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Flat Errors are not the Problem

Many people work very hard to produce good flats. Yet measurements show that many of the efforts, while fun, may not be particularly productive. Using T-shirt flats, I describe a series of tests that demonstrate how some huge "errors" in the flat "source" can sometimes make no difference, while some minor errors do affect results.

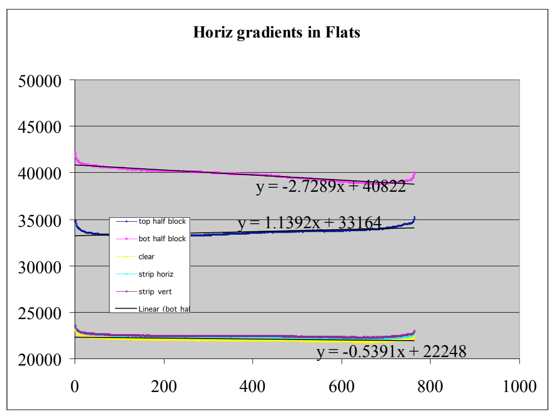
Discussion

Using my 18inch Newtonian (f4) with an ST402 camera, I conducted a series of tests of flats. The flat was two layers of bed sheet (ie, similar to a Tee shirt flat) covering the end of the telescope which was inside a ten foot observatory with the slit closed. Thus, all lighting of the end of the scope was indirect, though not particularly uniform.

I did five tests:

- Clear, that is, no obstructions
- Top half of the scope opening covered with cardboard
- Bottom half covered
- 1inch strip of cardboard horizontally across the scope
- 1 inch strip vertically across the scope

Graph 1 shows the intensity across the middle of the image (using Maxim Line function). One can see that the "clear" image shows a gradient of -1.8% across the image as determined by a least square fit to the intensity curve. The bottom covered shows +2.6% and the top covered shows -3.0% gradient.



Several points:

- The "clear" gradient is relatively small at -1.8% (more on this later)
- The top vs bottom gradients are reasonably symmetric about the "clear" gradient, ie., the data are internally consistent
- The most important observation: even the gross error in preparing this "flat", namely, covering half the aperture with cardboard, still introduced less than 2% gradient error in the flat image
- The 1 inch strip across the aperture introduced 0.5% gradient

The "clear" gradient of -1.8% is caused by a mixture of effects including uneven illumination, and various optical asymmetries inside the system. One can tease out some of these by rotating the flat light source and/or the camera in various combinations. But the lesson is this: gross errors in the flat (even half covering the opening with cardboard) produce only modest (several percent) gradients, while a multitude of minor errors can contribute errors approaching 1%. It is easy to do a flat to a few percent, it is VERY hard to do one better than 1 %.

Note that even these gross errors in the flat source (ie, covering part of the Tee Shirt with cardboard) cause little problem because the flat source (and any gradients in it) is so out of focus. However, if one is making a sky flat, the scope is focused on infinity, and gradients within the field of view will be in focus and show up in the flat. Thus, common gradients of a few percent over the field of view will show in the flat image. Such gradients may change within minutes or even seconds so that the flats from one set to another will not be consistent.

One error frequently ignored is that flooding the field (scope aperture and camera) with light is not the way we actually use a scope. When making a flat in this way, we are filling the FOV with light to make it easy to determine the variation of sensitivity over the field by making a simple measurement of intensity vs position on the image. However, most of the time the scope sees a dark field, sprinkled with low intensity light (stars or small nebula). Thus, when making a flat with light flooding in, the slightest internal reflection in the scope or camera will cause distortions of the measurement, thus leading to a flat containing errors if then applied to the dark field images. These errors can easily reach several percent, and are very hard to evaluate and remove. See my paper in SAS 2006 for more discussion and measurements on this point.

But not to worry: usually what one is after is to correct vignetting in which the sensitivity is perhaps 10-30% down in the corners, or to correct dust bunnies (doughnuts) that may only be a few tenths of a percent in amplitude, but which are fairly small. In both cases, a fair quality flat (such as this) will correct the error to high precision: you don't need perfect flats! Which is just as well: you can't MAKE perfect flats, anyway!