Lithium in Cool Stars Detected in EUV Surveys: ZAMS, PTTS, or PMS?

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Abstract:
High-resolution spectra in the region of the Li i 6707.8 Å doublet were obtained for more than 50 stars, of spectral type from F5 to K5, EUV–selected with the ROSAT WFC. We find that one third of these stars are as young as the Pleiades or younger. In particular there are 11 stars that are between the Pleiades and IC 2602 lithium upper envelopes, which means that they are just arrived or are arriving on the ZAMS. Four stars of our sample are in a region where only PMS stars should lie. These results, though preliminary, would imply that the PMS stars detected by Neuhauser et al. (1997) are in fact due to a high concentration of young objects in the Gould Belt.

1. Introduction

Large samples of stellar X-ray sources have been discovered serendipitously by the Einstein, EXOSAT and ROSAT Observatories. Optical follow-up studies have demonstrated that these samples are composed mainly of active stars like RS CVn and W UMa binaries, pre-main sequence and other very young stars, and BY Dra flare stars (Fleming et al. 1988, 1989; Tagliaferri et al. 1992, 1994; Favata et al. 1993; Pye et al. 1995; Neuhauser et al. 1997).

Over the past few years we carried out extensive photometric and spectroscopic observations of cool stars serendipitously detected by EXOSAT (Tagliaferri et al. 1992; 1994; Cutispoto et al. 1996). We have shown that, in addition to dMe flare stars, at least one third of the EXOSAT serendipitous sources is constituted by young stars, with ages comparable to or younger than the Pleiades. Another third consists of RS CVn binaries, while the physical nature of the remaining sources is more uncertain: they could be either young objects or very active binaries. A large fraction of these stars is variable at optical wavelengths, and the observed variability is best interpreted as produced by cool spots on their surface. Similar results have been obtained for a sample of cool stars X–ray selected with the Einstein satellite by Favata et al. (1993, 1995) and, more recently, by other authors using ROSAT data. Jeffries (1995) determined the Li abundances for a sample of late-type stars EUV-selected with the WFC on board ROSAT. He confirmed that a high proportion of these stars are as young as the Pleiades or younger and based on their kinematics he suggested that these stars are part of a group of young open clusters and nearby B stars.

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known as the Local Association. Finally, Neuhausser et al. (1997) performed
an optical follow-up on 111 late-type stars detected in the RASS south of the
Taurus molecular cloud. Twenty-four off-cloud stars have a lithium-excess and
they classified them either as PMS (9) or young ZAMS (15).

Following our work on the EXOSAT sample, we defined a new sample of
active cool stars EUV-selected with the ROSAT WFC (Pounds et al. 1992; Pye
et al. 1995) and performed spectroscopic (Li i 6708 Å, Hα and Ca ii H&K lines)
and photometric optical follow-up using the CAT and 50cm ESO telescopes in
the South and the McMath telescope at Kitt Peak and 80cm APT telescope at
the Catania Observatory in the North.

Here we present a subset of these data, focusing on high-resolution spectra
in the region of the Li i 6707.8 Å doublet for the Southern stars of our sample.

2. Data Sample and Results

The data for more than 50 stars, of spectral type from F5 to K5, were obtained
in January and August 1995 using the ESO 1.4m CAT telescope with the CES
spectrograph and CCD detector yielding an effective resolution of about 50,000.
The spectra are centered on the Li i 6707.8 Å doublet, and cover the range \( \approx 6690 - 6730 \) Å. Standard data reduction was performed using the IRAF software
package.

In Figure 1 we report for a comparison the Li EW determined by us for
our sample (star symbols) together with those given by Jeffries (1995) for an-
other sample of EUV-selected cool stars with the ROSAT WFC in the Northern
hemisphere (circle symbols). The filled symbols represent stars that are in both
samples (three). As it can be noted while for two of these our values and those
from Jeffries are in good agreement, the third one is not (HD 197890 = Speedy
Mic), both in \( B-V \) and Li EW. In particular the Jeffries’ EW = 630 mÅ is much
higher than our value (EW = 420 mÅ). There is also another measurement of the
Li EW for this star by Robinson et al. (1994), who give an EW = 220. We did
a careful analysis of our three spectra and we are quite confident on our mea-
surements, however the reader should treat this value with care, also because
the \( v \sin i \) of Speedy Mic is very high (170 km s\(^{-1}\)), making the determination
of the Li EW very difficult. Note that the Jeffries’ sample is equally distributed
between G and K stars, while our sample is dominated by stars earlier than
K2 (this is due to the fact that usually stars cooler than K2 were too faint to
be observed with the CAT). However, the two samples are clearly very similar
with respect to the Li values and they seem to be dominated by young stars, as
expected. In the figure we also plot the line above which stars are considered to
be younger than 300 Myr (see Jeffries 1995).

From Figure 1 it is clear that some of our stars have very high Li EW values.
To better quantify this we plot again our values in Figure 2, where the typical
Li values for stars in the Hyades (solid line) (from Soderblom et al. 1990),
the lithium upper envelope for the rapid rotating Pleiades stars (dashed line)
(from Soderblom et al. 1993), the lithium upper envelope for IC 2602 stars
(dashed-dotted line) (from Randich et al. 1997), as well as an upper envelope to
the lithium values for TTS (dotted line) (from Neuhausser et al. 1997) are also
plotted. IC 2602 is \( \sim 30 \) Myr old (Stauffer et al. 1997).
3. Conclusions

The conclusions that we can draw from Figure 2 are very similar to the one we obtained for the EXOSAT sample. More than one third of our EUV-selected cool stars are as young as the Pleiades or younger. In particular, there are 11 stars that are between the Pleiades and IC 2602 lithium upper envelopes, which means that they are just arrived or are arriving on the ZAMS (in IC 2602, G-type stars are essentially on the ZAMS, while stars of spectral type K are still slightly above the ZAMS (Randich et al. 1997)).

One third of our stars have Li values between the Hyades and the Pleiades and they will most likely turn out to be RS CVn-type systems or other very active stars. Our spectroscopic data in the Hα and Ca II H&K lines regions and our photometric data will allow us to better characterize them.

Finally, four stars of our sample are in a region where only PMS stars should lie. The star plotted as a green square has already been classified as a PMS star.
Figure 2. Li EW for our stars. The solid line represents the typical Li values for stars in the Hyades (from Soderblom et al. 1990). The lithium upper envelope for the rapid rotating Pleiades stars (dashed line) and for IC 2602 stars (dashed-dotted line) (Soderblom et al. 1993; Randich et al. 1997), as well as an upper envelope to the lithium values for TTS (dotted line) (Neuhäuser et al. 1997) are also plotted.

associated to a star forming region (Brandner et al. 1996), while the filled blue circle represents Speedy Mic.

If we compare our results with those of Neuhäuser et al. (1997), we do not seem to find as many PMS stars as they do. Our stars are scattered all over the sky, while Neuhäuser et al. studied a region of the sky South of the Taurus molecular cloud that is projected onto the Gould Belt (Gould 1874), that was recognized long ago as a band of young stars. Thus, our results, though preliminary, would imply that the PMS stars detected by Neuhäuser et al. are in fact due to a high concentration of young objects in the Gould Belt.
References

Gould, B.A. 1874, American Journal of Science and Arts, 8, 325