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: **Ultracompact Binaries in the Southern Hemisphere**
Type: PhD, within the UCT/SAAO-based SARChI group of Paul Groot

Project Description

1 Problem Statement

Ultracompact binaries consists of two stellar remnants (white dwarfs, neutron stars or black holes) in very tight orbits with periods of less than one hour. They are known by their population names as AM CVn systems (semi-degenerate, mass-transferring white dwarf binaries), double degenerates (non mass-transferring white dwarfs) or ultracompact X-ray binaries (UCXBs). These binaries are rare survivors of stellar/binary evolution, where they have experience two common-envelope phases. They are the strongest known gravitational wave emitters in the mHz regime that will be opened up by the LISA space mission. *The currently known population of these systems holds no more than 50 systems, with the vast majority of them only visible from the Northern Hemisphere. This project aims to find and study the population of these systems in the Southern Hemisphere.*

2 Aims and Objectives

This project aims to find and characterise ultracompact binaries for a number of reasons:
a) to increase the known population to allow for a better understanding of the population itself and their progenitor evolution.
b) to increase the known population of LISA-detectable binaries
c) to find the most extreme cases that challenge our understanding of the physics of the interiors of these systems and allow us to test our understanding of gravity.
The most extreme systems show orbital periods in the range of 5-10 minutes, and orbital decay due to the emission of gravitational waves can be measured within a year. If masses can be determined independently (e.g. through optical spectroscopic observations), the gravitational wave-derived masses and the optical-spectroscopy-derived masses can be compared. Any mismatch between these needs to be explained, either due to systematic errors in the optical estimates, due to additional orbital angular momentum sinks due to tidal effects, or due an incomplete understanding of gravity.

The project will use data from the MeerLICHT and BlackGEM wide-field survey telescopes, in combination with high-cadence photometry from the Las Cumbres network and phase-resolved spectroscopy with the SALT and ESO-VLT telescopes to find and characterize these systems. The work is primarily observationally based, but results will be interpreted within the framework of binary stellar evolution and the theory of tides in degenerate matter. Particular emphasis will be put on LISA-detectable systems, where it is imperative to find and understand these systems now as a ten-year baseline (until the launch of LISA) will be needed to derive period derivatives and double-derivatives.

Selection of possible new ultracompact binary systems will be done on the colours and photometry provided by MeerLICHT and BlackGEM which are both covering the Southern Hemisphere repeatedly. Follow-up spectroscopy and photometry using SALT, 1.9m SAAO, LCO and ESO telescopes will be used to identify the candidates. Confirmed sources will be followed intensely using SALT, VLT and NTT.

The objective of the study is to double the amount of known systems from 50 to 100 binaries.

3. Potential Impact

The impact of this study is manifold:

a) a better understanding of the Galactic population of ultracompact binaries will provide strong limits on the expected Galactic foreground in the LISA mission

b) detection of angular moment sinks through tides will give direct information on the equation of state of degenerate matter

c) understanding the progenitor evolution of these systems will also allow the asses the ‘loss-rate’ in the previous evolution due to the explosion as supernovae Type Ia, whose progenitors are expected to largely follow the same path.

4. Alignment with National Imperatives

This project alignes 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 (MeerLICHT, SALT, SAAO telescopes) as well as globally (e.g. the telescope of the European Southern Observatory)

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, SALT, MeerLICHT, IDIA/Ilifu