Section A: Overview of the Research Project Proposal

1. Title of Research Project: A MeerKAT statistical HI search in the Hubble Frontier Field Abell 370

2. Area of Research Science

3. **Academic level:** PhD

4. Abstract:

This project aims to make a statistical (i.e. stacked) detection of HI at z~1 in the volume behind the Hubble Frontier Field cluster, Abell 370. This is partly of a recently approved and highly-ranked MeerKAT UHF-band observing proposal to search for HI in the so-called Great Arc - a highly magnified galaxy at z~0.7 (PI: Tariq Blecher). However, this is a powerful dataset with a wide range of scientific opportunities that this proposed PhD project will exploit, and in turn use the results to plan future MeerKAT UHF observations that are either deeper or of more fields.

5**. Primary Supervisor:** Prof Roger P. Deane

6**. Institution:** University of the Witwatersrand

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.*

The most well studied clusters from a lensing perspective are arguably the Hubble Frontier Fields (HFF, Lotz et al. 2017). The campaign is a dedicated HST and Spitzer Space Telescope program to observe 6 of the most massive (>~ 10^15 solar mass) galaxy clusters that range in redshifts between z~ 0.3 to 0.6. The HFF campaign features photometric data spanning a wide wavelength range from UV to near-IR (0.2–8 micron) and there are hundreds of spectroscopic redshifts per field. Using this dataset, the gravitational potential and associated lensing properties in these fields have been extensively modelled by many independent groups (e.g. Kawamata et al. 2016, 2018, Mahler et al. 2018, Lagattuta et al. 2019).

Our team has used ray-tracing simulations to estimate the HI magnifications, images and fluxes of known sources in the Frontier Fields. From these simulations, we predict that Abell 370 poses the highest probability of a successful lensed HI detection out of the four HFF fields accessible to MeerKAT, and were successful in obtaining a MeerKAT time for this in the most recent Call. However, this PhD project will focus on one or perhaps two additional science application within the same dataset, namely HI stacking at a mean redshift of z~1 and the UHF continuum mapping of the radio halo at the centre of the cluster.

Statistical HI emission measurement at z~1

Stacking is a statistical method that can be used to detect faint HI emission up to high redshifts. The co-adding of HI images or spectra can boost the strength of an HI signal and minimise the noise, producing a statistically meaningful average detection for a sample (e.g. Bera et al. 2019, 2020). This

technique is used to detect sources that might otherwise be too faint to be detected above the noise. We aim to use spectral line stacking in the image domain, i.e. for spectra extracted from sources with known positions and spectroscopic redshifts. The HFF catalogues (Shipley et al. 2018), contain extensive OIR data, including spectroscopic redshifts behind the clusters. Combining this catalog with the recently published MUSE observation Lagattuta et al. (2019) yields approximately 200 sources accessible to the UHF band.

Assuming 10 hours of on-source integration time, and velocity widths of 200\kms, stacking the 78 spectra from the Shipley et al. (2018) catalogue, with the 150 additional redshifts from Lagattuta et al. 2019, we will stack the spectra of 228 sources. For this, we predict an effective rms noise of 6 uJy/beam at z~1, This corresponds to a 5-sigma detection limit of MHI = 3 x 10^{10} solar masses, assuming unlensed sources and an HI mass of MHI = 4 x 10^9 solar masses using an average magnification of mu ~ 7 which is the average magnification obtained via ray tracing simulations of the 78 sources in the Shipley et al. (2018) catalogue.

High-fidelity imaging of the radio halo in Abell 370

A diffuse Mpc-scale radio halo detected in Abell 370 by the VLA at 1.4~GHz and the uGMRT at 325~MHz has been recently published in (Xie et al., 2020). The origin of the halo emission is still debated. With this observation in the UHF band, we will be able to map the halo at an intermediate frequency and hence better constrain the frequency variation between the VLA and uGMRT observations.

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, Wits University is extremely well equipped to perform this with purpose-installed compute servers running all necessary software.

Calibration and imaging of datasets using the exact same correlation mode and field are ongoing and should be well-established by the start of this PhD. Since this project is not critically reliant on HI detection, even though this is expected, since the radio continuum analysis will be compelling enough for an PhD project. The primary supervisor has a strong record of successful proposals on radio telescopes, and his students and postdocs with MeerKAT. The required data for this project is secure and any additional be secured in the next MeerKAT call - either deeper integration on the same field for additional fields, depending on what these data point to is the most effective and promising direction to take.

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 and SARAO Legacy Survey Projects that aim to constrain the

evolution of HI in galaxies as a function of cosmic time, as well as the characterisation of diffuse radio emission in cluster environments.

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.
Some programming experience, particularly with Python will be beneficial.