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Coronal mass ejection and solar flare initiation processes without appreciable changes of the large-scale magnetic field topology

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Abstract

We demonstrate that spurious three-dimensional re-constructions from two-dimensional images and movies of solar flares and coronal mass ejections can arise as a result of viewing conditions and projection effects, which are not always properly taken into account in the current literature. Theory and observations indicate that eruptions can proceed with or without large-scale topological changes of prominences and coronal magnetic fields. Electric currents and plasma drifts in crossed electric and magnetic fields play not negligible, but important role. This means that large-scale magnetic reconnections understood as topological transitions in the magnetic field are not always necessary for eruptions. The scenario of expanding and rising non-planar systems of preexisting loops and arcades, which are deforming when shearing at bottom parts, twisting and rotating at summits, satisfactory fits available observations. Movies are presented demonstrating this type of behavior with a preserved magnetic connectivity.

Keywords: Sun; Coronal mass ejections; Prominences; Solar flares

1. Introduction

Three-dimensional structures of solar eruptions are not well investigated. The interpretation of available two-dimensional images and movies is not quite unique. It is because of pre-assumptions about the geometry, which need justification by some other methods, for example, by spectroscopic and Doppler measurements. The main difficulty resides in the solution of inverse problems, which are usually not correct or ill posed without such additional information in hands. Movies present continuous mapping of three-dimensional plasma structures on the image plane and could be helpful in the de-convolution. Future STEREO project (http://stp.gsfc.nasa.gov/missions/stereo/stereo.htm) is promising for obtaining a better knowledge about three-dimensional shapes, but it is also restricted in capabilities to solve all corresponding problems.

Available TRACE and SOHO/EIT movies show the cases of the coronal mass ejection and solar flare initiation processes with and without noticeable large-scale topology modifications in observed features. The appearance of new intermediate scales is omnipresent in the erupting region structures when the overall configuration is preserved. Examples of this kind are indicated and discussed in this paper and compared with existing magnetic field reconnection paradigms. It is demonstrated that spurious large-scale reconnections and detachments can be produced due to the projection effects in poorly resolved images of twisted loops and sheared arcades especially when deformed parts of them are underexposed or not seen in the images only because of this reason. Other parts, which are normally exposed or overexposed, can make the illusion of ''islands'' or

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detached elements in these situations though in reality they preserve the initial magnetic connectivity. Spurious "islands" of this kind could be wrongly interpreted as signatures of topological transitions in the large-scale magnetic fields in many instances described in the vast literature in the past based mainly on fuzzy YOHKOH images, which resulted in the myth about universal solar flare models elaborating the scenario of detached magnetic island formations with new null points in the large-scale magnetic field. The better visualization with a higher resolution and sensitivity limits allowed to clarify this confusion and to avoid this unjustified interpretation.

The aims of the present paper are as follows:

1. Discussion of the role of electric fields and currents in the dynamical processes on the Sun.
2. Demonstration of the fact, that eruptions on the Sun can proceed without noticeable large-scale topological changes of prominences and coronal magnetic fields.
3. Presentation of the case, when spurious cusps could mimic 'magnetic reconnection'.
4. Description of explanatory scenario and illustrative movie of the eruptive process on the Sun without large-scale topological transition of the magnetic field.

We advocate that topological changes obviously can happen in the coronal magnetic fields, but these changes are not always necessary ingredients at least of all coronal mass ejections and solar flares. The scenario of the magnetic field opening is not universal for all ejections. Otherwise, expanding ejections with magnetic configurations anchored on the Sun can be produced by the fast E cross B plasma drifts in strong inductive electric fields, which appear as a result of sufficiently rapid time variations of the magnetic flux.

2. Electric currents and magnetic forces in the solar corona

In the past 1960th–70th, Severny and Gopasyuk as well as their co-workers in Crimea were inspired by physically sound and clear ideas described in the earlier works especially by Alfvén. They performed original works, which demonstrated the existence of "vertical" electric currents in active regions of the order of up to 1 TA and more. There was a number papers on all this. Burnett et al. (2004) recently also reported about electric currents and concluded that coupling between photospheric and coronal altitudes exist. This conclusion is based on the analysis of photospheric magnetograms and coronal YOHKOH images. The important dynamical role of electric currents and fields as well as magnetic forces in space plasmas is understood and appreciated by many authors (see, e.g., Alfvén and Carlquist, 1967; Gopasyuk, 1987; De Jager, 1988; http://public.lanl.gov/alp/plasma/universe.html; and also Kiepenheuer (1953)) for a review of early ideas. Unfortunately, this role is still often disregarded in some papers and textbooks on the solar plasma dynamics. It is purely because of subjective reasons and not because of their unimportance. We do not repeat here all arguments and refer the reader to our previous publications, if he/she is not quite convinced in the important role of electric drifts in the prominence eruptions and coronal mass ejections (Veselovsky, 1998, 2002). On the opposite side, we found sometimes wrong ideas and unjustified exaggerations of the role of electric fields as in the case of the "Electric Sun" paradigm (http://www.electric-cosmos.org/sun.htm). It is not our purpose here to critically discuss in details the history and all this fight of correct and wrong ideas in the solar physics. Nevertheless, we should mention that the modern fashion shift in the well accepted paradigms of the solar activity to the "Magnetic Sun" is also not quite adequate to the real physical situation. We are taught now that "The Sun's magnetism seems to be the cause of the most of the solar activity" (http://www.lmsal.com/lobby.htm) or that "The Sun's magnetic field, which is concentrated into flux tubes in the photosphere, affects the radiance" and again "The sum of all magnetic features on the whole solar disc affects the Sun's irradiance" (Solanki, 2002). Most and possibly even all of the irradiance variations are caused by the Sun's magnetism and its variation, according to this popular point of view. Contrary to this, magnetic fields on the Sun as a star and in its lower atmosphere do not seem to be primary free energy reservoirs. Corresponding magnetic energy and power appear to be small if compared with the heat and gravity according to reasonable estimates of governing dimensionless parameters (Veselovsky, 2004a). According to these views, convective heat machine of the Sun drives the radiation and magnetic fields of the solar atmosphere. Temperature variations in subphotospheric layers and at the surface feed the thermal radiation variations.

The solar activity is understood now as the solar variability in all time scales. The 'magnetic activity' is only one important part and cannot substitute the whole 'solar activity'. Magnetic regimes are mostly submagnetosonic and subalfvénic in the subphotospheric layers and in the lower atmosphere of the Sun. Hence, magnetic fields and many other manifestations on the Sun, which are tracing this variability because of the lack of equilibrium in mechanical and thermodynamic sense, play an important, but subsidiary role in the overall budget of the free energy circulation in solar interiors and in the solar atmosphere taken globally as a whole. Nevertheless, the magnetic energy and its dissipated power can dominate in some parts of the volume inside