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Ubiquitous solar eruptions driven by magnetized vortex tubes

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Abstract

The solar surface is covered by high-speed jets transporting mass and energy into the solar corona and feeding the solar wind. The most prominent of these jets have been known as spicules. However, the mechanism initiating these eruption events is still unknown. Using realistic numerical simulations we find that small-scale eruptions are produced by ubiquitous magnetized vortex tubes generated by the Sun's turbulent convection in subsurface layers. The swirling vortex tubes (resembling tornadoes) penetrate into the solar atmosphere, capture and stretch background magnetic field, and push the surrounding material up, generating shocks. Our simulations reveal complicated high-speed flow patterns and thermodynamic and magnetic structure in the erupting vortex tubes. The main new results are: (1) the eruptions are initiated in the subsurface layers and are driven by high-pressure gradients in the subphotosphere and photosphere and by the Lorentz force in the higher atmosphere layers; (2) the fluctuations in the vortex tubes penetrating into the chromosphere are quasi-periodic with a characteristic period of 2-5 minutes; and (3) the eruptions are highly non-uniform: the flows are predominantly downward in the vortex tube cores and upward in their surroundings; the plasma density and temperature vary significantly across the eruptions.

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Keywords

magnetic fields, magnetohydrodynamics (MHD), methods: numerical, plasmas, Sun: chromosphere, Sun: photosphere, turbulence