AN ISOCAM MID-IR SURVEY OF TMC-2

Searching for sub stellar objects

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Abstract We are conducting a mid-infrared survey of the Taurus Molecular Cloud 2 complex (TMC-2) in order to identify new low mass members and build a more complete IMF down to the sub stellar regime. Here we present a preliminary analysis of one of the surveyed fields. This field contains two previously known members of TMC-2. Based on the observed mid-IR excess we identify 6 new member candidates. Assuming a distance of 140 pc we find luminosities of $\sim$1.5$-$3.5 10^{-3} $L_\odot$ for these objects, placing them squarely in the brown dwarf domain. In addition to the two known stars and the 6 new brown dwarf candidates, we do not detect more luminous stars or brown dwarfs with IR excesses.

Introduction

The mass spectrum of newly formed stars – the so called initial mass function (IMF) – is an important tool towards understanding the process of star formation. Stars form through the gravitational collapse of molecular clouds. In principle physical quantities like the density, temperature and turbulence of the parent molecular cloud are reflected in the relative numbers of stars of each mass that form. Nearby (within 200 pc) young (less than 5 million year old) stellar clusters are excellent laboratories for studying the initial mass function. The main advantage of such young clusters is the fact that dynamical effects are expected not to be important and therefore *all* the stars that initially formed are believed to be still present in the close vicinity of their birth place. Also, during the first few million years the least massive and least luminous members are still contracting, which makes these objects hotter, brighter and easier to detect than in older clusters at the same distance.

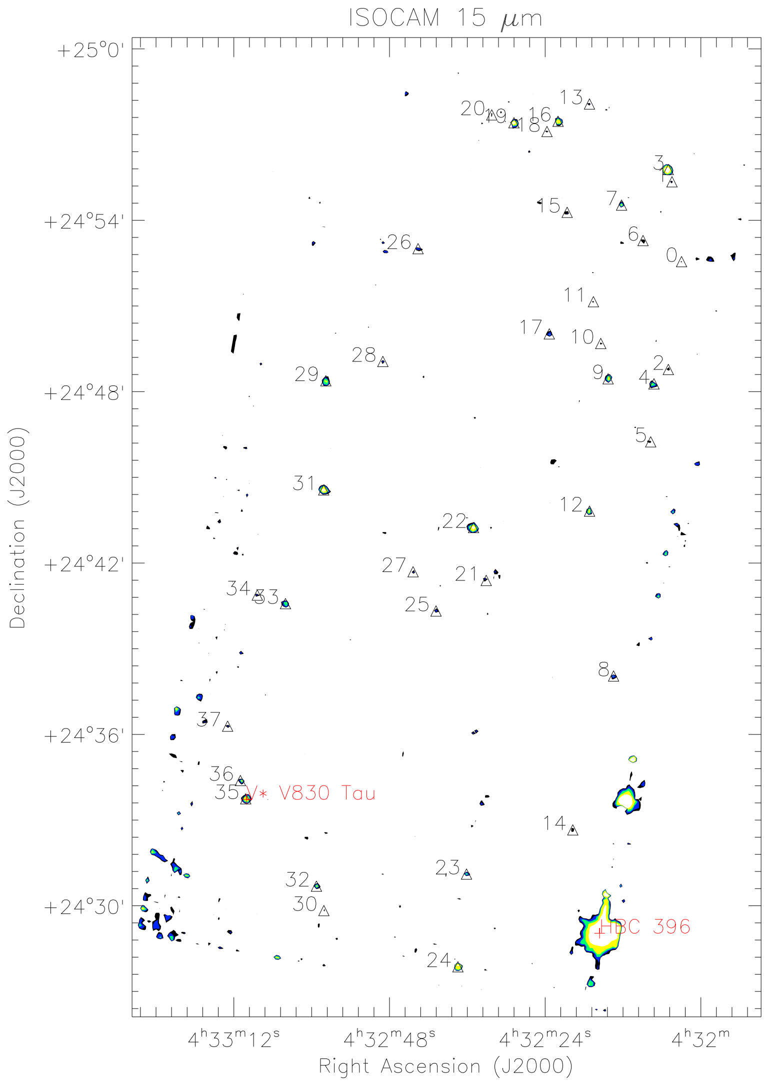

Figure 1. 14.3 μm image obtained with ISOCAM. The detected point sources are indicated with triangles. The two brightest sources near the bottom right are saturated and not used in the analysis. The two known members of the Taurus cluster are indicated in red.

The main disadvantage of these young clusters is due to the fact that they still contain much of the gas and dust from which the stars were formed. This causes most of the stars to be heavily obscured. This extinction is the main reason to conduct surveys of young stellar clusters in the IR. Another reason to conduct these surveys in the IR lies in the fact that the lowest mass members are cool, i.e., red, making them again easier to detect in the IR. Finally, the

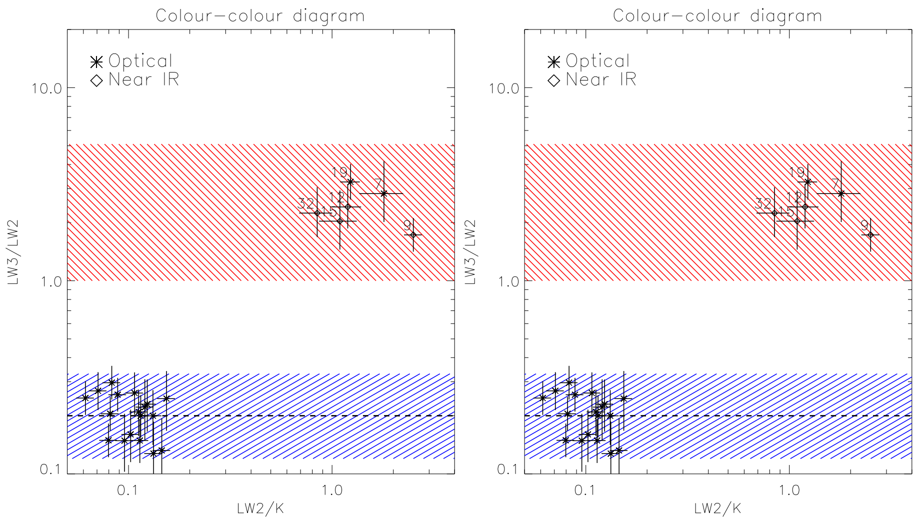

Figure 2. Colour-magnitude diagram for the sources detected at 14.3 μm (left panel). There is a clear separation between photospheric sources (in the blue shaded area) and IR excess sources (red shaded area). The dashed line indicates the theoretical photospheric ratio. The upper-limits indicate sources that are detected at 14.3 μm that lack a 3σ detection at 6.7 μm. The right panel shows that the same IR excess sources are also well separated in the LW2 versus K band flux.

newly formed objects may still be surrounded by a disk. Such a disk can be easily distinguished through its mid-IR colours.

We have conducted a mid-IR survey of selected areas in the Taurus complex to investigate the low end of the IMF. The Taurus star forming complex is particularly interesting because optical and near-IR surveys have indicated that this region has proportionally fewer brown dwarfs than other star forming regions (Briceño et al., 2002 and references therein). This deficit may be related to the relatively low density of the Taurus star forming region.

1. Observations

We have obtained 6.7 and 14.3 μm images with the ISOCAM instrument (Cesarsky et al., 1996) on-board of the Infrared Space Observatory (Kessler et al., 1996). The data cover two fields in the vicinity of TMC-2 with a total area of $\sim$0.5 square degree. The average noise level per pixel is 0.15 and 0.20 mJy at 6.7 μm (LW2) and 14.3 μm (LW3) respectively. In the preliminary analysis that we present here we have identified 40 point sources in the LW3 image. These sources are indicated in Fig. 1. We have cross-correlated the positions of these sources with the 2MASS (near-IR) point source catalogue and the Tycho and USNO optical catalogues. There are 22 sources with a matching

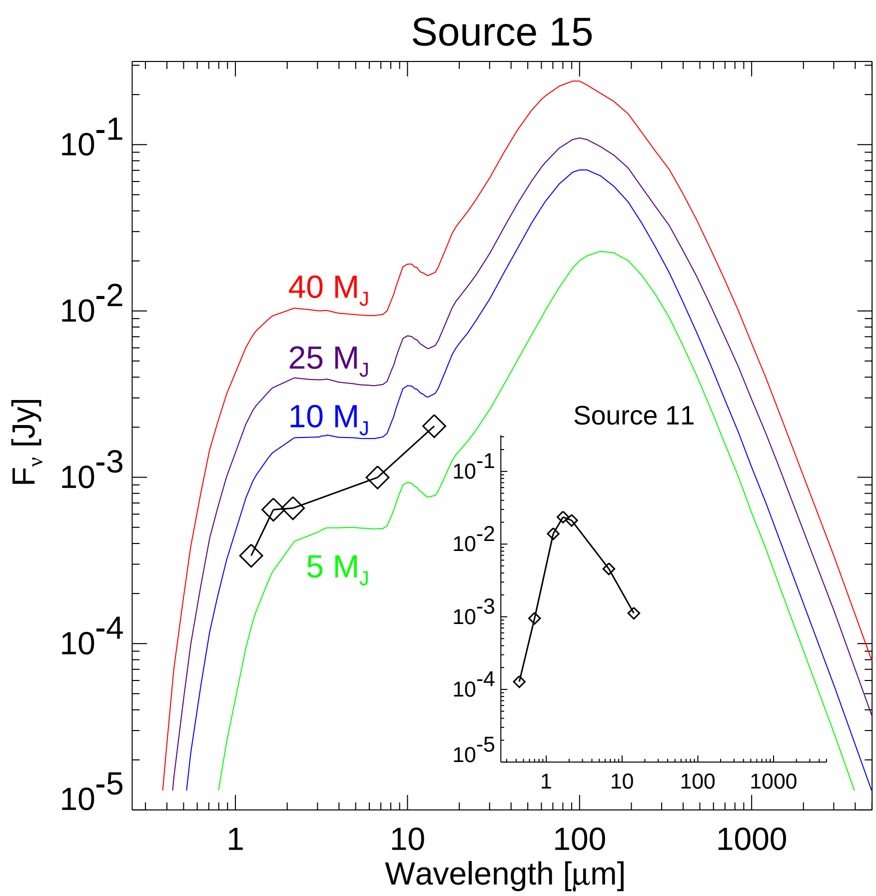

Figure 3. The SED of source 14.3 from the ISOCAM and 2MASS observations as an example of the red sources in Fig. 2. For comparison we show the modelled SEDs of brown dwarfs (age=2 Myr) with a disk at 140 pc (adapted from Natta & Testi, 2001). The inset shows source 11 a star without IR excess.

near-IR and optical source, 4 sources with only a near-IR counterpart and 14 extremely red sources without matching counterpart at shorter wavelengths. The nature of this last group of sources requires further investigation.

2. Results & Discussion

In Fig. 2 we show the ratio of the 14.3 μm flux over the 6.7 μm flux. This ratio is not affected by interstellar extinction because the IR optical depth is small and very similar at 6.7 and 14.3 μm and therefore the objects that exhibit an IR excess are clearly separated from the non-excess sources without confusion between reddened background stars and intrinsically red member stars.

Leaving aside the sources without near-IR counterpart we find 6 new member candidates. In the panel on the right we show that these sources are also easily detected through their mid-IR/near-IR colour. This leaves the possibility to identify further candidates among the ∼200 detected sources in the 6.7 μm observations on the basis of their LW2/K colour.

We have determined the luminosity of the detected excess sources by direct integration of the photometry and assuming that they are at a distance of 140 pc. They all fall in the $1.5-3.5\,10^{-3}$ $L_\odot$ range, typical for young, low mass brown dwarfs. Fig. 3 shows a comparison between brown dwarf+disk models of Natta & Testi and the photometry of one of the new excess sources. The similarity strongly suggests that even down to these low masses disk are present around brown dwarfs.

It is interesting to note that we find six brown dwarf candidates in a field of 0.25 square degree while previous studies have found ten brown dwarfs in 8 square degree (Briceño et al., 2002), pointing to a deficit of brown dwarfs in the Taurus region. However, these results are not in contradiction since the previous surveys are geared to finding more massive brown dwarfs down to 0.02 $M_\odot$ with limited reddening. In fact we have not found any new candidates in the luminosity range expected for brown dwarfs with masses above ∼0.02 $M_\odot$, also pointing to a similar deficit.

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