The Arecibo Radiotelescope

World's largest radio/radar telescope

The Radio Telescope of the Arecibo Observatory

National Astronomy and Ionosphere Center

- Reflector diameter of 305 meters (1000 ft)
- Built in 1963 by Cornell University, it underwent major upgrades in the 1970s and the 1990s.
- Operated by Cornell University, under a cooperative agreement with the U.S. National Science Foundation.

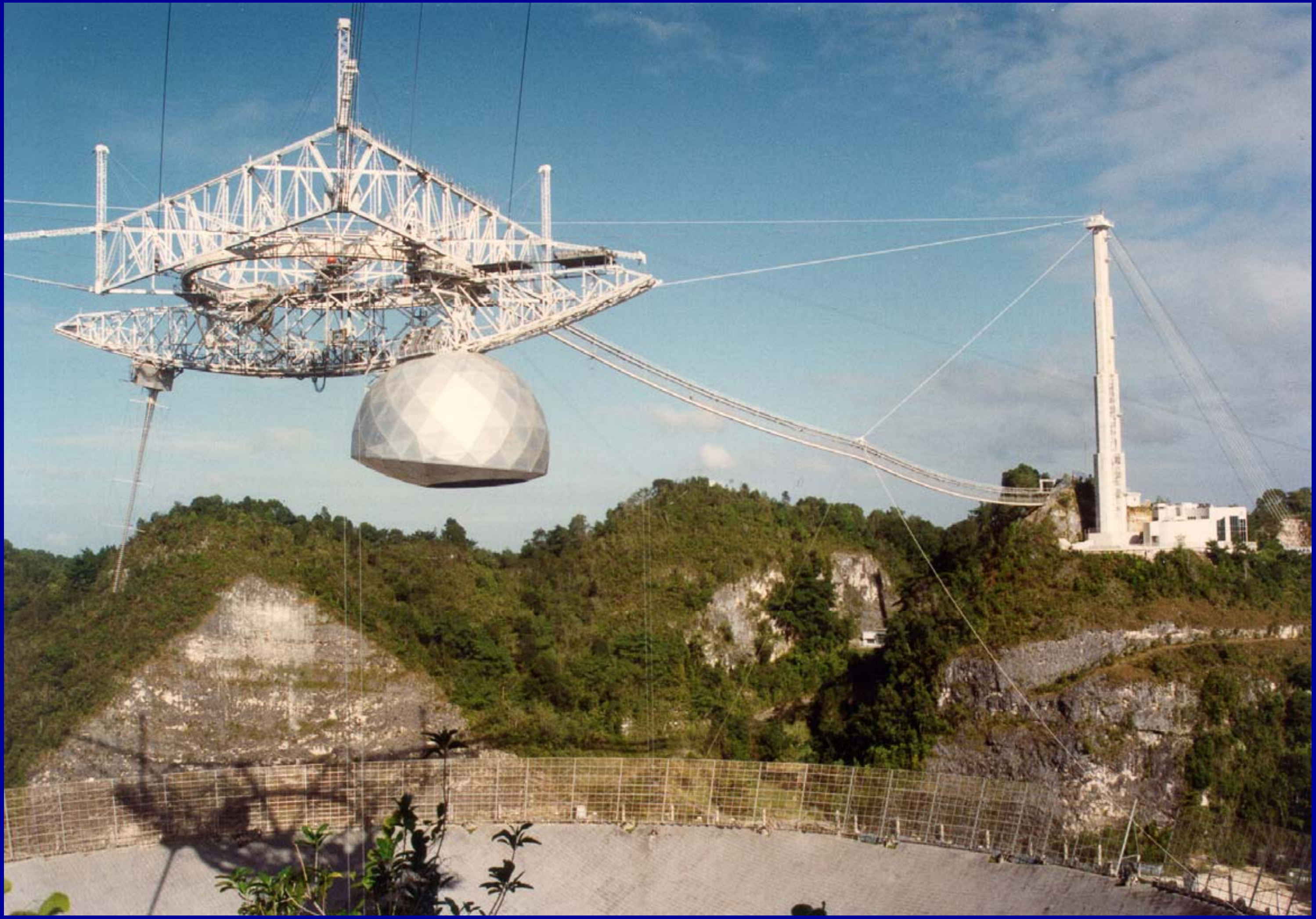
The Arecibo telescope was built at this site in order to take advantage of the vicinity to the Equator and of the topography of the terrain, which provided a nearly spherical valley and minimized excavation.

History of Arecibo

June 1960

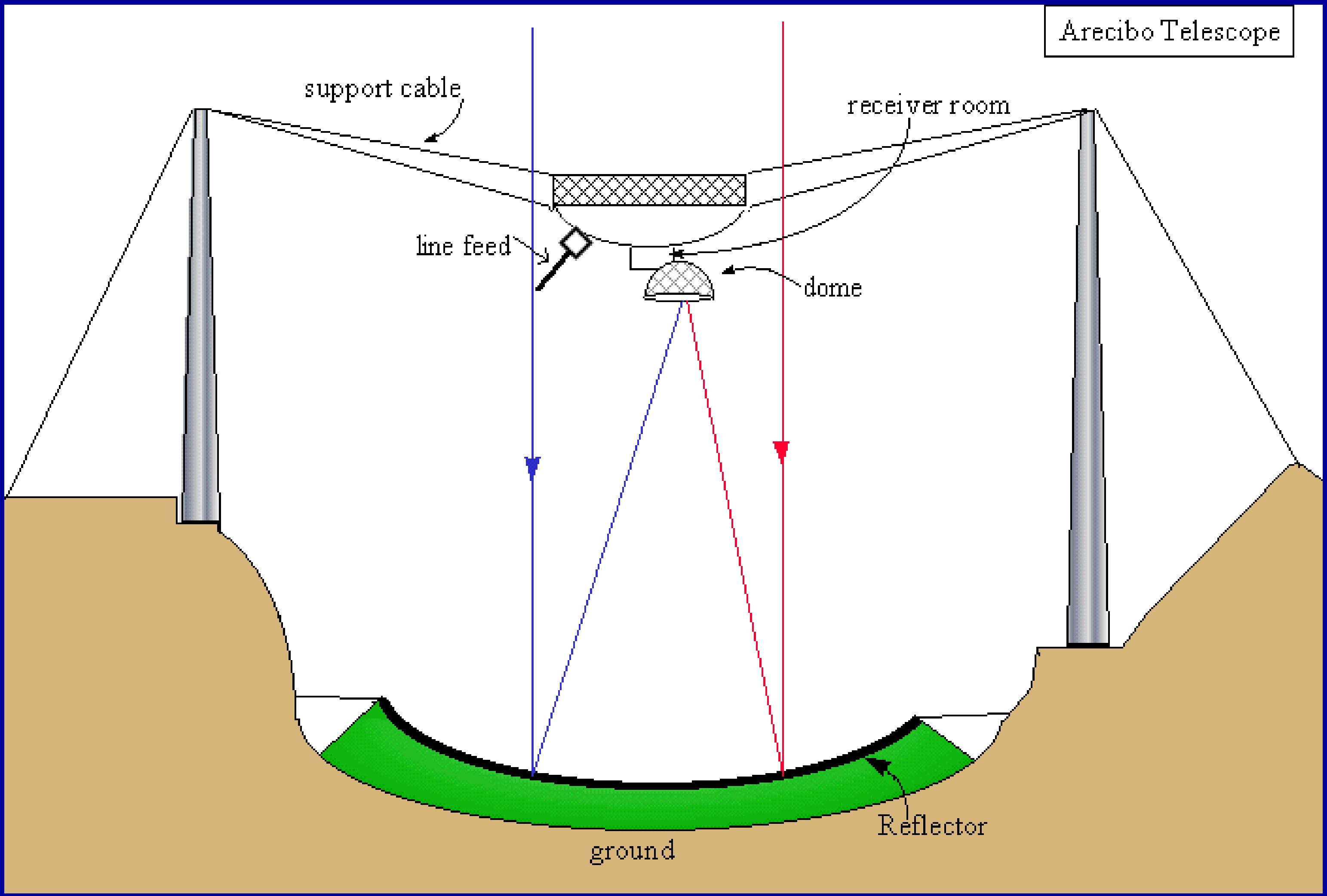
Dec 1960

History of Arecibo



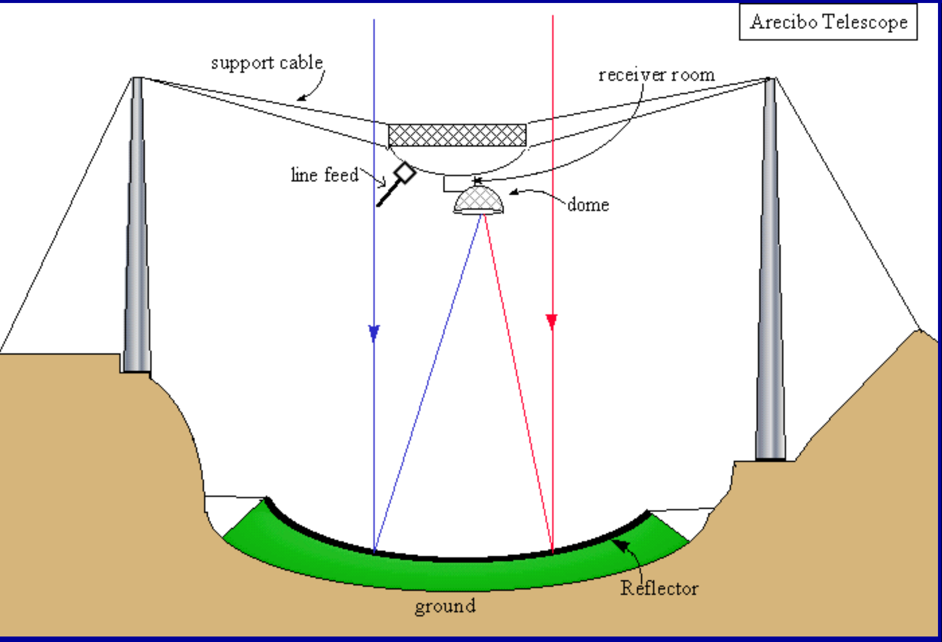
While the primary reflector (the “dish”) is suspended just above ground level over a network of steel cables, the focal structure with all the receiving equipment – which weighs 900 tons - is suspended 150 meters above the ground, and can be steered to point at cosmic sources within 20 degrees of zenith.

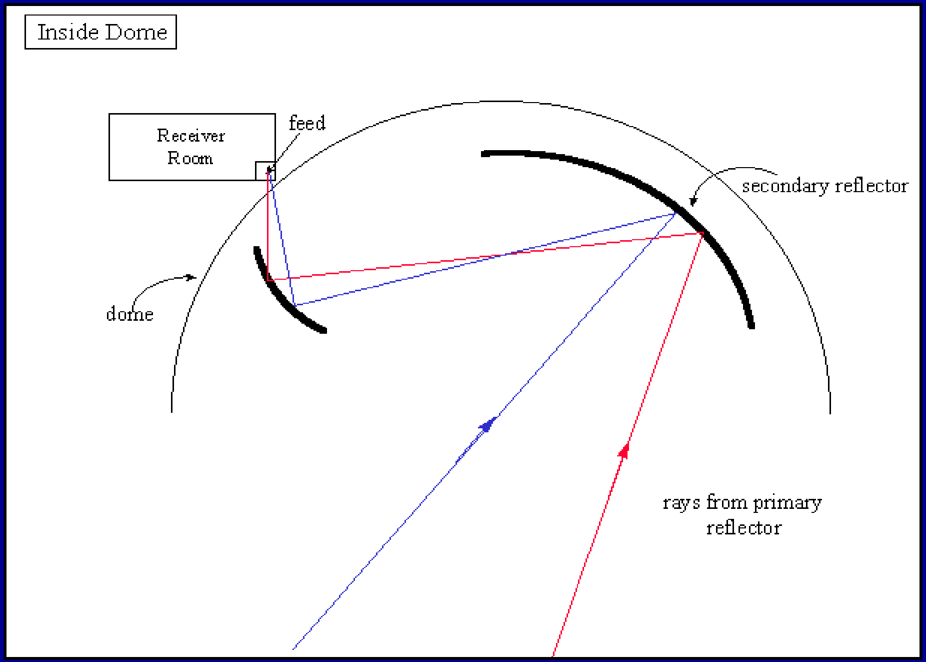
The Arecibo Radiotelescope

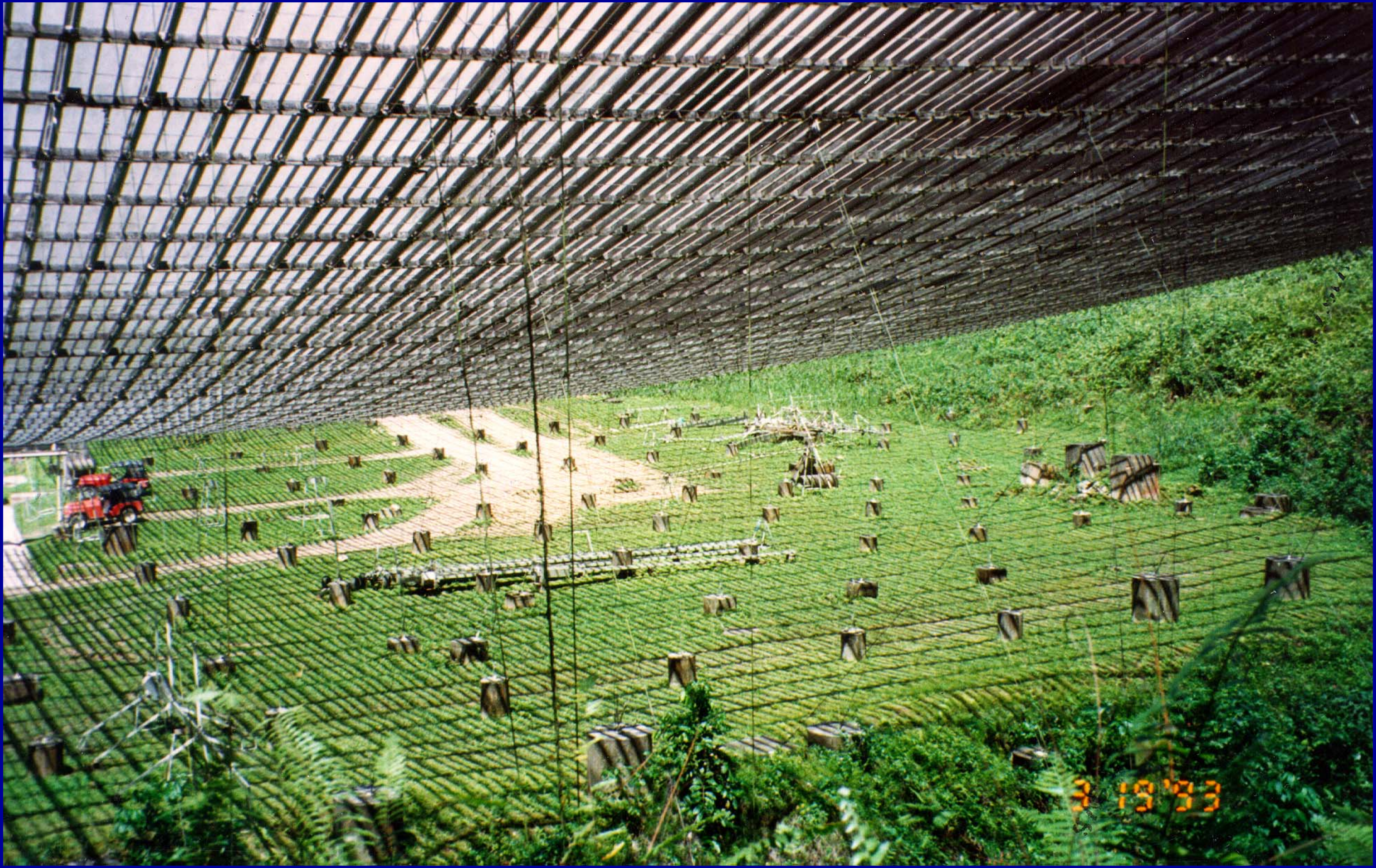


Gregorian Optics

- The dome is referred to as the “Gregorian”.
- A “Gregorian” focus refers to one in which the secondary reflector is placed behind the focal point of the primary reflector.
- In this case, there are 3 reflectors: primary, secondary, tertiary.







Under the Arecibo dish, roads snake around among a network of support and tension cables, amidst lush tropical vegetation.

"Feed"

- Smaller antenna (waveguide horn) that transfers incoming signal to receiver
- Term originated with antennas used for radar transmissions

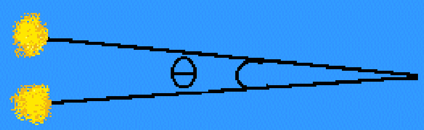
Receivers at Arecibo

Receiver Name	Freq Range (GHz)
327-MHz	0.312-0.342
430-MHz	0.425-0.435
610-MHz	0.6075-0.6115
ALFA	1.225-1.525
L-wide	1.15-1.73

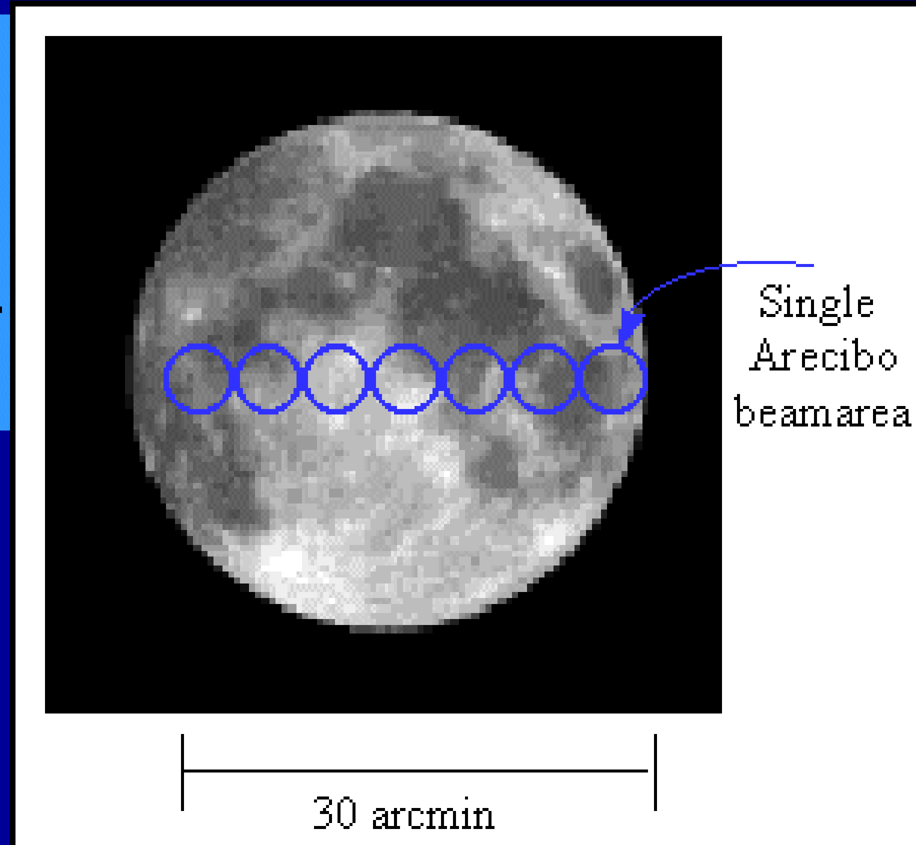
Receiver Name	Freq Range (GHz)
S-low	1.8-3.1
S-narrow	2.33-2.43
S-high	3-4
C	3.85-6
C-high	5.9-8.1
X	7.8-10.2

L-band: 1.1-1.8 GHz, 18-25 cm
21 cm HI line at 1420.4058 MHz (if at rest)

Resolution of the Arecibo Telescope



$$\Theta = \frac{1.22 \times \text{wavelength (cm)}}{\text{diameter of telescope (cm)}}$$



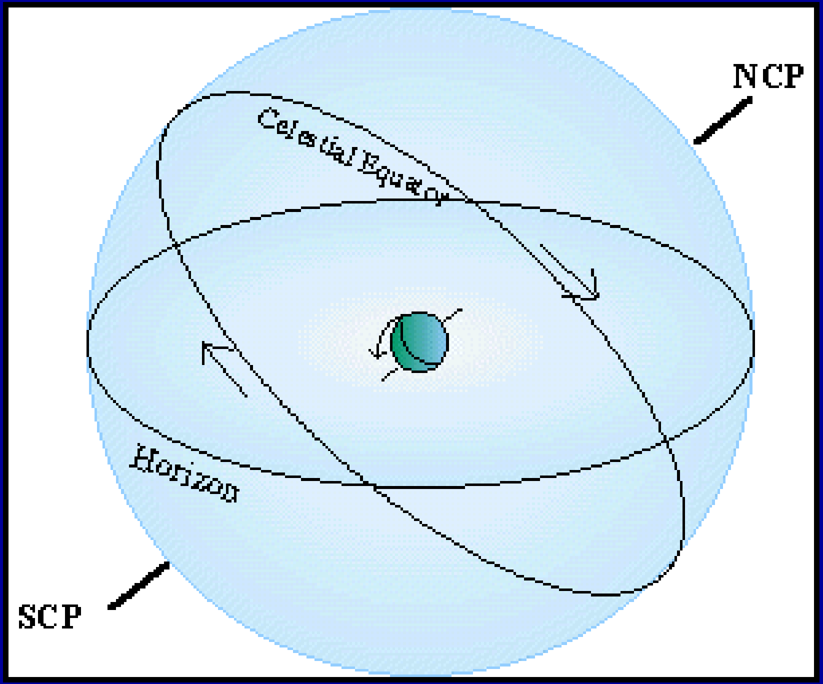
Feed illuminates an annulus of
700 ft ~ 213 m = 2.1×10^{5}cm
L-band $\Rightarrow$ λ=21 cm

$$\Theta(\text{rad}) = \frac{1.22 \times 21}{2.1\times10^{4}}$$

$$= \quad 1.22 \times 10^{-3} \text{ radians} \sim 4 \text{ arcmin}$$

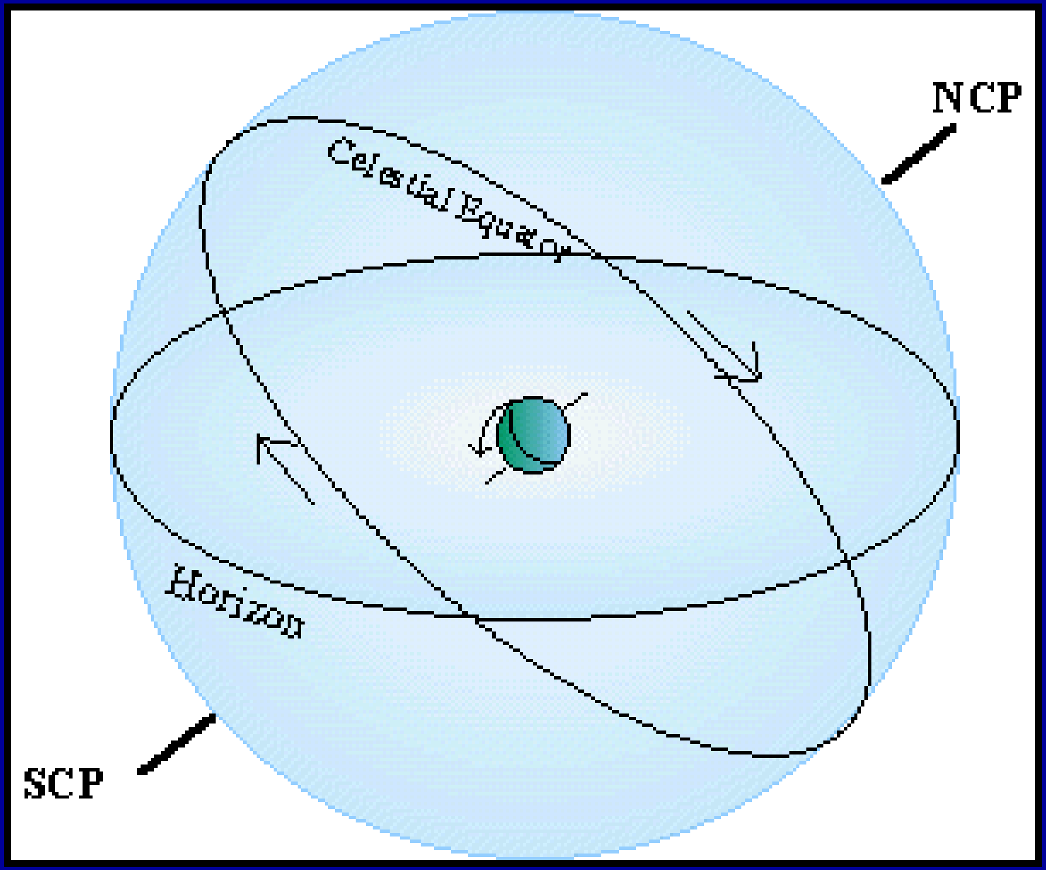
Three Perspectives of the Sky

Heliocentric	Geocentric	Local
Centered on Sun with Sun fixed	Centered on Earth with Earth fixed (not moving)	Centered on observer (Your view of the sky)



Celestial sphere: Imaginary sphere of huge radius centered on Earth and aligned with Earth's poles.

Celestial Sphere



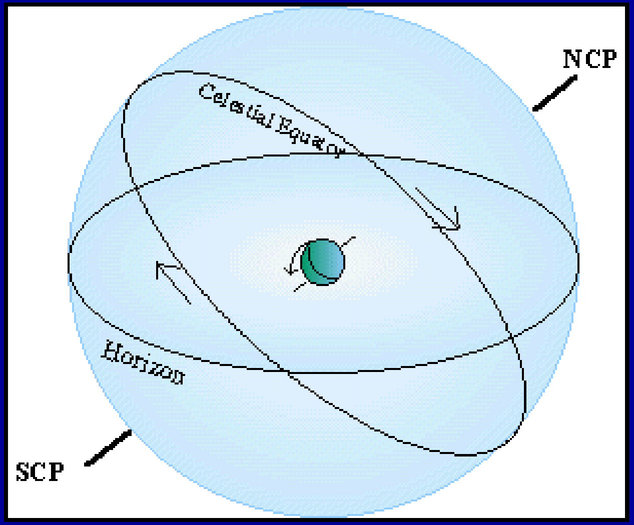
North Celestial Pole (NCP)
Extension of Earth's axis northward to celestial sphere

Celestial Equator (Cel. Eq.)
Extension of Earth's equator out onto celestial sphere.

South Celestial Pole (SCP)

- The stars have (essentially) fixed locations on the celestial sphere.
- The Sun, Moon and planets move (with respect to the stars)

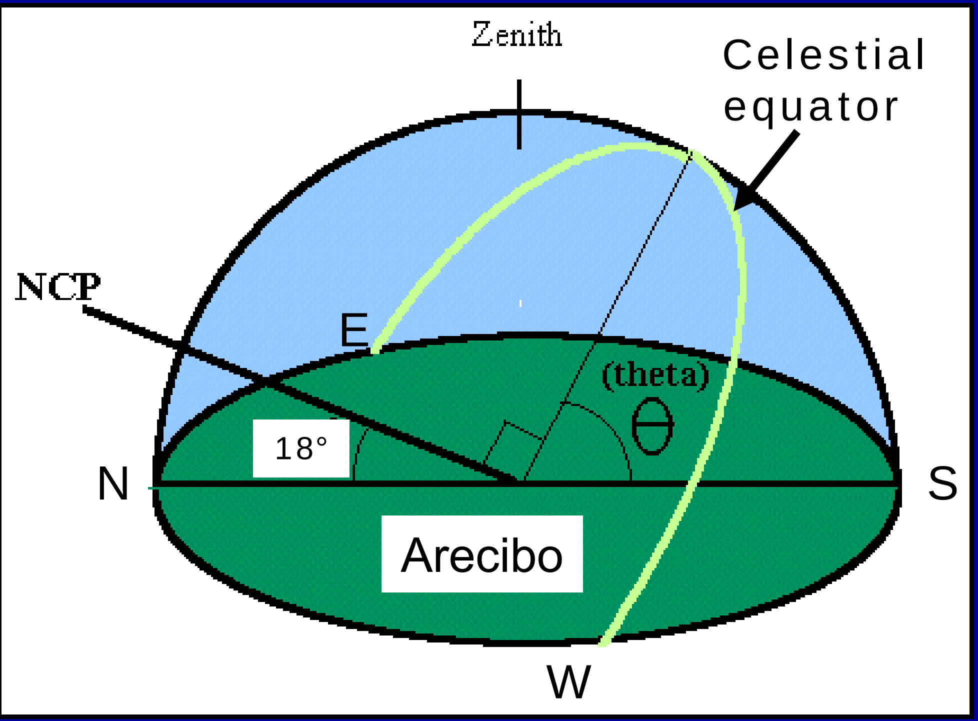
Coordinates



<u>On Earth</u>	<u>On Celestial Sphere</u>
Longitude	Right Ascension
Latitude	Declination
Equator (lat = 0°)	Celestial Equator (Dec. = 0°)
†Greenwich meridian (long=0°)	†Vernal Equinox (R.A.=0°)

† By convention

Azimuth & Zenith Angle



- Azimuth Angle
  - Measured in degrees
  - Tells how far east of north the source is located as measured along the horizon
- Zenith Angle
  - Measured in degrees
  - Tells how far down from the zenith a source is located

The Arecibo feeds can be steered to receive signals from the sky within 20 degrees of the Arecibo zenith.

Some Arecibo Facts

- Observatory located at +18° N Latitude; can observe within 20° of zenith (overhead)
- Main reflector is 305 feed in diameter, but feeds illuminate annuli of about 700 feet in diameter
- Receiver systems operate from 6m - 3cm (47 MHz - 10 GHz)
- Slew rate of 25°/min in azimuth and 2.5°/min in zenith angle
- Pointing accuracy of 5 arcseconds
- 3 pairs of cables that lead under dish for mm precision placement of platform
- Tie downs are controlled dynamically in real time, keeping platform level.

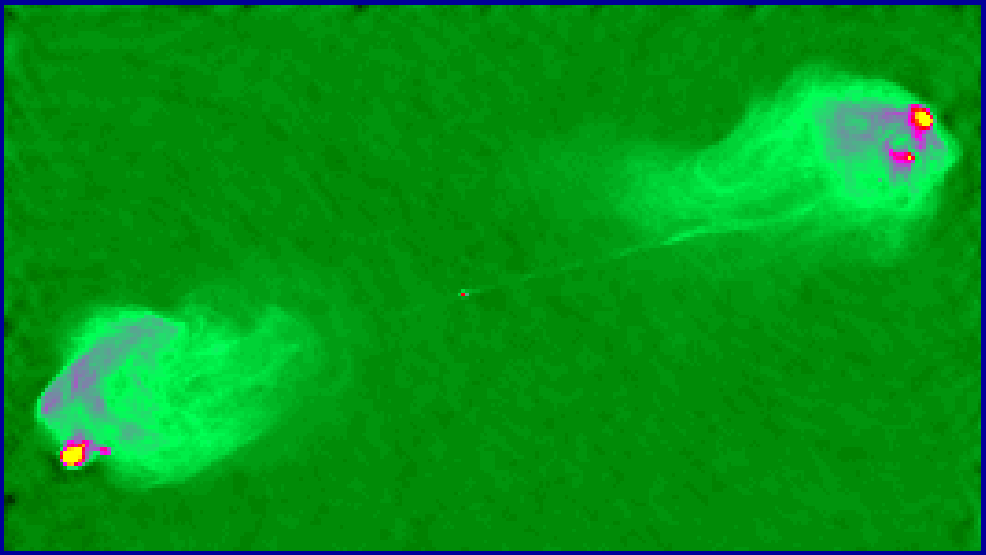
Research at Arecibo

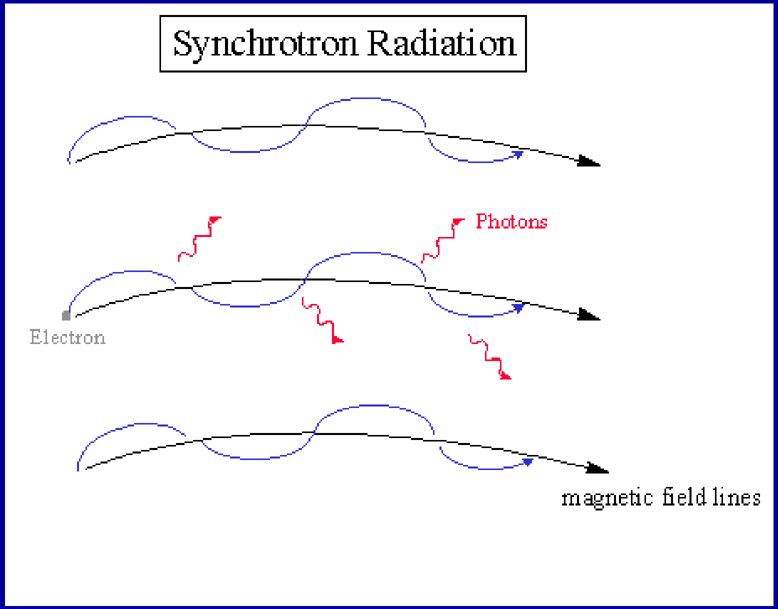
- Atmospheric Science
  - Measures composition, temperature, and density of upper atmosphere
  - Measures the growth and decay of disturbances in the ionosphere
- Radar Astronomy
  - Radio energy is transmitted, reflected and then collected.
  - Studies surface features, composition, size, shape, rotation and path of target
  - Studies objects within our solar system

Radio Astronomy at Arecibo

- Continuum Observations: detection, monitoring
  - Thermal radiation (hot gas)
  - Non-thermal radiation (synchrotron: electons in magnetic field)
- Pulsars: Discovery, timing, monitoring
- VLBI (Very Long Baseline Interferometry)
- Spectral Line Observations
  - HI line 1420.4058 MHz/ 21 cm line
  - OH lines (1612, 1665, 1667, 1720 MHz)
  - CH, H_2CO, methanol, etc.

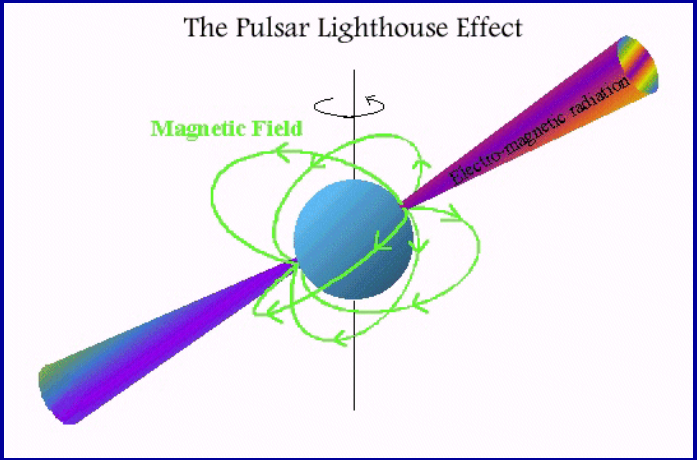
Continuum Observations

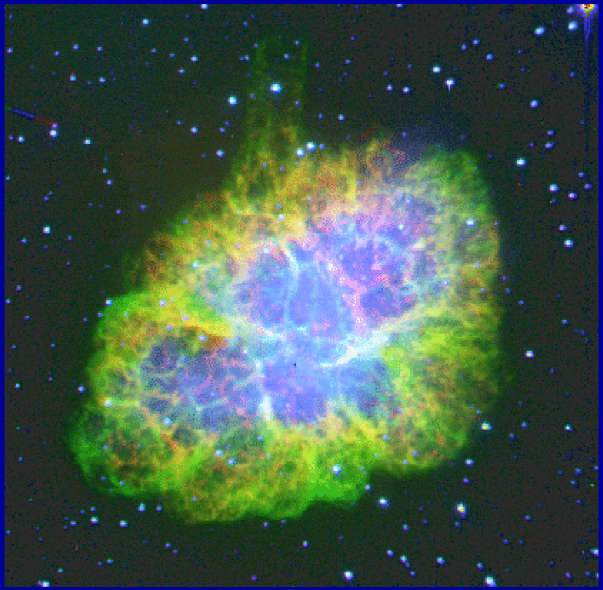




- Radio frequency observations over a wide range of frequencies (wide bandwidth)
- Example: studying synchrotron emission in our own galaxy or other galaxies

Pulsars

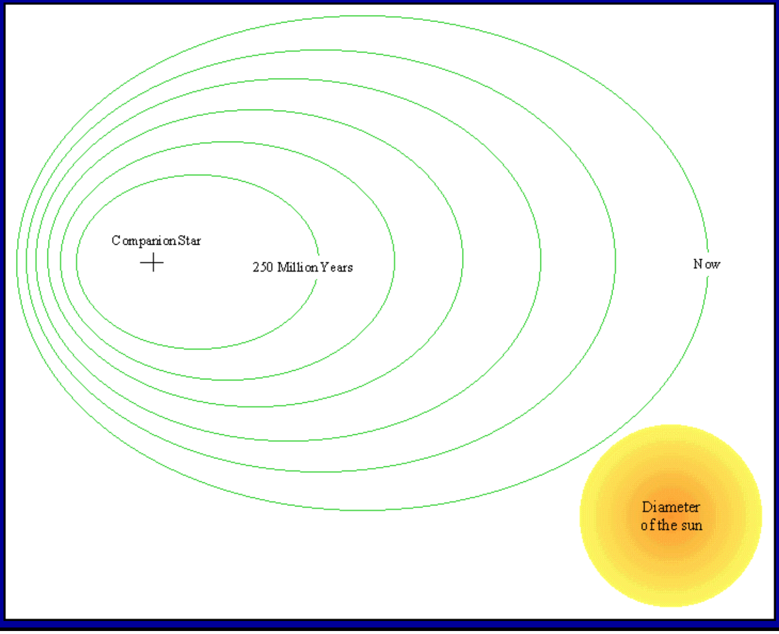


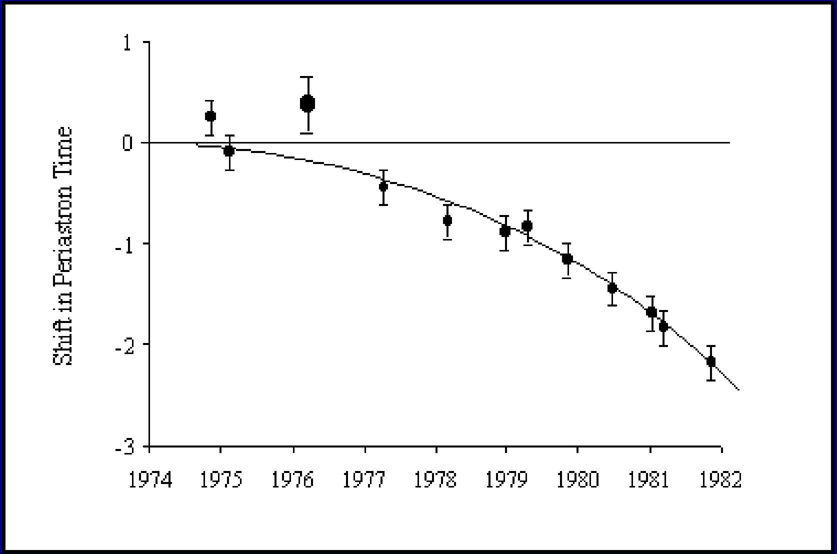


Crab Nebula

- Neutron stars were a purely theoretical concept until observations of the 33-ms pulsar in the Crab Nebula in 1968
- Rapidly rotating neutron stars emit when synchrotron radiation in beam; we see it when beam sweeps past Earth
- Magnetic axis and rotation axis not aligned

The Binary Pulsar PSR 1913+16





- Discovered in 1974 by Russ Hulse and Joe Taylor at Arecibo
- Shrinking of orbit due to loss of energy by gravitational radiation as predicted by Einstein
- 1993 Nobel prize to Hulse and Taylor

PSR B1257+12 and its Planets

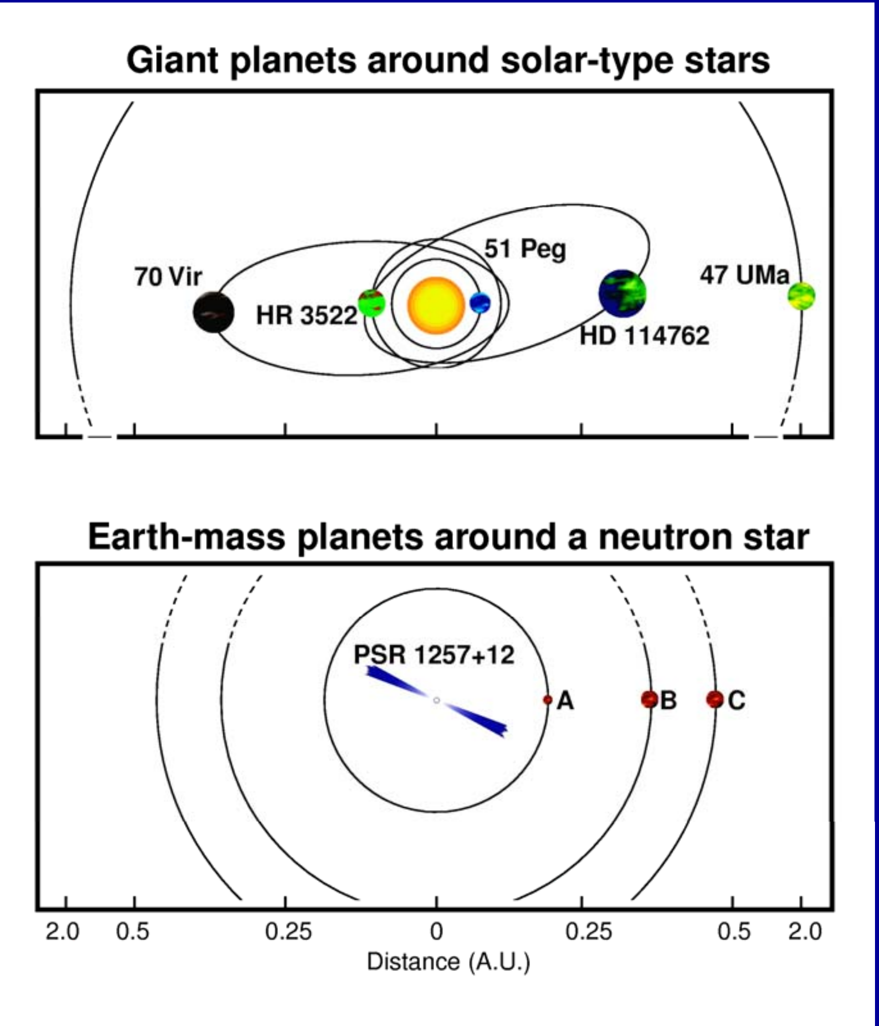
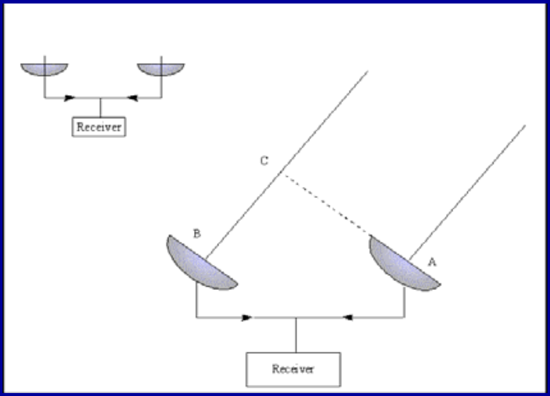
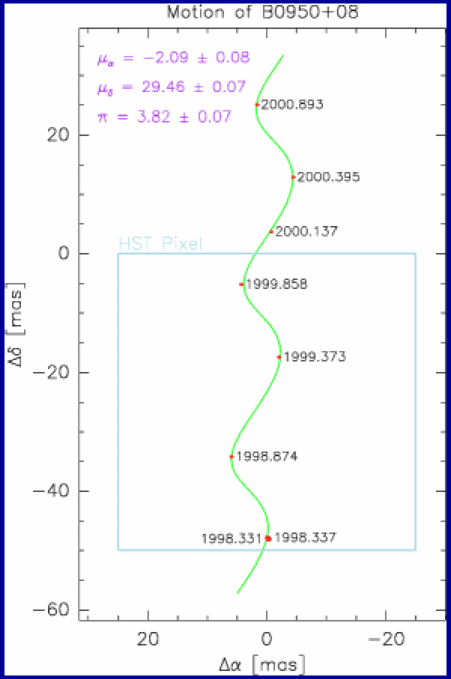


Figure from Alex Wolszczan

- First detection of an extrasolar planet EVER
- Discovered by Alex Wolszczan & Dale Frail through pulsar timing
- At least 3 bodies of Earth-like masses around PSR B1257+12

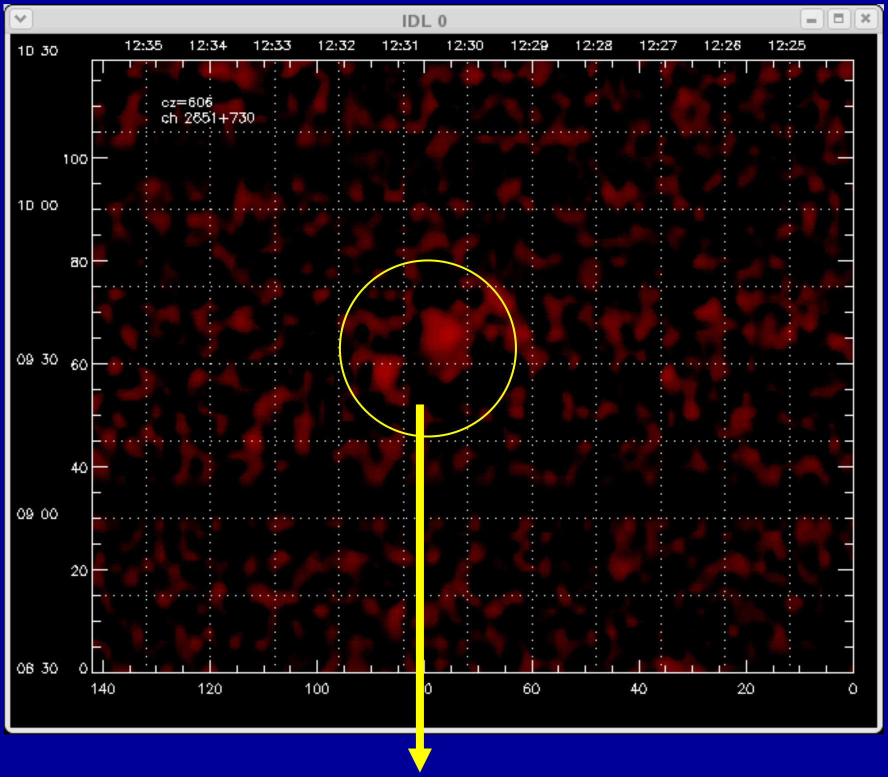
VLBI - Very Long Baseline Interferometry

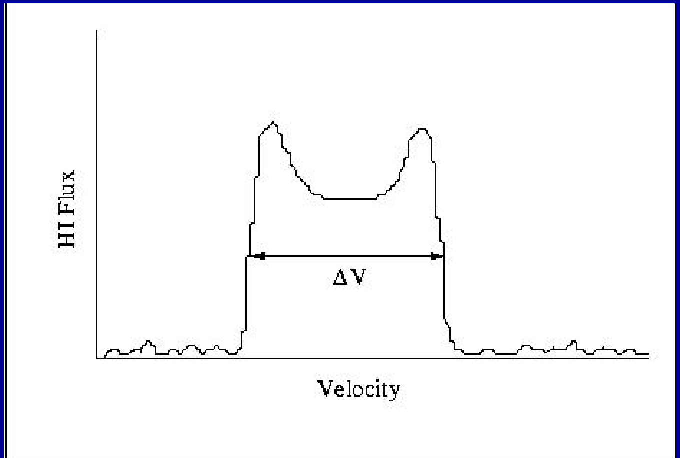




- Joined the VLBI network in the late 1990s
- NAIC commits 4% of AO's telescope time to VLBI
- Broad bandwidth video recorders record signals and are then replayed later in the same location
- Now incorporated into High Sensitivity Array (HSA)
- Track time evolution/motion of sources with extreme precision (micro-arcseconds)

Spectral Line Observations





- Discrete radio emission over small range of frequencies
- When we search for the 21-cm line, we cannot be sure where to look due to a galaxy's redshift
- Could be emission or absorption

How do I get time on the telescope?

- Telescope operates 24 hours a day (although some experiments must run during night (or day!)
- Submit a proposal which is judged by a panel of referees
- Deadlines are February 1st, June 1st, and October 1st
- Oversubscription rate is 4:1
- Open to qualified observers regardless of affiliation; Cornell scientists do not have preferred access

ALFALFA is approved for up to 900 hours/year