Multiwavelength Observations of Transiting Disintegrating Planetesimals around a WD  
Croll et al.

- **SCIENTIFIC JUSTIFICATION**

Recently the first transiting low-mass objects around a white dwarf were announced: Vanderburg et al. (2015) reported that the white dwarf WD 1145+017 hosted up to six or more disintegrating candidate planetesimals in extremely short-period orbits. K2 photometry revealed six distinct occultations with periods <5 hours, and ground-based follow-up displayed ~5 min eclipse events with transit depths as deep as 40% (Figure 1). The objects displayed the variable transit depths and the asymmetric transit profile (with a longer transit egress than ingress) that we have come to associate with disintegrating, low-mass objects - material is being driven from these planetesimals that is forming long cometary tails streaming behind them. That WD 1145+017 might be the best example of a white dwarf orbited by close-in planets/planetesimals is strengthened by two additional lines of evidence (Vanderburg et al. 2015): the spectrum of WD 1145+017 is significantly polluted (a visible spectrum revealed lines of calcium, aluminum, magnesium, silicon, nickel and iron), and it displays an infrared excess (likely arising from a larger planet or asteroid-sized body was orbitally perturbed, and then tidally disrupted leading to the observed debris disk). Therefore, WD 1145+017 is arguably the most compelling example of the many white dwarfs that have been observed to be significantly polluted as a result of what has been claimed to be the accretion of rocky bodies (Jura et al. 2003; Zuckerman et al. 2007, 2010). The most likely explanation for finding these planetesimals in these short period orbits around WD 1145+017 is that a larger planet or asteroid-sized body was orbitally perturbed, and then tidally disrupted leading to the observed debris disk, the polluted white dwarf spectra, and the multiple, transiting planetesimals in short-period, relatively stable orbits.

However, follow-up multiwavelength photometry by Croll et al. (submitted) indicated that the exact number and rough periods of the orbits of these planetesimals is uncertain. It appears like there are multiple orbiting objects in this white dwarf system with periods of ~4.5 hours, and that the transits of these bodies may disappear on timescales as short as a few days (Figure 2). One explanation for the observations of this system to date (Vanderburg et al. 2015; Croll et al. submitted) may be that we are observing a larger body that is in the midst of being tidally disrupted by this white dwarf. Tidal disruption events have been previously suggested to endure for as short as a few years (Debes et al. 2012; Xu & Jura 2014). Therefore rather than observing just a handful of objects in stable orbits around WD 1145+017, we may be observing a swarm of objects that are being tidally disrupted with material accreting onto the white dwarf.

The longitudinal coverage of the Whole Earth Telescope (WET) will offer a crucial advance in determining the number of objects in this system. If the observations occur during February/March 2016, WD 1145+017 will be visible from most sites for ~8 hours per night, allowing us to usually detect two transits per night from ~4.5 hour period objects from a single site. Stitching together photometry from many sites distributed in longitude will even further stretch this baseline. The day/night gaps of single-site photometry of WD 1145+017 to date (Vanderburg et al. 2015; Croll et al. submitted) has prevented us from detecting many transits in a row, and therefore determining the number of transiting planetesimals in the system. The longitudinal coverage of the WET network will allow us to closely monitor the evolution of the depth and shape of the transits (such as in Figures 1 and 2) for long stretches of time, allowing us to determine the number of transiting objects in the system and whether these planetesimals are quickly disintegrating and accreting onto their star.

By using multiwavelength photometry from larger telescopes (>1-meter) in the WET network we can place constraints on the particle sizes of the dusty material in the cometary tails trailing these planetesimals. In Croll et al. (2015) we have already used photometry from the ~1 - 4-meter class telescopes to place a limit on the particle sizes in the cometary tails of these objects of ~0.15 \( \mu m \) or larger, or ~0.06 \( \mu m \) or smaller with 2\( \sigma \) confidence. WET multiwavelength photometry from telescopes greater than 1-meter in diameter should be precise enough that if we observe a 40% transit depth (as has been observed previously for this object; Figure 1; Vanderburg et al. 2015) we will be able to differentiate between 0.1 and 1.0 \( \mu m \) pyroxene particles with strong confidence - for 0.1 \( \mu m \) particles the transit depth should be demonstrably deeper than at very near-infrared wavelengths. By observing for many days in a row the WET photometry should allow us to detect many deep transits, and

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determine if the particle size in the cometary tails is consistent from transit-to-transit, and for each of the short-period objects in the system.

Such strict particle size limits will help to determine the disintegration mechanism (collisions, tidal disruption, a Parker wind, etc.) that has led to both the cometary tails and the arrival of these planetesimals in such short period orbits. Naively, tidal disruption and collisions with other planetesimals or the debris disk would lead to large particle sizes, while the conventional scenario of free-streaming of metal vapours that condense at altitude would likely lead to sub-micron particle sizes. We will be able to differentiate between these scenarios with high confidence.

Lastly, photometry with large telescopes (>3-meter) if available will also greatly improve our understanding of this system. Large telescope photometry will allow us to obtain accurate optical photometry, even with short exposure times (~20 s); this will allow us to sensitively probe the transit profiles of the disintegrating planetesimals, therefore confirming or ruling out trailing and leading cometary tails, and whether the transit profile is consistent from transit-to-transit, or object-to-object. Previously, our Discovery Channel Telescope (~4.3-meter) observations of WD 1145+017 indicated that this star displayed low level variability at all times (Figure 3), rather than just during the deep ~10 - 40% transit events. The likely explanation for this behaviour is that dusty material is constantly passing in front of the white dwarf, either from the debris disk or from discarded material from the planetesimals. Follow-up large telescope optical observations will reveal whether this low level variability is a ubiquitous feature of photometry of WD 1145+017, or whether this low level variability has evolved from this past year. If it has evolved, this would represent concrete evidence that we are witnessing a planet/planetesimal that is in the midst of being tidally disrupted, and significant evolution is occurring on timescales of a year or less.

References:
Vanderburg, A. et al. 2015, Nature, accepted;
Fig. 1.— Photometry of two transit events in a single night of WD 1145+017. Note the 40% transit depths!

Fig. 2.— Photometry of WD 1145+017 from four transit events on four consecutive nights believed to be due to the same disintegrating object. Note the evolution in the transit shape and depth from night-to-night.
Fig. 3.— DCT/LMI observations of WD 1145+017 on UTC 2015 May 11 in the V-band. The observed low level variability is unlikely to be due to pulsations, and is likely due to dusty material passing in front of the white dwarf and scattering light out of the line of sight.