BOOK OF ABSTRACTS / REPORT OF CONTRIBUTIONS

Anisotropies in core-collapse supernova explosions 2

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Massive stars end their lives with supernova explosions, some of them being associated with collimated gamma-ray bursts.
Core-collapse explosions always show signatures of anisotropies, ranging from small perturbations in the velocity/density/chemical composition of the ejecta, up to massive and energetic structures. The study of anisotropies can shed light on the physical processes involved in the explosion mechanism and on the structure of the progenitor star.
A proper study of these complex physical systems requires a multi-wavelength approach and a tight link between data analysis and theoretical modeling, as well as the need to exploit the diagnostic power of multi-messenger astronomy.

The final aim of this meeting is gathering people from different fields, to present the most recent results and discoveries. Ample time will be given to discussions to facilitate the transfer of knowledge and contribute to the creation of new connections and fruitful collaborations.

Edited by: Laura Leonardi

Anisotropies induced in supernova explosions by rotation and magnetic fields

The collapse of fast-rotating and magnetized stellar cores opens up the possibility of developing explosions where the concourse of rotation and magnetic fields induces very large anisotropy in the early supernova ejecta. In this talk, I will review the properties of the supernova explosions driven under various degrees of rotation and magnetic fields. Particular attention will be paid to the differences in the nuclear yields and bolometric light curves produced by different initial conditions.

Primary author: ALOY, Miguel Ángel (University of Valencia)

Presenter: ALOY, Miguel Ángel (University of Valencia)

X-ray synchrotron polarization in partially random magnetic fields. General theory and applications to SN 1006.

"In a previous work (Bandiera & Petruk 2016) we have investigated the effects of a partially random magnetic field on the polarization of the synchrotron emission, under the assumption that the energy distribution of the emitting particles follows a power law. These results are useful, for instance, for the analysis of radio synchrotron emission from supernova remnants.
The great achievement of the IXPE satellite has been to finally provide detailed measurements on the polarization also in the X-ray spectral window, then requiring a parallel improvement of the theory. While our previous results are still valid for sources, like pulsar wind nebulae, in which the synchrotron spectrum is a power law also in the X-ray band, this is not the case for those sources, like supernova remnants, in which the synchrotron emission shows the presence of a spectral cutoff. The theoretical treatment of this more general case is more complex than that of a pure power law, so that no fully analytical solution can be found.
We have devised and efficient way to treat the problem numerically. Here we discuss the results of this work. We have also chosen the supernova SN 1006 as the first object on which to apply these results."

Primary author: BANDIERA, Rino (Istituto Nazionale di Astrofisica (INAF))

Co-author: PETRUK, Oleh (Istituto Nazionale di Astrofisica (INAF))

Presenter: BANDIERA, Rino (Istituto Nazionale di Astrofisica (INAF))

Pre-supernova outbursts in Galactic Red Supergiants: predicting the next Galactic SN event

"The investigation of pre-supernova outbursts has primarily relied on archived data of extragalactic supernovae (SNe). These surveys, which are conducted after SN (i.e., ""a-posteriori""), suffer from a bias against the rich population of lower luminosity Red Supergiants (RSGs), and they lack uniform pre-SN data. Recent discoveries of a coeval and co-distant large sample of RSGs in the Scutum-Crux region provide an opportunity to shift the observational paradigm of pre-SN outburst studies. We are carrying out a photometrically homogeneous monitoring program to detect late-stage outbursts and compare them with the latest models of the final phases of lowmass RSGs before the SN explosion. This approach may enable us to predict the core collapse before it occurs. We report on methods and observations' status."

Primary author: BOCCHINO, Fabrizio (Istituto Nazionale di Astrofisica (INAF))

Co-authors: CHIEFFI, Alessandro; LIMONGI, Marco (Istituto Nazionale di Astrofisica (INAF)); MICELI, Marco (Istituto Nazionale di Astrofisica (INAF)); ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF)); PASTORELLO, A.; PETRUK, Oleh (Istituto Nazionale di Astrofisica (INAF))

Presenter: BOCCHINO, Fabrizio (Istituto Nazionale di Astrofisica (INAF))

The GRB fundamental plane relation, its interpretation and application as cosmological tool

"The X-ray afterglow plateau emission observed in many gamma-ray bursts (GRBs) has been interpreted as being fueled either by fallback onto a newly formed black hole or by the spin-down luminosity of an ultra-magnetized millisecond neutron star. If the latter model is assumed, GRB X-ray afterglow light curves can be reproduced analytically. We fit a sample of GRB X-ray plateaus, interestingly yielding a distribution in the diagram of magnetic field versus spin period (B-P) consistent with B ∝ P 7/6, which is consistent with GRB expectations of the well-established physics of the spin-up line for accreting Galactic X-ray pulsars. The normalization of the relation that we obtain perfectly matches spin-up line predictions for typical neutron star masses (~1 M⊠) and radii (~10 km), and for mass accretion rates typically expected in GRBs, {10}-4 {M}⊠ {{{s}}}-1< \dot{M}< {10}-1 {M}⊠ {{{s}}}-1. Short GRBs with extended emission (SEEs) appear toward the long-period end of the distribution, and long GRBs (LGRBs) toward the short-period end. This result is consistent with expectations from the spin-up limit, where the total accreted mass determines the position of the neutron star in the B-P diagram. The B-P distributions for LGRBs and SEEs are statistically different, further supporting the idea that the fundamental plane relation—a tri-dimensional correlation between the X-ray luminosity at the end of the plateau, the end time of the plateau, and the 1 s peak luminosity in the prompt emission—is a powerful discriminant among those populations. Our conclusions are robust against suppositions regarding the collimation angle of the GRB and the magnetar braking index, which shift the resulting properties of the magnetar parallel to the spin-up line, and strongly support a magnetar origin for GRBs presenting X-ray plateaus.
The application of this correlation as a cosmological tool has proven to be successful to obtain similar uncertainties as the other probes, but up to z=5."

Primary author: DAINOTTI, Maria Giovanna (NAOJ)

Co-authors: BOGDAN, Malgorzata; FRAIJA, Nissim; LENART, Aleksander

Presenter: DAINOTTI, Maria Giovanna (NAOJ)

Evidence for thermal X-ray emission from the synchrotron dominated shocks in Tycho's supernova remnant

"While a faint thermal signature left by shocked interstellar medium (ISM) should be found in X-ray synchrotron dominated spectra in the vicinity of SNR shock waves, proof for such emission in Tycho's SNR has been lacking. Switching from traditional fitting methods to
Bayesian inference allows for new perspectives, even when using the same Chandra archival data as in the literature. Such an approach allows not only to detect and characterize the properties of shocked ISM in Tycho's SNR, but also to make predictions for the upcoming X-IFU instrument onboard the Athena space mission. Indeed, the refined spectral resolution at low energy (0.5 - 1 keV) of X-IFU should confirm our results for Tycho, and open a new window on our understanding of SNR blast waves in general."

Primary author: ELLIEN, Amaël (Anton Pannekoek Instituut, University of Amsterdam)

Co-authors: GRECO, E. (INAF); VINK, J.

Presenter: ELLIEN, Amaël (Anton Pannekoek Instituut, University of Amsterdam)

The metamorphosis of the Type Ib supernova 2019yvr: late-time interaction

"Stripped-envelope (SE) SNe show little hydrogen (IIb), no hydrogen (Ib), and no helium (Ic) in their spectra. The progenitors from which they arise are a matter of discussion, as the former star must have lost its outer layers through strong mass-loss processes. Furthermore, it has been recently detected an increasing number of SESNe that showed late-time signatures of interaction between the ejecta and hydrogen- or helium-rich circumstellar material (CSM), which provides valuable information of the latest evolutionary stages of their progenitors.
This is the case of the Type Ib SN 2019yvr, which also constitutes one of the few SNe of its Type in having progenitor detections on archival HST images. In our study, we present observational evidence of late-time interaction, focusing on the appearance of Halpha emission at ~70 days post-maximum, and the nearly simultaneous light curves flattening. We also estimate key quantities such as the CSM inner radius, the mass-loss rate prior to explosion, and the progenitor pre-SN mass. Finally, we study its nebular spectra to further our analysis of the progenitor and to derive the possible symmetries of the interacting CSM."

Lucía Ferrari, Gastón Folatelli, Hanindyo Kuncarayakti, Maximilian Stritzinger, Keiichi Maeda, et al.

Primary author: FERRARI, Lucia (Instituto de Astrofísica de La Plata, Argentina)

Co-authors: Ms FOLATELLI, Gastón; KUNCARAYAKTI, Hanindyo; MAEDA, Keiichi; STRITZINGER, Maximilian

Presenter: FERRARI, Lucia (Instituto de Astrofísica de La Plata, Argentina)

Anisotropies in neutrino driven supernovae

Supernova (SN) are some of the most violent events in our universe releasing huge amounts of energy in a very short time. Their related large luminosities make these explosions objects of astronomical and astrophysical studies since many centuries. They can be seen far out in the universe as point sources. However, only recently, the observations and theoretical studies have reached a level of detail and resolution that we can study SN and their remnants in full 3D in the computer and in our galaxy. Also lightcurve modelling, observations of polarization and light echos show that SN are genuine 3D objects. The related anistropies are strongly related to the explosion mechanism, where hydrodynamical instabilities give rise to the onset of aspherical shock expansion, and the stellar progenitor structure, which determines the growth of Rayleigh-Taylor instabilities that lead to fragmentation of these initial anisotropies and can accelerate the ejected material. Further, the energy input due to beta decay influences on the final morphology of the ejecta supernova by inflating and accelerating 56Ni-rich regions. The final shape during the evolution of a SN into its remnant is then determined by the interaction of the ejecta with the circumstellar and interstellar material. Here we will review the processes until about a few years after the onset of the explosion until the effects of the beta decay cease.

Primary author: GABLER, Michael (University of Valencia)

Co-authors: GIUDICI, Beatrice; JANKA, Hans-Thomas

Presenter: GABLER, Michael (University of Valencia)

Instabilities in core-collapse supernovae: the study 14 red super giant progenitor models in three dimensions

"We investigate core-collapse supernovae (CCSNe) explosion simulations of 14 different red super-giant star (RSG) progenitors.
The RSG stars were evolved as single-star progenitors in 1D and have zero-age main-sequence (ZAMS) masses between 12.5 Msun and 27.3 Msun.
The explosions were modelled with the neutrino-hydrodynamics code Prometheus-HotB.
The simulations were done in full-3D geometry and were evolved from the onset of core-collapse until 10 days after the explosion.
The obtained explosion properties, like explosion energies or nickel yields, and the properties of the neutron star (NS) are in agreement with theoretical expectations, previous work and observations.
The main question we are interested is the mixing of elements in 3D and how it can be related to the properties of the progenitor star.
In particular, we investigate the growth of Rayleigh-Taylor instabilities at (C+O)/He and He/H interfaces.
These instabilities have an important role in the outward mixing of 56Ni into the hydrogen envelope.
Moreover, we analyze the velocity of the 56Ni yields at different times throughout the explosions and relate them with the respective progenitor structure. We claim that the initial stellar profile of the function ρr^3 plays an important role in the propagation of the shock (Sedov 1959), and in particular its shape in the He shell has been proven to have a fundamental role in SN explosions characterization."

Primary author: GIUDICI, Beatrice (University of Valencia)

Co-authors: GABLER, Michael; JANKA, Hans-Thomas

Presenter: GIUDICI, Beatrice (University of Valencia)

Evidence for proton acceleration and escape from the Puppis A SNR using Fermi-LAT observations

Supernova remnants (SNRs) are the best candidates for galactic cosmic ray acceleration to relativistic energies via diffusive shock acceleration. The gamma-ray emission of SNRs can provide direct evidence of leptonic (inverse Compton and bremsstrahlung) and hadronic (proton-proton interaction and subsequently pion decay) processes. Puppis A is a ~ 4 kyr old SNR interacting with interstellar clouds which has been observed in a broad energy band, from radio to gamma-ray. We performed a morphological and spectral analysis of 14 years of observations with Fermi-LAT telescope in order to study its gamma-ray emission. We found a clear asymmetry in high-energy brightness between the eastern and western sides of the remnant, reminiscent to that observed in the X-ray emission. The eastern side, interacting with a molecular cloud, shows a spectrum which can be reproduced by a pion decay model. Moreover, we analyzed two gamma-ray sources located close to the remnant. The hardness of their spectra suggests that the gamma-ray emission can be due to particles escaping from the shock of Puppis A.

Primary author: GIUFFRIDA, Roberta (Istituto Nazionale di Astrofisica (INAF))

Co-authors: FUKUI, Yasuo; GAMICI, Stefano; LEMOINE-GOUMARD, Marianne; MICELI, Marco (Istituto Nazionale di Astrofisica (INAF)); SANO, Hidetoshi

Presenter: GIUFFRIDA, Roberta (Istituto Nazionale di Astrofisica (INAF))

Evidence for a Pulsar Wind Nebula in SN1987A

Since the day of its explosion, supernova (SN) 1987A has been closely monitored to study its evolution and to detect its central compact relic. However, the only hint of such an object comes from the detection in the Atacama Large Millimeter/submillimeter Array (ALMA) data of a feature that is compatible with the emission arising from a protopulsar wind nebula (PWN). I am going to talk about the simultaneous analysis of multiepoch Chandra, XMM-Newton, and NuSTAR observations, coupled with state-of-the-art three-dimensional magnetohydrodynamic simulation of SN 1987A. We reconstructed the asymmetric absorption pattern due to the cold ejecta lying within the hearth of SN1987A. We included the effects of absorption in the spectral analysis finding that a heavily absorbed power law, consistent with the emission from a PWN in SN 1987A, is needed to properly describe the high-energy part of the observed spectra. The information extracted from our analysis is used to infer the physical characteristics of the pulsar and the broadband emission from its nebula. Analysis of the synthetic spectra also shows that, in the near future, the main contribution to the Fe K emission line will originate in the outermost shocked ejecta of SN 1987A.

Primary author: GRECO, Emanuele (INAF)

Co-authors: BOCCHINO, Fabrizio (Istituto Nazionale di Astrofisica (INAF)); DOHI, Akira; LEI, Sun; MICELI, Marco (Istituto Nazionale di Astrofisica (INAF)); NAGATAKI, Shigehiro; OLMI, Barbara (Istituto Nazionale di Astrofisica (INAF)); ONO, Masaomi; ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF)); Prof. PERES, Giovanni (Istituto Nazionale di Astrofisica (INAF)); SAPIENZA, Vincenzo (Istituto Nazionale di Astrofisica (INAF)); VINK, Jacco

Presenter: GRECO, Emanuele (INAF)

Anisotropies in core-collapse supernova explosions: Modeling the evolution of a magnetorotational supernova remnant

"The core-collapse Supernovae (CCSNe) whose explosion is driven by magnetorotational instabilities (MRIs) are believed to be viable sources of extremely interesting astrophysical phenomena, such as hypernovae, super-luminous SNe, magnetars and gamma-ray bursts. Observations of the supernova remnants (SNRs) resulting from these objects pose as an important tool for their study. To this end, numerical simulations offer valuable insights. Here my goal is to investigate to which extent the SNR of an MR-SN retains memory of the explosion asymmetry, and to study the morphology of the stellar ejecta throughout the evolution. I performed a three-dimensional hydrodynamic simulation of a MR-SNR, by evolving a state-of-the art MR-SN model available in the literature. The simulation covers from a few hours after the shock breakout to ~ 10,000 yrs, with the adoption of an analytically prescribed circumstellar medium (CSM). The early outflow jet-like asymmetry, characteristic of MR-SNe, causes the formation of a Mach disk in the equatorial plane. This turns into a torus-like high pressure region and leads the SNR to a bicone morphology. The pristine bipolar jet-like structure shows an asymmetry in the ejection time. The simulation indicates that the remnant keeps memory of this asymmetry, presenting a narrower morphology in the direction of the first ejected jet. The forward shock presents an elongated morphology, with a polar-to-equatorial ratio of ~ 1.12 for the first ~ 200 yrs, decaying quite rapidly (down to 1 ~ .06) at ~ 500 yrs. The stellar ejecta exhibit a higher ratio of up to 1.20. The ejecta asymmetry increases when they extend to the forward shock through Rayleigh-Taylor instabilities, deforming the shock since ~ 200 yrs. A comparison between a proxy of the X-ray emission and an X-ray Chandra observation of Kes 73 (a SNR hosting a magnetar) indicates some similarities, though a more accurate treatment of the CSM could significantly improve the agreement with observations. This first glimpse into the evolution of anisotropies in SNRs originating from MR-SNe indicates that the SNR keeps memory of the anisotropies in the MR explosion on a time scale of centuries, rather than millenia."

Primary author: LA MALFA, Giorgio (Università degli Studi di Palermo/INAF)

Presenter: LA MALFA, Giorgio (Università degli Studi di Palermo/INAF)

The asymmetric explosion of SN 1987A

The nearby SN 1987A provides a unique observational probe of asymmetries in an exploding star. The ejecta are spatially resolved and expanding freely inside the ring of circumstellar matter, which means that the 3D emissivity can be reconstructed from spatially resolved spectroscopy. Such reconstructions have revealed a large-scale asymmetry in the form of a "broken dipole", as well as substructure on smaller scales. The observations also show significant mixing of different elements. In this talk I will give an overview of the asymmetries observed in SN 1987A, with particular focus on recent results from JWST. I will also discuss the connection with the asymmetric circumstellar medium and compare with results from other SN remnants.

Primary author: LARSSON, Josefin (KTH Royal Institute of Technology)

Presenter: LARSSON, Josefin (KTH Royal Institute of Technology)

Supernova remnants and pulsar wind nebulae at gamma-ray energies

"Over the past decade, gamma-ray observations of supernova remnants (SNRs) and pulsar wind nebulae (PWNe) 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 SNRs detected at gamma-ray energies has steadily increased, clearly demonstrating that shocks are capable of accelerating particles to multi-TeV energies. On their side, PWNe dominate the TeV sky and are among the most efficient accelerators detected so far in the Galaxy.
This presentation will review the main results obtained by the various gamma-ray instruments, highlighting sources detected by Fermi."

Presenter: LEMOINE-GOUMARD, Marianne (LP2i Bordeaux)

Presupernova evolution of massive stars

I will present an overview of the evolution of rotating and non rotating massive stars at various metallicities up to the onset of the iron collapse.

Primary author: LIMONGI, Marco (Istituto Nazionale di Astrofisica (INAF))

Co-authors: CHIEFFI, Alessandro; ROBERTI, Lorenzo (Konkoly Observatory, Research Centre for Astronomy and Earth Sciences)

Presenter: LIMONGI, Marco (Istituto Nazionale di Astrofisica (INAF))

Asphericity in Stripped-envelope SN explosions

"The properties of the SNe connected with Gamma Ray Bursts will be reviewed, in the context of the core-collapse phenomenon. Type Ic SNe are the result of the collapse of massive stars stripped of their outer H and He envelopes. SNe Ib only lost the outer H envelope. GRB/SNe are a special class of SNe Ic, and have in common a large explosion energy and a large luminosity.
They are probably the result of the collapse of very massive stars (Mzams ~ 40-50 Mo). The birth of a black hole is probably responsible for the GRB, although not every collapse event is expected to produce one.
However, the SN explosion kinetic energy estimated from modelling is so large that additional energy sources other than classical neutrino driving are almost certainly required.
While the explosion kinetic energy of SE SNe is highly variable, GRB/SNe have the larges values and show the strongest signs of asphericity, as derived from accurate spectral modelling. The clearest evidence is found in the late-time spectra of these SNe.
There is also evidence that the collapse of a star of Mzams ~ 20Mo to a neutron star can, under certain conditions (stripped envelope, high rotation) give rise to a SN with higher-than-normal kinetic energy accompanied by an XRF, the soft analogue of a GRB. Magnetic activity on the nascent neutron star is probably responsible for this type of event, which is apparently much less aspherical than the GRB/SNe, but it may also be responsible for the properties of GRB/SNe."

Primary author: MAZZALI, Paolo (Liverpool John Moores University)

Presenter: MAZZALI, Paolo (Liverpool John Moores University)

Magnetars and their supernova remnants

Magnetars are a small class of (isolated) neutron stars powered mainly by magnetic energy. They appear as persitent or transient pulsed X-ray sources, sometimes associated with supernova remnants and are characterized by activity periods in which they emit bursts and flares on a wide range of energies and timescales. I will briefly review the main properties of magnetars and discuss in particular the aspects more relevant for the topic of this conference. These include the formation and birthrates of magnetars, the evidences for asymmetric SN explosions in their remnants and in other properties, their relevance for other classes of astrophysical phenomena such as gamma-ray bursts, fast radio bursts, super luminous supernovae.

Primary author: Dr MEREGHETTI, Sandro (Istituto Nazionale di Astrofisica (INAF))

Presenter: Dr MEREGHETTI, Sandro (Istituto Nazionale di Astrofisica (INAF))

Systematic 3D MHD simulations of core-collapse supernova and implications for multi-messenger signals

Systematic studies of core-collapse supernovae have been conducted based on hundreds of one-dimensional artificial models (O'Connor & Ott 2011,2013; Ugliano et al. 2013, Ertl et al. 2015) and two-dimensional self-consistent simulations (Nakamura et al. 2015, 2019; Burrows & Vartanyan 2021). We have performed three-dimensional core-collapse simulations for 16 progenitor models covering ZAMS mass between 9 and 24 solar masses. We find that neutrino-driven explosions occur for all models within 300 ms after bounce. We also find that early shock evolution is sensitive to the mass accretion rate onto the central core, reflecting the density profile of the progenitor stars. The most powerful explosions with diagnostic explosion energy E_dia ~ 0.7 x 10^51 erg are obtained by the 23 and 24 solar-mass models, which have the highest compactness among the examined models. Our models show a wide variety of shock evolution and explosion energy, as well as multi-messenger signals including neutrinos and gravitational waves. We present the dependence of these explosion properties on the progenitor structure.

Ko Nakamura, Tomoya Takiwaki, Jin Matsumoto, and Kei Kotake

Primary author: NAKAMURA, Ko (Fukuoka University)

Co-authors: KOTAKE, Kei; MATSUMOTO, Jin; TAKIWAKI, Tomoya

Presenter: NAKAMURA, Ko (Fukuoka University)

Tracing Core-Collapse Supernova Echoes in Remnant Structures

The remnants of core-collapse supernovae (SNe) exhibit intricate morphologies and a highly non-uniform distribution of stellar debris. In the case of young remnants, their properties encode valuable insights into the inner processes of the SN engine, including nucleosynthetic yields and large-scale asymmetries originating from the early stages of the explosion. Additional characteristics of the remnants can reflect the nature of the progenitor stars and the interactions between the remnants and the circumstellar medium (CSM), resulting by the progenitor's mass-loss history. Therefore, interpreting observations of SN remnants is of paramount importance for gaining a deeper understanding of the physics behind core-collapse SNe and the progenitor stars. In this talk, I will explore a few illustrative examples to demonstrate how self-consistent models, which describe the evolution from the core-collapse to the formation of a full-fledged remnant, can serve as the key to deciphering observations and extracting insights into the anisotropies originatig from the core-collapse, the final phases of massive star evolution, and the elusive mechanisms governing their mass loss.

Primary author: ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF))

Presenter: ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF))

X-ray Microcalorimeter Observations of Supernova Remnants: A Window into Asymmetries in Supernovae and Their Progenitors

Asymmetries in supernovae remain imprinted upon the ejecta decades and centuries after the event. In this talk I will discuss how X-ray micro calorimeters with eV resolution can be used to probe asymmetries, and employed to reconstruct the energetics of the explosion. I will discuss the notional NASA APEX probe mission LEM, and present how LEM will probe the physics of the supernova engine.

Dan Patnaude (on behalf of the LEM team)

Primary author: PATNAUDE, Daniel (Center for Astrophysics | Harvard & Smithsonian)

Presenter: PATNAUDE, Daniel (Center for Astrophysics | Harvard & Smithsonian)

Toward understanding the radio history of SN1987A

The famous remnant of supernova SN1987A is regularly monitored in different bands. We report the massive 3D simulations which result in a numerical model of the radio evolution of SN1987A. Namely, the model recovers the radio light curve, the sequence of the radio images spanning a few decades in time and the polarization map at the age of 30 years after the explosion. In particular, we restore development of the East-West asymmetry in the polarized and unpolarized images and the distribution of the polarization vectors over the surface of SN1987A observed by the Australia Telescope Compact Array. In the talk, we demonstrate the sensitivity of the model to different parameters and shed light on the history of interaction of the forward shock with complex structures of density and magnetic field around the supernova progenitor.

Primary author: PETRUK, Oleh (Istituto Nazionale di Astrofisica (INAF))

Co-authors: BESHLEY, V.; BOCCHINO, Fabrizio (Istituto Nazionale di Astrofisica (INAF)); MICELI, Marco (Istituto Nazionale di Astrofisica (INAF)); ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF))

Presenter: PETRUK, Oleh (Istituto Nazionale di Astrofisica (INAF))

A diagnostic to trace shocked ejecta in SN 1987A using XRISM - Resolve

"Supernova 1987A is one the best candidates to exploit the capabilities of the upcoming XRISM satellite, offering the unique opportunity to observe the rapid evolution of the non-equilibrium ionization (NEI) plasma in a very early stage supernova remnant (SNR).
Recent studies provide compelling evidence that in the forthcoming years, the X-ray emission from SN 1987A will increasingly stem from the ejecta.
Our aim is to assess the proficiency of the XRISM - Resolve high resolution spectrometer in pin-pointing signatures of the shocked ejecta in SN 1987A.
Taking advantage of a self consistent state-of-art simulation, we synthesized XRISM - Resolve spectrum, simulating the allocated observation during the performance verification (PV) phase, expected to occur in 2024.
Our forecast suggests that the bulk motion Doppler broadening from the fast moving ejecta will dominate over the thermal broadening in all the visible ion emission lines.
Therefore, we can strongly link the broadened line emission to the freshly shocked ejecta, using it as a diagnostic tool to retrieve the ejecta dynamics from the X-ray emission."

Primary author: SAPIENZA, Vincenzo (Istituto Nazionale di Astrofisica (INAF))

Co-authors: BOCCHINO, Fabrizio (Istituto Nazionale di Astrofisica (INAF)); BOMBA, Aya; GIUFFRIDA, Roberta (Istituto Nazionale di Astrofisica (INAF)); KATSUDA, Satoru; LEE, Shiu-Hang; MICELI, Marco (Istituto Nazionale di Astrofisica (INAF)); NAGATAKI, Shigehiro; ONO, Masaomi; ORLANDO, Salvatore (Istituto Nazionale di Astrofisica (INAF)); Prof. PERES, Giovanni (Istituto Nazionale di Astrofisica (INAF)); TERADA, Yukikatsu

Presenter: SAPIENZA, Vincenzo (Istituto Nazionale di Astrofisica (INAF))

Prospects for the candidate PeVatron SNR G106.3+2.7 with the ASTRI Mini-Array

"The SNR G106.3+2.7, along with its associated molecular cloud complex, is a candidate TeV counterpart of LHAASO J2226+6057, one of the 12 LHAASO Galactic Pevatrons. Another contender is the Boomerang PWN, linked to PSR J2229+6114. Multiple gamma-ray facilities have detected this VHE region with an elongated morphology: the SNR is in the ""tail"" of the VHE emission, and the PWN is at the ""head."" Pinpointing the emission's exact location at > ~100 TeV is crucial for distinguishing between the hadronic or leptonic origin of the gamma-ray emission, which, in turn, constrains the acceleration mechanism.

The MAGIC telescopes recently resolved this TeV region for the first time, revealing that E>10 TeV emission originates solely from the tail region, where SNR G106.3+2.7 is situated. However, further precise measurements are needed to validate these findings.

In this context, the ASTRI Mini-Array can play a vital role. With its exceptional sensitivity and high angular resolution in the multi-TeV range, this facility will contribute significantly to understanding the nature of TeV emissions and their potential relation to cosmic ray origins.

Leveraging the latest results from the MAGIC collaboration, our work aims to investigate the ASTRI-MiniArray's potential in studying this source's complex morphology and showcasing the improvements attainable through deep observations, highlighting its key role in advancing our comprehension of this phenomenon."

A. Tutone, M. Cardillo, A. D'Aì, E. Amato, G. Morlino, B. Olmi for the ASTRI Project

Primary author: Dr TUTONE, Antonio (Istituto Nazionale di Astrofisica (INAF))

Co-authors: AMATO, Elena (Istituto Nazionale di Astrofisica (INAF)); Dr CARDILLO, Martina (INAF- IAPS); Dr D'AI', Antonino (Istituto Nazionale di Astrofisica (INAF)); MORLINO, Giovanni; OLMI, Barbara (Istituto Nazionale di Astrofisica (INAF))

Presenter: Dr TUTONE, Antonio (Istituto Nazionale di Astrofisica (INAF))

Modelling Supernova Nebular lines in 3D NLTE

It is well established that supernovae are asymmetric by nature, and that the morphology is encoded in the line profiles during the nebular phase, months after the explosion. Here I will present the newest results of ExTraSS (EXplosive TRAnsient Spectral Simulator), which takes multi-dimensional explosion simulations as input to evolve to the nebular phase. The code calculates the energy deposition from the radioactive decay of 56Ni->56Co -> 56Fe and uses this to determine the Non-Local Thermodynamic Equilibrium temperature, excitation and ionization structure across the nebula. From the physical condition solutions emissivities can be generated to construct spectra, which depend on viewing angles. The results display large variations in the line profiles with the viewing angles, based on the shifts, widths and skewness moments. I will show the first results of nine different models, spanning a range of initial He-core masses and explosion energies and compare between these.

Primary author: VAN BAAL, Bart (Stockholm University)

Co-authors: JANKA, Thomas; JERKSTRAND, Anders; WONGWATHANARAT, Annop

Presenter: VAN BAAL, Bart (Stockholm University)

Resolving core-collapse supernova with quantum optics

We are building the QUASAR (QUantum Astrophysics for Super Angular Resolution) detector to reach resolutions of micro-arcecond in the optical. Although its primary aim is to image accretion disks, the surface of core-collapse supernova could be resolved up to distances of 100 kpc. I will introduce the detection principles, the detector development, schedule and performance and hope to get back from the workshop with constrains and models as input for simulations.

R. Walter et al.

Primary author: WALTER, Roland (Department of Astronomy, University of Geneva)

Presenter: WALTER, Roland (Department of Astronomy, University of Geneva)

First Study of the SNR Population in the LMC with eROSITA

The study of the entire population of SNRs in a galaxy helps us to understand the underlying stellar populations, the environments in which the SNRs are evolving, and the stellar feedback on the ISM. The eROSITA telescopes are the best instruments currently available for such a study due to their large field of view and high sensitivity in the softer part of the X-ray band. We performed a multi-wavelength analysis of previously known SNR candidates and newly detected SNRs and SNR candidates. We applied the Gaussian Gradient Magnitude (GGM) filter to the eROSITA images of the LMC to highlight the edges of the shocked gas in order to find new SNRs. Furthermore, we compared the X-ray images with their optical and radio counterparts to investigate the true nature of the diffuse emission. We used the Magellanic Cloud Emission Line Survey (MCELS) for the optical data. For the radio comparison, we used data from the Australian Square Kilometre Array Pathfinder (ASKAP) survey of the LMC. Using the VISTA survey of the Magellanic Clouds (VMC) we have investigated the possible progenitors of the new SNRs and SNR candidates in our sample. We present the most updated catalogue of SNRs in the LMC. The eROSITA data allowed us to confirm two of the previous SNR candidates with a 3σ significance. We discovered 15 new extended sources. We can confirm 3 of them as new SNRs with a 3σ significance, while we propose the remaining 12 as new X-ray SNR candidates. We present comparisons between the results of the spectral analysis of eROSITA and XMM-Newton data. We also present the first analysis of the follow-up XMM-Newton observation of the eROSITA discovered SNR J0456–6533. Among the new candidates, we propose J0614–7251 as the first SNR candidate in the Magellanic Bridge.

Federico Zangrandi, Katharina Jurk, Manami Sasaki, Dominic Bernreuther, Jonathan Knies, Miroslav Filipovi´c, Frank Haberl, Patrick Kavanagh, Bärbel Koribalski, Chandreyee Maitra, Pierre Maggi, Sean Points, and Lister Staveley-Smith

Primary author: ZANGRANDI, Federico (Dr. K. Remeis Observatory (FAU))

Presenter: ZANGRANDI, Federico (Dr. K. Remeis Observatory (FAU))