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Finding Planets Around Massive Stars

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Introduction

During the formation stages of a solar system, huge clouds of gas and dust contract into a disk around the growing star. These disks are the birthplace of planets, and are essential to our understanding of solar system formation. Historically, the search for planets outside of our solar system has typically been constrained to stars that are similar to the sun. However, Herbig Ae/Be (HAe/Be) stars offer promising results. HAe/Be stars are 2-10 times larger than the sun and retain their formation disks. These disks around these stars are brighter and larger than those around solar type stars, so they are excellent candidates for observing planets. Observing planets around HAe/Be stars would allow us to place constraints on formation timescales and planetary masses, which are invaluable to our understanding of the solar system.

Methodology

One of the major problems associated with directly imaging exoplanets is choosing objects to observe. Simply pointing a telescope at a random object hoping to detect a planet is highly inefficient and costly. However, many observations of HAe/Be stars are already stored in archives at the Hubble Space Telescope (HST). Archival data can used as a screening tool for flagging objects that warrant closer investigation and follow up observations.

The direct imaging of planets within their formation disks is easier said than done. Additionally, the dust grains within the disk glow brightly in similar wavelengths to the planets, so it can be difficult to detect the planets amidst the noise of the disk. Only telescopes with high-resolution are capable of detecting these planets due to their small size. Additionally, at visible wavelengths a star can be a billion times brighter than the planet around the star, and a million times brighter in the near-infrared. To mitigate the brightness problem, a special telescope attachment called a coronagraph is used. A coronagraphs, or coronagraphic mask, is placed in front of the star to block its light and allow the disk to be seen. However, using a coronagraph introduces another problem. As light enters a telescope, the optics of the telescope will force it to naturally bend and diffract, creating a shape called a Point Spread Function (PSF). Adding a coronagraphic mask causes a significant amount of diffraction to occur, and creates noise in the light that we receive from the star. This noise must be accounted for as we look for planets in the disk.

To remove the noise generated by the coronagraph, we create model PSFs that represent the diffraction due to the optics. These models can then be removed from the images of the disk using a program called PynPoint1. PynPoint uses a statistical process known as Principle Component Analysis (PCA) to remove the PSF. PCA is a machine learning technique that marks significant features of the model PSF and maps them to the real PSF of the image. These features are then removed from the real images, and the residual output will show if there are any planets within the disk.

Results
The majority of this research focused on HAe/Be star HD100546. This star is the only HAe/Be star with a confirmed planet (HD100546b) (Quanz et al., 2015), and one theorized planet that has yet to be detected (Currie et al., 2014). HD100546 was chosen as the main test subject for this method to determine if planets are detectable within the HST archival data. During the original stages of this project, Emily Safsten, a former masters student at BYU, created a model with the HST data that we believed contained both the confirmed planet and the theorized planet hosted by HD100546 (Safsten 2017). Unfortunately, we were unable to recreate her results and believe that it was a false positive.

Discussion

There are many reasons to doubt the subtraction produced by Safsten 2017. First, the HST images were taken in optical wavelengths of light while planets are typically easiest to find in the infrared. Second, the data seen in the residual images is very noisy and it is difficult to determine which features are planets or simply noise. Third, the algorithm used to perform the PSF subtraction is highly aggressive and could easily have generated a false positive within the residual images. Fourth, the angular resolution of the coronagraph must be considered. The second, unconfirmed planet resides close to the host star and it is very possible that they are too close to differentiate within the archival data.

Conclusion

Exoplanets around HAe/Be stars are undetectable in HST Archival Data with current processing techniques.

References


1 https://pynpoint.readthedocs.io/en/latest/