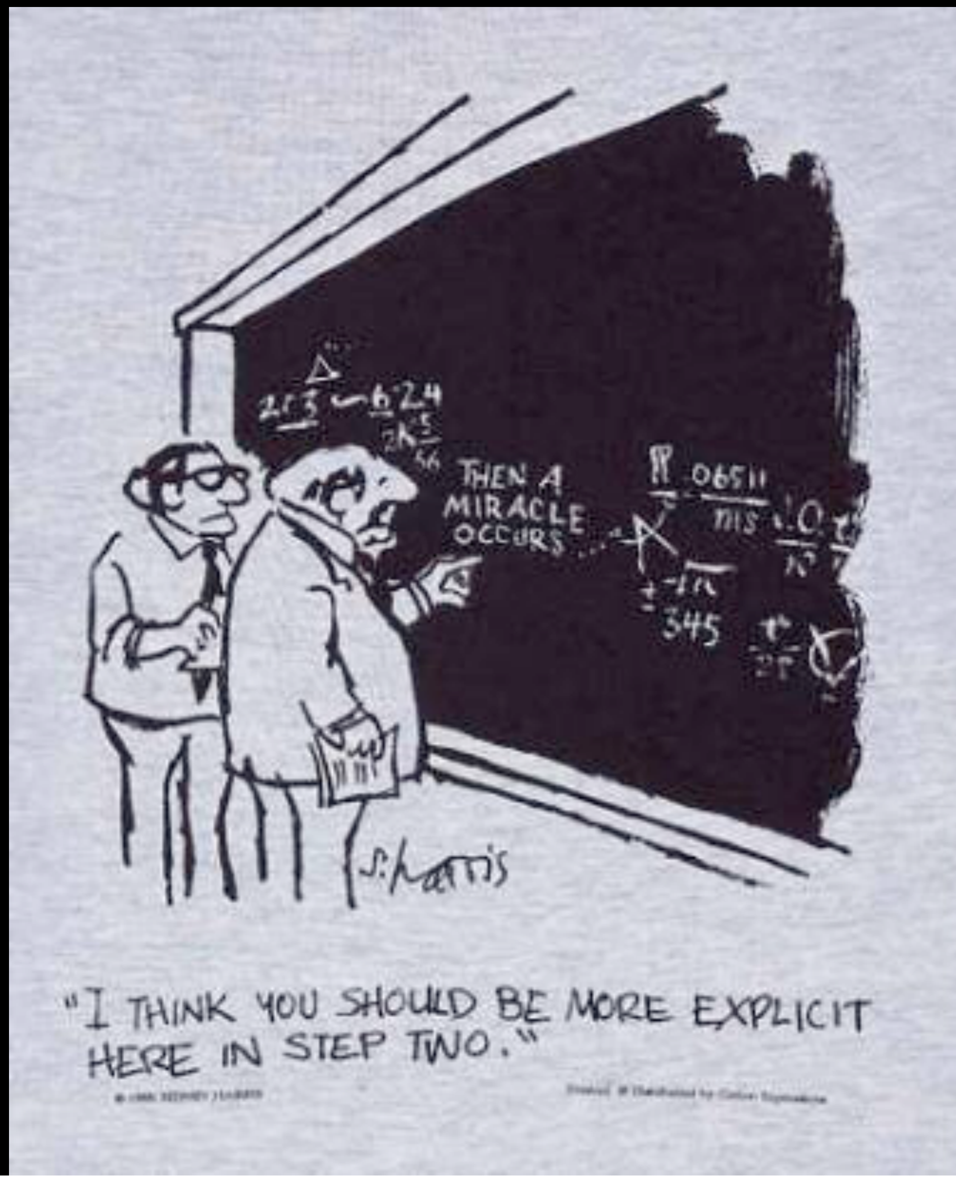
ASTR 380
The Challenge of Interstellar Travel



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Distances to other stars
Conventional time to travel to stars
Types of conventional spacecrafts
The multigenerational challenge

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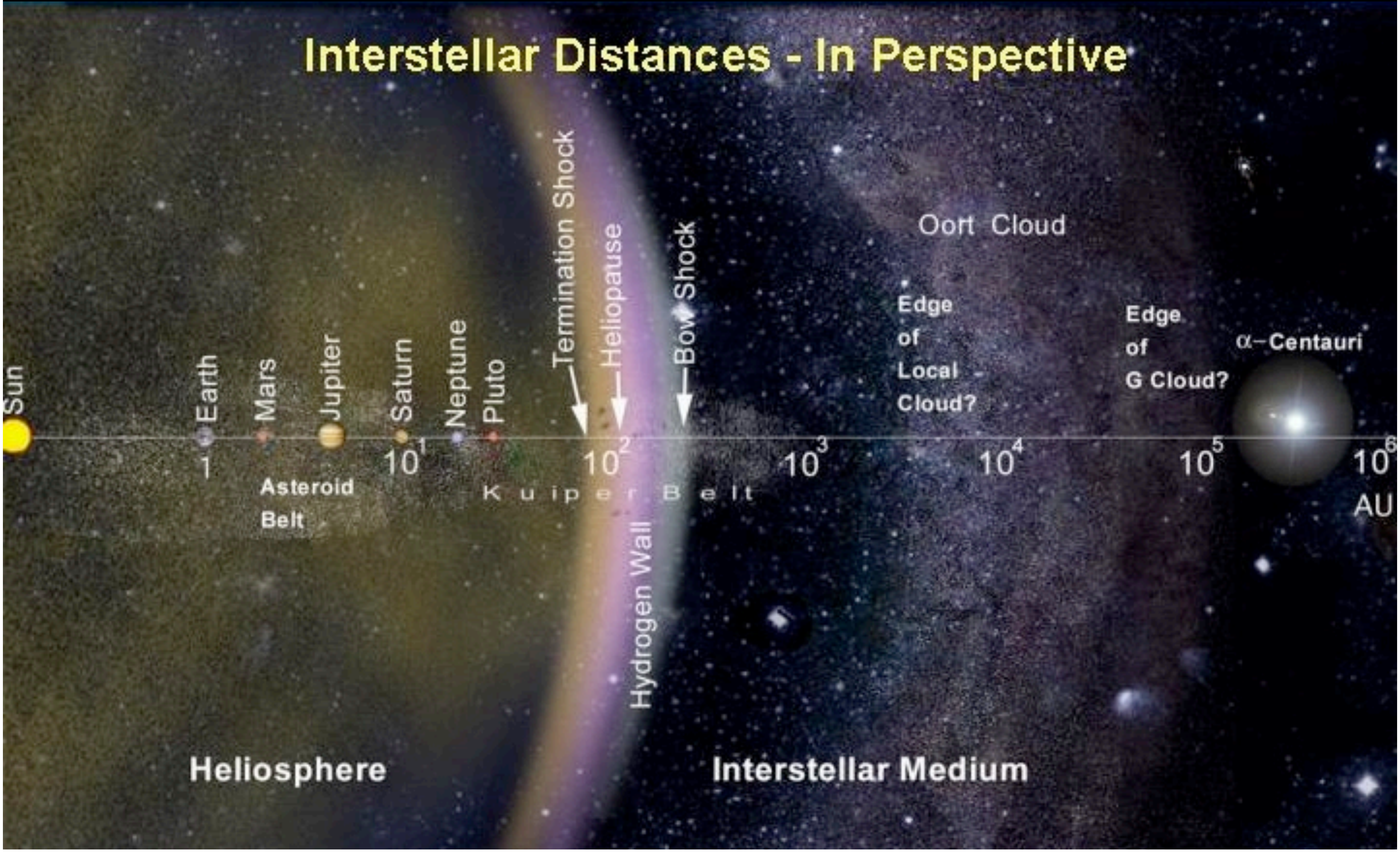

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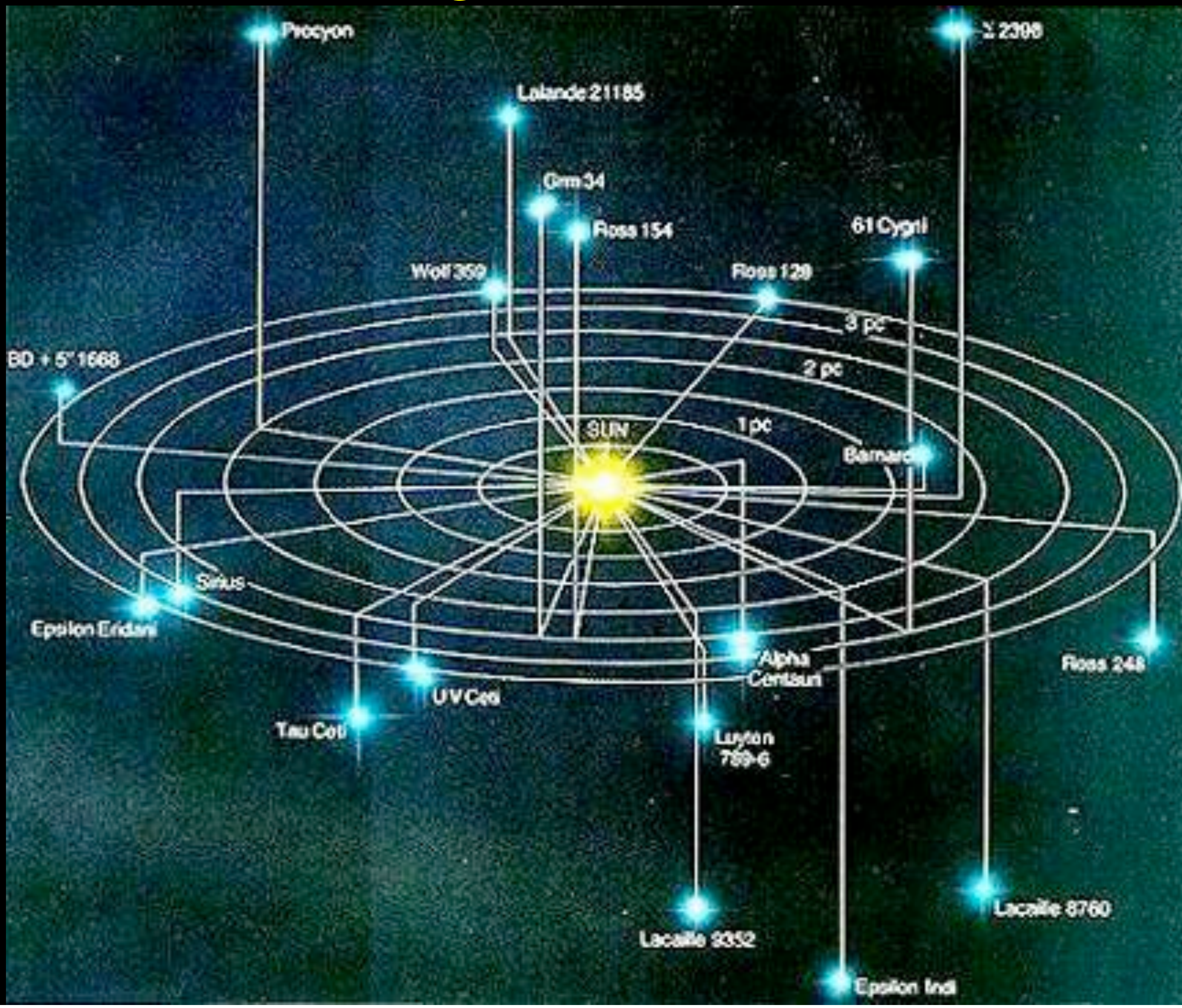

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4.4 Lyrs Alpha Centauri – 3 star system

A is sun-like star

B is a K star

C is a red dwarf and flare star

5.9 Lyrs Barnard's Star – red dwarf

7.8 Lyrs Wolf 359 – red dwarf and flare star

8.3 Lyrs Lalande 21185 – M star – red star

8.5 Lyrs UV Ceti – double red dwarf system

8.6 Lyrs Sirius – double system, A star and white dwarf

9.7 Lyrs Ross 154 – red dwarf

10 Lyrs Ross 248 – red dwarf

10.5 Lyrs Epsilon Eridani – sun-like with known planet

Really need to consider 10 light years as the goal

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Travel times to cover 10 light years

Speed (mi/hr)	Speed/c	Travel Time	Travel time
100	0.00000015	67 Myrs	By car
10,000	0.000015	671,000 yrs	Mach 12
40,000	0.00006	167,000 yrs	Fastest spacecraft to date
600,000	0.00089	11,184 yrs	15 x fastest spacecraft
4 Million	0.006	1677 yrs	100 x fastest spacecraft
80 million	0.12	84 yrs	2000 x fastest spacecraft

Need to get speeds of 0.03 to 0.2 times speed of light to make travel time “reasonable” – 50 to a few hundred years!

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Travel times to cover 10 light years

Of course, to get from 0.03 to 0.2 the speed of light you need to press on the accelerator pedal for some time. To get to a velocity of 0.1 C you need to accelerate for:

Acceleration in gravities	Time with pedal to the metal	Description
0.1	1 year	Mild pinning to seat
1.0	0.1 years	Like full gravity
5.0	1 week	Blackout time!

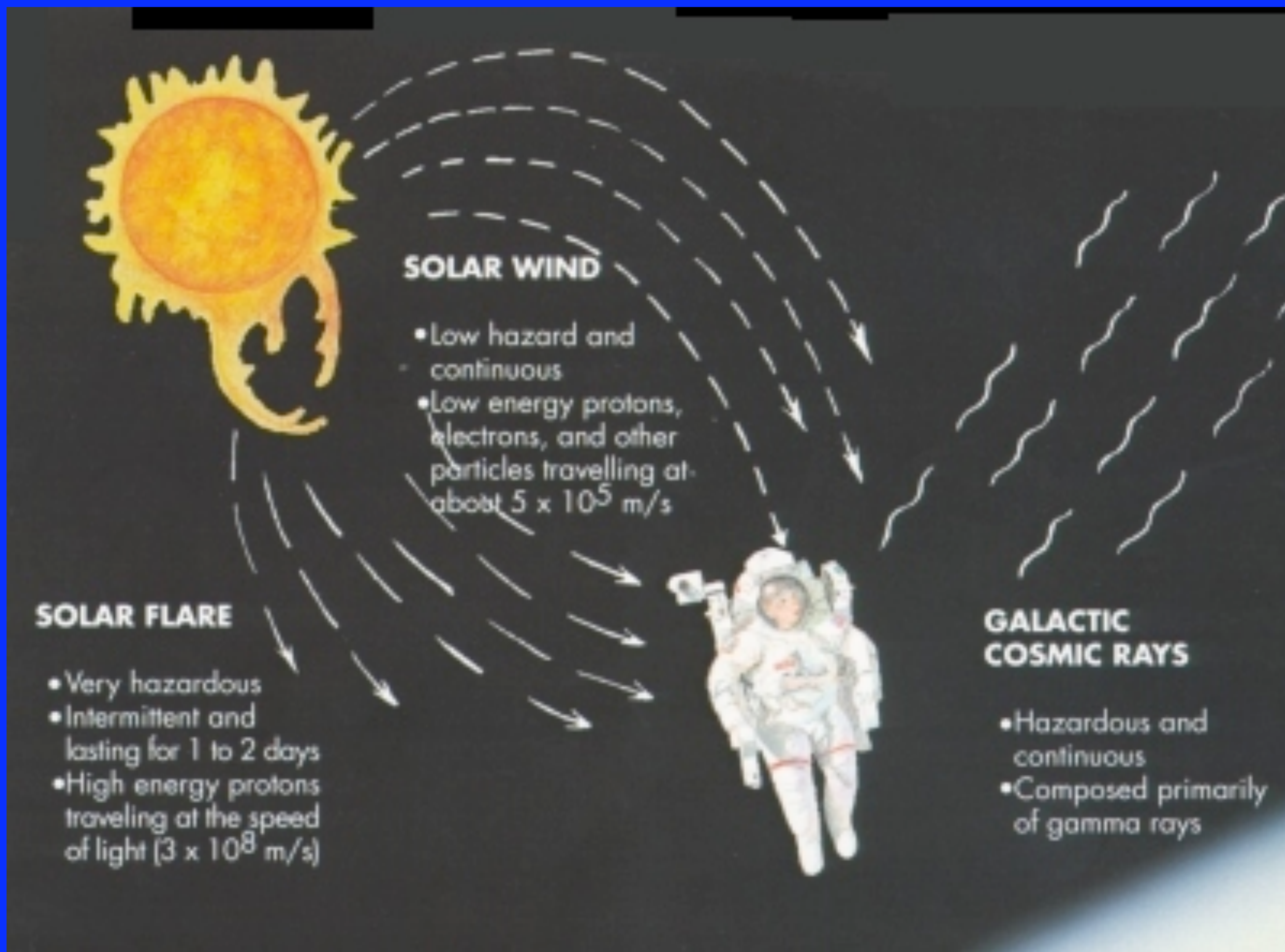
So accelerating at 0.1 to 1 gravities gets you going fast in a reasonable time compared to a 100-ish year trip.

Hazards: Being Self-Contained

- No supermarkets in space!
- Must carry along all food, water, oxygen, ...
- First experiment on Earth (Biosphere 2) not successful; would have killed passengers in space

Biosphere 2

Hazards: High Energy Particles



http://www.nsbri.org/HumanPhysSpace/introduction/radiation2.jpg

Radiation and Particles

- On Earth, gamma rays and X-rays are stopped by our atmosphere
  Hull of ship would work
- High-energy particles are charged, hence are deflected by our magnetic field
- Ship is much smaller, so would need much stronger magnetic field; probably not realistic
- Mutation even of eggs or embryos?

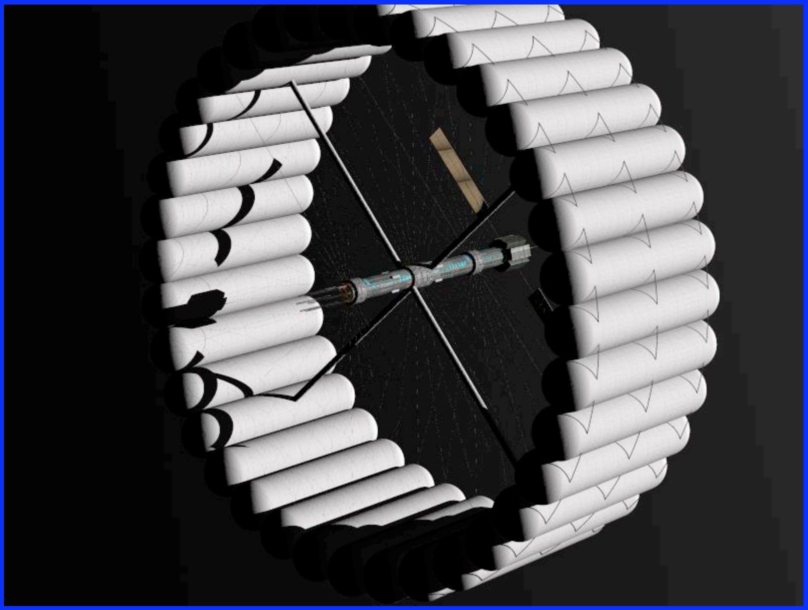
Hazards: Weightlessness

- Free fall in orbit (gravity exists, but everything falls)
- Over months, lose muscle tone, bone mass
  Difficulty walking
- Strenuous exercise still is less than sleeping on Earth
- We need our 1g load!

http://www.africaninspace.com/images/gallery/4401.jpg

Getting Around Weightlessness

- Linear acceleration simulates gravity, but tough to maintain
- Rotation could work 3/min, 100 meter diam
- Probably essential for long trips



http://semiarch.com/PIC/RESEARCH/SPACE%20HABITAT

Hazards: Micrometeoroids

- Or dust, which is plentiful in space
- Hitting at tens of kilometers per second!
- Cumulative effect is a lot of damage on ship
- Can't be deflected by magnetic fields

http://ksjtracker.mit.edu/wp-content/uploads/2007/08/bbspacegun.jpg

Hazards: Isolation

- How many people would be along?
- If small number, on long trip, conflicts or isolation could be deadly; no way out!
- Need at least hundreds to approximate diversity

Bruce Dern in “Silent Running”

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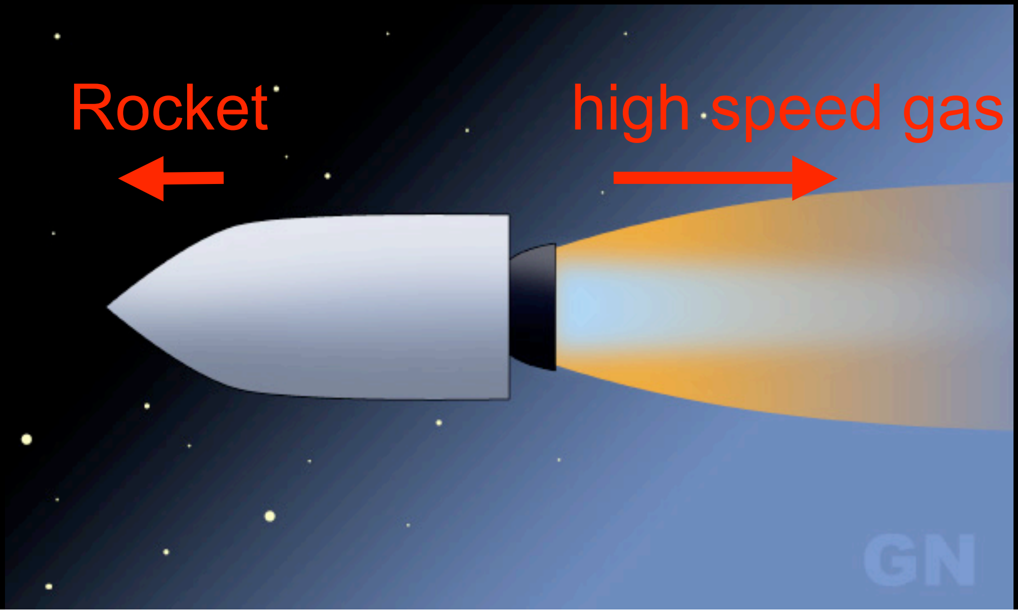
So how do rockets work anyway? Physics my friend!

"For every action, there is an equal and opposite reaction."

Rockets eject material out the back at high speed to push the body of the rocket forward.



How Fast Can You Go?

- You might think it is simple.
- Momentum conservation, so if you kick out mass M as fuel at speed v and are left with payload+passenger mass of m, you end up going a speed $v_{final}=(M/m)v$
- If this were true (it isn't!), how well would this work?

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A rocket moves forward faster as more material is shot out the back. The simplest physics is momentum conservation:

Mass x velocity(fuel) = mass x velocity(spacecraft)

Minimum fuel to payload ratio to achieve 0.1 speed of light

Speed of ejecta (km/sec)	$\frac{M(\text{fuel})}{M(\text{craft})}$	Type of rocket
4.5	6,000	Space shuttle – solid and liquid fuel
29	1000	Ion thruster – exist as small models
300	100	Plasma thruster – under development
300,000	0.1	Light thruster -- theory

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So for a current liquid rocket, you would need 6000 pounds of fuel to get 1 pound of payload up to 0.1 speed of light!

And the real situation is worse because this simple calculation assumed that you instantly shot out all of the fuel.

In real life, you carry a lot of fuel up to high speed and you need fuel for your slowdown at the end of your trip – else you never stop!!!

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When we take into account that the fuel itself needs to be accelerated, we find that the final speed is really

$$v_{final}=v_{ejecta} \ln[M(fuel)/M(craft)]$$

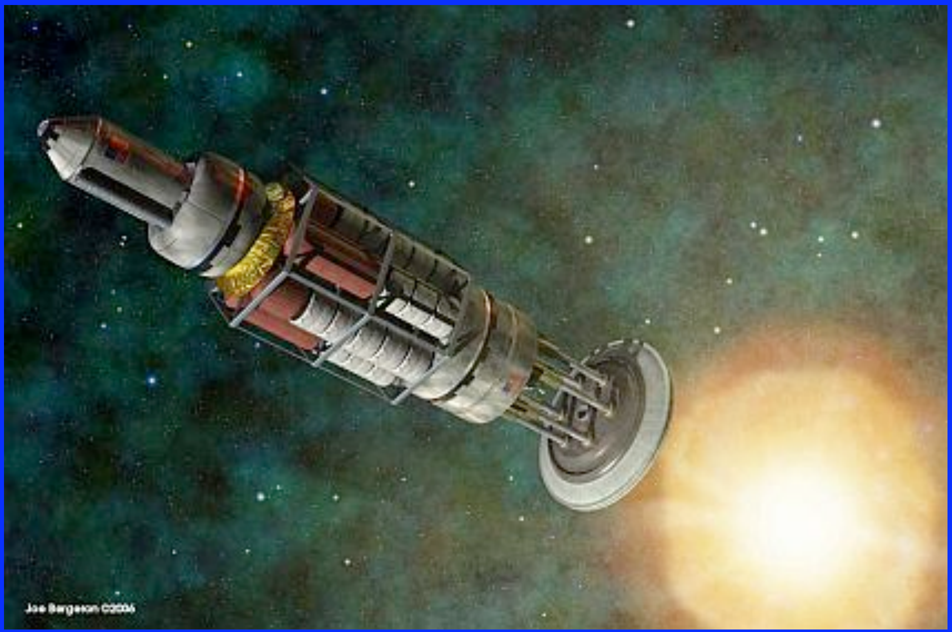
Need huge fuel mass to get to high speeds if v_{ejecta} is low!

Minimum fuel to payload ratio to achieve 0.1 speed of light

Speed of ejecta (km/sec)	$\frac{M(fuel)}{M(craft)}$	Type of rocket
4.5	10^{2900}	Space shuttle – solid and liquid fuel
29	10^{450}	Ion thruster – exist as small models
300	$2.7x10^{43}$	Plasma thruster – under development
300,000	0.1	Light thruster -- theory

Project Orion

- Blow up nuclear bombs behind ship to propel it
  Bwa ha ha!!!
- Could accelerate to ~0.1 of speed of light
- Couldn’t launch from Earth; fallout danger



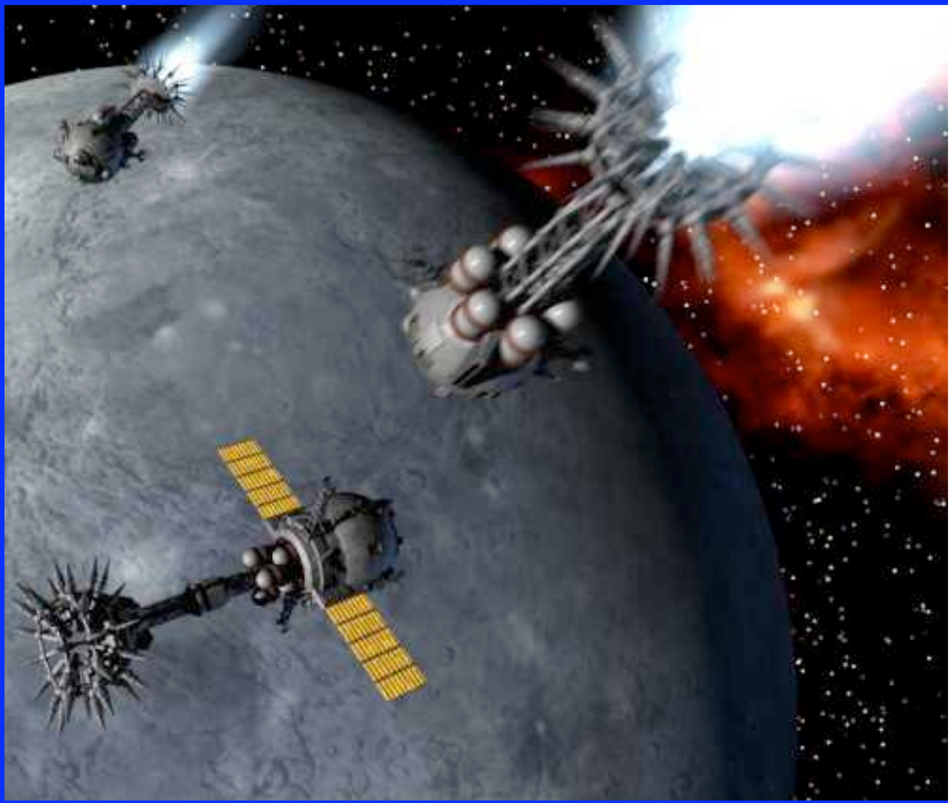
http://www.gizmowatch.com/images/orion1_48.jpg

Light Drive

- A third less calories than the regular drive? No!
- If your send light out your rocket, it travels at the speed of light
- Therefore, all you need is a way to make the light and to channel it

Fusion Drive

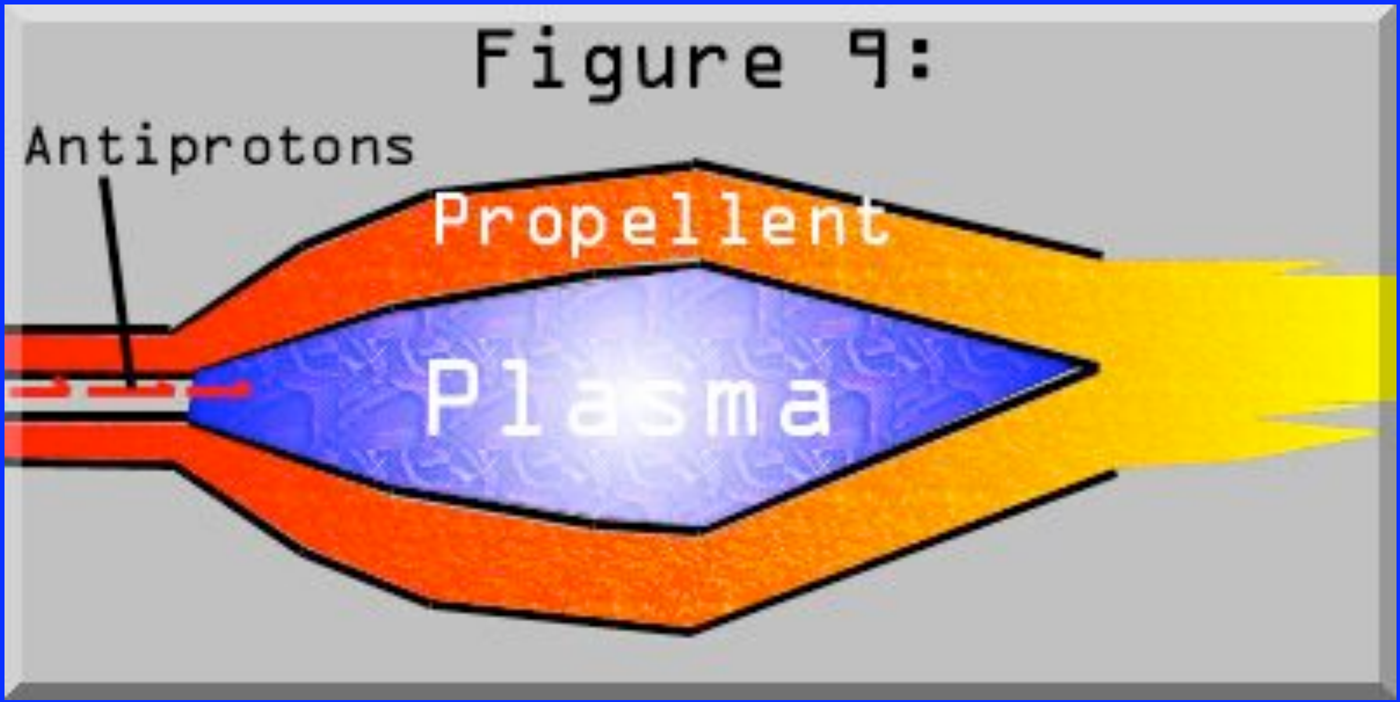
- Hydrogen fusion releases 0.7% of the mass-energy
- Therefore, at best, could only get to 0.7% of the speed of light
- Can we do better?



http://www.projectrho.com/rocket/Lafayette_Surrenders_sm.jpg

Antimatter Drive

- Antimatter!
- Completely annihilates with matter; 100% efficient
- How would this work, and what are the issues?



http://ffden-2.phys.uaf.edu/213.web.stuff/Scott%20Kircher/figure9.jpg

Antimatter: The Good News

- With an equal amount of matter, converts completely to gamma rays
- Focusing or mirror technology could send the light out the rocket
- If half the mass were annihilated in this way, could get up to speeds near the speed of light. Then, journey in one human lifetime!

Antimatter: The Bad News

- Antimatter is extremely expensive to make
  Happens to tiny degree in accelerators
  Need factor of 30 million in efficiency
- Antimatter is difficult to confine
  Any that leaks out will annihilate
  Magnetic confinement, maybe, but the more antimatter the tougher it is
- Might we find ways around these problems?

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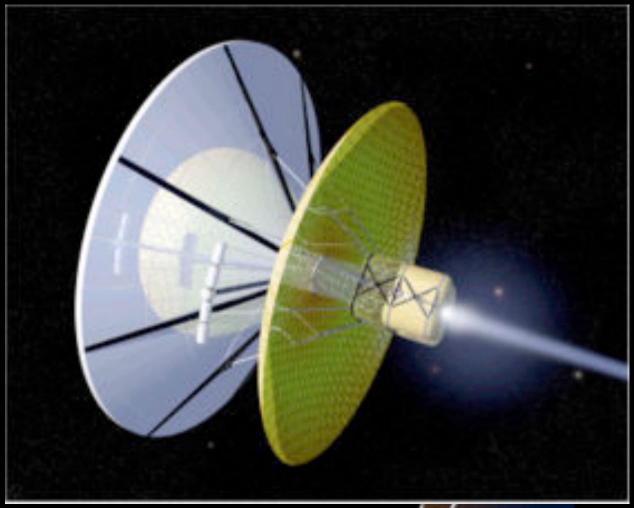


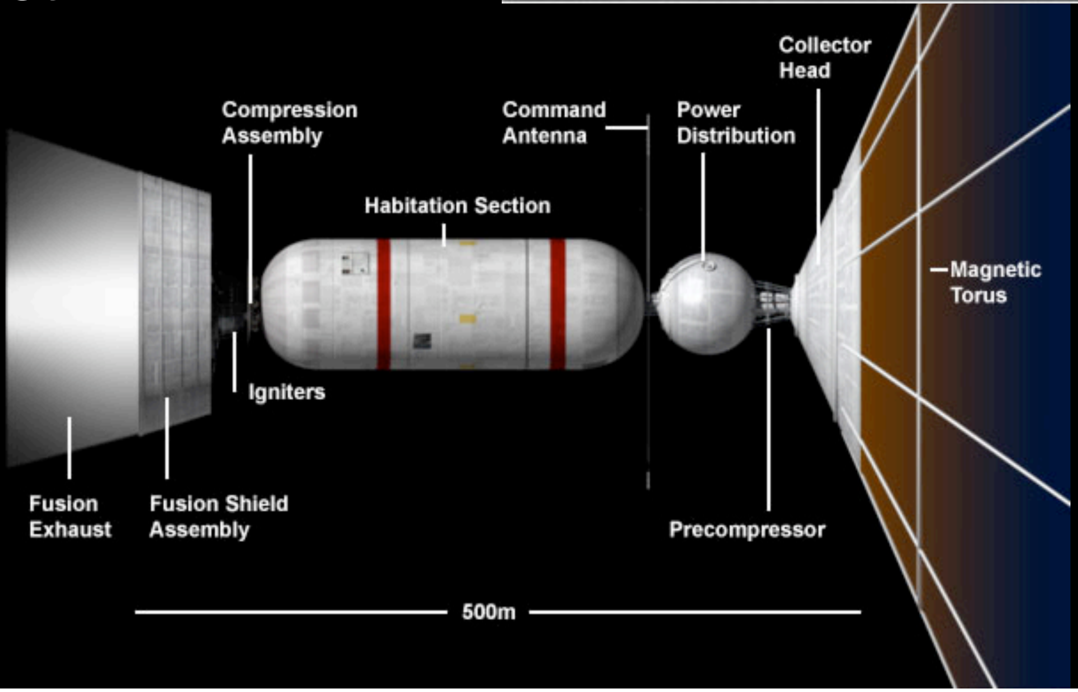
Interesting alternatives:

Bussard Ramjet – collects hydrogen from space using a magnetic field web and uses the hydrogen to fuel a fusion reaction jet.

You carry no fuel!

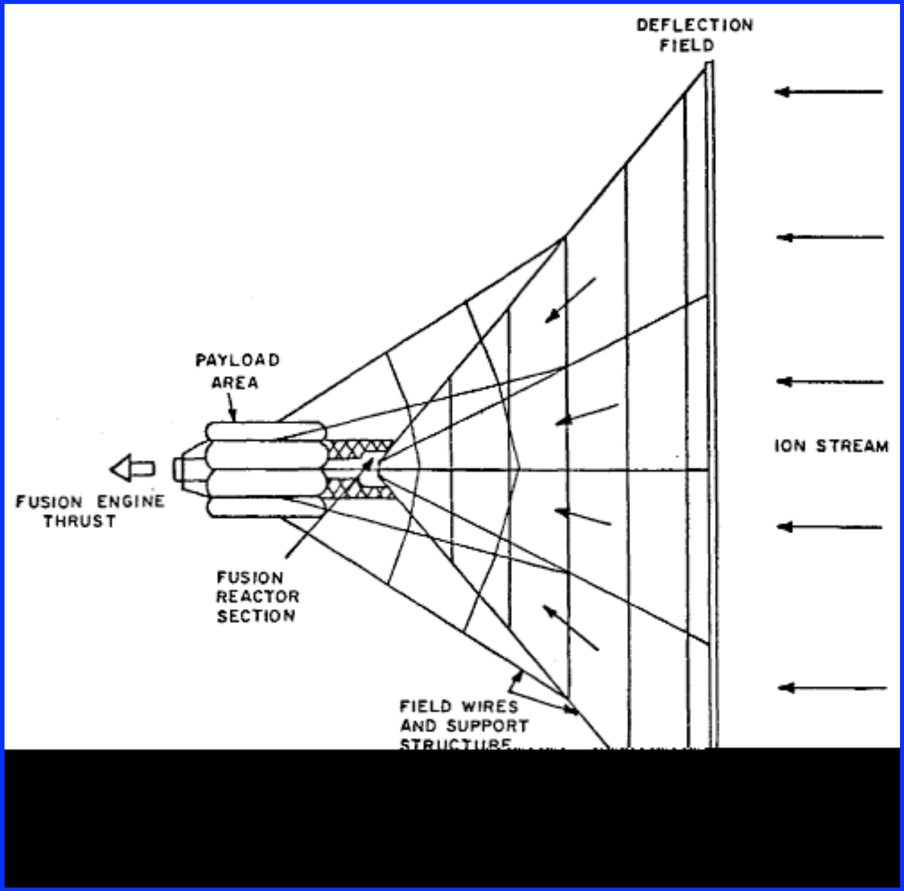
Could happen.

Difficult job!



Problems With Ramjet

- Sounds nice, but scooping up hydrogen means that there is drag on the interstellar medium
- Calculations suggest that this will outweigh thrust in any conceivable scoop design



http://www.daviddarling.info/images/Bussard_ramjet.gif

Externally Supplied Thrust?

- Even if the ramjet doesn’t work, maybe there is another way around accelerating all your fuel
- If the thrust were provided by something else, the ship could be accelerated much better
- What are our options?

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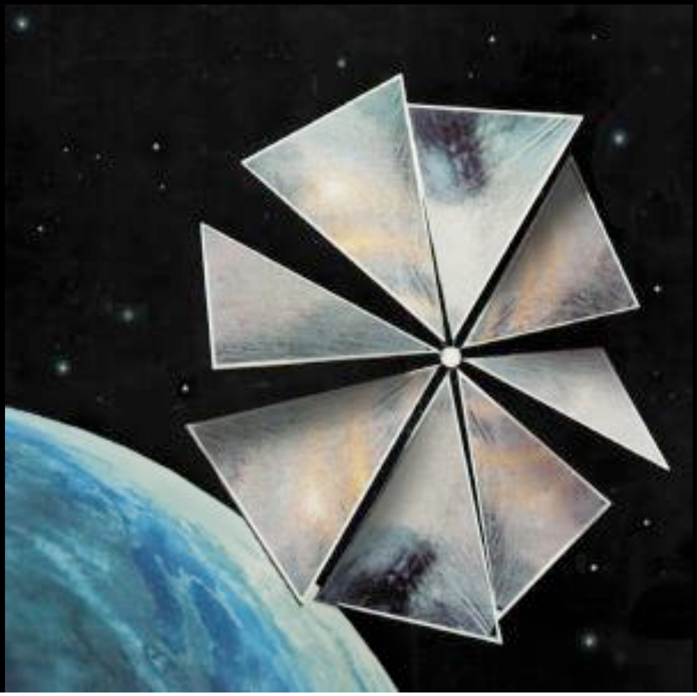
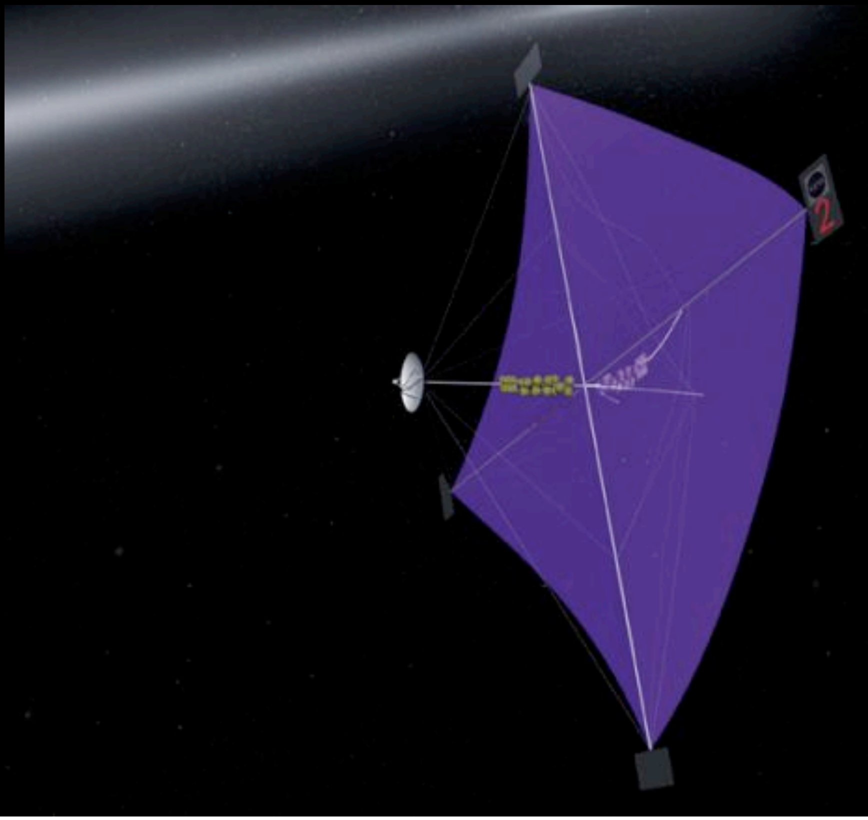
Interesting alternatives:

Solar Sails: uses light from the star – reflecting it off of an enormous sail to accelerate the spacecraft – no fuel.





Problems With Light Sail

- Need very low-mass but tough sail
- Also has to be huge compared to ship
- Dependent on light from star
  Decreases with distance like $1/r^2$
- Is there any other way we could use light for propulsion?

Laser Propulsion?

- Instead of the Sun's light, why not use lasers?
- Intensity can be much greater than the Sun's
  Still drops like $1/r^2$
- Robert Forward has calculated that we could speed ship up to half light speed
- Needs 75,000,000 GWatts!!!

My role model

http://www.holmsund.nu/karlsson/public/dr-evil.jpg

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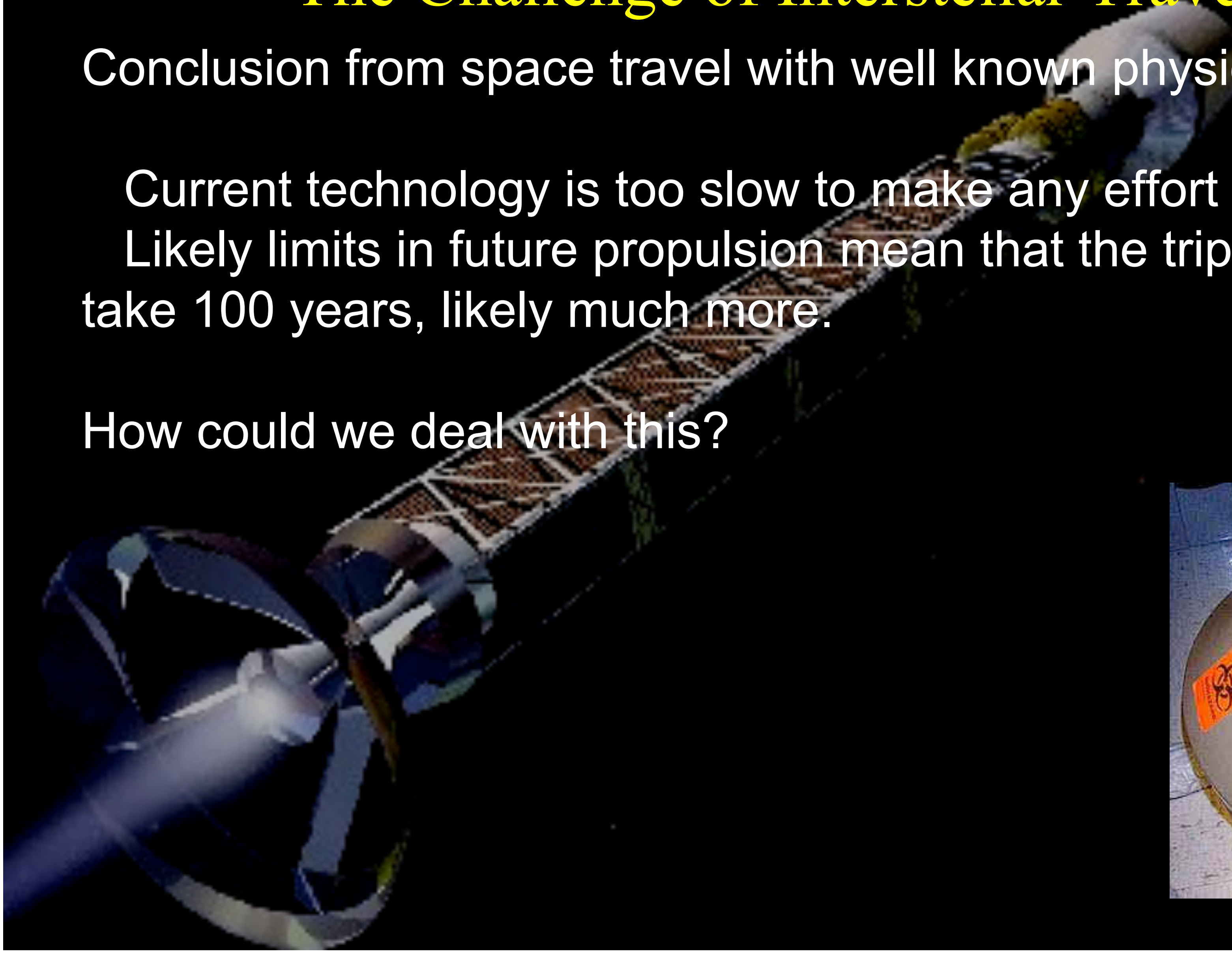
Conclusion from space travel with well known physics:

Current technology is too slow to make any effort sensible.
Likely limits in future propulsion mean that the trip will take 100 years, likely much more.

How could we deal with this?

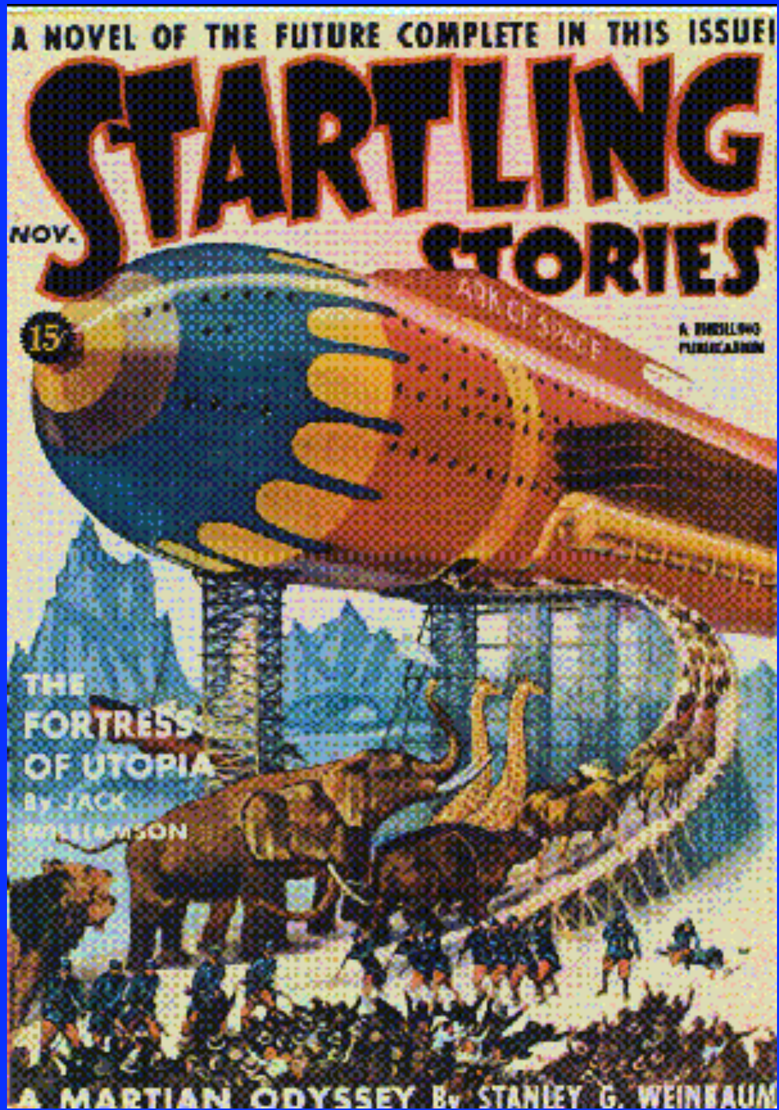


The Wisdom of Long Trips

- Before discussing long trips, should we take them?
- Suppose we had a way to get to a likely star 10 light years away in 1000 years
- Progress in technology means that we would develop better propulsion in a century and get there in 500 years, say
  Therefore, should wait

Interstellar Arks

- Colony of people living normal lives
- Full ecosystem needed
- Many generations would pass before reaching destination
- Advantage: people to make decisions
- Would aims of colony remain constant for many generations?



http://www.daviddarling.info/images/generation_ship_1.gif

Resources on Interstellar Arks

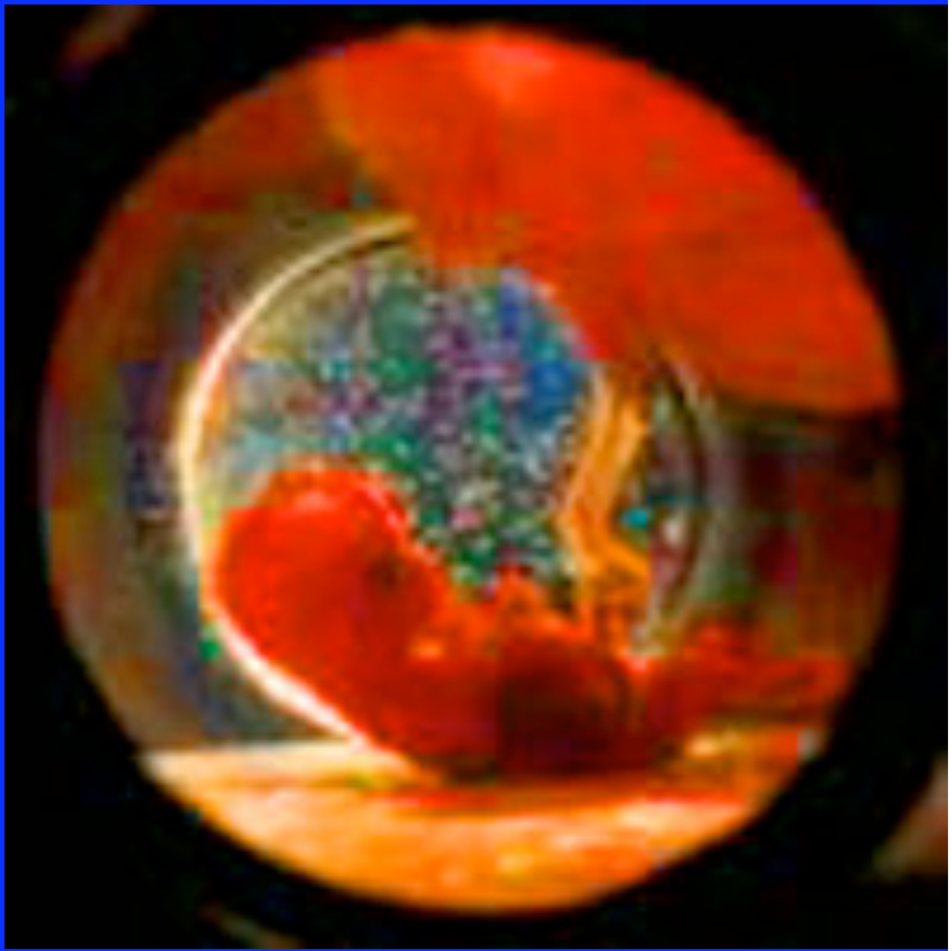
- Another problem: full ecosystem requires substantial energy
  Not from starlight or geothermal!
  Maybe use fusion?
- Also, wastes.
- Planning would have to be very careful

Suspended Animation

- Keep people alive, but at a low metabolic rate
- Possibly in cryogenic sleep
- Might wake people up in rotation to deal with critical issues
- Advantage: fewer resources
- Disadvantage: handling of emergencies?

Frozen Embryos

- Or eggs
- Easier to keep suspended than full adult
- Advantage: negligible resources needed, and could do same thing with other plants and animals
- Disadvantage: would need completely automated ship, and robot parents upon landing



http://www.projectrho.com/rocket/womb01.jpg

Store Humans as DNA?

- Why not go all the way?
- Human DNA has about 3 billion base pairs, at 1/4 byte each
- Current computers can easily store 1 Terabyte
  >1000 human DNAs!
- If also send frozen nutrients, could grow
- Need to be careful about persistence of computer memory

http://files.turbosquid.com

Summary

- Tough to project technology, but fast trips seem unlikely
- However, given patience and robustness of ships, manned or unmanned ships could be sent across the galaxy
- Then why aren't aliens here already?
  Tune in to the next class...