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Origin and acceleration mechanisms of backstreaming ion populations in the Earth's quasi-perpendicular Ion Foreshock: Full-particle 2D simulation results

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The ion foreshock located upstream of the Earth's bow shock is populated with ions reflected back by the shock front with an high energy gain. In-situ spacecraft measurements have clearly established the existence of two distinct populations in the foreshock upstream of the quasi-perpendicular shock region (i.e. for $45^{\circ} \leq \Theta_{Bn} \leq 90^{\circ}$, where $\Theta_{Bn}$is the angle between the shock normal and the upstream magnetostatic field): (i) field-aligned ion beams (or " FAB ") characterized by a gyrotropic distribution, and (ii) gyro-phase bunched ions (or " GPB ") characterized by a NON gyrotropic distribution, which exhibits a non-vanishing perpendicular bulk velocity.

The use of 2D PIC simulations of a curved shock, where full curvature effects, time of flight effects and both electrons and ions dynamics are fully described, has evidenced that the shock front itself can be the possible source of the different backstreaming ions.

Our analysis evidences the importance of the interaction time (Δ_{inter}) with the shock front, in particular " GPB " and " FAB " populations are characterized by a short (Δ_{inter}= 1 to 2 τ_{ci}) and much larger (Δ_{inter}= 1 to 10 τ_{ci}) interaction time respectively, where τ_{ci} is the ion upstream gyroperiod. This discrimination allows a deeper statistical analysis:

(i) backstreaming ions are splitted into both " FAB " and " GPB " populations depending on their injection angle when hitting the shock front (i.e. defined between the local normal to the shock front and the gyration velocity vector at the time ions hit the front).

(ii) As a consequence, ion trajectories strongly differ between the " FAB " and " GPB " populations at the shock front. In particular, " FAB " ions suffer multi-bounces along the curved front whereas " GPB " ions make only one bounce. Such differences can explain why the " FAB " population loses their gyro-phase coherency and become gyrotropic which is not the case for the " GPB ".

As also evidenced by these simulations, the origin of both populations can be associated directly to their interaction with the shock front itself and do not require any upstream instability which can be another source for such backstreaming ions.