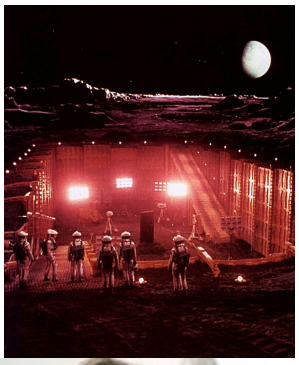
AST 205. Lecture 23. December 8, 2003
SETI, Interstellar Travel and the Fermi Paradox

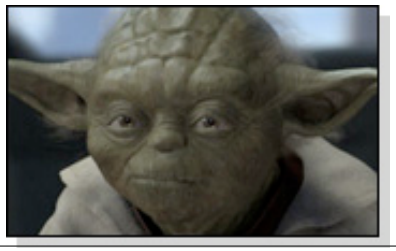
- Evaluation of the Drake Equation
- SETI: Search for Extraterrestrial Intelligence
  - Good news
  - Bad news
- Interstellar travel & colonization
  - It is difficult/impossible
  - It is easy/inevitable
- The Fermi Paradox
  - We are alone
  - Maybe not

Assignments for week of Dec 8

- An open precept discussion on the topics listed below (individual basis, no set "teams").
- Bring a one page brief to precept outlining your views/reasoning & be prepared to discuss them.
- TOPICS: Will extraterrestrial life be found elsewhere in the Solar System? Will TPF discover terrestrial planets orbiting in the habitable zones around nearby stars? If so, will some of these planets have biomarkers detectable by TPF or other planned future facilities? Will SETI projects succeed in detecting signals broadcast by extraterrestrial civilizations in the foreseeable future?
- Problem Set 9 due in lecture on Dec 10

Extraterrestrial intelligent life (ETI) is clearly the most interesting & important possibility

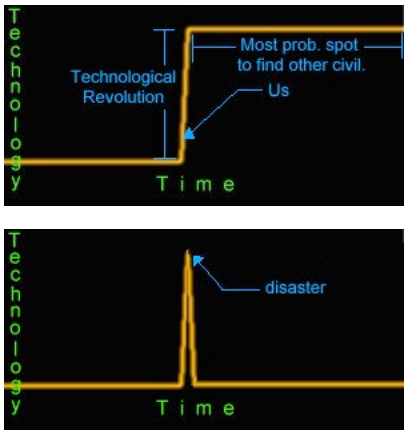




$$N = f(p)n(e)f(l)f(i)f(c)R_*L$$

- $0.1 \leq f(p) \leq 1$
- (tiny number) $\leq n(e) \leq$ few
- (tiny number) $\leq f(l) \leq 1$
- (tiny number) $\leq f(i) \leq 1$
- (tiny number) $\leq f(c) \leq 1$
- $R_* \approx 10$/yr
- 100 yr $\leq L \leq 10^9$ yr
- $1 \leq N \leq 10^{10}$ [0/1, 10^3, 10^6, 10^8] $N \approx L$

At best, if L is not large, N cannot be either.



- Our estimates of N depend on *prediction* of the longevity of technical civilizations.
- But note that it is an *average* value that matters, so a few very long lived cases can dominate.
- Observing N -> L !

SETI: The good news

- Radio technology has been sufficient to communicate over interstellar distances since the late 1950s!
- Current radio technology capable of communicating over most of the Galaxy.
- The technology developed for radar and radio astronomy purposes is well suited for such a project in most respects.
- Cost and effort required is thus modest.
- Artificial signals could differ dramatically from any plausibly produced by "natural" processes.

Scientific SETI began with the 1959 publication of Cocconi & Morrison's *Nature* paper

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†

Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for a time comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

* Now on leave at CERN, Geneva.

† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

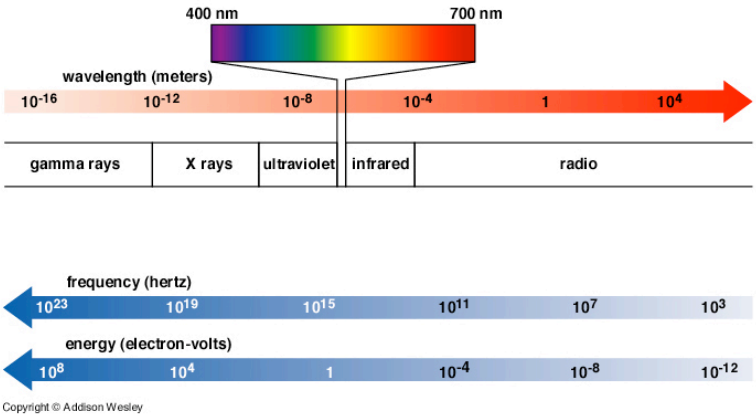
Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

Arecibo radio telescope & radar could communicate with a twin system many thousands of light years away.

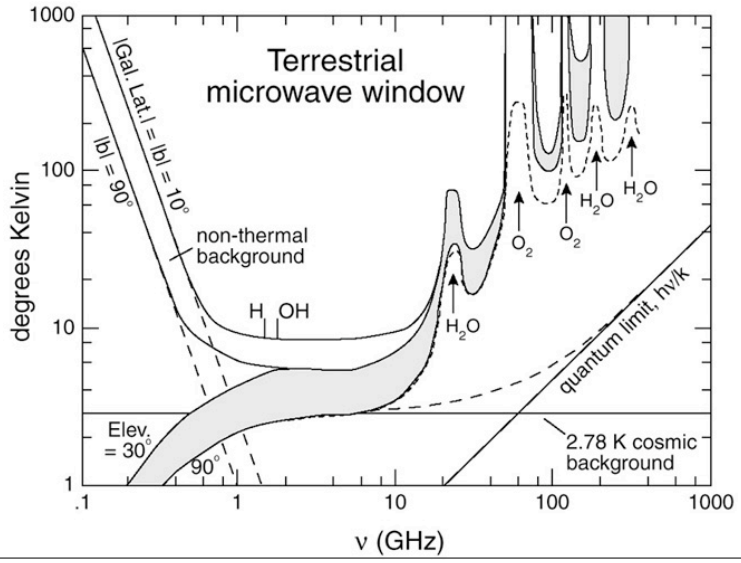
SETI: The bad news

- Signal can be detected only if it can be found
- The search space is enormous and multi-dimensional
  - Frequency/wavelength (expect to be *very* narrow band)
  - Space (which star) or direction (in the sky)
  - Time (look when they are sending toward us + lag)
  - Encoding protocols (several possibilities)
- Current technology only allows exploration of the search space to a very limited extent
- Two way conversation/dialog will be very/too slow (but one way message can be *extremely* rich)
- Quite possible that our assumptions about their communication technology and/or interest are *grossly* wrong or biased

Lost in the electromagnetic spectrum

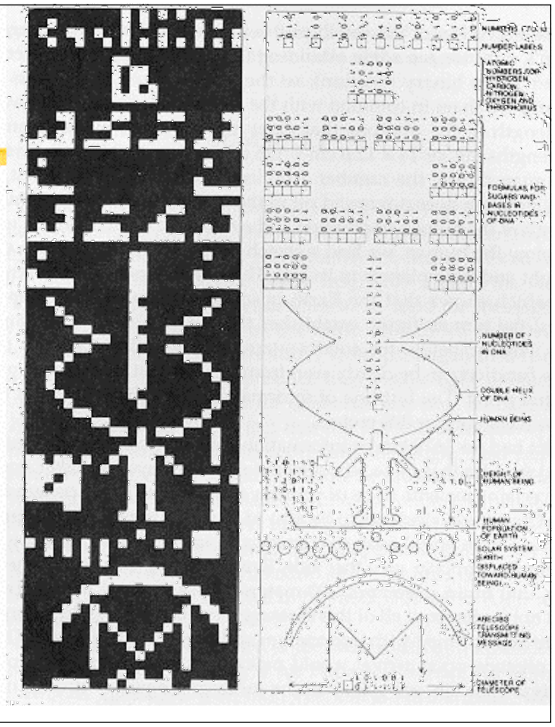


Radio frequency selection considerations



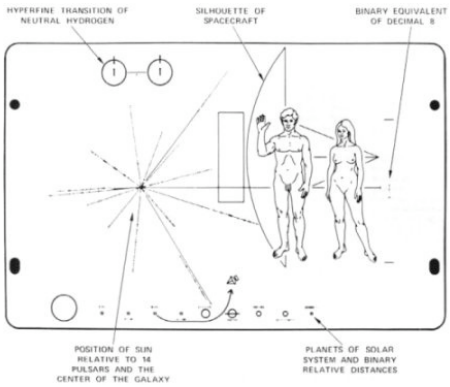
Decoded Arecibo Message

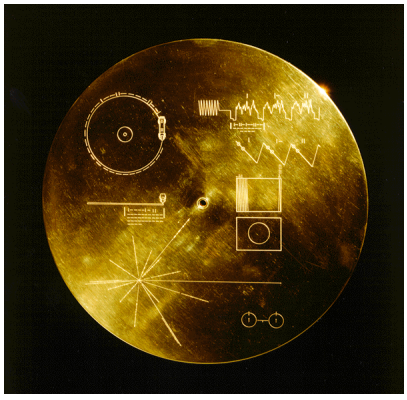
1974 demonstration "decodable" pictoral interstellar message transmitted from Arecibo.



Binary encoding of the Arecibo message

Attempts at “decodable” pictoral interstellar messages aboard spaceprobes leaving the SS



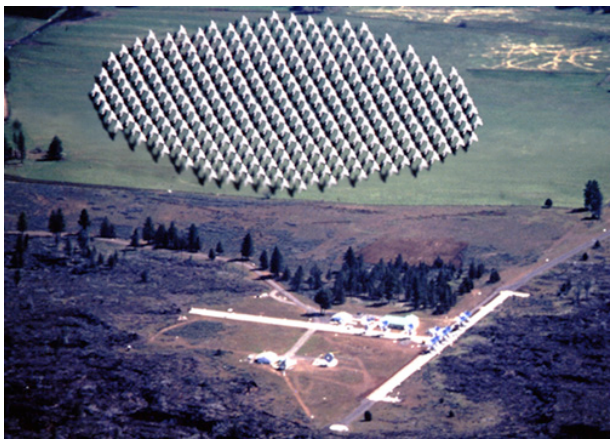


Forty years of radio and optical SETI projects in the US and elsewhere

- Project Ozma (1960) by Frank Drake at NRAO
- NASA funded a dedicated project for several years but canceled in 1993 by Congress -> private funding
- Project Phoenix (since 1995) mobile facility for targeted surveys & serendipity projects
- SETI @ home (on your PC!)
- Optical SETI (@Princeton) [http://observatory.princeton.edu/oseti]

BUT NO LUCK YET

Allen Telescope Array (under construction in Nonrthern California): dedicated SETI facility

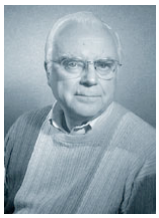


Array of 350 6-meter dishes (funded by Microsoft founder Paul Allen)

SETI Pioneers

Philip Morrison

Frank Drake

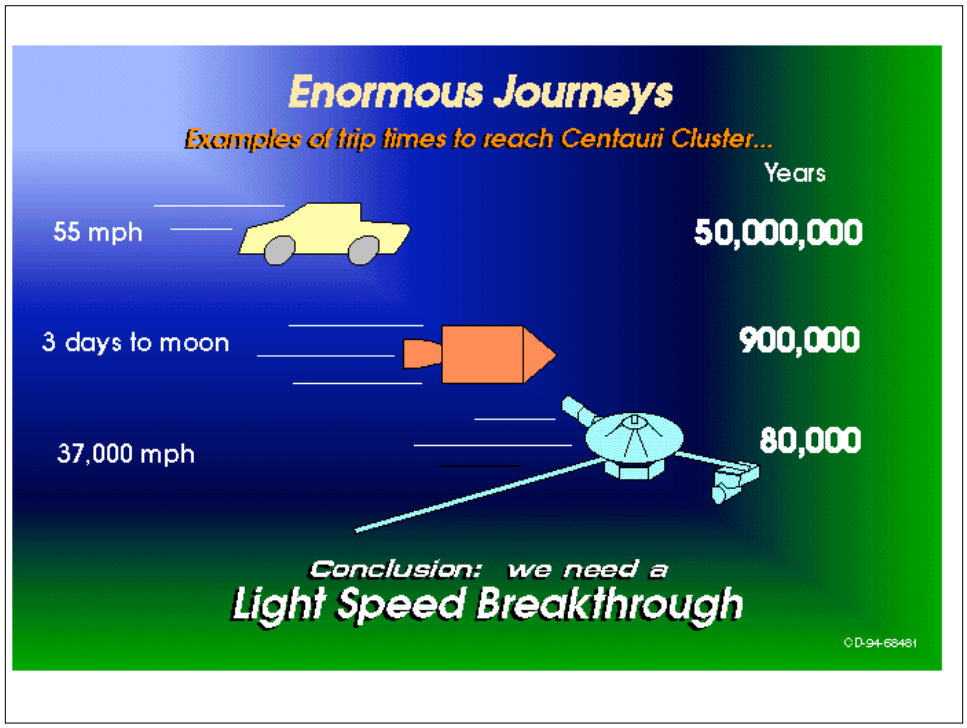


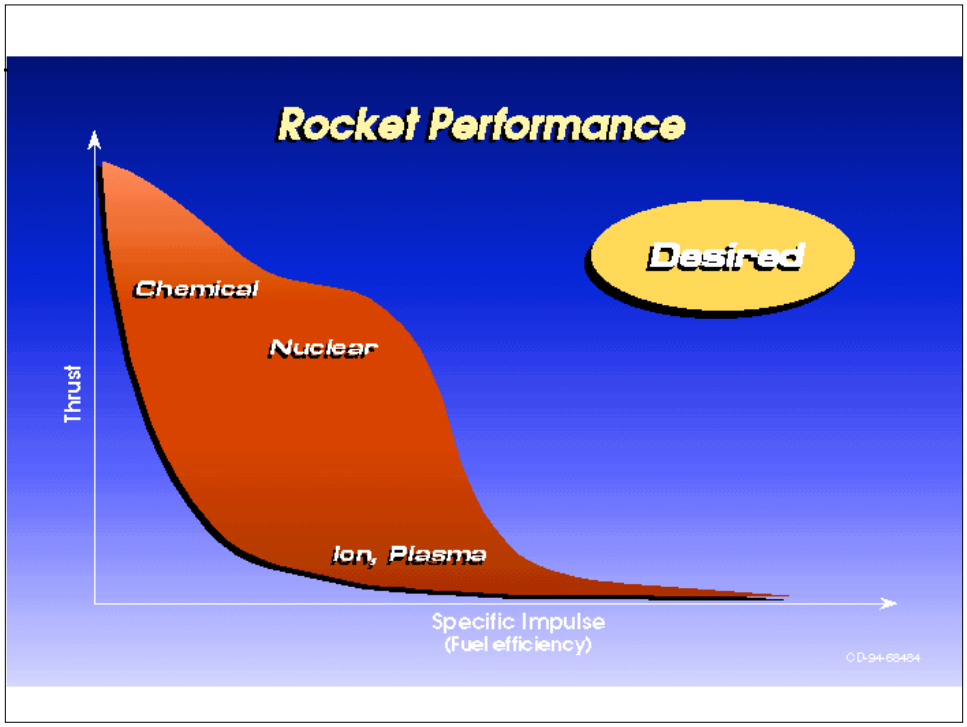
Carl Sagan

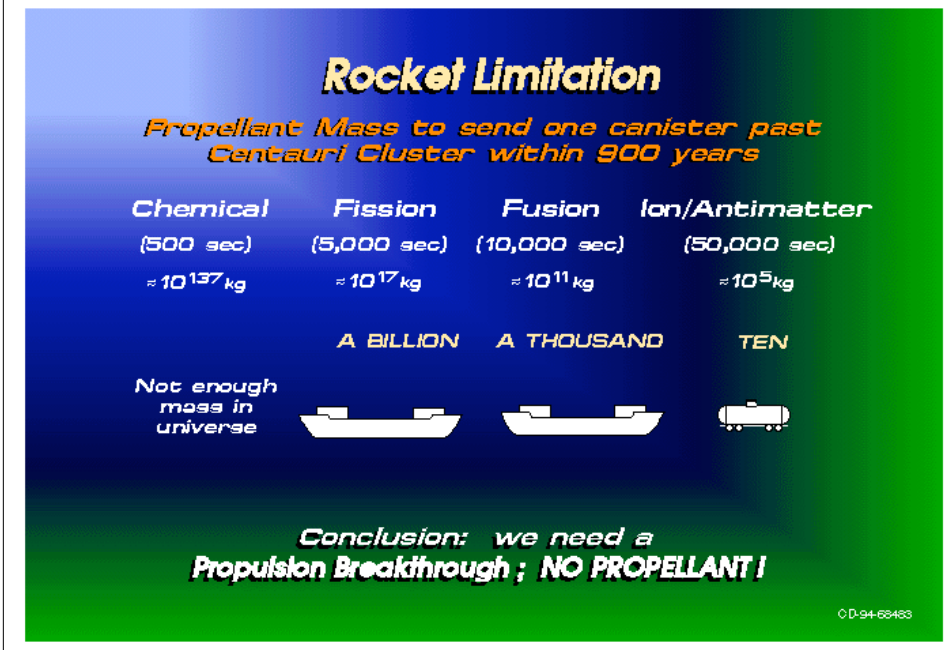
Jill Tarter

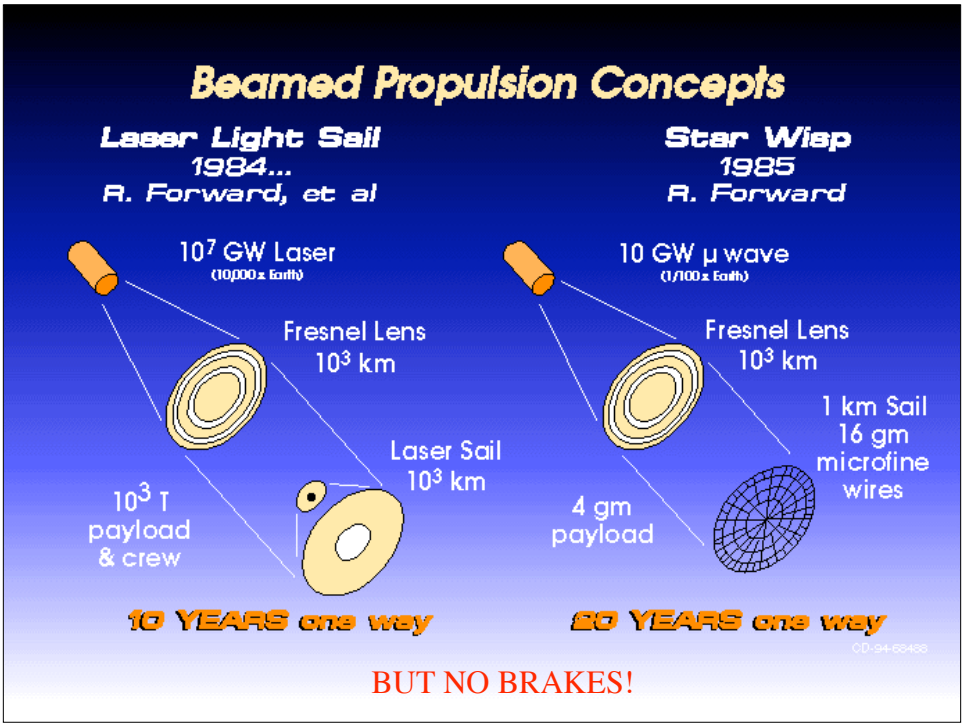
Interstellar Travel

- Interesting -> Important
- Does not depend on anyone being out there or on what they choose to tell us, if anything
- Natural extrapolation of our human and biological history: Cosmic Manifest Destiny
- The best strategy to increase L
- Job security for NASA

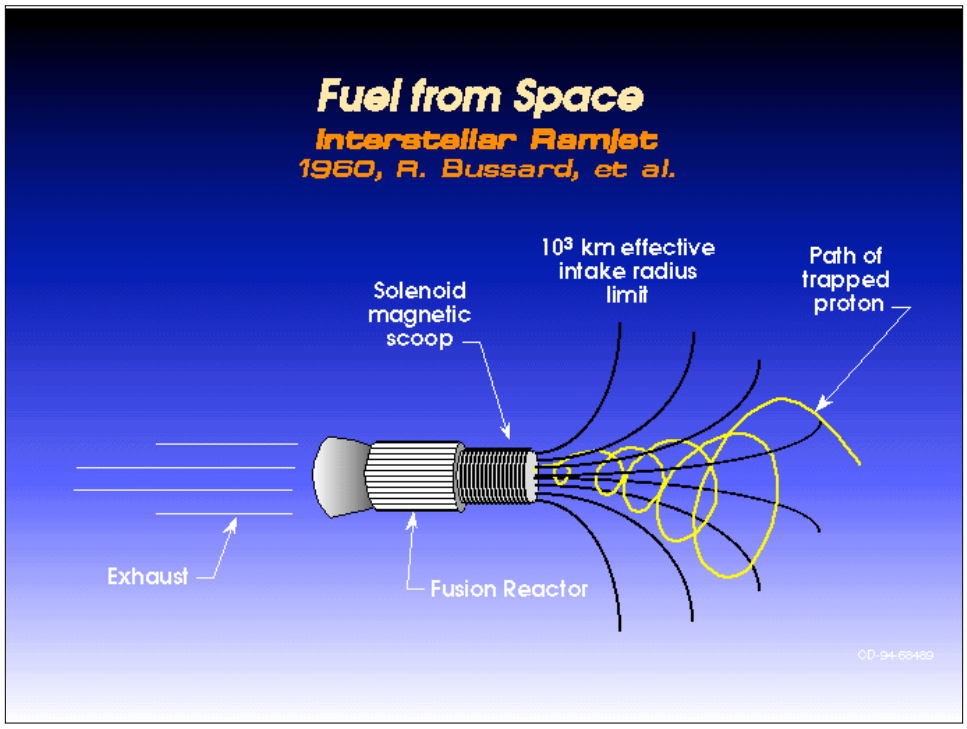

Enormous Journeys
Examples of trip times to reach Centauri Cluster...
Years
55 mph
50,000,000
3 days to moon
900,000
37,000 mph
80,000
Conclusion: we need a
Light Speed Breakthrough
CD-94-68481


Rocket Performance
Desired
Chemical
Nuclear
Ion, Plasma
Thrust
Specific Impulse
(Fuel efficiency)
CD-94-68484





BUT NO BRAKES!



Large Interstellar Ship -- Basic Features

1 Million travelers, 100 Million ton mass, ~ $ 20 Trillion, Launch 2500 A.D.

600 km/s cruising speed
(lower power, softer collisions)

On-board observatories

One-way voyage for thousands of years

≥10 decks of living / working space
water shielding in outermost deck
each deck has 5 m high ceilings
total living/working floor area
= 2π x 10 x 1 km x 2 km
= 125 km^2 (nearly 2x Manhattan land area)
thus **≥ 125 m^2 total/person**

2 km

1 rpm yields 1 g of inward acceleration
v = 2π x 1000/60
= 100 m/s
a = v^2/r = 10 m/s^2

2 km

Great Pyramid of Cheops, to scale, for comparison; has 1/16 mass of ship

Our current understanding of physics indicates that "warp drives" are unlikely to be possible, but the "experts" have been wrong before.

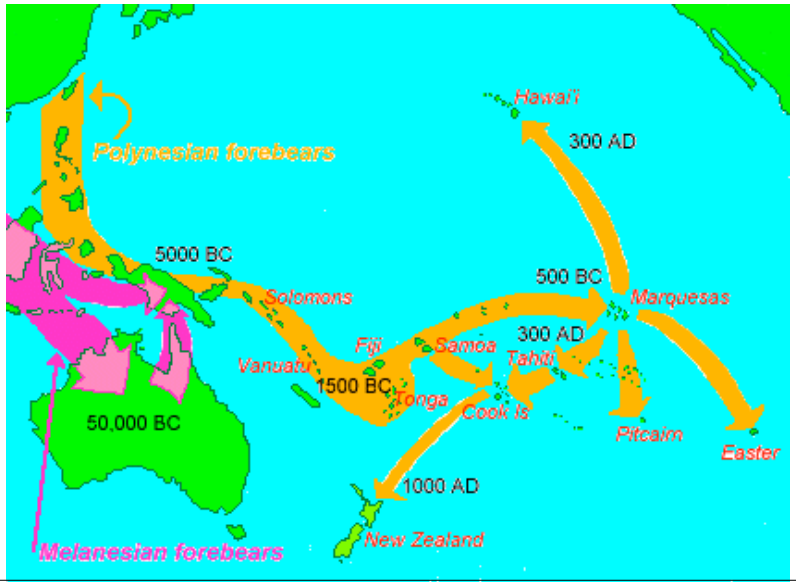
Interstellar travel via advanced biotechnology

- Extended life spans/disable aging process
- Reduced environmental & resource requirements
- Hibernation/suspended animation
- Send genetic material/information only
- Specialized (space adapted) organisms/species
- Artificial intelligence/robots
- Nanotechnology

The Fermi Paradox

- Suggested by Enrico Fermi at lunch in Los Alamos during the Manhattan Project supposedly
- Interstellar travel -> interstellar colonization/migration
- Life would spread through the Galaxy/universe via successive/hierarchical waves of colonization
- Even with conservative net speeds (0.1-1% of light speed), colonies would spread throughout the Galaxy in a short time compared to its age (10-100 million yr)
- They should already have arrived at Earth long ago if they had even a modest "head start" on terrestrial life
- Since they aren't here, we are alone
- Perhaps because L is small (Manhattan Project context)

Colonization of ploynesia as a model of interstellar colonization



Solutions to the Fermi "Paradox"

- We are "first"
- Interstellar travel is not practical, or is very rare
- Zoo hypothesis: they are watching us (from near or far)
- We are in a Galactic wilderness area
- They are enroute but it takes much longer than estimated
- They are not interested in planets or us or…
- They are otherwise engaged
- They are here or were here but are hiding or long gone

Assignments for week of Dec 8

- An open precept discussion on the topics listed below (individual basis, no set "teams").
- Bring a one page brief to precept outlining your views/reasoning & be prepared to discuss them.
- TOPICS: Will extraterrestrial life be found elsewhere in the Solar System? Will TPF discover terrestrial planets orbiting in the habitable zones around nearby stars? If so, will some of these planets have biomarkers detectable by TPF or other planned future facilities? Will SETI projects succeed in detecting signals broadcast by extraterrestrial civilizations in the foreseeable future?
- Problem Set 9 due in lecture on Dec 10