Section A: Overview of the Research Project

1. **Title of the research project:**
Multiwavelength Study of High-mass Star Forming Region G320.2325−0.2844 Using MeerKAT, ALMA, Spitzer and Gaia

2. Broad area of research:

Science

3. Academic level of research project:

MSc

4. Abstract of research:

Observational study of high-mass star forming regions is gaining more interest and attention because of improved sensitivity and angular resolution offered by newly developed and upgraded instruments around the world. Understanding the formation processes of high-mass stars is very challenging from observational point of view due to the elusive nature of massive protostars. This project will investigate the multiwavelength nature of G320.2325−0.2844 star forming region using MeerKAT, ALMA, Spitzer and Gaia Data, with the aim of characterizing the physical, chemical and kinematic properties of the region. The study will provide valuable insight into the observed evolutionary stages of high-mass star forming regions which has been a subject of astronomical interest. The radio properties of the region will be obtained from the MeerKAT data. The ALMA data will provide the chemical and kinematic properties of the region. The infrared and optical properties of the region will be provided from the Spitzer and Gaia data. Combining the results of these observations will enable one to reconstruct the evolutionary stages of high-mass star forming region.

5. Primary supervisor's details:

1. **Full name of primary supervisor:** Prof James O. Chibueze
2. **Email address:** chibujo@unisa.ac.za
3. **University:** University of South Africa

Section B: Details of Research Project

1. Scientific merit:

High-mass star formation is one of the most promising research areas in astronomy. However, their early formation processes remain poorly understood from observational point of view. This is because

massive protostars are rarely observed, evolve quickly, located at far distance and continue to accrete even in their main-sequence stage. Within the last two decades, observational studies of high-mass stars have advanced considerably due to significant increase in the number of sensitive, high-resolution data sets available at mid-infrared, millimeter and submillimeter wavelengths. Unlike the low-mass star formation, the observed evolutionary stages of high-mass stars formation are still under debate. High-mass star formation is mostly believed to evolve into four stages namely: infrared dark clouds, high-mass protostellar objects, hot molecular cores and HII regions. One of the science goals of SARAO MeerKAT Galactic Plane Survey (SMGPS) is to identify HII regions, which are high-mass star forming regions. G320.2325−0.2844 is one of the known HII regions identified in the SMGPS and a good source to explore ongoing high-mass star formation processes such as outflows, rotating structures (disk or envelope) and episodic accretion.

The radio properties of G320.2325−0.2844 such as the ionizing photon rate and dynamical age will be obtained from the MeerKAT data. The ALMA data will provide the chemical (column density, fractional abundance, chemical age) and kinematic (outflows or disks) properties of the region. Complementary analysis will be carried out using the Spitzer and Gaia data to obtain the photometric properties such as the age, extinction and star formation rate. The study will provide an improved understanding of the observational sequence of evolution of high-mass stars.

2. Feasibility:

Data availability and analysis techniques:

The project will make use of MeerKAT, ALMA, Spitzer and Gaia data. All the data are freely available online and will be downloaded from the hosted websites of the different observations. Observational and analytical techniques will be employed in the study using CASA and python packages.

The procedures will involve calibrating and re-imaging of ALMA data using CASA, extracting the radio and dust continuum properties, analyzing spectral line data, which includes modelling and identification of lines using MADCUBA package, carrying out rotation-diagram analysis, creating moment maps and PV-diagrams using CASA, carrying out Keplerian fitting with SpectralCube and pvextractor packages, calculating the physical properties, such as the mass and column density, estimating the outflow mass, momentum, energy and the driving force of outflows, identifying star clusters using DBSCAN clustering algorithm and estimating the photometric properties.

Resources and equipment:

The IDIA/ilifu cloud computing facilities will be accessible to the student for the purpose of calibration, imaging and analysis of the data. The IDIA support team and other researchers are always available to interact and assist the students in the computing aspect. The student will have usual access to other facilities like desk and office space, internet and library.

High level breakdown of activities:

- - Extensive literature review on massive star formation and HII regions (2026)
- - Calibrate and image the data (2026)
- - Analyze the data (2026)
- - Identify star clusters (2027)
- - Extract spectroscopic and photometric parameters (2027)
- - Calculate the physical properties (2027)
- - Write and submit thesis/paper (2027)

3. Relevance to SARAO research priority areas:

This project falls under the **highest priority area: MeerKAT** for science as listed in the application guide. A detailed study of one of the sources (G320.2325−0.2844) observed in SMGPS will be provided in this project. The project will utilize data from SMGPS, which is already available in the archives and repository.

4. Skills/experience useful to the student on this project:

Good python programming skills and experience in the use of CASA software will be an added advantage. However, student without prior skills and experience will acquire the skills during study.