The Search for Extraterrestrial Intelligence

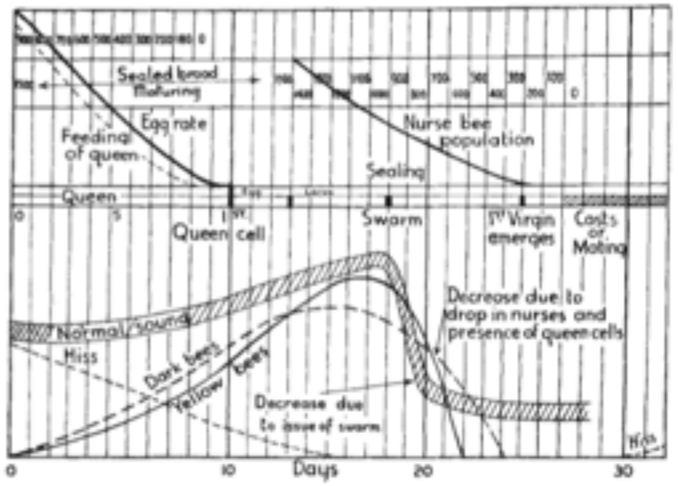


Fig. 3. Swarm cycle

warble. Furthermore, the warble 'radiates' from the queen, which is usually at the top of the brood-box, away from the entrance.

Disturbance was eliminated, and the relative volume of the warble increased by placing a microphone permanently inside the hive at the top, but the adverse conditions of heat and humidity destroyed the (crystal) microphone fairly quickly, and the running cost of one microphone per hive per season was excessive.

A scheme which has proved successful and economical utilizes a hole in the back of the brood-box at the top, with an internal screen of perforated zinc, and plugged with a rubber bung. This bung is removed and the microphone, mounted in an identical bung, plugged in. This third plan also removes a disadvantage of the second, namely, the variability of microphones, especially after some weeks in the hive.

Headphones, of the familiar stethophone pattern, are used as a detector, but later development may permit the use of a visual indicator, at an increased cost. An automatic alarm system is also possible for use in large centralized apiaries.

The 'Apidictor' was primarily visualized as a swarm predictor, for which it has obvious economic advantages, but it has a great range of other uses. It removes almost completely the uncertainty of queen introduction and queen cell acceptance, it detects abnormalities such as queen failure, that is, drone breeding, and it enables an accurate check to be made of the health of the colony in winter, even during heavy frost.

I wish to acknowledge the enthusiastic and skilled co-operation of many friends, but particularly of Mr. E. F. Birch of Hereford, who has been working with me since 1951, and of Mr. C. B. Dennis of Harrow, who has co-operated with me for the past three years. I also wish to thank Messrs. Wayne Kerr Laboratories of Surrey, for invaluable technical assistance.

¹ British Patent No. 720,067 (1955).

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 times 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.

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-

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

the channel must or in the Earth's ow ~1 Mc./s., and ar absorption lines ... ption band- ossible

domains demand urce or very com- io-band from, say, rational choice. ust compete with n of its own local angular resolution ar since the source arc of its nearby along the line of

pendence of these quiet Sun would a distance R (in

... of diameter l_d- lux multiplied by

t of the galactic equal to :

o spectrum of the from the angular ea of the detector. ground is defined minimum lies at :

and $l_d = 10^3$ m.,

gion of this broad

A long spectrum frequency is diffi- radio region there frequency, which in the universe: e at 1,420 Mc./s. It is reasonable for this frequency e development of he expectation of , and the present leed justifies the t most promising ,420 Mc./s.

Source

the 21-cm. line

for about two-thirds of the directions in the sky. In the directions near the plane of the galaxy there is a background up to forty times higher. It is thus economical to examine first those nearby stars which are in directions far from the galactic plane.

If at the source a mirror is used l_s metres in diameter, then the power required for it to generate in our detector a signal as large as the galactic background is:

$$\frac{dW_s}{df} = \frac{dW_b}{dS\, d\Omega\, df}\left(\frac{\lambda}{l_s}\right)^2\left(\frac{\lambda}{l_d}\right)R^2 = 10^{-24.5}\, R^2/l_s^2 l_d^2 \quad \text{W.(c./s.)}^{-1}$$

For source and receiver with mirrors like those at Jodrell Bank ($l = 80$ m.), and for a distance $R \simeq 10$ light years, the power at the source required is $10^{3.5}$ W.(c./s.)$^{-1}$, which would tax our present technical possibilities. However, if the size of the two mirrors is that of the telescope already planned by the U.S. Naval Research Laboratory ($l = 200$ m.), the power needed is a factor of 40 lower, which would fall within even our limited capabilities.

We have assumed that the source is beaming towards all the sun-like stars in its galactic neighbourhood. The support of, say, 100 different beams of the kind we have described does not seem an impossible burden on a society more advanced than our own. (Upon detecting one signal, even we would quickly establish many search beams.) We can then hope to see a beam toward us from any suitable star within some tens of light years.

Signal Location and Band-Width

In all directions outside the plane of the galaxy the 21-cm. emission line does not emerge from the general background. For stars in directions far from the galactic plane search should then be made around that wave-length. However, the unknown Doppler shifts which arise from the motion of unseen planets suggest that the observed emission might be shifted up or down from the natural co-moving atomic frequency by $\pm \sim 300$ kc./s. (± 100 km. s.$^{-1}$). Closer to the galactic plane, where the 21-cm. line is strong, the source frequency would presumably move off to the wing of the natural line background as observed from the direction of the Sun.

So far as the duration of the scanning is concerned, the receiver band-width appears to be unimportant. The usual radiometer relation for fluctuations in the background applies here, that is:

$$\frac{\Delta B}{B} \propto \sqrt{\frac{1}{\Delta f_d \tau}}$$

where Δf_d is the band-width of the detector and τ the time constant of the post-detection recording equipment. On the other hand, the background accepted by the receiver is:

$$B = \frac{dW_b}{df}\,\Delta f_d \text{ and } \tau \propto \frac{\Delta f_d}{(\Delta B)^2}$$

If we set ΔB equal to some fixed value, then the search time T required to examine the band F within which we postulated the signal to lie is given by:

$$T = \frac{F\tau}{\Delta f_d} \propto \frac{F}{(\Delta B)^2}$$

independent of receiver band-width Δf_d.

Of course, the smaller the band-width chosen, the weaker the signal which can be detected, provided $\Delta f_d \geqslant \Delta f_s$. It looks reasonable for a first effort to choose a band-width Δf_d normal in 21 cm. practice, but an integration time τ longer than usual. A few

uency range F using or hours.

Possible Sources

as finding the signal. be pulse-modulated ery slow compared to idth and of rotations. for a time measured turn in any event for peat, from the begin- ferent types of signals rs. For indisputable nal, one signal might ence of small prime thmetical sums. oted to examining the stars within 15 light nd lifetime similar to e lie in the directions τ Ceti, o₂ Eridani,

ε Eridani, and ε Indi. All these happen to have southern declinations. Three others, α Centauri, 70 Ophiucus and 61 Cygni, lie near the galactic plane and therefore stand against higher backgrounds. There are about a hundred stars of the appropriate luminosity among the stars of known spectral type within some fifty light years. All main-sequence dwarfs between perhaps $G0$ and $K2$ with visual magnitudes less than about +6 are candidates.

The reader may seek to consign these speculations wholly to the domain of science-fiction. We submit, rather, that the foregoing line of argument demonstrates that the presence of interstellar signals is entirely consistent with all we now know, and that if signals are present the means of detecting them is now at hand. Few will deny the profound importance, practical and philosophical, which the detection of interstellar communications would have. We therefore feel that a discriminating search for signals deserves a considerable effort. The probability of success is difficult to estimate; but if we never search, the chance of success is zero.

GES INDUCED IN MAMMALIAN ERYTHROCYTES WHOLE-BODY X-IRRADIATION

ROF. D. A. RAPPOPORT and B. W. SEWELL
iochemistry, Baylor University College of Medicine, Houston, Texas

d radium in medicine, ring 1895–96, estab- gnosis and treatment r were the lethal and netrating rays recog- of men have become man-made radiation. penetrating radiation reliable indicator of e. What is precisely rate indicator which ge with the radiation

l biological radiation or tissue component nded periods follow-) this change can be also important that able for intermittent subject and without xamination.

rocytes

e used in considering ate a working hypo- assumed that any cause changes in the ction of these changes is dependent on (a) the sensitivity to radiation of a particular enzyme system under evaluation and (b) the degree of sensitivity of the analytical methods employed.

Implicit in the above specifications is the fact that the tissue must be incapable of extensive internal repair if it is to reflect any post-irradiation changes.

This immediately eliminates tissues with large populations of mitotic cells and suggests erythrocytes as the tissue component of choice. In man the erythrocyte has a life-span of 110–120 days[3], in the rat this span is 49–55 days[4], in other mammals erythrocyte life-spans are between these values[5]. Since mammalian erythrocytes are enucleated, no resyntheses of proteins can occur, and any radiation damage incurred on the enzyme-proteins, such as denaturation or rupture of peptide linkage, should be detectable by changes in enzymic reactions. This rationale suggests the erythrocyte enzymes for examination as a test system.

If the hypothesis is held that any absorbed radiation will affect enzymes in all cells, how is it that no enzymic changes have been observed in erythrocytes after moderate whole-body irradiation? This may be explained on the basis that up to the present time few erythrocyte enzymes have been tested after radiation treatment. Erythrocyte enzymology has now been more thoroughly explored[6,7]. With the complete elucidation of glycolysis, the hexosemonophosphate shunt, the transketolase and transaldolase enzymes, and nucleoside phosphorylase in erythrocyte extracts, re-examination of the radiation effect on these enzyme systems is in order.

Nucleoside Metabolism

Investigators concerned with the preservation of blood have found that when inosine or adenosine is added to blood the integrity of the erythrocytes is maintained during storage and their survival following transfusion is improved[8]. This was attributed to the resynthesis of metabolites essential for erythrocyte integrity.

Methods for searching for life

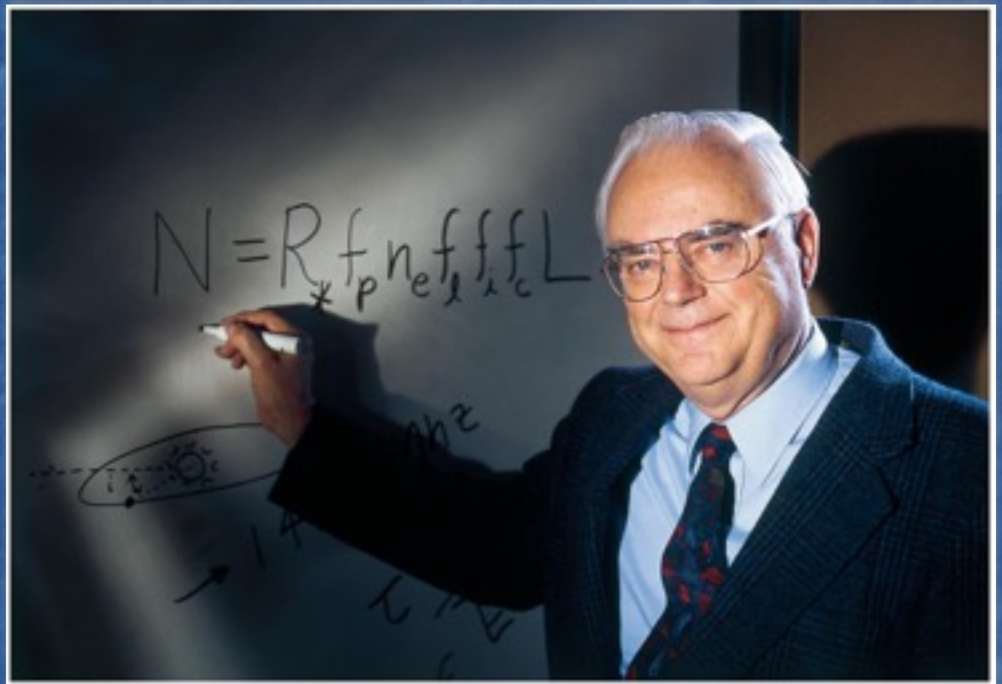
- Direct searches for microbial life in the solar system
  - rovers, sample return missions to Mars, Europa, etc.
- Indirect searches for signs of life in the atmospheres of extra-solar planets
  - biomarkers such as methane, ozone, etc.
- Detection of signals from intelligent civilisations
  - the Search for Extraterrestrial Intelligence (SETI)

Where Should SETI Look?

- The Solar System?
  - no signs of intelligent life elsewhere in the solar system
- Nearby Sun-like stars (with habitable planets?)
- The Milky Way Galaxy
  - several hundred billion stars
  - how far can we look?
- Beyond the Milky Way?
  - much more difficult

The Drake equation

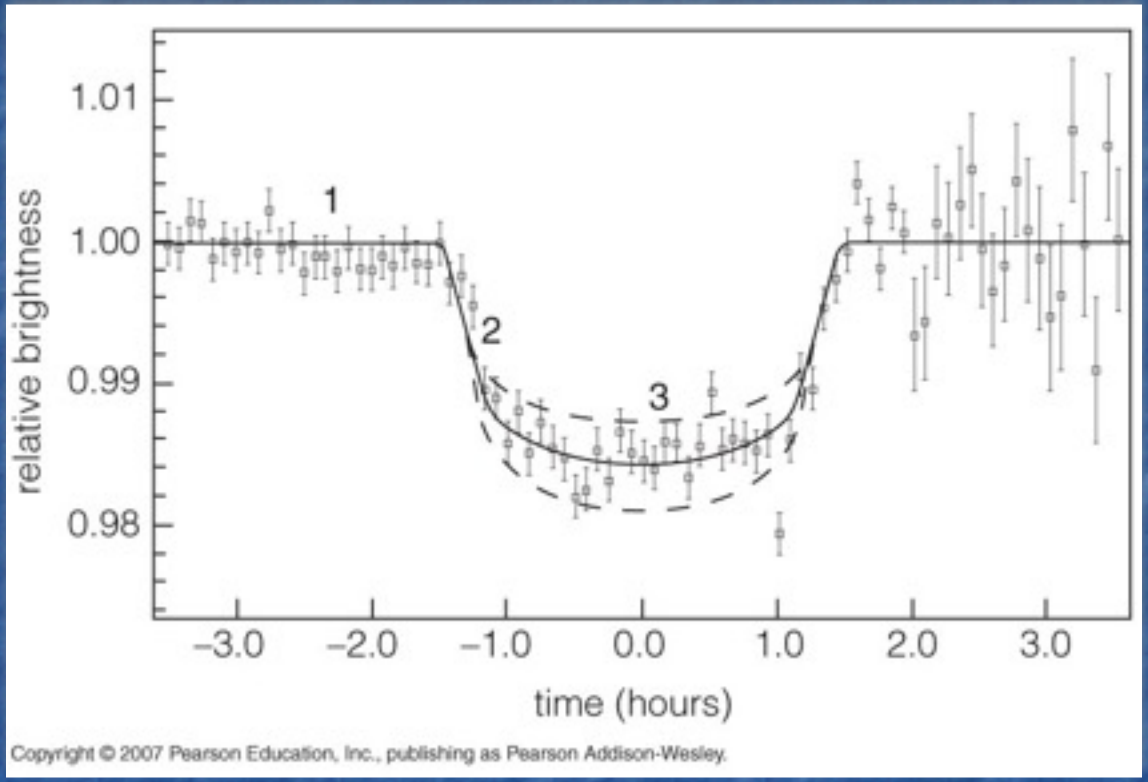
- Approximately how many civilisations capable of sending signals are currently present in the Milky Way?
- While we don't know the answer, Frank Drake summarized the key factors which go into estimating this number, in what is called the Drake Equation

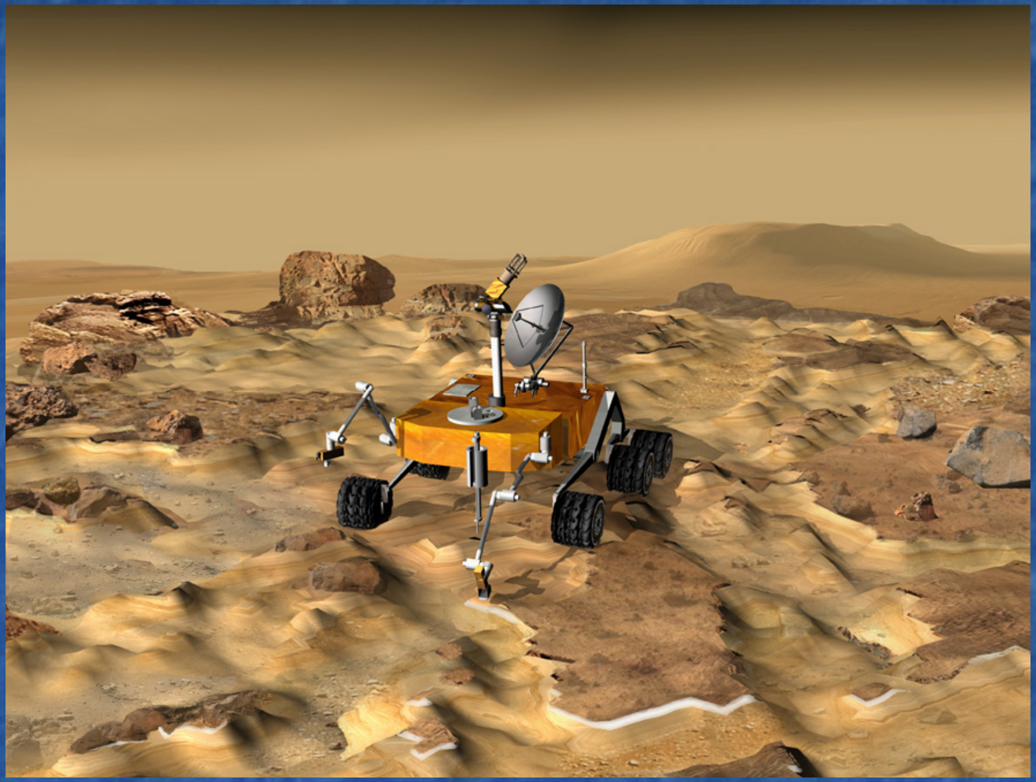


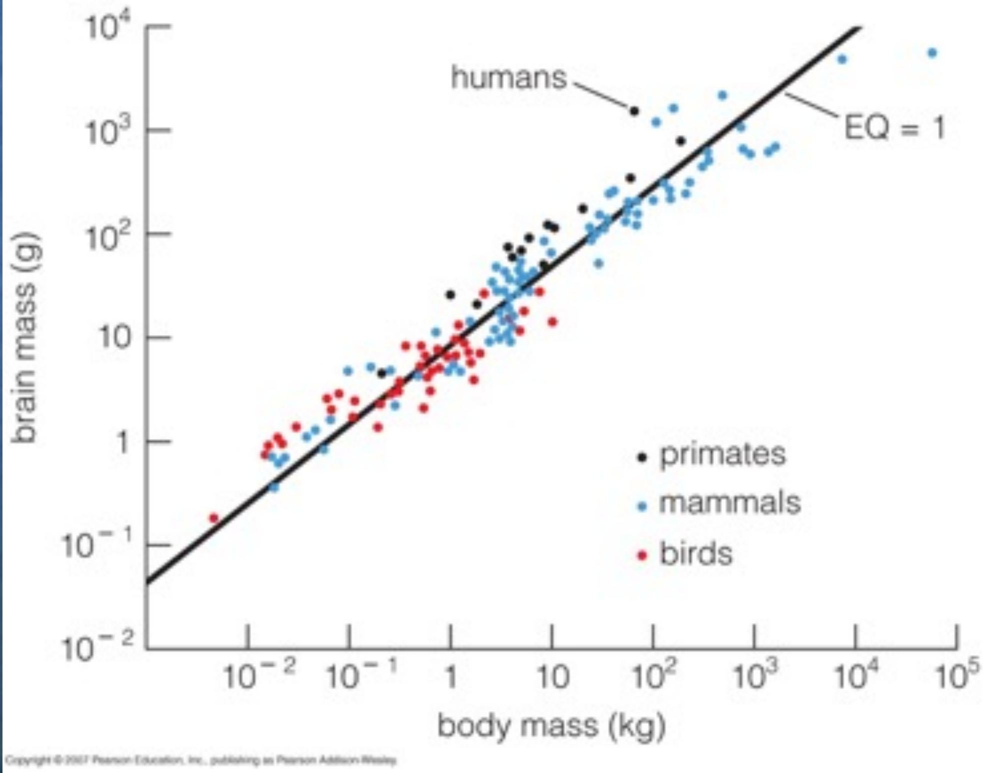
A simplified version of the Drake equation

- $N = N_{HP} \times f_{life} \times f_{civ} \times f_{now}$
- N = total # of detectable civilizations in Milky Way
- N_{HP} = # of habitable planets in the Milky Way
- f_{life} = fraction of habitable planets which have life
- f_{civ} = fraction of life-bearing planets upon which a civilization capable of sending signals has arisen
  - either in the past or at present
- f_{now} = fraction of these planets which have the capability of sending signals now

How can we improve our estimates of the factors in the Drake equation?







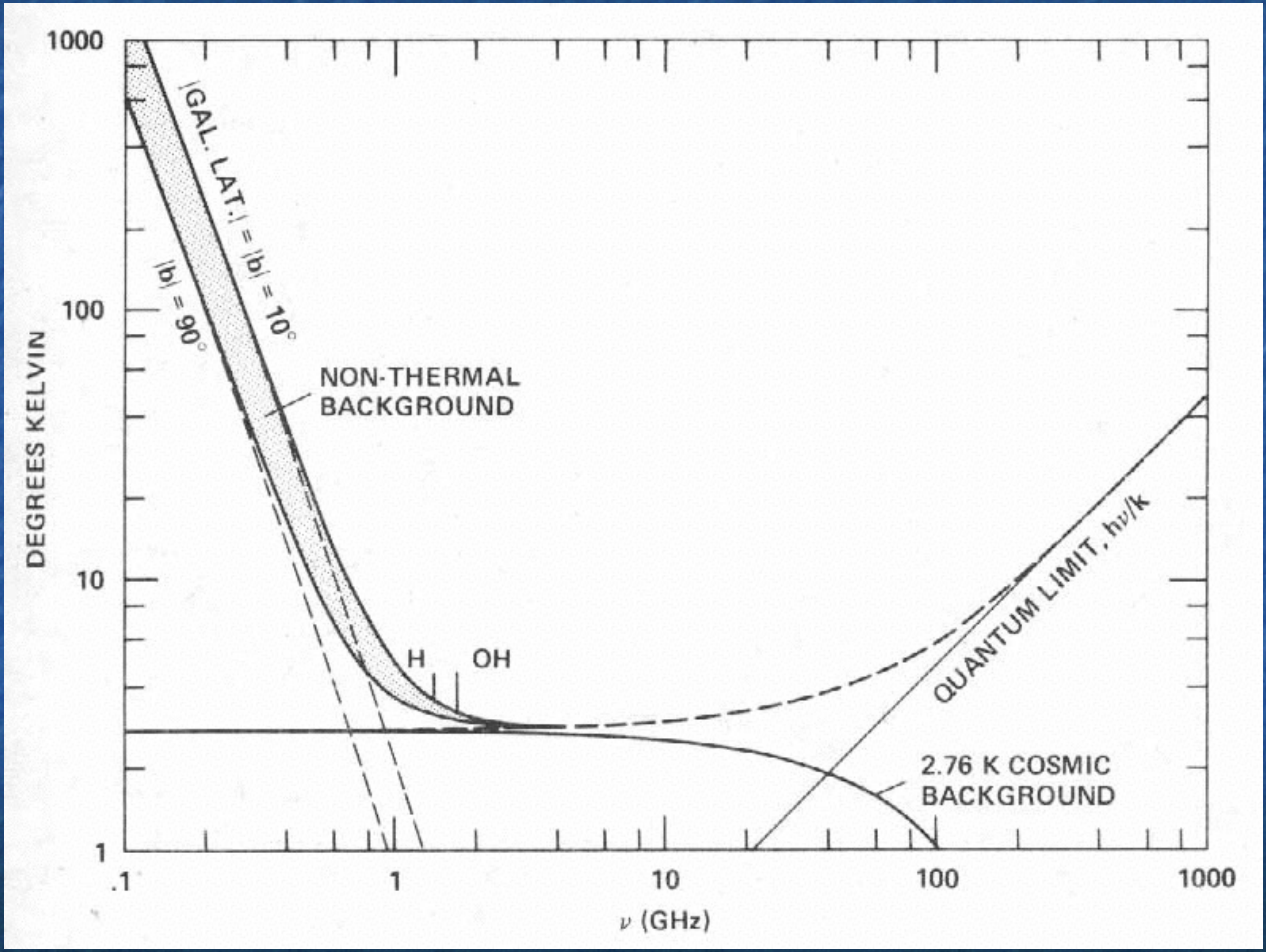
What should SETI look for?

- The primary method of searching for advanced civilizations is to try to detect signals
  - while most people think of SETI listening for these signals, sound cannot travel through empty space!
  - instead, SETI watches for signals (often using radio telescopes)
- The goal is to look for light that changes with time (a variable signal)
  - otherwise, it is nearly impossible to discern between light from aliens vs. light from stars, etc.
- Most SETI projects are carried out using the radio part of the spectrum, though some is done in the optical too
- Confirmation that a signal is from an advanced civilization means ruling out other possible sources
  - human transmissions, satellites, airplanes, etc.
  - natural sources which vary with time
    - e.g., pulsars, variable stars
  - noise peaks

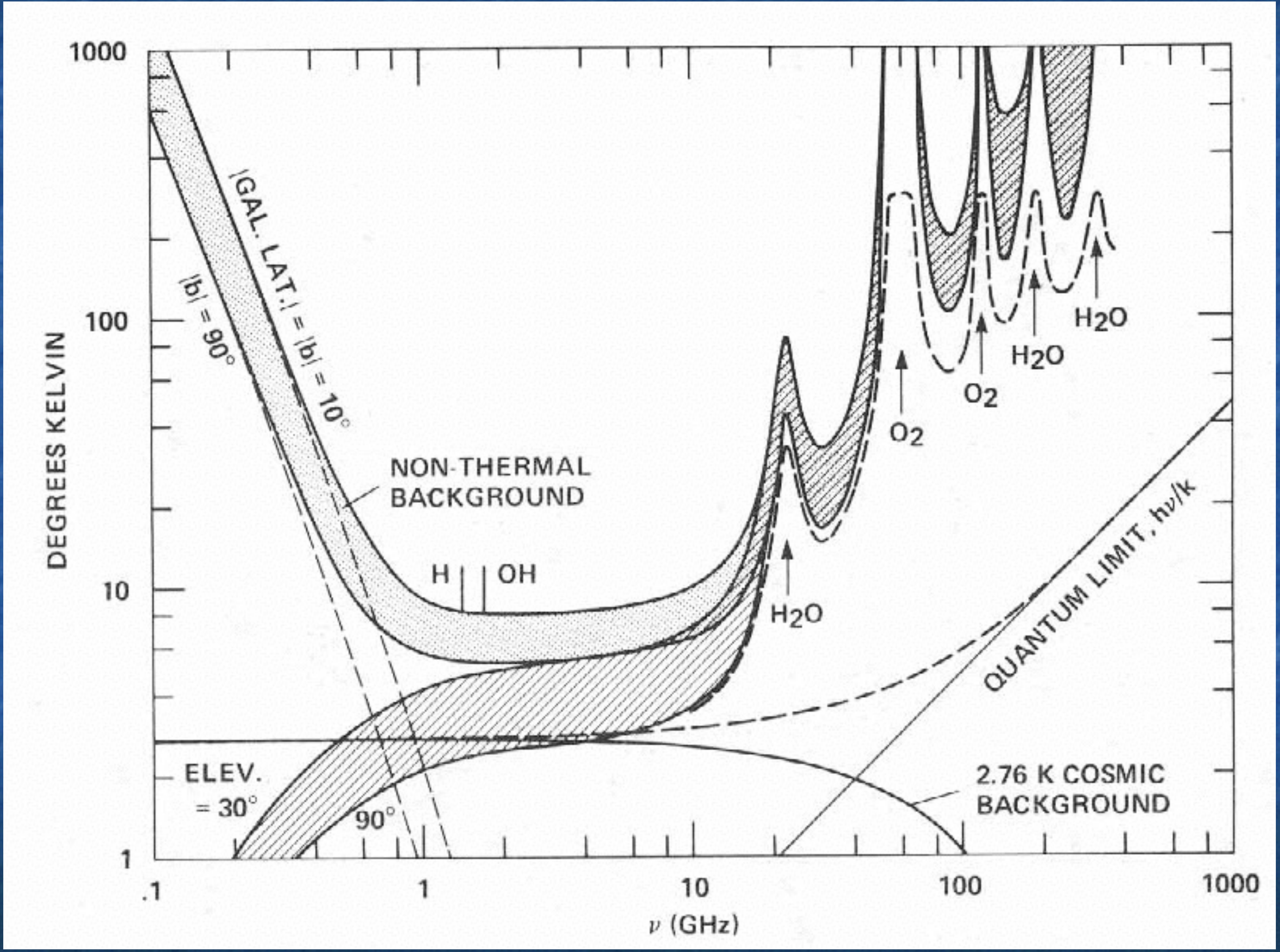
Parameter space to be searched

- Potential signals may have a wide variety of properties, and therefore there are many factors to consider when carrying out a SETI search
  - Location on the sky
    - One approach is to target individual nearby Sun-like stars
    - Another approach is to sky large swaths of sky in less detail
  - Frequency or wavelength
    - The radio part of the spectrum is most popular, especially the 1420 MHz (21 cm) frequency
  - Width of frequency channel
  - Signal strength
  - Signal duration
  - Etc.!

The radio spectrum and the water window



The radio spectrum and the water window



The Arecibo radio observatory: 300m diameter radio dish

Current Radio SETI Projects

TABLE 12.1 *Current Radio SETI Projects*

Name	*Institution*	*Telescope*	*Type*	*Total Number of Channels*	*Width of Single Channel*	*Band Covered*	*Detectable Power for 100-Meter Transmitter at 100 Light-Years*
Inner Galactic Plane Survey*	SETI Institute	Allen Telescope Array	Survey	450 million	1 Hz	1,390–1,720 MHz	70 megawatts
SERENDIP	University of California, Berkeley**	Arecibo Radio Telescope (305 m)	Sky Survey	168 million	0.6 Hz	1,370–1,470 MHz	1 megawatt
Southern SERENDIP	SETI Australia Centre	Parkes Radio Telescope (64 m)	Sky Survey	58 million	0.6 Hz	1,418–1,421 MHz	1 megawatt
SETI Italia	Istituto di Radioastronomia, Bologna	Medicina radio telescope (32 m)	Sky Survey	24 million	0.6 Hz	Bands centered at 1.4, 2.8, 6.4, and 22.4 thousand MHz	Typically 30 megawatts

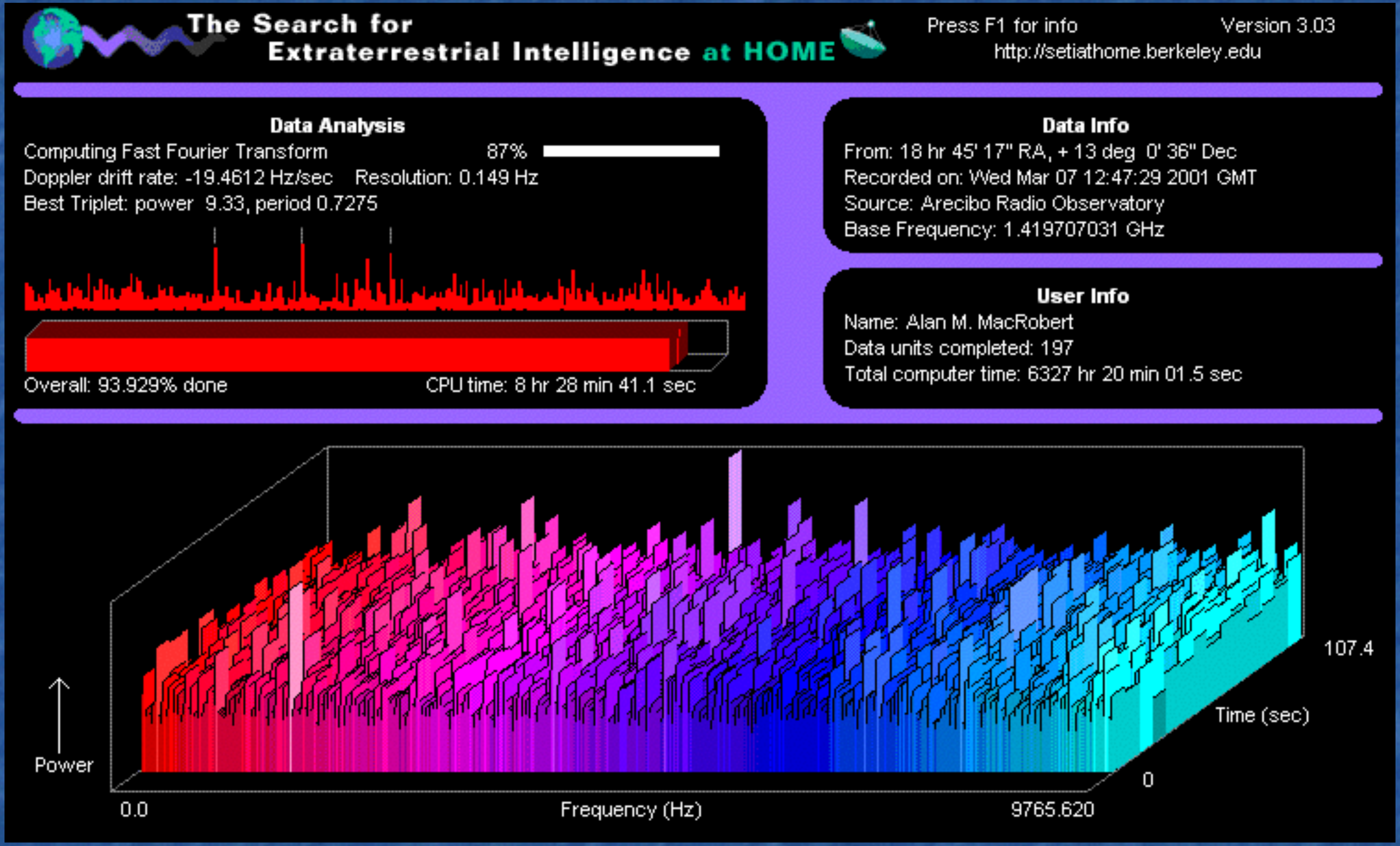
* Values given here are for the Allen Telescope Array capabilities at the end of 2006, when it will have 42 of its 6-meter antennas in operation. As more antennas are added (eventually reaching a total of 350), the sensitivity will increase and the observing mode will switch to a targeted search of stars within 1,000 light-years.

** About 2.5% of the data collected by the SERENDIP project is being distributed over the Internet for processing on a downloadable screen saver. This project (called SETI@home) has involved more than five million home computer users.

What are the most distant signals we can expect to detect?

- The largest radio transmitter/receiver on Earth is the 300m diameter Arecibo radio telescope.
- The strongest signal it can produce is around 10^7W.
- Arecibo can detect a signal of this strength, produced using a similar antenna, up to 1000 Ly away.
- This corresponds to a signal strength at Earth of 10^{-32}W.
- For comparison, the strongest terrestrial signals are of order 10^6W (TV antennae and military radar).
- Note that the changeover to digital signal transmission is making the Earth radio “quiet” (signals are 100 times weaker).
- Therefore, an alien Arecibo could detect our TV (broadcast today) at 100 Ly and our modern digital transmissions at 10 Ly.

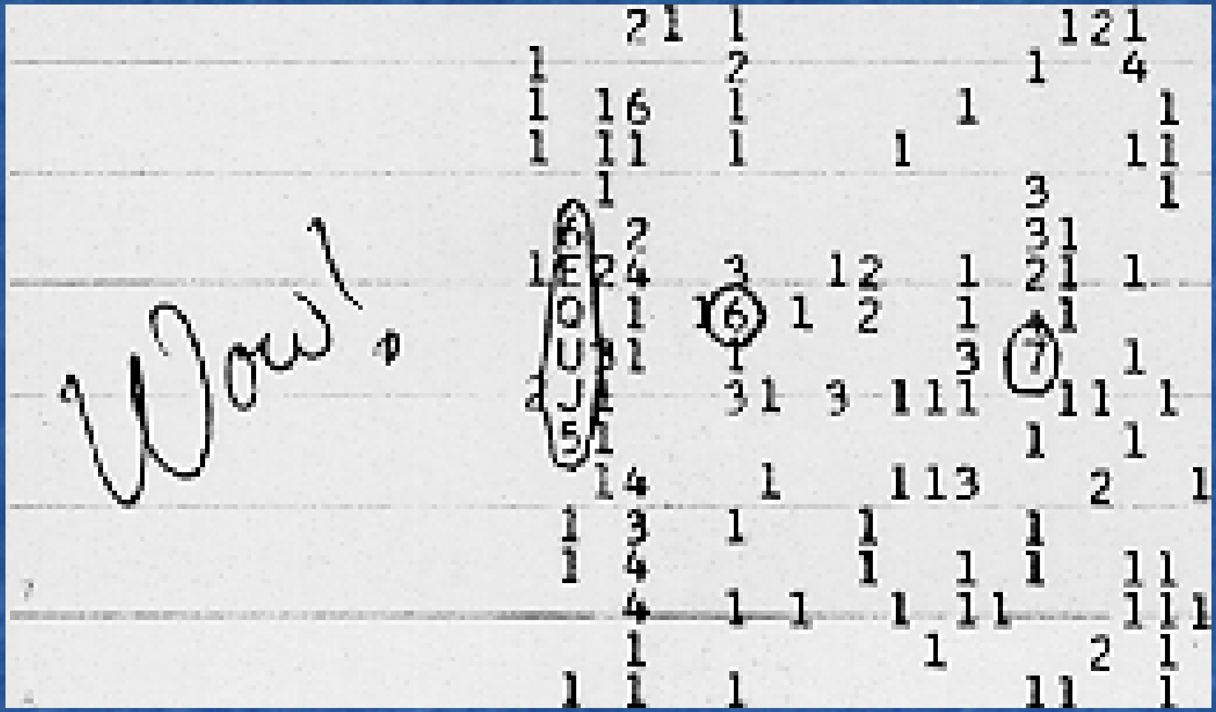
SETI@home

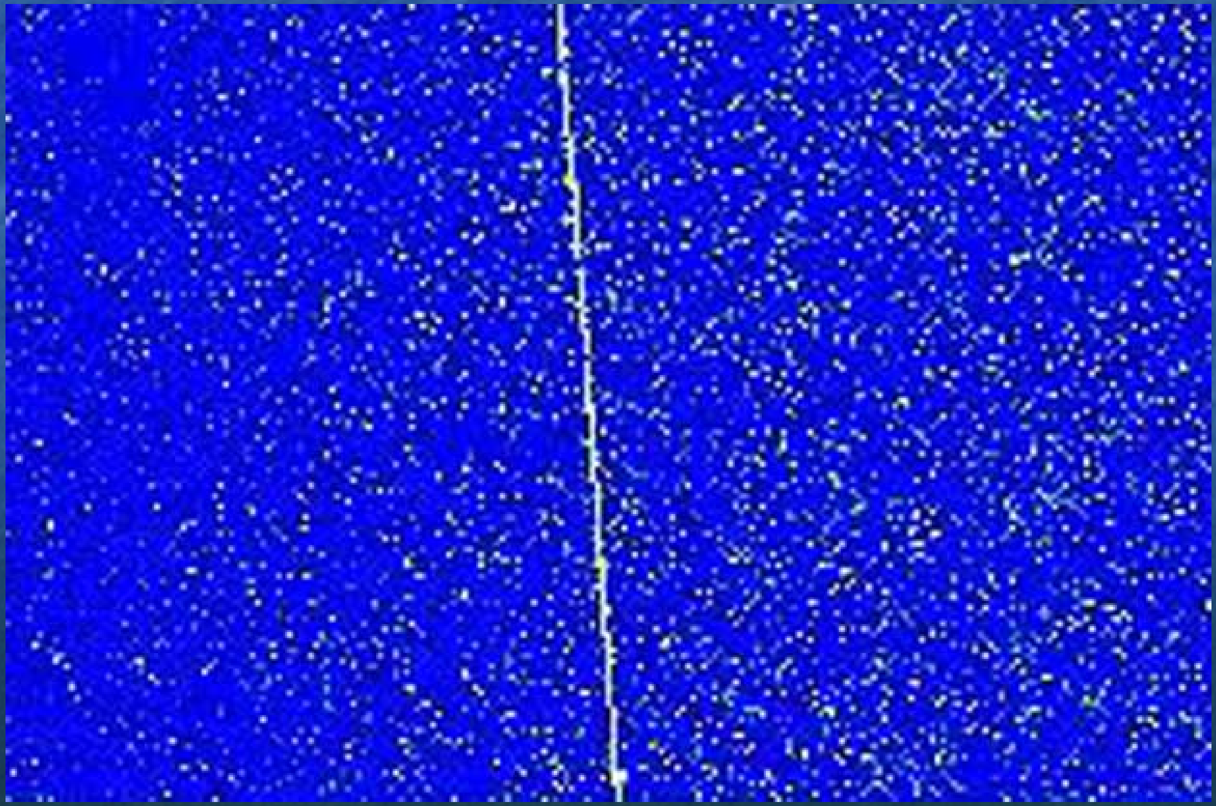


The Search for Extraterrestrial Intelligence at HOME
Press F1 for info
Version 3.03
http://setiathome.berkeley.edu
Data Analysis
Computing Fast Fourier Transform 87%
Doppler drift rate: -19.4612 Hz/sec Resolution: 0.149 Hz
Best Triplet: power 9.33, period 0.7275
Overall: 93.929% done
CPU time: 8 hr 28 min 41.1 sec
Data Info
From: 18 hr 45' 17" RA, + 13 deg 0' 36" Dec
Recorded on: Wed Mar 07 12:47:29 2001 GMT
Source: Arecibo Radio Observatory
Base Frequency: 1.419707031 GHz
User Info
Name: Alan M. MacRobert
Data units completed: 197
Total computer time: 6327 hr 20 min 01.5 sec
Power
0.0
Frequency (Hz)
9765.620
0
Time (sec)
107.4

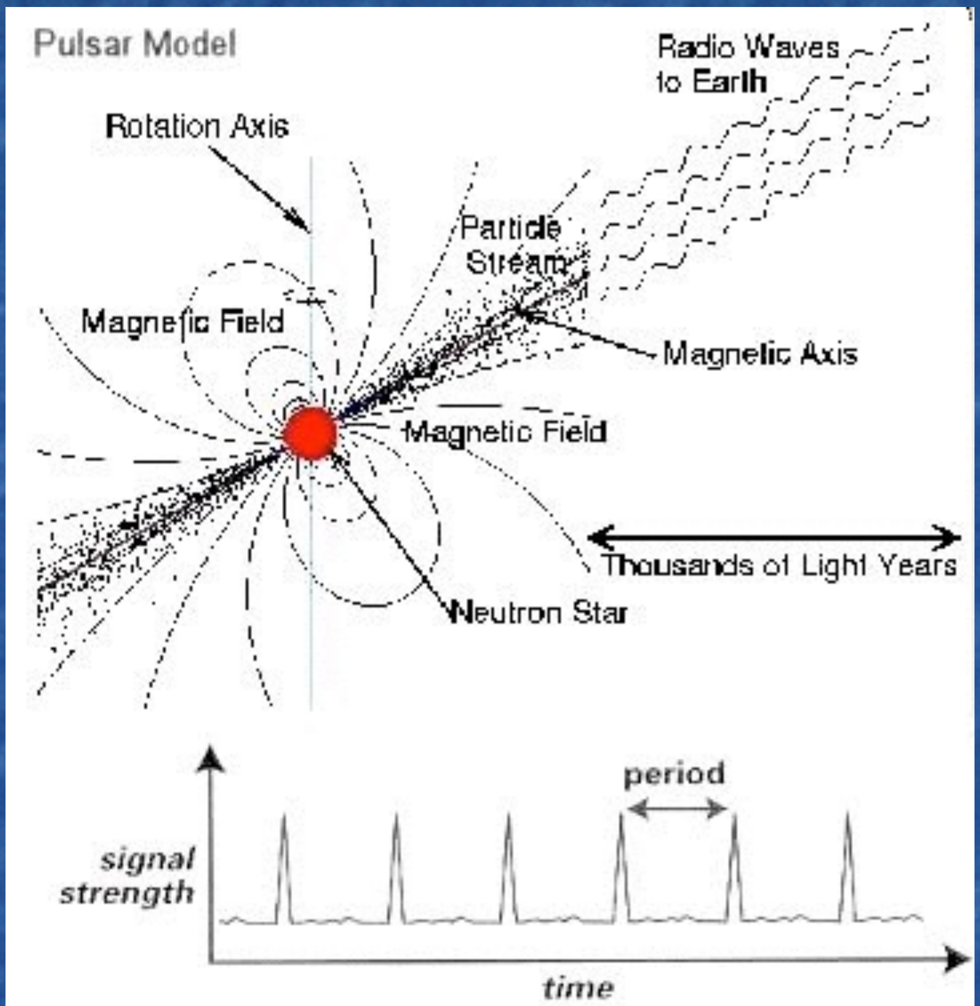
Any Detections Yet??

- There have been no confirmed SETI detections to date
- There have been a number of possible detections
- Many "false positives" occur due to human activity
  - satellites, planes, radar, etc.





LGM-1



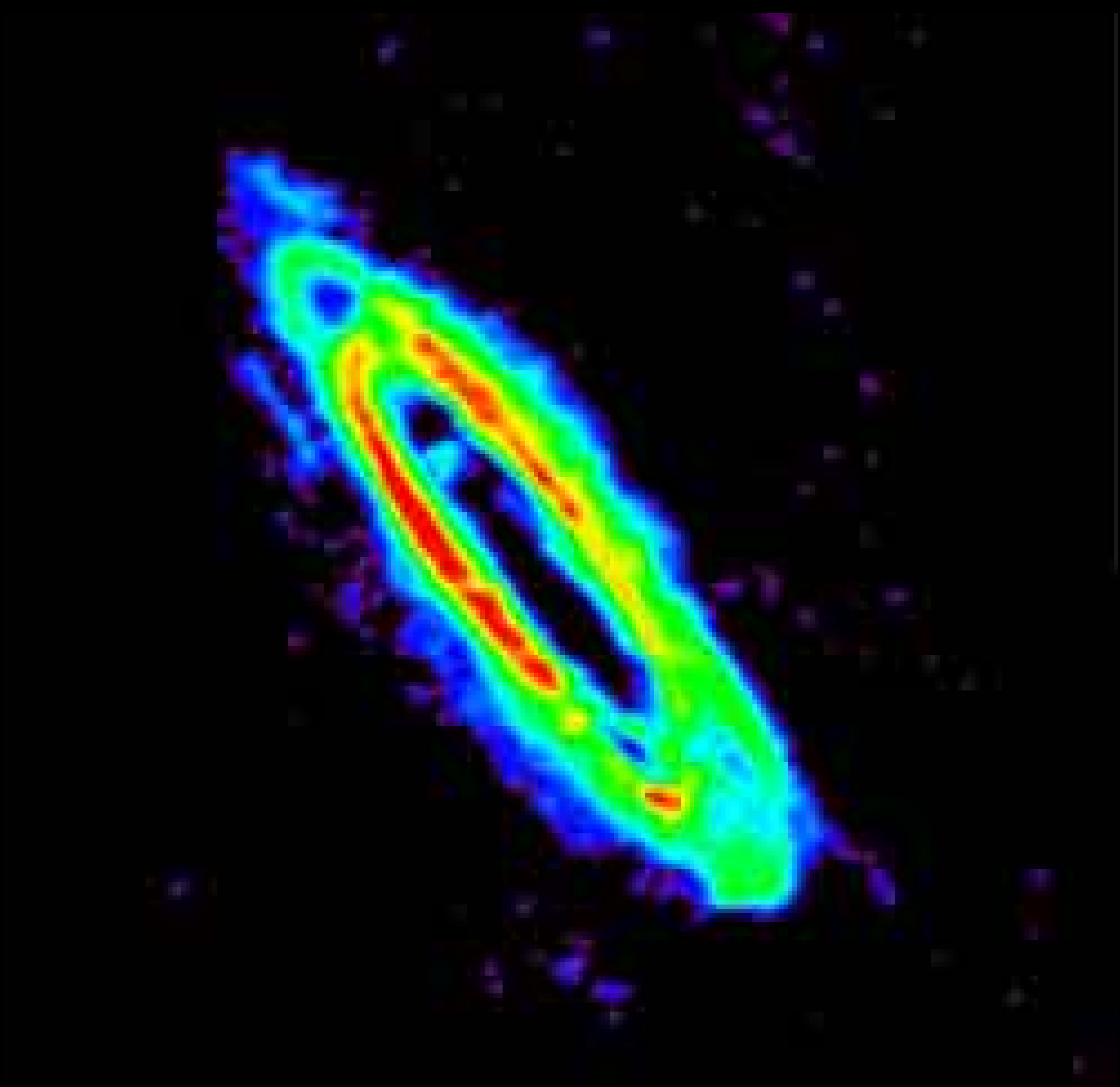
According to the "lighthouse" model, a pulsar consists of a rapidly rotating neutron star that emits radiation in two oppositely directed beams along its magnetic axis. As the beams sweep around, distant observers detect regular pulses of signal.

- Detected as a periodic radio signal in 1967.
- Signal detected at 0.74 Hz.
- Labelled (playfully) as LGM (Little Green Men) 1.
- Upon announcing the signal as arising from an unknown class of astronomical object, Fred Hoyle almost immediately identifies it as a rapidly rotating neutron star - dubbed a pulsar.

The Allen Telescope Array

- Will consist of 350 6-metre radio telescopes in Hat Creek, California
  - 42 of these telescopes are now active
- Primarily funded by Paul Allen (co-founder of Microsoft)
- Will be used for SETI and for other radio astronomy projects

First Image Taken by the Allen Telescope Array



Radio

Optical

Stephen Hawking and Russian Billionaire Launch $100 Million Search for Alien Life

July 20, 2015 Mbiyimoh Ghogomu Leave a comment

123 4

World-renowned astronomer and theoretical physicist Stephen Hawking has teamed up with Russian billionaire Yuri Milner to launch a massive privately-funded hunt for alien life.

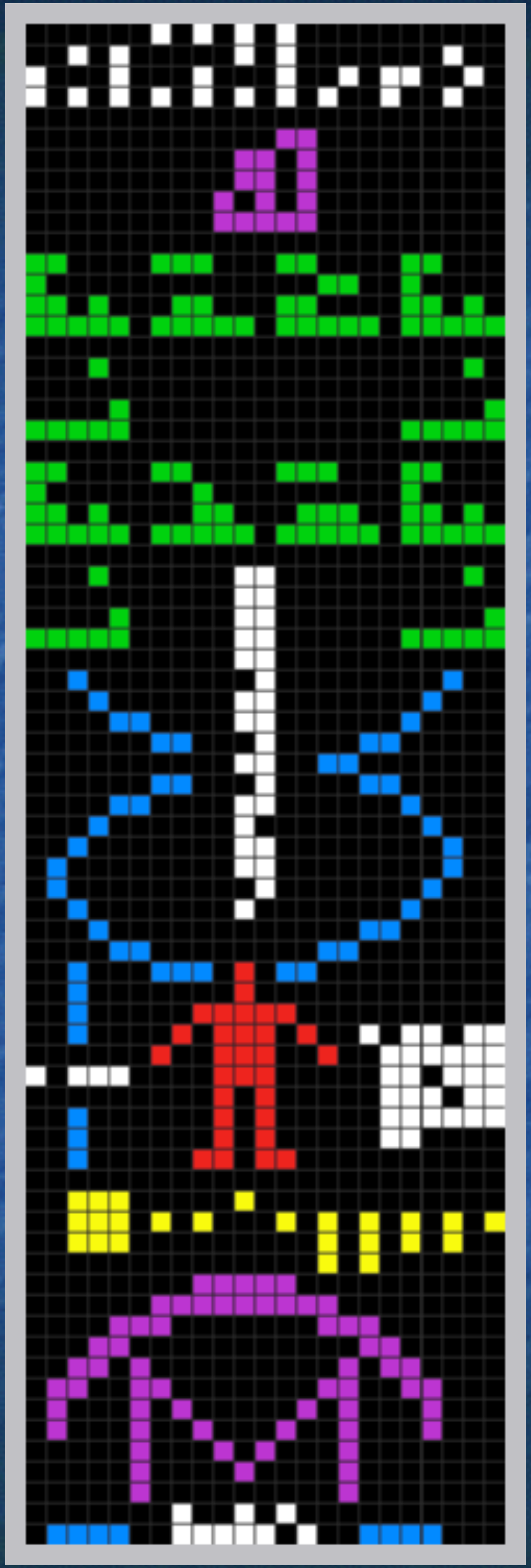
The $100 million project, called Breakthrough Listen, was announced during a press conference at the Royal Society in London on Monday.

Can they detect us?

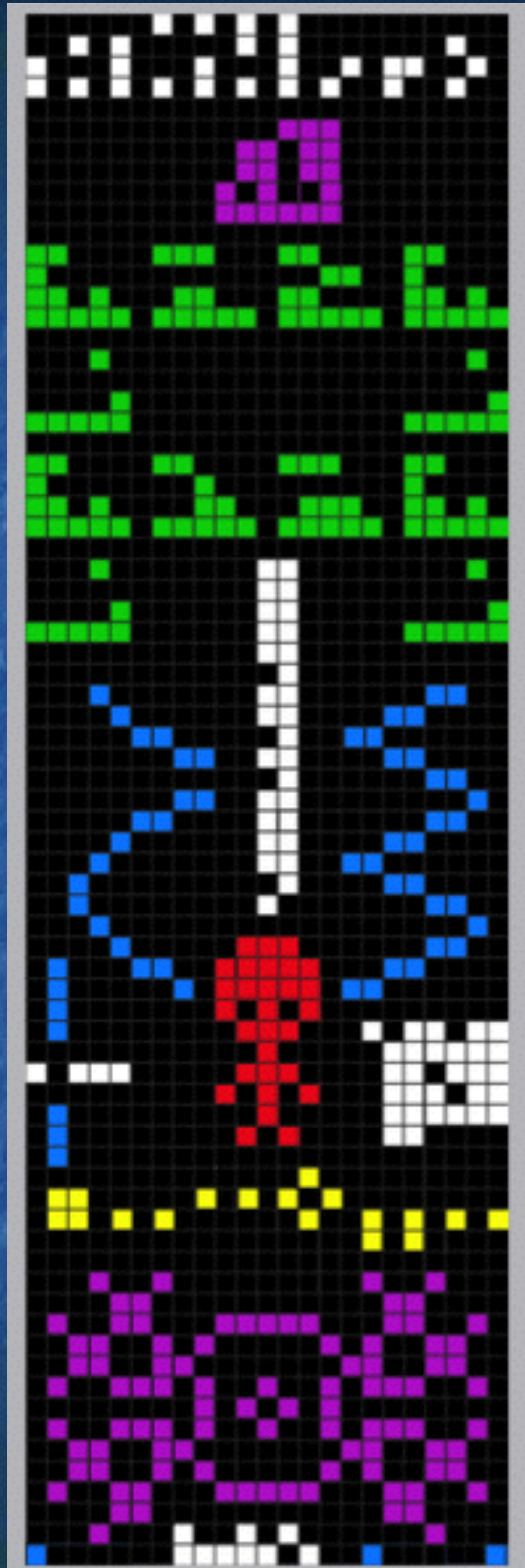
- Other civilizations may be able to detect signals from us (and reply!)
- We have been broadcasting TV (and other signals) outwards from the Earth for about 80 years
- However, only the very closest stars could receive and reply to these transmissions within our lifetime

The Arecibo message

- Beamed to the globular cluster M13 on 16 November 1974.
- M13 is 25,000 Ly away.
- The signal consisted of 1679 digits amounting to 210 bytes of information.
- Transmitted at 2320 MHz with 1 MW of power.
- 1679 is a semi prime number equal to 23x79.
- Re-arranging the digit stream as a 23x79 rectangle reveals the "message"



- The numbers one (1) through ten (10)
- The atomic numbers of the elements hydrogen, carbon, nitrogen, oxygen, and phosphorus, which make up deoxyribonucleic acid (DNA)
- The formulas for the sugars and bases in the nucleotides of DNA
- The number of nucleotides in DNA, and a graphic of the double helix structure of DNA
- A graphic figure of a human, the dimension (physical height) of an average man, and the human population of Earth
- A graphic of the Solar System
- A graphic of the Arecibo radio telescope and the dimension (the physical diameter) of the transmitting antenna dish



- Our attempts at communication are not always taken seriously.
- The Arecibo reply message took the form of a crop circle discovered close to a UK radio telescope in 2001.
- It does raise the question though, "why did we send the original message"?
- In the 25,000 years taken for the signal to reach M13, the globular cluster will have moved out of the original beam and the signal will miss the target.
- The 1974 message was more of a demonstration of what is possible/publicity stunt than a serious attempt at communication.

MESSAGE

If we or others succeed in discovering another civilization, what – if anything – should we say to them?

Breakthrough Message aims to encourage debate about how and what to communicate with possible intelligent beings beyond earth. It takes the form of an international competition to create messages that could be read by an advanced civilization. The message must be in digital format, and should be representative of humanity and planet Earth.

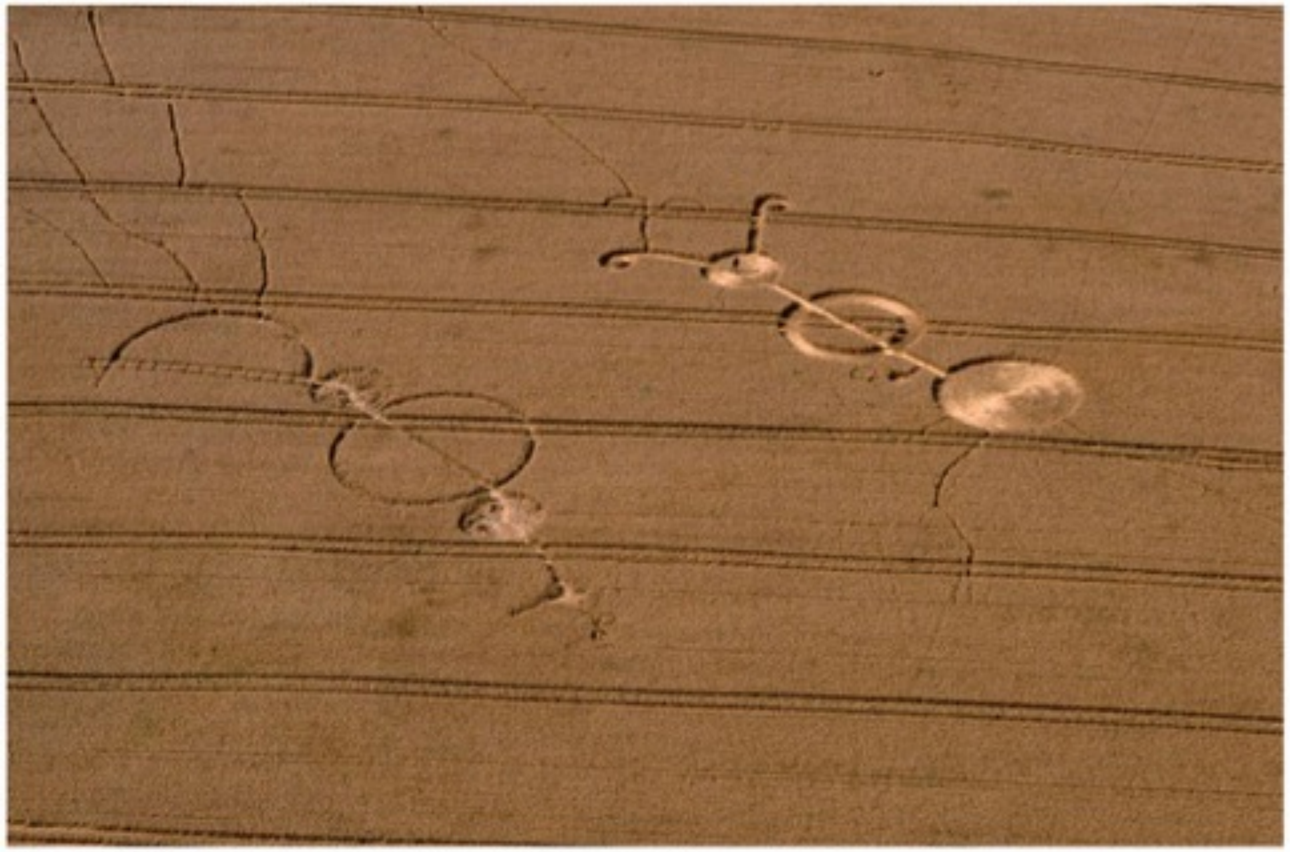
The pool of prizes for the best messages totals $1,000,000. The competition is open to everyone.

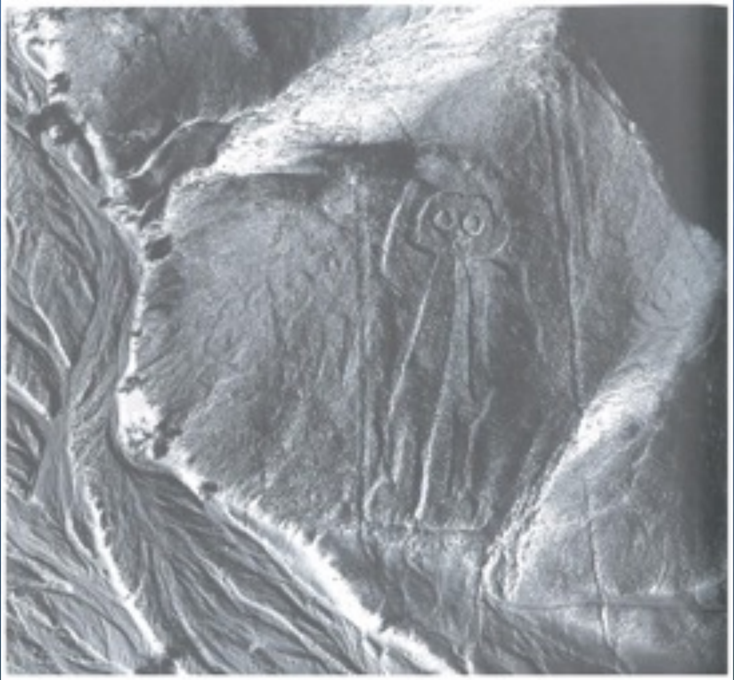
Developing a message that could both speak for us and be understood by alien intelligences is a hard problem. It may require insight in fields from mathematics and physics to linguistics, psychology and art.

For the moment we have **no plan to send these messages**. The program is a way to learn about the possibilities and constraints associated with interstellar correspondence. To encourage global discussion on the ethical and philosophical issues of sending messages into space, we pledge not to transmit any message until there has been a wide-ranging debate at high levels of science and politics on the risks and rewards of contacting advanced civilizations.

Details of the competition will be announced soon.

Have aliens been here already?





The context of SETI within the scientific community

- "The probability of success is difficult to estimate; but if we never search, the chance of success is zero."
  Morrison and Cocconi, Nature, 1959
- Should a SETI experiment detect an alien civilisation the results will have a tremendous social and scientific impact.
- But what do we learn if SETI experiments continue to discover nothing?
- We learn that the number of civilisations within a given volume broadcasting according to an anthropocentrically defined set of criteria is zero, placing an upper limit on the density of such civilisations.
- A number of scientist have questioned (some vehemently) whether this is "worthwhile" science.