Project Title: Characterizing the Proto-Cluster population with cosmological simulations.

Supervisors: Alex Saro (asaro@units.it), **Stefano Borgani** (sborgani@units.it)
Collaborators: Veronica Biffi (veronica.biffi@inaf.it), **Gabriella De Lucia** (gabriella.delucia@inaf.it), **Elena Rasia** (elena.rasia@inaf.it), **Veronica Strazzullo** (veronica.strazzullo@inaf.it), **Maurilio Pannella** (mpannella@units.it), **Luca Di Mascolo** (ldmascolo@units.it)

Project Description:

Proto-clusters offer a unique chance to observe how transformational processes, such as mergers and violent relaxation in galaxy clusters at redshift $z \gtrsim 1.5$ - 2, affect the evolution of the thermo- and chemo-dynamical properties of their intracluster medium (ICM), and of the galaxy population within these extreme environments. The epoch corresponding to this redshift range, is a crucial one: it corresponds to when the progenitors of brightest cluster galaxies (BCGs) are expected to assemble through violent mergers between actively star-forming galaxies, while moving through a rapidly evolving potential within a pressurizing proto-ICM hot atmosphere. This is also the quasar era, during which accretion onto super-massive black holes in the forming BCGs reaches the peak of activity and the properties of the ICM are set. Proto-cluster regions are expected to accrete large amount of gas, forming a hot ($\gtrsim 10^7$ K) ICM that should be observable either through X-ray bremsstrahlung, or through the inverse Compton (IC) scattering of cosmic microwave background (CMB) photons off ICM electrons, the Sunyaev-Zeldovich (SZ, Sunyaev & Zeldovich 1972) effect. To date, however, few proto-clusters have been studied at great depth with multi-wavelength data sets and therefore a proper characterization of this crucial population is still missing. The “Spiderweb” complex (Fig. 1) with its large multi-wavelength coverage (from radio to X-rays) represents one notable exception. In particular our group, in the last couple of years has acquired a large amount of proprietary data associated with the Spiderweb, including the largest italian-led program with Chandra, deep ALMA observations, and deep and wide radio observations (VLA, uGMRT, MeerKAT). A proper theoretical interpretation of this plethora of observational data-sets is therefore urgently required.

The line of research proposed for this PhD project will focus on the characterization of the properties of proto-clusters. The project aims at investigating the properties of galaxies identified in high-resolution cosmological hydrodynamical simulations of galaxy clusters and in semi-analytical models, the co-evolution of the forming ICM, and the impact of feedback processes (i.e. SN and AGN) on both the galaxy population and ICM properties in the crucial epoch of “proto-clusters” to “cluster” transformation.

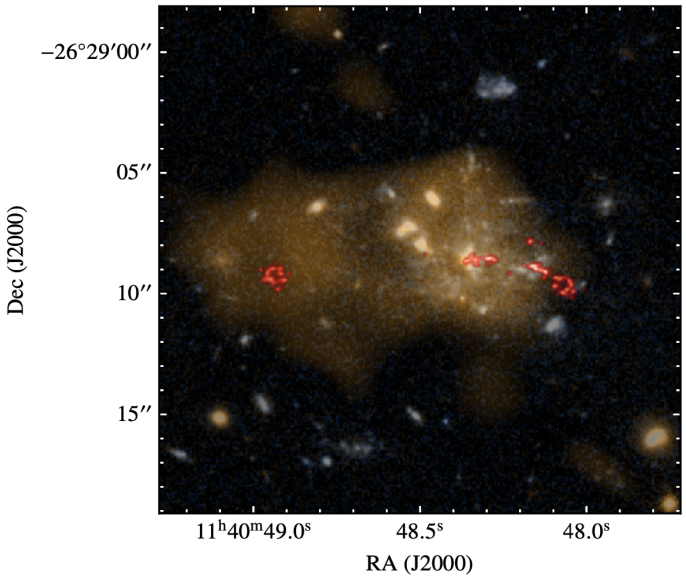

Fig. 1: The Spiderweb proto-cluster at redshift z = 2.16. HST image shows the complex structure of the forming massive BCG, resembling a Spiderweb catching its flies (the infalling merging galaxies). Overlaid in red and yellow ALMA data showing the strong feedback from the central AGN (red) and the forming ICM (yellow).