Section A: Overview of the Research Project Proposal

1. Academic level:	MSc
2. Broad field of research:	Astronomy/Astrophysics
3. Title of the research project:	A MeerKAT morphological and spectral index study of M87
4. Supervisor:	Prof Roger P. Deane
5. Institution:	University of Pretoria

Section B: Research Project Proposal

1. **Scientific merit:** *describe the objectives of the research project, placing them in the context of the current key questions and understanding of the field.*

M87 is one of the most famous objects in the sky, having been studied from radio to gamma-ray wavelengths for decades. A century ago, Curtis noticed a mysterious "ray" that was pointed directly toward the central nucleus of the giant elliptical galaxy host. This was the first known observation of a resolved synchrotron jet, which has been the subject of detailed analyses ever since. What has been studied to a lesser degree are the more extended radio jets and radio halo, so far only detected by very low-frequency radio observations (LOFAR 15-200 MHz and VLA 327 MHz). M87 is at a distance of ~17 Mpc, affording a number of unique observational opportunities for this class of object, including the recent first imaging of a black hole shadow using mm-VLBI (EHT Collaboration, 2019). While it has been imaged with radio telescopes for decades, there has been a morphological discontinuity between the metre-wavelength observations and cm-wavelength observations that appear to completely resolve out the extended radio jets and halo (VLA 1.5 GHz and upward). In a recent MeerKAT observation of this famous source, we have been able to make an image which successfully recovers this large-scale emission (with just 3% of the total bandwidth), thanks to the sensitivity, dynamic range, and short-spacing imaging fidelity of the MeerKAT telescope.

The primary objectives of this project are to generate a full-bandwidth map of M87 with MeerKAT and study its large-scale radio lobes and halo. This will also enable a detailed comparison with the LOFAR ~50 MHz and VLA 327 MHz maps, as well as reconciling these with the in-band spectral index maps possible with MeerKAT, due to the extremely high SNR. The science driver of this is to measure the spectral index in the outer, more diffuse regions of the map in order to probe the electron cooling history. In order to constrain this reliably, a wide range of frequency coverage is required, as it is a curvature measurement that need be made. Connecting the innermost parts of the M87 central engine as revealed by the EHT and cm-VLBI with the outmost lobes and halo is an important ingredient in assessing the full energy budget in what is often used as a prototypical radio source. This project, through the requisite MeerKAT data, has the potential to provide much greater insight in this connection. In addition, HI absorption may be possible to detection, providing more clues on the evolution of radio source.

2. Feasibility: *outline the methods that will be used to achieve the objectives. Provide details on the availability of required data / access to required equipment / availability of research facilities and other resources required. Include any relevant expected intermediate milestones and associated timeframes towards attaining the overall objectives of the project.*

Calibration and imaging of MeerKAT datasets is a computationally expensive process, however, the University of Pretoria is extremely well equipped to perform this, by virtue of its membership to the Inter-University Institute for Data-Intensive Astronomy (IDIA). All calibration and imaging will be performed on the IDIA cloud.

Since the map with just 20 MHz of bandwidth has been successfully made and is of high fidelity, the primary risk factor associated with this project (bad data), has already been shown to be mitigated. The angular resolution is comparable to the LOFAR and VLA 327 MHz maps, which will simplify the spectral index analysis.

All required MeerKAT data for this project is in hand.

3. **Link the proposed project to one or more of the SARAO research priority areas for 2020** *(refer to Section 4 of the Application Guide), and explain in some detail how the proposed research will contribute to the priority area(s).*

This project of course relates directly to Science topics with MeerKAT, playing a complementary role to a number of MeerKAT Large Survey Projects that aim to further understand radio galaxies (e.g. MIGHTEE, Fornax). Moreover, it is relevant to the data processing and interferometric calibration area, given the significant dynamic range requirements (M87 's peak flux is ~30 Jy at 1.4 GHz).

4. If relevant, describe any particular qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed.

Some experience with interferometric calibration and imaging will be beneficial but not essential.