# EVIDENCE FOR ASYNCHRONISM IN THE MAGNETIC CATACLYSMIC VARIABLE EU UMA (RE1149+28)

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ABSTRACT. We present the results of optical time-resolved spectroscopy of the magnetic cataclysmic variable EU UMA (RE1149+28), which were obtained with the scanner of the 6 m telescope on April 3 and 4, 1994. Analysis of the behaviour of the parameters of Balmer and HeII emission lines in the spectra of EU UMA has revealed the following:
-dips in the equivalent widths of the lines repeatable with the orbital period. Considering the dips as a result of eclipse of the most part of the accretion stream by the secondary we have improved the value of the orbital period as $90.1441 \pm 0.0007$min and have estimated the inclination of the system to be $\approx 70°$;
- in addition to radial velocity variations over the orbital period the oscillations with the period of 45-min and 37-min of the velocities of the centers of gravity and the peak of the lines, respectively. We associate the 45 min oscillations with the radiation from the accretion curtain or the beginning of the magnetic part of accretion stream and the 37 min variations with the radiation from the strong resonance magnetic fields which was observed as the monochromatic pulsations in the spectra of intermediate polars (Somov et al.,1997, 1998a,1998b, 2000,2001). The presence of 45-min oscillations is an argument in favor of diskless accretion in the system. The 37-min variations point to asynchronous rotation of the white dwarf over the spin period $\approx 74$ min.

The spectral light curves (integrated flux in the range of wavelengths 4000-5000 Å) have shown significant changes of the mean fluxes ($\approx 4$ times) and of the composition of quasi-periodic oscillations in the range of periods 20-120 min on a time-scale of 1 day. In the high state of brightness on April 3, 1994 the spectral light curve showed a hump which corresponds to the longitude of the accretion spot of 45°in the standard model of polars.

In the low accretion state on April 4, 1994 the spectral light curve showed a step-like jump when the mean brightness of the object increased $\approx 2$ times. Such a behaviour of the system can be the result of the change of the magnetic part of accretion trajectory due to the asynchronism. We found a relationship between the jump of brightness and the jump of the phase and amplitude of the 37-min oscillations. On the basis of all the detected properties we conclude that the system is an asynchronous magnetic rotator with a polar-like magnetic field and with the magnetic and rotation poles close to each other.

**Key words**: accretion – stars: binaries: close – stars: individual: EU UMA (RE1149+28) – stars: cataclysmic variables – stars: rotation – oscillations.

## 1. Introduction

Magnetic cataclysmic variables (MCVs) are close binary stars in which a strongly magnetized white dwarf primary accretes matter from a Roche lobe–filling late–type secondary. MCVs form two subclasses: polars known as AM Her stars are synchronous systems in which $P_{spin} = P_{orbit}$, where $P_{spin}$ is the spin period of the white dwarf and $P_{orbit}$ is the orbital period (Liebert and Stockman, 1985; Cropper, 1990; Warner 1995), and intermediate polars (IPs) known as DQ Her stars (Patterson, 1994). The subclass of IPs includes the objects containing magnetic, rapidly and asynchronously rotating ($P_{spin} \ll P_{orbit}$) white dwarfs. The principal criterion of asynchronism of the IPs is the presence of a rapid periodicity in the light curve, usually at optical or X–ray wavelengths. In addition to this periodicity some intermediate polars manifest emission–line profile variations over the spin period which affect the whole profile (Patterson, 1994). The Monochromatic Quasi–Periodic Oscillations (MQPOs) with the spin period in the narrow wavelength passbands (1 Å) were detected in the profiles of emission lines in the optical spectra

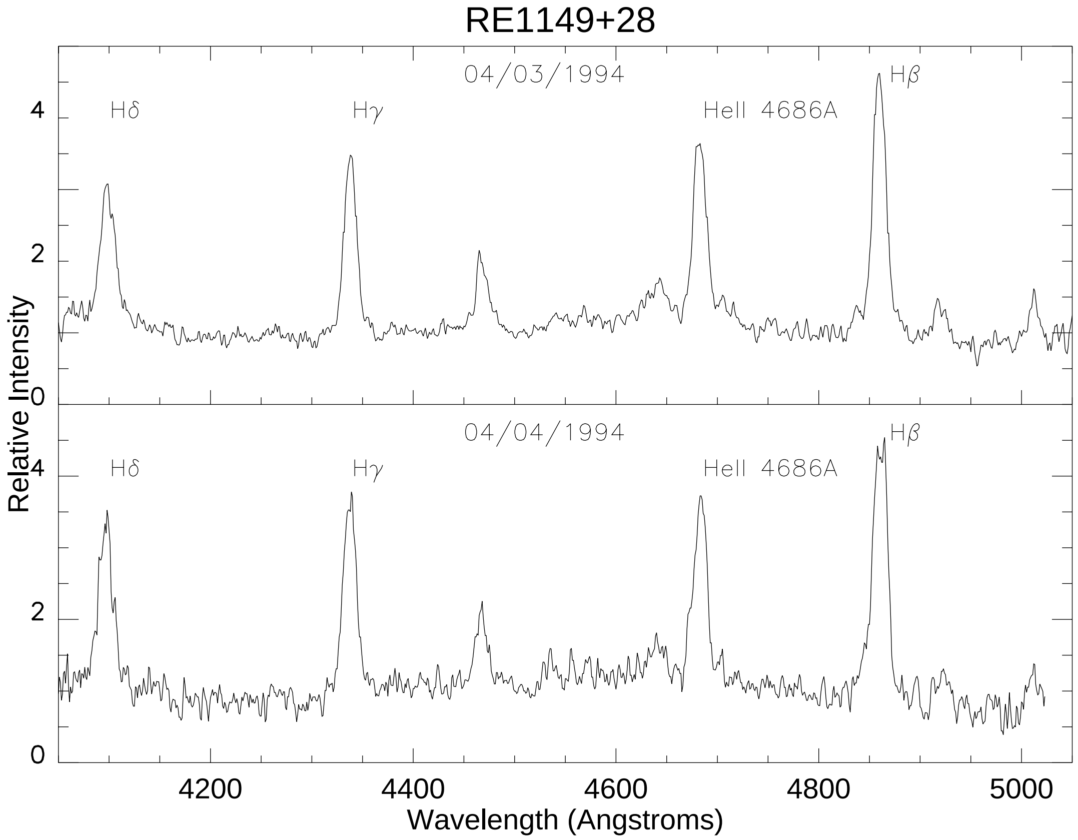

Figure 1: The mean relative intensity spectra which were obtained on April 3 and 4, 1994

of the IPs with polar–like magnetic fields (Somov et al., 1997, 1998a,b, 2000, 2001). Spectral variations of the emission–line profiles over the spin period are the secondary criterion of asynchronism of the MCVs.

## 2. Observations

Spectral observations were carried out at the Special Astrophysical Observatory on April 3 and 4, 1994, using the spectrograph SP–124 (Afanasiev et al., 1991) placed at the Nasmyth focus of the 6 m Big Telescope Azimuthal (BTA). The spectrograph equipped with a 1200 lines/mm grating gave a reciprocal dispersion of 50 Å/mm. A multichannel photon-counting system or a television scanner with two lines of 1024 channels recorded two spectra simultaneously (Somova et al., 1982; Drabek et al., 1986). A 2–arcsecond slit was used. The spectra were obtained in a wavelength passband of ≈ 1000 Å within the range 3900–5100 ÅÅ with a dispersion of 1 Å/channel (spectral resolution ≈ 2*Å*) and a temporal resolution of 32 ms. The spectra were recorded continuously, and a He–Ne–Ar lamp was observed before and after the exposures for the wavelength calibration. The behaviour of the parameters of emission lines (equivalent width, relative intensity, radial velocities of the peak and the center of gravity ) was investigated from the spectra with the temporal resolution of 270 s. Spectral light curves or the integrated flux within the wavelength range 4000–5000 ÅÅ were measured from the spectra with the temporal resolution of 27 s.

## 3. Results

In Figure 1 we show the mean relative intensity spectra which were obtained on April 3 and 4, 1994. The spectra contain, as it is typicaly for MCVs, the emission lines of hydrogen, HeII 4686 Å HeI, the blend of lines CIII–NIII 4640–4650 Å. The emission lines have a narrow and a broad components superimposed on each other. The mean spectra of April 3 and 4, 1994 are only slightly different from each other.

Spectral light curves on April 3 and 4, 1994 are presented in Figure 2. The spectral light curves have showed significant changes of the mean fluxes (≈ 4 times) and of the composition of quasi-periodic oscillations in the range of periods 20-120 min on a timescale of 1 day. In the low accretion state on April 4, 1994 the spectral light curve showed a step-like jump at the phase of 0.86 when the mean brightness of the object increased ≈ 2 times. In the high state of brightness on April 3, 1994 the spectral light curve showed a hump which corresponds to the longitude of the accretion spot of 45 degrees in the standard model of polars. Analysis of the behaviour of the parameters

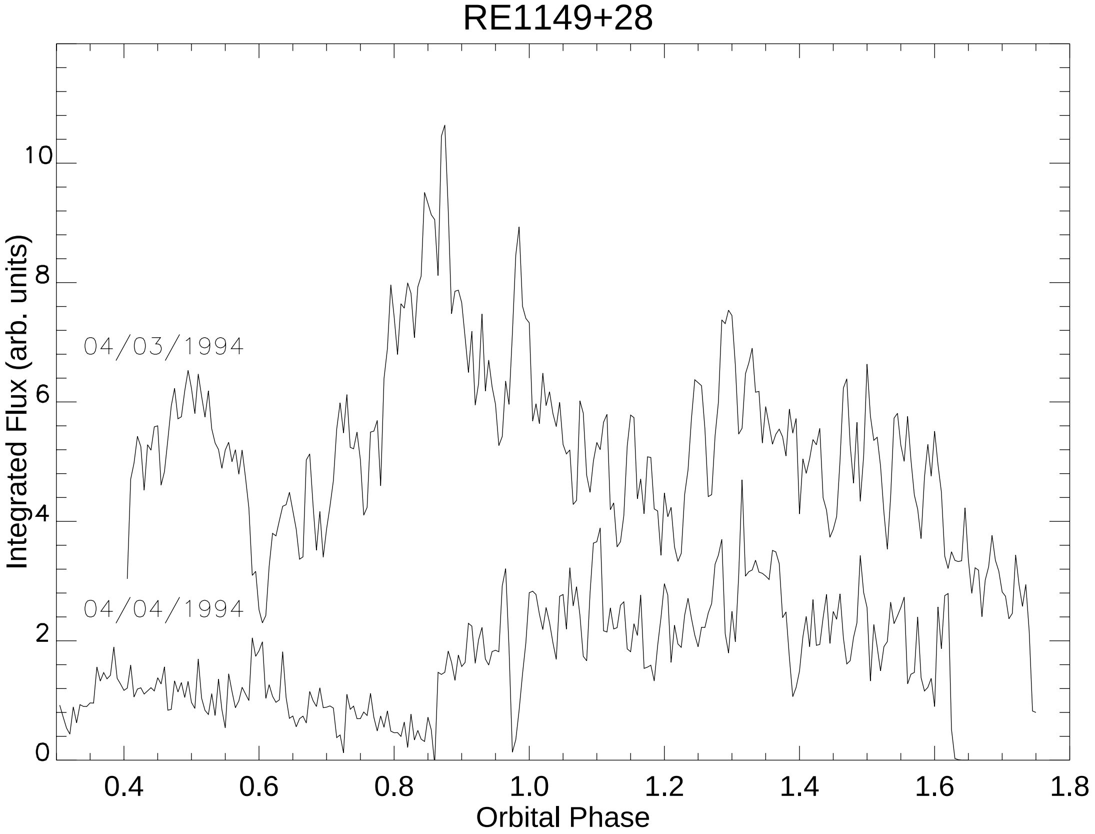

Figure 2: The spectral light curves which were obtained on April 3 and 4, 1994

of Balmer and HeII emission lines in the spectra of EU UMA has revealed dips in the equivalent widths of the lines repeatable with the orbital period. The variations of equivalent widths of the $H\beta$, $H\gamma$ and HeII 4686 Å emission lines over the orbital period, which were recorded on April 3 and 4, 1994, are shown in Figure 3.

Considering the dips as a result of eclipse of the most part of the accretion stream by the secondary and using the results of spectral observations of EU Uma in 1993 (Somova et al., 2003) we have improved the value of the orbital period of $90.1441 \pm 0.0007$ min and have estimated the inclination of the system to be $\approx 70°$;

Analysis of radial velocity variations has detected, in addition to the changes over the orbital period, the oscillations of the velocities of the center of gravity and the peak of the lines with a period of 45 min and 37 min, respectively.

The behaviour of radial velocities of the peak and center gravity of the $H\beta$ emission line over the orbital period on April 3, 1994 with the 45 min variations of the center of gravity (left top panel) and the 37 min oscillations of the peak (right top panel) of the line are plotted in Figure 4.

We associate the 45 min oscillations with the radiation from the accretion curtain or the beginning of the magnetic part of accretion stream and the 37 min variations with the radiation from the strong resonance magnetic fields which was observed as the monochromatic pulsations in the spectra of intermediate polars (Somov et al.,1997, 1998a, 1998b, 2000, 2001). The presence of the 45 min oscillations is an argument in favor of synchronous rotation of the accretion curtain with the orbital motion or diskless accretion in the system. However the 37 min variations point to asynchronous rotation of the white dwarf over the spin period $\approx$ 74 min. The 74 min period was observed in the radial velocity of the peak of HeII 4686Å in 1993 (Somova et al., 2003)

The variations of O-C of radial velocities of the peak and center of gravity of the $H\beta$ emission line over the orbital period on April 4, 1994 are presented in Figure 5. The relationship between the jump of brightness at the phase 0.86 and the jump of the phase and amplitude of the 37 min oscillations is seen in the right panel. As for the 45 min oscillations of the center of gravity (left panel), after the step-like jump the oscillations have disappeared, and the 28 min noise oscillations are presented in the Figure 5 (left panel).

We consider the step-like jump of brightness and the jumps of the phase, amplitude and mean value of the 37 min variations as a result of the change of

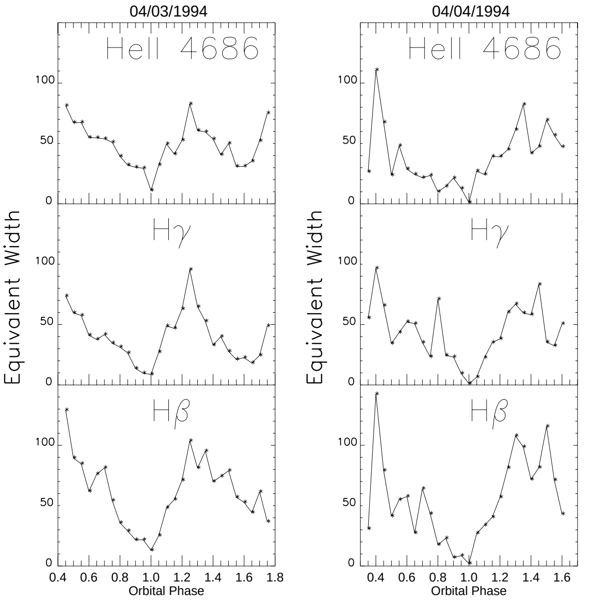

Figure 3: The variations of equivalent widths of the $H\beta$, $H\gamma$ and HeII 4686Å emission lines over the orbital period which were recorded on April 3 and 4 1994

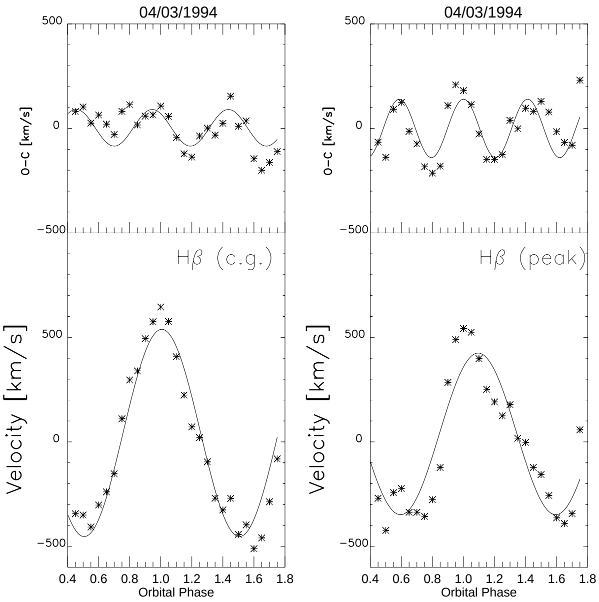

Figure 4: The variations of radial velocities of the peak and center gravity of the $H\beta$ emission line over the orbital period which were recorded on April 3, 1994

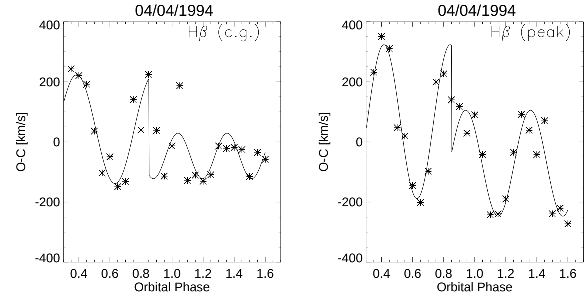

Figure 5: The variations of O-C of radial velocities of the peak and center of gravity of the $H\beta$ emission line over the orbital period which were recorded on April 4, 1994

the magnetic part of accretion trajectory caused by the asynchronism of the system.

The primary criterion of asynchronism of MCVs or the periodical pulsation in light curve, was observed in the periodogram of the spectral light curve on April 4, 1994 as the dominating feature at the 37 min period. The absence of the 74 min or 37 min pulsations in X-ray light curves indicates that the magnetic and rotation poles close to each other.

## 4. Conclusion

On the basis of the detected 37 min oscillations of the peak of emission lines (secondary criterion) and the presence of the 37 min pulsations in in the spectral light curve in low accretion state (primary criterion) we conclude that the system is an asynchronous magnetic rotator with polar-like magnetic field and with the magnetic and rotation poles close to each other.

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