Numerical simulations of the heat-flux driven buoyancy instability in the intracluster medium

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Abstract

Galaxy clusters are the largest gravitationally bound objects in the Universe (typical scales attain the order of the Mpc), with the vast majority of their mass being found as dark matter ($\sim 80\%$) and a hot, weakly-collisional plasma ($\sim 15\%$) : the intracluster medium (ICM). As such, they serve as a sandbox to understand the hierarchical formation and growth of structures, which might be strongly affected by the thermodynamical evolution of the ICM itself. Indeed, X-rays observations show that this ionized gas is subject to subsonic turbulent motions, arising from multiple origins, such as galaxy mergers, accretion from the cosmic web, AGN feedback, and possibly MHD instabilities.

Indeed, although being convectionally stable according to Schwarzschild's criterion, the ICM is suspected to be unstable to other buoyant MHD instabilities, which occur because of the anisotropic heat transport exclusively along magnetic field lines. In the context of this internship, we study the turbulent saturation of the Heat-flux driven Buoyancy Instability (HBI), prone to occur when the temperature gradient of the plasma is in the opposite direction of gravity, as is the case in cool-core galaxy clusters.

A deeper understanding of the HBI's non-linear saturation might help to better constrain the thermodynamics of cool-core clusters, along with the cooling flow problem. Thanks to numerical simulations, performed with the finite volume code IDEFIX, we thoroughly investigate the turbulence instigated by the HBI in idealized local cartesian boxes. A parametric study of the thermal diffusivity in the ICM and its effects on the turbulence levels in the saturated phase is conducted. As the internship is still ongoing, further work might include the addition of anisotropic viscosity, the study of a small-scale dynamo, or the implementation of a global spherical model.