SF2A 2010
S. Boissier, M. Heydari-Malayeri, R. Samadi and D. Valls-Gabaud (eds)

A SPARSE POPULATION OF YOUNG STARS IN CEPHEUS

A. Klutsch[1]

Abstract. Once mixed in the ambient galactic plane stellar population, young stars are virtually indiscernible because neither their global photometric properties nor the presence of nearby gas can help to disentangle them from older ones. Nevertheless, the study of the RasTyc sample revealed 4 lithium-rich field stars displaying the same space motion, which are located within a few degrees from each other on the celestial sphere near the Cepheus-Cassiopeia complex and at a similar distance from the Sun. Both physical and kinematical indicators show that all these stars are young, with ages in the range $10 - 30$ Ma. Multivariate analysis methods were used to select optical counterparts of XMM-Newton / ROSAT All-Sky Survey X-ray sources cross-identified with late-type stars around these 4 young stars. Recent intermediate- and high-resolution spectroscopic observations of this sample allowed to discover additional lithium-rich sources. The preliminary results show that some of them share the same space motion as the 4 original stars. They have properties rather similar to the members of the TW Hydrae association, although they are slightly older and located in the northern hemisphere. Nearby young stars in the field are of great importance to understand the recent local history of star formation, as well as to give new insight into the process of star formation outside standard star-forming regions and to study the evolution of circumstellar discs.

Keywords: stars: formation, stars: pre-main sequence, X-rays: stars, stars: kinematics and dynamics

1 Introduction

Most stars detected by the ROSAT mission are younger than 1 Ga (e.g. Motch et al. 1997). Taking account this property, Guillout et al. (1999) cross-correlated the ROSAT All-Sky Survey (RASS) with the Tycho catalogue creating the largest (≈ 14000 active stars) and most comprehensive set of late-type stellar X-ray sources, the so-called *RasTyc* sample. This stellar population can be used as a tracer of young local structures (Guillout et al. 1998). Presently, nine nearby ($30 - 150$ pc) young ($5 - 70$ Ma) associations are already identified in the southern hemisphere (see the reviews of Zuckerman & Song 2004, and Torres et al. 2008): e.g. the TW Hydrae association (TWA) around TW Hya (Gregorio-Hetem et al. 1992; Kastner et al. 1997). In particular, the SACY project (Torres et al. 2006, 2008) allowed to identify many of them and their members. Its sample can be considered as a sub-sample of the *RasTyc* population in this hemisphere. In the northern hemisphere, Guillout et al. (2009) identified 5 young stars among the optically bright *RasTyc* sources. They are located in various over-densities of the whole *RasTyc* sources, but none is near the largest one (Klutsch et al. 2010). The sky density of the youngest stars is fairly uniform (Klutsch 2008). The difference of more than one order of magnitude less than in the SACY survey is consistent with the significant asymmetry in the all-sky *RasTyc* distribution with respect to the galactic plane shown by Guillout et al. (1998).

2 Discovery of four comoving T Tauri stars

Using the optically faint sample, Klutsch (2008) and Guillout et al. (2010a) discovered an unusual group of 4 lithium-rich stars (green filled squares on Fig. 1) towards the Cepheus-Cassiopeia (Cep-Cas) complex. Although this sky area is rich in CO molecular regions (Dame et al. 2001) and dark clouds (Dobashi et al. 2005), these stars are projected several degrees off-clouds in front of a region devoid of interstellar matter, which correspond precisely to the sky area with the highest density of *RasTyc* sources (Fig. 1). They have all typical spectral signatures of young stars (Guillout et al. 2010a) as i) a Hα emission or a filled-in profile, ii) a strong lithium

[1] Universidad Complutense de Madrid, Departamento de Astrofísica, Facultad de Ciencias Físicas, 28040 Madrid, Spain

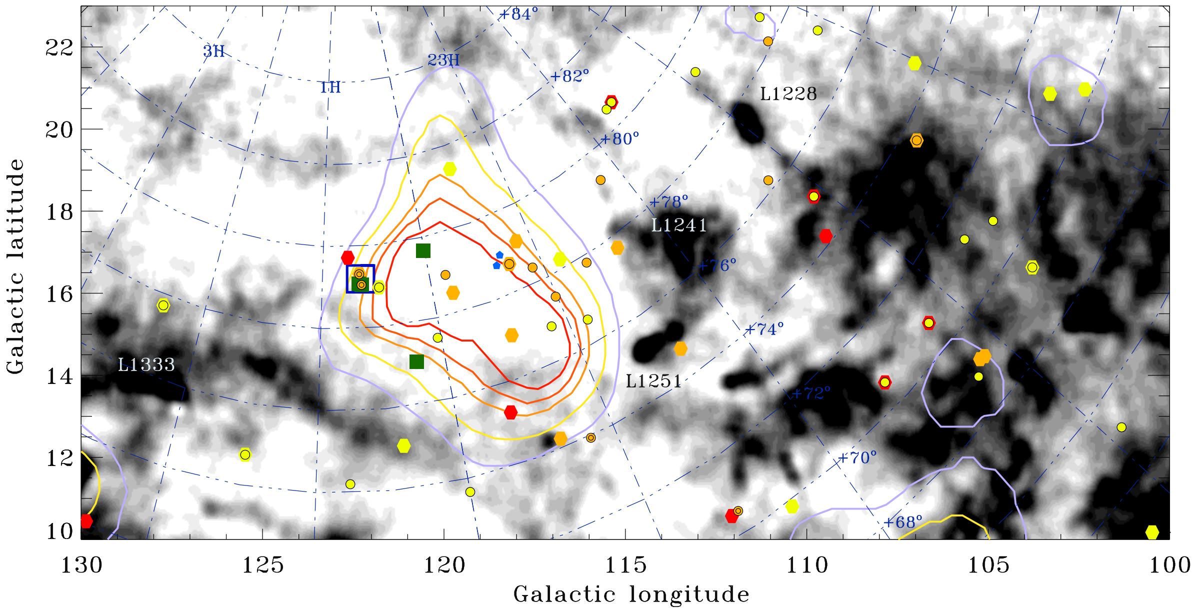

Fig. 1. Spatial distribution of stellar X-ray sources located near the 4 original comoving TTSs (green filled squares) as well as the naked TTS V368 Cep and its comoving companion (pentagons), which are over-plotted on the Dobashi et al. (2005) extinction (A_v) map. For selected targets (hexagons) as well as Tachihara et al. (2005) single stars (circles) and visual binaries (double circles), each symbol is filled in orange, red or yellow if the source displays a strong, moderate or no lithium line, respectively. The main clouds near the CO void region are labeled. I also indicated the density iso-contours for the whole *RasTyc* sources and the locus of an unusual concentration of at least 7 young stars (big blue open square) outside of SFRs.

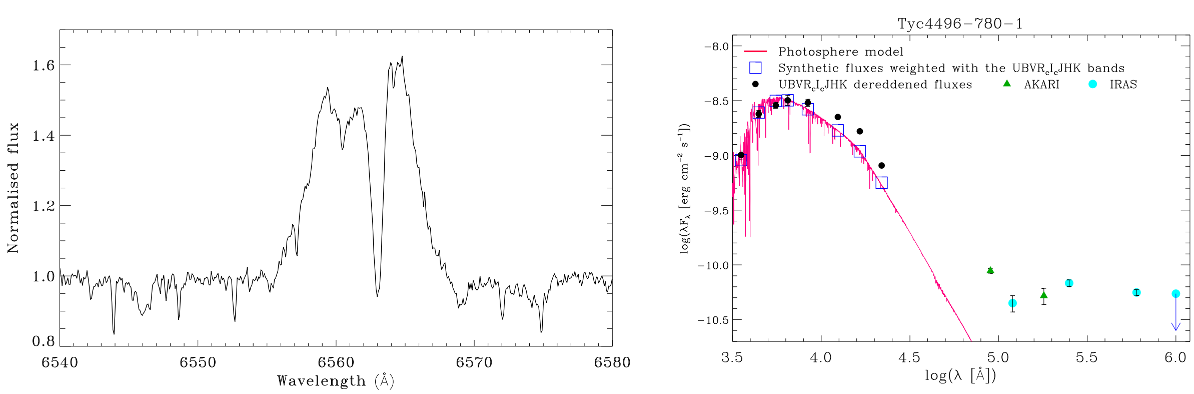

Fig. 2. *Left*: Spectrum of TYC 4496-780-1 displaying a strong Hα emission profile. *Right*: Spectral energy distribution of this source showing a near- and far-infrared excess, a typical signature of an accretion disc (Guillout et al. 2010a,b).

line corresponding to a lithium abundance close to the primordial one, and iii) a X-ray luminosity (L_X) of $\sim 10^{30.4}$ erg s^{-1} (within 0.2 dex), which is similar to that observed for weak-line T Tauri stars (WTTS) in Taurus-Auriga-Perseus star-forming regions (SFRs). Only TYC 4496-780-1, the star with a strong Hα emission profile (Fig. 2, left panel), displays a near- and far-infrared excess (Fig. 2, right panel). This feature is typical of class II infrared sources, i.e. T Tauri stars (TTSs) still surrounded by an accretion disc. Guillout et al. (2010b) characterized its properties because this star is the optical counterpart of one infrared source detected by both AKARI and IRAS missions. Because of the lack of relevant infrared excess, the 3 other sources are likely WTTS or post-T Tauri stars whose discs have already been dissipated as most stars with an age between $10 - 70$ Ma.

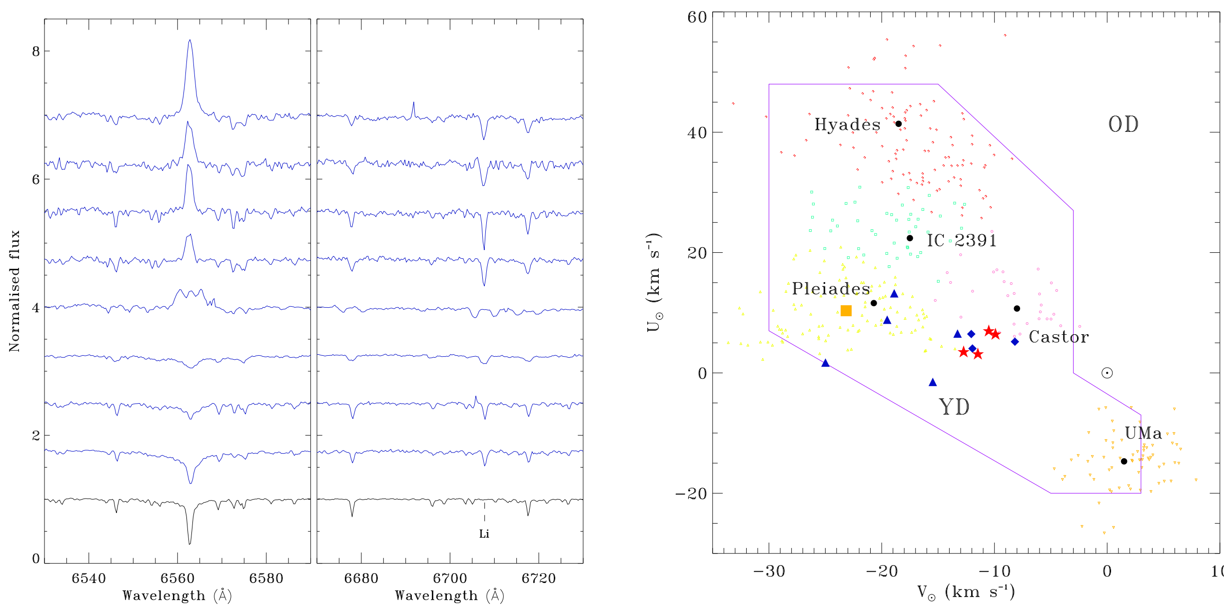

Fig. 3. *Left*: IDS spectra in the Hα (left panel) and lithium (right panel) spectral regions of 8 new lithium-rich stars. I also displayed the spectrum of a "non-active" standard star (black). *Right*: $U - V$ kinematic diagram for these 8 young comoving candidates seen as single stars (triangles) and spectroscopic systems (diamonds) with the cross-correlation technique. I also plotted the space velocities of the 4 original TTSs (star symbols), the naked TTS V368 Cep (square), some late-type members of some young stellar kinematic groups (SKG) as well as the average velocity components (dots) of these SKG. The loci of the young-disc (YD) and old-disc (OD) populations are also marked.

Unfortunately, their Tycho parallaxes are useless and one must rely on photometric distance estimations. To cover a wide range of possibilities, Guillout et al. (2010a) estimated two distances for each star. We considered that the *lower limit* is $80 - 100$ pc assuming the stars are on the zero-age main sequence and that the *upper limit* is $130 - 180$ pc assuming a stellar age of 15 Ma. Using a lower age would be in contradiction to our photometric observations showing that no stars suffer major interstellar extinction. Whatever the distance is, all these stars share the same kinematics (within a few km s^{-1}) proving that they form a homogeneous group with a common origin (Guillout et al. 2010a, Fig. 4) and they are unrelated with the naked TTS V368 Cep (Fig. 3, right panel).

We also consider a possible link with the Cep-Cas complex. We can not exclude that these stars are runaway objects originated in L1251, L1241 or L1228, but their high-escape velocity and their similar space motion cast doubt on this hypothesis. The more plausible explanation for the formation of these TTSs is the in-situ model.

3 New young stars in the CO Cepheus void

Selecting an appropriate sample of targets is the major difficulty for searching other young comoving stars in this sky area. Klutsch et al. (2010) picked optical counterparts of XMM-Newton / RASS X-ray sources cross-identified with stars using multivariate analysis methods (Pineau 2009) allowing to disentangle the stellar population from the extragalactic component (galaxies and quasars) also emitting in X-ray.

All candidates are in a region 30° wide around the 4 original TTSs and compile following selection criteria: i) late-type stars ($B - V > 0.6$), ii) faint ($V > 10$ mag), iii) X-ray luminous ($L_X > 10^{30}$ erg s^{-1}), and iv) within 170 pc of the Sun. Our first intermediate- and high-resolution spectroscopic observations on this ongoing project [semester 2009B on T193/Sophie (OHP), 2.2m/FOCES (CAHA) and INT/IDS (La Palma)] showed that 25 and 23 sources (i.e. about 20 % and 18 % candidates already observed) display a strong lithium line similar to that of the original TTSs and a moderate lithium line, respectively. Out of 8 lithium-rich stars discovered with IDS (Fig. 3), 4 are good young comoving candidates, but 3 turn out to be spectroscopic binaries. Spectra of the remaining 17 are in the reduction/analysis phase. Most of the others are classified as M-type stars.

On Fig. 1, I showed the spatial distribution of selected stars (hexagons). Some of lithium-rich stars (including one of the original TTSs) were already identified as WTTS (orange filled circles) by Tachihara et al. (2005). All stars from this paper will be also included in the future observing runs to determine their radial velocity and kinematics for finding a possible connection with the 4 comoving TTSs. Presently, 15 stellar X-ray sources (i.e. 7, 5 and 3 stars discovered by this work, Tachihara et al. and both, respectively), located in the CO Cepheus void, are rich in lithium. Out of them, 3 are good young comoving candidates. I also detected an unusual concentration (blue open square on Fig. 1) of at least $7-8$ lithium-rich stars formed by two of the original TTSs (the visual binary, RasTyc0038+7903 or [TNK2005] 4, and the spectroscopic binary, RasTyc0039+7905) and another visual binary, [TNK2005] 5, for which one component turns to be a binary or a triple system. These preliminary results seem to confirm a possible link between many (not all) young stars of this region.

4 Conclusions and perspectives

TYC 4496-780-1 was classified as a class II young infrared source, i.e. a TTS still surrounded by an accretion disc. However, presently, few of these sources have been found outside of SFR's cores (e.g. TW Hya). This source share the same galactic motion as three comoving TTSs. They are located in a region devoid of dark clouds and near at least other 10 stellar X-ray sources displaying a strong lithium line. These properties are similar to the TWA, although slightly older and located in the northern hemisphere. The runaway hypothesis is highly improbable for explaining the formation of this homogeneous comoving group because of their kinematical properties and the identification of a great number of new T Tauri candidates in this sky area. Some of them also form an unusual concentration of $7-8$ lithium-rich stars. That raises the question of the in-situ star-formation scenario in low-mass cloud environments (as in many other SFRs). Afterwards the GAIA mission will certainly shed light on this issue and on the origin of this group which could be related to the Cep-Cas complex.

This work was supported by Universidad Complutense de Madrid (UCM), the Spanish Ministerio de Ciencia e Innovacin (MICINN) under grants AYA2008-00695, and "The Comunidad de Madrid" under PRICIT project S2009/ESP-1496 (AstroMadrid). My collaborators for this project are: D. Montes[1], P. Guillout[2], A. Frasca[3], F.-X. Pineau[2], N. Grosso[2], E. Marilli[3], and J. López-Santiago[1] ([1]UCM, Madrid, Spain; [2]Observatoire Astronomique de Strasbourg, Université de Strasbourg, CNRS, UMR 7550, 11 rue de l'Université, F-67000 Strasbourg, France; [3]INAF - Osservatorio Astrofisico di Catania, via S. Sofia, 78, 95123 Catania, Italy).

References

Dame, T. M., Hartmann, D., & Thaddeus, P. 2001, ApJ, 547, 792

Dobashi, K., Uehara, H., Kandori, R., et al. 2005, PASJ, 57, 1

Gregorio-Hetem, J., Lepine, J. R. D., Quast, G. R., et al. 1992, AJ, 103, 549

Guillout, P., Frasca, A., Klutsch, A., et al. 2010a, A&A, in press (ArXiv:1009.2587)

Guillout, P., Grosso, N., et al. 2010b, in preparation

Guillout, P., Klutsch, A., Frasca, A., et al. 2009, A&A, 504, 829

Guillout, P., Schmitt, J. H. M. M., Egret, D., et al. 1999, A&A, 351, 1003

Guillout, P., Sterzik, M. F., Schmitt, J. H. M. M., et al. 1998, A&A, 334, 540

Kastner, J. H., Zuckerman, B., Weintraub, D. A., & Forveille, T. 1997, Science, 277, 67

Klutsch, A. 2008, Ph.D. thesis, ULP and Strasbourg Observatory

Klutsch, A., Montes, D., Guillout, P., et al. 2010, Proceeding "16th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun", Astronomical Society of the Pacific Conference Series (Poster F02).

Motch, C., Guillout, P., Haberl, F., et al. 1997, A&AS, 122, 201

Pineau, F.-X. 2009, Ph.D. thesis, ULP and Strasbourg Observatory

Tachihara, K., Neuhäuser, R., Kun, M., & Fukui, Y. 2005, A&A, 437, 919

Torres, C. A. O., Quast, G. R., da Silva, L., et al. 2006, A&A, 460, 695

Torres, C. A. O., Quast, G. R., Melo, C. H. F., & Sterzik, M. F. 2008, in Handbook of Star Forming Regions, Volume II, edited by Reipurth, B., Astronomical Society of the Pacific Monograph Publications, 757

Zuckerman, B., & Song, I. 2004, ARA&A, 42, 685