# Exercises Astronomical Observing Techniques, Set 10

## Exercise 1

a) The pixel size of the ACS WFC CCD camera on the 2.4m Hubble Space Telescope is 0.05 arcsec. At which wavelengths is an image properly sampled?

b) At wavelengths shorter than those determined in a) the image is not properly sampled. Which observing technique can compensate/solve for this problem without altering/changing the telescope or CCD itself?

## Exercise 2

a) We want to achieve the best sensitivity with a CCD at the red end of the visual spectrum. Discuss whether you would prefer to use a front illuminated or a back illuminated CCD.

b) the same as a) but now for the blue end of the visual spectrum.

c) Back illuminated CCD usually have undergone thinning, what is the reason for doing this thinning?

## Exercise 3

How do you think a color image can be produced with a CCD (like in a camera)? Describe at least two different solutions.

## Exercise 4

a) In which wavelength range is a bolometer used? Why don't we use it in other wavelength ranges?

b) For which two reasons is the operation and production of a bolometer more difficult than the CCD?

## Exercise 5

Consider a perfect (i.e., no detector noise) but small, 66 pixel detector array, which is exposed to a uniform sky background that will produce a constant flux level plus the associated photon shot noise. In addition to the sky background we are observing a very faint star. For simplicity, we assume that

- the flux from the star will be uniformly spread across four pixels
- the star will illuminate the central four pixels of the array
- the signal from the star has no associated shot noise.

The measured pixel values of the array are given in Figure 1. a) Calculate the mean and the standard deviation of the pixel values of the array. Since we know that the central four pixels contain the source we exclude them from the statistics. What is the relative noise ($1\sigma$/mean) in percent?

| | | | | | |
|---|---|---|---|---|---|
| 101.6 | 110.9 | 105.7 | 116.9 | 94.7 | 104.8 |
| 106.7 | 93.9 | 103.4 | 94.5 | 89.1 | 88.2 |
| 110.8 | 111 | 113.3 | 94.2 | 85.2 | 101.7 |
| 117.3 | 100.8 | 113.1 | 130.2 | 106.5 | 101.2 |
| 108.1 | 105.7 | 94.6 | 90.1 | 106.2 | 105.7 |
| 101.6 | 95.3 | 99.9 | 83.1 | 70.7 | 100.6 |

Figure 1: Pixel values

b) Now we consider if we can claim a detection of a source on a pixel-by-pixel basis. We know that the four central pixels see the source flux. What are the significances of detection (in standard deviations) for each of the four pixels?

c) In order to improve the S/N we now re-bin the 66 onto a 33 array. In other words, we combine (coadd) the values from 22 neighboring pixels. What are the pixel values now? Draw a 3x3 table.

d) Calculate the mean and the standard deviation of the re-binned array.Again, exclude the central pixel, which contains the source, from the statistics. What is the relative noise in percent? How does it compare with the previous "single pixel" S/N?

e) What is the significance of detection of the star in the central pixel? Is the level of confidence high enough to claim a reliable detection?