# Astronomy 203 Problem Set #4

Due 19 October 1999

1. a. Show that the plate scale at the detector in Figure 1, is $f_1/f_2$ times the plate scale at the telescope focus.

   b. Suppose the two ray bundles in Figure 1 represent light from two point objects separated by a small angle $\theta$ in the sky, and the effective focal length of the telescope is *f*. Show that the (small) angle between the two bundles of rays in the collimated portion of the beam is $\theta' = (f/f_1)\theta$.

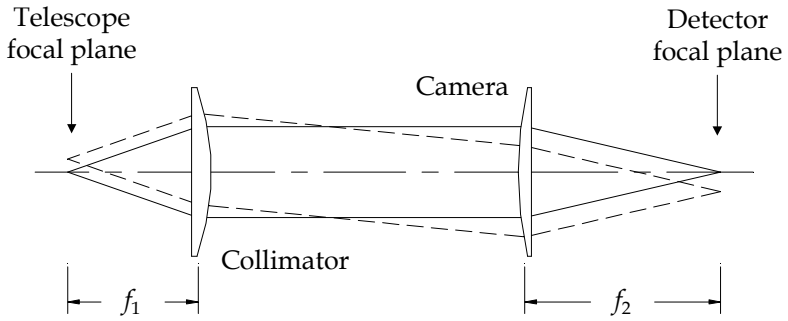


Figure 1: collimator and camera lenses for reimaging; on-axis (solid lines) and off-axis (dashed lines) shown.

2. The arrangement of the lenses in Figure 1, planoconvex with the curved surfaces facing the collimated light, was chosen on purpose, to minimize the SA of these lenses. Use RayTrace to demonstrate that this is true. Take the lens focal lengths to be 20 cm and 30 cm and to be separated by 50 cm. Plot spot diagrams at the detector focus, and measure the RMS spot size at the paraxial focus, for the lens shapes shown in the figure, for the lenses reversed (flat sides facing the collimated beams) and for the lenses replaced with equiconvex lenses of the same focal lengths.

3. The numerical inputs for this problem were taken from the example Pan-Cinor treated in Kingslake's *Lens design fundamentals*, pages 63-66.

   a. The focal lengths of the lenses in Figure 2 are $f_a$, $f_b$, and $f_c$, from left to right. Show that the back focal distance $i_c$ is given for $\Delta = 0$ by

$$i_c = \frac{\left[dD - f_b(D-d)\right]f_c}{dD - f_b(D-d) - f_c D - f_b f_c} \quad .$$

   b. Show similarly that the plate scale is

$$PS = -\frac{dD - f_b(D-d) - f_c D - f_b f_c}{f_a f_b f_c} \quad .$$

   c. A certain zoom has $f_a = 7.15959$ cm, $f_b = -1.95959$ cm, $f_c = 3.35410$ cm, $D$ = 4.15959 cm and $d$ = 1.69451 cm. Replace $d$ and $D$ by $d+\Delta$ and $D+\Delta$ in the equations above, and plot the image displacement, $\delta(\Delta) = i_c(\Delta) + d + \Delta - \left[i_c(0) + d\right]$, and the plate scale as a function of $\Delta$ from –0.5 to

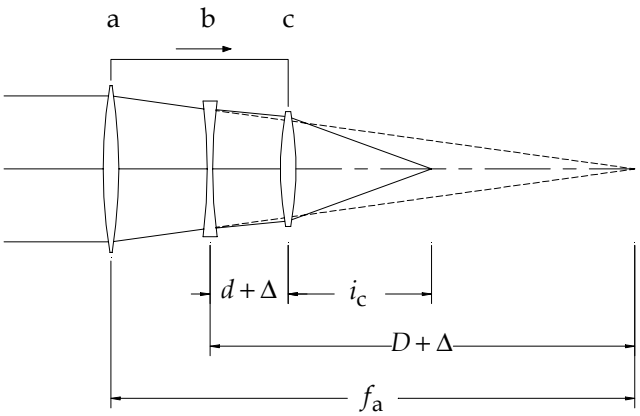


Figure 2: the Pan-Cinor zoom.

2.5 cm. Show thereby that the image is displaced by at most 0.068 cm, and that the plate scale increases by a factor of 3.0, as Δ runs from zero to 2 cm.

4. UR infrared astronomers frequently use their newest infrared camera, built by Profs. Bill Forrest and Judy Pipher, at the Wyoming Infrared Observatory. WIRO has a classical Cassegrain optimized for infrared performance. The primary mirror is a 2340 mm diameter paraboloid with focal length 4800.1 mm. The secondary has diameter 202.8 mm and focal lengths 431.7 mm and 5380.0 mm. Its edge comprises the aperture stop. 269.5 mm past the Cassegrain focus there is an achromatic doublet lens with focal length 76.37 mm. The detector array sits at the final focus.

   a. Calculate the outer diameter and position of the entrance pupil.

   b. Calculate the outer diameter and position of the exit pupil. Is it real or virtual? Would it make a good Lyot stop?