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New scaling relations for the galaxy cluster diffuse radio emission

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The Universe hierarchical formation process can be investigated through the fundamental relations of galaxy cluster observables. Since the matter accretion is gravity-dominated, the hot plasma within galaxy clusters displays a self-similar behaviour, following precise scaling relations that link spatially resolved quantities to global ones. Similarly, the diffuse, non-thermal cluster component (radio halo) is tightly connected to the system properties, with the total radio halo power showing a strong correlation with the system's mass (P - M relation). However, only integrated quantities have been systematically investigated for this component, leaving the non-thermal emission on sub-cluster scales largely unexplored.

In my talk, I address this gap by exploiting the wide and deep radio survey conducted by the SKA pathfinder LOFAR (the LoTSS), which allows for the detection of a large number of radio halos with sufficient angular resolution to characterise in detail their emission.

To this aim, I consider a well selected sample of clusters observed by the LoTSS, also leveraging deep XMM-Newton data from the CHEX-MATE project. I use these data to derive novel scaling relations that link global and spatially resolved radio halo emission with the cluster properties.

Using an analytical model to describe the halo radial profiles, I obtain several key results. I demonstrate how the various features displayed by the halo surface brightness profiles are recovered by properly accounting for the cluster mass and redshift. Furthermore, this analysis provides an assessment of the role of cluster dynamics in shaping the non-thermal emission. By comparing model predictions and observed scaling relations, it also yields constraints on the impact of different radio halo properties, such as the halo average emissivity and the halo size.

Finally, I adopt a physically motivated model to improve the conventional treatment of the observed P-M relation. By explicitly incorporating the magnetic field contribution, this methodology provides, for the first time, a statistical estimate of the average cluster magnetic field. Remarkably, thanks to the novel approach adopted, I can derive a scaling relation between the cluster magnetic field and its mass, with results that align consistently with independent literature estimates.

The presented analysis shows the great capabilities of the future observations of large samples of objects that will be performed with SKA, allowing for statistical studies of cluster non-thermal emission and deriving constraints on the large scale magnetic field.

Topics

Galaxy Clusters & LSS (relativistic particles and magnetic fields)

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