Exercises Astronomical Observing Techniques – Set 8

17 November 2008

NAME: _____

Exercise 1

a) Explain the difference between Strehl ratio (SR) and encircled energy (EE).

b) Calculate the Strehl ratio of a PSF produced by an optical system with a wavefront error of $\lambda/14$.

Exercise 2

Consider a perfect (i.e., no detector noise) but small, 6×6 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:

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

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.

Mean: _____

Std-dev: _____

What is the relative noise (1σ/mean) in percent: _____

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?

Std-dev for the central four pixels: _____/_____/_____/_____

In order to improve the S/N we now re-bin the 6×6 onto a 3×3 array. In other words, we combine (co-add) the values from 2×2 neighboring pixels. The "pixel" values then are:

Calculate the mean and the standard deviation of the pixel values of the re-binned array. Again, exclude the central pixel, which contains the source, from the statistics.

Mean: _____

Std-dev: _____

What is the relative noise on the mean (in percent): _____

How does it compare with the previous "single pixel" S/N? _____

_____

Now we check again the significance of the detection of the star in the central pixel.

Std-dev for the central pixel: _____

Is the level of confidence high enough to claim a reliable detection? _____

Exercise 3

The sky background in the visible is approximately V = 21 mag/arcsec^2. How long would you have to integrate on a 3.6m telescope with a perfect system and detector (no losses or additional noise contributions) to detect a faint galaxy of V=25.0^m, at a signal-to-noise ratio (SNR) > 3?

Use that the spectral irradiance (flux density) of a source with $V = 0^m$ is 3.92×10^{-8} W m^{-2} μm^{-1}, and assume a seeing of 1" (the galaxy remains unresolved). The V-band filter used is centered at 0.55 μm and has an effective bandwidth of $\Delta\lambda = 0.089$ μm.