Magnetic Fields and Particle Injection at Collisionless Shocks

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A number of lines of argument suggest that a pre-existing suprathermal population of ions is necessary ahead of a shock in the extended solar corona for significant particle acceleration to occur. Such ions are more readily injected into the diffusive shock acceleration process, and act as “seed particles” for solar radiation storms, otherwise known as Solar Energetic Particle (SEP) events, which constitute the major space weather hazard for instrumentation and astronauts in orbit.

Making the assumption that wave growth ahead of the shock is a necessary condition for particle injection and subsequent acceleration, conditions which the suprathermal particle distribution, Alfvén Mach number and the shock obliquity must satisfy for injection can be derived. Injection is more favorable with stronger non-thermal particle distributions and at quasi-parallel as opposed to quasi-perpendicular shocks. At the higher Alfvén Mach number shocks relevant to supernova remnants (SNRs), the efficiency of ion injection is much less sensitive to shock obliquity and suprathermal distribution function. This appears to be reflected in the cosmic ray amplified magnetic field seen around the rims of many galactic SNRs.

Electron injection at SNRs remains highly dependent on shock obliquity, being strongly favored at parallel shocks. While the cosmic ray ion generated magnetic field is expected to be quasi-isotropic, becoming more quasi-perpendicular when compressed by the shock, a long standing puzzle has been the inference of radial (i.e. quasi-parallel) magnetic field from radio synchrotron emission. A likely solution appears to be that proposed recently by West et al. (2017), whereby only the quasi-parallel field lines are lit up by synchrotron radiation, since these are the only field lines where electron injection occurs.