HIGH RESOLUTION SPECTROSCOPY OF STELLAR X-RAY SOURCES

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1. Introduction

Cool stars constitute a significant fraction of sources detected in soft X-ray surveys (Gioia et al. 1990; Giovinni et al. 1991; Schmitt 1992). X-ray observations are in fact a powerful tool for studying stellar surface activity and its variation with stellar evolution (e.g. Rosner et al. 1985; Pallavicini 1989). The ROSAT Full-Sky survey, in conjunction with high-resolution optical studies, will fully exploit the potential of this approach (see Schmitt 1992).

About one hundred late-type stars have been detected with the Low Energy Telescope and CMA detector on board the EXOSAT satellite (Giovanelli et al. 1991). The nature of these EXOSAT sources remains largely unclear although they are likely to include very active stars, such as RS CVn-type binaries, BY Draconis stars and PMS objects, in particular Post T-Tauri stars (PTTS).

Since PTTS do not show the extreme properties of classical T Tauri stars (e.g. strong H\textalpha{} emission, infrared excess, irregular variability) they are difficult to detect by conventional optical methods (see however Pallavicini et al. 1992a and Martin et al. 1992). Hundreds of PMS stars that lack strong H\textalpha{} emission, infrared excess and continuum veiling have been detected in soft X-ray images of star forming regions (Walter et al. 1988). However, many of these stars, that have been called Weak-lined or Naked-T Tauri stars, appear to be coeval with classical T Tauri stars (e.g. Baer et al. 1991) and therefore cannot be regarded as PTTS in the sense outlined above. Nevertheless PTTS are expected to be vigorous X-ray coronal sources and X-ray surveys could be a powerful way to identify them. One PTTS (HD560B) has already been serendipitously detected by EXOSAT (Tagliaferri et al. 1988). We expected therefore that some of these elusive objects, whose study can provide crucial information on the evolution of stellar coronal activity during the pre-main sequence phase, could be present in our sample.

2. Observations

In order to study the nature of the cool stars in our sample, we started a campaign of medium to high-resolution optical observations at the European Southern Observatory. High-resolution spectra are essential to determine the true physical nature of these stars. We have obtained spectra in H\textalpha{}, in the Ca II H&K lines and in the Li I 6708 Å line. Moreover, in
order to measure radial and rotational velocities and to ascertain whether some of these stars are binaries, we observed most of them using CORAVEL. Extensive and repeated UBVRI photometric observations were also obtained (Cutispoto et al. 1991).

Here we present preliminary results from high resolution spectra of 26 stars (all of spectral type later than F) obtained in the Li 6708 Å line region. The observations were carried out at ESO in two different runs (March 1990 and October 1990). We used the Coudé Echelle Spectrometer fed by the CAT telescope, with the short camera and a CCD detector. The nominal resolving power was R=60,000.

3. Results

We derived Li abundances from the equivalent widths (EW) using curves of growth and stellar parameters derived from our photometry. We note that the Li doublet line at 6707.81 Å is close to the Fe I line at 6707.44 Å. In some of our stars these line are resolved, but for those that are rapid rotators (vsini \geq 10\text{Km s}^{-1}) the two lines are blended and, therefore, synthetic spectra should be used to derive the accurate contribution of Fe to the Li line. We are currently doing this analysis and we will present the results elsewhere. As a first approximation, here we will ignore the Fe contribution to the Li equivalent width. Many of our stars have a Li line so strong that the correction for the Fe contribution would not affect our results appreciably.

The Li line was detected in 22 out of the 26 stars observed. For ten sources this line was comparable to or stronger than the nearby Ca I 6718 Å line. In figure 1 we compare the Li abundances of the EXOSAT stars with those of stars in young clusters and star forming regions, namely Tau-Aur (Basri et al. 1991), α Per (Balachandran et al. 1989), the Pleiades (Duncan and Jones 1983) and the Hyades (Cayrel et al. 1984). We see that about one third of our stars have the same Li abundances as stars of the same Teff in the Tau-Aur star formation complex. In particular these stars have Li abundances comparable to or larger than the primordial value for Pop I stars (i.e. log N(Li) > 3.1), thus suggesting that they are most likely PMS objects.

All our remaining objects (except four for which we have only an upper limit) have Li abundances comparable to those of stars in young clusters. These stars could be either young main-sequence stars or evolved active stars such as those studied by Pallavicini et al. 1992b. (i.e. RS CVn binaries or FK Comae stars). Their active nature is also confirmed by the spectroscopic observations in Hα and the Ca II H&K lines. Actually, high resolution spectra in Hα and in the Ca II H&K lines, together with extensive UBVRI photometry and CORAVEL data, can help understand their nature. The analysis of these data is currently under way.

We note that only one star of our sample is close to a star forming region. This star is included in the list of PMS members of the Orion Population published by Herbig and Bell (1985), although it is classified as a non-member of the Orion cluster by them. All other stars in our sample are not known to be members of young clusters or star forming regions. Those of them that appear to be PMS objects are therefore more likely Post-T Tauri (PTT) rather than Weak-lined T Tauri or Classical T Tauri stars in regions of star formation.
Fig. 1. Li abundances versus effective temperature for the X-ray selected stars of our sample, pre-main sequence stars in the Tau Aur complex and main sequence stars in young open clusters.
To conclude, we have obtained high resolution spectra in the Li 6708 Å line for a sample of X-ray selected cool stars. These observations show that our sample contains a significant fraction of PMS stars, possibly PTT stars. The rest of our sample could be constituted by either young main sequence stars or evolved chromospherically active stars. In both cases, high-resolution optical observations have proved to be essential for determining the nature of these X-ray selected objects. Spectroscopic facilities on much larger telescopes (such as the VLT) will be necessary to study the optical counterparts of the fainter sources that have been detected by ROSAT or that will be detected by future X-ray missions like AXAF and XMM.

4. References
Herbig, G.H., Bell, K.R.: 1988, Third Catalog of Emission-Line Stars of the Orion Population, Lick Observatory Bulletin No. 1111, University of California, Santa Cruz, USA

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