PhD Supervisor: Prof. Paul Groot (UCT/SAAO/Radboud)
Co-Supervisor:
Email address: paul.groot@uct.ac.za, p.groot@saao.ac.za
Registration: Student will be expected to register at the University of Cape Town (UCT)
Project Title: **Relativistic transients: gamma-ray bursts and gravitational wave events**
Type: **PhD**, within the UCT/SAAO-based SARChI group of Paul Groot

Project Description

1 Problem Statement

The most massive binary stars end their lives with a relativistic transient event: a gamma-ray burst/hypernova in which a black hole is formed, and/or the merger of two black holes and/or neutron stars. Observationally we see these events as gamma-ray bursts and/or gravitational wave events, where a short-duration optical transient follows either a flash of gamma-rays or a gravitational wave event, or both.

Gamma-ray bursts have been known to be associated with either a massive star collapse or the merger of neutron stars since the late 1990s. Gravitational wave events have only been detectable since 2015 and only one event (GW170817) has been detected in both gravitational waves as well as electromagnetic waves, where the event was accompanied by a short gamma-ray bursts and a multi-wavelength ‘kilonova’ event.

With only one detected event in coincidence between gamma-ray bursts and gravitational wave events, the link between the two classes is yet to be explored, and for both categories it is still unclear how they exactly fit in the evolutionary scenarios of massive stars and what determines which outcome. The purpose of the PhD project is to shed light on both the physics of these relativistic transients as well as their link to massive star evolution. Particular emphasis will be put on the earliest-detectable phases of both types of events by using the MeerLICHT and BlackGEM optical telescopes, in conjunction with the other telescopes at SAAO Sutherland (in particular SALT and Lesedi), the MeerKAT radio array and facilities around the world, to provide a multi-wavelength picture.

2 Aims and Objectives

The aim of the PhD project is to detect the multi-wavelength electromagnetic emission of gamma-ray bursts and gravitational wave events and to place these events in the evolutionary sequence of massive stars. What is the evolution leading up to the transient event? What kind of stars end up in which event? What is the environment in which the event occurs: star-forming regions, globular clusters, or Galactic halos? What is the physics of the ‘kilonova’ light coming from gravitational wave events, and how does the spectral evolution of the event depend on initial conditions such as masses, mass ratios, viewing angles and the nature of the higher mass component in the system (black hole or neutron star).

The project will be mostly observationally oriented, and strong use will be made of the South African facilities: MeerLICHT, SALT, Lesedi, MeerKAT, LCO, in conjunction with facilities around the world. The MeerLICHT (and BlackGEM) telescopes will automatically respond to triggers from high-energy satellites and/or gravitational wave detectors and can be on-location within minutes obtaining multi-band data. Our current investigations show that these early data can reveal a rich scala of physics and evidence for continued energy injection in the first phases of afterglow data.

This project will be part of a larger, global set of collaborations on gravitational wave events and gamma-ray bursts, but the student will have their own focused goal, in particular on early-time multicolour data in conjunction with later-time radio data.

3. Potential Impact

The impact of this study is manifold:

a) the possible detection and study of several EM-counterparts to gravitational wave events

b) establishing the nature of the link between gravitational wave events and short gamma-ray bursts.

c) understanding the similarities in physics between tidal-disruption events and black hole – neutron star mergers.

d) a detailed understanding of the early-time multi-colour evolution of afterglows and the evolution of late-time radio emission.

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