Reconnection Simulations of Impulsive Flare Events in the presence of Helium-3 and Helium-4

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BACKGROUND

Helium-3 abundance enhancements in impulsive SEP events have been observed since the 1970s, yet their cause remains unknown. Fisk (1978) and Temerin and Roth (1992) proposed that these enhancements could be caused by ion cyclotron waves and that helium-3 would be preferentially heated due to its unique gyrofrequency. In order to test this theory, we have run kinetic simulations of magnetic reconnection in the corona using the particle-in-cell code p3d. Initial parameters were set to coronal values: 5% helium-4 number density, β equal to 0.1, and the guide field equal to 0.5 times the reconnecting field. Initial results showed instabilities develop along the separatrices of the reconnection outflows, though temperature anisotropies associated with ion cyclotron waves were not present. Fourier transforms in time of the parallel electric field at multiple locations along the separatrices showed frequencies between 1.2 and 1.6 times the proton cyclotron frequency. A second simulation with the same parameters including helium-3 as test particles is being performed to investigate the effects on helium-3.

TEMPERATURE ANISOTROPIES

While the helium-4 showed significantly more heating than the protons and instabilities are clearly present along the bottom and top separatrices, the temperature anisotropy typically associated with ion cyclotron waves, $T_{\text{perp}} > T_{\text{par}}$, is true for only a small region along the center of the current sheet.

ABSTRACT

Observations of impulsive solar energetic particle events occasionally show enhancements of helium-3 up to $~10^3$ greater than coronal abundances. Fisk (1978) and Temerin and Roth (1992) proposed that these enhancements could be caused by ion cyclotron waves and that helium-3 would be preferentially heated due to its unique gyrofrequency. In order to test this theory, we have run kinetic simulations of magnetic reconnection in the corona using the particle-in-cell code p3d. Initial parameters were set to coronal values: 5% helium-4 number density, $\beta$ equal to 0.1, and the guide field equal to 0.5 times the reconnecting field. Initial results showed instabilities develop along the separatrices of the reconnection outflows, though temperature anisotropies associated with ion cyclotron waves were not present. Fourier transforms in time of the parallel electric field at multiple locations along the separatrices showed frequencies between 1.2 and 1.6 times the proton cyclotron frequency. A second simulation with the same parameters including helium-3 as test particles is being performed to investigate the effects on helium-3.

P3D SIMULATION

Reconnection simulations were done using the particle-in-cell code p3d (Zeiler et al., 2002). The code is self-consistent for all three particle species: electrons, protons, and alphas. Initial parameters were set to coronal values:

- $\beta = 0.1$
- Helium-4 number density = 5%
- Guide field to reconnecting field ratio = 0.5
- $c/v_s = 15^*$
- $m_i/m_e = 1/25^*$

$^*$The speed of light and electron to ion mass ratio used are both non-physical values to make the simulation less computationally expensive.

The size of the simulation was 102.4 x 51.2, in units of the ion inertial length, and it is periodic in both dimensions. Analysis was performed on the top left reconnection outflow, which is outlined in black in Figure 2 below.

3D SIMULATION

RECONNECTION

Conclusions

In conclusion, we have run kinetic simulations of magnetic reconnection in the corona using the particle-in-cell code p3d. Initial parameters were set to coronal values: 5% helium-4 number density, $\beta$ equal to 0.1, and the guide field equal to 0.5 times the reconnecting field. Initial results showed instabilities develop along the separatrices of the reconnection outflows, though temperature anisotropies associated with ion cyclotron waves were not present. Fourier transforms in time of the parallel electric field at multiple locations along the separatrices showed frequencies between 1.2 and 1.6 times the proton cyclotron frequency. A second simulation with the same parameters including helium-3 as test particles is being performed to investigate the effects on helium-3.

REFERENCES