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

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

for M = M (electron)

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

ν = frequency

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

Ratio ~ 10^{9} (and photon gets there in 4 yrs)

100 M watt transmitter - 1 yr

\$ 40×10^{6}

Spacecraft to nearest star

~ \$ 5×10^{16}

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)

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

	Birth Rate	L_ℓ	N_ℓ
Happy Feller	20	3×10^9	6×10^{10}
Angela Angst	5×10^{-4}	3×10^9	1.5×10^6
Average Guy	2.2	3×10^9	6.6×10^9

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 exploration,

Except

No Round Trips

Distances to Stars ~ Light Years

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

Round trip = 80 y

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: $^{2}H + ^{3}H \longrightarrow ^{4}He + n$

deuterium tritium — causes problems (n)

Daedalus: $^{2}H + ^{3}He \longrightarrow ^{4}He + p$

charged, control with mag. Field (p)

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

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

Design: $v = 0.12c$ travel for 50 yrs

500 ton payload

54,000 tons at takeoff

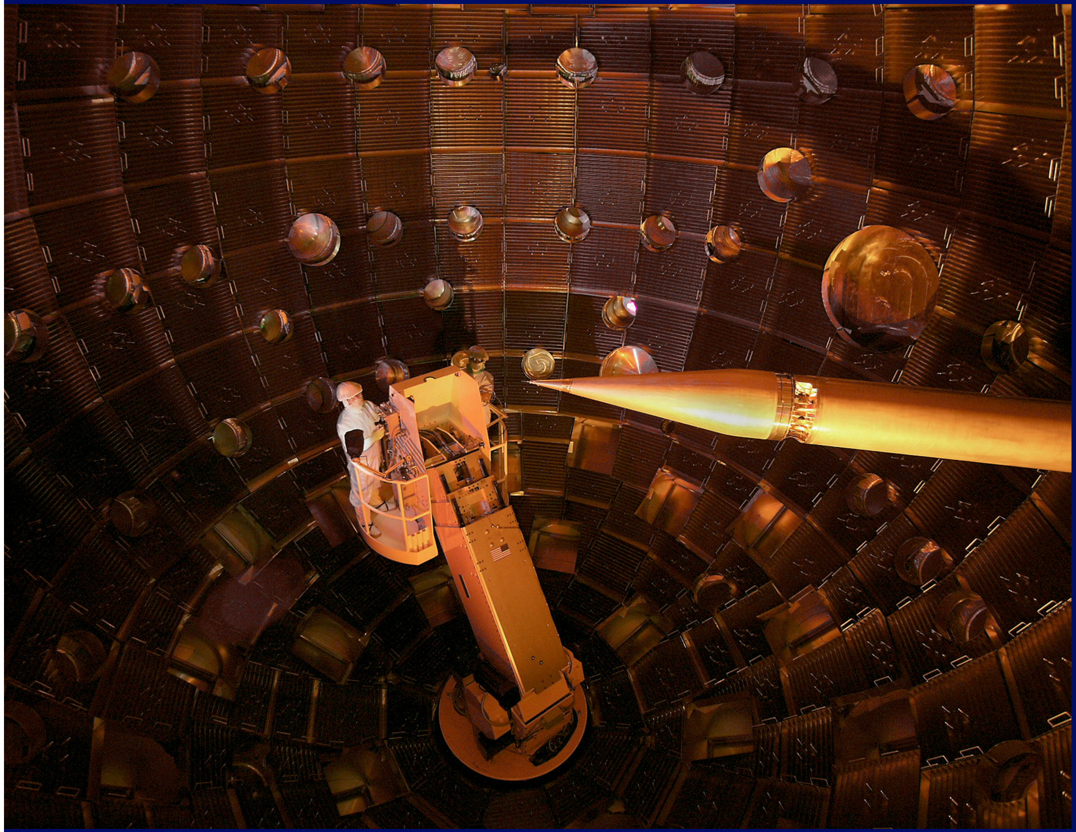
50,000 tons of fuel

$v_e = 10^4$ km s^{-1}

$R_M = 12$ or 100 (payload)

s.i. = 10^6 sec

Current Status of Laser Fusion



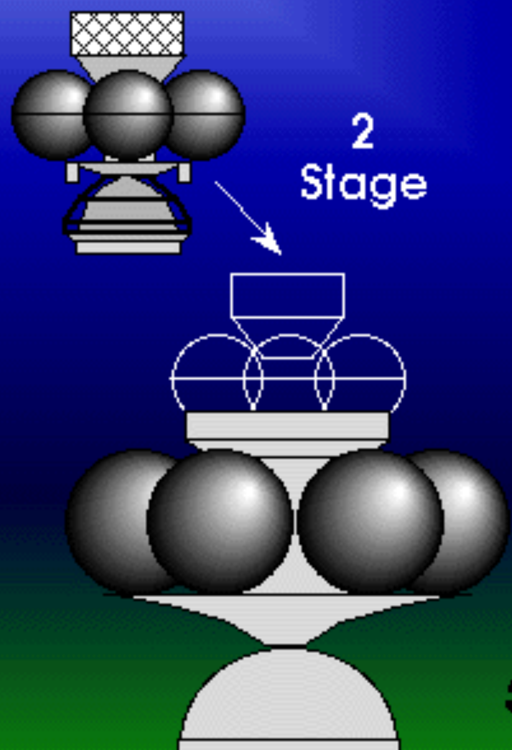
National Ignition Facility
Livermore National Lab

Beginning experiments with new lasers
192 lasers focused on a tiny pellet of deuterium and tritium.
Goal is controlled fusion.

https://lasers.llnl.gov/

Nuclear Concepts

Project Daedalus
1973-1978
British Interplanetary Society



2 Stage

10^2 T payload

10^6 Isp
12% Light speed

Micro-Fusion explosions
~ 250/sec

36 YEARS* Interstellar fly-by

* Was 50 years to Barnard's star ≈5.9LY

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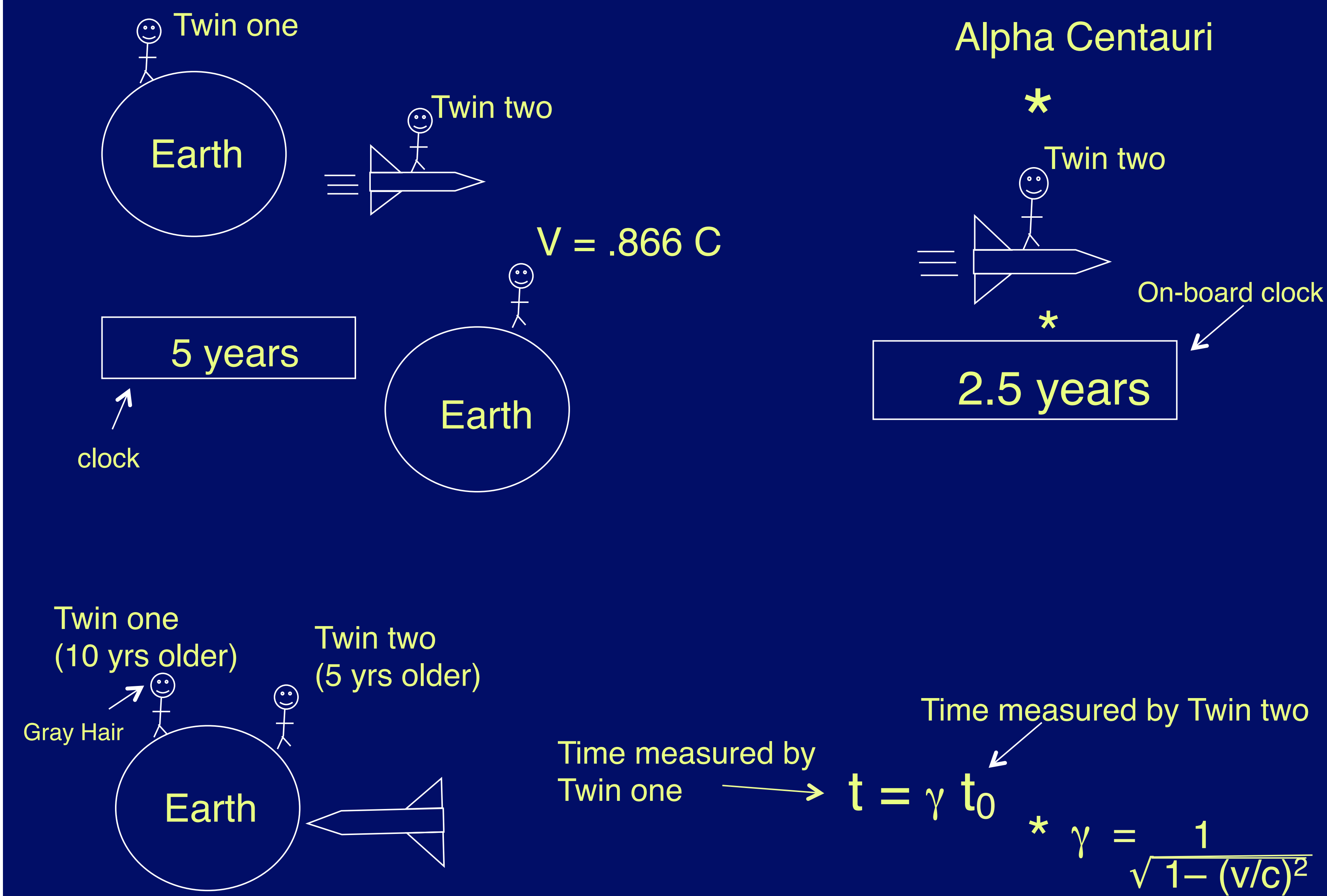
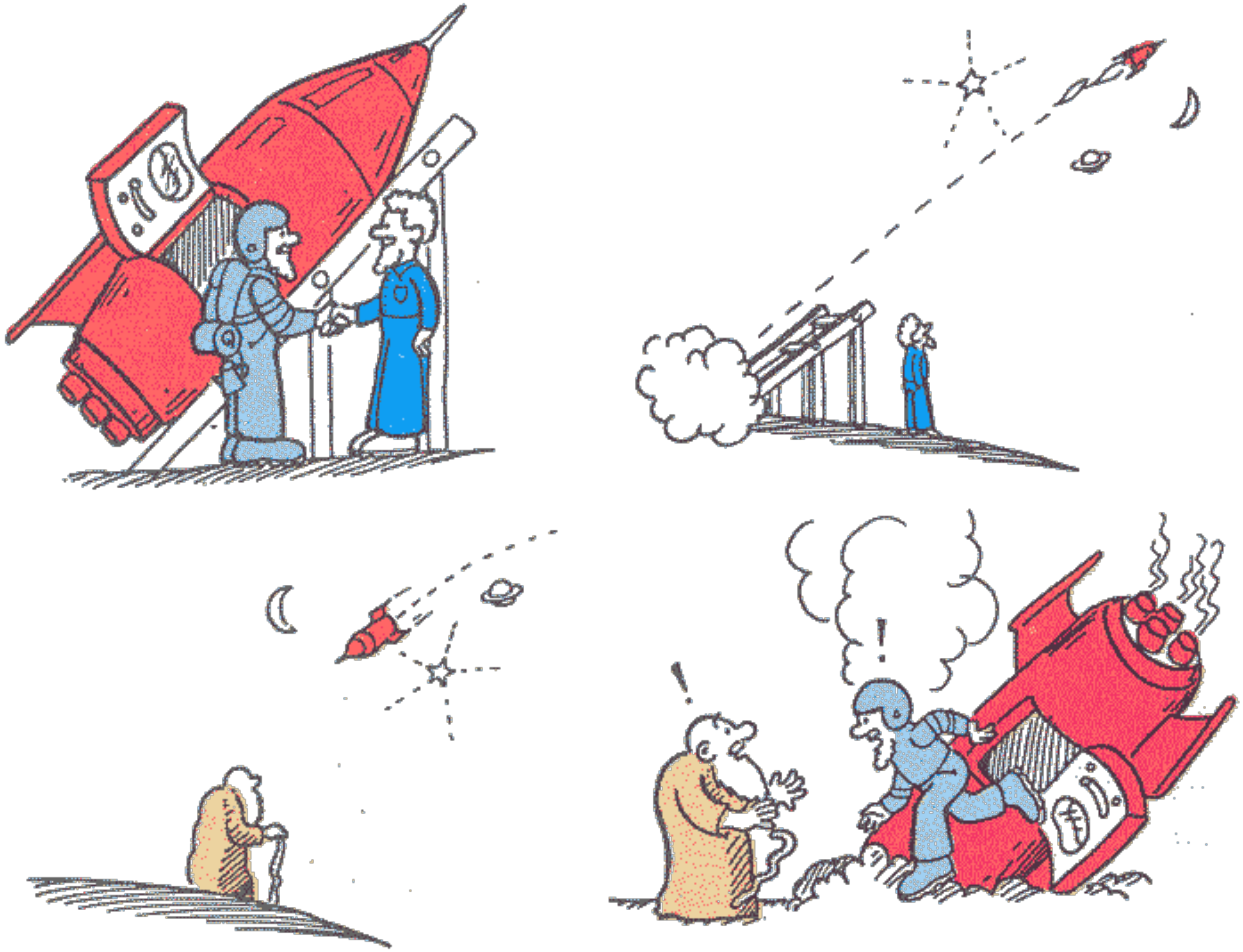
Faster Travel?

- 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

The Twin Paradox





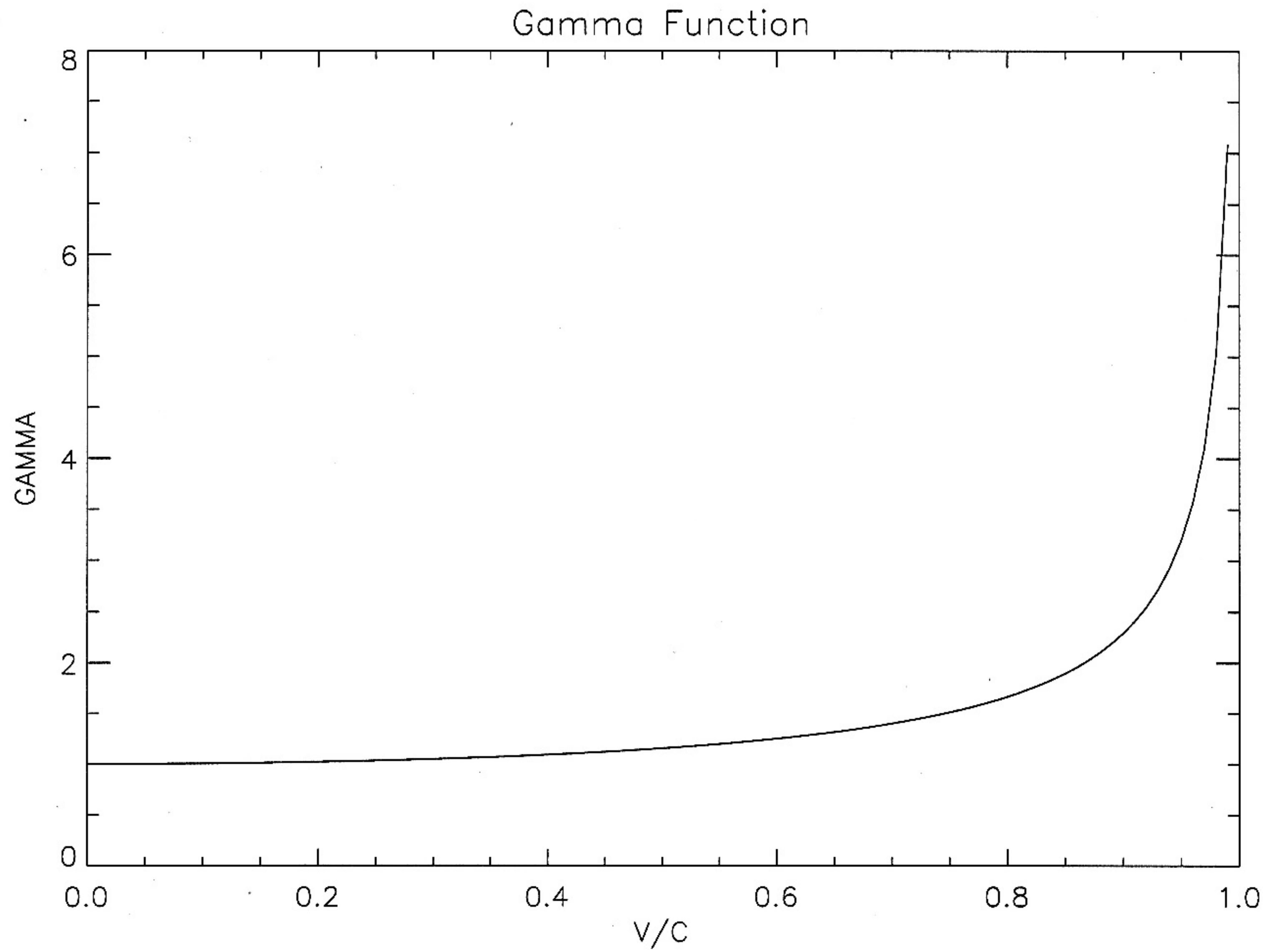

Gamma Function
GAMMA
V/C
0
2
4
6
8
0.0
0.2
0.4
0.6
0.8
1.0

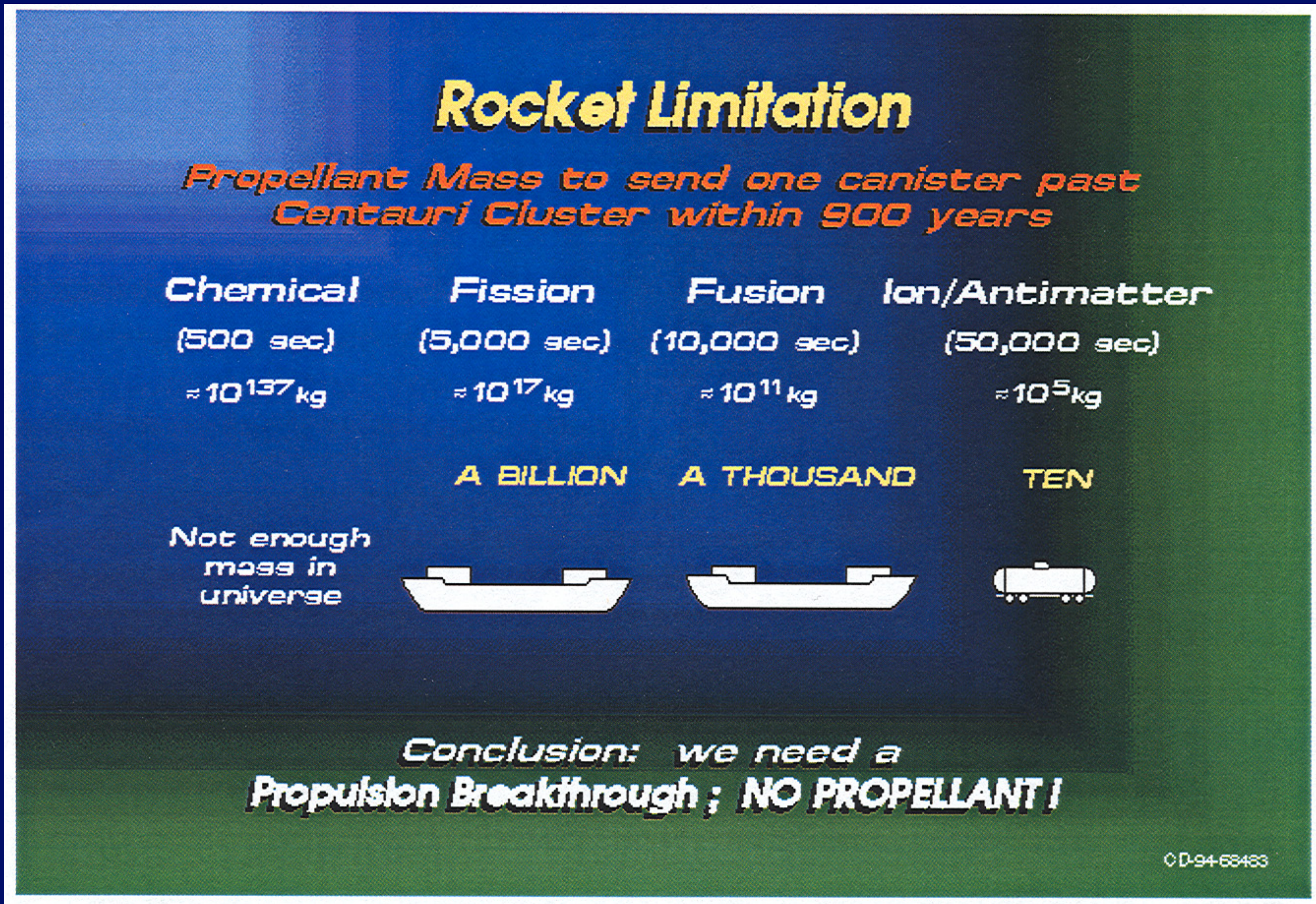
TABLE 18.2 Round-Trip Times for Journeys at an Acceleration of 1 g*

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.

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
    - $R_M = 14 \times 14 = 196$
- To return you need all this fuel as payload
  - $R_M = 196 \times 196 \sim 40{,}000$
- And you need antimatter-matter for R_M=14


Rocket Limitation
Propellant Mass to send one canister past
Centauri Cluster within 900 years
Chemical
(500 sec)
≈ 10^{137} kg
Fission
(5,000 sec)
≈ 10^{17} kg
Fusion
(10,000 sec)
≈ 10^{11} kg
Ion/Antimatter
(50,000 sec)
≈ 10^{5} kg
A BILLION
A THOUSAND
TEN
Not enough mass in universe
Conclusion: we need a
Propulsion Breakthrough ; NO PROPELLANT !
CD-94-68483

No Propellant?

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

Future Fantasies?

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

Wormholes

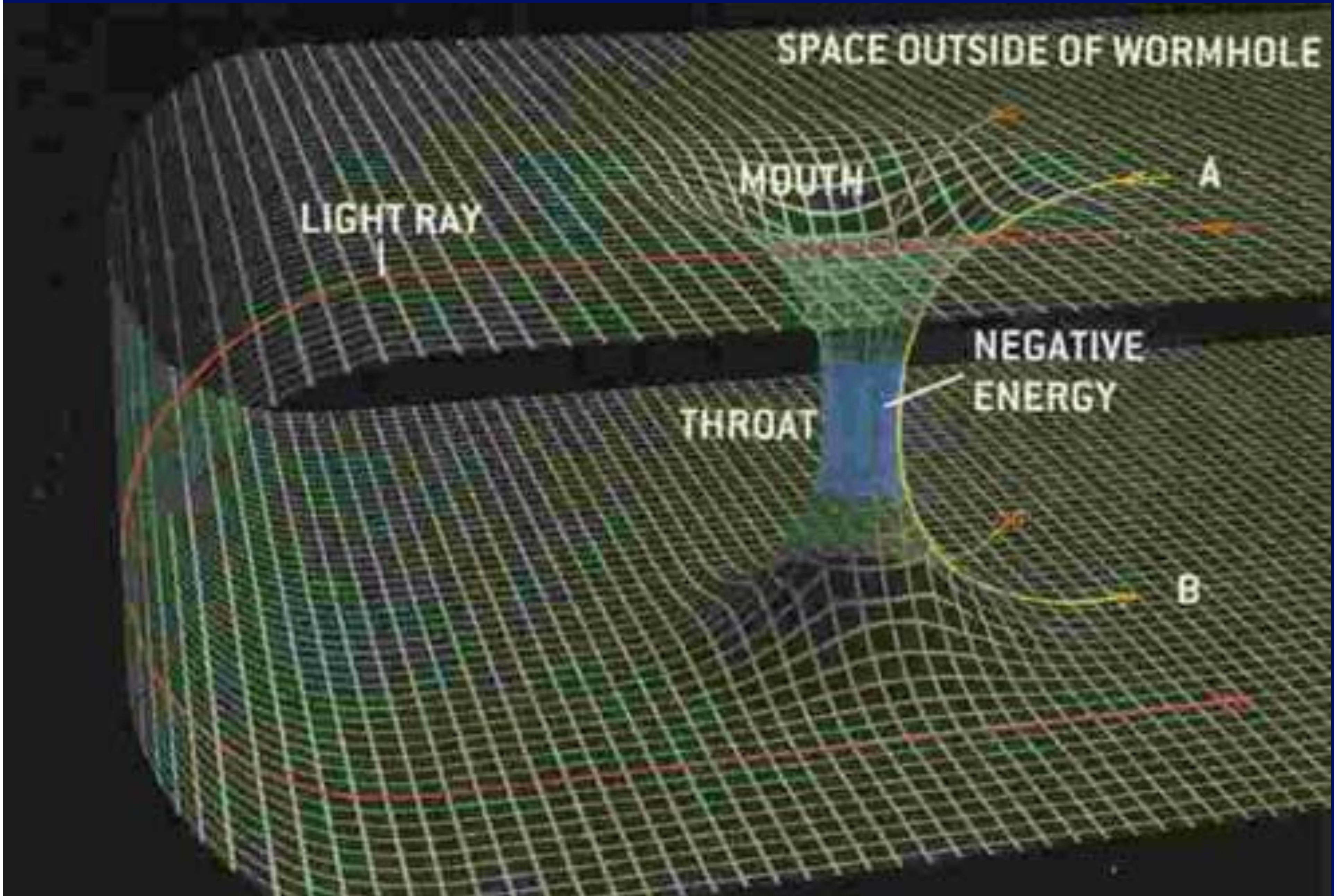
General relativity: A. Einstein

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 (maybe)


SPACE OUTSIDE OF WORMHOLE
MOUTH
A
LIGHT RAY
NEGATIVE
ENERGY
THROAT
B

Wormholes

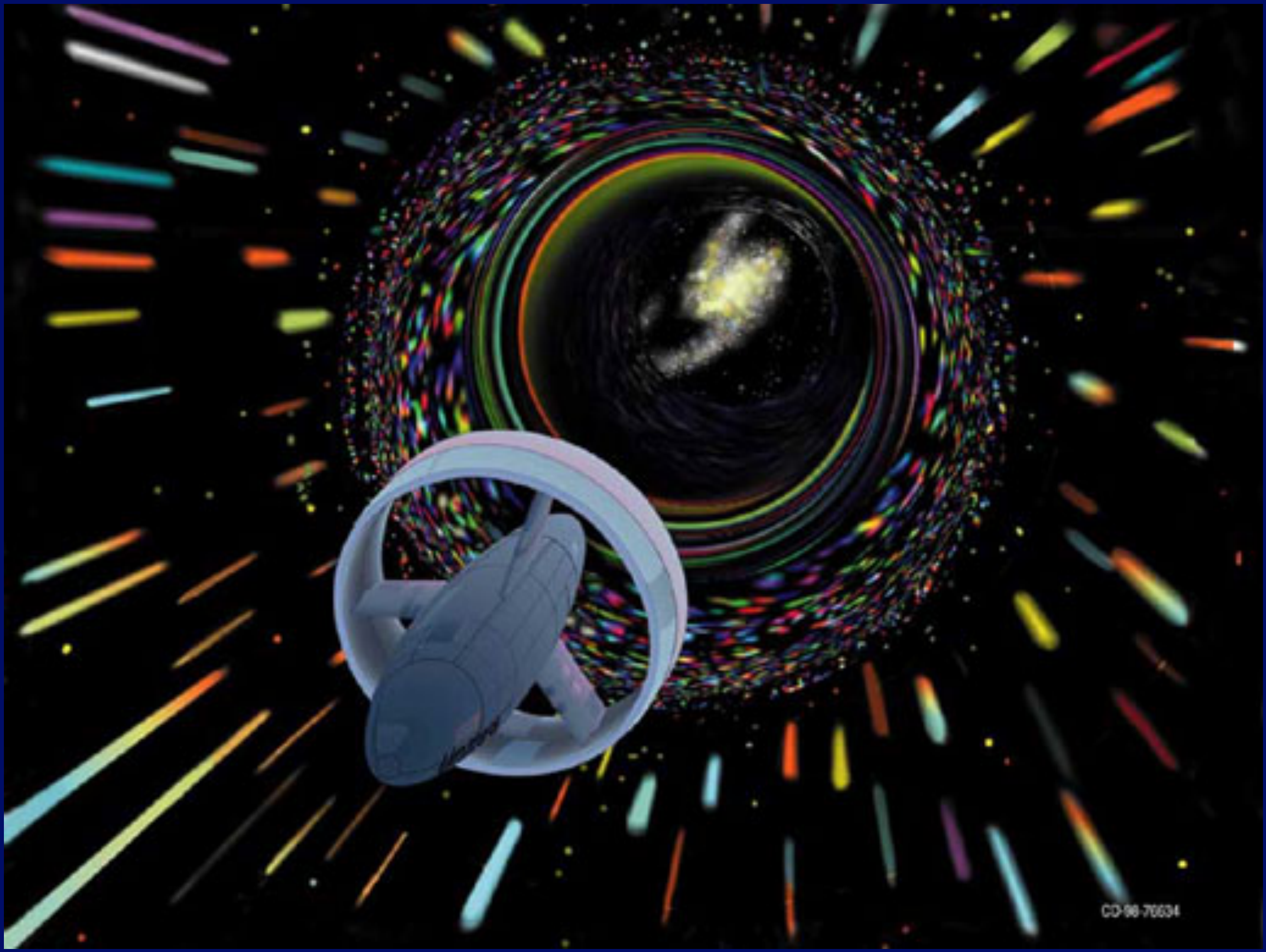
Unlikely to form when a star collapses

If it forms, it is unstable

Traveler probably cannot pass through

Loophole - stabilize it somehow?
Exotic Matter?

View entering a wormhole
artist's conception



Warp Drives

Faster than light travel?

Not possible for ordinary matter, physics

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

Loophole:

c is a speed limit for motion **in** space-time

not **of** space-time

e.g., The space-time of the universe expanded faster than c during **very** early **inflationary** expansion

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

Source unknown

Acts like antigravity on **large** scales

Could we ever control this?

Back to Reality

- Hard to decide if very advanced civilizations might develop such schemes
- Use only laws of physics as constraint -
  apply to all civilizations, no matter how advanced their technology

Colonization

Assume Daedalus technology (v = 0.1 c)

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

Multi-generational travel
(space colony + propulsion)

How long to colonize galaxy?

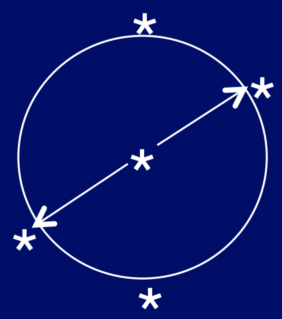
Colonization

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

$$v_{exp} = \frac{2d_*}{t}$$

$$t = \frac{d_*}{v} + t_{reg}$$

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



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

If $r_{gal} = 80 \times 10^3\ ly$

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

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

$$5 \times 10^6\ yr$$

Colonization

Time available: Age of galaxy minus time for first advanced civilization to arise:

$10 \times 10^9 - 5 \times 10^9 \simeq 5 \times 10^9$

$t_{colonization} << t_{Galaxy}$

How likely?

How many civilizations ever developed?

Colonization

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

	Birthrate		age of Galaxy		$N_{(ever)}$
Happy Feller	20	×	5×10^9	=	2×10^{11}
Angela Angst	5×10^{-8}	×	5×10^9	=	250
Average Guy	0.94	×	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 **chose** 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 to life on a new planet than “we” think.
   We need 20 essential amino acids

4. Optimist’s 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