
Direct Imaging Assignment

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1 MEDIAN COMBINED IMAGE

1.1 CONTRAST CURVE

The procedure to make the contrast curve is described as following.

1. Add unsaturated PSFs into original un-rotated images as fake planets. Fake planets are evenly placed 0 to 3 arcsec away from the peak of the primary star. A median combination of images with fake planets is presented in Figure 1.2. The peak value of the fake planet is fixed, and defined as Amp_{PSF}
2. Noise is measured in an annulus around the fake planet. The inner and outer radii of the annulus are 15 and 20 pixels. I define the noise as the square root of the second moment of the pixel values in the annulus to avoid negative value due to Primary subtraction.

$$\text{Noise} = \sqrt{\frac{1}{n} \sum_{i=1}^n F_n^2}$$

3. S/N is defined as peak value of PSF Amp_{PSF} and the Noise calculated as above. Contrast curve is defined as the relationship of S/N and angular separation. Figure 1.3 presents the contrast curve for median combined image with $\text{Amp}_{\text{PSF}} = 2000$.

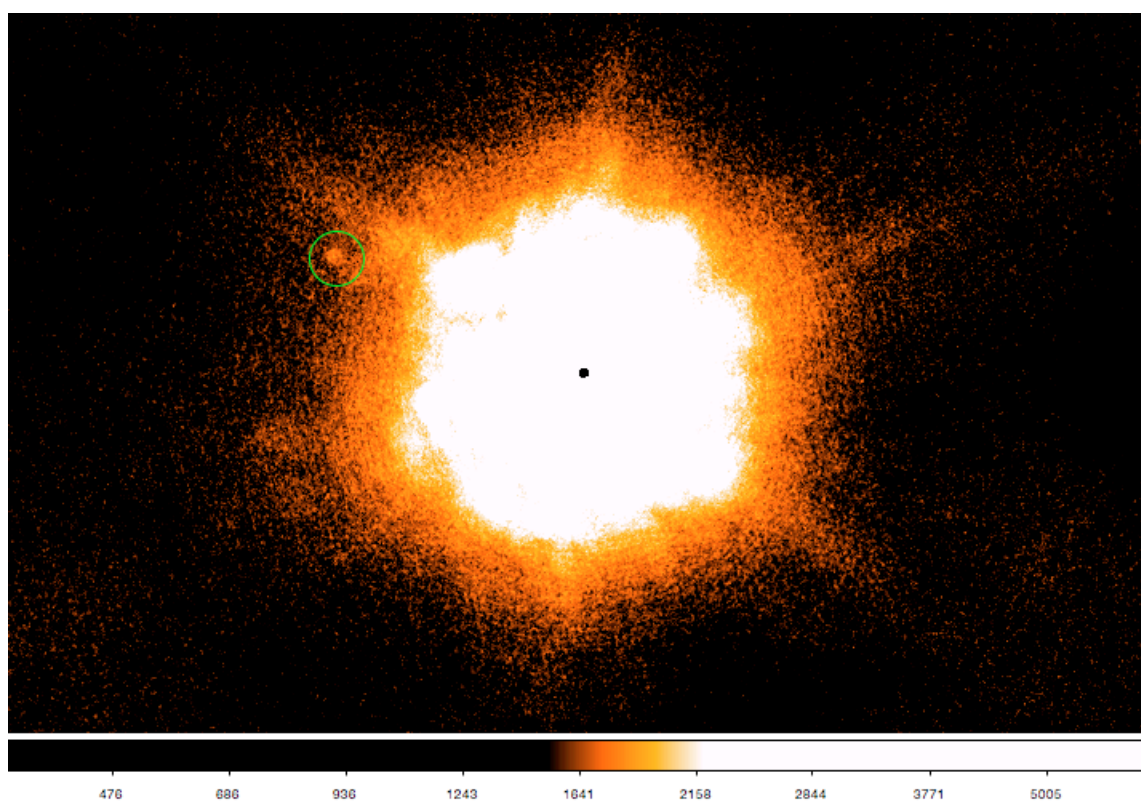


Figure 1.1: Median Combined Image for HR8799 system. On this image, only HR8799 b is clearly shown.

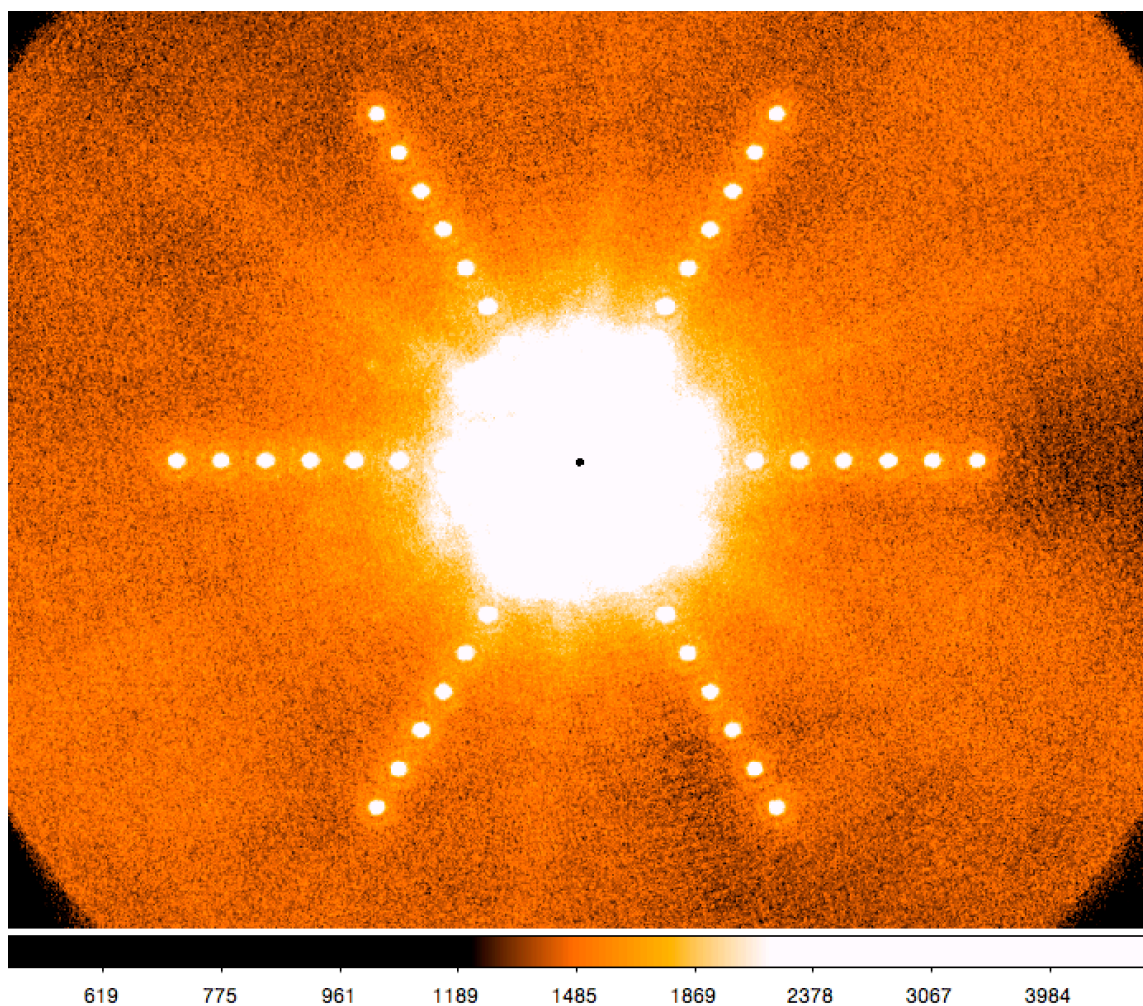


Figure 1.2: Median combination of images with fake planets adding in.

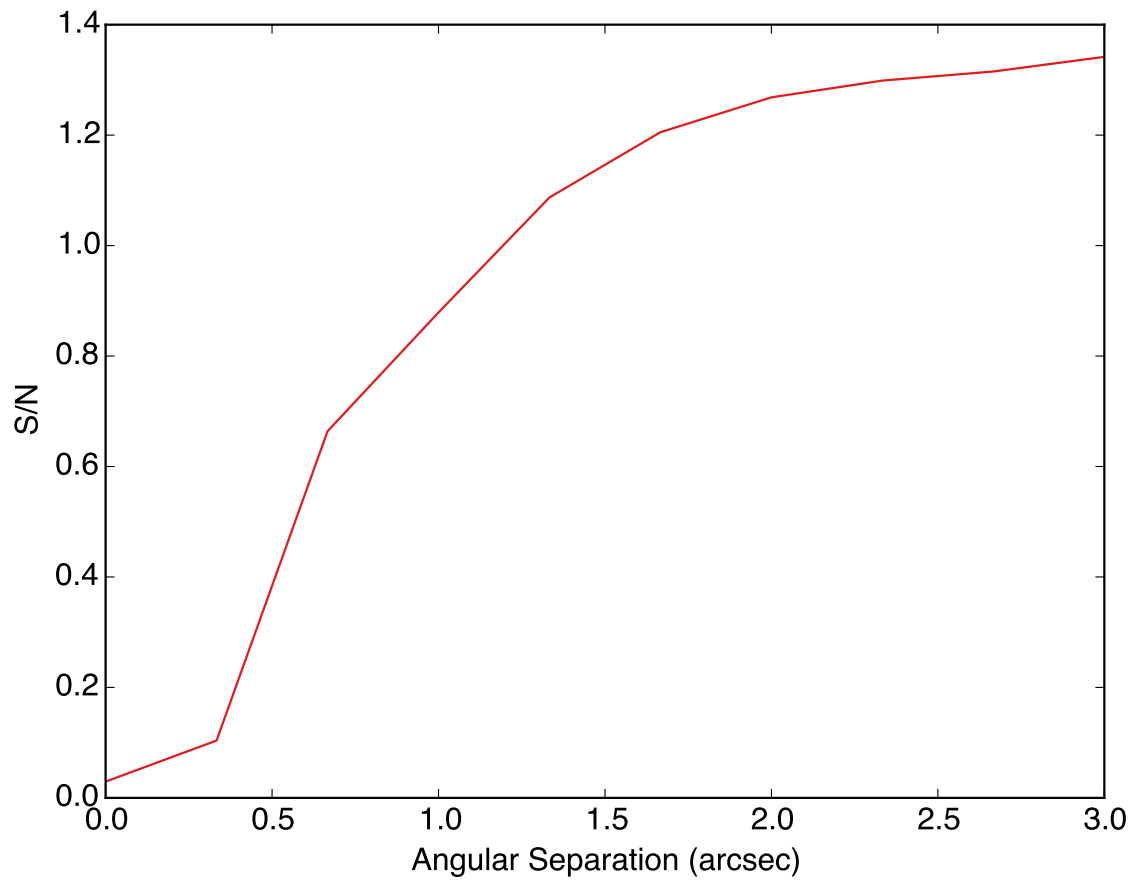


Figure 1.3: Contrast curve for median combined image. The PSF that used as fake planet is scaled so that the peak value is equal to 2000.

2 ADI

3 SIMPLE ADI

ADI method applied here is the simplest case that illustrate in Marois et. al. (2008). Every image except the target image is treated as PSF image. The PSF is constructed by the median combining of all PSF images. No selection of PSF images or calculation of any scale factors is carried out here. The result of simple ADI application is shown in Figure 3.1.

ADI processed image with fake planets injected is shown in Figure 3.2. In the image, it is clearly shown that self subtraction is very severe. This is due to coarse selection of PSF images. In a more sophisticated manner, the PSF images should be selected with angular distances that are above certain threshold compare to the target image to avoid self subtraction.

S/N curve is shown in Figure 3.3. In general, ADI improves signal to noise significantly. However, odd shape of the curve appears at around $2.5''$. I think this is also caused by self subtraction.

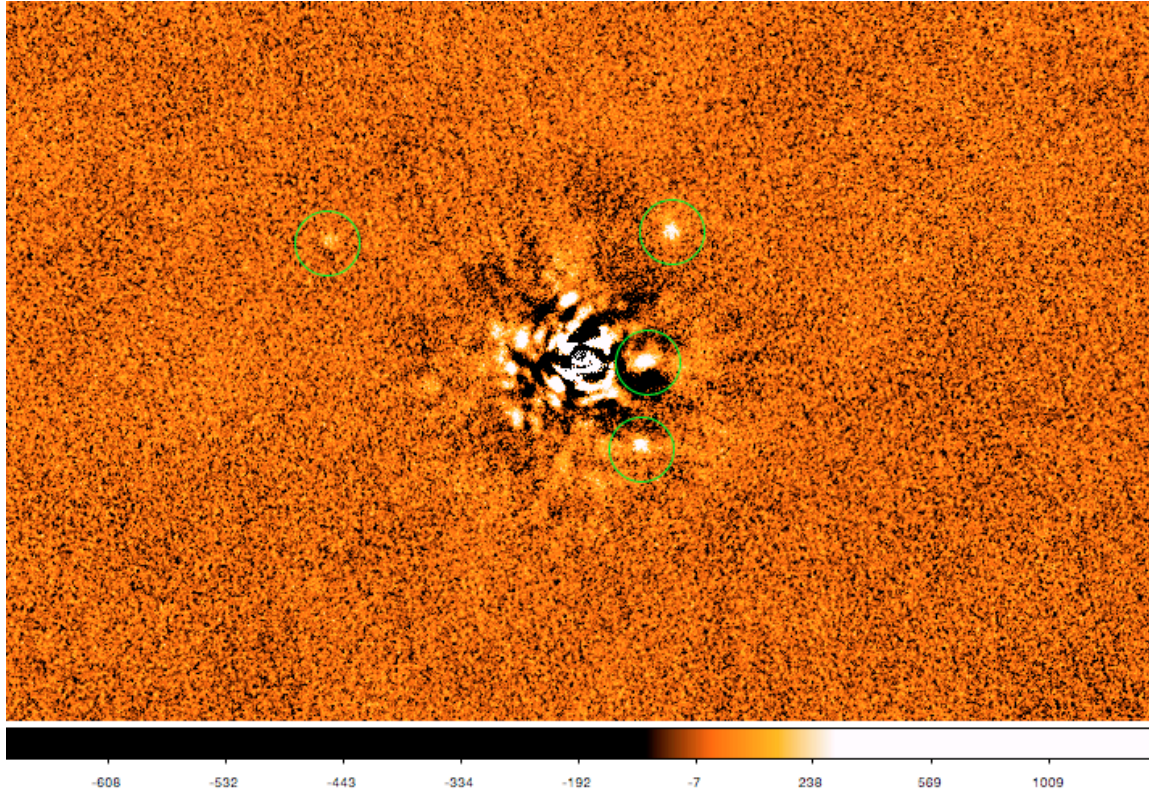


Figure 3.1: HR8799 primary star subtracted with ADI technique. HR8799b, c, d now are clearly shown on the image. The bright spot near HR8799e is hardly tell whether it is the image of HR8799e or it is a quasi bright speckle.

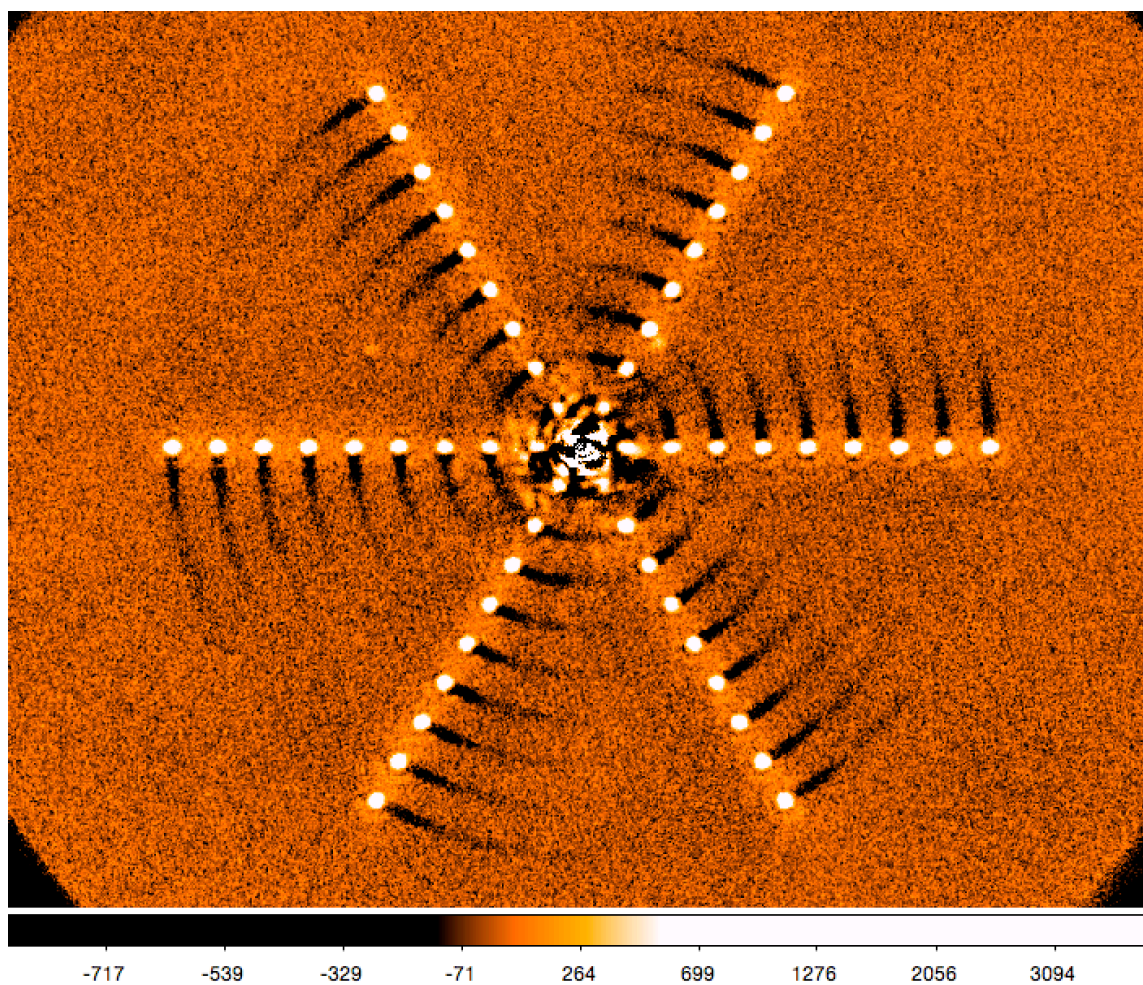


Figure 3.2: Image with primary subtracted using ADI with fake planets adding in.

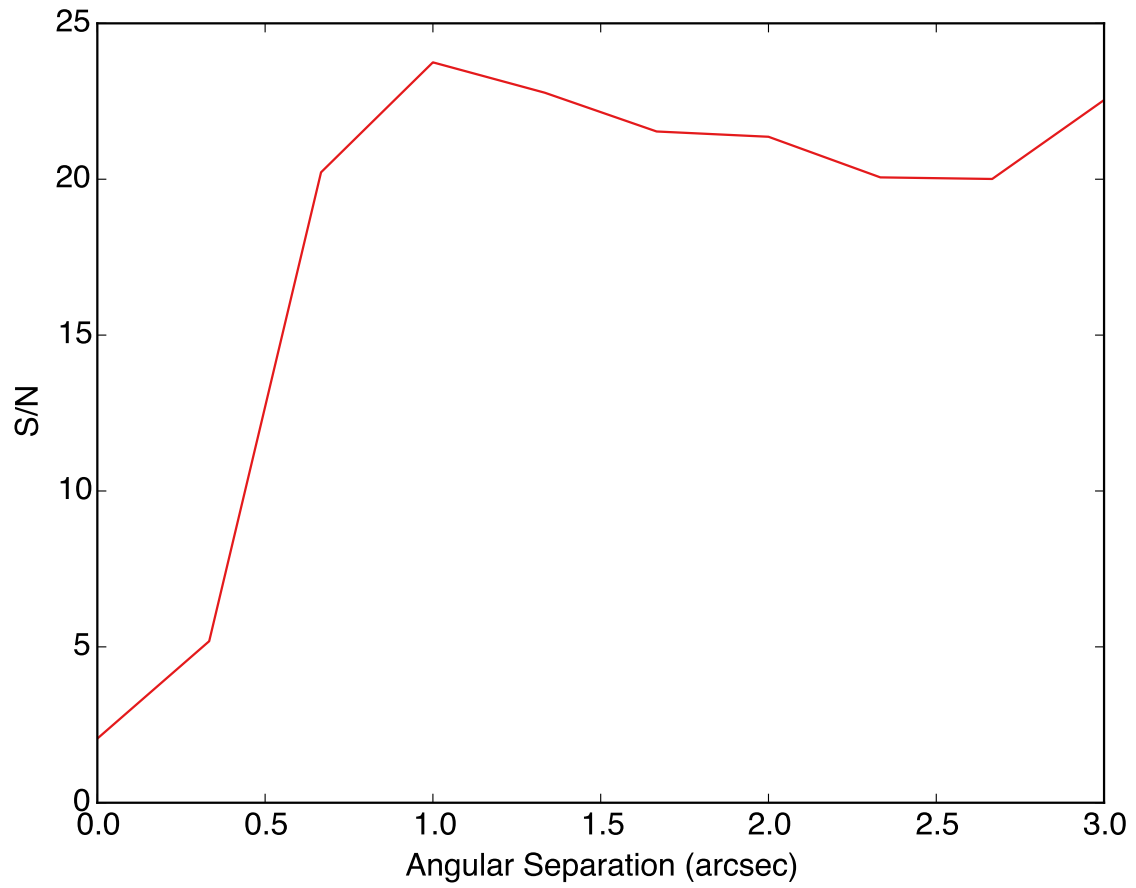


Figure 3.3: Contrast curve for image that is shown in Figure 3.2 . The PSF that used as fake planet is scaled the same way as in Figure 1.2

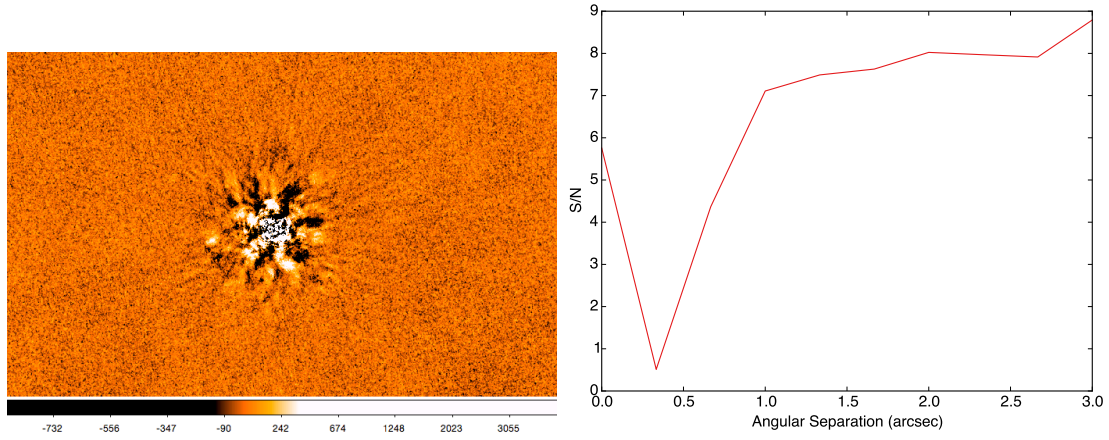


Figure 3.4: ADI with centering error. All planets are barely seen

3.1 ADI WITH CENTERING ERROR

If ± 5 pixels uncertainties in x and y coordinates are added, the performance of ADI reduced significantly. All planets are barely seen. Therefore, precisely align images is essential in high contrast image processing.

4 LOCI

Table 4.1: Star/planet brightness ratio of HR8799 system measured from LOCI image

Planet	b	c	d	e
Δmag	10.71	10.0	9.72	9.02

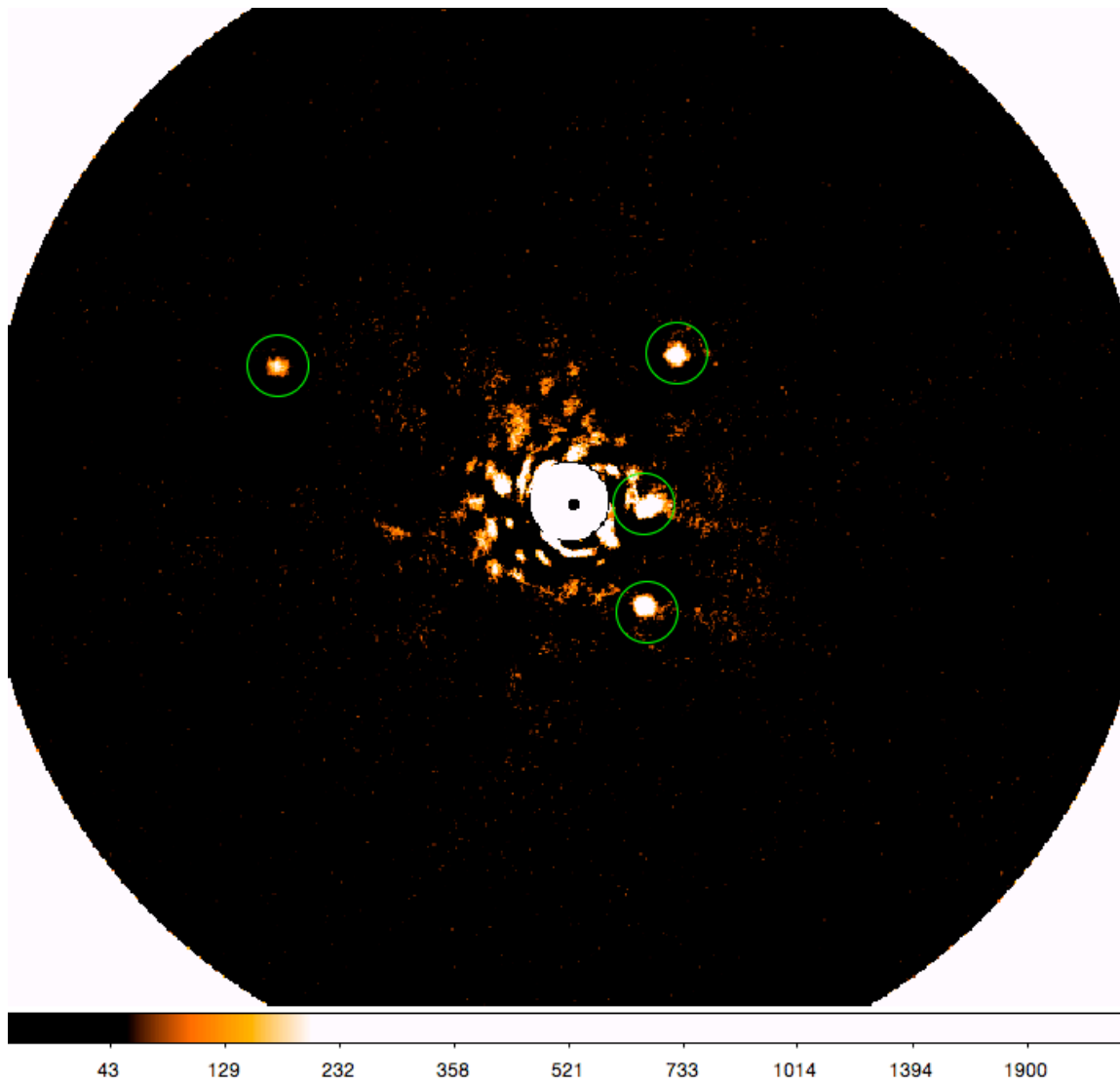


Figure 4.1: Image processed by LOCI