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ORIGINAL ARTICLE

Does the region of flare-energy release work as a vacuum-cleaner?

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Abstract We aim to explore the unusual flare event which took place in the solar atmosphere on September 22, 2011 and propose its theoretical interpretation. We analyze the process of energy release in the twisted magnetic flux-rope associated with the event, assuming the excitation of anomalous resistivity of turbulent plasma in the rope, and solve numerically nonlinear two-dimensional (2D) magnetohydrodynamic (MHD) equations. The analytical approach to the problem of flare-energy release show that the conditions of excitation of anomalous resistivity can be satisfied in the twisted magnetic flux-rope whose parameters fits well the SDO observational findings. One of the most remarkable properties of the flare phenomenon under the present consideration was the permanent sucking of the coronal/chromospheric gas from the very remote points to the flare filament, i.e. into the low-lying hot region of the flare energy release. This unusual phenomenon has been simulated by numerical methods in terms of ideal MHD. The numerical results reveal that siphon back-flow exhibits characteristic spatial signatures which mimic the observational findings. The flare-energy release region, as a part of strongly twisted magnetic flux-rope, is able to work as a vacuum-cleaner.

Keywords Magnetohydrodynamics (MHD) · Sun: atmosphere

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1 Introduction

Solar Dynamics Observatory (SDO) with the on-board devices Helioseismic and Magnetic Imager (HMI) and Atmospheric Imaging Assembly (AIA) opened up a new era for the study of flare processes. The SDO data, collected in the UV-lines, revealed a number of new features which are of great importance for understanding physical nature of many solar phenomena. One of them took place on September 22, 2011 when AIA registered in the north-eastern part of the solar disk in the line HeII ($\lambda = 304$ Å) a X1 class flare event (Fig. 1, left-top). This flare lasted for a very long time, about 12 hours, and during all this time cold plasma was moved from the surrounding low corona directly into the very hot plasma which settled in the flare-energy release region (Fig. 1). This cold plasma moved with a relatively low speed (about few $\mathrm{km\,s^{-1}}$), and this effect could be revealed clearly only in a very long, continuous monitoring mode of observations. This phenomenon could not be detected if the duration of the observational session was limited, as often happens, to few minutes or even to 1–2 hours only. In the latter, visible dislocations of individual bright blobs of gas, on the bases of which the phenomenon was detected, could be too small to be spotted. Being propelled slowly from a very distant point which is located behind the limb, the plasma of low corona moved along a nearly horizontal helical trajectory, which is evidently located along the helical magnetic field lines (Fig. 1). While approaching the hot flare region, the plasma accelerated; at the moment of its direct penetration the (projected on the plane) speed of individual plasmoids reached a value of 10–20 $\mathrm{km\,s^{-1}}$. Simultaneously, the gas rotated, manifesting a twist in the magnetic flux-tube, which comes out from the flare-energy release region. This rotation is remarkably well seen near the hot flare region and is hardly discernible at distant region (Fig. 1, bottom panels). Note that this phenomenon has

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