1. Level of the project: Masters

2. Name of primary supervisor: Prof. Oleg Smirnov

3. Institution supervisor: Rhodes University

4. Name of co-supervisor: Prof. Gianni Bernardi; Dr. Ntsikelelo Charles

5. Institution of co-supervisor: INAF-IRA & Rhodes University, SARAO

6. Contact details of supervisor and co-supervisor: o.smirnov@ru.ac.za; giannibernardi75@gmail.com, ntsikelelo.charles@gmail.com

7. Project title: Observations of the Epoch of Reionization with Hydrogen Epoch of Reionization Array (HERA)

8. Description of project, including the aims and anticipated outcomes, what will be expected of the student, and any special qualifications required (maximum 500 words). Please also stipulate if any specific skills are required (eg, computational skills):

One of the outstanding questions in modern cosmology is to understand how the first luminous structures (stars, galaxies) formed (likely at $z \sim 30$) and how they subsequently evolved and completely ionized the intergalactic medium ($z \sim 6$). These two epochs are generally known as Cosmic Dawn and Epoch of Reionization. One of their best observational probes is the redshifted 21 cm line emitted from neutral Hydrogen, observable in the 50-200 MHz radio window. The Hydrogen Epoch of Reionization Array (HERA, deBoer et al. 2017) is currently is in its final construction stage at the Karoo site, and its goal is to measure the evolution of the 21 cm emission from the Cosmic Dawn to the Epoch of Reionization. The HERA collaboration has recently published the most stringent upper limits on the 21 cm signal in the $6 < z < 10$ range, indicating that the intergalactic medium must have been heated by a population of early sources,

likely X-ray binaries in early galaxies, although with different properties than what observed in the nearby Universe (HERA collaboration, 2022; 2023). In the next season, HERA observations will reach a deeper sensitivity and will likely be able to place tighter constraints on the expected 21 cm signal. The main threat to the detection of the 21 cm signal remains, however, the contamination from foreground emission (i.e. radio emission from our own Galaxy and from the population of extragalactic sources) due to calibration errors.
In this thesis project, the candidate will analyze HERA observations with the goal to make all-sky images and study the foreground properties in unprecedented detail. Very little effort has gone into all-sky imaging within the HERA collaboration, and this project will push the envelope of the analysis of HERA observations. The candidate will produce source catalogues as well as a statistical description of the Galactic diffuse emission that will be used to quantify the contamination to the 21 cm signal from foreground sources, and will help characterize - and, therefore, mitigating - systematic effects.

Familiarity with python programming and radio interferometry is preferable but can also be learned throughout the project.

Supervisor

Oleg Smirnov 14 March 2025