Supernovae

Contents

1. Topics **1933**
1.1. ICRANet participants 1933
1.2. Past collaborators 1933
1.3. Ongoing collaborations 1933
1.4. Sabatical Visits, 2005-2009 1934

2. Brief description **1935**

3. Publications (2008-2009) **1939**

4. Invited talks at international conferences (2008 - 2009) **1951**

5. APPENDICES **1953**

A. Highlights occurred in 2008-2009 **1955**
A.1. SN 2008D/XRF 080109: a link between SNe and GRBs 1955
A.2. GRB 090423: a Flash of light at z=8.1 1956

Bibliography **1957**

1. Topics

- Supernovae (Photometric and Spectroscopic Evolution, Rates)
- Supernova and Gamma-ray Burst connection
- Novae
- Supernovae Ia and Gamma-ray Bursts as rulers for cosmological parameters

1.1. ICRANet participants

- Massimo Della Valle

1.2. Past collaborators

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

1.3. Ongoing collaborations

- Nino Panagia (STScI, Baltimore)
- Guido Chincarini (Bicocca University, Milano) and the SWIFT team

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

1.4. Sabatical Visits, 2005-2009

- 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)

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 (2008-2009)

[1] *The supernova rate in local galaxy clusters* Mannucci, F., Maoz, D., Sharon, K., Botticella, M. T., Della Valle, M., Gal-Yam, A., Panagia, N. 2008, MNRAS, 383, 1121

A measurement of the supernova (SN) rates (Type Ia and core-collapse) in galaxy clusters is reported. Early-type cluster galaxies show a Type Ia SN rate (0.066 SNuM) similar to that obtained by Sharon et al. and more than three times larger than that in field early-type galaxies (0.019 SNuM). This difference has a 98 per cent statistical confidence level. We examine many possible observational biases which could affect the rate determination, and conclude that none of them is likely to significantly alter the results. We investigate how the rate is related to several properties of the parent galaxies, and find that cluster membership, morphology and radio power all affect the SN rate, while galaxy mass has no measurable effect. The increased rate may be due to galaxy interactions in clusters, inducing either the formation of young stars or a different evolution of the progenitor binary systems. We present the first measurement of the core-collapse SN rate in cluster late-type galaxies, which turns out to be comparable to the rate in field galaxies. This suggests that no large systematic difference in the initial mass function exists between the two environments.

[2] *Novae as a Class of Transient X-Ray Sources.* Mukai, K., Orio, M., Della Valle, M. 2007, 677, 1248

Motivated by the recently discovered class of faint (1034-1035 ergs s-1) X-ray transients in the Galactic center region, we investigate the 2-10 keV properties of classical and recurrent novae. Existing data are consistent with the idea that all classical novae are transient X-ray sources with durations of months to years and peak luminosities in the 1034-1035 ergs s-1 range. This makes classical novae a viable candidate class for the faint Galactic center transients. We estimate the rate of classical novae within a 15′ radius region centered on the Galactic center (roughly the field of view of XMM-Newton observations centered on Sgr A*) to be 0.1 yr-1. Therefore, it is plausible that some of the Galactic center transients that have been announced to date are unrecognized classical novae. The continuing monitoring of the Galactic center region carried out by Chandra and XMM-Newton may therefore provide a new method to detect classical novae in this crowded and obscured region, where optical surveys are not, and can never hope to be, effective. Therefore, X-ray monitoring may provide the best means of testing the completeness of the current understanding of the nova populations.

[3] *The complex light curve of the afterglow of GRB071010A* Covino et al. 2008, MNRAS, 388, 347

The results of an extensive observational campaign devoted to GRB071010A, a long-duration gamma-ray burst detected by the Swift satellite, are presented. This event was followed for almost a month in the optical/near-infrared (NIR) with various telescopes starting from about 2min after the high-energy event. Swift XRT observations started only later at about 0.4d. The light-curve evolution allows us to single out an initial rising phase with a maximum at about 7min, possibly the afterglow onset in the context of the standard fireball model, which is then followed by a smooth decay interrupted by a sharp rebrightening at about 0.6d. The rebrightening was visible in both the optical/NIR and X-rays and can be interpreted as an episode of discrete energy injection, although various alternatives are possible. A steepening of the afterglow light curve is recorded at about 1d. The entire evolution of the optical/NIR afterglow is consistent with being achromatic. This could be one of the few identified GRB afterglows with an achromatic break in the X-ray through the optical/NIR bands. Polarimetry was also obtained at about 1d, just after the rebrightening and almost coincident with the steepening. This provided a fairly tight upper limit of 0.9 per cent for the polarized-flux fraction.

[4] *Outliers from the Mainstream: How a Massive Star Can Produce a Gamma-Ray Burst* Campana et al. 2008, ApJ, 683, L9

It is now recognized that long-duration gamma-ray Bursts (GRBs) are linked to the collapse of massive stars, based on the association between (low redshift) GRBs and (Type Ic) core-collapse supernovae (SNe). The census of massive stars and GRBs reveals, however, that not all massive stars produce a GRB. Only 1are able to produce a highly relativistic collimated outflow, and hence a GRB. The extra crucial parameter has long been suspected to be metallicity and/or rotation. We find observational evidence strongly supporting that both ingredients are necessary in order to make a GRB out of a core-collapsing star. A detailed study of the absorption pattern in the X-ray spectrum of GRB 060218 reveals evidence of material highly enriched in low-atomic-number metals ejected before the SN/GRB explosion. We find that, within the current scenarios of stellar evolution, only a progenitor star characterized by a fast stellar rotation and subsolar initial metallicity could produce such a metal enrichment in its close surrounding.

[5] *The Metamorphosis of Supernova SN 2008D/XRF 080109: A Link Between Supernovae and GRBs/Hypernovae* Mazzali,P., Valenti,S., Della Valle, M., Chincarini, G., Sauer, D. +36 Co-Is Science, 2008, 321, 1185

The only supernovae (SNe) to show gamma-ray bursts (GRBs) or early x-ray emission thus far are overenergetic, broad-lined type Ic SNe (hypernovae, HNe). Recently, SN 2008D has shown several unusual features: (i) weak x-ray flash (XRF), (ii) an early, narrow optical peak, (iii) disappearance of the broad lines typical of SN Ic HNe, and (iv) development of helium lines as in SNe Ib. Detailed analysis shows that SN 2008D was not a normal supernova: Its explosion energy (E $\sim 610^{51}$ erg) and ejected mass [$\sim$ 7 times the mass of the Sun (are intermediate between normal SNe Ibc and HNe. We conclude that SN 2008D was originally a $\sim 30 M_s un$. When it collapsed, a black hole formed and a weak, mildly relativistic jet was produced, which caused the XRF. SN 2008D is probably among the weakest explosions that produce relativistic jets. Inner engine activity appears to be present whenever massive stars collapse to black holes.

[6] *Transient Heavy Element Absorption Systems in Novae: Episodic Mass Ejection from the Secondary Star* Williams, R., Mason, E., Della Valle, M., Ederoclite, A. 2008, ApJ, 685, 451

A high-resolution spectroscopic survey of post-outburst novae observed at ESO, reveals short-lived heavy element absorption systems in a majority of novae near maximum light, having expansion velocities of 400-1000 km s-1 and velocity dispersions between 35 and 350 km s-1. A majority of systems are accelerated outward, and they all progressively weaken and disappear over timescales of weeks. A few of the systems having narrow, deeper absorption reveal a rich spectrum of singly ionized Sc, Ti, V, Cr, Fe, Sr, Y, Zr, and Ba lines. Analysis of the richest such system, in LMC 2005, shows the excitation temperature to be 10^4 K and elements lighter than Fe to have abundance enhancements over solar values by up to an order of magnitude. The gas causing the absorption systems must be circumbinary and its origin is most likely mass ejection from the secondary star. The absorbing gas exists before the outburst and may represent episodic mass transfer events from the secondary star that initiate the nova outburst(s). If SNe Ia originate in single degenerate binaries, such absorption systems could be detectable before maximum light.

[7] *Massive stars exploding in a He-rich circumstellar medium - I. Type Ibn (SN 2006jc-like) events.* Pastorello, A.; Mattila, S.; Zampieri, L.; Della Valle, M.; Smartt, + 24 Co-Is, 2008, MNRAS, 389, 113

New spectroscopic and photometric data of the Type Ibn supernovae 2006jc, 2000er and 2002ao are presented. We discuss the general properties of this recently proposed supernova family, which also includes SN 1999cq. The early-time monitoring of SN 2000er traces the evolution of this class of objects during the first few days after the shock breakout. An overall similarity in the photometric and spectroscopic evolution is found among the members of this group, which would be unexpected if the energy in these core-collapse events was dominated by the interaction between supernova ejecta and circumstellar medium. Type Ibn supernovae appear to be rather normal Type Ib/c supernova explosions which occur within a He-rich circumstellar environment. SNe Ibn are therefore likely produced by the explosion of Wolf-Rayet progenitors still embedded in the He-rich material lost by the star in recent mass-loss episodes, which resemble known luminous blue variable eruptions. The evolved Wolf-Rayet star could either result from the evolution of a very massive star or be the more evolved member of a massive binary system. We also suggest that there are a number of arguments in favour of a Type Ibn classification for the historical SN 1885A (S-Andromedae), previously considered as an anomalous Type Ia event with some resemblance to SN 1991bg.

[8] *Broadband observations of the naked-eye -ray burst GRB080319B,* Racusin, J. L., Karpov, S. V., Sokolowski, M. et al. 2008, Nature, 455, 183

Long-duration γ-ray bursts (GRBs) release copious amounts of energy across the entire electromagnetic spectrum, and so provide a window into the process of black hole formation from the collapse of massive stars. Previous early optical observations of even the most exceptional GRBs (990123 and 030329) lacked both the temporal resolution to probe the optical flash in detail and the accuracy needed to trace the transition from the prompt emission within the outflow to external shocks caused by interaction with the progenitor environment. Here we report observations of the extraordinarily bright prompt optical and γ-ray emission of GRB080319B that provide diagnostics within seconds of its formation, followed by broadband observations of the afterglow decay that continued for weeks. We show that the prompt emission stems from a single physical region, implying an extremely relativistic outflow that propagates within the narrow inner core of a two-component jet.

[9] *The short GRB070707 afterglow and its very faint host galaxy*. Piranomonte et al. 2008, A&A, 491, 183

We present the results from an ESO/VLT campaign aimed at studying the afterglow properties of the short/hard gamma ray burst GRB 070707. Observations were carried out at ten different epochs from 0.5 to 80 days after the event. The optical flux decayed steeply with a power-law decay index greater than 3, later levelling off at R 27.3 mag; this is likely the emission level of the host galaxy, the faintest yet detected for a short GRB. Spectroscopic observations did not reveal any line features/edges that could unambiguously pinpoint the GRB redshift, but set a limit z ¡ 3.6. In the range of allowed redshifts, the host has a low luminosity, comparable to that of long-duration GRBs. The existence of such faint host galaxies suggests caution when associating short GRBs with bright, offset galaxies, where the true host might just be too dim for detection. The steepness of the decay of the optical afterglow of GRB 070707 challenges external shock models for the optical afterglow of short/hard GRBs. We argue that this behaviour might results from prolonged activity of the central engine or require alternative scenarios.

[10] *Using Spatial Distributions to Constrain Progenitors of Supernovae and Gamma Ray Bursts*. Raskin, C., Scannapieco, E., Rhoads, J., Della Valle, M. 2008, ApJ, 689, 358

We carry out a comprehensive theoretical examination of the relationship between the spatial distribution of optical transients and the properties of their progenitor stars. By constructing analytic models of star-forming galaxies and the evolution of stellar populations within them, we are able to place constraints on candidate progenitors for core-collapse supernovae (SNe), long-duration gamma ray bursts, and supernovae Ia. In particular we first construct models of spiral galaxies that reproduce observations of core-collapse SNe, and we use these models to constrain the minimum mass for SNe Ic progenitors to approximately 25 solar masses. Secondly, we lay out the parameters of a dwarf irregular galaxy model, which we use to show that the progenitors of long-duration gamma-ray bursts are likely to have masses above approximately 43 solar masses. Finally, we introduce a new method for constraining the time scale associated with SNe Ia and apply it to our spiral galaxy models to show how observations can better be analyzed to discriminate between the leading progenitor models for these objects.

[11] *Measuring the cosmological parameters with the Ep-Eiso correlation of Gamma-Ray Bursts* Amati, L., Guidorzi, C., Frontera, F., Della Valle, M., Finelli, F., Landi, R., Montanari, E. 2008, MNRAS, 391, 577

The Ep-Eiso correlation of GRBs has been used to measure the cosmological parameter $Omega_M$. By adopting a maximum likelihood approach which allows us to correctly quantify the extrinsic (i.e. non–Poissonian) scatter of the correlation, we constrain (for a flat universe) $Omega_M$ to 0.04-0.40 (68% confidence level), with a best fit value of $Omega_M \sim 0.15$, and exclude $Omega_M = 1$ at 99.9% confidence level. If we release the assumption of a flat universe, we still find evidence for a low value of $Omega_M$ (0.04-0.50 at 68% confidence level) and a weak dependence of the dispersion of the Ep-Eiso correlation on $Omega_\Lambda$ (with an upper limit of $Omega_\Lambda \sim 1.15$ at 90% confidence level). Our approach makes no assumptions on the Ep,i-Eiso correlation and it does not use other calibrators to set the "zero' point of the relation, therefore our treatment of the data is not affected by circularity and the results are independent of those derived via type Ia SNe (or other cosmological probes). Unlike other multi-parameters correlations, our analysis grounds on only two parameters, then including a larger number (a factor ∼3) of GRBs and being less affected by systematics. Simulations based on realistic extrapolations of ongoing (and future) GRB experiments (e.g., Swift, Konus-Wind, GLAST) show that: i) the uncertainties on cosmological parameters can be significantly decreased; ii) future data will allow us to get clues on the "dark energy" evolution.

[12] *Five supernova survey galaxies in the southern hemisphere. I. Optical and near-infrared database* Hakobyan, A. A., Petrosian, A. R., Mamon, G. A et al. 2009, Ap, 52, 40

The determination of the supernova (SN) rate is based not only on the number of detected events, but also on the properties of the parent galaxy population. This is the first paper of a series aimed at obtaining new, refined, SN rates from a set of five SN surveys, by making use of a joint analysis of near-infrared (NIR) data. We describe the properties of the 3838 galaxies that were monitored for SNe events, including newly determined morphologies and their DENIS and POSS-II/UKST I, 2MASS and DENIS J and Ks and 2MASS H magnitudes. We have compared 2MASS, DENIS and POSS-II/UKST IJK magnitudes in order to find possible systematic photometric shifts in the measurements. The DENIS and POSS-II/UKST I band magnitudes show large discrepancies (mean absolute difference of 0.4 mag), mostly due to different spectral responses of the two instruments, with an important contribution (0.33 mag rms) from the large uncertainties in the photometric calibration of the POSS-II and UKST photographic plates. In the other wavebands, the limiting near infrared magnitude, morphology and inclination of the galaxies are the most influential factors which affect the determination of photometry of the galaxies. Nevertheless, no significant systematic differences have been found between of any pair of NIR magnitude measurements, except for a few percent of galaxies showing large discrepancies. This allows us to combine DENIS and 2MASS data for the J and Ks filters.

[13] *SN 2006gy: was it really extra-ordinary?* Agnoletto et al. 2008, ApJ, 2009, 691, 1348

Optical photometric and spectroscopic data of the very luminous type IIn SN

2006gy, for a time period spanning more than one year, are presented and discussed. In photometry, a broad, bright ($M_R \sim -21.7$) peak characterizes all BVRI light curves. Afterwards, a rapid luminosity fading is followed by a phase of slow luminosity decline between day $\sim$ 170 and $\sim$ 237. At late phases ($>$ 237 days), because of the large luminosity drop ($>$ 3 mag), only upper visibility limits are obtained in the B, R and I bands. In the near-infrared, two K-band detections on days 411 and 510 open new issues about dust formation or IR echoes scenarios. At all epochs the spectra are characterized by the absence of broad P-Cygni profiles and a multi-component Halpha profile, which are the typical signatures of type IIn SNe. After maximum, spectroscopic and photometric similarities are found between SN 2006gy and bright, interaction-dominated SNe (e.g. SN 1997cy, SN 1999E and SN 2002ic). This suggests that ejecta-CSM interaction plays a key role in SN 2006gy about 6 to 8 months after maximum, sustaining the late-time light curve. Alternatively, the late luminosity may be related to the radioactive decay of $\sim 3M_{\odot}$ of ^{5}6Ni. Models of the light curve in the first 170 days suggest that the progenitor was a compact star ($R \sim 6 - 810^{(}12$)cm, $M_{ej} \sim 5 - 14M_{\odot}$), and that the SN ejecta collided with massive ($6 - 10M_{\odot}$), opaque clumps of previously ejected material. These clumps do not completely obscure the SN photosphere, so that at its peak the luminosity is due both to the decay of 56Ni and to interaction with CSM. A supermassive star is not required to explain the observational data, nor is an extra-ordinarily large explosion energy.

[14] *Type Ib Supernova 2008D Associated With the Luminous X-Ray Transient 080109: An Energetic Explosion of a Massive Helium Star*, Tanaka, M. et al. 2009, ApJ, 692, 1131

We present a theoretical model for supernova SN 2008D associated with the luminous X-ray transient 080109. The bolometric light curve and optical spectra of the SN are modeled based on the progenitor models and the explosion models obtained from hydrodynamic/nucleosynthetic calculations. We find that SN 2008D is a more energetic explosion than normal core-collapse supernovae, with an ejecta mass of $M_{ej} = 5.31.0M_{\odot}$ and a kinetic energy of $E_K = 6.0 \pm 2.5 \times 10^{51}$ erg. The progenitor star of the SN has a 6-8 $M_{\odot}$ sun He core with essentially no H envelope ($< 5 \times 10^{-4}M_{\odot}$) prior to the explosion. The main-sequence mass of the progenitor is estimated to be $M_{MS} = 20 - 25M_{\odot}$, with additional systematic uncertainties due to convection, mass loss, rotation, and binary effects. These properties are intermediate between those of normal SNe and hypernovae associated with gamma-ray bursts. The mass of the central remnant is estimated as 1.6-1.8 $M_{\odot}$, which is near the boundary between neutron star and black hole formation.

[15] *The Prompt, High-Resolution Spectroscopic View of the "Naked-Eye" GRB080319B*, D'Elia, V., Fiore, F., Perna, R. et al. 2009, ApJ, 694, 332

GRB080319B reached fifth optical magnitude during the burst prompt emission. Thanks to the Very Large Telescope (VLT)/Ultraviolet and Visual Echelle Spectrograph (UVES) rapid response mode, we observed its afterglow just 8m:30s after the gamma-ray burst (GRB) onset when the magnitude was R 12. This allowed us to obtain the best signal-to-noise (S/N), high-resolution spectrum of a GRB afterglow ever (S/N per resolution element 50). The spectrum is rich of absorption features belonging to the main system at z = 0.937, divided in at least six components spanning a total velocity range of 100 km s-1. The VLT/UVES observations caught the absorbing gas in a highly excited state, producing the strongest Fe II fine structure lines ever observed in a GRB. A few hours later, the optical depth of these lines was reduced by a factor of 4-20, and the optical/UV flux by a factor of 60. This proves that the excitation of the observed fine structure lines is due to "pumping" by the GRB UV photons. A comparison of the observed ratio between the number of photons absorbed by the excited state and those in the Fe II ground state suggests that the six absorbers are 2-6 kpc from the GRB site, with component I 3 times closer to the GRB site than components III-VI. Component I is characterized also by the lack of Mg I absorption, unlike all other components. This may be both due to a closer distance and a lower density, suggesting a structured interstellar matter in this galaxy complex.

[16] *The optical afterglows and host galaxies of three short/hard gamma-ray bursts*, D'Avanzo, P., Malesani, D., Covino, S. et al. 2009, A&A, 498, 711

Our knowledge of short gamma-ray bursts (GRBs) has significatively improved in the Swift era. Rapid multiband observations from the largest ground-based observatories led to the discovery of the optical afterglows and host galaxies of these events. In spite of these advancements, the number of short GRBs with secure detections in the optical is still fairly small. Short GRBs are commonly thought to originate from the merging of double compact object binaries but direct evidence for this scenario is still missing. Aims: Optical observations of short GRBs allow us to measure redshifts, firmly identify host galaxies, characterize their properties, and accurately localize GRBs within them. Multiwavelength observations of GRB afterglows provide useful information on the emission mechanisms at work. These are all key issues that allow one to discriminate among different models of these elusive events. Methods: We carried out photometric observations of the short/hard GRB 051227, GRB 061006, and GRB 071227 with the ESO-VLT starting from several hours after the explosion down to the host galaxy level several days later. For GRB 061006 and GRB 071227 we also obtained spectroscopic observations of the host galaxy. We compared the results obtained from our optical observations with the available X-ray data of these bursts. Results: For all the three above bursts, we discovered optical afterglows and firmly identified their host galaxies. About half a day after the burst, the optical afterglows of GRB 051227 and GRB 061006 present a decay significatly steeper than in the X-rays. In the case of GRB 051227, the optical decay is so steep that it likely indicates different emission mechanisms in the two wavelength ranges. The three hosts are blue star forming galaxies at moderate redshifts and with metallicities comparable to the Solar one. The projected offsets of the optical afterglows from their host galaxy center span a wide range, but all afterglows lie within the light of their hosts and present evidence for local absorption in their X-ray spectra. We discuss our findings in light of the current models of short GRB progenitors.

[17] *The very short supersoft X-ray state of the classical nova M31N 2007-11a*, Henze, M.,Pietsch, W.,Della Valle, M. et al. 2009, A&A, 498, L13

Classical novae (CNe) have been found to represent the major class of supersoft X-ray sources (SSSs) in our neighbour galaxy M 31. Aims: We determine the properties and evolution of the two first SSSs ever discovered in the M 31 globular cluster (GC) system. Methods: We have used XMM-Newton, Chandra and Swift observations of the centre region of M 31 to discover both SSSs and to determine their X-ray light curves and spectra. We performed detailed analysis of XMM-Newton EPIC PN spectra of the source in Bol 111 (SS1) using blackbody and NLTE white dwarf (WD) atmosphere models. For the SSS in Bol 194 (SS2) we used optical monitoring data to search for an optical counterpart. Results: Both GC X-ray sources were classified as SSS. We identify SS1 with the CN M31N 2007-06b recently discovered in the M 31 GC Bol 111. For SS2 we did not find evidence for a recent nova outburst and can only provide useful constraints on the time of the outburst of a hypothetical nova. Conclusions: The only known CN in a M 31 GC can be identified with the first SSS found in a M 31 GC. We discuss the impact of our observations on the nova rate for the M 31 GC system.

[18] *The first two transient supersoft X-ray sources in M 31 globular clusters and the connection to classical novae* Henze, M., Pietsch, W., Haberl, F. et al. 2009, A&A, 500, 769

Short supersoft X-ray source (SSS) states (durations $<$ 100 days) of classical novae (CNe) indicate massive white dwarfs that are candidate progenitors of supernovae type Ia. Aims: We carry out a dedicated optical and X-ray monitoring program of CNe in the bulge of M 31. Methods: We discovered M31N 2007-11a and determined its optical and X-ray light curve. We used the robotic Super-LOTIS telescope to obtain the optical data and XMM-Newton and Chandra observations to discover an X-ray counterpart to that nova. Results: Nova M31N 2007-11a is a very fast CN, exhibiting a very short SSS state with an appearance time of 6-16 days after outburst and a turn-off time of 45-58 days after outburst. Conclusions: The optical and X-ray light curves of M31N 2007-11a suggest a binary containing a white dwarf with $M_{WD} > 1.0M_{\odot}$

[19] *Nebular Phase Observations of the Type Ib Supernova 2008D/X-ray Transient 080109: Side-viewed Bipolar Explosion* Tanaka, M., Yamanaka, M., Maeda, K. et al. 2009, ApJ, 700, 1680

We present optical spectroscopic and photometric observations of supernova (SN) 2008D, associated with the luminous X-ray transient 080109, at ¿300 days after the explosion (nebular phases). We also give flux measurements of emission lines from the H II region at the site of the SN, and estimates of the local metallicity. The brightness of the SN at nebular phases is consistent with the prediction of the explosion models with an ejected 56Ni mass of 0.07 $M_{\odot}$, which explains the light curve at early phases. The [O I] line in the nebular spectrum shows a double-peaked profile while the [Ca II] line does not. The double-peaked [O I] profile strongly indicates that SN 2008D is an aspherical explosion. The profile can be explained by a torus-like distribution of oxygen viewed from near the plane of the torus. We suggest that SN 2008D is a side-viewed, bipolar explosion with a viewing angle of $> 50°$ from the polar direction.

[20] *Nebular emission-line profiles of Type Ib/c supernovae - probing the ejecta asphericity*, Taubenberger, S., Valenti, S., Benetti, S. et al. 2009, MNRAS, 397, 677

In order to assess qualitatively the ejecta geometry of stripped-envelope core-collapse supernovae (SNe), we investigate 98 late-time spectra of 39 objects, many of them previously unpublished. We perform a Gauss-fitting of the [OI] λ 6300, 6364 feature in all spectra, with the position, full width at half maximum and intensity of the 6300 Gaussian as free parameters, and the λ 6364 Gaussian added appropriately to account for the doublet nature of the [OI] feature. On the basis of the best-fitting parameters, the objects are organized into morphological classes, and we conclude that at least half of all Type Ib/c SNe must be aspherical. Bipolar jet models do not seem to be universally applicable, as we find too few symmetric double-peaked [OI] profiles. In some objects, the [OI] line exhibits a variety of shifted secondary peaks or shoulders, interpreted as blobs of matter ejected at high velocity and possibly accompanied by neutron-star kicks to assure momentum conservation. At phases earlier than 200d, a systematic blueshift of the [OI] λ 6300, 6364 line centroids can be discerned. Residual opacity provides the most convincing explanation of this phenomenon, photons emitted on the rear side of the SN being scattered or absorbed on their way through the ejecta. Once modified to account for the doublet nature of the oxygen feature, the profile of MgI] λ 4571 at sufficiently late phases generally resembles that of [OI] λ 6300, 6364, suggesting negligible contamination from other lines and confirming that O and Mg are similarly distributed within the ejecta.

[21] *Type II Supernovae as Probes of Cosmology*, Poznanski, D. et al. 2009, Astro2010: The Astronomy and Astrophysics Decadal Survey, Science White Papers, no. 237

Constraining the cosmological parameters and understanding Dark Energy have tremendous implications for the nature of the Universe and its physical laws. - The pervasive limit of systematic uncertainties reached by cosmography based on Cepheids and Type Ia supernovae (SNe Ia) warrants a search for complementary approaches. - Type II SNe have been shown to offer such a path. Their distances can be well constrained by luminosity-based or geometric methods. Competing, complementary, and concerted efforts are underway, to explore and exploit those objects that are extremely well matched to next generation facilities. Spectroscopic follow-up will be enabled by space- based and 20-40 meter class telescopes. - Some systematic uncertainties of Type II SNe, such as reddening by dust and metallicity effects, are bound to be different from those of SNe Ia. Their stellar progenitors are known, promising better leverage on cosmic evolution. In addition, their rate - which closely tracks the ongoing star formation rate - is expected to rise significantly with look-back time, ensuring an adequate supply of distant examples. - These data will competitively constrain the dark energy equation of state, allow the determination of the Hubble constant to 5%, and promote our understanding of the processes involved in the last dramatic phases of massive stellar evolution.

[22] *Type Ia supernova science 2010-2020*, Howell, D. A.; Conley, A.; Della Valle, M. et al. 2009, White paper submitted to the Astro2010 committee

In the next decade Type Ia supernovae (SNe Ia) will be used to test theories predicting changes in the Dark Energy equation of state with time. Ultimately this requires a dedicated space mission like JDEM. SNe Ia are mature cosmological probes — their limitations are well characterized, and a path to improvement is clear. Dominant systematic errors include photometric calibration, selection effects, reddening, and population-dependent differences. Building on past lessons, well-controlled new surveys are poised to make strides in these areas: the Palomar Transient Factory, Skymapper, La Silla QUEST, Pan-STARRS, the Dark Energy Survey, LSST, and JDEM. They will obviate historical calibrations and selection biases, and allow comparisons via large subsamples. Some systematics follow from our ignorance of SN Ia progenitors, which there is hope of determining with SN Ia rate studies from $0 < z < 4$. Aside from cosmology, SNe Ia regulate galactic and cluster chemical evolution, inform stellar evolution, and are laboratories for extreme physics. Essential probes of SNe Ia in these contexts include spectroscopy from the UV to the IR, X-ray cluster and SN remnant observations, spectropolarimetry, and advanced theoretical studies. While there are an abundance of discovery facilities planned, there is a deficit of follow-up resources. Living in the systematics era demands deep understanding rather than larger statistics. NOAO ReSTAR initiative to build 2-4m telescopes would provide necessary follow-up capability. Finally, to fully exploit LSST, well-matched wide-field spectroscopic capabilities are desirable.

[23] *Prompt Ia Supernovae Are Significantly Delayed*, Raskin, C., Scannapieco, E., Rhoads, J. Della Valle, M. 2009, ApJ,

The time delay between the formation of a population of stars and the onset of type Ia supernovae (SNe Ia) sets important limits on the masses and nature of SN Ia progenitors. Here we use a new observational technique to measure this time delay by comparing the spatial distributions of SNe Ia to their local environments. Previous work attempted such analyses encompassing the entire host of each SN Ia, yielding inconclusive results. Our approach confines the analysis only to the relevant portions of the hosts, allowing us to show that even so-called "prompt" SNe Ia that trace star-formation on cosmic timescales exhibit a significant delay time of 200-500 million years. This implies that either the majority of Ia companion stars have main-sequence masses less than 3 solar masses, or that most SNe Ia arise from double-white dwarf binaries. Our results are also consistent with a SNe Ia rate that traces the white dwarf formation rate, scaled by a fixed efficiency factor.

[24] *GRB090423 at a redshift of z 8.1*, Salvaterra, R., Della Valle, M., Campana, S. et al. 2009, Nature, 461, 1258

Gamma-ray bursts (GRBs) are produced by rare types of massive stellar explosion. Their rapidly fading afterglows are often bright enough at optical wavelengths that they are detectable at cosmological distances. Hitherto, the highest known redshift for a GRB was z = 6.7, for GRB080913, and for a galaxy was z = 6.96. Here we report observations of GRB090423 and the near-infrared spectroscopic measurement of its redshift, z =8.1 This burst happened when the Universe was only about 4 per cent of its current age. Its properties are similar to those of GRBs observed at low/intermediate redshifts, suggesting that the mechanisms and progenitors that gave rise to this burst about 600 Myrs years after the Big Bang are not markedly different from those producing GRBs about 10 Gyrs later.

[25] *Supernovae and Gamma-ray Bursts: Flashy and Somber Explosions*
Della Valle, M. 2009, AIPC, Vol. 1111, p. 393

We review the observational status of the Supernova/Gamma-Ray Burst connection. Several lines of evidence suggest that long duration Gamma-ray Bursts are associated with bright SNe-Ic. However recent observations of GRB 060614 puzzle this scenario, pointing out the existence of long-duration Gamma-ray Burst not accompanied by a bright supernova. An analysis of the association GRB 060218/SN 2006aj and X081009/SN 2008D finds that SNe and GRBs are coeval events within 0.1 days. Current estimates of the SN and GRB rates yield a ratio GRB/SNe-Ibc in the range 0.2%-3%.

4. Invited talks at international conferences (2008 - 2009)

[1]*Measuring the cosmological parameters with the Amati correlation of GRBs* Della Valle, M. 5th Italian-Sino Workshop May 28-June 1, 2008 - Teipei-Hualian, Taiwan

[2]*VLT Observations of GRB-SNe*, invited talk, given at Kolkota, 2008

[3]*SN 2008D: GRB or Shock Break-out?* invited talk given at the conference on the "Transient Universe", Tel-Aviv, 2008

[4]*JDEM mission: Preliminary Estimates of SN detections*, Invited talk given at the Meeting on the JDEM mission, Paris, 2008

[5]*Supernovae and GRBs: Flashy and Somber Explosions* Della Valle, M. III Cefalú Conference, September 2008

[6]*Supernova rates vs. Environments* Della Valle, M. invited review talk given at the SN-Ia Conference, Princeton, 2009

[7]*The Accelerating Universe* Della Valle, M. invited review talk given at the SAIt Meeting, Pisa, 2009

[8]*Latest Highlights on GRBs from Ground-Based Telescopes*, Della Valle, M. invited talk, plenary session, given at the Marcell Grossmann meeting; Paris, 2009

[9]*Observational signatures of SNe in GRBs*, Della Valle, M. invited talk, parallel session, given at the Marcell Grossmann meeting; Paris, 2009

[10]*Supernova- GRB connection: Observational Outcome* Della Valle, M. Invited review talk given at the Swift meeting on GRBs, Venice 2009

[11]*Supernova Taxonomy*, Della Valle, M., Invited review talk given in the Vulcano meeting on Multiwavelengths Observations, Vulcano, 2009

[12]*Latest Highlights from SN-GRB connection*, Della Valle, M., Invited talk given at I Galileo-Xu Guangqi Meeting, given in Shanghai, 2009

[13]*Gamma-ray Bursts as cosmological Tools*, Della Valle, M, invited talk given at the Korea-Italy Meeting, Seoul, 2009

5. APPENDICES

A. Highlights occurred in 2008-2009

A.1. SN 2008D/XRF 080109: a link between SNe and GRBs

On 2008 January 9.57 UT the X-Ray Telescope (XRT) on board Swift detected a X-ray Flash (XRF 080109) in the galaxy NGC2770 (Berger & Soderberg 2008). Optical follow-up revealed the presence of a supernova coincident with the XRF (SN 2008D, Deng et al. 2008). Early spectra (Valenti et al. 2008) showed broad absorption lines superposed on a blue continuum, and lacked hydrogen or helium lines. The spectra resembled those of the XRF-SN 2006aj although much more reddened: we estimate that $E(B-V)_{tot} = 0.65$ mag (Mazzali et al. 2008).

In addition to the weak XRF, SN 2008D shows a number of peculiar features: i) the optical light curve had two peaks a first, dim maximum was reached less than 2 days after the XRF. After a brief decline the luminosity increased again, reaching principal maximum ($V = 17.37$) $\sim$ 19 days after the XRF. A 18-20 day risetime is typical of GRB-HNe while normal SNe Ic reach maximum in 10-12 days.

Another unusual feature is the spectral metamorphosis. Unlike SNe 2006aj and other GRB-SNe the broad absorptions did not persist. As they disappeared, He I lines developed (Modjaz et al. 2008). Broad lines require material moving with velocity $v > 0.1c$, therefore their quick disappearance implies that the mass moving at high velocities was small.

Mazzali et al. 2008 (see also Tanaka et al. 2008) have reproduced the spectral evolution and the light curve of SN 2008D after the first narrow peak using a model with $M_{\rm ej} \sim 7M_\odot$ and spherically symmetric $E \sim 6 \cdot 10^{51}$ erg, of which $\sim 0.03M_\odot$, with energy $\sim 5 \cdot 10^{50}$ erg, are at $v > 0.1c$. Our light curve fits indicate that SN 2008D synthesised $\sim 0.09M_\odot$ of ^{56}Ni, like the non-GRB HN SN Ic 2002ap and the normal SN Ic 1994I but much less than the luminous GRB-HN SN 1998bw. Comparing the mass of the exploding He-star that we derived with evolutionary models of massive stars, we find that the progenitor had main sequence mass $\sim 25 - 30M_\odot$. A star of this mass is likely to collapse to a black hole, as do GRB/SNe.

The X-ray spectrum of SN 2008D can be fitted with either a simple power-law indicating a non-thermal emission mechanism or a combination of a hot black body ($T = 3.8 \cdot 10^6$ K) and a power law. In the latter case, the unabsorbed luminosity of the black-body component is a small fraction of the total X-ray luminosity (about 14%) and the angular size (about 6°) of the emitting area (radius $R_{\rm ph} \sim 10^{10}$ cm) is typical of GRB jets. This leads naturally to a scenario, which is alternative to the shock break-out model proposed by Soderberg et al. 2008. XRF 080109 was the breakout of a failed relativistic jet powered by a central engine as in GRBs. The jet failed because its energy was initially low or because it was damped by the He layer, which is absent in GRB-HNe, or both. The scenario proposed by Mazzali et al. 2008 implies that GRB-like inner engine activity exists in all black hole-forming SNe Ibc, but only a small percentage of them (about 5%, see Guetta & Della Valle 2007) are able to produce a GRB, while mostly SNe-Ibc do not. SN 2008D has significantly higher energy than normal core-collapse SNe (although less than GRB/HNe), therefore, it is unlikely that all SNe Ibc, and even more so all core-collapse SNe produce a weak X-ray flash similar to XRF 080109. This conclusion is supported by the following argument. Type II SNe in late Spiral/Irr galaxies (the typical Hubble type of GRB hosts) are about 6 times more frequent than SNe Ib (Mannucci et al. 2005). Although the serendipitous discovery of an SN Ib by XRT may be a statistical fluctuation, it may also suggest that the soft X-ray emission accompanying SN 2008D is typical of overenergetic SNe Ib, and absent (or very weak) in normal core-collapse SNe.

A.2. GRB 090423: a Flash of light at z=8.1

GRB 090423 was detected by NASA's Swift satellite on 23 April 2009 at 07:55:19 UT as a burst of duration $T_{90} = 12.2 \pm 0.6$ s. As observed by the Swift Burst Alert Telescope (BATT), it had a 15–150 keV fluence $F = (6.5 \pm 0.4) \times 10^{-7}$ erg cm^{-2} and a peak energy $E_p = 48^{+6}_{-5}$ keV. Its X-ray afterglow was identified by the Swift X-ray Telescope (XRT), which began observations 73 s after the BAT trigger. A prominent flare was detected at $t \sim 170$ s in the X-ray light curve that follows a typical "steep decay"- "plateau" -"normal decay" behaviour (see Figure 1 in Salvaterra et al. 2009). The Swift UltraViolet Optical Telescope (UVOT) did not detect a counterpart even though it started settled explosures only 77 s after the trigger. Evidence that this burst occurred at high redshift, was given by the multi-band imager Gamma-Ray Burst Optical/Near-Infrared Detector (GROND; from g' to K band) which provided a photometric redshift of $z = 8.0^{+0.4}_{-0.8}$ (Tanvir et al. 2009)

Salvaterra et al. (2009) used the 3.6m Italian Telescopio Nazionale Galileo (TNG) with the Near Infrared Camera Spectrometer (NICS) and the Amici prism to obtain a low-resolution ($R \approx 50$) spectrum of GRB 090423 $\sim$ 14 hrs after the trigger. NICS/Amici is an ideal instrument to detect spectral breaks in the continuum of faint objects because of its high efficiency and wide simultaneous spectral coverage (0.8-2.4 μm). The spectrum (see Figure 2 in Salvaterra et al. 2009), reveals a clear break at 1.1 μm. We have derived a spectroscopic redshift of the GRB of $z = 8.1^{+0.1}_{-0.3}$, interpreting the break as Lyman-α absorption in the intergalactic medium. This redshift is substantially higher than that measured for any previous GRB (e.g. GRB 080913 at $z = 6.7$, Greiner et al. 2008) or any other cosmological object. This result was later confirmed by Very Large Telescope/ISAAC observations $\sim$ 17.5 hrs after the burst (Tanvir et al. 2009).

The rest-frame $\gamma-$ and X-ray light curve of GRB 090423 is remarkably akin to those of long GRBs at low, intermediate and high redshifts (see Figure 1), thus suggesting similar physics and interaction with the circum-burst medium. The analysis of the XRT data in the time interval 3900s–21568s suggests the presence of intrinsic absorption (in excess of the Galactic value) with $N_H(z) = 6.8^{+5.6}_{-5.3} \times 10^{22}$ cm^{-2} (90% confidence level). Since the absorbing medium must be thin to "Thomson" scattering, the metallicity of the circum-burst medium can be constrained to be $>$ 4% solar. The implication is that previous supernova explosions have already enriched the host galaxy of GRB 090423 above the *critical metallicity* of $Z \sim 10^{-4}\ Z_{\odot}$ (Schneider et al.2002) that the prevent the formation of very massive stars (the "so called" Population III stars). Therefore the progenitor of GRB 090423 should belong to a second stellar generation. Its explosion injected fresh metals into the interstellar medium, further contributing to the enrichment of its host galaxy. The existence of GRB 090423 supports empirically the cosmological scenarios in which stars and galaxies, already enriched by metals, are in place only $\sim$ 600 million years after the Big Bang. The occurrence of a GRB at $z \sim 8$ has important implications for the cosmic history of these objects. In a first simple approach, we can assume that: i) GRBs trace the cosmic star formation history, given the well-known link of the long GRBs with the deaths of massive stars, and ii) GRBs are well described by a universal luminosity function. However, under these assumptions the expected number of bursts at $z > 8$ with an observed photon peak flux larger than or equal to that of GRB 090423 is extremely low, $\sim 4 \times 10^{-4}$ in $\sim$ 4 yrs of Swift operation. Hence, one or both above assumptions may be oversimplified. The detection of a very high-z burst such as GRB 090423 could be accomodated if the GRB luminosity function were shifted towards higher luminosity according to $(1+z)^{\delta}$ with $\delta \sim 1.5$ or if the GRB formation rate were strongly enhanced in galaxies with $Z \sim 0.2\ Z_{\odot}$. An intriguing explanation could be that high-redshift galaxies are characterized by a top-heavy (bottom-light) stellar initial mass function with a higher incidence of massive stars than in the local Universe, providing an enhanced number of GRB progenitors.

Bibliography

Deng, J. et al. 2008, GCN 7160
Greiner, J. et al. 2008, ApJ, 693, 1610
Guetta, D. & Della Valle, M. 2007, ApJ, 657, L73
Mannucci, F., Della Valle, M., Panagia, N. et al. 2005, A&A, 433, 807
Mazzali, P., Valenti, S., Della Valle, M. et al. 2008, Science, 321, 1185
Salvaterra, R. et al. 2009, Nature, 461, 1258
Schneider, R. et al. 2002, ApJ, 571, 30 Soderberg, A. et al. 2008, Nature, 453, 469
Tanaka et al. 2009a, ApJ, 692, 1131
Tanaka et al. 2009b, ApJ, 700, 1680
Tanvir, N. et al. Nature, 461, 1256
Valenti, S. et al. 2008, GCN, 7171