New uGMRT Images Reveal Complexity of Galaxy Cluster Abell 2256 and new insights on Merging Events

Researchers have used the upgraded Giant Metrewave Radio Telescope (uGMRT) in India to produce the most detailed image yet of the galaxy cluster Abell 2256. The new uGMRT images reveal that radio emission is more extended at low frequencies and previously undetected regions where plasma processes such as turbulence and shocks accelerate particles, causing radio emission. The study shows a large complex filamentary structure in the north. At the cluster center, the observed radio emission morphology resembles that of X-ray emission, suggesting strong links between them. Further investigation with state-of-the-art X-ray telescopes revealed that radio emission is connected to past merging events such as cold fronts, gas motions, and shocks. The high sensitivity and resolution of GMRT also allowed astronomers to map unusual numbers of radio galaxies, with a monstrous supermassive black hole at their centers, with weird morphologies.

Galaxy clusters are enormous collections of hundreds or thousands individual galaxies immersed in giant oceans of extremely hot (with a temperature of ten million kelvin or even higher) gas and are considered to be the largest structures in the Universe held together by gravity. Collisions and mergers between galaxy clusters release tremendous amounts of energy unlike anything witnessed since the Big Bang. Abell 2256 is located approximately 1000 million light-years away from Earth and is known for its complex structure and high level of activity, including mergers between its member galaxies, which release tremendous amounts of energy. These characteristics make Abell 2256 an interesting object of study for astronomers.

An international team of astrophysicists led by Kamlesh Rajpurohit from the University of Bologna has used some of the most powerful telescopes in the world, including the upgraded Giant Metrewave Radio Telescope (uGMRT), the LOw-Frequency ARray (LOFAR), the Karl G. Jansky Very Large Array (VLA), Chandra, and XMM-Newton to study the peculiar radio features of the galaxy cluster Abell 2256. The team used these telescopes to capture different types of light, which allowed them to map finer details never seen before and gain new insights into the properties of Abell 2256, including how particles like electrons are accelerated on very large scales (about mega light-years).

The image below shows Abell 2256, revealing details of the interactions between at least three clusters, consists of over 500 colliding galaxies, creating a rich variety of fascinating phenomena that only radio telescopes can see. The radio portion (shown in red) of the image comes from new observations made with uGMRT combined with earlier data from ESA's XMM-Newton X-ray observatory (shown in blue).

Processes, including collisions and supermassive black hole nuclei, that lead to the formation of galaxy clusters like Abell 2256 release energy through turbulence and shocks. Such processes accelerate electrons to high speeds in the hot gas, which then release radio waves when they encounter the magnetic field. This produces large-scale radio emission structures, called radio halos and radio relics, which can only be observed with radio telescopes. However, radio emission is generally very low in surface brightness, especially at GHz frequencies, making it difficult to detect. At lower frequencies, the brightness increases, and these regions can be uncovered.

The new uGMRT images reveal that the radio emission is about two-three times more extended than previously known, and also new emission features. Kamlesh Rajpurohit says "before planning uGMRT observations, there were no other hints of such a large-scale radio emission in this system – we were pleasantly surprised to see this huge extension as well as filamentary morphology below GHz frequencies". The high sensitivity of the uGMRT also allowed astronomers to map weird-shaped radio galaxies and at least 50 previously undetected compact sources. The team continues to analyze their data to learn more about these mysterious radio galaxies, the complex histories of collisions, and the physical processes at

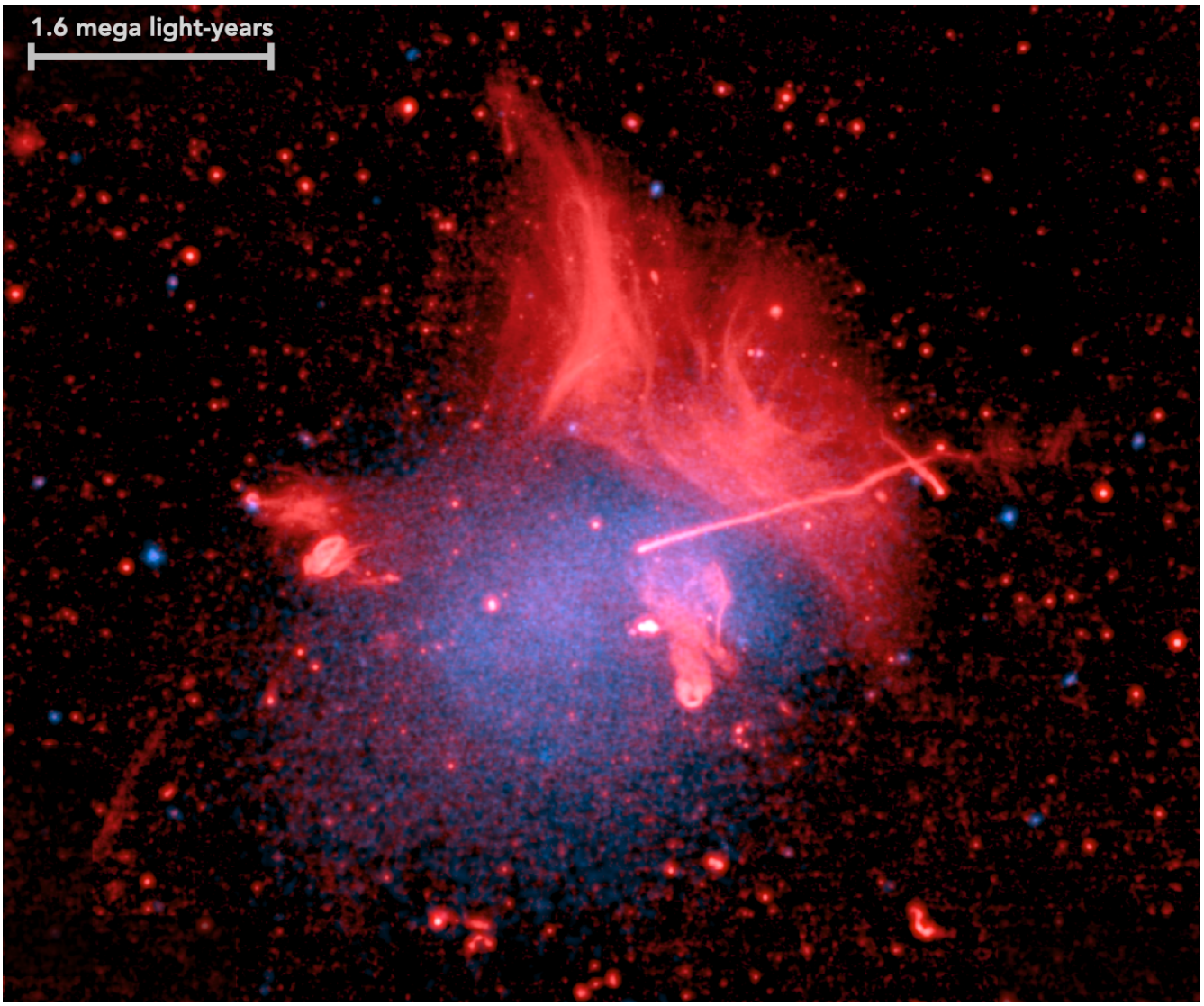

Figure 1: *Multi wavelength image of the galaxy cluster Abell 2256. The intensity in red shows the radio emission observed with the uGMRT, revealing plethora of emitting features caused by particles accelerated to high speeds by multiple collisions between galaxy clusters. The intensity is blue shows the X-ray emission observed with the XMM-Newton telescope.*

work in such encounters".

Yashwant Gupta, Center Director at NCRA, said, "The uGMRT offers a window into the universe at low radio frequencies with high sensitivity and resolution, revealing previously undetected regions and structures, such as extended radio emission in several objects like Abell 2256".

GMRT is a leading international radio telescope operated by the National Centre for Radio Astrophysics (NCRA) of the Tata Institute of Fundamental Research (TIFR), India. The scientists reported their findings in the January 2023 issue of the *Astronomy and Astrophysics Journal* (https://doi.org/10.1051/0004-6361/202244925). The research was funded by the ERC Starting Grant "MAGCOW" no. 714196.

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