The XMagnet Project:
Probing Intracluster Medium Physics with Exascale MHD Simulations

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Understanding the complex physics governing the intracluster medium (ICM) is essential to build a consistent theory of its thermal regulation. The ICM is a multiphase environment, where hot, diffuse gas coexists with denser, cooler structures. Its evolution is shaped by the intricate interplay of turbulence, magnetic fields, cosmic rays, active galactic nucleus (AGN) feedback, radiative cooling, and possibly thermal conduction. These processes are deeply interconnected, making it crucial to capture their full dynamical range in simulations. **In this talk, I will present the XMagnet project, a suite of high-resolution MHD simulations of AGN feedback in a cool-core galaxy cluster. These simulations were run on Frontier[1], the first exascale supercomputer available to academic researchers**.

I will start by introducing the numerical strategy behind this project, which is based on AthenaPK—a performance-portable adaptation of Athena++ optimized for exascale computing—and discussing its main computational challenges. I will then present our simulation setup, which models a 6.4 Mpc–wide galaxy cluster while resolving its inner $(250\,\mathrm{kpc})^3$ with a Cartesian grid of $(2,560)^3$ cells. Finally, I will highlight our first key findings on the role of turbulence in the ICM. A visualization from our fiducial MHD run is presented in Fig. 1.

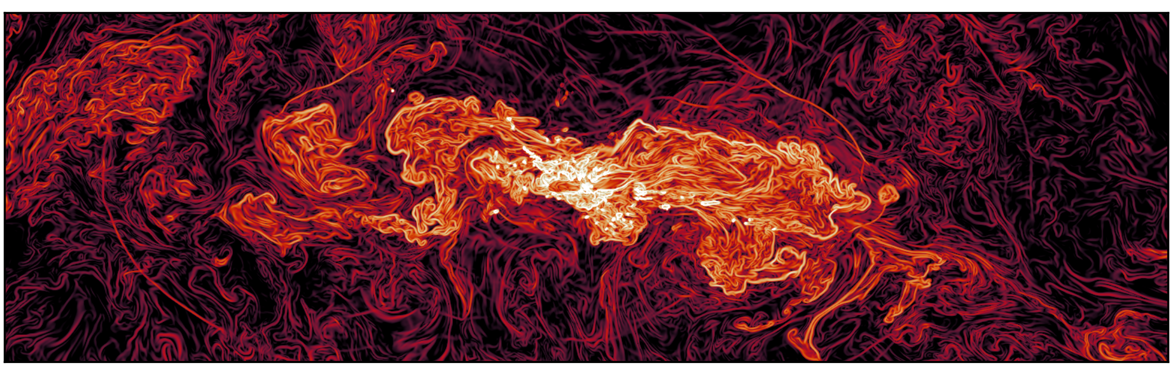

Figure 1: Slice of the gas density gradient magnitude in our fiducial MHD run at $t = 3.2$ Gyr. The edges of the AGN cavities, as well as shock and ICM turbulence is visible. The width of the image is 200 kpc.

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