Proposal for SARAO-funded Postgraduate Research in 2022

Details of Research Project:

Section A: Overview of the Research Project:

1. **Title of the research project**: Probing the association of Galaxy clusters with Bent-tailed radio sources using the MeerKAT Cluster Legacy Survey
2. **Broad Area of the research**: Science
3. **Academic level of research project**: M.Sc.
4. **Abstract of research project**: Galaxy clusters are some of the largest conglomerations of galaxies and such, key to our understanding of large scale structure in the universe. The methods used to detect galaxy clusters include direct detection at optical wavelengths, using X-ray observations or using the Sunyaev-Zeldovich effect. However, these methods suffer from considerations such as observation time required, dust extinction. An alternate method is to use Bent-tailed radio sources to detect galaxy clusters. Bent-tailed radio sources have been historically associated with galaxy clusters and do not suffer from issues like dust extinction. New-generation radio telescopes like MeerKAT excel at detecting these diffuse sources, by virtue of their high sensitivity. But while previous studies have assumed that all Bent-tailed radio sources are associated with galaxy clusters, the question of how many galaxy clusters contain Bent-tailed radio sources has not been yet satisfactorily answered. In this project we plan to use the MeerKAT Legacy Cluster Survey (MLCS) to probe the association of galaxy clusters with Bent-tailed radio sources. MLCS is an ideal dataset, being chosen through both radio and X-ray observations. The project consists of identification of Bent-tailed radio sources in the images of the MLCS sources and statistical associations of the detection rates with parameters such as cluster redshifts and cluster mass.
5. **Primary Supervisor's details**:
a. Full name of primary supervisor: Dr. Kshtiij Thorat
b. Primary supervisor's email address: kshitijthorat.astro@gmail.com
c. University where primary supervisor is employed: University of Pretoria

6. **Co-supervisor/ Research Supervisor's details:**
a. Full name of the co-supervisor/research supervisor: Prof. Roger Deane
b. University where co-supervisor/research supervisor is employed: WITS, University of Pretoria

Section B: Details of the Research Project:

1. **Scientific/Engineering merit:** Clusters of galaxies are large collections of galaxies, extremely hot gas and dark matter, forming at the nodes of the cosmic web. As such galaxy clusters are used for studies of cosmic structure formation, gravitational lensing and evolution of galaxies in dense environments (Serra et al. 2016).

Locating galaxy clusters has traditionally relied on methods such as direct detection through optical observations, through X-ray observations of hot intracluster gas or through the Sunyaev-Zeldovich effect and through association of Bent-tailed radio sources. Bent-tailed radio sources are AGN-powered radio galaxies, the structure of which is postulated to have arisen as a consequence of their motion through the intracluster medium (Burns 1998). The non-radio detection methods suffer from issues like dust extinction and large observational time requirements. Bent-tailed radio sources on the other hand can be seen to large redshifts, are not affected by extinction and can be seen in relatively short observational time, especially through highly sensitive new-generational radio telescopes like MeerKAT. With the advent of such telescopes the detection of clusters through observations of Bent-tailed radio sources can become a powerful method.
A caveat in this method is that while all Bent-tailed radio sources have been assumed to be associated with galaxy clusters, the reverse association of how many galaxy clusters host Bent-tailed radio sources has not been examined in detail, particularly in the Southern hemisphere. Simulations show that bent-tailed radio sources prefer relatively massive clusters (Mguda et al. 2015). Recent studies have also failed to fully confirm the association between detected bent-tailed sources with known galaxy clusters (O'brien et al., 2018). While the latter might be attributed to selection effects, a study which looks at the incident rate of bent-tailed radio sources in known galaxy clusters is certainly important.
In brief, the project will examine the galaxy cluster images in the MLCS and identify Bent-tailed radio sources, using both manual and Machine-Learning assisted methods (Aniyan and Thorat, 2017). The incident rate of Bent-tailed radio sources will then be associated with parameters such as cluster redshift, cluster masses and distance from the cluster centre and crossmatch with optical hosts where possible to answer what fraction of galaxy clusters are possible to detect with observations of bent-tailed radio galaxies.

2. **Feasibility**: The project primarily relies on 1) availability of radio data for clusters and 2) ease of detection of bent-tailed radio sources. The first point is addressed by i) access to the pre-existing MeerKAT Legacy Cluster Survey, a large sample of galaxy clusters observed by the MeerKAT telescope, 70% of which are radio selected and the rest are X-ray selected and also by ii) extensive cluster observations in the MeerKAT archival data. At the time of proposal submission, the project outline has been already added as a student-led project in the list of projects for GCLS.
Both the supervisors have access to the GCLS data.
The second point is addressed since both supervisors have experience with morphological classification of radio sources and have also been pioneers in novel methods of morphological classification using Machine learning (e.g. Aniyan and Thorat, 2017).
The project also requires moderate computing facilities, which we plan to address by using Inter-University Institute for Data Intensive Astronomy facilities or in-house computing facilities (both University of Pretoria and WITS have access to excellent computing facilities dedicated to the respective astronomy groups).
We expect the classification and identification of Bent-tailed radio sources in the radio images to take no longer than three months including training the student in the process. The formation of

such a dataset as well as the comparison between manual and Machine-learning bases identification already forms a scientifically useful resource. The calculation of metrics of association between galaxy clusters and bent-tailed sources, and the conclusion of the study is expected to take longer (between eight to ten months), together giving a timescale of one and a quarter year for the project completion including overheads. The rest of the time would be devoted to publication as well as thesis writing.
As such, the project is low-risk, high return venture and is highly feasible.

3. **Link with MeerKAT:** Since the project requires the use of MeerKAT legacy cluster survey, the project is directly linked to the MeerKAT telescope, as mentioned in section 5. The identification of bent-tailed radio sources alone forms an important part of the cataloguing process of cluster sources. The project will also contribute to MeerKAT research by examining the feasibility of Machine Learning methods for MeerKAT images. These outputs are of course supplemented by the main aim of the study, through which we may establish what fraction of galaxy clusters host bent-tailed radio galaxies.
4. **Qualifications needed**: The qualifications needed from the student include a previous degree in astrophysics/physics. Familiarity with radio astronomy would be highly useful but is not necessary. To a much lesser degree, familiarity with Machine learning methods and statistical analysis would be desirable but again, not necessary.

Bibliography:

1. Aniyan, A. K.; Thorat, K., APJS, 230, 20A
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4. Mguda Z., Faltenbacher A., van der Heyden K., Gottlöber S., Cress C., Vaisanen P., Yepes G., 2015, MNRAS, 446, 3310
5. O'Brien, Andrew N.; Norris, Ray P.; Tothill, Nick F. H.; Filipović, Miroslav D, MNRAS, 2018, 481, 4
6. Serra, P.; de Blok, W. J. G.; Bryan, G. L. et al. 2016, https://arxiv.org/abs/1709.01289