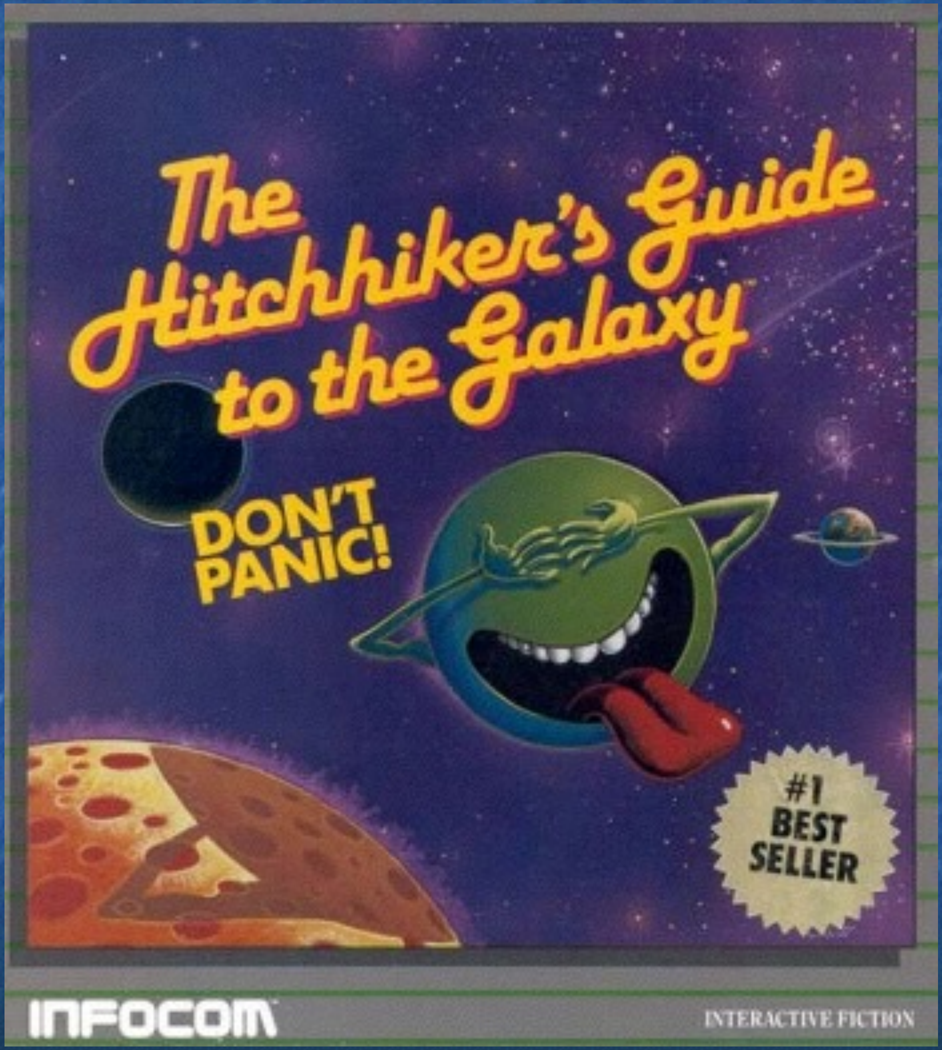
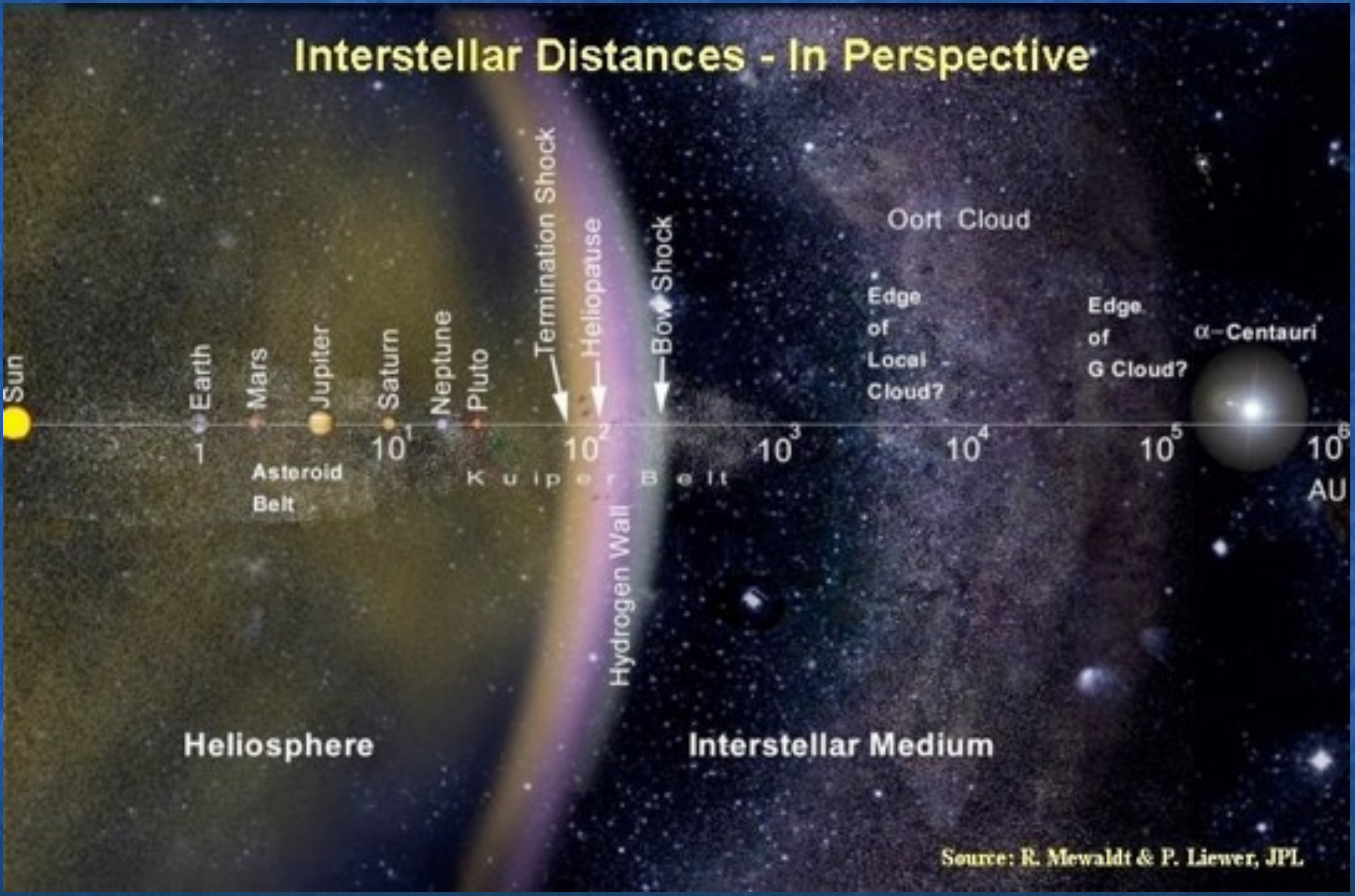
The challenge of interstellar travel



The challenge of interstellar travel

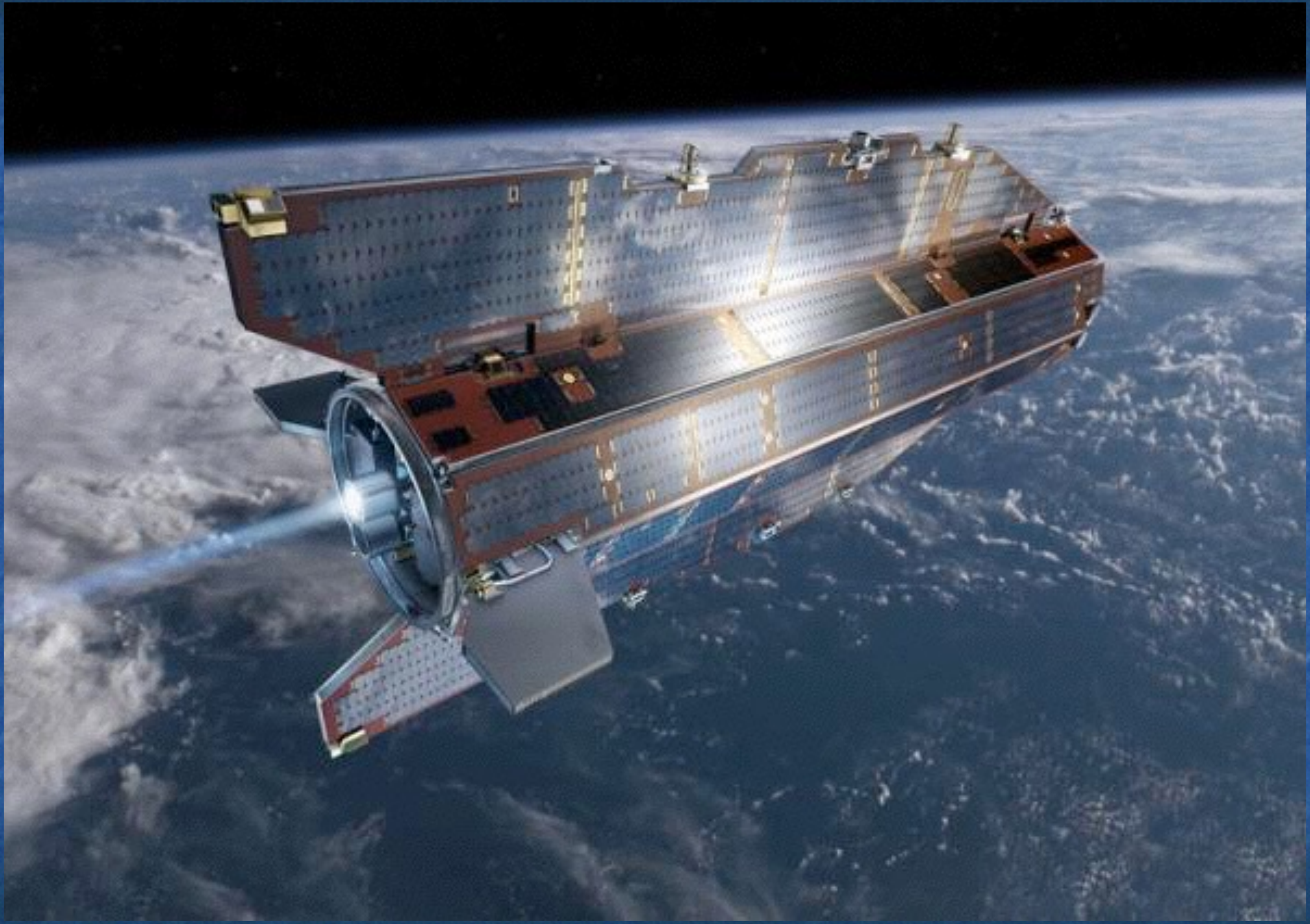
- Interstellar travel - travel between star systems - presents one overarching challenge:
- The distances between stars are enormous compared with the distances which our current spacecraft have travelled
  - Voyager I is the most distant spacecraft, and is just over 100 AU from the Earth
  - The closest star system (Alpha Centauri) is 270,000 AU away!
- Also, the speed of light imposes a strict upper limit to how fast a spacecraft can travel (300,000 km/s)
  - in reality, only light can travel this fast

How long does it take to travel to Alpha Centauri?



Propulsion

Chemical rockets



$F = ma$

- Newton's third law.
- Force = mass x acceleration.
- You bring the mass, your engine provides the force, acceleration is the result

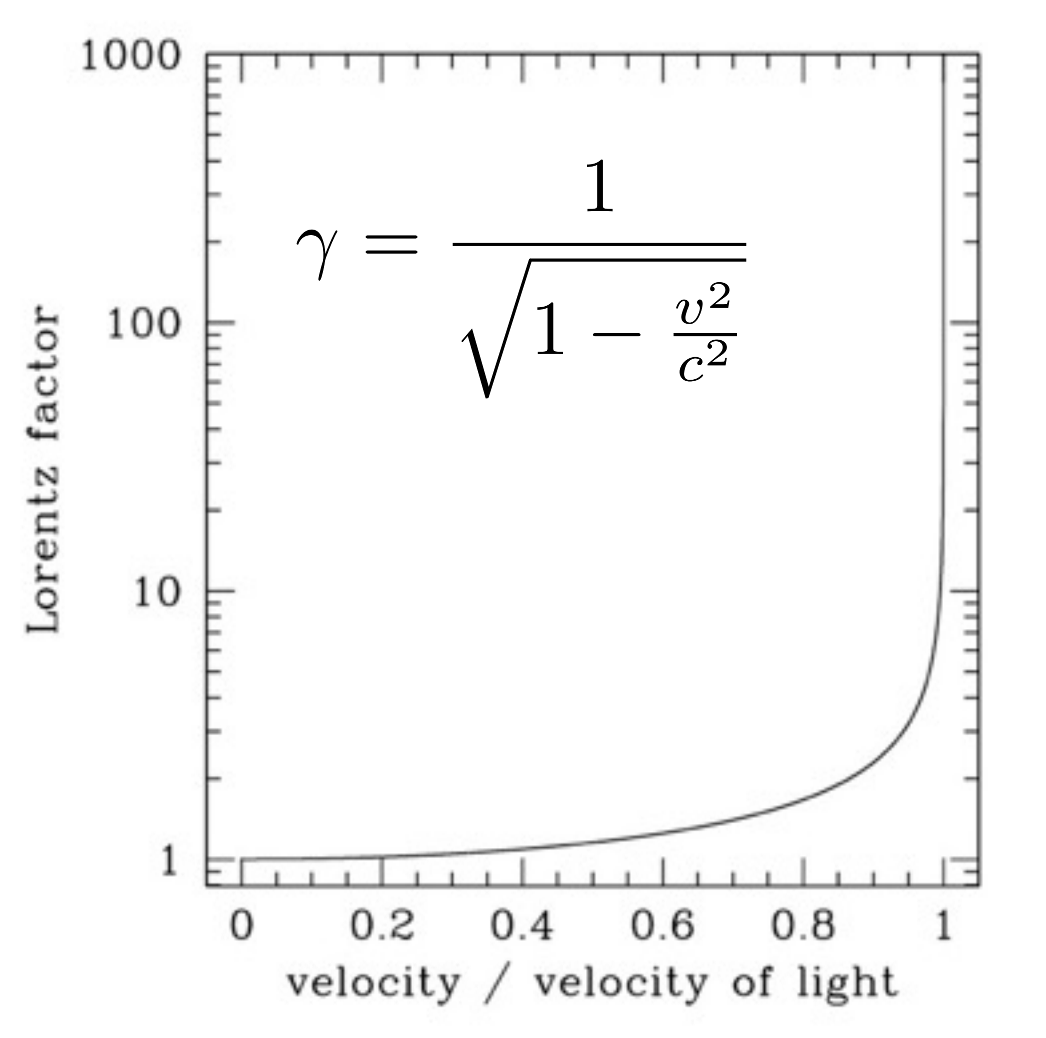
The constant acceleration case - plus its problems

- Let's take the case of Alpha Centauri.
- You are provided with an ion thruster.
- You are told that it provides a constant 1g of acceleration.
- Therefore, you keep accelerating until you reach the half way point before reversing the engine and decelerating the rest of the way - coming to a stop at Alpha Cen.
- Sounds easy?

Relativity and nature's speed limit

- What does it take to maintain 1g of accelaration?
- At low velocities compared to light to accelerate a 1000kg spacecraft at 1g ($10ms^{-2}$) requires 10,000 N of force.
- However, as the velocity of the spacecraft approaches the velocity of light relativity starts to kick in.
- The relativistic mass can be written as γ x mass, where γ is the relativistic Lorentz factor.
- γ increases without limit as you approach "c".
- Therefore, to maintain constant acceleration, you have to apply more force as the velocity increases.
- Eventually you reach the limit of your engine at $v \ll c$.
- This is nature's way of keeping you under the speed limit.

The Lorentz factor



$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The paradoxes of relativity

- It's all relative!
- The observations you make of the world around you depend upon the relative velocity between you and the thing being observed.
- Time dilation: moving clocks run slow $T_{obs} = \gamma \times T_{rest}$
- Length contraction: moving rulers become shorter $L_{obs} = \gamma \times L_{rest}$

Back to the future

- Einstein's theory of special relativity says that time slows down when you travel very fast
- This time dilation makes it possible to greatly reduce interstellar travel times
- For a spaceship travelling at speed v, its time will slow down by the Lorentz factor.

TABLE 13.1 *Round-Trip Travel Time to Vega*

This table shows the time that passes on Earth and the time that passes for the crew of a spaceship on round-trip journeys at various speeds to the star Vega, a trip of 25 light-years in each direction. Speeds are given as fractions of the speed of light, c = 300,000 km/s. Note that the first-row speed of 0.00005c is equivalent to 54,000 kilometers per hour, which is roughly the speed of our fastest chemical rockets today.

Speed	*Time Measured on Earth*	*Time Measured on Ship*
0.00005*c*	1,000,000 yrs	1,000,000 yrs
0.1*c*	500 yrs	498 yrs
0.5*c*	100 yrs	86 yrs
0.7*c*	72 yrs	52 yrs
0.9*c*	56 yrs	24 yrs
0.99*c*	50 yrs	7 yrs
0.999*c*	50 yrs	2.2 yrs
0.9999*c*	50 yrs	8 months

Are faster speeds possible?

- None of these propulsion systems are capable of speeds faster than a few percent of the speed of light
- Several more speculative ideas may allow for speeds closer to the speed of light
  - Matter-antimatter engines
  - Interstellar ramjets

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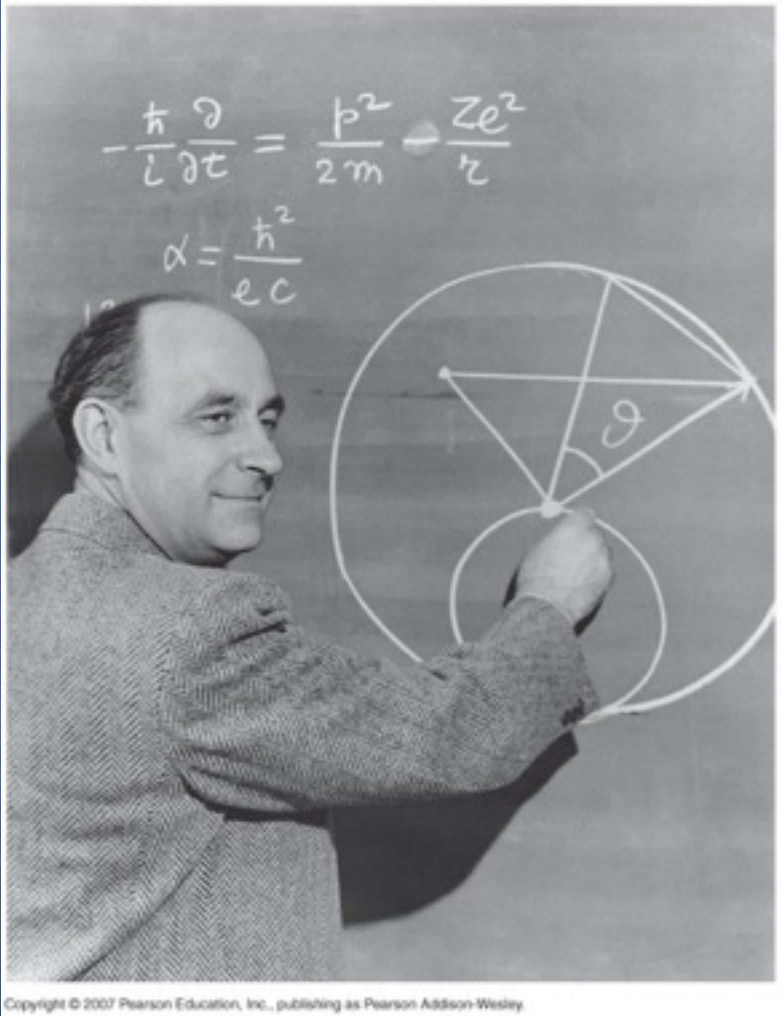
INTERSTELLAR
MANKIND WAS BORN ON EARTH. IT WAS NEVER MEANT TO DIE HERE.
NOVEMBER 2014

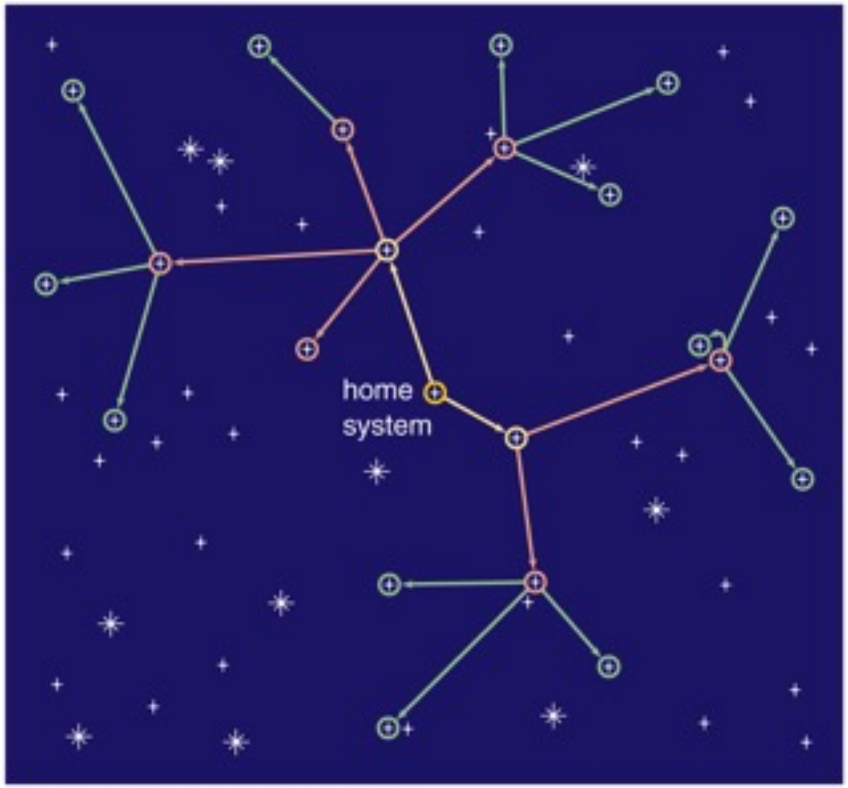
The Fermi Paradox

- Given time, it seems likely that an advanced civilization should be able to colonize the Milky Way
- Assuming Earth is not special, other advanced civilizations should have arisen in our galaxy
- So, where is everybody?
- This is the Fermi paradox



Colonization

- If advanced civilizations last for many thousands or millions of years, most should be much more advanced than we are
  - we've only been capable of space travel for about 50 years
- Even at modest speeds of travel, they should be able to colonize the Milky Way in well under a billion years



Possible Explanations of the Fermi Paradox

- We are alone
  - or at least, the first to arise in the Milky Way
- Civilizations are common, but no one has colonized the Galaxy, because
  - it is too challenging technologically
  - they choose not to
  - civilizations always destroy themselves early on
- There is a Galaxy-wide civilization, but we haven't found it yet
  - perhaps they are even deliberately staying hidden

Some Related/Alternative Explanations

- They are already here
- They have been here in the past
- Everyone is listening, but no one is signalling
- Cloudy skies are common
- Intelligence is extremely rare
- Etc.!

What Steps Can We Take Towards Resolving the Fermi Paradox?

- SETI
  - if successful, we would resolve the paradox by establishing the existence of other civilizations in the Milky Way
- Detection of habitable extra-solar planets
  - In principle, we should be able to make a much better estimate of how common Earth-like planets are
    - if they turn out to be very rare, this would help to explain the paradox (with the "We are alone" option)
  - Even better, if we detect signs of life, we will know life is common
- Detection of independently arising microbial life in the solar system
  - this would imply that life is common throughout the galaxy, and therefore that other civilizations are more likely to exist
- Long term human survival
  - if we can survive climate change, nuclear war, etc., we will know it is possible for other civilizations to survive too

Astrobiology in the 21st Century