Project Title: Low-frequency Study of Merging Galaxy Clusters using uGMRT Observations
Research Area: Astronomy
Academic Level: MSc
Primary Supervisor: Dr Kenda Knowles
Co-supervisor: Dr Swarna Chatterjee
Institution: Rhodes University

Project Description:

Galaxy clusters are the largest gravitationally bound structures in the Universe. Cluster mergers are complex processes that generate shocks, cold fronts, and turbulence, which thermalize the intracluster medium (ICM), amplify the cluster magnetic field, and accelerate/re-accelerate electrons and protons to relativistic speeds. When observed at radio frequencies, clusters exhibit large-scale diffuse radio emissions, such as giant radio halos and relics, that are valuable tracers of merger-driven particle acceleration. These emissions have steep spectra ($\alpha < -1$ where $Sv \propto v\alpha$) and low-surface brightness and, thus, appear brighter in the low-frequency radio bands. Low-frequency radio observations are crucial for detecting this steep-spectrum emission, which provides insight into the physical mechanisms driving turbulence and shock acceleration in the ICM. This project aims to investigate the diffuse radio emission in merging galaxy clusters using low-frequency uGMRT observations, focusing on spectral properties and their connection to cluster dynamics.

Feasibility and Methodology:

- **Data Availability:** The project will use existing uGMRT observations of selected galaxy clusters, ensuring an immediate start without the need for new observations.
- **Data Processing:** The student will perform data reduction using CASA and/or SPAM to obtain high-quality images.
- **Multi-Wavelength Comparisons:** The radio results will be compared with X-ray data (Chandra/XMM-Newton) to explore correlations between radio emission and ICM properties.
- **Physical Interpretation:** The results will be analyzed in the context of the role of cluster merger dynamics.

Skills Required

- Basic knowledge of radio astronomy.
- Experience with Linux environment and Python programming.
- Familiarity with interferometric data analysis (helpful but not mandatory).

Skill Development

- Hands-on experience with uGMRT data calibration, imaging, and analysis.
- Multi-wavelength data comparison techniques for astrophysical studies.