Physics & Astronomy PhD Project Proposal

Project Title: Time-resolved analyses to determine a new gamma-ray burst classification scheme.

Project reference: STFC - Evans

Groups: Astrophysics

Supervision Team:

- 1st Supervisor: Dr Phil Evans (pae9@leicester.ac.uk)
- 2nd Supervisor: Dr Rhaana Starling (rlcs1@leicester.ac.uk)

Three Key Points

- Exploring a newly reopened mystery: how can we identify the causes of the most powerful explosions in the universe?
- Your results will lead to a better understanding of the origins of the heaviest chemical elements, such as gold.
- You will be developing tools for *real-time* astronomy, classifying explosions within minutes of their detection.

Project Description

Gamma-ray bursts (GRBs) are the most powerful explosions in the universe, emitting around 10^{44} J in a handful of seconds. They are typically detected by their initial burst of gamma-rays, arising from an ultra-relativistic jet blasting out from around newly-formed black hole. Multi-wavelength follow-up observations then reveal a steadily decaying "afterglow" from material around the burst.

Since 1993, GRBs have been divided into two classes: the "long" GRBs, in which the gamma-ray emission lasts more than 2 s; and the "short" GRBs, which are <2s in duration and spectrally harder than the long bursts. The long bursts are unambiguously associated with stellar collapse, thanks to many detections of supernovae following a GRB. Short GRBs were long theorised to arise from the merger of two neutron stars. This was confirmed in 2017 when LIGO-Virgo detected a neutron-star merger simultaneous with a short GRB. A 'kilonova' – infrared emission from *r*-process nucleosynthesis -- was also observed from this event and is considered the "smoking-gun" electromagnetic indicator of a neutron star merger. The nature of the long and short GRBs has thus been solved.

Or not.

Thanks to improving observational facilities, including the James Webb Space Telescope, kilonovae have recently been detected from two archetypical *long* GRBs, indicating that these events arose from neutron-star mergers!

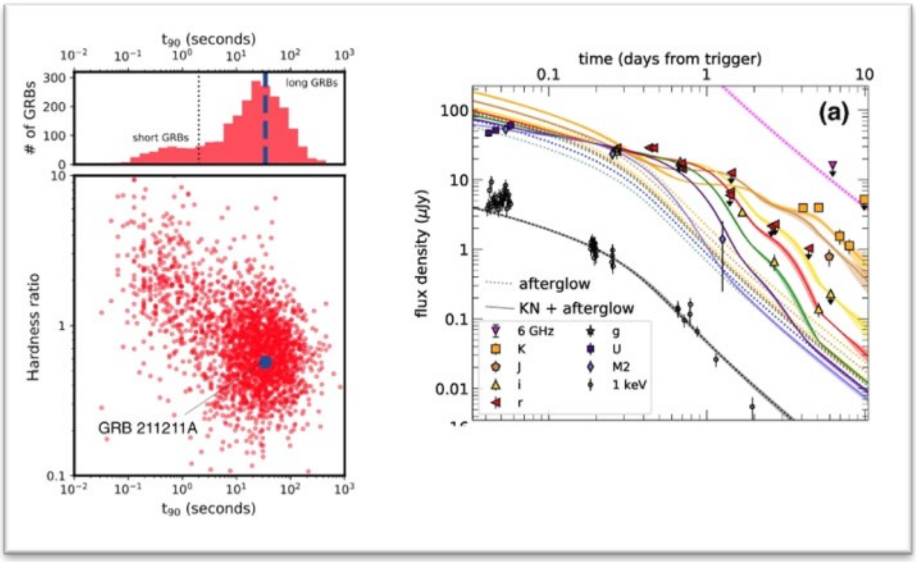
We must, therefore, return to the data to devise a new scheme to *physically* classify GRBs based on their gamma-ray emission properties. The old scheme used time-averaged properties. That has failed, so we must now dig deeper into the time-resolved discovery space. That is the focus of this PhD project which is part of a Leverhulme Trust funded multi-university research project, *GOLDMINE*.

You will work with data from the NASA-UK-Italian *Swift* satellite, studying the high-energy emission from GRBs to identify the similarities and differences between those arising from mergers and those from stellar collapse and help devise a new scheme. This will be applied to archival and new data, potentially classifying bursts as collapse or merger events in real time, and opening further avenues for study of these powerful, enigmatic objects.

Further Reading:

- *Multi-messenger Observations of a Binary Neutron Star Merger*, Abbot B.P., et al., 2017, ApJL, 848, L12: https://doi.org/10.3847/2041-8213/aa91c9
- *A Kilonova Following a Long-Duration Gamma-Ray Burst at 350 Mpc*, Rastinejad J.C., et al., 2022, Nature, 612, 223, https://arxiv.org/abs/2204.10864
- https://www.swift.ac.uk

Images/Graphics:



GRB 211211A. *Left:* The gamma-ray properties seen by *Fermi* compared to the population of GRBs; this event is the very type of a long GRB. *Right*: multi-wavelength follow-up observations showing an infrared ‘hump’ about a day after the GRB, fitted with models of kilonovae emission – expected from merging neutron stars. Adapted from Rastinejad et al., 2022.

Application advice: Please see web page

https://le.ac.uk/study/research-degrees/funded-opportunities/stfc