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A deep optical survey of IC 2391

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Abstract. We report the outcome of a deep optical photometric survey of a 30×30 square arcmin area in the IC 2391 young open cluster, complemented by IR photometry from the 2MASS catalogue and the Spitzer space telescope. The optical data were obtained by using the Wide-Field Imager (WFI) at the ESO 2.2m telescope; the photometric completeness limit of this survey at 3σ level (V=24.7, R_C=23.7 and I_C=23.0) is ∼2 magnitudes fainter than previous optical surveys of this cluster and is sufficient for the detection of low-mass members down to the brown dwarf (BD) boundary of ∼0.03 $M_\odot$. We aim at uncovering new low-mass members and BDs in order to constrain the shape of the Initial Mass Function (IMF) of IC 2391 in the low-mass domain, which is currently under debate. In addition, the age (∼50 Myr) and distance (∼150 pc) of IC 2391 offer a unique combination to study the evolution of debris-disks around low-mass stars, which is a crucial step toward our understanding of the terrestrial planet formation mechanism. By merging our optical data with IR photometry from 2MASS and Spitzer, we search for IR excess emission in the cluster members, which is indicative of debris-disks, and aim at investigating the disk properties.

Key words. Stars: low-mass – Stars: brown dwarfs – Stars: circumstellar disks – Galaxy: open clusters – Individual objects: IC 2391

1. Introduction

Our candidate selection procedure follows the prescriptions by Spezzi et al. (2007) and is based on the use of optical and near-IR colour-magnitude diagrams (CMDs, see an example in Fig. 1). The selection is reinforced by using the previously known cluster members to define the pre-main sequence locus in the CMDs, as well as by means of proper motions from the NOMAD catalogue (Zacharias et al. 2004). Using the procedure outlined in Spezzi et al. (2007), we also estimated the physical parameters of our candidates (A_V, T_{eff}, $L^\star$, mass, age), which further support their membership to the cluster. Our selection yielded 35 new candidate members of IC 2391.

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2. On the IMF and the BD fraction of IC 2391

Our parametrization procedure allowed us to determine the stellar luminosity of the low-mass members of IC 2391. Since their spectral classification is available from previous studies, we can determine the clus-

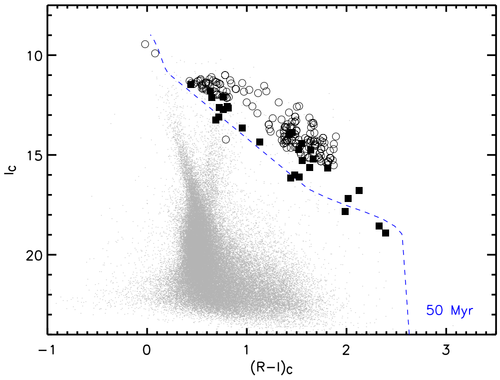

Fig. 1. I_C vs. (R_C-I_C) diagram for the point-like objects extracted from our WFI survey in IC 2391. The dashed line represents the 50 Myr isochrone transformed by us to the WFI-Cousins photometric system, and shifted by the cluster distance modulus (5.9 mag). The squares indicate our candidate members, while the open circles represent the previously known cluster members.

ter IMF via the HR diagram. We use the usual approximation for the low-mass IMF ($dN/dM \propto M^{-\alpha}$). We concentrate in the range $0.08 \leq M/M_\odot \leq 1$ and, considering the uncertainties on T_{eff} and $L^\star$, adopt mass bins of $\log(M/M_\odot)$=0.15. We found an IMF slope of α=1.19±0.22, in agreement with the determination by Barrado y Navascués et al. (2004). According to these authors, the sub-stellar IMF in IC 2391 presents a sudden drop below 0.07 $M_\odot$, which is partly explained by the lack of completeness beyond I≈18.5 (i.e. 0.05 $M_\odot$ for cluster members). Though our survey is complete at 100% and 80% levels down to 0.05 $M_\odot$ and 0.03 $M_\odot$, respectively, we found only a handful of new possible sub-stellar members. Considering the previously known members of IC 2391, the fraction of sub-stellar objects in this cluster is 9% and up to 14% when adding our BD candidates. Moreover, our physical parametrization indicates that all our BD candidates have $2900 \lesssim T_{eff} \lesssim 3100$ K, i.e. very close to the Hydrogen burning limit for 50 Myr old objects. Thus, the results of our deeper survey confirm the lack of members with spectral type later than M7-M8 in IC 2391 and support the idea by Dobbie et al. (2002) of the onset of larger-size dust grain formation in the upper atmosphere of objects with M7-M8 spectral types or later, which would be responsible of the local drop in the shape of the luminosity-mass relation.

3. Hosting debris-disk candidates in IC 2391

We identified hosting debris-disk objects in IC 2391 by measuring 24μm flux densities in excess with respect to the expected photospheric emission, following the prescriptions by Siegler et al. (2007). We found 11 objects showing IR excess, namely 4 previously known cluster members and 7 new candidates. We further investigated the circumstellar material around these objects by comparing their spectral energy distributions (SEDs) with the Robitaille et al. (2006) disk models. The 11 objects present SED slopes typical of IR class III sources (α[K & MIPS 24μm]<-1.6) according to the classification by Lada et al. (2006), i.e. they have optically thin disks. Their SEDs rise around 24μm, indicating the presence of an inner disk hole ($R_{in} \gtrsim 70$ AU). Their disk to stellar luminosity ratio is typical of non-accreting disks. Thus, these 11 sources posses evolved disks, whose inner part might have already been cleared by the formation of large-sized bodies such as rocks.

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