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An assessment of Li abundances in weak-lined and classical T Tauri stars of the Taurus-Auriga association*

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ABSTRACT

Context. Accurate measurements of lithium abundances in young low-mass stars provide an independent and reliable age diagnostics. Previous studies of nearby star forming regions have identified significant numbers of Li-depleted stars, often at levels inconsistent with the ages indicated by their luminosity.

Aims. We aim at a new and accurate analysis of Li abundances in a sample of ~100 pre-main sequence stars in Taurus-Auriga using a homogeneous and updated set of stellar parameters and model atmospheres appropriate for the spectral types of the sample stars.

Methods. We compute Li abundances using published values of the equivalent widths of the Li λ6708 Å doublet obtained from medium/high resolution spectra.

Results. We find that the number of significantly Li-depleted stars in Taurus-Auriga is greatly reduced with respect to earlier results. Only 13 stars have abundances lower than the interstellar value by a factor of 5 or greater. All of them are weak-lined T Tauri stars drawn from X-ray surveys; with the exception of four stars located near the L1551 and L1489 dark clouds, all the Li-depleted stars belong to the class of dispersed low-mass stars, distributed around the main sites of current star formation. If located at the distance of Taurus-Auriga, the stellar ages implied by the derived Li abundances are in the range 3−30 Myr, greater than the bulk of the Li-rich population with implication on the star formation history of the region.

Conclusions. In order to derive firm conclusions about the fraction of Li-depleted stars of Taurus-Auriga, Li measurements of the remaining members of the association should be obtained, in particular of the group of stars that fall in the Li-burning region of the HR diagram.

Key words. stars: abundances – stars: evolution – stars: formation – open clusters and associations: individual: Taurus-Auriga

1. Introduction

The use of lithium as an alternative and secure method to derive the ages of young, very low-mass ($M \sim 0.1$–$0.6\ M_\odot$) stars is now well established on theoretical and observational grounds. These stars are fully convective; thus they have a simple internal structure and the physics of their Li depletion during the pre-main sequence (PMS) phases is well understood and not affected by major uncertainties. Theory predicts that they start depleting their surface Li after ~2 Myr from birth, and eventually exhaust all the internal supply in about 10−50 Myr (e.g. D'Antona & Mazzitelli 1994; Baraffe et al. 1998; Siess et al. 2000). The timescale of Li depletion depends on mass, with lower mass stars being the slowest ones. Therefore, in a cluster or association of a given age there is a clear/sharp transition, the so-called lithium depletion boundary (LDB), between fully depleted objects and those with the initial lithium content. The mass at which the boundary occurs reveals the age of the cluster. Observationally, the LDB test has been successfully applied to a number of young open clusters in the age range 30−120 Myr (e.g., Stauffer et al. 1998, 1999; Barrado y Navascués et al. 2004; Jeffries & Oliveira 2005; Manzi et al. 2008).

The physics of lithium depletion is considerably more complex for higher mass stars in the range $M \sim 0.6$–$1.2\ M_\odot$ that develop a radiative core during PMS evolution. The exact amount of depletion in these stars depends on a number of parameters and assumptions entering the models (e.g., Jeffries 2006); hence, use of Li abundances to derive exact ages of stars in this mass range is considerably uncertain, although it still allows distinguishing between very young and more evolved PMS stars.

In addition to providing absolute age estimates, Li abundances can also be used to obtain information on the magnitude of the age spread within less evolved system that are too young for the development of the LDB. Recently, Palla et al. (2005, 2007) have measured Li abundances in a large sample of low-mass members of the Orion Nebula Cluster (ONC), whose bulk population is only ~1−2 Myr old. They found that, in addition to the overwhelming population of stars with Li abundances consistent with the initial interstellar value (log N(Li) = 3.1 ± 0.2, e.g. Jeffries 2006, and references therein), six high probability members are strongly Li depleted, with Li depletion ages greater than 10 Myr. For four of these stars the agreement with the isochronal ages derived from the position of stars in the HR diagram is excellent. Similarly, Li depleted stars were found in Upper Scorpius (Martín 1998) and σ Orionis (Sacco et al. 2007). The presence of older stars mixed with younger members reveals an extended phase of star formation that lasted for much more than a few dynamical times.

Another region that has been the object of extensive Li studies in the past is the Taurus-Auriga (Tau-Aur) association. The

* Table 1 is only available in electronic form at http://www.aanda.org

largest collection of Li data has been presented in a series of papers by Basri et al. (1991, hereafter B91), Magazzù et al. (1992, hereafter M92), and Martín et al. (1994, hereafter M94). These studies demonstrated for the first time that the majority of young stars have Li abundances consistent with the initial interstellar value, but that a significant number (about 30) stars are characterized by low or very low abundances. If real, the observed depletion level would imply large Li depletion ages ($\gtrsim$10 Myr), in excess of the bulk of the undepleted population ($\sim$1−3 Myr). However, the interpretation of the data remained controversial, since the measured Li abundances were not entirely consistent with the predictions of theoretical models. In particular, the lowest mass stars of the samples indicated too much Li destruction at the observed luminosity. In other words, these T Tauri stars were too young, as indicated by the isochronal ages, to have undergone significant nuclear burning and Li destruction. The interpretation of this result was not straightforward and the possible explanations invoked large uncertainties in the stellar parameters (effective temperature, luminosity, surface gravity), problems with model atmosphere used to derive Li abundances, and limitations of the PMS evolutionary models. More recently, Wichmann et al. (2000, hereafter W00) have presented a detailed analysis of the young population discovered by ROSAT in and near the Tau-Aur complex. Using high resolution echelle spectra, they measured lithium equivalent widths and used these measurements as a selection criterion for youth, expanding in this way the sample of candidate low-mass TTS of Tau-Aur. Since the knowledge of the properties of the stellar population of Tau-Aur has greatly increased in the last decade (e.g., Kenyon & Hartmann 1995; Briceño et al. 2002; Luhman et al. 2003; Güdel et al. 2007), and new atmospheric (e.g., Pavlenko et al. 2001) and evolutionary (Siess et al. 2000; Baraffe et al. 2002; D'Antona & Montalbàn 2003; Montalbàn & D'Antona 2006) models have been developed, the time is ripe for a careful re-analysis of the Li abundances in T Tauri stars in this important star forming region.

The structure of the paper is the following: in Sect. 2 we describe the sample, stellar parameters, method of analysis, and results obtained by B91, M92, M94 and W00; in Sect. 3 we present our new analysis of the sample and the resulting Li abundances based on updated stellar parameters and curves of growth (COGs). In Sect. 4 we address issues related to the origin of the Li-depleted stars, to the completeness of the sample and the possibility of a new survey aimed at discovering new Li depleted TTS. Section 5 closes the paper.

2. Lithium in Taurus-Auriga: previous observations

Our new analysis of the Li abundance of TTS in Tau-Aur is based on the results of the three major studies performed by B91, M92, M94 and on that by W00. Beside these studies, there have been other measurements of Li abundance in Tau-Aur in a small number of stars, addressing specific issues such as the influence of accretion on the Li line (e.g., Stout-Batalha et al. 2000) or the presence of accretion disks around Li-depleted stars (e.g., White & Hillenbrand 2005). Here, we summarize the observations and results obtained by B91, M92, M94, and W00.

Basri et al. (1991): the sample includes 49 classical and weak-lined T Tauri stars (CTTS and WTTS, respectively) of Tau-Aur. 28 of these were observed with the Hamilton echelle spectrometer at Lick Observatory, with a spectral resolution $R \sim 40\,000$; the remaining 21 stars were retrieved from Walter et al. (1988) and Strom et al. (1989) and observed with resolving powers between 10 000 and 24 000. Spectral-types of the whole sample are in the range G2-M0. For the estimate of effective temperatures ($T_{\rm eff}$), B91 adopted the conversion from spectral types by Cohen & Kuhi (1979), while the luminosity was taken from the literature. When necessary, measured Li equivalent widths (EW) of the 28 stars observed at Lick were corrected for veiling and the Li abundance was then derived using a code developed by Spite (see Spite & Spite 1982) and model atmospheres by Gustafsson (1982, private communication). Corrections for non-LTE effects were not taken into account in the analysis. The main results found by B91 are the following: (i) Li undepleted stars have an average Li abundance of $\log n(\mathrm{Li}) = 3.6 \pm 0.3$, larger (but consistent within the uncertainties) than the initial interstellar value and the maximum abundance in young main-sequence F and G stars ($\log n(\mathrm{Li}) = 3.1 \pm 0.2$, Randich et al. 2001); (ii) about 1/3 of the stars show large amount of Li depletion, much larger than predicted by models; most of these stars are cooler than 4000 K; (iii) the Li pattern of CTTS and WTTS is indistinguishable. B91 discuss the large uncertainties in the stellar parameters and model atmospheres appropriate for TTS and conclude that they represent a fundamental limitation for the determination of accurate and reliable Li abundances.

Magazzù et al. (1992): M92 analyzed a sample of 13 stars in Tau-Aur; for three of them (BP Tau, V410 Tau, GM Aur) they obtained new spectra with the Intermediate Dispersion Spectrograph (IDS) at Isaac Newton Telescope (INT), providing a resolution $R \sim 20\,000$. The remaining stars were retrieved from Walter et al. (1988) and are in common with the sample of B91. Note that, while B91 considered for their analysis the maximum Li EW given by Walter et al., M92 instead took an average of the minimum and maximum values. To estimate $T_{\rm eff}$, M92 used the calibration by de Jager & Nieuwenhuijzen (1987), while the luminosities were adopted from the literature. M92 performed veiling corrections for BP Tau and GM Aur with the same technique of B91, but employed a different method for the determination of Li abundances. Specifically, they extrapolated Gustafsson models atmospheres to higher atmospheric levels, where the optical depth of the Li line is below 0.05, and solved the non-LTE problem for the Li line in the $\log n(\mathrm{Li})$ range covered by their stars. COGs were then computed in both NLTE and LTE in the $T_{\rm eff}$ interval 4000−5000 K and extrapolated for lower temperatures. For all but one Taurus members the non-LTE abundances resulted higher than the LTE value by $\sim$0.3−0.6 dex. In spite of these upward correction, M92 also found examples of depleted stars (factors up to $\sim$100). Unlike B91, the average interstellar abundance was found to be $\log n(\mathrm{Li}) = 3.2 \pm 0.3$, consistent with the meteoritic value.

Martín et al. (1994): M94 carried out new observations of 32 CTTS and WTTS Taurus members/candidates using the IDS spectrograph at the INT, ISIS at the William Herschel telescope, and IACUB at the Nordic Optical Telescope. The spectral resolution varied between $R \sim 10\,000$ and 30 000. To this sample they added 23 stars retrieved from the literature, for a total of 55 stars. Three stars were then discarded from the sample due to their too strong Hα emission and veiling, while abundances for another two were not given because they were too cold. As M92, they adopted the temperature scale of de Jager & Nieuwenhuijzen (1987) taking into account both spectral-type and luminosity. Luminosities for most of the stars were retrieved from the literature, while for a few stars were calculated by M94 using their own photometry. Since the sample included only WTTS, M94 did not need to correct measured EWs for veiling effects. Li abundances were computed both in LTE and non-LTE using the same extrapolation method of M92, but model atmospheres by Kurucz, rather than those of Gustaffson. According to M94, their COGs were more accurate than those of M92; they found that NLTE corrections are typically below ~+0.1 dex, much smaller than the error bars due to the uncertainty in the stellar parameters (~0.2–0.3 dex). Overall, M92 found an average value for the sample of $\log n(\mathrm{Li})$ 3.1–3.2, thus confirming the correspondence with the meteoritic value and settling the problem of the high abundance initially determined by B91. The large majority of the TTS showed Li abundances in the range 2.9–3.4, with a tail in the distribution of Li-depleted objects (15% of the total). In particular, all stars with luminosity $\log L < 0.5\ L_{\odot}$ were characterized by $\log n(\mathrm{Li}) < 2.4$, corresponding to depletion factors greater than 5.

Wichmann et al. (2000): W00 identified a sample of 22 PMS candidate members of Tau-Aur, covering spectral range from G1 to M1.5. These stars were selected on the basis of the X-ray properties, Li-equivalent widths, and proper motion. Spectra were obtained with ELODIE at the Observatoire de Haute Provence with a resolution of ~40 000. W00 measured Li *EW*s, but did not attempt to derive abundances on the assumption that the latter were uncertain and model dependent. They also assigned spectral types based on the previous analysis of Wichmann et al. (1996) and identified the PMS candidates by their position in the effective temperature-equivalent width diagram and comparison with the Pleiades distribution. Since in several cases the measured *EW*s were rather low (less than ~200 mÅ), suggesting some level of Li depletion, it is important to compute accurate Li abundances also for this group of WTTS.

2.1. Previous results on lithium abundances

The three major studies by B91, M92, and M94 described above have allowed the determination of Li abundances in 76 stars of the Tau-Aur association, 21 CTTS and 55 WTTS. Their properties are listed in Table 1 where for each star we give a sequential number, name, class (c = classical, w = weak-lined), spectral type, effective temperature, luminosity, surface gravity, *EW*(Li), Li abundance from literature, reference, our newly derived Li abundances, and method used by us to derive $\log n(\mathrm{Li})$. Note that our determination of the Li abundance has been done using both the original values of the stellar parameters listed by the authors and our own most recent compilation (partially presented in Güdel et al. 2007, see below). This explains the multiple entries for each star given in Table 1. In addition, 24 stars have been observed more than once by different groups and all the values of *EW*(Li) and $\log n(\mathrm{Li})$ are listed in the table: apart from few exceptions, the derived abundances are mutually consistent within the uncertainties.

Overall, the studies by B91, M92, and M94 have proved that most TTS of Tau-Aur have Li abundances close to the initial interstellar value. However, there are 40 measurements of the Li abundance in 31 stars below a value of $\log n(\mathrm{Li}) = 2.6$ which we set (rather conservatively) as the threshold between depleted and undepleted stars, considering the uncertainty in the derived values. Of these 31 stars, 24 are WTTS and 7 CTTS (including DE Tau, DF Tau, DG Tau, HL Tau, UZ Tau W, GM Aur, and DR Tau). The amount of depletion varies between 3 and 60 and in four cases only upper limits on $\log n(\mathrm{Li})$ could be measured, indicating depletion factors much greater than 20. In four cases (035135+2528SE, Lk Ca 3, Lk Ca 4, and Lk Ca 7), the Li abundance derived by different authors for the same star is quite discrepant (up to a factor of 10), beyond the uncertainty of the individual measurements.

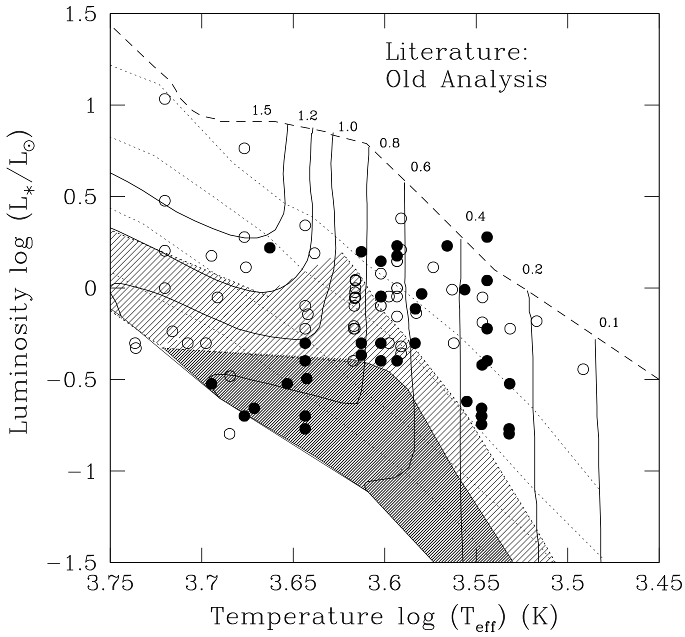

Fig. 1. HR diagram for low-mass stars in Taurus Auriga and location of the expected Li depletion region. Evolutionary tracks for masses between 0.1 and 1.5 $M_{\odot}$ are indicated, as well as the birthline and isochrones of 1, 5, 10, and 30 Myr. The ZAMS is also shown. The hatched regions indicate different levels of predicted lithium depletion: $\log n(\mathrm{Li})$ down to 1/10-th of the initial value (light gray) and below 1/10-th (dark gray). The stars were observed by B91, M92, and M94, and we adopted here stellar parameters and Li abundances from the source papers ($\log n(\mathrm{Li})$ computed under LTE assumptions by M92 and M94). Filled circles represent Li-poor stars ($\log n(\mathrm{Li}) \leq 2.6$), while the open ones are Li-rich stars.

The distribution in the HR diagram of the 31 TTS stars with $\log n(\mathrm{Li}) \leq 2.6$ is shown in Fig. 1, along with the birthline, evolutionary tracks and isochrones from Palla & Stahler (1999). In addition, Fig. 1 displays the location of the predicted Li depletion region, according to the models of Siess et al. (2000): the lightly shaded gray region is for stars that have depleted up to 1/10th of the initial Li content, while the dark gray zone is for depletion factors greater than 10. In the figure, filled symbols indicate stars with $\log n(\mathrm{Li}) \leq 2.6$, while open symbols are for stars with $\log n(\mathrm{Li}) > 2.6$. Note that the distribution in the HR diagram would not change significantly by adopting NLTE or non-LTE values. Among the 31 Li depleted stars, five of them are in the region of expected partial depletion and five in that of complete depletion. Interestingly, the position of the five stars (034903+2431, 035135+2528NW, 035135+2528SE, 041529+1652, and 042835+1700) with depletion factors greater than 10 is consistent with the derived value of $\log n(\mathrm{Li})$ (between 1.1 and 2.3). Two of these stars (034903+2431 and 042835+1700) have multiple values of stellar parameters and of $\log n(\mathrm{Li})$ that place them also in the region of partial depletion, but close to the border of complete destruction. The other three stars (VY Tau, 041559+1716, and IP Tau) that fall in the light gray region have values of $\log n(\mathrm{Li})$ consistent with the theoretical prediction. The remaining 21 stars with $\log n(\mathrm{Li}) \leq 2.6$ are distributed in the portion of the HR diagram where the luminosity is too high for any Li burning in the center. This fact highlights the basic problem of the interpretation of the survey by B91, M92 and M94, justifying a more refined assessment of both the stellar parameters and lithium abundances, as we now discuss.

3. Lithium in low-mass stars of Tau-Aur

3.1. New analysis of B91, M92, and M94

Our new analysis of the available data consists of two steps. In the first one, we recomputed the Li abundance using the input values for the stellar parameters ($T_{\rm eff}$, L, and surface gravity) and EWs provided by the authors. In the second step, we adopted the set of stellar parameters recently compiled by one of us (F.P.) for the study of the overall population of Tau-Aur and described in several papers (Palla & Stahler 2000; Luhman et al. 2003; Güdel et al. 2007). The values of the stellar parameters are also listed for each star in Table 1, with the exception of two objects (035120+3154 and 045230+1746). We note that the recent work by Bertout et al. (2007) on the membership of a subsample of TTS of Tau-Aur has 47 objects in common with our sample for which they derived accurate estimates of the stellar parameters. In most cases their values agree with ours, but discrepancies in spectral-type (and $T_{\rm eff}$) and/or luminosity are found for about 10 stars. These objects will be further discussed in Sect. 3.6. Finally, for the calculation of derived quantities, such as mass (and thus surface gravity), we used the PMS evolutionary models of Palla & Stahler (1999).

For the determination of the Li abundance, we have proceeded in different ways, depending on the effective temperature: (a) for stars with $T_{\rm eff} \geq 3800$ K, we used both the spectral analysis code MOOG (Sneden 1973–2002 version) with model atmospheres by Kurucz (1995) and (b) the COGs by Soderblom et al. (1993) or their extrapolation for stars with $3800 \lesssim T_{\rm eff} \lesssim 4000$ K; (c) stars cooler than 3800 K were analyzed with COGs constructed by us and based on spectra provided by Ya. Pavlenko (private communication; a partial set of COGs has been published by Palla et al. 2007). The synthetic spectra cover a grid of parameters from 3000 to 3800 K in $T_{\rm eff}$ (100 K steps), from 3 to 5 in $\log g$ (0.5 dex steps), and from −1 to 3.5 in $\log n$(Li) (0.5 dex steps). Different sets of COGs were computed depending on the spectral resolution of the original data from each author: in particular, $R = 40\,000$ for the B91 data, $R = 20\,000$ for M92, $R = 10\,000/20\,000/30\,000$ for M94. Note that at the time when B91, M92, and M94 studies were performed, researchers were referring to EWs rather than to pseudo-EWs (pEWs), i.e. equivalent widths of atomic absorption lines measured with respect to the pseudocontinuum formed by the haze of molecular lines (Pavlenko 1997). In our case, the COGs were derived based on measurement of pEWs on synthetic spectra convolved to the different resolutions. Li abundances were then derived from COGs (see Palla et al. 2007, for details) under the assumption that the quoted EWs in the literature studies were indeed pEWs. Note that, since synthetic spectra were available for $-1 \leq n(\mathrm{Li}) \leq 3.5$, for several stars cooler than 3800 K we were able to provide only a lower limit $\log n(\mathrm{Li}) > 3.5$ to Li abundances.

The resulting Li abundances and method used by us are given in the last two columns of Table 1.

3.2. Errors

Errors in derived abundances are usually due to uncertainties in stellar parameters (with the major contribution coming from errors in $T_{\rm eff}$) and EWs or pEWs. Given our approach, we do not consider here uncertainties in stellar parameters, since abundances computed with the different sets of stellar parameters already provide an idea of the systematic and random errors involved. On the other hand, when the uncertainty in EWs is available from the source paper, we estimated the corresponding error in n(Li) and list it in Table 1.

As to other sources of systematic errors, we warn that the COGs by Soderblom et al. (1993) were derived assuming $\log g = 4.5$ and $\xi = 1.0$ km s^{-1}, since they were optimized for main sequence stars (F, G, and K-type). On the other hand in the MOOG analysis, we have adopted the $\log g$ values listed in Table 1 and a microturbulent velocity $\xi = 1.5$ km s^{-1}, in agreement with literature estimates for PMS stars in the $T_{\rm eff}$ range ∼4000–5000 K (D'Orazi et al. 2008). For stars with $T_{\rm eff} \sim 4000$ K up to 5000 K a change in ξ of ±0.5 km s^{-1} results in a difference of ∼±0.04–0.08 dex in $\log n$(Li). Also, differences of ±1.0 dex in $\log g$ reflect into $\Delta\log n$(Li) of up to ∼∓0.15 dex. Therefore, the possible errors introduced by using the COGs by Soderblom et al. (1993) can be as large as ∼0.15–0.20 dex. For this reason, Li abundances computed with MOOG are probably more reliable (particularly in cases when $\log g$ significantly differs from 4.5), although the quoted uncertainties are comparable to the errors in $\log n$(Li) and are not critical to distinguish if a star is strongly Li depleted or not. We note, however, that for stars with $\log g \sim 4.5$ the abundances derived with MOOG are systematically higher than those derived with Soderblom's COGs and they would be even higher if assuming a $\xi = 1.5$ km s^{-1}. While in most cases this offset does not affect our conclusions, we will discuss in detail the few stars that turn out to be Li depleted/undepleted if considering Soderblom or MOOG abundances, respectively.

3.3. Li-abundance using the original stellar parameters

Here we present the results of the calculation of $\log n$(Li) using as input values the stellar parameters provided by the authors. The new $\log n$(Li) are listed in the last two columns of Table 1 where we give the numerical value and the method used to derive the abundance. For each star we also give a value of the error on $\log n$(Li) as derived from the uncertainty in the EW. It turns out that the derived error is the same for abundances derived with MOOG and the COGs by Soderblom. The main finding of the new analysis is that the values of $\log n$(Li) are systematically higher than in the original derivations (discussed in Sect. 2.1). The average change is about +0.2–0.3 dex, but in a few cases differences by an order of magnitude are found. Therefore, the net result is a substantial decrease of the number of Li-depleted stars. In particular, only 13 stars remain with $\log n$(Li) below the threshold value of 2.6. Interestingly, all of them are WTTs, but DR Tau. Because of the difference between the abundances derived using MOOG or the COGs by Soderblom, the number of Li-depleted stars is 5 in the former case and 8 for the latter. Finally, the 5 coldest and least luminous TTS of the sample are confirmed as strongly Li-depleted using Pavlenko's analysis. The distribution in the HR diagram of the Li depleted and undepleted TTS is displayed in Fig. 2. Lines are used to connect the same star with different values of (L, $T_{\rm eff}$), as given by the authors. Comparison with Fig. 1 immediately reveals that the major inconsistency found in Sect. 2 is removed: all the stars in the upper portion of the diagram where no depletion is expected to occur have $\log n$(Li) consistent with the interstellar value. In addition, several TTS that lie close to the region of partial depletion in Fig. 1 are removed. On the other hand, the group of 5 stars of with spectral type M1–M2 and very low luminosity indeed remains Li-depleted at levels inconsistent with the position in the HR diagram. Similarly, there is one early-type (K1) and bright ($\log L = 1.66\,L_\odot$) star, 042417+1744, with $\log n(\mathrm{Li}) = (2.62, 2.32) \pm 0.36$ which is marginally Li-depleted, considering

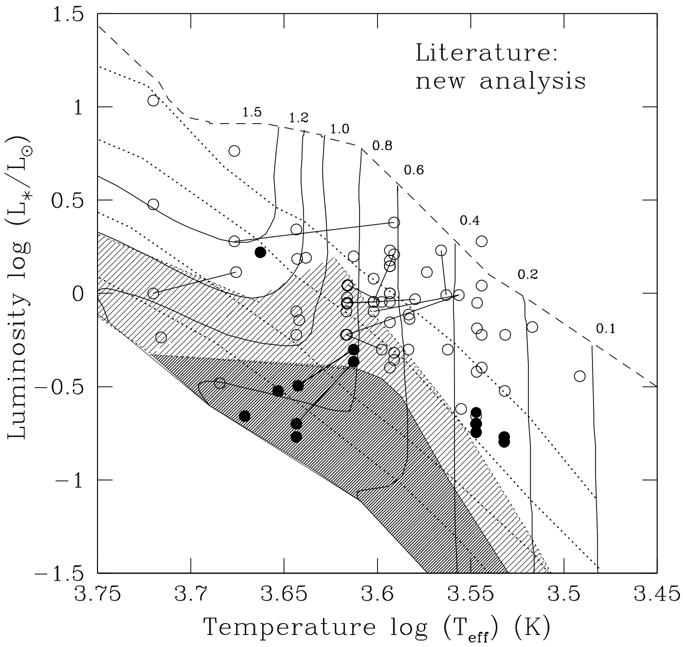

Fig. 2. Distribution of WTTS and CTTS of Tau-Aur as in Fig. 1, but with Li abundances computed by us using stellar parameters from the source papers and updated COGs. Stars with multiple values of $\log n(\mathrm{Li})$ are connected by a line. Filled dots represent stars with $\log n(\mathrm{Li}) \leq 2.6$. Note the large decrease of Li-depleted TTS compared to Fig. 1.

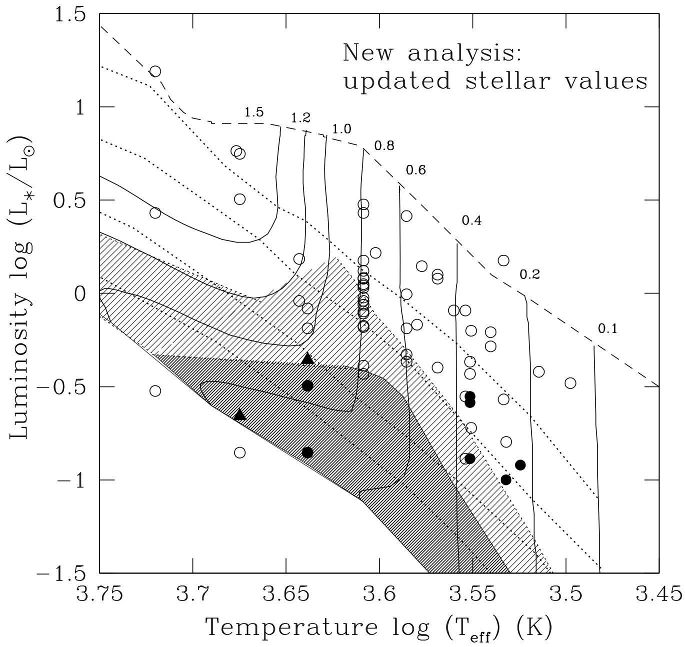

Fig. 3. As in Fig. 2, but with updated stellar properties. Filled circles refer to bona fide Li-depleted stars, while triangles are for marginally Li-depleted objects. Note the further improvement in the location of the Li-depleted and undepleted (empty circles) stars.

the large uncertainty. Finally, five stars in the dark-gray region are confirmed to be Li depleted in the new analysis. Overall, these results suggest that the strong and unexpected Li depletion found by B91, M92, and M94 for low-mass TTS is an artifact of the analysis and the associated uncertainties.

3.4. Li-abundance using updated stellar parameters

In order to improve our analysis, we have examined the individual values of luminosity and effective temperature of each star using more recent compilations available in the literature and a homogeneous temperature scale for the conversion from spectral type to effective temperature. In practice, we have used the data collected by one of us (F.P.) on the overall population of TTS in Tau-Aur and available in Palla & Stahler (2000) and Güdel et al. (2007). The latter represents a survey made with the XMM-Newton satellite of the X-ray properties of a large sample of TTS of Taurus, distributed along the major star forming sites (i.e. the filaments) of the molecular complex. Güdel et al. (2007) provide comprehensive tables that summarize the stellar properties of all the target stars. In this way, we have been able to provide recent values of (L, T_{eff}) for all the stars listed in Table 1. For the temperature scale, we have used the conversion of Kenyon & Hartmann (1995) for spectral types down to M0 and that of Luhman (1999; intermediate scale) for later type stars. The new values are listed for each star in the last rows of Table 1, along with the estimate of the surface gravity computed using the PMS evolutionary models of Palla & Stahler (1999).

The main result of the exercise is the further reduction in the number of reliable Li-depleted stars. We find only 9 stars (and 14 measurements) below the threshold value of $\log n(\mathrm{Li}) = 2.6$. Note that we do not consider V410 Tau as depleted, since there is only one measurement below the threshold and it is affected by a large uncertainty in the *EW*. Also, as mentioned, in two cases (034903+2437, 035135+2528NW) the analysis from MOOG and Soderblom gives discordant results, with the former slightly above the threshold for Li-depletion. Considering this uncertainty, the new analysis shows that there are only 7 WTTs out of the original sample of 76 stars of Tau-Aur with secure indication of severe Li-depletion. These stars are: 040047+2603W, 040047+2603E, 040142+2150SW, 040142+2150NE, 040234+2143, 041529+1652, and 042835+1700. The other four Li-depleted stars according to the analysis of the previous subsection are now removed from the list for the following reasons: 035135+2528SE, 042147+1744, and DR Tau had an effective temperature too low (4500 K, 4600 K, and 3920 K, respectively) for their spectral types (K0 = 5250 K, K1 = 5080 K, K7 = 4060 K); the luminosity, and thus the surface gravity, of Anon 1 has changed from 0.77 $L_\odot$ to 2.60 $L_\odot$.

The new distribution of all the 76 TTS in the HR diagram is shown in Fig. 3. Only three stars fall in the region of full depletion, 2 in the region of partial depletion, and 4 are outside (but close to the boundary of) the locus of Li-burning. The Li-depletion factor varies between ~5 and ≫1000. As seen in Fig. 3, the Li-depleted stars are divided in two groups: one with spectral types K3−K5 falling in the fully depleted region, and one with late types (M2−M3) close to the partial depletion region. For the first group, the observed Li-abundance is consistent with the theoretical prediction for solar-type stars, with the exception of 035135+2528NW, that should be much more depleted for its luminosity. This result, however, is not completely unexpected: on the one hand, as mentioned in Sect. 1, the predicted amount of Li depletion for stars more massive than ~0.6 $M_\odot$ is model dependent; on the other hand, we note that K-type stars in the 30−50 Myr old clusters IC 2602 and IC 2391 are much less Li-depleted than predicted by models (Randich et al. 2001) and have Li abundances $\log n(\mathrm{Li}) \sim 2{-}2.5$, comparable to that of 035135+2528NW. We conclude that, taken at face value, the implied isochronal ages of Li-depleted K-type stars exceed 10 Myr and the Li ages might be even older, up to ~30 Myr: these stars

Table 2. Li abundances in T Tauri stars of Taurus-Auriga: Wichmann et al. (2000) sample.

#	Star RX J	Sp.T.	$T_{\rm eff}$ (K)	L ($L_\odot$)	$\log g$	EW (Å)	n(Li)	Method
1	0403.3+1725	K3	4730	0.65	4.38	0.49 ± 0.03	(3.97, 3.71) ± 0.10	a, b
2	0405.3+2009	K1	5080	1.55	4.12	0.35 ± 0.03	(4.00, 3.57) ± 0.18	a, b
3	0405.7+2248	G3	5830	3.16	4.08	0.25 ± 0.03	(4.31, 3.72) ± 0.24	a, b
4	0406.7+2018	G1	5945	2.51	4.16	0.21 ± 0.03	(4.04, 3.54) ± 0.21	a, b
5	0409.1+2901	K1	5080	1.29	4.17	0.41 ± 0.03	(4.31, 3.93) ± 0.17	a, b
6	0409.2+1716	M1	3705	0.26	3.92	0.30 ± 0.03	0.15± 0.20	c
7	0409.8+2446	M1.5	3632	0.23	3.91	0.23 ± 0.03	<0.0	c
8	0412.8+1937	K6	4205	0.49	4.14	0.43 ± 0.03	(3.01, 2.72) ± 0.11	a, b
9	0420.3+3123	K4	4590	0.28	4.49	0.37 ± 0.03	(3.24, 2.97) ± 0.17	a, b
10	0423.7+1537	K2	4900	0.71	4.30	0.36 ± 0.03	(3.72, 3.38) ± 0.19	a, b
11	0424.8+2643	K1	5080	2.09	4.04	0.41 ± 0.03	(4.34, 3.93) ± 0.16	a, b
12	0435.9+2352	M1.5	3632	0.49	3.54	0.49 ± 0.03	2.54 ± 0.30	c
13	0437.2+3108	K4	4590	0.34	4.41	0.36 ± 0.03	(3.19, 2.91) ± 0.17	a, b
14	0438.2+2023	K2	4900	0.49	4.51	0.32 ± 0.03	(3.49, 3.12) ± 0.14	a, b
15	0438.2+2302	M1	3705	0.14	4.21	0.19 ± 0.03	0.57 ± 0.27	
16	0438.4+1543	K3	4730	0.21	4.63	0.38 ± 0.03	(3.45, 3.25) ± 0.16	a, b
17	0438.6+1546	K1	5080	1.45	4.14	0.42 ± 0.03	(4.34, 3.99) ± 0.14	a, b
18	0441.8+2658	G7	5630	2.45	4.09	0.23 ± 0.03	(3.91, 3.36) ± 0.22	a, b
19	0445.8+1556	G5	5770	4.79	3.93	0.36 ± 0.03	(5.04, 4.46) ± 0.20	a, b
20	0457.0+1517	G3	5830	1.35	4.36	0.20 ± 0.03	(3.84, 3.36) ± 0.20	a, b
21	0457.2+1524	K1	5080	1.86	4.07	0.45 ± 0.03	(4.17, 4.12) ± 0.10	a, b
22	0458.7+2046	K7	4060	0.47	4.04	0.45 ± 0.03	(2.92, 2.66) ± 0.10	a, b

Method – a: MOOG; b: COGs by Soderblom et al. (1993); c: our own COGs.

might thus represent the tail of the much younger population of Tau-Aur.

The situation for the second group of stars is completely different, since they show much larger amounts of Li-depletion for their luminosity. These stars have estimated mass ~0.2–0.4 $M_\odot$ and thus should have fully convective interiors for which the theoretical predictions for Li-burning and depletion are quite robust and model independent (e.g., Bildsten et al. 1997). In order to reconcile the Li-measurements with the stellar properties, the latter should be incorrect by large factors (more than 200 K in temperature and a factor of 3–4 in luminosity). Although large, such uncertainty is possible for these poorly studied WTTs.

3.5. Li-abundance of the Wichmann et al. sample

We have computed the Li abundance for the 22 candidate PMS stars identified by W00 following the same method described in Sect. 3.1. Namely, for stars cooler than 3800 K we have used the COGs based on Pavlenko's models, while for hotter stars we have employed both MOOG and the COGs by Soderblom et al. (1993). The stellar properties and derived $\log n$(Li) are listed in Table 2. Spectral type, luminosity and EW(Li) have been taken from W00, while for the temperature scale and the derivation of surface gravity we have proceeded as in Sect. 3.1. The analysis shows that only four WTTS have Li abundances well below the initial value. These stars are the coolest of the sample and their position in the HR diagram is displayed in Fig. 4, along with the other WTTS. In three cases, the amount of Li-depletion is marginally consistent with the predictions of theoretical models, while the fourth star (RX J0435.9+2352) that lies above the Li-depletion region has a value of $\log n$(Li) $\simeq 2.6 \pm 0.3$. In this respect, the situation is similar to that found for the five low-mass, Li-depleted stars shown in Fig. 3. The fact that all the other stars of the W00 sample do not show evidence for Li-depletion is not too surprising considering that the selection criterion used for the identification of the candidate TTS was the presence of the Li absorption line with an equivalent width greater than 100 mÅ. What is more surprising is the high values of the derived $\log n$(Li) obtained with both methods, in most cases well in excess of the standard interstellar value. We explain this result as due to poor measurements of the intrinsic EWs for stars that are rapid rotators. In fact, most of the stars listed in Table 2 have values of $v \sin i$ greater (or much greater) than 10–20 km s^{-1}. Viceversa, three of the Li-depleted stars are slow rotators ($v \sin i \sim 6$–8 km s^{-1}), hence their EW measurements are more reliable. On the other hand, the fourth Li-depleted star, RX J0409.2+1716, is a fast rotator, but the nature of the system is uncertain (possibly an SB2 system according to W00).

3.6. Comparison with the sample of Bertout et al. (2007)

As anticipated in Sect. 3, Bertout et al. (2007) have studied a group of about 70 stars of Tau-Aur with known parallaxes, belonging to a newly identified moving group (see Genova & Bertout 2006). For all of them, they have re-derived photospheric luminosities, while most spectral-types and effective temperatures were taken from Kenyon & Hartmann (1995). Overall, there are 47 stars in common with our sample, 43 of those listed in Tables 1 and 4 from W00. In most cases, the stellar parameters are very similar to those adopted by us and the difference does not affect the derivation of the Li abundance. Significantly, all of the Li depleted stars in common with Bertout et al. (2007) have the same values of L and $T_{\rm eff}$.

However, there are 13 stars for which the discrepancy with our values is quite large, beyond the error uncertainty in the determination of both luminosity and spectral types. To evaluate the impact on the determination of the Li abundance, we have recomputed $\log n$(Li) for all of them, assuming $T_{\rm eff}$ values and luminosities given by Bertout et al. The resulting values are listed in Table 3, with the usual notation for the abundances derived with MOOG, Soderblom et al., and with our COGs. We find that

Table 3. Stars with discrepant stellar parameters in Bertout et al. (2007). $n(\mathrm{Li})_{\mathrm{BSC}}$ indicates Li abundances computed using stellar parameters (T_{eff}, L) of Bertout et al.

#	Star	Sp.T.	T_{eff} (K)	L ($L_\odot$)	$\log g$	EW (Å)	$n(\mathrm{Li})_{\mathrm{BSC}}$	Method
1	Hubble 4	K7	4060	0.48	4.05	0.61	3.33, 3.08	a, b
2	V410 Tau ABC	K4	4730	1.41	4.07	0.42	3.83, 3.45	a, b
						0.57	4.33, 3.96	a, b
3	RY Tau	K1	5080	6.59	3.72	0.27	3.48, 2.99	a, b
4	IP Tau	M0	3850	0.34	3.98	0.50	2.87, 2.65	a, b
5	V927 Tau AB	M3	3470	0.60	3.25	0.51	3.52	c
6	043124+1824	G8	5520	2.93	4.03	0.31	4.42, 3.84	a, b
						0.23	3,78, 3,23	a, b
7	DR Tau	K7	4060	1.97	3.43	0.46	3.16, 2.69	a, b
8	GM Aur	K3	4730	1.23	4.11	0.50	4.14, 3.74	a, b
						0.59	4.38, 4.02	a, b
9	RW Aur A	K4	4590	1.72	3.95	0.67	4.36, 3.88	a, b
10	RX J0405.7+2248	G0	6030	5.47	3.95	0.25	4.53, 3.93	a, b
11	RX J0406.7+2018	F8	6200	3.78	4.12	0.21	4.29, 3.78	a, b
12	RX J0423.7+1537	G5	5770	1.00	4.46	0.36	4.89, 4.46	a, b
13	RX J0457.0+1517	G0	6030	1.75	4.34	0.20	4.01, 3.55	a, b

Method – a: MOOG; b: COGs by Soderblom et al. (1993); c: our own method.

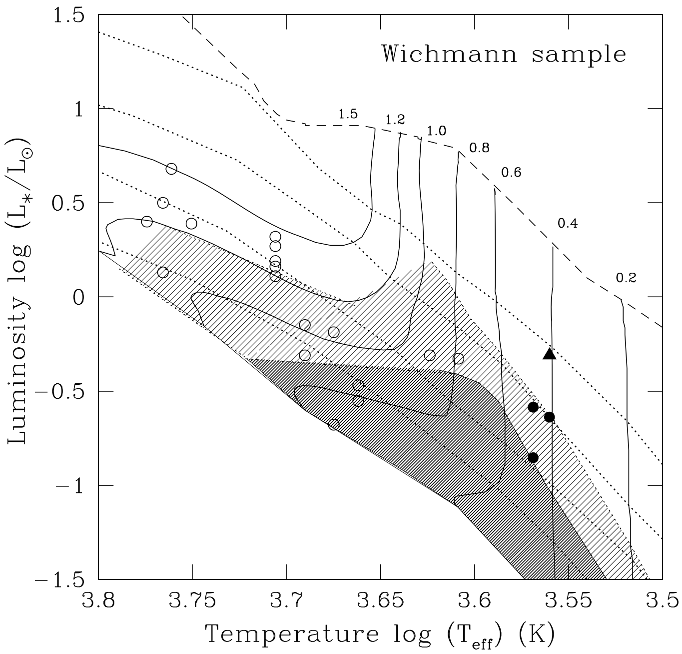

Fig. 4. Location in the HR diagram of the 22 WTTS from Wichmann et al. (2000). As in Fig. 3, the Li-depleted stars are shown by the filled symbols.

even with the new parameters the derived abundances are consistent with the initial interstellar value. Therefore, we conclude that there are no Li depleted stars in addition to those already discussed in the previous sections.

4. Li-depleted stars of Tau-Aur

Overall, our new determination of Li abundances has shown that of the about 100 low-mass stars of Tau-Aur with Li *EW* measurements, only 13 objects can be considered bona-fide Li-depleted, i.e. with values of $\log n(\mathrm{Li})$ lower than 2.6. A summary of the properties of these stars is given in Table 4, where in addition to the quantities introduced in Tables 1 and 2 we give the radial velocity (from Walter et al. 1988; Hartmann et al. 1986; W00), the proper motion (from Doucourant et al. 2005), and the kinematic membership to the Tau-Aur moving group (from Bertout & Genova 2006). All of the Li-depleted stars are WTTS drawn from X-ray selected surveys (*Einstein* for Walter et al. 1998; and *ROSAT All Sky Survey* for Wichmann et al. 2000) and are widely dispersed across the complex, away from the main star forming sites. The few exceptions are 041529+1652 and 042835+1700 in the area of the L1551 region; RX J0435.9+2352 and RX J0438.2+2302 in the L1536 region. This raises the question on the origin of this small group of Li-depleted stars, and in particular whether they can be considered as members of Tau-Aur. In fact, we note that ten out of 13 stars have radial velocities between 14 and 17 $\mathrm{km\,s^{-1}}$ (see Table 4), consistent with membership since the distribution of the overall population is strongly peaked at 16−17 $\mathrm{km\,s^{-1}}$ (Walter et al. 1988; Hartmann et al. 1986). Of these ten stars, five have proper motions (also listed in Table 4) consistent with membership according to the analysis by Bertout & Genova (2006) who identified a Tau-Aur moving group on kinematic grounds. Only three of them (040047+2603E, 041529+1652, 042835+1700) belong to the moving group, while there is no information on the other two stars (RX J0409.2+1716 and RX J0435.9+2352). Interestingly, the three kinematic members are located near the L1551 and L1489 dark clouds and may represent the earliest stars that formed within these units.

Several of the other seven stars that are non-kinematic members of the moving group according to the proper motion analysis have radial velocities consistent with membership to the Tau-Aur association and are located away from the current sites of star formation. Briceño et al. (1997) have argued that the majority of the dispersed population of X-ray active stars is the result of different star formation episodes in a variety of star forming sites that have spread with time over large distances. However, they concluded that in addition there could be a few, widely dispersed and relatively young PMS stars selected on the basis of their X-ray and Li properties that had been missed by previous searches limited to the boundaries of the molecular cloud complex. The small group of Li-depleted stars discussed here could be an example of such a population.

We conclude that the low Li abundance and the kinematic properties, along with the position in the HR diagram, confirm

Table 4. Properties of the Li-depleted stars of Taurus-Auriga.

#	Star	Sp.T.	$T_{\rm eff}$	L	log g	EW	n(Li)	Method	$V_{\rm rad}$	PM		Memb.
										$\mu_\alpha \cos\delta$	μ_δ	
			(K)	($L_\odot$)		(Å)			(km s^{-1})	(mas/yr)	(mas/yr)	
1	NTTS034903+2431	K5	4350	0.44	4.30	0.37 ± 0.08	(2.93, 2.62) ± 0.20	a, b	9.8	20	−48	N
						0.33 ± 0.02	(2.70, 2.38) ± 0.14	a, b				
						0.31 ± 0.02	(2.57, 2.25) ± 0.14	a, b				
						0.35 ± 0.02	(2.81, 2.50) ± 0.13	a, b				
2	NTTS035135+2528NW	K3	4730	0.2	4.60	0.22	2.51, 2.17	a, b	9.9	–	–	–
						0.24 ± 0.01	(2.65, 2.30) ± 0.08	a, b				
3	NTTS040047+2603W	M2	3560	0.28	3.78	<0.07	<−0.30	c	14.4	27	−36	N
4	NTTS040047+2603E	M2	3560	0.26	3.88	<0.06	<−0.50	c	14.4	6	−23	Y
5	NTTS040142+2150SW	M3.5	3345	0.12	3.78	<0.25	<1.34	c	16.2	−11	8	N
6	NTTS040142+2150NE	M3	3415	>0.05	<4.23	<0.30	<1.74	c	16.2	−17	0	N
7	NTTS040234+2143	M2	3560	0.13	4.06	0.34 ± 0.02	1.84 ± 0.17	c	16.7	31	11	N
8	RX J0409.2+1716	M1	3705	0.26	3.92	0.30 ± 0.03	0.15 ± 0.20	c	14.7	3	−11	Y
9	RX J0409.8+2446	M1.5	3632	0.23	3.91	0.23 ± 0.03	<0.0	c	10.9	30	−43	N
10	NTTS041529+1652	K5	4350	0.14	4.67	0.19 ± 0.01	(1.77, 1.46) ± 0.07	a, b	15.8	11	−14	Y
11	NTTS042835+1700	K5	4350	0.32	4.39	0.15	1.39, 1.24	a, b	16.7	10	−28	Y
						0.19 ± 0.04	(1.72, 1.46) ± 0.23	a, b				
						0.11 ± 0.01	(1.11, 1.01) ± 0.08	a, b				
12	RX J0435.9+2352	M1.5	3632	0.49	3.54	0.49 ± 0.03	2.54 ± 0.30	c	16.9	13	−23	Y
13	RX J0438.2+2302	M1	3705	0.14	4.21	0.19 ± 0.03	0.57 ± 0.27	c	15.7	−8	−16	N

Method – a: MOOG; b: COGs by Soderblom et al. (1993); c: our COGs.

the presence of a subpopulation of stars more evolved than the bulk of the Li-undepleted stars, but younger than the diffuse background population with ages ≲100 Myr.

4.1. Completeness of the sample

The sample of ~100 low-mass stars with accurate measurements of EW(Li) and log n(Li) represents about 1/3 of the known (candidate) members of Tau-Aur. According to our own compilation, the current tally includes about 300 members and the number is bound to increase as soon as follow-up observations of new candidates identified by *XMM-Newton* (Scelsi et al. 2007) and *Spitzer* (Rebull et al. 2007) will become available. Therefore, the conclusion of our abundance analysis on the small number of Li-depleted stars, although statistically significant, is still not conclusive. A rather large number of known members without lithium EW measurements do actually fall within or close to the Li-burning region in the HR diagram. As shown in Fig. 5, considering only stars with mass ≲0.6 $M_\odot$, there are more than 20 objects for which the determination of log n(Li) would be highly desirable.

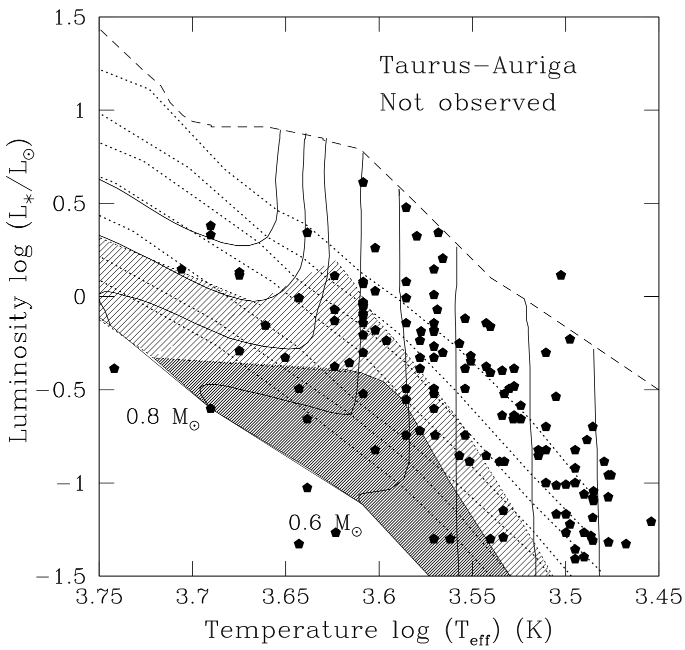

Fig. 5. The distribution in the HR diagram of the known population of low-mass stars of Tau-Aur without measurements of the Li abundance. The sample is based on the compilations by Palla & Stahler (2000) and Güdel et al. (2007).

5. Conclusions

We have computed Li abundance in a sample of ~100 T Tauri stars of Tau-Aur with published values of EW(Li) obtained from high resolution spectra. The Li abundance was derived using updated atmospheric models and a set of homogeneous stellar data as inputs. The most significant results are the following:

- The serious inconsistency found in previous studies on the relatively high number of Li-depleted of TTS at the wrong luminosity is removed. Only 13 stars have Li abundance below a value log n(Li) = 2.6, corresponding to depletion factors greater than five. We attribute the early findings to incorrect Li-abundance analysis and/or to the use of inconsistent stellar parameters.
- The majority of the Li-depleted stars lie in the HR diagram either within or close to the boundary of the theoretical region of Li-burning in low-mass stars. Conversely, most of the remaining stars with Li abundance consistent with the initial interstellar value are distributed in the appropriate portion of the HR diagram.
- Unlike previous results, none of the 21 CTTS included in the sample shows evidence for Li-depletion. On the other hand, all of the 13 Li-depleted stars are WTTS identified in X-ray surveys. Most of them belong to the widely dispersed population distributed away from (or at the periphery of) the main star forming sites. In several cases the radial velocity

and proper motions are consistent with membership to the Tau-Aur moving group.

- If located at the distance of Tau-Aur, the Li depletion and isochronal ages of the Li-depleted stars are in the range $\gtrsim 3-15$ Myr, greater than the bulk of the undepleted population.
- In order to draw firm conclusions on the Li-content of TTS in Tau-Aur, it is necessary to obtain high quality measurements of the remaining known members of the complex, which outnumber the group studied here by a factor ~3. In particular, a group of ~25 stars that lie inside the Li-burning region constitutes an interesting subsample that will be the subject of a future study.

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Table 1. Li abundances in T Tauri stars of Taurus-Auriga.

#	Star	Class	Sp.T.	$T_{\rm eff}$ (K)	L ($L_\odot$)	log g	EW (Å)	n(Li)$_{\rm lit}$	Ref.	n(Li)$_{\rm our}$	Method
1	032641+2420	w	K1	5100	0.5	4.5	0.47	4.3	B91	4.43, 4.14	a, b
			K1	4985	0.5	4.5	0.35 ± 0.02	3.4 ± 0.35	M94	(3.72, 3.37) ± 0.20	a, b
			K1	5080	0.5	4.5	0.47		us	4.41, 4.13	a, b
			K1	5080	0.5	4.5	0.35 ± 0.02		us	(3.92, 3.58) ± 0.12	a, b
2	034903+2431	w	K5	4400	0.50	4.3	0.37 ± 0.08	2.6 ± 0.30	B91	(2.92, 2.68) ± 0.22	a, b
			K5	4100	0.50	4.14	0.33 ± 0.02	1.73 ± 0.30	M92	(2.40, 2.14) ± 0.11	a, b
			K5	4391	0.32	4.45	0.31 ± 0.02	2.3 ± 0.35	M94	(2.62, 2.30) ± 0.15	a, b
			K5	4391	0.32	4.45	0.35 ± 0.02	2.3 ± 0.35	M94	(2.85, 2.56) ± 0.14	a, b
			K5	4350	0.44	4.30	0.37 ± 0.08		us	(2.93, 2.62) ± 0.20	a, b
			K5	4350	0.44	4.30	0.33 ± 0.02		us	(2.70, 2.38) ± 0.14	a, b
			K5	4350	0.44	4.30	0.31 ± 0.02		us	(2.57, 2.25) ± 0.14	a, b
			K5	4350	0.44	4.30	0.35 ± 0.02		us	(2.81, 2.50) ± 0.13	a, b
3	035120+3154SW	w	G0	5900	0.9	4.5	0.29	4.6	B91	4.58, 4.14	a, b
			G0	5943	0.77	4.63	0.13 ± 0.01	3.10 ± 0.35	M94	(3.23, 3.02) ± 0.10	a, b
			G0	6030	0.77	5.12	0.29		us	4.62, 4.26	a, b
			G0	6030	0.70	5.22	0.13 ± 0.01		us	(3.31, 3.10) ± 0.10	a, b
4	035120+3154NE	w	G5	5660	0.7	4.5	0.26	3.6	B91	4.14, 3.62	a, b
			G5	5200	0.58	4.78	0.26 ± 0.01	3.14 ± 0.29	M92	(3.62, 3.07) ± 0.09	a, b
			G5	5770	0.70	5.07	0.26		us	4.15, 3.74	a, b
			G5	5770	0.58	5.17	0.26 ± 0.01		us	(4.15, 3.74) ± 0.08	a, b
5	035135+2528NW	w	K3	4750	0.2	4.7	0.22	2.2	B91	2.54, 2.20	a, b
			K3	4690	0.22	4.60	0.24 ± 0.01	2.2 ± 0.35	M94	(2.59, 2.24) ± 0.08	a, b
			K3	4730	0.22	4.60	0.22		us	2.51, 2.17	a, b
			K3	4730	0.22	4.60	0.24 ± 0.01		us	(2.65, 2.30) ± 0.08	a, b
6	035135+2528SE	w	K2	4950	0.3	4.6	0.24	2.4	B91	3.02, 2.60	a, b
			K1	4500	0.30	4.46	0.23 ± 0.01	1.87 ± 0.29	M92	(2.21, 1.91) ± 0.07	a, b
			K2	4835	0.33	4.54	0.29 ± 0.1	2.7 ± 0.35	M94	(3.18, 2.80) ± 0.66	a, b
			K0	5250	0.34	4.73	0.24		us	3.44, 2.98	a, b
			K0	5250	0.34	4.73	0.23 ± 0.01		us	(3.38, 2.92) ± 0.08	a, b
			K0	5250	0.34	4.73	0.29 ± 0.1		us	(3.80, 3.35) ± 0.71	a, b
7	SAO 76411A	w	G1	5840	5.1	4.0	0.15	3.0	B91	3.36, 3.04	a, b
			G1	5945	5.1	3.9	0.15		us	3.44, 3.14	a, b
8	040012+2545N+S	w	K2	4839	0.16	4.81	0.36 ± 0.04	3.35 ± 0.35	M94	(3.49, 3.29) ± 0.20	a, b
			K2	4900	0.16	5.21	0.36 ± 0.04		us	(3.56, 3.38) ± 0.22	a, b
9	040047+2603W	w	M2	3524	0.20	3.90	<0.07	<−0.2	M94	<−0.50	c
			M2	3560	0.28	3.78	<0.07		us	<−0.30	c
10	040047+2603E	w	M2	3524	0.20	3.90	<0.06	<−0.2	M94	<−0.50	c
			M2	3560	0.26	3.88	<0.06		us	<−0.50	c
11	SAO 76428	w	F8	6000	3.0	4.1	0.18	3.4	B91	3.79, 3.38	a, b
			F8	6200	3.0	4.6	0.18		us	3.94, 3.56	a, b
12	040142+2150SW	w	M3	3404	0.17	3.69	<0.25	<0.50	M94	<1.44	c
			M3.5	3345	0.12	3.78	<0.25		us	<1.34	c
13	040142+2150NE	w	M3	3404	0.16	3.72	<0.30	<1.0	M94	<1.78	c
			M3	3415	>0.05	<4.23	<0.30		us	<1.74	c
14	040234+2143	w	M2	3524	0.18	3.90	0.34 ± 0.02	1.3 ± 0.35	M94	1.85 ± 0.16	c
			M2	3560	0.13	4.06	0.34 ± 0.02		us	1.84 ± 0.17	c
15	LkCa 1	w	M4	3288	0.66	3.11	0.56 ± 0.03	–	M94	>3.5	c
			M4	3270	0.38	3.34	0.56 ± 0.03		us	>3.5	c
16	V773 Tau A	w	K2	4750	5.80	3.63	0.47	3.9	B91	4.23, 3.69	a, b
			K3	4730	5.60	3.64	0.47		us	4.19, 3.65	a, b
17	LkCa 3	w	M1	3680	1.70	3.10	0.57	1.8	B91	>3.5	c
			M1	3657	0.98	3.33	0.55 ± 0.03	3.1 ± 0.35	M94	>3.5	c
			M1	3705	1.66	3.05	0.57		us	>3.5	c
			M1	3705	1.66	3.05	0.55 ± 0.03		us	>3.5	c
18	LkCa 4	w	K7	4000	0.90	3.73	0.51	2.6	B91	3.11, 2.80	a, b
			K7	4130	0.89	3.79	0.71 ± 0.04	3.3 ± 0.35	M94	(3.72, 3.31) ± 0.07	a, b
			K7	4130	0.89	3.79	0.51 ± 0.03	3.3 ± 0.35	M94	(3.29, 2.90) ± 0.09	a, b
			K7	4060	0.85	3.78	0.51		us	3.19, 2.85	a, b
			K7	4060	0.85	3.78	0.51 ± 0.03		us	(3.19, 2.85) ± 0.10	a, b
			K7	4060	0.85	3.78	0.71 ± 0.04		us	(3.61, 3.25) ± 0.06	a, b
19	LkCa 5	w	M2	3522	0.38	3.62	0.55 ± 0.03	2.5 ± 0.35	M94	>3.5	c
			M2	3560	0.37	3.65	0.55 ± 0.03		us	>3.5	c
20	041529+1652	w	K5	4400	0.17	4.61	0.19 ± 0.01	1.5 ± 0.35	M94	(1.82, 1.52) ± 0.06	a, b
			K5	4350	0.14	4.67	0.19 ± 0.01		us	(1.77, 1.46) ± 0.07	a, b

Table 1. continued.

#	Star	Class	Sp.T.	$T_{\rm eff}$ (K)	L ($L_\odot$)	$\log g$	EW (Å)	n(Li)$_{\rm lit}$	Ref.	n(Li)$_{\rm our}$	Method
21	V410 Tau ABC	w	K3	4750	1.90	3.69	0.42 ± 0.3	3.55 ± 0.1	B91	(3.98, 3.48) ± 0.15	a, b
			K7	3900	2.40	3.24	0.57 ± 0.05	2.76 ± 0.20	M92	(3.32, 2.86) ± 0.12	a, b
			K7	4060	1.50	3.52	0.42 ± 0.3		us	(2.97, 2.55) ± 0.13	a, b
			K7	4060	1.50	3.52	0.57 ± 0.05		us	(3.46, 2.99) ± 0.12	a, b
22	CZ Tau AB	w	M1	3590	0.24	3.83	0.46 ± 0.02	2.1 ± 0.35	M94	3.05 ± 0.15	c
			M3	3415	0.27	3.70	0.46 ± 0.02		us	3.00 ± 0.15	c
23	Hubble 4	w	K7	4133	0.95	3.75	0.61 ± 0.03	3.3 ± 0.35	M94	(3.55, 3.15) ± 0.07	a, b
			K7	4060	2.70	3.26	0.61 ± 0.03		us	(3.64, 3.08) ± 0.07	a, b
24	Anon 1	w	M0	3830	0.77	3.59	0.48 ± 0.02	2.6 ± 0.35	M4	(2.87, 2.57) ± 0.07	a, b
			M0	3850	2.60	3.07	0.48 ± 0.02		us	(3.07, 2.61) ± 0.07	a, b
25	041559+1716	w	K7	4000	0.5	4.0	0.53	2.6	B91	3.08, 2.85	a, b
			K7	3900	0.48	3.98	0.60 ± 0.08	2.70 ± 0.27	M92	(3.15, 2.92) ± 0.17	a, b
			K7	4142	0.4	4.14	0.46 ± 0.05	2.70 ± 0.35	M94	(3.04, 2.76) ± 0.25	a, b
			K7	4060	0.41	4.12	0.53		us	3.13, 2.90	a, b
			K7	4060	0.41	4.12	0.60 ± 0.08		us	(3.29, 3.06) ± 0.16	a, b
			K7	4060	0.41	4.12	0.46 ± 0.05		us	(2.92, 2.69) ± 0.17	a, b
26	BP Tau	c	K7	4000	0.90	3.73	0.69 ± 0.03	3.15 ± 0.1	B91	(3.49, 3.17) ± 0.06	a, b
			K7	3900	1.62	3.42	0.62 ± 0.04	2.94 ± 0.23	M92	(3.37, 2.79) ± 0.08	a, b
			K7	4060	0.95	3.73	0.69 ± 0.03		us	(3.59, 3.22) ± 0.05	a, b
			K7	4060	0.95	3.73	0.62 ± 0.04		us	(3.47, 3.10) ± 0.07	a, b
27	V819 Tau AB	w	K7	4136	0.80	3.84	0.62 ± 0.03	3.3 ± 0.35	M94	(3.54, 3.17) ± 0.07	a, b
			K7	4060	0.91	3.75	0.62 ± 0.03		us	(3.46, 3.10) ± 0.07	a, b
28	LkCa 7 A	w	M0	4000	0.80	3.78	0.60	2.9	B91	3.31, 3.02	a, b
			M0	3600	0.98	3.51	0.63 ± 0.4	2.29 ± 0.22	M92	>3.5	c
			K7	4133	0.60	3.96	0.63 ± 0.03	3.3 ± 0.35	M94	(3.52, 3.18) ± 0.07	a, b
			K7	4133	0.60	3.96	0.52 ± 0.03	3.3 ± 0.35	M94	(3.27, 2.93) ± 0.09	a, b
			K7	4060	1.20	3.63	0.60		us	3.47, 3.06	a, b
			K7	4060	1.20	3.63	0.63 ± 0.40		us	(3.52, 3.12) ± 0.50	a, b
			K7	4060	1.20	3.63	0.63 ± 0.03		us	(3.53, 3.12) ± 0.08	a, b
			K7	4060	1.20	3.63	0.52 ± 0.03		us	(3.27, 2.87) ± 0.09	a, b
29	DE Tau	c	M2	3500	0.60	3.41	0.99 ± 0.13	2.3 ± 0.2	B91	>3.5	c
			M2	3560	0.81	3.31	0.99 ± 0.13		us	>3.5	c
30	RY Tau	c	K0	5250	3.00	4.10	0.27 ± 0.04	3.3 ± 0.2	B91	(3.76, 3.21) ± 0.31	a, b
			G1	5945	7.60	3.98	0.27 ± 0.04		us	(4.61, 3.99) ± 0.31	a, b
31	T Tau	c	K0	5250	10.80	3.54	0.34 ± 0.05	3.8 ± 0.25	B91	(4.33, 3.73) ± 0.32	a, b
			K0	5250	19.90	3.36	0.34 ± 0.05		us	(4.35, 3.73) ± 0.32	a, b
32	LkCa 21	w	M3	3400	0.60	3.29	0.72 ± 0.04	2.9 ± 0.35	M94	>3.5	c
			M3	3415	0.62	3.28	0.72 ± 0.04		us	>3.5	c
33	IP Tau	w	M0	3832	0.50	3.79	0.50 ± 0.03	2.6 ± 0.35	M94	(2.88, 2.63) ± 0.09	a, b
			M0	3850	0.43	3.86	0.50 ± 0.03		us	(2.88, 2.65) ± 0.10	a, b
34	DF Tau B	c	M2	3500	1.90	2.82	0.79 ± 0.10	2.0 ± 0.2	B91	>3.5	c
			M3	3415	1.50	2.88	0.79 ± 0.10		us	>3.5	c
35	DG Tau	c	M0	3920	1.50	3.73	0.51 ± 0.16	2.5 ± 0.5	B91	(3.02, 2.73) ± 0.36	a, b
			M0	3850	1.70	3.65	0.51 ± 0.16		us	(2.96, 2.67) ± 0.33	a
36	042417+1744	w	K1	5250	1.6	4.2	0.28 ± 0.09	3.40 ± 0.45	B91	(3.81, 3.28) ± 0.60	a, b
			K1	4600	1.66	4.12	0.27 ± 0.05	2.32 ± 0.29	M92	(2.62, 2.32) ± 0.36	a, b
			K1	4913	0.89	4.29	0.28 ± 0.09	2.80 ± 0.35	M94	(3.24, 2.84) ± 0.55	a, b
			K1	5080	1.40	4.19	0.28 ± 0.09		us	(3.54, 3.06) ± 0.60	a, b
			K1	5080	1.40	4.19	0.27 ± 0.05		us	(3.47, 2.99) ± 0.36	a, b
			K1	5080	1.40	4.19	0.28 ± 0.09		us	(3.54, 3.06) ± 0.60	a, b
37	DI Tau AB	w	M0	3826	0.73	3.61	0.69 ± 0.03	3.3 ± 0.35	M94	(3.32, 3.02) ± 0.05	a, b
			M0	3850	0.99	3.49	0.69 ± 0.03		us	(3.40, 3.05) ± 0.06	a, b
38	UX Tau A	w	K0	5250	1.00	4.41	0.42 ± 0.05	4.2 ± 0.2	B91	(4.51, 4.19) ± 0.26	a, b
			K2	4740	1.30	4.12	0.43 ± 0.02	3.6 ± 0.35	M94	(3.88, 3.51) ± 0.10	a, b
			K5	4350	0.90	4.13	0.42 ± 0.05		us	(3.20, 2.85) ± 0.26	a, b
			K5	4350	0.90	4.13	0.43 ± 0.02		us	(3.24, 2.89) ± 0.10	a, b
39	UX Tau B	w	M1	3650	0.50	3.57	0.60 ± 0.03	3.1 ± 0.35	M94	>3.5	c
			M2	3560	0.19	3.94	0.60 ± 0.03		us	>3.5	c
40	DK Tau AB	c	M0	3920	1.40	3.49	0.65 ± 0.06	2.9 ± 0.2	B91	(3.43, 3.04) ± 0.12	a, b
			K7	4060	1.32	3.58	0.65 ± 0.06		us	(3.59, 3.15) ± 0.12	a, b
41	V927 Tau AB	w	M5.5	3101	0.36	3.75	0.51 ± 0.03	–	M94	2.87 ± 0.26	c
			M5.5	3115	0.33	3.21	0.51 ± 0.03		us	2.90 ± 0.26	c

Table 1. continued.

#	Star	Class	Sp.T.	$T_{\rm eff}$ (K)	L ($L_\odot$)	$\log g$	EW (Å)	n(Li)$_{\rm lit}$	Ref.	n(Li)$_{\rm our}$	Method
42	042835+1700	w	K5	4400	0.40	4.3	0.15	1.3	B91	1.45, 1.31	a, b
			K5	4100	0.43	4.16	0.19 ± 0.04	0.97 ± 0.35	M92	(1.41, 1.19) ± 0.24	a, b
			K5	4400	0.20	4.60	0.11 ± 0.01	1.15 ± 0.35	M94	(1.20, 1.08) ± 0.07	a, b
			K5	4350	0.32	4.39	0.15		us	1.39, 1.24	a, b
			K5	4350	0.32	4.39	0.19 ± 0.04		us	(1.72, 1.46) ± 0.23	a, b
			K5	4350	0.32	4.39	0.11 ± 0.01		us	(1.11, 1.01) ± 0.08	a, b
43	HL Tau	c	K7	4000	1.40	3.66	0.48 ± 0.12	2.4 ± 0.5	B91	(3.12, 2.71) ± 0.31	a, b
			K5	4350	1.53	3.67	0.48 ± 0.12		us	(3.59, 3.07) ± 0.32	a, b
44	V710 Tau B	w	M3	3402	0.30	3.61	0.58 ± 0.03	2.4 ± 0.35	M94	>3.5	c
			M2	3560	0.63	3.37	0.58 ± 0.03		us	>3.5	c
45	042916+1751	w	K7	4138	0.62	3.85	0.49 ± 0.05	3.15 ± 0.35	M94	(3.22, 2.85) ± 0.16	a, b
			K7	4060	0.62	4.25	0.49 ± 0.05		us	(2.96, 2.79) ± 0.15	a, b
46	V827 Tau	w	K7	3960	0.90	3.71	0.57	2.8	B91	3.22, 2.91	a, b
			K7	4130	1.11	3.69	0.57 ± 0.03	3.3 ± 0.35	M94	(3.49, 3.06) ± 0.08	a, b
			K7	4060	1.10	3.67	0.57		us	3.38, 2.99	a, b
			K7	4060	1.10	3.67	0.57 ± 0.03		us	(3.38, 2.99) ± 0.08	a, b
47	V928 Tau AB	w	M0.5	3745	1.30	3.29	0.64 ± 0.03	3.1 ± 0.35	M94	>3.5	c
			M0.5	3778	1.40	3.27	0.64 ± 0.03		us	>3.5	c
48	GG Tau A	c	K7	4000	1.20	3.50	0.72 ± 0.03	3.2 ± 0.1	B91	(3.65, 3.22) ± 0.06	a, b
			K7	4060	1.50	3.50	0.72 ± 0.03		us	(3.76, 3.26) ± 0.05	a, b
49	UZ Tau W	c	M2	3500	1.10	3.11	0.74 ± 0.18	1.8 ± 0.3	B91	>3.5	c
			M3	3470	0.52	3.42	0.74 ± 0.18		us	>3.5	c
50	UZ Tau E	c	M0	3920	1.00	3.44	0.72 ± 0.15	3.0 ± 0.3	B91	(3.56, 3.16) ± 0.31	a, b
			M1	3705	0.40	3.74	0.72 ± 0.15		us	>3.5	c
51	042950+1757	w	K7	4000	0.4	4.1	0.54	2.6	B91	3.07, 2.87	a, b
			K7	3900	0.44	4.12	0.60 ± 0.06	2.72 ± 0.24	M92	(3.11, 2.92) ± 0.13	a, b
			K7	4060	0.37	4.16	0.54		us	3.14, 2.92	a, b
			K7	4060	0.37	4.16	0.60 ± 0.06		us	(3.27, 3.06) ± 0.14	a, b
52	GH Tau AB	w	M2	3520	0.89	3.26	0.66 ± 0.03	2.9 ± 0.35	M94	>3.5	c
			M1.5	3632	0.81	3.35	0.66 ± 0.03		us	>3.5	c
53	V830 Tau	w	K7	4000	0.90	3.73	0.70 ± 0.06	3.0 ± 0.2	B91	(3.51, 3.19) ± 0.11	a, b
			K7	4134	0.89	3.80	0.65 ± 0.03	3.5 ± 0.35	M94	(3.61, 3.22) ± 0.06	a, b
			K7	4060	0.78	3.82	0.70 ± 0.06		us	(3.57, 3.23) ± 0.11	a, b
			K7	4060	0.78	3.82	0.65 ± 0.03		us	(3.49, 3.15) ± 0.06	a, b
54	IS Tau	w	K7	4130	1.10	3.71	0.62 ± 0.03	3.2 ± 0.35	M94	(3.59, 3.16) ± 0.07	a, b
			K7	4060	0.66	3.90	0.62 ± 0.03		us	(3.40, 3.10) ± 0.07	a, b
55	DL Tau	c	M0	3920	0.90	3.51	0.80 ± 0.12	3.2 ± 0.3	B91	(3.66, 3.28) ± 0.15	a, b
			K7	4060	1.16	3.49	0.80 ± 0.12		us	(3.88, 3.38) ± 0.16	a, b
56	CI Tau	c	K5	4400	0.60	4.07	0.57 ± 0.06	3.5 ± 0.2	B91	(3.77, 3.38) ± 0.16	a, b
			K7	4060	0.87	3.77	0.57 ± 0.06		us	(3.34, 2.99) ± 0.14	a, b
57	AA Tau	c	M0	3920	0.70	3.81	0.64 ± 0.03	2.9 ± 0.1	B91	(3.29, 3.03) ± 0.06	a, b
			K7	4060	0.80	3.81	0.64 ± 0.03		us	(3.47, 3.14) ± 0.06	a, b
58	DN Tau	c	M0	3920	1.00	3.52	0.65 ± 0.05	2.9 ± 0.15	B91	(3.42, 3.04) ± 0.10	a, b
			M0	3850	0.65	3.63	0.65 ± 0.05		us	(3.27, 2.97) ± 0.11	a, b
59	043124+1824	w	G8	5450	0.5	4.6	0.31	3.8	B91	4.20, 3.77	a, b
			G8	5445	0.47	4.65	0.23 ± 0.01	3.10 ± 0.35	M94	(3.62, 3.15) ± 0.08	a, b
			G8	5520	0.5	5.0	0.31		us	4.18, 3.85	a, b
			G8	5520	0.47	5.1	0.23 ± 0.01		us	(3.65, 3.23) ± 0.07	a, b
60	043220+1815	w	F8	6000	1.5	4.4	0.17	3.4	B91	3.68, 3.32	a, b
			F8	6200	1.5	5.0	0.17		us	3.83, 3.50	a, b
61	043230+1746	w	–	3500	0.40	4.22	0.57 ± 0.03	1.4	B91	>3.5	c
			M2	3524	0.22	3.84	0.57 ± 0.03	2.6 ± 0.35	M94	3.31 ± 0.25	c
			M2	3560	0.43	3.57	0.57 ± 0.03		us	3.34 ± 0.25	c
62	LkCa 14	w	K7	4134	0.88	3.67	0.60 ± 0.03	3.3 ± 0.35	M94	(3.57, 3.13) ± 0.06	a, b
			M0	3850	0.65	3.68	0.60 ± 0.03		us	(3.16, 2.87) ± 0.07	a, b
63	HV Tau AB	w	M2	3521	0.65	3.37	0.64 ± 0.03	2.8 ± 0.35	M94	>3.5	c
			M1	3705	0.65	3.37	0.64 ± 0.03		us	>3.5	c
64	VY Tau AB	w	M0	3920	0.40	3.92	0.52	2.4	B91	3.00, 2.76	a
			M0	3850	0.47	3.82	0.52		us	2.95, 2.70	a
65	LkCa 15	w	K5	4385	0.72	4.01	0.47 ± 0.02	3.1 ± 0.35	M94	(3.46, 3.09) ± 0.07	a, b
			K5	4350	0.74	4.13	0.47 ± 0.02		us	(3.38, 3.04) ± 0.08	a, b
66	IW Tau	w	K7	4130	1.10	3.70	0.44 ± 0.02	2.9 ± 0.35	M94	(3.09, 2.68) ± 0.08	a, b
			K7	4060	0.87	3.77	0.44 ± 0.02		us	(2.96, 2.63) ± 0.07	a, b
67	DR Tau	c	M0	3920	1.70	3.30	0.46 ± 0.06	2.1 ± 0.25	B91	(2.99, 2.59) ± 0.19	a, b
			K7	4060	0.96	3.88	0.46 ± 0.06		us	(3.00, 2.69) ± 0.20	a, b

Table 1. continued.

#	Star	Class	Sp.T.	$T_{\rm eff}$ (K)	L ($L_\odot$)	log g	EW (Å)	n(Li)$_{\rm lit}$	Ref.	n(Li)$_{\rm our}$	Method
68	DS Tau	c	K5	4400	0.80	4.10	0.66 ± 0.09	3.7 ± 0.25	B91	(3.94, 3.59) ± 0.20	a, b
			K5	4350	0.65	4.17	0.66 ± 0.09		us	(3.82, 3.51) ± 0.20	a, b
69	UY Aur AB	c	M0	3920	1.40	3.49	0.87 ± 0.14	3.2 ± 0.2	B91	(3.76, 3.37) ± 0.21	a, b
			K7	4060	1.20	3.62	0.87 ± 0.14		us	(3.90, 3.47) ± 0.20	a, b
70	GM Aur	c	K7	4000	0.90	3.85	0.50 ± 0.05	2.5 ± 0.2	B91	(3.04, 2.77) ± 0.15	a, b
			K7	3800	0.93	3.74	0.59 ± 0.05	2.56 ± 0.24	M92	(3.07, 2.81) ± 0.11	a, b
			K7	4060	0.67	3.75	0.50 ± 0.05		us	(3.17, 2.82) ± 0.14	a, b
			K7	4060	0.67	4.00	0.59 ± 0.05		us	(3.31, 3.04) ± 0.12	a, b
71	LkCa 19	w	K5	4348	1.55	3.90	0.48 ± 0.02	3.1 ± 0.35	M94	(3.51 3.07) ± 0.07	a, b
			K5	4348	1.55	3.90	0.43 ± 0.02	3.1 ± 0.35	M94	(3.32 2.89) ± 0.10	a, b
			K0	5250	1.70	4.19	0.48 ± 0.02		us	(4.79 4.48) ± 0.09	a, b
			K0	5250	1.70	4.19	0.43 ± 0.02		us	(4.62 4.23) ± 0.10	a, b
72	045226+3013	w	K5	4950	1.5	4.1	0.44 ± 0.05	3.8 ± 0.2	B91	(4.25, 3.86) ± 0.24	a, b
			K5	4100	1.58	3.60	0.47 ± 0.04	2.55 ± 0.34	M92	(3.20, 2.76) ± 0.15	a, b
			K5	4350	1.5	4.4	0.44 ± 0.05		us	(3.18, 2.93) ± 0.20	a, b
			K5	4350	1.58	4.3	0.47 ± 0.04		us	2.99 ± 0.19	a, b
73	SU Aur	c	G2	5770	12.10	3.62	0.24 ± 0.02	3.55 ± 0.1	B91	(4.20, 3.58) ± 0.16	a, b
			G2	5860	9.90	3.75	0.24 ± 0.02		us	(4.29, 3.68) ± 0.15	a, b
74	045251+3016	w	K7	4000	0.8	3.9	0.58	2.8	B91	3.16, 2.96	a, b
			K7	4130	1.0	3.63	0.52 ± 0.03	3.15 ± 0.35	M94	(3.38, 2.93) ± 0.08	a, b
			K7	4060	0.8	4.2	0.58		us	3.17, 3.02	a, b
			K7	4060	1.0	4.1	0.52 ± 0.03		us	(3.04, 2.87) ± 0.07	a, b
75	V836 Tau	c	K7	3960	0.50	3.93	0.57	2.7	B91	3.16, 2.91	a, b
			K7	4139	0.60	3.93	0.57 ± 0.02	3.2 ± 0.35	M94	(3.41, 3.06) ± 0.06	a, b
			K7	4060	1.21	3.59	0.57 ± 0.02		us	(3.42, 2.99) ± 0.06	a, b
			K7	4060	1.21	3.60	0.57 ± 0.02		us	(3.41, 2.99) ± 0.06	a, b
76	RW Aur A	c	K5	4400	2.20	3.87	0.67 ± 0.07	3.9 ± 0.2	B91	(4.07, 3.62) ± 0.15	a, b
			K3	4730	1.70	4.11	0.67 ± 0.07		us	(4.52, 4.13) ± 0.10	a, b

Notes: n(Li)$_{\rm our}$ – our derivation of Li abundance and error, using the method listed in the next column.
Method – a: MOOG; b: COGs by Soderblom et al. (1993); c: our COGs (resolution depending on the literature data).