Galaxy Clusters seen with new eyes: gain from the new generation of X-ray telescopes.

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Since 40 years the X-ray astronomy has provided a unique view of galaxy clusters, the only places in the Universe where a joint study of thermo-dynamical and chemical properties of diffuse cosmic baryons can be carried out. In particular, the current generation of X-ray telescopes onboard the NASA Chandra and ESA XMM-Newton satellites offers exceptional images of the intracluster medium, a diffuse hot gas that permeates the space between the $\sim 10^3$ galaxies belonging to a cluster. The X-ray spectra furnish important indication on the physical properties of these objects, that have played a key role over the last decade both in determining cosmic evolution as a whole and in shedding light on the astrophysical processes driving the evolution of galaxies. Far from extinguishing its power, the X-ray community is ready for a leap forward thanks to instruments characterized by wider collecting area, sharper angular resolution and much finer spectral resolution, such as XRISM(~2022), and Athena XIFU and WFI (~2030).

Thanks to a collaboration between INAF - Astronomical Observatory of Trieste and the Department of Physics of the University of Trieste, our research group, active in the field of computational cosmology, has an established long-standing role in several projects to substantiate the interpretation of X-ray observations from past and current telescopes. With the preparation of next-generation hydrodynamical simulations of galaxy clusters, we are currently building the framework to support future X-ray observatories and to maximize their scientific return.

In this context, we propose a PhD project, based on high-resolution state-of-the-art numerical simulations that follow the formation and evolution of galaxy clusters in a cosmological setting.
The main goals of this project will focus on:

- Thermo-dynamical properties of galaxy clusters: the outcomes of direct analysis of simulated clusters would be compared with the results from X-ray analysis of mock images obtained by convolving the X-ray emission from these objects with specific instruments responses. In particular, the intrinsic properties of the cluster gas (such as gas density, temperature, pressure, and entropy) will be related with similar properties obtained from the X-ray analysis of mock images that will account for the response of CCD detectors (such those of current X-ray telescopes) and future microcalorimeters (such those of XRISM and Athena-XIFU). Combining the gas density and the temperature (or the pressure) and assuming hydrostatic equilibrium, we aim at deriving the X-ray mass, evaluating any possible bias with respect to the true mass of the simulated object, and connecting the possible mass bias with the dynamical properties of the gas as measured from high-resolution X-ray spectra.

- Chemical enrichment: high-resolution cosmological hydrodynamical simulations will offer the possibility to realistically explore the observability of the chemical species enriching the diffuse gas in clusters, probing the impact of energetic feedback processes and interaction between the hot intra-cluster medium and the cluster galaxies through cosmic time. Combining the intrinsic predictions from simulations with the expected performance of up-coming high-resolution X-ray instruments like XRISM and Athena, we aim at constraining the concrete possibility to distinguish between different enrichment scenarios and at probing the detectability of chemical elements not only inside clusters but also beyond their boundaries, along filaments connecting them within the cosmic web. The high resolution of the simulations will further allow us to explore in detail the interplay between the stellar component in the galaxy population, responsible for the production of the chemical elements, and the intra-cluster medium, during the assembly and evolution of clusters.