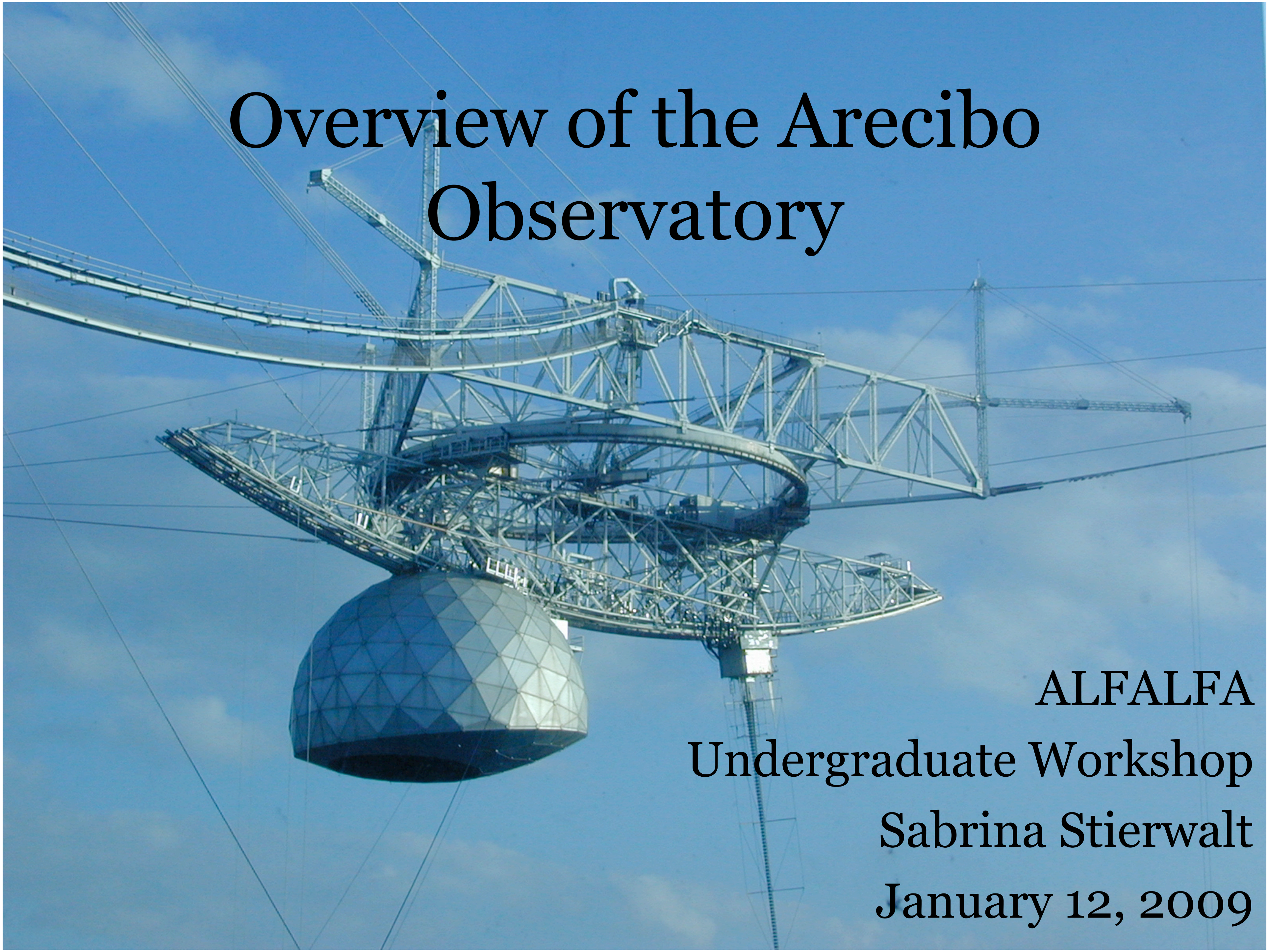
Overview of the Arecibo Observatory



ALFALFA

Undergraduate Workshop

Sabrina Stierwalt

January 12, 2009

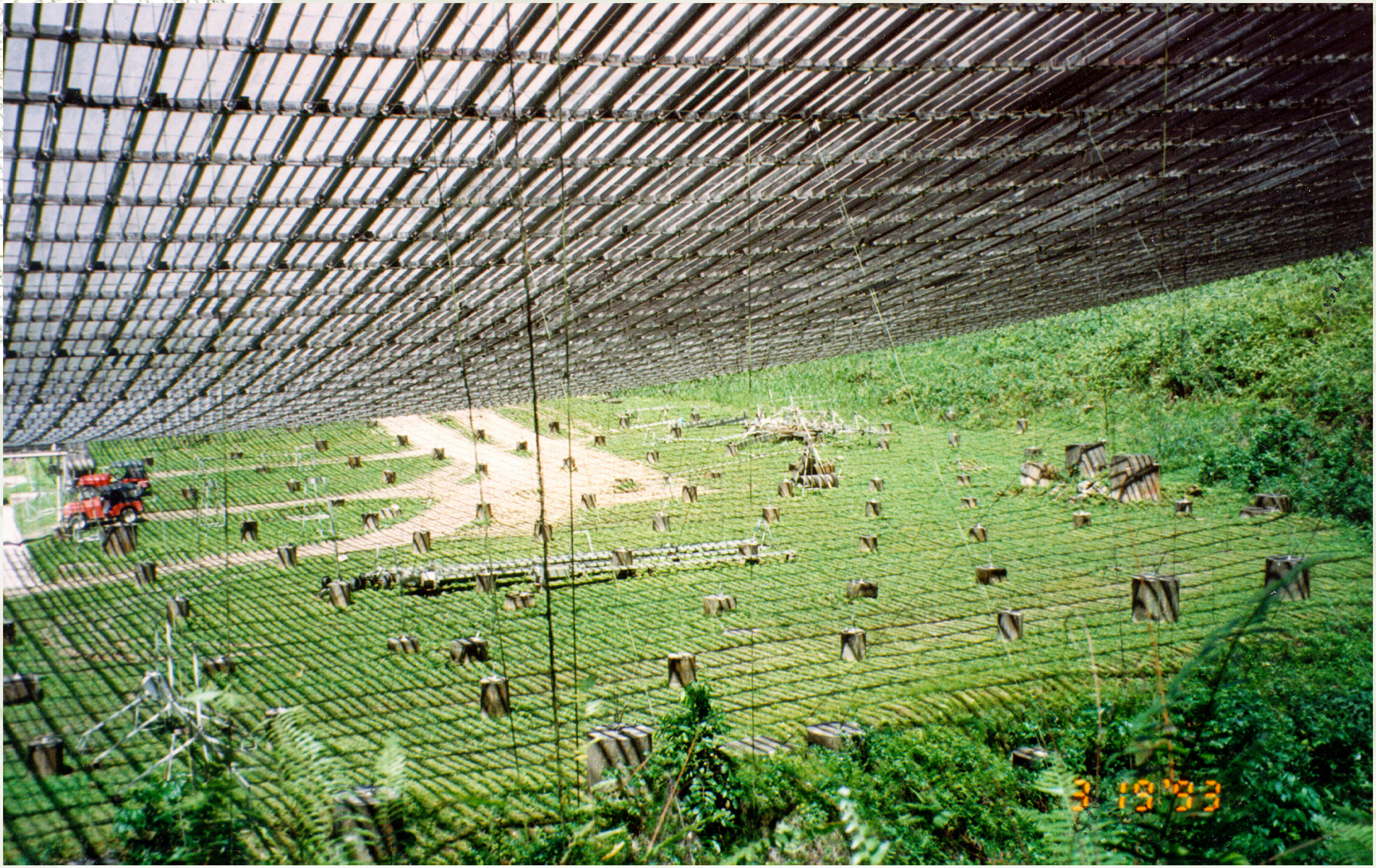
- Designed by then Cornell Professor William Gordon to study the ionosphere
- Opening ceremony on November 1st 1963
- Now part of NAIC (National Astronomy and Ionosphere Center)
- Operated by Cornell University under cooperative agreement with NSF

Employees

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

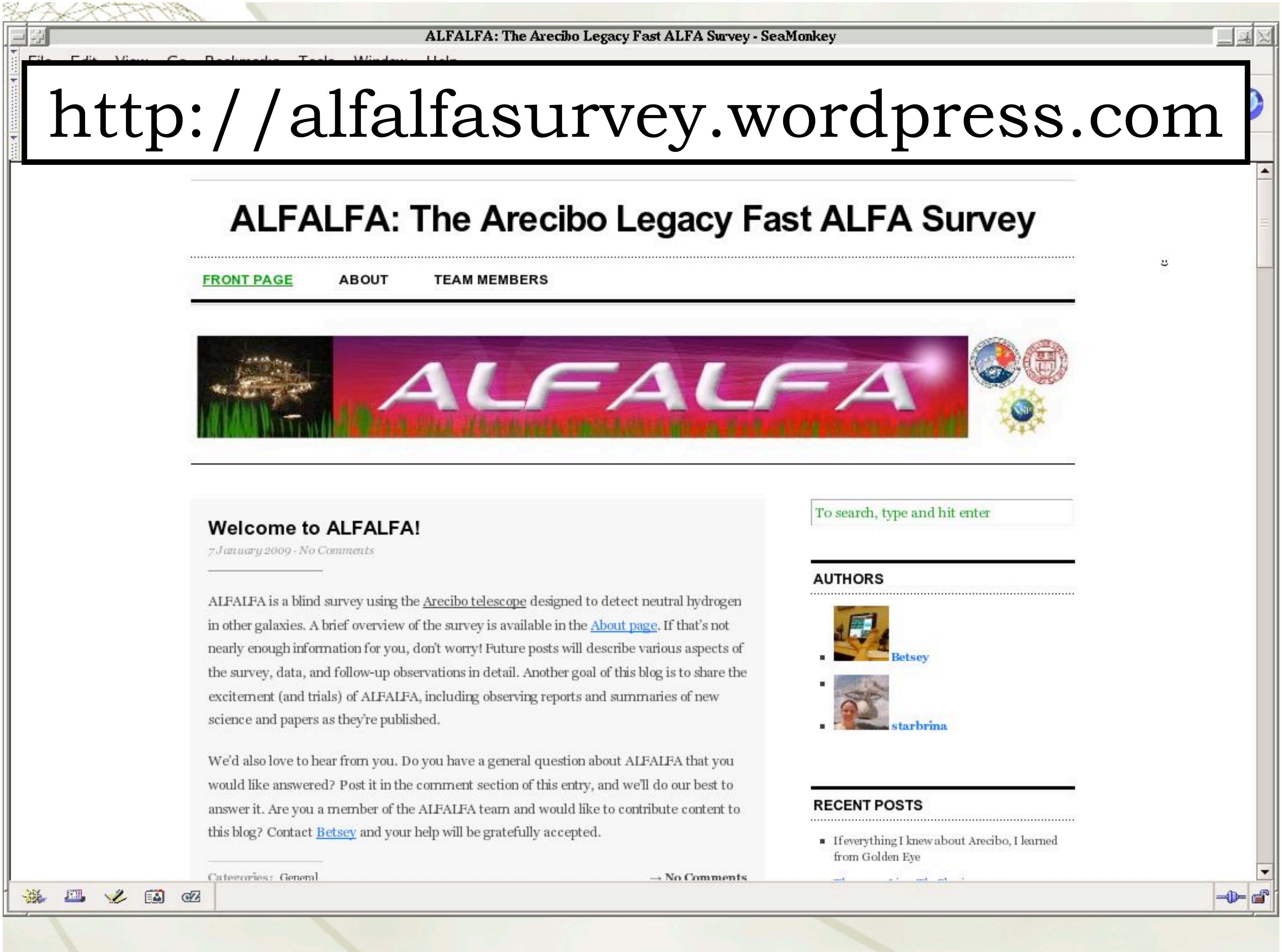
Location, Location, Location

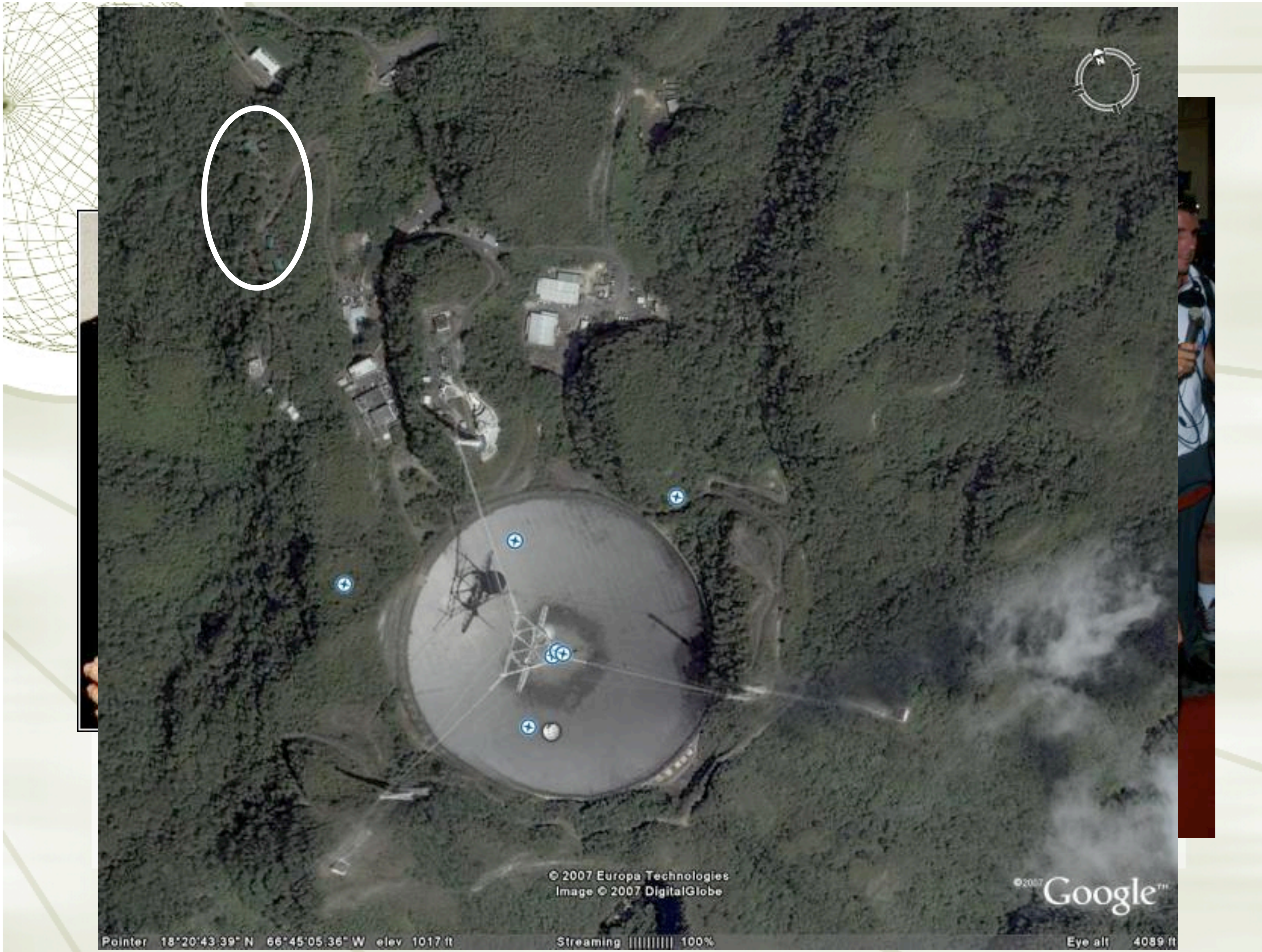
- Built in a limestone sinkhole in Arecibo, Puerto Rico
- Constructed near the equator in a place where all of the planets in our solar system are visible) so the radar used to study the ionosphere could also be used for the planetary observations
- Latitude: $18^{o}\ 20'\ 58''$ N

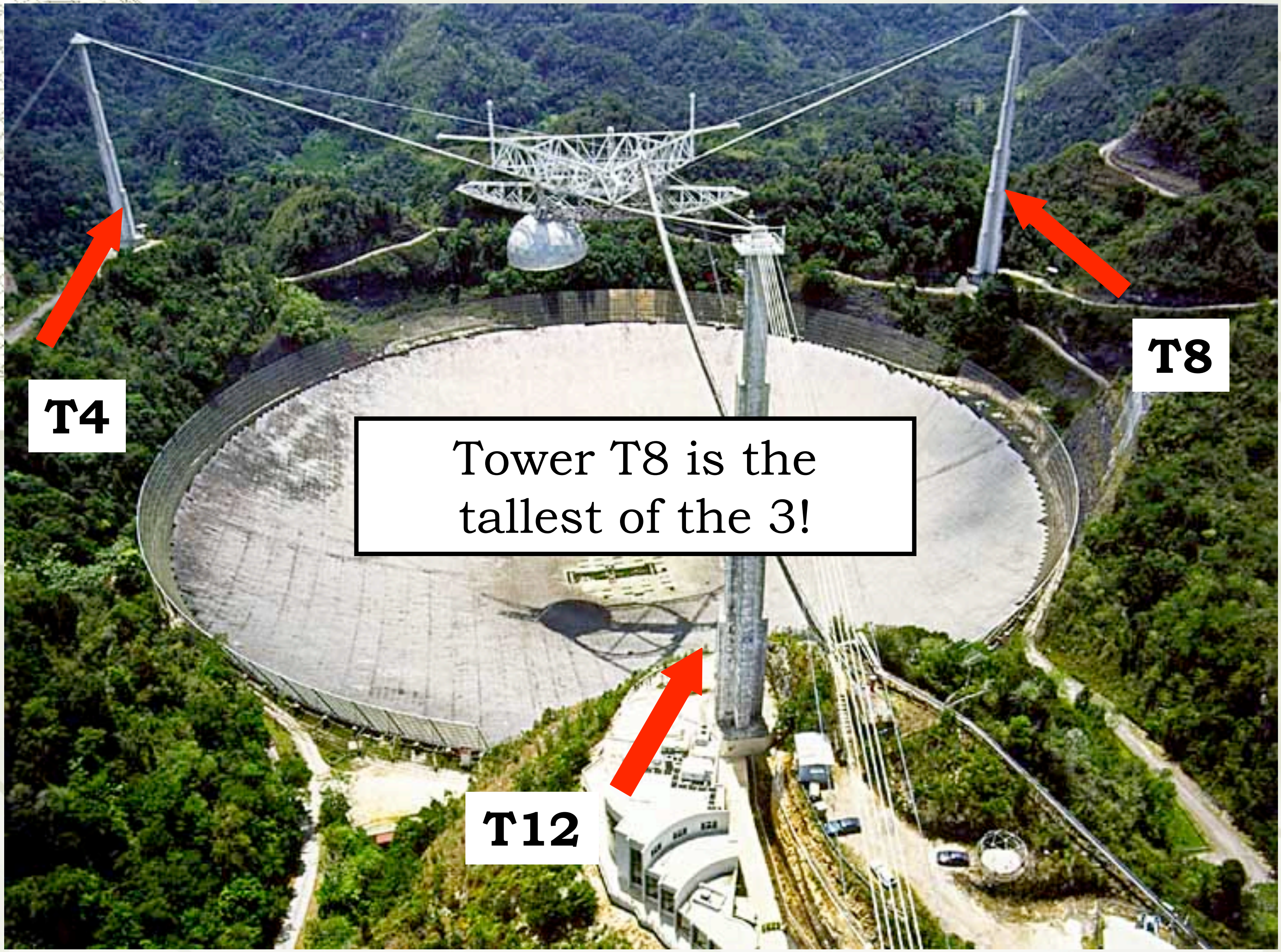

3 19 '93

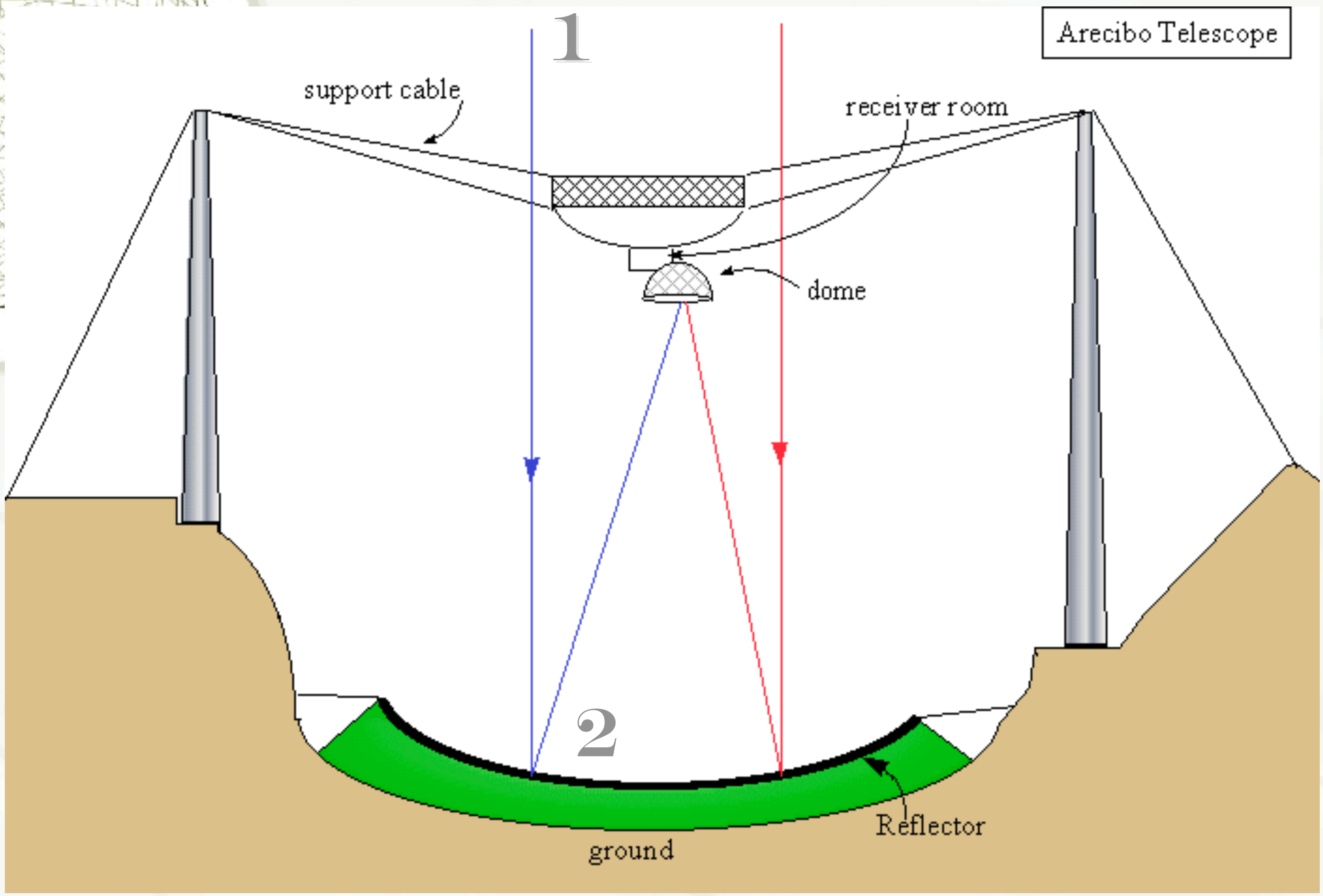

Zapatos para el reflector
Para poder caminar sobre el reflector se utiliza un zapato especial. Estos protegen los paneles distribuyendo el peso de la persona.
Reflector shoe
A special shoe is required to work on the reflector. These protect the panels by distributing the persons weight.

http://alfalfasurvey.wordpress.com

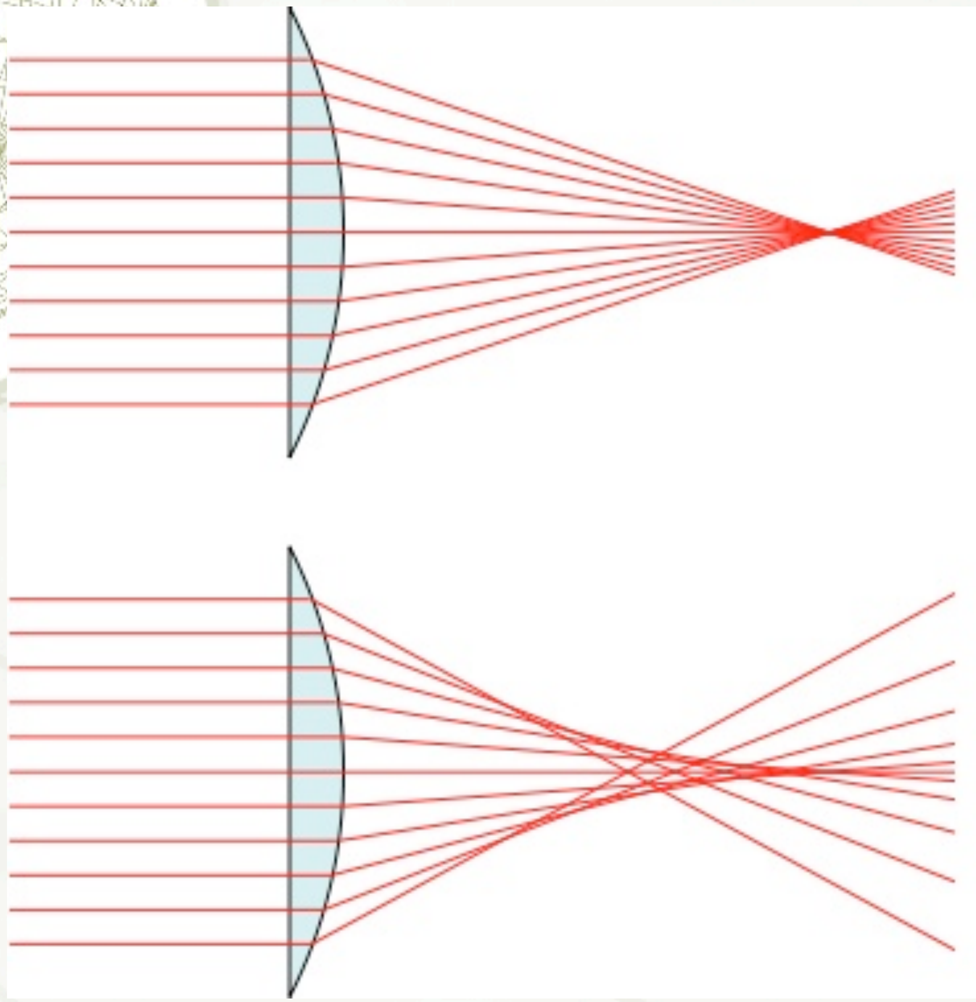



© 2007 Europa Technologies
Image © 2007 DigitalGlobe
©2007 Google™
Pointer 18°20'43.39" N 66°45'05.36" W elev 1017 ft
Streaming |||||||||| 100%
Eye alt 4089 ft


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

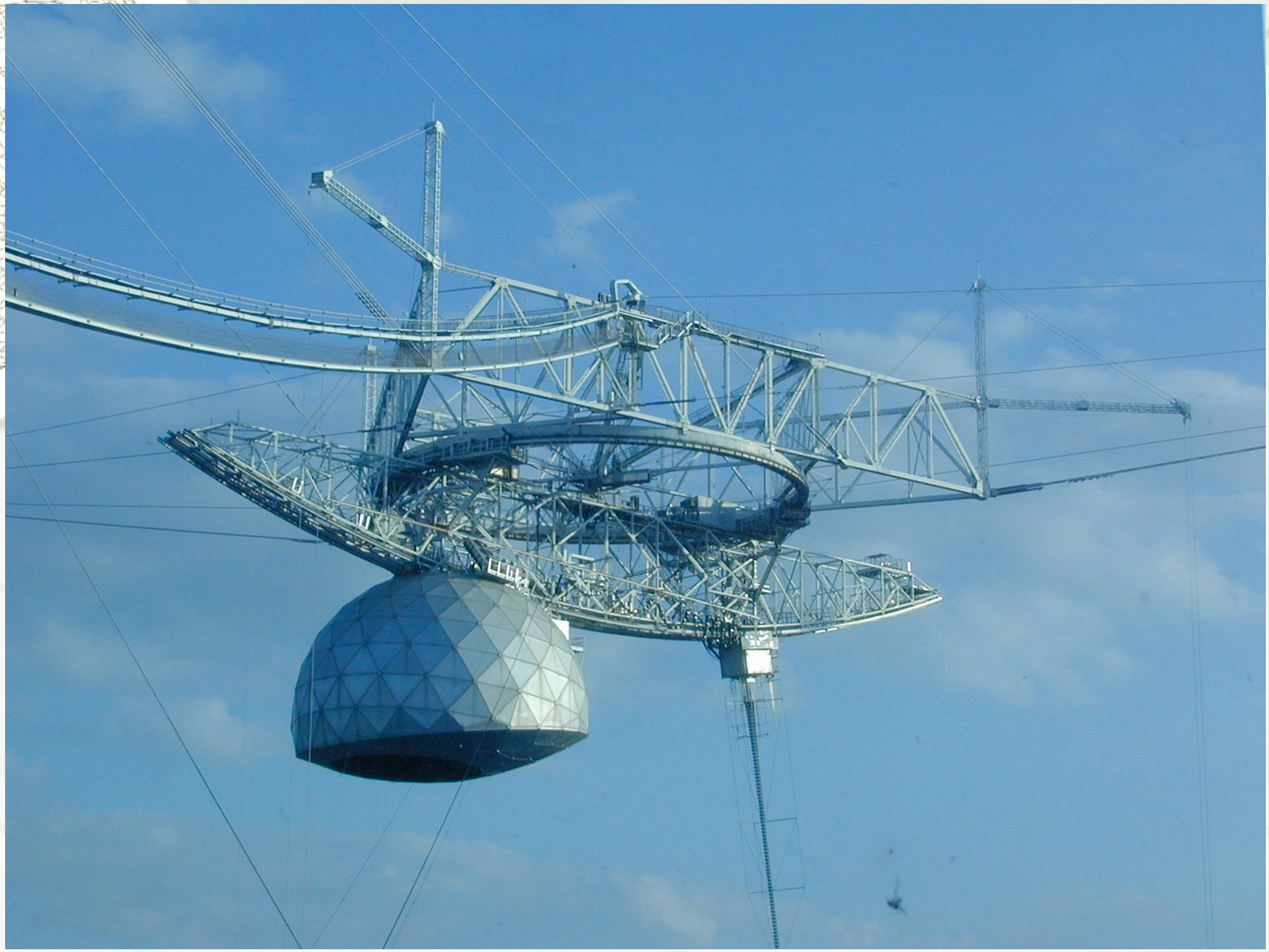


Arecibo Telescope
1
support cable
receiver room
dome
2
Reflector
ground



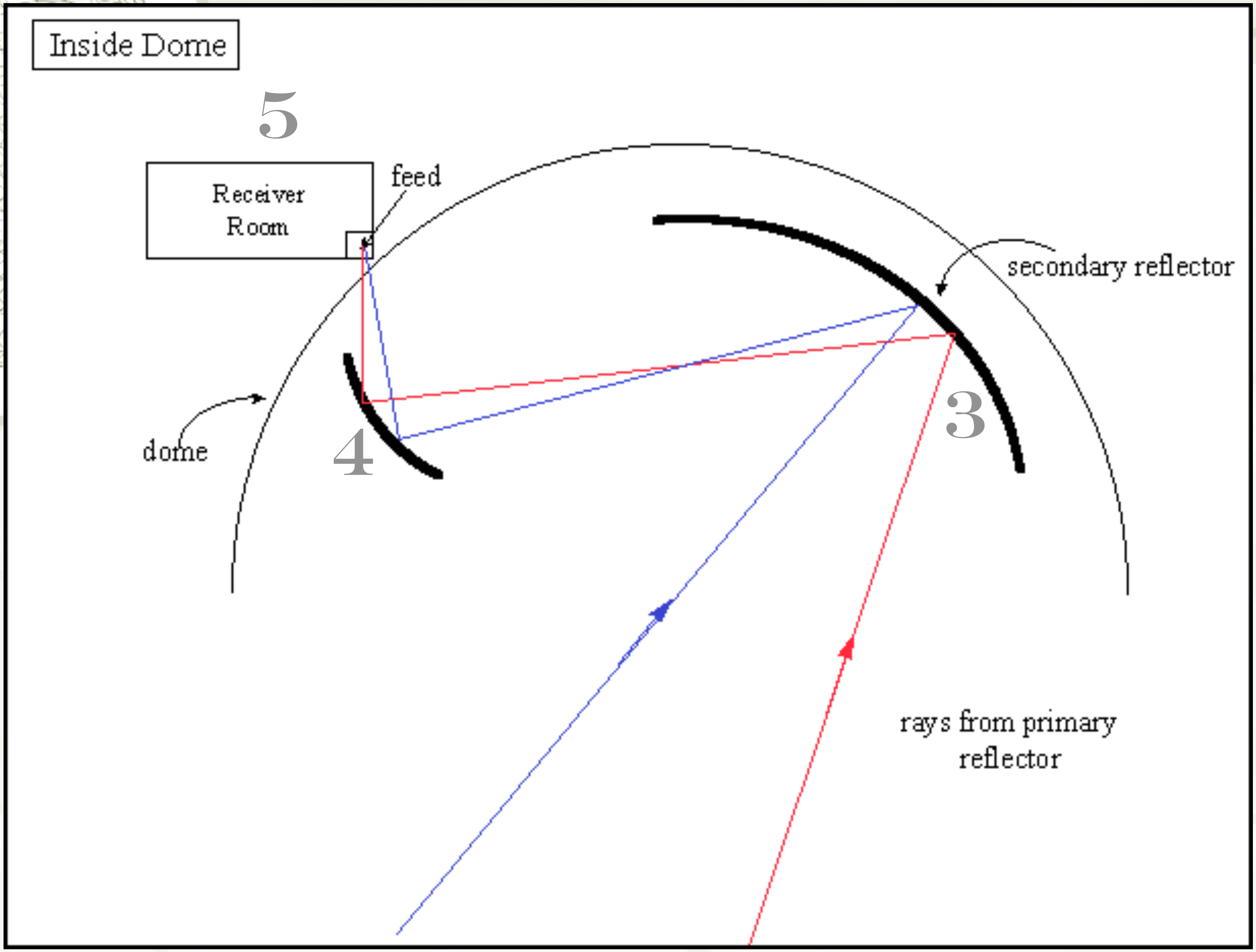
Parabolic Reflector

Spherical Reflector



430 MHz Antenna

- “Very long line feed”
- 96 feet in length
- Receives & transmits radio waves at 430 MHz
- Main instrument used in study of the ionosphere
- What popular movie features a fight between the hero and the bad guy on the long line feed?


Inside Dome
5
Receiver
Room
feed
secondary reflector
dome
4
3
rays from primary
reflector

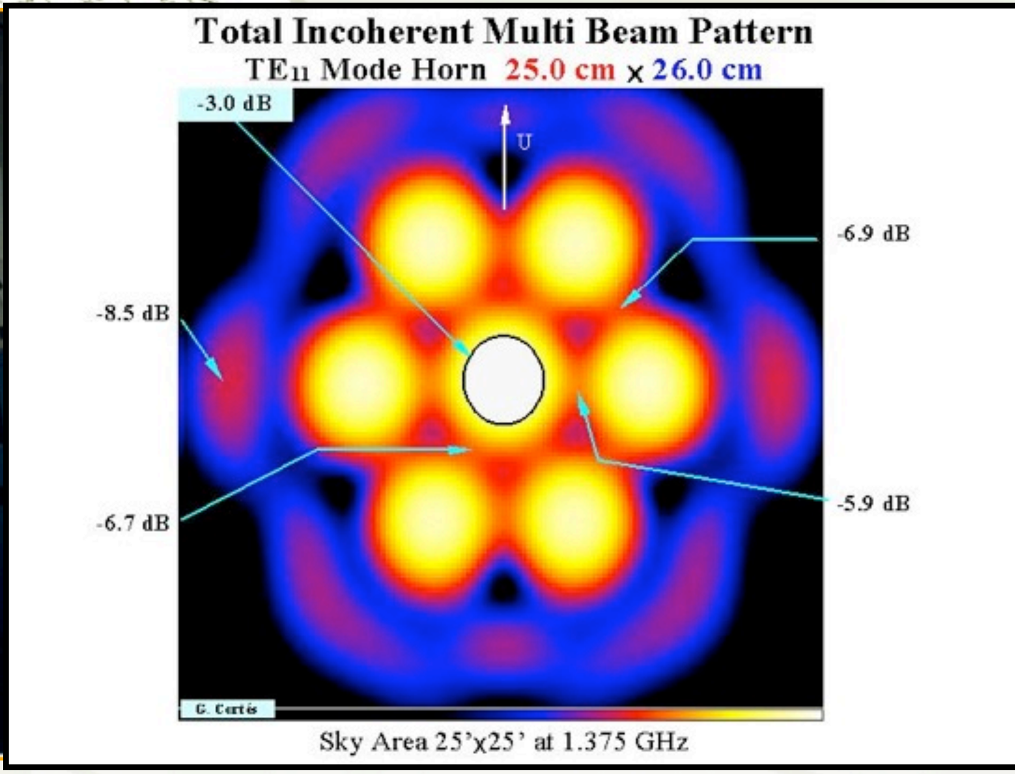
Gregorian

- The dome is referred to as the “Gregorian”.
- A Gregorian focus means the secondary reflector is placed behind the focal point of the primary reflector.
- The Gregorian protects the receivers from RFI and weather.

What are some advantages of Gregorian optics over line feeds?

Advantages of Gregorian Optics

- Each line feed covers a narrow frequency band and a limited number of line feeds can be used at one time
- With Gregorian optics, an array of receivers covering the whole 1-10 GHz range can be easily moved onto the single focal point where the incoming signal is focused.

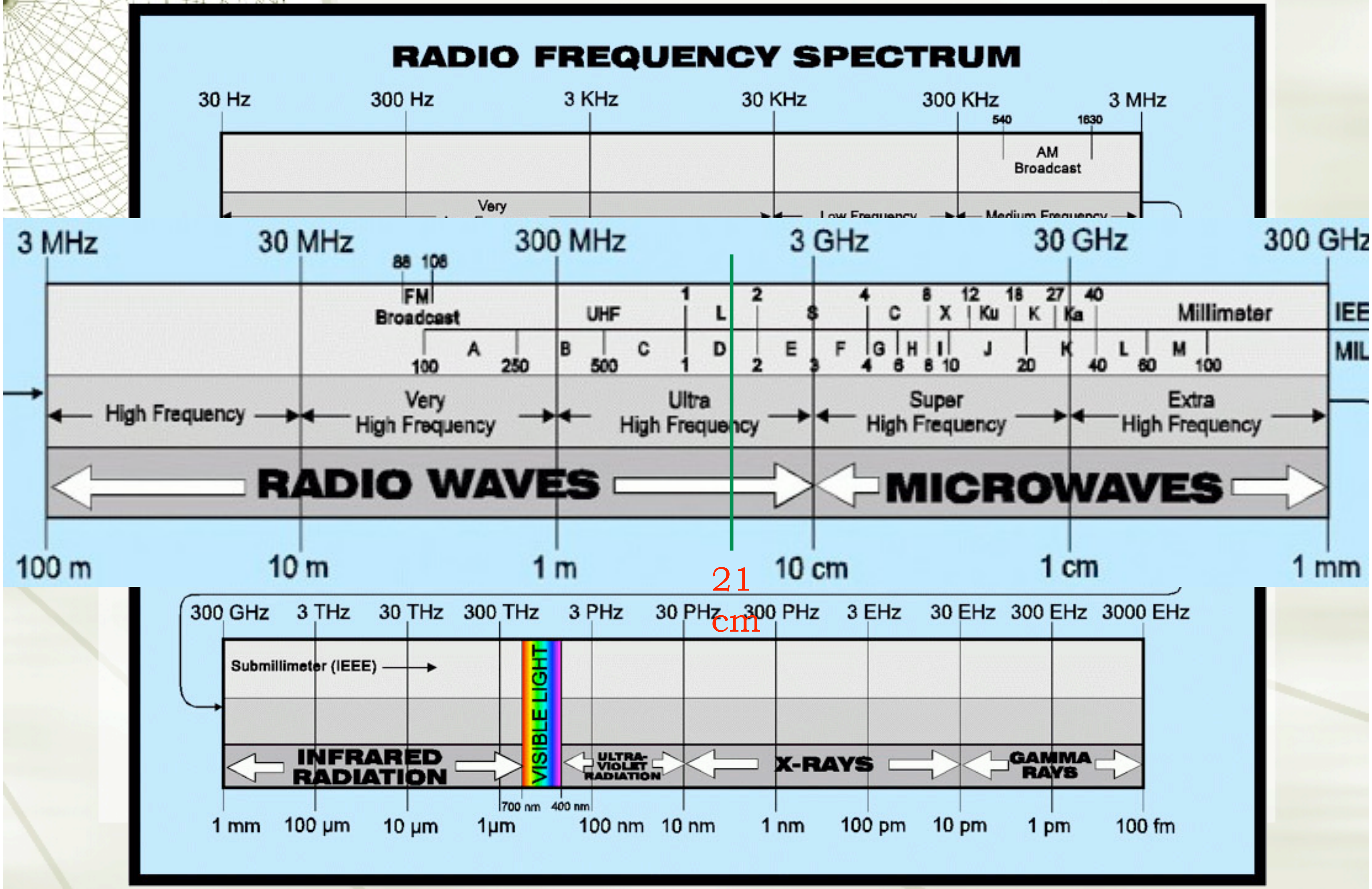


Available Receivers: 327 MHz, 430 MHz, 610 MHz, ALFA, L-Wide, S-Low, S-Narrow, S-High, C, C-High, X

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

L-Band


RADIO FREQUENCY SPECTRUM
30 Hz
300 Hz
3 KHz
30 KHz
300 KHz
3 MHz
540
1630
AM Broadcast
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz
FM Broadcast
88 108
UHF
L
S
C
X
Ku
K
Ka
Millimeter
IEE
MIL
A
B
C
D
E
F
G
H
I
J
K
L
M
High Frequency
Very High Frequency
Ultra High Frequency
Super High Frequency
Extra High Frequency
RADIO WAVES
MICROWAVES
100 m
10 m
1 m
21 cm
10 cm
1 cm
1 mm
300 GHz
3 THz
30 THz
300 THz
3 PHz
30 PHz
300 PHz
3 EHz
30 EHz
300 EHz
3000 EHz
Submillimeter (IEEE)
INFRARED RADIATION
VISIBLE LIGHT
ULTRA-VIOLET RADIATION
X-RAYS
GAMMA RAYS
700 nm
400 nm
1 mm
100 µm
10 µm
1µm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
100 fm

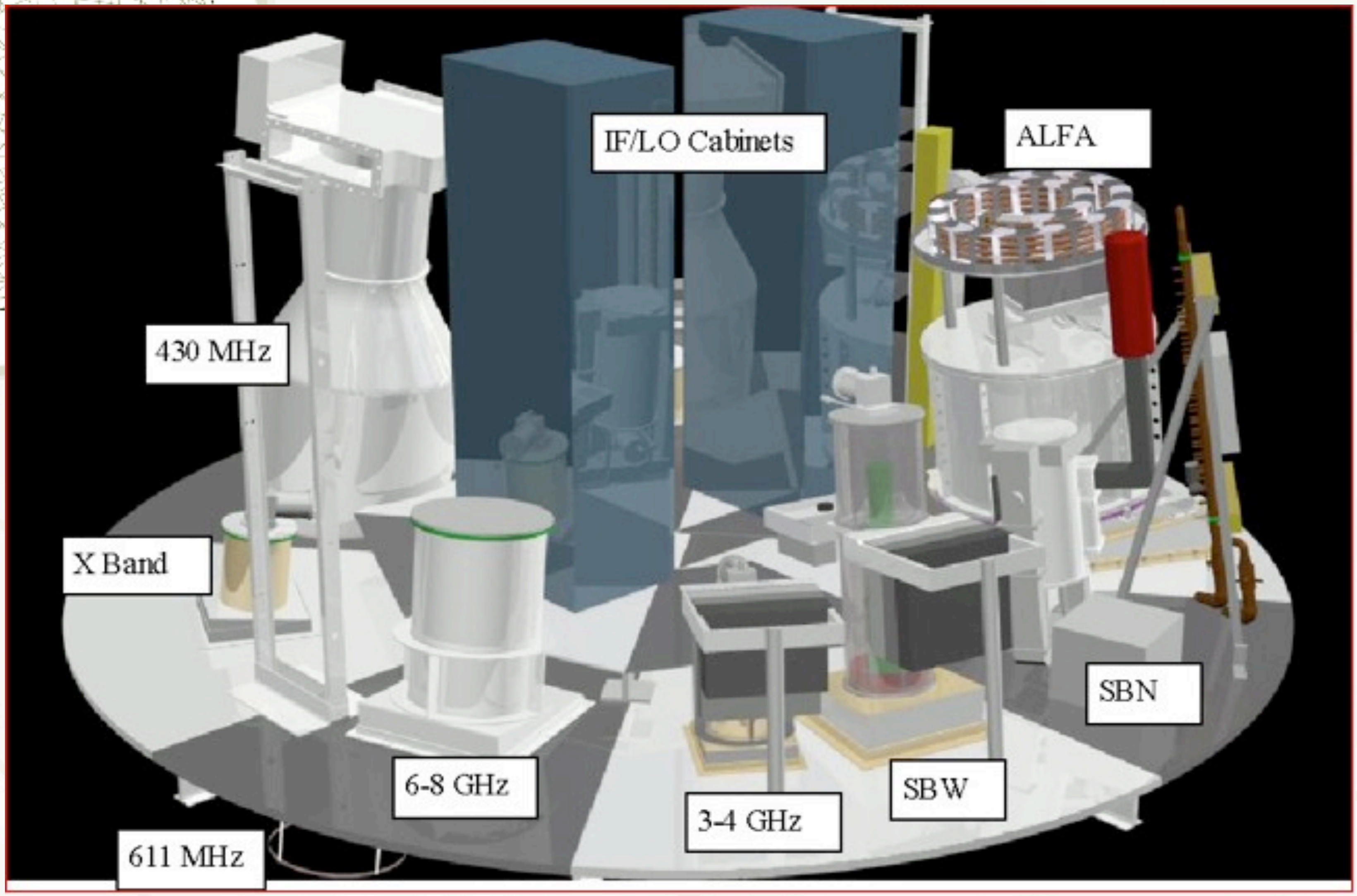


Diagram courtesy of José Alonso

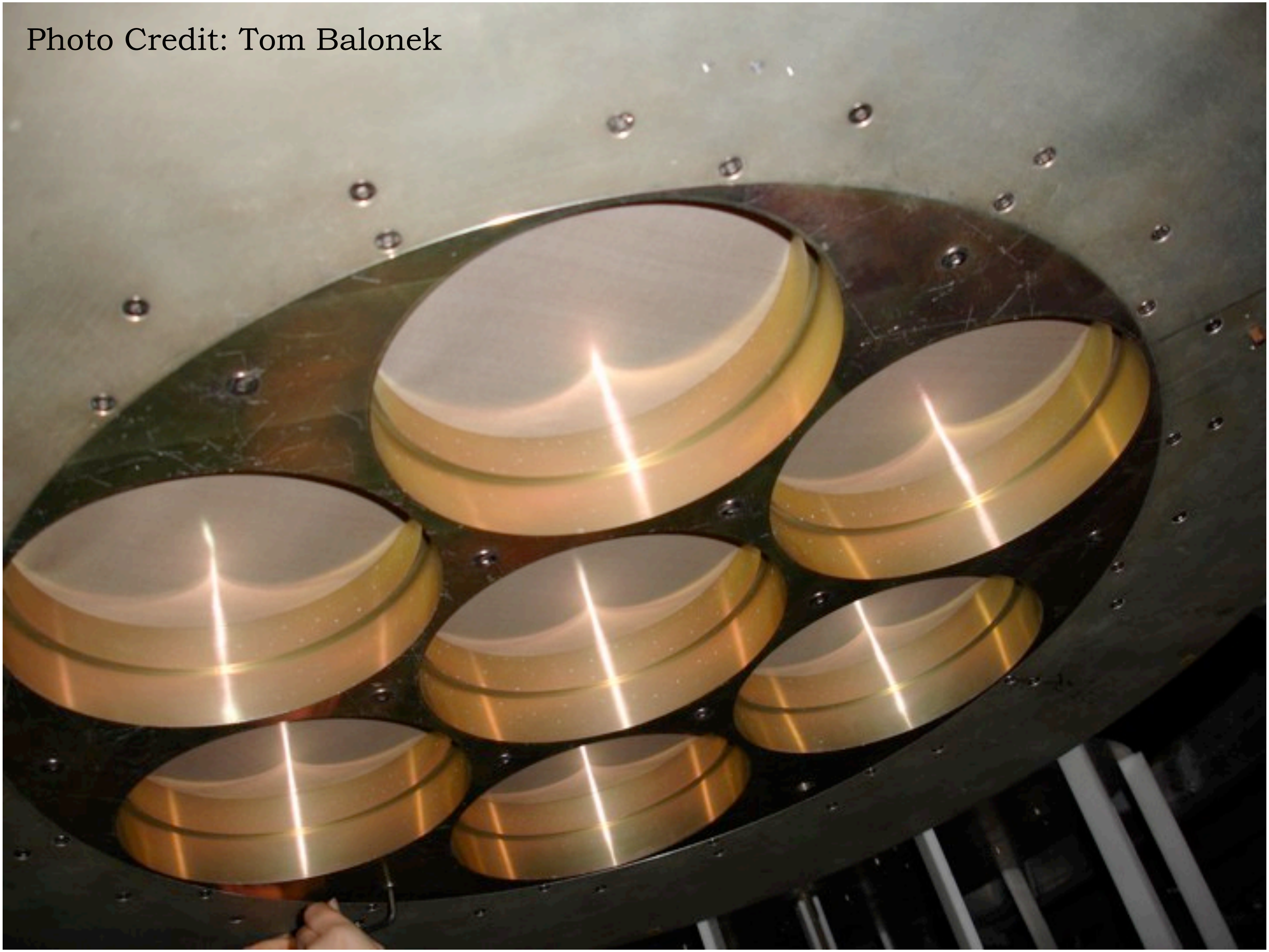


Photo Credit: Tom Balonek

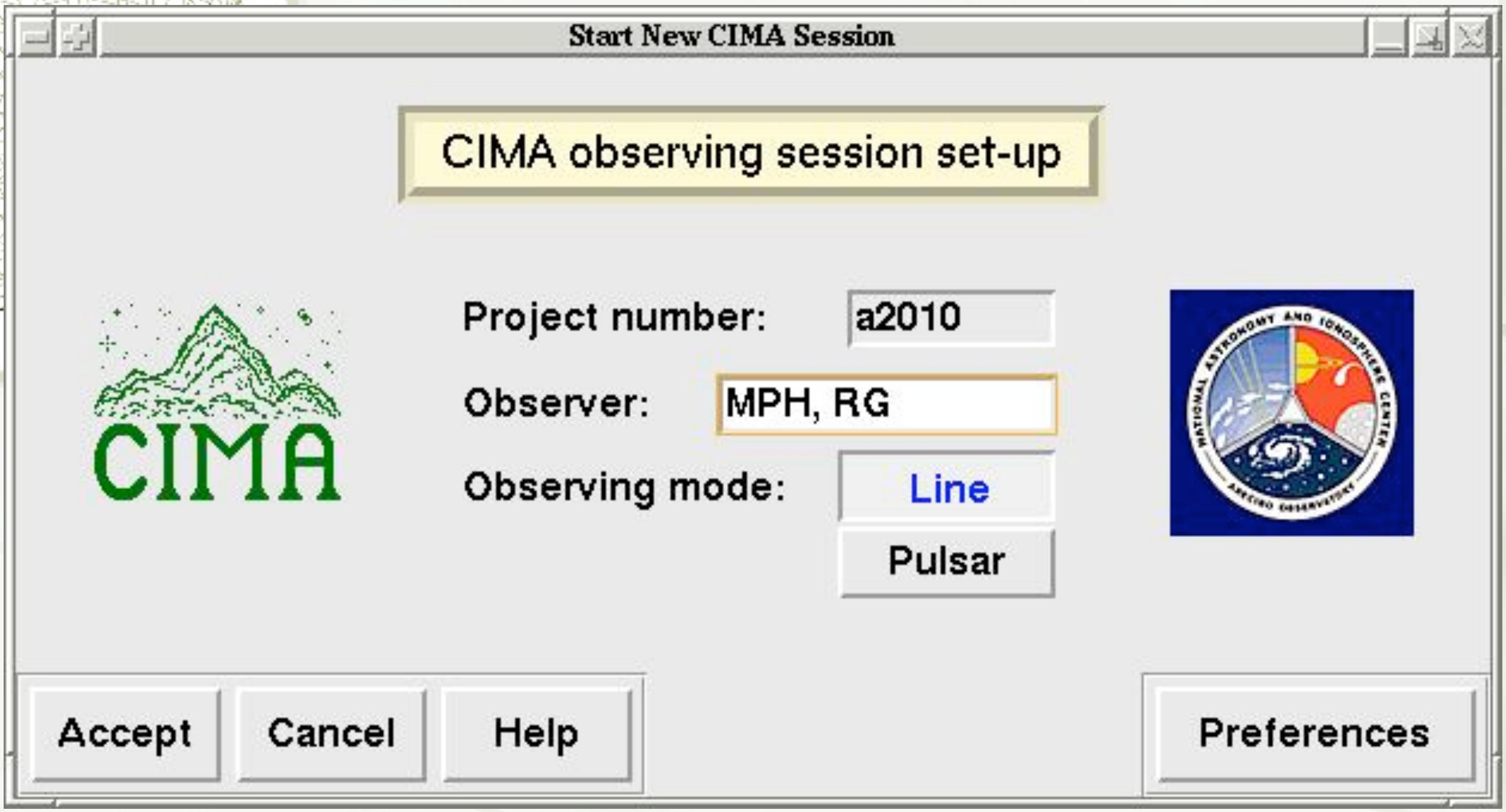
IF/LO

- Impedance of transmission lines increases with frequency so signals are down-converted to lower frequencies before traveling away from the telescope
- Conversion done with a mixer which requires an oscillating signal of a specific frequency
- IF stands for Intermediate Frequency (the lower frequency the signal is converted to)
- LO stands for Local Oscillator (the locally-produced signal being mixed with the cosmic signal)

Backend

- The components of the telescope the signal enters after having been down-converted
- Several different backends are available at Arecibo with different frequency spans
- Tonight we will use the 4 WAPPs (Wideband Arecibo Pulsar Processor)

CIMA

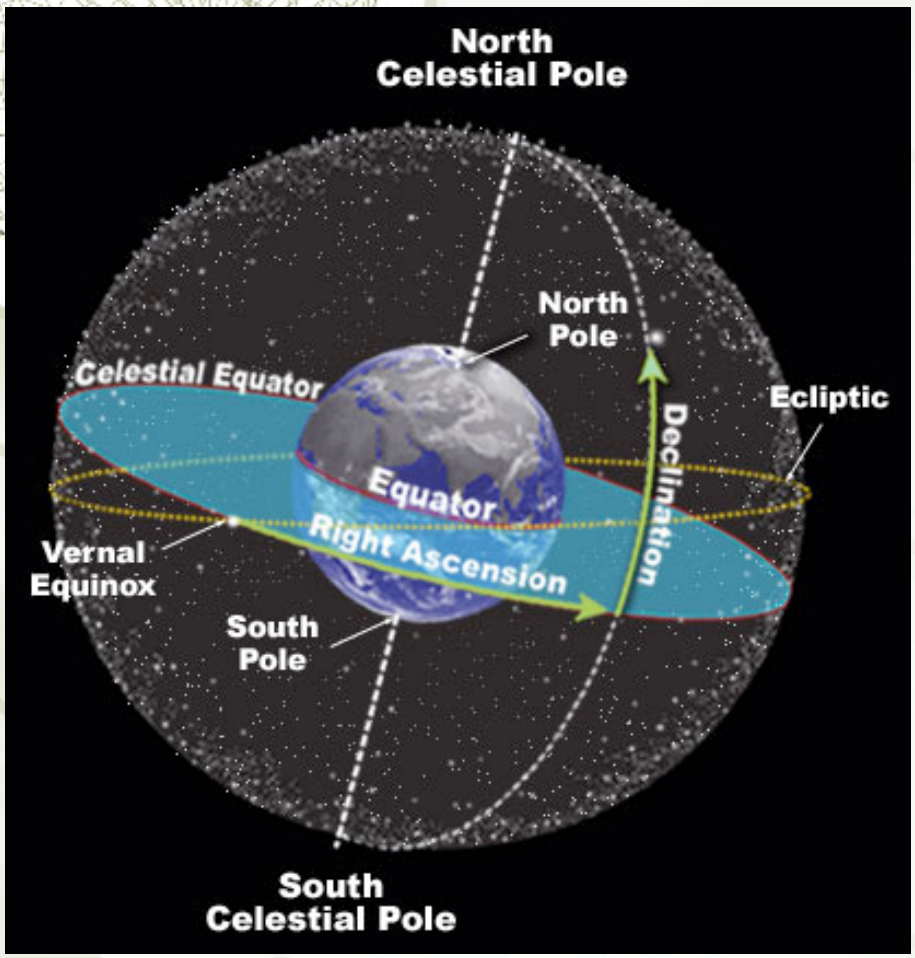


Control Interface Module for Arecibo: a graphical interface that makes observing as easy as clicking buttons (more on this later…)

Arecibo Stats

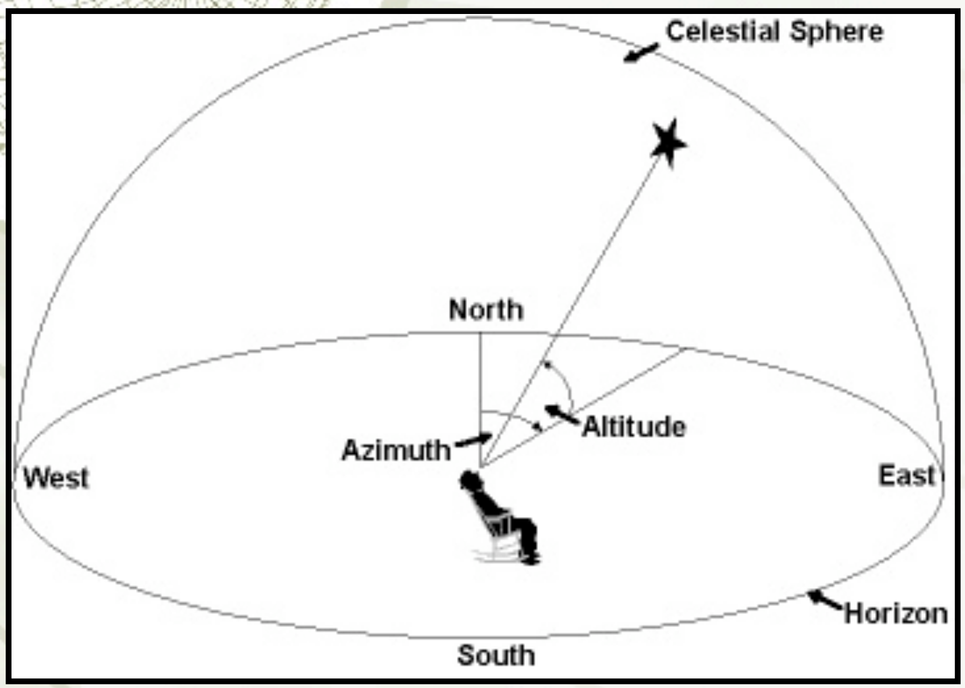
- Covers 6m - 3cm (47 MHz - 10 GHz)
- Slew rate of 25°/min in azimuth
- Slew rate of 2.5°/min in zenith
- Pointing accuracy of 5 arcseconds
- 3 pairs of cables that lead under dish for mm precision placement of platform
- Can view objects within ~40° cone about local zenith (0 to 36 degrees in dec)

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!

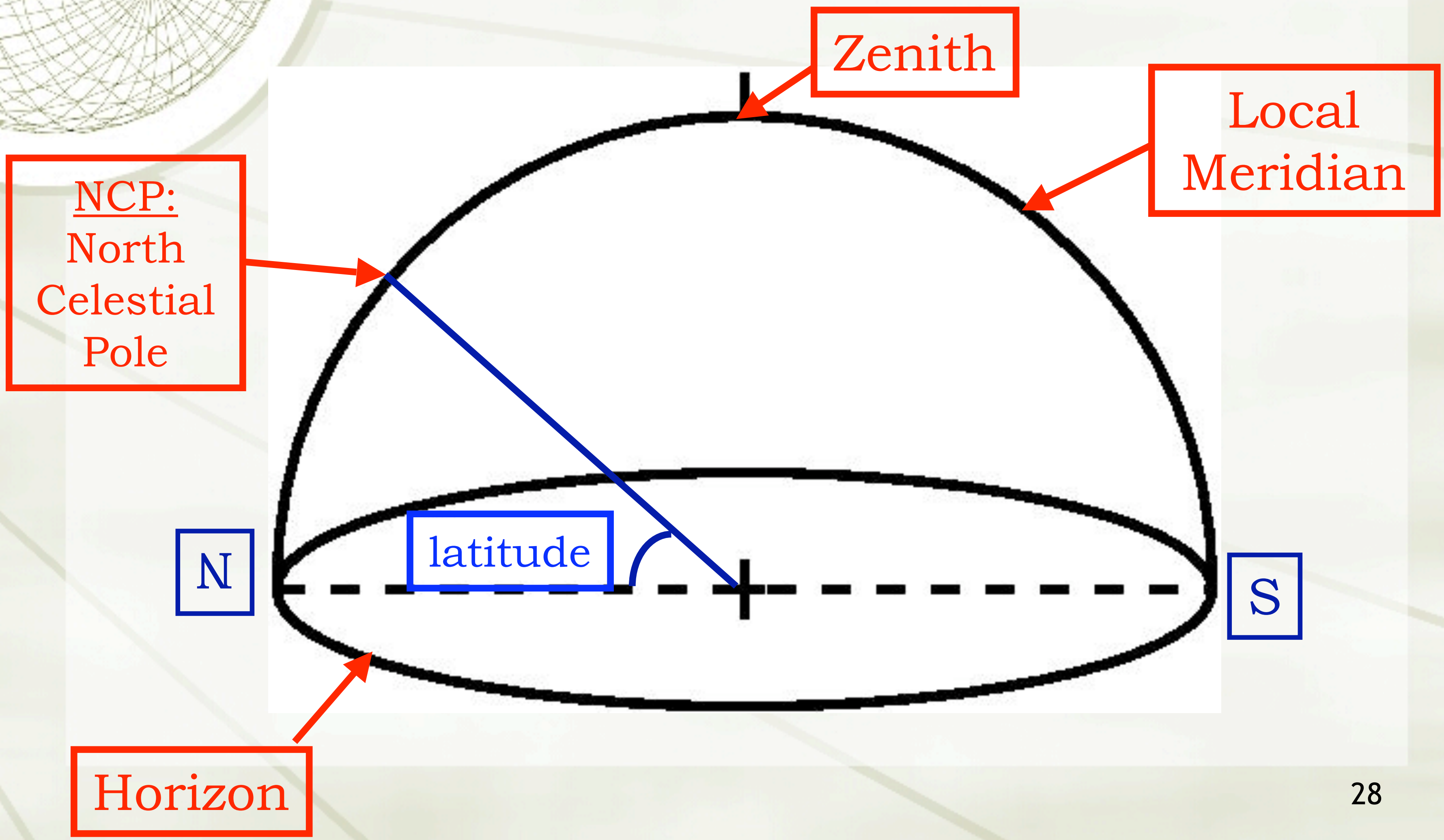
Azimuth & Zenith



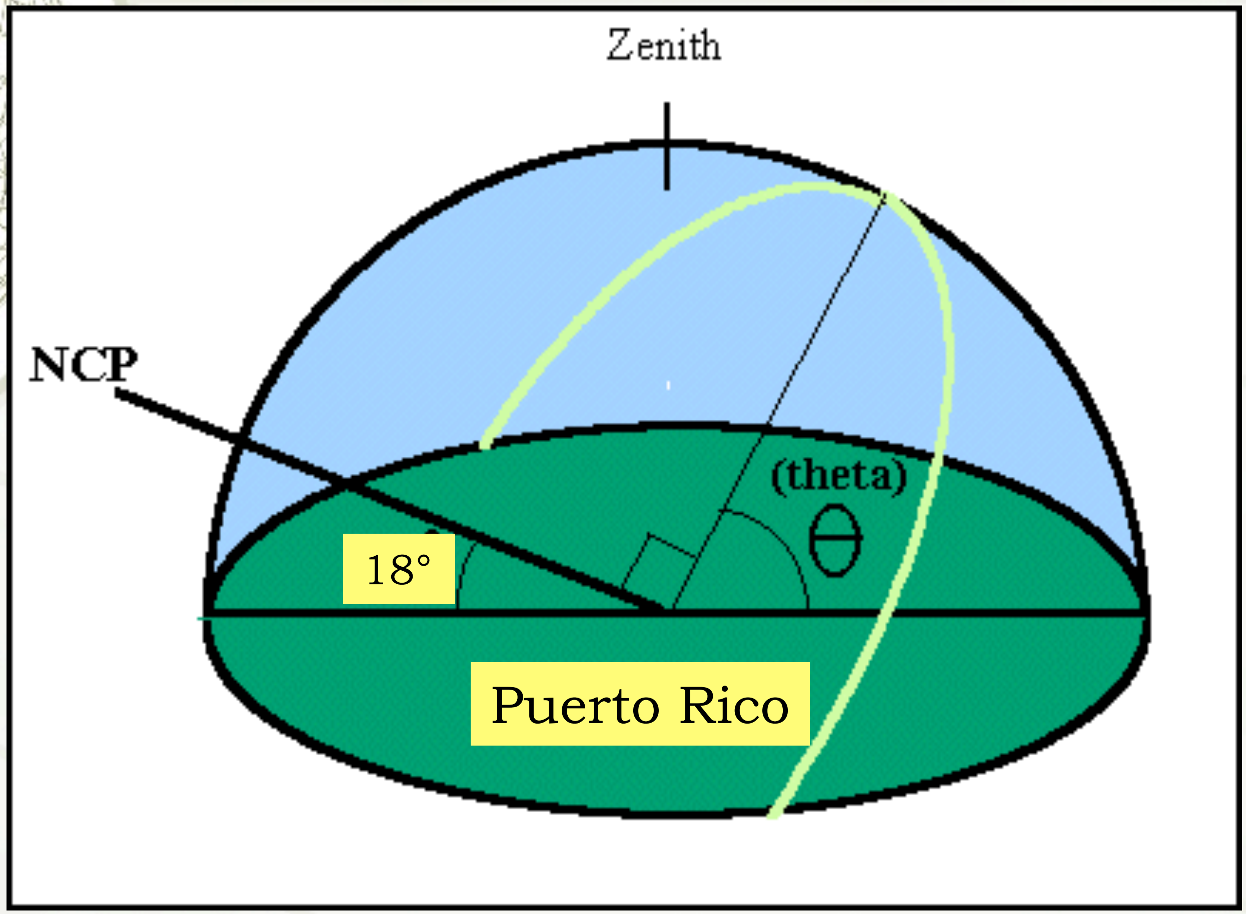
- Azimuth Angle
  - Measured in degrees
  - Tells how far east of north the source is located
- Zenith Angle
  - Measured in degrees
  - Tells how far below zenith a source is located
- They depend on the observer's location!

Local Perspective

The altitude of the North Celestial pole (as measured up from the horizon) is equal to the latitude of the observer.



Arecibo, Puerto Rico, lat = 18° North

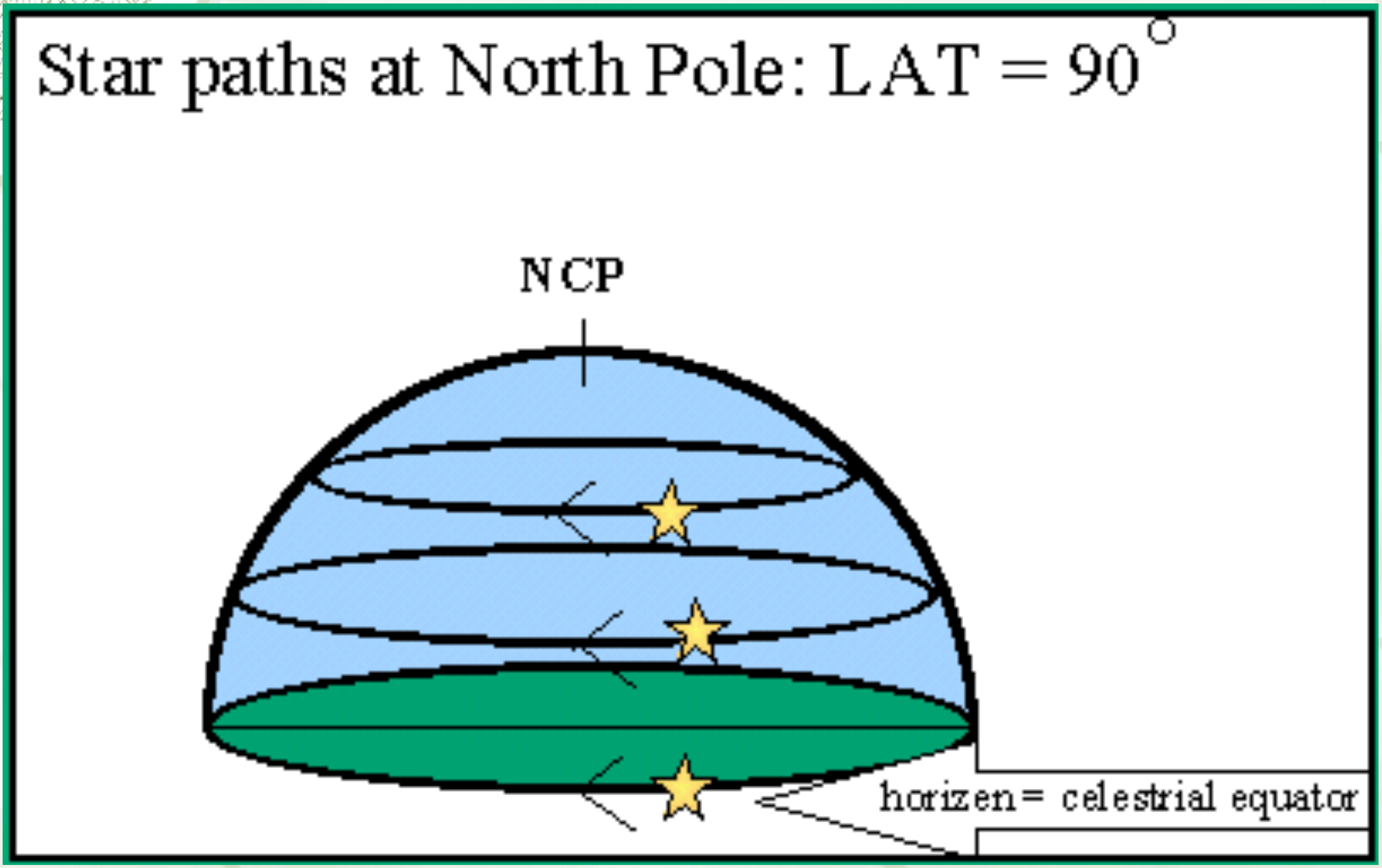


The altitude of the intersection of the Celestial Equator with the meridian is $\theta = 180^\circ - 18^\circ - 90^\circ = 72^\circ$.

Local Perspective: North Pole

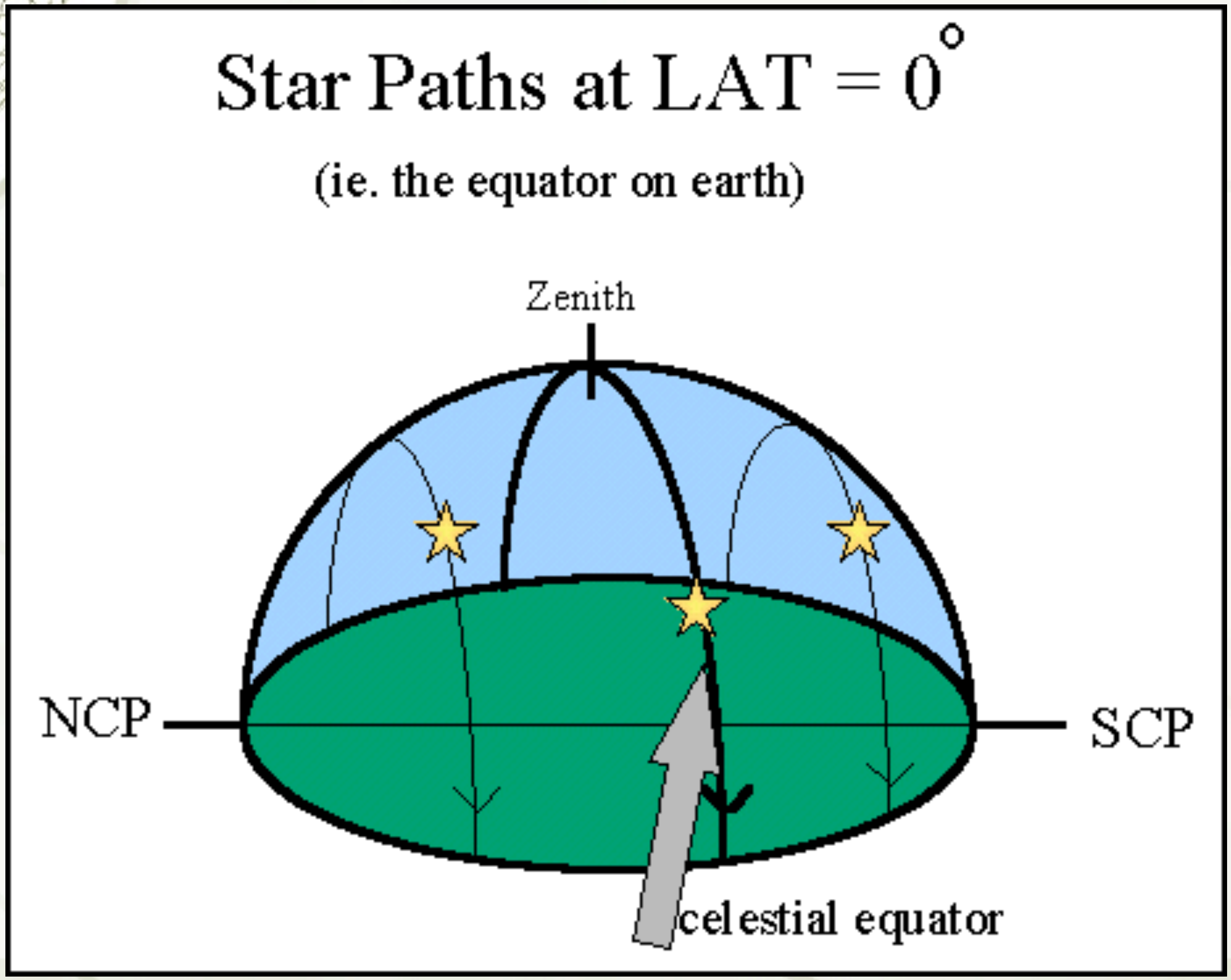
At the North or South Pole:

Half of the stars are above the horizon all of the time. The other half of the stars are never visible.



Local Perspective: Equator

All of the stars are visible above the horizon but only half of the time



The Sun's Apparent Path

- The Sun's apparent position among the stars changes throughout the year with an eastward annual drift.
- Unlike a star, the Sun (Moon and planets) moves with respect to the (much more distant) stars.
- Right Ascension & Declination of Sun (Moon & planets) change throughout the year.
- The path the Sun (Moon and planets) takes across the sky on any given day depends on its Declination on that day.
- Noon-time altitude (above horizon) varies
- Length of time to cross from East to West along the path on a given day varies.

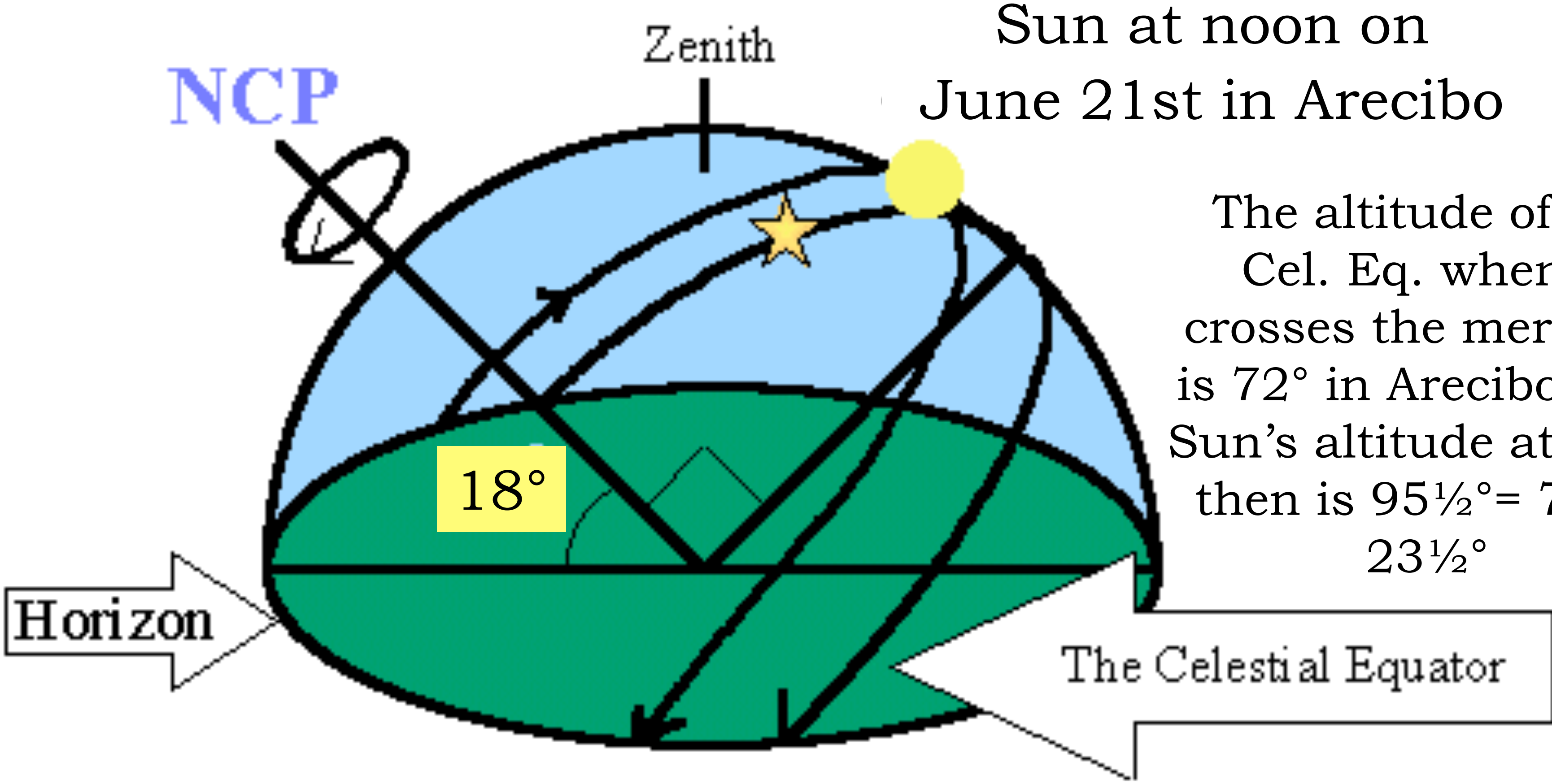
The Sun's Path Throughout the Year

- The Sun's Declination changes throughout the year due to the inclination of the Earth on its axis.
- On Sep 20th and Mar 20th, the Sun's Declination is 0°.
  - The Sun's path follows the Celestial Equator.
  - These are called the autumnal and vernal equinoxes.
- On Dec 21st, the Sun's Declination is -23½°.
  - At noon, the Sun crosses the meridian south of the Celestial Equator.
  - Winter in the northern hemisphere; summer in the South.
- On Jun 21st, the Sun's Declination is +23½°.
  - At noon, the Sun crosses the meridian north of the Celestial Equator.
  - Summer in the northern hemisphere; winter in the South.

Sun's Path: June 21st

Sun's declination is +23½°

Sun's path is || Cel. Eq. but 23½° N of it



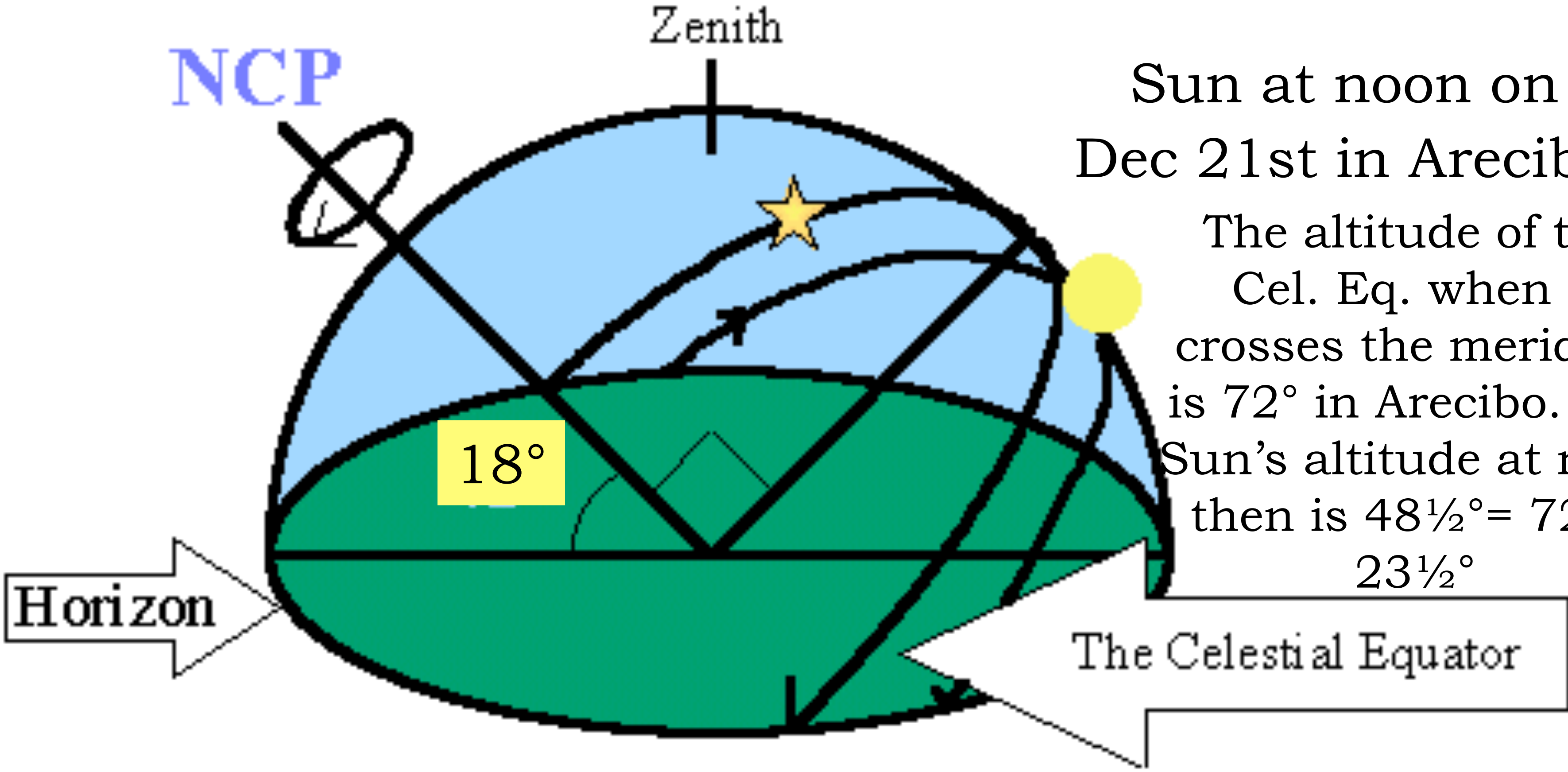
Sun at noon on June 21st in Arecibo

The altitude of the Cel. Eq. when it crosses the meridian is 72° in Arecibo. The Sun's altitude at noon then is 95½°= 72° + 23½°

Sun's Path: Dec 21st

Sun's declination is -23½°

Sun's path is || Cel. Eq. but 23½° S of it

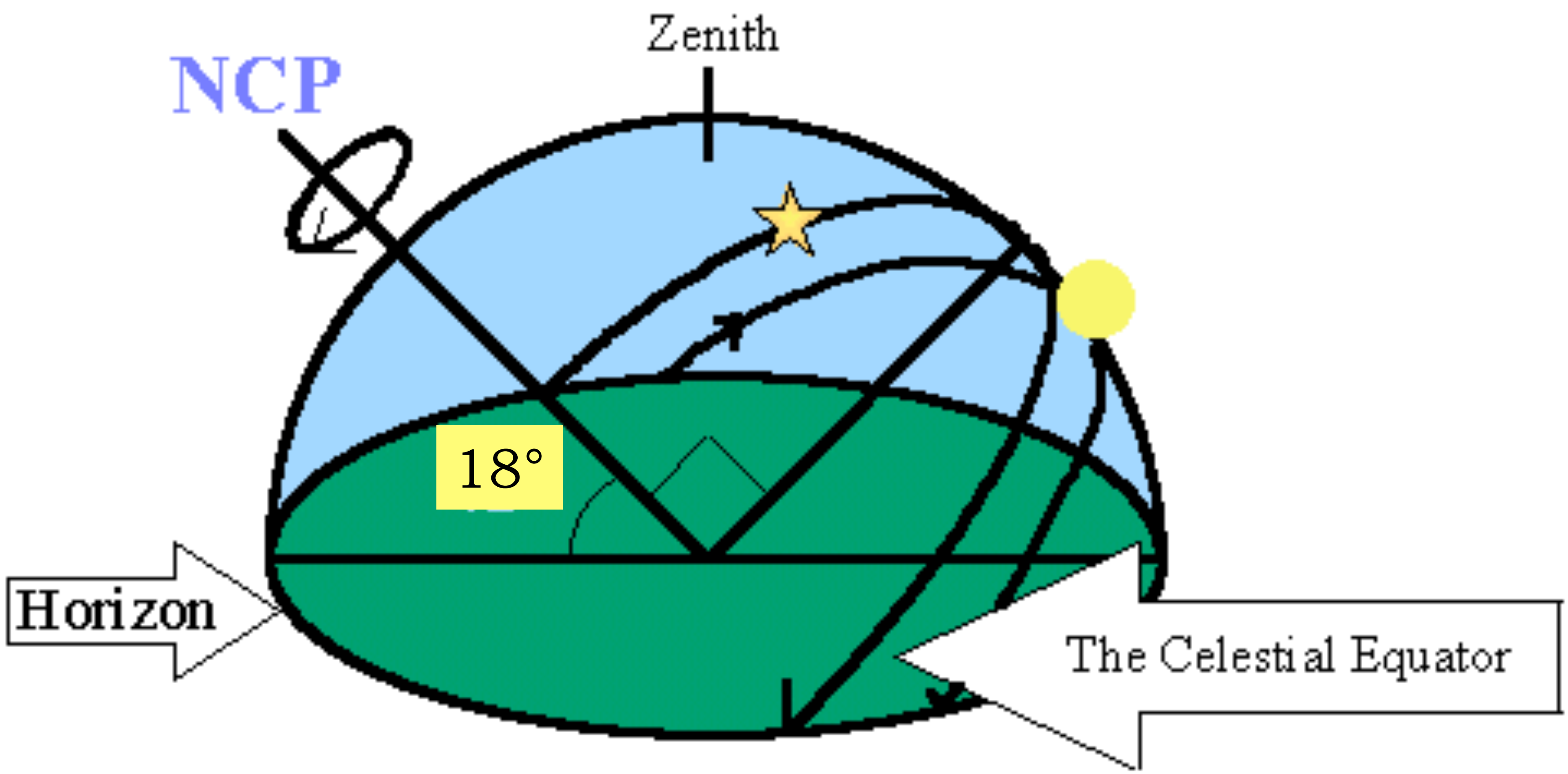


Sun at noon on Dec 21st in Arecibo

The altitude of the Cel. Eq. when it crosses the meridian is 72° in Arecibo. The Sun's altitude at noon then is 48½°= 72° - 23½°

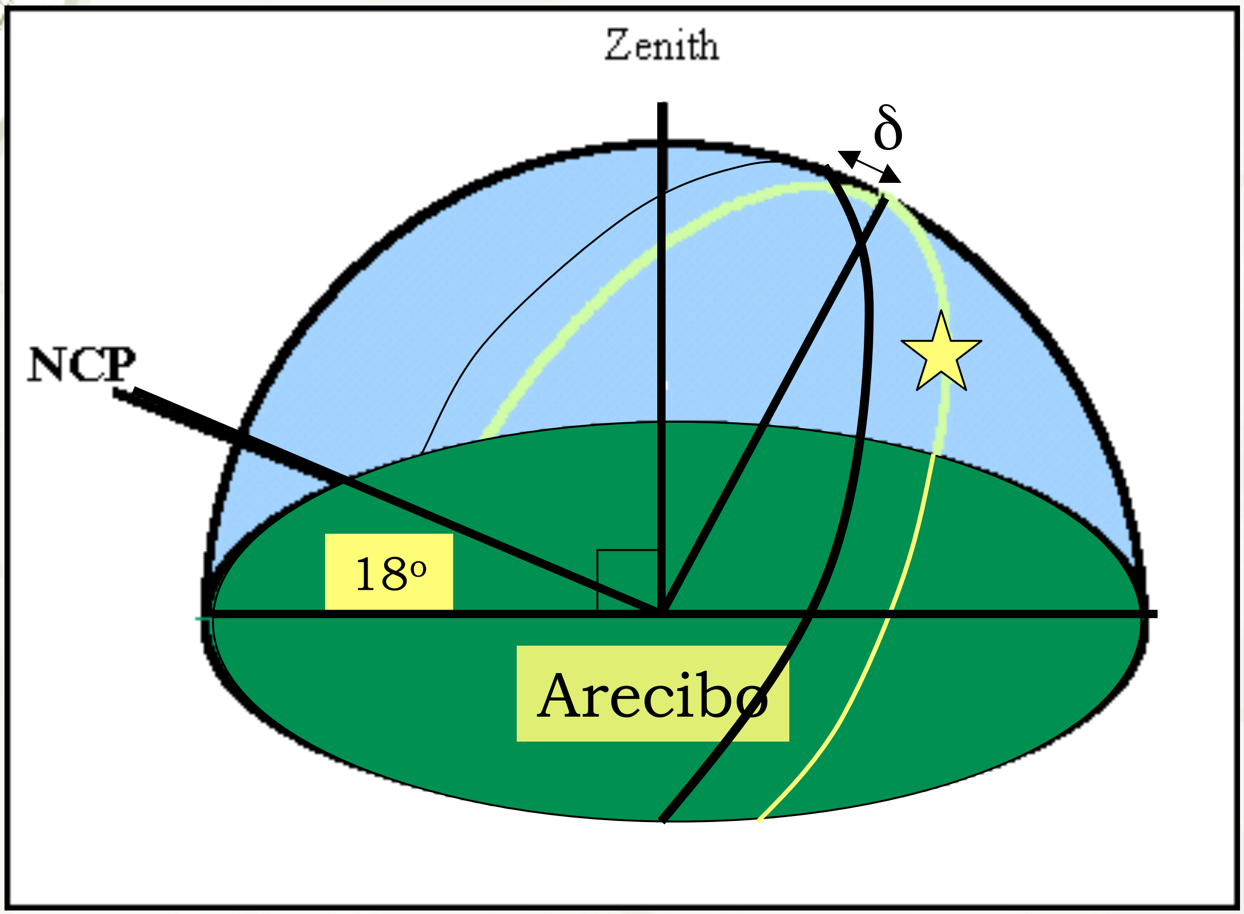
Sun's Path: Jan 13th

Sun's declination somewhere between its declinations at the summer and winter solstices, but closer its path on Dec 21st.



Zenith Angle of a Drift 14p2 ($\delta = +03^o24'24''$)

$$ZA = 18^o20'58'' - \delta = 14^o56'34''$$

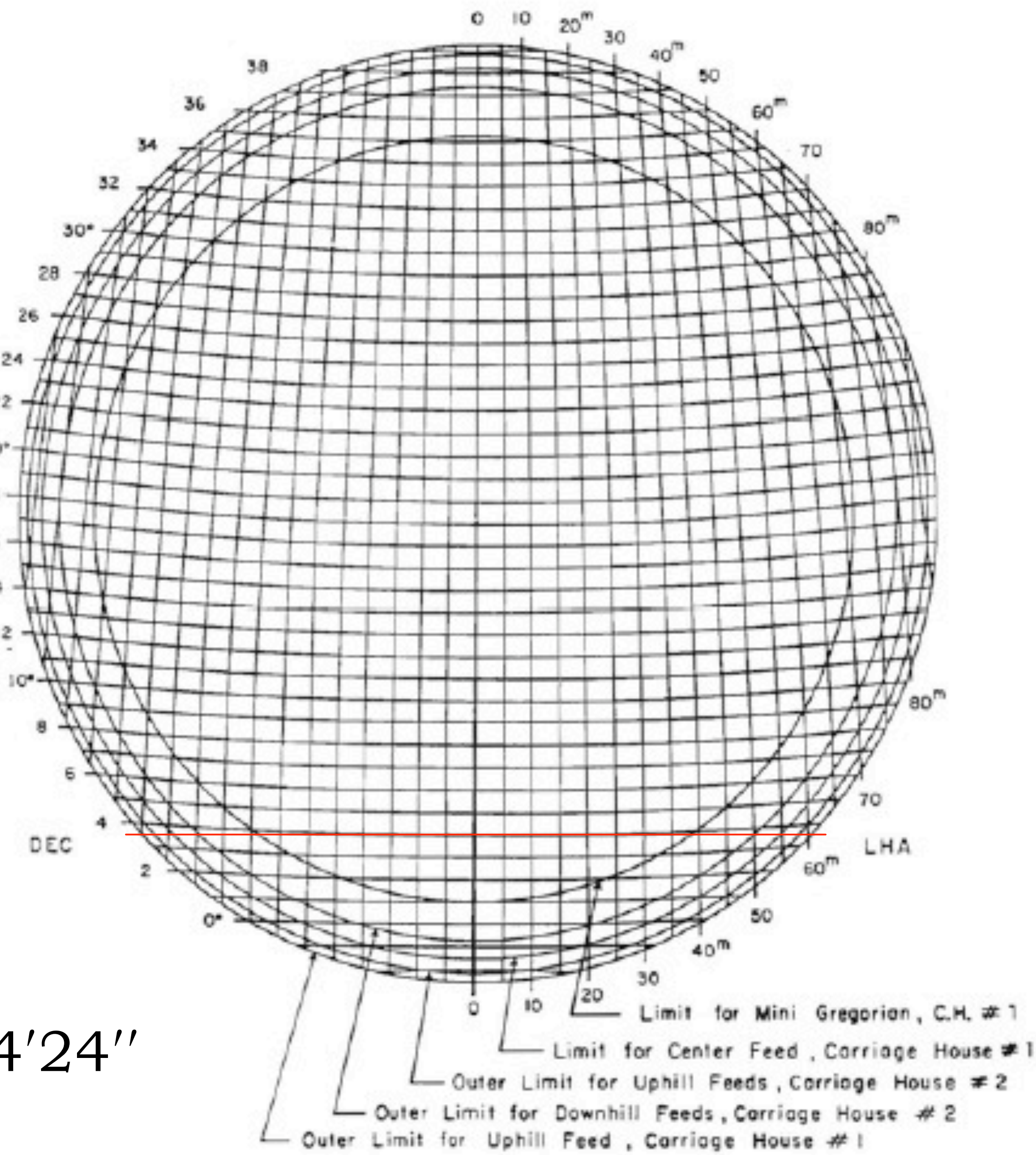


Azimuth = 360° (source is S of zenith)

How long is a source "up"?

Dec (deg)	-1	0	5	10	15
Time (h:mm)	0:30	0:58	2:18	2:27	2:42

Dec (deg)	20	25	30	35	38
Time (h:mm)	2:46	2:40	2:20	1:35	0:10



$\delta = +03^{o}24'24''$

How do I get time on the telescope?

- Telescope operates 24 hours a day
- Submit a proposal which is judged by a panel of referees
- Deadlines are February 1st, June 1st, and October 1st

Arecibo Observatory Telescope Schedule

January 1 - January 15, 2009

TRANSMITTERS

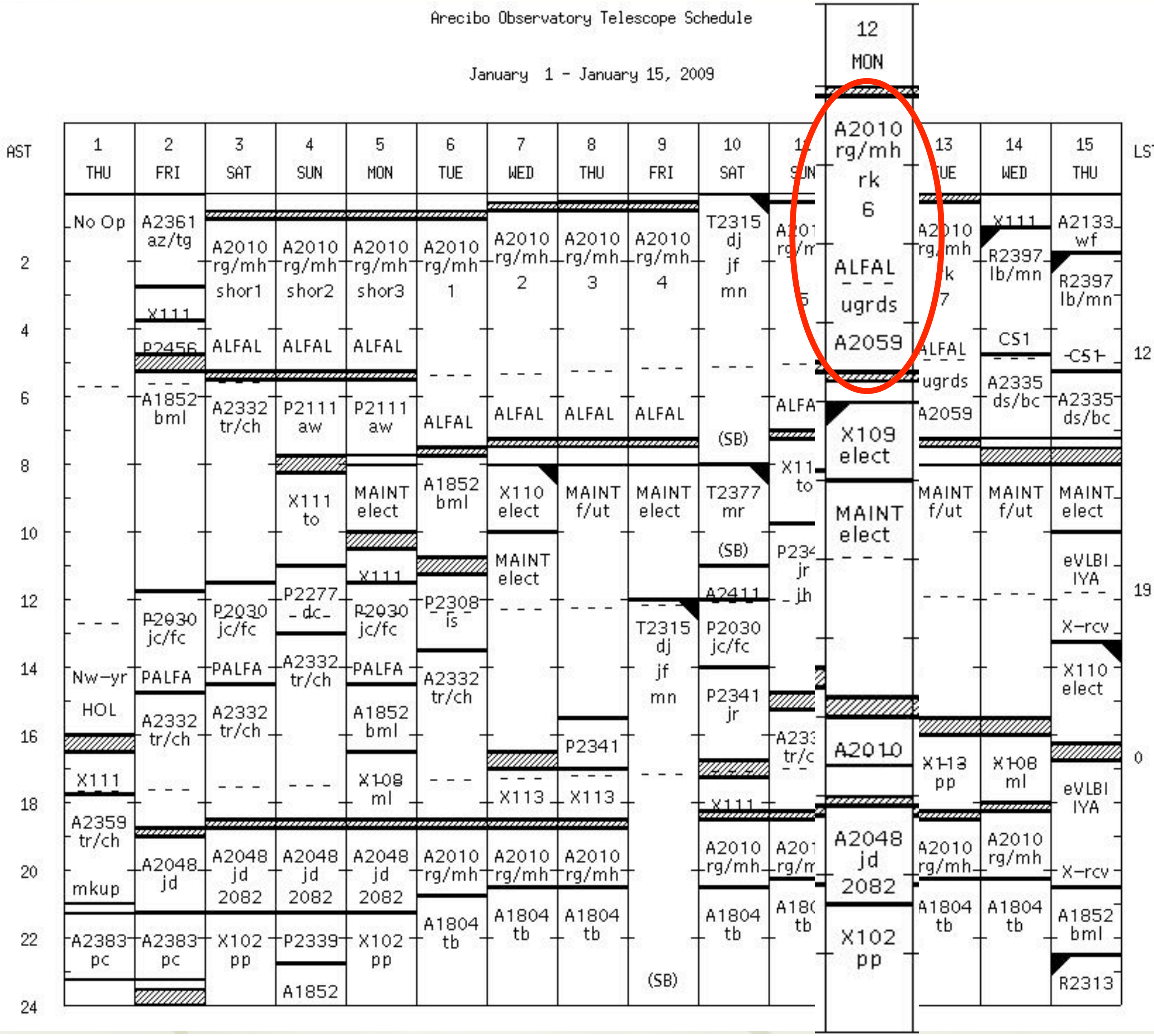
2380 430 HF

Opt 47 System Checks

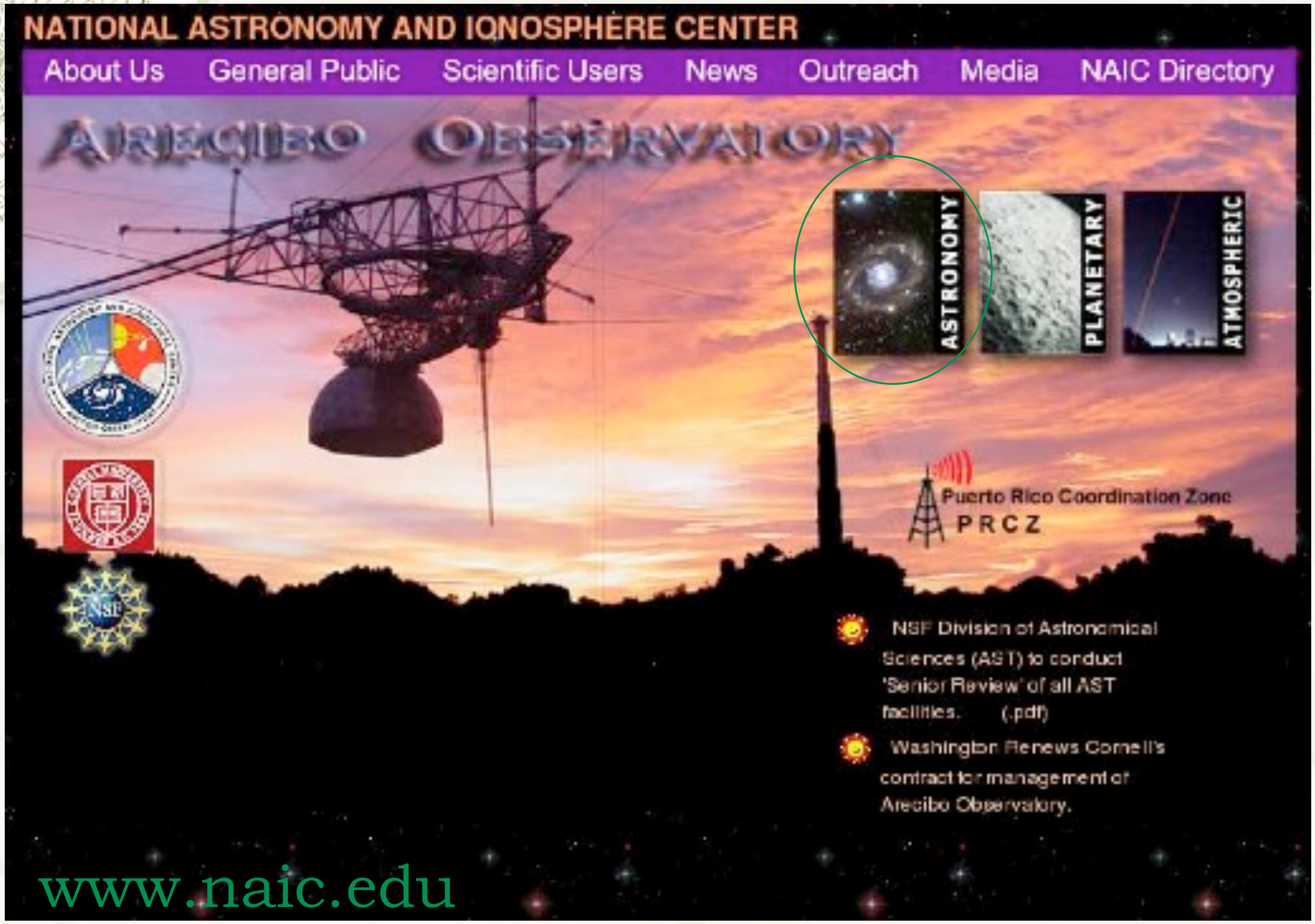
VISITORS
(or PIs)
M. Rapp
R. Giovanelli
M. Haynes
R. Koopman
T. Bania
R. Rood
L. Benner
A. Zauderer
A. Wolsczan
T. Robishaw
C. Heiles
J. Cordes
F. Camilo
J. Rankin
D. Champion
J. Davies
P. Castangia
D. Lorimer
D. Janches
E. Araya
C. Magri
D. Schiminovich
B. Catinella

COMMENSAL PROGRAMS:
_ A2059c with A2010
- A2059c with A2048

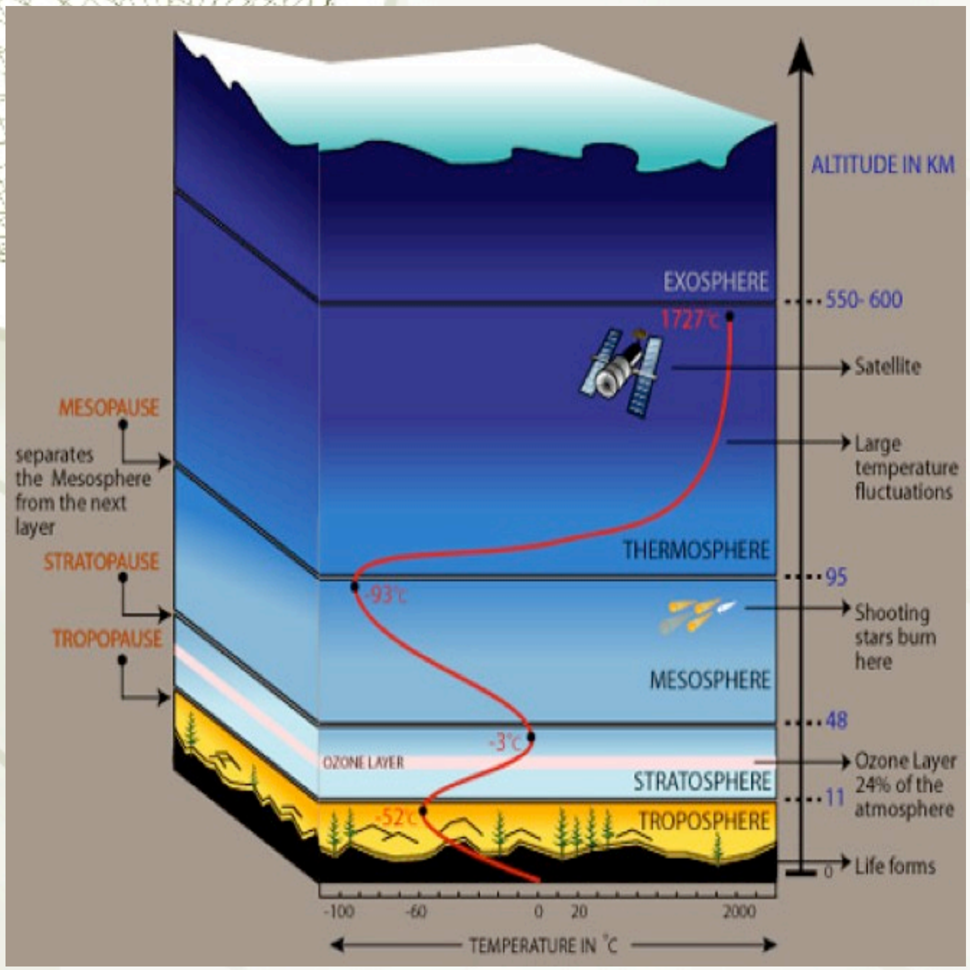
VER 5.0 - 010808



For More Information…

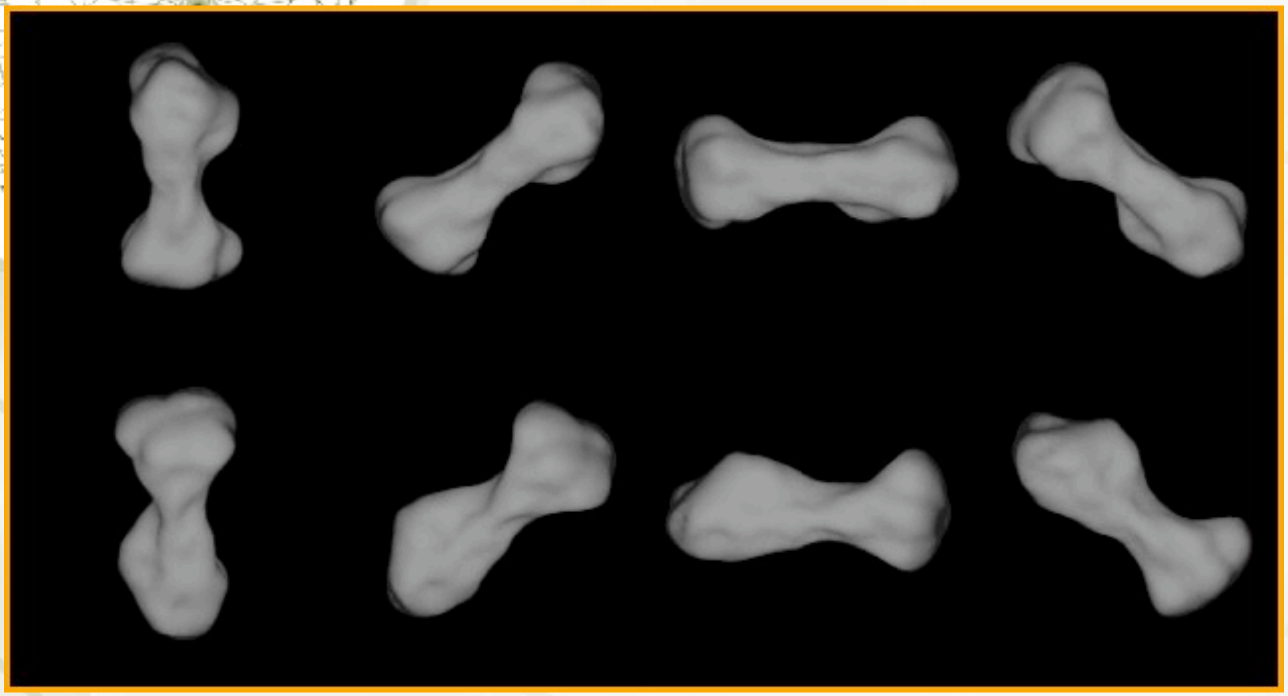


Areas of Study at Arecibo



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

Radio Astronomy: Radar



Asteroid Kleopatra 216

- 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: Continuum Observations

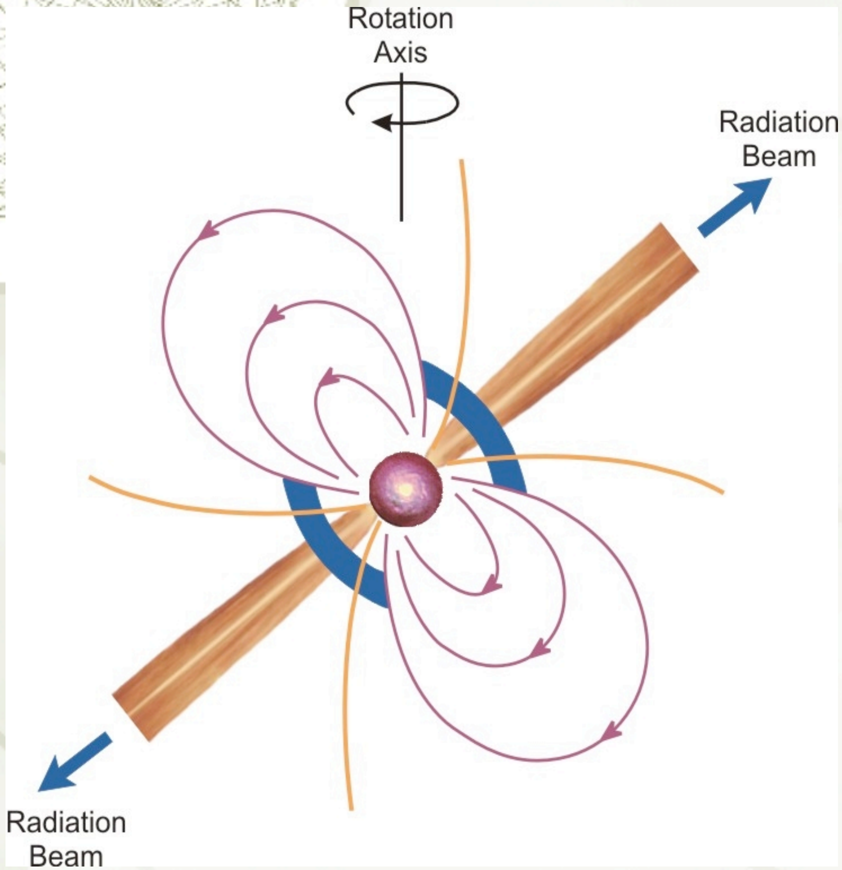
- Radio frequency observations over a wide range of frequencies
- Example: studying synchrotron emission in our own galaxy

Radio Astronomy: Pulsars

Crab Nebula

- Neutron stars were a purely theoretical concept until observations of the 33-ms pulsar in the Crab Nebula in 1968
- Proved connection proposed by Baade & Zwicky that neutron stars are connected to supernova remnants and the end stages of stellar life

Radio Astronomy: Pulsars II

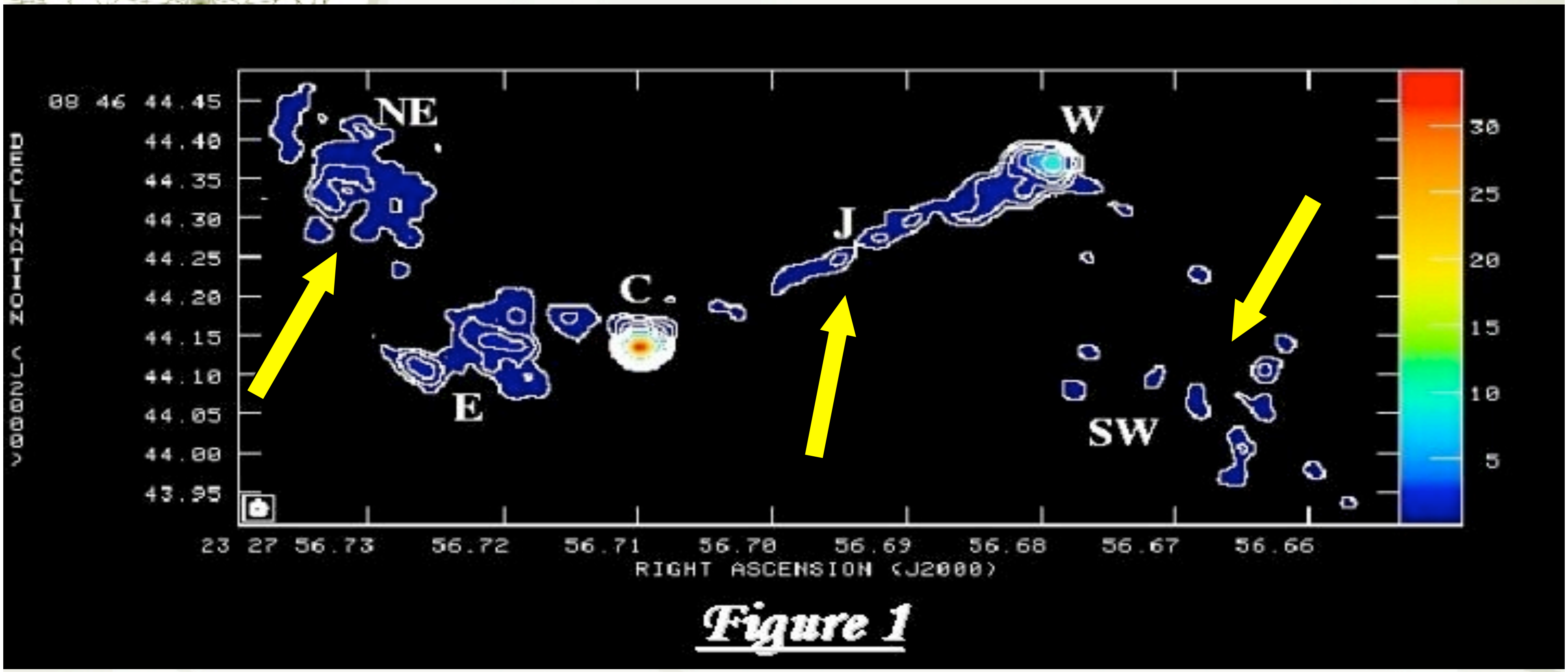


- First detection of an extrasolar planet EVER
- Discovered by Alex Wolszczan & Dale Frail through pulsar timing
- At least 3 bodies of Earth-like masses around PSR B1257+12

VLBI - Very Long Baseline Interferometry

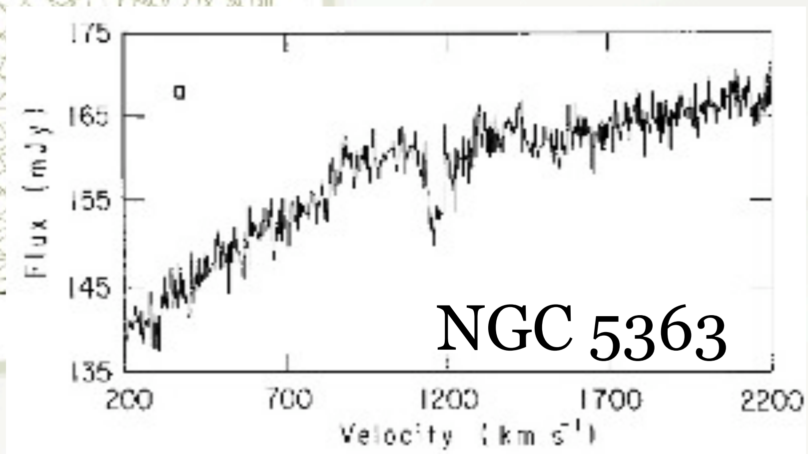
- Joined the VLBI network in the late 1990s
- NAIC commits 4% of AO's telescope time to VLBI
- Broad bandwidth video recorders record signals and are then replayed later in the same location

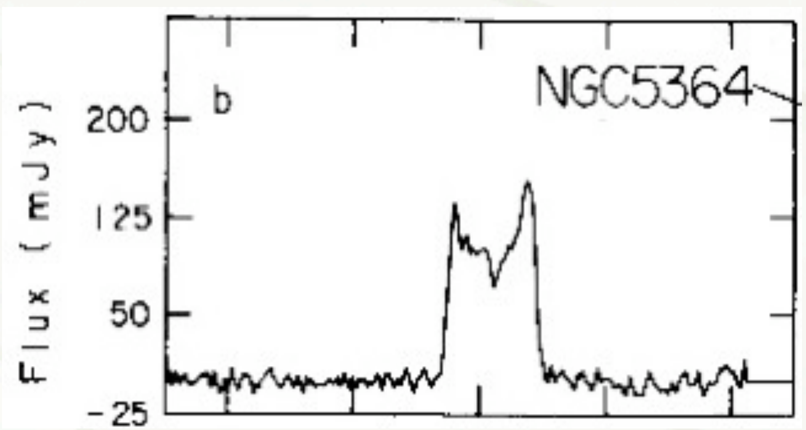
The Seyfert 2 - NGC 7674



Contour Plot courtesy of E. Momjian

Spectral Line Observations





Spectra from Haynes & Giovanelli, 1981

- Discrete radio emission
- 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
- Lines could be narrow or broad and have Gaussian shape or double-horned structure