KINETIC SIMULATIONS OF PERPENDICULAR SHOCKS

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In order to render the problem computationally tractable, simulation codes make approximations which limit the physics they can represent. Because of the disparity between electron and ion characteristic scales, simulating a fast magnetosonic shock with a full particle electromagnetic code is a daunting task, which requires compromises. We have developed an electromagnetic code in the Darwin approximation, whereby the transverse part of the displacement current is neglected. This neglect affords us a larger timestep than the Courant condition would otherwise impose on a grid resolving the Debye scale length.

We consider a perpendicular geometry, where x points into the shock and the electromagnetic field structure is $\mathbf{E} = (E_x, E_y, 0)$ and $\mathbf{B} = (0, 0, B_z)$. Moderate shocks with Mach number $M_a \sim 2$–4 and isothermal upstream plasma ($\beta_i = \beta_e \sim 0.1$–$0.3$) are addressed. The 1D3V code has open boundaries with upstream and downstream particles traversing the left and right boundaries, respectively. The simulation is carried out in the frame of the shock. We initiate the computation by loading the particles according to profiles of density, temperature, and fields which are modeled consistently with conservation laws (Rankine-Hugoniot). Particles and fields are then left to evolve self-consistently. Importantly, due to the partial decoupling of ions and electrons which occurs in the magnetic ramp, the electrostatic field E_x builds up a large spike whose role is to slow down the ions and reflect a small fraction thereof. The reflected ions are accelerated by the transverse electric field E_y, gyrate back into the shock front, and are finally transmitted downstream. After several thousand timesteps a quasi-stationary shock structure is formed.

We discuss the simulation techniques used and compare the results of our shock model with those from a fully electromagnetic particle code [Lembege (2003)]. This is done for a set of parameters accessible to the fully electromagnetic code, such as: a ratio of electron gyro-to-plasma frequency $\Omega_e/\omega_{pe} = 1/2$ and a ratio of the thermal velocity to the speed of light $v_e/c = 1/15$. We then indicate how results change for parameter values which apply more realistically to shocks in the solar wind.