Chromospheric Surface Structures on EI Eridani and HD 199178

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1. Introduction

Several groups at this meeting are presenting maps of the spatial distribution of either brightness or effective temperature in the *photospheres* of rapidly-rotating, late-type stars. It is generally believed that structure seen in these maps traces the magnetic topology, in analogy with the Sun. We expect the structure of the outer atmospheres (i.e., chromosphere and corona) of these stars to be even more directly tied to the magnetic topology; the magnetic structure is *three-dimensional.* In order to probe the radial dimension of stellar atmospheres, we need to combine maps of the spatial distribution of emission from *chromospheres* and coronae with these detailed photospheric maps.

Along with collaborators at Armagh, Catania, Boulder, Paris, Helsinki, and Stony Brook, I have been obtaining high-dispersion ultraviolet spectra of several rapidly-rotating, late-type stars using the IUE spacecraft. I discuss results for two stars, EI Eridani and HD 199178, for which photospheric maps are presented elsewhere at this conference.

2. EI Eridani = HD 26337

We observed EI Eri with IUE continuously for one rotational cycle in September 1988, and almost continuously for most of the following rotational cycle. As the light curves clearly demonstrate (Figure 1), most of the features did not repeat from one cycle to the next (the vertical dashed line is drawn at the end of the first two days, or one rotational cycle). The top panel shows the variation of the transition region emission lines. There appear to have been several flares in the first cycle. The relative enhancement of the transition region lines during these flares is higher than for the chromospheric lines (second panel). The third panel shows the flux modulation in the Mg II k line, which doesn't appear to correlate very well with anything else. The bottom panel shows the FES light curve obtained as accurately as possible with one data point between each IUE exposure.

The Mg II k fluxes shown in Figure 1 were measured using a two-component gaussian fit (one for the stellar emission and one for the interstellar absorption) to the observed profiles. The centroids of these fits are systematically *redshifted* by $\sim$10 km s^{-1} with respect to the known photospheric velocity. Either there is an unidentified error in the IUE wavelength scale, or there is a net flow of the emitting plasma. The most direct way to test the wavelength scale would be to compare the measured Mg II k interstellar component velocity with an independent measure of

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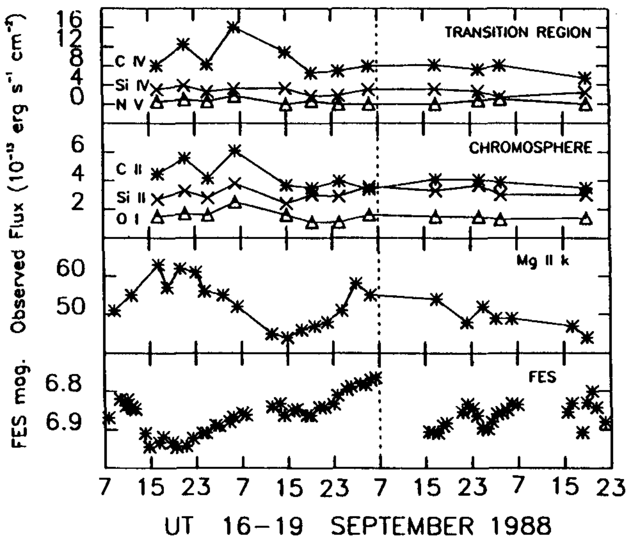

Fig. 1. The ultraviolet emission line fluxes from the transition region (top panel) and chromosphere (second panel) of EI Eri are plotted v. time for the September 1988 observing run. Also shown are the Mg II k emission line flux and the FES magnitude (roughly equivalent to B-band). The vertical dashed line is drawn at the end of the first rotational cycle (~2 days).

the interstellar flow velocity in this line of sight. The interstellar Mg II k absorption component could then serve as an *absolute* wavelength reference (it is currently used only as a relative reference, because we do not know the LISM flow velocity *a priori*). There are some noteworthy Mg II k profile variations. Because of the uncertainties introduced by the systematic redshift, we have not yet mapped the phase-dependent asymmetries into chromospheric active regions, but such work is in progress.

The chief lesson to be learned from these data is that active stars do vary on timescales comparable to the rotational cycle. Becuase only light-curve or line-profile features that **repeat** at the same phase in several cycles can be mapped into spatial structures, it is crucial that observations be obtained *continuously for at least two rotational cycles.*

3. HD 199178

We observed HD 199178 with IUE in September 1986 and September 1987. Also included in our study are all the spectra obtained at other epochs that are available in the IUE archives. Preliminary results were presented by Neff *et al.* (1988), and our final results are presented by Neff *et al.* (1990). I will highlight a few of the most significant results.

Figure 2 (left panel) shows the emission line fluxes for C IV (1550 Å), C II (1335 Å), and O I (1305 Å) as a function of rotational phase, using the ephemeris of Jetsu *et al.* (1990). Plotting all of the data together, it is evident that the highest fluxes indicate stellar flares (see Neff *et al.*, 1989), which are most enhanced for

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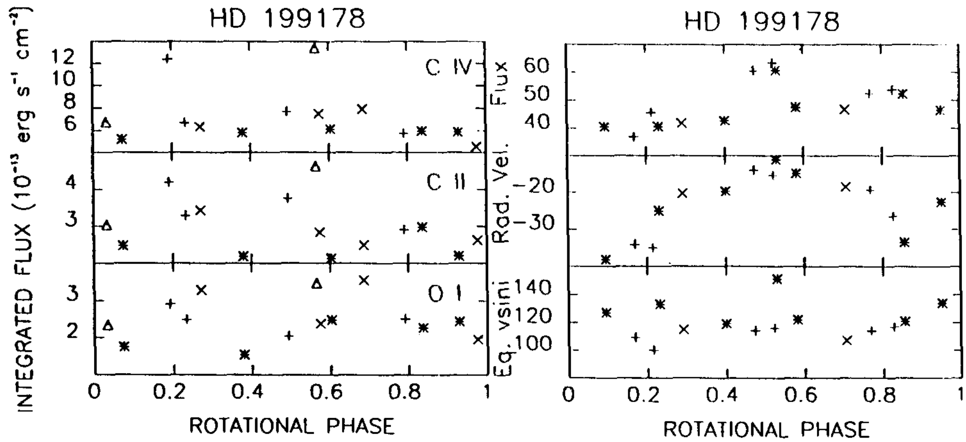

Fig. 2. (left) The integrated emission line fluxes from low-dispersion IUE spectra are plotted using the ephemeris of Jetsu *et al.* (1990). The different symbols represent different epochs. (right) The parameters of the unconstrained round of two-component fits to the Mg II k profiles.

C IV. The results from two-component gaussian fits (stellar plus interstellar) are shown in the righ-hand panel of Figure 1. Several more flares are evident here (these are discussed by Neff, 1990). The most significant result from this first round of fits, which was unconstrained except that the interstellar absorption line width is assumed to be instrumental, was a quasi-sinusoidal velocity curve with a peak-to-peak amplitude one-third of $v \sin i$. This is surprising because Huenemoerder (1986) demonstrated conclusively that HD 199178 is a single star with a radial velocity of –28 km s^{-1}. If the IUE wavelength scale is correct, then the line profile is asymmetric and variable, but *only on the red wing*. If, on the other hand, we apply a 5 to 10 km s^{-1} systematic redshift to the IUE wavelengths (as required for the EI Eri data), then the profile variations imply a large-scale brightness non-uniformity of the star. As for EI Eri, the only conclusive test would be an independent measure of the interstellar flow velocity in this line of sight.

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