Solar flare science with microwave imaging spectroscopy beyond the standard model

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Over recent decade, a novel methodology that employs microwave imaging spectroscopy data opened an entirely new window to look at coronal phenomena; notably solar flares. This methodology yields evolving maps of such coronal parameters at the flare sites as the magnetic field and the thermal plasma density along with parameters of the nonthermal electrons, primarily, their number density and spectral index in their distribution over energy. These diagnostics is the key to uncover otherwise elusive physics of magnetic energy transformations and particle acceleration in solar flares. Indeed, release of the magnetic energy due to reconnection is believed to drive such transient phenomena as solar flares, eruptions, and jets. This energy release should be associated with a decrease of the coronal magnetic field. Therefore, the quantitative measurements of the evolving magnetic field strength in the corona, that we are reporting here, are required to find out where exactly and with what rate this decrease takes place. Here, we report microwave observations of several solar flares, showing spatial variations and temporal changes in the coronal magnetic field at various coronal locations [1-4]. We discovered a fast decay of the magnetic field in the coronal loops and cusp regions [1,3]; well below the nominal reconnection X point implied by the standard model of solar flare. The field decays at a rate ranging from a fraction of Gauss up to ~ 10 Gauss per second in various events and locations. This fast rate of decay implies a highly enhanced, turbulent magnetic diffusivity and sufficiently strong electric field to account for the particle acceleration that produces the microwave emission. In addition, we report such phenomena, that are beyond the standard model, as bulk electron acceleration in the cusp region [5], where the magnetic field displays the fast decay, and a new high-energy, MeV-peaked, electron component in a corona volume [6]. We report 3D coronal maps of such important parameters as Alfven speed and plasma beta [4]. Finally, we review novel results on the spectral energy evolution of the nonthermal electrons accelerated in flares and oscillations of physical parameters in event(s) with quasiperiodic pulsations.

References:

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