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PIC simulations of SNR's shock waves with a turbulent upstream medium

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We present how to simulate a plasma **shock wave** with **pre-existing turbulence** using particle-in-cell code.

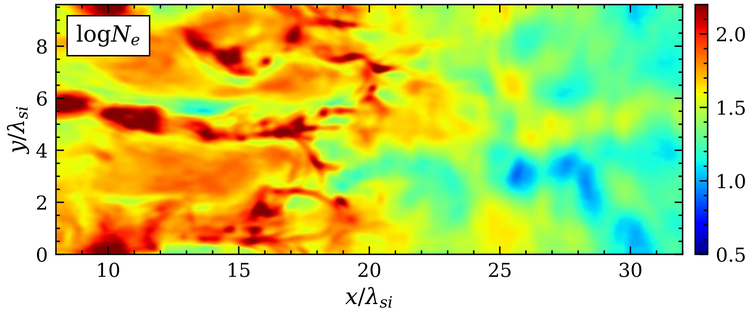

Fig 1. Shock structure of a high-Mach-number shock with pre-existing turbulence.

How?

- **generate** – bulk velocity disturbance
- **inject** – matching method
- **run** – reflecting wall

Turbulence

- compressive
- long-lived (few ion Larmor times)
- represents high-Mach-number and low plasma beta regime

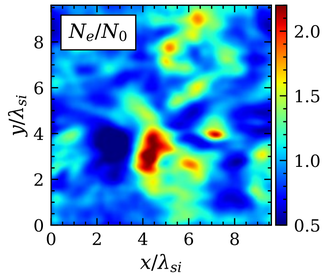

Fig 2. Turbulent structure of particle number density.

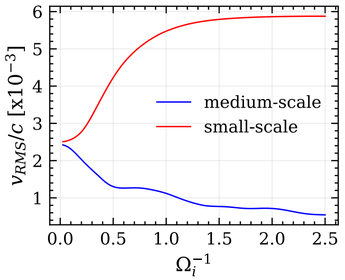

Fig 3. Initial velocity disturbance **heats** partcicles.

Introduction

Supernova remnants (SNR) are plausible candidates for sources of the Galactic Cosmic Rays. The particles gain energy via Diffusive Shock Acceleration (DSA, see Fig. 4), which requires that their Larmor radii must be comparable to the shock width. Thermal electrons do not satisfy this condition, hence some **electron pre-acceleration** mechanism has to operate.

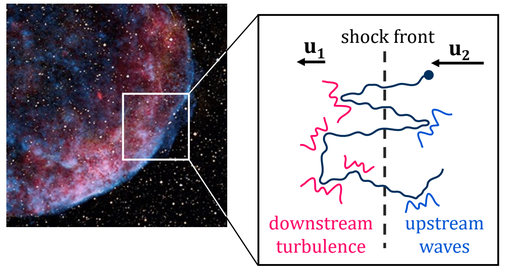

Fig 4. A particle gains energy crossing the shock multiple times.

Motivations

Previous SNR's shock simulations assumed **homogenous upstream** medium (all the turbulence ahead the shock was driven by reflected particles), but space physics research indicates **importance of pre-existing turbulence**.

Methods

To capture electron scale physics we use a particle-in-cell code (**PIC**), which solves kinetic plasma equations. A slab of turbulent plasma is generated separately in a periodic box simulation, then it is injected into a shock simulation. State of the pre-fabricated plasma is different than state of the plasma from the simulation, so we need to **match** them.

Results

- A compressive turbulence plasma slab is **generated** via superposition of velocity waves**.**
- The pre-fabricated slabs are matched using cell-wise procedure – **weights** for magnetic and electric fields, and particles.
- In order to satisfy Maxwell's equations after imposing weights the **correction** for $\mathrm{div}\mathbf{B}$ and $\mathrm{div}\mathbf{E}$ is needed.
- The shock is obtained by the reflecting wall setup.

Conclusions

Our framework allows to perform more realistic simulations of shock waves in various astrophysical environments.