(Astro)Physics 343 Lecture # 14:

the Search for Extra-Terrestrial Intelligence

Astrobiology: a useful starting point

astrobiology (Lafleur 1941)

cosmobiology (Bernal 1952)

exobiology (Lederberg 1960)

bioastronomy (IAU 2004)

1941 definition by Lafleur: "consideration of life in the universe elsewhere than on earth"

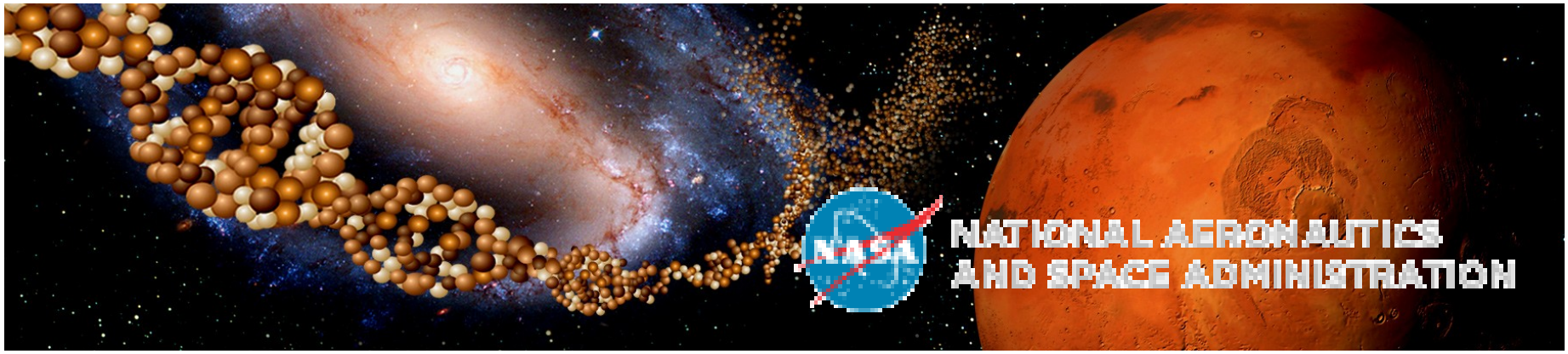
1964 comment by Simpson: "this 'science' has yet to demonstrate that its subject matter exists!"

2008 definition by NASA: "study of the living universe"

Astrobiology vs. SETI

Astrobiology research is funded by NASA.

NASA Astrobiology Institute (http://astrobiology.nasa.gov/nai/) started in 1998 as a virtual institute to coordinate research.



SETI has not been funded by NASA since 1993, when Congress killed the Ames/JPL "High Resolution Microwave Survey".

Should "astrobiology" include life on Earth?

To address many astrobiological questions, we have no choice but to extrapolate from a sample of one.

Is this legitimate?

Copernican principle: our circumstances are not special

anthropic principle: our circumstances are special, because we're here

Relevant to SETI because insights about astrobiology guide our choice of search strategy.

What astrobiology encompasses

astronomy

geology

chemistry

atmospheric science

marine science

biochemistry

biology

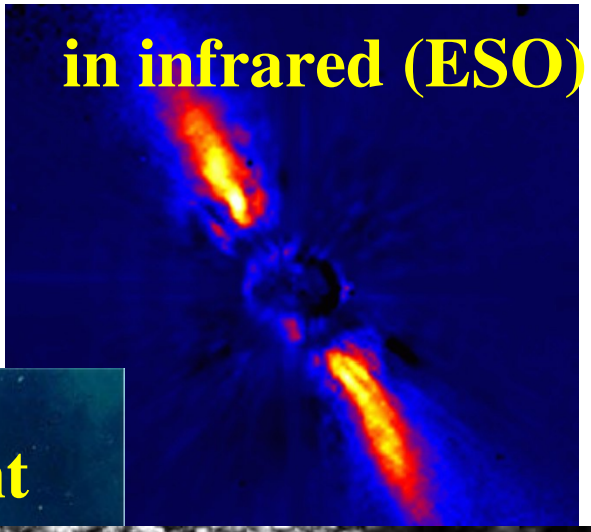
anthropology

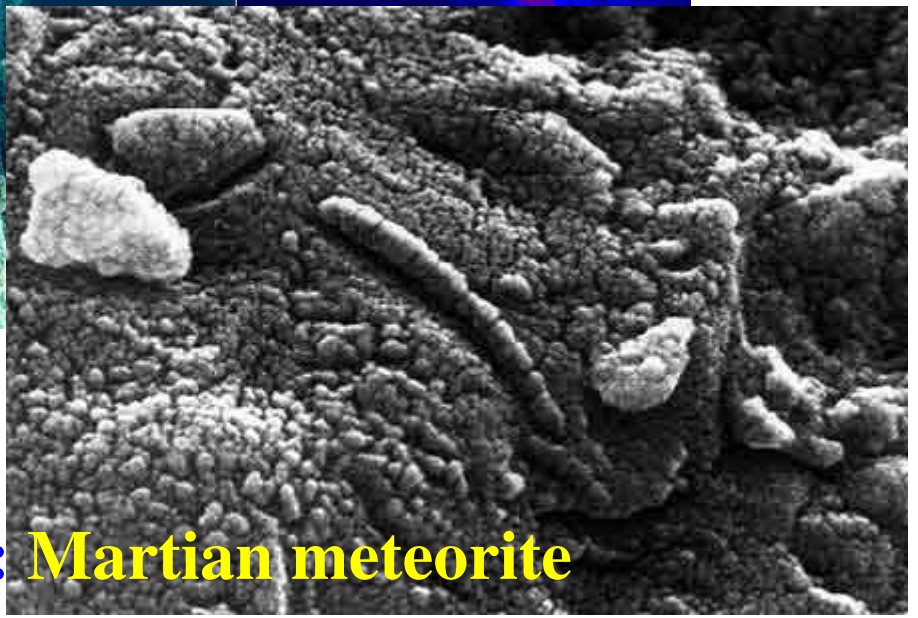
sociology

physics

planetary science

Beta Pictoris





Quantifying our ignorance...

UC Santa Cruz astronomer Frank Drake in Green Bank, WV

November 1960: a secret meeting in WV

Ten scientists met in Green Bank, WV to discuss the prospect for existence and detection of extraterrestrial life.

Location inspired by Drake's first SETI experiment.

Participants included astronomers, biologists, engineers, and a chemist whose Nobel Prize was announced during the meeting; nicknamed themselves "Order of the Dolphins".

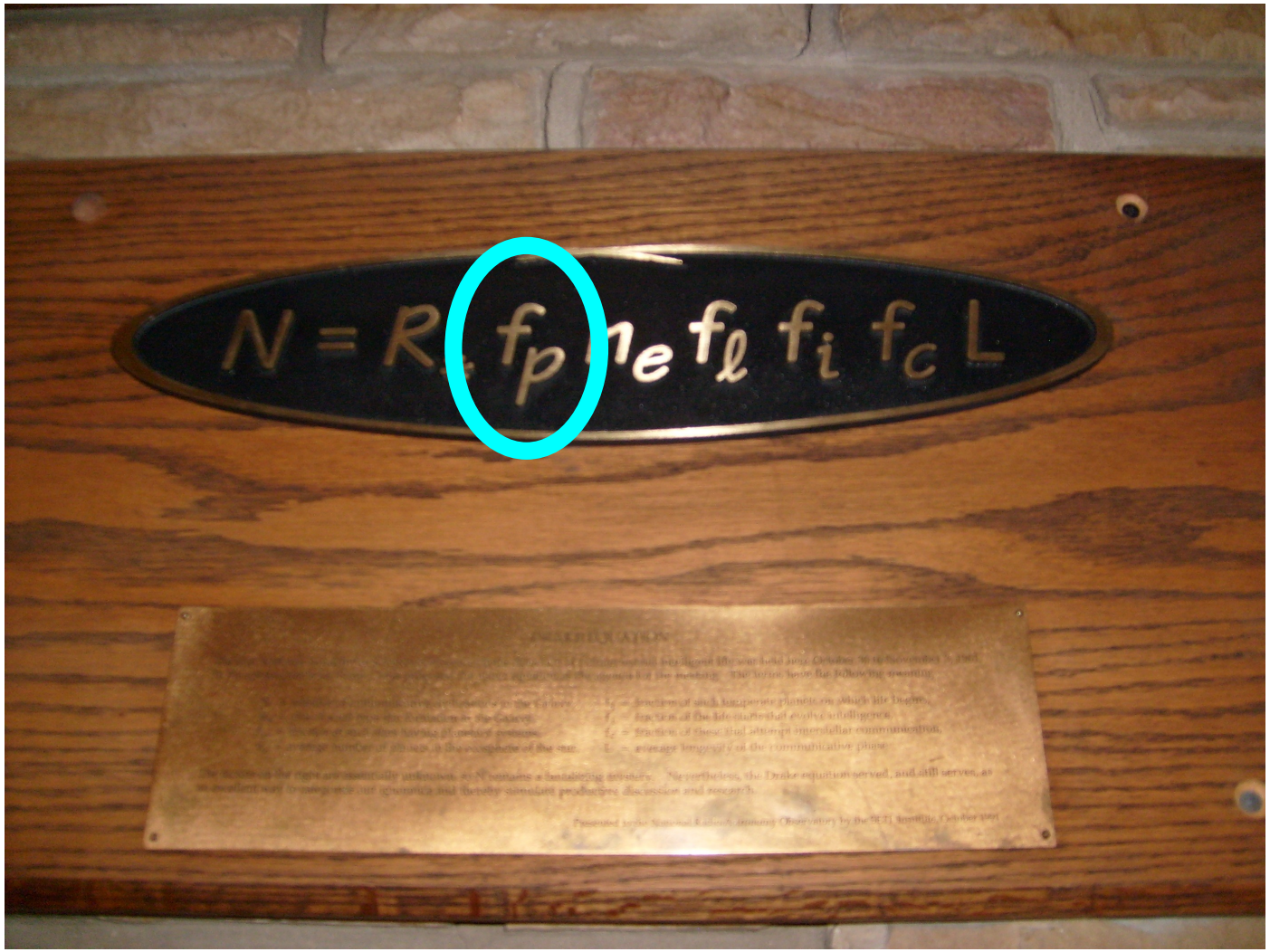
The Drake Equation

***N* = number of transmitting civilizations in the Milky Way**

The Drake Equation

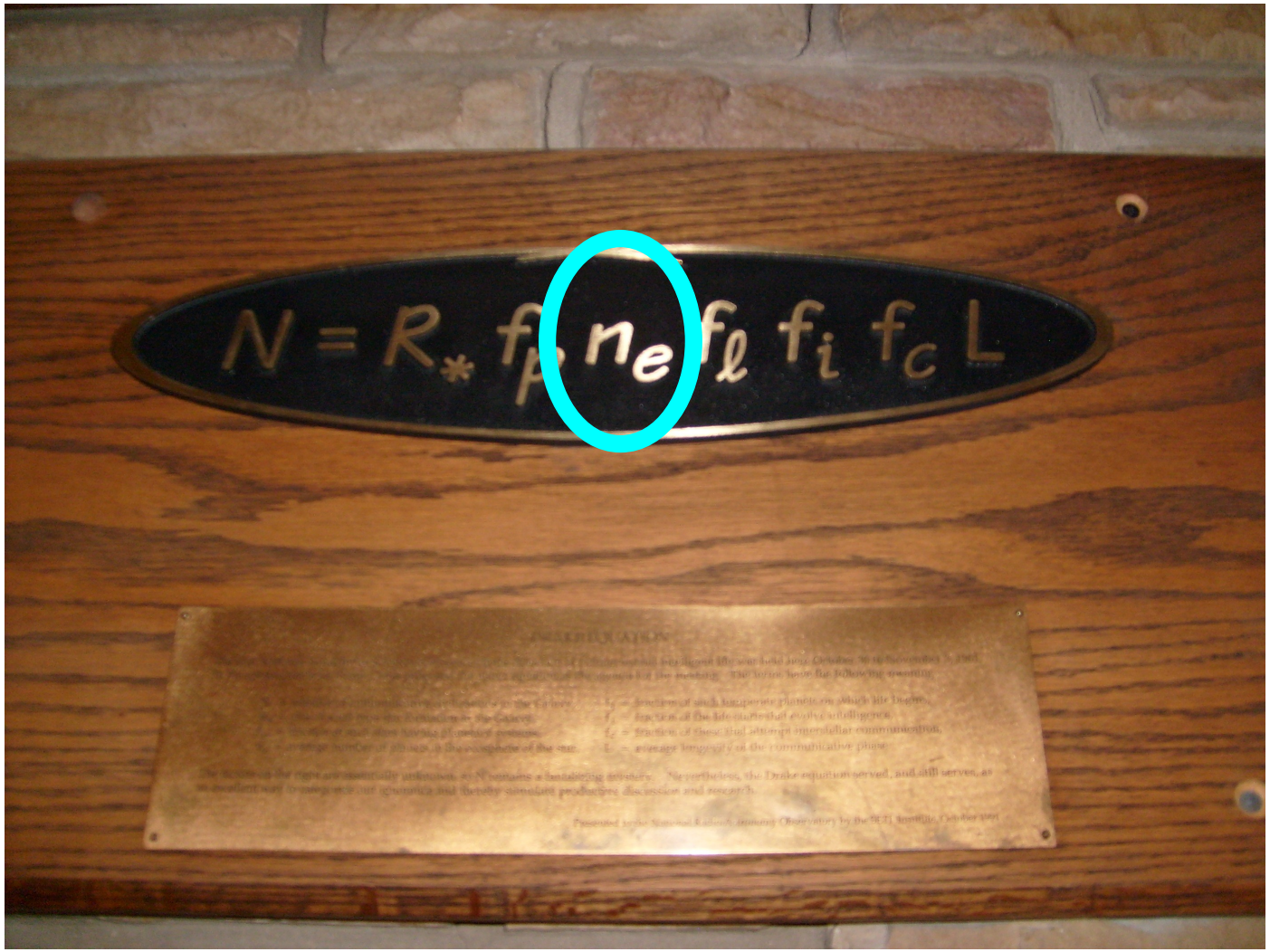
R_* = rate at which suitable stars form in Milky Way (yr^{-1})

The Drake Equation



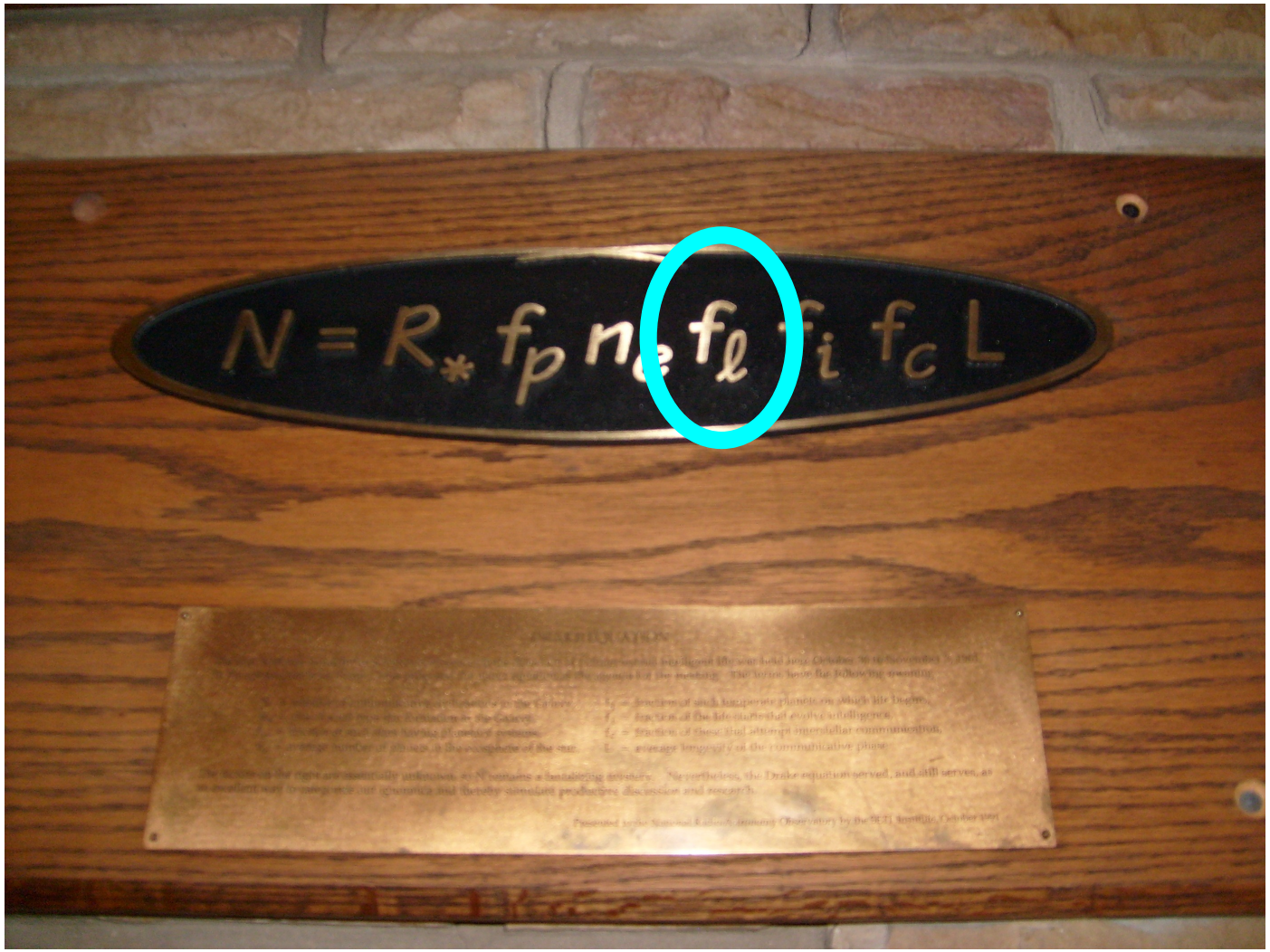
f_p = fraction of such stars that have planets

The Drake Equation



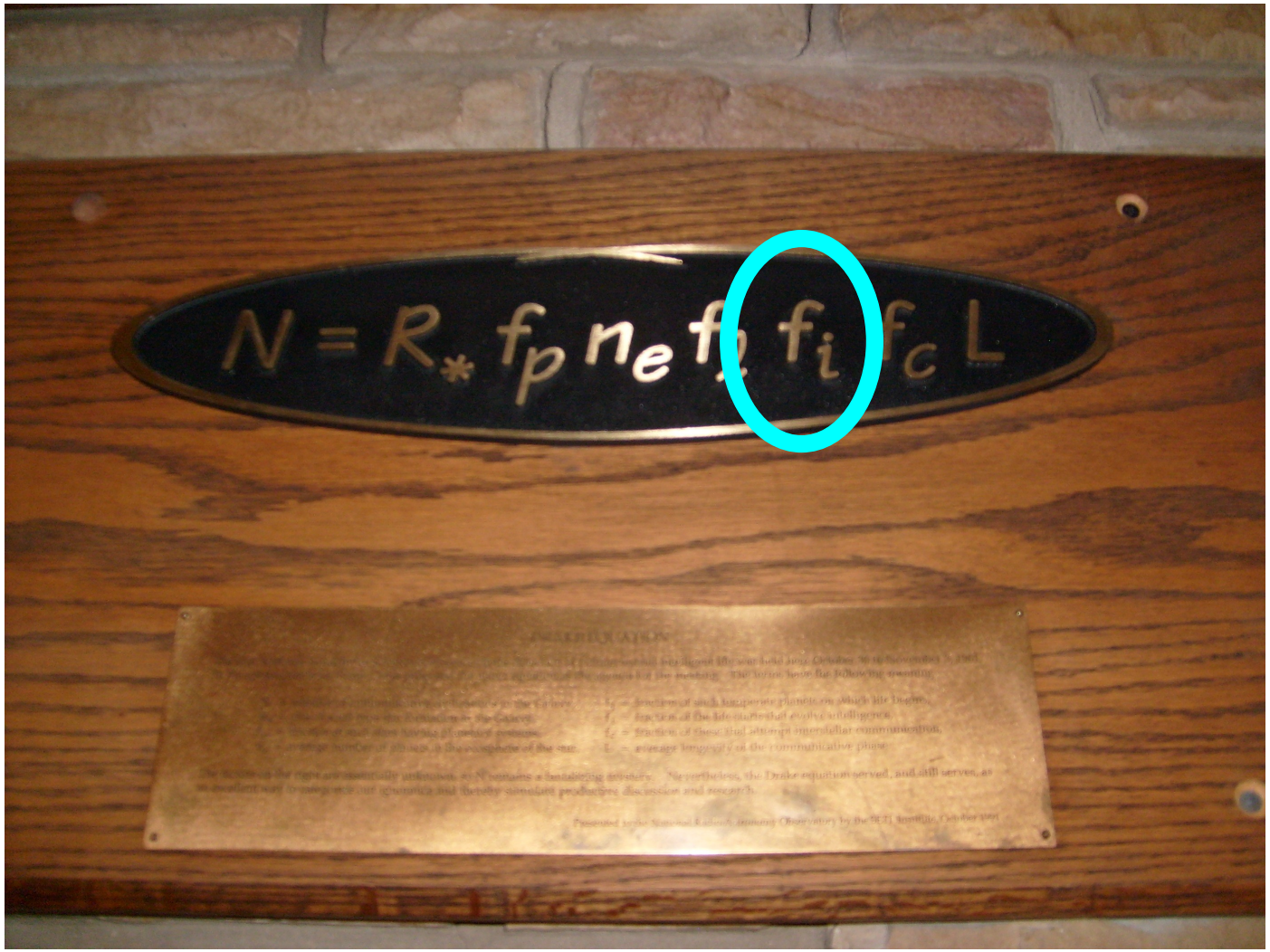
n_e = mean number of planets per solar system that *could* support life

The Drake Equation



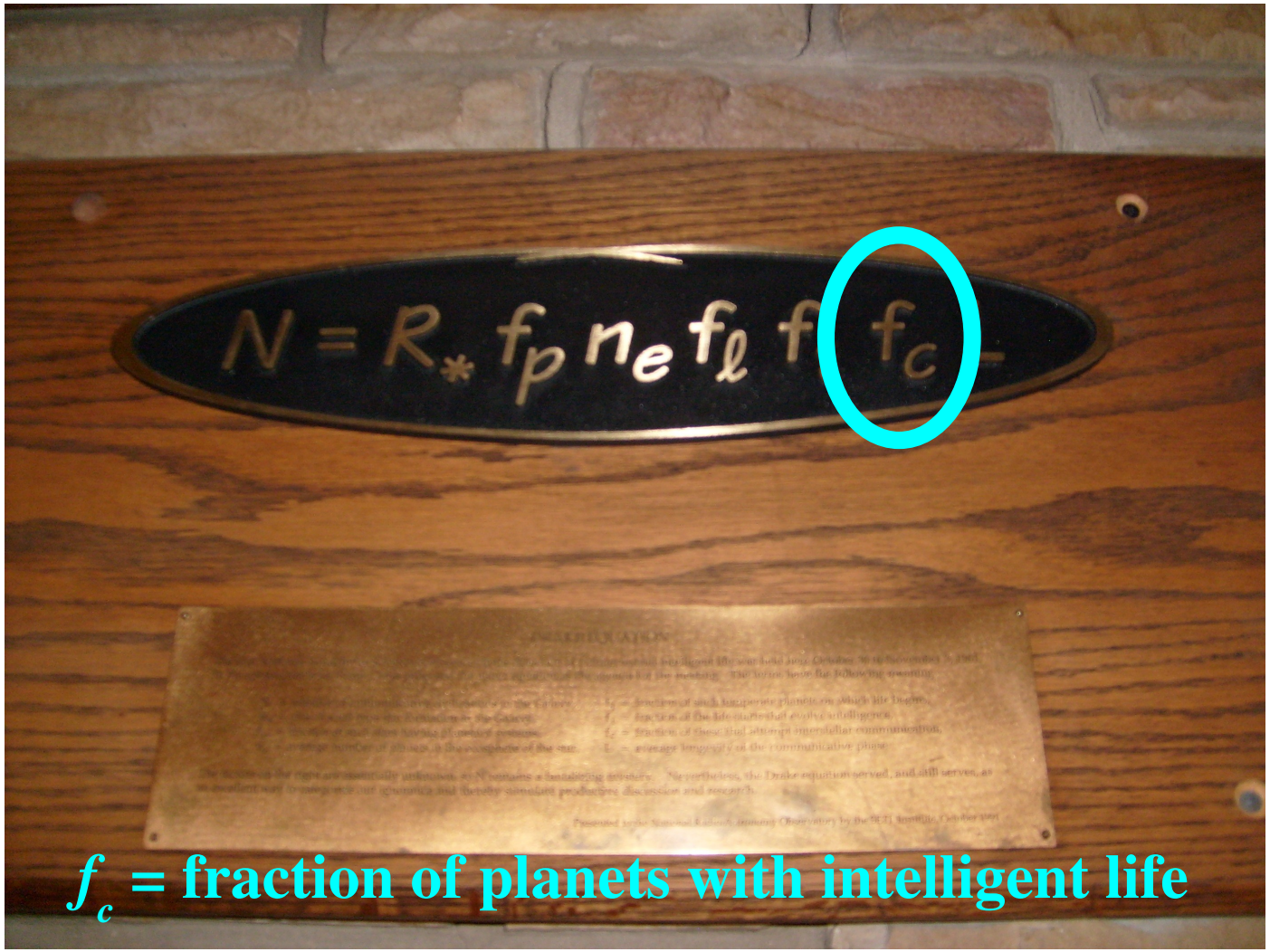
f_l = fraction of habitable planets on which life *did* evolve

The Drake Equation



f_i = fraction of planets with life on which intelligence evolved

The Drake Equation

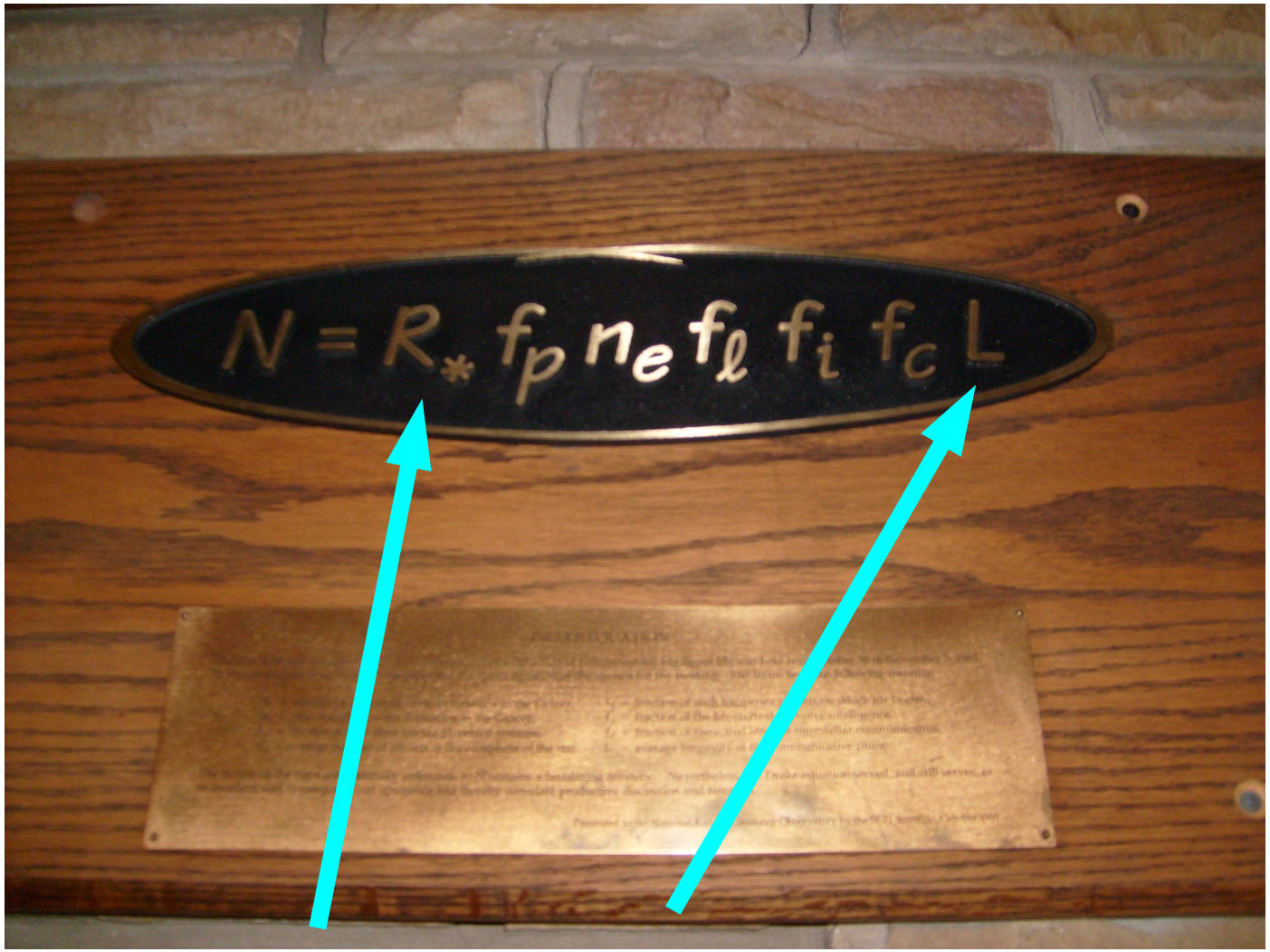


on which a transmitting *civilization* arises

The Drake Equation

***L* = mean lifetime of a transmitting civilization (yr)**

The Drake Equation



units: R_* ~ yr^{-1} and L ~ yr ⇒ N is dimensionless

What did Frank Drake guess in 1961?

$R_* \sim 10\ \mathrm{yr}^{-1}$

$f_p \sim 0.5$

$n_e \sim 2$

$f_l \sim 1$

$f_i \sim 0.01$

$f_c \sim 0.01$

$L \sim 10^4\ \mathrm{yr}$

$\Rightarrow N \sim 10$

Key value of the Drake Equation: highlights the fact that some factors are less certain than others!

Overall strategy for contacting ETI

If we want to get in touch with ETI, should we

(a) send messages?

(b) listen for messages?

(c) wait to be visited?

The relative youth of our technological civilization argues that (b) is better than (a), but also begs the question of why we have not already been visited!

Latter question is known as the Fermi Paradox. Possible answers: they don't exist, they're far away, or they're hiding.

The listening strategy for SETI: details

Two key questions:

(1) Where do we look on the sky?

(2) Where do we look in the electromagnetic spectrum?

Most straightforward answers draw from our own experience:

(1) Look near stars like the Sun, which could have planetary systems like our solar system.

(2) Look in the radio, where interstellar dust and a planetary atmopshere will not absorb/scatter a signal.

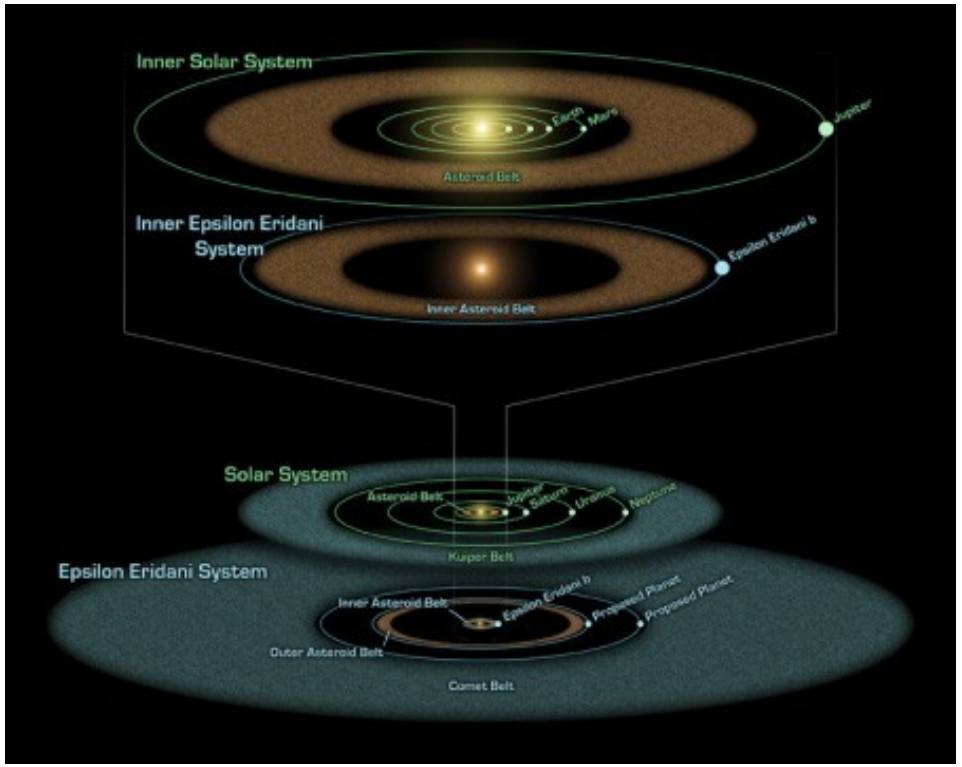
Project Ozma

1960: Frank Drake used the 85 foot telescope in Green Bank to observe two nearby stars at ν ~ 1420.4 MHz (a single 100 Hz channel scanned 400 kHz of bandwidth; compare to mode 1 of SRT receiver, which obtains 500 kHz at 7.8125 kHz resolution). Frequency was chosen for cheap cost ($2000). Strip chart and tape recorder stored data. Observed 150 hrs.

Targets chosen to be like the Sun: Epsilon Eridani (3.22 pc) and Tau Ceti (3.65 pc). No astronomical signals detected.

Epsilon Eridani: the picture today

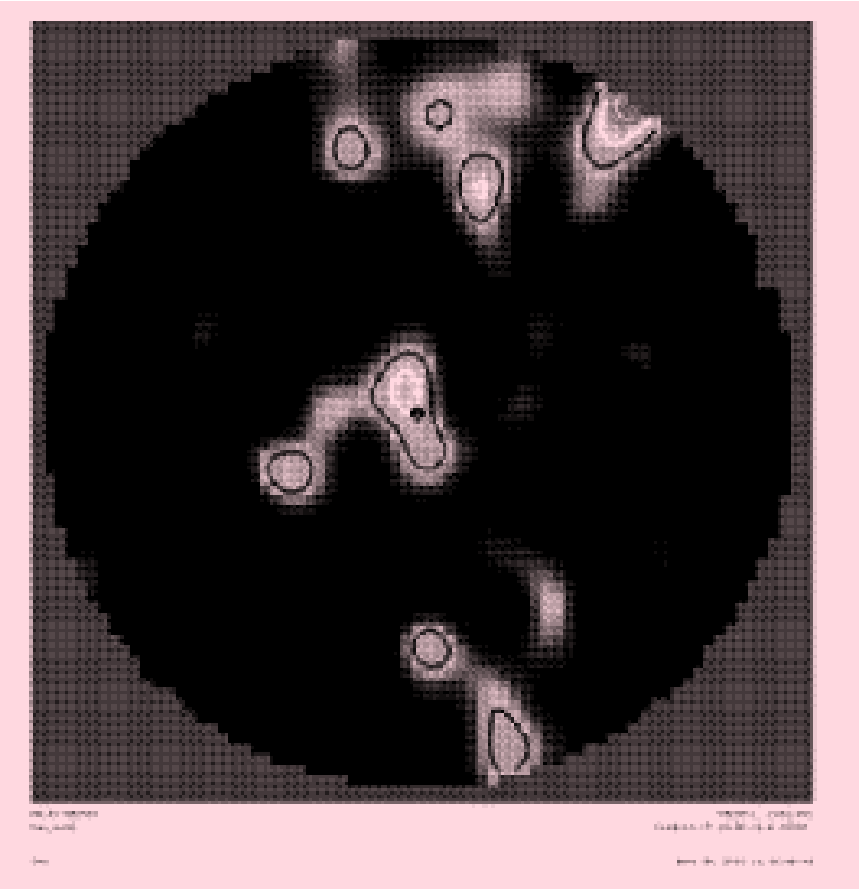
Bumps in dust spectrum imply existence of two asteroid belts confined by three planets (one also seen in radial velocities) and an icy quasi-"Kuiper belt"... but only 850 Myr old, so no time for intelligent life to develop (Backman et al. 2008).



Courtesy NASA/JPL.

Tau Ceti: the picture today

No evidence for planets in radial velocity searches, but submillimeter photometry indicates a debris disk ten times as massive as our Kuiper belt... which presumably implies a ten-times-higher rate of major impacts than what the Earth suffers.



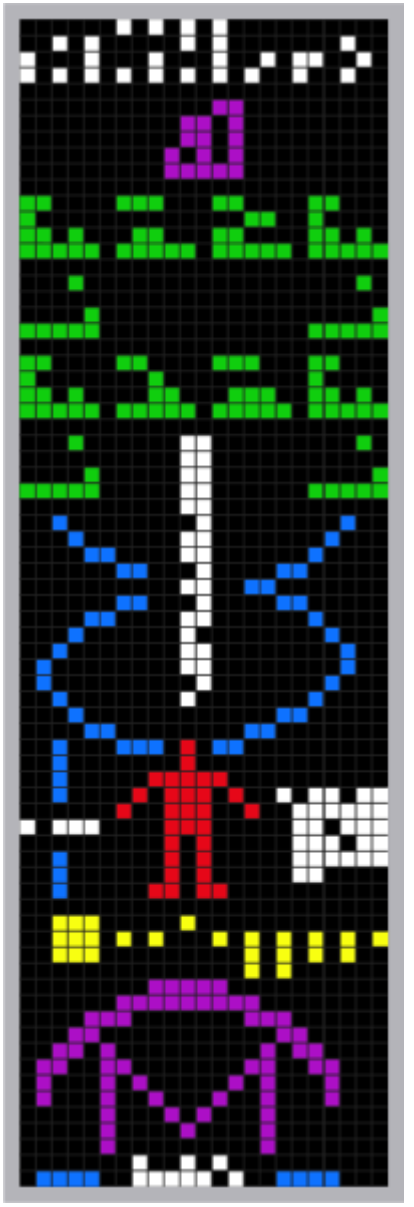
Greaves et al. (2004)

What sort of signals are expected?

What sort of signals have we (deliberately) sent?

1974 Arecibo Message: 23 × 73 sequence of pulses at two different frequencies, to suggest arrangement into a 2D array.

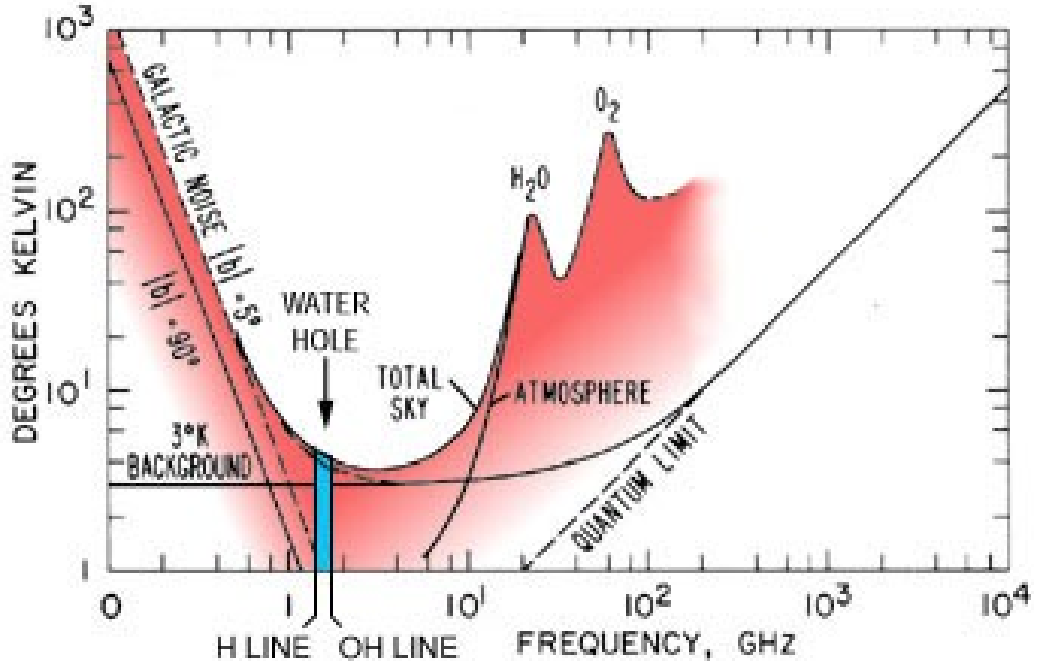
This was beamed towards the globular cluster M13, which will move out of its path before the 25,000 year travel time has elapsed!



Where might we look in frequency?

Close to the 21cm HI line, which is an obvious point of reference for all radio astronomers (Morrison & Cocconi 1959).

1420 MHz through 1662 MHz (frequency of strong OH lines) defines the low-background "water hole" (B. Oliver), which might be appealing to species with a common biology.



Signal frequency unlikely to be stationary

Search strategies need to check for repeatability but allow for Doppler drift: transmissions from a planet or a satellite in orbit will in general reflect line-of-sight motions.

Conclusion: want to search wide frequency ranges at very high frequency resolution.

Post-Ozma searches from Green Bank

Later programs could take advantage of the 140 ft and 300 ft telescopes at NRAO Green Bank.

1971-72: "Ozpa" searches towards 9 nearby stars (including allowance for Doppler drift) over a meager 13 hours

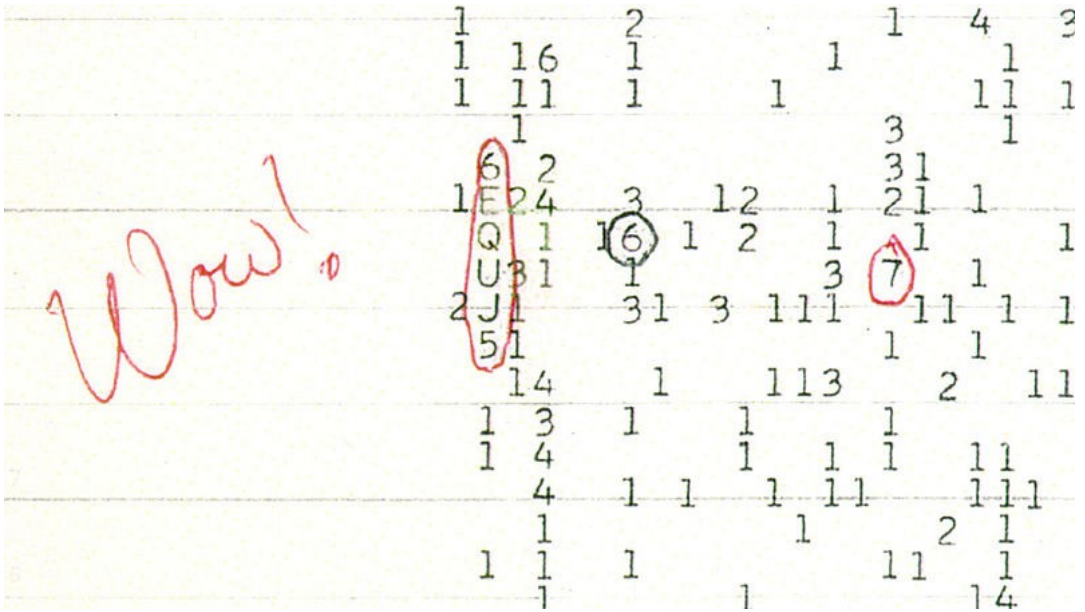
1972-76: "Ozma II" searches towards 674 stars over 500 hours; target stars selected to be between F5 and K4, to avoid short stellar lifetimes and small habitable zones

The first university-based SETI effort

Ohio State's "Big Ear" (1963-1998): drift field telescope with feed horns on a cart at base of flat reflector. SETI work began in 1973 and continued over two decades.

August 15, 1977: the "wow" signal

While observing in the direction of Sagittarius, Big Ear detected a strong, narrow-band signal in one of its two feed horns that was not repeated. Nevertheless, Jerry Ehman was quite enthusiastic!



1979: NASA gets on board

NASA established the "Microwave Observing Program" (MOP) to pursue a mixture of targeted and all-sky searches.

This attracted mixed attention from Congress: Sen. William Proxmire (D-WI) gave it a "Golden Fleece" award in 1979, and succeeded in killing funding in 1982.

Funding reestablished in 1983 after Carl Sagan and others paid Sen. Proxmire a visit...

MOP observations: 1992-93

MOP surveys began in 1992 at Arecibo (305m, targeted, 800-1000 stars, led by NASA Ames) and Goldstone (34m, all-sky, led by NASA JPL).

Renamed the "High Resolution Microwave Survey".

HRMS signal processing

Targeted survey:

searched 1 – 3 GHz in 20 MHz chunks, each divided into 20 million channels, for 1 – 28 Hz bandwidth signals

All-sky survey:

searched 1 – 10 GHz in 320 MHz chunks, each divided into 16 million channels

Compare to early "Big Ear" searches of 50 channels at a time!

Funding killed by Sen. Richard Bryan (D-NV) in 1995.

Onward via private support

First private funding of SETI: The Planetary Society (1980 – present, http://www.planetary.org/), which funnelled donations from Steven Spielberg and others into the Sentinel (131 kchan), META (8.4 Mchan), and BETA (250 Mchan + rapid retuning) projects on the 26m telescope in Harvard, MA.

Alas: the 26m telescope was blown over by strong winds in 1999...

Project Phoenix

Resuscitation of HRMS targeted search under the leadership of Dr. Jill Tarter of the SETI Institute.

Used 64m Parkes radio telescope in Australia (1995 – 1996) + Green Bank 140 foot (1996 – 1998) + Arecibo (1998 – 2004) to survey 800 stars within 200 light-years of earth over 1 – 3 GHz range.

Targeted search requires (temporary) control of the telescope.

SERENDIP

Like the Sentinel/META/BETA efforts, SERENDIP targets an all-sky survey, but in this case by piggybacking on science observations with Arecibo.

SERENDIP IV data are analyzed by the SETI@home program.

A semi-dedicated SETI interferometer

The Allen Telescope Array (ATA) has been built in California thanks to the generosity of Paul Allen, who contributed $25M (half the cost) of the first 42 (of 350) 6.1m dishes...

Simultaneous SETI (Search for ET Intelligence) and other research; first proposal deadline was last year!