A Search for Habitable Planets Around White Dwarfs in Field0

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The search for planets in the habitable zone has so far focused on solar-type stars and M dwarfs. However, transiting planets in the habitable zone around white dwarfs (WDs) may be common (Agol 2011, ApJ, 731, L31) and they provide our best chance to detect bio-markers on an exoplanet (Loeb & Maoz 2013, MNRAS, 432, L11). The habitable zone around WDs extends from 0.005 AU to 0.02 AU (P = 4-30 h, Agol 2011) for WDs older than about 1 Gyr. Since WDs are slightly larger than Earth, Earth-size and even smaller planets can easily be detected. We expect the planets within 1 AU of solar type stars to be destroyed in the giant phase. Hence, planets in the habitable zone around WDs must arrive there after this phase. There are several ways to form such planets near the WD or bring them closer (see the Kepler white paper by our team; arXiv:1309.0009). Planets have been detected around evolved, post-main-sequence stars. In addition, tidally disrupted asteroids and dwarf planets have been detected around 4.3% of WDs in the form of debris disks (Barber et al. 2012, ApJ, 760, 26). If the history of exoplanet science has taught us anything, it is that planets are ubiquitous and they exist in the most unusual places, including very close to their host stars and even around pulsars.

Here we propose to take advantage of the unique capability of the Kepler 2 mission to perform a transit survey of the WDs in Field 0. Using spectroscopy, photometry, and astrometry data from the McCook & Sion White Dwarf catalog, the Sloan Digital Sky Survey (SDSS), and the SuperCosmos Sky Survey (SSS), we identify 109 WDs with g = 13.4-19.9 mag within 12 deg of Field0. The attached target file contains the most precise coordinates for these targets, after taking into account proper motion information from the SDSS, SSS, and the literature. Only five of these targets are within 6 deg of the nominal Field0 pointing. However, this number can be significantly increased if Kepler points away from the Galactic plane and at areas previously imaged by the SDSS or SSS. We propose SC observations of the targets brighter than 18th mag and LC observations for the fainter targets. If there are not enough SC slots available for the brighter targets, LC mode data will still be useful for these WDs. Planets in the habitable zone would eclipse their stars for about 2 min. Hence, the LC mode data will dilute the transit signal by a factor of 15. However, since the transit depth is $>$50% for an Earth-size or bigger planet around an average size WD, these transits will have $>$ 3% depth in the LC data, and they will still be visible. Even with the decreased sensitivity of the 2wheel mode, Kepler can still detect transits of Earth-size or bigger planets around WDs.

Based on the model fits to the SDSS spectroscopy data, there are two DAV WD candidates, 111.874167+15.376361 (g = 17.6 mag) and 112.934500+16.072278 (g = 17.2 mag), among the SC targets. DAVs have pulsation periods of $\sim$10 min. SC data on these two likely DAVs would provide invaluable constraints on the interior models for WDs. In addition, there are two double degenerate systems in our target list: the 12-min period 102.888917+28.739833 with g = 19.1 mag and the 1.17 day period 93.444042+20.841750 with g = 15.8 mag. The former system is rapidly shrinking due to gravitational waves and it shows ellipsoidal variations, doppler boosting, primary, and secondary eclipses. Even though it is relatively faint, SC data on this system would turn Kepler into an indirect gravitational wave detector. LC data would still be useful for detecting a third body in this system.

The probability for a transit by an Earth-size planet at 0.01 AU is 1%. Hence, the discovery of habitable planets around WDs requires a survey of at least 100 targets, if all of them have such planets. This number can be built up over time through observations of the other fields (0 through 8) in the K2 mission. Our proposed survey is extremely cheap due to the small number of targets in Field0. On the other hand, this survey is capable of finding the first planets in the WD habitable zone, and the James Webb Space Telescope is capable of obtaining the first spectroscopic measurements of such planets (Loeb & Maoz 2013).