Section A: Overview of the Research Project Proposal

1. Title: **Observations of the Abell 141 cluster with MeerKAT**
2. Broad field of research: **Science**
3. Academic level of research project: **Masters**
4. Abstract: Almost two decades of observations of radio emission in galaxy clusters have proven the existence of relativistic particles and magnetic fields that generate Mpc-scale synchrotron emission in the form of radio halos. In the current scenario, radio halos are generated through re–acceleration of relativistic electrons by turbulence generated by cluster mergers. Recent low frequency (< 200 MHz) observations have recently revealed the presence of diffuse radio emission on a few Mpc scales in cluster pairs that are in an early merger phase (Govoni et al., 2019; Botteon et al., 2020). The third (chronologically speaking) system known that shows radio emission on such large scales detected at low frequencies is the Abell 141 cluster. For none of these systems, however, higher frequency observations are available.
   In this project the candidate will analyze MeerKAT observations of the Abell 141 cluster with the purpose of detecting the large scale radio emission and measuring its spectral index (or place meaningful upper limits to it) in order to provide the first constraints on particle acceleration and magnetic fields on cosmological scales.
5. Radio emission on such large scales poses challenges for models of particle acceleration: although cosmological simulations show that turbulence can acce
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7. Research supervisor: **Dr. Gianni Bernardi,** INAF-IRA (Italy) & Rhodes University

Section B: Details of Research Project

1. Scientific merit: Galaxy clusters are the largest gravitationally bound systems and are believed to be formed via mergers of smaller systems. They have masses of the order of 10^{14}−10^{15} $M_\odot$, with 15−20% in the form of a hot (10^8 K) gas that pervades the cluster volume, emitting X–rays via the Bremsstrahlung mechanism and mm-wave radiation via the Sunyaev–Zeldovich (SZ) effect. The presence of a non–thermal (i.e. relativistic particles and magnetic fields) component emitting synchrotron radiation has been revealed by a variety of radio observations over the last two decades particularly in the form of diffuse sources like radio halos of relics.

Recent low frequency (< 200 MHz) observations revealed, however, the presence of diffuse radio emission on a few Mpc scales, in the region interconnecting cluster pairs that are likely in a pre-merger state (Govoni et al., 2019; Botteon et al., 2020). The cluster Abell 141 is one of the three (known so far) examples of systems that may hold large scale, diffuse radio emission.

Abell 141 is a massive cluster ($M_{500} > 6\times10^{14} M_{\odot}$) at z= 0.23. It is a bimodal system studied in the optical and X-rays that has two X-ray clumps (A141N and A141S) separated by a projected distance of about 700 kpc. Both clumps have a highly distorted morphology, indicating that they are undergoing individual mergers. The high temperature (~10 keV) observed in the region between the two clumps suggests that the gas has been compressed and heated during the collision between A141N and A141S. Given its dynamical status, current models would predict the presence of a radio halo due to turbulence-accelerated relativistic particles. Observations at 168 MHz with the MWA telescope revealed diffuse radio emission across the cluster extension (Duchesne et al., 2017) that remained undetected at 610 MHz (Venturi et al., 2007), implying a steep spectral index.

MeerKAT observations of the Abell 141 cluster at 1.4 GHz were granted during the last open time call (proposal MKT-20175). The goal of the project is to detect (or place meaningful upper limits) to diffuse radio emission at 1.4 GHz either in the form of a radio halo or as a bridge of radio emission extending for ~700 kpc across the two X-ray clumps. Through these observations the candidate will be able to constrain the spectral index of the halo and the (possible) interconnecting bridge and, therefore, constrain models of halo formation and particle acceleration on cosmological (~Mpc) scales.

2. Feasibility: This project is a standard project - in terms of methodology. The candidate will reduce the MeerKAT observations of Abell 141 that are expected to be taken well before the start of the project. They will produce high quality images at a range of angular resolutions in order to look for diffuse emission in the halo and the bridge connecting the two X-ray clumps. Constraints on the spectral index of the halo and bridge will be interpreted in the light of halo formation models and particle acceleration on cosmological scales.
Storage and computing resources for this project will be made available at the Radio Astronomy Techniques & Technologies (RATT) Centre at Rhodes University.

3. Link to SARAO research priority areas for 2021: This is a science project that uses MeerKAT data (focus area 5.1).

4. **Qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed:**

Familiarity with interferometry and physics of radiative processes would be advantageous but not required.

Supervisor

Oleg Smirnov 22 February 2021