AGA5802
Telescopes

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What is a telescope for?

“Looking far”

Yet, a telescope, by itself, is meaningless

What does a telescope need?

(at least) an instrument

A mount

A dome

An astronomer

Telescopes

The first one to use a telescope has been...

Thomas Harriott

… but he did not tell anyone!

The first victim of *publish or perish*.

Galileo Galilei (1564 - 1642)

“Invented” the scientific method

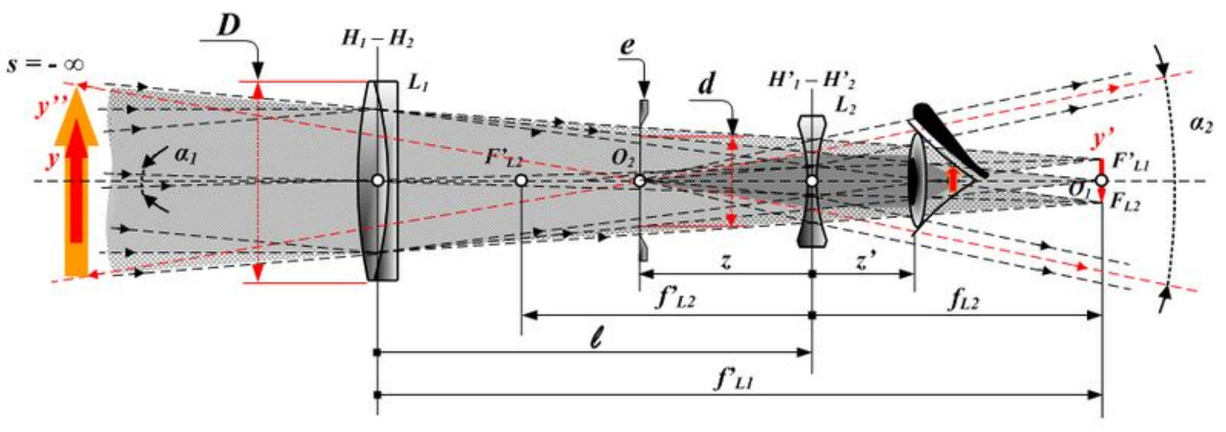
Observed both the Moon and the Sun

Discovered the 4 largest moons of Jupiter

Discovered that the Milky Way is made of stars

Galilei’s Telescope

2 lenses



Lens

A lens can be convex or concave.

Lensmaker Equation:

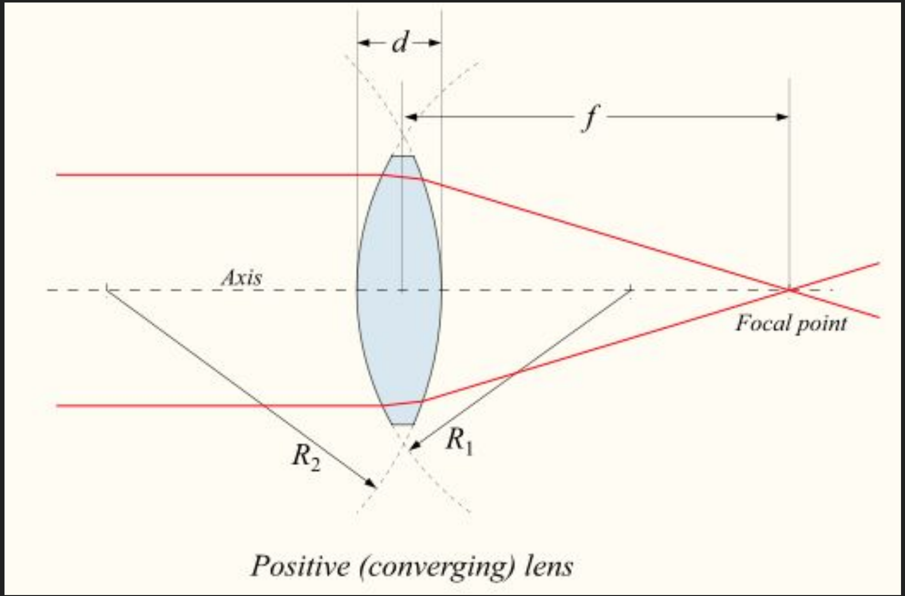
$$1/f = (n-1)\,[1/R_1 - 1/R_2 + (n-1)d/nR_1R_2]$$

Where:

f focal length of the lens

n refractive index of the lens **(function of lambda)**

d thickness of the lens



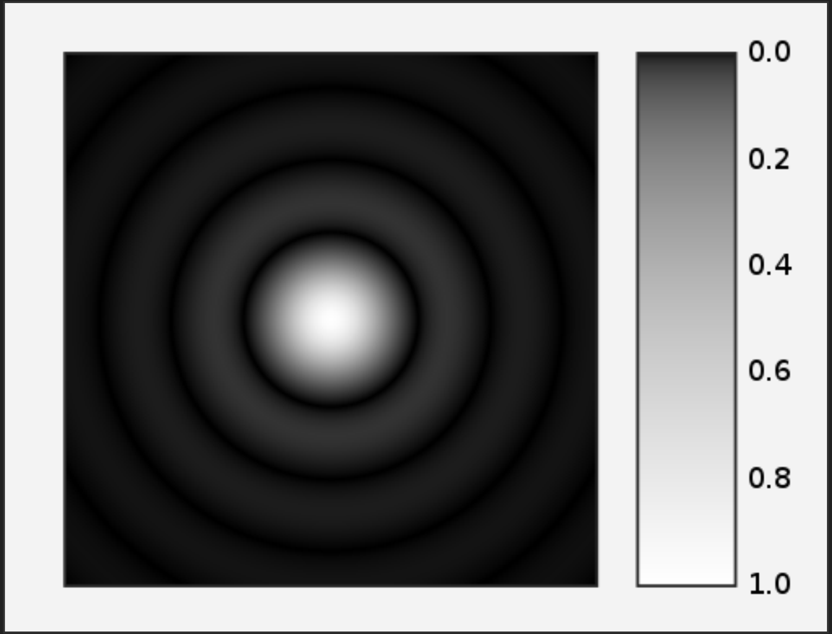
What does the size of a telescope tell us?

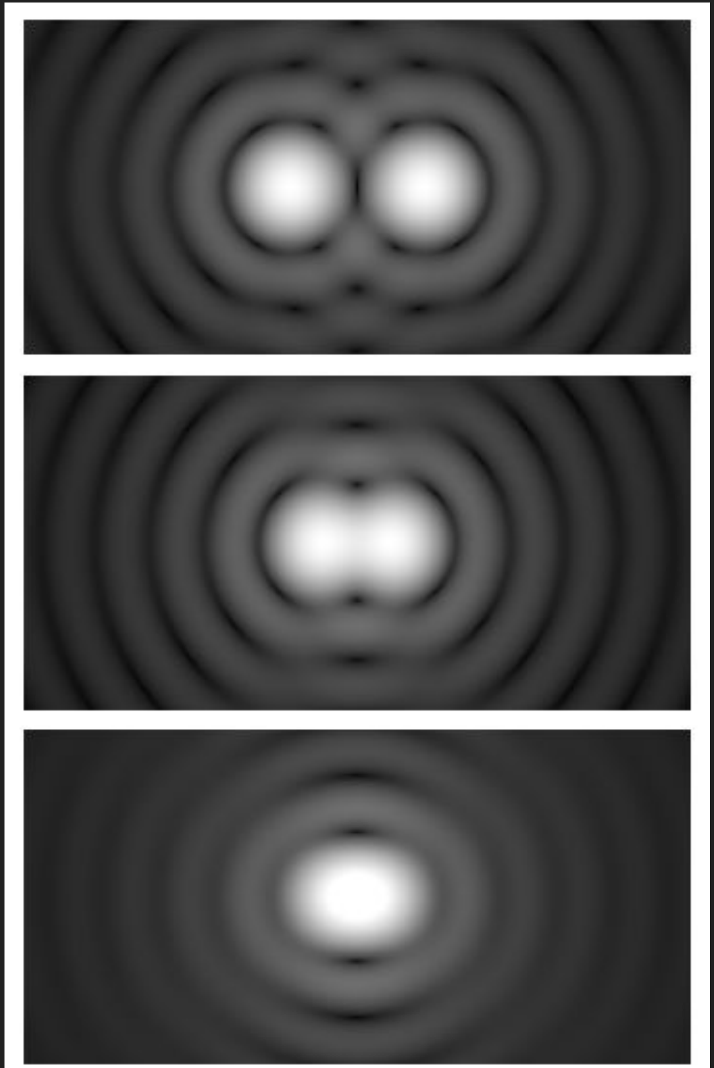
Collecting area!

Resolution!

Diffraction

r = 1.22 λ/D => Airy disc and Rayleigh criteria





Focus

Is being out of focus a bad thing?

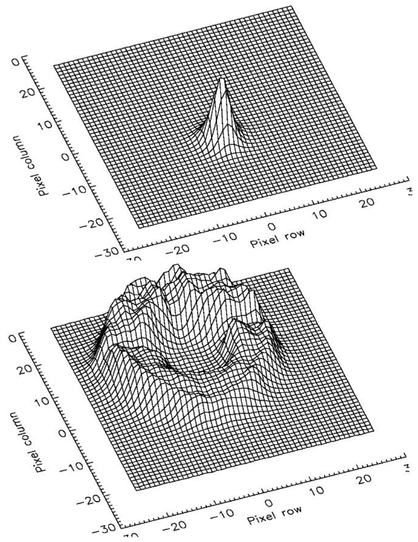


Fig. 1.— Surface plots of two PSFs. Upper panel: PSF of XO3 (2012/02/11) with the telescope well focused and an exposure time of 12s. Lower panel: PSF of HATP22 (2014/01/13) with the telescope defocused heavily allowing for a much longer exposure time of 195s. Both stars are of same brightness (see Table 2).

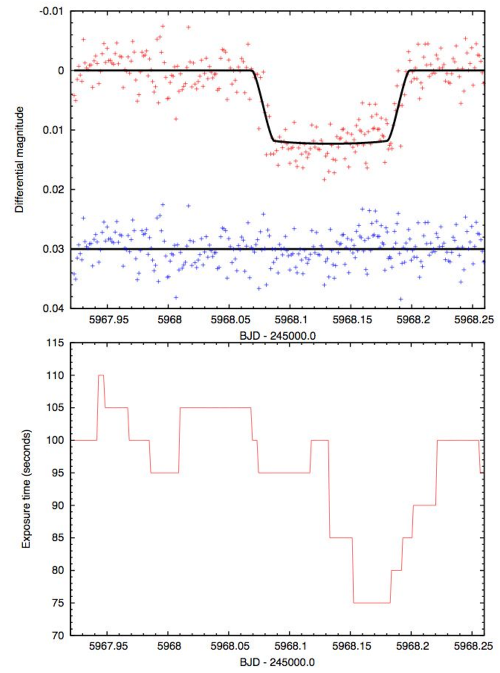
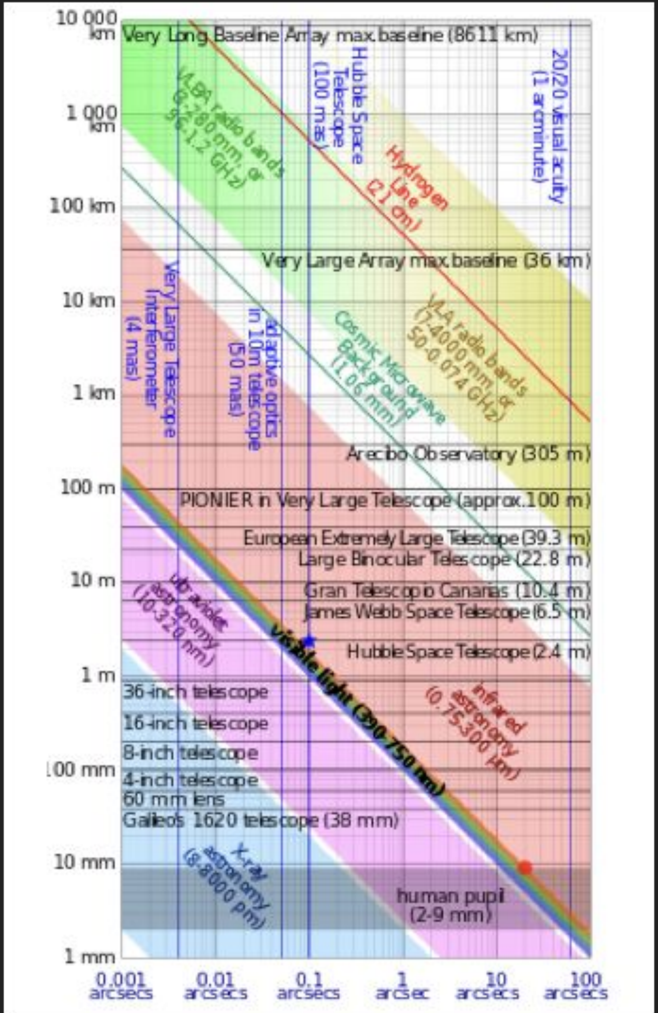


Fig. 3.— Light-curve of XO5 as observed on 2012/02/10 with the telescope in focus. Upper panel: The RMS scatter around the best-fit model is 2.98 mmag. The large scatter does not allow for a detailed limb-darkening treatment. Ingress and egress phases are not characterised well. The mid-transit time is at BJD $2,455,968.13350 \pm 0.00061$. Lower panel: Various choices of exposure times during the observing period. Some correlations between short exposures and large scatter is visible.

http://adsabs.harvard.edu/abs/2015JASS...32...21H

Examples

	Diameter	wavelength	Resolution
Human eye	5mm	550nm	69”
Galileo’s telescope	2cm	550nm	7”
OPD	1.6m	600nm	0.09”
GTC	10.4m	600nm	0,01”
GMT	24m	600nm	0,007”
GMT	24m	2.4µm	0,03”
VLTI	100m	2.4µm	0,006”



10 000 km
1 000 km
100 km
10 km
1 km
100 m
10 m
1 m
100 mm
10 mm
1 mm
0.001 arcsecs
0.01 arcsecs
0.1 arcsecs
1 arcsec
10 arcsecs
100 arcsecs
Very Long Baseline Array max.baseline (8611 km)
VLBA radio bands (3-780 mm, or 96-1.2 GHz)
Hubble Space Telescope (100 mas)
Hydrogen Line (21 cm)
20/20 visual acuity (1 arcminute)
Very Large Array max.baseline (36 km)
Very Large Telescope Interferometer (4 mas)
adaptive optics in 10m telescope (50 mas)
Cosmic Microwave Background (1.06 mm)
VLA radio bands (7-4000 mm, or 50-0.074 GHz)
Arecibo Observatory (305 m)
PIONIER in Very Large Telescope (approx.100 m)
European Extremely Large Telescope (39.3 m)
Large Binocular Telescope (22.8 m)
Gran Telescopio Canarias (10.4 m)
James Webb Space Telescope (6.5 m)
Hubble Space Telescope (2.4 m)
ultraviolet astronomy (10-320 nm)
visible light (390-750 nm)
infrared astronomy (0.75-300 μm)
36-inch telescope
16-inch telescope
8-inch telescope
4-inch telescope
60 mm lens
Galileo's 1620 telescope (38 mm)
X-ray astronomy (8-8000 pm)
human pupil (2-9 mm)

Collective Area

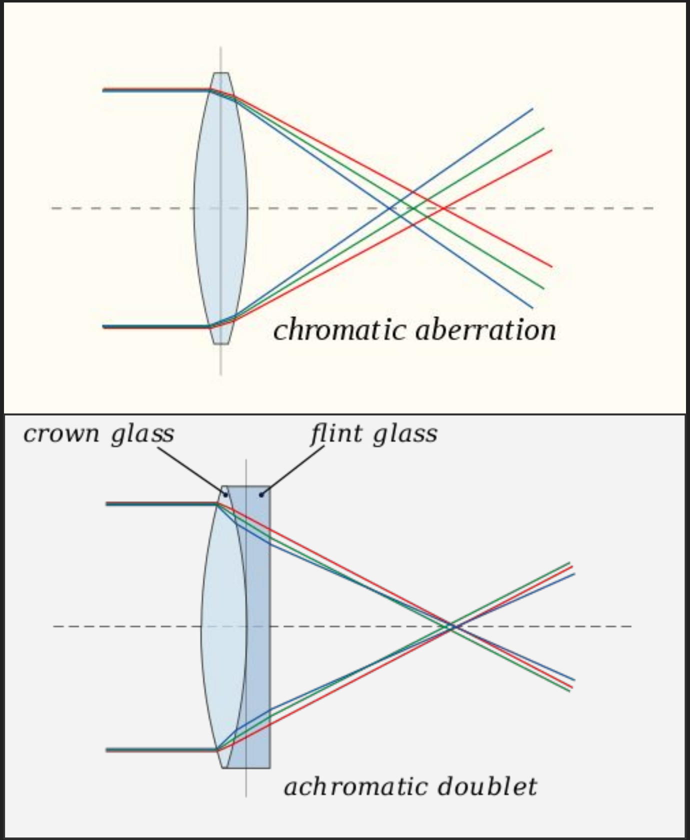
Amount of photons collected scales linearly with area

This means that it scales quadratically with telescope diameter!

Refractive telescopes downsides

https://en.wikipedia.org/wiki/List_of_largest_optical_refracting_telescopes

<= Yerkes 40inches (~1m)



Expensive

Difficult to make

Suffer chromatic aberration

Sir. Isaac Newton (1643 - 1727)

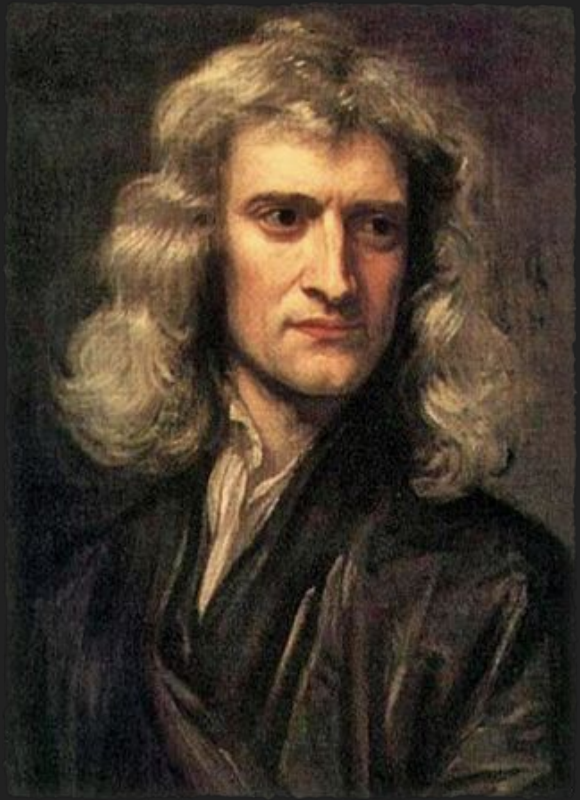
Invented optics.

Invented calculus.

Invented classical mechanics.

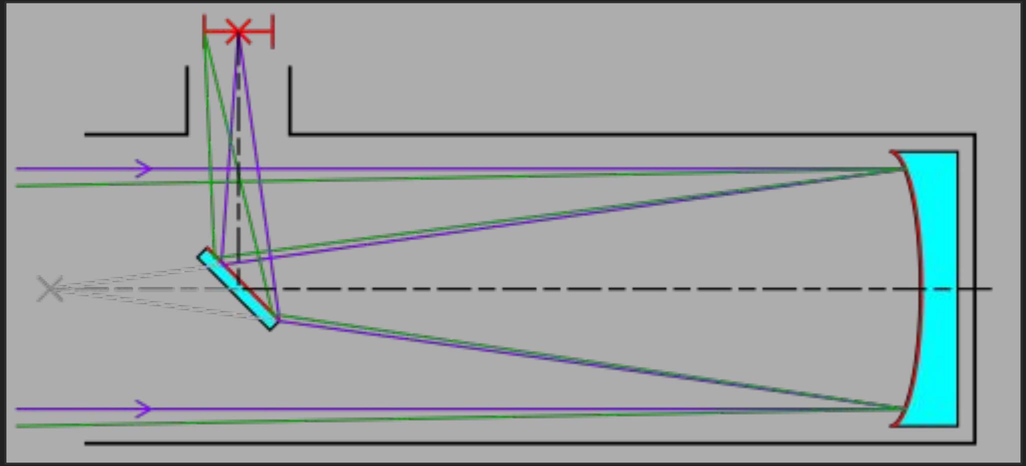
Invented gravity.

Invented the reflective telescope.



Newtonian Telescope

One parabolic mirror and a flat mirror



Focal Length

f/D -> f-ratio

Small f-ratio => fast optics

Large f-ratio => slow optics

Plate scale: 1 / f

Plate scale (“/mm) = 206 265 / f (mm)

Different types of optical designs

Newtonian

Cassegrain

Ritchey Chretien

Gregorian

Cassegrain and Ritchey-Chrétien

Cassegrain

2 mirrors

Parabolic primary

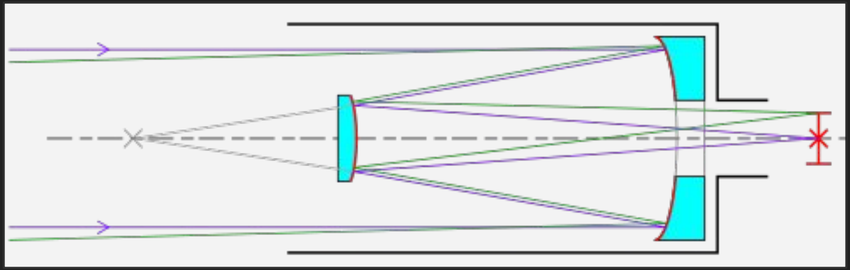
Hyperbolic secondary

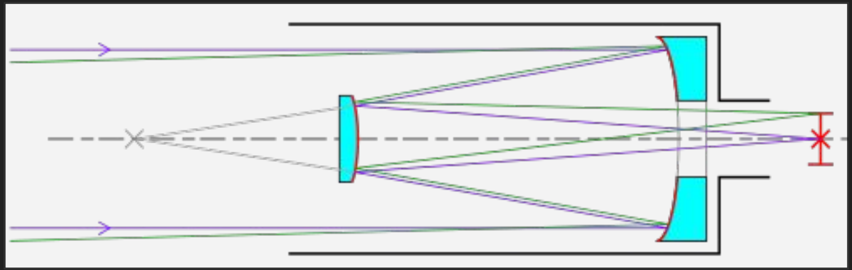
Ritchey-Chretién

2 mirrors

Hyperbolic primary

Hyperbolic secondary





RC telescopes

1.6 OPD

SOAR

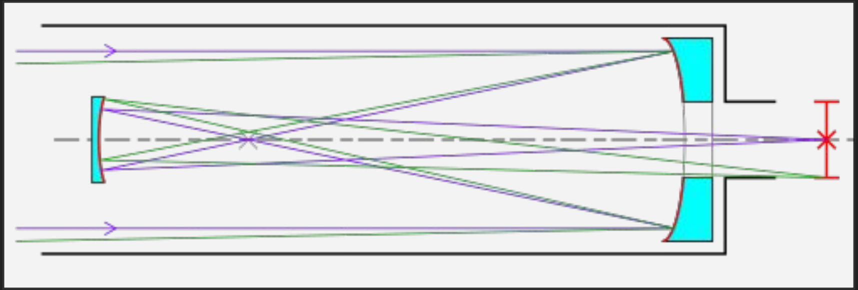
Gemini

VLT

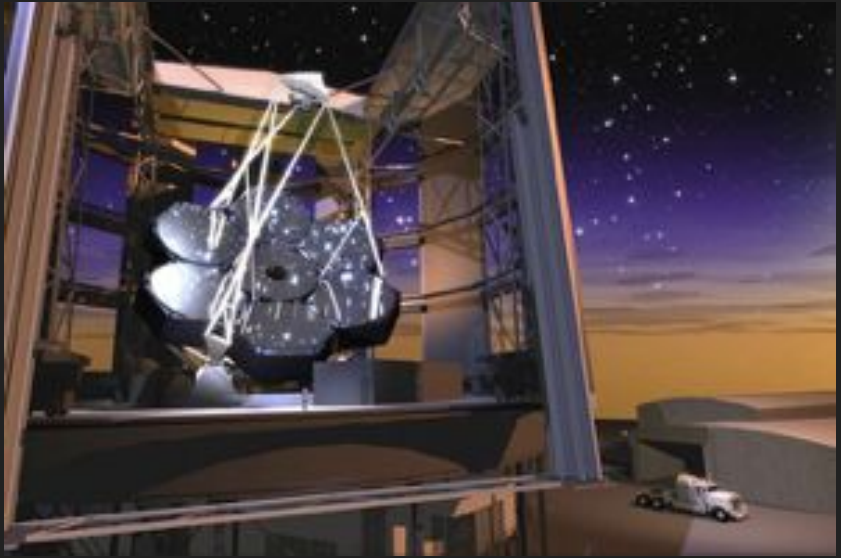
HST

Gregorian design

Main characteristics: the secondary **after** prime focus.

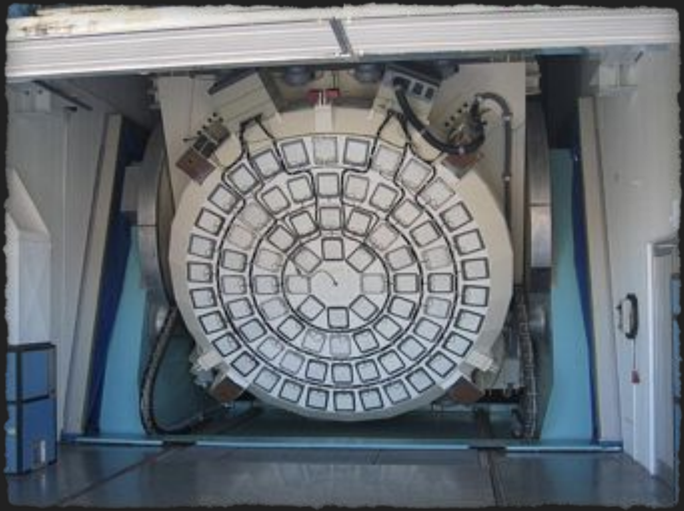


Famous Gregorian telescopes: LBT, Magellan telescopes and GMT



Active Optics

Compensation of the deformation of the optics under its own weight.



Mounts

Telescope Mount

Equatorial

Alt-azimutal

Role of the mount: point the telescope and track (i.e. compensate for Earth's rotation)

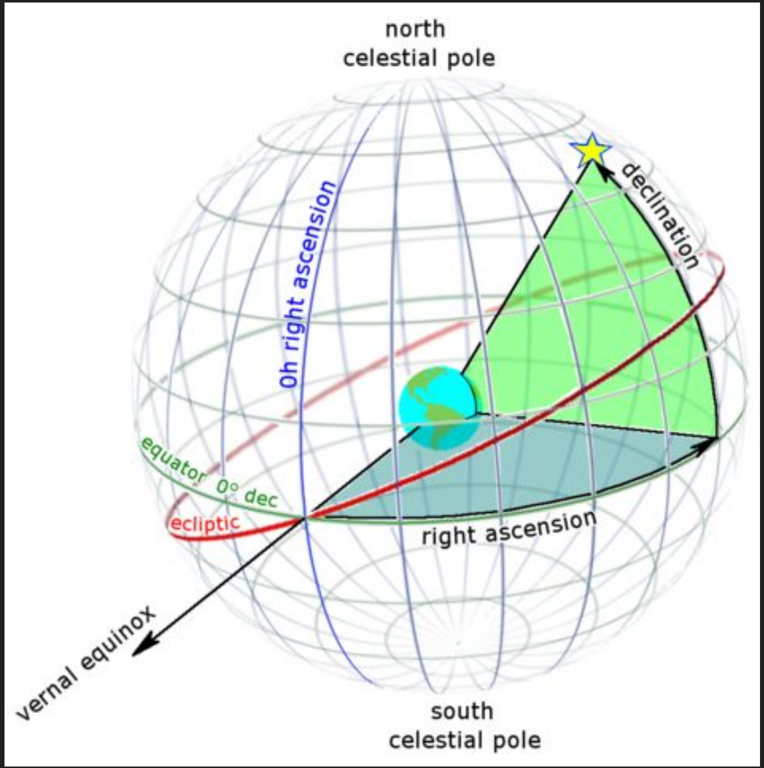
Equatorial Coordinate System

Rotates about the rotation axis of the Earth.

Celestial Equator is the projection of the Terrestrial Equator

Coordinates:

- Right Ascension (crossing of equator and ecliptic = 0h)
- Declination (equator = 0; poles=+/-90)



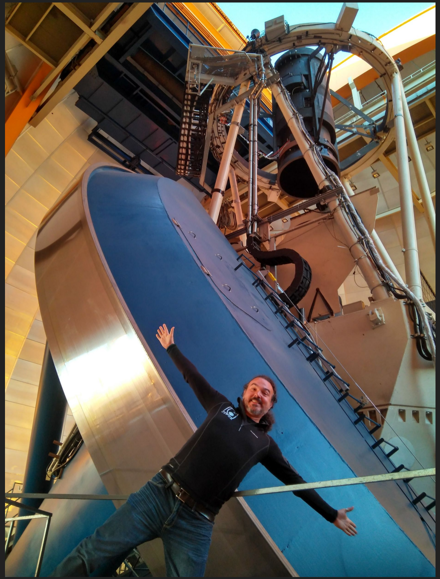
Equatorial Mounts

One axis is aligned with Earth's rotation.

In principle, only one axis need to move to compensate for Earth's motion.

Types:

- German Equatorial (T80/JAST)
- Horseshoe (Blanco @ CTIO)
- Open fork (Isaac Newton Telescope)

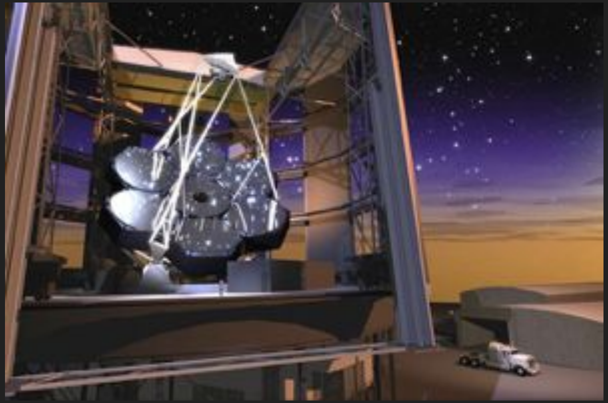


Alt-azimuthal Mounts

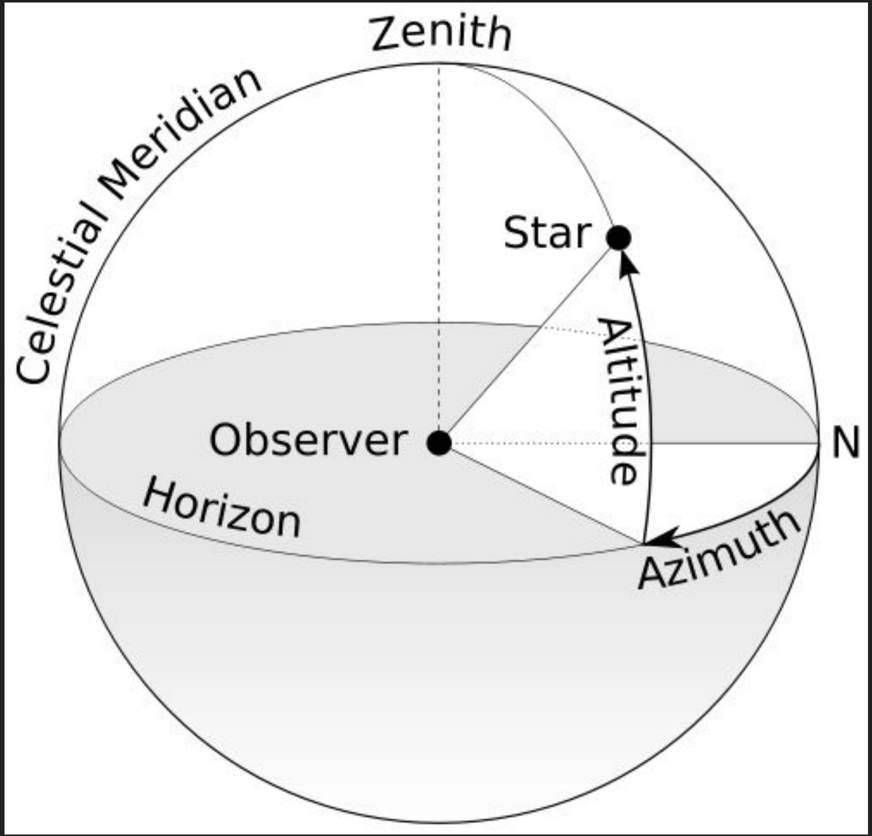
Three axis system.

Requires computing position of object every millisecond => fast Telescope Control System

Cannot point at zenith!

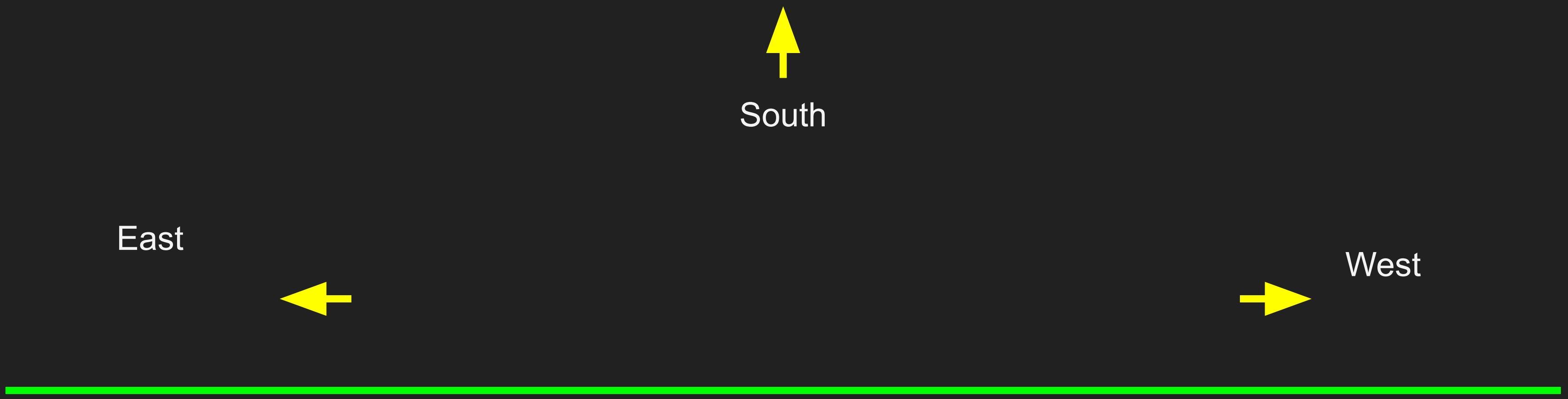


Horizontal Coordinate System



Field Rotation

As a field rises, culminates and sets, in alt-azimuthal coordinates, it seems to rotate.



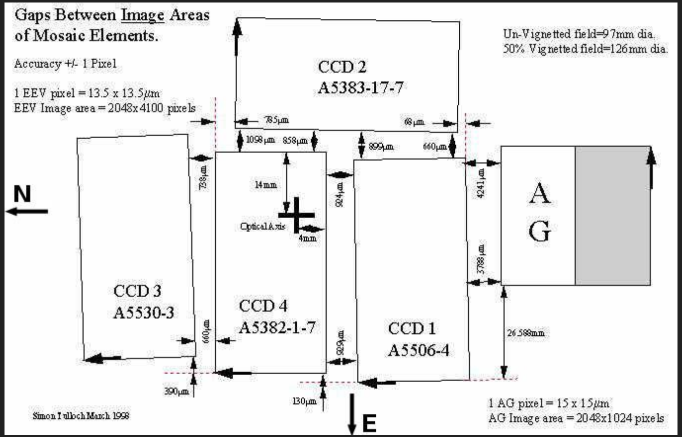
Tracking vs Guiding

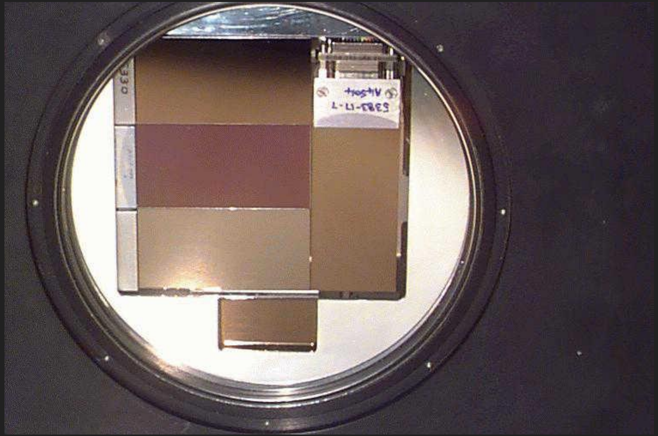
The movement of the telescope to compensate for Earth's rotation is called: "tracking"

"Tracking" is often good, within a few tens of arcsec in a few minutes.

What to do for very long (e.g. t_{exp} > 5 minutes) exposures?

You "anchor" your telescope to a star. This is done with a small fast readout camera.





http://www.ing.iac.es/Engineering/detectors/ultra_wfc.htm

Focal Stations

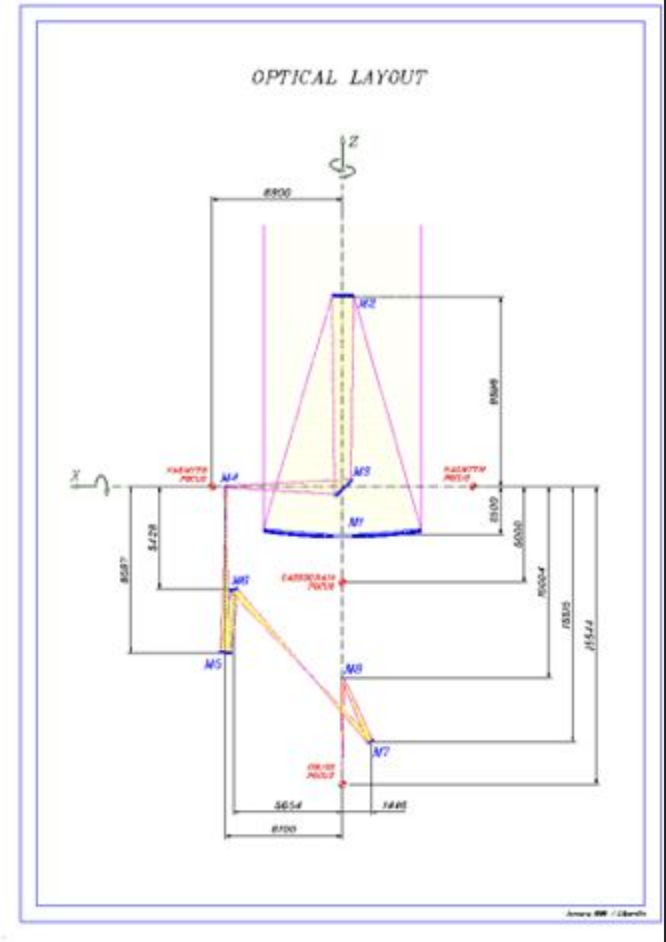
Prime focus

Cassegrain

Nasmyth

Coudé

(a mirror reflects ~90% of light)

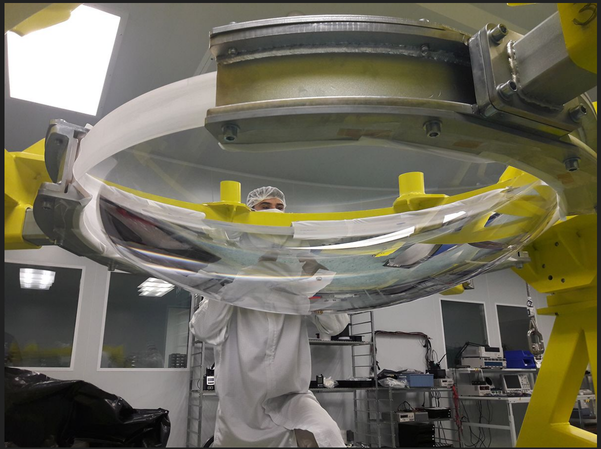


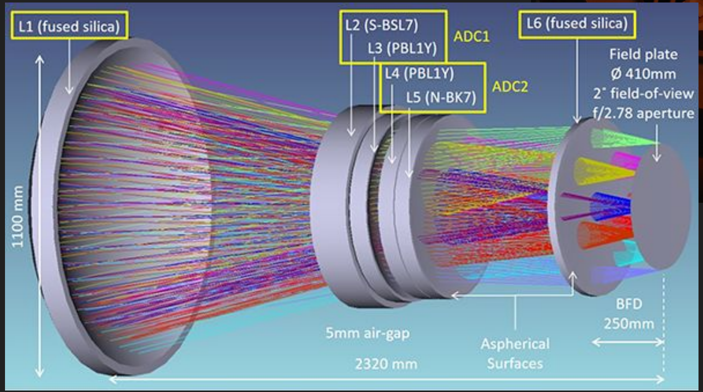
Prime Focus

Wide field.

Typically requires a field corrector (which is a very big lens).

http://www.ing.iac.es/PR/press/weave_jan_2020.html





Cassegrain focus

Easy to handle.

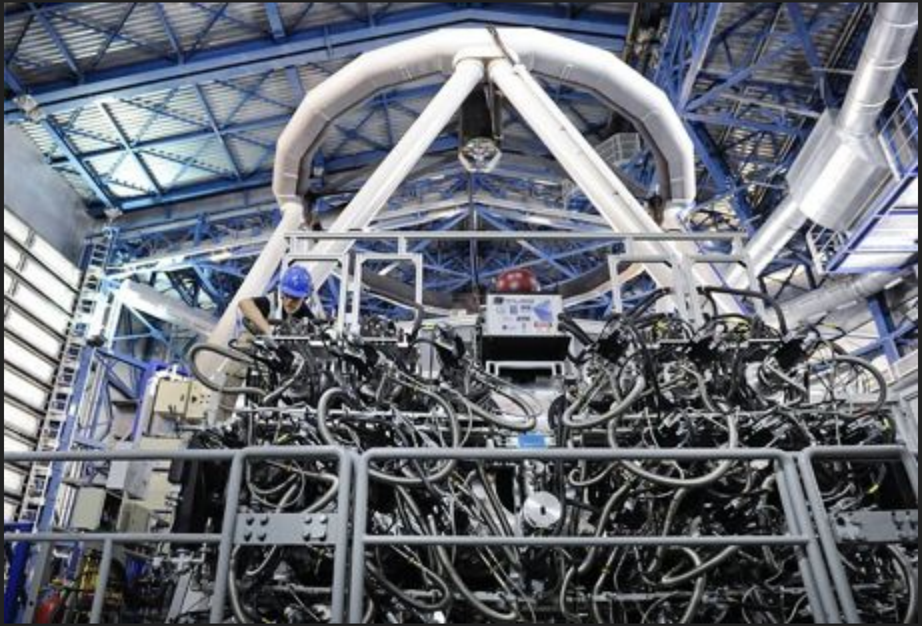
Constraints on size and weight of instrument.

Nasmyth Focus

Only available on alt-az mounts.

Light passes through alt-axis using a tertiary mirror.

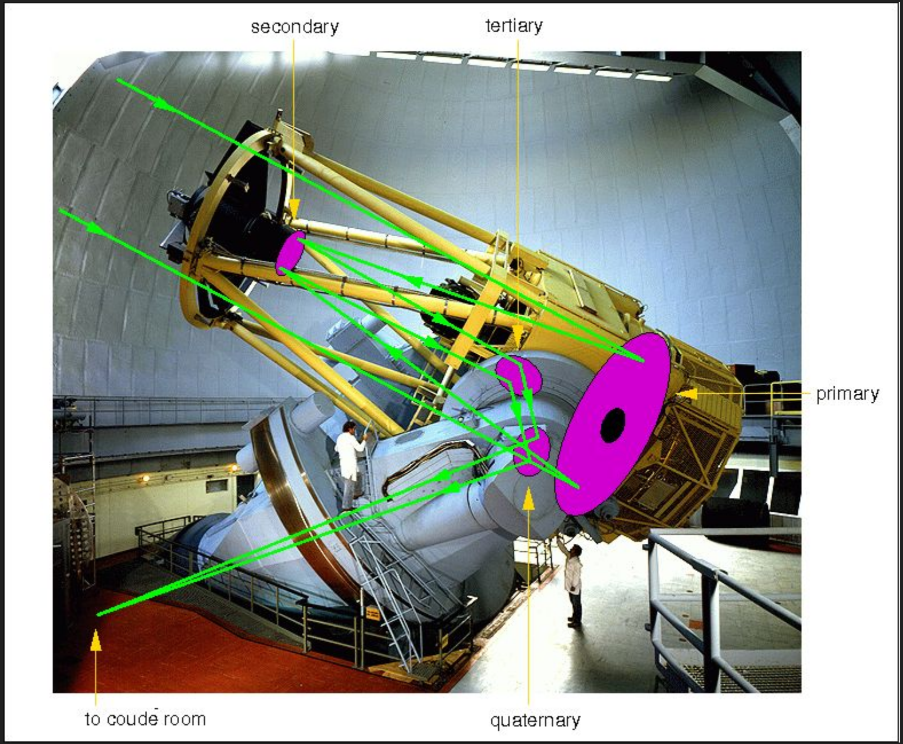
Allow for larger instruments.



Coudé Focus

Used for spectroscopy; has the longest focal length.

Nowadays, mostly replaced by fibres.



Domes

“Dome” vs. “Enclosure”

Active thermal control! => Air conditioning - Temperature during the day is maintained at the same expected value for the beginning of the following night.

Good ol' domes

Until the early '90s people were expected to spend long periods at observatories.

Domes were built to host workshops, offices and, at least, a small cafeteria.

Telescope’s New Concept and New “Enclosure”

New Technology Telescope -> prototype for this and much more

NTT is perhaps one of the last “new telescopes” with a control room inside the building.

The whole building rotates => No Toilet Telescope

“Excercise”

Read this:

http://lnapadrao.lna.br/gemini/anuncios/chamada2020b

And this:

http://lnapadrao.lna.br/SOAR/chamadas-propostas/Chamada-para-envio-de-propostas-de-observacao%202020A