The Cosmos

Planets & Life
PHYS 214

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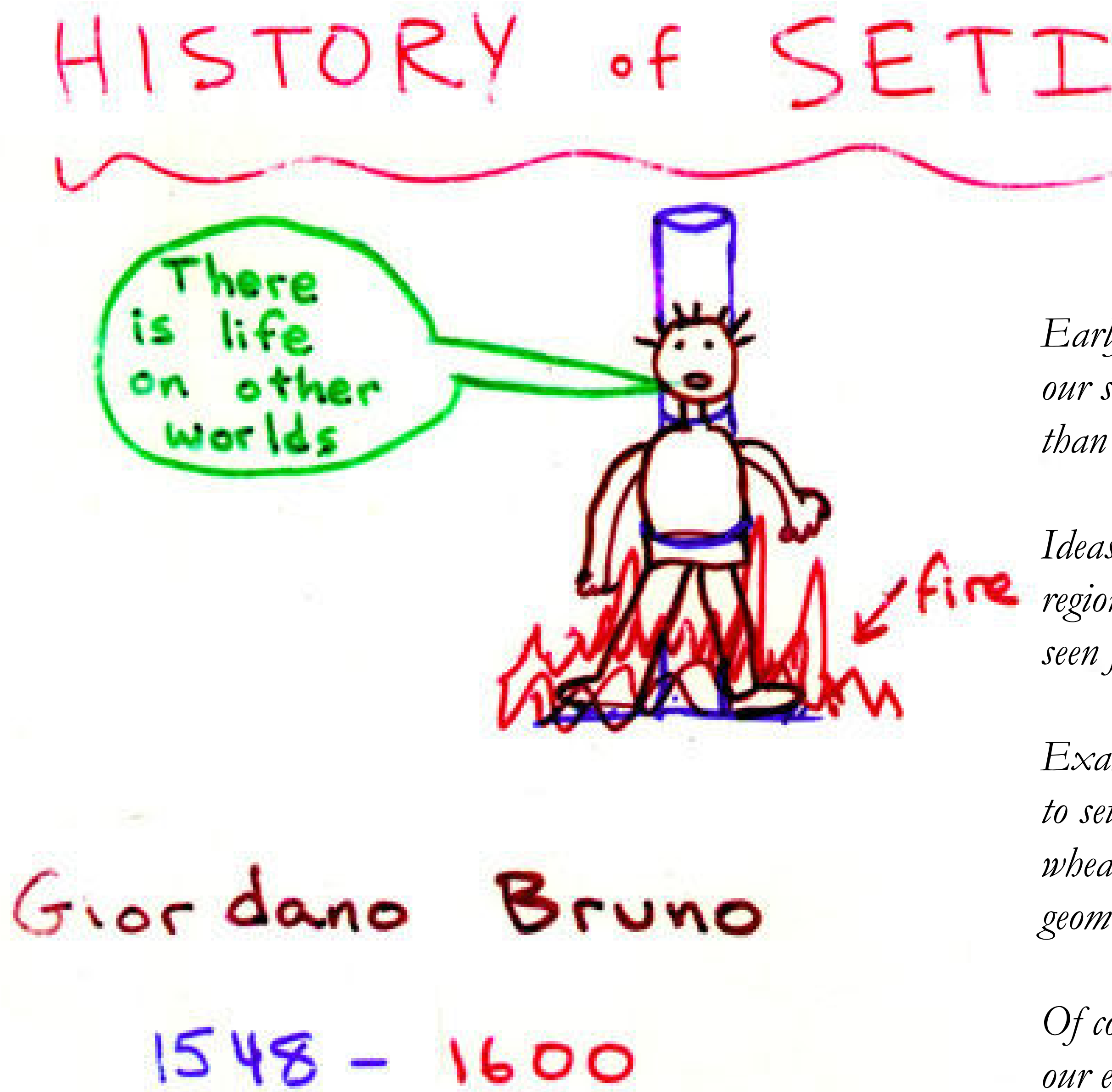
Please start all class related emails with “214:”

Today's Lecture

- SETI
  - how and where to look
  - What to look for

"An absence of evidence is not evidence of absence" Sir Martin Rees



Credit: *From presentation by* Dan Werthimer

Early (1800s) SETI ideas focused on our sending (visible) messages rather than detecting "them".

Ideas focused on creating large regions on Earth that could be seen from outerspace:

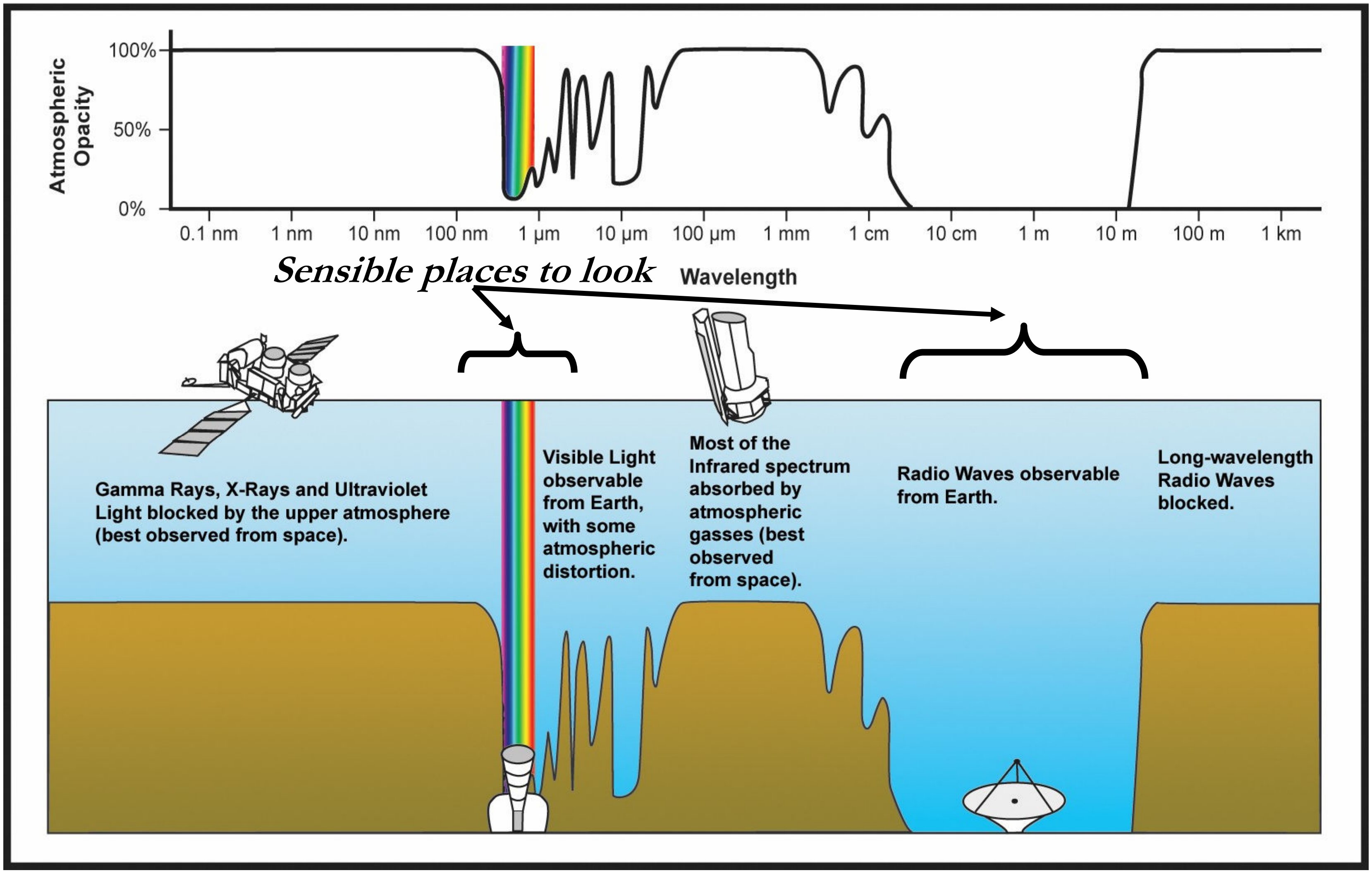
Example: Gauss's (1820) idea to set up enormous fields (trees or wheat for example) that were geometrically aligned .

Of course we nowadays we broadcast our existence much more readily.

Where & what should we look for?

- Which frequencies?
  - Radio
    - Leaked or intentional messages?
  - Optical
    - Powerful lasers can outshine stars in small wavebands
  - The "next big discovery"…
- Direction?
  - Targeted search?
  - All-Sky survey?

Atmospheric EM spectrum transmission



Categories of signals

- We can look for 3 different types of signals
  1) Leakage signals associated with local communication on a planet (10^6 W)
  2) Signals used to communicate of world perhaps to another colony or space craft (10^8 W*)
  3) Intentional beacons designed to be "heard" (10^{12} W*?)
- It seems unlikely to us 3 will occur, but at present our detection limits force us to look for these kinds of signals

**These are equivalent isotropic powers, the signal would actually be beamed in a small angle*

From previous lecture: Comparison of some SETI searches

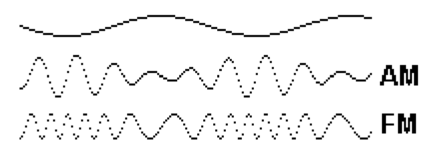
Survey	# of stars	Detection threshold/ W m^{-2}	EIRP at 4 ly / W	EIRP at 1000 ly / W
Arecibo	280	8×10^{-27}	10^{8}	9×10^{12}
Allen Telescope (SETI Inst., 2010?)	100000	$\sim1\times10^{-25}$	2×10^{9}	10^{14}
SKA (2016?)	100000	8×10^{-29}	10^{6}	9×10^{10}

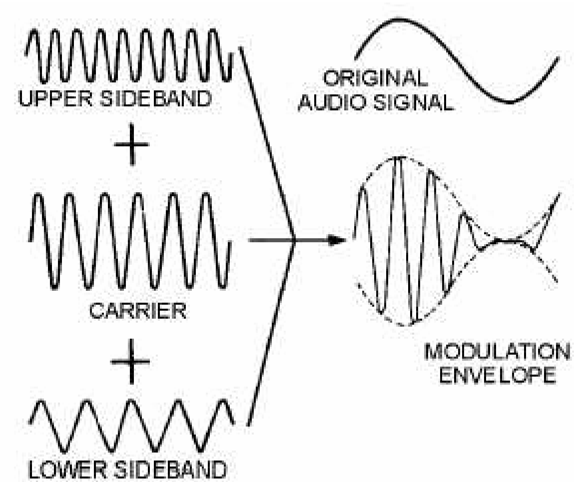
EIRP=Equivalent isotropic radio power, corresponds to the strength of the transmitter

Only the SKA could detect a 10^6 W antenna at 1 ly away (it could at 4 ly actually)

Frequencies, bandwidth & channels

- Amplitude modulation (AM) radio works by modulating the amplitude of the carrier wave & a "side band"
- Frequency modulation (FM) radio works by modifying the frequency of the carrier wave
- Both of these methods require more frequencies around the central frequency to carry information
  - The total amount of frequency range required is the *bandwidth*
- A *channel* is a region of frequency space centered on the central carrier, thus allowing the signal riding on the carrier wave to be detected
  - So if you want to detect signals you need as many channels as possible





Typical terrestrial radio frequencies

Band name	Abbr	ITU band	Frequency & Wavelength	Uses
Low freq.	LF	5	30-300 kHz, 10km-1km	Longwave broadcasting
Medium freq.	MF	6	300-3000 kHz, 1km-100m	AM radio
High freq.	HF	7	3-30 MHz, 100m-10m	Amateur radio
Very high freq.	VHF	8	30-300 MHz, 10m-1m	FM radio, some TV
Ultra high freq.	UHF	9	300-3000 MHz, 1m-100mm	TV, microwave ovens, mobile phones
Super high freq.	SHF	10	3-30 GHz, 100mm-10mm	Microwave devices, wireless LAN
Extremely high freq.	EHF	11	30-300 GHz, 10mm -1mm	Radio astronomy

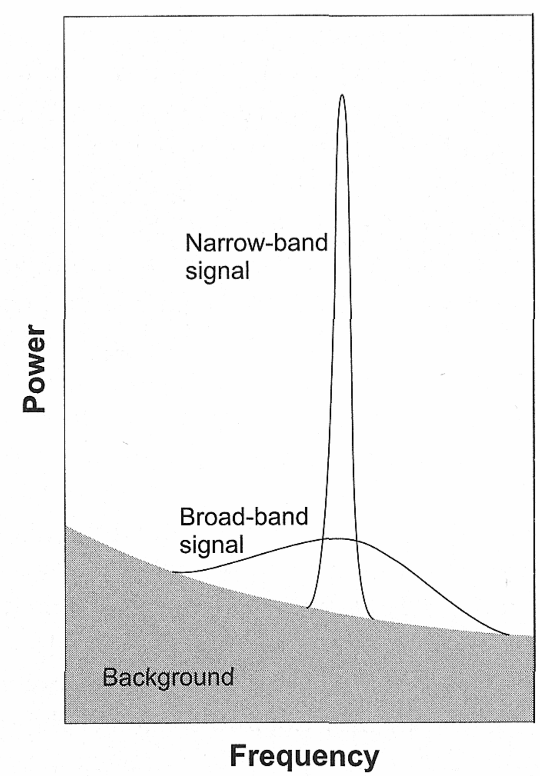
ITU=International Telecommunications Union

Conflict of radio astronomy with new communication technologies

- As technology improves terrestrial wavebands are increasing in frequency and also bandwidth
- The International Telecommunications Union is responsible for allocating different frequency bands to different technologies
- Thus far, wavebands associated with important molecules (such as H, NH_3) have been protected
- However, in the future it is unclear whether increasing economic pressure to assign bandwidth will eventually make high sensitivity radio astronomy virtually impossible

What about the interstellar medium?

- Optical signals can be easily obscured by clouds of dust
- Radio can travel through the dust easily though
- However, at lower frequencies (below 1 GHz) background noise from the galaxy becomes a problem
  - Easier to see a narrow band signal above the noise than a wideband one
- Signal will also spread out due to Doppler shift & interaction with interstellar medium

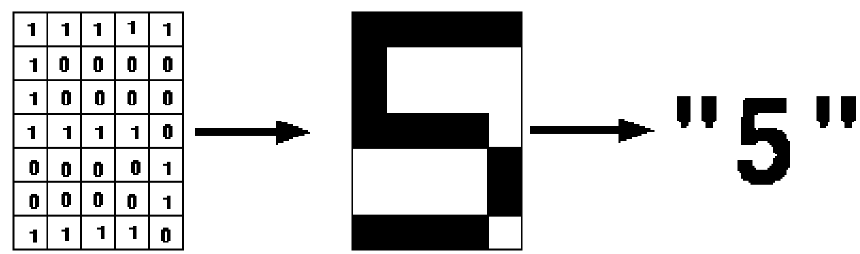


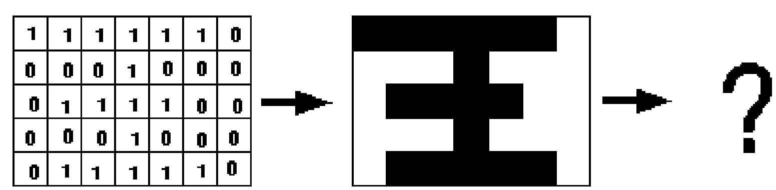
What kind of message should we look for?

- The signal should be immediately differentiable from any natural sources
  - Most natural signals tend to be irregular and widely spaced in frequency (but not always! There is one very famous example)
- We can appeal to mathematical relationships for example:
  - Prime numbers: 1,2,3,5,7,11,13,17,19,..
  - Mathematical constants, π,e for example
  - Space signals in frequency space? (Sagan)
- What about encoding pictures? If we send a signal that has a length that is a product of 2 prime numbers that could be interpreted as describing a 2d map

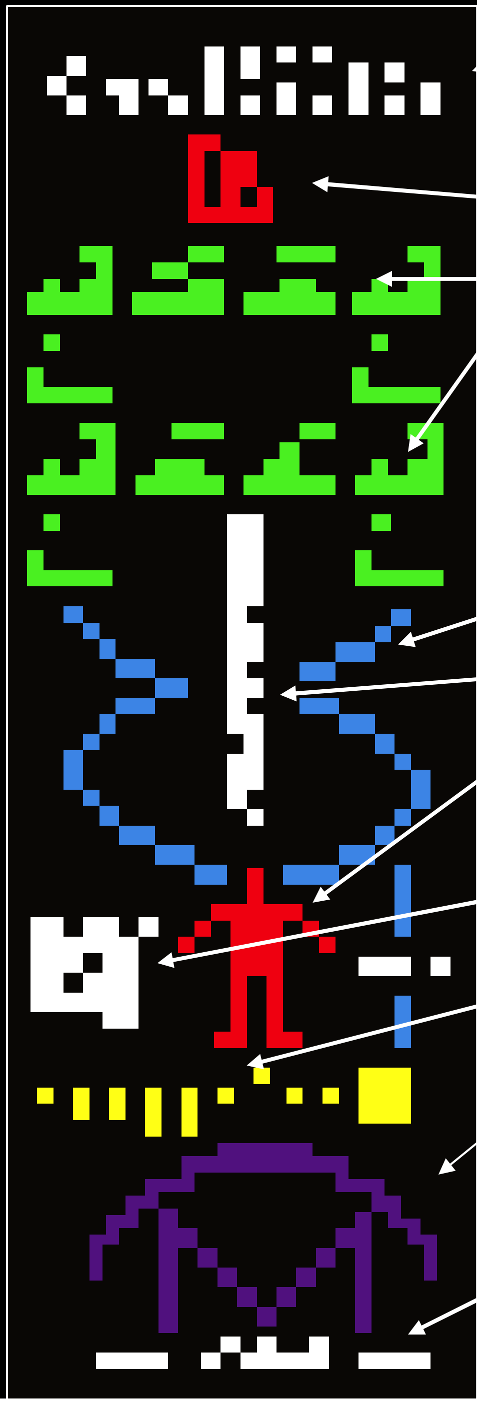
Consider the following binary message

- 11111100001000011110000010000111110
- With 35 bits it can be arranged as 5x7 or 7x5





- While we recognize the first one, who's to say that the second version isn't used by a civilization somewhere?
- However given a long enough message a natural ordering may well be apparent



The Arecibo Message

*2d map is encoded into binary and sent, 1679 bits=23*73*

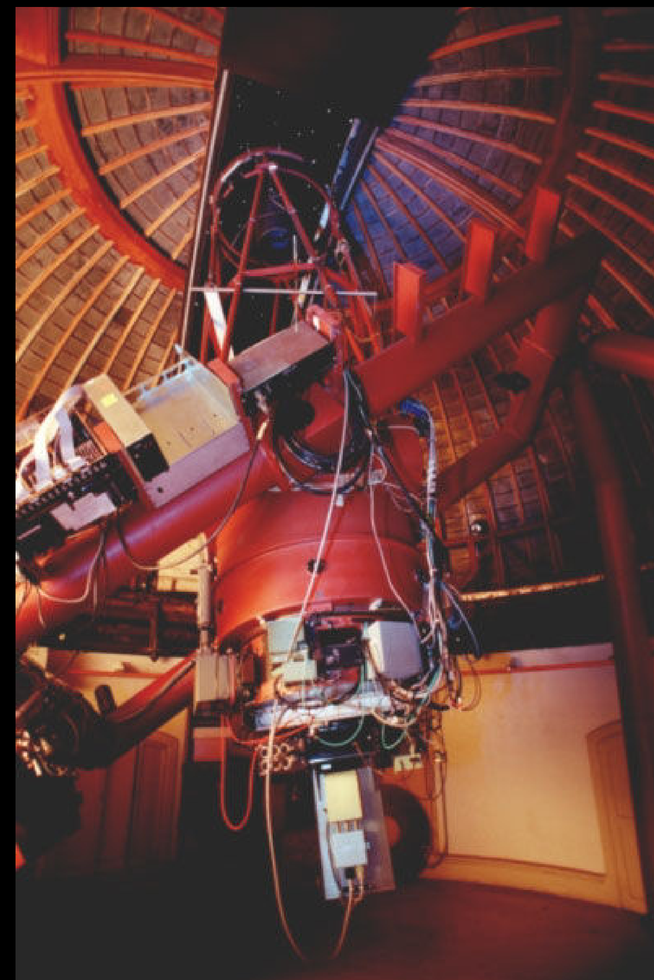
The LGM-1 event

- Graduate student Jocelyn Bell was responsible for searching through miles of graphical output from the new Cambridge radio telescope
- She found a pulse with a 1.337 second period
  - First assumed to be noise due to its regularity
- After that, the discoverers half-seriously proposed, as an alternative explanation, that the signal might be a beacon or a communication from an intelligent extraterrestrial civilization and named it *LGM-1*
  - *LGM="little green men"*
- Later realized to be caused by a rotating neutron star

Optical SETI

- In 1961 Charles Townes pointed out that sending pulses of laser light could be a potential mechanism for broadcasting a civilizations existence
  - The light must be distinguishable from the star, but a directed laser can be much brighter than a star in a narrow waveband
  - It is easy for planets to overwhelm their suns in radio waves, but not visible
    - Jupiter is the strongest radio source in the sky
- Powerful lasers have a very well defined wavelength
- Results? Reines and Marcy in 2002 searched 577 nearby stars with sensitivity to detect >60 kW lasers focused from a 10m telescope
  - Nothing was detected

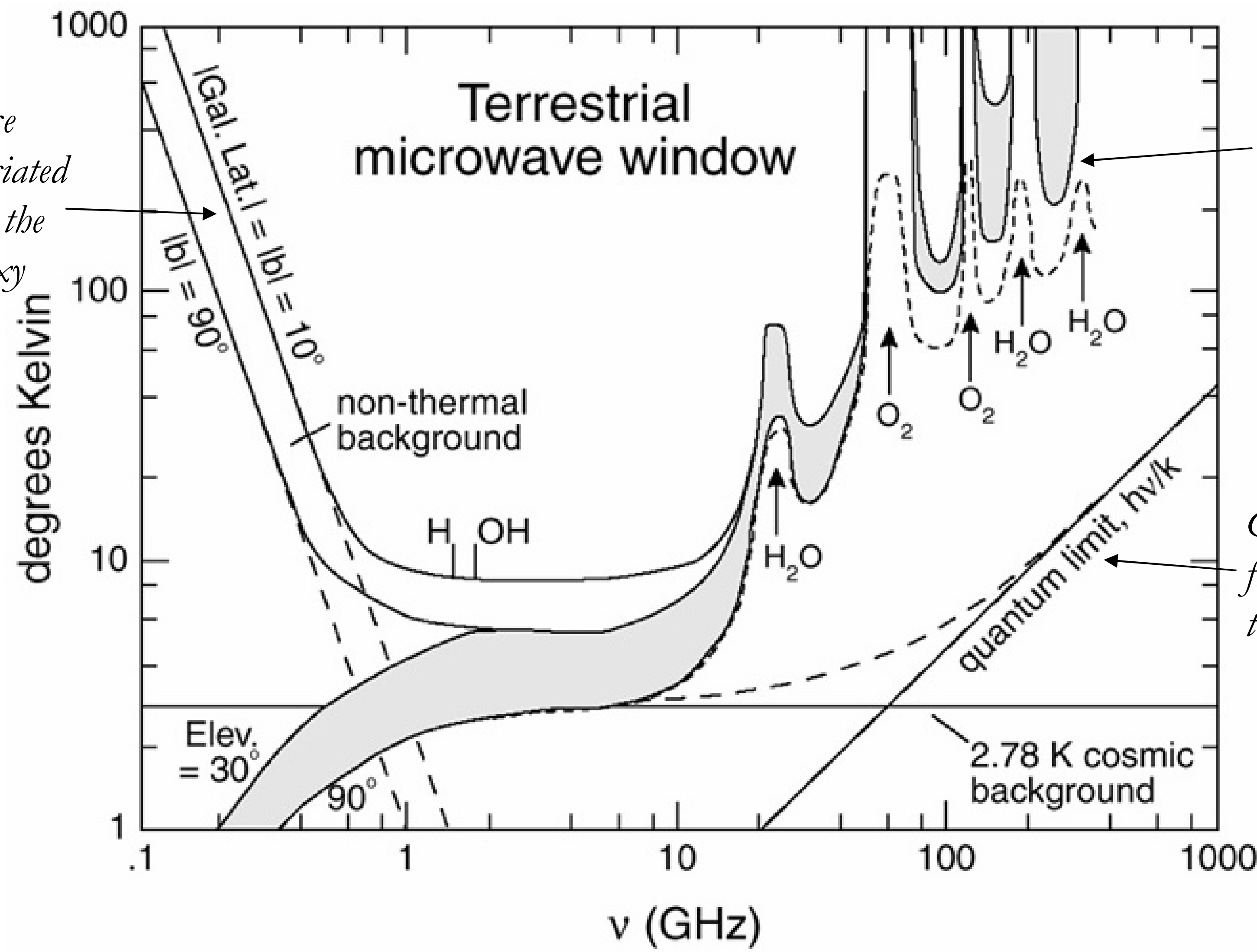
Optical SETI at the Lick Observatory



For a recent report on Optical SETI see: http://www.spectrum.ieee.org/nov06/4710

Any technical society with radio astronomy will know this.

The Water Hole



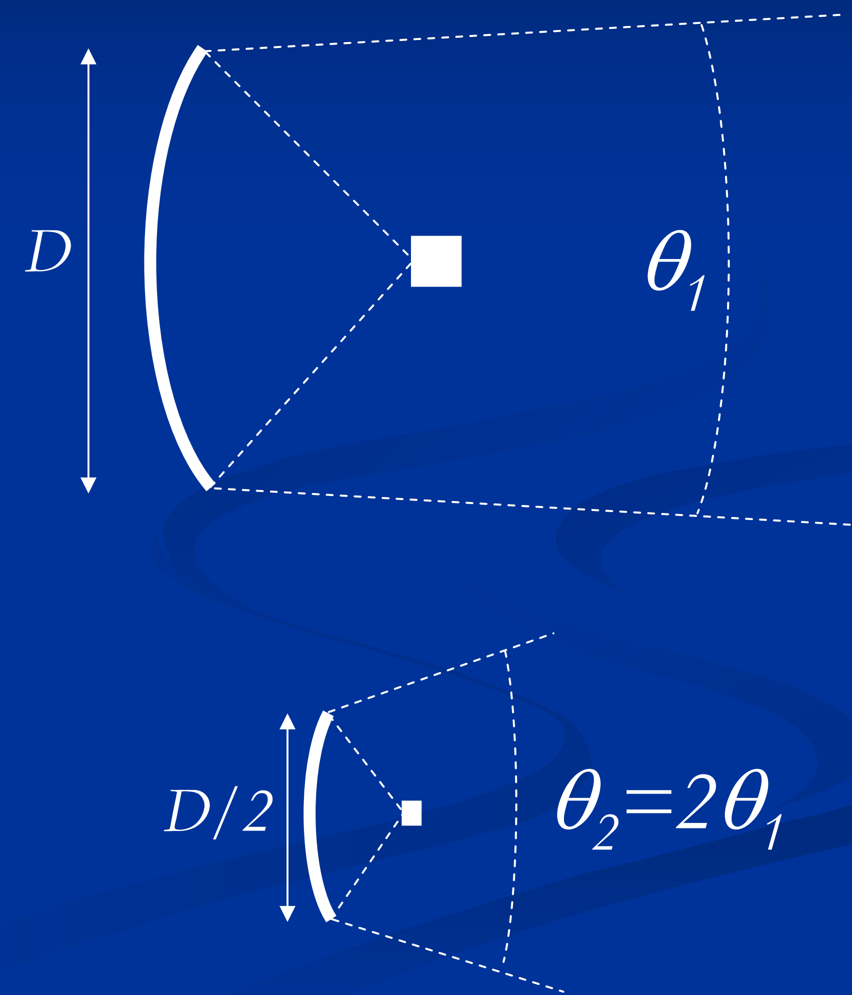
Noise associated with the galaxy

Emission from our own atmosphere

Can't get away from noise in the detector

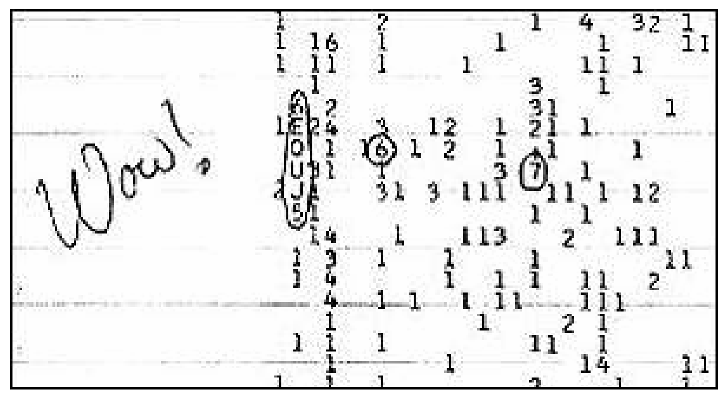
Radio telescope field of view

- Sensitivity of a telescope is proportional to the area times the channel bandwidth times time of pointing
  - $S \propto D^2 \sqrt{\Delta\nu \times t}$
  - Dictates large D
- However, we do not know where the source comes from
  - Dictates a large field of view
- Field of view is given by $\theta = \lambda / D$ – argues for smaller telescopes
- For a large dish, the number of pointings you need to make increases as the square of the diameter



Famous SETI projects

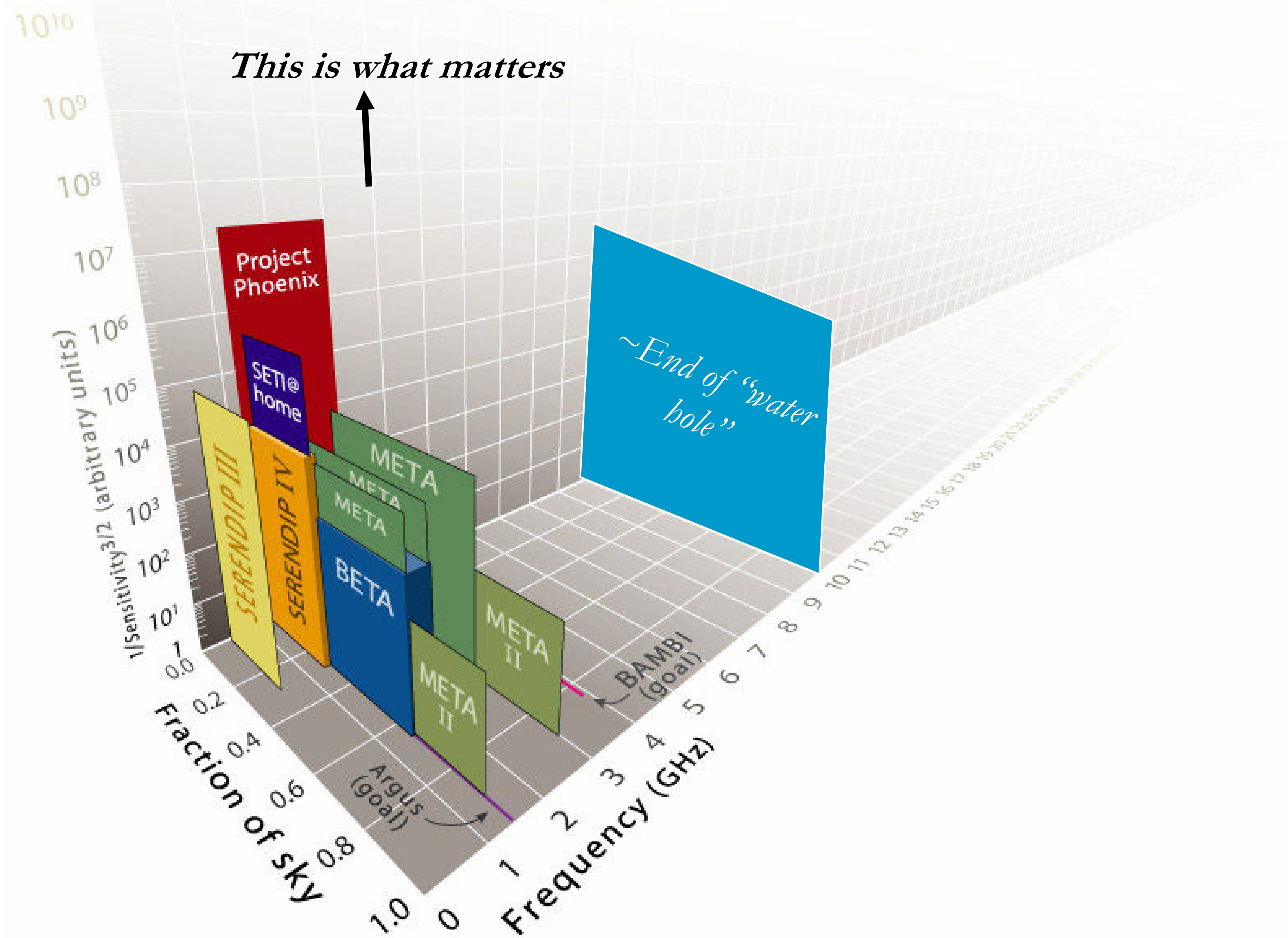
- OZMA (Frank Drake) - The first modern radio search (at Green Bank)
  - 200 hours of observing two nearby stars
- Ohio SETI program
  - Used the "Big Ear" telescope, detected the infamous "Wow!" signal
- META (1985, Paul Horowitz) – 8.4 million channels monitored
  - Partly funded by Steven Spielberg



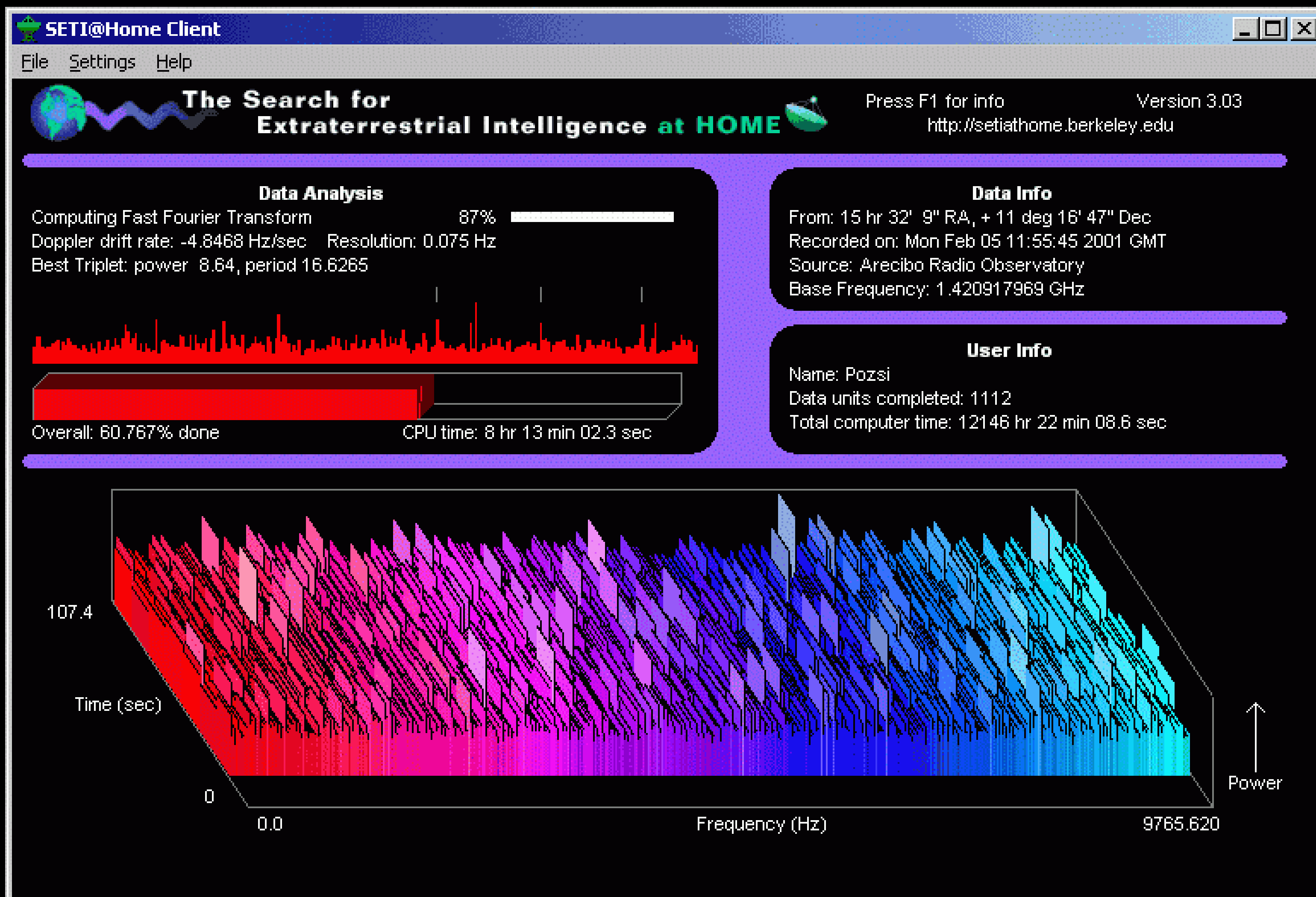
Project Phoenix

- Following the cancellation of the NASA SETI program, this project has been funded entirely by private sources
- Ran from 1995-98 on radio telescopes in Australia & USA (Parkes, Green Bank & Arecibo)
  - Looked at both southern & northern hemisphere stars
- 800 sun-like stars within 200 ly, at frequencies of 1-3 GHz, 1Hz at a time.
- The search is for narrow-band "artificial" signals

(Radio) SETI search space



SETI@home: Lots of data to process



Scientifically, the computing methods involved in SETI@home have proven very productive.

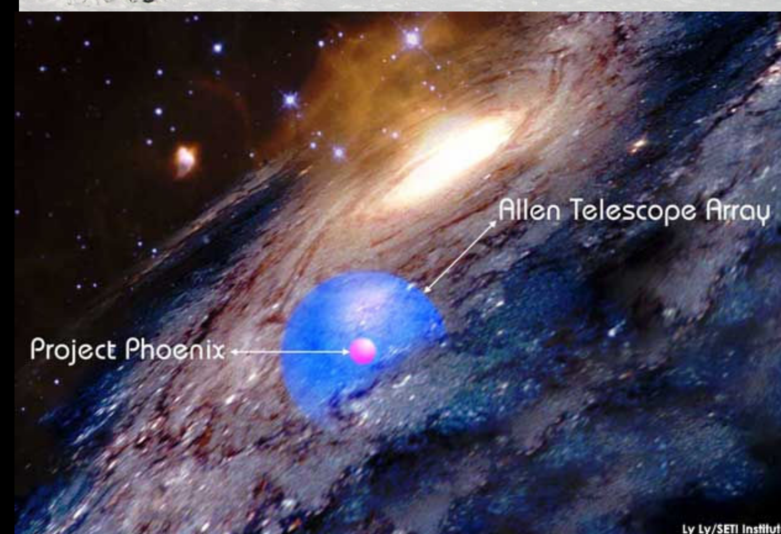
SETI funding

- SETI is a truly unusual endeavour inspiring passions on both sides
  - Cynics, with strong arguments, dismiss it as a utter waste of time
  - Proponents, with strong arguments, believe it to be of monumental significance
- As of 2007, SETI is currently not funded by any government agencies anywhere
  - In the US, SETI funding was stopped in 1994
  - However, strong public interest continues to provide private funding
- The continuing growth of interest in astrobiology at both public and political levels, seems to indicate that SETI probably will receive public funds again in the future
  - However, I'd like to get results from TPF/Darwin for p_l before we start doing that – if we don't find planets with atmospheres indicating life, then SETI is a complete waste of time in IMHO
  - You are free to draw your own conclusions – the stakes are clearly significant

Allen Telescope Array

- UC Berkeley, SETI Institute collaboration
  - 13.5 million donated by Paul Allen (Microsoft cofounder)
- 350 6.1m antennas, about 1/7th area of Arecibo
  - TO be completed 2008-9?
- Many small dishes, so large field of view
- 100% devoted to SETI research
- Should cover at least 100,000 stars and possibly up to 1 million
- Proving to be a scientifically useful proving ground for technology that could be adapted to the SKA

Array elements in snow!



SETI Contact protocol

1) Is it really extraterrestrial?
2) Get confirmation from other astronomers.
   (If extraterrestrial, tell your government about it).
3) If convincing: announce to International Astronomical Union, Secretary General of the UN, inform SETI groups.
4) Make the first public announcement
5) Make data available to all.
6) Everyone carefully record & disseminate signals
7) Protect frequencies.
8) Don't broadcast back to the ETs! Requires Debate.
9) Study signals. The SETI Committee of the International Academy of Astronautics keeps a list of experts to call on.

What about UFOs and all that?

- (Ahem!) No credible evidence
  - "Oh, the government and scientists are just covering it all up!"
    - Scientists are extremely competitive people, trust me, if someone had found something worth knowing about they'd let people know
- UFO sightings tell us nothing more than every now and again there are things in the sky we can't explain
- What about crop circles, abductions etc?
  - Would you travel a hundred trillion miles to mow down some wheat?
  - Sleep paralysis, false memories
- They're here already and they don't want us to know
  - Impossible to argue against, but do you really believe that?

Summary of lecture 30

- Both radio and optical searches for SETI are possible
- The main problems are
  - Large frequency space to search
  - Low signal power requires high sensitivity
- Searching over large areas of sky presents unique problems
  - High sensitivity requires a big dish, which enforces a small field of view
  - Must point separately at different areas of sky
- SETI is currently not funded by government grants, but now has its own dedicated facility – the ATA

Final lecture

- Future technology ideas
  - Comments on the final