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Self-similar hierarchical energetics in the ICM of massive galaxy clusters

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Abstract. Massive galaxy clusters (GC) are filled with a hot, turbulent and magnetised intracluster medium (ICM). They are still forming under the action of gravitational instability, which drives supersonic mass accretion flows. These partially dissipate into heat through a complex network of large scale shocks, and partly excite giant turbulent eddies and cascade. Turbulence dissipation not only contributes to heating of the ICM but also amplifies magnetic energy by way of dynamo action. The pattern of gravitational energy turning into kinetic, thermal, turbulent and magnetic is a fundamental feature of GC hydrodynamics but quantitative modelling has remained a challenge. In this contribution we present results from a recent high resolution, fully cosmological numerical simulation of a massive Coma-like galaxy cluster in which the time dependent turbulent motions of the ICM are resolved (Miniati 2014) and their statistical properties are quantified for the first time (Miniati 2015, Beresnyak & Miniati 2015). We combine these results with independent state-of-the art numerical simulations of MHD turbulence (Beresnyak 2012), which shows that in the nonlinear regime of turbulent dynamo (for magnetic Prandtl numbers$\gtrsim 1$) the growth rate of the magnetic energy corresponds to a fraction $C_E \simeq 4 - 5 \times 10^{-2}$ of the turbulent dissipation rate. We thus determine without adjustable parameters the thermal, turbulent and magnetic history of giant GC (Miniati & Beresnyak 2015). We find that the energy components of the ICM are ordered according to a permanent hierarchy, in which the sonic Mach number at the turbulent injection scale is of order unity, the beta of the plasma of order forty and the ratio of turbulent injection scale to Alfvén scale is of order one hundred. These dimensionless numbers remain virtually unaltered throughout the cluster's history, despite evolution of each individual component and the drive towards equipartition of the turbulent dynamo, thus revealing a new type of self-similarity in cosmology. Their specific values, while consistent with current data, indicate that thermal energy dominates the ICM energetics and the turbulent dynamo is always far from saturation, unlike the condition in other familiar astrophysical fluids (stars, interstellar medium of galaxies, compact objects, etc.). In addition, they have important physical meaning as their specific values encodes information about the efficiency of turbulent heating (the fraction of ICM thermal energy produced by turbulent dissipation) and the efficiency of dynamo action in the ICM (C_E).

References

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