Communication

Communication

Much cheaper than travel

Energy needed for Mass (M) at speed (v)

$E = 1/2\ Mv^2$ if v much less than c

e.g., travel to nearest star (4 *ℓ*y) in 40 yr

$\Rightarrow$ v = 0.1 c $\Rightarrow$ $E = 4.1 \times 10^{-9}$ ergs

for M = M (electron)

Photon $E = h\nu$ $h = 6.6 \times 10^{-27}$

ν = frequency

$= 6.6 \times 10^{-18}$ ergs if $\nu = 10^9$ Hz

Ratio ~ 10^9 (and photon gets there in 4 yrs)

100 M watt transmitter - 1 yr

$\$ 40 \times 10^6$

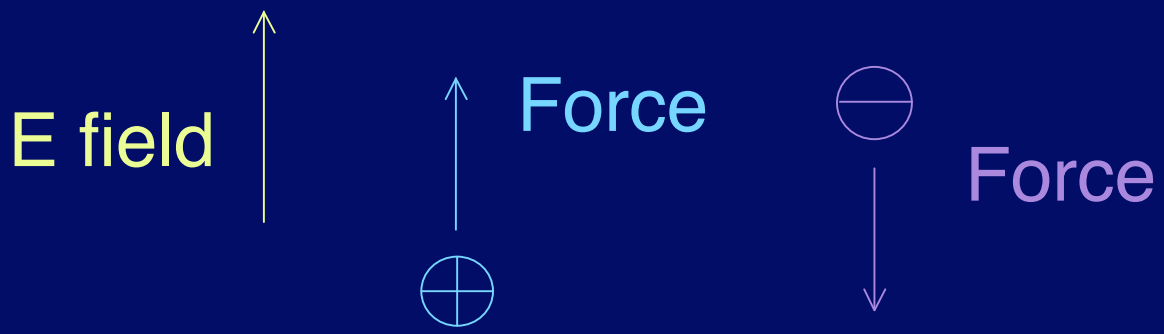
Spacecraft to nearest star

~ $\$ 5 \times 10^{16}$

(some recent analysis questions this conclusion)

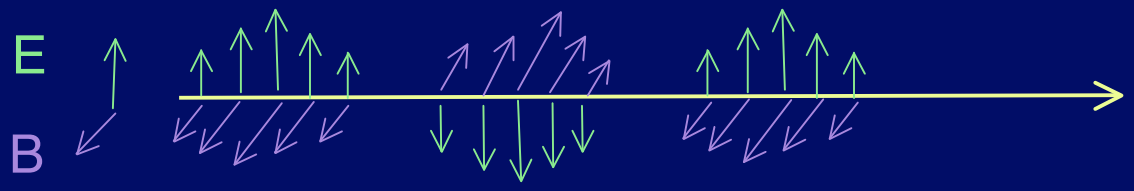
Light is an Electromagnetic Wave

Electric Field: Indicates force on charged particle

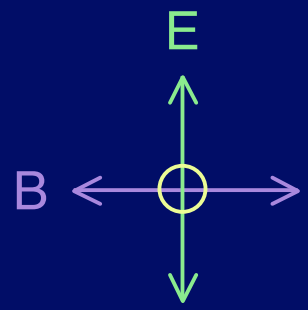


Magnetic field: created by changing electric field. At right angle to electric field.

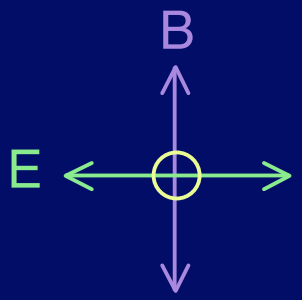
Electromagnetic Wave



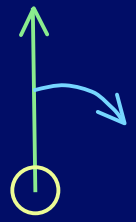
Motion of wave



Vertically Polarized



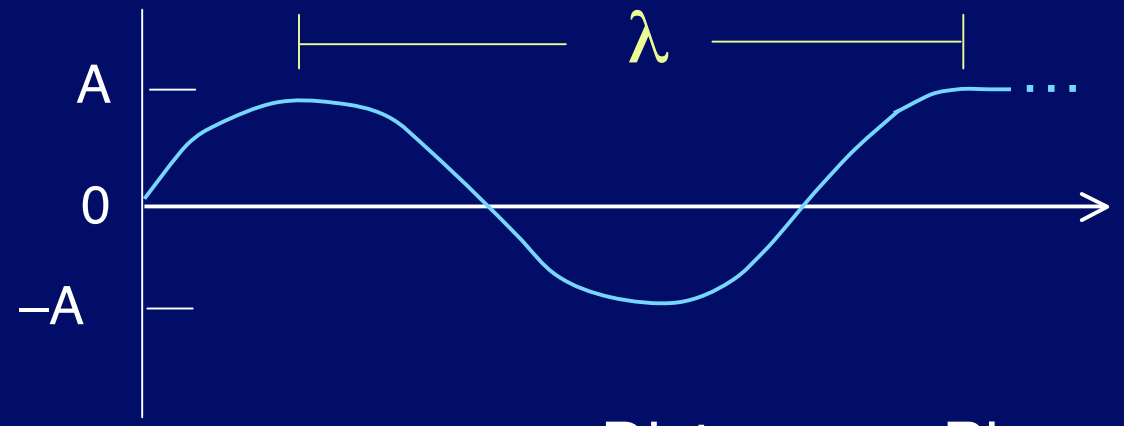
Horizontally Polarized



Circularly Polarized

Wave Properties

Snapshot

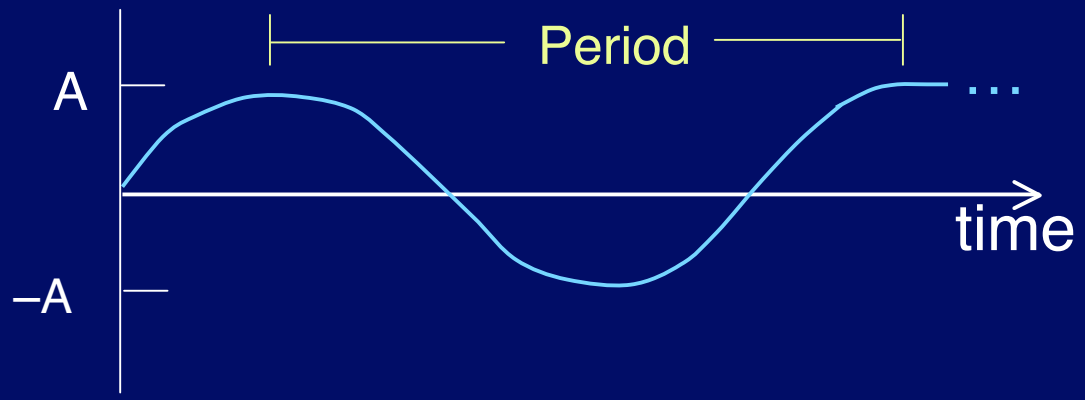


A = Amplitude

λ = Wavelength

Wave Properties

Look at one point along wave



ν = frequency = $\frac{1}{\text{period}}$

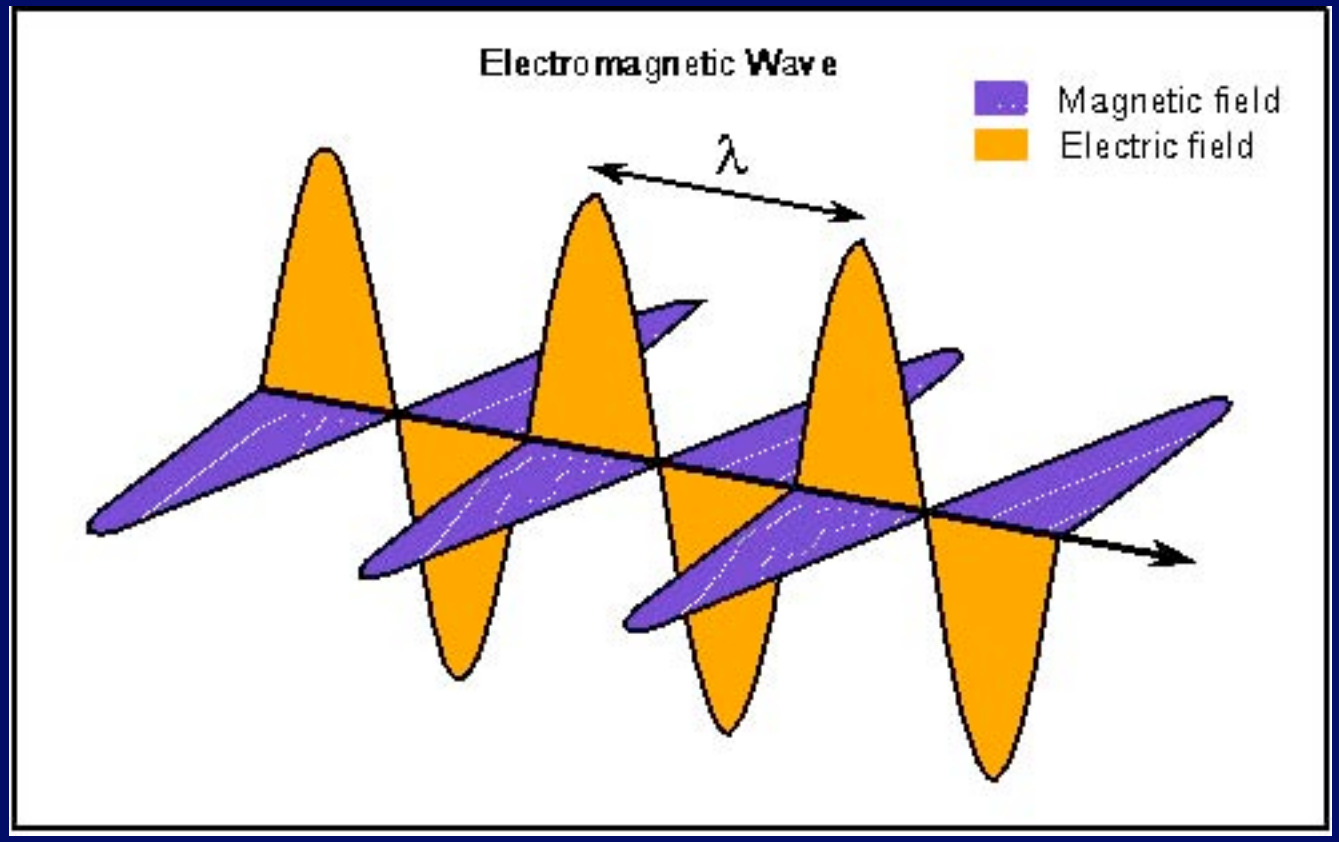
# of cycles per second (hertz, Hz)

1 kHz = 10^3 Hz 1 MHz = 10^6 Hz

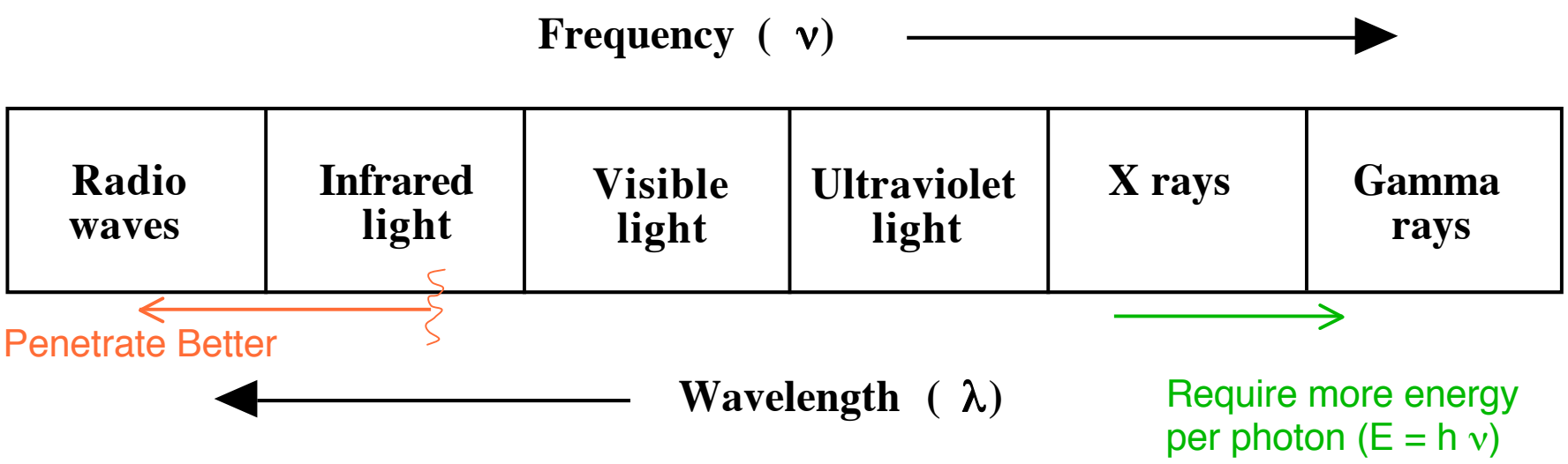
1 GHz = 10^9 Hz

Speed of light $c = \lambda\nu \Rightarrow \lambda = \frac{c}{\nu}$

A Wave Demo

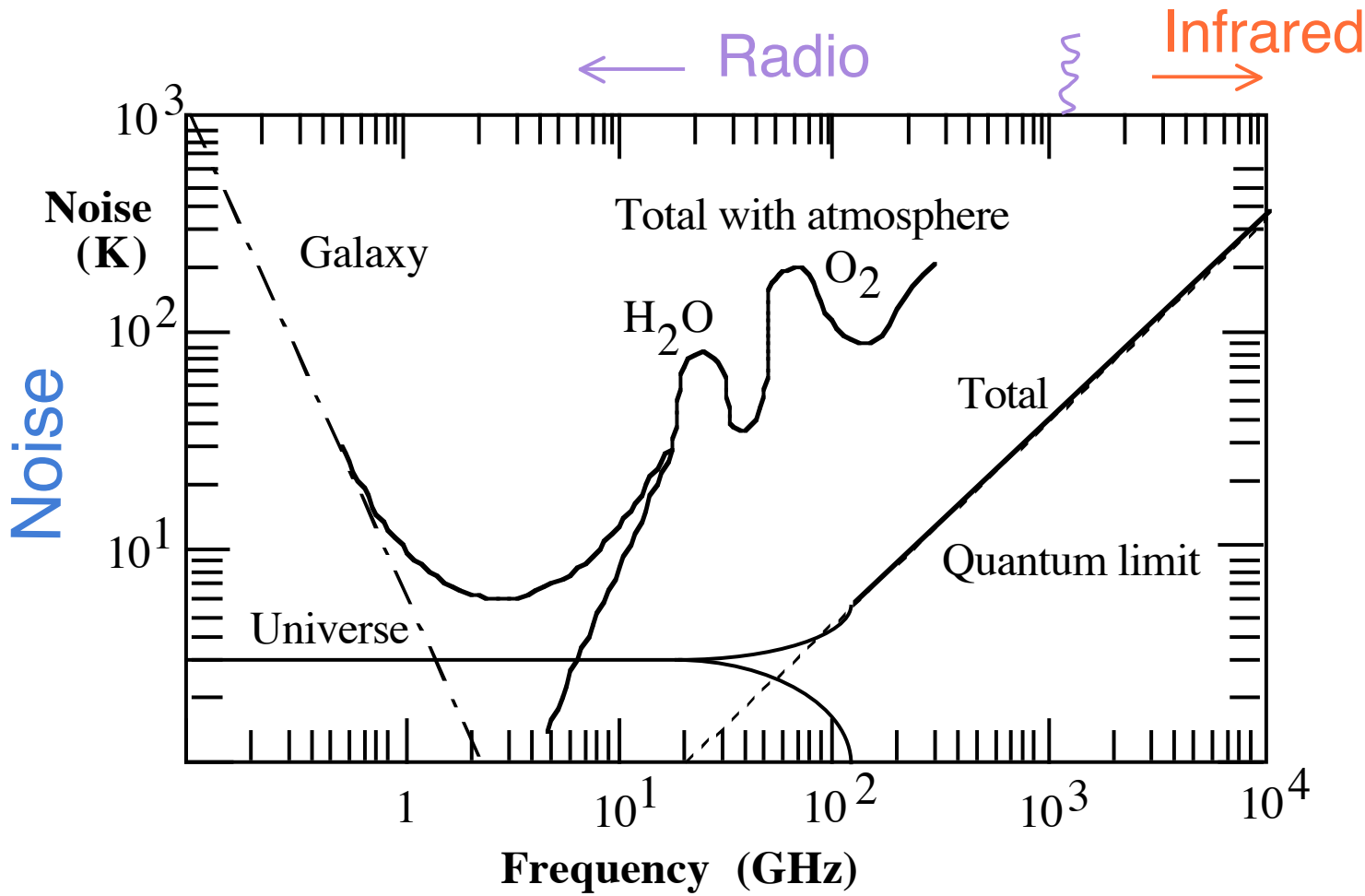


Electromagnetic Spectrum (Light)



Noise: Any unwanted signal

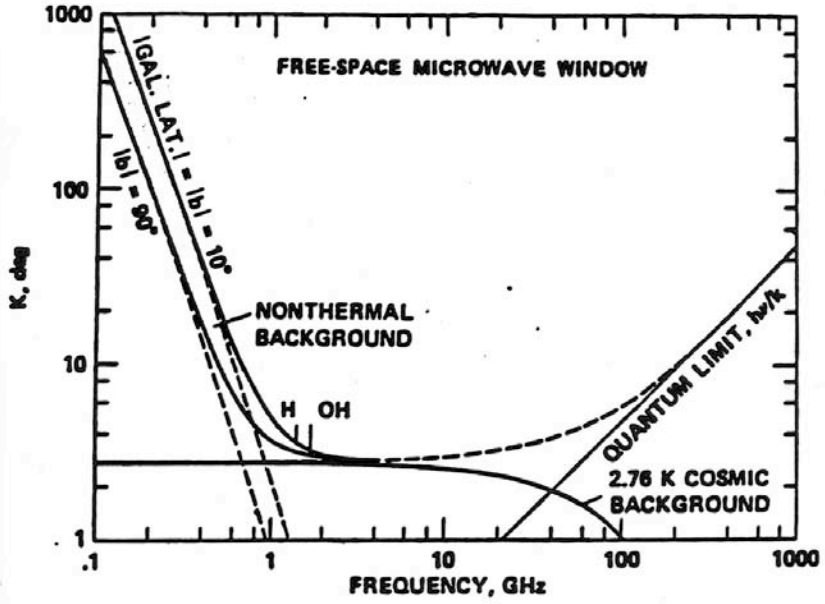
Artificial, Natural



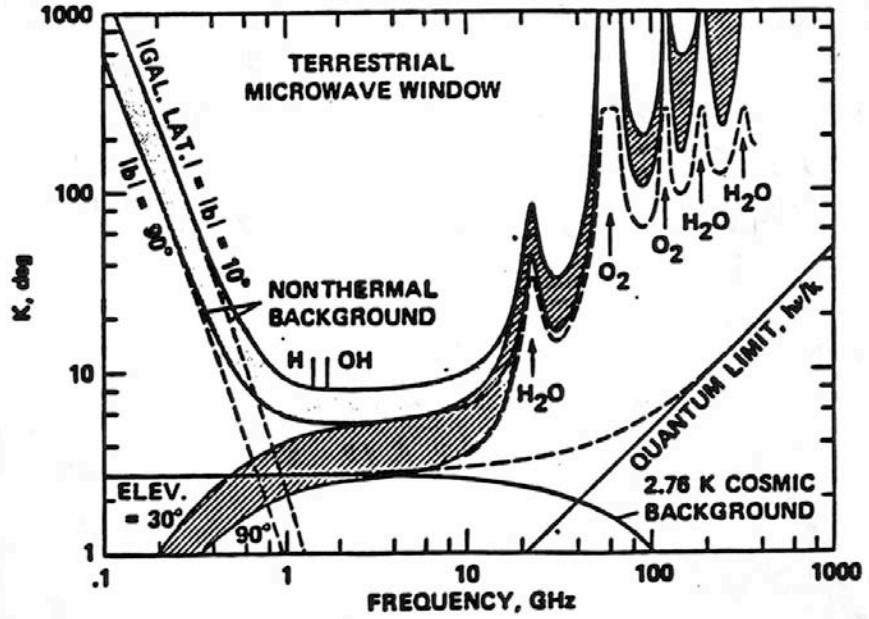
ν = (GHz)

10^9 Hz

Figure 6.8



Free-space microwave window, in which the basic noises that limit radio communication over interstellar distances are least disruptive.



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.

Magic Frequencies

1. Morrison & Cocconi 1959

   $\nu = 1.42$ GHz $\lambda = 21$ cm

   H atoms

2. Water "Hole"

   OH 1st molecule discovered at Radio λ

   $\nu = 1.6$ GHz

   $H + OH \longrightarrow H_2O$

   Low Noise "Hole"

   1.4 1.6 GHz

3. Kuiper - Morris

Use fundamental constants

$\nu = \frac{c}{\text{length}}$ all very high ν

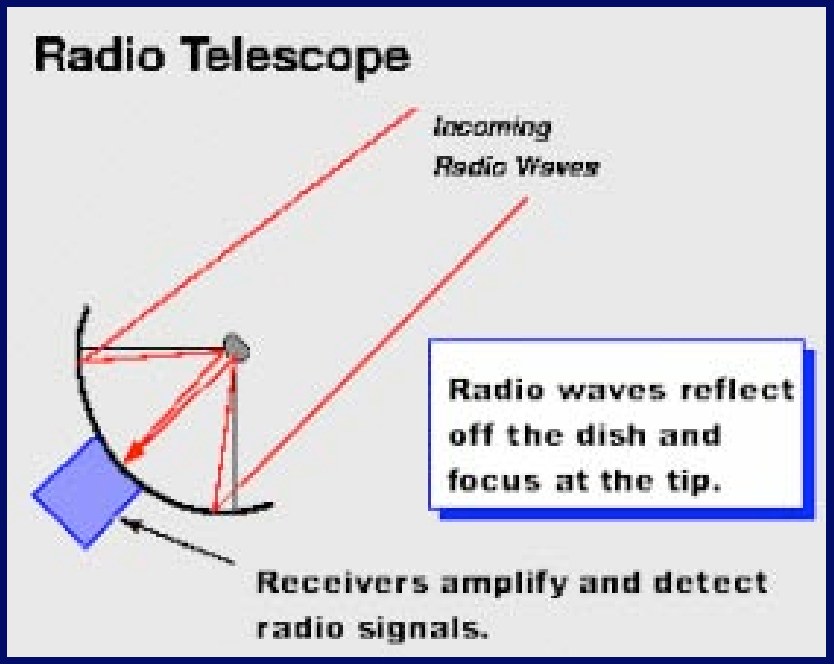
Most plausible is electron “radius”

Scale by powers of “fine structure constant”

$\sim \frac{1}{137}$ (if multiply 5 times, get to radio)

$\longrightarrow \quad \nu = 2.5568$ GHz

Radio Telescope Principle



Green Bank Telescope (GBT)

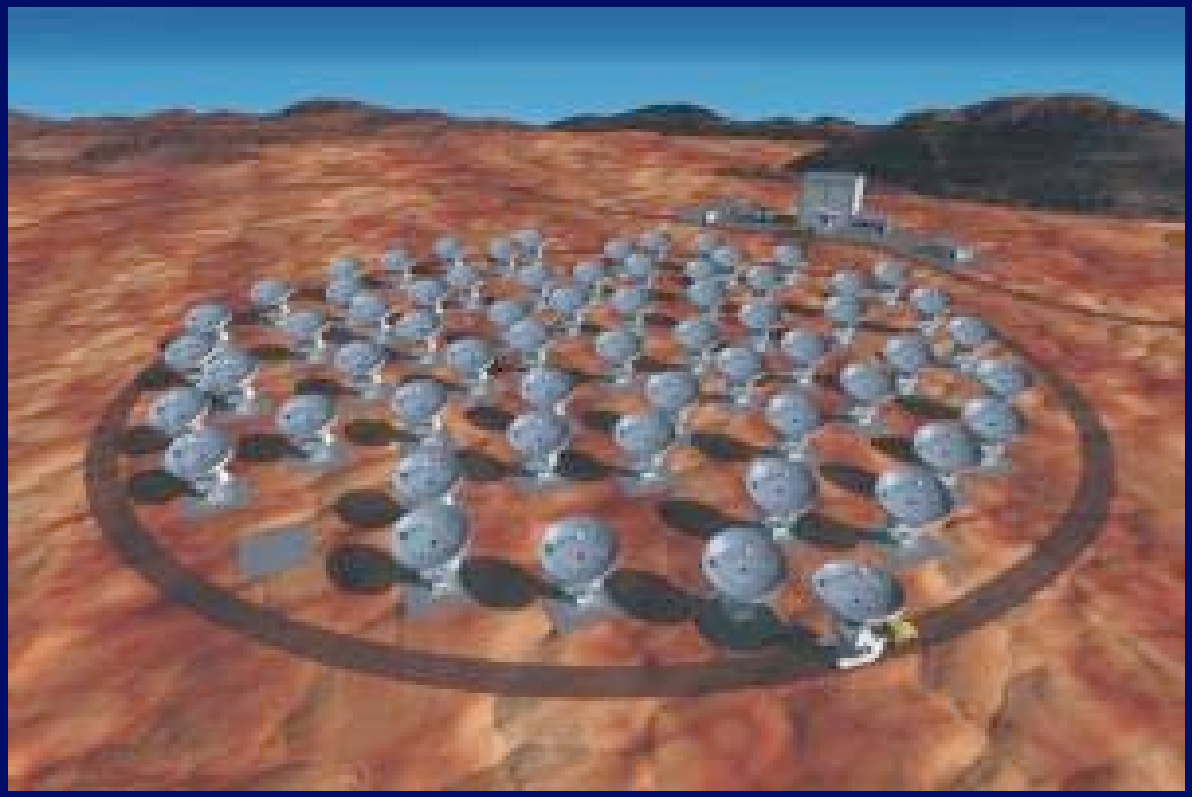
Arecibo Telescope

Very Large Array (VLA)

Very Long Baseline Array (VLBA)

Caltech Submillimeter Observatory (CSO)

Atacama Large Millimeter Array (ALMA)



Allen Telescope Array (ATA)

Prototype Test Array