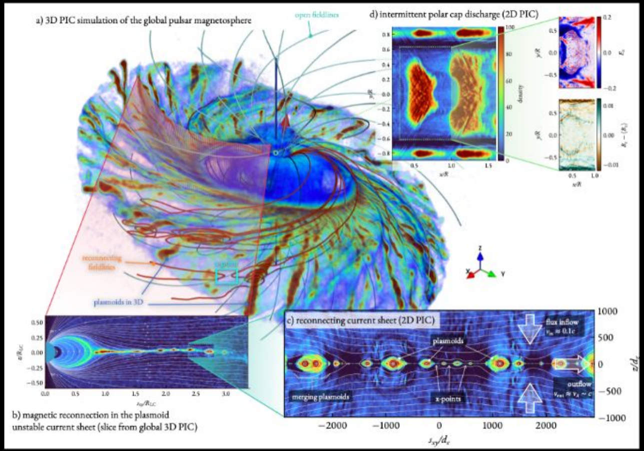
Simulating Physical Systems

- Can fluid dynamics codes be compared across systems? nuclear collisions, neutron star mergers, astrophysical plasmas,...
- How do we share numerical techniques and learn from each other?
- What are the limits of fluid models? Relativistic collisionless plasmas?
- Can attractors (like in heavy-ions) be found in other systems?
- Overlap in fields: Scattering diagrams, EOS, hydro EOM in GR
- Visualizations in nuclear physics, what can we learn from astro?
- Agreed upon convergence tests? 2nd vs 4th order PDEs
- Should large codes be treated like experiments? Accelerator physicists, data analysis, builders etc
- Can machine learning help us discover new physics?
- Can interdisciplinary approaches help with the Fermion sign problem?
- Effective models: boiling down complexity to simple parts

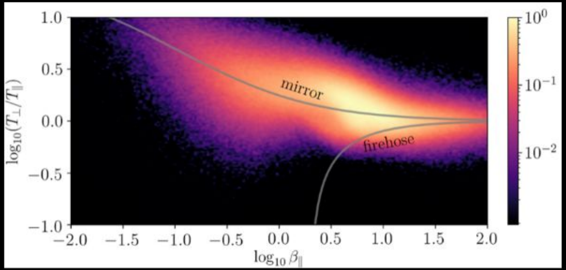
Challenges: separation of scales and missing collisionless physics



How to study validity of (ideal) fluid models?

Approach 1: first-principles, reduced separation of scales: great to study dynamics

Approach 2: fluid, moment-like equations: advantages of AMR and overstepping time-scales

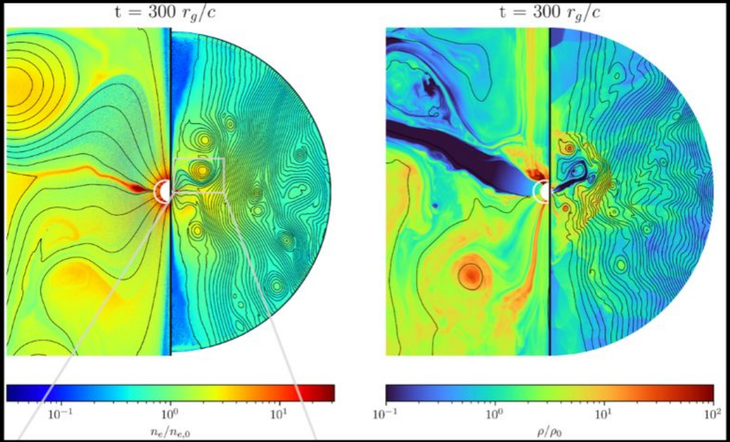


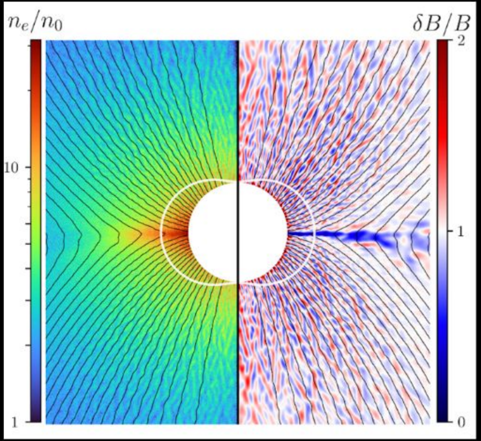
$$u^\alpha \nabla_\alpha q^{<\mu>} = -\frac{\mathfrak{q}}{m}(e - mn + P + \Pi)\, e^\mu - \frac{\mathfrak{q}}{m} e_\alpha \pi^{\alpha\mu} - \frac{\mathfrak{q}}{m} b^{\mu\alpha} q_\alpha + \nabla^{<\mu>}(e - mn) - (e - mn + P + \Pi)\,\dot{u}^\mu - \theta q^\mu + \dot{u}_\alpha \pi^{\mu\alpha} - q^\alpha \nabla_\alpha u^\mu - \frac{1}{\tau_q} q^\mu , \quad (60)$$

$$u^\alpha \nabla_\alpha (P + \Pi) = -\frac{2}{3}\frac{\mathfrak{q}}{m^2} e_\mu q^\mu + \frac{2}{3} m \nabla_\mu q^\mu - \frac{1}{3}\theta (P + \Pi) - \frac{2}{3} m q^\mu \dot{u}_\mu - \frac{2}{3}\sigma_{\mu\nu}\pi^{\mu\nu} , \quad (61)$$

$$u^\alpha \nabla_\alpha \pi^{<\mu\nu>} = -2\frac{q}{m^2} e^{<\mu} q^{\nu>} + 2\frac{q}{m} b^{\alpha<\mu}\pi^{\nu>}_{\alpha} + 2m\nabla^{<\mu} q^{\nu>} - \theta\pi^{\mu\nu} - 2m\dot{u}^{<\mu} q^{\nu>} - 2\nabla_\alpha u^{<\mu}\pi^{\nu>\alpha} + (P + \Pi)\,\sigma^{<\mu\nu>} - \frac{1}{\tau_\pi}\pi^{\mu\nu} . \quad (62)$$

GRPIC **GRMHD**





Both have to go hand in hand with improving our understanding of fundamental plasma processes: turbulence, dynamo, reconnection, etc.