PIC simulations of SNR shocks with a turbulent upstream medium

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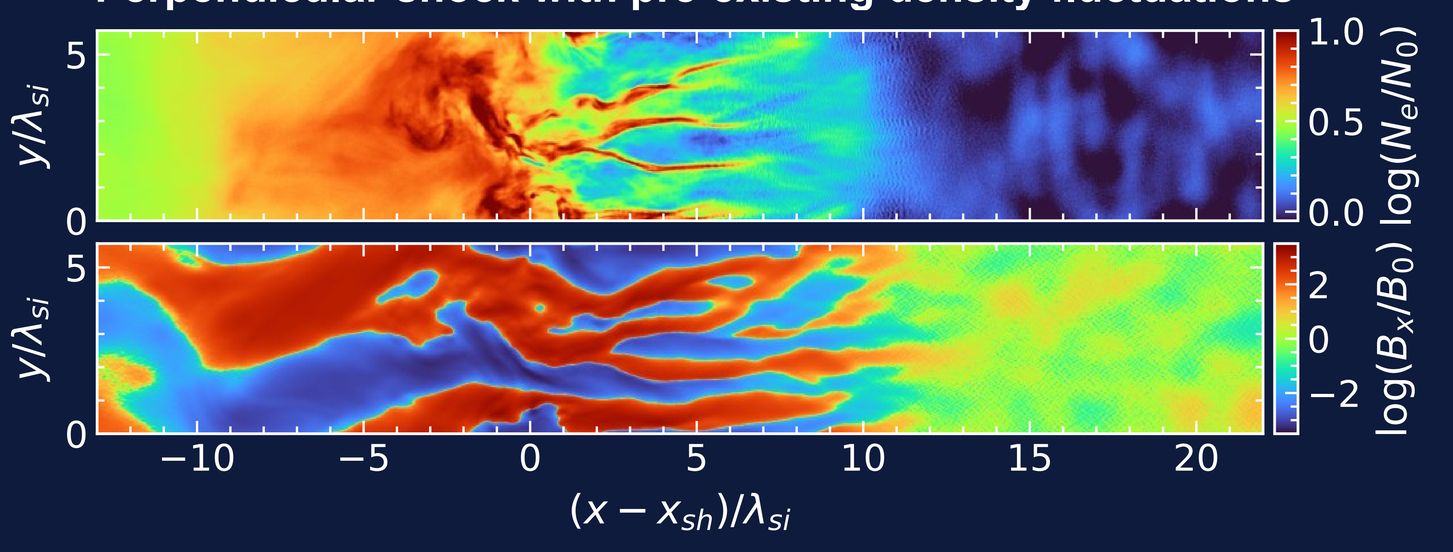
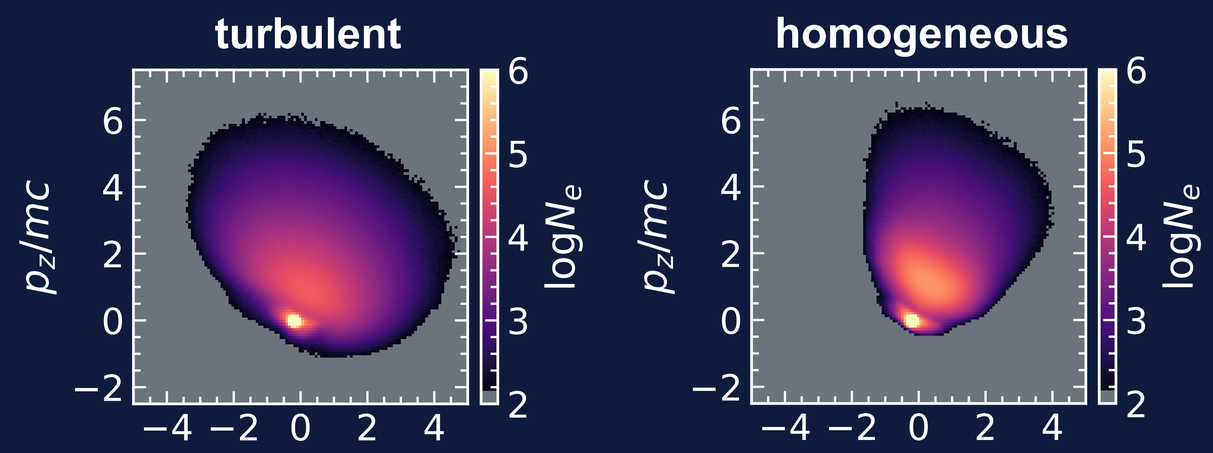
PRE-EXISTING TURBULENCE AFFECTS THE PHYSICS OF SHOCK WAVES

Perpendicular shock with pre-existing density fluctuations



At **PERPENDICULAR SHOCKS** pre-existing density fluctuations lead to local **variations** of the shock **obliquity angle**.

At **OBLIQUE SHOCKS** with turbulence, shock-reflected electrons are **hotter** and travel significantly **shorter** distances away from the shock front.



Introduction

Particles in supernova remnants gain energy via **Diffusive Shock Acceleration** (DSA), 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.

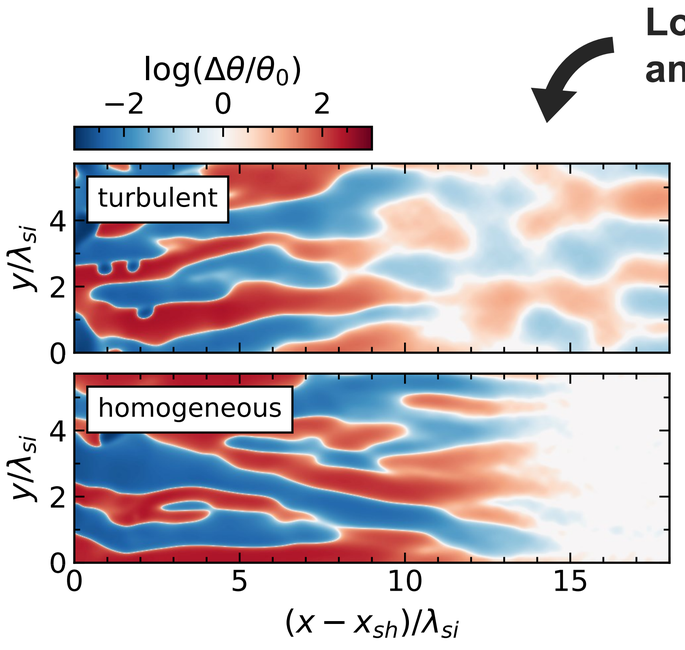
Motivations

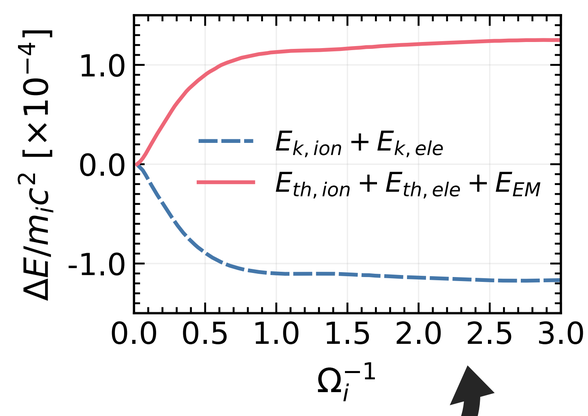
Previous studies assumed a **homogeneous upstream** medium, so all turbulence ahead of a shock was driven by the shock-reflected particles. Here we investigate the influence of **pre-existing turbulence** on particle acceleration, which is poorly understood.

Methods

To study plasma phenomena on electron kinetic scales we use the particle-in-cell (**PIC**) approach. Using a **novel technique** we simulate non-relativistic shock waves propagating in a medium filled with **compressive turbulence**.

Local variations of the obliquity angle at perpendicular shocks





Turbulence dissipates energy into particle heating

Results and conclusions

- The **level** of pre-existing upstream turbulence on kinetic scales is **limited** by **particle heating**. To maintain $M_S > 30$ the maximum amplitude of density fluctuations should be $\delta n/n \sim 10\%$ (on the scale of $\lambda_{si}/4$).
- Density fluctuations **enhance variations** in the upstream **magnetic field**, but their levels remain too low to significantly influence the behaviour of electrons at perpendicular shocks.
- Properties of the **electron foreshock** at oblique shocks are **affected** by pre-existing density fluctuations with an amplitude of $\delta n/n \approx 15\%$. This region becomes **narrower** and **hotter**.

REFERENCES

1. Fulat et al. 2023, subm. to ApJ
2. Morris P.J., et al., 2023, ApJ, 944
3. Bohdan., et al., 2022, PoP, 29

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