RELATIONS BETWEEN CORONAL AND CHROMOSPHERIC ACTIVITY DIAGNOSTICS IN T TAURI STARS

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ABSTRACT. The study of the relationships between various activity diagnostics in T Tauri stars (TTS) suggests that the CaII K, MgII k and H_α lines are formed in a similar region of TTS' atmosphere. For the more active TTS, an extended circumstellar region seems to be the major source of the emission, whereas a solar-type atmosphere alone may be able to account for the emission spectrum of low-activity TTS.

1. INTRODUCTION

The atmosphere of TTS is the seat of a high degree of non-radiative heating which results in a number of emission lines (CaII, MgII, H_α) typical of the spectrum of these low-mass pre-main-sequence stars and in a strong X-ray emission, up to 10^3 times larger than the X-ray flux observed in late-type dwarfs. Two broad classes of models have been proposed to account for TTS' emission line spectrum. The "deep chromosphere" model assumes that TTS possess a solar-like chromosphere beginning however at higher optical depth than in the Sun /1/. The second class of models assigns the origin of the emission line spectrum to an extended circumstellar region of a few stellar radii /2/. It seems now widely accepted that both a chromosphere and an extended envelope are needed to describe the various features of TTS' emission spectrum. However, the detailed structure of the immediate circumstellar environment of TTS remains unclear.

2. ACTIVITY DIAGNOSTICS

Informations about the structure of stellar atmospheres can be gained from the analysis of relationships between activity diagnostics formed at different atmospheric levels. Such relationships are known to exist for late-type dwarfs where the intensities of various chromospheric diagnostics (CaII, MgII, H_α) are linearly correlated /3,4/ whereas coronal X-ray emission varies with the intensity of chromospheric diagnostics following a power-law with a slope of 2.6 /5/. The existence of these

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 369–372.

https://doi.org/10.1017/S0074180900156748 Published online by Cambridge University Press

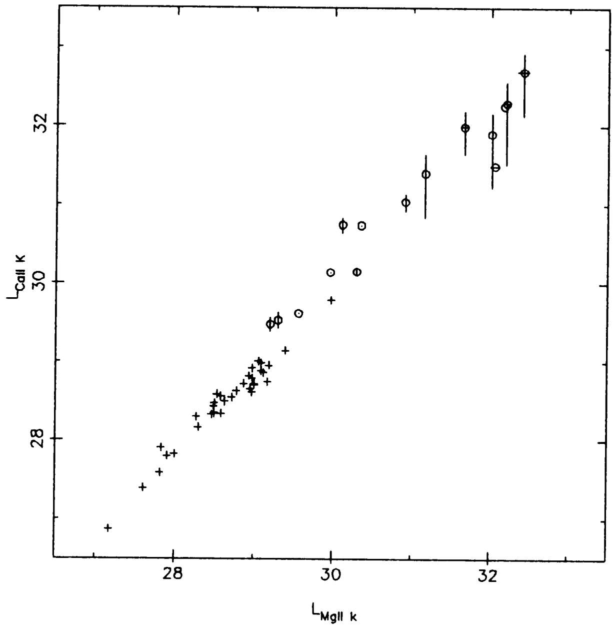

Fig. 1. CaII K-line luminosity versus MgII k-line luminosity for dwarfs(+) and T Tauri stars(o).

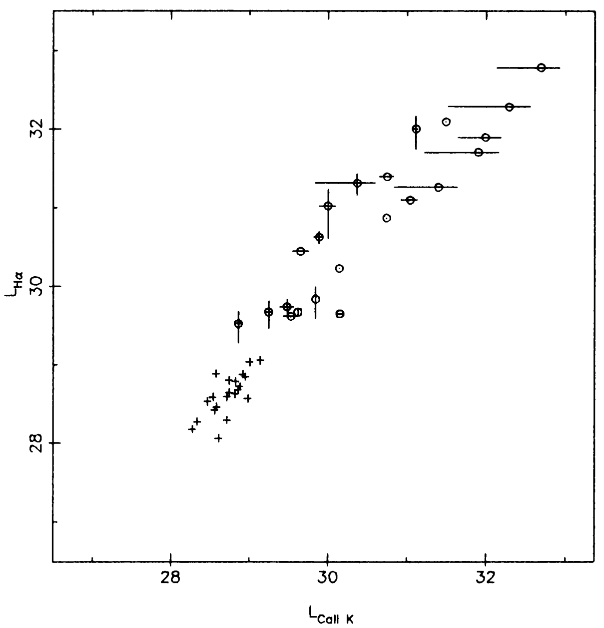

Fig. 2. H_α-line luminosity versus CaII K-line luminosity for dwarfs(+) and T Tauri stars(o).

tight correlations between various activity criteria implies that the different atmospheric layers are physically associated by a unifiing mechanism which, in the case of late-type dwarfs as in the solar case, is believed to be the magnetic field/6/. In Figures 1 to 4 we study the relationships between several activity criteria in TTS and compare them to those found in dwarfs. In each figure, the crosses represent late-type dwarfs and the open circles represent TTS. The bars associated with TTS reflect the range of observed variability between consecutive measurements. The axis are luminosities expressed in erg/s on a logarithmic scale. In figure 1 we have plotted the stellar luminosity observed in the CaII K-line versus that measured in the MgII k-line. The one-to-one correlation appears clealy for dwarfs and seems also to be fulfilled by TTS. Although this result doesn't indicate a similar atmospheric structure between dwarfs and TTS nor does it mean that the heating mechanism is the same in the two stellar groups, it suggests that the CaII K and MgII k lines are formed in the same region of TTS's atmosphere. This conclusion appears to be valid also for the H_α-line, the luminosity of which is plotted versus the CaII K-line luminosity in Figure 2. Although the scatter, both for dwarfs and for TTS is much higher than in Figure 1, these two diagnostics seem to be linearly correlated. The in-

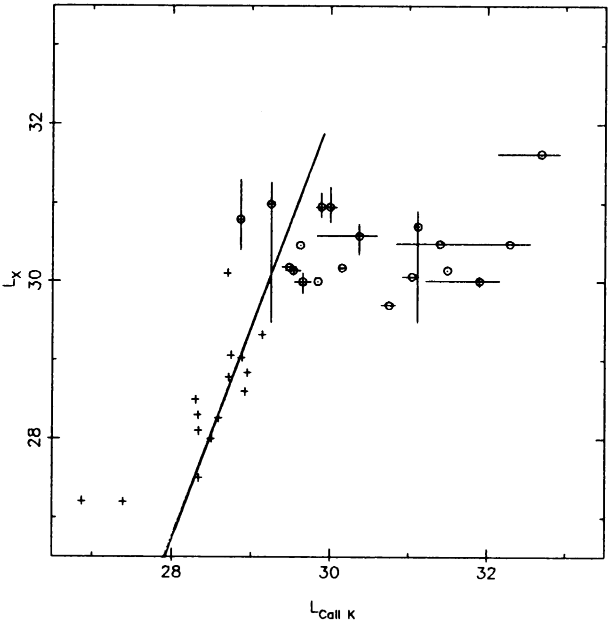

Fig. 3. X-ray luminosity versus CaII K line luminosity for dwarfs(+) and TTS (o). Solid line: $L_X \propto (L_{CaII\ K})^{2.6}$.

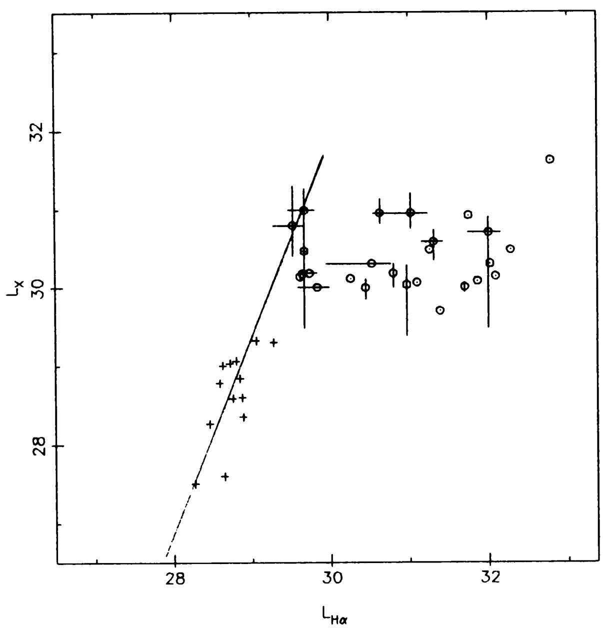

Fig.4. X-ray luminosity versus H_α-line luminosity for dwarfs(+) and TTS(o). Solid line: $L_X \propto (L_{H_\alpha})^{2.6}$.

creased scatter may arise from the fact that, in dwarfs, the H_α-line forms at higher chromospheric level than CaII K-line so that these two lines are more loosely connected than are the CaII K and MgII k lines. Remarkable is that the above relationships are valid over almost five decades and appear to remain the same for low-mass and high-mass TTS.
In Figure 3 and 4 we plotted the stellar luminosity observed in the X-ray range versus the one observed in the CaII K and H_α-line respectively.
In dwarfs the luminosities of these activity diagnostics are related by a power-law with a 2.6-slope which is represented in both figures by a solid line. Obviously this statistical relationship breaks down when dealing with TTS: whereas the intensity measured in the CaII K and H_α lines describes almost four decades, the X-ray luminosity varies only over one decade.

3. DISCUSSION

Clearly, most of the TTS in our sample namely the more active ones, do not appear to fit the solar-like atmosphere assumption. The failure appears in Figure 3 and 4 where the departure of a number of TTS from the correlation found in dwarfs goes in the direction of an excess of emission line intensity relative to X-ray emission. Moreover, emission line intensity and X-ray emission seem to a large extend uncorrelated in TTS contrary to what is expected in the case of a solar-

https://doi.org/10.1017/S0074180900156748 Published online by Cambridge University Press

like atmosphere governed by magnetic fields. Thus it appears necessary to call for an extended circumstellar envelope as the main contributor of the emission line intensity observed in the more active stars of our sample. And the conclusions drawn from the one-to-one correlations existing between CaII K, MgII k and H_α-line intensities in TTS seem to indicate that these three activity diagnostics form mainly in the circumstellar envelope. However, few TTS displaying lower emission characteristics lie on the extrapolation of the correlation between coronal and chromospheric diagnostics verified by dwarfs, a result that suggests that these low-active TTS do not possess large circumstellar envelopes and that the emission arises mainly from a solar-like atmosphere.

4. CONCLUSION

The study of various activity diagnostics reinforces the growing evidence that two different circumstellar regions may play a leading role in the emission characteristics of T Tauri stars. For low-active TTS a solar-like atmospheric structure may account for the behaviour of the different activity diagnostics although a larger non-radiative heating input than in the Sun is necessary to reproduce the observed activity level /7/. For more active TTS an hot, extended circumstellar region seems to be the main contributor to the intense emission line spectrum, keeping in mind that the additive contribution of an underlying solar-type atmosphere cannot be dismissed.

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