A near infrared classification of pre main sequence stars

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T Tauri stars are young solar analogues ($M_* \leq 1.5 M_\odot$), harbouring a disc and with ongoing accretion. The T Tauri phase has been estimated to last around 10 Myr. We have obtained *J* and *K* band spectra with WHT/LIRIS and NOT/NOTCam of 112 T Tauri stars in the Taurus star forming region. By measuring the equivalent widths of common and strong spectral features, known to follow a tight relation with temperature, we aim at providing a direct and fast method to derive stellar effective temperatures. Line ratios of strong absorption features relatively close in wavelength are used to overcome the effects of veiling. Besides, the Al I (1.313µm) line is strongly gravity-dependent and used to discern between surface gravities. Finally, we estimate accretion rates using the H-lines Pa-β and Br-γ.

SAMPLE & OBSERVATIONS

The sample consists of 112 YSOs (SpT≈G0-M6) from the Taurus-Auriga region (1-3 Myr). In terms of SEDs classes, the sample covers from Class I down to Class III. In **Fig. 1** we show a color-color diagram of our young sample.
The *J and K* band spectra was taken at NOT/NOTCam and WHT/LIRIS with a spectral resolution R≈2000. For a better sky removal the targets were observed in different slit positions following the typical ABBA patetrn.

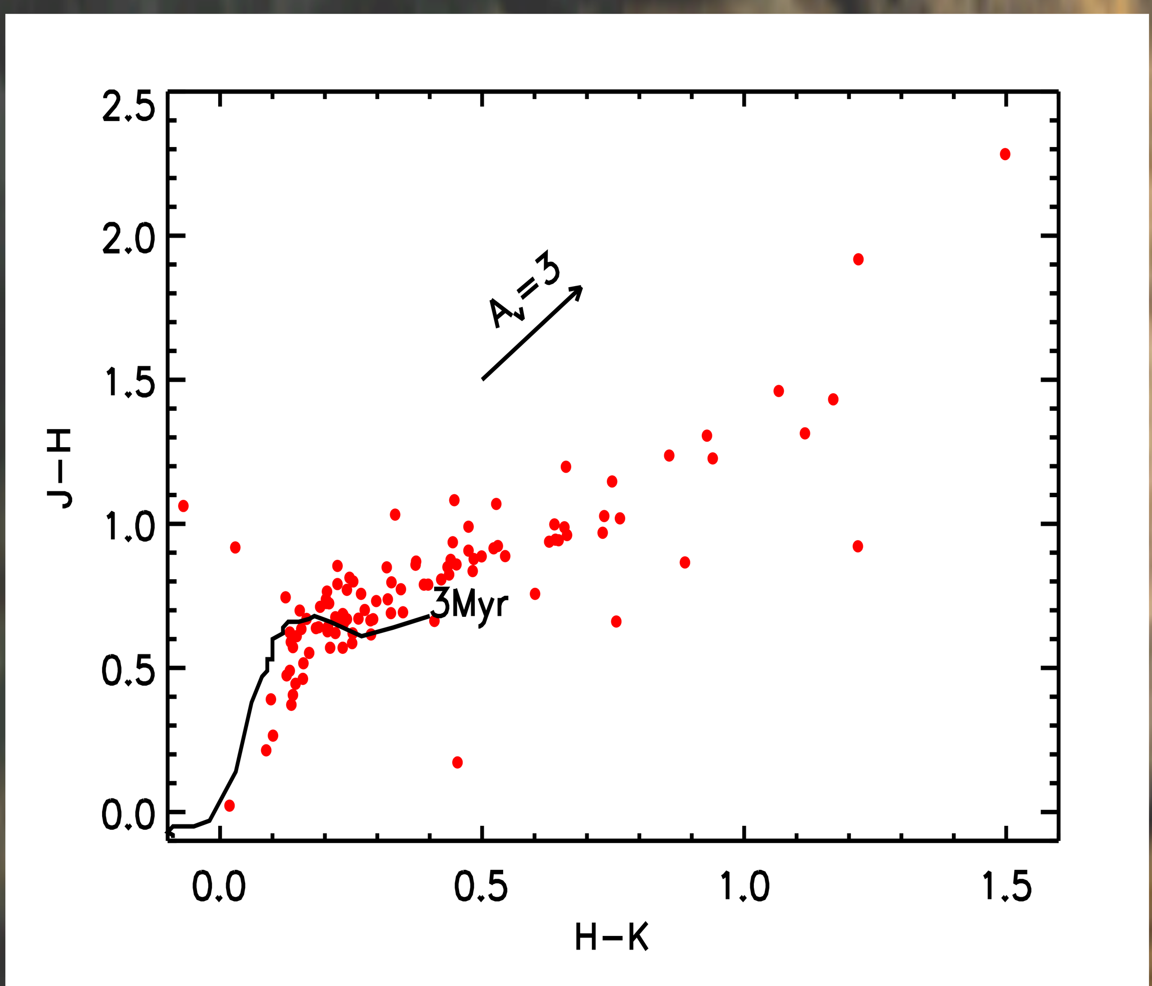

Fig. 1. J-H vs. H-K diagram. The 3 Myr isochrone (Siess et al. 2002) and extinction vector A_v are indicated.

THE SPECTRA

The *J* and *K* band spectra (**Fig. 2**) are well populated with absorption features (e.g. K I, Mg I, Al I, Na I and Ca I) with a photospheric origin. Many sources show H I in emission, associated with acretion. Beyond 2.3µm the spectra is dominated by rotational transitions of ^{12}CO most likely coming from the disc. Some of these lines ratios show a tight dependence with the stellar effective temperature; and in some cases are affected by the surface gravity.

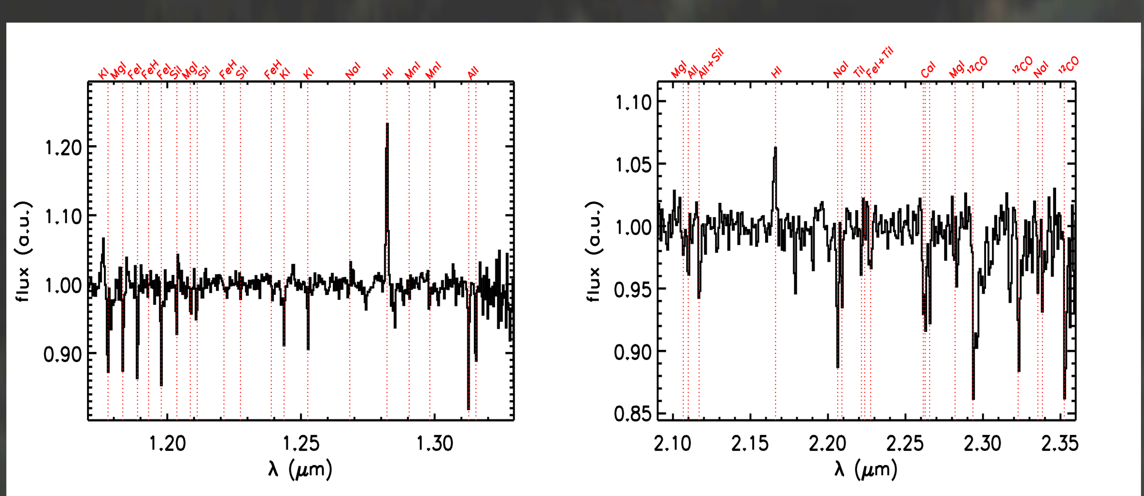

Fig. 2. The spectra of AA Tau in *J* (*left*) and *K* (*right*) bands.

RESULTS

In the range 3000-7000 K the best temperature indicators are, K I 1.253µm/Mg I 1.183µm, K I 1.253µm/Al I 1.313µm, Na I 2.208µm/Mg I 2.281µm and Ca I 2.265µm/Mg I 2.281µm. In general, the temperatures we obtained are compatible with previous estimates. The spectral types peak at M3, i.e. T_{eff}≈3400 ± 110 K.

The mass accretion rates obtained using H I lines are, within errors, similar to literature values. We additionally find a factor two difference with mass-loss rates derived using [OI] 63µm.

METHODOLOGY

The K I and Mg I lines in the *J* band (**Fig. 3**) and the Na I and Ca I ones in the *K* band (**Fig. 4**) for the stars in the IRTF Spectral Library (Rayner et al. 2009) show a tight dependance with temperature in the range 3000-7000 K. Also clear is the different trends followed by dwarf and giant stars due to their different surface gravities (log *g* = 3–5 vs. log *g* = 0–3). To overcome the effects of veiling, line ratios of strong absorption features relatively close in wavelength are used. Among others, K I 1.253µm /Mg I 1.183µm, K I 1.253µm/Al I 1.313µm, Na I 2.208µm/Mg I 2.281µm and Ca I 2.265µm/Mg I 2.281µm ratios are the best indicators for stars cooler than 5000 K (**Figs. 5 & 6**). These ratios are best fitted, and more often, by exponential laws and in a few cases by polynomial or linear fits. To discern between luminosity classes we use the Al I line (**Fig. 7**). Preliminary results compare well with literature values (**Fig. 8)**, within two spectral subtypes.

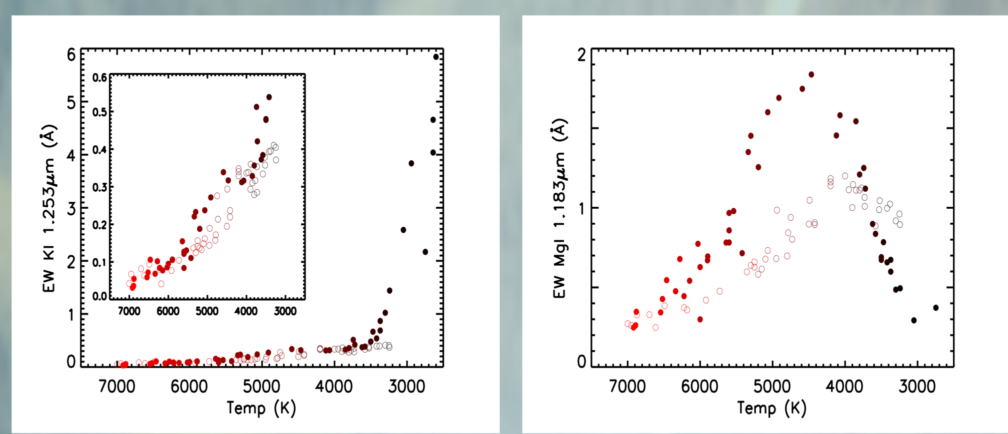

Fig. 3. The EWs of K I and Mg I as a function of effective temperature for dwarfs (*filled*) and giants (*empty*).

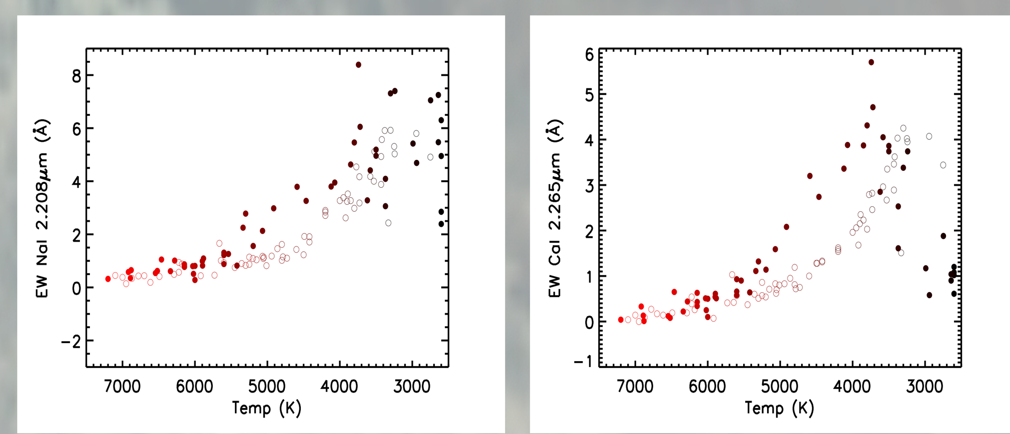

Fig. 4. The EWs of Na I and Ca I as a function of effective temperature (Cesetti et al. 2012).

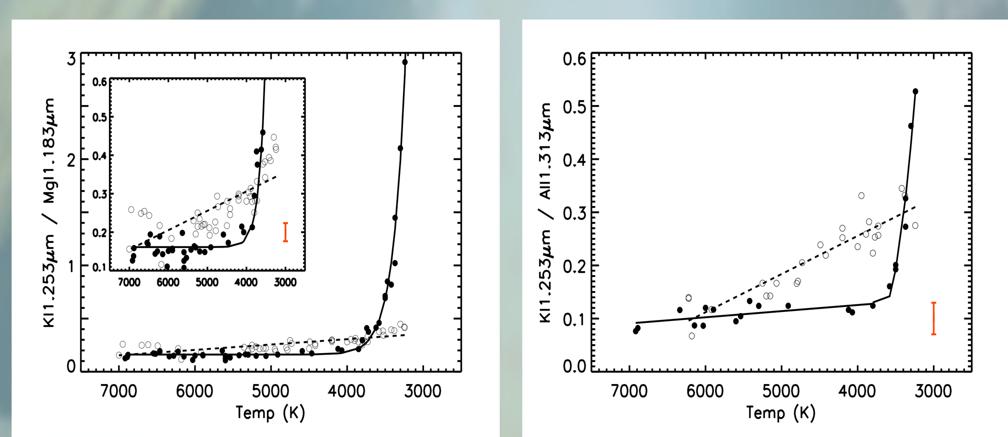

Fig. 5. The K I/Mg I (*left*) and K I/Al I (*right*) line ratios as a function of the effective temperature. Errors are indicated.

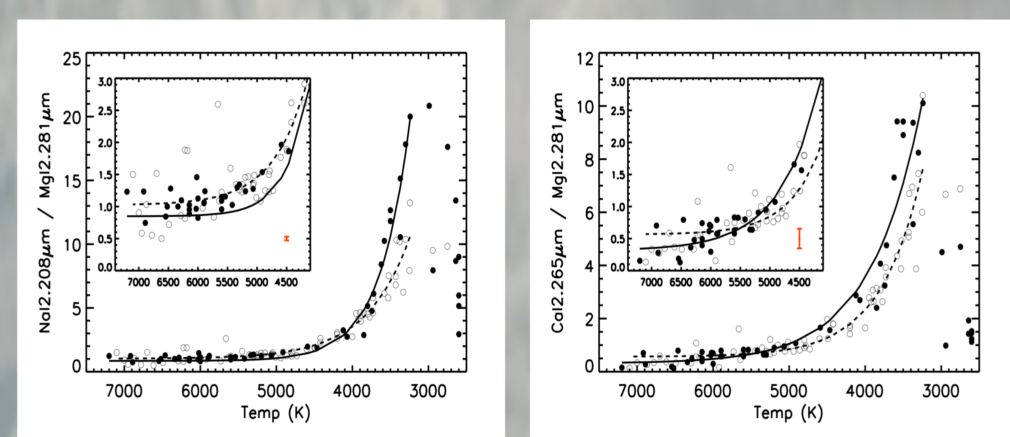

Fig. 6. The Na I/Mg I (*left*) and Ca I/Mg I (*right*) line ratios as a function of the effective temperature.

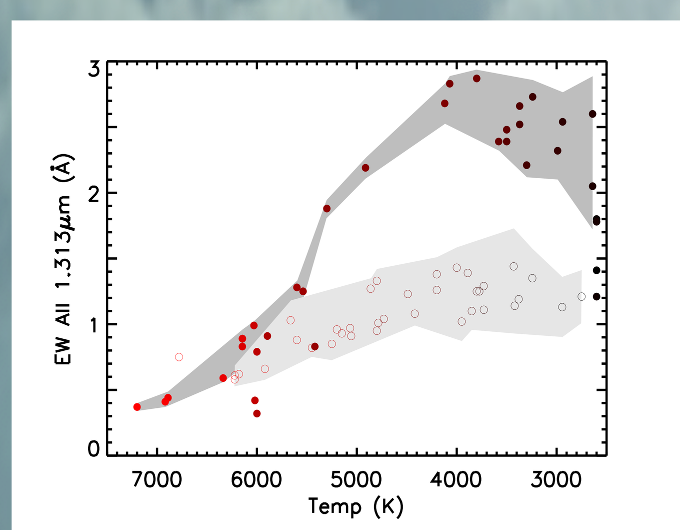

Fig. 7. Al I 1.312 µm line (Rayner et al. 2009). Shaded regions are the confident areas to discern luminosity classes of dwarfs and giants.

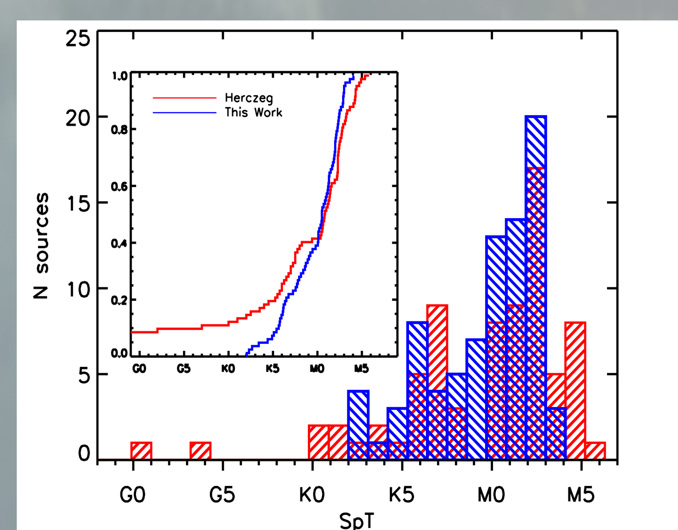

Fig. 8. Preliminary SpT distribution (*blue*) as compared to prior estimates in Herczeg et al. 2013 (*red*). Cumulative probability is also shown.

ACCRETION

The Pa-β and Br-γ lines arise in the accretion process and are suitable to study this phenomena. First, the EWs of H I lines are converted to fluxes using 2MASS *JK* photometry (**Fig. 9**). Accretion related parameters are then obtained using literature prescriptions: (1) Accretion luminosities (L_{acc}, Muzzerolle et al. 1998); (2) stellar masses (M_{star} , Baraffe et al. 1998); and (3) accretion rates (M_{acc}, Alcalá et al. 2014). The M_{acc} estimates compare well with previous estimates and are, on average, a factor two higher when compared to the mass-loss rates using *Herschel's* [OI] 63µm line. An extra finding is the tentative relation between PACS continuum flux at 100 µm and H I lines (**Fig. 10**).

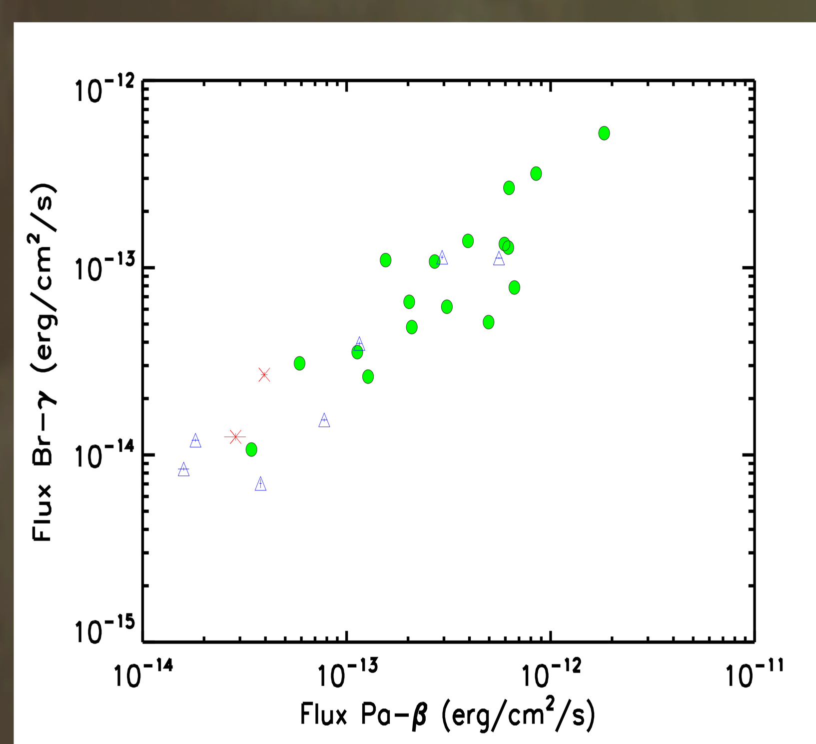

Fig. 9. Correlation between H I lines. Circles and triangles are accretors and non-accretors, respectively. Crosses indicate peculiar objects.

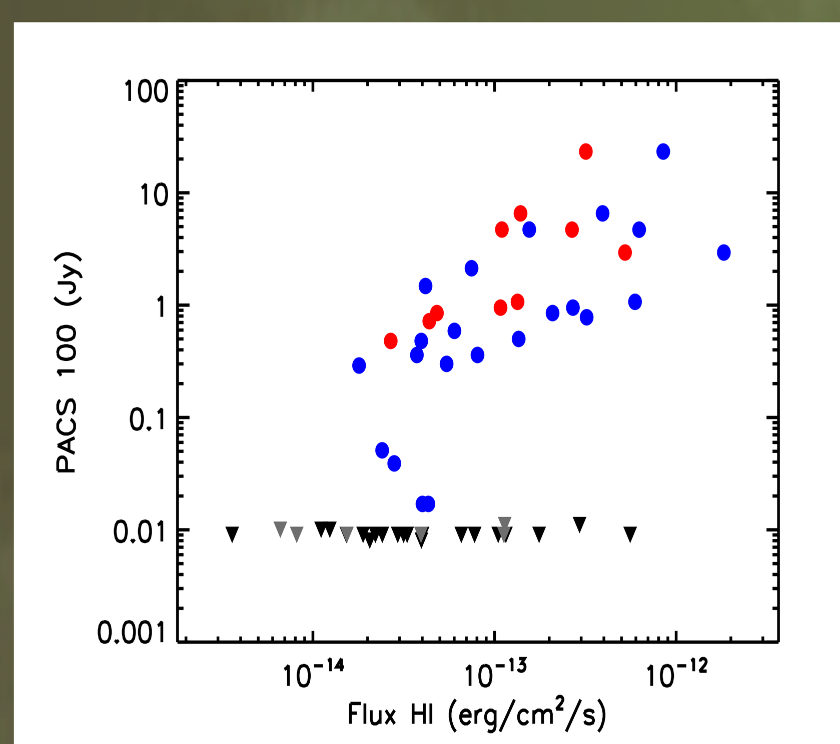

Fig. 10. Continuum at 100 µm (PACS, Howard et al. 2013) as a function of Pa-β (*blue*) and Br-γ (*red*). Triangles are upper limits.

ONGOING WORK

A deeper analysis of the source properties (SED modelling) will be performed to better understand the accretion process and its relation with the presence of jets using *Herschel* data.

The relation, if any, between near-IR CO lines and those in the far-IR will also be investigated.

Background image: An accreting star surrounded by a disc (Credits: NASA/JPL-Caltech).

Reference: Alonso-Martínez et al., in prep.