



# Ion-driven magnetic amplification and electron injection at collisionless shocks



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## Motivation: Electron acceleration suppressed at quasi-parallel shocks

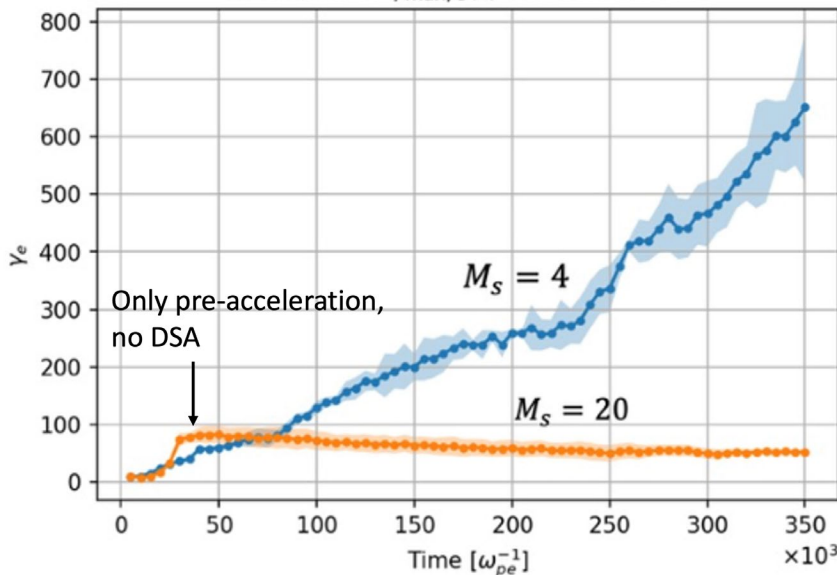
- Quasi-parallel collisionless shocks: (1) efficient ion acceleration; (2) strong ion-driven magnetic amplification.
- Electron acceleration is an open problem.
- **Electrons need to be injected into diffusive shock acceleration (DSA) to get to high energy range.**

## Result: Strong magnetic amplification suppresses electron injection

- Long-term **1D3V PIC simulations** show why some shocks fail to inject electrons into **DSA**.
- **Electron acceleration stalls when final amplified field,  $B_{tot}$ :**  

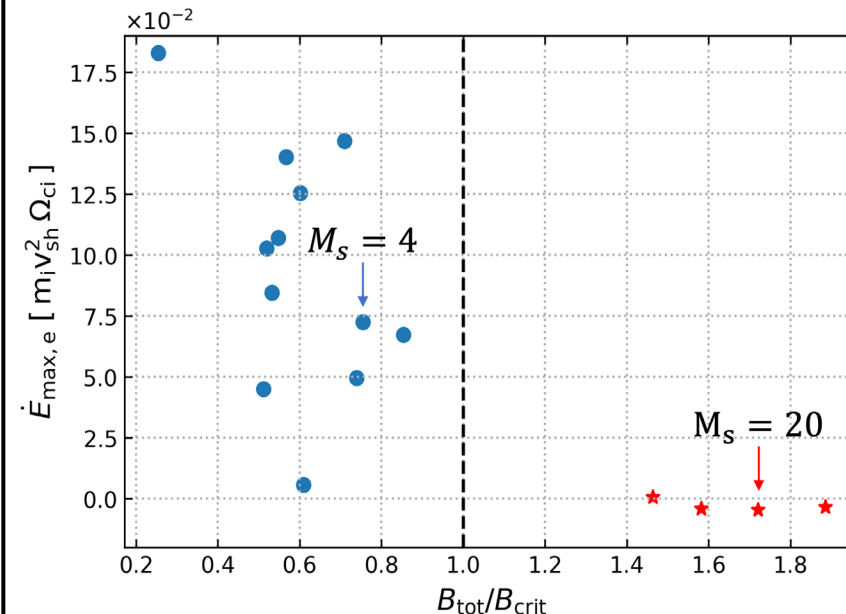
$$B_{tot} > B_{crit}$$
- Above this threshold, the upstream shock becomes **locally superluminal**, blocking efficient electron acceleration.

Evolution of  $\gamma_{max,e}(t)$  for different  $M_s$



- Two simulations  $M_s = 4$  and  $M_s = 20^*$ .
- $M_s = 20$  shows **no injection to DSA. Acceleration stalled.**

\*  $M_s$  is sonic Mach number



**Energy gain rate**  
(slope of the left figure)

$$\dot{E}_{max,e} = \frac{d(E_{max,e}/m_i v_{sh}^2)}{d(t\Omega_{ci})}$$