Photometry Procedure and Results

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Constructing a PSF

The first thing I had to do to perform the PSF photometry was to create an ePSF. I mainly followed the procedure outlined in the astropy tutorial[1]. First, I summed image frames 40, 56, 71, 88, and 103 so that Vega would be spaced out and that the PSF builder function can use all of them to construct a PSF. I then made a table of stars using the function "find_peaks" which records the positions of peaks that lie outside of a set threshold from the background. Scattering those positions over the image allowed me to make sure that there were no other objects included in the table.

The star cutouts from which we build the ePSF must have the background subtracted. Here I used the function "sigmaclipped_stats" to retrieve the sigma-clipped median value and used that as the background level with sigma set to 2. I then used the function "extract_stars" to extract cutout images centered on stars defined in the input table. From there, I used the function "epsf_builder" to create a PSF to use later. Figure 1 shows the 4 star cutouts of Vega and the created ePSF.

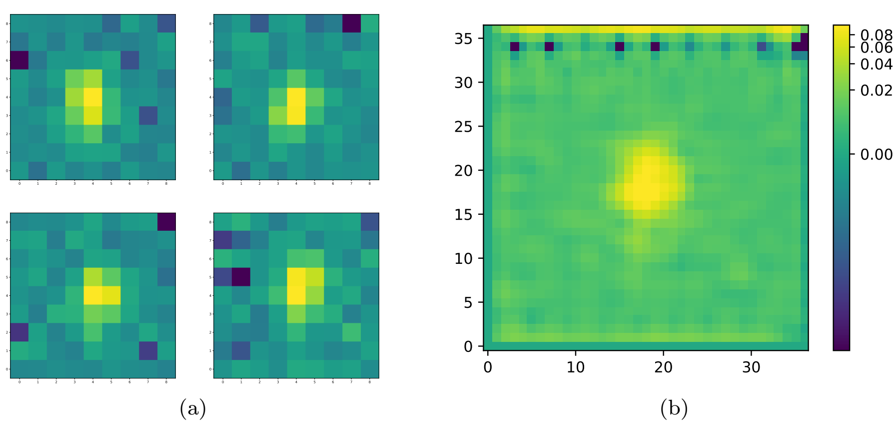

Figure 1: (a)The star cutouts from the summed image. (b) The created ePSF with oversampling = 4.

Tracking Vega with Stamps

In order to use astropy star tracking functions, I needed to create stamps around Vega in each frame. This decreased the chance of the functions identifying objects and noise other than Vega. Vega oscillates along the y-axis and travels up the x-axis of the image. So I made the y length fixed by subtracting 20 pixels from its minimum y value and adding 20 pixels to its max y value. For the x-direction, I made the length 30 pixels centered around the first x value recorded. Then for each frame, I add 1 pixel to the max and min x value of the stamp (called window) so it would follow the star as it moves up the x-axis. Figure 2 displays a sample of the stamps created. This procedure was repeated with the wavelength data extension.

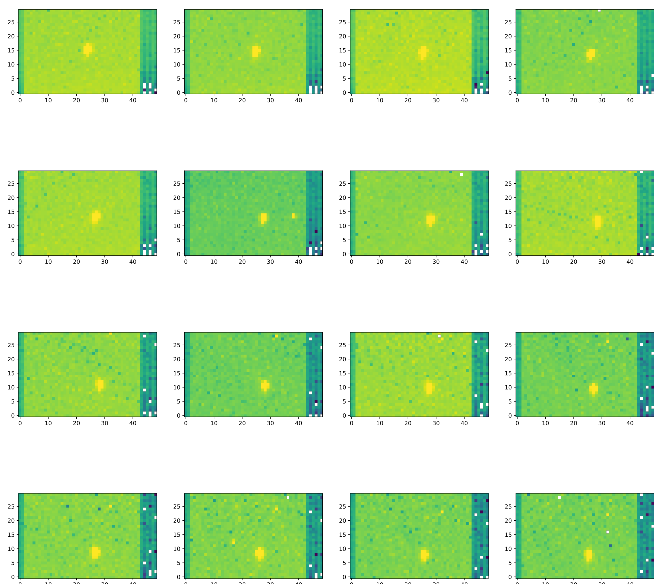

Figure 2: A sample of the stamps created. The astropy function "DAOStarFinder" was used to find Vega's centroid within each stamp.

Performing PSF Photometry

For each stamp, I used the astropy function "DAOStarFinder" to detect Vega and find its centroid. Unfortunately, there were some misidentifications that I had to manually go through and delete. After that, I created boxes of length 3 pixels around the x and y coordinates of the centroids. I repeated the procedure for the wavelength extension. Within those boxes I performed the PSF weighted average using Equations 1 and 2.

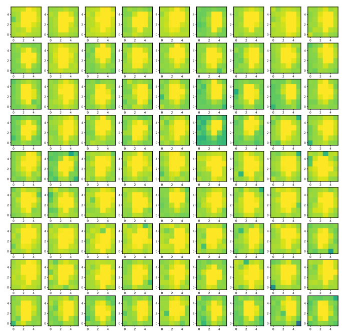

Figure 3: The boxes in which I took the PSF weighted average of the flux.

$$\langle F \rangle = \int \frac{F(x,y)P(x,y)dxdy}{P(x,y)dxdy} \tag{1}$$

$$\langle \lambda \rangle = \int \frac{\lambda(x,y)P(x,y)dxdy}{P(x,y)dxdy} \tag{2}$$

$$1W/cm^2/sr = 10^{13}nW/m^2/sr \tag{3}$$

With $P(x, y)$ being the ePSF I created. The LEISA flux data had units of $W/cm^2/sr$, which was converted into units of $nW/m^2/sr$. I did this by using the conversion factor in Equation 3. Figure 4 shows the plot of this converted flux versus wavelength in microns. Notice that the flux values are on the scale of around 10^{10}.

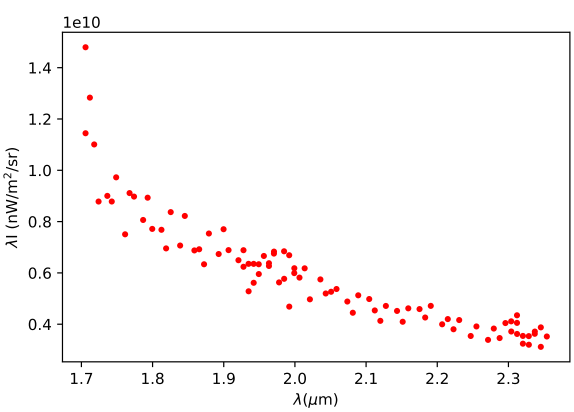

Figure 4: The resulting plot of flux in $nW/m^2/sr$ versus wavlength in μm

Vega Model

The flux data in the model[2] I found had units of $ergs/cm^2/s/sr/nm$. I converted this into units of $nW/m^2/sr$ in several steps. First, I used Equation 4 to convert from $ergs/cm^2/s/sr/nm$ to $W/m^2/sr/nm$. Then I used Equation 5 to convert from $W/m^2/nm/sr = nW/m^2/nm/sr$. Finally, I multiplied these values by the corresponding wavelength in nm. Equation 6 shows the general formula after combining the steps outline in Equation 4 and 5.

$$1ergs/cm^2/s/sr/nm = 10^{-3}W/m^2/sr/nm \tag{4}$$

$$1W/m^2/nm/sr = 10^9 nW/m^2/nm/sr \tag{5}$$

$$\lambda I_{final} = I_{initial} * \lambda[nm] * 10^6 nW/m^2/nm/sr \tag{6}$$

Figure 5 shows the plot of the converted model flux versus wavelength in microns. This flux is on the scale of 10^{15}, which is about 5 orders of magnitude greater than the flux I calculated with LEISA.

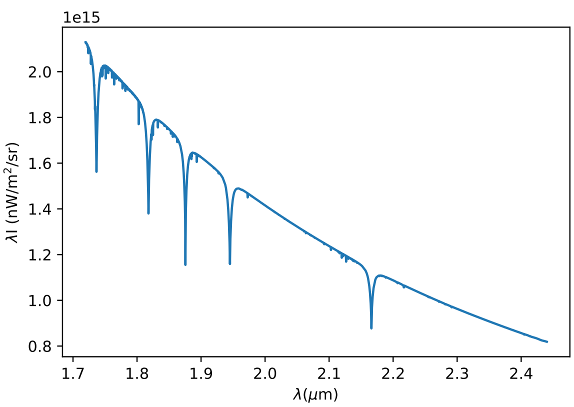

Figure 5: The model of Vega's spectrum.The flux values are much greater than the values I calculated with LEISA's data.

References

[1] https://photutils.readthedocs.io/en/stable/epsf.html#build-epsf

[2] http://kurucz.harvard.edu/stars/vega/