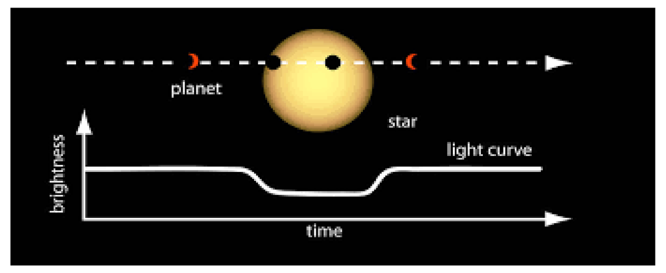
Analyzing Exoplanet Transits Using Differential Photometry

Joshua Smee

University of New Hampshire – Department of Physics and Astronomy

Introduction

Exoplanets are planets that exist outside of our solar system. The first exoplanet was discovered in the 1990's, and thousands more have been discovered since. Exoplanet research aids us in the understanding of how planetary systems form. The transit method measures a slight dimming in a star's brightness as the star's planet passes in front of it as seen from Earth using a telescope. When a planet passes in front of its host star, we can detect this by the reduction in flux (brightness) during the transit. This is done by taking a series of exposures of a star that presumably has an orbiting planet during its predicted transit length. Ideally begin imaging approximately one hour before the start (ingress) of the transit and one hour after the end (egress) of the transit. Ingress being the point in time in which the planet begins to pass in front of its host star. Egress being the point in time in which the planet exits its path in front of its host star. Taking images an hour before and an hour after allows for an out of transit baseline that helps identify the depth of the transit successfully.

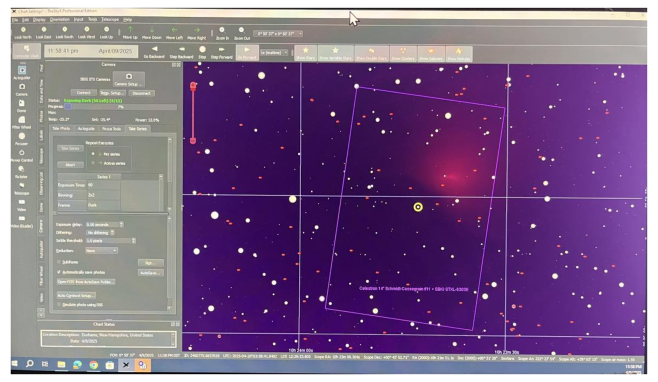


Objective

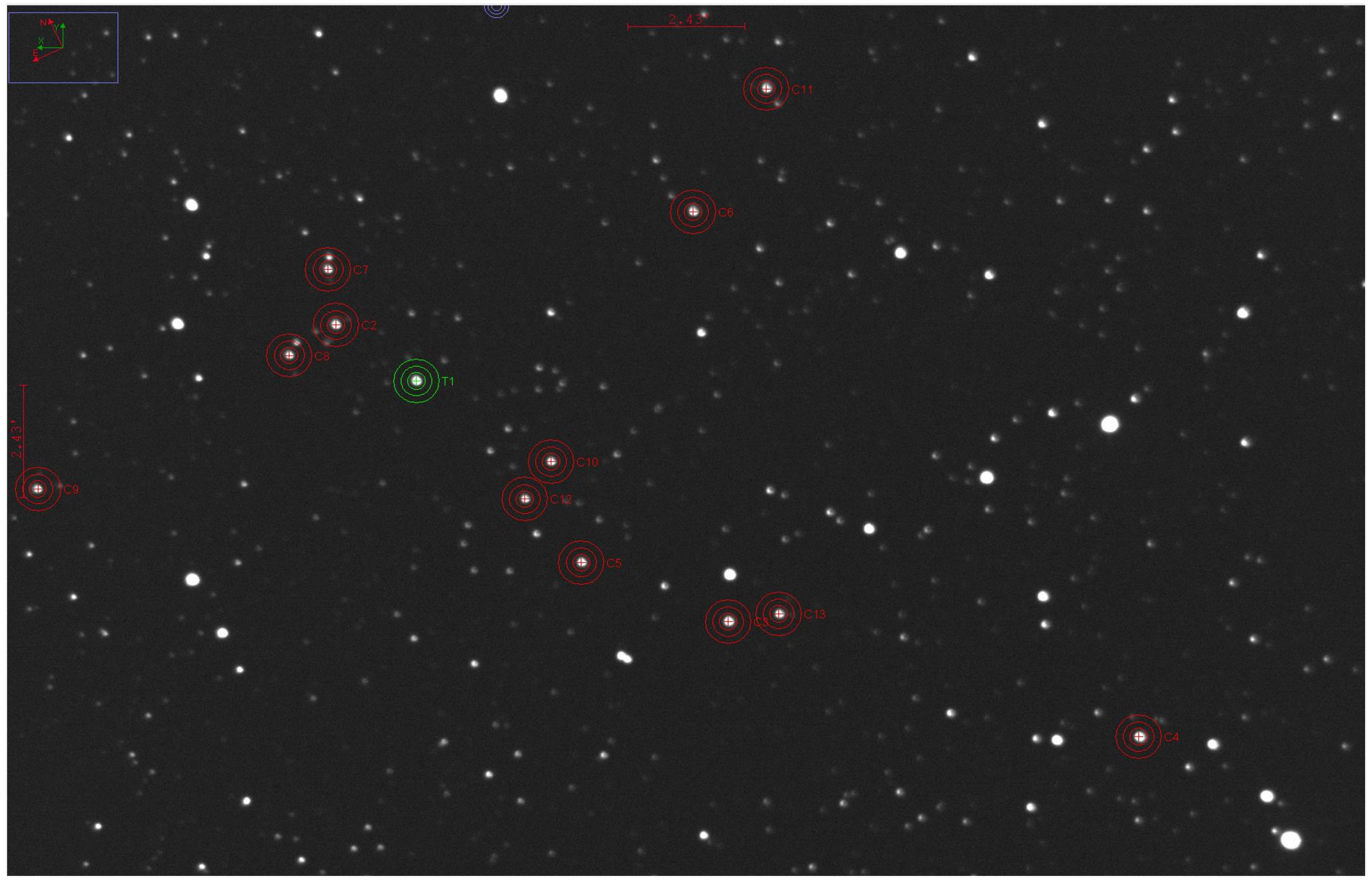
Ground-based observations were conducted at the University of New Hampshire's Observatory, and Blue Sky Observatory using differential photometry utilizing AstroImageJ. Light curves were produced for the exoplanet transit of Qatar-1b. These light curves help confirm the existence of the exoplanet and provide verification of key parameters, such as transit depth and planet radius and mid-transit time, as previously measured by other research programs such as Qatar, HAT-P, and TESS.

Observatory and Equipment

At the University of Hampshire, the telescope is a Celestron C-14 (f/11), F.L.= 3911.6 mm telescope with a SBIG STXL-6303E CCD camera mounted to the telescope. The camera while running was set to be cooled to -25 degrees Celsius to minimize electronic noise in all electronic devices. The telescope mount and camera were controlled using the SkyX Professional Control Software. This program allowed the telescope to slew to the target star and track it while having the camera take a continuous series of images while the transit was occurring.



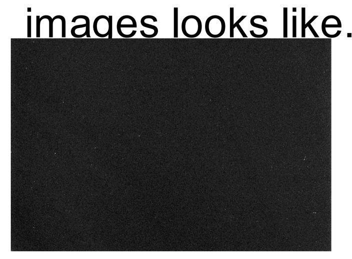
Images of the observatory, telescope, mount and SkyX program used to conduct this research.



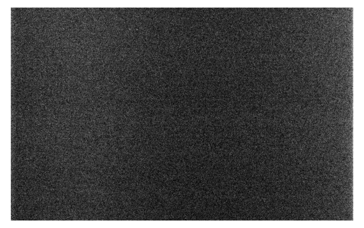
The field of view when observing the transit of Qatar-1b. Its host star, Qatar-1 is highlighted by the green circles while comparison stars are targeted in red circles. Image taken by Professor John Gianforte at the Blue Sky Observatory

Calibration

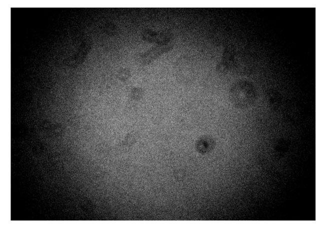
When doing photometry for exoplanet transits, calibration images are required to remove artifacts from images taken. There are three types of calibration images that are required for photometry. There are the dark frames, bias frames, and flat fields. The dark frame images are to eliminate the camera's sensor noise. Bias images, are taken to eliminate the systematic noise of the camera itself. Flat field images are used to remove the dust motes and debris in the optical path that may be interfering with the images. Once all three types of calibration images are taken, they are then used in AstroImageJ to improve photometric analysis. The following images are examples of what each calibration images looks like.



Dark Frame



Bias Frame



Flat Field

The Target Star: Qatar-1

Qatar-1 is located approximately 185.615 parsecs away from us in the constellation Draco. Qatar-1 is a K-Type star, which is an orange main sequence star. Its radius being 0.82 times the radius of the sun and 0.804 times its mass.

The Target Exoplanet: Qatar-1b

Current data on NASA's Exoplanet Archive shows Qatar-1b transit depth to be 0.02044 radius to be 1.143 the size of Jupiter's radius and 1.294 times Jupiter's mass. While its orbital period is 1.42 days. This planet has been classified as a hot Jupiter that orbits relatively close to its host star.

Results

The images of Qatar-1b were 75-second-long exposures, that way there is enough of a signal to noise ratio when doing photometry. AstroImageJ produced a light curve that shows the transit depth of Qatar-1b to be 0.0202 and therefore making its radius 1.132 times the size of Jupiter's radius and its mid transit time is 3:46 AM UTC. These values accurately represent current research data found on NASA's Exoplanet Archive. Which verifies that the exoplanet does indeed orbit Qatar-1. Sources of error include unstable weather, telescope tracking errors, internal camera errors, and other sources of noise such as moonlight and campus light pollution.

Conclusion

This project demonstrates that through ground-based astronomy it is possible to observe and potentially discover exoplanets orbiting distant stars. I have successfully shown that Qatar-1b does in fact exist and that the measured values are accurate and coincide with previously measured values on NASA's Exoplanet Archive.

Acknowledgements

I would like to thank Professor John Gianforte for guiding the experimental and analysis phases of the investigation.