Mass accretion rates in the Carina Nebula: the case of Trumpler 14

Giacomo Beccari (ESO), Guido De Marchi (ESA), Nino Panagia (STScI),

Martino Romaniello (ESO), Giovanni Carraro (ESO), Loredana Spezzi (ESO)

Want to know more?
www.starformation.org

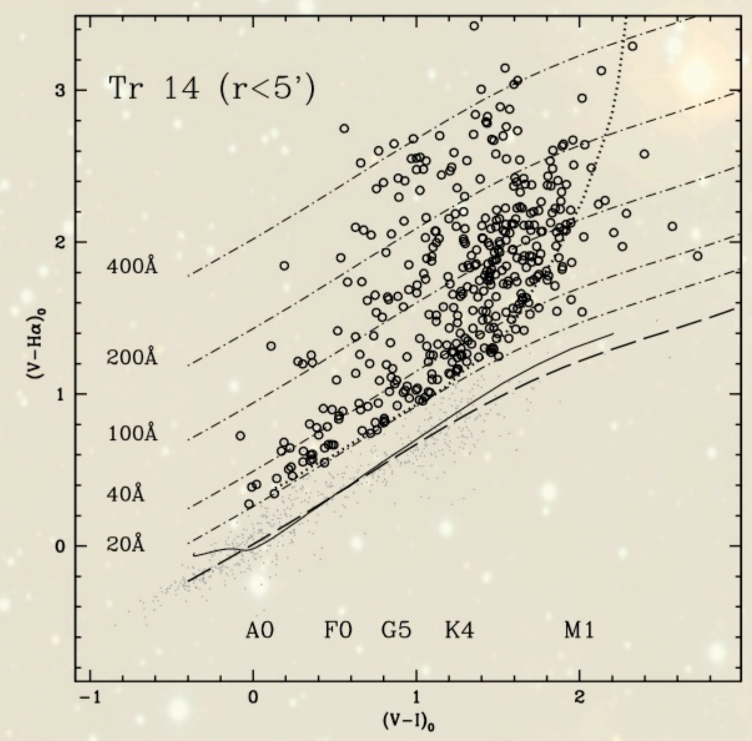

Figure 1 — Application of our method. Stars with small photometric errors in V, I and Hα (in grey) define the reference template of normal stars (i.e. with no Hα emission), shown here as a dashed line. Objects with large (> 5 σ) excess are bona-fide PMS stars (circles). Their L(Ha) luminosity is readily determined from their (V-Ha) excess relative to the reference line. The dot-dashed lines show the position of stars at different levels of Hα emission (different equivalent widths). The dotted line shows the detection limit at 50% photometric completeness.

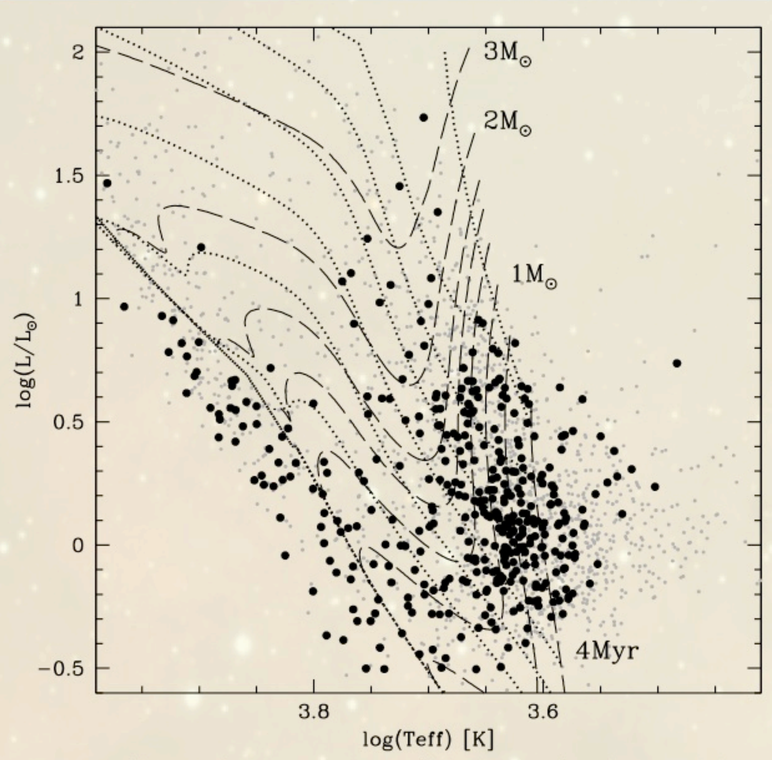

Figure 2 — Ages of bona-fide PMS stars (black dots), obtained by comparison with theoretical isochrones of 0.25, 0.5, 1, 2, 4, 8, 16 and 32 Myr (dotted lines) and 0.6 to 3 $M_\odot$ PMS tracks (dashed lines) from Degl'Innocenti et al. (2008), reveal that in Tr 14 there are at least two populations separated by ~10 Myr.

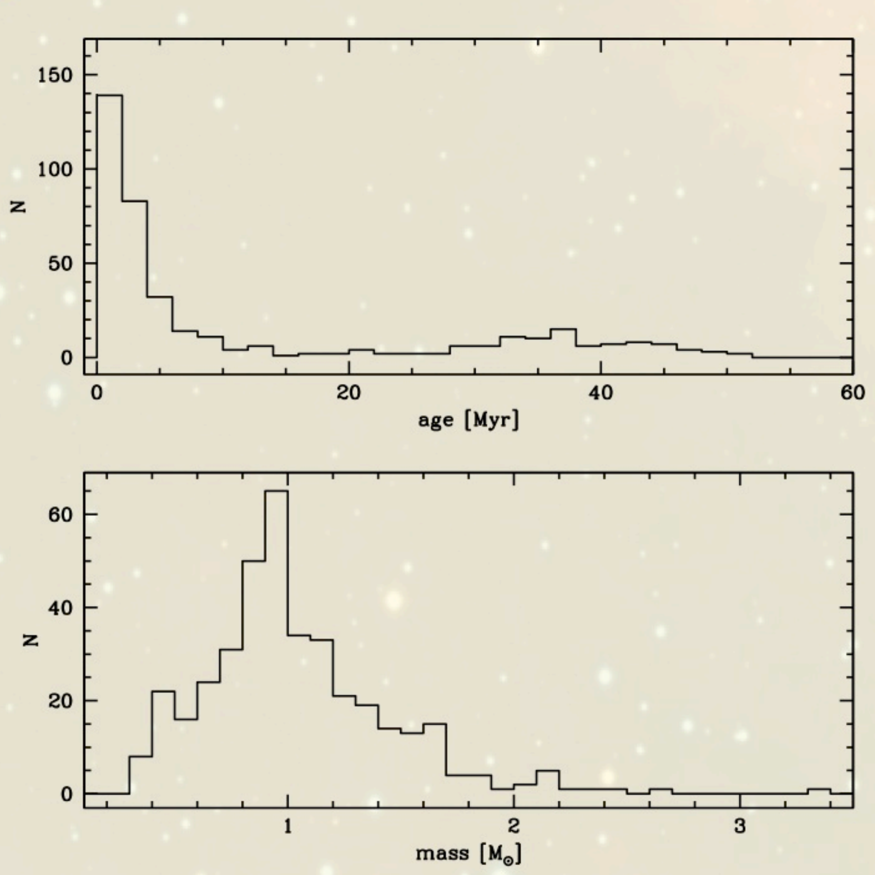

Figure 3 — Age and mass distribution of PMS stars (upper and lower panel, respectively) in Tr 14. Ages and masses are derived through the comparison with the PMS evolutionary tracks of the Pisa group (Degl'Innocenti et al .2008)

Summary

Using the Wide Filed Imager at the ESO/MPG2.2m (La Silla), we have undertaken a systematic study of pre main sequence (PMS) stars spanning a wide range of masses (0.5 – 4 $M_\odot$) in the Carina region. Here we report the characterisation of PMS stars in a region of 5' around the center to Trumpler 14 (Tr 14).

Thanks to a novel method that we have developed to combine broad-band (V, I) photometry with narrow-band Hα imaging (De Marchi et al. 2010), we have identified more than 200 bona-fide PMS stars still undergoing mass accretion (Figure 1). We have determined their physical parameters, including temperature, luminosity, age, mass and mass accretion rate ($\dot{M}_{acc}$) through a comparison with PMS theoretical models (Figure 2). This is presently the largest and most homogeneous sample of PMS objects with known physical properties in Tr 14.

Noticeably, the distribution of PMS ages (upper panel of Figure 3) confirms that ~30% of the objects have ages > 10 Myr. This implies that in this region star formation started definitely more than 10 Myr ago, possibly more than 30 Myr ago, and that a second major burst followed in the last 2-5 Myr.

The mass distribution of bona fide PMS objects peaks near 1 $M_\odot$ (Figure 3, lower panel). As expected, the number of stars more massive than 1 $M_\odot$ decreases, being the PMS evolution timescale faster for more massive objects. On the other hand, the apparent decrease of the number of stars of mass < 1$M_\odot$ is due to the drop of the photometric completeness of the WFI observations.

The derived $\dot{M}_{acc}$ values are shown as black dots in Figure 4, as a function of their PMS stars' age. The typical $\dot{M}_{acc}$ of the objects in our sample is much higher than that expected from models of viscous disc evolution (Hartmann et al. 1998; black line in Figure 4). In order to better understand the origin of this apparent discrepancy, we used the r' ,g' and Hα bands photometric catalogue of T-Taury stars of the H II region IC 1396 in Cepheus OB2, including Tr 37, published by Barentsen et al. (2011; B11). We applied the same method used on the WFI data of Tr 14 to derive the physical parameters and $\dot{M}_{acc}$ of the PMS stars. The $\dot{M}_{acc}$ values that we find in this way for Tr 37 are shown as grey dots in Figure 5. The values are in full agreement with viscous disc models (see also Figure 16 in B11) and this confirms the validity of our approach in studying the $\dot{M}_{acc}$ of PMS stars.

The most likely explanation of the difference in the distributions of $\dot{M}_{acc}$ values is offered by Figure 5. While in Tr 14 the mass distribution of PMS stars peaks at ~1 $M_\odot$ (solid line), in Tr 37 (dashed line) the majority of PMS objects there have masses from 0.1$M_\odot$ to 0.6$M_\odot$, with a peak at 0.3 $M_\odot$. Since, the $\dot{M}_{acc}$ scales with at least the first power of the stellar mass (De Marchi et al. 2011), the large difference in the mass ranges sampled in the two clusters fully justifies the differences observed in the average $\dot{M}_{acc}$ values.

Finally, to confirm that the older PMS stars are effectively still surrounded by a circumstellar disc, we have studied their spectral energy distribution in the range 0.5 – 8 µm (see Figure 6), finding in all cases the signature of an unmistakable infra-red excess. We conclude that the lifetime of circumstellar discs must therefore be longer than currently assumed.

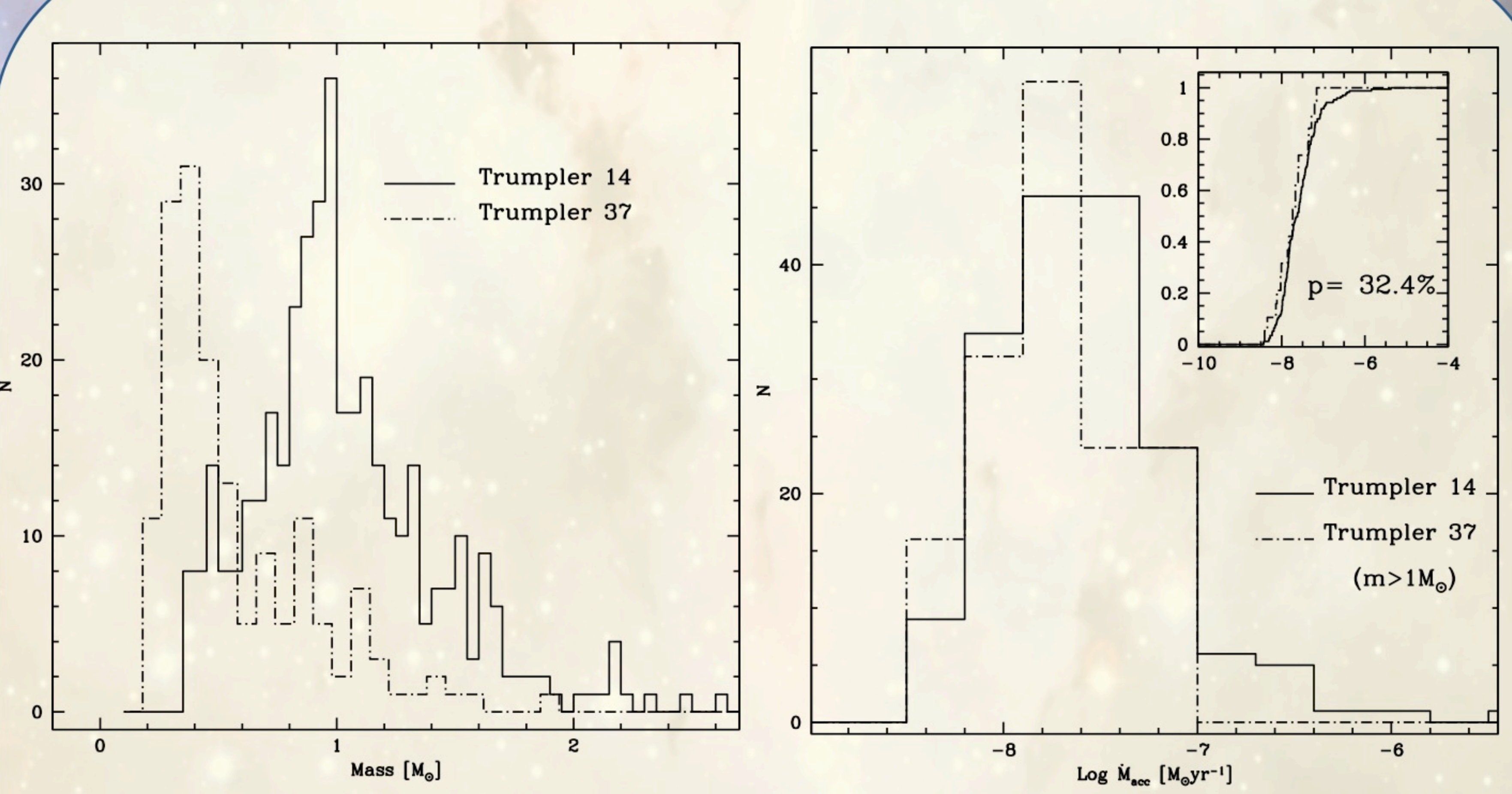

Figure 5 — Left panel: Histograms showing the mass distribution of PMS stars in Tr 14 and Tr 37 from B11 (solid and dashed-dotted lines, respectively). **Right panel:** Histogram showing the $\dot{M}_{acc}$ for stars with mass > 1$M_\odot$ in Tr 14 and 37 (solid and dot-dashed lines, respectively). The inset shows the comparison of the cumulative distributions of $\dot{M}_{acc}$ in the two clusters. The probability from a KS test is also given.

References — Barentsen, G., Vink, J., Drew, J., et al. 2011, MNRAS, 415, 103 • Degl'Innocenti, S., Prada Moroni, P. G., Marconi, M., Ruoppo, A. 2008, Ap&SS, 316, 25 • De Marchi, G., Panagia, N., Guarcello, M., Bonito, S. 2013, MNRAS, in press • De Marchi, G., Panagia, N., Romaniello, M. 2010, ApJ, 715, 1 • De Marchi, G., Panagia, N., Romaniello, M., et al. 2011, ApJ, 740, 11 • Hartmann et al. 1998, ApJ, 495, 385 • Hauschildt, P., Allard, F., Ferguson, J., et al. 1999, ApJ, 525, 871

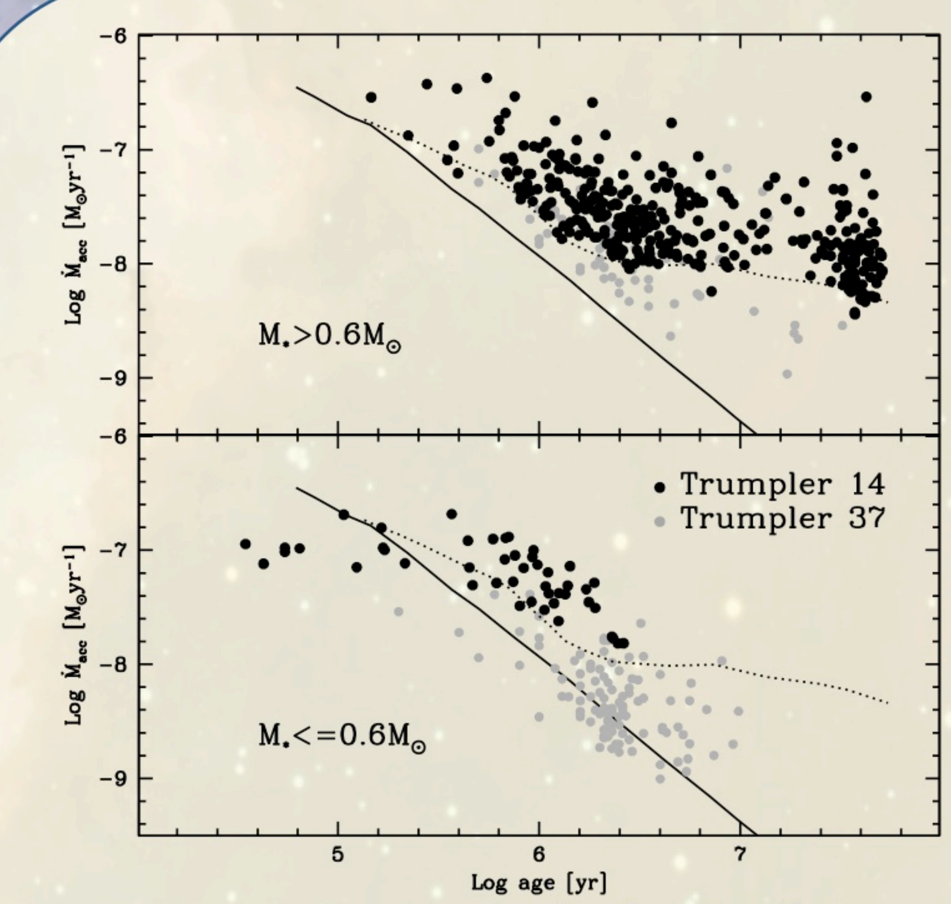

Figure 5 — Mass accretion rate as a function of stellar age for stars with mass higher (upper panel) and lower (lower panel) than 0.6 $M_\odot$. The bona-fide PMS stars in Tr 14 are indicated as black dots. Grey dots show the value of $\dot{M}_{acc}$ for stars in Tr 37. The solid line corresponds to the predictions of the models of viscous disc evolution of Hartmann et al. (1998).. The dotted line show the detection limit down to the 50% of photometric completeness.

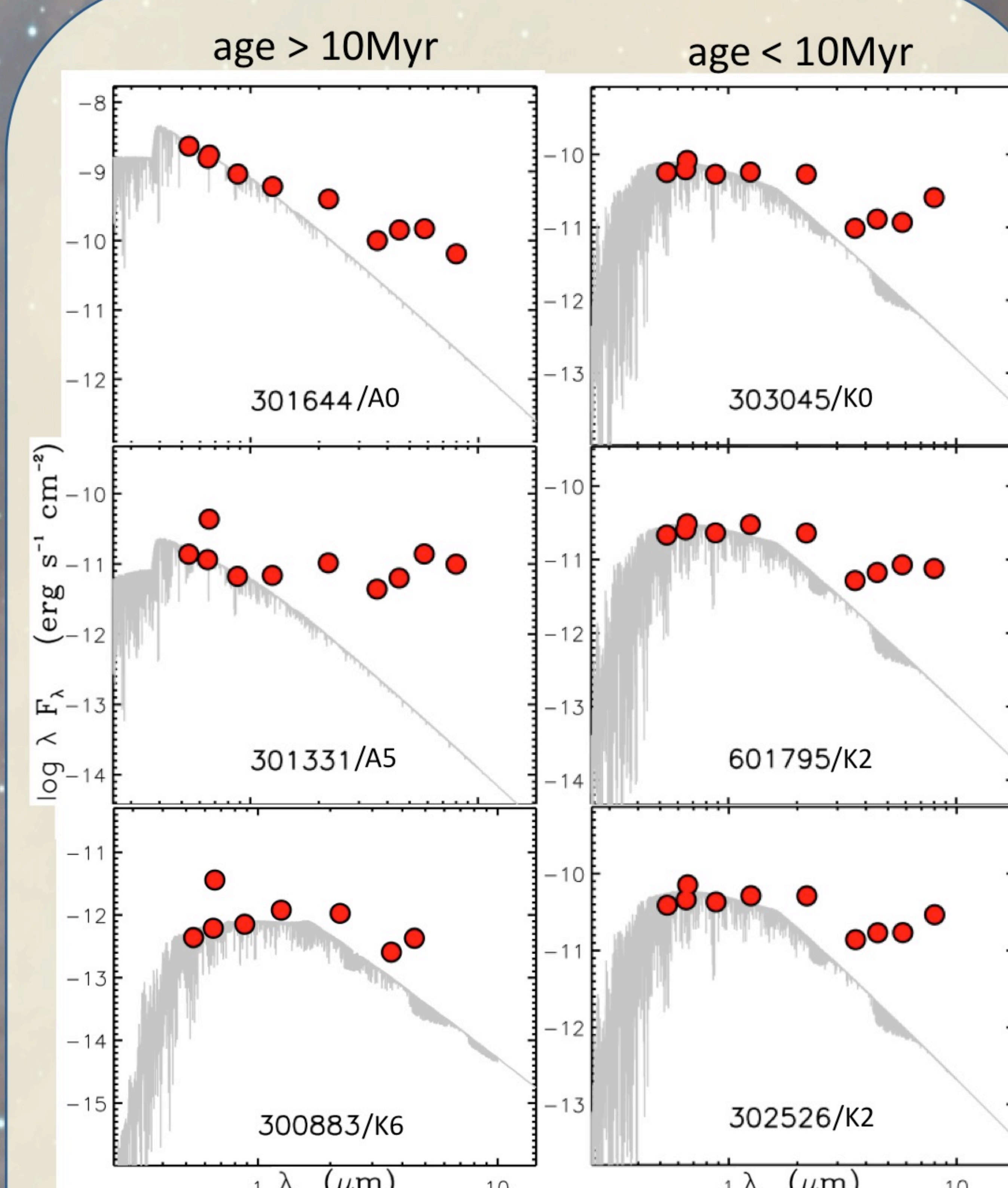

Figure 6 — Examples of SEDs of OLD (> 10Myr) and YOUNG (<10Myr) PMS objects in Tr 14. The SED were obtained by combining optical WFI data with near- and mid-IR observations from SOFI and Spitzer/IRAC, respectively. The presence of an infra-red excess is seen in all these objects, when the observations are compared to the NextGen (Hauschildt et al. 1999) spectra of the type indicated in each panel after the star's ID. This confirms that circumstellar discs are still present around these stars, even those older than ~10 Myr. A similar result has been recently found in the Eagle Nebula (NGC 6611) by De Marchi et al. (2013), suggesting that lifetimes for circumstellar discs are considerably longer than currently assumed.