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Registration: Student will be expected to register at the University of Cape Town (UCT)
Project Title: **Early-time evolution of core-collapse supernovae**
Type: **PhD**, within the UCT/SAAO-based SARChI group of Paul Groot

Project Description

1 Problem Statement

Massive stars end their lives with core-collapse supernovae leaving behind a black hole or a neutron star. The vast majority of massive stars are also part of binary or higher-order systems, often in such close orbits that interactions take place during the evolution of the system. It is therefore to be expected that a large fraction of supernovae take place in binary systems, where the companion is another star, or an evolved object if it has exploded already.

Although signs of prior interactions are evident in the types of core-collapse supernovae, in particular in the hydrogen-deficient classes of Type Ib/Ic's, there is still scant evidence for interactions with a companion **during** the supernova explosion itself. The most evident reason for this is that supernovae are generally discovered (long) past the moment at which the interaction took place, which is at the very earliest phases, within minutes to hours of the supernova shock breaking out of the photosphere of the star. In this PhD project we will address the binary setting of supernovae and the link with massive, binary, star evolution.

2 Aims and Objectives

The aim of the project is to detect evidence for companion-interactions in the very early light curves of supernovae. To be able to do this, it is imperative that we detect supernovae at the very earliest times, within hours of exploding, with multi-colour observations, as e.g. the ultraviolet-blue light is expected to decay much faster than the visual-red light in some interaction scenarios. The means to achieve this goal is in the combined use of the MeerLICHT and BlackGEM wide-field, multi-colour survey telescopes. MeerLICHT is located at SAAO Sutherland and BlackGEM has just begon operations at the ESO La Silla Observatory in Chile. A major part of both observing programs is their 'Local Transients' survey where a set of nearby galaxies is monitored multiple times per night in multiple bands to detect new transients. With both MeerLICHT and BlackGEM we can not only detect new transients within hours at *each* of these facilities, but also *between* the two facilities (giving a time baseline of 4-5 hours between South Africa and Chile, and ~16 hours between Chile and South Africa. Given the depth of observations of MeerLICHT and BlackGEM we should be able to detect core-collapse supernovae within their first hours of explosion out to distances of ~100 Mpc. The long baseline built up with MeerLICHT also allows an investigation of interactions in the years before the supernova explosion, e.g. due to envelope stripping by the binary companion.

Once detected the supernovae will be followed-up with observations with Lesedi, SALT, LCO, and the facilities at ESO, to obtain high-quality photometric and spectroscopic time-series. Expected evidences for binary interactions include blue excess features in the early light curves as well as spectroscopic flash-ionization features of the companion photosphere at shock-break-out times.

3. Potential Impact

The impact of this study is manifold:

a) detections of early binary interactions will allow a mapping of morphological supernova type (II-n/p/x/, etc, Ib, Ic) to the type of companion at the time of explosion (main-sequence, giant, Wolf-Rayet, compact object)

b) detections of supernovae at the very earliest times allow a determination of the radius of the exploding star, directly linking this to stellar evolution calculations.

c) understanding the binary configuration of core-collapse supernova links these to later phases of evolution where we see (short) gamma-ray bursts and/or gravitational wave mergers.

d) a detailed spectroscopic record at early times allows the identification of chemical elements, and a better understanding of the chemical evolution and enrichment of galactic environments.

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