Remaining schedule

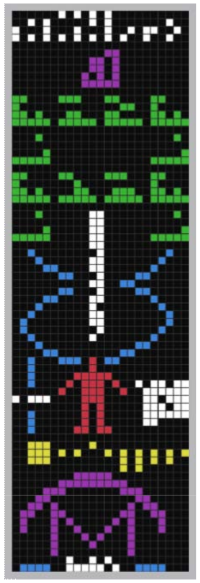
Previous Thursday Nov. 20: (nearly) finished up “Intelligence” material.
Sec. 6.5, 12.2 in textbook.

Today: Begin (and complete?) SETI searches: strategies, programs
Textbook Chapter 12.3
Partial review sheet will be available over Thanksgiving break.

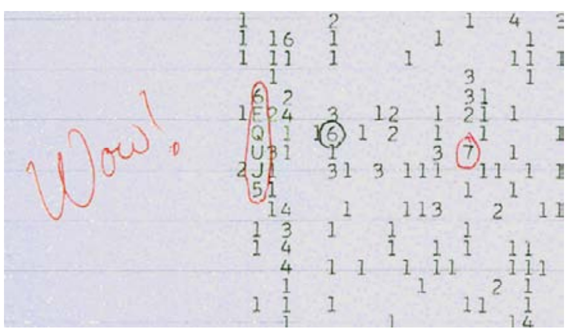
Thursday: Thanksgiving break.

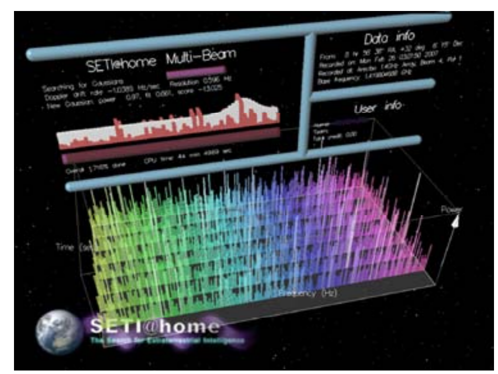
Full review sheet online Monday, Dec. 1.
Tuesday Dec. 2:
Complete SETI material.
Star Travel + Fermi paradox (ch.[13.1],13. 2, 13.3 in text) + review

Thursday Dec. 4: Last day of class -- Exam 5.




SETI


Wow!


SETI@home Multi-Beam
Data info
User info
SETI@home

SETI web sites ("links" at course web site)

SETI at

Space.com http://www.space.com/searchforlife/index.html

SpaceRef.com
http://www.spaceref.com/Directory/Astrobiology_and_Life_Science/seti/

Ongoing SETI searches:

SETI Institute/Allen Telescope Array http://www.seti.org/

Project SERENDIP, UC Berkeley http://seti.ssl.berkeley.edu/serendip/serendip.html

SETI@home http://setiathome.berkeley.edu/

Sourthern SERENDIP, Univ. Western Syndey http://seti.uws.edu.au/

SETI Italia http://www.seti-italia.cnr.it/

Optical SETI at

Berkeley http://seti.ssl.berkeley.edu/opticalseti/

Harvard http://seti.harvard.edu/oseti/

Amateur SETI:

Project BAMBI http://www.bambi.net/

SETI League http://www.setileague.org/

Project ARGUS http://www.setileague.org/argus/index.html

STRATEGIES FOR COMMUNICATION WITH EXTRATERRESTRIAL CIVILIZATIONS

- SETI is concerned with searches for **signals** from extraterrestrial civilizations, not spectral "biomarkers" we discussed earlier in course, or actual travel to other star systems (Ch.13).

- Except for 1974 signal to globular cluster M13 (thousands of light years away), we only try for reception, no transmission. ("What if they are all listening?")

- "Signals" could be intentional (they are trying for contact) or nonintentional (we eavesdrop, one way or another). A few unintentional candidates listed on next slides, but we are most concerned with intentional signals, and with establishing a two-way conversation.

- Remember: Distance to even the nearest 1000 or so stars ~ 50 light years, and we expect only a tiny fraction of them to have life, let alone intelligent communicating life, so we are necessarily asking whether to undertake a search with a guaranteed *very low probability of success*, and, even if successful, *communications will involve decades or even centuries.*

You can see why funding for SETI is sparse!

Four types of *nonintentional* types of signals:

- *Leakage radiation* from radio, TV, or other radio broadcasts.

Earth as example: Many TV stations broadcasting different shows, or same shows at different times ➔ radio waves emanating from Earth have always been *incoherent, completely scrambled*. **It is *not* true that alien SETI could be seeing our early TV shows!** (See next two slides for details. This was covered in class.)

- *Alien communications*, e.g. between home planet and colonies.

We would have to be almost exactly in the line of sight between home planet and colony, and guess the frequency range.

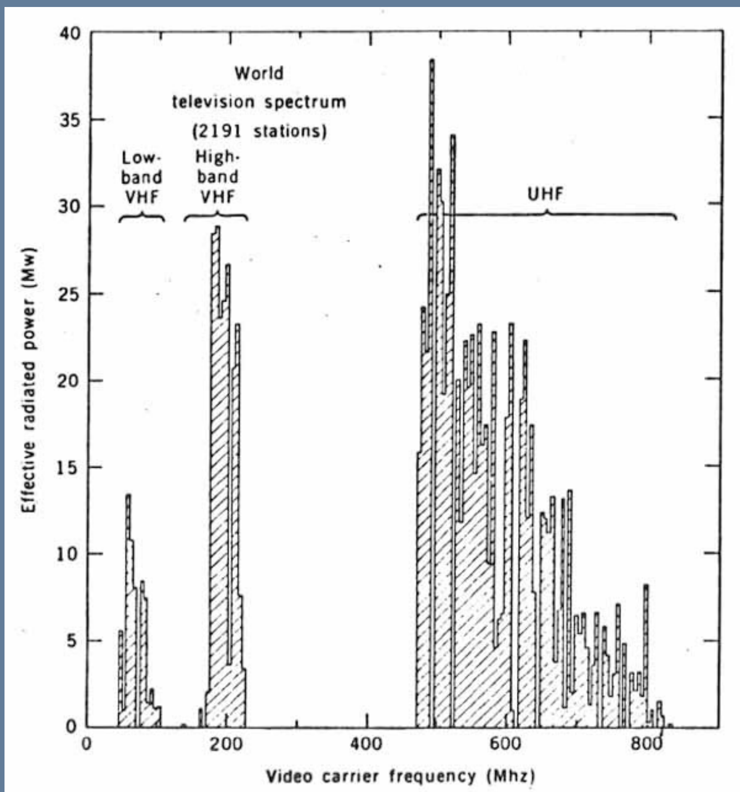
Seems very unlikely.

- *Dyson spheres* -- hypothetical constructs built by advanced civilizations in order to collect nearly *all* the energy of their parent star.

Spherical shell at same distance from star as the home planet. The intercepted energy is somehow channeled to planet. But shell is heated by the incident radiation: **What will its temperature be? At what wavelength would you conduct a search for Dyson spheres?**

- *Products of technological activity* – e.g. gamma rays from their (hypothetical) fusion propulsion systems, … CFC molecules from their air conditioners…

TV leakage radiation



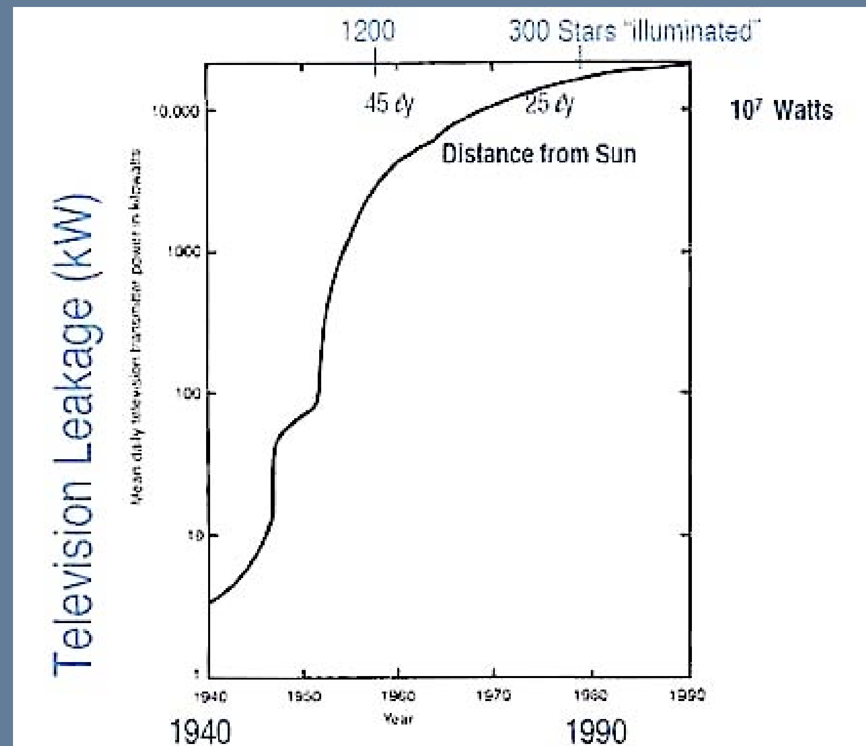
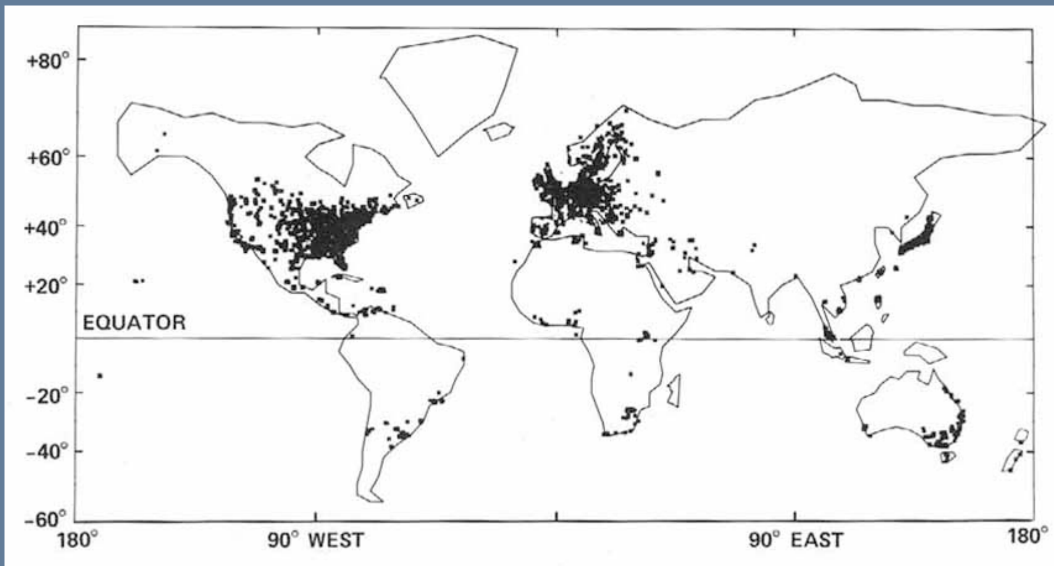


Figure 19.8 The Earth's power output in the radio region of the spectrum has increased many thousandfold since the start of the World War II in 1939.

World TV spectrum

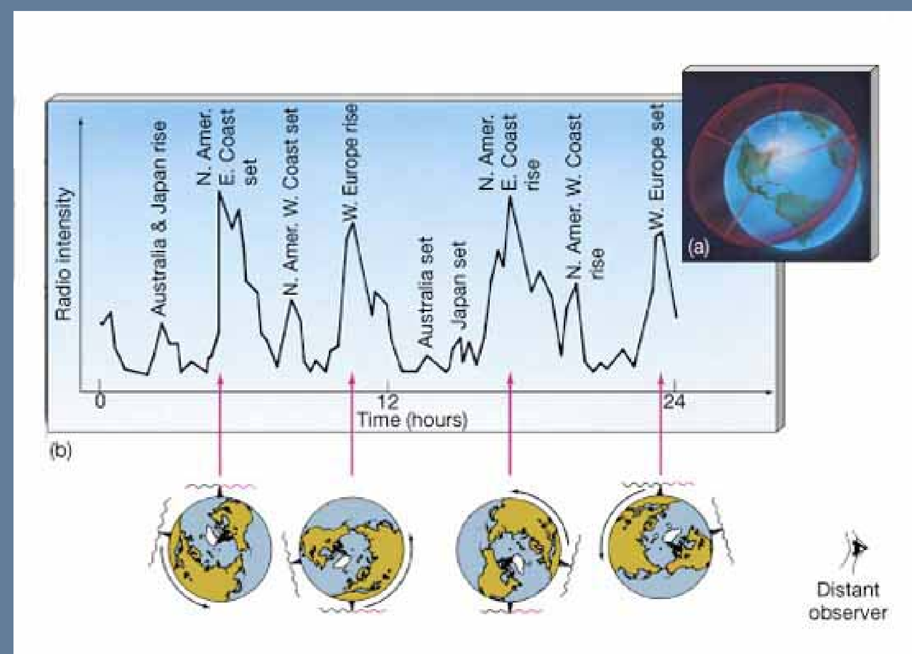
World TV power vs. time

Geographical distribution of TV stations



Geographical distribution of TV stations

As Earth rotates, this "pattern of populated areas" is the only evidence for TV broadcasts



How would an alien civilization try to communicate across many light years of space?

The only thing that is almost certain is that **they will use photons**—fastest and cheapest way to transmit information that exists (as far as we know).

Even though photon signals are the only choice we can think of, that still leaves many considerations that we need to guess about:

- Where to point our telescopes? What kind of stars should we point our telescopes toward? Or would it be better to survey the whole sky?
- Wavelength: What wavelength region should we expect is optimum for sending interstellar signals? Radio? Optical? Other?
- Bandwidth: What *range* of wavelengths? *Broadband or narrow-band*? WHY?
- Recognition and Interpretation: How would a message, or some sign that it is not a natural phenomenon, be distinguished, and how would a meaningful message be encoded?

We'll discuss each of these in turn.

WHERE TO POINT?

a. Sky survey. Survey entire sky with telescope's "beam" – this might involve millions of directions for typical radio telescopes. If you want to finish in your lifetime, you could only spend a very brief time on each direction, so you could only detect very *strong* signals. But at least you won't miss any of them. And the method doesn't make any assumptions about what the most likely stars are for signal reception.

→ This is a **low-sensitivity** method, but complete for strong signals.

b. Targeted search. Point at the nearest (less than about 50 to 1000 l.y.) stars roughly like the sun and cooler (recall conditions for habitable planets). Could detect *weaker* signals, i.e. would have higher sensitivity.

But you will only cover a tiny fraction of the sky.

→ This is a *high-sensitivity* method, but severely incomplete.

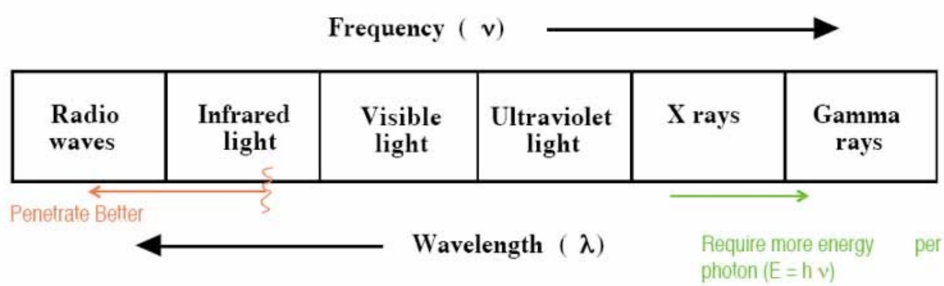
Most current searches have shifted to a sky survey mode (a), as listed in a table in Ch. 12. However plans change rapidly—the Allen Telescope Array (largest current project) will combine both approaches.

And some "optical SETI" searches (see below) are targeted searches.

Important: Understand why sky surveys can only detect the strongest of signals, another way of saying that they have poor sensitivity (to weak signals).

What frequency should be used to listen or send interstellar messages?

From the Earth's surface, most radiation is blocked by the atmosphere.
The exceptions are **optical** (visual) and **radio** photons.



Earth's atmosphere also blocks out most of the **infrared** part of the spectrum due to water vapor in our atmosphere. From the highest mountains or a jet plane, the infrared is barely accessible, but not for the continuous kinds of surveys we have in mind.

Note that if we could do such a survey from Earth orbit (expensive), or, if we only had about $100 billion dollars so that we could build a facility for SETI on the far side of the moon ("Project Cyclops"), our considerations might be different.

- **Why have most SETI searches concentrated on radio wavelengths instead of optical?**

A single amazingly influential paper by Cocconi and Morrison (1960 Nature) set the stage.
Their arguments for radio SETI are on next slide.

Reasons for radio SETI:

1. ***Interstellar dust*** selectively blocks shorter wavelengths (higher frequencies) ➞ strongly suggests we use the IR or radio parts of the spectrum (long wavelengths or small frequencies). But IR is dominated by Earth's atmospheric molecular emission if search from surface, so that leaves radio.

Notice that radio SETI allows reception from the entire galaxy, but optical isn't *that* bad, since we can see stars out to ~ 1 kpc. Besides, most radio searches areconcentrating on nearby stars anyway. (We don't want 1000-year "conversations.")

2. ***Radio photons are cheaper*** to send than optical photons (because energies are ~ 100,000 times smaller for radio).

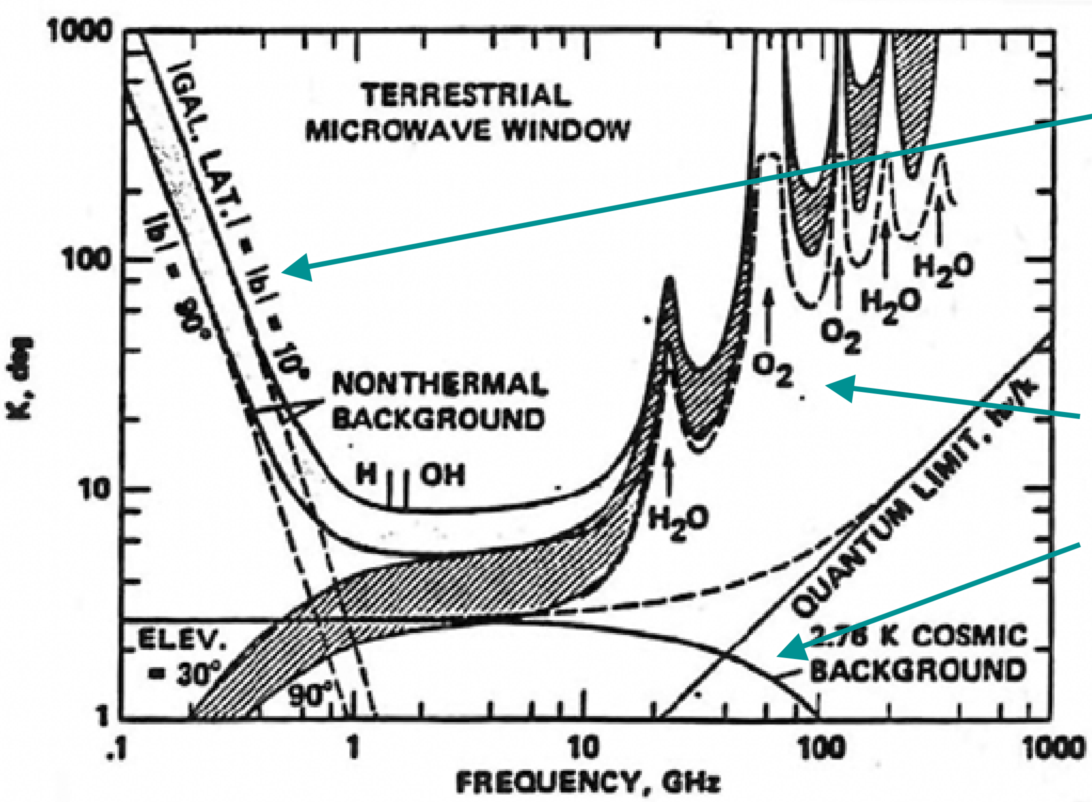
3. The main consideration is ***noise*****:** Here "noise" means anything that is not an alien signal--any kind of interference.

We should listen (or send) where the noise is minimized, so that we can recognize the (probably weak) signal. Noise is minimum in a region of the radio part of the spectrum. This is summarized in a classic graph shown on next slide.

Arecibo
Home of SERENDIP,
former home of Phoenix

Allen Telescope Array,
SETI Institute, N. Calif.

Alien signaling: Choosing a wavelength range that minimizes "noise" -- anything that is not an alien signal



Terrestrial microwave window. Atmospheric water vapor and oxygen degrade the upper end of the microwave window for receivers on Earth's surface and raise the temperature in the lower portion of the window.

Avoid very small frequencies (wavelengths *too* large), because synchrotron radiation from supernova remnants dominates there. (Far left in figure)

Avoid frequencies larger than about 10 GHz because of H2O and O2 emission from Earth's atmosphere.

Cosmic microwave background radiation sets "floor" at intermediate frequencies, and that is where the noise is minimum, and where we should search.

A message will arrive in a narrow wavelength band or bands, not spread over the whole 1-10 GHz region. *There are 10 billion 1 Hz bands in this range*. How to decide which ones to pick? First, must understand ***bandwidth***.

Which frequency?

If it is true that narrow-band signal is the only sensible approach, how will we decide which
band to use?
Suggested “beacon frequencies” (or “hailing frequencies” or “magic frequencies”):

HI (neutral hydrogen) 21cm (wavelength) line? The frequency is 1420 Megahertz = 1.42GHz
Natural, abundant, but lots of interference by interstellar gas. (Latter has apparently been forgotten.)

OH line at 1.7 GHz? H + OH = H2O, so maybe region between these two
--> **“the waterhole”**. Alien civilizations will know that these two lines are from the dissociation products of water, whatever they call H and OH. Not taken too seriously, But convenient range to strive for. (Allen Telescope Array uses this range, and more.)

OTHER ‘MAGIC” FREQUENCIES
Some frequency based on combinations of fundamental constants of nature? (e.g. speed of light, Planck’s constant, …) The combination can be expressed without referring to “our” units (e.g. meters)

- ″Intergalactic″ frequency standard based on temperature of cosmic background radiation?

Many others have been suggested. *Too* many! None in use today.

The importance of bandwidth

Basic idea:

Can pack more power in a narrow frequency range (narrowband signal) than spreading out over a large range (broadband signal).

So can distinguish a narrowband signal from the background more easily.

Think of the everyday radio analogy again, and it should be clear!

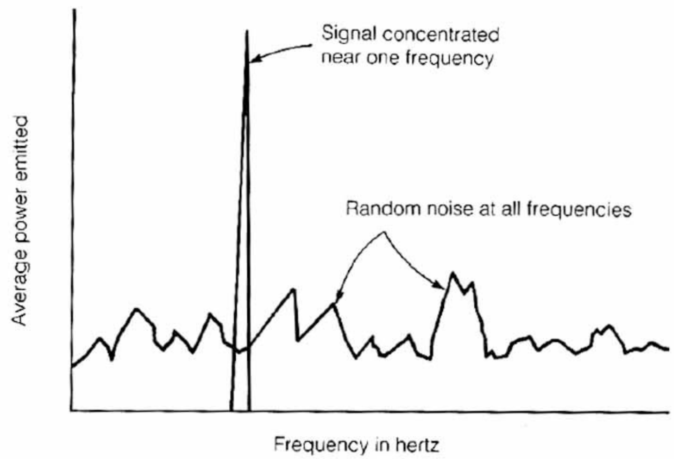
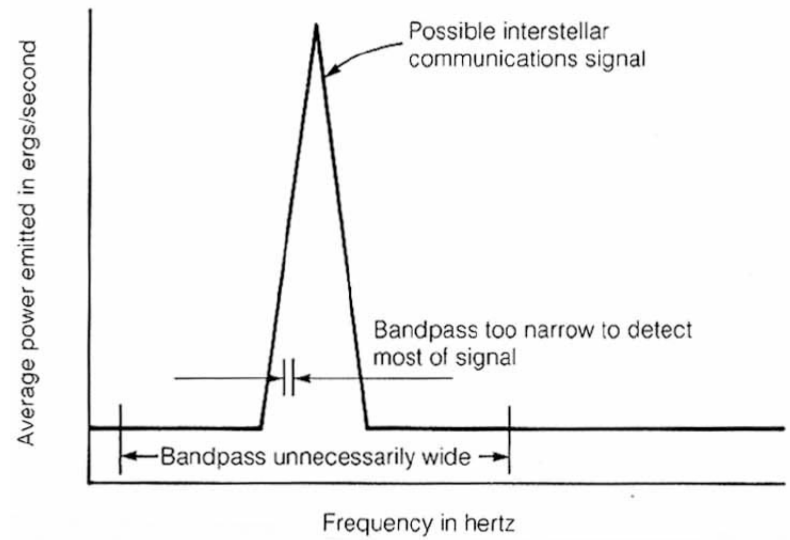
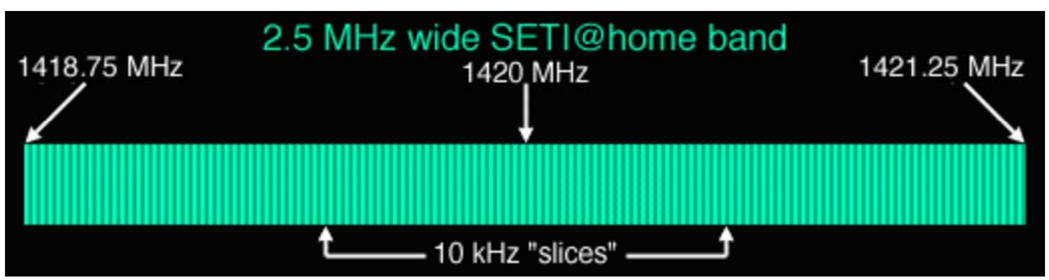


Figure 19.5 Concentrating a signal into a narrower bandpass makes it much easier for the signal to stand out against the background noise that exists at all frequencies.



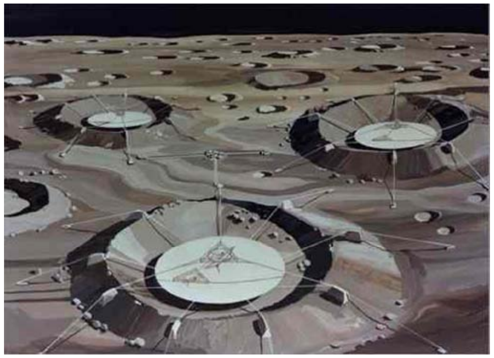


SETI@home: Each vertical "band" is a 10 kHz "slice" of the 2.5 MHz wide SERENDIP data. There are 250 such "slices." But search is for signals *much narrower than these bands.*

SETI projects: partial historical list

Ozma (1960)--brief, but sent out one of only Earth transmissions.

NASA asks for SETI proposal, astronomers propose **"Project Cyclops"**, 1000 100 meter radio telescopes on back side of moon, costing $10 billion (1970s). NASA asks for more moderate plan, planning for next ~ 17 years.



Ohio State SETI: 1977-1997 (replaced by golf course).
Best known for the **"wow" signal**.

Harvard, Paul Horowitz and Project **META** (millions of bands in frequency), Project **BETA** (billion bands in frequency). Horowitz and Sagan 1993 Astrophysical Journal summarize results. One of first SETI papers in refereed journal.

Harvard and Horowitz now converted to Optical SETI, largest in world.

UC Berkeley's Project **SERENDIP. Since 1977!** Part of data analyzed by 5 million home computers through SETI@home.

Dec. 1991. NASA funds $100 million SETI effort ("MOP"). Detailed plan for combined targeted and sky survey searches. 1993: Funding removed by senate amendment

Project Phoenix (SETI Institute) rises from the ashes. Piggy-backs off various radio telescopes, mainly Arecibo.

2001: Paul Allan and others fund the **Allen Telescope Array**, 350 6meter telescopes. 42 complete by Oct. 2007.

SERENDIP

One of oldest operational SETI searches--since 1979, UC Berkeley.

1997--installed as piggyback at Arecibo radio observatory (picture below), largest single-dish radio telescope in world (but can only point in one direction).

SERENDIP = Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligence Populations. SERENDIP IV is the fourth instrument of the project, collects data by 'piggybacking' on top of the Arecibo radio telescope.

SERENDIP IV instrument is basically a 200 billion operations per second supercomputer that scans 168 million narrow (0.6 Hz) channels every 1.7 seconds for signals that are significantly 'louder' than the background static (like our radio tuning explanation).

Some of its data is analyzed through **SETI@home** for desktop computers--so far millions of users, largest distributed computing project in world, led to ~ 100 other distributed computing projects, e.g. folding@home, prime@home, climatenet@home, …
(discussed last time)

The Arecibo radio telescope in Puerto Rico, used by both SETI Insitute for Project Phoenix, and by UC Berkeley for their SERENDIP IV.

SETI@home: Now searching for pulses

August 2008: SETI@home switches to search for *pulsed* radio signals.

Observations are from SERENDIP piggy-backed on radio telescope at Arecibo that is built into a mountain. This dish only points in one direction as sky drifts across this direction--the drift takes about 12 seconds for a given point in the sky.

SETI@home searches for signals that rise and fall in 12 seconds--any object will do this, but most will be broad-band sources (top image).

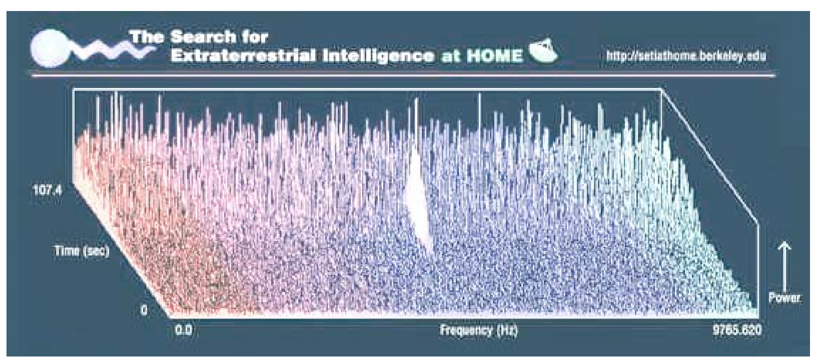
Narrow search by requiring narrowband signal (2nd image). Will check for several different bandwidths.

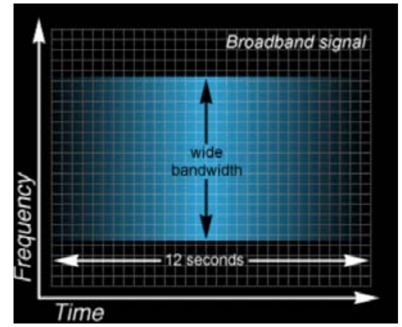
Information in image? Search for pulsed signal (3rd image).

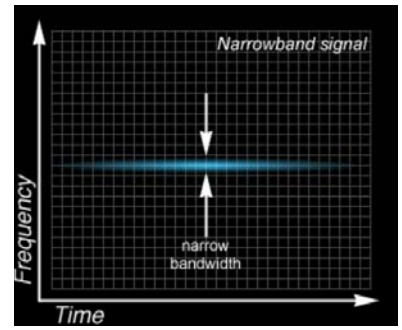
If from planetary system, should also be Doppler shifting (“chirped” signal), as in 4th image.

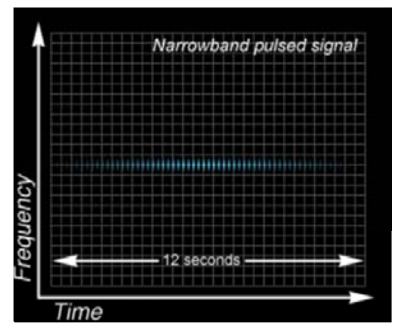
Home computers look for various combinations of frequencies, bandwidths, and chirp rates. *See if you can understand why the white “thing” in the illustration below might be a signal…*

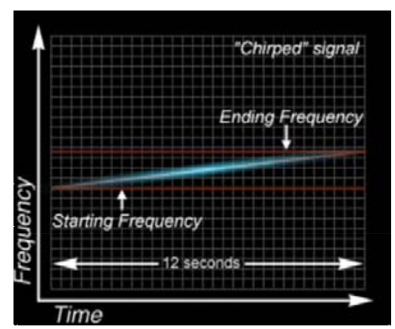
SETI@home screensaver
Can you see the alien signal??











Allen Telescope Array (ATA)

Eventually 350 6 meter antennas, equivalent to 100 meter single dish.
42 dishes saw "first light" in 2008.

Unique features:

- Large field of view, so can scan sky faster in survey mode.
- Large range of frequencies (1-10 GHz for targeted search, five times range of Phoenix), and width small bandwidth (~ 1Hz), using more than a billion channels.
- Finally offers SETI 24/7 monitoring

  (Phoenix had Arecibo for only about 3 weeks per year 1998-2004)

Goals:

- Survey 10^6 stars with good sensitivity between 1 and 10 GHz for weak non-natural transmitters. (Targeted search)
- Survey ~ 40 billion stars of inner Galactic plane in "water hole" range 1420-1720 MHz for very strong non-natural transmitters. (Sky survey)

Optical SETI (OSETI)

(Incomplete slide 12.1.08

With current equipment can send out pulsed laser beam 5000 times brighter than the Sun.

Current projects:

Harvard: since 1998, using 61 inch telescope. Nearly 100,000 observations.

Dec. 2000: new 72 inch telescope dedicated to an all-sky survey. Can detect nanosecond (billionth of a second) pulses and cover entire sky in 200 nights.

Lick Observatory

Encoding a message

- SETI researchers focus on a signal *anyone* could comprehend. *Not* clear this is sensible!
- It ***is*** very sensible to expect digital, binary, not analogue signal.
- How to encode a picture into a string of binary (0,1) signals?

The simplest and most efficient way to encode a message (we think) is *binary code*. Use only 2 characters, e.g. a 1 and a 0, or a + and a - , or "on" and "off", ... Each 1 or 0 (or whatever) is a "bit". Then the message can just be sent as a series of pulses.

Expect the message to be a two-dimensional *picture* that is encoded in a one-dimensional binary string that factors into ***prime numbers***.

e.g. 551 = 29 x 19 (or 19 x 29); 1679 = 23 x 73 (the 1974 Arecibo transmission).

Example: We receive signal 1111100000101011010110101.

This factors into 5 x 5, giving a picture of the greek letter "pi".

Or try the letter "E", etc.

But why would ETI send out signals that *anyone* could decode? Perhaps they send out signals which could be understood only by others who are already "at the same level" as they are.

What would be a difficult signal for us to recognize?
Maybe the test would be to recognize some sort of "meaning" in the message. (Think about musical signals. At present, there is no viable theory of musical meaning in music analysis, philosophy, cognitive science, pattern recognition, or any other field that has approached the problem.)

Deeper questions: Will symbolic communication systems be universal among intelligent creatures? Is “grammaticity” hard-wired into our brains? Another example of single mutation?