Photometric treatment of HD100453

Semester Project

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Abstract

TODO

1 Introduction

1.1 Observations

HD 100453 A, hereafter referred to HD 100453, is a Herbig Ae/Be Star with a protoplanetary disk located in the Lower Centaurus Association. HD 100453 has also an early-M star companion, called HD 100453 B. A background star is also located to the top left of Hd 100453. In this work four observations were used, all taken from the ZIMBOL imager.

One set of observation is called cyc116 and it consists of one observation with the R_PRIMfilter, central wavelength 626.3 nm, and the other with the I_PRIMfilter, with central wavelength of 789.7 nm.

The other set, called ND4, was taken with the same filters but additionally a neutral density filter (ND4) was applied. The neutral density filter reduces the counted photons on average by a factor of $1 \cdot 10^{-4}$ depending on the wavelength of light.

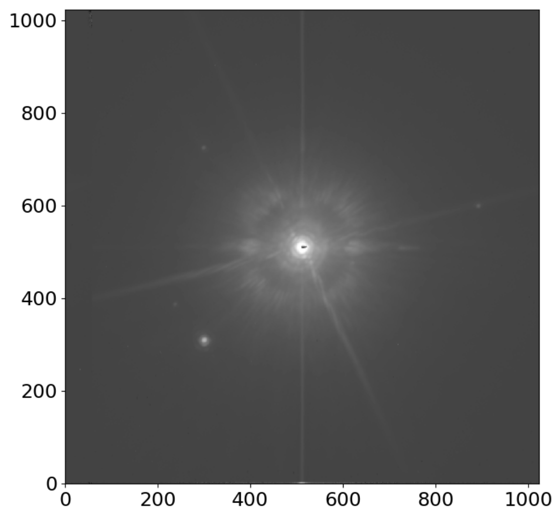
For all observation we have 4 frames corresponding to the 4 Stokes parameters.

The radial stokes parameter

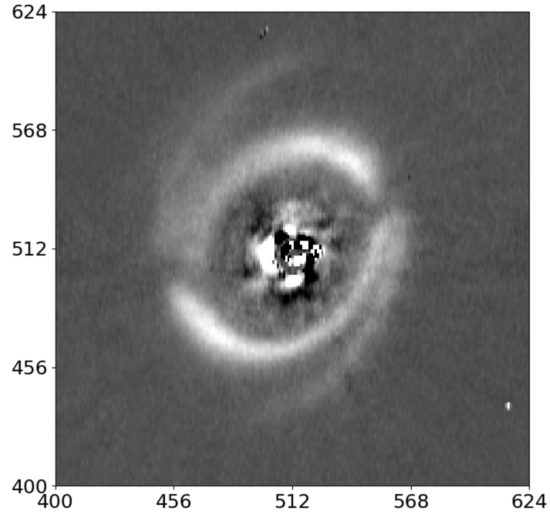
$$Q_\phi = -Q\cos 2\phi + U\sin 2\phi,$$

where ϕ is the position angle of the location (x, y) with respect to HD 100453 at (x_0, y_0) and is written as $\phi = \arctan\frac{x-x_0}{y-y_0}$, was also used. For more information see [1].

Additionally we used another set of images called point spread function (PSF). The PSF describes how a point source of light is spread over the detected image.



(a) I_Q frame in the I-band of cyc116 in logarithmic scale.



(b) Zoomed in picture of the radial polarization Q_ϕ of cyc116 in the I-band.

Fig. 1 (a): The over saturation of is visible by the black spot in the center. The companion HD 100453 B is visible in the lower left corner of the figure. The distant star is located in the upper left corner. There are also two ghosts from the instrument visible.
(b): We see the disk as well as two spiral caused by the orbit of the companion.

Looking at cyc116 we see a problem. Namely that the star is over saturated. This poses a problem to the flux measurement hence, we don't have a complete and faultless observation to do the analysis. For this purpose we have the ND4 set. There we have a faultless observation of the star but much weaker. The objective is then to rescale the ND4 profile to match that one of cyc116 to reconstruct the peak of HD 100453.

1.2 Methods

Two different methods were used to analyse the data.

1.2.1 Aperture Photometry

Aperture photometry is the simplest method to obtain a flux measurement of an object. it consists of integrating all the pixel counts within an circular aperture centered on the object and then subtracting the background noise. One way to subtract the background was to calculate the average count in an annulus around the object and multiplied by the number of pixels inside the aperture. We also tried a different method of subtracting the background. We removed the aperture from the data and fitted a second order polynomial to the rest of the data. The final flux was than obtain by subtracting the polynomial from the aperture. We will compare these two method in section 2.2.

After obtaining the fluxes of all the frames, we can calculate the color index of the objects by taking the logarithm of the flux of the I-band divided by those of the R-band. With the color index one can estimate the temperature of a given star. The same procedure is also applicable to the disk of HD 100453 with a slight modification. Instead of using an circular aperture we use an annular aperture to ignore the counts produce by the star and only count outside of it's influence.

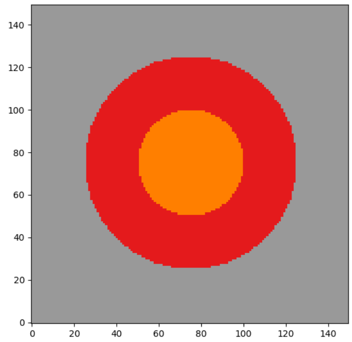


Fig. 2 Example with an orange aperture and red annulus.

1.2.2 Azimuthal averaged profile

An azimuthal averaged profile, hereafter referred as profile, is created by averaging over all points which have the same distance from the center of the image. This makes for a simple data reduction method to simplify the data to 1 dimension, because we expect that the profile of the star is radial symmetric.

2 Data analysis

2.1 Intensity ratios

To get comparable results it is important to chose the same aperture for every object. We calculated from table 2 in [2] an estimate of 0.18 mag for the $R - I$ index of HD 100453. Depending on the size of the aperture we find values ranging from -0.04 mag to -0.16 mag. This discrepancy can be explained by looking at HD 100453 in the two bands (see figure 3). The over saturation in the R-band covers more of the peak than in the I-band. For this reason we should expect a negative result, which we got. The rest of the results are located in section A. (Maybe mention other ratios?)

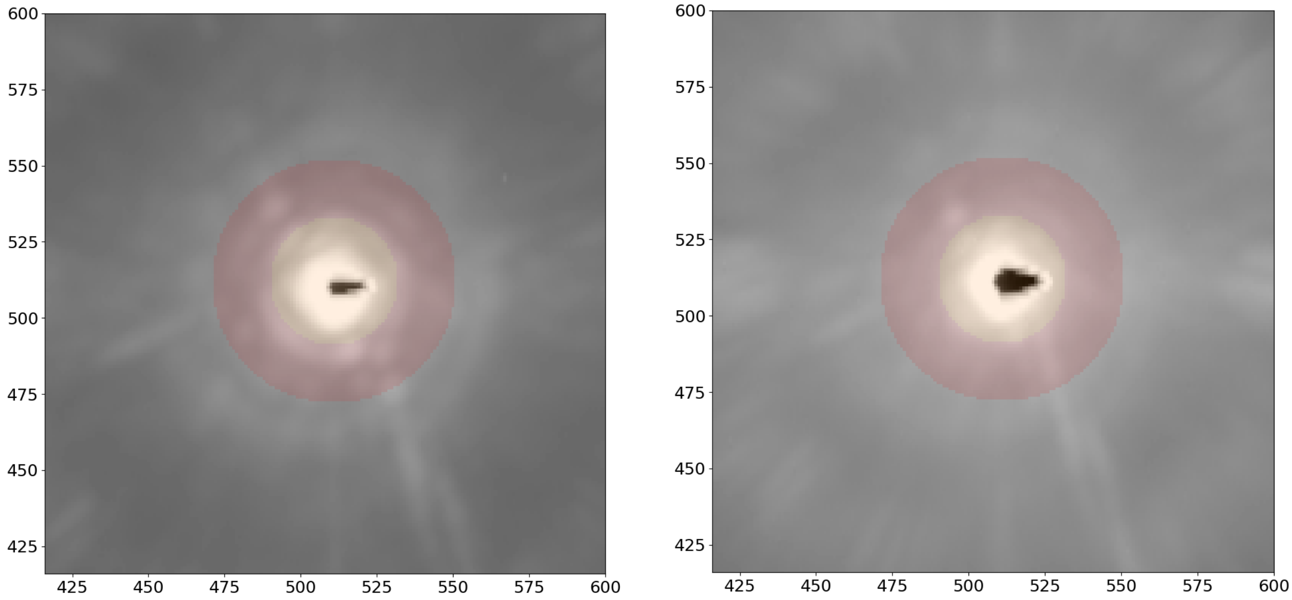
2.2 Background removal

To compare the two background removal methods we will like at the companion and the ghost on the right. These object were chosen because the surrounding of the companion is simple and the surrounding of the ghost is complex because of the spider.

For the first method, the flux is written in table 2. By changing the size of the outer annulus the counts of the companion changes by $\pm 10\,000$ and that of the ghost by ± 1000.

The same size of aperture with the second method results in a flux count with background removed of 389 605 for the companion and 16 473.

The values of the second method are well within a 3σ interval of the first, meaning we don't have a significant difference between the two methods. It is better to just use the first simple method instead of the other.



(a) HD 100453 in the I-band.

(b) HD 100453 in the R-band.

Fig. 3 HD 100453 in both bands with an aperture of size 21 px and annulus radius of 40 px.

2.3 Reconstructing of peak

To reconstruct the peak, we used the profile to simplify the fitting process to a 1 dimensional problem. To get a complete peak for the cyc116 profile, the profile of the ND4 observation needs to be rescaled to fit that of cyc116. A simple multiplication with just a scaling factor is not sufficient. The ND4 profile is reduced by a factor of 10^{-4}, so the background will also get amplified by the same factor. This leads to unwanted results because of the background. To prevent this from happening, it was necessary to first subtract a constant to reduce the background. A fitting function was used with the following function to accomplish the above:

$$f_1(x, a, b) = a \cdot (x - b) \tag{2.1}$$

We are mostly interested in reconstruction the peak. This allows us to adjust the fitting region. We can ignore the inner most data points to avoid the over saturation and also outside a given radius. We confined to fitting region to the interval 14 px-65 px and also included some point in between 120 px-200 px ("tail") to control the residue on the outside. To make up for the fewer points inside the tail, the weight of those points got increased. To further improve the fit, we also estimated the fitting parameters a, b by calculating the reduction factor of the neutral density filter for a and the median of the background for b to give as starting values. Indeed the fitting method yielded values close to our estimate.

Next we wanted to fit the PSF profile as above to the scaled profile, obtained by the fitting above. This would allow use to determine the intensity of the disk by subtracting the PSF profile from the cyc116 profile. In a first step we adopted the above method with slight changes to the fitting region. Instead of the interval we just used the first 32 px. We only used the pixels by the peak because the PSF profile and scaled profile have a difference away from the peak consequently to the reflected light from the disk. To improve the fit of the PSF, we convolved the profile with a Gaussian of standard deviation σ. This resulted in the fitting function:

$$f_2(x, a, b, \sigma) = a \cdot (gauss(x, \sigma) - b) \tag{2.2}$$

The fitting method performed poorly due to the amplified noise of the scaled profile in the outer region. The difficulty was to chose good points to control the residue. In a first attempt, only the points where chosen, which are within 34% of the cyc116 profile value. This method resulted often in errors because for some configuration of the fitting method they were no points close to the cyc116 profile. We settled for a much simpler method, by creating a new mixed profile. The mixed profile consisted of the first 80 px of the rescaled profile while the rest was the cyc116 profile. This assured us that we have a correct fit of the peak, while having good control on the outside values. The resulting profiles are show in figure 4.

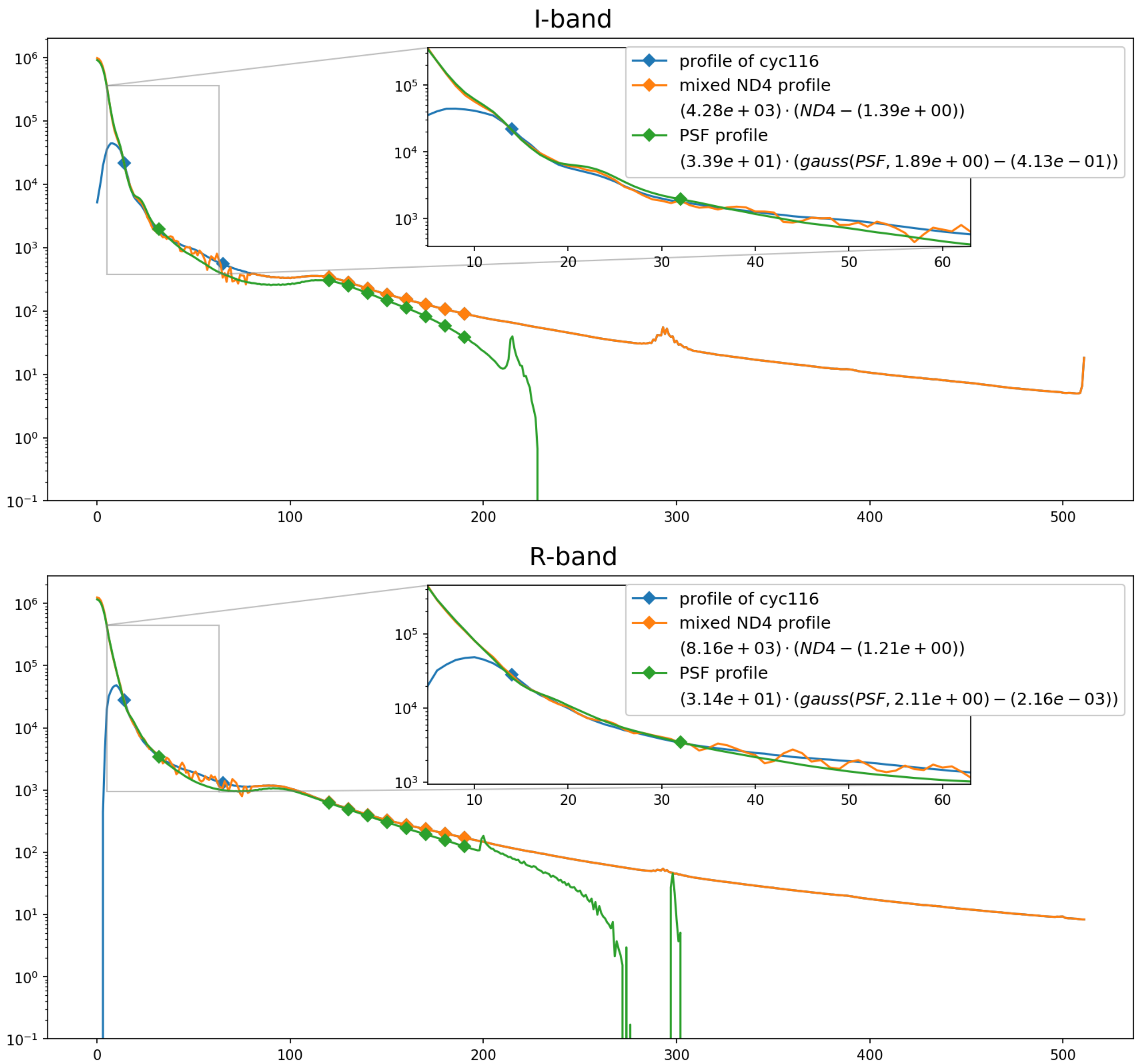


Fig. 4 The dots in the plot mark the fitting region. (Need more explanation?)

The results looks good but there are still some problems. One problem is that the fitted PSF profile goes sometimes over and sometimes under the profile of cyc116. This results in positive and negativ values when we do the subtraction, more on that in the next section. We can compare the profile to one another by dividing the sum of counts inside a given radius of one profile by the other.

We see with the ND4 lines, that we lost around 8% to 10% of the flux, due to the over saturation of cyc116. We also see the before mentioned problem of the crossing from the rescaled ND4 and PSF profile inside the peak.

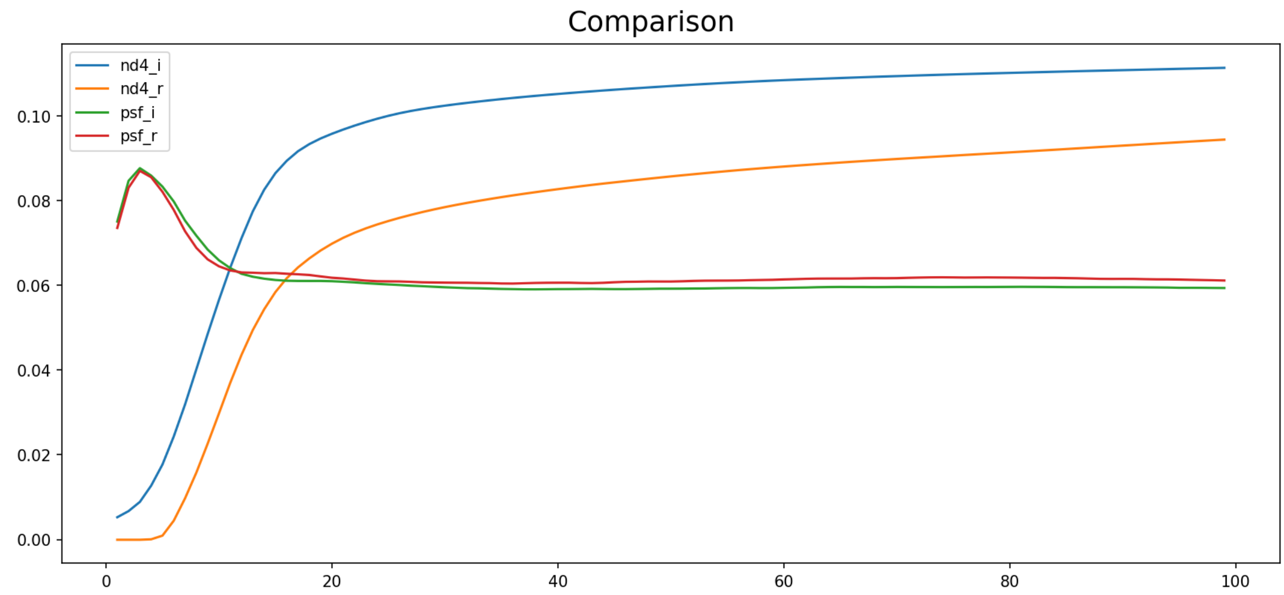
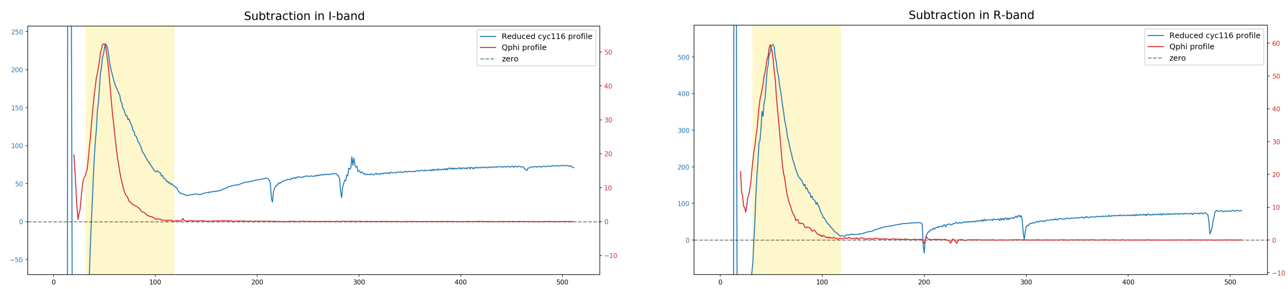


Fig. 5 (First version. Doesnt work as intended but works fine as a first estimate)
The nd4 lines compares the cyc116 profile to the rescaled nd4 profile in the respective band. The psf lines compares the rescaled nd4 profile to the rescaled psf profile.

2.4 Isolating disk

For a first estimate of the disk flux we can subtract the cyc116 profile and PSF profile.



(a) Disk profile and Q_ϕ profile in the I-band.

(b) Disk profile and Q_ϕ profile in the R-band.

Fig. 6 The cyc116 profile subtracted by the rescaled PSF profile and the profile of Q_ϕ. The points inside the yellow region were used to estimate the flux of the disk. Scale on the left for the blue line and scale on the right for the red. (Need to make Text bigger in Plot)

We can clearly see a peak around 50 px, which corresponds to our disk.This is further validated by the Q_ϕ profile. We also see some problems of the fit. We have a ver¡ negative signal in the first few pixels and can't clearly determine where the disk starts. We also have some kind of shift between the outside values of the cyc116 profile and the rescaled PSF profile. Which leads to the increase of the subtracted profile further out.

To get a first estimate of the flux, we summed up the values inside the yellow region and subtracted the median of region outside of 130 px.

3 Outlook: 2d fitting

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	I-band	R-band	
	Counts	Counts	I/R Ratio
Disk profile	4084	13252	0.31
Q_ϕ profile	1421	1662	0.85
Rescaled peak	4894349	62591555	0.78

Table 1: Calculated fluxes for the Disk, Q_ϕ and rescaled peak. (Numbers aren't final)

4 Conclusion

TODO

5 References

[1] Christian Tschudi. Dust cloud movement in r aquarii. 2018.

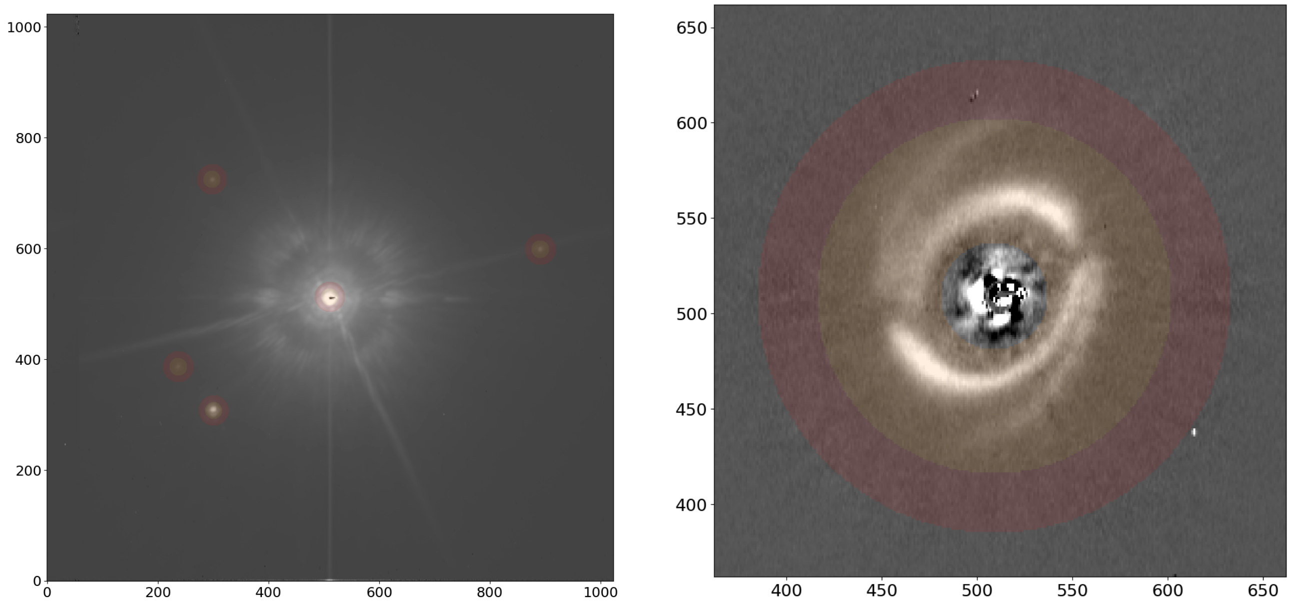
[2] S. L. A. Vieira, W. J. B. Corradi, S. H. P. Alencar, L. T. S. Mendes, C. A. O. Torres, G. R. Quast, M. M. Guimares, and L. da Silva. Investigation of 131 herbig ae/be candidate stars. *The Astronomical Journal*, 126(6):2971–2987, dec 2003.

Appendices

A Intensity ratio data

	I-band		R-band			
	Counts	w/o background	Counts	w/o background	I/R Ratio	Magnitude
HD 100453 A	26978510	24052300	309515524	25829800	0.9312	-0.08
HD 100453 B	443508	397725	172548	113359	3.5085	1.36
Distant Star	42143	13052	62033	9968	1.3093	0.29
Ghost left	37657	6295	60594	5990	1.0509	0.05
Ghost right	37107	17972	51016	17332	1.0369	0.04

Table 2: Calculated fluxes for an aperture size of 20 px and annulus size of 39 px.



(a) I_Q frame in the I-band.

(b) Q_ϕ of cyc116 in the I-band.

Fig. 7 Cyc116 image with marked apertures.