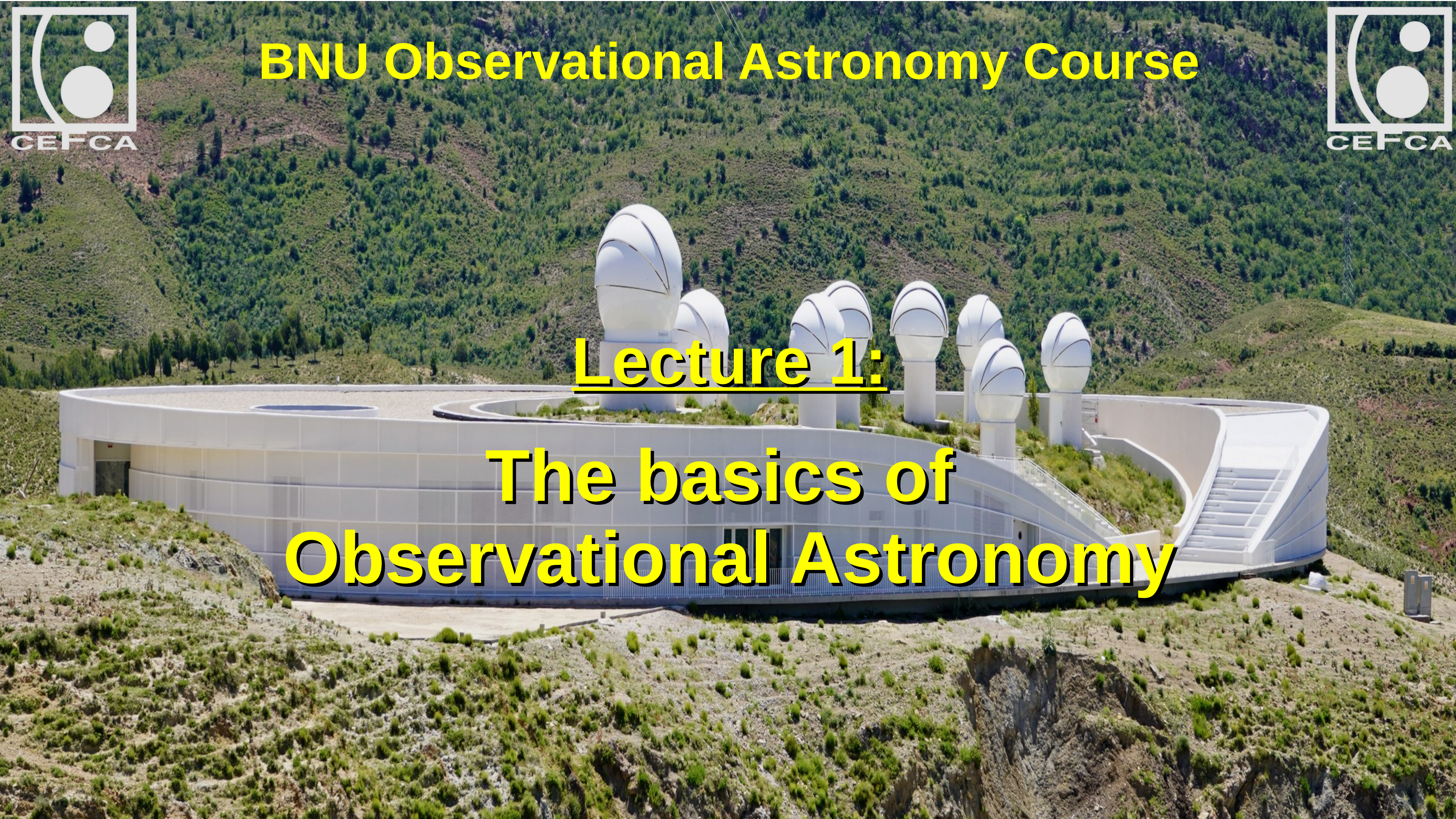


BNU Observational Astronomy Course

Lecture 1:

The basics of Observational Astronomy

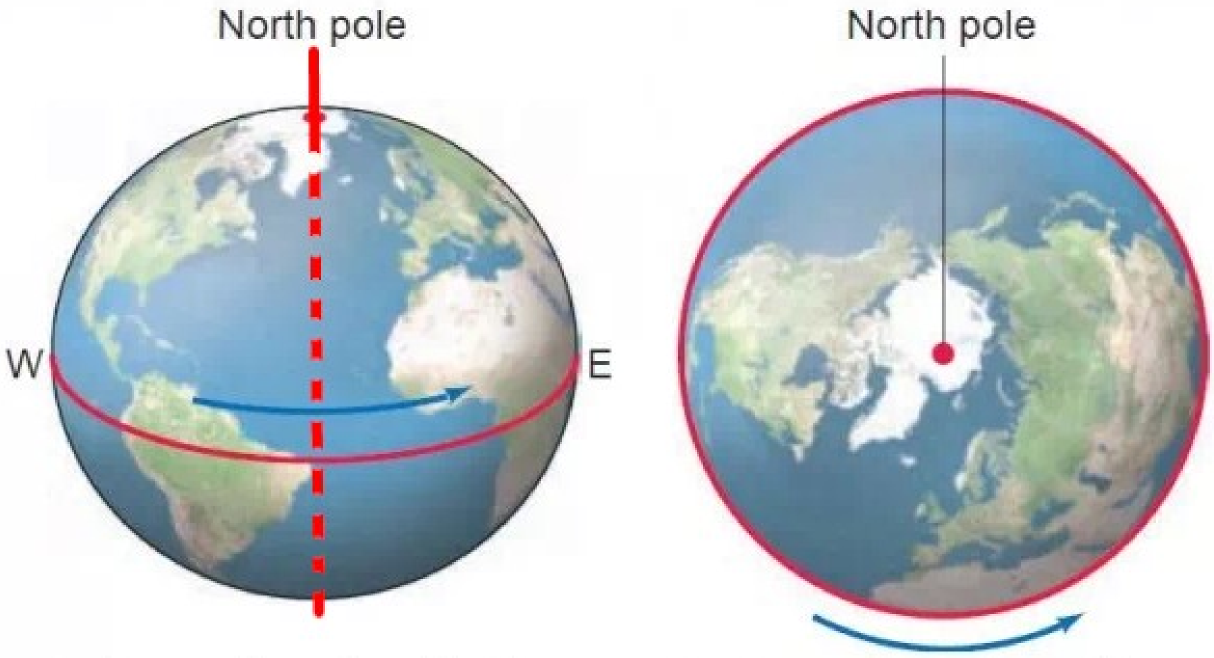
CONTENTS

- **PART 1:** The celestial sphere, coordinates and planning observations
- **PART 2:** Telescopes and Mounts
- **PART 3:** The GT80

The celestial sphere, coordinates and planning observations

The basics...

Earth’s rotation



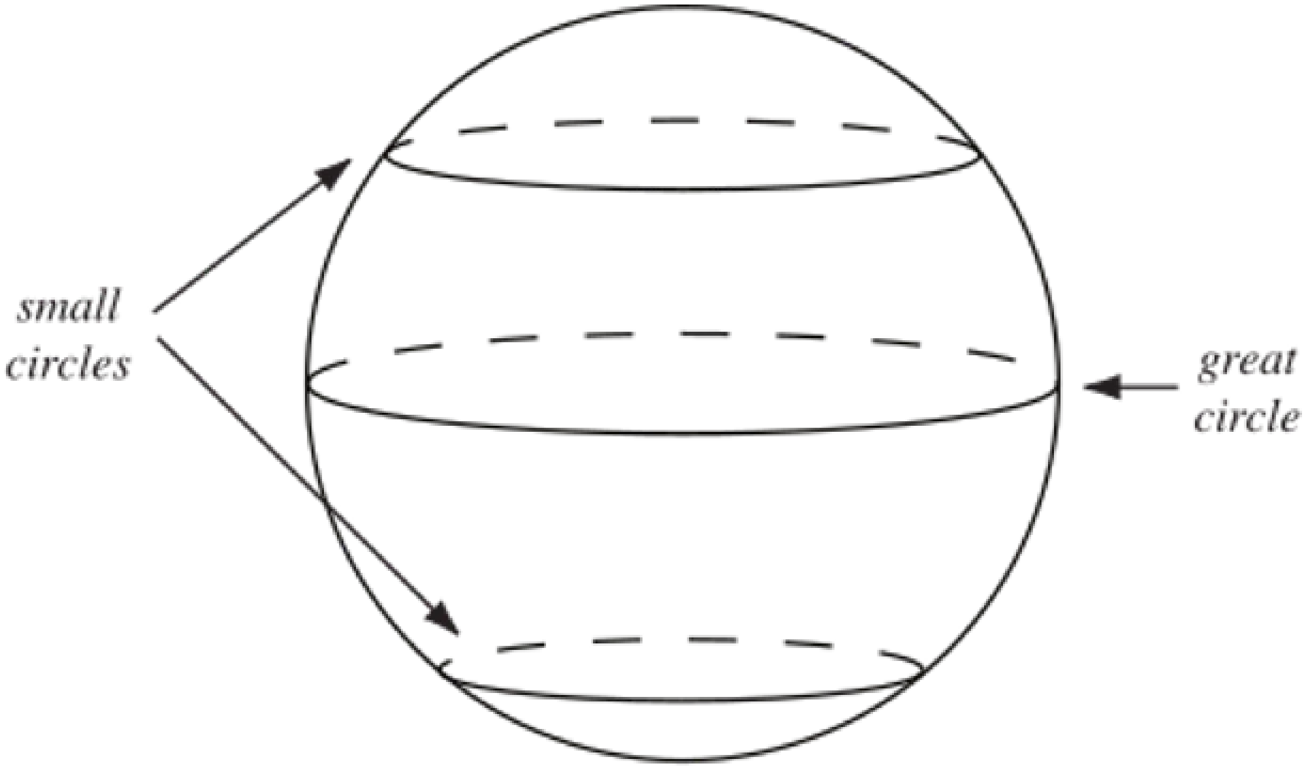
▲ As seen from the side, the rotation is eastward.

▲ As seen from above, the rotation is counterclockwise.

The Earth’s ***axis of rotation***, is the line that connects the North and South poles, through the Earth’s center.

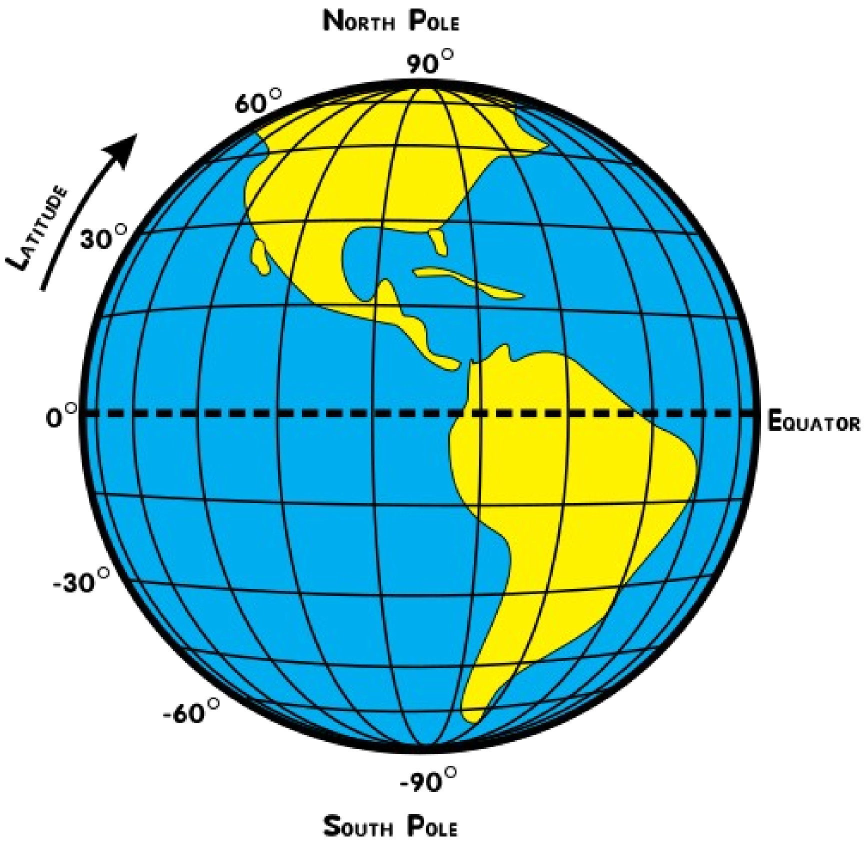
The Earth rotates around its axis from West to East, that is in a counter-clockwise motion

Great circle – an important definiton



A ***great circle*** is any (circular) section of a sphere, whose diameter is also a diameter of the sphere

Earth coordinates - latitude



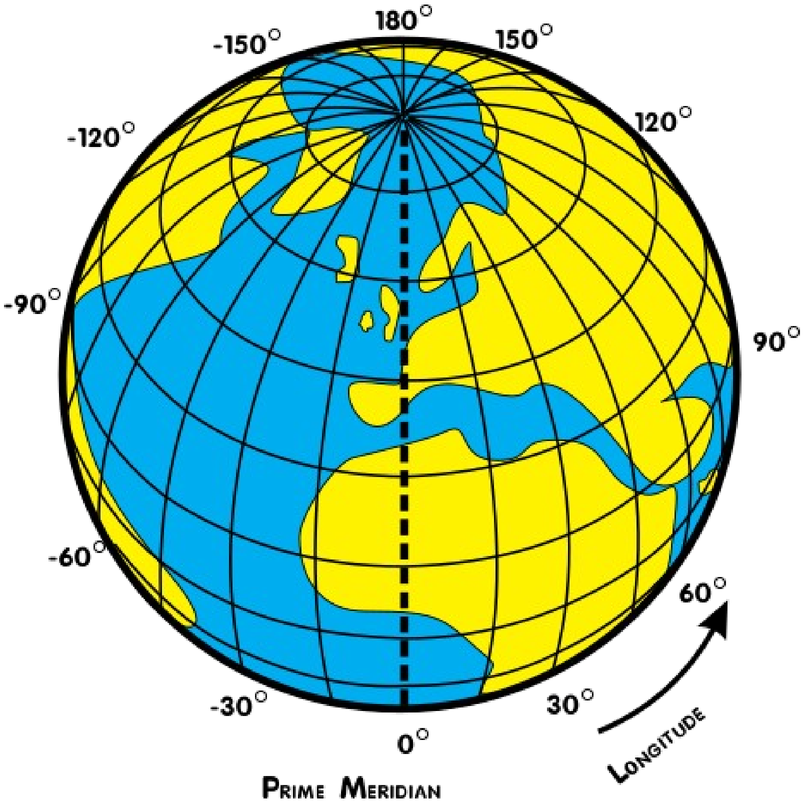
The great circle ***perpendicular*** to the axis of Earth's rotation is called the ***Equator.***

It divides the Earth in the northern and southern hemispheres.

Any small circle ***parallel*** to the Equator is called a circle/line of ***latitude*** or simply a ***parallel.***

By convention, latitudes are *positive* towards the North, and *negative* towards the South.

Earth coordinates - longitude



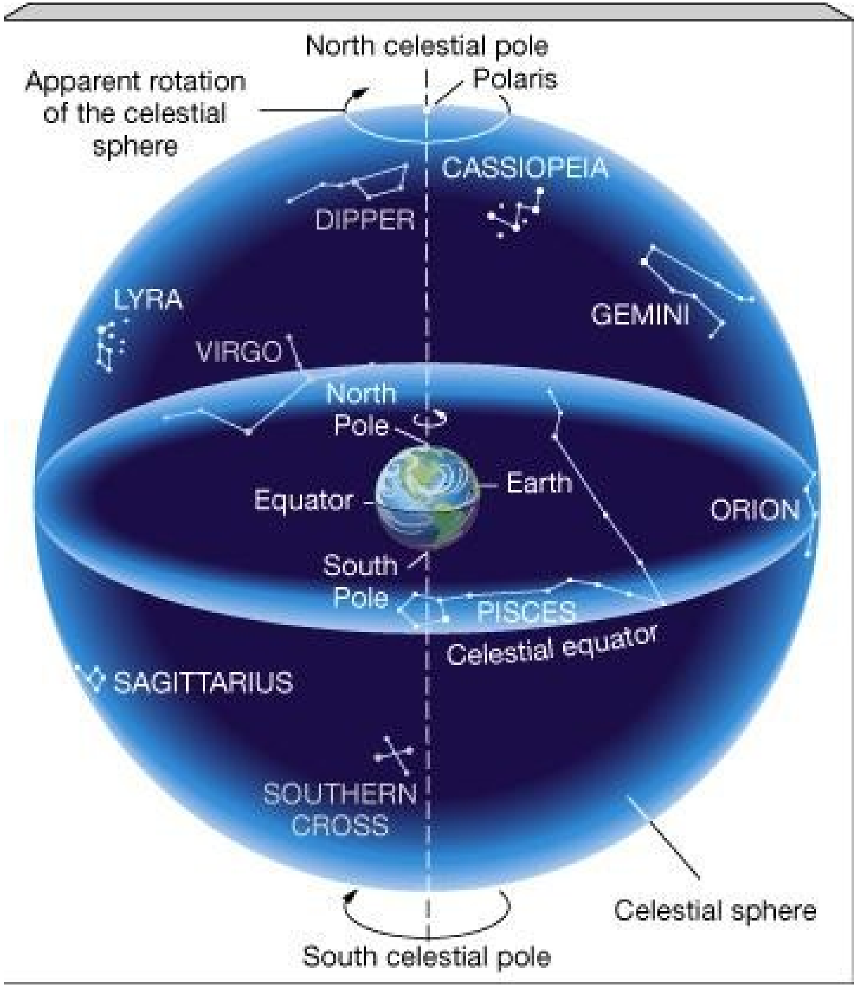
Any great circle ***perpendicular*** to the Equator is called a circle/line of ***longitude*** or a ***meridian.***

The ***prime meridian*** is the meridian passing through the Royal Greenwich Observatory in the UK.

It divides the Earth in the eastern and western hemispheres.

By convention, longitudes are *positive* towards the East, and *negative* towards the West.

The Celestial Sphere



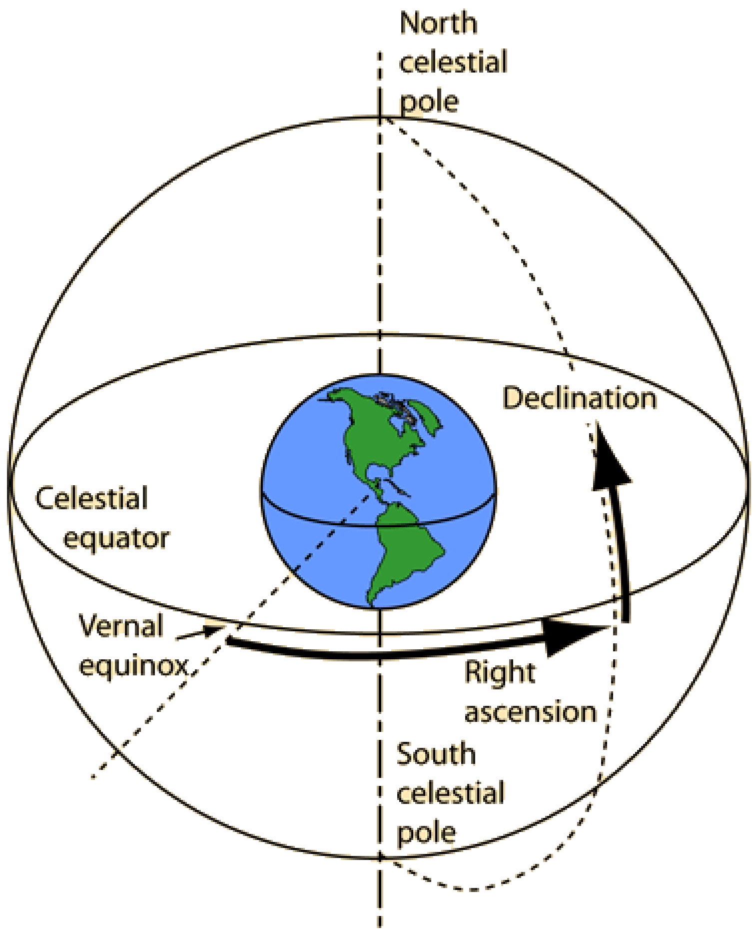
The ***celestial sphere*** is a sphere of infinite radius with Earth at its center.

We assume that the stars are located on the surface of the celestial sphere.

The extension of the Earth's Equator defines the ***celestial equator.***

The extension of the Earth's rotation axis is considered to be the rotation axis of the celestial sphere and defines the ***North*** and ***South celestial poles***.

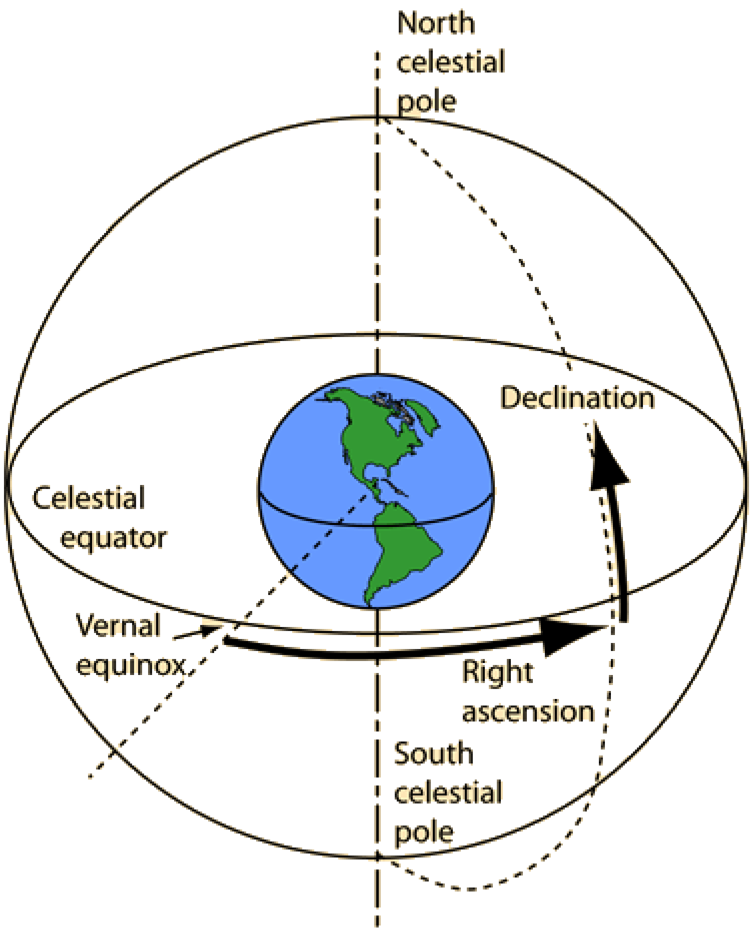
Equatorial Coordinates



We can extend the definitions of *__latitude__* and *__longitude__* to define a set of astronomical coordinates called ***declination*** and ***right ascension***.

Declination and Right Ascension, together, are called ***equatorial coordinates***.

Equatorial Coordinates

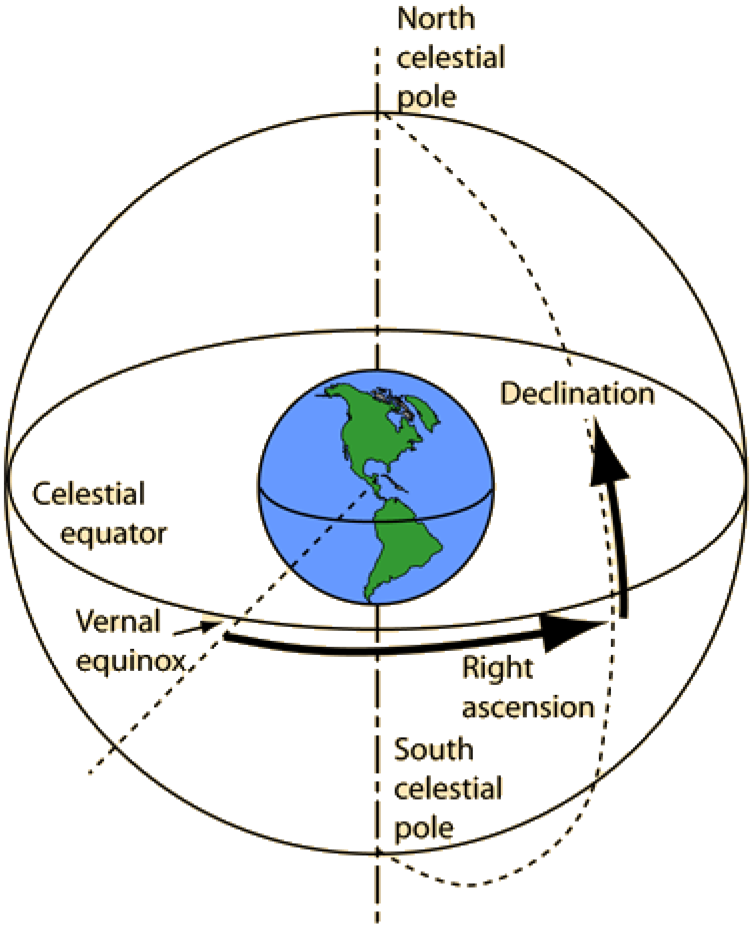


Declination (**Dec** or **δ**) is an extension of *latitude*. It's an angle measured above or below the celestial equator.

Much like latitude, declination is considered positive towards the north, and negative towards the south.

Declination runs from **-90º** to **+90º**

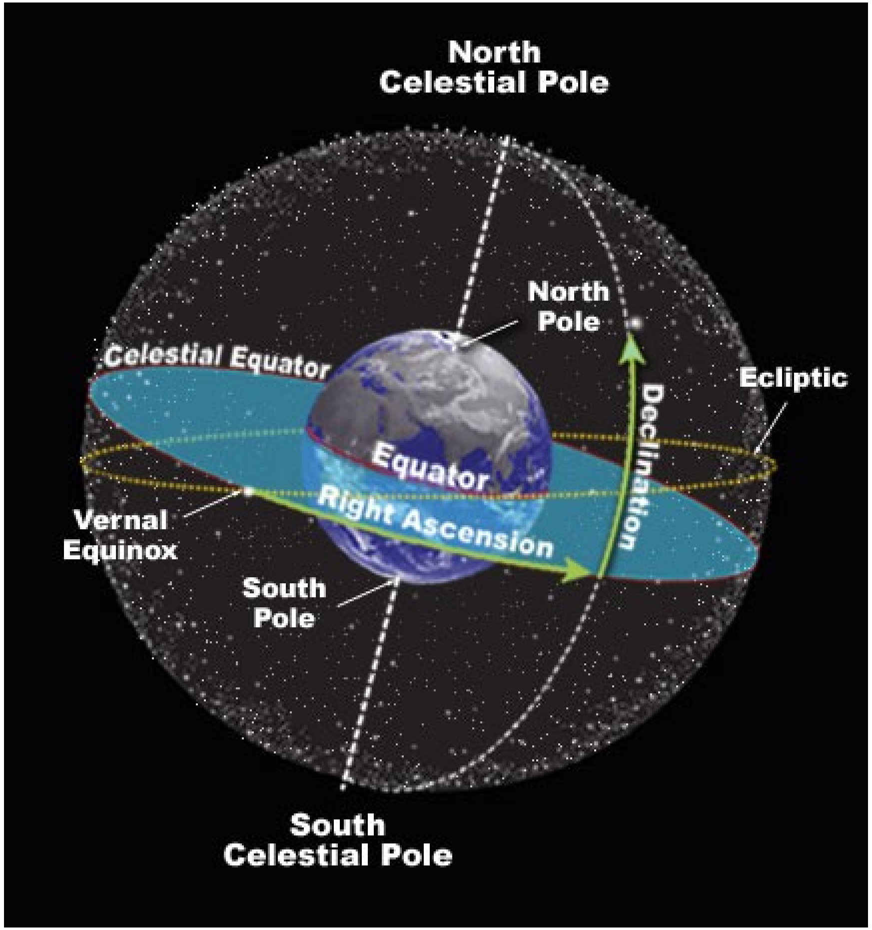
Equatorial Coordinates



Right Ascension (**RA** or **α**) is an extension of *longitude*. Similar to longitude, we need to define a starting/reference point.

The starting point for RA (“Greenwich”) is the ***vernal equinox*** point.

Equatorial Coordinates



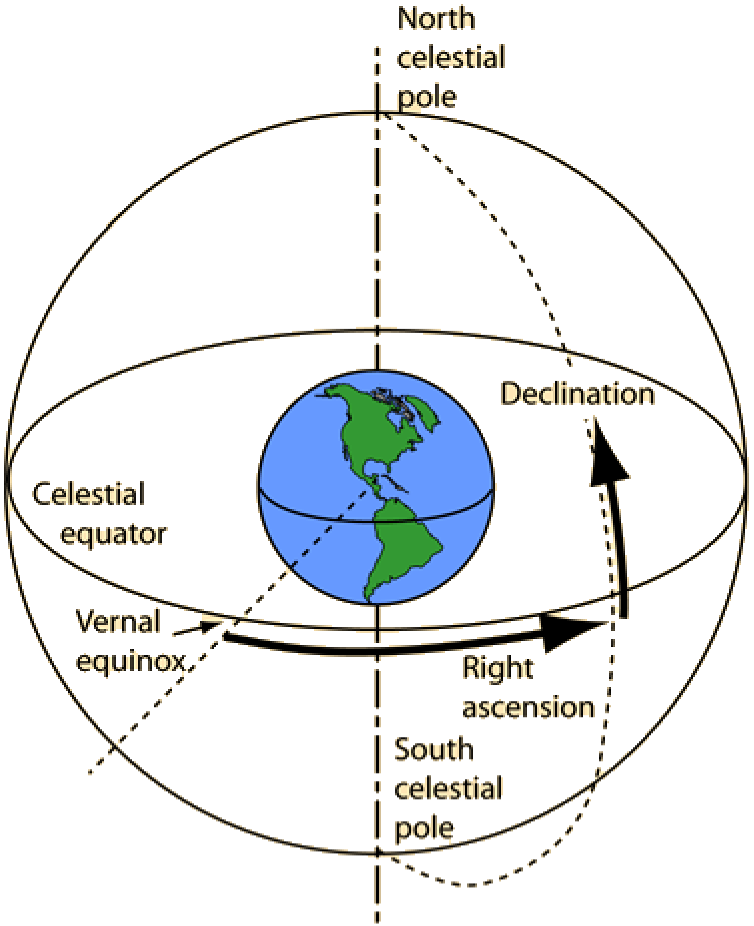
The plane of the Earth's orbit around the Sun is called the ***ecliptic***. Viewed from the Earth, the Sun's apparent motion in a year traces the plane of the ecliptic.

The ***ecliptic*** intersects the ***celestial equator*** in the two ***equinox points***:

- Vernal/Spring equinox: March
- Autumn equinox: September

The ***vernal equinox*** point is the start point ("Greenwich") for measuring right ascension.

Equatorial Coordinates



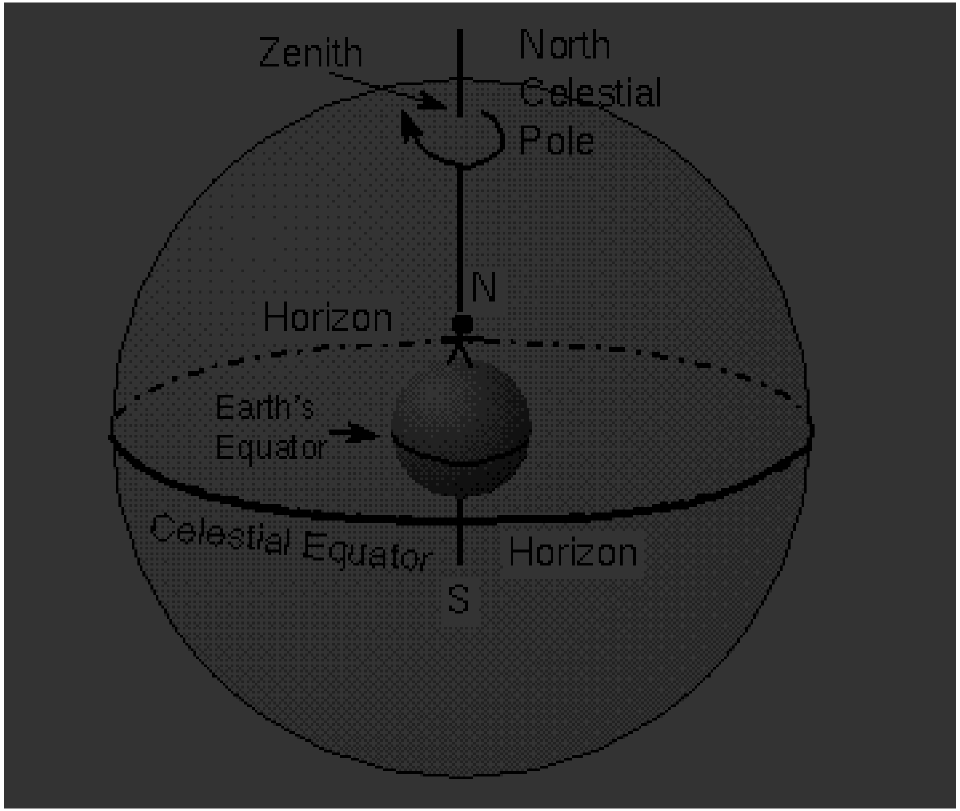
Right Ascension (**RA** or **α**) is an extension of *longitude*. Similar to longitude, we need to define a starting/reference point.

The starting point for RA ("Greenwich") is the ***vernal equinox*** point.

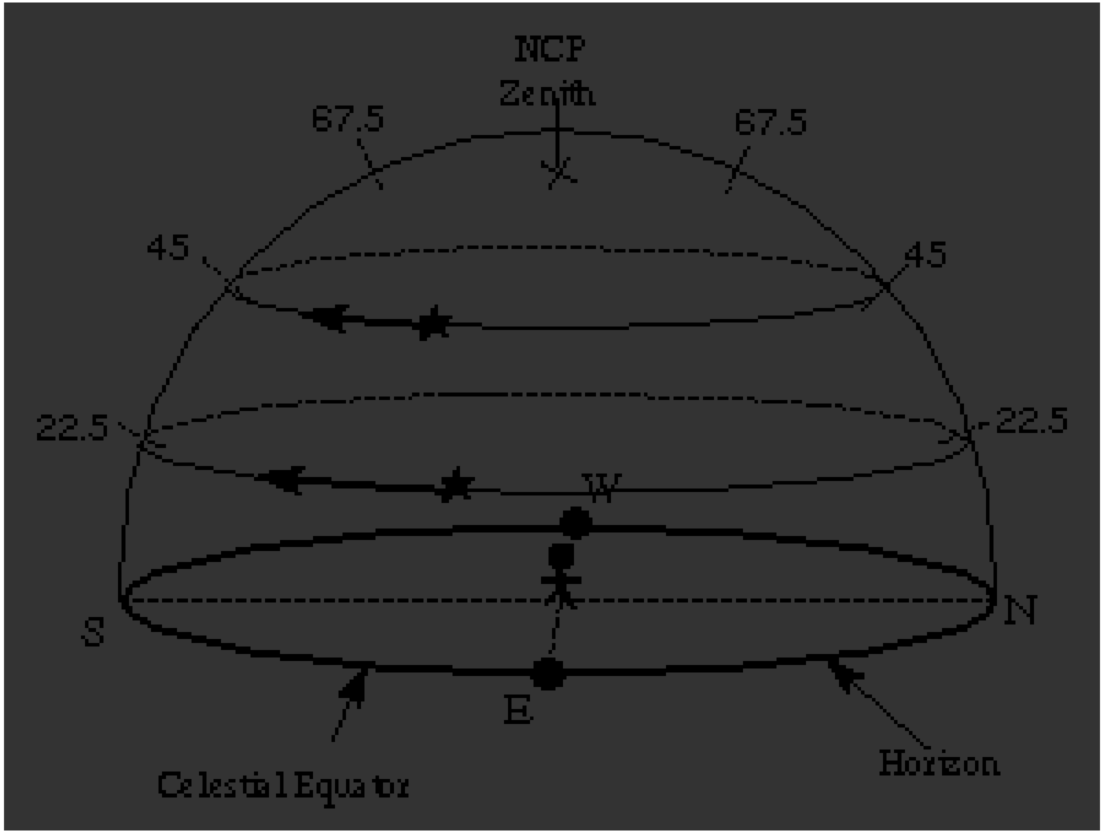
Right ascension is ***only*** positive; contrary to longitude, there is no negative RA.

RA is either given in ***hours (0-24)*** or ***degrees (0º-360º),*** with one hour equal to 15 degrees.

The sky for different observers

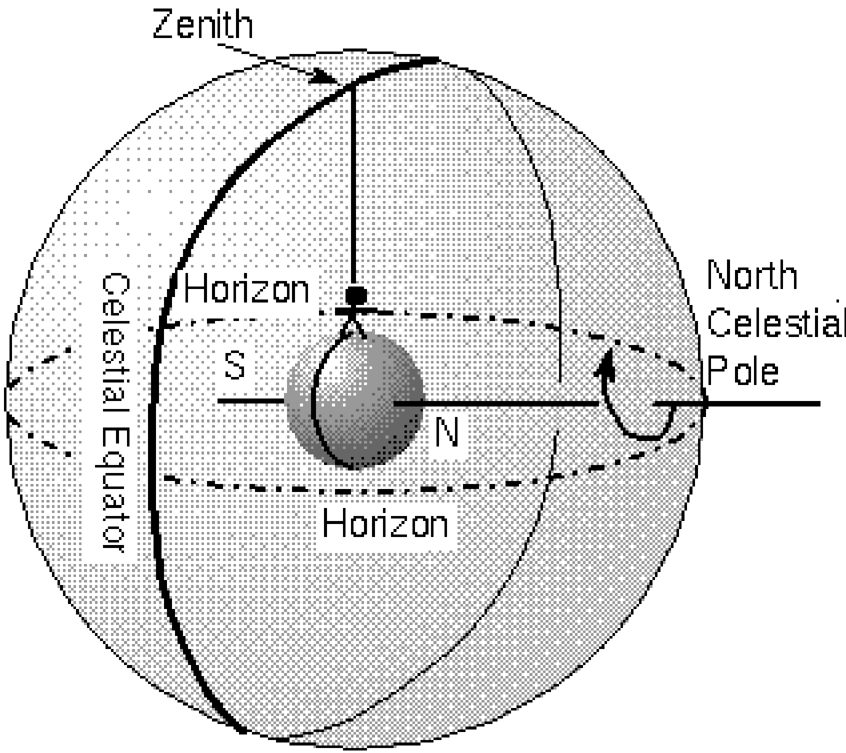


An observer at the ***North Pole***

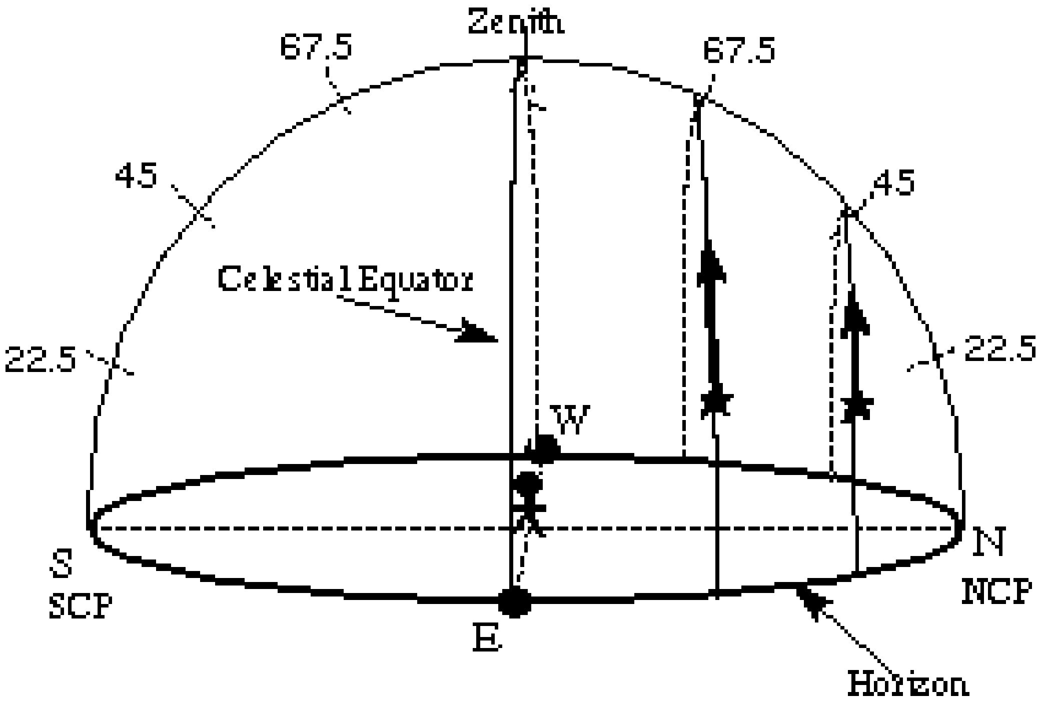


Stars move in circles ***parallel*** to the horizon

The sky for different observers

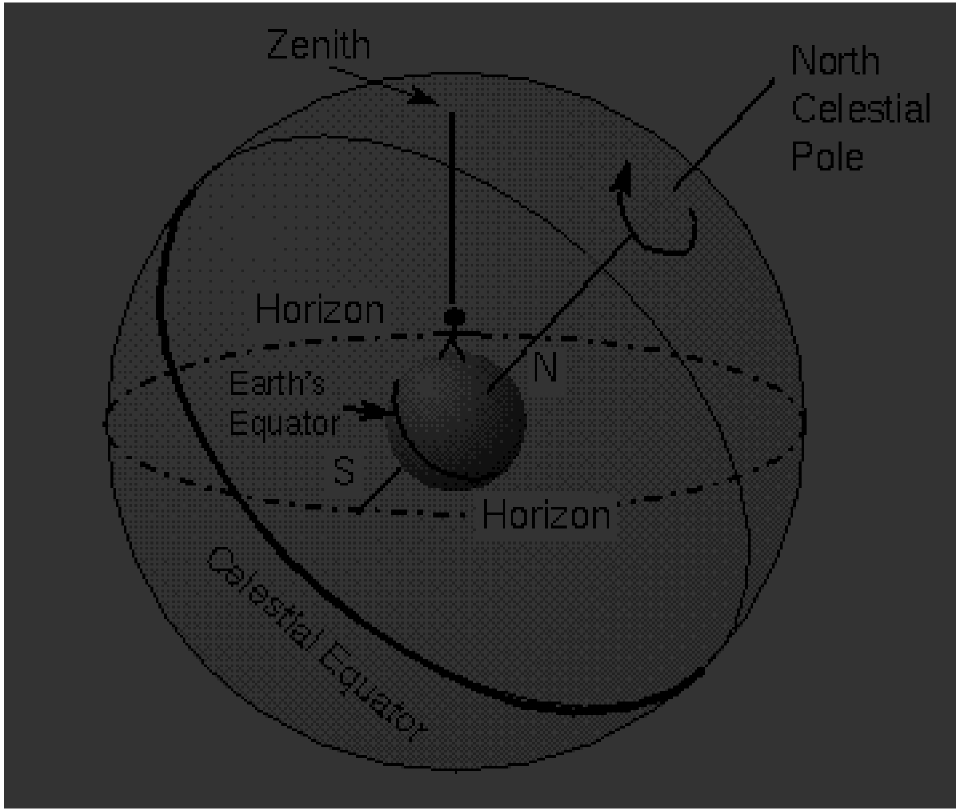


An observer at the ***Equator***

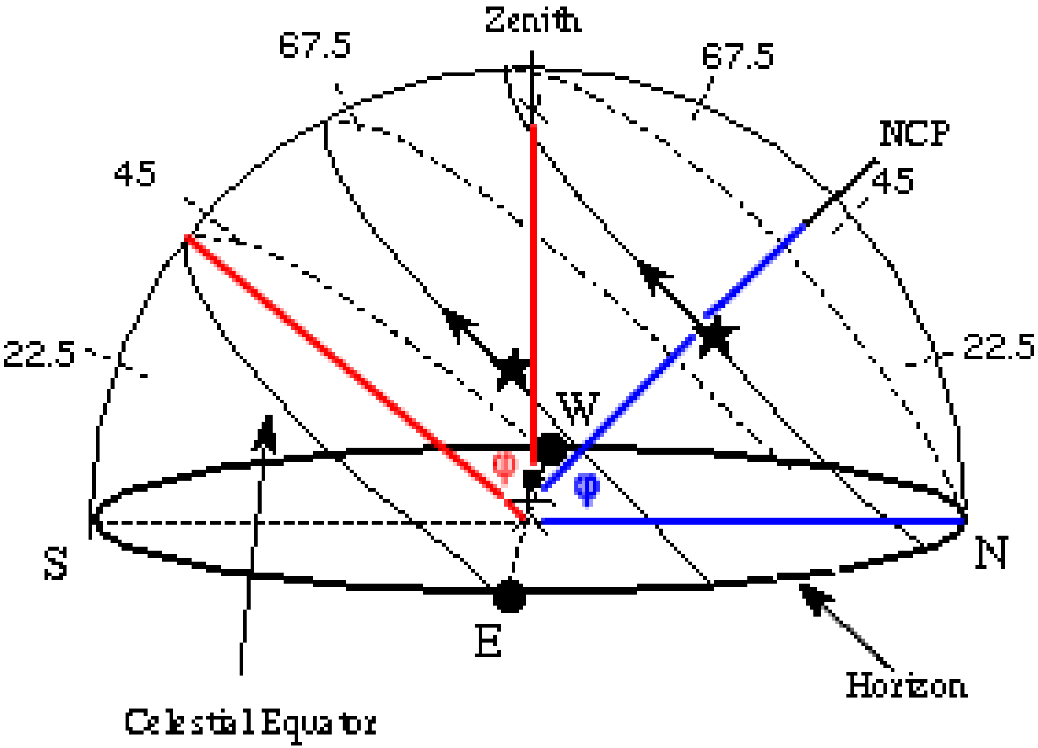


Stars move in circles ***perpendicular*** to the horizon

The sky for different observers

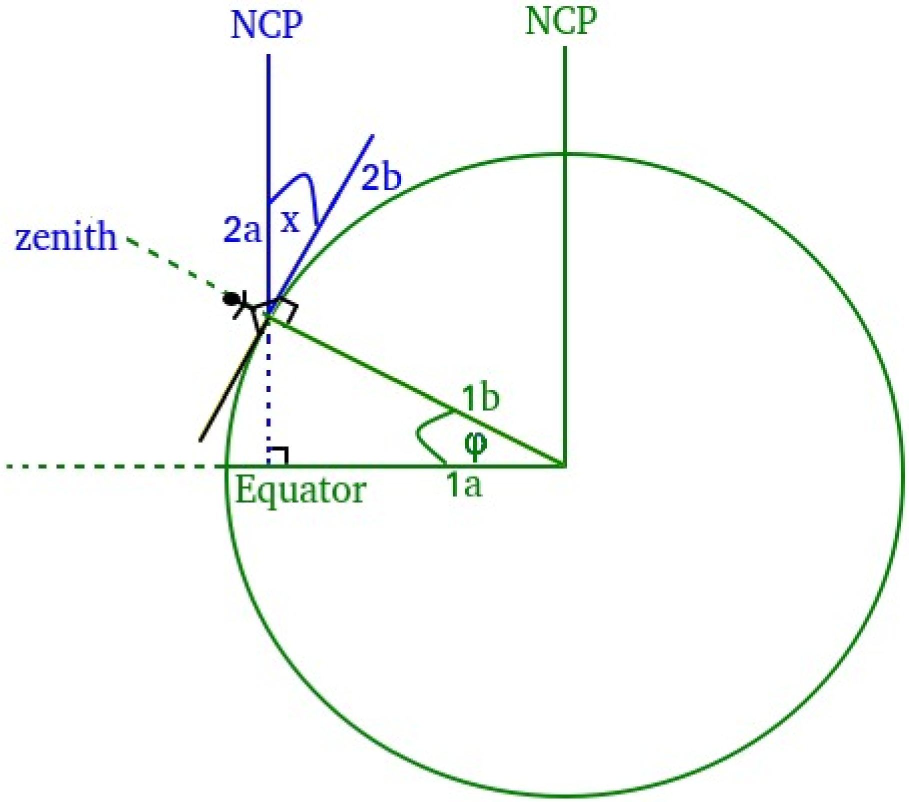


An observer at an ***intermediate latitude φ***



Stars move in circles ***inclined*** with respect to the horizon, with dependence on ***φ***

The sky for different observers



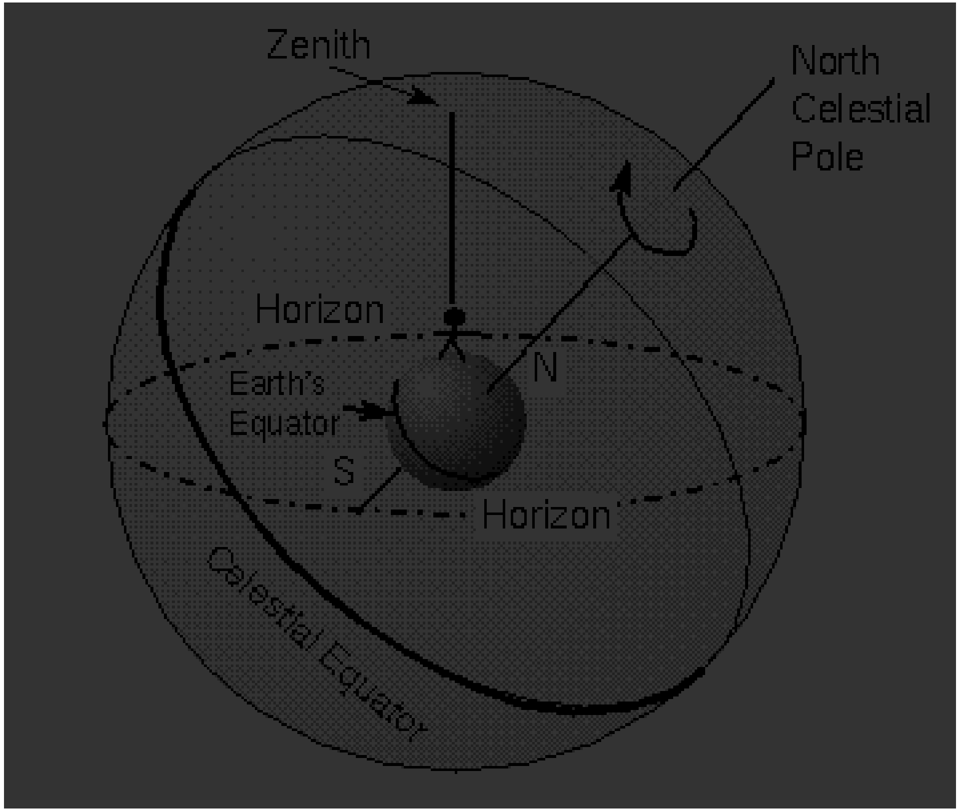
For an observer at latitude φ:

- **Side 1a** and **Side 2a** are perpendicular
- **Side 1b** and **Side 2b** are perpendicular

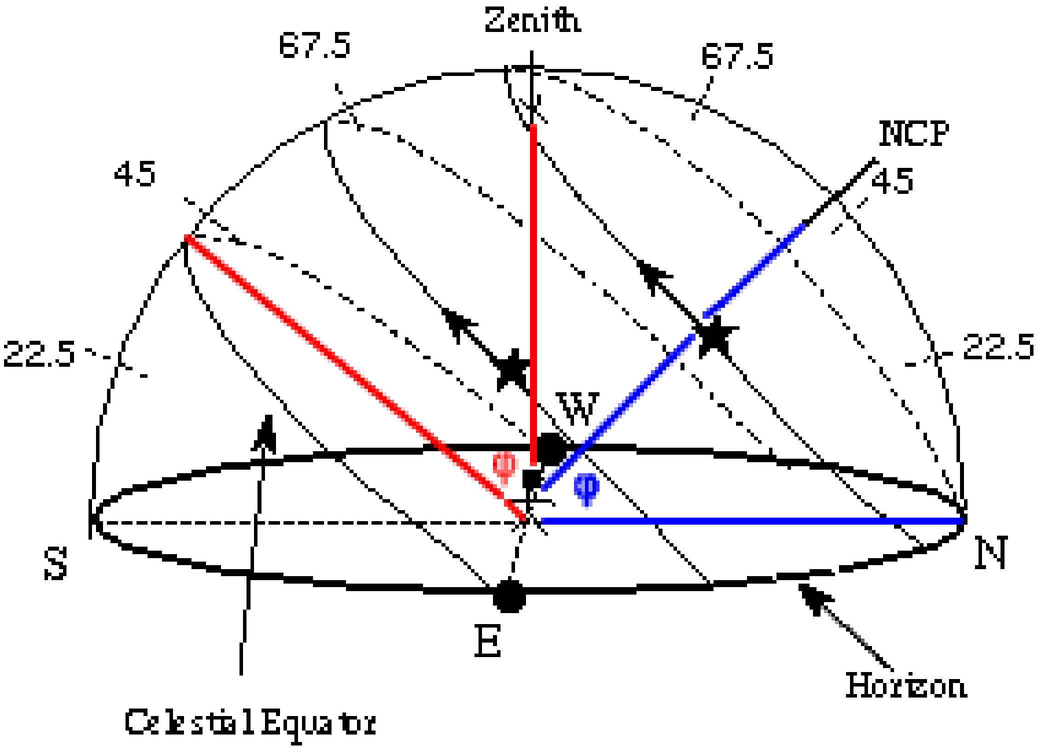
The angles φ and x have their sides pair-wise perpendicular to each other.

Therefore x = φ

The sky for different observers

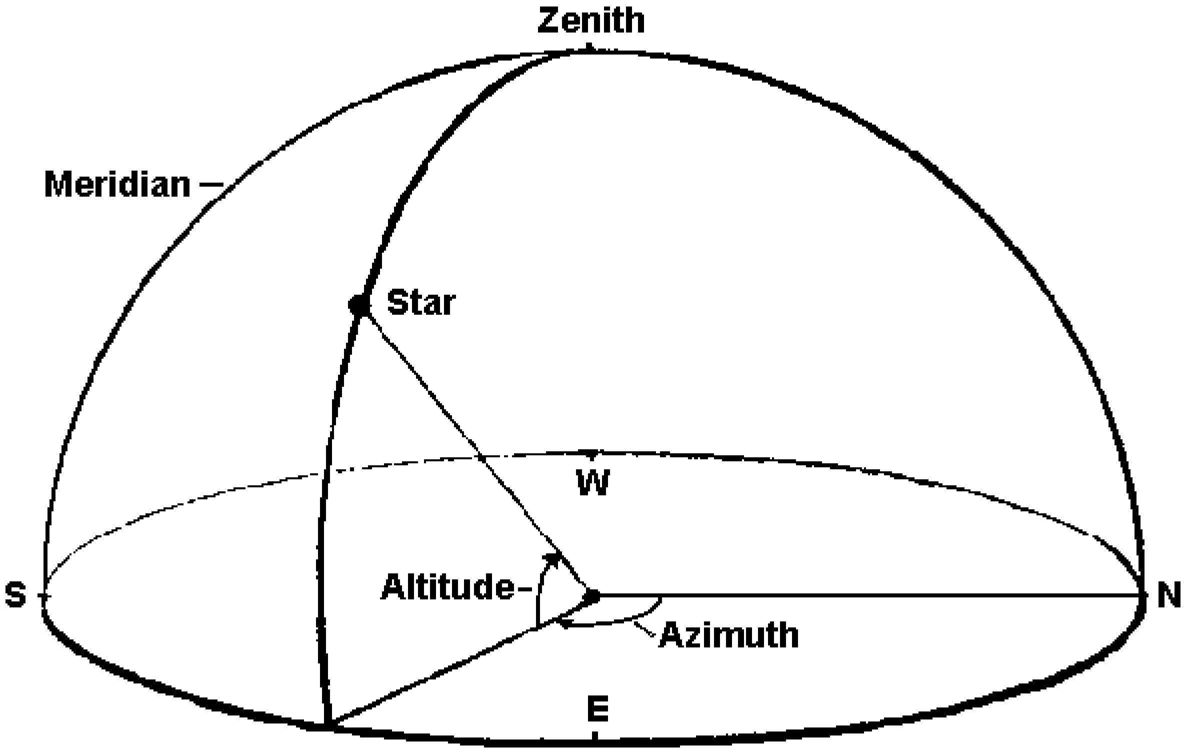


An observer at an ***intermediate latitude φ***



Stars move in circles ***inclined*** with respect to the horizon, with dependence on ***φ***

Horizontal coordinates



Azimuth (Az) and Altitude (Alt) form the horizontal coordinates

Azimuth runs from ***0º*** to ***360º*** in a clock-wise direction (N – E – S – W)

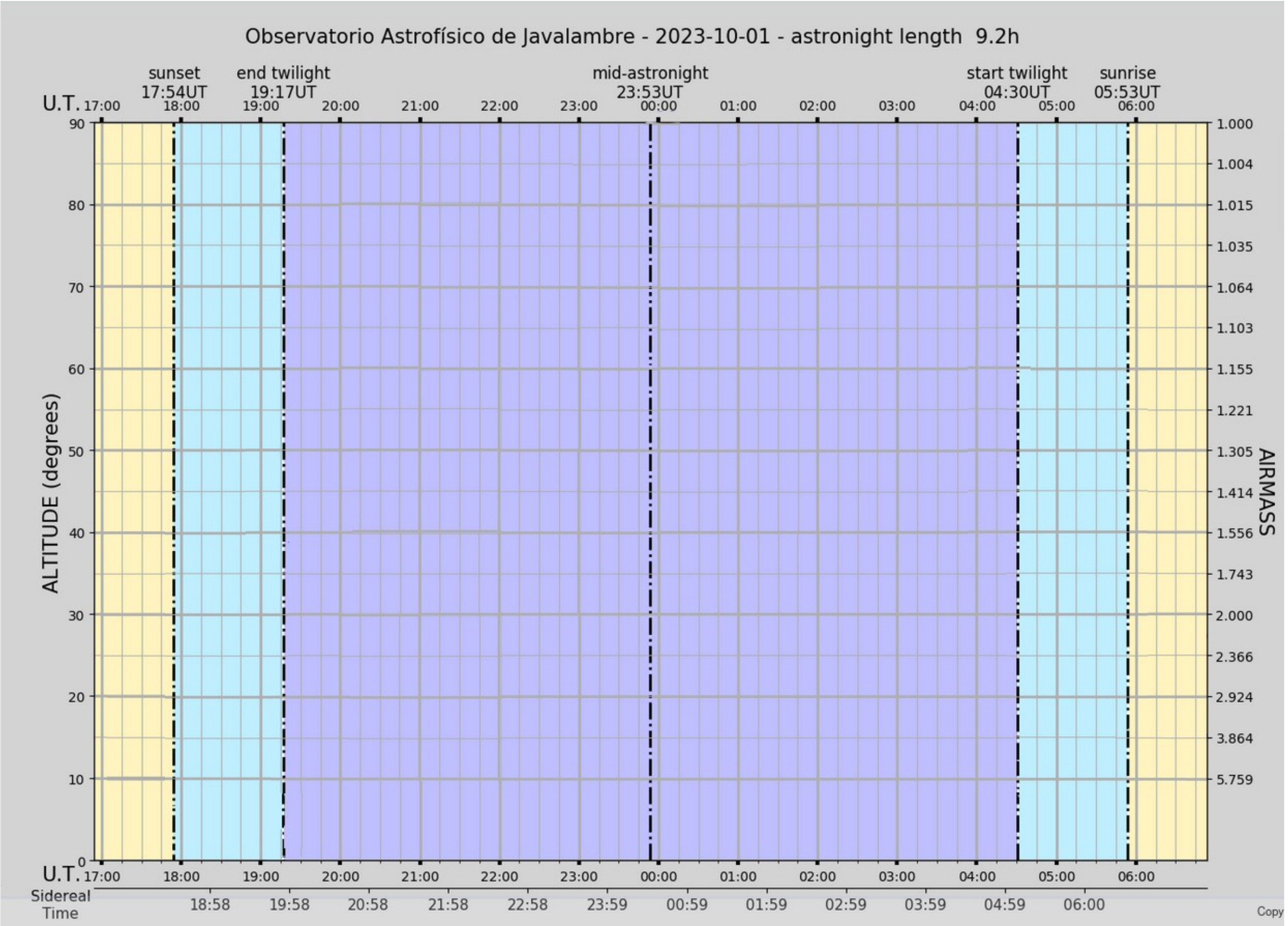
Altitude runs from ***0º*** at the horizon, to ***90º*** at the zenith.

Both the azimuth and the altitude of a celestial object change during the night!

Planning

observations

Planning observations



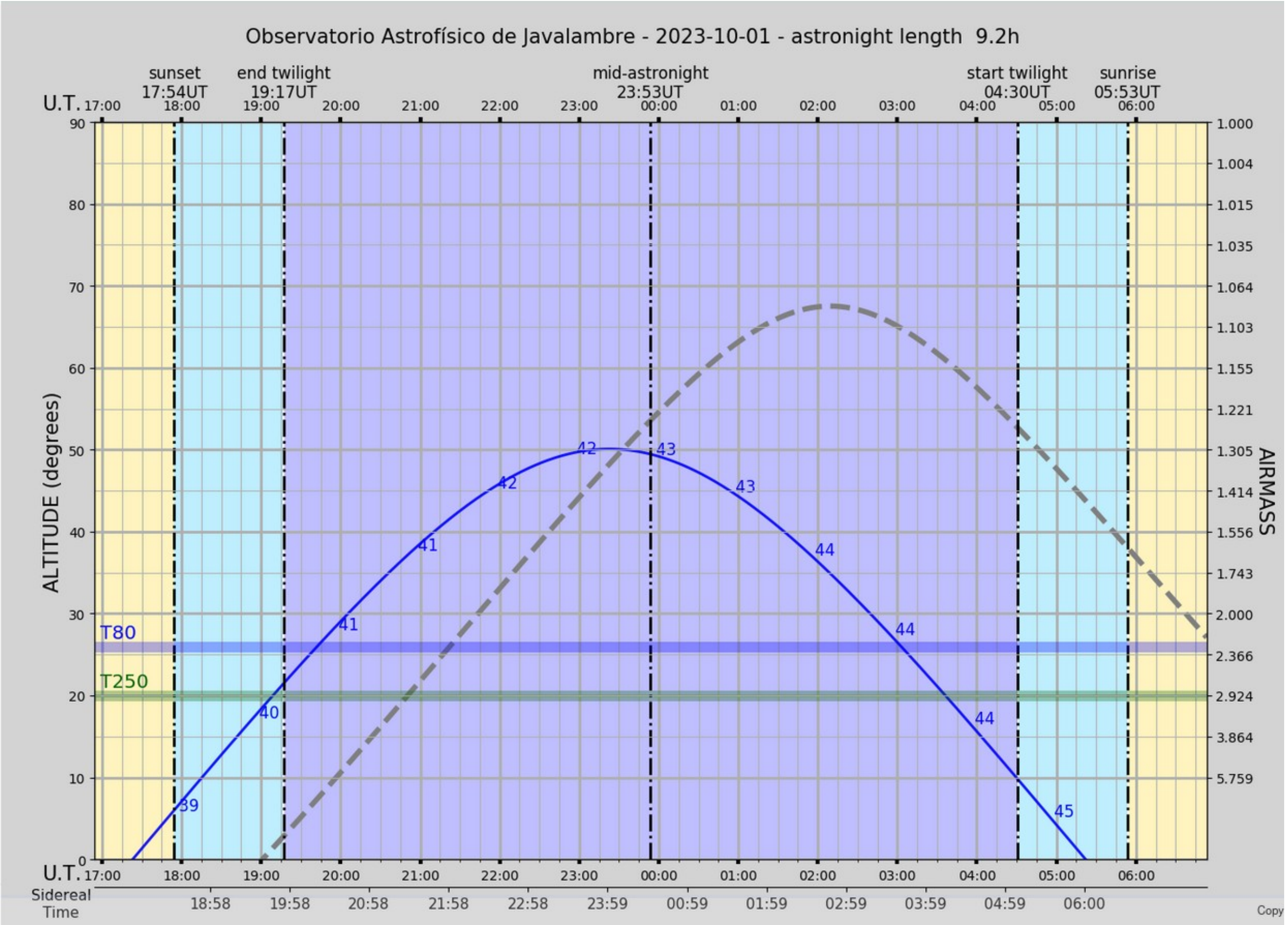
When we are talking about planning observations, what we are interested in is the visibility of celestial objects on a given night.

A tool like **StarAlt** plots the altitude of an object with respect to time for a given Night.

Tool access:

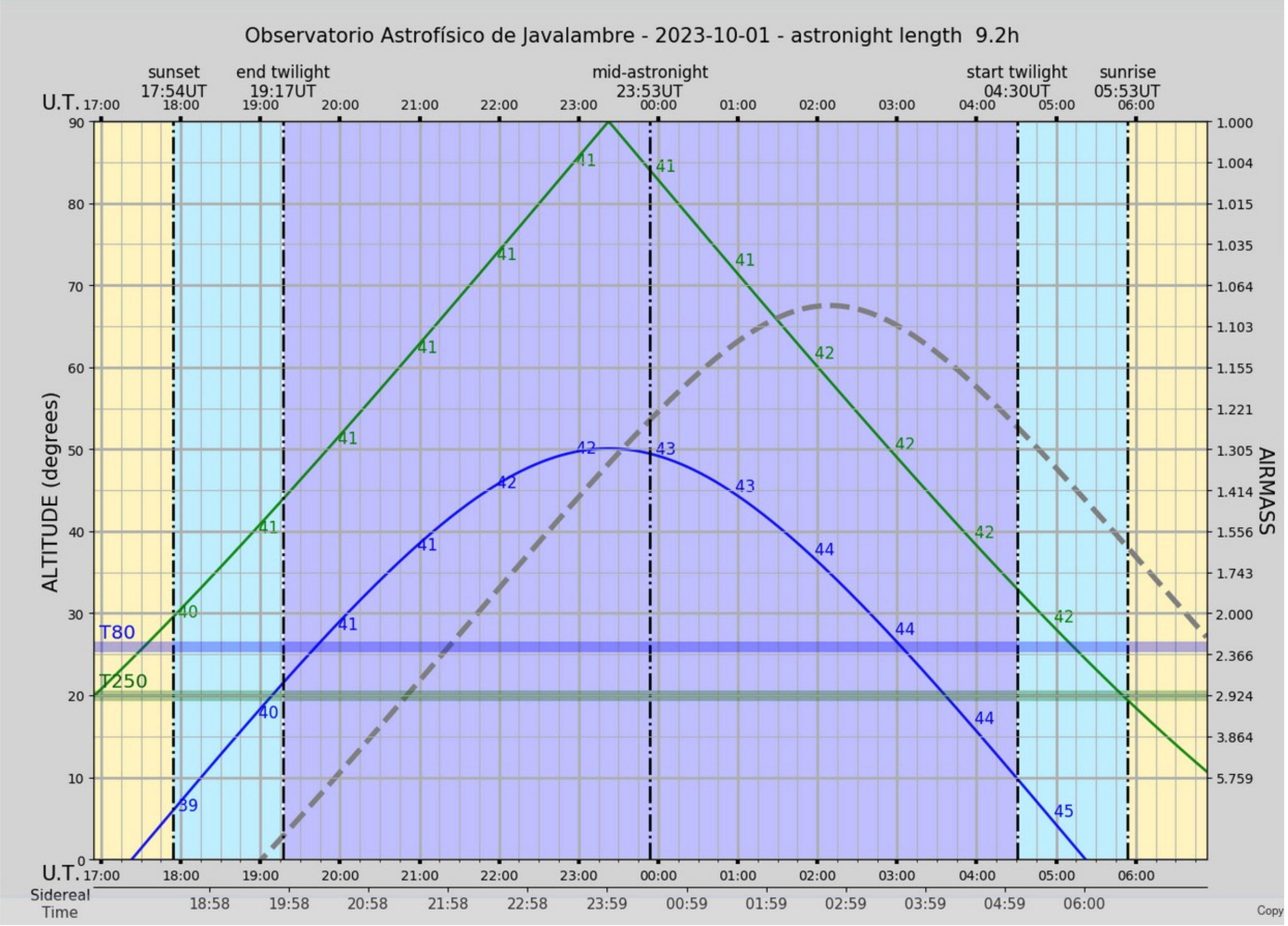
http://catserver.ing.iac.es/staralt/

Planning observations



Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

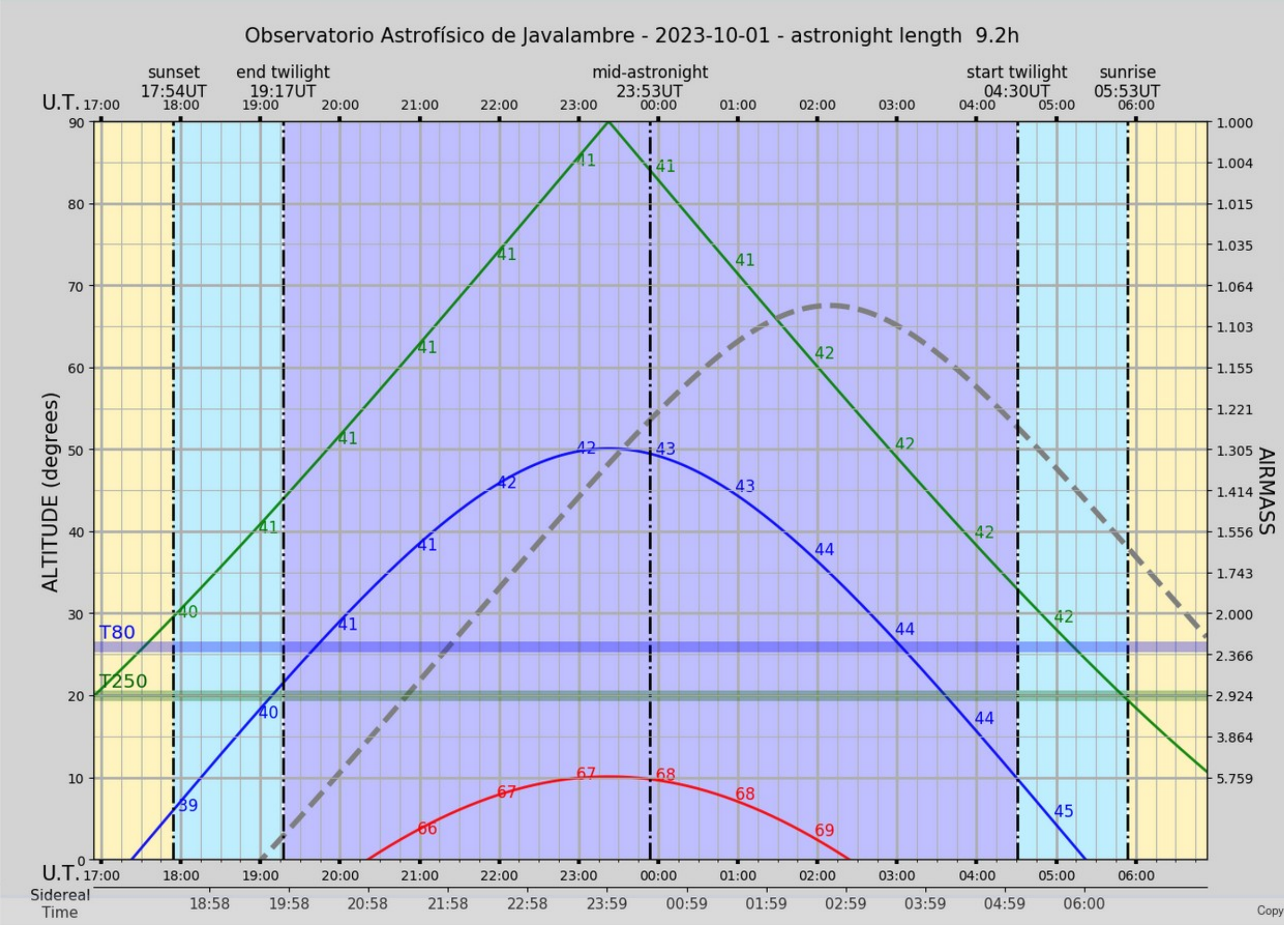
Planning observations



Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

Star2: RA= 00h 00m 00s
Dec = +40d 00m 00s

Planning observations

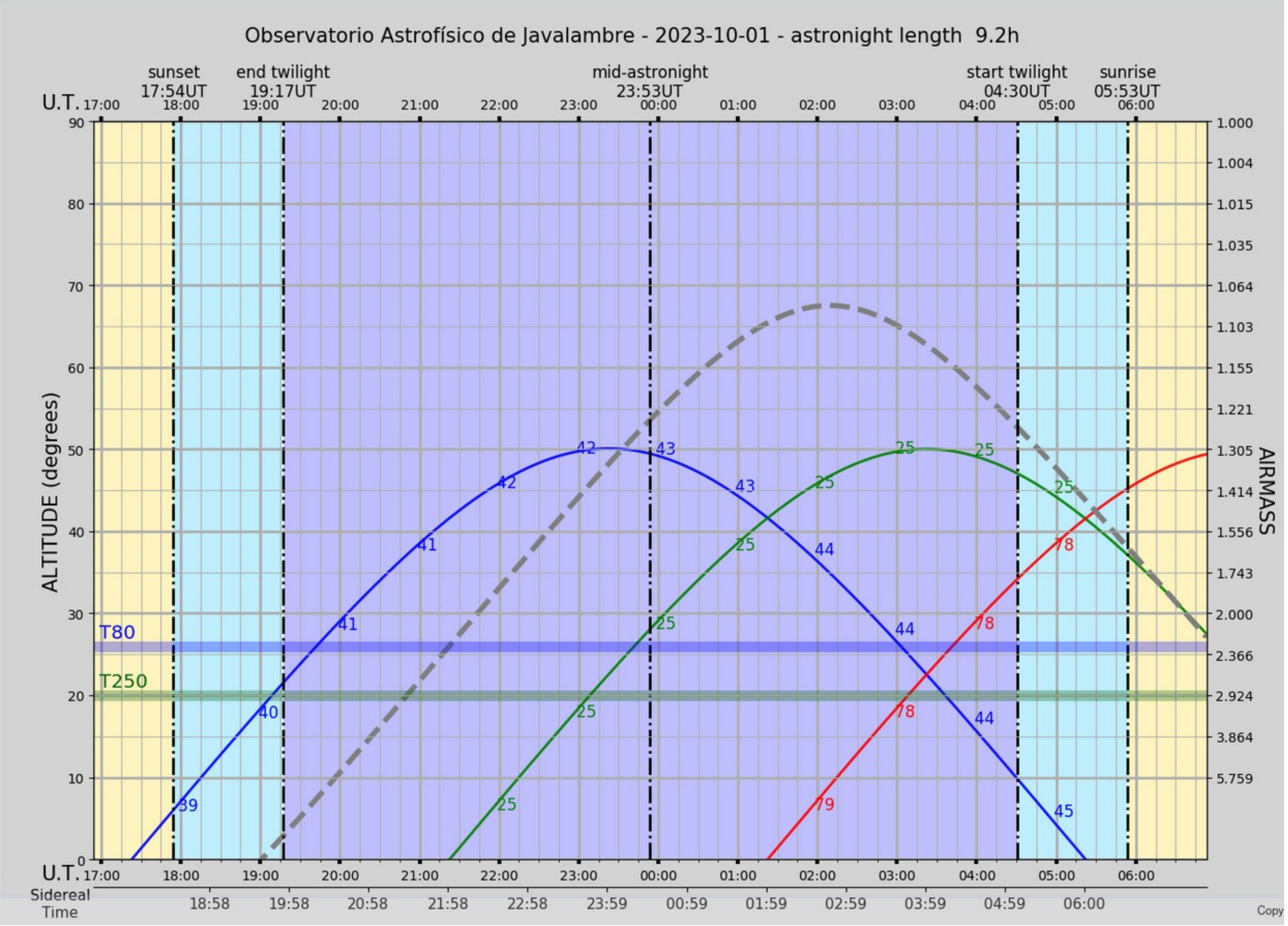


Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

Star2: RA= 00h 00m 00s
Dec = +40d 00m 00s

Star3: RA= 00h 00m 00s
Dec = -40d 00m 00s

Planning observations



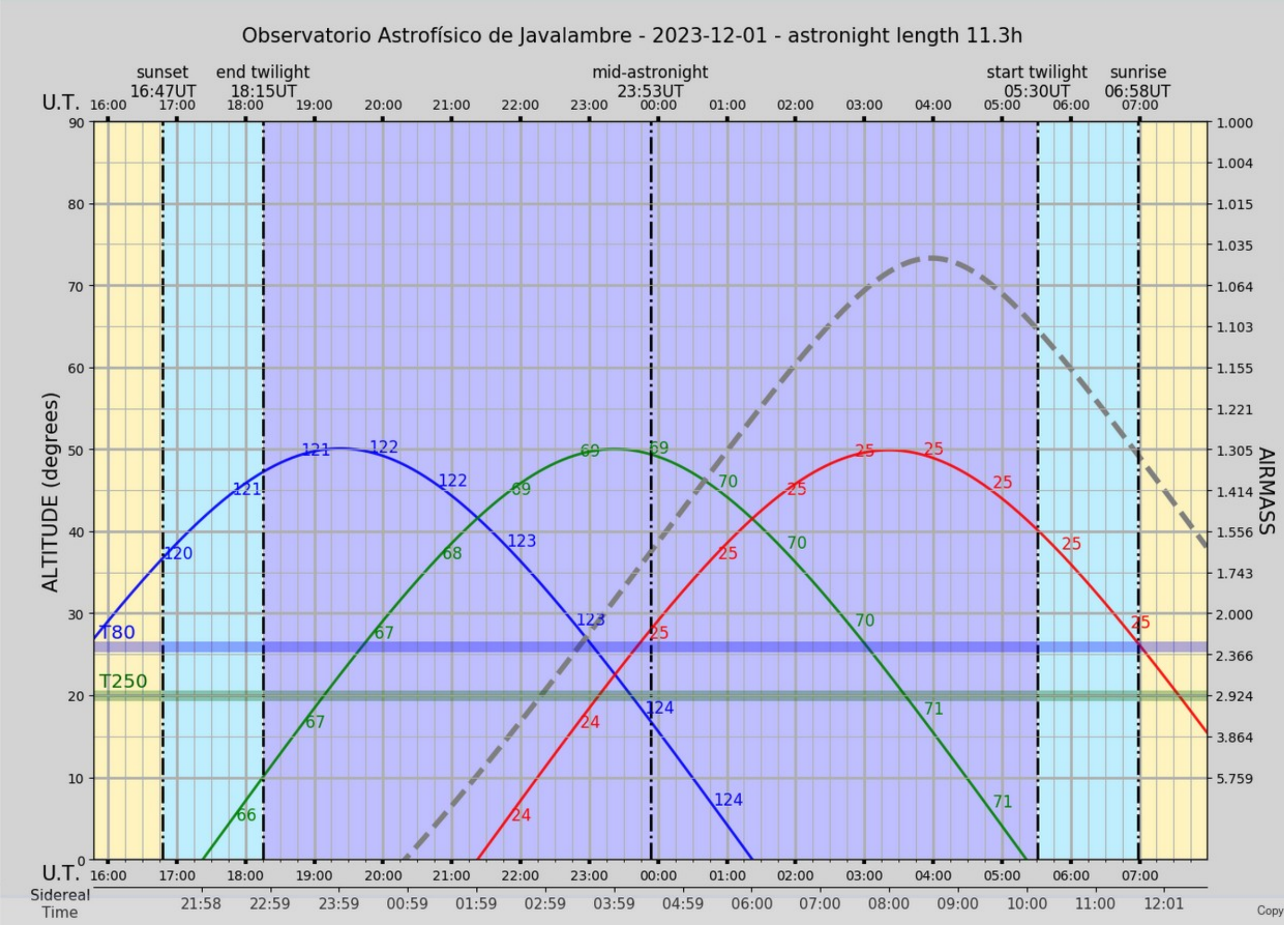
Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

Star2: RA= 04h 00m 00s
Dec = 00d 00m 00s

Star3: RA= 08h 00m 00s
Dec = 00d 00m 00s

Night of October 1st

Planning observations



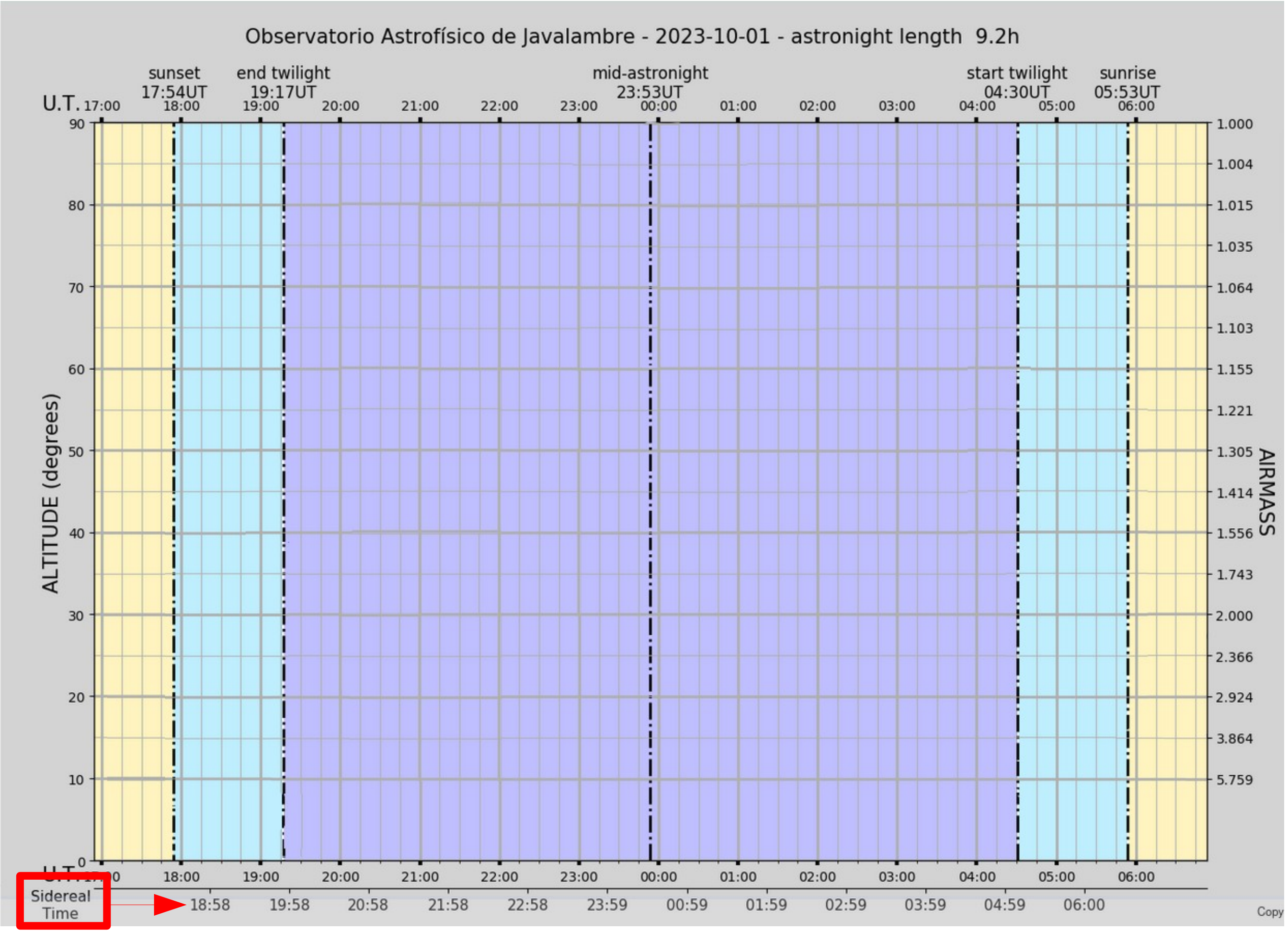
Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

Star2: RA= 04h 00m 00s
Dec = 00d 00m 00s

Star3: RA= 08h 00m 00s
Dec = 00d 00m 00s

Night of December 1st

Planning observations

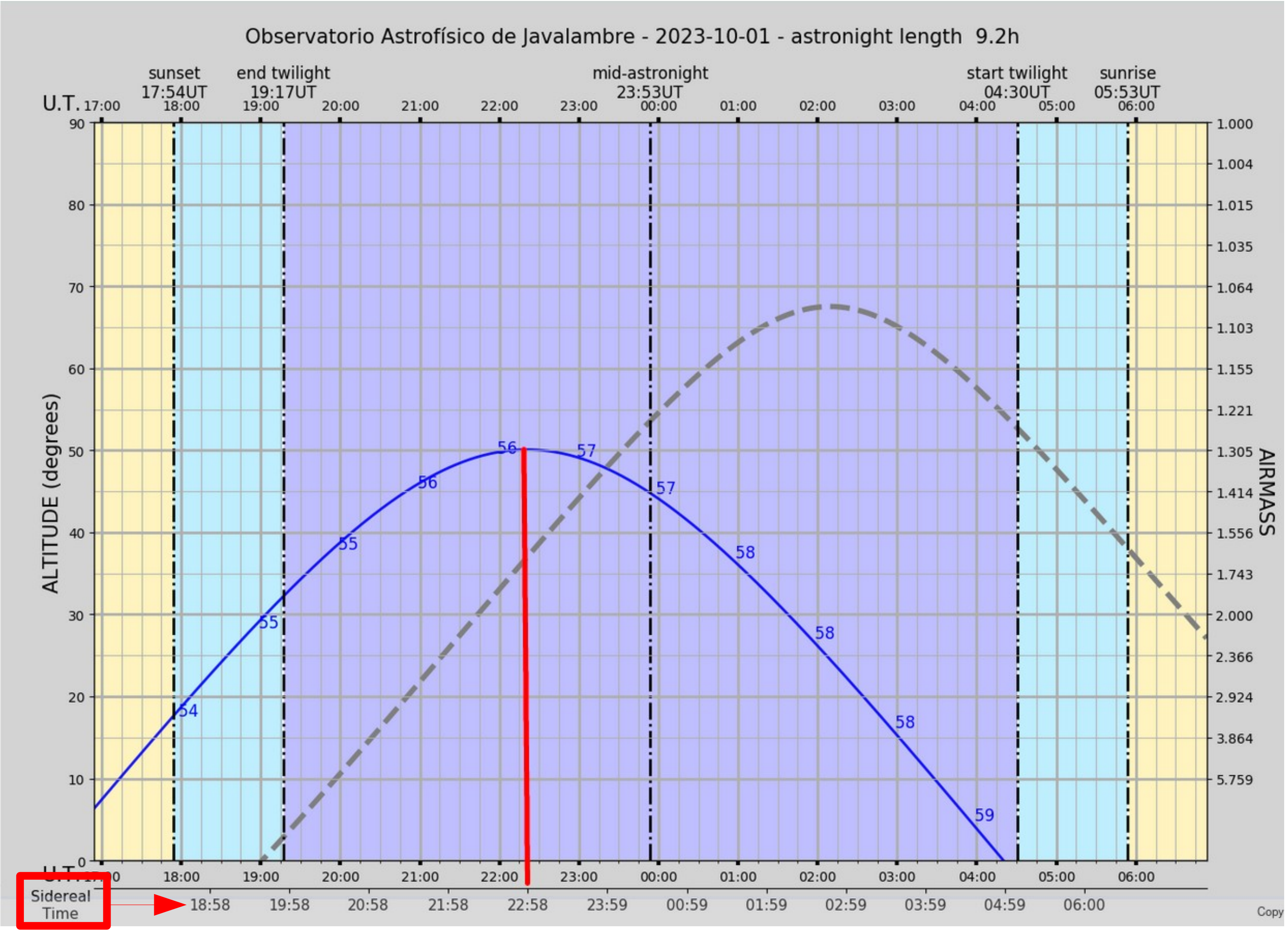


How do we know what RA is visible on a given night?

We can have a look at the **Local Sidereal Time (LST)**

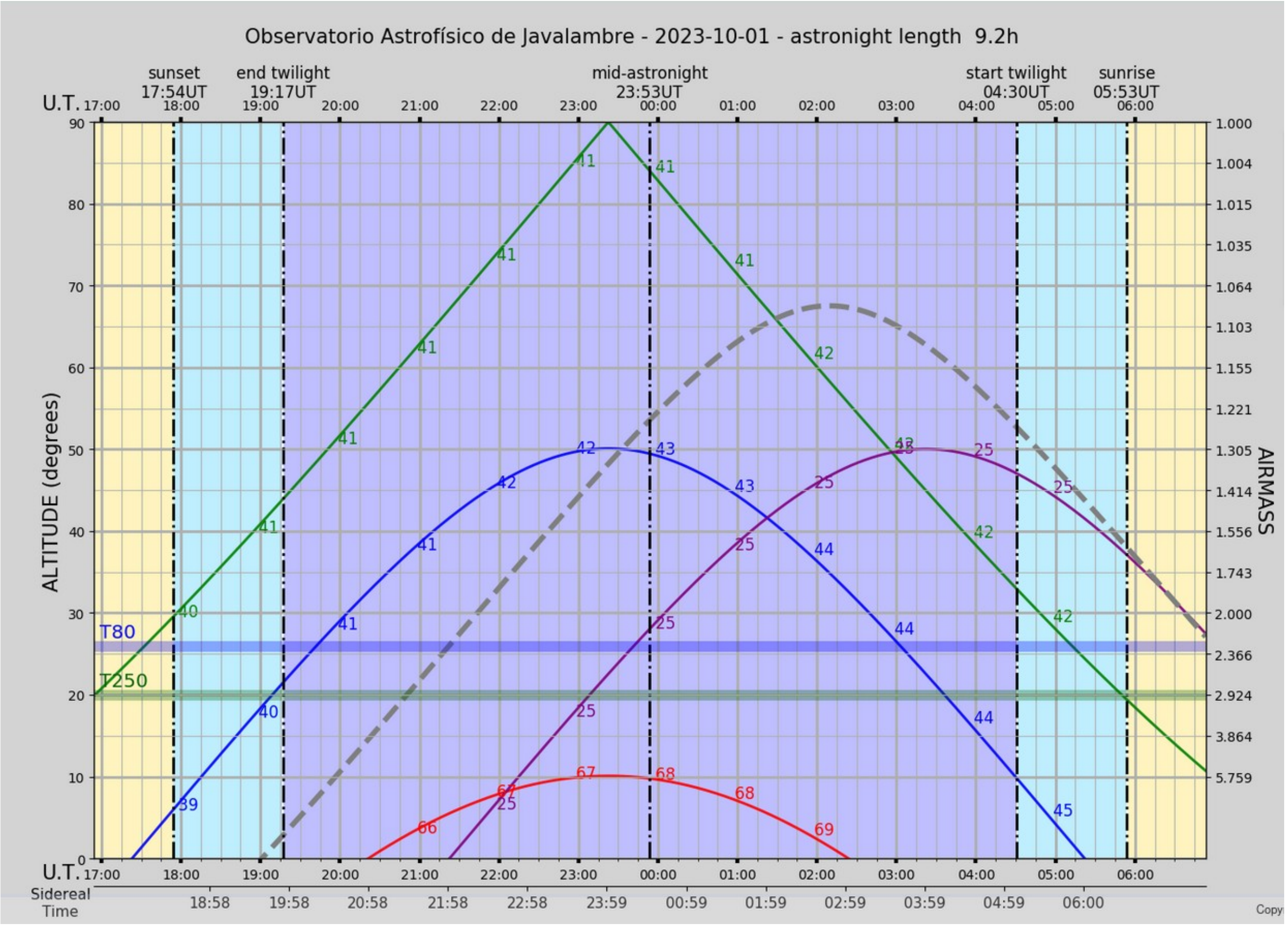
The **LST** corresponds to the RA of an object crossing the meridian (highest point)

Planning observations



Choosing LST 22:58 and plotting the visibility of a star with RA 22:58:00

Planning observations



Star1: RA= 00h 00m 00s
Dec = 00d 00m 00s

Star2: RA= 00h 00m 00s
Dec = +40d 00m 00s

Star3: RA= 00h 00m 00s
Dec = -40d 00m 00s

Star4: RA= 04h 00m 00s
Dec = 00d 00m 00s

Considerations

- What is my desired altitude?
  – Depends on Dec
- How long do I want to observe?
  – Depends on RA *and* Dec

Telescopes and telescope mounts

Telescopes

Refractors
they use *lenses*

Reflectors
they use *mirrors*

Newtonian

Compact

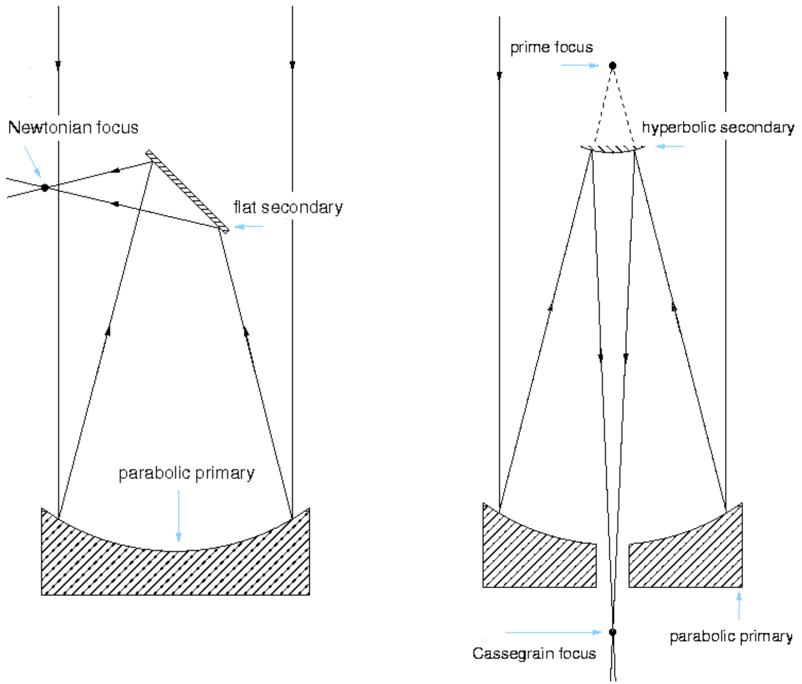
Telescopes

Refractors
they use *lenses*

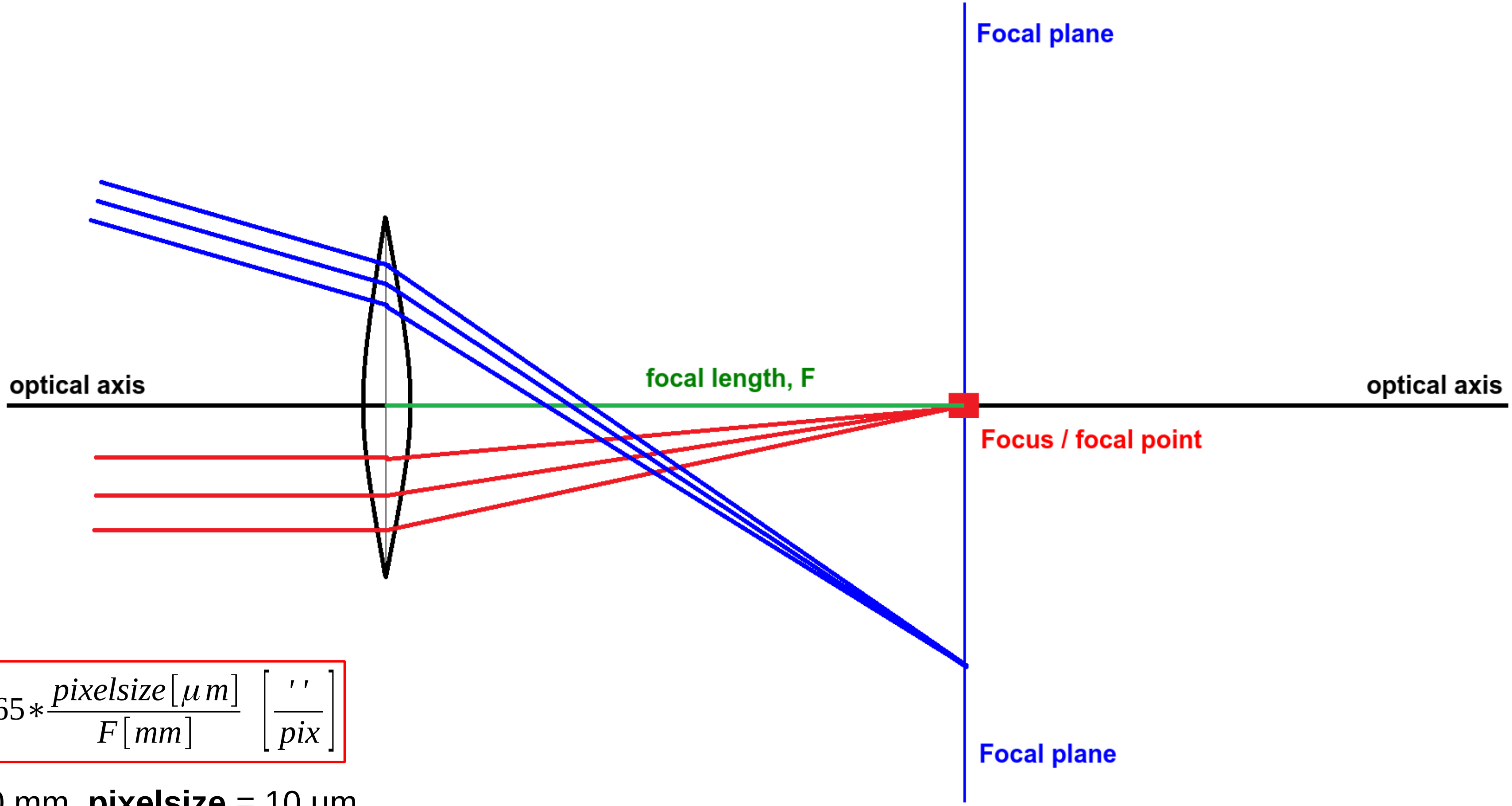
Reflectors
they use *mirrors*

Newtonian

Compact



Basic definitions for optics



$$pixel\,scale = 206.265 * \frac{pixelsize[\mu m]}{F[mm]} \left[\frac{''}{pix}\right]$$

Example: **F** = 3700 mm, **pixelsize** = 10 μm
then the pixel scale = 0.557 [arcsec/pixel]

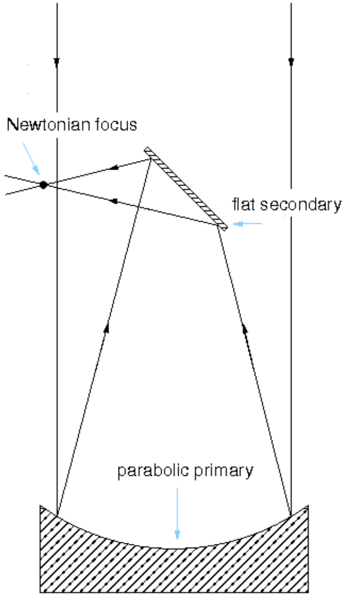
Telescopes

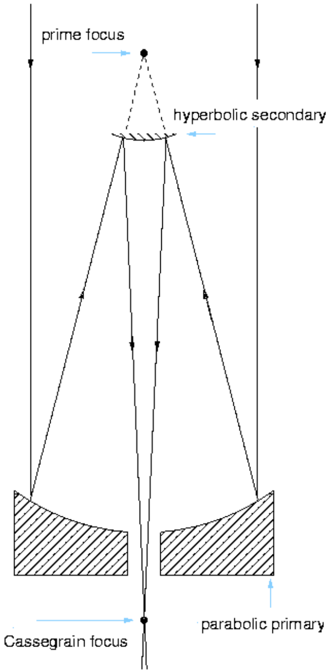
Refractors
they use *lenses*

Reflectors
they use *mirrors*

Newtonian

Compact

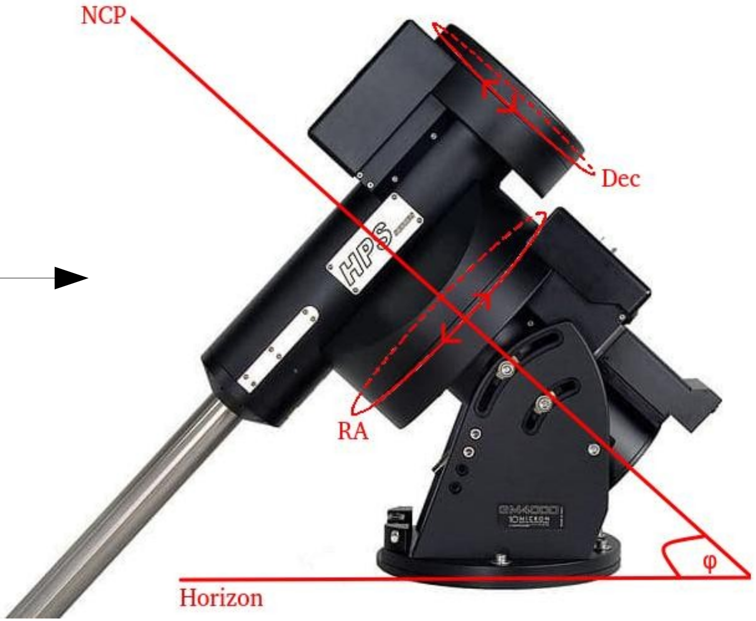




Mounts

Equatorial

they follow RA and Dec



Mounts

Altazimuthal
they follow Az and Alt

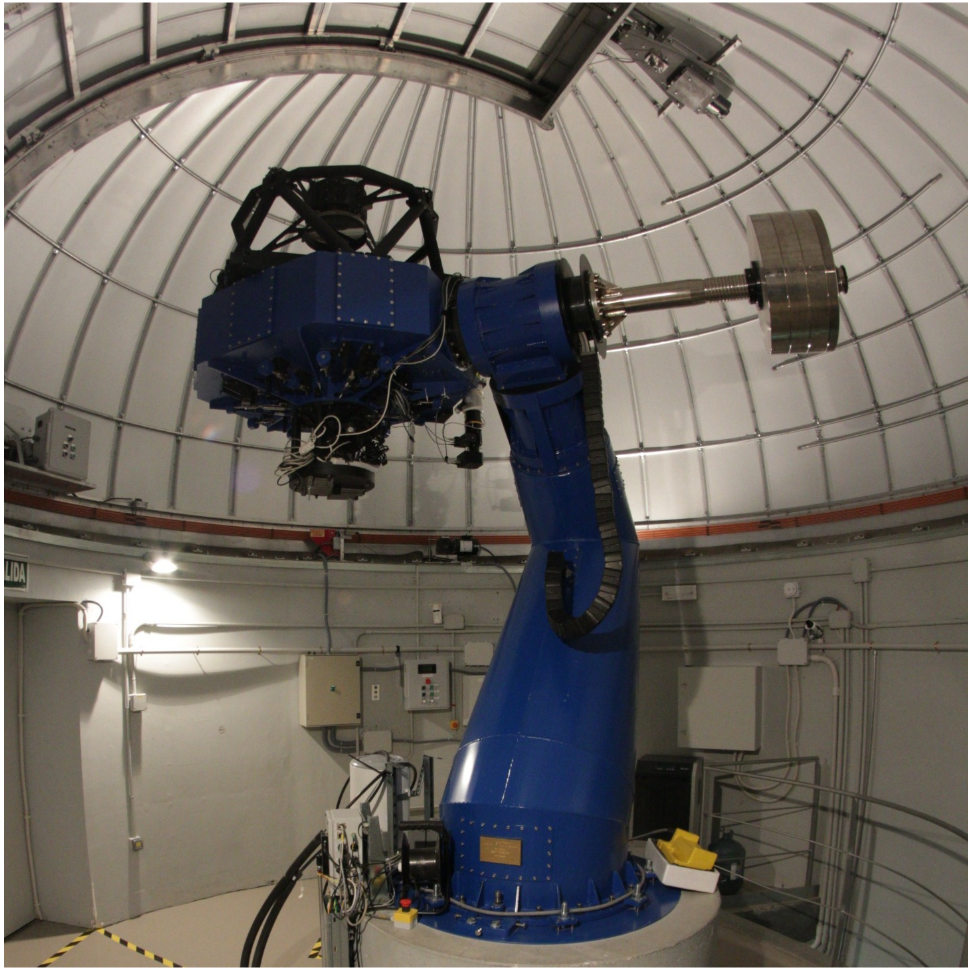
In amateur astronomy these telescopes are referred to as “Dobson”

Telescopes and Mounts

Yerkes refractor,
the world's largest one
(Wisconsin, USA)

- Diameter = 1.02m (40")
- Focal length = 19.4m
- Equatorial mount

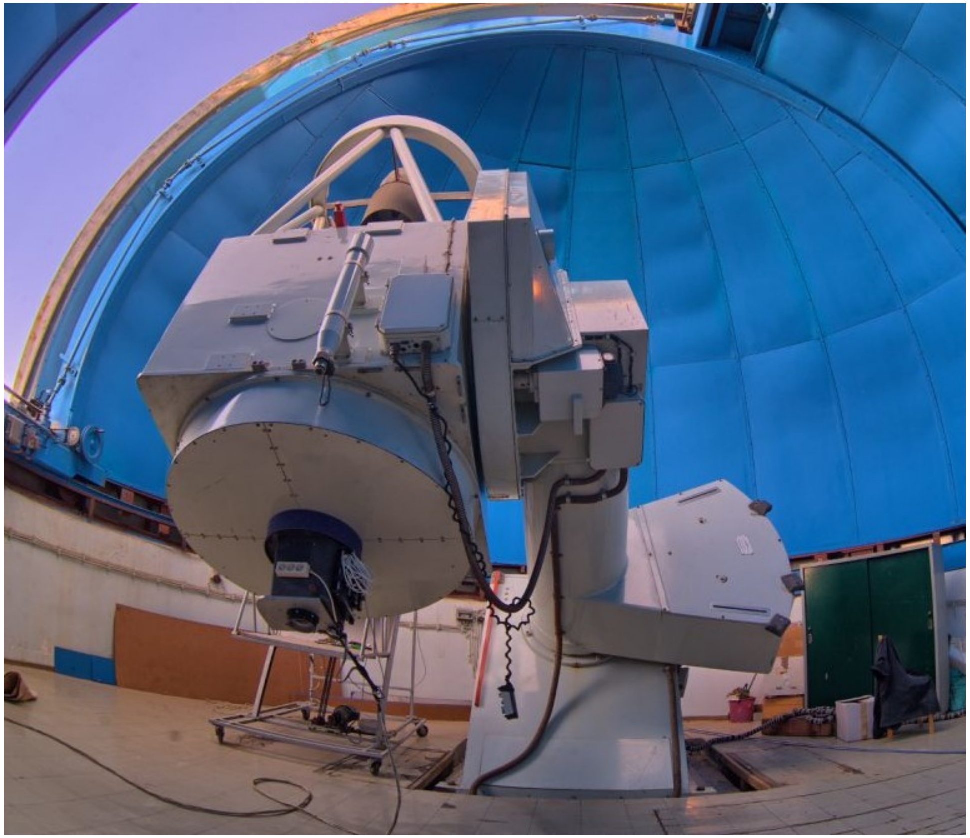
Telescopes and Mounts



JAST80
(OAJ, Spain)

- Diameter = 0.80m
- Focal length = 3.7m
- Equatorial mount

Telescopes and Mounts



The Kryoneri telescope
(Corinth, Greece)

- Diameter = 1.2m
- Focal length = 15.6m
- Equatorial mount

Telescopes and Mounts

The OGS telescope
(OT, Tenerife, Spain)

- Diameter = 1.0m
- Focal length = 13.3m
- Equatorial mount

Telescopes and Mounts

The Isaac Newton Telescope
(ORM, La Palma, Spain)

- Diameter = 2.5m
- Focal length = 8.36m (prime)
  = 38.13m (Cass)
- Equatorial mount

Telescopes and Mounts

The Hale telescope
(Palomar, California, USA)

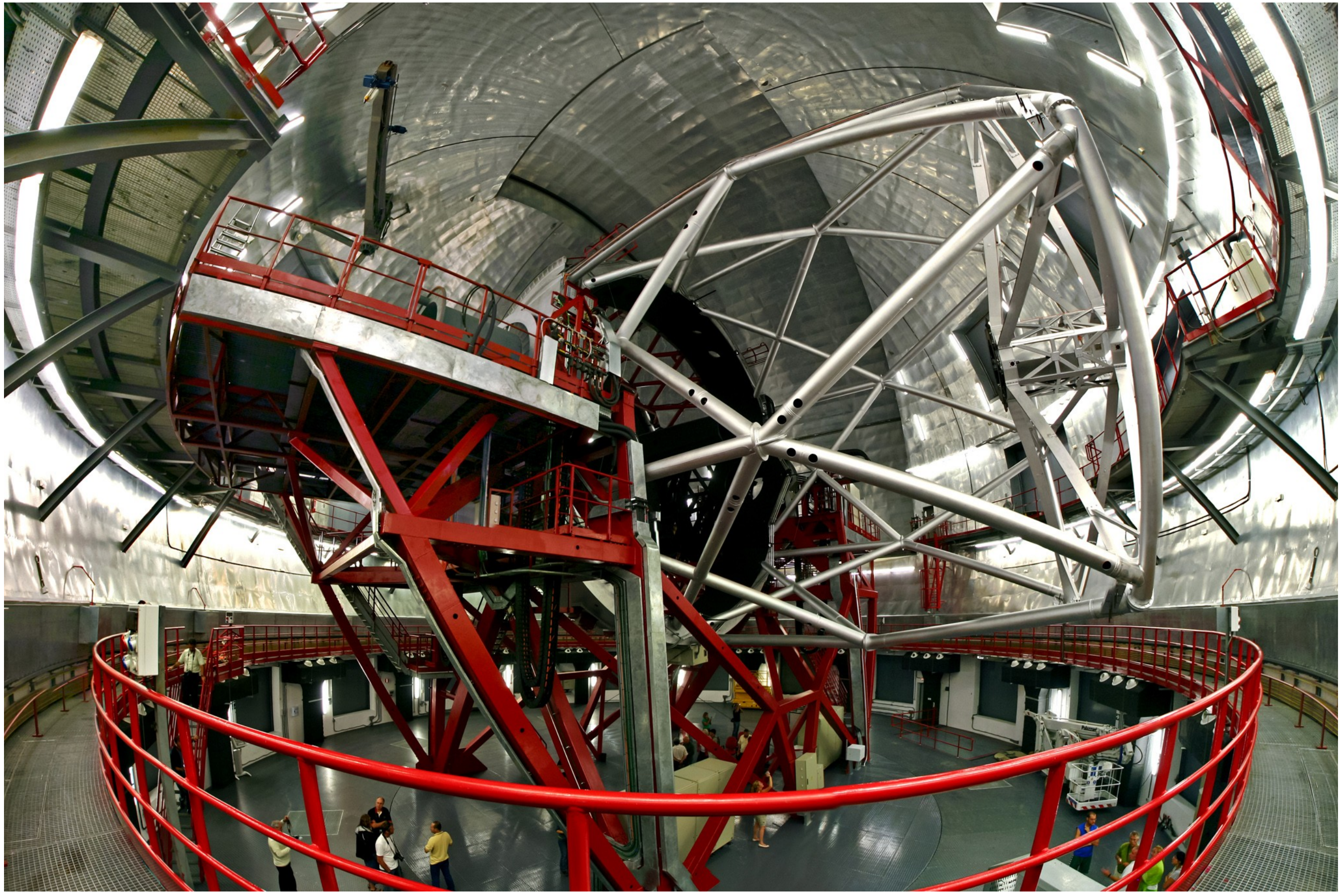
- Diameter = 5.1m (200”)
- Focal length = 16.76m (prime)
  = 81.30m (Cass)
- Equatorial mount – Hale is the largest telescope on such a mount in the world

Telescopes and Mounts

The JST250 telescope
(OAJ, Spain)

- Diameter = 2.5m
- Focal length = 9.1m
- Altazimuthal mount

Telescopes and Mounts



The GTC telescope,
the largest optical telescope

(ORM, La Palma, Spain)

- Diameter = 10.4m
- Focal length = 170m (effective)
- Altazimuthal mount

Taking a closer look

at the GT80

The GT80

- Astrosysteme Austria (ASA), AZ800
- Aperture: 80 cm (diameter)
- Focal length: 5600 mm
- Focal ratio (F/D): f/7

The GT80 – the mount

- What type of mount does the GT80 have?

Altazimuthal, aka AltAz

Altitude/elevation axis

Azimuth axis

The GT80 – the telescope

- What kind of telescope is the GT80?

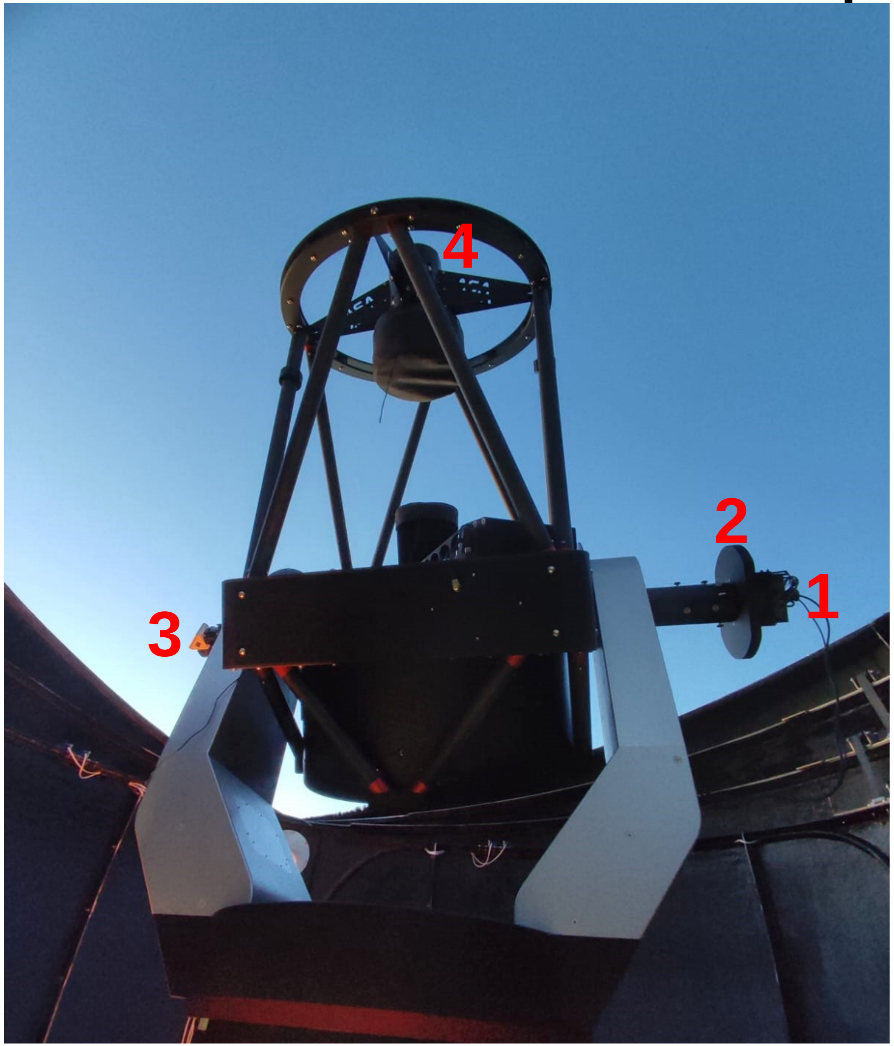
A (compact) reflector. That means that the main optical elements are mirrors

Secondary mirror

Primary mirror

Ritchey-Chrétien: both mirrors are hyperbolic in shape (concave primary, and convex secondary)

The GT80 – other parts of the telescope



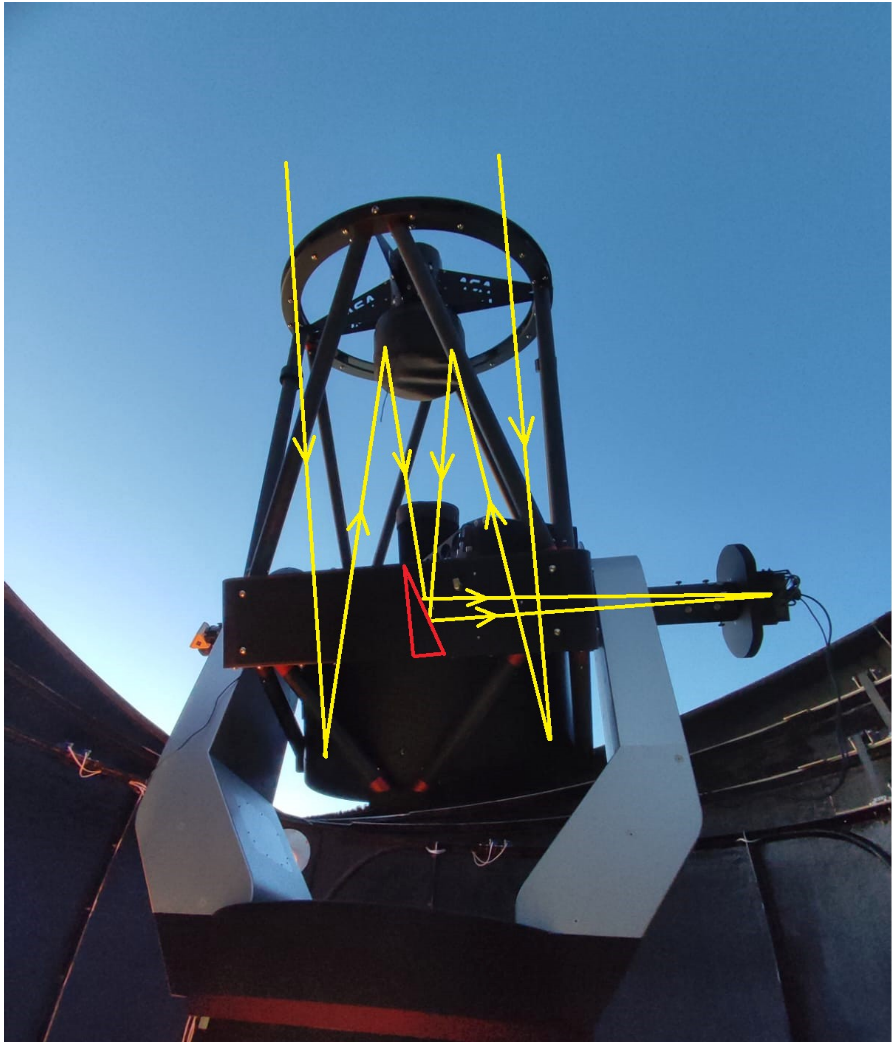
(1) CCD

(2) Filter wheel

(3) Eyepiece

(4) Focuser

The GT80 – the optical path

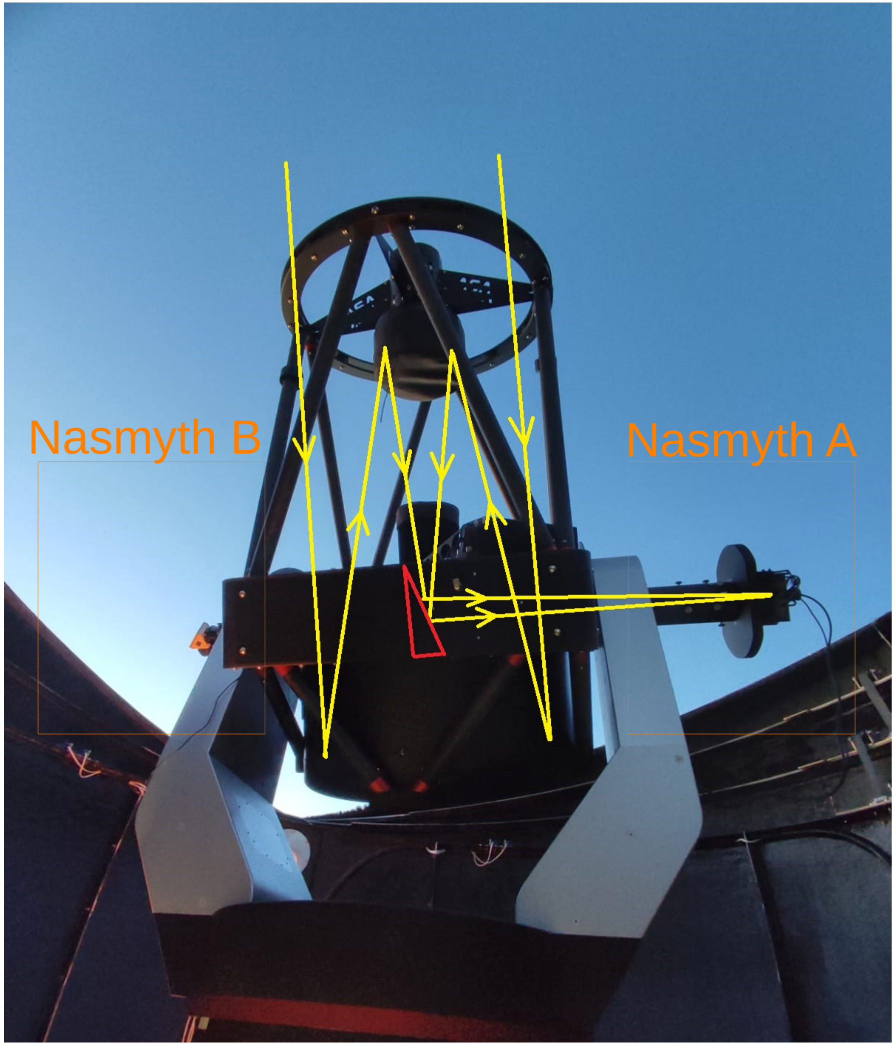


Incoming light from celestial objects is gathered by the primary mirror

The light is then reflected towards the secondary mirror

From there, it is reflected again towards the primary, but meets the (diagonal) ***tertiary*** mirror and is redirected towards the CCD

Instrument mount points

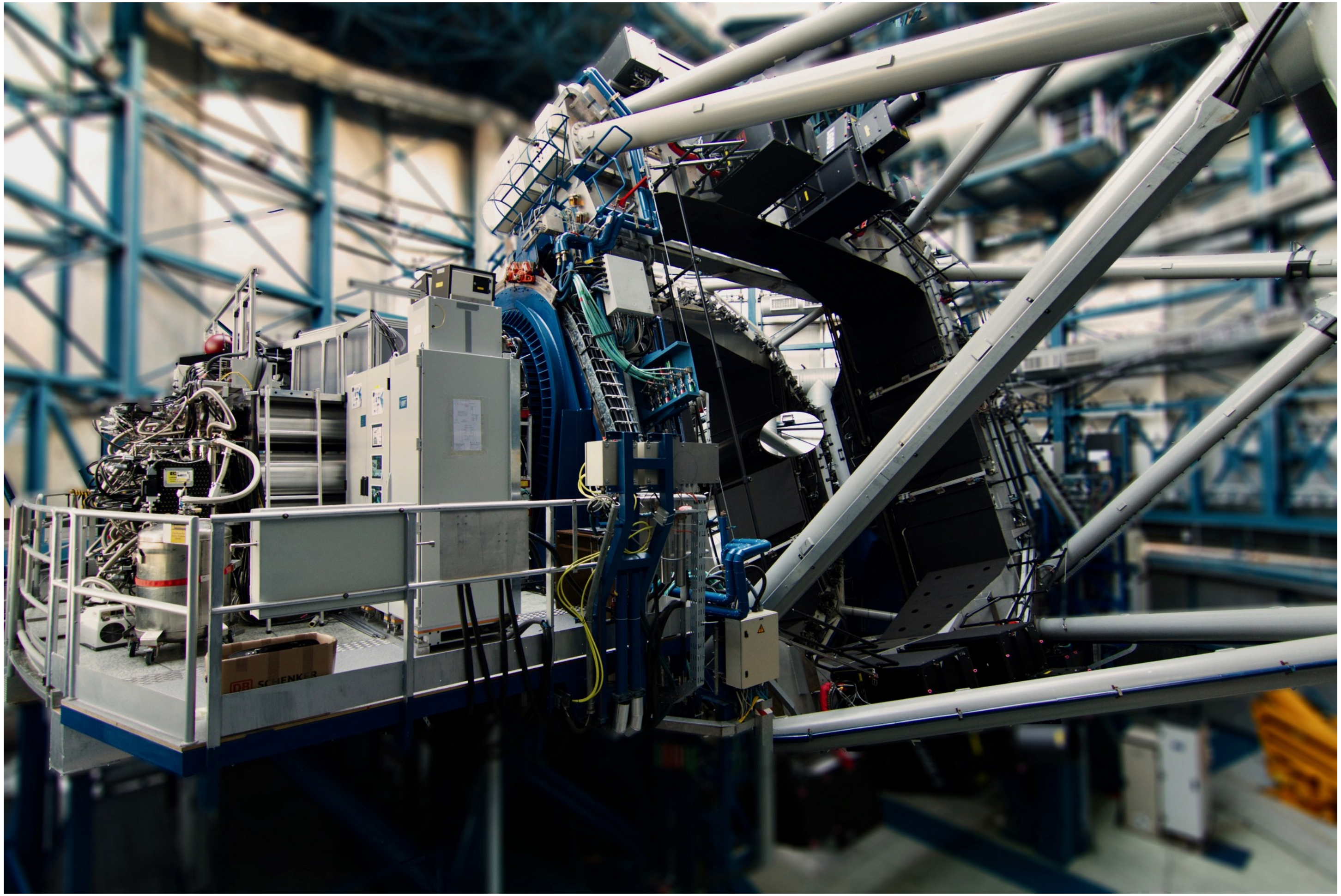


In telescopes with a three-mirror design, we can mount instruments on both sides of the telescope.

These two mount points (or focal points) are known as Nasmyth.

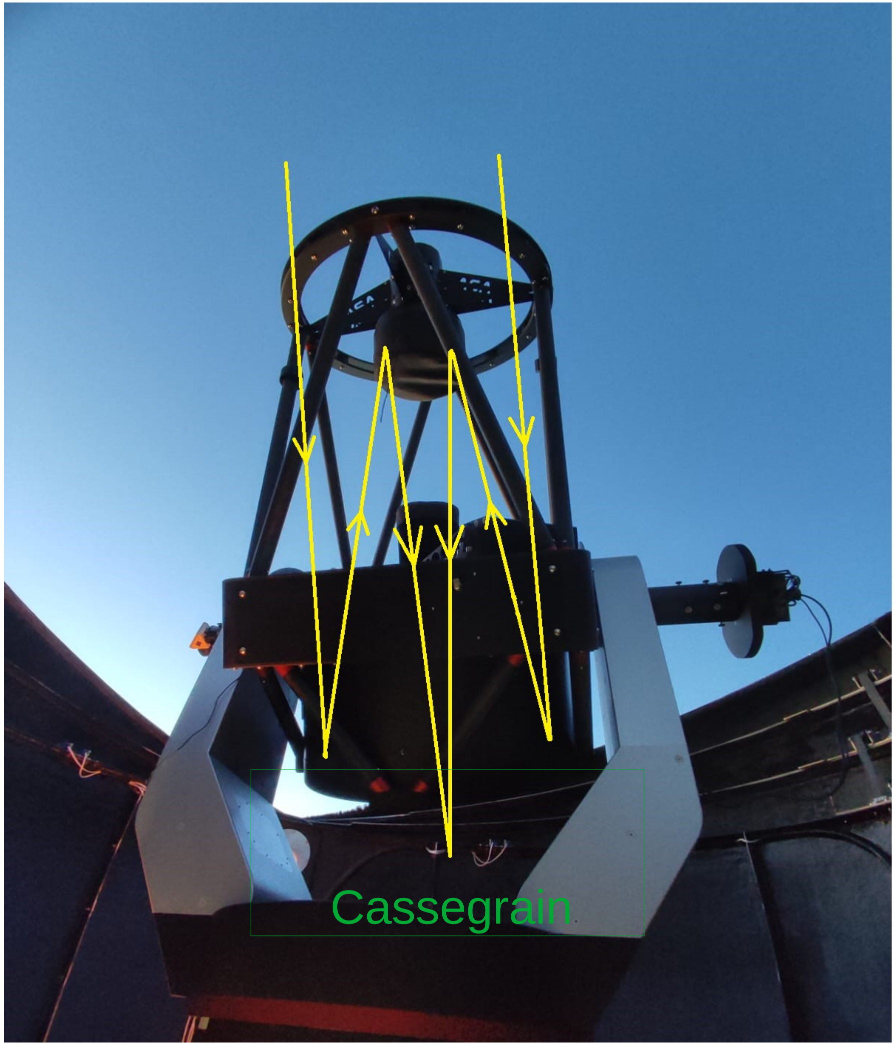
Examples of professional instruments mounted at a Nasmyth focus:

1. *EMIR* – 10.4m GTC @ ORM
2. *HARPS-N* – 3.6m TNG @ ORM
3. *MUSE* – 8.2m VLT/UT4 @ Paranal



MUSE at the Nasmyth focus of VLT/UT4. Credit: R. Bacon

Instrument mount points

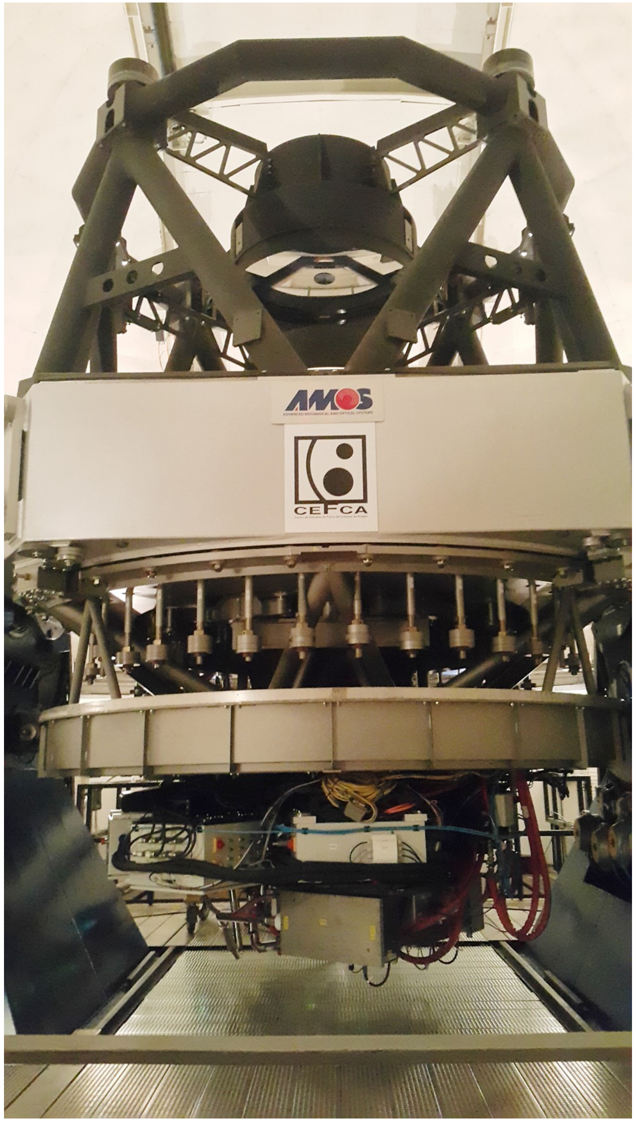


In telescopes with the more traditional two-mirror design, the Nasmyth focal points are no longer available

However, a new mout point becomes available, behind the primary mirror, called the Cassegrain focal point.

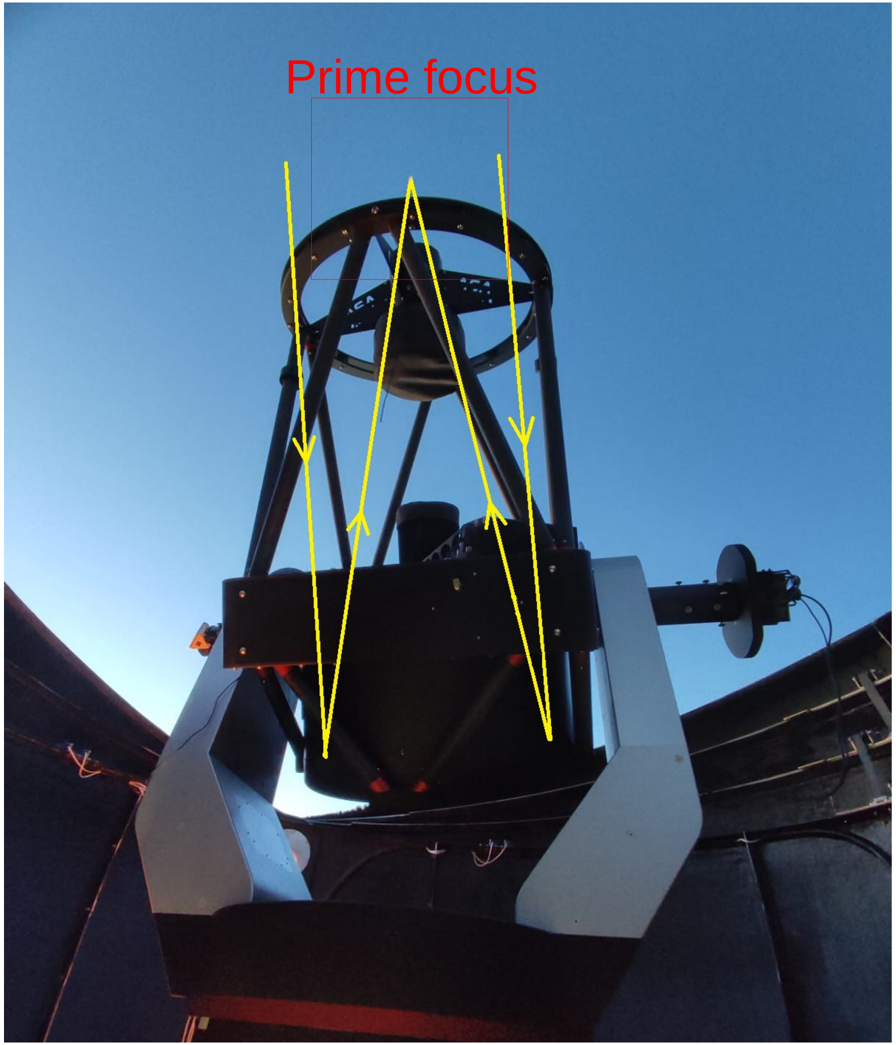
Examples of professional instruments mounted at a Cassegrain focus:

1. *JPCAM* – 2.5m JST @ OAJ
2. *ALFOSC* – 2.5m NOT @ ORM
3. *XShooter* – 8.2m VLT/UT3 @ Paranal



JPCAM mounted at the Cassegrain focus of the JST @ OAJ

Instrument mount points



Athough it is very uncommon, one could have a single-mirror telescope design

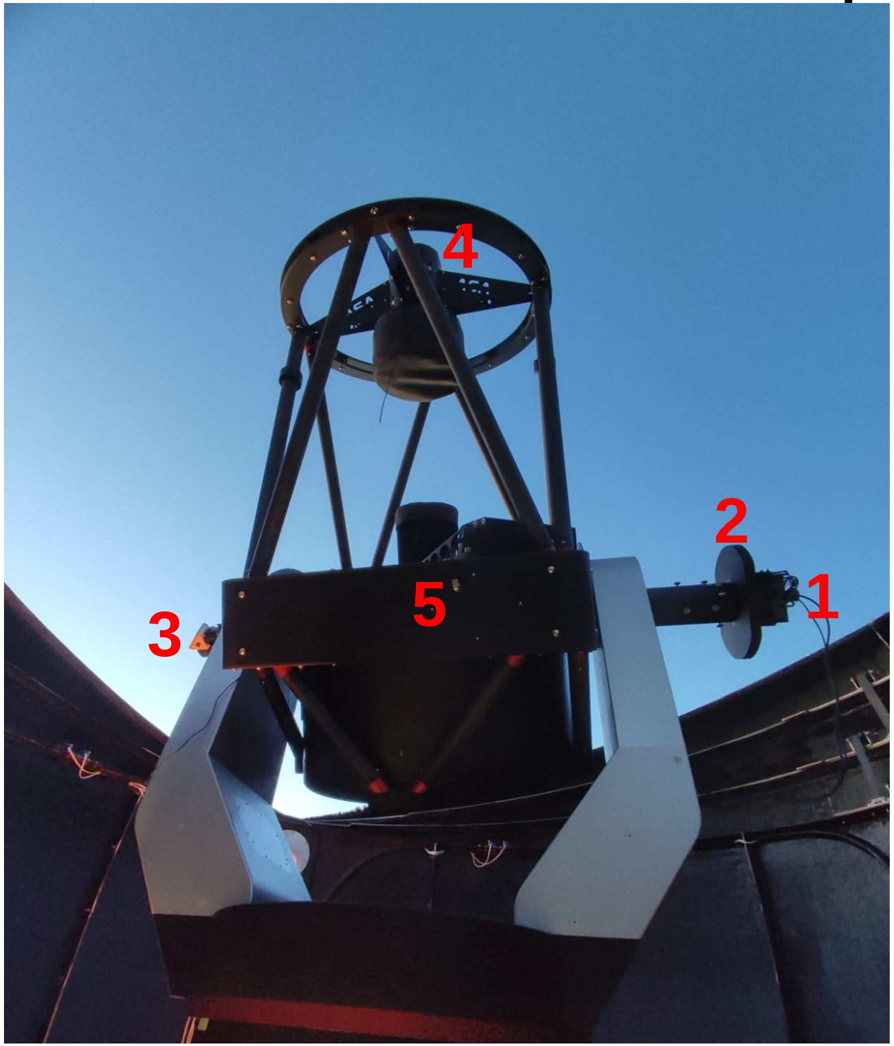
This would enable the prime focus mount point

Examples of professional instruments mounted at the prime focus

1. *WFC* – 2.5m INT @ ORM
2. *WEAVE* – 4.2m WHT @ ORM

WEAVE mounted at the prime focus of the WHT.
Credit: Javier Méndez, ING

The GT80 – other parts of the telescope



(1) CCD (Nasmyth A)

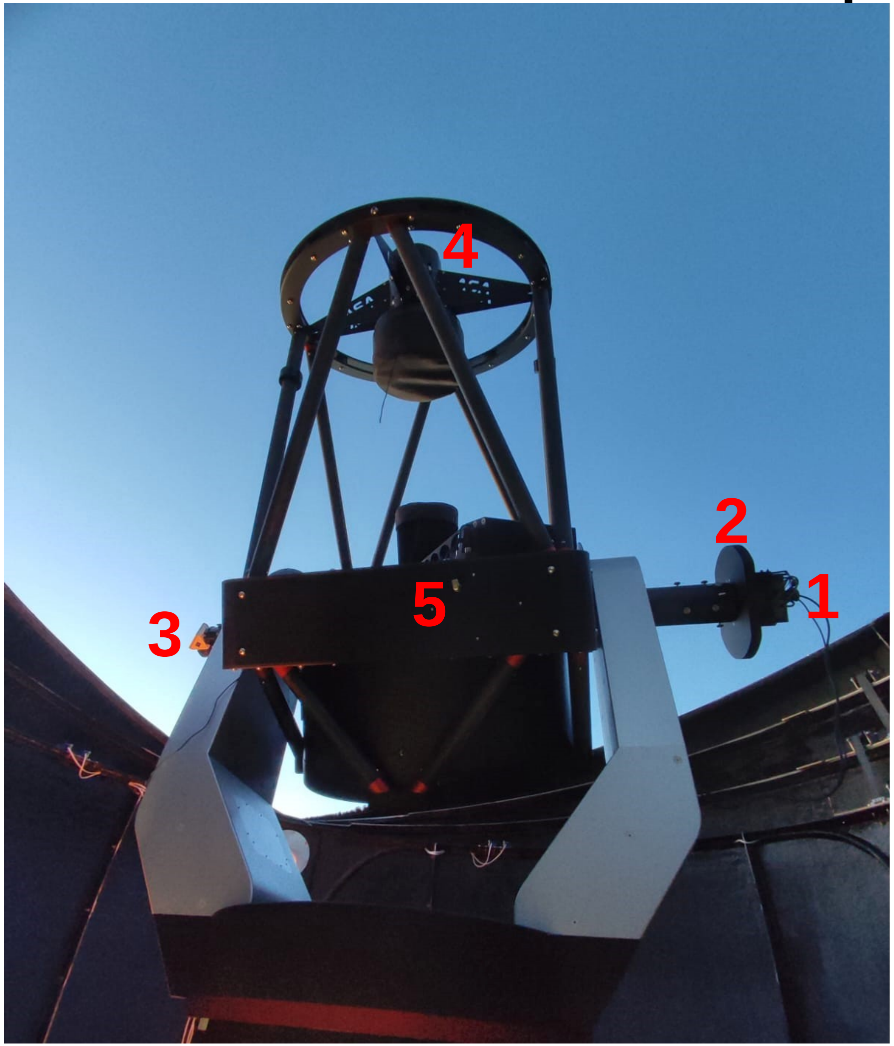
(2) Filter wheel

(3) Eye piece (Nasmyth B)

(4) Focuser

(5) Tertiary mirror

The GT80 – other parts of the telescope



(1) CCD (Nasmyth A)

(2) Filter wheel

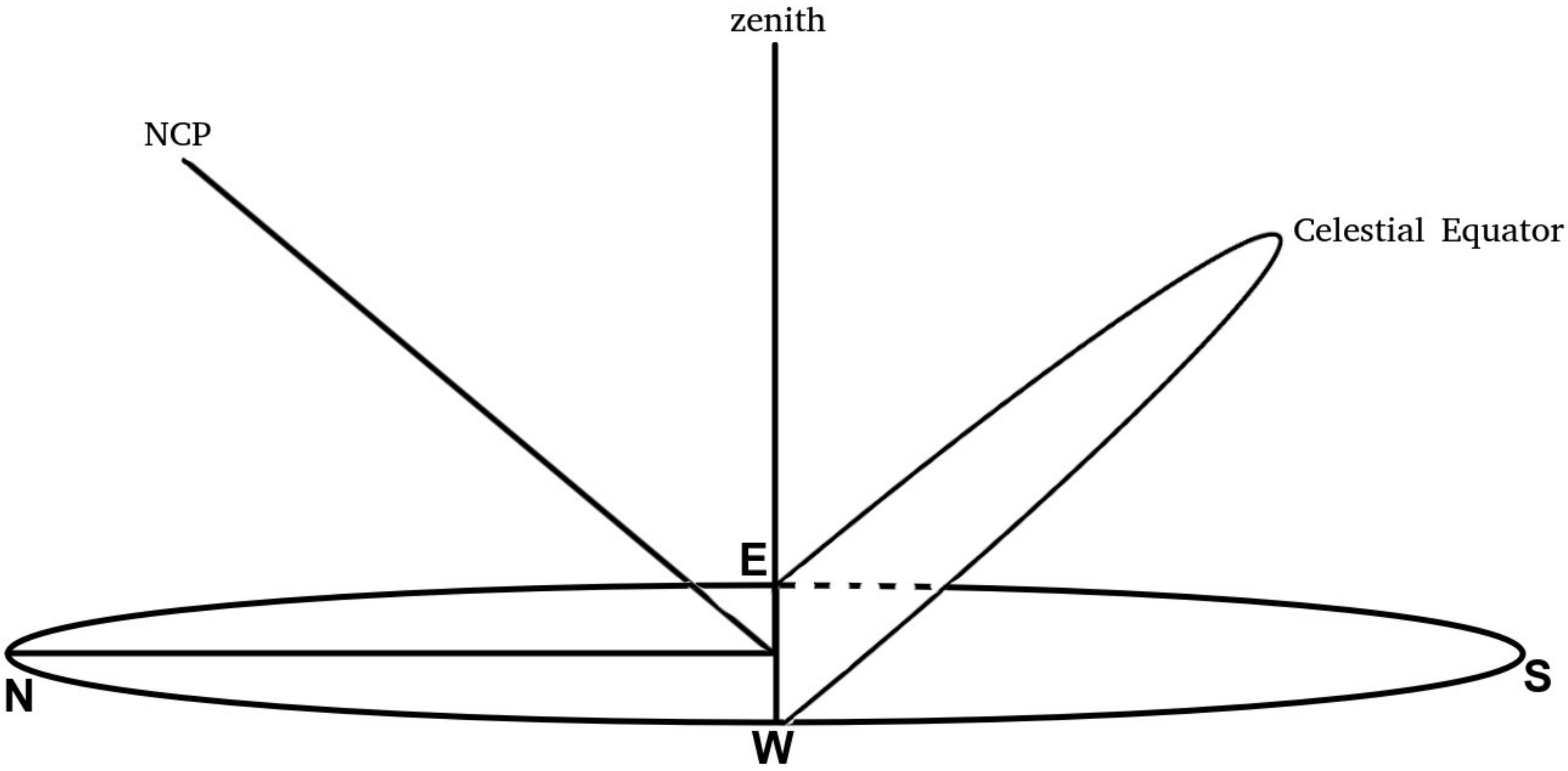
(3) Eye piece (Nasmyth B)

(4) Focuser

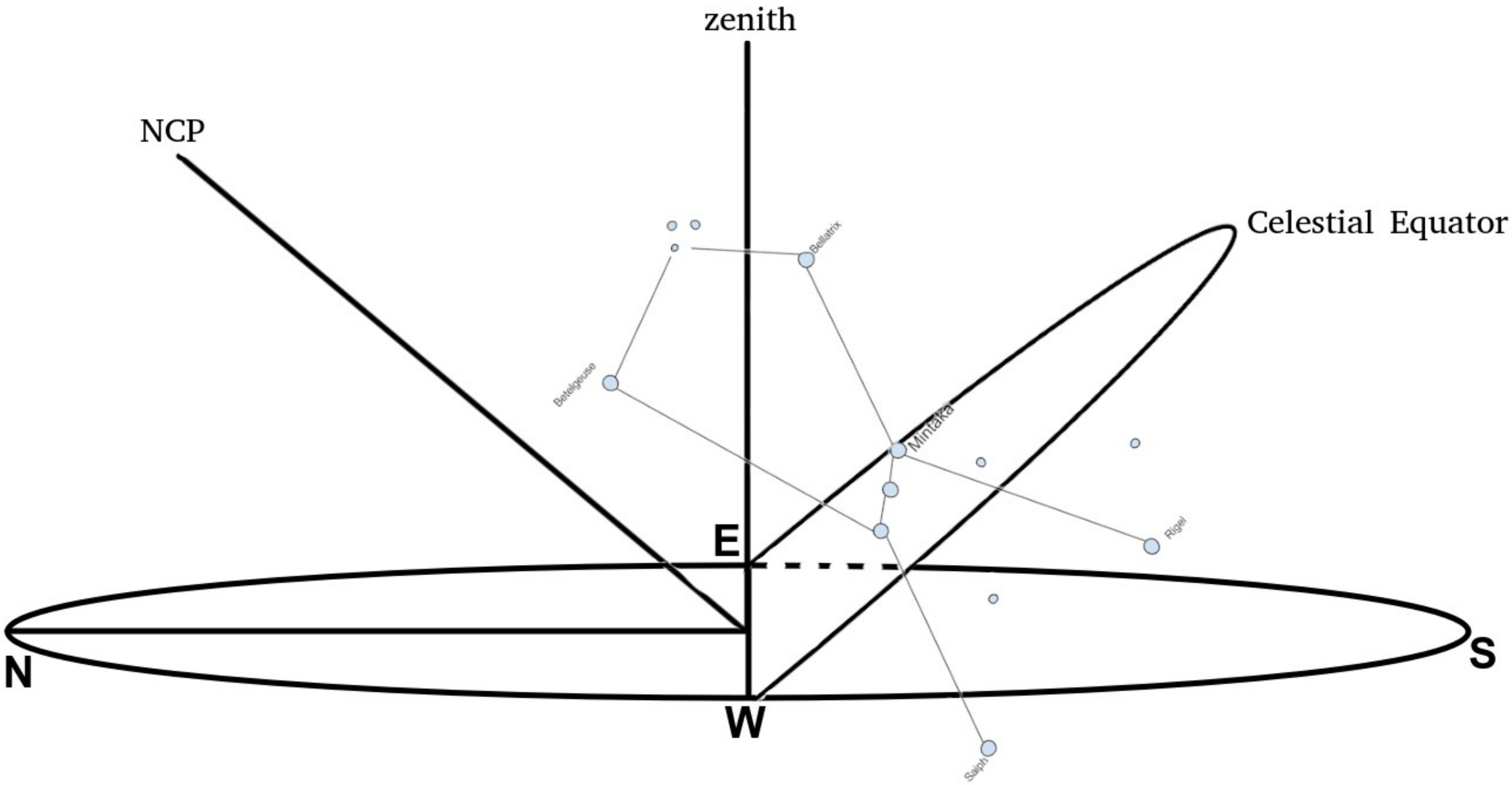
(5) Tertiary mirror

(6) ???

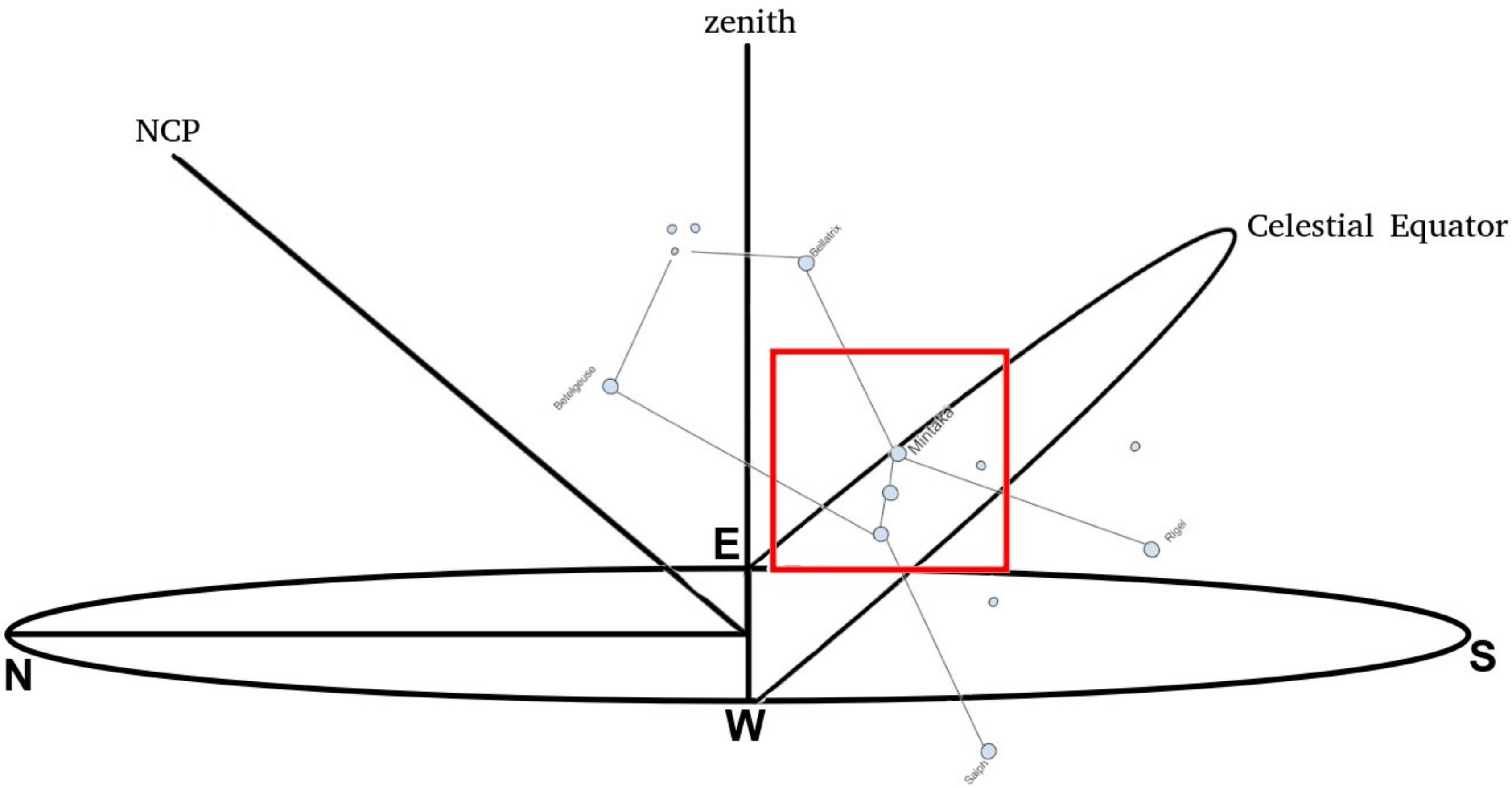
Field rotation – looking East



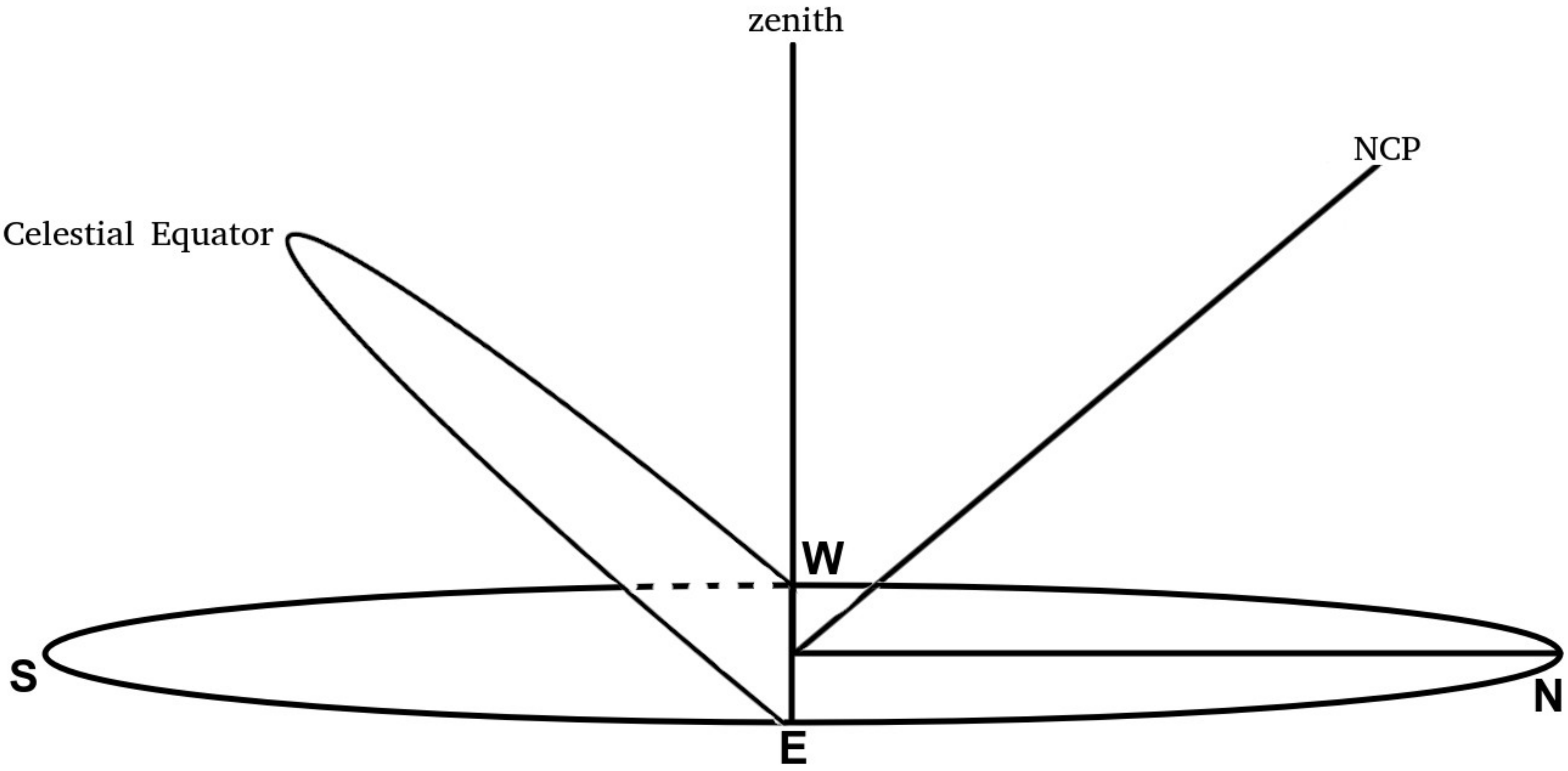
Field rotation – looking East



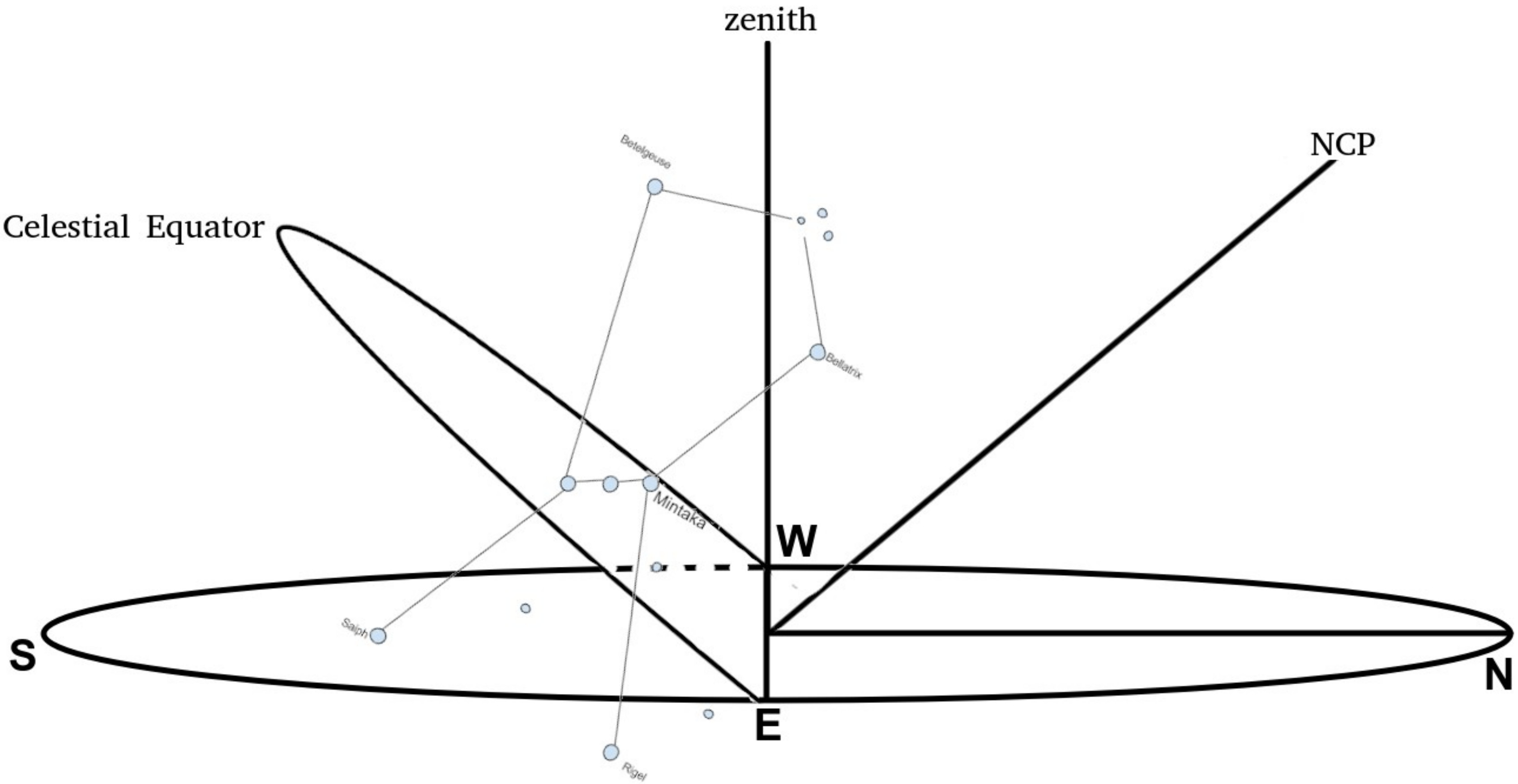
Field rotation – looking East



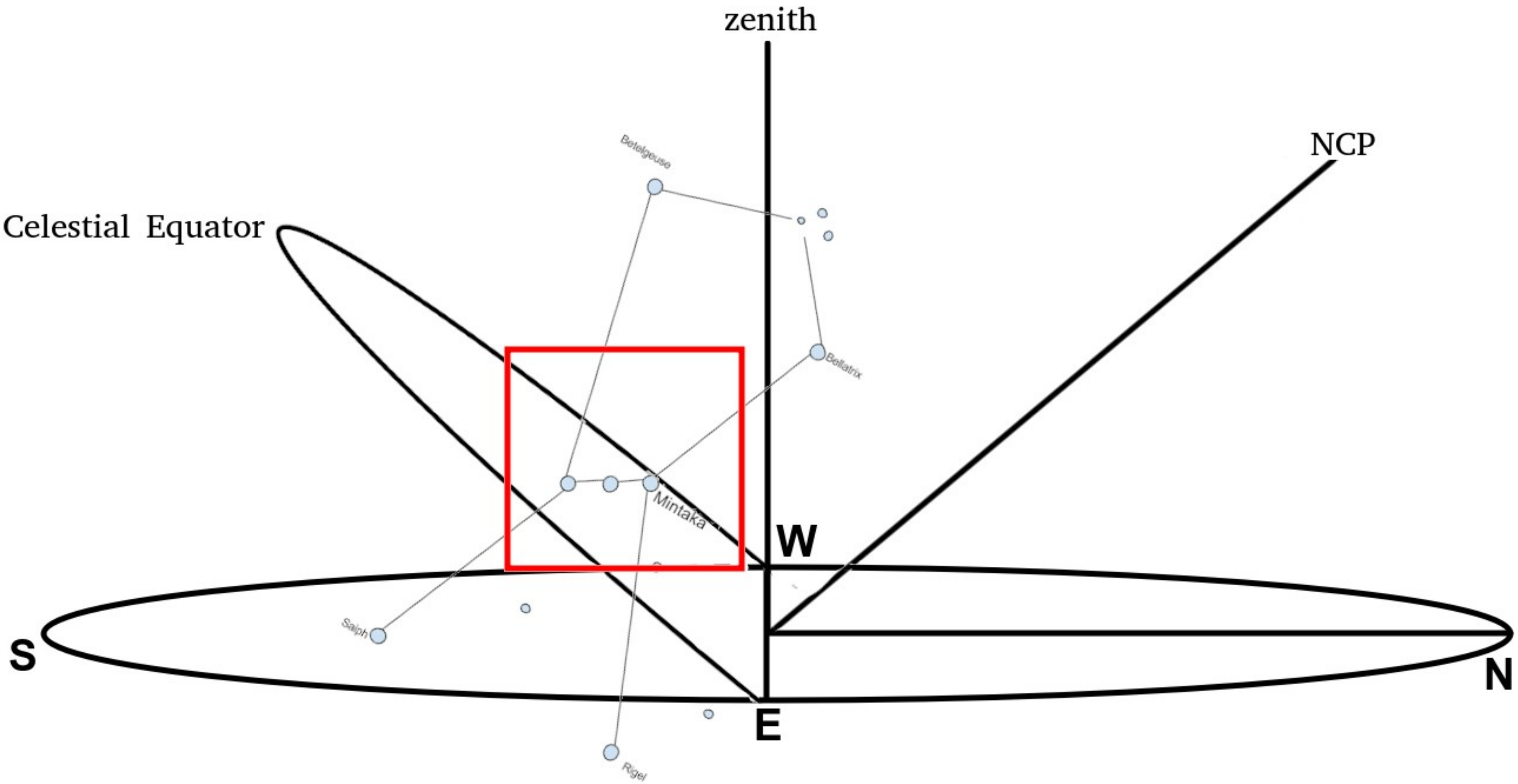
Field rotation – looking West



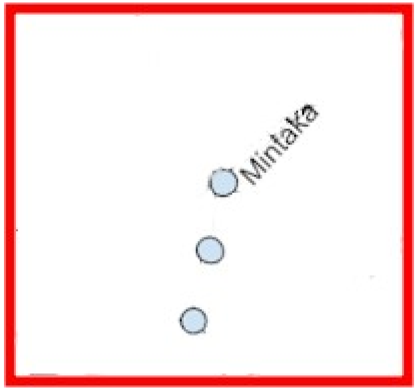
Field rotation – looking West



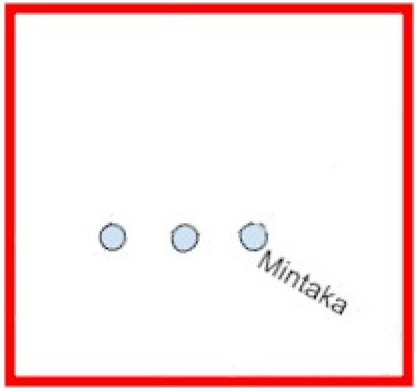
Field rotation – looking West



Field rotation – comparing the two images

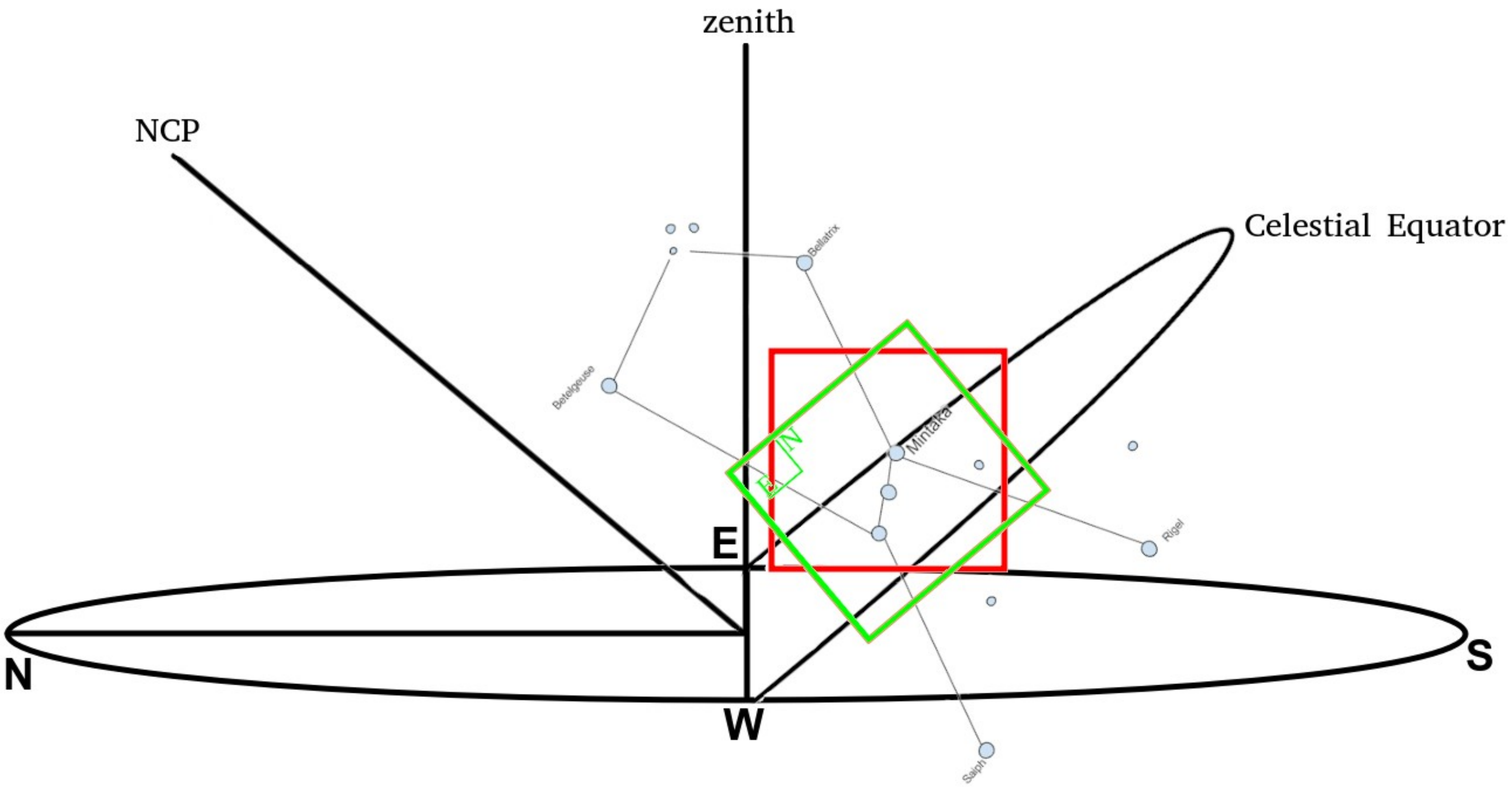


EAST

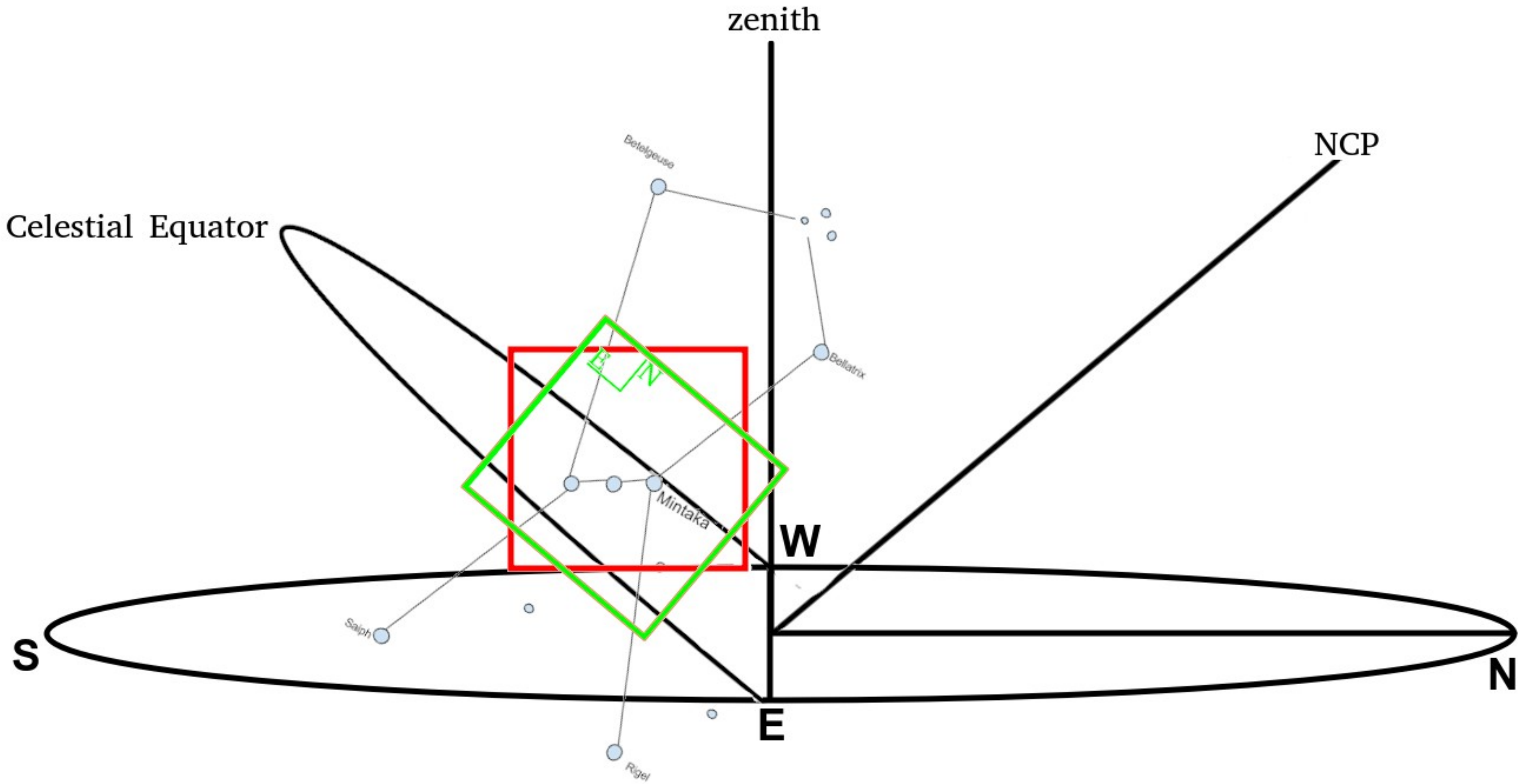


WEST

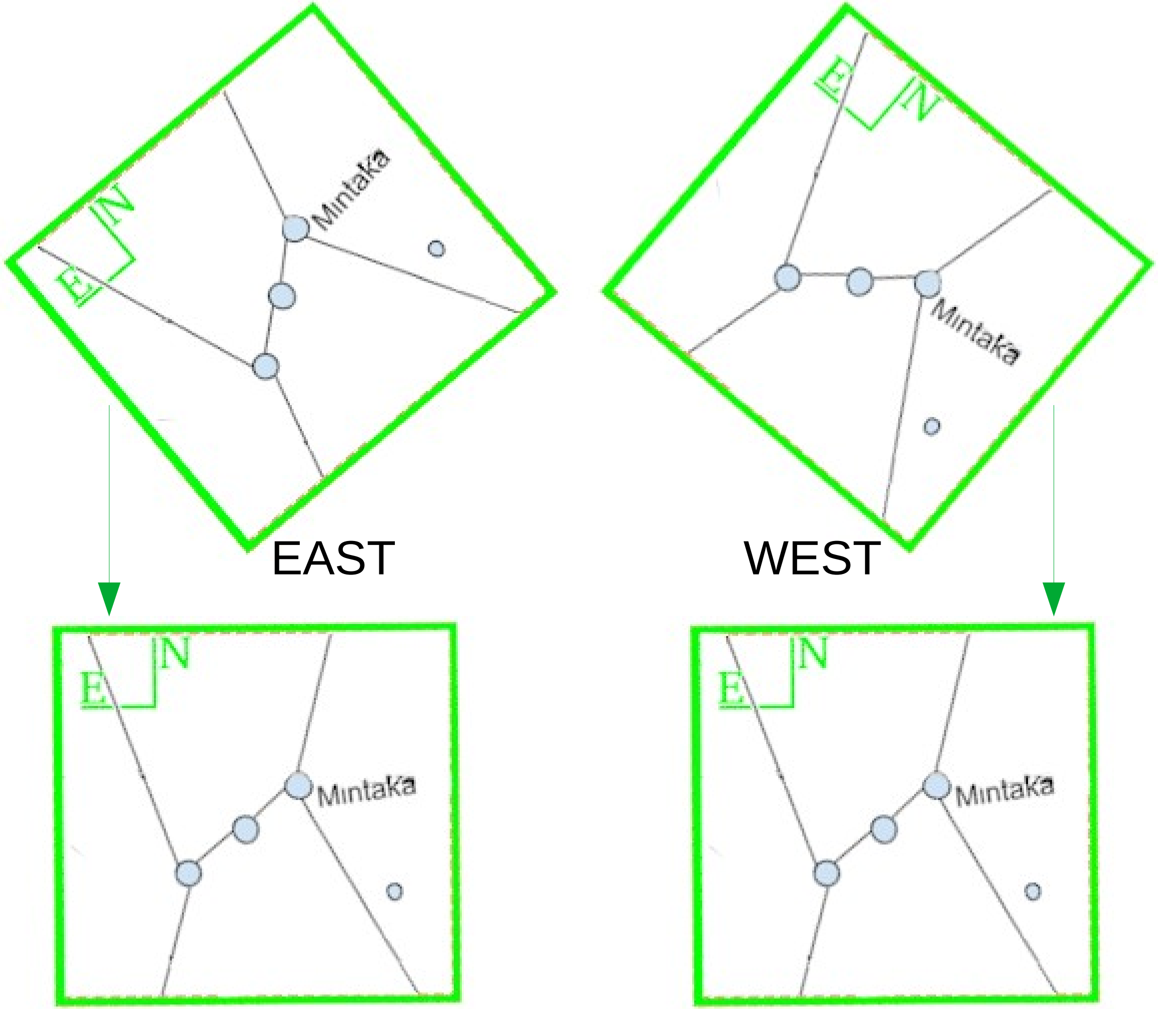
Field rotation – rotating the CCD counter clock-wise when looking East



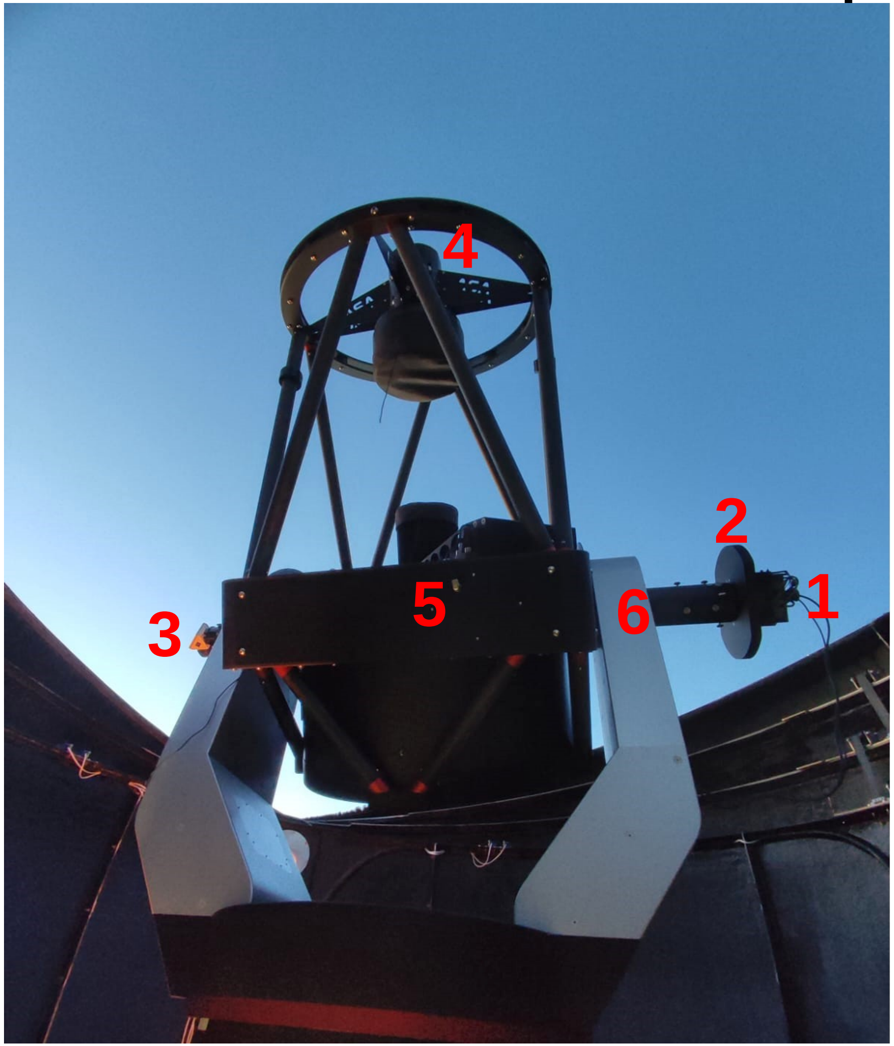
Field rotation – rotating the CCD clock-wise when looking West



Field rotation – comparing the two images



The GT80 – other parts of the telescope



(1) CCD (Nasmyth A)

(2) Filter wheel

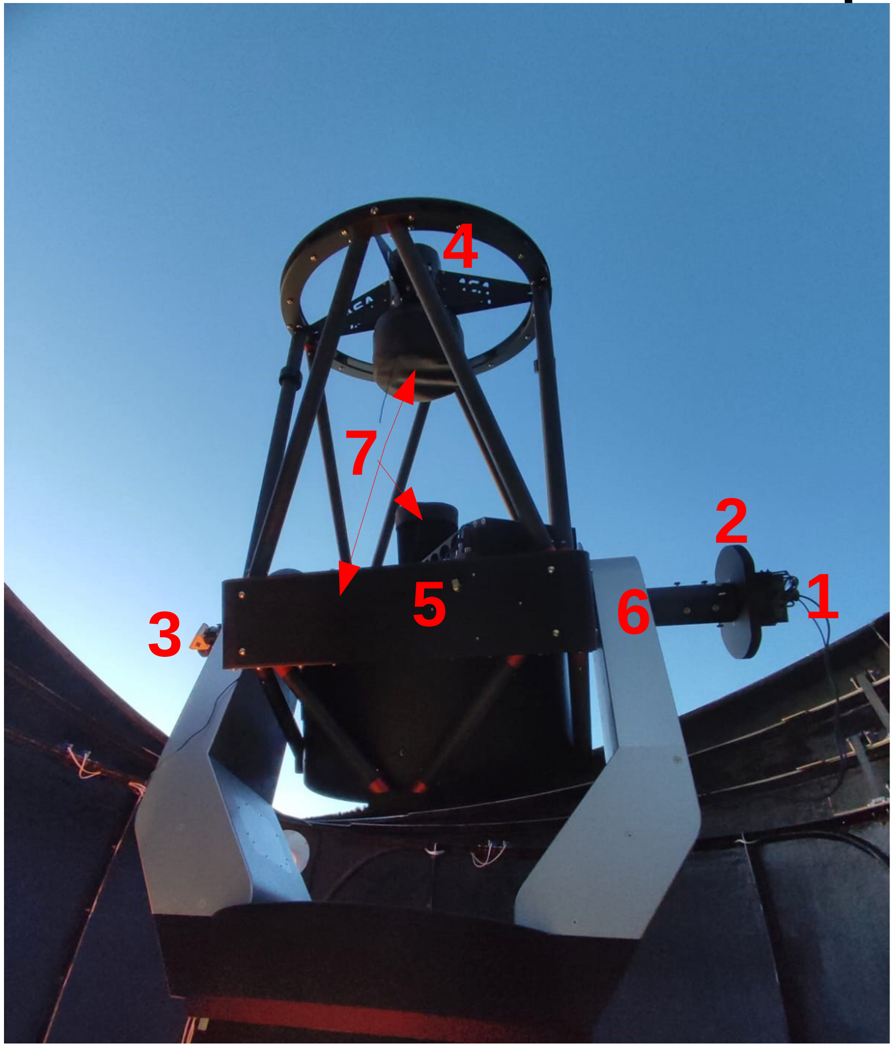
(3) Eye piece (Nasmyth B)

(4) Focuser

(5) Tertiary mirror

(6) Rotator

The GT80 – other parts of the telescope



(1) CCD (Nasmyth A)

(2) Filter wheel

(3) Eye piece (Nasmyth B)

(4) Focuser

(5) Tertiary mirror

(6) Rotator

(7) Protection (primary mirror petals, secondary & tertiary mirror caps)