

2nd UNDARK School: The multi-messenger non-thermal universe

Electron–Ion Energy Partition in Supernova Remnant Shocks: A Monte Carlo-Particle-In-Cell Approach

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Background: How are particles energized in perpendicular shocks?

Particle energization in:

- weakly magnetized
- non-relativistic
- perpendicular shock

$$l_{\text{diff}} > L_{\text{sh}}$$

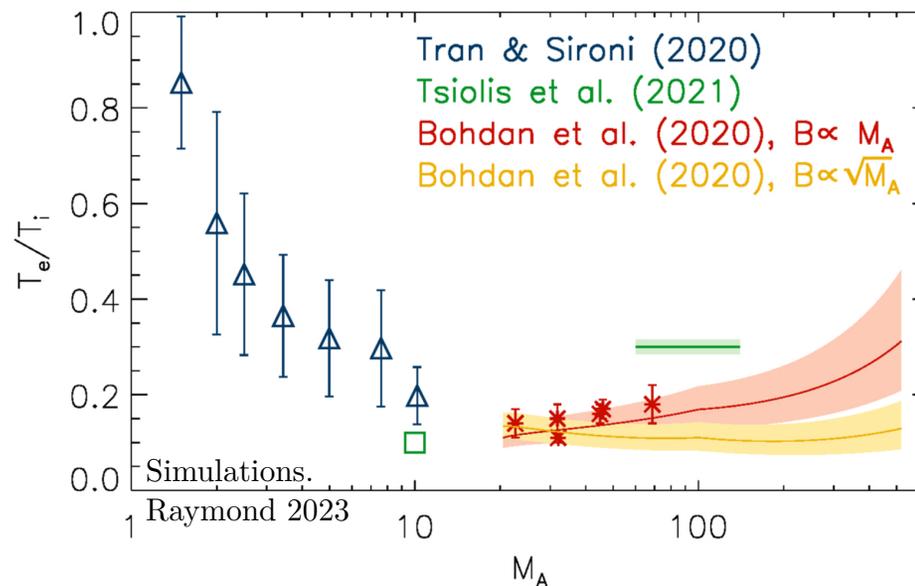
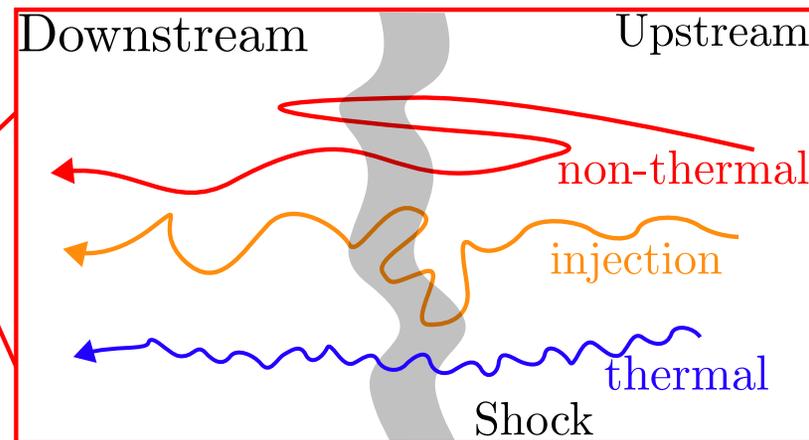
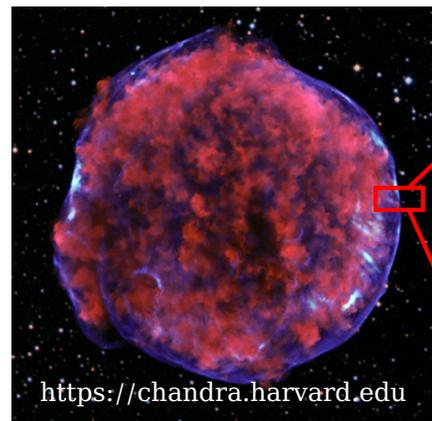
$$l_{\text{diff}} \sim L_{\text{sh}}$$

$$l_{\text{diff}} \ll L_{\text{sh}}$$

Fermi acceleration
for high-energy particle

Heating through
inter-species interaction

M_A dependence of T_e/T_i

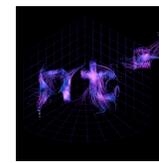


Scale at r_L

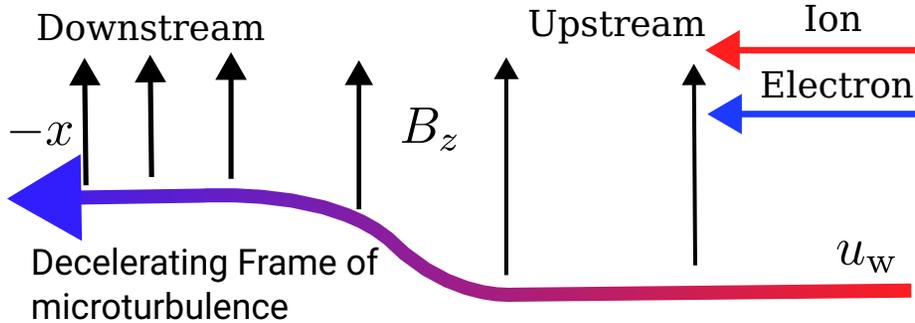
Kinetic Scales

→ A new method

Monte Carlo-Particle-In-Cell Method



ENTITY: a GPU based coordinate-agnostic PIC code



Background Field
Decelerating Turbulent Field

$$\frac{dp_{|w}^i}{dt_{|w}} = \boxed{qF^b_a p_{|w}^a} + \boxed{q\delta F^b_a p_{|w}^a - m\dot{u}_w}$$

Equation of Motion in turbulence frame

PIC: Maxwell-Vlasov solver of interaction between particles and **background fields**

Monte Carlo: Turbulence → Scattering
3D → 1D

$$\Rightarrow \boxed{qF^b_a p^a} + \boxed{\text{Scattering}_{|w}}$$

Summary

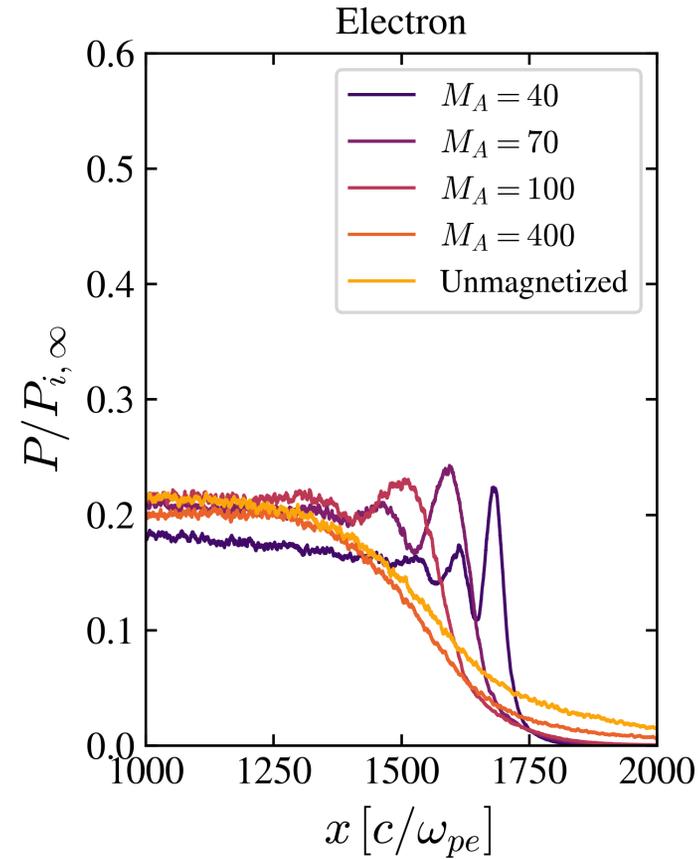
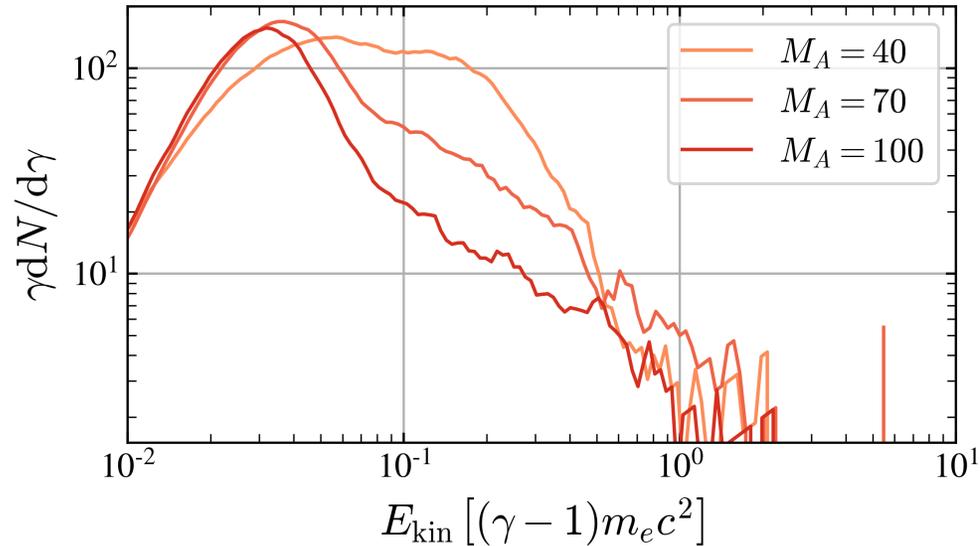
Two regimes of magnetization

1. Strong magnetized

gyration dominates: $L_{\text{sh}} = r_g$

T_e increases with M_A

Acceleration more efficient for high M_A



2. Weakly magnetized

scattering dominates $L_{\text{sh}} = \lambda_i$

T_e almost independent of M_A