SPATIAL & TEMPORAL ACTIVITY VARIATIONS ON AD LEO

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ABSTRACT  Multiwavelength data of AD Leo show only weak rotational modulation of magnetic and quiescent C IV fluxes, but significant UV variability on all timescales $1 \leq t \leq 60$ s. Si IV flux arises from quiescent:microflare:flare heating in approximately a 35:25:40 ratio.

INTRODUCTION, OBSERVATIONS AND ANALYSIS

AD Leo, a single M3.5Ve flare star, was the target of a large international monitoring campaign on 8–9 May 1991. Data were obtained using HST GHRS, IUE, ROSAT, GINGA, VLA, Arecibo, CSO, and numerous optical sites.

Just before the campaign (2–6 May 1991), we obtained high resolution ($\lambda/\Delta \lambda = 45,000$) IR K band spectra ($70 \leq S/N \leq 150$) with the NOAO 4m FTS to study the Zeeman sensitive Ti I multiplet there. Assuming $P_{\text{rot}} = 2.7$ days (Spiesman & Hawley 1985), our (coadded) observations correspond to phases $\phi = 0.28$, 0.60, and 0.91 ($\phi = 0$ at 0 UT 8 May). The spectra were reduced following Saar & Linsky (1985). Assuming that the magnetic field did not significantly change over 7 days, we compare the magnetic data from the Ti I lines to explore correlations between magnetic flux and rotationally modulated activity diagnostics.

The Hubble GHRS data permit investigation of UV emission variability on short ($1 \leq t \leq 60$ s) timescales. These data were taken in the rapid-readout mode, alternating $\lambda$ settings between 120 nm $\leq \lambda \leq 142$ nm and 139...
nm ≤ λ ≤ 165 nm with a cadence of ≈ 30 min for a total exposure of ≈ 5 hours (see Bookbinder et al. 1992). Spectra were reduced using the instrument team software written in IDL. IUE SWP and LWP spectra were taken to supplement the HST data, and were reduced with the standard RDAF software.

Hα spectra were obtained with the NSO McMath stellar spectrograph, the NOAO Coude feed, the Ritter Obs. echelle, 60 in Mt. Hopkins with the Z machine, and the Lick Coude Feed + Hamilton spectrograph. Figure I shows variations in the transition region C IV flux, the chromospheric He II flux, and the Hα equivalent width as a function of phase. Several flares can be seen.

Four lines of the IR Ti I multiplet was first modeled following Saar et al. (1990). The ratios of the line absorption coefficients were held fixed at their theoretical values. Both the filling factor of magnetic regions (f) and their mean field strength (B) were determined. These models could not reproduce the “blurred” lines observed, suggesting the existence of a horizontal or vertical distribution of B values. We then used the very simple, schematic, “half gaussian” height gradient model of Saar (1992), which combines a constant B at large z (a pseudo-canopy) with a gaussian distribution over the line formation. The σ_B of the gaussian was found to be σ_B ≈ 2000 G.

Variations in the IR spectra suggest magnetic fields on AD Leo were inhomogeneous: spectra near φ = 0.91 show somewhat narrower lines than those near φ = 0.28, where a stronger central component is seen (see fig. 5 in Saar 1993). Fits to the three phases yielded: f = 30%, B = 3.5 kG at φ = 0.28; f = 45%, B = 2.7 kG at φ = 0.6; and f = 40%, B = 3.0 kG at φ = 0.91. Thus, there is tentative evidence for a variable fB (at the 20% level) on AD Leo. The fB variations roughly correspond to those seen in the “quiescent” C IV emission (Fig. I), but show a steeper dependence on fB than suggested by Schrijver (1990) or GK dwarfs (Linsky et al., these proc.). The weak rotational modulation is consistent with the low inclination of AD Leo (i ≈ 30°).

We have also investigated the variability of UV emission on 5, 10, and 30 second timescales in several lines using the HST data (Fig. II). Variability is seen
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FIGURE II  Timeseries of Si IV and C I photon fluxes (gaps removed), binned in 10 and 30 sec (heavy line) intervals (left) and histogram of Si IV photons/10 s bin (right). Variability is seen at all binning intervals. A Poisson (dashed) fit to the base of the photon distribution reveals a high energy excess due to flares and microflares.

in all lines at each of these timescales. If we assume a constant “background” level of activity exists (the star rotates < 30° during the HST observations), and fit the lower end of the Si IV 10 s bin histogram with Poisson distribution, a long “tail” of excess counts results. If we define flares as all Si IV bins with ≥ 60 photons, the fractional contribution to the total Si IV flux is 35% quiescent, 40% flare and 25% other (presumably microflares + active region emergence). Alternate definitions of a “flare” can alter these ratios, but generally at least 10 – 20% of the flux is neither quiescent nor flare. Microflares thus make a small but significant contribution to the total TR energy budget. In contrast, the chromospheric C I line shows ≈80% quiescent contribution.

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