PhD project in ASTROPHYSICS

Title of the Project: Physics of non-thermal components in galaxy clusters and the LOFAR revolution

Supervisor: G. Brunetti

Scientific Case: Galaxy clusters emit diffuse steep-spectrum synchrotron radiation due to relativistic electrons interacting with magnetic fields in their volume. This evidence poses important questions on the origin of non-thermal components and on their interplay with the thermal matter. In the last decade, we demonstrated a connection between the radio emission and the dynamics of galaxy clusters, suggesting that a fraction of the kinetic energy of dark-matter and baryons is channeled into magnetic fields and high energy particles. Mechanisms responsible for powering the non-thermal components involve turbulence and shocks operating in physical regimes that are still poorly explored. Thanks to its unprecedented sensitivity at low frequencies, LOFAR is achieving a breakthrough in the field, allowing us straightforward tests of theories and pushing studies into a completely new regime.

Outline of the Project: We propose two lines for a PhD project which combine data analysis and theoretical interpretation:

1. Formation rate of radio halos in galaxy clusters at different cosmic epochs
LOFAR surveys (LoTSS, LoLSS) are expected to detect about 1000 galaxy clusters extending the limited ranges of masses, redshifts and statistics, that are severely limiting present studies. Data from 5700 square degrees (DR2 area, 27% of the northern sky) are already available to our group. We plan to analyze the data of the 309 clusters of the PSZ2 catalog that are in this LoTSS-DR2 area to obtain unprecedented information on the statistical properties of diffuse emission in clusters. Importantly, we will investigate the occurrence of radio halos in an unexplored range of clusters masses and redshifts (up to z=1), obtaining fundamental constraints on the magnetic field amplification and particle acceleration, and testing current models.
Coll : R. Cassano, D. Dallacasa, A. Bonafede

2. Superclusters and radio bridges
LOFAR observations have discovered steep-spectrum diffuse radio emission from bridges of matter that connect pairs of massive clusters in a pre-merger phase. These radio bridges presumably trace dynamically active and vast filaments connecting massive clusters where turbulence amplify magnetic fields and accelerate relativistic particles. A statistical assessment of the occurrence of radio bridges and a firm measure of their radio spectrum is possible only with LoTSS and LoLSS data. During the project we plan to exploit the vast wealth of the available LOFAR data to step into this very new territory and to carry out a comparison with current models.
As a further step we plan to search for diffuse radio emission from super-clusters. Detection of radio emission on super-clusters scales would provide important information on the heating mechanisms in the large scale structures and in particular on the physics of turbulence, shocks and magnetic fields in these environments. The first target of the project will be the Corona Borealis that has been recently observed for about 70 hrs with LOFAR in the HBA band.
Coll : R. Cassano, T. Venturi, D. Dallacasa, A. Bonafede, F. Vazza

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