Kepler light curves of hot subdwarf binaries

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Subluminous B stars or hot subdwarfs (sdBs) are core helium-burning stars with thin hydrogen envelopes and masses around $0.5\,M_{\odot}$ (see Heber 2009, ARA&A, 47, 211 for a review). A large proportion of the sdB stars ($40\,\%$ to $80\,\%$) are members of short-period binaries (e.g. Maxted et al. 2001, MNRAS, 326, 1391). Several studies aimed at determining the orbital parameters of short-period subdwarf binaries and have found periods ranging from $0.05\,\mathrm{d}$ to more than $10\,\mathrm{d}$ with a peak around 0.5 to $1.0\,\mathrm{d}$. For these close binary sdBs, common envelope (CE) ejection is the only feasible formation channel. The nature of the close companions to sdB stars is hard to constrain in general, since most of those binaries are single-lined with the hot subdwarf being the only star detectable in the spectrum. Measuring the Doppler reflex motion of this star from time-resolved spectra, the radial velocity (RV) curve can be derived and a lower limit can be given for the mass of the companion from the binary mass function. These lower limits are in general compatible with main sequence stars of spectral type M or compact objects such as white dwarfs.

Subdwarf binaries with massive WD companions are candidates for supernova type Ia (SN Ia) progenitors because these systems lose angular momentum through the emission of gravitational waves and start mass transfer. This mass transfer, either from accretion of helium onto the WD during the sdB phase (see Wang et al. 2013, A&A, 559, 94 and references therein), or the subsequent merger of the system (e.g. Webbink 1984, ApJ, 277, 355), may cause the companion to explode as SN Ia. Two of the best known candidate systems for SN Ia are sdB+WD binaries (Maxted et al. 2000, MNRAS, 317, L41; Geier et al. 2007, A&A, 464, 299; Geier et al. 2013, A&A, 554, 54). More candidates, some of which might even have more massive compact companions (i.e. neutron stars or black holes), have been found as well (Geier et al. 2010, A&A, 519, 25).

Eclipsing sdB binaries with cool, low-mass companion are called HW Virginis systems. The characteristic light curves of those binaries not only show eclipses, but also a sinusoidal variation caused by the irradiated hemisphere of the cool companions. Those companions usually have masses close to the nuclear-burning limit of $\sim 0.08\,M_{\odot}$ and with the discovery of two close brown-dwarf companions (Geier et al. 2011, ApJ, 731, L22; Schaffenroth et al. 2014, A&A, accepted) it was shown that substellar companions are able to eject a CE. Objects like brown dwarfs or even planets might therefore have a yet underestimated influence on late stellar evolution.

Several close binary sdB stars have been observed by the Kepler mission. Due to the unprecedented accuracy of the Kepler light curves it was possible to detect the eclipses of an earth-sized compact companion as well as general relativistic effects like Doppler boosting and even microlensing in the sdB+WD binary KPD 1946+4340 (Bloemen et al. 2011, MNRAS, 410, 1787). Those Only a few more sdB binaries with main-sequence and WD companions could be studied (Østensen et al. 2010, MNRAS, 408, 51; Østensen et al. 2011, MNRAS, 414, 2860; Pablo et al. 2012, MNRAS, 422, 1343; Telting et al. 2012, A&A, 544, 1), because of the rareness of those evolved objects in the original Kepler field.

Even with the lower accuracy achieved by the K2 mission, all close-binary subdwarfs will show characteristic signatures in their light curves caused by eclipses, the reflection effect from the cool companion, the ellipsoidal deformation of the sdB primary or the relativistic Doppler boosting. Since many of these effects are undetectable from the ground, the K2 mission provides a unique opportunity to study such objects. We have selected 36 hot subdwarf stars and candidates observable in campaign 1 from different photometric and spectroscopic surveys (e.g. MUCHFUSS, Geier et al. 2011, A&A, 530, 28; GALEX, Nemeth et al. 2012, MNRAS, 427, 2180). The sample contains two known close binary subdwarfs. PG 1136$-$003 has been discovered by the MUCHFUSS project and shown to be a close sdB+WD binary ($P = 0.2\,\mathrm{d}$, Geier et al. 2011, A&A, 526, 39). HE 1130$-$0620 is another solved sdB binary with an orbital period of $1.06\,\mathrm{d}$. The companion type is not known yet (Kupfer et al. in prep.). HE 1140$-$0500 and SDSS J113417.99+015322.1 show radial velocity variations and are most likely close binaries as well (Napiwotzki priv. comm.; Geier et al. in prep.). Those four objects should be priority targets. The rest of the sample consists of blue, UV-excess objects. Most of them are likely to be hot subdwarf stars, which are the dominant population in this magnitude range. Given the high binarity fraction of hot subdwarf stars, we expect to find at least 10 more close binaries in our sample.

The K2 mission provides us with the unique opportunity to study high-precision light curves of a large sample of hot subdwarf stars. In campaign 1 the number of good targets is especially high, because a part of the SDSS footprint is crossed. Therefore we propose 36 targets for long-cadence mode in campaign 1.