THE CHROMOSPHERIC AND TRANSITION LAYER EMISSION OF STARS WITH DIFFERENT METAL ABUNDANCES

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ABSTRACT

We report preliminary results on observations of chromospheric and transition layer emission of stars with different metal abundances. Metal deficient stars generally show reduced emission in the Mg II resonance lines and also in the other chromospheric and transition layer emission lines. This is interpreted as showing that energy fluxes other than acoustic fluxes must at least be co-responsible for the coronal and transition layer heating.

INTRODUCTION

Let me state in the beginning that this is not the final word on the subject matter but rather a progress report. We are continuing our observations.

To date we have looked at 13 metal poor stars of varying metal abundances and at one super metal rich star 31 Aql. By means of this study we want to get information about the heating mechanisms for the chromospheres, the transition layers and the coronae.

If only acoustic flux is responsible for the heating, we expect very little difference for population I and population II stars. The noise generation in the convection zones should be nearly the same since the convective velocities are hardly influenced by the metal abundances (Böhm-Vitense[1)] 1971).

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If, however, we observe that the heating in the chromospheres and transition layers is different for metal poor stars then some other mechanism must be responsible for it. Judging from solar observations we would assume that it is the magnetic field. This may decay with increasing age of the stars.

THE OBSERVATIONS

GENERAL DESCRIPTION

13 metal deficient stars were observed up to now, excluding the two metal poor horizontal branch stars HD 109995 and HD 161817 which did not show any signs of chromospheric emission. Since for a given electron density and temperature the line emission is proportional to the metal abundance Z we purposely selected mainly stars of moderate metal deficiency.

A comparable number of normal metal abundance stars was also observed.

For most stars we have studied the cores of the Mg II resonance lines as well as the short wavelength chromospheric and transition layer emission line spectrum.

THE EMISSION IN THE MG RESONANCE LINES

In order to determine the absolute fluxes we used the absolute calibration of Castella and Selvelli[2] (1980) for the high resolution spectra, which gave somewhat lower values than a calibration of our measured average intensity at 2740±50Å by the absolute intensities measured by Thompson[3] et al. 1978 for $\lambda \sim 2740$Å.

The results of our measurements for the k_2 emission line fluxes are displayed in Figure 1 where we have plotted the ratio RF of the flux in the Mg II k_2 line to the total flux σT^4_{eff}. We find generally lower Mg II emission for the metal deficient stars analoguous to the decreased Ca II K_2 emission. The reduction is about a factor three, surprisingly independently of the amount of metal deficiency.

THE SHORT WAVELENGTH EMISSION LINES

We have restricted this discussion to the intensities of the carbon lines at 1657Å(CI), 1335Å(C II) and 1549Å(C IV), which span nearly the whole range of temperatures observed.

The results of our measurements are given in Figures 2-4. We have not seen with certainty any shortwave emission lines in any of the metal deficient stars except some emission in the CI 1657Å line which often appears as a broad feature. We do not quite know what we see. We have tried to estimate upper limits from little humps that may be real or not, or from looking at the noise of the tracings and estimate how large the intensity could be without being recognized as a line.

Unfortunately the upper limits are not as low as we would like them to be. We have to take still longer exposures of the brightest of the metal deficient stars.

We do not consider for the moment the 1657Å lines for HD 140283 and μ Cas, since we do not really know what they are. From the figures it is then clear that the higher the necessary temperature for the line emission, the steeper is the intensity decrease of the line with decreasing temperature. One gets the impression that the normal metal abundance stars break up into two branches. The high intensity branch being mainly populated by stars with some peculiarity. 31 Aql which appears to be super-metal rich, but is a high velocity star, does not know on which branch it belongs. The branches, though not very obvious, are still somewhat preserved on Figures 3 and 4.

We also see that the metal poor stars show less emission than the normal metal abundance stars. Again the reduction of the intensity is present for low metal deficiency as well as for large metal deficiencies.

Even for slight metal deficiencies we do not see with certainty any emission lines.

THEORETICAL IMPLICATIONS

The fact that the intensity reduction of the emission lines in metal deficient stars is not correlated with the degree of metal deficiency tells us that it is not a direct effect of the reduced metal abundance but rather due to a common property of all metal deficient stars which presumably is their large age. Since apparently metal enrichment happened fast the ages of all metal poor stars and the oldest normal metal abundance stars do not differ very much. We therefore conclude that the reduced chromospheric emission of metal poor stars tells us that the energy input into the chromospheres decreases with increasing age of the stars. Since the convection and therefore the acoustic flux do not change with time there must be an important additional energy input mechanism which does change with time. Solar observations suggest that it is the magnetic field even though the details of the heating mechanisms are not yet well understood. With increasing age of the stars rotation and with it the magnetic fields of the stars may decay (Kippenhahn[4]) 1972).

We might ask is this conclusion not drawn too hastily? Could not the same amount of energy be fed into the outer layers of the stars, and we would not see the radiation because of the lower metal abundances or because of stratification differences like a lower electron density in the chromosphere and transition layer or a steeper temperature gradient?

If the same amount of energy is fed into the outer layers then the energy balance requires that it must come out somewhere. If it would come out as a stellar wind we might not see it. This wind would then have to be stronger than for stars with transition layer emission. A stronger wind however requires either higher coronal densities and/or higher temperatures. Both would lead to higher X-ray emission than for normal metal abundance stars, which is not observed. As Dr. Vaiana[5] (1980) points out, the X-ray emission of metal deficient stars is at the lower end of the observed X-ray flux distribution for stars.

A steep temperature gradient in the transition zone could lead to a large conductive heat transport back into the chromosphere, but since Mg II and Ca II emission is weak we do not see it being radiated away from the chromosphere either.

It then appears that less energy input into chromosphere, transition layer and corona is required for old stars, telling us that magnetic fields are important for the heating.

REFERENCES

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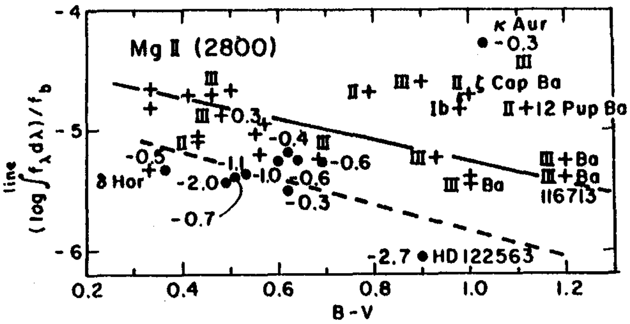

Figure 1: The Mg II (2795) k_2 emission line intensities $\int F_\lambda d\lambda$ divided by the bolometric flux F_b are plotted as a function of B–V for the stars. x mark stars with normal metal abundances or apparently super metal rich stars. Dots mark metal deficient stars. The log Z–log $Z_\odot$ values are given at the points. Luminosity classes are also indicated.

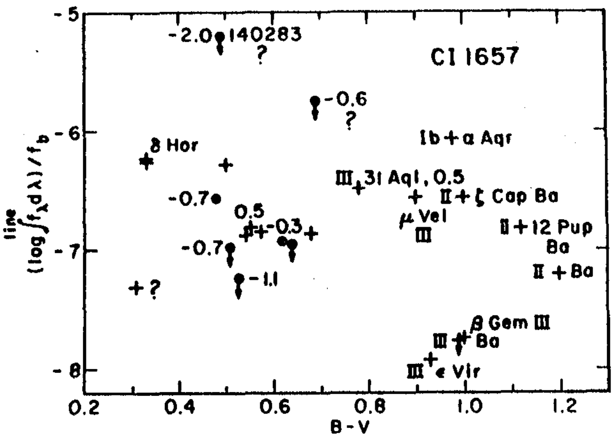

Figure 2: The emission line surface fluxes in the CI line at 1657Å divided by the total flux σT_{eff}^4 are plotted as a function of B–V of the stars. Notation as in Figure 1.

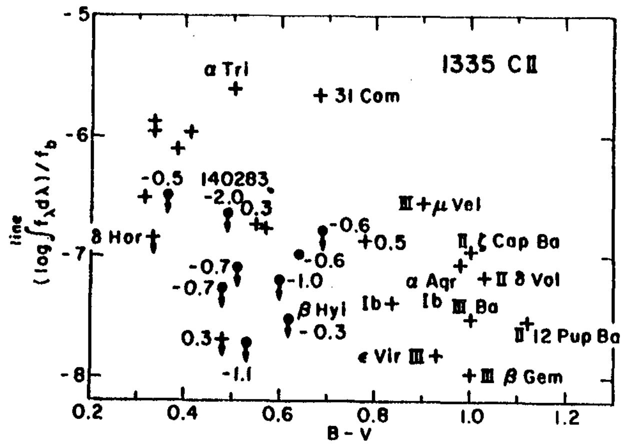

Figure 3: The emission line surface fluxes in the C II lines at 1335Å divided by the bolometric flux σT^4_{eff} are plotted as a function of B-V. Notations as in Figures 1 and 2.

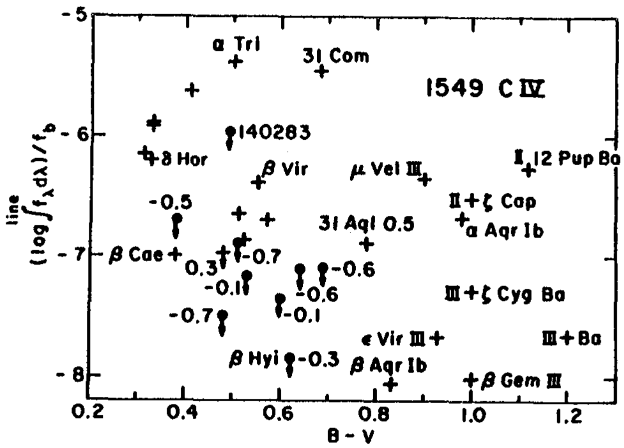

Figure 4: The emission line surface fluxes in the C IV lines at 1549Å divided by σT^4_{eff} are plotted as a function of B-V. Notation as in Figures 1-3.