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Photometric, astrometric, and spectroscopic survey of the old open cluster Praesepe

S. Boudreault[1,2] and N. Lodieu[1,2]

[1] Instituto de Astrofísica de Canarias (IAC), C/Vía Láctea s/n, E-38200 La Laguna, Tenerife, Spain e-mail: szb@iac.es
[2] Departamento de Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Tenerife, Spain

Abstract. We analysed the wide-field near-infrared survey of the Praesepe cluster carried out by the UKIDSS Galactic Clusters Survey and released by the Data Release 9. We compare our Praesepe mass function with the ones of the Pleiades, α Per, and the Hyades. We also present preliminary results of a spectroscopic follow-up for the low mass members ($M \leq 0.1\,M_{\odot}$) in Praesepe, α Per and Pleiades using the OSIRIS spectrograph on the 10.4-m Gran Telescopio Canarias. We also present the optical spectrum of the first L dwarf in Praesepe.

1. Introduction

Over the past decades, open clusters have been the subject of many studies (e.g. Bastian et al. 2010, and references therein). Such studies have brought new insights into brown dwarf (BD) formation, on the discovery of young L and T dwarfs and free-floating planets and on our understanding of the stellar/substellar mass function MF and their populations in the Galactic field and in open clusters. The extension of MF studies to older clusters is vital as it allows us to study the intrinsic evolution of BDs and how the stellar and substellar population itself evolves. Praesepe is an interesting open cluster to study the MF in the stellar and substellar regimes, considering its age (590^{+150}_{-120} Myr; Fossati et al. 2008), distance ($181.97^{+5.96}_{-5.77}$ pc; van Leeuwen 2009), proper motion ($\mu_{\alpha}\cos\delta = -35.81 \pm 0.29$ mas yr^{-1} and $\mu_{\delta} = -2.85 \pm 0.24$ mas yr^{-1}; van Leeuwen 2009), and the low extinction towards this cluster ($E(B-V) = 0.027 \pm 0.004$ mag; Taylor 2006).

Send offprint requests to: S. Boudreault

2. Astrometric and photometric survey of Praesepe

We analysed the wide-field (~36 square degrees) near-infrared ($ZYJHK$) survey of the Praesepe cluster carried out by the DR9 of the UKIRT Infrared Deep Sky Survey (UKIDSS) Galactic Clusters Survey (GCS). We selected cluster member candidates of Praesepe based on astrometry and five-band photometry. With our candidate list, we derived the MF of Praesepe from 0.6 down to $0.072\,M_{\odot}$. We observed that our determination of the MF of Praesepe differs from previous studies: while previous MFs present an increase from 0.6 to $0.1\,M_{\odot}$, our MF presents a decrease (Boudreault et al. 2012). In Fig. 1 we com-

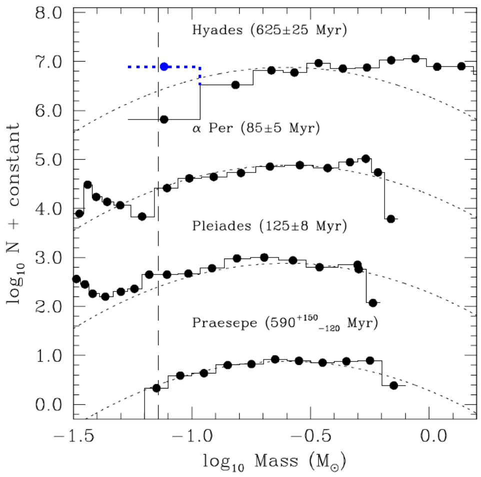

Fig. 1. MFs of the Hyades, α Per, the Pleiades, and Praesepe. The dotted mass bin in the Hyades MF includes the 12 L dwarf candidates from Hogan et al. (2008). We also show the system Galactic field star MF (Chabrier 2005) as the dotted curved lines and the substellar limit as a vertical dashed line. We normalised all the MFs to the log-normal fit of Chabrier (2005) at ~0.3 $M_{\odot}$ ($\log M$ ~0.5).

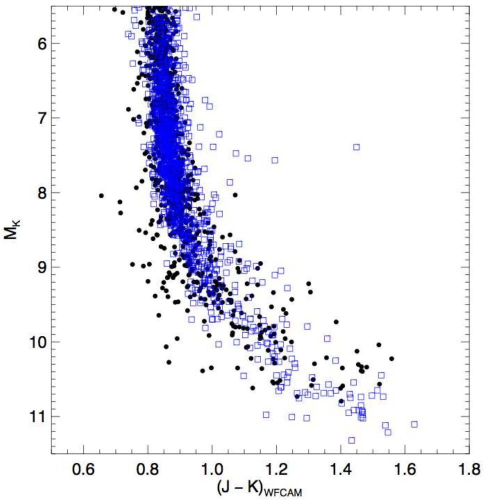

Fig. 2. ($J - K$,M_K) diagram for the Pleiades (open squares) and Praesepe (filled dots).

pare our Praesepe MF with the ones of the Pleiades (Lodieu et al. 2012a), α Per (Lodieu et al. 2012b), and the Hyades (Bouvier et al. 2008). We concluded that our MF of Praesepe is more similar to the MFs of α Per and the Pleiades, although they are respectively of 85±5 Myr (Barrado y Navascués et al. 2004) and 120±8 Myr (Stauffer et al. 1998), compared to 625±50 Myr for the Hyades (Bouvier et al. 2008).

A possible explanation for the discrepancy is an incompleteness of the MF of the Hyades from Bouvier et al. (2008). We noticed that adding 12 L dwarf cluster candidates in the Hyades (Hogan et al. 2008) reduces the discrepancy between the two MFs (Fig. 1). Another possible explanation for the discrepancy is an overestimation of the age of Praesepe. The fact that the MF of Praesepe is more similar to the ones of α Per and the Pleiades than the one of the Hyades, implies a similar dynamical evolution history. In addition, the ($J - K$, M_K) CMD of Praesepe and the Pleiades show an overlap between the two sequences, pointing towards a similar age/distance combination for both regions (Fig. 2).

3. Spectroscopic survey

We are embarked in a spectroscopic follow-up of low-mass member candidates (≤0.1 $M_{\odot}$) selected in α Per, the Pleiades, and Praesepe to constrain their membership, using OSIRIS (Optical System for Imaging and low Resolution Integrated Spectroscopy) on the 10.4 m Gran Telescopio de Canarias (GTC) in the Roque de Los Muchachos Observatory in La Palma (Canary Islands). We used the R300R grism and a 1.0 arcsec slit with a 2×2 binning, yielding a spectral resolution of R = 348 at 6865Å.

Among our targets, we confirmed spectroscopically the first L dwarf in Praesepe (Fig. 3). We derive a spectral type of L0.3±0.4, an effective temperature of 2279±371 K, and a mass of 71.1±23.0 $M_{\rm Jup}$, placing it at the hydrogen-burning boundary. The equivalent width of the gravity-sensitive Na I doublet adds credit to the membership. We also derived a probability of 79.5% of being a member of Praesepe and argue that it is a possible binary because of its

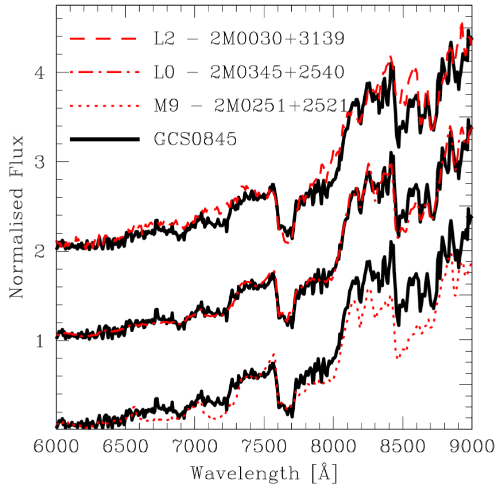

Fig. 3. GTC/OSIRIS optical spectrum of GCS0845 (black thick line), classified as a L dwarf member candidate of Praesepe, based on proper motion and photometry. Overplotted are spectra of field dwarfs (Kirkpatrick et al. 1999) observed with the same instrumental configuration: 2M0251+2521 (M9; dotted line), 2M0345+2540 (L0; dash-dotted line), and 2M0030+3139 (L2; dash line). All spectra are normalised at 7500Å with offset of +1 between each spectra for clarity.

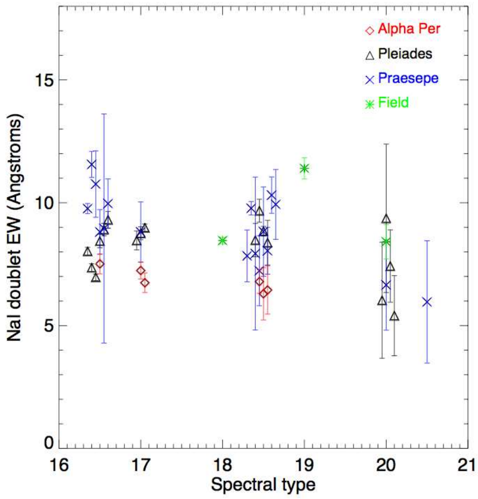

Fig. 4. Equivalent widths of the Na I doublet as a function of spectral type for cluster member candidates in the Pleiades (triangles), α Per (diamonds), Praesepe (crosses), and field dwarfs (asterisks).

location in various colour-magnitude diagrams (Boudreault & Lodieu 2013).

The Na I doublet at 8182/8194Å is not resolved at our resolution. The equivalent widths (EW) of the unresolved Na I doublet at 8188Å are plotted as a function of spectral type in

Fig. 4 for the several member candidates in the three cluster under study (α Per, the Pleiades, and Praesepe) and for field M and L dwarfs observed with the same instrumental configuration. For a given spectral type, the EWs increase with older ages and decrease with cooler temperatures. The distribution of EWs for candidates in Praesepe and the Pleiades suggests that Praesepe is indeed older than the Pleiades.

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