Supernovae

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1 Topics

- Supernovae (Photometric and Spectroscopic Evolution, Rates)
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1.1 ICRANet participants

- Carlo Luciano Bianco
- Letizia Caito
- Massimo Della Valle

1.2 Past collaborators

- John Danziger (INAF-Trieste)
- Roberto Gilmozzi (ESO, Garching, Munchen)
- Mario Livio (STScI, Baltimore)
- Piero Madau (Santa Cruz, California University)
- Nino Panagia (STScI, Baltimore)
- Saul Perlmutter (Lawrence Berkeley National Laboratory, University of California)
- Sumner Starrfield (Arizona State University)
- Robert Williams (STScI, Baltimore)

1.3 Ongoing collaborations

- Lorenzo Amati (INAF-Bologna)
- Guido Chincarini (Bicocca University, Milano) and the SWIFT team
- Roberto Gilmozzi (ESO, Garching, Munchen)
- Filippo Mannucci (INAF-Arcetri, Firenze)
- Dani Maoz (Tel-Aviv University)
- Francesca Matteucci (Trieste University, Trieste)
- Ken Nomoto (University of Tokyo)
- Nino Panagia (STScI, Baltimore)
- Andrea Pastorello (Queen's University, Belfast)
- W. Pietsch (MPE-Garching)
- Evan Scannapieco (Arizona State University)
- Robert Williams (STScI, Baltimore)

1.4 Sabatical Visits, 2005-2010

- European Southern Observatory, Munchen (2005)
- STScI, Baltimore, (2005)
- KAVLI Institute, Santa Barbara (2006, 2007)
- Tokyo University (2006)
- Dark Cosmology Center, Niels Bohr Institute, Copenhagen (2007)
- Queen's University, Belfast (2007)
- European Southern Observatory, Munchen (Jan 2008- Jun 2009)

1.5 Students

- Luca Izzo (IRAP PhD, Italy)
- Bernardo Machado de Oliveira Fraga (IRAP PhD, Brazil)

2 Brief description

My ongoing research concern the study of several classes of transient phenomena such as: supernovae, gamma-ray bursts and novae .

Gamma-ray bursts and their Afterglows. My interest in this area started in 2000 when I became member of the SWIFT follow-up team. Most efforts were (and still are) devoted to the study of the connection between Supernovae and GRBs. Currently, I'm PI of a VLT proposal *A spectroscopic study of the Supernova/GRB connection* aimed at following the spectroscopic evolution of nearby SN-GRB associations. This project is carried out in collaboration with other members of SWIFT follow-up team. I point out 3 highlights from this programme, occurred in 2008/2009. i) the discovery of a transition object (SN 2008D/XRF 080109) between GRBs and standard Core-Collapse SNe; ii) the detection of a GRB-SN at z=0.53 and iii) the discovery of GRB 090423 at z=8.1 that is the farthest astrophysical source ever detected (see Appendix).

Supernovae. Photometric and the spectroscopic study of all types of SNe (Ia, Ib/c, II-linear, II-plateau) near maximum light and at late stages and their theoretical modeling. The observations at maximum provide us with the necessary data for using SNe (Ia and II) as standard candles. The observations at later stages allow one to discriminate among different energy sources (i.e. radioactive decay, pulsar, light-echo), to model the mechanisms of the explosion, and to shed light on the nature of the progenitor (In collaboration with N. Panagia and the Padova and Belfast SN groups.)

Supernovae at high z. The study of Supernovae has been extended to objects at high-z (in collaboration with the Supernova Cosmology Project). The search for SNe at high z is twofold important. On the one hand the evolution of the SN rate with redshift contains unique information on the star formation history of the universe, the IMF of stars and the nature of the progenitors in Type Ia events. On the other hand SNeI-a at $z \sim 1 - 1.5$ are valuable tracers of cosmological models . Both aspects are currently investigated both on observational and theoretical grounds.

Search for obscured Supernovae. The "true" value of the SN rate is considerably underestimated because of extinction. This problem can be partially solved by observing in the infrared. We have started two NIR SN searches in ultra-luminous galaxies, the former at NTT and TNG the latter with HST-NICMOS (In collaboration with F. Mannucci).

Search for environmental effects on the properties of type Ia SNe. This is a long-term project (in collaboration with F. Mannucci, Nino Panagia, R. Gilmozzi and F. Matteucci) aimed at throwing light on the still unknown origin of the progenitors of type Ia Supernovae. Our results have been reported in 8 papers so far published (since 2005).

Novae. The systematic study of extragalactic novae in galaxies of different Hubble types has shown, that nova frequency (number of nova outburst per year) depends on the Hubble type of the parent galaxy. In particular, we find that spiral galaxies are more prolific nova producers, by a factor about 4, in units of K-band luminosity, than ellipticals and S0's. We show that this result could be explained by assuming that novae in late– and early–type galaxies originate from two different classes of progenitors.

The use of the maximum magnitude *vs.* rate of decline relationship, calibrated on the nova population of M31 and LMC, has allowed us to re-define the distance scale from the Local Group up to Fornax cluster and to measure the Hubble constant. The distance moduli so derived compare very well (i.e. within 0.2 mags) with those obtained via Cepheids, thus demonstrating that classical novae are indeed good distance indicators perfectly suitable to calibrate the absolute magnitude at maximum of type Ia occurred in early type galaxies. In collaboration with R. Gilmozzi we have explored the possibility to use nova stars as standard candles for measuring the cosmological parameters, with an Extremely Large Telescope (40m). Observations carried out with Bob Williams and Elena Mason on a sample of galactic Novae have shown the existence of stationary material, coming from the secondary star, around the circumburst area. Implications for Nova (and possibly SN-Ia) progenitors are under investigations.

Cosmological Parameters with GRBs. Observations of SNe-Ia in the range of redshift $z \approx 0.3 \div 1.3$ (Perlmutter et al. 1998; Perlmutter et al. 1999; Riess et al. 1998; Riess et al. 2004) have shown that their peaks magnitude appear (at $z \sim 0.5$) dimmer than expected by ~ 0.2 mag. This result has been taken as evidence for the existence of a "cosmic jerk", then suggesting that the Universe may accelerate its expansion. On the other hands the cosmological interpretation rely on the lack of evolutionary effects on progenitors of type Ia SNe. Recent results on SNe-Ia progenitors, which imply the existence of two different classes of progenitors for SNe-Ia (Della Valle & Panagia 2003, Della Valle et al. 2005, Mannucci et al. 2005, 2006, 2007, Sullivan et al. 2006, Aubourg et al. 2007) occuring in different environments and at different redshift, may cast some doubts on this assumption. In addition recent versions of the Hubble diagramm for SNe-Ia (e.g. Wood-Vasey et al. 2006) display peculiar distributions of the residuals, which are also suggestive for the presence of systematics. This situation calls for an independent measurement of the cosmological parameters besides the one obtained via SNe-Ia. We show that GRBs can be used to measure Ω_M (see Amati et al. 2008; Della Valle &

Amati 2008).

3 Publications 2010

1. *Weird and Wild Supernovae*, Della Valle, M. Invited review at the Frascati Workshop 2009, Multifrequency behaviour of high energy cosmic sources, Vulcano, May 2009 Mem.SAIt, 81, 367

I report about an upgraded "state of the art" review on new types of stellar explosions.

2. *X-ray monitoring of classical novae in the central region of M 31. I. June 2006 - March 2007*, Henze, M. et al. 2010, A&A, in press

Classical novae (CNe) have recently been reported to represent the major class of supersoft X-ray sources (SSSs) in the central region of our neighbour galaxy M 31. We carried out a dedicated monitoring of the M 31 central region with XMM-Newton and Chandra in order to find SSS counterparts of CNe, determine the duration of their SSS phase and derive physical outburst parameters. We systematically searched our data for X-ray counterparts of CNe and determined their X-ray light curves and spectral properties. Additionally, we determined luminosity upper limits for all novae from previous studies which are not detected anymore and for all CNe in our field of view with optical outbursts between May 2005 and March 2007. We detected eight X-ray counterparts of CNe in M 31, four of which were not previously known. Seven sources can be classified as SSSs, one is a candidate SSS. Two SSSs are still visible more than nine years after the nova outburst, whereas two other nova counterparts show a short SSS phase of less than 150 days. Of the latter sources, M31N 2006-04a exhibits a short-time variable X-ray light curve with an apparent period of (1.6+-0.3) h. This periodicity could indicate the binary period of the system. From the 14 SSS nova counterparts known from previous studies, ten are not detected anymore. Additionally, we found four SSSs in our XMM-Newton data without a nova counterpart, one of which is a new source. Out of eleven SSSs detected in our monitoring, seven are counterparts of CNe. We therefore confirm the earlier finding that CNe are the major class of SSSs in the central region of M 31. We use the measured SSS turn-on and turn-off times to estimate the mass ejected in the nova outburst and the mass burned on the white dwarf. Classical novae with short SSS phases seem to be an important contributor to the overall population.

3. *X-ray monitoring of classical novae in the central region of M 31. II. Autumn and winter 2007/2008 and 2008/2009*, Henze et al. 2010, A&A, in press

Classical novae (CNe) represent the major class of supersoft X-ray sources (SSSs) in the central region of our neighbouring galaxy M 31. We performed a dedicated monitoring of the M 31 central region with XMM-Newton and Chandra between Nov 2007 and Feb 2008 and between Nov 2008 and Feb 2009 respectively, in order to find SSS counterparts of CNe, determine the duration of their SSS phase and derive physical outburst parameters. We systematically searched our data for X-ray counterparts of CNe and determined their X-ray light curves and spectral properties. We detected in total 17 X-ray counterparts of CNe in M 31, only four of which were known previously. These latter sources are still active 12.5, 11.0, 7.4 and 4.8 years after the optical outburst. From the 17 X-ray counterparts 13 were classified as SSSs. Four novae displayed short SSS phases (¡ 100 d). Based on these results and previous studies we compiled a catalogue of all novae with SSS counterparts in M 31 known so far. We used this catalogue to derive correlations between the following X-ray and optical nova parameters: turn-on time, turn-off time, effective temperature (X-ray), t2 decay time and expansion velocity of the ejected envelope (optical). Furthermore, we found a first hint for the existence of a difference between SSS parameters of novae associated with the stellar populations of the M 31 bulge and disk. Additionally, we conducted a Monte Carlo Markov Chain simulation on the intrinsic fraction of novae with SSS phase. This simulation showed that the relatively high fraction of novae without detected SSS emission might be explained by the inevitably incomplete coverage with X-ray observations in combination with a large fraction of novae with short SSS states, as expected from the WD mass distribution. In order to verify our results with an increased sample further monitoring observations are needed.

4. *X-ray variability with WFXT: AGNs, transients and more*, Paolillo, M. et al. 2010, Proceedings of "The Wide Field X-ray Telescope Workshop", held in Bologna, Italy, Nov. 25-26 2009 (arXiv:1010.5889). To appear in Memorie della Società Astronomica Italiana 2010

The Wide Field X-ray Telescope (WFXT) is a proposed mission with a high survey speed, due to the combination of large field of view (FOV) and effective area, i.e. grasp, and sharp PSF across the whole FOV. These characteristics make it suitable to detect a large number of variable and transient X-ray sources during its operating lifetime. Here we present estimates of the WFXT capabilities in the time domain, allowing to study the variability of thousand of AGNs with significant detail, as well as to constrain the rates and properties of hundreds of distant, faint and/or rare objects such as X-ray Flashes/faint GRBs, Tidal Disruption Events, ULXs, Type-I bursts etc. The planned WFXT extragalactic surveys will thus allow to trace variable and transient X-ray populations over large cosmological volumes.

5. *The afterglow and host galaxy of GRB 090205: evidence of a Ly-α emitter*

at z = 4.65, D'Avanzo, P. et al. 2010, A&A, 522, 20

Context. Gamma-ray bursts (GRBs) have proven to be detectable to distances much larger than any other astrophysical object, providing the most effective way, complementing ordinary surveys of studying the high redshift universe. Aims: We present the results of an observational campaign devoted to the study of the high-z GRB 090205. Methods: We carried out optical/NIR spectroscopy and imaging of GRB 090205 with the ESO-VLT starting from hours after the event to several days later to detect the host galaxy. We compared the results obtained from our optical/NIR observations with the available Swift high-energy data of this burst. Results: Our observational campaign led to the detection of the optical afterglow and host galaxy of GRB 090205 and to the first measure of its redshift, z = 4.65. As in other high-z GRBs, GRB 090205 has a short duration in the rest frame with T90,rf = 1.6 s, which suggests that it might belong to the short GRB class. The X-ray afterglow of GRB 090205 has a complex and interesting behavior with a possible rebrightening at 5001000 s from the trigger time and late flaring activity. Photometric observations of the GRB 090205 host galaxy imply that it is a starburst galaxy with a stellar population younger than $\sim 150 Myr$. Moreover, the metallicity of $Z > 0.27 Z_{\odot}$ derived from the GRB afterglow spectrum is among the highest derived from GRB afterglow measurement at high-z, suggesting that the burst occurred in a rather enriched environment. Finally, a detailed analysis of the afterglow spectrum shows the existence of a line corresponding to Lyman- emission at the redshift of the burst. GRB 090205 is thus hosted by a typical Lymanα emitter (LAE) at z = 4.65. This makes the host galaxy of GRB 090205 the farthest GRB host galaxy, spectroscopically confirmed, detected to date.

6. *Supernova 2010bh = GRB 100316D* Bufano, F. et al. 2010, CBET 2227

F. Bufano, S. Benetti, and E. Cappellaro, Istituto Nazionale di Astrofisica (INAF), Osservatorio Astronomico di Padova (OAP); S. Covino, INAF, Osservatorio Astronomico di Brera (OAB); S. Vergani, Galaxie, Etoile, Physique, Instrumentation (GEPI), Observatoire de Paris, and Astroparticule et Cosmologie (APC), Universite Paris 7; P. Goldoni, APC, Universite Paris 7, and Service d'Astrophysique, Commissariat a l'Energie Atomique (CEA); M. Della Valle, INAF, Osservatorio di Capodimonte; E. Pian, INAF, Osservatorio Astronomico di Trieste; S. Campana and G. Tagliaferri, INAF, OAB; D. Malesani and J. Fynbo, Dark Cosmology Centre, University of Copenhagen; M. Turatto, INAF, Osservatorio Astronomico di Catania; F. Patat, European Southern Observatory (ESO); and P. Mazzali, INAF, OAP, on behalf of a larger collaboration, report that a high-dispersion optical spectrum (range 350-900 nm, resolution 0.02 nm) of the afterglow associated with GRB 100316D (cf. GCN 10496; visible at http://gcn.gsfc.nasa.gov/gcn3/10496.gcn3) was obtained with the Very Large Telescope (+ XShooter) at ESO/Paranal on Mar. 23.04 UT. The spectrum of the source located at R.A. = 7h10m31s.8 and Decl.

= -56o15'20".2 (equinox 2000.0; as measured on the XShooter acquisition image) shows very broad bumps with peaks measured at about 430 and 670 nm, reminiscent of an emerging broadline type-Ic supernova (in agreement with Chornock et al., GCN 10541). Indeed, above 600 nm, the spectrum of this source shows some similarities with that of SN 1998bw (Patat et al. 2001, Ap.J. 555, 900) taken seven days after outburst. There are, however, major differences with the spectrum of this transient, showing a significant flux deficiency in the range 450-550 nm, in comparison with SN 1998bw. The designation 2010bh is assigned to this supernova.

7. *Unveiling the origin of X-ray flares in gamma-ray bursts*, Chincarini, G. et al. 2010, MNRAS, 406, 2113

We present an updated catalogue of 113 X-ray flares detected by Swift in the 33 per cent of the X-ray afterglows of gamma-ray burst (GRB). 43 flares have a measured redshift. For the first time the analysis is performed in four different X-ray energy bands, allowing us to constrain the evolution of the flare temporal properties with energy. We find that flares are narrower at higher energies: their width follows a power-law relation w $\sim E^{-0.5}$ reminiscent of the prompt emission. Flares are asymmetric structures, with a decay time which is twice the rise time on average. Both time-scales linearly evolve with time, giving rise to a constant rise-to-decay ratio: this implies that both time-scales are stretched by the same factor. As a consequence, the flare width linearly evolves with time to larger values: this is a key point that clearly distinguishes the flare from the GRB prompt emission. The flare 0.3-10keV peak luminosity decreases with time, following a power-law behaviour with large scatter: $L_{pk} \sim t^{-2.7\pm-0.5}pk$. When multiple flares are present, a global softening trend is established: each flare is on average softer than the previous one. The 0.3-10 keV isotropic energy distribution is a lognormal peaked at 10^{51}erg, with a possible excess at low energies. The flare average spectral energy distribution is found to be a power law with spectral energy index $\beta \sim 1.1$. These results confirmed that the flares are tightly linked to the prompt emission. However, after considering various models we conclude that no model is currently able to account for the entire set of observations.

8. *Nearby Supernova Rates from the Lick Observatory Supernova Search. IV. A Recovery Method for the Delay Time Distribution*, Maoz, D. et al. 2010, MNRAS, in press

The supernova (SN) delay-time distribution (DTD) - the SN rate versus time that would follow a brief burst of star formation - can shed light on SN progenitors, and on chemical enrichment timescales. Previous attempts to recover the DTD have used comparisons of mean SN rates vs. redshift to cosmic star-formation history (SFH), or comparison of SN rates among galaxies of different mean ages. We present an approach to recover the SN DTD that avoids such averaging. We compare the SFHs of individual galaxies to the

numbers of SNe discovered in each galaxy (generally zero, sometimes one or a few SNe). We apply the method to a subsample of 3505 galaxies, hosting 82 SNe Ia and 119 core-collapse SNe (CC SNe), from the Lick Observatory SN Search (LOSS), with SFHs reconstructed from SDSS spectra. We find a $> 2\sigma$ SN Ia DTD signal in our shortest-delay, "prompt", bin at $< 420 Myr$. Despite a systematic error, due to the limited aperture of the SDSS spectroscopic fibres, which causes some of the prompt signal to leak to the later DTD bins, the data require prompt SNe Ia at the $> 99\%$ confidence. We further find, at 4σ, SNe Ia that are "delayed" by $> 2.4 Gyr$. Thus, the data support the existence of both prompt and delayed SNe Ia. The time integral over the CC SN DTD is 0.010 ± 0.002 SNe per $M_\odot$, as expected if all stars of mass $> 8 M_\odot$ lead to visible SN explosions. This argues against a minimum mass for CC SNe of $> 10 M_\odot$, and against a significant fraction of massive stars that collapse without exploding. For SNe Ia, the time-integrated DTD is 0.0023 ± 0.0006 SNe per $M_\odot$ formed, most of them with delays $< 2.4 Gyr$. We show, using simulations, that application of the method to the full existing LOSS sample, but with complete and unbiased SFH estimates for the survey galaxies, could provide a detailed measurement of the SN Ia DTD.

9. *The Afterglows of Swift-era Gamma-ray Bursts. I. Comparing pre-Swift and Swift-era Long/Soft (Type II) GRB Optical Afterglows*, Kann, D. et al. 2010, ApJ, 720, 1513

We have gathered optical photometry data from the literature on a large sample of Swift-era gamma-ray burst (GRB) afterglows including GRBs up to 2009 September, for a total of 76 GRBs, and present an additional three pre-Swift GRBs not included in an earlier sample. Furthermore, we publish 840 additional new photometry data points on a total of 42 GRB afterglows, including large data sets for GRBs 050319, 050408, 050802, 050820A, 050922C, 060418, 080413A, and 080810. We analyzed the light curves of all GRBs in the sample and derived spectral energy distributions for the sample with the best data quality, allowing us to estimate the host-galaxy extinction. We transformed the afterglow light curves into an extinction-corrected z = 1 system and compared their luminosities with a sample of pre-Swift afterglows. The results of a former study, which showed that GRB afterglows clustered and exhibited a bimodal distribution in luminosity space, are weakened by the larger sample. We found that the luminosity distribution of the two afterglow samples (Swift-era and pre-Swift) is very similar, and that a subsample for which we were not able to estimate the extinction, which is fainter than the main sample, can be explained by assuming a moderate amount of line-of-sight host extinction. We derived bolometric isotropic energies for all GRBs in our sample, and found only a tentative correlation between the prompt energy release and the optical afterglow luminosity at 1 day after the GRB in the z = 1 system. A comparative study of the optical luminosities of GRB afterglows with echelle spectra (which show a high number of foreground ab-

sorbing systems) and those without, reveals no indication that the former are statistically significantly more luminous. Furthermore, we propose the existence of an upper ceiling on afterglow luminosities and study the luminosity distribution at early times, which was not accessible before the advent of the Swift satellite. Most GRBs feature afterglows that are dominated by the forward shock from early times on. Finally, we present the first indications of a class of long GRBs, which form a bridge between the typical high-luminosity, high-redshift events and nearby low-luminosity events (which are also associated with spectroscopic supernovae) in terms of energetics and observed redshift distribution, indicating a continuous distribution overall.