The stellar and substellar mass function in central region of the old open cluster Praesepe from deep LBT observations

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Abstract. Studies of the mass function of open clusters of different ages allow us to study the efficiency with which brown dwarfs are evaporated from clusters to populate the field. Surveys in relatively old clusters (age $\gtrsim 100$ Myr) do not suffer from problems found in young clusters, such as intra-cluster extinction and large uncertainties in brown dwarf models. In this paper, we present the results of a photometric survey to study the mass function of the old open cluster Praesepe (age of ~ 590 Myr and distance of ~ 190 pc), down to the substellar regime. We have performed optical (riz and Y-band) photometric survey of Praesepe with the Large Binocular Telescope Camera, for a spatial coverage of 0.61 deg^2 from ~ 90 M$_J$ down to a 5σ detection limit at 40 M$_J$.

1. INTRODUCTION

Several studies over the past ten years presented surveys of open clusters in order to study the mass function (MF) of low-mass stellar and substellar populations. Studies of relatively old open clusters (age $\gtrsim 100$ Myr) are important for the following two reasons: first, they allow us to study the intrinsic evolution of brown dwarfs (BDs), e.g. their luminosity and effective temperature, and to compare this with structural and atmospheric models; second, we may investigate how the BD population as a whole evolves, e.g. the efficiency with which BDs evaporate from clusters. Numerical simulations of cluster evolution have demonstrated that the MFs can evolve through dynamical interaction (Adams et al. 2002). These interactions result in a decrease of the open cluster BD (and low-mass star) population. This was observed by [5] with the MF of the Pleiades (120 My) and of the Hyades (625 My).

Most previous studies of the substellar MF have focused on young open clusters with ages less than ~ 100 Myr, and in many cases much younger (< 10 Myr). This is partly because BDs are bright when they are young, thus easing detection of the least massive objects. However, intra-cluster extinction in young clusters plagues the determination of the intrinsic luminosity function from the measured photometry. Moreover, in this regime BD models have large uncertainties [2], which makes the determination of low-mass MF for very young clusters (age $\lesssim 1$ Myr) unreliable [6]. BDs in older clusters do not suffer from these problems, but have the disadvantage that much deeper surveys are required to detect them.

The old open cluster Praesepe is an interesting target considering its age and distance. It is located at a distance of $190^{+6.0}_{-5.8}$ pc [12] and has an age of 590^{+150}_{-120} Myr [7]. The determinations of the metallicity of Praesepe yield some discrepancies: from [Fe/H] $= 0.038 \pm 0.039$ [8], and $+0.13 \pm 0.10$, [3] to $+0.27 \pm 0.10$, [15]. Hambly et al. 1995 presented a ~ 19 deg^2 survey of the Praesepe cluster down

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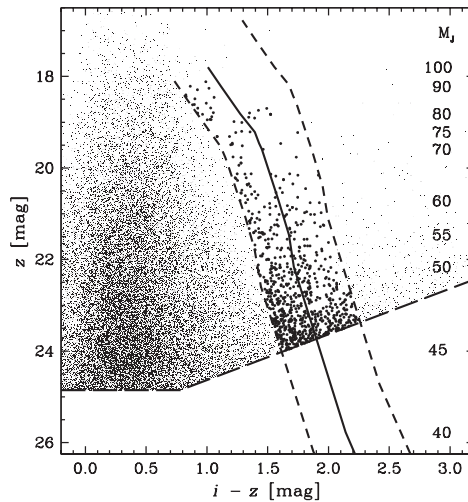
Figure 1. CMD with i and z bands used in the selection procedure. The solid lines is the isochrone computed from an evolutionary model with a dusty atmosphere (the DUSTY model). The numbers indicate the masses (in M_J) on the model sequence for various z magnitudes. The dashed lines delimit our selection band.

to masses of $\sim 0.1\,M_\odot$ and observed a rise of the MF at the lowest masses. From this, they concluded that this rising MF implied a large population of BDs. A shallow survey complete to $I = 21.2\,$mag, $R = 22.2\,$mag over $800\,\mathrm{arcmin}^2$ uncovered one spectrally confirmed very low-mass star or BD (spectral type of M8.5V) with a model-dependent mass of 0.063–$0.084\,M_\odot$ [13]. A survey over the central $1\,\mathrm{deg}^2$ with 10σ limits of $R = 21.5$, $I = 20.0$ and $Z = 21.5\,$mag revealed 19 BD candidates and the first MF determination of Praesepe down to the substellar limit [16]. Adams et al. (2002) presented a $100\,\mathrm{deg}^2$ study of Praesepe based on proper motions and were able to obtain the radial profile of this cluster, but their MF does not reach the substellar regime. Another comprehensive substellar MF determination of Praesepe was performed by [9] down to a 5σ detection limit of 0.050–$0.055\,M_\odot$ with one new substellar candidate, but their survey covered only $1177\,\mathrm{arcmin}^2$. Finally, Boudreault et al. (2009) has reported their results based on optical and near infrared photometric survey over $3.1\,\mathrm{deg}^2$ down to a 5σ detection limit at $0.05\,M_\odot$.

In this proceeding, we present the results of a program to study, in detail, the MF of the open cluster Praesepe down to the even lower mass regimes ($0.04\,M_\odot$) based on the LBT blue and red cameras. The main aims of this study are to search for new BDs and to determine the MF of the Praesepe down to the substellar regime, which allows us a better understanding of the evolution of this cluster.

2. OBSERVATIONS AND DATA REDUCTION

The observations were carried out with the LBT (Large Binocular Telescope), located on Mount Graham, Arizona [11], using the Large Binocular Cameras (LBC). We observed the central 0.6 square degrees of Praesepe in four bands, namely, the SLOAN r, i, z filters and the Y-FAN filter in March, December 2008 and February 2009.

The standard reduction steps (bias subtraction, flat fielding) for the LBT data were performed using IDL astronomy package on a nightly basis and on each CCD chip. Then, the individual images were registered and combined using IRAF for each field and each filter. We subtracted bright stars to improve faint source detections and obtained both aperture photometry and psf photometry. Astrometric solution was achieved using the SDSS catalogues as a reference, with an accuracy of $\sim 0.10\,$arcsec.
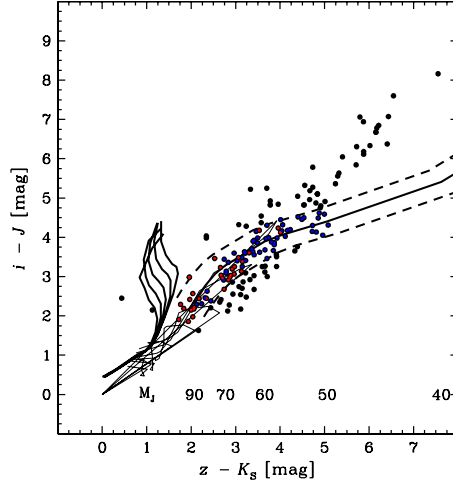
Figure 2. Colour-colour diagram with izJ and K_s-bands used in the selection procedure. Filled circles are those lie in between broken lines in Fig. 1. Lines have the same meaning as above.

The photometric calibration was performed for the riz bands by comparing our measurements with the SDSS catalogue, and for the Y band by contrasting with the UKIDSS catalogue.

2.1 Preliminary results

The candidate selection procedure is done as follows. Candidates were first selected based on colour-magnitude diagrams using i and z-band (cf. Fig. 1). A second selection was performed by introducing the the J and Ks bands measurements from Boudreault et al. (2009), and using the colour-colour diagram with izJ and K_S-band (cf. Fig. 2). In the third and final selection step, we used the known distance to Praesepe to reject objects based on a discrepancy between the observed magnitude in J and the magnitude in this band computed with the isochrones and our estimation of T_{eff}. To be considered as a cluster member, an object has to satisfy all the three criteria.

We identified a final list of 53 photometric candidates, for which 46 have a mass below the hydrogen burning limit. We found that the MF decreases from $0.1\,M_\odot$ to $0.08\,M_\odot$ as found by Boudreault et al. (2009) and then increases and is flattened till $\sim 40\,M_J$. This result is consistent with that found in the Trapezium cluster (cf. Muench et al. 2002, Fig. 12), but with different turnover masses ($\sim 0.1 M_\odot$ for Praesepe and $\sim 0.03 M_\odot$ for the Trapezium).

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