Part II Astrophysics Essay 2021

Planetary Systems Around White Dwarfs

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All stars like our Sun will one day evolve to become giants, before ending their lives as cool, compact remnants known as white dwarfs. Whilst inner planets may be engulfed and planetary orbits will expand, the outer regions of our Solar System should survive this stellar evolution to become a planetary system orbiting a white dwarf. This essay should discuss the observational evidence for planetary systems around white dwarfs and our theoretical understanding of the origin of the observations. There are a number of directions that could be explored. To summarise the main observational evidence for planetary systems around white dwarfs:

White dwarf pollution:
White dwarfs have thin, hydrogen or helium atmospheres, which should be devoid of heavier elements due to their strong gravity. About 30% of white dwarfs (Zuckerman et al, 2010) exhibit signatures of metals in their spectra. Most white dwarfs are thought to have accreted planetary material dominated by typical rocky elements, such as those that dominant Earth's bulk composition, including Mg, Fe, Si and O. A handful of objects are icy. It is not clear whether the white dwarfs have accreted one or many bodies, but they are typically assumed to be approximately asteroidal in size (up to minor planets).

Dusty emission close to white dwarfs:
Infrared observations find dust close to 1-4% of white dwarfs. This dusty material plausibly traces the accretion of planetary bodies onto the star. In a handful of cases, strong variability in the infrared emission is thought to trace the stochastic nature of the accretion processes (e.g. Xu et al, 2014, Farihi et al, 2018).

Gasesous Emission:
Most notably emission from the calcium triplet from gas found close to a handful of polluted white dwarfs. Again, this presumably traces the accretion of metals onto the star. However, open questions remain as to the geometry of the accretion and why only a handful of objects have detections. In most cases, the gas is variable (Manser et al, 2016)

Transiting planetesimals?
The famous white dwarf WD 1145+017 is regularly partially blocked by dusty material passing between us and the star. Whilst regular orbital periods of around 4 hours suggest that the white dwarf may be orbited by a (number) of planetesimals just outside the tidal disruption sphere, features in the transit light curve appear and disappear and there is yet to be a good explanation for the observations.

Planets around white dwarfs:
Vanderburg et al, 2020, annouced the discovery of a giant planet candidate transiting the white dwarf, WD 1856+534 every 1.4 days. The planet candidate is roughly the same size as Jupiter.

References
J. Farihi, Circumstellar debris and pollution at white dwarf stars, vol. 71, pp. 9-34, Apr. 2016, doi: 10.1016/j.newar.2016.03.001.
J. Farihi et al., Dust production and depletion in evolved planetary systems, vol. 481, no. 2, Art. no. 2, Dec. 2018, doi: 10.1093/mnras/sty2331.
C. J. Manser et al., Doppler imaging of the planetary debris disc at the white dwarf SDSS J122859.93+104032.9, vol. 455, pp. 4467:4478, Feb. 2016, doi: 10.1093/mnras/stv2603.
A. Vanderburg et al., A disintegrating minor planet transiting a white dwarf, vol. 526, pp. 546"549, Oct. 2015, doi: 10.1038/nature15527.

Vanderburg, A., Rappaport, S.A., Xu, S. et al. A giant planet candidate transiting a white dwarf. Nature 585, 363–367 (2020). https://doi.org/10.1038/s41586-020-2713-y
D. Veras, Post-main-sequence planetary system evolution, Royal Society Open Science, vol. 3, p. 150571, Feb. 2016, doi: 10.1098/rsos.150571.
S. Xu and M. Jura, The Drop during Less than 300 Days of a Dusty White Dwarf's Infrared Luminosity, vol. 792, p. L39, Sep. 2014, doi: 10.1088/2041-8205/792/2/L39.
B. Zuckerman, C. Melis, B. Klein, D. Koester, and M. Jura, Ancient Planetary Systems are Orbiting a Large Fraction of White Dwarf Stars, vol. 722, pp. 725736, Oct. 2010, doi: 10.1088/0004-637X/722/1/725.