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Production of non-gyrotropic and gyrotropic backstreaming ion distributions in the quasi-perpendicular ion foreshock region : Origin and acceleration mechanisms.

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Collisionless shock waves are well-known structures in the environment of planetary magnetospheres which decelerate the bulk flow of the solar wind and converts it in thermal energy. Spacecrafts have firmly established the existence of the so-called foreshock region magnetically connected to the shock and filled with energized particles backstreaming from the shock front. One of the important unresolved problem is the exact origin of these high-energy backstreaming charged particles.

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 $45^{\circ} \leq \quad \Theta_{Bn} \leq 90^{\circ}$, where Θ_{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.

A recent analysis has evidenced that both populations can be discriminated in terms of interaction time (Δ_{inter}) with the shock front. "GPB" and "FAB" populations are characterized by a short ($\Delta_{inter} \sim 1\ \tau_{ci}$) and much larger ($\Delta_{inter} \geq 2\ \tau_{ci}$) interaction time respectively, where $\tau_{ci}$is the ion upstream gyroperiod.

In addition, present statistical results evidence that:

(i) backstreaming ions are splitted into "FAB" and "GPB populations " depending on their injection angle when hitting the shock front (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 may explain why the "FAB" population loses their gyro-phase coherency and become gyrotropic which is not the case for the "GPB".

Then, the differences observed between “FAB” and “GPB” populations do not involve some distinct reflection processes as often claimed in the literature but follow from different particle time histories at the shock front. Both “FAB” and “GPB” ions suffer the same reflection process but only “FAB” population loose their initial phase coherency by suffering several bounces.

This important result was not expected and greatly simplifies the question of their origin.