## Flow Crossover during Collisionless Magnetic Reconnection: A Particle-Labelling Particle-in-Cell Study

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1. INTRODUCTION: PLASMA "BULK" FLOW DURING COLLISIONLESS RECONNECTION IS NORMALLY THOUGHT OF AND MODELLED LIKE IT WOULD IN THE CASE OF COLLISIONAL RECONNECTION.



Fig.1 A typical model of plasma flow during reconnection -- Plasma from 2 inflow sidesflow from on above and below and meet at the

3. ION FLOW CROSSOVER --> ION "BULK" FLOW SIGNIFICANTLY CROSSES OVER THE MIDPLANE BEFORE GOING OUT AS AN OUTFLOW.



Fig.3 2D plots of ion density initially from region 1 overplotted with its velocity streamlines.

\*Purely MHD flow → Perpendicular to B → No crossover
\*To have crossover, we need source(s) of parallel flow
\*Diffusion region is the key source of parallel flow for ions

5. THE FLOW CROSSOVER FEATURE IS GENERAL FOR COLLISIONLESS RECONNECTION AND REALIZING THE FEATURE MIGHT BE USEFUL IN HELPING US UNDERSTANDING MORE COMPLICATED RECONNECTION



Fig5. 2D plots of ion and electron densities overplotted with the velocity stream lines of each species. The top panel is for all populations. The bottom panel is for region1 population.

stagnation point before turning thecorner and become the outflow to the left and right.



Fig6. 2D plots of ion and electron densities overplotted with the velocity stream lines of each species. The top panel is for all populations. The bottom panel is for region2 population.

2. SIMULATIONS: WE REVEAL HIDDEN FLOW FEATURES IN COLLISIONLESS RECONNECTION USING PARTICLE-IN-CELL SIMULATIONS THAT ALLOW IONS AND ELECTRONS TO BE LABELLED BY THEIR INITIAL LOCATIONS.



4. ELECTRON FLOW CROSSOVER --> STRONGER CROSSOVER FLOW DUE TO PARALLEL FLOW GENERATION NEAR SEPARATRICES



Fig.2 Initial condition of a typical reconnection run with 3-zone particle labelling.

Fig.4 2D plots of electron density initially from region 1 overplotted with its velocitystream lines.

\*Stronger parallel flow source than ions' → stronger crossover flow

## **SUMMARY**

During collisionless magnetic reconnection, there exists a flow crossover feature: bulk flow from one side cross the midplane to the other side.

The key is that there are sources of parallel flow near the reconnection sites and these sources are not only confined in the diffusion region

Realizing this flow feature might be useful for understanding complicated reconnection.