Section A: Overview of the Research Project

TITLE: Multi-Wavelength Studies of Infrared-Bright SFGs and AGN with MeerKAT

AREA OF RESEARCH: Science

ACADEMIC LEVEL: Master

ABSTRACT: IR/submm-bright galaxies dominate the star formation rate density of the Universe at redshift z=1-3. Both star formation and AGN activity are contributing to the high infrared/submm luminosities of these objects, but the underlying physics of such emission is still under debate. In this project, we aim to contribute to the understanding of the nature of IR/submm galaxies by exploiting Radio and multi-wavelength datasets.

PRIMARY SUPERVISOR: Dr Lucia Marchetti, lucia.marchetti@uct.ac.za, University of Cape Town

CO-SUPERVISORS:
Prof Mattia Vaccari, mattia.vaccari@uct.ac.za, University of Cape Town
Dr Carlotta Gruppioni, carlotta.gruppioni@inaf.it, INAF-Bologna Observatory

Please note that all supervisors here indicated will be responsible for supervising the student's research.

Section B: Details of Research Project

SCIENTIFIC MERIT: Herschel enabled the observations of the "obscured" side of galaxy evolution, finding that the peak of the SF rate density, SFRD, is dominated by objects defined as SF-AGN "composite" objects (Gruppioni et al. 2013, 2015), showing both SF and AGN activity in their broad-band spectral energy distribution (SEDs, from UV to far-IR). Interestingly, these Herschel high-z objects, which are more difficult to observe, appear to show the same SEDs of local IR galaxies such as the IRAS Revised Bright Galaxy Sample - RBGS, Sanders et al. 2003 or the IRAS 12-µm Galaxy Sample - 12MGS, Rush et al. 1993. These IR local galaxies can thus be exploited as a gateway to understanding the physics at play not only in the low-z regime but also in their high-z analogues. With this in mind, we have started coordinated observing campaigns with MeerKAT and SALT to study these sources in great detail. In particular, we have already obtained MeerKAT snapshot observations (MeerKAT survey of the RBGS "MeerLIRGs", PID: SCI-20210212-TJ-01, PI: Jarrett) of ALL the 298 RBGS (S(60µm) > 4.24 Jy) distributed across the Southern sky (Condon et al. 2021, Moloko et al. 2024 – MNRAS submitted) and for 43 complementary 12MGS sources (PID: SCI-20220822-LM-01, PI: Marchetti). A wealth of multi-wavelength data is already available for these sources, including SALT optical spectra and Spitzer IRS mid-infrared spectra for the 43 12MGS objects. Combined with radio data and spectral models, this makes it possible to strongly constrain the AGN and the SF activities in these galaxies.

The MSc student will become part of the MeerLIRGs team and will have the opportunity to exploit the MeerKAT data and corresponding multi-wavelength data to work on one (or more) of the following scientific topics, based on his/her skills and interests:

- We will separate the contributions of star formation and AGN activity using e.g. multi-wavelength SED fitting analysis with CIGALE. SFGs have global FIR/radio flux-density ratios in a narrow range around S(60µm)/S(1.4GHz) ~100, and significantly lower ratios reveal radio-loud AGN. For resolved galaxies, we can measure spatially-resolved FIR/radio ratios to pinpoint AGN emission and perform spatially-resolved multi-wavelength SED fitting analysis to identify how the star formation rate changes in the different regions of the galaxies.

- The RBGS is the best (complete) sample of luminous star-forming galaxies in the nearby universe. We will obtain total flux densities from MeerKAT (Southern Sources) and VLA (Northern Sources) images to constrain the local radio luminosity function (Mauch & Sadler 2007; Condon et al. 2019) of starburst galaxies, especially LIRGs with 10^23 W/Hz < L(1.4 GHz) < 10^24 W/Hz, and specify the recent star-formation rate density with the lowest possible statistical errors, limited only by cosmic variance in the all-sky volume extending to lookback times $\tau \sim 1$Gyr. This luminosity range is dominant when most stars were formed near the "cosmic noon" at redshifts $z \sim 2$, and we will use it as the best available local anchor for radio models constraining the evolving star-formation history of the universe (Mauch et al. 2020a).
- Accurate radio positions pinpoint the locations of the compact optically-obscured starbursts in galaxy mergers. Their far-infrared and/or radio luminosities accurately measure their star formation rates, and their 2MASX (Jarrett et al. 2000) 2-μm luminosities are good proxies for their stellar masses. We will use the subsample of our sources with the best multi-wavelength data and the results of CIGALE SED fitting to carefully assess the accuracy of our estimates based on monochromatic luminosities. We will combine radio positions, sizes, and luminosities with IR data to compute the specific star-formation rate (SSFR=SFR/SM) of our objects and trace the evolution of starburst activity as a function of merger-stage progressing from close pairs of disk galaxies through compact starbursts in "train wrecks" to quenched elliptical galaxies.
- We will measure the radio fluxes of the sources detected in the extended pointings of MeerKAT around our targets. All the pointings together covers ~300 square degree in the southern sky so by measuring the fluxes of all the sources detected we will provide a radio catalogue that can serve several other targeted studies in other bands.

FEASIBILITY: The project relies on the exploitation of MeerKAT and SALT data that have already been collected and processed. Moreover, the student will have access to IDIA's ilifu cloud computing facility where we expect that most of the analysis will be carried out. The student will be based at UCT and will thus have access to the direct technical and scientific support provided by (the supervisors and) the IDIA researchers. The student will also be able to visit Dr Carlotta Gruppioni in Italy. Travel funding will be available to the student to travel to INAF-IRA through the ISARP RADIOMAP Joint Research Scheme (DSI-NRF Grant Number 150551).

RELEVANCE TO SARAO RESEARCH PRIORITY AREAS: This project falls under the highest priority area for science (exploiting MeerKAT).

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Education & Professional Qualifications

Academic Qualifications

2006 **BSc in Astronomy**, *University of Padova, Italy*.

2008 **MSc in Astronomy**, *University of Padova, Italy*, 110/110 Cum Laude.

2012 **PhD in Astronomy**, *University of Padova, Italy*.

Professional Qualifications

2016 **Postgraduate Course in Science Communication - *Science Communication: an introduction to theory, best practice and practical skills***, *Centre for Research on Evaluation, Science and Technology (CREST), University of Stellenbosch, South Africa*, NQF level 8, Credits 15.

2022 **NRF Rating**, *SA National Research Foundation*, C Rated.

Research & Academic Experience

- Extensive knowledge of multi-wavelength astronomy observing principles and of the scientific applications and exploitations of multi-wavelength observations.
- Extensive knowledge of studies of the statistical probes for Observational Cosmology Studies such as luminosity/mass functions, star formation rate estimators and strong lensing search and multi-wavelength characterisation.
- Extensive experience as PI or co-PI of observing proposals with a number of international observing facilities
- Extensive experience in image processing and source extraction techniques.
- Extensive experience with 2D and 3D visualisation software (VR and digital planetaria) for astronomical and multi-disciplinary research.
- Extensive experience in creating and managing large astronomical databases, including the the production and public release of multi-wavelength source catalogues and related documentation
- Extensive experience interfacing with Community Support Groups, Mission Planning and Data Processing Teams.
- Experience designing and working with both ESA-led space missions (Herschel, Euclid) and international space missions (Hubble, Spitzer, Akari).
- Extensive experience supervising PhD students, Masters, Honours and Bachelor students (6 Honours, 1 Bachelors, 4 MSc, 3 PhD students (co)supervised in the period 2017-2023).
- Extensive experience in undergraduate teaching, tutoring and mentoring.
- Extensive experience in giving contributed and invited talks at scientific conferences/meetings and technical workshops.
- Extensive experience liaising with academic and University management boards at the highest levels.

Project Management & Engagement Experience

- Extensive project management experience within both academic research projects, international scientific collaboration and University/public facilities (e.g. laboratory and Planetaria)
- Extensive experience in managing big collaborations and working as part of a team either as a team member or as (an elected) board/exec member, working group chair of international consortia/professional bodies
- Broad experience in writing funding requests to National and European funding agencies (e.g., the *European Commission*, the *Science and Technology Facilities Council* - STFC in the UK, the DSI/NRF in SA and the Italian Ministry of Foreign Affairs and International Cooperation).
- Project management experience within both academic projects and National (SA, UK, IT) or International science communication & education projects.
- Experience in administrative and financial management of national/international projects.
- Experience in creating and maintaining a website as well as in creating contents for media releases.
- Experience liaising with policymakers and stakeholders at the National (SA and UK) and International level.
- Knowledge of impact evaluation strategies for both National (SA, UK and Italy) and International projects.
- Extensive experience in transferring and filtering my technical and scientific knowledge for educational and communication purposes

- Extensive experience in public speaking and in liaising with the media including video/audio interview recording
- Experience in planning, organising and hosting international workshops and conferences.

Employment History

Academic & Research appointmens

Nov 2012 – March 2017 **STFC Post-Doctoral Research Associate in Astronomy**, *the Open University, Milton Keynes, UK.*
• Develop statistical studies of galaxy formation and evolution processes combining multi-wavelength observations • Leadership within the Herschel/ATLAS and Herschel/HerMES Consortia in the identification, follow-up observations and physical classification of strong gravitational lensing candidates exploiting all the Herschel Extragalactic Surveys (∼1000 deg^2) and multi-wavelength observing programs.

April 2017 – Feb 2020 **SARChI Post-Doctoral Research Fellow in Astronomy**, *the University of Cape Town & the University of the Western Cape (joint position), Cape Town, SA.*
• Galaxy formation and evolution research from a multi-wavelength perspective • Teaching Assistant and Course Coordinator for the course *Introduction to Galaxies and Cosmology* (PHY327) • PI of the multi-cycle (cycle-25, cycle-26) HST snapshot proposal: "SNAPshot observations of the largest sample of lensed candidates in the Equatorial and Southern Sky identified with Herschel".• PI of 2 observing programs with the South African Large Telescope (SALT) • Student supervision

Jan 2019 – present **IDIA Visualisation Lab Project scientist/Deputy Director**, *University of Cape Town, Cape Town, SA.*
• Managing the development of the VR software iDaVIE • Manage the operations of the lab and of the developers team (2.5 people) • Develop the new strategy of the lab integrating multi-disciplinary aspects and collaborations • Manage the international collaborations of the lab • Supervise students working on data visualisation projects

March 2020 – present **Senior Lecturer in Astronomy**, *University of Cape Town, SA.*
• Lecturer of the second year undergraduate course *Astrophysics* (AST2002H) `http://www.ast.uct.ac.za/ast/undergraduate/ast2002h` • Galaxy formation and evolution research from a multi-wavelength perspective • SA co-I in the EU funded project *SKilled, Innovative & Entrepreneurial Scientists*, SKIES (Call: EC-H2020-SwafS-2020-1; Grant Agreement: 101006212), devoted to create and deliver training for astronomy PhD students and early career researchers on innovation and entrepreneurship • Co-PI of the NRF ISARP 2023-2025 Italy-SA Bilateral program RADIOMAP+ aimed at foster the collaboration of the two countries in the SKA era • 4MOST Hemisphere Survey of the Nearby Universe (4HS) Survey exec member as Data Management Unit/Catalogue/Database Manager. • Students supervision at different academic levels. • Board member of the UCT Science Faculty Research Committee, a committee that oversee the faculty's research strategy, postgraduate and funding matters.• Exec member of the International Astronomical Union (IAU) Division J *Galaxies & Cosmology*, the international representative body for professional astronomers.

Vocational - Science Communication, Public engagement and Project Manager Roles

Jan 2014 – March 2016 **Chair of the Education & Outreach UK National working group for the *International Year of Light 2015* (IYL2015) UNESCO initiative**.

Jan 2014 – Oct 2016 **Project manager of the Open University participation as gold international sponsor in the *International Year of Light 2015* (IYL2015) UNESCO initiative**.

Jan 2017 – 2020 **Project Manager & Scientific Advisor of the "Hemelliggaam, or the Attempt to be here now" art project.**, *`https://www.hemelliggaam.com`*.

Jan 2019 – present **Coordinator of the Soapbox Science Cape Town initiative**, *`http://soapboxscience.org`*, An outreach project to promote women in science.

Jan 2019 – present **Past president/advisor of the African Planetarium Association**, *`https://africanplanetarium.org/`*.

Student supervision

Starting from 2016 to date I have supervised **6 honours** NASSP (National Astrophysics and Space Science Programme) students all affiliated at the University of Cape Town
All NASSP students successfully completed their honours and continued with their Masters at the University of Cape Town and at the University of the Western Cape. Between 2018 and 2021 I have served as advisor for **PhD student Mr Marc Yao Fortune Harris at the University of Cape Town**, who was under the supervision of Prof. Tom Jarrett, Dr Michelle Cluver and Prof. Mario Santos. His thesis aimed to study the statistical properties of WISE selected galaxies in the GAMA-23 survey.
In 2020, when my position changed to academic, I have co-supervised a **Masters student (Mr Edoardo Borsato) and a Bachelor student (Miss Cecilia Giorgi) at the University of Padova** in collaboration with Prof. Enrico Maria Corsini (University of Padua, IT) and Dr Mattia Negrello (University of Cardiff, UK). Mr Borsato successfully obtained his

Masters with distinction in October 2020 and Miss Giorgi successfully completed her Bachelor degree in Astronomy both at the University of Padua. Mr Borsato has then started a **PhD under my co-supervision** continuing with the analysis he started in his Master. He should complete his PhD in 2023. The analysis conducted by Mr Borsato has already contributed to works published in 2021 (e.g., Berta et al. 2021), others published in 2022 (e.g., Dye et al. 2022 and Liu et al. 2022) and more to come in 2023.
In 2020 I have also supervised **Miss Valentine Nyirahafashimana**, a **Master's student at the University of Rwanda**, East African Institute for Fundamental Research (ICTP- EAIFR). She obtained her degree in February 2021. In 2020 I have also started to serve as co-supervisor for **Mr Alex Sivitilli**, a **PhD student at the University of Cape Town** who successfully graduated in 2023.
In 2021 I have started to supervise **Miss Malebo Ella Moloko, a PhD student at the University of Cape Town**, together with Prof. T. H. Jarrett. She is due to complete her PhD in 2024. Between 2021 and 2023 I have supervised (together with Prof. Julien Larena and Dr Pierre Fleury), **MSc students Mr Daniel Johnson**, who has conducted a thesis focused on the analysis of the line-of-sight effect in strong gravitational lensing events. Mr Johnson has graduated with Distinction in 2023.
Finally, starting in 2023, I have started supervising **Mr Boaz Keren Gil in his MSc in Computer Science at the University of Cape Town**. Mr Keren Gil has developed a prototype software for the extension of the VR software iDaVIE-p under development in the IDIA visualisation lab. He has submitted his thesis and is due to graduate in 2024.

Publications, Talks and Grants

Publications

2010 - present Published **155 publications of which 109 are papers on refereed journals** (the rest are proceedings and other publications/products), 18 of which have received more than 100 citations each. The number of citations generated by refereed papers is 6001, leading to an Hirsch impact factor with an **h index of 40**. A complete list of my publications is attached, but it is also available online through the SAO/NASA Astrophysics Data System (`https://bit.ly/3OvTgKa`) or Scopus.

Talks

2009 - present >20 Astronomical public conferences/discourses/posters and workshop with general public, students, teachers and amateur astronomers. An **average of 2 public talks a year.**

2009 - present >30 scientific talks at international conferences/workshops. An **average of 3 contributed talks a year** at international conferences/workshops.

2012 - present **12 invited contributions at international conferences, workshops or events.**

Grants

2014 - 2015 Open University internal grant to manage the Open University IYL2015 initiatives (10 kGBP).

2015 Royal Astronomical Society grant to co-produce an animation for the International Year of Light 2015 (1.5 kGBP).

2015 SEPnet grant to co-produce an animation for IYL2015 (1.5 kGBP).

2015 SEPnet grant sponsorship to participate to "Soapbox Science 2015 - Bringing science to the public" (`soapboxscience.org`).

2015 Royal Astronomical Society travel grant to attend the International Astronomical Union General Assembly (1 kGBP).

2015 International Astronomical Union travel grant to attend the International Astronomical Union General Assembly (1.5 kUSD).

2015 Merit Award from the Faculty of Science ad the Open University in recognition of the work done for the International Year of Light 2015 (1.5 kGBP).

2016 South African DST-NRF visiting fellowship for young researchers from the UK (220 kZAR).

2017-2020 3-years long SA National Research Foundation grant to develop/manage the *Hemelliggaam* project as part of the NRF History of Astronomy Roadmap (1 MZAR), `https://www.hemelliggaam.com`.

2019 SA National Research Foundation and Department of Innovation grant to coordinate the Soapbox Science project in Cape Town (60 kZAR), `http://soapboxscience.org`

2019 ADASS2019 travel grant to attend the ADASS2019 conference (15 kZAR)

2020-2021 SA National Research Foundation and Department of Innovation grant to coordinate the Soapbox Science project in Cape Town (40 kZAR), `http://soapboxscience.org`

2021-2022 EU Horizon Grant - EC-H2020-SwafS-2020-1 - in support of the 2 years SKIES project (20 kEUR were given to UCT, of the 300 kEUR granted to the entire consortium made of 7 partner Institutions)

2021 UCT Enabling Grant Seeker Excellence Awards to support the SKIES project (20 kZAR)

2022 UCT Seed Research Grant in support of Rated Researcher (20 kZAR)

2022 NRF grant in support of Rated Researcher (50 kZAR)

2023-2025 NRF Incentive Research Grant in support of rated researchers (720kZAR over three years)

2023-2025 NRF ISARP 2023-2025 Italy-SA Bilateral program RADIOMAP+ (co-PI; 1.5 MZAR over 3 years)

2021-present An average of 6kZAR a year of UCT block grant for publication records and student supervision.

Experience in Organisation meetings & Public Events - some highlights

2014 LOC member of the International Workshop: "Workshop on LM-band spectroscopy with the E-ELT", held at the Open University, Department of Physical Sciences, Milton Keynes (UK).

2015 Co-organiser of the UK IYL2015 Opening Ceremony at Saint James Palace, London (UK).

2015 Co-organiser of the IYL2015 dedicated "Lates" event at the Science Museum, London, UK (`http://www.sciencemuseum.org.uk/visitmuseum/plan_your_visit/lates`).

2018 Organiser of the Hemelliggaam art exhibition at the Iziko Museum, Cape Town.

2019 Co-organiser of the `Data2Dome` workshop at Colgate University `http://www.datatodomecolgate.org`, October 18,20, 2019.

2019 – present Project coordinator & event organiser of the Soapbox Science Cape Town project. `http://soapboxscience.org/cape-town-local-organising-team/`

2020 LOC member for the conference *Cosmic flow, large scale structure & Visualisation*, 17 - 21 February, 2020, Stias, Stellenbosch `https://www.idia.ac.za/cosflow2020/`.

2022 Organiser of the SKIES training workshop and mentorship program for postgraduate and early career researchers, 4 - 8 April 2022, UCT Graduate School of Business Conference Center, Cape Town, SA, `https://www.groundstation.space/skies-training-and-mentorship-programme-south-africa/`.

2022 LOC member of the conference "SPARCS XI: The Rise of Sky Surveys", November 21 – 25 2022, Pretoria, `https://www.idia.ac.za/sparcs-2022/`

2023/2024 SOC member of the Focus meeting "All-Inclusive AGN" that will take place during the IAU GA in Cape Town, August 2024