Application of the Transit Method of Exoplanet Detection

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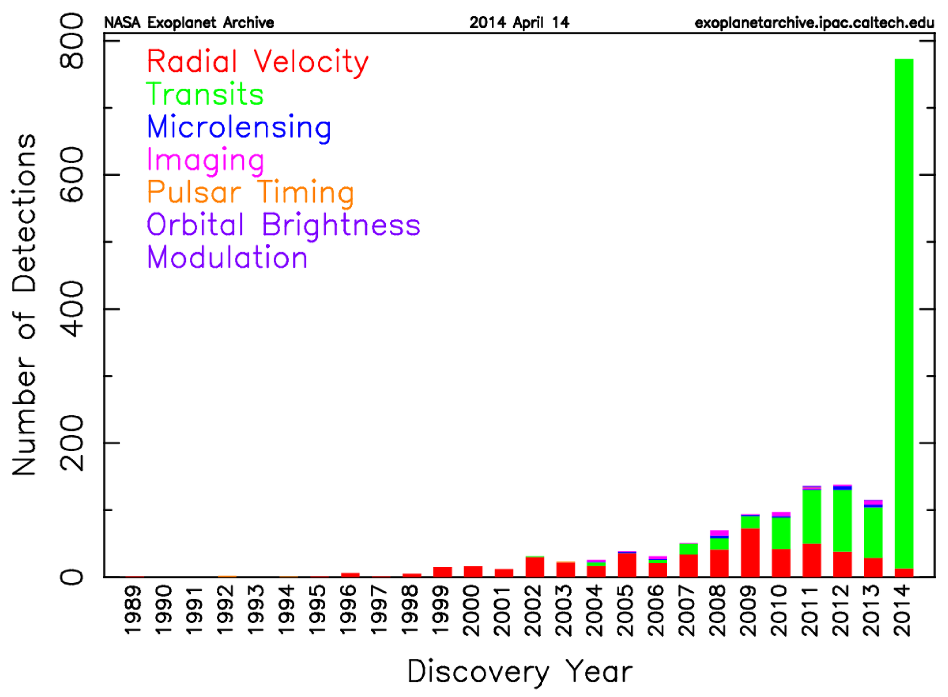
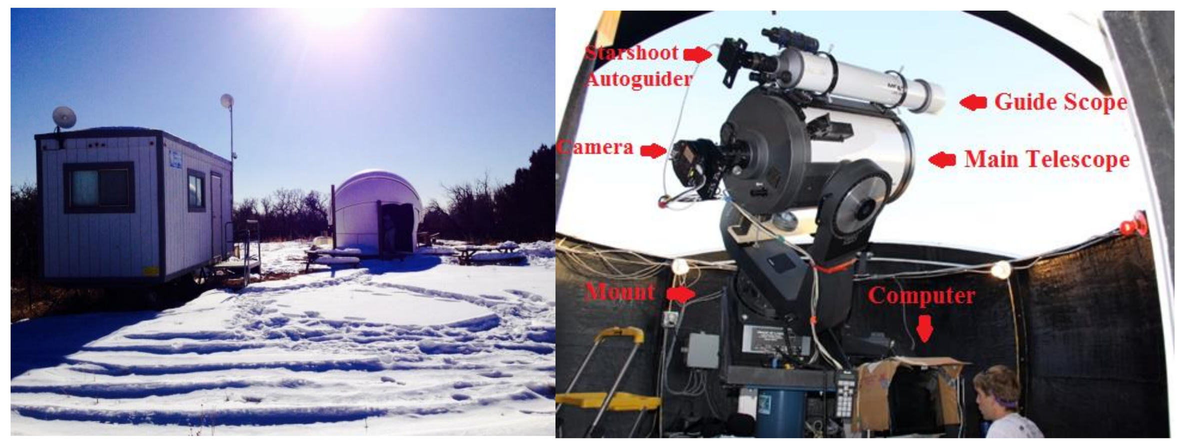
Abstract

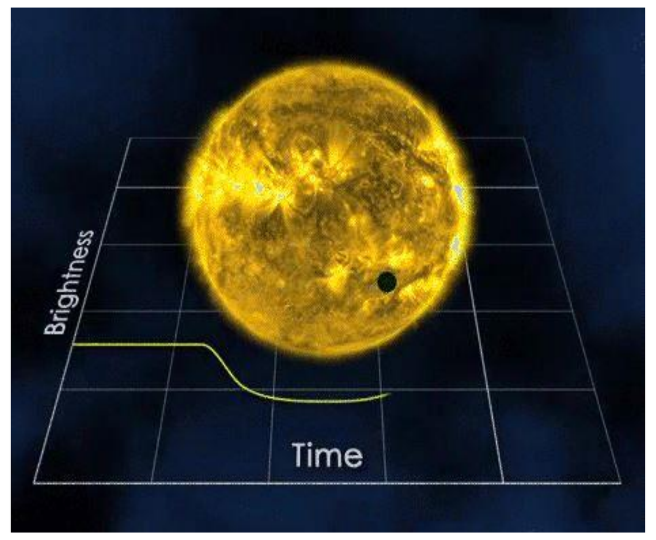
Data were collected on the star WASP-43 in order to verify the presence of an expected orbiting planet, WASP-43 b, using the Photometric Transit Method. SuperWASP data was used to predict the transit time of the exoplanet, which was observed several times throughout the course of 5 months [1]. Due to time and equipment constraints, only verification of the differential change in magnitude was possible. To accomplish this project, the coordinates for a star in the SuperWASP field of view that was predicted to dim in brightness at a time and date between November 2013 and March 2014 was acquired. The star was observed at the time and date predicted by the SuperWASP data using the telescope at the Fort Lewis College Observatory. For several nights, the transit was recorded with a series of images that were taken with a CCD camera through the telescope as the planet traversed the star. Each night, the images were processed and the brightness of WASP-43 was compared to six other stars. These comparisons were plotted separately and then averaged together to create a plot of the average change in brightness for WASP-43, as shown in the light curves to the right.



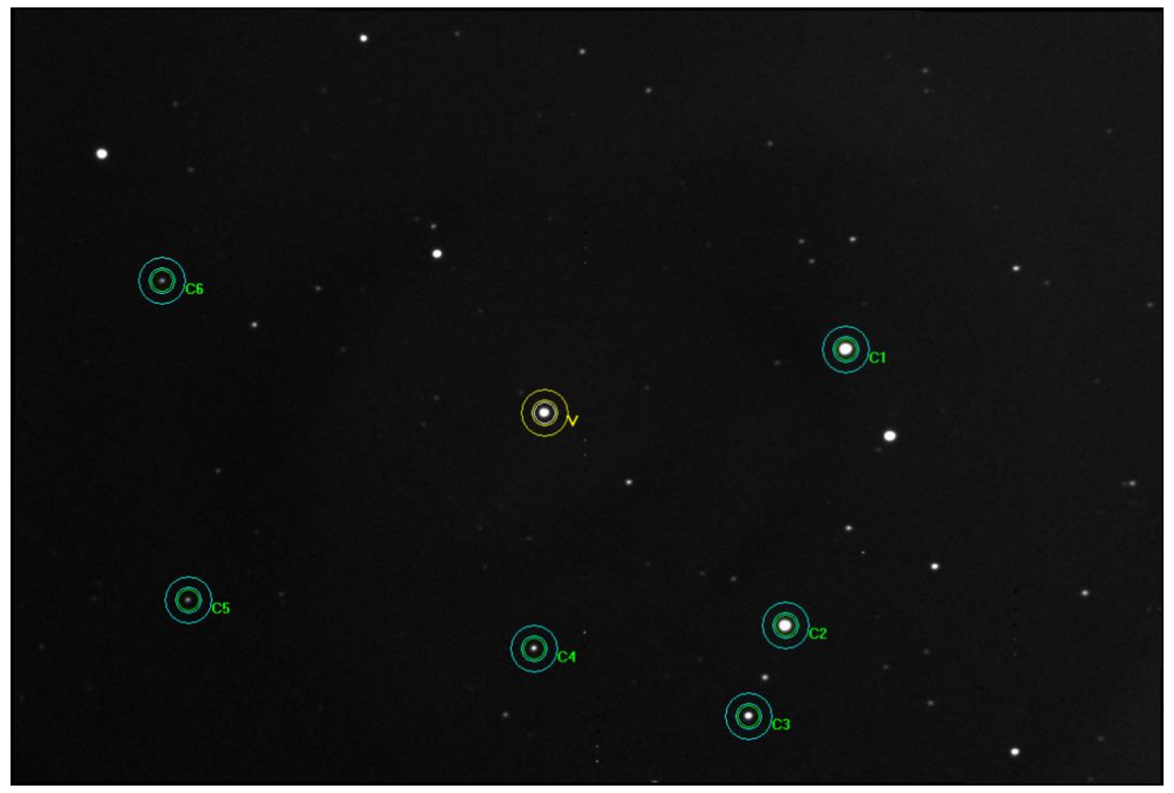
The above image shows the number of exoplanets discovered by year and detection method. The two most common methods are the Radial Velocity Method and the Transit Method. The Radial Velocity Method was first used in 1989 and dominated the field until around 2009 when the Kepler Space Telescope was launched and activated by NASA. Image courtesy of the NASA Exoplanet Archive [3].



The Fort Lewis College observatory (left), and the 16" telescope with its CCD camera, mount, and guide scope with camera (right). This experiment will help determine if the equipment at the Fort Lewis College Observatory is sensitive and precise enough to reliably detect the change in brightness of a star due to a transiting known exoplanet.



The Transit Method measures the changes in the luminosity of a star, which will dim in brightness when a planet transits between it and the observer. The light emitted by the star will dim in a steady, repeatable pattern. In the image to the left [4], the black dot is the planet and change in brightness is shown as a curve below.

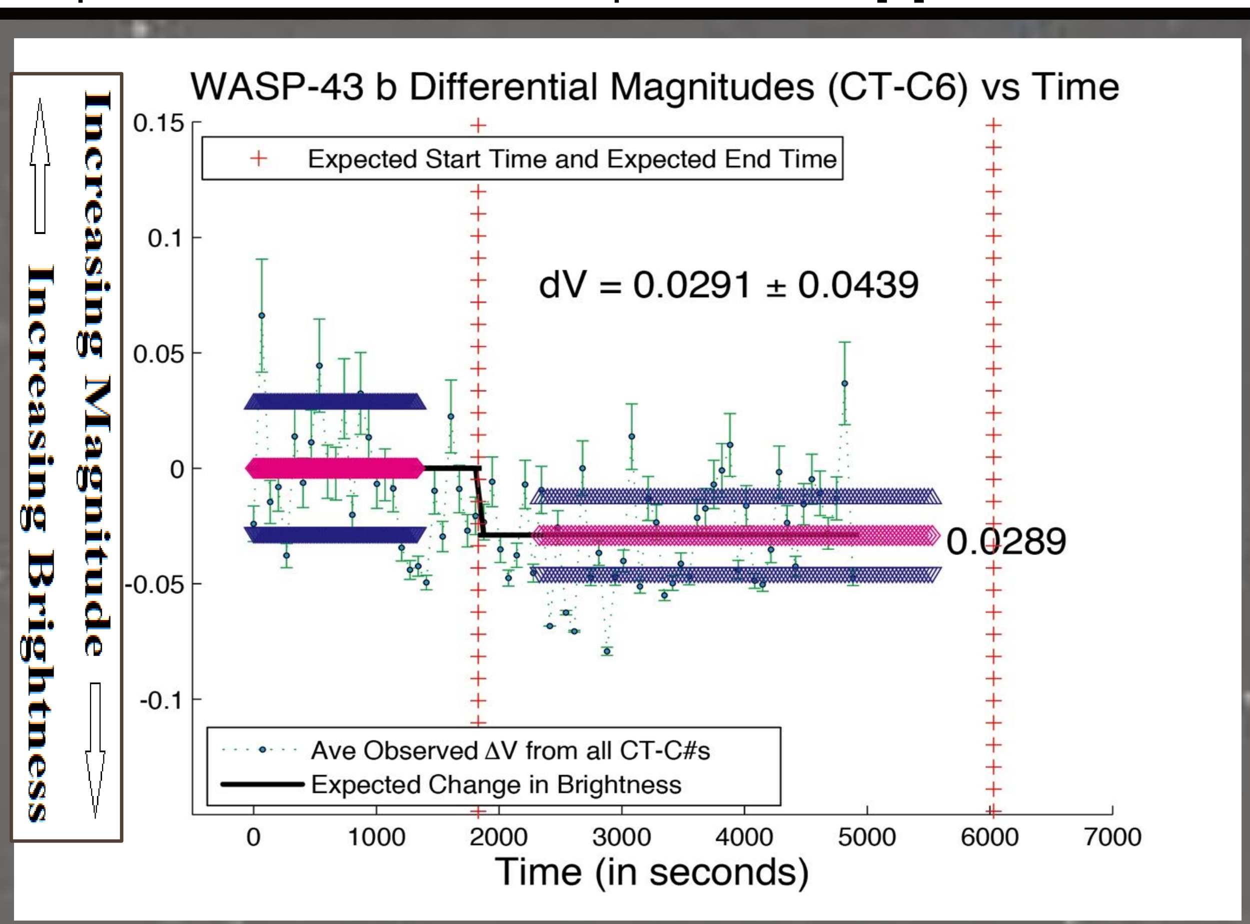


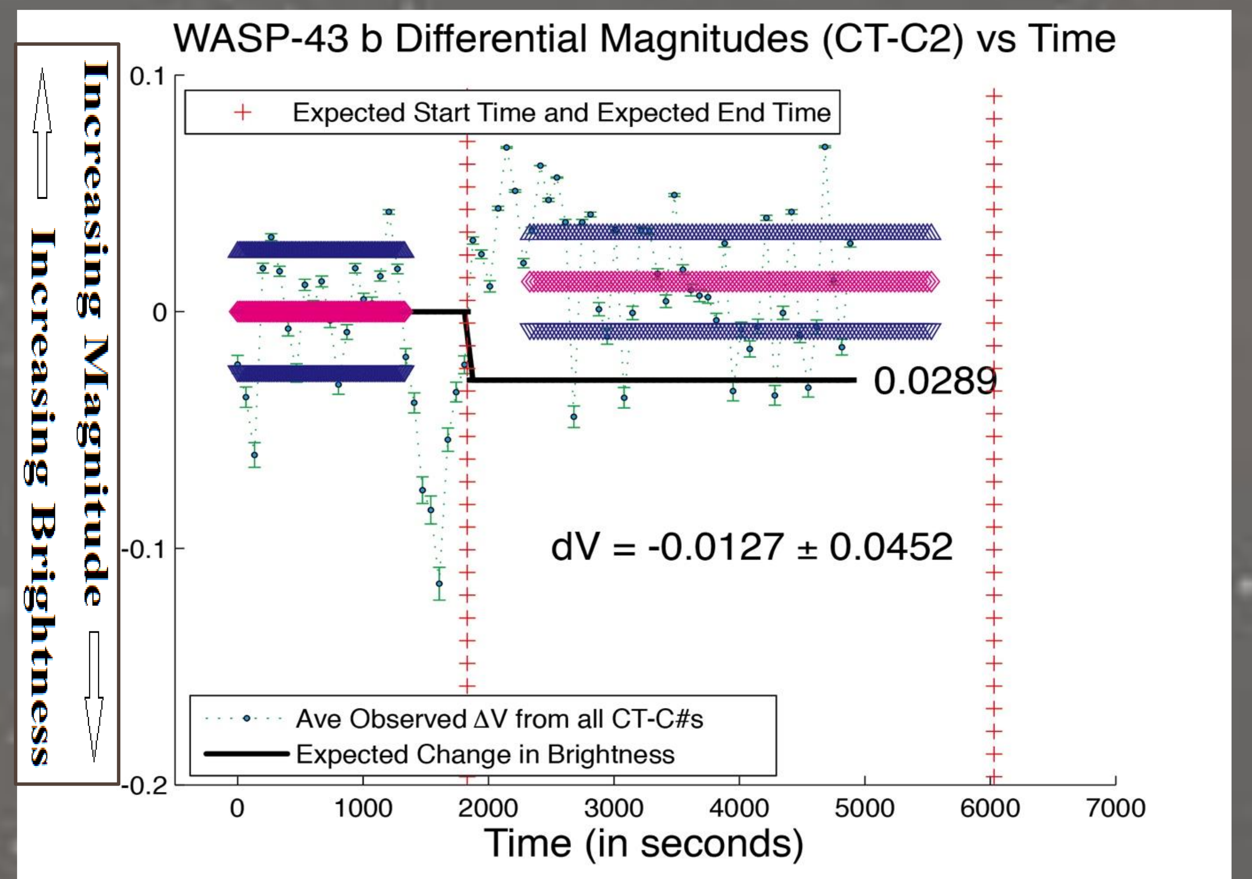
The image above shows WASP-43 in yellow and six comparison stars in green. The rings around them are used in the process of calculating magnitudes. Calculating the magnitude of a star is done by comparing how much light is detected from a target star with how much light is detected from one or more stars around it. The amount of light detected from a star is categorized into "counts," which are the number of photons that strike the pixels of the camera's sensor to make up the image of the star [2]. Software was used to get the counts for the target star, the background sky, and several comparison stars in the same image for each image taken during the transit.

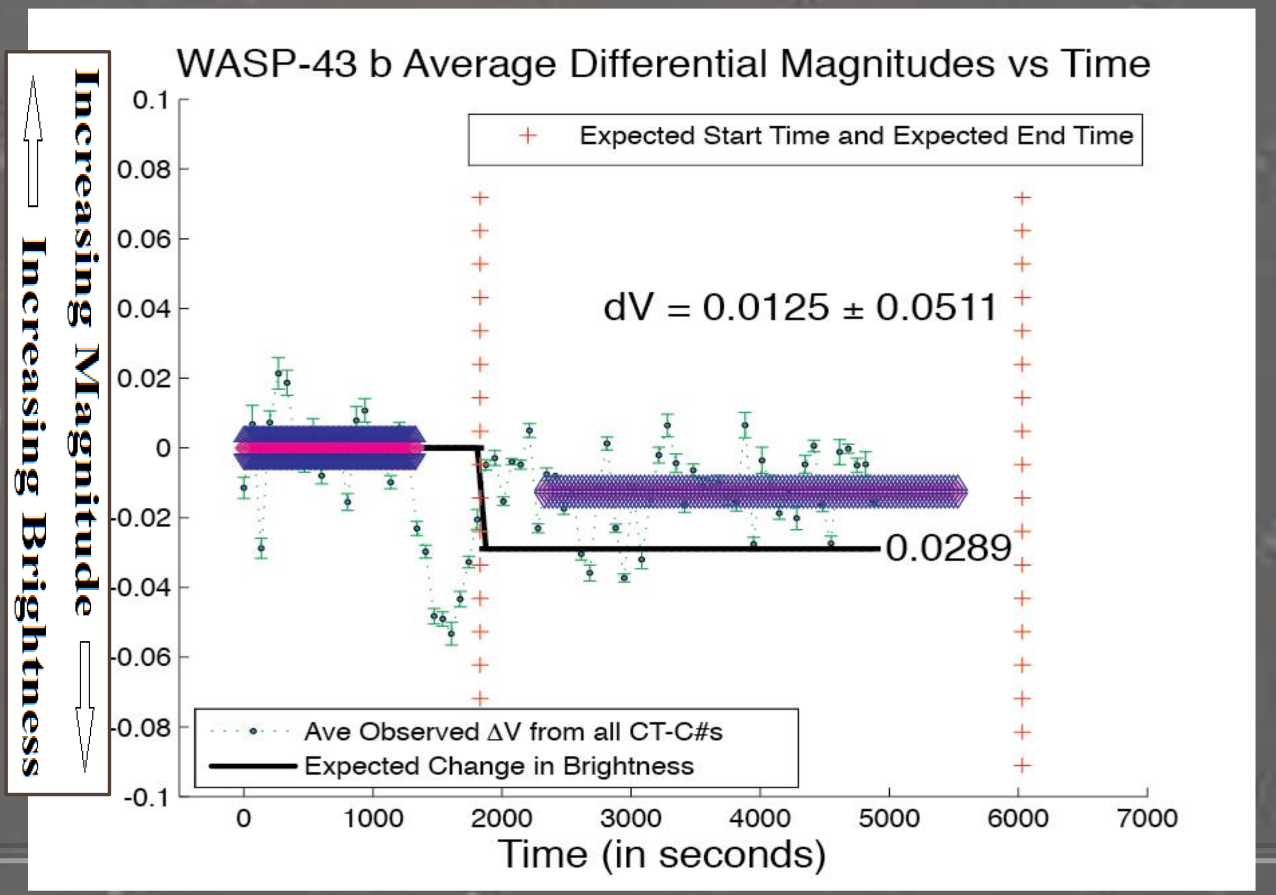
The magnitude of the target star was computed with respect to the comparison star, Δm.

$$\Delta m = m_t - m_c = -2.5 \log\left(\frac{C_t}{C_c}\right)$$

In this equation m_t is the magnitude of the target star, m_c is the magnitude of the comparison star, C_t is the number of photon counts of the target star, and C_c is the number of photon counts of the comparison star [2].







Conclusion

The observed average change in brightness due to WASP-43 b did not quite match the referenced change in brightness from the SuperWASP program, which was 0.0289 magnitudes. Most of the individual graphs were close to the expected value but two were not, which brought the average change down. More investigation is required to determine why these sets of data, such as CT-C2 shown at left, were inconsistent. For example, the comparison stars used, like C2, may be variable stars or the images may have been too saturated on those stars to get an accurate measure of their brightness. Despite the results of the average plot, the light curve for CT-C6 was encouraging. This plot clearly shows that the Fort Lewis College observatory is technically capable of detecting exoplanets with a change in brightness of around 3%. With more time, additional research can be done on the comparison stars to raise the accuracy of the average, and with some equipment and logistical improvements, such as automating the observatory and devoting it solely to exoplanet research over a longer time frame, the observatory would be a reliable tool for this field of study at Fort Lewis College.

References

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[2] J. B. Richard Berry, The Handbook of Astronomical Image Processing, 2nd Edition, Richmond, VA: Willmann-Bell, Inc., 2011. Page 274.

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Acknowledgements

Special thank you to my advisor, Dr. Charles Hakes, for all his help with this project. Thanks also to Justin Revard for his assistance in this project.