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Search for young sub-stellar objects in the Chamaeleon II cloud using wide-field imaging techniques

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Abstract. We present preliminary results on the selection of low-mass Pre-Main Sequence (PMS) stars and young Brown Dwarf (BD) candidates in the Chamaeleon II dark cloud using wide-field imaging techniques. We aim to study the Initial Mass Function (IMF) of Chamaeleon II in the very low-mass and sub-stellar regimes. The PMS and BD candidates were selected on the basis of color-magnitude diagrams (CMDs) and theoretical isochrones. We can also roughly estimate the effective temperature of the DB candidates and study the level of Hα emission of the candidates.

Key words. Low Mass Stars, Brown Dwarfs, IMF, Wide-Fied Imaging

1. Introduction

The determination of the Initial Mass Function (IMF) at low stellar and sub-stellar masses is a very important astrophysical problem, in particular for the very low-mass (VLM) and sub-stellar regimes. This is one of the main reasons why the major goal of surveys in star forming regions (SFRs) is the search for young Brown Dwarfs (BDs).

The Chamaeleon II (Cha II) dark cloud is particularly well-suited for studies of very low mass pre-main sequence (PMS) stars and young BDs. This region is characterized by the presence of $H\alpha$ emission line objects (Hartigan 1993) as well as of embedded class-I and class-II Infra-Red sources [(Whittet et al. 1991), (Prusti et al. 1992)] and X-rays sources (Alcalá et al. 2000). The mass spectrum of the so far known members of the Cha II cloud seems to be biased towards less massive stars relative to other SFRs like Taurus (Alcalá et al. 2000). This may be an indication that many VLM stars are still to be discovered in the region and offers the opportunity to search for young BDs and to study the stellar IMF below the Hydrogen-burning limit. Here we present preliminary results of a wide-field imaging survey in Cha II.

2. The Survey

Using the wide-field imager (WFI) at the ESO 2.2 m telescope, we surveyed an area of about

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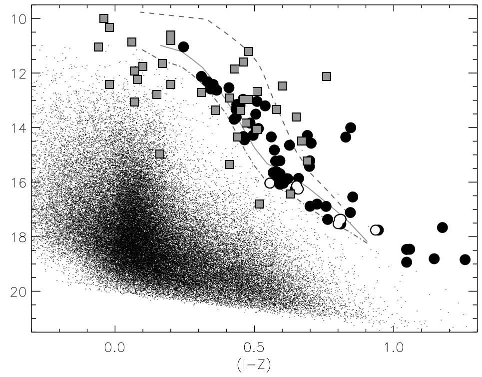

Fig. 1. Dereddened I_C versus (I_C-z) diagram for the point-like objects extracted from our WFI images in Cha II. The magnitudes were dereddened using the large scale extinction map by (Cambrésy 1999) and the extinction curve by (Savage & Mathis 1979). The lines represent the theoretical PMS isochrones for 1 (dashed line), 5 (full line) and 10 Myr (dash-dotted line), respectively, shifted to the distance modulus of Cha II (6.25 mag, (Whittet et al. 1997)). The previously known PMS stars are indicated with squares. The big dots represent the objects above the 10-Myr isochrone, i.e. the "photometrically-selected" candidates. The open circles represent 7 BD candidates with $H\alpha$ emission, according to our photometric criterium (see text for details).

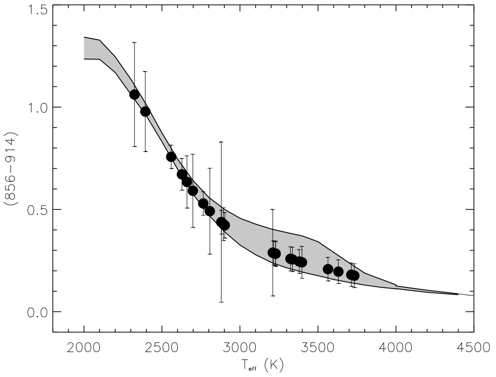

Fig. 2. Calibration of the photometric $(m_{856} - m_{914})$ index versus effective temperature obtained by using the DUSTY models (Allard & Hauschildt 1995). The shaded area displays the locus of the calibration relations that are slightly dependent on the stellar gravity; the extreme curves represent the relations for log g=5.0 (lower boundary) and log g=3.5 (upper boundary). The big dots represent the young low-mass candidates, whose temperature has been estimated from the average $T_{\rm eff}$–colour relation (log g=4.0).

1.75 square degrees in Cha II. The region was observed in the $R_{\rm c}$, $I_{\rm c}$ and z broad bands, in two $H\alpha$ filters, narrow ($H\alpha_7$, λ_c=658nm) and wide ($H\alpha_{12}$, λ_c=665nm), and in two medium-band filters centred at 856 and 914 nm.

3. Candidates selection

We select PMS and young BD candidates using colour-magnitude diagrams (CMDs) and theoretical isochrones (c.f. Fig. 1). Since the shape of the isochrones may vary significantly from one photometric system to another, we have computed ad-hoc isochrones for the ESO-WFI Cousins system, using the synthetic low-resolution spectra for low-mass stars and BDs calculated by (Allard & Hauschildt 1995) with their NextGen model-atmosphere code (see also Alcalá et al. 2005). The selection of the PMS star and BD candidates was also reinforced by using the previously known PMS stars in Cha II to define the PMS locus in the CMDs and the near-infrared colour-colour diagram (data from the Two Micron All Sky Survey catalogue, 2MASS) to check which candidates may have Infra-Red (IR) excess.

Using the synthetic spectra, we can also estimate the effective temperature of the candidates from their $(m_{856} - m_{914})$ colour (Fig.2); this index is very sensitive to the effective temperature for very cool stars ($T_{\rm eff}$ < 3800 K) since the 856-nm filter includes a strong TiO molecular band whose intensity grows with decreasing temperature (see also López-Martí et al. 2004).

We have also put forward a well defined calibration relation between the $H\alpha$ colour (wide minus narrow band) and the $H\alpha$ equivalent width (see Fig.3, upper panel) by exploiting both synthetic spectra and observed spectra of already confirmed PMS stars. This calibration allows us to have another strong criterion for the selection of PMS stars, picking up the emission-line objects (Fig.3, lower panel), and distinguish between classical and weak T Tau star candidates on the basis of their $H\alpha$ emis-

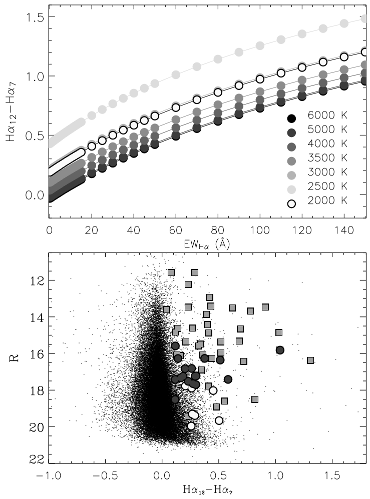

Fig. 3. Upper panel: Calibration relation between the $(H\alpha_{12} - H\alpha_7)$ index and the $H\alpha$ equivalent width. This relation is strongly dependent on the effective temperature for objects cooler than about 4500 K. **Lower panel:** dereddend R magnitude versus $H\alpha$ colour for the point-like objects in Cha II extracted from our WFI images. We have determined a threshold of $(H\alpha_{12} - H\alpha_7)$=0.1 mag for objects with $H\alpha$ equivalent width greater than about 5 Å, i.e. "genuine" $H\alpha$ emission-line objects. The previously known PMS stars are represented with squares, while the candidates with $(H\alpha_{12} - H\alpha_7) >$ 0.1 mag are represented with filled circles. The open circles represent the 7 BD candidates.

sion.
Finally, spectral energy distributions from the optical to the IR for the selected candidates are also obtained by merging our optical photometry with data from the 2MASS catalogue and from the *Spitzer* satellite. We can therefore obtain the bolometric luminosities of our candidates and place them on the HR diagram, estimating their masses by the comparison of their locations with theoretical evolutionary tracks. This study will be presented in a forthcoming paper.

4. Preliminary Results

By inspection of the colour-magnitude diagram compared to theoretical isochrones, scaled at the Cha II distance of 178 pc (Whittet et al. 1997), we have selected about 45 objects with ages lower than 10 Myr which also show IR excess. About 24 sources have an $H\alpha$ index indicating strong emission; 7 of them have I magnitudes in the range from 16 to 19 and colours $(R-I) > 1.7$ and $(I-z) > 0.6$ which, according to the theoretical isochrones computed by us as explained in Section 3, should mark the sub-stellar limit in Cha II. It also results that the good candidates (those with $H\alpha$ emission) have temperatures in the range from 2300 to 4000 K, consistent with young BDs and very low-mass stars.
These PMS star and BD candidates must be spectroscopically confirmed. Assuming that the 24 $H\alpha$ emission candidates result in PMS objects and that the 7 objects fainter than I = 16 are BDs and considering that the number of prevously known PMS stars in Cha II is about 40, the fraction of sub-stellar objects in ChaII would be about 10%.

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References

Alcalá, J.M. et al. 2000, A&A, 355, 629
Alcalá, J.M. et al. 2005, Mem. S.A.It., 76, 241
Allard, F., Hauschildt, P. 1995, ApJ, 445, 433
Allard, F. et al. 2000, ApJ, 540, 1005
Cambrésy, L. 1999, A&A, 345, 965
Hartigan, P. 1993, AJ, 105, 1511
López-Martí, B., et. al. 2004, A&A, 416, 555
Prusti, T. et al. 1992, A&A, 261, 151
Savage, B.D., Mathis, J.S. 1979, An. Re. A&A, 17, 73
Whittet, D.C.B. et al. 1991, A&A, 251, 524
Whittet, D.C.B. et al. 1997, A&A 327, 1194