

Spectroscopic companions of very young brown dwarfs

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Summary. I review here the results of the first RV survey for spectroscopic companions to very young brown dwarfs (BDs) and (very) low-mass stars in the ChaI star-forming cloud with UVES at the VLT. This survey studies the binary fraction in an as yet unexplored domain not only in terms of primary masses (substellar regime) and ages (a few Myr) but also in terms of companion masses (sensitive down to planetary masses) and separations (< 1 AU). The UVES spectra obtained so far hint at spectroscopic companions of a few Jupiter masses around one BD and around one low-mass star (M4.5) with orbital periods of at least several months. Furthermore, the data indicate a multiplicity fraction consistent with field BDs and stellar binaries for periods < 100 days.

1 Introduction

The multiplicity properties of brown dwarfs (BDs) are key parameters for their formation. For example, embryo-ejection scenarios predict few binaries in only close orbits (see Delgado-Donate, this proceeding [3]), while isolated fragmentation scenarios allow for an abundance of binaries over a wide range of separations. In recent years, numerous low-mass and BD binaries were detected by direct imaging in the field and in young clusters and associations (see Bouy, this proceeding [2]). Based on these observations, it was found that very low-mass stars (VLMSs) and BDs pair less frequently in binary systems than solar-like stars. However, these surveys cannot resolve the inner ~ 3 to 10 AU (depending on distance) around the objects. Companions orbiting at such close separations may have originated based on a substantially different companion formation mechanism than the one found so far by direct imaging. They can be detected indirectly by spectroscopic Doppler surveys. Precise monitoring of the radial velocities (RVs) of BDs became possible in the last years with the generation of 8–10 m class telescopes. Shortly after the high-resolution echelle spectrograph UVES at the VLT saw its first light in October 1999, two programs were started with this instrument in spring 2000 and 2001 in order to systematically search for close companions to BDs and VLMSs in the very young ChaI star-forming region (Joergens & Guenther 2001 [8]; Joergens 2005 [9]) and in the field (Guenther & Wuchterl 2003 [6]). In this article, we present and discuss the current results of the survey in ChaI.

2 Results of RV survey in Cha I

In order to probe BD multiplicity at very young ages an RV survey of BDs/VLMSs in the Cha I star-forming region (~ 2 Myr) was started by Joergens & Guenther (2001 [8]). Among a subsample of ten BDs/VLMSs ($M \leq 0.12 M_{\odot}$, M5–M8), nine do not show signs of companions down to masses of giant planets. The sampled orbital periods for them are < 40 day corresponding to separations < 0.1 AU (Joergens 2005 [9]). Monte-Carlo simulations show that the data set provides a fair chance ($> 10\%$) to detect companions even out to 0.4 AU (Maxted & Jeffries 2005 [11]). For the BD candidate Cha H α 8 (M6.5), RV data were recorded with a time base of a few years and they indicate the existence of a spectroscopic companion of planetary or BD mass with an orbital period of at least several months or even years (Fig. 1). Thus, among ten BDs/VLMSs, none shows signs of BD companions with periods less than 40 days and one with a period > 100 days. Furthermore, the low-mass star CHXR74 (M4.5) also exhibit long-term RV variations (Fig. 4) that are attributed to an orbiting companion with at least 19 Jupiter masses.

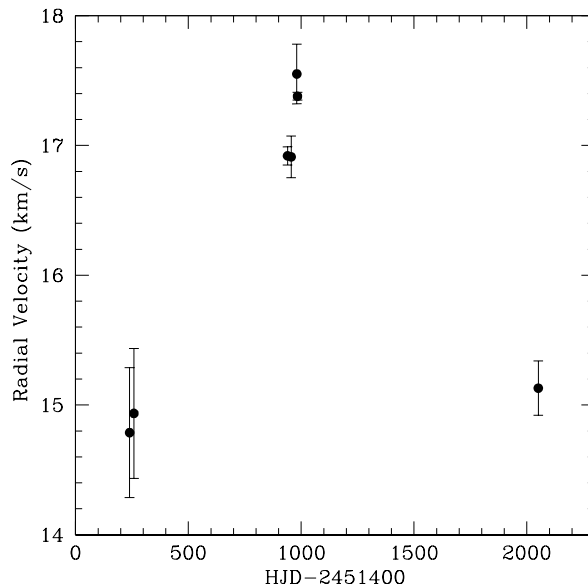


Fig. 1. Radial velocity data for the young BD candidate Cha H α 8 (M6.5) recorded with UVES/VLT: significant variability occurring on time scales of months to years hint at a companion at $a > 0.2$ AU and a mass $M \sin i$ of at least $6 M_{\text{Jup}}$ (Joergens 2005 [9]).

3 Detection of RV planets around BDs in Cha I feasible

The RV survey in Cha I revealed that very young BDs/VLMSs exhibit no RV noise due to surface activity down to the precision required to detect Jupiter mass planets (Joergens 2005 [9]). They are, therefore, suitable targets when using the RV technique to search for planets. In the upper panel of Fig. 2, the distribution of RV differences recorded for very young BDs and VLMSs ($M \leq 0.12 M_{\odot}$, M5–M8) is compared to the RV signal caused by a planet of 1–10 M_{Jup} . It shows that the RV signal of a giant planet is detectable well above the RV noise level for a BD primary. The lower panel of Fig. 2 displays as comparison RV data for T Tauri stars recorded by Guenther et al. (2001 [5]). The RV amplitude of a planet is completely swallowed by the large systematic RV errors of up to 7 km/s for them making planet detections by the RV technique around very young stars quasi impossible.

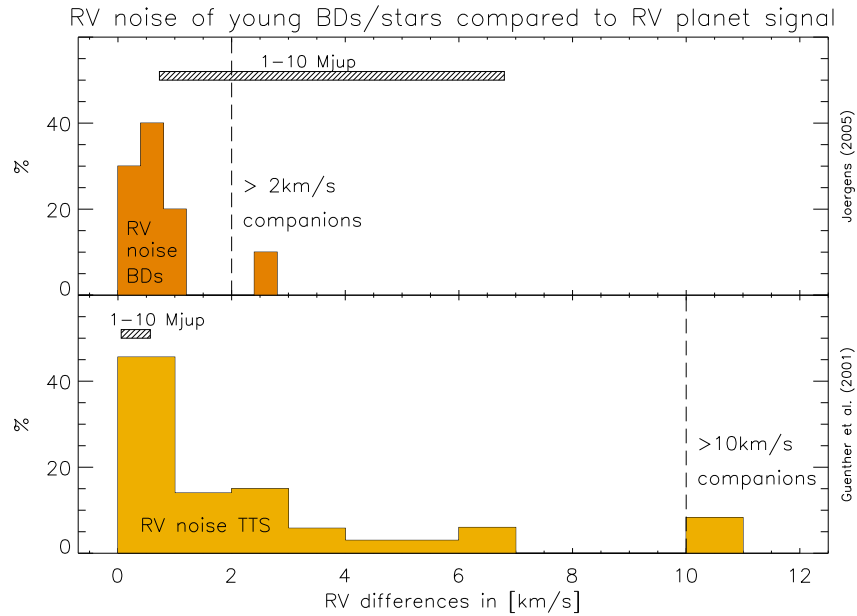


Fig. 2. Distribution of RV differences for very young BDs/VLMSs (upper panel, Joergens 2005 [9]) and for T Tauri stars (lower panel, Guenther et al. 2001 [5]). The plot shows that systematic errors caused by activity at very young ages are sufficiently small in the substellar mass regime to allow for detections of giant planets by the RV technique, which is not the case for T Tauri stars. RV differences/amplitudes in the plot are peak-to-peak values. Inserted ranges of RV planet signals were calculated based on circular orbits, a semi major axis of 0.1 AU and a primary mass of $0.06 M_{\odot}$ for BDs, and 1 AU and $1 M_{\odot}$ for T Tauri stars, resp.

4 Is the BD desert a scalable phenomenon?

If BDs form in the same way as stars, we should observe an equivalent companion mass distribution for both. Then, the BD desert observed for solar-like stars could exist as a scaled-down equivalent also around BD primaries, this would be a *giant planet desert*, as illustrated in Fig. 3 (Joergens 2005 [9]). The here presented RV survey started to test its existence for BDs in Cha I. For higher than solar-mass primaries, there are indeed hints that the BD desert might be a scalable phenomenon: while RV surveys of K giants detected a much higher rate of close BD companions compared to solar-like stars (e.g. Hatzes et al. 2005 [7], Mitchell et al. 2005 [12]), with only one exception they all do not lie in the BD desert when scaled up for the higher primary masses.

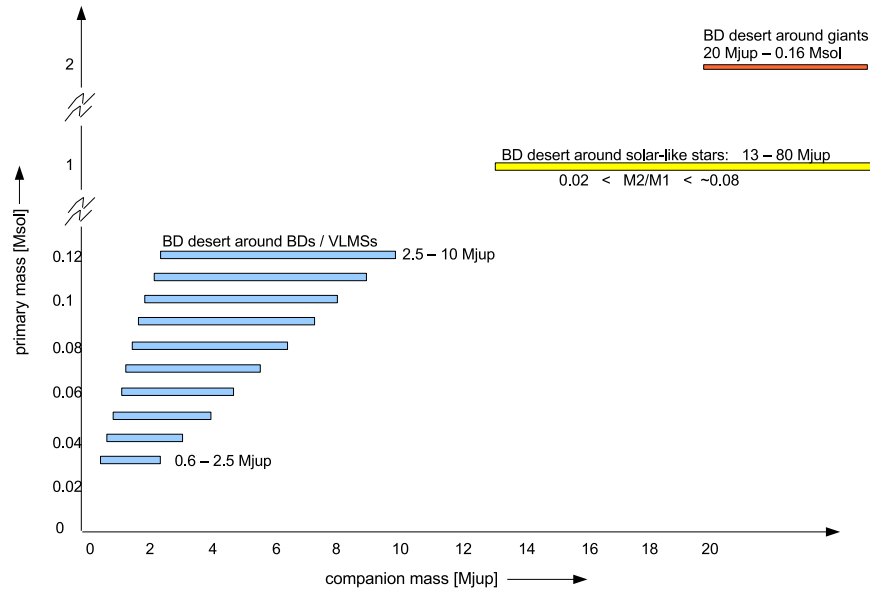


Fig. 3. Schematic illustration of the BD desert as observed for solar-like stars, and of a scaled version of it for lower primary masses (BDs/VLMSs), and for higher primary masses (giants).

5 Conclusions

The study of the multiplicity properties of BDs for separations of less than $\sim 3\text{--}10$ AU has been recognized as one of the main observational efforts that

are necessary in order to constrain the formation of BDs. This can be done by means of high-resolution spectroscopic surveys. We have presented here the current results of the first RV survey of very young BDs (Joergens 2005 [9]). It exploits the high resolving power and stability of the UVES spectrograph and the large photon collecting area of the VLT. A remarkable feature of this survey is that it is sensitive to planetary mass companions. This is due to a precise RV determination and to the fact that systematic RV errors caused by activity are sufficiently small for the targets to allow for the detection of Jupiter mass planets around them, as shown for the first time by this survey. Thus, very young BDs, at least in Cha I, are suitable targets for the search for close extrasolar planets in contrast to very young stars.

None of the BDs and VLMSs monitored shows signs of BD or planetary companions for separations smaller than 0.1 AU. This hints at a small binary fraction and a low frequency of giant planets in this separation range (zero of ten). Within the limited statistics, this result is consistent with the binary frequency found for field BDs/VLMSs ($12\pm 7\%$, Guenther & Wuchterl 2003 [6]) and with the frequency of stellar G dwarf binaries (7%, [4]) in the same separation range. For some of the Cha I targets also larger separations were probed leading to the detection of two candidates for spectroscopic systems: Both

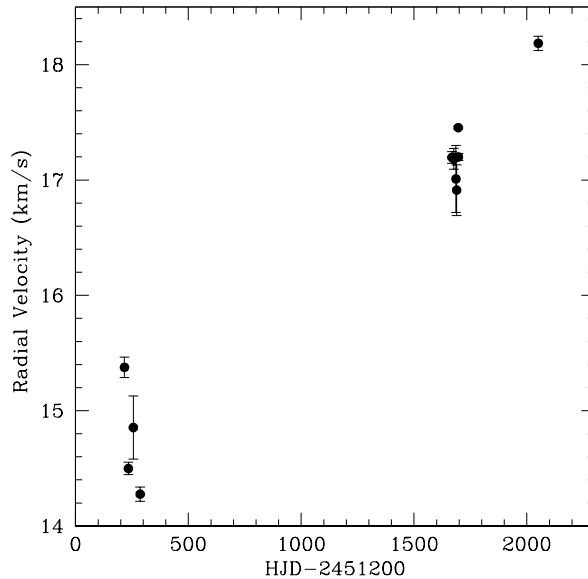


Fig. 4. Radial velocity data for the low-mass star CHXR 74 (M4.5) recorded with UVES/VLT: significant variability occurring on time scales of months to years hint at a companion at $a > 0.4$ AU and a mass $M \sin i$ of at least $19 M_{\text{Jup}}$ (Joergens 2005 [9]).

the BD candidate Cha H α 8 (M6.5) and the low-mass star CHXR74 (M4.5) exhibit long-term RV variations that were attributed to orbiting companions with several Jupiter masses at minimum. Orbit solutions have to await follow-up observations, however, the data suggest orbital periods of at least several months, i.e. separations of > 0.2 AU and 0.4 AU, resp.

Direct imaging surveys found a significantly lower frequency of BD binaries with separations $a > 3$ – 10 AU compared to solar-like stars [2]. This might be (partly) caused by a shift to smaller separations for lower mass primaries. The first surveys that probe the inner few AU around BDs by spectroscopic means are the one presented here (Joergens & Guenther 2001 [8], Joergens 2005 [9], fair detection efficiency for $a < 0.4$ AU [11], sensitive to M_{Jup} planets), and the following ones by other groups: Basri & Martín (1999 [1], detection of first spectroscopic BD binary), Reid et al. (2002 [13], single epoch spectra, sensitive to double-lined spectroscopic binaries), Guenther & Wuchterl (2003 [6], fair detection efficiency for $a < 0.7$ AU [11], sensitive to planetary masses) and Kenyon et al. (2005 [10], fair detection efficiency for $a < 0.02$ AU [11], sensitive to BD companions). These surveys do not hint at a higher BD binary fraction at $a < 1$ AU compared to stellar binaries indicating that also the overall binary frequency is lower in the substellar than in the stellar regime. While corrections have to be applied to the observed values because of selection biases (e.g. Burgasser et al. 2003) and sparse sampling of the velocity data (e.g. Maxted & Jeffries 2005 [11]), a primary goal is to enlarge and improve the available data set for BD spectroscopic binary studies in terms of sample sizes, phase coverage, and precision of RV data.

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