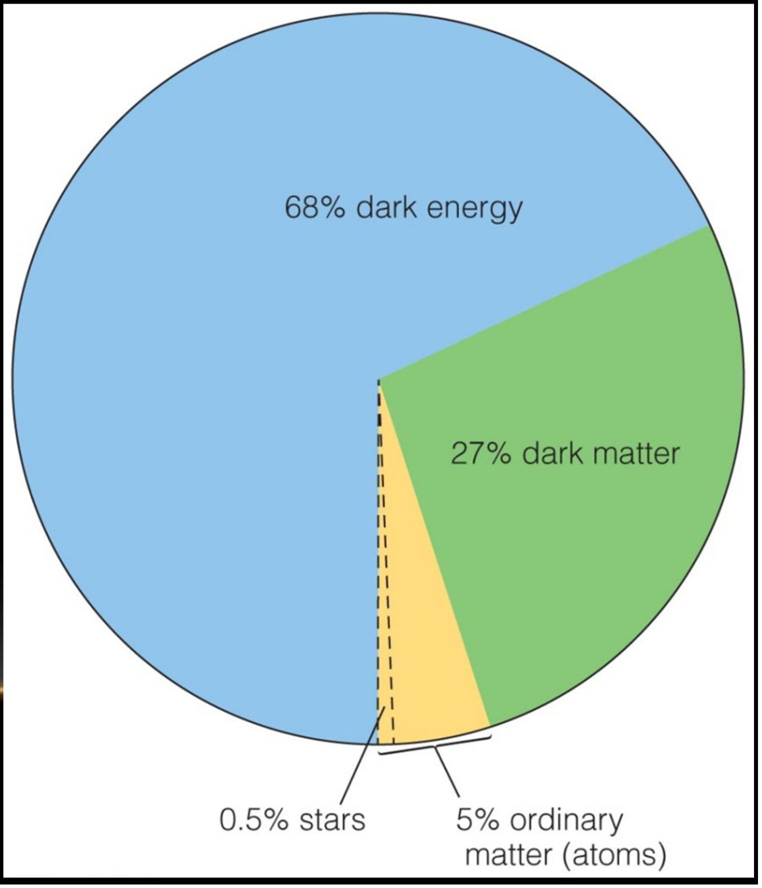
PUTTING IT ALL TOGETHER

- Spot size on the microwave background says universe is flat: Ω_0=1.00
- Total matter is only 31% of what's needed to make it flat (and/or put the brakes on expansion): Ω_m = 0.31 (*of which only 0.05 is normal matter*)
- That leaves Ω_Λ=0.69: enough matter/energy to make things flat: but it needs to make things expand rather than contract
  - This "Dark Energy" stuff



DARK ENERGY

- Was a long-dismissed term in Einstein's general relativity calculations
  - Λ, the "Cosmological Constant"
- While energy = mass ($E=mc^2$), it also adds a "pressure" to spacetime forcing an expansion
- About 69% of the mass of the universe appears to be in this form

THE WHOLE STORY

- Big Bang plus Inflation explains many observed things:
  - Expansion of universe
  - Formation of elements
  - Cosmic Microwave Background
  - Fluctuations in CMB, structure formation
  - Flatness of the Universe

THE WHOLE STORY

- Continued accelerating expansion could mean:
  - That we’re in for the eventual “heat death of the universe”
  - Or “cosmic red-out” (universe eventually is expanding so fast that we can’t see very far at all given the slow speed of light)
- When? Probably trillions of years in the future
  - Remember, the sun goes red giant, toasts us, then burns out 5 billion years from now, a much more immediate concern

LEFTOVER ODD BITS

- Dark Matter – what is it and why so much?
- Dark Energy – ditto only more so
- Knowing more about really high energy physics (Grand Unified Theories, String Theories?) would help out here
- We do research here at UMD to address these questions
  - Neutrinos, WIMPs, proton decay (another GUT prediction)

LIFE IN THE UNIVERSE

Ch.19

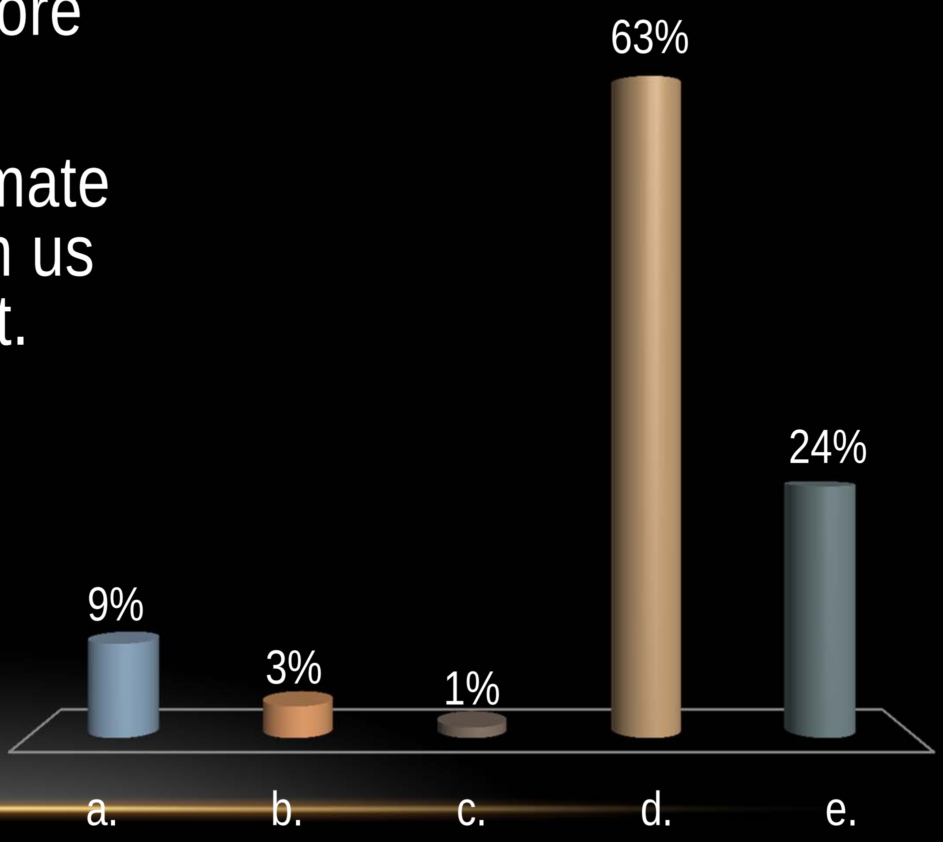
Note: this chapter won't be on the final, since I wasn't sure if we'd get to it

LOOKING FOR LIFE NEARBY

- Mars?
- Venus?
- On Europa or Enceladus?

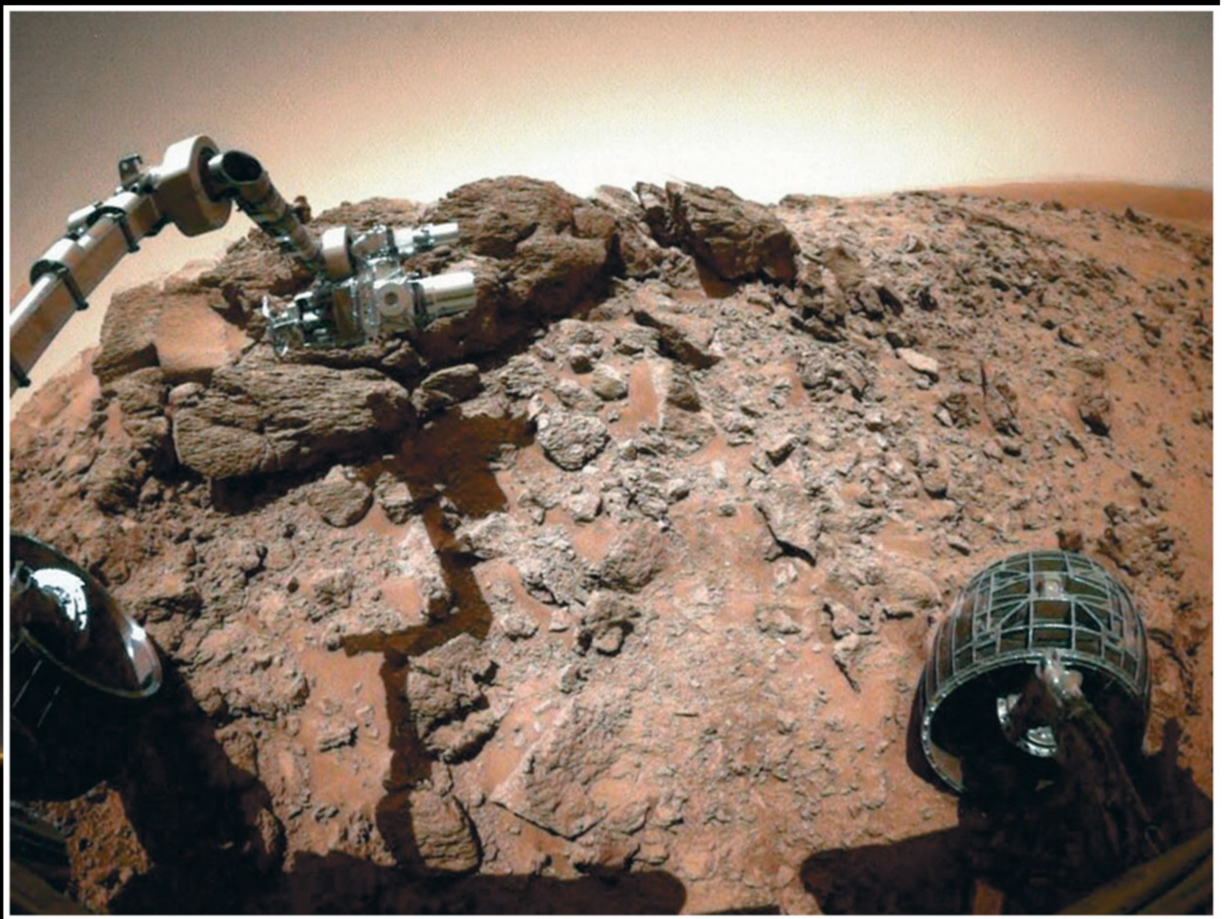
WHY MIGHT WE LOOK FOR LIFE ON MARS?

a. Evidence of liquid water, and evidence that there was more water in the past.
b. Mars has the next best climate than Earth. It is colder than us but was warmer in the past.
c. Mars has an atmosphere.
d. All of the above. ✓
e. A and C



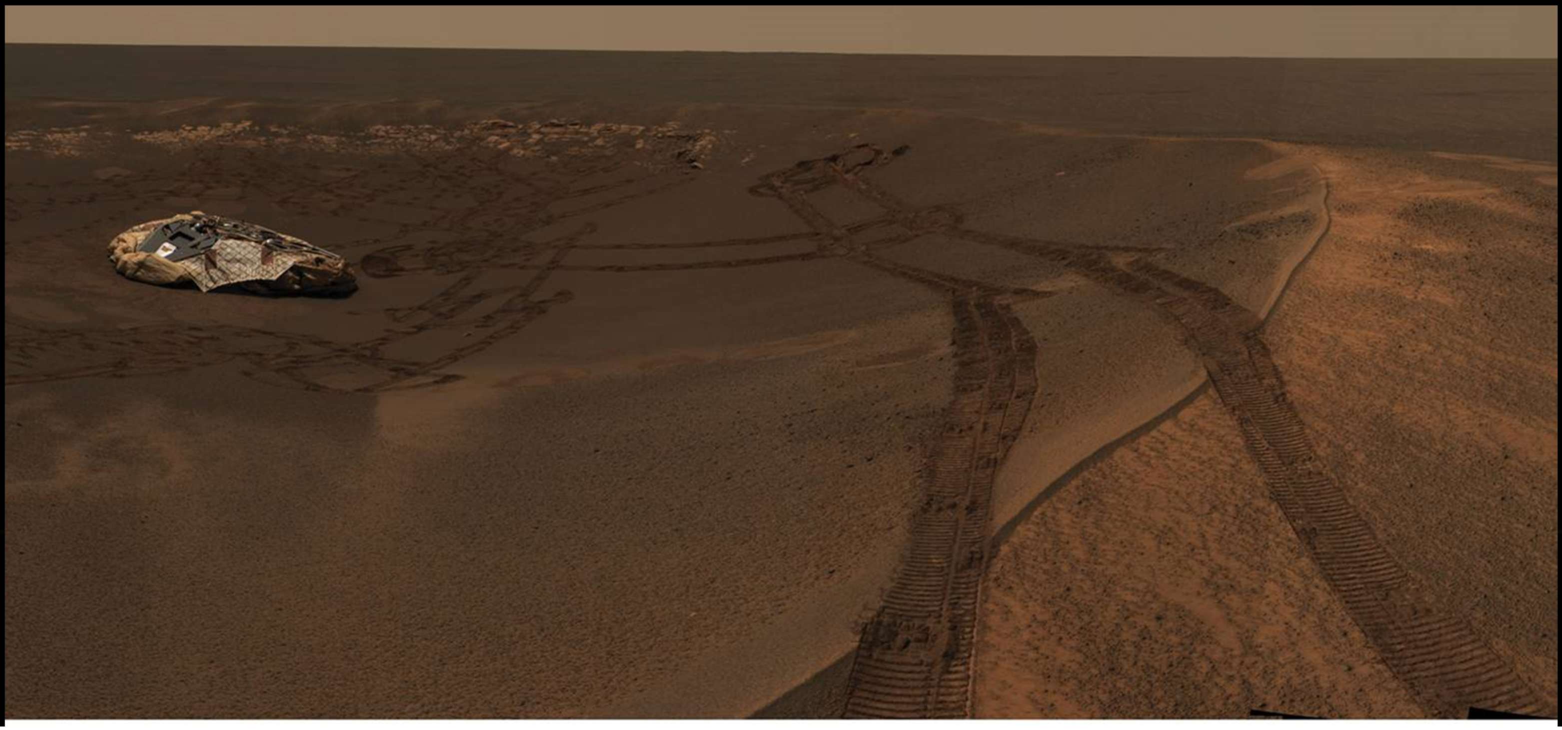
MARS

- Many landers, robots, rovers have gone to check
- Equipped with labs to test for current life:
    - None found

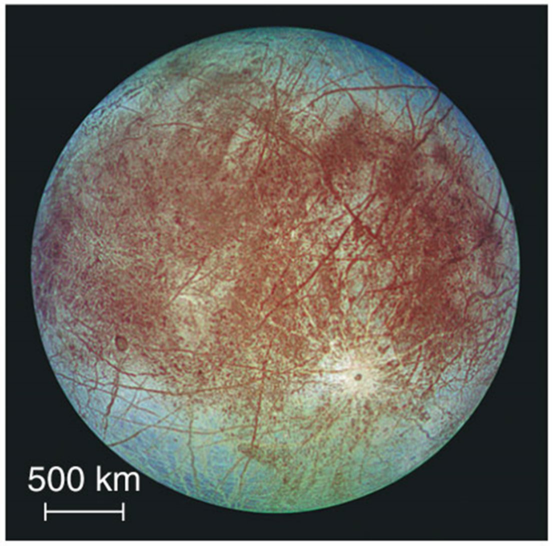


HOWEVER…

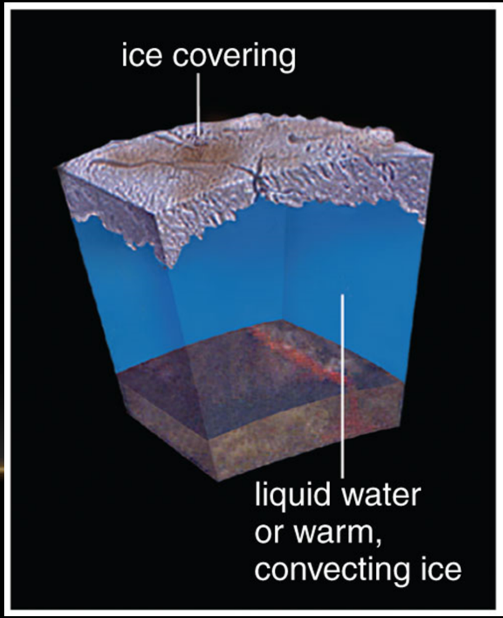
- We have found that Mars had much liquid water in the past, and still some in some places today
  - Life on Earth survives in tougher locations

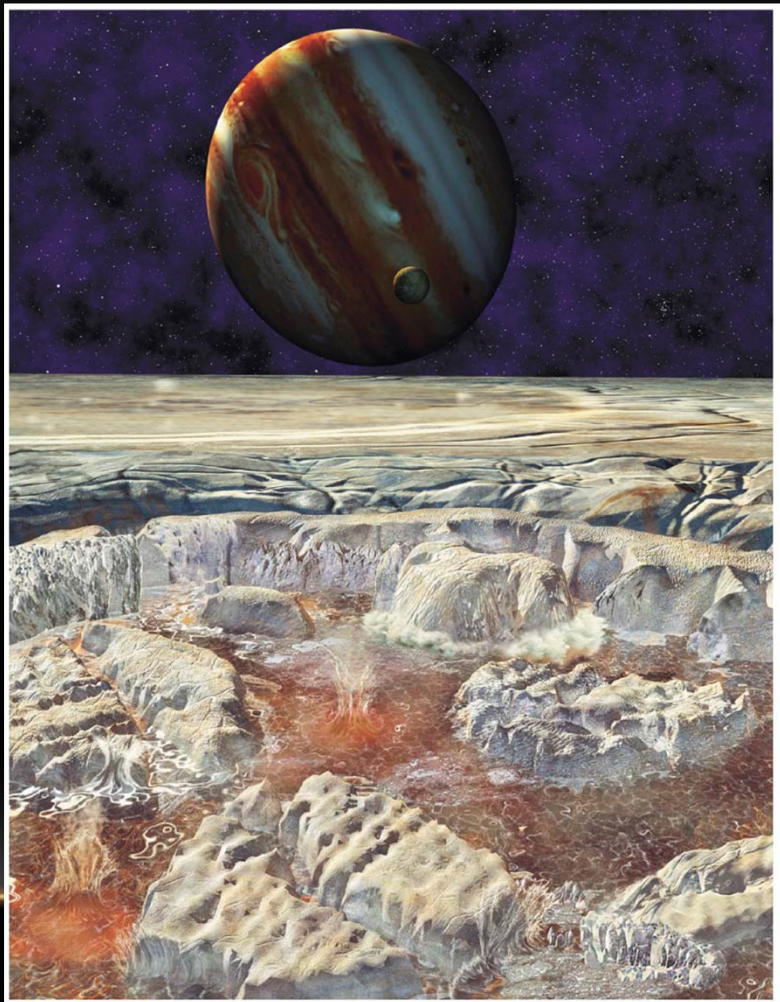


JOVIAN MOONS?



Europa has a large
Subsurface ocean

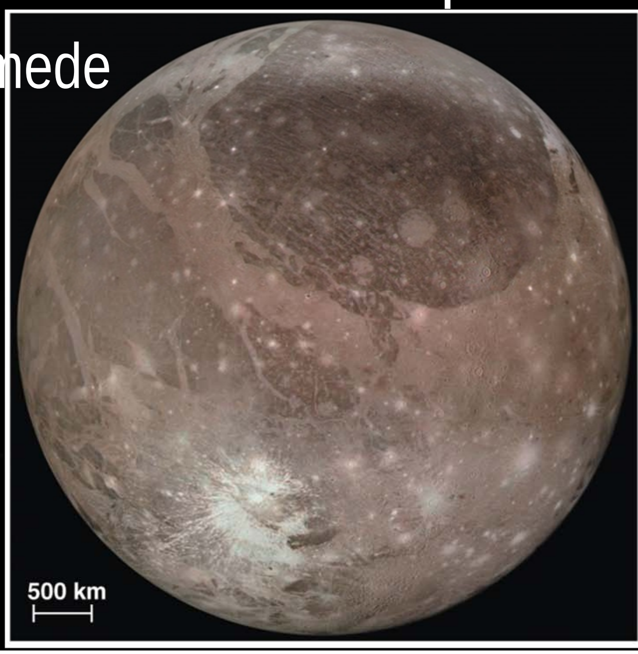


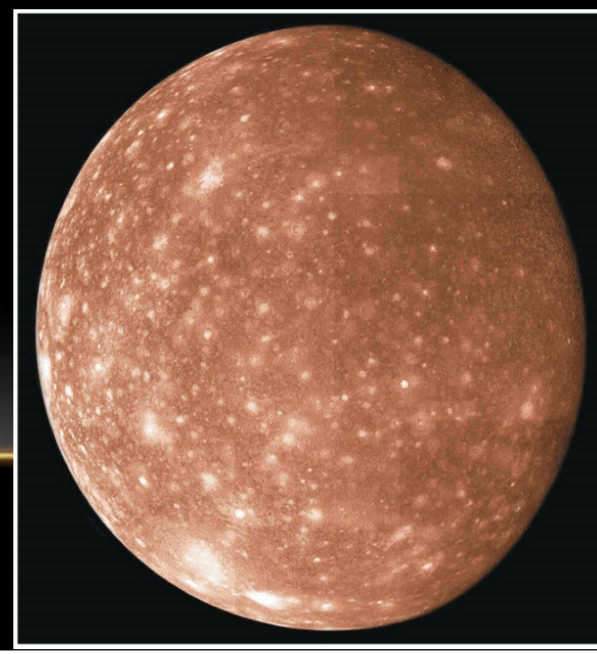


MORE POSSIBILITIES…

- Ganymede, Callisto also show some evidence for subsurface oceans
- Relatively little energy available for life, but still…
- Intriguing prospect of THREE potential homes for life around Jupiter alone

Ganymede

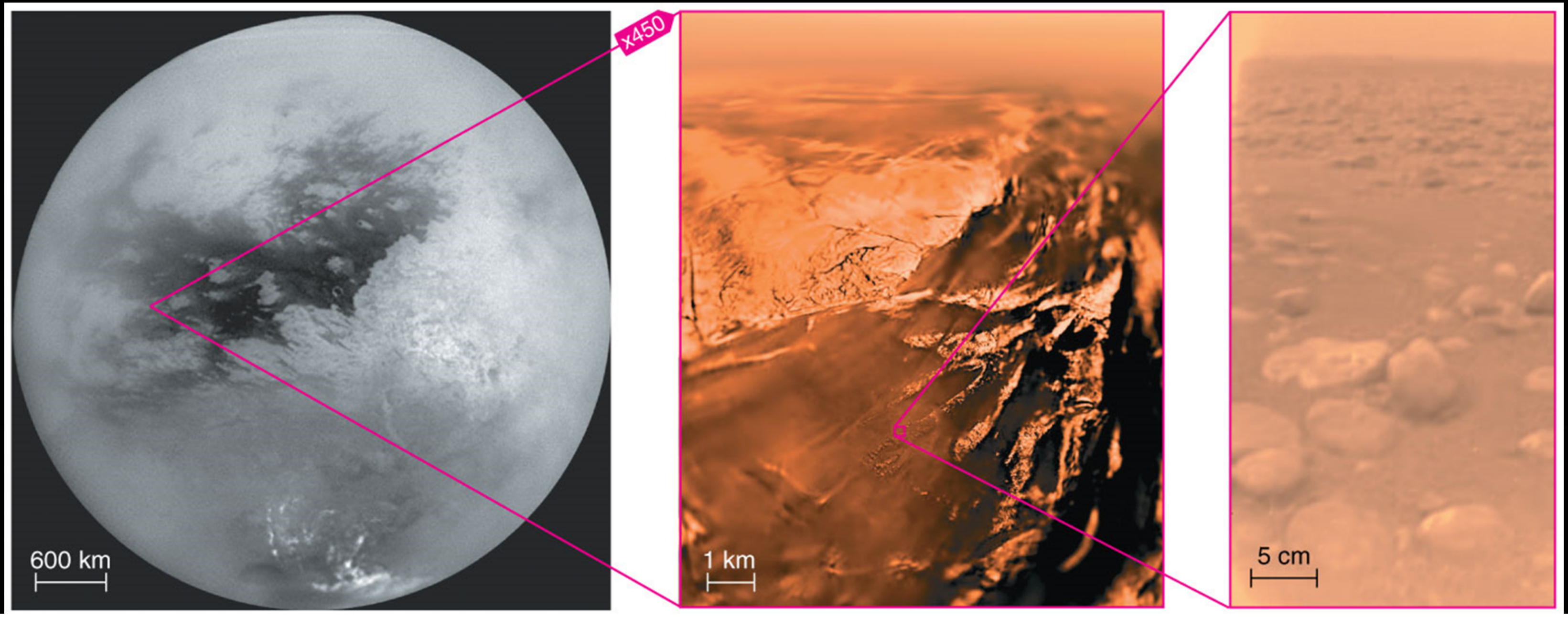




Callisto

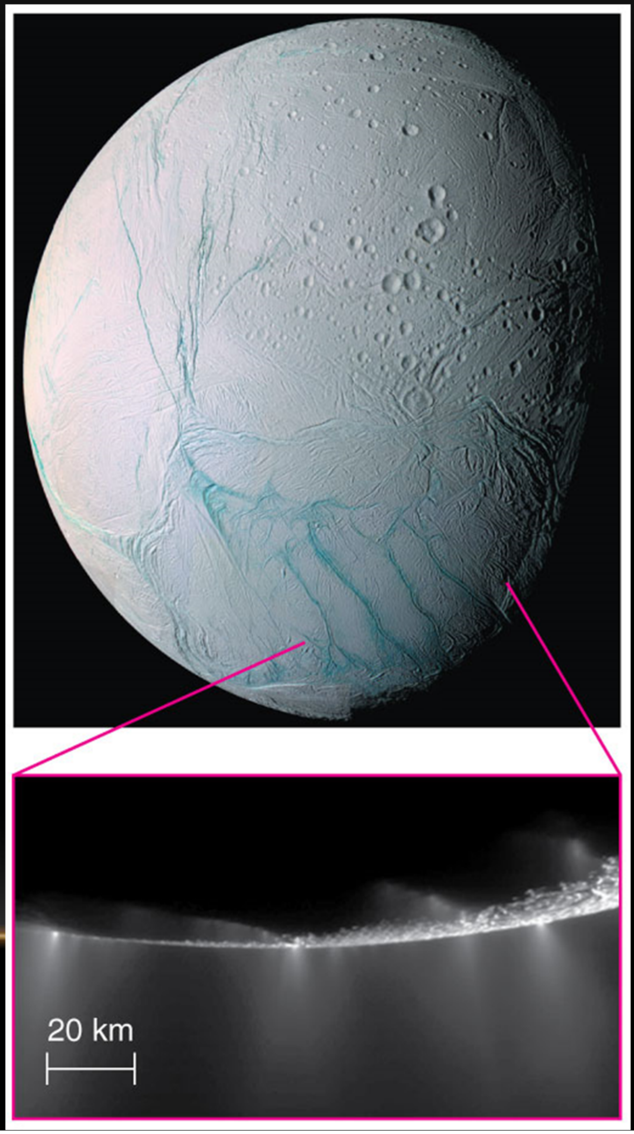
NEAR SATURN?

- Titan's Surface too cold for liquid water (but deep underground?)
- Liquid ethane/methane on surface
  - Other liquids might be able to play the role water does for us



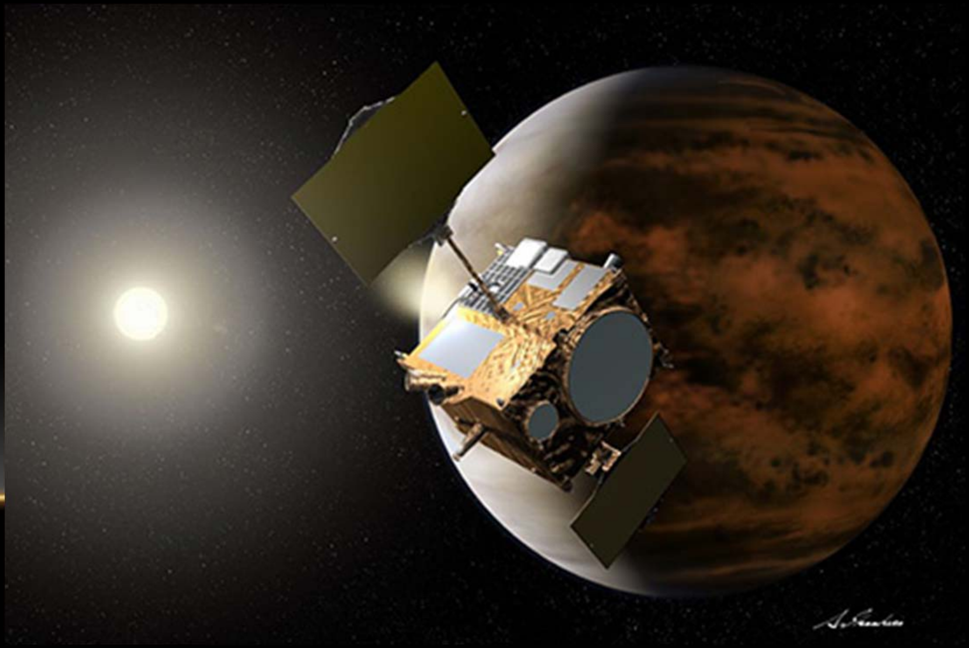
ENCELADUS

- Ice fountains on Saturn's moon Enceladus suggest that it might have liquid water below the surface



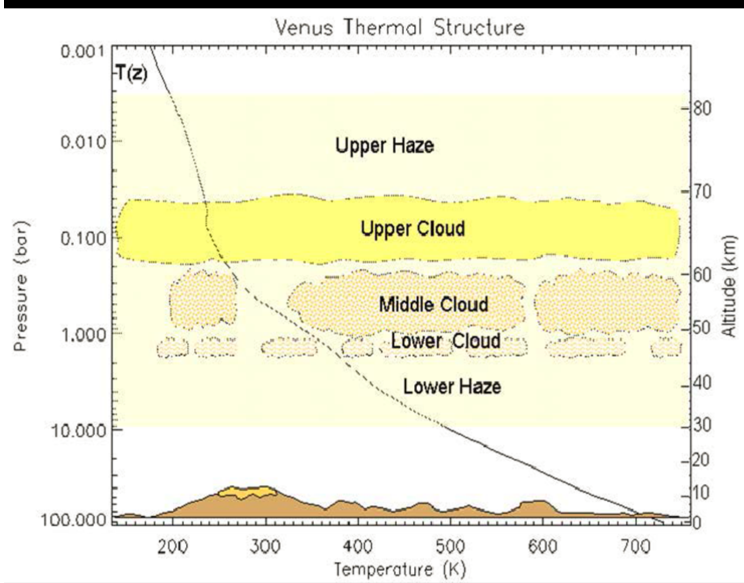
VENUS?

- Surface is really nasty
- But, up in the atmosphere temperatures and pressures are quite reasonable
- Japanese Venus Climate Orbiter "Akatsuki" has been in orbit since 2015 to study the atmosphere



VAMP

- Once we learn more about the atmosphere, Grumman has a cool idea for a balloon/glider hybrid
  - Venus Atmospheric Maneuverable Platform
  - Would cruise around under the clouds, popping back up to transmit data and recharge batteries



IS ANYONE ELSE OUT THERE?

- Search for ExtraTerrestrial Intelligence (SETI)
- We have not found alien life yet
- It has not found us yet
  - UFO stories abound…
  - All of those which have been investigated have been explained as something more mundane
- Could there be other worlds?
- Could we communicate?

RADIO SEARCHES

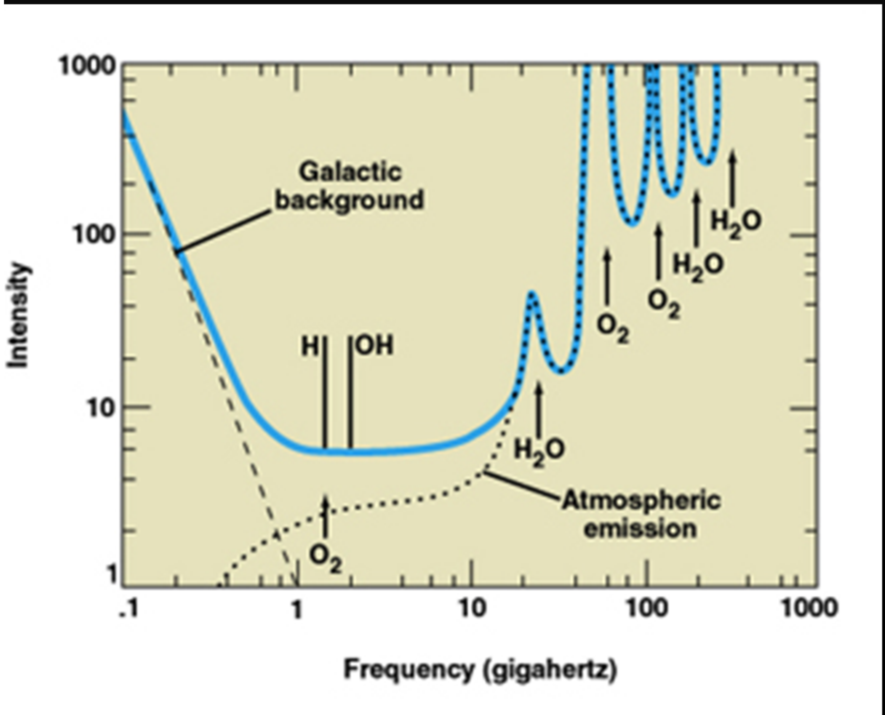
Arecibo Radio Telescope
1000 ft fixed dish (20 acres!)
in Puerto Rico

- Can we hear signals from other civilizations?
  - Either intentional
  - Or accidental
- People have been listening on and off for 40 years

HOW TO TUNE IN?

- There are a huge number of "channels"
- There are a huge number of places on the sky to look
- How to recognize a signal if you saw it?

CHANNELS



The “Water Hole”

- These are radio frequencies
  - Modern receivers can listen on many at once, but you still have a limited selection
- Avoid frequencies where natural sources are “loud”
- Good range – 1,000 to 10,000 MHz
  - 21cm H radiation promising
  - Astronomers would look there, and natural vs. artificial would be easy to see

WHERE TO LOOK?

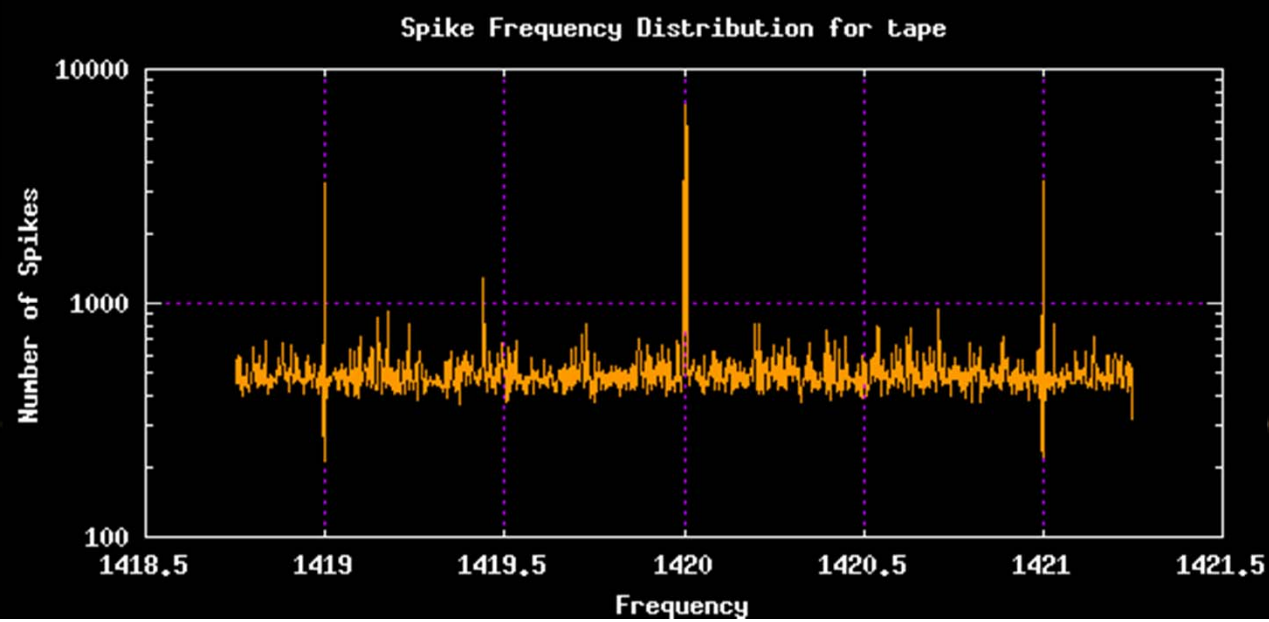
- First places watched are nearby stars, especially Sun-like ones
  - Getting telescope time (especially for a long-shot observation like this) is hard
- “Piggyback” mode popular
  - Signals from radio scopes being used to do other observations split off and analyzed for artificial signals

SETI@HOME

- That’s a LOT of data
- Clever idea – get many small computers crunching on it
- SETI@Home sends data chunks out to people’s screen savers
  - ~10 million people contributed many millions of CPU years
  - First of many such “distributed computing” projects

WHAT TO LOOK FOR?

- Signals which repeat
  - First pass – quickly (“beep beep beep”)
  - Second pass – is it still beeping if you come back later?



ELIMINATING NOISE

- Known frequencies can be eliminated
  - Equipment, earthly transmissions
- Odd signals which stick around and aren't known noise are investigated more closely
  - There are few enough of them that getting a dedicated chunk of follow-up telescope time is not unreasonable

COMMUNICATIONS

- Say we do find an artificial radio signal
  - What does it say? How to decode it?
- Or the reverse – what would we encode if we were trying to talk to ET?
  - Some messages have been beamed at promising stars
  - Not that we have much of a choice – aliens 50ly from here might already be trying to decode “I Love Lucy”

TIME DELAY

- A major problem – the speed of light is too darn slow
- Say SETI finds something, we send back an answer
  - How many years later do the ETs get our reply?
  - How many more years before we see their answer to our questions?

WHAT TO SAY?

- Try fundamental physical and mathematical things
  - The sequence of Prime Numbers
  - The structure of Hydrogen
  - The value of π
- Things which would be very hard for random noise to duplicate!

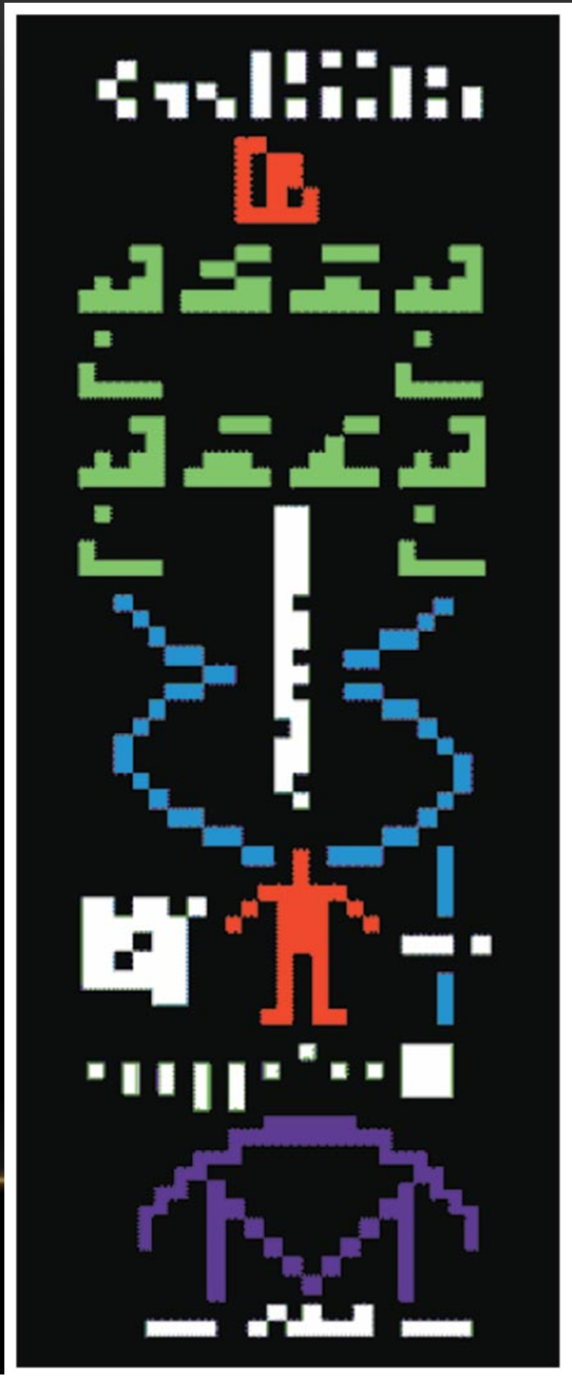
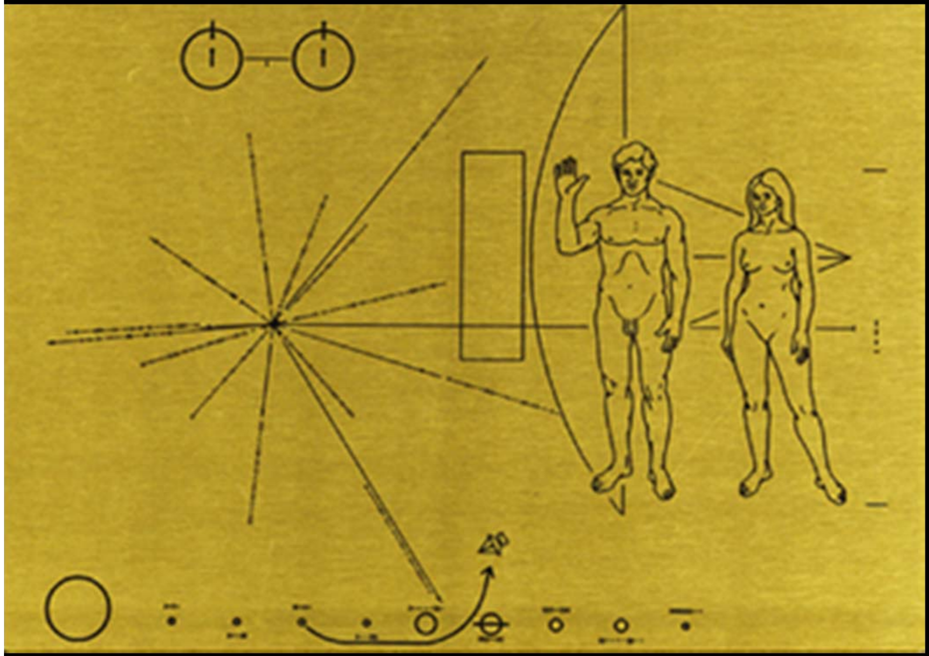


Fig. 19.21
Message sent in 1974
towards globular cluster M13

PHYSICAL COMMUNICATION

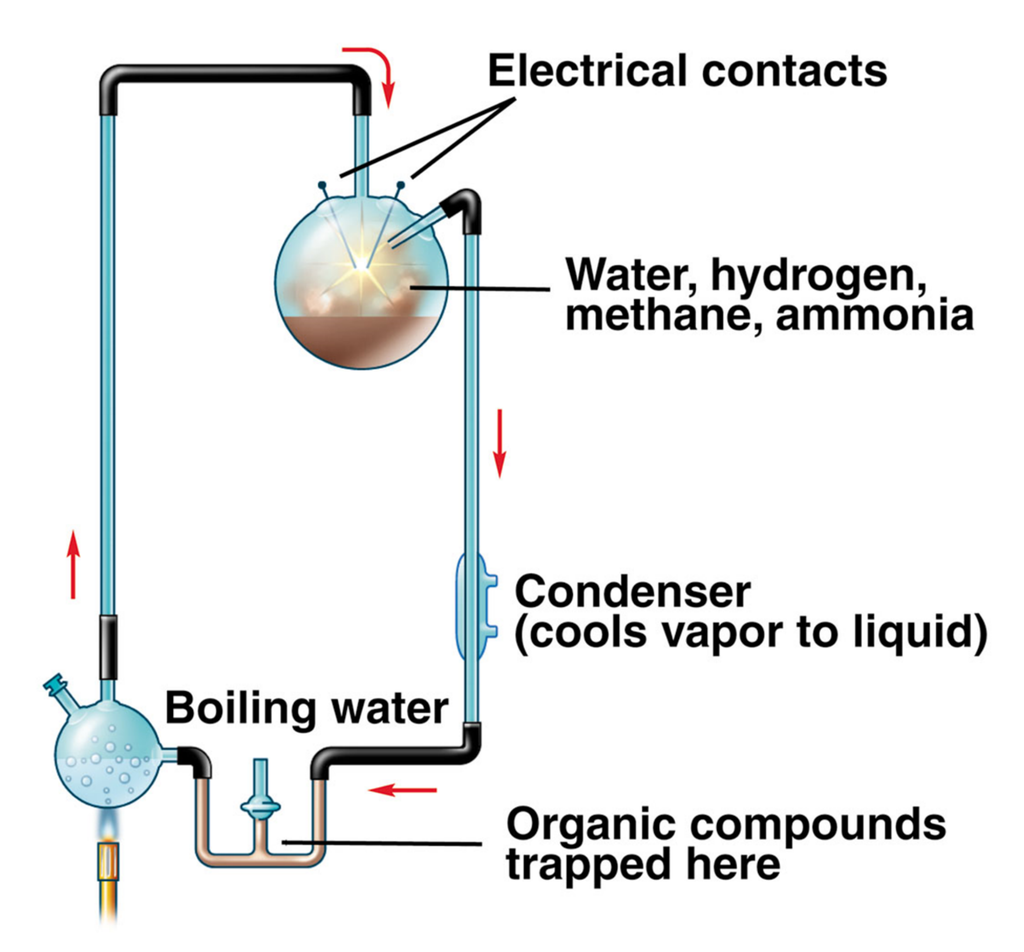


- Spacecraft headed out of the solar system carry information
  - Pioneer had these plaques
  - Voyager had records of “The Sounds of Earth”
- At least 40,000 ly before any probe will get within 2ly of a star, though

ORIGIN OF LIFE

- More of a Biology question, but if we are wondering about if other life is out there, we should see what we know about life here
- Haldane and Oparin suggested in the ’50s that Methane, Water, Ammonia, and Hydrogen (common things in the solar system and on the early Earth) could produce more complex organic compounds like amino acids if heated and zapped

SLUDGEMAKING



- Miller and Urey build this apparatus in 1950
- Test out the hypothesis, end up with sludge
  - Containing amino acids!
- CO_2, H_2O, N_2 were likely what was really around on the early Earth
  - Which work even better

LIFE HAPPENS

- Philosophical and Theological issues aside, the building blocks for life would exist on a new planet
- We also see them in interstellar space and on comets
- So it's not unreasonable to assume that other planets could get some form of life going

HOW COMMON IS LIFE?

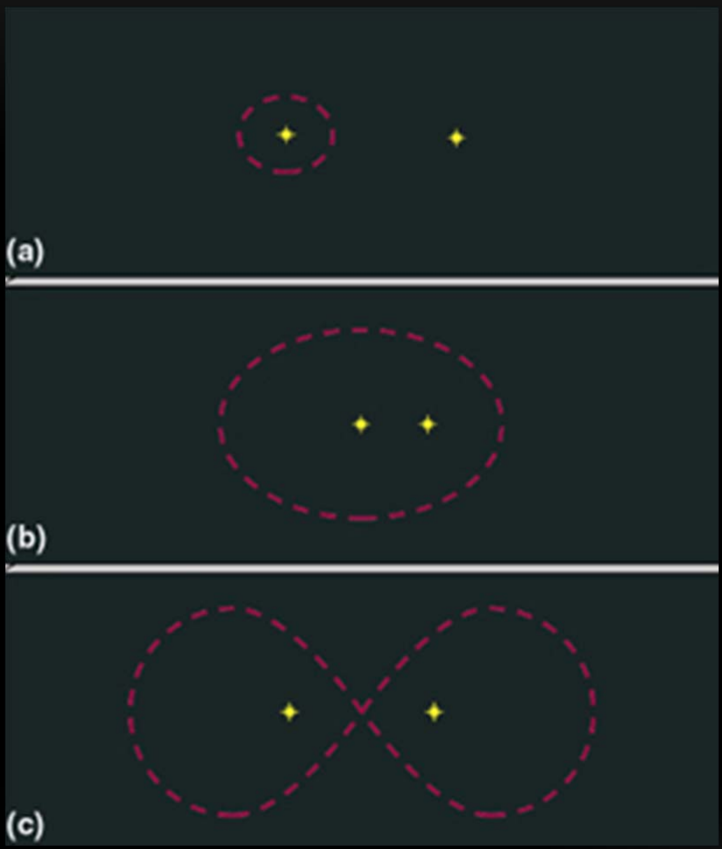
- For calculating things, a bunch of estimates isn't too bad sometimes
- "Order of Magnitude" analysis
  - Meaning OK within a factor of 10
  - *e.g.* the number of piano tuners in Boston?
- In this case, we use the Drake Equation

DRAKE EQUATION

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

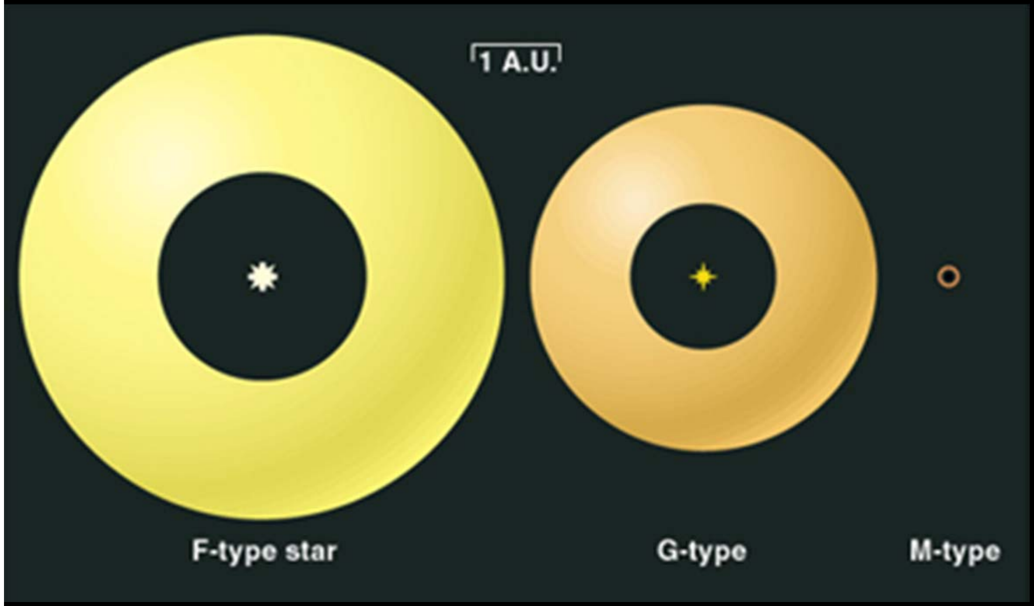
- R_* = rate of star formation
- f_p = fraction of stars with planets
- n_e = average # of planets per system that can support life
- f_l = fraction of those planets which develop life
- f_i = fraction of those planets where intelligence evolves
- f_c = fraction of intellegent species with the tech and interest to communicate
- L = average lifetime of such a civilization

PLANETS



- Most stars should form planets
  - We certainly see many close by
- Binary stars would have fewer planets though
  - Many stars are binary

"ZONE OF LIFE"



- Planets have to be close enough to star to be warm
- But not close enough to roast
- Bigger stars have too much UV radiation
- Bigger stars also do not last long enough for life to form

WHERE IN THE GALAXY?

- Need to be where stars with re-processed elements are (so not in the halo)
- Can't be where there are too many stars (SNe blasts would mess up life)
- Neat article saying that the stellar streams from where small galaxies have merged with the milky way might be a good place too

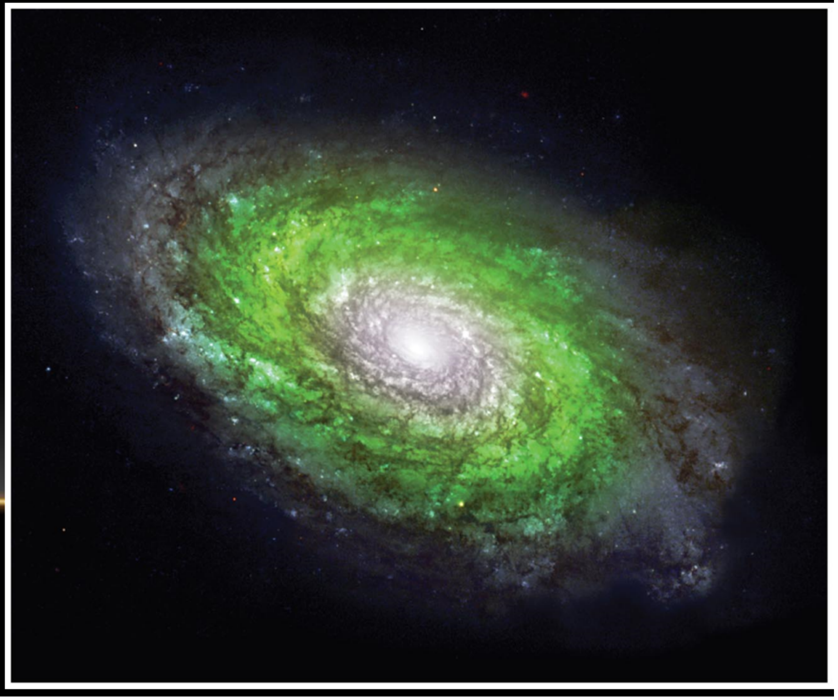
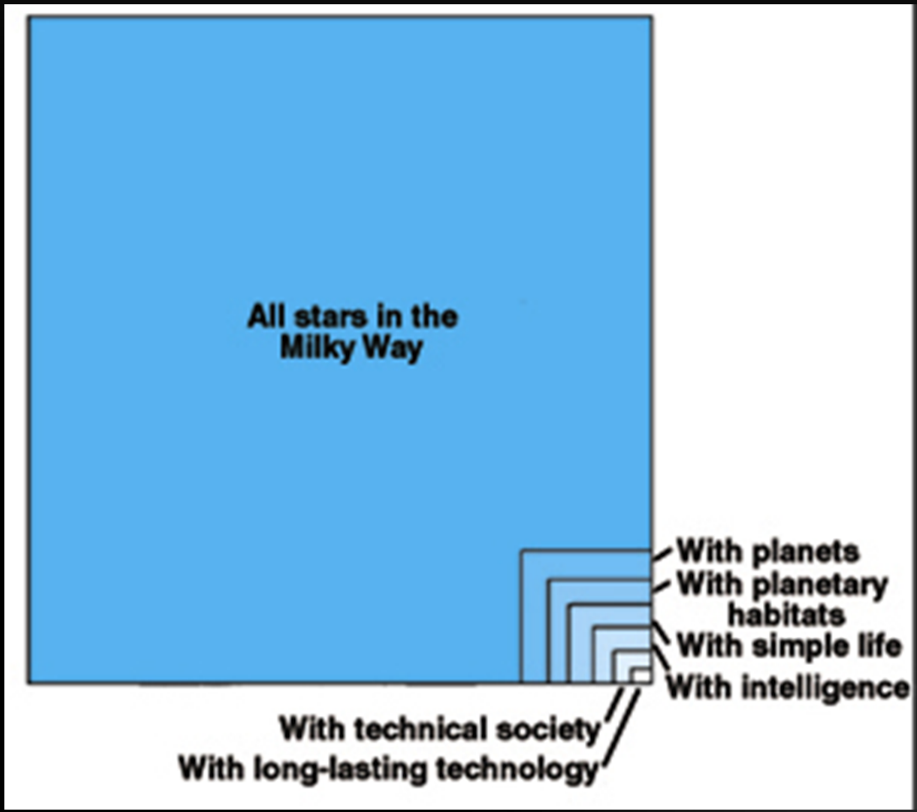


Fig.19.16

SO WHAT'S N?



- Estimates and Educated guesses range from:
  - 1 (us!)
  - to Millions (wow!)
- Try it yourself with this online calculator

An old graph: make that first cut much larger now that we can see so many other planets!

WHERE IS EVERYBODY?

- N could be near 1
- They could have visited us already (UFO’s not impossible, just none so far have been aliens)
- No one has ever broken the speed of light
  - Would make it really hard to travel

WHY LOOK?

- Curiosity!
- Not too hard to look
- Would be a Big Thing if we found extraterrestrial life