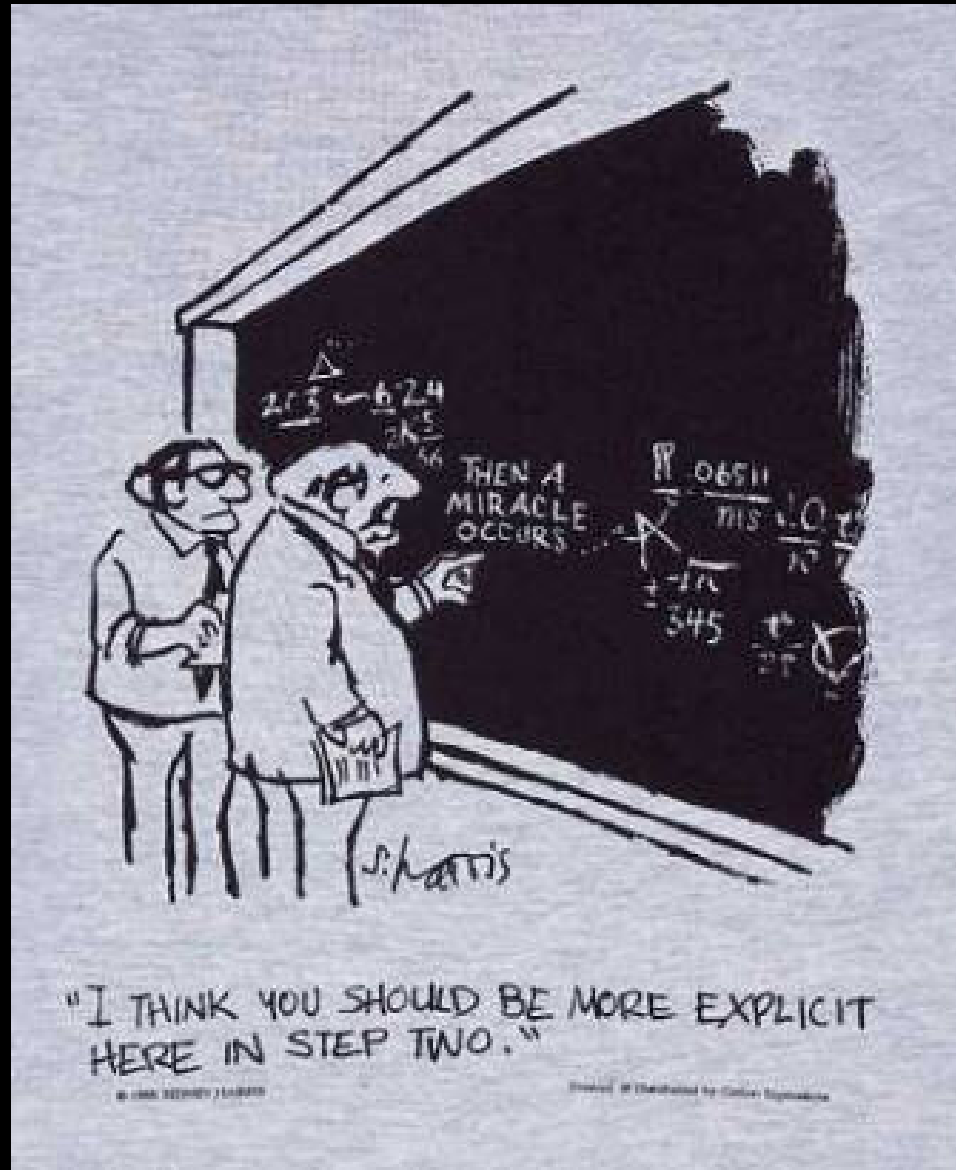


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"I THINK YOU SHOULD BE MORE EXPLICIT
HERE IN STEP TWO."

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Distances to other stars

Conventional time to travel to stars

Types of conventional spacecrafts

The multigenerational challenge

Theory of Relativity and Faster-than-Light Travel

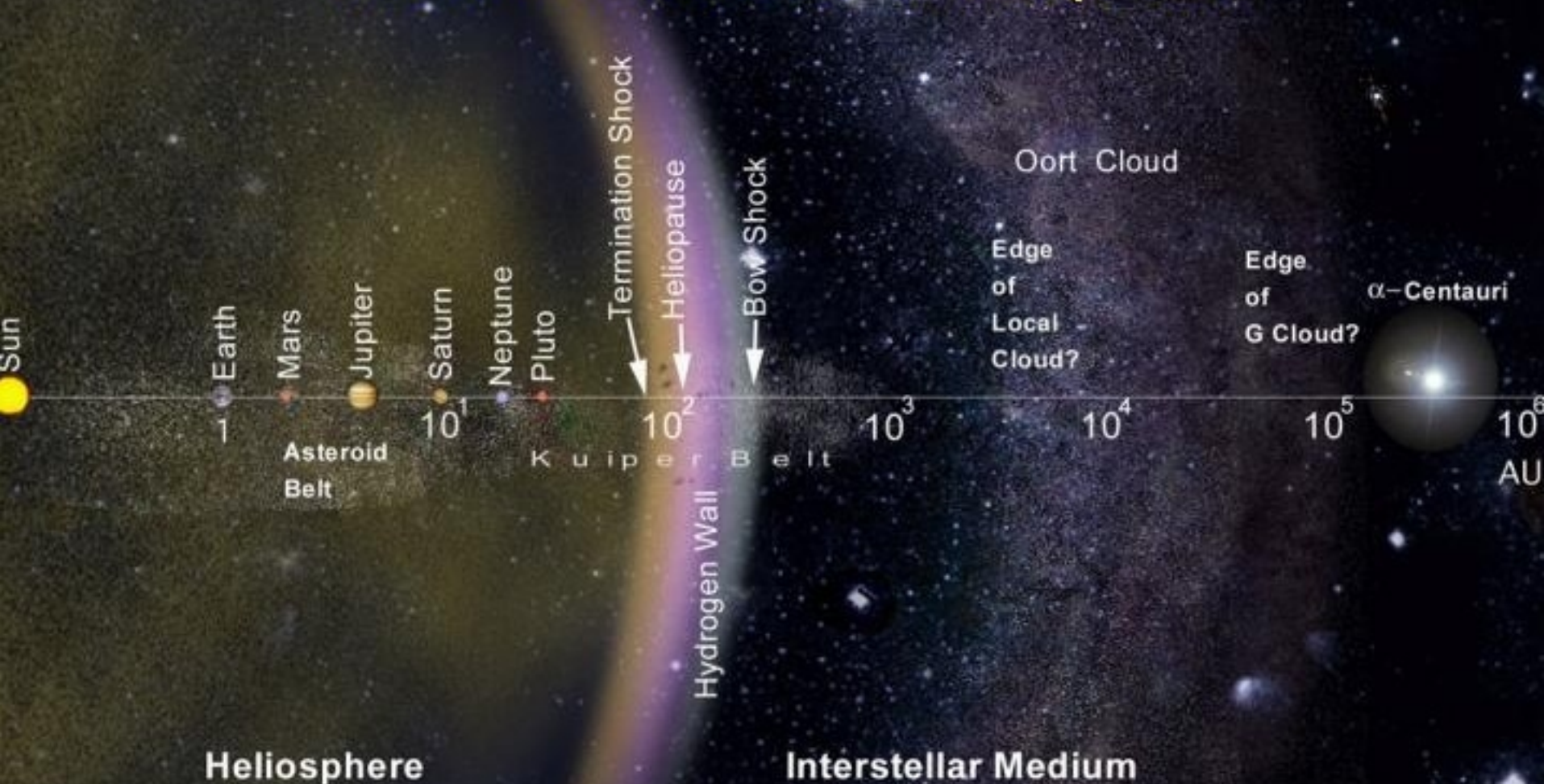
Wormholes and Black Holes

Other options?

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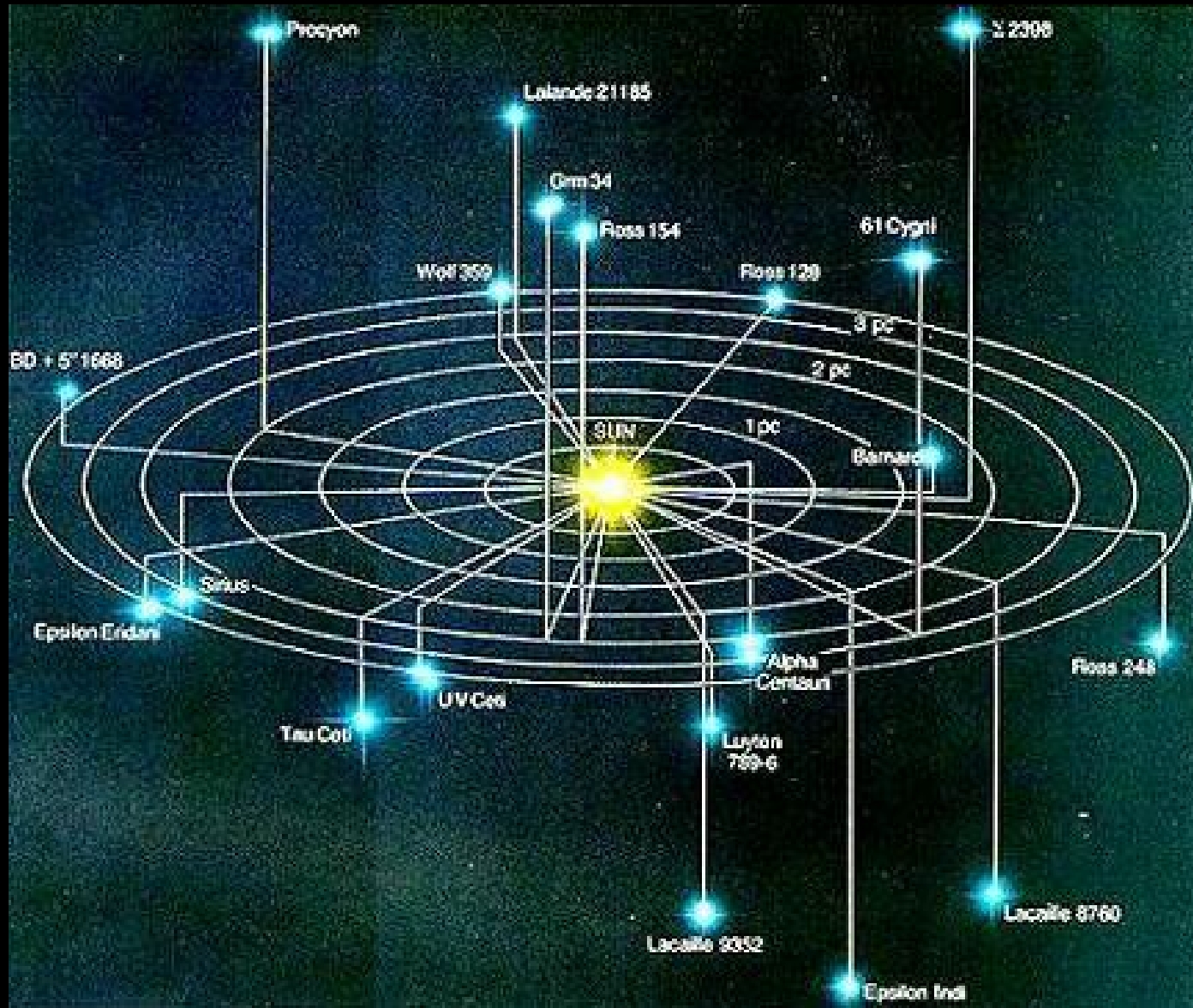
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Interstellar Distances - In Perspective



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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 Eridanus – 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 (m/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 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 to 0.03 to 0.2 the speed of light 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	2.5 months	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.

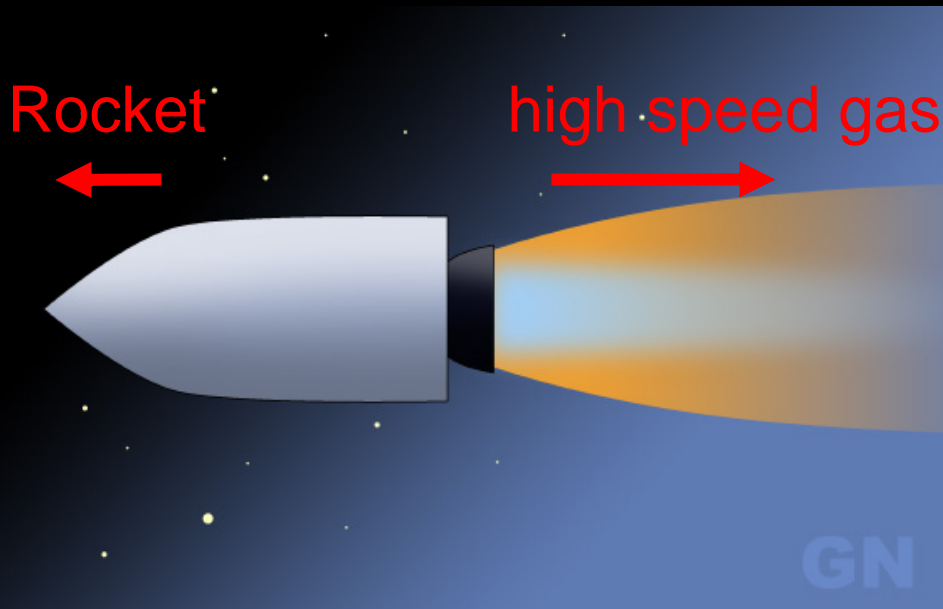
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So how do rocket work anyway? Physics my friend!

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

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



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

$$\text{Mass} \times \text{velocity}(\text{fuel}) = \text{mass} \times \text{velocity}(\text{spacecraft})$$

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!!!

You really need a light-drive!

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Light Drive – rocket which shoots out light as exhaust still has problems....how do you efficiently make the light? You need to turn mass into light...

Hydrogen fusion is only 3% efficient at this.

You need anti-matter which annihilates with matter to create light.... There are still many problems with this...

- creating that much antimatter
- containing the antimatter for years
- getting all of the photons headed out as exhaust

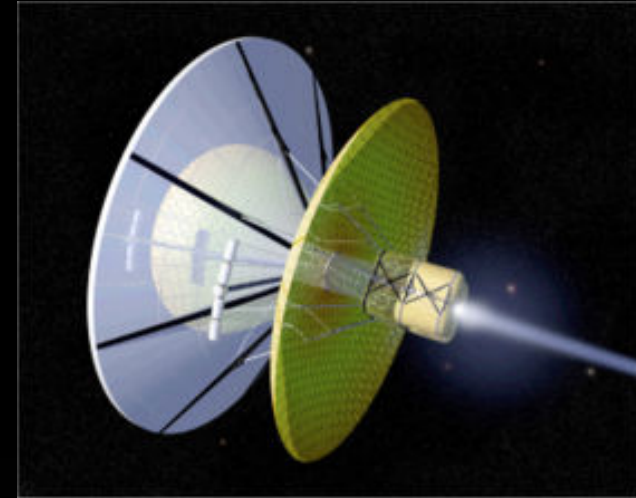
Perhaps you could get $M(\text{fuel})/M(\text{spacecraft})$ down to a few.

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Interesting alternatives:

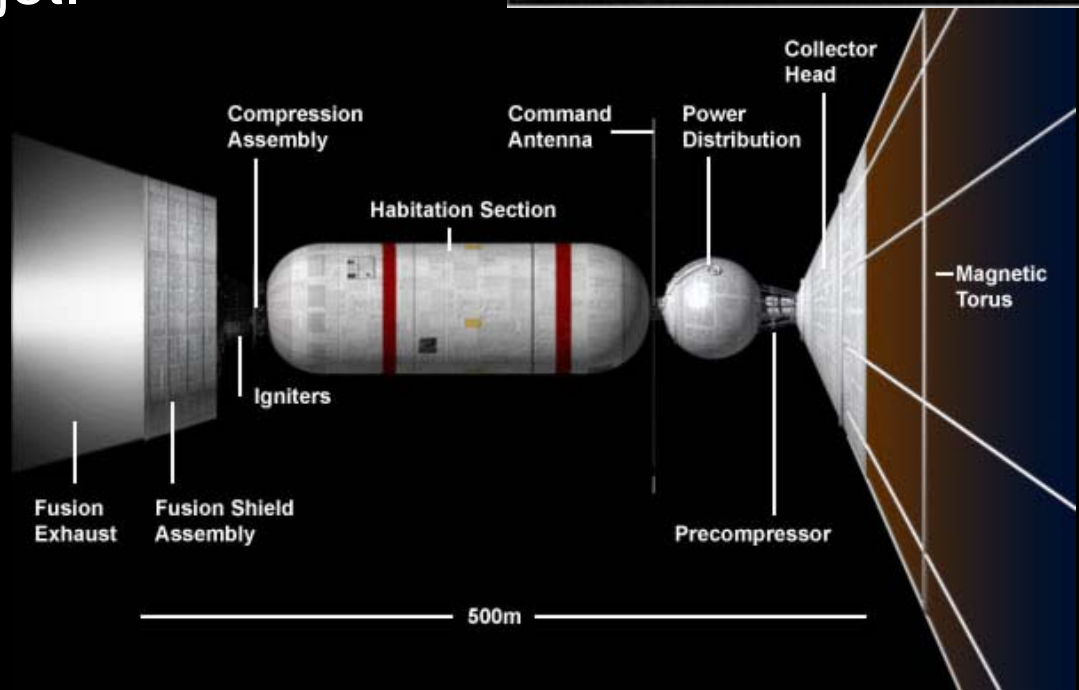
Bussard Ramjet – collects hydrogen from space using a magnetic field Web and uses the hydrogen to fuel a fusion reaction jet.



You carry no fuel!

Could happen.

Difficult job!



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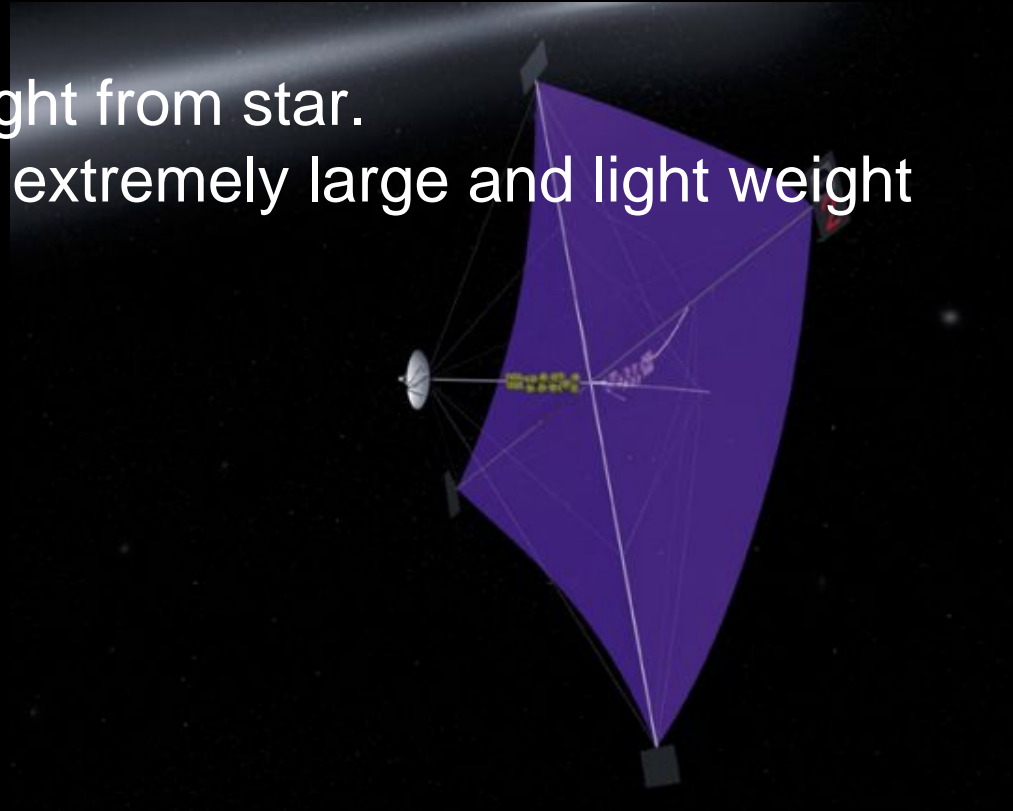
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Interesting alternatives:

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

Problems: dependent on light from star.

sails need to be extremely large and light weight



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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.

Multi-generational space travel seems one solution.

Simplest scenario:

- small group of trained adults

- equal number of babies

- 100's to 1000's of frozen embryos

- self-sustaining spacecraft – food, air, etc..



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Conclusion from space travel with well known physics:

Another possible solution is a cyber-ship with frozen fertilized eggs....

The ships computer runs for 100-300 years for the trip

Unfreezes the eggs and raises the new generation of humans....

Minimizes the needs for the spacecraft and removes the boredom factor for people.

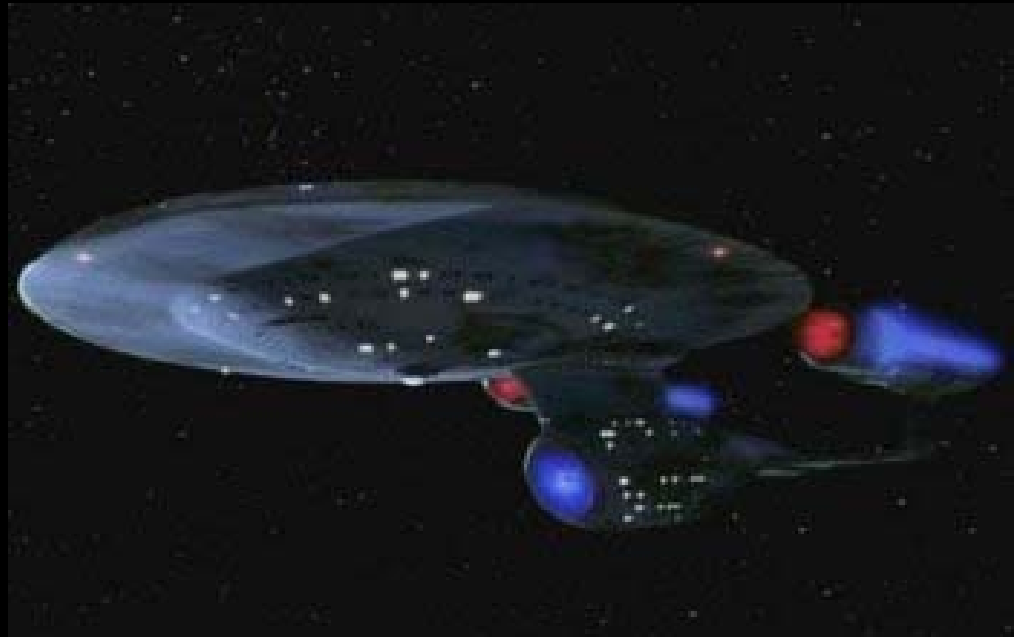
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Faster than light travel – “Warp speed”

Great concept – travel faster than speed of light and time passes slowly so you can go between stars in hours or days --- science fiction?

Unfortunately, no known physics allows this!



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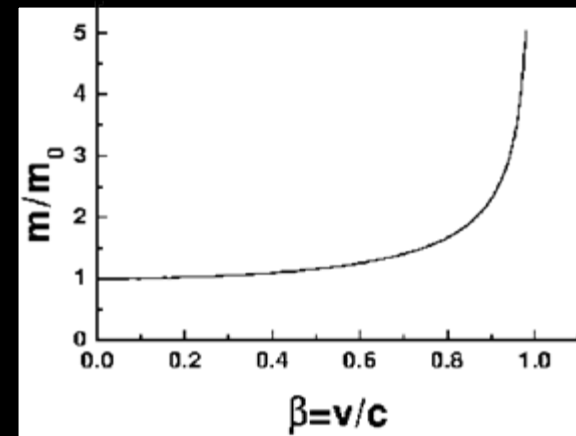
Faster than light travel – “Warp speed”

Fundamental problem:

As you push matter to go faster and faster – approaching the speed of light – an increasing amount of your effort goes into making the matter have more mass rather than speed.

We see this in particle accelerators – particles appear to become heavier as they go faster.

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$



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Faster than light travel – “Warp speed”

Fundamental problem:

The special theory of relativity says that matter becomes infinitely massive as you approach the speed of light.

Experiments strongly support that ordinary matter (us and everything around) cannot go at the speed of light or faster.

The Speed of Light
– it’s not just a good idea –
it’s the law!



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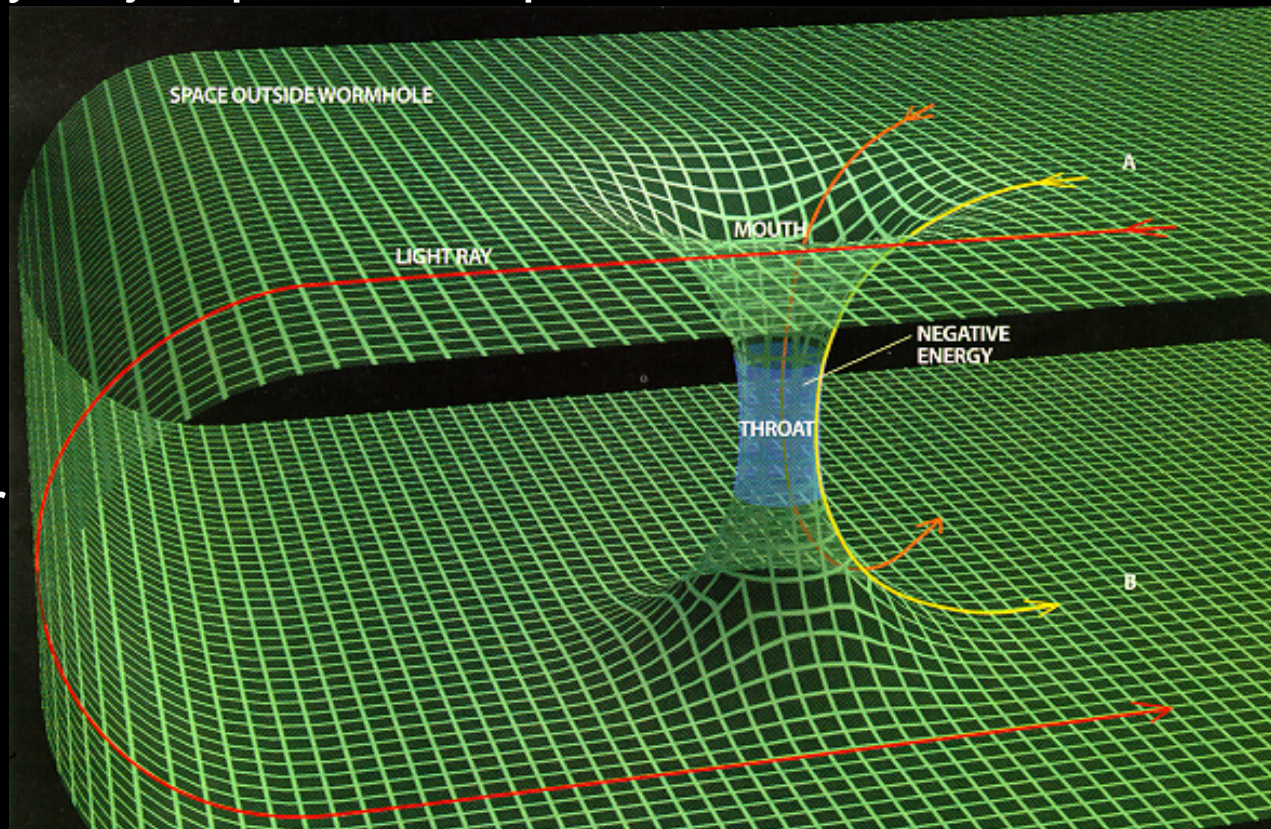
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Worm hole and Black holes

It is argued that Black holes and the associated worm holes might provide a way to jump across space....

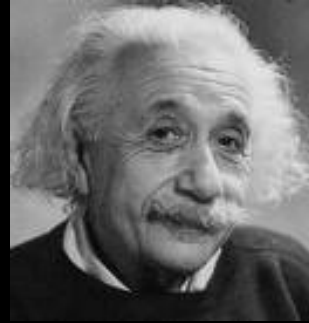
You enter a black hole in one place and pop out elsewhere.

Not traveling faster than light.. Just taking a shortcut in a folded space.



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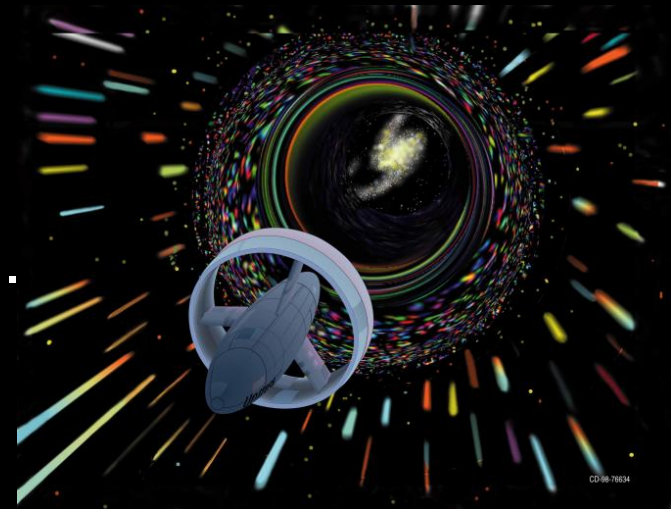


Worm holes and Black Holes:

Worm holes exploit possible solutions of the Equations of General Relativity --- but exactly where we expect General Relativity to fail.

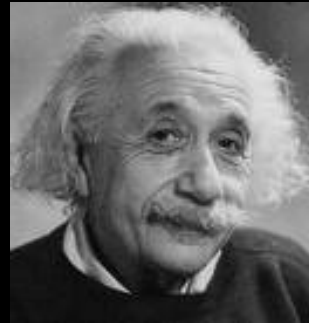
We know that General Relativity is wrong at some deep level because it is not compatible with Quantum Theory... but General Relativity is mostly correct...

But worm holes likely depend on the theory exactly where it is breaking down.



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Worm holes and Black Holes:

Science fiction ideas: pocket-size black holes?

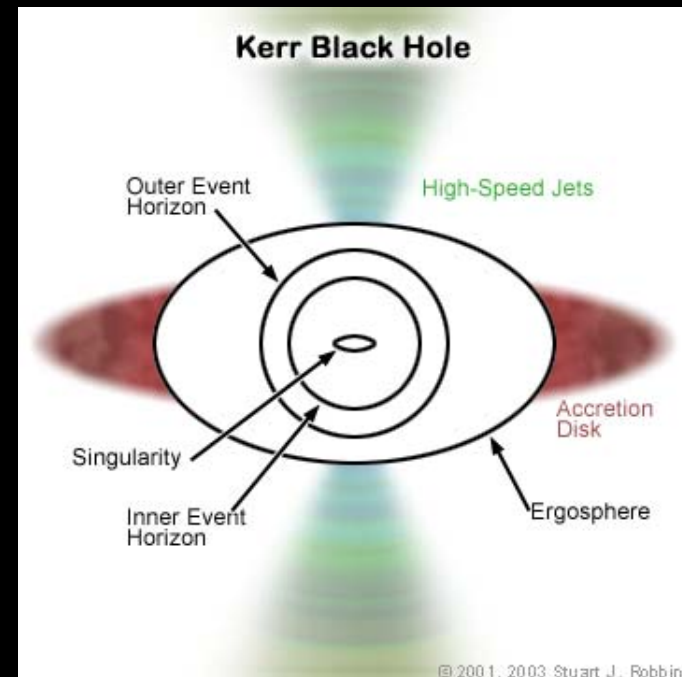
Could exist if made at creation of Universe...

No evidence for one to date... one with the mass of the Earth would be 2 cm across!

Time travel with Black Holes...

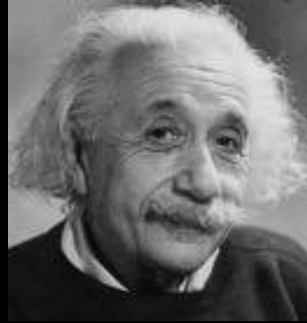
possible for spinning black holes

No evidence for worm holes in the Universe to date.



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Worm holes and Black Holes:

The real problem with using black holes for travel is that you would be stretched out to atoms by the tides as you approach the event horizon....

And you would be fried by the energy from other stuff flowing into the black hole.

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Quantum Drive?

Wild speculation... could there be a way to quantum mechanically tunnel from one place to another?

Other unknown physics?

BUT

If space travel is really easy....

and there are lots of planets with civilizations....

Why don't we see anybody?

The occasional "warp core breach"?

An intergalactic war here and there?