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Three-dimensional reconnection in the solar wind: ion kinetic effects and proton temperature anisotropies at ion-scale current sheets

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Solar wind plasmas have been observed to host a population of magnetic discontinuities which are associated with local plasma heating. These thin current sheets, which may be subject to a tearing instability, can heat the plasma via magnetic reconnection. However, the extent to which reconnection in the solar wind contributes to the solar wind heating problem is still an open question. Observations suggest that coupling between kinetic processes and tearing instabilities plays an important role in the evolution of current sheets and associated particle heating. Hence, a more complete understanding of kinetic effects on current sheet evolution is desirable. The reconnection process is well understood for seeded x-points in two-dimensions, and more recently significant progress has been made towards understanding the interaction of electron kinetic instabilities and tearing modes in electron-scale current sheets. Previous three-dimensional studies have shown that initially patchy reconnection may evolve towards a two-dimensional x-line structure. However the role of three-dimensional ion kinetic instabilities, particularly when coupled with a turbulent medium such as the solar wind, has not been fully explored. Recent work has demonstrated that proton temperature anisotropy plays an important role in the growth and evolution of the two-dimensional, collisionless tearing instability. Hence, we expand this study to incorporate three-dimensional effects by means of a three-dimensional hybrid code (particle ions, fluid electrons). The initial conditions of our simulations include two current sheets, each initialised in Harris equilibrium, with periodic boundary conditions in all dimensions. We present several simulations between which we vary i) temperature anisotropy in the background, ii) temperature anisotropy in the current sheet and iii) strength of the guide field. We confirm the effects of ion-cyclotron and firehose instabilities on reconnection rates, and demonstrate the emergence of persistent three-dimensional structure, including patchy reconnection sites and kinked flux tubes. In addition, we examine the evolution of these structures, discuss their role as a potential source of turbulence, and quantify local ion heating associated with the current sheet.