M41a Radiative MHD simulations for starspots in low-mass stars: Inward penumbral flows

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We present high-resolution three-dimensional radiative MHD simulations of starspots on cool main-sequence stars (1.0, 0.6, and 0.3 solar masses) using the R2D2 code, focusing on their penumbral flow structures. While solar observations have revealed the fine structure and dynamics of sunspots, characterizing the detailed structure of starspots on other stars remains observationally challenging. In low-mass stars, a lower convective Mach number near the surface is associated with a different balance among kinetic, magnetic, and internal energies compared to sunspots. Such differences in energy partitioning imply that starspots may form and evolve under different magnetohydrodynamic conditions distinct from sunspots. Under magnetic field strengths comparable to those in sunspots, our simulation shows that starspots develop predominantly inward-directed penumbral flows, unlike the outward Evershed flows in sunspots. We will present a detailed interpretation of this behavior in our talk.