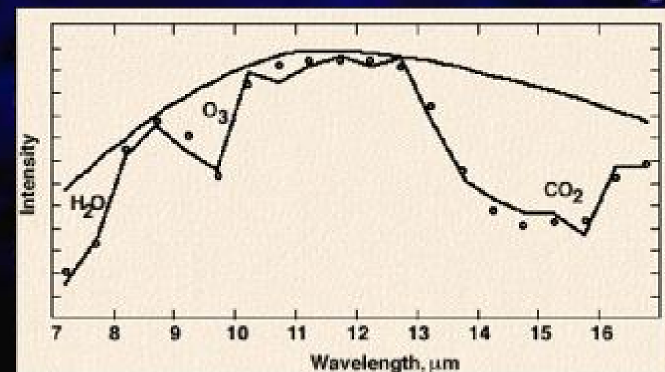
# HOW DO WE SEARCH FOR LIFE IN THE UNIVERSE?




# The Search for Life

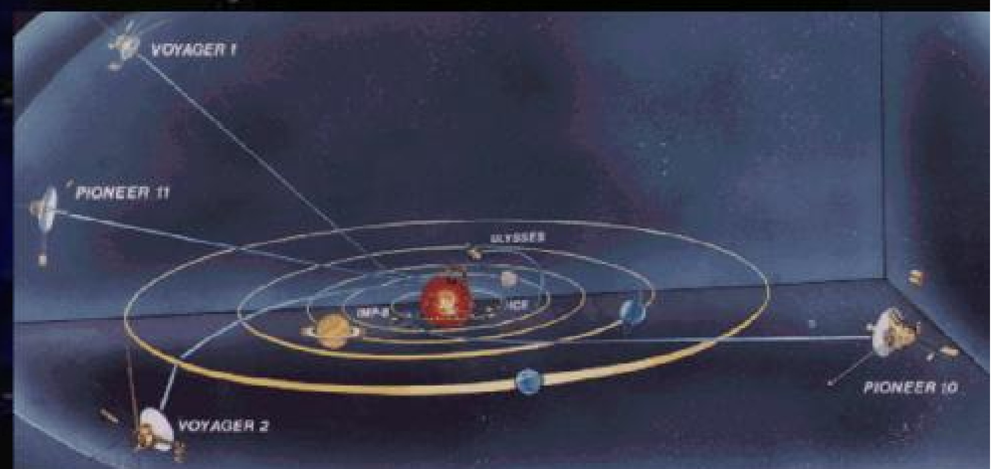
- Robotic Emissaries

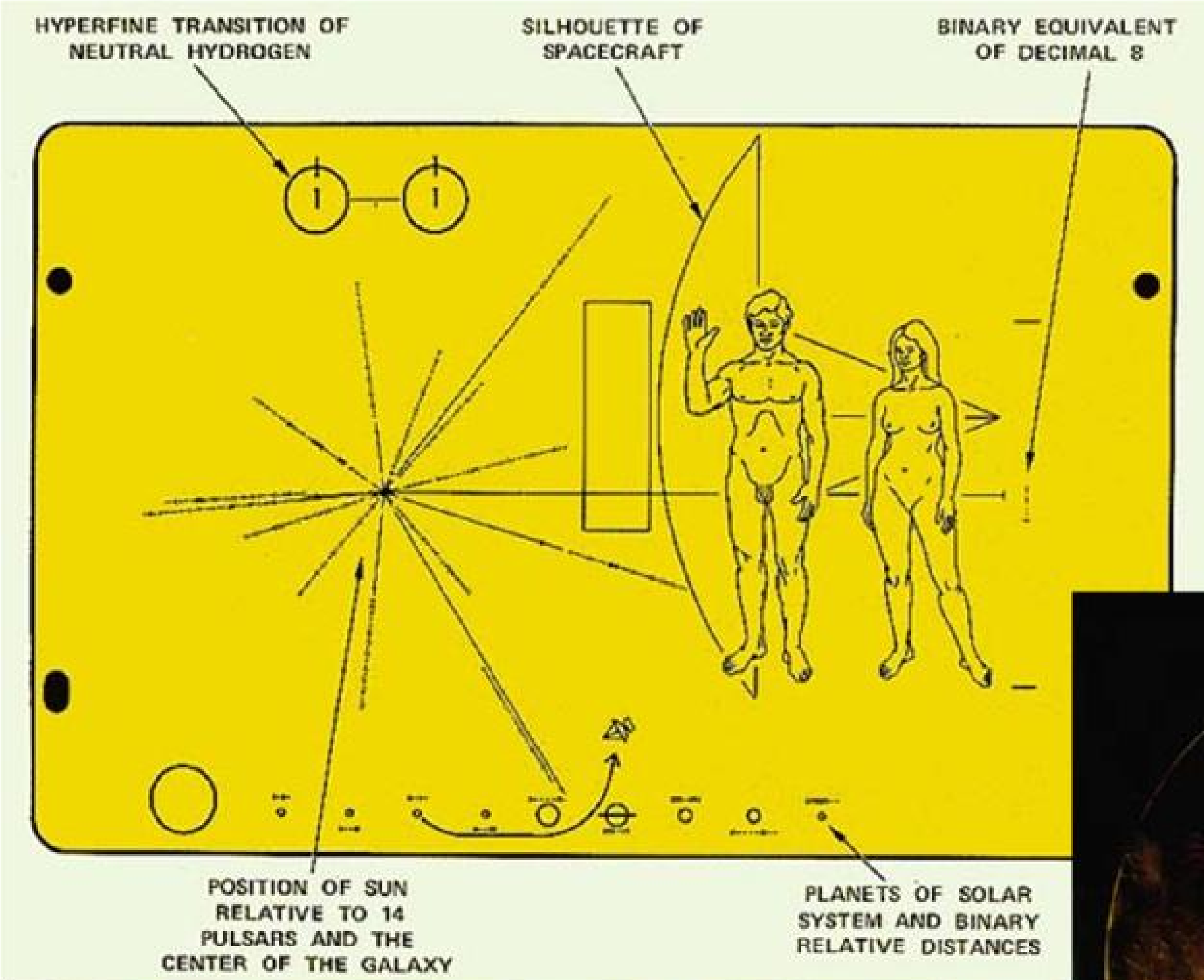
- Remote Detection

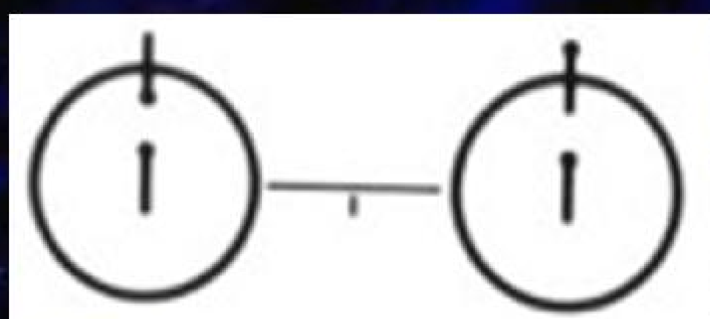
# Robotic Emissaries

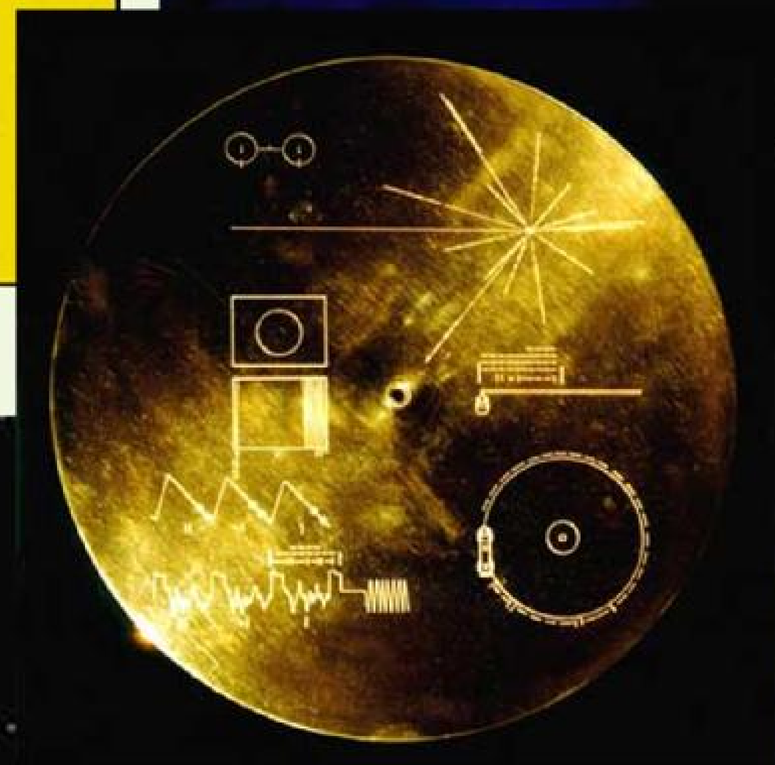
- Pioneer 10 & 11 (1972/3)
- Voyager 1 & 2 (1977)

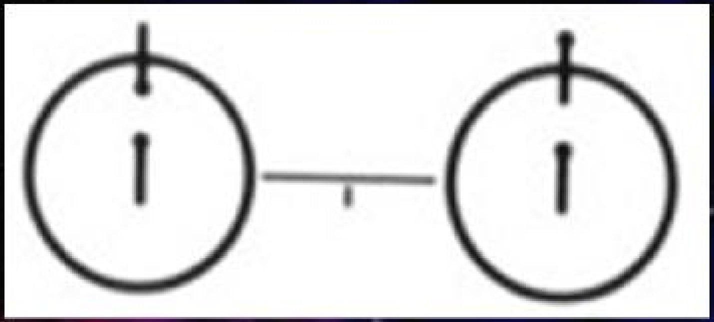
- Traveling 23,000 – 39,000 mi/hr
- Essentially no onboard guidance system
- Random encounter with a stellar system in $10^{19}$ years




HYPERFINE TRANSITION OF NEUTRAL HYDROGEN
SILHOUETTE OF SPACECRAFT
BINARY EQUIVALENT OF DECIMAL 8
POSITION OF SUN RELATIVE TO 14 PULSARS AND THE CENTER OF THE GALAXY
PLANETS OF SOLAR SYSTEM AND BINARY RELATIVE DISTANCES







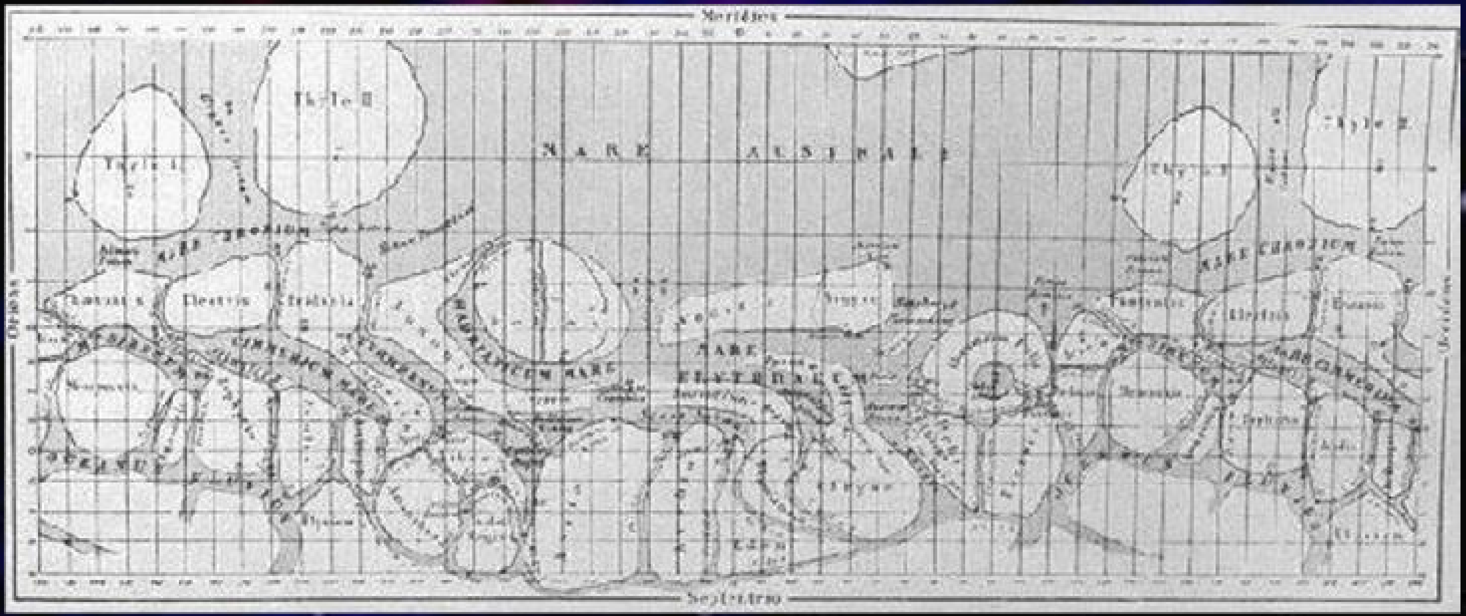
$\lambda = 21$ cm

$\nu = 1420$ MHz

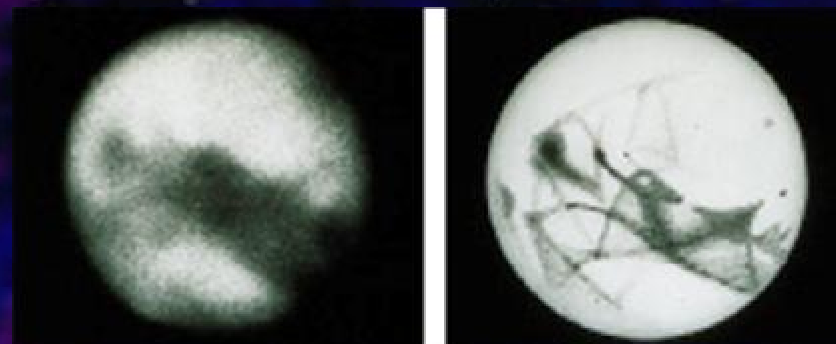
One cycle or wavelength passes every $7.042 \times 10^{-10}$ sec

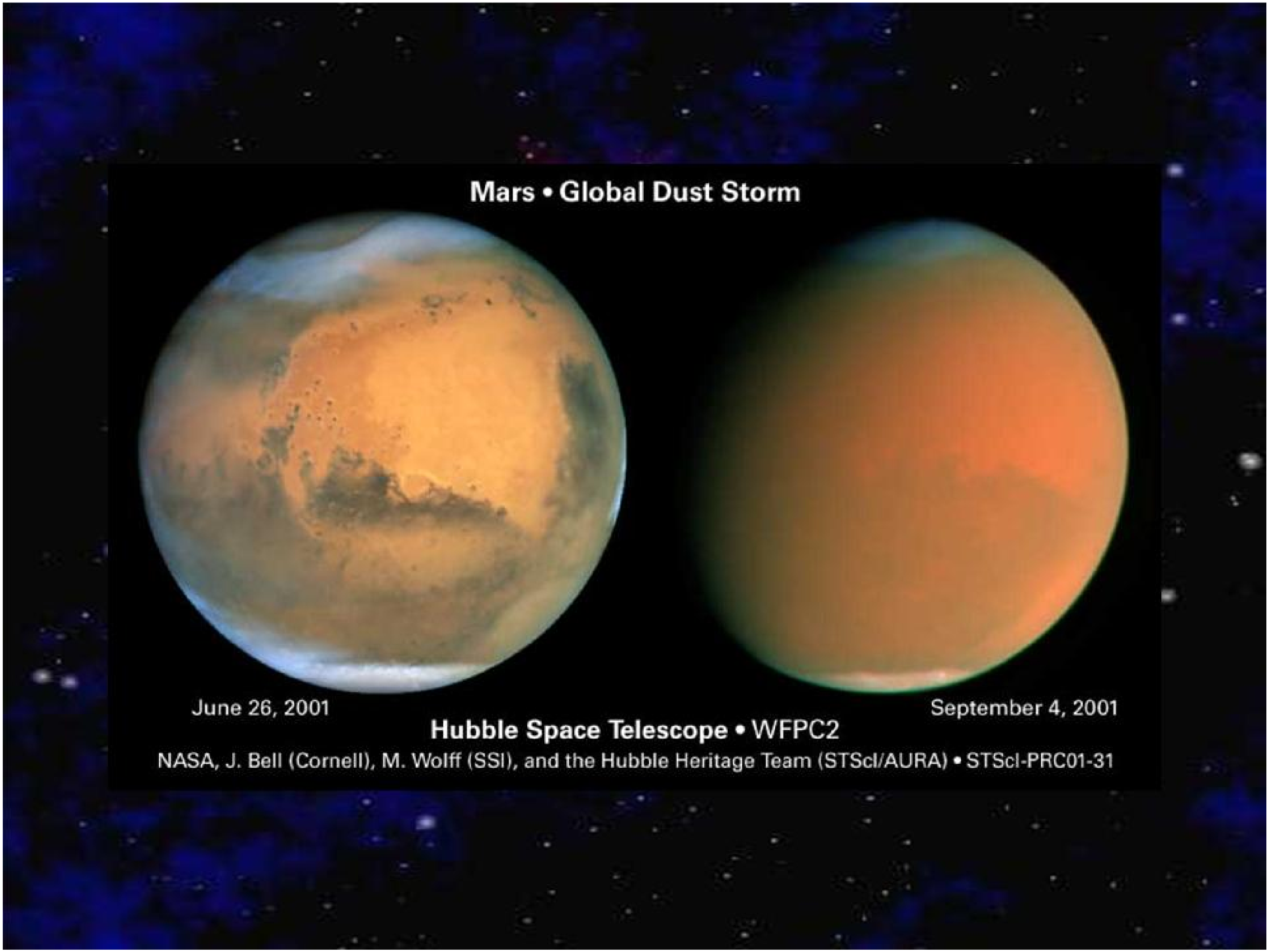
# The Search for Life on Mars

# Giovanni Schiaparelli (1877)

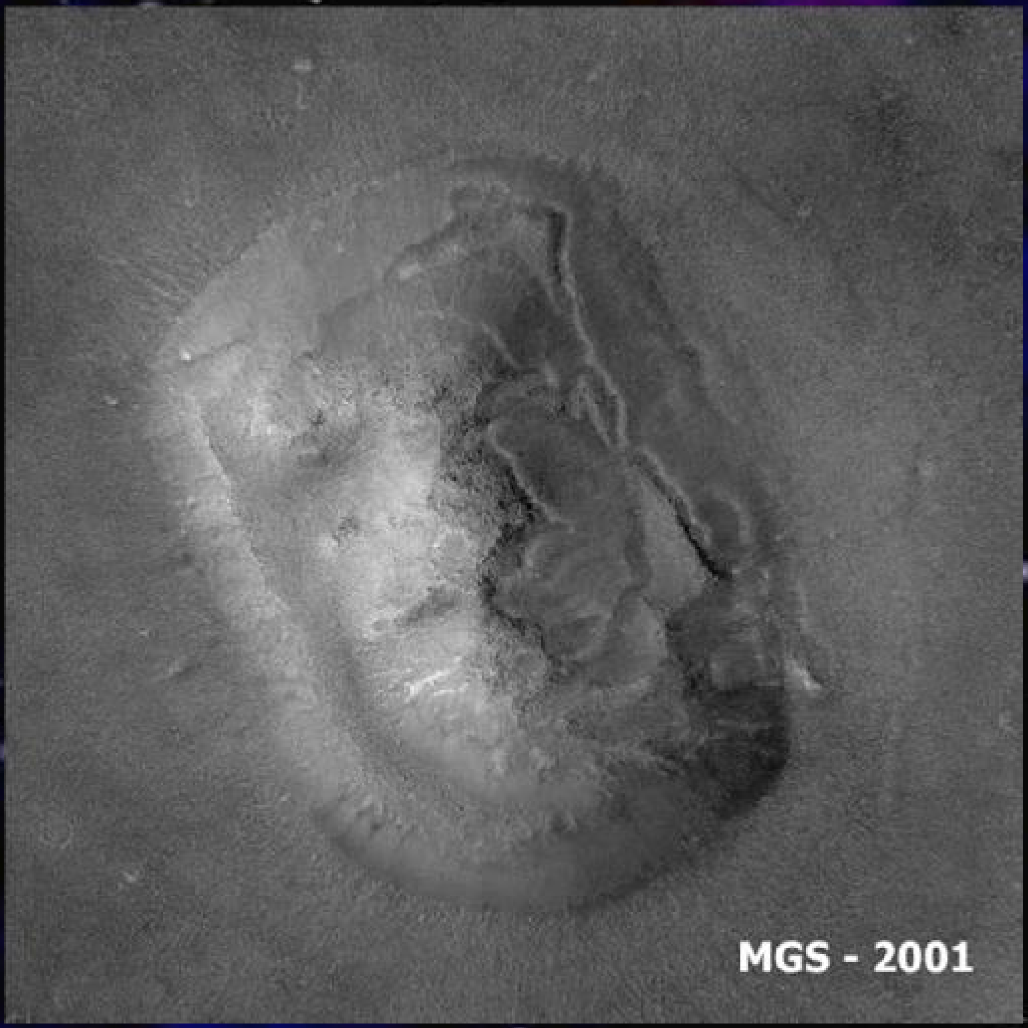


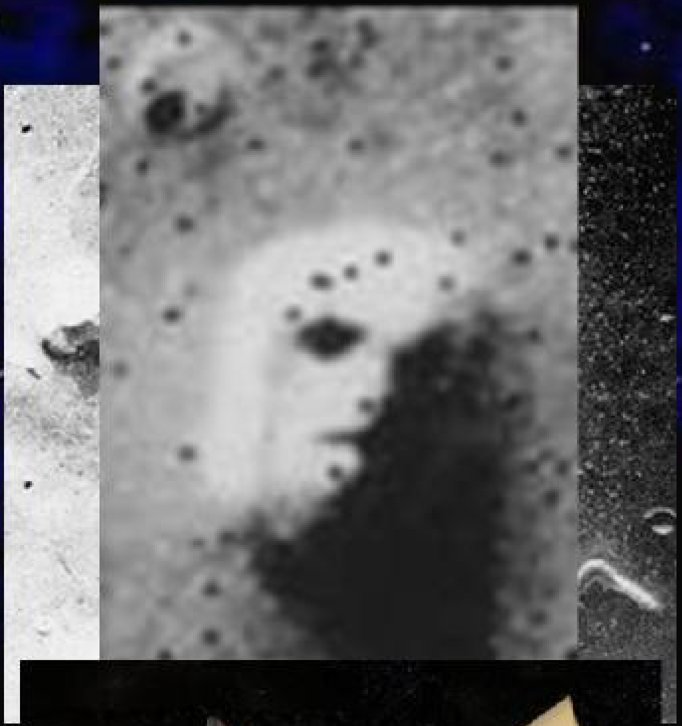
# Percival Lowell (1894 – 1916)




Mars • Global Dust Storm
June 26, 2001
September 4, 2001
Hubble Space Telescope • WFPC2
NASA, J. Bell (Cornell), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31

# The “Face” on Mars



# Martian Meteorites

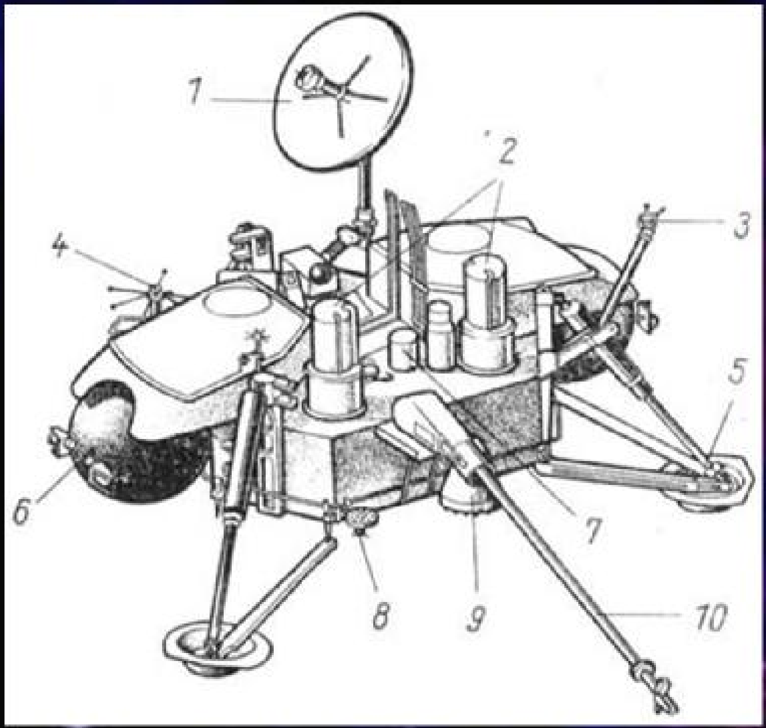
- Crystals of iron pyrite
- Nodules of carbonate
- PAH's (organic material)
- Fossil bacteria?

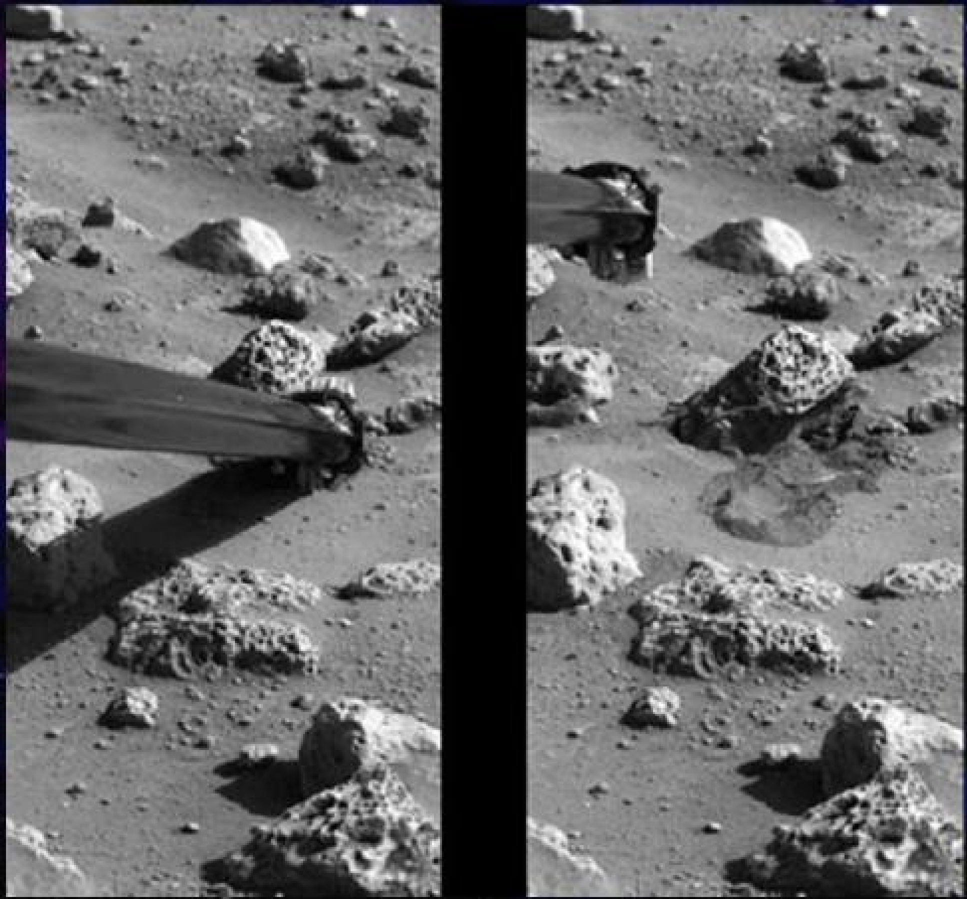

# Life on Mars?

- History of water
- History of thicker atmosphere
- Probable Earth-like geologic history



# Viking I & II (1976)

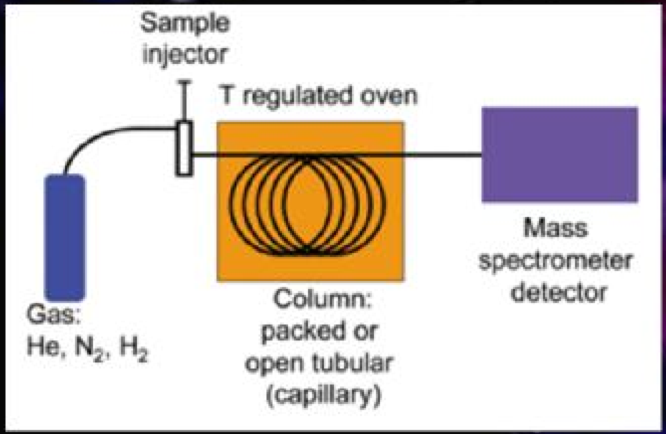


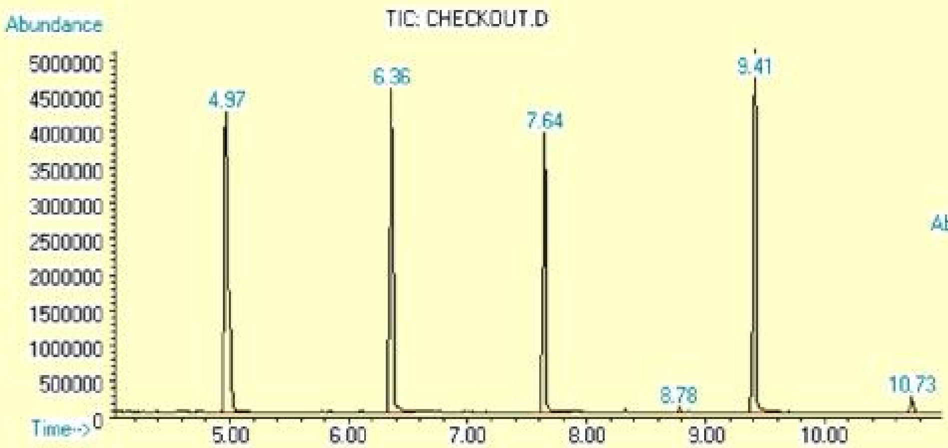



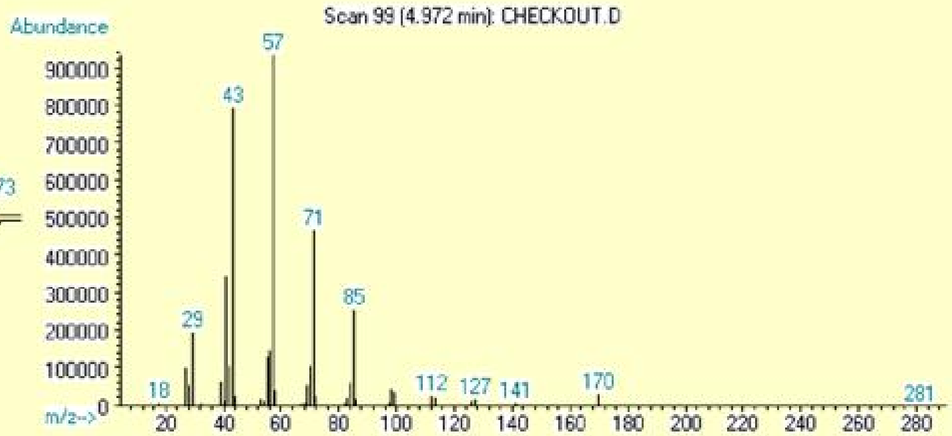
# Viking Biology Experiments

- No organic compounds found in soil
- Atmosphere: very small amounts of methane and nitrogen
- Biological experiments based on Earth-like life (is this realistic?)
- Three biological experiments performed on Martian soil

# GC-MS Gas Chromatography-Mass Spectrometry



# Viking Biology Experiments

**GEX**: Gas Exchange – "feed" the soil

- Gas chromatograph measured composition of gasses in chamber before/after feeding

**LR**: Labeled Release – look for respiration

- Look for radioactive carbon in gaseous form.

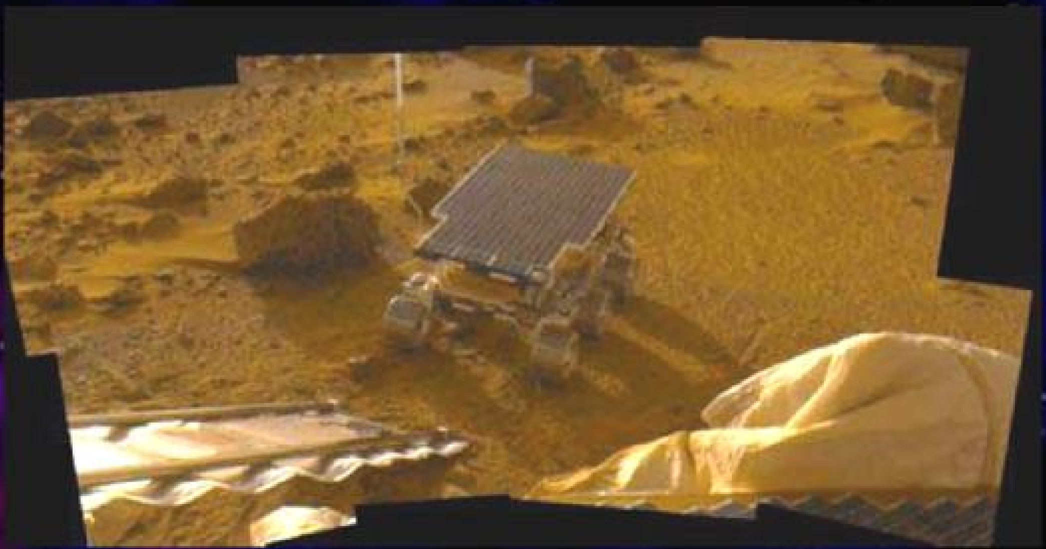
**PR**: Pyrolitic Release ($^{14}C$) – "Roast" the soil

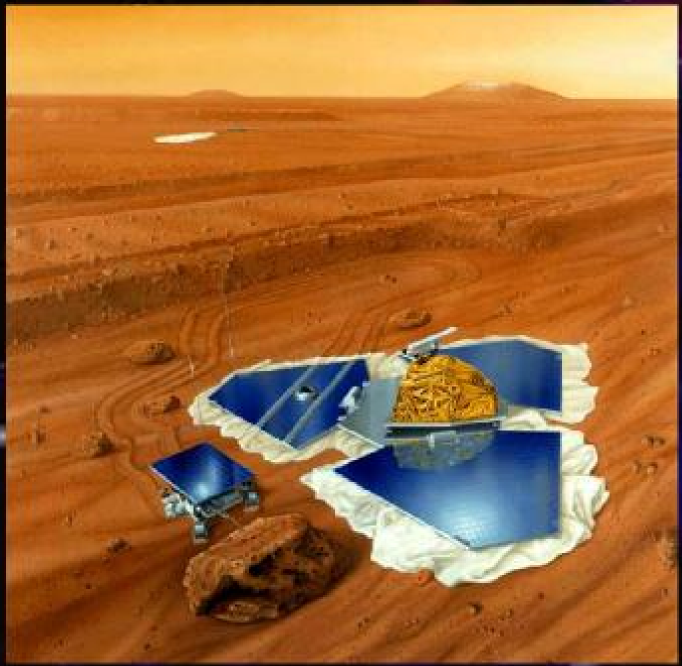
- look for radioactive carbon in atmosphere.

# Viking Biological Experiments Results:

- All 3 gave positive results!
- BUT!  All positive results can be produced by non-biological chemical reactions.

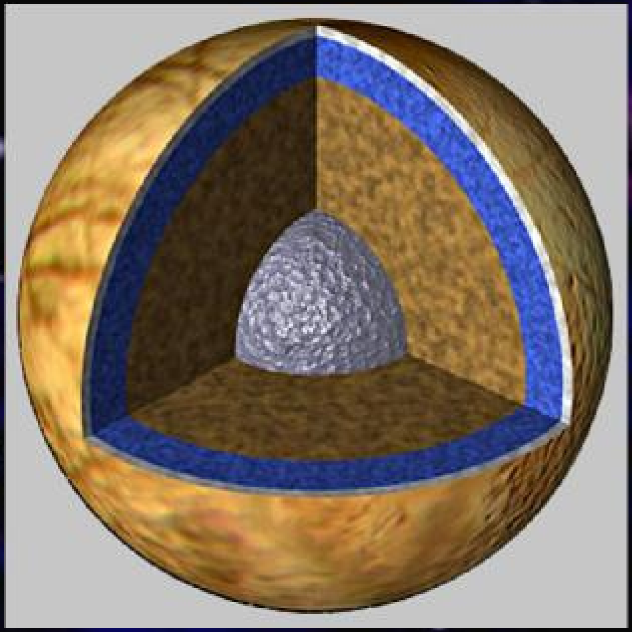
# Pathfinder
# (1997)

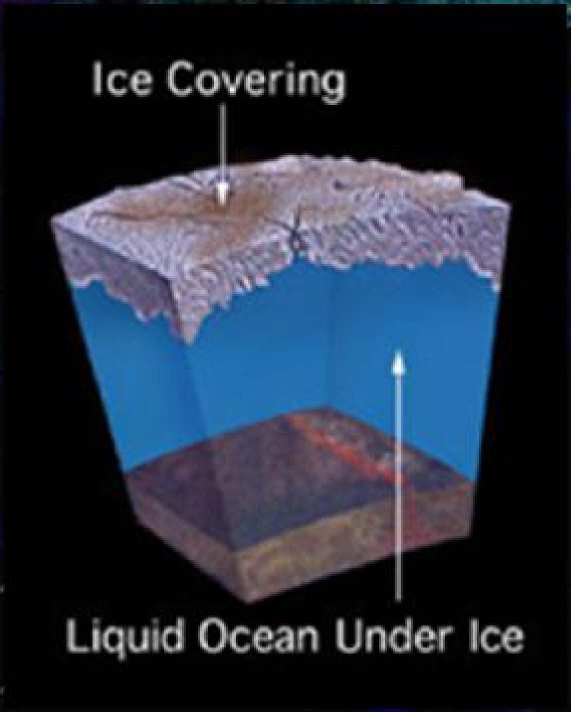




# Europa Ocean Explorer (20??)

- Arrive 20??





# The Search for Life:
## Remote Detection

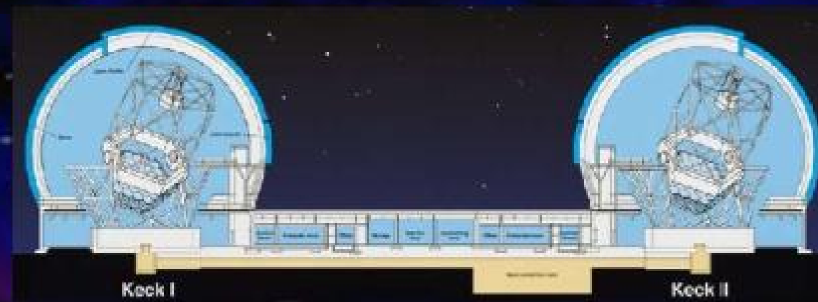
If it existed we currently couldn't detect it

Why?

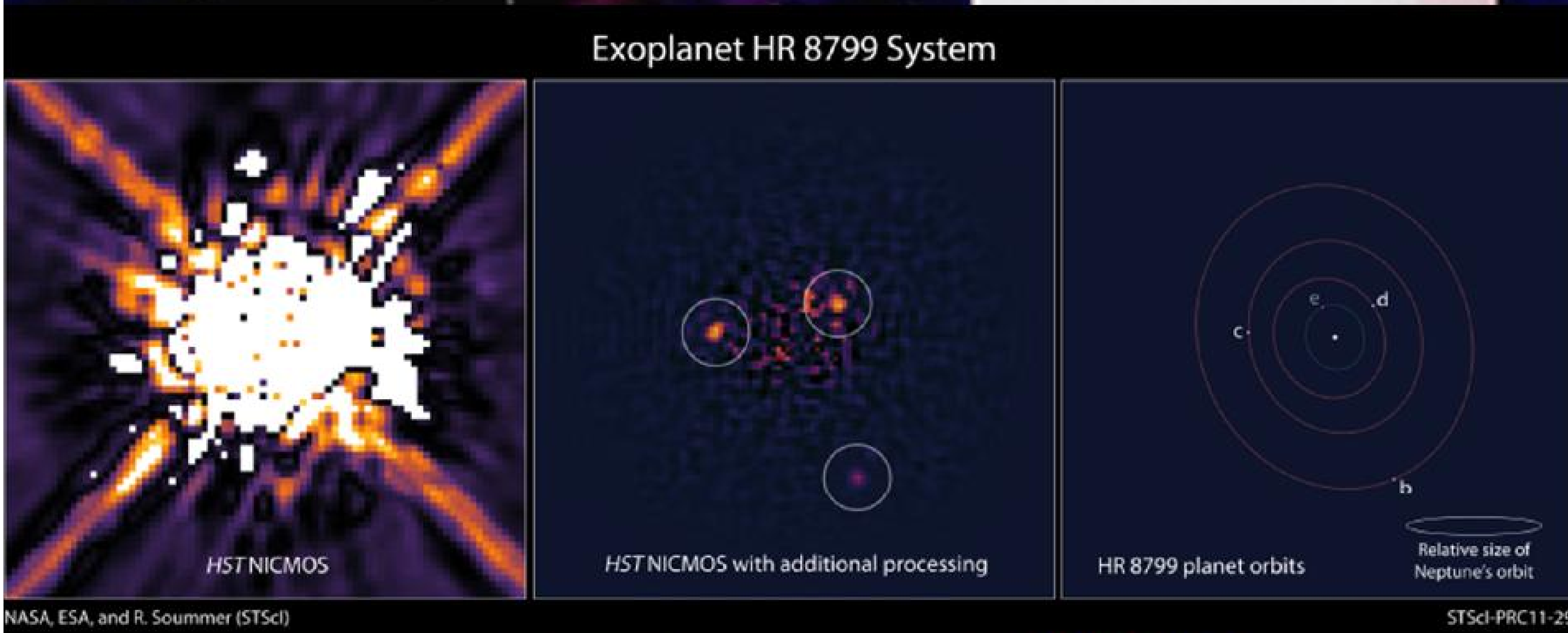
- We can detect the presence of extrasolar planets
- We cannot image the planets themselves
- Light from host star is too overwhelming

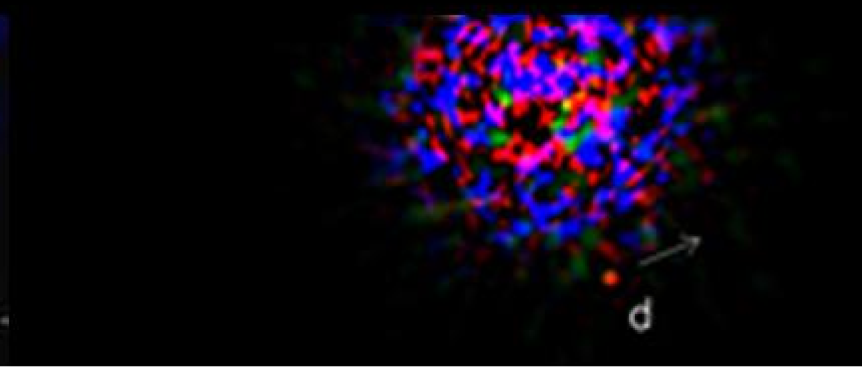
# What technology is necessary?

- Interferometry for high resolution
- Space based or ground based
- Nulling technology to reduce glare of host star




# Nulling Technology



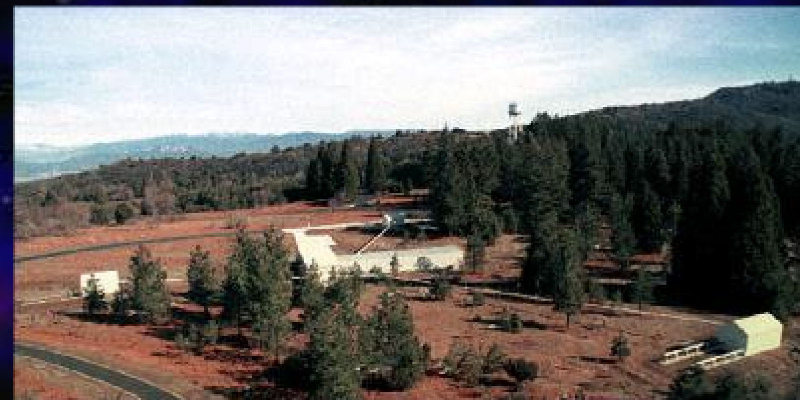
# What Do We Look For?

- Image extrasolar planets (if not planets maybe their moons)
- Look for chemical signatures for life
- Make detailed images of extrasolar planets

# Planetary Imaging

Interferometric Projects (ground based):

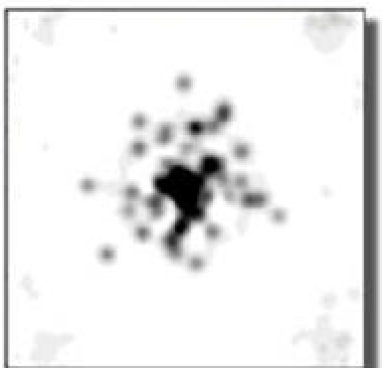
- Palomar Testbed Interferometer
- Keck Interferometric Array
- CHARA (Mt. Wilson)
- Others...

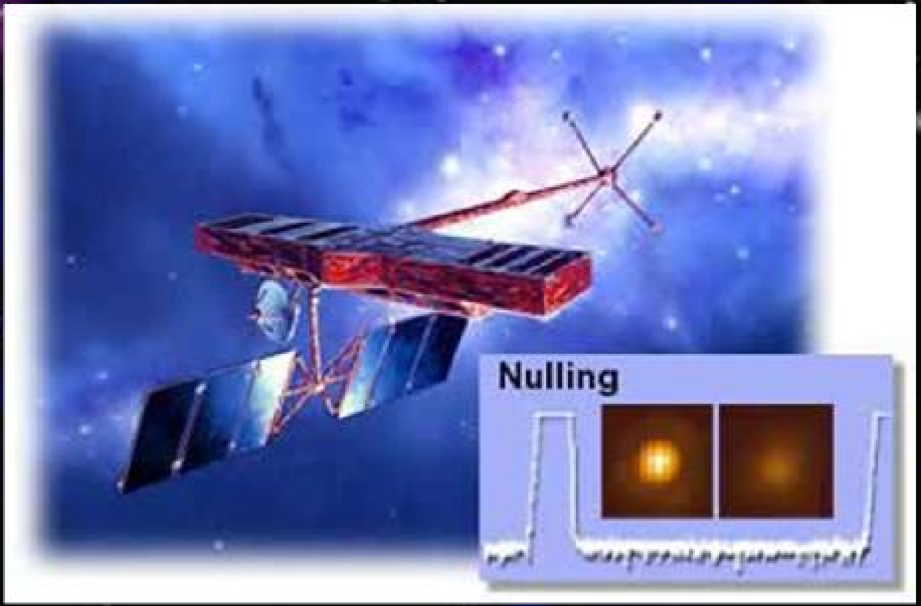


# Space Interferometry Mission (SIM, NASA)

- **Lower mass limit of 5 earth masses detection out to 10 parsecs (33 LY)**
- **Lower mass limit of 1 earth mass detection out to 16 LY**

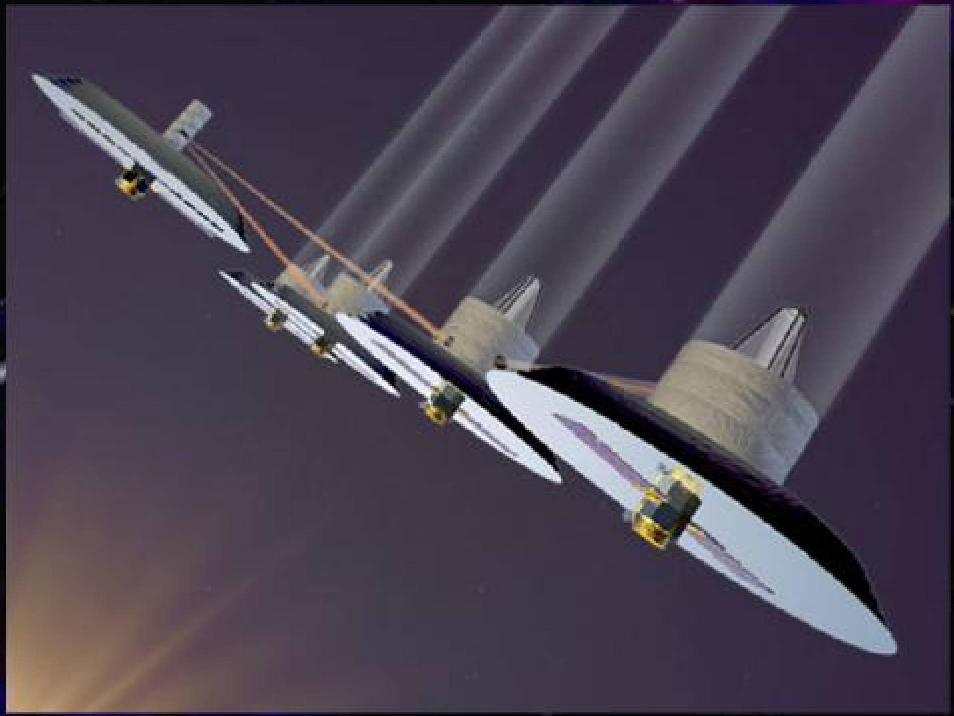

HST Imaging Resolution.

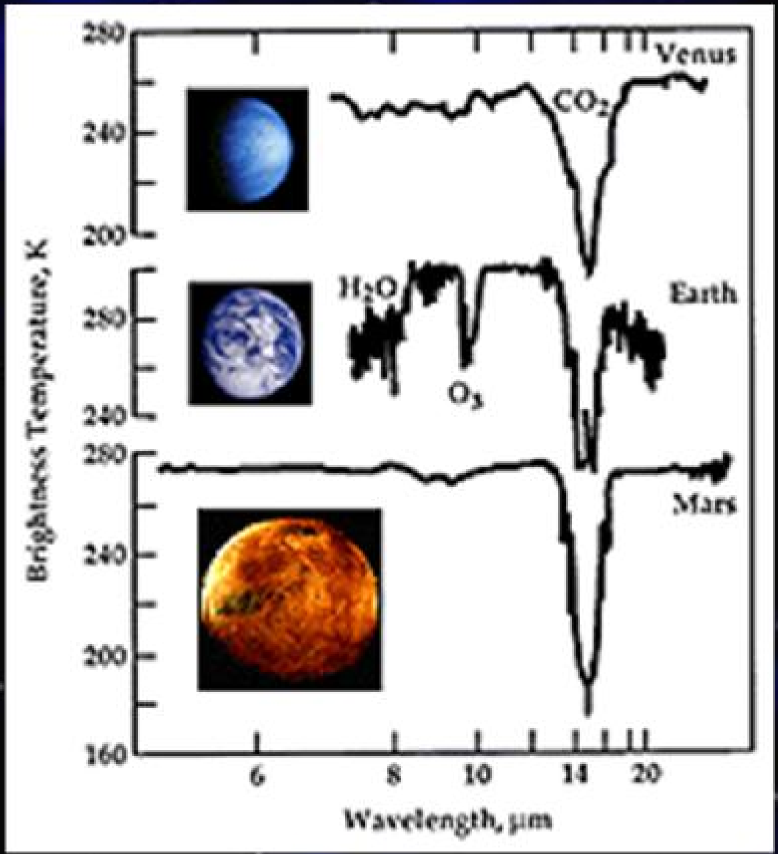

SIM Imaging Resolution (simulated).



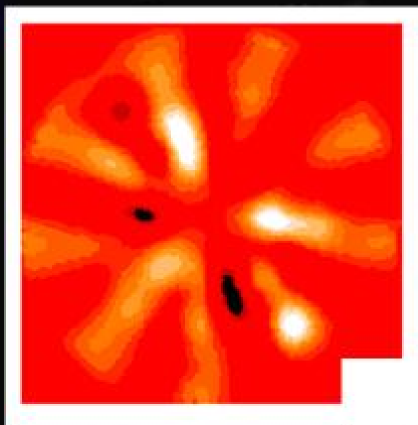
# Terrestrial Planet Finder
(TPF, NASA)

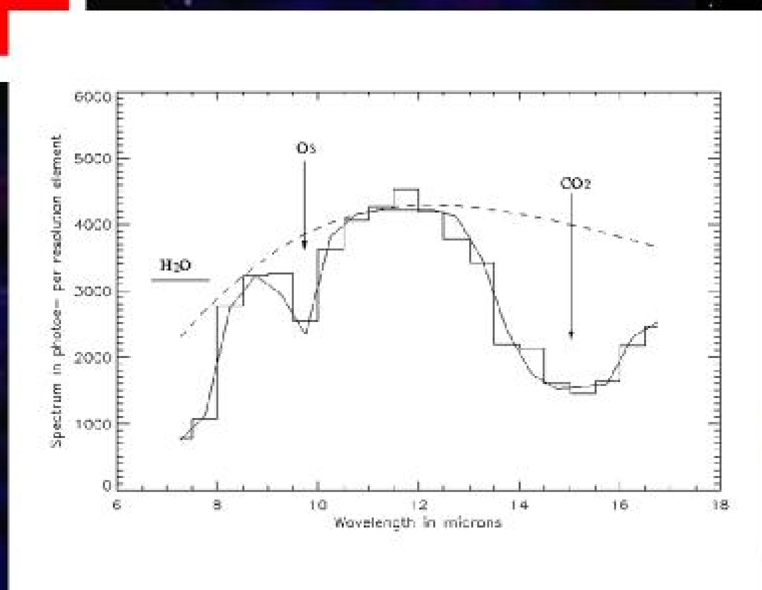
**Detection of 1 earth-mass planets out to a distance of 50 light years**





# DARWIN (ESA)

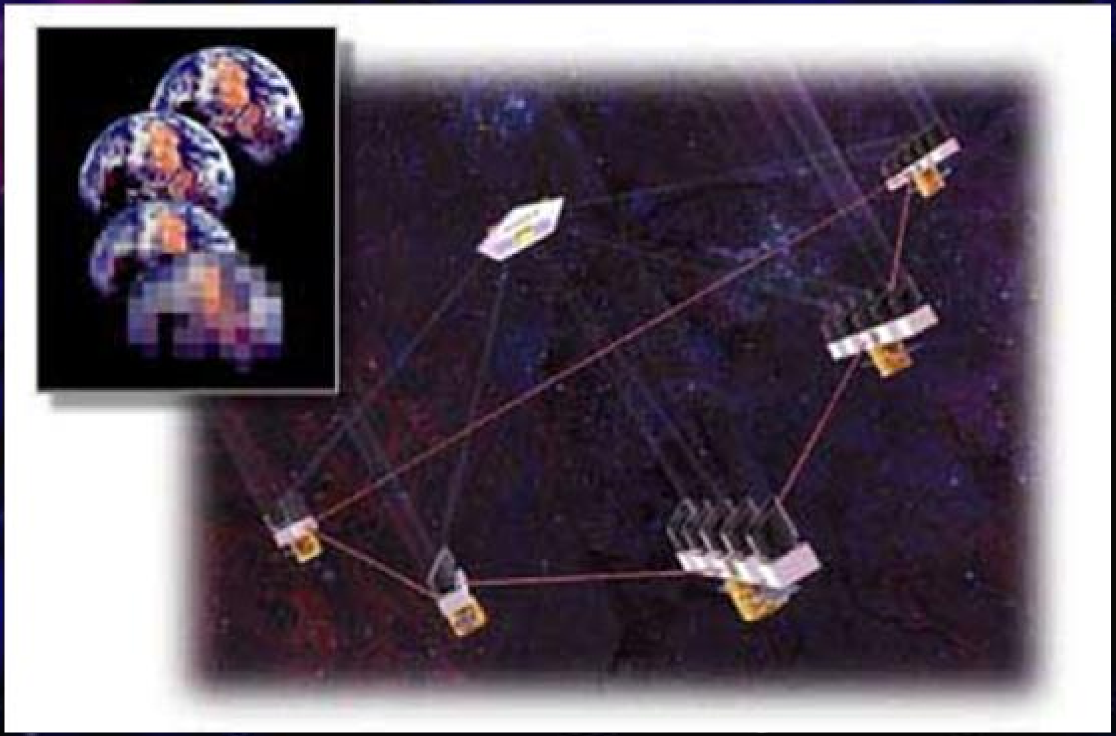



6000
5000
4000
3000
2000
1000
0
6
8
10
12
14
16
18
Wavelength in microns
O3
CO2
H2O

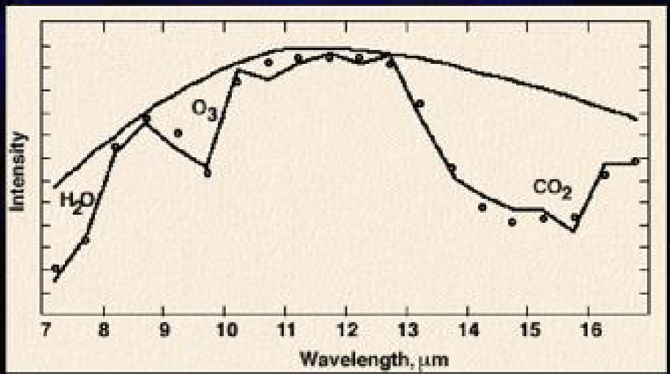

ALCATEL

# Planetary Imager (PI, NASA)

- 6000 km baseline
- 8-m telescopes



# HOW DO WE SEARCH FOR LIFE IN THE UNIVERSE?




# Necessary Assumptions

- All civilizations follow a certain set of broad universal pathways.
- There are civilizations that are far more advanced than we are.
- Not everyone is simply listening.
- Civilizations that have the desire to make contact would have done so by now.

# Remote Detection

- Assume that communication would be cheaper and more efficient than space travel.
- Eavesdropping vs. listening for a deliberate message.
- Comprehensive searching vs. targeted searching.

# Remote Detection (cont'd)

- Current technology allows detection of the equivalent of radio and television from nearest 1000 stars

Courtesy and ***caution*** suggest that:

- first we listen…
- then we send out our own *intentional* messages

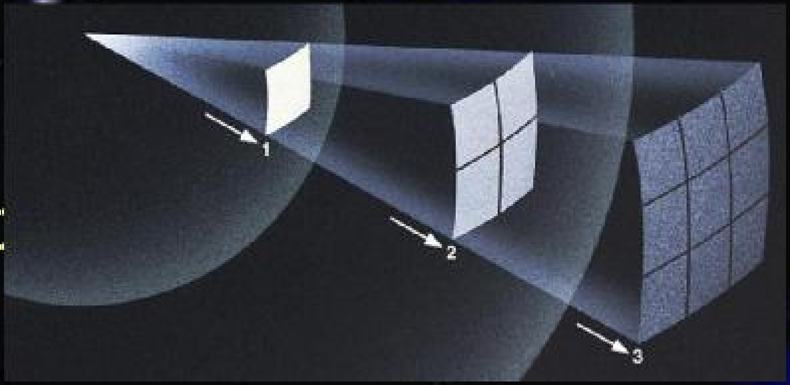
# Comprehensive Searching vs. Targeted Searching

**Comprehensive searching** involves a brief look at each region of the sky

- Wide field of view won't be sensitive to weak signals

The inverse-squared law of light:

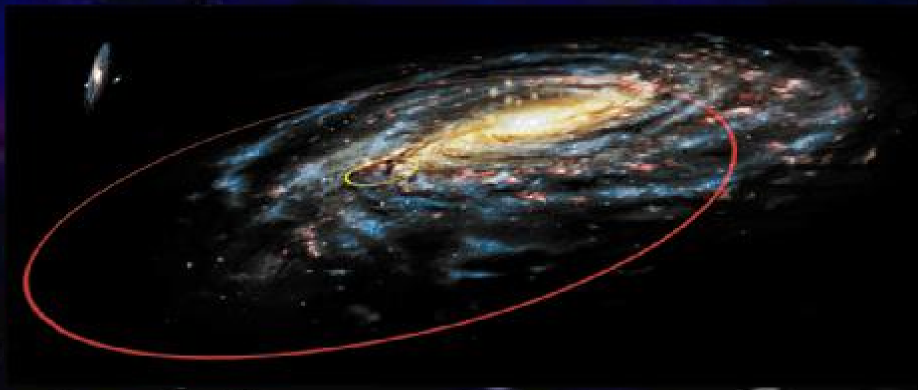
- Begin by looking at nearest candidates (expect stronger signals)



# Comprehensive Searching vs. Targeted Searching (cont'd)

**Targeted searching** involves lengthy observations of select stars

- Several thousand stars in solar neighborhood that qualify
- Sensitive to weak signals
- Time consuming...



*Why not do both?*

# Different types of signals

(1) **Local communication** (television/radio)

- First "strong" television signals – 1950's
- Signals are spread out
- Detectable out to 1 light year

**Military radar**

- More focused/higher energy
- Detectable out to 10's of light years

# Different types of signals (cont'd)

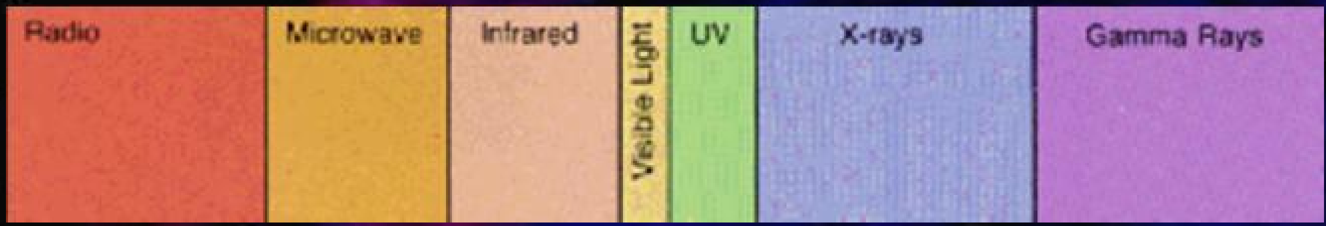
(2) **Interplanetary signals**

- No stronger than radio/television

(3) **Intentional ET signal**

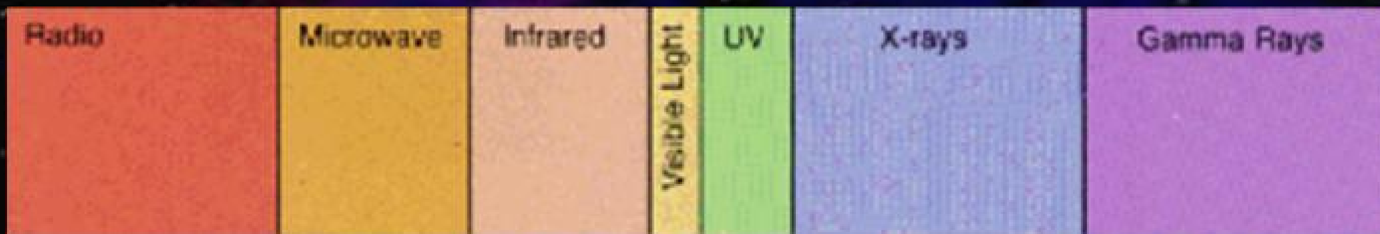
- Signals are strong and focused

# Searching the Electromagnetic Spectrum: Natural Sources




- Exotic Interactions: Gamma Ray, X-ray
- Quasars: X-ray, UV, Visible, Radio
- Pulsars: X-ray, Visible, Radio
- Stellar: UV-IR (near)
- Interstellar gas: Visible, Radio
- Interstellar Dust: IR
- Synchrotron radiation: Radio
- Cosmic Background Radiation: Microwave

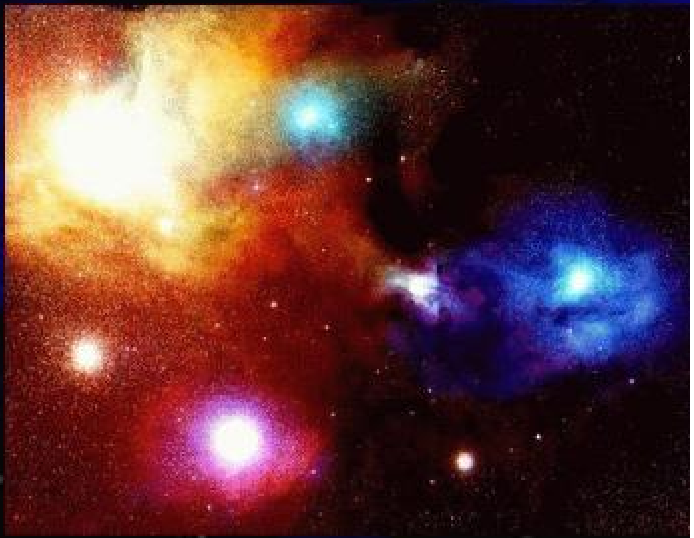
# What portion of the EM spectrum can be used?




- Natural sources allow us to eliminate certain regions of the EM spectrum
- Physical limitations allow us to eliminate other regions of the EM spectrum

# Problems with Visible Light

- Interstellar gas & dust absorb visible light
- Lasers are narrow and concentrated but must be pointed directly at target
- Visible light photons carry $10^6$ times more energy than radio and therefore require $10^6$ times more energy to send message
- Visible photons must compete with stellar host to be detected

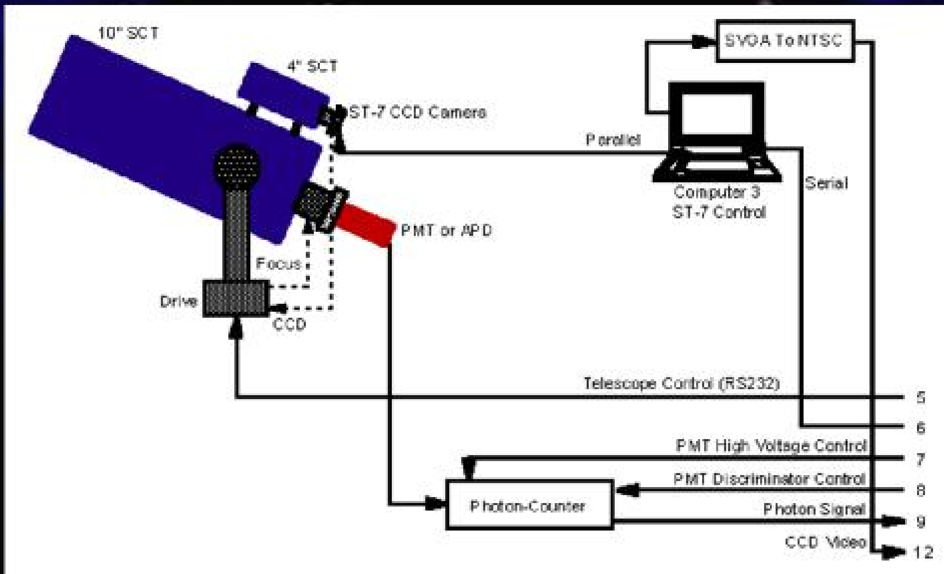


# Optical SETI

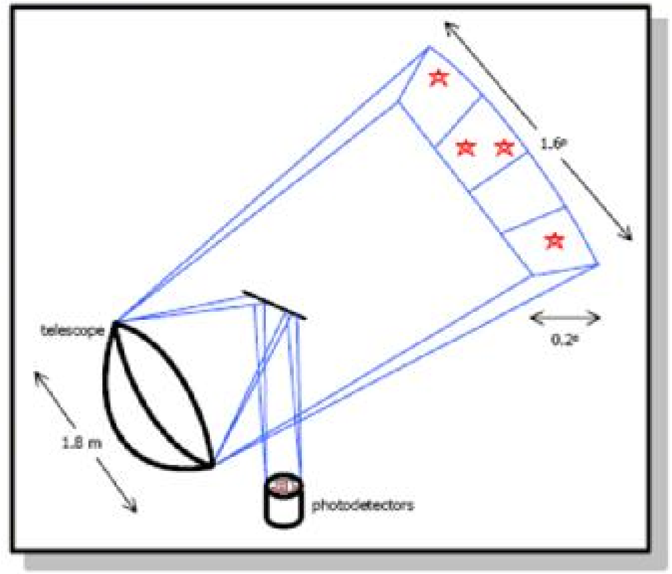
## Lick Observatory

- Search for continuous and pulsed emission from nearby stars
- Signal would appear as an ultra-narrow band emission line in the visible spectrum of a star
- “HELIOS” laser could send a one-nanosecond pulse that would appear 3000 times brighter than the Sun to worlds up to 1000 light years away

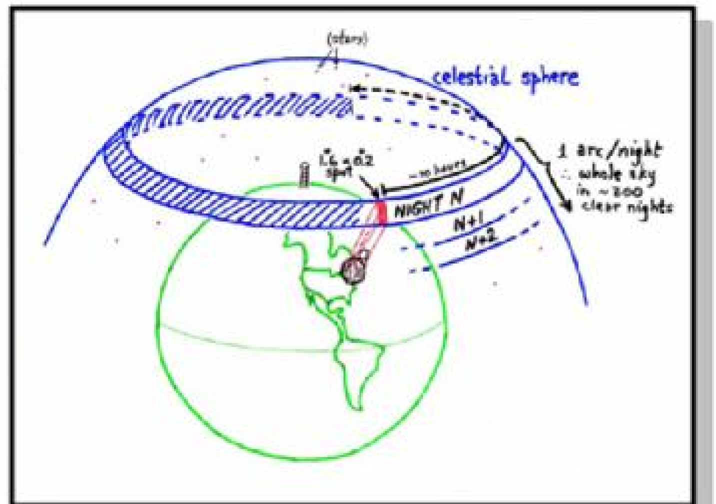
# Optical SETI








All-sky survey will employ a 1.8 m telescope observing a 1.6 x 0.2 degree field using two arrays of 512 photomultiplier tubes (coincidence arrangement not shown above).

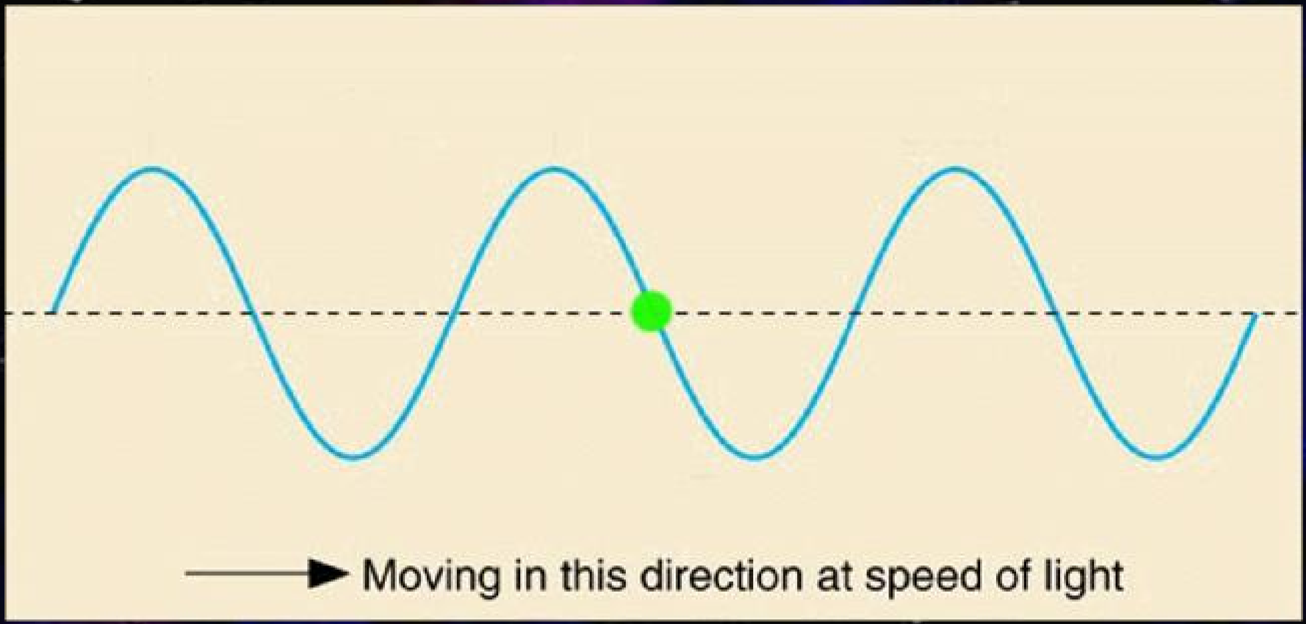


# Radio Light

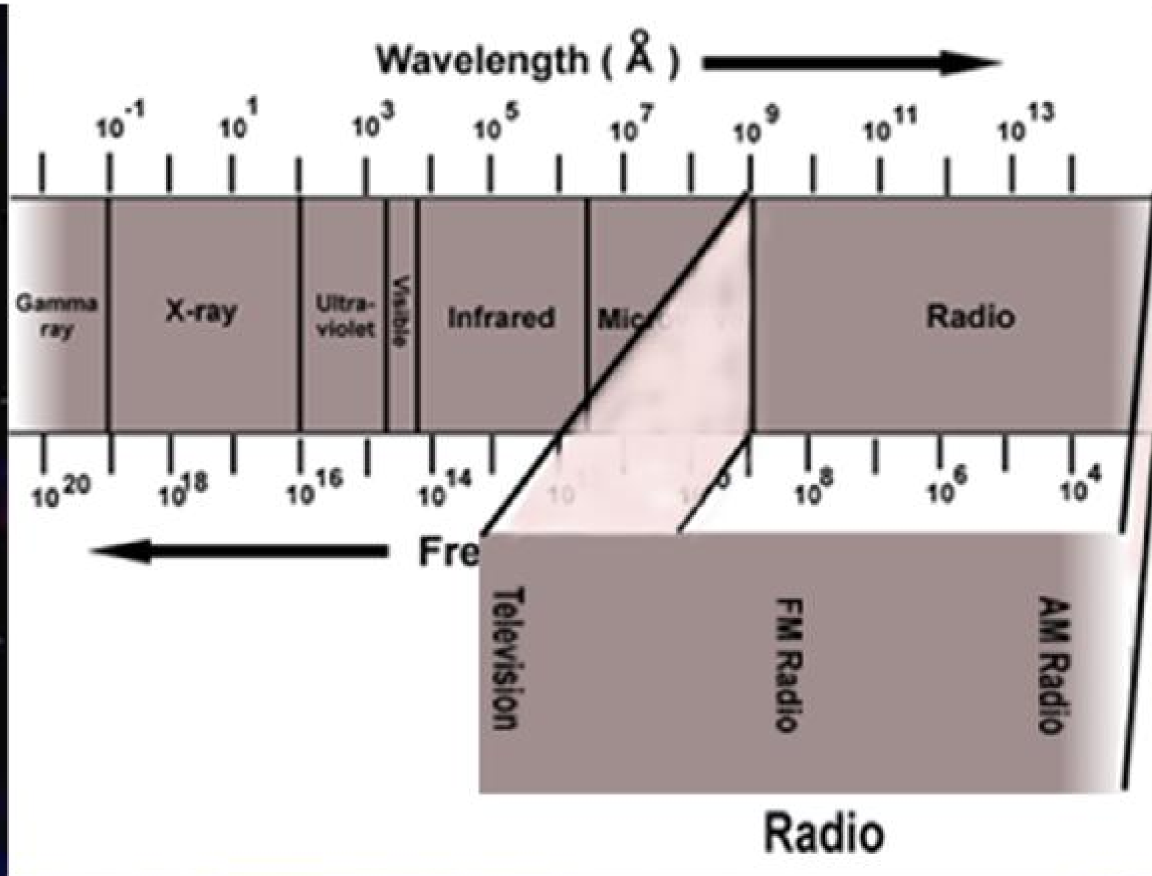
- Long wavelength can easily penetrate Interstellar gas and dust
- Natural part of radio and television signals leaked into space

**Might be a good sign of intelligence!**

# FREQUENCY




- The number of “cycles per second” that pass a given point.
- Hertz (Hz) where 1Hz = 1 cycle/second




AM Radio: 540 KHz – 1650 KHz

FM Radio: 88 MHz – 108 MHz

Television: 1 GHz – 100 GHz

# FREQUENCY

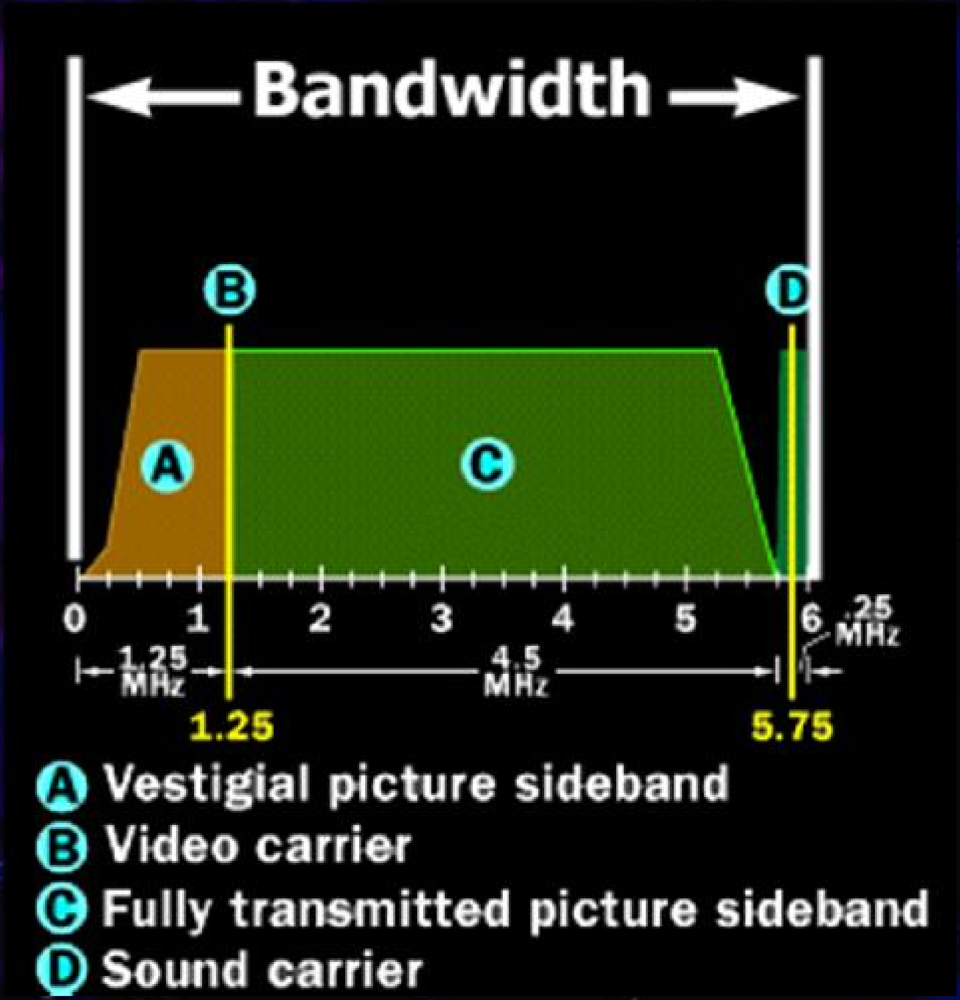
- Pronounced minimum of cosmic radio noise @ 1420 MHz

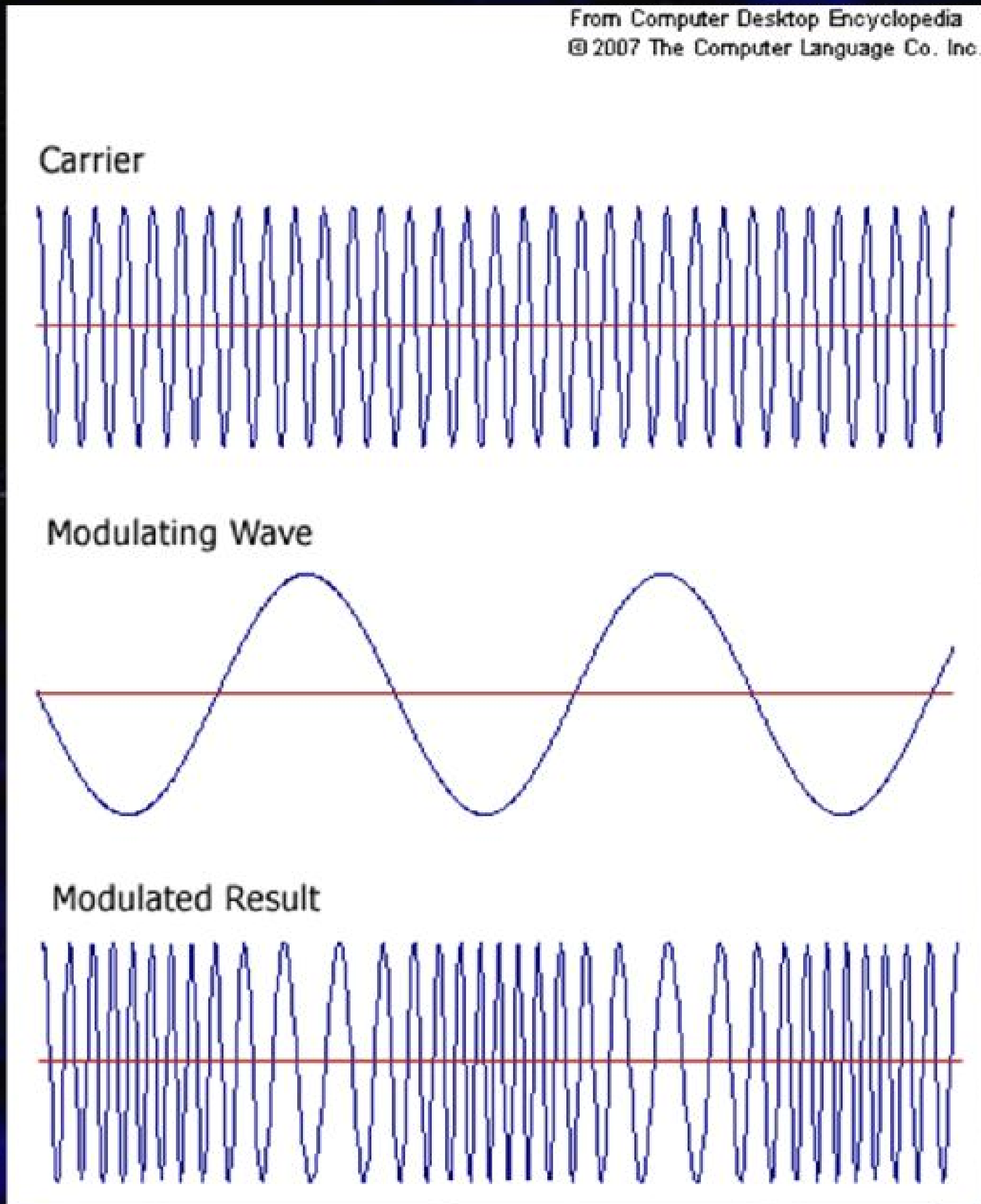
However corresponds to neutral hydrogen emission

- Frequencies surrounding 1420 MHz are relatively clear of noise
- 1721 MHz radio emission from OH molecule

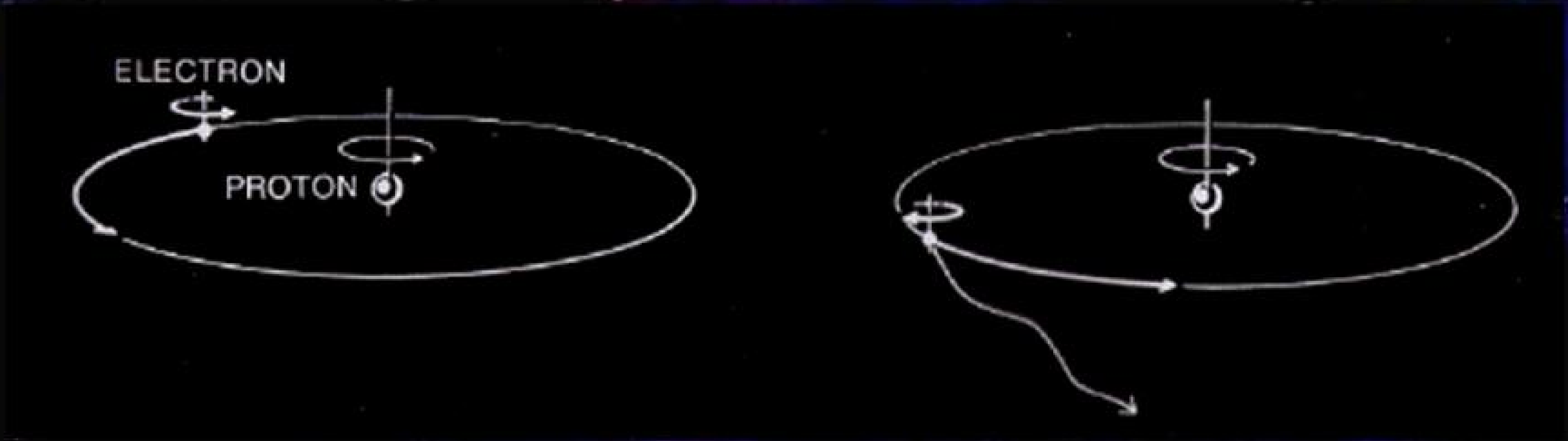
# Anatomy of a “signal”

- The ***carrier signal*** is the “channel”
- 6 MHz of BANDWIDTH
- Video + Audio



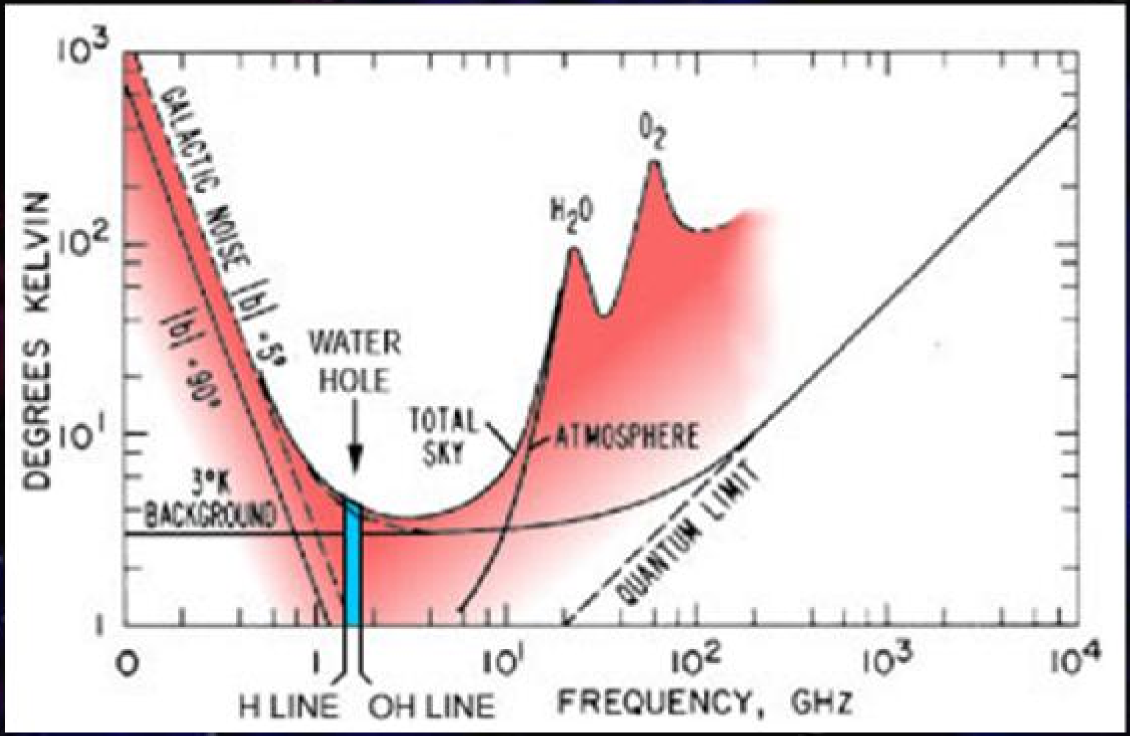

From Computer Desktop Encyclopedia
© 2007 The Computer Language Co. Inc.
Carrier
Modulating Wave
Modulated Result

# 21-cm Radiation

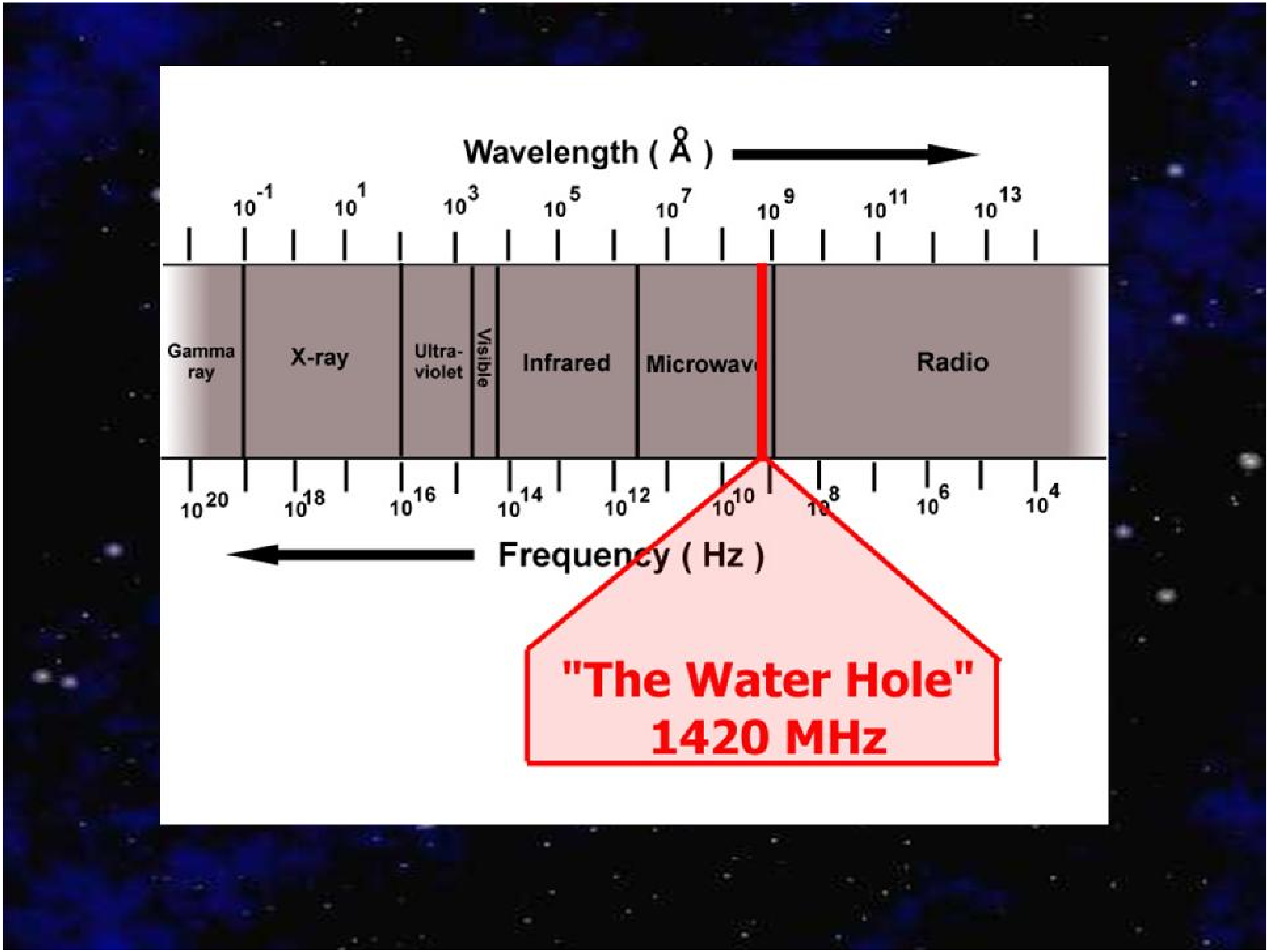



- spinning electron in hydrogen changes its axis of rotation from parallel to that of proton (higher energy state) to anti-parallel (lower energy state)
- hydrogen atom emits energy difference as photon of 21-cm wavelength (microwave)
- 21-cm wavelength = 1420 MHz frequency

# The "Water hole" **1420 – 1721 MHz**




- Bracketed by natural emission of neutral hydrogen and hydroxyl molecules.
- Not too many other choices
- Believed to be a good educated guess



Wavelength ( Å )
10 -1
10 1
10 3
10 5
10 7
10 9
10 11
10 13
Gamma ray
X-ray
Ultra-violet
Visible
Infrared
Microwave
Radio
10 20
10 18
10 16
10 14
10 12
10 10
10 8
10 6
10 4
Frequency ( Hz )
"The Water Hole"
1420 MHz

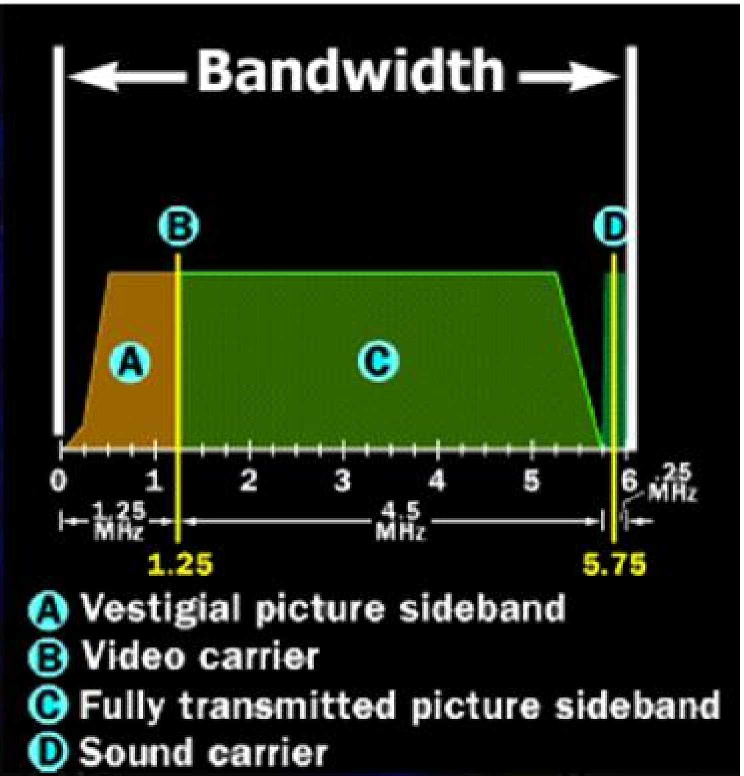
# BANDWIDTH

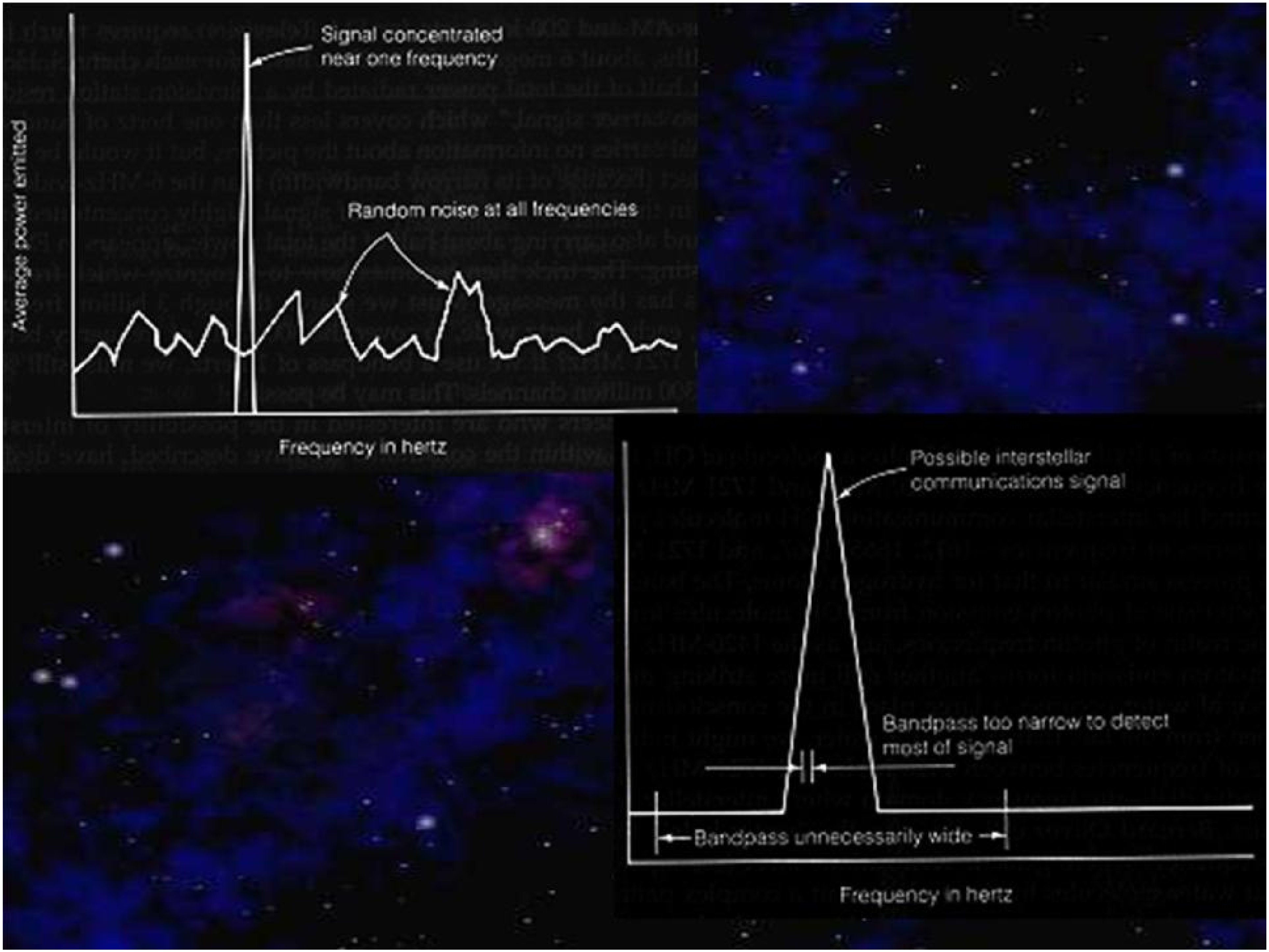
Expect signal to be a narrow bandwidth

- Will stand out amongst the “noise”
- The more narrow the bandwidth, the farther the signal will reach before becoming too weak for detection

However…

- Narrow bandwidth sends less information
- Searching a narrow bandwidth is time consuming





Signal concentrated near one frequency
Random noise at all frequencies
Average power emitted
Frequency in hertz
Possible interstellar communications signal
Bandpass too narrow to detect most of signal
Bandpass unnecessarily wide
Frequency in hertz

# BANDWIDTH (cont'd)

- 0.1 Hz bandwidth minimum due to interference with the ISM
- Most natural sources cover a wide range of frequencies
- Widely believed that anything less than 300 MHz would be artificial

# BANDWIDTH (cont'd)

300 MHz between 1420 & 1721 MHz

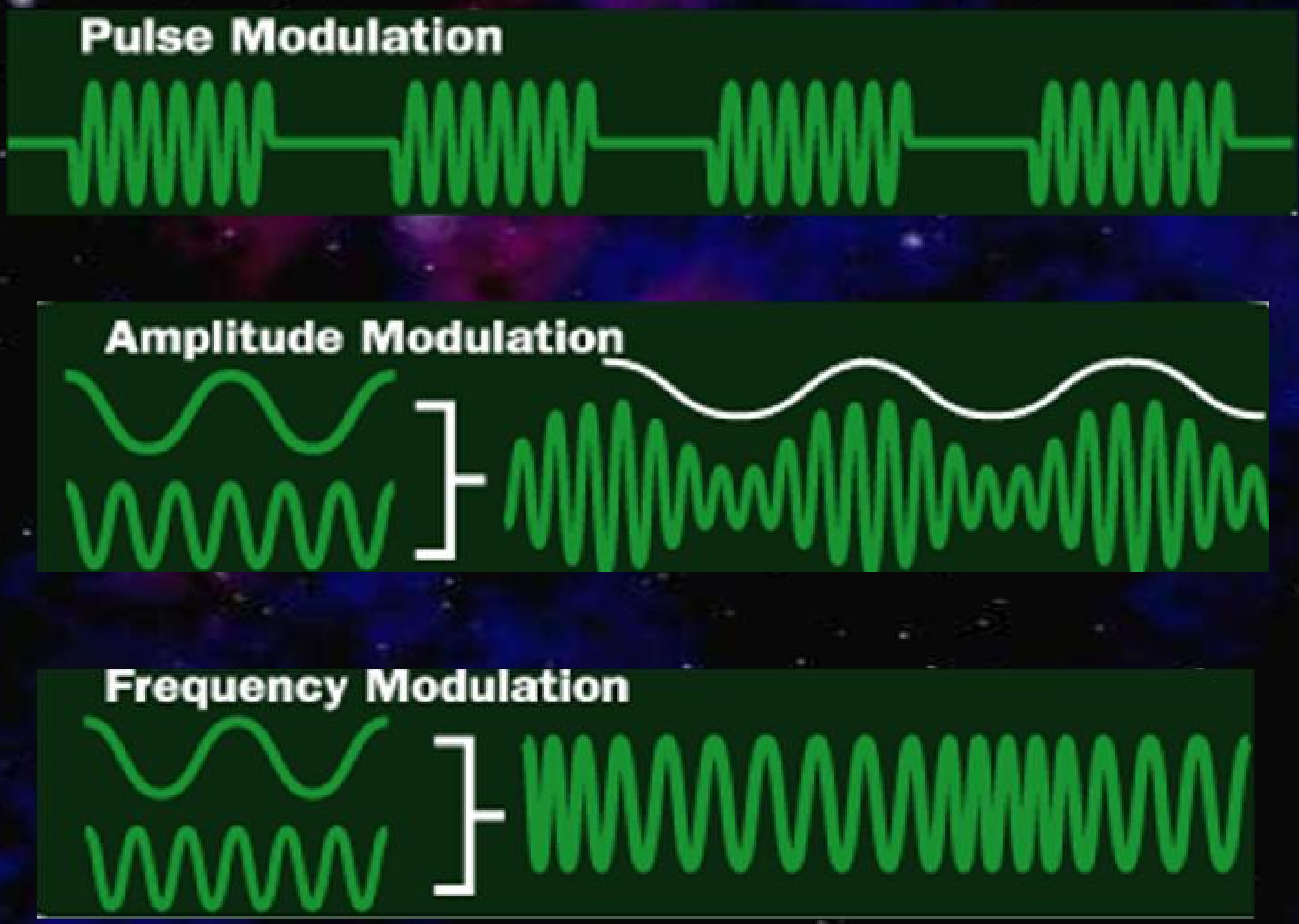
0.1 Hz bandwidth per channel

- 3 billion channels

1.0 Hz bandwidth per channel

- 300 million channels

# Type of Modulation



# Project OZMA
## Frank Drake (1960)

- Radio search of two nearby stars
- Precursor to SETI program
- Sent message to M13 globular cluster
- Find out results in ~ 50,000 years!

# Project PHOENIX
## SETI Institute (1995)

- Targeted search of 1000 sun-like stars out to 150 light years
- 1200 MHz – 3000 MHz with 1 Hz bandwidth
- Simultaneous search of 56 million channels
- 100,000 watts @ 100 LY
- Several minutes per star

# Project META
## Paul Horowitz, Harvard (1983)

- Narrow band signals near 1420 MHz
- Comprehensive northern sky survey over 5 years
- 2 minutes per target
- 60 trillion channels searched
- 37 anomalous events... none detected a second time

# Project BETA
## Paul Horowitz, Harvard (1995)

- 80 million channel simultaneous search
- 0.5 Hz bandwidth
- 40 MHz chunks
- 16 seconds per region
- Software scans 250 MB of data each second
- Potential sources are immediately scrutinized

# Project SERENDIP
## UC Berkeley, Arecibo (1997)

- Piggyback instrument to Arecibo radio receiver
- 100 million channels per second @ 0.6 Hz bandwidth
- 100 million MHz chunks 1370 - 1470 MHz
- 1 million watts @ 100 LY
- SETI@home

# Allen Telescope Array (2011)

- 350 6-meter dishes = 100 meter dish (42 done)
- More channels searched
- 24 hours a day
- Expansion from Project Phoenix's from 1,000 stars to 100 thousand or even 1 million nearby stars

# What Do We Look For?

- What would an alien signal look like?
- How would we know it is really from ET?
- Is the signal *THE* message or a carrier signal?
- How would we know how to decipher the message?

# What Do We Look For?