For this project, we utilized the Transit Method in locating and confirming an exoplanet. This was done through the telescope (Seyfert-Sanders Telescope (TSS)), a telescope designed to search for exoplanets, which provided us with reports of potential planet candidates. Using these reports, we predicted the transits of the best candidates and employed the use of the Leuschner telescope to officially verify the predicted transit of the most promising candidate. Through this process, we were able to confirm the existence of our monitored exoplanet.

To successfully understand our project, it is important to understand the terminology. To begin, an exoplanet is a planet that orbits around a star other than our sun. Since exoplanets are so far away from us, are small compared to their star, and don’t emit their own light as stars do, so direct imaging is impractical in most cases. To work around this limitation, there are two main methods of planet detection: the Radial Velocity Method and the Transit Method. We used the Transit Method, which is when one measures the amount of light from a star that reaches us as an object’s transits, or moves, in front of it compared to multiple close-by reference stars. In regards the dip in light as a result of the transit, we have to make sure that the dimming is due to an actual transit, as it could otherwise be the result of some other object, noise, or instrumental issue. A box around a large dip could indicate a binary star or gas cloud, and one that isn’t periodic would not be a planet.

Methodology - Observation and Analysis

After choosing our exoplanet candidate and getting telescope time for our proposed planet, the next step was to officially observe the transit. We made sure we were clear on our transit parameters beforehand, such as the transit depth, duration, and timing, allowing us to set up accordingly to them before the transit.

To set up the telescope we first found our planet at an RA of 20:09:04 and Dec of 33.882°. Then we applied the V-band filter and focused Leuschner to roughly 25,800 micrometers. This setup gave us a clear view of our star, as well as reference stars. We used these reference stars to compare our light curve against after viewing, as well as track movement throughout the viewing to ensure our star remained in frame.

To actually capture our data we used the camera on Leuschner to continuously take fifteen second exposures for the duration of our transit. From these exposures we were able to obtain numerical data on the flux of our target throughout the source of our transit. It is worth noting that we were not able to observe the entirety of the transit due to the humidity percentage reaching a dangerous level. Therefore, our data and photos do not show the entirety of the end of the transit.

To analyze the images and obtain the flux information we utilized AstroImageJ, a software designed specifically to process telescope images. We opened each image in AstroImageJ and calibrated it using the calibration frames, which included dark and flat frames. We then selected the region of interest (ROI) in the image that contained the exoplanet and its host star. Using the aperture photometry tool, we measured the flux of the star and the exoplanet in the ROI while also picking two reference stars to get relative flux. The relative flux was important because we needed to be sure that the transit dip due to our planet was not some outside error such as dust or our target being a variable star. If our target showed a dip in flux due to a transit compared to the reference stars, that would tell us that our planet did exist, as believed.

Analyzing our data began with using the light curve tool in AstroImageJ to plot relative flux over time. We then used Python to convert the flux measurements into normalized light curves. This was performed through the use of numpy, matplotlib, and a scikit package that bins flux measurements to clean up the noise in our data. We compared the flux from our target to two separate reference stars, then compared to both reference stars at once to remove artifacts and uncover a transit-like curve. From these graphs, we were able to use the transit parameters obtained from the model to determine the physical properties of the exoplanet, such as the radius of the planet and the distance from its host star.

Examining the transit depth we found that the data captured from the Leuschner telescope relatively matches with the TESS data provided. The planet radius was found to be ~20.1R

The left radius was the inner radius of the habitable zone and the right was the outer radius. The planet’s semi-major axis was found to be ~0.1 AU, meaning it was about ten times closer to its host star than Earth. With our habitable zone extending from 1.6-2.3 AU, we confidently determined our planet was not in the habitable zone.

Conclusion

Due to the poor weather conditions in the spring semester, we were only able to monitor a single transit for Pluvia. In this transit, we were forced to stop early in the transit due to the humidity, making the weather our greatest enemy during this project. In the future, we would hope to observe at least three full transits to lower our errors and officially confirm the exoplanet by TESS’s exoplanet follow-up standards to classify it as an exoplanet.

In addition to more observation opportunities, in the future we hope for more time to analyze our light curve data. Due to the quick turnaround time between our observation and the end of UCLA, we unfortunately were only able to compare our target star to two reference stars, rather than our preferred three.

References

1. “TESS Project Pipeline.” Data, MIT, tev.mit.edu

Acknowledgements

We would like to send a heartfelt thank you to Professor Gaspard Duchene for generously donating his time and expertise to our project. He not only taught all of us how to use the Leuschner telescope, he also helped set up countless viewing appointments and served as a wealth of knowledge during our eventual transit observation. In addition, we would like to thank the UCLA staff—Detective Mike Haura and Assistant Lab Manager Marissa Mehn, and Faculty Advisor Dan Kasen—for providing us with this pivotal research opportunity. We additionally thank the Berkeley Discovery Grant with Eugene as the PI. We could not have done this without all of you!