Brown Dwarfs
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Wide Brown Dwarf Companions to Main-Sequence Stars

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Abstract. Many widely separated companions to main-sequence stars have been found using 2MASS. These companions include both stars and brown dwarfs. I discuss a number of systems of particular interest. Present indications are that a few percent of G dwarfs have brown dwarf companions.

1. Introduction

Why study wide brown dwarf companions to main-sequence stars? Such companions offer special opportunities to learn about brown dwarfs in general as well as posing special problems of their own. First, the brown dwarf-star system serves as a kind of "mini-cluster," in which studies of the relatively well-understood primary star constrain the properties of the secondary brown dwarf. Second, a solution of the problem of the origin of these systems, and more broadly the origin of both stars and brown dwarfs, requires measurement of the frequency, separation distribution, and mass distribution of the secondaries. As seen elsewhere in this volume, some theories of brown dwarf formation predict that wide brown dwarfs will be very rare. Finally, searches for wide companions offer the opportunity to discover cooler companions than those yet known.

While astronomers typically think of the "brown dwarf" desert discovered by radial velocity surveys (see Halbwachs et al. 2000), there is no necessary connection between the frequency of brown dwarf companions at < 3 A.U. and at > 1000 A.U. Indeed, many of the most famous — at least in the cool star and brown dwarf community — very-low-mass stars are actually wide companions: Proxima Centauri (the nearest star to the Sun), VB8 (the prototype M7 dwarf), and VB10 (the prototype M8 dwarf). In the field, the (isolated) mass function seems to be continuous across the hydrogen-burning limit. The existence of wide companions just above the hydrogen-burning limit then suggests that we should not be too surprised by the existence of wide brown dwarf companions.

2. 2MASS and Wide Companions

The Two Micron All-Sky Survey (2MASS) has proven to be a prodigious source of isolated cool dwarfs, whether late-M, L, or T. Remarkably, a number of the 2MASS discoveries proved to be companions to previously known nearby F, G, K or M stars; that is, the wide companions are discovered by 2MASS independently of the primary.

Here I discuss a few examples of 2MASS discoveries. Although 2MASS has completed scanning the entire sky, the entire sky has not yet been searched. It is therefore reasonable to expect that many more wide companions await discovery; the systems discussed here are merely examples. Indeed, Gizis et al. (2000b) and Gizis (2002) include probable companions noticed in the course of other investigations that were not discussed at IAU211. Meanwhile, Lowrance and Kirkpatrick are searching the 2MASS database around the positions of known nearby stars to identify companions.

Gizis et al. (2000a) reported on two interesting M dwarf secondaries at distances of about 15 parsecs from the Sun. Gl 376B is M6.5 star that is obvious on the Palomar plates and in ROSAT database but had been previously overlooked. It lies 2000 A.U. from its G dwarf primary, which was part of the classic Duquennoy & Mayor (1991) analysis of G dwarf multiplicity. LP 213-67 and LP 213-68 appear in the NLTT catalog but had not been previously studied; follow-up work from the 2MASS rediscovery reveal that they are a M6.5 and M8 separated by 250 A.U. It's interesting to note this wide system's components are close to the H-burning limit; the lack of wide brown dwarf-brown dwarf systems is somewhat surprising in comparison. The possible wide double brown dwarfs reported by DENIS in this volume may be relevant here.

The Kirkpatrick et al. (2000) study of 67 new 2MASS L Dwarfs included two which were wide companions to G dwarfs. As in the case above, both of these primaries were in Duquennoy & Mayor (1991). These companions are discussed extensively in Kirkpatrick et al. (2001). The early discovery of LHS 102B by EROS, supported by DENIS, is described in Goldman et al. (1999). Gizis et al. (2001b) discuss an L dwarf companion to a young K dwarf.

Other 2MASS discoveries are reported by Wilson et al. (2001), who constructed a near-IR spectrograph to confirm L dwarfs with a small telescope. The larger sample of isolated L dwarfs is as yet unpublished, but wide companion discoveries include an

In general, chromospheric activity allows an age estimate of the primary star in these systems. Admittedly, such estimates are imperfect, but nevertheless a considerable improvement on the situation for isolated L and T dwarfs. The key concept is that the observables for brown dwarfs, luminosity and temperature, are degenerate in respect to estimating mass and age. An L2 dwarf may be a very old star, or a younger brown dwarf. (In principle, it might even be a jupiter-mass planet, but the observable lifetimes of such planets are so short that this possibility is insignificant for the 2MASS survey.) Wilson et al. show that of the three L dwarf companions, one is a star, one is a brown dwarf, and one might be either.

The crown jewel of the 2MASS companions is Gl 570D (Burgasser et al. 2000). This T dwarf proved to be a companion to a system consisting of a K dwarf and a pair of M Dwarfs.[1] The Hipparcos parallax allows Gl 570D's

[1] An audience member remarked that Hipparcos astrometry supports the existence of a second brown dwarf in orbit around the K dwarf. It's also interesting to consider that Gl 570D and VB8 both exist in very high order multiple systems; improved statistics are needed to assess the significance of this.

luminosity, and hence its temperature, to be estimated. The 800K temperature makes this object the coolest T dwarf known with a secure temperature.

Hipparcos parallaxes of the primary stars has provided a number of distances to calibrate the L dwarf sequence. It is worth observing, however, that the position of the L dwarf 'main sequence' in the HR diagram from Hipparcos parallaxes is in excellent agreement with that determined by United States Naval Observatory measurements of isolated L dwarfs (Dahn et al. 2002). Since L and T dwarf luminosities are a crucial piece of constraints on brown dwarf temperatures and even the behavior of clouds (see this volume), this independent agreement is welcome.

In summary, 2MASS has identified new companions from 0.1 down to 0.02 solar masses at separations of hundreds to thousands of A.U. A few percent of cool dwarfs selected from the 2MASS database prove to be companions to more massive main-sequence stars.

3. The Wide Companion Fraction

The difficulties in estimating the true wide brown dwarf companion fraction are significant at present. Problems include incomplete sky coverage, incompleteness in selecting L dwarfs, biases from luminosity-selection and the resulting sensitivity to only younger brown dwarfs, the incompleteness of nearby star catalogs and the 2MASS incompleteness near bright stars.

It is interesting to note that about half of the known wide brown dwarf companions have more than one star as the 'primary.' Conclusions at this stage are premature, but some theories discussed in this volume predict that the wide brown companion fraction will be different for single and double stars. A complete sample is badly needed, and may help rule out some formation theories.

In any case, there are important clues that the wide companion fraction is a function of primary mass. The companions found at $>$ 1000 A.U. have FGK (and one M0) primaries (i.e., greater than $0.5M_{\odot}$). Certainly, no double L dwarfs have yet been noticed by 2MASS with separations greater than 100 (or even 10) A.U., even though such systems should be easily detected. Wide L dwarf companions to M dwarf primaries are known, but 'merely' in the range 100-1000 A.U.

Gizis et al. (2001a) used the initial 2MASS companion discoveries, the space density of brown dwarfs, and the space density of potential primary stars to argue that the wide ($>$ 1000 A.U.) brown dwarf companion fraction is at least a few percent, much greater than the $<$ 1% percent in the 'desert' at $<$ 3 A.U. This is interesting, since for *stellar* companions to G dwarfs, Duquennoy & Mayor (1991) found similar companion fractions for these two ranges (13% vs. 12%). Not only the brown dwarf fraction in this range is uncertain: Duquennoy & Mayor assumed an incompleteness of 50% for the widest companions, an assumption perhaps justified by the example of the overlooked Gl 376B. If the wide companion mass function is like the field, then perhaps 3 to 12% of G dwarfs should have companions; if like the desert, then $<$ 1%. The estimates of Gizis et al. indicate that the wide companion star-to-brown dwarf ratio may be similar to, or simply somewhat depleted from, the field ratio.

I point out here that a different approach might be taken to estimating this ratio. Since the entire Duquennoy & Mayor sample is about 160 G dwarfs, and two brown dwarf companions are known, even if further analysis of the 2MASS data does not reveal any more companions, we still have a 1% companion frequency for this fundamental G dwarf sample. This should be an underestimate of the true brown dwarf fraction, because only young ($\sim$ 1 Gyr, with a strong mass dependence) brown dwarf companions are detectable by 2MASS at the distance of the G dwarf sample. Based on either the two brown dwarf companions, or the entire isolated 2MASS sample, only about $7-18\%$ of brown dwarfs would actually be detected as L dwarfs. Thus, the brown dwarf companion fraction is apparently $\sim 3-5\%$.

4. Summary

2MASS, largely accidentally, has discovered M, L, and T dwarf wide companions to main-sequence stars. These include both stars and brown dwarfs. The primaries include single stars, double stars, triple stars, and stars with planets. The frequency of brown dwarf companions at different separations, around different primary masses, and in high-order systems promises to provide new constraints on theories of the formation of stars and brown dwarfs.

A full analysis of the entire sky is needed to determine companion frequencies with confidence. Around the time of IAU211, Lowrance et al. (2002) announced the discovery of a stellar M dwarf companion to υ And. This is the second new 2MASS cool companion to a star with a known planetary system. Since 2MASS represents less than 10 seconds exposure on a 1.3-meter telescope, deep pointed observations have the potential to discover many more cooler brown dwarf companions. Albert et al. (this volume) are conducting a deep search with 4-meter class telescopes and mosaic cameras.

References

Burgasser, A.J., Kirkpatrick, J.D., Cutri, R.M., McCallon, H., Kopan, G., Gizis, J.E., Liebert, J., Reid, I.N., Brown, M.E., Monet, D.G., Dahn, C.C., Beichman, C.A., & Skrutskie, M.F. 2000, ApJ, 531, L57

Dahn, C.C., Harris, H.C., Vrba, F.J., et al. 2002, AJ, 124, 1170

Duquennoy, A. & Mayor, M. 1991, A&A, 248, 485

Gizis, J.E. 2002, ApJ, in press

Gizis, J.E., Kirkpatrick, J.D., Burgasser, A., Reid, I.N., Monet, D.G., Liebert, J., & Wilson, J.C. 2001a, ApJ, 551, L163

Gizis, J.E., Kirkpatrick, J.D., & Wilson, J.C. 2001b, AJ, 121, 2185

Gizis, J.E., Monet, D.G., Reid, I.N., Kirkpatrick, J.D., & Burgasser, A.J. 2000a, MNRAS, 311, 385

Gizis, J.E., Monet, D.G., Reid, I.N., Kirkpatrick, J.D., Liebert, J. & Williams, R.J. 2000b, AJ, 120, 1085

Goldman, B., et al. 1999, A&A, 351, L5

Halbwachs, J. L., Arenou, F., Mayor, M., Udry, S., Queloz, D. 2000, A&A, 355, 581

Kirkpatrick, J.D., Reid, I.N., Liebert, J., Gizis, J.E., Burgasser, A.J., Monet, D.G., Dahn, C.C., Nelson, B. & Williams, R.J. 2000, AJ, 120, 447

Kirkpatrick, J.D., Dahn, C.C., Monet, D.G., Reid, I.N., Gizis, J, E., Liebert, J., Burgasser, A.J. 2001, AJ, 121, 3235

Lowrance, P.J., Kirkpatrick, J.D., & Beichman, C. 2002, ApJ, 572, L79

Wilson, J.C., Kirkpatrick, J.D., Gizis, J.E., Skrutskie, M.F., Monet, D.G., & Houck, J.R. 2001, AJ, 122, 1989

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