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Brown Dwarf Companions to Solar-Type Stars and other Brown Dwarfs

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Abstract. We report on our ongoing imaging efforts to detect brown dwarfs orbiting solar-type stars and other brown dwarfs. We study the properties of brown dwarf companions as a function of primary mass. Our results indicate that the frequency of brown dwarf companions around solar-type stars for separations larger than about 40 AU is non-negligible. The frequency of brown dwarf binaries is about 20%. There is a dearth of brown dwarf binaries with separations larger than ~20 AU. We propose that brown dwarf systems are a scaled down version of stellar systems, which probably form via triggered collapse of small molecular cores.

1. Relevance of Brown Dwarfs for Bioastronomy

Bioastronomy is a multidisciplinary branch of science that connects the world of living organisms to the rest of the cosmos. Thus, many aspects of astronomical knowledge are relevant to bioastronomy, from the properties of comets to the chemical evolution of galaxies, just to mention two very disparate topics. Brown dwarfs are newcomers in the arena of scientific inquiry because even though they were predicted to occur as a natural consequence of the hydrogen burning minimum mass (Kumar 1963; Hayashi & Nakano 1963), they have been revealed in large numbers only recently (see http://www.astro.umontreal.ca/browndwarfs/ for an online catalog, which at the time of writing this paper includes 145 L dwarfs and 31 T dwarfs). It is thus worthwhile to mention a few issues about brown dwarf research that may be particularly relevant for bioastronomy.

- Brown dwarfs are a good example of the application of the ecological principle. Any niche that is not forbidden by a physical law will be filled. Brown dwarfs were elusive for several decades but now we know that they are numerous, perhaps as numerous as stars.

- Brown dwarfs can be studied directly, without the glare of a nearby star. Thus they provide the opportunity to learn about the physical properties of objects that overlap in size and temperature with exoplanets.

- The coolest object directly observed outside the solar system is the brown dwarf companion to the multiple system Gl 570 ABC (Burgasser et al. 2000). Searches for brown dwarf companions are likely to identify even cooler objects.

- Dynamical mass estimates from orbital parameters can be obtained for brown dwarf binaries (e.g. Lane et al. 2001), providing fundamental tests for evolutionary models of substellar-mass objects.

- The formation of brown dwarfs is connected to the formation of stars and planets. The properties of brown dwarf companions yield clues to their origins.

- It is possible that our Sun could have a yet undetected brown dwarf companion. The frequency and mass distribution of brown dwarfs at large separations from stars is important to estimate the probability that the Sun has a substellar companion (Nemesis).

- Habitable regions around brown dwarfs are stable for long periods of time (Andreeshchev & Scalo 2004). Brown dwarfs themselves are good targets to search for habitable planets because the brightness contrast is more favorable than in the case of planets around stars due to their intrinsic faintness.

2. Surveys for Brown Dwarf Companions

2.1. Radial Velocities

High-precision radial velocity searches have detected a low frequency ($\sim$0.5%) of brown dwarf companions to G- and K-type stars with separations a$<$3 AU (Marcy & Butler 2000). However, Gizis et al. (2001) estimate using 2MASS data that the frequency of brown dwarf companions at large separations (a$>$1000 AU) is comparable to that of stellar companions ($\sim$10%). Armitage & Bonnell (2002) have proposed that the dearth of short-period brown dwarfs around solar-type stars may be a natural consequence of the evolution of circumstellar disks. In this scenario, brown dwarfs around very low-mass stars and other brown dwarfs, and at large separations from solar-type stars, should not be rare.

One brown dwarf in the Pleiades cluster is a double-lined spectroscopic binary (Basri & Martín 1999), and three late-M dwarfs in the field are also DLSBs (Reid et al. 2002; Guenther & Wuchterl 2003). The frequency of DLSBs among very low-mass stars and brown dwarfs appears to be $\sim$6%, which is comparable to the frequency of DLSBs among solar-type stars (Duquennoy & Mayor 1991).

A short-period Jovian-mass candidate planet may have been detected around the nearby brown dwarf LP944-20 (Guenther & Wuchterl 2003). The same authors report no planets with masses larger than 3 Jupiters and periods shorter than 100 days in a sample of 20 ultracool dwarfs.

2.2. Direct Imaging

The first surveys for brown dwarf binaries were carried out by Martín et al. (1999, 2000) using HST/NICMOS and CFHT/PUEO. In a sample of 32 very-low mass stars and brown dwarfs, two binaries were found with subarsecond angular separations and brightness ratios close to unity.

Recent searches for very low-mass binaries have been carried out with HST/WFPC2 and Gemini/Hokupa'a (Bouy et al. 2003; Close et al. 2002). Figure 1 summarizes the main result. The lack of ultracool dwarf binaries at small separations is due to the limited spatial resolution (~2.0 A.U.) of present-day surveys. As we mentioned before, the frequency of ultracool DLSBs is similar to that of solar-type binaries. The absence of ultracool dwarf binaries with separations larger than about 20 AU is real.

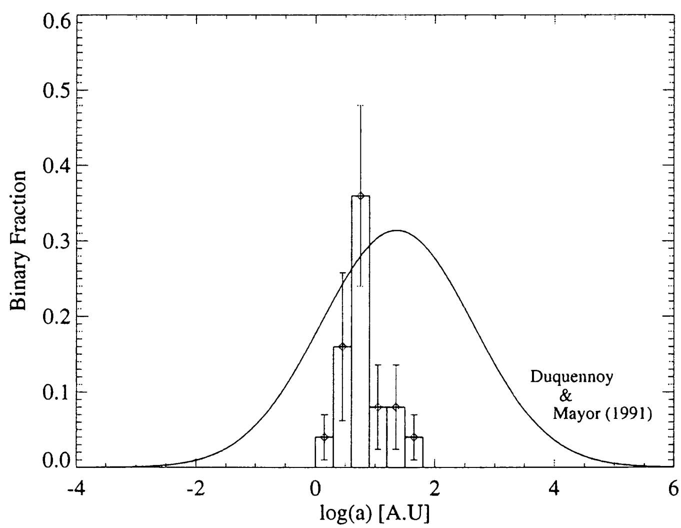

Figure 1. Distribution of separations for binary ultracool dwarfs (spectral type later than M7) in the field. The solid curve represents the distribution of Duquennoy & Mayor (1991) for G stars. Figure adapted from Bouy et al. (2002).

Direct imaging searches for brown dwarfs around main-sequence stars are uncovering a significant population of objects. Potter et al. (2002) found a binary brown dwarf in a sample of 31 young solar analogs, indicating a brown dwarf frequency of >3% at separations between 10 and 100 AU from the star. We have started a proper motion and photometric survey for brown dwarf companions to nearby (d<25 pc) G-type stars in the separation range 500-5000 AU.

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3. Discussion

The evidence indicates that brown dwarf systems are a scaled-down version of stellar systems. Since objects of brown dwarf mass are well below the typical Jeans mass in star-forming regions ($M_{Jeans} \sim 1\ M_{\odot}$), they are not expected to collapse spontaneously. However, brown dwarfs could form out of small self-gravitating molecular cores with typical sizes <20 AU and masses <0.1 $M_{\odot}$ (such low-mass cores are observed to be abundant in rho Ophiuchi; Motte et al. 1998) if they collapse under the effects of external triggering mechanisms, such as shock waves caused by stellar winds, supernovae or outflows from very young stars. If many brown dwarfs form in a similar way as stars, one important implication is that planets may be common at small separations from brown dwarfs, and that some of them may populate the habitable region. A search for planetary transits in brown dwarfs would be sensitive to terrestrial-sized planets due to the small radius of the primaries. Doyle et al. (2000) have recently proven that terrestrial planet transit detection around a very low-mass star is feasible with ground-based small telescopes.

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