ENERGETIC IONS AND RELATED PHYSICAL PROCESSES AT EARTH'S BOW SHOCK - ION ACCELERATION AT THE EARTH'S QUASI-PARALLEL BOW SHOCK – IAGA DIVISION 4. SOLAR WIND AND INTERPLANETARY FIELD

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Collisionless shocks in space plasmas have a great scientific importance in their own right, but also because they are involve in a very wide range of physical phenomena from planetary bow shocks to supernova explosions. It also known that shock waves can accelerate particles to high energies through the so-called Diffusive Shock Acceleration (DSA) mechanism or first-order Fermi acceleration. We report on observations of energetic ions upstream of the Earth's quasi-parallel bow shock by Cluster at times of large inter-spacecraft separation distance of about 1-1.5 Earth radius distance. We analyzed several individual upstream ion events under various solar wind and plasma conditions in order to demonstrate how these different conditions influence the physical process of energetic ion scattering. The method of the analysis is the same in all cases: using a bow shock model we determine the distance of SC1 and SC3 from the bow shock surface parallel to the magnetic field. The CIS-HIA instrument onboard Cluster provides partial energetic ion densities in 4 energy channels between 10 and 32 keV. Using the differences of the partial energetic ion densities observed on SC1 and SC3 and the distances of the spacecraft from the bow shock, we determined the spatial gradient of partial energetic ion densities at various distances from the bow shock. The gradient in all energy channels decreases exponentially with distance and the e-folding distance of the gradients depends approximately linearly on energy but there is a non-negligable difference in their values obtained at the analysed upstream ion events.

Our study provides an in-depth explanation of the cause of differences in the e-folding distance and diffusion coefficient values. We demonstrate for the first time that under specific interplanetary conditions the mechanism of the diffuse ion scattering can change significantly and results in a much stronger diffusive process charactized by an unusually small e-folding distance.

It is well known that shocks in space plasmas can accelerate particles to high energies. On the other hand, many details of the shock acceleration mechanism are still unknown. A critical element of shock acceleration is the injection problem; i.e. the presence of a so-called seed particle population that is needed for the acceleration to work efficiently. For our analysis we use simultaneous multi-spacecraft measurement data provided by the Cluster spacecraft ion (CIS), magnetic (FGM) and electric field and wave instrument (EFW) during a time period of large inter-spacecraft separation distance. In our case study we present for the first time observational evidence of gyroresonant surfing acceleration in front of the Earth’s quasi-parallel bow shock resulting in the appearance of the long-suspected seed particle population. Our results show that the gyroresonance surfing acceleration takes place as a consequence of interaction between circularly polarized monochromatic (or quasi-monochromatic) transversal electromagnetic plasma waves and short large amplitude magnetic structures (SLAMS). The magnetic field inhomogenity mirror force provides the resonant conditions for the ions trapped by the waves and results in increasing efficiently the particle velocity. Since monochromatic wave packets with circular polarization and different kinds of magnetic structures are very commonly observed in the front of the Earth’s quasi-parallel bow shock the gyroresonant surfing acceleration proves to be an important particle injection mechanism resulting in the formation of the seed particle population.

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