'Observational and theoretical developments in Gamma-ray Bursts with new and up-coming facilities. (GRB)' Abstracts

Talks

Righting the Radio Light Curve of the BOAT (GRB 221009A)

Authors

Helena-Margaret Grabham (1), Dr Gavin Lamb (1)

(1) Liverpool john Moores University

Abstract

The Brightest-of-All-Time GRB 221009A, aka. the 'BOAT' remains the most energetic gamma-ray burst (GRB) ever recorded. Spanning over 15 orders of magnitude, the BOAT released an isotropic energy on the order of ~55 ergs, causing disturbances in the Earth's ionosphere and drawing the attention of astronomers globally. This unique 1 in 10,000 year event puzzled astronomers due to its incredible luminosity and excess radio flux contribution within the long-lasting afterglow emission. Classical afterglow models only predict the optical and X-ray radiation and not the complex radio signature. This triggered deep searches for a supernova association, however, after no evidence was found, the shallow decline from the radio emission remained unsolved. We show how the multi-band afterglow can be reproduced using a nested tophat model, a combination of two GRB jet models with simple modifications applied to the micro-physics of the jet parameters. This provides better knowledge of where energy release occurs inside jets and allows us to build a quasi-universal model for all GRBs to fit. I will present the jet dynamics governing the nested tophat and explain how this accurately matches the BOAT's observational data, providing an advanced structural analysis applicable to the next generation of GRBs.

Time-Resolved Analysis of Prompt Emission Spectra of Bright Collapsar and Merger GRBs

Authors

Makenzie E. Wortley (1), Dr Benjamin Gompertz (2), Dr Maria Edvige Ravasio (3), Dr Phil Evans (4)

(1) University of Birmingham
(2) University of Birmingham, UK
(3) ICE-CSIC (Institute of Space Sciences), Barcelona, Spain
(4) University of Leicester, UK

Abstract

Gamma-ray bursts (GRBs) arise from one of two progenitors: compact object mergers (commonly assumed to be NS-NS), or the collapse of a massive star. GRB lightcurves display considerable diversity and the identification of a “long-merger” subgroup of bursts (namely 211211A and 230307A) has significantly complicated classifying them into these two progenitor classes with ease. In this talk, I will present a finely time-resolved broadband spectral analysis of the prompt emission of three bright long-merger GRBs, and three long GRBs from stellar collapse that explores potential spectral differences between collapsar- and merger-driven GRBs. By applying physically motivated synchrotron and thermal emission models, I perform analysis on finely sliced time intervals of these bursts in order to track the evolution of the prompt spectra and infer the underlying physics that drives it. I compare my findings to Gompertz et al. (2023) who showed the long-merger GRB 211211A has an evolving synchrotron spectrum that transitions from fast to slow cooling at around 50s. I aim to find if this behaviour is different in collapsar-driven GRBs, and if the other merger-driven GRBs in our sample follow the behaviour exhibited by GRB 211211A.

The Oates Relation: testing a structured jet origin

Authors

Cairns Turnbull (1), Gavin Lamb (1), Conor Omand (1)

(1) Liverpool John Moores University

Abstract

Empirical correlations have been identified in many aspects of GRB phenomena, e.g. Ghirlanda, Amati, Yonetoku, etc, all of which lack physical explanation. One correlation in particular between the early-time intrinsic brightness and average decay rate of long GRB afterglow light curves, observed across all wavebands from GeV to radio, was first reported by Oates et al. (2012), though it is not predicted by the standard afterglow model. Using synthetic GRB X-ray afterglow simulations, we infer the 1 keV luminosity at 200 seconds and post-200s decay index in order to reproduce this correlation. Simulations with top-hat and Gaussian jet structures suggest the correlation is largely independent of jet structure and mainly driven by viewing angle. This implies the correlation could serve as a cosmographic tool, offering a luminosity constraint independent of jet geometry. I will describe a physical origin for this correlation and discuss the implications for GRB energetics, environments and, perhaps ambitiously, for use as standard candles to provide a new constraint on the Hubble parameter.

Automated optical follow-up of Swift GRBs with Palomar-60 inch telescope: sample characteristics

Authors

Aleksandra Bochenek (1), Daniel Perley (1), S. Bradley Cenko (2)

(1) Astrophysics Research Institute, Liverpool John Moores University
(2) University of Maryland; NASA Goddard Space Flight Center

Abstract

We present the largest and most sensitive study to date of a complete sample of GRB optical afterglow properties, using the full data set from the 11-year Palomar 1.5m (P60) automatic follow-up programme, which ran from 2005 to 2016. The P60 telescope was able to respond to alerts from well-localized bursts in less than three minutes, reaching a typical limiting magnitude of r ~ 20.5 mag in a 60s exposure. We focus on bursts followed-up within an hour of Swift trigger, forming a sample of 88 events. We characterize the observed and intrinsic distributions of time-dependent luminosity, decay index, peak time, and spectral index for the GRB afterglow population. Using our data together with additional information on early afterglow properties and available Swift-XRT data, we examine implications for the circumburst environment and constrain outflow geometry. The sample also provides insight into the population of fast-decaying and low-luminosity GRBs, bridging the gap to the parameter space currently being explored by Einstein Probe and SVOM. Finally, we compare the P60 detection statistics to the afterglow recovery rates in wide-field surveys such as ZTF and characterize expected rates for LSST.

Dusting off the BOAT: GRB221009A afterglow through the reddened eyes of JWST

Authors

Nguyen Minh Khang (1), Helena-Margaret S. Grabham (1), Gavin Lamb (1), Conor Omand (1)

(1) Liverpool John Moores University

Abstract

GRB 221009A, more famously known as the Brightest Of All Time (BOAT), is by far the most energetic long-duration gamma-ray burst (GRB) event to date. Unfortunately, despite being a relatively close-by event (z =_ 0.151), the event lies along the line-of-sight through the Galactic plane. This means that any observations are heavily affected by the local Galactic extinction. Additionally, many existing studies of the BOAT have varying and inconsistent treatments for the reddening of this event and could, therefore, potentially lead to incorrect interpretations, especially of the physical nature of the ambient environment. In this project, we examined observations of the BOAT made via JWST (NIR) and VLT X-Shooter (Optical) over the first two weeks post-burst. By using a physically motivated, double-broken power law consistent with synchrotron cooling and peak breaks, we have successfully constrained a definitive line-of-sight extinction and the intrinsic spectral energy density (SED).

The intrinsic luminosity–decay correlation in subsamples of GRB X-ray afterglows

Authors

Samuel Shilling (1), Samantha Oates (1), Judith Racusin (2), Brad Cenko (2), Rahul Gupta (2), Pi Nuessle (2), Mat Smith (1), Gavin Lamb (3), Cairns Turnbull (3)

(1) Lancaster University
(2) NASA Goddard Space Flight Center
(3) Liverpool John Moores University

Abstract

Studies of long GRB (LGRB) afterglows have observed a correlation between the luminosity measured at an early time and the average rate of decay past this time, suggesting that more luminous afterglows decay, on average, faster than less luminous ones. The correlation has previously been observed in LGRBs across multiple frequencies: radio, optical/UV, X-ray and GeV. We have compiled an updated sample of X-ray afterglows observed with Swift/XRT over 20 years, covering double the mission operation time as in the previous X-ray study, resulting in a sample size increase of ~75%. With our larger sample, we investigate the correlation in detail by separating GRBs into subsamples beyond LGRBs, such as; short GRBs (SGRBs); SGRBs with extended emission; low-luminosity LGRBs; and well-sampled LGRBs. At this meeting, we will present these results, investigate sources of scatter in the correlation, and discuss the possible causes of the correlation.

Revisiting Gamma-Ray Burst Classification with Data-Driven Approaches

Authors

Dimple (1)

(1) University of Birmingham

Abstract

Gamma-ray bursts (GRBs) display a remarkable diversity in their light-curve morphologies and spectral properties, arising from the complex physics of relativistic outflows and radiation processes in extreme environments. Conventional classification schemes, such as the long–short or Type I–Type II dichotomy, offer a simplified phenomenological framework but increasingly fail to capture the full breadth of observed behaviour.
This work investigates whether the observed diversity of GRBs can be exploited as a diagnostic of the underlying physical mechanisms rather than treated as mere observational scatter. We employ a data-driven approach that integrates unsupervised machine learning techniques with physically motivated modelling of prompt emission pulse structures. In particular, we analyse the clusters identified through dimensionality reduction and clustering algorithms, and examine whether these groupings correspond to distinct physical regimes or instead reflect degeneracies inherent in the observed parameter space. This approach aims to move beyond traditional classification toward a more physically grounded understanding of GRB diversity.

Buried in dust: A possible super-luminous supernova in Ultralong GRB 220706A

Authors

Nusrin Habeeb (1), Benjamin Gompertz (2)

(1) University of Leicester
(2) University of Birmingham

Abstract

Ultra-long gamma-ray bursts offer a rare window into the most prolonged episodes of central-engine activity and may probe progenitor channels distinct from those of the broader long gamma-ray burst population. Their extended high-energy and X-ray behaviour makes them important laboratories for testing how long-lived engines operate and how they relate to the deaths of massive stars. In this talk, I will discuss the peculiar behaviours of GRB 220706A. Based on its engine duration, as measured by the $t_{\rm burst}$ metric, we find that it lies comfortably within the ultra-long GRB population and hosts one of the longest-lasting central engines yet identified in a GRB. Its X-ray light curve exhibits strong flaring, with clear evidence for activity as late as 27 rest-frame days after the initial trigger, making this the latest recorded central-engine activity seen in any GRB. In contrast, the optical afterglow is intrinsically faint at early times, but we identify a likely supernova that is slightly more luminous than SN 1998bw. After accounting for the high optical extinction, this dark burst may instead host a highly luminous supernova resembling SN 2011kl, which accompanied the notable ultra-long GRB 111209A, and is consistent with the superluminous supernova population. I will present a detailed multi-band analysis of the observational data and discuss possible powering mechanisms for the unusually late central-engine activity, as well as the implications of these results for models of ultra-long GRB progenitors.

EP250827b / SN 2025wkm: A Fast X-ray Transient Supernova from photospheric to nebular phase

Authors

Gregory Corcoran (1), Antonio Martin-Carrillo (1)

(1) University College Dublin

Abstract

Long gamma-ray bursts (GRBs) have often been associated with broad-lined type Ic supernovae. With the arrival of missions more sensitive to soft X-ray emission, such as Einstein Probe (EP) and the Space Variable Objects Monitor (SVOM), there has been an explosion of X-ray dominated events, known as fast X-ray transients (FXTs). While some FXTs seem to be the soft end of the tail of classical GRBs, we are unveiling a new population of cases at cosmological distances, of weakly relativistic jets with optical emission dominated by the supernova component.

In this work, I present the results of the FXT EP250827b with an associated supernova SN 2025wkm, an FXT-SN at z=0.1196, making it one of the most nearby FXT's to date. This proximity allowed for an extensive photometric and spectroscopic monitoring from the photospheric to the nebular phase, making this the first ever FXT-SN with a nebular spectrum. This nebular spectrum can provide insight into the progenitor mass, narrowing potential progenitor channels. In addition, the radio observations associated with this event point towards a very weak or non-existent jet unlike similar FXT-SNe cases.

Echoes Across the Universe: A Fresh Search for Gravitationally Lensed Gamma-Ray Bursts

Authors

David O'Neill (1), Ben Gompertz (1), Graham Smith (1)

(1) University of Birmingham

Abstract

Gamma-ray bursts (GRBs) are among the most energetic transients in the universe, releasing as much energy as a supernova on timescales of seconds to minutes. Their inherent brightness enables detection at high redshift ($z \geq 1$), making them ideally placed to be strongly lensed by foreground clusters at $z \simeq 0.2$–0.5. Compared to other lensed transients, GRB prompt emission is timed with sub-second precision, reducing time-delay uncertainties by orders of magnitude. A multiply-imaged GRB would also sample two distinct sight lines through the jet, offering a rare direct probe of jet structure.
Previous searches targeted galaxy-scale lensing, looking for repeated pulses separated by seconds within a single burst. However, discriminating repeated lensed emission from intrinsic variability at these timescales is exceedingly difficult. Here we pivot to cluster-scale lensing, where time delays of hours to days allow independent GRB triggers to be matched by spatial coincidence alone. We present the most promising candidates and outline the methods now deployed for identifying lensed GRBs in real time.

Probing the Physics of Early Afterglows of Fermi/Swift GRBs and Einstein Probe FXTs through rapid ground-based follow-up

Authors

Rahul Gupta (1), Judith Racusin (1), ALBERTO JAVIER CASTRO TIRADO (2), Samantha R. Oates (3), Amar Aryan (4)

(1) NASA Goddard Space Flight Center
(2) Instituto de Astrofisica de Andaluc\'{i}a (IAA-CSIC), Glorieta de la Astronom\'{i}a s/n, E-18008, Granada, Spain
(3) Department of Physics, Lancaster University, Lancaster, LA1 4YB, UK
(4) Graduate Institute of Astronomy, National Central University, 300 Jhongda Road, 32001 Jhongli, Taiwan

Abstract

Early-time observations of relativistic transients provide critical insight into the physical processes governing ultra-relativistic jets, including their composition, magnetization, and interaction with the circumburst medium. Rapid optical follow-up by robotic and autonomous telescope networks enables observations within minutes to hours of high-energy triggers. In this talk, I will present results from coordinated ground-based campaigns targeting gamma-ray bursts (GRBs) detected by Fermi and Swift, together with fast X-ray transients (FXTs) discovered by the Einstein Probe (EP).

Early optical light curves of GRBs exhibit a wide range of temporal behaviors, including flares, rebrightenings, and afterglow onset peaks. In several events, these features are consistent with reverse shock emission, providing constraints on jet magnetization and ejecta composition. I will highlight GRB 140102A, where a bright and rapidly fading optical component observed by the BOOTES network indicates a magnetized outflow, and discuss early observations of the exceptionally bright event (BOAT), which show no evidence for a dominant reverse shock. I will also present the case of GRB 230204B, an extremely energetic, multi-pulsed burst whose luminous optical afterglow and multi-wavelength modeling reveal a narrowly collimated jet expanding into a dense interstellar medium with a low magnetic energy fraction.

I will then extend the discussion to EP FXTs, focusing on results from a systematic optical follow-up of 42 FXTs observed from the Lulin Observatory during the first year of EP operations. Optical counterparts are detected for only a minority of events and are typically faint and rapidly fading, while a large fraction remain undetected despite timely observations. These nondetections point to an emerging population of dark FXTs, analogous to dark GRBs. FXTs with detected optical emission occupy the faint end of the GRB luminosity distribution, whereas the absence of optical counterparts in many cases likely reflects a combination of intrinsic faintness, rapid decay, high redshift, or dust extinction. Overall, these results emphasize the critical role of rapid follow-up observatories in connecting GRBs and FXTs and in constraining the jet physics and environments of extragalactic relativistic transients at the earliest observable times.

Posters

Multi-messenger Joint Inference of Massive Stellar Populations: a Unified Framework Informed by Fermi-GBM Short Gamma-ray Bursts and LIGO-Virgo-KAGRA Black Hole Binary Observations

Authors

August Muller (1), Christopher Berry (1), Rachel Gray (1), Storm Colloms (1)

(1) University of Glasgow

Abstract

As both short gamma-ray bursts (SGRBs) and gravitational waves (GWs) are produced by mergers of massive compact objects, SGRBs can be used in tandem with GWs to understand the formation and evolution of their progenitor massive stellar binaries. Although it is not typically possible to determine the evolutionary pathway of a single binary system from its corresponding transient, population-level information such as event rates as a function of redshift can be used to place constraints on underlying stellar evolution parameters more generally. The specifics of stellar formation pathways can be inferred by comparing observations of individual transients with population-synthesis models of binary stellar evolution. While this method has been successfully applied separately to SGRBs and GWs, we present a statistical method to perform joint hierarchical analysis of both SGRB (neutron star progenitors) and GW (black hole progenitors) observations together in order to constrain properties of massive stellar populations as a whole. As a result of the distinct selection effects governing SGRB and GW observations, joint inference allows us to take advantage of stellar formation information encoded within multiple sub-populations of the overall distribution of massive stellar binaries. We provide an overview of the specific statistical considerations required when performing simultaneous analysis of distinct multi-messenger datasets and explain how to apply our framework in the case of public Fermi-GBM SGRBs and LIGO-Virgo-KAGRA GWs in order to constrain stellar evolution using both datasets simultaneously. This method can be applied to a wide array of open questions in stellar astrophysics, including constraining beaming properties of short gamma ray burst emission, measuring rates across multiple predicted binary stellar evolution channels, and describing of the merger rate of massive binaries over cosmic time.