Supernovae

Contents

1 **Topics** **2179**
1.1 ICRANet participants 2179
1.2 Past collaborators 2179
1.3 Ongoing collaborations 2180
1.4 Sabatical Visits, 2005-2010 2180
1.5 Students 2181

2 **Brief description** **2183**

3 **Publications 2013** **2187**

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

- Carlo Luciano Bianco
- Filippo Frontera
- Luca Izzo
- Massimo Della Valle
- Lorenzo Amati

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)
- Evan Scannapieco (Arizona State University)

1.3 Ongoing collaborations

- Lorenzo Amati (INAF-Bologna)
- Guido Chincarini (Bicocca University, Milano) and the SWIFT team
- Filippo Frontera (Ferrara University)
- 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)
- Martin Henze (MPE-Garching)
- Evan Scannapieco (Arizona State University)
- Robert Williams (STScI, Baltimore)
- Bruno Leibundgut (ESO)
- Martin Henze (Max-Planck)
- Giampiero Tagliaferri (INAF-Milano)
- Enrico Cappellaro (INAF-Padova)
- Massimo Turatto (INAF-Padova)
- John Danziger (INAF-Trieste)

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)
- Aspen Center for Physics (2007)
- Queen's University, Belfast (2007)
- European Southern Observatory, Munchen (2008-2009)

1.5 Students

- Cristina Barbarino (IRAP PhD, Italy)

2 Brief description

My research field 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 4 highlights from this programme, occurred in 2008/2011: 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 GRB ever (spectroscopically) confirmed; iv) the discovery and the follow-up of a new case of association between GRBs and SNe, i.e. GRB100316D/SN 2010bh, which takes advantage of the performances of X-shooter at VLT.

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. 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. We currently have an ESO proposal at VLT, "SN rate at high redshift and the composition of the universe" (PI B.Leibundgut in collaboration with P. Rosati, D. Maoz. S. Blondin, M. Postman and A. Riess) which has been awarded with 15h at VLT.

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, R. Maiolino and G. Cresci).

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 10 papers so far published (since 2005), see items 5 and 8.

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. This result has been recently confirmed by X-ray monitoring of Super-Soft sources observed in M31 (see item 2 and 3).

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). High resolution spectroscopic observations carried out with Bob Williams, Elena Mason and A. Ederoclite 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; 1999; Riess et al. 1998; 2004; Schmidt et al. 1998) 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). In a recent review paper (Amati & Della Valle 2013), we measure $\Omega_M = 0.28$ through the use of the Amati relationship.

3 Publications 2013

1. *Supersoft X-rays reveal a classical nova in the M 31 globular cluster Bol 126*, Henze, M. et al. 2013; A&A, 549, 120

Classical novae (CNe) represent the main class of supersoft X-ray sources (SSSs) in the central region of Andromeda Galaxy. Only three confirmed novae and three SSSs have been so far discovered in globular clusters (GCs) of any galaxy, and one nova and two SSSs (including the nova) were found in M 31 GCs. To study the SSS state of CNe we carried out a high-cadence X-ray monitoring of the M 31 central area with XMM-Newton and Chandra. This project is supplemented by regular optical follow-up programmes at ground based observatories. We analysed X-ray and optical monitoring data of a new transient X-ray source in the M 31 GC Bol 126, discovered serendipitously in Swift observations. Our optical data set was based on regular M 31 monitoringprogrammes from five different small telescopes and was reduced using a homogeneous method. Additionally, we made use of Pan-STARRS 1 data obtained during the PAndromeda survey. We extracted light curves of the source in the optical and X-rays, as well as X-ray spectra. Our observations reveal that the X-ray source in Bol 126 is the third SSS in an M 31 GC and can be confirmed as the second CN in the M 31 GC system. This nova is named M31N 2010-10f. Its properties in the X-ray (high black-body temperature, short SSS phase) and optical (relatively high maximum magnitude, fast decline) regimes agree with a massive white dwarf ($> 1.3M_{\odot}$) in the binary system. Although still based on small-number statistics, there is growing evidence that the nova rate in GCs is higher than expected from primordial binary formation and under conditions as in the field. Dynamical binary formation and/or additional accretion from the intracluster medium are possible scenarios for an increased nova rate, but observational confirmation for this enhancement has been absent, so far. Regular X-ray monitoring observations of M 31 provide a promising strategy to find these novae.

2. *Bright radio emission from an ultraluminous stellar-mass microquasar in M 31*, Middleton, M. et al. 2013, Nature, 493, 187

A subset of ultraluminous X-ray sources (those with luminosities of less than $10^{40} ergs^{-1}$) are thought to be powered by the accretion of gas onto black holes with masses of $\sim 5-20$ $M_{\odot}$, probably by means of an accretion disk. The X-ray and radio emission are coupled in such Galactic sources; the radio emission originates in a relativistic jet thought to be launched from the innermost regions near the black hole, with the most powerful emission occurrig when the rate of infalling matter approaches a theoretical maximum (the Eddington limit). Only four such maximal sources are known in the Milky Way, and the absorption of soft X-rays in the interstellar medium hinders the determination of the causal sequence of events that leads to the ejection of the jet. Here we report radio and X-ray observations of a bright new X-ray source in the nearby galaxy M 31, whose peak luminosity exceeded $10^{39} ergs^{-1}$). The radio luminosity is extremely high and shows variability on a timescale of tens of minutes, arguing that the source is highly compact and powered by accretion close to the Eddington limit onto a black hole of stellar mass. Continued radio and X-ray monitoring of such sources should reveal the causal relationship between the accretion flow and the powerful jet emission.

3. *The distance to NGC 1316 (Fornax A): yet another curious case*, Cantiello, M. et al. 2013, A&A, 552, 106

The distance of NGC 1316, the brightest galaxy in the Fornax cluster, provides an interesting test for the cosmological distance scale. First, because Fornax is the second largest cluster of galaxies within $<$ 25 Mpc after Virgo and, in contrast to Virgo, has a small line-of-sight depth; and second, because NGC 1316 is the single galaxy with the largest number of detected Type Ia supernovae (SNe Ia), giving the opportunity to test the consistency of SNe Ia distances both internally and against other distance indicators. We measure surface brightness fluctuations (SBF) in NGC 1316 from ground- and space-based imaging data. The sample provides a

homogeneous set of measurements over a wide wavelength interval. The SBF magnitudes, coupled with empirical and theoretical absolute SBF calibrations, are used to estimate the distance to the galaxy. We also present the first B-band SBF measurements of NGC 1316 and use them together with the optical and near-IR SBF data to analyze the properties of field stars in the galaxy. We obtained a distance of d = 20.8 0.5(stat.) 1.5(sys.) Mpc. When placed in a consistent Cepheid distance scale, our result agrees with the distances from other indicators. On the other hand, our distance is 17% larger than the most recent estimate based on SNe Ia. Possible explanations for this disagreement are the uncertain level of internal extinction, and/or calibration issues. Concerning the stellar population analysis, we confirm the results from other spectro-photometric indicators: the field stars in NGC 1316 are dominated by a component with roughly solar metallicity and intermediate age. A non-negligible mismatch exists between B-band SBF models and data. We confirm that such behavior can be accounted for by an enhanced percentage of hot horizontal branch stars. Our study of the SBF distance to NGC 1316, and the comparison with distances from other indicators, raises some concern about the homogeneity between the calibrations of different indicators. If not properly placed in the same reference scale, significant differences can occur, with dramatic impact on the cosmological distance ladder. Our results on the stellar populations properties show that SBF data over a broad wavelength interval are an efficient means of studying the properties of unresolved systems in peculiar cases like NGC 1316.

4. *SUDARE at the VST*, Botticella, M.T. et al. 2013, Messenger, 151, 29

The SUpernova Diversity And Rate Evolution (SUDARE) programme on the VLT Survey Telescope aims to collect an unbiased and homogeneous sample of supernovae (SNe) in all types of galaxies out to redshift 0.6. In four years, around 500 Type Ia and core-collapse SNe are expected to be discovered, including significant numbers of rare SN types. The programme is outlined and 100 SNe candidates have already been detected in the first year of the programme.

5. *X-ray source variability study of the M 31 central field using Chandra HRC-I*, Hoffman, F. et al. 2013, A&A, 555, 65

The central field of the Andromeda galaxy (M 31) was monitored from 2006 to 2012 using the Chandra HRC-I detector (about 0.1-10 keV energy range) with the main aim of detecting X-rays from optical novae. We present a systematic analysis of all X-ray sources found in the 41 nova monitoring observations, along with 23 M 31 central field HRC-I observations available from the Chandra data archive starting in December 1999. Based on these observations, we studied the X-ray long-term variability of the source population and especially of X-ray binaries in M 31. We created a catalogue of sources detected in the 64 available observations that adds up to a total exposure time of about 1 Ms. To study the variability, we developed a processing pipeline to derive long-term Chandra HRC-I light curves for each source over the 13 years of observations. We also searched for extended X-ray sources in the merged images. We present a point-source catalogue containing 318 X-ray sources with detailed long-term variability information, 28 of which are published for the first time. The spatial and temporal resolution of the catalogue allows us to classify 115 X-ray binary candidates showing high X-ray variability or even outbursts, as well as 14 globular cluster X-ray binary candidates showing no significant variability. The analysis may suggest that outburst sources are less frequent in globular clusters than in the field of M 31. We detected seven supernova remnants, one of which is a new candidate, and also resolved the first X-rays from a known radio supernova remnant. In addition to 33 known optical nova/X-ray source correlations, we discovered one previously unknown super-soft X-ray outburst and several new nova candidates. The catalogue contains a large sample of detailed long-term X-ray light curves in the M 31 central field, which helps in understanding the X-ray population of our neighbouring spiral galaxy M 31.

6. *GRB 081007 and GRB 090424: The Surrounding Medium, Outflows, and Supernovae*, Zhi-Ping, J. et al. 2013,

We discuss the results of the analysis of multi-wavelength data for the afterglows of GRB 081007 and GRB 090424, two bursts detected by Swift. One of them, GRB081007, also shows a spectroscopically confirmed supernova, SN 2008hw, which resembles SN 1998bw, while the maximum magnitude may be fainter, up to 0.7 mag, than observed in SN 1998bw. Bright optical flashes have been detected in both events, which allows us to derive solid constraints on the circumburst-matter density profile. This is particularly interesting in the case of GRB 081007, whose afterglow is found to be propagating into a constant-density medium, yielding yet another example of a gamma-ray burst (GRB) clearly associated with a massive-star progenitor which did not sculpt the surroundings with its stellar wind. There is no supernova component detected in the afterglow of GRB 090424, likely due to the brightness of the host galaxy, which is comparable to the Milky Way. We show that the afterglow data are consistent with the presence of both forward- and reverse-shock emission powered by relativistic outflows expanding into the interstellar medium. The absence of optical peaks due to the forward shock strongly suggests that thereverse-shock regions should be mildly magnetized. The initial Lorentz factor of outflow of GRB 081007 is estimated to be 200, while for GRB 090424 a lower limit of ¿ 170 is derived. We also discuss the prompt emission of GRB 081007, which consists of just a single pulse. We argue that neither the external forward-shock model nor the shock-breakout model can account for the prompt emission data and suggest that the single-pulse-like prompt emission may be due to magnetic energy dissipation of a Poynting-flux-dominated outflow or to a dissipative photosphere.

7. *Measuring cosmological parameters with Gamma-Ray Bursts*, Amati, L. & Della Valle, M. 2013, JMPD, Vol. 22, No. 14

In a few dozen seconds gamma ray bursts (GRBs) emit up to 10^{54}, erg in terms of an equivalent isotropically radiated energy Eiso, so they can be observed up to z 10. Thus, these phenomena appear to be very promising tools to describe the expansion rate history of the universe. Here we review the use of the Ep,i - Eiso correlation (Amati relationship) of GRBs to measure the cosmological density parameter Ω_M. We show that the present data set of Gamma-Ray Bursts, coupled with the assumption that we live in a flat universe, can provide independent evidence, from other probes, that $\Omega_M \sim 0.3$. We show that current (e.g., Swift, Fermi/GBM, Konus-WIND) and forthcoming GRB experiments (e.g., CALET/GBM, SVOM, Lomonosov/UFFO) will allow us to constrain Ω_M with an accuracy comparable to that currently exhibited by Type Ia supernovae and to study the properties of dark energy and their evolution with time.

8. *SN2012ca: a stripped envelope core-collapse SN interacting with dense circumstellar medium*, Inserra, C. et al. 2013, MNRAS, 178

We report optical and near-infrared observations of SN2012ca with the Public ESO Spectroscopy Survey of Transient Objects (PESSTO), spread over one year since discovery. The supernova (SN) bears many similarities to

SN1997cy and to other events classified as Type IIn but which have been suggested to have a thermonuclear origin with narrow hydrogen lines produced when the ejecta impact a hydrogen-rich circumstellar medium (CSM). Our analysis, especially in the nebular phase, reveals the presence of oxygen, magnesium and carbon features. This suggests a core-collapse explanation for SN2012ca, in contrast to the thermonuclear interpretation proposed for some members of this group. We suggest that the data can be explained with a hydrogen- and helium-deficient SN ejecta (Type I) interacting with a hydrogen-rich CSM, but that the explosion was more likely a Type Ic core-collapse explosion than a Type Ia thermonuclear one. This suggests that two channels (both thermonuclear and stripped envelope core-collapse) may be responsible for these SN 1997cy-like evens.

Non-refereed publications

1. *VLT observations of GRB 130427A*, Melandri, A. et al. 2013, GCN 14673

2. *GRB 130702A: TNG spectroscopic observations of the emerging supernova.*, D'Elia, V. et al. 2013, GCN 15000

3. *GRB 130702A in the ep,i - eiso plane.*, Amati, L. et al. 2013, GCN 15025

4. *Five Supernova Survey Galaxies in the Southern Hemisphere: Supernova Ia Rates*, Hakobyan, A. et al. 2013, IAUS, 281, 24

5. . *Supernova 2013dx = GRB 130702A*, Melandri, A. et al. 2013, CBET 3587