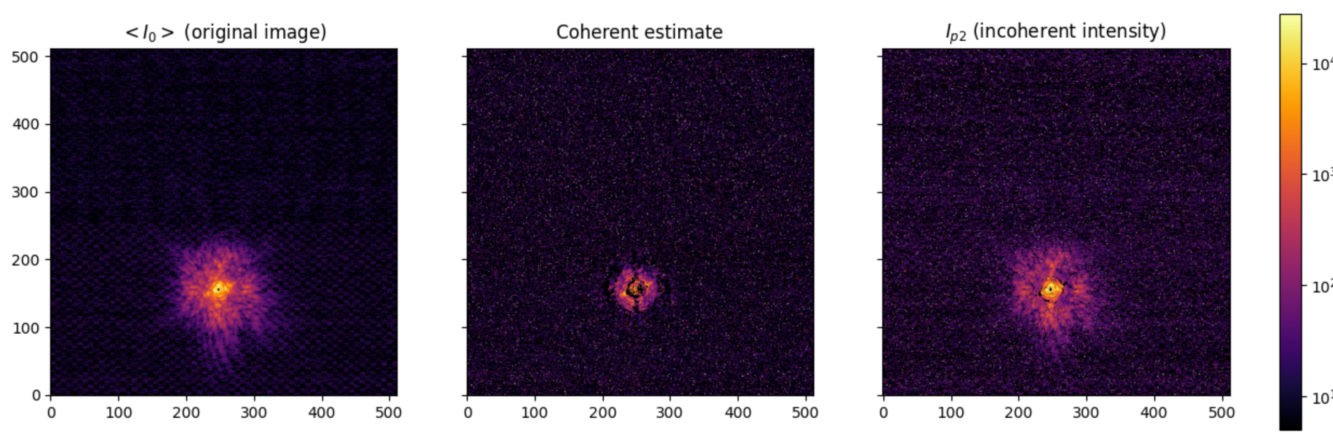
CDI-SAN Results

The main goal is to use the CDI-SAN algorithm on some data to generate a preliminary subtracted image and to see how well it subtracts the speckles. Our dataset consists of 8 iterations, each having the original image plus the 4 probe images modulated by DM electric field. The first step is to use the equation in Nishikawa et al. to calculate the incoherent intensity.

$$I_{p2} = \langle I_0 \rangle - \frac{\langle (I_1^+ - I_1^-)^2 \rangle - V_1^+ - V_1^-}{8(\langle I_1^+ \rangle + \langle I_1^- \rangle - 2\langle I_0 \rangle)} - \frac{\langle (I_2^+ - I_2^-)^2 \rangle - V_2^+ - V_2^-}{8(\langle I_2^+ \rangle + \langle I_2^- \rangle - 2\langle I_0 \rangle)}, \tag{9}$$

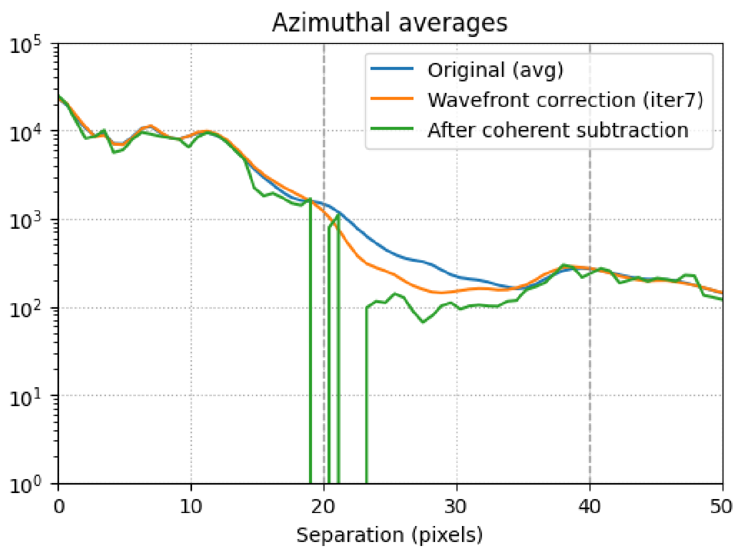
Here I means the images and V are noise variances. We don't have half exposures so are ignoring any noise for now, such as photon or readout noise. The resulting images are shown below.



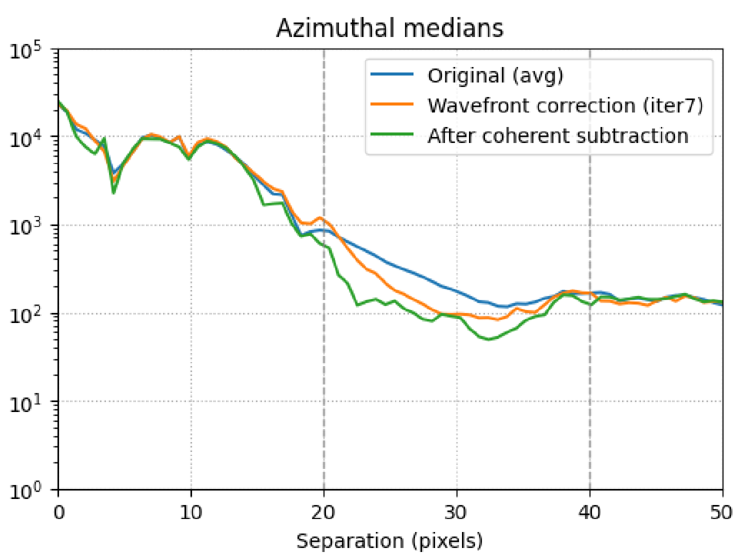
The result looks good. Although we only applied modulation to the right half of the image (the dark hole), we can see that the algorithm was able to estimate the whole image quite well. However, at the edge of the probe region we can see a ring of over-subtraction (negative region), likely due to field variation or large modulation.

Next, we proceed to analyze the contrast. We calculate the azimuthal averages, or average intensity as a function of radial distance from the PSF center. The PSF center is calculated from the reference PSF image by finding the point with largest intensity. We then use the prysm library to convert the image to polar coordinates. With these coordinates, we can apply an angular mask for the probe region $(-\pi/2.1, \pi/2.1)$, and calculate the mean using only values in that region.

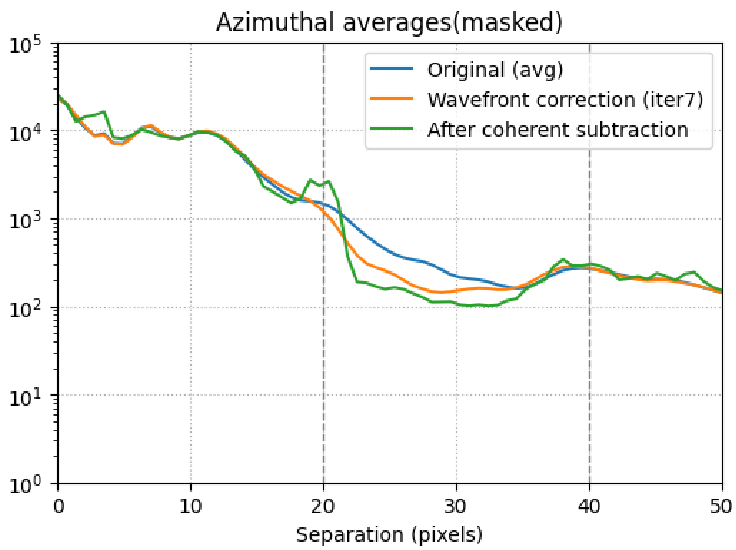
Here is the azimuthal averages for the original images, wavefront corrected image (last frame), and the CDI-subtracted image. The vertical dashed lines correspond to the start and end point of the dark hole.



We noticed that in regions where over-subtraction is heavy, the averages are highly negative, making the sharp drops in the plot. Otherwise, this looks promising. To address the over-subtracted region, we make another plot of the azimuthal medians in the exact same angular region:



Now we have a nicer plot. However, using the median still counts the zeros, and when there are a lot of zeroes, we might be overly optimistic. So, we applied a mask that drops any negative values, and use only the remaining values to calculate the average:



These results show that overall, the CDI-SAN algorithm achieves a stronger suppression of speckles than wavefront correction alone, mainly in the probed region, even without considering any noise. However, without considering the noise properly, we risk over-subtraction.