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New low-mass member candidates of Taurus

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Abstract. A widely used tool to characterise the formation of stars is the initial mass function (IMF). It has been suggested that it departs significantly from the universal form in Taurus. To bring them into agreement, about 330 new low-mass members need to be identified. We aim to find those objects in an area located 5 deg to the north of the main clouds. We analysed the already known Taurus members and found in our UKIDSS GCS-based data sample 253 objects showing similar characteristics. 43 of those new member candidates were observed spectroscopically. 11 of them show strong signs for membership to the region. Since we observed only 17% of our selection, we would expect up to 65 objects in our hunting ground. Those numbers indicate a possible unknown population of Taurus away from the main clouds. The answer to whether the IMF of Taurus is different might be located in its off-cloud parts.

Key words. Stars: formation – Stars: late-type – Stars: low-mass – Stars: mass function

1. Introduction

Since the famous work by Salpeter (1955), the initial mass function (IMF) is the most important tool to characterise the formation of stars. This connection between quantities and masses of stellar objects gets described by a combination of broken power laws (Kroupa 2002) and a log-normal function (Chabrier 2003). In most regions, the function shows quite an universal form reaching from high-mass objects down into the substellar regime.

In this work, we concentrate on the Taurus star-forming region. It shows a unique form of the IMF, forming one of the strongest arguments against the proposed universality (see e.g. Guieu et al. 2006). This could be explained by the low density of the region (1 to 10 stars pc^{-2}; Scelsi et al. 2007) or the lack of about 330 low-mass objects (< 0.5 $M_{\odot}$). Such sources are best visible in Taurus due to their youth (1 Myr) and relative proximity (140 pc; Kenyon et al. 1994).

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We aim to find those missing objects in a region of 25 sq.deg. located 5 deg to the north of the main clouds.

2. Methods

This area is covered by the the DR7 of the Galactic Clusters Survey (GCS), which is a subsurvey of the UKIRT Infrared Deep Sky Survey (UKIDSS; Lawrence et al. 2007). It delivers photometry in the five near-infrared (NIR) filters $ZYJHK$ (Hewett et al. 2006) and reaches with $J = 19.5$ mag about 3 to 4 mag deeper into the field than 2MASS. For our main database, we cross-match the data with optical NOMAD, NIR 2MASS, and mid-infrared (MIR) Spitzer/IRAC data of a small common subregion. Additionally, we calculated proper motions using the cross-matches of the UKIDSS-2MASS and NOMAD-2MASS data. We then compared this sample to the photometric and kinematic characteristics of the 351 already known Taurus members (Luhman et al. 2010).

Due to the distant location and patchy reddening of our hunting ground, we applied as many photometric criteria as possible to select new member candidates (see e.g. Lodieu et al. 2007, 2012). Therefore, a high-resolution (1.5 arcmin) NIR extinction map was calculated following the NICER (NIR Color Excess Revisited) technique developed by Lombardi & Alves (2001). We compared all available information of the already known Taurus members and model data to the observed and dereddened photometry and kinematics of our data sample. All available colour-magnitude- and colour-colour-diagrams were considered. The magnitudes were restricted to include only objects of low mass ($J > 12$ mag) and to ensure the feasibility of spectroscopic observations ($J < 15.5$ mag). We selected 253 member candidates out of 600 000 sources using 40 selection criteria.

Eventually, 43 (17%) candidates, 37 (11%) already known Taurus members and 31 more evolved field dwarfs were observed with low-resolution ($R < 1500$) optical spectroscopy. Between 2005 and 2010 we used the CAHA2.2/CAFOS, CAHA3.5/TWIN, NOT/ALFOSC, and WHT/ISIS instruments. With these data, we could identify new members by comparing the member candidates to the reference stars and by searching them for signs of youth. Those include lower surface gravity and the presence of an accretion disk manifesting itself by MIR excess emission and strong and broad line features (e.g. Martín et al. 2001).

3. Analysis & results

We assigned spectral types to the observed objects and found 65% of the member candidates, 65% of the Taurus members, and 45% of our observed field dwarfs to be of type M. We measured the prominent emission line of hydrogen ($H\alpha$; Barrado & Martín 2003) and the calcium infrared triplet (Ca II IRT). Both features get excited by chromospheric activity and shocks produced by the fall down of accretion disk material onto the stellar surface. Also, we measured the sodium (Na I) and potassium (K I) absorption doublets, which are both sensitive to the surface gravity (Martín et al. 2004).

We found 32% of the Taurus members to show signs for classical T Tauri stars. 18% of our observed member candidates show the line in emission. However, we only identify two of them to show signs for an accretion disk. For the Na I doublet we find an empirical upper limit of 4 Å for a source to be a possible member of Taurus; 32% of our candidates show those values.

All together, we identified up to 11 objects with spectral types from M0 to M4.5 showing strong membership probability (see Fig. 1). Since we observed only 17% of our candidate sample, we expect up to 65 new member candidates in our hunting ground and up to 500 in all distant off-cloud parts of the Taurus star-forming region. The new sources are not connected to any molecular cloud. Whether they have moved from their birth sites to their present location or the filaments they were born into already disappeared, remains an open question.

Our contribution to the IMF of Taurus is very small and biased in the mass range of our search. However, the mere existence of the new

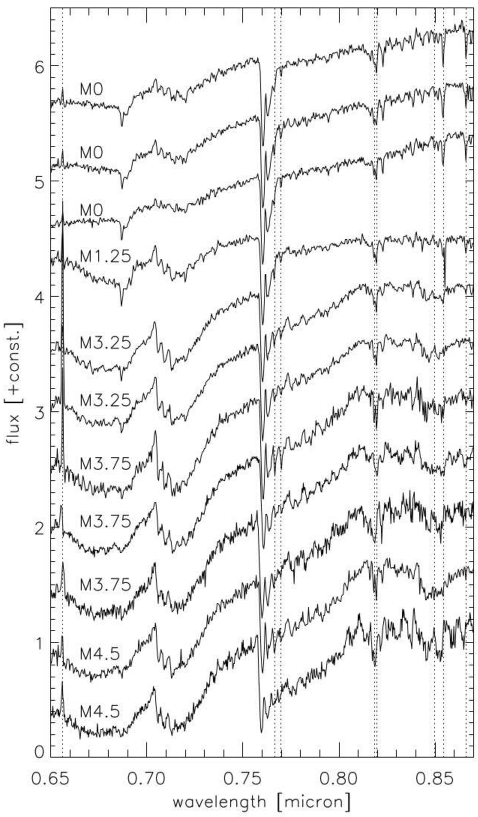

Fig. 1. Spectra of the 11 new member candidates of Taurus. We indicate spectral types and measured line features (left to right: $H\alpha$, K I & Na I doublets, Ca II IRT).

low-mass member candidates in the outer parts of the region indicates already a possible unknown population, which could help to explain the unusual form of the Taurus IMF. We therefore expect the answer to its uniqueness to be located in those off-could parts and conclude that the region is probably more stretched out and of lower density than previously assumed. In the future, we will include the newest data release of the UKIDSS GCS in our search and connect the data with the all-sky WISE and HERSCHEL MIR photometry. We plan to observe our whole candidate sample with higher resolution and larger telescopes in order to detect the lithium resonance line at 6708 Å and to reach down into the substellar regime.

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