PIC simulations of low-Mach-number, high-β shocks from reconnection outflows

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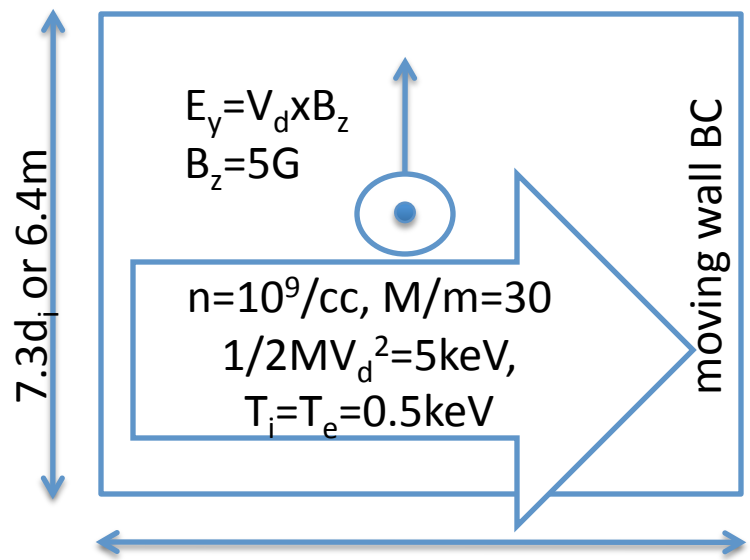
We want to study shock formation and particle acceleration in shocks in solar magnetic reconnection outflows

- MHD reconnection simulations (Workman et al. '11) found supersonic outflows and fast mode shocks
- OSIRIS simulations study dissipation mechanisms and non-thermal particle generation in perpendicular shocks
  - Moving wall BC controls shock speed in the simulation frame
  - with particle tracking
- Low-Mach-number and high-β shocks
  - $M=2.5$ ($M_A=6.8$), $\beta=8.1$
- For a hydrogen plasma, $V_d=10^3$ km/s

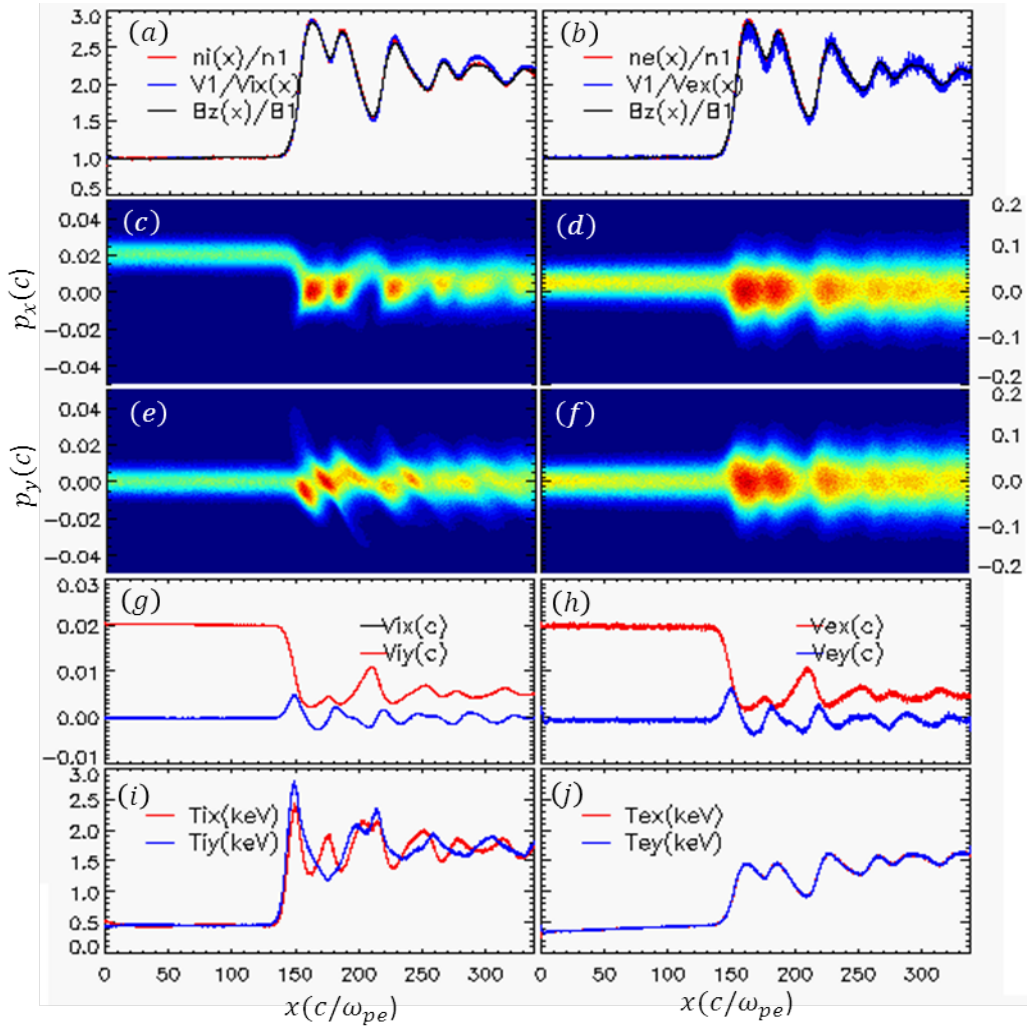


$62d_i$ or 54m

$d_e=c/\omega_{pe}=0.16$ m

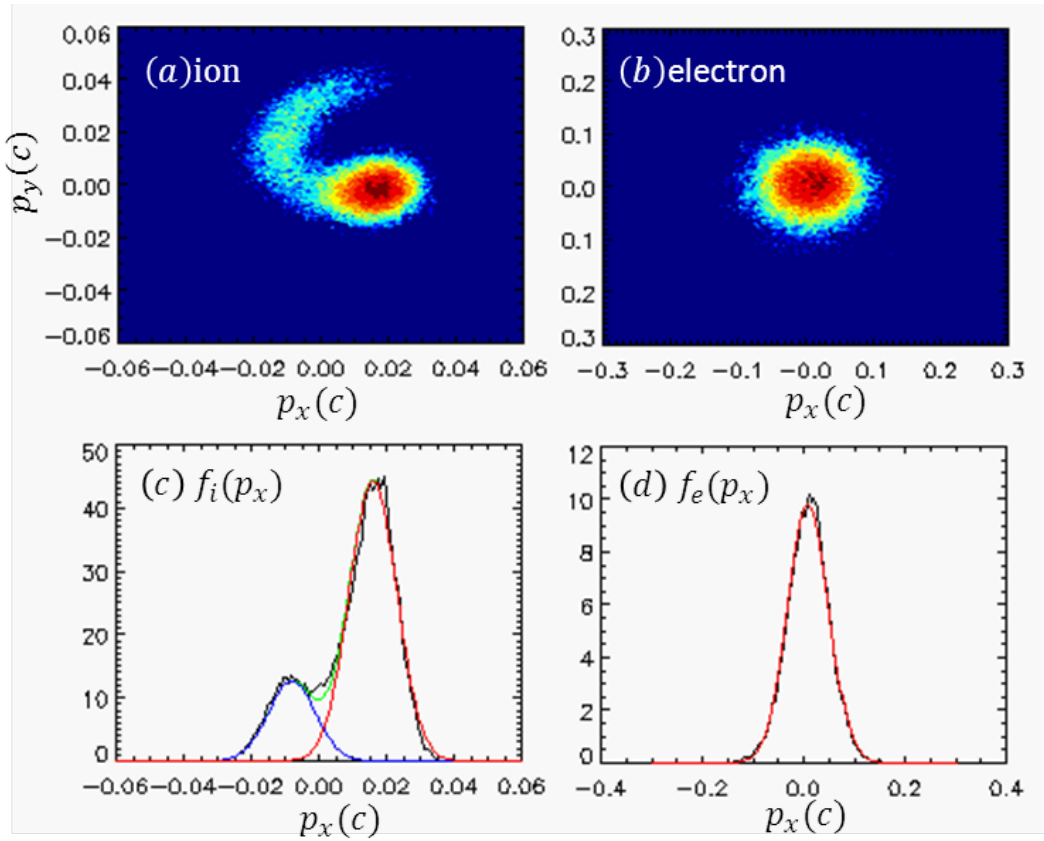
PIC shows the formation of a shock with low dissipation

ion electron



r_{MHD}=2.6

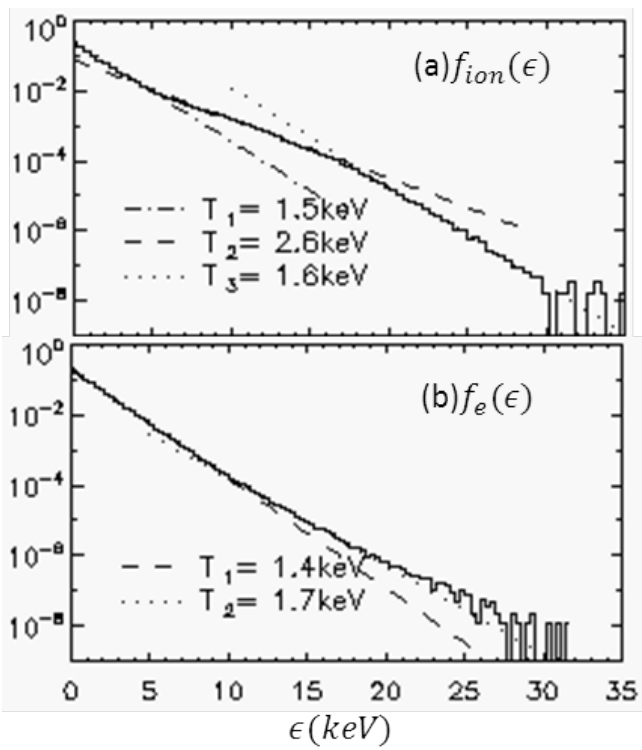
Modified two-stream instabilities provide the necessary dissipation



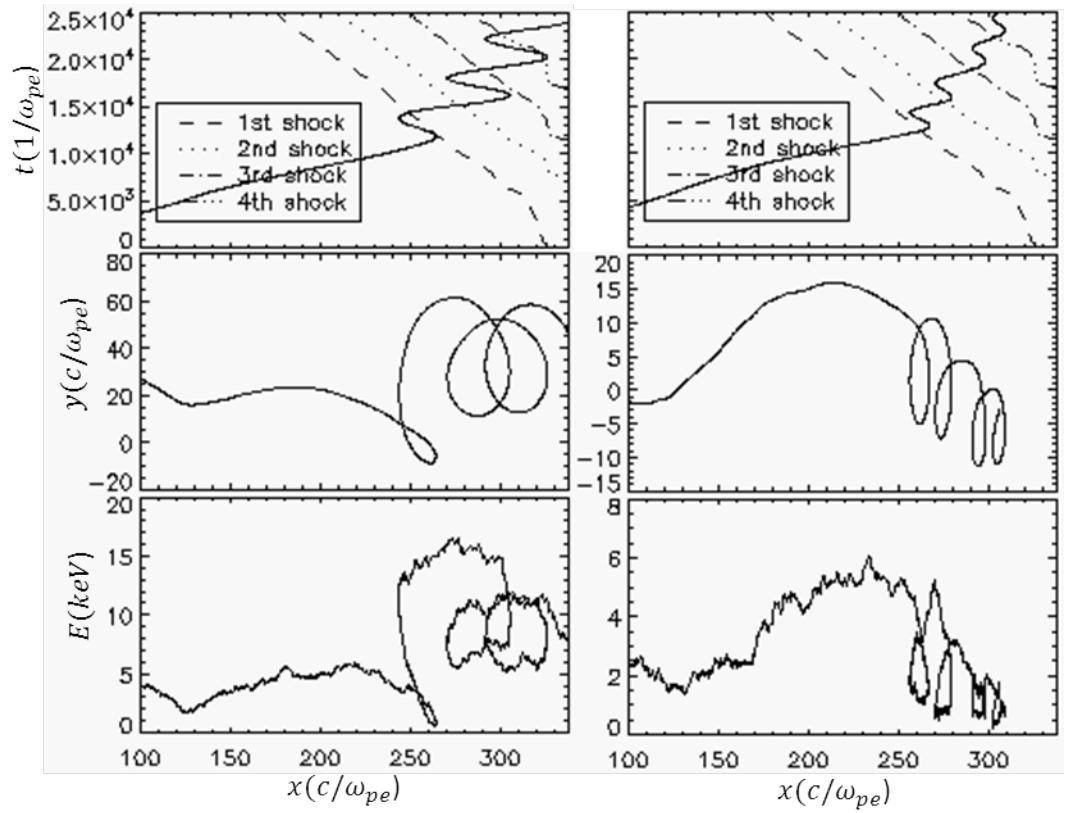
- Predicted k_x=0.2/d_e matches the simulation
- No Buneman-type k_y modes observed
  - consistent with low-M and no shock surfing acceleration

Particle heating via shock drift acceleration is observed

ion & e- distributions



two ion trajectories



adiabatic heating in low energy and SDA in high energy
with the break point of 7-12 keV

Experiments would study of dissipation and particle acceleration mechanisms

scaling

- $d_i \sim (M/n)^{1/2}$, for $d_i \sim 1$ mm, $n \sim 5\times10^{16}$/cc
- $M_A \sim (E_d n/B^2)^{1/2}$, $\beta \sim Tn/B^2$, $B \sim 3.5$T;
- $V_d \sim 10^3$km/s, $E_d \sim 5$keV, $T \sim 0.5$ keV, flow dominated

Comparison of experiments and simulations can help our understanding in magnetic reconnection and shock physics