THE LOW-MASS PRE-MAIN SEQUENCE POPULATION AMONG THE ROSAT X-RAY SELECTED STARS IN THE CHAMAELEON CLOUD COMPLEX

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ABSTRACT. We report the results of a high–resolution (R $\approx$ 20,000) spectroscopic study on a sample of stars classified as new weak–line T Tauri stars on the basis of the ROSAT all–sky survey, found widely spread over a large area in the Chamaeleon dark cloud complex.

We derive equivalent widths for the lithium λ 6708 Å, as well as radial and rotational velocities for these stars. By applying a strict criterion based on the value of lithium excess with respect to Pleiades stars of the same spectral type, we are able to discriminate between *bona-fide* pre-main sequence (PMS) stars and possible *contaminating* active field stars in the original sample.

The majority of the stars in the sample are indeed confirmed to be young, PMS stars (most with estimated ages less than 5×10^6 yr), while the remaining appear to be relatively older (probably Pleiades–like), foreground, active main–sequence stars.

A clear segregation in radial velocity is observed between the strong–lithium and the weak–lithium stars, with the former showing, in most cases, radial velocities consistent with the radial velocity distribution observed for stars in the Cha I dark cloud, and the latter having somewhat different and more widely spread radial velocities. These two groups also show somewhat different rotational properties, thus providing one more evidence that they belong to distinct stellar populations in different evolutionary stages.

1. Introduction

X-ray observations of star forming regions (SFR's) proved to be a powerful means to detect young low-mass stars (Walter et al., 1988). In particular, the all-sky survey conducted with the ROSAT X-ray satellite (RASS) combined with optical medium-low resolution spectroscopic observations was used to identify low-mass pre-main sequence (PMS) stars in the surroundings of several nearby SFR's (Krautter 1996, and references therein). However, as recognized in particular by Briceño et al (1997), in order to assess firmly the pre-main sequence nature of these stars it is necessary not only an unambiguous identification of the Li 6708 Å line, but also that this line be stronger than observed in ZAMS stars of the same mass.

In 1995, we started a program of high-resolution spectroscopic observations with CASPEC at the ESO 3.6m telescope aiming, first of all, to ascertain the pre-main

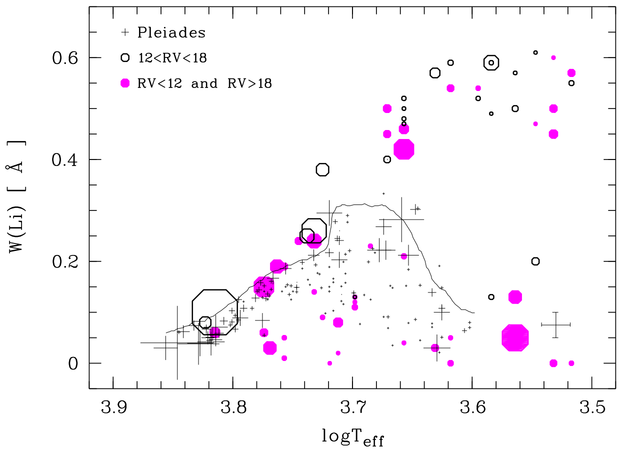

Fig. 1. Equivalent width of the Li λ 6708 Å versus effective temperature. Open circles represent stars with radial velocity in the interval 12<RV [km/s] < 18, filled circles indicate stars having radial velocity out of this range. The plusses represent the Pleiades stars from Soderblom et al. (1993), and the solid line represents the upper envelope defined by that sample. All symbol sizes are proportional to the $v \sin i$ of the stars.

sequence nature of the stars found from previous optical identification campaigns, as well as to investigate their kinematics (from radial velocity measurements), and rotation properties (from determination of projected rotational velocities). Ultimately, lithium abundance determinations will be derived, in order to address the question of lithium depletion versus stellar activity and rotation.

2. Results from high-resolution spectroscopy

Here we concentrate on the most significant results we have obtained for the stars previously identified as WTTS on the basis of medium/low–resolution optical follow-up spectroscopy of ROSAT all-sky survey sources in the Chamaeleon star forming region (Alcalá et al. 1995). We determined the equivalent widths of the lithium λ 6708 Å resonance line, as well as radial and rotational velocities for these stars.

By applying a strict selection criterion based on the value of the lithium excess with respect to Pleiades stars of the same spectral type, we were able to discriminate between *bona-fide* PMS stars and possible *contaminating* active field stars in our sample (Covino et al. 1997). The majority of the stars in the original sample are indeed confirmed to be young, PMS stars (most of which with estimated ages less than 5×10^6 yr), while the remaining appear to be relatively older (probably Pleiades–like), foreground, active main–sequence stars.

A clear segregation in radial velocity is observed between the strong–lithium and the weak–lithium stars, with the former showing, in most cases, radial velocities in the interval 12<RV [km/s] < 18, consistent with the radial velocity distribution observed for stars in the Cha I dark cloud (Dubath et al. 1996), and the latter having very different and more widely spread radial velocities (see Fig. 1). These two groups also show somewhat different rotational properties, which provides one further evidence that they belong to distinct stellar populations in different evolutionary stages.

It is remakable the fact that the lithium equivalent widths show a clear bimodal distribution for $\log T_{eff} < 3.7$. Very importantly, these observations confirm the existence of some very young stars far from the main Chamaeleon clouds, while there is an apparent lack of post-T Tauri stars in the region.

3. ZAMS versus pre-main sequence stars

High-resolution spectroscopy allows us to clarify the nature of the stars previously identified as WTTS from medium resolution spectroscopy.

While it is true that some contamination cannot be avoided by using mid-resolution spectroscopy, we find that a major fraction of the stars previously classified as WTTS do in fact show strong lithium, and most of them also are found to share common kinematical properties. These stars are thus confirmed to be truly young, PMS stars, associated with the Chamaeleon star forming region. On the other hand, the contaminating objects, which represent not more than 40% of the original sample, apparently are a rather heterogeneous group, showing a wide spread in both lithium strength and radial velocity. Most of the contaminating stars are, most likely, foreground active ZAMS stars, as suggested by Briceño et al. (1997), while just a few of them show in their spectrum interstellar absorption features with radial velocity consistent with that of the gas in the main Chamaeleon cloud and hence result to be background stars to the star forming clouds.

We are now in a position to compare the observational results with the model predictions by Briceño et al., based on the assumption of star formation spatially uniform and constant with time. According to that model, some 90% of the stars previously identified as WTTS from mid-resolution spectroscopy should be foreground active ZAMS stars. This prediction is in obvious contrast with the observational result. In addition, we also notice that the comparison between the model predictions and Alcalá et. al.'s (1995) original WTTS sample, as presented by Briceño et al. (1997) in their Fig. 6 (panel b), appears rather misleading. These authors compare in fact the distribution of visual magnitudes predicted from their model for a restricted spectral type interval (late G–early K), with the entire observational sample in Chamaeleon from Alcalá et. al. (1995) (see Fig. 2, panel a, adapted from Briceño et al.). However, if the original observational sample is restricted to the same interval of spectral types considered in the model, a mismatch between the model prediction and the observations is already apparent (Fig. 2, panel b). The discrepancy between the model prediction and the observations is found to be more dramatic when the comparison is made with the actual distribution of stars which turn out to be non-WTTS from our high-resolution spectroscopic study (filled histogram in panel b). Some possible explanations for such a discrepancy are discussed by Covino et al. (1997).

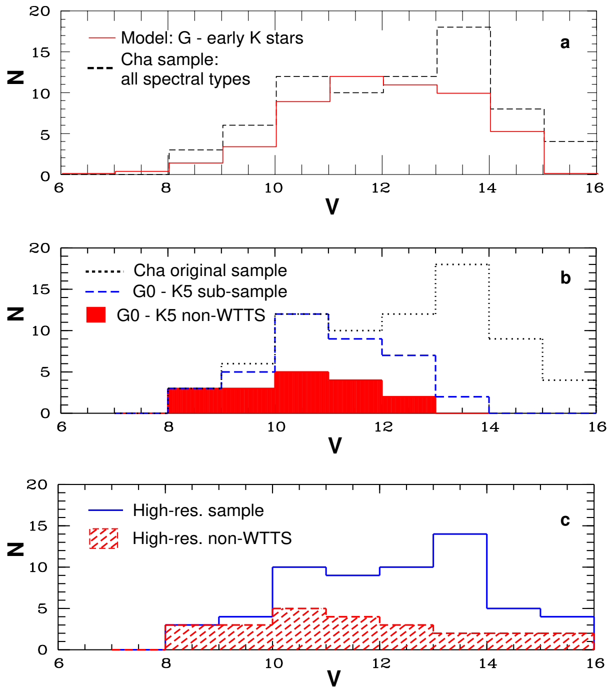

Fig. 2. **panel a)** comparison between the distribution of visual magnitudes for G–early K, ZAMS stars which are expected to be identified among the RASS sources according to Briceño et al.'s (1997) model (thin solid line), and the entire observational sample of WTTS in Chamaeleon selected by Alcalà et al. (1995) (dashed line); **panel b)** observed distributions for the Chamaeleon stars: Alcalà et al.'s original sample ((dotted line), the G–K5 sub-sample (dashed line), and sub-group of non-WTTS in the G–K5 interval (filled area); **panel c)** distributions for the Chamaeleon stars observed with high-resolution spectroscopy: the solid line represents the whole sample, the dashed area indicates the non-WTTS sub-group of all spectral types.

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