On the Detection and Characterization of Polluted White Dwarfs

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Background

Observations of circumstellar disks provide a method of studying planet composition, formation, and evolution. Between 1/3 and 1/4 of white dwarfs (WDs) cooler than 20,000 K are "polluted," or display the presence of atoms heavier than helium in their atmospheres.[7] Due to the fast gravitational settling times of heavy elements in a WD atmosphere, the presence of those heavy elements is linked to the accretion of dust from planetesimals perturbed by unseen planetary systems. **Most importantly, spectroscopic determination of the abundances of these heavy elements in the atmospheres of WDs provides an indirect, but uniquely powerful tool to determine the detailed elemental compositions of accreted extrasolar planetesimals.**[7]

With Polluted WDs:

Observe the tidal disruption of a minor planet

Determine the compositions of rocky, extrasolar bodies

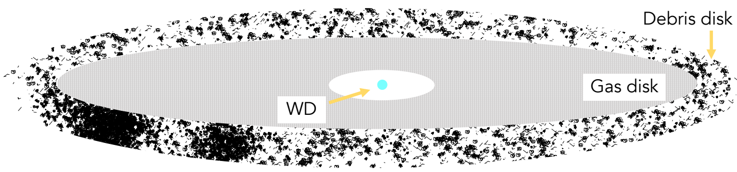
Polluted WD Stats

- ~ **30%** of WDs are polluted by metals[3]
- **~10** WDs show gas emission lines
- **~2%** of WDs show an IR-excess consistent with dust rings near the tidal disruption radius for these stars[4]
- **~15** WDs have at least five detected pollutant elements in their atmospheres

Case Study: **WD1145+017**

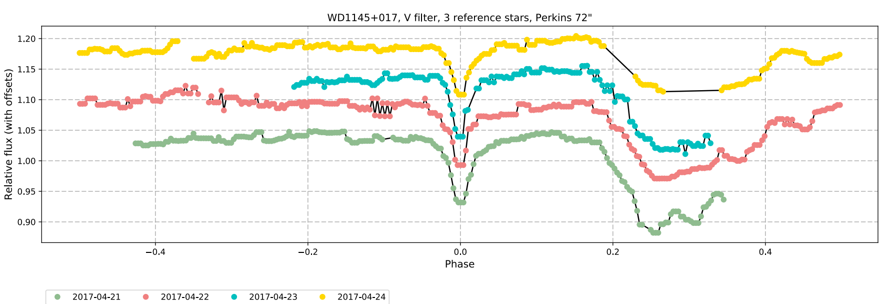
Observed features of WD1145+017

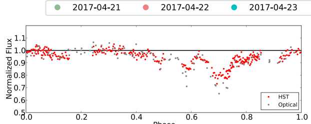
- Monthly variation
- Phase drifts
- Shallower UV transits

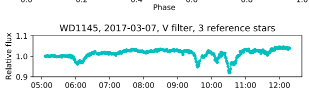


- Rapid changes of circumstellar gas
- Accretion from volatile-depleted differentiated rocky material

Planetesimal Detection

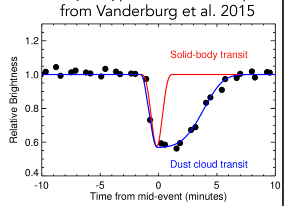




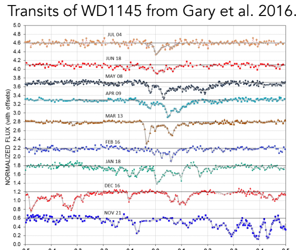


Top: 4 nights of observations of WD1145+017 in April 2017 we obtained at Lowell Observatory.
Left top: A UV light curve (from COS) of WD 1145 taken nearly simultaneously with the optical light curve (from the ARIES telescope) in February, 2017. The transit depth is ~10% shallower in the UV than in the optical (Xu et al. in prep).
Left bottom: A transit of WD1145 we observed with the Perkins 72" telescope. The shape of the transits varied from late February to late April.
Right: FLWO transits (black circles) compared to a solid body transit and a dusty tail transit models. The model bodies transit a white dwarf in a 4.5 hour orbit.[2]

Object type and transit shape from Vanderburg et al. 2015



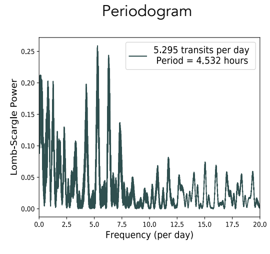
Transits of WD1145 from Gary et al. 2016.



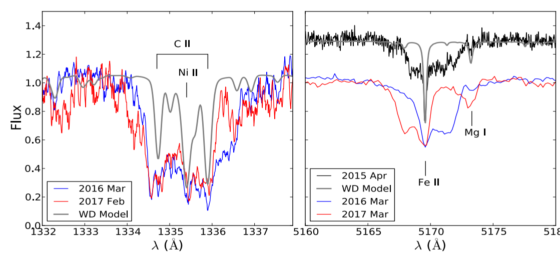
Characterization

WD1145 has a mass of 0.6 $M_\odot$ and radius of 1.4 $R_\oplus$.[2] If we assume the planetesimal mass is much less than the WD mass, then we find that the planetesimal with a period of ~4.5 hours orbits at an average distance of ~90 R_{WD}. This distance is less than the Roche limit assuming a fluid satellite (i.e. a rubble pile), R_{rl} >100 R_{WD}.

Periodogram



Gas Detection



Both panels show cool circumstellar lines (left panel: COS and right panel: Keck/HIRES and ESI). From 2016 to 2017, the circumstellar lines change in both the UV and optical parts of the spectrum from mostly red-shifted to blue-shifted. In general, the lines are stronger in the UV because the transition typically comes from a lower energy level with a higher oscillator strength. On the right, the circumstellar line from the original discovery in 2015 is shown in black for comparison. From Siyi Xu et al. in prep.

Characterization

Heavy element (dominant) mass	6.6×10^{23} g (70% M_{Ceres})
Total mass of heavy elements	O, Fe, Mg, Si
Mass fraction of oxygen	60%
Mass accretion rate (steady state)	4.3×10^{10} g s^{-1}

What's next?

- Continued multi-wavelength photometric and spectral observations
- Search for WD1145 analogs

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References
1. Koester et al. 2014, 2. Vanderburg et al. 2015, 3. Gary et al. 2016, 4. Xu et al. 2016, 5. Croll et al. 2017, 6. Bonsor et al. 2017, 7. Jura & Young 2014, 8. Kral, Clarke, & Wyatt 2017