

National Centre for Radio Astrophysics (NCRA-TIFR), Pune

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Pune's uGMRT uncovers a complex picture of a Galaxy Cluster

Pune based researchers have used the upgraded Giant Metrewave Radio Telescope (uGMRT) in India to produce the most detailed image yet of the galaxy cluster Abell 521. The new uGMRT observations led to the discovery new extended radio emission below GHz frequencies for the first time which allows the study of turbulence and shocks in the plasma. Radio Images show beautiful arc-like radio structures at the south of the cluster, and diffuse emission at the cluster center. The X-ray emission, detected by Chandra observatory, reveals a very tight resemblance with the radio structures near the cluster centre. A detailed investigation of the X-ray map reveals a strong connection for the origin of the radio structures via high velocity gas motions during the process of cluster merger. The high sensitivity and resolution of GMRT provide astronomers with new dimensions to gain knowledge about the mysteries of cluster physics.

Galaxy clusters are the largest gravitationally bound systems in the Universe. The galaxy clusters comprise of hundreds to thousands of galaxies bound together by gravity. At the heart of the galaxy clusters lies a vast sea of hot (with a temperature of ten million kelvin or higher) plasma. The collisions between galaxy clusters release a huge amount of energy, which significantly impacts this plasma medium. The galaxy cluster Abell 521 is one of such massive giants, situated at 3 billion light years away from Earth, famous for its highly disturbed medium.

A team of astronomers from India, Italy, and the USA has used cutting-edge telescopes, which include the upgraded Giant Metrewave Radio Telescope (uGMRT), Chandra, and XMM-Newton, and innovative methodologies. The team led by PhD candidate Ramananda Santra and his guide Prof. Ruta Kale of NCRA used these telescopes to map faint structures of the plasma, never seen before, that provided new insights on the connection between the plasma, relativistic electrons and magnetic fields. The colored image shows the galaxy cluster Abell 521, undergoing a collision between two clusters. The radio light from uGMRT is shown in red colour, X-ray light in blue colour and optical light in yellow colour.

Charged particles like electrons get boosted to relativistic velocities by these turbulence and emit radio light, when they encounter a magnetic field. This process leads to the formation of large-scale structures (a few billion light years), known as radio halos and radio relics. Radio waves emitted by them are very faint, making them challenging to detect via radio telescopes. The radio imaging pipeline 'CAPTURE' and real time radio frequency interference excision system developed by scientists at NCRA were crucial in addressing the challenges. Before the uGMRT observations, such a large-scale emission mapped in detail, from this cluster was not available. The high sensitivity of the uGMRT has allowed astronomers to witness this enigmatic view of this cluster in the radio band. The team continues to understand the complex physics via different theoretical

approaches and computer simulations.

The research team consists of R. Santra (NCRA-TIFR), R. Kale (NCRA-TIFR, India), S. Giacintucci (NRL, USA), M. Markevitch (NASA-GSFC, USA), F. De Luca (INAF, Italy), H. Bourdin (INAF, Italy), D. Dallacasa (University of Bologna, Italy), T. Venturi (INAF-Istituto di Radio Astronomia, Bologna, Italy), G. Brunetti (INAF-Istituto di Radio Astronomia, Bologna, Italy), R. Cassano (INAF-Istituto di Radio Astronomia, Bologna, Italy) and K.D. Buch (GMRT, NCRA-TIFR, India).

This article is based on the Published work “A Deep uGMRT view of the ultra steep spectrum radio halo in Abell 521” which was recently published in the international journal The Astrophysical Journal (<https://iopscience.iop.org/article/10.3847/1538-4357/ad1190>).

The GMRT is an array of thirty 45-meter antennas spread over a 25 km in Khodad village, Narayangaon, India. It was built and is operated by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research, India, under the Department of Atomic Energy.

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Fig1: *Multiwavelength image of the cluster Abell 521 is shown. The red color shows the light captured by uGMRT in radio band, the blue color is the emission observed with Chandra telescope in X-ray band and the yellow color shows the optical emission (DSS2).*

