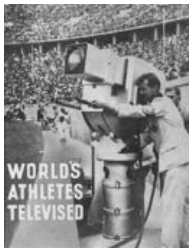
Sociological Factors

- **f_c = 1/2 ?**
  - at least 1, maybe 3 intelligent species on Earth
  - 1 with technology for remote communication
- **L > 75 years**
  - "Longevity" - how long are they detectable?
  - leakage of VHF/UHF signals into space
  - we have been detectable for over 75 years



Putting it all Together:

N ≈ 8 x 0.6 x 1.0 x 0.5 x 0.5 x 0.5 x L

N~ 0.6 x L

The number of other technical civilizations in our galaxy equals 3/5 the number of years that they are able (and willing) communicate

Could be ~ 45 in our galaxy right now!

Contact or 'just' communication ?

- To go to a star 10 light years away ... and back in one (long) lifetime:
  - need 6×10^{28} ergs (20 years of Earth's total energy production!)
  - most efficient fuel: matter+antimatter (100 *tons* each way)
  - shielding against gamma rays...
  - **nah**...
- Contacting and communicating with other civilizations is a generation-to-generation project

How far away?
How many stars to search?

L	nearest civilization	number of stars to search
75	3,600 ly	365,000,000
1000	1,500 ly	100,000,000
1,000,000	150 ly	100,000

Communication?

consider... value in one-way communication

Culture	separation in	common language	medium	an example
Ancient Egyptians	time (4000 years)	hieroglyphics	tomb carvings papyri	
	space (light years)	universal truths: science, math	light, radio, sentinel spacecraft	

SETI: Search for Extraterrestrial Intelligence

- (Radio) Searches for narrowband signals
  - **narrow band = non-natural origin**
- need to scan billions of frequencies
  - we don't know their "standards"
  - FM radio - only 200 indep. frequencies
- need to point at LOTS of solar-type stars

Why Radio?

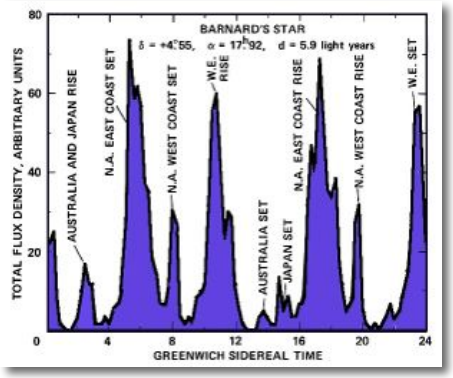
- cheap to produce high-power beam
- easy to detect with simple technology
- long-range
  - Galaxy transparent to radio waves
  - Galaxy relatively noise-free at useful wavelengths

Arecibo Observatory

And we already have some huge radio telescopes!

- can detect "earthly" signals across the Milky Way
- scan thousands of nearby stars

Unintentional Signals



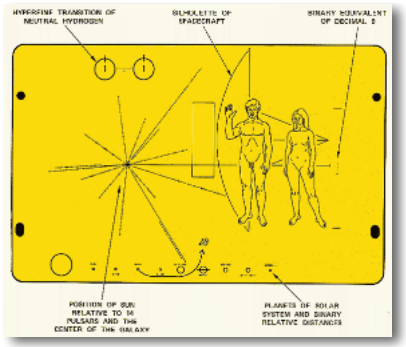
Earth UHF/VHF TV, viewed from Barnard's star
(Sullivan et al. 1978)

- most radio signals will be unintentional
- Earth example -
  - TV broadcasts
  - Cell Phones
  - Military Radar
- all spilling out into interstellar space

Discovery would be profound *even if never decoded*

Examples: intentional messages

The plaque aboard Pioneers 10 and 11



now beyond our solar system
over 7.5 billion miles away

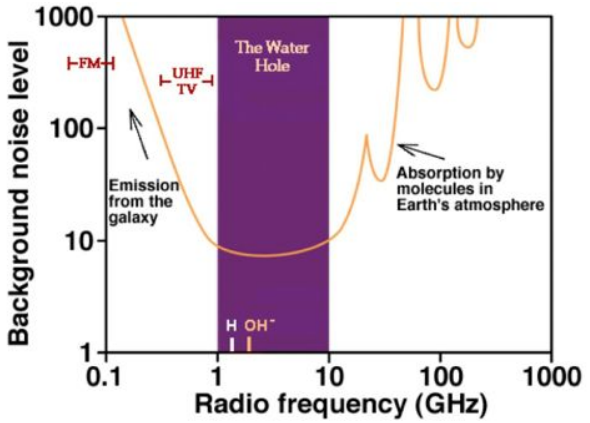
The Arecibo Message (1974)

23x73

now 38 *light-years* away

What frequencies?

the "Water Hole"



"Magic" frequencies: 1.42 GHz, 2.84, GHz ...

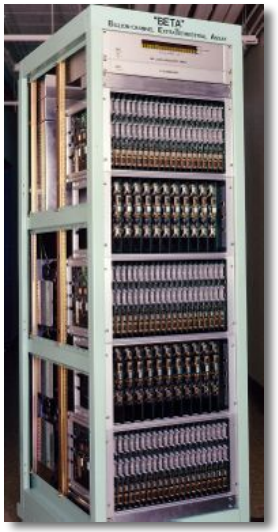
Project Ozma:

the first search, 1960

- Frank Drake (again!)
- 85ft Green Bank Telescope
- 3 months, 6h/day
- 2 stars
- monitored 1 frequency
  - 1420 MHz, HI line
- found nothing
  - except a secret military radar

Modern Searches

- The more frequencies, the better
  - Project Phoenix, @The SETI Institute
    (Frank Drake is Chair of the Board)
  - Paul Horowitz @ Harvard, project BETA
- Look for narrow bandwidth, pulsed signals
- Search LOTS of stars
- Automated data analysis
- Independent verification (lots of false alarms)



Intentional messages: **a simple example:**

121 'bits' repeating

00000000000000000100000000010100000
00100010000010000010001010100010001
00000100000100010000000101000000000
10000000000000000

77 'bits' repeating

00000010000000000101000000100010000
01010001000001000100000001010000000
0010000

35 'bits' repeating

00001000000101000111010001010000010 0

finally...

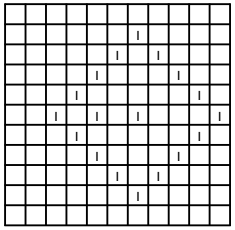
00011101000010 1

Intentional messages: **a simple example:**

121 'bits' repeating

00000000000000000100000000010100000
00100010000010000010001010100010001
00000100000100010000000101000000000
10000000000000000

- 121 = 11x11 (product of two prime numbers)
  - 00000000000 00000010000 00000101000 00001000100 00010000010 00101010001 00010000010 00001000100 00000101000 00000010000 00000000000
- draw the signal into a 11 x 11 grid



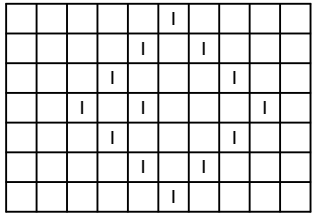
- a 5x5 square with something in the middle!

Intentional messages: **a simple example:**

77 'bits' repeating

00000010000000000101000000100010000
01010001000001000100000001010000000
0010000

- 77 = 7x11 (product of two prime numbers)
  - 00000010000 00000101000 00001000100 00010100010 00001000100 00000101000 00000010000
- draw the signal into a 7 x 11 grid
- a 4x4 square with something in the middle!



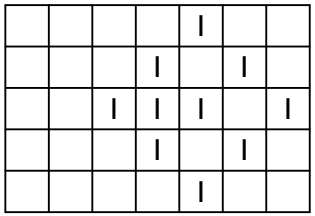
Intentional messages: **a simple example:**

35 'bits' repeating

00001000000101000111010001010000010 0

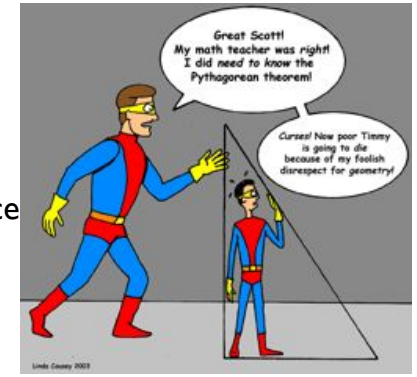
- 35 = 5 x 7 (product of two prime numbers)
  - 0000100 0001010 0011101 0001010 0000100
- draw the signal into a 5 x 7 grid:

- a 3-unit square with something in the middle!

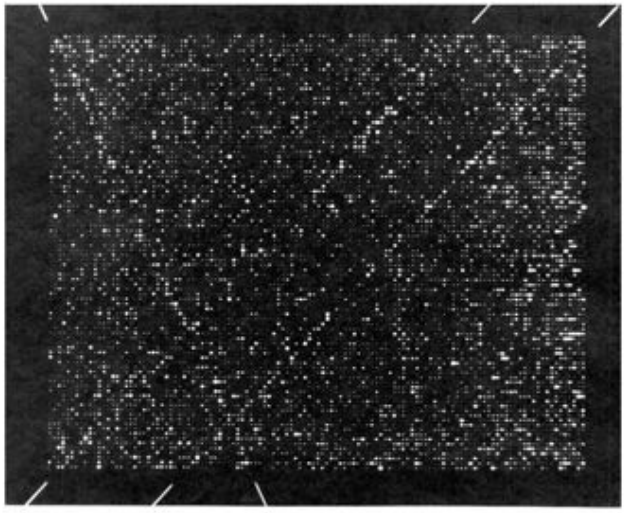


Intentional messages: **a simple example:**

- 3x3, then 4x4, then 5x5...
  - the Pythaogrean Theorem!



- oh, and that last thing...
  0001110100000101
  - group into units of 5 and notice there are always even sums:
    00011 10100 00101
  - the first digit makes the rest even within each byte
  - the numbers 3, 4, and 5 in binary...



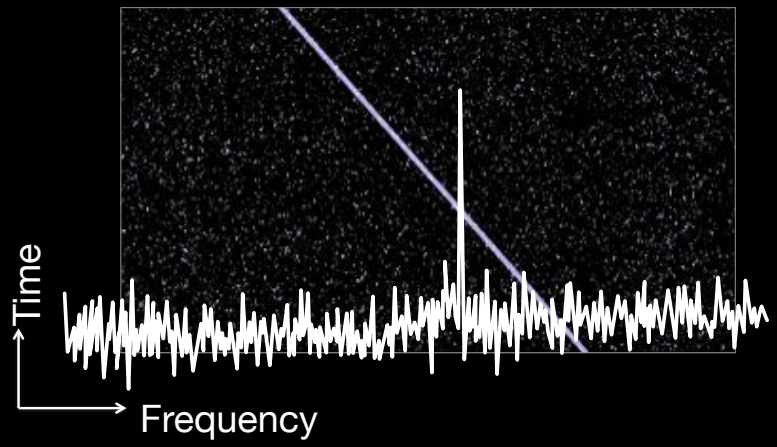
Each line of raster shows the power in each output channel, or "bin," for 120 adjacent channels during one sample. Ninety successive samples are shown. There is a general field of noise in which the probability of a given brightness falls off exponentially with brightness. Included are three drifting CW signals. The two with a slope of 45° represent signals decreasing in frequency 1 bin per sample. The right-hand signal is always centered in the bin at the middle of the sample. The left-hand signal straddles two bins at the middle of the sample. The resulting loss in detectability is evident. The third signal is increasing in frequency ½ bin per sample and is alternately at bin center and at bin edge. For all the signals, the SNR is 2; that is, the signal power is twice the average noise power per bin.

FIGURE 4. Detection of CW Signals

ALLEN TELESCOPE ARRAY

SETI INSTITUTE

Voyager 1 Signal from 106 AU Away

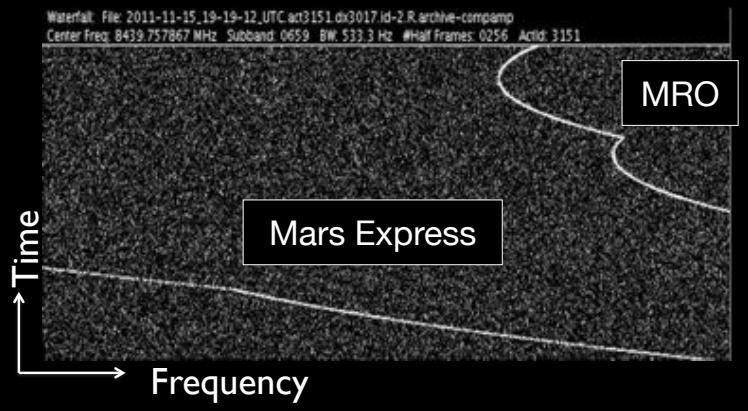


from Jill Tarter - SETI institute

ALLEN TELESCOPE ARRAY

SETI INSTITUTE

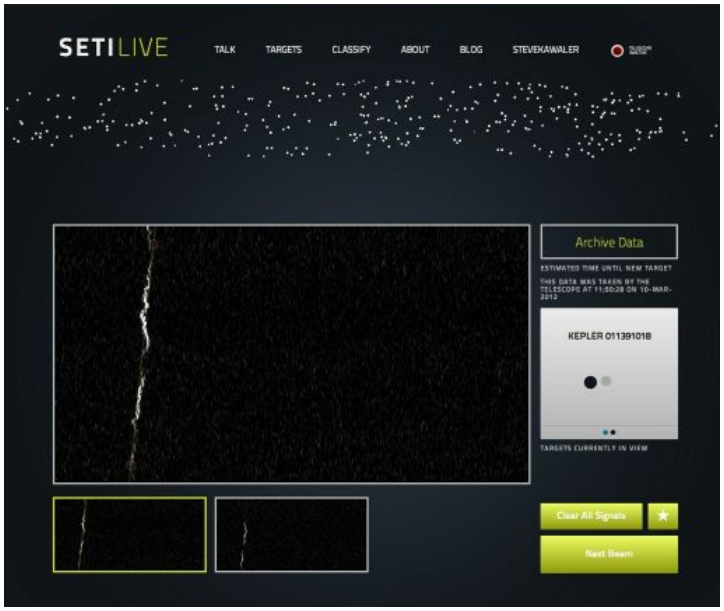
Last Month Looking at Mars



from Jill Tarter - SETI institute

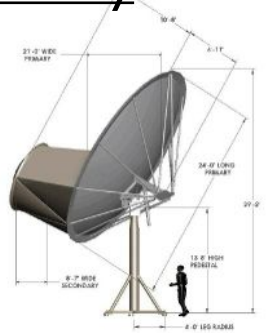
Data analysis example : SETILive.org

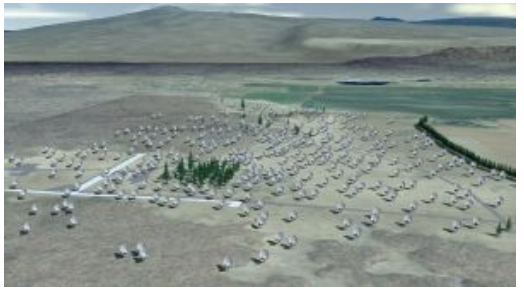
http://setilive.org



Next: The Allen Telescope Array

- A large array of ~350 20 ft. radio telescope dishes
- work together as a single telescope
- cover the whole sky at all frequencies
- funded by Paul Allen (Microsoft Gazillionaire)
- **400,000,000 stars within 30 years - via software!**





and now for something completely different

- light from stars arrives as individual photons
- purely Poisson statistics for arrival times
- example: our Sun, viewed from 100 light-years away:
  - 0.6 meter telescope (Fick) would see 10^6 photons per second; i.e. arrival rate = 1 MHz
- telescope instrumentation:
  - nanosecond (1000 MHz) timing resolution
  - mostly nothing; a pulse every 1000 nanoseconds

can we do better?

Charlie Townes thought so back in 1961...

- push 10 photons through the door in 1 nanosecond... from 100 light years away!
- what amount of energy is required?
  - 10^{23} Joules
- over a nanosecond this is a power output of
  - 10^{14} Watts

Existence Proof: petawatt lasers today

- lasers developed for fusion studies reach 1 quadrillion watts
- laser pulses up to 1 ns (one billionth of a second) in duration
- Pointed at a star, they could outshine the sun for that nanosecond!

What about Optical SETI?

- Radio is cheap and easy with today's technology
- future technology will enable high-power optical transmitters
- optical communication networks between interplanetary and interstellar spacecraft is likely in the distant future
  - unintentional emission is therefore possible
- What does it take?
  - High powered directed lasers to produce the signal
  - a clear shot!
  - fast electronics to detect pulsed emission

OSETI strategy

- 1 meter telescope, solar star at 100 light years
- photons arrive from a star about 1,000,000/second
- a pulsed petawatt laser could pump a few photons into the telescope in 1 nanosecond
- look for several photons arriving within 1/1000 of the 'average' arrival time of stellar photons

The power of numbers:

when the starlight hiccups

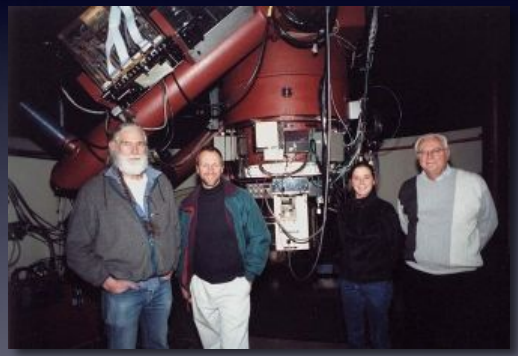
- average photon arrival rate - 1 million / second
  - 1000 nanoseconds between photons
- chance of two arriving within 1 nanosecond
  - once per night (the Princeton + Harvard way)
- chance of three arriving within 1 nanosecond
  - once per century (the Berkeley way)

• Equipment to do this is "cheap" and available

• Can be done easily on ordinary optical telescopes

The Lick/Berkeley System

- built by an undergraduate, with a little help



Shelley Wright at the telescope

OSETI, Iowa State Style...

- The 10-m Whipple Air Cherenkov Telescope