Search For Planets In Binary Stars in Campaign 9 and 10 Field of View

We are searching for transiting planets in binary stars with the K2 mission. This planet survey takes advantage of the large field of view (FOV) and the exquisite photometric precision of the Kepler satellite (Howell et al. 2014), observing an unprecedentedly large sample of binary stars (~1100 systems in total, 73 in Campaign 9, 162 in Campaign 10). By the end of the K2 mission, we will directly measure the planet occurrence rate in binary stars with a precision of a few percent.

Two surprising results arise when analyzing our binary sample (see Campaign 6-7 GO proposal for target selection details). First, two hot Jupiters (KOI-13 and WASP-85) were found among 208 Kepler+K2 binary stars (from Campaign 0 and 1). Given the rare occurrence of HJs, i.e., ~1% (Wright et al. 2012) and the geometric transiting probability (~10%), it is not expected that any hot Jupiters would be found among these binary stars. The other surprising result is that no other planet was found in these binary stars. Given the sample size, 3-4 planet candidates are expected given the overall planet detection rate for Kepler, i.e., ~4000 planet candidates from 150,000 Kepler stars. The two surprising results motivate us for this project. We have had a successful GO proposal for Campaign 6 and 7. This DDT proposal will increase our sample size by 27% (from 847 to 1082) and hence improves the statistics of our result. Table 1 summarizes the planet occurrence rate in binary stars and its uncertainty for a sample of ~1100 binary stars.

Table 1. *Planet occurrence rate in different scenarios of planet detection(s) for a sample of 1100 binary stars in the Kepler and K2 FOVs*

Detection(s)	1	2	3	4	5
Kepler+K2 (1100 stars)	$1.6^{+1.6}_{-1.6}$%,	$3.2^{+2.0}_{-3.2}$%,	$4.8^{+2.7}_{-3.1}$%,	$6.4^{+3.0}_{-3.4}$%,	$8.1^{+3.3}_{-3.6}$%,

While we missed the deadline for submitting the normal peer review proposal due to two key members changing institutions (Wang to Caltech, Huang to U Toronto), we are making progress in developing data reduction pipeline and scheduling future follow-up observations.

We developed a pipeline to extract and analyze the light curves from the Kepler main mission and the K2 mission (Huang et al. 2012, 2015). We have analyzed the data for 141 binary stars from the Kepler main mission, and 67 binary stars from Campaign 0 and 1 of the K2 mission. We detected only one planet candidate, EPIC 201862715 (Fig. 1 Left). It is a hot Jupiter on a 2.7-day orbit. This candidate is also known as WASP-85b (Brown et al. 2014). The independent detection of WASP-85b demonstrates that our pipeline functions properly and delivers scientific discoveries. Fig. 1 Right shows the photometric precision for binary stars in the Kepler and K2 FOVs. We are working on optimizing the light curve extraction code and increase the typical photometric precision for bright stars.

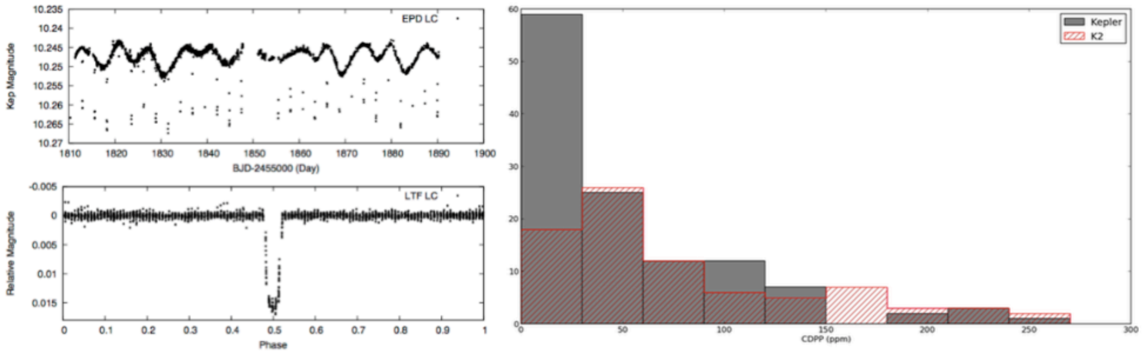

***Figure 1**. **Left**: Planet candidate from Campaign 1 (EPIC 201862715), time sequence data on top and phase folded data on the bottom. The candidate is known as WASP-85b (Brown et al. 2014). WASP-85b, and KOI-13, two hot Jupiters are the only two planet candidates in our binary star sample for the Kepler main mission and K2 Campaign 0 and 1. **Right**: distribution of 6.5-hour combined differential photometric precision (cdpp) for binary stars in the Kepler and K2 mission.*

All binary stars will be observed by Robo-AO at KPNO, an extremely efficient system for following up Kepler and K2 targets (Law et al. 2014), through collaboration with the Robo-AO team. AO imaging follow-up observations are critical in validating planet candidates (Barclay et al. 2013, Wang et al. 2013). The AO observation also determines the flux ratio of binary stellar components, which is necessary in the planet completeness study. One should make sure that flux dilution is considered when injecting simulated planet transiting signal. For example, a 1.4 Earth-radii planet would look like a 1 Earth-sized planet in an equal-brightness binary system.

We believe that this DDT proposal will contribute to our understanding of planet formation in binary stars, especially given the two surprising results we have seen from the Kepler and K2 Campaign 0 and 1 data.