Observational Astrophysics I

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Requirements to pass:

- Attend the lectures (9 lectures)
- Do the home work and report it in the class
- Do telescope lab
- Take written exam
- Book: *Kitchin: Astrophysical Techniques, IoP, 5th ed. or*
  Chromey: To Measure the Sky, 2nd ed.

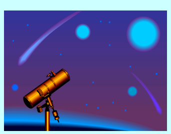
Check the schedule carefully!

Kitchin 5th ed.: pp 51-65, 89-107; Chromey 2nd ed.: 113-161

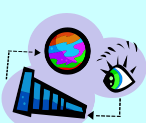
Why do we need telescopes?

Collect photons and create image of a region on the sky (<u>F</u>ield <u>o</u>f <u>V</u>iew)

See small details (angular resolution)



Follow objects on the sky (Tracking)

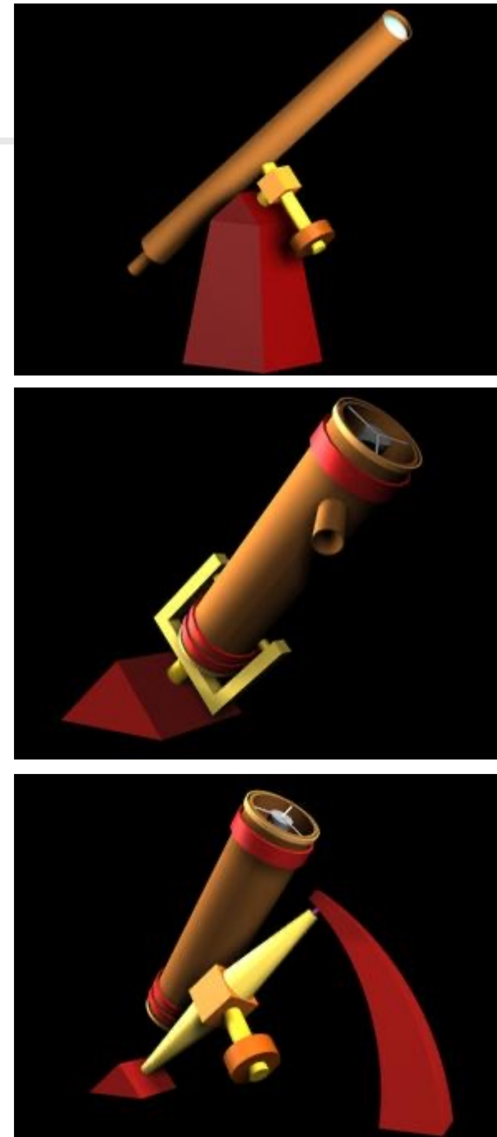


Feed light to multiple instruments

How telescopes can help?
(Tracking objects)

Telescope mounts:

- Equatorial
  - German mount
  - Fork mount
  - English mount
- Alt-Azimuth



Zelentchuk 6m BTA, Russia

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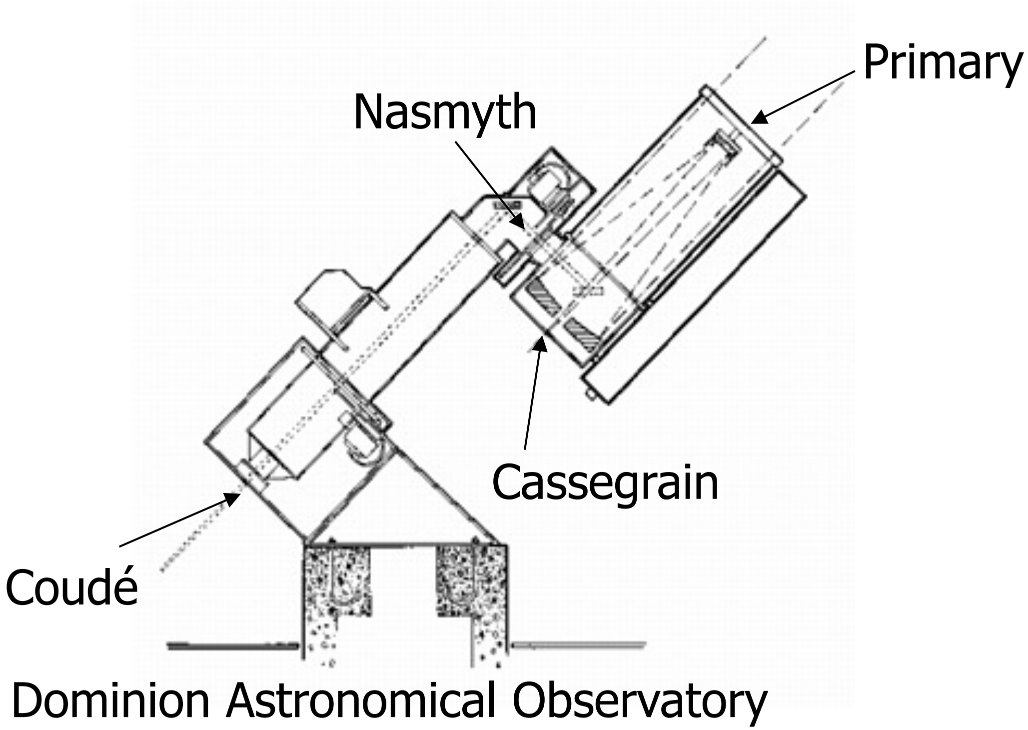
Creating image (telescope focii)



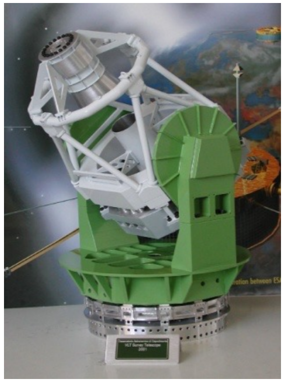
Dominion Astronomical Observatory

Large Binocular Telescope

?

Telescope mounts: equatorial versus alt-azimuth

ESO VST

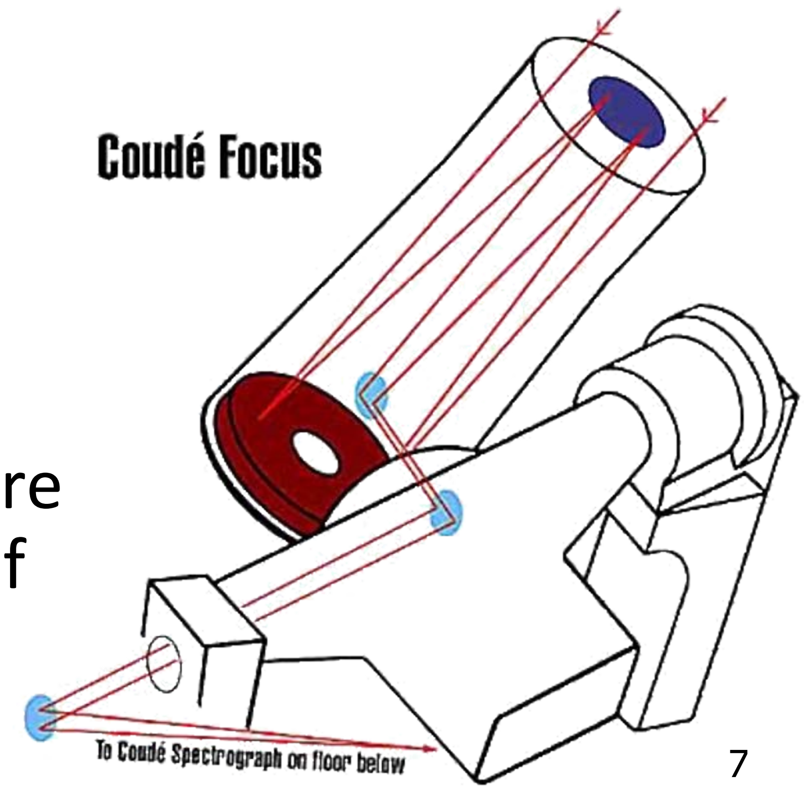


- Gravity center location and flexure:
  In alt-azimuth mount the support force passes precisely through the gravity center thus canceling any torque - very important for large and heavy telescopes.
- FoV behavior while tracking:
  In any focus located on the tube of an equatorially mounted telescope the field of view does not rotate. In coudé focus rotation velocity is constant.

ESO 3.6m La Silla

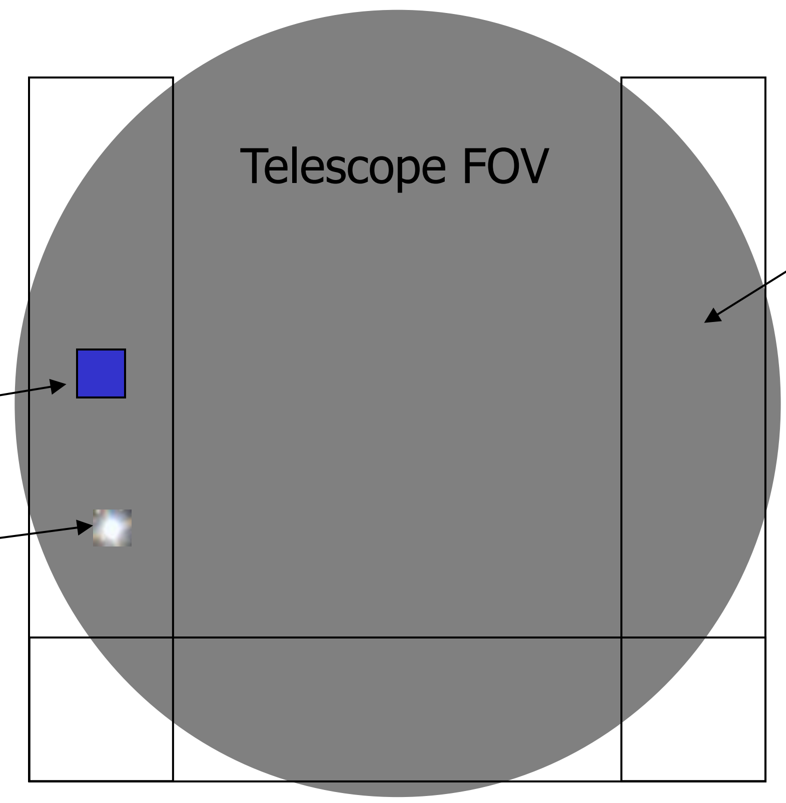
Home work:

- Look at the BWT and answer the following questions:
    1. While tracking does one need to change the azimuthal velocity?
    2. If yes, when the azimuthal velocity is largest?
    3. Which way the field of view rotates?
- Look at the optical scheme of coudé train of an equatorially mounted telescope shown here and figure out how the field of view rotates



Tracking and Guiding

Tracking is not good enough for long exposures…



… we need the offset guiding as it locks the motion speed and rotation of the FoV

Collecting photons

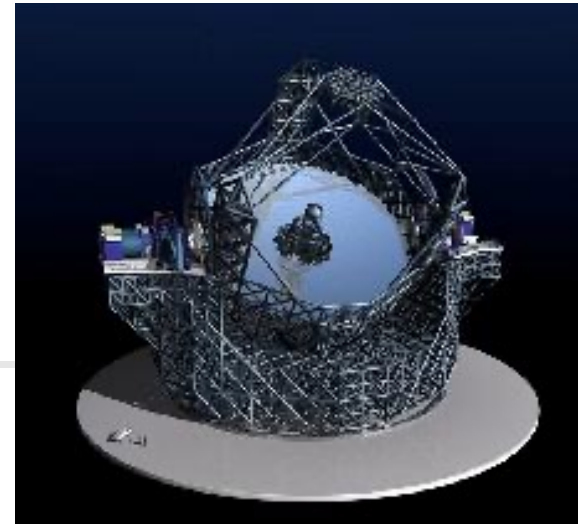
ELT	39m	Sierra Armazones	Segmented mirror, under construction.
LBT	2 x 11.8m	Pinaleno, Arizona	Two telescopes on a single mount.
Keck I & II	2 x 10m	Mauna Kea, Hawaii	Segmented telescopes, interferometer.
Hobby-Eberly	9.2m	Mt Fowlkes, Texas	A fixed elevation, low cost spectroscopic telescope.
Subaru	8.3m	Mauna Kea, Hawaii	Active telescope made in Japan.
VLT	4 x 8.2m	Cerro Paranal, Chile	ESO flagship, works as a single unit.
Gemini	2 x 8.0m	Mauna Kea, Hawaii Cerro Pachon, Chile	Twin 8-m telescopes in the Northern and Southern hemispheres.
Magellan	2 x 6.5m	Las Campanas, Chile	Twin 6.5-m telescopes; also known as the *Walter Baade* and *Landon Clay* telescopes.

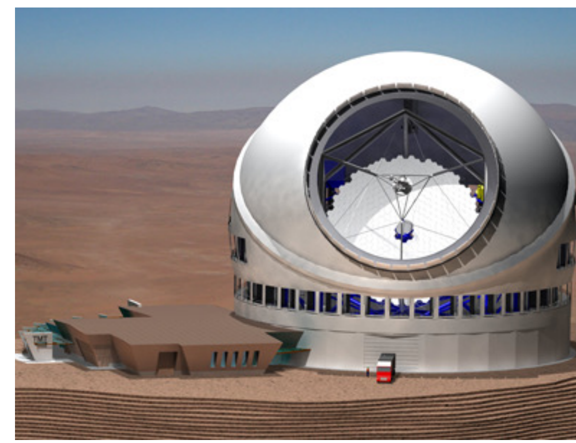
Future:

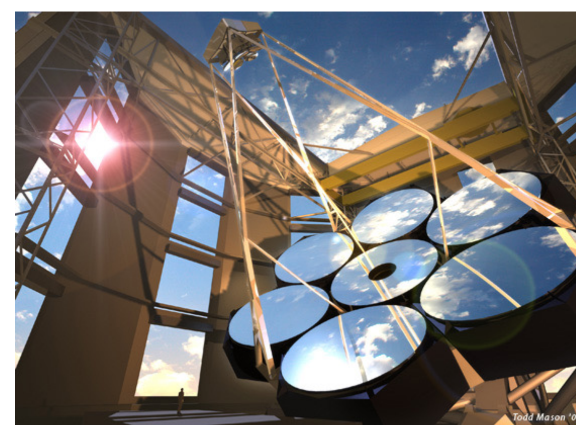
- European Southern Observatory Extremely Large Telescope (ELT, 39m under construction in Chile)

- The Thirty Meter Telescope (TMT)

- The Giant Magellan Telescope (GMT, 24.5m)







Optomechanics

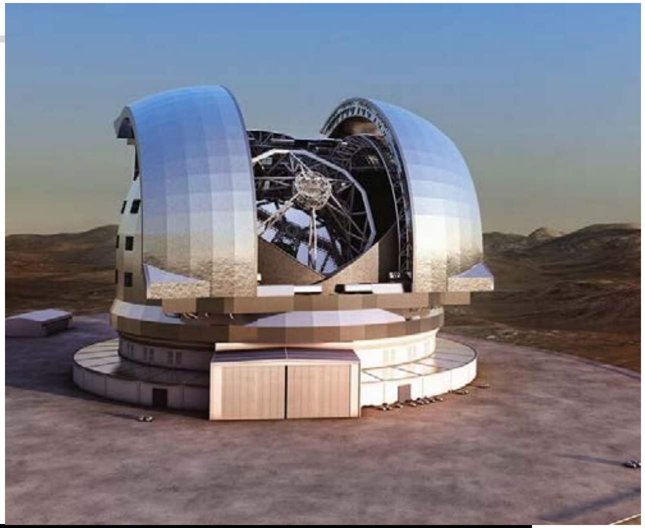
- Following objects on the sky (tracking) must be very smooth.
- Sources of vibration: mechanical roughness and wind.
- Amplitude of vibration goes down with frequency (with exception of resonances).
- *Important design goal:* damp resonances of the telescope at low frequencies (<10 Hz).

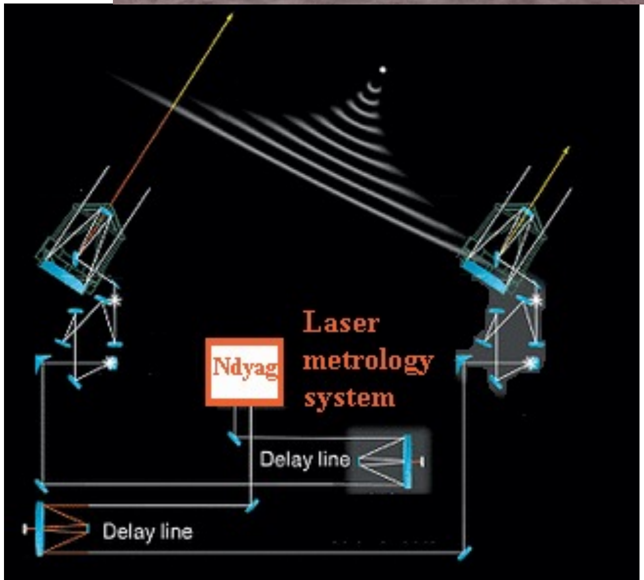
Angular resolution

- Angular resolution goes as λ/D, wavelength/diameter

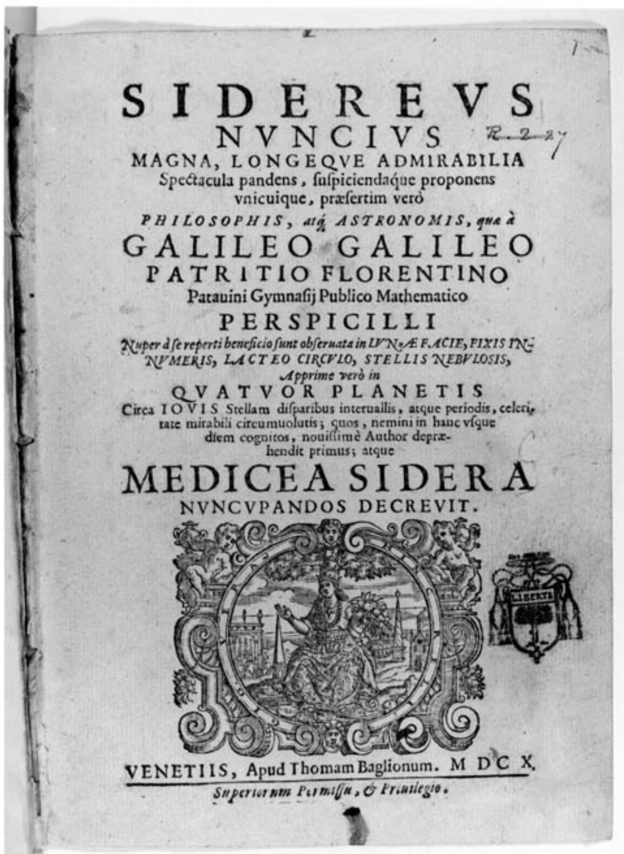
- or λ/B, wavelength/baseline for interferometers

ESO ELT 39m





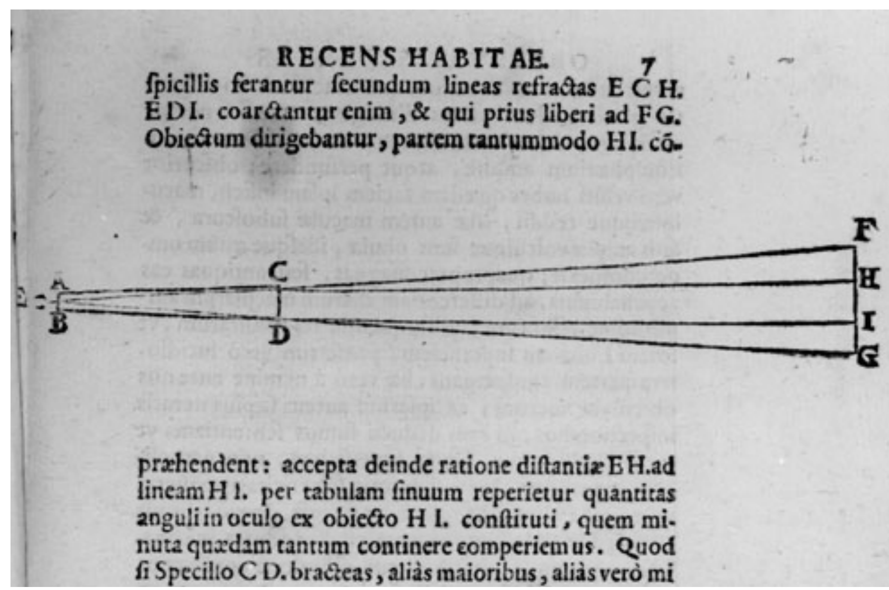
Little bit of history



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, ſuſpiciendaque proponens
vnicuique, præſertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnaſij Publico Mathematico
PERSPICILLI
Nuper à ſe reperti beneficio ſunt obſeruata in LVNÆ FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam diſparibus interuallis, atque periodis, celeri-
tate mirabili circumuolutis; quos, nemini in hanc vſque
diem cognitos, nouiſſimè Author depræ-
hendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permiſſu, & Priuilegio.

Galileo Galilei (1564-1642)

Telescope description published in *Sidereus Nuncius* (Starry Messenger) 1610



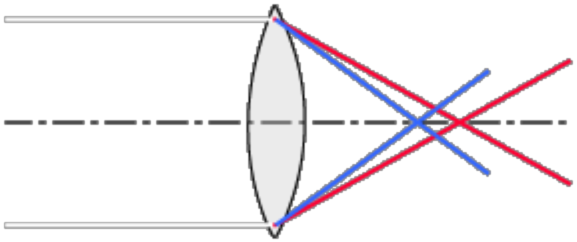
RECENS HABITAE. 7
ſpicillis ferantur ſecundum lineas refractas E C H.
E D I. coarctantur enim, & qui prius liberi ad F G.
Obiectum dirigebantur, partem tantummodo H I. cō-
prehendent: accepta deinde ratione diſtantiæ E H.ad
lineam H I. per tabulam ſinuum reperietur quantitas
anguli in oculo ex obiecto H I. conſtituti, quem mi-
nuta quædam tantum continere comperiemus. Quod
ſi Specillo C D. bracteas, aliàs maioribus, aliàs verò mi

With permission of the Master and Fellows of Trinity College Cambridge

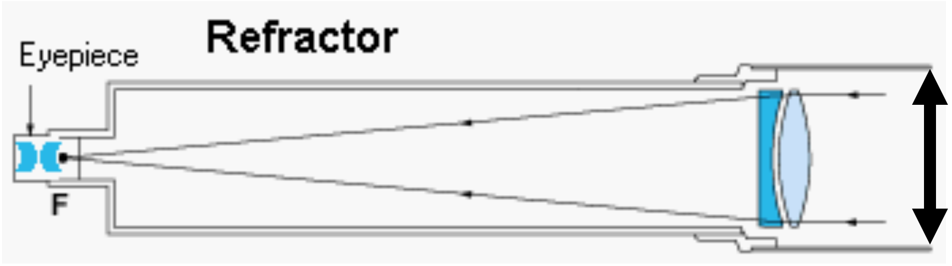
Refractors

Refractors are based on lenses
- Easy to make, can combine several elements

Chromatic aberrations:

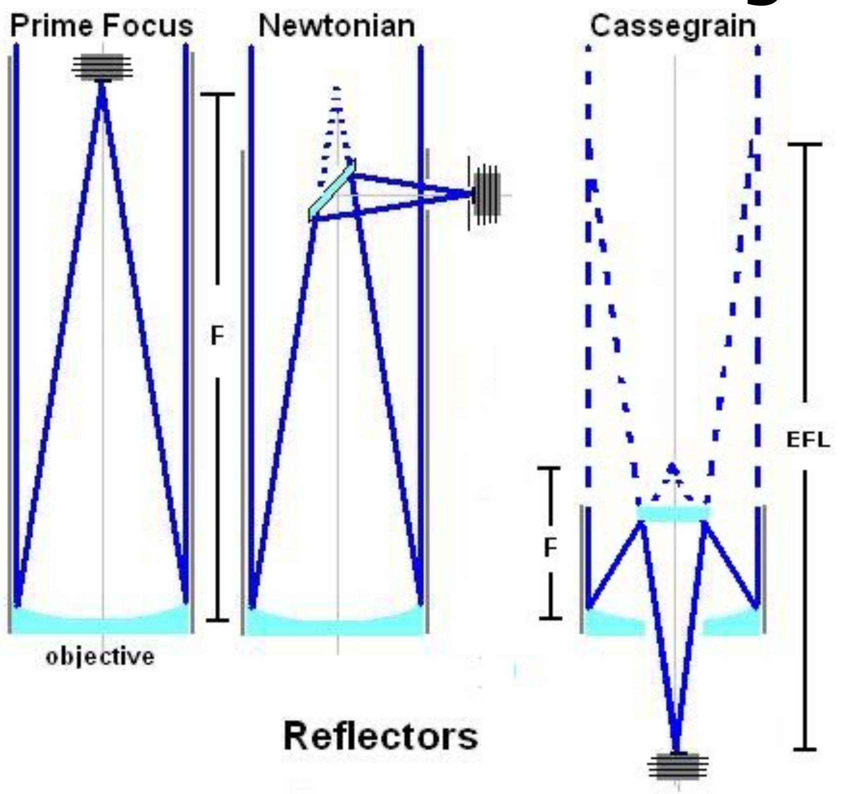


Largest refractor (1897):
- Yerkes Obs. 40”, f/19



Reflectors

Lots of options: from basic single mirror to Newtonian and Cassegrain



Summary: refractors

- Axial symmetry
- Combination of multiple elements
- Compact
- Cheap for small sizes
- Chromatism
- Difficulty making few meter size lenses
- Heavy
- Impossible to make segmented lenses

Summary: reflectors

- 👍 Light (high surface/weight ratio)
- 👍 Large choice of materials (e.g. temperature insensitive materials)
- 👍 Can be made in large sizes
- 👍 Can be made segmented and so even larger
- 👍 Shape can be adjusted ("flexible" mirrors)
- 👎 Difficult to combine several mirrors
- 👎 Hard to make axial systems (vigneting)

Specialized telescopes:

1. Wide field (Schmidt camera combining reflective and refractive elements)
2. Infra-red (coatings, thermal control)
3. Automatic/robotic telescopes (complex telescope control system)
4. Solar telescopes (heat)
5. With fixed primary (Large&Cheap)

Home work: find a description of a specialized telescope on the web and prepare a one page report of what is different, why and how it is done? The report will be presented in class. Two pages including figures and two slides for the presentation.

Conclusions:

- Binoculars, photo and video cameras, small telescopes – refractors
- Intermediate size telescopes – combined reflectors/refractors
- Large telescopes - reflectors

Next time…

- A bit more about telescope optics
- Image distortions (aberrations)
- Active optics
- Adaptive optics
- Coatings of optical surfaces