Measurements of transiting objects and variable star periods in the age of large surveys

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Summary

We report on the measurement of a potential low-amplitude variable star in the field of the transiting exoplanet KELT-16 b, on the importance of including survey data when measuring the period of variable stars, and on the timing of a transit of the object KELT-1 b.

KELT-1 b: Measurement of transit

The transiting object KELT-1 b was discovered in 2012[1], with revised periods reported in 2015[2] and 2017[3]. The predicted time of transit using the 2017 period and 2012 epoch was at a barycentric Julian date (BJD) of 2459472.897762. We set out to determine whether a more accurate period was possible in 2021, and also to place an upper limit on how far off current period measurements of KELT-1 b could be. Observations were done on September 14th, 2021, using the 16" Cassegrain telescope and 16MP CCD camera installed at the Paul P. Feder Observatory in Glyndon, MN.

Data was calibrated using `reducer`[4] and an initial fit of the transit light curve of KELT-1b from that night was created using `stellarphot`[5], as shown in Figure 1. No detrending was done because the Bayseian Information Criterion (BIC) indicated doing so would not significantly improve the fit. The fitting technique in this approach does not provide a meaningful estimate of the error.

To obtain an uncertainty, we used EXOTIC[6], which uses Markov Chain Monte Carlo (MCMC) to fit the light curve, using as priors the data on KELT-1 b in the NASA Exoplanet Archive. The final fitted lightcurve is shown in Figure 2 and the other fit parameters are in Figure 3.

Our measured midpoint of transit is 2459472.89761 ± 0.00072 (BJD on the TDB time scale). The difference between this and the predicted transit time, 1.52×10^{-4} day, is well within our uncertainty. This confirms that the 2017 period is accurate within current observational abilities.

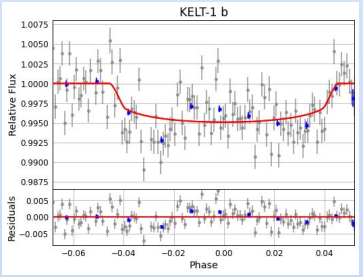

Figure 2
Final fitted lightcurve of KELT-1 b transit from 2021-09-14, using EXOTIC.

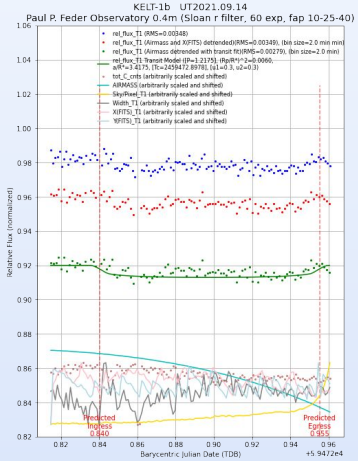

Figure 1
Transit fit of KELT-1 b data taken on 2021-09-14, with predicted transit start and end times indicated in red, and the fitted transit curve in green.

Figure 3: Planetary Parameters from EXOTIC.

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FINAL PLANETARY PARAMETERS

Mid-Transit Time [BJD_TDB]: 2459472.89761 +/- 0.00072
Radius Ratio (Planet/Star) [Rp/Rs]: 0.064 +/- 0.0023
Transit depth [(Rp/Rs)^2]: 0.41 +/- 0.029 [%]
Semi Major Axis/ Star Radius [a/Rs]: 3.67 +/- 0.047
Airmass coefficient 1: 0.04283 +/- 0.00012
Airmass coefficient 2: -0.0057 +/- 0.0014
Residual scatter: 0.28 %
Transit Duration [day]: 0.1108 +/- 0.0016
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Variable star periods in the age of surveys: KELT-16 b

A recent paper[7] on the star field of KELT-16 b proposed four new variable stars and three known variable stars received period estimates. The authors compare the period obtained from their data, which spans two months, to that obtained for the ASAS-SN survey[8], which spans several years. In one case, ASASSN-VJ205552.88+314615.9[9], labelled V2 in the paper, arriving at a significantly different period than that reported from the survey. We sought to assess the period of that star using our data combined with data from ASAS-SN and ZTF[10] using the data sources in Figure 4.

We calculated a multiband Lomb-Scargle periodogram[13] shown in Figure 5. Multiband Lomb-Scargle periodogram does a simultaneous fit to data in each of the filters provided while requiring that different bands have the same phase. A folded light curve created using the best period is in Figure 6. The best period is double the period at which the periodogram is maximum, which is not unusual for eclipsing binary systems.

The paper also proposes that GSC 02688-02285[14] may be an eclipsing binary system, in part because they did not observe changes in other nights. We observed fluctuations of around .02 mag on several nights, which suggests it may not be eclipsing.

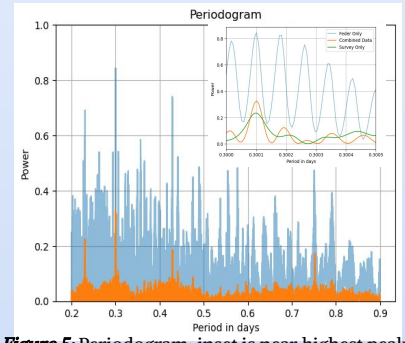

Figure 5: Periodogram; inset is near highest peak

Data set	Start date	End date	Span	Filter
Feder	2018-07-23	2021-09-26	3.18 yr	Sloan r
ASAS-SN[11]	2015-03-20	2018-07-17	3.33 yr	V
ZTF[12]	2018-04-09	2021-03-27	2.97 yr	zr

Figure 4: data sets included in periodogram

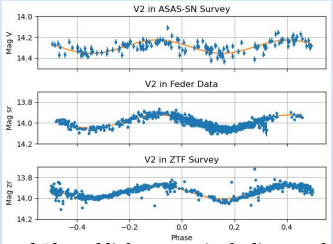

Figure 6: Phased light curve, including model.

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