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The impact of rotational discontinuities on ions acceleration at the Earth's bow shock

Julia A. Kropotina[1] , Andrei M. Bykov[1]

[1] Ioffe Institute of Physics and Technology of the Russian Academy of Sciences. A.F. Ioffe Institute of Physics and Technology of the Russian Academy of Sciences

juliett.k@gmail.com

Superthermal particles, likely accelerated by the first order Fermi mechanism [1], are often observed in the vicinity of the Earth's bow shock. In this study we mainly focus on their interaction with rotational discontinuities frequently crossing the shock. By means of our hybrid kinetic code “Maximus” we built a numerical model of such interaction and found that rotational discontinuities are able to sweep superthermal ions from the foreshock to the downstream region. This can be seen from both spatial distributions and individual trajectories of energetic ions, and is also supported by ARTEMIS and MMS observations. [2]

During the interaction with the shock precursor filled with energetic particles and electromagnetic waves the structure of the rotational discontinuity is altered, and the current inside the current sheet increases, in some cases more than order of magnitude [3]. Also the maximal and mean energy of accelerated particles grow up for some period, as well as total pressure in nonthermal particles. Some time after the discontinuity passage the acceleration efficiency relaxes down to its usual value of about 15% (we define the efficiency as a fraction of the bulk energy going into particles with energy greater than 10 E_{sh}, where E_{sh} is the upstream proton energy). In case when rotational discontinuities come regularly, the Fermi acceleration is boosted continuously, so that the total pressure in nonthermal particles and their maximal energy grows faster than in case of uniform upstream (about 20% of the bulk energy goes into accelerated particles).

We found that for parameters typical for the Earth’s bow shock (the alfven Mach number of order 5 and plasma beta about unity) it is enough for rotational discontinuities to come each 10 minutes to sustain greater ions acceleration efficiency. This period is comparable with what is actually observed [4,5], so we can conclude that upstream rotational discontinuities alter the ion acceleration process and change the thermal/nonthermal pressure balance in the vicinity of the Earth’s bow shock. These results could be also extrapolated for other astrophysical shocks propagating into turbulent medium, as far as turbulence tends to evolve into discontinuities.

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