Wide-field Infrared Survey Explorer (WISE)

Diffraction Spike Profiles For WISE Band 1, Derived From Blue Tube Measurements

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2008 October 6

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WSDC D-T003

Introduction

The goal of this analysis was to use laboratory measurements to quantify the observed diffraction spikes for WISE in Band 1 to provide input for data simulations. Specific items of interest were:

1. Ratio of integrated intensity in the diffraction spikes to the total integrated source intensity.

2. Radial profile of a spike.

3. Cross-sections at various places along a spike.

The measurements on which the analysis is based were collected at SDL on 2008 Sep 6 using the Blue Tube setup in conjunction with the near-angle scatter procedure. The test procedure involved imaging a bright point source at various places on the focal plane. The present analysis was limited to the image at the center of the focal plane.

Procedure

Because the diffraction spikes were visible only for a saturated source, it was necessary to estimate the central portion of the point source response on the focal plane by scaling up from corresponding images taken using a neutral density filter and a shorter exposure time. The following images were selected for this purpose:

1. Image #115 (SUR 8, no ND): Saturated, showing diffraction spikes

2. Image #114: Corresponding dark image.

3. Image #111 (CDS 3-2, ND 1): Unsaturated image showing central part of point-source response.

4. Image #112: Corresponding dark image.

Each of those four images was obtained by averaging a set of 5 exposures. The steps involved in estimating the PSF profile (including the diffraction spikes) were then as follows:

1. Subtract the darks.

2. Estimate the scaling factor necessary to apply to the unsaturated image so that it matches the saturated image in the unsaturated wings; the matching was based on a least squares fit to the latter.

3. Replace the saturated portion of the bright image with the corresponding portion of the unsaturated image.

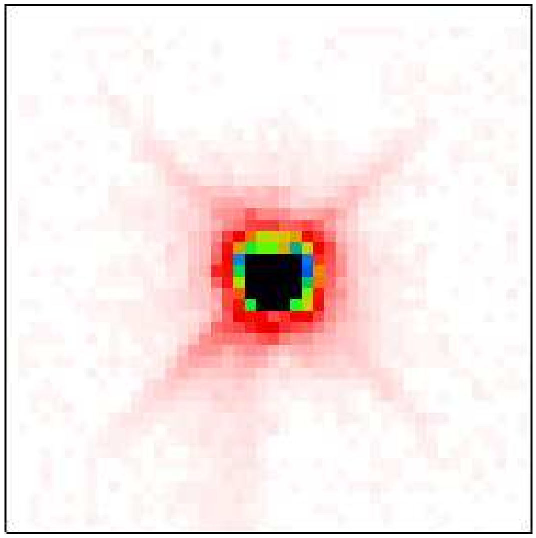

Figure 1: Estimated PSF for band 1, at the center of the focal-plane array. The field of view is 45×45 pixels (1 pixel = $2.75''$). The pseudocolor stretch was adjusted to bring out the diffraction spikes, resulting in the central portion of the image (shown in black) being clipped. The clipping level corresponds to 2% of the peak.

4. Center the image by cross-correlating with a Gaussian. The result, representing the PSF estimate itself, is shown in Figure 1.

5. Rotate the image by 45° so that the diffraction spikes line up with the x- and y-axes. This was done to facilitate the estimation of radial profiles through the spikes.

6. Average the 4 quadrants of the PSF in order to increase the signal to noise ratio in the image, assuming that the true PSF is (at least approximately) invariant to rotations by multiples of 90°.

Results

Figure 2 shows the estimated radial profile of the PSF. The solid line represents a slice through the quadrant-averaged PSF at a position angle which passes through the diffraction spike. In the interval dominated by the diffraction spike ($7 \leq r \leq 20$ pixels), the profile is well fit by an exponential. The best fit is shown by the dotted line, whose functional form is:

$$f(r) = 4.69 \times 10^{-3} \exp(-0.152\, r) \tag{1}$$

where $f(r)$ is the diffraction spike response at radial distance r [pixels], expressed as a fraction of the PSF peak. Also shown for comparison (dashed line) is the profile currently being used in WISE data simulations. The plot shows that although there

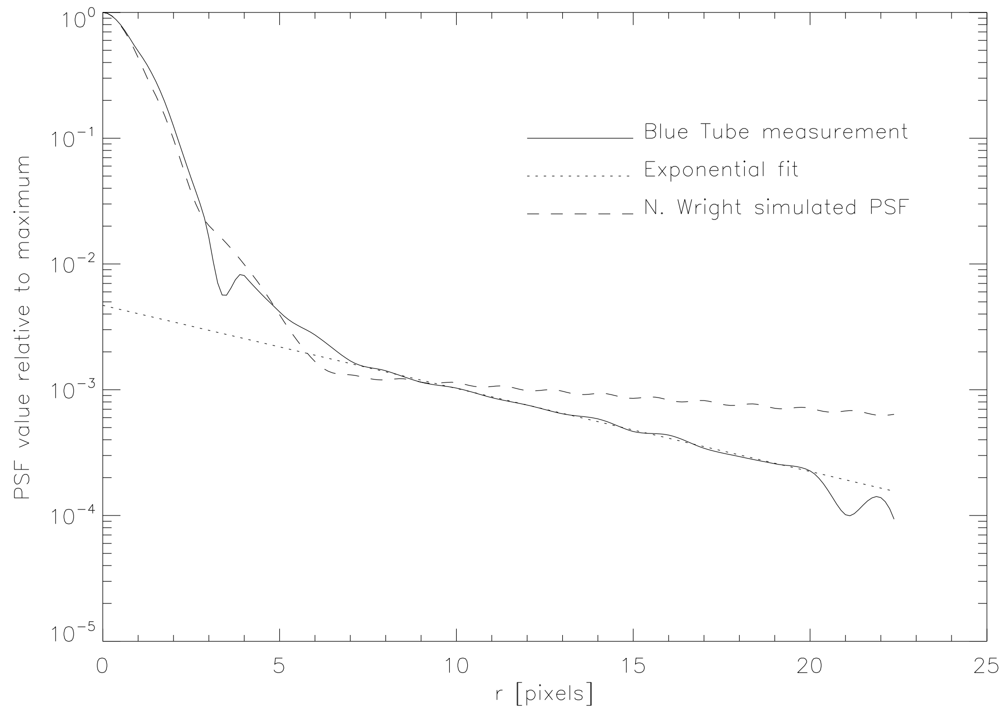

Figure 2: Radial profiles of PSF. Solid line: estimated from Blue Tube measurements. Dotted line: Exponential fit to diffraction spike. Dashed line: Profile of PSF currently being used in simulations.

is agreement between the fractional responses of measured and assumed diffraction spikes at a radial distance of 9 pixels, the measured spike falls off more rapidly with radial distance than the currently assumed profile.

Figure 3 shows cross sections through the diffraction spike at various radial distances.

Figure 4 shows the fractional power in the diffraction spikes beyond various radial distances, r. The diffraction spikes themselves were integrated over strips of width 6 pixels perpendicular to the spike, and the result expressed as a fraction of the total integrated PSF. The lowest value of r plotted is 5 pixels, since for smaller radial distances, the response is dominated by the halo of the PSF rather than the diffraction spikes.

Conclusion

The principal conclusion is that the true diffraction spike falls off more rapidly with radial distance than is currently being assumed in the simulations. The falloff is well represented by an exponential of the form given by Equation (1).

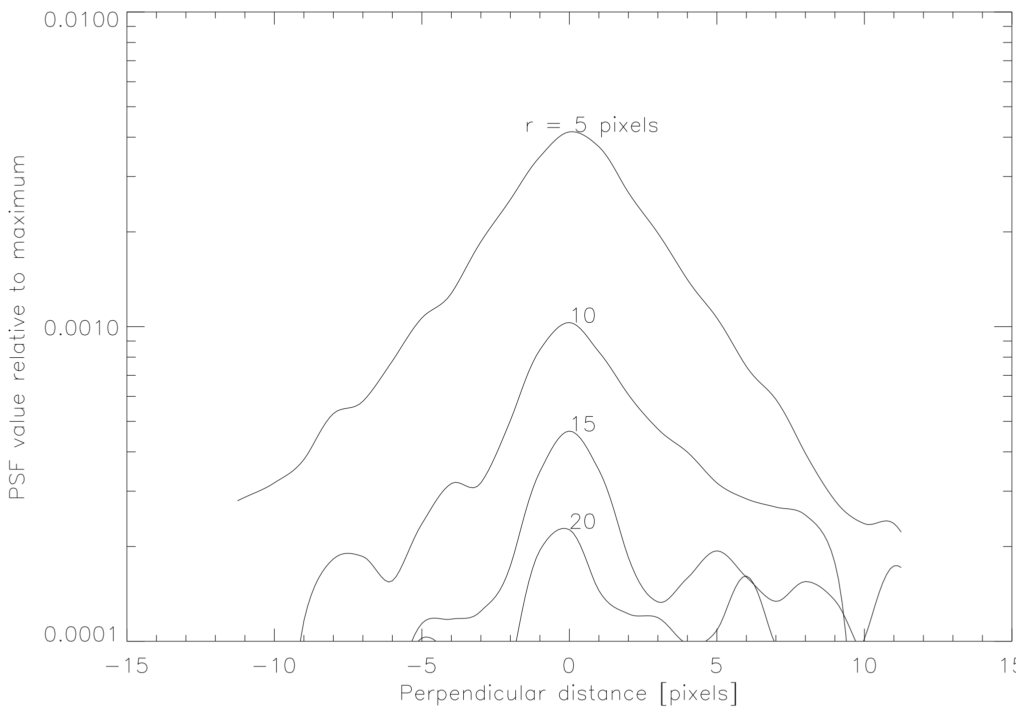

Figure 3: Cross sections through average diffraction spike at the radial distances (in units of pixels) indicated.

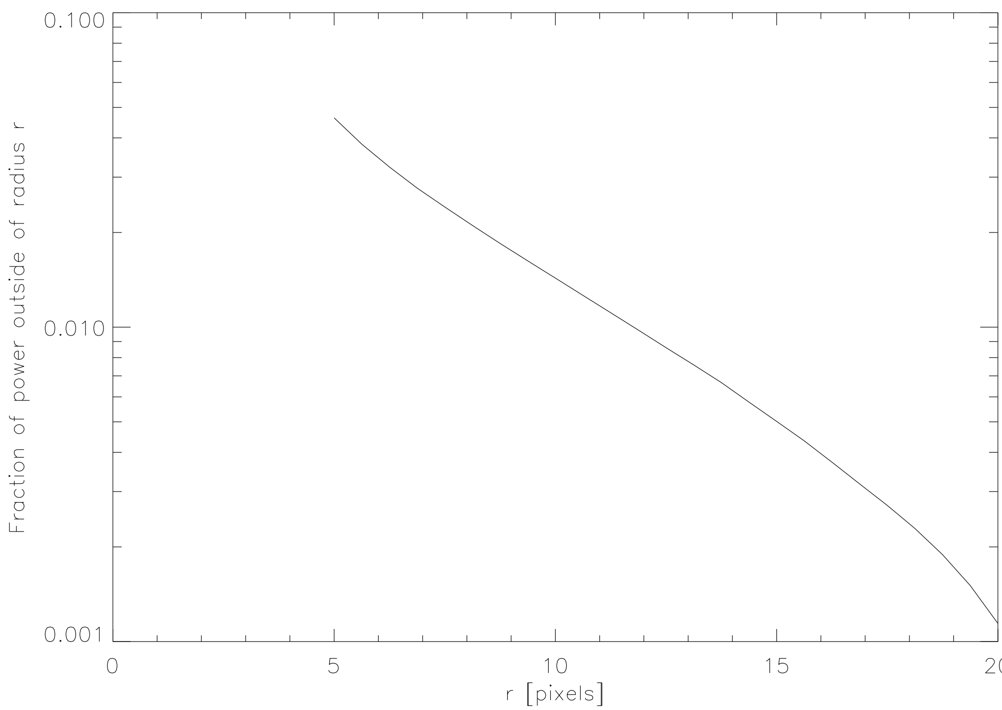

Figure 4: Fractional power in diffraction spikes. The power in all 4 spikes beyond a radial distance r [pixels] is plotted as a function of r. The power is expressed as a fraction of the integrated PSF.