# 1 SITe/Loral Shutter Correction

The SITe and Loral CCDs as used on the Perkins telescope have a very slow shutter. (The Navy CCD uses a different shutter and does not suffer from this problem.) On short exposures, the six-petal shutter can be seen blocking some of the incoming light from the CCD; on a one-second V sky flat, the most obscured part of the CCD has only 96% as many ADUs as the center of the chip. However, regardless of the length of the exposure, the shutter blocks a certain amount of light from the CCD.

I devised a method for creating a shutter correction image and applying it via IRAF to a list of images. The shutter correction image is created by comparing long integration flats to short integration flats of the same filter. A "long integration" flat should be thirty seconds or longer. An image I call the Long Flat is created by combining as many long integration flats from an observing run as is practical. If enough long integration flats exist, taking the median of them is best; if there are few, then averaging is necessary.

The Long Flat is used to flat field all "short integration" flats; that is, those flats that are two seconds or shorter, taken through the same filter. The "processed" short flats, which I will call Interim Images, should clearly show the shutter pattern. Five or six Interim Images is typical with the SITe CCD, but with the Loral's faster readout time, it is possible to take more short integration flats and thus get more Interim Images.

To use these Interim Images to create a shutter correction, the number of ADUs in the center pixel of the Interim Image is found. A shutter correction image can then be made from each of the Interim Images with the following recipe (image variables are indicated with an accent):

$$\hat{S} = \frac{M - \hat{I}_{flat}}{M} \cdot T,$$

where M is the number of ADUs in the center of the Interim Image, $\hat{I}_{flat}$ is the Interim Image, and T is the exposure time of the short integration flat that was made into the Interim Image. $\hat{S}$ is then the shutter correction. This formula scales the "picture" of the shutter according to both the intensity of the Interim Image and the exposure time of the Interim Image.

Once a shutter correction has been made from each of the Interim Images, all of the shutter correction images should be averaged to make a master shutter correction. This master shutter correction should be tested on a few of the (unflatted) short integration flats to check for any errors in the above procedure. Some brief testing has demonstrated that the master shutter correction is independent of filter. However, due to the flat fielding part of the above process, Interim Images and shutter correction images should be created separately for each filter, and then all filters' shutter correction images can be averaged to make the master shutter correction. The shutter pattern also does not seem to change over time, at least on time scales of a few months. However, it is recommended that a master shutter correction image be made for each observing run.

Once the master shutter correction has been made, each image (including the flat fields) can be corrected with the following formula:

$$\hat{I}_{true} = \frac{\hat{I}_{obs}}{T - \hat{S}} \cdot T$$

In this case, $\hat{S}$ is the master shutter correction image, $\hat{I}_{obs}$ is the observed image, and $\hat{I}_{true}$ is the corrected image. A longer image will obviously be less affected by the slow shutter, and so longer images have a smaller correction.

Once the master shutter correction image is made, correcting the individual images of the run becomes routine. I have written an IRAF procedure which has been used to correct all of our images.