A Flare on AD Leo observed in Optical, UV and Microwaves.

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Summary

We report a simultaneous IUE, VLA and ground-based photometric observation of a flare on the dMe star, AD Leo, on 2nd February 1983. The optical flare was extremely impulsive, lasting in total only about 3 mins. A relatively longlived 6 cm flare was observed with the VLA which was initially 100% polarized. An IUE spectrum, taken ≈ 8 min after the onset of the optical U band flare, shows more than a factor of 2 increase in the He II λ1640Å emission line. The other mid-transition region lines such as C IV λλ1548/52Å show almost no response.

1. Introduction

As part of a coordinated international campaign of multi-wavelength observations of the flare star, AD Leo, simultaneous ground-based optical photometry and spectroscopy, IUE ultraviolet spectroscopy and VLA microwave observations were made from 2nd to 5th February 1983 (Byrne *et al.* 1983, Gary *et al.* 1988, Byrne *et al.* 1989). A number of flares were seen independently in the three wavebands but one, on 2nd February 1983 beginning at ≈ 11:37 UT, was seen in all three bands simultaneously. We discuss this flare here.

2. The optical flare

The light curve of the optical (U-band) flare is shown in the upper panel of Fig. 1. It exhibits the classical time-evolution of a simple optical flare with a fast (≈ 10 sec) rise to peak light, followed by an initially fast ($\tau_{1/2}$ ≈ 1 sec) fall which slows later in the flare. The main outburst is effectively over in ≈ 3–4 min. A smaller, secondary flare occurs about 17 min later at ≈ 11:54 UT.

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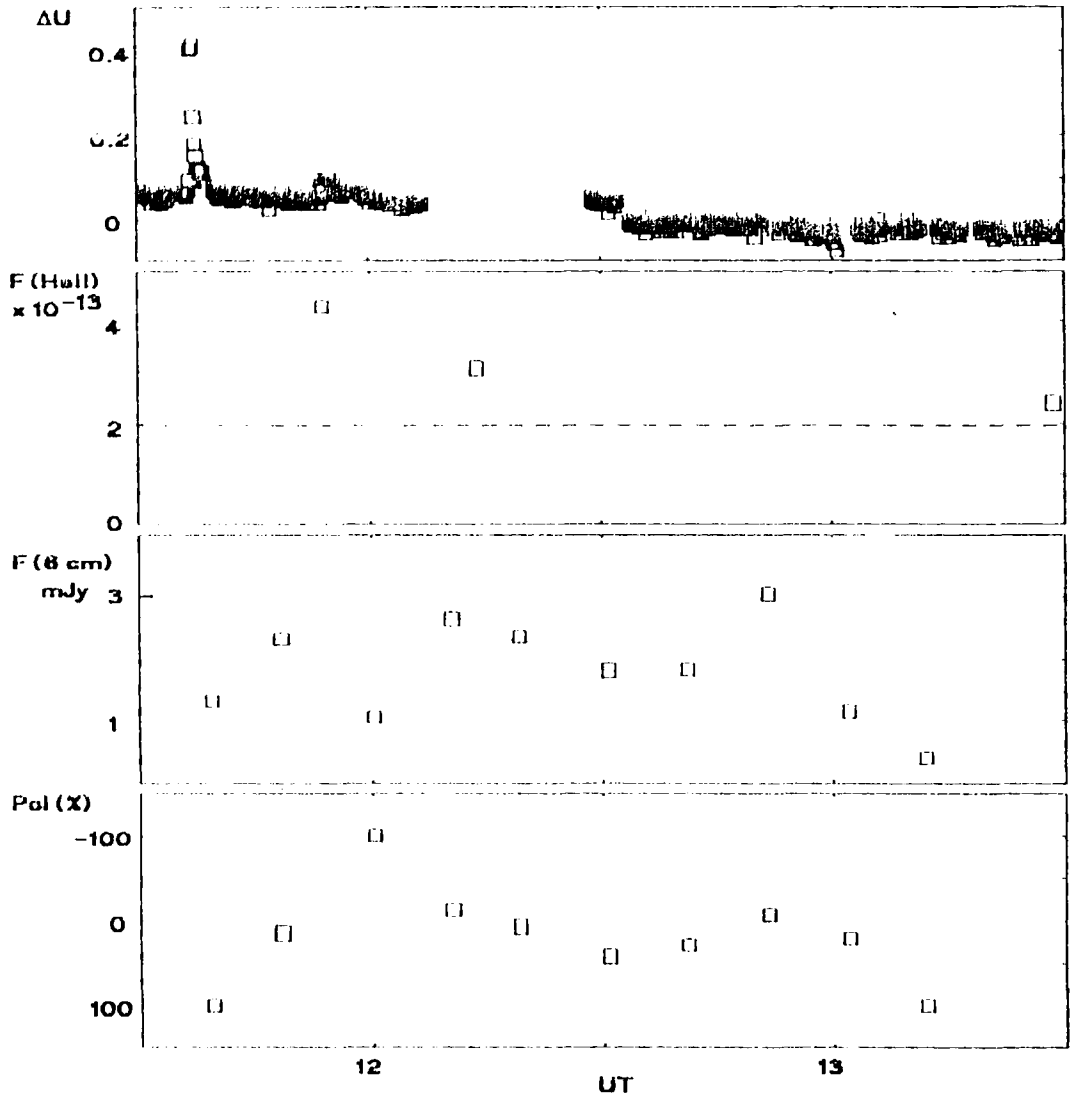

Fig. 1. The flare of 2 Feb 1984 as observed in optical U-band (upper panel), He II λ1640Å (second panel), and 6 cm total flux (third panel) and circular polarization (lower panel). Note that negative polarization is LCP and that the dashed line in the He II plot is the mean preflare level.

3. The ultraviolet flare

Seven ultraviolet spectra were taken with the IUE satellite's short wavelength (1150Å - 1950Å) camera in its low resolution (≈ 5Å) mode on 2 February 1983 between 08:00 UT and 14:04 UT. Each of the first six of these was a double exposure wherein the star was moved on the spectrograph slit between exposures in a direction perpendicular to the dispersion. Each exposure thus obtained was of 20 min duration.

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Unfotunately, no short wavelength exposure was in progress at the time of onset of the optical flare. One was started ≈ 7 min later, however, and it shows a ≈ 250% increase in the He II λ1640Å line emission (Fig. 1) but no significant reponse from the other transition region lines (i.e. C II λ1335/6Å and C IV λ1548/52Å). The following spectrum, taken 20 min later, shows the He II λ1640Å line still enhanced over quiescent. The Lyα response to the flare was also measured. It shows an even more delayed response, peaking in a spectrum centred ≈ 37 min after the optical peak and continuing until at least 75 mins after flare peak when the ultraviolet monitoring ended.

4. The microwave flare

AD Leo was also being monitored by the VLA at 6 cm at the time of the onset of the optical flare. Owing to instrumental difficulties the array was working at reduced sensitivity and data recording only began at ≈ 11:34 UT. Unfortunately, due to the reduced sensitivity this data must be binned into 10 min bins to achieve adequate signal-to-noise. Thus the first measurement of the night includes the flare onset and no measurement of the preflare level is possible.

Nevertheless, the 6 cm data provide interesting observations which are summarized in Fig. 1 as a plot of total intensity and circular polarization against time. The first integration is 100% left-hand circularly polarized. In the following integration there is no net polarization while ten minutes later the polarization is again 100% but in the reverse sense. Significant 6 cm flare emission is seen over a total of at least 90 min.

5. Discussion

The long lasting He II and Lyα response to the relatively impulsive optical flare ($\tau \approx 1$ hr) is suggestive of a timescale typical of the soft X-ray component of solar flares rather than the impulsive hard X-rays. In general, the transition region response in solar flares is itself relatively impulsive and this is consistent with the lack of response from the C IV resonance doublet. It is therefore surprising to find the He II persisting over such a long time since its temperature of formation in thermal equilibrium is $\log T_e \approx 4.7$. A picture consistent with this observation would be one of soft X-ray back-heating by the post-flare loop. Evidence for soft X-ray photoexcitation of the He atom has been previously discussed by Kohl (1977)

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for the solar case and for the late type stars by Byrne and Doyle (1988).

The microwave flare occurs on a similar timescale to the Lyα and He II emission. At onset it is completely circularly polarized, however, suggesting a non-thermal process. Even theslower component of the flare cannot easily be interpreted as thermal since a thermal plasma would produce a flux at Earth of

$$S = \frac{2\nu^2 kT}{c^2} \frac{R^2}{d^2}$$

This can be evaluated for a post-flare plasma temperature, $T \approx 10^7$ K at the distance of AD Leo, i.e. $d \approx 5$ pc, and solved for the source radius. The observed flux density of ≈ 2.5 mJy leads to a source radius of $R \approx 75\, R_*$. Filling such a large volume with plasma at temperature $\approx 10^7$ K presents severe difficulties.

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