Labex UnivEarthS
WP I7: Gamma-Ray Bursts: a unique laboratory for modern astrophysics

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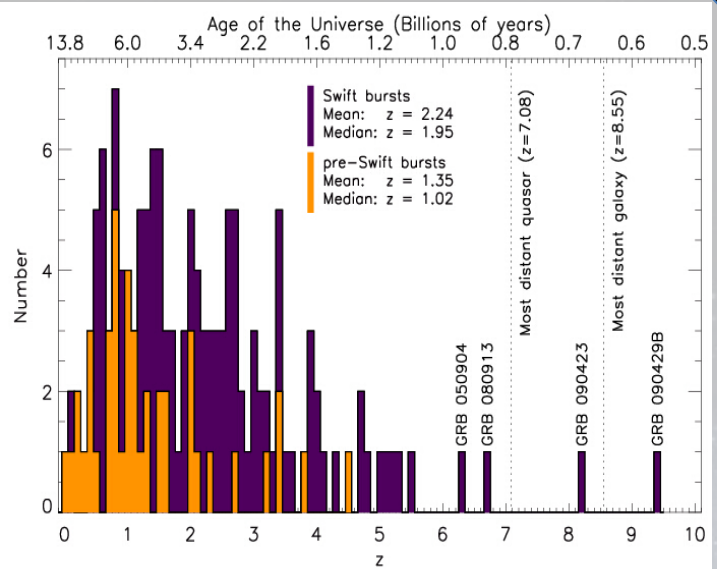
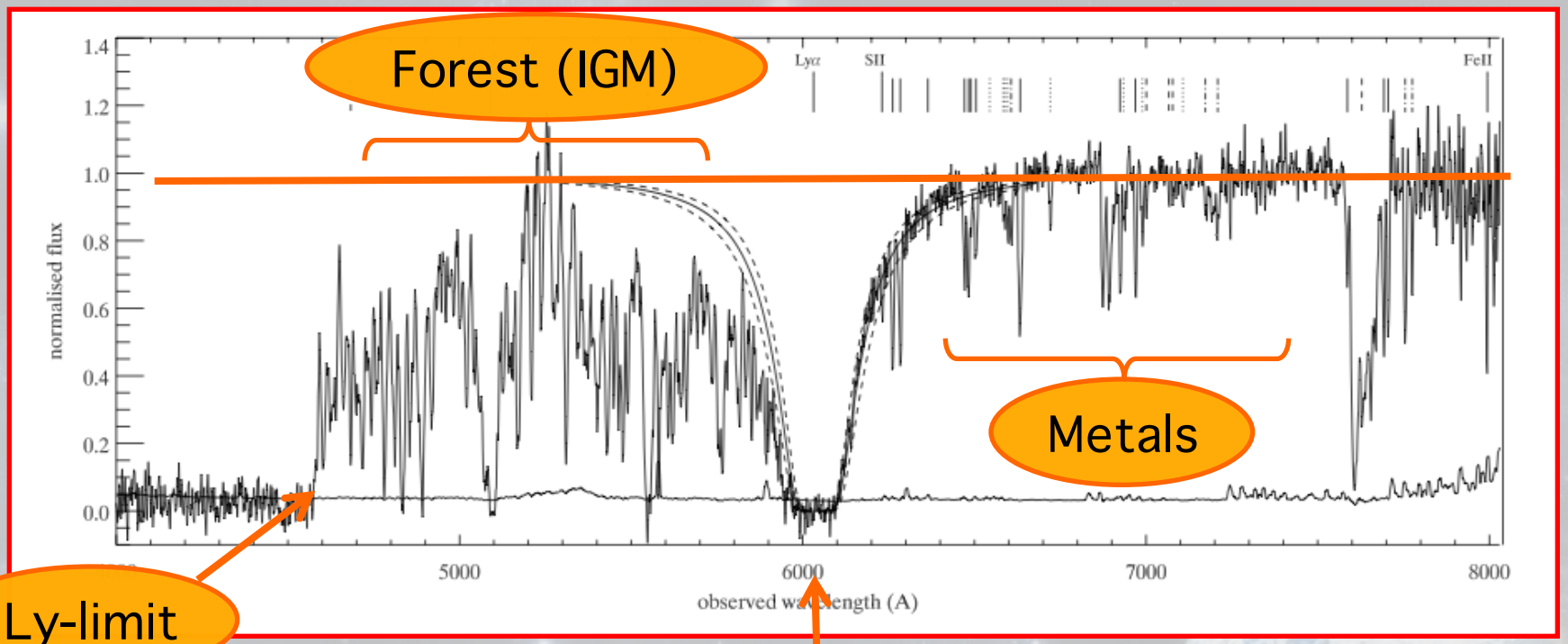
Gamma-Ray Bursts as probes

- ✓ GRBs are the most luminous transients in the Universe, outshining temporarily the luminosity of their host galaxy
- ✓ Thanks to their brightness (during prompt and afterglow emission), Gamma Ray Bursts (GRBs) can be detected up to very high redshifts (GRB 090423 at z = 8.2 and GRB 090429 at z = 9.4)
- ✓ GRBs represent a unique tool to study the Universe over a wide redshift range (potentially up to the re-ionization era), as they can be used as *in situ* probes of the GRB environment



Gamma-Ray Bursts as probes

✓ The power of GRB afterglow spectroscopy



Ly-limit

HI(Lya)

Gamma-Ray Bursts as probes

- ✓ Here we summarize the results obtained thanks to the LabEx hiring at AIM of M. Arabsalmani, who started her postdoc under the supervision of E. Le Floc'h (AIM) and S. Vergani (GEPI) in September 2016

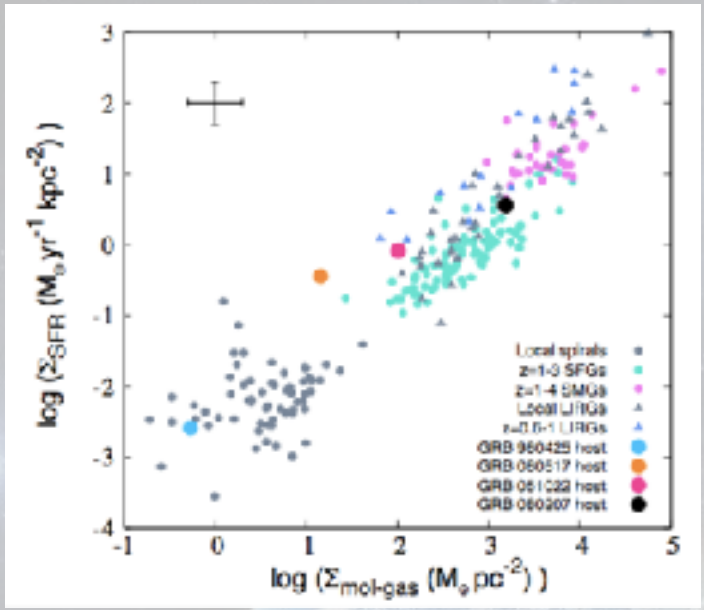
- ✓ The physical properties of the environments where Long Gamma-Ray Bursts (LGRBs) originate have been extensively studied over the past 20 years. Nonetheless, it is still debated whether these environments are representative of the whole population of star-forming galaxies across cosmic time or if they are biased toward a peculiar class of sources.

- ✓ For instance, the metallicity of the GRB close environment, as well as its star formation efficiency, could play a major role in driving the probability for a GRB to occur in a given galaxy. Addressing these questions remains the central theme of many on-going research projects on LGRB hosts, as it has critical impact on understanding how LGRBs can probe galaxy evolution in the distant Universe.

Gamma-Ray Bursts as probes

- ✓ The content of LGRB hosts in molecular gas as well as their efficiency in converting this gas into stars is still controversial. In particular, the previous lack of CO detection in GRB hosts had led to the idea that these galaxies could be deficient in molecular gas, hence questioning whether GRBs rather probe a specific mode of star formation compared to field galaxies

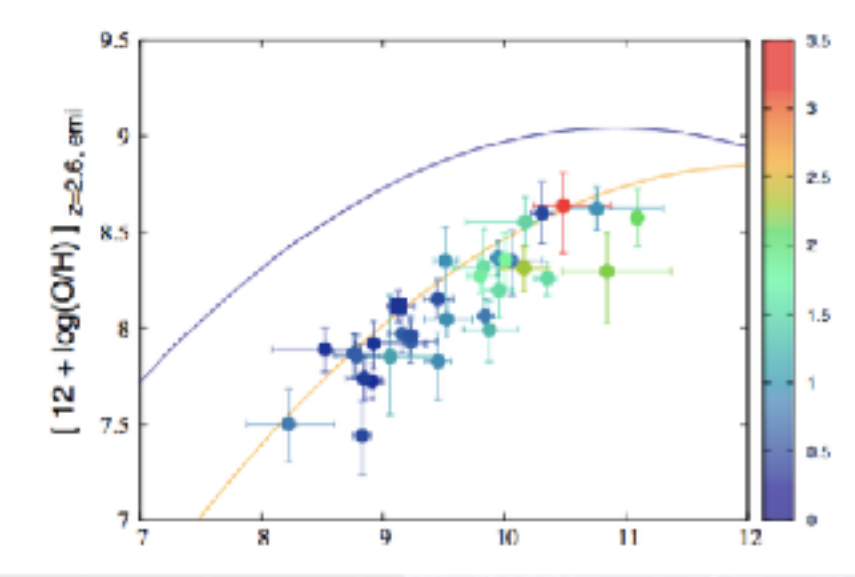
- ✓ Using the NOEMA interferometer, we carried out CO observations of the GRB080207 host, which is a luminous and massive galaxy at z=2. Contrary to other GRBs that occurred in systems referred as "starbursts" (i.e., sources with elevated Star Formation activity for their stellar mass and gas content), we found this host galaxy to be quite rich in molecular gas and to follow the standard scaling relations between the stellar mass, the star formation rate and the molecular gas mass observed among the general population of star forming galaxies



Arabsalmani et al. 2017, MNRAS, submitted

Gamma-Ray Bursts as probes

✓ Using 82 spectra of GRB optical afterglows and GRB host galaxies we explored the metallicities (derived from both absorption and emission lines) and line velocity widths of GRB hosts as a function of their stellar mass. Our main result shows that GRB host galaxies follow a mass-metallicity relation similar to that observed among field star-forming galaxies (with a small offset consistent with uncertainties & systematics). Our study thus reinforces the idea that LGRBs are able to probe a wide range of environments, in particular galaxies and star-forming regions characterized by a broad range of metallicities.



Arabsalmani et al. 2017, MNRAS, in press

Gamma-Ray Bursts as probes

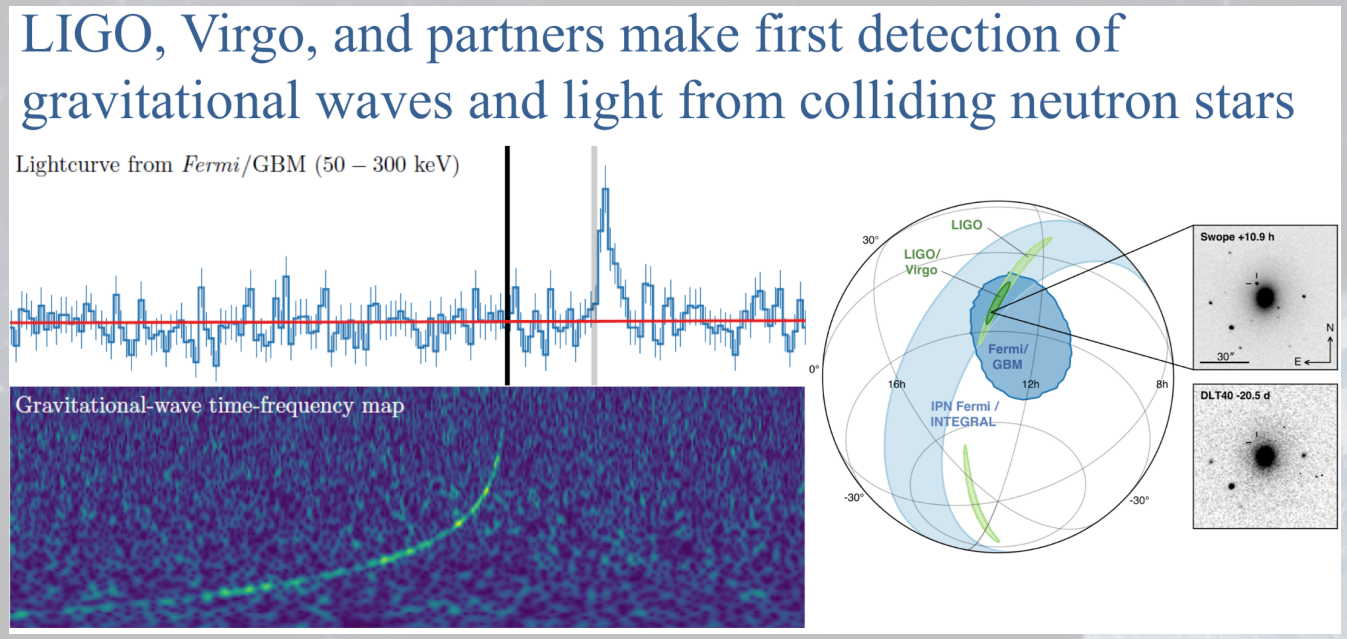
✓ Future prospects:

- ✓ We began exploiting the observations that we obtained at the Giant Meter Radio Telescope (GMRT) so as to constrain the atomic gas in the host galaxies of nearby Super-Luminous Supernovae. Our goal is to explore the physical properties of the environments where these events take place, and to address their potential connection with the origin and the occurrence of Long Gamma-Ray Bursts.

- ✓ We are also initiating the second phase of the project initially planned as part of the LabEx post-doc position, which is to use one of the most recent phenomenological models of galaxy formation (EGG, Schreiber et al. 2017) to investigate the expected link between the cosmic star formation history and the occurrence rate of LGRBs across cosmic time. Our goal is to explore in particular the impact of physical parameters such as metallicity, star formation efficiency and star formation mode. In order to complete this program, we submitted several observation requests, and we need to complete the dedicated post-doc in 2018.

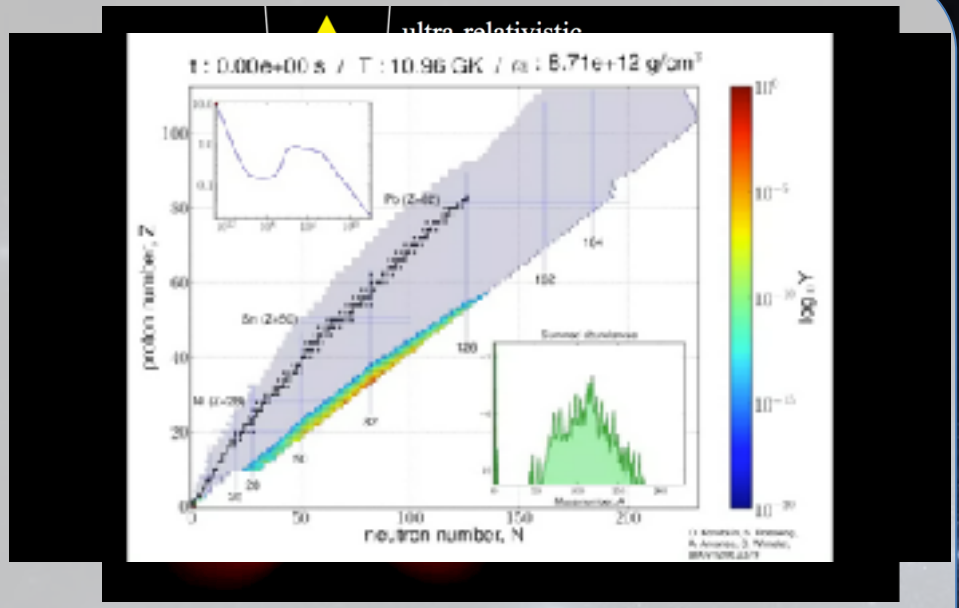
Gamma-Ray Bursts as Multi-messengers

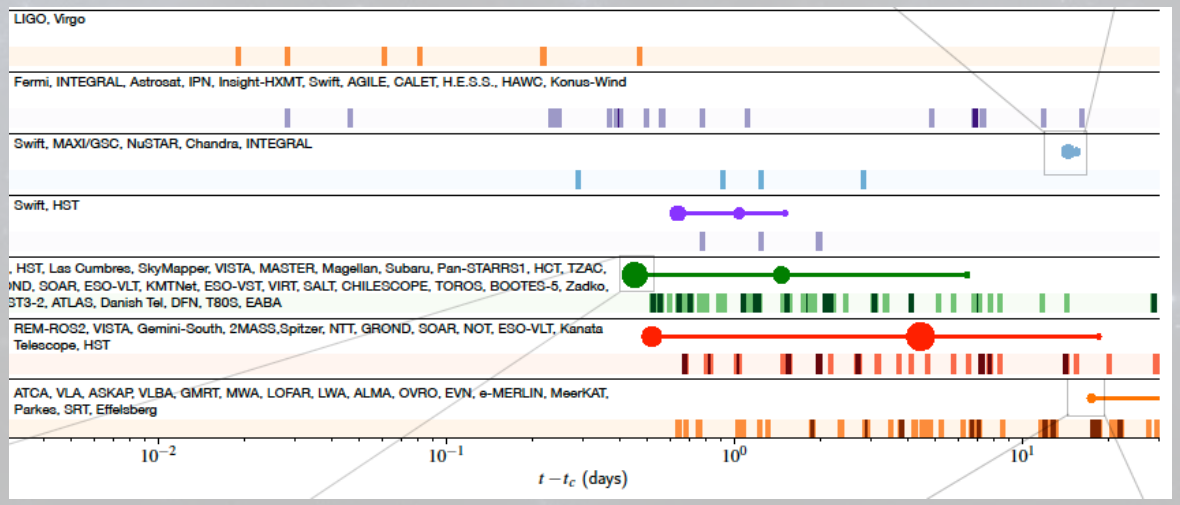
- ✓ On August 17th 2017 we witnessed the spectacular confirmation of the Multi-messenger nature of Gamma-Ray Bursts (see our LabEx workshop on that theme back in 2014)
- ✓ The short GRB 170817 detected by Fermi/GBM and INTEGRAL/SPI ACS was in spatial an temporal coincidence with a BNS merger signal detected by aLIGO (confirmation of the BNS model for short GRBs!)

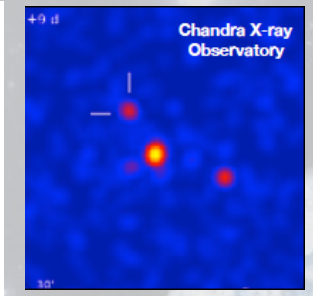


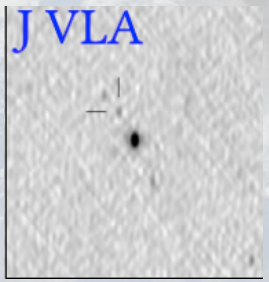
Gamma-Ray Bursts as Multi-messengers

- ✓ The simultaneous detection triggered one on the most intense follow-up campaign of all times leading to the discovery of an optical/NIR counterpart, finally identified as a macronova/kilonova, the place of production of the heaviest elements in the Universe







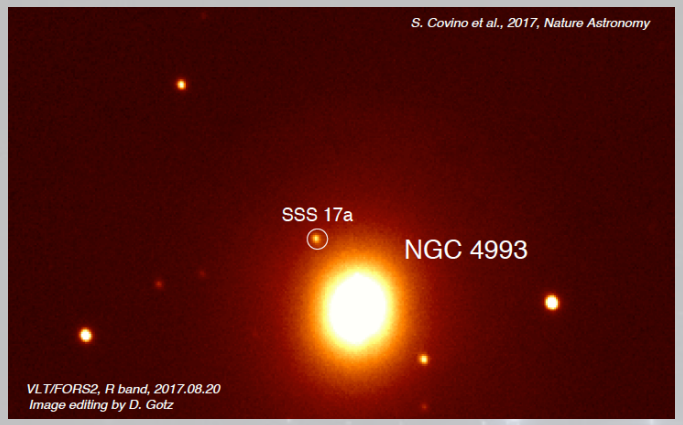


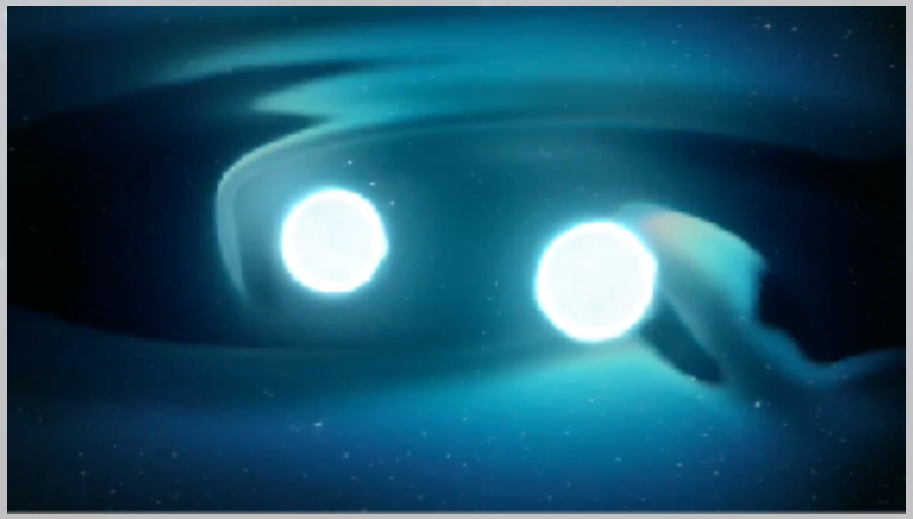
Gamma-Ray Bursts as Multi-messengers

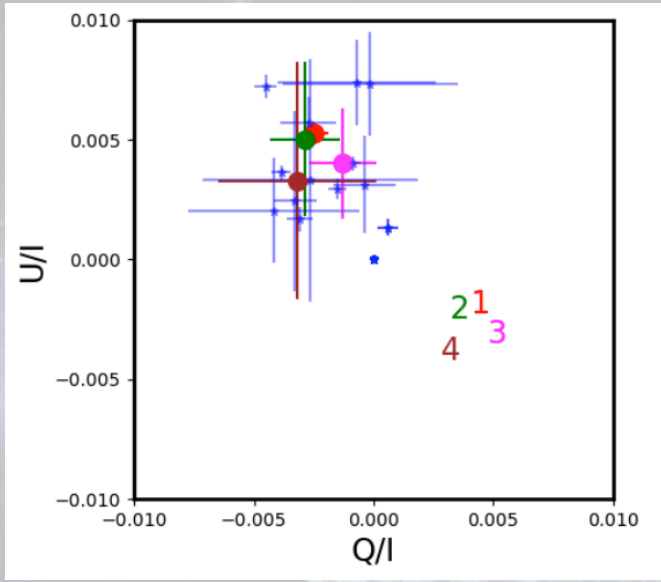
- ✓ More than hundred papers have been published on this event on October 16th. For a complete list of papers, see www.kilonova.org
- ✓ Some members of the LabEx (S. Vergani, D. Götz, P. Laurent) were involved in the multi-messenger follow-up of the GW 170817 event (despite our project was « mildly » supported by the LabEx)
- ✓ E.g. DG involved in the follow-up of the event using the FORS2 data at VLT measuring the polarization of the optical counterpart (Covino et al. Nature Astronomy), SV involved in the spectroscopic follow-up using X-SHOOTER at VLT (Pian et al. Nature), PL involved in the INTEGRAL data analysis (Savchenko et al. ApJ)
- ✓ It is not a surprise that the GRB community played a fundamental role in the follow-up of the BNS merger event, since we trained for at least 40 years. GRBs are the MM sources!

Gamma-Ray Bursts as Multi-messengers

- ✓ Polarization of light is a powerful investigation tool, complementary to light curves and spectra
- ✓ The absence of polarization signal (see Covino & Götz 2016) confirms that we are measuring the Macronova and not the afterglow (jetted) component







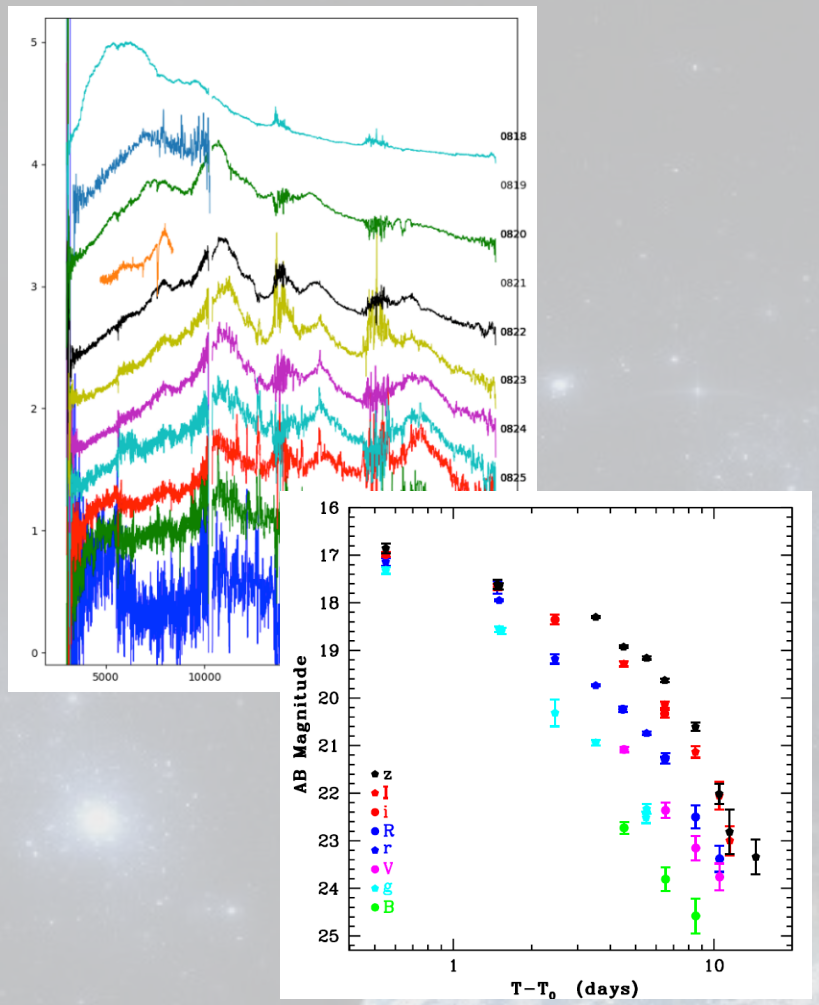
Covino et al., Nature Astronomy, 2017

Gamma-Ray Bursts as Multi-messengers

✓ Proposed programme for the last 2 years of the (current) LabEx:

- ✓ The next (O3) Ligo/Virgo run is foreseen in Fall 2018.
- ✓ In order to fully exploit the new era of multi-messenger astrophysics in conjunction with GRB science, we ask the LabEx to fund a two year post-doctoral contract (under the supervision of C. Lachaud and E. Chassande-Mottin at APC) in order to further investigate the strategy of the optical follow-up of GW alerts.
- ✓ We note that the detection of August 17th event was obtained in a particularly lucky configuration for which three interferometers could detect the signal, the source was nearby, and the gamma-ray sky monitors were not occulted by the Earth.
- ✓ In the next LIGO/Virgo run we expect a higher variety of cases, which can require more complex strategies (follow-up on the Salafia et al. paper)
- ✓ In addition, no early time X-ray observations could be performed for GW 170817. Current models predict isotropic X-ray emission associated to the merging of two neutron stars in case the final product of the merger is not a black hole. The post-doc shall, starting from the currently available theoretical models, propose (in analogy to the Salafia et al. paper) an observation strategy for X-ray observations, and in particular for the future MXT telescope on board SVOM

- ✓ In addition, during 2018 the first light of the SVOM Ground based Wide Angle Cameras is foreseen: the GWACs are a set of optical cameras able to monitor the sky over 5000 square degrees with a limiting magnitude of about 16 (V).
- ✓ The optical counterpart is much bluer and brighter than expected
- ✓ Good prospects for the GWACs during O3
- ✓ GWAC is the only experiment able to access the first instants of the Macro/Kilonova
- ✓ The post-doc can continue to the GWAC data analysis and to the optimization of the observing strategy



Pian et al. Nature, 2017

Project Publications

- ✓ O.S. Salafia, M. Colpi, M. Branchesi, E. Chassande-Mottin, G. Ghirlanda, G. Ghisellini, S. Vergani, 2017, « Where and When : Optimal Sheduling of the Electromagnetic Follow-up of Grawitational-wave Events Based on Counterpart Light-curve Model, ApJ, 846, 62
- ✓ R. Martone, L. Izzo, M. Della Valle, L. Amati, G. Longo, D. Götz, 2017, "False outliers of the Ep,i-Eiso correlation?", A&A, in press, arXiv/1708.03873
- ✓ A.B. Higgins, R.L.C. Starling, D. Götz, et al., 2017, "Investigating the nature of INTEGRAL Gamma-Ray Bursts and sub-threshold triggers with Swift follow-up", MNRAS, 470, 314
- ✓ N. Globus, D. Allard, E. Parizot, C. Lachaud, T. Piran, 2017, "Can we reconcile the TA Excess and Hotspot with Auger Observations?", ApJ, 836, 163
- ✓ Abbott,…,D. Götz, …,S. Vergani,…, et al., 2017, "Multi-messenger observations of a neutron star merger", ApJ, in press
- ✓ M. Arabsalmani, E. Le Floc'h, …, S. Vergani, et al., 2017, "A Molecular gas rich GRB host galaxy at the peak of cosmic star formation with significant outflowing gas", submitted to MNRAS
- ✓ M. Arabsalmani, …, E. Le Floc'h, …, S. Vergani, et al., 2017, "Mass and metallicity scaling relations of high redshift star-forming galaxies selected by GRBs", MNRAS, in press

Conclusions

- ✓ Thanks to the hiring of M. Arabsalmani, we were able to produce two first author papers in 2017 on the GRB environment topic

- ✓ We expect that with the hiring of a post-doc on the GRB Multi-messenger subject in 2018-2019 we could similarly expect a leading role in the GW follow-up field also making use of the SVOM GWAC instrument. O3 is in 2018, we cannot wait for the LabEx renewal.

- ✓ As for the first workshop in 2015, we ask for funding for the third SVOM scientific workshop (to be held in May 2018 at the Ecole de Physique des Houches), which will focus on the « Merging Universe » in the SVOM era.