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Multidimensional Structure of a High Beta Low Mach Number Shock and Particle Acceleration
高ベータ低マッハ数衝撃波の多次元構造と粒子加速

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Multidimensional structure of a quasi-perpendicular high beta and low Mach number shock is investigated by using two dimensional particle-in-cell simulation. Despite of the high beta and low Mach number condition, shock transition region shows rather complex structures with ion to electron scales. Some electrons are accelerated through the interactions with those structures.

1. Introduction

High beta and relatively low Mach number shocks are commonly present in a variety of space and astrophysical environments, like the earth's bow shock, the heliospheric termination shock (effective beta is rather high due to the presence of pickup ions), galaxy cluster merger shocks, etc. Even such high beta shocks often show some evidences that high energy particles are accelerated there. In this study we perform two-dimensional full particle-in-cell simulation to discuss structure of the shock as well as the acceleration process of electrons.

2. Particle-In-Cell Simulation

Two dimensional particle-in-cell simulation is performed by using the K computer at RIKEN. 10,000×1,024 spatial grids are used to simulate the physical spatial region of 67.45 c/ω_{pi} × 6.91 c/ω_{pi}, where c/ω_{pi} denotes ion inertial length. The so-called injection method is utilized to form a shock wave. The injection plasma is composed of electrons and ions whose velocity distribution functions are Maxwellian. The number of superparticles is 80 per cell for each injection electrons and ions. The ion to electron mass ratio is m_i/m_e = 1,836, the electron plasma to cyclotron frequency ratio $\omega_{pe}/\Omega_e = 3$, and the upstream plasma beta is 3 ($\beta_e = \beta_i = 1.5$). The Alfven Mach number is $M_A = 7.1$, while the magnetosonic Mach number is $M_{ms} = 2.6$. The shock angle, defined by the angle between upstream magnetic field and shock normal, is $\Theta_{Bn} = 85^o$.

3. Results and Summary

Fig.1 shows field profiles at $\omega_{pi}t = 823$. The left (middle) panels show three components of magnetic (electric) field. The shock is formed at X ≲ 15. Relatively large structure in the y-direction seen downstream in B_x and B_z is due to ion cyclotron instability driven by reflected ions. This appears to result in the rippled structure of the shock surface which is seen in B_y (~ B) as well as in electron and ion density profiles in the right panels. In addition, small scale waves are observed in the foot at X ~ 15 mainly in B_x, B_y, B_z, and E_x. They are generated through modified two-stream instability. Further, the whistler instability is also confirmed with smaller scales.

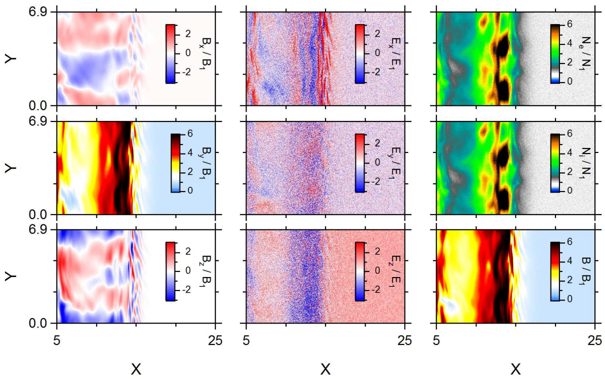

Fig.1 Shock structure obtained by 2D PIC simulation

Downstream electron distribution function indicates non-thermal nature (not shown). Some particles are strongly accelerated when they transmit the shock through the interactions with the above complex fields.