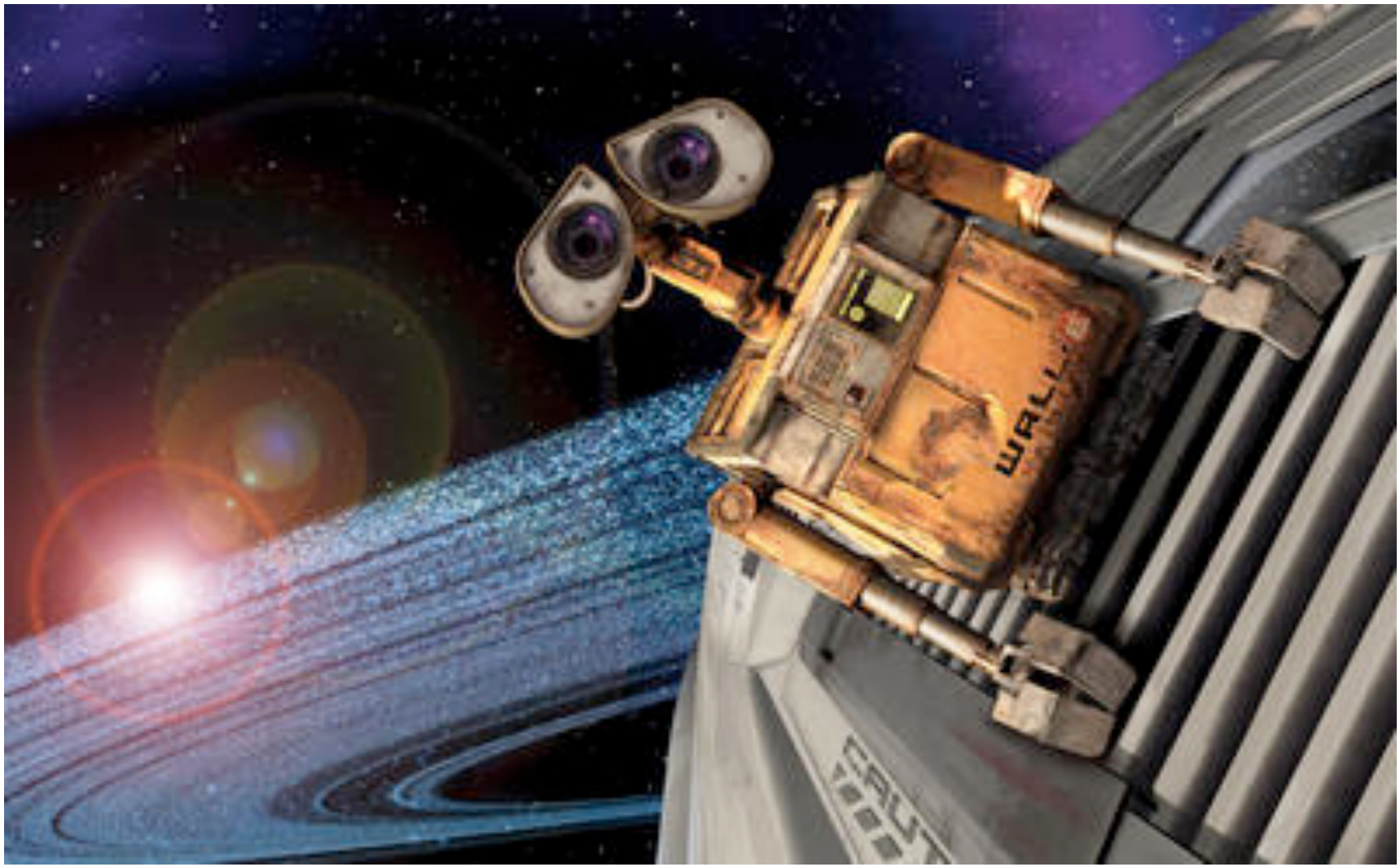
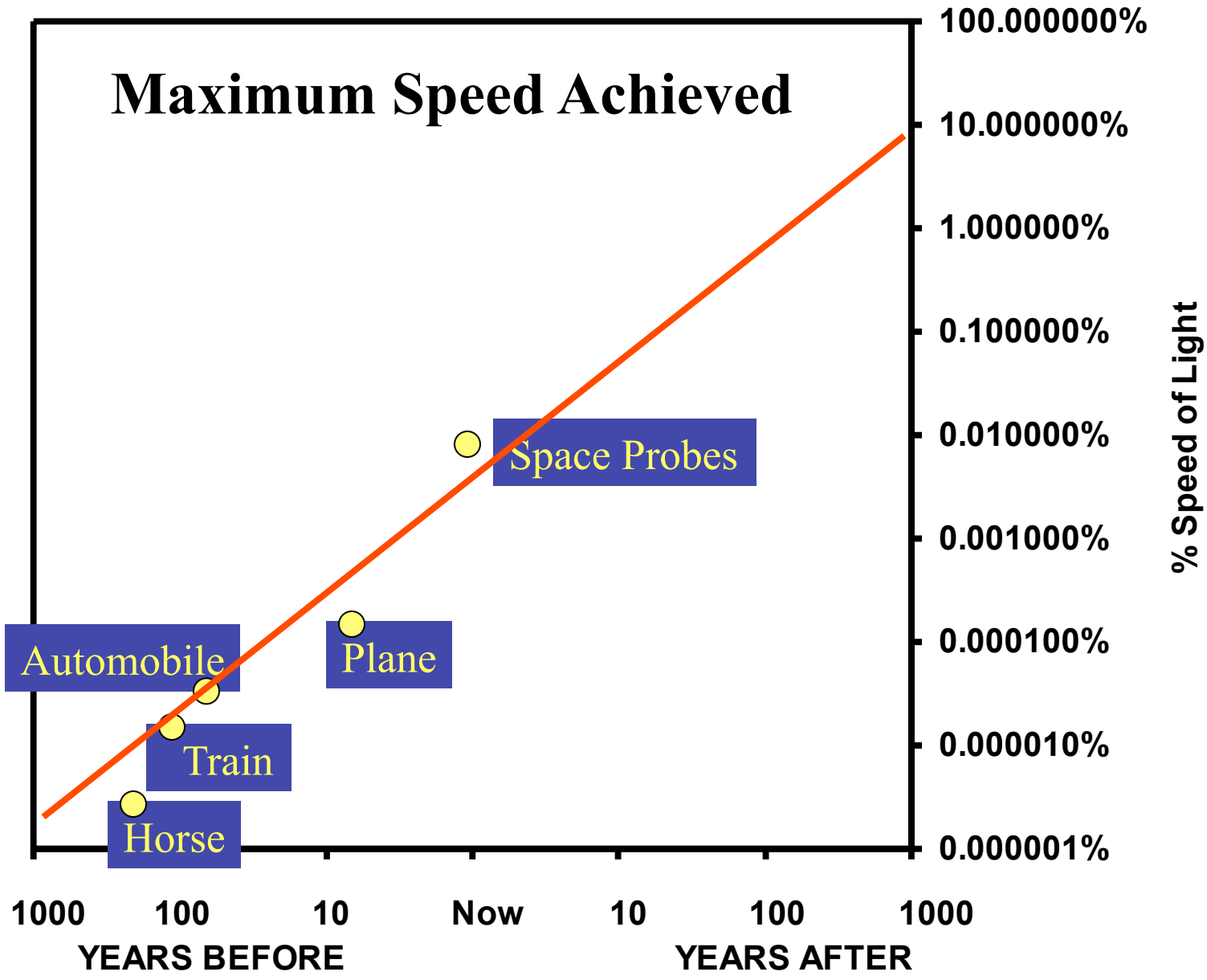
Interstellar Travel & The Fermi Paradox




Maximum Speed Achieved
Space Probes
Plane
Automobile
Train
Horse
100.000000%
10.000000%
1.000000%
0.100000%
0.010000%
0.001000%
0.000100%
0.000010%
0.000001%
% Speed of Light
1000
100
10
Now
10
100
1000
YEARS BEFORE
YEARS AFTER

Rocket Limitation

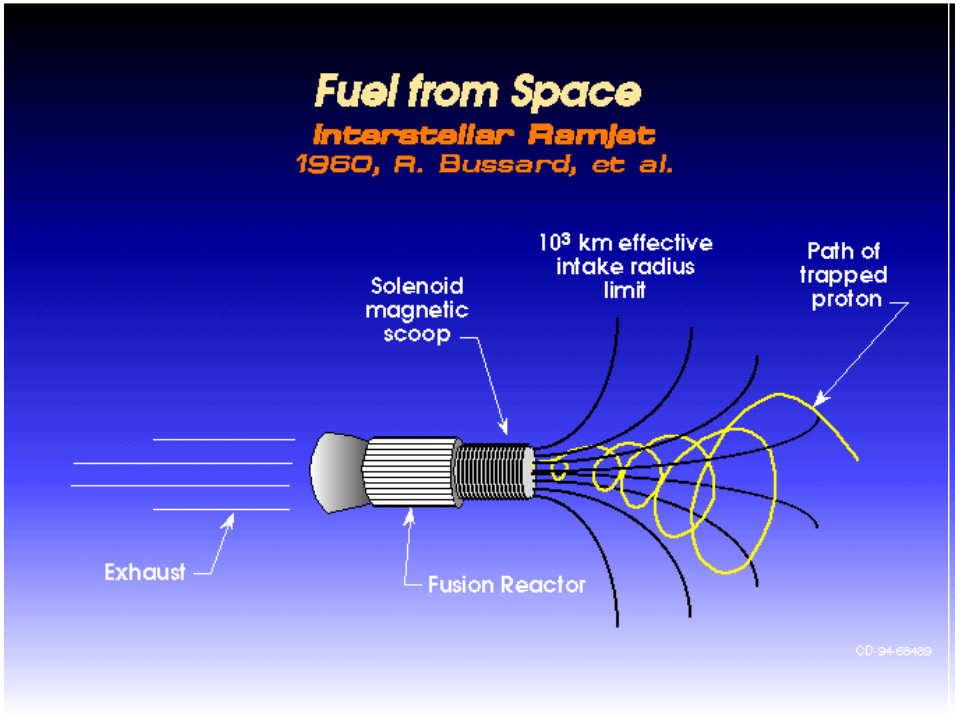
Propellant Mass to send one canister past Alpha Centauri within 900 years

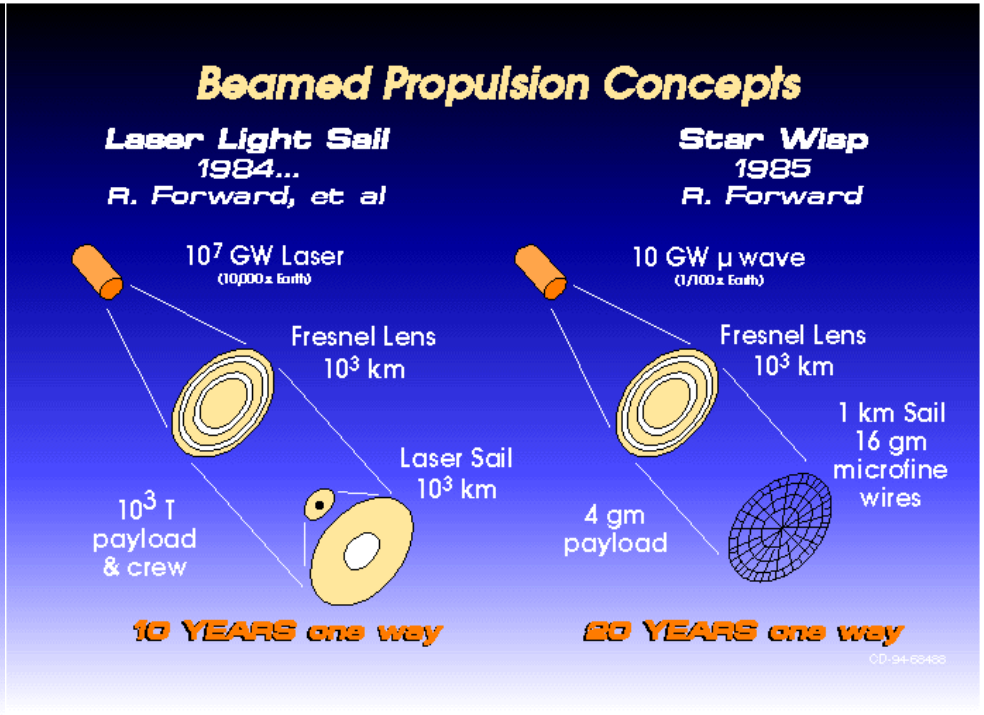
Chemical	Fission	Fusion	Ion/Antimatter
(500 sec)	(5,000 sec)	(10,000 sec)	(50,000 sec)
$\approx 10^{137}$ kg	$\approx 10^{17}$ kg	$\approx 10^{11}$ kg	$\approx 10^{5}$ kg
	A BILLION	A THOUSAND	TEN

Not enough mass in universe

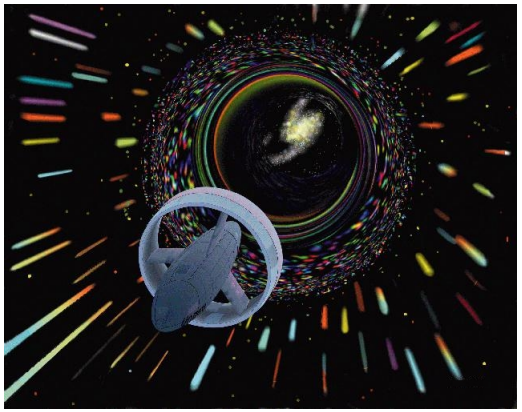
Conclusion: we need a Propulsion Breakthrough ; NO PROPELLANT !

Some ideas for the future





There are plausible ideas to work on, but **warp drive and worm holes** may have to wait.



Interstellar Travel: Issues

1. How far do we have to go?
   To reach another star: α Centauri, 4.2 light years away.
   To reach a known planetary system: ε Eridani, 10 light years away
   To reach a planet like the Earth: who knows?

2. How long do we want to wait?
   Adult life: 50 years
   Multigeneration travel: 30 generations = 1000 years?
   (Linguistic & Cultural stability becomes an issue…)

3. How long will it take?
   At 30 km/s (solar sail, ramjet): 4.2 light years in 42,000 years

   At 3000 km/s (nuclear pulse): 4.2 light years in 420 years

   Near the speed of light (a-matter): 4.2 light years in 4.2 years
   Galactic Centre in 26,000 years
   Nearby galaxies *in 2-10 million years*

Note: Teleportation — remote reconstruction of matter at light speed — is not ruled out by the laws of physics. Quantum collapse of the wave function does not prevent it.

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Slow transport is possible, and the only option to carry any significant payload.

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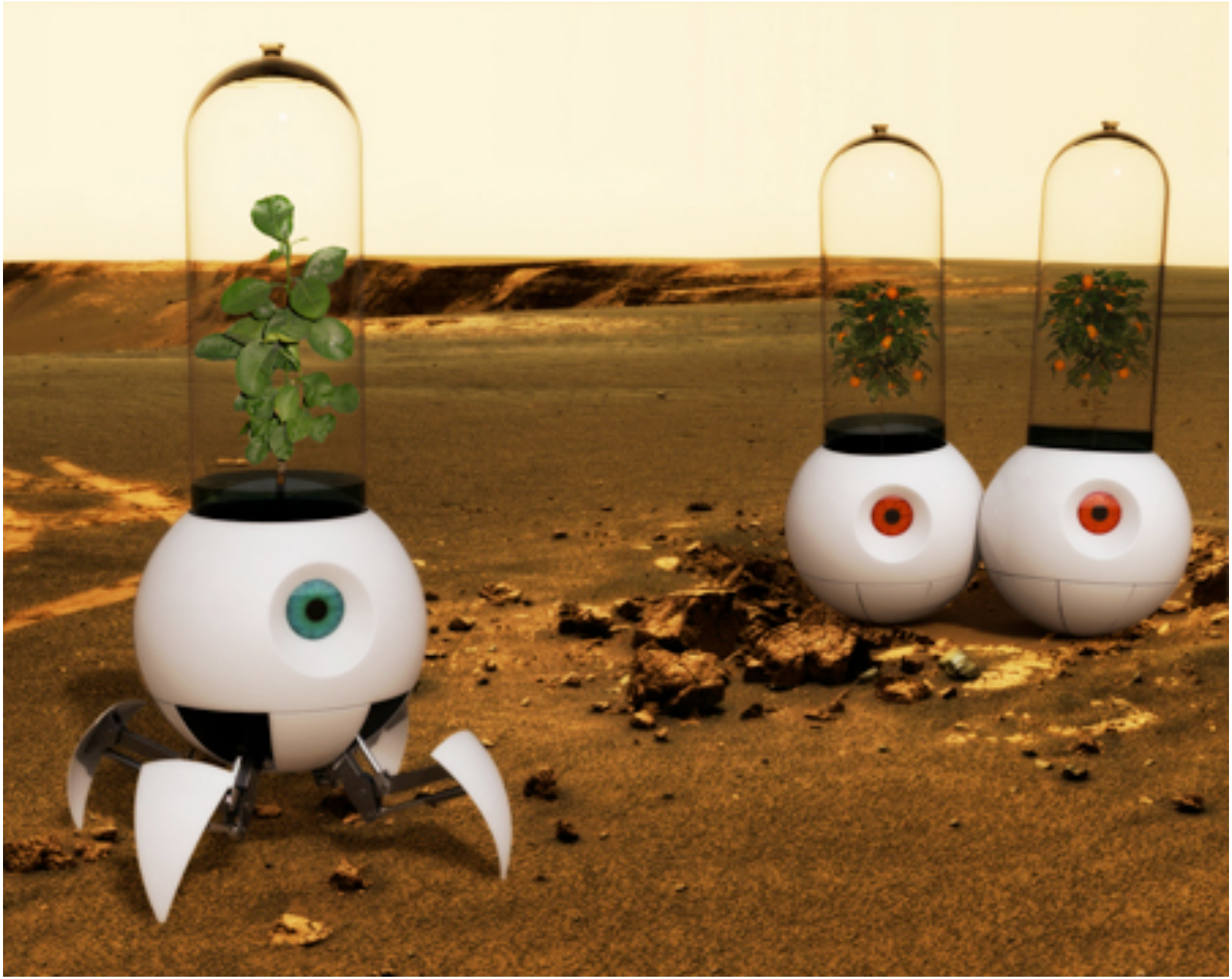
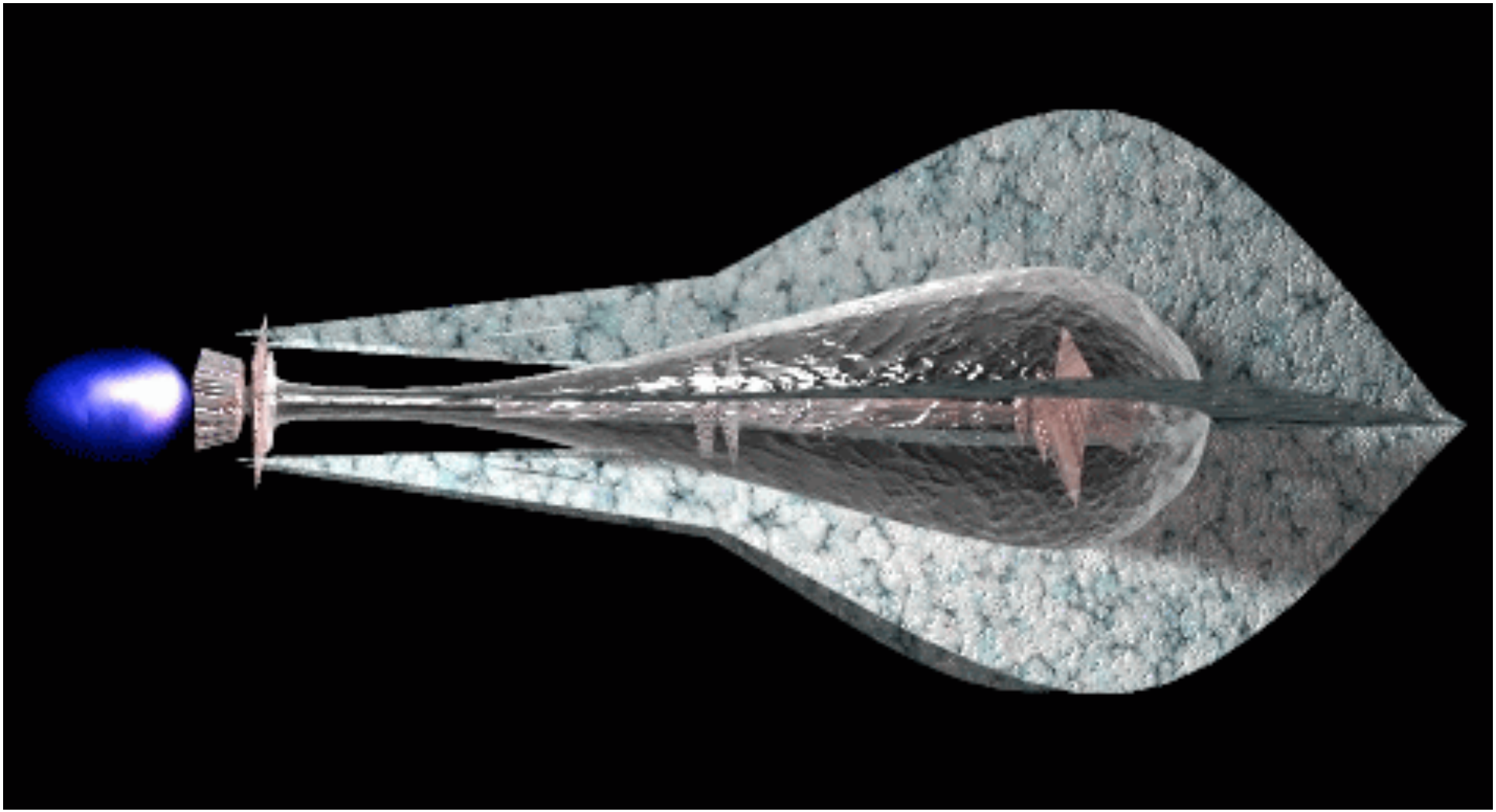
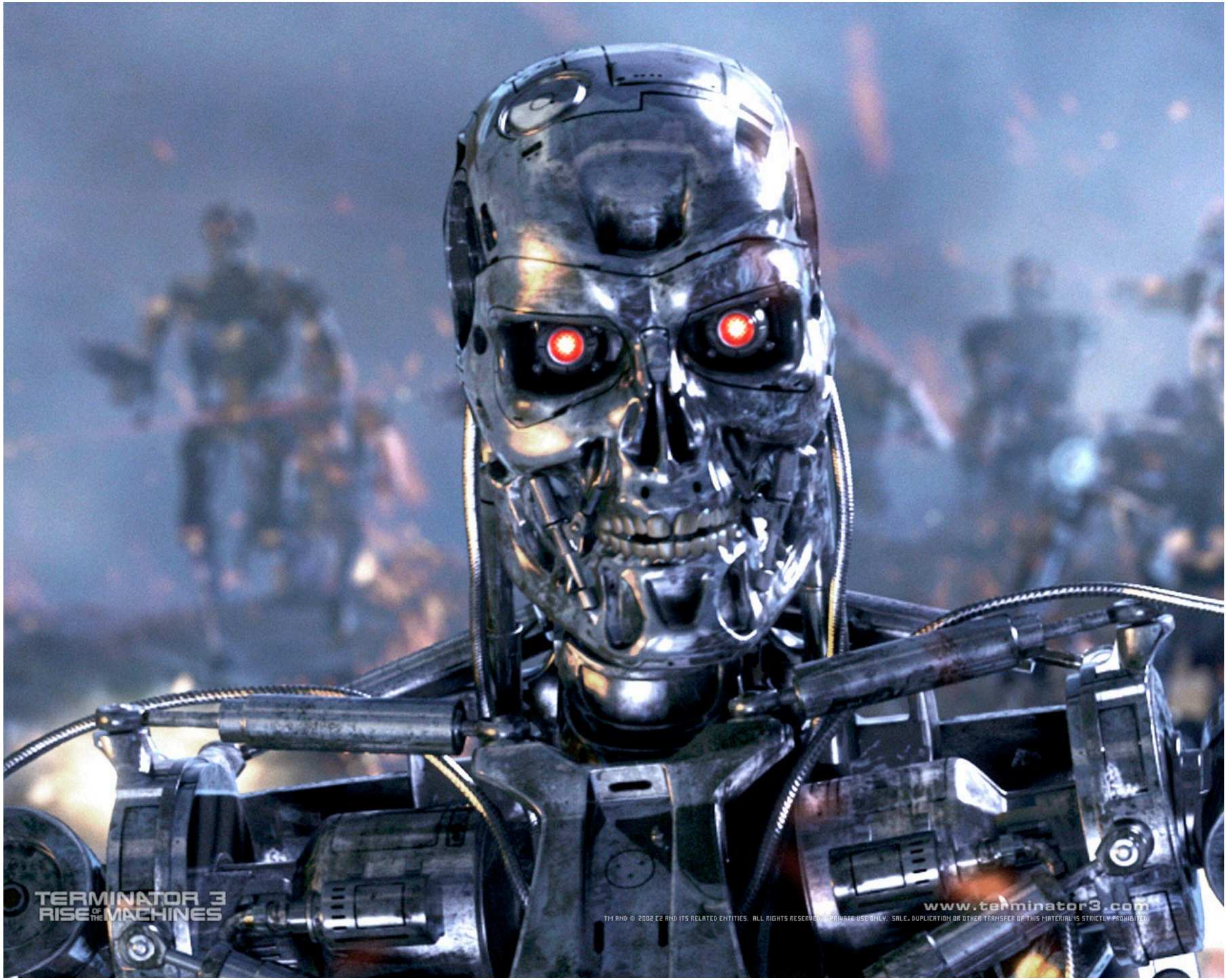


Von Neumann Machine
Self Replicating Interstellar Probe

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Average distance between Habitable planets?

How can we calculate this?

(1) Need to know how many Habitable Planets. Units: NONE

(2) Figure out ***volume*** of Milky Way. What is "shape" of Milky Way Galaxy? Units: lightyear^3

Average distance between planets?

Assume best estimates from Kepler of Habitable terrestrial planets:

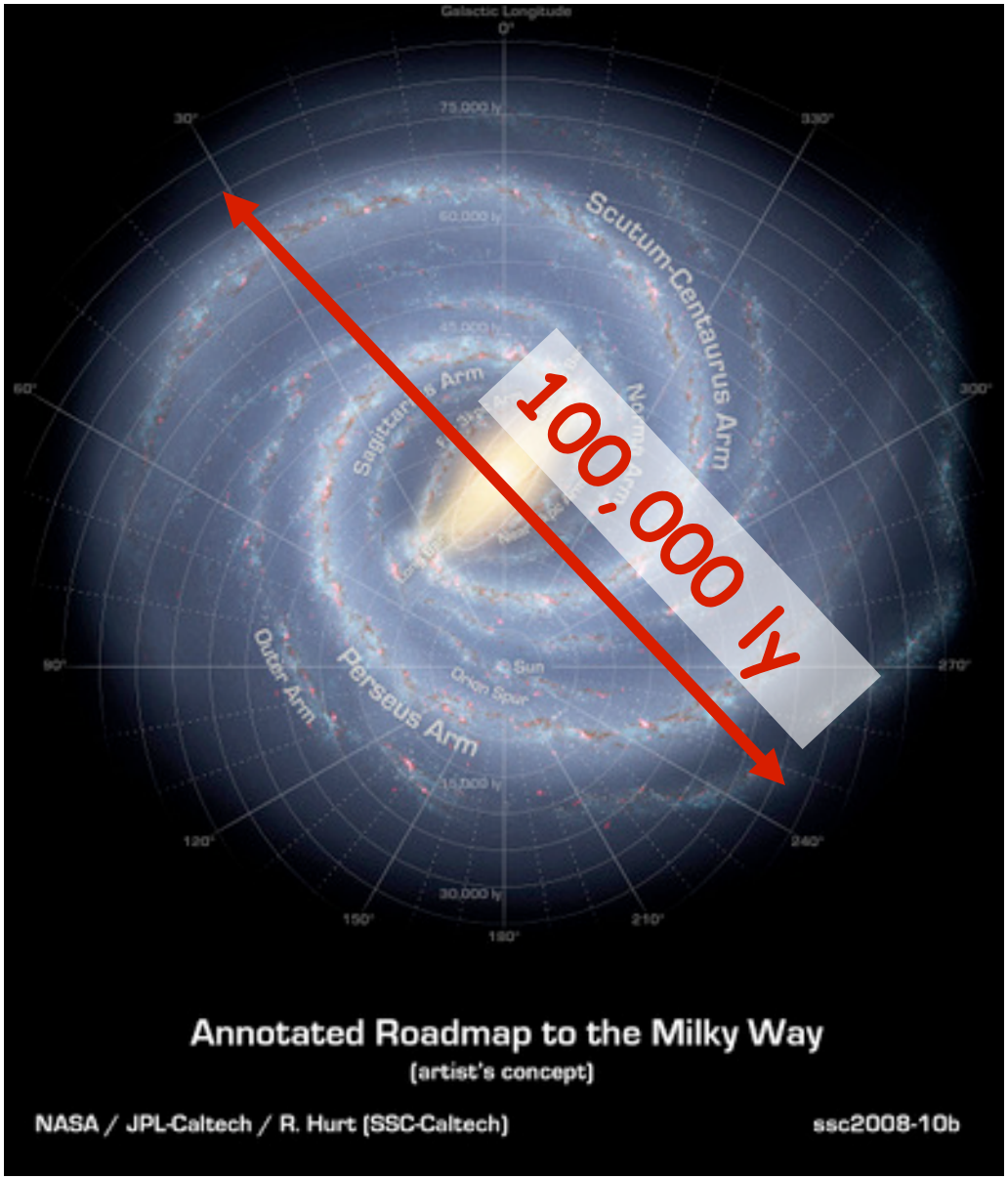
~ 1 billion planets

Milky Way ~ pancake

R ~ 50,000 ly

H ~ 1,000 ly

Volume = $\pi R^2 H$



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(3) Calculate density of Habitable Planets : units $1 / \text{lightyear}^3$

Average distance between HB planets?

Density = Number of planets / Volume

$$\text{Density} = \frac{1 \times 10^{9} \text{ planets}}{\pi\,(50{,}000 \text{ ly})^{2}\,(1000 \text{ly})} \sim 1 \times 10^{-4} \text{ planets/ly}^{3}$$

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(4) Convert density into average distance assuming planets are evenly distributed in Milky Way

Avg. Distance ~ $(1 / \text{Density})^{1/3}$
Convince yourself that the units work out!

Average distance between planets?

Density = Number of planets / Volume

If we assume the star systems are uniformly distributed, then the typical distance between them is:

$$\text{Distance} = (1/\text{Density})^{1/3}$$

$$\text{Distance} = (1 \,/\, 1 \times 10^{-4})^{1/3} \sim 20 \text{ ly}$$

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Galactic Colonization

Depending on assumptions, ~1 billion habitable planets in Milky Way
Distance between suitable planets: about 20 lightyears

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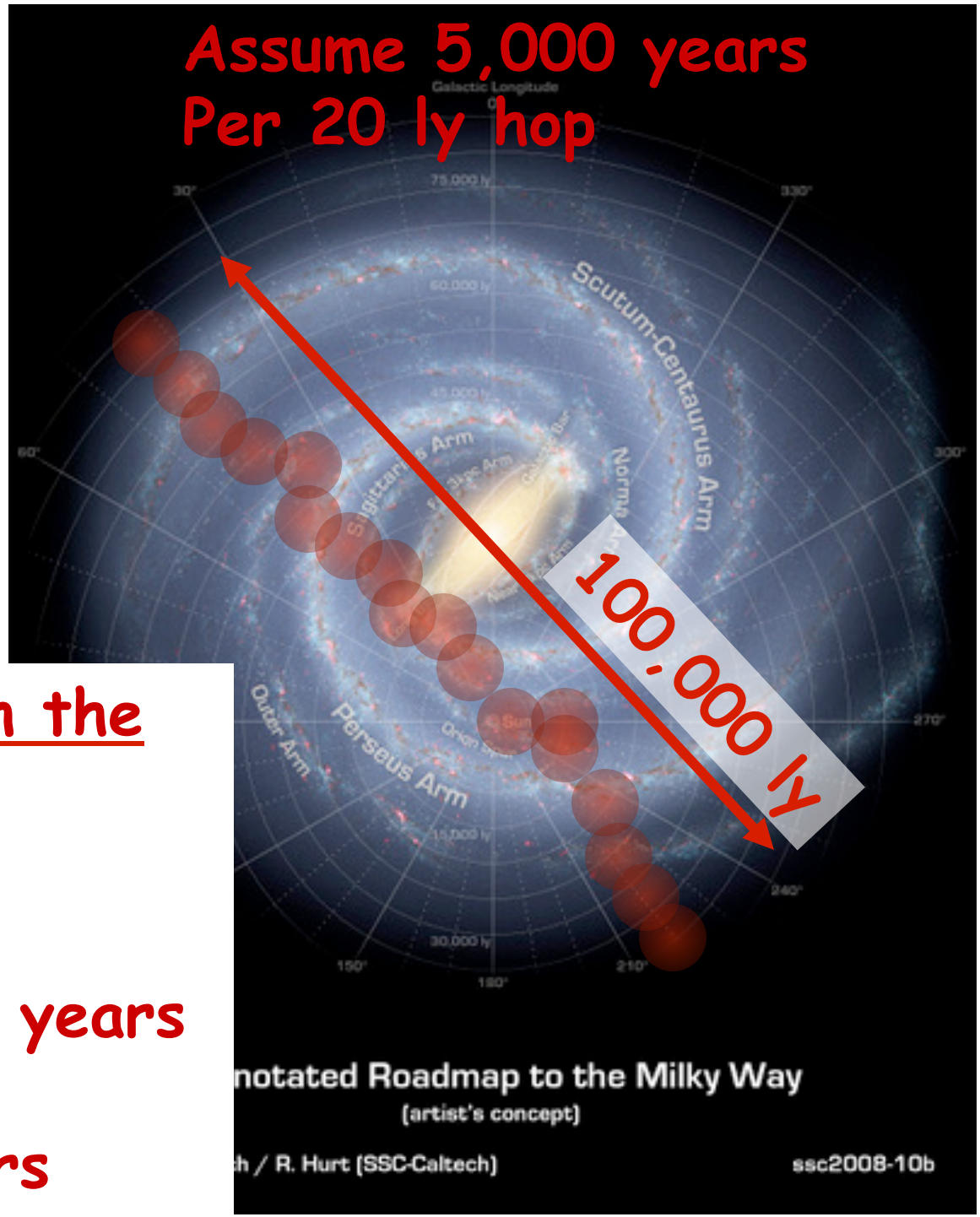
How long to colonize?



Total time to span the Galaxy:

5000 hops x 1,000 years

= 5 million years

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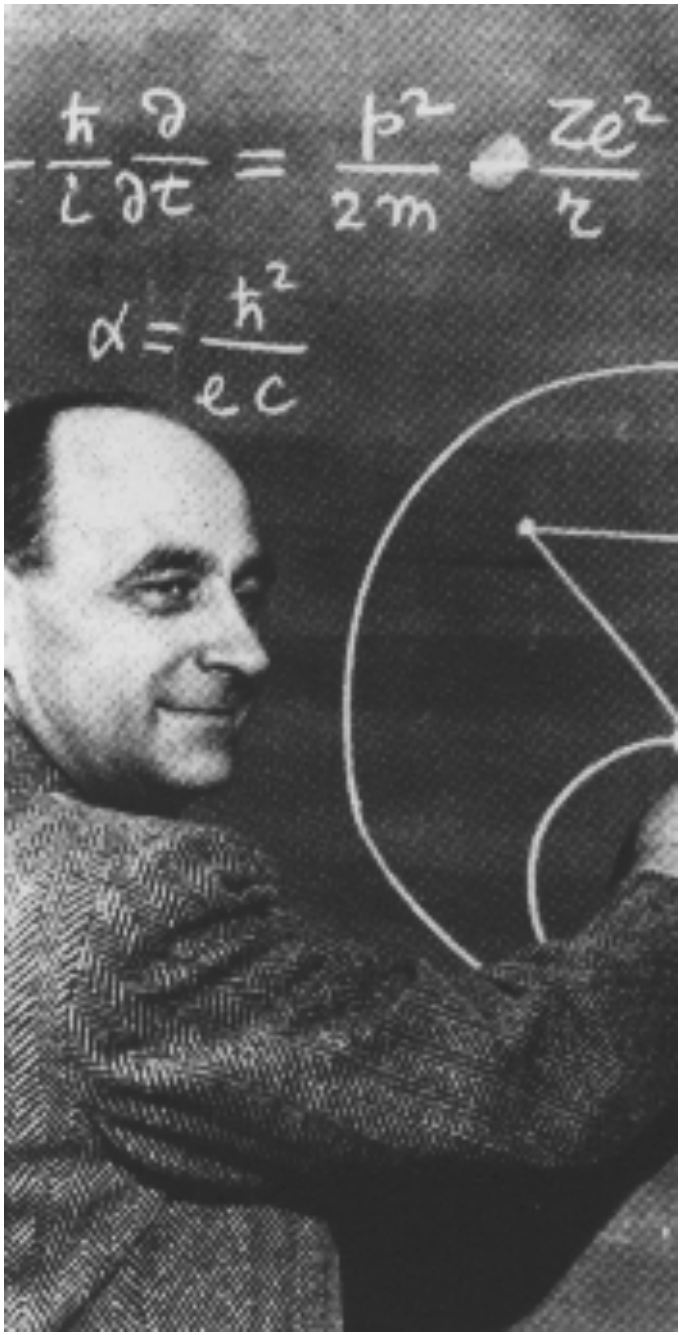
If new craft are built and sent out soon after colonization, we'd span the Galaxy in ~5-50 Myr. ***Could any civilization do this? Will we?***

"Where Are The Aliens?"



The Fermi Paradox

As originally phrased by Erico Fermi, it seems a reasonable proposition that:

• Our civilization and technology is very young; life forms with much more advanced technology could have remarkable capabilities.

• A modest extrapolation of current technology allows us mine asteroids or moons, and create probes that could create replicas of themselves and propagate through the galaxy.

• There are many likely sites for complex life, and plenty of time for technology to develop, billions of years before Earth formed.

"Where Are They?"

Some Solutions to Fermi's Paradox

- We are alone
  - civilizations are extremely rare and we are the first one to arise
  - then we are unique, the first part of the Universe to attain self-awareness

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  - perhaps interstellar travel is even harder or costlier than we imagine
  - perhaps most civilizations have no desire to travel or colonize
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- There *is* one or more Galactic civilizations
  - it has deliberately concealed itself from us
  - we are the Galaxy's novices, on the verge of a great adventure


PRIME DIRECTIVE: NEVER MESS WITH PRE-WARP CIVILIZATIONS
SHIPS NOT CAMOUFLAGED

Should We Be Trying to Contact ?

So, let me get this straight. You're going to fly this thing up to the Mother Ship and upload a virus?

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- We may know which solution is correct within the near future!