HIGH RESOLUTION SPECTROSCOPY OF WEAK-LINE T TAURI STAR CANDIDATES IN ORION

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ABSTRACT. The results of high-resolution ($\lambda/\Delta\lambda \geq$ 20,000) spectroscopic observations of a sub–sample of the lithium stars found on the basis of the ROSAT all-sky survey (RASS) scattered in the direction of the Orion star forming region (SFR) and classified as weak-line T Tauri stars (WTTS) are reported. The sample seems to be a mix of different stellar populations namely, true low-mass PMS and young active main sequence stars. The stars previously classified as WTTS candidates represent the majority among the lithium stars found on the basis the RASS in Orion. The origin of the scattered WTTS is not clear, but it might be related to the formation of the Gould Belt.

1. Introduction

The optical follow-up observations of the ROSAT all-sky survey (RASS) X-ray sources, have revealed hundreds of lithium-rich stars scattered over hundreds of square degrees in the general direction of SFRs (Neuhäuser 1997). On the basis of a strong Li I λ6708 absorption and late spectral type, these stars have been classified as weak-line T Tauri stars (WTTS) in previous mid-resolution spectroscopic studies. Assuming that these stars are located at the same distance as the SFR where they have been found, one finds that their masses and ages are in the range for typical T Tauri stars. However, the origin of these scattered lithium stars is a matter of debate. Obviously, the assumption of a single distance for stars scattered on several square degrees in the sky may not be realistic. On the other hand, in low-resolution spectra the LiI line is blended with the FeI $\lambda\lambda$6703, 6705 and 6710 Å lines and, hence, its strength might be overestimated. Moreover, other stellar parameters like mass and rotation may affect the lithium strength. Given the fact that ZAMS stars in clusters like α Per and the Pleiades, show lithium absorption, some authors have put into question the PMS nature of the RASS lithium stars (Briceño et al. 1997). They argue that the majority of the RASS lithium stars are in reality Pleiades-like stars, old enough to have diffused from their birth places, producing a more or less uniform spatial distribution of X-ray sources in the galactic plane. Thus, it is of crucial importance to investigate the samples of RASS lithium stars by means of high-resolution spectroscopy. In this contribution we report the results of the high resolution spectroscopy of a subsample of the RASS lithium stars found in the direction of the Orion SFR by Alcalá et al. (1996, henceforth A96).

2. The observations

We obtained single order echelle spectra for 65 RASS lithium stars using the Multiple Mirror Telescope (Arizona), the 1.5m Tillinghast reflector (Whipple Observatory, Arizona), and the 1.5m Wyeth reflector at Oak Ridge Observatory (Massachusetts). These observations have a resolving power of about 35,000, and cover a 45 Å wavelength range centered at 5187 Å. Since these spectra do not include the lithium line we have also observed 20 stars using the Fibre Optics Cassegrain Echelle Spectrograph (FOCES) attached to the 2.2m telescope of the Max-Planck Institut für Astronomie, in the Calar Alto Observatory. Some seventy orders are included in these spectra covering a range from 3900 to 7000 Å with a resolving power of 20,000.

The single-order echelle spectra are used to obtain radial velocities (RV) and rotational velocities ($v \sin i$) using cross-correlation techniques, as well as to estimate effective temperatures. The FOCES spectra were used to derive Li equivalent widths, W(Li), as well as RV and $v \sin i$. Details concerning W(Li), RV, $v \sin i$ and effective temperature will be described in a forthcoming paper (Alcalá et al., in preparation). We estimate a mean error of 1 km/s for RV and of 15 mÅ for W(Li). The RV's as derived from the single order echelle spectra and the FOCES spectra are in agreement within the errors.

3. The RASS lithium stars in Orion

In the high-resolution spectroscopic study by Covino et al. (1997 and these proceedings), it is found that the sample of Chamaeleon RASS Li stars is contaminated by a heterogeneous sample of field stars, most of them probably Pleiades-like, and that this sample represents less than 40% of the original one. Other studies in the Lupus and south of the Tau-Aur SFRs find a contamination of less than 30% (Neuhäuser 1997).

Although we are aware that the W(Li) values for most of the stars reported in A96 are uncertain and that the comparison of data obtained with very different spectral resolutions may be somewhat subjective, we have compared our sample with that of the Pleiades by Soderblom et al. (1993) in a lithium equivalent width versus $logT_{eff}$ plot (cf. Fig 1a adapted from Alcalá et al. 1997, henceforth A97). This comparison can already give some indications about the percentage of stars falling in the Pleiades area in the W(LiI)–$logT_{eff}$ plane, provided that a correction for the overestimation in the W(Li) values of our sample is applied. A mean correction can be estimated by comparison of the low and high resolution W(Li) values for the same set of stars. This comparison for RASS Li stars in Orion is shown in Fig. 1b (adapted from Sterzik et al. 1997). From this figure, Sterzik et al. (1997) conclude that, within the errors of the low-resolution, there is a reasonable agreement between the low and high resolution W(Li) values and that the overestimation on the low-resolution W(Li) values is less than 100 mÅ. Taking this into account and by inspection of the Li-data in Fig. 1a, one finds that the majority of the RASS Li stars (more than 60 %) found in the direction of Orion are actually true low-mass PMS stars. This is in good agreement with the findings in the Chamaeleon SFR. Thus, the RASS Li sample in Orion may also be a mix of populations, ie. true PMS stars and likely Pleiades-age stars.

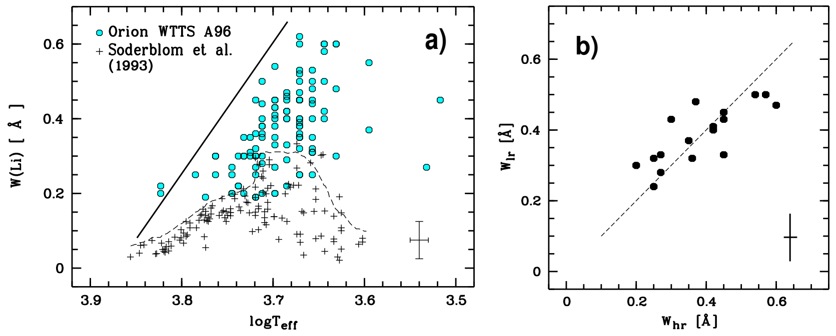

Fig. 1. a) W(Li) vs. $log\ T_{eff}$ plot for the A96 sample. The data and the upper envelope for the Pleiades (pluses and dashed line) are overplotted. The mean errors are also overplotted. The primordial lithium abundance, in the $log(H)$=12 scale, is represented by the continuous line; b) comparison of the low and high resolution W(Li) values. The line at 45° is overplotted as a reference (dashed line). The mean errors are also indicated.

4. Radial velocity distribution

In Fig. 2 the RV distribution of the subsample of RASS Li stars in Orion (RV_{RASS}) is compared with the RV distribution of T Tauri stars in Taurus and Orion by Hartmann et al. (1986). The RV_{RASS} distribution is wide with a velocity dispersion of about 9 km/s and apparently shows a double peak, one at RV≈18 km/s and the other at RV≈24 km/s. This suggests that the A96 Li sample in Orion might be in reality composed by two RV groups of stars. Interestingly, the mean RV for Taurus is $<RV>_{Tau} \approx$ 17 km/s, while for Orion it is $<RV>_{Ori} \approx$ 25 km/s. These mean values practically coincide with the two peaks of the RV_{RASS} distribution. Thus, one of the two RV groups of the A96 sample can be associated to the Orion SFR at about 460pc from the Sun. It is hard to believe, however, that the other RV group can be associated only to the Taurus SFR, since the RASS Li stars are located projected onto the Orion complex, several degrees away from Taurus. Instead, we beleave that the strong events giving rise to the formation of the Gould Belt some 30 Myr ago may have triggered low-mass star formation on a large scale, producing a more or less "disk-like" structure in which OB and T associations are also embedded. Thus, when observing in the general direction of Orion, more distant than other well known SFRs like Taurus, Chamaeleon or Lupus, we are actually tracing the star formation through a larger space volume along the line of sight. Therefore, the other RV group might be associated to the Gould Belt.

In a recent study, Sterzik et al. (1997) have investigated the spatial distribution of 1400 coronally active young star candidates from the RASS in more than 5000 square degrees. They identify three distinct groups of PMS stars, which they call clustered, halo and background populations. The clustered population is associated to dense regions and sites of active and recent star formation in the Orion complex. The halo population is mainly composed of PMS stars apparently associated to the Gould Belt in the general direction of Taurus and Orion. Finally, the background population contains weak–lithium ZAMS and other active stars. This three–population hypothesis is also

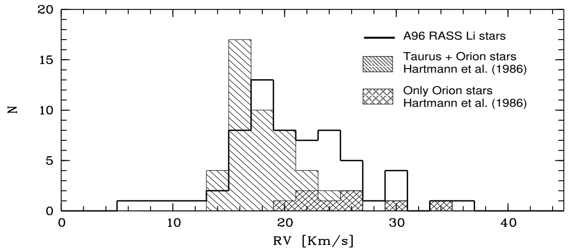

Fig. 2. Comparison of the RV distribution of the RASS Li stars in Orion by A96 (thick line) with the RV distribution of PMS stars in Taurus and Orion by Hartmann et al. (1996) (hatched and cross-hatched histograms respectively).

supported by the fact that stars with higher interstellar extinction and stronger Li tend to be concentrated on the Orion molecular clouds (A97, Sterzik et al. 1997). These findings are very much in line with our conclusions drawn from the RV_{RASS} distribution in Orion.

5. Conclusions

We have carried out high-resolution spectroscopy of a subsample of WTTS candidates found in the direction of the Orion SFR. By comparison of the low and high-resolution lithium (λ 6708 Å) equivalent widths for a sample of 20 stars, we find that the overestimation in the low-resolution W(Li) values of the Orion sample is less than about 100 mÅ. Taking this into account, we conclude that more than 60% of the original sample of the WTTS candidates are true low-mass PMS stars. The remaining may be foreground Pleiades-age stars. The RV distribution of the Orion sample apparently shows a double peak suggesting two RV groups. One of these can be definitely associated to the Orion complex. The other might be associated with the Gould belt. Our conclusions regarding lithium and radial velocities are consistent with the hypothesis that the RASS Li sample in Orion is actually a mix of three populations, namely: true low-mass PMS stars associated with Orion, low-mass PMS stars associated with the Gould Belt and Pleiades-age stars.

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