Least Asymmetry Algorithm

Dr. Nate Lust

August 4, 2016

Least asymmetry was originally devised by James Gunn (Princeton University) for use in radio astronomy. A non-exhaustive search through the literature did not produce references, so we present the full algorithm here.

We begin with an asymmetric distribution that is a result of the optical aberrations in the system as well as the presence of noise in the measured signal. Figure **??** depicts such an asymmetric signal. We propose that the center is the point about which the distribution is most symmetric. We define the asymmetry of the signal as a function of position as

$$A(x, y) = \sum_{0}^{R} Var(\Phi(r)) * N(r), \tag{1}$$

where the discrete index r indicates the particular radial bin, Var is the variance operator, Φ is the flux, and $N(r)$ gives the number of pixels at a given radius for weighting. Equation **??** remaps images to a space in which the intensity is more normally and symmetrically distributed, as demonstrated by fitting a Gaussian to the image in asymmetry space *vs* flux space. In principle, if this were a continuous dataset, we could continue this process until the point of minimum asymmetry was absolutely determined. Because datasets collected using imaging arrays are discretely sampled, we take advantage of the increased symmetry and use established centering routines to determine the point of minimum asymmetry to sub-pixel accuracy.

To determine the point of minimum asymmetry, we calculate the value of asymmetry about each pixel in the shaded region in Figure **??**. The calculation begins by laying an aperture about a given pixel as indicated in Figure **??**. This region, which we note extends outside the window undergoing transformation, is used to create a radial profile, (see Figure **??**), with discrete radii corresponding to the pixel centers, as shown in Figure **??**. The radial profile for the particular pixel shown in Figure **??** is given in Figure **??**. Because we only choose radii corresponding to pixel centers, the radial bins are groupings of points at discrete distances. As a general example of asymmetry, Figure **??** shows profiles corresponding to low (top) and high (bottom) asymmetry.

The generated radial profile is used in conjunction with Equation **??**, to calculate the value of asymmetry. We repeat this process for each pixel in the conversion window to produce the asymmetry values depicted in Figure **??**. Finally, we use a traditional centering method in asymmetry space to determine the center with sub-pixel accuracy. In our cursory tests, we determined Gaussian centering performed better than center of light.

It is improper to do photometry on Figure **??** as the values correspond to sums of variances and not flux values. The figure does not represent a cleaned up image but is merely an array representation of the distribution of asymmetry values of the original image. The center as determined from this distribution must be used in flux space to determine photometric measurements.

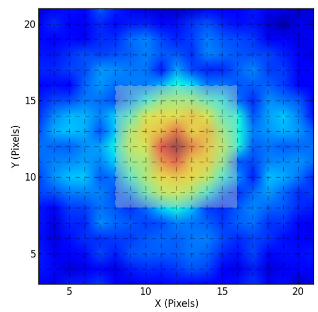

Figure 1: Asymmetric image for which the center is to be determined. The asymmetry value will be calculated for each pixel in the shaded region near the center of the image.

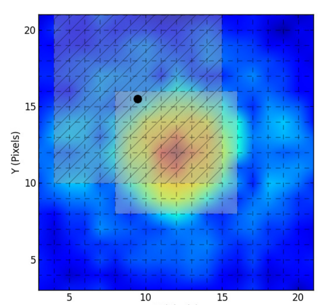

Figure 2: Asymmetric image with thatched region to indicate the region of transform for the dotted pixel

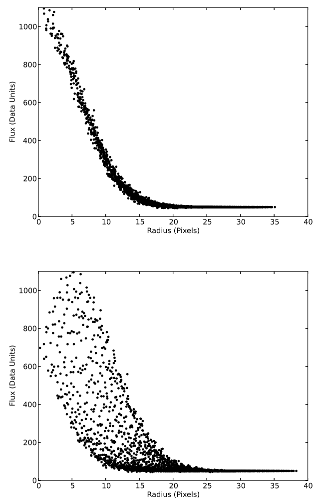

Figure 3: Stellar radial profiles. Top: When the profile is centered on the star, the variance in each radial bin is small, indicating low asymmetry. Bottom: When the profile is centered five pixels from the stellar center, the variance in each bin is high because the light is asymmetrically distributed about this point. The least asymmetry method works by minimizing the sum of the variances in all of the radial bins.

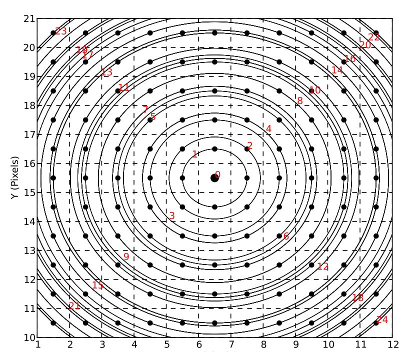

Figure 4: Radii used to generate radial profile in the region of transformation.

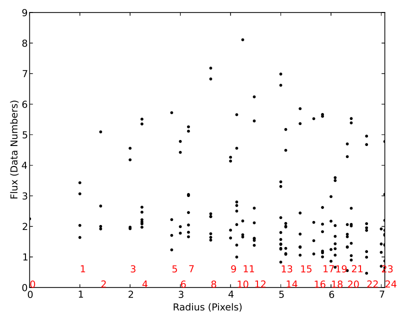

Figure 5: Radial profile corresponding to our region of transformation. Red numbers correspond to the labels of radii shown in Figure **??**

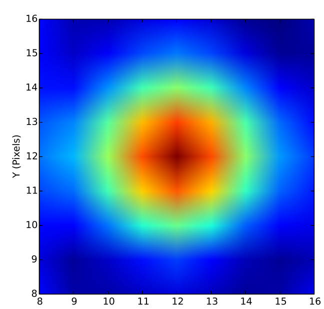

Figure 6: Image of asymmetry space for the region converted from Figure **??**.