Exoplanet Transit Observations

[Adham Ramy EL-Araby, Yousef Mohammed, Muneeb Abdelrahman, Aryan Irfan, under guidance of Dr. A. Smith]
Newton British Academy, Barwa City, Qatar
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Abstract

Exoplanet detection via transit photometry has become one of the most thriving fields in all of physics in the last decade. An exoplanet transit refers to the event where a planet in orbit around a host star passes between the line of sight of us and a host star, when observed (during a transit), the apparent magnitude can be plotted to create a light curve (a star's brightness throughout time), the observer would be able to notice a drop in the star's brightness due to the interference of the planet. Using multi aperture photometry and light curves from an exoplanetary transit, estimates about the exoplanet itself like radius, orbital period and density can be calculated. Our team conducted transit photometry on the star WASP-98 (a G7 star part of the Eridanus constellation), which is host to the single planet WASP-98b, which was done using the Las Cumbres Observatory's SBIG 0.4-meter telescope. In this paper we present evidence for detection of WASP-98b, estimates of its radius, semimajor axis and orbital period, as well as the method used to analyze and manipulate the data.

Instrument:

The process of our observations in the project using the Las Cumbres Observatory specifically used for observing a light flux of exoplanets orbiting stars outside of our solar system. The 0.4 SBIG telescope located in Chile consists of SBIG STL6303 cameras with suitable guiding navigation systems with the default configurations of 29.2 x 19.5 arc minutes field of view, fielding a wide range of neighbouring comparison stars. Therefore, we have used a RP filter to increase the resolution by removing excess red light emitted by dim neighbouring stars. The filter in the image was removed during the acquisition due to the faint 11+ magnitude to amplify the signal to noise ratio. We have inputted the navigation coordinates to focus from the wide view onto a single focal point (the target star) which kept it in a single position centered in the middle, using a suitable tracking system rotating the telescope. Following the path of the star along with respect to our orbit and rotation of an accuracy of ~1". The RCD tubing is equipped with a 3-element-optics using c-ring equatorial mounting aligning axis to the celestial pole against the earth's rotation at a speed of 10 degrees per second.

0.4SBIG robotic telescope, Chile	LCO SBIG 0.4-meter Telescope Main Telescope Specification: Optical type : Schmidt-Cassegrain reflector Format :3Kx2K 9-micron Mirror diameter : 400 mm Focal length : 2790 mm : 1760 (with focal reducer f0.63) Detector : CCD Camera STL-6303 Filters : Sloan u',g',r',i',**z',** Johnson-Cousins B, V, Pan-STARRS w Field of view : 29.2 x 19.5 arc minutes Pixel size : 0.571(1x1binning,arsec) Cycle time :14s Read noise (e-) : 14.5 Gain : 1.6e-/ADU Dark current :0.03 @ -100 C (estimated) Guide Specification: equatorial mounting

Figure 1

Analysis

Relative flux data used for light curve generation was gathered using the multi-aperture photometry setting in AstroImageJ. In this process, the target star is chosen along with comparison stars in the region as shown in Fig.2, to calculate the relative flux. It is important that the chosen stars maintain a constant flux (non-pulsar) throughout the transit duration since these stars are used as a control to determine if the target's brightness/apparent magnitude changes. Using a variable star for comparison can skew results. After generating the flux data, we plotted the light curve using AstroImageJ's light-curve generation plugin and performed planet parameter calculations.

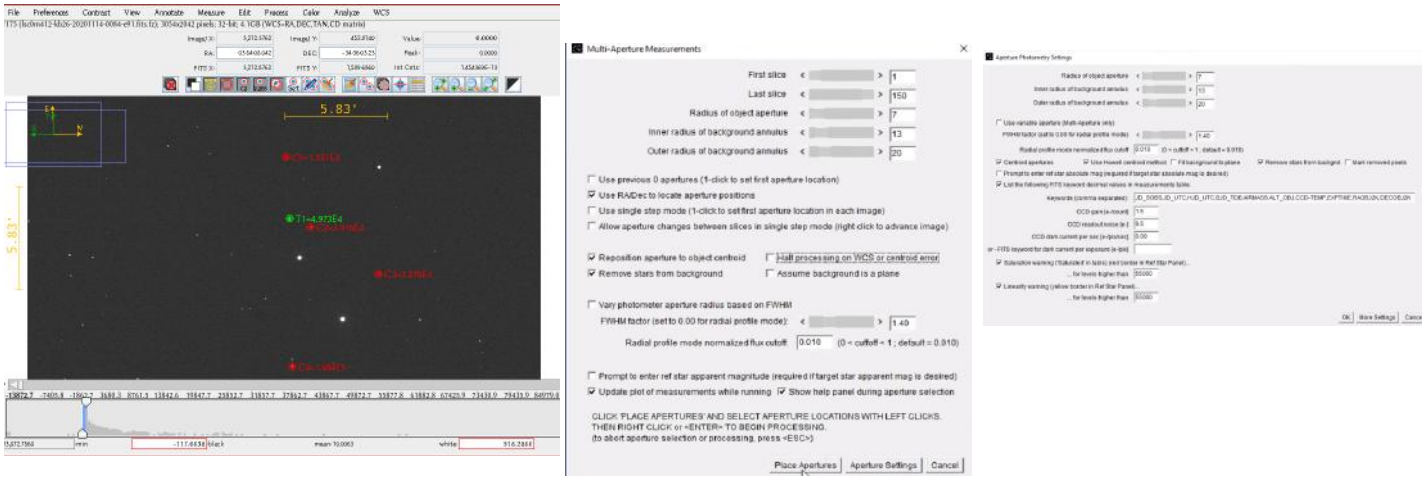


Figure 2: Selection process of host star (T1) and comparison stars (C2, C4)

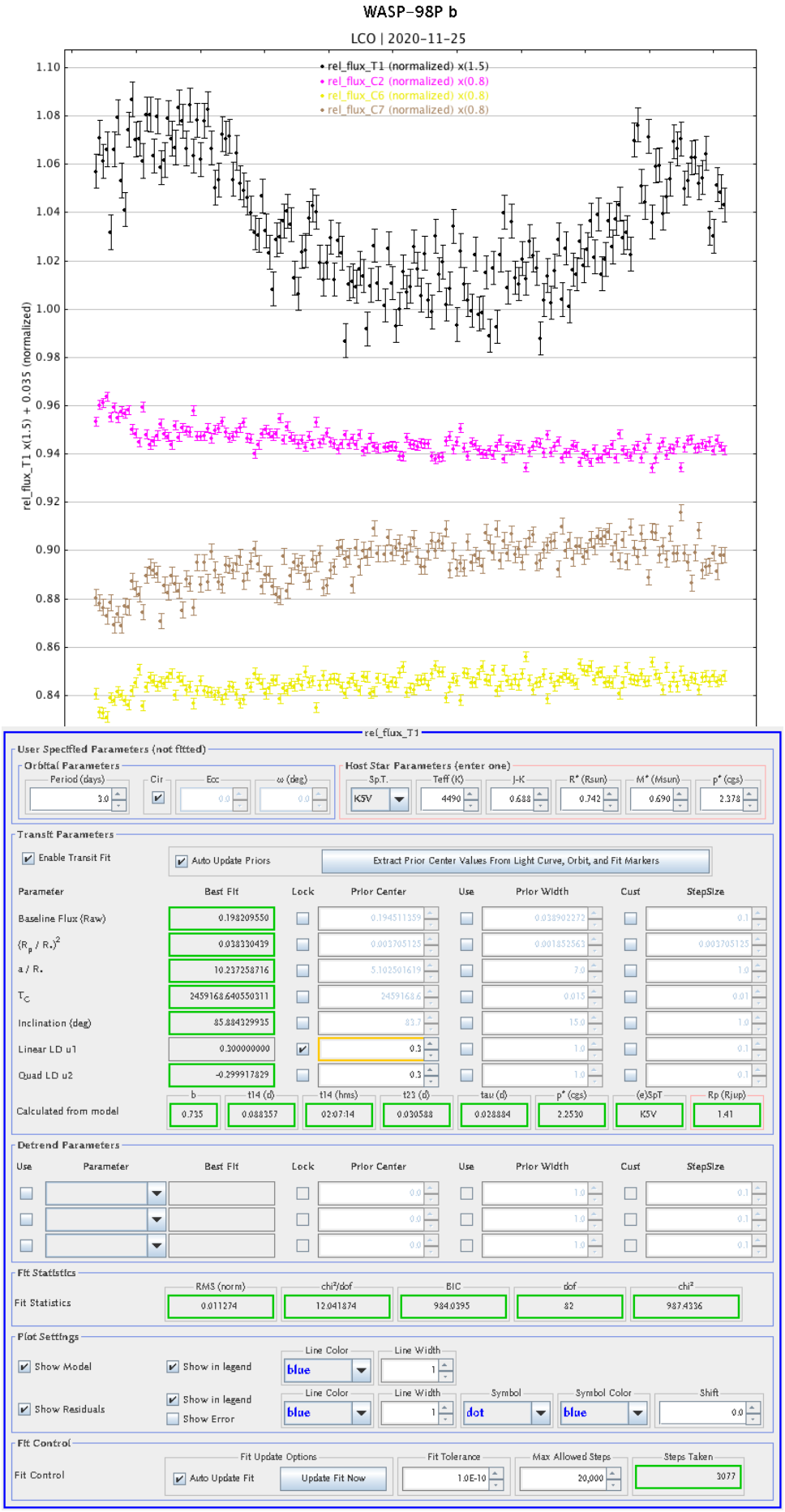
Results

The exoplanet observation successfully commenced amidst all seasons from Chile, whereby the sky is clear (with low rainfall and a cloudless sky) to provide for the most accurate observations. The technique used to re-confirm the exoplanet, used a light flux evaluation during an event with the configured instrument. The wide range of exoplanets observed from the multiple observatories and delays from interfering conditions and factors have shown a similar pattern of large transits from large flux changes. However, with respect to the magnitude the flux was unmeasurable small or occasionally unchangeable except from a specific inclination over specific periods with its repeating intersection at equal intervals giving the orbital periods. **Table 1** shows the properties of the exoplanet transit which was detected and observed with complete success. The telescope showed its ability to produce familiar shapes of curves with high resolution, a 11+ magnitude and 0.01-0.02 depth magnitude is observable. Due to the weak magnification, it required an exposure time sufficient to obtain and compare the data between 2-4 hours involving the time of transit and the normal light intensity. Apparently, the signal to noise ratio affected other various observations giving errors before the final one encountering difficulties with ranges below or above the exceeding magnitude set out. Another complication faced by our team was repeating an observation for the same star, both due to environmental factors and other observatories using the telescope restricting our access. The environmental factors included; temperature fluctuations, light pollution, dark lined traps, blooming and dust rings. Overloading the CCD pixel count which had to be reduced from the data using AstroImageJ adding dark, bia and flat frames to resolve the issue. Nevertheless, this was the only observation encountered due to its perfect location and optimized function. The exposure time was lengthened by using a defocusing method, which used comparison stars to fill the gap in our results, by using areas where the telescope atmosphere point of vision was normalized, this avoided saturation and overlapping of images.

Table 1

Object Name:	**RA (Right Ascension):**	**Declination**	**Magnitude (V mag)**	**Transit Depth (mag):**	**Duration (min):**	**Period (Days):**
WASP-98	03:53:42.0	-34:19:42	13.0 V	0.0276 mag	114.48 mins	2.96 days
WASP-29 b	23 51 31.08	-39 54 24.2	11.13 V	0.0108 mag	157 mins	3.92 days
WASP-122b	07 13 12.3	-42 24 35.1	11 V	0.0151 mag	131 mins	1.71 days

Figure 3. WASP-98b light flux plot.



Summary

A comparison between our plotted data and the quality indicator showed that our result lied between the 2 and 3 margins, showing room for improvement to provide a more precise plot by implementing a higher signal to noise ratio (S/N) and also using a larger optics with a larger telescope, such as the 2.0 SBIG telescope.

Orbital radius between wasp-98 and wasp-98b	0.35-0.45 Au
Mass	0.83Re
Radius	1.1Me
Temperature	1180K
Orbital period	3-days
Type of planet	Hot Jupiter and a gas giant

Table 2

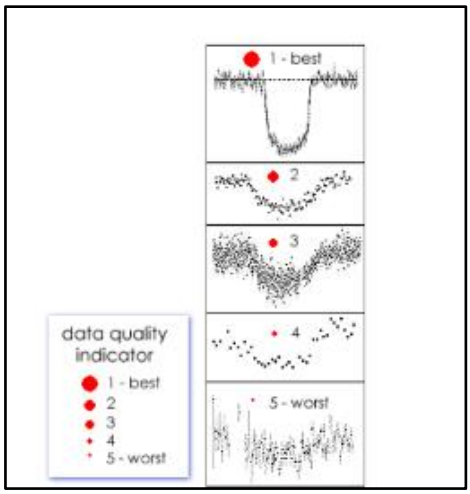


Figure 4. Exoplanet transit light curve quality indicator.

Acknowledgements

The advanced facilities provided by the Las Cumbres observatory in cooperation with Qatar National Library has enabled our team to find incredible planetary systems using telescopes that gave us the ability to investigate and make calculations regarding the exoplanet's density and magnitude. In doing so, we gained a virtual experience of space by scanning a large area of the sky that contain a numerous number of stars at once; to find more extrasolar planets. We express our gratitude to both Qatar National Library and Las Cumbres observatory for capacitating us to a highly scientific program, where we indulged in a mixture of critical thinking and analyzing data skills.

Bibliography:

- https://www.researchgate.net/publication/300449571_Exoplanet_transit_observations_at_Bosscha_observatory
- http://exoplanet.eu/catalog/wasp-98_b/
- http://www.ifa.hawaii.edu/users/mickey/ASTR110L_S05/Pleiades.html
- https://arxiv.org/pdf/2008.02533.pdf
    - Discovery of white dwarf WASP-98A
- https://lco.global/observatory/instruments/sbig-stl-6303/
    - Data About LCO's SBIG Telescopes