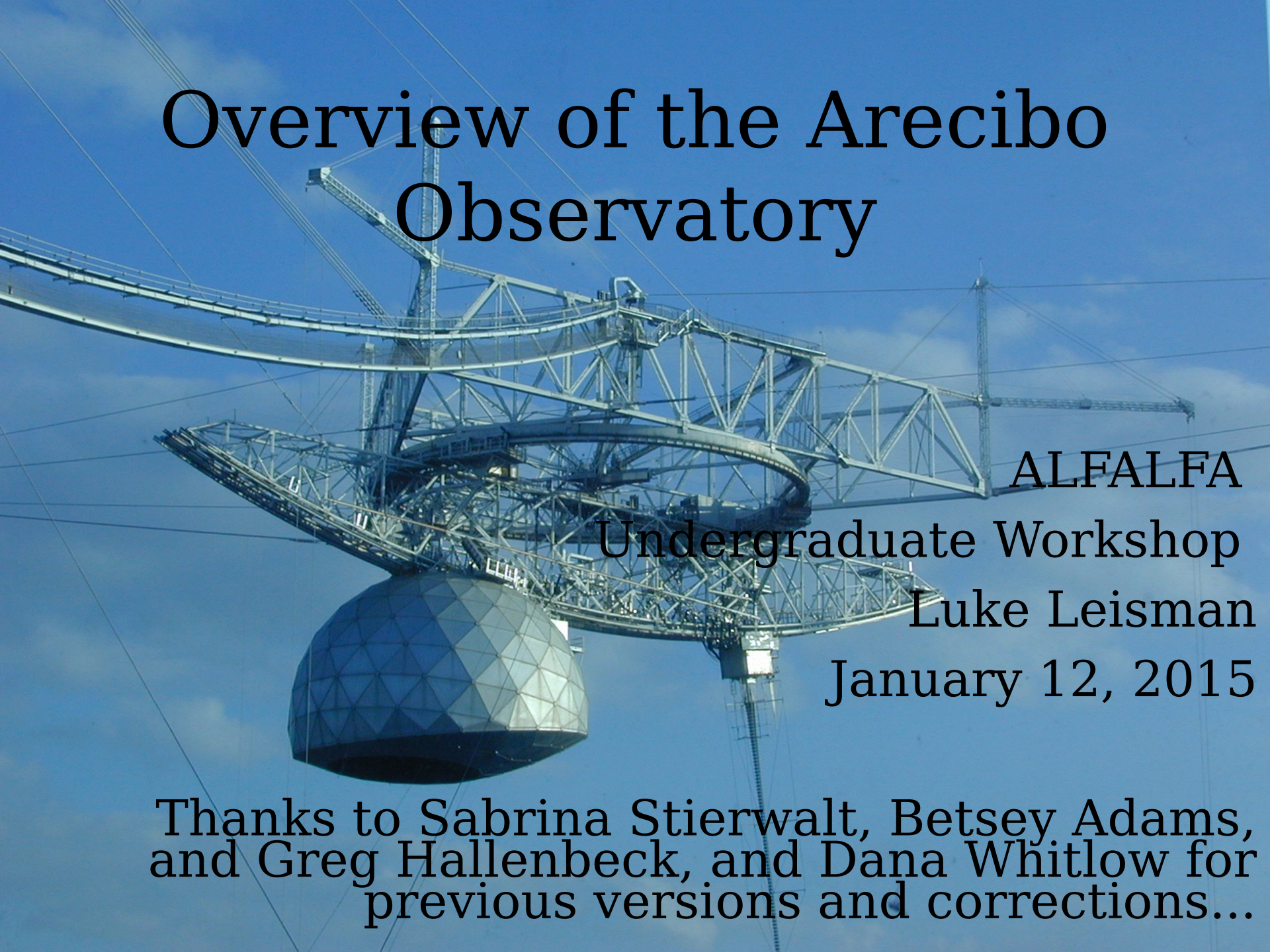
Overview of the Arecibo Observatory



ALFALFA

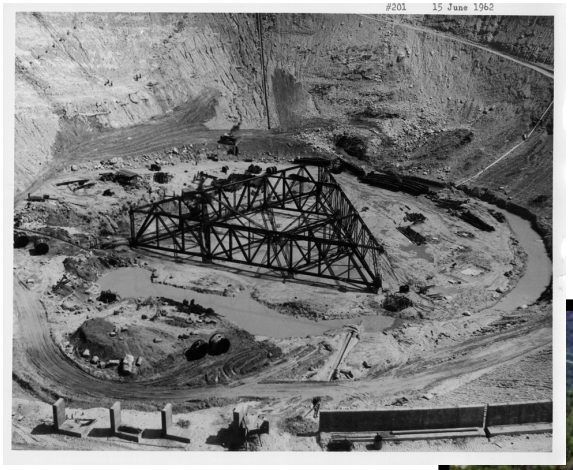
Undergraduate Workshop

Luke Leisman

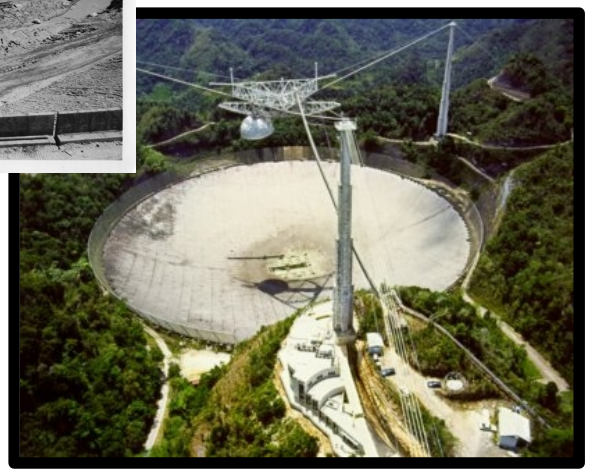
January 12, 2015

Thanks to Sabrina Stierwalt, Betsey Adams, and Greg Hallenbeck, and Dana Whitlow for previous versions and corrections...

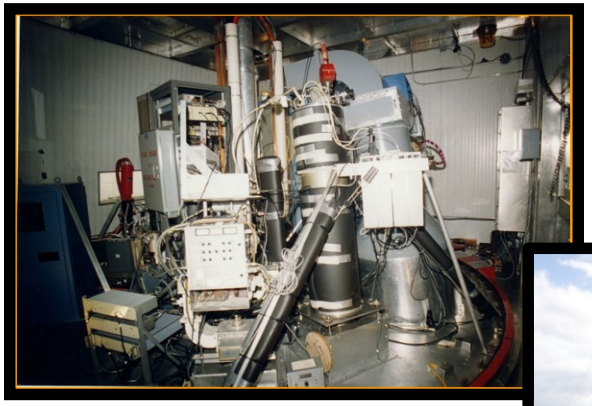
Talk Outline



- History



- The Telescope Facility



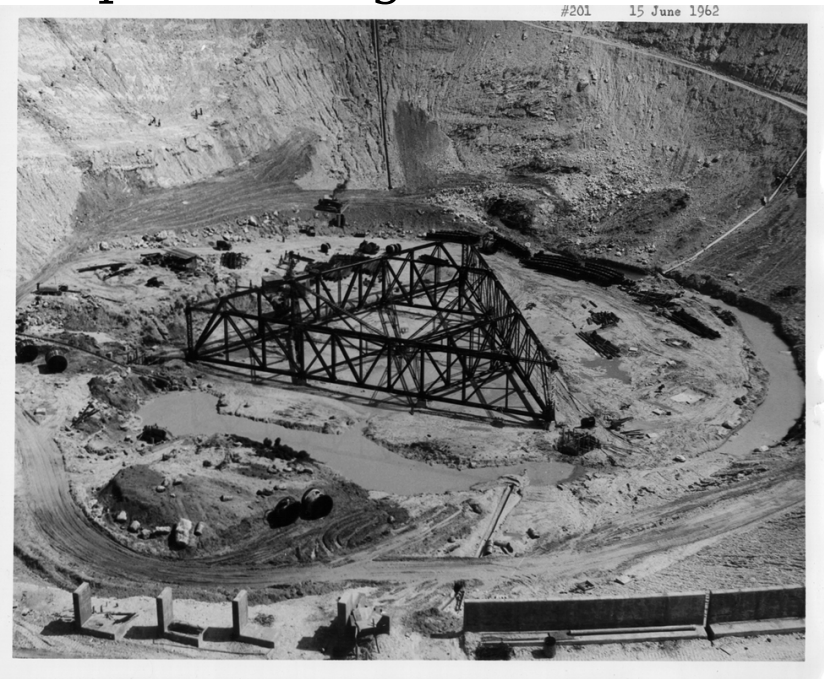
- Hardware for Observing

- Science at Arecibo

Location, Location, Location

- Built in a karst formation (limestone sinkhole)
- Near the equator - why??
- Latitude: 18° 20′ 58″ N

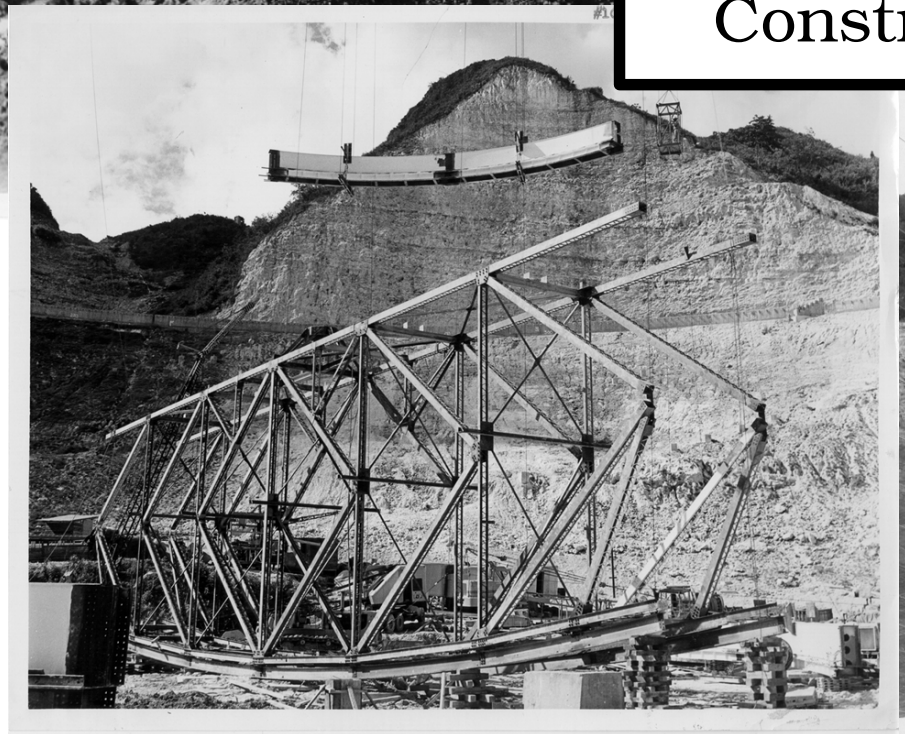
- Designed by then Cornell Professor William Gordon to study the ionosphere
- Opened November 1st 1963
- Now part of NAIC (National Astronomy and Ionosphere Center)
- Operated by Cornell for almost fifty years; now operated by SRI, USRA and UMET under cooperative agreement with NSF

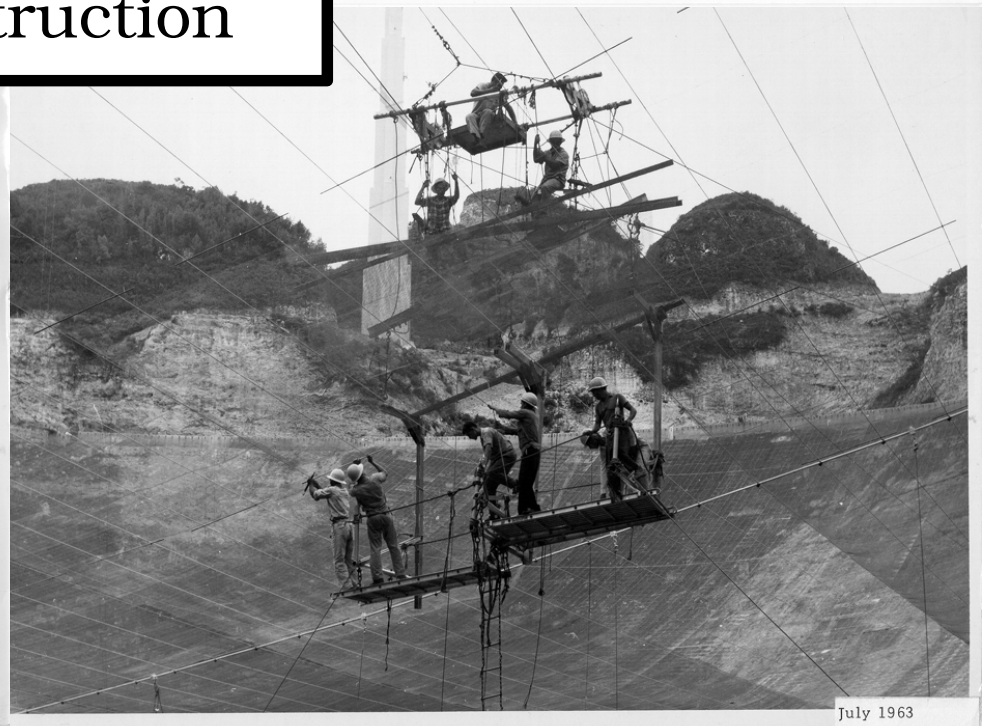


Employees

- Scientific staff
- Engineering & Computer staff
- Maintenance
- Administration
- Public Outreach

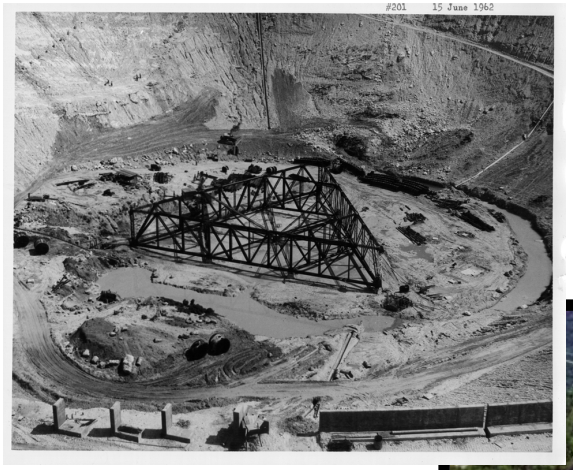
Construction



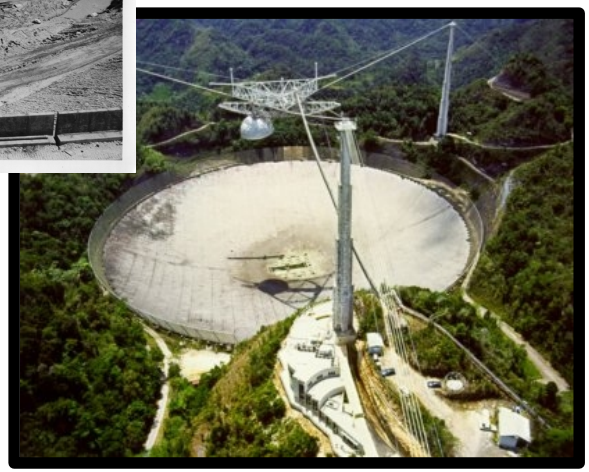


History: Upgrades…

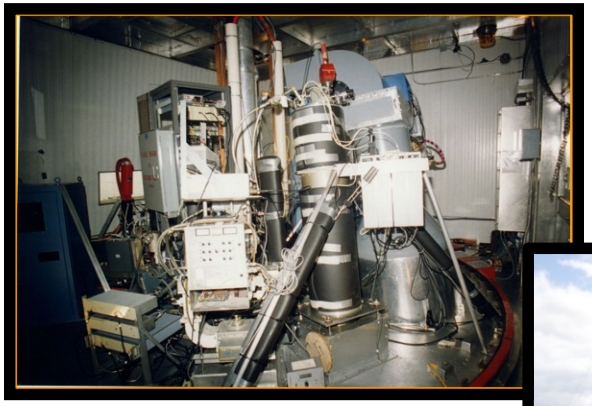
Talk Outline



- History



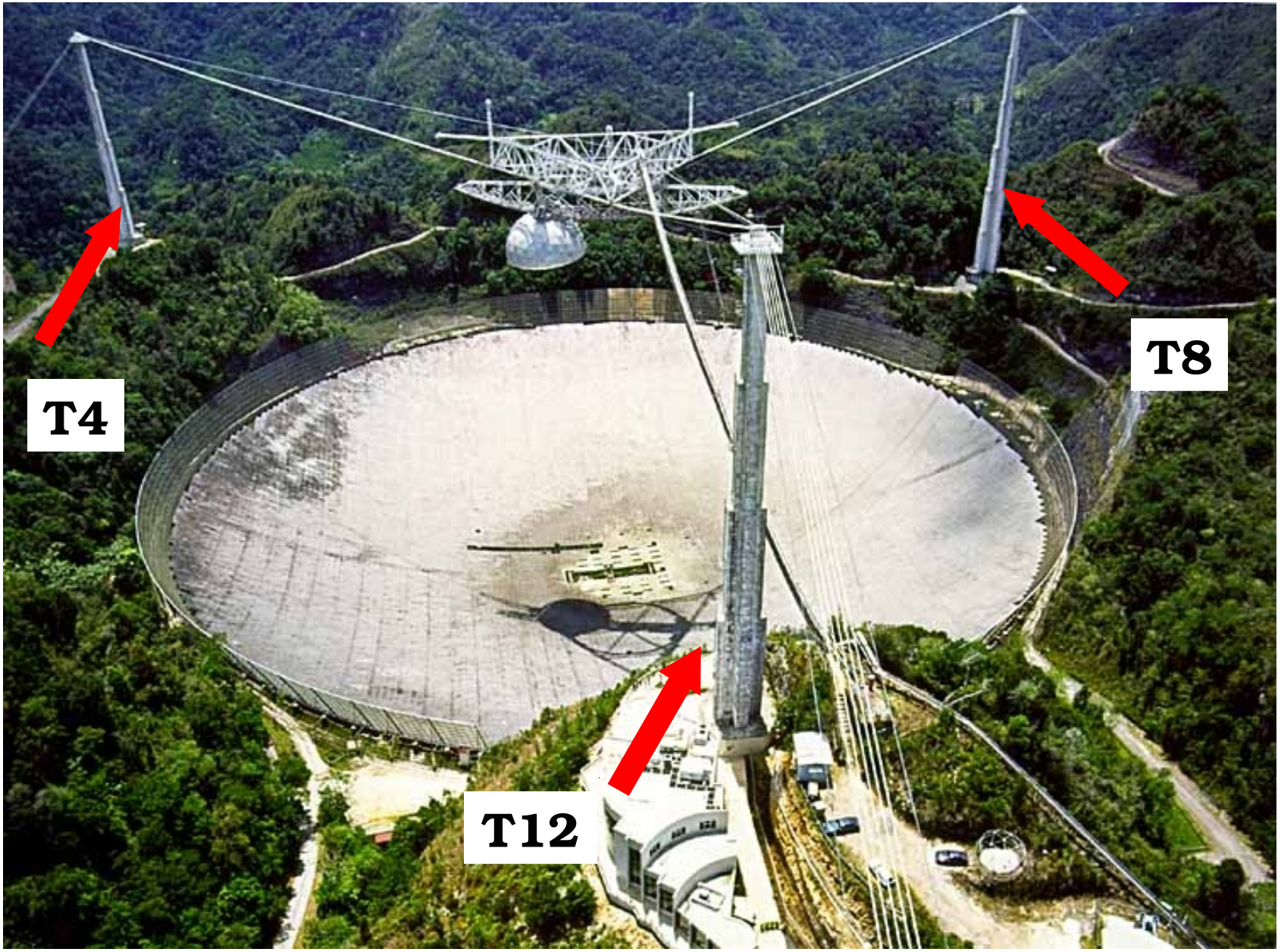
- The Telescope Facility

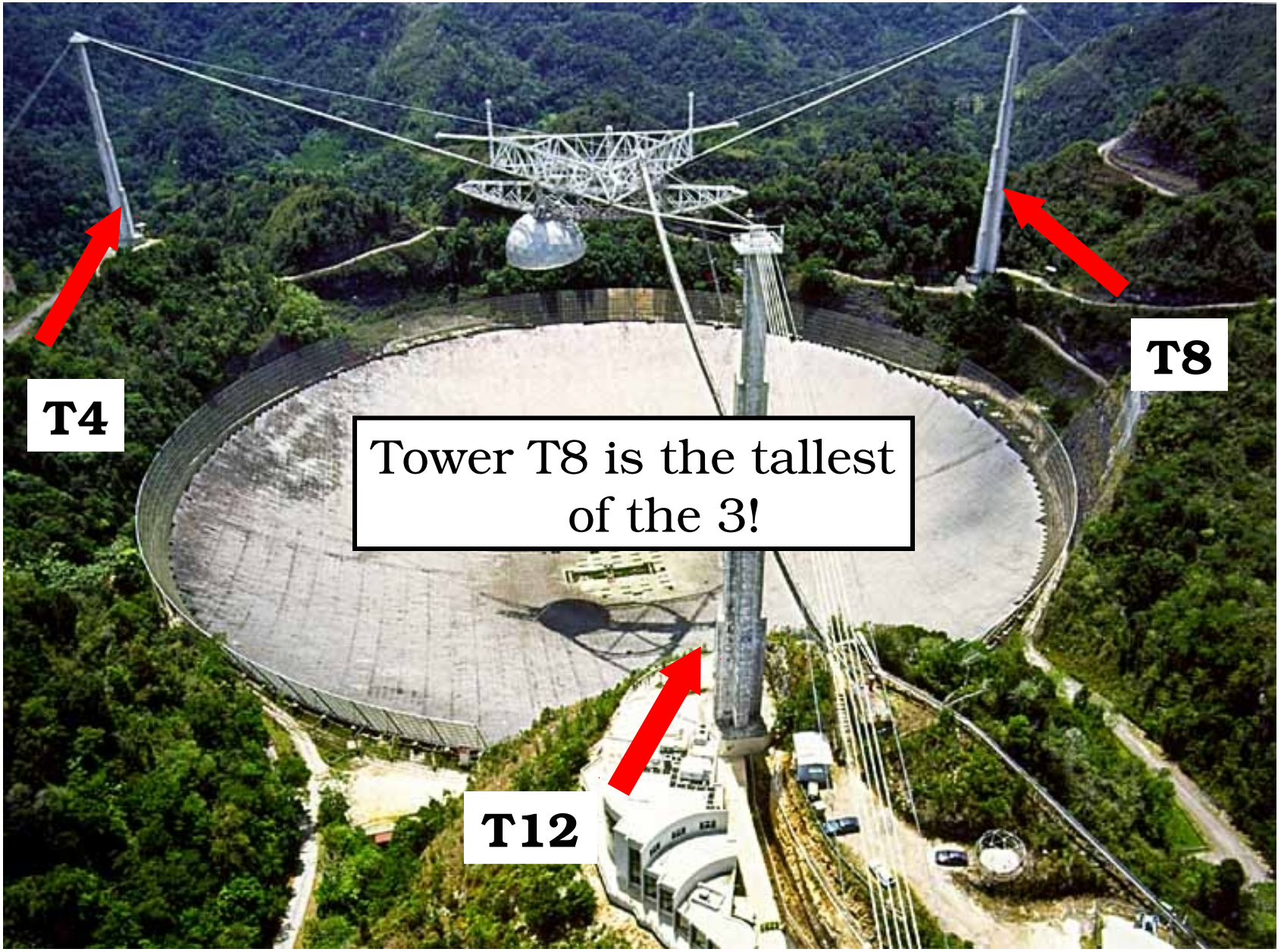


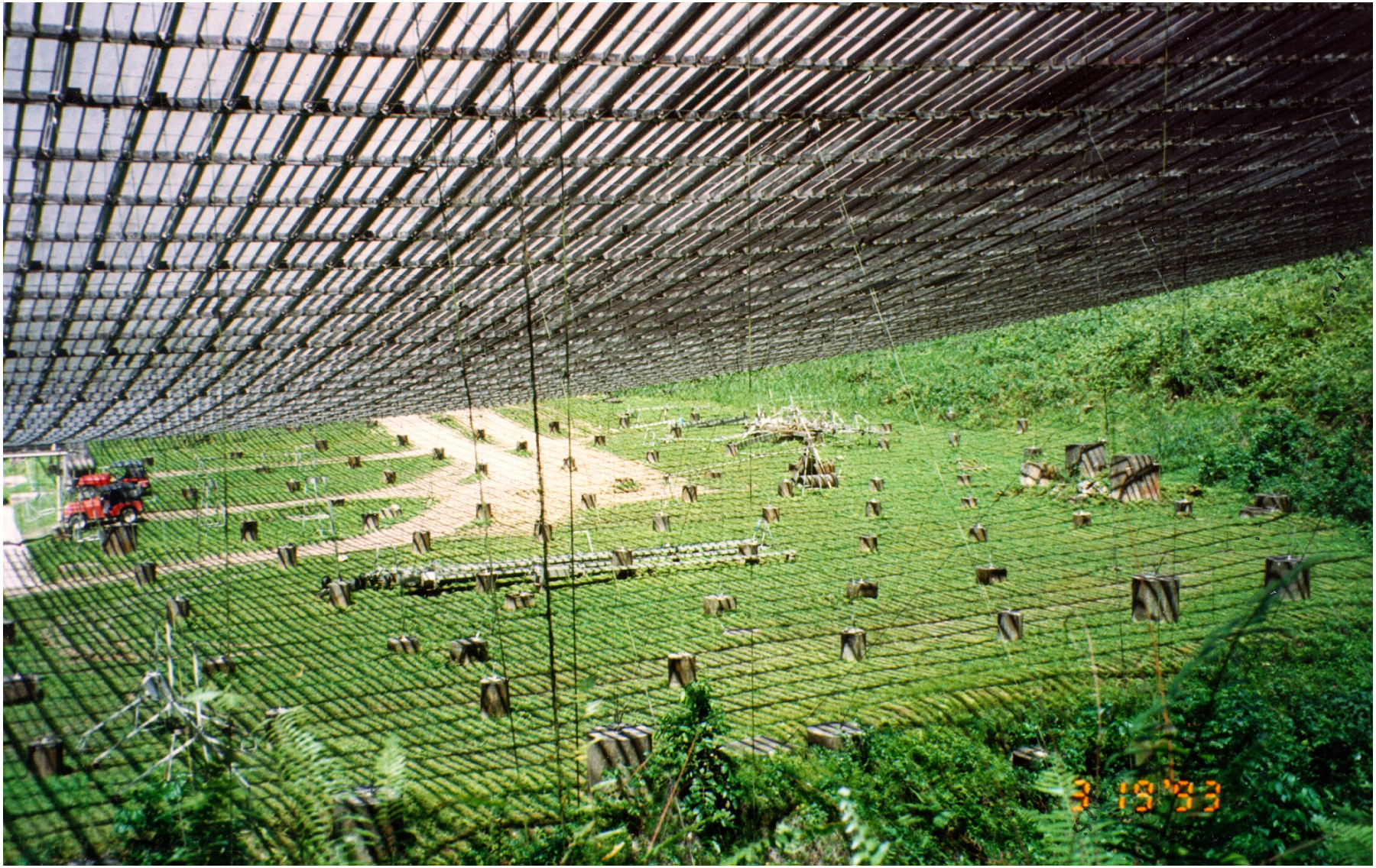
- Hardware for Observing

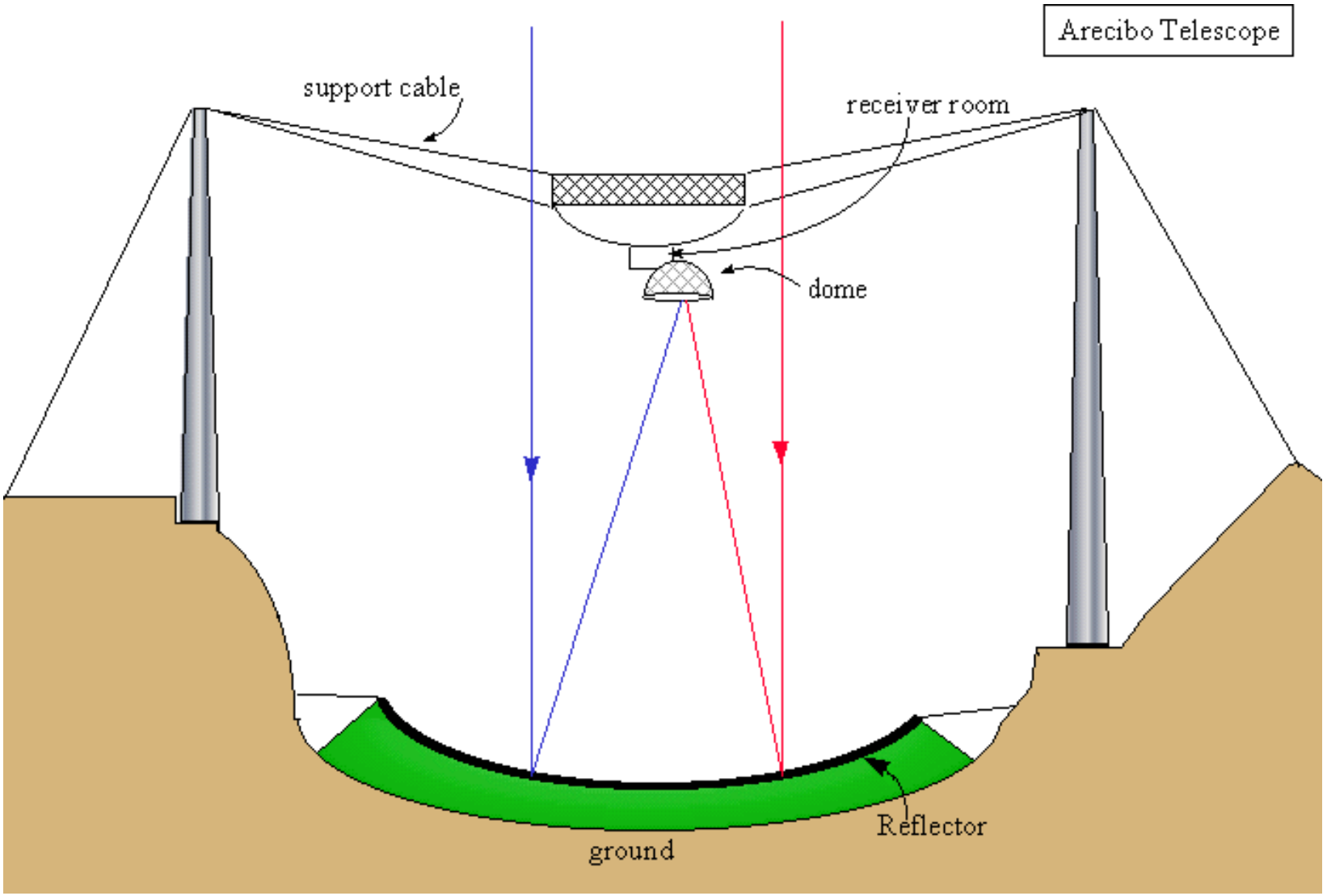
- Science at Arecibo

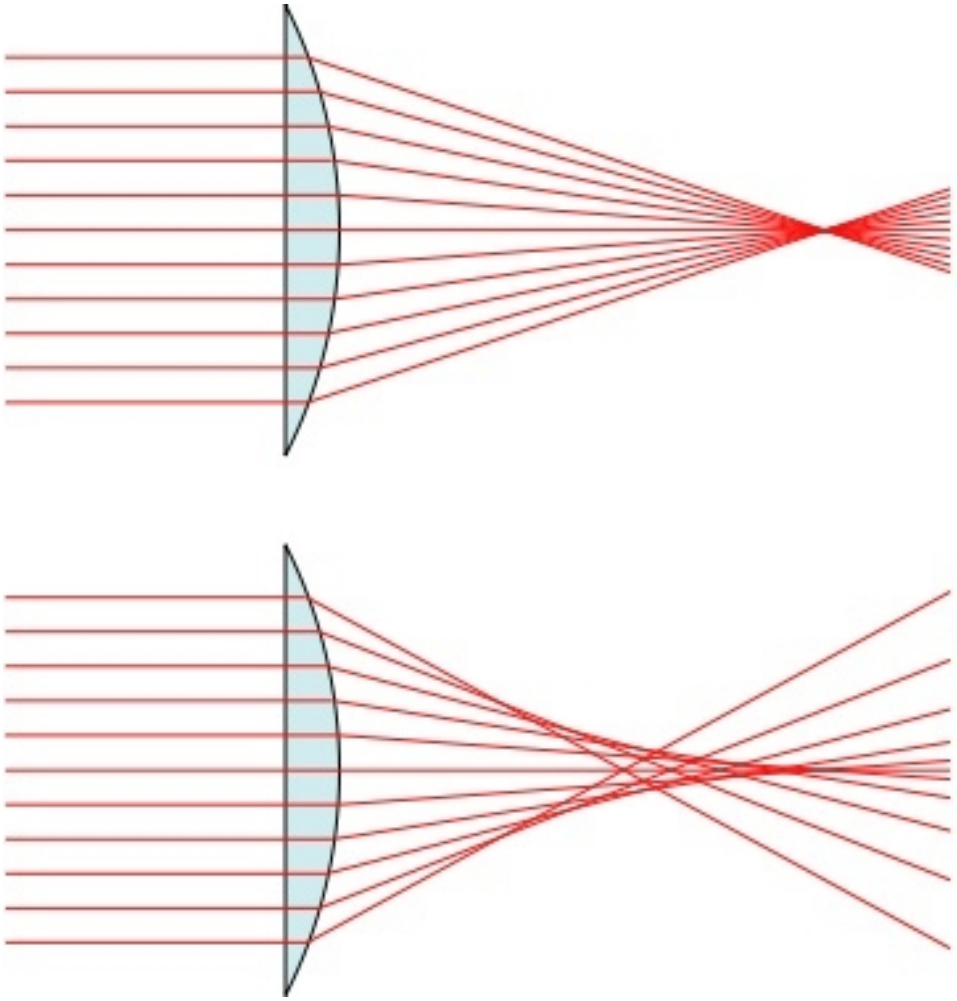
Arecibo: The Telescope


T4
T8
T12


T4
T8
Tower T8 is the tallest of the 3!
T12


3 19 '93

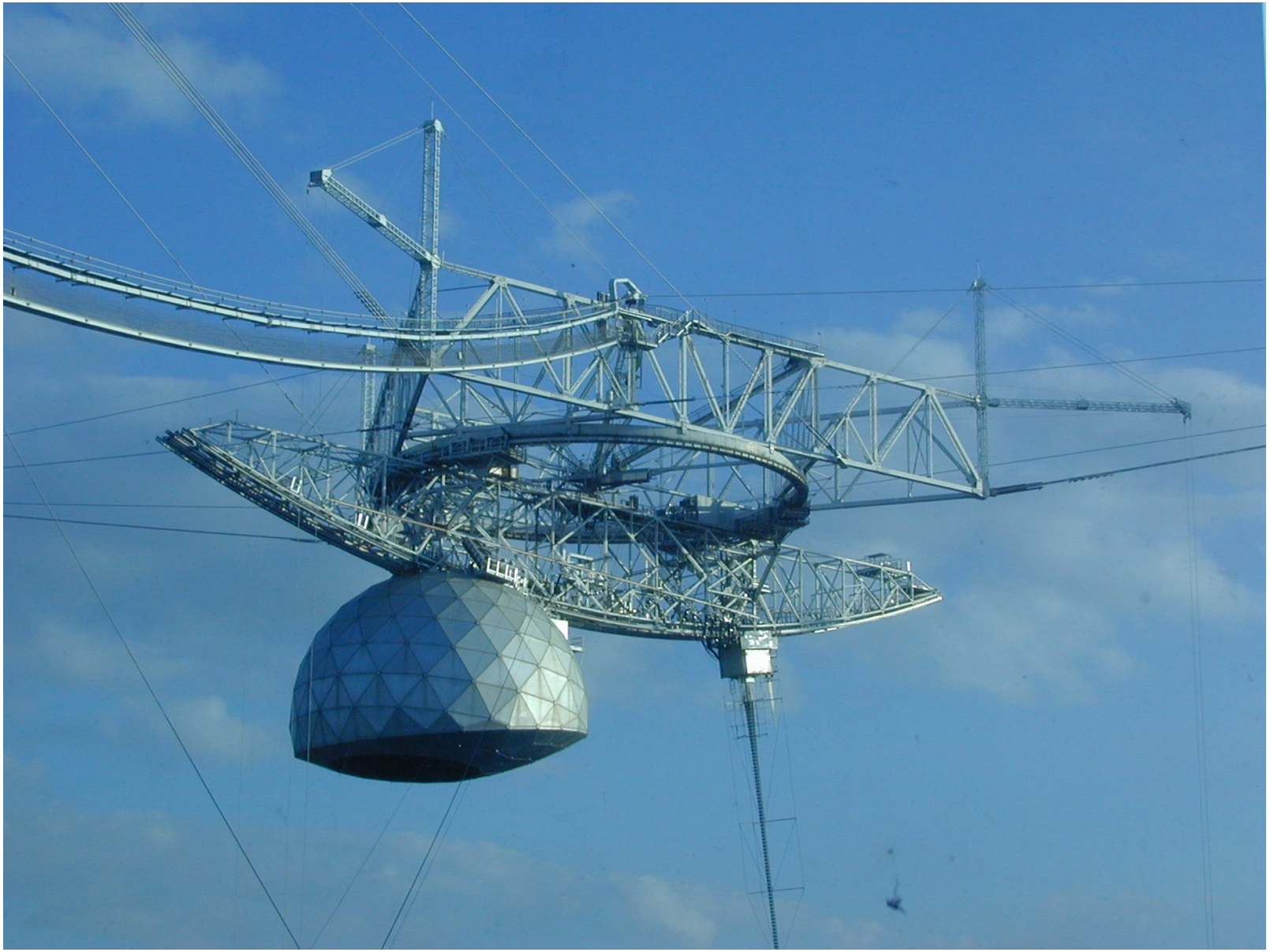

Arecibo Telescope
support cable
receiver room
dome
Reflector
ground



Parabolic Optics

Spherical Optics

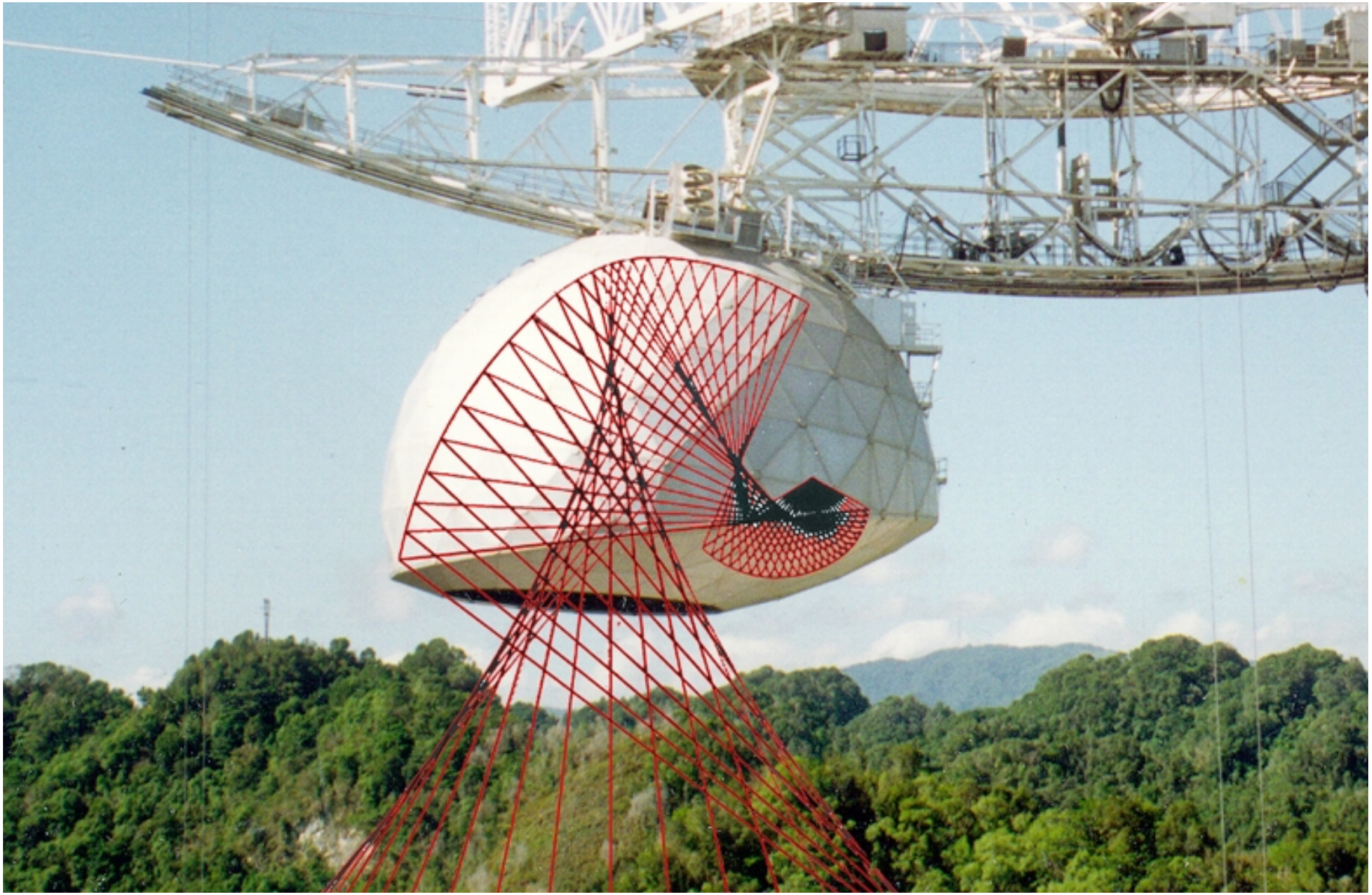
The 430 MHz Antenna and the Dome



430 MHz Antenna

- "Very long line feed"
- 96 feet in length
- Receives & transmits radio waves at 430 MHz
- Sits along the focal *line* of the optics
- Main instrument used in study of the ionosphere

Gregorian Dome



Gregorian Dome vs. Line Feed

Gregorian Dome

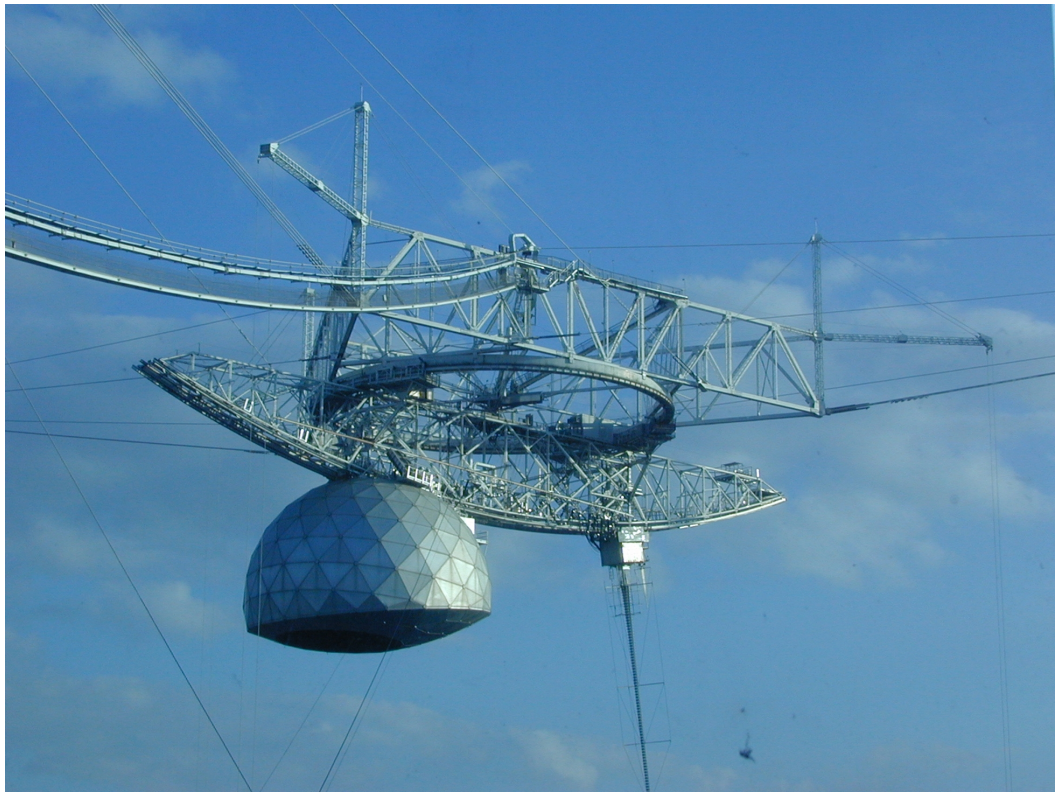
- Wider range of frequencies per receiver; easily movable receivers
- Receivers are much smaller (but must all fit into the small receiver room)
- Receivers are moderately difficult to add and remove
- Dome shields the receivers from RFI

Line Feed

- Narrow range of frequencies per feed
- Feeds are extremely large and heavy
- Feeds are very difficult to add, remove, and move into place

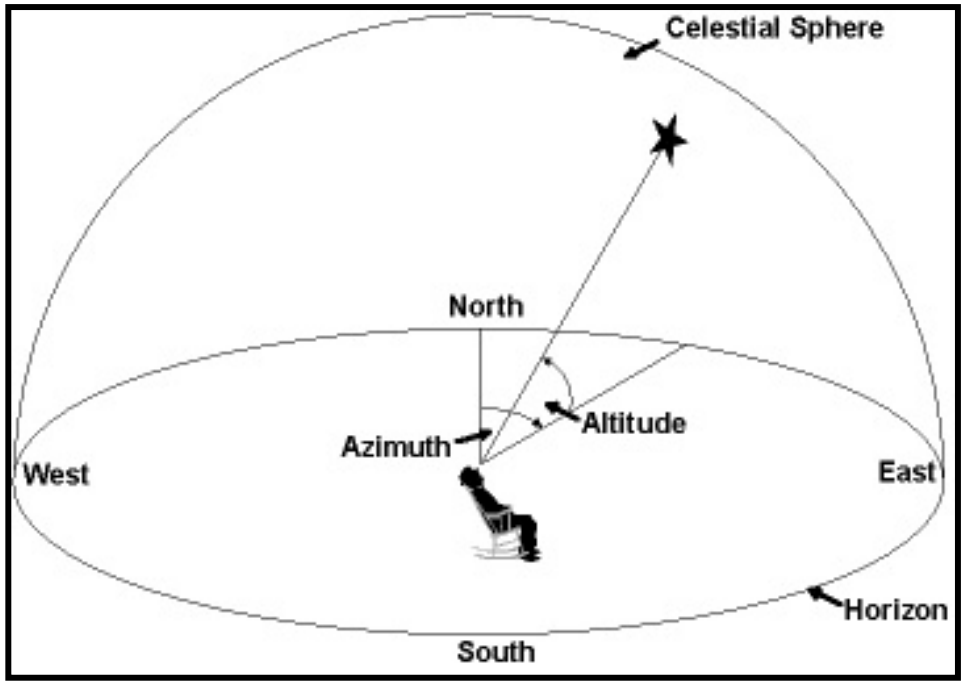
Arecibo Stats

- Covers 1m - 3cm (300 MHz - 10 GHz)
  - Additional 47 MHz transmitter
- Slew rate:
  - 25°/min in azimuth
  - 2.5°/min in zenith
- Pointing accuracy of five arcseconds



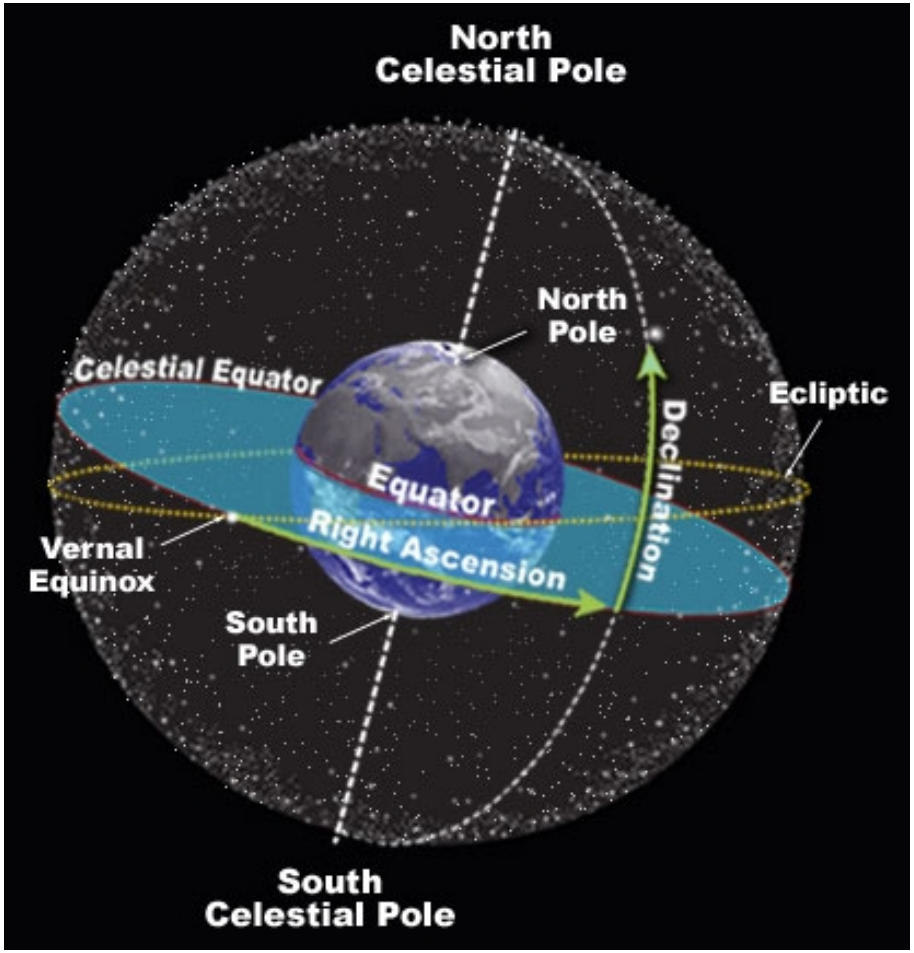
- Can view objects within ~40° cone about local zenith (0 to 36 degrees dec)

Azimuth & Zenith



- Azimuth Angle
  - Measured in degrees
  - Tells how far east of north the source is located
- Zenith Angle
  - Measured in degrees
  - Tells how far below zenith a source is located
- They depend on the observer's location!

Equatorial Coordinates

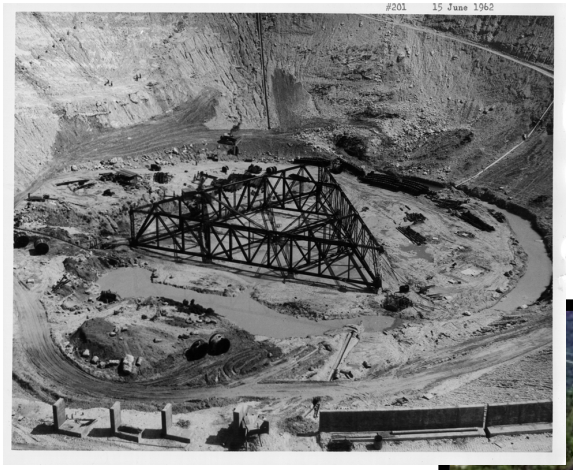


- Right Ascension
  - Measured in hours (0 to 24)
  - Zero-point toward constellation Pisces (increases to the east)
  - Similar to longitude
- Declination
  - Measured in degrees
  - Zero-point is the equator
  - Similar to latitude
- They are the same for every observer location and time!

Pointing Limits of Arecibo

- Can move dome to zenith angle position of 19.7°
  - But only to ~18° with good performance
- Can move dome to within 1.06° of zero zenith angle
  - 1.1° recommended

Talk Outline



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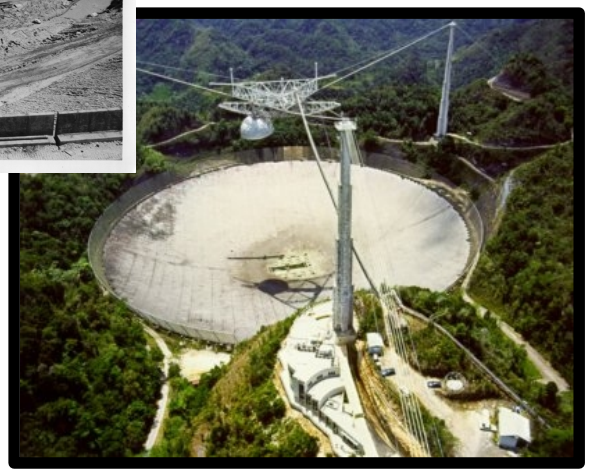

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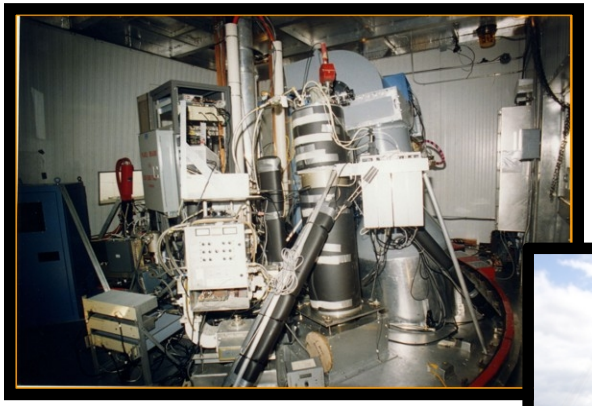
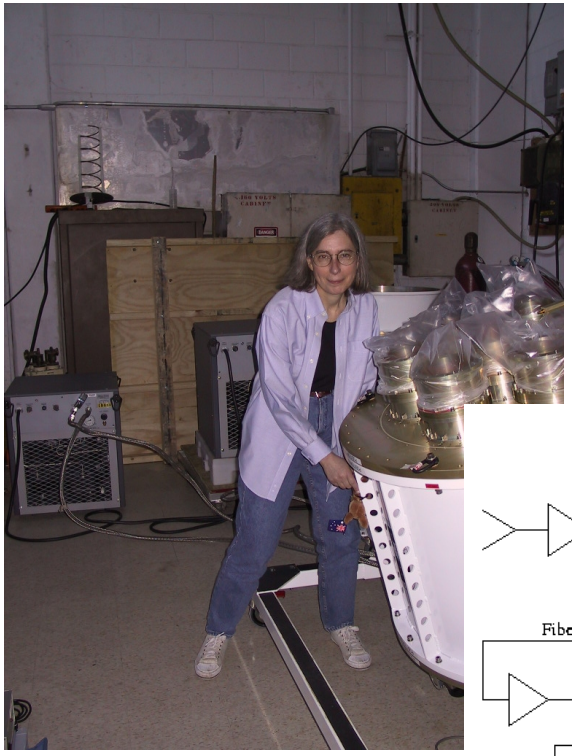


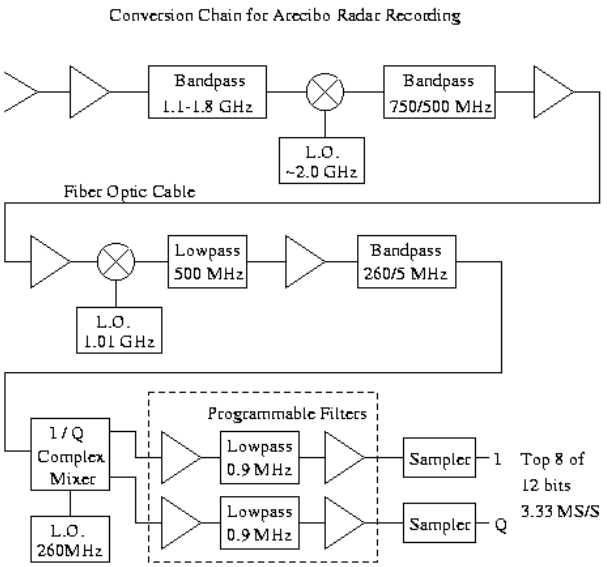
- Hardware for Observing

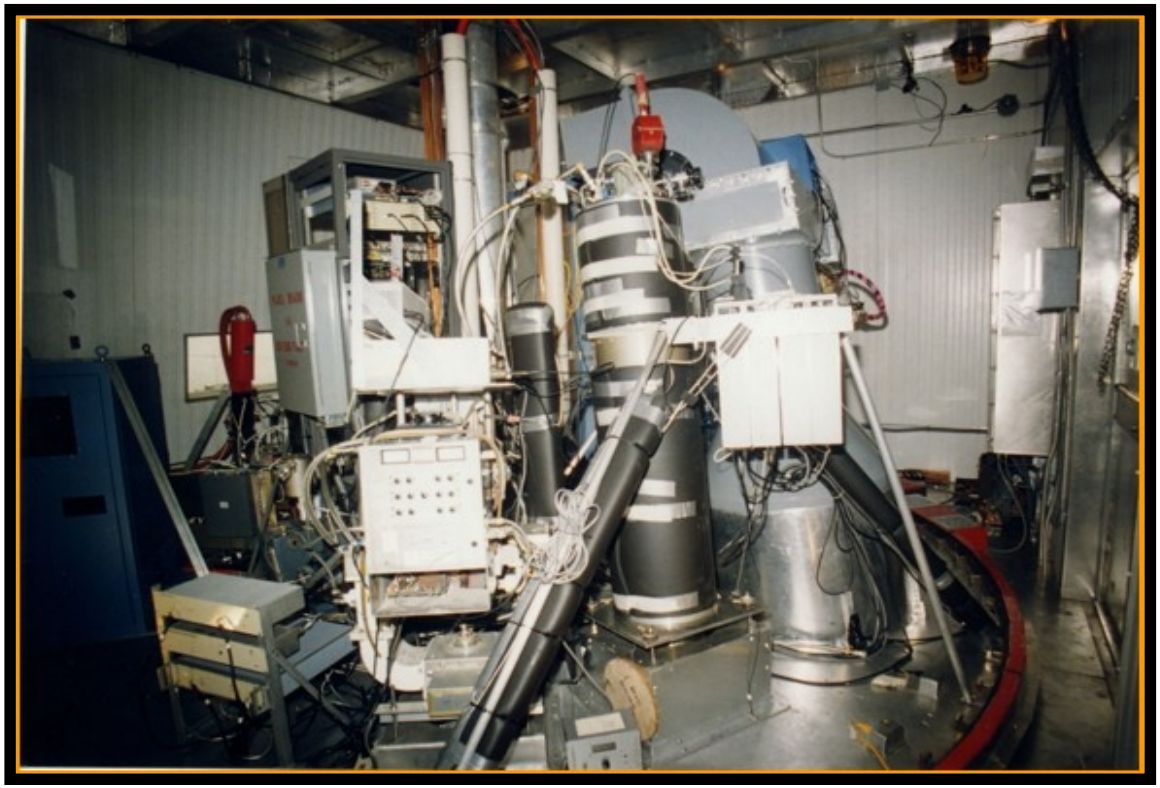
- Science at Arecibo

Telescope Hardware: The Path to Detection

- Detected with receivers in Gregorian Dome
- Amplification
- Frequency conversion
- Transportation
- Backend: Correlation







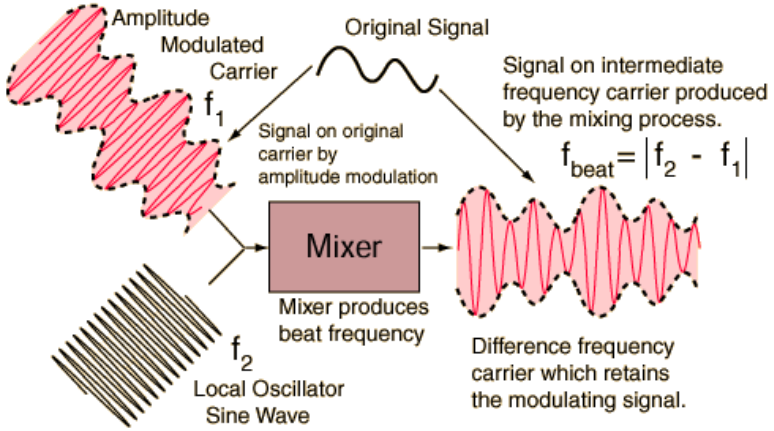
Available Receivers: 327 MHz, 430 MHz, 610 MHz, ALFA, L-Wide, S-Low, S-Narrow, S-High, C, C-High, X

Each have different frequency ranges, sensitivities, temperatures, and beam sizes

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
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

The Detection Path: IF/LO

- Transmission losses increase with frequency
- Convert to lower frequency before transmitting signals off of the platform
  - Intermediate Frequency
  - Local Oscillator
- Today, IF signals are transported along fiber optics (this also stops lightning strikes from causing sparks in the control room)

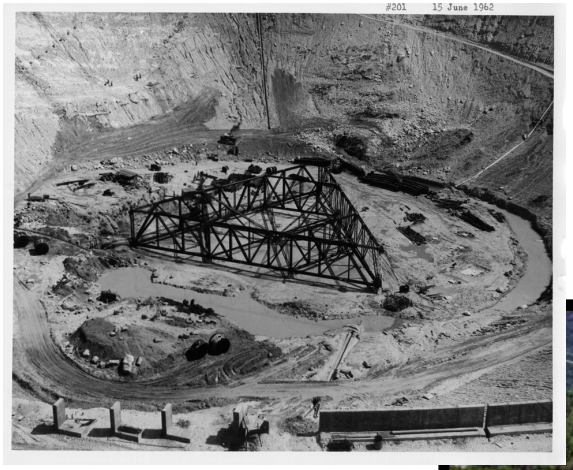


Taken from http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html

Backend

- Responsible for signal processing: setting frequency range, breaking into channels, etc.
- Several are available, with ranges of capability
  - For L-band wide observations with known redshift, we use the the stable and reliable “Interim” Correlator
  - For L-band wide in search mode, and for ALFALFA, we used the WAPPs: less reliable, but more coverage
  - Others: galspect, Mock Spectrometer, PUPPI

Talk Outline



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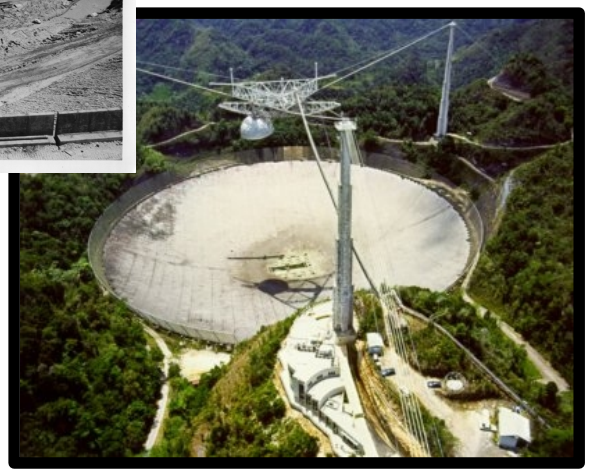

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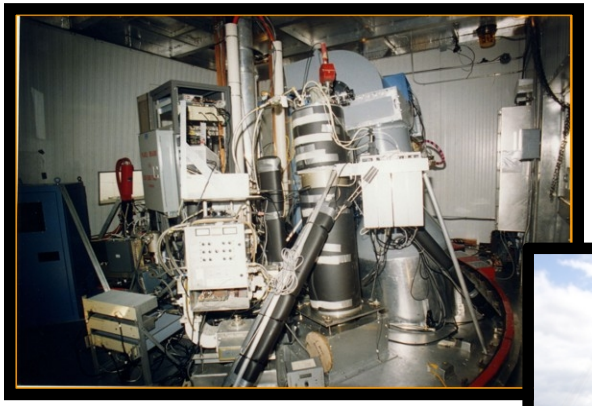
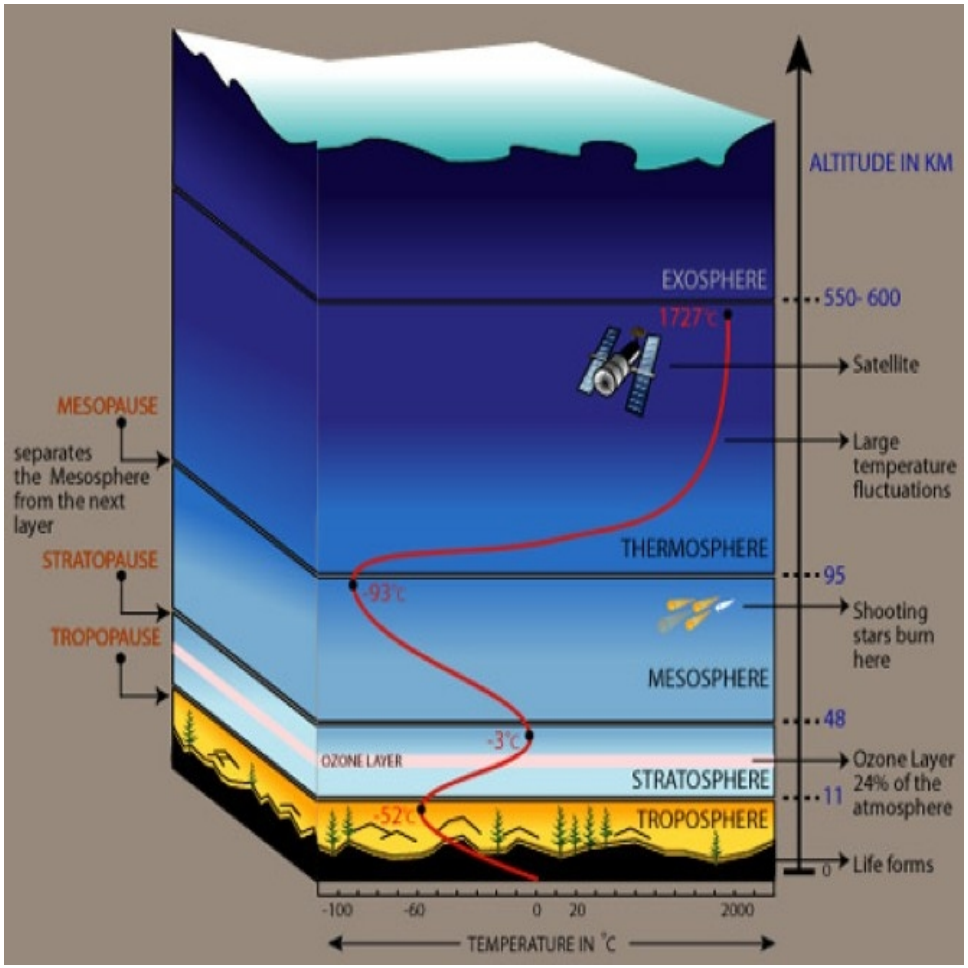


- Hardware for Observing

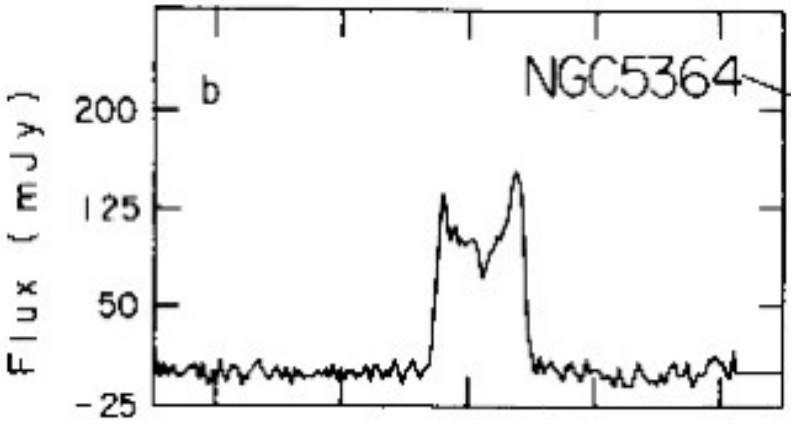
- Science at Arecibo

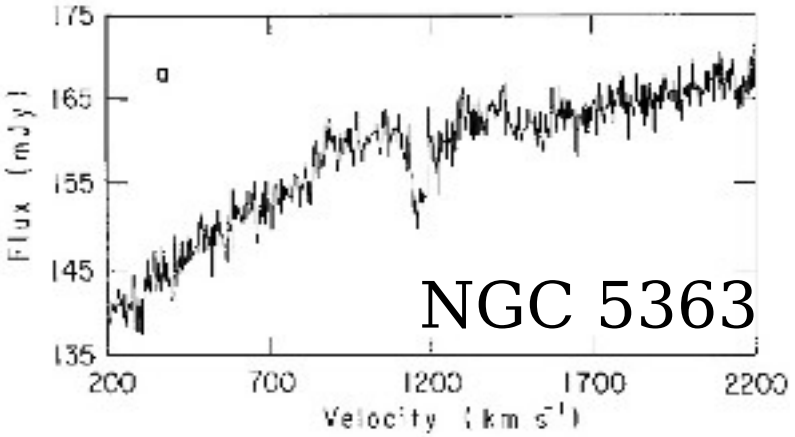
Areas of Study at Arecibo



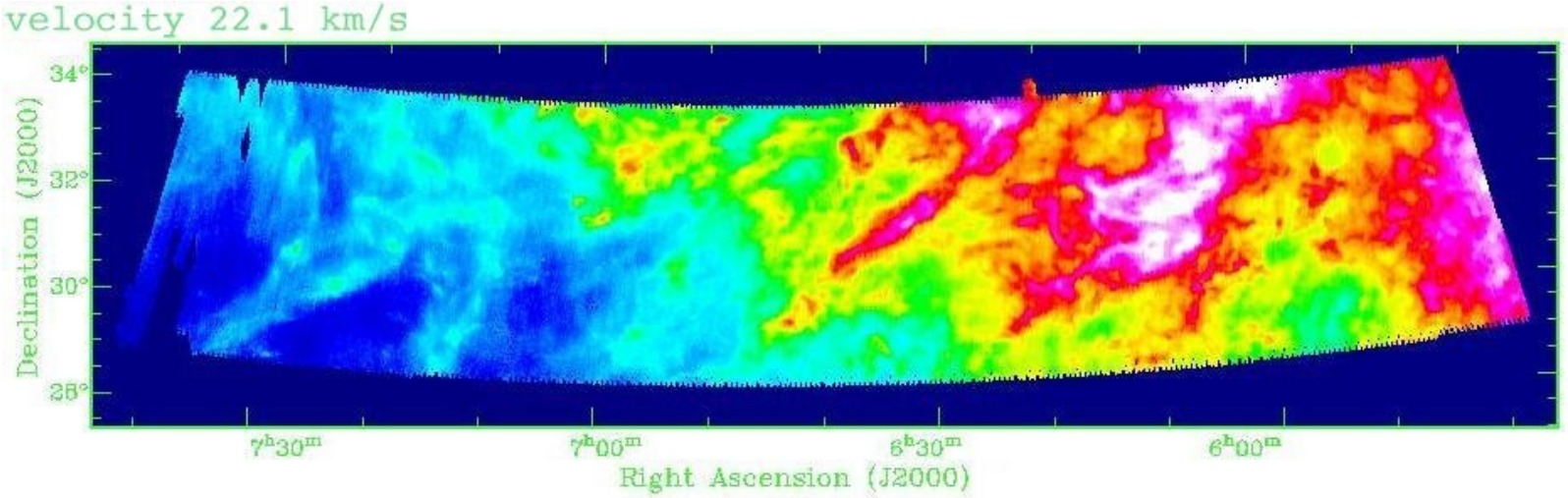
- Atmospheric Science (20%)
  - Measures composition, temperature, and density of upper atmosphere
  - Measures the growth and decay of disturbances in the ionosphere
- Radio Astronomy (80%)
  - Spectral Lines
  - Continuum
  - Radar
  - Pulsars
  - VLBI

Spectral Line Observations



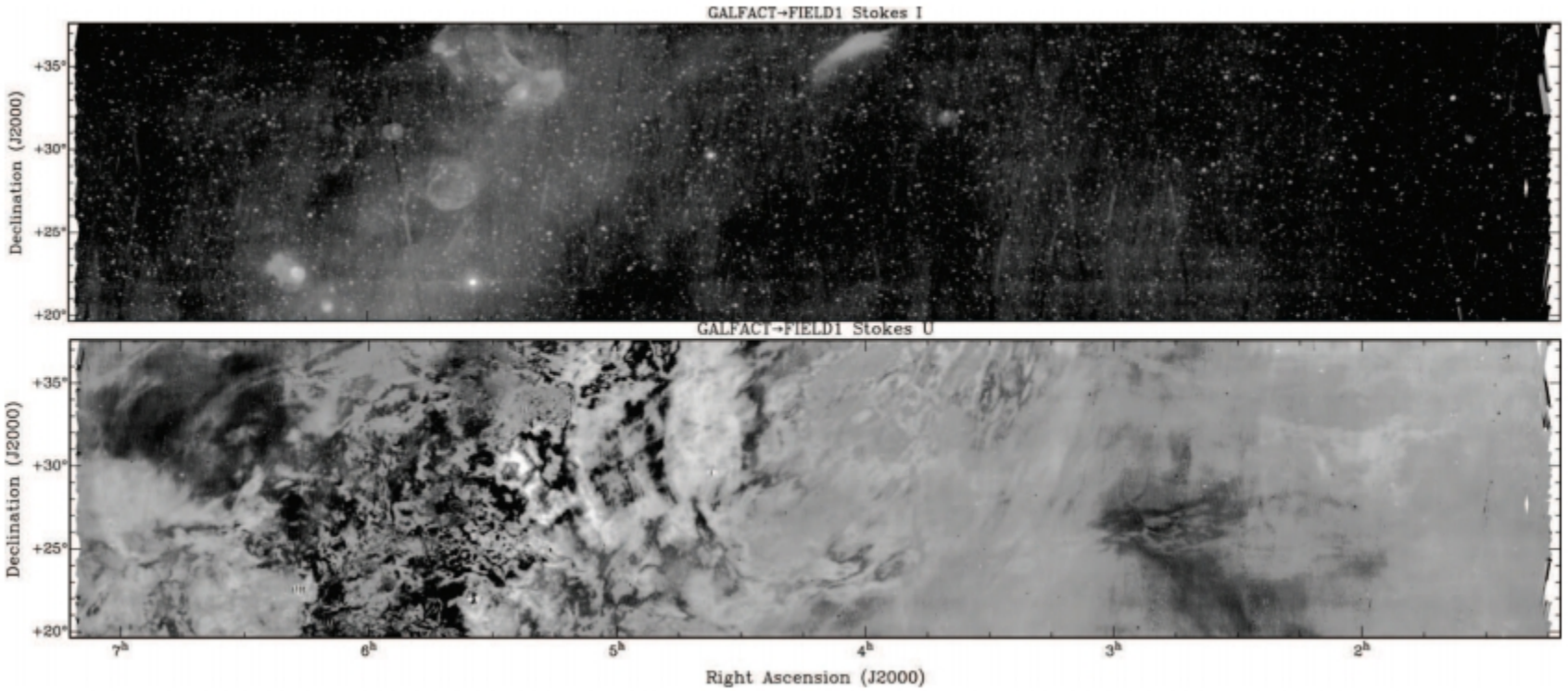


Spectra from Haynes & Giovanelli, 1981



GALFA 21cm map of Milky Way

Radio Astronomy:
Continuum Observations

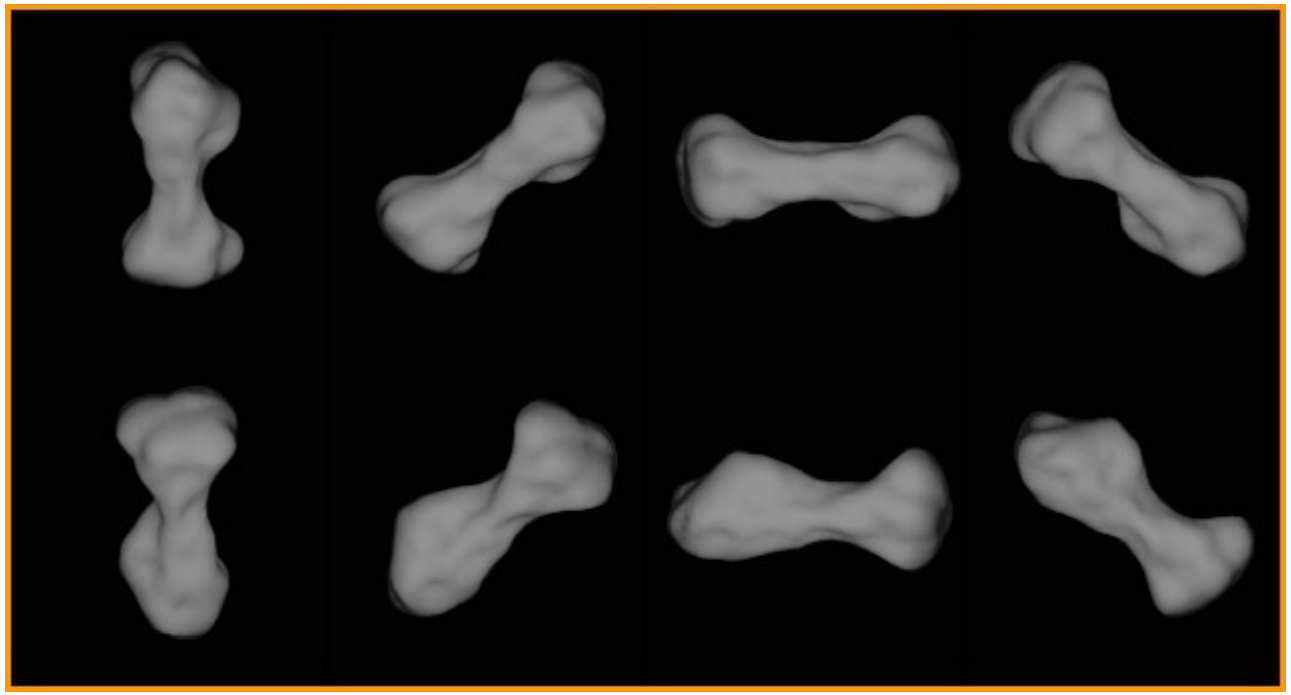


1.4 Ghz continuum intensity (top) and polarization (bottom) at galactic center – probing magnetic fields!

Broad Trends instead of narrow lines!

GALFACTS survey; from Taylor and Salter 2010

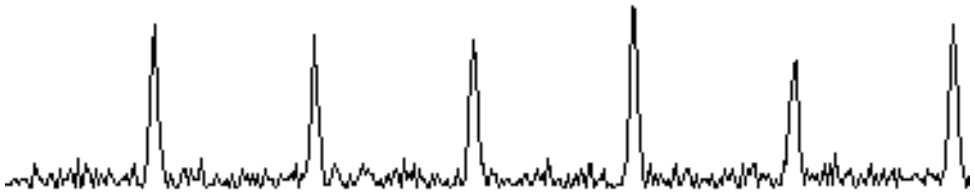
Radio Astronomy: Radar



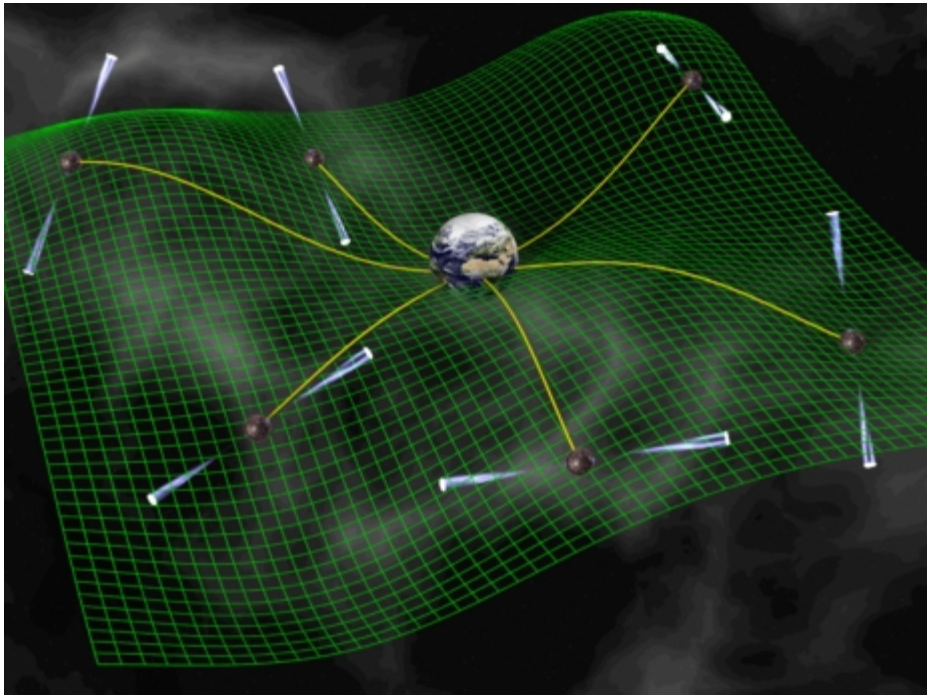
Asteroid Kleopatra 216

Active observations of solar-system objects – more from Patrick Taylor Wednesday!

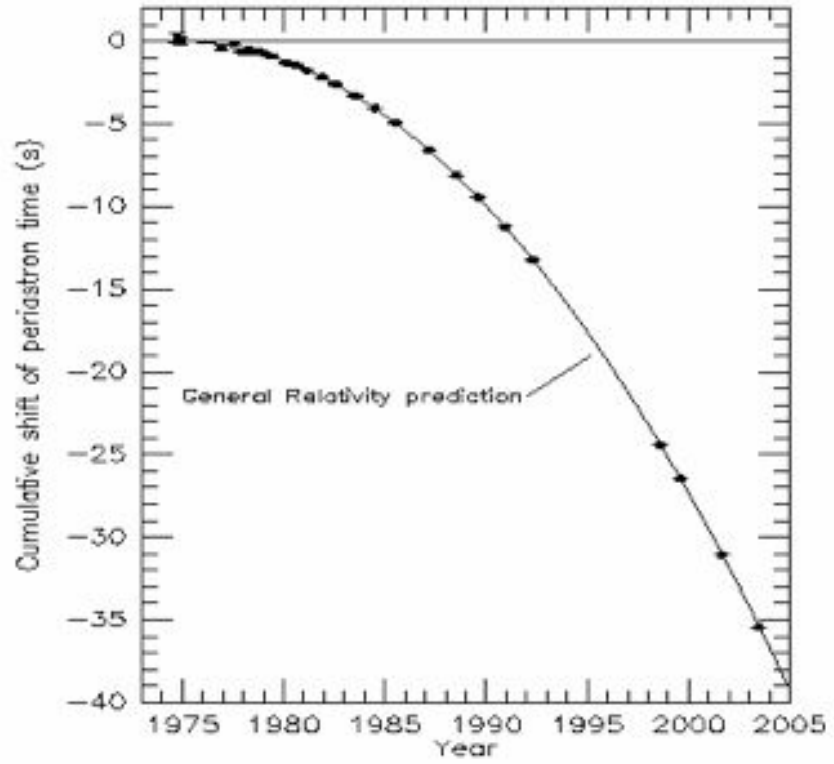
Radio Astronomy: Pulsars



A schematic of a pulsar signal

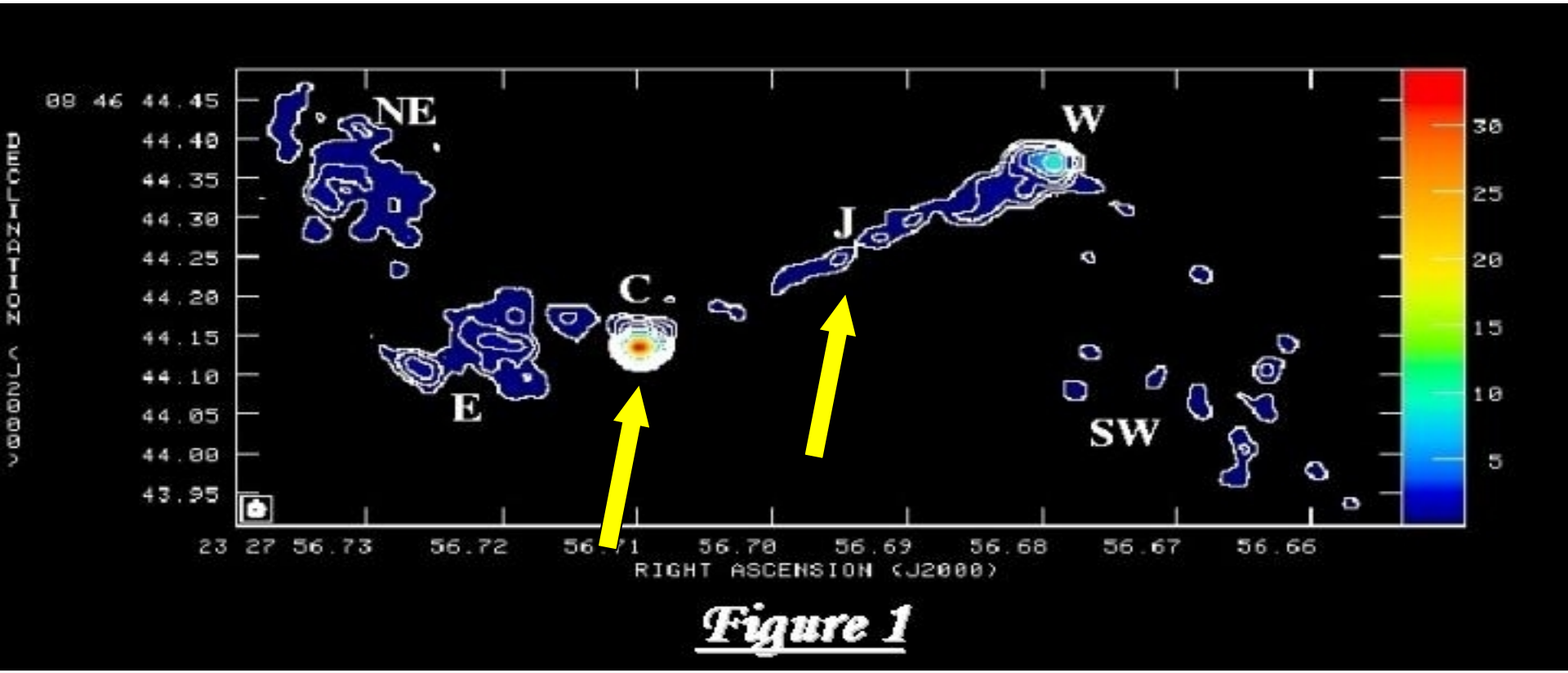


Pulsars are used to search for gravitational waves



Lots of additional pulsar science:
-The first planets
-Dynamics of merging systems
-Tests of General Relativity
-Nature of the ISM

VLBI - Very Long Baseline Interferometry

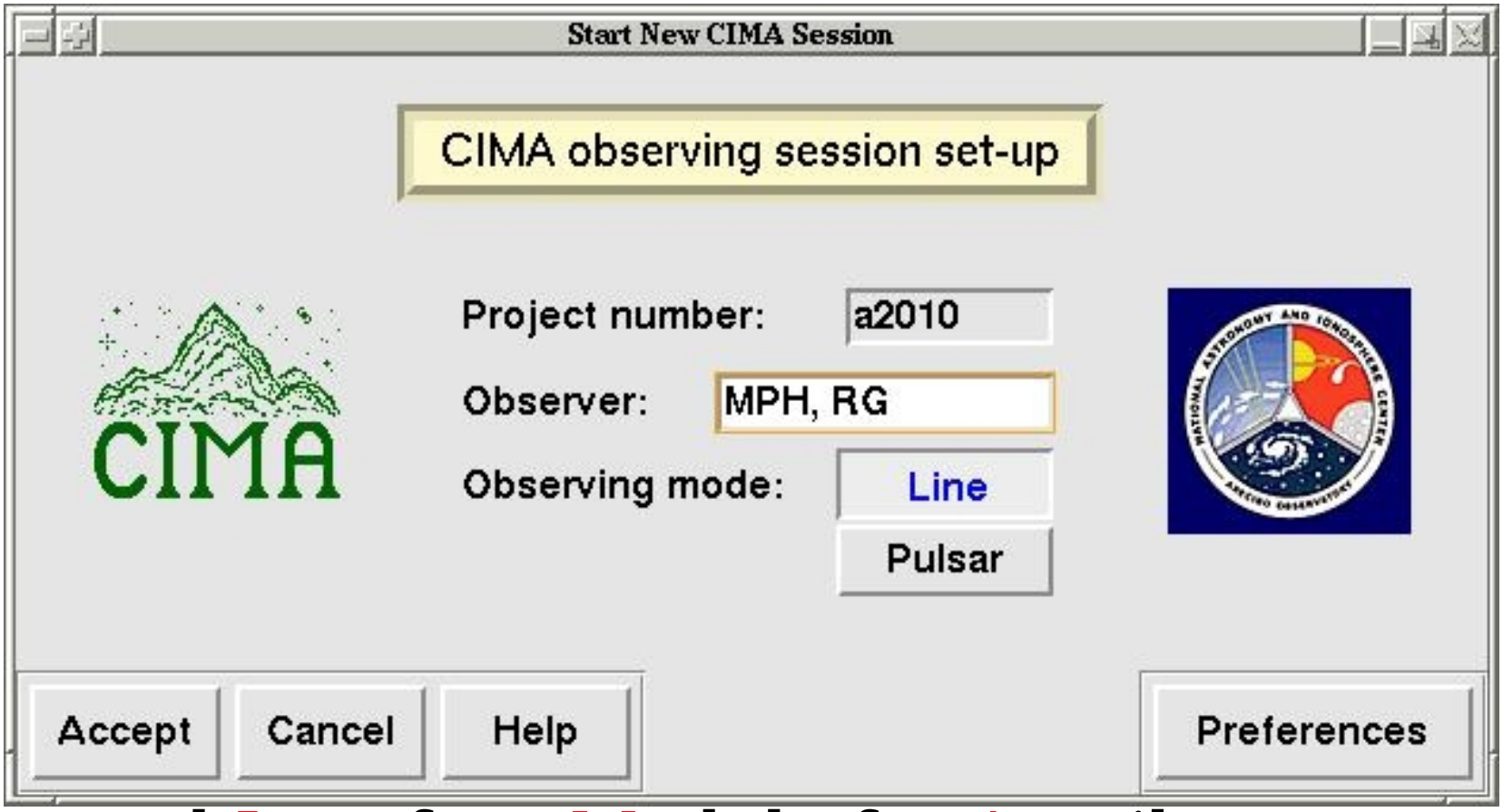


Contour Plot of NGC 7674 courtesy of E. Momjian

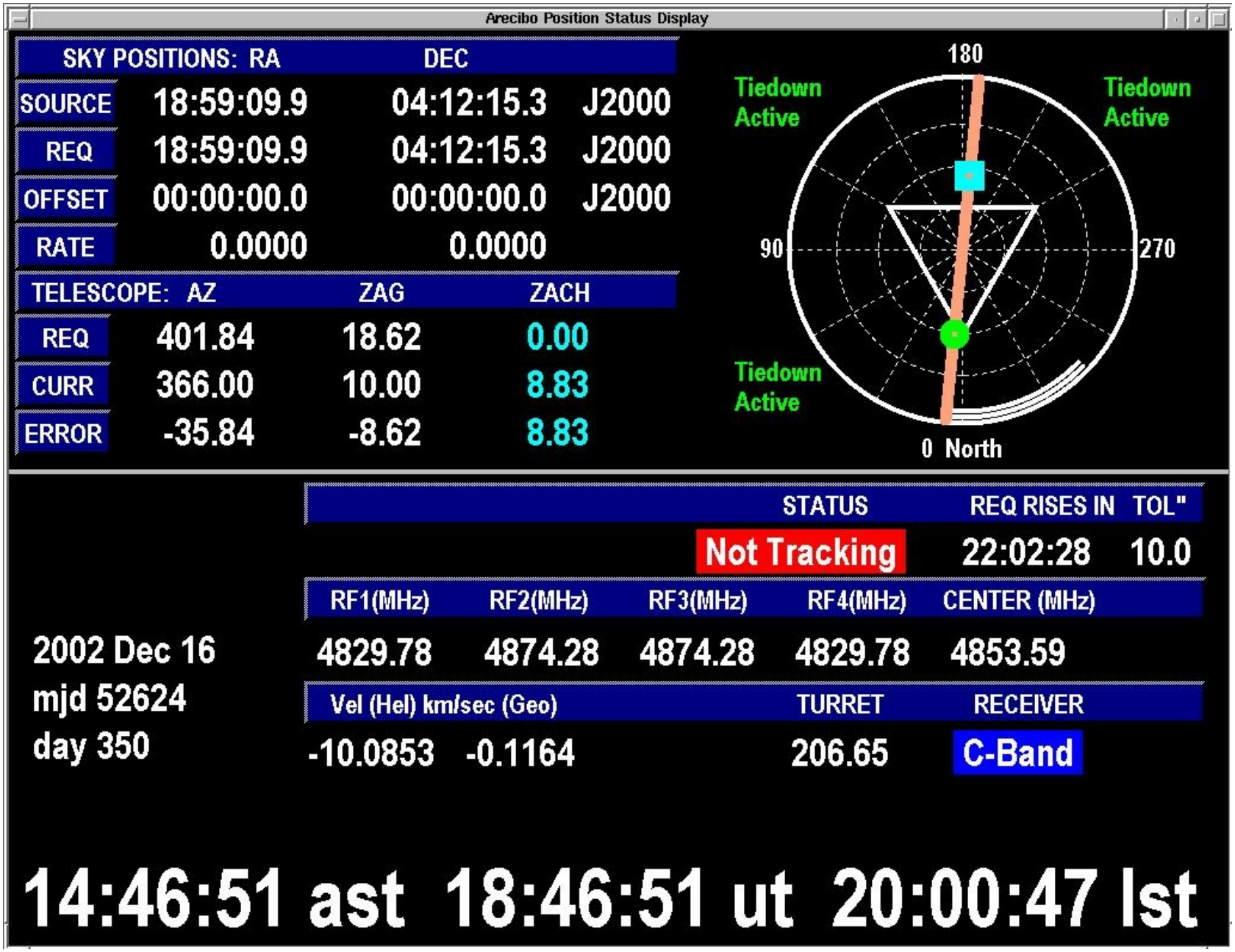
Summary

- Arecibo has been in operations for >50 years
- Arecibo has a wide range of capabilities
- Arecibo is still doing cutting edge science

CIMA



Control Interface Module for Arecibo: a graphical interface that makes observing as easy as clicking buttons (more on this later…)


Arecibo Position Status Display
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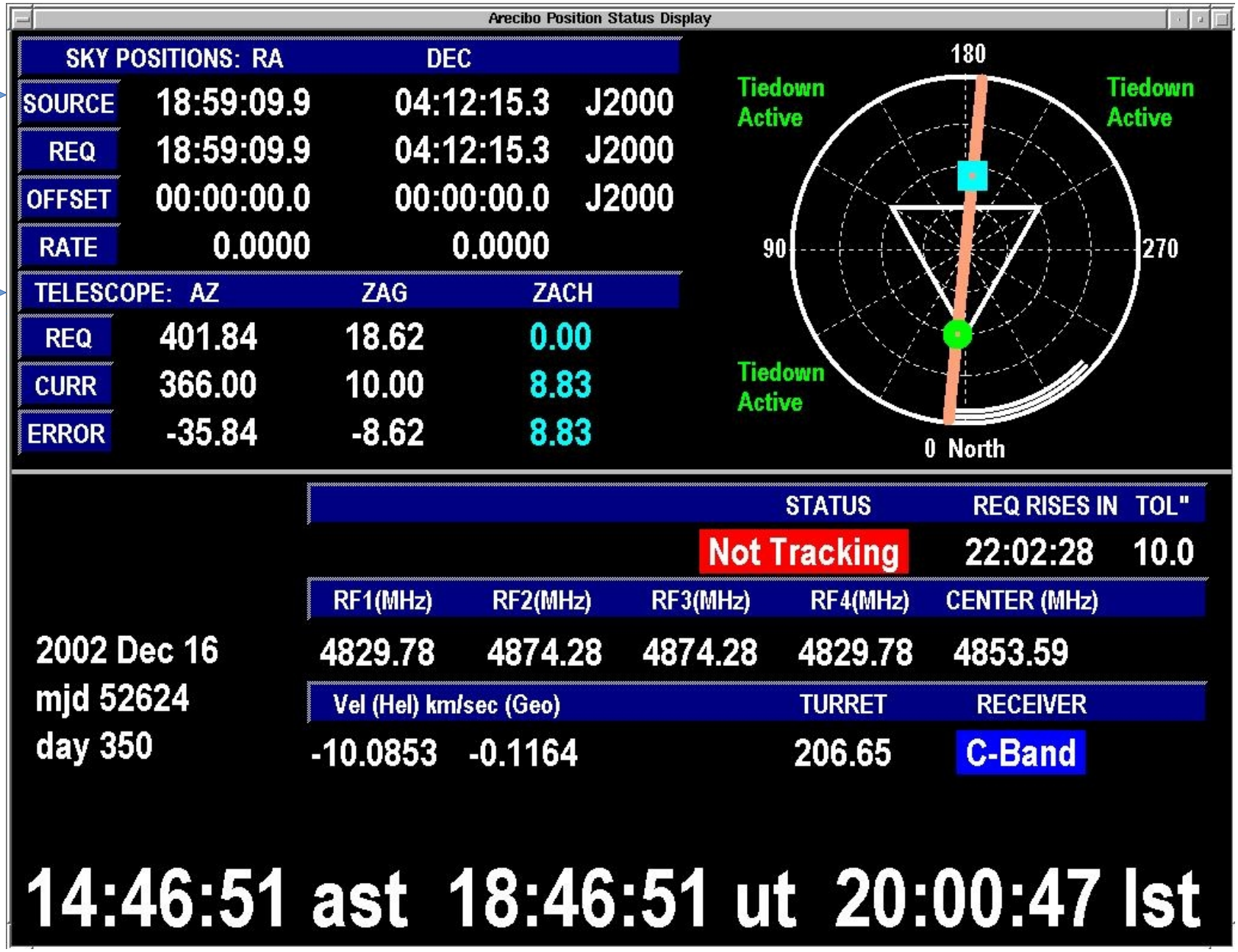
REQ 18:59:09.9 04:12:15.3 J2000
OFFSET 00:00:00.0 00:00:00.0 J2000
RATE 0.0000 0.0000
TELESCOPE: AZ ZAG ZACH
REQ 401.84 18.62 0.00
CURR 366.00 10.00 8.83
ERROR -35.84 -8.62 8.83
180
Tiedown Active
Tiedown Active
90
270
Tiedown Active
0 North
STATUS REQ RISES IN TOL"
Not Tracking 22:02:28 10.0
RF1(MHz) RF2(MHz) RF3(MHz) RF4(MHz) CENTER (MHz)
2002 Dec 16
mjd 52624
day 350
4829.78 4874.28 4874.28 4829.78 4853.59
Vel (Hel) km/sec (Geo) TURRET RECEIVER
-10.0853 -0.1164 206.65 C-Band
14:46:51 ast 18:46:51 ut 20:00:47 lst


Arecibo Position Status Display
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REQ 18:59:09.9 04:12:15.3 J2000
OFFSET 00:00:00.0 00:00:00.0 J2000
RATE 0.0000 0.0000
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Vel (Hel) km/sec (Geo) TURRET RECEIVER
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14:46:51 ast 18:46:51 ut 20:00:47 lst


N
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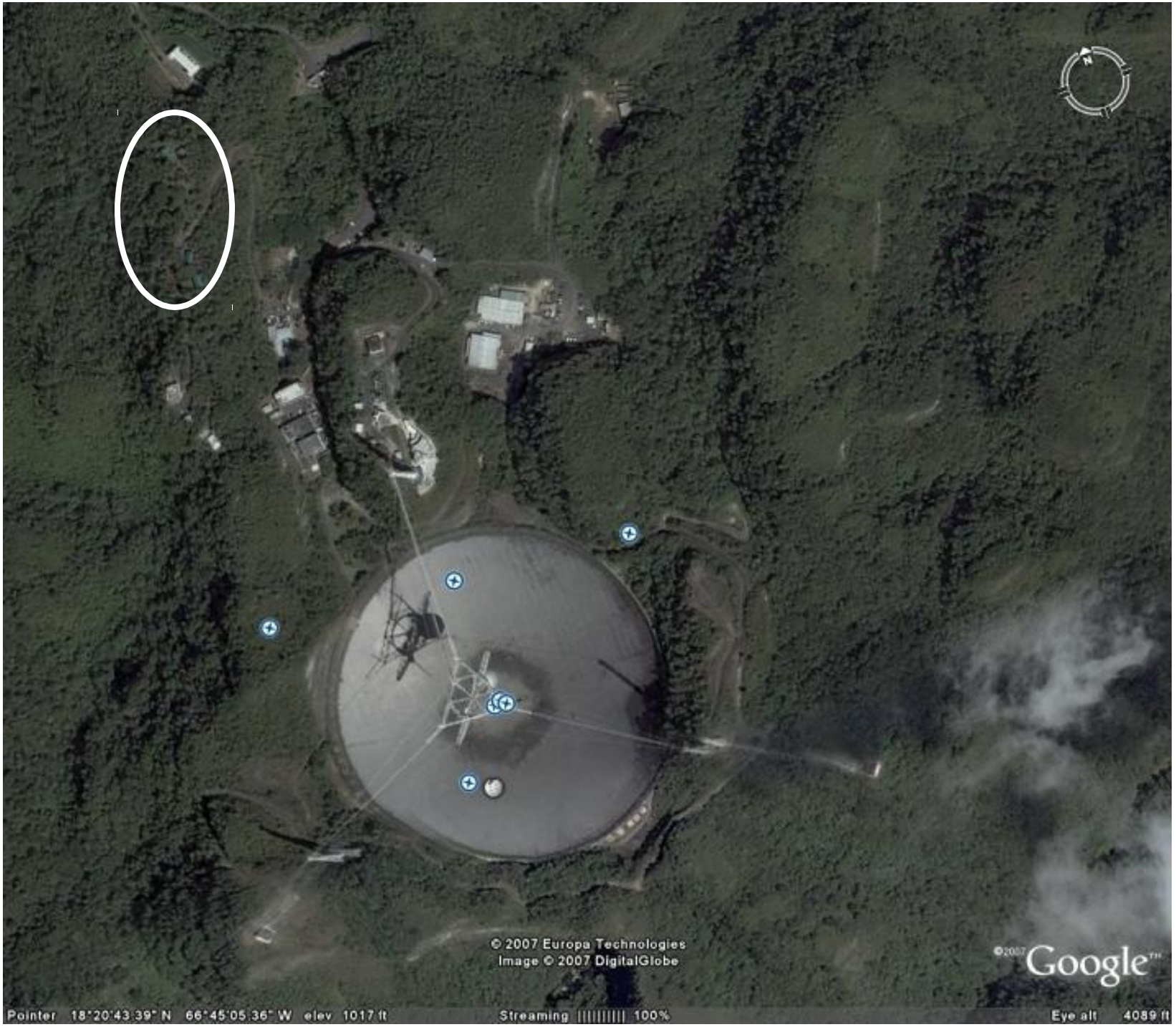
Pointer 18°20'43.39" N 66°45'05.36" W elev 1017 ft
Streaming 100%
Eye alt 4089 ft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Pointer 18°20'43.39" N 66°45'05.36" W elev 1017 ft
Streaming 100%
Eye alt 4089 ft