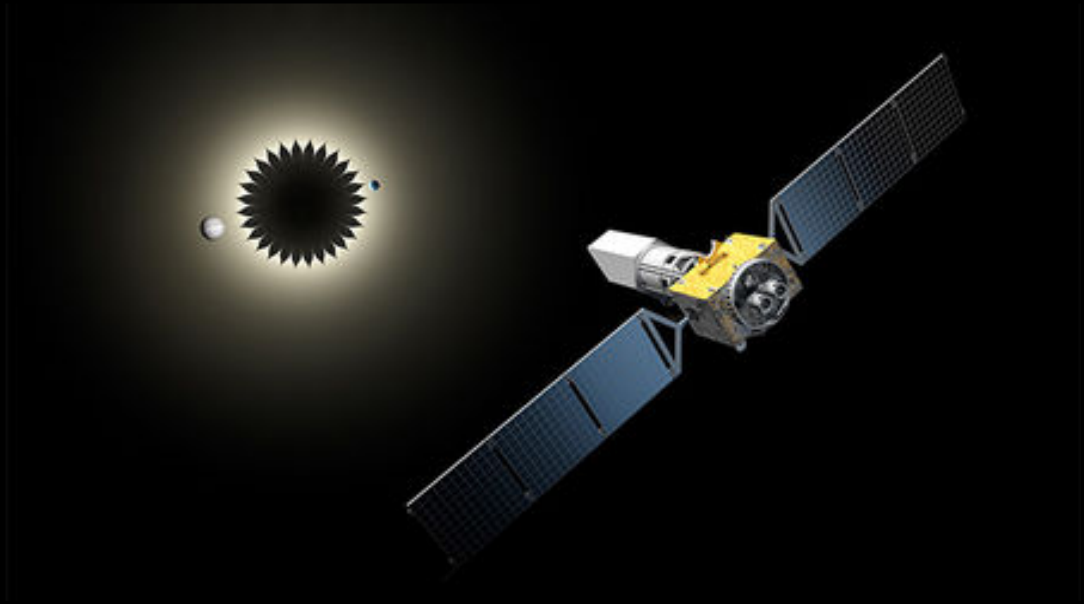
Photometry with Starshade



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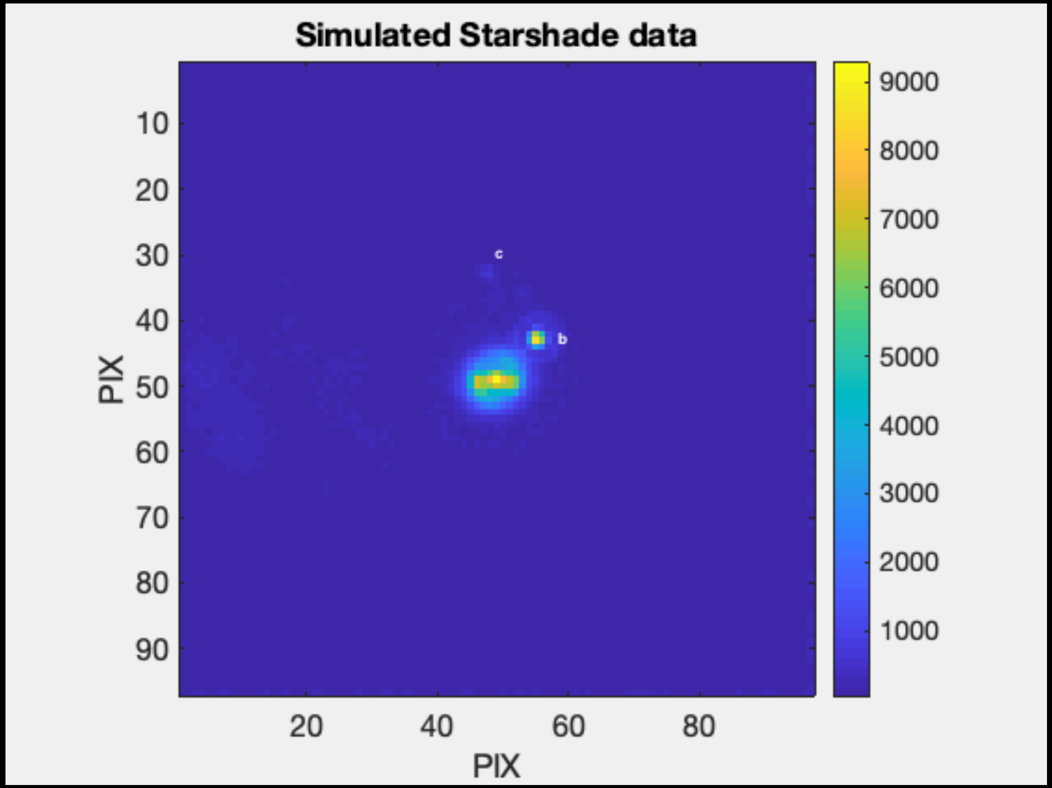
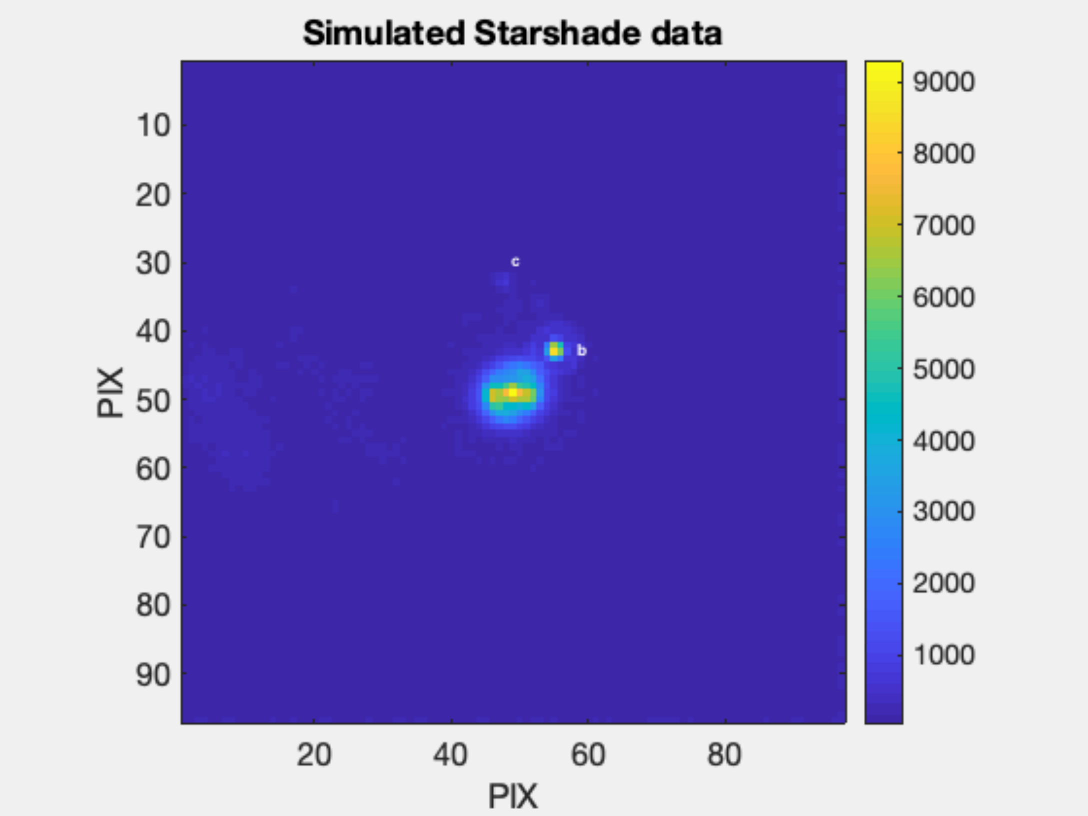
This is a short tutorial on how to deal with aperture photometry and the Starshade simulated data for the WFIRST CGI Exoplanet Data Challenge.

At the end of this presentation you'll find the command lines in Matlab used to produce these images and results. It should be easy to translate them into any other language of your choice.

Let's begin with some simulated data similar to the CGI Notebook. The astronomical scenario is the *same*, including integration time (105,600 sec) and detector noise. The optical system is not the HLC coronagraph of WFIRST but the Starshade Rendezvous mission concept.



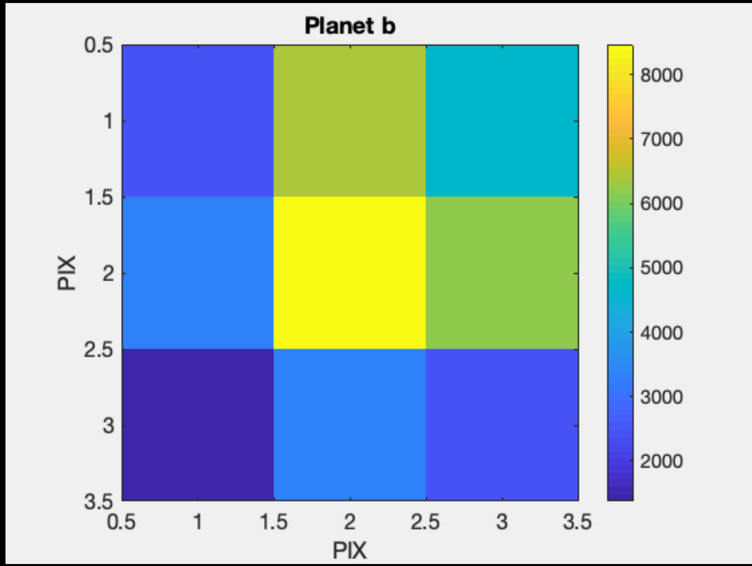


The vertical orientation compared to the image shown in the CGI tutorial is swapped simply because this is the default in Matlab's 2D array plotting function, instead of the one in Python.

You can clearly see planets 'b', 'c' and in between there's planet 'd' albeit much fainter and close to the noise level.

The center of the image is dominated by starlight, solar glint and exozodiacal emission that is 5 times as bright as the solar system case.

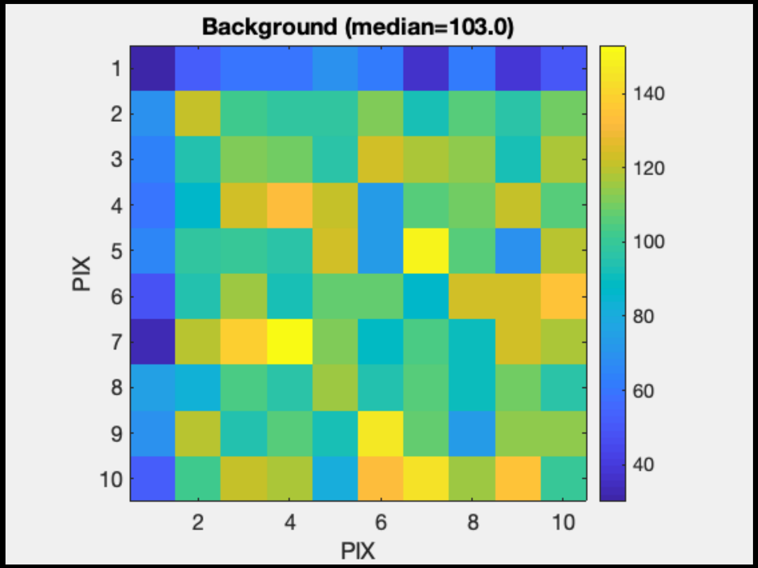
Let’s take a square area of 3x3 pixels around the maximum of planet ‘b’



The planet counts in a box of 3x3 pixels with background is 38670.

The PSF gets attenuated if the planet is close to the star, but for the simulated data in this challenge, one does not need to worry about it (the factor is smaller than a percent).

Let’s estimate the background on this simulation. We choose a portion of the data that is not affected by other planets, starlight, etc.



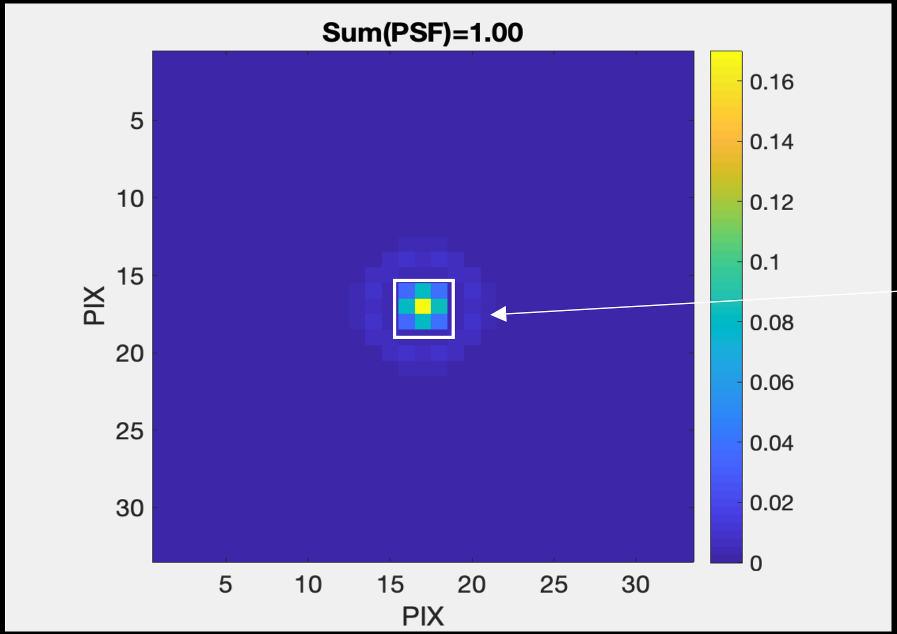
The median value of the counts is 103 per pixel and there are 9 pixels in the planet’s area. Thus:
The planet counts in a box of 3x3 pixels without background is **37743**.

PS: notice that errors in the estimated background will amount to very small errors on the estimated photometry of the planet because the background level is about 2.5% of the total counts and relative errors of 10%, imply corrections of order 0.2%.

Let's estimate the counts associated with the star, without being blocked by the Starshade.

From the [Reference Sheet for the Starshade]() (sheet #3), the total star counts are 1.9238×10^8 photons/sec, the total integration time* is 105,600 sec and the instrumental factor to convert photons to counts at the detector is 0.75.

On the other hand, in an similar box of 3x3 pixels centered at the maximum of the PSF, we find a fraction of 0.6453 of the total energy.



3x3 box

Therefore, the star counts would be 9.832×10^{12} (= $1.9238 \times 10^8 * 105600 * 0.75 * 0.6453$)

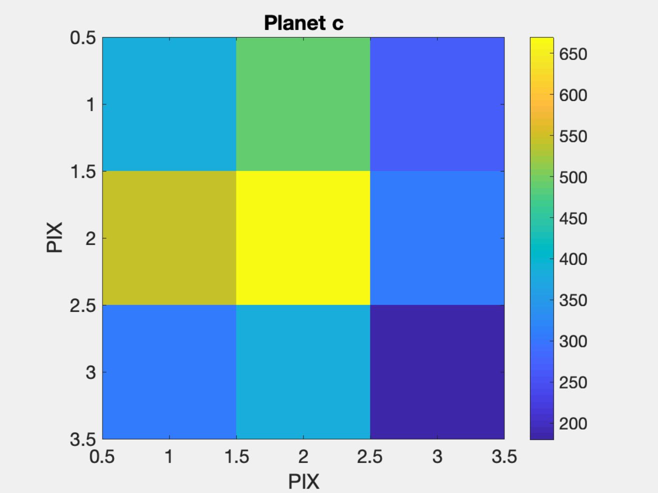
* ***Notice that the official data have instead 1.5 days=129,600 sec***

Finally, the flux ratio of planet ‘b’ is:

$37743 / 9.832 \times 10^{12}$ = $\mathbf{3.84 \times 10^{-9}}$

The input flux ratio in the simulation for planet ’b’ was 4.17e-9.

The relative error of our estimated flux ratio is **-7.9 %**.
The relative error in the CGI simulation was **6.5 %**.



We can perform a similar analysis for planet ‘c’ in the SS data. Following the same steps as before, we find that planet ‘c’ flux ratio is $\mathbf{2.64 \times 10^{-10}}$, whereas the input value is 2.77×10^{-10}. The relative error in this case is **-4.6 %**.

Obviously, the estimation will be less precise if the planet is more affected by the background (exozodiacal light, higher local zodiacal light, etc).

Download code and data in the same folder and open a Matlab session. Copy and paste line by line to get previous figures and results.

Best wishes for the Challenge data*!

** Notice that the official data have a total integration time of 1.5 days=129,600 sec*

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