Travel

Recall Argument Against Travel

Communication is much cheaper than travel

Energy needed for Mass (M) at speed (v)

$E = 1/2\ Mv^2$ if v much less than c

e.g., travel to nearest star (4 ℓy) in 40 yr

$\Rightarrow$ v = 0.1 c $\Rightarrow$ E = 4.1×10^{-9} ergs

for M = M (electron)

Photon $E = h\nu$ $h = 6.6 \times 10^{-27}$

                                         $\nu = $ frequency

$= 6.6 \times 10^{-18}$ ergs   if $\nu = 10^9$ Hz

Ratio $\sim 10^9$ (and photon gets there in 4 yrs)

100 M watt transmitter - 1 yr

$\$ 40 \times 10^6$

Spacecraft to nearest star

$\sim \ \$ 5 \times 10^{16}$

(some recent analysis questions this conclusion)

Why Consider Travel?

Reasons for Interstellar Travel

Reasons:

1. Communication if searches fail

2. Exploration of other planetary systems

   Planetary Science

   Exobiology (many bacterial planets)

$$N_\ell = \underbrace{R_* f_p n_e f_\ell L_\ell} \qquad L\ell > 3 \times 10^9 \text{ yr on Earth}$$

	Birth Rate	Lℓ	Nℓ
Happy Feller	50	3×10^9	1.5×10^{11}
Angela Angst	7.5×10^{-4}	3×10^9	2.3×10^6
Average Guy	2.2	3×10^9	6.7×10^9

Other Reasons

- Colonization
  - Species Immortality
  - Could survive the end of life on Earth
- The explorer's urge
  - "to boldly go …"

Pattern of Solar System Exploration

1. Ground-based observations (telescopes)
2. Fly-by missions, Radio back results
3. Orbit or land, Radio back results
4. Mission with human beings
   Return to Earth (Moon Only)
5. Permanent Base (Not Yet)

Expect similar for Interstellar
Except
No Round Trips
Distances to Stars ~ Light Years

$$\text{Time} = \frac{\text{Distance (Ly)}}{\text{Speed (Ly/y)}} \simeq \frac{4 \text{ Ly}}{0.1 \text{ c}} = 40 \text{ yr}$$

Round trip = 80 y   Travel Faster?

Project Daedalus

Design study for Fly-by
Barnard's Star   6 ly away

Inertial confinement fusion
(Ignite pellets of hydrogen w/lasers, particles)
Terrestrial fusion: $^2H + ^3H \quad \longrightarrow \quad ^4He + n$
              deuterium tritium   causes problems
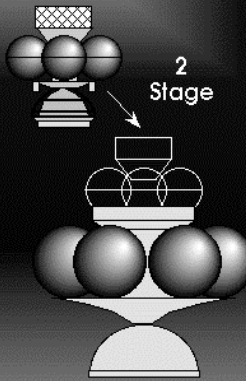
Daedalus: $^2H + ^3He \longrightarrow {}^4He + p$

                charged, control with mag. Field

$\Delta E = 4 \times 10^{-3} mc^2$

Problem: ^3He rare $\Rightarrow$ Mine Jupiter?

Design: v = 0.12c   travel for 50 yrs

500 ton payload   54,000 tons at takeoff
                         50,000 tons of fuel

$v_e = 10^4$ km s^{-1} R_M = 12 or 100
                         (payload)

s.i. = 10^6 sec

Faster Travel?

- If we could travel close to speed of light
- Time Slows down
- Could travel more light years than years on the space ship clock
- Though not on the clock on the home planet

e.g. Twin Paradox

Twin one

Earth

Twin two

V = .866 C

5 years

clock

Earth

Alpha Centauri

*

Twin two

On-board clock

*

2.5 years

Twin one
(10 yrs older)

Twin two
(5 yrs older)

Gray Hair

Earth

Time measured by Twin two

Time measured by
Twin one

$t = \gamma \, t_0$

$* \; \gamma = \dfrac{1}{\sqrt{1- (v/c)^2}}$

Gamma Function

GAMMA

8

6

4

2

0

0.0   0.2   0.4   0.6   0.8   1.0

V/C
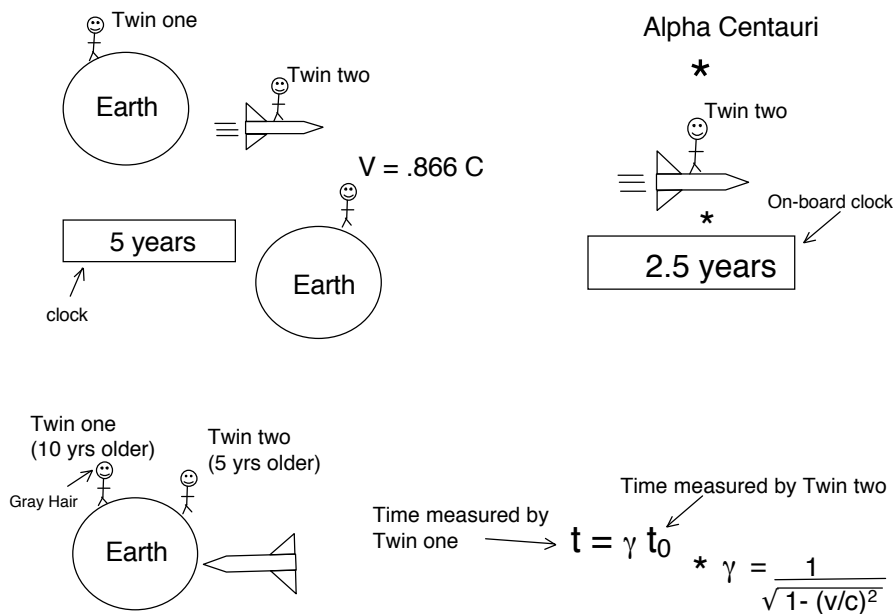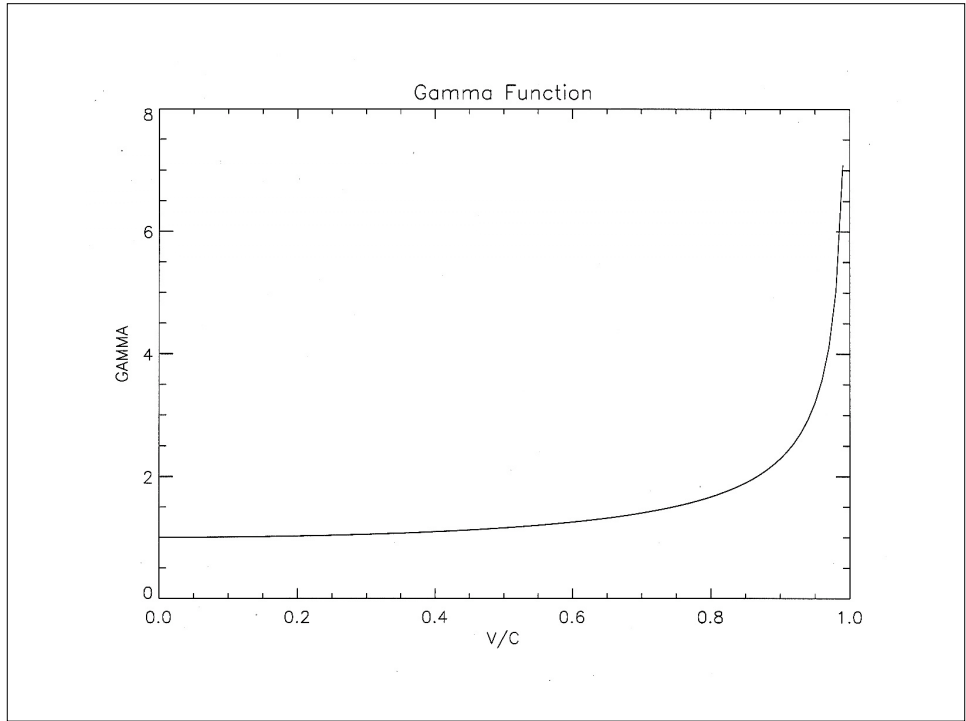
TABLE 18.2 Round-Trip Times for Journeys at an Acceleration of 1 g[*]

Time as Measured by Spacecraft Crew (years)	Time as Measured on Earth (years)	Greatest Distance Reached (light years)	Farthest Object Reached
1	1	0.06	Comets
10	24	9	Sirius
20	270	140	Hyades
30	3100	1,500	Orion Nebula
40	36,000	17,500	Globular cluster
50	420,000	170,000	Large Magellanic Cloud
60	5,000,000	2 million	Andromeda galaxy

[*] Following an example given by Sebastian von Hoerner, we imagine a spacecraft that accelerates at 1 g; that is, the force of acceleration or deceleration equals the force of gravity at the Earth's surface. After one year, such a spacecraft would be moving at a velocity very close to the speed of light.

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Problems with fast travel

- Mass ratio (R_M) increases rapidly with v
  - $M = M_o \gamma$
  - at v = 0.99c, best possible fuel: R_M = 14
- You have to take fuel to slow down
  - Fuel is payload on the way out
    - R_M = 14 x 14 = 196
- To return you need all this fuel as payload
  - R_M = 196 x 196 ~ 40,000
- And you need antimatter-matter for R_M=14
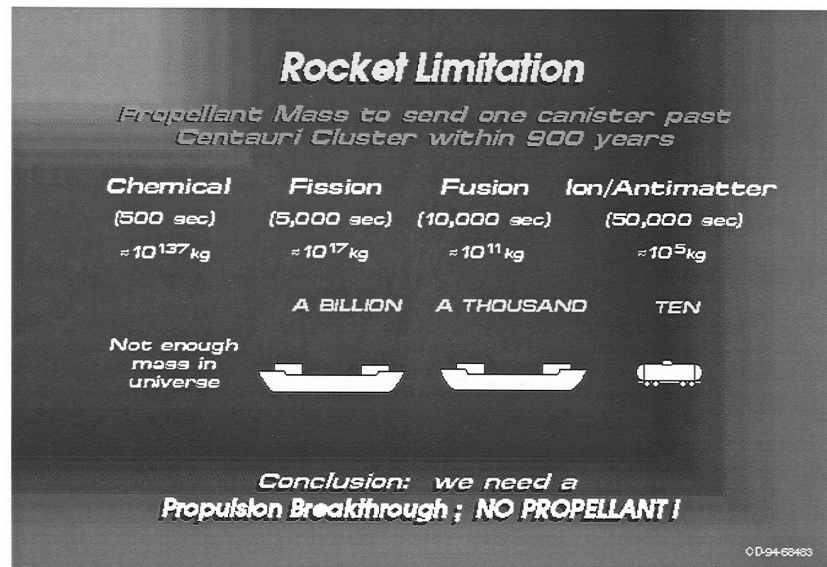
No Propellant?

- Bussard RamJet
    - Scoop up fuel as you go
    - Problems
        - Very diffuse (need huge scoop)
        - Hydrogen is low-grade fuel
        - You want rare $^2H + {}^3He$

Hard to decide if very advanced civilizations might develop such schemes

$\Rightarrow$ Use only laws of physics as constraint - apply to all civilizations, no matter how advanced their technology

Consider now some things that are outside physics as we know it, but **might** be possible.

Warp Drives

Faster than light travel?

Not possible for ordinary matter, physics

$M = \gamma M_0 \Rightarrow \quad M \to \infty$ as $v \to c$

Loophole:

c is a speed limit for motion <u>in</u> space-time

not <u>of</u> space-time

e.g. The space-time of the universe expanded

faster than c during <u>very</u> early <u>inflationary</u>

expansion

The Universe now seems to have a lot of
"dark energy"

Source unknown

Acts like antigravity on <u>large</u> scales

Could we ever control this?

Wormholes

General relativity: A. Einstein

Matter warps space-time
This warp is gravity

e.g. Black holes pinch off a piece of the
Universe - even light cannot escape

Rotating black hole $\longrightarrow$ wormhole
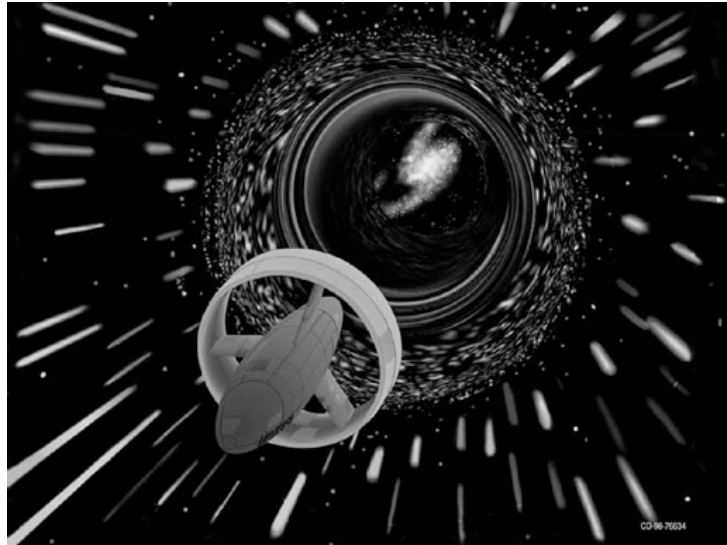
Wormholes

Unlikely to form when a star collapses

If it forms, it is unstable

Traveler probably cannot pass through

Loophole - stabilize it somehow?
Exotic Matter?

View entering a wormhole
artist's conception

Alcubierre Warp

~ 1994   Miguel Alcubierre suggested use of
"exotic matter" to surf a space-time distortion

Contract space in front, expand behind

Does exotic matter (negative mass) exist?
Can we control it?
Energy requirements

Originally thought to exceed that available in entire
universe

Later caluclations are less extreme

Colonization

Assume Daedalus technology   (v = 0.1 c)

$$t = \frac{d_*}{v} \sim \frac{4\ ly}{0.1} = 40\ yrs$$

Multi-generational travel
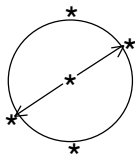(space colony + propulsion)

How long to colonize galaxy?

Colonization

$$t_{gal} = \frac{r_{gal}}{v_{exp}}$$

$$v_{exp} = \frac{2d_*}{t} \qquad t = \frac{d\ *}{v} + t_{reg}$$

e.g.   v = 0.1 c t_{reg} = 500 yr

$$\Rightarrow v_{exp} = \frac{4\ ly \times 2}{540} \simeq 0.015\ c$$

If r_{gal} = 80 × 10³ ly

$$t_{gal} = \frac{80 \times 10^3}{1.5 \times 10^{-2}}$$

$$\sim 50 \times 10^5$$

t_{gal} << age of galaxy 5×10^6 yr

Colonization

With "reasonable" assumption,

$$t_{colonization} \ll t_{Galaxy}$$

How likely?

How many civilizations ever developed?
(Time available: 10×10^9 - $5 \times 10^9 \simeq 5 \times 10^9$)

Colonization

Birthrate $\times$ age of Galaxy $= N_{(ever)}$

Happy Feller	50	$\times$	5×10^9	$=$	2.5×10^{11}
Angela Angst	7.5×10^{-8}	$\times$	5×10^9	$=$	375
Average Guy	0.93	$\times$	5×10^9	$=$	4.7×10^9

If even one of these decided to colonize, it should already have happened!

Possible consequences:
1. Galactic community
2. Solar-system has been visited
3. Solar-system being monitored
4. Solar-system leakage radiation detected?

Hart Hypothesis

Fact: There are no intelligent beings from outer
Space on the Earth now.

Only 5 possible explanations:
1.   Space travel is not feasible
2.   Civilizations <u>chose</u> not to colonize
3.   Not enough time to colonize galaxy
4.   The Earth was visited but they did not colonize
5.   There are no other advanced civilizations

"Answers" to the Hart Hypothesis

1.   Colonization may be much slower
     10^6 yr regeneration $\rightarrow$ t_{colon} > 10^{10} yrs

2.   Nomads/explorers make trips, not colonists!

3.   May be harder to adapt life on a new planet than
     "we" think.
     We need 20 essential amino acids

4.   Optimists time scale for colonization > t for biological evolution
     Maybe >>

5.   Possible development of "ecological ethic"
     Do not interfere

6.   They <u>are</u> here!   UFO's