

A WFI survey in the Chamaeleon II dark cloud^{★,★★,★★★}

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ABSTRACT

Aims. We present the results of an optical multi-band survey for low-mass pre-main sequence (PMS) stars and young brown dwarfs (BDs) in the Chamaeleon II (Cha II) dark cloud. This survey constitutes the complementary optical data to the c2d Spitzer Legacy survey in Cha II.

Methods. Using the wide-field imager (WFI) at the ESO 2.2 m telescope, we surveyed a sky area of about 1.75 square degrees in Cha II. The region was observed in the R_c , I_c , and z broad-bands, in $H\alpha$ and in two medium-band filters centred at 856 and 914 nm. We selected PMS star and young BD candidates using colour-magnitude diagrams (CMDs) and theoretical isochrones reproduced ad-hoc for the WFI at the ESO2.2m telescope system. We reinforced the selection criteria by using the previously known PMS stars in Cha II to define the PMS locus on the CMDs and by investigating the infrared (IR) colours of the candidates. By exploiting the WFI intermediate-band photometry we also estimated the effective temperature and the level of $H\alpha$ emission of the candidates.

Results. Our survey, which is one of the largest and deepest optical surveys conducted so far in Cha II, recovered the majority of the PMS stars and 10 member candidates of the cloud from previous IR surveys. In addition, the survey revealed 10 new potential members. From our photometric characterisation, we estimate that some 50% of the 20 candidates will result in true Cha II members. Based on our temperature estimates, we conclude that several of these objects are expected to be sub-stellar and give a first estimate of the fraction of sub-stellar objects.

Key words. stars: low-mass, brown dwarfs – stars: formation – stars: pre-main sequence – ISM: clouds – ISM: individual objects: Chamaeleon II

1. Introduction

Recent investigations in star-forming regions (SFRs) point out that the fraction of young brown dwarfs (BDs) relative to low-mass and more massive pre-main sequence (PMS) stars may vary significantly among different SFRs (Kroupa 2002). In particular, the fraction is different in T and in OB associations (Briceño et al. 2002; Hillenbrand & Carpenter 2000; Luhman et al. 2000; Muench et al. 2003; Preibisch et al. 2003). Different environments may give rise to different initial conditions for star and planet formation and, hence, to differences in the observed spectrum of masses (Kroupa 2001, 2002). This may have strong consequences on the initial mass function (IMF), in particular in the sub-stellar domain. It has also been proposed that BDs may form as members of small groups of objects, which may be ejected by dynamical interactions before they can grow to stellar masses (Reipurth & Clarck 2001); as a result, many low-mass and sub-stellar objects might have escaped detection in surveys that concentrate sharply in the cores of SFRs. Thus, one possible reason for the differences in the fraction of young sub-stellar objects in T and OB associations can in principle be ascribed to

the photometric and spatial incompleteness of the imaging surveys. Spatially complete deep-imaging surveys are thus crucial in order to single out low-mass star and BD candidates to be investigated by follow-up spectroscopy. Only then, problems like mass segregation in SFRs and the low-mass end of the IMF can be addressed.

In this paper, optical wide-field imaging observations in the Chamaeleon II dark cloud (hereafter Cha II), complemented with *JHK* photometry from 2MASS (Cutri et al. 2003), are used to search for low-mass PMS stars and young BDs. Our survey covers almost 2 square degrees in the Cha II cloud.

Because of its proximity to the Sun ($d \approx 178$ pc, Whittet et al. 1997), young age (0.1–10 Myr, Hughes & Hartigan 1992), and relatively high galactic latitude ($b \approx -15$ deg, Schwartz 1991), which decreases the effects of contamination by background stars, the Cha II dark cloud is particularly well-suited to studies of low-mass PMS stars and young BDs. It is indeed characterised by the presence of objects with $H\alpha$ emission (Hartigan 1993; Hughes & Hartigan 1992), as well as of embedded Class-I and Class-II IR sources (Larson et al. 1998; Prusti et al. 1992; Whittet et al. 1991) and X-rays sources (Alcalá et al. 2000).

Investigations in the near-IR by the DENIS survey have revealed several candidate young BDs in Cha II (Vuong et al. 2001); however, a spectroscopic follow-up by Barrado y Navascués & Jayawardhana (2004) failed to confirm the young BD candidates, although it revealed the least massive classical T Tauri star in the cloud. Persi et al. (2003) performed ISOCAM observations and IR spectroscopy of several objects in the core of Cha II and found a number of sources with IR excess. Their most promising candidate, ISO-CHA II 13, has been recently

* Based on observations carried out at the European Southern Observatory, La Silla, Chile under proposals numbers 67.C-0225 and 68.C-0311.

** Appendices and Fig. 14 are only available in electronic form at <http://www.aanda.org>

*** Table 7 is available in electronic form at <http://www.aanda.org> and at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/470/281>

confirmed as the first BD in the region known to be surrounded by a disk (Alcalá et al. 2006). An optical wide-field imaging survey by López-Martí et al. (2005) proposes two young BD candidates. However, that survey covers only about 10% of the cloud area.

The Cha II cloud has also been included in the Spitzer Legacy survey “From Molecular Cores to Planet Forming Disks” or c2d (Evans et al. 2003) as a test case of a cloud with moderate star-formation activity. Results of the c2d survey in Cha II have been published recently by Young et al. (2005), Allers et al. (2006), and Porras et al. (2006). The data presented in this paper constitute the optical ancillary data for the c2d survey in Cha II. As such, they are part of a multi-wavelength study of the Cha II cloud that will be presented in a forthcoming paper (Alcalá et al., in preparation).

The outline of the paper is as follows. In Sect. 2 the observations, data reduction and calibration procedures are described. In Sect. 3 we present specific tools for the analysis of the photometric data. Section 4 describes the criteria for the selection of PMS star and BD candidates in Cha II, using the tools developed in Sect. 3. The results of the survey and, in particular, the fraction of sub-stellar objects estimated in Cha II are discussed in Sect. 5. Our conclusions are presented in Sect. 6 and, finally, a few notes on some individual objects are presented in Appendix C (available only in electronic form).

2. Observations and data reduction

The observations were carried out in two observing runs (27–30 April 2001 and 20–23 March 2002) using the wide-field imaging (WFI) mosaic camera attached to the ESO 2.2m telescope at La Silla (Chile). The mosaic consists of eight $2k \times 4k$ CCDs forming an $8k \times 8k$ array with a pixel scale of $0.238''/\text{pix}$; hence, a single WFI pointing covers a sky area of about $30' \times 30'$. The Cha II dark cloud has an extension of about 2 square degrees (Hughes & Hartigan 1992). Thus, seven adjacent WFI pointings allowed us to cover about 70% of the cloud area. The distribution on the sky of the WFI pointings is shown in Fig. 1. The overlap of about $2'$ between adjacent pointings allowed us to check the consistency in the photometry and in the astrometry.

The observations were performed in the R_C , I_C and z broad bands, in two $H\alpha$ filters, narrow ($H\alpha_7$, $\lambda_c = 658$ nm and $FWHM = 7.4$ nm) and wide ($H\alpha_{12}$, $\lambda_c = 665$ nm and $FWHM = 12.1$ nm), and in two intermediate-band filters centred at 865 and 914 nm. In order to cover the gaps between the WFI CCDs and to correct for moving objects and cosmic ray hits, a sequence of typically five ditherings was performed for every pointing in each filter. The journal of the observations is presented in Table 1. The RA (in hh:mm:ss) and Dec. (in dd:mm:ss) of each pointing are indicated between parenthesis; total exposure time (T_{exp}), seeing and air mass (X) values correspond to the final staked images (see Sect. 2.1).

2.1. Pre-reduction and astrometry

The pre-reduction of the raw images, passing through bias subtraction, flat-fielding and correction for fringing, was performed on a nightly basis, using the *mscred* package under IRAF¹, following the guidelines described in Alcalá et al. (2002). The

resulting pre-reduced images are uniform to about 1%. To correct for large-scale illumination variations, a super-flat was used.

The astrometric calibration and relative flux scaling between ditherings were done using the ASTROMETRIX tool². It performs a global astrometric solution that takes overlapping sources falling on adjacent CCDs in different ditherings into account. For each pointing, the astrometric solution was first computed for the R -band dithering set using the USNO-A2.0 catalogue (Monet et al. 1998) as a reference. A catalogue of sources was then extracted from the re-sampled R -band image and used as the reference catalogue for all the other bands. Within the global astrometry process, the astrometric solution was constrained for each CCD by both the positions from the R -band catalogue and those from overlapping sources in all the other CCDs. The co-addition of the different dithered images for a given filter and pointing was performed using the SWARP tool³. The resulting $8k \times 8k$ stacked images were normalised by the exposure time. The absolute astrometric precision of our images is about 0.35 arcsec, corresponding to the RMS accuracy of the USNO-A2.0 catalogue, while the internal RMS, computed from overlapping sources in different exposures, is within 0.05 arcsec, indicating the good performance of ASTROMETRIX.

2.2. The photometric calibration

In order to transform the R and I instrumental magnitudes to the standard Cousins system, the Landolt standard fields SA 98, SA 101, and SA 107 (Landolt 1992) were observed nightly. The standard R_C and I_C magnitudes were determined using the transformation equations:

$$R_C = r_0 + c_R \cdot (r_0 - i_0) + ZP_R \quad (1)$$

$$I_C = i_0 + c_I \cdot (r_0 - i_0) + ZP_I \quad (2)$$

where r_0 and i_0 are the instrumental magnitudes corrected for atmospheric extinction and c_R and ZP_R and c_I and ZP_I the colour terms and zero points for the R and I bands, respectively. The standard magnitudes from Stetson (2000) were used to determine the zero points and colour terms.

The intermediate-band instrumental photometry was transformed to the standard AB photometric system following the prescriptions by Jacoby et al. (1987) and Alcalá et al. (2002) by using the equation

$$m_{AB}(\lambda) = m_0(\lambda) + ZP_\lambda \quad (3)$$

where m_0 is the instrumental magnitude in a given intermediate-band filter corrected for atmospheric extinction, and ZP_λ the zero point derived by using the spectrophotometric standard stars Hiltner 600, LTT 4364, and Eg 274 (Hamuy et al. 1992), which were observed by us in the same run. The resulting magnitudes in the intermediate band filters are in the AB system.

The nightly calibration coefficients (atmospheric extinction coefficient, K , zero point, ZP , and colour terms, c), are reported in Table 2.

2.2.1. The z -band photometric calibration

The calibration of the z magnitudes required more effort, because there are no data for standard stars available in the literature.

² Available at: <http://www.na.astro.it/radovich>

³ Available at: <http://terapix.iap.fr/cpllt/oldSite/soft/swarp>

¹ IRAF is distributed by the National Optical Astronomy Observatories (NOAO).

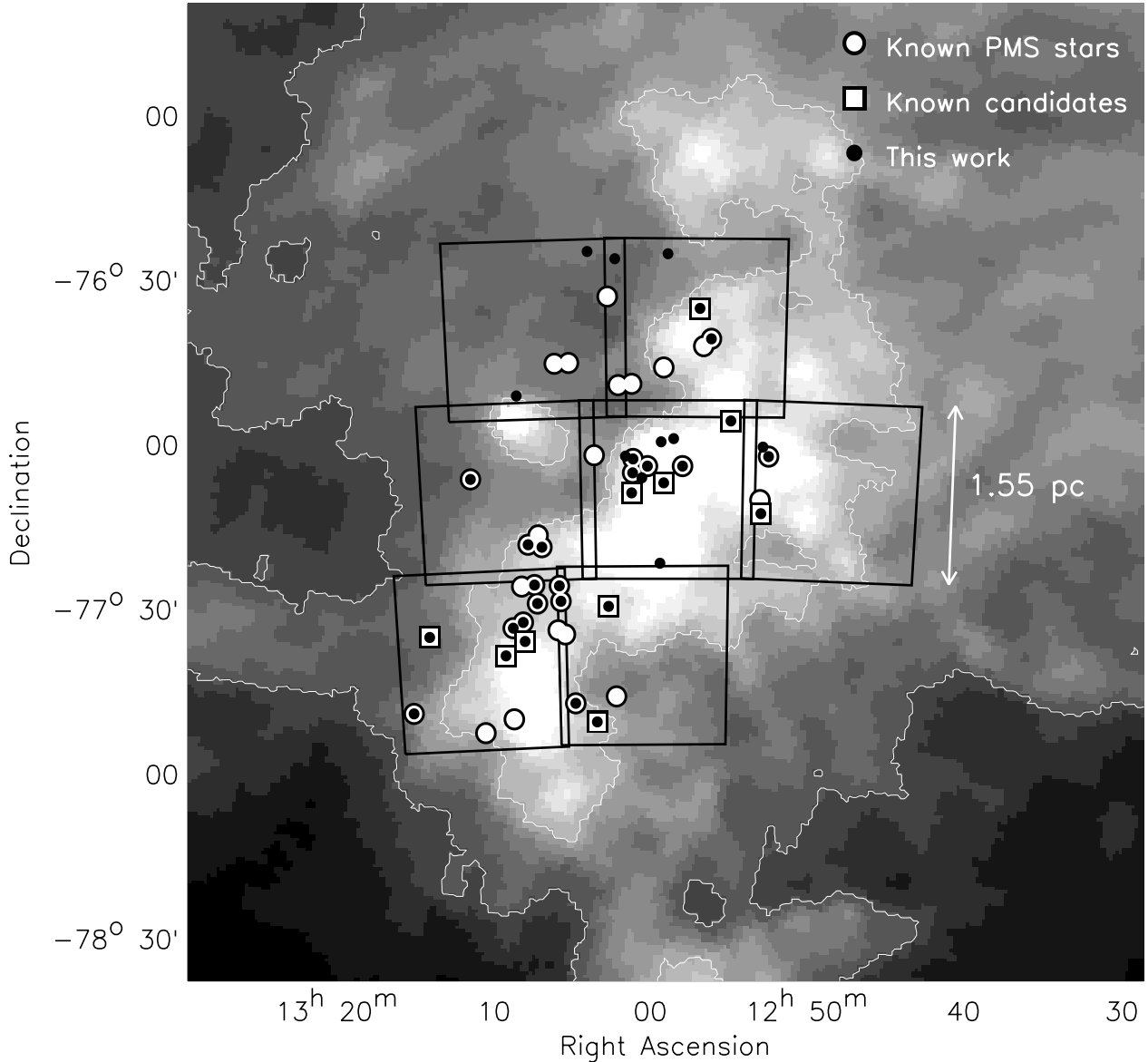


Fig. 1. IRAS $100\ \mu\text{m}$ dust emission map of the Cha II dark cloud. The contours, from 10 to $40\ \text{MJy} \times \text{sr}^{-1}$ in steps of $2.5\ \text{MJy} \times \text{sr}^{-1}$, are also drawn (white lines). The big polygons define the area covered by the seven ESO2.2m+WFI pointings. The confirmed members of the cloud and the candidates selected in previous surveys are represented with open circles and squares, respectively; the black dots mark the objects recovered by our selection criteria (see Sect. 4).

Since we aimed at determining the colour-magnitude diagrams (CMDs) of the sources in Cha II (Sect. 4) and their spectral energy distributions (SEDs, Sect. 5), we needed both to tie the z magnitudes with some “reference” photometric system and to determine the flux at Earth of a star with magnitude $z = 0$. To this aim, we observed the same Landolt standard fields in the z filter. In the Landolt SA 98 field, we selected the A0-type star SA 98 653, whose visual magnitude and colours are reported in Table 3. This star is characterised very well and its absolute spectrophotometry well-determined (Gutiérrez Moreno et al. 1988). For this A0-type star, we can assume $(I_C - z) = 0$, thus defining the “standard” z -magnitude system as that for which the colour $(I_C - z)$ is zero for A0 type stars. The zero point of this calibration is then determined as

$$Zp = z - z_0 = I_C - z_0 \quad (4)$$

where $I_C = 9.522$ is the standard magnitude of SA 98 653 in the Cousins system and z_0 its z -band instrumental magnitude corrected for atmospheric extinction. We then applied this zero-point correction to the z_0 instrumental magnitude of all the stars in the Landolt fields. In this way we obtained a catalogue of Landolt stars with z magnitudes and $(I - z)$ colours in our internal WFI-Cousins system. We then used this catalogue to find the least-square solution to the equation

$$z = z_0 + c_z \cdot (i_0 - z_0) + ZP_z \quad (5)$$

where z_0 and i_0 are the standard stars instrumental magnitudes corrected for atmospheric extinction and ZP_z and c_z the z calibration coefficients for the newly-defined WFI-Cousins photometric system. The nightly mean values obtained for ZP_z and c_z are reported in Table 2.

Since the absolute spectrophotometry of SA 98 653 is available from Gutiérrez Moreno et al. (1988), we can use this star

Table 1. Journal of the observations.

Field (RA, Dec.)	Date (d/m/y)	Filter	T_{exp} (min)	Seeing ($''$)	\bar{X}
ChaII_1 [†] (13:06:18, -76:44:21)	22/03/02	$R_c/162$	2×5	1.2	1.48
	22/03/02	I_c/Iwp	2×5	1.2	1.48
	22/03/02	$z+/61$	2×5	1.2	1.49
	21/03/02	$H\alpha/7$	5×4	1.0	1.54
	21/03/02	$H\alpha/12$	3×5	1.0	1.51
ChaII_2 (12:57:31, -76:44:20)	22/03/02	$R_c/162$	2×5	1.2	1.55
	22/03/02	I_c/Iwp	2×5	1.2	1.53
	22/03/02	$z+/61$	2×5	1.2	1.51
	21/03/02	$H\alpha/7$	5×5	1.0	1.53
	21/03/02	$H\alpha/12$	3×5	1.0	1.56
	23/03/02	856/14	4×5	1.0	1.50
ChaII_3 (13:08:13, -77:14:27)	29/04/01	$R_c/162$	10×5	2.7	1.84
	29/04/01	I_c/Iwp	10×5	2.7	1.69
	29/04/01	$z+/61$	10×5	2.7	1.60
	21/03/02	$H\alpha/7$	5×5	1.2	1.64
	21/03/02	$H\alpha/12$	3×5	1.2	1.59
ChaII_4 (12:59:03, -77:13:58)	22/03/02	$R_c/162$	2×5	1.4	1.49
	22/03/02	I_c/Iwp	2×5	1.4	1.50
	22/03/02	$z+/61$	2×5	1.4	1.50
	21/03/02	$H\alpha/7$	5×5	1.2	1.50
	21/03/02	$H\alpha/12$	3×4	1.2	1.51
ChaII_5 (12:49:53, -77:13:59)	23/03/02	856/14	4×5	1.2	1.57
	24/03/02	914/27	5×5	1.2	1.54
	22/03/02	$R_c/162$	2×5	1.2	1.60
	22/03/02	I_c/Iwp	2×5	1.2	1.62
	22/03/02	$z+/61$	2×5	1.2	1.66
ChaII_6 (13:10:07, -77:45:08)	21/03/02	$H\alpha/7$	5×5	1.2	1.75
	21/03/02	$H\alpha/12$	3×5	1.2	1.66
	23/03/02	856/14	4×5	1.0	1.49
	23/03/02	914/27	5×5	1.0	1.50
	30/04/01	$R_c/162$	10×6	2.0	1.67
ChaII_7 (13:00:28, -77:44:39)	30/04/01	I_c/Iwp	10×6	2.0	1.57
	30/04/01	$z+/61$	10×6	2.0	1.52
	21/03/02	$H\alpha/7$	5×5	1.4	1.61
	21/03/02	$H\alpha/12$	3×5	1.4	1.66
	23/03/02	856/14	4×5	1.2	1.67
ChaII_7 (13:00:28, -77:44:39)	23/03/02	914/27	5×5	1.2	1.74
	22/03/02	$R_c/162$	2×4	1.2	1.78
	22/03/02	I_c/Iwp	2×5	1.2	1.74
	22/03/02	$z+/61$	2×5	1.2	1.69
	21/03/02	$H\alpha/7$	5×5	1.0	1.52
ChaII_7 (13:00:28, -77:44:39)	21/03/02	$H\alpha/12$	3×5	1.0	1.51
	23/03/02	856/14	4×5	1.0	1.58
	23/03/02	914/27	5×5	1.0	1.62

[†] Not observed in the 856-nm and 914-nm bands.

to obtain the absolute flux calibration in the z filter, i.e. to obtain the flux at Earth of a star with $z = 0$. Following the procedure outlined in Appendix A (available only in electronic form) we derive

$$\begin{aligned}
 F(z = 0) &= (8.4 \pm 0.1) \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1} \\
 &= (2608 \pm 31) \text{ Jy}.
 \end{aligned}$$

This value can be used to derive the flux in the z -band of the sources in our catalogue using their corresponding z -band magnitudes.

Table 2. Photometric calibration coefficients.

Filter	Date	K^r	ZP	c
R	04/27/2001	0.096	24.418 ± 0.004	-0.038 ± 0.010
"	04/28/2001	0.096	24.388 ± 0.001	-0.056 ± 0.008
"	04/29/2001	0.096	24.445 ± 0.004	-0.023 ± 0.003
"	03/21/2002	0.096	24.397 ± 0.003	-0.030 ± 0.003
I	04/27/2001	0.082	23.413 ± 0.012	0.222 ± 0.002
"	04/28/2001	0.082	23.399 ± 0.001	0.216 ± 0.003
"	04/29/2001	0.082	23.431 ± 0.001	0.221 ± 0.007
"	03/21/2002	0.082	23.335 ± 0.001	0.222 ± 0.002
z	04/27/2001	0.080	21.546 ± 0.804	0.336 ± 0.311
"	04/28/2001	0.080	21.246 ± 0.303	0.230 ± 0.143
"	04/29/2001	0.080	21.248 ± 0.353	0.214 ± 0.140
"	03/21/2002	0.080	21.460 ± 0.014	0.373 ± 0.001
$H\alpha_7$	03/20/2002	0.096	21.249 ± 0.095	/
$H\alpha_{12}$	03/20/2002	0.096	21.733 ± 0.133	/
856 nm	03/22/2002	0.080	20.894 ± 0.089	/
914 nm	03/22/2002	0.080	21.018 ± 0.082	/

[†] The mean atmospheric extinction coefficients for La Silla have been adopted.

Table 3. Standard photometry of SA 98 653 (RA = 06:52:05, Dec. = -00:18:18) from Stetson (2000).

V	$(B - V)$	$(U - B)$	$(V - R_c)$	$(R - I_c)$
9.539	-0.004	-0.097	0.007	0.008

2.3. The catalogue extraction

2.3.1. PSF-fitting procedure

The PSF-fitting photometry was performed by using the IRAF/*daophot* package (Stetson 1987). Since we are interested in the faintest stellar objects, the threshold level was defined in order to select all the sources having a signal-to-noise ratio (σ) greater than 3. This choice may lead to the extraction of many spurious detections, however *daophot* allows us to distinguish between stars, extended sources (galaxies), saturated objects, and other spurious detections. The PSF fitting procedure was reiterated twice for each Cha II field; given the moderate crowding of these fields, this choice allowed us to detect the faintest neighbours to bright stars while keeping the number of spurious detections relatively small. The typical residual of the PSF-fitting is less than 2% of the peak brightness. A single catalogue comprising all the stellar sources detected in all the available photometric bands was finally produced. In Fig. 2 the internal photometric errors of all the detected point-like sources are plotted against the magnitude for all the available filters; the relative exponential fits are over-plotted. Table 4 summarises the number of point-like sources detected in the surveyed area in each filter and the limiting magnitudes achieved at the 10σ , 5σ , and 3σ levels, respectively.

2.3.2. Completeness

The completeness of our catalogues was estimated in the standard way by inserting artificial stars into the images and recovering them using the same extraction parameters as for the real objects; the fraction of recovered artificial objects provides a measure of the completeness. We used the IRAF/*addstar*

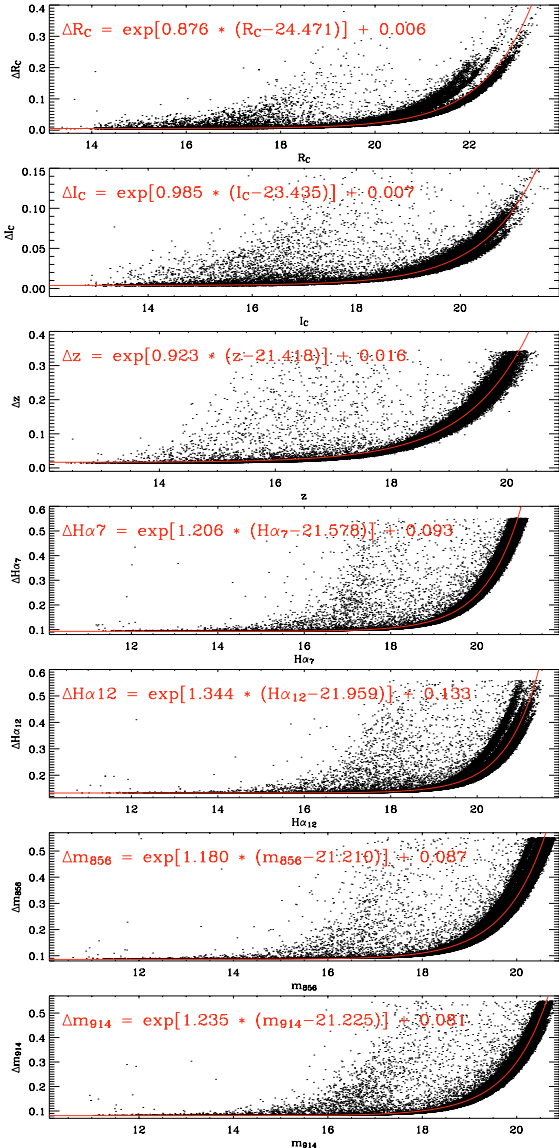


Fig. 2. Photometric errors versus magnitudes and relative exponential fits for all the point-like sources detected in Cha II and for all the available filters. The “double sequence”, clearly visible in R and $H\alpha_{12}$ bands, is due to different seeing conditions in the individual exposures.

package to perform the exercise. We inserted 3000 artificial sources; this number should not alter the crowding statistics in the images significantly. The profile for the artificial sources was generated by using the same PSF model as used for the source extraction; the positions of the artificial objects are randomly distributed over the entire area of the mosaic, and their magnitudes range uniformly between the detection and the saturation limits in each band. As an example we show the results for the ChaII_2 field (see Table 1). Figure 3 shows the fraction of recovered artificial objects as a function of magnitude for each filter. The corresponding magnitude limits at 95% completeness level ($C = 95\%$) are reported in Table 4.

3. Tools for candidate selection

Our primary criterion for selecting low-mass PMS star and BD candidates from the extracted catalogue was based on the comparison of the object location in CMDs with theoretical

Table 4. Number of stellar sources (N^*) detected in each filter and relative limiting magnitudes at the 10σ , 5σ , 3σ and 95% completeness level.

Filter	N^*	Mag 10σ	Mag 5σ	Mag 3σ	Mag ($C = 95\%$)
$R_C/162$	141 400	21.8	22.6	23.2	21.3
I_C/Iwp	141 000	21.0	21.7	22.3	21.0
$z+/61$	79 000	18.7	19.6	20.2	18.8
$H\alpha/7$	72 500	17.5	19.8	20.4	18.0
$H\alpha/12$	84 200	17.8	19.9	20.8	18.4
856-nm	76 700	18.6	19.4	20.0	18.0
914-nm	80 400	18.9	19.5	20.1	18.0

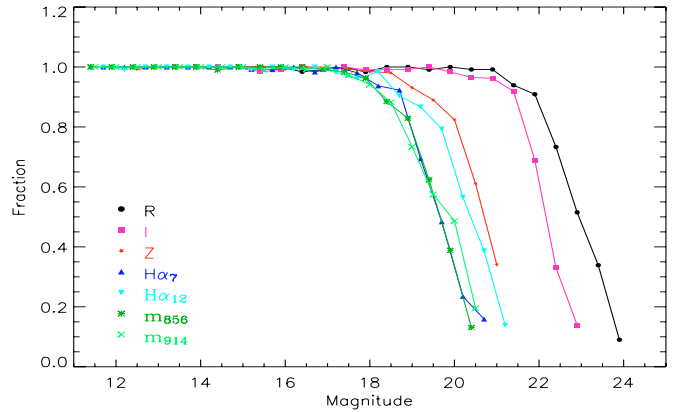


Fig. 3. Completeness plots for extraction of artificial stars from the ChaII_2 mosaic (see Table 1) for all the photometric bands used in this work (see text).

isochrones. In addition, our WFI data in the 865-nm and 914-nm intermediate-bands allowed us to obtain a first estimate of the effective temperature of the candidates, whereas the measurements in $H\alpha$ provided us with a diagnostics for possible $H\alpha$ emission. Our selection method exploits the tools now described.

3.1. Theoretical isochrones

Theoretical isochrones for low-mass stars and BDs down to $0.001 M_\odot$ are provided by Baraffe et al. (1998) and Chabrier et al. (2000) in the Cousins photometric system (Bessel 1990). Since the transmission curves of the WFI filters are somewhat different from the original Cousins ones, in particular for the I -band, it is crucial to transform the colours and magnitudes into the appropriate photometric system. We thus transformed the isochrones by Baraffe et al. (1998) and Chabrier et al. (2000) into the WFI-Cousins system as described in Appendix B (available only in electronic form). In this way, we can use the isochrones to define the PMS locus in the CMDs (e.g. Fig. 9) in a photometrically consistent way.

In Fig. 4 the theoretical R_C vs. $(R - I)_C$ CMD is shown. The 95% completeness limit was determined from the values reported in Table 4. For $A_V = 0$, our survey is complete down to $0.02 M_\odot$ at the 95% level for objects younger than 10 Myr. For an average extinction $A_V \approx 2$ mag for Cha II (Cambrèsy 1999), a 95% completeness limit corresponds to $0.03 M_\odot$.

3.2. The $(m_{856} - m_{914})$ index vs. temperature relation

Late-type dwarfs are characterised by strong molecular absorption bands essentially due to metallic oxides (TiO and VO). The ESO-WFI medium-band filter centred at 856 nm covers

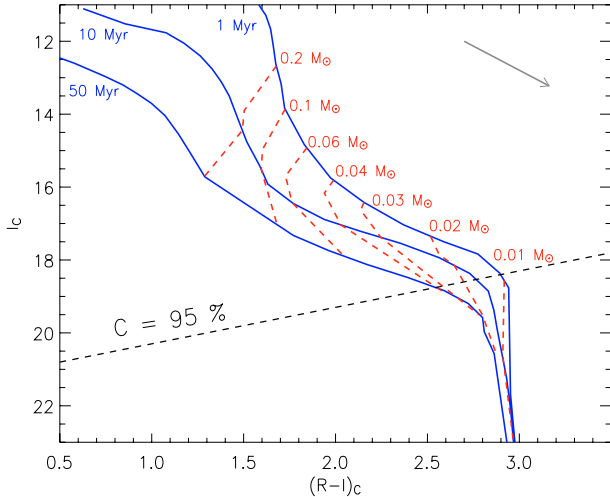


Fig. 4. Theoretical R_C vs. $(R-I)_C$ diagram. The isochrones (continuous curves) and PMS tracks (dashed curves), shifted to the distance modulus of Cha II (6.25 mag, Whittet et al. 1997) are in the WFI-Cousins photometric system. The dashed straight line represents the 95% completeness limit. The $A_V = 2$ mag reddening vector is shown.

important TiO absorption features that deepen with decreasing temperature, while the medium-band filter centred at 914 nm lies in a wavelength range that is relatively featureless in late-type objects (see Fig. B.1 lower panel, in Appendix B). Thus, the $(m_{856} - m_{914})$ colour index is sensitive to the effective temperature for very cool objects ($2000 \text{ K} \lesssim T_{\text{eff}} \lesssim 3800 \text{ K}$), where TiO dominates the opacity (Allard 1990; Burrows & Liebert 1993; O’Neal et al. 1998). In the absence of interstellar extinction, this index can provide a first reliable guess for the temperature of the cool candidates.

Using the filter transmission curves for the corresponding intermediate-band filters and the synthetic low-resolution StarDusty spectra for low-mass stars and BDs by Allard et al. (2000), we derived the relationship between the $(m_{856} - m_{914})$ index and the effective temperature, applying the methods described in Appendix B. The synthetic $(m_{856} - m_{914})$ index, derived by integrating the StarDusty spectra under the filter transmissions and CCD quantum efficiency curves, is in the instrumental WFI system. As such, it was transformed into the standard AB photometric system by applying the zero points derived from the spectrophotometric standard stars Hiltner 600, LTT 4364, and Eg 274, observed with WFI in the 856-nm and 914-nm bands (see Sect. 2.2). From the standard fluxes (Hamuy et al. 1992) integrated under the WFI passbands, likewise the StarDusty spectra, we found an average zero-point correction for the $(m_{856} - m_{914})$ colour of -0.13 mag, which allowed us to obtain the calibrated synthetic $(m_{856} - m_{914})$ index as

$$(m_{856} - m_{914})_{\text{calib}}^{\text{synt}} = (m_{856} - m_{914})_{\text{instr}}^{\text{synt}} - 0.13. \quad (6)$$

In Fig. 5 we show the resulting $(m_{856} - m_{914})$ index versus temperature relation. This relation depends on the stellar gravity, as indicated by the shaded area in Fig. 5, which encompasses all the calibrations for models in the range $3.5 \leq \log g \leq 5$. We also derived this relationship using other stellar atmosphere models (e.g. NextGen, COND, etc.); the StarDusty models were chosen because they match better the empirical relationship between the $(m_{856} - m_{914})$ index and the effective temperature by López-Martí et al. (2004) (straight line in Fig. 5). Furthermore, Allard et al. (2001) found that silicate dust grains can form abundantly in the outer atmospheric layers of the latest M dwarfs and BDs.

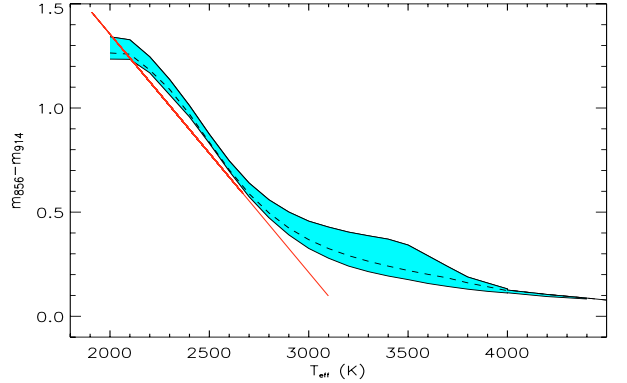


Fig. 5. The $(m_{856} - m_{914})$ index versus effective temperature relation derived from the corresponding WFI intermediate-band filters and the synthetic low-resolution StarDusty spectra for low-mass stars and BDs by Allard et al. (2000). The two solid curves show the relation for $\log g = 5.0$ (lower boundary) and $\log g = 3.5$ (upper boundary); the dashed curve represents the T_{eff} -colour relation for $\log g = 4.0$. The straight line is the empirical relationship derived by López-Martí et al. (2004).

In the case of high interstellar extinction ($A_V \gtrsim 5$ mag), the temperature derived from this relation may be underestimated because the $(m_{856} - m_{914})$ index becomes larger than in the absence of extinction. Thus, without any reliable evaluation of A_V , we can use these temperature estimates only for candidate selection purposes (see Sect. 4).

3.3. $H\alpha$ equivalent width calibration

The WFI $H\alpha_7$ filter covers the $H\alpha$ line, while the $H\alpha_{12}$ filter lies in a wavelength range that is affected by neither the $H\alpha$ wings nor strong photospheric lines (see Fig. B.1 mid panel, in Appendix B). The $(H\alpha_{12} - H\alpha_7)$ index is thus sensitive to the intensity of the $H\alpha$ line. We used the StarDusty spectra by Allard et al. (2000) to define a calibration relation between this index and the $H\alpha$ equivalent width ($EW_{H\alpha}$). In order to simulate stellar spectra with different values of $EW_{H\alpha}$, we added a Gaussian emission profile centred at $H\alpha$ (656.2 nm) and having a $FWHM$ of 3 \AA to the synthetic spectra. The latter value was fixed by considering the $H\alpha$ line profiles of a sample of 75 PMS stars presented by Fernández et al. (1995). We found that the typical $FWHM$ of the $H\alpha$ emission lines of these objects is around 3 \AA , although it can be higher for classical T Tauri stars ($5-6 \text{ \AA}$). However, from tests made by using profiles with different $FWHM$, we have verified that the $FWHM$ value has no significant effect on the $(H\alpha_{12} - H\alpha_7)$ vs. $EW_{H\alpha}$ calibration.

By applying the method described in Appendix B and correcting the synthetic $(H\alpha_{12} - H\alpha_7)$ colour by the mean $(H\alpha_{12} - H\alpha_7)$ colour of the spectrophotometric standard stars used to transform the intermediate-band photometry into the AB system (see Sect. 2.2), we obtained the calibration relation $(H\alpha_{12} - H\alpha_7)$ vs. $EW_{H\alpha}$ displayed in Fig. 6. This relation does not depend on the $FWHM$ of the Gaussian emission core but strongly depends on the effective temperature for objects cooler than about 4500 K. As expected from the contribution of the $H\alpha$ absorption wings (see Fig. B.1, mid panel), for a fixed $EW_{H\alpha}$ the $(H\alpha_{12} - H\alpha_7)$ index is higher for cooler objects; however, between 3000 and 2000 K, this trend is inverted because the $H\alpha_{12}$ filter covers strong molecular absorption bands that heavily affect the continuum of very cool stars.

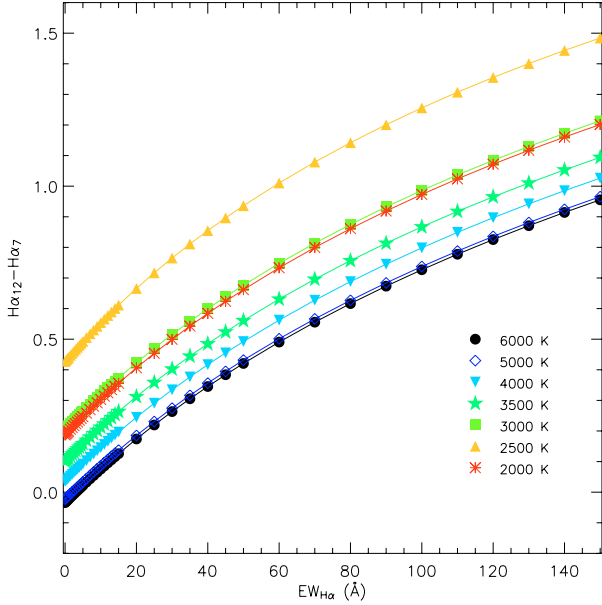


Fig. 6. Calibration relation between the $(H\alpha_{12} - H\alpha_7)$ index and the $H\alpha$ equivalent width derived from the corresponding WFI intermediate-band filters and the synthetic low-resolution StarDusty spectra for low-mass stars and BDs by Allard et al. (2000).

The relationship between the $H\alpha$ index and $EW_{H\alpha}$ derived above was checked by using unpublished WFI $H\alpha$ photometry and the spectroscopy of already confirmed PMS stars in the L1616 cometary cloud obtained with HYDRA@WIYN3.5m (Alcalá et al. 2004) and FORS@VLT (Alcalá et al., in preparation). The spectra of the PMS stars in L1616 were integrated under the transmission curves of the WFI $H\alpha$ filters to derive their “synthetic” $(H\alpha_{12} - H\alpha_7)$ index. This index was then transformed into the AB system by using the mean $H\alpha$ colour index of the corresponding spectrophotometric standard stars observed in the L1616 run. The WFI $H\alpha$ photometry of these PMS stars was then used to compare the observed $(H\alpha_{12} - H\alpha_7)$ index with the one derived from the spectra. Figure 7 shows the results. The best-fitting line (continuous line in Fig. 7) has a slope close to 1 and an offset close to zero, and this implies that no significant correction must be applied to the $(H\alpha_{12} - H\alpha_7)$ vs. $EW_{H\alpha}$ relation deduced from the synthetic spectra. Based on the errors of the observed $(H\alpha_{12} - H\alpha_7)$ index, we conclude that *bona-fide* emission line objects will have an $H\alpha$ index greater than 0.1, corresponding to $EW_{H\alpha} \approx 10 \text{ \AA}$ for an object with $T_{\text{eff}} \approx 4000 \text{ K}$.

The $H\alpha$ index versus $EW_{H\alpha}$ relation was also checked using data from the literature for the Cha II PMS stars. In Fig. 8 the $H\alpha$ equivalent width derived from spectroscopic data (Hughes & Hartigan 1992), $EW_{H\alpha}(\text{spec})$, is compared with the one derived from the $H\alpha$ photometric index, $EW_{H\alpha}(\text{phot})$. The effective temperatures reported by Hughes & Hartigan (1992) were used to estimate the latter, while the temperature reported by Barrado y Navascués & Jayawardhana (2004) was used for the PMS star C 41. From Fig. 8, the $EW_{H\alpha}$ values derived from the $H\alpha$ photometric index are in good agreement with those derived from spectroscopic data. The computed RMS suggests that the relationship shown in Fig. 6 can be used to estimate the $EW_{H\alpha}$ from the WFI $H\alpha$ photometry for objects with $EW_{H\alpha} \geq 10 \text{ \AA}$ and $EW_{H\alpha} \geq 30 \text{ \AA}$, at the 1σ and 3σ levels, respectively, provided we have an estimate of the stellar temperature.

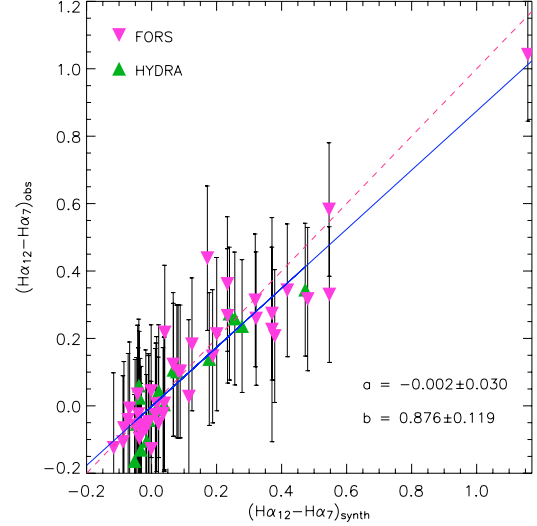


Fig. 7. $(H\alpha_{12} - H\alpha_7)$ observed colours for PMS stars in L1616 as a function of the synthetic $(H\alpha_{12} - H\alpha_7)$ colours (see text). The continuous line represents the best fit of the data; the dashed line has the offset $a = 0$ and slope $b = 1$.

4. Selection of the candidates

For the selection of low-mass PMS stars and young BD candidates, we exploited both the optical data from our survey and the JHK photometry available from the 2MASS catalogue (Cutri et al. 2003), using the tools described in the previous section. A matching radius of $0.5''$ was used to merge the WFI and the 2MASS catalogues, and this value was set by taking the astrometric accuracy of both catalogues into account.

Low-mass PMS star and BD candidates in SFRs can be identified in optical CMDs. In these diagrams, the colour increases rapidly for late spectral types; hence, the contamination from foreground stars is expected to decrease. A first sample of candidates was then selected based on the I_C vs. $(I_C - z)$ and I_C vs. $(R - I)_C$ CMDs. All the point-like sources detected in Cha II above the 3σ level were placed in these CMDs (Fig. 9) and their position was compared with the theoretical isochrones. The isochrones transformed into the WFI-Cousins system, as described in Sect. 3.1, were scaled to the Cha II distance of 178 pc (Whittet et al. 1997) in both CMDs. We then selected all the objects falling above the 10 Myr isochrone in both CMDs (Fig. 9). This criterion takes into account the age spread of the previously known PMS stars in Cha II (0.1–10 Myr, Hughes & Hartigan 1992) and the PMS locus that they define on the CMDs, as well as the uncertainties in interstellar extinction. In this way we selected 114 objects out of which 17 were previously known Cha II members.

However, the 97 new candidates from the selection above may still be contaminated by background giants and highly-reddened objects. We therefore investigated the properties of the selected sample in the JHK bands using their 2MASS magnitudes. It has been found by different authors that the intrinsic $(J - H)$ and $(H - K)$ colours of young late-M objects are dwarf-like with, in some cases, an $(H - K)$ excess, mainly arising from a circumstellar disk or an in-falling envelope (Lee et al. 2005; Luhman & Rieke 1999; Meyer et al. 1997). Furthermore, Meyer et al. (1997) found that classical T Tauri stars, with prominent IR excesses due to circumstellar accretion disks, exhibit a narrow range of colours in the $(J - H)$ vs. $(H - K)$ diagram (Fig. 10). By using the $(J - H)$ vs. $(H - K)$ diagram we then performed

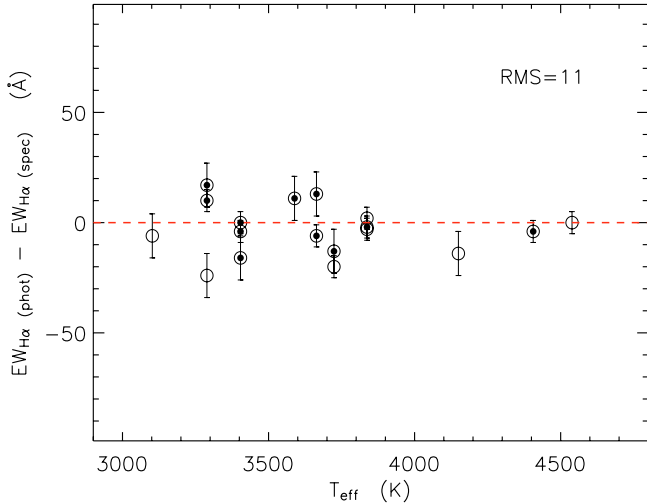


Fig. 8. Comparison between the $H\alpha$ equivalent width estimated in this work from the $(H\alpha_{12} - H\alpha_7)$ photometric index and the one measured by Hughes & Hartigan (1992) and Barrado y Navascués & Jayawardhana (2004) for confirmed PMS stars in Cha II (open circles). The smaller black dots mark the objects recovered by our selection criteria (see Sect. 4).

a secondary selection on the sample coming from the optical CMDs, following similar criteria to those in Lee et al. (2005). The sub-sample of all the objects falling below the dividing line between giants and dwarfs (cf. Fig. 10) should be less contaminated by background giant stars. In this way we end up with a sub-sample of 84 objects, which still include the 17 previously known members.

The sub-sample passing the secondary selection may still contain foreground and highly-reddened background objects. We thus performed a third-level selection as follows. We assumed that the objects passing the primary and secondary selections above are all at the distance of Cha II and estimated their temperature and luminosity as described in Sect. 5. Although these are first guesses of the actual stellar temperatures and luminosities, these values already provide good estimates for candidate selection purposes. We then constructed the HR diagram of our candidates sample and selected all the objects falling between the birth-line and the 20 Myr isochrone, using the models by Baraffe et al. (1998) and Chabrier et al. (2000). Although the age distribution of the confirmed members of Cha II ranges between 0.1 and 10 Myr (Hughes & Hartigan 1992), the more relaxed criterion of a 20 Myr cut-off for the candidates with a high membership probability was set by taking the uncertainties on the distance to the Cha II cloud ($\Delta d = 18$ pc, Whittet et al. 1997) and the interstellar extinction into account. The evolutionary tracks of low-mass PMS stars run almost parallel to the luminosity axis of the H-R diagram. Thus, although mass estimates are not greatly affected by interstellar extinction, the age dispersion may be considerably increased if the adopted extinction for each candidate is not well-determined. The mean uncertainty on our visual extinction determinations is ~ 1.5 mag (see Sect. 5.3.1); this would correspond to a luminosity uncertainty of $\sim 16\%$ and, hence, an age uncertainty of ~ 2 Myr for an object with mass $\sim 0.5 M_{\odot}$ and age 2–3 Myr, i.e. the typical values in Cha II (Alcalá et al., in preparation). Thus, the criterion of the 20 Myr isochrone ensures that the selected objects are, to a first approximation, consistent with Cha II membership.

The theoretical isochrones depend on the physics involved in the models. As such, they may be rather uncertain, in particular

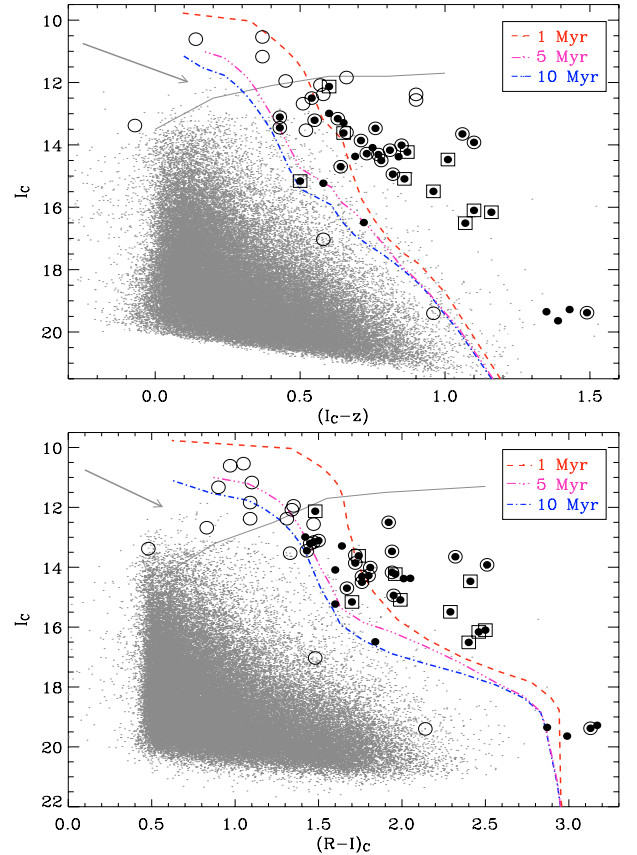


Fig. 9. I_C vs. $(I_C - z)$ and I_C vs. $(R - I)_C$ diagrams for the point-like objects in our survey (small gray dots). The lines represent the theoretical isochrones derived as explained in Sect. 3.1, shifted to the distance modulus of Cha II (6.25 mag, Whittet et al. 1997). The continuous line in each diagram represents the saturation limit. The big black dots represent the 37 sources selected from our criteria, while the open circles and squares represent the known PMS stars and candidates selected from previous surveys, respectively. The magnitudes reported by Hughes & Hartigan (1992) were used to plot the objects above and/or close to our saturation limits in any of the three broad-bands. The $A_V = 2$ mag reddening vector is shown in both diagrams.

in the very low-mass domain. We have thus tested the reliability of our selection criteria using as test bench the publicly available samples of confirmed PMS stars and BDs in Taurus and IC348 reported by Briceño et al. (2002) and Luhman et al. (2003), respectively. As can be seen in Fig. 14 (available only in electronic form), the selection criteria recover the vast majority of the previously known PMS stars and BDs in these regions, providing a good check that they work well on selecting these type of objects.

5. Results of the survey

The already confirmed Cha II population members consist of some 36 objects, comprised of 33 PMS stars (Alcalá et al. 2000; Hughes & Hartigan 1992; Young et al. 2005), one BD (Alcalá et al. 2006), and two planetary-mass objects (Allers et al. 2006; Jayawardhana & Ivanov 2006).

The screening of our data lead, on the other hand, to selection of 37 interesting objects. Of these, 17 were already known (16 PMS stars plus the BD) and 10 are candidates with high probability of membership based on their selection in previous surveys (Allers et al. 2006; Persi et al. 2003; Vuong et al. 2001;

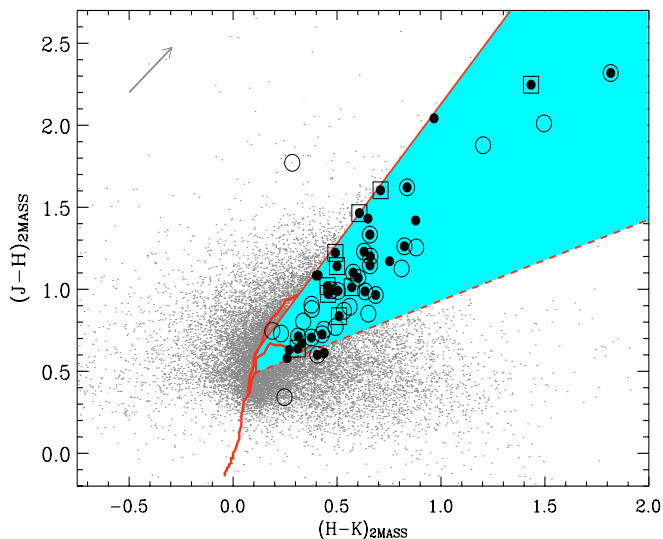


Fig. 10. $(J - H)$ vs. $(H - K)$ diagram for the sources detected in Cha II (small gray dots). The solid curve shows the relation between these indexes for main sequence stars (lower branch) and giants (upper branch). The dashed line indicates the classical T Tauri stars locus by Meyer et al. (1997). The continuous line is the dividing line between giants and dwarfs. The shaded area indicates the locus presumably uncontaminated by giants. The previously known PMS stars and candidates are indicated with open circles and squares respectively. The big black dots represent the objects selected in this work. The $A_V = 2$ mag reddening vector is shown. The two PMS stars which fall outside the selection area are the heavily veiled star Sz 47 (below the shaded area) and the binary Sz 60E (above the shaded area).

Young et al. 2005). The remaining 10 selected objects are completely new candidates. The other 13 previously known PMS stars are saturated and/or close to the saturation limit in at least one of our broad-band RIZ images, so we could not apply our selection criteria. However, using their magnitudes and colours from the literature (Alcalá et al. 1995; Hughes & Hartigan 1992), these objects would fall within our selection; this means that, adding these to the 17 previously known non-saturated objects, our criteria recover 30 of the 36 previously known Cha II members.

There are a few exceptions in which the above selection criteria fail: the heavily veiled T Tauri stars Sz 47 (Hughes & Hartigan 1992) and C 41 (Barrado y Navascués & Jayawardhana 2004), which exhibit strong UV excess that affects their colours, and the Class-I source IRAS 12500-7658 (Young et al. 2005), which is a deeply embedded object. These three sources are sub-luminous in both CMDs. In addition, the other Class-I source, ISO-CHA II 28, is not detected in any of our images. Although this type of objects would escape our selection, they are expected to be rare in Cha II (Young et al. 2005; Alcalá et al., in preparation). The two planetary-mass candidates reported by Allers et al. (2006) also escaped selection because they were barely detected only in our I -band images. The Herbig-Haro object HH 54 (Giannini et al. 2006) and the Class-0 source BHR 86 (Garay et al. 2002) are also associated with Cha II. HH 54 was detected only in our R -band and $H\alpha$ images, while BHR 86 was not detected in any of the optical bands. These objects will be discussed in detail in a forthcoming paper (Alcalá et al., in preparation).

In conclusion, our selection criteria recover the majority (about 80%) of the confirmed and candidate members of Cha II

reported in previous surveys. For the sake of clarity, in all the diagrams we use dots to represent the 37 objects selected with our criteria, open circles to represent the already confirmed members, and open squares to represent the 10 candidates selected in previous surveys. The 10 new candidates appear simply as dots in all the diagrams.

In Table 7 we report all the objects with at least one photometric measurement in the optical bands⁴. The table contains the confirmed members of Cha II, the candidates selected by previous surveys, and the new candidates selected in this work, as well as other sources identified as possible candidates in previous studies but that were rejected by our selection criteria. The latter sample includes objects like the candidates reported by López-Martí et al. (2005)⁵ and some of the sources identified by Persi et al. (2003). Comments on some individual objects are given in Appendix C.

In the following we concentrate on the sample of 20 candidates, namely the 10 candidates selected from previous surveys, but also recovered from our selection criteria, and the 10 new candidates. They are reported in Table 6 and their spatial distribution is shown in Fig. 1. The 10 previously known candidates recovered in our selection have also been proposed as young members of Cha II by recent studies (Allers et al. 2006; Vuong et al. 2001; Young et al. 2005), which supports their membership to the cloud and, at the same time, the reliability of our selection method. Moreover, several of them possess $H\alpha$ emission (see Sect. 5.2). We note that these are the candidates with the highest membership likelihood, but we do not exclude the possibility that a few true Cha II members could have escaped some of our selection criteria, in particular if they are heavily veiled, deeply embedded, or if they are components of unresolved binaries. If all the 20 candidates are confirmed by spectroscopy, the population of Cha II will increase to some 56 members. Two of the 10 new candidates in our sample (WFIJ12585611-7630105 and WFIJ13005531-7708295) have been spectroscopically confirmed as PMS stars (Alcalá et al., in preparation).

5.1. Possible contaminants

One possible source of contamination of our candidates is represented by field dwarfs. In order to estimate the number of possible foreground dwarfs in the field of Cha II, we followed the prescriptions by Burgasser et al. (2004). We used the low-mass luminosity function simulations from Burgasser (2004) and the absolute magnitudes for late M and L field dwarfs from Dahn et al. (2002). Assuming a limiting magnitude of $I = 20$, i.e. the I magnitude of our faintest candidates, and a mass function $dN/dM \propto M^\alpha$ with $0.5 < \alpha < 1.5$, we expect 8–10 foreground dwarfs with $2000 < T_{\text{eff}} < 3000$ K in the ~ 2 square-degree area observed in Cha II. Therefore, up to about 50% of the candidates might be foreground dwarfs unrelated to the SFR.

Another possible source of contamination is represented by faint galaxies that may have colours similar to those of PMS objects, in particular of BD candidates. From the K -band galaxy number counts toward the celestial south pole, the expected number of background galaxies with $K \lesssim 13$ mag, i.e. the K magnitude of our faintest candidates, in a ~ 2 square-degree area is ~ 20 (Minezaki & Kobayashi 1998). Only diffuse interstellar extinction, which is negligible (~ 0.02 mag) at the K -band

⁴ Table 7 is published only in electronic form.

⁵ The BD candidates selected by López-Martí et al. (2005) do not comply with our selection criteria, probably because the colour effects on the isochrones due the WFI filters were not taken into account.

(Jones et al. 1981), is considered for this estimate. In Cha II, the extinction may be as high as $A_V \approx 6\text{--}8$ mag, i.e. $A_K \approx 1$ mag. Thus, in order to contaminate our sample, the background galaxies should have $K \lesssim 12$ mag; the predicted galaxy number count at this magnitude is less than 2 in the surveyed area. In addition, our PSF extraction methods remove the extended objects quite efficiently; thus, the only contaminants may eventually be the point-like extra-galactic objects, mainly QSO's. According to Prescott et al. (2006), only a handful of QSO's are expected to be present in 2 square degrees for magnitudes brighter than $R = 20$ mag. The number increases for fainter magnitudes, but the vast majority of our candidates are brighter. Thus, we do not expect that extra-galactic objects represent a major contamination problem.

5.2. $H\alpha$ emission of the candidates

The calibration relation between the $(H\alpha_{12} - H\alpha_7)$ index and the $EW_{H\alpha}$ (see Sect. 3.3) allows us to investigate a possible $H\alpha$ emission of the candidates. Based on this calibration, a threshold of $(H\alpha_{12} - H\alpha_7) = 0.1$ mag would translate into an equivalent width $EW_{H\alpha} \approx 10 \text{ \AA}$ at the 1σ level of detection (cf. Sect. 3.3). Most of the previously known PMS stars and candidates have a larger $H\alpha$ index than this value (cf. Fig. 11). Forty per cent of the 20 candidates show $H\alpha$ emission at the 1σ level, but only 2 of the 20 show it at the 3σ level. Considering that the $H\alpha$ line can be strongly variable in young objects, we cannot use the index as a major diagnostic for the selection of the candidates, but only as a consistency check on their possible PMS nature. However, the 1σ level detections are still consistent with recent spectroscopic evidence of $H\alpha$ emission (Alcalá et al., in preparation). Moreover, the $EW_{H\alpha}$ range covered by our candidates ($10\text{--}35 \text{ \AA}$) is in line with what is found by White & Basri (2003) for the slowly rotating, non-accreting stars and for BDs in Taurus-Auriga. For the remaining candidates, the $(H\alpha_{12} - H\alpha_7)$ index does not indicate any clear evidence of $H\alpha$ emission. For three objects (WFIJ12533662-7706393, WFIJ12583675-7704065, and WFIJ13005297-7709478), the level of $H\alpha$ emission could not be estimated because they are not detected in our $H\alpha$ images (the magnitude limit is ~ 20.5 mag at the 3σ level). These very faint candidates are indeed relevant because their optical colours resemble those of ISO-Cha II-13 (Alcalá et al. 2006). Note that ISO-Cha II-13 was also not detected in our $H\alpha$ images. The $H\alpha$ information drawn from our data for the selected candidates is reported in Table 6.

5.3. Towards the fraction of sub-stellar objects in Cha II

An interesting and important quantity in this investigation is the number of sub-stellar objects compared to the PMS stars in Cha II. In order to determine this quantity, we must single out the sub-stellar objects. According to Chabrier et al. (2000), the sub-stellar limit for 3–4 Myr objects, the approximate age of Cha II (Alcalá et al. 2000; Cieza et al. 2005; Hughes & Hartigan 1992) falls at a temperature of about 2900 K. Using the tools described in Sect. 3 and exploiting the potential of our photometric data, we attempted a first estimate of the temperature of the candidate members of Cha II and thus a guess at the fraction of sub-stellar candidates relative to the PMS stars. We first derived the dereddened SEDs of the candidates and then provided a first estimate of their temperature.

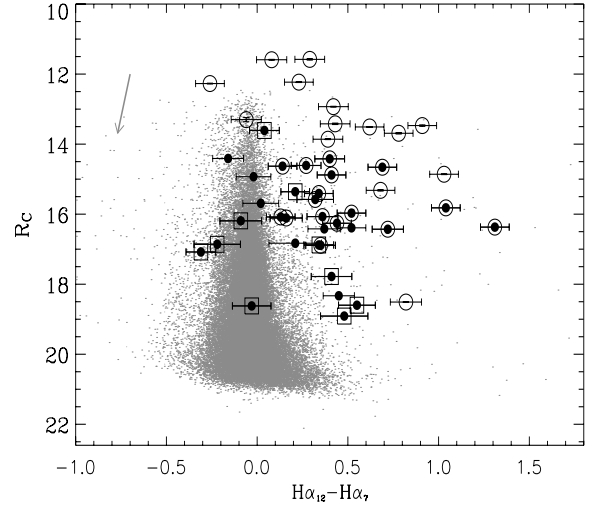


Fig. 11. R_C magnitudes versus $(H\alpha_{12} - H\alpha_7)$ colours for the point-like objects in Cha II (small gray dots). The previously known PMS stars and candidates are indicated by open circles and squares, respectively, whereas the sources selected in this work are represented with big black dots. The $A_V = 2$ mag reddening vector is shown.

Table 5. Absolute flux calibration constants and effective wavelengths for the optical and near-IR pass-bands.

Filter	F_λ^0 ($\text{erg} \cdot \text{s}^{-1} \cdot \text{cm}^{-2} \cdot \text{\AA}^{-1}$)	λ_{eff} (μm)	Ref.
R_C	2.25×10^{-9}	0.64	Cousins (1976)
I_C	1.19×10^{-9}	0.79	Cousins (1976)
z	8.40×10^{-10}	0.96	This work
J	3.13×10^{-10}	1.25	Cutri et al. (2003)
H	1.13×10^{-10}	1.62	Cutri et al. (2003)
K	4.28×10^{-11}	2.20	Cutri et al. (2003)

5.3.1. Dereddened SEDs

The SEDs were derived by merging the RIZ WFI-Cousins photometry with the 2MASS JHK magnitudes. The standard fluxes at each of the optical and near-IR pass-bands have been derived from the observed magnitudes using the expression $F_\lambda = F_\lambda^0 \cdot 10^{-0.4 \cdot \text{mag}_\lambda^{\text{corr}}}$, where $\text{mag}_\lambda^{\text{corr}}$ is the observed magnitude corrected for interstellar reddening and F_λ^0 the Earth flux of an A0-type star of magnitude $V = 0$ (Table 5). In order to derive the visual extinction, A_V , a SED minimization procedure was used as follows. We assume that the observed magnitude at each wavelength (m_{obs}^λ) can be derived by the following equation

$$m_{\text{obs}}^\lambda - m_{\text{ref}}^\lambda = A_V \cdot \frac{dA_\lambda}{dA_V} + S \quad (7)$$

where m_{ref}^λ is a distance-scaled reference magnitude at a given wavelength (λ) and temperature (T_{eff}). In Eq. (7), A_V is the visual extinction, A_λ the wavelength-dependent extinction, and S a scaling factor depending only on the stellar radius. Using a grid of reference magnitudes and temperatures, we perform a linear fit to the previous expression where $\frac{dA_\lambda}{dA_V}$ and $m_{\text{obs}}^\lambda - m_{\text{ref}}^\lambda$ are the independent and dependent variables, respectively, and A_V and S the two free parameters of the fit. The $\frac{dA_\lambda}{dA_V}$ term was derived using the extinction law by Cardelli et al. (1989), assuming the standard value $R_V = 3.1$. The grid of reference SEDs was

constructed by combining the tabulations of colours as functions of spectral types by Kenyon & Hartmann (1995), Luhman et al. (2003), and Ducati et al. (2001). The A_V value of the reference SED minimizing the χ^2 of the fit corresponds to the best approximation of the actual visual extinction. As a check, we compared the results from our fitting procedure with the extinction derived from the spectral types and the observed colours of previously known PMS stars in Cha II. The RMS difference in A_V is less than 1.5 mag, with only one object having a residual of about 4 mag.

In Fig. 12 the SEDs of the 10 new candidates selected in this work are shown. For six of these, we found a match in the c2d Spitzer catalogues, and their IRAC and/or MIPS fluxes are also included. As appears from their SEDs, no significant IR excess is detected in these six objects. If they are spectroscopically confirmed as Cha II members, they will most likely correspond to weak-line T Tauri stars (WTTS) or to BDs with thin disks. For the four remaining objects lacking Spitzer data, we cannot assess the presence of strong IR excess. However, for three of these we estimate an $H\alpha$ equivalent width greater than about 20 \AA .

It is interesting to note that the number of WTTS relative to CTTS in Cha II is very small. Even assuming that all the candidates in our sample (see Table 6) were to result in WTTS, which is not likely because several of them show strong $H\alpha$ emission, the CTTS would outnumber the WTTS by a factor ~ 2 . This would contrast with what it is found in other clouds, like Cha I and Taurus, where WTTS dominate the PMS population (Feigelson & Montmerle 1999). Our selection based on the $(J - H)$ vs. $(H - K)$ diagram picks up objects later than about K5. This might lead to the conclusion that some earlier type WTTS could have escaped our selection. However, such objects would have been detected in the previous ROSAT X-ray surveys by Alcalá et al. (1995, 2000). Only two WTTS in the cloud, namely RXJ1301.0-7654a and RXJ1303.1-7706 were discovered in these surveys. Thus, the low fraction of WTTS in Cha II seems to be real. More details on this will be discussed in a future c2d paper (Alcalá et al., in preparation), with a more complete set of SEDs for the Cha II members.

5.3.2. Temperature

The temperature of the candidates was estimated using the T_{eff} vs. $(m_{856} - m_{914})$ calibration relation reported in Sect. 3.2. This calibration is valid for cool objects with temperatures in the range 2000–3800 K, corresponding to a dereddened $(m_{856} - m_{914})$ index in the range 1.16–0.16 mag. Thus, we applied the calibration to objects with a dereddened index $(m_{856} - m_{914}) > 0.16$ mag. The A_V values determined as explained in Sect. 5.3.1 and the extinction law by Cardelli et al. (1989) were used to deredden the $(m_{856} - m_{914})$ index. For objects with $(m_{856} - m_{914}) < 0.16$ mag, i.e. hotter than about 3800 K, a temperature estimate was done by fitting a grid of reference SEDs to the dereddened SEDs. The grid of reference SEDs was constructed by combining the tabulations of colours as a function of spectral type by Kenyon & Hartmann (1995), Luhman et al. (2003), and Ducati et al. (2001); the best approximation to the dereddened SED was then obtained by χ^2 -minimization of the flux differences between the dereddened SED and the reference SED. The minimization procedure was applied to the short-wavelength portion ($\lambda \leq \lambda_J$) of the SED, which is less affected by an eventual IR excess. The method turns out to be accurate within 250 K relative to the spectroscopic temperature estimates for most of the previously known PMS stars. This is shown in the upper panel of Fig. 13, where the residuals

between the temperature derived from the dereddened SED fitting, T_{fit} , and that obtained from spectroscopy by Hughes & Hartigan (1992), T_{spec} , are shown. For ISO-CHA II 13 we adopt the temperature value determined spectroscopically by Alcalá et al. (2006).

For the cool candidates, we also performed a consistency check between the temperature derived from SED fitting and what is coming from the T_{eff} vs. $(m_{856} - m_{914})$ calibration. We find that the two methods yield consistent results within ~ 200 K, as can be seen from the lower panel of Fig. 13. We can then use the T_{eff} vs. $(m_{856} - m_{914})$ calibration confidently for those objects with dereddened $(m_{856} - m_{914}) > 0.16$ mag.

The resulting temperature for each of the candidates is reported in Table 6. Using these estimates, we attempted to determine their radius and luminosity as follows:

1. First the reference SED of the same effective temperature as the object was selected and scaled to the Cha II distance ($d = 178$ pc, Whittet et al. 1997):

$$F'_{\text{ref}} = F_{\text{ref}} \cdot \left(\frac{R^*}{d} \right)^2 \quad (8)$$

where R^* is the stellar radius. Since R^* is an unknown quantity, we let it vary between 0.1, i.e. the value expected for a BD at the Deuterium burning limit (Baraffe et al. 2003), and $10 R_{\odot}$; for the objects whose effective temperature could not be estimated from the $(m_{856} - m_{914})$ index, both T_{eff} and R^* were set as free parameters in the assumption that the short-wavelength side of the dereddened SED ($\lambda \leq \lambda_J$) is mainly influenced by T_{eff} .

2. The best estimate of R^* was then obtained by minimizing the flux differences between the observed dereddened SED and the reference one. The minimization procedure was performed, as above, on the short-wavelength portion ($\lambda \leq \lambda_J$) of the SED;
3. Finally, we calculated the bolometric luminosities by applying bolometric corrections to both the dereddened I -band and J -band data. Bolometric corrections were taken from Kenyon & Hartmann (1995) for objects earlier than M6 (i.e. $T_{\text{eff}} \gtrsim 3000$ K), while for cooler objects we followed the prescriptions by Luhman (1999) and combined the compilations of bolometric corrections as a function of temperature by Bessel (1991), Monet et al. (1992), Tinney et al. (1993), and Leggett et al. (1996).

Having an estimate of the temperature and luminosity of the candidates, we determined their masses and ages by comparison with the set of evolutionary tracks by Baraffe et al. (1998) and Chabrier et al. (2000) on the HR diagram.

5.4. The fraction of sub-stellar objects

Previous investigations (Alcalá et al. 2000; Hughes & Hartigan 1992) showed some evidence that the mass spectrum in Cha II might be biased towards very-low mass objects. It is thus interesting to investigate what our data suggest on this matter.

Assuming that all the 20 candidates are true cloud members, we end up with 6 candidates with $T_{\text{eff}} \leq 2900$ K, i.e. below the substellar limit for 5 Myr old objects. The remaining 14 objects turn out to be PMS star candidates (see Table 6). Taking the BD ISO-CHA II 13 and the 33 confirmed PMS stars into account, the resulting fraction of sub-stellar objects ($0.02 M_{\odot} < M < 0.08 M_{\odot}$) relative to the PMS stars ($0.08 M_{\odot} < M < 10 M_{\odot}$),

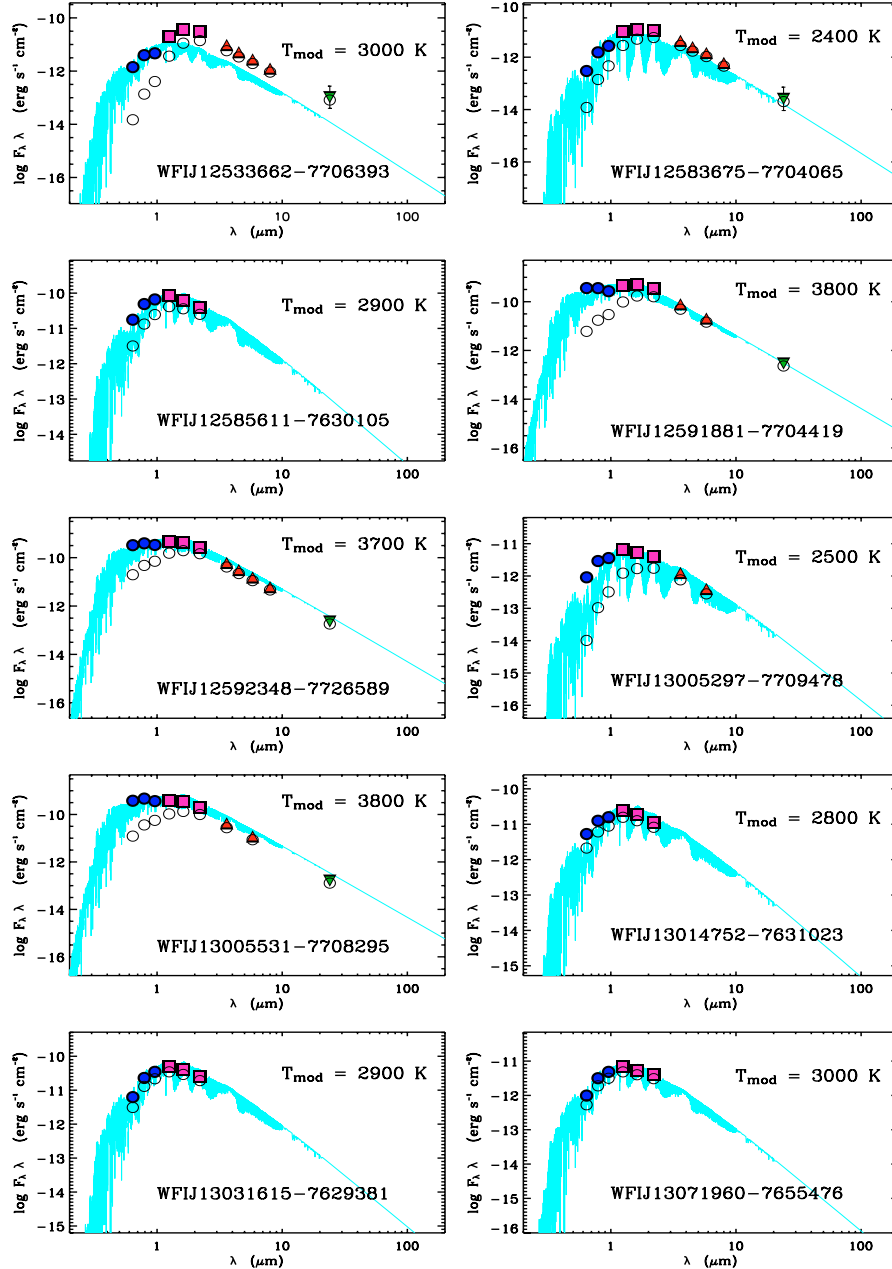


Fig. 12. Spectral energy distributions of the 10 new candidates selected in this work. Dereddened optical data are represented with filled circles; the IR data are from 2MASS (filled squares), IRAC@Spitzer and MIPS@Spitzer (filled triangles and upside down triangles, respectively). The open circles represent the observed fluxes. The best-fitting StarDusty spectra by Allard et al. (2000) with the same temperature as the objects are over-plotted (see Sect. 5.3.2). WFIJ12585611-7630105, WFIJ13014752-7631023, and WFIJ13031616-7629381 fall outside the areas mapped with MIPS and IRAC; although WFIJ13071960-7655476 and WFIJ13005297-7709478 fall in the area surveyed with MIPS, they were not detected.

$R_{ss} = \frac{N(0.02-0.08)}{N(0.08-10)}$, in Cha II would be $\sim 15\%$ (19% if we consider the two planetary-mass objects reported by Jayawardhana & Ivanov 2006). This last value would imply a peculiar mass spectrum for the population of Cha II relative to other T associations (where $R_{ss} = 12-14\%$, Briceño et al. 2002; López-Martí et al. 2004), in particular in the sub-stellar domain. If we assume that only the candidates having $H\alpha$ emission are true cloud members, the R_{ss} value would drop to $\sim 10\%$ (15% if we consider the two planetary-mass objects reported by Jayawardhana & Ivanov 2006), i.e. more similar to that measured in other T associations and lower than measured in OB associations ($\sim 26\%$, Barrado y Navascués et al. 2001; Boulanger et al. 1998; Briceño et al. 2002; Hillenbrand & Carpenter 2000; Muench et al. 2002). If

R_{ss} in Cha II is similar to other T associations, we expect that at least 50% of the candidates reported in Table 6 will be genuine Cha II members.

Assuming that the 7 IRAS sources with $H\alpha$ emission discussed in Appendix C are PMS stars, the fraction of substellar objects would drop to about 8% or 13% depending on whether the two planetary-mass objects are counted among the substellar ones.

By comparing the position of the candidates in the HR diagram with the Baraffe et al. (1998) and Chabrier et al. (2000) evolutionary tracks, their age distribution would peak between 2 and 3 Myr, if they were genuine Cha II members. This would be fairly consistent with the average age of 3.6 Myr determined by

Table 6. The 20 candidates selected in this work.

Designation	$EW_{H\alpha}$ (Å)	A_V (mag)	T_{eff} (K)	A_V^{lit} (mag)	$T_{\text{eff}}^{\text{lit}}$ (K)	Ref.	Classification in this work
WFIJ12533662-7706393	Not Det.	5.58	†3000 ± 250				PMS star cand.
C 17	No Em.	5.95	★3600 ± 200	5.1		b	PMS star cand.
C 33	No Em.	4.48	†3700 ± 250	2.4		b	PMS star cand.
IRAS 12535-7623	No Em.	3.38	★3900 ± 200	5		a	PMS star cand.
WFIJ12583675-7704065	Not Det.	3.84	†2400 ± 200				BD cand.
WFIJ12585611-7630105	30	1.91	†2900 ± 200				BD cand.
ISO-CHA II 29	No Em.	5.94	★3900 ± 200	11.5		b	PMS star cand.
WFIJ12591881-7704419	No Em.	4.98	★3800 ± 200				PMS star cand.
WFIJ12592348-7726589	No Em.	3.33	†3700 ± 250				PMS star cand.
WFIJ13005297-7709478	Not Det.	5.50	†2500 ± 200				BD cand.
WFIJ13005531-7708295	No Em.	4.13	★3800 ± 200				PMS star cand.
IRAS F12571-7657	No Em.	3.95	★★>3000	8,13		b, c	PMS star cand.
WFIJ13014752-7631023	No Em.	0.88	†2800 ± 200				BD cand.
C 50	20	3.46	†3000 ± 200	2.0		b	PMS star cand.
C 51	20	1.16	†3300 ± 250	2.3		b	PMS star cand.
WFIJ13031615-7629381	15	0.61	†2900 ± 200				BD cand.
C 62	35	3.53	†3000 ± 200	4.1, 4	3140	b, c	PMS star cand.
WFIJ13071960-7655476	25	0.50	★3000 ± 200				PMS star cand.
C 66	25	3.87	†2900 ± 200	3.7, 0	2793	b, c	BD cand.
2MASS13125238-7739182	10	1.36	†3400 ± 250			d	PMS star cand.

Notes to Col. 4: † Temperature derived from the dereddened ($m_{856} - m_{914}$) colour index (Sect. 3.2). ★ Temperature derived from the SED fitting method described in Sect. 5.3.2. ★★ See Appendix C.

References: (a) Larson et al. (1998); (b) Vuong et al. (2001); (c) Allers et al. (2006); (d) Young et al. (2005).

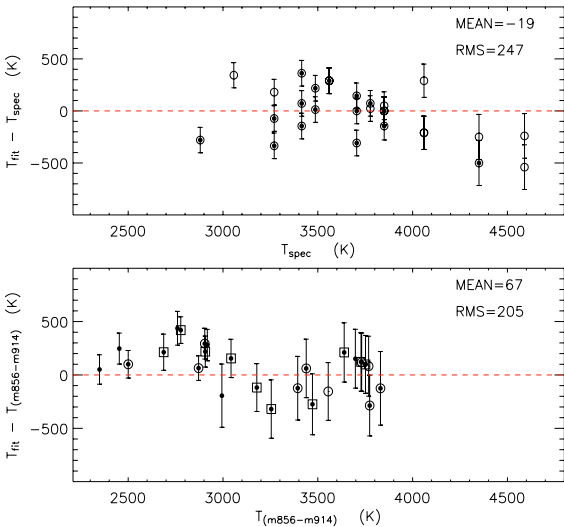


Fig. 13. Upper panel: comparison between the effective temperature resulting from the SED fitting procedure described in Sect. 5.3.2 and that derived from the spectral classification for the confirmed T Tauri stars in Cha II reported by Hughes & Hartigan (1992) and, for C 41, by Barrado y Navascués & Jayawardhana (2004) (open circles). The black dots mark the objects recovered by our selection criteria. The point at $T_{\text{spec}} \approx 2900$ K represents ISO-CHA II 13 as reported by Alcalá et al. (2006). Lower Panel: comparison between the effective temperature resulting from the SED fitting procedure described in Sect. 5.3.2 and that derived from the T_{eff} vs. ($m_{856} - m_{914}$) calibration. The open circles and squares represent previously known PMS stars and candidates, respectively. The black dots mark the objects recovered by our selection criteria.

Cieza et al. (2005) for a sample of T Tauri stars in Cha II. Taking the candidates into account, the mean mass in Cha II would be $\sim 0.5 M_{\odot}$, i.e. slightly lower than the mean mass of the confirmed

members alone ($0.6 M_{\odot}$) and comparable to the mean mass for the Cha I population ($\sim 0.45 M_{\odot}$)⁶.

6. Conclusions

The optical survey presented here is one of the deepest and more extensive conducted so far in Cha II, and it constitutes the optical ancillary data for the c2d Spitzer Legacy survey in this cloud. The photometric selection based on our optical imaging data, combined with data in the near-IR from the 2MASS, allowed us to recover basically all the previously known members of the cloud, including 10 candidates from previous IR surveys, with a high membership probability. Furthermore, we provided 10 new likely member that have not been detected by previous surveys, thereby increasing the total number of candidates to 20. Should all these objects be spectroscopically confirmed as PMS stars and young BDs, the population of Cha II will increase to 56 members.

Up to 50% of the sample may be contaminated by field dwarfs. According to our characterisation criteria of the candidates, we estimate that at least about 50% of them will result in true Cha II members and, based on our temperature estimates, several of these objects are expected to be sub-stellar. Under these assumptions, we conclude that the fraction of substellar objects relative to the PMS stars in Cha II is $\sim 19\%$, i.e. more than reported for other T associations like Taurus. In the most conservative hypothesis in which only the candidates showing $H\alpha$ emission would result in true members of the cloud, this fraction would drop to $\sim 15\%$, i.e. comparable to what is measured in other T associations.

⁶ Luminosity and temperature determinations are reported by Luhman (2004) for 144 members of Cha I. We derived masses and ages for these objects using the evolutionary tracks by Baraffe et al. (1998) and Chabrier et al. (2000) in a homogeneous way.

From the completeness of our survey, both in space and flux, we conclude that the optical population of Cha II members discovered so far is nearly complete. We do not expect to find many more PMS stars based on optical observations. More clues to these issues will be addressed in a forthcoming paper by combining the optical data presented here with those from the MIPS@Spitzer and IRAC@Spitzer observations in Cha II (Alcalá et al., in preparation).

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Online Material

Table 7. Optical photometry of objects in the Cha II dark cloud.

Designation	RA J2000 (hh:mm:ss)	Dec J2000 (dd:mm:ss)	R_c	I_c	z	$H\alpha_7$	$H\alpha_{12}$	m_{86}	m_{914}	Main Ref.	Note
IRAS 12416-7703	12:45:06.43	-77:20:13.52	S	S	S	11.86±0.09	12.10±0.13	S	S	i	•
IRAS 1248-7650	12:48:25.70	-77:06:36.72	S	S	S	13.15±0.09	13.55±0.13	S	S	i	•
IRAS F12488-7658	12:52:30.49	-77:15:12.92	S	S	S	15.48±0.10	15.60±0.13	S	S	f,i	•
IRAS 12496-7650	12:53:17.17	-77:07:10.63	12:53:36.62	13:92±0.01	S	16.12±0.10	16.84±0.14	13:52±0.10	13:52±0.10	a	•
WFI J12533662-7706393	12:53:36.62	-77:06:39.31	22:22±0.14	15:09±0.04	18:00±0.04	ND	ND	19:26±0.20	18:58±0.12	m	•
C 17	12:53:38.84	-77:15:53.21	17:08±0.01	15:09±0.01	14:22±0.01	17.67±0.10	17.36±0.13	15.10±0.09	14.79±0.08	f	•
IRAS 12500-7658	12:53:42.79	-77:15:11.59	21.54±0.08	19.40±0.01	18.44±0.06	20.81±0.38	21.24±0.46	19.43±0.23	19.06±0.15	i	•
IRAS 12551-6000	12:55:16.00	-76:46:21.83	21.85±0.09	19.28±0.02	18.27±0.05	ND	ND	19.26±0.17	18.65±0.11	i	•
Chall 305	12:55:16.48	-76:46:20.89	21.82±0.09	19.30±0.01	18.29±0.05	ND	ND	19.20±0.17	18.68±0.12	j	•
C 33	12:55:25.72	-77:00:46.62	16.86±0.01	15.16±0.01	14.66±0.01	17.15±0.22	16.93±0.13	15.22±0.09	14.79±0.08	f	•
2MASS J2560549-7654106	12:56:05.43	-76:54:10.69	15.95±0.01	14.54±0.01	14.04±0.02	16.17±0.10	16.15±0.13	14.58±0.09	14.42±0.08	i	•
Sz 46NW	12:56:32.85	-76:45:44.78	18.45±0.01	17.69±0.17	17.56±0.04	18.72±0.13	18.70±0.14	17.96±0.10	18.07±0.09	a	•
Sz 46N	12:56:33.59	-76:45:45.18	14.61±0.01	13.16±0.01	12.68±0.01	14.80±0.10	15.07±0.13	13.24±0.09	13.08±0.08	a	•
Sz 46S	12:56:49.54	-76:45:49.54	16.81±0.01	16.05±0.02	15.93±0.02	17.07±0.10	17.03±0.13	16.32±0.09	16.38±0.08	a	•
Sz 47	12:56:58.63	-76:47:06.72	13.86±0.01*	13.38±0.01*	13.45±0.01	13.68±0.10	14.07±0.13	13.72±0.09	13.86±0.08	a	•
IRAS 12533-7632	12:57:00.49	-76:48:35.10	21.19±0.12	19.76±0.01	ND	ND	20.90±0.38	19.92±0.33	19.83±0.29	e	•
IRAS 12535-7623	12:57:11.64	-76:40:11.14	13.61±0.01	12.13±0.01	11.53±0.02	13.69±0.10	13.73±0.13	12.22±0.09	12.03±0.08	e	•
ISO-CHA II 13	12:58:06.67	-77:09:09.22	22.51±0.27	19.38±0.01	17.89±0.04	ND	ND	19.44±0.19	18.33±0.11	g,k	•
WFI J12583675-7704065	12:58:36.75	-77:04:06.53	22.45±0.25	19.33±0.01	17.85±0.04	ND	ND	19.51±0.20	18.27±0.10	m	•
WFI J12585611-7631005	12:58:56.11	-76:30:10.48	16.39±0.01	14.38±0.01	13.54±0.02	16.08±0.09	16.60±0.13	14.34±0.09	13.81±0.08	m	•
C 41	12:59:09.86	-76:51:03.49	18.51±0.01	17.03±0.01	16.45±0.02	18.06±0.10	18.88±0.14	17.31±0.09	17.07±0.08	fh	•
ISO-CHA II 29	12:59:10.19	-77:12:13.72	16.19±0.02	14.23±0.01	13.36±0.01	16.41±0.19	16.32±0.13	14.37±0.09	13.91±0.08	gi	•
WFI J12592348-7726589	12:59:23.48	-77:26:58.96	14.41±0.01	14.09±0.01	13.34±0.01	15.86±0.10	15.88±0.17	14.19±0.09	13.86±0.09	m	•
IRAS 12592-7731	12:59:26.50	-77:47:08.70	S	S	S	12.34±0.09	14.62±0.12	13.13±0.09	12.75±0.08	m	•
WFI J13005297-7709478	13:00:52.97	-77:09:47.77	22.63±0.30	19.64±0.07	18.25±0.05	ND	ND	19.85±0.25	18.66±0.12	i	•
Sz 48NE	13:00:53.15	-77:09:09.18	16.08±0.01	14.32±0.04	13.55±0.01	16.11±0.09	16.24±0.13	14.44±0.09	14.02±0.08	a	•
Sz 49	13:00:53.26	-76:54:14.98	14.86±0.01	13.53±0.03	13.01±0.01	13.90±0.09	14.93±0.13	13.62±0.09	13.35±0.08	a	•
Sz 48SW	13:00:53.56	-77:09:08.28	16.26±0.01	14.50±0.02	13.72±0.01	16.33±0.09	16.57±0.13	14.51±0.09	14.19±0.08	a	•
Sz 50	13:00:55.28	-77:10:22.01	14.42±0.01	12.50±0.01*	11.96±0.02	14.34±0.10	14.74±0.13	12.79±0.09	12.43±0.08	a	•
WFI J13005531-7708295	13:00:55.31	-77:08:29.54	14.93±0.01	13.29±0.01	12.64±0.01	15.26±0.14	15.24±0.13	13.39±0.09	13.15±0.09	m	•
RXJ1301.0-76544	13:00:56.22	-76:54:01.76	11.59±0.01*	10.54±0.01*	10.17±0.01	11.63±0.09	11.71±0.14	10.61±0.09	10.66±0.09	d	•
IRAS F12571-7657	13:00:59.21	-77:14:02.80	18.62±0.01	16.16±0.01	15.00±0.01	19.26±0.14	19.23±0.16	16.48±0.23	15.79±0.14	g	•
ISO-CHA II 73	13:01:58.94	-77:16:02.89	16.31±0.02	15.12±0.01	14.68±0.01	16.71±0.22	16.55±0.13	15.38±0.09	15.13±0.08	e,g	•
WFI J13014752-7631023	13:01:47.52	-76:31:02.32	16.83±0.05	15.22±0.01	14.65±0.06	18.84±0.20	17.05±0.21	15.77±0.17	15.18±0.12	m	•
Sz 51	13:01:58.94	-77:51:21.74	13.47±0.02*	12.38±0.01*	11.80±0.02	12.46±0.09	13.57±0.13	12.55±0.09	12.29±0.08	a	•
CM Cha	13:02:13.49	-76:37:57.68	12.93±0.01	11.84±0.01	11.18±0.01	12.15±0.10	12.57±0.13	11.55±0.09	11.62±0.08	b	•
C 50	13:02:22.82	-77:34:49.51	17.78±0.01	15.49±0.02	14.53±0.01	17.78±0.10	18.19±0.20	15.48±0.09	14.93±0.08	f,g	•
IRAS 12589-7646	13:02:47.73	-77:02:46.32	S	S	S	12.72±0.09	12.92±0.13	12.92±0.13	12.92±0.13	i	•
RXJ1303.1-7706	13:03:04.46	-77:07:02.75	12.27±0.01*	11.17±0.01*	10.80±0.01	12.34±0.09	12.08±0.13	11.29±0.09	11.16±0.08	c	•
C 51	13:03:09.04	-77:55:59.52	16.88±0.01	14.47±0.01	13.46±0.02	16.82±0.10	17.16±0.13	17.16±0.13	14.03±0.10	f	•
Chall 376	13:03:12.45	-76:50:50.82	16.31±0.01	15.45±0.01	15.33±0.05	16.40±0.10	16.42±0.13	14.39±0.09	NO	j	•
WFI J13031615-7629381	13:03:16.15	-76:29:38.15	16.42±0.01	14.41±0.03	13.68±0.03	16.30±0.10	16.67±0.15	NO	NO	m	•
ISO-CHA II 98A	13:03:25.85	-77:01:48.36	17.09±0.02	16.42±0.04	16.24±0.03	17.53±0.10	17.27±0.11	16.83±0.09	17.17±0.24	g	•
ISO-CHA II 98B	13:03:26.10	-77:01:48.40	17.09±0.02	16.37±0.01	16.18±0.02	17.47±0.10	17.24±0.11	17.68±0.43	16.99±0.22	g	•
ISO-CHA II 110	13:04:18.96	-76:53:59.96	14.52±0.01*	14.03±0.01	14.03±0.01	14.59±0.09	14.58±0.13	NO	NO	g	•
Hn 22	13:04:22.78	-76:50:05.86	13.51±0.01*	12.68±0.01*	12.17±0.02	13.23±0.09	13.85±0.13	NO	NO	b	•
Hn 23	13:04:24.06	-76:50:01.39	12.23±0.01*	11.33±0.08*	S	12.11±0.09	12.34±0.13	NO	NO	b	•
Sz 52	13:04:24.84	-77:52:30.11	16.89±0.01	14.94±0.01	14.12±0.01	17.00±0.10	17.35±0.13	14.84±0.09	14.43±0.08	a	•
Hn 24	13:04:55.74	-77:39:49.21	13.30±0.06*	11.95±0.02*	11.50±0.02	13.49±0.09	13.43±0.14	12.19±0.09	12.01±0.08	b	•

Table 7. continued.

Designation	RA J2000 (hh:mm:ss)	Dec J2000 (dd:mm:ss)	R_c	I_c	z	$H\alpha_7$	$H\alpha_{12}$	m_{856}	m_{914}	Main Ref.	Note
Hn 25	13:05:08.51	-77:33:42.66	16.11 ± 0.01	14.17 ± 0.02	13.36 ± 0.01	16.45 ± 0.12	16.61 ± 0.13	14.40 ± 0.09	14.01 ± 0.09		★ I ₁
Sz 53	13:05:12.66	-77:30:52.56	15.58 ± 0.02	13.86 ± 0.02	13.15 ± 0.01	15.58 ± 0.09	15.90 ± 0.18	15.16 ± 0.12	14.47 ± 0.08		★ I ₁
Sz 54	13:05:20.80	-77:39:01.48	11.58 ± 0.02*	10.61 ± 0.06*	10.47 ± 0.43	11.28 ± 0.10	11.57 ± 0.13	10.80 ± 0.09	11.05 ± 0.15		★ I ₁
Sz 55	13:06:30.49	-77:34:00.12	16.37 ± 0.01	14.70 ± 0.06	14.06 ± 0.47	15.65 ± 0.09	16.96 ± 0.13	14.61 ± 0.09	14.53 ± 0.08		★ I ₁
Sz 56	13:06:38.70	-77:30:35.39	15.41 ± 0.01*	13.47 ± 0.02*	12.71 ± 0.44	15.41 ± 0.09	15.75 ± 0.13	13.67 ± 0.09	13.15 ± 0.08		★ I ₁
Sz 57	13:06:56.56	-77:23:09.46	15.97 ± 0.01	13.65 ± 0.01	12.59 ± 0.41	15.71 ± 0.09	16.23 ± 0.13	13.74 ± 0.09	13.07 ± 0.08		★ I ₁
Sz 58	13:06:57.35	-77:23:41.46	14.63 ± 0.01	13.16 ± 0.01	12.53 ± 0.43	14.44 ± 0.09	14.58 ± 0.13	12.98 ± 0.09	12.78 ± 0.08		★ I ₁
Sz 59	13:07:09.23	-77:30:30.24	13.42 ± 0.02*	12.08 ± 0.01*	11.51 ± 0.43	12.96 ± 0.10	13.39 ± 0.13	12.57 ± 0.09	12.50 ± 0.08		★ I ₁
C 62	13:07:18.04	-77:40:53.00	18.60 ± 0.01	16.10 ± 0.01	15.00 ± 0.44	18.42 ± 0.11	18.97 ± 0.17	16.23 ± 0.09	15.60 ± 0.08		★ I ₁
WFI J13071960-7655476	13:07:19.60	-76:55:47.64	18.33 ± 0.01	16.49 ± 0.02	15.77 ± 0.02	18.12 ± 0.10	18.57 ± 0.14	NO	NO		I ₁ NEW
Sz 60W	13:07:22.30	-77:37:22.62	14.88 ± 0.02*	13.45 ± 0.02*	13.02 ± 0.46	14.60 ± 0.09	15.01 ± 0.13	13.42 ± 0.09	13.23 ± 0.07		★ I ₁
Sz 60E	13:07:23.33	-77:37:23.20	15.32 ± 0.02*	13.60 ± 0.01*	12.94 ± 0.46	15.01 ± 0.09	15.69 ± 0.13	13.98 ± 0.09	13.61 ± 0.08		★ I ₁
Hn 26	13:07:48.50	-77:41:21.73	16.07 ± 0.01	14.31 ± 0.01	13.54 ± 0.46	15.89 ± 0.11	16.25 ± 0.13	14.41 ± 0.09	14.13 ± 0.08		★ I ₁
Sz 61	13:08:06.33	-77:55:05.05	13.69 ± 0.02*	12.38 ± 0.01*	11.48 ± 0.42	12.69 ± 0.09	13.47 ± 0.13	12.27 ± 0.09	12.14 ± 0.08		★ I ₁
C 66	13:08:27.19	-77:43:23.41	18.91 ± 0.01	16.51 ± 0.01	15.44 ± 0.44	19.24 ± 0.14	19.72 ± 0.22	16.76 ± 0.09	16.03 ± 0.08		★ I ₁
IRAS F13052-7653NW	13:09:09.81	-77:09:43.52	15.37 ± 0.01	14.04 ± 0.02	13.52 ± 0.44	15.59 ± 0.09	16.11 ± 0.13	14.02 ± 0.09	13.84 ± 0.08		★ I ₁
IRAS F13052-7653S	13:09:10.67	-77:09:46.84	13.49 ± 0.01	12.57 ± 0.01	12.38 ± 0.47	13.09 ± 0.09	13.04 ± 0.13	12.69 ± 0.09	12.77 ± 0.08		★ I ₁
IRAS F13052-7653N	13:09:10.98	-77:09:44.14	13.47 ± 0.01	12.42 ± 0.02	12.07 ± 0.45	13.51 ± 0.09	13.74 ± 0.13	12.54 ± 0.09	12.47 ± 0.08		★ I ₁
Sz 62	13:09:50.44	-77:57:23.94	14.03 ± 0.02*	12.56 ± 0.02*	11.66 ± 0.43	NO	NO	NO	NO		★ I ₁
Sz 63	13:10:04.12	-77:10:44.62	14.66 ± 0.01	13.21 ± 0.01	12.66 ± 0.44	14.40 ± 0.09	15.09 ± 0.13	13.25 ± 0.09	13.03 ± 0.08		★ I ₁
2MASS J1302531-7729082	13:10:25.26	-77:29:08.70	16.49 ± 0.01	15.36 ± 0.05	14.95 ± 0.48	16.49 ± 0.10	16.49 ± 0.13	15.54 ± 0.09	15.43 ± 0.08		★ I ₁
2MASS J1310329-7653330	13:11:03.27	-76:53:32.89	14.50 ± 0.01	13.85 ± 0.00	13.68 ± 0.01	14.62 ± 0.09	14.57 ± 0.13	NO	NO		★ I ₁
2MASS J13125238-7739182	13:12:52.37	-77:39:18.58	15.36 ± 0.01	13.62 ± 0.02	12.97 ± 0.47	15.57 ± 0.09	15.78 ± 0.13	13.83 ± 0.09	13.51 ± 0.08		★ I ₁
Sz 64	13:14:03.83	-77:53:07.48	15.82 ± 0.01	14.01 ± 0.01	13.16 ± 0.45	15.25 ± 0.09	16.29 ± 0.13	14.40 ± 0.09	13.65 ± 0.08		★ I ₁

Notes: The positions for most objects are from the R -band images. For saturated objects in the R -band the positions are from the $H\alpha_{12}$ images; the coordinates of Sz 62, not observed in $H\alpha$, are from the z -band image. Magnitudes marked with an asterisk are taken from the literature (see the relative references) and correspond to objects saturated in our images. Comments about some of these objects are given in Appendix C. Symbols and labels are as follows:

- ★ = Confirmed member
- ● = Previously known candidate
- I₁ = Object recovered by our selection criteria
- I₁ NEW = Member candidate firstly identified in this work
- I₂ = Object rejected on the basis of our selection criteria
- ☆ = Veiled object
- ☆ = Embedded object
- ♣ = Component of a visual binary or multiple system
- S = Saturated object
- ND = Object not detected
- NO = Object not observed

Main references: a Hughes & Hartigan (1992); b Hartigan (1993); c Alcalá et al. (1995); d Covino et al. (1997); e Alcalá et al. (2000); f Vuong et al. (2001); g Persi et al. (2003); h Barrado y Navascués & Jayawardhana (2004); i Young et al. (2005); j López-Martí et al. (2005); k Alcalá et al. (2006); l Allers et al. (2006); m This work.

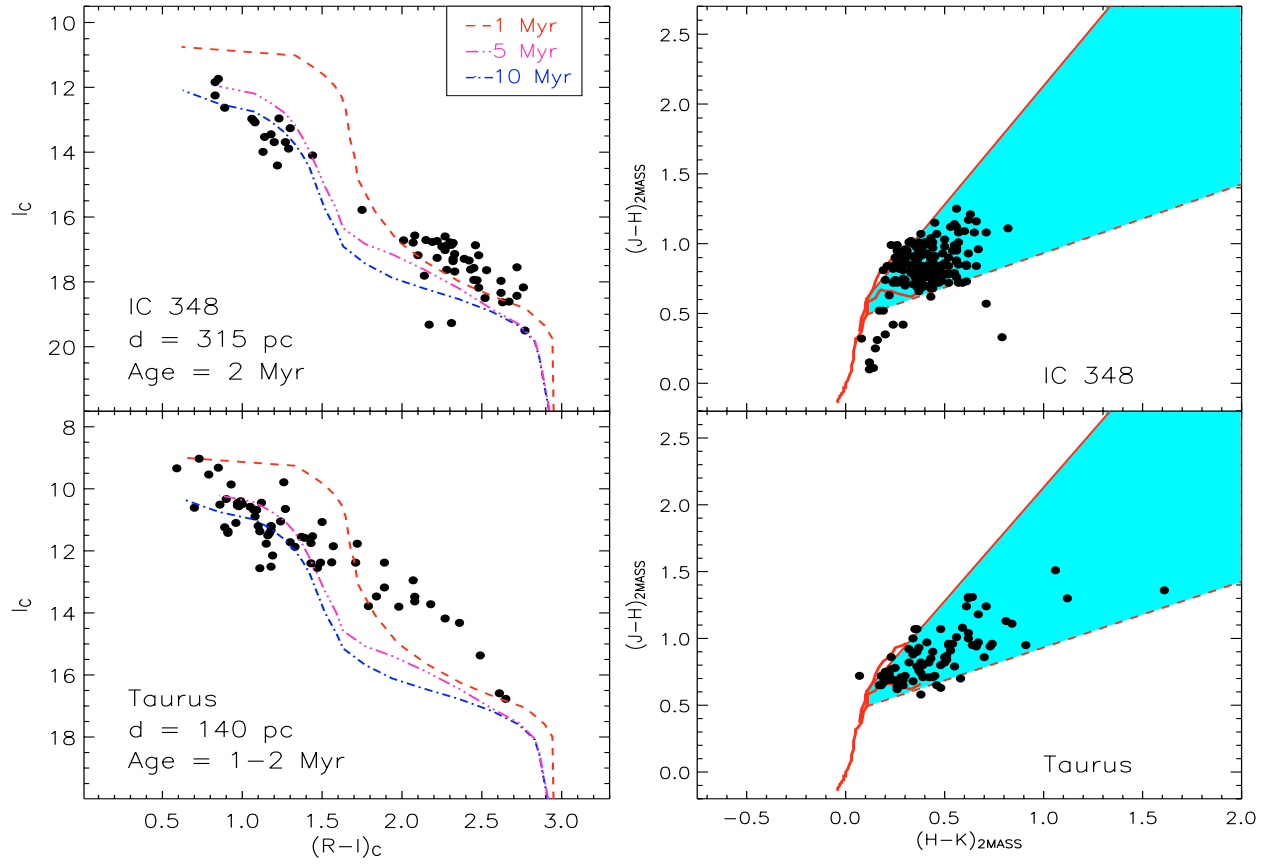


Fig. 14. I_C vs. $(R-I)_C$ and $(J-H)$ vs. $(H-K)$ diagrams for the PMS populations in Taurus and IC348. The isochrones, shifted by the corresponding distance modulus, are as in Fig. 9. The selection limits in the $(J-H)$ vs. $(H-K)$ diagrams are as in Fig. 10.

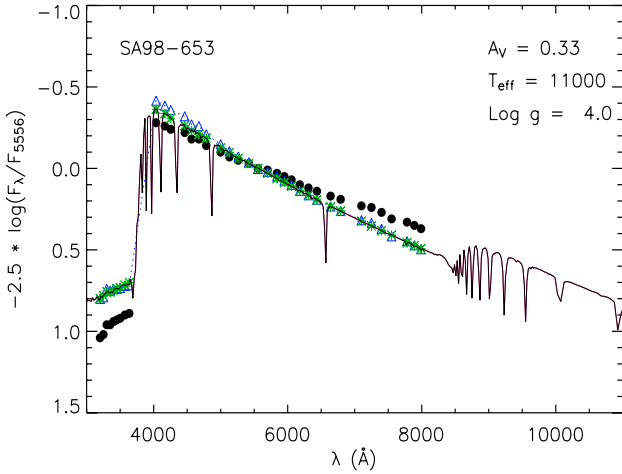


Fig. A.1. Observed (dots) and dereddened (open triangles) spectral energy distribution of SA 98 653 normalised to the flux at 5556 Å. The best fitting model by Kurucz (1979) is over-plotted (continuous line).

Appendix A: Flux at $z = 0$

In order to derive the flux at zero magnitude in the z band we used the following procedure:

1. The spectrophotometry of SA 98 653 is available from Gutiérrez Moreno et al. (1988) in the form of monochromatic instrumental magnitudes, covering a wavelength range from 3200 to 8000 Å, in steps of 40 Å for $\lambda \leq 5400$ Å and 80 Å for $\lambda > 5400$ Å. Since the z band is centred at 9648 Å ($FWHM = 616$ Å), we need the spectrophotometry in a wider wavelength range. We thus extrapolate the SED of SA 98 653, up to 16000 Å, by using the Kurucz grid of stellar atmosphere models (Kurucz 1979) in the following way. We first deredden the SED of SA 98 653 using the canonical absorption-to-reddening ratio $R_V = 3.2$, as suggested by Chen et al. (2001) for the SA 98 field. Assuming that SA 98 653 is a main sequence star, as indicated by its spectrophotometry and broad-band photometric indexes, we derive its distance by comparing its observed V magnitude with the expected absolute visual magnitude ($M_V = 0.7$, Gray 1992) for an A0-type main sequence star. Assuming an error of two spectral sub-classes on SA 98 653 spectral type, we constrained its distance between 300 and 450 pc, i.e. $0.30 \text{ mag} < A_V < 0.45 \text{ mag}$. Note that the extinction of the nearby star SA 98-667 (spectral type B9V) is $A_V = 0.33$ calculated from its Hipparcos parallax (Chen et al. 2001), which is consistent with the range of values allowed for SA 98 653. The interstellar extinction coefficients at each wavelength were derived by using the extinction curve by Cardelli et al. (1989). We then performed a two-parameters least-square fit to the observed spectrophotometry of SA 98 653 by taking as free parameters the extinction (in the range $0.30 \text{ mag} < A_V < 0.45 \text{ mag}$ in steps of 0.01 mag) and the effective temperature of the model spectrum. Both the Kurucz models and the dereddened SED of SA 98 653 were normalised to the flux at 5556 Å. A minimum χ^2 for a model with $T_{\text{eff}} = 11000$ K, $\log g = 4$ and $A_V = 0.33$ was derived (Fig. A.1). We then used this synthetic spectrum reddened with $A_V = 0.33$ to extrapolate the spectrophotometry of SA 98 653 in the near-IR.

2. The absolute Earth flux at 5556 Å of a star with magnitude V^* calibrated with Vega, the primary photometric standard, is given by (Gray 1992)

$$\log(F_{5556}^*) = -0.400 \cdot V^* - 8.451 \quad (\text{A.1})$$

in units of $\text{erg} \cdot \text{cm}^{-2} \cdot \text{s}^{-1} \cdot \text{Å}^{-1}$.

When this expression is used for stars whose effective temperature is different from Vega ($T_{\text{eff}} = 9790$ K), as in the case of SA 98 653, a small systematic error is introduced because the effective wavelength of the V band is 5480 Å, i.e. 76 Å shorter than the reference wavelength (5556 Å). An adequate correction for this is given by the following colour term (Gray 1992)

$$\log\left(\frac{F_{5556}^*}{F_{5480}^*}\right) = -0.006 + 0.018 \cdot (B - V)^*. \quad (\text{A.2})$$

Considering the dereddened visual magnitude of SA 98 653 and its intrinsic $(B - V)$, and applying Eqs. (A.1) and (A.2), respectively, we obtain

$$V_{\text{SA 98 653}}^{\text{corr}} = 9.24$$

and

$$\log[F_{\text{SA 98 653}}^{5556}] = -12.1465.$$

We now can calculate the flux of SA 98 653 at any wavelength with respect to the flux at 5556 Å as

$$F_{\text{SA 98 653}}^{\text{synt}}(\lambda) = F_{\text{SA 98 653}}^{5556} \times 10^{-0.4 \cdot \text{mag}_{\text{SA 98 653}}^{\text{synt}}(\lambda)} \quad (\text{A.3})$$

where $\text{mag}_{\text{SA 98 653}}^{\text{synt}}$ is the synthetic magnitude of SA 98 653 at each wavelength normalised to the magnitude at 5556 Å, determined in the previous step.

3. We finally determined the synthetic flux of SA 98 653 in the z band by integrating its synthetic spectrum $F_{\text{SA 98 653}}^{\text{synt}}(\lambda)$ in the z filter transmission curve T_λ , i.e. the product of the detector quantum efficiency and the filter transmission curve:

$$F_{\text{SA 98 653}}^z = \frac{1}{A_z} \cdot \int_{\lambda_1}^{\lambda_2} F_{\text{SA 98 653}}^{\text{synt}}(\lambda) \cdot T_\lambda \cdot d\lambda \quad (\text{A.4})$$

where

$$A_z = \int_{\lambda_1}^{\lambda_2} T_\lambda \cdot d\lambda. \quad (\text{A.5})$$

We obtained

$$F_{\text{SA 98 653}}^z = 1.62 \times 10^{-13} \text{ erg} \cdot \text{cm}^{-2} \cdot \text{s}^{-1} \cdot \text{Å}^{-1}$$

where $F_{\text{SA 98 653}}^z$ is the flux in the z filter of an A0 type star with visual magnitude $V = 9.539$ and $z = I_C = 9.522$. What we need, in order to obtain an absolute flux calibration for the z band, is the flux of an A0-type star with $V = 0$ and $z = 0$ (F_{A0V}^z). Since SA 98 653 is an A0-type star and we have defined its intrinsic colour as $(I_C - z) = 0$, we have

$$z_{\text{SA 98 653}} \stackrel{\text{def}}{=} I_{\text{SA 98 653}} = 9.522. \quad (\text{A.6})$$

Thus, we derive F_{A0V}^z as

$$F_{\text{A0V}}^z = F_{\text{SA 98 653}}^z \times 10^{(0.4 \cdot z_{\text{SA 98 653}})}. \quad (\text{A.7})$$

By considering the uncertainties on magnitude and interstellar extinction measurements, we obtain

$$\begin{aligned} F_{\text{A0V}}^z &= (8.4 \pm 0.1) \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1} \\ &= (2608 \pm 31) \text{ Jy}. \end{aligned}$$

A slightly smaller absolute flux calibration constant for the WFI z band has been estimated by F. Comerón (private communication) using the absolute flux calibration of Vega obtained by Bohlin & Gilliland (2004) with the Space Telescope Imaging Spectrograph (STIS). Using these data we derive a value of $7.2 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$. However, for the sake of homogeneity, we prefer to use the value we derive above.

Appendix B: Isochrones

In order to transform the colours and magnitudes of the isochrones reported by Baraffe et al. (1998) and Chabrier et al. (2000) into the WFI-Cousins system we determined first the WFI synthetic magnitudes, $m_{\Delta\lambda}$, as

$$m_{\Delta\lambda} = -2.5 \cdot \log_{10}(f_{\Delta\lambda}) + C_{\Delta\lambda} \quad (\text{B.1})$$

where $C_{\Delta\lambda}$ is the absolute calibration constant of the photometric system, tied to the Earth flux of an A0-type star with magnitude $V = 0$ (see Table 5), and $f_{\Delta\lambda}$ is the observed flux.

In order to compute the expected flux of a PMS star or a young BD in the pass-band $\Delta\lambda$ of a given filter we proceeded as follows. We first determined the transmission curve, T_λ , i.e. the product of the detector quantum efficiency and the given filter transmission curve⁷. We then compute

$$f_{\Delta\lambda} = \frac{1}{A_{\Delta\lambda}} \cdot \int_{\lambda_1}^{\lambda_2} F_\lambda \cdot T_\lambda \cdot d\lambda \quad (\text{B.2})$$

where

$$A_{\Delta\lambda} = \int_{\lambda_1}^{\lambda_2} T_\lambda \cdot d\lambda \quad (\text{B.3})$$

and F_λ is the absolute flux of a given PMS star or BD. For this purpose we used the synthetic low-resolution spectra for low-mass stars by Hauschildt et al. (1999) calculated with their NextGen model-atmosphere code. For simulating very cool objects (i.e. $T_{\text{eff}} < 3000 \text{ K}$) we used the StarDusty and BD-Dusty atmosphere models by Allard et al. (2000), which include dust opacity.

As an example of our procedure we show in Fig. B.1 (upper panel) two model spectra and the R , I and z WFI+ESO2.2m transmission curves over-plotted. However, the flux $f_{\Delta\lambda}$ that we obtained in this way is the one at the surface of the star. The observed flux at any distance (d) is given by

$$f_{\Delta\lambda}(d) = f_{\Delta\lambda} \cdot \left(\frac{R^*}{d}\right)^2 \quad (\text{B.4})$$

where R^* is the object radius. The values for R^* can be computed from theoretical PMS evolutionary tracks, which in our case are those by Baraffe et al. (1998) for low-mass stars and those by Chabrier et al. (2000) for sub-stellar objects (i.e. $M \lesssim 0.1 M_\odot$). Finally, setting $d = 10 \text{ pc}$ and using Eq. (B.1), one can derive the absolute magnitudes for a given T_{eff} , age and R^* and hence, determine the isochrones in the CMDs.

Note that, consistently with the RIZ photometric calibration of the sources in Cha II, the absolute calibration constants used in Eq. (B.1) are those of the WFI-Cousins photometric system (see Table 5). However, a non-negligible difference between the I -WFI and the I -Cousins pass-bands arises from the fact that the

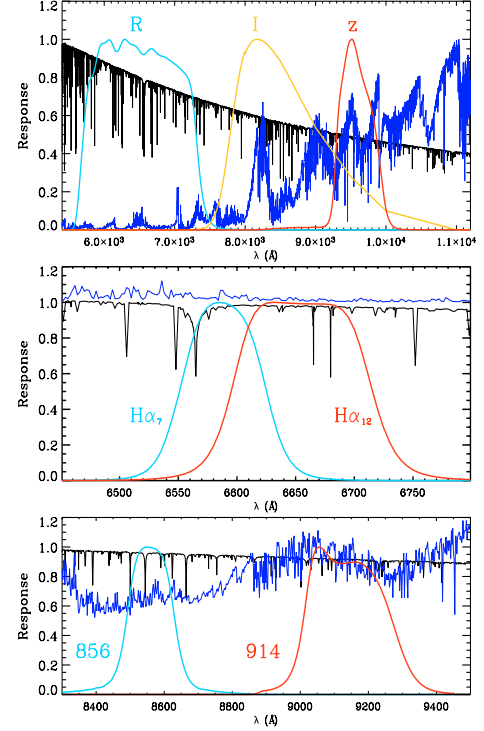


Fig. B.1. The R , I , z (upper panel), $H\alpha_7$, $H\alpha_{12}$ (central panel), 856 and 914 nm (lower panel) WFI+ESO2.2m transmission bands. Examples of two normalised NextGen spectra (Hauschildt et al. 1999) with $T_{\text{eff}} = 2500 \text{ K}$ and $T_{\text{eff}} = 6000 \text{ K}$ are over-plotted.

red cut-off of the I -WFI filter is defined by the CCD response and it is centred on a redder wavelength ($0.85 \mu\text{m}$) with respect to the standard Cousins I filter ($0.79 \mu\text{m}$). In order to take into account this difference in the determination of the theoretical isochrones, we have exploited the relations between the WFI-Cousins $(R - I)_C$ and $(I_C - z)$ standard colours and the WFI instrumental colours for the standard stars in the Landolt's fields. By a least-square linear fitting (Fig. B.2), we derive the coefficients which allow us to correct the colours of the computed isochrones

$$(R - I)_{\text{synt}} = 0.75 \cdot (R - I)_{\text{instr}} \quad (\text{B.5})$$

$$(I - z)_{\text{synt}} = 1.10 \cdot (I - z)_{\text{instr}} \quad (\text{B.6})$$

In this way we were able to report in the WFI-Cousins photometric system the isochrones originally calculated by Baraffe et al. (1998) and Chabrier et al. (2000) in the Cousins system of Bessel (Bessel 1990). This allows us to use the isochrones in a photometrically homogeneous way.

In Fig. B.3, the 1, 5 and 10 Myr isochrones by Chabrier et al. (2000) are compared with those derived by us in the WFI-Cousins photometric system. Note the large difference, in particular for the coolest objects, i.e. $(R - I)_C > 1.7$, where the use of the isochrones in the Bessel-Cousins system would have produced many spurious member candidates.

In order to check our procedure, we used the standard filters of Bessel (1990) and we were successful in reproducing the isochrones presented by Chabrier et al. (2000) (see the smaller panel in Fig. B.3).

⁷ Available at: <http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/WFI/filters>

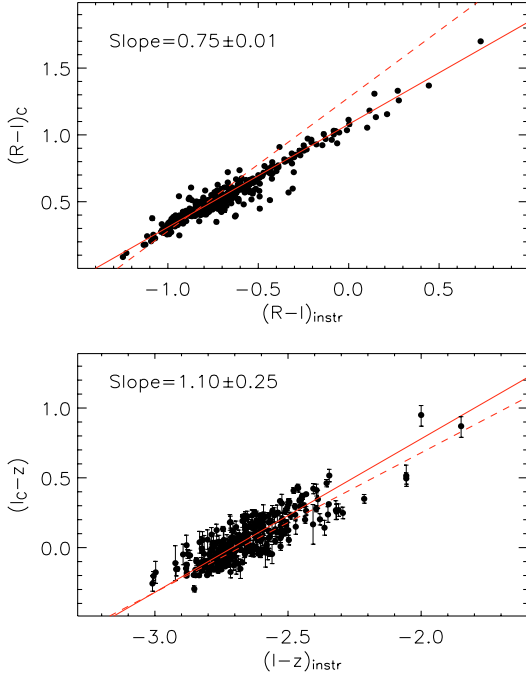


Fig. B.2. The Cousins colours as a function of the WFI instrumental colours for the standard stars in the Landolt's field SA 98. The continuous lines display the best fit of the data while the dashed lines have slope equal to 1 (i.e. no correction).

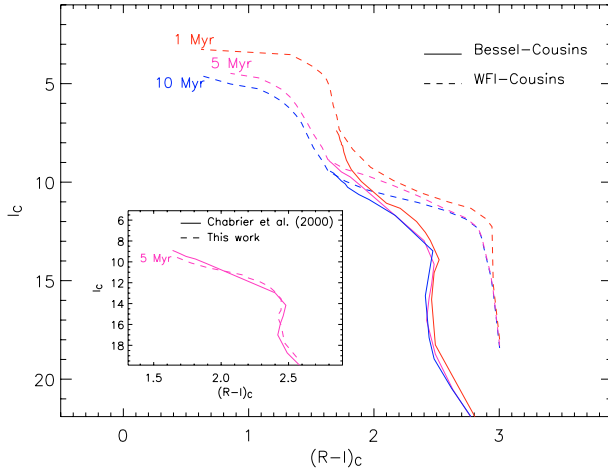


Fig. B.3. Theoretical isochrones by Baraffe et al. (1998) and Chabrier et al. (2000) for the Cousins photometric system of Bessel (continuous line) and for the WFI-Cousins system (dashed lines, this work). In the smaller panel the 5 Myr isochrone by Chabrier et al. (2000) (continuous line) is compared with that reproduced by our algorithm when using the same Bessel filters (dashed line).

Appendix C: Comments on individual objects

IRAS 12416-7703, *IRAS 12448-7650*, *IRAS F12488-7658*,
IRAS 12556-7731, *IRAS 12589-7646*

These objects were selected as member candidates of Cha II by Young et al. (2005) on the basis of MIPS@Spitzer observations. *IRAS F12488-7658/C 13* was also previously proposed as a young object by (Vuong et al. 2001). We cannot conclude whether our selection criteria are satisfied for these objects because they are saturated in at least one of the three broad-bands *RIz*. However, their $(H\alpha_{12} - H\alpha_7)$ indices suggest $H\alpha$ emission

(see Table 7) at $\sim 2\sigma$ level and their location on the $(J - H)$ vs. $(H - K)$ diagram is consistent with the PMS stars locus (see Sect. 4 and Fig. 10).

Chall 304, *Chall 305*, *Chall 376*

ChaII 376 was the only $H\alpha$ emitter detected by López-Martí et al. (2005) in their WFI pointing. They also proposed that their candidates *ChaII 304* and *ChaII 305* are two low-mass BDs or planetary-mass objects close to the Deuterium burning limit. These two objects, however, do not satisfy our selection criteria. The early classification of these objects as possible Cha II members by López-Martí et al. (2005), though based on WFI images taken with the same set of filters as in our survey, is probably not accurate because the isochrones in the Cousins system of Bessel (Chabrier et al. 2000) used for the selection are inadequate for the WFI-Cousins photometric system (see Appendix B). From their dereddened $(m_{856} - m_{914})$ colour index we estimate an effective temperature of 2800 K and 3000 K for *ChaII 304* and *ChaII 305*, respectively. Assuming these temperature values, we find that the location of the two objects on the HR diagram would be inconsistent with membership to Cha II. We found that the optical colours of *ChaII 376* are inconsistent with membership, as also asserted by López-Martí et al. (2005), and we do not detect any significant $H\alpha$ emission for this object. Moreover, its *R*-band magnitude (16.31 mag) is remarkably brighter than the one reported by López-Martí et al. (2005) (18.38 mag). Since the magnitude of this object in the other bands are in fair agreement with ours, we think that the *R*-band magnitude reported in López-Martí et al. (2005) may be incorrect. This may explain why *ChaII 376* was selected as their only $H\alpha$ emitter.

Sz 46

This is one of the 19 PMS stars originally identified by Schwartz (1977) in Cha II. Subsequent photometric observations by Hughes & Hartigan (1992) showed that the object is a visual triple system. The $H\alpha$ emission star originally discovered by Schwartz (1977), *Sz 46N*, has two companions, namely *Sz 46NW* and *Sz 46S*; both are bluer than *Sz 46N* and are probably unrelated to it (Hughes & Hartigan 1992). Based on our analysis, both *Sz 46NW* and *Sz 46S* have optical colours inconsistent with membership to the Cha II cloud, their temperature is well above 4000 K according to their $(m_{856} - m_{914})$ index and the $(H\alpha_{12} - H\alpha_7)$ colour suggests no $H\alpha$ emission. Thus, *Sz 46NW* and *Sz 46S* are most probably not PMS stars and hence, not physically associated with *Sz 46N*.

IRAS 12533-7632, *IRAS F13052-7653*

These objects were detected as ROSAT X-rays sources (Alcalá et al. 2000) and proposed as possible members of Cha II by different authors (Larson et al. 1998; Prusti et al. 1992; Young et al. 2005).

IRAS 12533-7632 appears on our images as a point-like object associated with a nebulosity, consistently with what reported in Prusti et al. (1992). However, it was not detected in our *z* and $H\alpha$ images; its *RI* magnitudes and 2MASS near-IR colours are inconsistent with those expected for a PMS star.

In Young et al. (2005) *IRAS F13052-7653* is reported as CHIXR 60 which is a non-existent identifier. This must be a typo because *IRAS F13052-7653* is identified with the ROSAT source CHIXR 37 (Alcalá et al. 2000). The optical counterpart

of IRAS F13052-7653 appears as a visual triple system (Larson et al. 1998) whose components are designated as IRAS F13052-7653N, IRAS F13052-7653NW and IRAS F13052-7653S in Table 7. None of the three components was recovered by our selection criteria, most likely because their colours, both in optical and near-IR, may be contaminated. However, two of them, namely IRAS F13052-7653N and IRAS F13052-7653NW, fall just below the 10 Myr isochrone and their ($H\alpha_{12} - H\alpha_7$) indices suggest $H\alpha$ emission above 3σ level (see Table 7); moreover, their near-IR colours are also consistent with those expected for PMS stars. IRAS F13052-7653S is not detected in 2MASS; its optical colours are inconsistent with membership to Cha II and its $H\alpha$ colour does not indicate significant emission.

IRAS F12571-7657

This object was detected in X-rays with ROSAT (Alcalá et al. 2000). Its optical and near IR colours are consistent with those of a PMS star with strong IR excess (see also Young et al. 2005). Previous authors (Allers et al. 2006; Vuong et al. 2001) report an extinction value significantly higher than the one determined by us (Table 6). Given the strong IR excess, our procedure for the temperature estimate provides unreliable results. Therefore, it may be a deeply embedded source or a highly reddened PMS star.

C 62, C 66

These sources were first detected by DENIS and proposed as young stellar object candidates of Cha II by Vuong et al. (2001) based on their IR colours and, more recently, by Young et al. (2005) and Allers et al. (2006) on the basis of IRAC@Spitzer and MIPS@Spitzer observations, respectively. From the effective temperature and A_V estimates provided in Table 6, and calculation of their luminosities as explained in Sect. 5, we estimate a mass of 0.08 and 0.06 M_\odot for C 62 and C 66, respectively. The age we derive for both objects using the Baraffe et al. (1998) and Chabrier et al. (2000) tracks is around 2 Myr. These estimates of mass and age are fairly consistent with those derived by Allers et al. (2006). From their $H\alpha$ index we also notice strong line emission ($\sim 3\sigma$ level) in both objects (see Table 6).

ISO-CHA II 29

This source has been detected in the near and mid-IR by Persi et al. (2003), but it was first revealed as an X-ray emitting source, CHIIXR3, by Alcalá et al. (2000). The association of this object with IRAS 12551-7657 is still unclear. Based on this evidence and the effective temperature estimated by us (Table 6), ISO-CHA II 29 is proposed to be a PMS star in Cha II with a mass of about 1 M_\odot .

ISO-CHA II 73, ISO-CHA II 98, ISO-CHA II 110

None of these sources, originally identified by Persi et al. (2003), was selected with MIPS@Spitzer by Young et al. (2005). These sources do not satisfy our criteria and their ($H\alpha_{12} - H\alpha_7$) index suggests no emission in $H\alpha$.

In our optical images, ISO-CHA II 98 appears as a visual binary, but the colours and magnitudes of its components are inconsistent with our selection criteria. We stress that ISO-CHA II 98 was wrongly identified in SIMBAD with the ROSAT X-ray source CHIIXR 24 by Alcalá et al. (2000). The optical

spectrum of CHIIXR 24 shows the Li I 6708 Å absorption line, but the $H\alpha$ line is well in absorption (Alcalá et al. 2000). Being classified as a G7-type star, CHIIXR 24 is most likely a field object unrelated to Cha II.

2MASS 13102531-7729085, 2MASS 13110329-7653330, 2MASS 13125238-7739182

These sources are reported in the list of candidates by Young et al. (2005). While 2MASS 13102531-7729085 and 2MASS 13110329-7653330 are rejected by our selection criteria, 2MASS 13125238-7739182 is selected as a PMS star candidate. The first two sources have $H\alpha$ indices indicating no $H\alpha$ emission, while the $H\alpha$ index of the last suggests $H\alpha$ in emission at 1σ level. Thus, it is likely that 2MASS 13102531-7729085 and 2MASS 13110329-7653330 are field stars unrelated to Cha II.