

変革を駆動する先端物理・数学プログラム (FoPM)

国外連携機関長期研修 報告書

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Taking the advantage of the International Research Experience provided by FoPM, I visited the Institute of Radio Astronomy (IRA), located on the CNR research campus, in Bologna, Italy. During my stay in Bologna, I worked on the theoretical modeling of the extended radio emission in galaxy clusters, under the supervision of Prof. Gianfranco Brunetti. Such radio emission traces the relativistic particles and the magnetic field, so it is deeply related to the particle acceleration and the dynamo effect working inside the clusters. Very recently, novel progress has been achieved with Low Frequency Array (LOFAR) observation, which revealed the existence of the radio structures up to virial radii of galaxy clusters (see [Cuciti et al. 2022](#), [Botteon et al. 2022](#) for their beautiful images). This clarifies the strong connection between the dynamics at a very large scale, or the structure formation of galaxy clusters, and the non-thermal physics, such as particle acceleration and dynamo. However, there is no theoretical explanation for this radio “mega halos” so far. My primary purpose for this stay is to build the very first model for the mega halo. Since many researchers in IRA make a significant contribution to this field, Bologna is one of the most favorable places to work on this problem.

The research activity during the stay was very successful and fruitful, thanks to the support of the people there. I and Prof. Brunetti first discussed the possible theoretical model that could explain the diffuse emission in the peripheral region of clusters, making an analytical estimate of the acceleration efficiency. Since the physical environment of the cluster periphery differs from the central region in many points, e.g., gas density, temperature, magnetic field, and turbulence, it is not obvious whether the theoretical models for classical halos found in the central regions work or not. Considering previous studies on large-scale radio emission and the hydrodynamical simulation of clusters, we presumed that the particles can be accelerated through interaction with turbulence. After confirming the promising theoretical model, we have been conducting a numerical calculation of spectral evolution. At this stage, I am collaborating with Prof. Franco Vazza and Prof. Claudio Ghellar. The state-of-art numerical simulation by Prof. Vazza provides the information about turbulent nature of the cluster periphery with a fine spatial resolution. Prof. Ghellar helps me to improve my calculation code and instructed me on the usage of the supercomputing system, Pleiadi. The rich computational resource Pleiadi enables me to conduct the calculation of particle acceleration in clusters on an unprecedented scale. In this calculation, we detect some interesting statistical features. We are considering releasing those results in a paper, which would hopefully be the very first theoretical model for the “mega halos” in galaxy clusters.

Besides the research work, there were so many wonderful experiences in Bologna. Most impressively, lunchtime talk with colleagues seems to be more vital in Italy than in Japan. People have lunch at the same table and have. We used to have a cup of coffee (espresso, usually) after the meal and had another conversation. On Friday nights, the Ph.D. students gathered and had Aperitivo (aperitif) together, and talked a lot. Those conversations with my colleagues made up a certain fraction of my work time, and it was somewhat in contrast to my



Fig. 1 CNR research campus

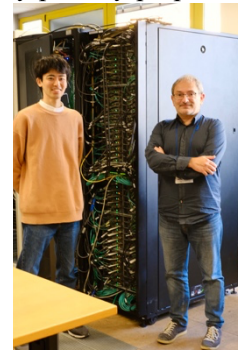


Fig.2 Picture of me and Prof. Brunetti, in front of Pleiadi



Fig. 3 Arcade featuring Portico

usual life in Japan. The people in IRA took so much care of me, and I could enjoy socializing with them.

Needless to say, the food in Bologna is excellent. I had time to try various food there, such as Tagliatelle al ragu (pasta Bolognese), Lasagna, and Tortellini, in addition to Mortadella, Parmigiano Reggiano, etc... As in many cities in Italy, the city wandering in Bologna itself can be great entertainment. There are arcades supported by famous Portico (porches) in front of the buildings in the old city. The astonishing basilica of San. Petronio is definitely worth visiting, and also the view from the tower of Bologna is amazing. The security of the city seems to be rather safe at least in usual streets and stores, yet there exist seemingly dangerous corners.



Fig. 4 Tagliatelle al ragu

Last but not least, I would like to thank Prof. Brunetti for his kind hospitality before, during, and after the stay. This stay was really wonderful and I felt the time has just flown by. I strongly recommend other FoPM students to go to Bologna, if they have some connection to the researcher in that city. Please watch out for your wallet, it is less likely to be picked by someone but more likely to lose weight at the expense of delicious foods (note that there is NO daily allowance in this program).