Communication, 2.

Search Strategies

- Basic Problem: where to look?
- Possible Scenarios
  - Powerful, omnidirectional beacons
    - Implies very advanced civilization
    - Seeking to attract attention of new civilizations
  - Nearby, not so advanced, broadcasting to us
    - Unlikely
  - Detect leakage radiation

Leakage Radiation

- Various sources
  - TV, radio, …
    - Repeatable pattern due to Earth rotation
    - Switch to digital TV in June 2009
      - Some changes, but similar frequencies used
  - Defense radars
    - Most powerful, but won’t repeat

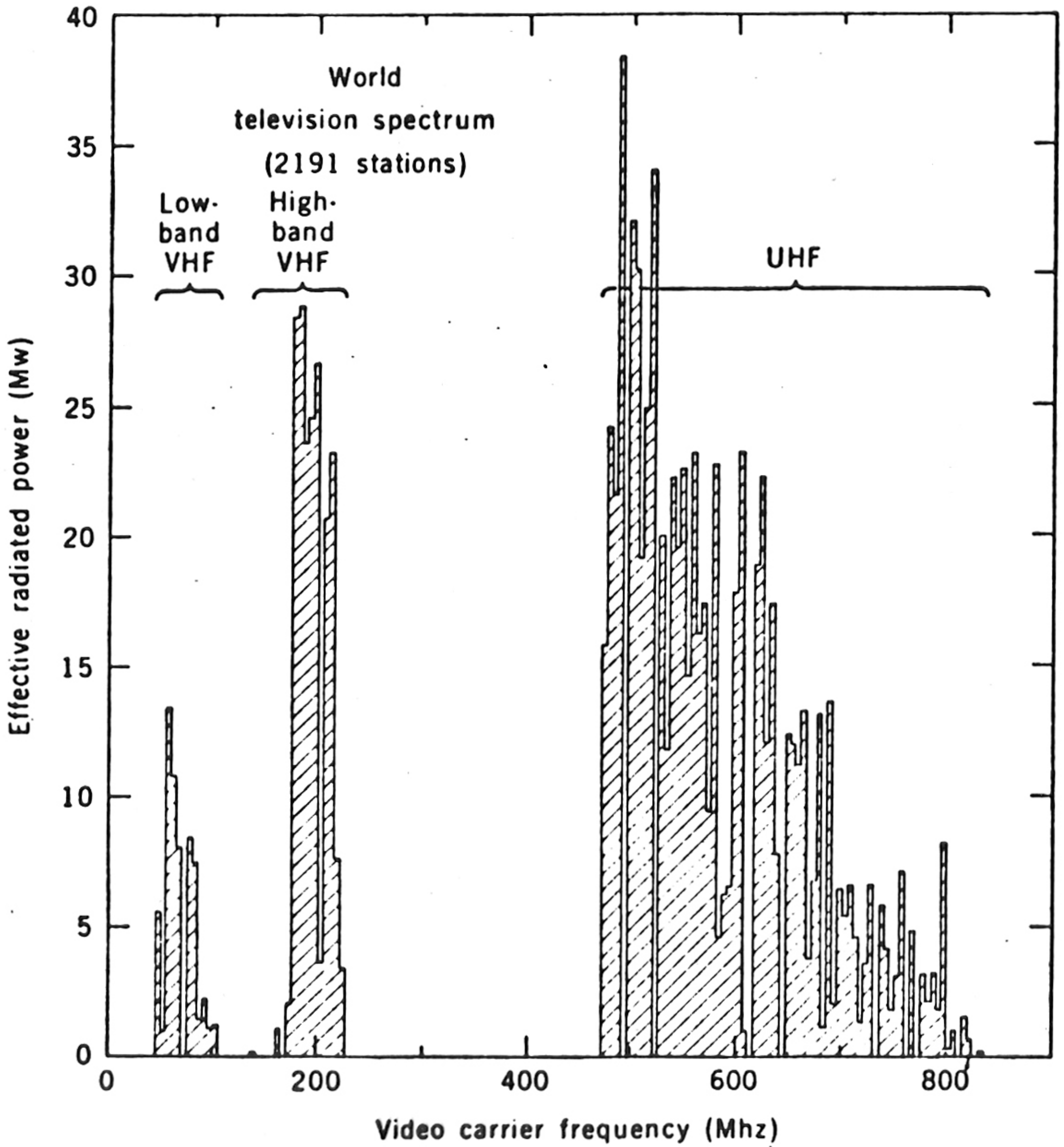
TABLE 20-1

ESTIMATED POWER OUTPUT OF VARIOUS RADIO-PHOTON SOURCES THAT OPERATE AT FREQUENCIES GREATER THAN 20 MHz

Source	Frequency Range (MHz)	Number of Transmitters	Fraction of Time that Transmitters Emit	Per Individual Transmitter: Maximum Power Radiated (watts)	Per Individual Transmitter: Effective Frequency Bandwidth (hertz)	Total Average Power Radiated (watts per hertz of bandwidth)[a]
Citizen-band radios	27	10,000,000	1/100	5	2	200,000
Professional landmobile radios	20–500	100,000	1/10	20	1	200,000
Weather, marine, and air radars	1000–10,000	100,000	1/100	10,000 to 1,000,000	1,000,000	10 to 1000
Defense radars[b]	400	2	1/10	10,000,000,000	0.1	20,000,000,000
FM radio stations	88–108	10,000	1	4000	0.1	400,000,000
TV stations (for photons that carry picture, not sound)	40–850	2000	1	500,000	0.1	10,000,000,000

[a]The last column shows the power radiated *per hertz of bandwidth*. Systems that cover a wider bandwidth (most noticeably, weather, marine, and air radars) will radiate a greater total power over *all* frequencies than this column would suggest. This table, as well as Figures 20-7, 20-8, and 20-9 follow the results of a study made by W. Sullivan III, S. Brown, and C. Wetherill in *Science*, vol. 199, p. 377, 1978.

[b]We have considered only the most powerful defense radars; these dominate the total power output from all such radar systems.



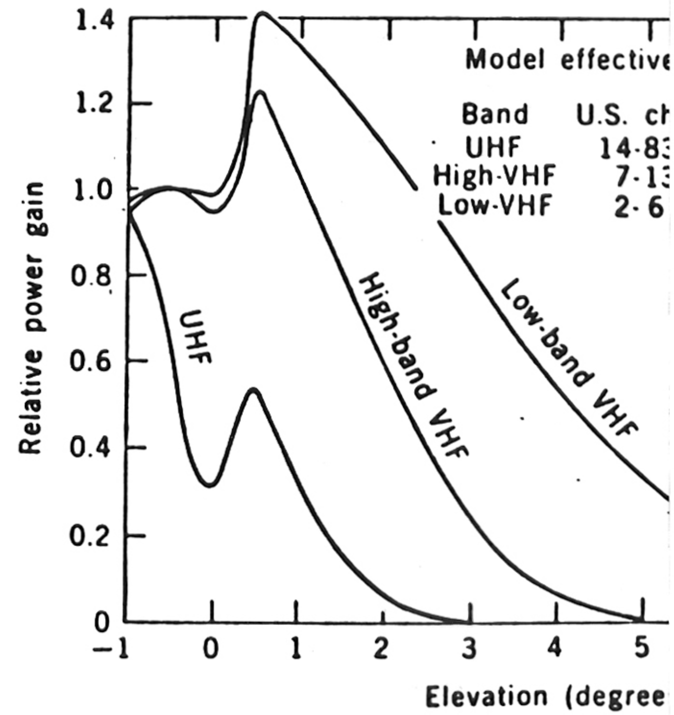
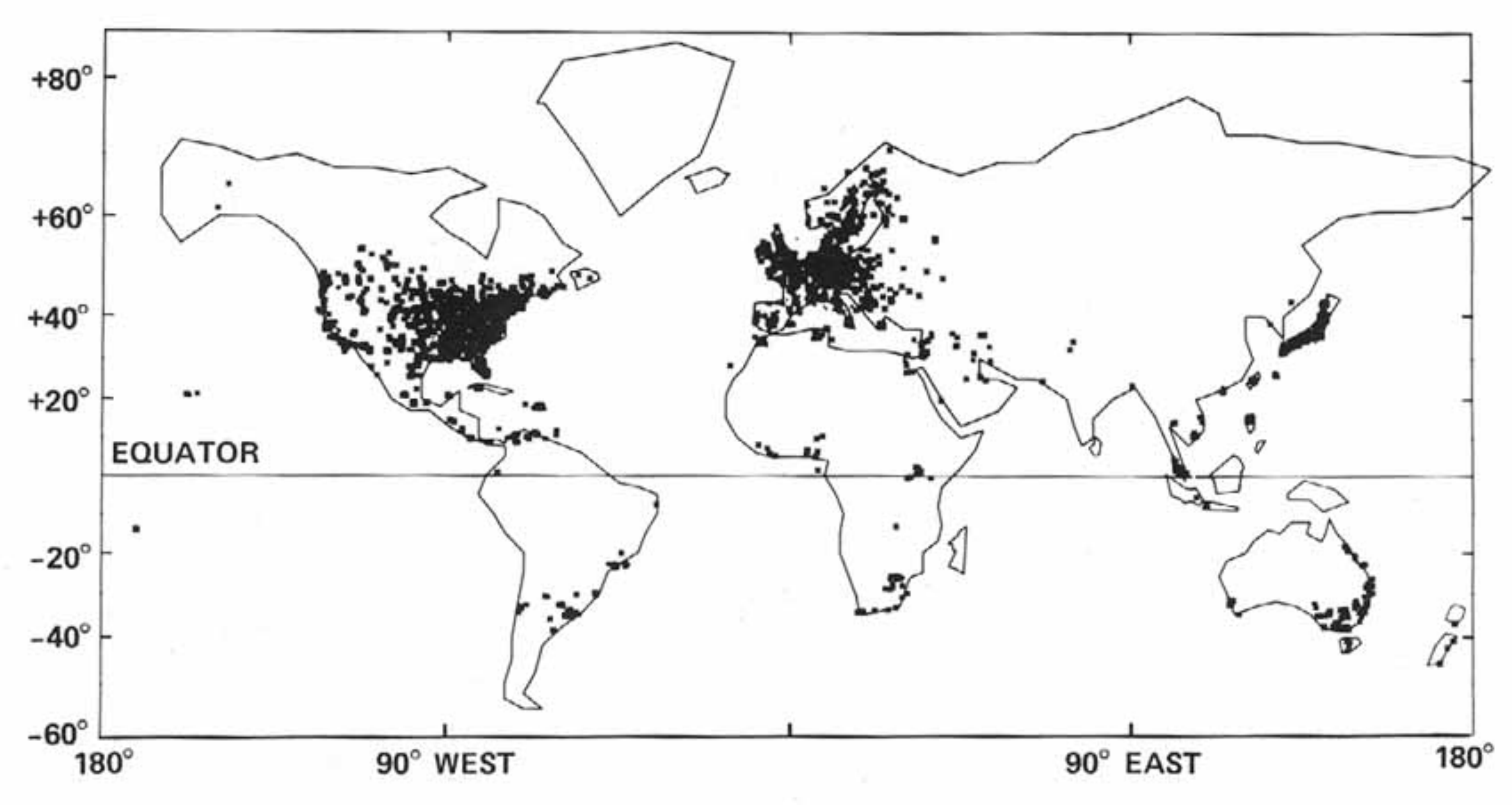
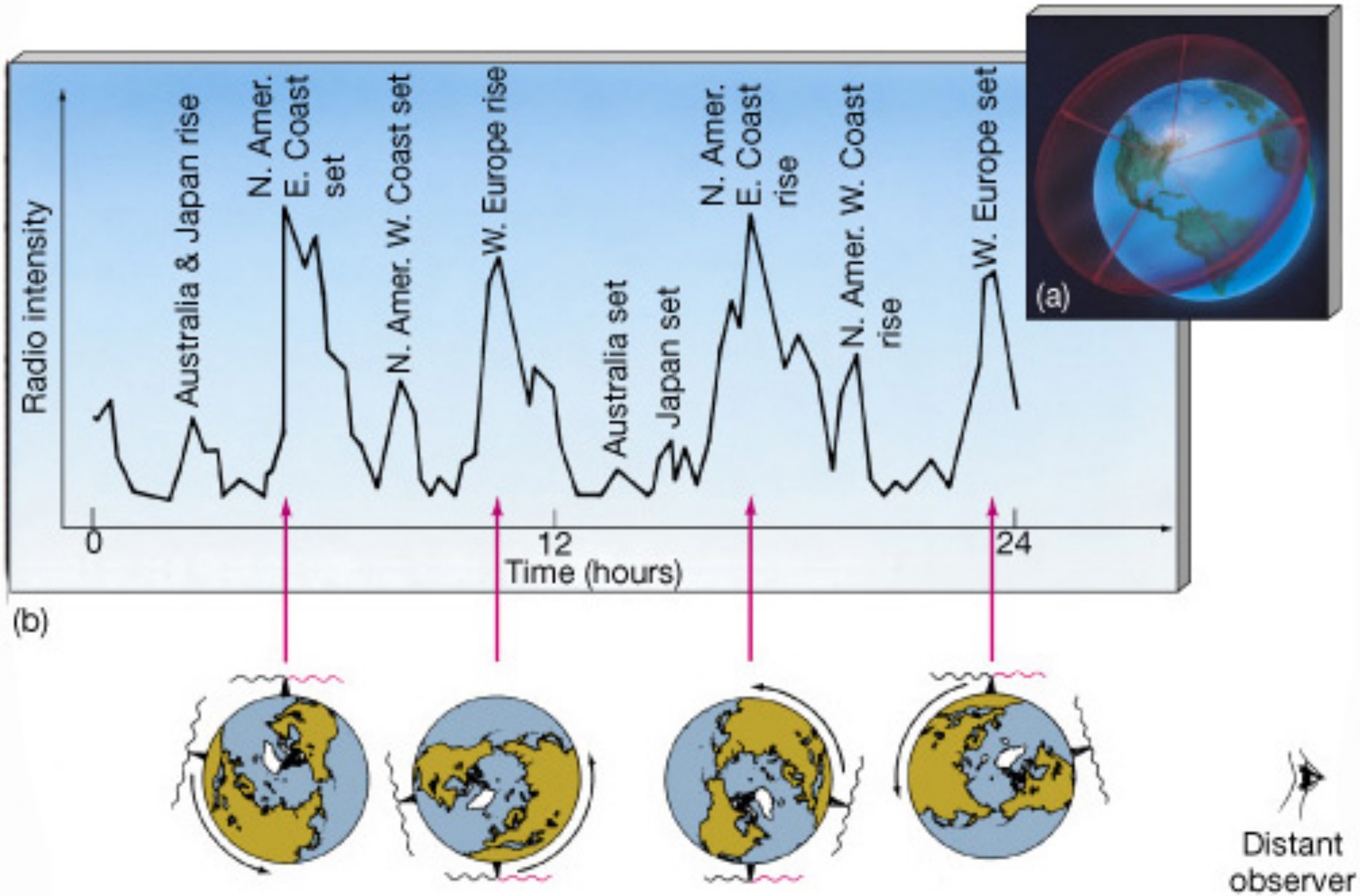


Fig. 3 (left). World television spectrum, show which the most power is radiated (5-Mhz-w primary bands (channels 2 to 6, 7 to 13, and States) are also indicated. A distant extrater a frequency resolution of 5 Mhz would at n spectrum roughly of this shape. Fig. 4 tenna power patterns adopted in the model television frequency bands. The radiation is s to the local horizon of each transmitter and directional in azimuth.

World Television Transmitters




(a)
Radio intensity
Australia & Japan rise
N. Amer. E. Coast set
N. Amer. W. Coast set
W. Europe rise
Australia set
Japan set
N. Amer. E. Coast rise
N. Amer. W. Coast rise
W. Europe set
0
12
24
Time (hours)
(b)
Distant observer

THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

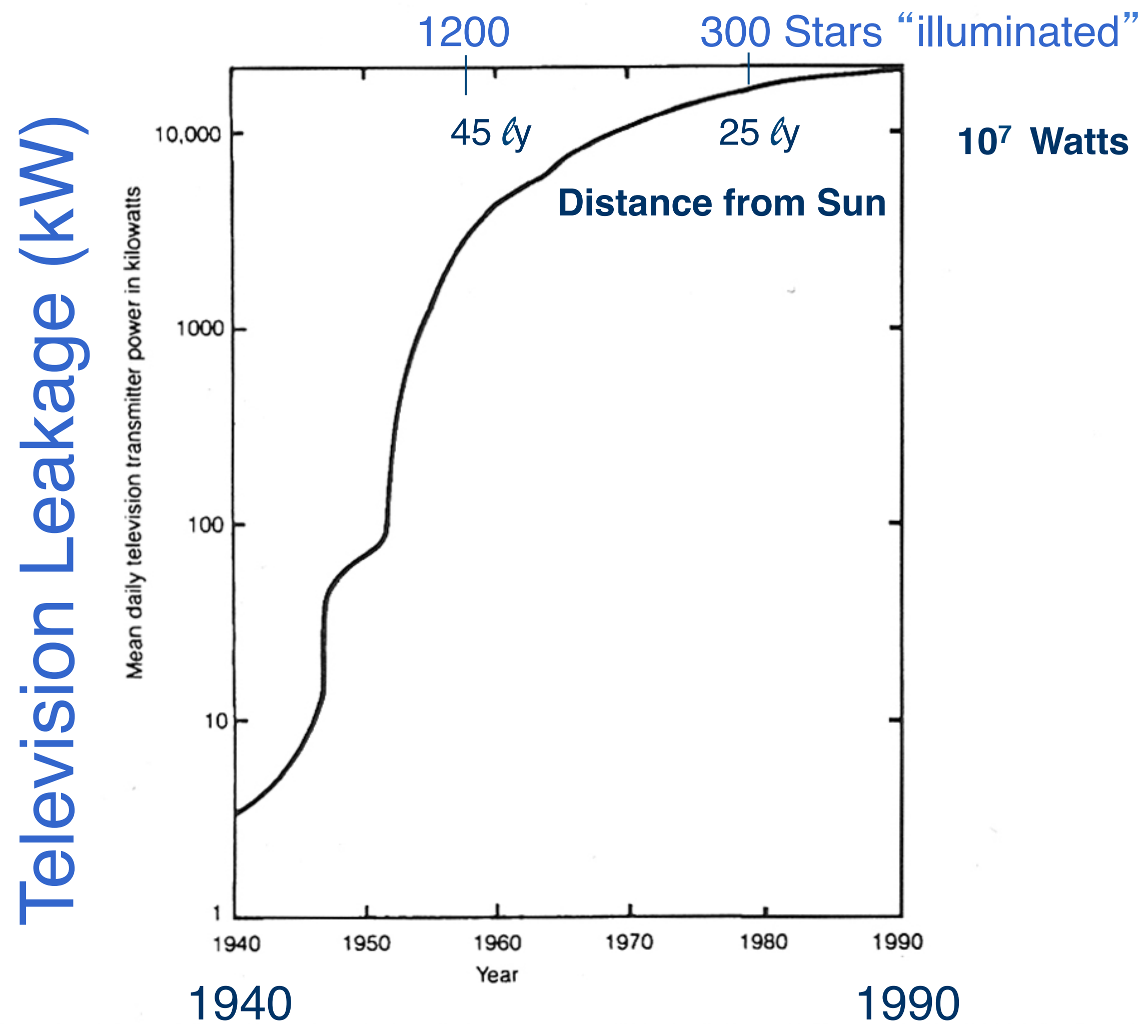
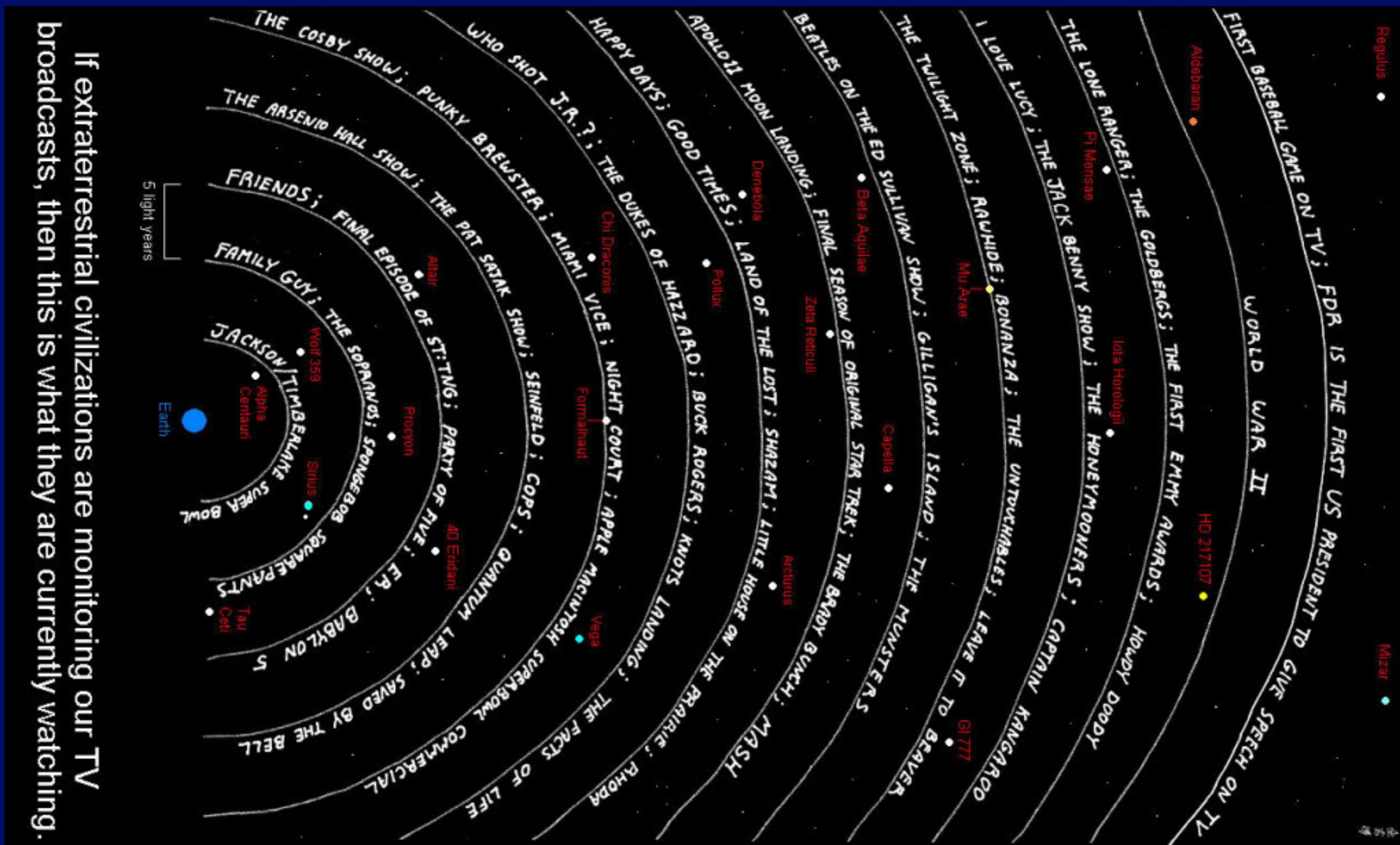


Figure 19.8 The Earth's power output in the radio region of the spectrum has increased many thousandfold since the start of the World War II in 1939.

By 2014, 73 ly, 3300 stars for earliest TV
54 ly, 1700 stars for 1960 transmissions

What are they watching???



The Cosmic Haystack

Frequency

Large frequency range

But narrow channels

⇓

Lots of channels

Direction

Large number of directions

Small beam

Conflict

Sensitivity

$S \propto D^{-2}\, t^{-1/2}$

want small S

Large telescope

Long time per direction

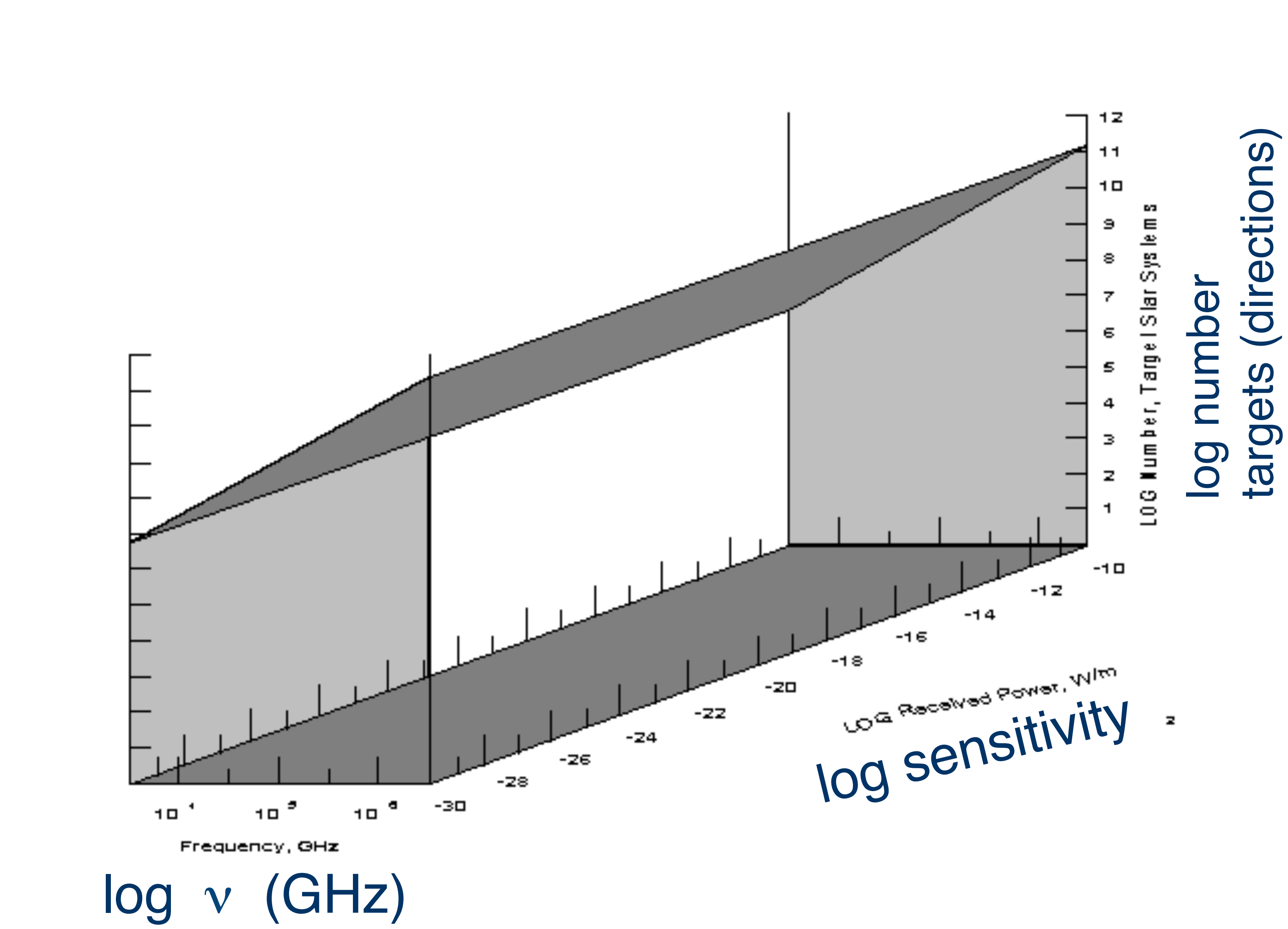
Strong signals, unknown origin

⇒ Small telescope, short t , cover sky

Weak signals, nearby stars

⇒ Large telescope, longer t , only stars

Cosmic Haystack



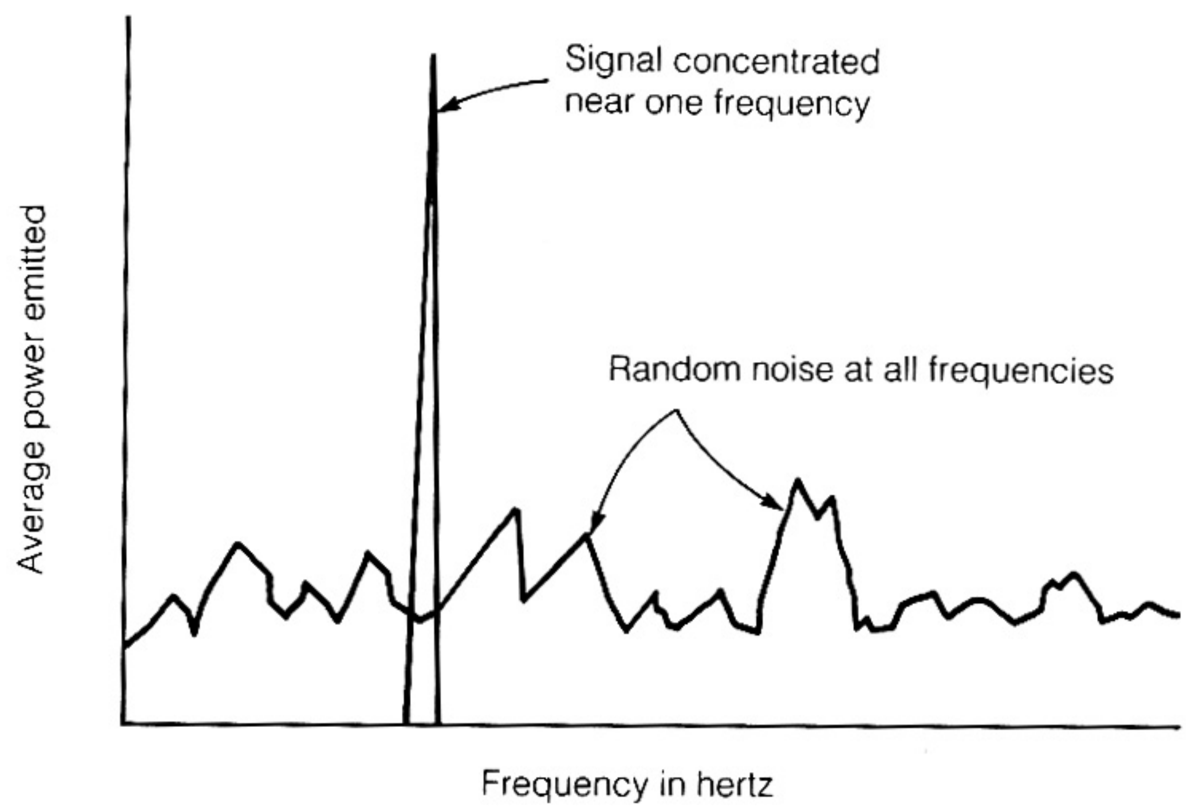
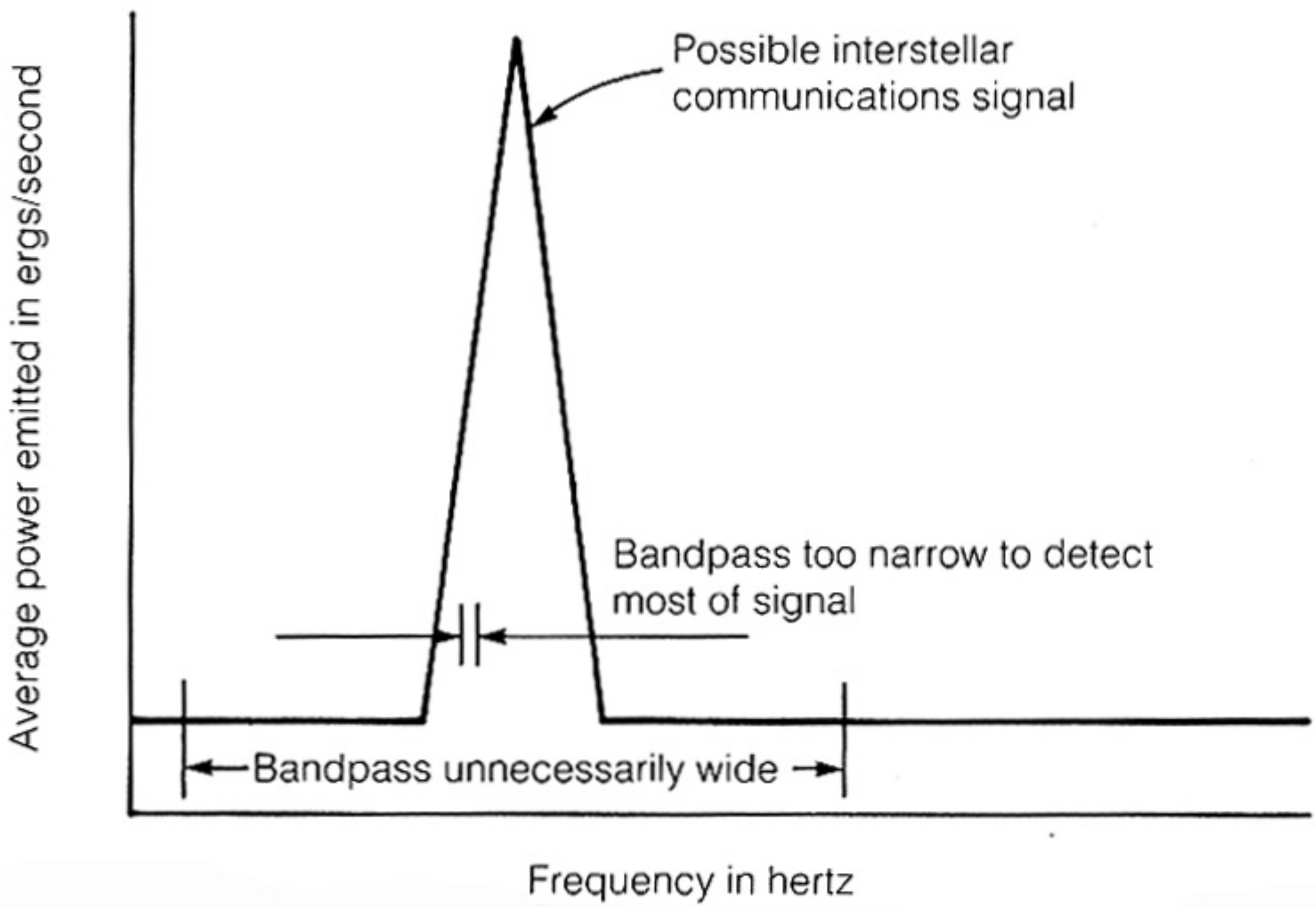
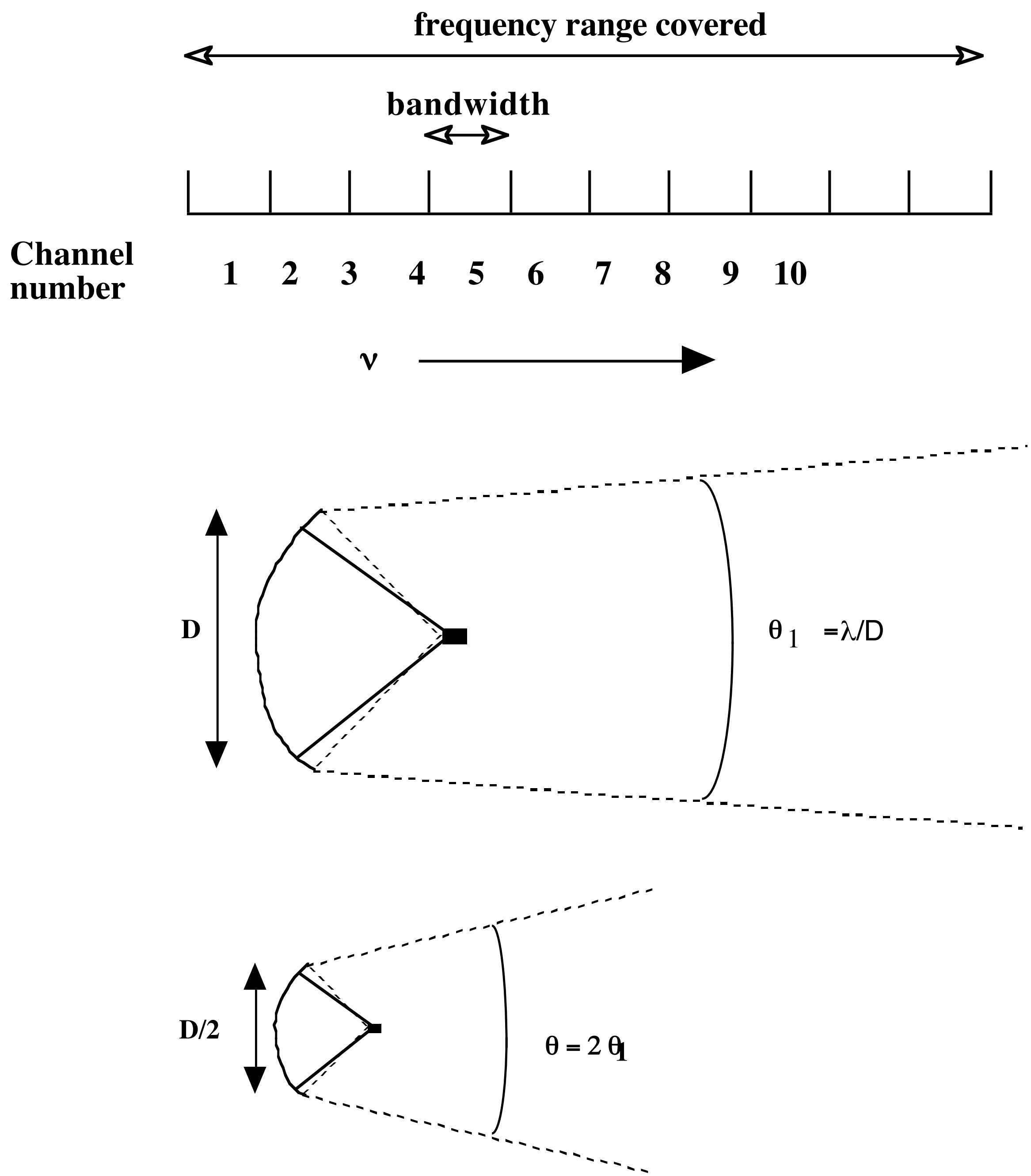
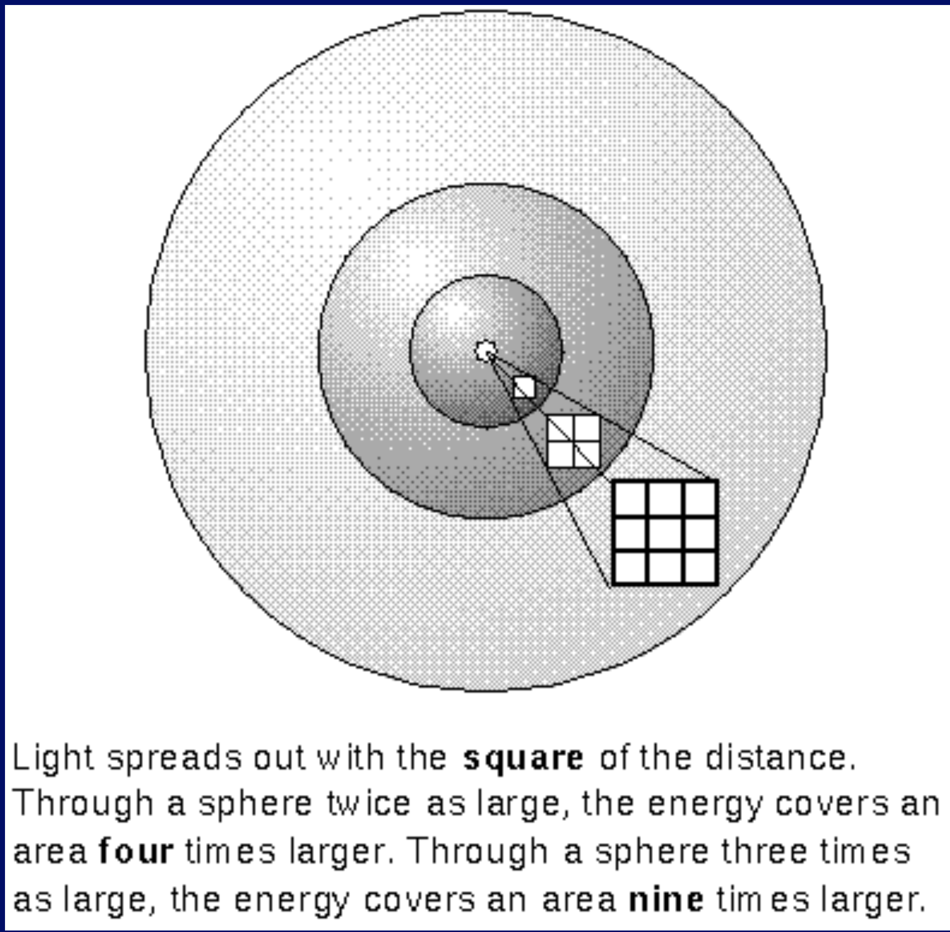


Figure 19.5 Concentrating a signal into a narrower bandpass makes it much easier for the signal to stand out against the background noise that exists at all frequencies.


Possible interstellar communications signal
Bandpass too narrow to detect most of signal
Bandpass unnecessarily wide
Average power emitted in ergs/second
Frequency in hertz


frequency range covered
bandwidth
Channel number
1 2 3 4 5 6 7 8 9 10
ν
D
θ 1 =λ/D
D/2
θ = 2 θ1

Sensitivity



Signal per area $\propto$ distance^{-2}

Sensitivity (S):
How weak a signal can we detect?
The bigger the collecting area ($\propto D^2$), the weaker the signal I can detect ($S \propto D^{-2}$).
The longer I average, the weaker the signal, but only $S \propto t^{-0.5}$
Summary: $S \propto D^{-2} t^{-0.5}$

This image is courtesy of Nick Strobel at www.astronomynotes.com

The Cosmic Haystack

Frequency

Large frequency range

But narrow channels

⇓

Lots of channels

Direction

Large number of directions

Small beam

Conflict

Sensitivity

$S \propto D^{-2} t^{-1/2}$

want small S

Large telescope

Long time per direction

Strong signals, unknown origin

⇒ Small telescope, short t , cover sky

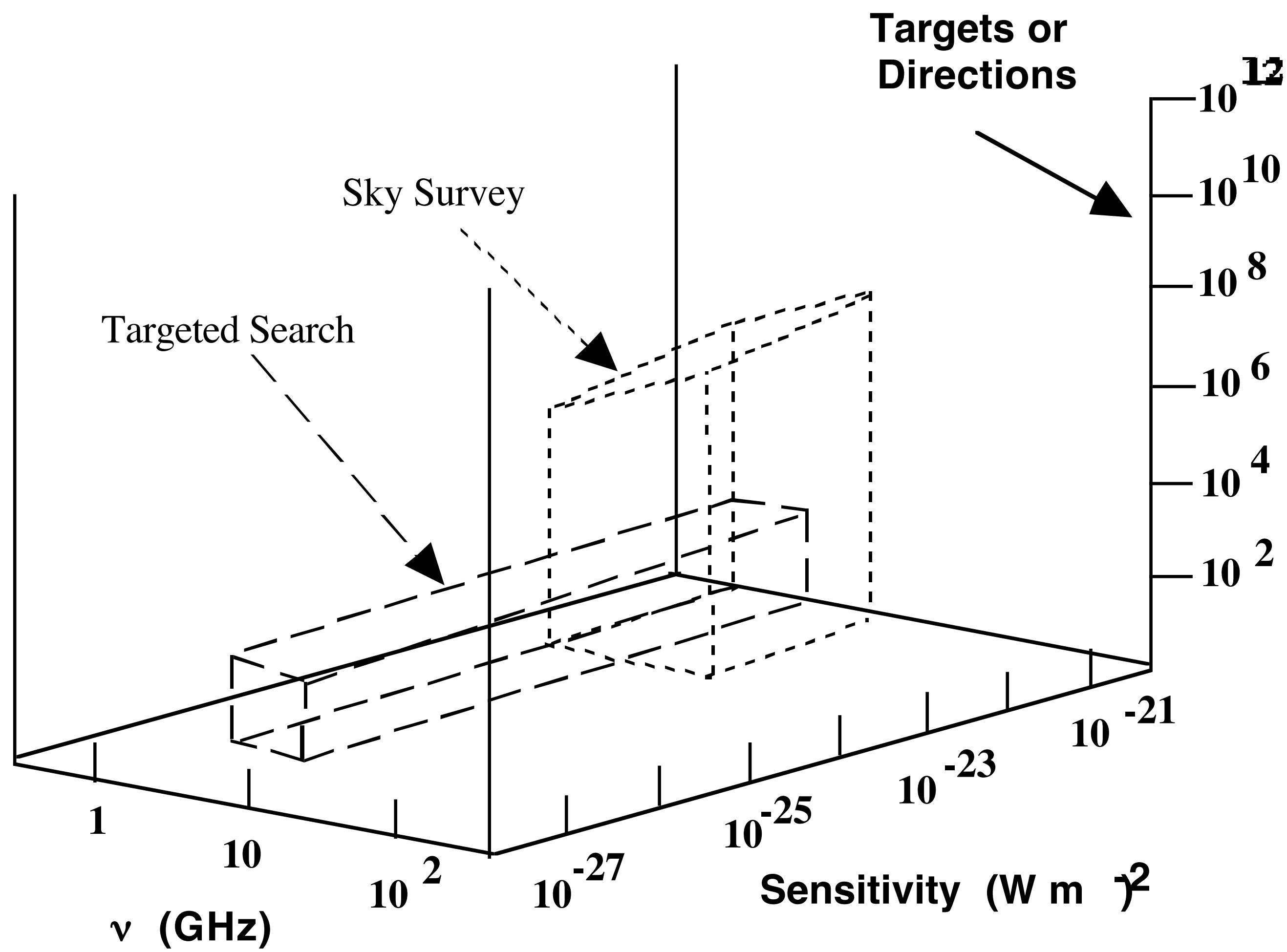
Sky Survey

Weak signals, nearby stars

⇒ Large telescope, longer t , only stars

Targeted Search

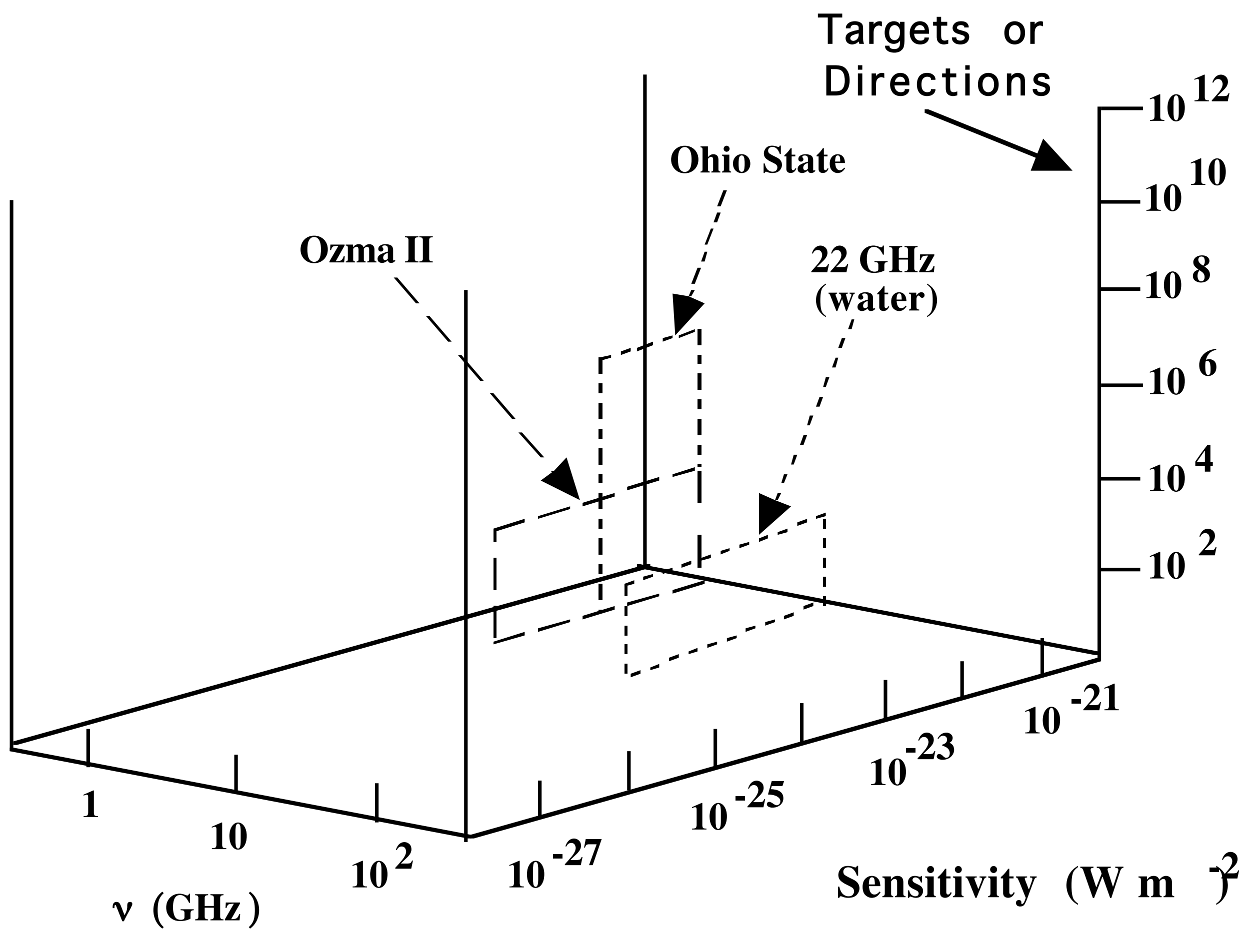
Targeted Search vs Sky Survey



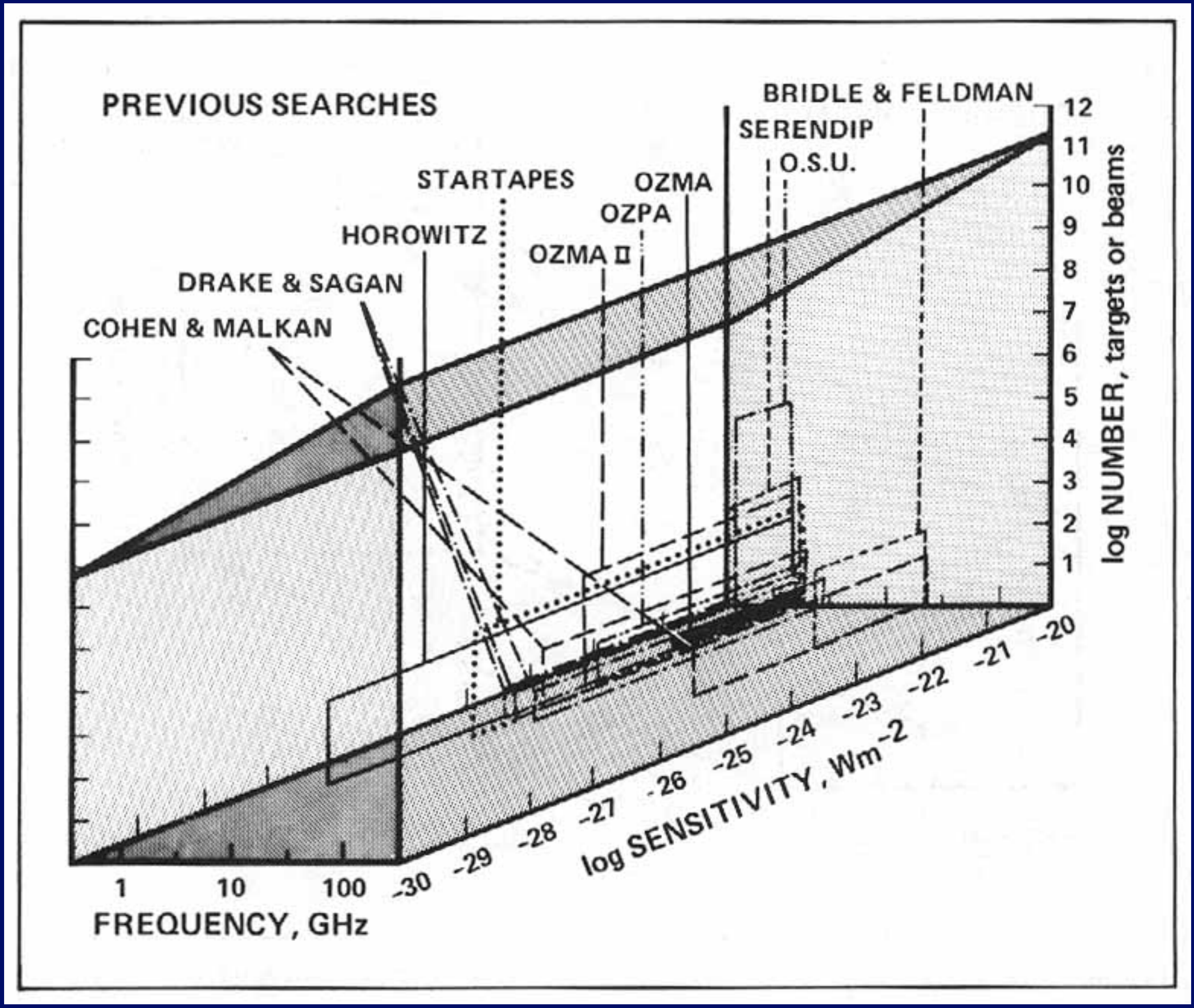
Some Searches for ETI

Year	Names	Frequency (MHz)	Telescope size (m)	# of stars
1960	Ozma (Frank Drake)	1420	26	2
1972	Ozma II (Zuckerman & Palmer)	1420	91	602
1985	Meta (Horowitz; Planetary Soc.; Spielberg) [8 million channels]	1420	26	All sky
1992 ↑ Oct. 12, 1992	NASA search Discrete source mode	1200-3000	300	244
		+ selected ν Up to 25 GHz	34	800
	All sky Survey	1000 - 10,000 + selected ν	34	All Sky

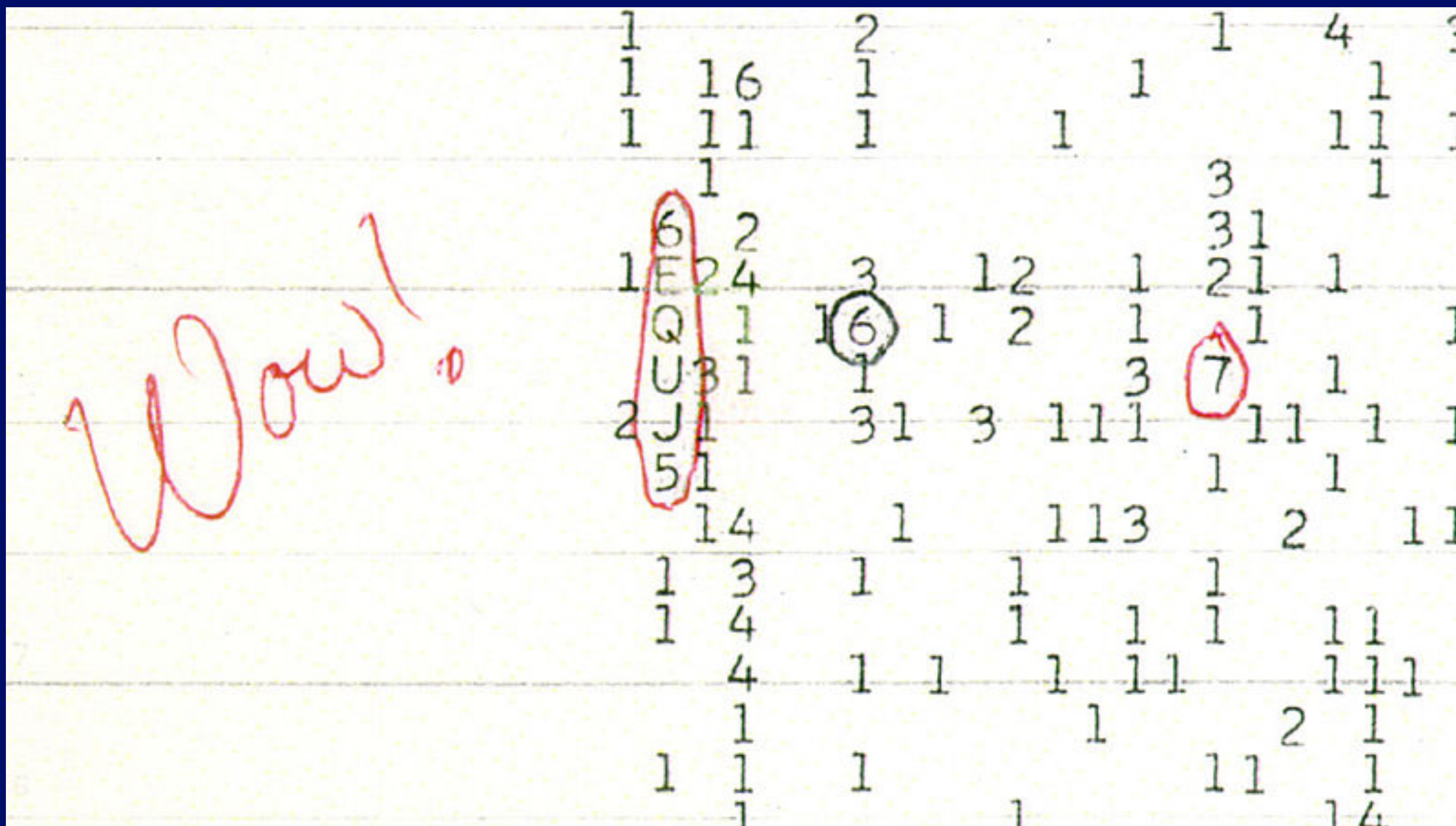
Some Searches



Previous Searches



The Wow! Signal



SERENDIP - SETI@home

- Latest version:
  SERENDIP IV
  Used ARECIBO telescope
  while regular obs.
  going on

$\nu = 1420$ MHz

5×10^{-25} W m^{-2}
very sensitive

Data analyzed by screen savers
on millions of PC's SETI@HOME

Report on Project META
Megachannel Extra Terrestrial Assay

Horowitz & Sagan, 1993, *Astrophysical Journal*, **415**, 218.

5 years of searching at 1.420 GHz

8×10^6 channels — channel width: 0.05 Hz

coverage: 400 kHz

Covered sky 3 times — 1.7×10^{-23} W m^{-2}

37 candidate events: narrow-band, apparently not interference

But none repeated

8 signals truly hard to explain as noise

Probably electronic "glitches"

But some tendency to lie in plane of galaxy $\Rightarrow$ extraterrestrial ?

Nothing convincing.

Fig. 5a

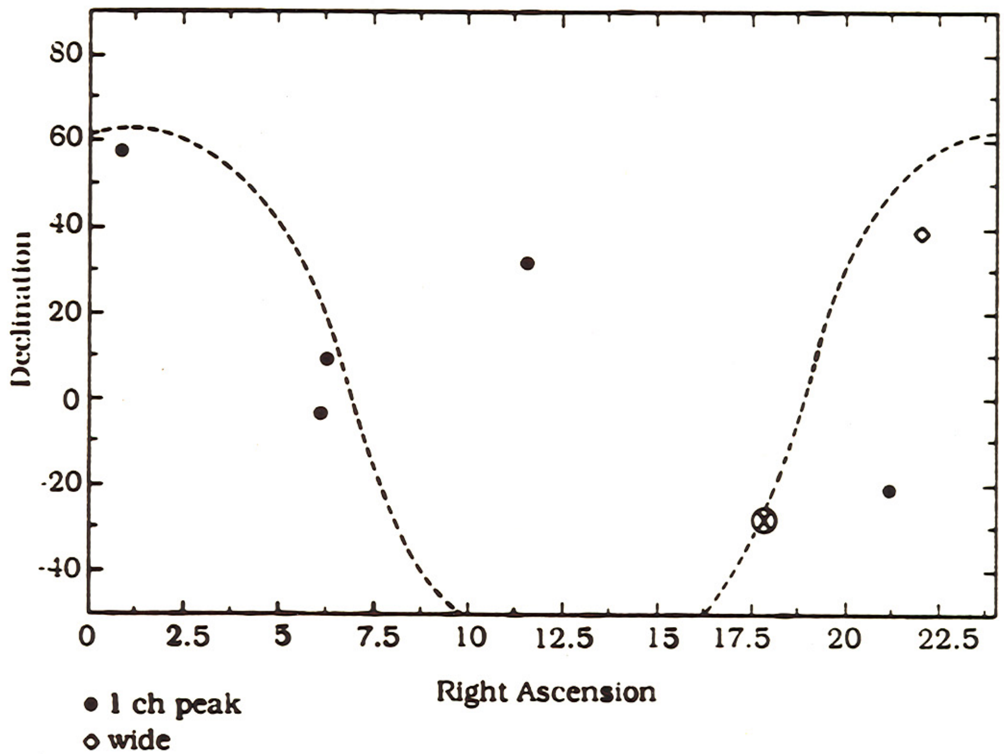


Fig. 5b

5.—Coordinates of strong spectral features for run A (1420 MHz). Thresholds are (*a*) $22P_0$ and (*b*) $28P_0$. The dashed line is the Galactic pla
center.

NASA Search

~~To begin~~ Oct. 12, 1992 → began → ended → ~~revived?~~ → Died out

Microwave Observing Program (MOP)

Main improvement: frequency coverage

2 parts:

1. All sky survey - JPL - run

   Telescopes of modest 34-m diameter

   California, Australia, …

   Cover 1 - 10 GHz

   2×10^6 channels 16×10^6 channels (~ 1996)

   Channel width: 20 Hz

Coverage: 40 MHz , 320 MHz

right and left circular polarization

Sensitivity: only spend a few sec. per direction

$\Rightarrow$ strong signal

(Arecibo Planetary Radar)

out to 25 ℓy

Timespan: 6 years to cover sky once

2. Targeted search - Ames - run

(~ 800 Nearest (< 75 ly) stars like Sun)

Largest telescopes available:

Arecibo 300 m (244 stars)

+ Australia, France, …

Cover: 1 - 3 GHz

16×10^6 channels

Channel width: 1 Hz

Coverage: 10 MHz

right and left circular polarization

Sensitivity: ~ 10^3 sec. per star

$\Rightarrow 10^{-27}$ W m^{-2}

$P_{trans} = 10^{-27}$ W m$^{-2} \cdot 4\pi\, d^2(m)$

$d(m) \simeq 10^{16}\, d(\ell y)$

$P_{trans} \simeq 10^6\, d^2(\ell y)$ = 1 M Watt at 1 ℓy

e.g. 100 Mega Watts at d = 10 ℓy

Defense radars to ~ 1000 ℓy

HR 5158

EXCERPTS REGARDING SETI

101st Congress of the United States, 2nd Session

<u>From Senate Report 101-474, to accompany H.R. 5158</u>, from the Departments of Veterans Affairs, HUD and Independent Agencies Appropriation Bill, 1991, dated September 16, 1990 (Senator Barbara Mikuski--chair):

Regarding the NASA budget:

> "...For life sciences, the Committee recommends the following:
>
> -$25,000,000 from the $168,000,000 requested for life sciences, to be taken as a general reduction, subject to the normal reprogramming guidelines. None of this reduction is to be taken from the request for the search for extraterrestrial intelligence (SETI) program.
>
> "In recommending the full budget request of $12,100,000 for the SETI program, the Committee reaffirms its support of the basic scientific merit of this experiment to monitor portions of the radio spectrum as an efficient means of exploring the possibility of the existence of intelligent extraterrestrial life. While this speculative venture stimulates widespread interest and imagination, the Committee's recommendation is based on its assessment of the technical and engineering advances associated with the development of the monitoring devices needed for the project and on the broad educational component of the program. The fundamental character of the SETI program provides unique opportunities to explain principles of such scientific disciplines as biology, astronomy, physics, and chemistry, in addition to exposing students to the development and application of microelectronic technology.
>
> "The Committee has included the full request of $2,000,000 for the Lifesat project..."

1990

$14.5 MILLION FY92

<u>From the Joint House-Senate Conference Report for Veterans Affairs, HUD and Independent Agencies</u> (approved on October 17, 1990):

$0 FY94 !

Regarding the NASA budget:

> "...- $25,000 from Life Sciences
>
> "The Conferees agree that within the balance of funds available in this action, $12,100,000 shall be allocated to the Search for Extraterrestrial Intelligence and $2,000,000 for Lifesat..."

SETI Office/10-90

SEARCH IS DESCRIBED IN CHAP. 9

Congress may hang up on research of E.T.s

■ Extraterrestrials won't be able to phone home if there's nobody on earth to take the call

By Keay Davidson
New York Times News Service

SAN FRANCISCO — Who killed E.T.?

An effort by the National Aeronautics and Space Administration effort to detect signals from extraterrestrials has been axed by Congress.

Experts blame everything from its "giggle factor" to poor salesmanship to Congress' unwillingness to cut politically stronger programs.

Hollywood has made big money from fictional extraterrestrials, and they clutter TV shows and grocery-store tabloids.

But NASA's $104 million attempt to find real aliens — the Mountain View, Calif., High Resolution Microwave Survey — was too costly for a joint congressional committee. It agreed to end the program just one year into its planned 10-year search. The program is popularly known by its previous name, Search for Extraterrestrial Intelligence, or SETI.

"I'm pretty depressed," said Pe-

Critics accuse Congress of making SETI a sacrificial lamb after failing to kill two programs — the oft-maligned space station and the $3 billion Advanced Solid Rocket Motor, which *Reader's Digest* last year called "the unstoppable pork booster." It's based in Yellow Creek, Miss., home to Democratic Rep. Jamie Whitten, who until last year chaired the House Appropriations Committee.

Project staff members took pride in the program's size. "Each space shuttle launch has been estimated to cost as much as $1 billion. That's a century worth of SETI research," said Seth Shostak of the quasi-private SETI Institute in Mountain View.

But politically, "the SETI people made a fundamental mistake — stupid, stupid, stupid! — in the way they've been lobbying for their programs," said John Pike, a policy expert with the Federation of American Scientists in Washington. "SETI is one of the things that is most readily understood and widely appreciated by the public.

Ralph De Gennaro, a senior budget analyst for Friends of the Earth in Washington, D.C., shed no tears for SETI.

"I'm sick and tired of being told that we can't afford to save this planet but we do have enough money to listen to aliens on other

Project Phoenix 1998-2004

SETI Institute (- minus NASA $$)

Private Funding (Packard of HP)

Relocated to Australia 64 - m telescope

Used various other telescopes, including Arecibo

1.2 - 3.0 GHz , 28×10^6 channels, 1 Hz channel width

Targeted search: 850 nearby stars within 240 ℓy

Sensitivity ~ 1×10^{-26} W m^{-2}

Could detect 1 Mega Watt if beamed to us by similar size telescope

Used a second telescope to discriminate against interference

No civilizations found

Allen Telescope Array (ATA)

SETI Institute, UC Berkeley

Major telescope dedicated to SETI

Partially constructed, some operations (2006)

Cost ~ 26 M \$ ~ 1/2 provided by Paul Allen,
Nathan Myrvold (Microsoft)

Hat Creek, California 350 × 6 m antennas

1 - 10 GHz

Began operation with 42 telescopes in Oct. 2007

Allen Telescope Array (ATA)

First major telescope designed for searching for signals from other civilizations.

Initial funds from Paul Allen (Microsoft)

Goals for Allen Telescope Array

Survey 1,000,000 stars for non-natural extraterrestrial signals with enough sensitivity to detect the equivalent power of the Arecibo radar out to 1000 light-years within the frequency range of 1 to 10 GHz

Survey the 4×10^{10} stars of the inner Galactic Plane in the “water hole” frequency range from 1420 MHz to 1720 MHz for very powerful, non-natural transmitters

Was not completed. They need funding for more antennas. Now operated by SRI, got some funds from tech entrepreneur, still seeking more.

Expanding the Search Radius

Comparison of the Allen Telescope Array and Project Phoenix

Searches with Visible Light

For pulsed signals, visible light from lasers.
Some advantages. Can concentrate light in narrow band, short pulses to distinguish from star light.
They have to be beamed toward us.

Optical SETI at Harvard: 1.5-m telescope
4×10^{-9} W m^{-2} in nanosecond pulses
Plan to observe 13000 stars. Also a northern sky survey.

Optical SETI in California 1-m telescope
Multiple detectors to avoid false signals.

Leakage Radiation with Visible Light

- Hard because stars emit visible light
  - But fluorescent/LEDs have different spectra
  - Could detect major city light from object in outer solar system
  - Maybe later around other stars with much bigger telescopes
  - Loeb and Turner, 2012

“Leakage” Radiation in Infrared

- Kardashev classified Very advanced civs.
  - Type 1 all solar energy on planet
  - Type 2 all energy of star
    - Dyson sphere (emits in infrared)
  - Type 3 all energy of galaxy
    - Should have huge infrared excess around 10-20 micrometers wavelength
    - Recent Search: none with more that 85%
    - All probably starbursts, but some unusual ones
    - Griffith et al. 2015

Future Dreams

- Square Kilometer Array (SKA)
  - Use many smaller units
  - Total area about 1 square km
  - Similar to, but beyond, “Argus” in Contact
  - Probably will be three separate arrays
    - To cover full range: 100 MHz to 50 GHz
    - Two decided, one in Australia, one in South Africa

Square Kilometer Array (SKA)