Data Preparation

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This document is a summary of using TinyTim PSF to measure the photometry of 2M1207 system.

2M1207 system has a very small separation between the primary and secondary. The peak of primary and secondary separates about 6 pixels. A perfect match of primary image and PSF is required at an extreme level to ensure a good photometry measurement of 2M1207b. Image of the same system with different roll angle is an option for PSF subtraction. However, considering coarse sample rate of WFC3 IR, to shift the image can generate large artifact no matter what interpolation method is using. Also, in our data, the angle telescope rolled is 30 degree, which could cause self-subtraction of the secondary.

The advantage of TinyTim PSF is that TinyTim can produce 10x super sampled PSF so that image shifting and interpolation is no longer a problem. The downside of TinyTim is that it has several knobs, such as jittering, secondary mirror shift to tune and even using the best matched parameter set, TinyTim PSF are not good at modeling diffraction spiders and coma due to intrinsic problems.

1 GENERATE PSF

1. specify spectrum for PSF using `tiny1`, and generate the input script for `tiny2`

2. using python script `PSF_generator.py` to modify the input script and run `tiny2` and `tiny3` to generate PSF
   Lines in the input script that need to be changed:

   - line 2, the output file name
   - line 8, the filter
   - line10, major axis jitter in mas
   - line 11, minor axis jitter in mas
   - line 14, the x and y position on the detector, in integer
   - line 260, secondary mirror displacement

3. the way to generate a 10x sampled PSF using `tiny3`: `tiny3 input.script sub=10`

2 Least χ^2Fit

To match the center of PSF and star image, fit the PSF to image in a grid of dx and dy. The least χ^2fit calculates the amplitude of PSF and a sky level. Amplitude and sky level can be solved analytically.

$$\begin{aligned}\chi^2 &= \sum_i \frac{(\mathrm{Img}_i - a\cdot\mathrm{PSF}_i - b)^2}{\sigma_i^2}\\ &= \sum_i \frac{\mathrm{Img}_i^2 + a^2\cdot\mathrm{PSF}_i^2 + b^2 + 2ab\cdot\mathrm{PSF}_i - 2a\cdot\mathrm{Img}_i\mathrm{PSF}_i - 2b\mathrm{Img}_i}{\sigma_i^2}\end{aligned} \tag{2.1}$$

To obtain least χ^2, $\frac{\partial\chi^2}{\partial a} = 0$, $\frac{\partial\chi^2}{\partial b} = 0$. So that

$$\begin{bmatrix} \sum_i \frac{\mathrm{PSF}_i^2}{\sigma_i^2} & \sum_i \frac{\mathrm{PSF}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{PSF}_i}{\sigma_i^2} & \sum_i \frac{b}{\sigma_i^2} \end{bmatrix} \cdot \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} \sum_i \frac{\mathrm{Img}_i\cdot\mathrm{PSF}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{Img}_i}{\sigma_i^2} \end{bmatrix} \tag{2.2}$$

a and b can be easily solved using simple linear algebra.

3 Fit 2 PSFs together.

Simply change equation 2.2 to

$$\begin{bmatrix} \sum_i \frac{\mathrm{PSF1}_i^2}{\sigma^2} & \sum_i \frac{\mathrm{PSF1}_i \cdot \mathrm{PSF2}_i}{\sigma_i^2} & \sum_i \frac{\mathrm{PSF1}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{PSF1}_i \cdot \mathrm{PSF2}_i}{\sigma^2} & \sum_i \frac{\mathrm{PSF2}_i^2}{\sigma_i^2} & \sum_i \frac{\mathrm{PSF2}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{PSF1}_i}{\sigma_i^2} & \sum_i \frac{\mathrm{PSF2}_i}{\sigma_i^2} & \sum_i \frac{b}{\sigma_i^2} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \\ b \end{bmatrix} = \begin{bmatrix} \sum_i \frac{\mathrm{Img}_i \mathrm{PSF1}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{Img}_i \mathrm{PSF2}_i}{\sigma_i^2} \\ \sum_i \frac{\mathrm{Img}_i}{\sigma_i^2} \end{bmatrix} \tag{3.1}$$