Imaging Brave New Worlds

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INTRODUCTION

With the launch of the James Webb Space Telescope (JWST) in 2021, resolving the companion objects of host stars has entered the frontier of photometry. Methods for this data reduction have become pivotal for imaging potential exoplanets, white dwarfs, or other small and dim objects. This research aims to streamline point source function (PSF) subtraction methods using JWST data to create a simple program in Python for the telescope's NIRCam coronographic data, the aim of which is to image these elusive satellites. The processed final images will be used in the construction of a model built at the Jet Propulsion Laboratory (JPL) to synthesize reference PSFs used in future observations.

OBJECTIVES

1. Reduce errors in data reduction through modifying PSF subtraction post-JWST processing pipeline
2. Reduce errors in observational astronomy by providing data for synthesizing reference PSFs

METHODS

9 reference PSF images of the star HD-115640 and 2 science PSF images of the star HD-14174 and its white dwarf companion were obtained from the Mikulski Archive for Space Telescopes (MAST) for JPL NIRCam proposal 1441 Coronagraphic Suppression Verification.

The 2 science images were co-added into data cubes from the original 64 frames, and the 9 reference images were co-added into data cubes from the original 7 frames using their median pixel counts.

Two methods were used for reducing this error: the reference PSFs were first averaged through a median function before subtraction and were subtracted individually. Each method resulted in a similar product. Continuing with the averaged reference PSF, we now determine the luminosity and stellar shifting scale factors to apply to the reference PSF. Two methods were employed: calculating the scale factors for each science image by dividing the median reference pixel value by the median target pixel value and calculating the root mean square of localized annuli shells around the stellar region to construct a subtractable mask for the reference images that, when subtracted from the science images, eliminates the residual starlight, revealing the white dwarf in orbit. These methods are currently being compared with respect to error reduction. Following the determination of these scale factors, the images will be de-rotated from the angle of observation and applied toward the on-going construction of a model to synthesize reference PSF data, removing the need for long observation times and error within the reference images.

Figure 1: Science Image 1

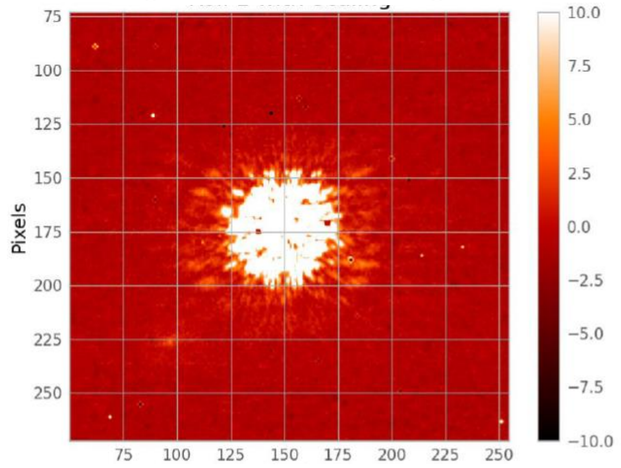
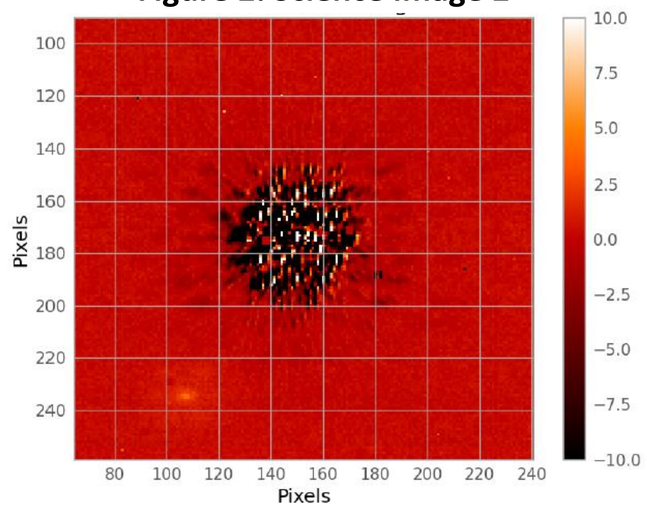


Figure 2: Science Image 2

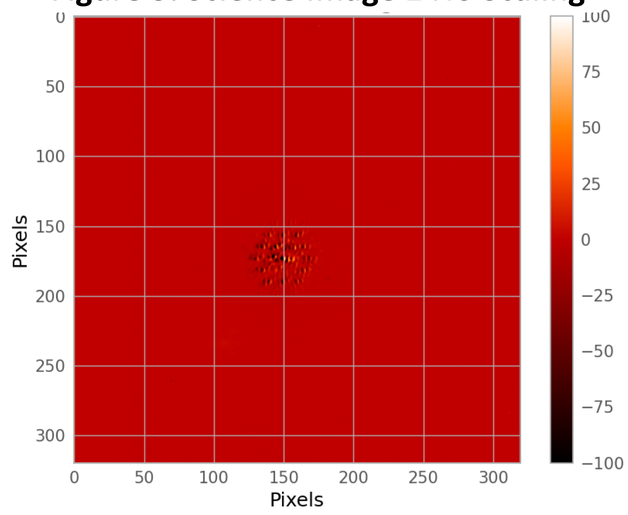


RESULTS

Originally, the JWST post-processing pipeline was unsuccessful in removing a detrimental hot pixel in the second science image. Coadding the reference images before PSF subtraction succeeded in eliminating the outlying data.

The simplified scale factor calculation using reference averages resulted in over-subtraction in science image 1 (Fig. 1) and under-subtraction in science image 2 (Fig. 2). The localized annuli rms method is being employed to reduce luminosity subtraction error in the final coronagraphic image. Science image 2 with no scaling in the subtraction (Fig. 3) shows the location of the coronagraphic mask with the white dwarf in the center.

Figure 3: Science Image 2 No Scaling



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REFERENCES

Girard, J. et. al. 2022, *SPIE: Optical, Infrared, and Millimeter Wave*(Vol. 12180, pp. 1383-1402).

2004, *ACS: Advanced Camera Survey Data Handbook,* Online. *(Version 5.0).*

JWST User Documentation. NIRCam Coronagraphic Imaging. Retrieved October 22, 2022