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Bulletin of the AAS • Vol. 56, Issue 5 (HEAD 21 Abstracts)

Testing multi-scale physics via measurements of merger-driven ICM density fluctuations

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Published on: May 03, 2024

URL: https://baas.aas.org/pub/2024n5i401p03

Most of a galaxy cluster’s baryonic matter lies in the intracluster medium (ICM), which offers a unique laboratory to test multi-scale physics in numerical simulations and probe the physics of hot, weakly magnetized, diffuse plasmas. Outside of cool-cores, ICM gas dynamics are dominantly driven by cluster mergers and remain poorly understood. Before direct gas velocity measurements become available with XRISM and NewAthena, indirect techniques can constrain velocities. In this talk, I will describe results utilizing archival Chandra observations to measure multi-scale ICM density fluctuations in 80 galaxy clusters out to a radius of R2500c. These measurements can be used to constrain gas velocities, non-thermal pressure fractions, and clumping factors. I will compare these measurements to cosmological simulations, finding an underprediction of density fluctuation amplitudes in relaxed clusters at scales smaller than 0.75 R2500c, suggesting these systems are most sensitive to physics missing from simulations. Finally, I will explore plasma physics of the ICM by examining turbulent re-acceleration of cosmic rays and the suppression of effective viscosity in the bulk ICM by cluster magentic fields.