Chaotic magnetic field lines may answer the coronal heating problem

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It is known that the sun's corona—the outermost layer of the sun's atmosphere—is roughly 100 times hotter than its photosphere—the sun's visible layer. The reason for this mysterious heating of the solar coronal plasma, however, is not yet entirely understood. A research team in India has developed a set of numerical computations to shed light on this phenomenon, and present this week in *Physics of Plasmas*, analysis examining the role of chaotic magnetic fields in potential heating mechanisms.

Operating under the idea that chaotically tangled magnetic field lines exist throughout astrophysical plasmas, the team used high-performance computer simulation to gain an understanding of these chaotic field lines. Specifically, they investigated conditions that create ribbons of intense electric current, known as current sheets.

The current sheets, believed to be produced in the coronal plasma, are potential sites for magnetic reconnections, which provide a mechanism for extreme heating of the corona. Moreover, within the current sheets, the electric field peaks up and accelerates charged particles.

"We want to go one step forward to explain the spontaneous generation of these current sheets," said Sanjay Kumar, a member of the research team.

The research method focused on allowing an incompressible, thermally homogeneous magnetofluid with infinite electrical conductivity to relax via viscous dissipation, toward a characterized final state. The computations were made consistent with well-accepted magnetostatic theory and resulted in spontaneous current sheet development, making them relevant for the study of particle acceleration in astrophysical plasmas.

Using Vikram-100, the 100TF High Performance Computing facility at the Physical Research Laboratory, the researchers simulated the viscous relaxation and verified accurate flux-freezing, a conservative behavior a reliable simulation must demonstrate. The team plotted the maximal intensities of volume current densities for specific trends of increasing magnetic field chaos, which provided a measure of the production of current sheets. Additionally, the maximal magnitudes of volume current density were found to scale with the numerical resolution used in the computer simulation, which showed the expected scaling of current sheet development.

The simple fact that the maximum value of volume current density was increased with increasing magnetic field line chaos, called "chaoticity," suggests a direct proportionality between the intensity of the current sheet and chaoticity.

In the three cases studied, the researchers found the formation of two different sets of current sheets. One set was arranged along the y-axis, while the second formed in a different location and at a time later than the first. From their analysis of this occurrence, the team determined that a favorable evolution bring non-parallel magnetic field lines into close proximity and intensify current sheets.

These simulations provide new and novel insight regarding the influence of chaotic magnetic field lines on the spontaneous development of current sheets, and hence potential places of particle acceleration.

"This is the first time we have explained the role of chaotic field line in generating these spontaneous current sheets," Kumar said, referring to the scientific community as a whole.

More information: Sanjay Kumar et al, Chaotic magnetic field lines and spontaneous development of current sheets, *Physics of Plasmas* (2017). DOI: 10.1063/1.4996013

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