

Mining the sky for isolated very young stars

P. Guillout¹,
and

A. Frasca², D. Montes³, F.X. pineau¹, A. Klutsch³, E. Marilli², N. Grosso¹

1- Observatoire Astronomique de Strasbourg; 2- INAF - Osservatorio Astrofisico di Catania, Italy; 3- Universidad Complutense de Madrid

Accreting young stars whose origin cannot be unmistakably linked to standard stellar birth places are extremely rare and also challenging candidates for the commonly accepted theory of stellar formation. We present preliminary results of optical observations conducted on “isolated” stars showing strong near- and far-infrared excess that are likely due to circumstellar discs. We acquired high-resolution optical spectra allowing us to investigate in details their nature and physical parameters. Using the crosscorrelation technique and other tools, we derived accurate radial and rotational velocities and performed an automatic spectral classification. The spectral subtraction technique was used to derive their chromospheric activity level and their lithium abundance. Both indicators show that the stars presented hereafter are very young, with age around 10 Myr or even younger. They offer the opportunity to study the stage between transition and debris circumstellar discs and may help to shed new lights on atypical formation processes of stars and planets in low-mass clouds.

Scientific background

Although newly-formed stars are usually confined to the locations of their parental clouds, many processes tend to disperse them. Once mixed in the galactic plane environment, young stars are virtually indiscernible because neither their global photometric properties nor the presence of nearby gas can help to disentangle them from older stars. During the last ten years, *isolated* very young stars have been detected and it has become increasingly evident that a considerable number of such stars, are present in the solar neighbourhood. Given their age and proximity, *very young nearby stars in the field* are of great importance to better understand the recent local star formation history and to give new insight into the process of star formation outside standard formation regions (i.e. association and clusters). Moreover, they offer a unique opportunity to study the evolution of circumstellar discs (i.e. the transition phase of disc dispersal) as well as planet formation and migration processes. Stellar soft X-ray surveys may virtually contain hundreds of such hidden young stars.

Searching for accreting isolated very young stars

Accreting T Tauri stars (TSS) whose origin cannot be unmistakably linked to standard stellar nurseries (i.e. in loose associations) are extremely rare: except TW Hya itself, HEN 3-600A, TWA 14 [1], and TWA 31 a new member of the TW Hya association recently discovered with GALEX [2], HD319139 which is member of the β pic moving group [3], and possibly the *RasTyc* [4] system TYC4496-780-1 [5] that display the H α accretion and circumstellar disc signatures, none are actually known. Discovering *isolated* very young stars with age around 10Myr is extremely important for studying phenomena related to planet formation, especially in the gap between 3 and 50 Myr respectively covered by star forming regions (SFRs; like Taurus and Chamaeleon for example) and open clusters near the zero-age-main sequence.

Selecting an appropriate sample of targets is the major difficulty in such studies. Extending the concept of the *RasTyc* sample to fainter catalogues requires sophisticated tools because, only on the basis of positional coincidence, the probability of false identifications drastically increases with optically fainter catalogues. Thanks to statistical multivariate analysis methods, developed for the automatic classification of XMM-Newton X-rays sources [6, 7], we have constructed the RASS-Stars catalogue (RSC). The RSC encompass the *RasTyc* sample and extends it by a factor 3 or so, with good identification of active young stars down to $V=18$. Moreover, the correlation of the RSC with the AKARI IRC mid-IR all-sky survey (S9W and L18W filters) [8] offers the opportunity to search for “isolated” and possibly accreting stars (i.e. TW Hya analogs).

We used color-color diagrams, to select, a priori, young stellar objects from the RSC-AKARI cross-correlation sample. In the B-V vs. V-S9W diagram (Fig.1, left panel), stars showing IR excess are clearly visible on the right side of the major sequence. They are also outsiders in the right upper region of the J-L18W vs. S9W-L18W diagram (Fig.1, right panel). A bibliographic survey of about 100 stars, initially selected, shows that about 60% of them are already known TTS, Herbig Ae/Be or Wolf-Rayet stars. About 10% of them turn out to be composed of very well-known objects like O-type and Mira-type stars. Interestingly, we also found a few RS CVn systems. Finally, we found about 10 stars observable from the north hemisphere with no reference in the literature that show an IR excess. This excess could originate from dust emission and these stars are likely exhibiting circumstellar discs. Although some of them are close to known SFRs and could be SFRs accreting TTS members, not yet identified, a few of them are located quite far away from any known SFRs, in sky region mostly void of dense interstellar matter. We also note that TW Hya itself and TYC4496-780-1 were part of the selection which makes us confident on the effectiveness of the selection method we used.

Figure 1. Color-color diagrams from which we selected the candidate young stellar objects (red symbols). Among these about hundred stars we finally retained only 10 candidates fulfilling our selection criteria: mid- and far-IR excess, far away from any known SFRs and bright enough to be observed at the T1.93 Observatoire de Haute Provence (OHP) telescope with the SOPHIE spectrograph.

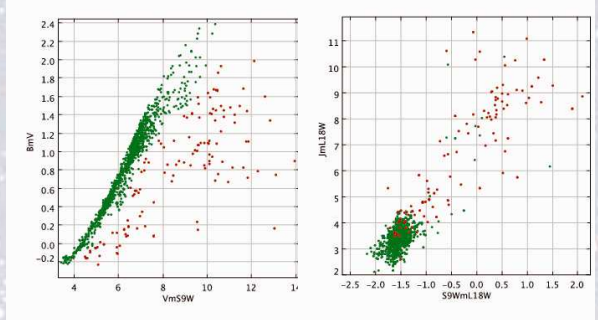
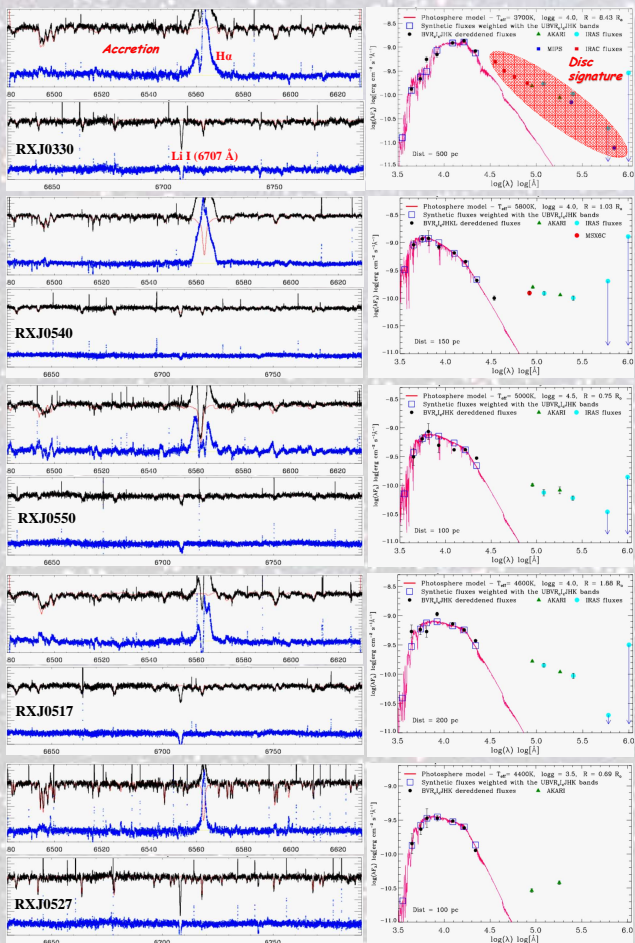


Figure 2. Optical spectra (black) of the 5 stars (from top to bottom) observed with *Sophie* spectrograph for which the H α profile (upper spectra) and lithium content (lower spectra) leave no doubt on their youth. The red line shows the synthetic spectrum build up with a spectra of a *non-active lithium poor* reference star, broadened at the $v \sin i$ of the star and Doppler-shifted according to its radial velocity. Blue line display the residuals. For each star, the right panel show the spectral energy distribution exhibiting strong near-IR excess likely due to a circumstellar disc.



Observation campaign

High resolution optical spectroscopy was acquired to discriminate young stars from older ones thanks to spectral features. High lithium content is now widely accepted as a youth criteria and according to the concept of the magnetospheric accretion model, the large H α line width (several hundred km/s) is indicative of large-scale gas flow while the inverse P Cygni profile traces gas infall [1,9]. Observations were conducted on 2 meter class telescopes at the *Observatoire de Haute Provence* with the *Sophie* spectrograph and with *Mercator/HERMES* at *Calar-Alto* observatory.

Among the 13 field stars initially selected from the RSC-AKARI cross-correlation because of their near- far-IR excess, 5 exhibit large H α emission profile (Fig.2, upper spectrum) and high lithium abundance (Fig.2, lower spectrum) typical of TTS. They also show strong H α variability (Fig.3) like observed in TTS. Except RXJ0330 which is already recognized as a young stellar object thanks to *Spitzer* observations, the other ones were unknown. Based on these observational criteria, they are classified as likely *isolated* pre-main sequence accreting TTS and their age estimated to be 5–10 Myr.

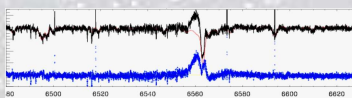


Figure 3. H α region of RXJ0550 spectra acquired on January 2011. Note the strong temporal variability of the H α profile compared to the observation acquired on November 2010 (left side), a phenomena often observed in accreting TTS.

Conclusions and perspectives

We have discovered 5 field TTS probably still in their accretion phase from a circumstellar disc according to spectroscopic diagnostic. Although not strictly isolated, *all are located several degrees apart from the cores of SFR in the vicinity*. A careful analysis of the spectroscopic data will allow to characterise these 5 candidates, in particular their effective temperature, gravity, metallicity, radial and projected rotational velocities. Additional photometric observations will better constrain the SED from which an independent age estimation can be derived by circumstellar disc modelling. Finally, the kinematics should shed light on their origin and possible relation with SFR in the vicinity.

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