BEAR Team Observations of Exoplanets, Asteroid 2343 Siding Spring, and Supernova ASASSN-16ad

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Abstract

In September 2015, Bridgewater State University was awarded a MA NASA Space Grant to run a 1-year pilot observing program: the BSU Experimental Astrophysics Research (BEAR) Team. Since that time, the eight official student participants have observed multiple exoplanets, asteroid 2343 Siding Spring, and Supernova ASASSN-16ad among other targets, such as mystery star KIC 8462852 and various galaxies and nebulae. We present preliminary light curves of the photometry targets.

BEAR Team

During the 2015-16 academic year, BSU started a pilot program for the Bridgewater Experimental Astrophysics Research (BEAR) Team funded by the Massachusetts NASA Space Grant Consortium. Students who are part of the BEAR Team engage in mentored research in one (or more) of the following three areas: Asteroids, Exoplanets, or Type Ia Supernovae. During every clear night, student team members make observations to support some or all of these activities. This organizational structure makes maximum use of our research grade telescope and imaging system. On cloudy nights and some days, team members engage in other research activities like image processing and analysis. There are weekly team meetings and ongoing communication through a Blackboard site. Students earn $10 per hour for their time and they do not earn credits. In this pilot year, 6 students were officially part of the program in the fall (one graduated in December), and in the spring we added 2 more. Of the original 6 students officially participating, 2 are graduating (one has been accepted and one is applying to graduate school), and the remaining 4 (3 of whom are women) have applied or intend to apply for summer astronomy-related research programs on and off campus. Two have been accepted to summer research programs.

Methods

Targets are chosen by BEAR Team members and mentors. Finder charts are generated with the AAVSO Variable Star Plotter[1]. For asteroids, coordinates on each observation night are found using the IAU Minor Planet Center's ephemeris service[2].

Observations are made using the BSU Observatory's 14-inch Celestron Edge-HD with attached Apogee Alta U47 CCD and Apogee FW50, mounted on a Paramount ME with The Sky6 and Tpoint software (Fig. 1). The filter wheel houses standard 50mm round Astrodon UBVRI and Luminance filters and a Star Analyzer 200 diffraction grating. Standard calibration procedures each observation night include at least 12 twilight flats through B, V, R, and Luminance filters (others if necessary) with count levels between 30% and 55% saturation level. Ideally, at least 12 short-exposure darks are taken to match flat exposure times, and at least 12 darks are taken to match each data exposure time that night. Biases are acquired at least once every four months. The CCD is operated at temperatures ranging from -25 °C to -10.3 °C depending on ambient temperature, and controlled with MaxIm DL 5.

Since Bridgewater's campus is a brightly lit area, we take steps to minimize the amount of directional light entering the optical system. We limit targets to those at or above 35° altitude, allowing us to close the dome's lower shutter. This cuts out much of the light that would directly enter the optical tube from campus facilities (e.g. parking lots and the football stadium). Certain directions – E, S, and SW – are the brightest in Bridgewater, and targets far from zenith in these directions are avoided if possible. Light sources in the dome are taped over.

Exoplanets are observed in R and Luminance from approximately one hour before to one hour after a predicted transit. Some exoplanets are also observed in V. Exoplanet exposures have been consistently 30 seconds. Asteroids are observed in R with exposure times ranging from 15 to 120 seconds. Supernovae are observed each clear night for at least one month through B, V, R, and Luminance for 30 minutes each, with individual exposures of 30 seconds. Image calibration, stacking, and photometry are performed in MaxIm DL 5 or 6. Exoplanet and asteroid images are stacked if signal-to-noise ratios are low – in that case, several images in a row are combined and used as single points on lightcurves. For supernovae, the highest quality images through one filter from a night are stacked to generate images with matching effective exposure times for each date. These exposure times are ≥20 minutes.

For all target types, MaxIm DL 6's photometry tool is used to generate light curves and export photometric data.

Fig. 1: The BSU Observatory's primary instrument.

Exoplanets

Exoplanets are planets that orbit stars outside of our solar system. One approach to observing these planets is the transit method: we measure how the magnitude of a host star changes as a planet passes in front of it. As the planet transits in front of the star, the brightness of the star dims because the planet blocks some of the light. The two exoplanets we focused on this semester were Qatar-1b and TrES-5b (Table 1).

We performed differential aperture photometry in MaxIm DL 6 to generate lightcurves for both Qatar-1b and Tres-5b. Multiple stars in each field were tested for stability before settling on a reference star (see Fig. 2 and 5). We took these data and loaded them into the model-fit application of the Exoplanet Transit Database site[3]. We then were able to see how well our data fit the known models for these exoplanet systems, and we confirmed that our results were consistent with previously observed transits. Error bars are generated by propagating MaxIm DL's standard mag. error for photometry targets and reference stars.

	TrES-5 b	Qatar-1 b
Exoplanet Mass	1.788 M_J	1.09 M_J
Exoplanet Radius	1.209 R_J	1.164 R_J
Transit Depth	0.0215 mag	0.0204 mag
Transit Duration	111.312 min	96.7 min
Magnitude of Host Star	13.75 mag	12.84 mag
Distance from Earth	360 pc	-

Table 1

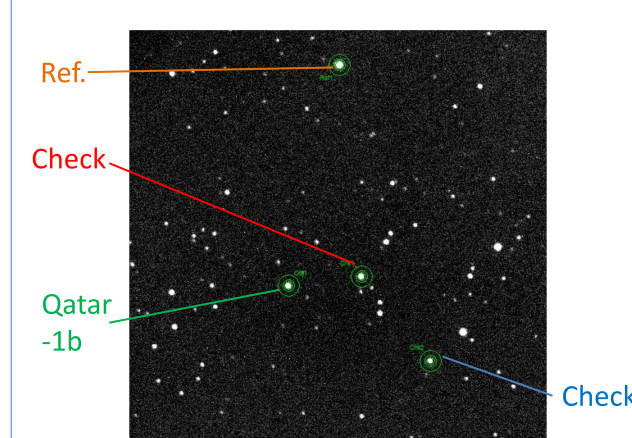

Fig. 2: R Filter star field of Qatar-1b with photometry apertures, showing chosen check and reference stars.

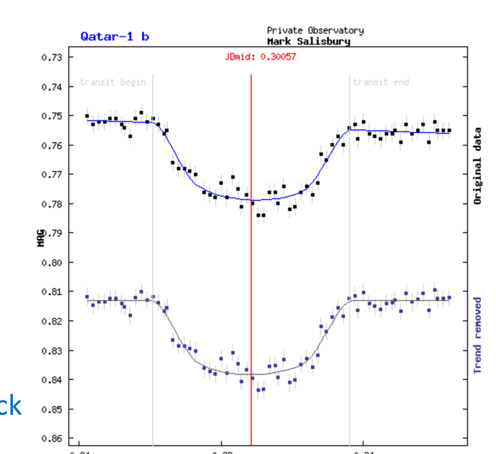

Fig. 3: Data for Qatar-1b in the R filter published by Mark Salisbury from a private observatory. Taken January 7th 2016 (ETD).

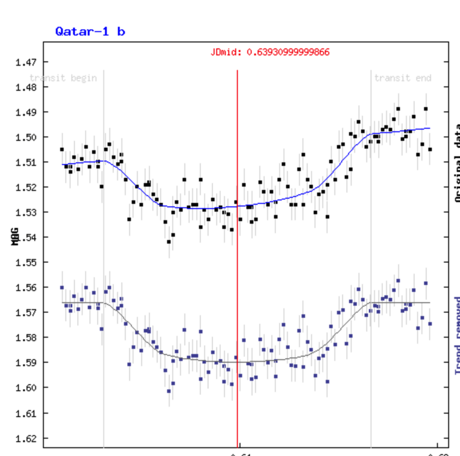

Fig. 4: Qatar-1b lightcurve generated from BEAR Team data in the R filter. Taken on October 12th, 2015.

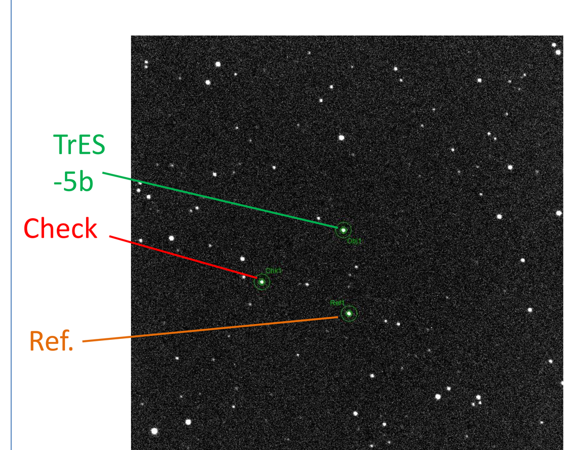

Fig. 5: R filter star field of TrES-5b with photometry apertures, showing chosen check and reference stars.

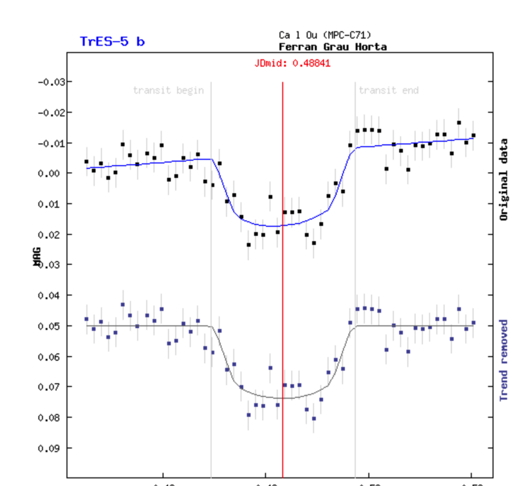

Fig. 6: Data for TrES-5b in the R filter published by Ferran Grau Horta. Taken on October 15th, 2015 (ETD).

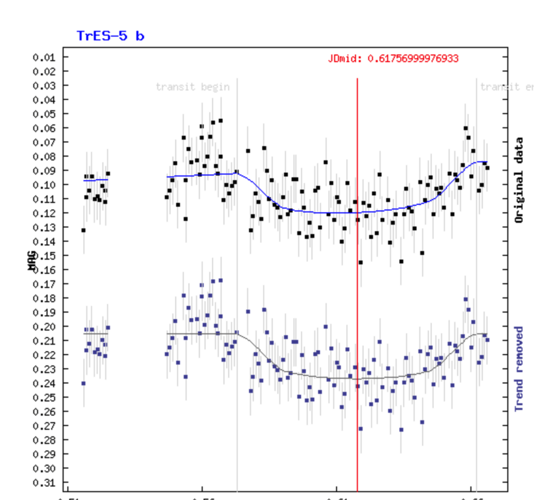

Fig. 7: Data for TrES-5b in the R generated from BEAR Team data. Taken on September 25th, 2015.

Plan for continued exoplanet work

The BEAR team has made it possible to collect data for HAT-P-37b, TrES-3b, HAT-P-10, WASP10b, and WASP-52b in addition to the exoplanet systems with lightcurves above and those previously researched at BSU. M. Patrone plans to continue this work and eventually obtain data and analyze light curves from exoplanet candidates on the Kepler Objects of Interest list. This work may also become part of a summer research project as well as her honors thesis.

2343 Siding Spring

Asteroids have uneven surfaces and as a result, when they rotate, the magnitude of their reflected light changes in a periodic way. 2343 Siding Spring is a main belt asteroid chosen for its relatively long availability, high altitude, and expected magnitude within our observing range[2]. Our observations range from ~1.5 to 2.25 hours in length. Fig. 9 shows a preliminary R lightcurve from 11/3/15. Relative instrumental magnitudes for Siding Spring are measured compared to a reference star (see Fig. 8). Check stars are used to gauge the suitability of the reference star. All otherwise suitable reference stars in this field are variable – ensemble photometry will be necessary to correct for errors introduced by reference star variation. Despite this, a clear rotation curve is evident with a period of about 2 hours.

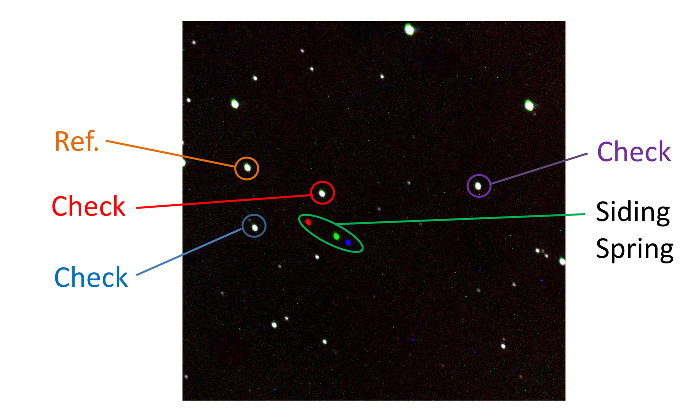

Fig. 8: False RGB image of cropped Siding Spring field at three distinct times on 11/3/16, revealing the asteroid's location. Reference and check stars are labeled.

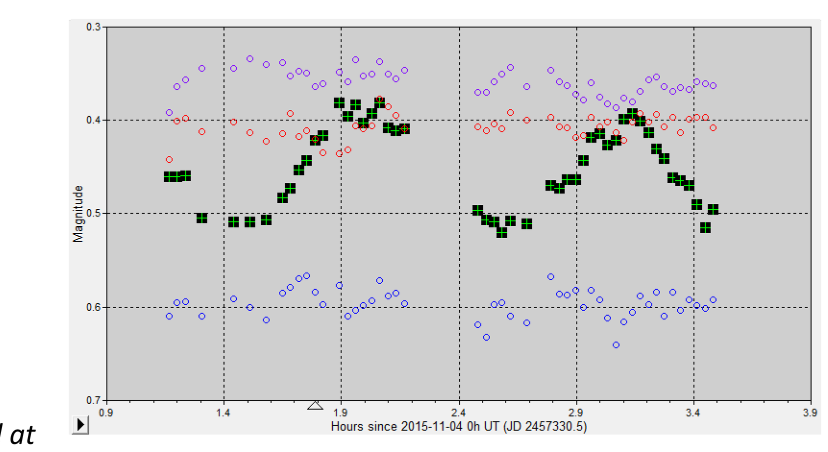

Fig. 9: Relative instrumental magnitudes of Siding Spring (black and green boxes) and 3 check stars (circles) on 11/3/15.

Plan for continued asteroid work

S. Boni will participate in an asteroid observing project at Colgate University this summer and will choose asteroids to observe in the fall. Ensemble photometry on Siding Spring will allow a more accurate measurement of the asteroid's rotation period to be attempted.

Supernova ASASSN-16ad

A supernova is a star whose brightness increases suddenly and then dims over an extended period of time. Ideally, supernovae are observed throughout the entire process of brightening and dimming. The discovery of ASASSN-16ad by the All Sky Automated Survey for SuperNovae was reported on Jan. 9, 2016[5]. This target was in a good location for us to observe, likely to be pre-peak, and relatively bright at 16.2 V-mag. The BEAR Team acquired observations on 9 dates from 1/11/16 – 3/2/16. A redshift of 0.016138 was applied to correct the observation times for time dilation (the "stretch" correction) to generate the light curve[6].

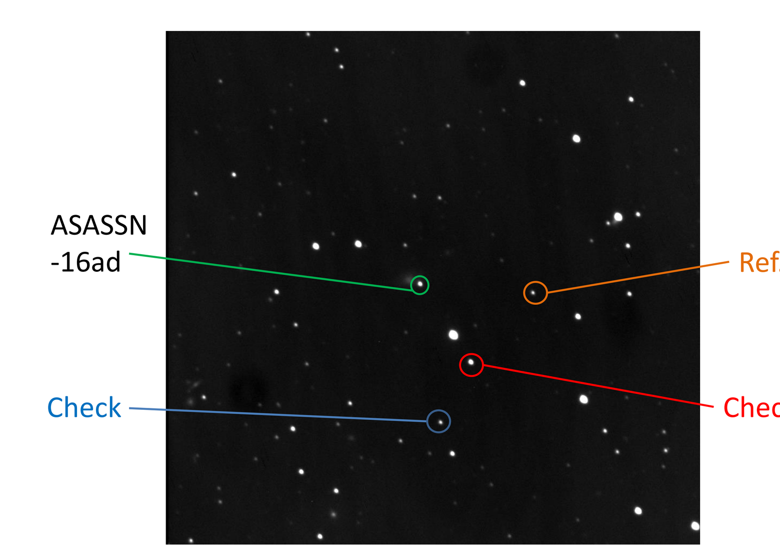

Fig. 10: 60 stacked 30-sec luminance images of ASASSN-16ad field on 1/27/16.

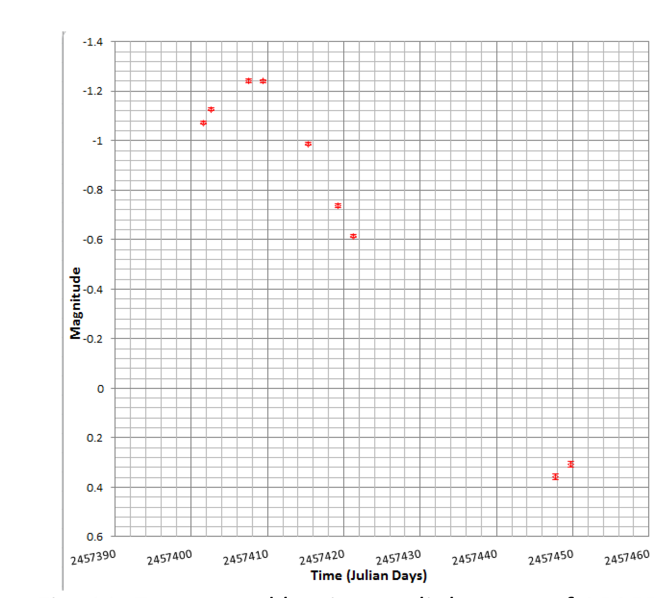

Fig. 11: Z-corrected luminance lightcurve of ASASSN-16ad. Magnitudes are relative to the reference star.

Plan for continued supernova work

In addition to ASASSN-16ad, three type Ia supernovae had previously been observed for extended periods of time at the BSU Observatory, through class work and a summer Massachusetts NASA Space Grant awarded to S. Johnson. A. Gustafson intends to continue this work this summer by continuing to observe preferred targets and applying extinction corrections to the existing data. A width-luminosity relationship in luminance is hypothesized.

References

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6: Wegner, G. et al. "A Survey of the Pisces-Perseus Supercluster. V. The Declination Strip +33.5° to +39.5° and the Main Supercluster Ridge." *Astronomical Journal.* vol. 105, no. 4, p. 1251-1270.

Acknowledgements

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