ASTR 1120
:: Stars and Galaxies ::

Life in the Universe (are we alone?)

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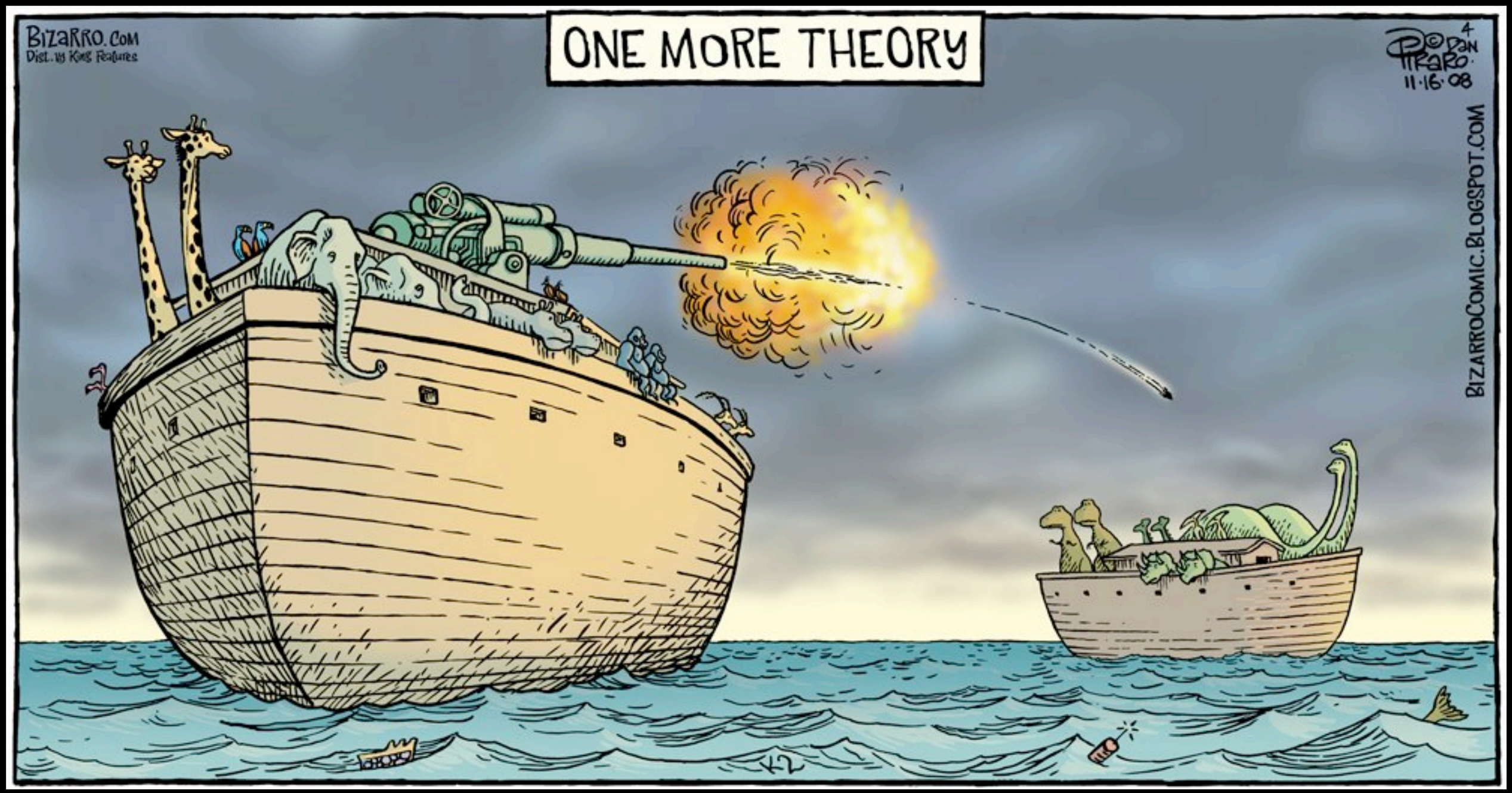
First, some information on Earth's history

- Earth's Timeline?
  - Earth formed ~4.5 billion years ago
  - The moon formed from a giant impact roughly tens of millions of years after that
  - Heavy bombardment (lots and lots of asteroid and comet impacts) lasted until roughly 3.9 billion years ago
  - Once bombardment subsided, life could finally take hold -- earliest record suggest life formed as early as 3.85 billion years ago

Life!

- Sort of... depends on your definition, but sidestepping that...
  - First “life” consisted of single-celled organisms capable of growing and reproducing
    - Some of these had considerable feedback effects on their environment -- cyanobacteria filled our atmosphere with oxygen!
  - Oxygen allowed for life to develop further and there was a progression from single-celled to multicellular organisms and eventually the earliest plants and animals appear
- Roughly 225 to 250 million years ago early dinosaurs and mammals begin to the walk the earth
  - Dinos dominate at first, until a mass extinction occurred ~65 million years ago -- mammals get the opportunity to thrive!
- We (humans) walk on the scene only a few million years ago -- after 99.9% of the Earth’s history had already gone by

Or...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What does one need for life?

- From our somewhat biased vision of "life", it boils down to three things:

1. A source of nutrients from which to build living cells
2. Energy to fuel the activities of life (sunlight, chemical reactions, heat of Earth)
3. Liquid water

Before we get too carried away, any other life in our solar system?

- Mars?
  - Liquid water may have flowed on the surface at some point
  - Likely that there is subsurface ice
- Europa?
  - Decent probability that it has a deep ocean below its icy crust
  - Tidal heating could provide a heat source

Life around other stars

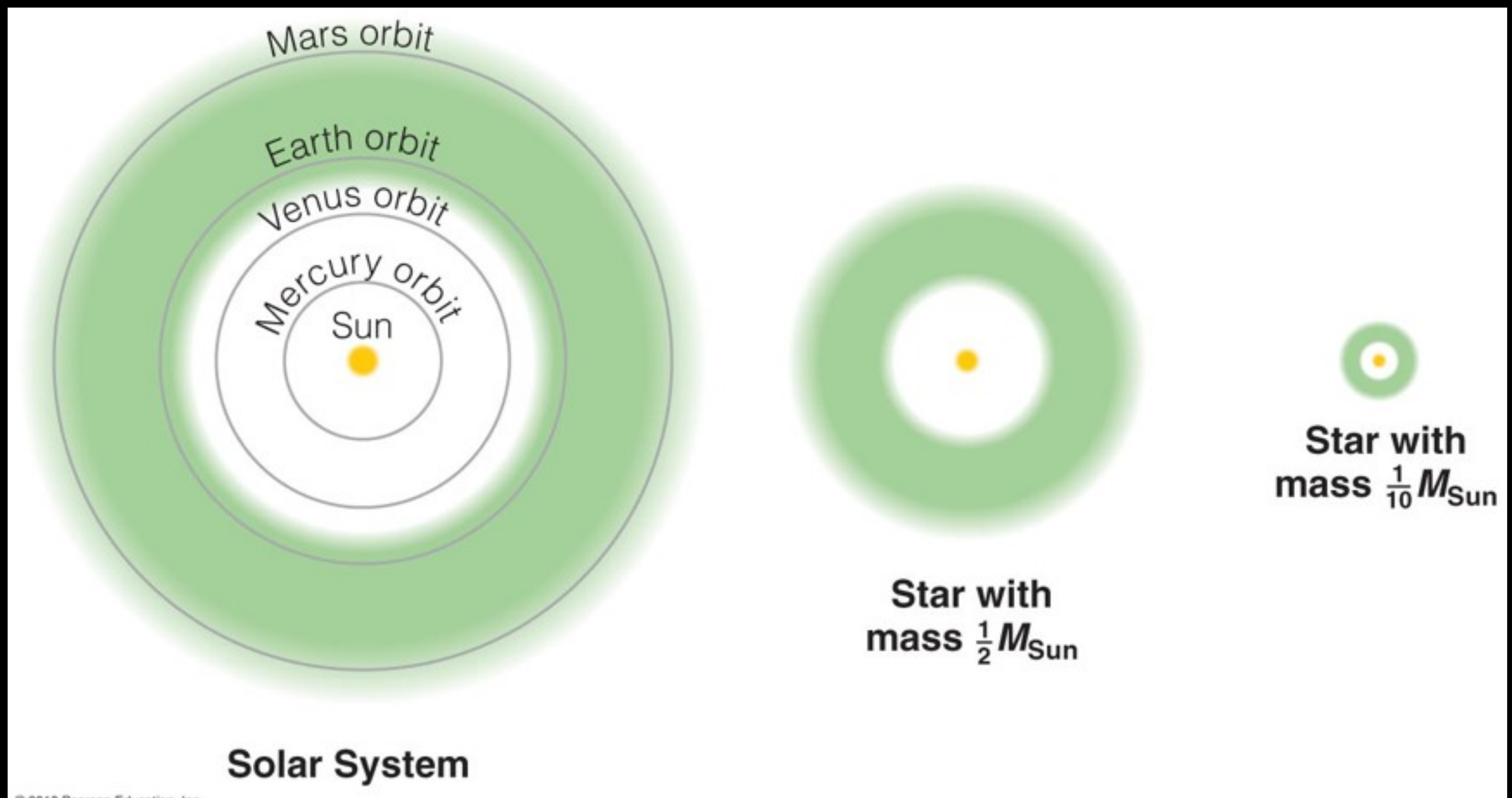
- Until very recently, the majority of detected exoplanets had been jupiter-like (massive gas giants)
  - Very low chance of life as we know it
- The Kepler Spacecraft may be succeeding in finding Earth-like planets (defined as being less than 2 R_{Earth})

What are the conditions needed for life-supporting planets?

- Life needs time to form and evolve, this rules out planets around massive stars (why?)
  - This only rules out ~1% of all stars
- A life-supporting planet would ideally need to have a stable orbit, such orbits would be less likely around multiple star systems
  - This rules out roughly half of the remaining stars
  - Still have 100 billion or more viable star systems in our galaxy

The habitable zone

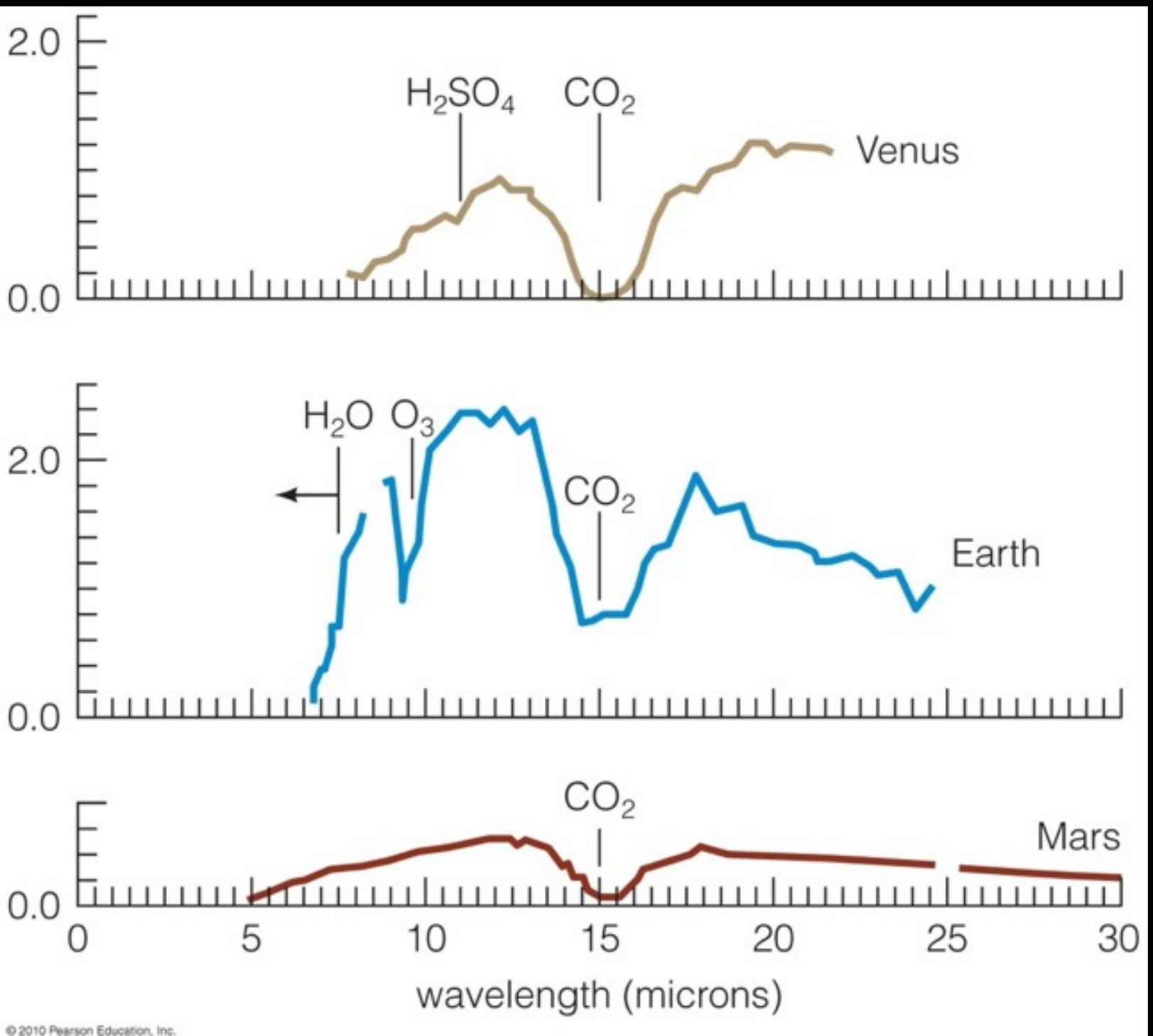
- Assuming you have a single star system with a long enough lifetime, where would the planet need to be?
  - Need a surface temperature that would allow for liquid water



The difficulty of finding such planets

- They are small!
- They are close to the star they orbit
- Analogy: Looking for an earth-like planet is like standing on the East Coast and trying to spot a pin head on the West Coast

Once we find them, how will be know if they are truly habitable?



- Taking spectra should tell us something about the atmosphere

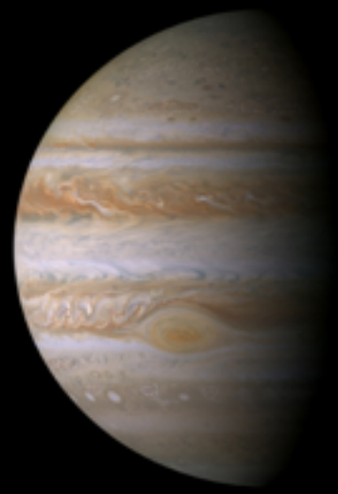
Rare Earth Hypothesis

(Peter Ward and Don Brownlee)

- Up to this point we've just been assuming that if you have the kind of star, you can end up with the right kind of planet
- But does is that enough to ensure that life will arise and evolve?
- Did we just have a lot of good luck?

Rare Earth Hypothesis

- Galactic Constraints
  - Only a relatively small region of the Milky way may actually form Earth-like planets -- a galactic habitable zone
    - Low abundance of heavy elements in the outer edge of the galaxy
    - High supernova rates in the inner regions due to high stellar density
- Planetary system constraints
  - Jupiter could have been our big brother that scares off the bullies?
  - Shorter bombardment period because Jupiter “kicks out” dangerous objects
  - Gas giants could move terrestrial planets out of the sweet spot



- Climate stability concerns
  - Plate tectonics help regulate climate through carbon dioxide cycle -- is this trait common to terrestrial planets?
  - Giant moon keeps our planet in alignment, if the axis were titled further, seasons might be considerably harsher

The Search for E.T.

- If *intelligent* life is our there, we could search in an entirely different away
  - SETI: Search for Extraterrestrial Intelligence
    - Attempt to detect signals that other intelligent being might be sending into space, intentional or otherwise
  - How many signals might be broadcasting such signals right now?

The (simplified) Drake Equation

- Proposed by Frank Drake at the first conference on the search for extraterrestrial intelligence held in 1961
- Number of Civilizations = N_{HP} x f_{life} x f_{civ} x f_{now}
  - N_{HP}: number of habitable planets
  - f_{life}: fraction of habitable planets that have life
  - f_{civ}: fraction of life-bearing planets upon which a civilization has *at some point* been capable of interstellar communication
  - f_{now}: the fraction of civilization-bearing planets that happen to have such a civilization right *now*

What are we looking for?

- How does SETI work?
  - If we assume other civilizations are like our's then they are probably leaking radio transmissions out in to space
  - Or perhaps they have tried sending a message, we've sent one of our own!
  - We should be able to pick up these signals with high-sensitivity radio telescopes

The Arecibo Radio Message

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1010101010100100100000000000000000000000000000000000000110000000000000000
0011010000000000000000000011010000000000000000000010101000000000000000000000111
110000000000000000000000000000000011000011100011000011000100000000000000011
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1000100001000100100010010001000000000100010100010000000000000010000100001000
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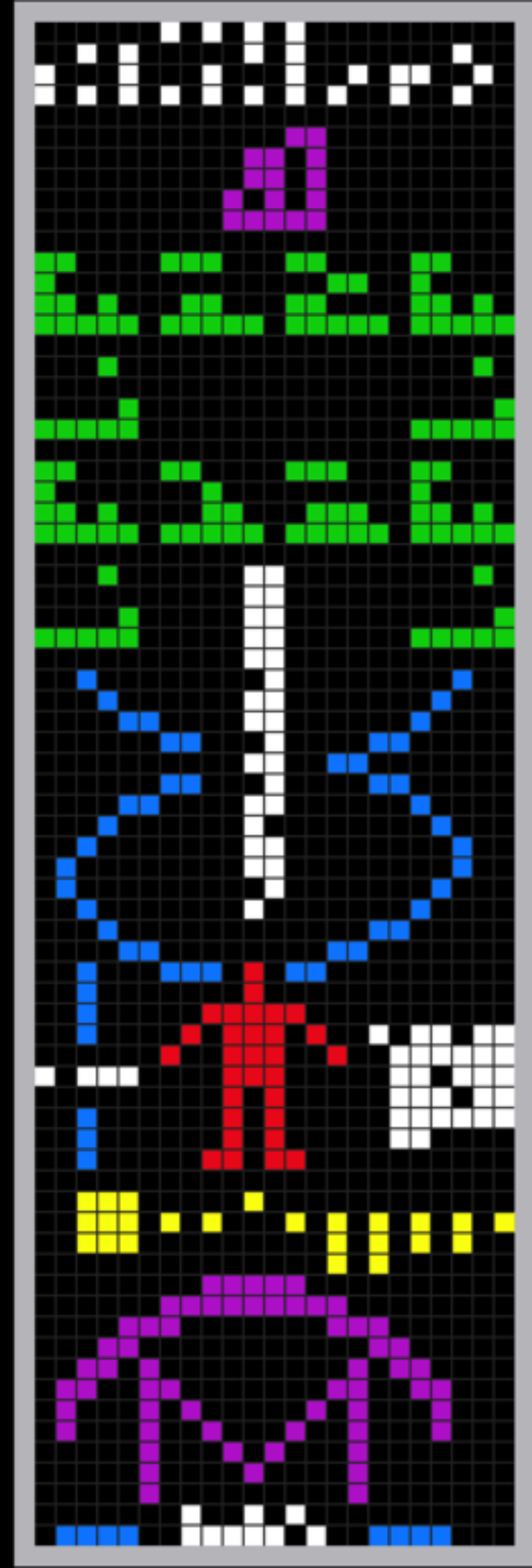
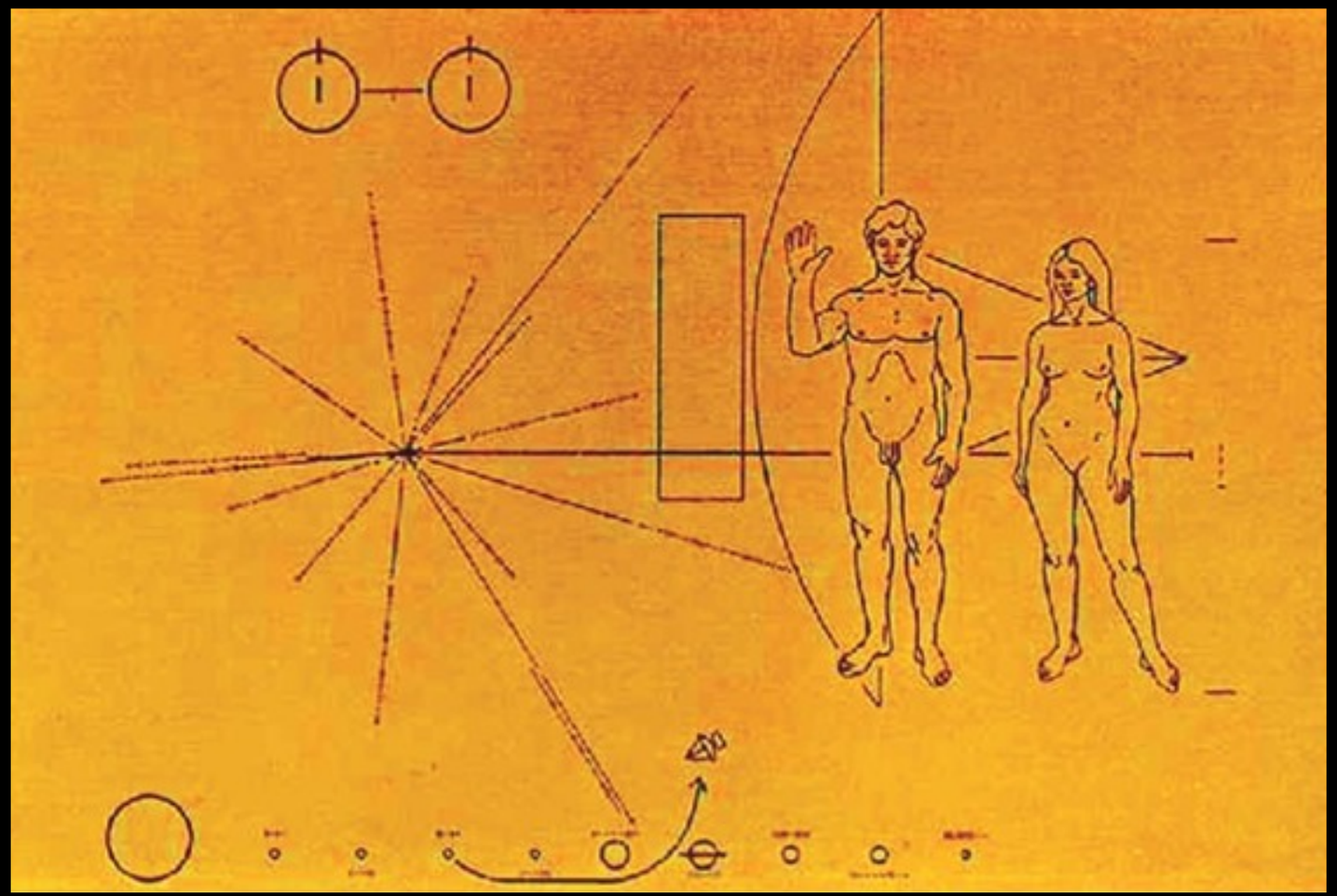
The Arecibo Radio Message

- Beamed toward M13
  - Lots of stars, maybe good chance of a civilization?
  - Far away, ~21,000 ly
- Only 3 minutes long
- Coded in binary
- 73 rows, 23 columns -- prime numbers!





Other Messages

^ Pioneer

Voyagers 1 and 2 >

The End!

now.... pizza and Jeopardy!