OPTICAL CHROMOSPHERIC SPECTRAL LINES IN K AND M DWARF STARS

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Abstract. *Observations are reported of the Ca II resonance lines and Hα in dK and dM stars, made with high S/N ratio and high spectral resolution. Ca II emission is found in all stars observed, and those having weak Ca II exhibit marked Hα absorption. It is found that the strengths of the two kinds of chromospheric lines are not tightly correlated, an effect which can be shown to be independent of the effective temperature of the stars. The result implies that a one-parameter description (e.g. heating rate) of the chromospheres is not viable. While lateral inhomogeneities are likely to be an important second parameter, we also suggest that the Hα line may be formed in a region considerable higher that in which the Ca II lines are formed.*

Introduction.

Chromospheric emission in the cores of the Ca II H and K resonance lines is a very common—perhaps universal—feature of the optical spectra of K and M dwarf stars. Emission in $H\alpha$ also occurs, although in a much smaller fraction of the earlier stars than Ca II: stars with an obvious $H\alpha$ emission feature are designated with an (e) classification. The strengths of Ca II and $H\alpha$ emission lines are correlated, and stars with strong emission in both lines show a strong propensity to flare. Chromospheric activity and the flaring phenomenon are related to electrodynamic processes, but the mechanisms are poorly understood.

A number of remarkable properties of the Ca II and $H\alpha$ lines in dK and dM stars have emerged from observational and theoretical studies over the past few years. Following pioneering work by Fosbury (1974), Cram and Mullan (1979) predicted that dM and late dK stars having "intermediate" levels of chromospheric activity might exhibit relatively strong *Hα absorption*. This has been partially confirmed by Stauffer and Hartmann (1986) and Giampapa *et al.* (1988). This work implies the existence of stars having a level of chromospheric activity sufficiently strong to have $H\alpha$ delicately balanced between emission and absorption, and a few stars belonging to this class have now been identified (e.g. Young *et al.* 1984; Stauffer and Hartmann 1986; Bopp 1987; Robinson and Cram 1988). They have been named the "marginal BY Draconis stars" by Bopp.

Recent work on the optical chromospheric lines of dK and dM stars has also raised a number of problems. For example, Stauffer and Hartmann (1986) found a wide scatter in the strength of $H\alpha$ absorption in stars of selected photospheric colour. While this presumably reflects differing levels of chromospheric activity, a satisfactory interpretation has not yet been advanced since there is an ambiguity regarding the physical origin of line weakening (since both lower and higher chromospheric heating rates may lead to weaker $H\alpha$). Giampapa *et al.* (1988) attempted to resolve this ambiguity by observing both Ca II and $H\alpha$ in a small sample of stars. They found that there is a wide scatter between the two chromospheric lines, implying that a one-parameter description of the

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chromospheres may not be viable.

In a attempt to elucidate some of the physical processes at work in the formation of the Ca II and $H\alpha$ lines in dK and dM stars we have been using the 3.9 m Anglo-Australian Telescope (AAT) to obtain high S/N, high dispersion spectra of a large sample of dK and dM stars chosen from Gleise's (1969) catalogue. We present here a brief report on the highlights of the results of these observations to date.

Observations.

The data discussed here refer to a sample of about 50 stars observed on the nights of 1987 August 7-9, using the RGO Cassegrain spectrograph. The $H\alpha$ line was observed using a GEC CCD detector, with an effective spectral resolution of about 150 mÅ, while the Ca II H and K lines were observed using the Image Photon Counting System (IPCS) with an effective resolution of 400 mÅ. The spectra were exposed for sufficient time to attain a S/N ratio in the continuum of about 20 at Ca II and 80 at $H\alpha$, for most objects. The quality of our Ca II data, in particular, appears to be substantially superior to previously published blue-violet spectra of such late-type stars (cf. Giampapa *et al.* 1981), reflecting the high efficiency and good dynamic range of the IPCS.

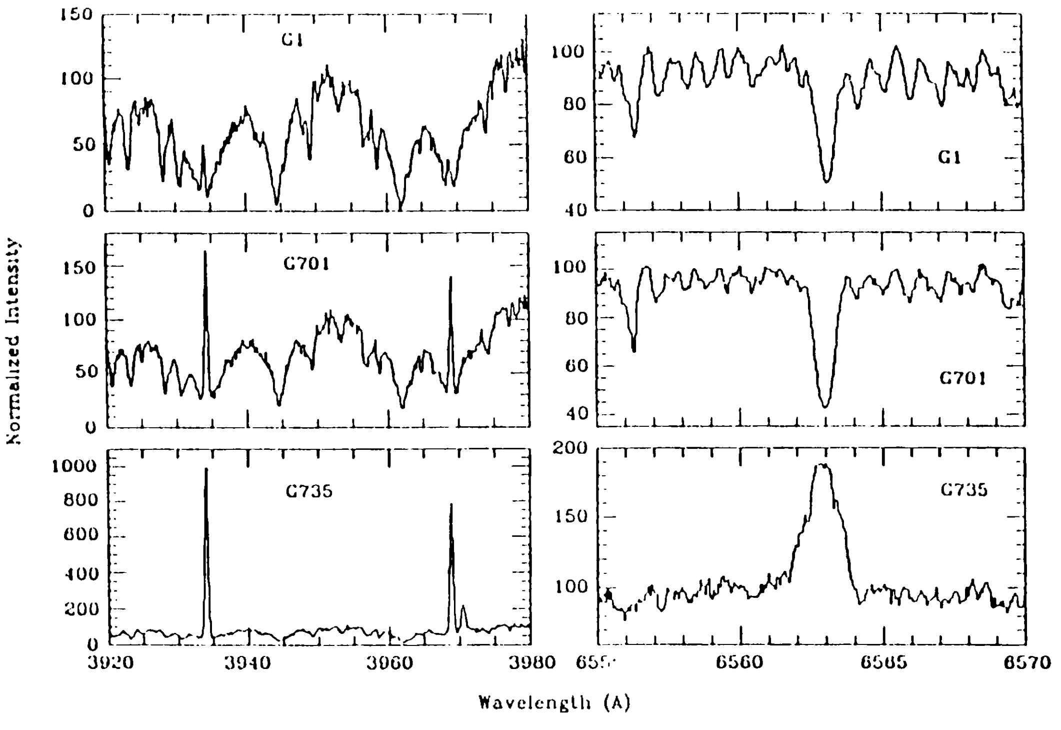

Figure 1: *Ca II and $H\alpha$ spectra of 3 stars in the sample chosen from Gleise's catalogue.*

Samples of the spectra are displayed in Figure 1. The Ca II spectra reveal the existence of a "continuum" between the Ca II lines reminiscent of that in the solar spectrum. This opens up the possibility of using the damping wings of the Ca II lines to provide a new way to probe the structure of the outer *photospheres* of these stars. The spectra permit the ready determination of the emission flux in the Ca II K line (the Ca II H line is contaminated by $H\epsilon$) and in $H\alpha$, and an important result of our work is

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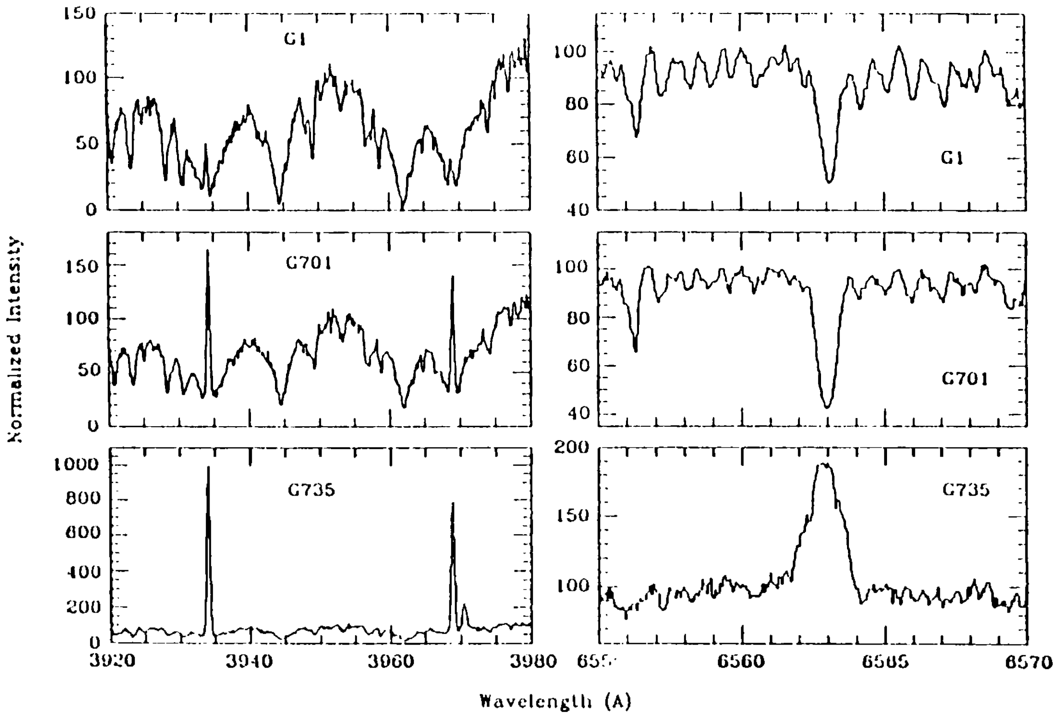

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Cram and Giampapa (1987) also discussed a simple extension of their model which takes account of the possible existence of lateral inhomogenities on the star. If the chromospheres can be represented by two states (i.e. "active" and "quiet") then the $H\alpha$ *versus* Ca II plot will form another locus connecting two points on the original U-shaped curve, parametrised by the fractional area occupied by the two components. Since we might expect only a weak correlation between the heating rates in the two states and the fractional area covered, it may be concluded that stars can fall almost anywhere above the U-shaped locus. This conclusion is not in disagreement with the observations, although the implication that the lower envelope of the observed points should form a U-shaped locus is not well supported.

An important feature of our data is the existence of large values of $H\alpha$ absorption equivalent width (> 300 mÅ) over an extensive range of Ca II emission levels. While this might be explained partly in terms of the special properties of lateral inhomogeneities in dK and dM stars, we conjecture that, alternatively, it may provide evidence for the existence of rather large volumes of relatively low pressure, heated $H\alpha$ absorbing material, analogous to solar prominences. The widespread occurrence of such material in a given star would lead to strong $H\alpha$ absorption in its spectrum, independently of the level of Ca II emission which is presumably produced principally in low-lying, compact analogues of solar plages.

Further investigation of this conjecture requires more data, particularly for stars of later spectral type in which the photospheric contribution to $H\alpha$ is negligible, and also a more complete analysis of the line formation processes than is available at present. If found to be correct, the proposal that dK and dM stars possess widespread "prominence" activity might provide a clue to the disposition of the large amounts of magnetic free energy which are presumably required to power intense stellar flares.

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