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Ca II K Emission in Canopus

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Abstract. The changes in the Ca II K line profile of the F0 supergiant Canopus have been studied from the high dispersion coude spectrograms obtained since 1975. The emission in the core of the line is variable in a timescale of few days. Similar activity seems to be occurring in Mg II h and k lines also. This is attributed to the variability in the appearance of plage areas on the stellar surface.

Key words : Ca II K line—Mg II h and k lines—chromospheres— plages

1. Introduction

One of the questions in the study of stellar chromospheres is whether the outer atmospheres of stars change in a fundamental way near spectral type F as convection zones become thin and carry little flux with increasing stellar effective temperature. This question was investigated by Bohm-Vitense & Dettmann (1980) who surveyed 21 F and 13 A-type stars for the Mg II and other chromospheric (transition region) lines in the ultraviolet with IUE satellite. They find that the chromospheric emission lines begin to appear at $(B - V) \gtrsim 0.32$ (about spectral type F0) on the main sequence, but to the right of the Cepheid instability strip for the more luminous stars. Thus the supergiants F8 to G0 occupy the transition region for stars with and without chromospheres. The surface convection zones due to H, He ionization are considered as necessary condition for the formation of stellar chromospheres (Bohm-Vitense & Nelson 1976). In this context it is of particular interest to investigate chromospheric activity of the supergiants. Canopus (F0 Ib) is one of the prime candidate for such an investigation.

Ca II K line emission was first detected by Warner (1966) on Radcliffe coude spectra of 6.8 Å mm^{-1} dispersion. The emission was bright enough to facilitate a measure of its width. This value turned out to be much smaller than that expected from an Ib star from the K-line width—absolute magnitude relation of Wilson &

*After Dr Bappu's death on 1982 August 19, a few additional observations were made, and the manuscript was prepared by MVM & NKR.

Bappu (1951). Since the solar K-emission is principally dominated by emission from bright mottles, that is a feature of the convection below the photosphere, Bappu (1973) conjectured on magnetic field stimulated plages as means of explaining the deviation from the normal pattern of the K-line behaviour in the stars. An observational study to investigate K-emission of Canopus was initiated by one of us (Bappu in 1975). Since then Rakos *et al.* (1977) have detected a variable magnetic field in the star that ranges between + 600 and −100 Gauss. More recently Linsky & Marstad (1981) obtained IUE observations of Canopus and showed that Mg II h and k lines (at λλ 2795, 2802) do not show the chromospheric emissions. They dispute the claim by Evans *et al.* (1975) who detected chromospheric emission in Mg II lines from the *Copernicus* V2 spectrum.

We report in this study the observed variations of Ca II K-emission line structure.

2. Observations

The observations were all made at the coude focus of the Kavalur 102-cm reflector. The 1975 observations were made with an echelle spectrograph that provided a dispersion of 4 Å mm^{-1} at the K-line. Subsequent observations were obtained with a 2.84 meter camera and 400 ln mm^{-1} grating giving a dispersion of 2.8 Å mm^{-1}. Several of these profiles are displayed in figure 1, along with a tracing of the Radcliffe spectrogram obtained by Warner in 1965 (generously sent by Dr M. W. Feast to Bappu). The intensities were normalized at λ 3932.05. The zero of the wavelength scale refers to the wavelength of K-line as determined from the nearby Fe I lines.

3. Discussion

It is apparent from figure 1 that emission is variable. On several occasions the emission is not detectable (*e.g.* 1975 February, 1978 January, 1980 November), on other occasions the emission shows double peaks both K2V and K2R and central absorption K3 (1965 October, 1977 February, 1982 December 30). Some times only one, either K2V or K2R, is prominent. However, most of the time Canopus seems to show emission. Dravins (1982) has surveyed late type stars to see secular changes in K-emission with spectral types. At the time of his observation (1974 December 29) also Canopus showed chromospheric emission profile with both K2V, K2R and K3.

In order to study the variation of the K-emission we made an artificial photospheric profile of K-line by joining the shortward and longward side of the two different profiles which are not blended by emission (1982 December 2 and 1983 January 31 have been used). The difference from this photospheric profile brought out the changes in emission.

It was of particular interest to see whether any periodicity of 23–30 days exists which might correspond to the timescale of variation of magnetic field strength. A possible period of 22.3 days was obtained earlier by Rakos *et al.* (1977) for magnetic variations. Our present observations are not definitive, but they do indicate variation within 30 days. Plates obtained 7 days apart do not show major changes (1982 December 23, 30). So a timescale (though not strictly periodic) of 20–30 days is possible.

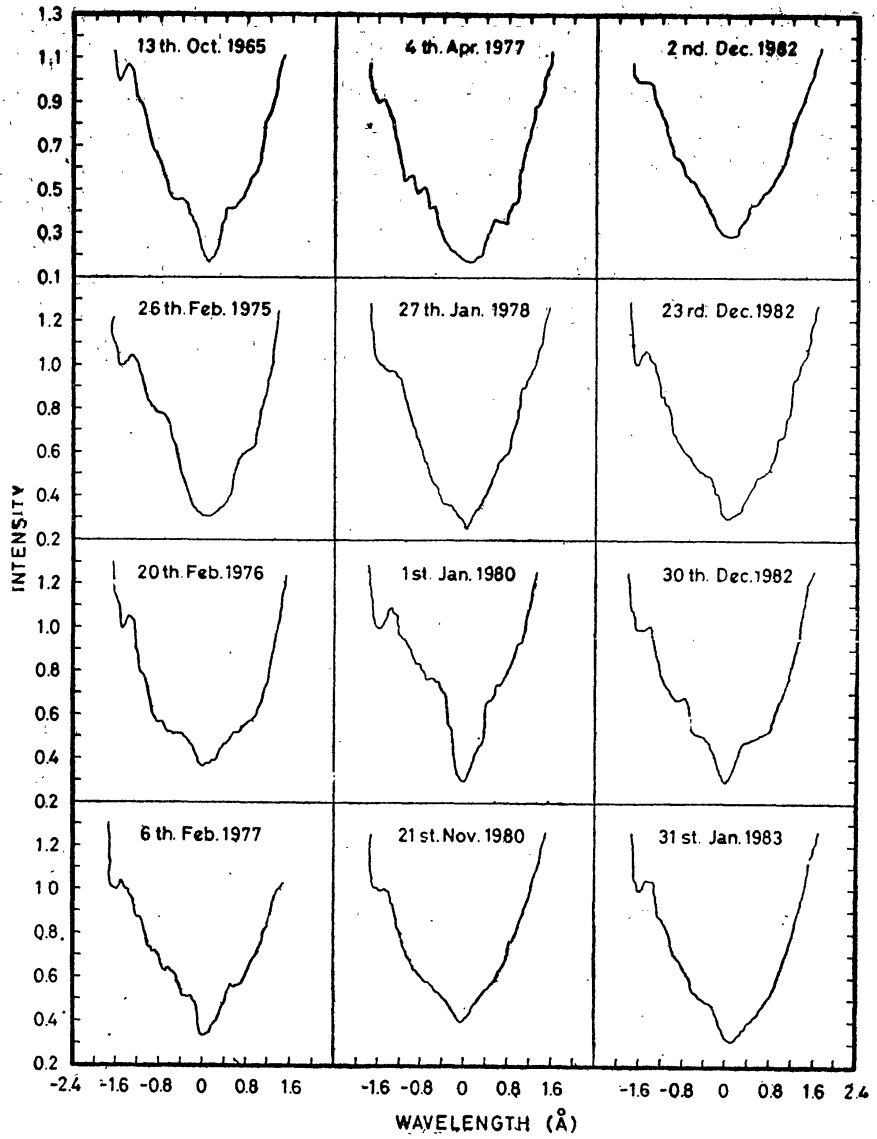

Figure 1. Profiles of Ca II K obtained on different occasions. The 1965 profiles are due to Warner (1966). The ordinate is relative intensity. The zero of the wavelength scale corresponding the Ca II K is obtained from the near by stellar Fe I lines.

Figure 2 shows the statistics of occurrence of both K2V and K2R, K2V or K2R, and no emission, from our plate material. Most of the time some sort of emission occurs, and 50% of the time the double emission seems to be present. In the double emission mostly both K2V and K2R are of equal intensity.

There does not seem to be any shift of K2 absorption peak in radial velocity.

The most puzzling aspect about the chromospheric emission in Canopus is the absence of Mg II emission reported by Linsky & Marstad (1981). On the few occasion it was observed by IUE apparently no Mg II emission (also no trace of transition region lines in λλ 1200–1900) occurs; unfortunately no concurrent observations of both Ca II and Mg II lines exist.

We also searched the IUE logs for observations of Mg II lines at λ2800 which have been obtained close to the time when we could see Ca II K emission in our

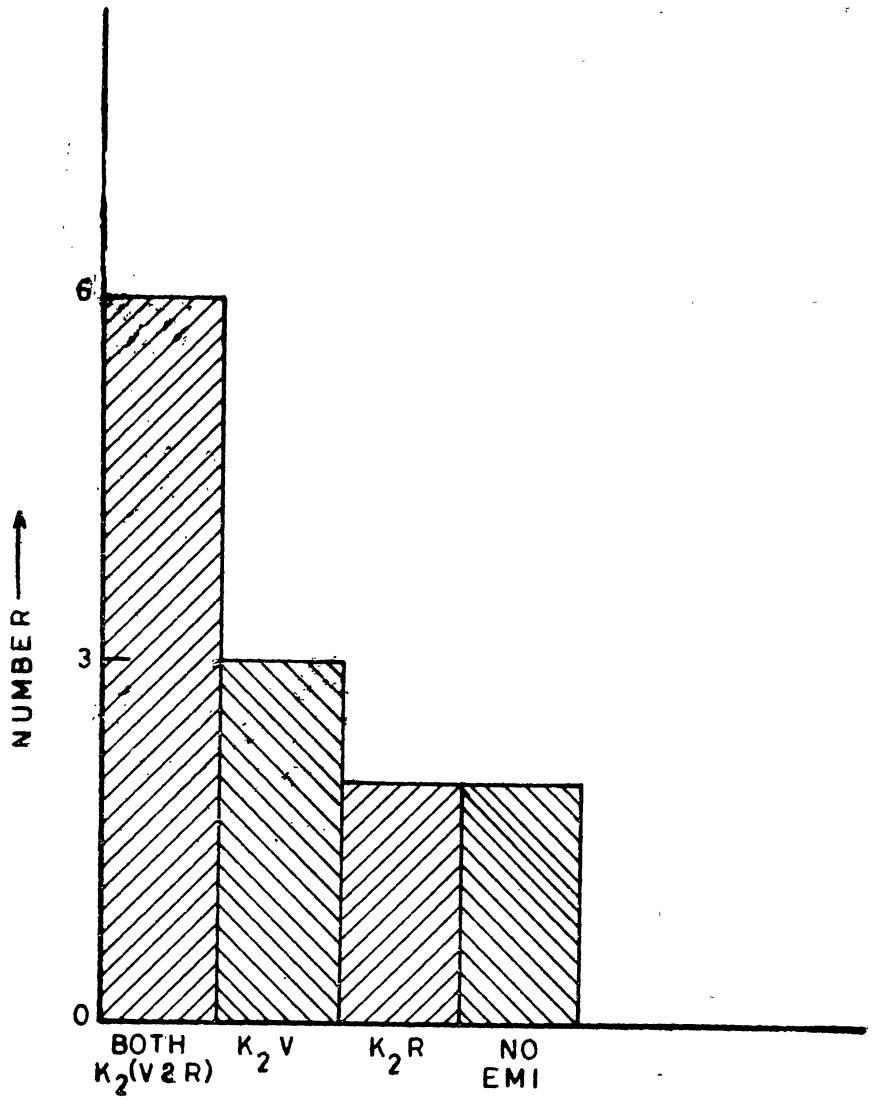

Figure 2. A histogram showing the number of occurrences of emissions.

observations. On 1980 January 1, there was emission at Ca II K line and the nearest IUE observation was apparently on 1980 March 18 (image LWR 7234 with 11s exposure with large aperture). To see whether there is any emission component in Mg II lines, we compared the line profiles of this image (LWR 7234) with an earlier observation obtained on 1979 March 3 (LWR 3919 with 9s exposure with large aperture). Figure 3 shows the superposition of the Mg II lines of these two images. There does seem to be emission present in Mg II lines at the time of 1980 March 18. Thus, like Ca II K, the Mg II emission is also variable and sporadic.

Canopus was also detected as a soft x-ray source by Vaiana *et al.* (1981) with flux 10^{30} erg s^{-1} and with ratio of surface fluxes in x-rays to optical comparable to solar coronal hole values indicating that a corona also exists.

The variable Ca II K emission does not appear to be due to stellar rotation since the $V \sin i$ value is close to zero and might reflect more of appearance and disappearance of plage areas on the surface. It is known that Ca II K line width in Canopus does not obey the Wilson-Bappu relation (Warner 1966). From the solar anology

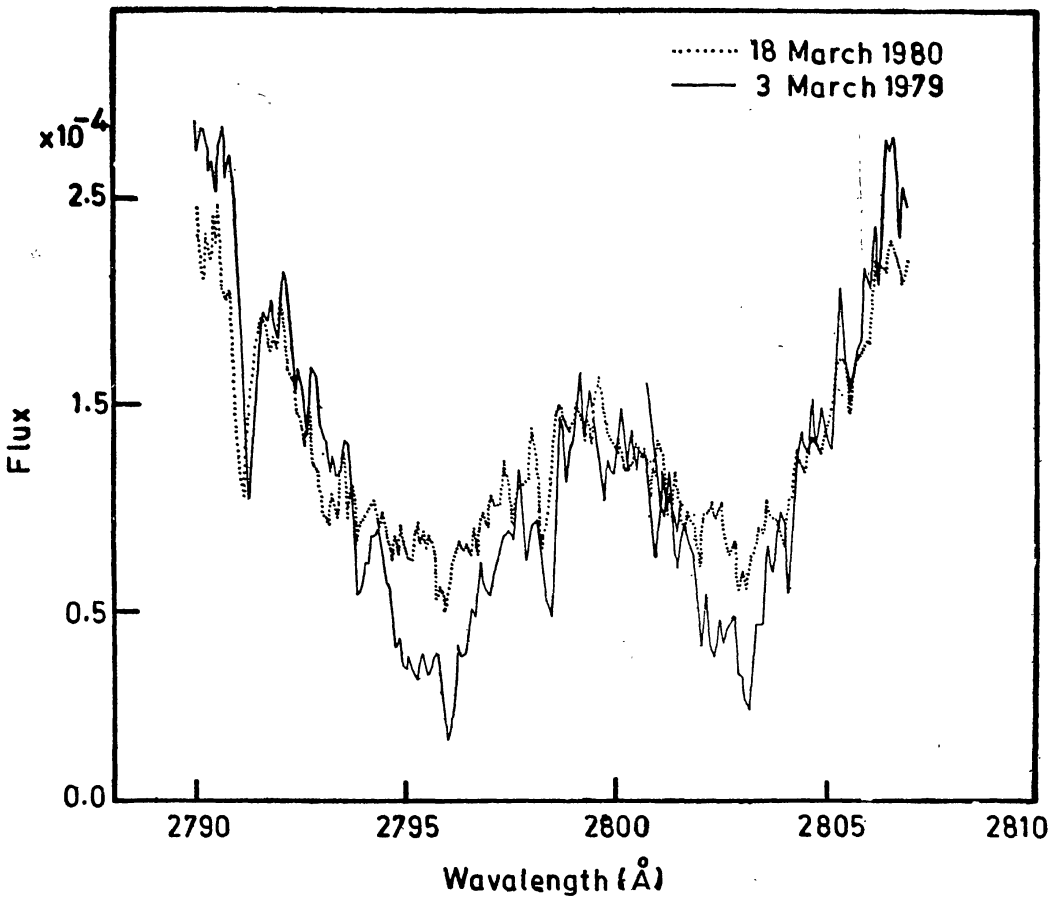

Figure 3. Mg II h and k profiles of Canopus obtained on two occasions with IUE satellite. Ordinate is relative flux. The sharp absorption in the cores of the lines might be due to interstellar medium.

this might indicate that the intense magnetic field in the plage areas will tend to narrow down the K_2 line width as a reslut of which the line width would be much smaller than what the luminosity of the star calls for.

In addition to the variable component, Canopus might also have a quiescent chromosphere which gives rise to the line emission as estimated by Linsky & Mastrad (1981).

Monitoring the Mg II profile simultaneous with Ca II in Canopus would be interesting. We are currently continuing our Ca II observations whenever possible.

Acknowledgements

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