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First Results of a Search for Brown Dwarfs in Taurus

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Abstract.
We present the first results of a new effort to search for brown dwarfs in Taurus star formation region. We obtained optical spectroscopy at the William Herschel Telescope in La Palma for 30 candidates, taken from a subset of a survey performed at CFHT. Four object showed very late spectral types, resulting VLM stars with high Taurus membership probability.

1. Introduction

Recent surveys in very young clusters have identified a population of substellar objects that appears to be of the same order of magnitude in number as that of stars (e.g. Béjar et al. 2001). Several brown dwarfs have been identified also in star formation regions (SFRs; Comerón et al. 2000). The Initial Mass Function (IMF) does not appear to change much from one region to another. Taurus is interesting because it represents a loose mode of star formation (density 1–10 pc^{-3}), in contrast to that of clusters such as the Trapezium (10^4 pc^{-3}). Recent searches in Taurus (Briceño et al. 1998, Luhman 2000) have failed to reveal any candidate members with spectral types later than M6.5V, estimated to be close to the substellar limit at the Taurus population age (Martín et al. 1999). Luhman (2000) proposed that the low-mass IMF in Taurus could be truncated around the substellar limit. Therefore, searches for substellar objects in Taurus are important in order to assess whether the IMF could be sensitive to the initial conditions of star formation.

2. Observations

Direct imaging observations of 11 fields in the Taurus SFR were obtained with the 3.6-m Canada-France-Hawaii Telescope (CFHT) CFH12K camera (Cuillandre et al. 2000) between December 1999 and December 2000. Broad band R,

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I and z as well as narrow band Hα filters were used. The field of view of each CFH12K frame is 0.327 square degrees, our survey covering a total area of 3.59 square degrees. A complete description of the survey and associated data reduction will be presented in Dougados et al. (2001, in preparation). The selection of Taurus low-mass candidates presented here is based on a subset of the total survey, covering 2.29 square degrees, and including only R and I photometry.

We selected candidate low-mass Taurus members by requiring that they lie two magnitudes above the observational ZAMS in the I, $R-I$ color-magnitude diagram. In addition to these (20) sources, 10 sources more, lying closer to the ZAMS, but suspected to be strong Hα emitters, were also included in the spectroscopic follow-up sample. All these candidates are brighter than $I = 18$.

Spectroscopic observations were carried out using ISIS at the 4.2-m William Herschel Telescope (WHT) in La Palma on 2000 September 28-29. The R158R grating on ISIS's red arm gave a wavelength coverage from 640.9 nm to 936.5 nm, with a spectral resolution of 7.2 Å. The data were reduced using standard routines for bias-subtraction and flat-field correction within the IRAF[6] environment. Wavelength calibration was made using the spectrum of a NeAr lamp. Instrumental response was calibrated using spectra of flux standards.

3. Results

Here we present four candidates with very late M spectral types, according to their WHT spectra (Figure 1).

Brown dwarfs in the Taurus SFR should be in a very early phase of gravitational contraction (age $\leq$ 4 Myr). Theoretical models indicate that their gravities are between 10 to 100 times lower than for VLM stars at the bottom of the main sequence (Chabrier et al. 2000). Collisionally dominated photospheric lines are thus very good tracers of low gravity atmospheres and can be used as a strong criterion to distinguish young BDs from old VLM stars. Luhman et al. (1998) noted that Na I and K I lines were much weaker in the M6 Taurus star V410 X-ray 3 than among field M6 dwarfs.

Table 1. Relevant data for our objects

Name	I	A_V	W_λ(Hα)	W_λ(Na I)	SpT
CFHT-BD-Tau 1	17.3	3.1	-19	<2.0	M7
CFHT-BD-Tau 2	16.7	0.0	-12	<1.4	M8
CFHT-BD-Tau 3	16.8	0.0	-52	<2.2	M9
CFHT-BD-Tau 4	15.6	3.0	-340	<1.1	M7

We find that our new Taurus VLM objects have weaker Na I and K I lines than same spectral type fields dwarfs (Table 1; equivalent widths are in Å). They have spectral types later than M7, which is considered the boundary between stars and brown dwarfs for the Pleiades cluster age. For younger ages, the

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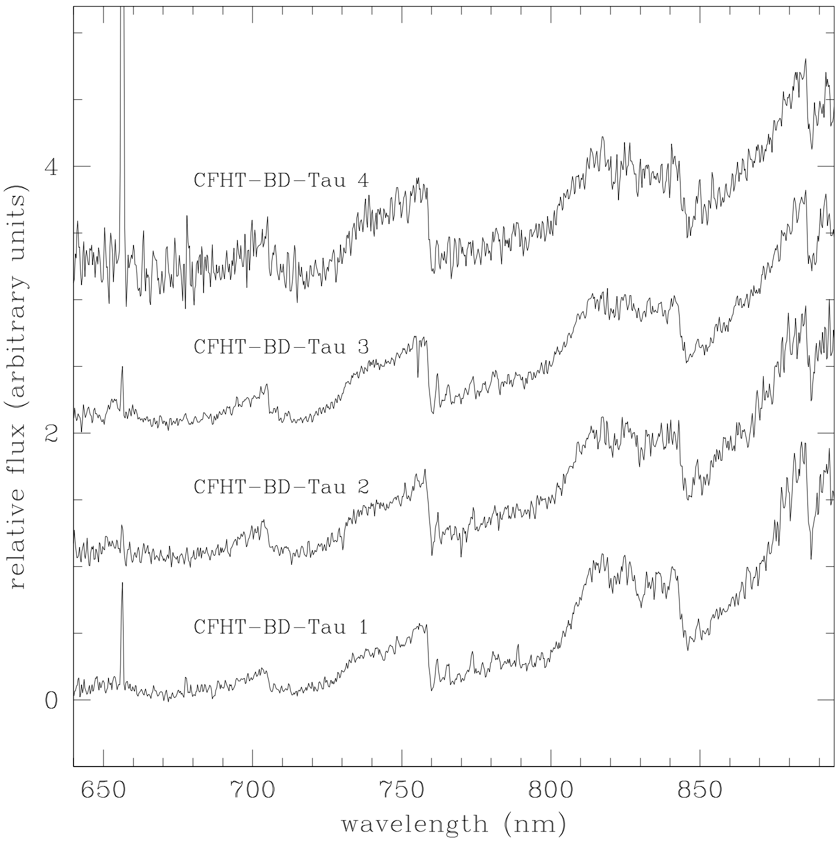

Figure 1. WHT spectra for CFHT Taurus BD members.

boundary should stay at M7 or move to slightly earlier spectral types (Martín et al. 1999). Thus, we conclude that these are very likely substellar members in the Taurus SFR. Prior to this work, the coolest known Taurus member was GG Tau Bb, an M7 object with an estimated age of 1.5 Myr and a mass of 0.04 $M_\odot$ (White et al. 1999). Two of our objects, namely CFHT-BD-Tau 2 and 3 are fainter than GG Tau Bb. Using the models of Chabrier et al. (2000) we obtain ages of about 1 Myr, and masses of about 0.03 $M_\odot$ for both CFHT-BD-Tau 2 and 3.

CFHT-BD-Tau 4 is located close to the Tau III group identified by Gómez et al. (1993). CFHT-BD-Tau 1, 2 and 3 could be associated with group V, for which only half a dozen members were known so far. Group V has much fewer known T Tauri members than groups II and III. It is remarkable that most of our new BDs are located in a sparsely populated group, and none in one of the richer groups. Our results suggest that BDs may preferentially be associated with groups with few T Tauri members. Martín & Kun (1996) found an isolated group of VLM young stars at high galactic latitude and suggested that VLM stars and brown dwarfs may form in small groups. A mass segregation in Taurus would explain the lack of brown dwarfs in the searches carried out by Briceño et al. (1998) and Luhman (2000), which concentrated on the densest groups of TTSs.

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