# Star Formation in the Galactic Region NGC 6357: Age and IMF of the Young Open Cluster Pismis 24


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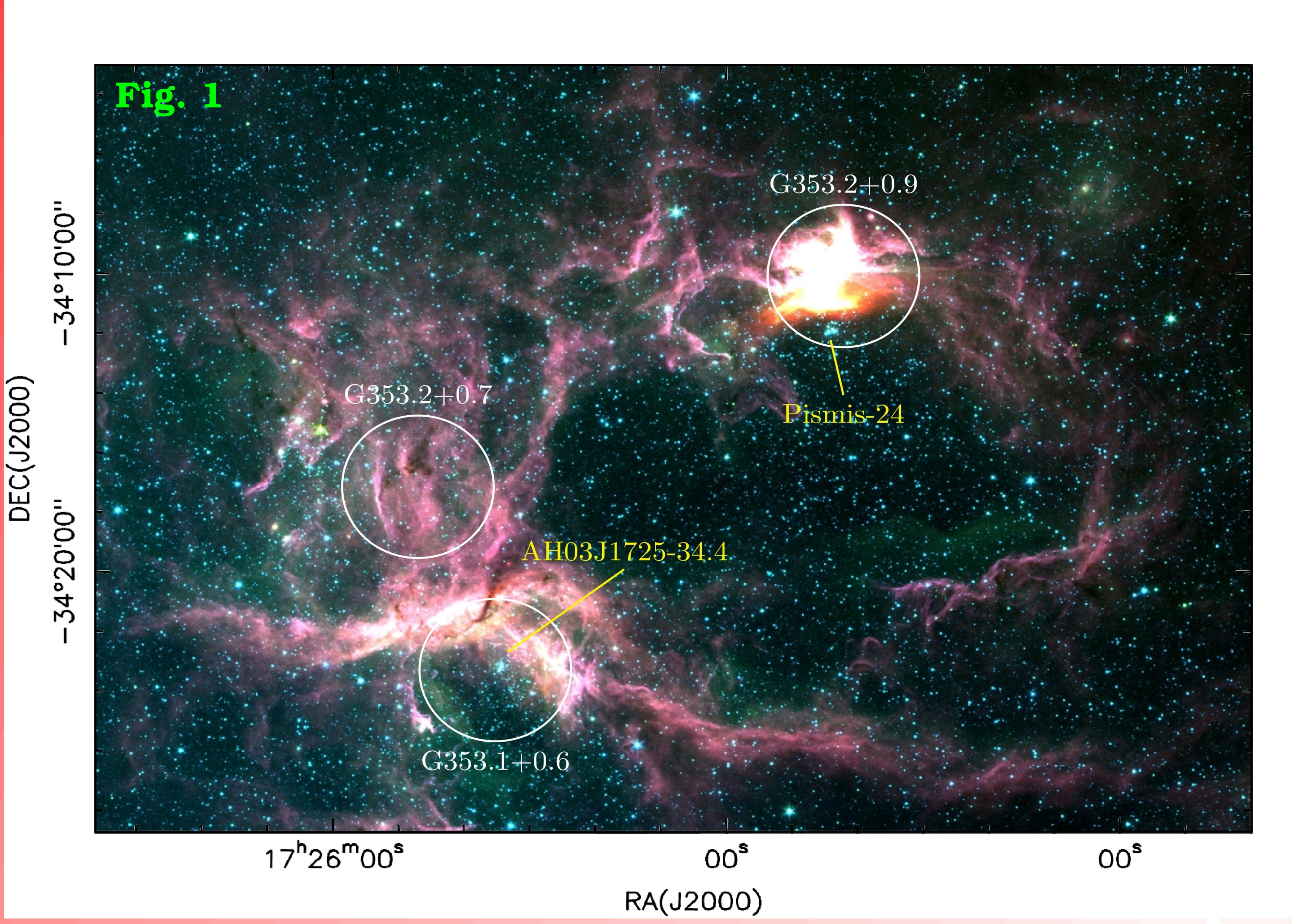
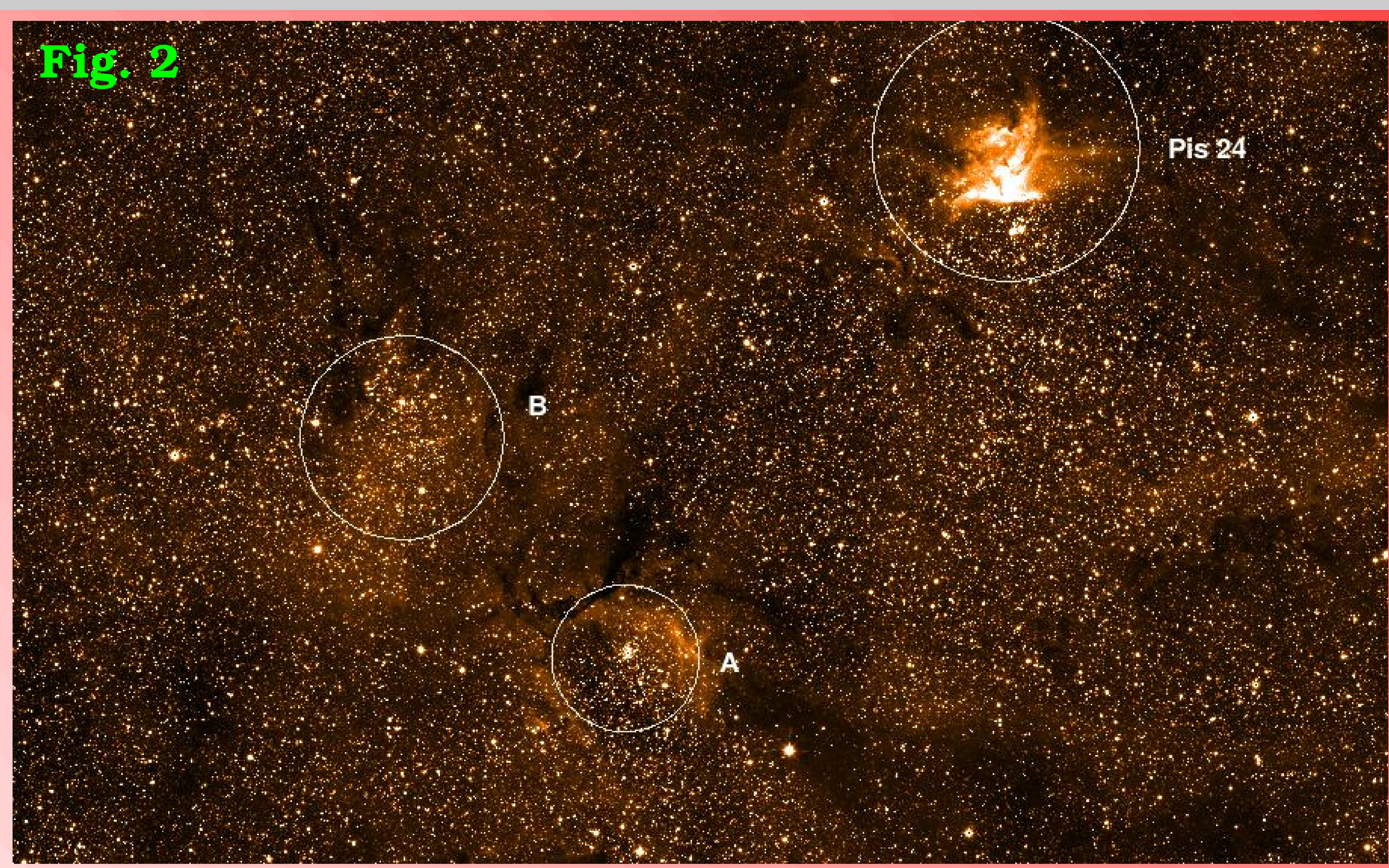
**ABSTRACT**

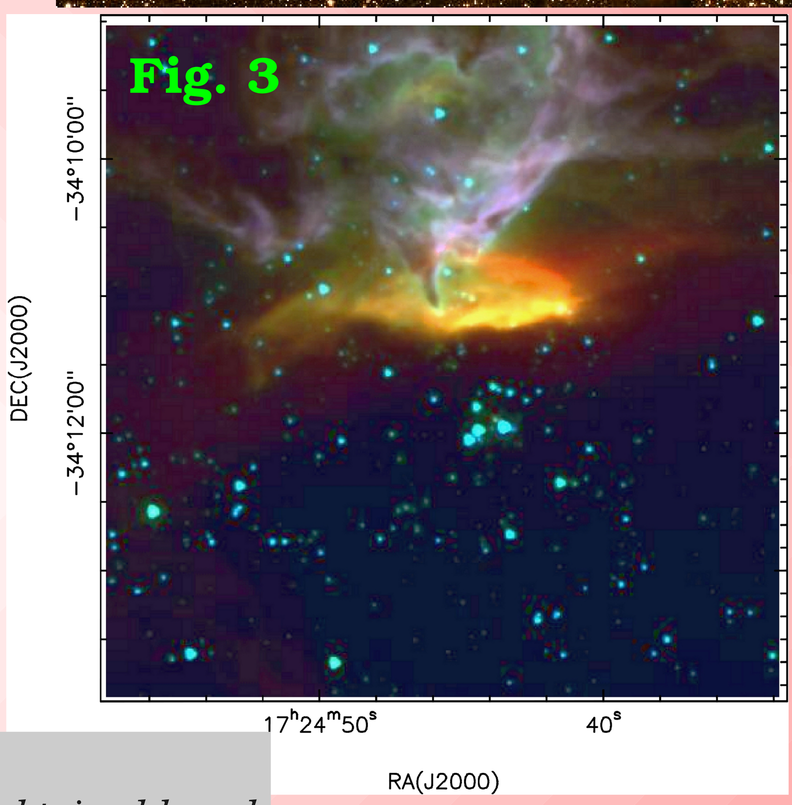
NGC 6357 is an active star forming region hosting very young open clusters and massive stars, as well as giant molecular clouds and ionized gas. It is located at l ~353°, b ~1°, at a distance of 1.7 kpc. It is a suitable region to study how star formation evolves on a scale of tens of parsec.

We have been studying the region for a long time (**see also poster 050 by J. Brand et al.**), at first with mm observations of the main giant molecular clouds in the complex (Massi et al. 1997, Giannetti et al. 2012). Recently, we have started an analysis of the stellar populations in the region as well, based on near-infrared (NIR) photometry. Here we show the results for one of the clusters associated with NGC 6357, namely Pismis 24. We used new deep JHKs images (SofI/NTT), deep archival IRAC/SPITZER images, and archival HST images in the optical VI bands, to derive the cluster age (1-3 Myr) and its K Luminosity Function (KLF). From these we found that the cluster Initial Mass Function (IMF) linearly increases with decreasing logarithmic mass, with a slope in the range 1-2 (Salpeter 1.3) down to about 2.5 $M_\odot$. Then it flattens at the low-mass end with a slope of 0-0.3. We estimated our K-band photometry to be complete down to young (1 Myr old) 0.2 $M_\odot$ stars. This points to a cluster stellar population in the range 4000-11000 members. The cluster itself appears to consist of several sub-clusters. The fraction of stars with a circumstellar disk ranges from ~0.3 to ~0.6 depending on the location within the cluster. We found indications of triggered star formation being in progress in surrounding areas.

We are currently extending the same analysis to the other clusters associated with NGC 6357. Our final purpose is understanding whether the star formation has propagated through the complex from a single initial episode, or rather has occurred independently in different locations due to large-scale turbulence.

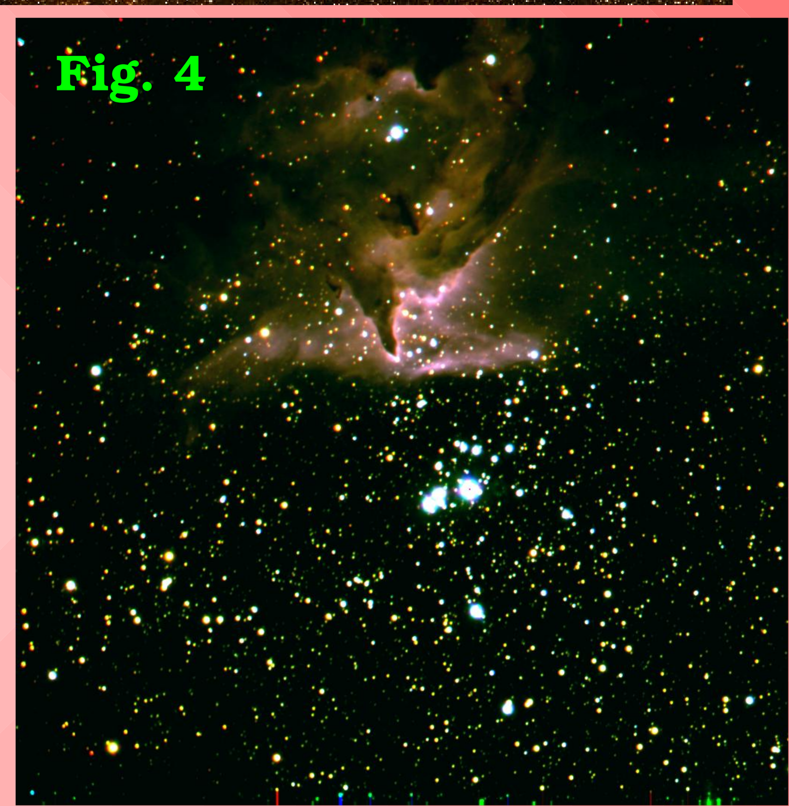
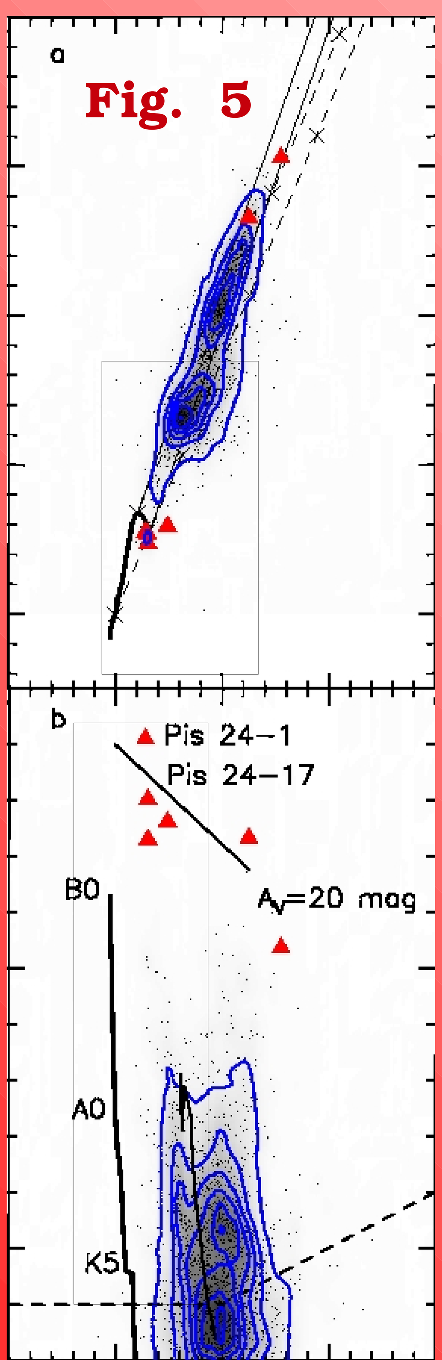




***Fig.1: IRAC/Spitzer three-colour image (3.6 μm blue, 4.5 μm green, 8.0 μm red) of NGC6357; Fig. 2: same area as in Fig. 1, imaged at Ks with UKIRT; Fig. 3: zoom-in of the Spitzer image on Pismis 24; Fig. 4: Sofi/NTT three-colour image (J blue, H green, Ks red) of Pismis 24. Pismis 24 and the other two large young stellar clusters found in NGC 6357 are marked in Figs. 1 and 2.***




## 1 – CLUSTER MEMBER SELECTION

*To derive the cluster IMF, a complete sample of cluster members has first been obtained based on NIR colours. As shown in Fig. 5, the cluster members are well identified in NIR colours (rectangular boxes). Panel (a) displays (SofI) J–H vs. H–Ks towards Pismis 24, whereas panel (b) displays (SofI) Ks vs. H – Ks. The data-point density after smoothing is shown with contours in all panels. The red triangles mark the 2MASS colours of bright saturated SofI sources. A few of these sources, associated with Pismis 24, are also identified. The thick solid line marks the main sequence locus (colours from Koornneef 1983, absolute magnitudes from Allen 1976). The dashed lines in panel (a) are reddening paths with crosses every $A_V$ = 10 mag (Rieke & Lebofsky 1985; thin solid lines: reddening paths according to the extinction law of Straizys & Laugalys 2008). The dashed line in panel (b) marks the completeness limit. Also shown as a full line parallel to the ZAMS in panel (b) is the sequence of PMS stars 1 Myr old (evolutionary tracks of Palla & Stahler 1999, for $A_V$=10 mag, and masses 0.1 – 6 $M_\odot$). A distance of 1.7 kpc is assumed for ZAMS and isochrones.*

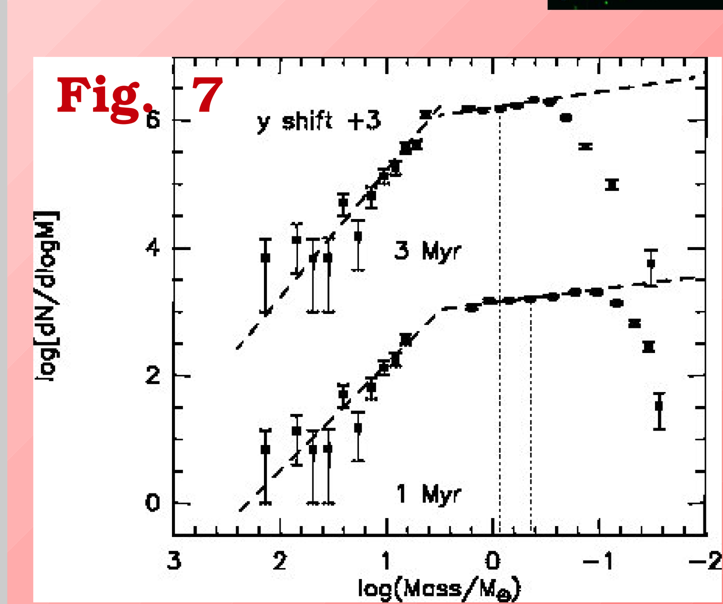
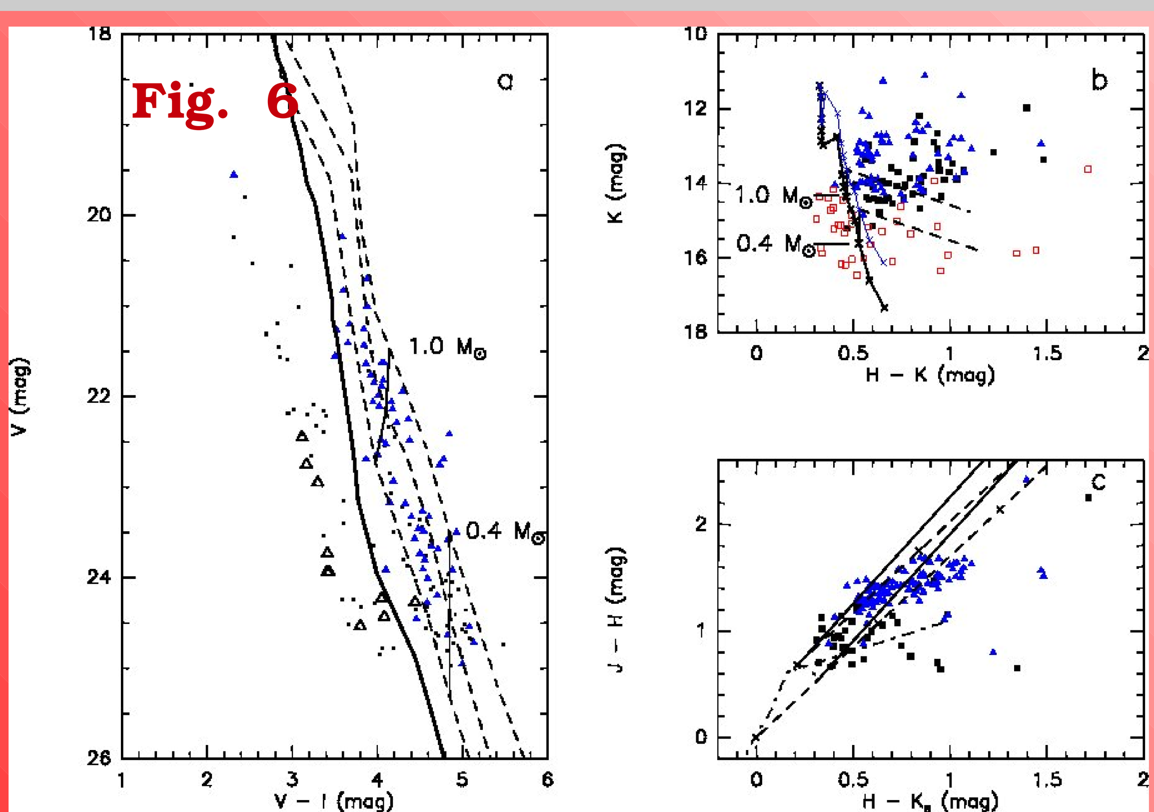



***Fig. 7 shows two of the IMF derived from the dereddened cluster KLF. These have been obtained by using the pms evolutionary tracks of Palla & Stahler (1999) assuming coeval star formation and ages of 1 and 3 Myr. The vertical dotted lines mark the estimated completeness limits.***




## 3 – CLUSTER AGE and IMF

*Fig. 6a shows that the ages of the cluster members range between 1-10 Myr. However, Fig. 6b shows that the NIR photometry yields higher masses than the optical one for most of the members. We interpreted this as an indication of infrared excess (as confirmed by Fig. 6c). In fact, by cross correlating optical, JHKs, and Spitzer (from the image in Fig. 3) photometry we derived a fraction of stars with a circumstellar disk of at least 0.3, which would be inconsistent with a cluster as old as ~10 Myr. We concluded that a cluster age of 1-3 Myr, as found in the literature, is more plausible.*

*Once the sample of cluster members was finally selected, we used our SofI JHKs photometry to construct a dereddened KLF following Massi et al. (2006). From that, we derived a set of IMF by assuming different evolutionary tracks and ages in the range 1-3 Myr. Two of these are shown in Fig. 7. All IMFs exhibit a linear increase down to ~2.5 $M_\odot$ with a slope ~1 – 2 (Salpeter 1.3), and a flattening down to the completeness limit.*

## 4 – SUMMARY

*Field star contamination and confusion-limited photometry have proven to be major problems in the study of the region. We used a full multi-wavelength analysis to try to circumvent these effects. Here is a list of the main results:*

- *Cluster age: < 10 Myr (1-3 Myr adopted)*
- *Estimated number of cluster members down to ~0.1 $M_\odot$: 4000-11000 (depending on the NIR colour range adopted)*
- *IMF down to ~2.5 $M_\odot$: log(dN/dlogM) ~ (-1 to -2)logM, flattens (0 to -0.2)logM for lower masses*
- *Fraction of stars with a circumstellar disk: 0.3 (ranging from 0.3 to 0.6 in different areas)*

## 2 – AGE DETERMINATION

*We have further revised our member selection through a careful comparison of optical, NIR, MIR and X-ray properties. The stellar ages have been revised using HST/WFPC2 photometry. This is shown in Fig. 6a: the full line marks the ZAMS, the dashed lines are isochrones for (from the right) 1, 3, and 10 Myr old PMS stars (Palla & Stahler 1999), all reddened by $A_V$ = 5.5 mag and scaled to 1.7 kpc. The loci of 1 and 0.4 $M_\odot$ are labelled near the 1 Myr isochrone. The small blue triangles are stars with an X-ray detection (from Wang et al. 2007). Panel (b) shows Ks vs. H – Ks for the NIR infrared counterparts of the optical stars (red open squares: stars on the left of the optical ZAMS; full squares: stars on the right of the optical ZAMS; blue full triangles: stars on the right of the optical ZAMS also detected in X-rays). The full lines are the isochrones for (from the right) 1 and 3 Myr old PMS tracks (Palla & Stahler 1999), same reddening and distance as above. The loci of 1 and 0.4 $M_\odot$ are also labelled and the dashed lines are their reddening paths (for 1 Myr old stars, up to $A_V$ = 10 mag; Rieke & Lebofsky 1985) Panel (c) shows J – H vs. H – Ks for the NIR infrared counterparts of the optical stars (same symbols as above, but stars on the left of the optical ZAMS are omitted). The full line is the unreddened MS, the dashed lines are reddening paths with crosses every $A_V$ = 10 mag (full lines, reddening paths according to Straizys & Laugalys 2008). The dot-dashed line marks the locus of Classical T-Tauri Stars (Meyer et al. 1997).*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