Thesis subject

Laboratory: Laboratoire d'Astrophysique de Marseille

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Title of the thesis subject: Catching the progenitors of the gamma-ray bursts

Description of the thesis subject:
At all times, the study of cosmic explosions has been connected with key advances in astronomy. This is especially true now that cosmic explosions are used as standard candles to pace the Universe (type Ia supernovae), as probes of the distant Universe (Gamma-Ray Bursts, GRBs), as extreme physics laboratories (tidal disruption event, fast radio burst, etc.), and as the only witnesses of the birth of compact objects (black holes and neutron stars). In the near future, cosmic explosions will stay at the forefront of astrophysics with the maturity of the astrophysics of multi-messengers (neutrinos and gravitational waves) and with the development of time domain astronomy.

In this scientific context, GRBs play a very specific role, as they are the most energetic explosions in the Universe after the Big Bang. They are associated with the death of the most massive stars (supernovae) or merging of compact stellar objects (neutron-star/neutron-star or neutron-star/black-hole). The radiated energy within a minute by a GRB is typically 10^{51} erg. Due to these extreme luminosities, GRBs can be used to probe the most observationally hostile and remote regions of the Universe.

The Sino-French SVOM (Space-based multi-band astronomical Variable Objects Monitor) mission will have a major contribution to this scientific domain by improving our understanding of the GRB phenomenon and by allowing their use to understand the infancy of the Universe. It is designed to achieve the best compromise between space and ground instrumentation. The onboard instruments permit the detection of the GRBs with a localization from arcminute to arcsecond accuracy, the study of the prompt emission and the early detection and follow-up of afterglow in the visible. The ground segment enables the precise localization of the GRBs, the follow-up of the afterglow down to the near-infrared and the redshift estimation.

In order to fulfill its scientific objectives, SVOM involves a fast robotic telescope, COLIBRI, offering really attractive performances, making it really unique at the international level: high availability for alert observations, very good sensitivity (1.3 m mirror diameter), very fast pointing speed (on target in less than 20 sec after the alert reception), multiband photometric capabilities (from visible to near-infrared, with three simultaneous arms), and large field of view (26 arcminutes).

SVOM was successfully launched on June 2024 from China, for at least a 3-year life span, and COLIBRI is now in operation in one of the best astronomical sites in the world, the Observatorio Astronómico Nacional San Pedro Mártir, Baja California, Mexico. The mission represents a major investment for France and for LAM in particular, which is the responsible of the COLIBRI telescope.

During the course of this thesis, we propose to play a very active role in the scientific exploitation of COLIBRI, which has just begun its scientific exploitation. This is a very unique opportunity to easily access very high-quality data. In particular, we propose to participate in the observations of the gamma-ray bursts detected by SVOM (and also from the NASA SWIFT and Einstein Probe missions), and in their analysis by combining data from the various observing instruments associated with the mission follow-up network.

A very special attention will be paid to all the gamma-ray bursts at low redshift ($z<0.5$). This is an area where COLIBRI will provide strong added value, thanks to its availability, sensitivity and capability to observe up-to infrared. By setting up a systematic long-term revisit program (under the student's responsibility), it will be possible to detect a possible supernova or kilonova (as it was the case for GRB 211211A). COLIBRI will be able to constitute a very homogeneous sample (around 5 per year) for the search for supernovae and kilonovae at $z<0.5$, with several visits, in the same filters, at the same time, and with the possibility of subtracting the host galaxy very cleanly thank to a late observation, which will reduce selection bias.

Thanks to these observations, it will be possible to characterize the nature of the progenitors associated with these events and confirm, for example, that a relatively large fraction of long GRBs at low redshift, as for the short GRBs, are likely to have compact merger progenitors. From this, it will be possible to provide very important constraints in the search for optical counterparts associated with gravitational waves, a major challenge for the international scientific community.

This work will be carried out with several Mexican collaborators from UNAM involved in the development of COLIBRI.

References:

- *COLIBRI, a wide-field 1.3 m robotic telescope dedicated to the transient sky*, S. Basa et al., SPIE 2022.
- *The SVOM gamma-ray burst mission*, eprint arXiv:1512.03323
- *A Kilonova Following a Long-Duration Gamma-Ray Burst at 350 Mpc*, arXiv:2204.10864
- *Progenitors of Low-redshift Gamma-Ray Bursts*, https://iopscience.iop.org/article/10.3847/2041-8213/ad2763/pdf