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Critical spin superflow in a spinor Bose-Einstein condensate
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— The hallmark of superfluid is the existence of critical velocity. In a spinor Bose-Einstein condensate (BEC), the stability of superflow is intertwined with internal spin degrees of freedom, which interestingly induces a new kind of critical behaviors. Here, we report our investigation on the critical dynamics of spin superflow in a spin-1 antiferromagnetic spinor BEC. A pure spin superflow is obtained in a trapped condensate by transmuting an easy-axis polar state into an easy-plane polar state under a magnetic field gradient. We observe that with the field gradient exceeding a certain critical value, the dissipation rate of spin superflow rapidly grows. The onset of dissipation is found to be related to the modulation instability of the two counterflowing spin components, which generates the dark-bright solitons. The solitons are split into vortices via snake instability, leading to the formation of spin turbulence. We also observe the generation of transient axial polar spin domains due to the dynamical excitation of transverse magnon mode via spin-exchange collisions, which develops the second critical point for spin superflow. Our work provides a comprehensive picture of spin superfluidity and its dissipation mechanisms in a spin-1 antiferromagnetic condensate system.

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