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A Simultaneous Hα and Radio Flare on the RS CVn System UX Ari

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Abstract. We report the results of coordinated Hα and radio observations of the RS CVn binary UX Ari. Spectrographic Hα observations were carried out at the M.G. Fracastoro Station of Catania Astrophysical Observatory (Mt. Etna), while the radio (5 GHz) observations were obtained by using the 32m radio telescope at the Noto VLBI Station of Institute of Radioastronomy of C.N.R., in October 2000. The decay phase of a giant flare was followed in both bands. On our knowledge, this is the first time that a simultaneous Hα and radio flare was observed in UX Ari. The onset of the flare and the whole light-curve in the radio could be established by combining the Noto data with Green Bank monitoring program data, estimating a total duration of the flaring period, at least, of 16 days.

The chromospheric and coronal energy budget is also estimated and typical spatial scale, magnetic field strength and plasma parameters are discussed.

1. Observations

Spectrographic Hα observations were carried out at the M.G. Fracastoro Station of Catania Astrophysical Observatory using the Echelle spectrograph connected to the 91-cm telescope through an optical fiber. A spectral resolution R = 15 000 is attained. Data were obtained for a total of 21 nights but here we report only those contemporaneously obtained with the radio observations (from October 9 to 18, 2000).

Equivalent width of Hα emission, $EW_{\mathrm{H}\alpha}$, was computed integrating the residual emission in the difference of each UX Ari spectrum with respect to a template built up by means of comparison inactive stars. In this way we have taken into account the behaviour of the quiescent absorption profile. Moreover, the obtained $EW_{\mathrm{H}\alpha}$ values were also corrected for the variation induced by the rotational modulation.

The radio observations here reported were performed with the on-off technique, using a cooled 5 GHz receiver (T_{sys}=40 K, at zenith) mounted at the

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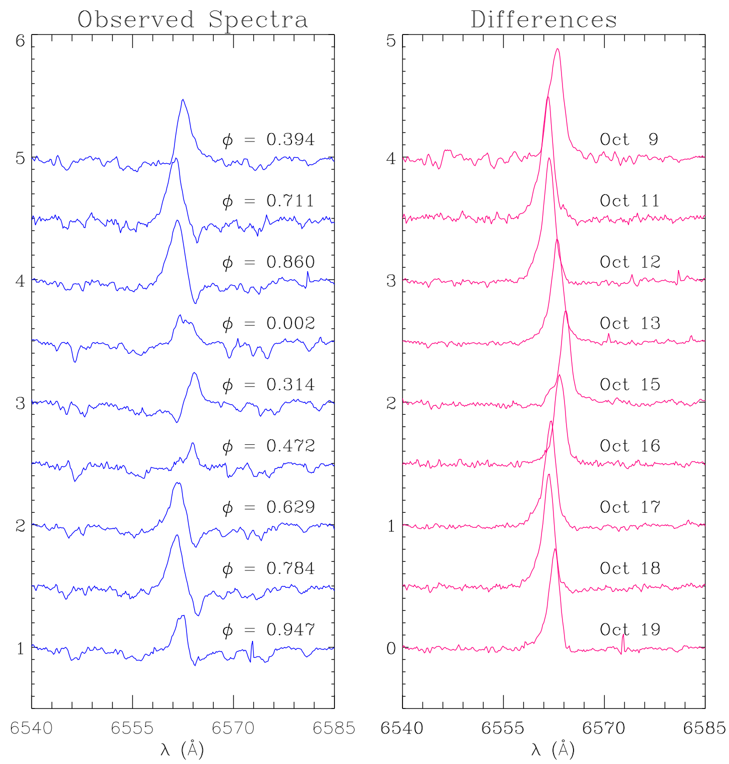

Figure 1. **Left panel.** Observed continuum-normalized spectra of UX Ari acquired during the flare event. Orbital phases of each observation are marked near the corresponding spectrum. **Right panel.** "Residual" spectra obtained as difference between the observed ones and the corresponding "photospheric templates" built-up with weighted, rotationally-broadened, Doppler-shifted spectra of non-active stars which mimic the two stars composing the UX Ari system.

secondary focus of the VLBI 32 m Noto Radio-telescope (C.N.R.). For a better signal to noise ratio, we used the whole available receiver band of 400 MHz. The flux density scale was fixed with respect to 3C123. The observations were carried out between October 11 and 18, 2000. From September 23 to October 6, 2000, we add data provided by the GBI (Green Bank Interferometer) monitoring program. GBI data, taken at 2.25 GHz and at 8.3 GHz, were interpolated to the Noto observing frequency of 5 GHz.

2. Results

Combining the Noto and Green Bank radio observations we got a nearly complete evolution of the giant radio-flare, as shown in figure 2. The flare starting can be set, from the radio data, on Oct 3, but only the final decay phase could be observed in Hα.

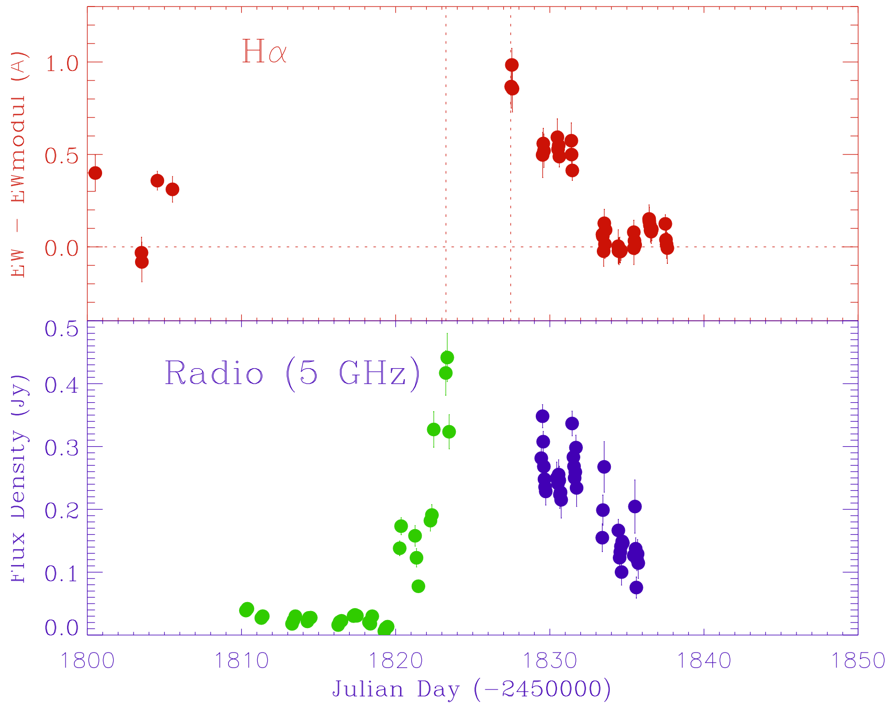

Figure 2. **Upper panel.** Hα equivalent width, corrected for modulation, as function of heliocentric JD. Vertical lines indicate possible times for flare onset. **Lower panel.** Radio flux density as function of the JD. Green dots represent data from the Green Bank monitoring program interpolated to 6 cm.

Results can be summarized as follows:

- The Hα and radio flares are contemporaneous.
- The decay of the Hα flare appears to be faster than the radio flare: the Hα equivalent width reaches its quiescent value on JD 2451832.0 (October 14, 2000), while the radio flux density is still several times its quiescent value.
- The total duration of the radio flare is about 18 days, while that of the Hα flare is ≤ 11 days
- From the observations in both spectral region, the energy budget in the chromosphere and in the corona can be determined.

2.1. Energy budget

We can evaluate the total energy emitted in the Hα in two possible scenarios:

i) in the hypothesis that the flare onset occurred at the same time as the radio (first vertical dotted line in the plot), we obtain

$$E_{\mathrm{H}\alpha} = 1.69 \times 10^{35} erg$$

ii) if the Hα flare onset occurred on the first day of our observation (second vertical dotted line), we obtain

$$E_{\mathrm{H}\alpha} = 6.64 \times 10^{34} erg$$

For the radio data, assuming a total radio band of 20 GHz (from 1.4 to 22 GHz), we derive a total energy emitted during the flare of

$$E_{\mathrm{Radio}} = 1.3 \times 10^{36} erg$$

3. Discussion

3.1. Energy storage

Strong flares in RS CVn's can be modelled in the framework of two-ribbon solar flare configuration (Kopp & Poletto, 1984).

Recent results on similar systems point out that a filament (length l), which become unstable, must be associated to the active component (Catalano & Frasca 1994; Catalano et al., 2000). In this hypothesis, we can estimate the total energy stored in the pre-flare magnetic configuration (Doyle et al., 1989)

$$E_{\mathrm{tot}} = 3.24 \times 10^{38} \frac{l}{R_{\odot}}\ erg$$

where we have assumed for the K component a surface magnetic field of 1500 G and a radius of $3R_{\odot}$

As typically observed in solar two-ribbon flares, only a small fraction of this energy (~ 0.003) will actually go to heat the plasma (Kopp & Poletto, 1984). The observed energy, released in the Hα line, is about $\frac{1}{3}$ of the total radiative energy from the chromosphere, then, comparing the total chromospheric losses with the energy stored in the filament, we can estimate the length of the filament to be of the order of $1R_*$ if the flare onset is coincident with the radio one, and $\sim \frac{1}{2}R_*$ if the onset occurs the first day of Hα observations.

Extended coronal magnetic structures of this size are also inferred from VLBI observations (Beasley & Güdel, 2000).

3.2. Single event versus multiple flares

The decay time of the observed radio flare, in the hypothesis of gyrosinchrotron emission, is $\tau_{\mathrm{decay}} \sim 8 \times 10^5 sec$, which implies a magnetic field B of the order of 30 G, too weak to confine a coronal thermal plasma with number density $n_e \sim 10^{11} cm^{-3}$ and temperature $T \sim 5 \times 10^7\ K$ (Güdel et al., 1999).

On the other hand, the magnetic field needed to confine such a plasma would be of the order of 70 G, which implies a $\tau_{\mathrm{decay}} \sim 1.4 \times 10^4 sec$, close to the typical duration of single radio flares observed in RS CVns. The observed flare could therefore be the result of a multiple event.

This confirms what already observed in other RS CVns, i.e. HR 1099, where radio flares are very rarely isolated events but are often clustered inside active periods that can last from several days to months (Umana et al., 1995)

4. Conclusions

For the **first time** a simultaneous Hα and radio (6 cm) flare has been observed in the RS CVn system UX Ari.
The present observation allowed:

- to compute the non-thermal energy emitted by the radio corona, signature of high-energy non thermal electrons, and compare it with chromospheric thermal Hα losses, which result to be comparable
- to derive typical size scale of the filament involved in the energy release process (in the framework of two-ribbon solar flare model).
- to infer that the observed flare could be composed by a series of multiple flares that mimics a single event.

These results support an energy release model where electron beams quickly propagate along loops from the corona to lower layers of the stellar atmosphere where they release their energy heating the plasma.

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