PhD Supervisor: Prof. Paul Groot (UCT/SAAO/Radboud)
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Registration: Student will be expected to register at the University of Cape Town (UCT)
Project Title: **Breaking the 1 Hz barrier: fast optical transients and variables**
Type: **PhD**, within the UCT/SAAO-based SARChI group of Paul Groot

Project Description

1 Problem Statement

Ultracompact binaries consist of two compact objects (white dwarfs, neutron stars and/or black holes) that are themselves the end products of binary stellar evolution. Ultracompact binaries consisting of two white dwarfs are the only confirmed population of objects to be seen by the LISA gravitational wave mission. Ultracompact binaries hosting neutron star and/or black holes are the source population of gravitational wave merger events seen by the LIGO/Virgo/KAGRA interferometers. Our understanding of the formation and evolution towards ultracompact binary systems is still rudimentary. The preceding (double) common-envelope phase is poorly understood, as well as the initialisation of mass transfer at a period of only a few minutes in binary white dwarf systems. What fraction merges, what fraction explodes (possibly as supernovae type Ia) and what fraction survives to form the AM CVn-type binaries of interacting white dwarfs? Understanding this better and preparing for the LISA mission requires that we uncover more of the Milky Way population of ultracompact binaries, as well as study the known ones in more detail. E.g. the role of tidal heating in the evolution of these systems is largely not understood, but potentially decisive whether two compact objects merger yes or no through the increased entropy (size) of the heated component.

2 Aims and Objectives

The aim of the PhD project is to better understand the population and physics of ultracompact binaries and ultrashort transients. The project is centered on the new Flash telescope, currently being commissioned at UCT, and which will be moved to Sutherland for operations. The Flash telescope will allow for a wide-field view of the night sky at cadences of ~1 Hz, to study the fastest variables and transients. It uses a state-of-the-art wide-field CMOS detector coupled to a 35cm wide-field telescope. The aimo for the PhD project is a combined scientific-technical one, where the PhD student is the central person in the move of the Flash telescope from UCT to Sutherland, its installation and commissioning on the plateau, the data processing and the scientific use for high-cadence wide-field observations. As a test bed we will be targeting known fast-changing compact sources, but a large fraction of the PhD will be on a fast-cadence survey of the Southern skies to identify and study new ultracompact binaries, in particular those that are sources of gravitational wave emission with the upcoming LISA satellite. We will also use the facilities at Sutherland, and if possible MeerKAT, to study known systems to establish system parameters, as well as to study the role of tides and the orbital derivatives. This will include SALT+RSS, the 1.9m and Lesedi. Usage will be made of international facilities such as at ESO when necessary.

3. Potential Impact

The impact of this study is manifold:

a) ultracompact binaries are the strongest known sources of gravitational wave radiation in the LISA band. The LISA satellite will be launched around 2034, but it is imperative to already now establish a thorough understanding of the detectable population and their parameters to be able to determine and ‘filter out’ their contribution to the total LISA signal.

b) Mergers of detached white dwarf systems are expected to be one of the main channels for the formation of Supernovae Type Ia, which themselves are used as the milemarkers of the accelerated expansion of the Universe. Establish the source population of SN Type Ia will therefore impact on our understanding of the whole Universe.
c) Neutron-star neutron-star and neutron-star black-hole binaries are an important source population of gravitational wave merger events seen by LIGO/Virgo. Their cosmological rates need to be reconsiled with the Galactic population of these systems.
d) Wide-field CMOS detectors are the way forward for optical high-cadence observations. The objective of the thesis project is also to try out this new technique in preparation for a larger scale project, where the idea is to either scale up in sky coverage with multipe units, or in collecting area with a new wide-field telescope. Given the investment in SKA, SALT and the partnerships in the Vera Rubin Observatory as well as the BRICS time-domain initiative this is a central piece of the South African multi-wavelength strategy.

4. Alignment with National Imperatives

This project aligns with the following national imperatives:
i) NRF Broad Category: Environmental, Material, Physical and Technology: Astronomy is a physical-technical discipline and strong usage will be made of cutting-edge technology in South Africa (MeerKAT, MeerLICHT, SALT, SAAO telescopes).
ii) National Priority: Transformation: the training of transformed, science-and-technology based researchers is the basis of South Africa's future in the Fourth Industrial Revolution.
iii) Grand Challenge: Astronomy: this project is astronomy, where usage is made of South Africa's cutting-edge technology to understand the Universe and our place in it.
iv) Sustainability Goals: Quality Education. Astronomy is a STEM-discipline that forms the basis of the future development of South Africa and an educated population.

5. National Infrastructure Platforms:

SAAO, SARAO/MeerKAT, SALT, MeerLICHT, IDIA/Ilifu, Flash