1. Title of research project: Chasing the Cosmic Dawn with HERA

2. Academic level: PhD

3. Supervisor's title and full name: Prof. Oleg M. Smirnov

4. Co-supervisor's title and full name: Prof. Gianni Bernardi, Dr. Cyril Tasse

5. Supervisor's university: Rhodes University

6. Overview and aims of the research project (maximum 300 words):
Our current understanding of the cosmic evolution from the epoch of Hydrogen recombination till the first billion years is very poorly known from an observational perspective, although it must have seen the growth of the initial density perturbations via gravitational attraction into the first stars and galaxies.
The 21-cm transition from neutral Hydrogen promises to be the best observational probe of this cosmic time and has driven the construction of the new generation of low frequency radio arrays including the HI Epoch of Reionization (EoR) Array (HERA) currently under construction in the Karoo.
At present, HERA includes more than 80 dishes and is routinely carrying out observations used for commissioning and early science results. With 350 elements expected to be completed by the end of 2020, it will be the most sensitive 21-cm telescope in the pre-SKA era. A significant instrumental upgrade is currently underway with the deployment of new feeds on the HERA dishes capable to extend the frequency range down to 70 MHz and, therefore, probe the Cosmic Dawn epoch, prior to widespread reionization.
We are seeking for an ambitious PhD candidate who is willing to become an observational 21-cm cosmologist and is ready to face the many challenges that such a field presents. The candidate will be able to participate in the HERA commissioning activities as well as its data analysis towards measurements of the 21-cm signal. In particular, the candidate is expected to work on the analysis of the low frequency (70-120 MHz) data in order to measure the power spectrum from the Cosmic Dawn.
An ideal candidate will have a good background in physics and mathematics, the willingness to learn about advanced radio interferometry, statistics, signal processing techniques and cosmology, but, mostly, the desire to contribute to the 21-cm cosmology revolution.

7. Relevance of the research proposed to the priority areas of MeerKAT and / or SKA refer to the application guide (maximum 200 words):
This project is part of the “Epoch of Reionization and Intensity Mapping data reduction and analysis” research area and has a significant connection with the “Interferometric Data Processing and Analysis, including calibration and imaging” research area. It uses data from one of the Karoo telescopes (HERA) that is an SKA precursor and has a significant South African partnership (through SKA SA and various SA universities).

8. Research work breakdown:

a. Research work structure for Year 1.
HERA is now well underway with 80+ dishes (and counting) under construction and commissioning is continuing as the array grows, with the first scientific results already appearing (e.g., Kohn et al. 2018, Carilli et al. 2018). Our group has been involved in the analysis of HERA data, in particular by producing the first all-sky images, developing an advanced calibration method (Grobler et al. 2018) and investigating foreground subtraction methods (Ghosh et al., in prep.).
In its first year, the candidate is expected to learn the principles of radio interferometry, with particular focus on the specific 21-cm techniques relevant for HERA, like redundant calibration and full-polarization imaging with a drift scan array, foreground subtraction and power spectrum estimation. The candidate is also expected to take part in the HERA commissioning activities.

b. Research work structure for Year 2.
During its second year, the candidate is expected to keep working on the commissioning of HERA data, particularly on the calibration and power spectrum estimation. The student will apply the standard calibration and power spectrum pipeline developed by the HERA collaboration with particular focus on the Cosmic Dawn epoch, i.e. the low frequency (< 110 MHz) range. This focus is motivated by the recent claimed detection of a global 21-cm signal absorption trough at 78 MHz (Bowman et al. 2018). This signal was found twice as bright as the most optimistic models, sparkling a huge number of interpretations that require exotic physics like collisional dark matter (e.g., Barkana et al. 2018).
If the signal is indeed so bright, HERA is the best telescope to confirm it via the measurement of its power spectrum and this will be the focus of the student's second year of work.

c. Research work structure for Year 3.
In its third year, the candidate will continue to work on the extraction of the power spectrum from the Cosmic Dawn in order to confirm the claimed 21-cm global signal. Depending upon the challenges found along the path (calibration, foreground subtraction), the student will take advantage of the calibration and foreground methods developed by our group in order to improve the analysis.
We anticipate that the candidate will make significant contribution to HERA in order to become a member of the builders list, granting its co-authorship on all the papers including HERA data (according to the collaboration rules). For an ambitious candidate, the detection of the 21-cm power spectrum from the Cosmic Dawn would be the culmination of their thesis work and an absolutely groundbreaking result.

9. Availability of required data / access to required equipment / availability of research facilities and other resources required (maximum 200 words):
The co-supervisor is one of the HERA co-PIs and has full access to the HERA data. The student will have the same rights. The Radio Astronomy Technologies and Techniques (RATT)

group established at Rhodes maintains a cluster consisting of 8 “fat” nodes (512GB RAM, 16-48 CPUs per node) with plenty of attached storage. This has, so far, supported a variety of efforts, including the analysis of PAPER and HERA data. The student will have access to this cluster, which is entirely adequate for the proposed project.

10. Signature of supervisor and date of proposal submission

31 August 2018