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On the dynamics of vortices in the solar atmosphere

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Small scale vortices in the solar atmosphere have received increasing attention in recent years. They are ubiquitous at photospheric and chromospheric levels and are a viable candidate mechanism for the exchange of waves, energy, and mass with the upper solar atmosphere.
In order to identify and study the dynamics of these vortices, we seek a suitable mathematical criterion for which an evolution equation exists. The vorticity and vorticity equation would be the classical options for this task. However, it is now well known that they can be biased by shear flows. Therefore, we adopt the swirling strength criterion, a generalisation of the vorticity, for which we derived an evolution equation from the basic equations of (magneto)hydrodynamics. We suggest the swirling strength and its dynamical equation as a novel tool for the analysis of vortex dynamics in numerical simulations.
We apply this novel tool to realistic numerical simulations of a small portion of the solar atmosphere realized with the radiative magnetohydrodynamic code CO5BOLD. We find a tight relation between unidirectional, vertical swirling motions and torsional magnetic field perturbations, which propagate upward at local Alfvén speed and are driven by magnetic tension forces. All together, these are clear characteristics of torsional Alfvén waves in the form of compact wave-packets or unidirectional pulses. These pulses naturally arise from a self-consistent numerical simulation of the solar atmosphere and we estimated the mean Poynting flux at the bottom of the chromosphere.

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