Section A: Overview of the Research Project

1. Title: **MeerKAT Observations of the Saraswati Supercluster (MOSS)**
2. Broad area of research : **Science**
3. Academic level of research project : **Masters**
4. Abstract: The evolution of galaxy clusters is a very complex and multicomponent merger system in the Universe. It is now well proven that massive galaxy clusters form and evolve at the intersection of the cosmic web filaments through merging and accretion of smaller mass systems. Previous radio telescopes were not enough sensitive to probe the radio emission from the cosmic filaments. Hence it is not well understood how the cosmic particles and magnetic fields are distributed at the cluster outskirts. MeerKAT, a SKA pathfinder, is very sensitive telescope operating at Gigahertz frequencies. This project aims to study how the diffuse radio sources are linked with the supercluster environment and formed within networks of galaxies filaments. We have observed the Saraswati supercluster, located within the SDSS stripe 82 region, with the MeerKAT telescope. Based on our initial analysis, the data is very good, and we have already detected diffuse radio sources in the supercluster MeerKAT data. The student will work on to analyse this MeerKAT data with MeerKATHI pipeline and perform optical cross-match with the radio data of the MeerKAT.
5. Primary supervisor: **Prof Oleg Smirnov,** o.smirnov@ru.ac.za, Rhodes University
6. Research supervisor: **Dr Viral Parekh,** Rhodes University & SARAO

Section B: Details of Research Project

1. Scientific merit: In the present paradigm of large scale structure formation, clusters of galaxy form hierarchically, with smaller objects (galaxies and groups of galaxies) forming first. High-resolution simulations of large scale structure formation reveal that in the standard λ CDM cosmology, clusters are mainly born within filaments of superclusters. Recent optical and X-ray observations also support this structure formation idea. One of the important features of galaxy clusters that can be studied through their radio observations are diffuse extended radio sources. These sources mainly probe the large scale magnetic fields and cluster dynamics. Further, these diffuse extended cluster-wide radio sources are grouped in three classes: radio halos, relics and mini-halos. Radio halos are found at the core of a cluster region, with a typical size of 1 Mpc and steep spectra. Relic sources are similar to halos in their low surface brightness, large size, and steep spectra, but are found typically in peripheral regions of the cluster. To understand how diffuse radio sources linked with supercluster environment, we observed the Saraswati supercluster with MeerKAT. In the MeerKAT open time proposal 2019, we have obtained 14 hours deep radio observations of the Saraswati supercluster. Saraswati supercluster is recently discovered in the famous equatorial stripe 82 SDSS region, at redshift z ~ 0.3. In this region, there are a large amount of multiwavelength (optical, infrared, etc) data available. This supercluster is unique regarding its shape, huge mass, richness, and in the detection of localised non-thermal diffuse radio emission, relating to its complex dynamical state. The total mass and size of this supercluster is 2 x10^16 solar mass and ~ 200 Mpc, respectively, making it one of the giant cosmic web structure in the Universe. This massive and large supercluster host 43 galaxy clusters at mean z ~ 0.28 and surrounded by a complex network of galaxy filaments and large voids. Our MeerKAT pilot observations include two pointings towards supercluster's central dense and most massive galaxy cluster A2631 and ZwCl 2341.1+0000 which is a very complex merging cluster hosts a radio relic source in the filament network. This project aims to detect and study cosmic shock driven diffuse radio sources associated with identified optical filaments (beyond virial radii of clusters) and probe any diffuse extended radio sources associated with galaxy clusters. The success of this pilot observation will inform planned future MeerKAT follow-up observations, which will ideally entail a full survey of the Saraswati supercluster.

2. Feasibility: The prospective student will take part in the MeerKAT data analysis and source identification using multiwavelength (SDSS) data. The radio data has already been obtained on June 2019 with all 64 MeerKAT dishes. We have analysed this data with CASA and it seems to be a very good observations (less RFI and no bright point source within the primary beam). The student will use more sophisticated pipeline MeerKATHI to improve image quality. Further students need to work on to apply primary beam corrections with available MeerKAT beams and source identification with available SDSS catalogues. In this project, all data is available so a student can immediately start to work on above mentioned scientific problem. The student will use Rhodes server to process and store the data. Based on our initial analysis, we already have detected extended diffuse radio sources into the MeerKAT data, hence there is a good opportunity to publish a few papers based on these findings. Below we have outlined the time frame in order to complete the project.

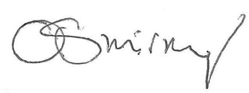
(1) First-year: We expect that within six months, the student can complete the data reduction work in collaboration with group members at Rhodes University and SARAO. In the next six months, the student will get familiar with multiwavelength data analysis such as optical and X-ray data. We do have SDSS catalogues, hence using TOPCAT and Aladdin astronomical tools, a student can perform the cross-match.

(2) Second-year: We expect to finish the catalogue generation work in a six month time. In the final six months, the student will work on thesis writing and final paper publications.

3. Link to SARAO research priority areas for 2021: This is a multiwavelength project where student will use MeerKAT, SDSS and X-ray data to understand how diffuse radio sources are associated with supercluster. MeerKAT has already proven its sensitivity to detect the faint radio emission in clusters and galaxies. Our project will provide critical information in order to detect and study diffuse radio emission, such as the required rms sensitivities and dynamic range, wide-field and wide-band imaging challenges, direction-dependent effects, etc. This will be helpful for future continuum radio survey such as the MIGHTEE.

4. Student qualifications: The student should familiar with radio astronomy and basic astronomy. It will be good if a student is familiar with the Python programming language. The student must be interested in radio interferometer data analysis and multiwavelength studies of galaxy clusters.

Supervisor



Oleg Smirnov 7 February 2020