Seeking the (very) Elusive

Optimising your equipment, eyes and techniques

Can a new (personal) regime significantly improve your deep sky observing?

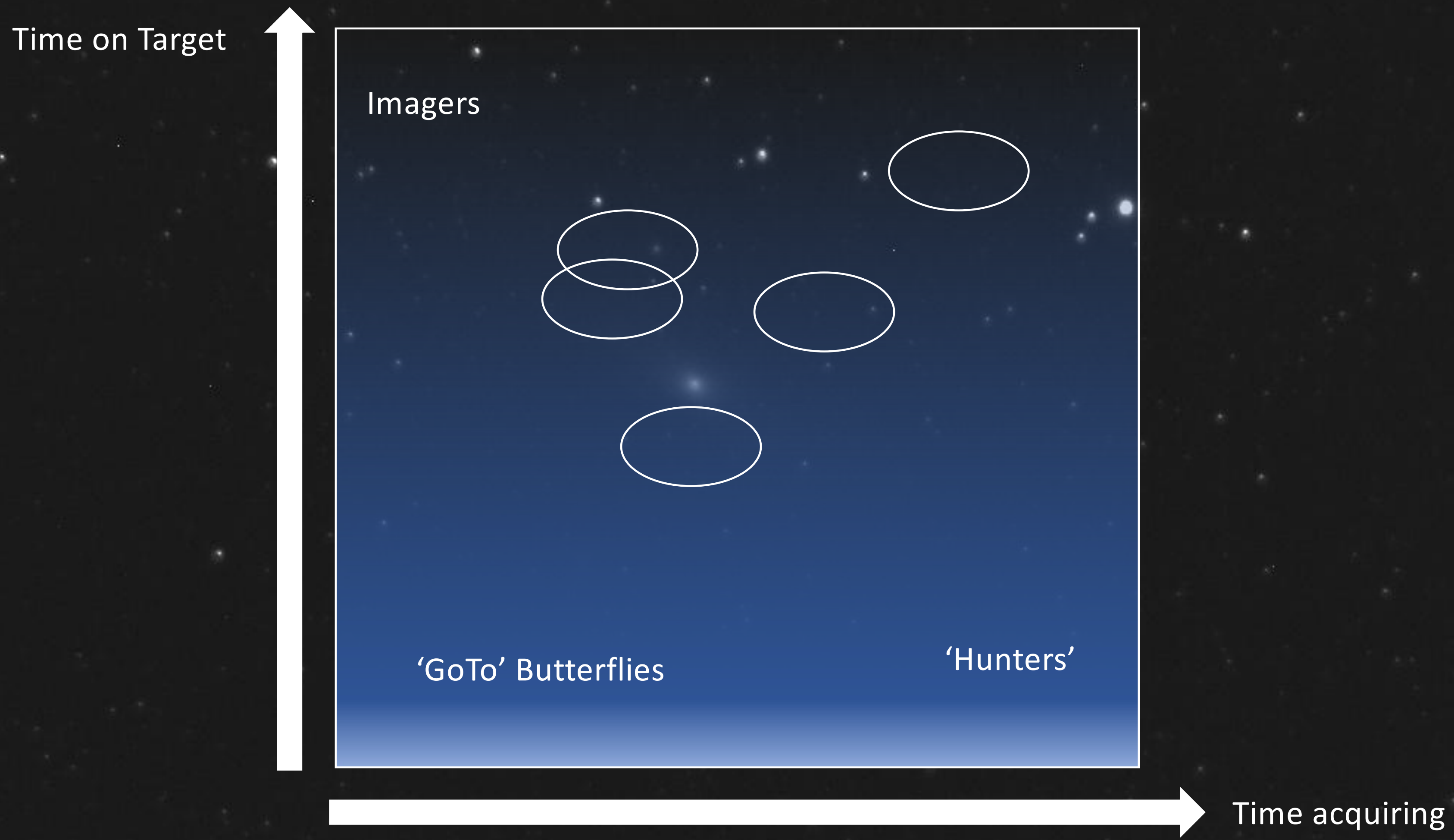
Keith Venables FRAS
IoA Cambridge
17th June 2023

Keith Venables FRAS
IOA, Cambridge
17th June 2023

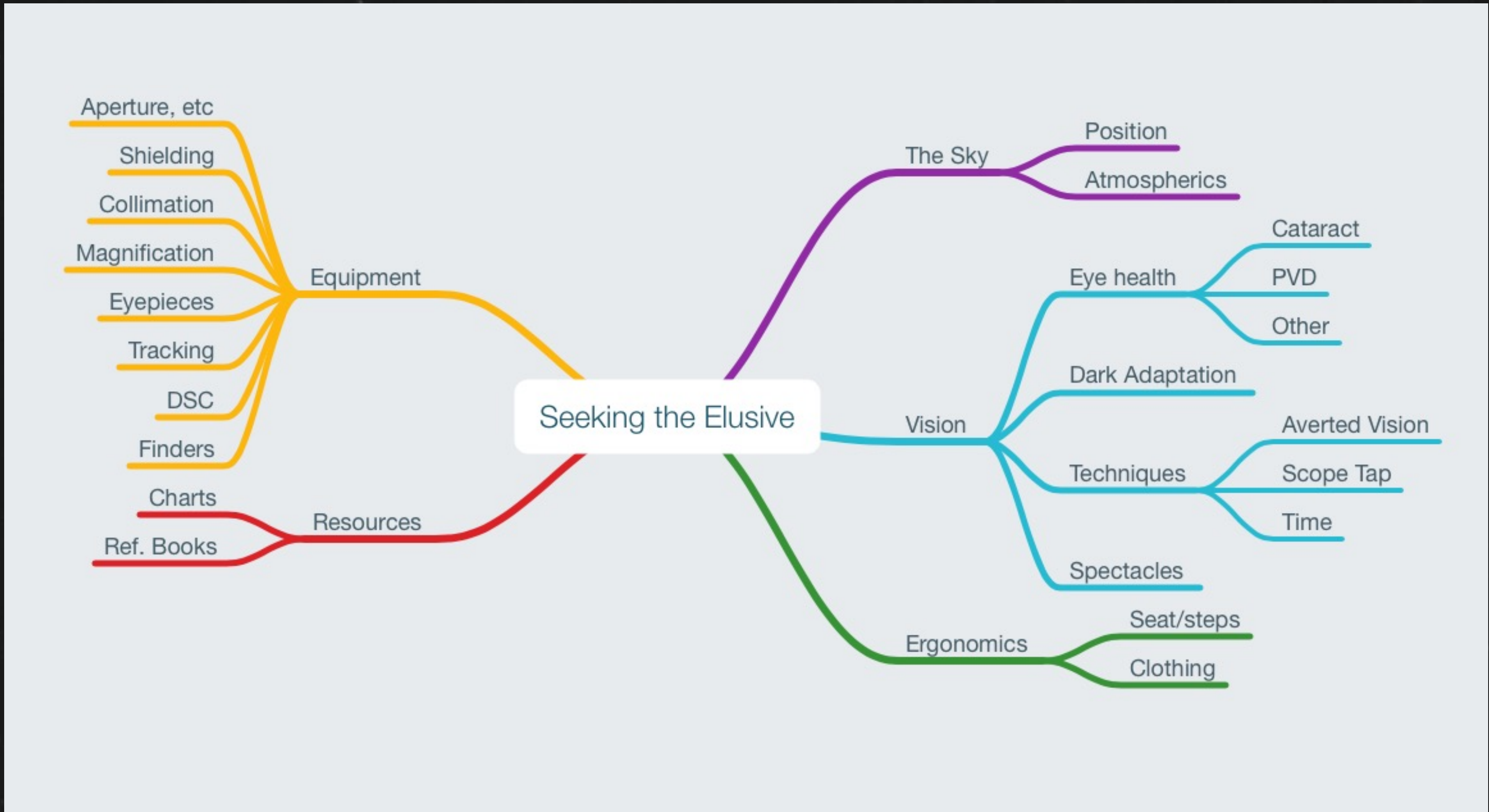
The basics for seeing the ‘elusive’

‘Find’	‘See’	‘Look’
Locate (with certainty) the correct star field at a suitable magnification “with the necessary magnification, locate the object position”	See the target, usually starting with a ‘glimpse’. Be able to re-look and acquire almost immediately.	Get comfortable and look for detail. Compare with reference images. Try different eyepieces and filters.....

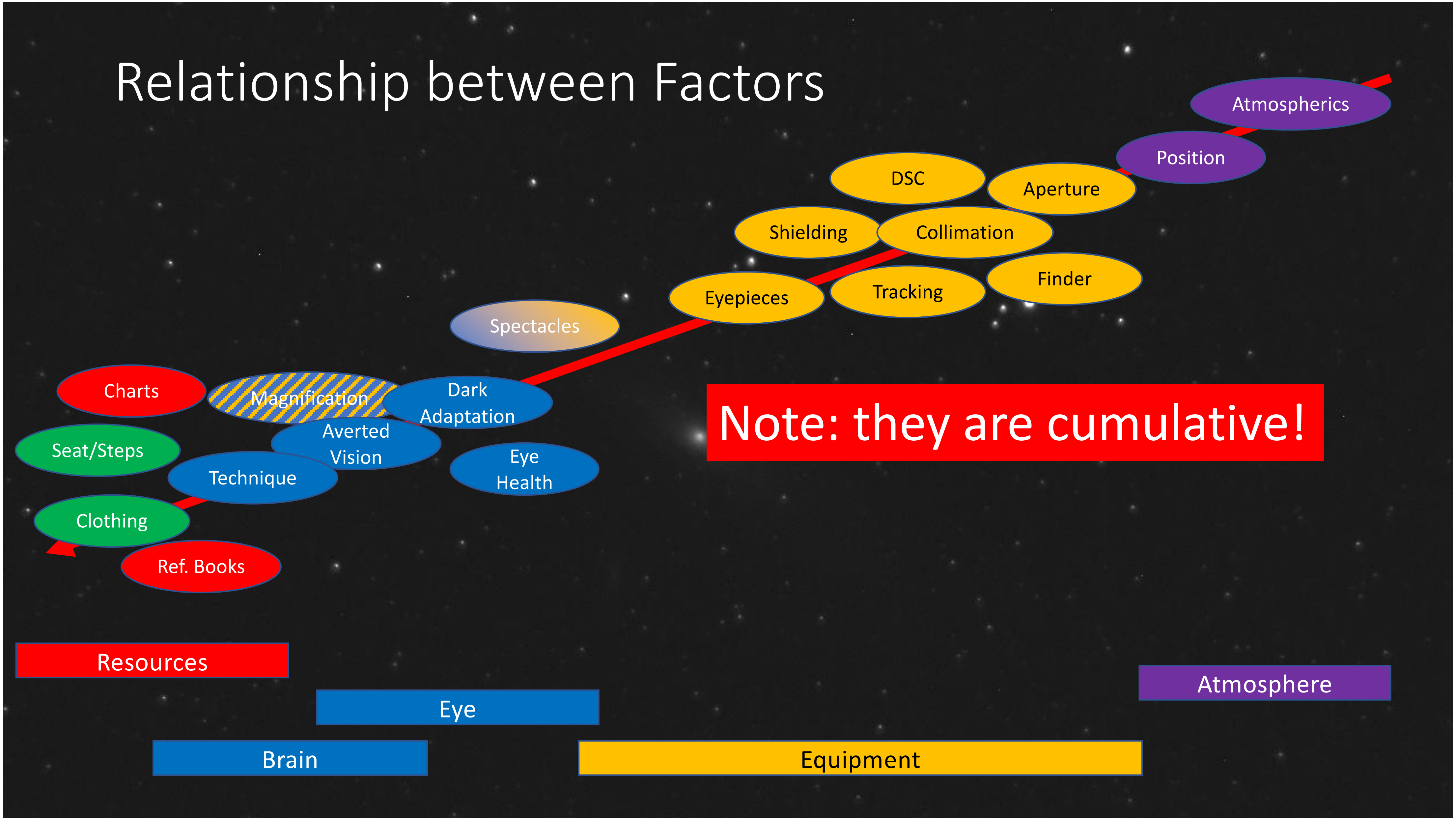
A spectrum of observer types



Exploring the factors



Survey results considered


Relationship between Factors
Atmospherics
Position
DSC
Aperture
Shielding
Collimation
Finder
Tracking
Eyepieces
Spectacles
Charts
Magnification
Dark Adaptation
Averted Vision
Seat/Steps
Technique
Eye Health
Clothing
Ref. Books
Note: they are cumulative!
Resources
Eye
Brain
Equipment
Atmosphere

5 top Factors in seeing difficult targets

Selection based on.....

- 30 years experience
- Analysis of CN & SGL posts
- Survey
- ’Interviews’

- Achieving maximum Dark Adaptation
- Observing Technique
- Magnification & Exit Pupil
- Eyes
- Finders

Dark Adaptation

- The most important factor?
- Basics are well known
- Less well quantified
  - Impact of background levels
  - <u>Actual</u> impact of red light (dim and bright)
  - Recovery from various light exposures
- Issues
  - Wavelength of the red
  - Intensity of lights
  - Durations of adaptation & disruption
  - Distraction effects

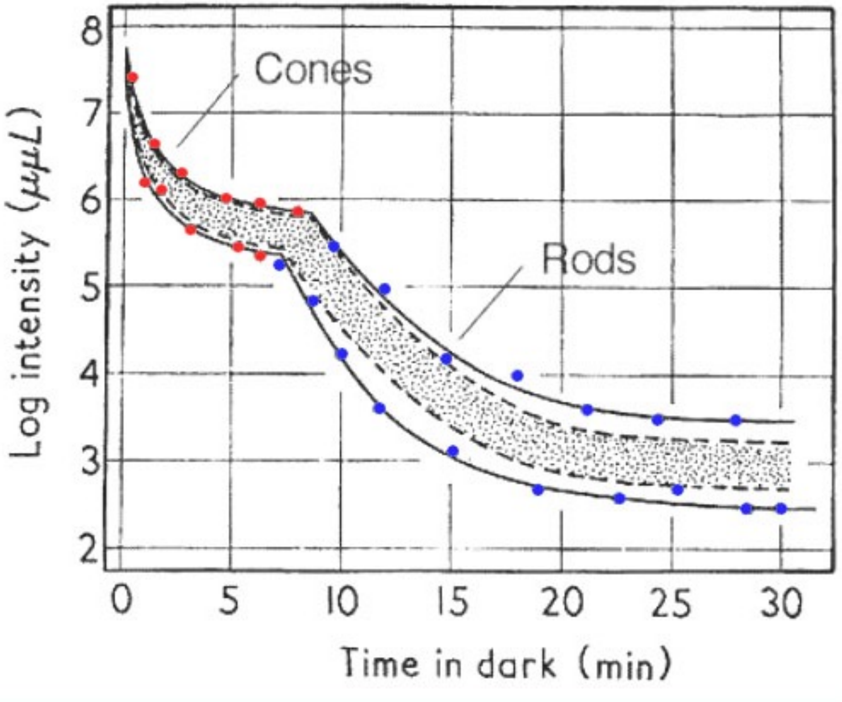
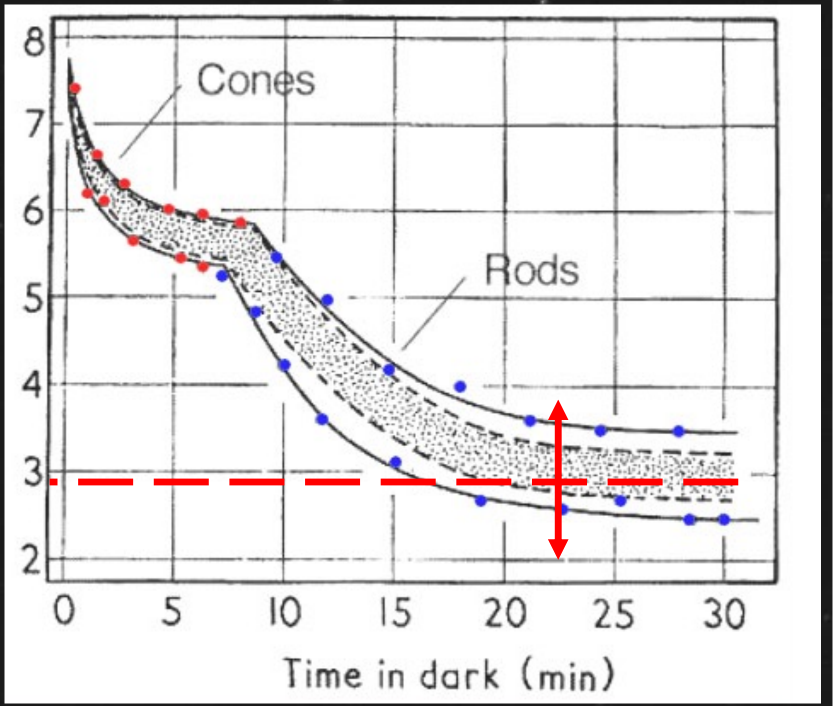


Figure 1. Dark adaptation curve. The shaded area represents 80% of the group of subjects. Hecht and Mandelbaum's data from From Pirenne M. H., Dark Adaptation and Night Vision. Chapter 5. In: Davson, H. (ed), The Eye, vol 2. London, Academic Press, 1962.

Problem in 3-dimensional space: Colour - Intensity - Duration

Dark Adaptation (cont.)

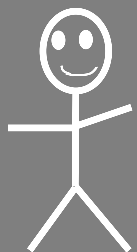
- Typical ‘floor’ of Dark Adaptation
  - ~ 2 mags on average higher than theoretical minimum
  - Anecdotal evidence of effect of different floors.
    - 6.5 is a ‘typical’ visual limiting magnitude
    - mag 8.5 if observing from a ‘black box’
  - How to get from 6.5 to 8.5?
- Techniques to aid pre-adaptation
  - Use of red goggles, eye patches, etc (Sidgwick et al)
  - Eye Condition
- Experiments needed!



Impact of ambient light level

Cepheus
Altitude ~ 80deg

2 hours outside
Sky was SQM21.5
red torch
Screens red and dim



18” f4.5
x254

Limiting magnitude estimate
15.0 (GAIA 2179697143977046784)

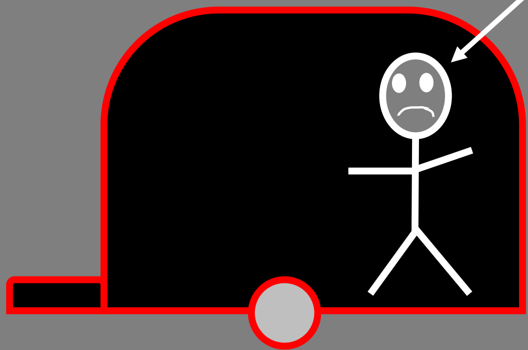
Impact of ambient light level

Cepheus
Altitude ~ 80deg

18” f4.5
x254

1 hour inside
Total darkness
No torches
No screens etc

Me, bored!



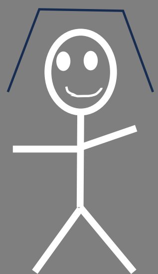
Impact of ambient light level

Cepheus
Altitude ~ 80deg

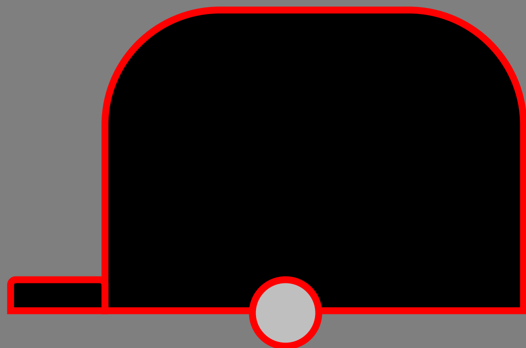
Immediately after

Limiting magnitude estimate
16.8 (GAIA 2179696250623855360)

Hood



18” f4.5
x254



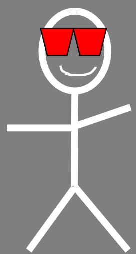
1.8 mag improvement!

Close to the ‘Ideal’ limit of 17.0 (Clark)

Impact of ambient light level

Cepheus
Altitude ~ 80deg

Continued outside
Sky was SQM21.5
Torches
Screens



18” f4.5
x254

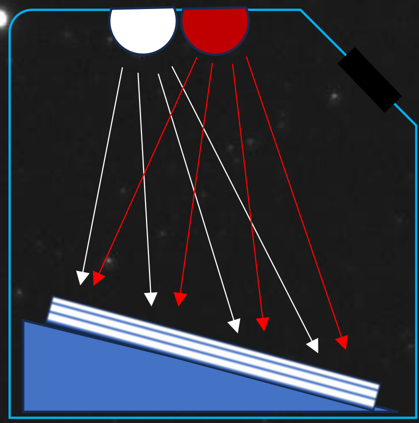
Limiting magnitude estimate
~ 16.1

1 mag improvement!

close to the ‘real’ limit
of 16 mag
(Sinnott & Garstang)

Another experiment

- Texas Star Party
  - Tested legibility of charts, using red & white light at various levels.
  - Measured impact on DA
- Dim white as good (better?) as bright red and much preferred for reading
- Recovery from dim white could be controlled.
  - 5-10 seconds of dim white reading, recovered full DA in ~30 seconds.
  - So, exposure to localised dim white light for short periods is OK (but problematic in a shared space)
- Recovery from red was faster
  - Dim red almost immediate, but charts couldn't be read satisfactorily
  - Brighter red took 15-20 seconds



Red light

- Longer than 640nm avoids rod response. (Deep red)
  - Continuous exposure slows down Dark Adaptation a little
  - Fast recovery from strong exposure when already Dark Adapted.

= Deep red has almost no effect on DA

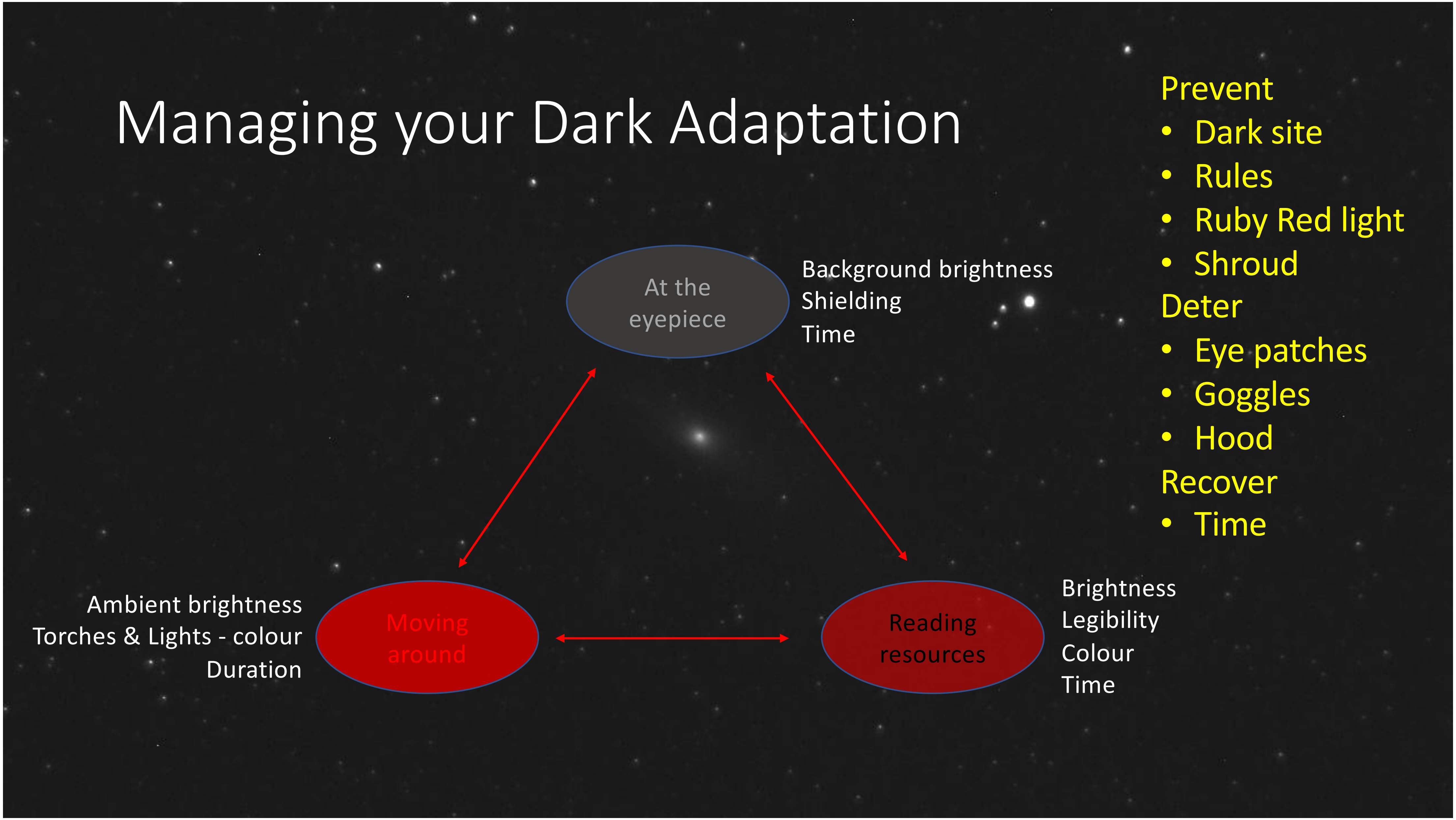
- But, difficult to read charts etc., unless rather bright

..... and can then be distracting

- Not a single astronomy red Led torch found > 630nm

White light

- Continuous exposure limits degree of Dark Adaptation achievable
  - Sets a ‘floor’ to the Dark Adaptation curve.
  - Requires time at the eyepiece to lower the ’floor’. Can be at least 30 minutes.
  - Thus Red goggles can help achieve and maintain Dark Adaptation
- When Dark Adapted
  - Recovery to short exposure of dim white is quite rapid.
  - Strong exposure will bleach the retina according to the strength of the source and need some minutes to recover.
  - Small and intermittent dim white lights produce obvious distraction, but not loss of DA


Managing your Dark Adaptation
At the eyepiece
Background brightness
Shielding
Time
Moving around
Ambient brightness
Torches & Lights - colour
Duration
Reading resources
Brightness
Legibility
Colour
Time
Prevent
• Dark site
• Rules
• Ruby Red light
• Shroud
Deter
• Eye patches
• Goggles
• Hood
Recover
• Time

Averted Vision

- A technique to exploit Dark Adaptation
- Distribution of rods isn't uniform.
  - Sidgwick et al, upper - lower bias
  - Individual variability – requires personal exploration
- Dwell
  - Stare (6 second integration time)
  - Comfort (seat and clothing)
- Scope Tap
  - Supplements Averted Vision

Right-eye in object space

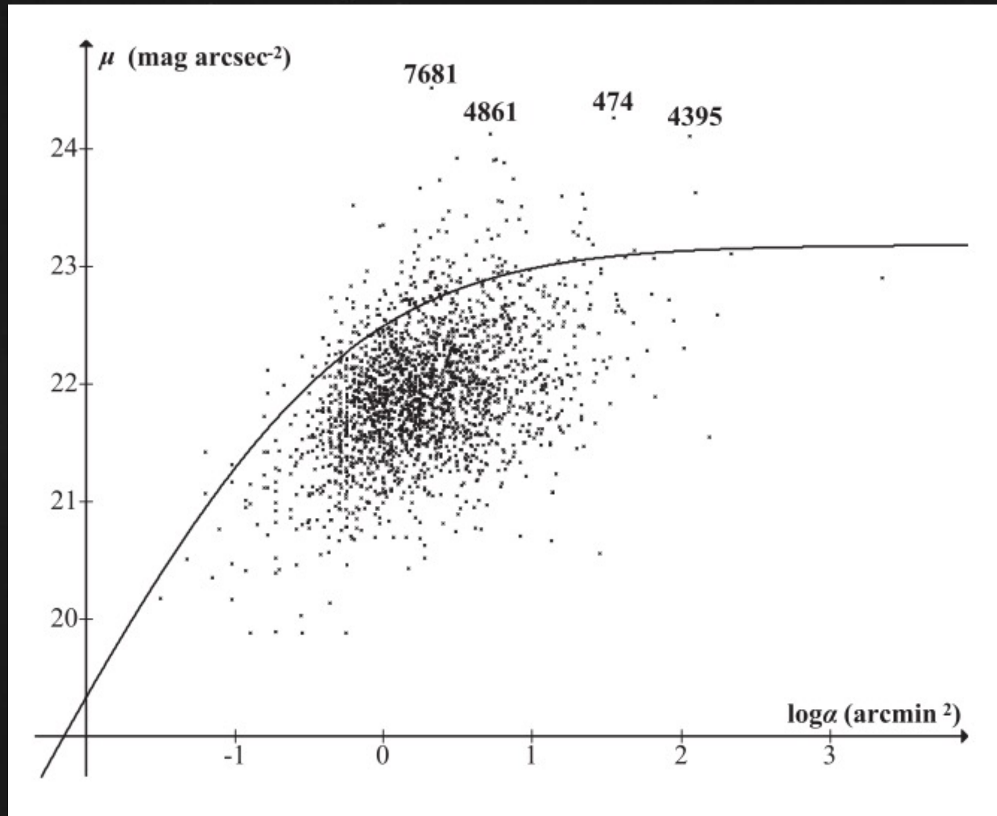
Magnification & Exit Pupil

- Well known optimum magnification relationship to resolve fainter detail (ref, Roger N Clark et al)
  - Increasing magnification reduces background brightness – good for ‘point’ sources
    - 50% increase in magnification darkens background by about 1 mag.
  - Increasing magnification (larger apparent target) improves detection of contrast
    - But target is getting dimmer too.
- Nothing is straightforward!
  - The eye has a typical noise threshold of about 26 mpsas
  - WWII studies suggested large targets of 28-29 mpsas may be ‘detected’.
  - For dark skies and <u>really</u> low Surface Brightness targets, try reducing magnification.
- Anecdotal evidence that exit pupils <2mm can be counter-productive for some observers, and ~3mm may be an optimum.

Human contrast threshold and astronomical visibility

Andrew Crumey, *MNRAS* ***442****, 2600–2619 (2014)*

- Thorough re-examination of previous work (Blackwell, Curtiss, Clark, Schaefer, et al)
- Normalised previous disparate findings using a number of factors (Observer, equipment, light pollution, etc).
- Applied his new analysis to the established data. From Herschel to O'Meera
- Attributes Critical Visual Angle to the 'Ricco Area' effect (ref. Ricco's Law)
- Highlights 3 good sources that indicate a peak in visual acuity at 3mm exit pupil.



Herschel's 17.5" ngc observations

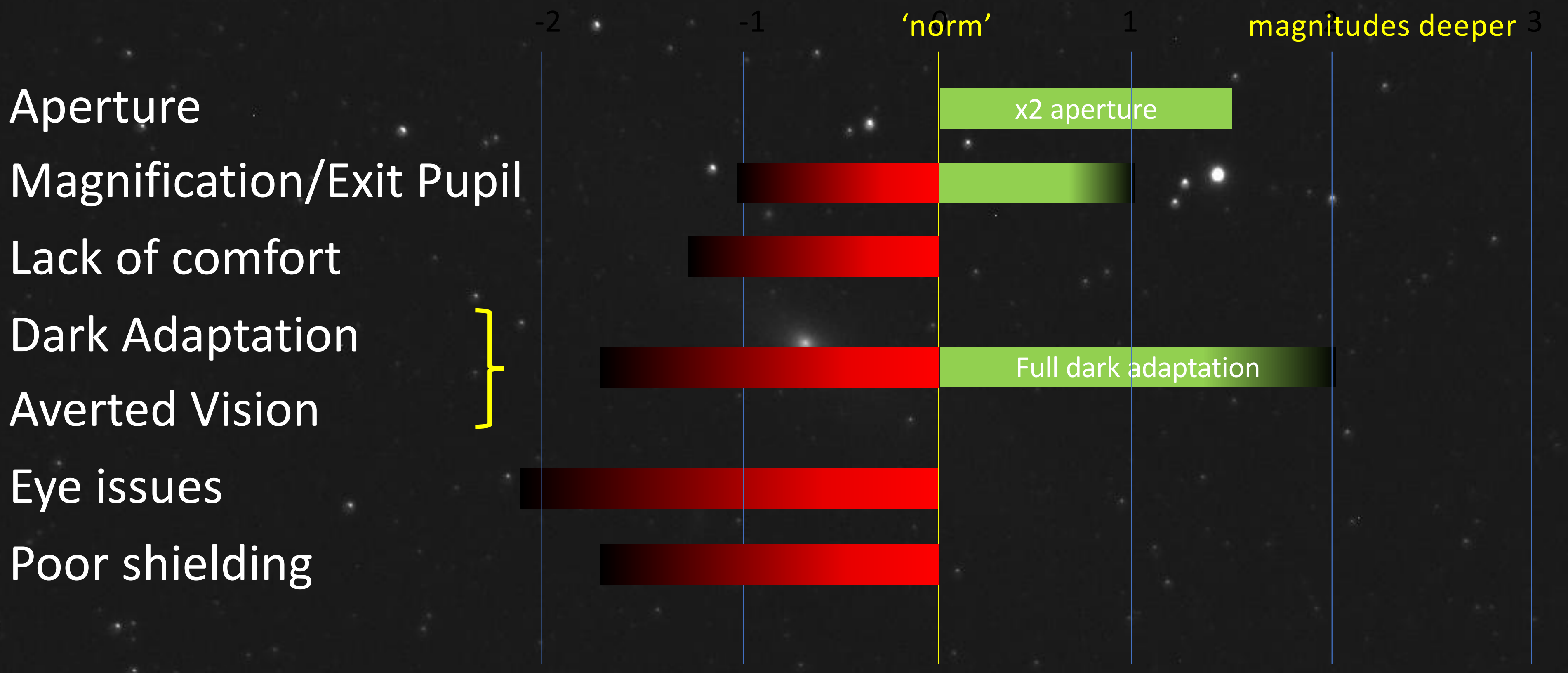
The Eyes & Eye Health

Eye Condition	Short term	Vitamin A good. Glucose & Oxygen for Rhodopsin regeneration.	But, quick changes in blood sugar can distort the eye.
	Long term	Diabetes impacts badly Cataracts Posterior Vitreous Detachment Macular Degeneration	L-lysine, Zinc, Vit C, Vit E, Lutein, Zeaxanthin
Spectacles		Eyepiece eye-relief issues Progressives Reduces eye-cup shielding benefits	Comfort Problematic
Alcohol & Smoking		Dims peripheral vision first Can cause fast change in blood sugar level – bad Decreases contrast sensitivity Slows pupil dilation	

Atmospherics

- Air Mass effect
  - Not very significant
  - 0.1 mag at 45 deg
  - 1 mag at 10 deg
- Aerosols
  - Even on a good night
    - MODTRAN6 model, Mid-latitude Winter, 23km vis
    - Moisture 50% absorption at 45deg, 1 mag at 20deg
- Light Pollution
  - Sky brightening under LP is the biggest issue
  - Particles (dust etc) add very significantly to losses and SQM.

‘Seeing’ the Elusive – League table



Remember – factors are additive

Note: All the above are cumulative!

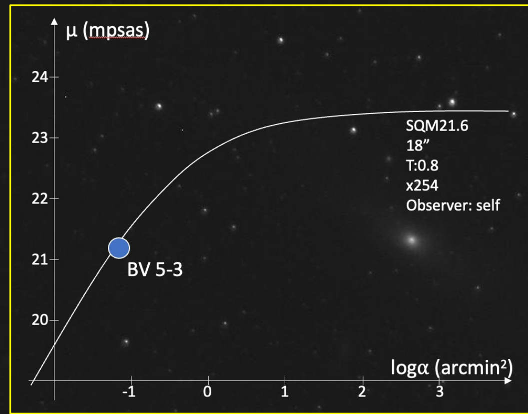
Practical aspects of 'seeing' - 1

- 4 magnitude difference between rods and cones sensitivity
  - Must maintain and protect the fullest dark adaptation
    - More time at the eyepiece and much less moving around and at charts etc.

- Averted Vision
  - Most effective when the target position in the eyepiece field is known.
  - 2 magnitudes difference across the rods alone
    - Averted Vision is difficult enough to start with – searching the field is not effective
    - You can avert to your 'sweet spot', (and not your blind spot!)
    - You can employ the 6 sec dwell technique

Practical aspects of ‘seeing’ - 2

- Let’s assume a target dim enough to require steady averted vision
  Do you,
  a. Get ’close enough’ & visually search, or
  b. Spend more time locating and get spot on.



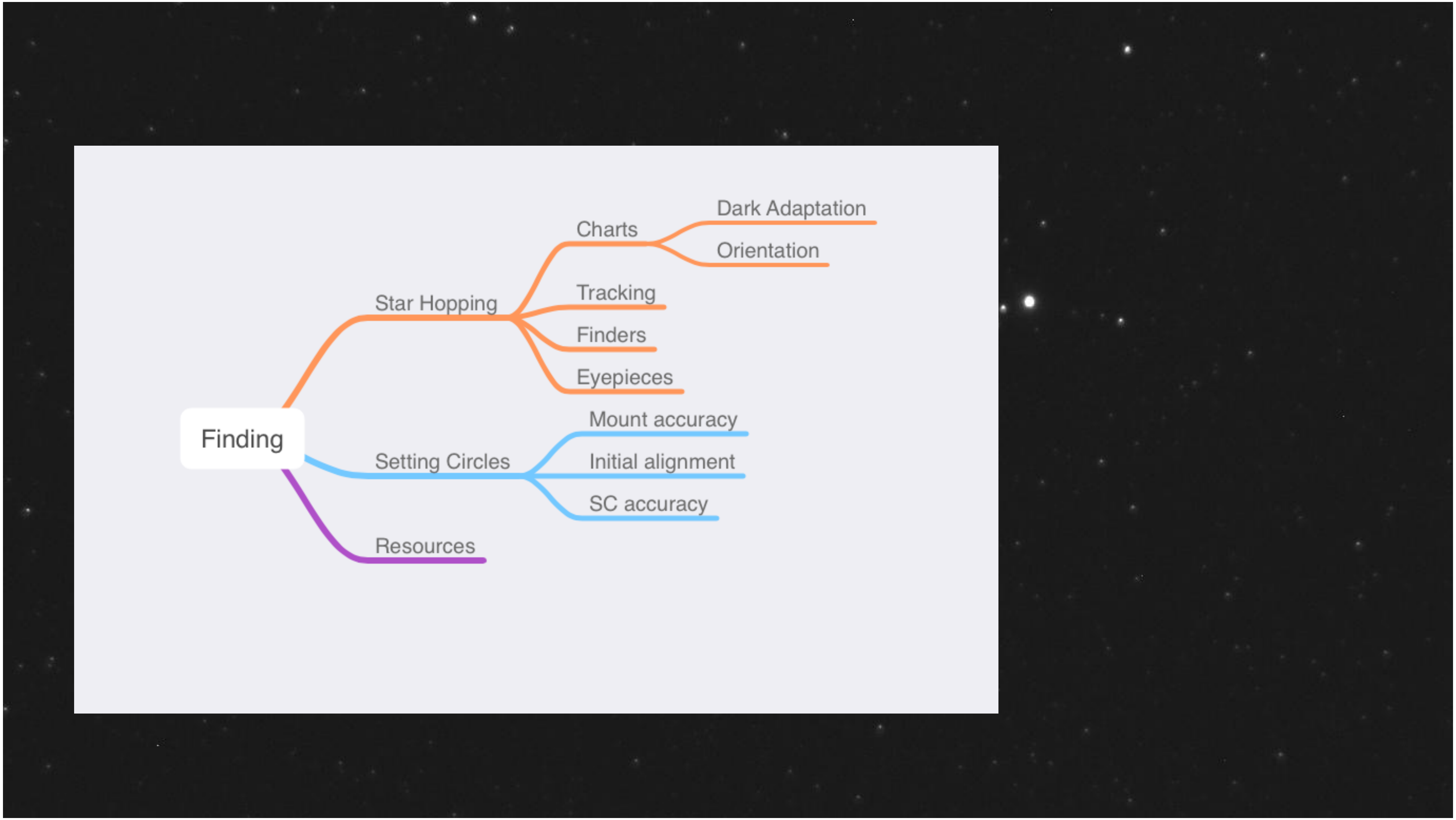
- Example: BV 5-3 - a challenging target (SB ~ 21. 2mag)
  - In the eyepiece field but 3 out of 4 observers couldn’t see it.
  - When told exactly where it was, 3 out of 4 could see it. (ie 2 more)

- Observing with a buddy often leads to seeing ‘more’

Knowing the position of the target in the field of view is critical

Finding the Target – a new approach

(For visual observers)


Finding
Star Hopping
Charts
Dark Adaptation
Orientation
Tracking
Finders
Eyepieces
Setting Circles
Mount accuracy
Initial alignment
SC accuracy
Resources

Finding the (elusive) Target

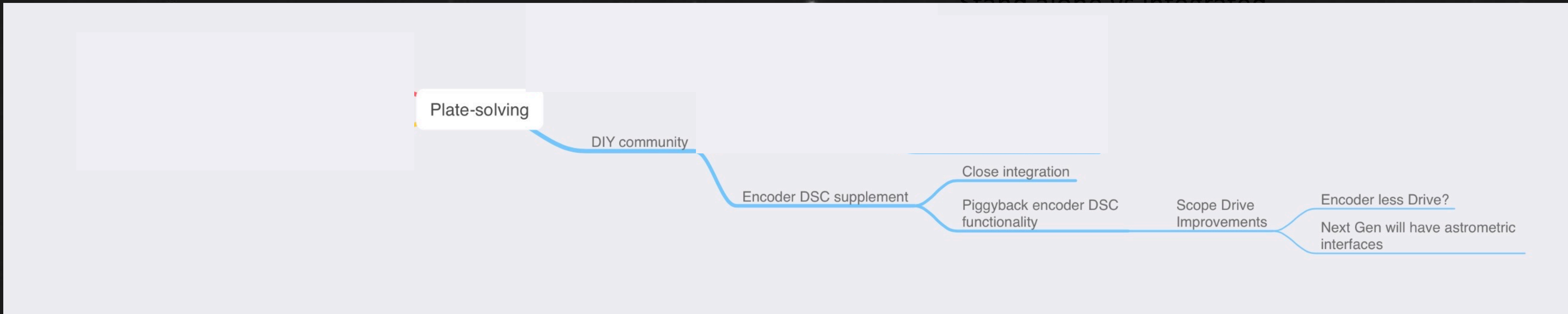
- Star-hopping
  - Low tech but requires practice and some skill
  - Maintaining Dark Adaptation while using charts needs care
  - Can take a time
  - Really benefits from a tracking mount
- Digital Setting Circles (DSC)
  - Relatively easy to fit
  - DSC in itself is accurate and powerful
  - Overall accuracy depends on the mount & initial alignment
    - Accuracy in practice is variable.
    - Usually still need some star-hopping (or ‘local syncs’) for difficult targets.
    - Many DSCs can build a model of a mount's systematic errors, but takes setup time
  - GoTo systems are dependent on DSC accuracy

Past & Recent developments in Plate-Solving

- Astro-photographers have long moved to plate-solving
  - Small camera TFOV.
  - They want maximum time on target
  - They had cameras and computers already.
  - Plate-solving for most has completely removed the need for accurate mount alignment
- Many plate-solving applications run on small SBCs and even smart phones.
- Celestron StarSense is the first commercial use of a plate-solving finder for <u>visual</u> use.
  - Growing in popularity but not easily integrated with other scopes

Future developments with Plate-Solving? (for Visual Observers)

Redo as commercial vs amateur diy



'eFinder' prototype

1 deg fov (custom f4 lens)
Mechanical alignment needed
LCD display issues
Dedicated gps dongle needed
Applies corrections to a DSC
Excellent but slow solve performance

‘eFinder’

6 deg fov (f1.8 cctv lens)
Semi-automatic alignment
Remote OLED display & control box
Fully integrated with Nexus DSC
Faster solving

‘eFinder’

Alternative ‘GUI’ display on pc or tablet (via wifi)

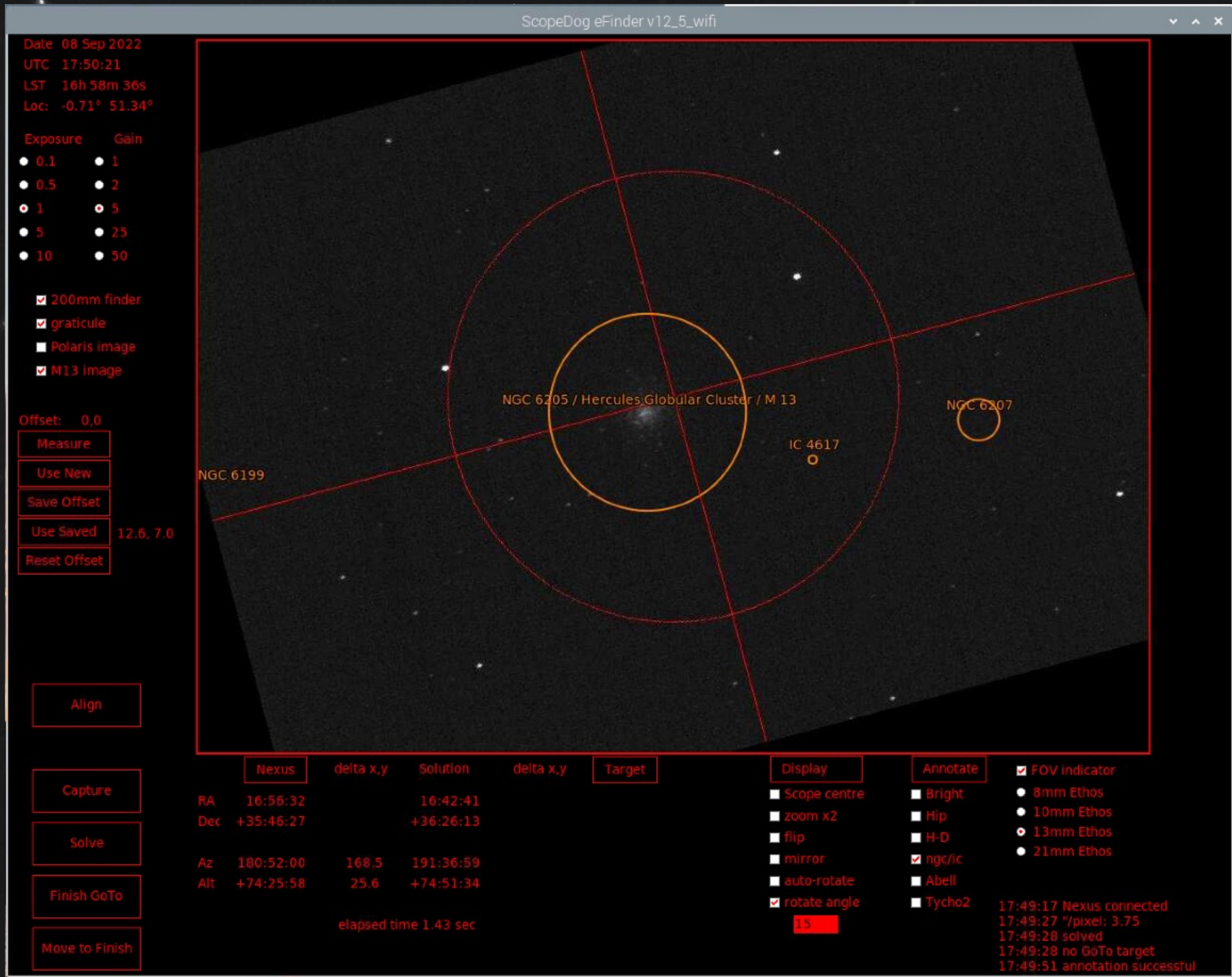
Display can show eyepiece field of view

Can rotate to match the eyepiece view. Manual or automatic.

Any or all types of object can be automatically annotated.

Currently working on adding Comets

Writing an Android App to simplify its use.



Digital Finder features

- Display current telescope position, with respect to true RA & Dec
- Simplify initial 2 star alignment
  - Actual stars not needed!
- Perform 'Local Sync' anywhere, without an actual star alignment
- Refine a GoTo, (aka GoTo++)
- Simplify mount modelling (eg Mpoint)
- Derive motor drive rates without need for scope initial alignment - 'Point and track'

Full integration is possible (and coming)

- Run the plate-solver code within the scope motor drive box.
- Plug a camera directly into the drive box
- Scope drive hand pad shows <u>absolute</u> scope eyepiece centre coordinates
- Accurate mount encoders are becoming less essential

‘Seeking the (very) Elusive’

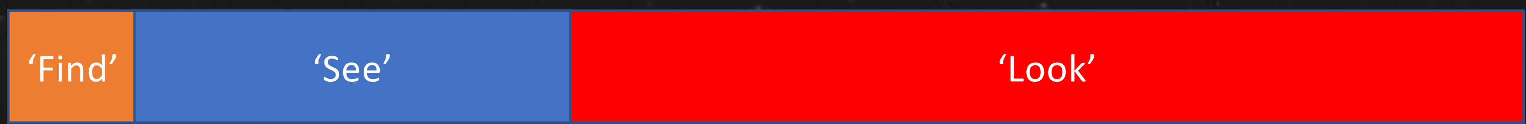
- Double check you are centered in the correct field
  - Finder Charts
  - OLED Tablet recommended
  - Consider a Digital Finder
- Maintain Dark Adaptation
  - Optimise your averted vision
- Be comfortable
  - clothing
  - seat
  - hydrated
  - fed
- Consider magnification & exit pupil
- Try nudging the scope
- Maintain good blood sugar levels – ‘AstroBrownies’
- Reference images
  - eg, Night Sky Observers Guide
- Spend more time at the eyepiece!
- Ultra wide eyepieces may be a disadvantage.
- Experiment & practice

In Conclusion……

- With some effort, up to two magnitudes deeper is possible.
- No great expense, just method and diligence.
- A massive difference to the visual observing experience

- Digital Finders could simplify future scope drives and the user experience.
- They allow scopes to be pointed to sub-arc minute accuracy with respect to actual sky.
- Especially useful with compact and lighter mount designs

- For me, better DA & minimising the 'hunt' allowed much deeper observations



Main reference sources

- Blackwell, H. R. (1946). Contrast Thresholds of the Human Eye. *J. Opt Soc Amer.* ***36*** *624-643*
- Bowen, K. P. (1984). Vision and the Amateur Astronomer. *Sky & Telescope April, 321-324*
- Clark, R. N. (1990). Visual Astronomy of the Deep Sky. *Cambridge University Press*
- Crumey, A (2014). Human contrast threshold and astronomical visibility. *MNRAS 442, 2600-2619*
- Curtis, H. D. (1901). On the Limits of Averted Vision. *Lick Obs Bull* ***2*** *67-69*
- Hecht, S., C. Haig & G. Wald (1935). The Dark Adaptation of Retinal Fields of Different Size & Location. *J Gen. Physiol.,* ***19****, 321-339*
- Jordan, F. Introduction to Deep Sky Observing. *Webb Society*
- Langley A*. (2004).* The influence of exit pupil diameter on visual acuity.... *, J. Br. Astron. Assoc., 2004,* ***114*** *73-77*
- Leibowitz, H. (1952) The Effect of Pupil Size on Visual Acuity.... J. *Opt Soc Am* ***42*** *416-452*
- Sidgwick, J. B. (1971). Amateur Astronomer's Handbook. *Faber & Faber*
- Steinicke W. And Jakiel R. Galaxies and How to Observe Them *(Astronomers' Observing Guides), Springer, 2007*
- Venables, K. (2007). Preserving Dark Adaptation. *Texas Star Party*

- *www.cloudynights .com. Deep Sky Observing Forum*
- *www.stargazerslounge.com. Observing – Deep Sky Forum*