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A NEW CONTACT ECLIPSING BINARY IN THE FIELD OF KOI 1152

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A new contact eclipsing binary star, designated in the WISE catalog as J194643.44+472029.4, was discovered during research on the transiting planet candidate KOI 1152. A search in the General Catalog of Variable Stars as well as a literature search in the SAO/NASA Astrophysics Data System revealed that this star has not yet been documented as a variable.

This field was observed on multiple nights from 2011-2014 with the 0.9 m optical telescope at Brigham Young University's West Mountain Observatory. Data were taken in the B, V, R, and I filters of the Johnson/Cousins system. The images were reduced using standard procedures in IRAF, and differential aperture photometry was performed using the BRIGHTER program (Ranquist 2013) that was developed at BYU. J194643.44+472029.4 has an apparent V magnitude ranging from about 16.25 to 16.75.

Initially, it was thought that this new variable was of the δ Scuti type. A closer inspection of the light curve, however, revealed characteristics, particularly the brief plateaus of the minima, that suggested the object is instead a contact eclipsing binary. The eclipses have very similar depths, indicating that the components have about the same effective temperature. Figure 1 shows phased light curves for the object in all four filters we used. From our observations and analysis, we estimated a color index of $B - V = 0.51$ mag, corresponding to a temperature of 6240 K according to the table for main sequence stars in Flower (1996). The 2MASS catalog lists J and K magnitudes for this object of 15.314 and 15.035, respectively, giving $J - K = 0.279$ (Skrutskie et al. 2006). According to Bessell & Brett (1988), this corresponds to approximately an F5 spectral type, which has a temperature of 6400 K. This corroborates our estimate of temperature from the $B - V$ color index.

We used the AoV period search algorithm in the VARTOOLS program to determine the period of this system and found it to be $P = 0.346178$ d (Schwarzenberg-Czerny 1989, Devor 2005, Hartman et al. 2008). It was difficult for the algorithm to acknowledge the presence of two different eclipses, due to their very similar depths and the scatter of our data, and the half-period of $P = 0.173089$ d was also a strong result. We thus recognize that J194643.44+472029.4 could indeed be an intrinsically variable star with a period of 0.173089 d, and spectral data may be needed to confirm the binary nature of this object. We also detected a period change in J194643.44+472029.4 towards the end of our available data. A period decrease of about 10 s occurred sometime between HJD 2456960.779091 and HJD 2456967.609178. The new period is $P \approx 0.346062$ d, or, if it is in fact an intrinsically variable star, $P \approx 0.173031$ d. We have one good observed time of minimum after this change, determined by the Kwee & van Woerden (1956) method to be HJD 2456969.6782, though it is unclear whether this is a primary or secondary minimum. We have not further analyzed the state of the system after this happens, due to our lack of data during this time, and thus leave that to future work.

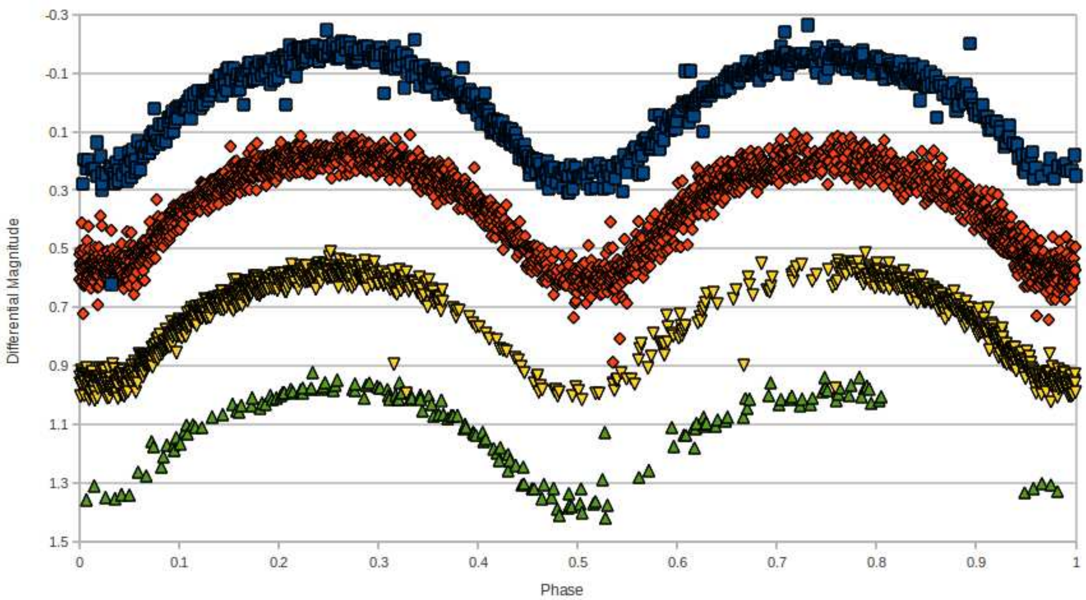

Figure 1. Phased light curves of J194643.44+472029.4 in, from top to bottom, B, V, R, and I filters.

We used the package PHOEBE, which makes use of the Wilson-Devinney code, to find a model for this object (Prša and Zwitter 2005). We worked with several of the different models that the program provides. In accordance with the determined color index, we fixed the temperature of the primary component at 6240 K in each model. The secondary temperature, T_2, was left free to vary except where doing so led to exorbitant parameter values, in which case it also was fixed at 6240 K. Other free parameters included the mass ratio q, the inclination i, the luminosities in each filter of the primary star, and the stars' dimensionless potential. Most of the results from the different models are in good general agreement with each other, giving a mass ratio of about 4-5 and an inclination of 85°-90°. The larger component is about 0-100 K warmer than its companion. The best fit comes from the overcontact binary of the W UMa type model. The results from this fit are a mass ratio of $q = 4.5$, an inclination of $i = 85°$, and a degree of contact $f \approx 34\%$. The secondary temperature T_2 was fixed at 6240 K. The semidetached model with the secondary component filling its lobe converged to a solution with a significant degree of contact and also gives a very good fit to the data. It is in good agreement with the W UMa model, giving $q = 5.2$, $i = 87°$, $T_2 = 6312$ K, and degree of contact of $f \approx 67\%$. Figure 2 shows the best fit solution, from the W UMa model, with our observed light curves in the B, V, R, and I filters, and Figure 3 gives a visual interpretation of the system at phase 0.25, as generated by PHOEBE.

The model described above provides the best fit to our observed curves, most notably in the plateaus of the minima. However, other models were found which, though they do not give the best fit, perhaps should not be entirely discarded. A system with $q \approx 3.2$, $T_2 \approx 6188$ K, and $i \approx 70°$, or a system with $q \approx 1.3$, $T_2 \approx 4616$ K, and $i \approx 70°$, both provide solutions which do not have flat minima but are within the scatter of our data. Thus, though the first model we described gives the best fit, perhaps other models should not be entirely ruled out, as they may also give valid solutions. We will further work with the models to refine our solution, explore other possible factors such as spots and a third light, and more precisely determine the parameter values.

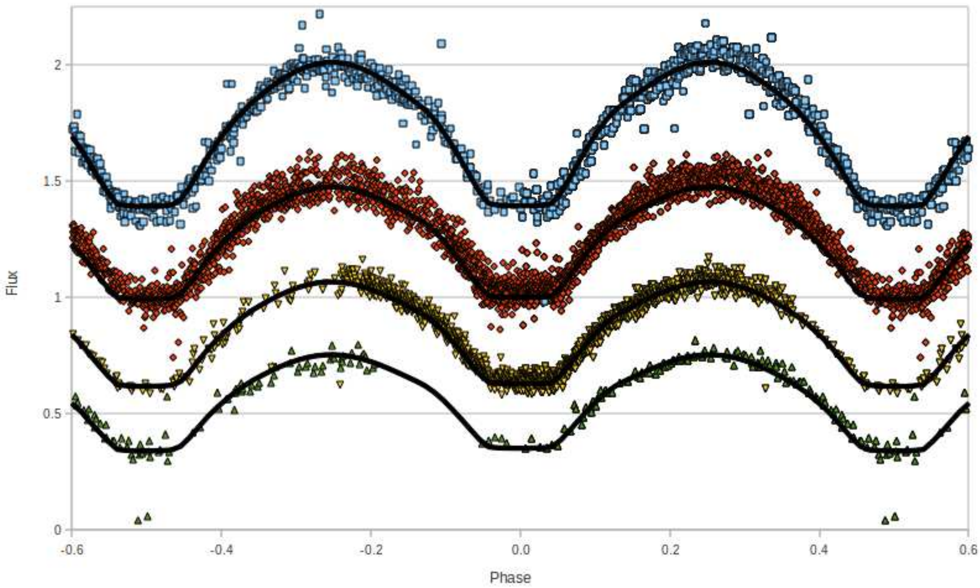

Figure 2. Observed data and solution light curves in, from top to bottom, B, V, R, and I filters. The calculated curves are shown as solid lines.

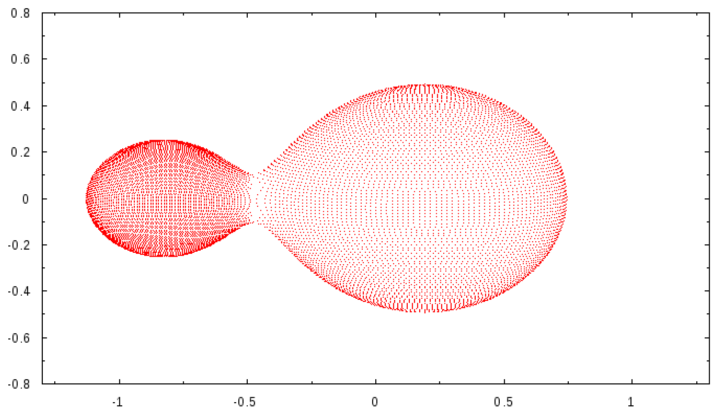

Figure 3. Geometric representation of J194643.44+472029.4.

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We had initially reported a period change in this binary system that occurred toward the end of our available data. Analysis of images obtained later on, however, did not show the new period to persist. Through further investigation, we found that, unbeknownst to us, there had been an error in the time in the telescope computer during the acquisition of the data at the end of our original set. This caused the observation times of these images to be off, which led to our interpretation of a period change. We have since corrected the error, and the binary's period remains consistent with the original value of $P = 0.346178$ d.

The authors