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On the induced activity of red dwarfs in close binary systems

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AE Aquarii is a star with unique flaring activity. It is a close binary system, which contains a K3V-K5V red dwarf (secondary) and a magnetized white dwarf rotating with the period of 33 s (primary). It is traditionally classified as a peculiar nova-like star and assigned to the DQ Her subclass of magnetic Cataclysmic Variables (CVs). However, extensive investigations during the passed decade have clearly shown these classifications to be not effective. Actually, AE Aqr is the only source among CVs in which

• the spin-down power of the primary exceeds the system bolometric luminosity,

• the material streaming from the secondary through the L1 point is neither accreted onto the primary surface nor stored in a disk around its magnetosphere, and

• the luminosity of the system irregularly varies by up to an order of magnitude on a time scale from a few minutes to a few hours.

The first two items mean that the star's energy budget is dominated by the spin-down power of the primary instead of the accretion power as it is usually observed in CVs. This raises a question about the spin-down mechanism and the form in which the rotational energy of the white dwarf is released. The clue is the spin-powered pulsar-like spin-down mechanism: the rotational rate of a strongly magnetized, fast rotating star decelerates mainly by the generation of the magneto-dipole waves and ejecting relativistic particles. As recently shown by Ikhsanov et al. (2004), many of puzzling properties of the system can be well understood within this so called "pulsar-like white dwarf" model.

At the same time, the mechanism of flaring activity of AE Aqr remains an open problem so far. Some characteristics of the flaring are:

I. Irregular brightness variations in all spectral bands (from radio up to X-rays). The *timescales* are (i) *single* flares: 5—15 min, (2) *clusters* of flares: 20—120 min, and (3) *quiescent* phase: 30—100 min. The *raise time* of flares is 1–2 min. Flaring in the optical, UV and X-rays *correlate* with each other.

II. The *spectrum* of flares reaches its maximum in the UV and in case of the most powerful flares (the maximum luminosity and total energy output are $L_{\rm f}^{\rm max} \sim 10^{33}\,{\rm erg\,s^{-1}}$, and $E_{\rm f} \sim (1-3) \times 10^{35}$ erg) can be fitted by a black body radiation with the temperature $\sim 20\,000$ K. The area of the emission region in this case is $A_{\rm f} \sim 10^{20}\,{\rm cm^2}$ (for a detailed description see Beskrovnaya et al. 1996 and references therein).

III. X-ray observations show no evidence for any short-timescale hard precursors of the optical flares. Furthermore, the X-ray spectrum is dominated by the soft (< 2 keV) component, which excludes a possibility of its accretion nature (see e.g. Choi et al. 1999).

IV. The velocities of the material during powerful flares are $> 3000\,{\rm km\,s^{-1}}$ (Walker 1981).

To fit the observed properties of flares one has to assume that the energy source is the spin-down power of the white dwarf. A possible scheme of the transmission of this energy to the observed radiation is shown in Fig. 1. This scheme is based on the fact that for the currently established system geometry (Eracleous et al. 1994) the trajectories of particles ejected from the magnetic poles of the white dwarf intersect the surface of the red dwarf

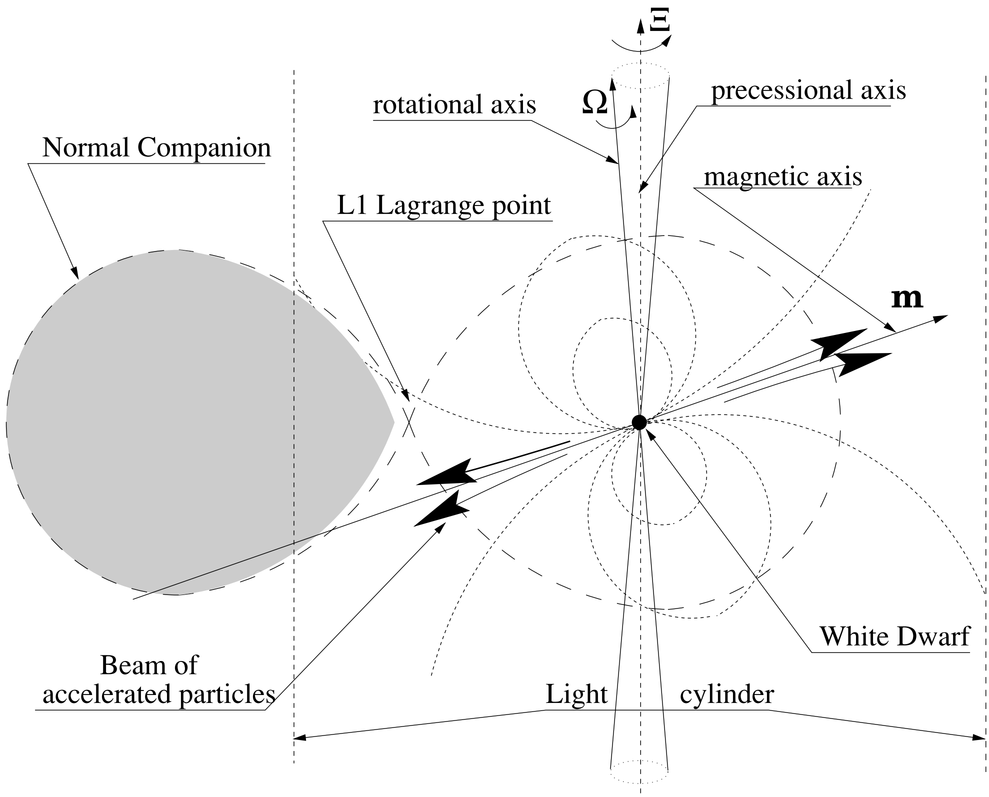

Figure 1. Schematic picture of AE Aqr. The trajectories of particles ejected from the magnetic poles of the white dwarf intersect the secondary's surface (see text).

and hence, the impact of particles onto the stellar atmosphere/photosphere is expected. The opening angle of the particle beam for the adopted parameters of the system (see Table 1 in Ikhsanov 2000) is $\sim 3\overset{\circ}{.}6$. This indicates that the flux of particles at the surface of the red dwarf can be as high as $\sim 10^{12}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$. Thus, the evaporation (gentle as well as explosive) of material from the red dwarf induced by the irradiation of its photosphere by particles accelerated in the magnetosphere of its degenerate companion can be expected. The basic parameters of this process will be presented in a forthcoming paper.

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