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On the widespread Weak-Line T-Tauri population detected in the ROSAT All-Sky Survey*

F. Favata[1], **G. Micela**[2], **and S. Sciortino**[2]

[1] Astrophysics Division – ESA/ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands
[2] Istituto e Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, I-90134 Palermo, Italy

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Abstract. We discuss the apparent widespread presence of Weak-Line T-Tauri stars (WTTS) among stellar coronal sources detected in the ROSAT All-Sky Survey (RASS), and their relative number with respect to young main-sequence stars in the same samples. The approach taken in most of the current literature for identifying and classifying WTT stars among RASS X-ray sources is based on the usage of low-resolution optical spectra only and on simple, mass-independent thresholds on the equivalent width of the Li I 6707.8 Å doublet. We show that this approach is likely to lead to putative WTTS samples which contain a large number of normal, young main-sequence stars masquerading as WTTS sources. Young main-sequence stars are known to be the dominant contributor in stellar X-ray selected samples at the limiting flux levels of the RASS, yet they appear to be very rare in the RASS samples discussed here. We argue that many of the putative WTTS sources are actually mis-classified young main-sequence stars, and that thus there is likely not a true "WTTS question" in the RASS samples.

Key words: stars: formation – stars: late-type – stars: pre-main sequence – X-rays: stars

1. Introduction

X-ray selection has been shown to be a powerful way of selecting pre-main sequence (PMS) late-type stars, already using *Einstein* observations of star-forming regions (SFR), as for example shown by Walter et al. (1994) in the Sco-Cen SFR, where they identified several previously unknown PMS stars by studying the newly detected X-ray sources. This technique has recently been extensively applied to the stellar counterparts of soft X-ray sources detected in the RASS (Alcalá et al. 1995, Alcalá et al. 1996, Alcalá et al. 1997, Wichmann et al. 1996, Wichmann et al. 1997, Krautter et al. 1997, hereafter collectively referred to as the "RASS-WTTS papers") yielding a large number of candidate PMS stars, which are generally referred to as "Weak-line T-Tauri Stars" (WTTS), as they do not show any of the extreme spectral characteristics (strong emission lines, and large amount of "veiling") typical of classical T-Tauri stars (CTTS). The abundance of PMS stars identified in the RASS, even far away from obvious sites of star formation, has raised several questions about the mechanisms of low-mass star formation, about the recent history of star formation in the solar neighborhood, and about the mechanisms responsible for the spatial diffusion of newborn stars from their sites of formation.

These questions have for example been addressed in detail by Feigelson (1996), who has discussed various possible models for the diffusion of young stars from their place of birth, to match the WTTS population identified around the Chameleon star forming region investigated by Alcalá et al. (1995). One persistent difficulty observed by Feigelson (1996) is that the putative age of the RASS WTTS population is consistently too young. One proposed way of accounting for such a large number of very young stars far away from their plausible birthplace is to assume the presence of a large number of spatially sparse, small sites of star formation which have, by the time these stars have been observed, dissipated away. The concentration of low-mass star formation in these small sites would challenge much of our understanding of low-mass star formation. As Feigelson (1996) remarks, these explanations must be considered as tentative, as the possibility that a fraction of the RASS high-lithium stars are already on the main sequence cannot be discarded.

Briceño et al. (1997) reach, for the RASS stars, the same conclusion which was reached earlier for the *Einstein* Extended Medium Sensitivity Survey (EMSS) by Micela et al. (1993), namely that the majority of low-mass stars detected in X-ray flux-limited surveys at the flux levels typical of the RASS and of the EMSS are likely to be young main sequence stars, rather than PMS stars. To support this statement, Briceño et al. (1997) use a numerical approach, similar to the one presented by Favata et al. (1992), and applied by Micela et al. (1993) and Sciortino et al. (1995) to the data from the EMSS, similarly concluding that the majority of the low-mass stars detected in the RASS are likely to be young main-sequence stars.

Send offprint requests to: F. Favata (ffavata@astro.estec.esa.nl)

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Very similar conclusions are reached by Guillot et al. (1996) who have developed a similar (although fully independent) model of galactic coronal X-ray source counts. Their work includes a more detailed modeling of the scale-height evolution of the young stellar populations, and thus succeeds in better predicting the low-latitude population. This model has been shown to match well the observations of low-latitude RASS fields (Motch et al. 1997), again showing the predominance of young main-sequence coronal sources.

The large numbers of WTTS identified in the RASS-WTTS papers is in contrast with the small number of young (from a few times 10^7 up to 10^8 yr of age) main-sequence stars in the same samples. For example, the low number of non-PMS coronal sources detected by Alcalá et al. (1995) contrasts sharply with the much larger number of such sources detected in the RASS by Motch et al. (1997). The contrast is even more striking if one considers that the latter sample has a shallower limiting flux. An analysis of the RASS-WTTS papers shows that the attribution of WTTS "nature" has been done on the basis of low-resolution spectra, and that no lithium abundance determination has been used to assess the (eventual) PMS status of individual sources. Either the eventual presence of a "strong" Li I doublet (the watershed feature used to discriminate between "WTTS" and "other active stars") is quoted as determining the "WTTS nature" of a source (without any quantitative definition of "strong", as in Alcalá et al. 1995) or a single mass-independent, minimum equivalent width of the Li I doublet is taken as discriminating between WTTS and other active stars (as in Wichmann et al. 1996). In all the above works, the equivalent width of the Li I doublet is measured using spectra with resolution ranging from $\simeq 4$ Å to $\simeq 10$ Å.

Experience shows that the detection, and, a fortiori, the measurement of weak spectral features in low-resolution spectra is an uncertain operation, and that the measurement of spectral features whose equivalent width is a small fraction of the spectral resolution is likely to be fraught with large systematic as well as statistical errors. To assess the reliability of a WTTS identification process based only on low-resolution spectra, we have analyzed the low- ($\simeq 4$ Å) and high-resolution ($\simeq 0.1$ Å) spectra of a number of active stars spanning a wide range of spectral types and lithium abundances. We have also studied the influence of the usage of a single watershed value for the equivalent width of the Li I feature as determining whether a source is a WTTS or not, noting the systematic biases in the resulting samples of X-ray selected WTTS.

The present paper is structured as follow: Sect. 2 briefly presents the sample of stars whose spectra have been studied here and describes the data reduction, Sect. 3 discusses the derivation of Li I doublet equivalent widths and compares in detail the results obtained from low- and high-resolution spectra, Sect. 4 discusses the effects of using a simple threshold in equivalent width of the Li I doublet in the identification of PMS sources, and Sect. 5 discusses the apparent lack of main-sequence stars in the samples from the RASS-WTTS papers. Finally, Sect. 6 discusses the implications of the findings of the present paper.

2. The observed sample

Our sample consists of a number of late-type stars which we have previously investigated in the context of our study of X-ray selected stars from the EMSS and the *Einstein* Slew Survey (ESS). For all these stars we had available both low- and high-resolution spectra. The stars were selected to span a range of spectral types, as well as of lithium abundance. The sample stars have spectral types ranging from G0 to M0, and have lithium abundances (as determined on the basis on high-resolution spectroscopy by Favata et al. 1995) ranging from below the detection limit in high-resolution spectra (implying equivalent widths of the Li I 6707.8 Å doublet smaller than $\simeq 10$ mÅ) up to cosmic lithium abundance ($N(\mathrm{Li}) \simeq 3.2$). Their spectra are representative of the larger EMSS and ESS samples. The characteristics of the sample stars are listed in Table 1. In addition, we have studied three M stars which are listed in Table 2 and are discussed in detail in Sect. 3.1. This small sample of M stars includes a main-sequence, very active star as well as two bona fide PMS stars, and, while not homogeneous in selection criteria with the first sample, it supplements it at the cooler end.

The low-resolution spectra used here have all been acquired using the ESO 1.5 m spectroscopic telescope with the Boller & Chivens spectrograph. The combination of grating and CCD chip used yielded a resolution of 1.9 Å per pixel, or a two-pixel resolution of $\simeq 4$ Å, very similar to the higher resolution employed by Alcalá et al. (1995). The high-resolution spectra were acquired using the ESO CAT 1.4 m telescope with the Coudé Echelle Spectrometer (CES). The short camera with the RCA CCD (ESO #9) was used, yielding an effective resolution of about 50 000 (or $\simeq 0.05$ Å per pixel). The spectra are centered on the Li I 6707.8 Å doublet, and cover the range $\simeq$ 6690–6730 Å. The data reduction procedure has been described in detail in Favata et al. (1993), to which the reader is referred for details. These spectra allow a measurement of the equivalent width of the Li I 6707.8 Å doublet to a precision of a few mÅ (depending on the rotational velocity), and thus form an excellent benchmark for checking the possibility of measuring the equivalent width of the same line at lower resolutions.

3. Derivation of lithium equivalent widths from low-resolution spectra

A representative segment of the low-resolution spectra used in the present work is shown in Fig. 1, in which the expected positions of the Li I 6707.8 Å doublet and of the nearby Ca I 6717.7 Å line are shown by vertical dashed lines. Fig. 2 shows an enlargement of the same spectra, trimmed to cover a small region near the Li I doublet, and expanded vertically by a factor of 5, for clarity. All the stars in the sample appear to have a spectral feature in absorption at the expected position of the Li I doublet.

We have measured the equivalent width of the line present in the low resolution spectra at the expected position of the Li I doublet, using the IRAF SPLOT task, by fitting two gaussians, one to the line identified with the Li I doublet itself, and the other to the nearby Ca I feature, which is often blended with the Li I

Table 1. The stars for which we have measured the equivalent width of the Li I 6707.8 Å doublet in both high-resolution (0.05 Å per pixel) and low-resolution (2 Å per pixel) spectra. The equivalent width of the real Li I doublet measured in the high-resolution spectra is taken from Favata et al. (1995) while the equivalent width of the feature at $\simeq$ 6708 Å visible in all the low-resolution spectra has been measured in the present work. The projected rotational velocity of each source (which gives a measure of the eventual rotational broadening of the lines), the lithium abundance and the $T_{\rm eff}$ are also from Favata et al. (1995). The last column gives the difference between the true and measured (on the low-resolution spectra) distance between the 6708 Å Li I feature and the 6717 Å Ca I feature. In all cases this difference is significantly smaller than the spectral resolution of $\simeq$ 4 Å, indicating the the identification of the measured feature with the lithium feature at 6708 Å appears to be reliable.

Einstein name	Other name	Spectral type	$T_{\rm eff}$	W(Li), Å (High res.)	N(Li)	$v\sin(i)$ km/s	W(Li). Å (Low res.)	$\Delta\lambda$ Å
1ES0412+06.0A	HD26923	G0V	5970	0.09	2.78	< 8	0.32	+0.41
1ES0637−61.4	HD48189	G1.5V	5970	0.13	3.30	15	0.45	−1.49
1ES0635−69.8	HD47875	G3V	5720	0.20	3.70	10	0.46	−0.46
1ES1044−49.1	HD93497	G5III	4860	≤ 0.01	≤ -0.30	–	0.42	−0.39
1ES0412+06.0B	HD26913	G8V	5540	0.06	2.14	< 8	0.40	+0.38
1ES0357−40.0	HD25300	K0e	5240	0.11	2.26	12	0.48	+0.33
1ES0250−12.9	HD17925	K1V	5050	0.20	2.88	< 8	0.42	−0.17
1ES0327−24.2	HD21703	K4V	4460	≤ 0.01	≤ 1.74	< 8	0.25	−1.08
1ES0457+01.7A	GJ182	M1Ve	4020	0.27	1.77	14	0.36	−0.43

feature. The best-fit equivalent widths are reported in Table 1, together with the difference between the true and measured (on the low-resolution spectra) distance between 6708 Å Li I feature and the 6717 Å Ca I feature. This last quantity can be used as a measure of the reliability of the identification of the feature near 6708 Å with the Li I line, as it should be significantly smaller than the spectral resolution (it indeed is for all the program stars).

We have found the measurement of such weak features (few hundreds of mÅ at most) on spectra of such low resolution to be an uncertain process. The lack of any line-free continuum in the neighborhood of the line in question makes continuum estimation a subjective process, and we estimate the uncertainty due to placement of the continuum alone to be at least some 100 mÅ. Such uncertainty is in line with the uncertainty quoted by Alcalá et al. (1995), for their measurements on similar spectra, of 150 mÅ (i.e. comparable, or often larger than the equivalent width being measured. Their quoted uncertainty is independent of the spectral resolution).

All the equivalent widths measured in the low-resolution spectra for the feature at $\simeq$ 6708 Å are higher than the true equivalent width of the Li I doublet, sometimes by several hundreds mÅ, and would, taken at face value, imply (following the criteria of the RASS-WTTS papers) that all the sources discussed here are PMS, or, more specifically, WTT stars. Yet, none of these stars shows evidence of being a WTTS when real lithium abundances are derived from high-resolution spectra of the same stars. The two later-type high-lithium sources in our sample, 1ES0250−12.9 and 1ES0457+01.7A, which could be suspected of being PMS stars, while certainly young, are also very close to the main-sequence, and not any longer on the Hayashi track, as unambiguously shown, on the basis of Hipparcos parallaxes, by Micela et al. (1997).

The measurement of the 6708 Å feature in low-resolution spectra of low-mass stars is thus very likely to lead to a significant over-estimate the true lithium abundance. Even worse, two sources (1ES0327−24.2 and 1ES1044−49.1) which have no measurable lithium down to less than 10 mÅ in their high-resolution spectra, appear to have a similar feature at 6708 Å as the stars with deep Li I doublets visible in their low-resolution spectra. Furthermore, there seems to be no clear relationship between the equivalent width of the 6708 Å feature measured in low-resolution spectra and the equivalent width of the Li I doublet, as the very large measurement error makes it impossible to simply subtract the (metallicity and effective temperature dependent) "foot" due to the contribution of the Fe I lines to the feature measured in the low-resolution spectrum to derive the "true" equivalent width of the Li I doublet. This is clearly illustrated in Fig. 3, which shows a scatter plot of the equivalent width of the the Li I feature measured in low-resolution spectra as a function of its "true" equivalent width.

Fig. 4 shows, superimposed, the high- and low-resolution spectra of 1ES0250−12.9, a high-lithium K1 dwarf. Both spectra are shifted to the rest wavelength of the spectral lines. As it is obvious from the plot, both the "Ca I" and the "Li I" feature in the low resolution spectrum are actually a blend of several spectral features, making it impossible to accurately derive the true equivalent width of the parent lines.

Fig. 5 shows the same type of spectra for 1ES1044−49.1, a G5 giant which has (as evident from the high resolution spectrum) no measurable lithium. Remarkably, the Fe I lines evident in the high-resolution spectrum "bunch" together, in the

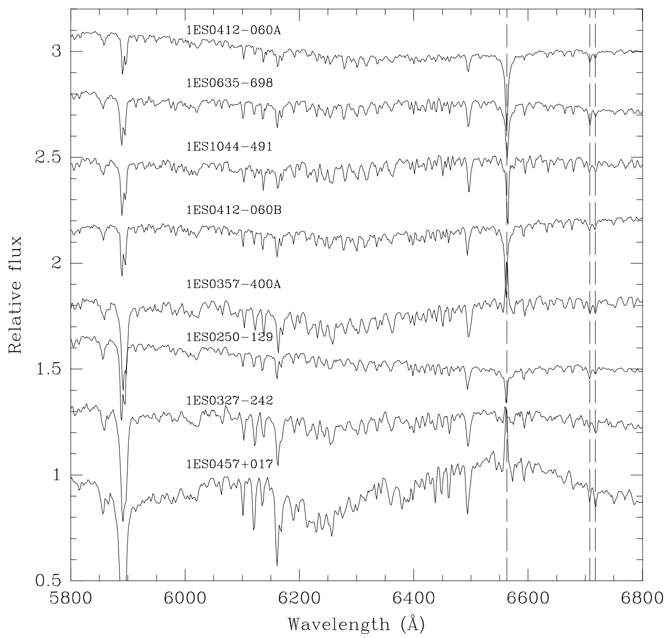

Fig. 1. A segment of the low-resolution (2 Å per pixel) spectra for the active stars of Table 1. The positions of the Li I 6707.7 Å doublet, as well as the position of the nearby Ca I 6717 Å line are marked by the vertical dashed lines. Also marked is the position of the Hα line. 1ES0637−61.4 has not been plotted to avoid excessive crowding.

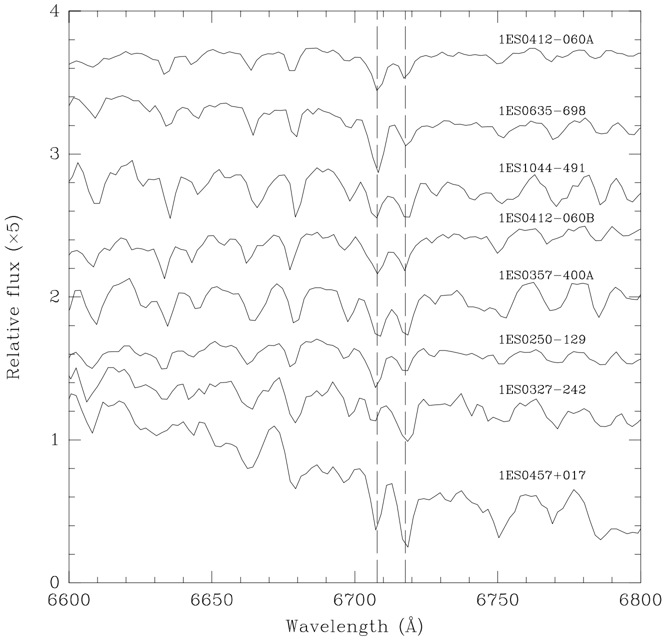

Fig. 2. The region of the Li I doublet, from the same spectra as in Fig. 1, vertically expanded by a factor of 5 to better show the spectral features. The positions of the Li I 6707.7 Å doublet, as well as the position of the nearby Ca I 6717 Å line are again marked by vertical dashed lines.

low-resolution spectrum, to mimic a feature at a wavelength not distinguishable (at these resolutions) from a feature containing a sizable contribution from the Li I doublet, and which would thus be confused with it in the absence of high-resolution spectra.

The strength of the 6708 Å feature visible in the low-resolution spectra of G and K stars thus appears not to be a reliable indicator of the equivalent width of the lithium doublet, and bears little relationship with the actual lithium abundance of the source. The presence of an absorption feature at 6708 Å in low-resolution spectra, should thus not, per se, be taken as an indication of the possible PMS status of a G- or K-type star. Further studies on both the low- and high-resolution spectra of large samples would be needed to asses whether, in the presence of a very accurate wavelenght solution for the low-resolution spectrum, the lithium-mimicking feature visible in Li-poor stars could be reliably distinguished from a true Li I feature. Even if this were the case, however, the problem of the associated large uncertainty in the derived equivalent width (related to the low resolution) would still stand.

3.1. M stars

M stars are likely to be easier targets for spotting WTTS sources from low-resolution spectra. In cooler stars most metallic lines (such as the Fe I lines in the region around the Li I doublet) become weak, and merge in a maze of molecular lines (mostly from TiO and from hydrides, specially MgH), forming, in a low-resolution spectrum, a pseudo-continuum against which a strong Li I doublet is likely to stand out. At the same time, for a given lithium abundance the equivalent width of the Li I doublet will be stronger, because of the lower ionization fraction of lithium at lower temperature. While we do not have available, for M stars, an extensive library of both high- and low-resolution spectra, we had a few low-resolution spectra of active M stars with no measurable lithium in their high-resolution spectra and of bona fide M-type WTTS with a strong lithium line visible in high-resolution spectra. At the low resolution discussed here (also $\simeq 4$ Å) these stars appear to be easily distinguishable. The low-resolution spectra of three of these M stars are shown in Figs. 6 and 7, which are analogous to Figs. 1 and 2 shown earlier for G and K stars. The bottom star in both figures (G102−21, which has been discussed by Micela et al. 1995) has no measurable lithium line in its high-resolution spectrum (and has no 6708 Å feature in its low-resolution spectrum), while the two top spectra are from bona fide WTT stars in the Sco-Cen SFR reported by Walter et al. (1994), and have clearly visible 6708 Å features. The presence of strong lithium in absorption in their spectra has been determined by Walter et al. (1994) on the basis of high-resolution spectra, and it is reported in Table 2. The low-resolution spectrum of G102−21 is very similar to the spectra of the WTTS, the only visible difference in their spectra being the Li I doublet in absorption.

The measured equivalent width of the Li I doublet in low- and high-resolution spectra for M stars are compatible within the large observational error of the low-resolution measurements. For M stars low-resolution spectra thus appear to be a useful tool to search for high-lithium stars. Again, however, any quan-

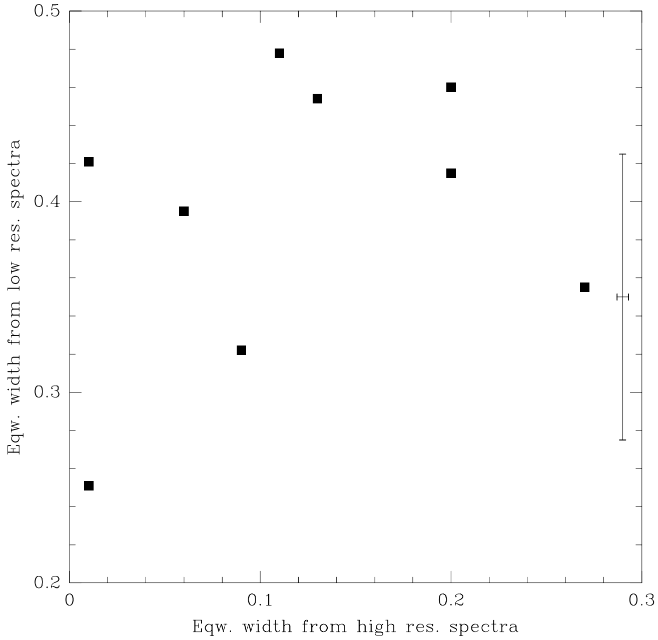

Fig. 3. The equivalent width of the 6708 Å feature derived from the low-resolution spectra plotted against the equivalent width of the Li I doublet from the high-resolution spectra for the program stars. Also plotted is a typical error bar (assuming a 150 mÅ uncertainty for the low-resolution measurements and a 5 mÅ uncertainty for the high-resolution measurements).

Table 2. The three M stars, two bona fide WTTS and an active M star with no lithium in its high-resolution spectra, for which spectra are shown in Fig. 6 and 7. The high-resolution Li I equivalent widths and rotational velocity are from Walter et al. (1994) for the two WTTS and from our own work (see Micela et al. 1995) for G102−21. $\Delta\lambda$ is defined as in Table 1.

Name	Spectral type	W(Li), Å (High res.)	W(Li), Å (Low res.)	$v\sin(i)$ km/s	$\Delta\lambda$ Å
ScoPMS020	M3	0.49	0.55	27	−0.8
ScoPMS019	M1	0.61	0.49	19	+0.5
G102-21	M2	≤ 0.01	≤ 0.1	20	–

titative attempt at measuring the equivalent width of the Li I doublet on low-resolution spectra is still likely to be affected by large errors, whose amount will depend both on the spectral resolution used and on the precise spectral type and metallicity of the star being observed.

4. Lithium equivalent width, age, and T-Tauri nature

The attribution of a precise age to individual stars is difficult, specially when individual accurate distances are not available, which, specially for young stars, allow the placement on evolutionary tracks. The only available indicator of WTTS status for individual low-mass stars of unknown distance is the presence of a very large lithium abundance: low-mass stars are supposed to burn lithium at the basis of their convective zones, with lower mass stars having proportionally deeper convection zones and thus shorter lithium depletion characteristics times. The available observational evidence, however, is not so simple, and all the currently available data point toward several factors, in addition to age, influencing the lithium abundance of a low-mass star.

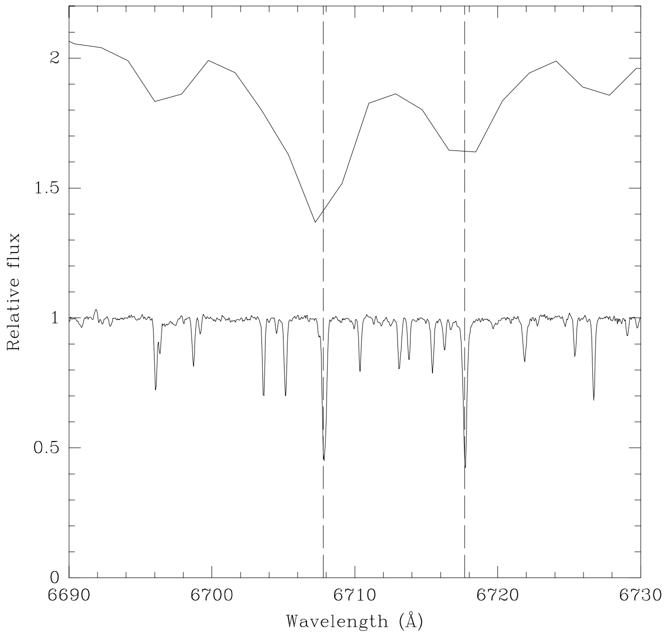

Fig. 4. High- and low-resolution spectra of the region around the Li I 6707.8 Å doublet for the K1 dwarf 1ES0250−12.9. The vertical lines mark the position of the Li I 6707.8 Å and Ca I 6717 Å features.

Old dwarfs earlier than G5 show a large range of lithium abundance, with lithium-rich stars being found at essentially any age (Pasquini et al. 1994, Favata et al. 1996), and the same stars still have essentially undepleted lithium when they are well in the main sequence stage (as in the Pleiades, Soderblom et al. 1993), showing that the lithium criterium is of little relevance for their being classified as PMS sources. For low-mass stars cooler than $\simeq$ G5, the evidence so far available points toward lithium being depleted with age, although young stars have a wide range of lithium abundance at any given age, as shown, for example, by Soderblom et al. (1993) for the solar-type stars in the Pleiades, and by Stauffer et al. (1993) for the α Persei cluster.

Thus, while high levels of lithium (i.e. comparable to the “cosmic” abundance, $N(\mathrm{Li}) \simeq 3.2$ on the usual scale where $N(\mathrm{H}) = 12.0$) are characteristic of G- and K-type PMS stars (and are a “necessary” condition for being classified as a PMS), a lithium abundance of order $\simeq 3.0$ is by no means sufficient for classifying a star as PMS, given than many stars down to mid-K spectral type in the Pleiades have a lithium abundance

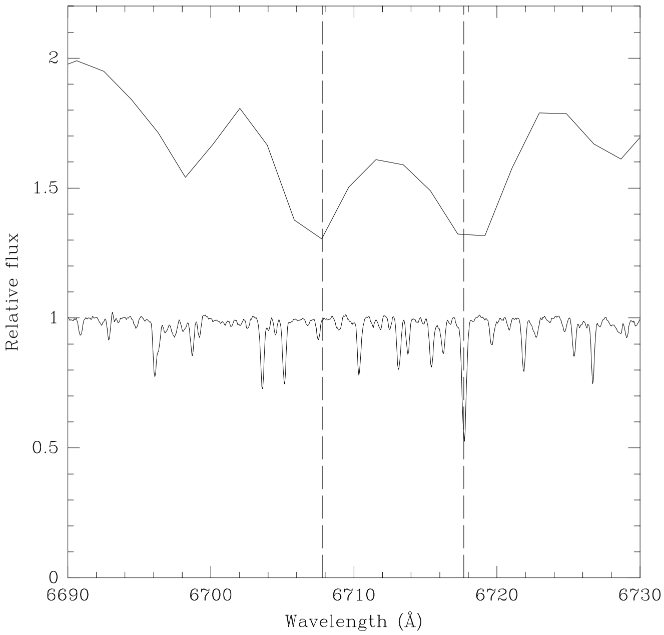

Fig. 5. High- and low-resolution spectra of the region around the Li I 6707.8 Å doublet for the G5 giant 1ES1044−49.1. The vertical lines mark the position of the Li I 6707.8 Å and Ca I 6717 Å features.

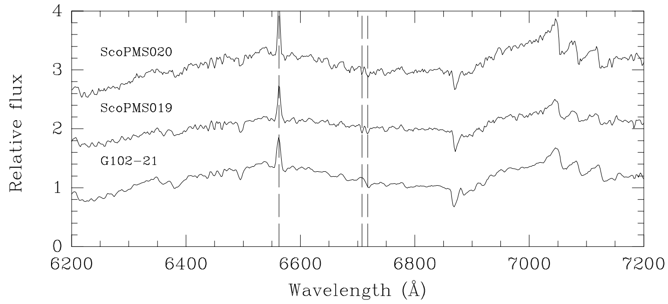

Fig. 6. A segment of the low-resolution ($\simeq$ 2 Å per pixel) spectra for the three M stars of Table 2. The positions of the Li I 6707.7 Å doublet, of the nearby Ca I 6717 Å line and of the Hα line are marked by vertical dashed lines.

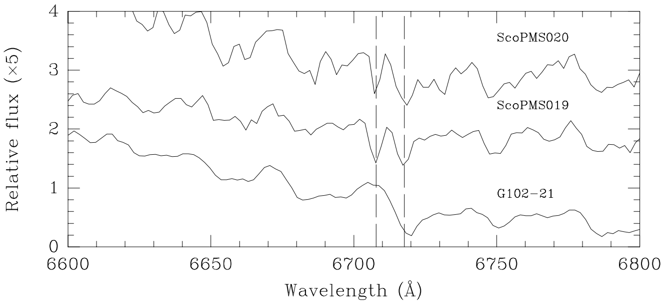

Fig. 7. The region of the Li I doublet, from the same spectra as in Fig. 6, vertically expanded by a factor of 5 to better show the presence of lines. The positions of the Li I 6707.7 Å doublet and of the nearby Ca I 6717 Å line are again marked by vertical dashed lines.

close to 3.0, yet they clearly are on (or very close to) the main sequence.

Given that cooler stars are expected (and generally observed) to be depleting their lithium more rapidly than higher mass solar-type stars, it is not possible to adopt a single, mass-independent threshold of the lithium abundance as discriminating between PMS and main-sequence stars, with the same lithium abundance having quite different implications on the evolutionary status in G, K or M stars.

In Fig. 8, we have plotted the lithium abundance implied by different (true) observed equivalent widths of the Li I doublet, for an equivalent width of 100, 200 and 300 mÅ. The region to the left of the thick vertical line in Fig. 8 is the region occupied by the early- to mid-G dwarfs, for which lithium cannot be used to separate PMS and main-sequence objects. The boundary of the dashed region is the approximate upper boundary of the lithium abundances measured in the Pleiades by Soderblom et al. (1993), so that any star lying outside the dashed region has lithium abundances compatible with its being a main sequence star. The region in which PMS stars can be discriminated from the lithium abundance is thus the dashed area in Fig. 8, although, given the spread of lithium abundance observed at any given age, the actual boundary has to be assumed to be quite fuzzy. Taking a mass-independent threshold of 100 mÅ for the equivalent width of the Li I doublet will select (as already remarked by Briceño et al. 1997), in addition to whatever true WTTS there may be in the sample, many stars which are simply young main sequence stars, thus inflating the detected number of WTTS with several spurious sources. A threshold of $\simeq$ 250 mÅ would approximately follow the sloping boundary of the shaded region, but at the same time it would miss many true WTTS among the hotter stars, as well as a few at the cooler end.

5. Where is the young main-sequence population?

As remarked in the Sect. 1, the RASS-WTTS papers show a severe lack of normal, young active main-sequence stars in their samples. For example, Alcalá et al. (1995) report (see their Table 4) to have investigated 112 X-ray sources (in an area of $\simeq$ 150 square deg) around the Chameleon SFR, and, among the 112 X-ray sources studied, to have found 75 new WTTS and only 10 active stars which are not classified as WTTS on the basis of their low-resolution spectra. It is suggestive, in the light of the results of Sect. 3 and 3.1, that the non-WTTS active stars reported by Alcalá et al. (1995) are all dMe stars, as it is at these spectral types that low-resolution spectra have some diagnostic value. In addition to this, they report another 13 non-WTT stellar sources which were previously known, although from their Table 6 it appears that some are early-type stars and thus non-coronal sources. Thus, 23 non-WTT stars, or 18, subtracting the early-type stars, in $\simeq$ 150 square deg. For the same sky area Alcalá et al. (1997) report a limiting sensitivity of $\log f_{\rm X} = -12.8$ (the same limiting sensitivity can be derived from the RASS exposure time in the region of $\simeq$ 2500 s reported

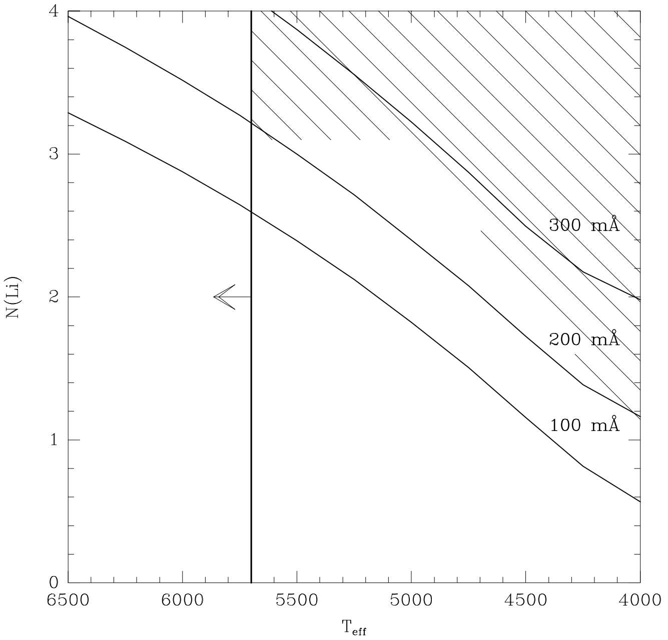

Fig. 8. The lithium abundance is shown, as a function of effective temperature, for equivalent width values of the Li I doublet of 100, 200 and 300 mÅ, following the curves of growth of Soderblom et al. (1993). The heavy vertical line represents the cool $T_{\rm eff}$ bound for $\simeq$ G5 stars, and the shaded region is the region which is expected to be occupied by bona fide PMS stars.

by Alcalá et al. 1995, leading to a limiting PSPC count rate of $\simeq 0.005\,{\rm cts\,s^{-1}}$). A computation based on the model of Favata et al. (1992) and Sciortino et al. (1995) predicts at this limiting flux level between 60 and 80 active non-PMS stars in that area of the sky, depending on the assumed value for the space density of RS CVn binaries. This is a factor of $\simeq$ 3 higher than the 23 active non-PMS stars reported by Alcalá et al. (1995), showing that many of the putative WTTS in their sample are likely to be misclassified main-sequence stars. Note that the computation discussed here is in full agreement with the observed numbers in the EMSS, i.e. these large numbers of young main-sequence objects are not only expected, at the X-ray flux levels, but their presence has already been verified on fully identified samples. The Guillot et al. (1996) model, predicts an even larger number of main-sequence stellar sources, i.e. about one per square degree at these fluxes and latitudes, approximately two thirds of which are expected to be of age 1 Gyr or older (and with a significant fraction of the ones younger than 1 Gyr being on the main sequence). A similar prediction is made by Briceño et al. (1997). The Guillot et al. (1996) model has been shown by Motch et al. (1997) to provide a good match to the RASS population of the Galactic plane, where they report 77 coronal sources in a sky area about half the size and at a limiting flux approximately twice as shallow of the one surveyed by Alcalá et al. (1995) — although at slightly lower galactic latitude.

Later works in the RASS-WTTS line find significantly higher fractions of non-PMS coronal sources. For example, Magazzù et al. (1997) find, in the Tau-Aur region (where the RASS exposure time is $\simeq$ 500 s), significant numbers of non-PMS coronal sources, even in a sample which had been optimized for searching for PMS sources. The difference in methodology is at least in part likely to be the cause of the difference in the detected source population, and in particular the larger spectral resolution employed ($\simeq$ 1 Å), which allows better discrimination of true WTTS from main-sequence stars.

6. Discussion

We have shown, by analysis of the low-resolution spectra of a number of low-mass stars spanning a wide range of spectral types as well as of lithium abundances, and by direct comparison of their low- and high-resolution spectra, that usage of low-resolution spectra alone is likely to lead, at least in G and K stars, to high inferred lithium abundances in late-type stars. An absorption feature at 6708 Å appears to be commonly present, in the low-resolution spectra of G and K stars, independently from their actual lithium abundance. Such feature appears to be present, for stars later than $\simeq$ M0, only in true high-lithium sources. Thus, classification of stellar counterparts to soft X-ray sources done exclusively on the basis of low-resolution optical spectroscopy is likely to significantly over-estimate the number of PMS stars present in the source population. We have also shown that, even with fully reliable Li I equivalent widths, the adoption of a single equivalent width threshold will lead to over-estimating the number of WTTS sources present in the sample.

As discussed in Sect. 1, several works have recently appeared in the literature which present the identification of stellar counterparts to soft X-ray sources based on low-resolution spectra alone. These works discuss X-ray sources in the general direction of star forming regions, but usually cover large region of the sky, extending to quite large projected distances from the SFR. A common feature to all these works is that they seem to find, in addition to the expected concentration of PMS stars in and around the SFR, a large number of widespread WTTS with no apparent immediate relationship with the SFR under investigation, which, as discussed in Sect. 1, are a challenge to current ideas of low-mass star formation. At the same time, the same samples lack the large number of young main-sequence coronal sources which are known to be present in X-ray selected samples at these flux levels.

We make the hypothesis that a non-negligible fraction of the "field WTTS" discussed in the RASS-WTTS papers are normal, active young low-mass stars, on, or very near to the main sequence. The arbitrary placement of foreground active stars at the distance of the putative parent SFR (which is common practice in the WTTS-RASS papers) will make them appear brighter then they actually are, and thus make them wrongly appear as still in a PMS contraction phase when placed on evolutionary tracks. The apparent large number of dispersed WTTS are thus most likely not the solution to the still standing puzzle of the apparent lack of the deficiency of stars older than $\simeq$ 2 Myr in most known star-forming regions (the so-called missing post-T Tauri problem), as discussed by Feigelson (1996). Palla & Galli

(1997) have recently argued that the post-T Tauri problem is a false one, as it is based on the assumption of a constant star-formation rate in giant molecular clouds, an assumption which, based on the similarity between the molecular cloud lifetime and the ambipolar diffusion time, they show to be unlikely. Rather, they argue, star formation accelerates sharply toward the end of a cloud's lifetime, thus justifying the lack of large numbers of older PMS in SFRs.

Micela et al. (1997) have recently used the Hipparcos parallaxes of the subsample of EMSS and ESS stars which have been observed by Hipparcos to accurately position these stars in an HR diagram, showing that only one of the stars in the sample is far away from the main sequence and clearly still in a contracting phase. The rest of the population is mostly composed of main-sequence objects, with $\simeq 20\%$ giants. While this subsample suffers from a bias toward brighter stars, and it is thus lacking many of the fainter and more active stars (some of which are known to be PMS stars from their lithium abundance), they show that all of the stars in their sample (seven) which would have been classified as WTTS using the Wichmann et al. (1996) 100 mÅ criterium (even using high-resolution spectra, and thus reliable Li I doublet equivalent widths) are very close to or on the main-sequence. Thus, while there certainly are a number of bona fide WTT stars in the sample of active stars selected from the *Einstein* surveys (as for example the low-gravity, very high lithium abundance stars of Morale et al. 1996), the majority of the low-mass stars appear however to be already on or very close to the main sequence stage. Given the similar limiting sensitivity of the RASS and of the EMSS, the detected source population has to be similar, and therefore, again, a large fraction of the RASS stellar sources are expected not to be in the PMS stage but rather young main-sequence stars.

Obviously, a (perhaps considerable) fraction of the stars identified in the RASS identification programs discussed above will be true WTTS, still contracting toward the main sequence, given also the vicinity of the surveyed areas to SFR's. However, lacking accurate, high-resolution based lithium abundances and distance measurements, they cannot be separated from the normal active main-sequence stars present in the sample. Given the type of biases and their dependence on the stellar mass, it is likely that the fraction of bona fide WTTS will be higher among late K and M stars, and lower for F and G stars. Any definitive assessment of the true nature of these RASS sources and of the (statistical) properties of RASS-selected PMS populations will thus have to wait for the availability of high-resolution spectroscopic data, including measurements of the Li I doublet, which will help in screening the bona fide WTTS sources in the sample, at least for the cooler stars.

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