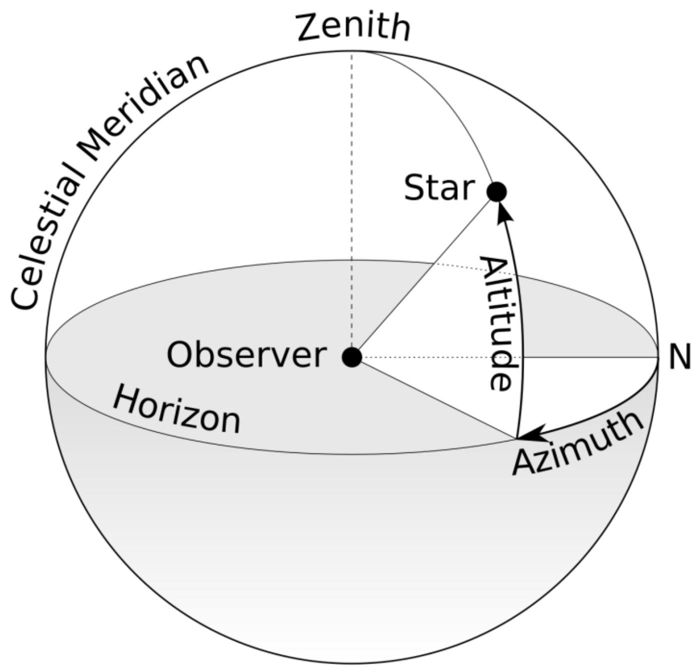
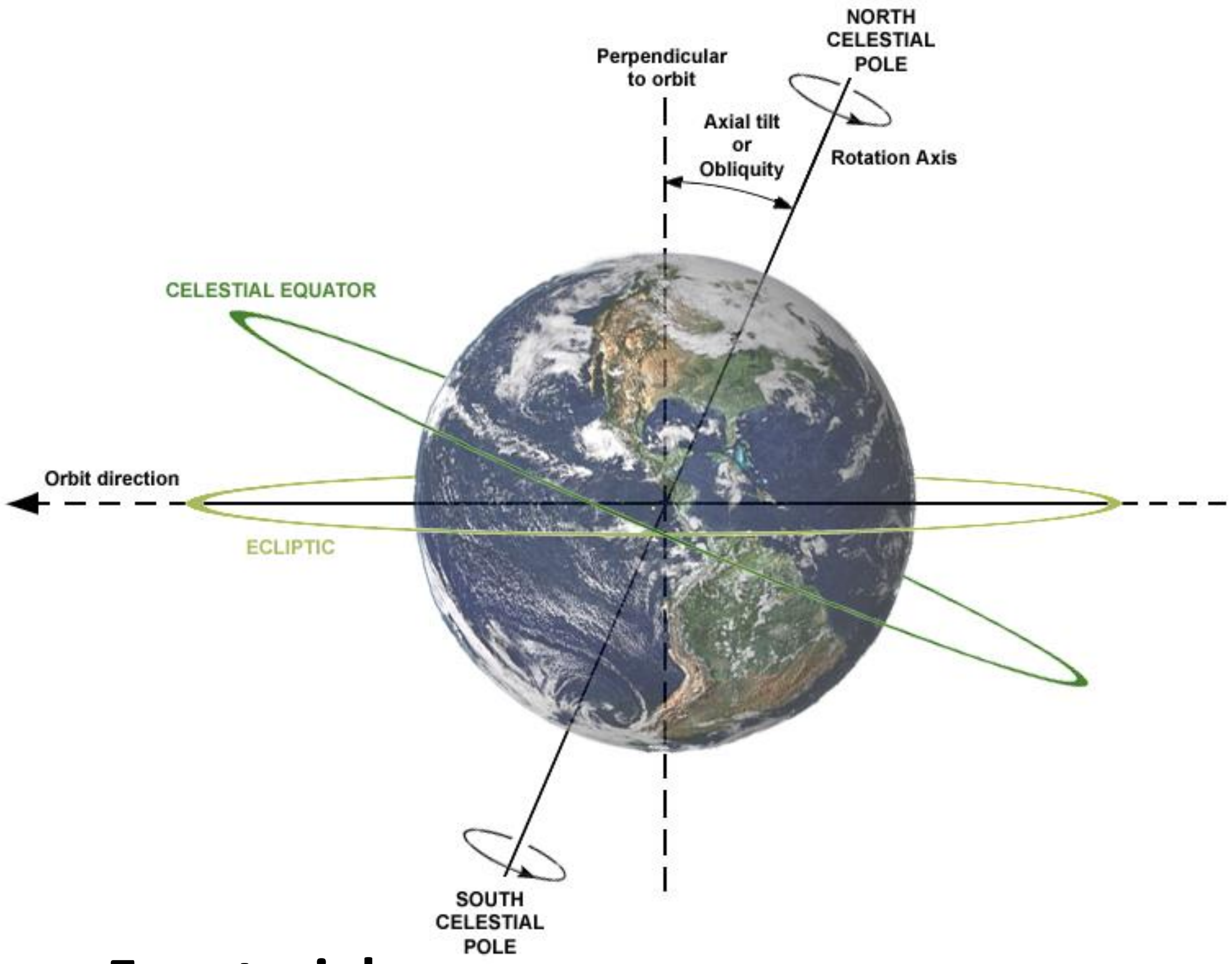



Observing and Photographing the Night Sky – First Steps

L. Teriaca

Coordinate Systems





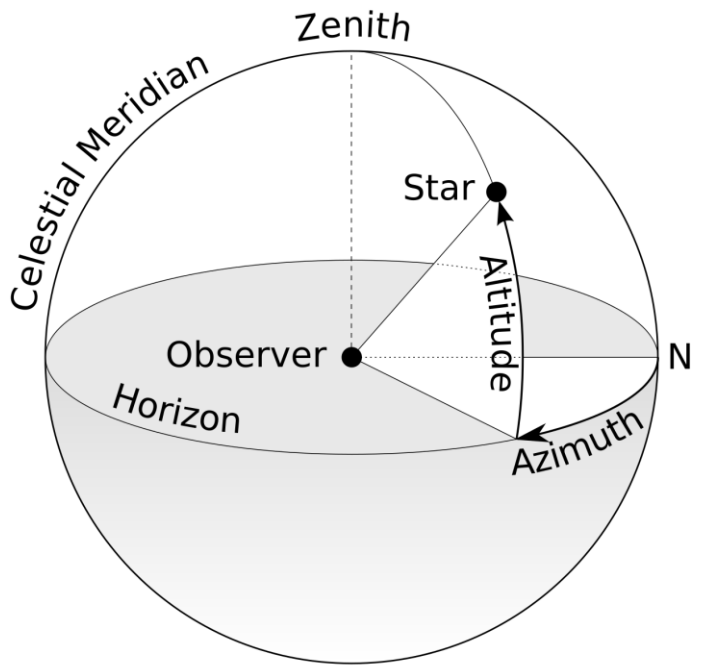
Alt-Azimuthal

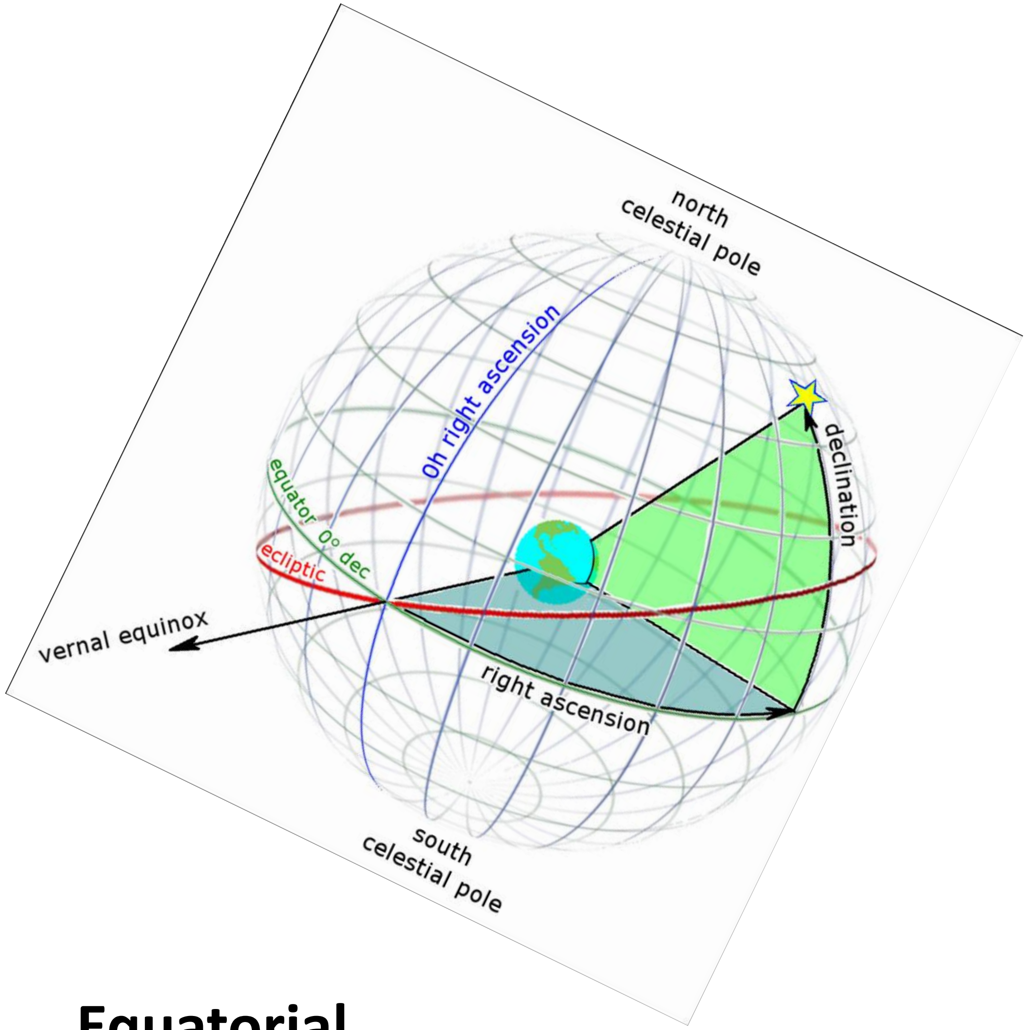
- Intuitive
- Depends on the observer's location

Equatorial

- Independent from observer's location

Coordinate Systems





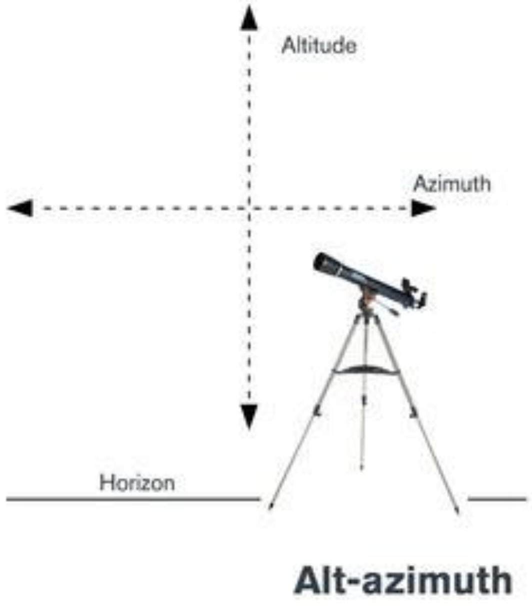
Alt-Azimuthal

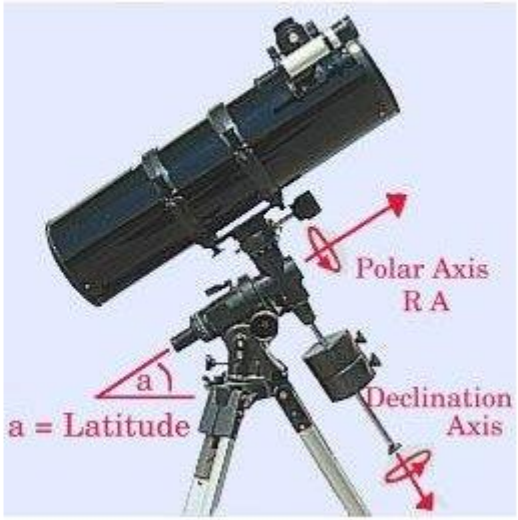
- Intuitive
- Depends on the observer's location

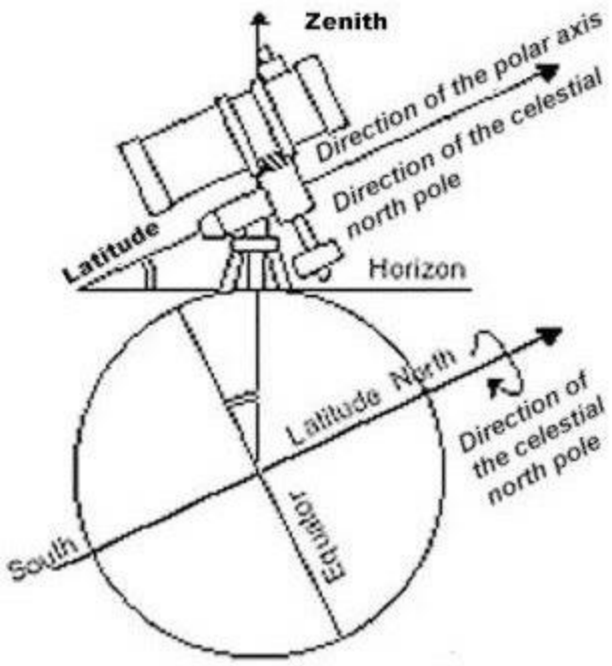
Equatorial

- Independent from observer's location
- It slowly changes over time due to precession

Mount types







Alt-Azimuthal

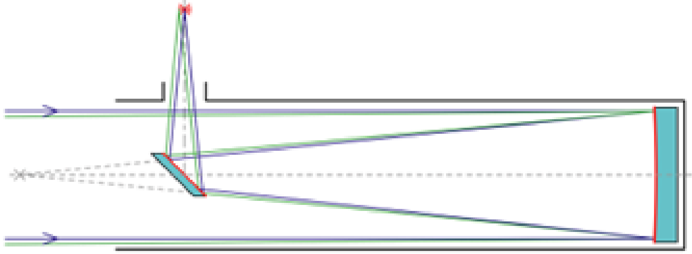
- Simple and fast to set up
- Good for visual and Skyscapes
- OK for Planetary High Res.
    - Good when goto.

Equatorial (German Eq. Mount or GEM shown. There are others!)

- Complex to set up (requires polar alignment)
- Necessary (generally) for long exposure astrophotography

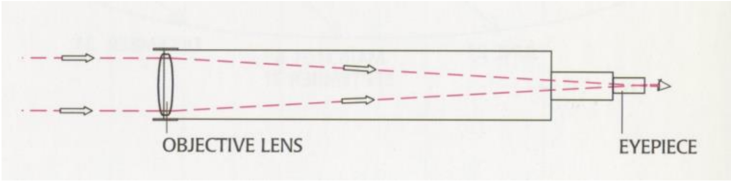
Main telescope types

Reflectors (Newtonians)



- Use only mirrors
- Newtonians (simplest) can be very cost effective
- Can be awkward for visual on a GEM
- Become quickly very large and heavy
- Require a coma corrector when fast

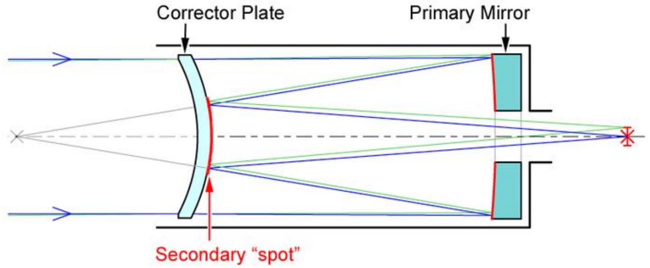
Refractors



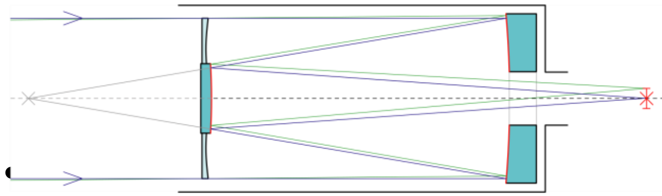
- Use only lenses
- Quite versatile
- Large diameters (>5”) prohibitive
- Excellent for astrophotography (higher quality models)
- Require diagonal for visual
- Require flattener for imaging

Catadrioptic

Maksutov-Cassegrain



Schmidt-Cassegrain



- Generally not good for wide field
- Very compact and easier to mount (by equal diameter)
- Excellent for planetary imaging
- Require diagonal for visual

A few useful formulas and expressions (1/2)

Telescopes (and camera objectives, where you, practically, can change D)

- D = diameter of the objective
- F = focal length of the telescope
- F/D = "speed" of the telescope. Also indicated as F/# (e.g., D=100 mm, F=500 mm is F/D=5 or F/5)
  - The smaller, the brighter the image, the most demanding the manufacturing
- Diffraction limited angular resolution $\theta = 1.22\ \lambda / D$

Binoculars

- Characterized by magnification x diameter of lenses (MxD). E.g., 8x42 has 42 mm lenses and provides 8x magnification
- D/M = exit pupil.
  - Human pupil at night is 7 mm max (in kids).
  - Older people get smaller pupils at night (≈5).
  - Exit pupils between 4 and 6 are good.
- Be aware of diameter fever! Things get heavy real fast!
- Other things are important too. Ask if interested!


20x70 (3.5)

A few useful formulas and expressions (2/2)

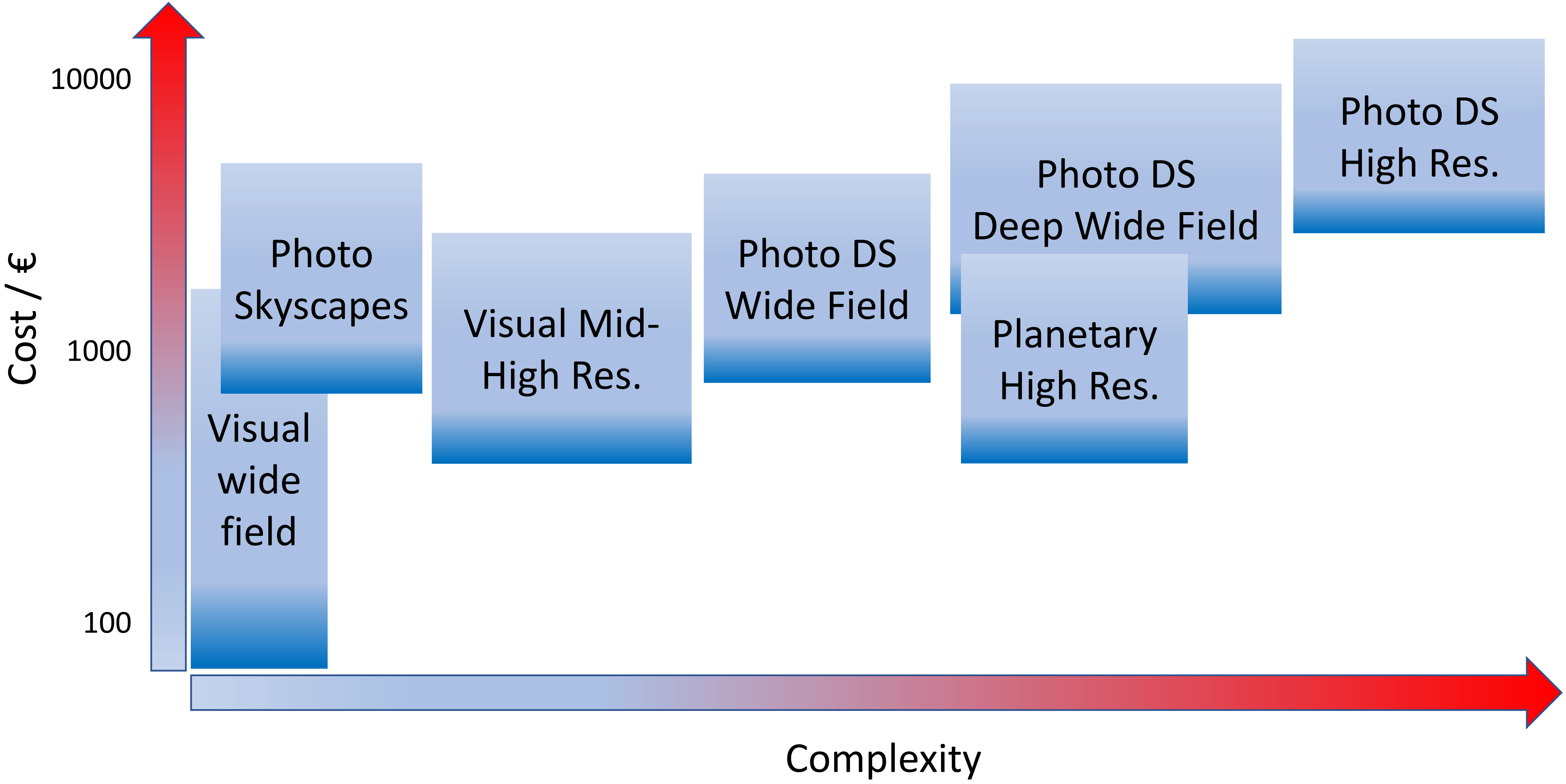
Telescopes – visual use

- Eyepieces are characterized by their focal length f in mm (always on barrel) and by the apparent FOV (AFOV) in degrees
- M=F/f is the magnification. A 9 mm eyepiece on a telescope with F=900 mm magnifies 100 times.
  - Maximum magnification usually useable is M = D (in mm)
    - Occasionally (good seeing) and with quality optics M can go up to 2D or more
- The True FOV (TFOV) can be estimated as TFOV = AFOV / M (however, real TFOV can be smaller)
  - You want at least one eyepiece with a large TFOV (large AFOV to start, low M = large f)
- Exit pupil = D / M. Good values for weak extended objects between 3 and 5
- Other things are important too. Ask if interested!

Telescope - imaging

- Signal from resolved objects N (phot s^{-1}) ≈ L (phot m^{-2} s^{-1} sr^{-1}) D^2 p^2 / F^2 , where p is the pixel size
  - For a given object, if p is fixed, N (phot s^{-1}) ≈ $(D / F)^2$
  - For a given object, if you can reach diffraction limit (p = 1.22 λ F / D) as in space, N = const.
  - For a given object, in Earth’s atmosphere (typical seeing s between 1” and 2”), p = s F and N ≈ D^2
  - Of course, extended objects do not have uniform radiance, resolution (hence contrast) increases with D until seeing kicks in

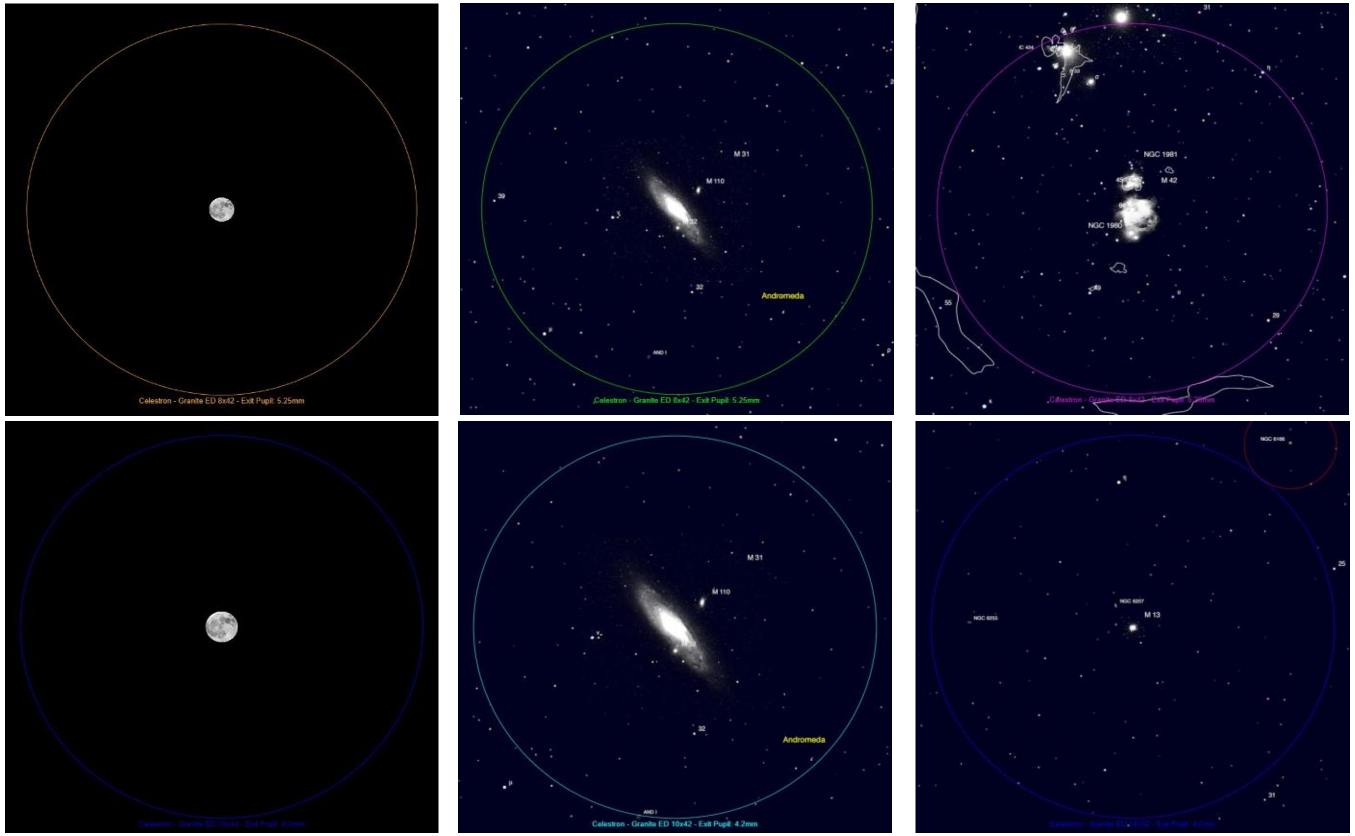
Cost and Complexity



Visual Wide Field

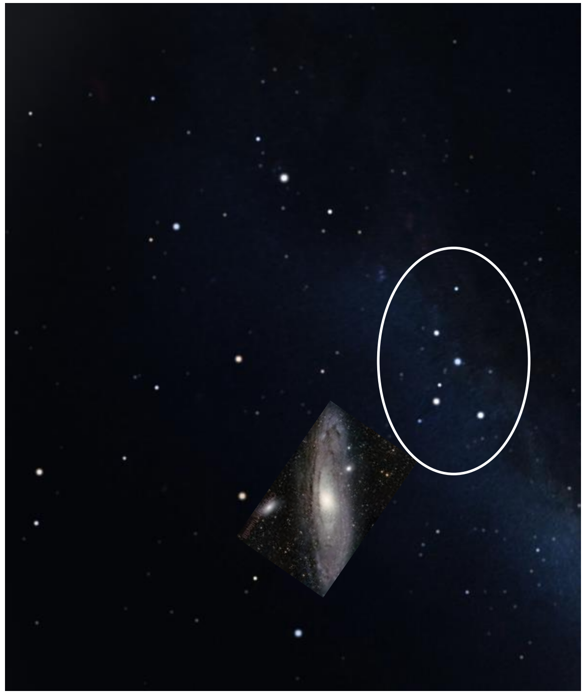
8x42
8.1°

10x42
6.5°

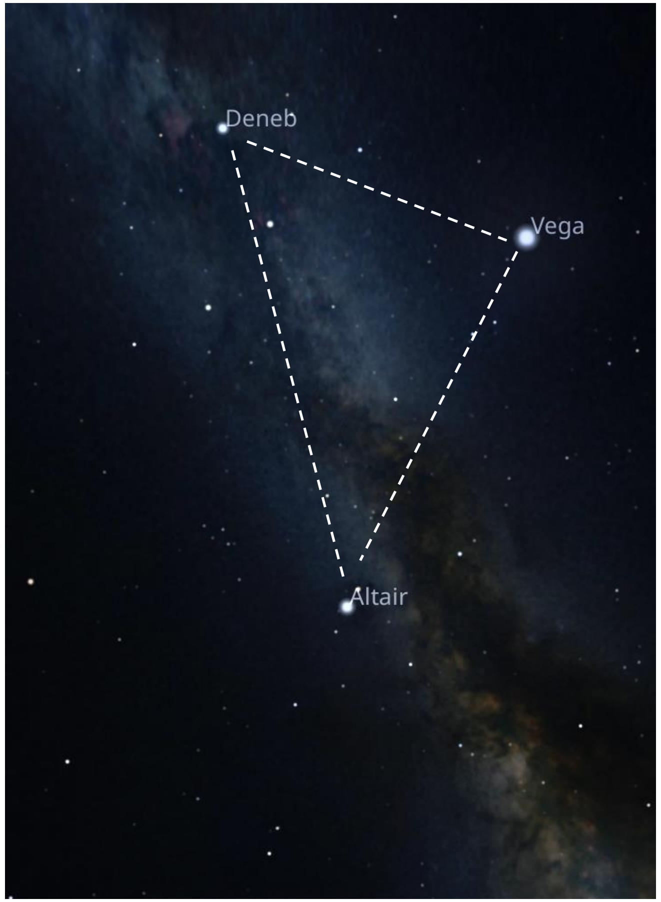


- Definitively the less demanding – naked eye observing is for free!
- Using (small) binocular can be done without a tripod
  - An 8x42 or a 10x42 are very good
- Short F refractors on an Alt-Az mount can also be a (more expensive option)

Visual Wide Field



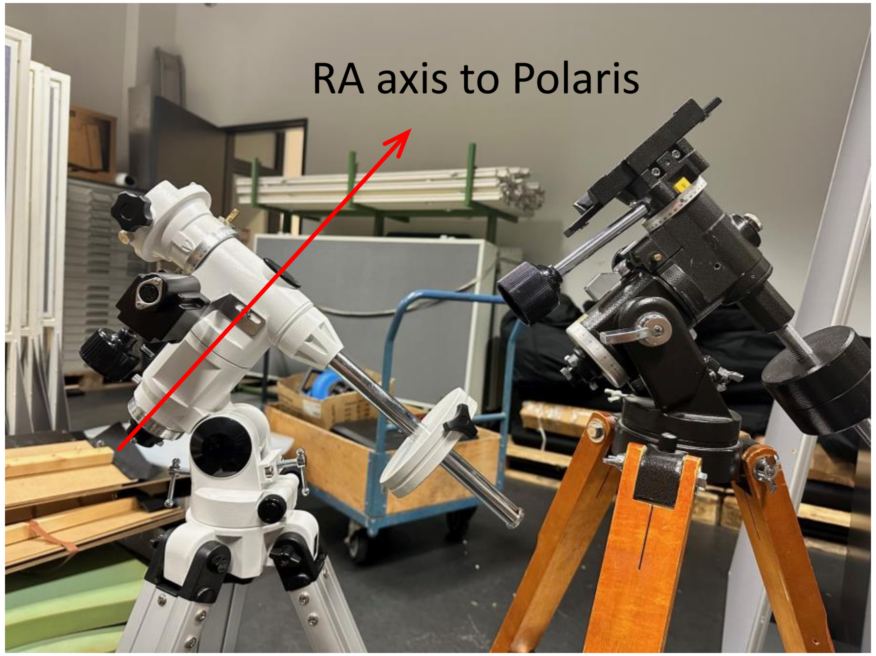
M31: Andromeda

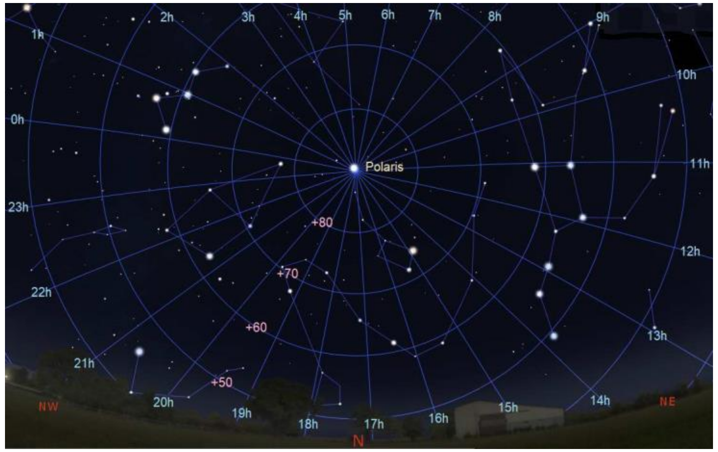


- Sky on September 4th at 22:00.
- What you can see with naked eyes?: Milky way, Saturn, Summer triangle, constellations, (Andromeda, Mizar-Alcor)
- What with a binocular? Milky Way star fields, Andromeda, M13, Mizar-Alcor

Visual Mid-High Res.

- MPS Newton 114/900 on GEM (but generally valid for any scope on a GEM)
- Align finder to main scope (easier in daylight)
- Level tripod (put bubble level on tray)
  - doesn't need to be very precise, just not too bad
- Set local latitude using elevation knobs
- Polar align: it is the most important step
  - Point R.A. axis towards Polaris (use the azimuth knobs)
  - If you now point scope to Polaris, Dec should read +90°
- Point a bright star not too far from the target
  - Unlock the AR circle (lower numbers for north hemisphere) and set it to the star AR. Dec should be roughly right. Lock the AR circle.
- Now move the scope to your target by matching AR & Dec values



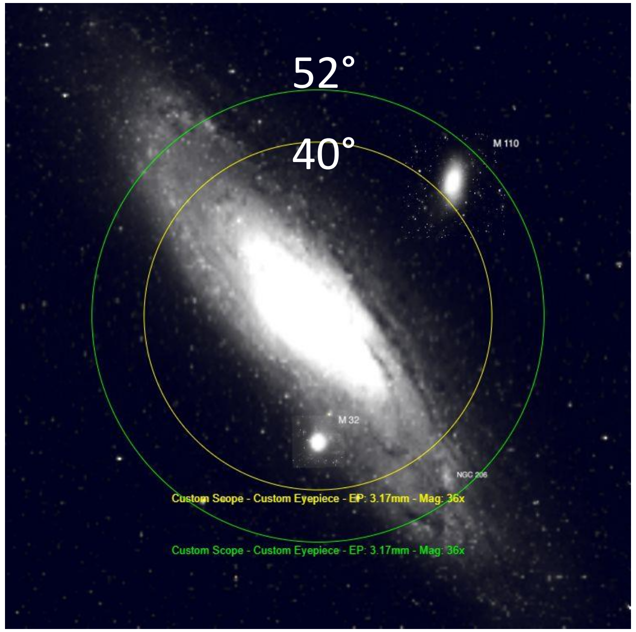


Visual Mid-High Res.

- MPS Newton 114/900 on GEM - Eyepieces

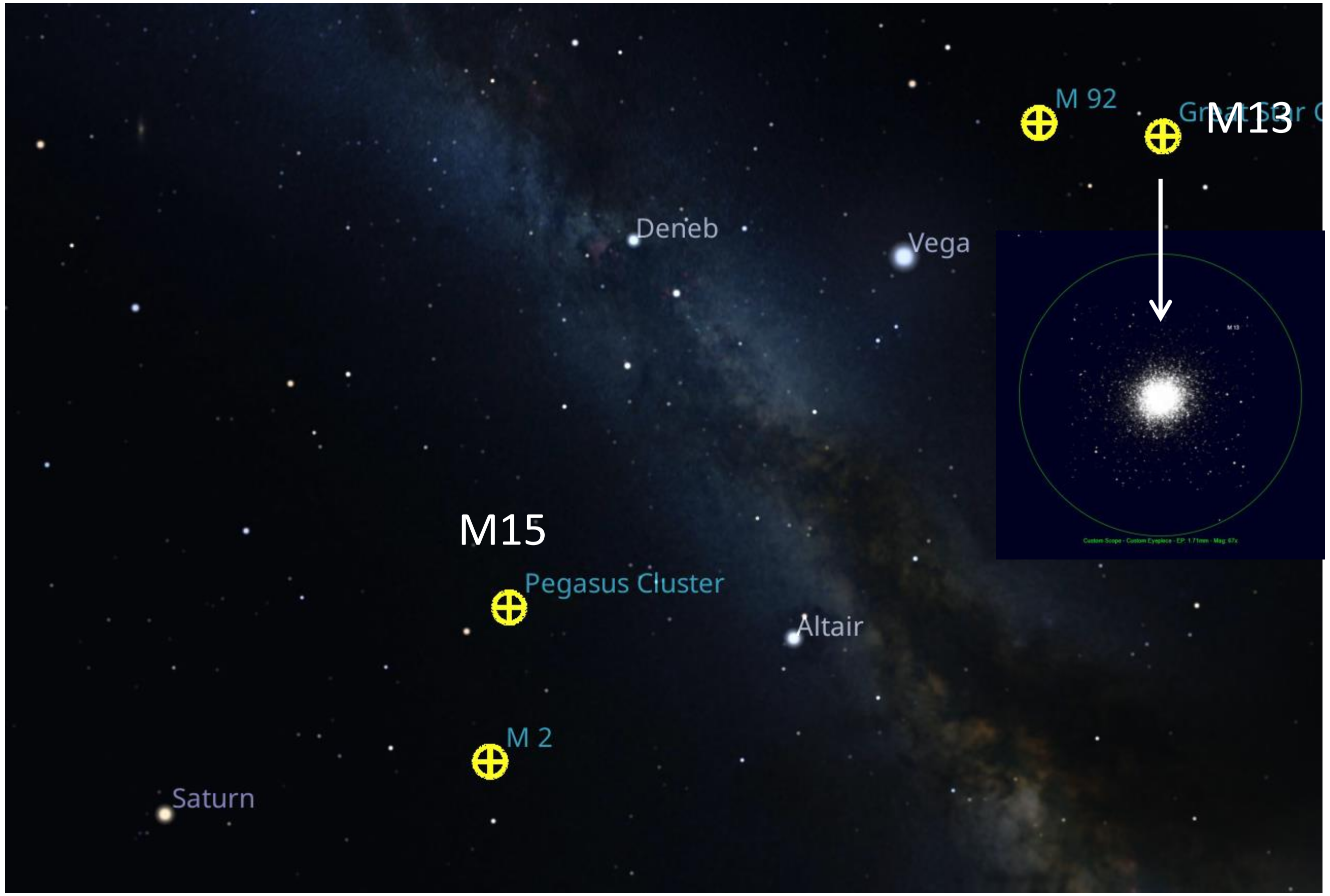
Telescope D = 114 mm, F = 900 mm			
f	M	Pupil	TFOV
25	36	3.16	1.1
12.5	72	1.58	0.55
9	100	1.14	0.4
4	223	0.51	0.18

- I do not know the AFOV of these eyepieces.
  - These are orthoscopic ones, so it is about 40° (not much)
- Use the finder first, then the 25mm eyepiece (see figure)
- Orthos have little eye relief. It may be a problem for people with glasses…



Globular clusters

Visual Mid-High Res.

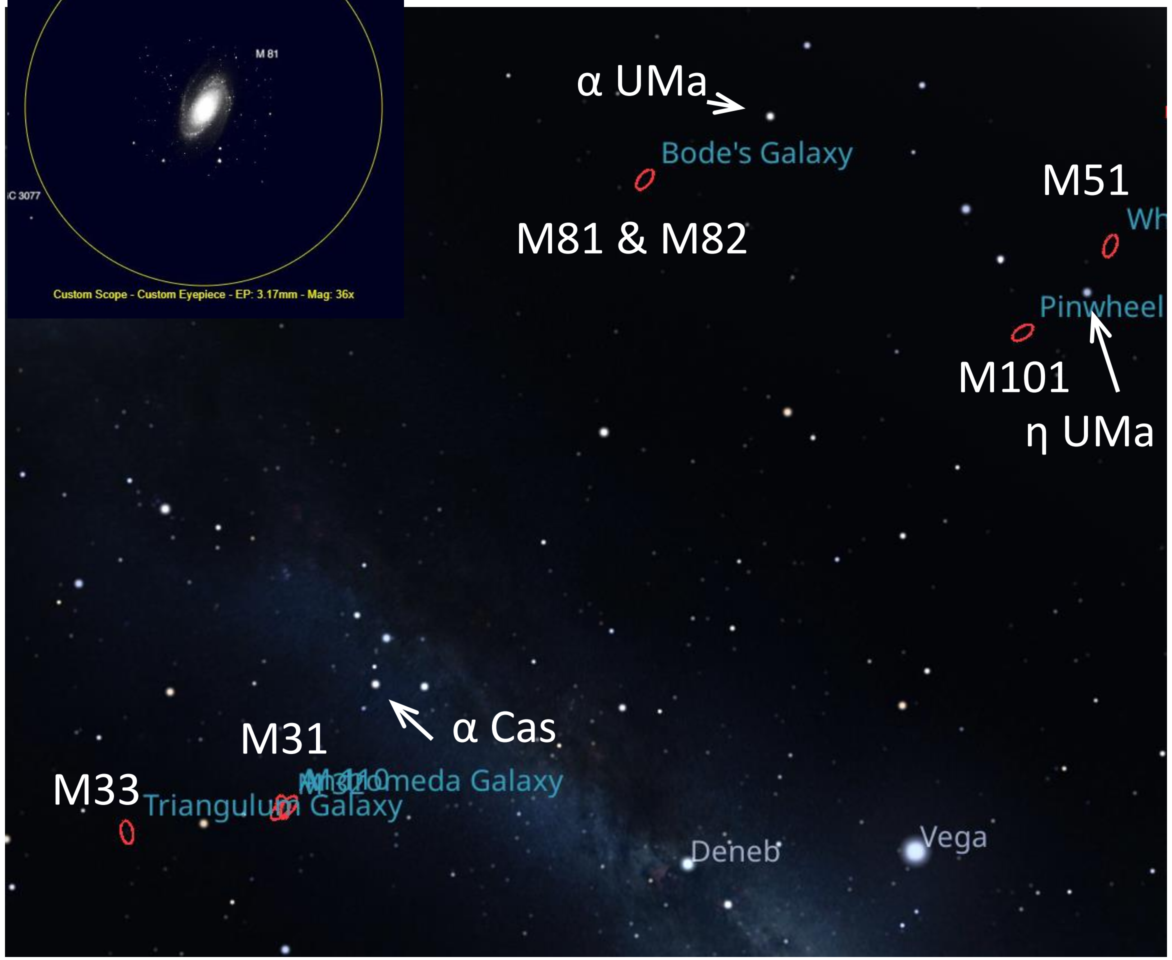


Cluster	AR	Dec
M2	$21^h\ 33^m\ 27.02^s$	−00° 49′ 23.7″
M13	$16^h\ 41^m\ 41.24^s$	+36° 27′ 35.5″
M15	$21^h\ 29^m\ 58.33^s$	+12° 10′ 01.2″
M92	$17^h\ 17^m\ 07.39^s$	+43° 08′ 09.4″

Use first the 25mm to find the clusters, then try the 12.5 or the 9mm (see insert)

Cluster	AR	Dec
Altair	$19^h\ 50^m\ 47.00^s$	+08° 52′ 05.96″
Vega	$18^h\ 36^m\ 56.34^s$	+38° 47′ 01.28″
Deneb	$20^h\ 41^m\ 25.9^s$	+45° 16′ 49″

- What with the 114/900? **M13, M15, M2, M92**, M31, M81, M27, M57, h&χ Persei, Mizar, 61 Cygni, (M33, M51, M101)



Spiral galaxies

Visual Mid-High Res.

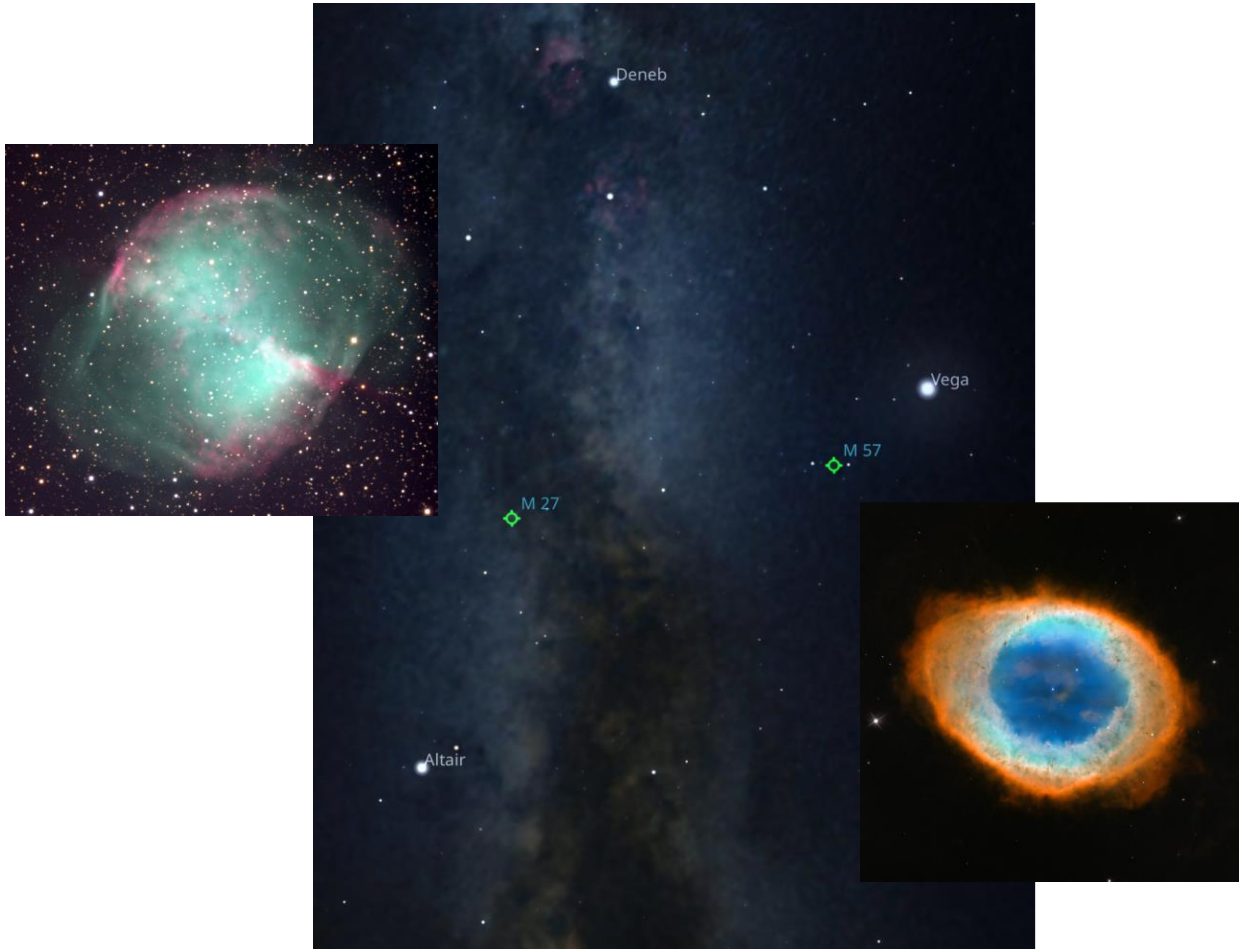
Galaxy	AR	Dec
M31	$00^h\ 42^m\ 44.3^s$	+41° 16′ 09″
M33	$01^h\ 33^m\ 50.02^s$	+30° 39′ 36.7″
M51	$13^h\ 29^m\ 52.7^s$	+47° 11′ 43″
M81	$09^h\ 55^m\ 33.2^s$	+69° 03′ 55″
M101	$14^h\ 03^m\ 12.6^s$	+54° 20′ 57″

Just use the 25mm

Cluster	AR	Dec
α UMa	$11^h\ 03^m\ 43.67^s$	+61° 45′ 03.72″
η UMa	$13^h\ 47^m\ 32.44^s$	+49° 18′ 47.76″
α Cas	$00^h\ 40^m\ 30.44^s$	+56° 32′ 14.39″

- What with the 114/900? M13, M15, M2, M92, **M31, M81,** M27, M57, h&χ Persei, Mizar, 61 Cygni, (**M33, M51, M101**)

Planetary Nebulae



Visual Mid-High Res.

Galaxy	AR	Dec
M27	$19^h\ 59^m\ 36.34^s$	+22° 43′ 16.09″
M57	$18^h\ 53^m\ 35.08^s$	+33° 01′ 45.03″

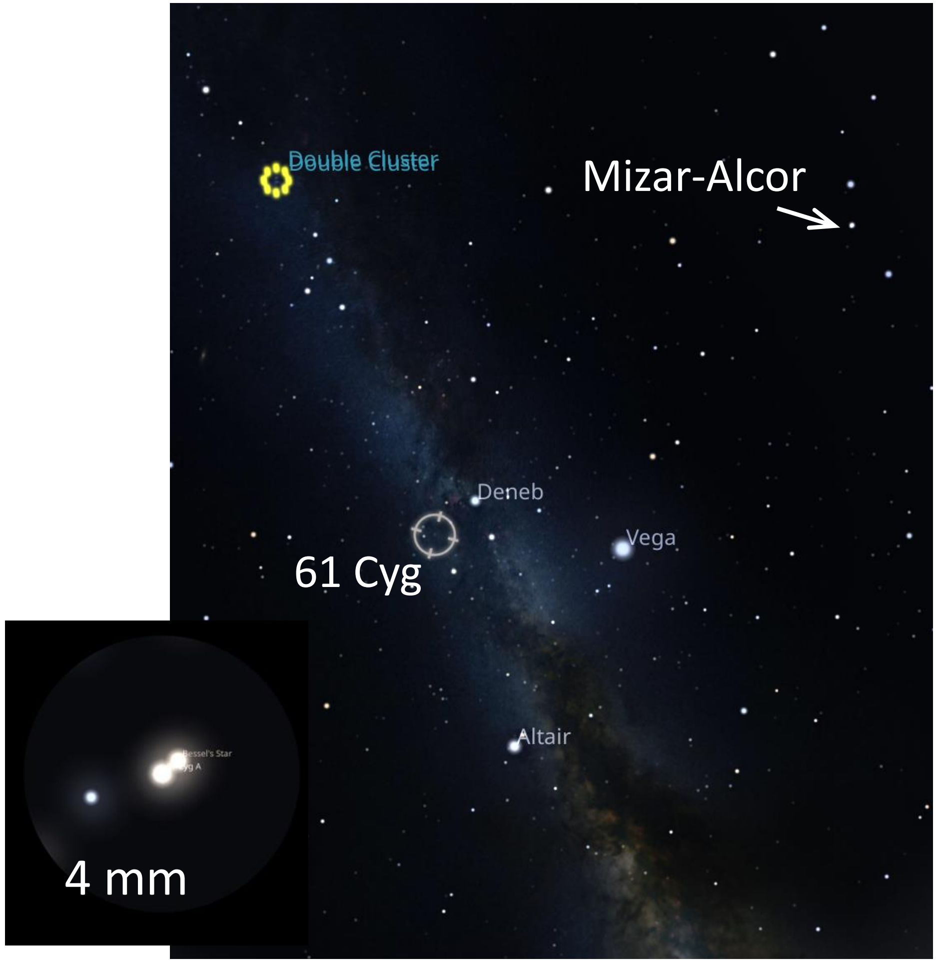
Use first the 25mm to find them. M27 is already good in the 25 mm. M57 will need the 9mm (can also try the 4 mm).

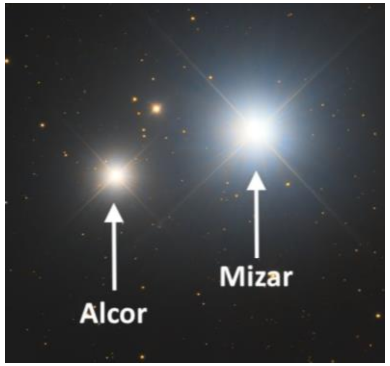
Cluster	AR	Dec
Altair	$19^h\ 50^m\ 47.00^s$	+08° 52′ 05.96″
Vega	$18^h\ 36^m\ 56.34^s$	+38° 47′ 01.28″
Deneb	$20^h\ 41^m\ 25.9^s$	+45° 16′ 49″

- What with the 114/900? M13, M15, M2, M92, M31, M81, **M27, M57**, h&χ Persei, Mizar, 61 Cygni, (M33, M51, M101)

Visual Mid-High Res.

Double Stars & Double Open Cluster





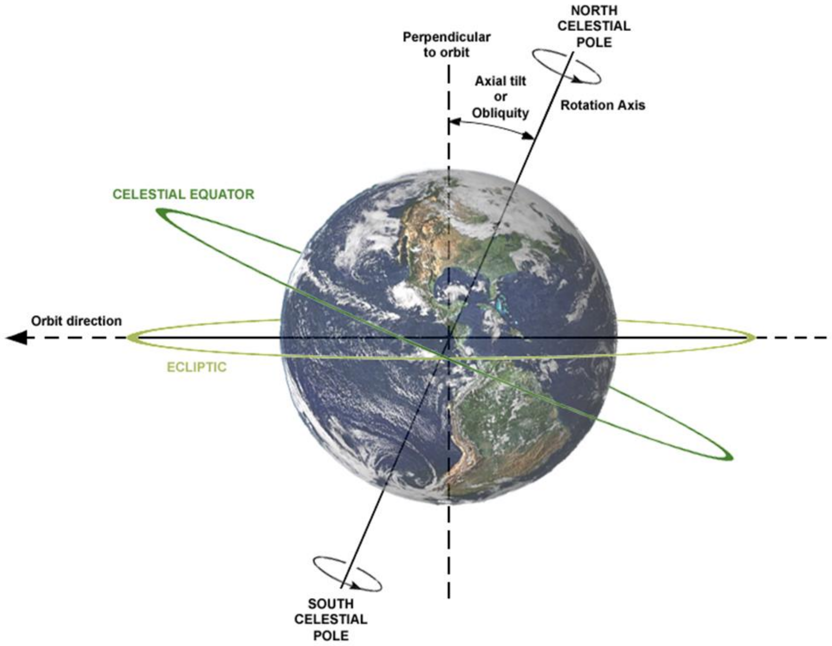
Galaxy	AR	Dec
h&χ	$2^h\ 20^m$	57° 08′
61 Cyg		

h&χ Persei and Mizar-Alcor require the 25mm. Go up to 9mm and 4mm (see insert)on 61 Cyg to see if you manage to split it…

Cluster	AR	Dec
Altair	$19^h\ 50^m\ 47.00^s$	+08° 52′ 05.96″
α Cas	$00^h\ 40^m\ 30.44^s$	+56° 32′ 14.39″
Deneb	$20^h\ 41^m\ 25.9^s$	+45° 16′ 49″

- What with the 114/900? M13, M15, M2, M92, M31, M81, M27, M57, **h&χ Persei, Mizar, 61 Cygni**, (M33, M51, M101)

Photo Skyscapes



Hours long exposure on a fixed tripod (from the Web)

- The Earth rotates so the sky apparently rotates at ω = 15° / h = 15″ / s at the celestial equator.
- So, on a sensor, you get a track of $L = \omega \times F$. If F = 50 mm, L = 3.6 µm / s!
  - Comparable to the typical pixel size of digital cameras.
  - It will have to move a few pixels before the elongation is noticeable.
  - An empirical rule for star fields is Texp (s) ≤ 300 / F

Photo Skyscapes

- For hand held photography Texp (s) ≤ 1 / F
  - VR can gain you a factor of 8-10
  - Still, only OK for the moon and the Sun at sunset
  - Even the Moon is small (31′ diameter)
  - On the focal plane this is ≈ F / 110 (F in mm)
    - At least F = 300 mm is requires to see details
- <u>It is practically impossible to go much above 1-2 s hand held, even with a wide lens (say 20 mm) and VR</u>
- To start to obtain something you need:
  - a decent tripod and a photo head (e.g., ball head)
  - A wide fast lens (F ≤ 24 mm, F/# ≤ 4)
  - A camera with good noise performance
  - Some post-processing skills and some decent software
  - <u>For starscapes, a good dark sky</u>
  - For the comet picture Texp=13s (300/24 = 12.5).

Single, hand held, shoot of the moon while entering into eclipse. Nikon Z6 with AF-P 70-300 @ 300mm f/5.6 ISO1000 1/50 s.

Single image from Pixhaier Teich, Harz, Germany
Nikon Z 6 @ ISO 6400. 13s with 24-70 f/4 @24mm @f/4

Photo Skyscapes

- For non-tracking skyscapes you need:
  - a decent tripod and a photo head (ball heads are good)!
  - A wide fast lens (F ≤ 24 mm, F/# ≤ 4)
  - A camera with good noise performance
  - Some post-processing skills and some decent software

Composite of the Total Solar Eclipse of July 2nd 2019.
Sigma 17-50 at f/5 (19mm) on Nikon D7100
The pictures during the partial phase are taken with a Baader astrofoil filter and 1/1000 s.
The frame during totality was obtained with a exposure time of 1/3 s (and no filter).

Photo Skyscapes

- Without tracking, you cannot increase the exposure time but you can improve the signal to noise ratio by registering and averaging several images
  - For this picture Texp=4s (300/70 = 4.3)

Comet Neowise between light clouds
combination of 25 frames of 4s taken at ISO6400 with a Nikon Z6 and a 24-70 f/4 @70mm @f/4

Tracking, then guiding

- Adding a tracking mount hugely expands possibility, depending on mount's quality
- However, cost and complexity adds up extremely fast

NGC 7000. 113 frames exposed 90 s. No guiding. Nikon 200 f/4 AI front stopped to F/5.4. Nikon D5100 with true dark hack.

Tracking, then guiding

- Guiding is the next step
  - Requires a guide camera and a guide scope
  - More complexity and cost
  - However, you can increase F and Texp
- Using a dedicated camera for astrophotography (cooled) increases a lot final quality, in particular a monochromatic camera with filters
  - Even more complexity and costs

M31. 80/400 Apo with ASI 183MM (-15 C°) on AVX
L filter: 30×180″(1h 30′)
B filter: 36×90″(54′)
G filter: 32×90″(48′)
R filter: 36×90″(54′)
Total integration 4h 20 min
Calibration frames: 40 darks, 25 flats, 25 dark flats (per filter)

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  - Even more complexity and costs

NGC 7000. Nikon 200 F/4 AI front stopped at F/5.4 with ASI 183MM (-15 C°) on AVX
Ha filter: 49×600”(8h 10’)
Calibration frames: 40 darks, 25 flats, 25 dark flats