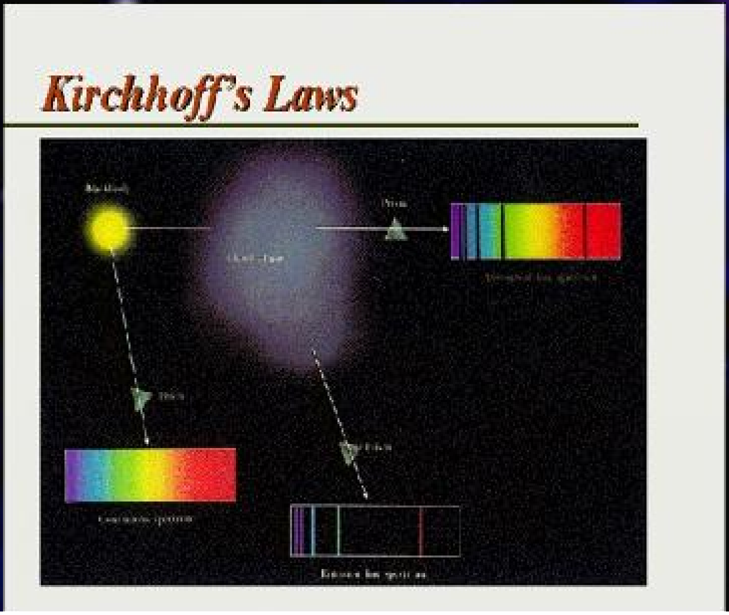
Arsenic concentrations at 200ppm (200uM)

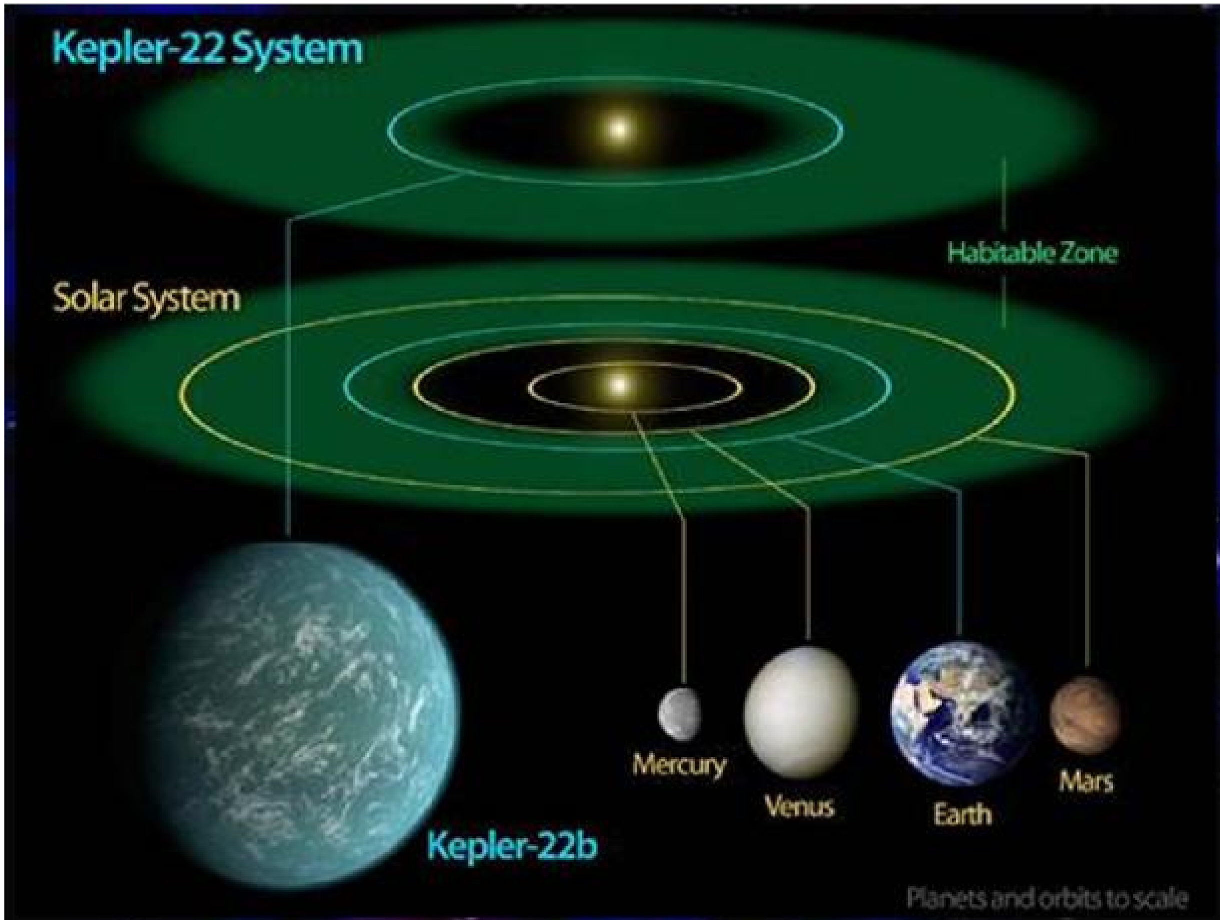
Super-Earth's atmosphere analyzed for first time

exoplanet GJ 1214b, which orbits a star 40 light-years away

6.5 times earth mass
2.5 times earth's radius

100 lb on earth would weight 104 lb on planet



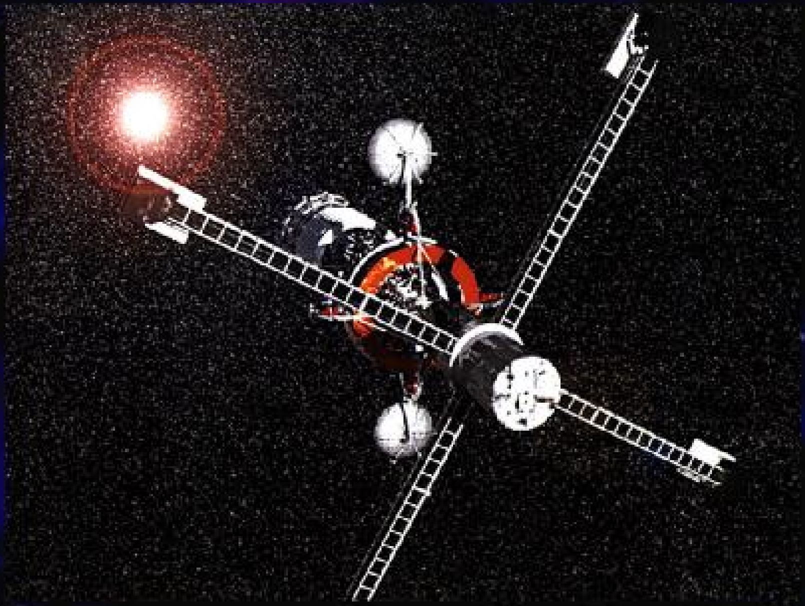


Kepler's haul: >2300
New potential planets
In first 16 months of
operation

G type star

INTERSTELLAR TRAVEL

The Good News... The Bad News..



Begin with the obvious:

- Distances between the stars is ***<u>overwhelming</u>***
- Life bearing planets are NOT simply the nearest neighboring stars
- Interstellar travel as portrayed by Hollywood GROSSLY OVERSIMPLIFIES the basic physical limitations and requirements

Funding interstellar missions would be difficult if not impossible

- Tremendous costs involved
- No immediate return from investment

Fallacy:

Interstellar travel can be achieved simply by future advances in technology.

Examples:

- The limits of sailing ships were exceeded with steam ships
- The speed limits of propeller aircraft were exceeded by jet aircraft
- The altitude of aircraft were exceeded by rockets

Issues to deal with:

- Overwhelming distances
- Energy limitations
- Propulsion
- Supplies
- Emergencies
- Who goes?

Science Fiction to the rescue:

Cue Breakthrough Inspirations

- 1880, P. Grec, "*Antigravity*"
- 1928, E.E. Smith, "*FTL*"
- 1931, J. Campbell, "*Hyperspace*"
- 1935, N. Schachner, "*Space Warp*"
- 1951, M. Gibbs, "*Warp Drive*"

1956, Forbidden Planet

1966, Star Trek

1999, Galaxy Quest

Perry Rhodan

1993, Babylon 5

1984, Buckaroo Banzai

1978, Douglas Adams
Infinite Improbability Drive

1977, Star Wars

Historical Achievements in Speed

Reaching Alpha Centauri (4.3 ly)

Automobiles (55 mph)

- 53 million years

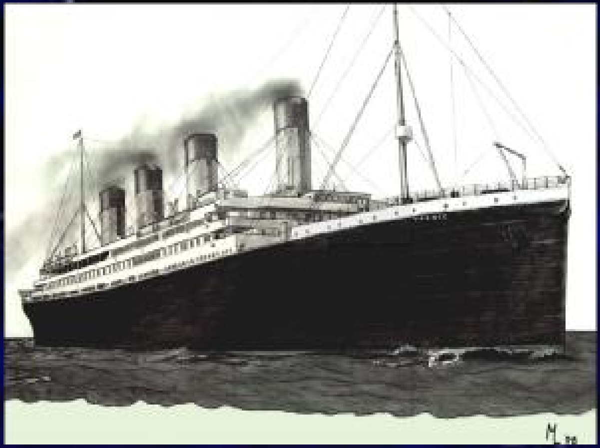
Apollo Lunar Missions (25,000 mph)

- 118,000 years

Interplanetary Missions (37,000 mph)

- 80,000 years
- (0.004% light speed) !

The Energy Issue:



A conservative estimate: Titanic

- 18,000 kg per passenger
- 100 million kg ship
- Traveling at 10% light speed
- 40 years to nearest stars
- 4.5×10^{22} joules of energy needed
- 10^8 times the world annual energy use.
- 10¢ per kilowatt hour = $\$3 \times 10^{16}$

Energy Considerations from a Supernova Explosion

Three releases of energy:

1. Electromagnetic (light)	1x
2. Kinetic energy of exploding material	100x
3. Neutrino escape	10000x

Energy Considerations from a Supernova Explosion

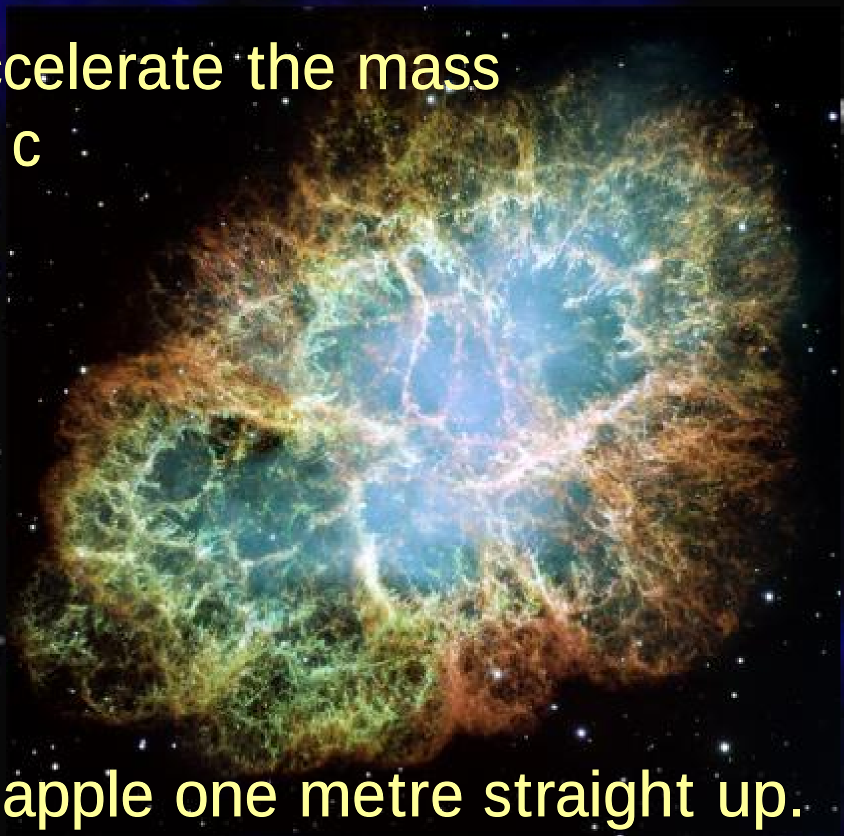
For a brief time a supernova explosion will out shine an entire galaxy in electromagnetic energy

Supernova 1987a

Energy Considerations from a Supernova Explosion

Kinetic energy: 100x the EM energy:

10^{47} Joules*, enough energy to accelerate the mass of the sun to 3.3% speed of light, c



*the energy required to lift a small apple one metre straight up.

Energy Considerations from a Supernova Explosion

- Neutrinos: chargeless, very small or massless, weakly interacting particle
- Produced by nuclear reactions
- As fuels at carbon and beyond burn in core of high mass star, their release goes up dramatically, cooling the core
- Pass through light years of lead and not interact
- 10^{10} pass through every cm^2 of your body every second

Neutrino release: 10000x the EM energy:

10^{49} Joules, enough energy to accelerate the mass of the sun to 99% speed of light, c

IST: Different levels of possibilities

IST over short timescales (days, weeks or months)

- Faster than light travel

IST over human lifetimes (years or decades)

- Near light speed travel

IST over multiple generations (centuries or hundreds of centuries)

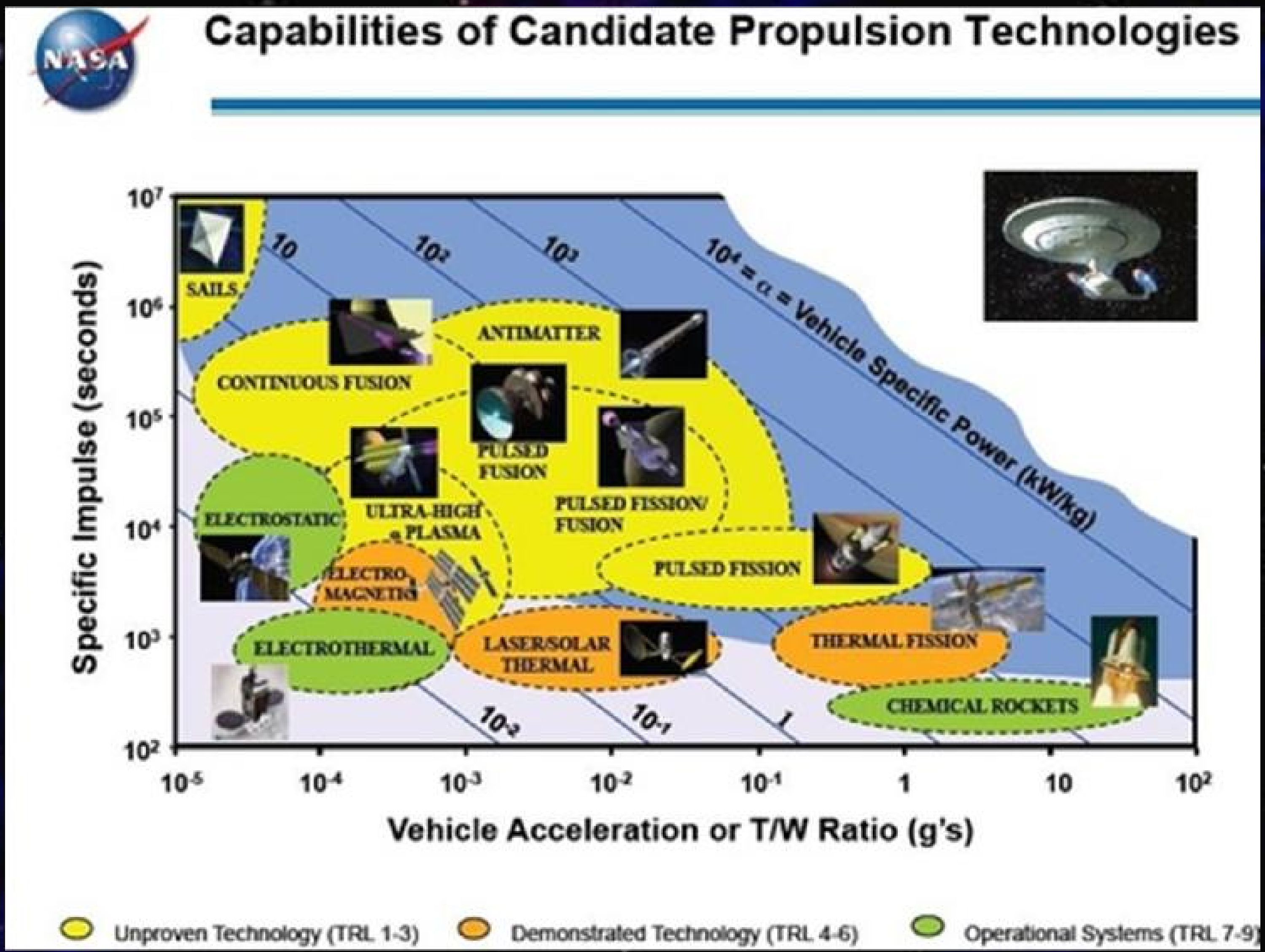
- Sub-light speed travel

The Propulsion Issue:

General problem:

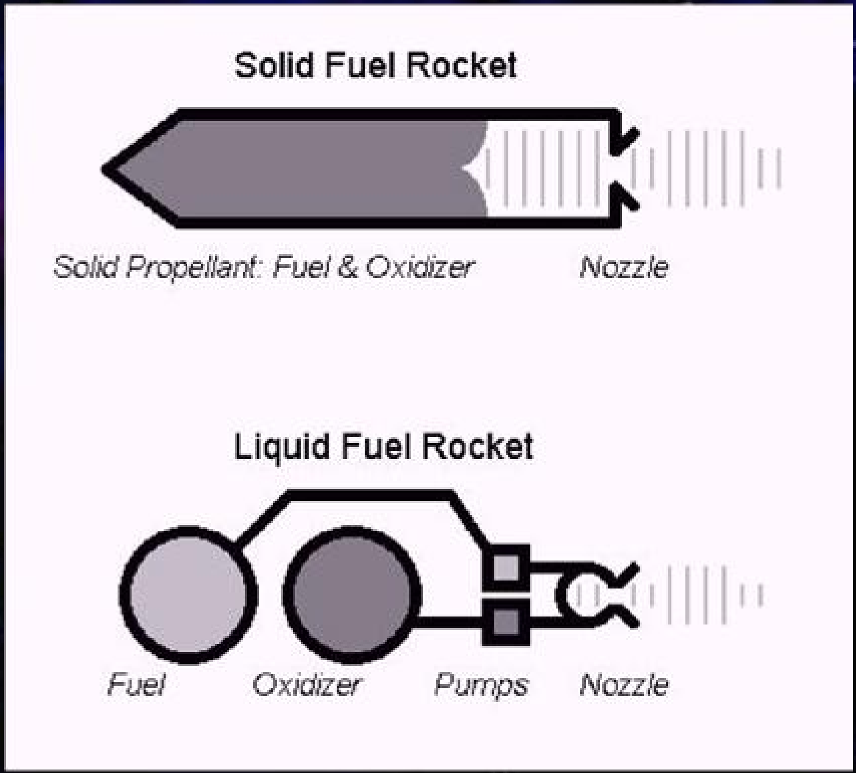
High thrust = Inefficient propulsion

The Propulsion Issue:



Chemical Bipropellant

Chemical reaction creates expanding gasses that are expelled out a very narrow nozzle propelling the spacecraft forward



Chemical Bipropellant (cont'd)

- Thrust: 0.1 - 10^7 Newtons
- Specific Impulse (measure of efficiency of engine): 100 – 400
- Pro: powerful, relatively cheap, abundant chemicals
- Con: largely inefficient

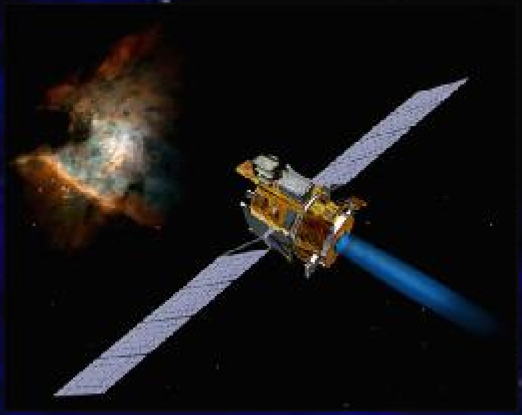
Currently the propellant of choice in modern rocketry

It represents the impulse (change in momentum) per unit amount of propellant used.

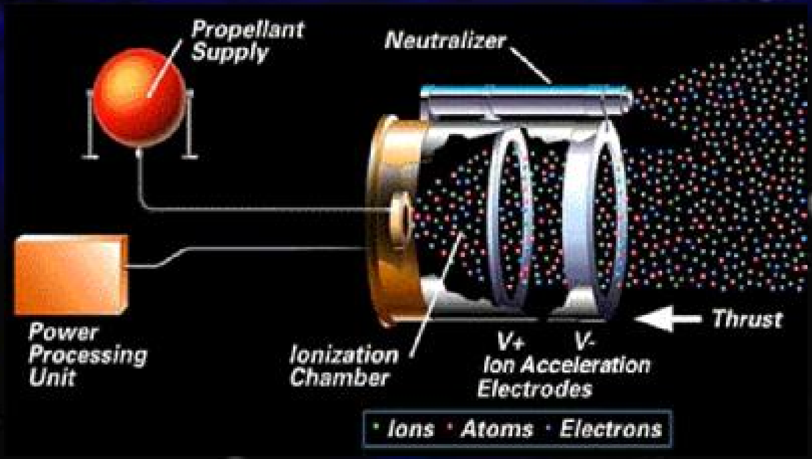
Example: Saturn V Rocket

- Oxygen + kerosene fuel mixture
- Multistage rocket more efficient
- Outweighed the payload 60:1

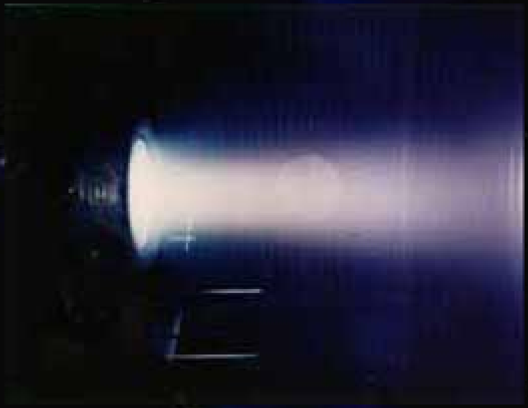
Electromagnetic Propulsion



Ionized gasses are electrically accelerated and expelled propelling a spacecraft forward



- Ionized Xenon gas
- Accelerated ionized gasses provide thrust
- Ejected ions travel at 67,000 mph



$M_i v_i = M_f v_f$

Person mass 100kg
Ball mass 100kg
Throws it at 10 mph

100(10) = 100(x)

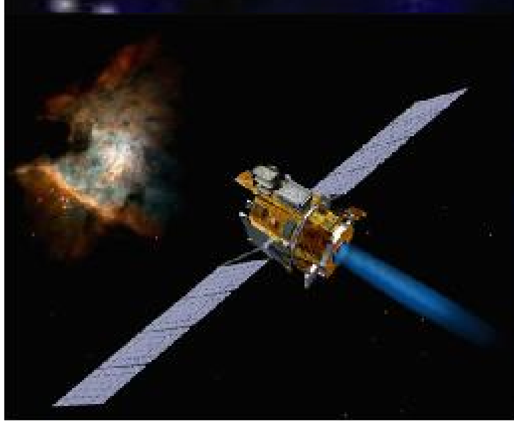
X = 10 mph

$M_i v_i = M_f v_f$

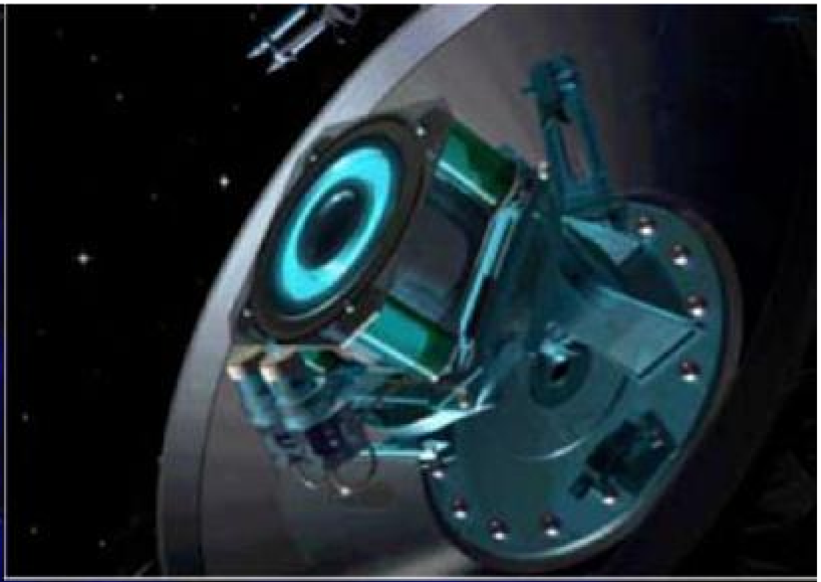
Xenon = 1000kg, velocity 67000mph

Payload 50kg, final velocity =

1000(67000) = 50(x)   1,340,000 mph

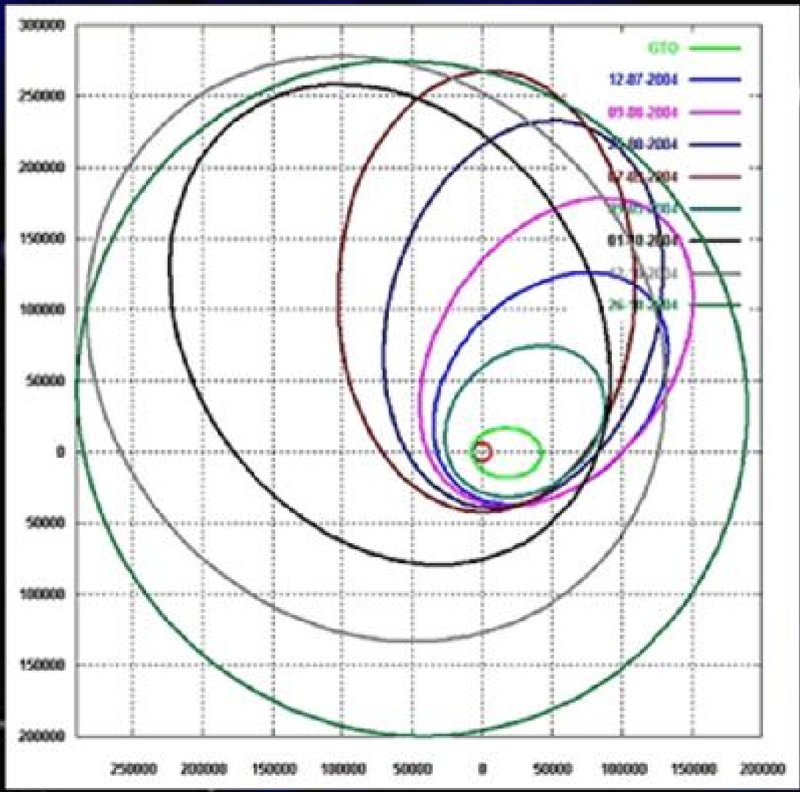


Electromagnetic Propulsion



SMART-1 mission to moon

- Ionized Xenon gas
- Thrust – 2 pennies in hand
- 48 liters Xenon
- 7000 hrs life of engine – full thrust



Electromagnetic Propulsion (cont’d)

- Thrust: 30 Newtons
- Specific Impulse (measure of efficiency of engine): 1200 – 5000
- Pro: relatively simple design...can efficiently achieve high velocities (10 times total speed of chemical rockets)
- Con: thrust is minimal... very low acceleration... not intended for massive payloads

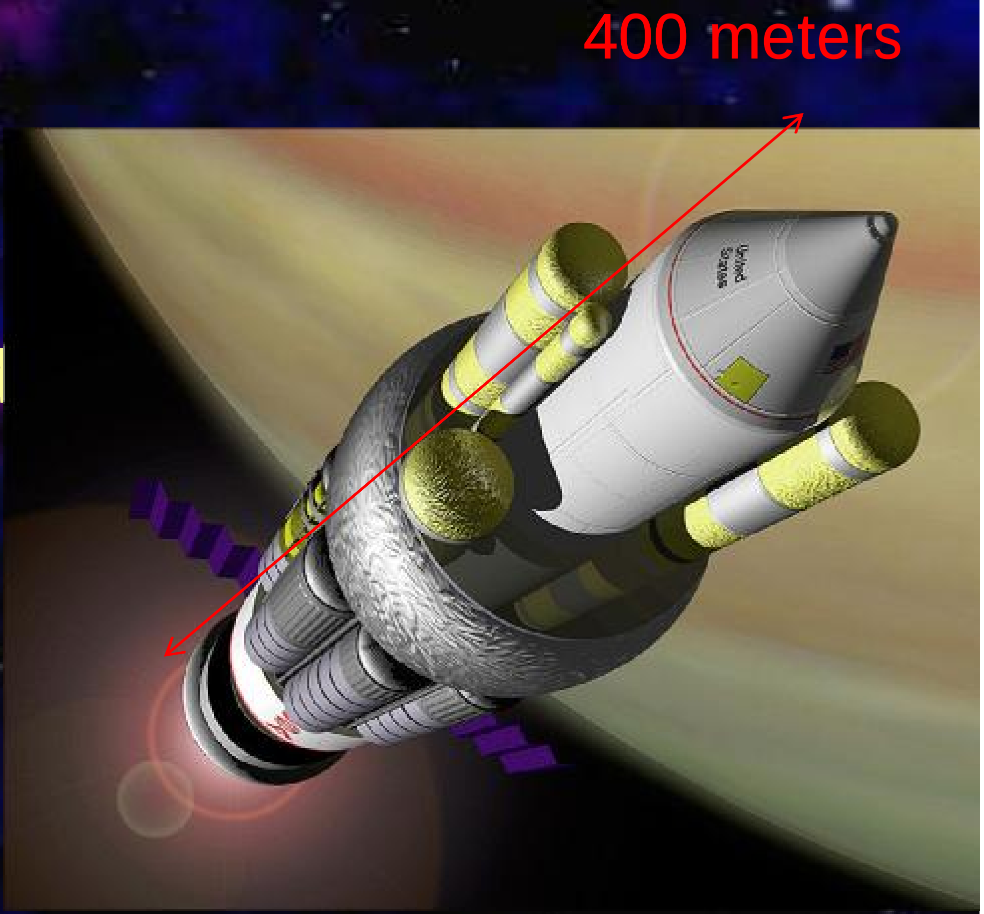
Nuclear Propulsion

Binding energy released from nuclear reactions used as energy source for propulsion

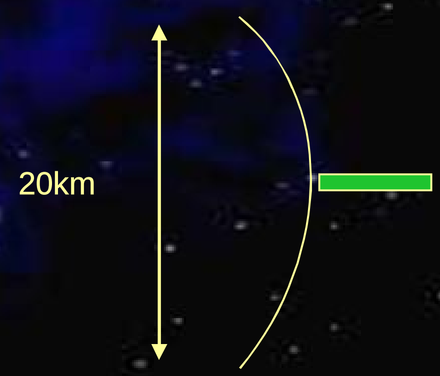
- High rate of thrust
- Very efficient
- Pro: Relatively high yield of energy from reaction... high speeds achievable
- Con: Dangerous to crew

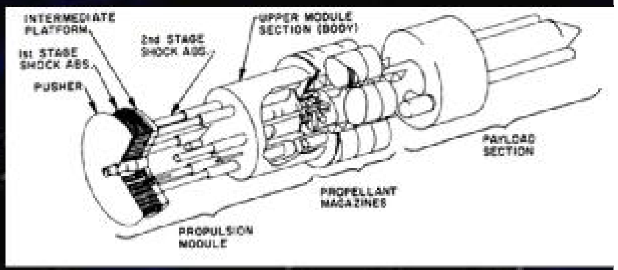
Project Orion (1950's, 60's)

- Nuclear detonations propel a rocket forward
- 8 million tons
- 1 – 5 detonations per second increasing in yield
- Thrust: $10^9 - 10^{12}$ Newtons
- Specific Impulse: 2000 – 100,000
- Speeds up to 10% c
- Scrapped due to Nuclear Test Ban Treaty

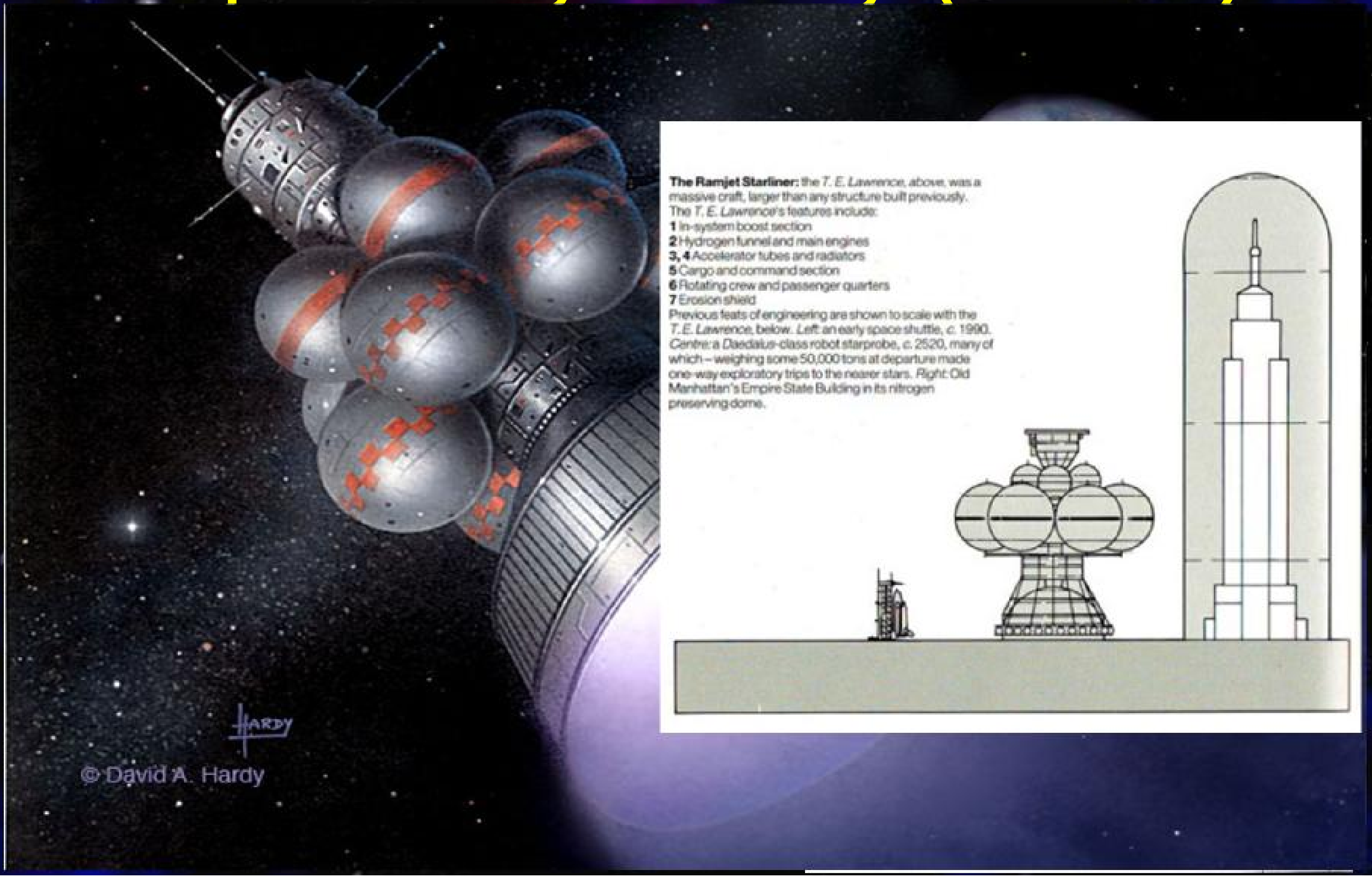


	"Energy Limited" Orion	"Momentum Limited" Orion
Ship diameter (meters)	20,000 m	100 m
Mass of empty ship (metric tons)	10,000,000 t (incl.5,000,000 t copper hemisphere)	100,000 t (incl.50,000 t structure+payload)
+Number of bombs = total bomb mass (each 1MT bomb weighs 1 metric ton)	30,000,000	300,000
=Departure mass (metric tons)	40,000,000 t	400,000 t
Maximum velocity (kilometers per second)	1000 km/s (=0.33% of the speed of light)	10,000 km/s (=3.3% of the speed of light)
Mean acceleration (Earth gravities)	0.00003 g (accelerate for 100 years)	1 g (accelerate for 10 days)
Estimated cost	1 year of U.S. GNP (1968)	0.1 year of U.S. GNP





Project Daedalus: British Interplanetary Society (1970's)

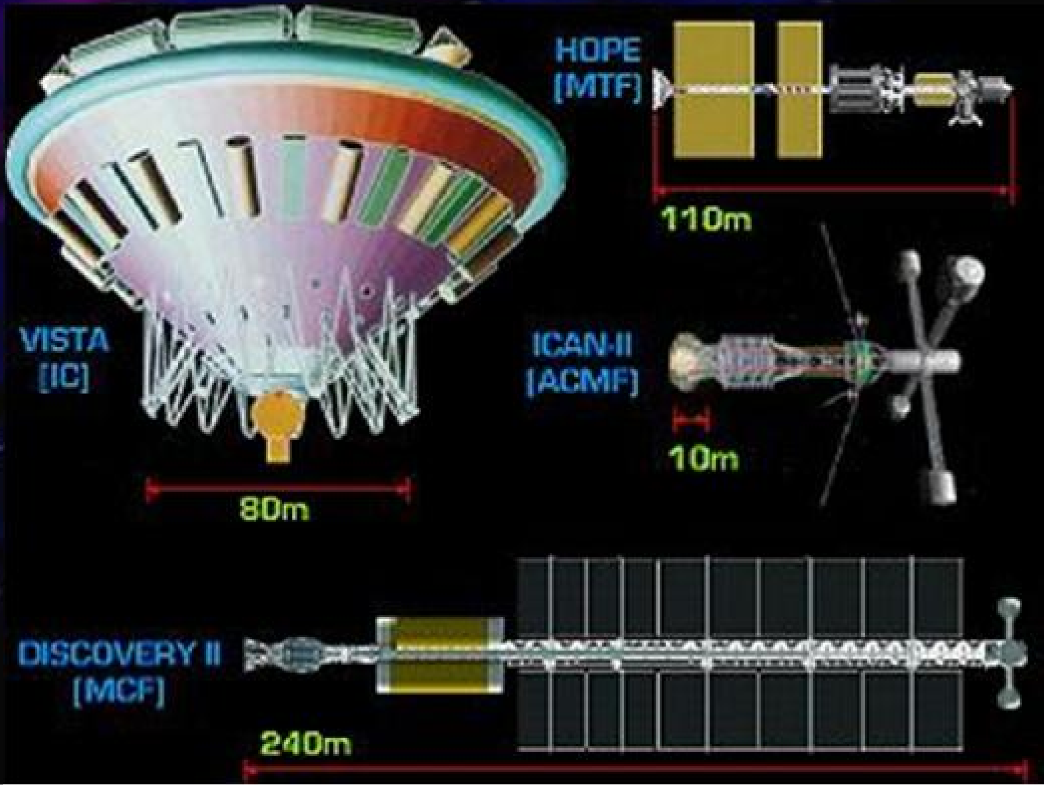


More recent designs using fusion propulsion (1987-2004)

Montage of fusion-powered rocket concepts from 1987–2004,
which could form the basis for an interstellar vehicle. Included are:
VISTA (Lawrence Livermore National Laboratories,1987),
Discovery II (NASA/GRC, 2002),
Human Outer Planet Exploration (NASA/MSFC, 2003),
ICAN-II (The Pennsylvania State University)

Fission: 0.1% energy release
Fusion: 0.3-0.9% energy release

Neutron energy loss **L**



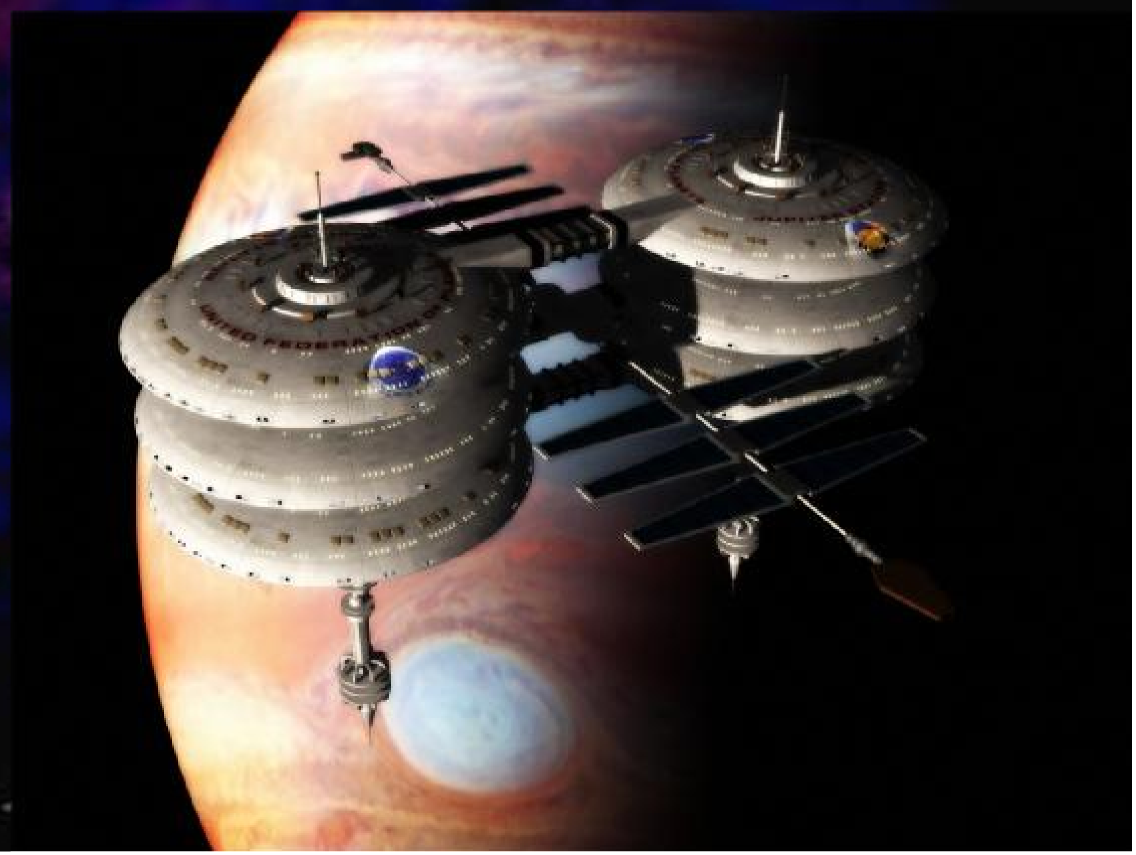
Fuel Source difficulties

^3H or ^3He

Fission: 0.1% energy release
Fusion: 0.3-0.9% energy release

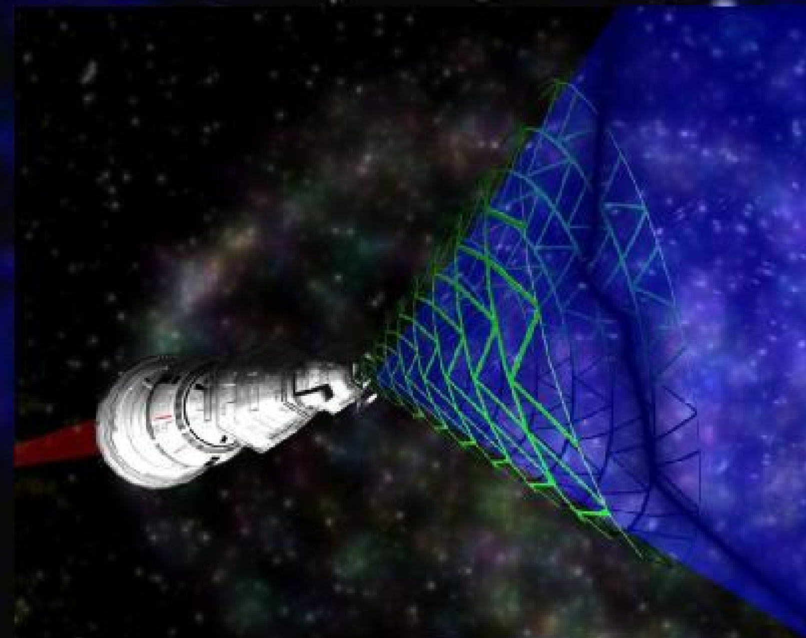
Neutron energy loss **L**

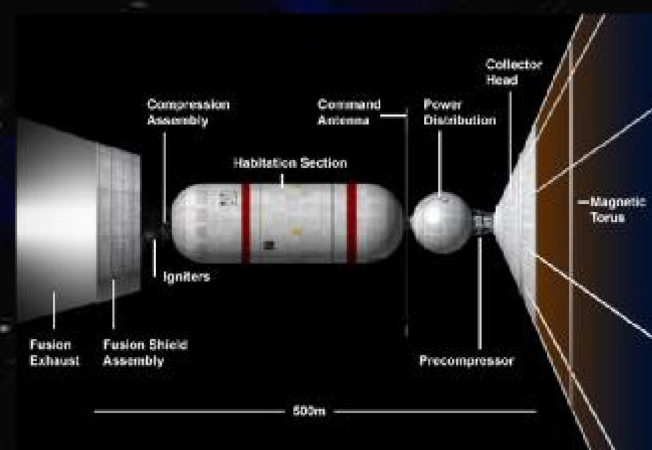
Cloud City on the planet Bespin



Bussard Interstellar Ramjet

- Large “scoop” collects interstellar hydrogen
- Hydrogen used in fusion propulsion
- Problems with the drag created by the “scoop”



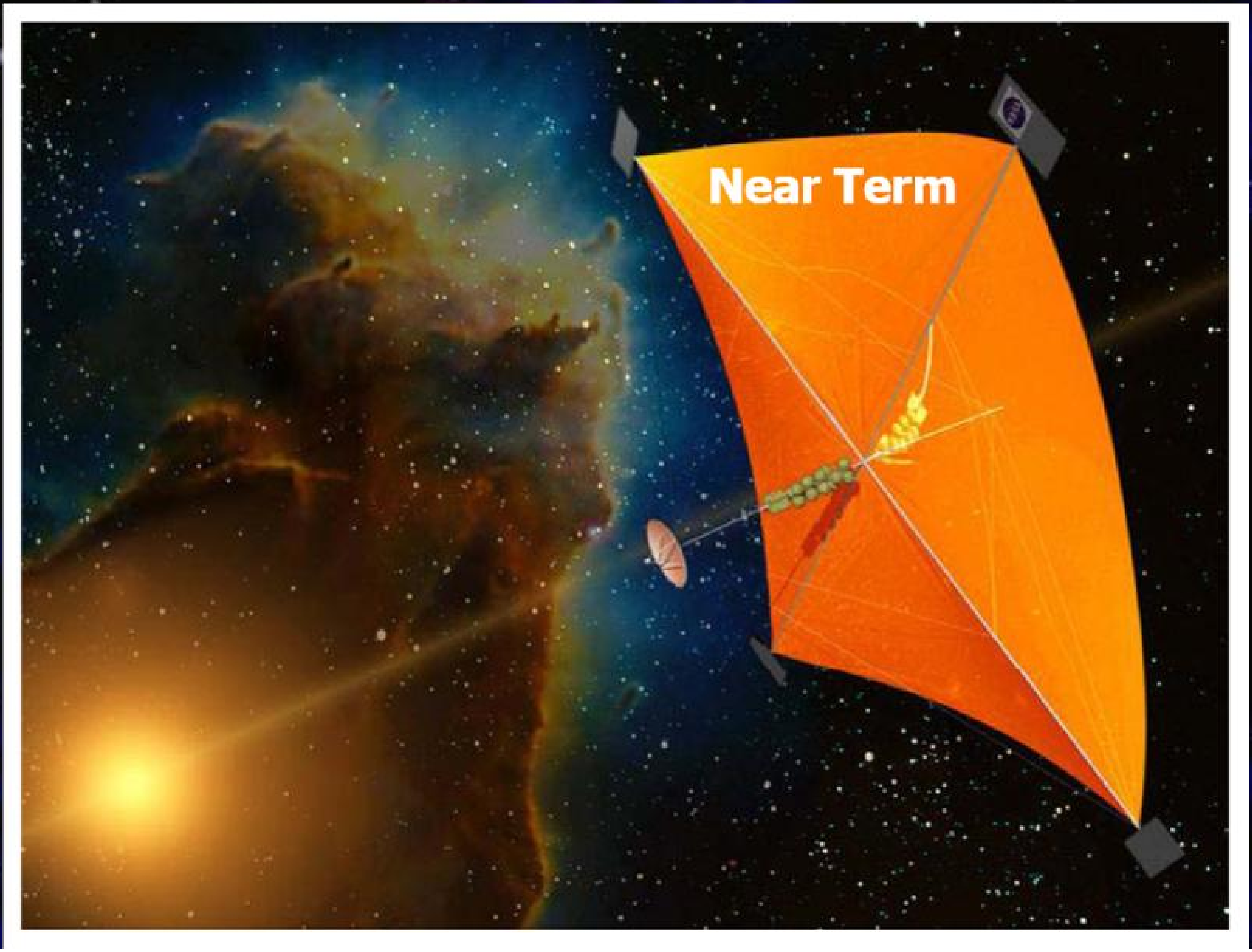


Matter/Antimatter Annihilation

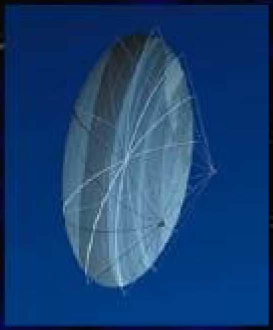
Combination of matter and antimatter yields energy via $E=mc^2$

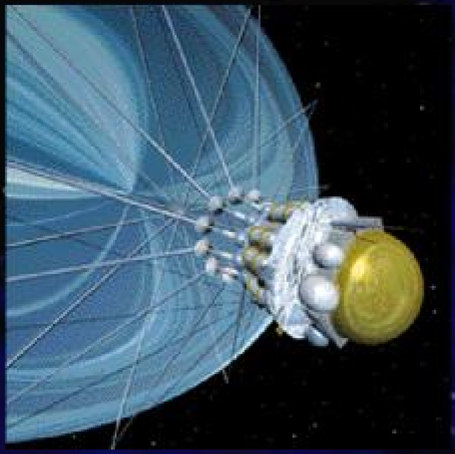
- 100% of matter is converted to energy
- 100 times more energy released compared to hydrogen fusion
- 30-50% c achievable
- Problems with manufacturing of antimatter and containment of antimatter
- For reference: 10 g AM to reach mars in 1 month

Laser Sail



Laser Sail

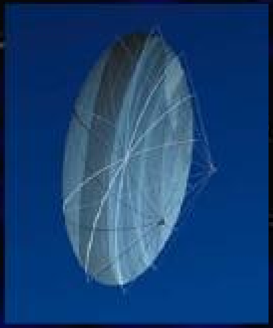


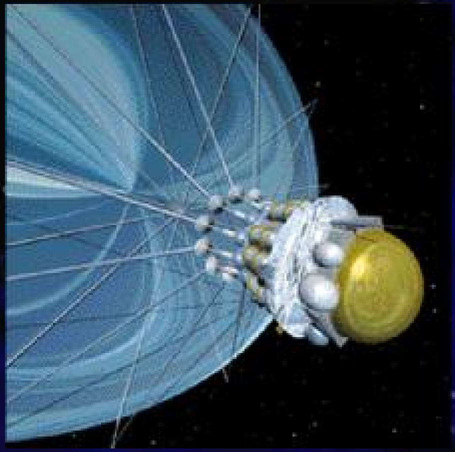


High energy laser beam is concentrated onto a lightweight sail (10's to 100's km size)

- Sail is propelled forward carrying a small payload
- Problems: ENORMOUS laser energies needed to propel even the smallest payload.
- Acceleration to 50% light speed would require 1000 times the power of all human power consumption!

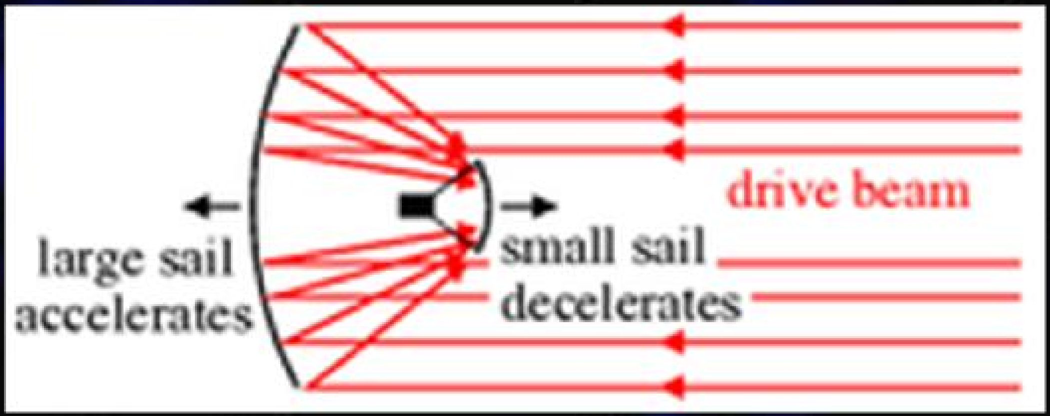
Laser Sail





Slowing down!!!

Any thoughts?



Side Bar……..must we send people?

To send a manned ship to α centuari in 40 years:

- Laser system would need to be 1000's of Giga watts
- More than ALL power generated on earth combined

To send a 10kg probe to α centuari in 40 years:

- 50 Giga watts required
- Still large but only 15% of total US output

Conclusion:

Every imaginable propulsion system has a monumental fuel problem

- Antimatter annihilation is most efficient
- If 99% light speed is desired
- ~200 x (mass of final payload) is necessary as fuel
- Roundtrip requires 40,000 x (mass of final payload) is necessary as fuel
- Skylab would have required 12 million tons of fuel for such a journey!

Revolutions in propulsion systems might make IST more efficient... BUT:

- Does not address limitations imposed by laws of physics
- Does not address limitations imposed by the hazards of IST
- Does not address limitations imposed by the human requirements of IST

Does this mean the we give up?

NASA's Breakthrough Propulsion Physics Project (BPP)

Goals:

- Discover new propulsion methods that eliminate or dramatically reduce the need for propellant
- Discover how to attain the ultimate achievable transit speeds to dramatically reduce deep space travel times
- Discover fundamentally new on-board energy production methods to power propulsion devices

VERRRY small budget... ~$100,000's

However

NASA and Defense Advanced Research Projects Agency funded to a private agency in January 2012

Hundred-year Starship (100YSS)

Goals:

- Work toward achieving IST within next 100 years
- Lay groundwork for organization that can carry work forward

Does this mean the we give up?

- The Good
  - Intellectually stimulating topic
  - Easy to be a pioneer while others shy away –
    by simply doing an honest, competent job
  - Coworkers offer encouragement *(to watch the arrows in your back)*
- The Bad
  - Virtually no funding
  - Difficult on your management (*"It doesn't fit our plan!"*)
  - Revolutionary work is disruptive
- And The Ugly
  - Attracts the *Lunatic Fringe*

Interstellar Travel at *NEAR* Light Speed

Why not travel *AT* light speed?

- Violation of laws of physics
- Relativity governs physics as we approach light speed:

As velocity increases so does kinetic energy. If v=c then K goes to infinity.

$$K = \frac{mc^2}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - mc^2$$

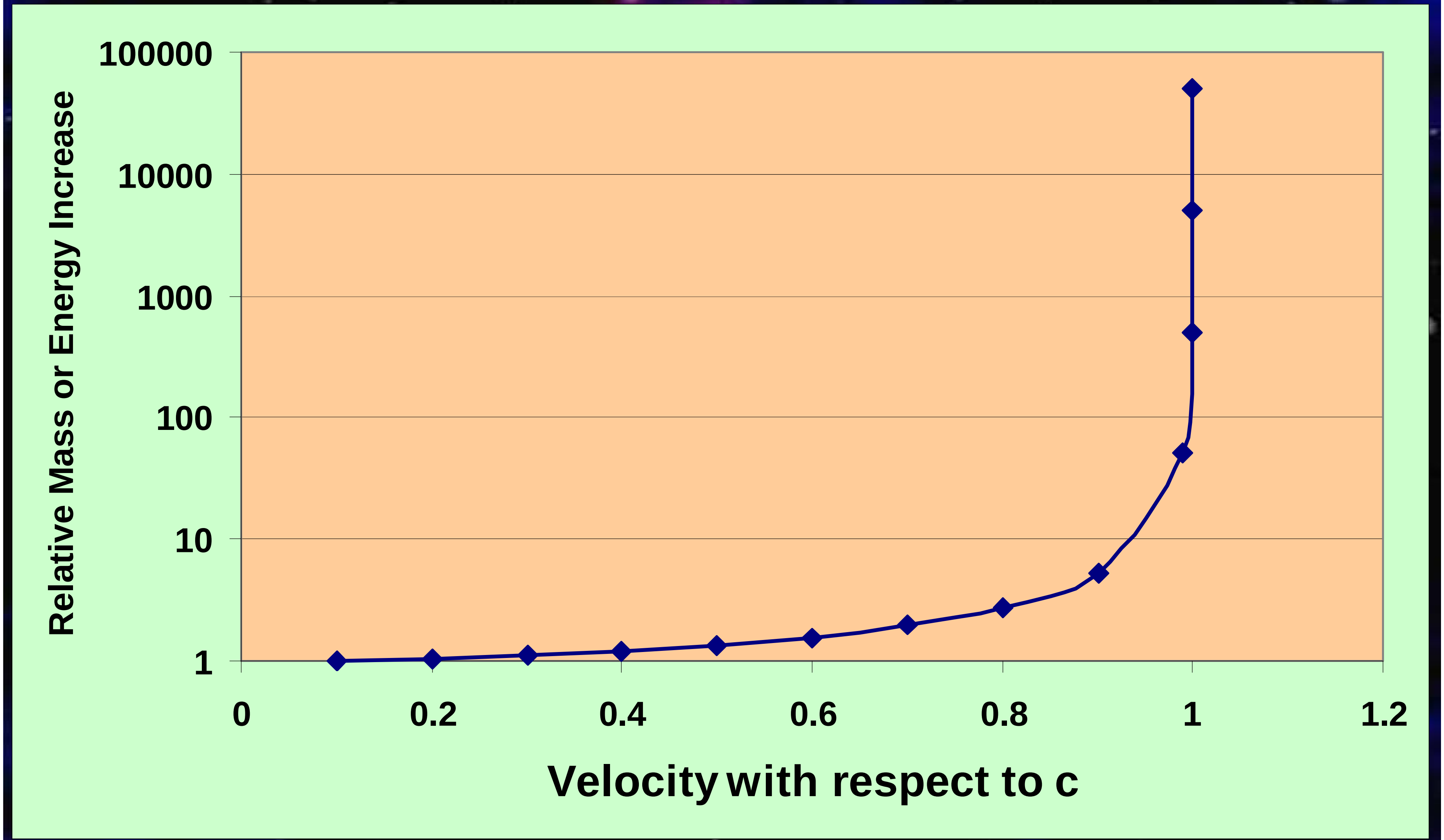
As velocity increases so does m_{moving}. If v=c then m_{moving} goes to infinity.

$$m_{moving} = \frac{m_{rest}}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

If object has mass of 1 kg, what is its mass at 80% c

$1-(.8/1)^2 = 0.36$ Sqrt 0.36 = 0.6 1kg/0.6 = 1.666kg

Effect of increasing velocity on Mass and Energy Requirements



RESULTS:

***<u>Nothing</u>* with mass can travel AT the speed of light**

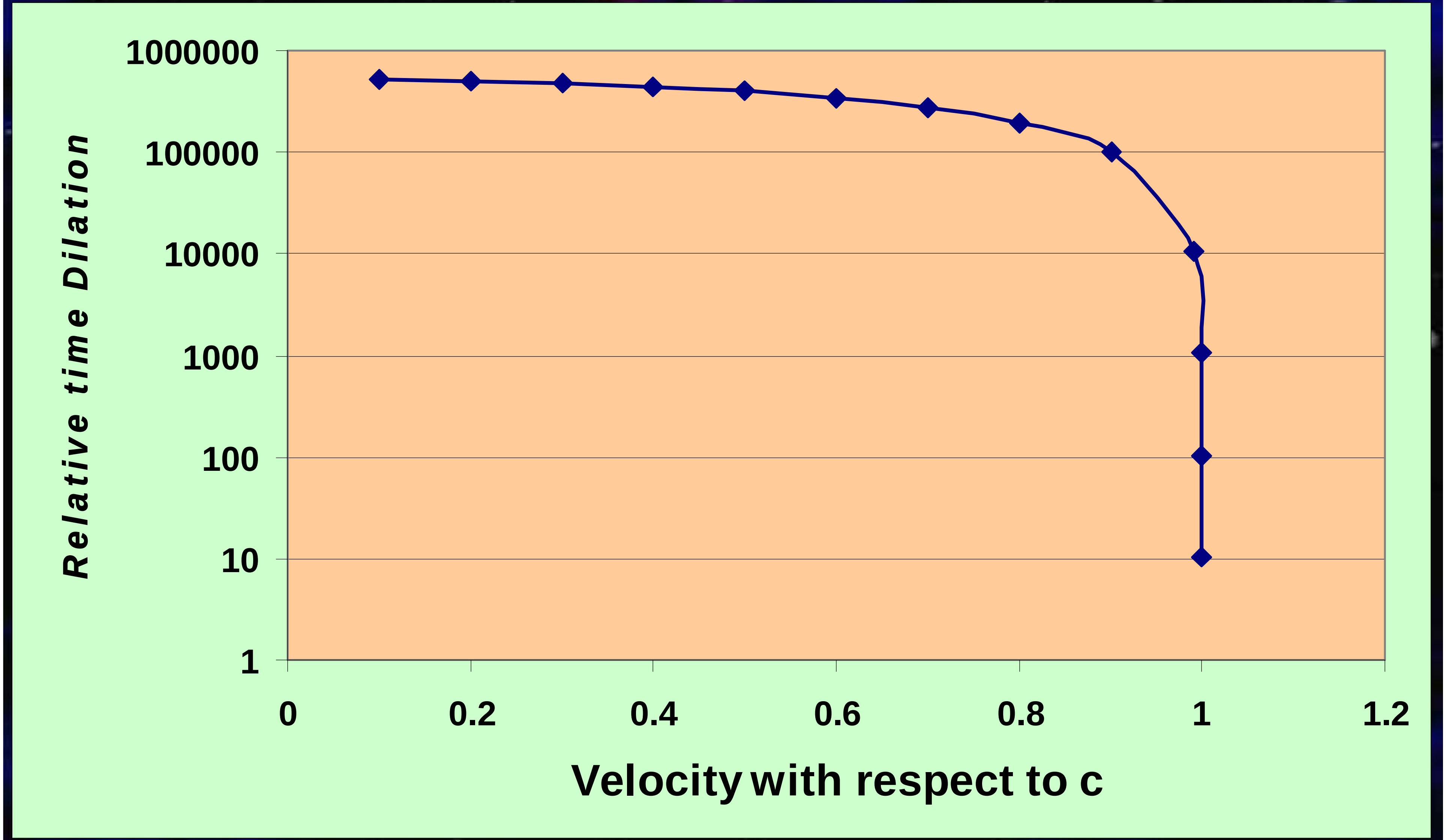
- However *<u>NEAR</u>* light speed is possible

Advantages of NEAR light speed travel: Relativistic Time Dilation

- The measurement of the passage of time is relative to the frame of reference
- The passage of time for someone moving at high speeds appears slower as seen by an observer at rest

$$\Delta t_{rest} = \frac{\Delta t_{moving}}{\sqrt{1-\left(v/c\right)^2}}$$

Time Dilation as velocity increases, 1year = 525600 minutes



50% light speed

At 50% c

- 1.15 seconds on earth pass for every 1 second measured by a traveler
- A 10 lightyear journey would take 20 earth years
- Travelers would experience a 17 .4 year journey

75% light speed

- 1.5 seconds on earth pass for every 1 second measured by a traveler
- A 10 lightyear journey would take 13 earth years
- Travelers would experience a 8.7 year journey

99% light speed

At 99% c

- 7 seconds on earth pass for every 1 second measured by a traveler
- A 10 lightyear journey would take 10.1 earth years
- Travelers would experience a 1 year 5 month journey

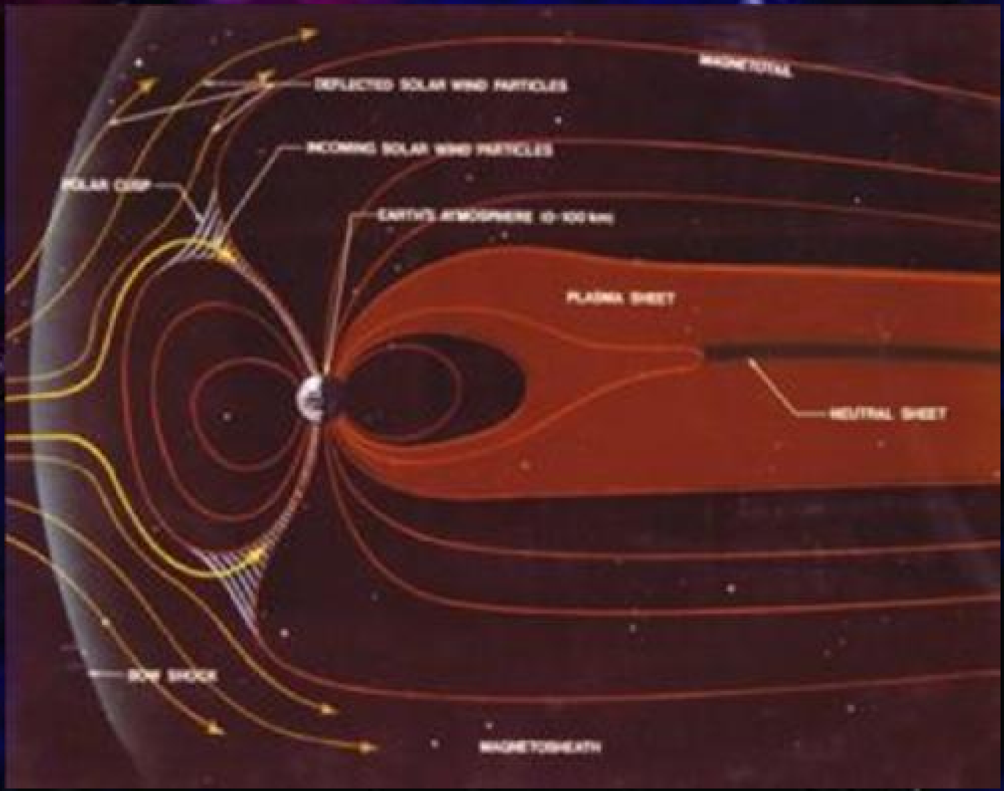
99.99% light speed

At 99.99% c

- 71 seconds on earth pass for every 1 second measured by a traveler
- A 10 lightyear journey would take 10 earth years
- Travelers would experience a 1 month 2 week journey

The Hazards of Interstellar Travel

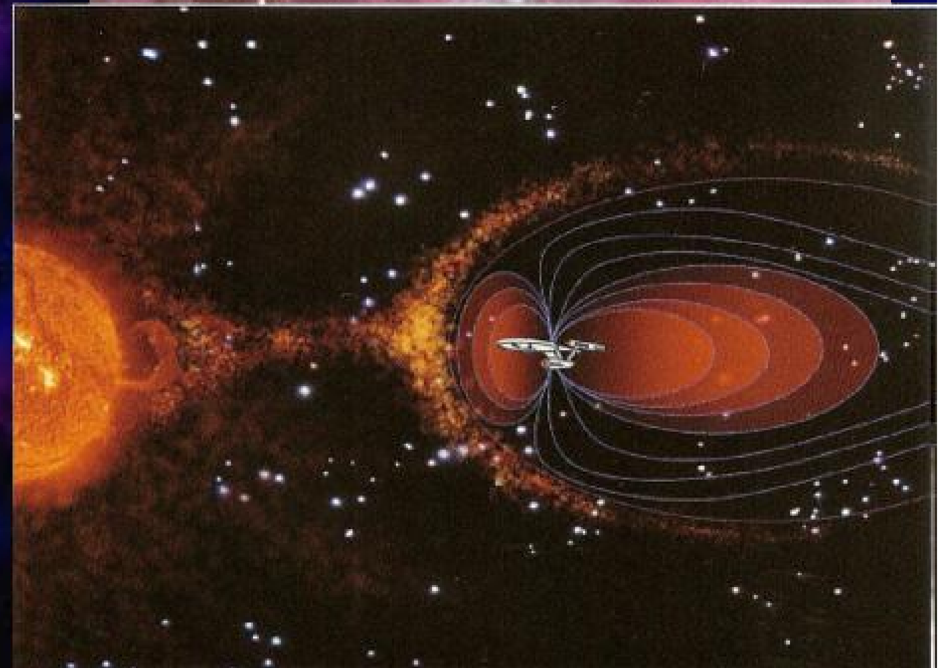
- **The Interstellar Medium is not empty!**



The Hazards of Interstellar Travel

- **The Interstellar Medium is not empty!**
- **Onboard supplies are limited**
- **What to do in an emergency?**

Hazards of the ISM



- Travel through the ISM requires more than simply avoiding stars
- The ISM contains atoms of gas and dust particles
- Travel at high velocities makes impacts devastating!

$$m_{moving} = \frac{m_{rest}}{\sqrt{1-\left(v/c\right)^2}}$$

Limited Onboard Supplies

- Bringing necessary supplies adds mass to the payload
- Added mass requires more fuel for propulsion
- How are supplies kept fresh?
- Possible solution could be to “grow as you go”
- What about items that are cannot be replenished?

Hibernation as a possible solution?

- Still problems with food
- Not proven to be a physical reality

What about emergencies?

- Mechanical problems
- Medical emergencies
- Help is *NOT* on the way...

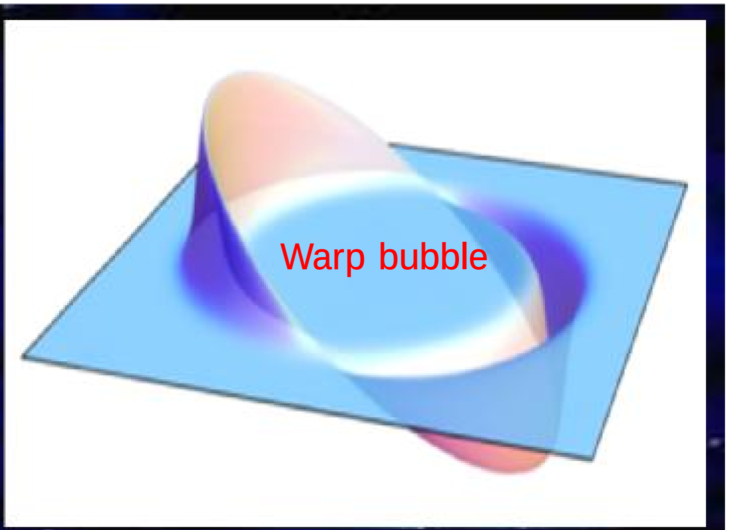
Faster Than Light Travel?

The General Theory of Relativity suggests dimensions beyond time and 3 dimensional space.

1. **Warp Travel**
2. **Worm Holes**

Warp Travel

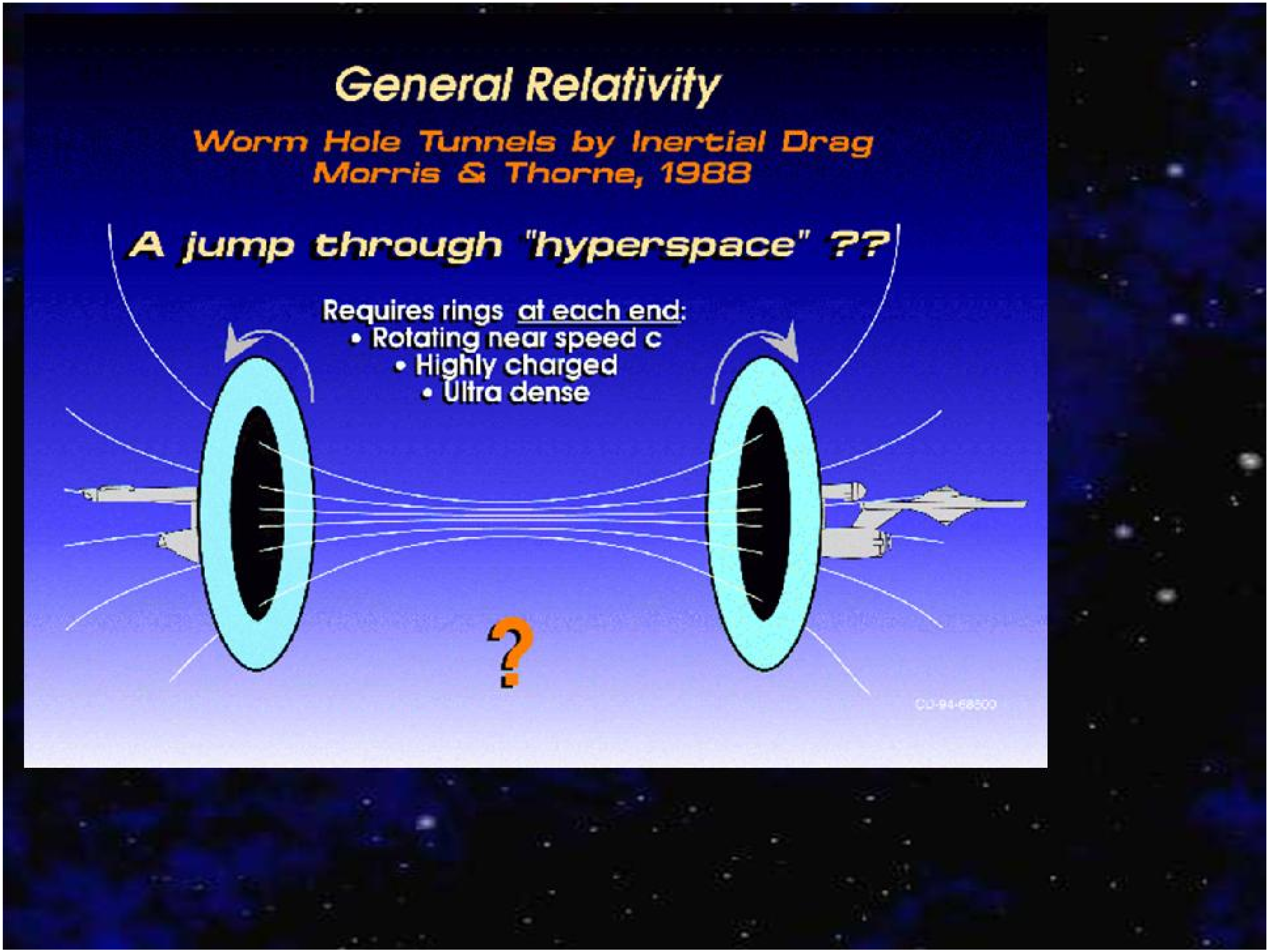
$$G_{\mu\nu} = 8\pi G T_{\mu\nu}$$



- Compress space in front of your spacecraft... expand space behind your spacecraft
- Relativity suggest it might be possible...
- Outside observers would see the spacecraft move “faster than light”
- Inside observers would not feel an acceleration
- Nullifies relativistic time dilation effects
- Known as Alcubierre drive, is a solution of Einstien’s eq.

Worm Holes

- Rotating black holes create a distortion in spacetime
- Complete Schwartzchild geometry allows for a black hole, a white hole and a worm hole in-between
- Severe distortions of spacetime allow multidimensional travel
- “Predicted” by Einstein’s General Relativity... however seems unlikely to exist
- If they exist, Relativity suggests they would be highly unstable and unpredictable


General Relativity
Worm Hole Tunnels by Inertial Drag
Morris & Thorne, 1988
A jump through "hyperspace" ??
Requires rings at each end:
• Rotating near speed c
• Highly charged
• Ultra dense
?

Food For Thought:

If a journey of hundreds of thousands of years or even thousands of years at best is undertaken...

- What is unknown and important to us today may not be important to the people of 10,000 or 100,000 years from now

Food For Thought:

A later ship with the ability to travel faster than the original ship would intercept the original ship before it even reaches its destination

Food For Thought:

- The very same physics that allows us to travel a near light speeds, also makes near light speeds extraordinarily hazardous!

If multigenerational journeys are undertaken:

- The visitors that arrive at an alien world will not be the ones who received the message...
- The ones being visited will not be the ones who sent the message...