Anisotropies in core-collapse supernova explosions

Report of Contributions

Contribution ID: **1** Type: **not specified**

Modeling Multiwavelength Emission of Super-Eddington accreting Black Hole ULXs

Elena Ambrosi (Speaker), Luca Zampieri

"Ultra-luminous X-ray Sources (ULXs) are point like off-nuclear X-ray sources whose bolometric luminosity exceeds the Eddington limit for a 10 solar masses Black Hole (BH) (Fabbiano, 1989).

Their observational properties, as the X-ray luminosity, the variability and the spectral changes, suggest that ULXs are compact object accreting via a disc (Makashima et al. 2000, Feng & Soria 2001).

In this work (Ambrosi et al. in prep.) we compute optical through X-ray emission of ULXs. We first calculate an extended grid of binaries which evolve through Roche Lobe Overflow (RLOF) considering case A mass transfer from massive donors (up to 25 solar masses) onto massive BHs (up to 100 solar masses). We calculate their optical emission with our model of super-Eddington accretion (Ambrosi & Zampieri 2018). Moreover, we compute their optical-through-X-ray Spectral Energy Distribution (SED) considering the effect of a Comptonizing corona which surrounds the innermost regions of the disc. We show that the evolutionary tracks occupy specific position on the color-magnitude diagram depending on the evolutionary stage of the donor and on the BH mass. We finally apply our model to well-known persistent ULXs."

Contribution ID: **2** Type: **not specified**

Equity, Diversity, and Inclusion in Astronomy

Rosaria Bonito

This talk will briefly present the issues related to equity, diversity, and inclusion in Astronomy. Unconscious bias on topics including nationality, gender, neuro-diversity, and different ability as well as projects already developed or under development to practice inclusion will be discussed.

Contribution ID: **3** Type: **not specified**

Highly magnetic neutron starts: an observational review

Alice Borghese

Magnetars are the strongest magnets we know of. Their X-ray emission is powered by the instabilities and decay of their huge magnetic field (~10^14 -10^15 G). The hallmark of these isolated neutron stars is the unpredictable and variable bursting activity observed in the X-/gamma ray regime and on different time scales (from milliseconds up to tens of seconds). These flaring episodes are often accompanied by enhancements of the persistent X-ray flux, which usually relaxes back to the quiescent level over months to years, the so-called outbursts. In this talk, I will review the observational properties of magnetars, showing a systematic analysis of outbursts and new results in the field. I will then finish with some considerations on magnetar-like activity from other classes of neutron stars and the possible evolutionary links between different neutron star families.

Contribution ID: **4** Type: **not specified**

The role of rotation on the evolution of massive stars.

Alessandro Chieffi (speaker) & Marco Limongi

I will briefly discuss the various phenomena induced by rotation on the evolution of a massive and on the final explosive yields.

Contribution ID: **5** Type: **not specified**

First 3D Morpho-kinematical model of a SNR. Case of VRO 42.05.01 (G 166.0 +4.3).

S. Derlopa, P. Boumis, A. Chiotellis, W. Steffen, S. Akras

"Supernova Remnants (SNRs) are the nebulae created after the violent death (Supernovae, SN) of certain stars (progenitor stars). Since SNRs are the final part of the chain of the stellar evolution, by probing them we gain valuable information about the nature and evolution of the progenitor star as well as about the explosion mechanism itself.

However, the data we obtain by SNRs observations are limited in 2-dimensions (2D). The missing information of the third dimension can be provided by 3-dimensional (3D) Morpho-kinematical (MK) models, something that contributes to a more concrete understanding of the evolutionary history of the remnant. Up to date, 3D MK modelling has been limited to Planetary Nebulae, due to their relatively small size. In this work we present the first 3D MK model of a SNR. As a study case we used the Galactic SNR VRO 42.05.01 (G 166.0+4.3), while for the purposes of our model the astronomical code "SHAPE"was employed . We present the results from our modelling and our conclusions about the origin and the evolution of this intriguing SNR. Finally, we discuss the applications of our method as a key tool to decipher the encoded information that SNRs carry about their progenitor stars and the SN explosion they originate."

Contribution ID: **6** Type: **not specified**

Discovery of an overionized jet-like structure in the SNR IC443

Emanuele Greco (speaker), Marco Miceli, Salvatore Orlando, Eleonora Troja, Giovanni Peres, Fabrizio Bocchino

"IC 443 is a supernova remnant (SNR) located in a complex environment and interacting with nearby clouds. Indications for the presence of overionized plasma have been found though the possible physical causes of overionization are still debated. Moreover, because of its peculiar position and proper motion, it is not clear if the pulsar wind nebula (PWN) within the remnant is the relic of the IC 443 progenitor star or just a rambling one seen in projection on the remnant. We addressed the study of the IC 443 X-ray emission in order to clarify the relationship between PWN and remnant, the presence of overionization and its origin. We identified an elongated (jet-like) structure with Mg-rich plasma in overionization. The jet is interacting with a molecular cloud and is aligned with the position of the PWN at the instant of the supernova explosion. Interestingly, the direction of the jet of ejecta is somehow consistent with the direction of the PWN jet. IC 443's jet is the first one which shows overionized plasma, possibly associated with the adiabatic expansion of ejecta. The match between the jet's direction and the original position of the PWN strongly supports the association between the neutron star and IC 443.

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Contribution ID: **7** Type: **not specified**

Jet-cocoon signatures in broad-line supernovae associated with gamma-ray bursts

L. Izzo

The progenitor stars of long gamma-ray bursts are rapidly rotating stripped-envelope massive stars. During the last moments of their lives, the collapse of the central core powers a supernova explosion while in the most central regions matter flows around a newly formed spinning black hole (or a magnetar). This leads to the formation of a powerful jet, which is capable to completely drill the dense external layers of the progenitor star along the core spin axis until it reaches the photosphere and escapes at relativistic speeds, emitting a GRB. I will briefly review the status-of-the-art in GRB/SN science and finally will present some new results that shed light on the role of the jet component in the collapse of stripped-envelope supernovae.

Contribution ID: **8** Type: **not specified**

3D hydrodynamical simulation of the clumpy supernova ejecta

Petar Kostić

We present a 3D hydrodynamical simulation of expanding ejecta of supernova. The code is written in C language. It uses the MUSCL-Hancock finite volume scheme. The ejecta is initialized as expanding density profile with kinetic energy far exceeding the internal energy. The integrated mass and total energy of the ejecta are 1.4 Ms and 10^51 erg. For the purpose of obtaining the Rayleigh-Taylor instabilities at the contact discontinuity, the density of ejecta is initially perturbed from cell to cell. In one case the perturbations were distributed all over the volume of the ejecta, and in the other they were present only in the outer shell near the edge of the ejecta. It is showed that the code reproduces Rayleigh-Taylor instabilities as expected.

Contribution ID: **9** Type: **not specified**

Tracing end of star from SNR observation

Ho-Gyu Lee

"We present results of near-infrared [Fe II] imaging and spectroscopic observations of young supernova remnants. Near-infrared [Fe II] line is a good tracer of dense shocked gas because of less extinction compared to optical wavelength and its relative strength compared to hydrogen line. We obtained images and spectra covering many positions of SNRs using recent integral-field spectroscopy and multi-object spectroscopy instruments. The observed morphological and kinematic distributions of young SNRs can give clue to the conditions of pre-supernova remnant and end of star."

Contribution ID: **10** Type: **not specified**

Anisotropies in the gamma-ray emission of SNRs

M. Lemoine-Goumard

Over the past decade, gamma-ray observations of supernova remnants with space-based instruments, such as the Fermi-Large Area Telescope (LAT), and ground-based instruments such as the High Energy Stereoscopic System (H.E.S.S.), the Major Atmospheric Gamma-Ray Imaging Cherenkov (MAGIC) telescopes, and the Very Energetic Radiation Imaging Telescope Array System (VERITAS) have significantly advanced our understanding of particle acceleration in the shocks of these highly energetic sources. The number of supernova remnants (SNRs) that are detected at gamma-ray energies has steadily increased, clearly demonstrating that shocks are capable of accelerating particles to multi-TeV energies. In a few cases, the large statistics as well as the good angular resolution in comparison to the size of the SNR, permit detailed studies of the morphology and spectrum of the source, as well as spatially resolved spectroscopy. This presentation aims to review the most important results obtained in these morphological studies of supernova remnants, highlighting the cases in which asymmetries are detected.

Contribution ID: **11** Type: **not specified**

Anisotropies in SN1987A

S. Nagataki, M. Ono, T. Takiwaki, A. Wongwathanarat, S. Orlando, M. Miceli, H. Umeda, T. Yoshida, G. Ferrand, I. Seitenzahl, F. Roepke

I would like to present our research history on SN1987A. Briefly I would like to present our recent study on Type Ia SNRs.

Contribution ID: **12** Type: **not specified**

Magnetorotational explosions and the road to proto-magnetars

M. Obergaulinger (speaker), M.Á. Aloy

Coupling special relativistic magnetohydrodynamics and spectral neutrino transport, we performed long-term simulations of the collapse of rapidly rotating stellar cores with strong magnetic fields. After their collapse, these cores may launch highly energetic explosions. Our models include cores in which the proto-neutron star at the centre of the core may collapse to a black hole as well as ones that, at least temporarily, avoid that fate. The latter case may allow for a proto-magnetar driving relativistic outflows as the central engine of a GRB. We explored the mechanisms that launch an explosion and the processes determining which of these two scenarios plays out.

Contribution ID: **13** Type: **not specified**

Pulsar Wind Nebulae and their winds

B. Olmi

"Pulsar Wind Nebulae (PWNe) are very fascinating and puzzling objects. They are bright at a very broad range of energies, showing various morphologies, a large variety of emission properties and complex features. They are among the most efficient particles accelerators in the Galaxy, with evidence of large escape and diffusion of particles from the nebulae in the surroundings.

Since they were originated by the interaction of the pulsar wind with the supernova ejecta, the eventual anisotropy of that wind reflects on different properties of the nebula, from the formation of the well known X-ray jet-torus morphology to the properties of polarization and turbulence in evolved systems.

Signatures of the anisotropy have been largely addressed thanks to numerical models, able to reproduce the complex physics needed to describe PWNe and to link the wind physical properties to dynamic and emission signatures.

Here I will discuss the most recent findings in the description and comprehension of those fascinating systems."

Contribution ID: **14** Type: **not specified**

Linking the morphology of SNRs to anisotropies in parent core-collapse SNe through MHD simulations

Orlando S.

The structure and morphology of SNRs reflect the properties of the parent SNe and the characteristics of the inhomogeneous environments through which the remnants expand. Linking the morphology of SNRs to anisotropies developed in their parent SNe can be essential to obtain key information on many aspects of the explosion processes associated with SNe. Nowadays, our capability to study the SN-SNR connection has been largely improved thanks to multi-dimensional models describing the long-term evolution from the SN to the SNR as well as to observational data of growing quality and quantity across the electromagnetic spectrum which allow to constrain the models. In this talk, I will review recent advances in the modeling of young SNRs, focusing on investigations aimed to link asymmetries and features observed in the remnants to anisotropies of their parent SN explosions.

Contribution ID: **15** Type: **not specified**

Gap transients and interacting supernovae

A. Pastorello

Modern surveys have revealed a wide of variety of stellar transients showing signatures of interaction between the most recent ejecta and pre-existing circumstellar material. Some of them are intermediate-luminosity objects (with absolute magnitudes ranging from -10 to -15), and can be faint SNe, non-terminal single outbursts of massive stars, giant eruptions of luminous blue variables, or the outcome of stellar mergers. Occasionally, outbursts are observed a very short time before a genuine supernova explosion. The resulting supernova will strongly interact with the circumstellar cocoon, producing long-lasting, energetics transients. I will provide an observational review the most recent discoveries in this field.

Contribution ID: **16** Type: **not specified**

Revisiting the ejecta asymmetries in CasA with a novel method for component separation in X-rays

Adrien Picquenot ; Fabio Acero

In the X-ray emission of supernovae remnants, the shocked interstellar medium, the shocked ejecta and the synchrotron possess a different spatial and spectral signature, but are closely entangled. Extracting the intrinsic spatial and spectral information of the individual components from this data is a challenging task. Current analysis methods do not fully exploit the 2D-1D (x,y,E) nature of the data, as the spatial and spectral information are considered separately. Here we investigate the application of a blind source separation algorithm (the General Morphological Component Analysis ; GMCA) that jointly exploits the spectral and spatial signatures of each component in order to disentangle them. The performance of the GMCA on X-ray data is tested using Monte-Carlo simulations of Cassiopeia A-like toy models, designed to represent typical science cases. We find that the GMCA is able to separate highly entangled components in X-ray data even in high contrast scenarios, and can extract with high accuracy the spectrum and morphological maps of each physical component. Applying the algorithm to the deep Chandra observations of Cassiopeia A, we were able to produce detailed maps of the synchrotron emission at low energies (0.6-2.2 keV), and of the red/blue shifted distributions of a number of elements including Si, S, Ar, Ca and Fe K. These maps, besides highlighting the asymmetries of some elements distribution in the ejecta of Cassiopeia A, exhibit their spatial distributions with a level of details never attained before. We were also able to retrieve, for the first time, an image of the Oxygen distribution.

Contribution ID: **17** Type: **not specified**

Pursuing the afterlife: unveiling the inner engine from late-time observations of supernovae

Terreran, Margutti, et al.

Late-time observation of supernovae have already proven to be an invaluable source of information, providing a privileged insight to the innermost region of the ejecta, and therefore on the core of the progenitor star. By waiting long enough for the ejecta to become optically thin, we could in principle reveal the compact remnant left by the explosion. Very late-time observations of a handful of stripped-envelope SNe are starting to show indirect evidences for the presence of the compact object left there by the stellar collapse (e.g. Milisavljevic et al., 2018). Optical spectra taken more than a decade after explosion appear to be dominated by forbidden emission of oxygen and sulfur, with velocities of 2500 km/s. These could result from the heating of the ejecta by a inner source, like a pulsar wind nebula. This is also supported by an enhancement of the X-ray and radio fluxes, possibly originated by the highly magnetized compact object. I present very very-late observations of SNe at t 6-16 years and discuss our findings into the context of pulsar wind nebulae inflated by the compact object.

Contribution ID: **18** Type: **not specified**

Anisotropies in winds and nebulae around Luminous Blue Variables.

Corrado Trigilio, Grazia Umana, Claudia Agliozzo, Carla Buemi, Filomena Bufano, Francesco Cavallaro, Adriano Ingallinera, Paolo Leto, Simone Riggi

Luminous Blue Variables (LBVs) are luminous, massive stars, which represent a crucial and relatively short phase of massive stars evolution between core-hydrogen burning O-type stars and helium burning Wolf- Rayet stars. They are characterized by ”micro”, ”moderate”variability, leading to very strong mass loss. Giant eruptions, the so called SN impostors, even if rarely observed, are witnessed by extended circumstellar nebulae (LBVN) around several LBV. The geometry of these nebulae is sometimes symmetric, other times show bipolar or asymmetrical morphology. LBV winds/outbursts are among the major contributors of processed material (gas and dust) and kinetic energy to the ISM. Moreover, as LBVs are SN progenitors, the structure of their ejecta may also influence the geometry of SN remnants. An overview of the LBVN characteristics, in particular as revealed by radio and IR observations, will be given, together with the possibility to derive the the circumstellar environment at the moment of the SN explosion.

Contribution ID: **19** Type: **not specified**

Neutron star mergers across the electromagnetic spectrum

E. Troja

The discovery of the gravitational wave transient GW170817 and its electromagnetic counterparts ushered in a new era of multi-messenger astrophysics, in which both gravitational waves and light provide complementary views of the same source. These observations gave astronomers the unprecedented opportunity to probe the merger of two neutron stars, solving decade-long mysteries about the origin of short duration gamma-ray bursts (GRBs) and the production of elements heavier than iron. In this talk, I will present the long-term evolution of GW170817 across the electromagnetic spectrum, and discuss its similarities with the sample of short GRBs at cosmological distances.

Contribution ID: **20** Type: **not specified**

3D MHD modeling from the onset of the SN to the full-fledged SNR

Antonio Tutone (speaker), Salvatore Orlando, Marco Miceli, Shigehiro Nagataki, Masaomi Ono, Gilles Ferrand, Giovanni Peres

"The physical properties and morphology of a supernova remnant (SNR) are expected to reflect possible asymmetries and anisotropies developed soon after the parent supernova (SN) explosion and the internal structure of the progenitor star.

The aim of this work is to bridge the gap between SNe and their remnants by investigating how post-explosion anisotropies of ejecta influence the structure and chemical properties of the remnant at later times.

We performed 3D MHD simulations starting soon after the breakout of the SN shock wave at the stellar surface and following the interaction of the ejected stellar debris with the circumstellar medium (CSM) (consisting in the wind of the progenitor star), obtaining the physical scenario of a SNR. Here we focussed the analysis on the case of a progenitor red supergiant of 19 Msun. We investigated how a post-explosion large-scale anisotropy in the SN affects the ejecta distribution and the matter mixing of heavy elements in the remnant, during the first 5000 years of evolution.

Our model shows that a post-explosion anisotropy in the inner ejecta distribution can generate a Ni/Si-rich jet. The anisotropy allows heavy elements to penetrate into the external regions of the ejecta, causing an inversion of the chemical layers in the remnant. We found that the properties of the jet and the level of matter mixing are sensitive to the initial velocity contrast of the anisotropy. Moreover, we found that the initial parameters of the clump influence the shocked mass of the heavy elements."

Contribution ID: **21** Type: **not specified**

Investigating the effects of the inhomogeneous interstellar medium in shaping the morphology of SNR IC 443

S. Ustamujic, S. Orlando, E. Greco, M. Miceli, F. Bocchino, and G. Peres

The morphology and the distribution of material observed in SNRs reflect both the interaction of the SN blast wave with the ambient environment, and the physical processes associated to the SN explosion and the internal structure of the progenitor star. IC443 is a SNR located in a quite complex environment: it interacts with a molecular cloud in the northwestern and southeastern areas and with an atomic cloud in the northeast. In this study we aim at investigating the effects of the inhomogeneous medium in shaping the morphology of IC 443 after the SN explosion. To this end, we have developed a 3D HD model for IC 443 describing the interaction of the SNR with the environment, parametrized in agreement with the results of the multiwavelength data analysis. From the simulations, we synthesized the X-ray emission and compared with XMM-Newton observations. Here we present our preliminary results.

Contribution ID: **22** Type: **not specified**

The anisotropy of the ejecta in Cassiopeia A

Jacco Vink

I will review the anisotropies of the ejecta in Cas A, with a special emphasis on the jet and the iron ejecta. I will also discuss the energies of the jet, as their are two widely different estimates in the literature. I will put these discussion also in the context of the available literature on core-collapse explosions.

Contribution ID: **23** Type: **not specified**

Detection of Late-Time Optical Emission from SN 1941C in NGC 4136

Kathryn E. Weil (speaker), Robert A. Fesen

We report the detection of broad oxygen emission lines from the site of SN 1941C nearly eight decades after outburst, making it the oldest detected core-collapse SN/youngest core-collapse SNR with a well determined age. In sharp contrast to the strongly blueshifted emission line profiles observed for some other late-time CCSNe thought to be due to dust extinction of rear hemisphere ejecta, SN 1941C's spectrum exhibits stronger redshifted emissions of [O I] 6300, 6364 [O II] 7320, 7330, and [O III] 4959, 5007. The oxygen emissions have rest frame radial velocities from -2200 to +4400 km/s. No other significant broad line emissions were detected including H-alpha emission. We discuss possible causes for this unusual spectrum and compare SN 1941C's optical and X-ray luminosities to other evolved CCSNe.

Contribution ID: **24** Type: **not specified**

Long-term evolution of core-collapse supernova asymmetries from shock revival to shock breakout

Annop Wongwathanarat, Thomas Janka, Ewald Mueller, Victor Utrobin

Over the past decade remarkable progress has been made in simulating long-term evolution of core-collapse supernova explosions in three dimensions. Current state-of-the-art simulations are able to follow the non-radial asymmetries fostered by the growth of hydrodynamic instabilities from the shock revival phase until the blastwave disrupts the entire progenitor stars. These simulation results will be the Rosetta stone that connects observations of supernovae and supernova remnants to the theory of explosion mechanism.

Contribution ID: **25** Type: **not specified**

Supernova remnants hosting magentars

Ping Zhou, Jacco Vink, Samar Safi-Harb, Marco Miceli

Magnetars are regarded as the most magnetized neutron stars in the Universe. The study of them is essential to understand the origin of neutron star diversity. Among the 30 magnetars, around 10 are associated with supernova remnants (SNRs). Since the SNR and magnetar share a common progenitor and are born in a single explosion, studying them together will result in a better mutual understanding of these objects and their origin. I will talk about the SNRs hosting magnetars and show how the properties of these SNRs allow us to learn what progenitor stars and which kinds of explosion can create magnetars. I will also show the very detailed metal distributions in SNRs to understand the SN explosion (a)symmetries. According to SNR studies in recent years, magnetars are not necessarily made from very massive stars but originate from stars that span a large mass range. Their explosion energies also span a large range. These results challenge the popular dynamo scenario to create these Galactic magnetars but imply fossil field origin.