SAAO PhD and MSc projects

Transients in the Rubin Observatory LSST Era

Supervisor:
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Potential Co-supervisors:
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Students will be registered at either the University of Cape Town (UCT), the University of the Free State (UFS) or North West University (NWU).

The supervisor is the South African PI Affiliate for Rubin Observatory LSST transient science, leading a team currently including 3 of the named potential co-supervisors (Potter, Pretorius & Woudt) and 3 graduate students. Many of the activities will involve existing and new international collaborations. Our programme focuses primarily on the various object classes, science drivers and preparatory activities within the RO-LSST *Transients and Variable Stars (TVS)* science collaboration, plus related projects within the *Stars, Milky Way and Local Volume (SMWLV)* collaboration.

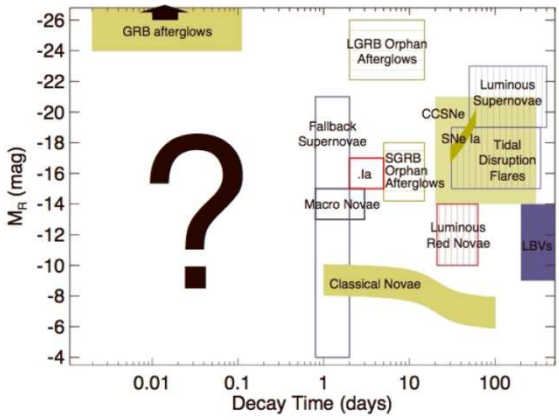
1. Details of Research and Problem Statement

The activities proposed for this programme involve supporting the planning for followup studies of optical transients discovered by the Rubin Observatory Legacy Survey of Space and Time (RO-LSST). When this 8.4-m telescope, with its ~10 square degree field and 3.2 gigapixel camera, is completed and commissioned in Chile in 2023, it will embark on a 10 year mission to continuously survey the southern sky, in multiple filters, every few days: the so-called Deep, Wide, Fast survey. This will be supplemented by smaller scale targeted surveys, some at a higher cadence. The science from RO-LSST will be a game-changer in terms of the number of transient or variable objects discovered, leading to the identification of new types of objects and phenomena.

South Africa will be heavily involved in the followup of these LSST-discovered transient using its own suite of optical, infrared and radio facilities.

The followup of transients from the RO-LSST presents some enormous challenges. New and clever techniques, some utilizing Artificial Intelligence and Deep Learning, will be required to sift through the millions of discoveries to select those objects that are the most astrophysically compelling to observe in more detail. The work involved in this project aims to contribute to the initial ground-work needed to support the RO-LSST project and covers a number of different areas.

The RO-LSST and its followup progamme will map the transient Universe to unprecedented levels and help open up a whole new discovery space of rapidly varying astrophysical objects, particularly in the relatively unchartered territory from sub-second to sub-day timescales. This will inevitably lead to discoveries of whole new classes of objects and phenomena.



2. Description of the aims and objectives of the study

These are focused on developments associated with the South African involvement in the Rubin Observatory's Legacy Survey of Space and Time (LSST). Some of the activities within this programme, for which a graduate student could potentially become involved, cover the following areas:

- participation in existing transient science projects within the scope of the existing SALT and MeerKAT (i.e. ThunderKAT) transient programmes, focusing on specific object classes of interest.
- multi-wavelength and multi-messenger transient followup of gravitational wave and neutrino events.
- developing automatic followup systems at SAAO/SALT to react to triggers from LSST observing brokers and participation in the African Intelligent Observatory (AIO) project.
- developing optimal cadencing strategies for Galactic transient from simulations of various compact binaries populations in the Galaxy and Magellanic Clouds.
- undertaking mini-surveys with local facilities like MeerLICHT, MONET-South or KMTNet to test detection algorithms and automated light curve classifications. This could include involvement in the new *KMTNet Synoptic Survey of Southern Sky (KS4)*, in collaboration with Korean and Australian colleagues.
- assisting with various task-force activities within the science collaborations, some of which are published in a series of science White Papers.

Additional objectives include using actual transient followup up experience (e.g. with the SALT Transient and ThunderKAT programmes) to test both event brokering and observation followup systems ("marshals") currently in use. This will include the opportunity for involvement in multi-wavelength followup observations of current transients alert projects, focusing on specific objects of interest. This work could also involve software development for data reduction pipelines and machine learning methods used in object detection and classification. This may involve utilizing existing transient databases (e.g. ZTF, MeerLICHT, MASTER-SAAO) to independently re-analyze images using new tools developed for LSST to test them and to see if there are potential improvements in detection methods that could be made.

Some of the science questions being addressed, which a student may become involved in, include:

- what strategies to employ in real time decision making when it comes to decide what is worth following up what is not
- how well Machine Learning (ML) techniques based on characterizing light curves actually perform by testing predictions with actual observations
- the nature of accretion in high amplitude out-bursting cataclysmic variables and X-ray binaries and specifically how the spectral and timing behaviour vary during an outbursts (e.g. development of QPOs, spectral lines, etc.)
- correlation of optical/X-ray variations in X-ray transients with the soft/hard state of the source and how these relate to the non-thermal emission detected at radio wavelengths (e.g. by MeerKAT)

The student will participate as a member and Junior Affiliate of the South African RO-LSST transients team, who are all members of the Rubin Observatory Legacy Survey of Space and Time (LSST) Transients and Variable Stars Science Collaboration (TVS). This collaboration has a number of sub-groups and the student's research may be involved in any of these:

1. Source Classification/Characterization: application of M-L
2. Fast Transients: FRBs, GRBs, multi-messenger sources, like gravitational wave and neutrino events
3. Galactic sources: active stars
4. Interacting Binaries: compact binaries with white dwarfs, neutron stars & black holes
5. Multiwavelength Classification/Characterization: using multi-wavelength data for SEDs
6. Eruptive Variables: novae, long period variables
7. Microlensing in the Galactic Bulge: exoplanets

The final choice of topics will depend on the student's interests and the requirements of the programme.

3. Details of Research: Potential Impact of the Research

The Rubin Observatory LSST will be the major discovery machine for optical transients when it becomes operational in 2023. South Africa will be an active participant, through the PI Affiliate programme, in the study of transient and variable objects discovered by RO-LSST. The synergy between SALT and other SAAO telescopes, plus MeerKAT and its supporting optical telescope, MeerLICHT, will have an enormous impact for the study of LSST discoveries across a wide variety of classes.

Some of the expected impacts include:
1. advancing knowledge of astrophysical transients
2. identification of multi-messenger sources, like gravitational waves and neutrinos
3. understanding accretion powered binary systems
4. advancing study of radio transients with MeerKAT and eventually SKA
5. preparation for the 10 year LSST Deep, Wide, Fast survey and other deep-drilling or high candence mini-surveys

4. Alignment to National Imperatives

Environmental, Material, Physical and Technology:

Astrophysics, being part of physics and utilizing state-of-the-art technologies, both for observations (telescopes, instruments), but also Big Data and Big Compute systems, under technology.

National Strategies:

Grand Challenge: Astronomy

In particular, supporting multi-wavelength astronomy. The project is part of a major compelling field of astronomy in which South African has demonstrated significant leadership and developed a reputation for excellence.

Alignment to Sustainability Development Goals

Innovation in terms of application of 4th Industrial Revolution through Machine Learning and Artificial Intelligence. Promoting international collaborations which foster education, outreach and a common humanity.

5. National Infrastructure Platforms:

SAAO: SALT, SAAO telescopes (including some hosted facilities)
SARAO: MeerKAT