Telescope Collimation

for Dummies

OASI Workshop 02 April 2008 P J O'Sullivan

What is telescope collimation?

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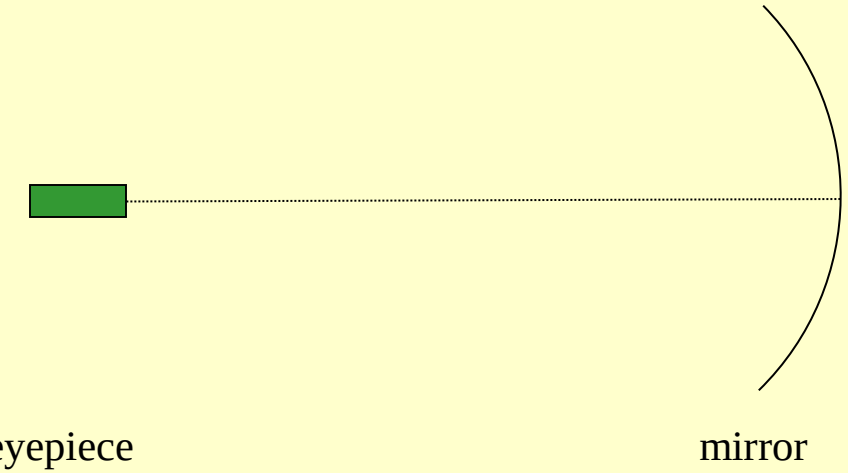
Aligning optical axis of eyepiece to optical axis of mirror or object glass.



Outline

- *Telescope basics*
- *Secondary mirror offset*
- *Coma - killer of optical image quality*
- *Collimation tools*
- *The 3 steps of collimation*
- *Collimating a refractor, etc.*
- *Star testing*
- *Summary*

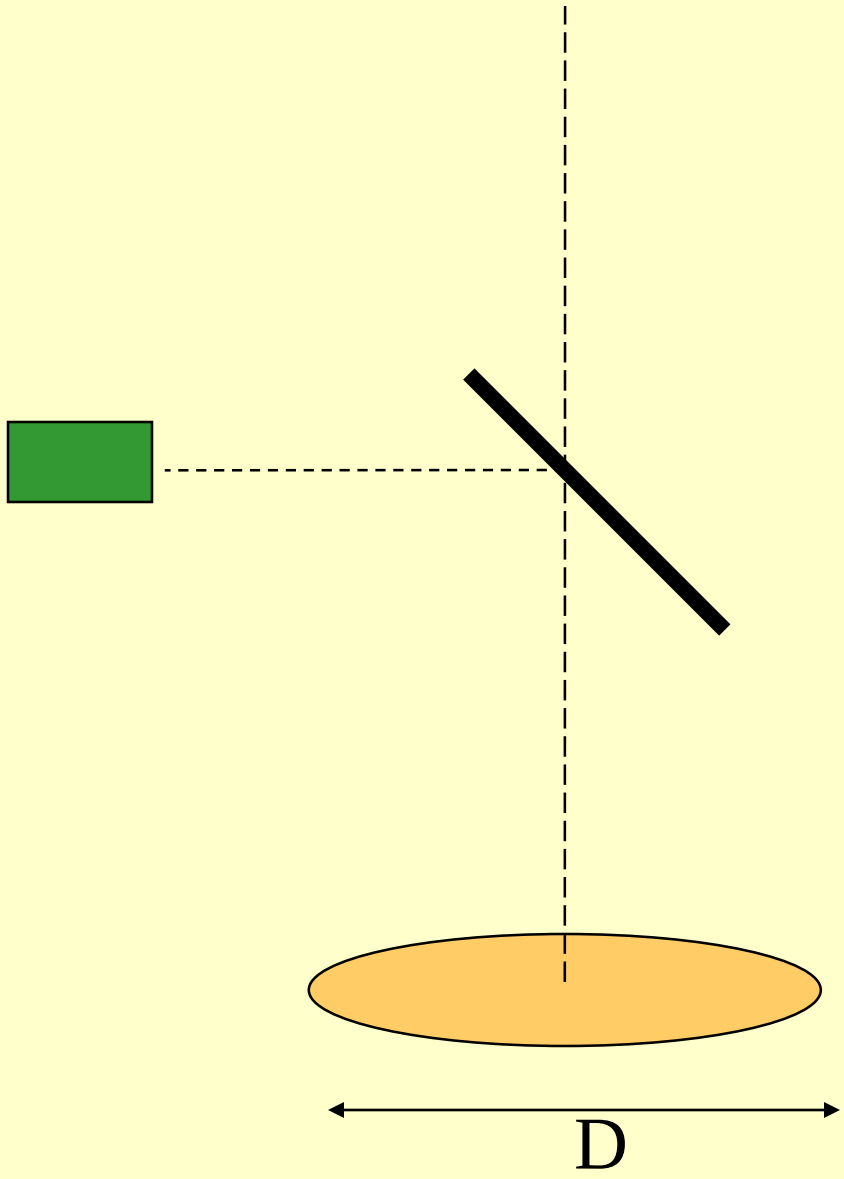
Telescope Basics- mostly Newtonian

Telescope Components.

Primary mirror in mirror cell with 3 collimating screws.

Secondary or diagonal mirror in holder which ca n be raised/lowered and rotated. Angle of mirror adjustable with 3 screws.

Eyepiece held in focus- which may or not be easily adustable.



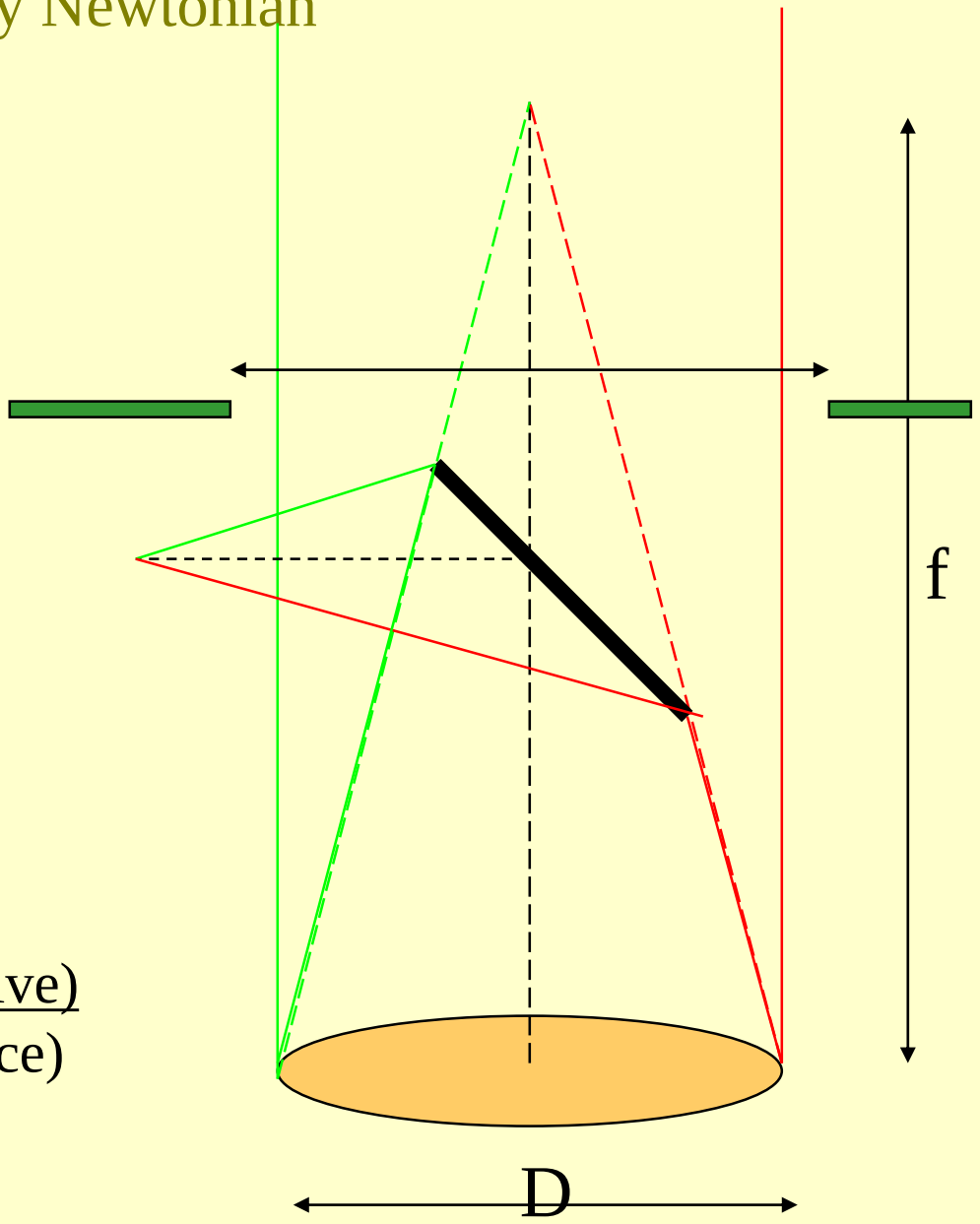
Telescope Basics- mostly Newtonian

Focal length = f
D = mirror diameter

F is focal ratio.
F = f / D

Examples:
f = 1000mm; D = 100mm
F = 10
Tomlin = 15
MMT = 4.5

magnification = $\frac{\text{f(objective)}}{\text{f(eyepiece)}}$

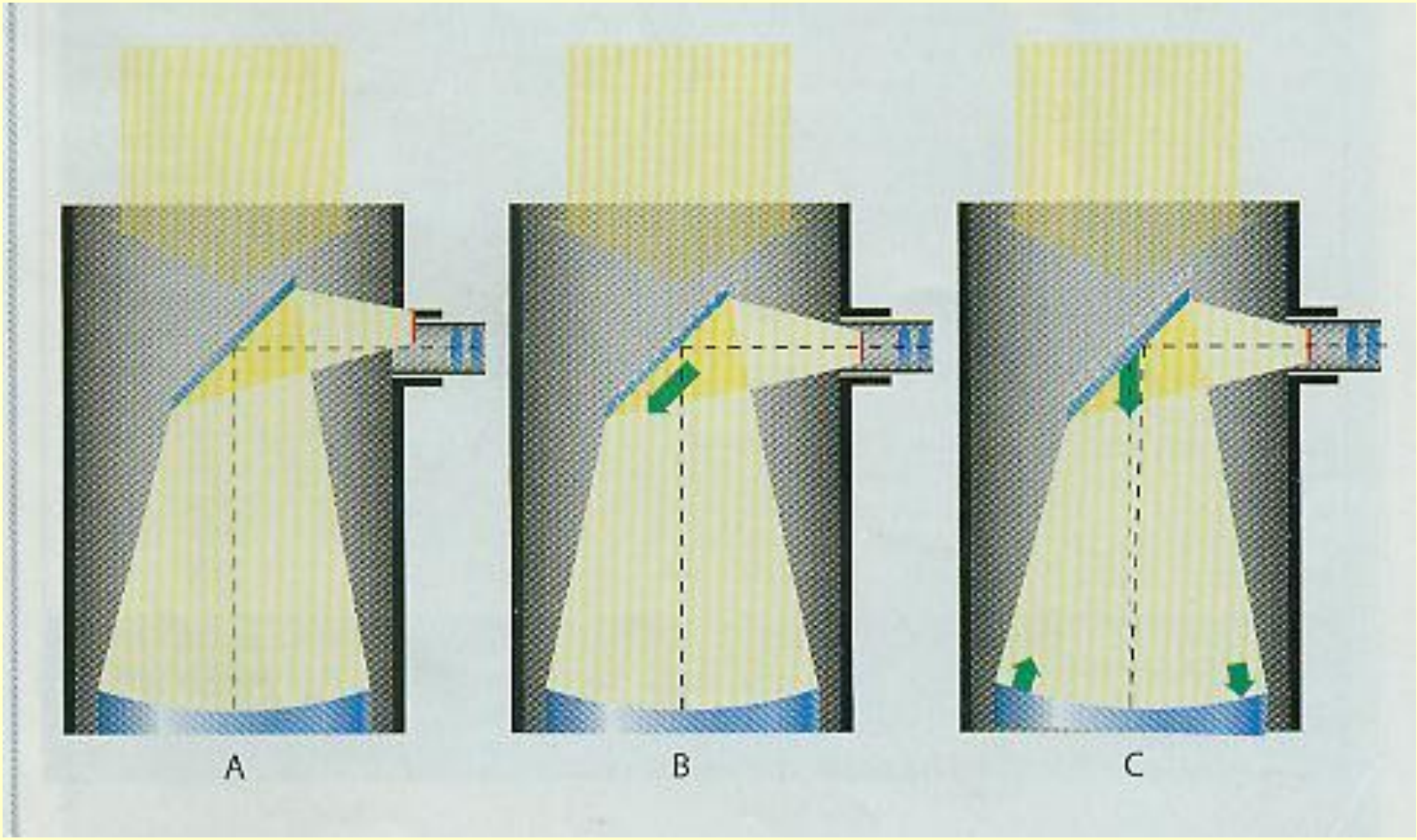


Secondary mirror offset

A. With non-offset 2ndry *Fully Illuminated Field* is displaced upwards.

B. Moving 2ndry down and back centres *F I F*.

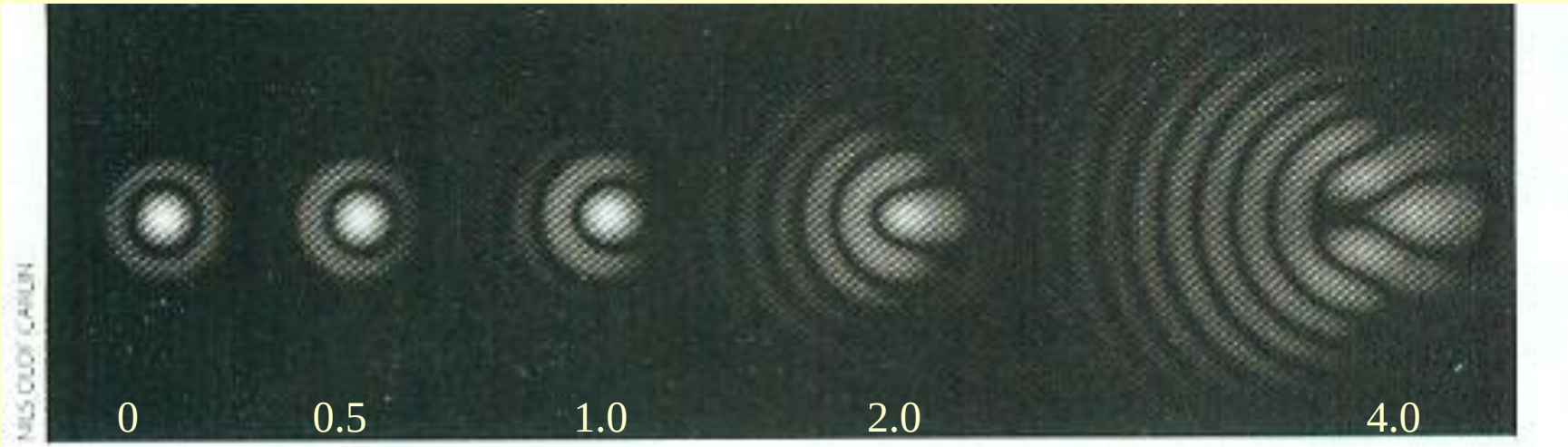
C. Moving 2ndry down and angling both mirrors can also centre *F I F*.



offset approx. = D(2ndry) / 4F$_{ratio}$

*** We use method C ***

Coma and Collimation

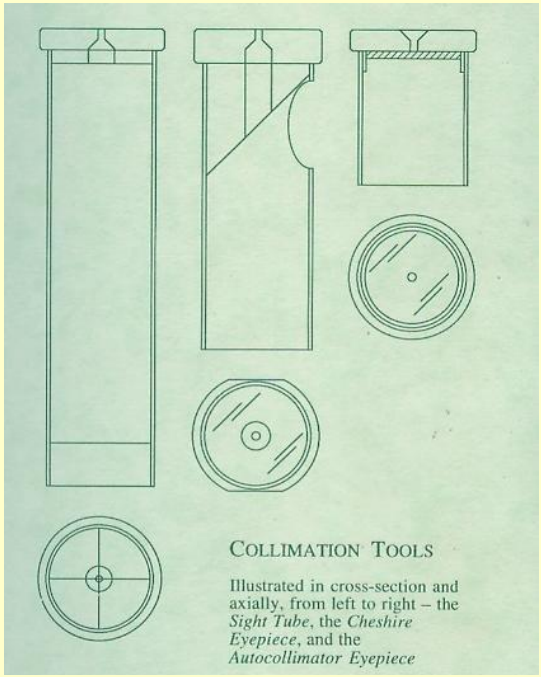


The aberration known as coma is Enemy Number One for Newtonian reflectors — even a perfectly made mirror suffers from it. Shown in these simulated star images (from left to right): a star at focus and centered in the eyepiece (images are coma free), halfway to the edge of the sweet spot (coma will have no visible effect), at the edge of the sweet spot (coma begins to have an effect), at twice the radius of the sweet spot, and at four times the radius of the sweet spot.

Mirror F ratio	4	4.5	5	6	10
Sweet Spot Diameter (mm)	1.4	2.0	2.8	4.8	11

Collimation Aids / Tools

- Primary mirror centre spot.



- Sight tube.
- Cheshire "eyepiece".
- Autocollimator

- Laser collimator

Collimation Aids / Tools

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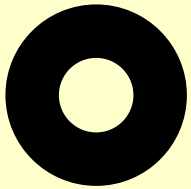
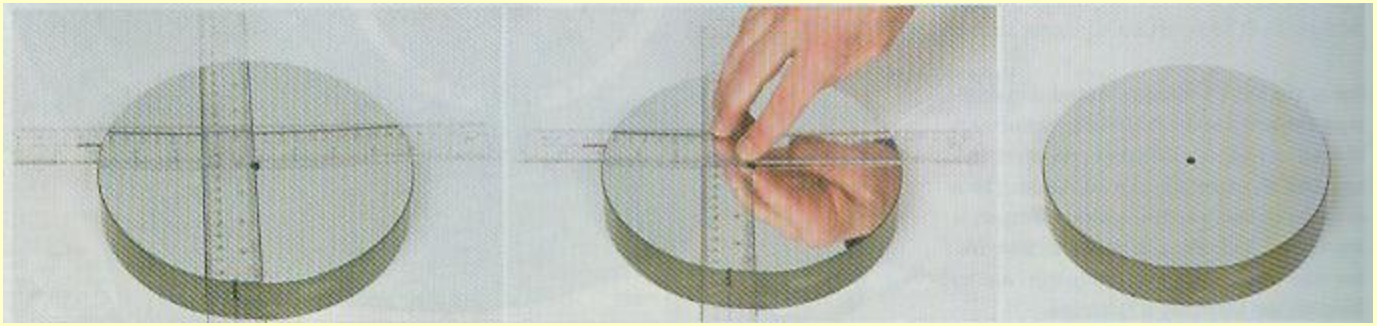
A popular choice for a centre "spot", is a blackened file reinforcement ring.



Works well with Cheshire eyepiece.



Collimation Aids / Tools

- Primary mirror centre spot.

- Sight tube.
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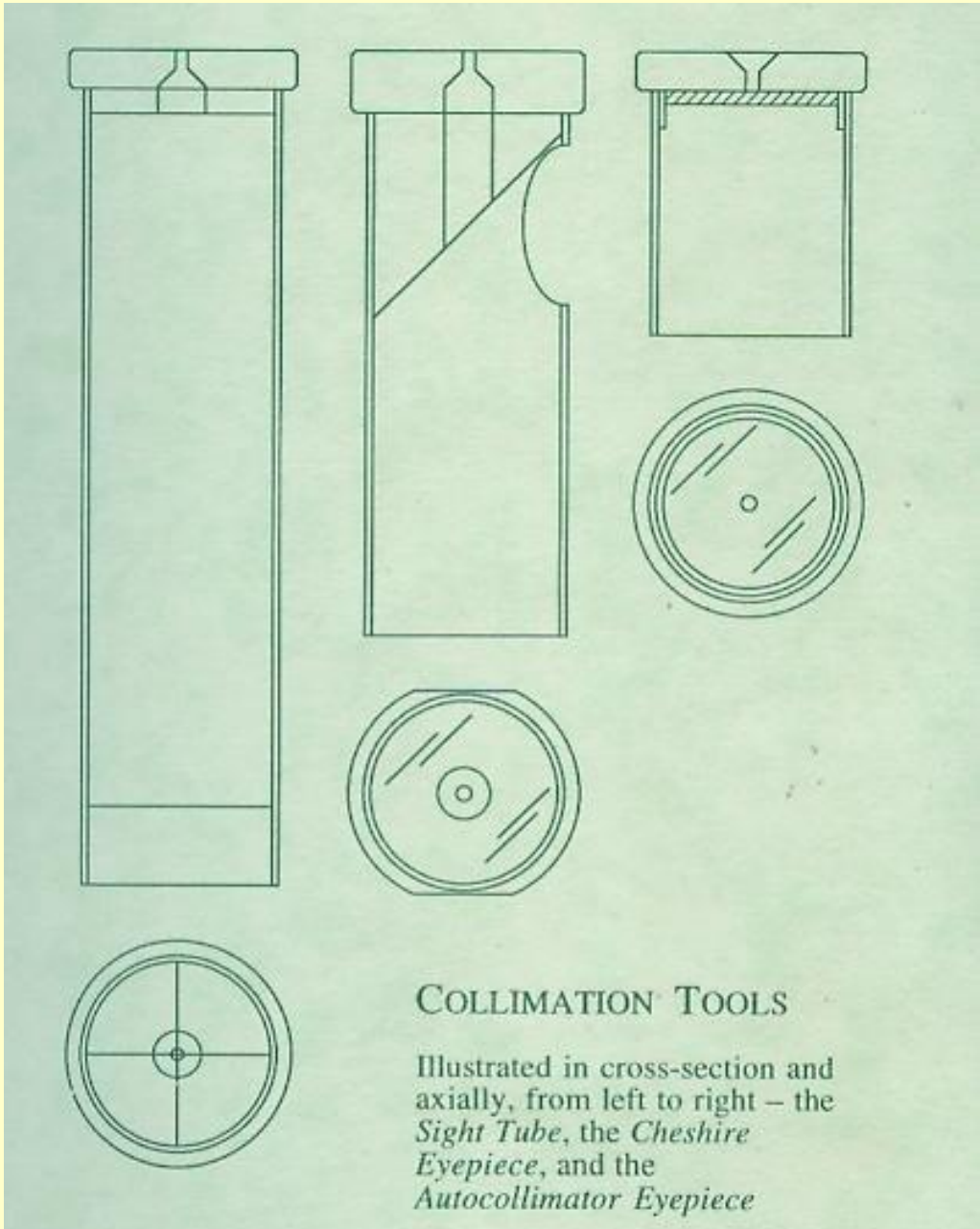


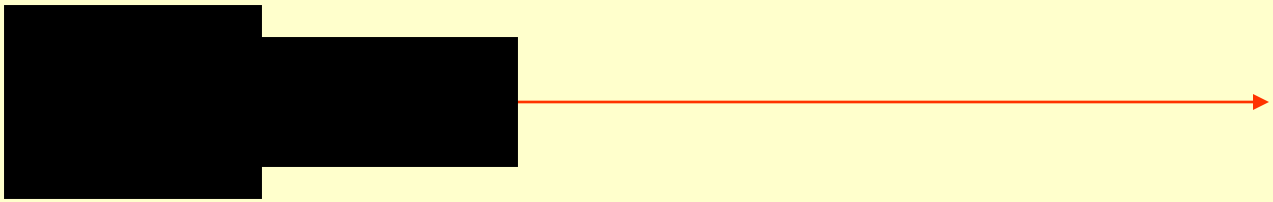
Collimation Aids / Tools

- Primary mirror centre spot.

- Sight tube.
- Cheshire "eyepiece".
- Autocollimator

- Laser collimator

- *Laser fits in standard eyepiece holder of focuser.*
- *Laser beam travels down centre axis of eyepiece - but check!*
- *When beam travels down optical axis to primary mirror and is reflected back along same path- system is collimated.*
- *There is an aperture in the side of the LC - so can observe emerging and reflected beam.*



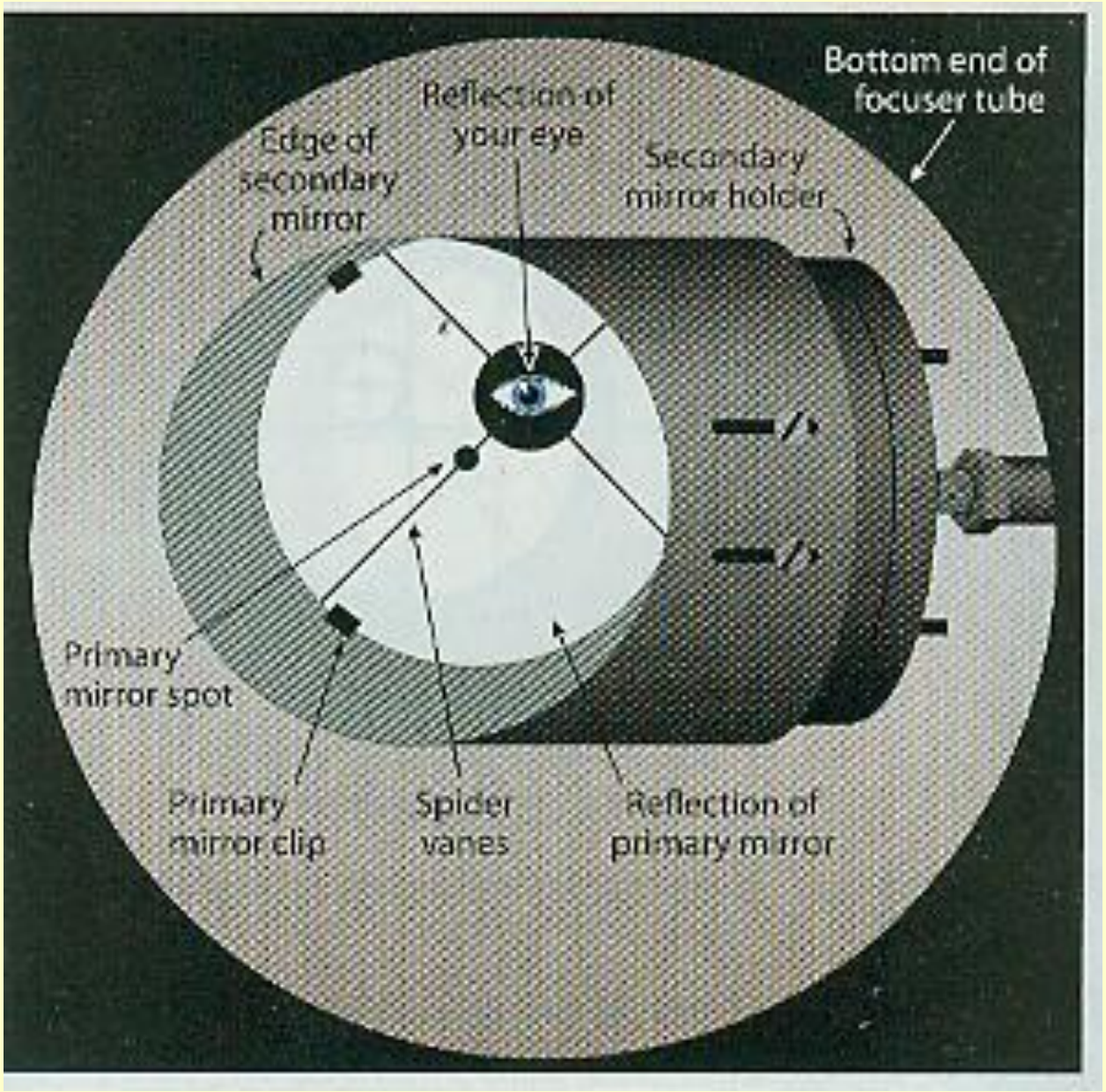
3 Steps of Collimation

1. Get secondary mirror in right position.

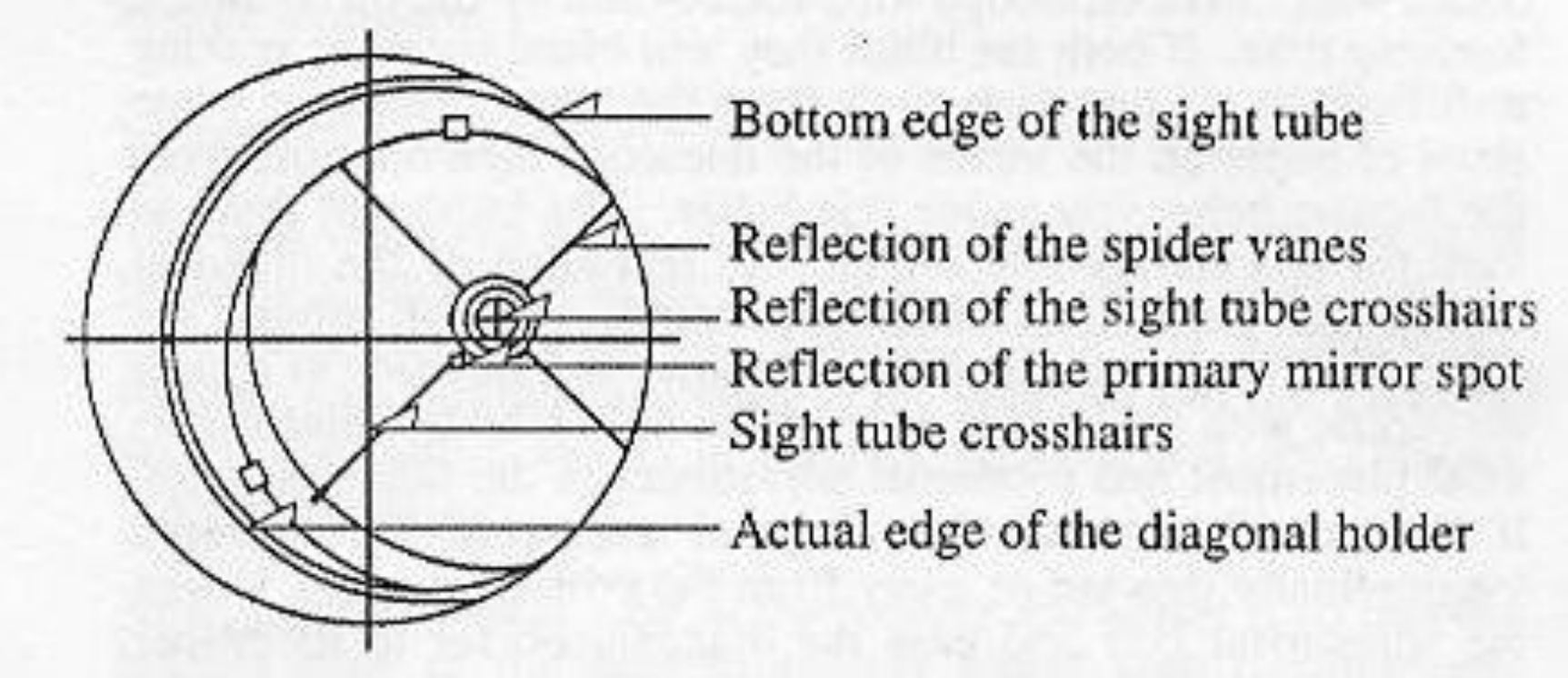
2. Get secondary mirror aligned- pointing in right direction.

3. Get primary mirror aligned- pointing in right direction.

BUT first you've got to know what you're looking at!

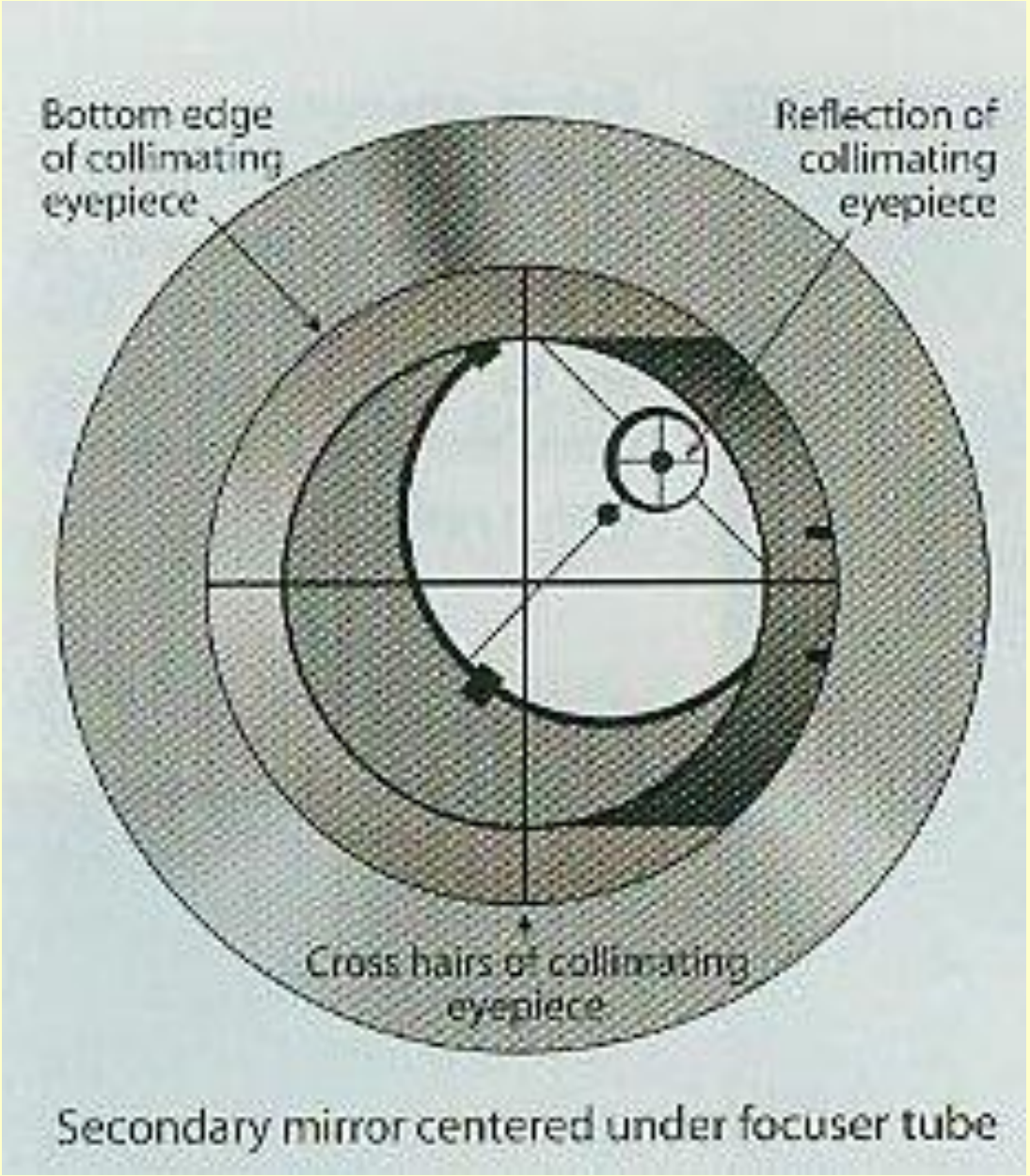


Put in Sight Tube (ST)



Step 1: 2ndry position

- *Insert sight tube (ST).*
- *Identify 2ndry mirror.*
- *Adjust "height" of mirror so that centred in sight tube.*
- *Can slide ST in or out to match diameter of 2ndry.*
- *May need glasses/ lens to focus on edges of tool and 2ndry mirror at same time.*
- *Rotate 2ndry till perfect circle.*
- *Check equal sideways spacing -if not adjust spider!*



Some extra points / tips:

1. Have GOOD illumination- this closes up your eye pupil and gives improved depth of focus. Don't be afraid to use glasses and/or lenses to help you focus.

2. If have difficulty in identifying edge of diagonal mirror- place piece of paper between diagonal and primary mirrors- makes it much easier.

3. Rack focuser IN and OUT. Check secondary remains centred. If not- need to adjust focuser until it does. Unless focuser has adjusters- will have to use shims.

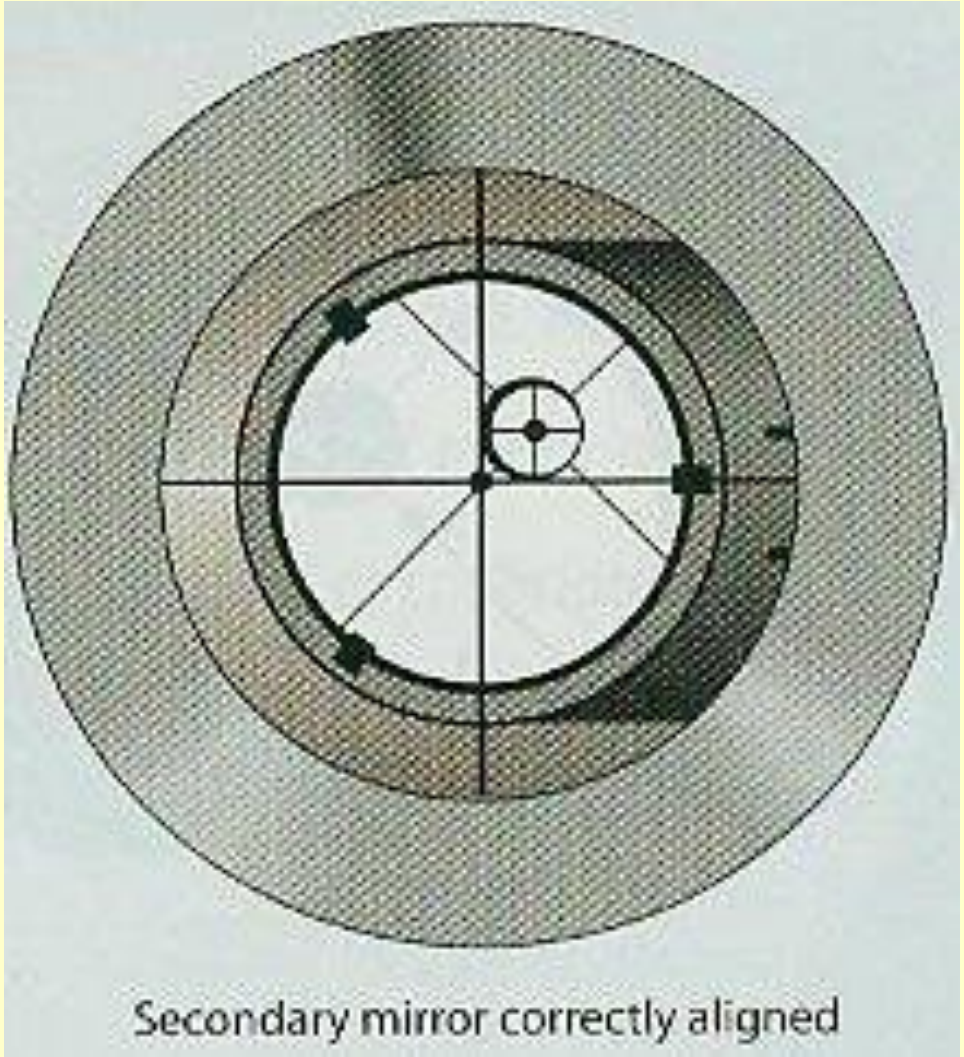
4. You still need to do STEP1 even if you have a laser collimator.

SOME GOOD NEWS

When Step1 done- shouldn't need re-doing for long time unless something gets moved!

Step2: 2ndry alignment.

- *Identify primary mirror and its centre spot.*
- *Adjust angle of secondary mirror to bring centre of primary mirror coincident with crosshairs. There are usually three screws at top of diagonal holder for this.*
- *If mirror is not centre spotted- then get the edges of the primary mirror circum-circular with the edges of the ST.*
- *If using a laser collimator- insert into focuser- adjust angle of secondary to direct laser beam to centre spot of primary mirror.*
- *The secondary mirror is now correctly aligned.*

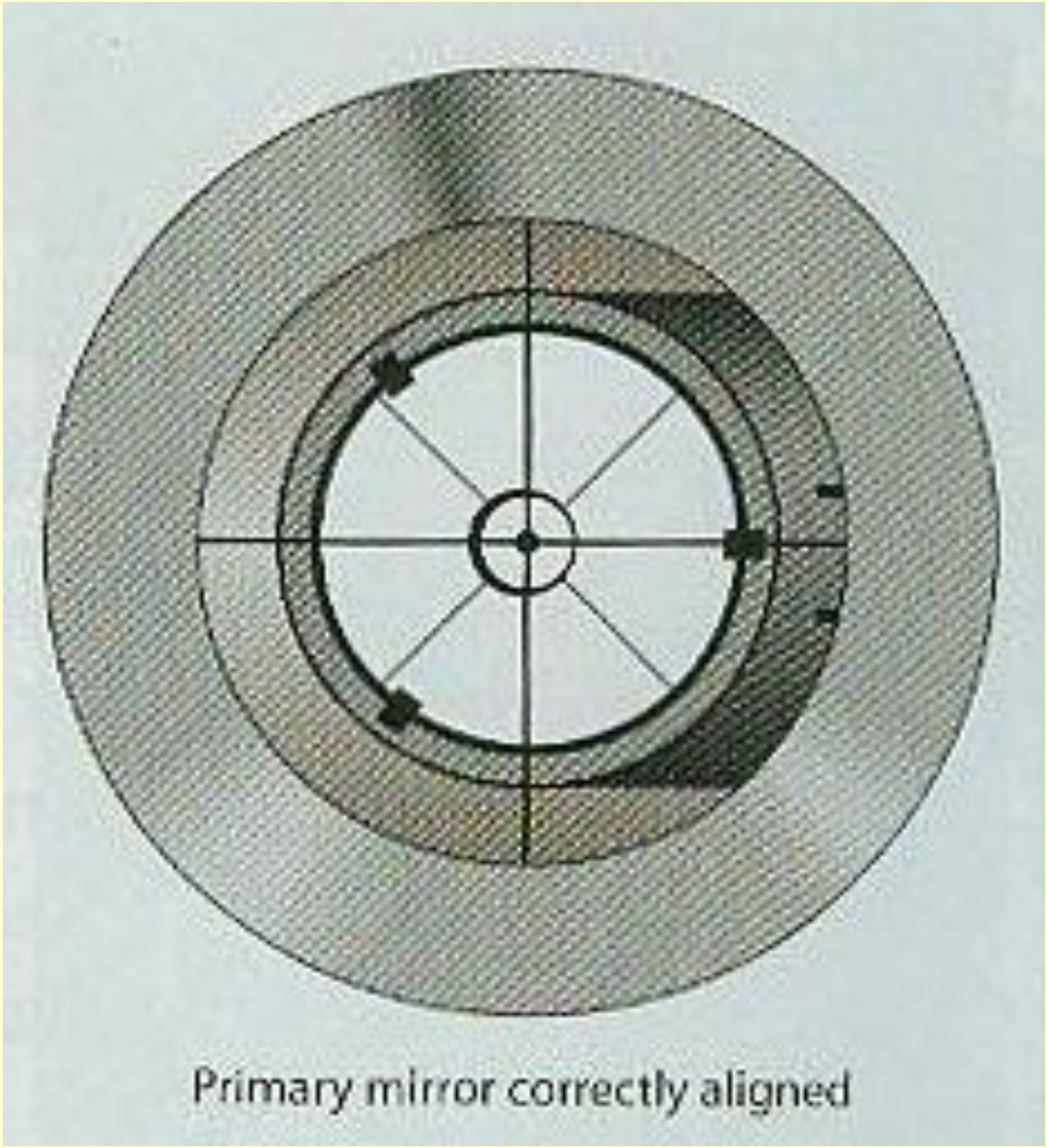


Step3: Primary mirror alignment

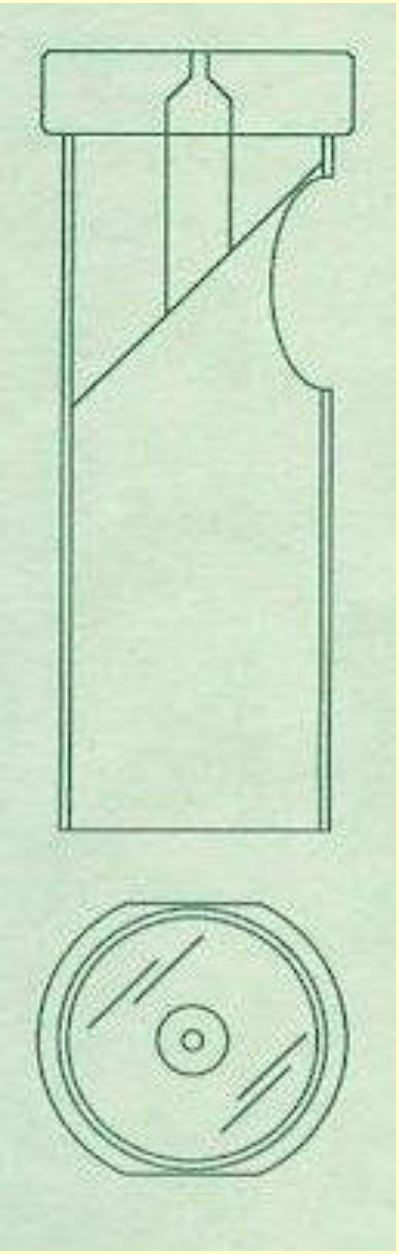
•*A. Using ST- adjust collimating screws on mirror cell to bring (small) reflection of crosshairs coincident with crosshairs in ST.*

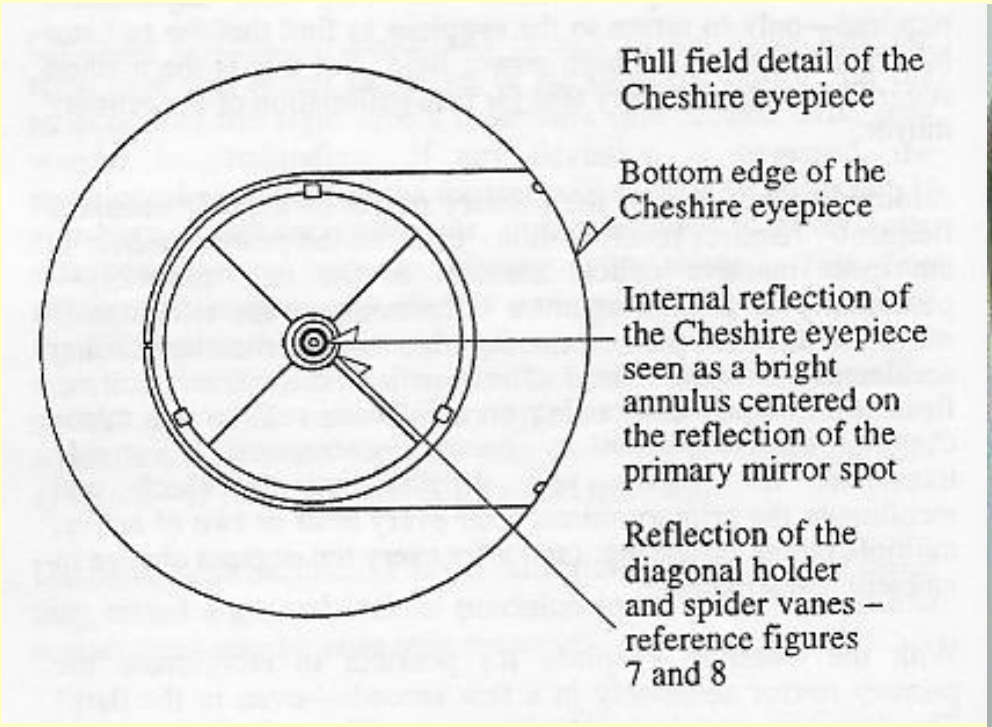
OR

•*B. Using Laser collimator- adjust collimating screws on mirror cell to bring reflected light beam to coincide with the beam emerging from the collimator.*



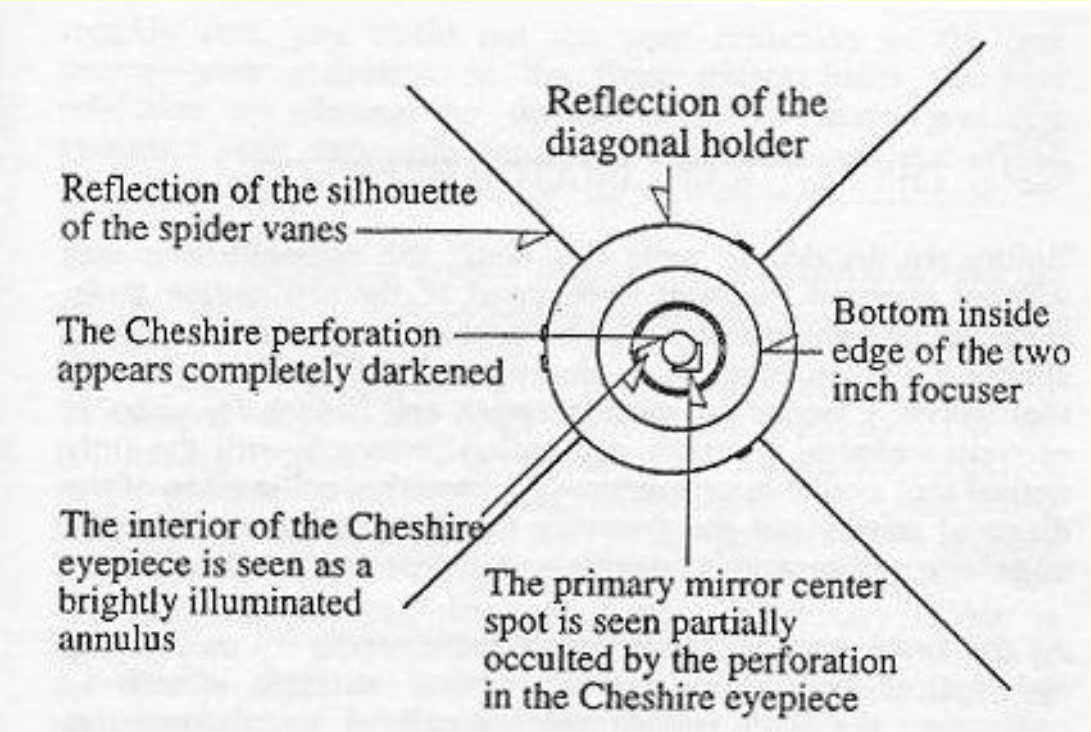
Step3: Primary mirror alignment- Cheshire eyepiece (CE)

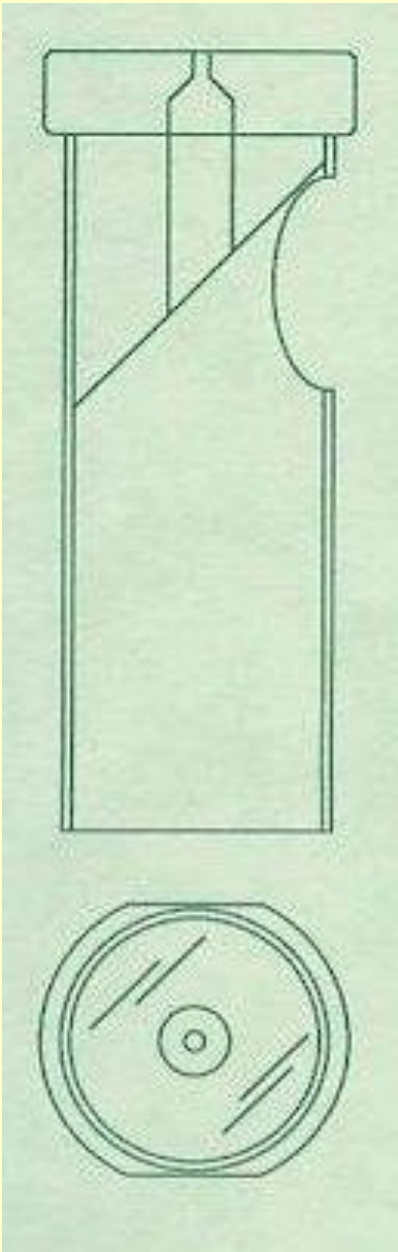




- *C. Insert Cheshire eyepiece. Illuminate it through side aperture.*
- *Identify reflection of CE- seen as a bright annulus with a dark centre. This is the reflection of the illuminated portion of CE with the dark peep hole at its centre.*

Step3: Primary mirror alignment- Cheshire eyepiece





- *With primary a little out of alignment the centre spot will be offset from reflection of CE central dark spot.*
- *The precise alignment inside our hollow dark ring is simple- using collimating screws on primary mirror cell. This operation can be carried out in the dark and only takes seconds.*

- *Telescope is now collimated.*

FIGURE 9

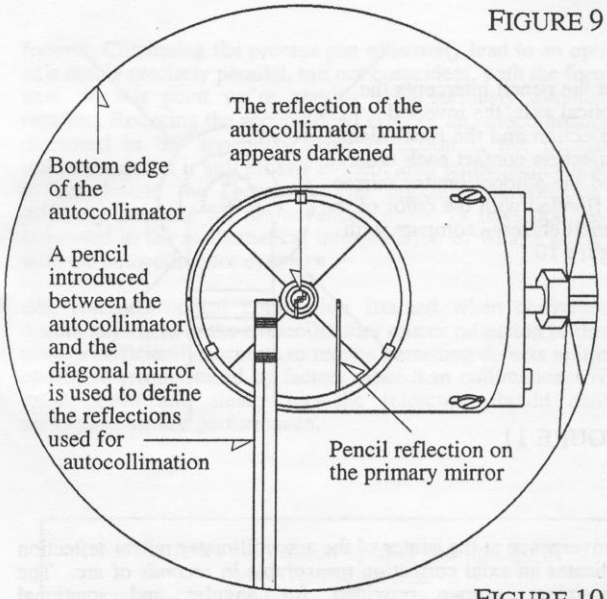
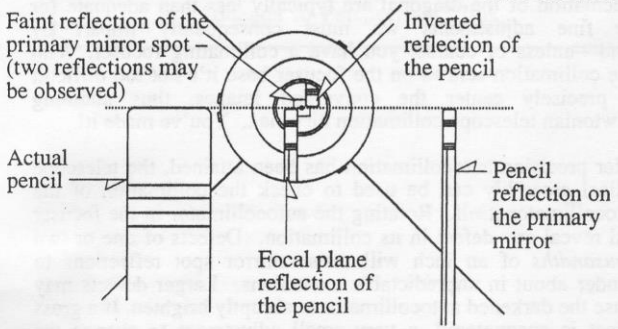
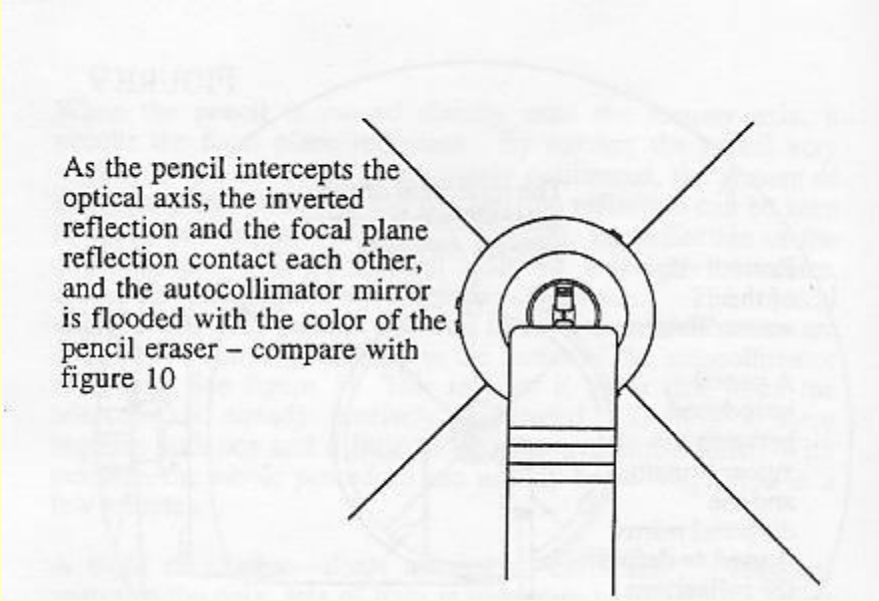


FIGURE 10



Autocollimator evaluation (diagonal mirror reflection detail after the autocollimator mirror has been darkened) – note the focal plane reflection and the inverted reflection, as well as the barely perceptible reflection(s) of the primary mirror spot

- *Further fine tuning of collimation requires the autocollimator (AC).*
- *This allows checking / rectifying that the centre spot coincides with the optical axis of primary mirror, that the focuser motion is "true", etc.*
- *Understanding how to use the AC is not simple- but could be future topic for a workshop if people were <u>really</u> interested.*

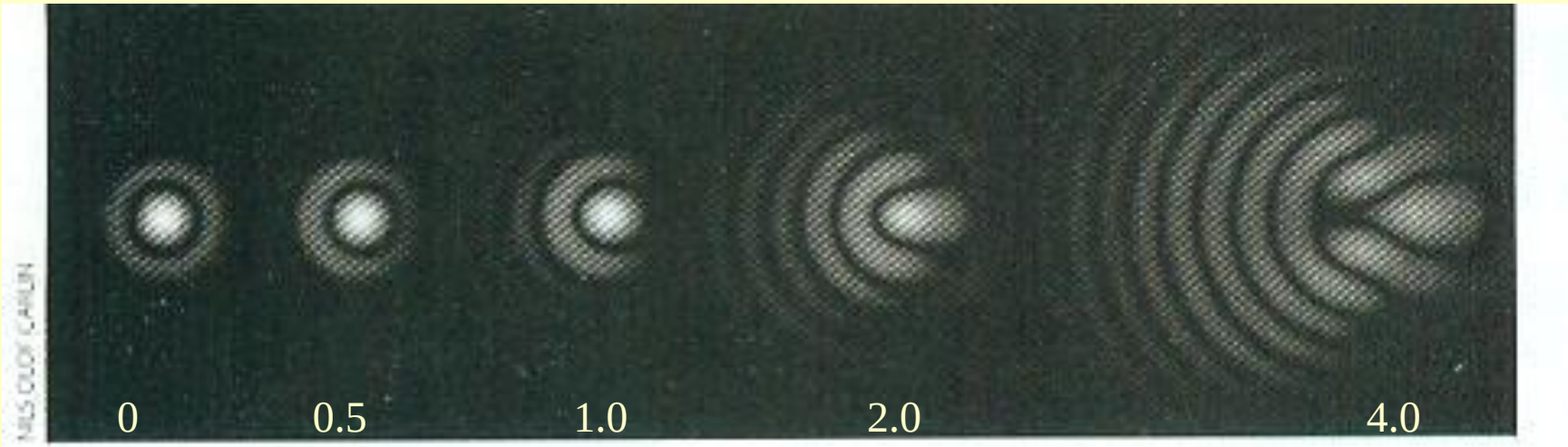


Comparison of conventional and laser tools

It is worthwhile to compare the relative strengths of these.

- *The laser tool is quick and simple to use for aligning secondary and primary mirrors. It can be used both in the light or dark.*
- *Laser (and conventional) tools can also be used to collimate refractor and other telescopes.*
- *A sight tube is needed to position the secondary (hopefully infrequently).*
- *The sight tube can be used to do a complete collimation- but only in the light.*
- *The Cheshire eyepiece gives better precision for aligning the primary, is speedy to use and can be used in the dark. Combined ST and CE tools are available.*
- *The autocollimator is the ultimate precision tool- but not easy.*
- *If something suddenly goes wrong with collimation- laser tool can quickly show where the problem is (e.g. mirror has moved, truss pole loose, ...)*
- *Precision Warning regarding lasers. If laser with 1mm error at 2m used on perfectly collimated MMT- would be 2mm out at focuser. Using this tool would put eyepiece 2mm off true optical axis.....*

Coma and Collimation



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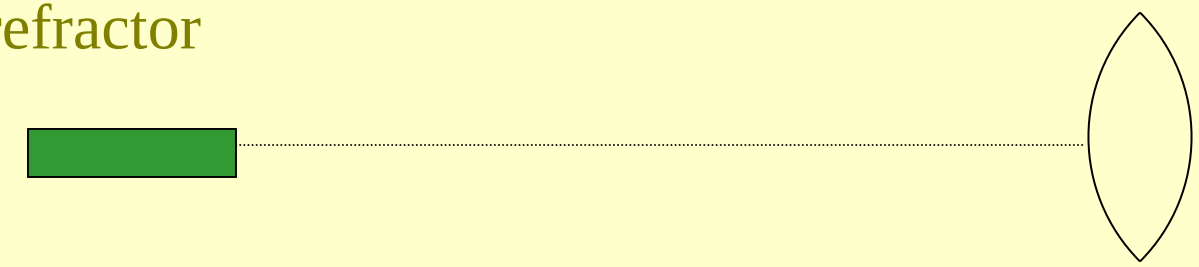
Collimating a refractor



- *Put Cheshire eyepiece (CE) in focuser and side-illuminate.*
- *Have end-cap over objective to exclude any light.*
- *2 or 3 faint reflections of the CE should be seen.*
- *The object glass cell (holder) needs to be adjusted to make these concentric.*
- *If the collimation is already good and only one image is discernable- flexing of the CE focuser tube should then reveal a second image.*
- *The focuser should be racked fully IN and OUT to check collimation is good- if not the focuser needs repositioning/ angling. Small adjustments should be make to find optimum position and angle- followed by a final recollimation.*
- *With laser collimator the collimation is good when reflected beam travels back into laser aperture- otherwise process is as for CE.*

Collimating other telescopes, etc.

•Some refractors cannot be collimated - "no user adjusable parts". Can only return telescope to manufacturer.
•If an external star diagonal is used- do the collimation without the diagonal in place. Then insert diagonal to collimate that.
•As a general principle- keep the system as simple as possible.

•Other Telescopes: In general the 3 basic steps- get the secondary in the right place, then aligned and finally the primary aligned is the correct way. The focuser also needs checking over its operating range.

•HOWEVER many commercial telescopes have complex light paths, e.g. with diagonals, corrector plates and wierd focusing mechanisms. It is best then, to follow the manufacturer's recommendations.

•Star Testing

•The final test of a telescope and its collimation is the star test.

•Insert a medium / high power eyepiece and centre a star in the field of view.

•At focus the star, the image should appear as a circular patch surrounded by one or more refraction rings. In excellent seeing conditions, breaks in the rings may be seen due to diffraction by the spider. Slight de-focus gives concentric rings.

•The star test result is due to a combination of: collimation, quality of both mirrors and eyepiece, temperature uniformity of those mirrors, air turbulence and background glare. So care is needed in interpretation of star images!

•If all else is perfect and you get COMA images- you need to recollimate.

•If your mirrors are not near-perfect, you will not get a proper test image.

•Background glare may hide the diffraction rings.

•Turbulance will give an unsteady image- making it difficult to even focus.

•One approach is to say- we are unlikely to get good enough conditions for a proper star test, so let's make sure we collimate it right.

Summary

- *Reviewed some telescope basics and how a centred secondary mirror offset puts the fully illuminated field centrally in the field of view*
- *Shown how Coma degrades image quality and how it is more critical for lower F_{ratio} telescopes, e.g. below 10 requires sub mm precision collimation.*
- *Have described conventional and laser collimation tools.*
- *Detailed the 3 steps of collimation for a Newtonian telescope.*
- *Briefly covered how to collimate a refractor and other telescopes.*
- *Described what Star Testing is and some limitations*

- *NOW DO IT!*