7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Small-scale vortices in solar plasmas and their dynamics

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Small-scale vortical motions at granular scales with dynamic timescales of a few minutes, that result from the turbulent dynamics of subsurface solar convection, appear within intergranular lanes, and largely populate the solar surface and the atmosphere above. They often lead, when interacting with co-local magnetic field concentrations, to the formation of magnetic tornadoes that penetrate several layers of the solar atmosphere from the photosphere up to the low corona. [1]

Figure 1 schematically illustrates different types of vortical flows in the solar atmosphere that are driven by different mechanisms such as rotation resulting from the conservation of angular momentum, photopheric rotational flows, rotating magnetic structures or plasma motion along twisted magnetic structures. Vortices often exhibit substructure[2] related to their complex dynamics or waves.

The rich tapestry of such flows is presently explored by high-resolution, ground-based observations and state-of-the-art magnetoconvection simulations and (magneto)-hydrostatic models. Detection methods of solar vortices in the solar photosphere are based on tracking of flow velocities (and relevant tensors and metrics), that either exist (in numerical datasets) or are reconstructed with Local Correlation Tracking (LCT) techniques (in observations). In more complex layers such as the solar chromosphere, where proper derivation of flow velocities with LCT is problematic, observational detection of chromospheric swirls is based on morphological[3] methods.

Small-scale vortex flows likely affect the dynamics of the quiet Sun and coronal holes solar chromosphere, and transfer mass and energy between the photosphere and the corona. The twisting and dynamics of the magnetic field lines within them are ideal for driving a wide variety of oscillations and for initiating a multitude of MHD waves[4,5], mainly of Alfvenic type, and flows that can potentially contribute to the solar atmospheric energetics at different heights.

With the combined use of observations and simulations we explore and discuss the nature and detection of vortex flows in the solar atmosphere, their physical properties and relevant dynamics and their role in the excitation and propagation of waves and the energetics of the solar atmosphere.

References

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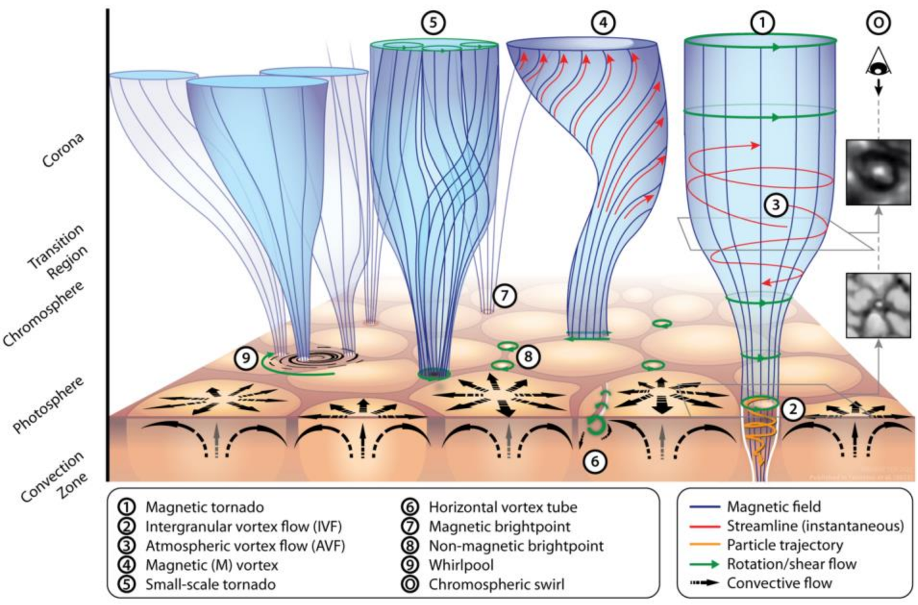

Figure 1. Schematic illustration of different types of small-scale vortex flows and related phenomena in the solar atmosphere (see figure legend for description). Shades of brown indicate solar granulation with arrows in foremost granules representing the convective flow field. Blue and red lines show, respectively, the magnetic field lines and instantaneous streamlines, while green arrows indicate the rotation of magnetic flux structures. From Tziotziou *et al* (2023)[1].