Astrophotometry of Eclipsing Binaries and Exoplanets

At the Saint Mary's College Geissberger Observatory

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In Abstract Terms

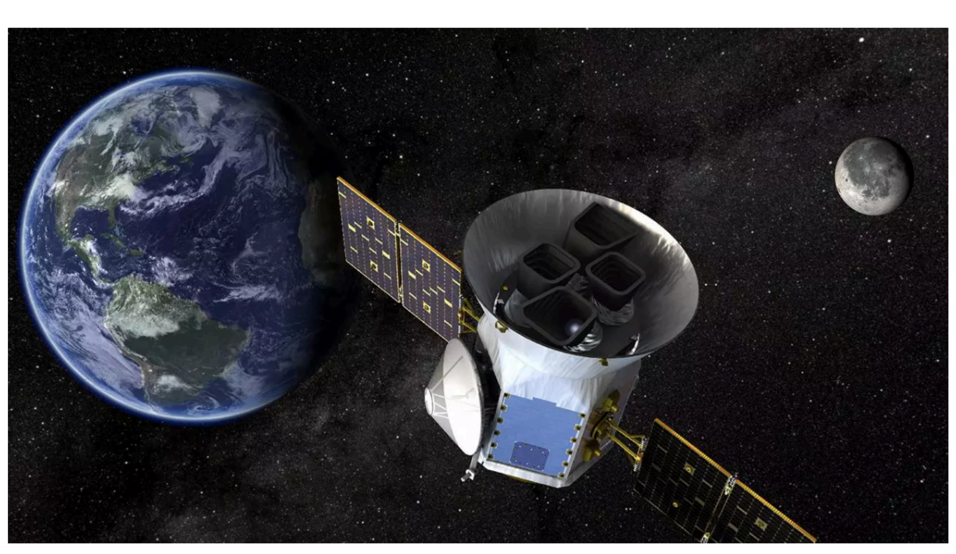
We used a 16" Meade Schmidt-Cassegrain reflector and 115mm Stellarvue refractor telescope to image exoplanet transits and eclipsing binaries. The images were calibrated and analyzed using AstroImageJ. The purpose of this project was to improve the precision and accuracy of the data taken with each of these telescopes. At the end of the summer, an application was sent to the TESS (the Transiting Exoplanet Survey Satellite) group at NASA to join their team. We were accepted in early August.

Here are Professor Hill and I in the Geissberger Observatory, preparing for a night of observing. (Photo Credit: Gerald Serrano)

Allow me to Introduce

On April 18th, 2018, NASA's Transiting Exoplanet Survey Satellite (TESS) was launched from Cape Canaveral. The objective of TESS is to scan the universe for exoplanets. These are stars with planets orbiting around them. TESS will identify these systems by taking images of stars and searching for drops in their light output, an indication that a planet has crossed the star. However, because of the large field of view of the TESS cameras (the area of the sky the camera takes an image of) there could be up to 10 stars covered by each pixel of the camera. This means that the images from the satellite will indicate the approximate area where a transit has occurred, but not the exact star around which a planet orbits.

Therefore, NASA is inviting other ground-based observatories to act as follow-up teams, to image the exoplanet candidates and determine which star, if any, in a particular field has an exoplanet eclipsing it.

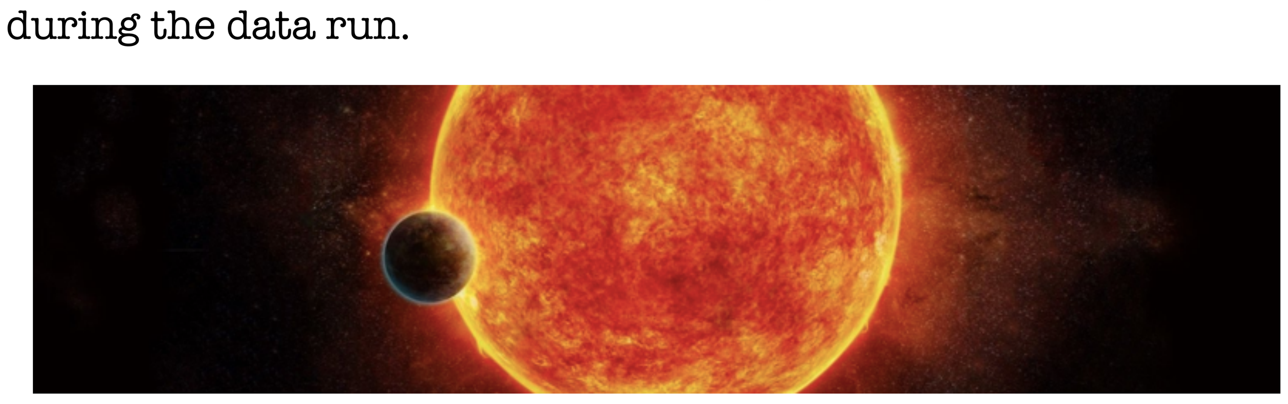


An Artist's Rendition of the TESS Satellite. (Credit:NASA Goddard Space Flight Center)

What we did, Methodically

The first targets imaged were eclipsing binary stars, as they are much easier targets than an exoplanet. A 115mm Stellarvue on a Losmandy GM8 mount was used. Eclipsing binaries are two stars usually of similar brightness that are circling each other. If both stars are relatively bright, then there can be up to a 50% change in light as the stars circle each other. When the stars are next to each other, they would be brightest, because they would appear as one large, bright star to the camera. When the stars eclipse each other, they appear as one slightly dimmer star.

The method of recording this change in light involves taking pictures of the star every few seconds for a long period of time. Then the images are calibrated, corrected for error, and the brightness of each star in the frame is analyzed. A graph of this data will show the eclipsing binary "star" getting dimmer and brighter during the data run.



An Artist's rendition of an Exoplanet orbiting a star. (Credit: M.Weiss Harvard Center For Astrophysics)

A process called differential photometry is used to measure the brightness of the eclipsing binary as it dims. Instead of measuring the absolute magnitude of the star, the relative brightness of the star is measured, or how much the dimming star is changing in comparison to the unchanging stars near it.

The same method was used to analyze the brightness of stars with exoplanets around them. Stars with exoplanets dim by about 3% at the most, but typically 1% or less than 1%. This is because the mass of an exoplanet is much smaller compared to a star, so the planet only covers a small fraction of its host star. The light that hits the planet does not reach the telescope, so the star seems to dim fractionally. The 16" Schmidt-Cassegrain was used to image exoplanets, as it has a much smaller field of view and can collect more light due to its size.

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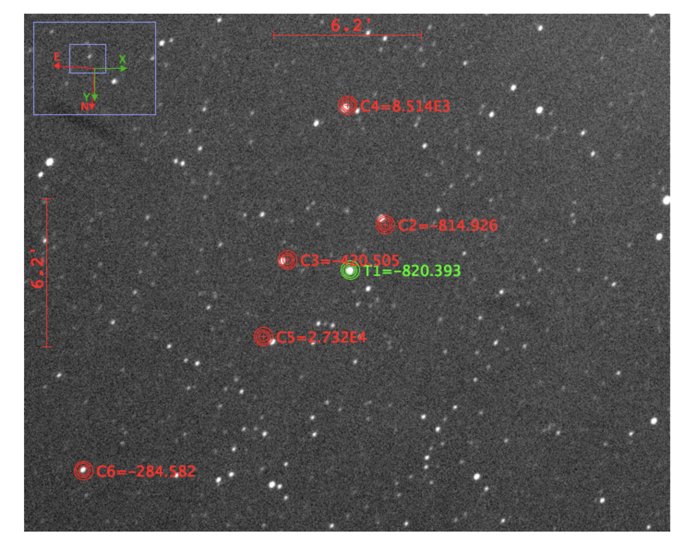
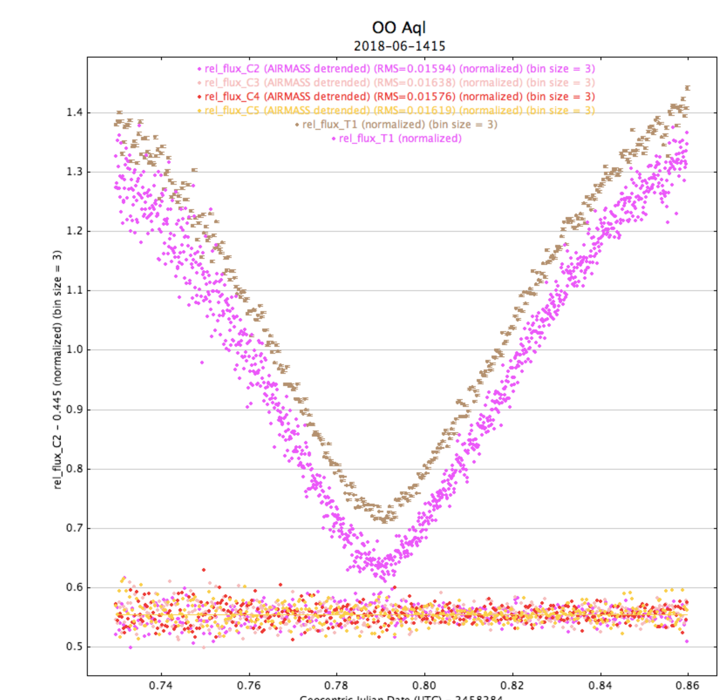
This is a binary star system in the constellation Aquila. It is a magnitude 7 star. 1147 pictures were taken at 6-second exposures across 3 hours. Below is an example of one of those pictures. The data was analyzed in AstroImageJ and the following graph was produced:

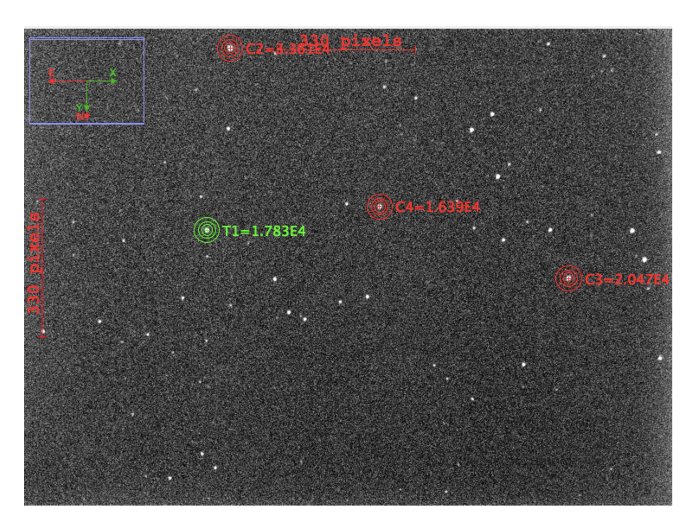


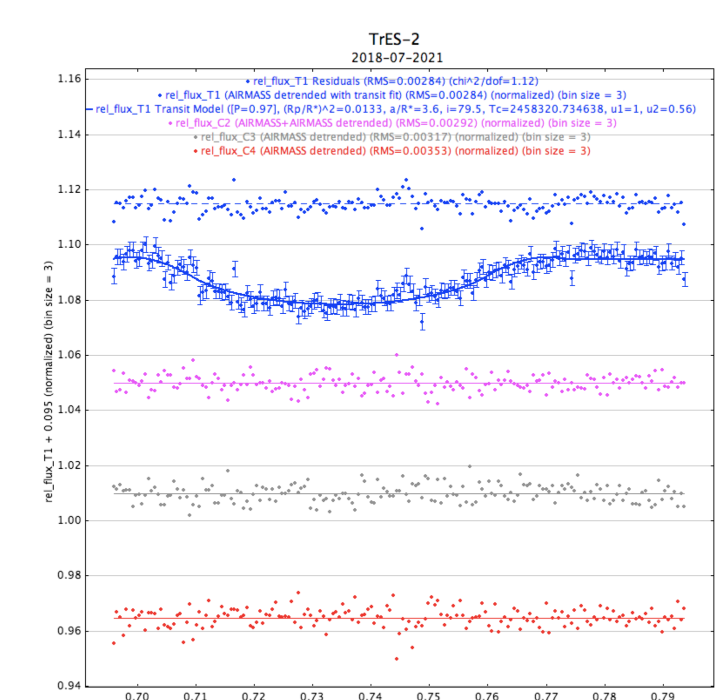


This graph shows how the binary star system changes in brightness relative to the non-changing stars in the field.

TrES-2

This is an exoplanet system in the constellation Cygnus. 541 pictures were taken over about 2 hours using a 15-second exposure. The star experiences a 1.6% drop in light. The following graph shows the drop in flux:





To Conclude,

As expected, the change in transit depth is very small but statistically significant and it is apparent that the transit of TrES-2 was fully captured. The data for the second graph was taken on the 16" reflector telescope in the Geissberger observatory, which allowed us to image the fainter star and clearly determine that a transit occurred. The data for this transit was submitted to the TESS Follow-Up Observing Program along with a detailed account of the equipment at Saint Mary's and we were approved to contribute to Sub Group 1. Moving forward we will be imaging possible exoplanets that TESS has found and looking for both confirmations and false positives.

Thank you!

I would like to thank the Summer Research Program for supporting this project and Dr. Brian Hill for his mentorship. This summer would not have been a success without the extensive and ongoing support of the Saint Mary's community.