PINCH-MODEL OF FLARES AND ITS OBSERVATIONAL CONSEQUENCES

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ABSTRACT The paper presents the basic ideas of pinch-model for UV Cet star flares. The observational consequences and predictions are discussed.

1. INTRODUCTION

Cooperative observations of UV Cet star flares carried on recent years revealed the important features of stellar activity such as the noticeable local surface magnetic fields, the spot structure of the surface, the fine temporal structure of the light curves in optics and X-rays. The interpretation of flare phenomenon is based on sunlike MHD models. However this approach, as was shown in [1], encounters a number of significant difficulties, primarily, in predicting the energy of powerful stellar flares ($\sim 10^{35}$ ergs) and explaining the fine structure of light curves. To overcome in some extent the disagreements with observational data, we developed the pinch-model of flares. The model is based on the qualitative and quantitative analysis of observational data, the properties of the laboratory pinch-discharge as well as the numerical modelling of the pinch processes in stellar atmospheres. The comprehensive description of the model is given in [2].

This paper reports the main ideas and observational consequences of the pinch-model.

2. THE MAIN IDEAS OF THE PINCH-MODEL

According to the model, the flare process can be represented as follows. The formation of the closed magnetic configuration with low value of β can be due to floating (or stimulated floating, see below) of the magnetic fluxes from the convective zone of a star with origination of an arch

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structure of local magnetic field and it's "cleaning" during floating. If the force tubes in the lower parts of an arch are reconnected, such configuration will compress with the containing plasma owing to magnetic field tension. This process can lead to origination of solenoidal configurations analogous to that formed in laboratory pinch-discharge. The numerical modelling of magnetic thor evolution has been performed by present authors within the framework of ideal one-liquid two-dimensional MHD. The calculations show the evolution process to consist of two stages of compression. At the initial stage, thor collapses to the symmetry axis Z, stretching along that. As a result, both the external and internal boundaries become plane. The final stage is characterized by pinch-column and "hot-spots"(the regions with a high-temperature dense plasma) formation. According to model, the column radiation has a form of an impulsive optical flare, whereas the "hot-spot" radiation is manifested as the X-rays flare.

3. THE OBSERVATIONAL CONSEQUENCIES OF THE PINCH-MODEL

3.1. Time-scale and energetics of the flare process

The duration of the first stage is due to sonic speed of plasma compression within a thor and is of the order 300 s (if the following values for parameters of initial configuration are adopted: radius $\sim 10^{8}$ cm, temperature kT$\sim$ 10 kev, density $\sim 10^{-12}$ cm^{-3}). The final stage is caused by stretchnings compression with Alfven speed during 1-10 s. The stretchnings have a fluctuative nature with lifetime of the order to 1-10 s. Further evolution of the process lead to an increase in stretchnings temperature and density. Under some conditions (see [3]), the thermonuclear channel of energy release is switched. If the initial energy of the magnetic field is $> 10^{33}$ erg, under above mentioned initial conditions, the thermonuclear release is dominant and reaches the values of the order 10^{35}-10^{36} erg. Thus the energy of powerful flares in considering model can be of thermonuclear nature.

3.2. Flare maxima in optics and X-rays.

The simultaneous observations of solar flares in optics and soft X-rays point to the delay (of about 2 min) of the maximum in soft X-rays relative to that in optics. Kodaira [7] also arrived at the same conclusion, when analysing the stellar flares. But, in this case, the delay is somewhat greater and amounts to 5 min. The interpretation of this fact encounters the difficulties within the framework of traditional flare models. At the same time, according to the developed model thesoft X-ray radiation is due to impulsive compression of stretchnings, therefore the difference between Alfven and sonic time-scales leads to agreement with observed time interval between maxima in optics and soft X-rays. However this problem requires the comprehensive statistical investigations.

The radiation in optical range results, as was said, from high-temperature ($\sim 10^5$K), dense ($\sim 10^{15}$ cm^{-3}) and opaque hydrogen gas-pinch-column. According to [4], it is such values of plasma parameters are necessary to explain the wide-range-variations of flare colours (U-B, B-V) and Balmer jump in flare maximum.

3.3. Energy spectrum of particles and X-ray spectrum of non-thermal phase.

The preliminary research on soft X-ray energy spectra of the solar an stellar flares shows that the particles spectra for stellar flares are rather sloping ($\gamma \sim$ 1.5-2.0). In the pinch model, the particles gather their energy by consecutive collisions with converging current shell of the pinch-column. This mechanism also predicts the sloping energy spectra.

3.4. Asymmetry and central depression of emission lines.

The asymmetry and central depression of emission lines in flares spectra were detected quite recently with appearing of high-resolution spectra. This effect is also peculiar to solar flares. It was also shown, that it cannot be accounted for by absorption of infalling matter or by Stark-effect and other models. However in the pinch-model, the compression of plasma and its subsequent extension with a velocity gradient leads to either asymmetry or central depressions of Hα line for both opaque and transparent gaseous shell [5]. The results of this paper are in satisfactory agreement with observational data.

3.5. γ - bursts of powerful stellar flares.

Under some initial conditions the compression of stretchnings generates the thermonuclear wave of deiterium burning, resulting in γ-ray radiation by free-free transitions and lines of heavy elements. The details of the problem are given in [6].

4. ON STIMULATED HYDROMAGNETIC NATURE OF STELLAR FLARES

Solar and stellar flares are characterized by preflare activity. At the present time, there is not generally accepted model for this stage, but it's clear that it can be considered as a trigger for flare. Our analysis of solar preflares permits to come to conclusion that under-photospheric impulsive energy release is the cause of this stage. The energy release heats plasma ($n \sim 10^{15} \div 10^{16} cm^{-3}$, $R < 10^{6}$ cm) up to $T \sim 10^{7}$K. It leads to stimulated floating of spontaneously lifting magnetic fluxes from convective zone via high-tempersture plasma extension. The stimulated floating speed is one order greater than spontaneous lifting speed. The recent data on solar anomal neutrino flux and its connection with flares indicates the under-photospheric nature of preflare.

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KONSTANTINOVA-ANTOVA: How can your model explain the very shortlived spike flares?

HAYRAPETYAN: They can be explained in a pinch-model as the "hot spot's" manifestation in the optical part of the spectrum. The characteristic time scales are from 0.1 to 1 second.

RODONO: The optical-X-ray delay of 2 minutes you mentioned is a minimum value or can your interesting model allow also for shorter delays?

HAYRAPETYAN: The pinch-model yields a wide interval of delay values, from some 10 seconds to several minutes. The actual value depends on the characteristic time of the second (Alfven) stage.