Collimation using your Barlow lens (concave/negative lens)

Roar Skartlien 3/2020

Collimation alternatives

1. A concave (negative) lens inserted between the objective and the focal point of the telescope
   - The concave lens shortens the instrument length considerably, increasing the mechanical rigidity of the arrangement
   - A Barlow lens is common to have so this can be used as the concave/negative lens, without buying anything

2. A convex (positive) lens inserted after the focal point
   - A convex lens must be used in slit spectrographs with the slit at focal point

- Slitless spectrographs can use both positive and negative collimators

Focal length f, of concave lens

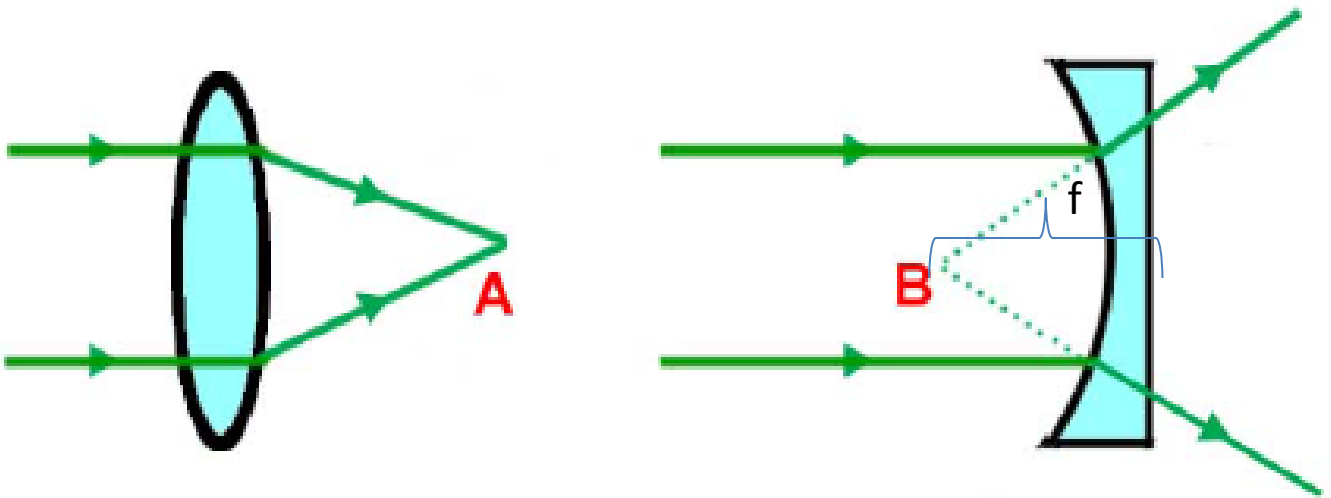

Figure 1. The positive lens on the left converges the incoming light to a focus at A. The negative lens on the right causes light to diverge as if it is coming from a virtual focus at B.

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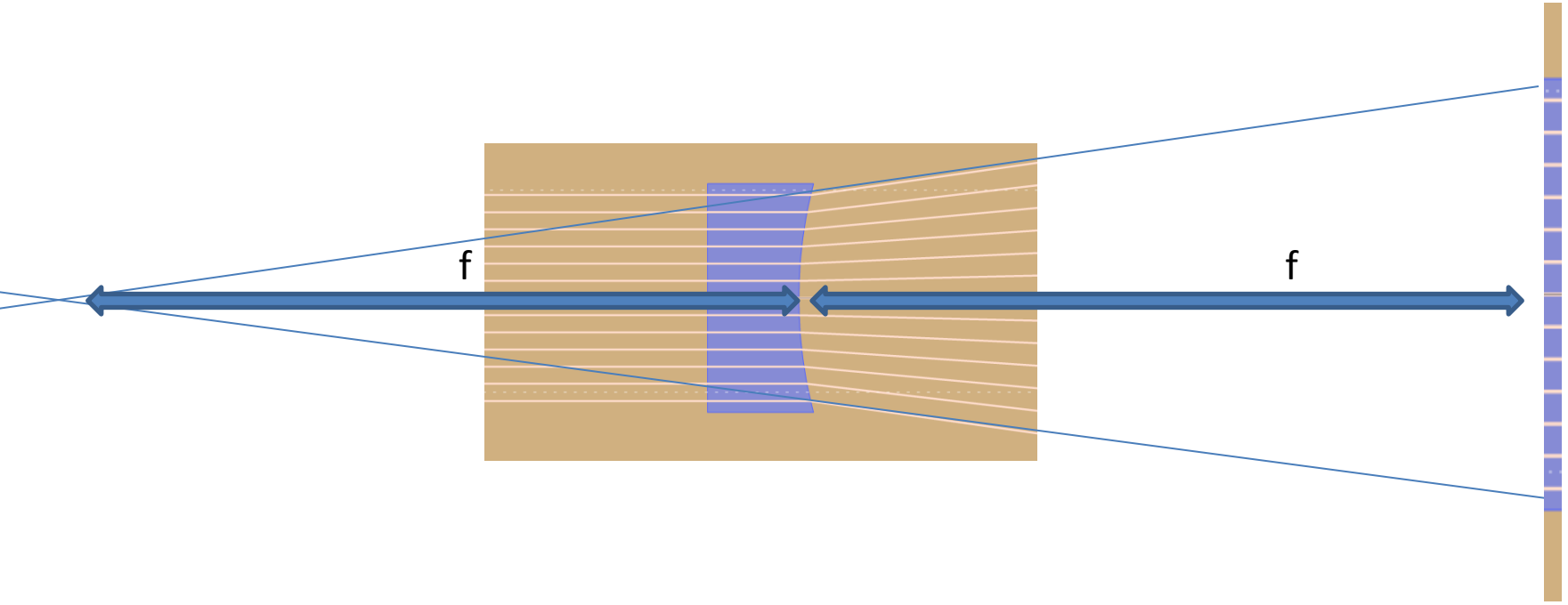

- f = distance where illuminated area (to the right) is twice the lens diameter
- Use the sun or a distant light source to measure f

The focal length of the Barlow is given by:

$$f = D*L/(C-D)$$

Where

D = Barlow diameter

L = separation of lens and paper

C = diameter of light circle on paper

Setting C=2D, gives f=L
C=3D, f=L/2
C=4D, f=L/3, etc.

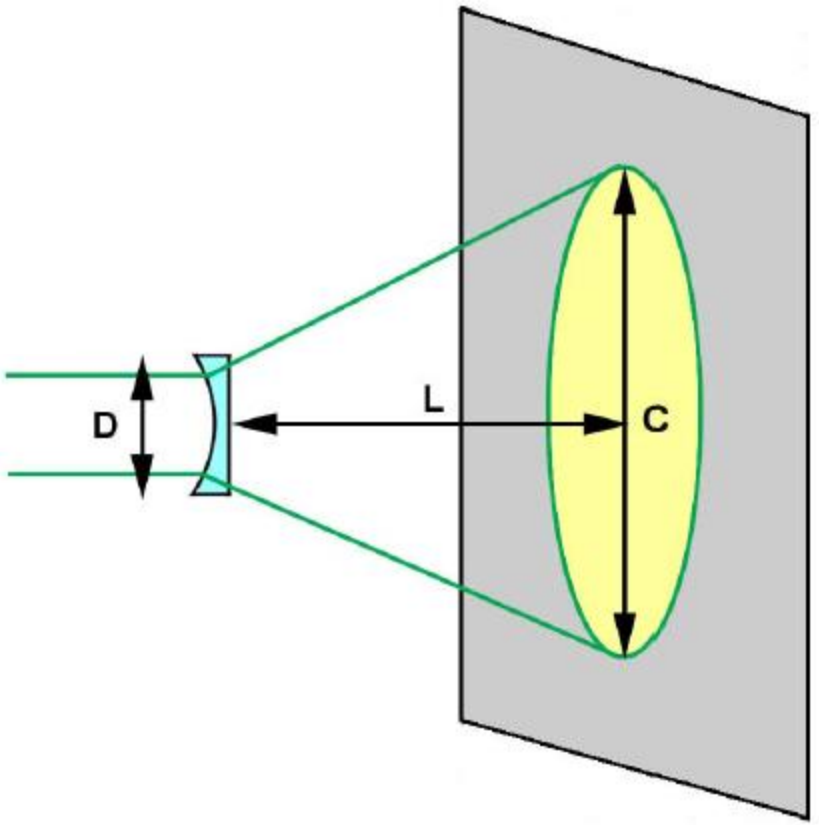

Figure 5. Measuring the focal length of a Barlow. The Sun is shining from the left.

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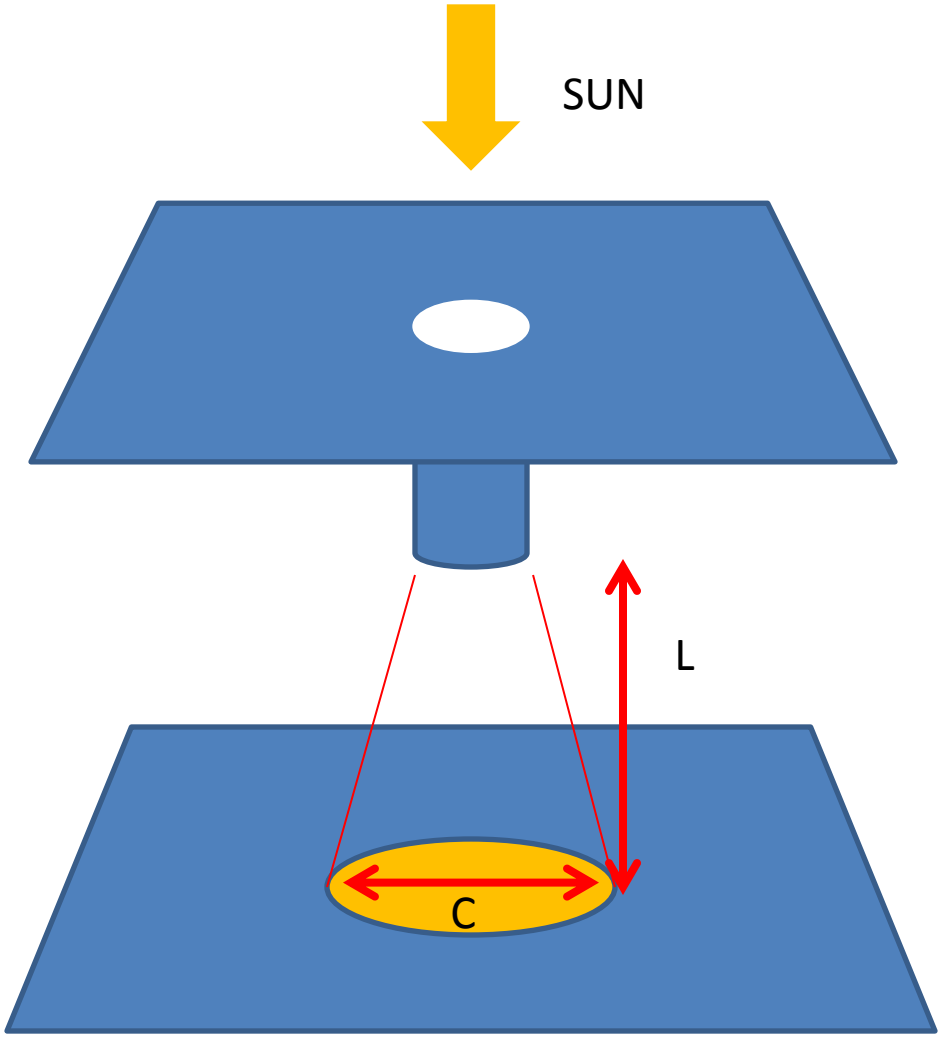
Setup



- Small cardboard box. Put Barlow lens through the top hole
- Ruler: measure L, C, and D. Look inside.

Amplification

Infinite amplification corresponds to parallel rays

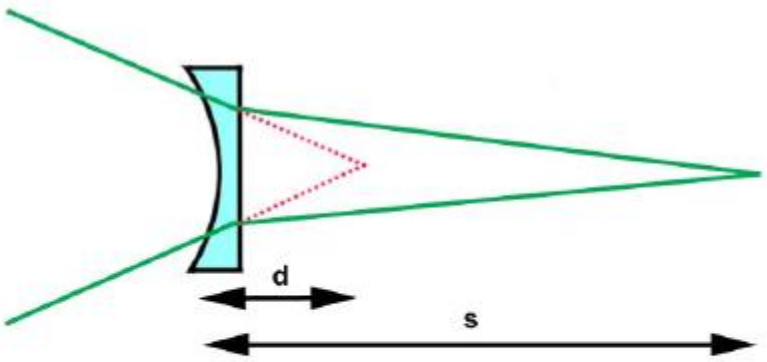


Figure 3. The Barlow is a distance 'd' inside the primary focus and 's' inside the secondary focus.

The amount of amplification (A) is given by either of these two formulae

i) $A = (s/f) + 1$
ii) $A = f/(f-d)$

So f=d gives collimation (A=inf)

s=f: A=2 (The 2x Barlow config)

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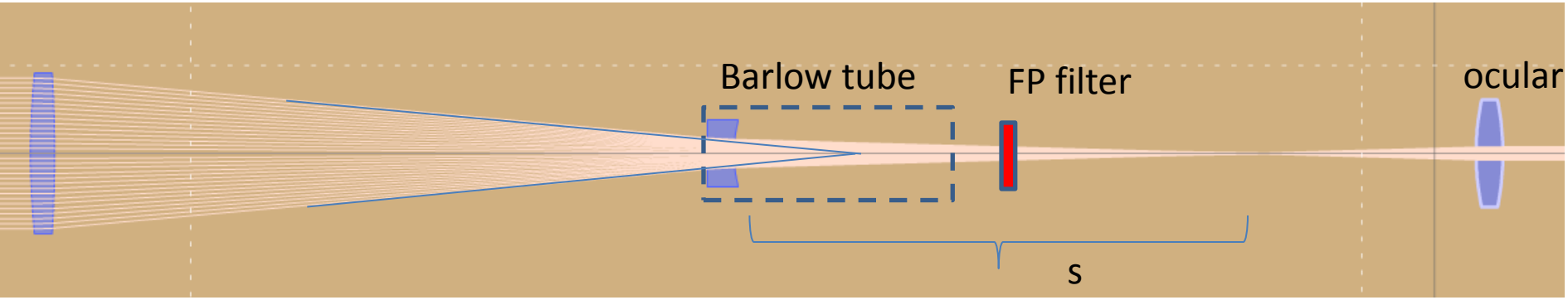
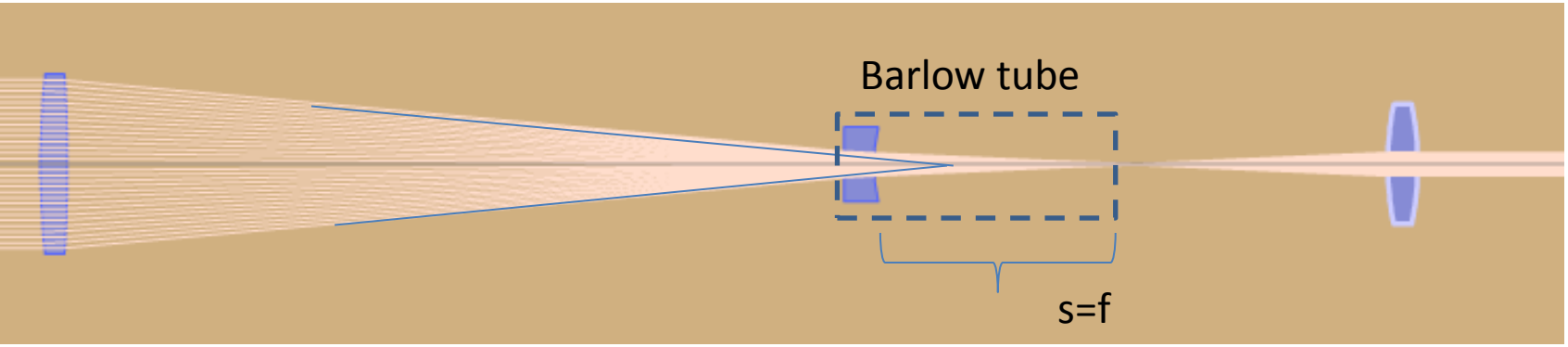
Sub-optimal configuration solar scope

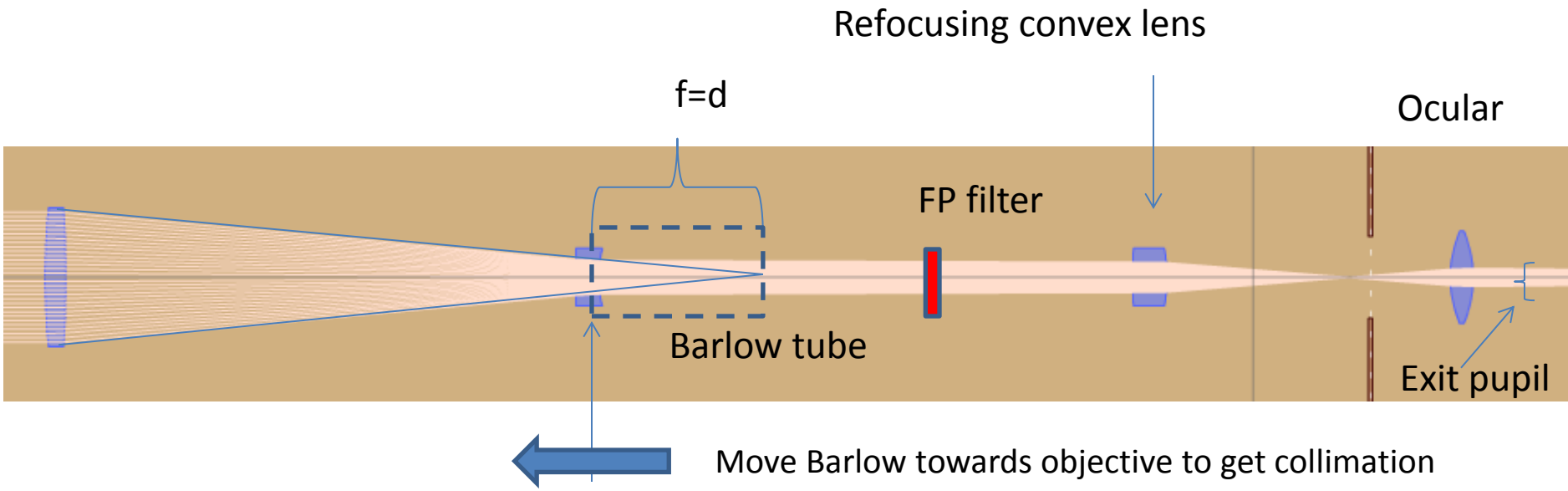


- Converging rays after Barlow: s > f, wider FP bandwidth than spec.



- 2 x config: s=f (the “standard” doubling the telescope focal length)
- Note here: s << telescope focal length: narrow angle cone length s is much less than original focal length !

Optimal configuration with ocular



Collimation/parallel rays occurs when Barlow placed within prime focus at a distance **d equal to the focal length f** of the Barlow lens

Will now need a refocusing lens, to enable viewing

Parallel rays into the eye (or almost, enabling focus on retina)

- **On-line ray tracing program:** http://nagykrisztian.com/synthrays/
- http://nagykrisztian.com/synthrays/synthrays.html

A simplifying collimation step, without knowing the focal length or the collimator

- A small telescope or finder-scope is an all-in-one solution for the refocusing lens and the ocular

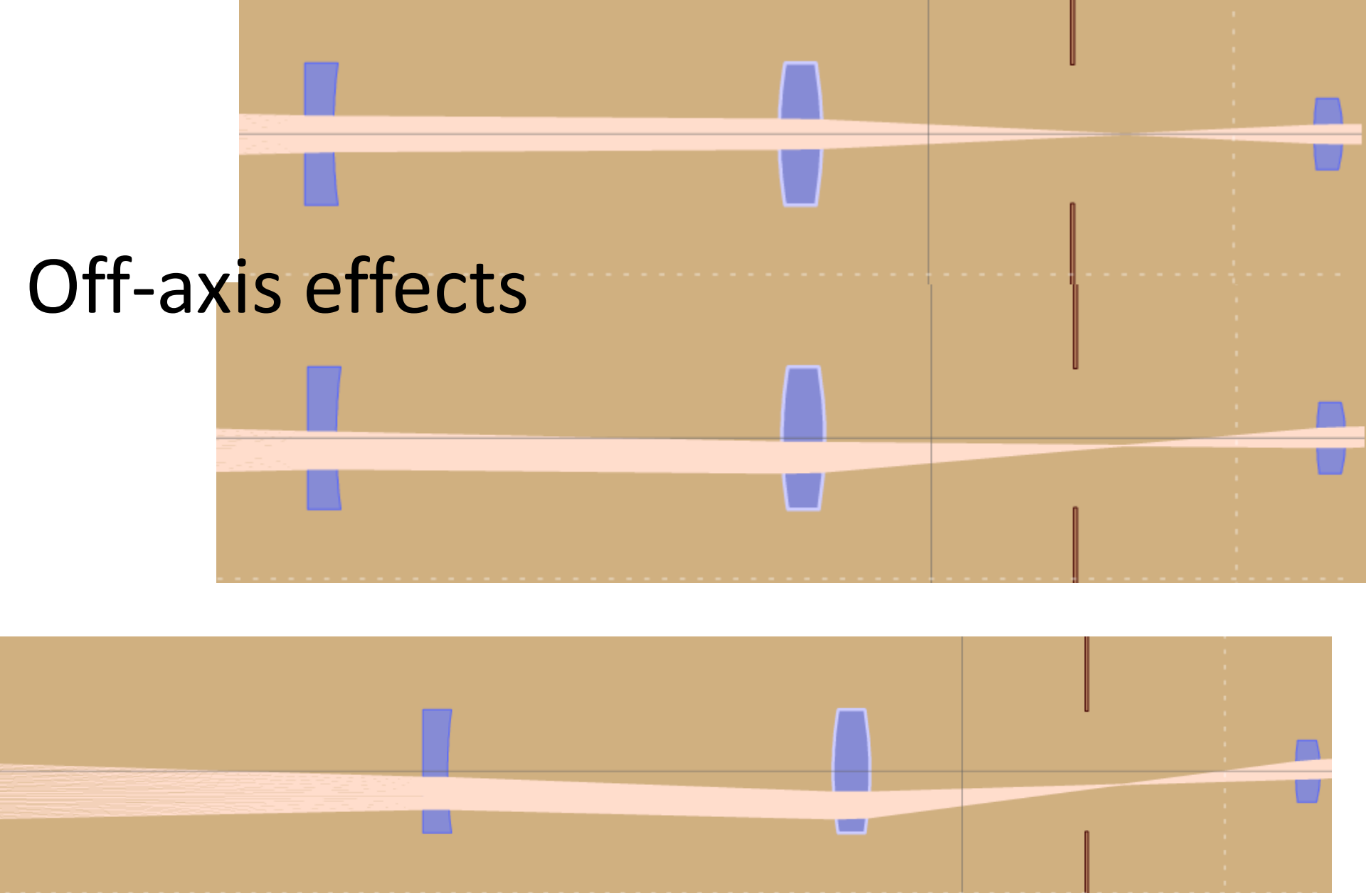
- This telescope should be in focus at infinity (e.g. focusing on a star or far-away object in day-time), thereby bringing only collimated beams into focus

- The collimator lens can then be moved along the optical axis until focus is reached in the small telescope, and then we have achieved a collimated beam!

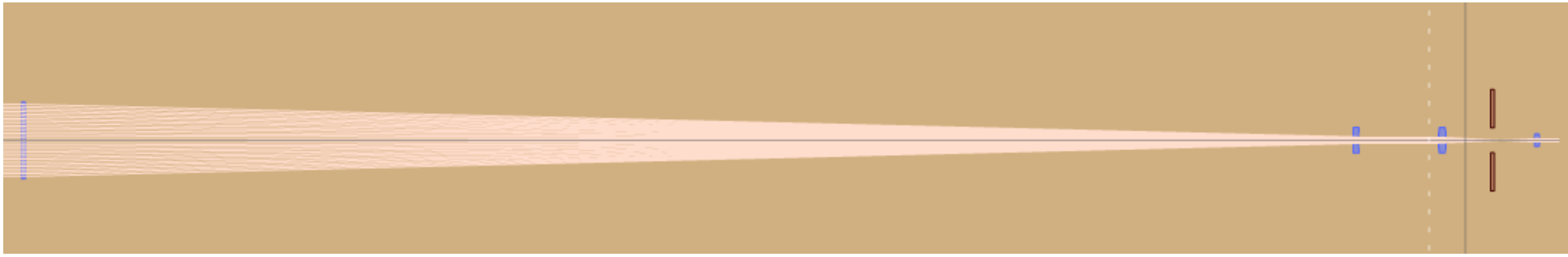
Issues with moving Barlow far inside the telespoce focal point

- May have to make extension on Barlow tube to move lens sufficiently far towards the objective from the back opening of the scope
- Danger of introducing aberration as more lens area is used (beyond spec.)
  - Less sensitive for monochromatic?
- Truncation of light cone from objective
  - Less sensitive for higher f-ratio of objective

Off-axis effects

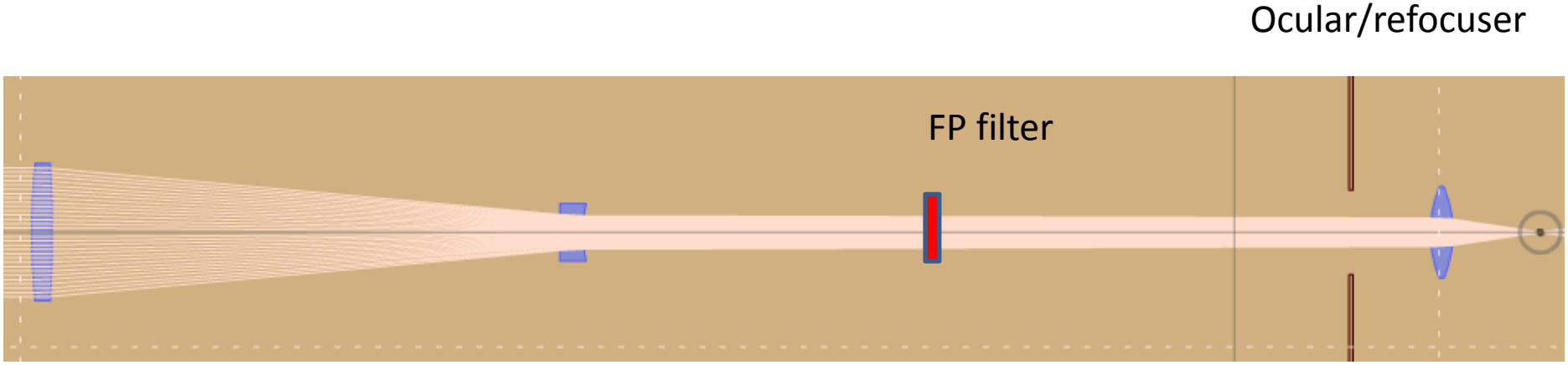


- 0,0.1,0.2 degrees off axis. Near parallel but slanted beam, so will not get same etalon filter response over solar disk



- Ray-trace-2 config closer to current telescope setup

Projection mode with camera



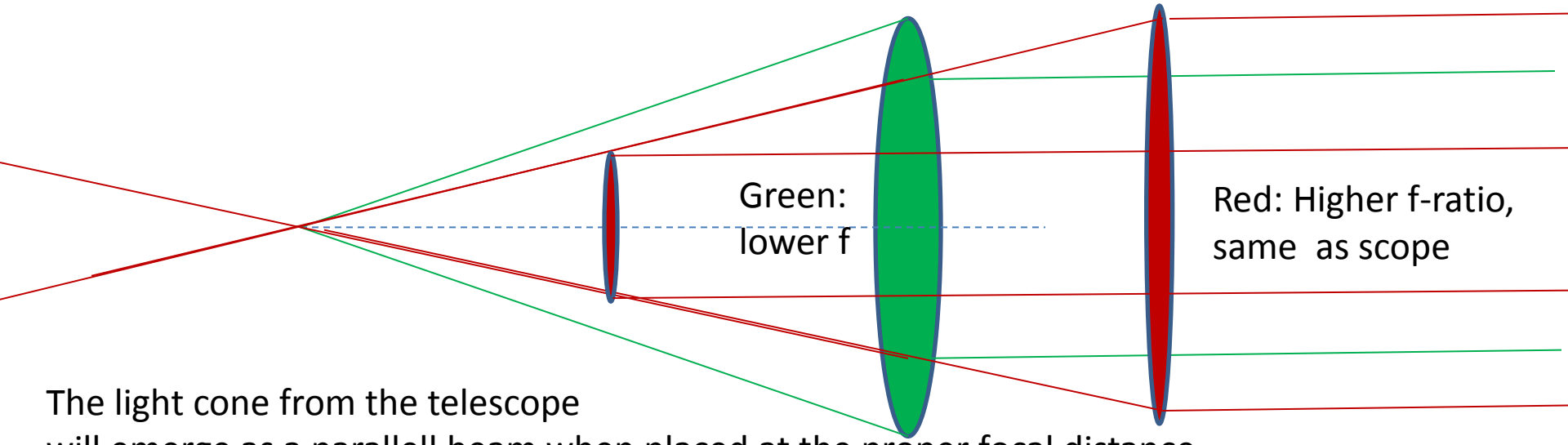
One lens (the refocuser or the ocular) provides converging rays onto the imaging plane

Enabling focus on CCD/film plane

- One lens less!

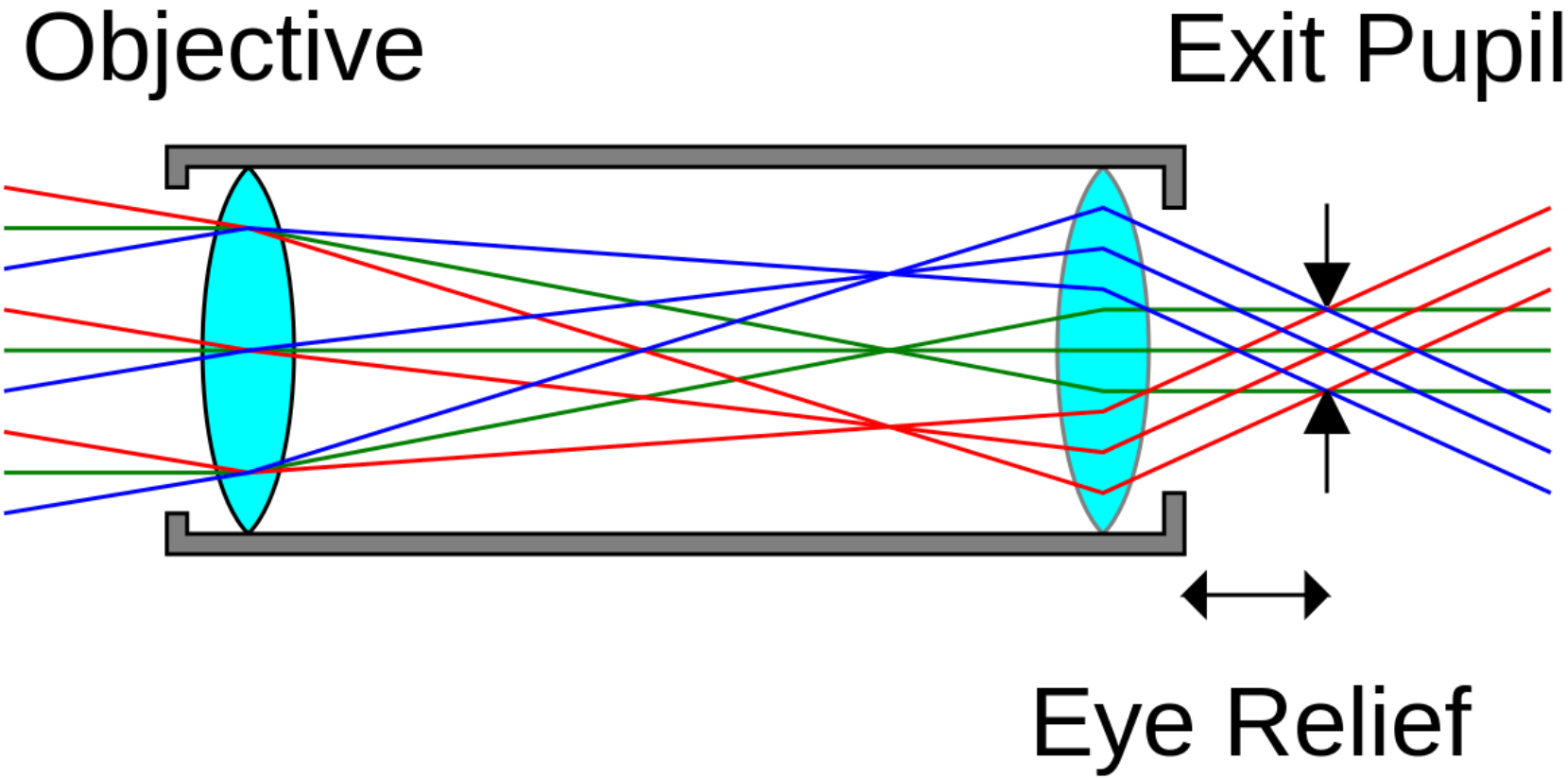
A note on positive lens collimators with arbitrary f-ratio

- The collimator lens focal point should coincide with the telescope focal point
- The f-ratio of the collimator lens does not have to be the same as the telescope f-ratio

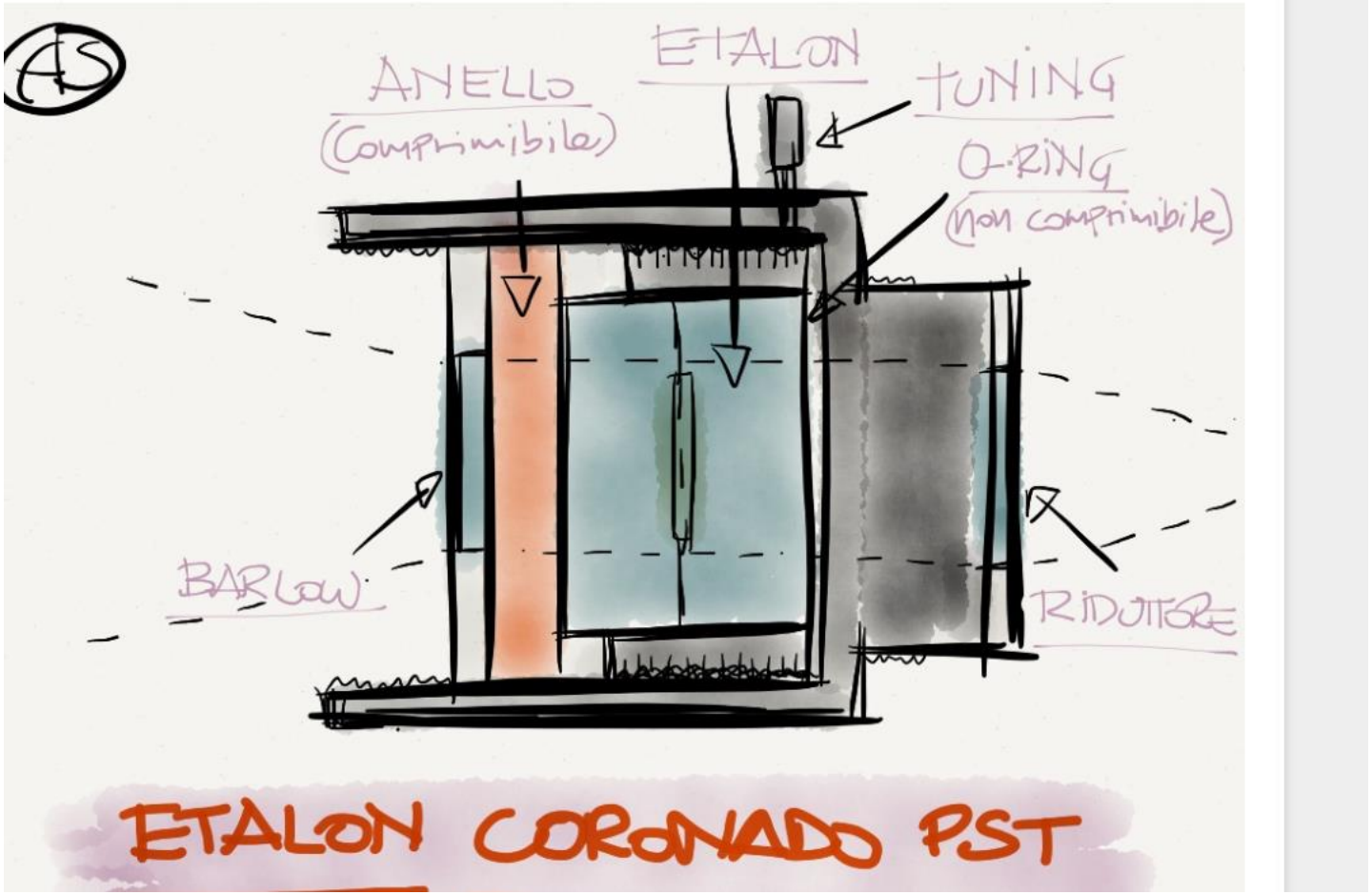


The light cone from the telescope
will emerge as a parallell beam when placed at the proper focal distance
The aperture is not filled out (lower f) or lens does not fill out cone (higher f than the scope)

Exit pupil is of concern: not too small



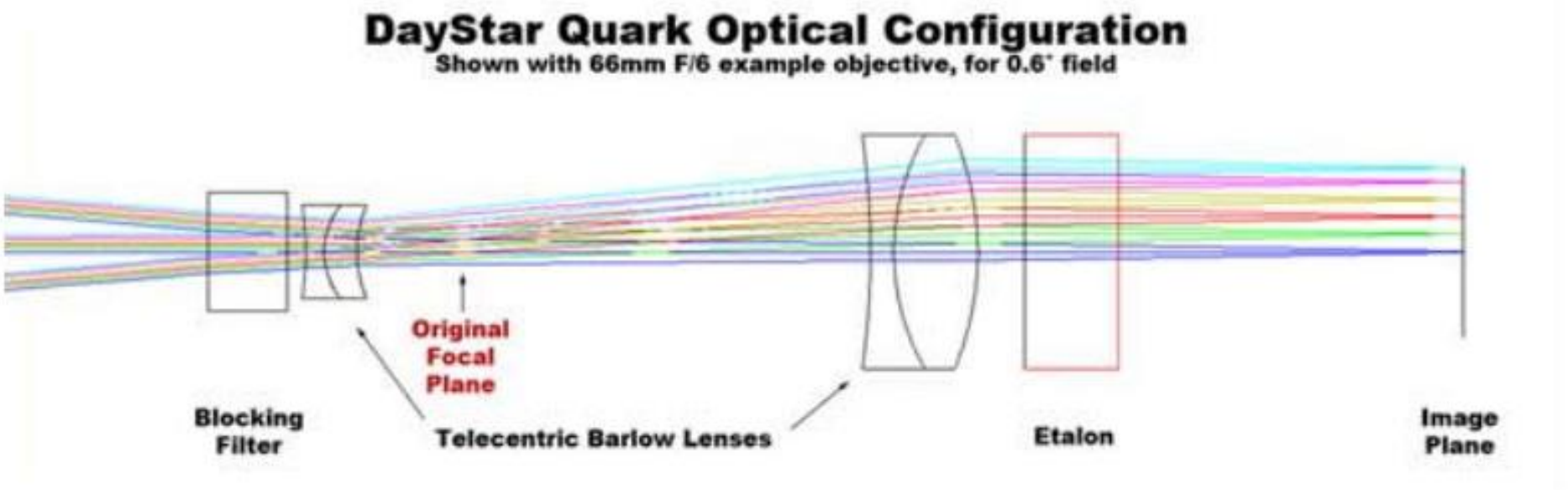
Coronado Personal Solar Telescope uses negative lens as collimator



- https://observingthesun.wordpress.com/double-stack-con-etalon-del-pst/

Omega filters with telecentric collimation

Peter Zetner, https://pbase.com/p_zetner/omega_halpha&page=all



- Daystar “Quark” also uses a telecentric system

Peter Zetner:

- The original intent was to use the eBay filter pair offered by eBay seller bjomejag (Omega Optical). This pair consists of a thick filter (narrowband + blocking) and a thin "cyan" filter (narrowband Halpha but passes some blue). I had some difficulties with the thick filter. It is a wedge design and different wavelength transmission modes are separated by a relatively small angle (restricting the field of view in the scope to the same small angle - beyond which you get overlapping solar images). The filters I used here are 2 of the thin "cyan" filters - no major problems with restricted angle in the fov.