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The structure of the magnetic reconnection exhaust boundary

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Switch-off slow shocks (SSS) are the key structure of driving the outflow in Petschek's reconnection model. Observations of reconnection in the solar wind in particular seem to suggest that reconnection X-lines and associated exhausts grow to very large scales and resemble the open outflow geometry predicted by Petschek. However, direct observations of SSSs in the Earth's magnetosphere and the solar wind are infrequent. Since it is the release of magnetic energy downstream from the X-line that ultimately drives the outflow rather than the dynamics close to the X-line, the absence of the SSS in observations and kinetic simulations calls into question the conjecture that fast collisionless reconnection actually can scale to very large systems. Thus, a key requirement for demonstrating the fast energy release of reconnection that takes place in large systems is to pin down the specific mechanism driving the Alfvenic outflow. We present a large 2-D reconnection simulation and its companion Riemann problem using a Particle-In-Cell code. The self-generated firehose-sense temperature anisotropy (*i.e.,* $T_{\parallel} > T_{\perp}$) by counterstreaming ions is found to be important in determining the structure of reconnection exhausts. This temperature anisotropy slows down the intermediate mode while speeds up the slow mode, and consequently prevents the formation of classical Switch-off Slow shocks in Petschek's model. Instead, the nonlinear coupling between the slow and intermediate waves constitutes the shock transition. A plateau of the firehose stability parameter $1-(\beta_{\parallel}-\beta_{\perp})/2$ at value 0.25 is observed inside these hybrid waves, which should also be observable in Earth's magnetotail and the solar wind. This special value is significant because it is the degeneracy point of slow and intermediate waves in anisotropic plasmas. The anisotropic Rankine-Hugoniot jump conditions are derived and compared with our simulations, while the pseudo-potentials of shocks are analyzed to explain the dynamics of forming these transition structures. The Walén relation is shown to fail at the core of reconnection exhausts, where the firehose instability is unstable. (*Ref: Yi-Hsin Liu, J. F. Drake and M. Swisdak, The structure of the magnetic reconnection exhaust boundary, Phys. of Plasmas, 19, 022110, 2012*)