Thesis subject

Laboratory : Laboratoire d'Astrophysique de Marseille

Thesis supervisor : Antonio de Ugarte Postigo

Co-supervisor : Stéphane Basa and Véronique Buat

Title of the thesis subject : The Universe's most luminous bursts: Quantifying the ordinary and the extraordinary

Description of the thesis subject :

The recent launch of the Sino-French SVOM (Space-based multi-band astronomical Variable Objects Monitor) mission presents a unique opportunity for French research to assume a leading role in the field of high-energy transients. The main research topic of this project is the study of gamma-ray bursts (GRBs), the most energetic electromagnetic explosions detected in the Universe, which are produced either by the collapse of very massive stars or by the merger of compact objects.

To support the scientific goals of SVOM we have developed a dedicated facility, the 1.3 m COLIBRÍ telescope, a fast robotic facility located at San Pedro Mártir observatory in Mexico with no real equivalent worldwide. COLIBRÍ is indeed capable of reacting to a SVOM alert within less than 20 seconds and creates detailed multicolour light curves in optical and near infrared, with three cameras that observe simultaneously. This telescope, which has been producing data since early 2025, is creating a unique collection of very detailed multi-wavelength light curves. In parallel, we have access to 8-10m facilities (8.2 m VLT in the Southern Hemisphere and 10.4 m GTC in the Northern Hemisphere) that complement the observations of COLIBRÍ through spectroscopy as well as late-time observations of the GRB afterglows, their associated supernovae or kilonova and host galaxies.

The PhD candidate will have access to extensive data from the SVOM mission, the COLIBRÍ robotic telescope and follow-up data from VLT and GTC. She/he will participate in the observational activities with these facilities. Beyond that, we lead a database with historic data of light curves and spectra of GRBs that already contains observations of hundreds of events. The goal of the work will be then to study the physics of GRBs, their progenitors and their host galaxy environment through the analysis of large, high-quality observational datasets in a way that has not been possible until now.

From the study of a GRB light curve shape, the bumps, wiggles, flares and spectral evolution that deviate from the standard afterglow behaviour, one can derive physical properties of the burst, of the ejecta released in the event, and of the ultrarelativistic jets that are formed. One can learn about the activity cycle of the central engine, a stellar black hole, and about

the structure of the interstellar material surrounding the progenitor. Analysing the continuum shape and the features in the GRB afterglow spectrum, one probes the host galaxy environment, its composition, dust content and dynamics. One can also obtain information on the distances from the progenitor to the absorbing clouds by observing how the GRB radiation excites and ionises the interstellar material, which results in the temporal variation of spectral features. Performing these studies in a statistical way, with limited biases, as proposed in this PhD project, will define the real characteristics of the GRB phenomena, how diverse these events are, and quantify the population of progenitors that produce them. This will give measurable evidence on the place of GRBs in stellar evolution as well as their role in environment enrichment and galaxy evolution.

The PhD work will be advised by Dr. Antonio de Ugarte Postigo, Dr. Stéphane Basa, and Dr. Veronique Buat. Dr. de Ugarte Postigo is an observational astrophysicist specialised in the study of astrophysical transients and the development of instrumentation for their study. He has 25 years of experience in the study of GRBs at all frequencies and leads the GRBSpec and GRBPhot databases that will be a key part of the PhD work. Dr. Basa is the French co-Principal Investigator of the SVOM mission and the Principal Investigator of the COLIBRÍ telescope, which is one of the main producers of GRB light curves in the field. Dr. Veronique Buat specialises in the study of galaxies and stellar populations, crucial for the understanding of the burst environments and their progenitors.

A tentative thesis schedule would be as follows (T0 being the starting date of the thesis):

- T0 to T0+6 months: bibliographical research on the subject and familiarisation with the observational techniques.
- T0+6 to T0+12 months: Creation of light curve and spectral samples for their study.
- T0+12 to T0+24 months: Write up paper on the light curve sample, quantifying their diversity, deviations and physical implications.
- T0+18 to T0+30 months: Write up paper on the spectroscopic sample, identifying the spectral features, their strengths and spectral profiles.
- T0+30 to T0+36 months: Write thesis manuscript, prepare defence

During the thesis period the PhD candidate will have the opportunity to visit some of the telescopes and participate in the observations, stay at collaborating institutions and take part in workshops and international conferences to create a research network, learn new techniques, and present her/his work.

References:

- *COLIBRÍ, a wide-field 1.3 m robotic telescope dedicated to the transient sky*, S. Basa et al., SPIE 2022, 121821, 1
- *The SVOM gamma-ray burst mission*, eprint arXiv:1512.03323
- *GRBSpec: a multi-observatory database for gamma-ray burst spectroscopy*, de Ugarte Postigo et al. SPIE 2014, 9152, 0