A survey to detect first sdB Planetary Transits

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Although only 2% of stars evolve through the subdwarf B (sdB) phase (Heber 1986, A&A 155, 33; see Heber 2009 ARA&A 47, 211 for a review on sdB/sdO stars), there are at least two good reasons to study sdB planets/BDs:

i. To date very little is known on the late-stage evolution of planetary systems. No planets detected yet orbiting a single white dwarf (e.g. Hogan et al. 2009, MNRAS 396, 2074). Theoretical models (e.g. Nordhaus & Spiegel 2013, MNRAS 432 , 500) predict a gap in the final distribution of orbital periods, due to the opposite effects of stellar mass loss (planets pushed outwards) and tidal interactions (planets pushed inwards) during the RGB and AGB. Observational constraints are essential to test the models.

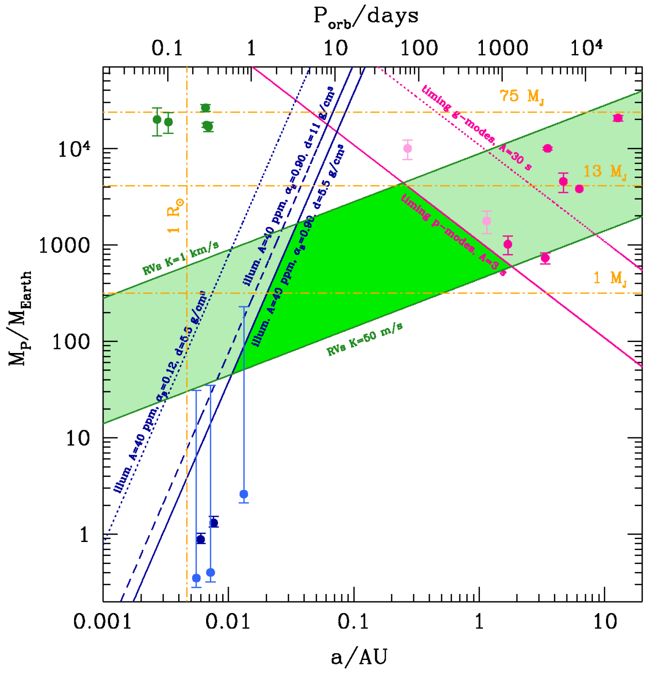
ii. The envelope ejection needed to form an sdB star is well explained in terms of close binary evolution for half of the sdBs that have a close stellar companion (Han et al. 2002, MNRAS 336, 449; 2003, MNRAS 341, 669), but is more problematic for the other half of apparently single sdB stars. The presence of close massive planets or BDs is a possible explanation (Soker 1998, AJ 116, 1308; Han et al. 2012, PASP Conf. Series 452, 3).

Over the last 6 years, almost 20 planets/BDs were detected, orbiting post-RGB extreme horizontal branch sdB stars (see Figure). They fall in 3 well separated regions of the $\mathbf{a} - \mathbf{M}_\mathrm{P}$ plane, corresponding to 3 different detection methods:

1. timing: 8 planet/BD candidates in wide orbits (3.2 to ∼16 yrs), 3 from pulsation timing in red and 5 from eclipse timing in pink (Silvotti et al. 2014, ASP Conf. Series, in press, and ref. therein) [→ *www.na.astro.it/∼silvotti/st.pdf*].

2. RVs: at least 5 BD candidates with very short orbital periods (1.8 to 7 h) in green (Geier et al. 2012, ASP Conf. Series, 452, 153 and references therein).

3. Illumination effects: 5 Earth-size objects in blue, likely remnants of planetary cores, in tight orbits (5.3 to 19.5 h), detected by *Kepler 1* (dark blue = Charpinet et al. 2011, Nature, 480, 496; cyan = Silvotti et al. in prep.).



Considering the 3d group, only 15 pulsating sdBs were observed by *Kepler 1* for a time sufficiently long to detect illumination variations of 20-50 ppm caused by Earth-size objects in tight orbits. Thus we can assume that 2/15 of sdBs have Earth-size objects orbiting at 0.005 AU from the star with $R_\mathrm{P} << R_{\mathrm{sdB}}$ and R_{sdB}=0.001 AU, giving a transit probability of 0.2. The probability to observe a transit is about 0.027, which means that, in average, we need to observe ∼40 sdB stars to see one transit.

Considering now the 2d group of more massive companions, Geier et al. (2012, ASP Conf. Series, 452, 153) found that 16% of their sample of 27 bright single-lined sdB stars do show small RV variations, that can be associated with massive sub-stellar companions. In this case the transit probability at 0.005 AU is about 0.28 (assuming R_P=0.9 R_{Jup}). So that, in average, 1 sdB out of ∼20 should show transits (and secondary eclipses).

As one can see, the 2 transit frequencies, obtained from independent methods/samples, are not very different !

The main goal of this proposal is to detect sdB planetary transits and measure for the 1st time sdB planet radii by targetting in SC ∼100 sdB/sdO stars in the 9 fields of *Kepler 2*. SC is required as the typical duration of the transit of a close planet with 6 h$<P_{\mathrm{ORB}}<$24 h is 15 to 40 min. The transit depth depends on the planet radius, varying between a 25% occultation for a Jovian planet down to 0.2% for Earth-like planets. Considering the high number of transits in a 83 days observation, *Kepler 2* should be able to measure objects with a radius smaller than the Moon. If we find transits, in 2-3 years from now PEPSI@LBT and EXPRESSO@VLT should be available to measure the star's RVs in order to obtain also the masses and densities of these extremely hot and peculiar planetary remnants.

The secondary goals is to detect photometric variations due to reflection effects by a faint stellar companion (WD or M-dwarf), ellipsoidal deformations, Doppler boosting. A subject important to shed light on sdB formation mechanisms and sdB evolution, in which *Kepler 1* has already given an important contribution. With *Kepler 2* we have the possibility to increase by a factor ∼5 to ∼10 the statistics of well studied sdB+WD and sdB+M-dwarf systems. We point out that the secondary goal is compatible also with LC data.

The attached list of candidates for field 0 contains 14 spectroscopically confirmed sdBs/sdOs for which we do not see any signature of stellar companions (the first 14 stars of the list) and 28 further candidates selected from UV excess and low PMs. We will try to obtain spectroscopic confirmation of those that will actually fall on silicon. From those already confirmed, we have seen that ∼50% of our candidates are sdB/sdO stars.
For the next fields, we have at the moment in average ∼50 sdB/sdO candidates per field and we are working on giving priorities and excluding binaries.