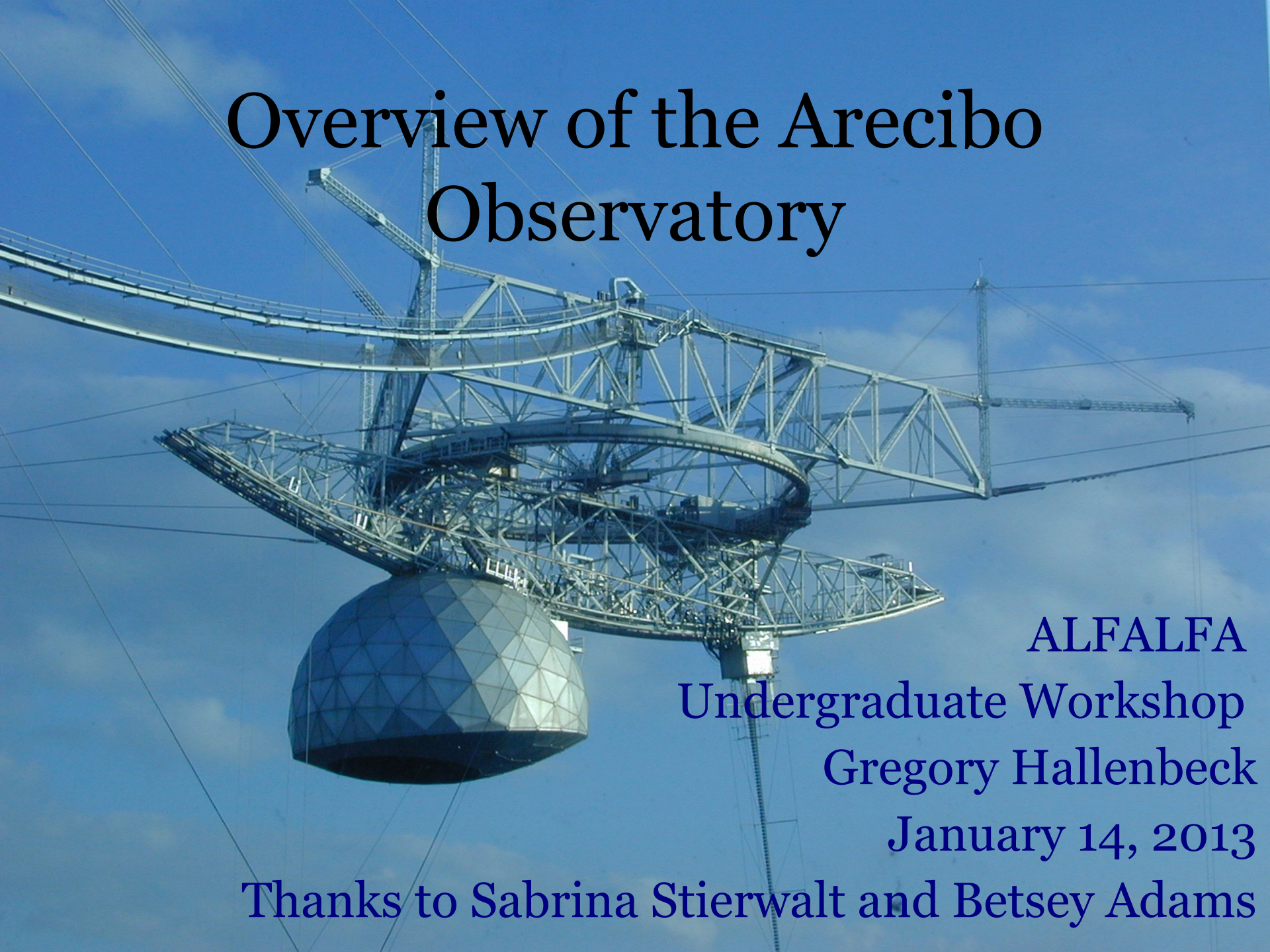


Overview of the Arecibo Observatory

ALFALFA
Undergraduate Workshop
Gregory Hallenbeck
January 14, 2013

Thanks to Sabrina Stierwalt and Betsey Adams

Welcome to the Arecibo Observatory!

Now turn off your:

-Cellphones

-Wireless Internet

-Bluetooth

-Wireless Mice

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 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

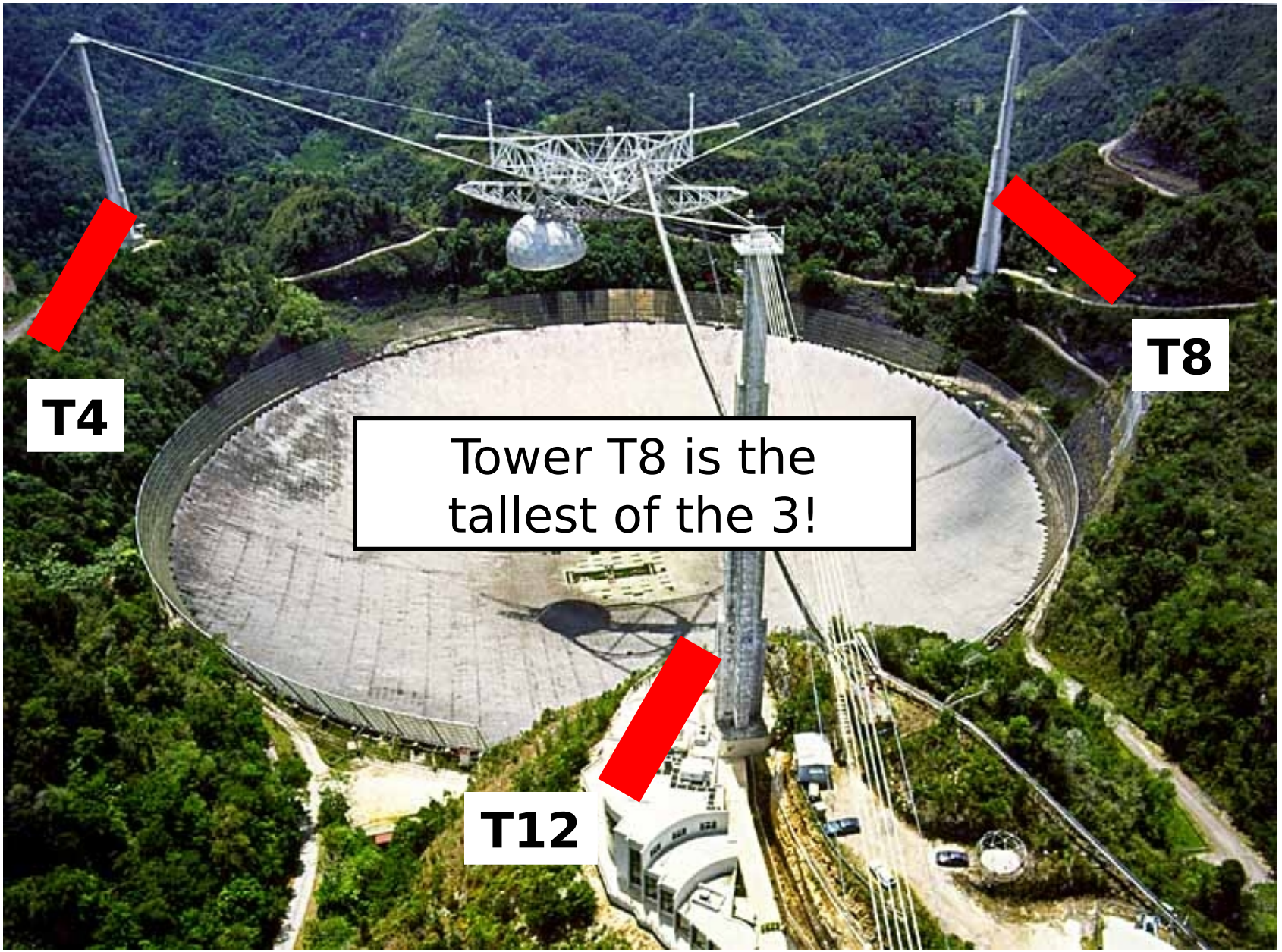
Location, Location, Location

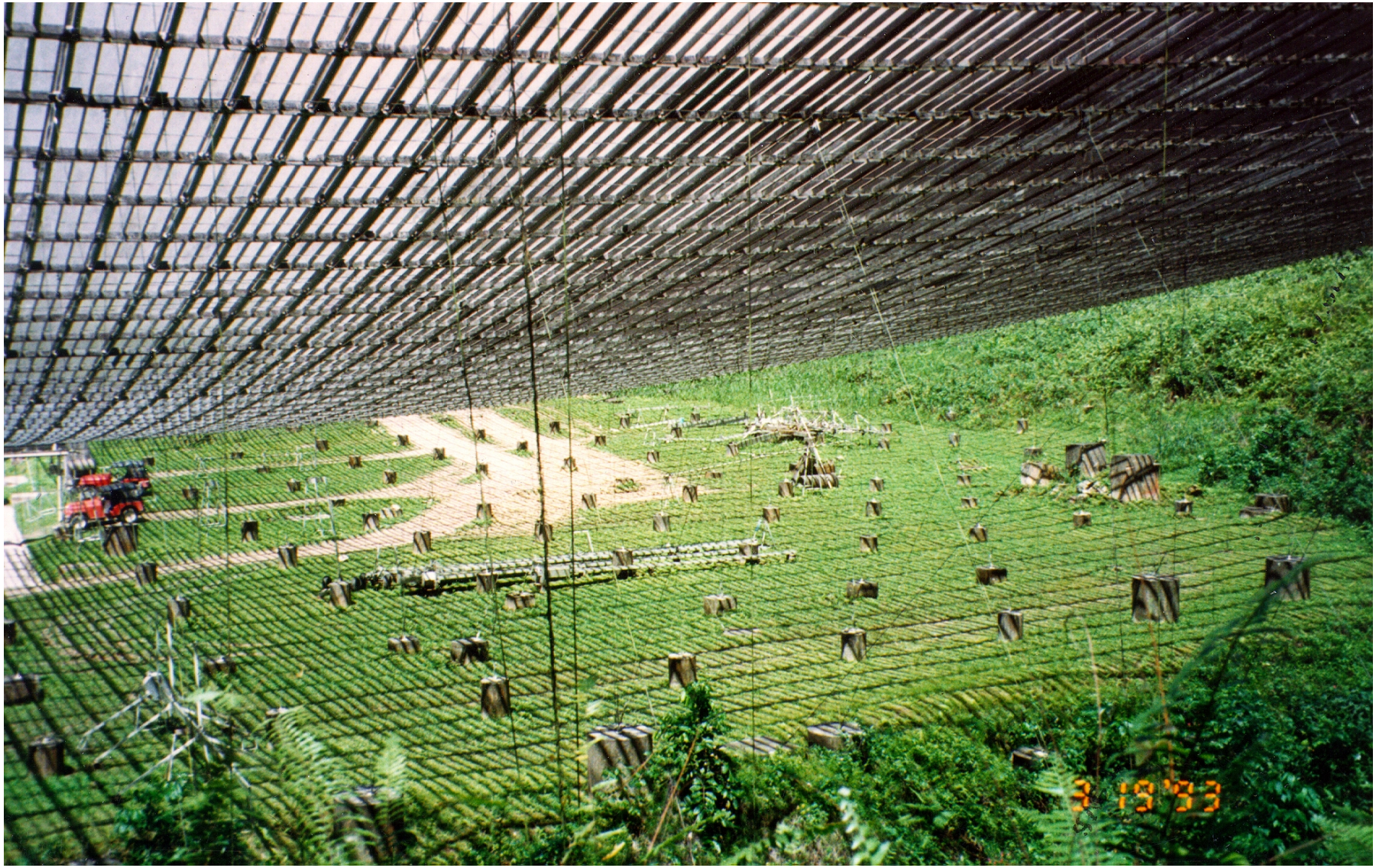
Built in a limestone sinkhole in Arecibo, Puerto Rico

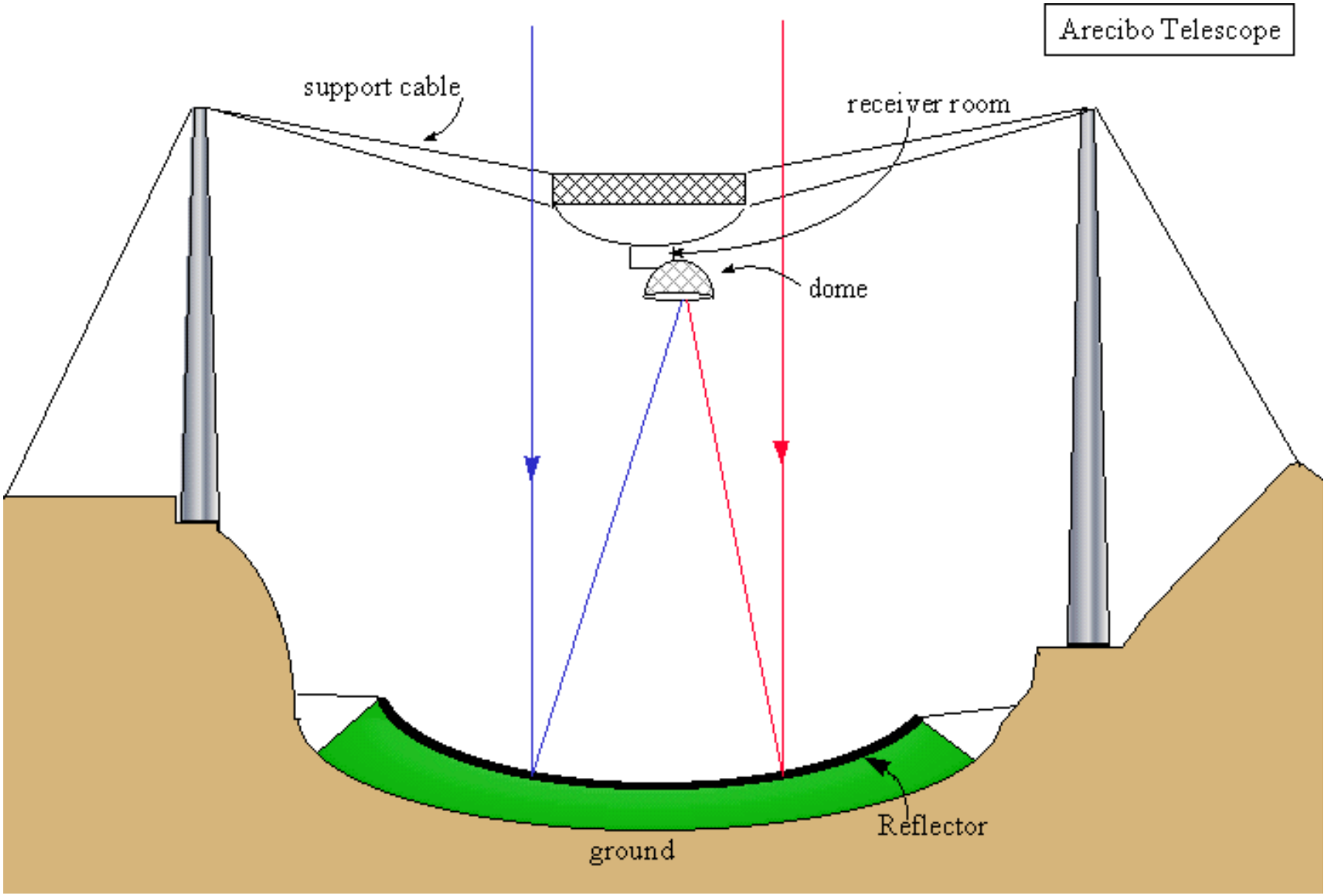
Constructed near the equator to enable radar studies of planets

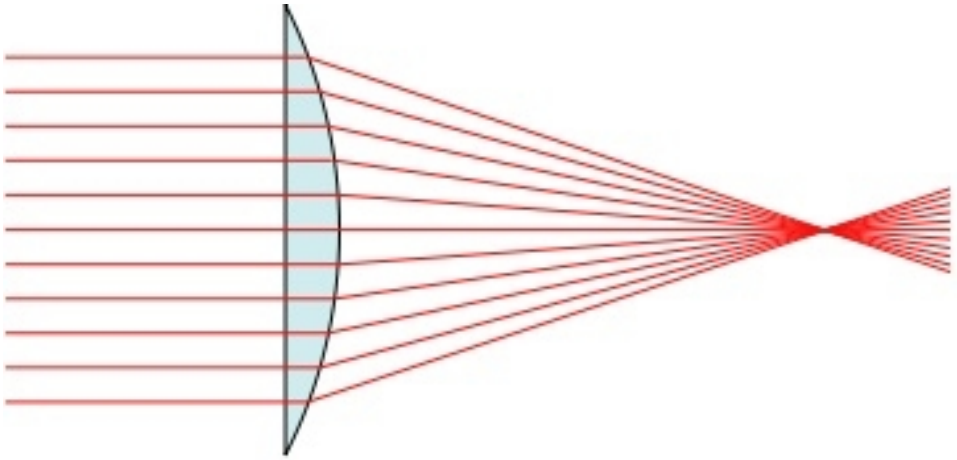
Latitude: 18° 20' 39'' N


© 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

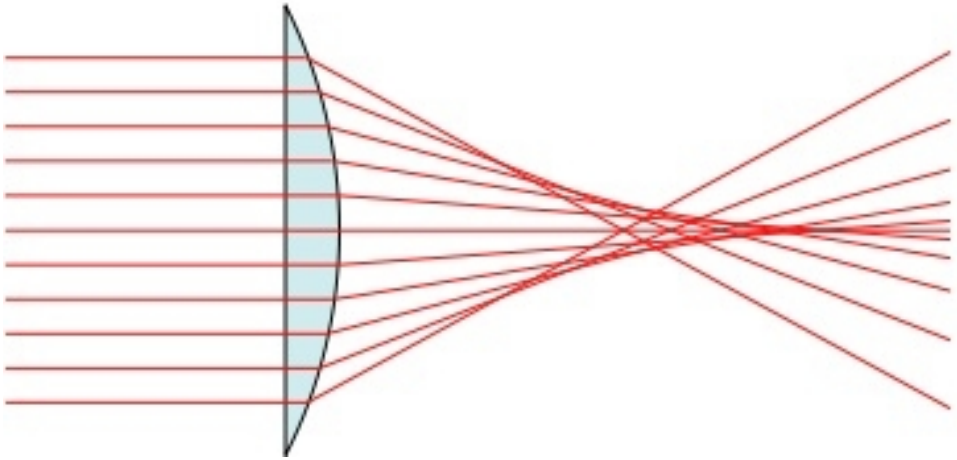

T4
T8
Tower T8 is the tallest of the 3!
T12


3 19 '93

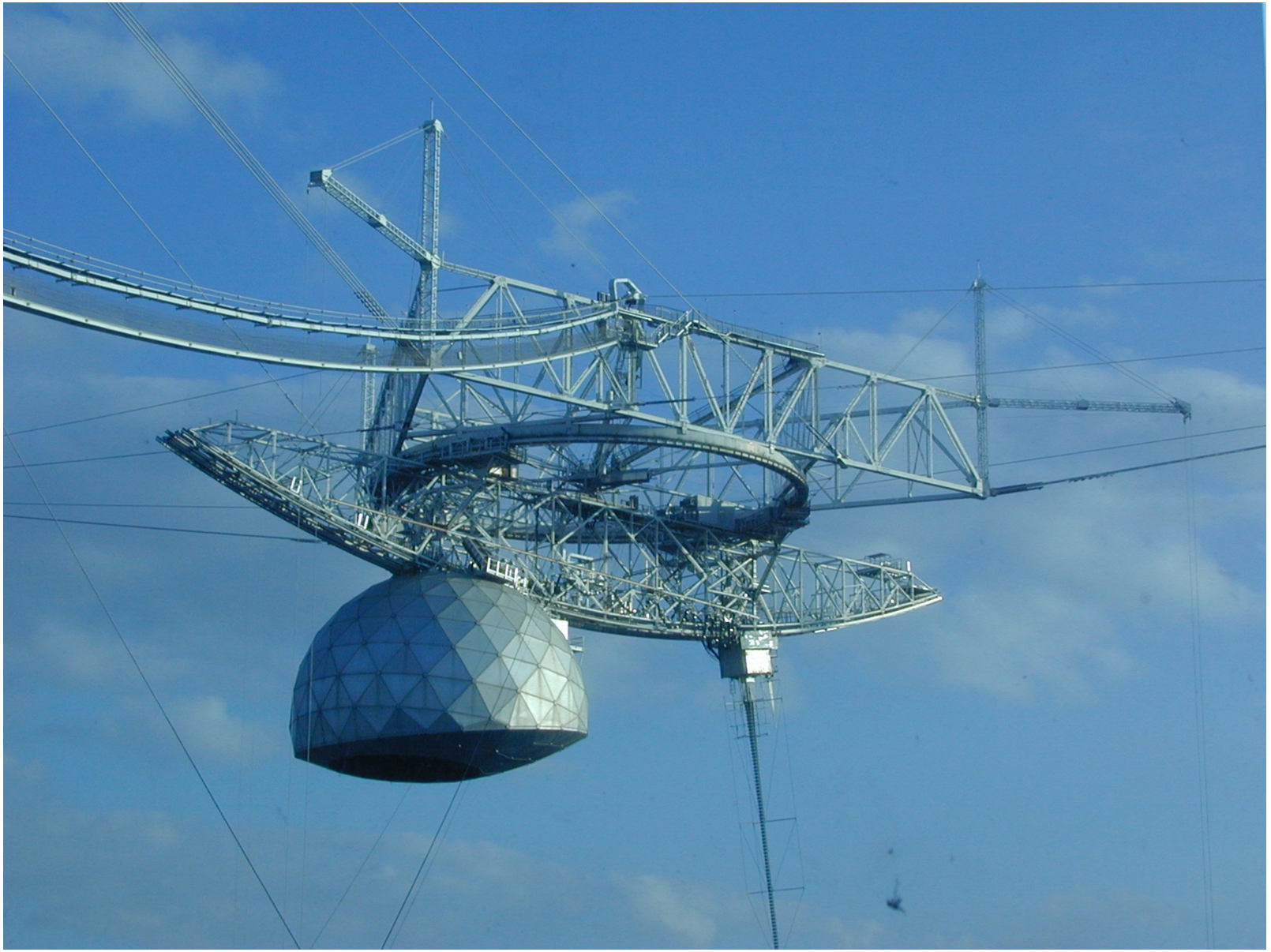

Arecibo Telescope
support cable
receiver room
dome
Reflector
ground



Parabolic Reflector



Spherical Reflector



430 MHz Antenna

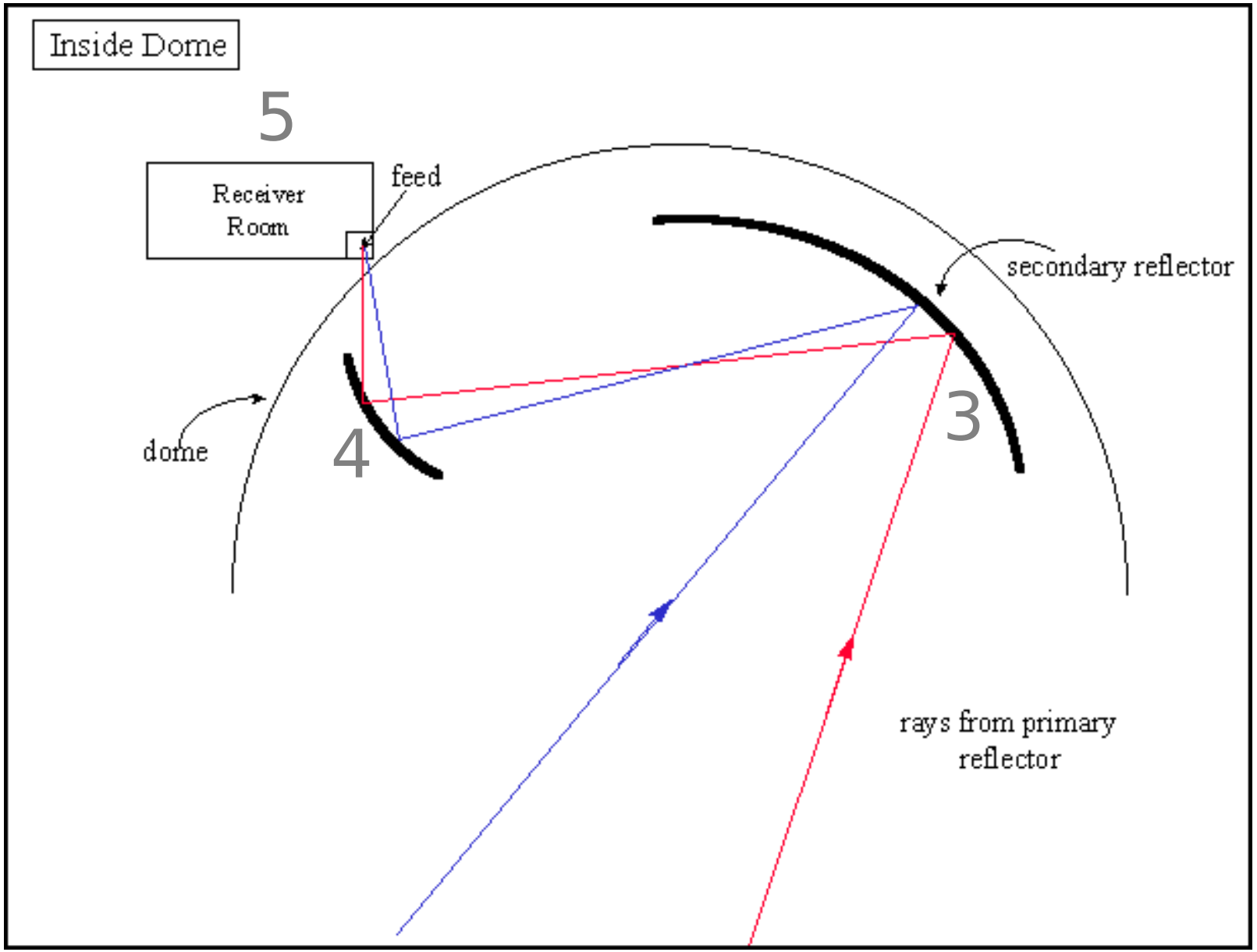
"Very long line feed"

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 dome 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

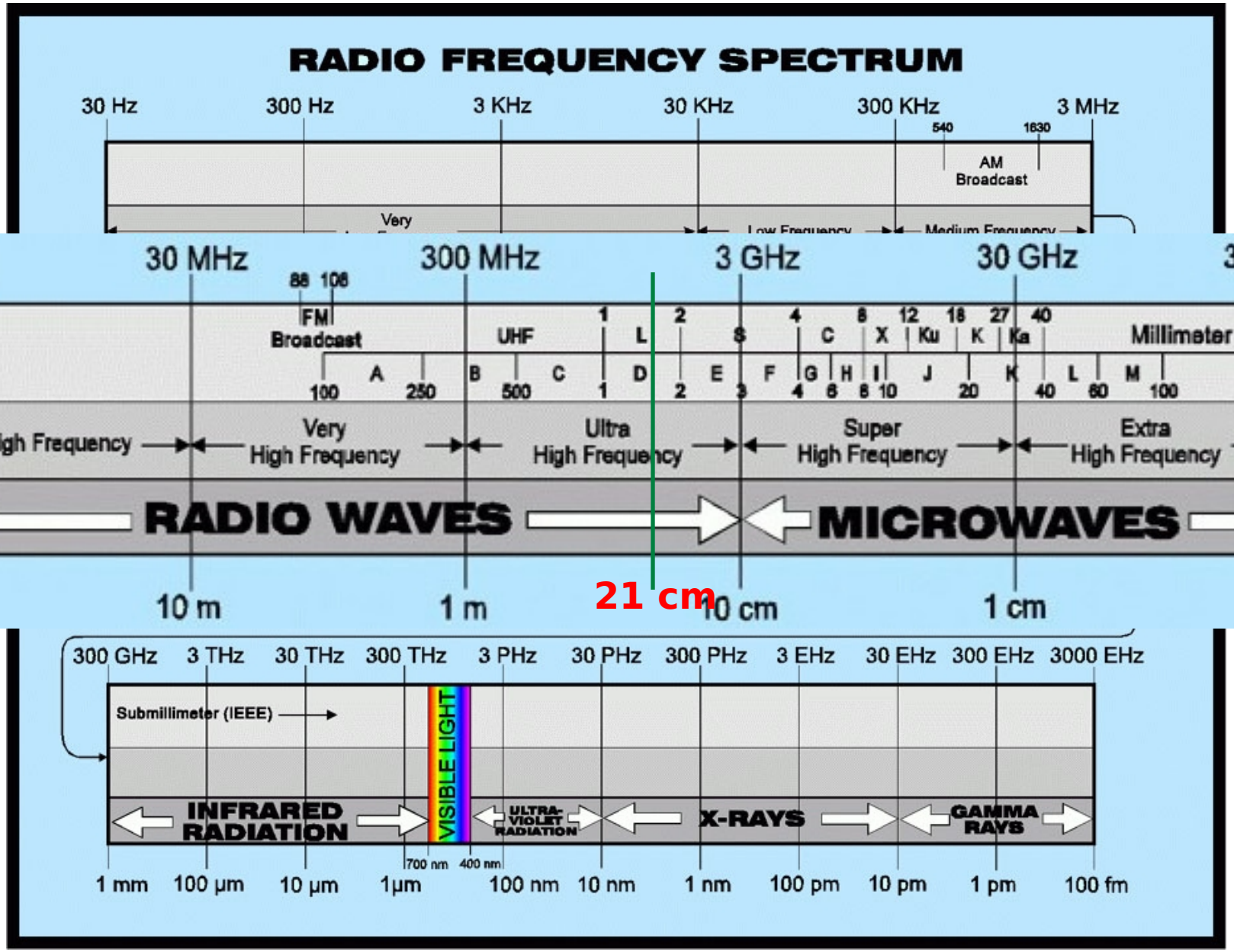
With Gregorian optics, an array of receivers covering the whole 1-10 GHz range can be easily moved onto the single focal point where the incoming signal is focused.

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
Very
Low Frequency
Medium Frequency
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz
88 108
FM Broadcast
UHF
L
S
C
X
Ku
K
Ka
Millimeter
IEE
MIL
A
B
C
D
E
F
G
H
I
J
K
L
M
100
250
500
1
2
3
4
6
8
10
20
40
60
100
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

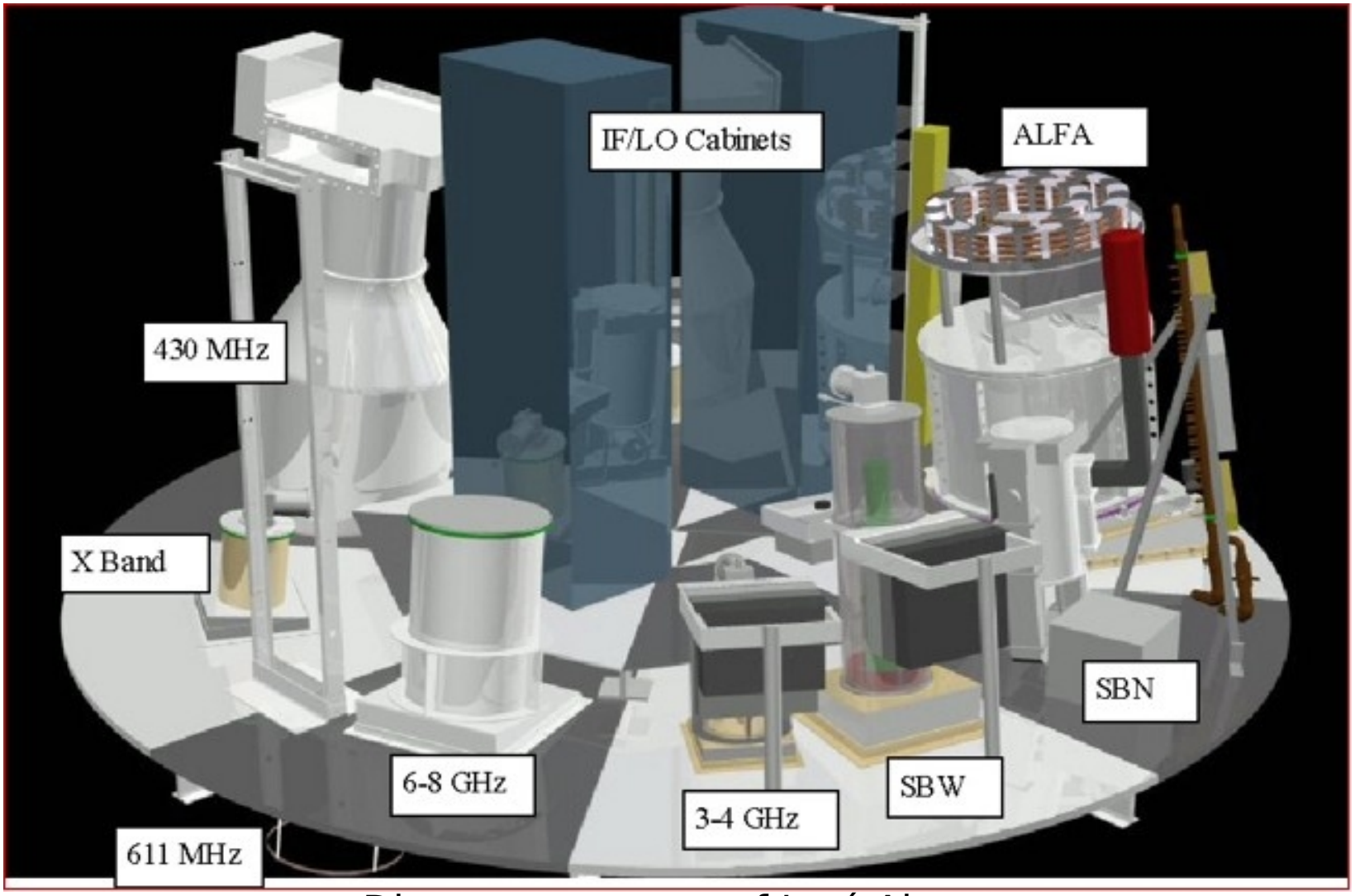


Diagram courtesy of José Alonso

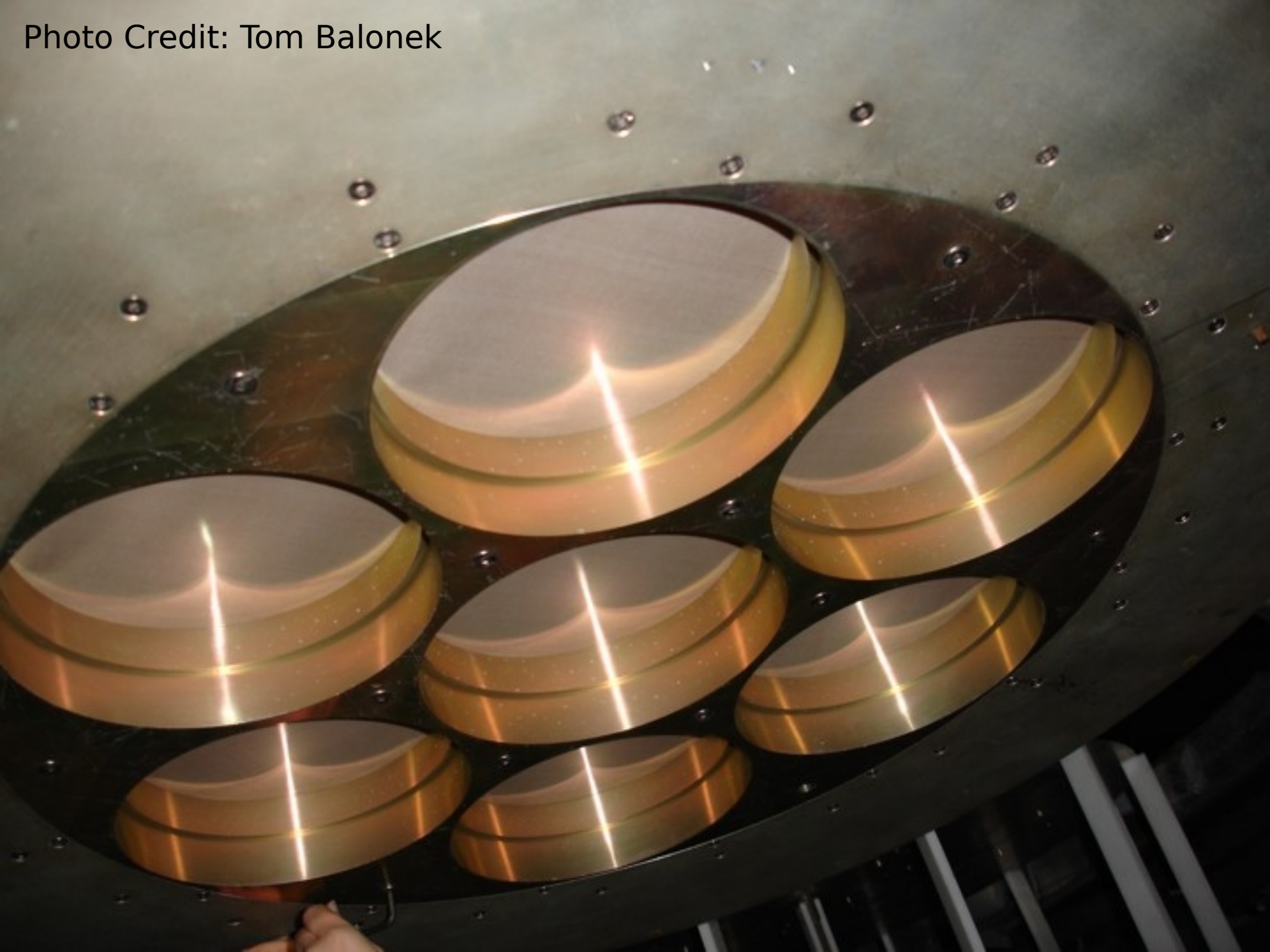


Photo Credit: Tom Balonek

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

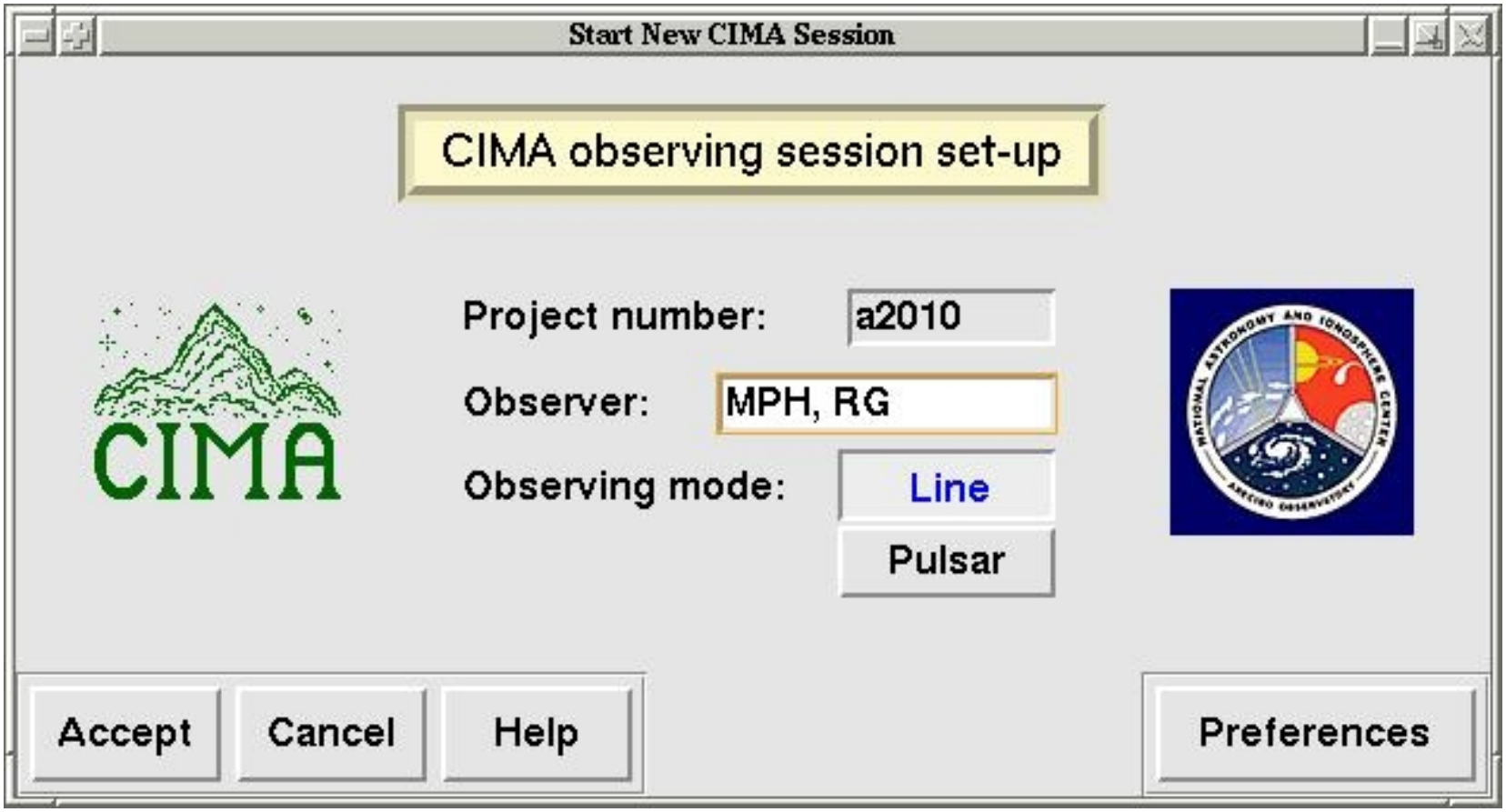
The components of the telescope the signal enters after having been down-converted

Several different backends are available at Arecibo with different frequency spans

For ALFALFA we use the 4 WAPPs (Wideband Arecibo Pulsar Processor)

Tonight, we will use the Interim Correlator for the L-band wide observations

CIMA



Control Interface Module for Arecibo: 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

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)

Pointing Limits of Arecibo

Can move dome to zenith angle position of 19.7°

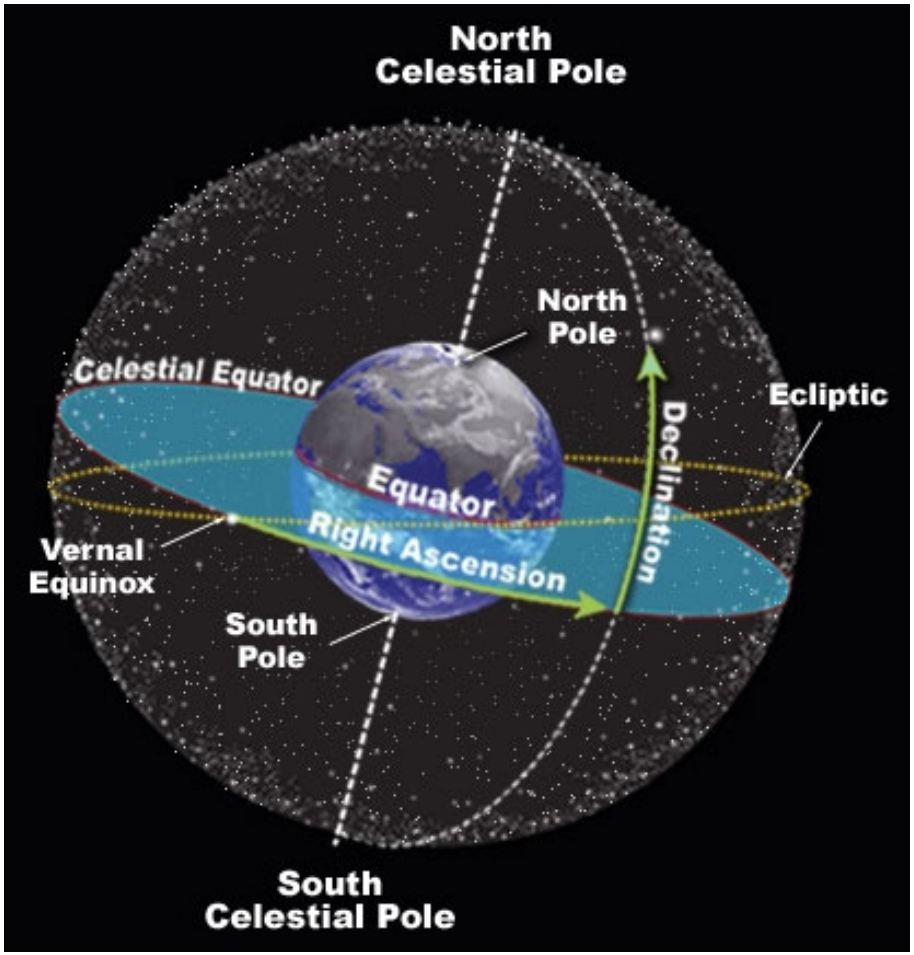
But only to ~18° with good performance

Can move dome to within 1.06° of zero zenith angle

1.1° recommended

Tracking limit

Equatorial Coordinates



Right Ascension

Measured in hours (0 to 24)

Zero-point toward constellation Pisces (increases to the east)

Similar to longitude

Declination

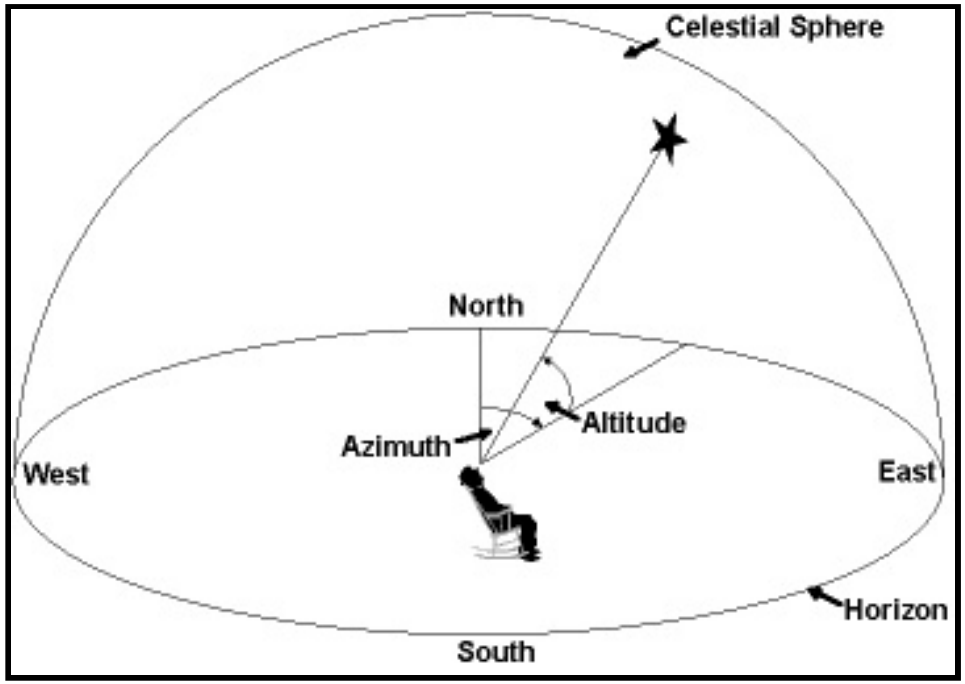
Measured in degrees

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

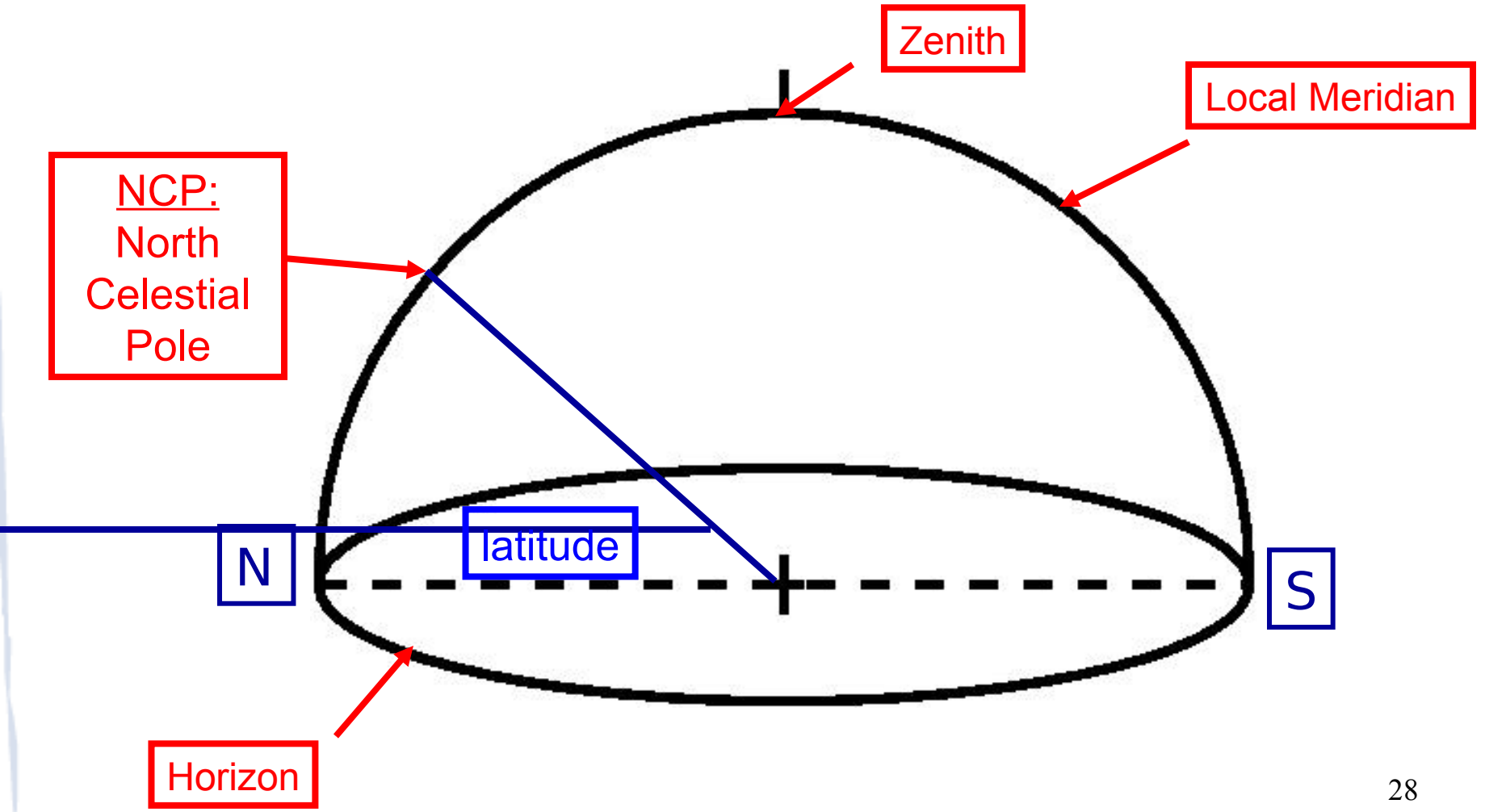
Measured in degrees

Tells how far below zenith a source is located

They depend on the observer's location!

Local Perspective

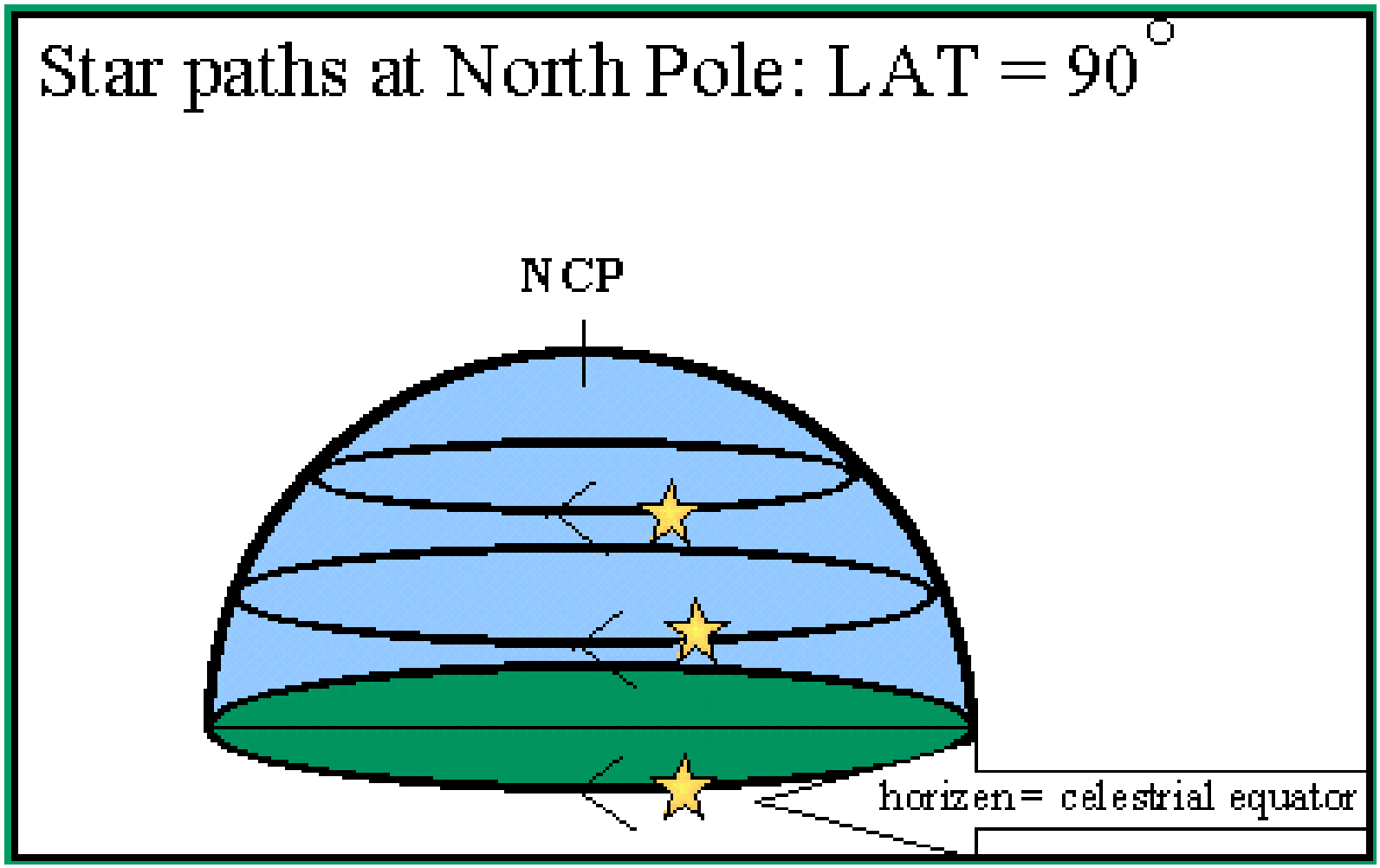
The altitude of the North Celestial pole (as measured up from the horizon) is equal to the latitude of the observer.



Local Perspective: North Pole

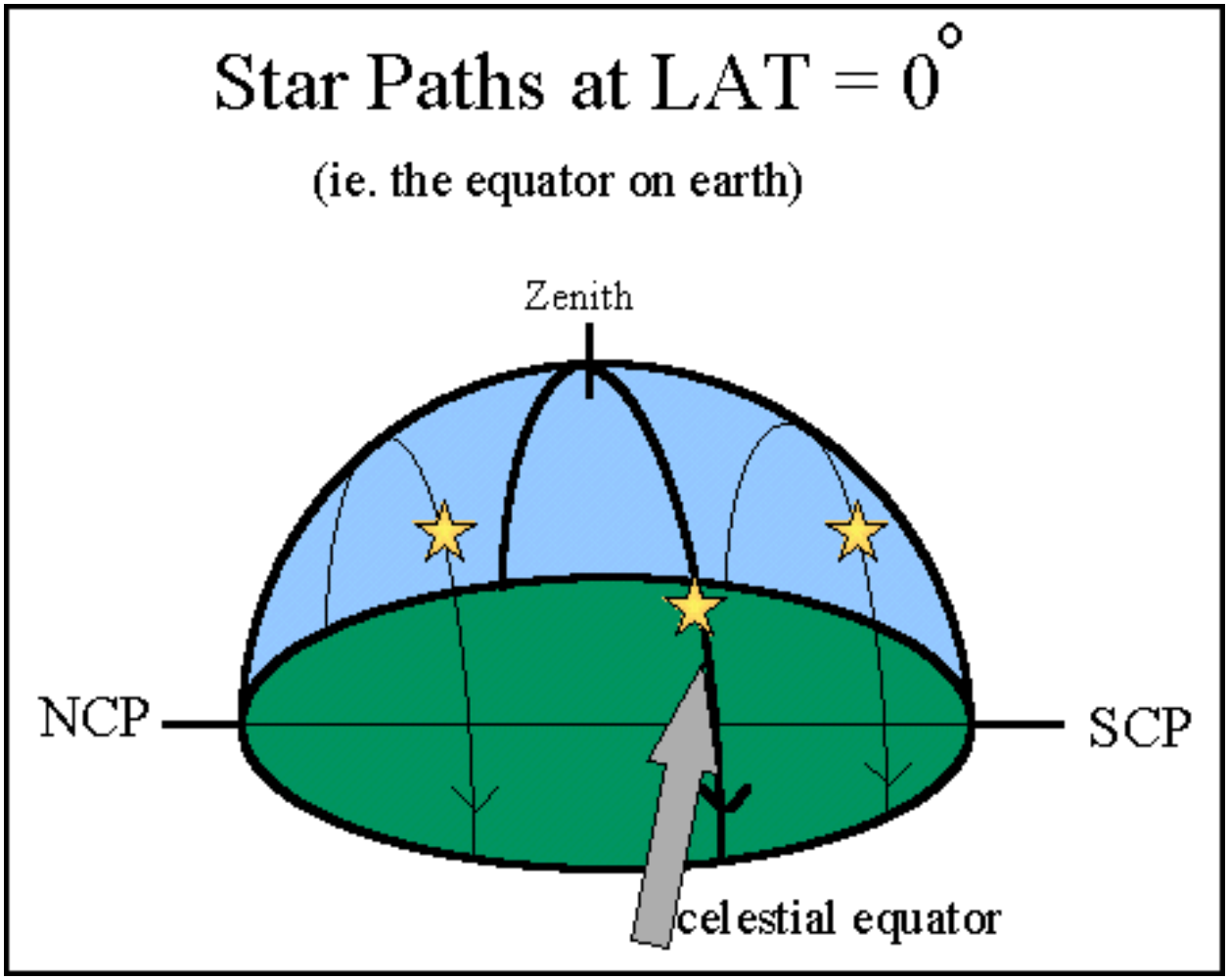
At the North or South Pole:

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

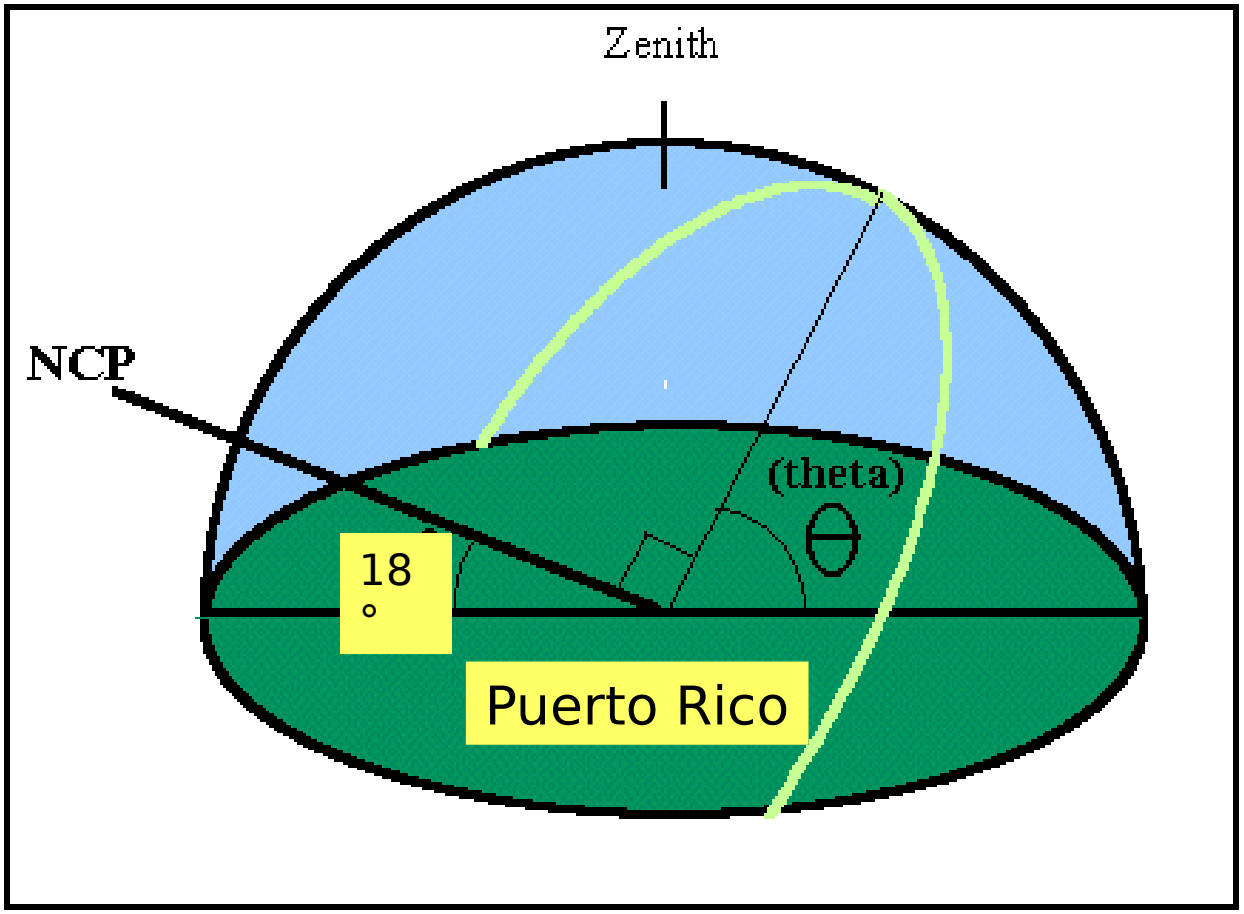


Local Perspective: Equator

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



Arecibo, Puerto Rico, lat = 18° North



The altitude of the intersection of the Celestial Equator with the meridian is θ = 180° - 18° - 90° = 72°.

The Sun's Apparent Path

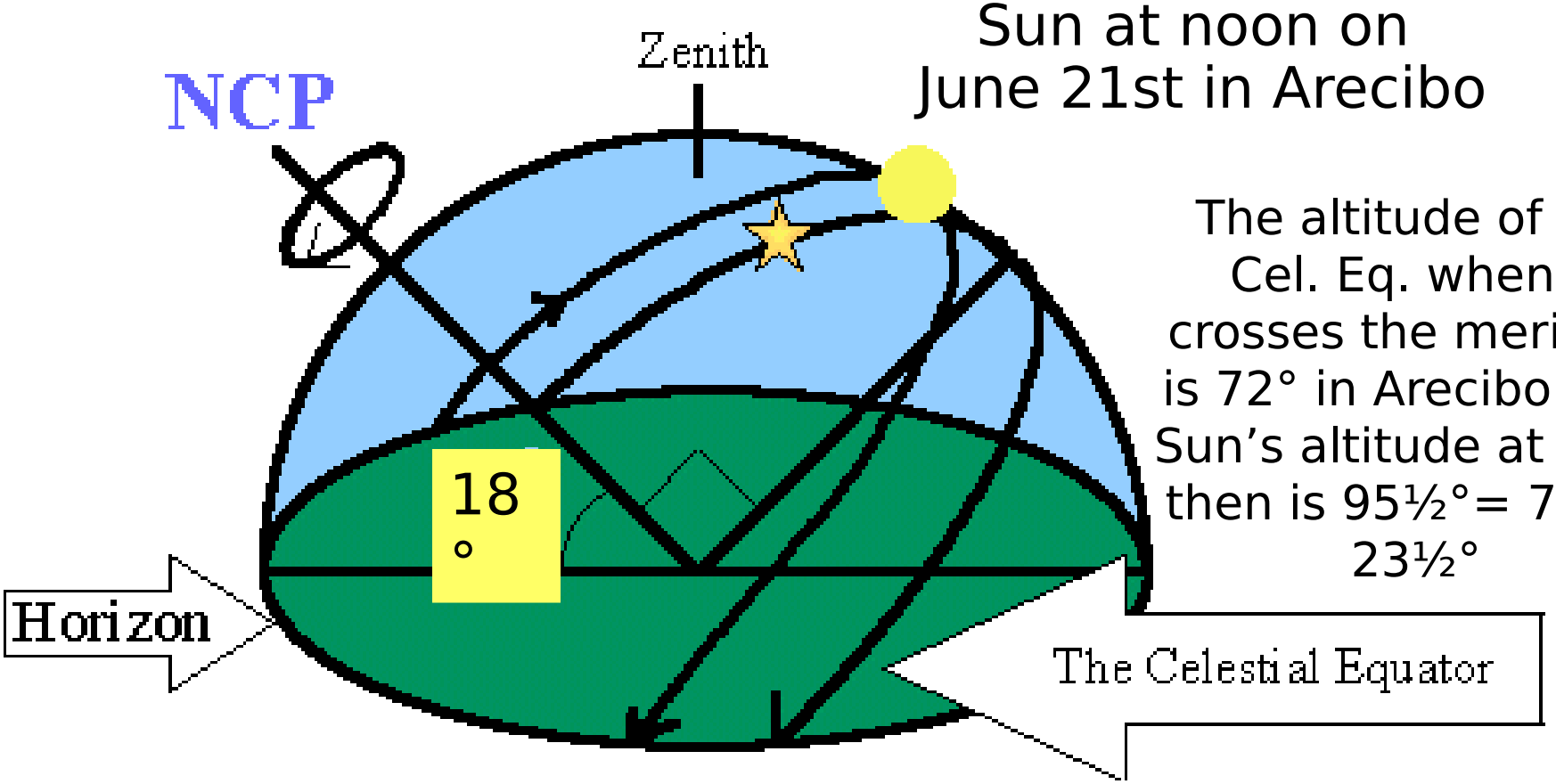
- The Sun's apparent position among the stars changes throughout the year with an eastward annual drift.
    - Sun, Moon and planets move with respect to stars.
    - Right ascension & declination change
- Path across the sky on any given day depends on declination
    - Noon-time altitude varies
    - Length of time to cross sky 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 furthest 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 furthest 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

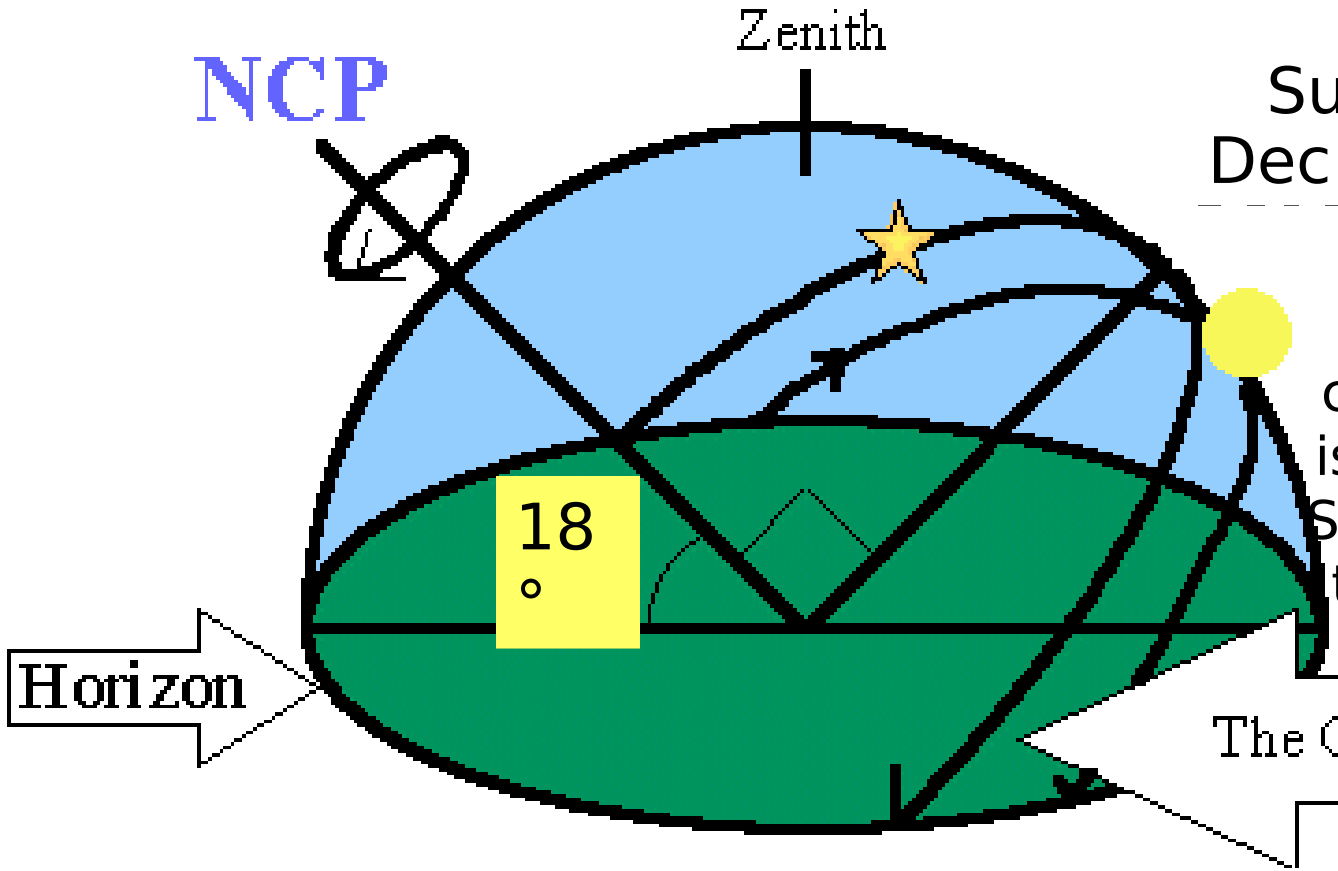


Sun at noon on June 21st in Arecibo

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



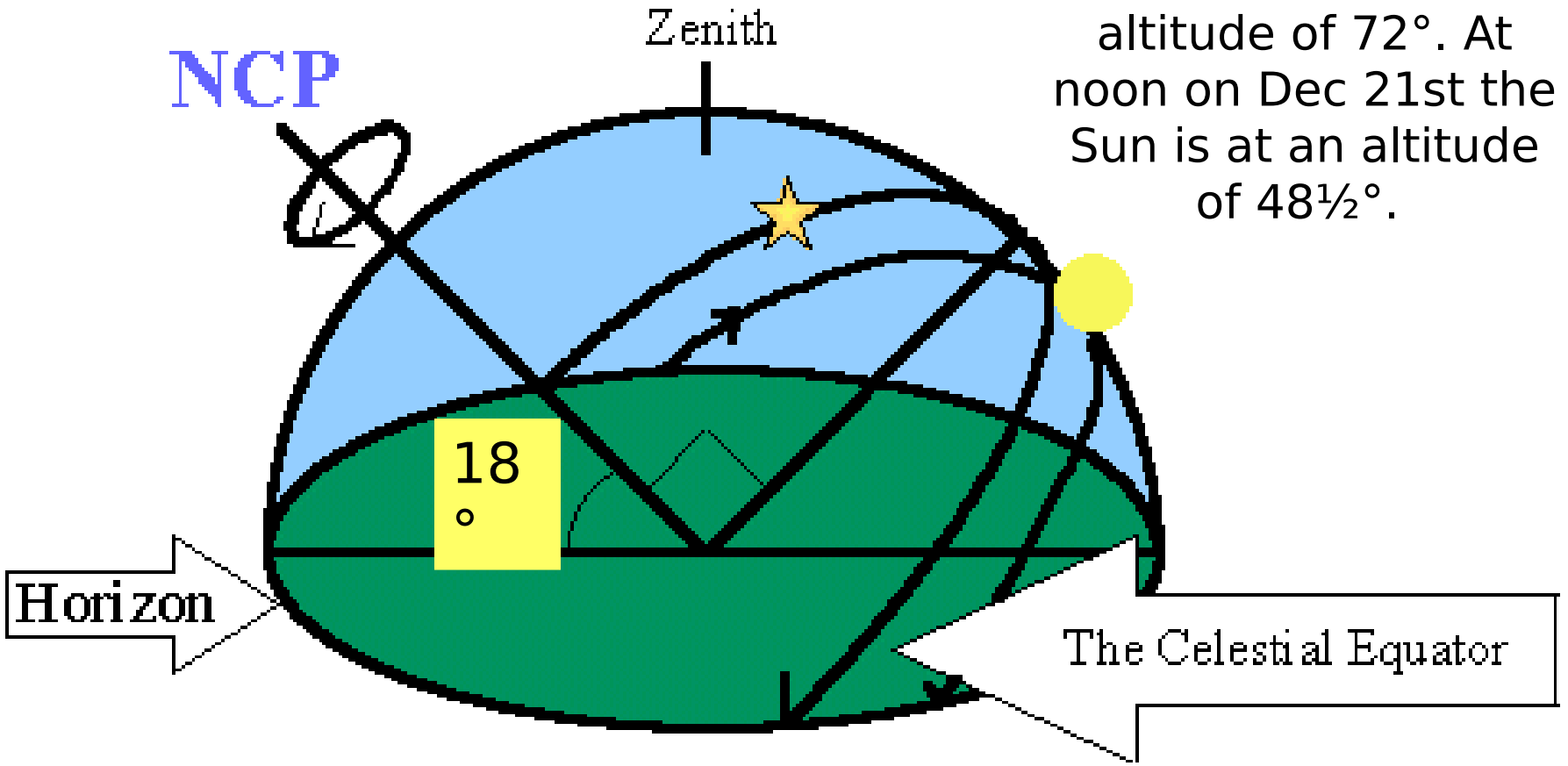
Sun at noon on Dec 21st in Arecibo

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 16th

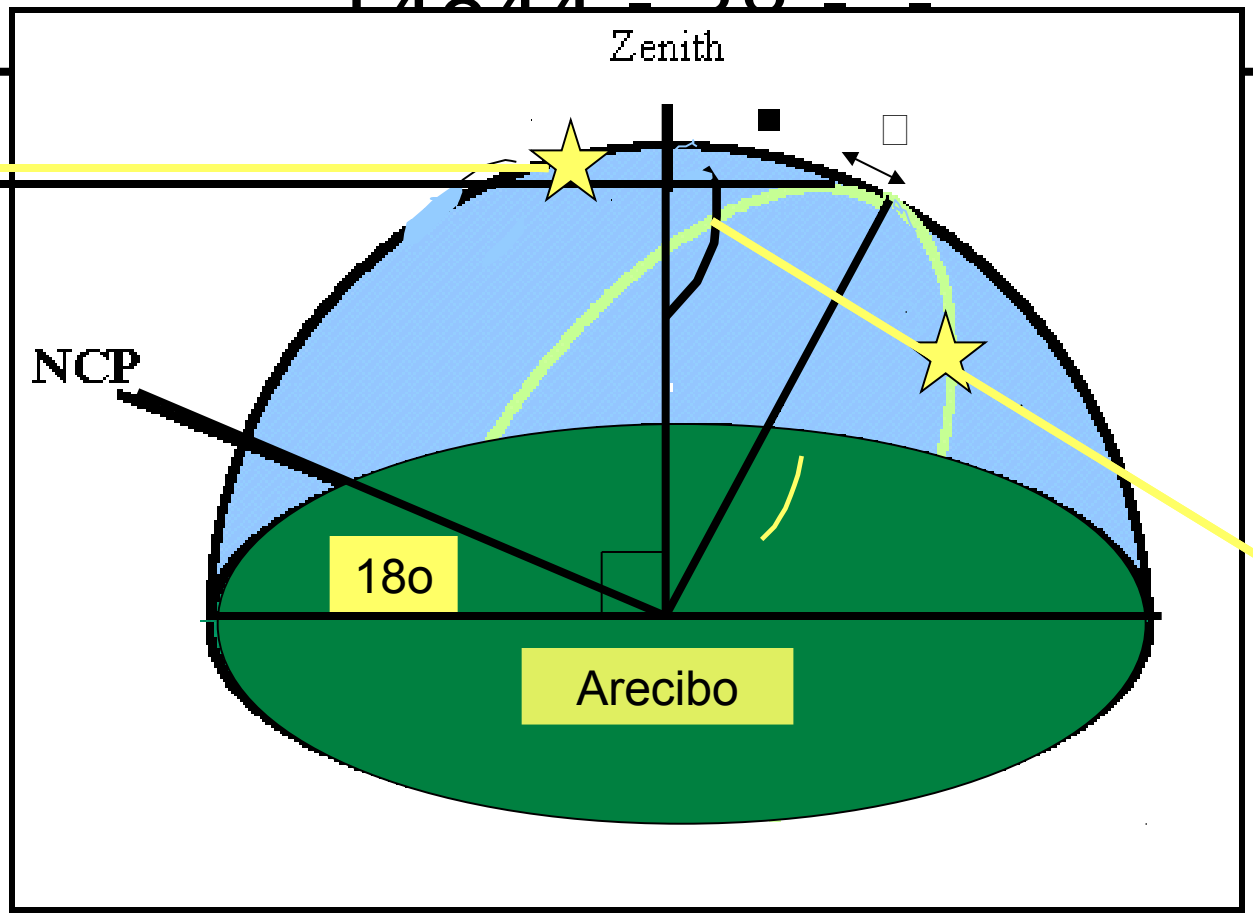
Sun's declination somewhere between its declinations at the vernal equinox and winter solstice, but closer its path on Dec 21st.

At noon on March 20 altitude of 72°. At noon on Dec 21st the Sun is at an altitude of 48½°.



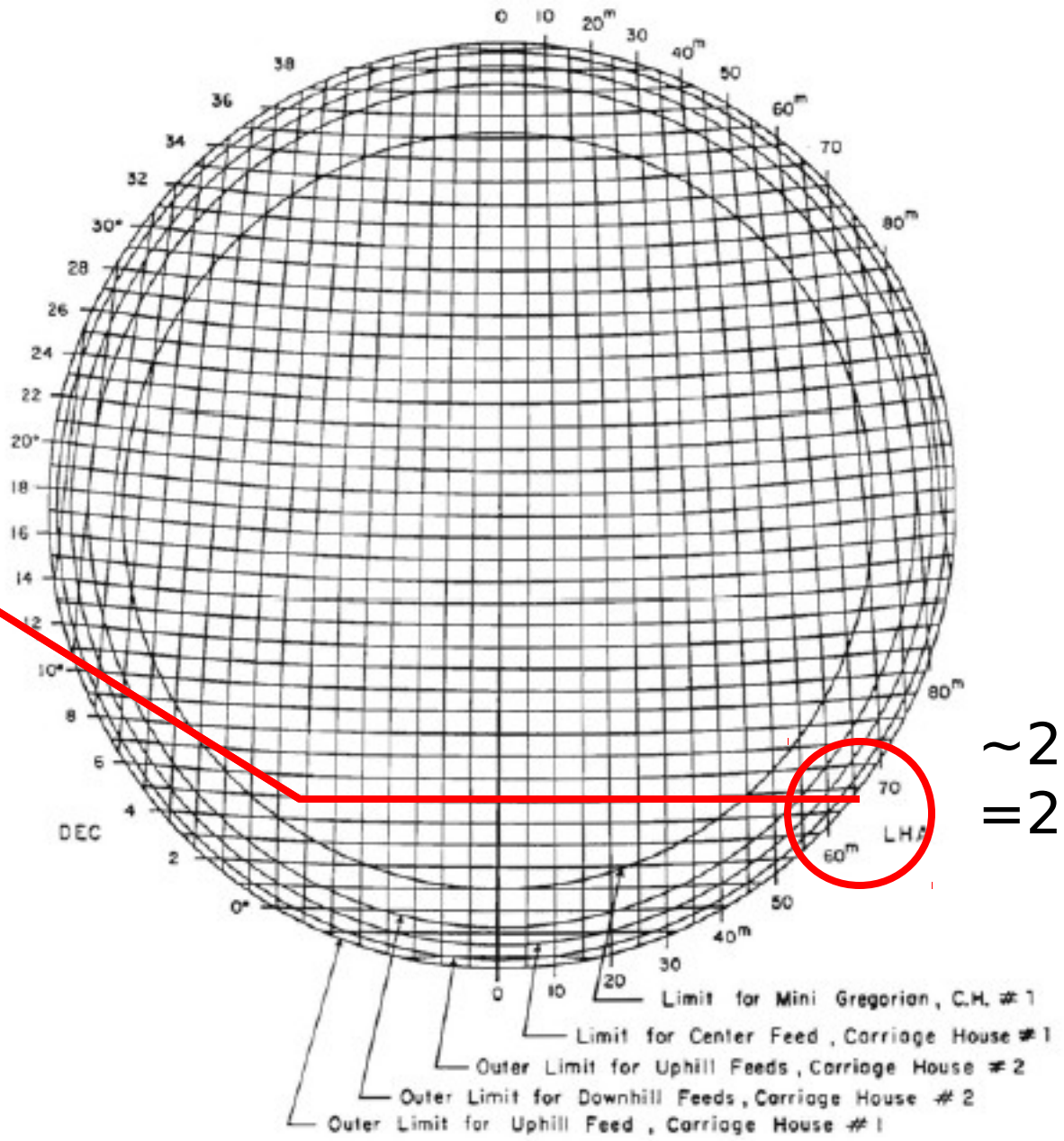
Zenith Angle of a Drift 136p2 (□ = +33o05□ 36□□)

ZA = ▪ -18o20▪58▪▪ =



Azimuth = 180o (source is N of zenith)

How long is a source "up"?



~2*65min
=2 hr 10 min

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, 2013

TRANSMITTERS

2380 | 430 | HF

Opt | 47 | System Checks

VISITORS
(or PIs)

A. R. Taylor
T. Pennucci
S. Ransom
T. Robishaw
A. Wolszczan
T. McIntyre
P. Henning
P. Demorest
D. Nice
M. Haynes
R. Giovanelli
P. Lazarus
L. Olmi
L. Goncharenko
J. Deneva
J. Davies
R. Minchin

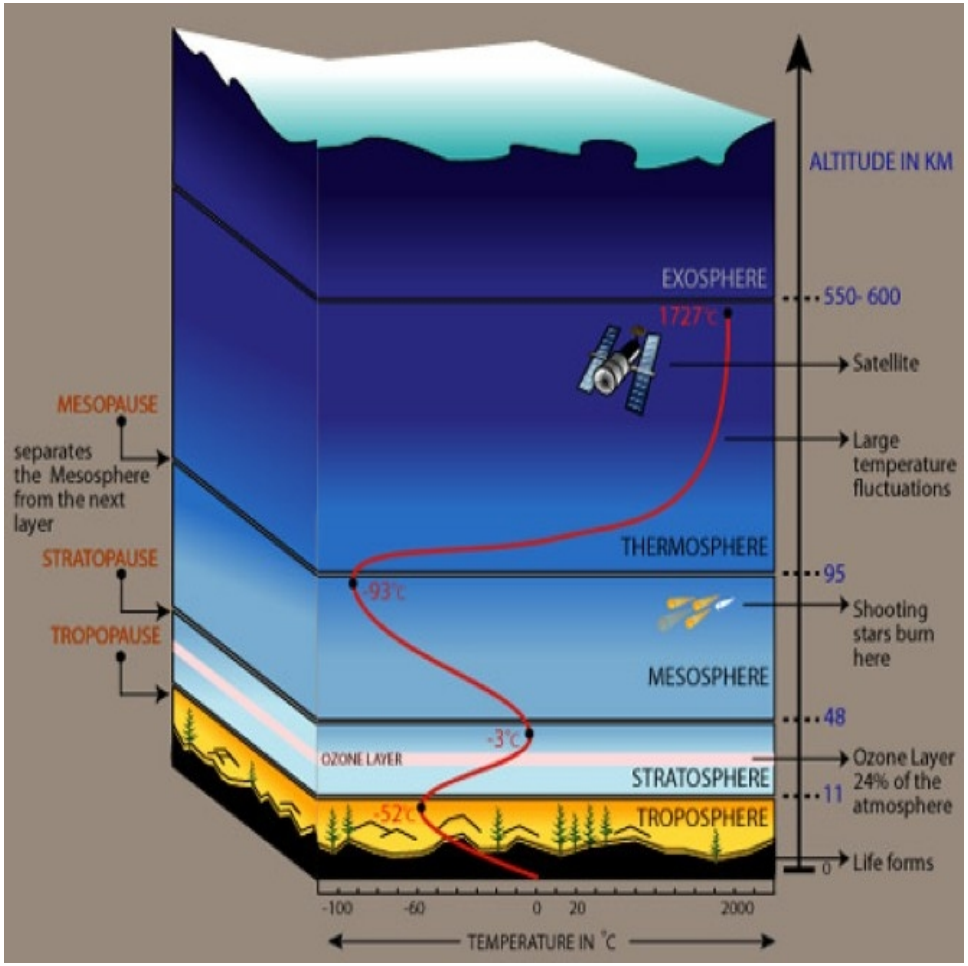
COMMENSAL PROJECTS:
Any ALFA Rx: A2774
A2754: P2030, A2757
A2048: A2059
A2772: A2763

[0]
VER 2.0 - 03Jan13

AST	1 TUE	2 WED	3 THU	4 FRI	5 SAT	6 SUN	7 MON	8 TUE	9 WED	10 THU	11 FRI	12 SAT	13 SUN	14 MON	15 TUE	LST
2	No Op	A2754	A2772 art cs	A2772 art cs	A2772 art cs	A2772 art cs	A2772 art cs	A2772 art cs	T1193 lg sg/ms	T1193 lg sg/ms	T1193 lg sg/ms	T1193 lg sg/ms	A2707 mh/rg	A2707 mh/rg	A2707 mh/rg	
4		X102 pp	Z2 GALFA	Z2 GALFA	Z2 GALFA	Z2 GALFA	Z2 GALFA	Z2 GALFA				Strat Warm (SB)	1/3	2/3	3/3	12
6			X111	X111	X111 to	P1693 jd	X111	RAstr								
8		MAINT f/ut	MAINT f/ut elect	MAINT f/ut elect	P1693 jd		P2780 pd/dn	MAINT elect (+DB)				MAINT elect (-DB)	A9999 aw	P1693 jd	eVLBI Test	
10						X111 to	1/9	T1193 lg sg/ms				P2780 pd/dn	P2780 pd/dn	P2723	MAINT f/ut elect	
12		P2723 tp/sr	AA Paint	AA Paint	A2760 P2723 tp/sr	P2722 pl (d60)							(c)	A2760 lo		19
14	Nw-Yr HOL	X110 elect			X111	X111						(b)	T1193 lg sg/ms	X111		
16			MAINT	MAINT			NANO Grav (a)					T1193 lg sg/ms		A2707 mh/rg	T1193 lg sg/ms	0
18	X107	X107	X111	X111	P1693	P1693								T1193 lg sg/ms		
20	A2048 jd 33PP	A2048 jd 33PP	A2048 jd	A2048 BM352 HSA (A9)	A2048 jd	A2048 jd	A2048									
22	A2764 tr	A2764 tr	A2764 tr		A2764 tr	A2764 tr	A2764 tr	Strat Warm (DB)	Strat Warm (DB)	Strat Warm (DB)	Strat Warm (DB)	Strat Warm (SB)	Strat Warm (SB)	Strat Warm (SB)	Strat Warm (SB)	
24	A2754	A2754	A2754	X111	A2754	A2754	A2754									

For More Information…

Areas of Study at Arecibo



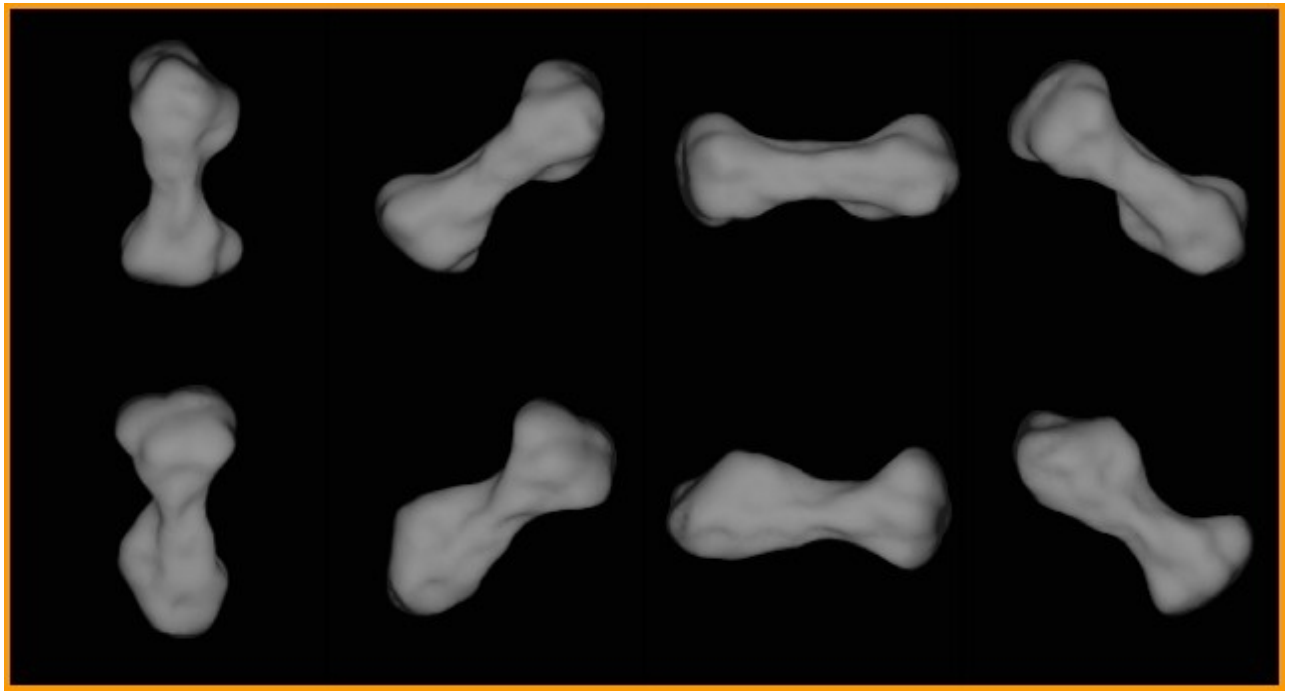
Atmospheric Science (20%)

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

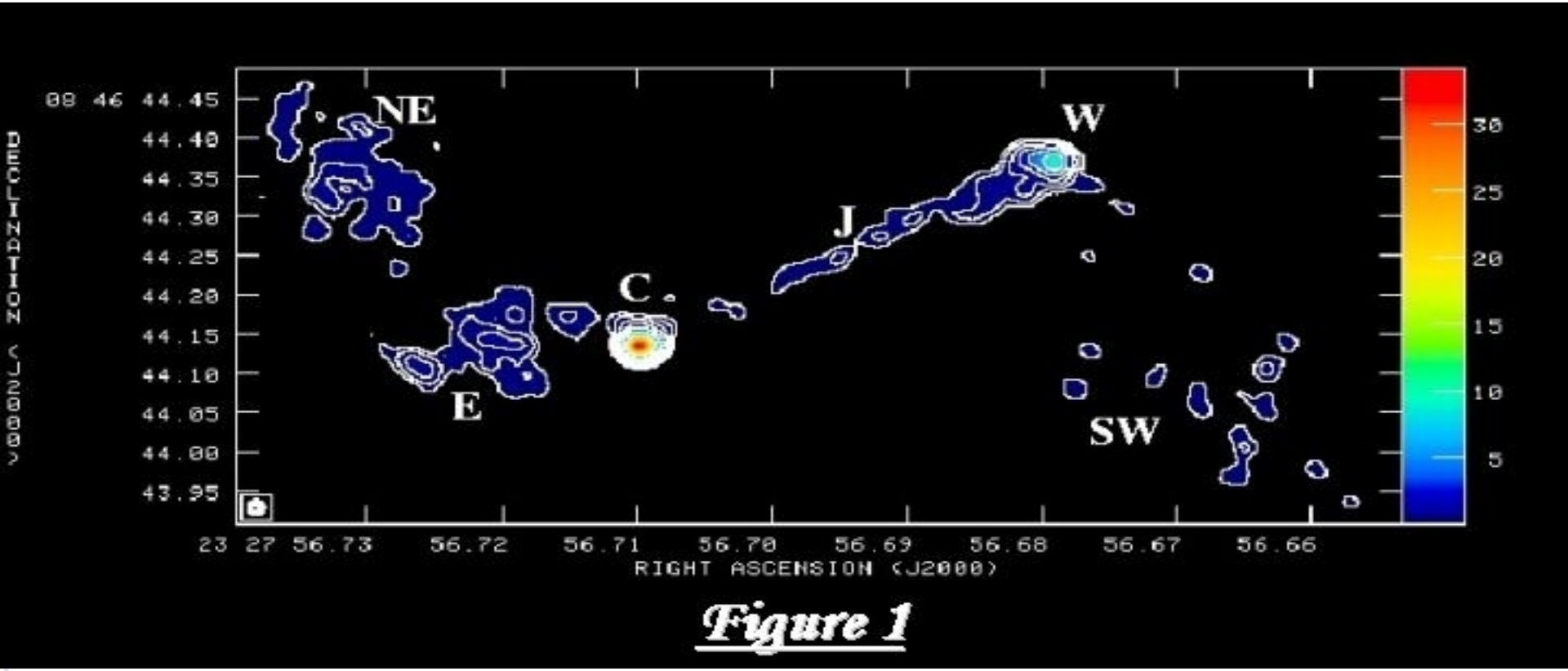
VLBI - Very Long Baseline Interferometry

Joined the VLBI network in the late 1990s

NAIC commits 4% of AO's telescope time to VLBI

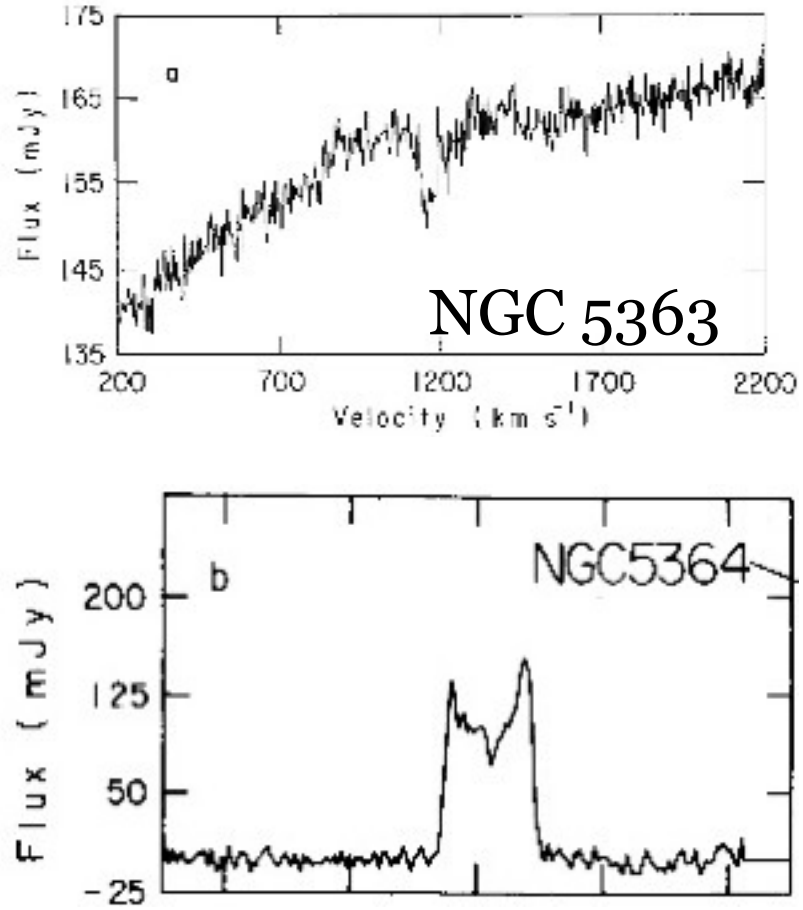
Broad bandwidth video recorders record signals and are then replayed later in the same location

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