Cosmology with Astrophysical Transients

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2.2 ICRANet participants

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3 Description

The current situation in astrophysics allows to use large archival astrophysical data from infrared, optical and very high energetic energies. This new possibility allows to study a single source in a multi-wavelength context, and permits to obtain more information about the physical mechanisms behind the observed radiation. But, following the Galileian principle, before the phase of ”theoretical inference”, the interpretation of data comes first, as well as the phase of data reduction and analysis. The advent of new and more powerful calculators and programming languages have largely improved the first step of the data reduction, allowing semi-automatization procedures for data acquiring and storing. But behind each of these procedures, as well as techniques for their interpretation, there is a human mind.

Recently we have started and developed a program involving the use of already existing software packages for space data reduction, as Swift, Fermi, XMM and HST, and on-ground facilities as optical telescopes at ESO and Canary Island. New collaborations started, about the study of optical transients, as well for the analysis in real-time of high-energy sources as GRBs, and their connection with cosmology, at low and high redshifts. In the following, we will provide a more detailed description of the on-going activity for each treated argument.

3.1 Multi-wavelength analysis of GRBs

The possibility of surveying the entire sky with the new generation of optical telescopes allows to match catalogs the large list of transients discovered with these surveys with catalogs of higher energetic astrophysical sources. A large fraction of these optical transients remains unclassified, and for this reason they could be related to other than the well-known galactic explosions, as cataclysmic variables, or extra-galactics ones, like supernovae. Beyond the spatial coincidence, astrophysics suggests that a particular time constraint must be taken into account in order to associate an optical transient with an high energetic source, as it can be a gamma ray burst (GRB). A first approach was developed, using the entire Asiago and Harvard catalog of known SNe Ia matched with the Fermi Gamma-ray Burst Monitor (GBM) log burst catalog [1]. Interestingly, all the candidates are nearby supernovae, but only in one case the association is strong, so that it was proposed for the first time a new nearby GRB-SN association in the case of GRB 120121B/SN 2012ba (z = 0.017). Consequently, also the rate of nearby GRBs provided by the Fermi GBM was inferred and found to be in agreement with other rates presented in literature.

Further applications of this catalog-matching technique (well-known in Big Data Analysis) will be developed, with particular refereeing to very large optical surveys and next generation of multi-wavelength detectors. This method will complement the search for counterparts of any astrophysical source and consequently obtaining precious physical information on their observed evolution.

3.2 Cosmology with GRBs

Gamma Ray Bursts are observed up to very large distances and this evidence has always suggested a possible use of them as possible cosmological probes. In literature there are plenty of works regarding GRBs as distance indicators, in particular by using some correlations between spectroscopic and photometric properties of GRBs which renders in a certain sense standardizable. However, all of these methods suffer for three main problems that avoid a correct use of GRBs as cosmological distance tools: 1) lack of a detailed physical explanation for their existence; 2) lack of a low distance set of GRBs calibrated with nearby standard candles (following the concept of a distance ladder); and 3) some selection effects and systematics, which can not be deleted at all.

In this light, and following long-standing works made by Izzo Luca in recent years on cosmology with GRBs, we have proposed a new method which overcomes the second point, and partly the first point. It is based on a property first reported by Bernardini et al. (2012) and Margutti et al. (2013), of a correlation between the prompt and afterglow quantities. Starting from this first evidence, we have proposed a more detailed correlation that was verified at first on a sample of 60 GRBs [2]. The application of this method, called Combo-relation, is very promising in constraining cosmological parameters with GRBs, and preliminary new results are very promising

3.3 Analysis of nova outbursts

The recent discovery of very high energy radiation in galactic novae, the possibility of investigating with large details the soft X-ray emission observed after the ejecta transparency, and the availability of high-resolution optical and near-infrared spectrographs represent a new set of instruments for investigating and shed the definite light on these astrophysical explosions. The evidences for a-sphericity in nova ejecta are still an enigma, particularly the physical mechanism beyond this evidence, which seems to act in different way for different novae. Moreover, photons with energy radiation larger than 100 MeV observed in five novae, from the launch of the Fermi satellite, can provide further constraints and at the same time additional information on the physical mechanisms acting in novae phenomenon.

The study of one of the most famous recurrent novae, T Pyx, and the outburst of one of the most luminous novae in recent years, V 1369 Cen, was considered. Time at large telescopes, as the 3.6 meters Telescopio Nazionale Galileo, the ESO/MPG 2.2 meters and 0.6 meters of the Pontificia Universitade Catolica de Chile was obtained for the study of these two novae. High-resolution spectra were obtained using these telescopes, and they allowed up to now to the identification of lithium in the ejecta of V1369 Cen [3]. It is the first time that lithium is detected in a nova outburst, thanks mainly to the very large luminosity of the nova and the high-resolution of the spectrographs used. This detection has very important consequences for the study of the chemical evolution of the Galaxy, solving a long-standing problem concerning the over–abundance of lithium observed in young star populations: classical novae are the main farms of lithium in the Galaxy and they strongly contribute to the enrichment of lithium of these stars.

In 2015-2016 two additional novae have been observed, V5668Sgr and Nova Lup 2016. We have found a large quantity of beryllium in V5668 Sgr that results in a value of lithium ejected from the nova of $\sim$ 10 million times larger than hte Solar value. This implies that we need only 5% of the total novae observed in the Galaxy to explain the over-abundance of lithium in the Galaxy. However, the evidence of aspherical emission in novae, as well the filamentary structures observed in nova remnants, suggests that the mass ejected must be corrected by 1) a filing factor parameter, and 2) a geometrical distribution of the ejecta. Only further observations, of novae in outburst and their remnant can definitely shed the definite light on this problem, as well provide insights on the physics underlining the nova explosion mechanisms.

Perspectives: to obtain information about the composition of the nova ejecta (from the nebular spectra analysis), the study of the nova evolution and information about the expanding systems and geometry (from evolution of P-Cyg absorption lines), the first detailed analysis of narrow absorptions, detected in V 1369 Cen, and more important, to provide a first high-resolution database for novae, in collaboration with a network of scientists all around the world. Since novae are supposed to be one of the first "farm" of metals in our Galaxy, the continuous monitoring of novae in outburst will continue for next years.

3.4 Support to the Swift and future space missions

The collaboration with lead teams in space astrophysics is vital for the entire astrophysical research. Moreover, it is a very good chance to learn with large details all the mechanisms that lie beyond the procedure of data reduction and analysis of space instruments, as it is the case of the Swift satellite. We join the Swift group three years ago, providing human time and "know-how" for the monitoring and real-time analysis of data obtained with the Burst Alert Telescope (BAT) and in particular the X-Ray Telescope (XRT). Every month, about five days are dedicated to the continuous monitor of new GRBs and high energetic transients that trigger the Swift-BAT detector and then followed-up by the XRT.

The support to the Swift mission ended on July 2016.

Moreover, in the last three years we join the LOFT community, providing simulations for the Wide Field Monitor instrument which will be dedicated completely to survey the energy range (2 – 50) keV, to catch photons emitted by GRBs. We are working on one of the most interesting bursts known, GRB 060218, for which we simulate the signal that the LOFT-WFM would have observed form this source [7]. Since the WFM is more sensitive than the BAT, we will have more information on such similar low energetic and nearby GRBs, which recent analysis suggest to be more numerous than the ones observed by the Swift-BAT.

3.5 Other activities

Other external collaborations were developed, particularly related to the know-how in data reduction of X-ray detectors (Swift-XRT, XMM, HST) and analysis of optical spectra. Indeed, two works regarding the analysis of optical data obtained with the Hubble Space Telescope (HST) and archival data of lensed systems were accepted and in publications on scientific journals [8,9].

Support to the ICRANet *compact objects* group is still provided : after the analysis and study of the emission from soft gamma repeaters (SGR) and anomalous X-ray pulsars (AXP) [10,11], we are collaborating in the data reduction and analysis of data from X-ray binary pulsars and magnetic with dwarfs.

Finally, continuous support and collaborations with the *grb1* group is one of the priority. The analysis in almost real-time of GRB X-ray afterglow light curves and their possible interest in cosmology, and the data analysis of possible IGC candidates from the identification of different episodes in GRB prompt emission light curves is one of the most important activities of the group since it allows to identify possible candidates of IGC binary-driven hyper novae [12,13,14] and then study with very large details and also follow their evolution in real-time, particularly for nearby sources.

Last, but not the least, the presence at public events was initiated with the national day of the research, with two main events in the last two years in Pescara. The possibility of presenting recent results in astrophysics, and also discuss of astronomy with people, is one way for the sensitization of the public opinion to the fundamental role of the astrophysical research in the human history.

4 Publications

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