Cefalù, 27-30 Settembre 2022

ABSTRACTS

Martedì 27 Settembre

Julien Malzac
Models for black hole X-ray binaries

I will present some recently developed models for the spectra and variability of accretion flows and jets of black holes accreting in X-ray binary systems.

Francesco Carotenuto
Decelerating jets from black hole X-ray binaries

Black hole X-ray binaries (BH XRBs) can launch powerful outflows in the form of radio-emitting discrete ejecta. Observing the entire trajectory of these ejecta allows us to model their motion with great accuracy and this is essential for measuring their physical properties. In particular, observing the final deceleration phase, often poorly sampled, is fundamental to obtain a reliable estimate of the jet's energy. In this context, I will present results on the modeling of the motion of relativistic ejecta from two BH XRBs: MAXI J1348-630 and MAXI J1820+070, which launched some of the most spectacular jets observed in the recent years.
During its 2019/2020 outburst, MAXI J1348-630 produced a single-sided jet that we monitored with the MeerKAT and ATCA radio-interferometers, and that we detected at large scales as it decelerated due to its interaction with the ISM. We successfully modelled the jet motion with a full dynamical model based on external shocks, which allowed us to constrain the jet initial Lorentz factor, inclination angle, mass and ejection date, as well as inferring the presence of an ISM cavity in which the system is embedded. Thanks to the dense coverage of the jet deceleration phase, we find that the jet was launched with an initial kinetic energy that is far greater than what commonly inferred for these objects from their synchrotron emission. Using the same dynamical model, I will also show preliminary results for the bipolar jets of MAXI J1820+070, for which we placed constraints on the same physical parameters as MAXI J1348-630, with the difference that MAXI J1820+070 is not believed to live in a low-density ISM cavity.

Elise Egron
Composition of the jet in the microquasar Cygnus X-1

We calculated the electron-positron pair production rate at the base of the jet of Cyg X-1 by collisions of photons from its hot accretion flow using the measurement of its average soft gamma-ray spectra by the Compton Gamma Ray Observatory and INTEGRAL satellites. We found that this rate approximately equals the flow rate of the leptons emitting the observed synchrotron radio-to-IR spectrum of the jet core, calculated using an extended jet model following that of Blandford & Konigl. This coincidence shows the jet composition is likely to be pair-dominated. The same coincidences were found before in the microquasar MAXI J1820+070 and in the radio galaxy 3C 120, which shows that the considered mechanism can be universal for at least some classes of relativistic jets.

Eleonora Veronica Lai

The stellar wind in Cygnus X-1: an X-ray spectral-timing view

High mass X-ray binaries accrete via the stellar wind of their supermassive companion. The stellar wind does not appear as a smooth flow, but it shows strongly dense and highly perturbed regions or clumps. As these clumps cross our line of sight, part of the X-ray emission is absorbed, leading to dipping events in the light curves.

We performed an analysis of the long XMM Newton monitoring of the black hole binary Cyg X-1/HDE 226868 during its hard state. This monitoring is part of the CHOCBOX (Cyg X-1 Hard state Observations of a Complete Binary Orbit in X-rays) campaign.

In this talk, I will present the latest results on the effects of the stellar wind on the spectral-timing properties of Cyg X-1 for more than one and a half orbital periods. In particular, I will focus on the changes in the intrinsic variability, in the intrinsic coherence and in the time lags due to the presence of the stellar wind.

Maxime Parra

The current state of disk wind observations in galactic Black Hole LMXBs through X-ray absorption lines

The first detection of X-ray wind signatures (mainly FeXXV/XXVI absorption lines between 6 and 8keV) in Black Hole Low Mass X-ray Binaries (BHLMXBs) took place more than 20 years ago. In the last decade, it has become apparent that these winds are only detected in strongly inclined objects, hinting at them originating from the disk, although there is still no unequivocal evidence for an MHD or Thermal origin. On the other hand, most detection occur during the soft spectral state (see e.g. Ponti et al. 2012), for reasons yet to be understood. We present an update of the current state of wind detection in BHLMXBs, through the analysis of all available XMM-EPIC and Chandra-HETG data of all LMXBs currently classified as BH/BH candidates, from the BlackCAT (Corral-Santana et al. 2016) and WATCHDOG (Tetarenko et al. 2015) catalogs. We will discuss the number of sources with statistically significant detection in the 6.-8. keV band, the associated EWs, blueshifts and line ratios, and the consequences on the inclination/spectral state dichotomy.

Guglielmo Mastroserio

Modelling X-ray time lags in stellar mass black holes

Spectral-timing analysis is a very effective technique to analyse stellar mass black holes and to constrain the characteristic parameters of these systems. I will present some of the recent results obtained combining spectral and timing analysis on stellar mass black holes. I will focus on the time lags as a function of energy that are observed in these sources with RXTE and NICER, and I will present how the recently developed RELTRANS model is able to fit these time lags self-consistently in a wide range of timescales. I will show how considering electron densities in the accretion disc up to 10^{20} cm^{-3} increases the amplitude of the X-ray reverberation lags in the model. Moreover, now RELTRANS takes into account the effects that time variations of the disc ionisation have on the reverberation lags, which are more relevant when the density in the disc is higher. Finally, I will demonstrate how X-ray reverberation lags can be used to constrain the mass of the accreting black holes and how crucial it is to include these new features when fitting the data.

Alberto Ulgiati

Timing analysis of Black Hole Transient Swift J1753.5-0127

Black Hole Transients (BHTs) are X-ray binaries in which a stellar-mass black hole accretes matter from a low-mass companion star. They alternate long periods of quiescence with short period of activity, called outbursts, in which intense and highly variable emission is observed over the entire electromagnetic spectrum, coming from a number of (inflowing and outflowing) components. Studying the correlation at high time resolution between emission at different wavelengths allows us to probe the fascinating regions in the immediate vicinity of the compact object, that are still relatively poorly understood.
I will present the results from timing analysis of two epochs of simultaneous infrared and X-ray fast-photometry observations of the BHT Swift J1753.5-0127. These are the first high time resolution observations of this source in the infrared band. The two epochs show a markedly different behaviour, with features in the cross-correlation function that had never observed before in other BHTs, confirming the ""odd-ball"" nature of this source. I will discuss these results in the context of the main interpretative scenarios.

Piergiorgio Casella

Constraining Jet Properties in the Black-Hole Transient MAXI J1820+070 through Fast Multi-Wavelength Variability

The study of fast multi-wavelength variable emission from X-ray binaries, in the last years, has opened a new window on the physics and the geometry of accretion and ejection in stellar-mass compact objects. By observing the variable flux over a wide range of wavelengths and timescales, we can constrain properties - like the geometry, scale, and speed of the jet - that would be otherwise difficult - and sometimes impossible - to measure. In this talk, I will present results from a large fast-timing multi-wavelength campaign on the black-hole transient MAXI J1820+070. The data, acquired over ten different wavebands - from radio to X-rays, allowed us to derive fundamental jet properties, by linking the variability properties in the different bands to the internal jet physics.

Alessio Marino

Accretion and ejection in Neutron Star Low Mass X-ray Binaries

Neutron Stars Low Mass X-ray binaries (NS LMXBs) are old and relatively compact binary systems composed of a low-magnetised neutron star and a solar or sub-solar companion star. These objects can display bright X-ray activity, as a result of the accretion of matter transferred by the Roche lobe-filling donor star. Many NS LMXBs are transients and spend most of their time in a low-luminosity state (quiescence) with no or little accretion ongoing, to then undergo sporadic and bright outbursts, sometimes peaking at the Eddington limit. When in outburst, short thermonuclear explosions, called type-I X-ray bursts, are often observed and are a signature of the NS nature of the accretion. The spectral and timing properties of these objects in outburst are also rapidly variable and a proper investigation of them allow us to scrutinise the geometry and the physical properties of the accretion flow around the compact object. Outflows in the forms of jets (bright in the radio band) and winds are also observed and their phenomenology is deeply intertwined with the accretion flow. However, the exact mechanisms underlying such an inflow-outflow coupling are still unclear. In this talk, I will provide an observational review of NS LMXBs, focusing on their classification, the properties of their multi-wavelength emission, the physical interpretation of the data and the future prospects to unsolve the many open questions regarding these systems.

Federico Vincentelli

A shared disk-jet accretion instability for black holes and neutron stars

Swift J1858.6-0814 is a transient neutron star low mass X-ray binary which between 2018 and 2020 underwent an outburst showing remarkably strong flaring on very short timescale across the almost all the electromagnetic spectrum. Here we present the analysis of an unprecedented dataset that included strictly simultaneous, high time resolution data in X-ray, UV, optical, IR, and radio conducted in August 2019. By modeling the measured X-ray to IR delays together with the radio variability, we found that the complex multiwavelength variability of Swift J1858 is quantitatively explained with accretion disk instabilities and discrete jet ejecta in the same way as it is done for the archetypal highly accreting black hole GRS 1915+105. Moreover we have found that the patterns observed in this neutron star are also common to other high accretion rate sources such as V404 Cyg or V4641 Sgr. This new association, therefore, allows us to identify the main physical components responsible for the fast multiwavelength variability of highly accreting compact objects, and unlocks the possibility of measuring the physical parameters of disks and jets in these sources.

Teo Munoz-Darias

Accretion disc winds from low-mass X-ray binaries

X-ray observations performed during the last few decades have provided a rich data base on low-mass X-ray binaries. A strong coupling between the properties of the accretion flow and the presence of outflows, such as radio-jets and hot X-ray winds, has been found to be a fundamental characteristic of their luminous outbursts. This picture has become even richer thanks to the discovery of powerful, cold (optical/near-infrared) accretion disc winds in several black hole and neutron star transients over the last few years.

I will briefly review the state-of-the-art of the field to then present high-quality optical/infrared spectroscopic observations of several X-ray binary transients. I will show that cold winds with terminal velocities of up to ~1 per cent the speed of light are a common feature in these objects. I will discuss the impact of these winds on the black hole accretion process, as well as their apparently close relation with the hotter outflows observed in X-rays, which suggest that accretion disc winds in X-ray binaries are multi-phase in nature.

Alessio Anitra

A thick forest of emission lines in the soft x-ray spectrum of LMXB Scorpius X-1

With an estimated luminosity between 0.9 L_{Edd} and 2.4 L_{Edd}, Scorpius X-1 is the brightest persistent LMXBs, hosting an NS, in the sky and it is considered the prototype of Z-sources.

Despite the number of studies carried out on this source, because of its extremely high luminosity, it was never observed in the soft X-ray range, with high-spectral resolution. In this work, we performed a spectral analysis of the system using the high-statistic data collected by Neutron Star Interior Composition Explorer (NICER) during three observations between 3-4 August 2020, with the aim to study the spectral features of the source in the soft X-ray range, focusing on the analysis of the emission lines and their evolution along the Z-track.

The models used to fit the continuum spectrum include a thermal, blackbody-like component, possibly emitted by the accretion disc, at a stable temperature (~ 0.42 keV) and a saturated Comptonisation model with an electron temperature of 2.1 keV, emitted by an optical thick Corona localized in the inner region of the system.

On top of the continuum, we observed a thick forest of emission lines. We detected ten emission lines in the spectrum that can be associated with emissions from C V, C VI, O VII, Ne X, Mg XII,

Al XIII, Si XIV, S XV, Ar XVIII, Ca XIX ions. Furthermore, we identified one line related to the Kα transition of the He-like Fe XXV at 6.6 keV and well-fitted by the diskline profile.
All the other lines were fitted with a Gaussian model, and since the lines do not show evidence of Doppler shifts, we propose they are emitted from an outer region of the disc. However, the ones related to S XV and Ar XVIII emission show a peculiar broad profile that can indicate an emission region closer to the compact object, or a blending of lines related to the He-like and H-like ions of the same element.
Further investigations are needed to clearly determine the nature and origin of each of these emission features.

Viviana Piga

A census of mathematical models of Quasi Periodic Oscillations

X-ray binaries are systems consisting of two stars: a compact object, namely a neutron star (NS) or a black hole (BH), and an extended companion star. The compact object, because of its strong gravitational field, subtracts mass from the other star (called “donor”). The mass lost by the companion star spirals around the compact object, forming the so-called accretion disk. The disk reaches extremely high temperatures, of the order of millions of degrees, and therefore emits radiation predominantly in the X-ray part of the electromagnetic spectrum.
By studying the luminosity as a function of time (the so called light curve) of such systems in the Fourier domain, it is possible to observe a peculiar phenomenon called Quasi Periodic Oscillations (QPOs). Over the decades, several models have been proposed to explain the observed QPOs: among these, are, for example, the Relativistic Precession Model (RPM), the Parametric Epicyclic Resonance and Precessing inner flow models and related extensions. In this work, I will review the most popular QPOs models, with a particular emphasis on their mathematical framework. In reviewing them, I will highlight their strengths and weaknesses, and propose possible modifications or extensions with the aim to improve their predictive capabilities.

Vittorio De Falco

Exploring metric departures from Schwarzschild black hole geometry

In this talk, I show how the combination of different astrophysical methods are able to detect deviations from General Relativity. For this analysis I select a particular class of static and spherically symmetric metrics within the f(R) gravity theory, encompassing small departures from the Schwarzschild metric. Specifically, when gravity is the only dominating interaction, we exploit the ray-tracing technique to reconstruct the image of a black hole, the epicyclic frequencies, and the black hole shadow profile. Moreover, when matter dynamics is also affected by an electromagnetic radiation force, we employ the relativistic Poynting-Robertson effect.

Filippo Ambrosino

Millisecond pulsars in the ultra-fast optical domain

Millisecond pulsars (MSPs) are old, low-magnetized, and very fast rotating neutron stars. They reach fast rotation periods as a result of Gyr-long phases during which they accrete matter and angular momentum from a companion star. After this phase during which the binary system shines as a bright low mass X-ray binary (NS-LMXB) powered by the accretion, the mass transfer rate stops and a radio (and/or gamma-ray) MSP powered by the rotation of its magnetic field is active. The ultimate proof of this evolutionary scenario is the discovery of transitional millisecond pulsars (tMSPs), systems swinging between accretion disk (LMXB) and rotation-powered (radio MSP) states on timescales down to a few weeks. Eclipsing MSPs are a sub-class of binary MSPs powered by the rotation of their magnetic dipole in which the pulsar hosts a low-mass companion star in a very tight orbit. Depending on the mass of the companion star, these pulsars are divided into two further sub populations, dubbed black widows (BWs) and redbacks (RBs).Starting from the review on MSPs from the observational point of view, I will also describe the state of the art in the research of their optical counterparts in the high time resolution domain. In particular, I will focus on the main results already obtained with the fast photometer SiFAP2 mounted at 3.6 m TNG and analyses still ongoing on the latest data acquired with such an instrument.

Alessandro Papitto

Spying on the quickly variable optical sky: millisecond pulsars and more

The development of detectors with a high time resolution has played a crucial role in measuring the properties of neutron stars. Whereas high-time resolution astronomy has become a standard in the radio wavelengths and the high- and very-high-energy bands, the progress in the visible band has been much slower. SiFAP2 is an efficient and versatile high-speed optical photometer currently operated at the 3.6 m INAF Telescopio Nazionale Galileo (TNG). It has discovered the first optical millisecond pulsar in a transitional binary system, and more recently it has also unveiled coherent optical pulsations from an accreting millisecond pulsar. These findings are hard to fit in the standard paradigm of pulsars and demand new unconventional solutions. Attempts to exploit SiFAP2 to detect impulsive and
aperiodic variability from bright accreting neutron stars, magnetars and fast radio bursts are also currently ongoing. I will review the main results obtained so far and highlight the discovery potential ensured by the much higher sensitivity granted by the throughput of optical telescopes compared to higher energies.

Arianna Miraval Zanon

UV/optical pulsed emission from accretion and rotation-powered millisecond pulsars

Millisecond pulsars are the fastest spinning compact stars and often found in close binary systems. During their evolution, they appear as radio pulsars powered by the rotation of the neutron star magnetic field or as X-ray pulsars powered by the accretion of mass transferred by a companion star. I will present the recent detection of UV and optical pulsations with HST/STIS and TNG/SiFAP2 from the accreting millisecond pulsar SAX J1808.4-3658, during the 2019 outburst. This discovery demonstrates that the acceleration of charged particles up to extremely high speeds can take place in the magnetosphere of a neutron star even when it is engulfed with the accreting matter. To explain how this is possible, I will discuss promising models for the emission of optical/UV/X-ray pulsations, highlighting the most recent progress in this field and the questions that still remain unanswered. I will also present new observations and results for the search of optical/UV pulsations in binary millisecond pulsars during thermonuclear bursts and when they don't show the presence of an accretion disk.

M. Cristina Baglio

Highs and lows of a transitional millisecond pulsar - the ultimate campaign on PSR J1023+0038

Transitional pulsars are an emerging class of sources linking X-ray binaries to millisecond radio pulsars. In the long term (decades), transitional pulsars alternate between a radio pulsar state and an active low-luminosity X-ray state. When active, transitional pulsars show two distinct emission modes (low and high), during which the X-ray flux remains constant, interleaved by random flares. The low-high mode episodes alternate rapidly and incessantly on a time scale ranging from minutes to hours, with rectangular-shaped drops and rises (at least in X-rays), occurring on a time scale of about 10s, and with a luminosity variation of a factor of ~7. X-ray to optical pulsations are only observed in the high mode. We present the results of the most extensive multi-wavelength observational campaign ever performed on the prototype of the transitional millisecond pulsars class, PSR J1023+0038.
The campaign involved strictly simultaneous observations performed with XMM-Newton, Nustar, HST, NTT/SOFI (Night1) and NICER, Swift, REM, VLT/FORS2, ALMA (Night2). In addition, non-strictly simultaneous data with FAST and GTC were also acquired.
The root reason for this puzzling behaviour has remained elusive until now. Taking advantage of our massive campaign, we show that the high-to-low mode transition is due to the evolution of the innermost accretion disc region that drives emission of discrete ejecta on top of a compact jet, and that the low-to-high mode transition is due to the re-enshrouding of the pulsar.

Giulia Illiano

Time lags between optical and X-ray pulsations of the transitional millisecond pulsar PSR J1023+0038

PSR J1023+0038 has been the first millisecond pulsar to be detected as an optical pulsar and, so far, is the only transitional millisecond pulsar that has shown a detectable pulsed emission in the optical and UV bands. Through a study of the phase lag between optical and X-ray pulsations, I will show how their emission mechanisms appear intimately connected. Analyzing simultaneous observations performed over about six years with XMM-Newton, NICER, and the fast optical photometers SiFAP2 and Aqueye+, I will test the proposed model which identifies the origin of optical and X-ray pulses in synchrotron emission from the intra-binary shock between the pulsar relativistic wind and the accretion disk, just beyond the light cylinder radius (~100 km from the pulsar). The measurements of the time lag of the optical pulsation relative to that in the X-rays obtained for the different simultaneous observations will be reviewed and discussed, highlighting their consistency with the expectations of the model.

Andrea Sanna

From the HERMES fleet to the flight of the ALBATROS: surfing the waves of quantum space-time

ALBATROS (Astonishingly Long Baseline Array Transients Reconnaissance Observatory in Space) is an ambitious astro- physical mission concept that uses a fleet of three small satellites to create an high-energy all-sky monitor with excellent localisation capabilities. The proposed orbits for the spacecrafts are three independent Earth-trailing heliocentric orbits, that will form a nearly equilateral triangular formation with 2.5e6 km arm length: the so-called cart-wheel formation. Each satellite is equipped with two opposite facing ~500 cm2 effective area detectors each consisting of a segmented array of crystal scintillators (GAGG) with a half-sky Field of View, keV-MeV energy band, and temporal resolution better than one microsecond. Thanks to the million km baselines, temporal triangulation techniques allow unprecedented location accuracies, few arc-second/few arc-minutes, for bright/faint transients in a wide energy band, few keV-few MeV crucial for hunting the elusive electromagnetic counterparts of Gravitational Waves, that will play a paramount role in the future of Multi-messenger Astronomy. This project is an example of high-energy distributed astronomy: a new concept of modular observatory consisting of a fleet of small satellites displaced over a large array, with sub-microsecond time resolution and wide energy band (keV-MeV). A pathfinder of ALBATROS is already under development through the HERMES (High Energy Rapid Modular Ensemble of Satellites) and SpIRIT (Space Industry Responsive Intelligent Thermal Nanosatellite) projects: a fleet of six 3U cube-sats (HERMES) to be launched by the end of 2023 plus one 12U cube-sat (SpIRIT) to be launched by the end of 2022.

ALBATROS will furnish the golden sample of GRBs needed to test the dispersion law theorised by some Quantum Gravity theories, which predict relative discrepancies of the speed of photons w.r.t. the speed of light proportional to the ratio of the photon energy to the Planck energy. This effect is extremely small, and GRBs occurring at cosmological distances represent the ideal target to explore it. We describe a compelling approach to this problem that statistically combines a large number of GRBs for which light-curves of the prompt emission over a wide energy band (keV-MeV) are available, and distances are known. We discuss how a golden sample of ~1000 GRBs with known redshift is sufficient to effectively constrain this dispersion law.

Maria Grazia Bernardini

Time-domain Astronomy with SVOM

SVOM (Space-based multiband astronomical Variable Objects Monitor) is a sino-french mission that is dedicated to Gamma-Ray Burst (GRB) science, expected to be launched in 2023. The mission includes four space-based and three ground-based instruments that, working together, will discover transients in general, and GRB in particular, providing also rapid multi-wavelength follow-up to obtain a complete coverage of their emission over seven decades in energy, from their discovery up to hours/days timescales. Apart from GRB science, SVOM will be also valuable in the study of many extra-galactic sources as Active Galactic Nuclei (AGN), Ultra-Luminous X-ray sources (ULX) and Tidal Disruption Events (TDE), galactic sources as accreting systems, pulsars, magnetars and flaring stars, and in the search for counterparts of gravitational wave or neutrino emitters. Thanks to its characteristics, SVOM will play a crucial role in time-domain and multi-messenger Astronomy.

Massimo Cappi

CTAO and CTA+ new opportunities for the CNOC community

I will review the new opportunities offered to the “CNOC community” which are foreseen after the Italian increased participation in CTAO and the project enhancement allowed by the CTA+ PNRR Program. In particular, this shall translate into a great opportunity for an (immediate) stronger Italian participation in the LST collaboration, and with direct/obvious new opportunities for the Italian participation in the transient/multi-messenger science at TeV energies

Sergio Campana

SOXS@NTT: the transient hunter

The SOXS (Son Of X-Shooter) is a single object, wide-band (350-2000 nm) spectrograph, built by an international consortium for the 3.6-m ESO New Technology Telescope at the La Silla Observatory. The consortium is focused on a clear scientific goal: the spectrograph will observe all kinds of transient and variable sources discovered by different surveys with a highly flexible schedule, updated daily, based on the Target of Opportunity concept. It will provide a key spectroscopic partner to any kind of imaging survey, becoming one of the premier transient follow-up instruments in the Southern hemisphere. SOXS will study a mixture of transients encompassing all distance scales and branches of astronomy, with fast reaction capabilities.

Angelo Adamo

Il parossismo dell'informazione sui buchi neri

In questo intervento mi propongo di passare rapidamente in rassegna alcune delle modalità più (ab)usate tra i divulgatori nel raccontare oggetti così esotici come i buchi neri per poi gettare uno sguardo su altri approcci ai quali anche io mi dedico (fumetto, cinema, teatro, …) e che, ancora poco gettonati, ma sempre più presenti, vanno facendosi strada nel moderno panorama divulgativo.

Mercoledì 28 Settembre

Lorenzo Ducci

High-mass X-ray binaries with neutron stars

High-mass X-ray binaries (HMXBs) are among the brightest X-ray sources in our Galaxy and its neighborhood. Their X-ray luminosity is powered by the dense outflows from a massive OB type star accreted onto a compact object which is, in most of cases, a strongly magnetized neutron star (NS). Since the birth of X-ray astronomy, HMXBs with NS have been the subject of numerous studies because they are good laboratories to study physical processes involving plasma and radiation in environments with strong gravity and magnetic fields. Furthermore, the NS in HMXBs is often used as "probe" to investigate the properties of the outflow emitted by the companion star. I will give an overview of the current state of knowledge on these systems, derived from observations and modeling of the accretion mechanisms and other physical processes responsible for the X-ray emission.

Marzia Campanelli

Reliability study of the CATS@BAR live project: follow-up observations of a sample of new X-ray pulsators

The detection of periodic signals from serendipitous sources in the X-ray flux of archival datasets is still one of the most powerful ways to identify new compact objects. Within the framework of Chandra ACIS Time Survey CATS@BAR live project (aimed at searching for new pulsators in a systematic and automatized fashion) I selected seven new pulsators with different fluxes, periods and signal statistical confidences and which have been subject of follow-up observations with the aims of validating the goodness of the search methodology (statistical fluctuation versus spurious signals versus intrinsic source signal) and at discerning

the origin of the signal itself (spin period versus orbital modulation). I report on the XMM-Newton EPIC (0.1-12keV) and Chandra ACIS (0.2–8 keV) timing and spectroscopic analysis of the above sample of pulsators. In all cases the found signals have been confirmed to be intrinsic to the source and, whenever possible, the period accuracy was improved.
In some cases, putting together both the timing and spectroscopic results (and optical data in one case) I was also able to unambiguously assess the origin of the signal/compact object. These results are put in a more general context of the known X-ray pulsators and the accretion model(s).

Elena Ambrosi

Disk precession to explain the super-orbital modulation of LMC X-4: results from the Swift monitoring campaign

We studied the spectral changes of the high-mass X-ray binary system LMC X-4 to understand the origin and mechanisms beyond its super-orbital modulation (30.4 days). To this aim, we obtained a monitoring campaign with Swift/XRT (0.3-10 keV) and complemented these data with the years-long Swift/BAT survey data (15-60 keV).We found a self-consistent, physically motivated, description of the broadband X-ray spectrum using a Swift/XRT and a NuSTAR observation at the epoch of maximum flux. We decomposed the spectrum into the sum of a bulk+thermal Comptonization, a disk-reflection component and a soft contribution from a standard Shakura-Sunyaev accretion disk. We applied this model to 20 phase-selected Swift spectra along the super-orbital period. We found a phase-dependent flux ratio of the different components, whereas the absorption column does not significantly vary. The disk emission is decoupled with respect to the hard flux. We interpret this as a geometrical effect in which the inner parts of the disk are tilted with respect to the obscuring outer regions.

Nicola La Palombara

A deep XMM-Newton observation of the X-Persei-like binary system CXOU J225355.1+624336

We report on the follow-up XMM-Newton observation of the persistent X-ray pulsar CXOU J225355.1+624336, discovered with the CATS@BAR project on archival Chandra data. The source was detected at fX(0.5-10 keV) = 3.4×10^(-12) erg/cm/2/s, a flux level which is fully consistent with the previous observations performed with ROSAT, Swift, and Chandra. The measured pulse period P = 46.753(3) s, compared with the previous measurements, implies a constant spin down at an average rate dP/dt =5.3×10^(-10) s/s. The pulse profile is energy dependent, showing three peaks at low energy and a less structured profile above about 3.5 keV. The pulsed fraction slightly increases with energy. We described the time-averaged EPIC spectrum with four different emission models: a partially covered power law, a cut-off power law, and a power law with an additional thermal component (either a black body or a collisionally ionized gas). The phase-resolved spectral analysis showed that a simple flux variation cannot explain the source variability and proved that it is characterized by a spectral variability along the pulse phase. The results of the XMM-Newton observation confirmed that CXOU J225355.1+624336 is a BeXB with a low-luminosity (LX~10^(34−35) erg/s), a limited variability, and a constant spin down. These results, compared with those previously obtained on other low-luminosity BeXBs, reinforce the source classification as a persistent BeXB.

Lara Sidoli

Sitting on the lowest X-ray luminosity state in a Supergiant Fast X-ray Transient

Supergiant Fast X-ray Transients (SFXTs) are the most variable X-ray emitters among high mass X-ray binaries with blue supergiant donors. A recent XMM-Newton observation has caught the SFXT IGR J08408-4503 in an extremely faint state. Thanks to the very low absorption towards the source, the X-ray spectrum could be deconvolved to three spectral components: two collisionally ionized plasma (with temperatures of 0.24 keV and 0.76 keV), together with a steep power-law model (photon index of 2.55) dominating above 2 keV. We interpreted the two-temperature plasma as the intrinsic X-ray stellar wind emission of the donor star (the bright O-type supergiant LM Vel), while the power-law component as residual accretion onto the compact object. This interpretation has led us to identify the lowest X-ray luminosity emitted by a compact object in a SFXT, to date: 5x10^31 erg/s (contributed by the power-law component only).

Matteo Bachetti

Ultraluminous X-ray sources: broadband and timing properties

Ultraluminous X-ray sources are off-nuclear extragalactic sources exceeding the Eddington limit for a stellar-mass black hole. Once thought to be excellent candidates for the elusive class of intermediate-mass black holes, the recent discovery of pulsations in a number of them suggests that the bulk of this population is instead composed of neutron stars. How they can reach the observed luminosities is, as of today, still in part a mistery. I will review the information that can be learned from their broadband spectral modeling and, in particular, from pulsar timing.

Ciro Pinto

Extreme accretion and feedback in ultraluminous X-ray sources

Ultraluminous X-ray sources (ULXs) are the most extreme among X-ray binaries, reaching luminosities 100 times the Eddington luminosity limit of a compact object. The recent, groundbreaking, discoveries of coherent pulsations, cyclotron lines and powerful winds in a substantial fraction of ULXs with high-quality data showed that these are mainly powered by neutron stars and stellar-mass black holes accreting well above their Eddington limit. ULX winds, found with high-resolution X-ray spectrometers, carry a huge amount of power owing to their relativistic speeds (0.1-0.3c). They are able to significantly affect the interstellar medium, likely producing the 100 pc superbubbles observed around many ULXs, and regulate matter accretion onto the compact objects. The study of ULX winds therefore enables us to understand 1) how fast can compact objects grow and 2) how strong is their feedback onto the surrounding medium at high accretion rates. This is also relevant for supermassive black holes at their peak of growth. I will provide an overview on this phenomenology, highlight recent, exciting, results and underline the role of future missions.

Alessandra Robba

Spectral-timing studies of ultraluminous X-ray sources

Super Eddington accretion is one of the most interesting and extreme processes in the life of black holes and neutron stars, with a significant impact onto their evolution. Ultraluminous X-ray sources (ULXs) are nearby accreting binaries with luminosities above the Eddington limit of a stellar-mass black hole (~10^39 erg/s), and represent the ideal systems in which we can investigate super-Eddington accretion. The recent discovery of powerful winds and pulsations in many ULXs confirms predictions from theoretical models of super-Eddington accretion. In this talk, I will present our recent results on ULXs with various spectral shapes which are related to the combination of accretion rate and system inclination. At first, I will focus on NGC 1313 X-2. In particular, we discovered that the correlation between luminosity and temperature for cool component is consistent with a wind-dominated X-ray emission region. Instead, the (L, T) relationship for the hottest component argues in favour of super-Eddington accretion with a thicker disc.
Secondly, I will focus on the changes in the intrinsic variability and in the time lags during high and low flux states of the source. Finally, I will report the identification and the properties of a new ULXs candidate in the galaxy NGC 55.

Francesco Barra

Sulla natura della sorgente ultraluminosa NGC 55 ULX-1

Ad oggi non è ancora chiaro se le transizioni spettrali nelle sorgenti ultraluminose ai raggi X (ULX) siano dovute ad una variabilità stocastica nel vento, nel tasso di accrescimento o nella geometria della sorgente. Nel talk che presenterò saranno mostrati i risultati del lavoro svolto sulla sorgente variabile NGC 55 ULX-1. Gli spettri presi con XMM-Newton sono stati modellati con due componenti di blackbody. La relazione luminosità - temperatura per ciascuna componente spettrale è in accordo con quanto atteso dal modello di disco sottile. Alle alte luminosità sono presenti, tuttavia, delle piccole deviazioni. Assumendo che esse siano dovute al superamento del limite di Eddington è possibile stimare la massa, e quindi la natura, dell’oggetto compatto nel range 6 -14 M☉, ovvero un buco nero.

Fabio Pintore

The highly variable story of the Ultraluminous X-ray source NGC 4559 X7

Ultraluminous X-ray sources (ULXs) are accreting black holes or neutron stars in binary systems reaching X-ray luminosities above 10^39 erg/s. Despite the large number of sources, most of them were scantly monitored and poorly is known about their long-term variability. Long-term Swift-XRT monitoring are showing however that the vast majority are variable on time scales from hours to days or months. Here we present the long-term properties of the source NGC 4559 X7, one of the brightest ULX. It reached a bolometric X-ray luminosity up to ~4-5e40 erg/s, with large variations in flux (up to a factor of almost 8). The most striking behaviour of the source is however the flaring activity that was catched only during its highest flux states, as observed by XMM-Newton. Flaring activities in ULXs are very rare, so detecting a source with these properties can allow us to understand the super-critical accretion mechanisms and likely the nature of the compact object. In this talk, we will show the results from the spectral and temporal analysis and we will propose some possibilities to explain the behaviour of this peculiar source.

Hamza El Byad

Studying the aperiodic X-ray variability in the M82 Galaxy

Quasi-periodic oscillations (QPO) are narrow-bandwidth variability phenomena routinely observed in a wide range of X-ray sources, including neutron star X-ray binaries and stellar black holes. They are often detected as Lorentzian features in periodograms, on top of wide-bandwidth (power-law or broken power law-like) variability. The Cigar Galaxy M82 has two Ultraluminous X-ray sources : one is powered by an accreting neutron star, and the other, reportedly, by an intermediate-mass black hole. The observed region that includes these bright sources shows routinely a quasi-periodic oscillation (QPO). We have studied the variability of this QPO (which appears in the frequency domain of the M82 X-ray flux) by applying statistical techniques of modelling estimation on the results of the systematic Fourier analysis of ~33 observations of the M82 galaxy taken by the NASA satellite NuSTAR between 2014 and 2022. We fitted the power density spectrum (PDS) using a combination of some common densities (controlled by different parameters) that would describe parts of this PDS. Since we do not have an informative prior knowledge about data to perform a Bayesian or Variational inference, we used the MLE method for parameter estimation and the bootstrap technique to improve the measure of uncertainty (standard errors and confidence intervals). As a result, we have got an important characterization of the QPO phenomena associated with the target source.

Matteo Imbrogno

The case of pulsating ULX M51 X-7: a QPO to find them all?

Pulsating ultraluminous X-ray sources (PULXs) are accreting neutron stars (NSs) whose luminosities can be as high as 500 times their Eddington limit, L = 1.3 x 10^38 erg/s. Although Super-Eddington accretion had been theorized since the '70s, the discovery of PULXs in 2014 offered for the first time an entire class of sources to test our theories about this extreme regime. How PULXs can sustain similar accretion rates and reach such high luminosities is still an open question. M51 ULX-7 (ULX-7) is one of the most recently discovered PULXs, with a spin period of P ~ 2.8 s. During a dedicated 400 ks-long XMM large program campaign of ULX-7 in 2021-2022, we found a quasi-periodical modulation in the X-ray flux with a timescale peaking at ~ 2 ks. ULX-7 was observed at a flux level and in a spectral state similar to those during which pulses at ~ 2.8 s were discovered, suggesting favorable conditions for the detection of the coherent pulsations. However, the search for these pulsations has given negative results so far, thus suggesting the presence of an underlying process, observed in this PULX for the first time, able to hide and/or wash them out. Such a phenomenon might represent another factor playing an important role in limiting the number of known PULXs. I analyzed our Large Program observations and archival data in order to infer the main spectral and timing properties of the QPOs and their occurrence in past observations. QPOs have been observed in at least another PULX (M82 X-2) and in many other non-pulsating ULXs: the study and comparison of the QPOs properties could represent an additional tool to identify new PULXs.

Andrea Tiengo

Recurrent X-ray flares from an extra-galactic globular cluster: quasi periodic eruptions from an intermediate mass black hole?

The ultraluminous X-ray source XMMU J122939.7+075333, located in the globular cluster RZ 2109 in the Virgo galaxy NGC 4472 have displayed several soft X-ray flares with a duration of ~3 hours, which might have been regularly repeating every ~30 hours. This X-ray source is very peculiar also in optical and its properties can be explained by the repeated partial tidal disruption of a white dwarf in a highly eccentric orbit around a ~1000 Msun black hole (BH). A similar scenario, involving BHs with three orders of magnitude larger masses, has been proposed to interpret the quasi-periodic eruptions (QPEs) that have been detected in the nuclear regions of a few galaxies. Long uninterrupted observations with instruments with large effective area at soft X-rays, possibly coordinated with optical spectroscopic observations, are definitely needed to confirm the proposed scenario and discover other similar systems. They would be scaled-down examples of the QPE phenomenon in a different environment, but characterized by a similarly high stellar density, which enhances the probability of forming such eccentric systems.

Roberta Amato

The ULX M81 X-6: clues of a precessing disc around a weakly

magnetised neutron star

Thanks to their proximity, ultraluminous X-ray sources (ULXs) represent a privileged astrophysical laboratory to study super-Eddington accretion. Currently, open questions concern the nature of the compact object and the mechanisms responsible for the observed spectral changes. To answer these questions, we focused on M81 X-6, a non-pulsating ULX, which has been suggested to harbour a neutron star, albeit pulsation has not yet been detected. Using the rich set of XMM-Newton, Chandra, NuSTAR and Swift/XRT archival data, we studied the long-term X-ray spectral and temporal evolution of the source and found that it oscillates between two main states: one harder and more luminous, the other softer and less luminous. We prove that the two regimes are due to neither changes in mass accretion rate nor to the propeller effect. Instead, they may be attributed to the precession of the accretion disc, motivated also by the know superorbital period. In this context, we tested two models: (1) Lense-Thirring precession, which favours a scenario with a weakly-magnetised accreting neutron star (B~10^10 G), and (2) precession due to the torque of the neutron star magnetic dipole, which predicts a stronger magnetic field (B> 10^11 G), but it is disfavoured based on the spin and superorbital periods of known pulsating ULXs. Under the hypothesis of Lense-Thirring precession, we predict a spin period of a few seconds. Overall, this analysis can be a powerful tool to discern between neutron star and black hole accretors in other non-pulsating ULXs.

Alfredo Luminari

A Powerful Time-Evolving Photo-Ionization Device for UV and X-ray Spectral Modeling of Ionised Outflows

The vast majority of baryons and metals in the Universe exist in gaseous form, often in the immediate surroundings of variable sources of ionizing radiations. This is the case of, e.g. the gaseous environment that surrounds compact galactic sources (e.g. X-Ray Binaries) and AGNs, or the interstellar medium (ISM) of a star-forming region soon after an explosive event (e.g. a Gamma-Ray Burst explosion). In all the above cases, the gas is photo-ionized by the incident ionizing radiation field and, at a given time, its temperature, ionization balance and electronic level population evolution with time depend on the exact source's ionizing lightcurve and the gas volume density. The first is directly observable, whereas the second is strongly degenerate with the distance of the gas from the illuminating source of radiation. Modeling time-resolved spectra of a variable photo-ionizing source with time-evolving photoionization models, provides the most powerful method for breaking this degeneracy, and thus assessing the mass and energetics of the ionised gas.
Here we present our newly developed (and soon to be publicly released) time-evolving photoionization code TEPID. TEPID includes all the main ionisation/recombination and heating/cooling mechanisms and allows one to compute the corresponding UV and X-ray time-evolving absorption spectra. Comparing predicted spectra with time-resolved observations (e.g. through the fitting package XSPEC) allows one to get an unprecedented characterisation of the physics, chemistry and kinematics of gas undergoing variable ionising flux, such as, e.g.,

XRB and AGN outflows.

Alessandra De Rosa

Accretion in strong field gravity with the enhanced X-ray Timing and Polarimetry mission - eXTP

eXTP is an X-ray astronomy mission designed to study matter under extreme conditions of density, gravity and magnetism. Primary goals are the determination of the equation of state of matter at supranuclear density, the physics in extremely strong magnetic fields and the study of accretion in strong-field gravity regime. Primary targets include isolated and binary neutron stars, strong magnetic-field systems like magnetars, and stellar-mass and supermassive black holes. Thanks to the simultaneous spectral-timing-polarimetry measurements in the energy range 0.5-30 keV, eXTP will allow us to study the physics and geometry of accreting black holes. I will present in this talk the scientific capabilities of eXTP to investigate the conditions of matter under strong field gravity regimes by observing physical and geometrical properties of accretion flows close to black holes.

Simone Scaringi

What's so great about accreting white dwarfs? A brief (and biased!) review

Accretion is the process that drives and regulates the growth of most objects in the Universe. Accreting white dwarfs are arguably the ideal laboratories to study and test accretion disk theory and ascertain whether the physics of accretion can be considered scale-invariant all the way up to disks feeding supermassive black holes. In this talk I will present a (very biased!) overview of the main results in accreting white dwarf research. This will include the detection and discovery of several new accretion-driven variability patterns observed with Kepler and TESS, and how these discoveries find close analogies to already known patterns in X-ray binaries. I will further discuss how the advent of Gaia has provided a leap forward in our understanding of close binary evolution, and how accreting white dwarfs are proving to be fundamental in this research. I hope to conclude by suggesting future endeavours in this research field.

Marcello Giroletti

Filming the evolution of symbiotic novae with VLBI: the 2021 explosion of RS Oph

Fifteen years after its previous outburst, the symbiotic recurrent nova RS Oph exploded again on 2021 Aug 8th, its first outburst during the Fermi era. In symbiotic novae, the material ejected from the surface of the white dwarf (WD) after the thermonuclear runaway drives a strong shock through the dense circumstellar gas produced by the red giant (RG) wind. This nova is a perfect real-time laboratory for studying physical processes as diverse as accretion, thermonuclear explosions, shock dynamics and particle acceleration; in many ways it is like a supernova remnant on fast forward. The experience of its previous outburst and of 2010 V407 Cyg (the first symbiotic nova that has ever occurred during the Fermi era), indicates that Very Long Baseline Interferometry (VLBI) observations can follow its evolution over a period of several weeks. This provides unique constraints on major outstanding problems, including the emission mechanisms, the physical processes at work, the presence and location of shock acceleration, the geometry of the system, and the density of the RG wind. We will present preliminary results from the VLBI observations carried out on weeks/months time scales after the August explosion and a comparison with the constraints derived from optical spectroscopy.

Ilaria Caiazzo

From Gaia to LISA, the new landscape of white dwarf studies

The advent of Gaia and of large photometric and spectroscopic surveys is changing the landscape of white dwarf studies. These incredible new data sets, together with improved models, have enabled tackling some unsolved mysteries concerning white dwarfs as a population, as well as discovering extremely peculiar objects that challenge our understanding of white dwarf formation and evolution. In my talk, I will show how the precise astrometry from Gaia has dramatically improved our capability of studying young star clusters, and therefore probe the evolution of white dwarfs born from single progenitor stars. On the other hand, time domain surveys, like the Zwicky Transient Facility, are shedding light on the evolution of white dwarfs in binary systems, substantially increasing the number of known white dwarf binaries that will be observed with LISA and finding the final products of such binaries. In fact, ZTF is discovering a large number of massive, rapidly rotating and highly magnetized white dwarfs whose extreme properties characterize them with high confidence as remnants of white-dwarf mergers. Finding a population of white dwarf merger remnants just below the Chandrasekhar mass can help constrain the number of mergers in the Galaxy and their contribution to the type Ia supernova rate, as well as help us understand the origin of strong magnetic fields in white dwarfs. I will present some early results of the search, including the discovery of some extremely peculiar white dwarfs.

Roberto Silvotti

Hot subdwarf binaries as hosts of compact objects and progenitors of cataclysmic variables.

Hot subdwarfs (sdO/B stars) are extreme horizontal branch stars that have lost almost all their H-rich envelope near the tip of the RGB. Most, if not all, of them are the product of binary evolution. About one third reside in short-period binaries with a WD or M-dwarf companion. Those with a massive WD companion are potential progenitors of SN Ia. Those with a dM companion can evolve into CV systems. In this talk I will give a general picture of sdO/B stars highlighting the various links with more compact objects and the importance of such objects as physics laboratories. As an example, I will describe recent results on the sdBV+dM system TIC137608661, based on TESS observations, that show how this system is on the way to synchronizing the sdB rotation to the orbital period.

Cristina Pallanca

The discovery of slow cooling White Dwarfs

White dwarfs (WDs) are the final evolutionary product of the vast majority of stars in the Universe. They are electron-degenerate structures characterized by no stable thermonuclear activity, and their evolution is generally described as a pure cooling process. Their cooling rate is adopted as cosmic chronometer to constrain the age of several Galactic populations, including the disk, globular and open clusters. The comparison between the WD luminosity function in the Galactic globular clusters M3 and M13 recently (Chen et al., 2021; Nature Astronomy, 5, 1170-1177) revealed the existence, in the latter, of “slowly cooling WDs”, i.e., WDs with active thermonuclear burning in their residual hydrogen-rich envelope, which increases their cooling time with respect to the predictions of pure cooling processes commonly adopted for these stars. The presence of a residual hydrogen envelope is explained by the fact that the progenitor stars of these WDs skip the asymptotic giant branch phase, because of a too low mass along the horizontal branch (HB). Indeed, the HB blue tail of M13 is populated by such low-mass stars, thus naturally explaining the presence of slowly cooling WDs in this cluster. To further explore this phenomenon, we investigated also the WD cooling sequence in NGC 6752 (Chen et al., 2022, ApJ, in press), another Galactic globular cluster with metallicity, age and HB morphology similar to M13, but achieving a luminosity one order of magnitude fainter than that reached in M13. The normalized WD luminosity function derived in NGC 6752 turns out to be impressively similar to that observed in M13, in perfect agreement with the fact that the stellar mass distribution along the HB of these two systems is almost identical. As in the case of M13, the comparison with theoretical predictions indicate that ~ 70% of the investigated WDs are evolving at slower rates than standard, purely cooling WDs.
In this talk I will provide evidence for the existence of slowly cooling WDs and further support to the scenario proposing a direct causal connection between this phenomenon and the horizontal branch morphology of the host stellar cluster. Moreover, because of the observational evidence of quiescent thermonuclear activity occurring in cooling WDs, I'll warning the audience on the use of the WD cooling rate as cosmic chronometer for low-metallicity environments.

Matteo Fratta

Identification and classification of Hα-excess candidates in the Northern Galactic Plane.

Systematic studies of the heterogeneous Hα-emitting stellar populations can provide a deeper insight about the composition and evolution of our Galaxy. To this end, large samples of unambiguously classified emission line sources are required. Historically, these objects are detected in narrow-band photometric surveys by searching for a clear Hα excess, relative to nearby stars of similar colour (position-based selection). While this approach usually yields very low percentages of spurious detections, it may fail in detecting intrinsically faint and/or rare Hα-excess sources. In order to try to fill this gap, we developed a novel technique to find Hα-outliers with reference to nearby objects in the colour-magnitude diagram (CMD-based selection). By combining position-based and CMD-based selections, we produced a catalogue of ~28,000 Hα-excess candidates in the Northern Galactic Plane. Our technique was tested with the support of the spectroscopic follow-up observation of 114 of these candidates. ~48% of the 31 outliers in our sample identified only by the CMD-based selection show clear Hα emission. These 15 sources would have been missed by the classic position-based selection technique.

Nicolò Oreste Pinciroli Vago
Artificial Intelligence in Astrophysics

Artificial Intelligence (AI) has shown its effectiveness in diverse fields [1, 2, 3, 4]. Machine Learning (ML) is a sub-field of AI that requires large amounts of data. In astrophysics, petabytes of data are going to be collected in the near future [5], and manually analyzing them is just impossible. ML techniques are insufficient for finding pulsating objects (e.g., PULXs), as only a limited amount of data is available. Discovering a pulsating object requires raw time series, which must be corrected to consider the Doppler shift, and find the correct orbital parameters. Good orbital parameter combinations correspond to a time series with clearly identifiable periodicity. A grid search can be used for estimating orbital parameters, as in [6], which uses three orbital parameters. This method is time-consuming and does not exploit information on the most promising search space regions. Genetic algorithms (GA) [7] are search heuristics that tend to converge towards better solutions without exploring the entire search space, imitating natural selection processes. Experimental results on pulsating objects show that GA can find a sub- optimal solution with a ≈ 200× to ≈ 1000× speed-up in the search process, which corresponds to more than 99.5% saving in computational time. Sub-optimal solutions can be the starting point for a narrower grid search. This is fundamental to analyzing greater quantities of data and generating a labeled data set, which labels each raw time series with the corresponding orbital parameters. Such a data set could be combined with ML-based methods [8, 9] to improve the speed-up. In my research, I have also focused on the classification of gravitational lens- ing systems [10] and helicity classification of magnetic fields [11]. A promising field of research is Multi-modal Weakly Supervised Learning (MMWSL), which combines multiple modalities (i.e., multiple types of data, such as images and time series), and Weakly Supervised Learning, which extracts detailed information from coarse-grained labels. MMWSL has shown its effectiveness in diverse fields [12, 13, 14, 15], but it has not been applied yet to astrophysical studies.

Giovedì 29 Settembre

Adriana Mancini Pires

Isolated neutron stars with eROSITA

The all-sky survey of eROSITA will unveil the X-ray faint end of the isolated neutron star population at unprecedented sensitivity; it has the unique potential to discover long-sought evolutionary missing links, constrain evolutionary models, and advance the understanding of the population as a whole. In this talk I'll give an overview of the first two years of the mission, including results of deep monitoring of the so-called Magnificent Seven and the first candidates from the survey lined up for follow-up investigations.

Stefano Ascenzi

A new finite-volume code for the thermal evolution of magnetized neutron stars in 3 dimensions

The study of the thermal and magnetic evolution of neutron stars in time is fundamental to understand the spectral and temporal properties of these sources and shed light on the origin of the different neutron star populations. To this aim, a numerical study of the heat diffusion and magnetic evolution equation is required, coupled with a detailed calculation of the microphysical property of the star, such as neutrino emissivity and heat and electric conductivity. Moreover, in order to account for non-axisymmetric effects, which are expected to lead to the formation of a non axisymmetric temperature distribution on the stellar surface, a solution of the equation in 3D is required. In this talk, I present the preliminary implementation of the thermal evolution part of our new 3D magneto-thermal evolution code, which aims to generalize the axisymmetric magneto-thermal finite-volume code previously developed by our group.

Michela Rigoselli

X-ray emission from isolated neutron stars: latest results from XMM-Newton and NICER data

The X-ray spectra of isolated neutron stars typically include a thermal component, that comes from the cooling surface and a non-thermal component, produced by highly-relativistic particles accelerated in the stellar magnetosphere. Hot spots from returning currents can also be detected. Middle-aged pulsars exhibit a mixture of these components. On the other hand, the XDINSs, a small class of older, radio-silent neutron stars likely originating from magnetars, do not show non-thermal components. They have a very soft thermal X-ray spectrum extremely

close to a pure blackbody, often with broad absorption features probably related to their large magnetic field (10^13 G). This picture has been progressively shaken thanks to detailed XMM-Newton and NICER observations of several objects that I will review. In particular, I will present the latest results on RX J1856.5-3754, which is the brightest among the seven XDINSs. The analysis of 20 years data allowed us to detect a second blackbody component (T2~150 eV, R2~20 m) as well as a hard power law, in addition to the cold blackbody of T1~60 eV and R1~5 km that is responsible for most of the weakly pulsed (~1%) X-ray flux.
Comparison with the other thermally emitting isolated neutron stars shows that the ratios T2/T1 and R2/R1 are similar for objects of different classes. The observed values cannot be reproduced with simple temperature distributions, such as those caused by a dipolar field, indicating the presence of more complicated thermal maps.

Nanda Rea
Magnetars and the transient multi-band sky

I will review recent results on pulsars and magnetars, and their crucial role in many different transient events from radio to X/gamma-rays.

Francesco Coti Zelati
Recent outburst activities within the magnetar class

I will present the results of X-ray and radio monitoring campaigns of two magnetars discovered through their short X-ray bursts and outbursts over the past two years: SGR 1830-0645 and Swift J1555.2-5402.
We observed SGR 1830 during the first 1.5 years of the outburst using XMM-Newton, NuSTAR and Swift. At the peak of the outburst, the X-ray emission was predominantly thermal and showed a complex modulation pattern at the spin period. Through a timing analysis, we were able to estimate the magnetic field and characteristic age of this source. No periodic or bursting radio emission was detected at the outburst peak. Our extensive campaign showed a progressive decrease in X-ray flux, spectral softening and a simplification of the pulse profile.
We have been monitoring Swift J1555 since its outburst onset using Swift, NICER and Insight-HXMT. Its X-ray emission has decreased by a factor of 4 in more than a year, suggesting an extremely slow outburst evolution or perhaps the recovery of a new quiescent level. During this time span, the soft X-ray emission was entirely thermal and showed only marginal spectral evolution. Again, no periodic or bursting emission was detected at radio frequencies close to the outburst peak.

Alice Borghese
Latest outbursts from radio magnetars

In this talk, I will focus on two radio magnetars, XTE J1810-197 and Swift J1818.0-1607, and their latest (re-)activation.
After 11 years of low activity, at the end of 2018, XTE J1810 underwent a new X-ray outburst event and reactivated as a radio pulsar. We initiated an X-ray monitoring campaign and found that (i) the spectrum is well described by multiple blackbody components, as found for the first outburst in 2003; (ii) the pulse profile always showed a sinusoidal shape and the phase of the pulse maximum changed with energy, a feature that is unique to this outburst. By modeling the observational results, we constrained the geometry of the emission regions.
Swift J1818 is one of the most recent additions to the magnetar family. It is an intriguing source: it is one of the fastest magnetars with a spin period of 1.36s, it showed pulsed radio emission and is one of the youngest neutron stars of our Galaxy. We monitored it from the activation of its first outburst in March 2020 until October 2021. I will present the results of our X-ray monitoring campaign, as well as of a VLA observation.

Davide De Grandis
Modelling Magnetar Behaviour with 3D Magneto-Thermal Simulations

The observational properties of isolated neutron stars are shaped by the structure of their magnetic field and surface temperature. Therefore, modelling how these quantities evolve and influence each other is key in understanding the behaviour of NSs, both in quiescence and during transient phenomena. To this end, in the last decades much effort has been put in developing numerical frameworks to treat the coupled induction and heat transport equations; recently, this brought to the development of codes able to tackle the problem in a 3D domain, devoid of symmetry assumptions. I will present a range of 3D simulations with the pseudo-spectral code PARODY, addressing both the long-term evolution and short-term violent phenomena. In particular, I will focus on magnetar outbursts, events of intense activity linked to small, inherently asymmetric hot regions appearing on the surface. Even though the exact mechanism that triggers these phenomena is not completely understood, following the evolution of a localised heat injection in the crust serves as a minimal model to study the unfolding of the event and link it to the properties of the crust itself. Amongst the many parameters involved in the problem, I will show that the magnetic topology holds a key role in determining the evolution of the event in time as well as the shape of the hot region on the surface.

GianLuca Israel
The EWOCS's gaze at the compact object population in Westerlund 1

"During 2020-2021, the star cluster Westerlund 1 was monitored for about 1Ms in the Chandra

Large Project EWOCS (Extended Westerlund One Chandra Survey). Among the many aims of the project are also the study of the magnetar CXOU J164710.2-455216 and the search for new compact objects with unprecedented sensitivity. The magnetar was observed at a flux much lower than during the past outburst or burst-active episodes and it also appeared to be slowly fading along the campaign. For the timing study of the magnetar in particular, we also made use of archival NICER data that, widening the baseline of the phase-coherent analysis, helped us to infer less biased physical parameters, such as magnetic field and characteristic age.
Of the more than 4000 unique sources detected in EWOCS, about 100 with enough counts (>100) for a sensitive examination were searched for periodic signals longer than about 7s (the minimum value allowed by the instrumental setup). The analysis is still ongoing, but a periodic signal at about 3hr was already discovered, clearly pointing to a binary system hosting a compact object. The probability that it belongs to the cluster is about 99%.
The nature of this new pulsator is still under investigation. I will show further results from HST data as well as from extensive theoretical simulations of the binary population of Westerlund 1.

Andrea Possenti

The FRBs' saga: mysteries, suspects and culprits

Since confirming their cosmic nature in 2013, Fast Radio Bursts have been playing a leading role on the stage of the astrophysics community, rewarding the aficionados with a long series of surprises and unexpected scene changes. We will rewind the tape of this hectic decade, stopping at the major plot twists and trying to get a glimpse of who will be the main characters who will appear at the end of the story, if there will be one…

Riccardo La Placa

Un nuovo modello unificato per i Fast Radio Burst

I Fast Radio Burst (FRB) sono, sin dalla loro prima detezione, tra gli eventi astrofisici di spiegazione più incerta a causa delle energie estreme in gioco e, negli ultimi anni, della apparente dicotomia tra sorgenti a lampo singolo e ripetitori. Presenterò un nuovo modello che permette di unificare entrambi i tipi di sorgenti tramite un solo meccanismo, con previsioni sull'andamento delle distribuzioni in energia osservate e del numero di sorgenti attese al variare del redshift; inoltre mostrerò le prime applicazioni del modello ad alcuni degli FRB più largamente studiati, tra cui FRB 121102.

Matteo Trudu

A multi-wavelength campaign on FRB 20180916B to unravel the nature of Fast Radio Bursts

Fast Radio Bursts (FRBs) are ms duration and Jy intensity bursts of extra-galactic nature whose origin is not yet assessed. To date FRBs have been observed only in the radio band.
On the 28th of April 2020 the Galactic magnetar SGR 1935+2154 emitted two radio bursts closely resembling to the ones produced by FRBs with simultaneous detections in the high-energy band. This unprecedented result places magnetars as the most plausible FRB sources and strongly motivates panchromatic campaigns towards FRB known sources in order to find, as in the case of SGR 1935+2154, their high-energy and also possibly optical counterparts. Despite their very elusive behaviour an FRB source, FRB 20180916B, shows a periodic trend every 16 days with an active window of 5 days, making it an extremely suitable target for this kind of observations.
In this talk I will present the results of a multi-wavelength campaign led by the Sardinia Radio Telescope (SRT), the upgraded Giant Metrewave Radio Telescope (uGMRT) and the Northern Cross (NC) in which we monitored FRB 20180916B between November 2020 and August 2021. In particular I will show the properties of the bursts detected in the radio band and I will discuss how the limits obtained in the other frequencies can constrain the origin and emission mechanism of these enigmatic objects.

Luca Zampieri

Fast-photometry observing campaigns of Fast Radio Bursts and magnetars with Aqueye+ and IFI+Iqueye

Following the simultaneous multiwavelength campaign on FRB20180916B carried out in February 2020 by our collaboration, a second longer campaign was undertaken between October 2020 and August 2021. Extensive optical coverage during periods of radio activity was attained with the fast photon counters Aqueye+ and IFI+Iqueye mounted at the Copernicus and Galileo telescopes, respectively, in Asiago. Here we report on the results of this optical campaign. We also report on the limits to the optical fluence and to the spectral index of the optical-to-hard-X-ray fluence of the magnetar SGR J1935+2154 obtained during a stage of burst/flaring activity of the source, when a hard X-ray burst was detected with the Fermi Gamma-ray Burst Monitor.

Marta Burgay

Searching for pulsar in unidentified gamma-ray sources with MeerKAT

I will report on the latest results obtained analysing 16 years of data collected on the unique Double Pulsar, one of the best test beds to probe relativistic gravity in the strong field regime" OPPURE "MeerKAT, the south african precursor of the Square kilometre array, is a great instrument for pulsar science. In this talk I will report on the recent discoveries that this powerful telescope has allowed us to do by searching for radio pulsations in unidentified gamma-ray sources. Highlights include a relativistic binary and a handful of new 'spider' pulsars.

Luca Del Zanna

Relativistic dynamo and magnetic field amplification in compact objects

Compact objects, and neutron stars in particular, archaracterised by strong magnetic fields that are crucial to explain the high-energy emission from the sources. These magnetic fields may be subject to complex evolution inside the hosting relativistic plasma, like dynamo or chiral processes amplifying initial seed fields in early stages. We present general relativistic magnetohydrodynamics (GRMHD) modeling and numerical simulations of such mechanisms.

Alessandro Ridolfi

The role of MeerKAT in the current renaissance of globular cluster pulsars

Globular clusters (GCs) are known to be amazingly rich natural laboratories. They are amongst the oldest stellar systems found in the Universe, and, as such, they host a large number a compact objects. The latter, because of the extreme stellar densities found in the core of GCs, can interact with other stars and produce dynamically formed binaries, which can in turn spin up neutron stars and, hence, form millisecond pulsars (MSPs). The high interaction rates in GCs can also alter the typical evolution of binary systems, resulting in the formation of exotic binaries, with extreme or unconventional properties. These can often be exploited to perform exciting astrophysics and/or fundamental physics experiments.In the last few years, the total known population of GC pulsars has increased dramatically, jumping from about 150 objects known in 2018, to more than 250 known today. The MeerKAT radio telescope in South Africa , which is the precursor of the SKA1-mid, has been a leading factor in the recent surge in new discoveries and the consequent ""renaissance"" of the field.
In this talk, I will present some of the highlights from the first couple of years of the MeerKAT globular cluster pulsar search and timing experiments, with particular emphasis on the case of some extremely eccentric binary millisecond pulsars and other peculiar objects.

Michele Ronchi

Long-period pulsars as possible outcomes of supernova fallback accretion

For about half a century the radio pulsar population was observed to spin in the ~0.002-12 s range, with different pulsar classes having spin-period evolution that differs substantially depending on their magnetic fields or past accretion history. The recent detection of several slowly rotating pulsars has re-opened the long-standing question of the exact physics, and observational biases, driving the upper bound of the period range of the pulsar population. In this talk, I will examine the spin-period evolution of pulsars interacting with supernova fallback matter and specifically look at the fallback accretion disk scenario using general assumption for the pulsar spin period and magnetic field at birth, as well as fallback accretion rates. I will show that this evolution can differ substantially from the typical dipolar spin down, and can be very dependent on the ranges of initial parameters at formation, resulting in pulsars that show spin periods longer than their coeval peers. In addition, I will apply the fallback model to the case of the two recently discovered periodic radio sources, the pulsar PSR J0901-4046 which has a spin period of 75.9 s and the radio transient GLEAM-X J162759.5-523504.3 with a periodicity of 1091 s. Similar long-period isolated pulsars might be more common than expected, being the natural result of supernova fallback accretion onto magnetars.

Elena Amato
Pulsar Wind Nebulae: a review

Pulsar Wind Nebulae are highly intriguing astrophysical objects in many respects. They are the brightest and closest class of relativistic sources, and hence the ultimate laboratory for the physics of relativistic plasmas, where we can study in unique detail processes such as acceleration and collimation of relativistic outlfows, or the acceleration of particles at relativistic shocks. In recent times, these sources have also attracted the attention of the Cosmic Ray physics community, as potential sources of cosmic ray positrons and PeV gamma-rays. I will review the current status of our understanding of Pulsar Wind Nebulae, as it emerges from modeling of their dynamics and high energy astrophysical observations. I will discuss, in particular, the exciting recent developments coming from Ultra High Energy (>100 TeV) gamma ray observations.

Barbara Olmi
Particle escape from evolved pulsars and their nebulae

Pulsars and their nebulae (PWNe) are known to be excellent particle accelerators, with the Crab nebula being the unique firmly identified leptonic accelerator in the Galaxy to date.
In last years high energy, and very high energy, observations of PWNe have proved that evolved systems efficiently load the surrounding ambient medium with energetic particles.
X-ray observations detected elongated, thin and quasi-monochromatic tails, apparently originating from the head of the bow shock nebulae produced by fast moving pulsars. They are almost one-sided and highly misaligned with respect to the pulsar motion.
At gamma-rays we have on one side the detection of extended TeV halos surrounding a couple of evolved pulsars (but possibly being a rather common feature), on the other the evidence of extremely powerful acceleration ongoing in the Galaxy — in many cases with a possible association to a pulsar/PWN -- as recent LHAASO data at PeV energies have shown. How, with which efficiency and what properties, energetic particles can escape from the pulsar/PWN

region of influence is then a fundamental step towards understanding those features. In this talk I will discuss what we have learned in the last years from a dedicated modeling.

Salvatore Orlando

Supernova Remnants: a storytelling about life, death and afterlife of massive stars

Supernova remnants (SNRs) are extended sources characterized by rather complex morphologies and intricate shock patterns. These characteristics reflect, on one hand, the asymmetries and anisotropies inherited from the parent supernova (SN) explosions and, on the other hand, the interaction of the remnants with the inhomogeneous and magnetized ambient environment. In the case of young SNRs, this environment is the circumstellar medium sculpted by the winds of the progenitor stars in the last stages of their evolution. Indeed SNRs encode in their structure the past life and the final fate of their progenitor stellar systems. Deciphering the observations of SNRs can be, therefore, an essential step to probe the physics of SN engines and to study the final stages of stellar evolution.
Here, I will review recent advances in the modeling of young to middle-aged SNRs, focusing on investigations aimed to link asymmetries and features observed in the remnants to their parent SN explosions and progenitor stellar systems. I will discuss the role of post-explosion anisotropies vs. inhomogeneous environments in the shaping of SNRs, highlighting the importance to disentangle the two effects when interpreting observations of SNRs. Finally, I will discuss future prospects in view of upcoming missions and possible improvements of current models.

Emanuele Greco

Evidences for a Pulsar Wind Nebula in SN1987A

Since the day of its explosion, supernova (SN) 1987A was closely monitored to study its evolution and to detect its central compact relic. The detection of neutrinos from the SN strongly supports the formation of a neutron star. Besides the detection in the ALMA data of a feature that is somehow compatible with the emission arising from a proto-pulsar wind nebula (PWN), the only hint for the existence of this elusive compact object is provided by the detection of hard X-ray emission in NuSTAR spectra. I present new results of the simultaneous analysis of multi-epoch observations of SN 1987A performed by Chandra, XMM-Newton and NuSTAR. I compare actual data with a 3D MHD simulation of SN 1987A. Both the phenomenological analysis and the comparison with the MHD model provide strong arguments against either a thermal origin for the hard X-ray emission. I show that a heavily absorbed power-law, perfectly consistent with the emission from a PWN embedded in the heart of SN 1987A, is needed to properly describe the observed X-ray spectra. Thanks to the results obtained, I also infer some physical characteristics of the pulsar and the broad-band spectrum of its nebula.

Andrea Giuliani

The ASTRI Mini-Array: status and perspectives

The ASTRI Mini-Array is an array of nine Cherenkov telescopes under construction at the Teide Astronomical Observatory in Tenerife, Spain. The ASTRI telescopes adopt a dual-mirror Schwarzchild-Couder optical design. In the focal plane, the ASTRI camera, based on silicon photon-multipliers detectors, will cover a large field-of-view (~10 deg in diameter). This system provides a good gamma-ray sensitivity also in the multi-TeV range (up to ~200 TeV) and large off-axis angles (up to ~5 degrees), combined with a good angular resolution.
The scientific goals of the ASTRI Mini-Array include spectral and morphological characterization of the LHAASO sources and other Pevatron candidates, studies of PWNe and TeV halos, Blazar monitoring at VHE, fundamental physics and follow-up of transient events.
The beginning of the scientific operations is planned for mid 2025. The first 3 years will be dedicated to the core science and the ASTRI Mini-Array will be run as an experiment. During the following years the facility will gradually move towards an observatory model, open to the community.

Martina Cardillo

Very High Energy Astrophysics and the search of the lost Pevatrons

Gamma-ray astronomy plays a fundamental role in the understanding of very high energy tricky and outstanding sources in our own Galaxy and their role in particle acceleration.
In thi s context, despite the enormous efforts done in very recent years, both theoretically and experimentally, Cosmic Ray (CR) origin remain without clear answers. Their commonly accepted galactic sources, Supernova Remnants, were no detected at PeV energies, where there is the direct proof of CR presence.
In the meantime, current VHE instruments added other candidate sources for CR acceleration such as massive star clusters, like the Cygnus one, and the Galactic Center, both detected at VHEs. Even Novae and microquasars jets were been recently detected at VHE, adding themselves to the fascinating world of Galactic accelerators. Moreover, the last results published by the LHAASO collaboration revealed the existence of several PeV sources likely related to PWNae, well known leptonic factories (e.g. the Crab Nebula for all).
Parameters understanding, multi-wavelength comparison, loewr spectral errors are fundamental ingredients to distingush hadronic and leptonic accelerators and to do another step forward the understanding of CR origin. In this context, the future Cherenkov telescopes as ASTRI Mini-Array and CTA, with their unprecedented sensitivity and angular resolution at E>10 TeV, will have a great role.

Silvia Crestan

Multiwavelength investigation of LHAASO J1908+0621: an unidentified galactic PeVatron

Recently LHAASO has detected more than a dozen of ultra-high energy (UHE) γ-ray sources in our Galaxy. Many of these seem to be connected with PWNe or SNRs (see Cao et al., 2021). Among these sources, one of the best PeVatron candidates is LHAASO J1908+0621, a remarkable source for its hard spectrum extending beyond 100 TeV and with no evidence of a cutoff. This source was also detected by other γ-ray instruments as HAWC, VERITAS and HESS. Due to the complexity of the morphological structure of the source and the limited angular resolution, the origin of its γ-ray emission has not yet been unambiguously identified. There are several objects in the region which could serve as counterparts to the TeV emission, including a supernova remnant (SNR G40.5-0.5) and various pulsars, precluding a firm identification of the extreme accelerator and making it difficult to distinguish between a hadronic or leptonic nature of the emission. Additionally, the LHAASO source is associated with an ICECUBE neutrino hotspot, although the significance is still too low (see Aartsen et al., 2020).
We performed a multi-wavelength analysis of LHAASO J1908+0621 to investigate its nature and the origin of its ultra high-energy emission (see Crestan et al., 2021). Using the Nobeyama Radio Observatory data on 12CO and 13CO molecular line emission, we found evidence of dense molecular clouds spatially correlated with the source region. Moreover, the 12-year analysis of Fermi-LAT data stresses the presence of a counterpart with a hard spectrum between 10 GeV and 1 TeV. Our new analysis of the XMM-Newton data translates into better constraints on the X-ray flux from this source. Thanks to the multi- wavelength approach, we showed that a single zone model cannot explain the whole set of multi-wavelength data, regardless of whether it accelerates protons or electrons, but a 2-component model is needed to explain the emission from LHAASO J1908+0621. The UHE emission appears most likely the superposition of a TeV PWN powered by PSR J1907+0602, in the southern part, and of the interaction between the supernova remnant G40.5-0.5 and the molecular clouds towards the northern region.

Venerdì 30 Settembre

Marica Branchesi

Perspectives of multi-messenger astrophysics in the Einstein Telescope era

Multi-messenger observations including gravitational-waves are revealing the enigmas of the most energetic transients in the sky, probing neutron-stars physics, relativistic astrophysics, nuclear physics, nucleosynthesis, and cosmology.
Based on current electromagnetic and gravitational wave observations of neutron star binary

mergers, gamma-ray bursts, and kilonovae, the talk will provide an overview of the exciting prospects of next-generation gravitational wave detectors, such as the Einstein Telescope and the Cosmic Explorer, in the astrophysics of compact objects.

Simone Dall'Osso

Compact objects as sources of continuous gravitational waves: highlights, news & challenges

I will review the current status in the search for continuous wave sources of GWs and their fundamental link with electromagnetic observations, highlighting new ideas, their challenges and their added value for detection and new discoveries.

Alberto Colombo

Multi-messenger observations of binary neutron star mergers in the O4 run

The discovery of the gravitational wave (GW) signal GW170817 by the LIGO-Virgo Collaboration, produced by a coalescing binary neutron star (NSNS), and the following detection of the associated multi-wavelength electromagnetic (EM) counterparts marked the beginning of a new era in multi-messenger (MM) astronomy. The EM follow up campaigns carried out during the last GW detector network O3 observing run, on the other hand, showed that even investing substantial observational resources might end up with only contaminants and loose constraints on the properties of the GW-emitting binaries. With the next year-long observing run O4 starting in a few months, the availability of detailed predictions to be used as a guide to the optimization of EM follow-up strategies will be fundamental in order to enhance the probability of discovering the associated rapidly fading transients. In order to predict the observational appearance of the EM emission associated to NSNS mergers that will be detected during O4, we built a MM population model for NSNS mergers, which self-consistently links the physical parameters of the GW sources to the emerging EM emission components, namely the kilonova (KN) and the gamma ray burst (GRB) jet-related emission (prompt and afterglow). I will present this study in detail and address key questions such as: do all detectable NSNS binaries produce an EM counterpart? Which counterpart is more likely to be detected in wide-area surveys or in targeted observations? How diverse are KNe in terms of brightness and other properties? How long after the merger do we expect to detect most of the GRB afterglows in the radio, optical and X-ray bands?

Andrea Pavan

Jet structure modelling with self-consistent binary neutron star merger environments.

GW170817/GRB170817A provided the first direct evidence for the existence of binary neutron star (BNS) systems capable of merging and producing incipient short gamma-ray burst (sGRB) jets. Moreover, the combination of gravitational waves and electromagnetic signals allowed us to infer unprecedented insights into the physics of NSs, the merger mechanism itself, and the properties of sGRB jets. Among the latter, the jet structure, which strongly affected the prompt and afterglow observations, has recently begun to attract considerable interest from the community. Indeed, understanding how such a structure is shaped would provide us with precious information about both the jet launching mechanism and the properties of the environment in which the jet propagates. To investigate this, numerical relativity simulations are currently employed, reproducing jet evolution up to scales relevant for the electromagnetic observations. In this talk, I will present results of simulations in which we modelled, for the first time, the three-dimensional (magneto-)hydrodynamic evolution of incipient sGRB jets propagating through post-merger environments that are directly imported from fully general-relativistic BNS merger simulations. Our results shed light on the role of the jet-environment interplay in the overall jet evolution, opening the way for a systematic investigation of how the physical conditions at the time of jet launch affect the structure of the jet itself.

Delphine Perrodin

The EPTA approach to the search for ultra-long period GWs

The high-precision monitoring (timing) of radio pulsars can be used to detect gravitational waves (GWs) in the nanohertz frequency range from sources such as supermassive black hole binaries. The European Pulsar Timing Array (EPTA) involves the collaboration of five large European radio telescopes with the scope of detecting GWs. As part of the EPTA, the Large European Array for Pulsars (LEAP) project involves the simultaneous observations of an array of pulsars at all EPTA radio telescopes in order to achieve a higher sensitivity for GW detection. The high time-resolution data acquired with LEAP also allows us to study specific pulsars in great detail. Using LEAP data, we detected quasi-period micro-structure in three millisecond pulsars at 1.4 GHz. We discuss how this micro-structure is possibly linked to recently-discovered Fast Radio Bursts which show a similar emission pattern.

Fabio Ragosta

The multi-messenger paradigm in the Vera Rubin Observatory's LSST

era

The search for kilonova (KN) emissions in the transient sky is one of the main challenges of the multi-messenger astronomy and thanks to the discovery of the first electromagnetic counterpart, named AT2017gfo (referred as GRB170817A or GW170817), we had the possibility to have the most reliable description of the physics that drives this type of phenomena. The search of the EM counterpart of a GW source is made extremely arduous both by the size of the error areas returned by the interferometers and by the observational properties of these objects which are very rapid and rare. Wide Field surveys, such as LSST, can represent the perfect tool to tackle these problems, due to their cadence and the big area they will screen. In this talk, I will present an extensive analysis on the detectability of KNe emission through LSST survey. This study will probe the possibility with such surveys to have a detailed census of these events and to have more constraints on their properties (e.g. opacity, ejecta mass and velocity).

John Rankin

X-ray Polarimetry with the IXPE observatory

The Imaging X-ray Polarimetry Explorer (IXPE) is a joint NASA-ASI Small Explorer mission that was launched on December 9th 2021. During its first year it is observing tens of sources, performing angular, time and energy resolved X-ray polarimetry in the 2-8 keV band. IXPE consists of three X-ray optics modules (provided by NASA) and three polarimeters based on the Gas Pixel Detector (provided by Italy). In this talk I will present the observatory and introduce its first astrophysical results.

Roberto Taverna

Polarized X-rays from the magnetar 4U 0142+61

The first detection of linear polarization in the X-ray emission of an ultra-magnetized neutron star with the Imaging X-ray Polarimetry Explorer (IXPE) is reported. IXPE observed the anomalous X-ray pulsar 4U 0142+61, revealing a linear polarization fraction of 12±1% in the 2-8 keV energy band. We detected a peculiar variation of the polarization properties with energy: the polarization degree is 14±1% at 2-4 keV, 41±7% at 5.5-8 keV and it drops below the instrumental sensitivity at around 4-5 keV; the polarization angle swings by ~90°, from ~50° at low energies to ~ -40° at higher ones. The observations performed with IXPE give us new information about the properties of the neutron star surface and its magnetosphere, lending further support to the expectations of the magnetar model in the presence of the quantum mechanical effect of vacuum birefringence.

Andrea Gnarini

Modelling Polarization Properties of NS-LMXBs

The X-ray emission of Low-mass X-ray binaries hosting neutron stars is generally described by thermal components from the NS surface and the accretion disc, Comptonized by a corona of hot electrons. The details of the emission (what component is Comptonized) and the geometry of the corona are however still matter of debate. X-ray polarimetry is potentially crucial to constrain the geometry of the system, and hence the physical processes at play. We present results of numerical simulations of the expected polarization performed with the fully relativistic Monte Carlo code Monk, assuming different geometrical configurations.
We will also discuss the observational perspectives in this field after the recent launch of the Imaging X-ray Polarimetry Explorer (IXPE), the NASA/ASI mission launched in December 2021, in particular comparing the results obtained from simulation with the first X-ray spectro-polarimetric observations.

Fiamma Capitanio

The first IXPE observation of a weakly magnetized neutron star X-ray binary GS 1826-238

We report here the results of the first IXPE observation of a weakly magnetized ATOLL source GS 1826--238 performed on 2022 March 29--31. An upper limit as low as 1.3\% on the linear polarization degree is obtained over the IXPE 2--8 keV energy range. The coordinated INTEGRAL and NICER observations were carried out simultaneously with IXPE. The spectral parameters obtained from the fits to the broad-band spectrum were used as inputs for Monte Carlo simulations considering different possible geometries of the X-ray emitting region. Comparing the IXPE upper limit with these simulations, we can put constraints on the geometry and inclination angle of GS 1826-238, lending support to previous claims that the source is viewed at a low inclination.

Ruben Farinelli

The first detection of polarization in the neutron star low mass X-ray binary Cyg X-2

Thanks to its brightness, Cyg X-2 is one of the most studied low mass X-ray binaries (LMXBs) with a weakly magnetized neutron star. Using the IXPE satellite, a polarization of about 1.5% in the 2-8 keV energy band was detected for the first time in this class of sources. Moreover, the polarization angle was found to be aligned with the radio jet which was formerly observed. The values of polarization degree and angle allow after a long time to put serious constraints about the accretion geometry of the soft state of LMXBs. We present spectral and polarimetric results of Cyg X-2 as well as complementary Montecarlo simulations which are fundamental to understand the physics of these astrophysical sources.

Niccolo' Bucciantini

A Polarized View of Relativistic Accelerators: PWNe and PSRs with IXPE

Pulsars and Pulsar Wind Nebulae (PWNe) are the relativistic foremost particle accelerators in the Galaxy, and constitute a unique laboratory where high energy processes, relativistic plasma outflows, and non-thermal radiation can be investigated. In the past years sophisticated Relativistic MHD models of the dynamics and emission of PWNe, have been developed to address the origin of their complex X-ray morphology, and have proved quite successful in reproducing the X-ray data. However, despite their high resolution, current observation cannot address the fundamental question of the small scale magnetic field structure that is so important to understand the physics of these objects. Still more uncertain are the properties and condition on the Pulsar magnetosphere. In recent years, the role of turbulence has been invoked to explain some of the long standing issues of PWN physics, like the origin of the low energy particles, flaring activity and possible particle diffusion. Now, for the first time, X-ray space resolved polarimetric measures on Pulsars and PWNe done with IXPE will enable us to answer these key questions, providing us a unique window into aspect of the internal dynamics otherwise not accessible. I will discuss recent results and findings, in the light of our expectations, of existing MHD simulations, and of PSR magnetosphere emission models, commenting on their impact on our understanding of these sources.

Riccardo Ferrazzoli

IXPE observations of supernova remnants: first results

Young supernova remnants (SNRs) are among the most important sources of non-thermal X-rays in the sky and the likely sources of most of Galactic cosmic rays.

The X-ray synchrotron emission from their shock fronts has been expected to be polarized for some time, with the polarization degree and direction providing unique constraints on the turbulence level and morphology of the magnetic field.

These pieces of information play a crucial role in theories of diffusive shock acceleration with efficient magnetic field amplification in SNRs.

The NASA/ASI Imaging X-ray Polarimetry Explorer (IXPE), that launched in December 2021, is the first mission entirely dedicated to X-ray polarimetry.

Its imaging-capable detectors allow us to perform spatially resolved X-ray polarimetry of extended sources, with SNRs being a prime target.

Here I present the first results obtained from the IXPE observation of the young SNRs Cas A, Tycho, and SN1006.

Romana Mikusincova

X-ray polarimetry as a tool to measure the black hole spin in microquasars: simulations of IXPE capabilities

Abstract: Observing the x-ray black hole binary source GRS1915+105 has been classified as a top priority during the first year of IXPE operation. The primarily occurrence of the source in thermal state makes it the perfect candidate for black hole spin measurements. To credibly assess the source polarimetric properties, we use a multicolor black body emission model accounting for thermal radiation from the disk accretion complemented by self-irradiation of the accretion disk. We simulate the future observations of GRS 1915+105 with IXPE and study the impact of a constant albedo on the polarization properties of the source. We demonstrate the capabilities of the mission and the precision of the black hole spin constraints. GRS1915+105 has been in an obscured state since 2018, and is therefore used as a test source in this study. However, the results obtained from our analysis are applicable to any bright source in thermal state.