1. An astronomer is considering using the MMT AO system to observe a crowded field. She has determined that a Strehl of >30% at H (1.65 um) band is necessary to achieve stable photometry and detection of fainter sources in the cluster. (Note: the MMT has “equivalent subapertures” 1 m on a side (in reality it corrects the first 56 Zernike modes) and can run at a top speed of 550 Hz.)

Notes: Assume $r_0$ in visible is 0.15 m
Assume the turbulence weighted wind speed is 10 m/s
Assume the mean height of the turbulence is 5 km.
The coefficient for the fitting error (a) is 0.55

a. If there is an infinitely bright guide star nearby, how far away (in arcsec) can it be before an object of interest has a Strehl below 30%?

b. If, instead, the object of interest is the guide star itself, how faint can it be before the 30% Strehl criteria is not met?

2. Betelgeuse has an angular diameter of 0.047 arcseconds, as first measured by Michelson and Pease (1927).

a. If Michelson was looking at the interference in the visible (550 nm), what baseline would he have seen the visibility reduced to zero?

b. Sketch out the visibility function Michelson might have seen as he increased his baseline from small values up to the zero of the visibility and beyond.

3. Using geometrical optics, build an optical coronagraph which consists of a large opaque disk located in front of the telescope. This geometrical coronagraph is to be designed to observe an Earth around a Sun at 10pc in the visible. It should block all starlight and let 50% of the planet light through.

a. Compute the angular separation and contrast between the two sources (for the contrast, an albedo of 0.1 with light reflected uniformly in all directions may be assumed for simplicity)

b. When using a 4-m telescope, how big does the opaque disk need to be, and how far should it be from the telescope?

c. Why will this not work when diffraction is taken into account?

4. A space coronagraph on a 4 m telescope is observing an Earth-like planet around a star at ~10pc. The star is mV=5, and the planet to star contrast is 1e-10. The observation is made in V band.

a. How large would a sine wave corrugation need to be on the primary mirror to create a speckle as bright as the planet?

b. Using realistic assumptions about the instrument throughput and detector efficiency (~40%), and a realistic observing bandpass (20%), how long would it take to see this speckle at SNR =3 . Assume the detector is perfect (no readout noise) for this computation.

c. Using the 2 previous answers, can you write down a requirement for the time stability of the primary mirror so that the onboard AO system can keep speckles below the planet level?