Brown Dwarfs and Extrasolar Planets
ASP Conference Series, Vol. 134, 1998
R. Rebolo, E. L. Martín and M. R. Zapatero Osorio (eds.)

A Young Population of Brown Dwarfs?

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Abstract. In a recent survey for faint red stars from a digital stack of Schmidt plates a number of candidate objects were identified. Parallax's for three of these objects have been reported showing them to have luminosities which interpreted within the available evolutionary models indicate them to be good brown dwarf candidates. The straightforward interpretation of their position in a colour magnitude diagram suggests that they are metal poor by 0.5–1.0 dex. However using standard spectral indices their spectra seem more consistent with the Pleiades brown dwarfs (PPL 15, Teide 1 and Calar 3) than with standard late-type M dwarfs. Our interpretation is that this is due to their selection by $R_F - I_N$ colours which at values > 3 preferentially selects objects with relatively low gravities. For late-type M dwarfs and brown dwarfs low gravities are expected to be a reliable indication of youth. We find some evidence that for a given spectral type dust formation is less prevalent in lower gravity objects. In addition to the spectral evidence the three stack objects whose parallax's have been measured show small tangential velocities which is a further indication of youth. We have constructed preliminary models for the number of brown dwarfs expected from the digital stack survey. We find that most of the objects expected are brown dwarfs less than 1 Gyr old and because of this it is important to make such models using a time-dependent scale height.

The main problem with the interpretation of finding young brown dwarfs from the plate stack is that their position in the HR diagram does not easily fit with the Pleiades sequence of brown dwarfs or the predictions of evolutionary models. The clear resolution of these issues probably requires further parallax measurements and follow-up observations of the new objects together with considerable work on high-temperature dust opacities and their inclusion in evolutionary models.

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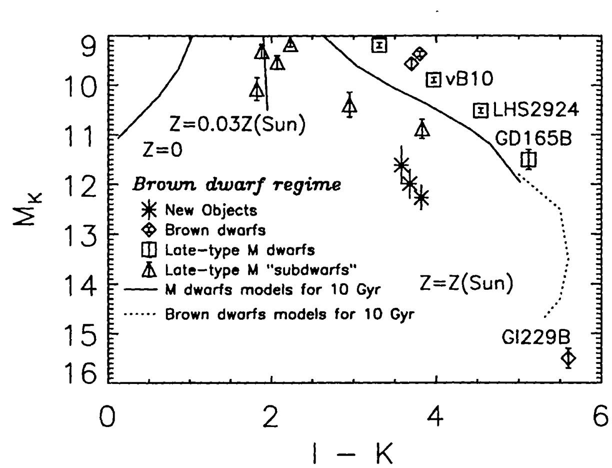

Figure 1. M_K versus $I - K$ for the objects from the stack with parallax measurements. The plot also includes standard late-type M dwarfs, 'sub-dwarfs', the known brown dwarfs and the predictions of current evolutionary models. All observational M_K's include Lutz & Keller (1977) corrections, an uncorrected version of this diagram is shown elsewhere in the proceedings.

1. Introduction

The reddest objects in earlier samples of low mass stars have $R_F - I_N < 3.1$ in the photographic system. The new sample from the stacked data contains 31 objects from $R_F - I_N = 3.0 - 3.6$, suggesting unprecedentedly low temperatures and luminosities. The low temperature for some of the stars in the sample was confirmed spectroscopically by Jones & Hawkins (1995). Parallax's have been determined for three of the new objects (Hawkins et al. 1997) and the resulting colour-luminosity diagram is shown in Fig. 1.

2. Spectral interpretation of the new objects

Martin et al. (1996 and references therein) have conclusively shown that young brown dwarfs exist in the Pleiades cluster (age $\sim 10^8$ yr). Martin et al. have recently presented spectra for these objects with a similar wavelength range and resolution to those presented that we have for the stack objects. They notice and quantify a number of distinct spectral differences between the Pleiades brown dwarfs and typical late-type M dwarfs. In particular they find that for a particular spectral type, young M dwarfs are relatively enhanced around 0.74 μm, show stronger VO absorption and a smaller equivalent width of Na at 0.819 μm. These differences have been carefully transformed into spectral indices by Martin et al. and Kirkpatrick et al. (1991) which are designed to avoid regions of the spectra where the accurate measurement of flux is relatively sensitive to the accurate correction for atmospheric features. We thus combine the spectral indicators of youth found by Martin et al., that is, PC2 (Martin et al. 1996),

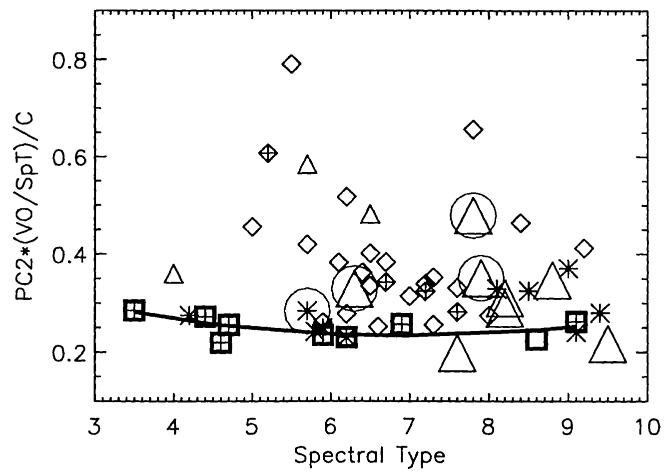

Figure 2. Comparison of spectral index [PC2 × (VO / SpT) / C] for a variety of late-type stars: the plate stack objects (diamonds); Pleiades brown dwarfs and vB10, LP412, BRI 0021-0214, Roque1 and Calar1 from Martin et al. 1996 (large triangles); giants (small triangles) from these observations; late-type M dwarfs from the spectral standards of Kirkpatrick et al. (1991)(bold squares); and late-type dwarfs 296A, BRI0021-0214, G208-45, Gl65AB, Gl865, RG0050-2722, SZ81 and vB10 from our AAT observations (asterisks). The crosses represent objects with known parallax's. Objects with lithium absorption are shown with circles: PPL15, Teide1, Calar3, 296A.

the VO index (Kirkpatrick et al. 1995) and the C index which measures the Na (0.819 μm) strength (Kirkpatrick et al. 1991) to produce an index serving to highlight spectral differences in objects due to gravity.

In Fig. 2 we plot PC2 × (VO / SpT) / C against SpT, where SpT is the average spectral type as determined from the indices PC3, PC4 and PC5 following the methodology of Martin et al. The figure shows that many of the stack objects have indices similar to the Pleiades brown dwarfs rather than those of field M dwarfs. This suggests that many of the stack objects have low gravities are young. Jones & Hawkins (ApJ, submitted) present other figures of spectral indices suggesting low gravities for the stack objects. Further evidence for youth is that the stack objects all have tangential velocities less than 15 km/s although even young-disk (early-type) M dwarfs typically have around 30 km/s.

3. Towards a brown dwarf mass function

Reliable models for the brown dwarf mass function need to take account of all the problems of M dwarf mass functions which have been rumbling in the literature for many years (e.g. Kroupa et al. 1995 and references therein). However there are additional problems which will plague the construction of brown dwarf mass functions. Many of these arise because brown dwarfs rapidly cool (but at different rates) to levels at which it is very difficult to detect them. All field

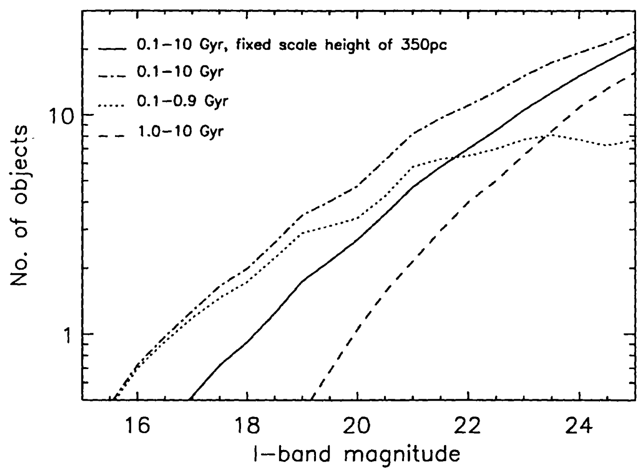

Figure 3. The relative importance of young brown dwarfs and the difference arising from using a fixed scale height. The calculation is for objects in the range 0.010–0.075 $M_\odot$ assuming $\alpha = -2.35$.

surveys so far conducted (even infrared-based) have much greater sensitivity to young brown dwarfs.

A most striking result apparent from our simulations including a time-dependent scale height is the importance of the contribution of young brown dwarfs (< 1 Gyr). Although by total number they represent a small fraction of the population of the simulations, they account for around 90 % of the brown dwarf population brighter than $I = 20$. In addition the largest contribution is from the youngest bins. This means that a reliable model for field brown dwarfs may need to incorporate a mass-dependent time for the length of time taken by low-mass objects to escape from their regions of formation and to be identifiable in 'field' surveys (highish galactic latitude regions chosen to avoid star clusters). In Fig. 3 it can also be seen that including a time-dependent scale height gives rise to a significant increase in the number of brown dwarfs expected from large area surveys.

References

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