Preparing to Observe TESS Exoplanet Candidates

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I. Introduction

The Paul P. Feder Observatory at Minnesota State University Moorhead has a 0.4-meter Cassegrain reflector on an equatorial fork mount manufactured by DFM Engineer. The camera used is the Apogee Aspen CG16M. This CCD is 4096 x 4096 pixels, each measured at 9 microns. The nominal dark current is 0.0186 e^-/pixel/sec and the nominal read noise is 9.5 e^-. The night on which the science images were taken was 07-23-2018. The data for ***Figure 1*** was taken on 06-01-2018. All data was collected using an 'r' filter.

II. Linearity & Camera Properties

The camera was brought back to campus and set up in an optics lab with a single light source. This way the CCD was evenly illuminated and any unwanted light could be removed. ***Figure 1*** shows how an evenly illuminated part of the CCD reacts at different exposure times. Taking twilight flats using ACP (*Astronomer's Control Panel*) has been found to be a reliable method.

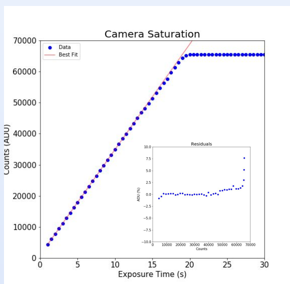


Figure 1

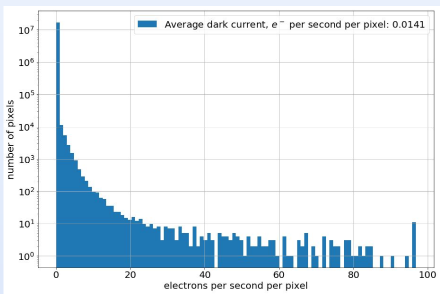


Figure 2

Figure 1. *Camera Saturation is measured by comparing exposure time (x axis) to counts measured in ADU (y axis).*

Figure 2. *Number of pixels with a given dark current. The average dark current most pixels has is .0141.*

At around an exposure time of 18 seconds, the camera starts to plateau at roughly 63,000 ADU. The data becomes non linear much sooner at around 43,000 ADU. The gain of the of the camera was measured to be 1.46 e^-/ADU with a read noise of 9.42 e^-. These values agree with the given specifications on the datasheet of the camera.

III. Tracking

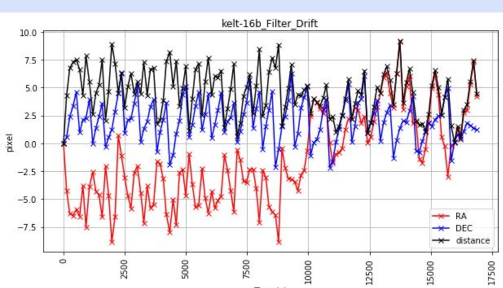


Figure 3. *The change in position of Kelt -16 on the CCD over the observation of the exoplanet in pixels. ACP recenters on Kelt -16*

Tracking was an issue at first. ACP was having trouble communicating with the Telescope Control System (TCS), and the tracking in TCS had to be tuned. Once those issues were addressed, ACP told the the telescope to recenter if Kelt -16 drifted more than 5 pixels from the center of the CCD. ***Figure 3*** shows the position of Kelt -16 on the CCD as a transit occurred on August 22, 2018. *Note this is not the same night as the transit presented in IV.*

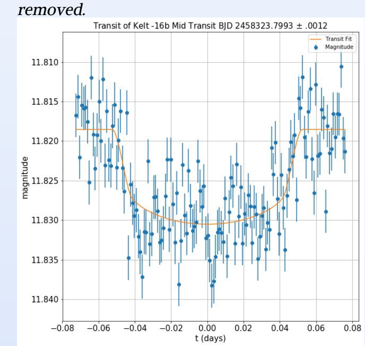
IV. Light Curve

Data was reduced using standard techniques [2] with the package *ccdproc* [5]. Stars were detected in a single image using the DAOFIND method and aperture photometry performed for all of the sources in the field of view for all images [6]. Instrumental magnitudes were transformed frame-by-frame to the standard magnitude system using APASS DR9 stars in that frame [7]. No further differential photometry was done. The error in the magnitudes were calculated using the CCD equation.

The transit of Kelt-16b was successfully measured, as shown in ***Figure 4***. The midpoint of the transit was BJD 2458323.7993 ± .0012, consistent with the published ephemeris [8]. The measured depth was also consistent with the published value. The transit fit was done using the method in [9].

Next steps are to fit the transit of Kelt-16 on August 22, 2018 to see if improved tracking reduces scatter in the light curve, and to observe a less deep transit.

Figure 4. *Light Curve of Kelt -16b with midpoint centered at 0, with atmospheric trends removed.*



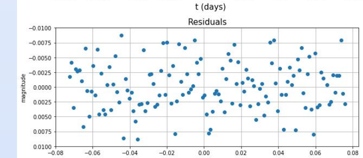


Figure 5. *Residuals of the light curve above shows the difference from the light curve fit and the transit data.*

V. References

[1] Conti, D. M. A Practical Guide to Exoplanet Observing (2018)
[2] State, B., & Cambridge, R. AAVSO Observing Manual (2014)
[3] Garner, Rob. "About TESS." *NASA* (2018)
[4] ANDOR, https://andor.oxinst.com/products/apogee-ccd-camera
[5] https://github.com/astropy/ccdproc ASCL 1510.007, DOI: 10.5281/zenodo.47652
[6] https://github.com/astropy/photutils DOI: 10.5281/zenodo.1340699
[7] Henden et al, "APASS - The Latest Data Release," AAS 225 (2015)
[8] Oberst et al, *Astronomical Journal* **v153 p. 97 (2017)**
[9] Poddaný et al, *New Astronomy* **v15** p. 297 (2010)

Link to github repository with a copy of the poster and all the software used.