Turbulent Reacceleration of Streaming Cosmic Rays: Fluid Simulations

Chad Bustard (Kavli Institute for Theoretical Physics), S. Peng Oh (University of California - Santa Barbara)

Why is this important:

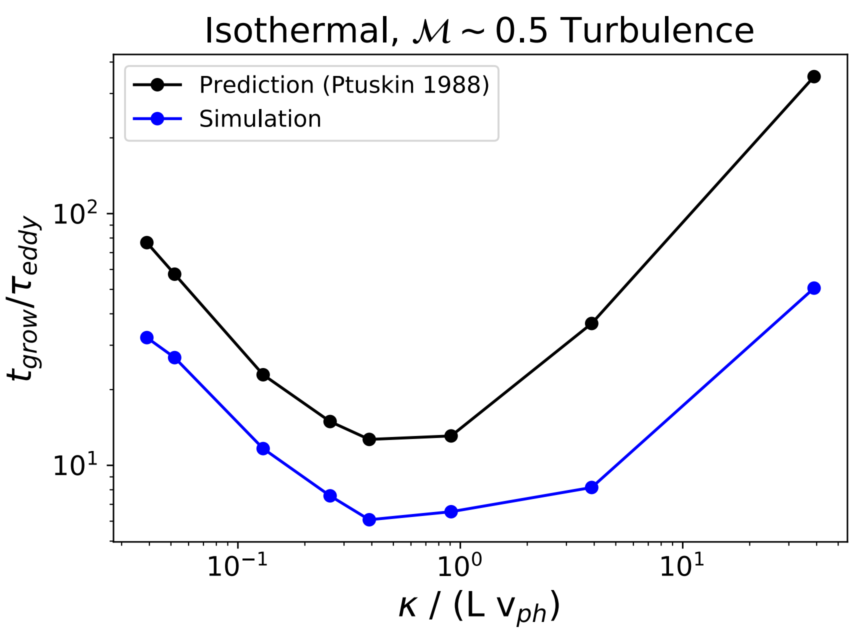
- While frequently invoked to explain primary-to-secondary ratios at ~GeV energies, the physical underpinnings of reacceleration for self-confined (E < 300 GeV) cosmic rays are unclear: resonant reacceleration fails because cosmic rays only co-move with forward waves excited through the streaming instability (both forward and background waves are required for reacceleration). *Non-resonant reacceleration of streaming cosmic rays has not been explored.*

What we do:

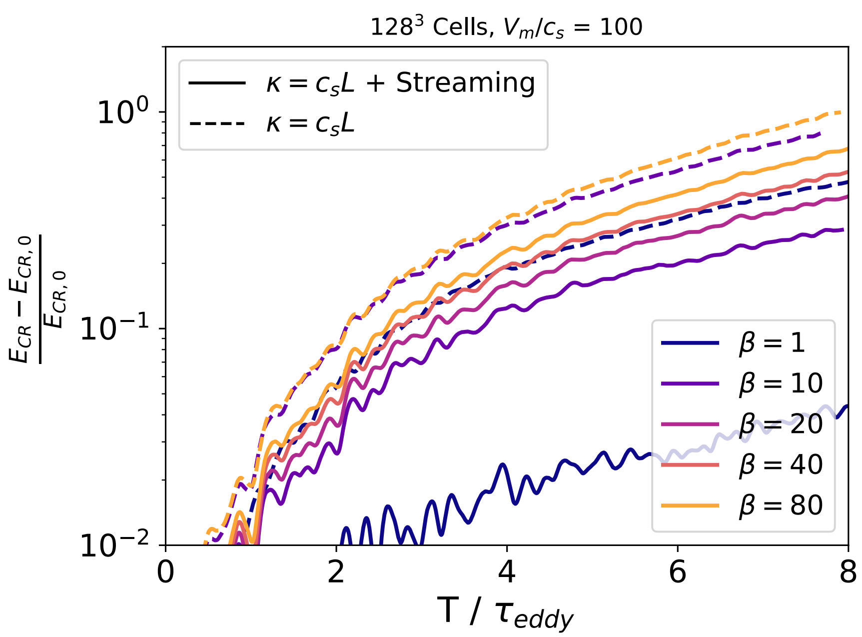
- We estimate the non-resonant reacceleration rate for streaming cosmic rays in subsonic, compressive turbulence, and we run Athena++ MHD simulations with driven turbulence to confirm our results

Some results:

- Non-resonant reacceleration of streaming CRs is greatly stunted by streaming energy loss
- Canonical equations for reacceleration rates should be significantly modified for E < 300 GeV (self-confined CRs)



Simulations with pure diffusion (no streaming) recover analytic growth rates *(Ptuskin 1988)* within a factor of 2, at least with $\kappa \lessapprox \kappa_{crit}$



Adding in streaming, even with $\kappa = \kappa_{crit}$, gives slow growth unless β is large

$$\frac{\partial E_{cr}}{\partial t} \sim -v \cdot \nabla P_{cr} + v_A \cdot \nabla P_{cr}$$

$$\frac{t_{grow,crit}}{t_{loss}} \sim \frac{1}{\sqrt{\beta} M_s^2}$$

↓

Unless $\beta \gg 1$, energy loss prevails over energy gain from subsonic turbulence