# HW Vir: are the circumbinary planets really there?

A DDT proposal for Campaign 10 by: M. Bours & M. Vučković

**Proposal summary:** We propose short-cadence observations of the unique, hot-subdwarf post common envelope binary system HW Vir, a prototype of detached eclipsing binaries comprising of a hot subdwarf B primary and a cool M-dwarf, in order to pin down the current orbital period variations and confirm the presence of the proposed circumbinary planets.

**Motivation:** Close binaries consisting of a compact object and a main-sequence star are the survivors of a spectacular phase of binary-star evolution (Ivanova et al. 2013). During the common-envelope phase that results from the more massive star evolving into a giant, the two stars orbit within a single envelope. This is then rapidly expelled when energy is frictionally transferred from the orbit to the envelope during the spiral-in phase. The emerging post-common-envelope (PCEB) binary typically consists of a white dwarf or hot-subdwarf star and a low-mass main sequence companion that orbit their common centre of mass every few hours. These important systems have been used to constrain many aspects of binary-star evolution (e.g. Schreiber et al. 2010; Zorotovic et al. 2010). In addition, when they are eclipsing, these binaries are ideal laboratories for measuring fundamental stellar and binary parameters (e.g. Parsons et al. 2010; Bloemen et al. 2011; Vučković et al. 2016).

Since the start of large all-sky and other ground-based surveys the number of eclipsing PCEBs has increased to $\sim 100$. High-resolution photometry can fully resolve the white dwarf / subdwarf eclipses, which is used to accurately measure eclipse times. This led to the discovery that almost all PCEBs that have been observed for at least several years show variations in their orbital period of several minutes (Bours et al. 2014; 2016 - in prep.).

There are currently two competing models that could explain the variations we see in the observed minus calculated (O-C) eclipse time diagrams. The Applegate and Lanza mechanisms propose that the underlying cause is in Solar-like magnetic cycles experienced by the M-dwarf (Applegate 1992, Lanza et al. 1998, Lanza 2006). These redistribute the star's angular momentum, causing a varying gravitational quadrupole moment, which couples to the binary's orbit and changes the orbital period semi-periodically. The second theory assumes that one or more unseen companions are present in wide, circumbinary orbits. The presence of this extra mass causes the binary to wobble around the system's centre of mass, thereby causing eclipses to be observed slightly advanced or delayed with respect to the expected eclipse time in a sinusoidal manner (Irwin 1959). Such planets must have either survived the common-envelope evolution of the host binary star, or they must have formed from material ejected at the end of the common-envelope phase as second generation planets (Perets 2011) – both exciting scenarios.

**The target:** HW Vir is a PCEB consisting of a hot subdwarf-B (sdB) star and a cool M-dwarf. It is the prototype of the detached eclipsing sdB binaries, such as KIC 9472174, which was extensively studied with Kepler (Østensen et al. 2010) and was recently claimed to host a planetary system (Baran et al. 2015). HW Vir has an orbital period of 2.8 h and it has been consistently monitored since its discovery (Menzies & Marang 1986).

Significant eclipse time variations were found by Kilkenny et al. (1994), who were the first to propose the presence of a third body in the HW Vir system. Subsequent observations (Kilkenny et al. 2003; İbanoğlu et al. 2004) further supported this theory. Based on 24 years of eclipse timings Lee et al. (2009) then proposed the presence of two circumbinary Jovian planets. However, subsequent observations disproved the validity of this model, which was also found to be dynamically unstable (Horner et al. 2012).

Beuermann et al. (2012) proposed a new planetary model, that does satisfy dynamical stability criteria, and also includes two Jovian planets. The most recent eclipse times, measured in 2013, agree with this model. In addition, we have recently found an infrared excess in WISE observations of HW Vir. This suggests the presence of a dusty disk around the close binary, which may be part of a planetary system. Since 2013 there have been no more eclipse observations of HW Vir, which is creating a critical gap in the eclipse time coverage and will introduce parameter degeneracy in any model trying to narrow down the parameters of the planetary system. Therefore, we urgently need eclipse observations of HW Vir! Observing this binary with the Kepler K2 mission will allow us to minimise this gap in coverage, and, more importantly, will allow us to test the most recent planetary model. In order to resolve the sdB eclipses, which only last 20 minutes, we request short-cadence observations. Kepler has already given a remarkable contribution to this field: besides KIC 9472174, two more planetary systems around single evolved sdB stars were claimed by measuring the photometric modulation caused by illumination effects (Charpinet et al. 2011; Silvotti et al. 2014). The K2 data are not long enough for these kinds of detections but the short-cadence K2 data on HW Vir, together with the existing long-term ground-based observations, have the strong potential for confirming the fourth sdB planetary system.

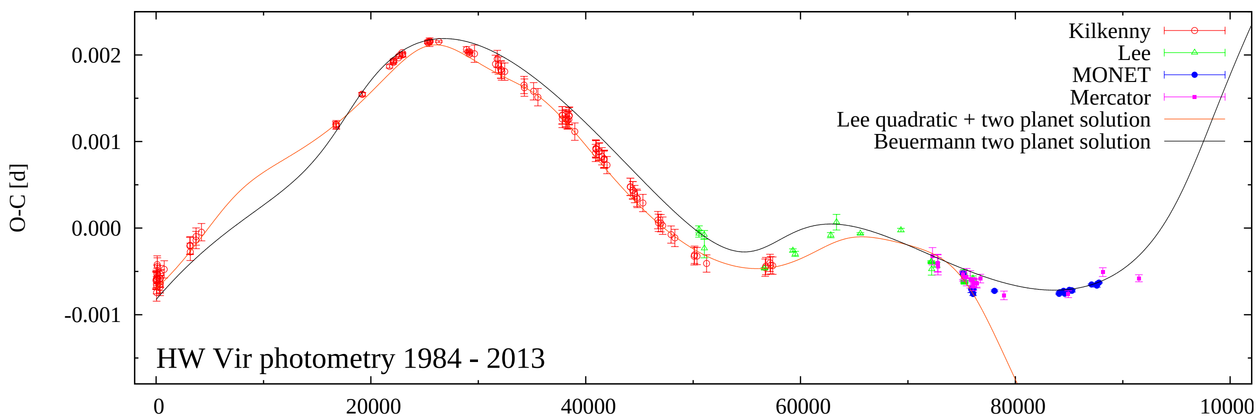


Figure 1: Observed minus calculated (O-C) eclipse times for HW Vir, including data published by various authors and with our own measurements in magenta. The last observations are from 2013. The solid lines indicate fits by Lee et al. (2009; red line) and Beuermann et al. (2012; black line), with the latter predicting O-C times of 0.002 days in late 2016.

**References:** Applegate, 1992, ApJ 385 ⋆ Baran et al. 2015, A&A 577 ⋆ Beuermann et al. 2012, A&A 543 ⋆ Bloemen et al. 2011, MNRAS 410 ⋆ Bours et al. 2014, MNRAS 445 ⋆ Charpinet et al. 2011, Nature 480 ⋆ Horner et al. 2012, MNRAS 427 ⋆ İbanoğlu et al. 2004, A&A 414 ⋆ Irwin 1959, AJ 64 ⋆ Ivanova et al. 2013, A&ARv 21 ⋆ Kilkenny et al. 1994, MNRAS 267 ⋆ Kilkenny et al. 2003, The Observatory 123 ⋆ Lanza et al. 1998, MNRAS 296 ⋆ Lanza 2006, MNRAS 369 ⋆ Lee et al. 2009, AJ 137 ⋆ Marsh et al. 2014, MNRAS 437 ⋆ Menzies & Marang 1986, IAUS 118 ⋆ Østensen et al. 2010, MNRAS 408 ⋆ Parsons et al. 2010, MNRAS 402 ⋆ Perets 2011, ApJ 727 ⋆ Schreiber et al. 2010, A&A 513 ⋆ Silvotti et al. 2014, A&A 570 ⋆ Skelton 2012, African Skies 16 ⋆ Udalski et al. 1992, AcA 42 ⋆ Vučković et al. 2016, A&A 586A ⋆ Zorotovic et al. 2010, A&A 520