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Reviews

T ASSOCIATIONS IN X-RAYS

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The X-ray emission properties of T Tau type stars and the basic results from the ROSAT X-ray mission are presented. The results of optical follow-up observations of ROSAT sources unidentified with known T Tau type stars are given. Surprisingly, some of them are located outside the classical borders of starforming regions, i.e. outside the dark clouds. Their kinematics and formation are discussed.

1. *Introduction: T Tauri stars and T associations.* The study of young stars is a step towards the understanding of star formation in the Galaxy and early phases of low-mass stellar evolution. Low-mass pre-main sequence (PMS) stars are referred to as T Tauri stars (TTS).

TTS were first recognized as a separate class of stars by Joy [1], studying the spectra of some bright RW Aurigae type stars. Soon, Ambartsumian [2] analyzing their high stellar density and unusual spectral properties, postulated that TTS are recently formed low-mass stars. This was a ground to introduce the new term T association for stellar groups of recently formed T Tauri stars having ages not exceeding a few million years.

Early definitions (e.g. Herbig [3], Bastian et al. [4]) describe TTS as young stellar objects (YSO) showing in their spectrum emission from the Balmer lines and the Ca II H and K lines, reflecting the fact that TTS were discovered in H_α surveys of nearby molecular clouds. For recent reviews we refer to Bertout [5], Appenzeller and Mundt [6] and Neuhäuser [7].

TTS with strong emission lines are called classical TTS (cTTS) and also show strong excess emission in the UV and in the infrared. TTS which show neither strong H_α nor strong infrared (IR) excesses are called weak-line TTS (wTTS). The ages of TTS range from $\sim 10^5$ to $\sim 10^7$ yrs. One of the best studied regions of on-going low-mass star formation is the Taurus (-Auriga) area, a T association at ~ 140 pc distance (Elias [8], Kenyon et al. [9], Preibisch and Smith [10], Wichmann et al. [11]).

The spatial extensions of star forming regions (SFR) is usually studied by CO surveys, e.g. Ungerechts and Thaddeus [12] for the Taurus area. Almost all TTS known prior to the ROSAT mission were situated in areas where molecular gas has been detected. Herbig [13] found that TTS share the radial velocity of their parent cloud. Also, members of a T association share the same proper motion (Jones and Herbig [14]), so that kinematic membership of a TTS to an association can be studied by determining its space motion.

2. *Discovering new T Tauri stars with ROSAT.* Prior to the ROSAT mission, ~ 60 wTTS were known in Taurus, half of which were discovered by ground-based optical follow-up observations of previously unidentified Einstein Observatory X-ray sources (Feigelson et al. [15], Walter et al. [16]). See Herbig and Bell [17] and Neuhäuser et al. [18] for lists of TTS known prior to ROSAT. From their Einstein Observatory studies, Walter et al. [19] concluded that there should be as many as ~ 10^3 wTTS in the Taurus clouds.

These newly found wTTS from the Einstein Observatory were also called naked TTS as they lack all the IR and mm excess emission typical for cTTS [16]. Also, there was a discussion as to whether these newly found naked wTTS also were the long-sought post-TTS, which should be somewhat older TTS, more evolved than cTTS, expected to be present in star forming clouds if star formation is on-going for as long as ~ 10^8 yrs [20]. However, Walter et al. [19] found that the newly discovered wTTS are coevel with the cTTS, so that they called them naked (w) TTS.

Among the advantages of the ROSAT All-Sky Survey (RASS) mission [21] is the complete sky coverage with a flux limit sufficient to detect most TTS in nearby SFRs [22]. A total of ~ 70 lithium-rich stars - claimed to be wTTS - have been discovered among RASS sources in the central parts of the Taurus T association [23]. Most X-ray discovered TTS are wTTS located on or very close to molecular clouds, but they do show a more widespread spatial distribution compared to cTTS, which are still closely associated with their parent clouds.

Prior to follow-up observations of RASS sources, TTS candidates were pre-selected using the X-ray data of the unidentified RASS sources following [24]. With ground-based optical follow-up observations of previously unidentified RASS X-ray sources, many late-type stars with lithium 6708 Å absorption and H_α in emission (or filling in the absorption) were identified as optical counterparts. They were found in all of the star forming regions investigated: Taurus ([23, 25-27], Orion [28,29], Lupus [30-32], ScoCen [33], Chamaeleon [34-36], and CrA ([37], in preparation).

Most of the ROSAT counterparts with lithium detected in spectra with low resolution (a few Å) were classified originally wTTS. Surprisingly, some of the young stars are located even outside the commonly accepted borders of the star forming regions.

However, there are two major problems with this interpretation, i.e. the question of whether they really are PMS stars, namely:

1) In particular, for stars which can no longer be associated with their parent clouds (like wTTS), it is difficult to determine or assume a distance. However, knowing the distance is crucial for placing the stars onto the HR diagram for estimating their ages by comparison with theoretical isochrones. The usual practice is to adopt the same distance as the clouds. However, if the star is really foreground to the clouds, one would underestimate the age [35,38]. Since ZAMS stars such as the Pleiades also show a high level of X-ray activity and optical spectra (with lithium) similar to wTTS, it is clear that some (or many) of the lithium-rich ROSAT stars could be young ZAMS stars rather than PMS stars [38].

2) It is possible to overestimate the lithium equivalent width in spectra with low resolution (as used in most RASS follow-up studies) due to blends with nearby iron lines and the assumption on the continuum level. Hence, some (or many) of the 'lithium-rich' ROSAT counterparts may actually have very weak lithium or no lithium at all [38]. Even ZAMS stars show a wide range in lithium strength due to different masses and rotational velocities.

To overcome these two major problems, one should

a) investigate distance-independent age indicators (such as lithium, and perhaps even surface gravity), and one should observe the stars with high spectral resolution to determine whether lithium is indeed stronger than in ZAMS stars of the same spectral type;

b) investigate the three-dimensional space motion (proper motion and radial velocity) of the stars to check for kinematic membership to the associations;

c) make efforts to obtain trigonometric parallaxes which, although very difficult to do from the ground for stars more distant than 100 pc, may be possible for stars foreground to the clouds.

Covino et al. [36] have performed high-resolution spectroscopy for nearly all the lithium-rich ROSAT counterparts classified as 'wTTS' by Alcalá et al. [34]. Their comparison of high- and low-resolution lithium equivalent widths - as displayed in their Fig.3 - clearly shows that lithium can be overestimated in late-F and G-type stars by large amounts. The reasons are the low lithium equivalent width (so that the relative errors in Li equivalent widths from low-resolution spectra are large) and the strong iron lines in G-type stars. In K-type stars, the overestimate decreases in relative terms with decreasing effective temperature because the Fe/Li ratio in cooler stars get smaller, as the lithium equivalent width is much more sensitive to the temperature than the Fe lines. In absolute terms the effect is smaller than 0.1 Å in K-type stars in any case. With two exceptions, lithium was not overestimated at all im M-type stars.

Hence, while it is difficult to estimate the true lithium equivalent width in G-type stars just from low-resolution spectra, this is very well possible for K- and M-type stars. Lithium data from low-resolution spectra are reliable for K- and M-type stars, but not for G-type stars.

Covino et al. [36] also compare the lithium data for their stars with those of the Pleiades. They clearly show that many K-type ROSAT stars in Chamaeleon show stronger lithium than K-type ZAMS stars. Also, the M-type Chamaeleon stars with lithium are clearly younger than ZAMS stars, as they burn all their lithium quite rapidly (no M-type Pleiades show lithium; only the much cooler brown dwarfs do). However, G-type ZAMS stars still show primordial levels of lithium, just as G-type TTS do, so that it is not possible to confirm their pre-MS nature using the lithium data alone. In Chamaeleon, [36] find a bi-modal distribution in lithium: stars with much more lithium than ZAMS stars (bona-fide TTS), and stars with lithium as weak as in ZAMS stars (which are also ZAMS stars). Covino et al. [36] find no intermediate lithium stars, i.e. no post-TTS. Another interesting point is that most of the lithium-rich stars share the Chamaeleon radial velocity.

The spatial distribution of their stars is shown in their Fig.7 [36]. Obviously, many of the lithium-rich stars are located on or very close to the clouds. In addition, there are several TTS far off the clouds, including M-type stars with lithium, which must be younger than 10 Myr. These stars are too young to have traveled the distance from the nearest clouds in their short life-time, if one adopts the canonical velocity dispersion in T associations (1 to 2 km/s). Hence, they may either have formed locally (in small cloud-lets which have dispersed since then; c.f. [41]), or they may have been ejected from the clouds with high velocities, and would be so-called run-away TTS [42].

In Fig.1 we show a diagram of lithium equivalent width versus effective temperatute of TTS newly discovered with ROSAT. We compare their lithium line strength with those of ZAMS stars in the Pleiades and IC 2602. All those stars with more lithium than ZAMS stars of the same spectral type (or effective temperature) are younger than ZAMS stars, i.e. PMS stars.

3. *Run-away T Tauri stars.* If the Li-rich stars (or at least some of them) found outside clouds, i.e. up to several degrees away from any nearby molecular cloud, are too young to have dispersed out of the Taurus clouds with velocities similar to the small velocity dispersions observed among TTS and clouds in central Taurus (2 to 3 km/s, Herbig [13], Jones and Herbig [14], Hartmann et. al [43]), then the question arises: how and where did these young PMS stars form? They may have formed locally (as suggested by Feigelson [41]), but we see no residual gas left over. Alternatively, they must have formed in the central cloud cores and were subsequently ejected with velocities larger than the typical dispersions in the radial velocities and proper motions (as suggested by [42]).

When Herbig [13] found that TTS usually share the radial velocity of their nearby parent clouds, he also listed six TTS with locations outside dense

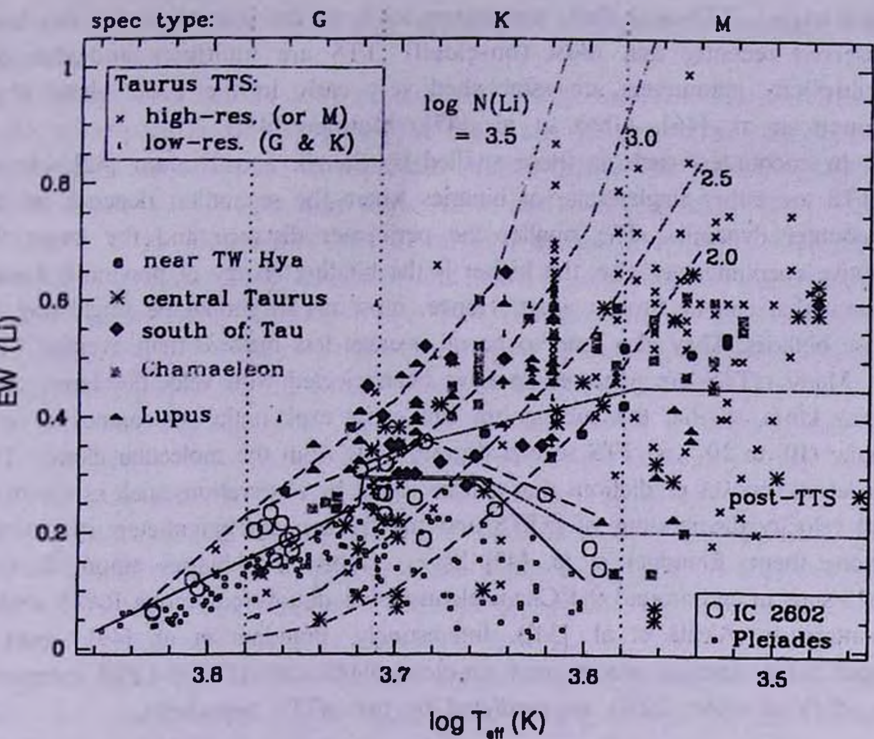

Fig.1. Lithium equivalent width (in Ångstrom) versus log effective temperature for young low-mass stars.

clouds that have radial velocities off the Taurus mean. He suggested three possible explanations for this observation: either (a) some stars might be accelerated as part of their formation process, for instance, by ejection of one component of a multiple star system; or (b) there are many non-spherical cloud filaments with very low binding energy; or (c) the Taurus cloud geometry is not permanent. Ghorti and Bhatt [44] modeled the ejection of protostars in encounters of protostars with clouds, and found that some protostars can indeed be ejected in such a way. Kroupa [45] showed that several percent of the members of a cluster as rich as the Trapezium can be ejected by close encounters with velocities exceeding 5 km/s.

Sterzik et al. [24] suggested that PMS stars found in follow-up observations of RASS sources outside the Orion molecular clouds have been ejected from their birth clouds with high velocities and called such stars 'run-away TTS' (raTTS). Neuhäuser et al. [25] showed that the (preliminary) radial velocity distribution of 15 Li-rich RASS source counterparts south of the Taurus clouds is consistent with (at least some of) them being such raTTS. Few-body encounters can happen early in the lifetime of a multiple protostellar system, so that they are also of relevance in establishing the fraction of binary (and triple) TTS and their parameters such as the separation. It has been observed recently that most (on-cloud) TTS are multiples and that the multiplicity parameters are established very early in the PMS phase (e.g., Leinert et al. [46], Ghez et al. [47], Mathieu [48]).

In encounters such as those studied by Sterzik and Durisen [42], ejected raTTS are either single stars, or binaries where the separation depends on the encounter dynamics: The smaller the pericenter distance and the larger the relative encounter velocity, the higher is the binding energy of previously bound system that can be broken apart. Hence, most raTTS should be single stars or close binaries. They also tend to be on average less massive than average TTS.

Many raTTS are expected to have been ejected with velocities larger than a few km/s, so that this mechanism can easily explain the appearance of very young (10^5 to 10^7 yrs) TTS several degrees away from the molecular clouds. The model also makes predictions that can be tested by observations such as the mass and velocity distributions of raTTS and the fraction and parameters of binaries among them. Brandner et al. [49] have searched for binaries among Li-rich PMS stars in and around the Chamaeleon clouds discovered among RASS source counterparts (Alcalá et al. [34]). Interestingly, Brandner et al. [49] report a larger binary fraction among new on-cloud PMS stars ($18.0 \pm 4.2\%$) compared to off-cloud ($8.4 \pm 3.0\%$), as predicted by the raTTS hypothesis.

3.1. *RATTS as transition systems between cTTS and wTTS.* Ejections of TTS from molecular clouds have also been studied by Armitage and Clarke [50]. They investigate in particular the effect of close encounters on circumstellar disks, which are frequent among very young low-mass protostars. Studying the encounter between a TTS without disk and a TTS with disk, they find that, the smaller the pericenter distance of encounter is, the more violent is the disruption of the disk, i.e. the smaller the outer radius of the surviving disk. E.g., for ejection velocities between 3 and 10 km/s implying pericenter distances of 2 to 25 AU, they find outer remnant disk radii of tyically less than 10 AU. This effect reduces the viscous evolution of the disk, so that accretion rapidly ceases (Armitage and Clarke [50]). Hence, this mechanism turns TTS with accretion disks (most of which are cTTS) into TTS without observable disks (most of which are wTTS). For their subsequent studies, they distinguished between TTS with high and low magnetic fields. For ejected TTS with low magnetic field, the duration of the cTTS phase can still be relatively long, so that they predict the existence of ejected TTS (without accretion but with IR excess emission) located outside molecular clouds. For the case of strong stellar magnetic dipole fields, which can couple with the inner disk region effectivly braking the stellar rotation rate (e.g., Bouvier [51]), the ejected cTTS will very rapidly turn into a wTTS without H_α and near - IR excess emission, which however should still be detectable at wavelengths > 5 μm due to emission from outer disk material.

Armitage and Clarke [50] predict that such transition systems should rotate with periods similar to cTTS. This can be tested by observation. While wTTS usually rotate with periods shorter than a few days, cTTS show rotation periods of four to nine days. All of the so-called 'naked' TTS found by Mundt et al. [52] and Walter et al. [19] among previously unidentified EO sources show weak H_α emission, and there is only one star also detected at mm wavelengths, namely V836 Tau (Skinner et al. [53]). With a rotation period of 7.0 days (Vrba and Rydgren [54]), this star is one of the slowest rotating wTTS. (The slow rotation of V836 Tau is probably not tidally forced by its companion, as the period of seven days is longer than the transition period between circular and eccentric orbits among PMS stars, which should also be the dividing line between synchronized and non-synchronized systems.) Hence, it may be posiible to use the rotation period of a wTTS to estimate the time that has elapsed since the (inside-out) disk dispersal begun; a fast rotating wTTS has cleared its disk completly, while a slowly rotating wTTS is just dispersing its disk.

Alcalá et al. [34] have performed optical and IR photometry of Li-rich PMS stars among RASS source counterparts in and around the Chamaeleon clouds. Most of their stars show spectral energy distributions consistent with black bodies, i.e. could be called naked TTS. Two stars, however, show strong HKLM excess emission typical of cTTS, one with weak H_α emission and one with highly variable H_α emission [55,34]. Both of these stars lie on-cloud but may be transition systems - as described by Armitage and Clarke [50] - with low accretion but still strong emission from the outer disk.

Three other stars in Alcalá et al [34] show weak H_α emission, no near-IR excess, but L and/or M excess emission, one of which lies several degrees off the nearest cloud, namely RXJ1001.1-7913 with spectral type M0, i.e. a low-mass raTTS candidate. By comparing its locus in the H-R diagram (assuming a distance of 150 pc) with D'Antona and Mazzitelli [57] tracks, Alcalá et al. [35] found its age to be just $1.57 \pm 0.56 \cdot 10^6$ yrs. With high-resolution spectroscopy, C97 confirmed that this star shows lithium, i.e. is very young, irregardless of any distance assumption. Also, C97 measured its rotational velocity to be ~ 15 km/s, i.e. relatively low for a wTTS. Its radial velocity being ~ 12 km/s (C97) indicates that it slowly moves towards us relative to the Chamaeleon clouds [36]. Its proper motion relative to the other Chamaeleon TTS, when it becomes available, may be able to show whether it could have been ejected from any of the Chamaeleon clouds.

3.2. *Run-away TTS south of Taurus*? The new PMS stars found south of the Taurus clouds [25-27] are located as far as 10° south of the southern border of the IRAS 100 μm contours, i.e. up to 24° south of the southern border of the known Taurus CO clouds (c.f. Fig.2). Their birth-place could be anywhere on the clouds in Taurus. To have moved 20° (i.e. 50 pc at a distance of 140 pc) in $\leq 10^7$ yrs implies a line-of-sight velocity dispersion $\geq 5/\sqrt{3}$ km/s $\simeq$ 3 km/s, which is consistent with the observed radial velocity dispersion of 2.8 km/s. At a distance of 140 pc, a proper motion of 10 mas per year corresponds to 6.7 km/s.

Any ejected raTTS south of Taurus should have proper motions indicating that they are currently moving to the south relative to the motion of the Taurus cloud complex as a whole. Among the 17 Li-rich stars in the sample

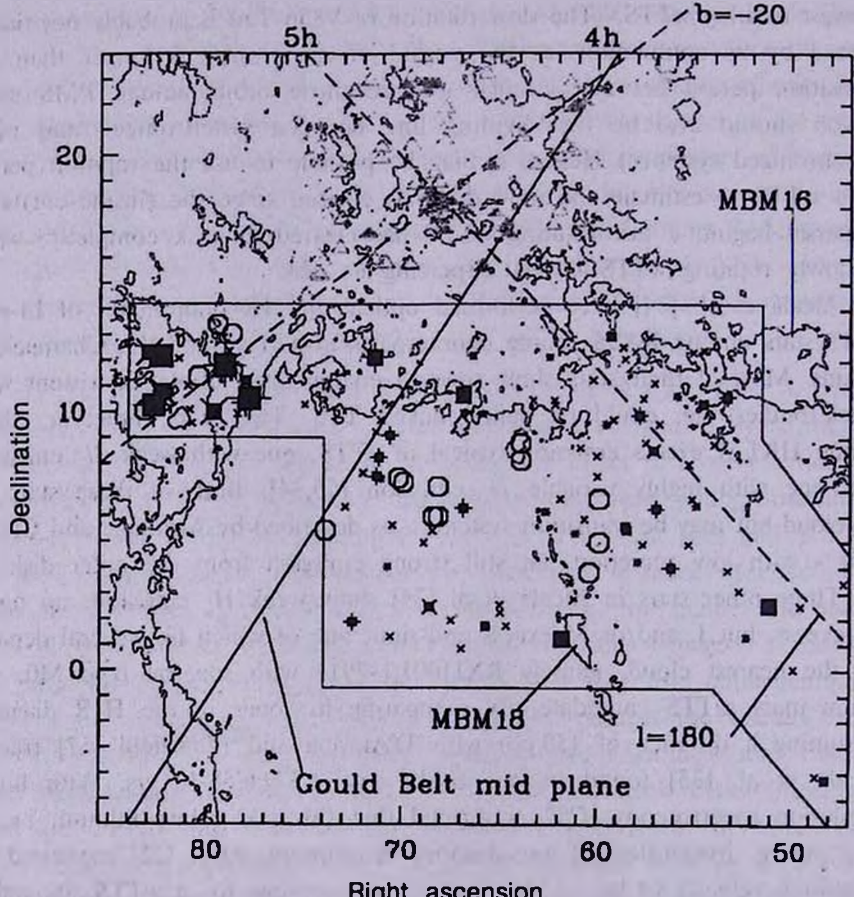

Fig.2. The area studied south of Taurus. Shown are two IRAS 100 μm contours overlapping with the area (black box) studied by Neuhäuser et al [27]. Symbols are as follows: New PMS stars (filled squares); new ZAMS stars (*); ROSAT counterparts with undetected lithium (×); previously known bona-fide TTS (filled triangles); and TTS discovered by Wichmann et al. [23] (open triangles). The new PMS stars have symbol sizes proportional to ther lithium excess above the ZAMS level. Those with radial velocity consistent with Taurus membership have a large + superimposed, and those consistent with Orion have a large ×. There are no lithium-rich stars in the strip indicated in the lower right, which extends out of the figure boundaries to $\delta = -17^\circ$. Lynds clouds (Lynds [56])are also shown (black circles).

south of Taurus that have known proper motions from Frink et al. [58], none is moving south relative to Taurus. The catalogs from which these proper motions were extracted (STARNET and PPM) are magnitude-limited, and, hence, are biased against low-mass stars. However, raTTS should be more frequent among the lowest-mass TTS, but may be less frequent among G- and K-type TTS (Sterzik and Durisen [42]), which constitute the majority in the sample.

At face value, these data would therefore seem to suggest that there are not more than ~10% raTTS among PMS stars outside molecular clouds. Interestingly, Neuhäuser et al. [27] have shown that ~10% of the bona-fide TTS in central Taurus do show either proper motion or radial velocity inconsistent with kinematic membership. These stars may also be raTTS - just ejected.

Of the pre-MS stars south of Taurus with proper motions from [58], six have radial velocity very different from the Taurus mean, but all six share the Taurus proper motion. Hence, their 3D space motions are consistent with them having been ejected from Taurus along the line of sight. Interestingly, their radial velocities are all smaller than the mean of Taurus, indicating that they are moving towards us, relative to the clouds. The probability of this happening by chance is less than 2%. Instead, this is simply because if they had been ejected in the opposite direction, we would probably not have detected them, since their greater distance would have made them too faint for detection in the RASS.

One of the new PMS stars south of Taurus can be identified as a very promising raTTS candidate, namely RXJ0511.2+1031, c.f. Neuhäuser et al. [27].

3.3. *Run-away TTS in Orion?* Parenago [59] presented a list of Orion nebula stars which included star number 1724, now called P1724, that has subsequently been shown to be one of the most active TTS known, as evidenced by the detection of a very powerful X-ray flare (Gagné et al. [60]; Preibisch et al. [61]). P1724 is a relatively bright ($V \simeq 10.6$ mag) star located only 15' north of the Trapezium cluster in Orion. There have been a number studies of the proper motion of P1724, and the probability of membership to the Orion association according to different authors has ranged from 0% and 97%. Preibisch et al. [61] presented a low-resolution spectrum showing $W_\lambda(H_\alpha) = 4$Å and $W_\lambda(\mathrm{Li}) = 0.47$Å. P1724 does not show excess infrared emission, and there is no IRAS source in the vecinity (Weaver and Jones [62]). Hence, one can classify this star as wTTS.

Recently, Neuhäuser et al. [63] have studied this star in great detail, with the following results:

Based on deep *R*-band imaging, no companion is found down to a separation of ~1" and a magnitude difference of $\Delta R = 7$mag. With hundreds of V, R, and I measurements obtained within twelve weeks, its rotation period is confirmed to be about 5.7 days. Repeated high-resolution spectra show very low amplitude radial velocity variability. This series of high-resolution, high S/N spectra exhibit variations in the line profiles that are common in spotted stars. Data reduction by Doppler-imaging techniques yields an image showing a pronounced dark feature at relatively low latitude. Its derived size and temperature indicate that it can easily produce the observed photometric and spectroscopic variability.

Multiple high-resolution spectra yield a rotational velocity $v \cdot \sin i = 71$ km/s, and a mean radial velocity of +23 km/s that is consistent with kinematic membership to the Orion star forming region. Therefore, the distance to P1724 is most likely also ~460 pc. Based on the proper motion of P1724 as listed in the STARNET catalog, the derived 3D space velocity shows that P1724 moves north relative to the Trapezium; in other words, its proper motion differs from most Trapezium stars, which is the reason why some earlier proper motion studies concluded that P1724 may not belong to the Orion star forming region.

Optical (*UBVRI*) and infrared (*JHK*) photometry of P1724 as well as the spectral energy distribution are presented, showing that P1724 is a naked (weak-line) T Tauri star. The bolometric luminosity is estimated to be 51 $L_{\odot}$, the spectral type to be K0, and the radius to be 9.0 $R_{\odot}$ (from both the Stefan-Boltzmann law based on the luminosity and temperature, and from the Barnes-Evans relation, which is consistent with a nominal distance to P1724 of ~460pc).

Although P1724 has lost all its circumstellar material, its bolometric luminosity places it very close to the birth-line at an age of only $\approx 2 \cdot 10^5$ years, with a mass of $\approx 3\,M_{\odot}$ (consistently found from four different sets of pre-main sequence tracks and isochrones). This age is consistent with its present location and 3D space motion (~10 km/s relative to the Trapezium) under the assumption that it was ejected from the Trapezium $\approx 10^5$ yrs ago.

P1724 thus appears to be a single, very young, naked, weak-line TTS moving north relative to the Trapezium, but sharing the Orion radial velocity. All the observations are consistent with P1724 being a run-away TTS, ejected from its birth place, the Trapezium cluster, only $\approx 10^5$ years ago (Neuhäuser et al. [63]).

Although the relatively large mass of this star, neither the Sterzik and Durisen [42] nor the Kroupa [45] scenario rule out the ejection of such massive stars, they are just a priori less likely. However, due to observational biases, it may even be more likely to find such a massive (and, hence, luminous) raTTS.

One of the newly-discovered PMS stars south of Taurus, RXJ0511.2+1031, has been identified as a very promising raTTS candidate. It was identified as a TTS with follow-up observations of ROSAT sources south of the Taurus clouds (Magazzù et al. [26], Neuhäuser et al. [27]). This star has a spectral type K7 with H_α emission (Magazzù et al. [26]) and W_λ (Li) = 0.65Å (which is the largest in the Magazzù sample). It is located on the λ Ori cloud. It it originated in Orion, it is now moving towards us with a radial velocity of ~ 10 km/s relative to the Orion clouds. This velocity translates into ~ 10 pc per million yrs, so that one would still expect the star to be more distant than ~ 400 pc if it originated in λ Ori, at ~ 460 pc. Unfortunately, its proper motion has not yet been measured. Repeated high-resolution spectra show no indications of binarity (Neuhäuser et al. [27], and Sterzik et al. [64]) found no visual companions down to 0".6 separation and ΔR up to 7 mag. The small observed rotational velocity of only ~ 5 km/s for this star (Neuhäuser et al. [27]) is consistent with the predictions for recently ejected raTTS (Armitage and Clarke [50]). This star has $V \simeq 14$ mag (from the GSC), while many other stars in the sample south of Taurus have $V \simeq 11$ to 12 mag (Magazzù et al. [26]). Such a difference in brightness is consistent with the difference in distance between Taurus and Orion.

3.4. *HIPPARCOS results for new TTS.* More recently, Neuhäuser and Brandner [65] have cross-correlated the list of ROSAT-discovered TTS with the HIPPARCOS catalog. Out of ~ 500 lithium-rich ROSAT counterparts, which were presumed to be low-mass PMS stars, 21 stars have been observed by HIPPARCOS. These 21 stars include three wTTS from the Wichmann et al. [23] sample in central Taurus, and one new PMS star found south of Taurus by Magazzù et al. [26].

The proper motions of these four Taurus TTS are consistent with membership to the Taurus T association and also agree well with proper motion data from the STARNET (or PPM) catalogue (Frink et al. [58]). Also, the distances of these stars - based on HIPPARCOS parallaxes - are in agreement with the mean distance of the Taurus TTS and clouds, which is ~ 140 pc.

For one of these four stars (HD 283798) precise photometry is available, and Neuhäuser and Brandner [65] have combined the spectral type, the photometry and the HIPPARCOS parallax to compute its absolute bolometric luminosity in order to place it on the H-R diagram. By comparison with evolutionary tracks and isochrones (D'Antona and Mazzitelli [57]), they determined for HD 283798 a mass of ~ 1.3 $M_\odot$ and an age of ~ 12 Myr. It lies clearly above the ZAMS.

Using the available photometry, Neuhäuser and Brandner [65] were able to place a total of 15 ROSAT-discovered lithium-rich stars on the H-R diagram using the HIPPARCOS parallaves. All of them lie above the ZAMS and thus are indeed PMS stars with ages ranging from 1 to 15 Myr. Only two of the stars are located on the Hayashi-tracks, whereas the other 13 are post-TTS, located on radiative tracks, with relatively low lithium abundance.

4. *On the origin of wide dispersed T Tau typa stars.* X-ray surveys have proved to be a powerful tool for finding PMS stars. Moreover, X-ray surveys of star-forming regions over the last several years have detected a widely dispersed population of candidate T Tauri or post - T Tauri type stars. With the ROSAT All-Sky Survey (RASS) as well as pointed Position Sensitive Proportional Counter (PSPC) and High Resolution Imager (HRI) observations it is now possible to search and investigate possible candidates of PMS stars in the areas of star forming and their neighboring regions, in a relatively systematic way. Young populations of low-mass stars have been found spread over large areas mostly devoid of molecular gas in Taurus (Neuhäuser et al. [25], Wichmann et al. [23]), Chameleon (Alcala et al. [28.34]), Orion (Sterzik et al. [24], Alcala et al. [35]) and Lupus (Krautter et al. [30], Wichmann et al. [31]).

The wide dispersal of these young low-mass stars is difficult to reconcile with the standard picture of star formation, in which stars are formed in molecular clouds and are found to be associated with them over essentially their entire PMS stage.

Various explanations have been proposed to account for the spatial distribution of these stars, all assuming star formation occuring over short time scales, less than 10 milion years (see, Neuhäuser et al. [25], Feigelson [41], Briceño et al. [38]).

One such scenario calls for dynamical ejection of wTTS from their parent clouds via stellar encounters in former multiple systems, thus producing so called "runaway TTS" (Neuhäuser et al. [25]).

An alternate approach has been taken by Feigelson [41] who proposed that star formation in short lived, rapidly moving cloudlets produces a widely dispersed population in time scales of order 10^7 yr and leave essentially no trace of molecular gas in association with those young stars.

Briceño et al. [38] proposed that the majority of these stars are not pre-main-sequence stars, but young main sequence stars of ages up to 10^8 yr.

The main criterion to establish the evolutionary status of these X-ray sources is the existence of strong Li absorption at 6708A. Indeed, Li is dragged deeply inside low-mass stars by convection, and thus progressively disappears from the outer layers. While Li mixing is poorly known, in general terms a high Li line equivalent width (> 0.5 Å) argues in favor of a PMS status, and a low equivalent width is more typical of young main sequence stars (e.g., the Pleiades). The reliability of the measurement of the Li equivalent width depends however crucially on the spectral resolution.

Resuming all above mentioned it seems that accurate measure of the Li equivalent width with high spectral resolution (< 0.1 Å) of significant amount of candidate stars may overcome the problem.

5. *Concluding remarks.* The number of true pre-MS stars amoung lithium-rich ROSAT counterparts certainly varies from region to region. Four different types of regions must be distinguished:

1) On-cloud and on the Gould Belt, e.g. Taurus, Lupus, Orion,
2) On-cloud, off-Belt (i.e. outside of the Belt), e.g. Chamaeleon,
3) Off-cloud, on-Belt, e.g. south of Taurus,
4) And off-cloud, off-Belt, e.g. far south of Taurus, far off Lupus.

The Table below summarizes the fraction of the different kinds of stars

Area	Li > IC 2606 wTTS ≤ 10^7 yr	Li ~ IC 2606 pTTS ~ 10^7 yr	Li ~ Pleiades ZAMS ~ 10^8 yr
on cloud, on Belt (1)	1/3	1/3	1/3
on cloud, off Belt (2)	2/3	-	1/3
off cloud, on Belt (3)	1/8	3/8	1/2
off cloud, off Belt (4)	1/20	1/20	9/20

Remarks: (1)

(truly young pre-MS stars, 30 Myr old post-TTS, and ZAMS stars) in the different regions. The numbers given are very rough estimates and do not take into account differences between the different star forming regions, like star formation efficiency and history. The estimates given are fractions found in the respective sample of ROSAT counterparts with detected lithium in low-resolution spectra. On the Taurus, Lupus, and Orion clouds. (2) On the Chamaeleon clouds. (3) Slightly south of Taurus. (4) The areas and stars referred to here in the strips far south of the Taurus clouds (Neuhäuser et al. [25,27]) and near Lupus (Wichmann et al. [32]) are only the areas outside the relevant (Taurus or Lupus) clouds and outside the relevant part of the Gould Belt, i.e. the stars on the cloud and the Belt studied in those papers are not included.

To summarize, the most important results of the follow-up studies of the ROSAT sources in and around the star forming regions are:

1) In any of the regions investigated, we find lithium-rich stars among the optical counter-parts of ROSAT sources, a mixture of young pre-MS stars, ZAMS stars and young MS stars.

2) Hundreds of new T Tauri stars are found in star forming clouds in the ROSAT sample.

3) Few pre-main sequence stars are found far away from clouds (possibly ejected run-away T Tauri stars or born in cloudlets?).

4) Among the post-TTS, some may be low-mass Gould Belt members.

5) The ZAMS population expected from galactic models is also seen.

We refer to the recent review by Neuhäuser [7] for more details. One of the main results of the ROSAT mission in the fact that T associations cover larger areas in the sky than previously thought.

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Т-АССОЦИАЦИИ В РЕНТГЕНОВСКИХ ЛУЧАХ

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Представлены свойства рентгеновской эмиссии звезд типа Т Тельца и основные результаты, полученные с помощью рентгеновской миссии ROSAT. Представлены результаты последующих оптических наблюдений ROSAT-овских источников неидентифицированных с известными звездами типа Т Тельца. Удивительно, что некоторые из них расположены вне принятых классических границ очагов звездообразования, т.е. вне темных облаков. Обсуждается их кинематика и образование.

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