Binocular Observing

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Introduction

"Every astronomical instrument is made twice. First in the shop of the artisan who makes it as expertly as he can. Second in the astronomical observatory where the astronomer carefully works out its errors and, by meticulously allowing for them, makes the instrument into a more nearly perfect device than it had been when it left the artisan's hands."

– Friedrich William Bessel (1784-1846) quoted in Isaac Asimov, "Eyes on the Universe" Boston: Houghton Mifflin, 1974. p.95.

Basics

- There is a formula stamped on the binoculars
  - MxD
  - M is the magnification
  - D is the diameter of the objective lenses
- Bigger M's make the binoculars more susceptible to 'hand-shake'
- Bigger D's gather more light, but make the binoculars physically bigger and heavier

Exit Pupil

- Divide objective diameter by magnification (D/M) to find the diameter of the bundle of light rays coming out of eyepieces
- During daylight the eye's pupil closes up to around 3mm diameter
- At night it expands to around 6-8mm
- Binoculars designed for day use will always have a small exit pupil (2-3mm)

Telescopic Aside

- The maximum usable magnification for a telescope is often described as 'double the aperture in millimetres'
- Hence M = 2D, but we just said D/M = exit pupil
- Therefore a telescope working 'flat out' will have an exit pupil of just 0.5mm!

Survey of Binoculars

Prescription	Exit Pupil		Prescription	Exit Pupil
7x42	6.0mm		10x21	2.1mm
8x20	2.5mm		10x25	2.5mm
8x21	2.6mm		10x26	2.6mm
8x22	2.8mm		10x28	2.8mm
8x24	3.0mm		10x32	3.2mm
8x25	3.1mm		10x42	4.2mm
8x30	3.8mm		10x50	5.0mm
8x32	4.0mm		12x50	4.2mm
8x40	5.0mm		16x32	2.0mm
8x42	5.3mm		20x50	2.5mm
8x56	7.0mm			

Magnification

- M = apparent field of view/actual

  – apparent field of view can normally be *estimated* at 50^0

  Therefore actual field of view ≈ 50/M

  So if M is 7, fov is around 7^0, and if M is 10 fov is 5^0

Field of View

- Linear measure at a set distance
  - Imperial, XX ft at 1000yds (divide by 52.5 to get angular field)
  - Metric, XX metres per kilometre or millimetres per metre (divide by 17.5 to get angular field)

Field of View

- Convert Linear Measure to Angular Measure
  - because we only use angular measure in the sky

- Stellar Field of View Test
  - Time in minutes, t, for star of declination, δ, to cross diameter, d
  - Then d in degrees = t cos δ/4

For a fov of 5^0 t will be 20 minutes and a fov of 7^0 t will be 28 minutes

Resolution

- The ability to see fine detail
  - Resolving power in theory =λ/D, but in practice is more accurately, 1.22λ/D Radians (λ for yellow light = 550nm, the "Rayleigh Criterion")
  - Resolving power r = 116/D in arc sec (the "Dawes Limit")
  - D = 25mm, r = 4.64". D = 50mm, r = 2.32"
- May not be achieved due to binoculars fixed low magnification

Limiting Magnitude

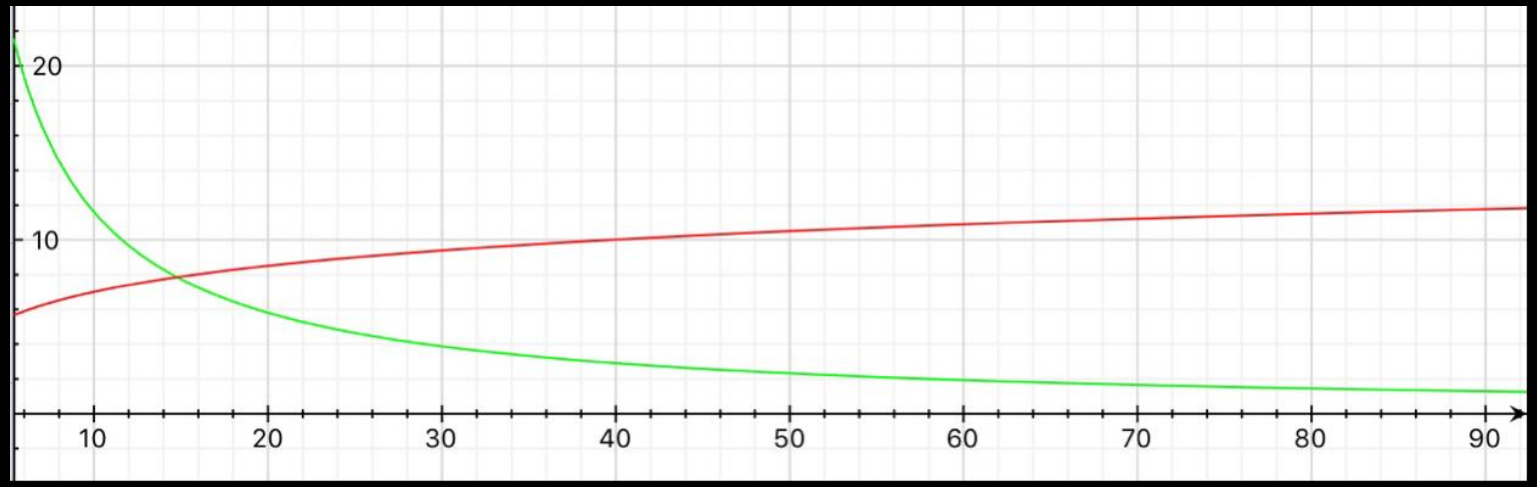
- The faintest object you can see
  - Night adapted eye pupil ≈ 8mm diameter, light gathering power over unaided eye = $D^2/8^2$
  - Limiting magnitude m of binoculars

    $= 2+5 \log_{10} D$

  - D = 25, m = 9.0. D = 50, m = 10.5

Graphs

Limiting Magnitude (Mag)
Resolution (Seconds of Arc)



Aperture (mm)

Telescopic Equivalent

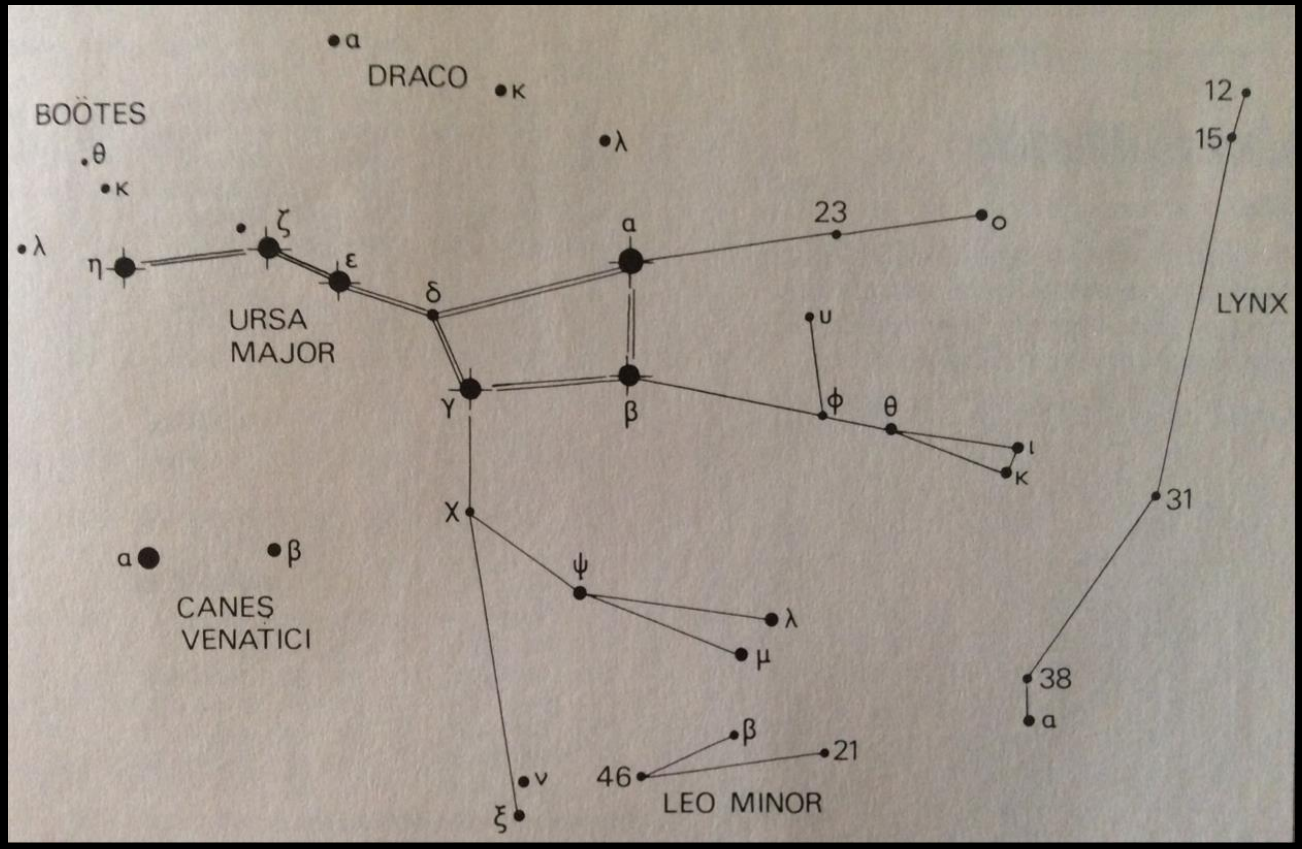
- Possibly 1.2 x?

Angle on the Sky

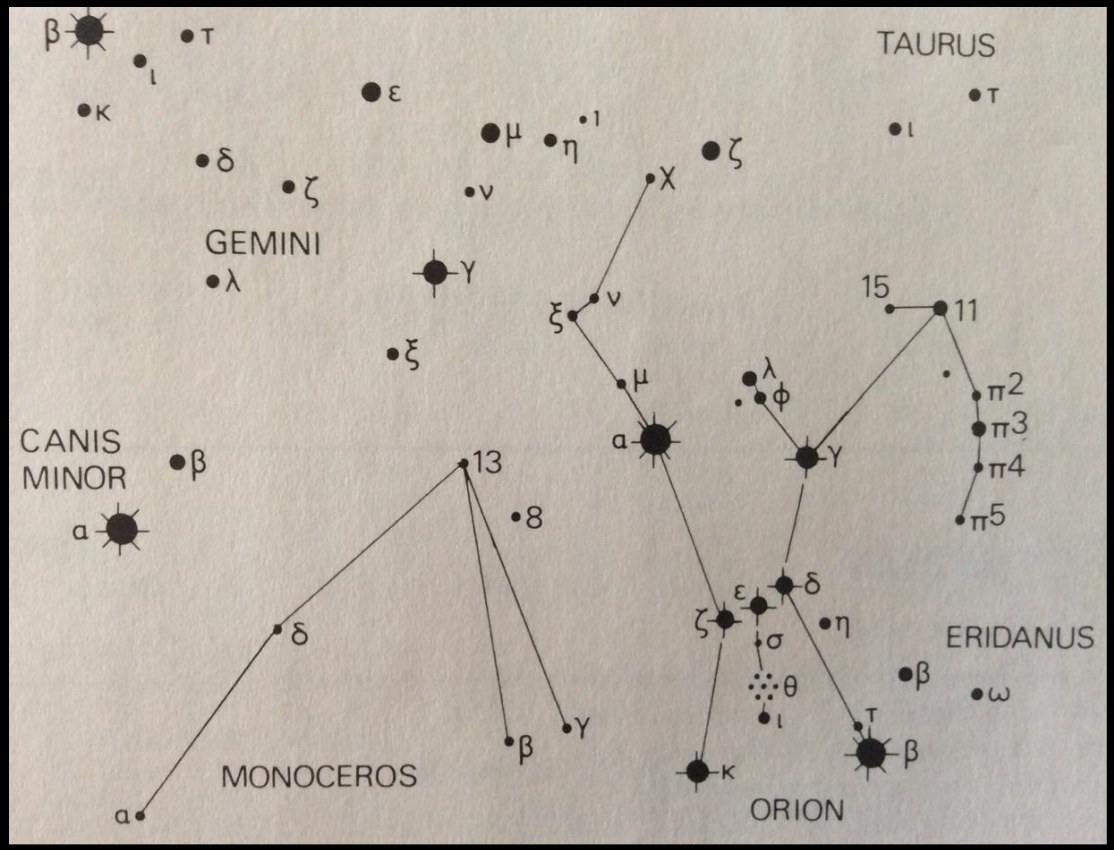
- 5.0^0
  - α to β Ursæ Majoris (The Pointers, Dubhe & Merak)
- 4.0^0
  - α to β Canis Minoris (Procyon & Gomeisa)
- 2.0^0
  - α to γ Aquilæ (Altair & Tarazed)
- 1.25^0
  - ε to δ Orionis (centre and right hand belt stars, Alnilam & Mintaka)
- 0.5^0
  - Moon's diameter

Your Hand as a Protractor

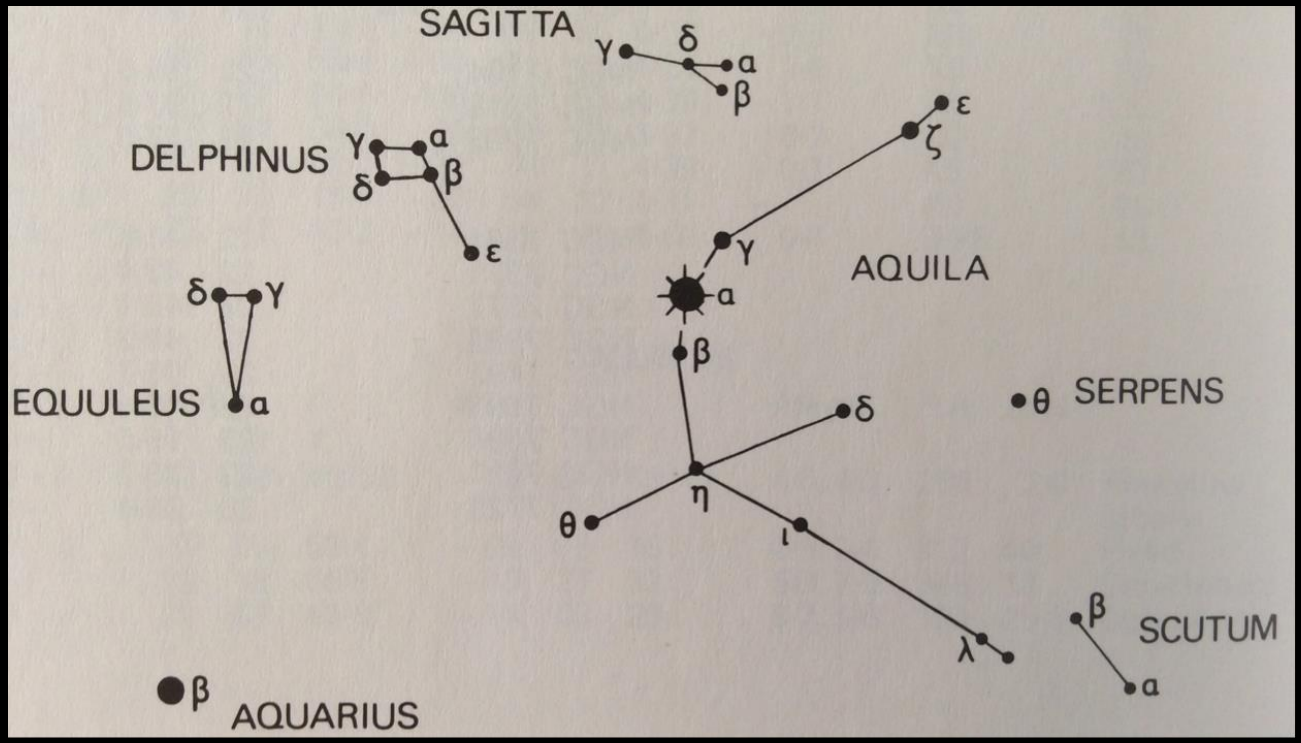
- 20^0
  - Outstretched thumb to little finger
- 10^0
  - Across knuckles
- 5^0
  - Width of middle three fingers
- 1^0
  - Width of little finger tip



– α to β Ursæ Majoris (The Pointers, Dubhe & Merak), 5^0



- α to β Canis Minoris (Procyon & Gomeisa), 4^0
- ε to δ Orionis (centre and right hand belt stars, Alnilam & Mintaka), 1.25^0

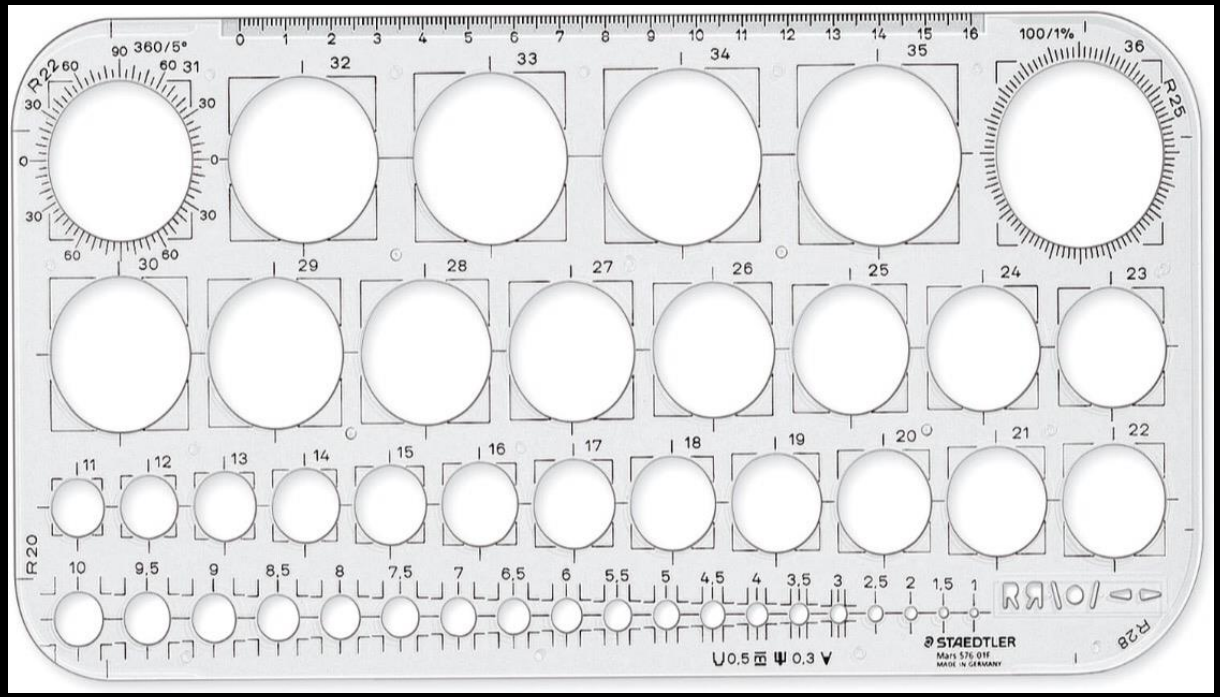


– α to γ Aquilæ (Altair & Tarazed), 2^0

Map Scales

- "Norton's Star Atlas"
  - Polar charts, 3.125mm/^{0} declination
  - Equatorial charts, 3.0mm/^{0} at +/-60^0 dec rising to 3.3mm/^{0} dec at the equator
- "Sky Atlas 2000"
  - Polar charts, 7.85mm/^{0} dec
  - Intermediate & Equatorial charts, 7.80mm/^{0} dec
- "Turn Left At Orion"
  - Finder charts 10mm/^{0}
  - Observing charts, no fixed scale?
- "Uranometria 2000"
  - All Charts 18.5mm/^{0}

Circle Template

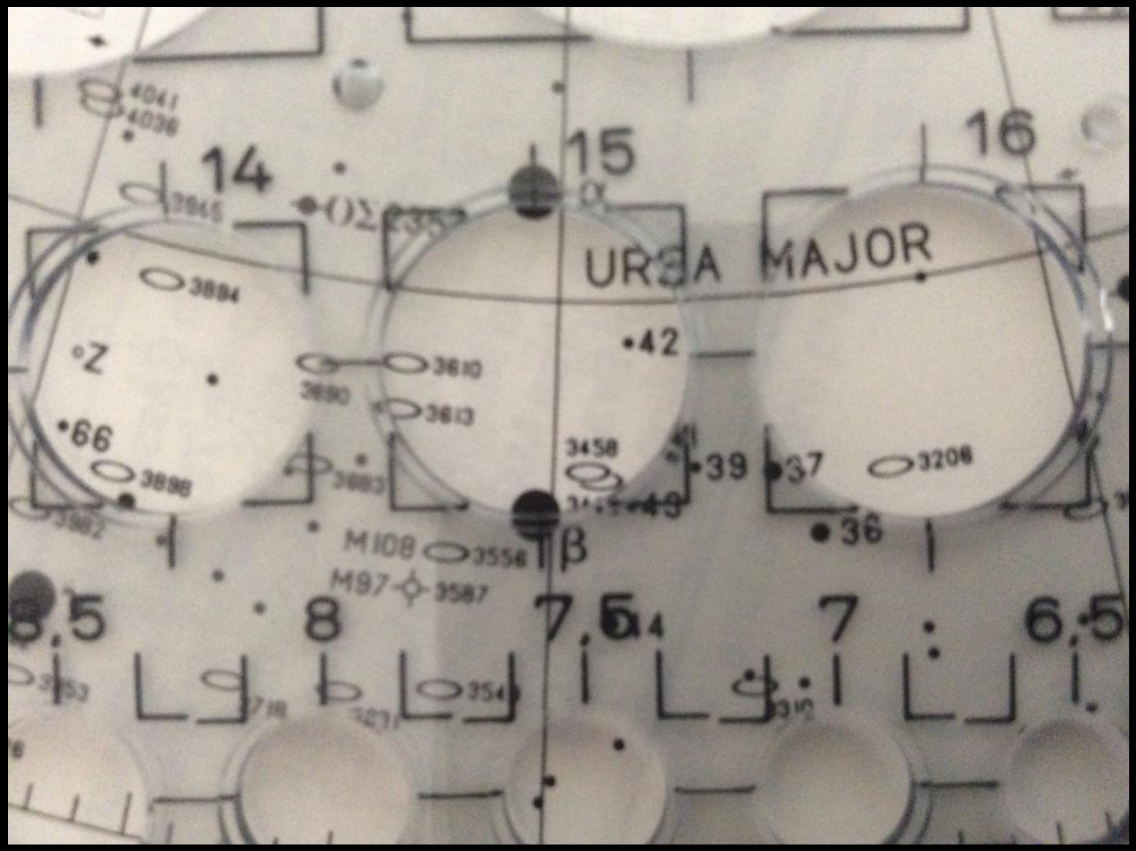


- 1mm to 10mm in 0.5mm steps
- 11mm to 36mm in 1mm steps

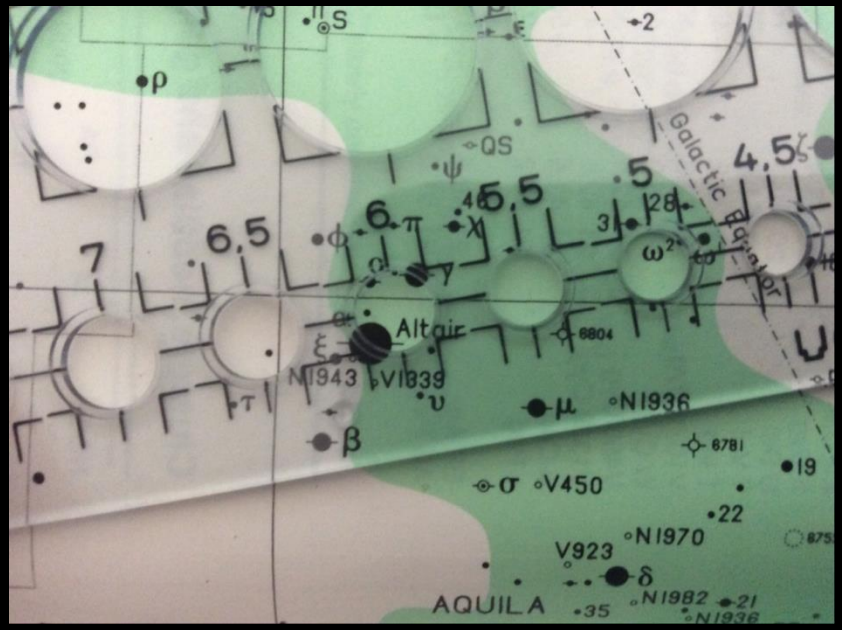
Circle Template on Star Charts

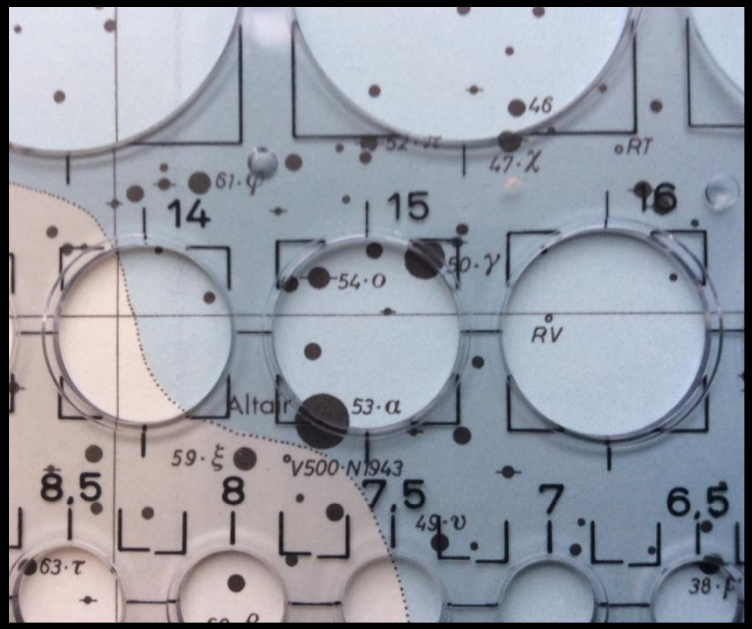
	Map scale	.5^0	1^0	1.5^0	2^0	2.5^0	3^0	3.5^0	4^0	5^0
Norton's	≈3.15mm/^{0}	1.5	3	5	6	8	9.5	11	13	16
Sky Atlas 2000	≈7.80mm/^{0}	4	8	12	16	20	23	27	31	39
Turn Left At Orion	10.00mm/^{0}	5	10	15	20	25	30	35	40	45
Uranometria 2000	18.50mm/^{0}	9.5	19	28	37	46	56	65	74	93

	Map scale	6^0	7^0	7.5^0	8^0	9^0	10^0	11^0	12^0
Norton's	≈3.15mm/^{0}	19	22	24	25	28	32	35	38
Sky Atlas 2000	≈7.80mm/^{0}	47	55	59	62	70	78	86	94
Turn Left At Orion	10.00mm/^{0}	50	55	60	65	70	75	80	85

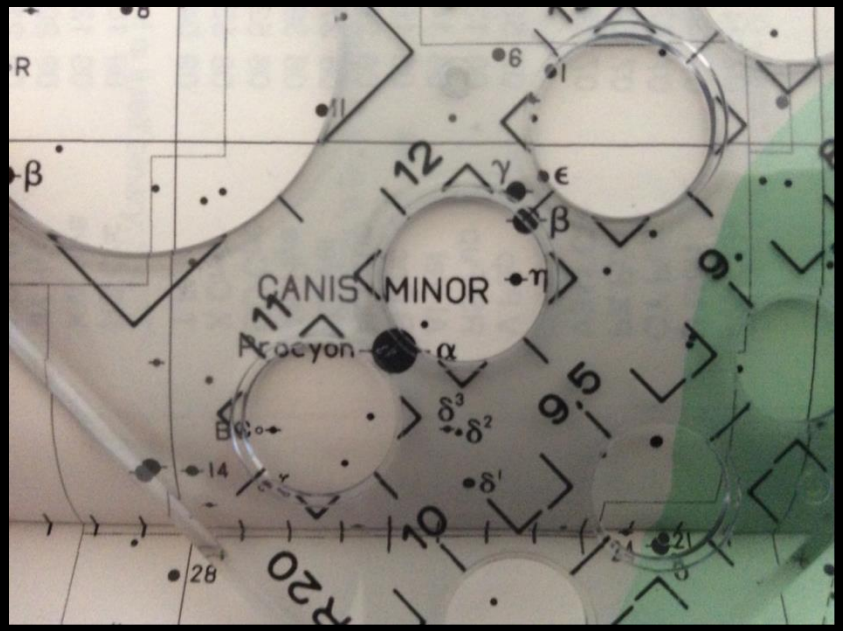


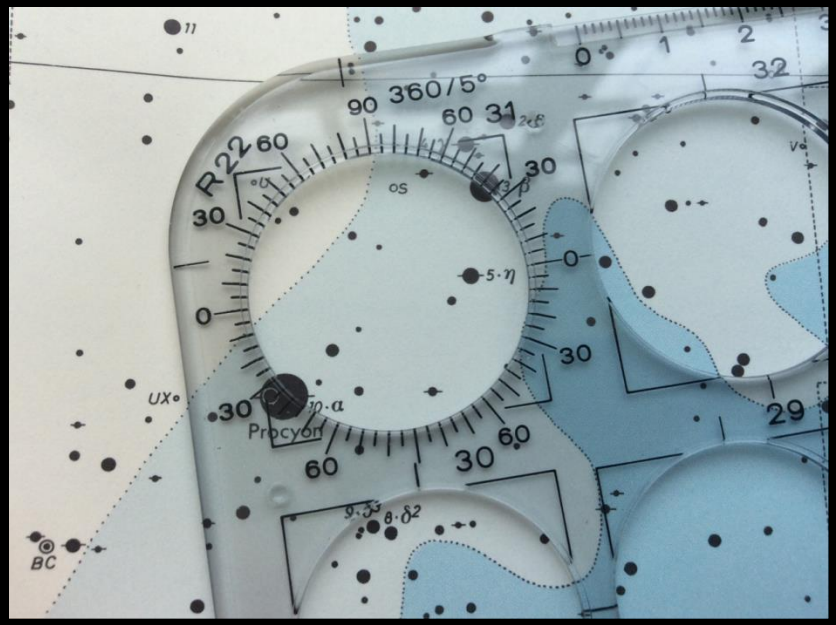
– α to β Ursæ Majoris (The Pointers, Dubhe & Merak)
– Norton's Star Atlas (5^0 at 3mm/^{0}) 15mm circle



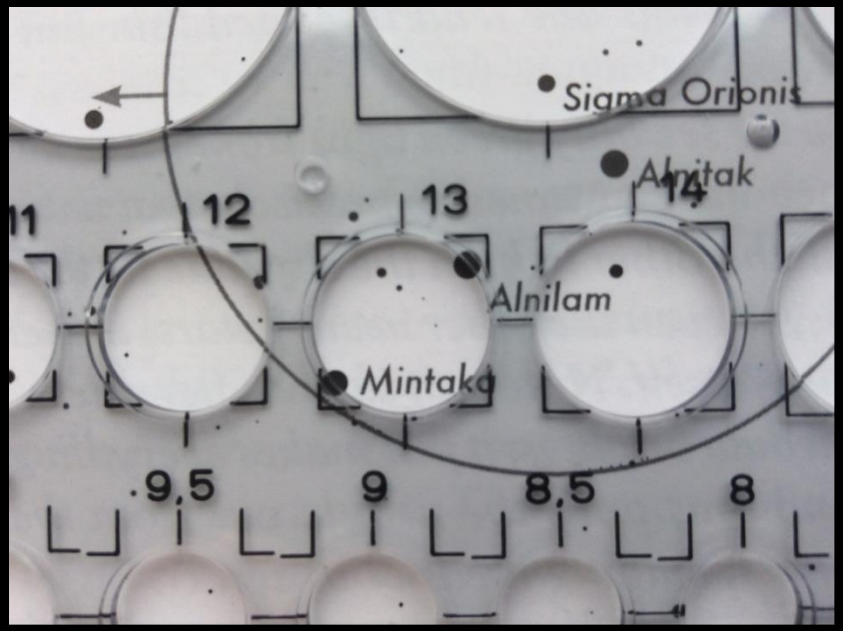


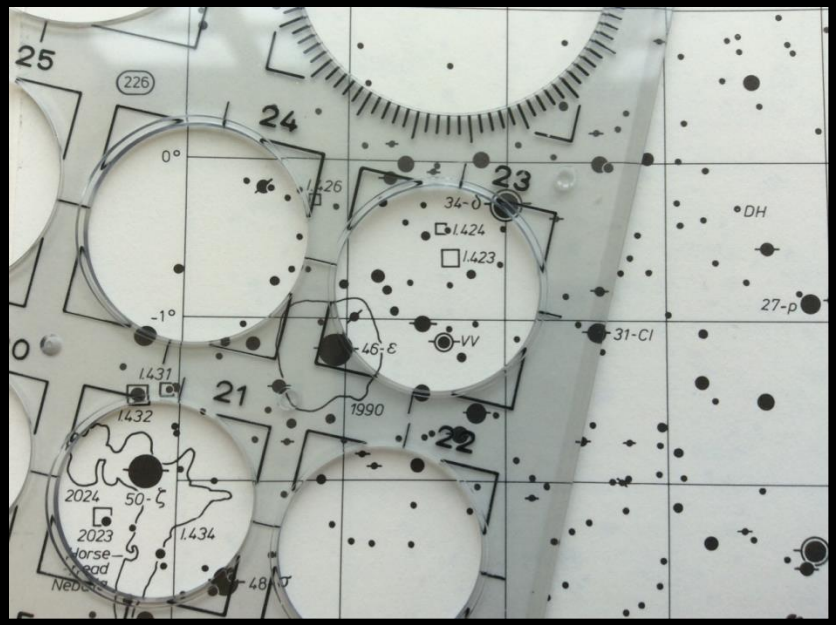
- α to γ Aquilæ (Altair & Tarazed), 2^0
- Norton's Star Atlas (2^0 at 3mm/^{0}) 6mm circle
- Sky Atlas 2000 (2^0 at 7.8mm/^{0}) 15mm circle





- α to β Canis Minoris (Procyon & Gomeisa), 4^0
- Norton's Star Atlas (4^0 at 3mm/^{0}) 12mm circle
- Sky Atlas 2000 (4^0 at 7.8mm/^{0}) 31mm circle





- ε to δ Orionis (centre and right hand belt stars, Alnilam & Mintaka), 1.25^0
- Turn Left at Orion (1.25^0 at 10mm/^{0}) 13mm circle
- Uranometria 2000 (1.25^0 at 18.5mm/^{0}) 23mm circle

Books/Further Reading

- "Norton's Star Atlas", Ian Ridpath, 18th edition 2000 or later.
- "Turn Left at Orion", Guy Consolmagno & Dan Davis, reprinted 4th edition 2013.
- "Sky Atlas 2000", Wil Tirion & Roger W. Sinnott, reprinted 1st edition 1985 or later.
- "Uranometria 2000", Wil Tirion, Barry Rappaport & George Lovi, reprinted 1st edition 1988 or later.