SPECTRAL IMAGES OF HD 199178

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ABSTRACT

We have obtained a series of high-resolution spectra of the Mg II k line of HD 199178. We are applying spectral imaging techniques to derive an image of the chromospheric structure and to study the transient behavior of the chromosphere. We have uniformly reduced and analyzed all spectra in the IUE archives, and we are comparing our results with ground-based observations of the photosphere. Four ultraviolet flares on HD 199178 have been observed; 3 of these occurred at roughly the same rotational phase There is no clear phase-dependence of the SWP line fluxes, but there is for the Mg II k flux The emission centroid of the Mg II k line varies in a quasi-sinusoidal fashion, presumably due to the rotation of a non-uniform chromosphere

Keywords. HD 199178, Spectral Imaging, FK Comae Stars, Chromospheres, Stellar Flares

1. INTRODUCTION

HD 199178 is a G giant star with a $v \sin i$ of 80 km s^{-1} and a photometric period of P=3.337 days, yet it has no measured radial velocity variation (Ref. 1). Its rapid rotation, therefore, probably is not due to spin-orbit coupling in a close-binary system, but perhaps is a result of binary coalescence. Bopp and Stencel (Ref. 2) classified it as one of three known FK Comae stars. The shape and behavior of its visible light curve suggest that its photosphere is non-uniformly spotted and that the photospheric structure changes on yearly, or even monthly, timescales (Refs. 3, 4, and 5). HD 199178 is one of very few stars for which this photospheric non-uniformity has been mapped using Doppler imaging techniques (Ref 6)

The two low-resolution spectra obtained in 1981 (Ref. 2) showed some suggestion that the SWP line fluxes were brightest near the phase of maximum photospheric brightness (ϕ=0.5), suggesting a spatial correlation between the chromospheric and photospheric structure. Spectra obtained in 1982 seemed to confirm this suggestion, but the differences were less pronounced.

Because HD 199178 is a single, rapidly-rotating star with bright chromospheric emission lines, we considered it an ideal candidate for an ultraviolet spectral imaging study. We therefore obtained a series of spectra in September 1986. Unfortunately, only 3 unique phases were observed. The high-resolution spectra of the Mg II k (2795 Å) lines showed gross, apparently phase-dependent asymmetries that seemed to be correlated with the large photospheric spot seen in the optical Doppler image (Ref. 6) and perhaps with a scattering patch inferred from linear polarization measurements made in 1982 and 1983 (Ref 3).

In order to map the spatial distribution of the chromospheric emission, we obtained a series of seven uniformly phased, high-resolution LWP spectra in September 1987. These spectra are being used, in conjunction with those available in the IUE archives, to construct an "image" of the system as seen in the light of Mg II

We present results of the first phase of this analysis and discuss the measured constraints on the spatial distribution of the chromosphere These constraints will be used to derive series of images showing the chromospheric brightness distribution at the observed phases We will compare these images with contemporaneous optical results—Doppler images, linear polarization measurements, and photometry—and with the rotational modulation of the low-resolution SWP line fluxes

2 SWP LINE FLUXES

All of the low-resolution SWP spectra available in the IUE archives were processed uniformly with the current processing software. Line fluxes were measured by a gaussian fit to the emission line and a quadratic function to the local background (see Ref. 7 for details). The results for C IV (1550 Å), C II (1335 Å), and O I (1305 Å) are shown in Figure 1. The different symbols represent different epochs. All epochs were phased to the ephemeris given in Ref. 4.

The peak C IV fluxes in 1981 and 1982 presumably indicate stellar flares The C II flux was less enhanced during these

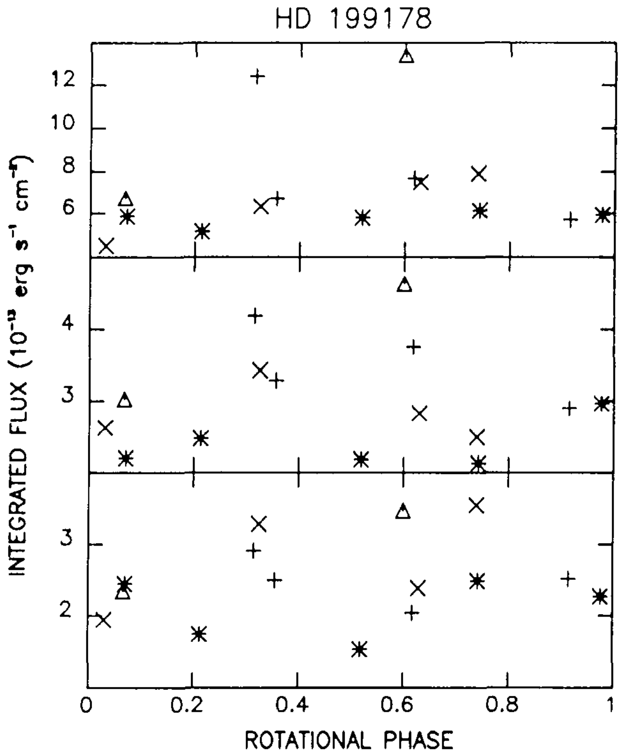

Figure 1. Integrated line flux v. rotational phase for C IV (top), C II (middle), and O I (bottom) are plotted with a common ephemeris. The symbols represent different epochs (Δ=1981, $\times$=1982, +=1986, $*$=1987). Each panel has a different flux scale.

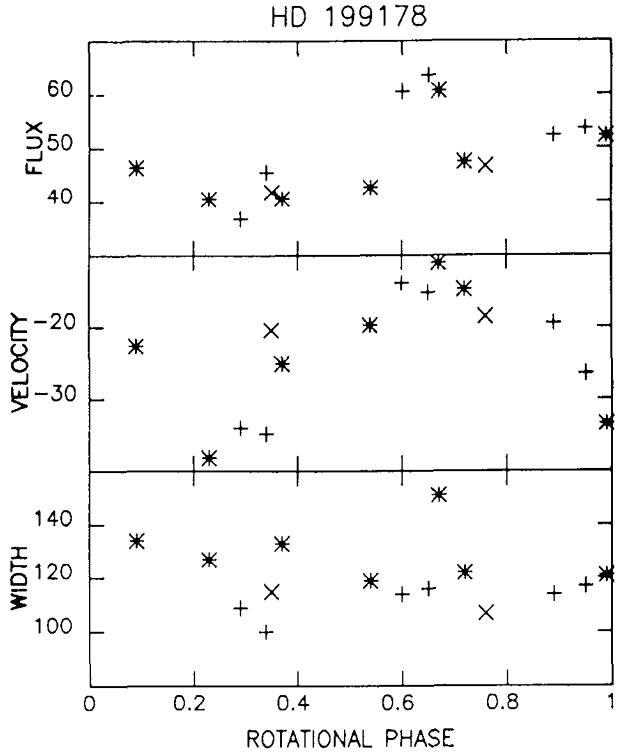

Figure 2 Parameters of the two-component gaussian fits to the Mg II k lines of all spectra available in the IUE archives. The symbols represent different epochs, as in Figure 1 (note that there were no high-resolution spectra obtained in 1981). The top panel shows the integrated stellar emission flux (corrected for interstellar absorption) in units of 10^{-13} erg s^{-1} cm^{-2}. The middle panel shows the centroid velocity of the stellar emission component, in km s^{-1}. The stellar radial velocity is -28 km s^{-1} (Ref. 1). The bottom panel shows the measured FWHM, expressed as km s^{-1}, with the instrumental width deconvolved.

flares, and the enhancement of the O I flux was smaller still. Contrary to earlier conclusions based solely on the 1981 (Ref. 2), 1982, and 1986 fluxes, there is no clear phase-dependence of the line fluxes. The 1987 fluxes are uniformly lower than those at other epochs.

The visible light curve of HD 199178 undergoes abrupt changes in amplitude (Refs. 4 and 5), and it is possible that the epoch of minimum light changes from year to year (Ref. 3). This system has been monitored regularly with the APT and by various observers. During the 1987 observing run, extensive photometry was obtained. A better understanding of the visible light curve is crucial to our interpretation of the ultraviolet variations.

3. TWO-COMPONENT FITS TO THE Mg II k LINES

As a first step in the spectral imaging procedure (see Ref. 8 for a detailed description of the technique), we fit all of the high-resolution Mg II k (2795 Å) spectra with two gaussian components: one to represent the global chromospheric emission and one to match the (unresolved) interstellar absorption line. In most cases these fits match the overall line profile well, but in a few cases line wing emission well in excess of the fit profile was seen. The parameters of the fitted stellar profiles are summarized in Figure 2.

Two flares (in 1986 and 1987), both at $\phi \sim 0.65$, are indicated by enhanced line fluxes (there was also a flare at this phase in 1981—see Figure 1). Aside from the flares, there is a clear phase-dependence of the Mg II k flux at all epochs, approximately in anti-phase with the visible light curve. In contrast to the SWP line fluxes, the mean Mg II k flux in 1987 is about the same as that seen at other epochs

The quasi-sinusoidal variation of centroid velocity (see Figure 2) with phase cannot be due to orbital velocity about a previously unknown companion, because visible spectroscopic observations (Ref. 1) place a much more stringent limit on any velocity variations (<2 km s^{-1}). The velocity variation therefore is probably due to the rotation of a non-uniformly bright star. A large, bright region in the chromosphere, centered at $\phi \sim 0.5$, could produce the oberved velocity variation. The peak Mg II k flux, however, is at $\phi \sim 0.0$, so this region does not account for the variability in the total flux (see Ref. 8 for another example of this phenomenon).

We will re-fit these spectra with a symmetric emission component centered at the predicted radial velocity plus an additional phase-dependent component This should provide a crude picture of the chromosphere. Any structure is likely large-scale, because no narrow features are seen to move across the line profile as the star rotates.

The measured line widths (Figure 2) are all significantly higher than the stellar $v \sin i$ (80 km s^{-1}). The profile was broadened by a tremendous amount during the 1987 flare, and the measured widths in 1987 are all higher than at the previous epochs

4. REFERENCES

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