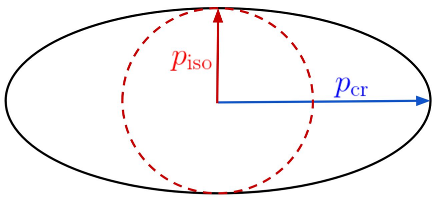
A Kinetic Study of the Saturation of the Bell Instability

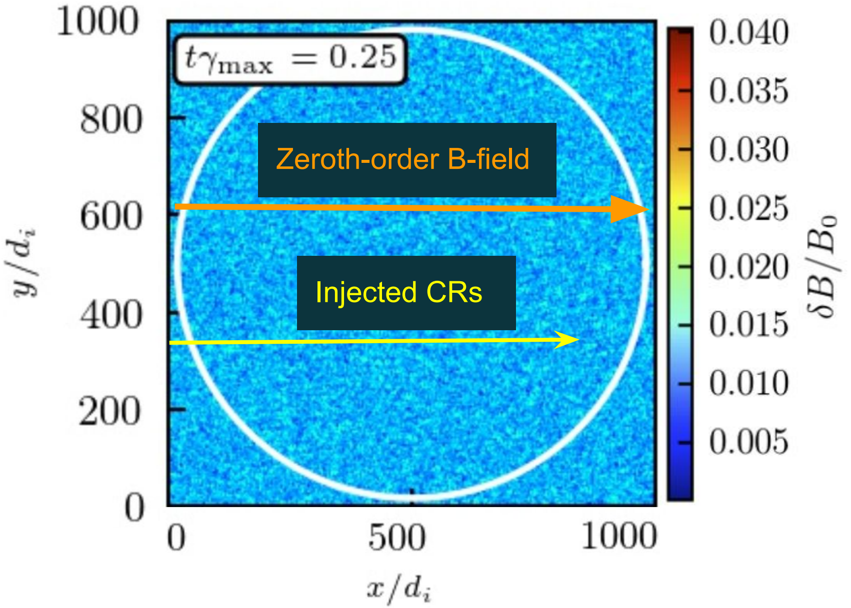
Georgios Zacharegkas, Damiano Caprioli, Colby Haggerty, Siddhartha Gupta

The problem

1. **Why does the instability saturate?**
2. **What is the final level of the magnetic field's strength?**



- To answer these questions from *first principles* we use self-consistent Hybrid simulations (*dHybridR* with kinetic ions and fluid electrons)
- Simulation setup:
  - Thermal plasma in a 2D box
  - Ambient magnetic field B_0
  - Small initial perturbations δB on B_0
  - CRs drift parallel to B_0
  - We inject CRs parallel to B_0 at a constant rate, with number density n_{cr}, and drift and isotropic momentum p_{cr} and p_{iso}



Results

1. Magnetic field **initially grows exponentially**
2. When the **field becomes non-linear ($\delta B \geq B_0$), CRs scatter** off the field structures
3. This transfers momentum from the CRs to the plasma
4. The Bell instability **saturates** because the CR current in the plasma's frame reduces
5. The final magnetic field is proportional to the **anisotropic CR momentum flux**:

$$\frac{B_z^2}{2} \approx \Pi_{\rm cr} \approx n_{\rm cr}\gamma_{\rm iso}\left[1+\left(\frac{p_{\rm iso}}{\gamma_{\rm iso}mc}\right)^{2/3}\right]\frac{p_{\rm cr}^2}{\gamma_{\rm cr}}$$