Particle Injection at the Mediated Shock

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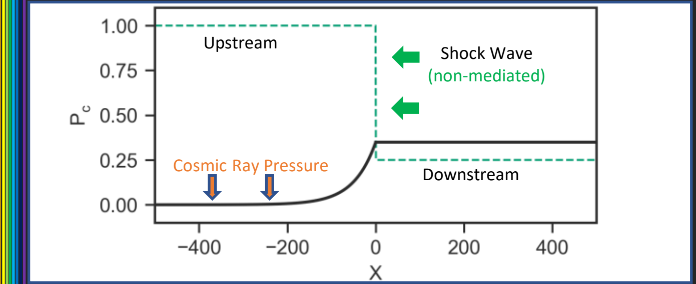
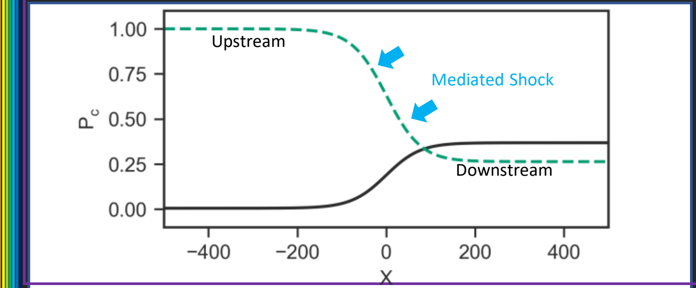
A.

Introduction

- Shock waves are discontinuities where the kinetic energy is converted into thermal energy.
- Shock waves in space are collisionless shocks where the particles don't touch, but instead, bounce off each others electromagnetic field.



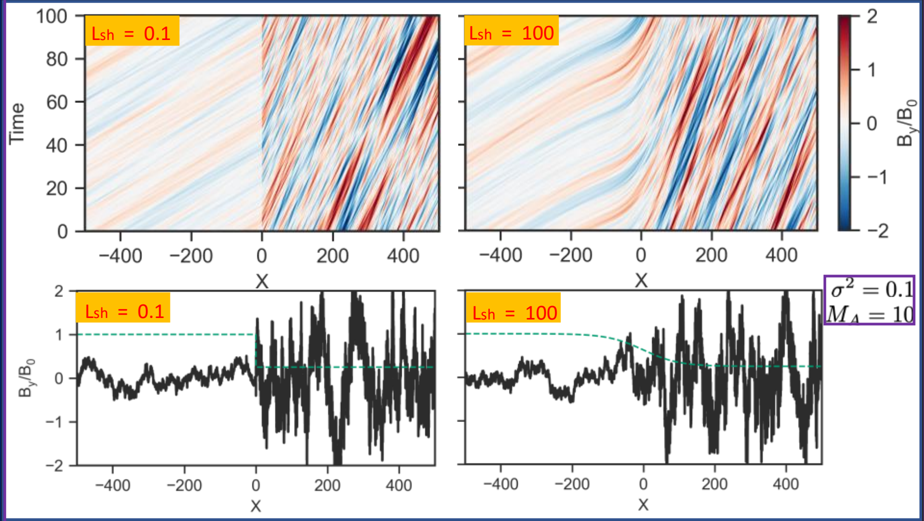
- Shock waves produce energetic particles (cosmic rays) via the diffusive shock acceleration (DSA) from pre-accelerated particles (seed particles).
- When the cosmic ray pressure dominates over the thermal pressure it can decelerate the incoming plasma flow, resulting in a mediated shock wave.
- It is not known how seed particles are produced in a mediated shock wave. This may be important, if the generational seed particles are less efficient, there will be less energetic particles through DSA!



B.

Method

- In this work, we perform a test particle simulation in which electromagnetic fields are given.
- In this simulation we vary the thickness (L_{sh}) of the shockwave to study the differences in particle behavior at the mediated shock and compare with the non-mediated shock.
- We assume Alfvenic turbulence, following a Kolmogorov spectrum. ($k^{-5/3}$)
- The variance of magnetic fluxuations is set to 0.1 and the Alfven Mach number is set to 10. This is shown in the purple box to the right of the figures. "B" represents the magnetic field.



Equations for thought!

Particle motion

$$m\frac{d\mathbf{v}}{dt} = q\left(\mathbf{E} + \mathbf{v}\times\mathbf{B}\right)$$

Velocity

$$\frac{d\mathbf{x}}{dt} = \mathbf{v}$$

Wave spectrum

$$G\left(k_n\right) = \Delta k_n k_n^{-5/3}$$

Wave amplitude

$$\delta B^2\left(k_n\right) = \sigma^2 G\left(k_n\right)\left(\sum_{n=1}^{N_w} G\left(k_n\right)\right)^{-1}$$

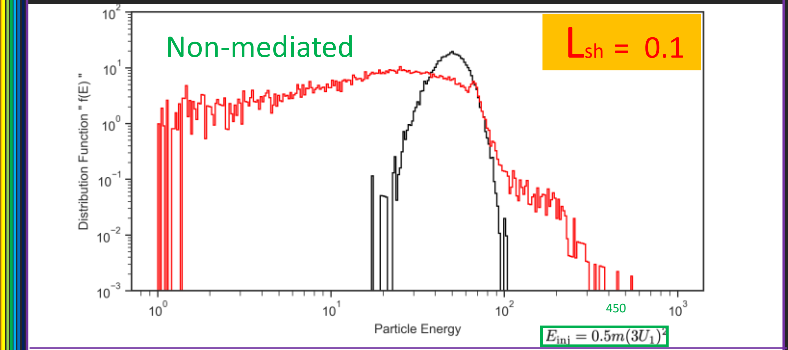
Velocity Profile (U1 is the upstream and U2 is the downstream, L_{sh} is the shock thickness.)

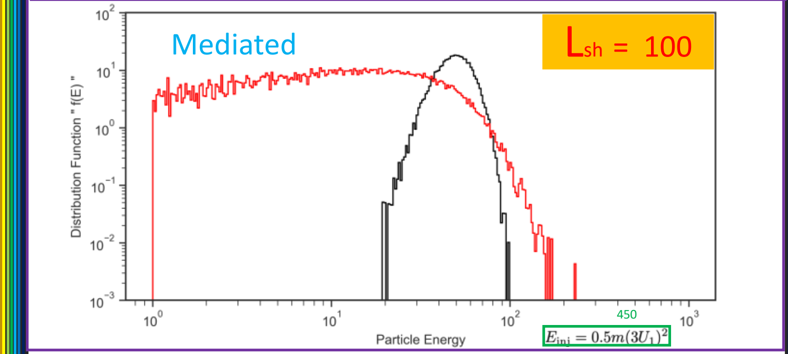
$$U = \frac{U_2 + U_1}{2} + \frac{U_2 - U_1}{2}\tanh\left(\frac{x}{L_{sh}}\right)$$

C.

Results

- These two energy distribution functions are similar but there are significant differences.
- The black curve corresponds to the initial conditions of the particles, while the red curve represents the state of the particles after their respective shocks.
- As you can see, the mediated shock has a significant particle energy dip compared to the non-mediated shock.
- This is exciting to see, as this was relatively expected although not much is known about mediated shocks or particle injection in reference to them.





Acknowledgments

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Summary

Shock waves occur all throughout the universe. These shock waves can be mediated or non-mediated. Little is known about these shocks or particle injection in reference to them. After performing test particle simulations in a mediated and non-mediated shock with Alfvenic turbulence we found that particle acceleration is significantly less efficient in the mediated shock. This result indicates particle injection at mediated shock waves are less efficient than that of the non-mediated shock. Little is known at about mediated shocks, however, this work and other work like it, may help to shed some light as to how exactly mediated shocks work and what role they play in cosmic phenomena.

References

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