An Analysis of Slow-Shock and Slow Shock-Like Structures Observed in the 2D Hybrid Magnetic Reconnection Simulations

*Nehpreet Kaur Walia[1], Kanako Seki[1], Takanobu Amano[1]

1. Department of Earth & Planetary Science, Graduate School of Science, University of Tokyo

Slow-shocks are present in the Petschek's reconnection model to achieve fast magnetic reconnection. The presence of slow-shocks has been established in the MHD and Hall-MHD regime by various simulations[e.g., 1, 2], however in the kinetic regime, slow-shocks are not always observed. Some hybrid and PIC studies have found slow-shocks in their reconnection simulations [e.g., 3], while in some no slow-shocks or slow shock-like-structure [e.g., 4,5] is seen. As for satellite observations, [6] and [7] reported the detection percentage of slow-shocks as 20% and 10% in the dayside magnetopause and the magnetotail, respectively. The possible reasons behind the low detection probability of slow-shocks can be the proximity of the crossings studied to the X-point, presence of flux-ropes, or high turbulence. The error in the determination of shock normal and the shock frame of reference can also lead to non-detection of slow-shocks. In order to study the structure of magnetic reconnection as we transition from ion inertial scale to MHD scale and to check the influence of the above mentioned parameters on the boundary structure, we performed 2D hybrid simulations.

The simulations were performed with two different beta values, and were checked for the presence of slow-shocks using Rankine-Hugoniot conditions, and the specific conditions for Mach number, normal angles etc. [6]. It was found that for high beta case, slow-shocks can be seen as close as ~10 λ_i (i = ion inertial length) from the X-point. For low plasma beta, a transition region exits, in which a slow shock-like structure is seen until ~70 λ_i. From ~70 λ_i slow-shock structure is present at all points. The slow-shock detection percentage in our simulations are found to be highly dependent on the determination of shock normal and on the angle at which the artificial spacecraft crosses the reconnection boundary. The ion distribution functions obtained show clear difference between the regions where slow-shocks are found and where they aren't. The downstream of slow-shocks is not thermalized and has two-component population, crescent-shaped hot beam population and cold population. These structures of ion distribution functions are similar to the ones observed by Geotail spacecraft slow-shock observations [8]. We will also report the trajectories and the energization mechanisms of particles of both the populations.

References

[1] Biernat et al., 1989, J. Geophys. Res., doi: 10.1029/JA094iA01p00287
[2] Hau and Wang, 2016, J. Geophys. Res., doi: 10.1002/2016JA022722
[3] Innocenti et al., 2015, Astrophys. J. Lett., doi: 10.1088/2041-8205/810/2/L19
[4] Lottermoser et al., 1998, J. Geophys. Res., doi: 10.1029/97JA01872.
[5] Higashimori and Hoshino, 2012, J. Geophys. Res., doi: 10.1002/2014JA020544
[6] Walia et al., 2018, Geophys. Res. Lett., doi: 10.1029/2018GL077580
[7] Saito et al., 1995, J. Geophys. Res., doi: 10.1029/95JA01675
[8] Seon et al., 1996, , J. Geophys. Res., doi: 10.1029/96JA02525

Keywords: Magnetic reconnection, Slow-mode shocks, Hybrid simulation