Numerical simulation on the production of anomalous cosmic rays in the heliospheric termination shock

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The solar wind plasma ejected from the sun radially spreads with a supersonic speed. It is decelerated to subsonic by forming the termination shock through the interaction with the interstellar medium. The Voyger 1 and 2 spacecraft crossed this termination shock in 2004 and 2007, providing detailed information on its nature. A surprising result was on the behavior of the anomalous cosmic rays (ACRs). Regarding the origin of ACRs, it was proposed that the pickup ions in the solar wind plasma are accelerated via the diffusive shock acceleration when interacting with the termination shock so that the ions gain energy of about 10 to 100 MeV. If this hypothesis is correct, the intensity of the ACRs should gradually increase with approaching the termination shock and then reach a constant value in the heliosheath. However, in the Voyager observations, the intensity continued to increase even after the shock crossings in contrast to the above simple expectations. To explain the observations, it has been now inferred that the termination shocks crossed by the Voyger 1 and 2 are inactive about acceleration due to the geometrical conditions, and it is the other region of the termination shock that accelerates the ACRs. Our goal in this study is to understand the acceleration process of ACRs and the position of the termination shock at which efficient acceleration occurs from the viewpoint of the particle orbit.

We performed three-dimensional test particle simulations using the electromagnetic fields reproduced by the global MHD simulation of the heliosphere assuming time stationarity (Wasimi, et al. 2015). In the MHD simulation, the solar wind velocity, density, magnetic field strength and temperature at 1 AU are assumed to be 400 km / s, 5.0 / cc, 35 μG and 10^5K, respectively. These quantities are simply extrapolated to the inner boundary of the simulation domain at 50 AU from the sun. For the outer boundary at 900AU, the corresponding parameters in interstellar plasma are 23 km / s, 0.1 / cc, 3 μG and 6300 K, respectively. Initially particles (protons) with an initial thermal velocity of a few keV are placed upstream the termination shock. The effect of pitch angle scattering through the interaction with waves was reproduced using the Monte Carlo method. First, it was confirmed in the MHD simulation that while the termination shock mostly has the shock angle very close to 90 degrees, the angle deviates from 90 degrees in some regions such as high latitude, and where the solar equatorial current sheet interacts with the termination shock. In the presentation, we will discuss the orbits and energy changes of particles accelerated at high latitude terminal shocks.

Keywords: anomalous cosmic rays, heliospheric termination shock, test particle simulation, global MHD simulation

