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Kinetic and magnetic vortices in the solar atmosphere

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Small scale solar vortices are ubiquitous in the photosphere, and they are believed to organize the magnetic fluxes, creating efficient conduits for energy transport and wave propagation. Another process linked to vortical flows is the generation of twisted magnetic flux tubes. In this work, the twisted magnetic flux is defined as a new typology of a solar vortex, and we applied forefront methodologies to detect both the kinetic and magnetic vortices tubes in realistic magnetoconvection simulations. Our results show that those types of vortices are found in distinct parts of the intergranular downflow. The magnetic vortices appear mostly in shear flow areas where plasma-$\beta > 1$, whereas the kinetic vortices are found in low plasma-β regions. The solar vortices present similar dynamics at different solar atmosphere levels, concentrating and perturbing the magnetic field lines. The kinetic vortices show upward jets and tend to encompass high magnetic fluxes; thereby, their dynamics is mainly dominated by magnetic forces. Based on the magnetic and kinetic energy ratio obtained for magnetic vortices, we determined that they can be classified into two distinct types, with considerable differences in the overall geometry of the magnetic field line. Our results indicate that the presence of rotational motion in the flow is not necessary for the appearance of magnetic vortices.

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