AM HERCULIS IN 1989-93: VARIOUS TYPES OF PHOTOMETRIC AND POLARIMETRIC BEHAVIOUR

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ABSTRACT. The types of variability of AM Her are discussed on the base of monitoring carried out at the 2.6m Shajn and 1.25cm AZT-11 telescopes of the Crimean Astrophysical observatory. The main types are the following: a) the wavelength–dependent regular variations with the orbital phase more pronounced in RI bands and observed at high and intermediate luminosity states; b) at the low and intermediate states the variations in UB which are usually in antiphase with RI; c) flares caused by the accretion events with colors close to that of the system; d) flares of the secondary of the UV Cet–type.

Key words: Stars: Cataclysmic Variables; Polars; AM Her.

The brightest polar AM Her was observed systematically in the Crimean Astrophysical Observatory since 1989. Mainly the object was observed in UBVRI bands simultaneously in photometric or polarimetric mode at 1.25 m telescope. Sometimes these observations were accompanied by measuring the circular polarization in V or wide R bands at the 2.6 m Shajn telescope. Altogether about 60 five–colors light curves and more that 40 polarization curves of AM Her were obtained. The preliminary analysis of these observations allows to distinguish the following types of photometric and polarimetric behaviour of this magnetic CV:

1. The regular variations with orbital period (1 and 2 harmonics) are dominating in the light curves in R and I bands at the *high* and *intermediate* brightness level of AM Her. The shapes of the light and polarization curves are very different. Usually the regular variations are accompanied by the irregular flares.

The colours of such flares are close to that of the system and they usually are pronounced in all bands (See Fig. 1-3). All data are plotted in the same scale for all bands. Phases are calculated by using the ephemeris by Aslanov et al. (1989) for the moment of the linear polarization pulse:

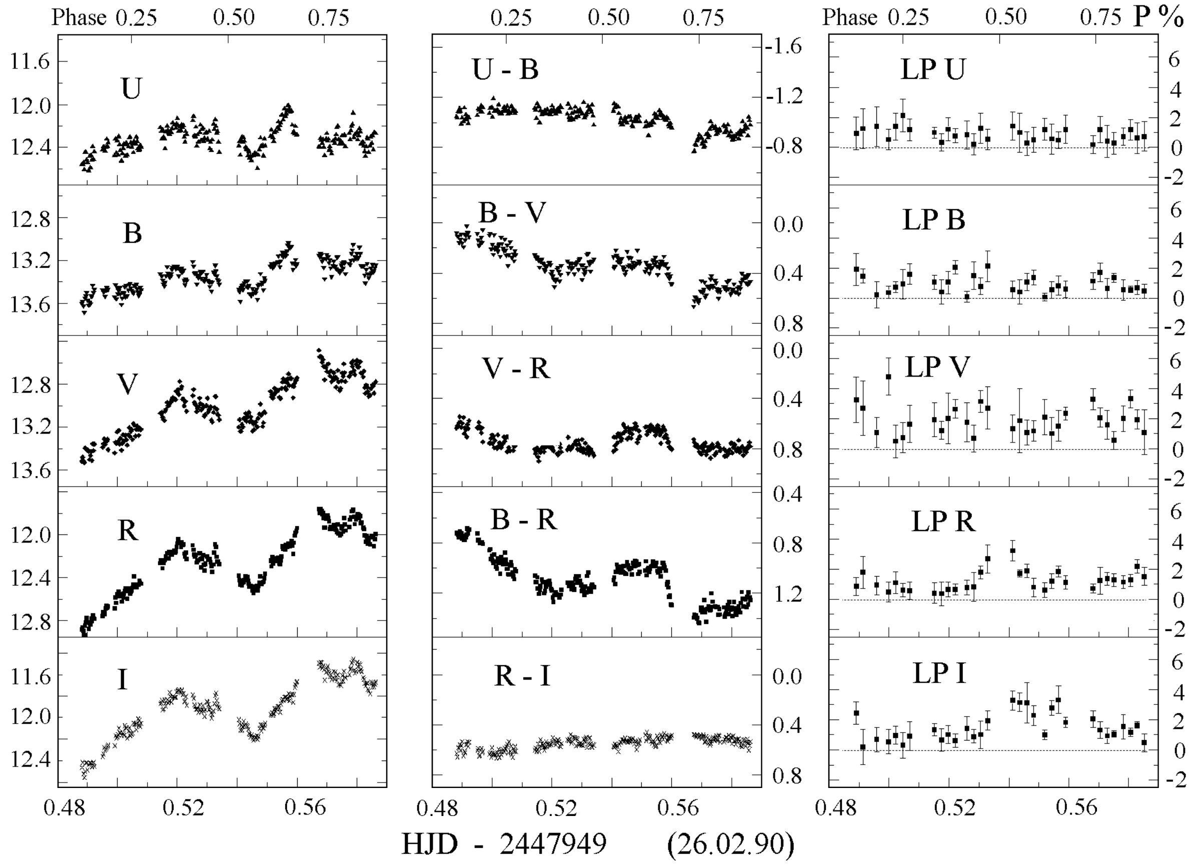
$$HJD_{max.pol} = 2443014.765 + 0.12892774 \cdot E.$$

The regular variations are better pronounced in the B–R colour because the contribution of flares are similar in different bands and thus are not seen in this colour.

The radiation of some (but not all) flares have the circular polarization in red bands. Circular polarization in R and I bands is usually negative.

Sometimes the reversal of sign of polarization was observed in V band at the time of the dips of polarization in red bands. In the U and B bands the polarization is small or absent. Evidently, the regular variations of brightness and polarization are connected with the changes of visibility of accretion columns with axial and orbital rotation; the "white" flares may correspond to the thermal and cyclotron radiation from separate "blobs" in the accretion flow.

The variations of the phases when circular polarization crosses zero may be interpreted by the changes of the orientation of the accretion column in respect to the rotating binary system both in longitude and latitude (Andronov



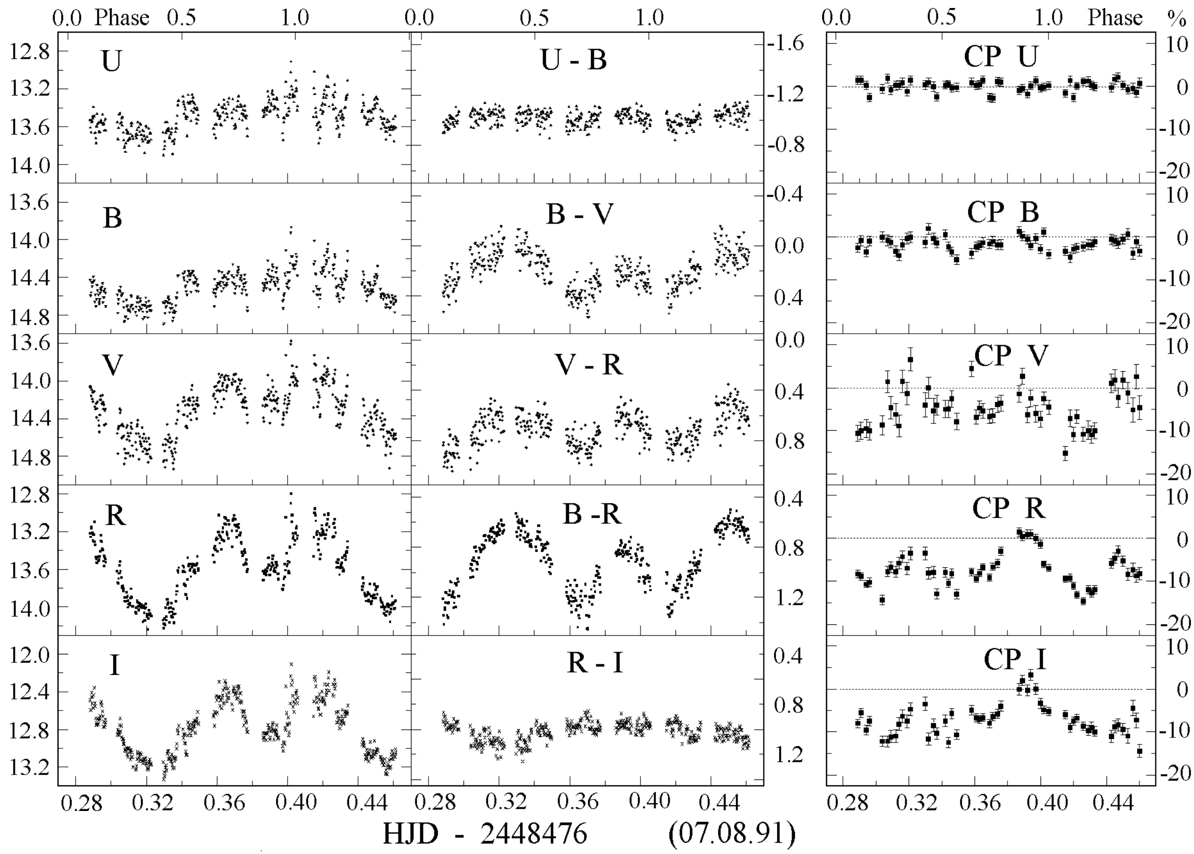
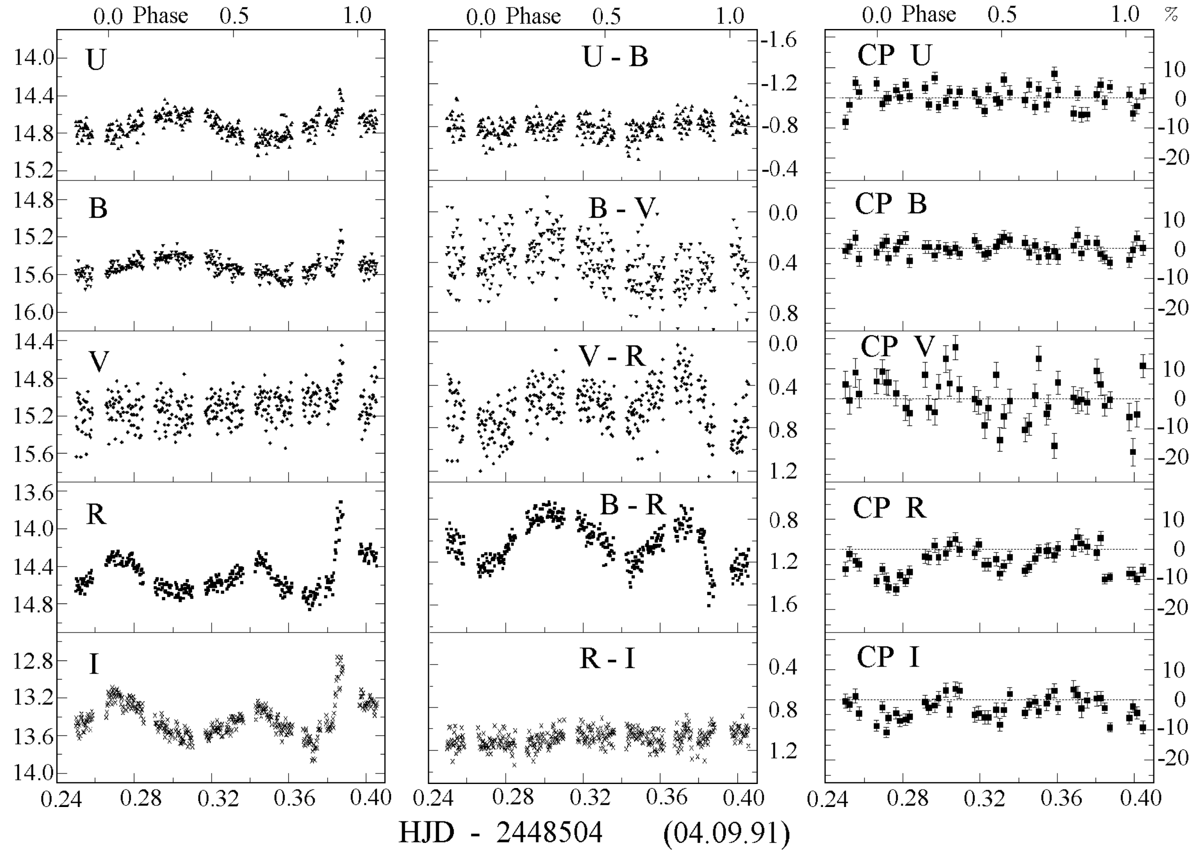


Figure 1 (Up): variations of magnitudes, colours and linear polarization of AM Her in UBVRI bands for 26.02.90.
Figure 2 (Bottom): The same but for circular polarization for 07.08.91.



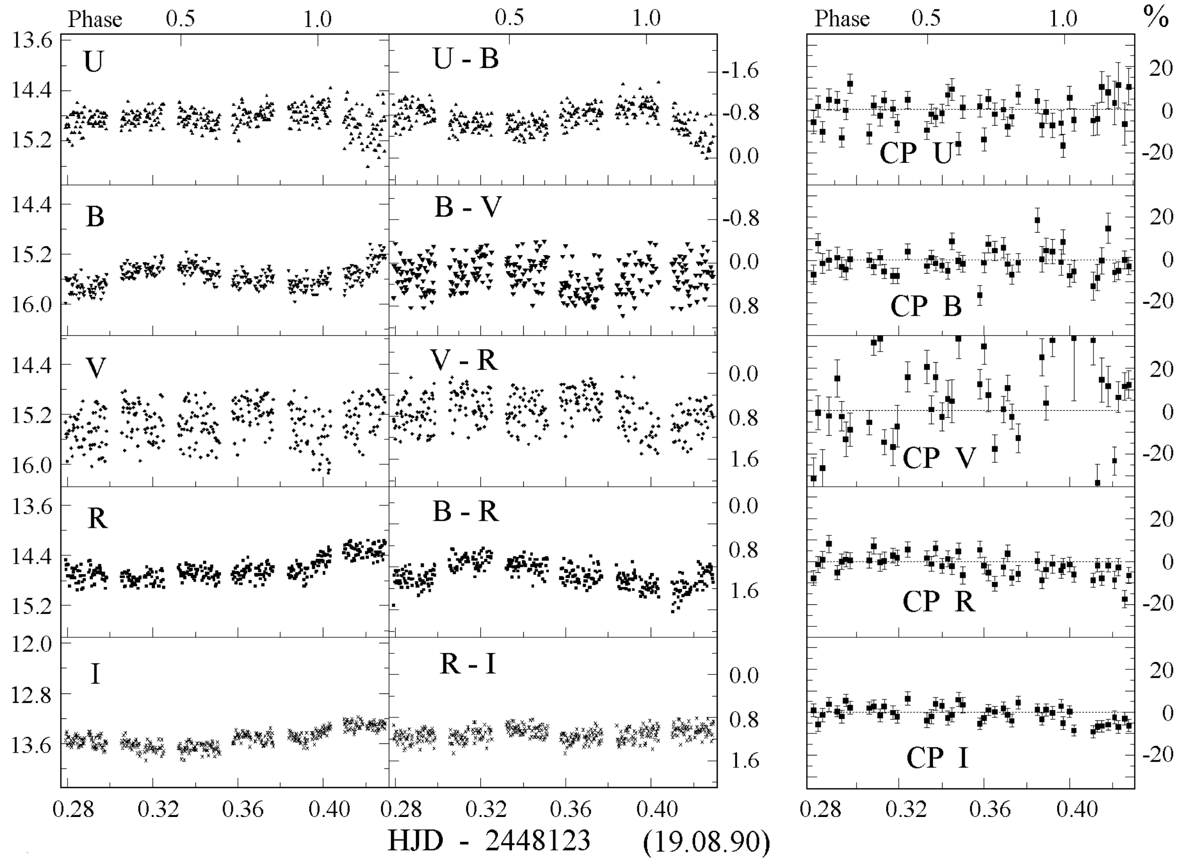
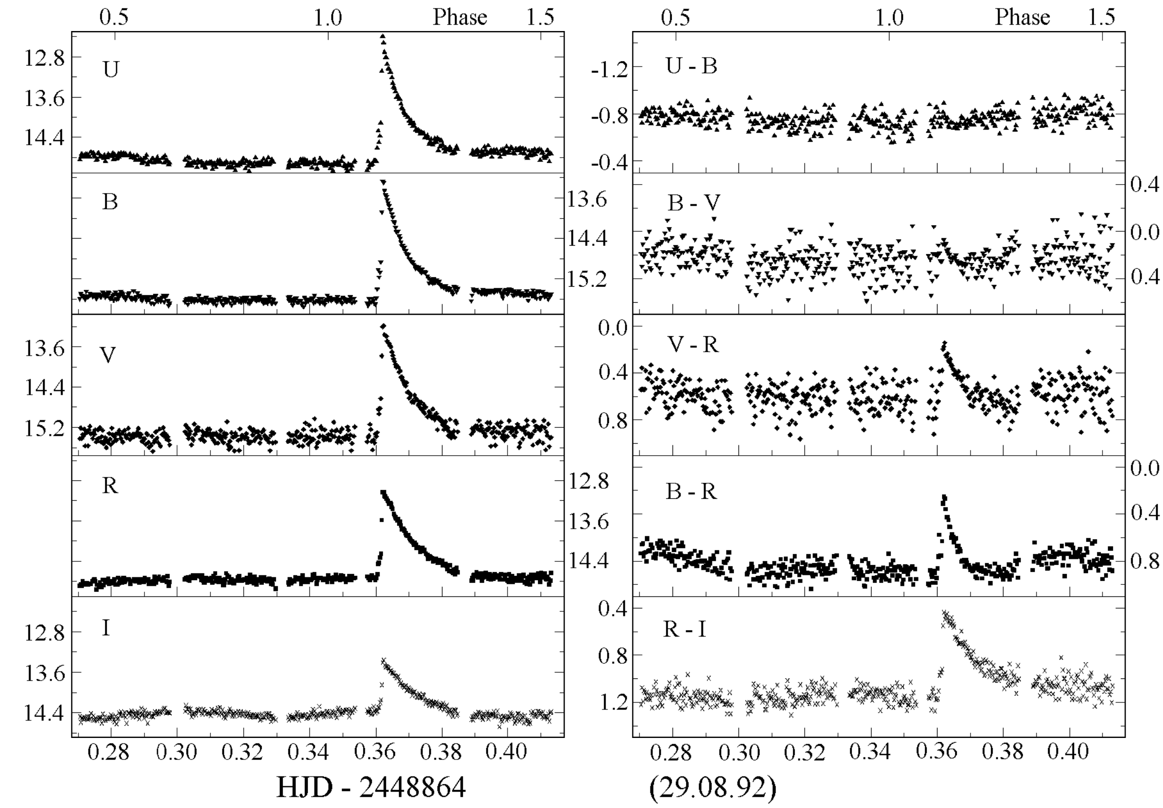


Figure 3 (Up): The same but for 04.09.91.

Figure 4 (Bottom): The same but for 19.08.90 - an extremely quiet state of AM Her.



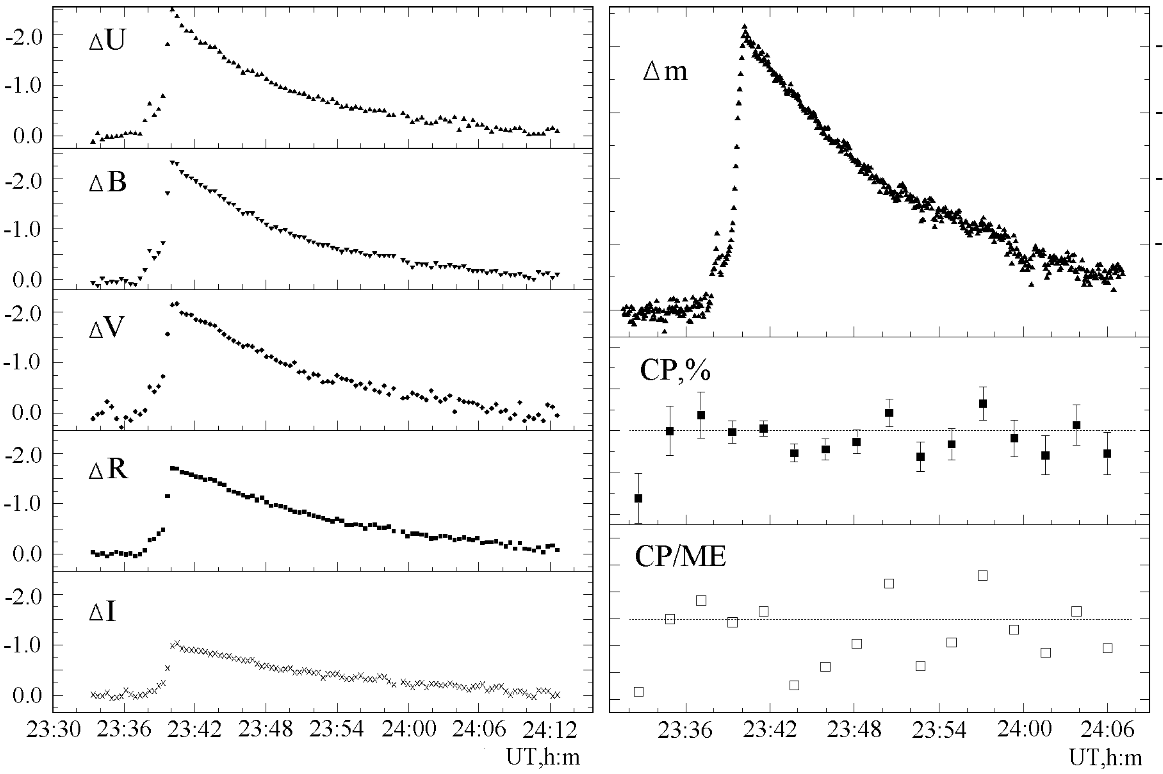


Figure 5 (Up): The light and colours curves of AM Her for 29.08.92 with strong blue flare.
Figure 6 (Bottom): The UBVRI light curves (left, 1.25m, $\Delta t = 12.5$s) and the brigthness and circular polarization in the wide R band (right, 2.6m, $\Delta t = 4$s) of flare 29.08.92.

et al. 1992) in agreement with the "swinging dipole" model (Andronov 1987).

The regular variations as well as the "white" flares may be completely absent at the extremely low levels of activity of AM Her (for instance, in July–August 1990 and in August 1992, when the circular polarization was absent, too). At this time the minute–scale variability (owed to accretion inhomogeneities) was practically absent (Andronov et al. 1992).

The mean power spectra of the runs of usual duration 8 min show a power law shape. The slope $\gamma = 1.28 \pm 0.10$ was maximal at the bright state 26.02.90 and close to zero $\gamma = 0.08 \pm 0.06$ and 0.20 ± 0.04 at low state 16.0890 and 19.08.90 (Andronov et al. 1992). The ACF analysis of the finite–length detrended data (Andronov 1994) allows to interpret the same data as the first–order autoregressive model with relative contribution to the variability increasing with mean brightness.

2. At the *low* or *intermediate* brightness level the smooth light variations (first harmonic of the orbital period) in U and B band are seen. Amplitudes of these variations are about 0.1–0.2 mag (Fig.3,4). Usually these variations are in antiphase with variations in R and I bands, but sometimes we have observed the another phase correlation between blue and red bands. This type of changes of brightness may be possibly explained by the reflection of light from the accretion columns or white dwarf by the secondary component of the binary system or with inhomogeneity of the surface of secondary (spots?).

3. Several "blue" flares were observed at the *low* state of brightness. The strongest flare of this type was recorded on August 29, 1992. At this night AM Her was at the extremely low and quiet state with V=15.40. Observed amplitudes of the flare in the UBVRI bands were 2.54, 2.36, 2.14, 1.71 and 0.84 mag, respectively. The rising time of flare was about 3 min and the time of full descending - about 30 min (Fig.5,6). One may also see a pre–flare of smaller amplitude. The shapes of the flare light curves and the intrinsic colours of flare radiation are very similar to the same characteristics of the strong flares on red dwarf stars of UV Cet type (Alexeev et al. 1994). The polarization in this flare was absent too, as well as during the flares of UV Ceti stars (Alexeev et al. 1994). At the maximum of the AM Her flare its intrinsic colours were similar to the colours of the blackbody radiation with T=12,000 K (Fig.7). The dimension of the radiating source estimated from its energy for the blackbody approximation is $\approx 10^{19}$ cm^2. This value is close to the area of the DA white dwarf disk. The full energy of the AM Her flare observed 29.08.92 in optics lies near the upper limit for the energy observed for the flares of red dwarf stars. We conclude that the giant flare 29.08.92 as well as some fainter blue flares of AM Her originated on the secondary red component of binary system – the M4.5 dwarf (Shakhovskoy et al. 1993).

In the case of AM Her the surface of the secondary lies inside the magnetosphere of the primary, and the strength of primary's magnetic field at secondary must be larger than the intrinsic secondary's photospheric fields. Nevertheless all observed characteristics of the flare in AM Her are very similar to those for flares of single red dwarf stars.

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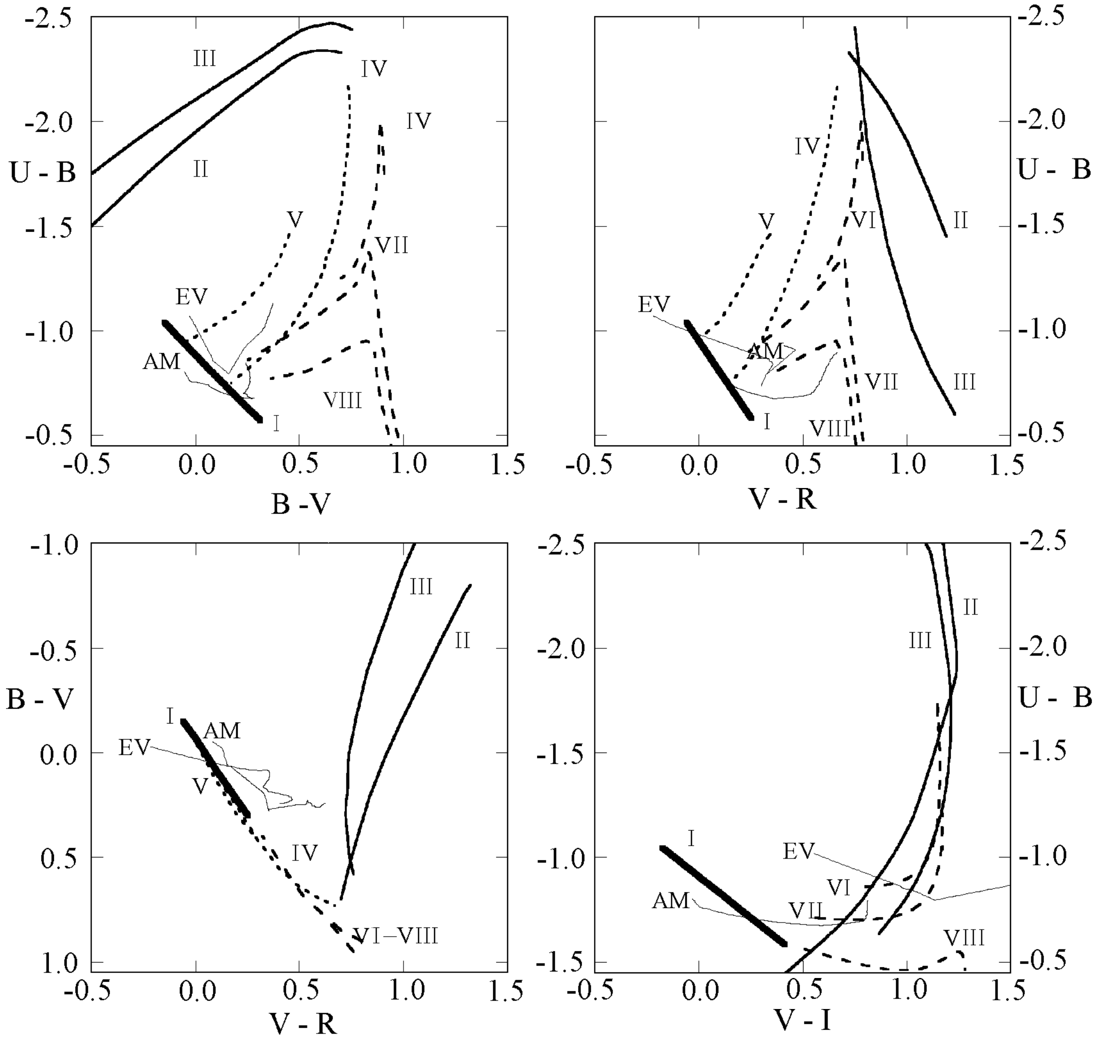

Figure 7: The two-colour diagramms for the flares of AM Her, EV Lac and for different theoretical models of the flare radiation from Alexeev et al. (1994) and Abdul-Zade et al. (1995). The legends are:
AM – track for the flare of AM Her on 29.08.92.;
EV – track for the flare of EV Lac on 15.09.91.
I – black body (temperature from 6,000 to 20,000 K),
II – optically thin hydrogen plasma with T_e =10,000 K, $n_e = 10^{12}$cm^{-3}.
III – –"–, $n_e = 10^{14}$cm^{-3}.
IV – optically thick plasma, T_e =10,000 K. V – –"– T_e =15,000 K.
VI – the photosphere of the red dwarf heated by the proton flux with $E = 1$ MeV.
VII – –"–, $E = 3$ MeV. VIII – –"–, $E = 5$ MeV.

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