

Overview of the Arecibo Observatory



ALFALFA

Undergraduate Workshop

Greg Hallenbeck

January 13, 2014

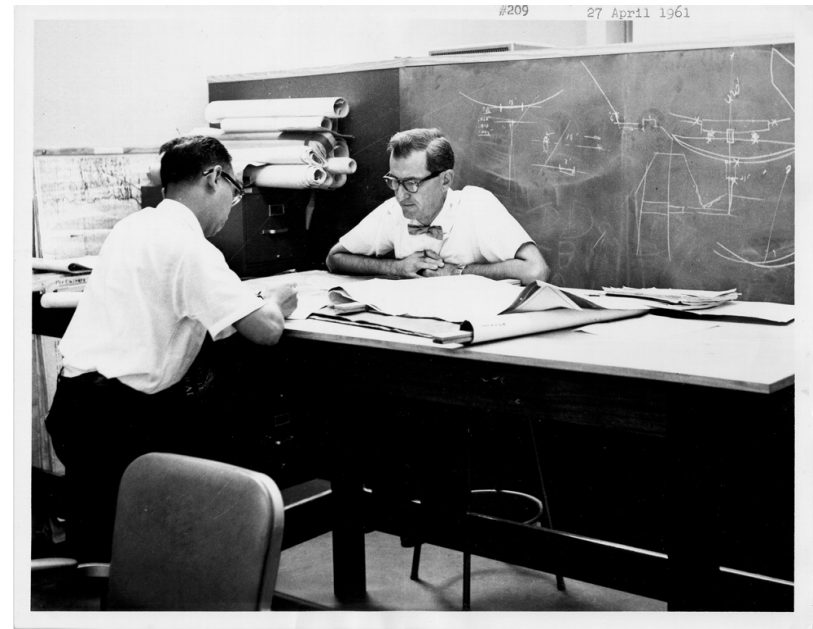
Thanks to Sabrina Stierwalt and Betsey Adams

Special Thanks to Dana Whitlow for help
correcting previous versions...

Talk Overview

- ✦ History
- ✦ The Telescope Facility
- ✦ Hardware for Observing
- ✦ Science at Arecibo

- ✦ 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

Location, Location, Location



- ★ Built in a karst formation (limestone sinkhole)
- ★ Near the equator to study planets
- ★ Latitude: 18° 20' 58" N





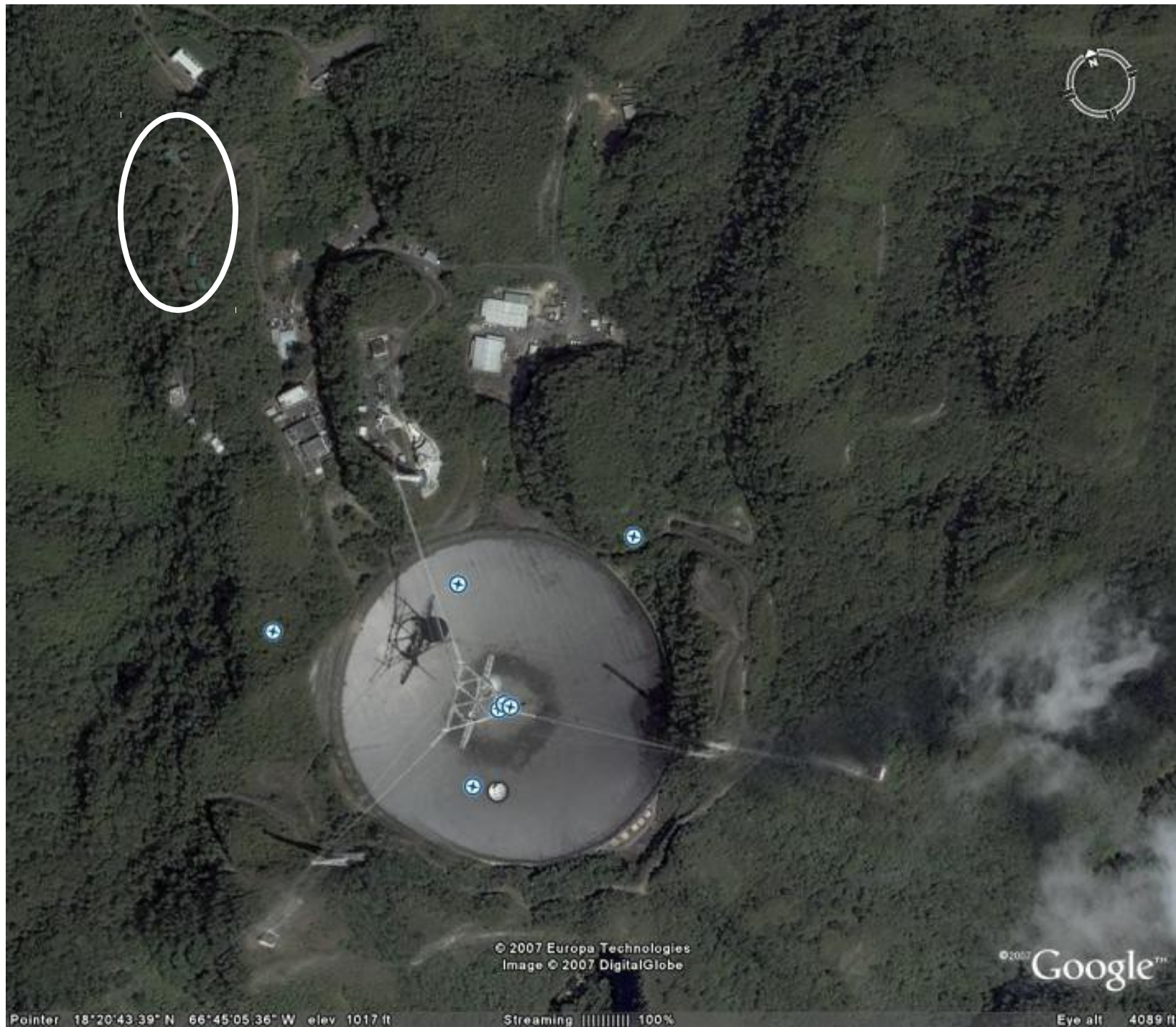
© 2007 Europa Technologies
Image © 2007 DigitalGlobe

© 2007 Google™

Pointer 18°20'43.39" N 66°45'05.36" W elev 1017 ft

Streaming ||||| 100%

Eye alt 4089 ft



© 2007 Europa Technologies
Image © 2007 DigitalGlobe

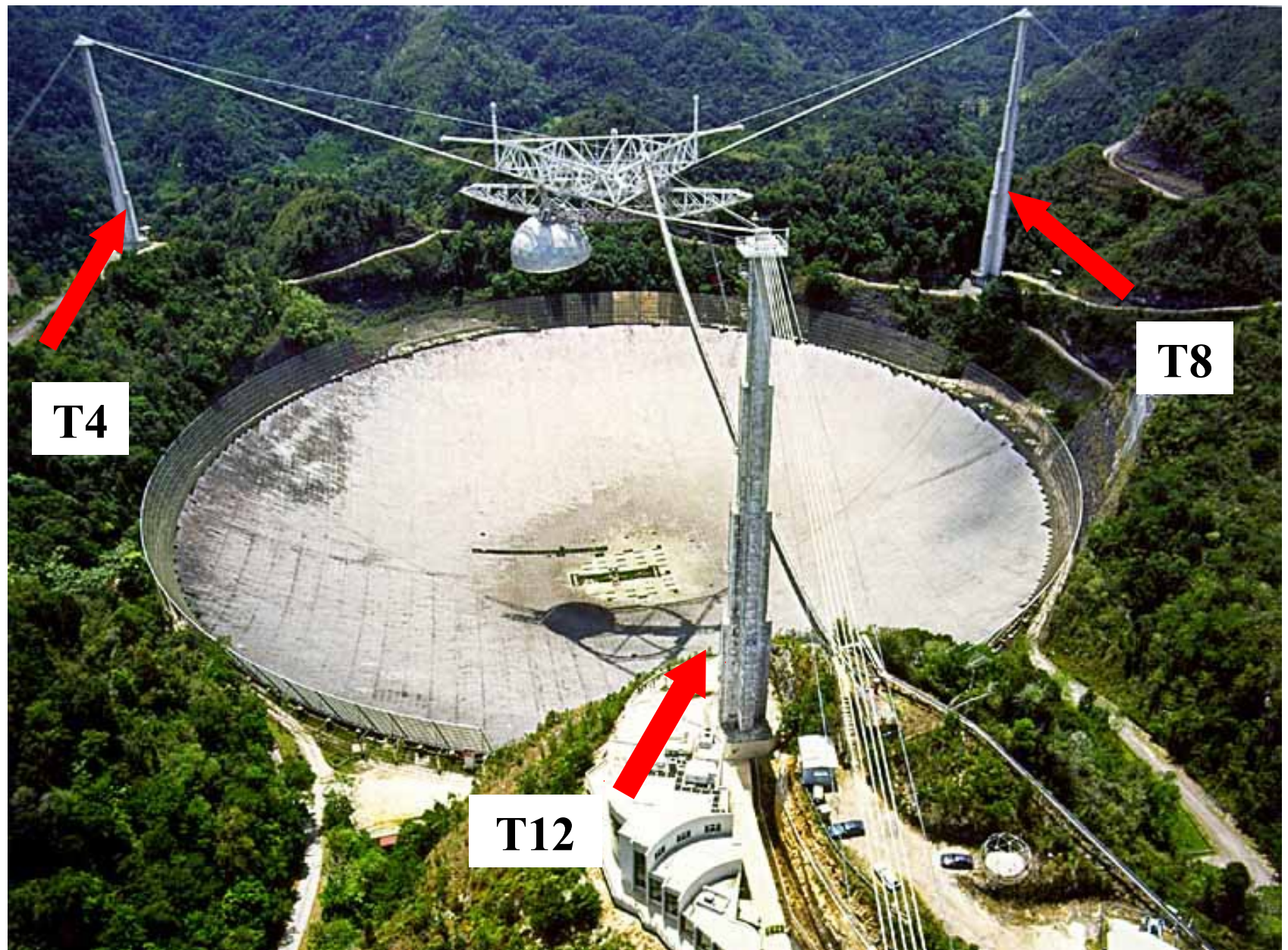
© 2007 Google™

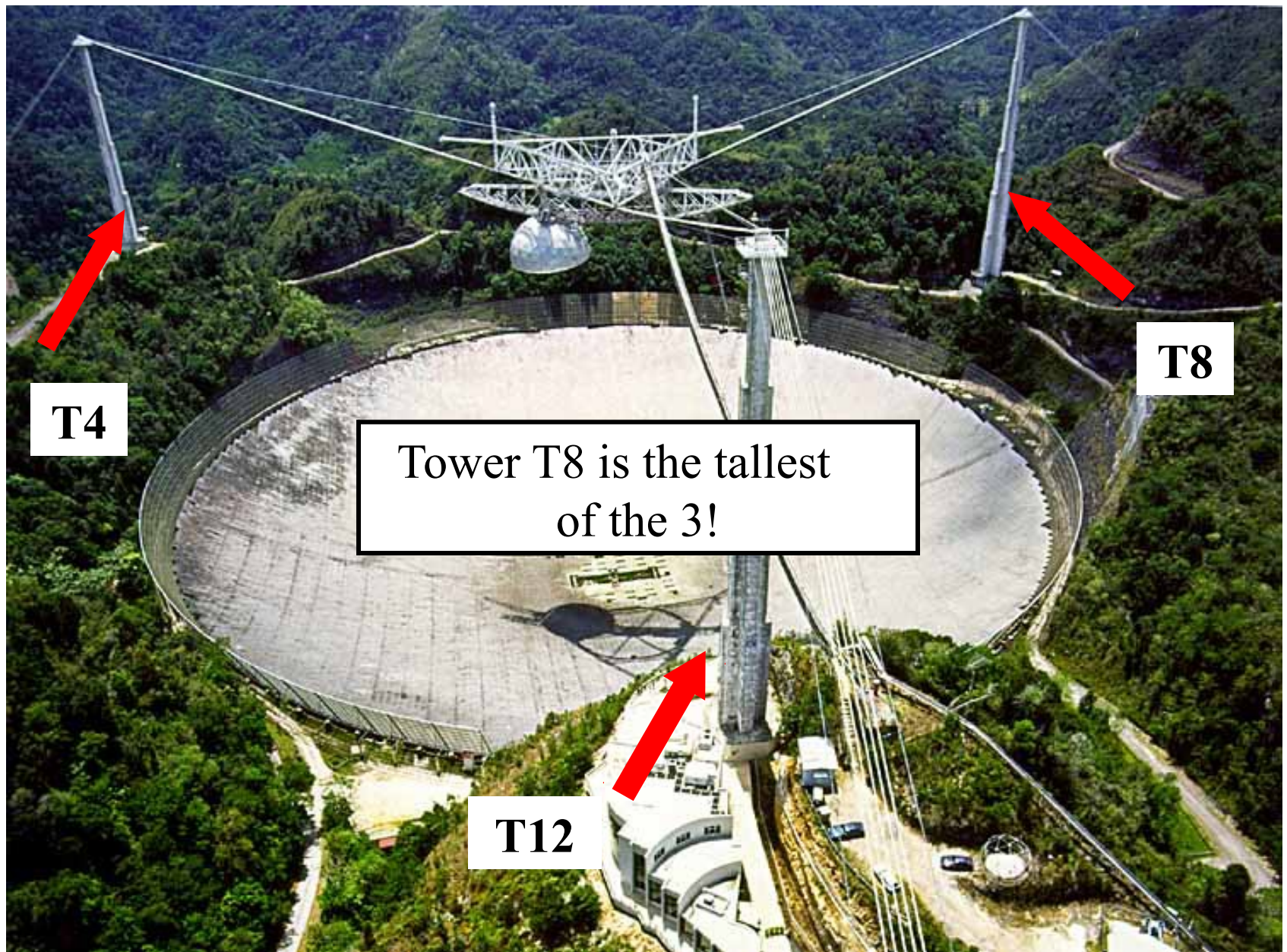
Pointer 18°20'43.39" N 66°45'05.36" W elev 1017 ft

Streaming ||||| 100%

Eye alt 4089 ft





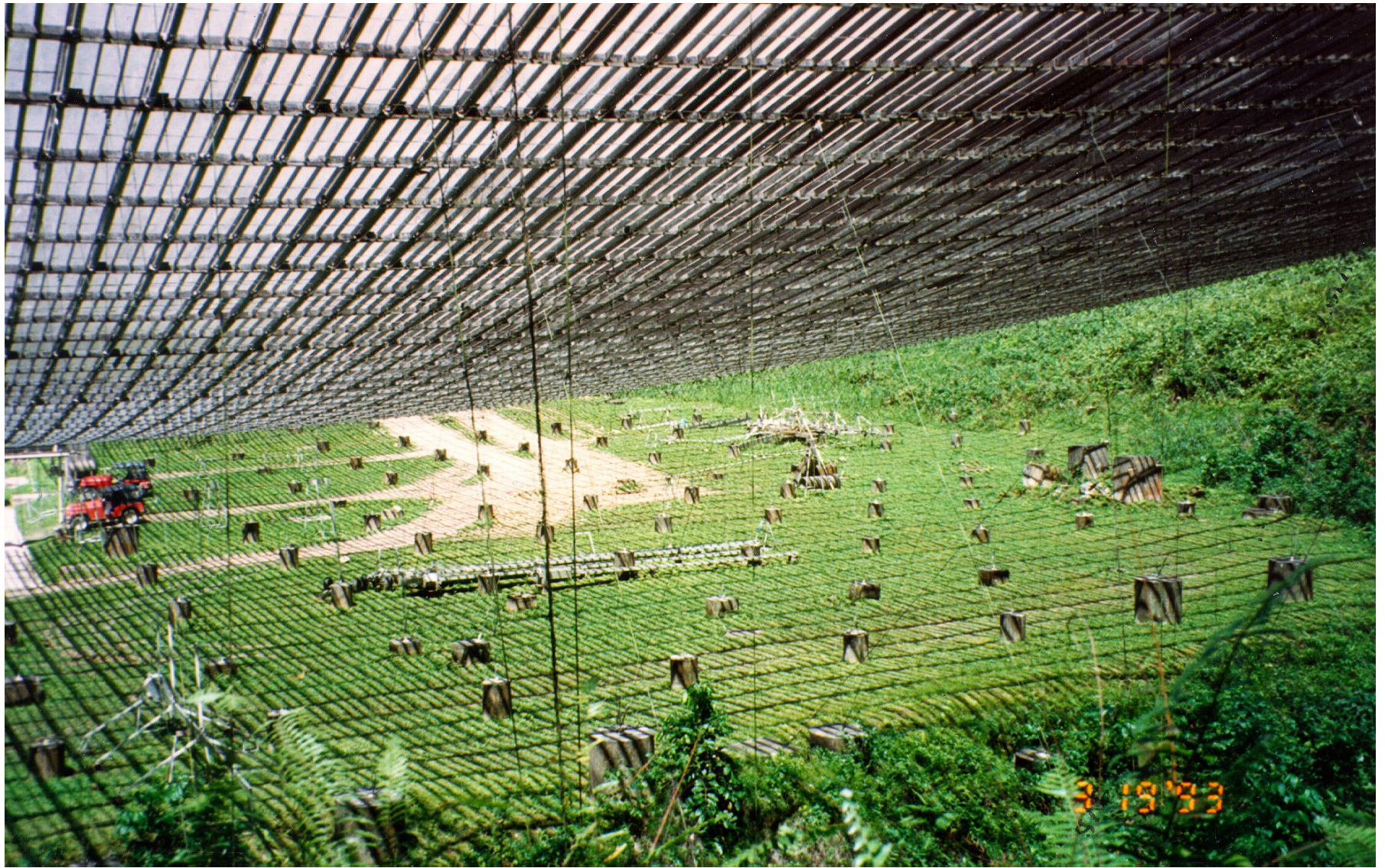


T4

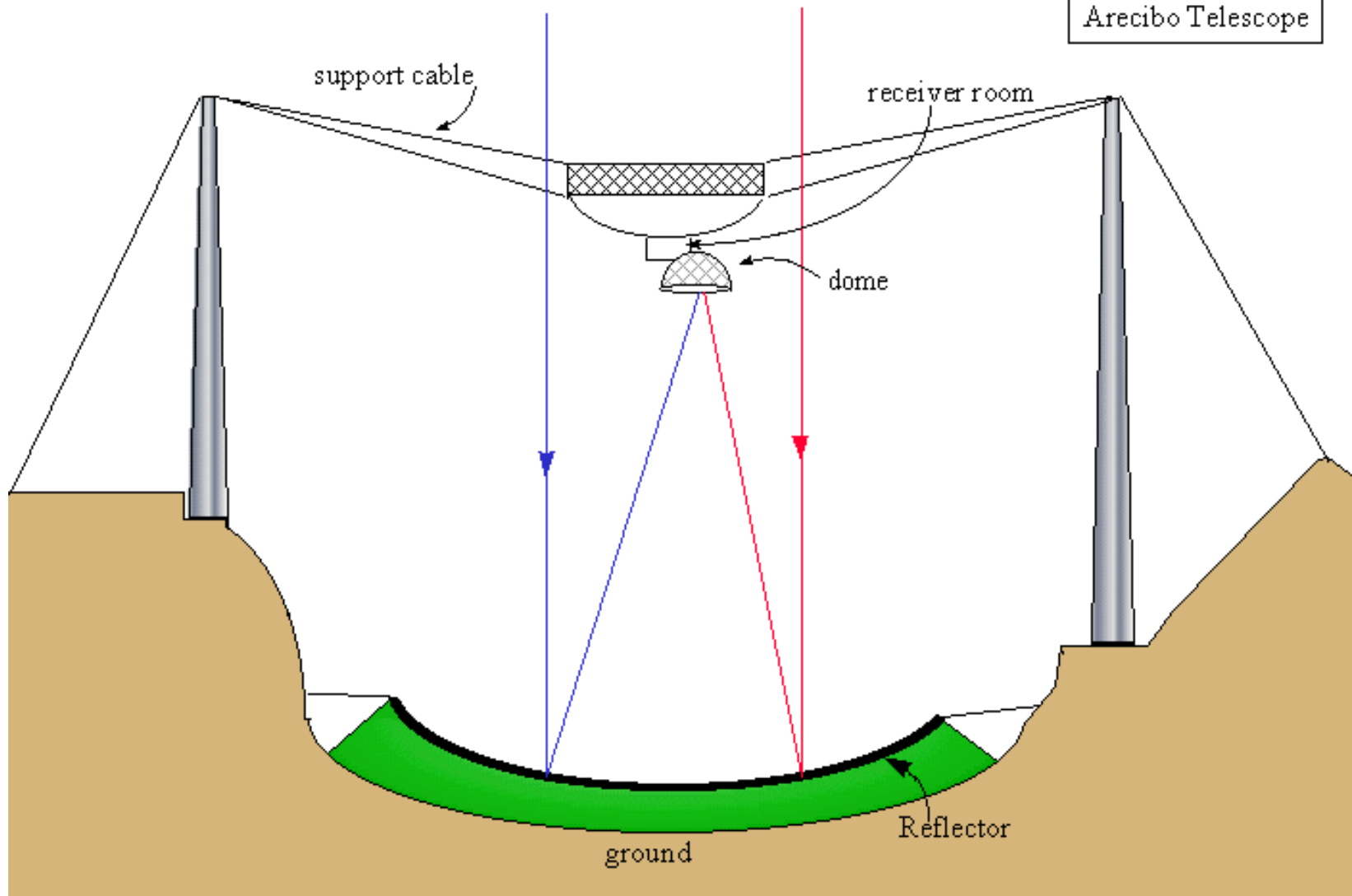
Tower T8 is the tallest
of the 3!

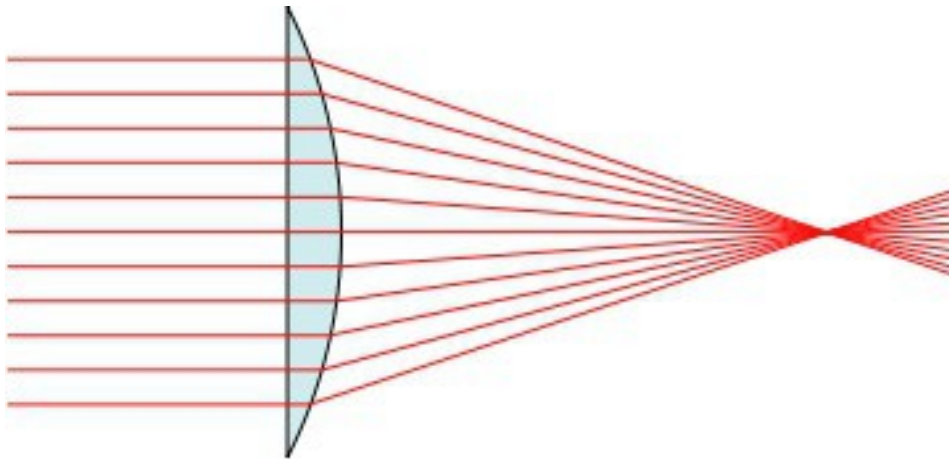
T8

T12

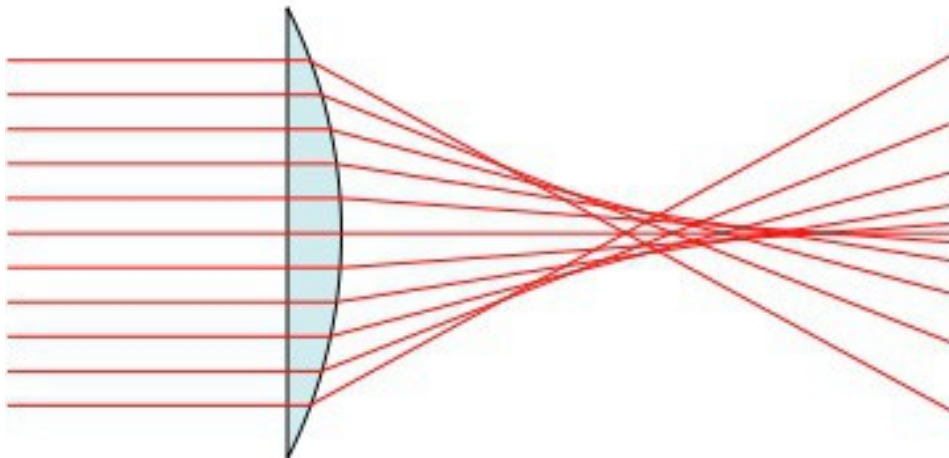


Arecibo Telescope





Parabolic Optics



Spherical Optics

The 430 MHz Antenna and the Dome

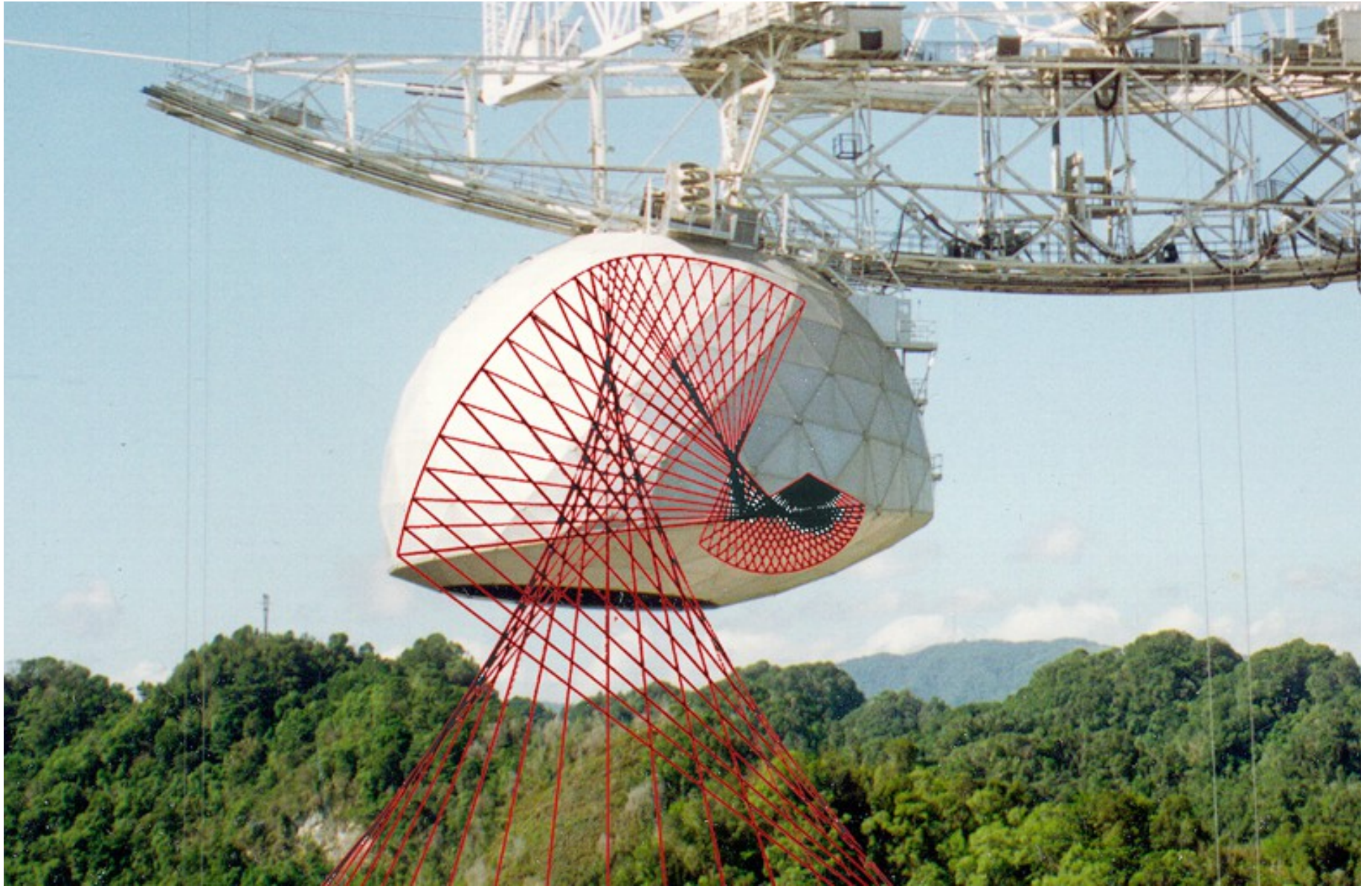


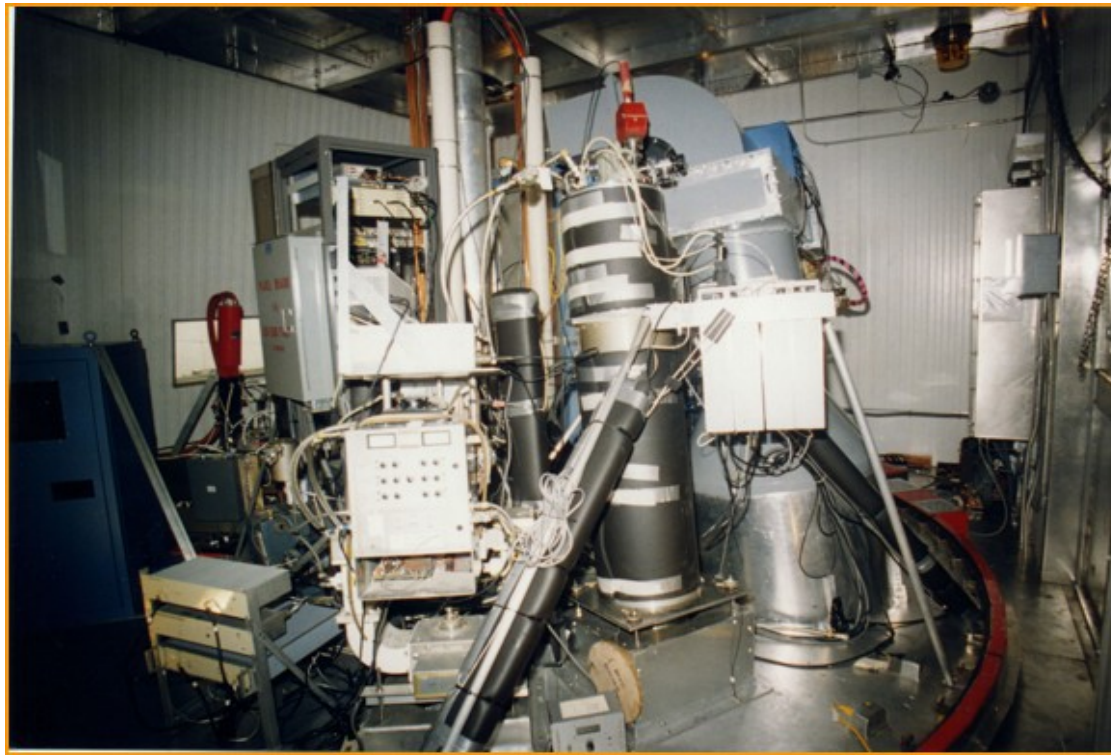
430 MHz Antenna



- ✦ “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

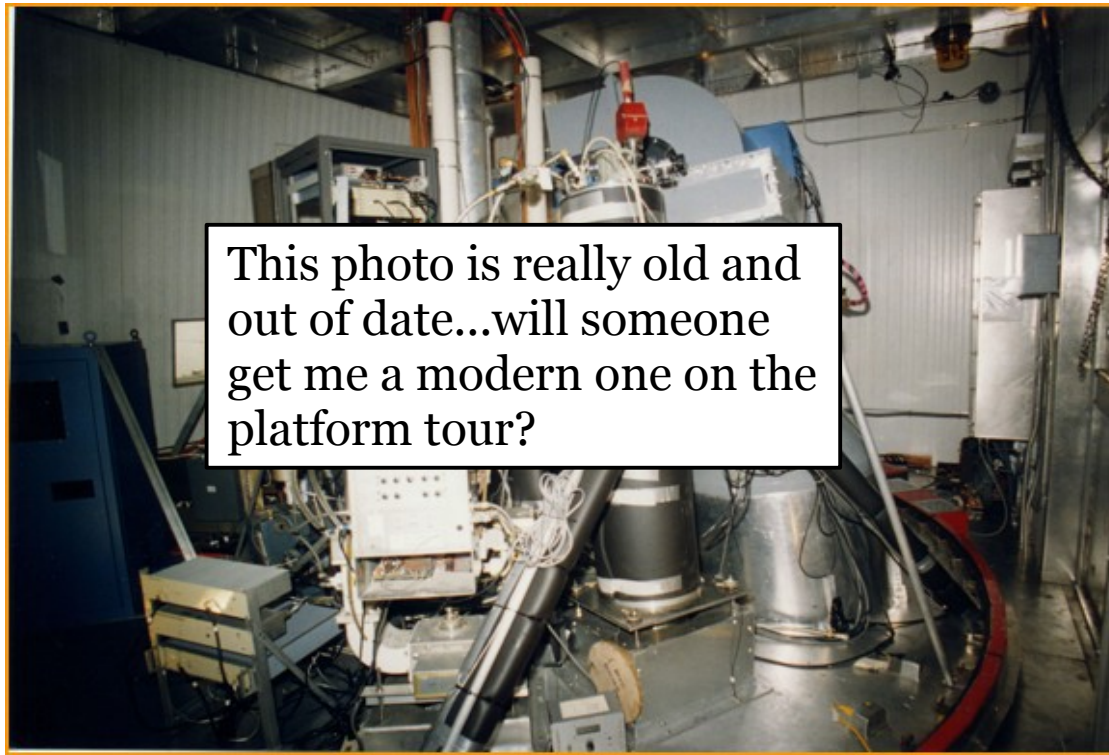
Gregorian Dome





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



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

Gregorian Dome vs. Line Feed

Gregorian Dome

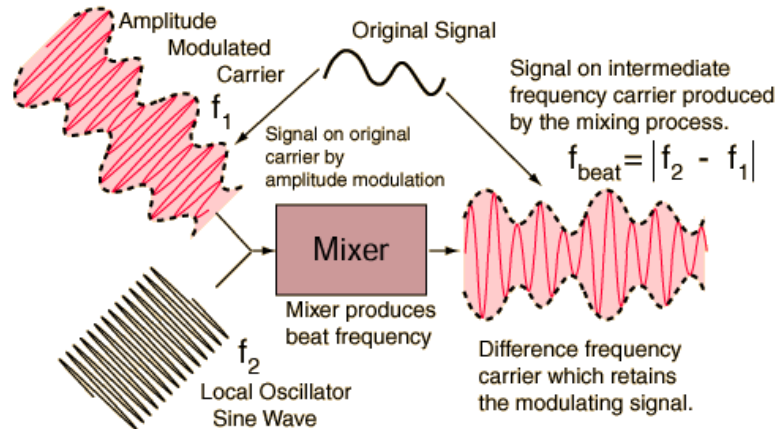
- ★ Narrow range of frequencies per receiver; easily movable receivers
- ★ Receivers are much smaller but must all fit into the small receiver room
- ★ Receivers are moderately difficult to add and remove
- ★ Dome shields the receivers from RFI

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

IF/LO

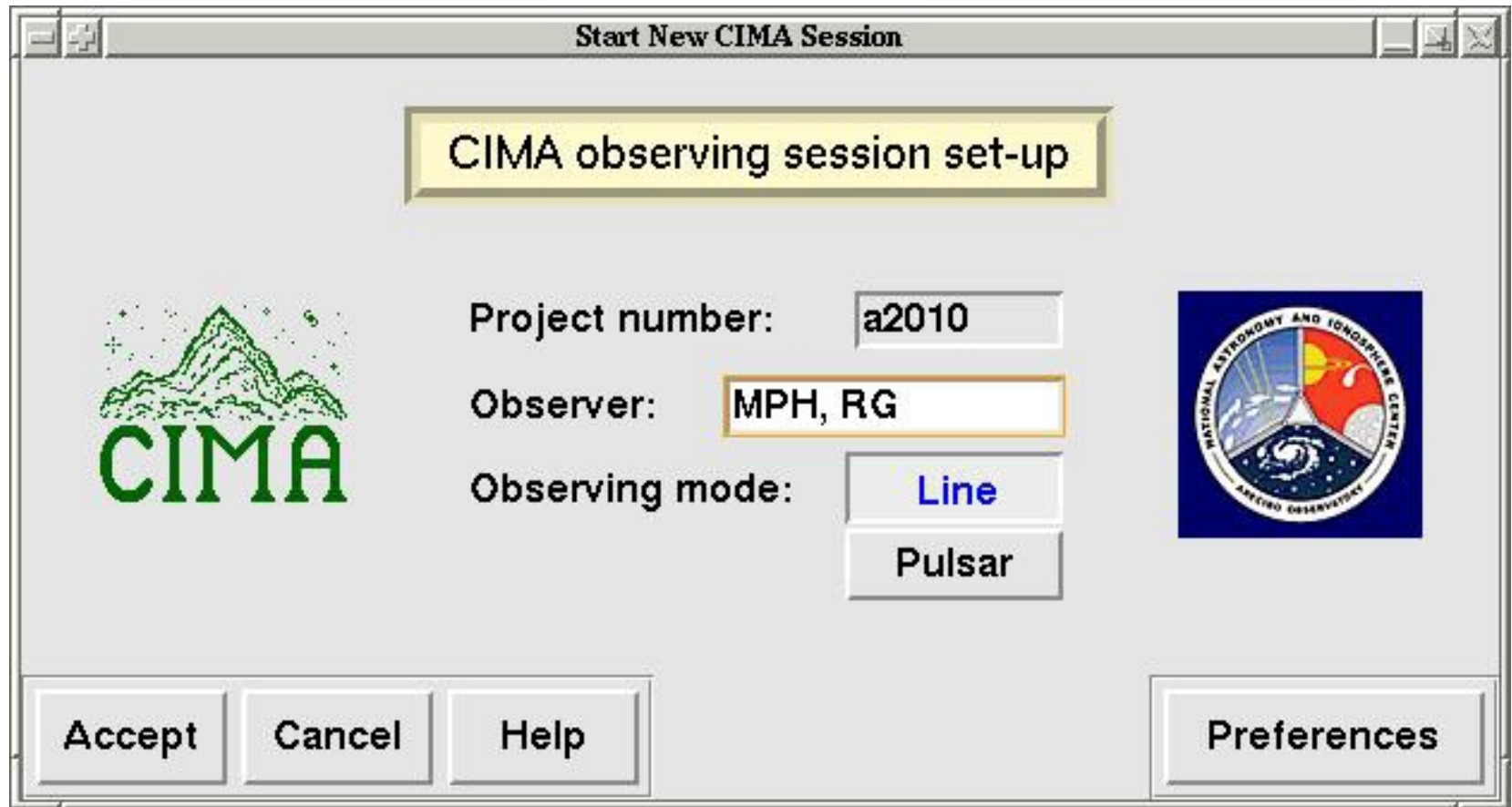
- ★ Transmission losses increase with frequency
- ★ Convert to lower frequency before transmitting signals off of the platform
 - Intermediate Frequency
 - Local Oscillator
- ★ Today, IF signals are transported along fiber optics
(this also stops lightning strikes from causing sparks in the control room)



Backend


- ★ Responsible for signal processing: setting frequency range, breaking into channels, etc.
- ★ Several are available, with ranges of capability
 - For L-band wide observations, the capabilities of the stable “Interim” Correlator are more than sufficient
 - ALFALFA used the WAPP, which often caused us problems, but is
 - Others: galspect, Mock Spectrometer, PUPPI

CIMA




Start New CIMA Session

CIMA observing session set-up

 Project number: a2010

Observer: MPH, RG

Observing mode: Line
Pulsar



Accept Cancel Help Preferences

Control **I**nterface **M**odule for **A**recibo: a graphical interface that makes observing as easy as clicking buttons (more on this later...)

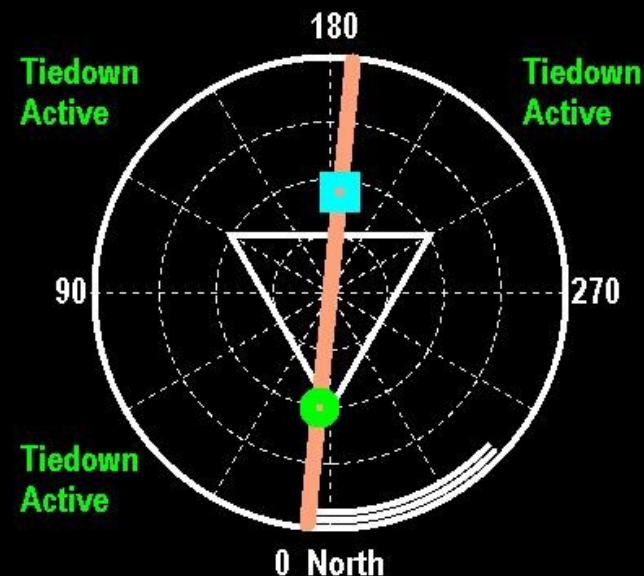
Arecibo Stats

- ★ Covers 1m - 3cm (300 MHz - 10 GHz)
 - ★ Additional 47 MHz transmitter
- ★ Slew rate of 25° /min in azimuth
- ★ Slew rate of 2.5° /min in zenith
- ★ Pointing accuracy of **5 arcseconds**
- ★ Can view objects within $\sim 40^{\circ}$ cone about local zenith (**0** to **36** degrees in dec)

Pointing Limits of Arecibo

- ★ Can move dome to zenith angle position of 19.7°
 - ★ But only to $\sim 18^\circ$ with good performance
- ★ Can move dome to within 1.06° of zero zenith angle
 - ★ 1.1° recommended

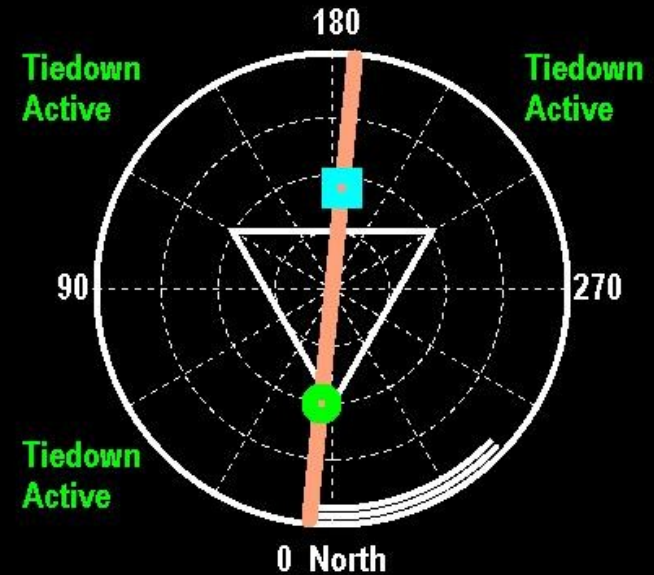
SKY POSITIONS: RA		DEC	
SOURCE	18:59:09.9	04:12:15.3	J2000
REQ	18:59:09.9	04:12:15.3	J2000
OFFSET	00:00:00.0	00:00:00.0	J2000
RATE	0.0000	0.0000	
TELESCOPE: AZ		ZAG	ZACH
REQ	401.84	18.62	0.00
CURR	366.00	10.00	8.83
ERROR	-35.84	-8.62	8.83



					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		4829.78	4874.28	4874.28	4829.78	4853.59	
mjd 52624		Vel (Hel) km/sec (Geo)			TURRET	RECEIVER	
day 350		-10.0853	-0.1164		206.65	C-Band	

14:46:51 ast 18:46:51 ut 20:00:47 lst

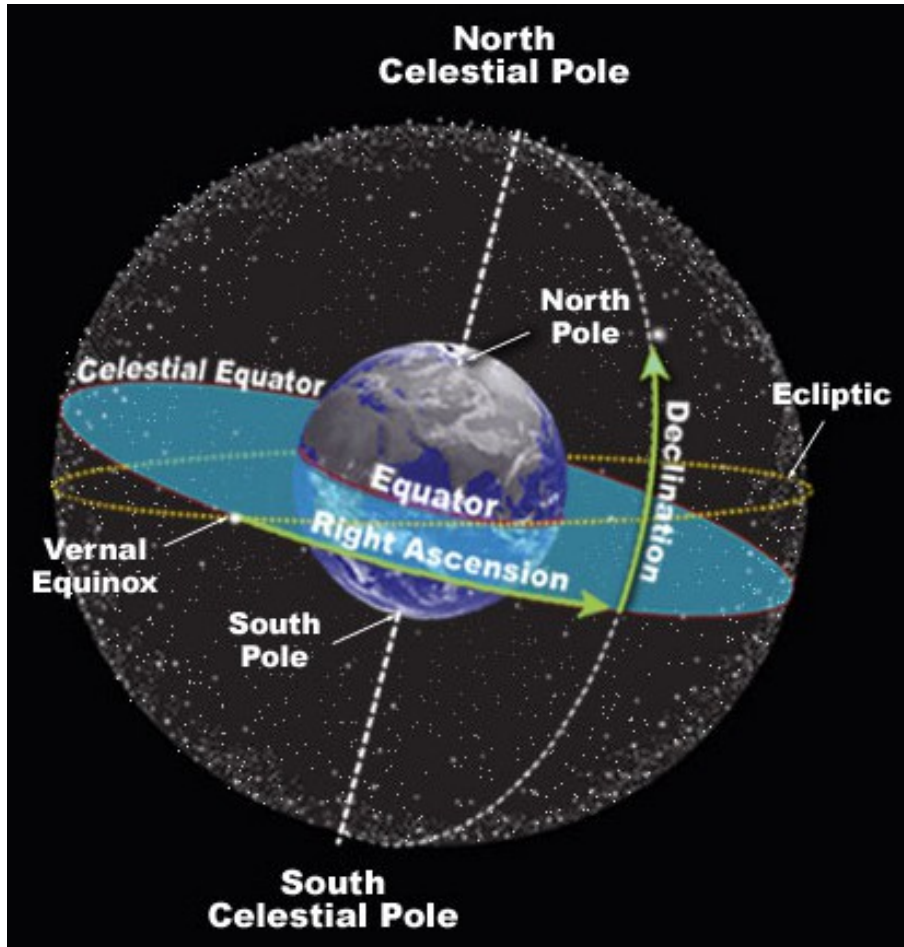
SKY POSITIONS: RA			DEC
SOURCE	18:59:09.9	04:12:15.3	J2000
REQ	18:59:09.9	04:12:15.3	J2000
OFFSET	00:00:00.0	00:00:00.0	J2000
RATE	0.0000	0.0000	
TELESCOPE: AZ			ZAG
REQ	401.84	18.62	0.00
CURR	366.00	10.00	8.83
ERROR	-35.84	-8.62	8.83



2002 Dec 16 mjd 52624 day 350	STATUS				REQ RISES IN	TOL"
	Not Tracking				22:02:28	10.0
	RF1(MHz)	RF2(MHz)	RF3(MHz)	RF4(MHz)	CENTER (MHz)	
	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

Equatorial Coordinates



★ Right Ascension

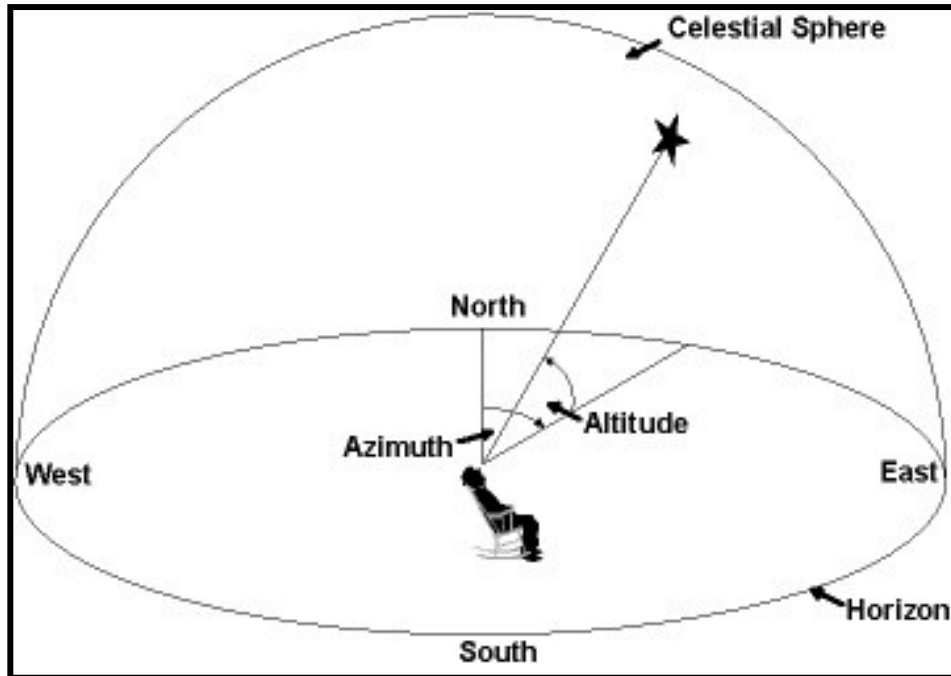
- ★ Measured in hours (0 to 24)
- ★ Zero-point toward constellation Pisces (increases to the east)
- ★ Similar to longitude

★ Declination

- ★ Measured in degrees
- ★ Zero-point is the equator
- ★ Similar to latitude

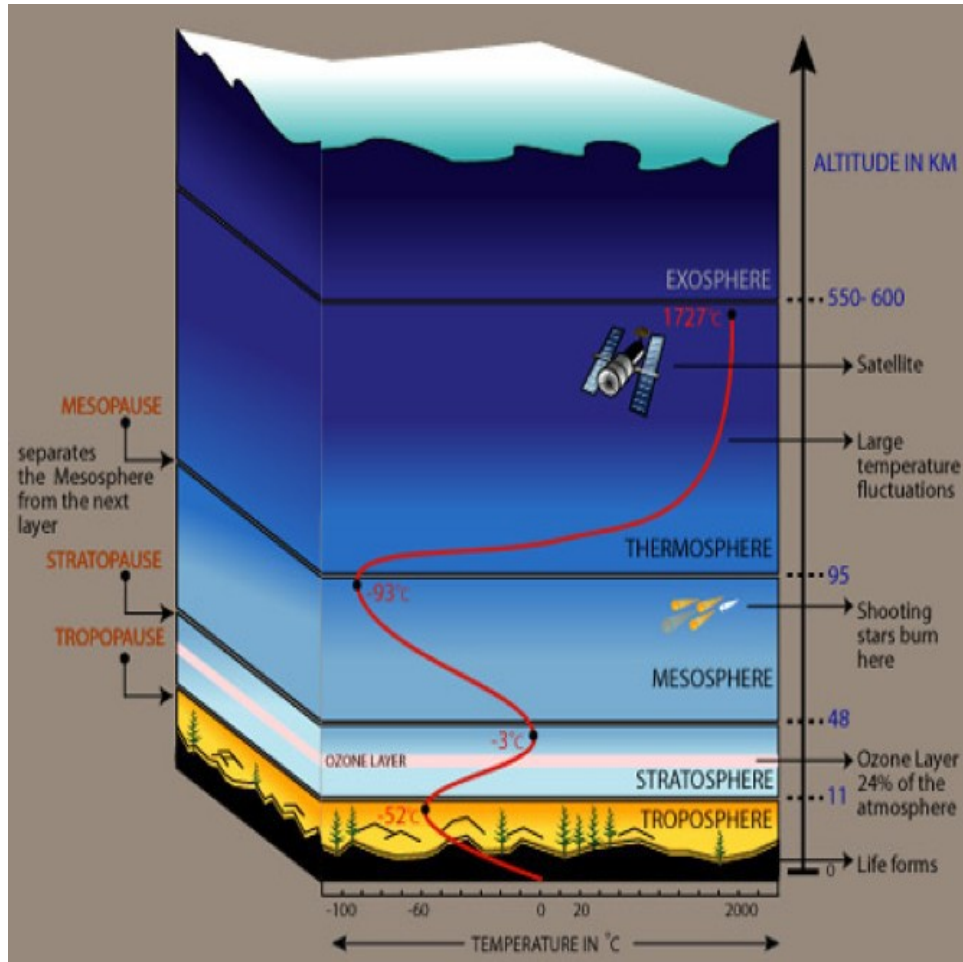
★ They are the same for every observer location and time!

Azimuth & Zenith



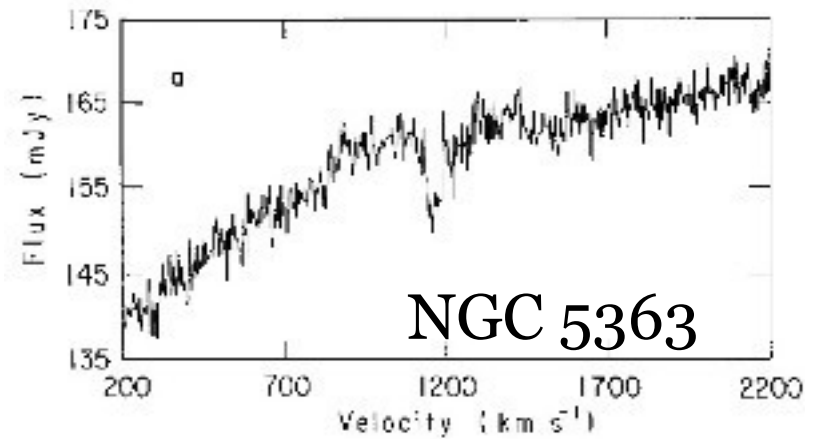
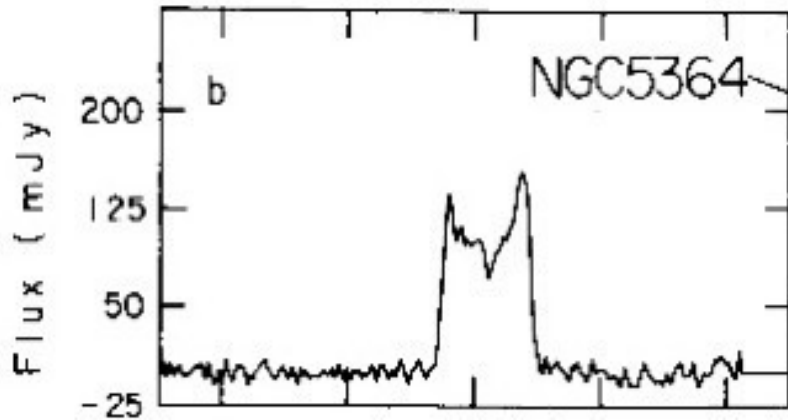
- ★ **Azimuth** Angle
 - ★ Measured in degrees
 - ★ Tells how far east of north the source is located
- ★ **Zenith** Angle
 - ★ Measured in degrees
 - ★ Tells how far below zenith a source is located
- ★ They depend on the observer's location!

Areas of Study at Arecibo



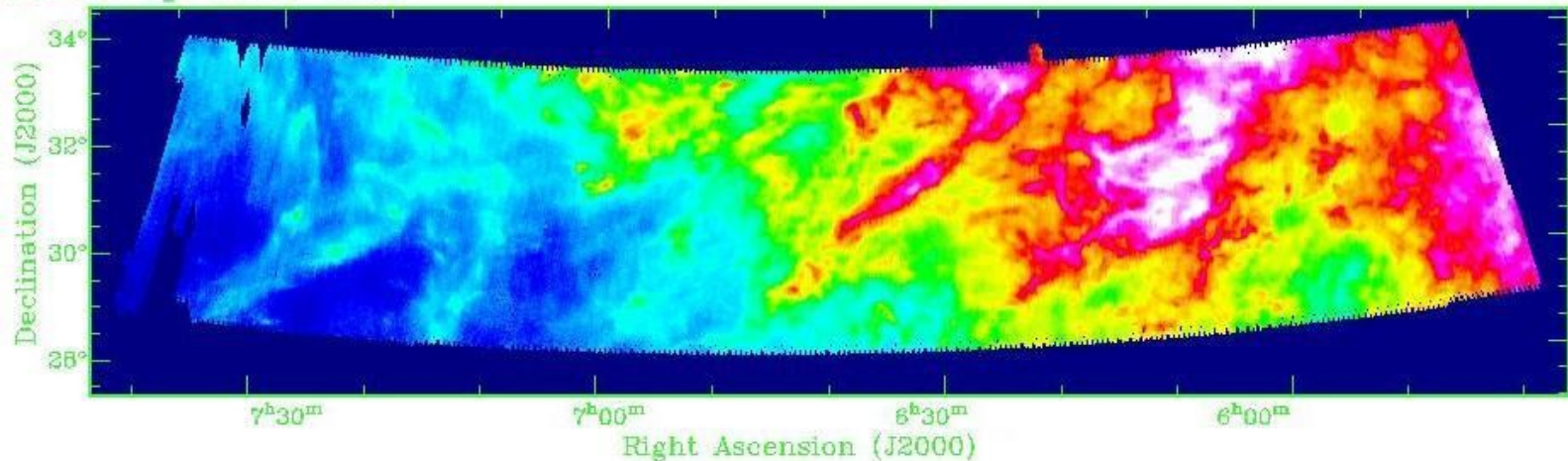
- ◆ Atmospheric Science (20%)
 - ◆ Measures composition, temperature, and density of upper atmosphere
 - ◆ Measures the growth and decay of disturbances in the ionosphere
- ◆ Radio Astronomy (80%)
 - ◆ Spectral Lines
 - ◆ Continuum
 - ◆ Radar
 - ◆ Pulsars
 - ◆ VLBI

Spectral Line Observations



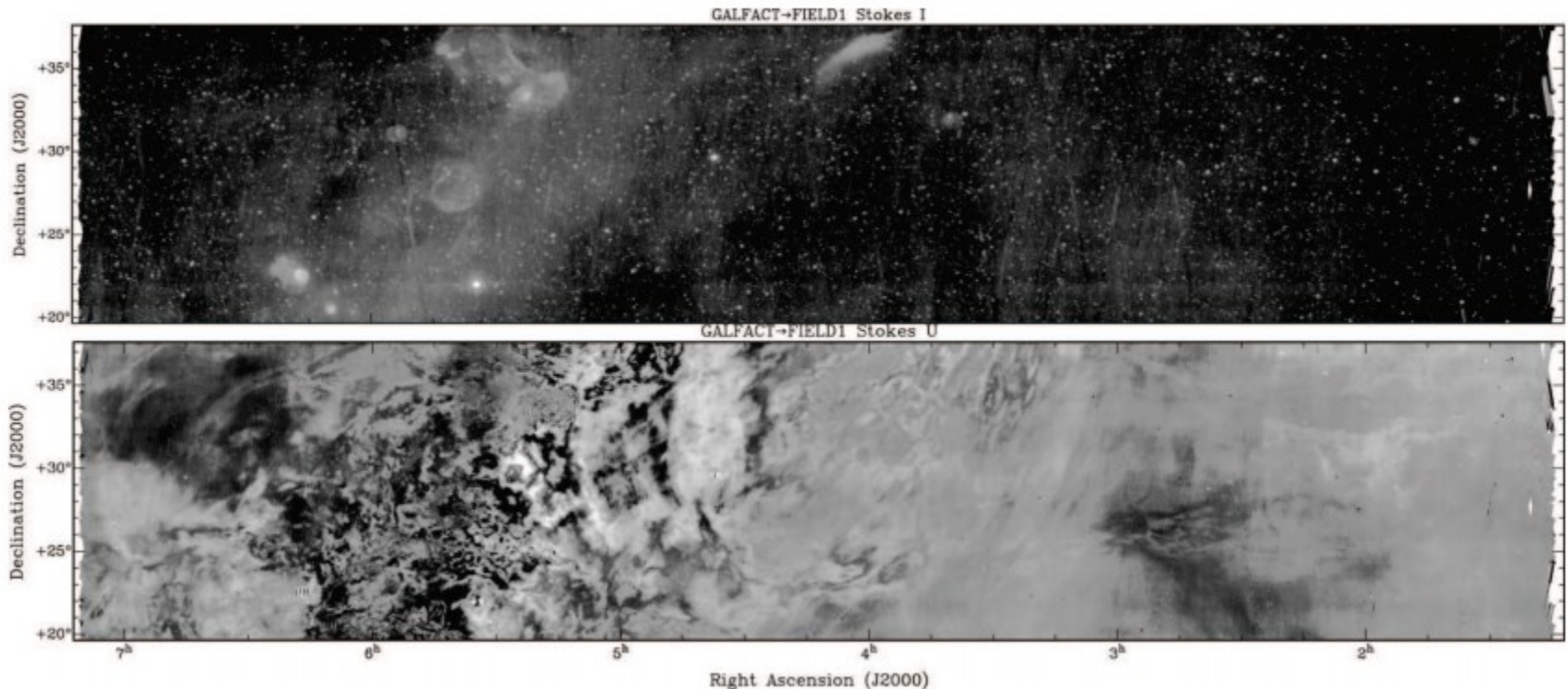
Spectra from Haynes & Giovanelli, 1981

velocity 22.1 km/s



GALFA 21cm map of Milky Way

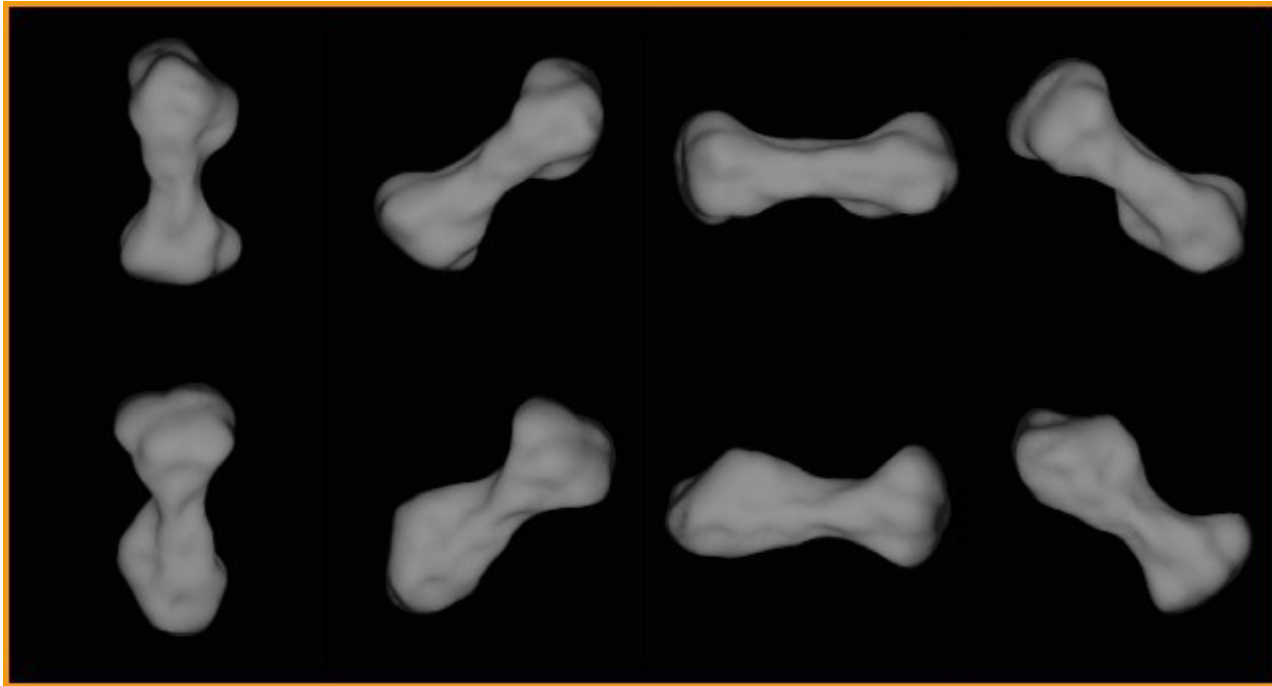
Radio Astronomy: *Continuum Observations*



1.4 Ghz continuum intensity (top) and polarization (bottom) at galactic center

Broad Trends instead of narrow lines!

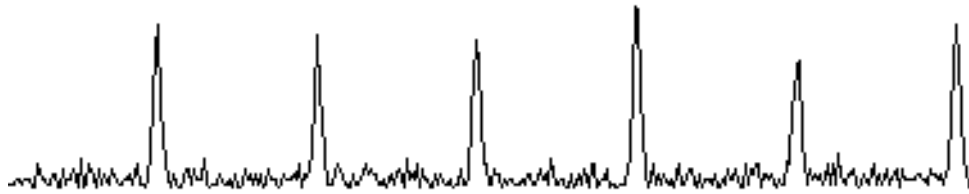
Radio Astronomy: Radar



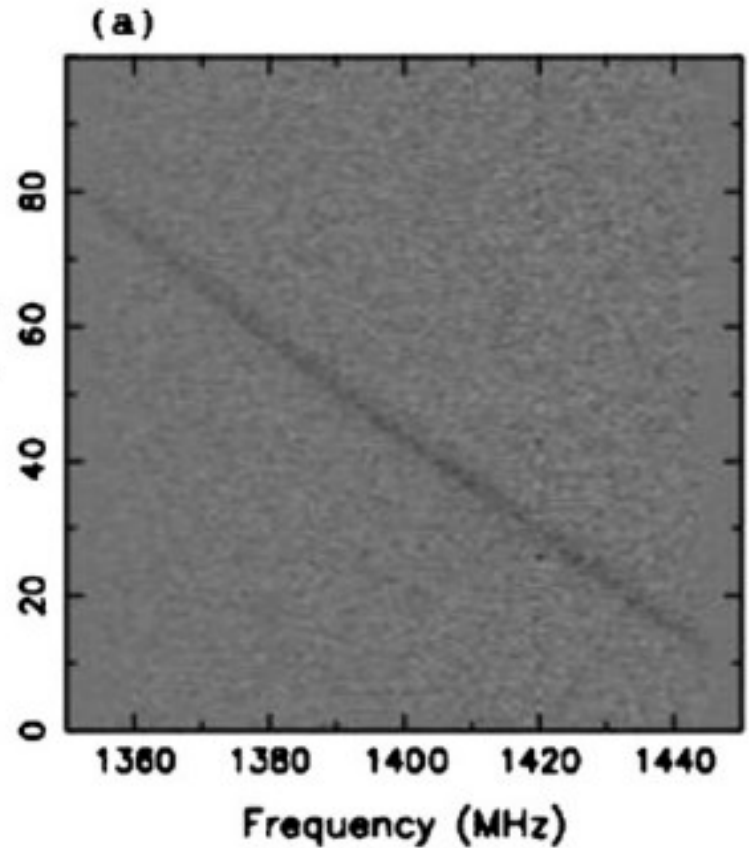
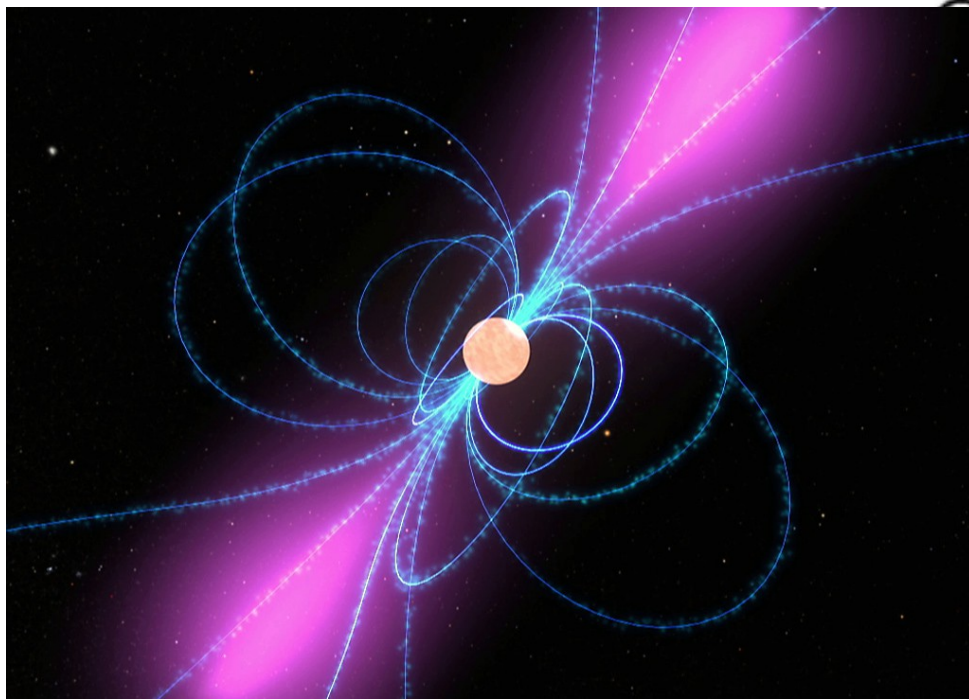
Asteroid Kleopatra 216

Active observations of solar-system objects

Radio Astronomy: *Pulsars*



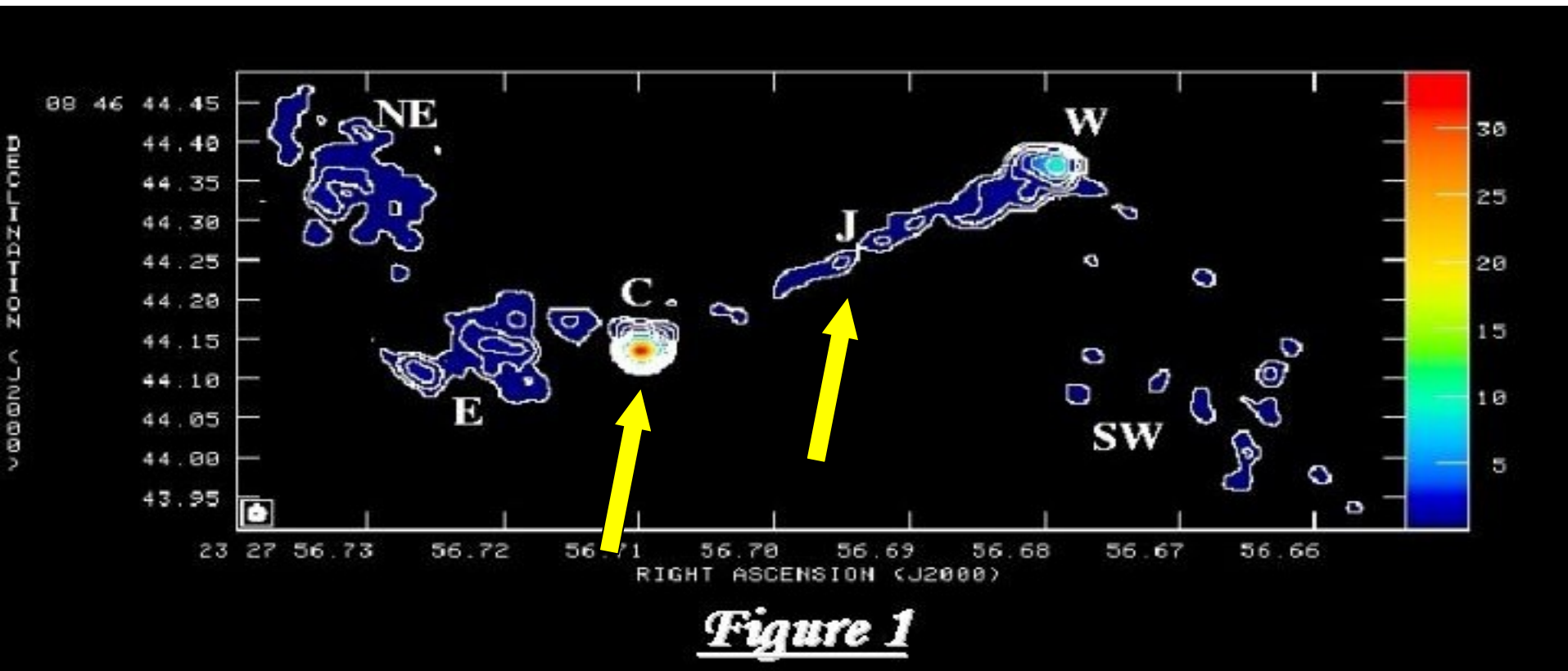
A schematic of a pulsar signal



Pulsar Detection from PALFA

Extremely pretty image from NASA with a whole lot of artistic license.

VLBI - *Very Long Baseline Interferometry*



Contour Plot of NGC 7674 courtesy of E. Momjian