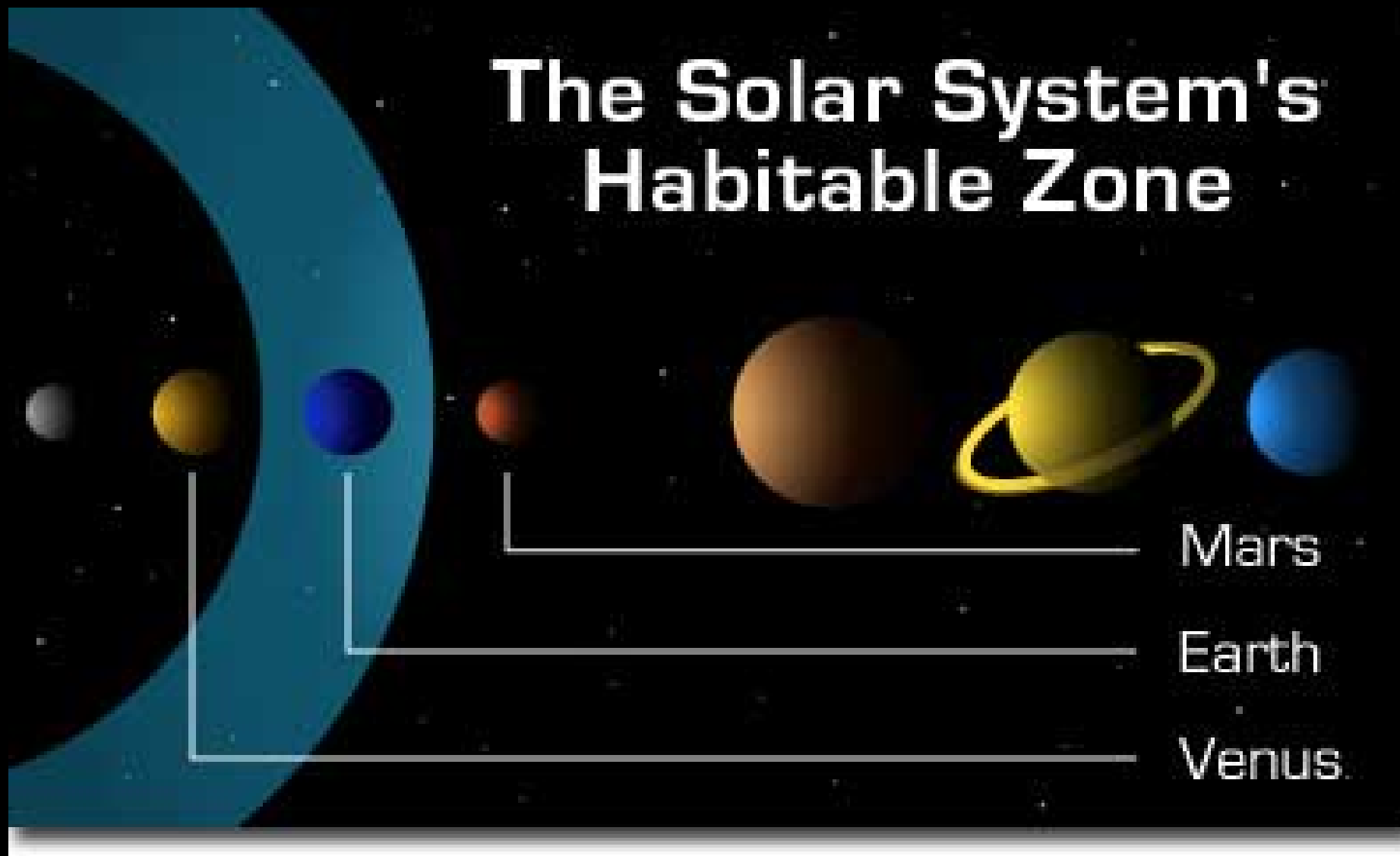
# Life on Earth

- Life on Earth appears to require water
- Liquid water allows other molecules to dissolve, move around, and interact with each other

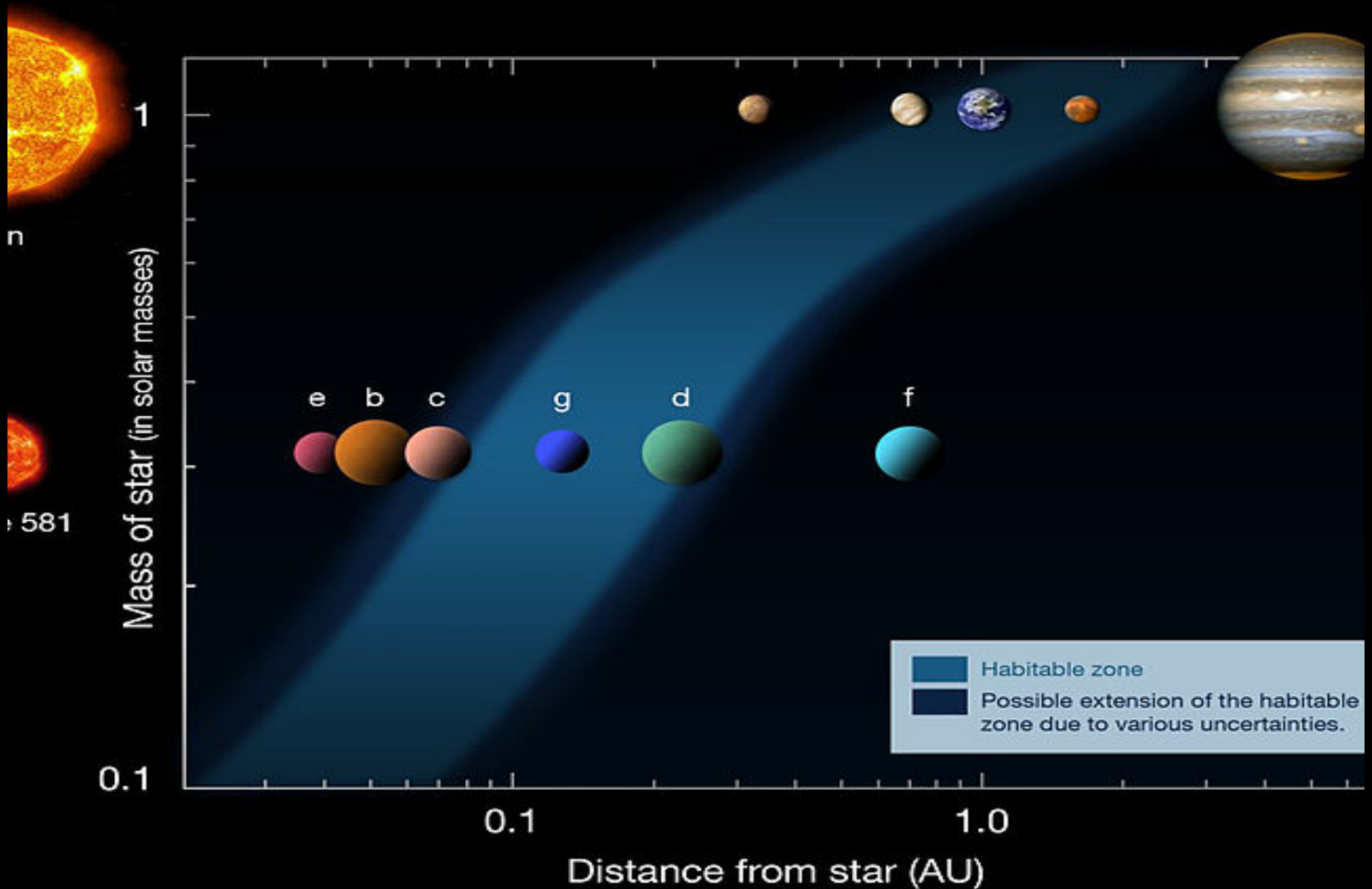
# Habitable zone

- The requirement for water suggests those planets which have liquid water may be the most promising havens for life.
- In order to have liquid water, a planet must be “not too cold and not too hot”, i.e. at a temperature between freezing and boiling.
- How warm a planet is depends on its distance from the sun.

# The Solar System's Habitable Zone



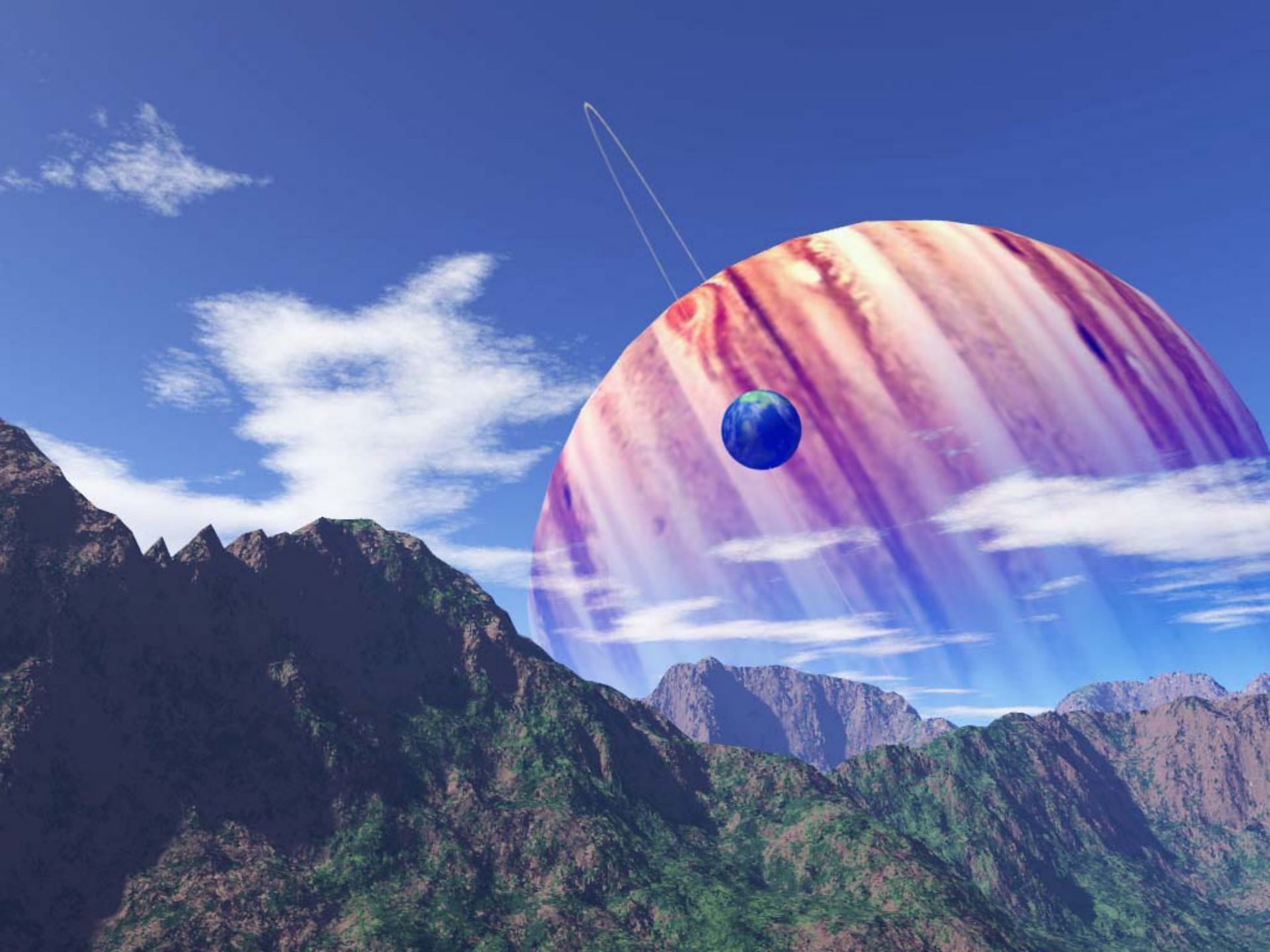
# Habitable Zone



# Best place to move?

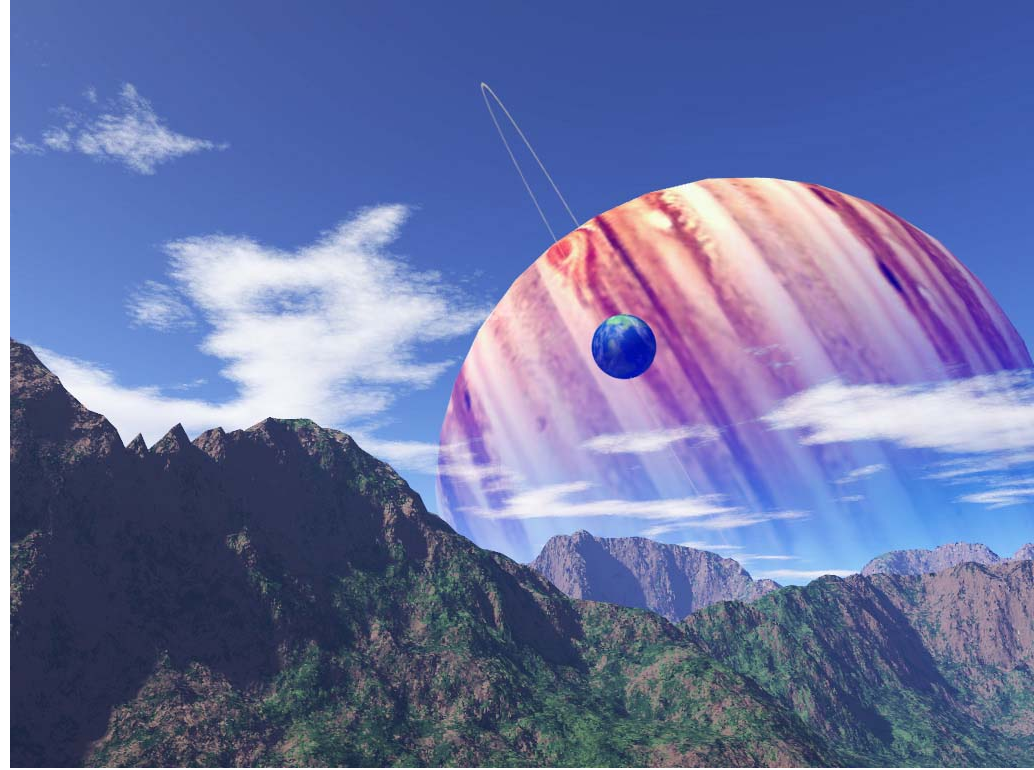


- Gliese 581G
- Star is a red dwarf
- Orbits in 37 days
- At right temperature to have liquid water
- Has mass three to four times that of Earth
- Thought to be rocky





# Best place to move?



- Fourth known planet of 55 Cancri is in habitable zone
- Has mass similar to Neptune, likely a gas giant
- Could have rocky moons
- Moons would be at the right temperature for liquid water
- Would have a cool view

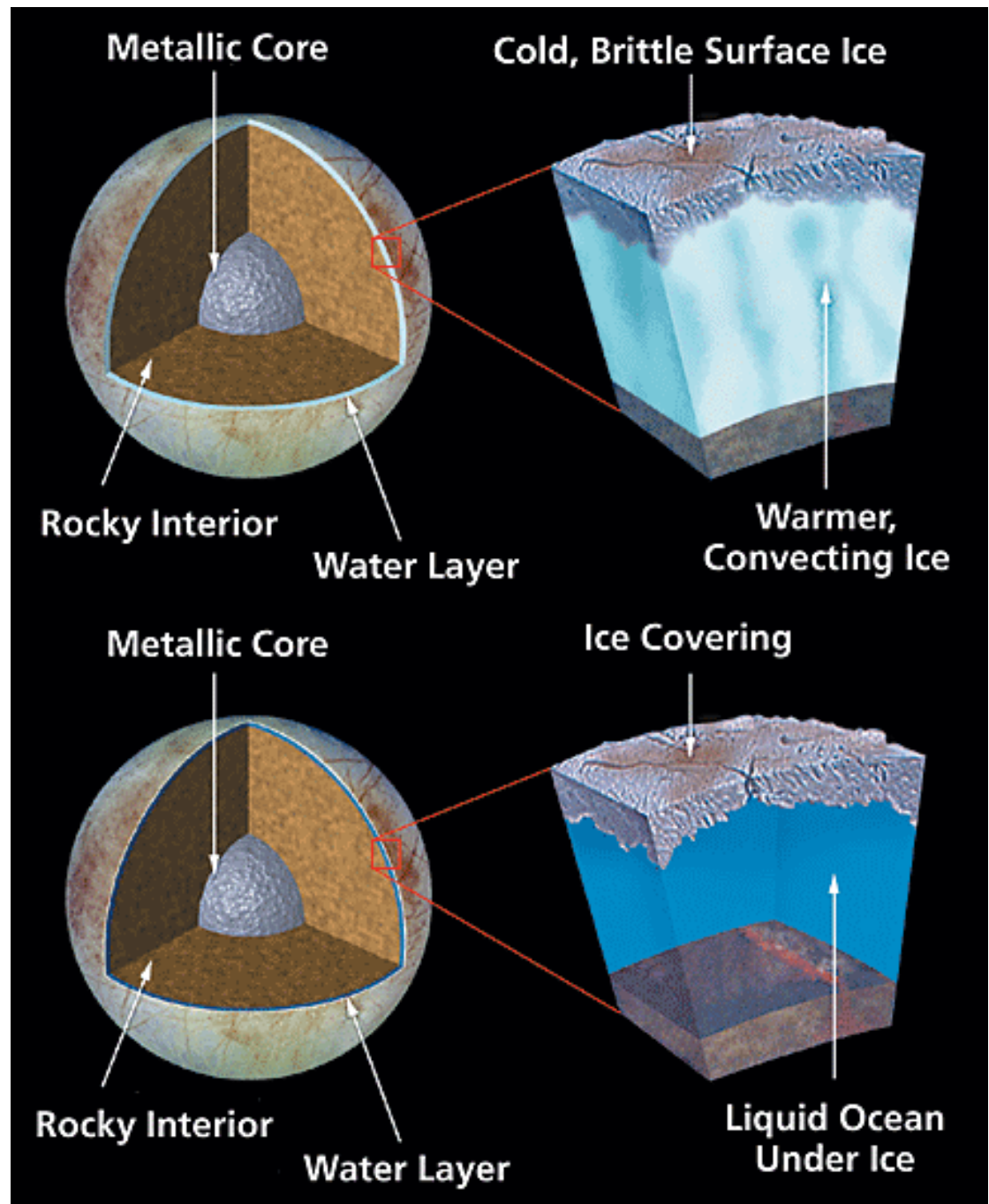
# Are there any exceptions to the habitable zone?

- Yes, if there are sources of energy other than the sun to keep a planet (or moon) warm.
- Possible energy sources
  - Radioactivity
  - Tides



# Europa

- Liquid water oceans are thought to exist on Jupiter's moon Europa



# Mars



- Mars may have had liquid water early on.

# Meteorites from Mars



- Some scientist have suggested that an ancient Martian rock that came to Earth as a meteorite may show evidence that microorganisms once existed on Mars (most scientist disagree)
- Additional rock samples are needed to test

Carbon is a good building block for life  
because

- A) It forms four strong bonds with other atoms.
- B) It is abundant in the universe.
- C) Carbon-based molecules can combine to form long complex chains.
- D) All of the above



# How did life first form on Earth?

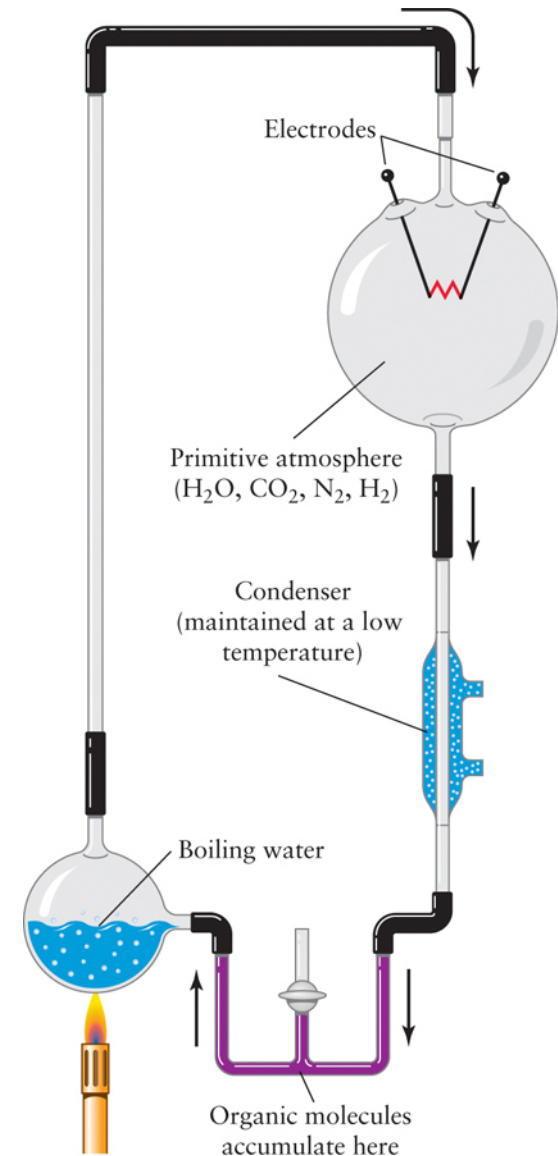


# Miller-Urey Experiment

- Demonstrated that simple chemicals can combine to form the chemical building blocks of life.
- In a closed container, they prepared a sample of the most common molecules in the solar system:
  - hydrogen ( $\text{H}_2$ )
  - ammonia ( $\text{NH}_3$ )
  - methane ( $\text{CH}_4$ )
  - water vapor ( $\text{H}_2\text{O}$ )

They then exposed this mixture of gases to an electric arc (to simulate lightning) for a week.

- The inside of the container had become coated with a reddish-brown substance rich in amino acids (carbon-based molecules found in all living organisms) and other compounds essential to life.



# Evolution of Life on Earth

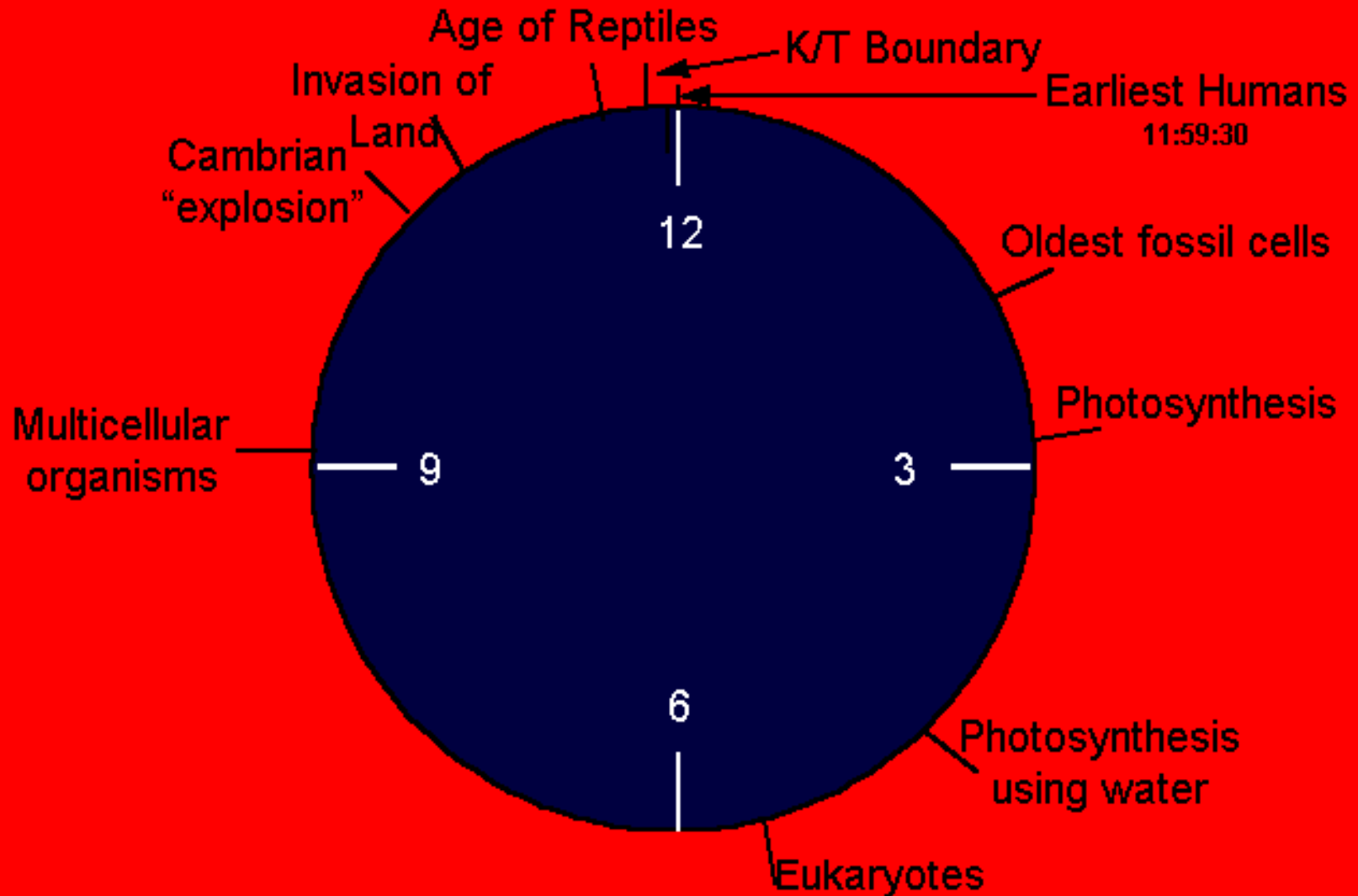
- Even if we find life on another planet, is it likely to be a higher form of life such as mammals or something simpler?
- What form of life occupied the Earth for most of its history?

# Evolution of Life on Earth

- 4.6 billion years ago – Earth formed
- 3.96 “ “ “ – oldest rocks
- 3.5 “ “ “ – oldest fossils – single celled life
- 0.7 “ “ “ – multicellular life
- 0.0001 “ “ “ – humans (homo sapiens)

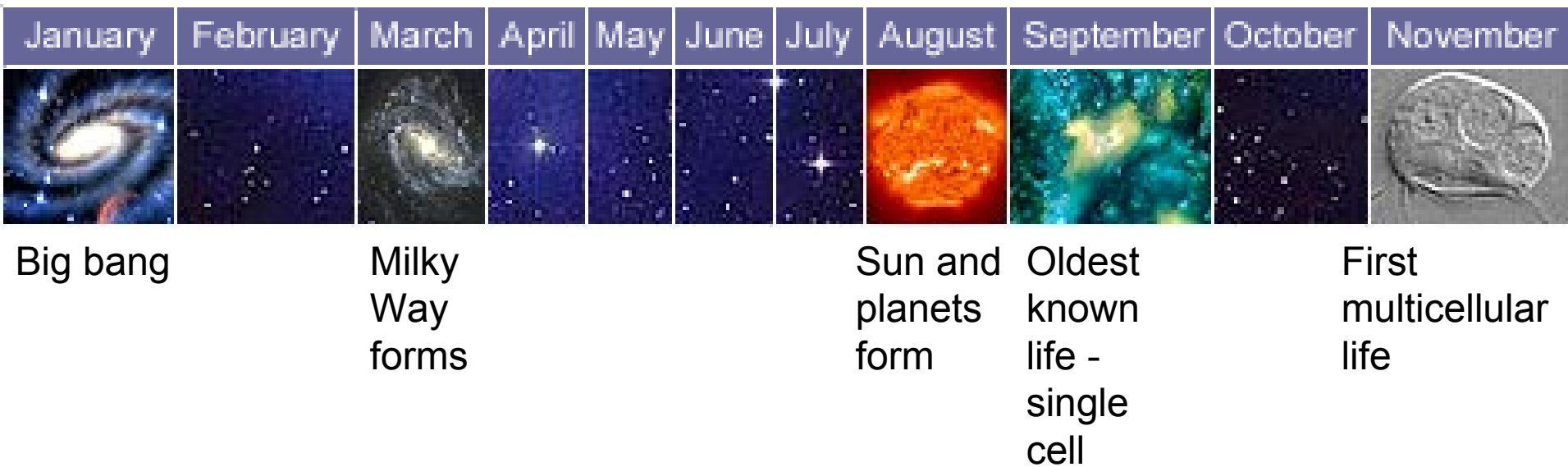


# History of life on Earth in 12 hours



# Carl Sagan's "Cosmic Calendar"

The history of the Universe in one year



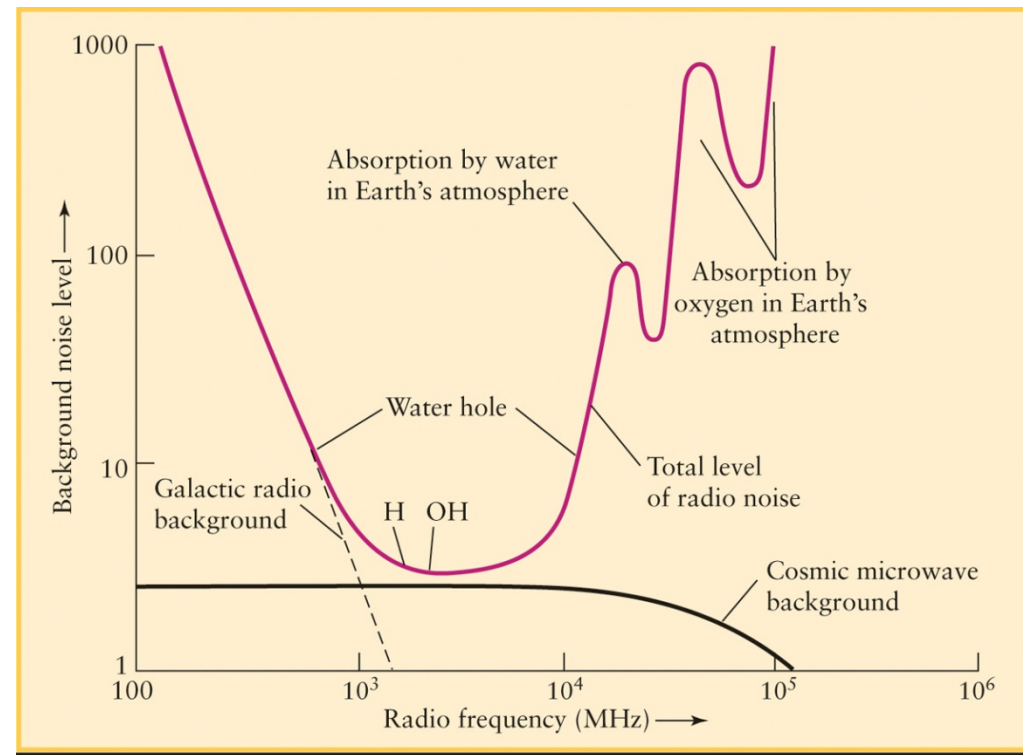
# December

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15 Cambrian Explosion (burst of new life forms)	16	17 Emergence of first vertebrates	18 Early land plants	19	20 First four-limbed animals	21 Variety of insects begin to flourish
22	23	24 First dinosaurs appear	25 First mammalian ancestors appear	26	27 First known birds	28
29 Dinosaurs wiped out by asteroid or comet	30	31 10:15am Apes appear 9:24pm First human ancestors to walk upright 10:48pm Homo erectus appears 11:54pm Anatomically modern humans appear 11:59:45pm Invention of writing 11:59:50pm Pyramids built in Egypt 1 second before midnight: Voyage of Christopher Columbus				

The importance of the Miller-Urrey experiment was that they were able to

- A) isolate organic molecules found in meteorites, proving that they were brought to Earth by impacts.
- B) create amino acids from gases found in Earth's primitive atmosphere.
- C) find evidence of previous life on Mars from meteorite samples.
- D) create simple life for a brief moment.

# Search for Extraterrestrial Intelligence (SETI)



- Searches are underway for signals from extraterrestrials.
- The Water Hole is a range of radio frequencies around  $10^3$  to  $10^4$  megahertz (MHz) in which there is little noise and little absorption by the Earth's atmosphere.
- This noise-free region may be well suited for interstellar communication.
- Same frequency range used for wireless on your laptop.

# Search for Extraterrestrial Intelligence (SETI)

- One thing that is needed is more computing power. You can volunteer your computer to process SETI signals while the screen saver is on at the web site <http://setiathome.ssl.berkeley.edu/>
- There are other searches for other types of signals including visible light lasers – it is possible to send laser signals as bright as the Sun, but they need to be beamed at specific solar systems

# What are the odds?

- Can we estimate the probability of at specific solar systems?
- What factors might be important?

# The Drake Equation

The number of technologically advanced civilizations in the galaxy may be estimated using an equation:

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

$N$  = number of extraterrestrial civilizations we might detect message from

$R^*$  = rate at which solar-type stars form in the galaxy

$f_p$  = fraction of stars that have planets

$n_e$  = number of planets per solar system suitable for life

$f_l$  = fraction of those planets on which life actually arises

$f_i$  = fraction that evolve into intelligent species

$f_c$  = fraction of those species that develop adequate technology and then choose to send messages out into space

$L$  = the lifetime of a technologically advanced civilization

Try your own estimates at:

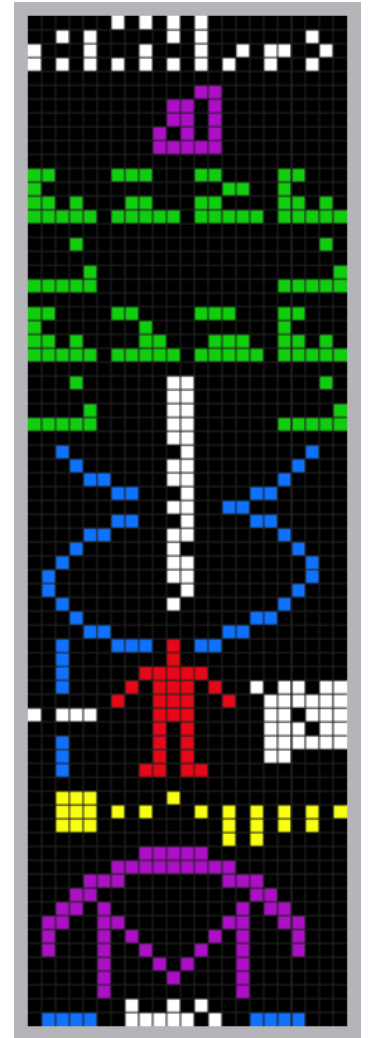
<http://www.pbs.org/wgbh/nova/space/drake-equation.html>



# Arecibo Message



Sent on 16 November 1974 at the globular star cluster M13 which is 25,000 light years away. Contains 1679 bits encoding a black and white image.



# METI - Messaging to Extra-Terrestrial Intelligence

- About a dozen later attempts have targeted closer stars known to have planets, mostly using a radio telescope in the Ukraine.
- A Message from Earth (AMFE) was sent on 9 October 2008 towards Gliese 581. There was a public competition to decide which messages to send.
- Radio and TV broadcasts not intended for extra-terrestrials could also be propagating out into space and could be picked up.

# The water hole is

- A) A range of radio frequencies over which little background noise occurs.
- B) The range of distances from a star where planets have surface temperatures allowing water to be liquid.
- C) The range of distances from the Galactic center where solar systems are deficient in water.
- D) Stellar masses that will never form planets with water.
- E) A bar in downtown Iowa City frequented by extra-terrestrials.

Should humans be sending  
messages into space?

A) Yes

B) No

# Review Questions

- What is needed for life?
- What are organic molecules?
- What is the habitable zone?
- Besides Earth, what are the most likely locations for life in our solar system?
- For what fraction of the history of the Earth have humans existed?