Section A: Overview of the research project

Project title:
UHF-COSMOS: Studying the fuelling and feedback of star-formation and AGN activity with MeerKAT

Broad area of research: Science
Academic level: PhD (Doctoral)

Abstract:

Primary Supervisor's Details
Name: Dr Jacinta Delhaize (UCT)
Email: jacinta.delhaize@uct.ac.za
Institute: University of Cape Town

Section B: Details of research project

Scientific merit:

Two important components of galaxies, which are thought to play important roles in their evolution, are the neutral hydrogen gas (HI) content and active galactic nuclei (AGN) activity. Yet very little is known about the relationship and interplay between these components and their host galaxies, particularly towards higher redshifts. Studies have previously been restricted by the sensitivity of available radio telescopes. However, with the sublime sensitivity and instantaneous uv coverage of South Africa's MeerKAT telescope, we are now entering a realm where we will be able to more directly examine the gas fuelling star formation and AGN activity, as well as the influence of subsequent AGN feedback on the gas in their host galaxies. This project will take advantage of the revolutionary HI and radio continuum observation powers of MeerKAT to understand the interplay between gas, star formation and AGN over cosmic time.

The project is primarily focused on taking full advantage of the MeerKAT Open Time Project UHF-COSMOS (Proposal ID: SCI-20210212-JD-01, PI: Delhaize, Technical Lead: Heywood). This is a single pointing (8hr track) in the COSMOS field with the UHF band receiver in 4k mode. The original purpose of the Open Time proposal was to conduct a spectral index analysis of giant radio galaxies in COSMOS. This particular science case is currently approaching completion (Charlton, Delhaize, Thorat, Heywood et al., in prep), however the UHF-COSMOS data still contain untapped treasure troves of exciting science. This project will encompass both continuum and spectral line aspects.

Aims for the continuum aspect of the project are:

- Perform and optimise source finding on the UHF-COSMOS continuum maps using ProFound, PyBDSF or similar.
- Cross-match with the MIGHTEE L-band continuum source catalogue (Whittam et al., 2022) and determine spectral indices of compact sources.
- Optimise spectral index determination for extended objects. This may require a re-reduction of the data with different uv tapering or robustness parameters.
- Combine with deep multiwavelength data in the field to classify previously uncatalogued radio sources as star-forming galaxies, high excitation radio galaxies or low excitation radio galaxies.
- Analysis of source counts, luminosity functions or other appropriate statistical properties and/or analysis of individual objects of interest. There is scope in the project here for submitting follow-up multiwavelength observing proposals.

Aims for the spectral line aspect of the project:

- Inspect the preliminary spectral line reduction of the UHF-COSMOS data
- Perform a re-reduction as necessary, with improved continuum subtraction and cleaning.
- Perform spectral line source finding for HI gas and OH masers in absorption and/or emission
- Source characterisation and analysis as appropriate

- Spectral stacking analysis to search for high redshift statistical detections. This could involve comparison with the continuum data to investigate HI content of AGN. This may be challenging due to the low spectral resolution (4k) and limited sensitivity (single track) of the data, so an preliminary feasibility study will first need to be conducted.

Depending on the interests and abilities of the candidate and the outcomes of the UHF-COSMOS analysis, the scope of the project can be expanded to incorporate involvement with the MIGHTEE (HI emission, HI absorption, continuum), and/or LADUMA (HI) large survey projects. For example, a comparison with lower-redshift results in the COSMOS field (MIGHTEE L-band) could be conducted, or a comparison with similar redshift results in a different field (LADUMA UHF-band).

Feasibility:

This project will optimise the science output of MeerKAT Open Time Project UHF-COSMOS (Proposal ID: SCI-20210212-JD-01, PI: Delhaize, Technical Lead: Heywood). The data were collected in 2021 and have since been thoroughly processed and imaged for continuum using OxKAT on ilifu (Delhaize, Heywood et al., in prep).

This project is entirely feasible since the observations have already been conducted, the continuum images already produced, and an initial attempt at HI spectral cube construction already made (Heywood). UHF-COSMOS is already an IDIA-supported project and appropriate computing and storage resources have already been allocated.

Delhaize has expertise in radio continuum and spectral line surveys, source finding, source characterisation and statistical analyses. Delhaize also has strong connections with the Observational Cosmology group at the University of Oxford (Lead: Jarvis, Senior researcher: Heywood). This project will be conducted in close collaboration with the Oxford research group, with potential for establishing formal co-supervision and research visits (pending appropriate funding). Heywood and Jarvis can particularly provide further expertise on data processing and analysis.

Within the scope of the proposed project is collaboration with the MIGHTEE and LADUMA MeerKAT LSP teams. Delhaize is an active and key member of both (e.g. co-lead of the LADUMA source finding provider working group) and is very familiar with the available data products, team policies and scientific scope. Similarly, Delhaize is a member of the multiwavelength COSMOS collaboration, and has access to proprietary data products such as spectroscopic redshift catalogues.

SARAO research priority areas:

This project is entirely based on science with MeerKAT, which is the top priority area identified by SARAO. Please see previous sections for further details.

Qualifications and experience:

- Requires an MSc or equivalent in astronomy, physics or closely related field.
- Candidate should be proficient with python and Jupyter notebooks and basic unix commands
- Experience with one or more of the following is highly beneficial but not required:
  - Source finding packages (e.g. profound, pybdsf, SoFiA)
  - MeerKAT continuum or spectral line reduction pipelines (e.g. OxKAT, processMeerKAT, Caracal)
  - Data visualisation software (e.g. Carta, ds9, Aladin)
  - Catalogue manipulation packages such as TopCat, astropy Tables or pandas
  - 21cm emission or absorption line analysis
  - Radio source classification and/or analysis

Section C: CV of primary supervisor

Please see below.

Curriculum Vitae - Dr Jacinta Delhaize

Contact Information

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Overview

Lecturer and research astronomer at the University of Cape Town with extensive experience in the field of galaxy evolution and extragalactic radio astronomy. Committed to the advancement of astronomy through pioneering research, dedicated teaching and supervision, and active large-scale public engagement. Passionately focused on empowering the next generation of African astronomers and science communicators to fully harness the transformative and revolutionary capabilities of the upcoming SKA Telescope.

Education

- **PhD,** Astronomy/Astrophysics, University of Western Australia, 2014
- **Bachelor of Science** (Physics) + First class Honours, University of Western Australia, 2008

Professional Experience

- **Lecturer/Academic Faculty** - Astronomy Department, University of Cape Town, South Africa.
    - **Period**: 1 Feb 2022 - ongoing (permanent)
    - **Key Responsibilities:**
        - Course coordinator and lecturer for AST3003S Galactic and Extragalactic Astrophysics.
        - Primary supervisor of four MSc students and one PhD student, and “RADHIANCE” research group leader.
    - **Research focus:** The RADHIANCE group uses SKA precursor telescopes to understand the cosmic evolution of hydrogen gas content, AGN activity and star formation in galaxies.

- **SARAO Postdoctoral Research Fellow,** Astronomy Department, University of Cape Town, South Africa. (Jul 2018 - Jan 2022)
- **ERC Postdoctoral Researcher,** Physics Department, University of Zagreb, Croatia. (Apr 2014 - Apr 2018)

Teaching Experience

- **Course**: AST3003S - Galactic and Extragalactic Astrophysics (3rd year undergraduate full semester course. 36 credits.)
    - 2023: 24 students. Course coordinator, Full-course lecturer (60 x 45min lectures)
    - 2022: 20 students. Course coordinator, Half-course lecturer (30 x 45min lectures)
    - 2021: 42 students. 2 x 45min guest lectures.

Postgraduate Supervision Experience

- **Primary Supervisor (Graduated students)**
    - Honours: Muphulusi Nekhavhambe, 2023, University of Cape Town.
    - Honours: Kathleen Charlton, 2022, University of Cape Town.
    - Honours: Leyya Stockenstroom, 2021, University of Cape Town.
    - Masters: Lana Ceraj, 2015, University of Zagreb.
- **Primary Supervisor (Current students)**
    - PhD: Tumelo Mangena, Oct 2022-ongoing, University of Cape Town.
    - MSc: Leyya Stockenstroom, Jul 2023-ongoing, University of Cape Town.
    - MSc: Ndivhuwo Mangena Jul 2023-ongoing, University of Cape Town.
    - MSc: Kathleen Charlton, Jan 2024-ongoing, University of Cape Town.
    - Occasional/MSc: Kale Boyes, Jan 2024-ongoing, University of Cape Town.

Recent Research Activity

- **Publications:** 45 refereed publications. Total citations: 43. H-index: 20. Two first-author publications with over 100 citations each (Delhaize+2013 and Delhaize+2017). For full list, please see http://tinyurl.com/yc8r5yxk
- **UCT Research Development Grant recipient:** Q2 & Q4 2022, Q2 2023. Total awarded: 129,619 ZAR. To fund research visits to the University of Oxford.
- **Research visit to the University of Oxford.** Q2 2023. 1 month collaboration visit with Prof Matt Jarvis and Dr Ian Heywood. Established formal Oxford co-supervision for 3 UCT MSc students. Resulted in ~1,600 GBP funding from the University of Oxford to host a research visit for students Stockenstroom and Charlton in Q3 2023. Assisted with advocating for Oxford-based PhD scholarships for African students from potential funder (details confidential).
- **Technical Lead:** Successful MeerKAT Open Time 2022 Proposal "The Interaction of NGC 4532/DDO 137 with the Virgo cluster." 8h.
- **Principal Investigator:** Successful MeerKAT Open Time 2021 Proposal "Low frequency follow-up of giant radio galaxies that shouldn't exist!". 8h.

Recent Committee Work

- **Chair, Astronomy Department Transformation and Inclusivity Committee** (2019-present).
- **Chair, Postgraduate Advisory Committee:** For UCT PhD student Malebo Moloko. Nov 2023.
- **Faculty of Science Transformation Committee,** member (2022-present) and Ad Hominem Promotions Subcommittee (Jan 2024-ongoing).
- **Candidate Selection Committee**, member Q4 2023-ongoing: For the position of Technical Officer in the Astronomy Department.
- **UCT Astronomy Departmental Review Committee**, member. Q3 2022 - present.

Recent Service Roles and Memberships

- **Provider Working Group Co-lead:** LADUMA Source Finding. 2020 - present.
- **SOC Member,** LOFAR-MeerKAT Collaboration Meeting. Nov 2022-present.
- **Invited editor:** 2020 Astronomy Special Edition of Science Matters, the NRF stakeholder magazine. Oct 2020. bit.ly/3wppYk9
- **External thesis examiner:**
  - MSc thesis, University of Pretoria, Nov 2022.
  - Honours thesis, Jan 2021, University of Cape Town.
- **Peer Reviewer for high-impact academic journals:**
  - Astronomy and Astrophysics (Q4 2022, Q4 2023),
  - Monthly Notices of the Royal Astronomical Society (Q2 - Q4 2022, Nov 2021),
  - The Astrophysical Journal (Jul 2021),
  - The Astronomical Journal (Apr 2019).
- **Observing proposal reviewer:**
  - International TAC Reader for the Australia National Telescope Facility. 4 semesters. Jan 2019 - Dec 2020
  - uGMRT observing proposal, Feb 2021
  - JCMT observing proposal x2, Apr 2021 & Oct 2019.
- **Invited Referee:** Postdoctoral Researcher application to the Estonia Research Foundation
- **Professional memberships:**
  - International Astronomical Union. Division J: Galaxies and Cosmology; Division C: Education, Outreach and Heritage. (2017-present). African Network for Women in Astronomy (2021-present). SKA HI and Continuum Working Groups (2023-present). South African Institute of Physics (2022-present).

Recent Science Communication Output (Abridged)

- **Founder, Producer, and Host, The Cosmic Savannah Podcast**: Created and led a pioneering science communication platform to share the wonders of the universe with a global audience, highlighting the work of African astronomers and the potential of the SKA telescope. Launched in 2019, ongoing.
  - **Finalists for the 2021 South African National Science Award**: Communication category.
  - Funding procurement: 2 x 60,000 ZAR financial support from the South African Agency for Science and Technology Advancement (SAASTA). (2021, 2022)
  - **Science Podcasting Bootcamp:** Developed and delivered a series of science communication workshops to South African scientists and astronomy postgraduate students (in collaboration with SAASTA).
- **TEDx Speaker, "How Can Giant Telescopes Help Humanity?"**. Mandurah, Western Australia. Apr 2023. https://www.youtube.com/watch?v=-L_uwGI1W98
- **Press release:** Wrote and coordinated the international press release associated with Delhaize et al., (2021), MNRAS: "Gigantic galaxies discovered with the MeerKAT telescope" (*bit.ly/3u9mNf1*). Altmetric Attention Score: 405.
- **Dean's Award of Special Acknowledgement** "for the popularisation and promotion of science". Faculty of Science, University of Zagreb. (Apr 2018)