VIMS Saturn Occultations: Imaging-Mode Systematics Corrections

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Abstract

1 The Metric

The metric that we will use is a simple comparison of how much light spills into the pixels adjacent to the brightest star-pixel, normalized by the brightest star-pixel. In the x direction, this ratio is defined as:

$$R_x = \frac{P_{x-1} - P_{x+1}}{P_x} \tag{1}$$

And in the z direction this ratio is defined as:

$$R_z = \frac{P_{z-1} - P_{z+1}}{P_z} \tag{2}$$

Where $P_x = P_z$ is the brightest pixel, and $P_{x\pm1}$ and $P_{z\pm1}$ are the adjacent pixels in each direction, as shown in Figure **??**.

This metric has many properties which make it useful. Theoretically, it should be monotonically increasing as the star position increases in pixel position. When light is dominantly shared between the brightest pixel and its neighbor in the negative direction, the metric will be negative. When the light is dominantly shared between the brightest pixel and its neighbor in the positive direction, the metric will be positive. When the light is centered on the central pixel, the value will be zero. For PSFs smaller than a pixel, there will be a plateau at zero. Away from this plateau (near the pixel boundaries) we have the best sensitivity to the position of the star. At metric values $R = \pm1$ the center of the star's PSF straddles the boundary with the neighboring pixel and we have the most sensitivity.

Figure 1: The pixels on the Cassini VIMS instrument are 0.5x0.25 μradians for images taken in the high-resolution mode. They are 0.5x0.5 μradians for images taken in the low-resolution mode. This is a diagram of the instrument field-of-view for a 16x4 high-resolution imaging-mode occultation, such as that for the AlpOri occultation of rev270s99. The pixels used in the calculation of the metric R are labeled.

2 The Pixel Scans

We have scans of the sensitivity of VIMS's spatial pixel as a function of the position of the star relative to the center of the pixel created by slewing the telescope around in a raster-scan pattern as shown in Figure **??**.

Figure 2: Black Box is pixel, Red scans are Z scans, Cyan scans are X scans. The spacecraft was slewed such that the center of the star passed along the paths shown by the scan-lines.

I would like these to be provided as a series of one-dimensional arrays.

3 Calculating the Theoretical Metric from the Scans

One of the most well-constrained and precisely repeatable parts of the VIMS camera is the interpixel distance (Phil Nicholson, private communication). Therefore, we should be able to reliably calculate the theoretical metric by simply

1. symmetrically padding the array of a scan with zeros until it is three pixels wide, plus some extra buffer
2. R = (P[:pixelwidth+buffer] - P[2*pixelwidth+3*buffer/2:3*pixelwidth+2*buffer]) / P[pixelwidth+buffer/2:2*pixelwidth+3*buffer/2]

where pixelwidth is the number of indices in the scan array corresponding to the width of a pixel. The buffer gives us a final array of the metric that extends beyond the edge of the pixel so that we can still test those values for completeness of the fitting algorithm described in the next section. The same process is repeated with the Z-direction scans and the pixel height instead of width.

The experimental value is similarly calculated by finding the brightest pixel within the aperture, and subtracting the two on either side and dividing by the brightest pixel.

4 Fitting the Experimental Metric to the Theoretical

Now we have a map of the metric along each scan extending beyond the edges of each pixel, and the observed value of the metric.

We begin to search for the best-fit center of the star's PSF with a quick, coarse search. At the points of approximate intersection between the vertical and horizontal scans (the "knots"), we calculate the χ^2_{red} of the centering metrics. At the knot where this is minimized, and any others within a $\Delta\chi^2_{red} < 1$, we call the "rough center".

We then have two methods for refining this to a coarse-center.

For the fast method:
First, we calculate along each scan-line the χ^2_{red} in only the relevant dimension until the nearest knot outside of the "rough center". Then we fit a parabola to each of these curves, and store the minima together with an uncertainty measured as the width of where the fitted parabola rises above $\Delta\chi^2_{red} > 1$. We then fit lines through these minima, weighted by their error bars, and find their intersection as our centering location.

For the slow method:
(It's late and I'll describe this tomorrow)

5 To Dos

TODO: How the VIMS instrument works

TODO: How the observations were taken