Study of the Sensitivity of Cusps to Pressure Gradients and IMF Orientation by PIC Code

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Abstract

We apply three IMF orientations along with an artificial depression in the solar dynamic pressure to study their impacts on the cusp dynamics and orientation. PIC EM Relativistic code was used to investigate the problem in hand. Particles and fields updates are carefully studied at both northern and southern cusps. The size, position and shape of the both cusps under the said conditions are thoroughly covered. Both cusps orientation, position and shape are found to be highly susceptible for dynamic pressure gradients and the orientation of IMF under short duration of time. Other featured outputs are reported, such as signature of reconnection at both north and south cusps.

Introduction

The cusps shape, position, dynamics and orientations is an important topic in space physics. Many statistical,and observational studies had been conducted to define cusps properties. The northern and southern cusps region are important to study the solar wind magnetospheric interactions. Despite the poor resources used to carry out this study, still the macro-structure of magnetospheric regions can be depicted. With the powerful supercomputing facilities available nowadays, this code version can generate case studies that can be used to deeper analytical processes scaled to ions lengths. In this study a code was run to 900 Δt a run time is enough to have retained the classical view of the magnetosphere. A depression in the solar wind was artificially generated by a sudden 40 % reduction in the dynamical pressure. Then the solar wind changed to original value. A gap was created and was followed with time sequence. Three IMF cases were tested. Now the code is under validation at the Institute of Astrophysique de Paris in terms of finer grid size and including ionosphere ions outflows.

Code Scaled parameters

The physical parameters (normalized) used in our simulation as pairs of numbers (unit-less values for electrons and ions) are as follow, the gyro-frequencies are $\tilde{\omega}_{ce,i} = \omega_{ce,i}\Delta t = (0.2, 0.0125)$, the thermal velocities for the two species are $\tilde{v}_{the,i} = v_{the,i}/(\Delta/\Delta t) = (0.1, 0.025) = (B\Delta m_e/\Delta t m_{e,i})$, the Debye length is $\lambda_{De,i} = \tilde{v}_{the,i}/\tilde{\omega}_{pe,i} = (0.11, 0.11)$, Larmour gyro-radii are $\tilde{\rho}_{ce,i} = \tilde{v}_{the,i}/\tilde{\omega}_{ce,i} = (1.25, 20)$, inertial lengths are $\tilde{\lambda}_{e.i} = \tilde{c}/\tilde{\omega}_{pe,i} = (0.559, 2.236)$. The impinged drift velocity of the solar wind along the Sun-Earth line is $V_{sw} = -0.25 = 0.5\tilde{c}$, where the speed of light's normalized value is taken $\tilde{c} = 0.5$, the ion to mass ratio is $m_i/m_e = 16$. The Normalized magnetic field is $\tilde{B} = \vec{B}(\frac{q(\Delta t)^2}{m_e\Delta})$, the IMF is northward $B_z(x) = 0.2$, the $\beta_{e,i} = (1.6, 6.4)$. The normalized ion temperature is $\tilde{T}_i = \tilde{v}^2_{thi} m_i = 0.04$, and for electrons the temperature is $\tilde{T}_e = \tilde{v}^2_{the} m_e = 0.01$, where the "$e$" and the "$i$" denotes electrons and ions respectively.

Results

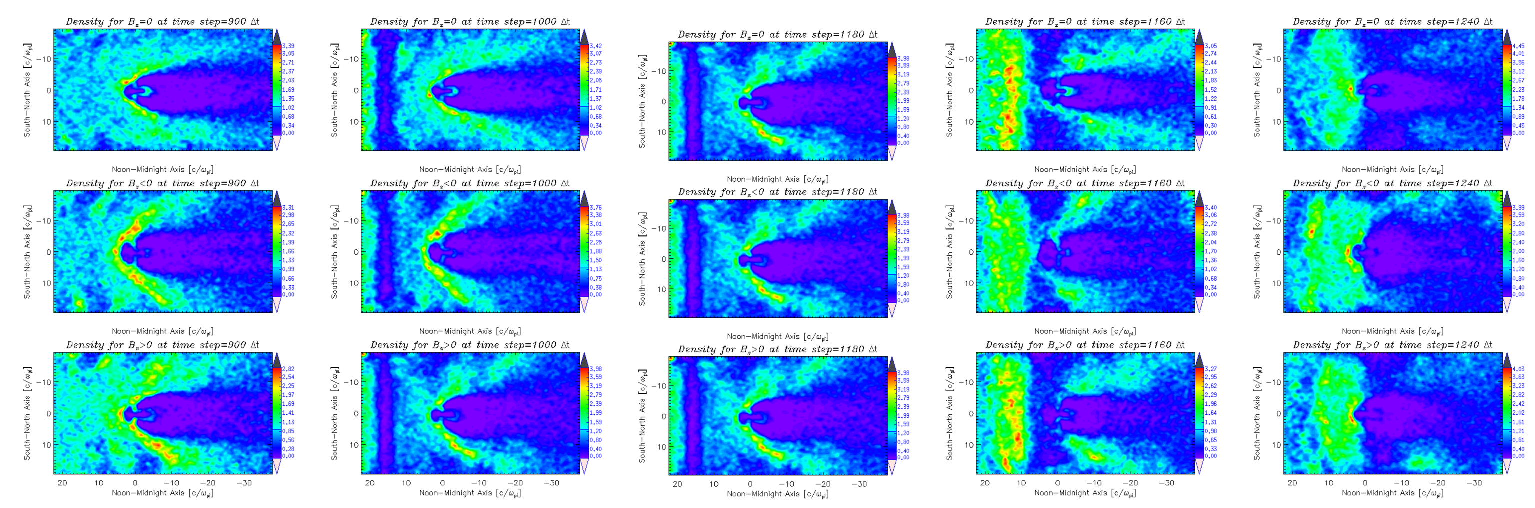

Figure 1: 2D plasma distribution along noon-midnight axis. Simulation run until the macroscopic magnetosphere is retained [first left figure at step time $900\Delta t$]. Solar wind speed is then reduced to $40\%$for $100\Delta t$. A gap in the stream generated due to this drop. Theo other figures show how the gap evolve with time and the cusps dynamics, width and orientation is depicted. The study was carried out for three IMF configuration i.e. $B_z = 0$, $B_z < 0$ and$B_z > 0$

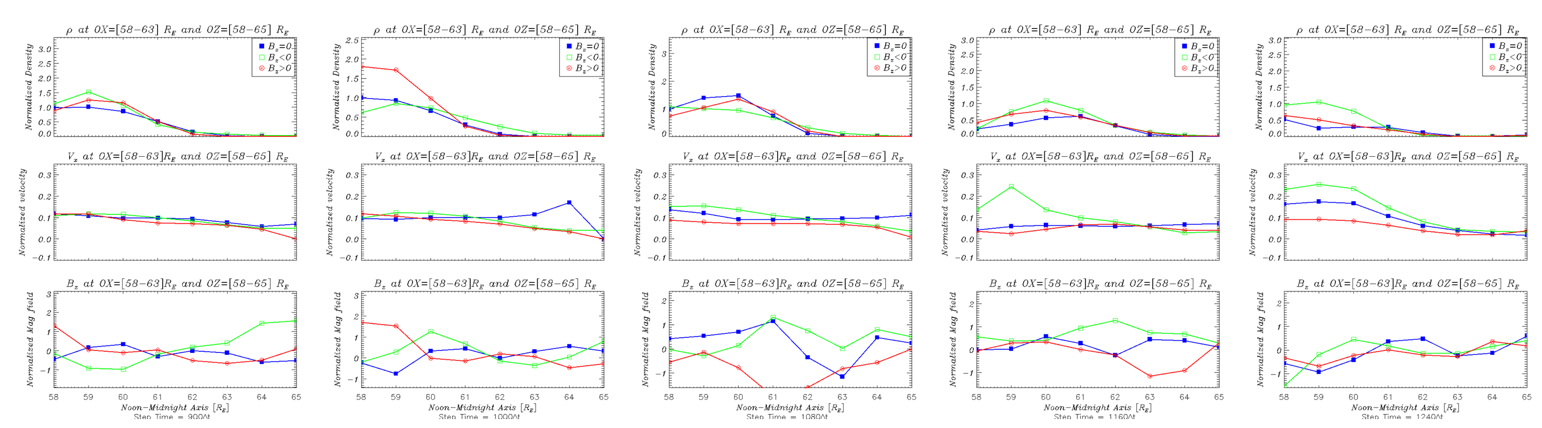

Figure 2: Density, velocity and magnetic field parameters zoomed in over the northern pole at OZ=[58-65] and along OX=[58-63] R_E for $B_z = 0$, $B_z < 0$ and$B_z > 0$ at step times 900,1000,1080,1160 and 1240 Δt

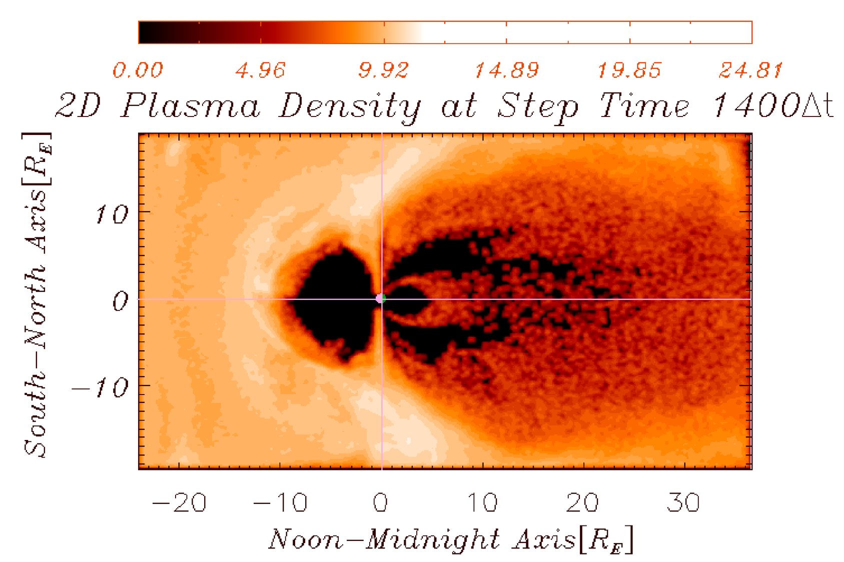

Figure 3: 2D plasma distribution with higher number of particles and larger simulation box

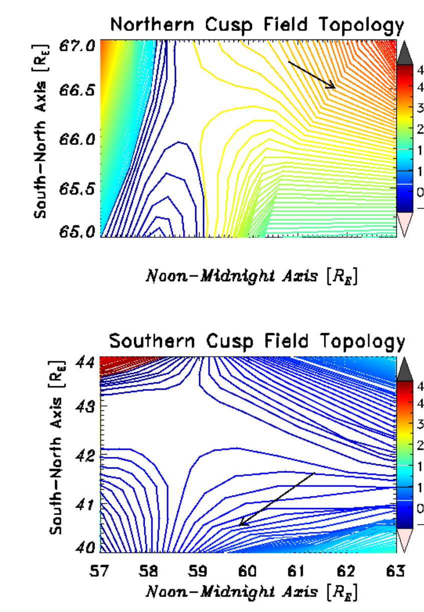

Figure 4: Northern and southern cusps magnetic field lines zoomed and where reconnection is clearly depicted take at time step $900\Delta t$

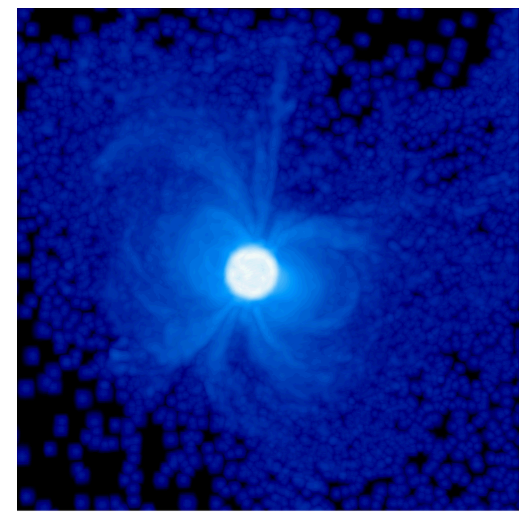

Figure 5: Newly developed code with finer grid size and larger number of loaded solar wind particles. New features to our older version includes, ionosphere, planet tilt, planet gravity effect(Baraka adn Ben Jaffel,2105)

Conclusions

- Simulation shows that cusps are in dynamical motion.
- Cusps thickness and orientation changed due to IMF effect
- Dynamic pressure change drag cusps to dayside direction and straightened them when their position feels directly the depression in the solar wind.
- This world was carried out in poor resources and could be very much better with our newly developed code.

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