PHENOMENON OF THE SUPERSTRONG MAGNETIC FIELDS IN SOLAR FLARES: OBSERVATIONS AND THEORY

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The spectral effects in Stokes $I \pm V$ and $I \pm Q$ profiles caused likely by superstrong magnetic fields were discovered in several solar flares observed on the Echelle spectrograph of the Astronomical Observatory of the Taras Shevchenko National University of Kyiv. These effects indicate on the magnetic field strength from 1 to 9 T, magnetic flux of about 10^{12} Wb, and life time from 3 to 20 min. The superstrong fields occur at the branch of magnetic structures with rapid evolution on the diagram "magnetic flux – life time" by Golovko [1]. One of the possible MHD models of such fields is a spherical magnetic vortex [5]. This model has two sets of intermittent discrete states, force-free and singular, and provides an evidence on unlimited high strengths for a short time of vortex evolution.

INTRODUCTION

The first observational results on the problem of superstrong magnetic fields in flares based on the Stokes $I \pm V$ profiles analysis were published in 1993 [2]. The careful verification of the following spectral effects was made in 1998 [3], and it was based on the larger number of observational data as well as on the Stokes $I \pm Q$ profiles. The main conclusion from these investigations is that the phenomenon is real and perhaps arises as a result of the magnetic field amplification at the peak of solar flares. Some observational evidences on existence of such an amplification ("magnetic collapse") was directly observed in the solar flare [3, 4].

In this paper we present a short report about some observational data on this problem obtained after 1998 and some new theoretical ideas.

OBSERVATIONS

Three types of spectral perturbations like Zeeman effect arised in a case of superstrong magnetic fields were detected in several solar flares [3]. One of such perturbations in the Fe I 543.45 nm line is presented in Fig. 1. Due to the very low Lande factor of this line (g = –0.014), similar spectral effects are possible only in a case of magnetic field strength of about a few tesla. The specific effects were observed also in the Fe I 512.37 (g = –0.013) and Balmer lines.

During July 2000 some interesting solar flares were observed on the Echelle spectrograph of the solar telescope of the Astronomical Observatory of the Taras Shevchenko National University of Kyiv. One of such flares, of July 19, 2000 had coordinates 14°S, 15° E, and the peak of metallic emission nearly 7:20 UT.

The preliminary investigation of the Stokes $I \pm V$ profiles of the Fe I 543.45 nm line in the flare of July 19, 2000 shows that some spectral manifestations to a superstrong field exist in this flare as well. However, due to the emission, the intensity in the flare of July 19 is much less than that in the flare of June 16, 1989, and an additional study is necessary to make more certain conclusion.

At present we can point to the following characteristics of the observational features with superstrong fields: the magnetic field strength from 1 to 9 T, both the horizontal and vertical scales of about 10^3 km (including the range of the upper photosphere, temperature minimum zone and low chromosphere), typical life time from 3 to 20 min, vertical magnetic field gradient of about 1–10 mT/km, magnetic flux of 10^{12} Wb. It is important to note that the field strengths are strongest at the flare peak rather than in the flash phase. The superstrong fields occur near the branch of magnetic structures with rapid evolution on the diagram "magnetic flux – life time" by Golovko [1].

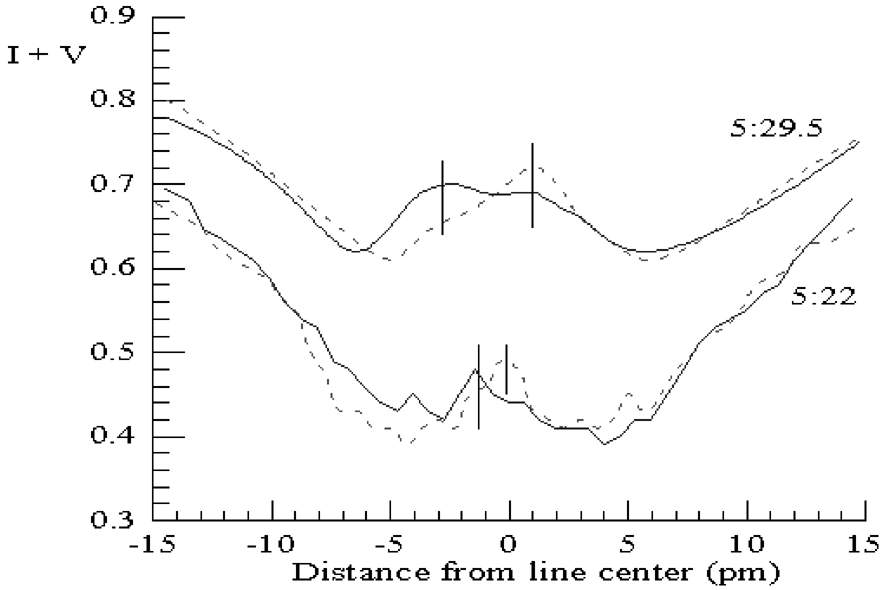

Figure 1: Observed Stokes $I \pm V$ profiles for Fe I 543.45 nm line (g = –0.014) in solar 2B-flare of June 16, 1989: 5:22 UT – the flash phase, 5:29.5 UT – the flare peak. One can see the very narrow ($\approx 3 - 5$ pm) emission peaks in the line core which are *shifted mutually along wavelengths*, and have *the opposite asymmetry*. These pecularities could evidence on the superstrong magnetic fields in the flare, about of 2.5 T for the flash phase and 9 T for the flare peak

THEORY

One of the possible MHD models of such fields is a spherical magnetic vortex [5]. This model has two sets of intermittent discrete states, the force-free and singular one. Two possible mechanisms could lead to the loss of the system's equilibrium: relatively slow Ohmic dissipation, and external perturbations rotating one of the inner magnetic tores by 180 degrees, and producing neutral current sheets inside the spheroid. The energetic and temporal estimates for this process are in agreement with observations.

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