Andean Cosmology School 2015
Lecture 4

Universidad de los Andes, Bogotá, Colombia

1. Flat field profiles of Tree Rings in the DECam CCDs

In this problem you will use master dome flats[1] taken with the Dark Energy Camera (DECam) for the Dark Energy Survey (DES), in the five g, r, i, z, Y photometric bands. The file names are: `flatcor_g_53.fits`, `flatcor_r_53.fits`, `flatcor_i_53.fits`, `flatcor_z_53.fits`, and `flatcor_Y_53.fits`. They are already normalized to have a median of 1. The goal of this exercise is to reproduce the azimuthally-averaged radial profiles due to the tree rings for each filter shown in the top panel of Figure 6 of the paper `arXiv:1403.6127`, and to find the relative (with respect to the g filter) multiplicative factor between them, as shown in Figure 8.

(a) Find the center of the rings by assuming that they are concentric. On `DS9`, identify points on several rings (arcs) and write a routine that fits for the common center simultaneously. Try to be as precise as possible when selecting the points on the arcs (and try to use points distributed all along the arcs), since an incorrect determination of the rings center will result in a radial profile with suppressed amplitude. If it helps, go to "Analysis" in `DS9` and smooth the image by a Gaussian of kernel 3 or so pixels to sharpen the rings. You can provide a first guess for your fitter by looking at the flat-field image. Make sure you include points from rings close to the center (not only from arcs far away).

(b) Calculate the distance between the center of the rings and the rest of the pixels in the image. Save them in a vector or array. Remember to save the ADU (analog-to-digital units) values corresponding to each distance, too. In addition, before doing this calculation, exclude those pixels too close to the edge (about 50 pixels is OK, to avoid the"glowing edge"), the tape bumps (boxes of about 50 by 50 pixels, but make sure of this for each tape bump by looking in `DS9`), and pixels close to midline (just 20 or so). Do this for just one of the sides of the CCD (the "left-hand side" or "A" amplifier side, for instance). So you would need only to consider the pixels for which $x < 1023$.

(c) Bin the ADU values in radial bins of the distance, and calculate the mean value in each bin. Experiment with the appropriate bin size (1,2,4,10 pix?). A too large bin size can wash out the signal from the rings.

(d) By now you should have two vectors: `r_bins`, `value_in_bin`. If you plot these, you will see that the oscillations of the rings are on top of a large-scale scale oscillation product from

[1] A master dome flat is the median of the best dome-flat exposures of each night, reduced, and normalized to 1

actual QE gradients in the flat field. You need to subtract this, by fitting either a polynomial or a cubic spline function to represent that large-scale mode. The (normalized) subtraction can be performed like this:

$$\texttt{new\_value\_in\_bin} = \frac{\texttt{value\_in\_bin} - \texttt{large\_scale\_value\_in\_bin}}{\texttt{large\_scale\_value\_in\_bin}} \tag{1}$$

where `large_scale_value_in_bin` is the output vector of your polynomial or spline function evaluated at the `r_bins` points.

(e) Now you should be able to see the wiggle pattern due to the rings oscillate about zero if you plot `r_bins` vs `new_value_in_bin`.

(f) Repeat the above procedure for all the remaining photometric bands (g, r, i, z, Y in total). Over-plot the different rings profiles for each band with different color codings.

(g) Due to the absorption length of light in silicon (smaller for blue photons and larger for red photons), we would expect the profiles to differ from each other just by a multiplicative factor, with the profile in the g band having the largest amplitude[2] Using the profile in the g band as a template, find these multiplicative factors and compare them with the measured numbers in Figure 8. Keep in mind, though, that those values are averages over all the 61 CCDs of DECam, and in this exercise you only calculated the values for one case.

[2] Due to the fact that photogenerated charge from blue photons will be generated, on average, closer to the back side of the CCD and thus would be subject to the transverse/lateral electric field that causes the rings for a longer time