

The X-ray Universe 2026

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ABSTRACT BOOKLET

Oral Contributions and Posters

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Chapter 1

Invited Speakers

Unveiling a Kaleidoscope of Fast X-ray Transients with Einstein Probe

Hui Sun¹

¹*National Astronomical Observatories, Chinese Academy of Sciences*

Einstein Probe (EP) is an X-ray mission designed to discover and characterize cosmic X-ray transients through its unique combination of a large field-of-view and unprecedented sensitivity in soft X-rays complemented with a rapid-response follow-up telescope. Since its launch on January 9, 2024, EP has detected approximately 150 fast X-ray transients with durations ranging from seconds to a few hours. Many of these events have been extensively followed up across multi-wavelengths and studied by both EP team and the broader community, thanks to the rapid dissemination of alerts worldwide. Notably, a significant fraction of these transients lacks bright gamma-ray counterparts, despite having gamma-ray detector coverage in their fields during EP detections. A small but growing number of transients were found to be associated with supernovae, suggesting a connection to the core collapse of massive stars. This talk will present scientific highlights from the first two years of EP science operations, focusing on fast X-ray transients and their associations with gamma-ray bursts, supernovae, and compact objects. These findings highlight the pivotal role of EP in unveiling the diversity of fast X-ray transients. Led by the Chinese Academy of Sciences, EP is an international collaborative mission with contributions from ESA, MPE and CNES.

Ultraluminous X-ray Sources: The State of the Art

Dominic Walton¹

¹*University of Hertfordshire, Hatfield, UK*

Ultraluminous X-ray sources (ULXs) are off-nuclear X-ray sources with luminosities that exceed the Eddington limit for typical stellar remnant black holes. This implies either the presence of larger, ‘intermediate mass’ black holes, or systems that have managed to violate their Eddington limits. Thanks to several major breakthroughs, most notably the discovery of a growing sample of ULXs powered by accreting pulsars, we now understand the ULX population to primarily dominated by super-Eddington accretors. The powerful outflows predicted for this accretion regime have now also been observed in a handful of systems. However, plenty of key questions remain unanswered. It is not clear how significantly neutron star accretors contribute to the demographics of the overall ULX population, and it is also not understood how these sources are able to radiate at such extreme levels. Multi-epoch spectroscopy leveraging the broadband coverage from NuSTAR is also revealing some unusual results that are challenging to interpret. I will discuss the current state of this rapidly evolving field, focusing mainly on an observational perspective.

Exploring the Physics of Supernova Remnants with High Energy Resolution

Aya Bamba¹

¹*The University of Tokyo*

The chemical composition and its evolution in our Galaxy are key parameters for understanding the universe. Supernova remnants distribute heavy elements into space and enrich the interstellar space — in other words, SNRs make the diversity of the universe. For the first time, XRISM enables us to measure the quantity and distribution of heavy elements produced by stellar explosions, and as a result, their explosion mechanism. In this paper, we highlight the XRISM first results on supernova remnants and future prospects with NewAthena.

Magnetars, anti-magnetars and everything in between

Alice Borghese¹

¹*European Space Agency/European Space Astronomy Center, Villanueva de la Canada, Spain*

Isolated neutron stars display a remarkable variety of observational behaviours, leading us to group them into several distinct families. In this talk, I will review the main classes that populate this landscape - from magnetars, the most magnetic objects known, to central compact objects, often dubbed 'anti-magnetars', passing through the rotation-powered pulsars and X-ray dim isolated neutron stars. I will then highlight the latest results and how some sources blur the boundaries between these groups, revealing hybrid properties that challenge our current classification. I will conclude with a few considerations about the upcoming NewAthena X-ray mission.

Unlocking the Universe with eROSITA: current achievements and future goals in cluster cosmology

Vittorio Ghirardini¹

¹*INAF OAS Bologna*

By tracing the most prominent peaks in the matter density field of the late time universe, galaxy groups and clusters offer a unique window into the growth of cosmic structure. They provide crucial insights into the nature of dark matter and the fundamental parameters governing the universe's composition and evolution. While historically viewed as a lesser cosmological probe, recent breakthroughs have transformed galaxy clusters into one of our most powerful tools, capable of high-precision cosmological insights. In this talk, I will outline the key factors driving this resurgence, with a specific focus on X-ray cluster detection analyses powered by the eROSITA telescope. Furthermore, I will explore how upcoming developments will cement the role of galaxy clusters at the forefront of future cosmological experiments.

3D radiative-transfer modelling of X-ray absorption and reflection in the era of XRISM

Bert Vander Meulen^{1,2}

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²*Sterrenkundig Observatorium, Ghent University, Ghent, Belgium*

X-ray sources are often surrounded by large amounts of cold gas and dust that obscure and reprocess their X-ray emission, producing complex X-ray spectra with spectral features that encode information on the structure, composition, and physical state of the obscuring medium. The advent of XRISM/Resolve marks a milestone in X-ray astronomy, enabling studies of X-ray absorption and reflection at unprecedented spectral resolution, shedding new light on the structure of AGNs, XRBs, and more.

In this talk, I will present a compilation of XRISM results based on 3D radiative-transfer modelling with the SKIRT code. SKIRT is a state-of-the-art Monte Carlo radiative transfer framework for modelling absorption, scattering, and re-emission in full 3D. SKIRT implements a comprehensive suite of X-ray physics, enabling realistic simulations of X-ray reprocessing at the resolution of XRISM/Resolve, while its computational efficiency enables the calculation of large model grids at high S/N.

Now widely adopted within the XRISM community, SKIRT provides a powerful framework for interpreting high-resolution spectra of obscured X-ray sources. After introducing the SKIRT framework, I will present some recent applications of SKIRT to early XRISM data on well-known X-ray sources such as the Circinus Galaxy, NGC 1068, Cen A, Cen X-3, Eta Car, and more.

Dynamics of hot gas in galaxy clusters: early insights from XRISM

Maxim Markevitch¹

¹*NASA GSFC*

The XRISM observatory, launched 2 years ago with an X-ray microcalorimeter onboard, is producing the first precise measurements of velocities of the hot plasma in galaxy clusters. We already have results for an interesting sample of nearby clusters that includes merging and relaxed systems, where we are probing their cool cores as well as the main hot gas volume. Some of the measurements are puzzling. I will present a brief review of these early results and some preliminary conclusions.

Resolving the innermost regions around supermassive black holes via X-ray reflection and reverberation

Dan Wilkins¹

¹*The Ohio State University, Columbus, OH, USA*

X-ray reflection and reverberation from the innermost regions of the accretion disk provides a unique probe of the extreme environment just outside the event horizon of a black hole. X-rays emitted by a region of particle acceleration close to the black hole known as the corona illuminate the inner disk revealing a wealth of information about these processes, and the properties of the innermost regions of the accretion flow and the black hole itself.

The high-resolution X-ray spectrometer on board XRISM, along with recent advances in the measurement of not just X-ray reflection, but also X-ray reverberation, where variations in the X-ray emission are seen to echo off of the inner accretion disk, are revolutionising our ability to resolve detailed structure of the inner accretion disk and corona. These measurements are giving us new insight into the physics behind rapid black hole growth and AGN feedback. I will discuss how high-resolution X-ray spectroscopy and measurements of reflection and reverberation from the inner accretion disk are revealing not just the structure but the time evolution of the corona, and how X-ray reverberation mapping is providing new measurements of the structure of accretion flows that approach or exceed the Eddington limit.

X-ray driven escape from exoplanet atmospheres

Peter Wheatley¹

¹*University of Warwick, Coventry, UK*

Exoplanets suffer irradiation by X-rays from the coronae their main-sequence parent stars, and it is thought that this XUV irradiation accounts for much of material observed to be escaping from planetary atmospheres. I will review observational evidence for escape from exoplanet atmospheres, including deep transits observed in the ultraviolet and from the meta-stable state of HeI in the near-infrared. I will also show how X-ray observations can constrain atmospheric escape rates and the efficiency of escape. And I will show how X-ray driven atmospheric escape is shaping the observed populations of close-in exoplanets. This includes the origin of the so-called Neptunian desert, and the period-radius valley. Finally, I will show how escaping material can be characterised through X-ray transit observations.

X-ray observations of galactic nuclei in real time

Margherita Giustini¹

¹*Centro de Astrobiología (CAB), INTA-CSIC*

Active galactic nuclei (AGN) are powered by mass accretion onto supermassive black holes (SMBHs) and are bright sources of X-rays. While the study of AGN has been the subject of research for decades, only in the last few years has the field reached the stage where it is possible to study SMBHs 'in real time' (on human timescales) – something that, until a decade ago, was exclusively associated with stellar-mass black holes. This advancement has been made possible by the discovery of changing-look AGN, of an increasing number of tidal disruption events, many of which are partial (repeating), and of X-ray quasi-periodic eruptions. Furthermore, mysterious fast X-ray transients are more and more often observed, and some of them might bring information on the elusive population of intermediate-mass black holes. Altogether these phenomena are helping to advance our understanding of SMBH physics and, consequently, of the growth and evolution of galaxies. I will present an overview of the latest observations of these rapidly varying X-ray sources in galactic nuclei and discuss the evidence for physical connections (or not) among them.

Relativistic jets in galactic accreting systems: observations, energetics, and open questions

Stéphane Corbel¹

¹*Université Paris Cité & CEA Saclay*

Relativistic jets are a fundamental manifestation of accretion onto compact objects and represent one of the most powerful channels through which black holes release energy into their environments. Over the past decades, Galactic X-ray binaries have emerged as unique laboratories for studying the physics of jet formation and evolution on humanly accessible timescales. Multi-wavelength campaigns have revealed a rich phenomenology linking accretion states to dramatic changes in jet properties, from steady compact outflows to powerful transient ejections associated with major accretion events.

Despite this progress, key questions remain open. The physical processes governing jet launching, particle acceleration, and radiative output are still debated, as is the role of jets in the global energy budget of accreting systems. In particular, the coupling between the accretion flow and the jet, and the mechanisms regulating the transition between different accretion states, continue to challenge both observational and theoretical frameworks.

In this review, I will summarize the current observational picture of jets in accreting stellar-mass systems, with emphasis on insights provided by X-ray observations and coordinated multi-wavelength studies. I will discuss recent progress on disk–jet coupling, jet energetics, and variability, and highlight the outstanding issues that future high-sensitivity X-ray missions will address.

XMM-Newton: past, present and future

Norbert Schartel¹

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Over the last 25 years, the XMM-Newton project has undergone significant development. This talk will provide an overview of the scientific drivers behind these changes. It will also review the project's current scientific status. XMM-Newton has great scientific potential for the next decade. The talk will highlight the opportunities that will arise by 2030.

10 years of multi-wavelength FBOTs

Raffaella Margutti¹

¹*UC Berkeley, US*

I will provide a review of the field of Fast and Blue Optical Transients (FBOT) across the electromagnetic spectrum over the 10 years since the first discovery of their bright X-ray and radio emission. Specifically, I will discuss in detail the temporal and spectral properties of FBOTs in the hard and soft X-rays, which are unique among known explosive transients and speculate about its physical origin.

XMM-Newton Observations of Interstellar Object 3I/ATLAS

Carey Lisse¹, Samuel Cabot², Daniel Wang³, Konrad Dennerl⁴, Scott Wolk⁵, Jose Miralles⁶, P.M. Rodriguez⁶, Darryl Seigman⁷

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⁷*Michigan State University*

3I ATLAS is the third macroscopic Interstellar Object (ISO) detected traversing our solar system. We report preliminary images, spectra, and lightcurves from the first ever successful spectrophotometric observations of an ISO in the soft x-ray (0.2-1.0 keV). These observations were obtained ~40 days post-perihelion from 03- to 04-Dec-2025 by XMM/NEWTON, when the exocomet had warmed up appreciably from its Gyr sojourn through interstellar space and was strongly sublimating neutral gas molecules.

From the XMM observations, we conclude the following:

- 3I is an exo-solar comet, of alien solar system origin, acting like one of our own solar system comets in how it interacts via Charge Exchange (CX) with the Solar Wind and emits x-rays.

- We saw variable x-ray emission from 3I as the normal solar wind waned and a flare overtook the ISO.

- X-ray measurements of 3I can provide an independent measure of $Q_{\text{gas}} \sim 10^{-28}$ molec/sec being emitted from the exocomet, and provide a demonstration of XMM's ability to detect an Oumuamua-like object down to $Q_{\text{gas}} \sim 10^{-26}$ molec/sec.

- Imagery of 3I's x-ray emitting region, when compared to contemporaneous large scale SPHEREx neutral gas coma imaging, may provide information on how emitted cometary molecules are destroyed (via CX vs. solar UV photolysis).

Chapter 2

Solicited Speakers

Multiphase accretion disc winds from X-ray binaries

Teo Muñoz-Darias¹

¹*Instituto de Astrofísica de Canarias*

X-ray binaries offer a unique opportunity to study accretion in relatively clean environments and on human-accessible timescales—much shorter than those typical of AGN and quasars. Over the past few decades, the coupling between accretion and ejection processes in these systems has been extensively investigated, primarily through X-ray and radio continuum observations. More recently, systematic studies of their X-ray, ultraviolet, optical, and infrared spectral lines have revealed the presence of accretion disc winds, showing that substantial amounts of both hot and cold gas are expelled from these systems. In this talk, I will highlight key observational advances of this rapidly evolving field, with emphasis on the likely multi-phase nature of the phenomenon and its possible impact on the dynamics of the accretion disc.

5XMM-DR15 : the latest XMM-Newton catalogue, with new products to facilitate your science

Natalie Webb¹, Iris Traulsen², On behalf of the XMM-SSC¹

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²*Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany*

5XMM-DR15 is a completely new version of the XMM-Newton catalogue composed from almost 25 years of XMM-Newton EPIC data. It includes 818,816 unique X-ray sources, observed 2,578,752 times, with some objects observed as many as 98 times, amounting to 2.7 Ms of exposure per source. This new version of the catalogue has been produced following a full reprocessing of the data made with the most recent calibration and software. It includes many new products with respect to the 4XMM catalogue, including improved data stacking procedures, revealing the faintest sources detected to date, the Optical Monitor counterparts, along with other multi-wavelength data, spectral fits, source classification, photometric redshifts and decades-long variability. We will present the catalogue for the first time and show some of the AGN, X-ray binary and stellar science that is now possible using only the catalogue data.

A New Sample of Transient Ultraluminous X-Ray Sources Serendipitously Discovered by Swift/XRT

Murray Brightman¹
¹ *Caltech*

Ultraluminous X-ray sources (ULXs) are our best laboratories for studying extreme super-Eddington accretion. Most studies of these objects are of relatively persistent sources; however, there is growing evidence to suggest a large fraction of these sources are transient. I will present a sample of five newly reported transient ULXs in the galaxies NGC 4945, NGC 7793, and M81 serendipitously discovered in Swift/XRT observations. Swift monitoring of these sources have provided well-sampled lightcurves, allowing for us to model the lightcurves with the disk-instability model of Hameury & Lasota, which implies durations of 60-400 days and that the mass-accretion rate through the disk is close to or greater than the Eddington rate. Of the three source regions with prior Hubble Space Telescope imaging, color-magnitude diagrams of the potential stellar counterparts show varying ages of the possible stellar counterparts. Our estimation of the rates of these sources in these three galaxies is 0.4-1.3 yr⁻¹. We find that, while persistent ULXs dominate the high end of galaxy luminosity functions, the number of systems that produce ULX luminosities are likely dominated by transient sources.

A XRISM view of chemical enrichment in galaxy clusters

François Mernier¹
¹ *IRAP, CNRS, Université de Toulouse, CNES, UT3-UPS, Toulouse, France*

An essential component of the cosmic cycle of metals is found in the hot, X-ray emitting gas pervading clusters (and groups) of galaxies and the cosmic web. On paper, the collisional ionisation equilibrium of the intracluster medium (ICM) allows extraordinarily accurate measurements of its abundances. In turn, these measurements offer the potential of a thorough understanding of the chemical history and dynamics of our Universe, as well as of the mechanisms of metal production through stellar nucleosynthesis and supernova explosions. In practice, however, the moderate spectral resolution of the latest generation of X-ray missions has limited the ICM abundance accuracy.

In this talk, we demonstrate how the high-resolution spectroscopy offered by XRISM Resolve is changing this paradigm and transforms our understanding of chemical enrichment in the ICM. The talk will focus essentially on the chemical composition (and its spatial distribution) of the Centaurus and the Perseus cluster cores, both observed very deeply (379 ks and 287 ks, respectively) during the XRISM Performance Verification phase. We will also discuss the potential (and current challenges) of XMM-Newton RGS to complement Resolve in ICM abundance studies.

The XRISM view of stars

Yael Naze¹
¹*FNRS/ULiege*

Stars are well-known X-ray sources. While numerous advances have been made in the last two decades, the high spectral resolution of XRISM is now putting the stellar X-ray emission under a fresh new light, providing direct insights into the plasma physics. Recent results on colliding winds, coronal sources, and accretion in binaries will be reviewed in this talk.

The realm of powerful outflows in ultraluminous X-ray sources

Ciro Pinto¹, Francesco Barra¹, Simona Caserta², Peter Kosec³
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²*Università degli Studi di Palermo, Italy*
³*CfA - Harvard & Smithsonian, Cambridge, MA, USA*

Most stars exist in binary systems, with many acting as interacting pairs where matter flows from a companion onto a compact object, forming an accretion disc that emits across the spectrum, peaking in X-rays. Ultraluminous X-ray sources (ULXs) represent the most extreme examples, reaching luminosities hundreds of times above the Eddington limit of a neutron star (10^{41} erg/s). Recent discoveries of pulsations, soft X-ray spectra, and relativistic winds (up to 30% speed of light) indicate that most nearby ULXs are powered by neutron stars or stellar-mass black holes accreting well above their theoretical limits. These winds regulate accretion and drive the formation of the 100-pc nebulae observed around many sources. This may also explain the transient nature of many ULXs. Despite progress, crucial questions remain regarding spectral transitions, the population distribution of black holes versus neutron stars, and wind structure. This talk provides an overview of the field, highlighting recent findings and demonstrating how future missions, notably NewAthena, will revolutionise our understanding of ULXs.

Gamma-ray bursts at the extreme

Andrew Levan^{1,2}
¹*Radboud University*
²*University of Warwick*

Gamma-ray bursts (GRBs) are typically defined as outbursts of radiation lasting from milliseconds to a few minutes. However, over the past decade, there has been a gradual increase in the population of bursts with far longer durations, extending to several hours, and at times with evidence of an engine that can input energy into the explosion for days. I will review the status of our understanding of these ultra-long duration GRBs, and focus in particular on new insights that have become possible thanks to the unique, repeating GRB 250702B, whose properties appear to be unlike any of the 10,000 GRBs seen before.

Two years of high-energy transients with the SVOM mission

Sebastien Guillot¹

¹*IRAP, U. of Toulouse*

Launched in June 2024, SVOM is a Chinese-French space mission dedicated to the study of Gamma-Ray Bursts (GRBs) and other high energy transient phenomena. The satellite carries a gamma ray spectrometer (15 keV to 5 MeV), a wide-field coded-mask hard X-ray imager (4-150 keV), a soft X-ray telescope (0.2-10 keV) and a dual-channel visible telescope (400-650 nm and 650-1000 nm). This instrumentation permits detection and localisation of transient emission in multiple bands and alert transmission within minutes. SVOM also includes a ground segment composed of wide-angle cameras and two 1-m class robotic telescopes. The pointing strategy of the satellite is optimized for GRB detection in the night hemisphere, to enable optical observations with robotic telescopes within minutes, and within hours for early spectroscopy of the optical afterglow with large telescopes to measure the redshifts. In addition to the GRB core program, SVOM detects other types of high-energy transients: quasars, X-ray binaries, magnetar and thermonuclear bursts. It also includes a general program of pointed observations. Finally, the ToO program responds to alerts from other multi-wavelength and multimessenger instrumentation. I will briefly present the mission (instruments, operations, science capabilities), but the presentation will focus on the past two years of scientific results.

The Hot Phase of the Milky Way: from eROSITA to XMM-Newton

Gabriele Ponti^{1,2,3}

¹*INAF Osservatorio Astronomico di Brera*

²*Max-Planck-Institut für extraterrestrische Physik*

³*Como Lake Center for Astrophysics, Università degli Studi dell'Insubria*

The hot phase of the circumgalactic (CGM) and interstellar medium (ISM) plays a central role in regulating gas flows and feedback in galaxies. In this talk, I will review recent progress in our understanding of the hot baryonic component of the Milky Way, driven by the eROSITA all-sky survey. I will present new constraints on the structure and physical properties of the hot CGM, the characterisation of the Galactic outflow, and the nature of the so-called “super-virial” CGM emission component. I will show that a significant fraction of this emission is produced by unresolved populations of low-mass stars, leading to a revised view of the hot halo.

I will then highlight how large and sensitive XMM-Newton surveys of the Galactic disc provide the key link between the hot CGM, the hot ISM, and X-ray source populations, enabling us to trace the connection between large-scale gaseous structures and their energy sources in the Galactic centre and inner disc. These results establish, at high resolution, a coherent picture of the multi-phase Galactic ecosystem, providing a benchmark for understanding the baryon cycle in Milky Way-like galaxies.

Galaxy Clusters as Seen with XRISM: Gas Motions and Core Structure

Naomi Ota¹

¹*Nara Women's University/AIfA Bonn*

XRISM is opening a new window on the intracluster medium through high-resolution X-ray spectroscopy, enabling direct measurements of gas motions in galaxy clusters. In this talk, I will present recent XRISM observations of galaxy clusters, with particular emphasis on cool-core systems, where XRISM allows us to probe the physical state of the gas in unprecedented detail. Using observations including A2029 as a key example, I will discuss constraints on gas motions in cluster cores and their implications for non-thermal pressure support and the dynamical state of the intracluster medium. I will place these results in the broader context of cool-core clusters, including the role of gas sloshing as a potentially common and dynamically important feature. I will also compare these results with observations of nearby clusters and with expectations from numerical simulations, including TNG cluster simulations, highlighting emerging insights into the structure of cluster cores.

Probing Magnetic Fields in Young Supernova Remnants with IXPE

Patrick Slane¹

¹*Center for Astrophysics — Harvard & Smithsonian, Cambridge, MA, USA*

Particle acceleration by shocks in supernova remnants is believed to produce a significant fraction of Galactic cosmic rays up to energies of hundreds of TeV. Direct signatures of the electron component of this relativistic particle population is observed in the form of X-ray synchrotron radiation. The acceleration process itself is understood to amplify magnetic fields, and the geometry and levels of turbulence in those fields strongly impact the efficiency of the acceleration. The magnetic field structure, in turn, can be modified by both the ambient medium and the accelerated particles themselves.

Synchrotron emission from the shock regions - through its polarization - provides crucial details about the magnetic field strength and orientation. Measurements of the field geometry and the levels of turbulence thus provide unique insights into the conditions leading to particle acceleration in fast shocks.

The Imaging X-ray Polarimetry Explorer (IXPE) has carried out observations of multiple young SNRs. These measurements of magnetic field properties show some common behavior, but also considerable differences between these SNRs. Here I provide a summary of results from IXPE studies of young SNRs, providing comparisons between the observed polarization and the physical properties of the remnants and their environments.

Galaxy-AGN co-evolution studies with eROSITA, SDSS-V and future multiwavelength spectroscopic surveys

Johannes Buchner¹

¹*Max Planck Institute for Extraterrestrial Physics*

I will summarize some recent discoveries of the eROSITA AGN working group enabled by the large AGN samples discovered by eROSITA's X-ray all-sky spectroscopic survey and characterized by optical spectroscopic surveys such as SDSS-V. Taken within four days, the pilot survey of eROSITA, eFEDS, revealed a diverse sample of over 20000 AGN. SDSS spectroscopy combined with sophisticated modelling techniques gives access to black hole mass estimates. The new multi-wavelength SED analysis code GRAHSP yields unbiased host stellar mass estimates even for luminous AGN. Combining these techniques reveals over-massive black holes (OMBHs) with 10x larger black hole masses than typical Milky-Way-mass galaxies. The discovery of abundant OMBHs at $z \sim 1$ is at odds with an interpretation of OMBHs as seed remnants and the tight correlations in galaxy evolution simulations. The subsequent 2 years of data taken in the eROSITA all-sky survey also provided a wealth of X-ray data. Rest-frame X-ray spectral stacks of SDSS quasars revealed the soft excess spectrum as a function of black hole mass, Eddington ratio, X-ray to UV luminosity ratio. The future is bright: With 4MOST, SphereX, Euclid and LSST, AGN multiwavelength spectroscopic surveys enable precision AGN-galaxy co-evolution studies and can reveal unusual modes of AGN accretion.

X-rays from Tidal Disruption Events: Accretion Theory

Andrew Mummery¹

¹*Institute for Advanced Study, Princeton*

When a star is torn apart by the tidal forces of a supermassive black hole – a so-called tidal disruption event (TDE) – it initiates a transient accretion episode onto the black hole, affording us the opportunity to study the onset and evolution of supermassive black hole accretion flows on human timescales. I will provide an overview of our current theoretical understanding of the production and evolution of X-rays in tidal disruption events, while also discussing recent results regarding analogies between TDE and X-ray binary disk evolution, with a focus on state transitions. I will finish with an overview of how TDEs provide the cleanest probes of near horizon accretion physics of any SMBH systems, and may in the future offer insight into the mass and spin distributions of black holes.

Chapter 3

Stars, White Dwarfs, Solar System, Exoplanets and their Host Stars

Preparing for the Next High-Energy Survey Era: Deep Learning Classification of Galactic X-ray Stars

Pooja Sharma¹, Ada Nebot²

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²*Adjoint Astronomer, Observatory of Strasbourg, France*

Population studies of X-ray-emitting stars are increasingly enriched by the growing scale and complexity of modern MWL surveys. We have combined XMM-Newton X-ray source properties with Gaia astrometry and photometry to identify 25,915 reliable counterparts using the ARCHES cross-matching tool. We found that over 50% of the sample remains unclassified, underscoring the need for automated methods ahead of upcoming data from eROSITA and NewAthena. We present a machine-learning framework to characterise the Galactic stellar X-ray population in a homogeneous and scalable manner using catalogue-level MWL data products and derived physical quantities. Using archival Simbad classifications to define training labels, we train a deep neural network to classify sources into five stellar categories: Main Sequence, Young, Evolved, Binary, and Peculiar systems. The resulting classifier achieves an overall accuracy of 77%, demonstrating the potential of deep learning to extend reliable classifications. We found that the model recovers mean X-ray luminosity trends accurately across well-sampled classes, while variance is underestimated for rare or sparsely populated populations. Finally, we show how physics-informed self-supervised machine-learning approaches can improve performance and prepare for the next generation of large-scale high-energy MWL/MM surveys.

Spatially and spectrally-resolved X-ray emission of the eclipsing CV UU Aqr

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Non-magnetic Cataclysmic Variables (CVs) show two distinct X-ray components: a hard, optically thin component and a soft, optically thick, blackbody-like component, both produced in the boundary layer between the accretion disk and the White Dwarf (WD). An additional soft component originating from a more extended region has been reported in few CVs. Using observations with NuSTAR and the XMM-Newton, we detect total eclipses in the orbital intensity profiles of this system in the hard X-ray band (3–10 keV with XMM and 3–25 keV with NuSTAR). However, the soft X-ray band (0.3–2.0 keV) shows no evidence of an eclipse. Detailed eclipse modeling, energy-resolved power spectral analysis and broadband spectral modeling indicate that the hard absorbed X-ray emission originates from a compact region near the WD, such as a boundary layer, while the soft, unabsorbed and un-eclipsed X-ray emission originates in an extended region. Neither scattering of hard X-rays nor colliding winds can account for the observed un-eclipsed soft emission. We instead propose that this component is produced by shocks within vertically extended, radiatively driven accretion-disk winds. We also provide new estimates on the emitting regions, mass and radius of the WD and the donor star using eclipse modeling.

Exploring High-Energy Signatures of the Most Exotic Massive Stars in Westerlund 1 with EWOCS

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Massive stars play a crucial role in the evolution of galaxies through their powerful winds, eruptions, and explosive deaths. Their short-lived evolutionary phases, however, remain poorly understood, requiring detailed observations of coeval stellar populations. The young and super-massive Galactic cluster Westerlund 1 provides a unique laboratory to investigate these processes, hosting the largest known sample of Wolf-Rayet (WR) stars as well as rare and peculiar massive stars. In this talk, I will present our results on the most powerful massive stars, using a very deep (1Msec) Chandra observation from the EWOCS (Extended Westerlund 1 and 2 Open Clusters Survey) project. I will present their X-ray properties including spectral and timing characteristics and the role of colliding winds in shaping their emission. These results provide valuable information on the role of binarity and mass transfer in stellar evolution, particularly in the rich and complex environment of Westerlund 1.

Mapping habitable zones with SRG/eROSITA

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Stellar high-energy radiation plays a crucial role in shaping exoplanetary atmospheres and influencing long-term habitability. In this talk, I will present a comprehensive analysis of the X-ray and extreme-ultraviolet (XUV) radiation environments of 3,750 main-sequence stars observed in the SRG/eROSITA all-sky survey and cross-matched with Gaia DR3. Using X-ray spectral fits from the eROSITA catalog, we derive stellar X-ray and EUV luminosities and estimate the corresponding XUV fluxes at their habitable zones, finding that most stars in the sample are significantly more active than the Sun, with fluxes spanning several orders of magnitude. Cooler, magnetically active stars show particularly high $L(\text{XUV})/L(\text{bol})$ ratios, pointing to potentially hazardous environments for orbiting planets. By applying an energy-limited escape model, we estimate atmospheric mass-loss rates for Earth-like planets and construct local maps (out to 500 pc) highlighting regions where stellar irradiation may strongly affect atmospheric evolution. These results demonstrate the power of X-ray surveys to characterize the high-energy environments of nearby planetary systems and provide new insights into the role of stellar activity in planetary habitability.

Diagnostics of plasma in multiple coronal mass ejections using geocoronal solar wind charge exchange with XRISM/Xtend

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We report an analysis of an enigmatic solar wind charge exchange (SWCX) event observed in August 2024, a period when multiple coronal mass ejections (CMEs) arrived near Earth. SWCX is a phenomenon in which highly ionized ions capture electrons from neutral atoms in Earth's exosphere and emit X-rays as they cascade into the ground state. SWCX provides a diagnostic for CME plasmas, however, previous X-ray missions lacked the field of view (FOV) and sensitivity to detect heavy elements such as Mg and Si. The Xtend instrument onboard XRISM features a remarkably low background and a large FOV ($38.5' \times 38.5'$), providing unprecedented sensitivity to extended emission. Using the Xtend data, we extracted two periods: the first corresponding to CMEs from M-class flares, and the second to a CME from an X-class flare. Through time-resolved spectral analysis of these periods, we detected spectral variations in emission lines of Ne, Mg, Si, and Fe with high significance ($> 10\sigma$). The ionization temperatures derived for each period exhibited a positive correlation with the peak X-ray intensities of the corresponding solar flares. Furthermore, the oxygen-normalized elemental abundances showed signatures of the inverse first ionization potential effect, characterized by depleted Si and S.

The retention of carbon molecules in XUV-irradiated sub-Neptune atmospheres

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High-energy (XUV) radiation from exoplanet host stars strongly influences the chemistry and escape of exoplanet atmospheres. Yet the response of key carbon species, especially CH₄ and CO₂, to stellar X-ray irradiation remains poorly constrained. We present a new multi-wavelength program that combines X-ray observations of host stars with infrared transmission spectroscopy of their planets to link stellar high-energy conditions with atmospheric carbon chemistry in super-Earth and sub-Neptune systems. We pair X-ray flux measurements with observations of CH₄ and CO₂ abundances to constrain upper-atmosphere thermal structure and photochemistry, and to test models of hydrodynamic escape and disequilibrium chemistry. We will report results from our pilot system, K2-18, 100 ks X-ray observations from XMM-Newton with recent IR transmission spectra to evaluate methane stability under moderate XUV irradiation. We also present early results from a coordinated XMM-Newton and VLT/CRIRES+ campaign targeting HD 21520, providing simultaneous constraints on stellar XUV irradiation and planetary atmospheric composition. Together, these observations provide a clear way to interpret atmospheric escape and to assess whether potential biosignature gases can persist in strongly irradiated environments.

Chromospheres and coronae in time, a new framework for stellar high-energy emission

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Coronal X-ray emission is one of the most prominent features of stellar magnetic activity, yet it represents only one facet of the high-energy emission of low-mass stars. Because chromospheres contribute equally important, a comprehensive picture of the stellar high-energy emission must include both components.

I will present results from combining two of the largest surveys: X-ray detections from eROSITA and Ca II IRT activity from Gaia RVS spectra. I will specifically describe how coronal and chromospheric emissions are related as a function of spectral type and activity level, and how new data from 4MOST will help to complete our picture of the stellar high energy emission.

Finally, I will demonstrate how such a holistic approach can be used to synthesize the long-term evolution of stellar high energy emission, which has profound implications for the development and stability of planetary atmospheres, as time-variable high-energy irradiation directly influences atmospheric photochemistry and escape rates.

The impact of X-rays on the model atmospheres of hot stars

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Quantitative spectral analyses of hot stars and their winds require adequate model atmospheres that account for non-LTE physics and spherical expansion, such as our Potsdam Wolf-Rayet (PoWR) code.

Hot stars are ubiquitously emitting X-rays, and it is generally assumed that their sources are embedded within the stellar wind. Using PoWR, we demonstrate on this poster the drastic impact of such X-ray fields on the emergent spectra of O- and B-type stars, in particular on the prominent P-Cygni profiles of UV resonance lines. Without including an X-ray field, certain spectral features - such as the O VI resonance doublet - would not appear at all.

We further show that the predicted spectra depend to some degree on the assumed properties of the X-ray emitting plasma, whether it is represented by a single-temperature component or by a distribution of temperatures along a full cooling sequence, described by a differential emission measure.

The impact of periastron passage on the X-ray and optical properties of the symbiotic system R Aquarii

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Symbiotic stars are excellent laboratories for studying accretion in non-relativistic regimes. In these interacting binaries, a white dwarf accretes material from the wind of a late-type giant, forming an accretion disc and a boundary layer where the accreted gas couples to the stellar rotation, producing X-ray emission. We present a multi-epoch X-ray study of the symbiotic system R Aquarii based on observations obtained with Chandra and XMM-Newton spanning 22 years (2000–2022), roughly half the orbital period. Using a component-based analysis, we disentangle soft emission from the jet and extended structures, a heavily absorbed thermal plasma from the boundary layer, and a reflection component explaining the 6.4 keV iron fluorescent line. We trace the evolution of the hard X-ray emission and evaluate the role of reflection in the disc. The hard emission variability is dominated by boundary-layer and reflected components and is closely linked to orbital phase. Optical observations reveal an anticorrelation between hard X-ray flux and disc luminosity. Radiative transfer models including X-ray physics constrain the disc geometry, physical conditions, and mass-accretion rates, providing a coherent multiwavelength view of accretion in symbiotic systems.

UV catalogue of serendipitous asteroid observations with the Optical Monitor of XMM-Newton

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The near-ultraviolet (NUV) spectral region provides key constraints on asteroid surface composition, particularly for primitive bodies where UV absorption is linked to hydrated minerals and space-weathering processes. GALEX observations demonstrated significant taxonomic differences in NUV–visible colours of asteroids, highlighting the diagnostic value of this wavelength range. However, UV measurements of asteroids remain limited and underexploited in archival datasets.

We present a catalogue of serendipitous asteroid detections obtained with the Optical Monitor (OM) onboard XMM-Newton, based on the SSOSS OM catalogue by Racero et al. 2022. We developed a semi-automatic pipeline that performs geometric cross-matching between asteroid ephemerides and OM imaging footprints, followed by archive retrieval, visual screening, astrometric validation, and calibrated aperture photometry in the AB system with full uncertainty propagation. The analysis targets observations including both NUV and optical exposures within a single visit, enabling quasi-simultaneous UV–optical colours. Our results show that archival OM data provide robust UV photometry of moving Solar System objects and extend GALEX-based studies toward complementary NUV wavelengths, offering new constraints on asteroid reflectance behaviour.

Long and short-term behaviour of gamma Cas analogs

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The subcategory of gamma Cas analogs gathers Be stars with a bright and hard X-ray emission, now understood to arise from accretion onto a WD companion of the Be star. Such systems display variability on various timescales. For 7 targets, we analyse multiwavelength monitorings combining optical spectroscopy, optical photometry, and X-ray data. This leads to the first orbital solutions for 5 new systems and shows how X-ray and optical fluxes correlate. In parallel, the full set of available X-ray data was examined to characterize short-term variations. We found "flickering" compatible with CV-like activity and stable periodicities possibly linked to the WD rotation.

Chapter 4

Accreting White Dwarf, Neutron Star and Black Hole binaries & ULXs

Identification of three new ultraluminous X-ray sources in NGC 4631 and NGC 1097: Evidence for stellar-mass black holes

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We investigate the ULX populations in NGC 4631 and NGC 1097 using archival Chandra, XMM-Newton, and Swift/XRT observations to identify new systems and constrain the nature of their compact objects and donor stars. We analyzed X-ray data obtained between 2000 and 2025. Spectral modeling was performed with absorbed power-law and diskbb models for sources with sufficient counts, and variability was examined through light curves and hardness-intensity diagrams. Optical color-magnitude diagrams and near-infrared spectral energy distributions were used to characterize potential donor stars.

In NGC 4631, we discovered two new transient ULXs, X-6 and X-7, both varying by more than an order of magnitude in count rate. For X-6, the relation $L_X \propto T^4$ supports accretion through a standard disk around a stellar-mass black hole. Optical counterparts within the X-ray error regions suggest high-mass X-ray binary candidates. In NGC 1097, we identified a new transient ULX, ULX-3, with luminosity variations of a factor of about 30 and evidence of spectral state transitions, consistent with either a stellar-mass black hole or a neutron star. Its near-infrared emission is stable and consistent with a red supergiant donor with a temperature of ~ 3300 K and a radius of $\sim 200 R_\odot$.

Iron fluorescent emission as a tracer of reprocessing environment in X-ray Binary Pulsars

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Strong iron fluorescence lines are ubiquitous in HMXBs. We systematically studied bright HMXB pulsars like GX 301-2, Vela X-1, and Cen X-3, which have strong iron emission lines. The high collecting area and excellent spectral resolution of XMM-Newton allow us to distinguish the neutral and ionised iron emission lines and to perform a detailed study of their spin variations. Spin phase dependency is expected in the presence of inhomogeneous matter distribution close to the NS, such as a temporary accretion disc or an accretion wake, along with clumpy winds from the companion star. In GX 301-2, we find an additional periodicity in the strong iron $K\alpha$ fluorescent emission, most likely produced by a clump of wind material in a Keplerian orbit around the NS. In the case of Cen X-3, we observe a spin variable component from all the iron $K\alpha$ and the $K\beta$ emission lines, which can be formed when the accretion stream in the NS cuts the line of sight of the observer. For Vela X-1, we observe orbital phase dependence in the spin-modulation of the iron emission line, which may be caused by the presence of a photoionisation wake in the system.

Accreting Millisecond X-ray Pulsars: An Observational Overview

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Low-mass X-ray binaries are interacting stellar systems in which a compact object accretes matter from a low-mass companion, radiating most of the liberated gravitational energy in the X-ray band. They provide a unique laboratory to investigate accretion physics, strong gravity, and radiative processes under extreme conditions. In this contribution, I will briefly introduce the phenomenology of low-mass neutron-star X-ray binaries and explain why they are key targets for studying the interplay among gravity, rotation, magnetic fields, and radiation.

I will then focus on accreting millisecond X-ray pulsars (AMXPs). This small but particularly informative subclass displays coherent pulsations produced by magnetically channelled accretion onto rapidly rotating neutron stars. I will review their main observational properties, including pulse phenomenology, broadband variability, and their behaviour across outburst stages, highlighting what we can learn about the accretion flow, hotspot formation, and the coupling between the inner disc and the stellar magnetosphere. Finally, I will discuss AMXPs in the broader evolutionary context as the natural link between accreting neutron stars and recycled radio millisecond pulsars, and outline open questions for which current and future high-energy facilities can deliver decisive progress.

Quiescent low-mass X-ray binaries are back - New M-R measurements from 47Tuc X7

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Neutron stars (NSs) have been heavily investigated to better understand matter and its behavior in extreme density conditions. In particular, measurements of their masses and radii allow us to investigate the equation of state (EOS) of this matter, which otherwise relies on nuclear physics theory. In this talk, we focus on NSs in quiescent low-mass X-ray binaries (qLMXBs). These systems have been used in the past for such measurements, but various sources of systematic uncertainties were put forward, possibly biasing the radius values by as much as 50%. I will describe a new method to constrain masses and radii of qLMXBs, inspired from pulse-profile modeling (PPM) of millisecond pulsars (MSPs), and accounting for known sources of uncertainties inherent to these systems to obtain more robust constraints on the radii. Using archival Chandra observations of the qLMXB 47Tuc-X7, we include the effects of rotation and of possible un-detected surface temperature anisotropies in the spectral modeling, to infer constraints on the parameters. I will show that mass-radius constraints are not significantly broadened by the addition of these effects. This new approach will allow to diversify the classes of neutron stars used for EOS studies alongside PPM of MSPs or NS-NS mergers.

The End of a 50-Year Search? A Candidate Optical Counterpart to the Rapid Burster in the Bulge fossil fragment Liller1

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The Rapid Burster MXB 1730-335 is a peculiar system discovered in 1976. It is a unique LMXB since it shows both type-I and type-II X-ray bursts. For about 50 years, despite a few attempts to search it, the optical/infrared counterpart remained undetected, mainly because of the challenging location in the innermost region of the largely extincted and crowded complex stellar system Liller 1.

In this talk I will report the possible identification of the optical counterpart. The identification was performed by taking advantage of a set of images acquired with the Hubble Space Telescope/Advanced Camera for Surveys in the optical band, and with the Gemini South Telescope in the near-infrared. The analysis of these images revealed a star with a position that might be compatible with the X-ray and radio-band coordinates of the Rapid Burster, and it varies significantly in the optical. According to its location in the color-magnitude diagram, the candidate companion appears to belong to the young (only ~ 1 -2 Gyr old) supersolar metallicity ($[M/H]=+0.3$) subpopulation recently discovered in Liller 1.

Finally, I will also discuss the need for further observations to confirm the association with the X-ray source and to better clarify the physical properties of the system.

Low-luminosity X-ray pulsations from an accreting millisecond pulsar: An ever-thinning thread between bright accretion and subluminous states

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A never-ending competition takes place around rapidly spinning, weakly magnetized neutron stars in low-mass X-ray binaries. Inflowing matter spirals inward and, during outburst, is channeled along the neutron star's magnetic field lines onto its magnetic poles, producing coherent X-ray pulsations. As the accretion rate declines, the rotating magnetosphere pushes back, halting accretion and switching off pulsations in the so-called “propeller” regime. In fast-spinning systems, this transition is particularly sensitive to small variations in the mass accretion rate. I will present an XMM-Newton Target of Opportunity observation of an accreting millisecond pulsar at the end of its 2025 outburst, complemented by radio and archival Chandra data. We detect X-ray pulsations with a remarkably high amplitude at a luminosity level where centrifugal inhibition of accretion is traditionally expected to dominate. This result challenges the standard accretion-propeller boundary and reveals an ever-thinning thread between bright accretion and subluminous disk states. Low-luminosity pulsations have been rarely observed, primarily due to instrumental sensitivity limits. This is set to change thanks to the advent of new-generation X-ray facilities, such as Einstein Probe, which are opening a new observational window on this faint accretion regime and the interplay between accretion flows and neutron star magnetospheres.

Double-hump spectrum, pulse profile dip, and pulsed fraction spectra from the low-accretion regime in the X-ray pulsar

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Accreting X-ray pulsars (XRP) undergo different physical regimes depending on mass accretion rate. Recent observations have shown a dramatic change in the emission properties of XRP at low luminosity. We explore timing and spectral properties of the XRP MAXI J0655-013 we recently observed in the low-luminosity regime (5×10^{33} erg/s) with XMM+NuSTAR. We explore several spectral models and study the pulsating nature of the source, finding a phase-connected timing solution. We explore the energy-resolved pulse profiles and the pulsed fraction energy-dependence. We also obtain NuSTAR pulsed fraction spectra (PFS) at different luminosities. MAXI J0655-013 spectrum is well fitted by a double Comptonization model, in agreement with recent observational results and theoretical expectations that explain the observed spectrum as being composed of two distinct bumps, each dominated by different polarization modes. We measure a spin period of 1081.86 ± 0.02 s, consistent with the source spinning-up compared to previous observations, yielding an upper limit for the magnetic field strength of $B < 9 \times 10^{13}$ G. Pulse profiles show a single broad peak interrupted by a sharp dip that coincides with an increase in the hardness ratio. The PFS obtained at high luminosity shows evidence of an iron 6.4keV emission line but no indications of a cyclotron line.

Discovery of ULX-like winds during the 2019 outburst of RX J0209.6-7427

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Accretion onto compact objects naturally leads to the launch of disc winds. These outflows are observed in Galactic X-ray binaries and are even more pronounced in extragalactic systems, which exhibit extreme luminosities such as ultraluminous X-ray sources (ULXs), whose winds approach relativistic velocities. At larger distances, however, their detection remains limited, and the physical mechanisms that drive these winds are difficult to constrain in detail. RX J0209.6-7427 provides an exceptional nearby laboratory to investigate super-Eddington accretion and associated relativistic outflows. This transient ultraluminous X-ray pulsar in the Small Magellanic Cloud underwent an outburst in 2019, during which it crossed the Eddington limit and exceeded a bolometric luminosity of 10^{39} erg/s. Using XMM-Newton data, we detected highly significant emission and absorption lines. We model these features by systematically exploring the velocity-temperature parameter space with state-of-the-art photoionisation and collisional-ionisation models. The results suggest a multiphase photoionised plasma composed of a rest-frame emitting gas and two blueshifted absorbing components with velocities of 0.1c and 0.2c. These components share properties with the outflows commonly observed in canonical extragalactic ULXs. In this presentation, I will discuss these results along with those obtained through our recent very large (1 Ms) XMM-Newton programme on ULXs.

Shock physics in novae revealed by charge exchange X-ray emission

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The X-ray spectra of novae usually exhibit an absorbed continuum, emission lines, or a combination of both, yet the origin and identification of many of these spectral features remain poorly understood.

We present a detailed spectral analysis of three novae. The first, YZ Ret 2020, reveals a unique X-ray signature of charge exchange (CX) emission from carbon and nitrogen. This is interpreted as arising from strong mixing between hot ions in the shock-heated ejecta and neutral atoms in the surrounding cold medium. We also observe narrow radiative recombination continua (RRCs), produced by interactions between hot ions and cold electrons. This constitutes an unambiguous detection of CX emission outside the solar system. Building on this discovery, we developed a dedicated analysis method for X-ray spectra of novae, which we subsequently applied to nova Sco2023 and to the recurrent nova RS-Oph (2006 and 2021 outbursts). High-resolution X-ray grating spectra of RS-Oph contain numerous previously unidentified lines, which we identify as CX emission from L-shell ions of Si, S, and Ar, another phenomenon uniquely observed in novae. These results highlight the diagnostic power of high-resolution X-ray spectroscopy and establish novae as excellent laboratories for studying shock physics and plasma interactions under extreme conditions.

The population of old Galactic novae as observed by the eROSITA All Sky Survey

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Nova eruptions are thermonuclear explosions on accreting white dwarfs in cataclysmic variable systems. The accreted envelope is ejected at thousands of km/h without the disruption of the progenitor system. Therefore, novae are recurrent events, with recurrence periods ranging from 1 to 10,000 years. Details of the explosion depend, among other factors, on the mass of the white dwarf and the accretion rate history between nova outbursts. The energetic explosion and ejection of matter are expected to disrupt the accretion disk and affect both the donor mass-transfer rate from the companion star and the accretion rate onto the white dwarf. However, observational constraints on these effects remain scarce, with most novae observed only in outburst.

The eROSITA All-Sky Survey has opened a new window for studying the X-ray properties of novae long after their eruptions, when the X-ray emission reflects ongoing accretion and can provide insight into the magnetic nature of the white dwarf. Using data from the eROSITA all-sky survey, we have conducted a population study of Galactic old novae in X-rays. We identify new magnetic candidates among old nova systems and, for the first time, place observational constraints on how the accretion rate evolves after a nova event.

PHANGS-X: Putting X-ray Emission in Nearby Galaxies into Context with Panchromatic, High Angular Resolution Data Sets

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The Physics at High Angular resolution in Nearby Galaxies (PHANGS) program has been compiling an impressive high-resolution multiwavelength data suite for 74 southern nearby (D ~ 3-30 Mpc) star-forming galaxies. These data provide precise ages and masses for ~100,000 star clusters (HST, JWST, and VLT/MUSE); metallicities, ionization states, and kinematics for HII regions (VLT/MUSE and HST); properties of molecular clouds (ALMA); morphologies and properties of dust structures (JWST); and detailed mappings of star-formation histories (SFHs) across the galactic extents (from the UV-to-IR suite). Recently, the PHANGS team was awarded large and legacy programs through Chandra and XMM-Newton, providing deep X-ray views of these extremely well-studied galaxies. I will provide an overview of the PHANGS-X program and first results on X-ray binaries (XRBs), the hot ISM, SNRs, and low-luminosity AGN in the context of the PHANGS data. I will summarize ongoing studies that incorporate the PHANGS data suite to (1) constrain how XRB populations vary with SFH and metallicity and (2) connect the properties of hot gas on subgalactic scales to the feedback from the underlying stellar populations. Finally, I will highlight forthcoming studies to utilize these data to address a variety of astrophysical problems.

A study of ultraluminous X-ray source population in local galaxies with high star formation rates

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Ultraluminous X-ray sources (ULXs) are extra-galactic, point-like objects with $L_X \geq 10^{39}$ erg s⁻¹, exceeding the Eddington limit for a $10 M_\odot$ black hole. Most are believed to be super-Eddington systems hosted by neutron stars or stellar-mass black holes, serving as local templates for accretion in the early universe. In normal galaxies, ULXs are typically detected at a rate of ~ 2 sources per unit star formation rate (SFR) of $1 M_\odot \text{ yr}^{-1}$. Thus, high-SFR galaxies are expected to host numerous ULXs. However, previous studies have reported that the observed number of ULXs in such galaxies is lower than predicted by up to a factor of 10, an inconsistency that requires further investigation. We explore the ULX population in high-SFR environments using a sample of Luminous Infrared Galaxies (LIRGs) within 100 Mpc, presenting an expanded catalog of ULXs in these systems. Despite the observed deficit, our sample provides improved statistical constraints on source properties. We report on the population characteristics, X-ray luminosity functions, and timing and spectral properties compared to ULXs in normal galaxies. Potential causes for the deficit are discussed.

A comprehensive search for high-velocity X-ray sources: New compact object binary candidates in the Gaia era

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Existing X-ray catalogues, including the *Chandra* Source Catalogue (CSC), the *XMM-Newton* Serendipitous Source Catalogue (4XMM), and the *Swift* Point Source Catalog (2SXPS), contain over a million sources. The recent *eROSITA* All-Sky Survey release (eRASS-DE DR1) has expanded this census into previously uncharted regions. Combined with the unprecedented precision of *Gaia* DR3 astrometry, these data now enable systematic kinematic studies of Galactic X-ray populations. Compact object binaries (COBs) hosting neutron stars or black holes are often luminous X-ray emitters. Supernova explosions can impart substantial systemic velocities, and many binaries survive these events and become high-velocity systems.

I will present our search for high-velocity X-ray sources selected from CSC, 4XMM, 2SXPS, and eRASS-DE DR1. Using a conservative method to estimate minimum peculiar velocities ($v_{\text{pec,min}}$), we identify over 2300 sources with a 1σ lower limit of $v_{\text{pec,min}} \geq 200 \text{ km s}^{-1}$ and high X-ray/optical ratios indicative of accretion. This threshold removes most contaminants (e.g. cataclysmic variables and active binaries) while retaining a sensible fraction of COBs, demonstrating that peculiar velocity is an effective indicator of compact object companions. These candidates are promising targets for radial velocity follow-up.

First discovery of a shocked, biconical outflow in an ultraluminous X-ray source revealed by high-resolution X-ray spectroscopy

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Ultraluminous X-ray sources (ULXs) are extreme X-ray binaries whose luminosities exceed the Eddington limit for a stellar-mass black hole. Most ULXs are powered by compact objects accreting at super-Eddington rates and launch relativistic outflows, revealed by absorption and emission features in high-resolution X-ray spectra. Despite the progress made in this field, key questions remain, including how wind properties scale with the accretion rate and their relevance in the ULX spectral transitions. To address these issues, we triggered deep XMM-Newton campaigns to study the disc–wind connection in variable ULXs. At first, I will present results on the cornerstone ULX NGC 5204 X-1. We detected, with high statistical significance, two collisionally-ionised plasma components moving in opposite directions along the line of sight ($|v| \sim 0.3c$), unveiling a biconical outflow geometry. Such a biconical structure has not previously been observed in ULXs and closely resembles that seen in SS433, the only known persistent super-Eddington accretor in our Galaxy. I will also report new findings for the persistent ULX NGC 4190 X-1 from our recent XMM-Newton campaign. High-resolution X-ray spectroscopy of these systems improves our understanding of super-Eddington accretion and constrains the geometry of binaries accreting in this extreme regime.

Weighing Black Holes in High-Mass X-ray Binaries: It Truly Takes Two to Tango

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Massive stars are the principle sources of stellar feedback and are the progenitors of neutron stars and stellar-mass black holes. HMXBs are a natural product of massive binary evolution and a gateway toward compact-object mergers. Yet the masses of black holes in HMXBs and their dependence on metallicity remain among the most contested quantities in astrophysics.

I will present our recent results from coordinated campaigns with the XMM-Newton, Chandra, and Swift, combined with observations by the HST and the JWST. We probe HMXBs hosting some of the most massive black holes across metallicities from solar to one-tenth solar. By developing a new framework that unifies X-ray and UV spectroscopy of accretion flows and irradiated donor winds, we fundamentally revise black hole mass estimates in the archetypal systems Cygnus X-1, M33 X-7, and Holmberg II X-1, establish mass transfer mechanisms, and constrain evolutionary paths of these systems.

These results demonstrate the necessity of self-consistently modeling donor stars and X-rays from accretion disks, and redefine how we weigh stellar-mass black holes in HMXBs. I will place our results in the broader context of black hole properties across redshifts, and chart a path toward understanding how HMXBs shape star-forming galaxies across cosmic history.

The First IXPE Detection of Strong X-ray Polarisation from the ADC Neutron Star LMXB 4U 1822-371

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4U 1822-371 is the prototype accretion disc corona neutron star LMXB, viewed at very high inclination, where the inner emission is obscured and the observed spectrum is dominated by scattering and reprocessing. We present the first measurement of its X-ray polarisation and the first broadband spectro-polarimetric analysis of the source, based on a simultaneous campaign with IXPE, XMM-Newton, NuSTAR, and Swift. The broadband spectrum is well described by a soft thermal component, a Comptonization continuum plus a hard tail and a self-consistent reflection component. In the IXPE band we detect a highly significant polarisation signal, with $PD = 8.0\% \pm 0.7\%$ and $PA = -21^\circ \pm 2^\circ$, making 4U 1822-371 one of the most highly polarised neutron star LMXBs observed so far. The polarisation degree increases linearly with energy, reaching $\sim 13\%$ at 6-7 keV, while the polarisation angle remains constant. An orbital phase resolved analysis shows no significant modulation of either PD or PA. The stability of the polarisation angle, together with the absence of clear wind related features, supports a geometry in which scattering in an extended, optically thin corona dominates the observed emission, producing a high polarisation degree and reducing the apparent luminosity to 4% of the intrinsic one.

Probing different accretion states in black-hole X-ray binaries with X-ray polarimetry

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Black-hole X-ray binaries are unique laboratories for studying accretion physics in the strong-gravity regime. X-ray polarimetry provides powerful constraints on the geometry of the accretion disk and the hot corona responsible for up-scattering thermal disk photons. Swift J1728.8-1613 is a recently discovered black-hole X-ray binary that underwent a full outburst cycle. Its unusually high brightness enabled detailed studies of typically elusive and faint state transitions. The IXPE satellite observed the source throughout the entire outburst, making it possible for the first time to measure X-ray polarization properties across all accretion states in the same source. We found that the relatively high polarization degree in the hard state decreased significantly during the soft state and recovered to its original value after the reverse soft-to-hard transition. These results provide direct evidence that X-ray polarization is highly sensitive to the structure of the innermost accretion flow and offers unique constraints on the physical properties of X-ray binary systems.

Beyond stellar ionization: ULXs, hot plasma, and the origin of nebular He II

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Nebular emission in low-metallicity star-forming galaxies implies ionization conditions that cannot be reproduced by stellar populations alone. Even extreme stellar populations, including young massive star clusters, fail to supply sufficient photons above 54.4 eV to account for nebular He II $\lambda 4686$ or the high-ionization line [Ne V] $\lambda 14.32 \mu\text{m}$ recently detected by JWST in dwarf starbursts. These observations point to a significant contribution from X-ray sources, including ULXs and hot diffuse plasma.

I will present new deep X-ray observations with XMM-Newton and Chandra that quantify how ULXs shape the ionizing spectrum in low-metallicity starbursts. Photoionization modeling with Cloudy is used to assess the relative contributions of ULXs, diffuse hot plasma, and young massive star clusters in powering the observed nebular emission. Chandra resolves individual ULXs and establishes their spatial association with nearby young clusters, allowing local modeled conditions to be compared with observations. XMM-Newton provides the soft X-ray sensitivity required to measure the thermal plasma component. Together, the XMM-Newton-constrained plasma emission and Chandra-resolved ULXs demonstrate that X-ray sources are a key driver of the ionizing field required for nebular He II in low-metallicity galaxies.

The influence of the accretion disc structure on X-ray spectral states in accreting binaries

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X-ray observations of accreting binaries frequently reveal the presence of the 6.4 keV Fe emission line. Although this feature is known to originate from fluorescence, it is commonly modeled using ad hoc Gaussian components that lack a direct physical interpretation. We present radiative-transfer calculations specifically designed for accretion discs in interacting binaries, consistently accounting for X-ray reflection from the surrounding material together with emission from the hot plasma in the boundary layer between the accretion disc and the accretor's surface. Applying our models to symbiotic star configurations, we successfully reproduce the diversity of observed X-ray spectral classes (α , β , δ , and β/δ types). The models naturally explain both continuum and line variability as a consequence of disc structure and viewing geometry. As a case study, we model the γ Cas analogue ζ Tau and show that its X-ray properties are consistent with an accreting white dwarf fed by the accretion disc of its Be companion. Our results provide a physically motivated framework for interpreting fluorescent Fe emission in accreting binaries.

Understanding the accretion geometry of M51 ULX-8

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Ultraluminous X-ray sources (ULXs) provide a valuable laboratory for studying accretion under super-Eddington conditions. We present a combined timing and spectral analysis of M51 ULX-8 to constrain its accretion geometry. Using multiple independent timing analysis techniques, we detect significant quasi-periodic oscillations (QPOs) at characteristic timescales of 20,894 s, 29,713 s, and 47,893 s, indicating variability in the accretion flow over a wide range of temporal scales. These long-timescale QPOs may be associated with geometric effects such as accretion disk precession expected in super-Eddington systems. We investigate the spectral evolution of the source across different luminosity states and find that the disk emission follows a luminosity–temperature relation consistent with LT2, supporting a slim disk accretion geometry in the system. The combined timing and spectral properties suggest a geometrically thick, radiatively inefficient accretion flow in M51 ULX-8, where variability is closely linked to changes in the accretion structure. These results provide new constraints on the accretion geometry of M51 ULX-8 and underscore the importance of joint timing–spectral analyses in understanding the physical mechanisms driving ULXs.

Accretion geometry through the eyes of accreting white dwarfs: systematic study of broad-band variability as a probe for disc viscosity

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Broad-band aperiodic variability is a fundamental diagnostic of accretion flow geometry in systems ranging from supermassive black holes to X-ray binaries (XRBs). In the propagating-fluctuations framework, variability arises from inward-moving viscosity perturbations in the disc, producing characteristic high-frequency breaks in the power spectrum associated with the local viscous timescale. Because this timescale scales with intrinsic system parameters, breaks provide a powerful, physically grounded probe of inner accretion structure. Accreting white dwarfs (AWDs) are the most numerous and nearby accreting objects, yet their inner disc–corona geometry remains poorly constrained compared to XRBs. We present the first systematic high-frequency timing study of 130 AWDs observed with TESS. Their power spectra reveal a distribution of break frequencies peaking at $\sim 6 \times 10^{-4}$ Hz. Furthermore, subsamples of nova-likes and dwarf novae in quiescence exhibit statistically distinct break distributions. Higher accretion-rate systems show systematically higher break frequencies, indicating a reduced inner disc radius or the presence of an additional inner hot flow component. This accretion-rate dependence closely parallels the disc–corona evolution seen in XRBs. Our results therefore provide an optical timing bridge to the X-ray emitting regions, offering new constraints on inner flow geometry and viscosity prescriptions that can be directly tested with coordinated X-ray observations.

X-ray characterisation of a cataclysmic variable showing bright radio pulses

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In recent years, the discovery of a dozen Long Period Transients (LPTs) has opened a new window onto the study of compact objects. LPTs are characterised by polarised radio emission, with bursts occurring periodically on timescales of a few minutes to a few hours. Different scenarios have been proposed to explain the observed properties of these bursts, but their exact physical origin is still unknown. In this talk, I will present our analysis of XMM-Newton and Einstein Probe observations of a new LPT. Optical data points towards an accreting white dwarf in a binary, and the X-ray light curve shows pulsations at a period consistent with the one detected in the radio band. The X-ray emission is bright and confirms a magnetic nature of the white dwarf binary, which is possibly entering an X-ray bright state.

Polarized X-ray emission from accreting millisecond pulsars

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Millisecond pulsars (MSPs) are the quickest-spinning neutron stars (NSs) known. The waveform of X-ray pulsations produced by hot spots on their surface encodes precious information on the mass and size of these compact objects. Accreting MSPs are among the best targets, but the effective area of X-ray instruments flown so far has proven insufficient to break the degeneracy between the many parameters shaping their pulse profiles. X-ray polarimetry is a potential game-changer which provides an independent measure of the geometry of the hot spots. Here, we present the Imaging X-ray Polarimetry Explorer (IXPE) discovery of polarised X-ray emission from two accreting millisecond pulsars, SRGA J144459.2-604207 and SAX J1808.4-3658. Both had a polarisation degree of 2-3%, with an energy dependence compatible with the expectation of Compton scattering in a hot slab. The application of the relativistic rotating-vector to the former source suggests that a moderately fan-beam emission from two point-like spots at low magnetic obliquity (10°) is compatible with the observed pulse profile and polarisation properties. We discuss the results in the context of the role played by X-ray polarimetry in the modelling of the pulse waveform of accreting millisecond pulsars.

Towards a truly unbiased X-ray survey of star-forming galaxies in the nearby Universe with eROSITA

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The integrated X-ray emission of star-forming galaxies arises from X-ray binaries (XRBs) and diffuse hot gas. Studying these components is crucial for understanding the most luminous XRBs and their connection to host galaxy properties. The eROSITA all-sky survey (0.2–8.0 keV) provides the least biased census of galaxy X-ray emission in the local Universe. By combining the HECATEv2 ($z < 0.048$) galaxy catalogue with eRASS1 survey, we investigate the integrated X-ray luminosity (L_X) of star-forming galaxies as a function of stellar mass (M_*), star formation rate (SFR), metallicity, and stellar age. We identify a sub-population of X-ray luminous starburst galaxies showing up to ~ 2 dex excess relative to current scaling relations. These systems exhibit higher specific SFRs, lower metallicities, and younger stellar populations. We examine possible origins of this excess, including enhanced hot-gas emission, luminous low-mass XRBs, stochastic sampling, and contamination from background or low-luminosity AGN. Our results suggest that high X-ray luminosities primarily stem from luminous XRBs associated with young, low-metallicity populations. Finally, we discuss how the deeper eRASS:4 observations and the inclusion of higher-redshift galaxies will tighten constraints on the L_X –SFR– M_* –Metallicity relation, reveal rare populations, and establish more robust correlations between X-ray emission and host galaxy properties.

Luminous SSS with Hot Donors: the “missing” HMXB-WD Systems

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There are now 5 Be supersoft X-ray sources (SSS) in the Magellanic Clouds, together with V Sge in our Galaxy, providing first indications of the long-sought population of HMXBs containing white dwarf compact objects. V Sge is the most extreme and peculiar of these (it is also the most optically luminous CV known); it appears to be undergoing heavy, Eddington-limited accretion from its more massive companion, implying a very rare, short-lived phase of its binary evolution, and explaining the circumbinary ring we have discovered (Hakala et al 2025). Some are transient, e.g. MAXI J0158-744 (Li et al 2012), others persistent, such as [HP99]159, the **only** BeX SSS with a He-star donor (Szegedi et al 2026), and all are long orbital period ($\sim 0.5\text{d} - \sim 50\text{d}$) and are strong SNIa candidates. There has even been the recent discovery of a recurrent nova in M31 (Shafter et al 2024) containing a Be donor. Their properties will be compared with those of dwarf novae, BeX systems and the possibly related extra-galactic “ultra-luminous” SSS (Liu & di Stefano 2008), and placed in the context of HMXB evolutionary scenarios.

The peculiar ultra-fast outflow of MAXI J1810-222

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The X-ray transient MAXI J1810-222 was discovered in 2018 and has been active ever since. A deep, multiwavelength monitoring campaign suggests a BH accretor, although the unusual outburst behaviour. Through a NICER monitoring campaign, we detected a strong absorption feature around 1 keV which was described with a photoionised absorber. A deep scan of the parameters space showed evidence for a spectral-state dependent outflow, with mildly relativistic speeds in the soft states. This is unlikely from thermal winds in X-ray binaries and must involve either strong radiation or (most likely) a magnetically-driven wind. In order to deeply investigate the nature of this feature, we obtained an XMM-Newton observation which was performed end of 2023. High resolution spectroscopy with RGS confirms the ultra-fast nature with a velocity of 0.06 c for this outflow. In addition, this line is intrinsically broad which suggests a combination of different velocities along the LOS. NuSTAR and EPIC show a further hotter Fe K component indicating a stratified or multiphase outflow. In this talk, I will present an overview of these exciting results, as well as XRISM simulations which can definitely confirm the NuSTAR detection and differentiate between a narrow and a broad line core.

A Decadal Study of GRS 1915+105 Outflows: New Constraints from Absorption Measure Distributions

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The low-mass X-ray binary GRS 1915+105 has been observed with X-ray telescopes for over two decades, exhibiting significant variability across epochs. While a clear outflow is frequently detected, its origin, launching mechanism, and internal dynamics remain poorly understood. In this work, we analyze four observations spanning a decade using the Absorption Measure Distribution (AMD) as a diagnostic tool. We identify a unique behavior in several observations where the AMD rises and then "breaks" at higher ionization—marking the first reported instance of an AMD featuring a negative slope and a decline in column density at high ionization states. By utilizing the AMD shape and total column density, we derive self-consistent measurements for the wind’s density, radius, and scale. These parameters, which are typically difficult to constrain through standard X-ray spectroscopy, are achieved here with high precision, providing new insights into the physical nature of the outflow.

A coordinated, multiwavelength investigation of the white dwarf pulsar J1912-44

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J1910-4410 is only the second confirmed white-dwarf pulsar after AR Sco. To fully characterize the new system, we have conducted a coordinated, multi-wavelength observational campaign from radio to X-ray wavelengths in September 2024, involving XMM-Newton, the SAAO 1.9m, and MeerKAT. We report on the relevant radiation mechanisms, the long-term ephemeris and spin-down of the white dwarf, the contributions of accretion-induced thermal and magnetospheric non-thermal components to the X-ray spectrum, and optical and X-ray variability on short and long timescales.

Systematic Study of Magnetic Cataclysmic Variables from Long-Term X-ray Observations

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Cataclysmic variables have the highest volume density of X-ray emitting accreting systems. However, many aspects of their accretion and emission processes remain unclear. In particular, although white dwarfs are large compared to neutron stars, they can have significant hard (> 5 keV) X-ray emission. We are undertaking a systematic observational study of CVs that have hard spectra to investigate the origin of the hardest emission and its periodic and long-term variability. A significant focus is on asynchronous polars, in which the spin period of the white dwarf is almost, but not quite, synchronized to the orbital period. We are primarily using the extensive light curves from the BAT, with the RXTE ASM and MAXI GSC providing broader energy coverage and longer temporal coverage. We will search for small levels of asynchronicity in well-established polars, such as AM Her, and quantify any relationship between long-term changes in accretion rate and synchronization. A newly developed algorithm that performs weighted additions of energy-separated power spectra increases signal-to-noise for the detection of periodic modulation. We will report results from an initial pilot study on periodic modulation detected with the BAT for five polars, at least two of which are asynchronous, and also long-term variability.

X-ray Doppler tomography of Fe K α emission in a low-mass X-ray binary 4U 1822–371 — a localized reflector at the accretion stream–disk overflow

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We present the X-ray Doppler tomography of the Fe K α (6.4 keV) fluorescence line of the low-mass X-ray binary 4U 1822–371 obtained with XRISM. Eleven orbits of this short period (5.57 hr) binary were covered. The Doppler shift of the line shows clear modulation with the orbital period, motivating us to apply the Doppler tomography in the X-ray band for the first time. The resulting velocity map reveals a compact feature at $(v_x, v_y) \sim (-550, +125)$ km s⁻¹. This is inconsistent with the emission originating from a symmetric accretion disk, an extended corona around the neutron star, or the surface of the neutron or companion star. Instead, it suggests that the emission originates from the accretion stream-disk overflow. Remarkably, the Fe K α velocity map closely resembles that of the O VI 3811 Å, indicating that both X-ray and optical lines arise from the same site irradiated by the central X-ray source. These results provide the first velocity-resolved X-ray map of the fluorescent line, directly localizing the major reflector in an X-ray binary and establishing X-ray Doppler tomography as a new probe of the structures of accreting systems.

Discovery of the first super-soft X-ray source in the Magellanic Bridge with eROSITA

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The Magellanic Bridge (MCB) is a stream of gas and stars formed during the most recent interaction between the Large and the Small Magellanic Clouds. eROSITA all-sky survey has detected several X-ray bright sources in the MCB region. We confirmed their association with the MCB using proper motion measurements from Gaia, following which we undertook a multi-wavelength follow-up campaign primarily using XMM-Newton and other ground-based facilities. As part of our campaign, we discovered the first super-soft X-ray source in the MCB. The source shows strong X-ray variability (factor of 10), while maintaining a stable spectrum with a temperature of ~ 0.03 keV. Lomb-Scargle periodograms of the long-term optical photometric monitoring from OGLE, ATLAS, and ASAS-SN reveal a periodicity of approximately 500 days. Its position in the Gaia color–magnitude diagram is consistent with a red-giant companion and optical spectroscopy revealing prominent Balmer and HeII(4686Å) emission lines. The combined X-ray and optical properties are consistent with a symbiotic binary system with the thermal X-ray emission and optical emission lines likely originating from the accretion flow around the compact object. Here we present the implications of the discovery of this source in the broader context of stellar-evolution in the Bridge.

The unusual X-ray and optical behaviour of the atypical black hole candidate AT2019wey

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The outburst of the peculiar black hole candidate AT2019wey has lasted over five years, much longer than typical LMXBs. Throughout this period the source remained in the hard or hard-intermediate state with occasional transitions to short-lived soft states characterised by X-ray flares. We present long term monitoring of AT2019wey with Swift, NICER and Las Cumbres Observatory. Beginning May 2025, the source entered another softening phase, but this time lasting over 8 months. This transition was followed by a decline in both X-ray and optical fluxes to very low levels before rising back to harder states. This has resulted in the source tracing a hysteresis in the hardness intensity diagram for the first time since its discovery. The optical/X-ray correlation is dominated by scatter, with some anti-correlated behaviour, deviating from known relations. Moreover, during this flux decay the optical colors remain unchanged, unlike the reddening expected from an irradiated disk. We will discuss the optical and X-ray properties of the source during the recent state transition, putting it in context of previous state transitions of the source. Furthermore, these results will help in drawing parallels with other similar systems like Z Cam type dwarf novae which show multi-year long outbursts.

Ultra-Compact X-ray Binaries: Taking the Population View

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Ultra-compact X-ray binaries are low-mass X-ray binaries with orbital periods shorter than 80 minutes. Such short periods imply compact Roche lobes that can only host hydrogen-deficient donor stars, making these systems key laboratories for accretion in hydrogen-poor environments and advanced binary evolution. They are also expected to be important low-frequency gravitational-wave sources for LISA.

I will present the current state of the art of this family, covering: (i) a comprehensive overview of the known population through UltraCompCAT, a catalogue compiling the available multi-wavelength information for confirmed and candidate ultra-compact and short-period systems; (ii) homogeneous X-ray studies aimed at characterising their spectral and accretion properties on a population basis; and (iii) ongoing efforts to identify new members using multi-wavelength diagnostics to expand the current census.

Together, these efforts move the field beyond individual case studies and towards a coherent population framework, allowing us to reassess the demographic, evolutionary and observational properties of the ultra-compact regime as a whole.

Simultaneous observations of Cir X-1 with XRISM, NICER, and NinjaSat in 2024 and 2025

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On September 7, 2023, the Japan Aerospace Exploration Agency launched the X-ray spectroscopic imaging satellite (XRISM) equipped with the microcalorimeter Resolve, achieving an energy resolution of 4.5 eV at 6 keV. In this study, we analyze two XRISM observations of the neutron-star X-ray binary Cir X-1, together with simultaneous observations by other satellites, and present results based on detailed broadband X-ray spectroscopy. Despite the significantly different X-ray luminosities and characteristics of emission and absorption lines observed in the two observations, results can be interpreted by a simple geometric scenario in which the partial absorber is localized along a limited region of the orbit: the first observation probes a line of sight intersecting the absorber, whereas the second does not, and the intrinsic luminosity during the second observation is about 100 times higher. In both observations, two plasma components are required: one highly ionized with a large outflow velocity, and another with lower ionization and a smaller velocity, with no significant changes in their parameters over one year. This study thus provides a unified model that consistently explains the broadband X-ray spectra of Cir X-1, including their temporal variability.

XRISM observation of black hole X-ray binary GS 1354–645 during its 2026 outburst

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To understand the physical mechanisms responsible for wind launching an suppression, as well as their roles in regulating the mass inflow-outflow balance, it is essential to determine at which stages of state transitions winds emerge and disappear. GS 1345–645 is a black hole X-ray binary that has undergone multiple outbursts in which the source remained in the hard state. We performed high-resolution X-ray spectroscopy with XRISM/Resolve using data obtained during its 2026 hard-state outburst. During the observation, the source brightened and softened in the first half, followed by a steady phase in the second half. The time-resolved spectra are power-law dominated and exhibit clear relativistically blurred disk reflection as in previous hard-state outbursts. Beyond this, Resolve’s high spectral resolution and sensitivity enabled the first detection of absorption-line features during a hard-state outburst in black hole X-ray binaries. The detected winds exhibit high velocities exceeding 5000 km s^{-1} and show clear temporal evolution. In this talk, we discuss the possible physical origin of these winds, the mechanisms driving the observed time evolution, and their implications for the net mass accretion.

A broadband X-ray view of stellar winds in high-mass X-ray binaries

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The spectral and timing behaviour of neutron star high-mass X-ray binaries (HMXBs) offers a unique opportunity to investigate accretion onto compact objects and the wind structures of massive stars. In particular, understanding the X-ray emission from neutron stars is a critical topic of research for current and future astrophysical studies, as highlighted by its prominence in the science cases of the upcoming NewAthena mission. In this talk, we will review the current state of the art in stellar wind accretion in HMXBs. In particular, we will focus on observations of key sources on the broad X-ray range using simultaneous XRISM, XMM-Newton and NuSTAR data. We investigate the clumpy structure of the material being accreted by the neutron star with an in-depth view into the accretion and photoionisation wakes, and provide valuable data for cross-calibration studies among modern and widely used X-ray telescopes. We will also present updated X-ray data analysis tools used during these studies, including the jaxspec spectral-fitting library, which enables approaches not possible with classical frameworks.

The population of X-ray emitting compact stars in the Magellanic system detected during the eROSITA all-sky survey

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The Magellanic Clouds are our closest star-forming galaxies with low Galactic foreground absorption and well determined distances. The SMC hosts a large population of Be/X-ray binaries associated with high star formation activity 25-40 Myr ago. The HMXB population in the LMC is associated with a star formation period at an earlier epoch and a lower HMXB formation efficiency. The Magellanic Bridge is a product of the tidal interaction between the LMC & SMC. It contains both gas and stellar components, with young stellar components (HMXBs) which is thought to have formed in situ, as well as an older population of stars. The recent eROSITA all-sky survey marks the first comprehensive X-ray coverage of the entire Magellanic system, offering a broad band X-ray coverage. Proximity to the SEP facilitates extended monitoring of LMC sources during each survey, enabling a deep total exposure and the exploration of long-term temporal behaviour of X-ray emitting compact stars. This presentation will unveil the findings from our study of the X-ray binary population across the MS through the SRG/eROSITA all-sky survey. Additionally, we will showcase unique discoveries, including a He burning white dwarf, double degenerate compact binary system and an X-ray burster in the Magellanic Bridge.

X-ray polarization and the coronal geometry in the soft state of Cyg X-1

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We present a detailed spectral analysis of X-ray observations of Cygnus X-1 obtained with NICER, NuSTAR, and INTEGRAL during observations simultaneous with IXPE on 20 June 2023. We developed a new model describing the thermal disk emission including returning radiation, and applied it together with precise treatments of Comptonization and relativistically broadened reflection. Based on the resulting spectral solution, we compute the expected polarization signal and compare it with IXPE measurements. The observed polarization is best explained by Comptonization in a corona undergoing a semi-relativistic outflow with a velocity of $0.3c$. Our study combines two methods of black-hole spin determination, i.e. disk-continuum fitting and relativistic reflection modeling. While the spectral fits formally allow for both low and high spin solutions, the polarization strongly favors a low spin, as higher spin values predict a polarization angle rotated too strongly relative to the observations. Apart from this rotation, general relativistic effects play only a minor role in shaping the polarization signal. In particular, we find at most a minor contribution from returning disk radiation, in contrast to previous analyses of the same dataset.

Super-Eddington Accretion in the pulsating ULX NGC 7793 P13: Fourteen Years of XMM-Newton and NuSTAR Observations

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Pulsating ultraluminous X-ray sources provide a framework to study super-Eddington accretion onto magnetized neutron stars. We present a uniform analysis of fourteen years of XMM-Newton and NuSTAR observations of NGC 7793 P13, complemented by Swift monitoring.

The spectra are modeled with two thermal components and one cut-off power law. At high luminosities ($\sim 10^{40}$ erg s⁻¹), the source follows a luminosity-temperature relation consistent with constant temperature rather than T^4 scaling expected for a standard Shakura-Sunyaev thin disc. During an off-state, when the luminosity decreases by two orders of magnitude and pulsations are not detected, the hotter thermal component remains stable in temperature, while the cooler component decreases.

Timing analysis confirms persistent spin-up throughout the campaign. Although the cut-off power law is expected to trace the pulsed emission, the pulsed fraction does not correlate with its flux fraction. Beyond its known anti-correlation with total flux, the pulsed fraction is anti-correlated with the flux of all model components, indicating that pulsations are not confined to the cut-off power-law emission.

Together, these results indicate that the off-state variability is driven primarily by changes in the structure and viewing angle of the super-Eddington accretion flow, rather than by intrinsic variations in the mass accretion rate.

Stochasticity effect on the integrated X-ray luminosity of star-forming galaxies

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The integrated X-ray luminosity (L_X) of star-forming galaxies is primarily produced by high-mass X-ray binaries (HMXBs). However, their discrete nature introduces stochastic effects that distort the underlying X-ray luminosity function (XLF) and bias inferred scaling relations. We investigate how stochastic sampling of the HMXB XLF affects the predicted integrated L_X across a wide range of star-formation rates (SFRs) and metallicities, and quantify the resulting scatter to provide a statistical framework for interpreting galaxy X-ray observations. Using Monte Carlo simulations, we derive L_X distributions over a broad grid of SFR and metallicity values. We parametrise the L_X scatter by fitting surfaces to the upper and lower L_X bounds as functions of SFR and metallicity in different confidence levels. We provide practical prescriptions to estimate the integrated L_X while fully accounting for stochastic effects, without requiring computationally expensive sampling of the XLF for individual galaxies. Application of these prescriptions to local and high-redshift samples shows that stochasticity must be considered before attributing L_X deviations to intrinsic population differences, especially in deep X-ray surveys.

X-ray luminous late-type giants: an overlooked population contributing to the Galactic ridge iron line emission

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The Galactic ridge X-ray emission (GRXE) has remained a central challenge in high-energy astrophysics since its discovery four decades ago. While deep surveys have resolved much of the GRXE continuum into cataclysmic variables (CVs) and active binaries (ABs), a discrepancy remains: these populations exhibit Fe XXV equivalent widths (EW) substantially lower than the observed in the total GRXE, leaving the origin of the prominent 6.7 keV emission unexplained. In this work, we leverage the XMM-Newton Heritage Survey of the inner Galactic disk ($|l| < 10^\circ$, $|b| < 1^\circ$) to identify an overlooked population of X-ray luminous late-type giants. These sources exhibit exceptionally strong Fe XXV emission with EW ~ 900 eV, naturally resolving the long-standing EW discrepancy. Classified as symbiotic star candidates (white dwarfs accreting from late-type giant companions), they represent a predicted but previously underestimated accretion-powered population. Our analysis indicates that while these symbiotic systems contribute $\sim 20\%$ of the GRXE continuum (2–10 keV), they account for $\sim 50\%$ of the narrow-band iron line flux (6.5–7.0 keV). These results provide observational evidence that symbiotic stars are the primary drivers of the Galactic ridge line emission, solving a major problem in Galactic astrophysics and opening a new window into the study of symbiotic evolution.

Timing and Spectroscopic studies of Vela X-1 with XPoSat/XSPECT

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Vela X-1 is an archetypal high-mass X-ray binary pulsar in which strong X-ray irradiation from the neutron star significantly affects the companion's stellar wind. A smooth, isotropic wind cannot explain the observed variability in the system, especially the orbital variation in the absorption column density, suggesting the presence of additional structures such as photoionisation/accretion wakes. Furthermore, the source intensity exhibits strong variability from orbit to orbit. India's first dedicated X-ray polarimetry mission, XPoSat, was launched on 1 January 2024 aboard PSLV-C58. The mission carries two payloads: the primary Polarimeter Instrument in X-rays (POLIX), operating in the 8.0-30.0 keV band to measure X-ray polarization, and the secondary X-ray Spectroscopy and Timing (XSPECT) instrument, covering the 0.8-15.0 keV energy range. XSPECT observed Vela X-1 during two epochs, comprising five consecutive out-of-eclipse and one full orbit observations. Using these data, we perform a detailed timing and spectroscopic study of Vela X-1 on orbital-period timescales. We find that the variability observed over the orbital period is driven by a comparable contribution from clumpy stellar winds, intrinsic source variability, and accretion/photoionisation wake structures. Furthermore, our results confirm that the wake structure has variability at shorter time scales.

Multiwavelength polarimetric studies of Scorpius X-1 and Cygnus X-2

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Vadim Kravtsov¹, Juri Poutanen¹

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The combination of optical and X-ray polarimetry is particularly efficient in probing the geometry and emission processes in neutron star X-ray binaries. We present the results of polarimetric campaigns on two systems.

Scorpius X-1 displays notable behaviour across wavelengths. X-ray polarimetry hints towards an intricate geometry of the inner accretion region, while optical photometry has shown a bimodal flux distribution with a 12.5 h lag behind the X-ray state transitions, consistent with thermal reprocessing within the disk. This suggests that the optical emission traces changes in the inner flow, yet no time-resolved optical polarimetry has tested this link. We conducted an optical campaign with the NOT and T60 telescopes to better constrain the system geometry and track the evolution of polarization across optical state changes.

Cygnus X-2 has an X-ray polarization angle aligned with the radio jet, suggesting an origin in the spreading layer or an accretion-disk wind. However, historical optical polarimetry reported a polarization angle significantly offset from the jet direction. To investigate whether this discrepancy reflects a spin-orbit misalignment of the system or is due to instrumental limitations, we obtained simultaneous optical and X-ray observations, with the NOT and IXPE, respectively.

Behind the masks of PSR J0437-4715: a multi-wavelength pulse profile modelling of MSPs

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In the recent years, we have determined new constraints on the nuclear physics of neutron stars thanks to the X-ray pulse profile modeling of millisecond pulsars that has provided measurements of their masses and radii. This technique also results in the determination of the object geometry (location of the emitting hot regions) and its surface temperature. In this work, we focus on the nearest and the brightest of those thermally-emitting millisecond pulsars, PSR J0437-4715. Using data from NICER and XMM-Newton for the X-ray pulse profile modeling, we complement this technique with the addition of far-ultraviolet thermal emission resulting from the entire warm (10^5 K) surface observed with HST. The combination of the observables (compactness from the pulse profile modeling, and redshifted radius from the spectroscopy of the warm surface) improve the measurements on the radius of PSR J0437-4715. We present the result of this analysis and its implication for the equation of state of dense matter.

Energy-dependent polarization properties in X-ray pulsars probed by IXPE

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Observations of accreting X-ray pulsars (XRP) carried out by the Imaging X-ray Polarimetry Explorer (IXPE) have provided completely new insight into these objects, thanks to the indispensable information embedded in their X-ray polarization. X-ray polarimetry enables us to measure the polarization angle (PA) and degree (PD) as a function of pulse phase for XRPs, allowing the system geometry to be determined. Additionally, the radiation from XRPs was expected to be highly polarized.

About a dozen XRPs have been observed by IXPE so far, and pulsar geometries have largely been determined by successful modeling of the pulse phase dependence of the PA with the Rotating Vector Model. Interestingly, IXPE observations of XRPs have unveiled significantly lower PDs than theoretical expectations.

Several individual XRPs have demonstrated particularly peculiar polarization properties, which adds to the pool of new questions raised because of the polarimetric information. Overall, the XRPs observed with IXPE show little energy dependence of their polarization properties. However, a couple of XRPs display clear and complex dependencies.

I will discuss the energy-dependent polarization properties of these sources, which vary in complexity and require different approaches to properly explain their behavior. I will also address unresolved questions and discuss the proposed solutions.

Capturing the Nature of X-ray Transients through Neuro-Parametric Machine learning Methods

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Low-mass X-ray binary transients undergo recurrent outbursts, briefly dominating the X-ray sky. Determining the nature of compact object in such systems, whether a black hole or a neutron star, remains challenging, particularly during the early phases of an outburst. Traditional classification relies on detailed analyses of complete light curves, power spectra, and broadband energy spectra, which can be challenging for rapid identification of large numbers of sources. With advent of multiple X-ray missions over the past three decades and recent launch of wide-field monitors such as SVOM and Einstein Probe, there is an increasing need for fast, scalable, and mission-independent classification techniques. In this work, we employ neuro-parametric machine-learning methods to infer the nature of X-ray binary transients using limited spectral information. Using archival RXTE data, we develop three neural-network models trained on: (i) spectral flux values, (ii) spectral fluxes with their associated uncertainties, and (iii) physically motivated accretion parameters obtained from spectral fitting. We achieve accuracies of 90–94% in distinguishing black hole and neutron star transients. Importantly, the model based on accretion parameters is largely mission-agnostic, allowing for a straightforward extension to current and future X-ray surveys. This approach provides a pathway to rapid, automated characterization of X-ray transients.

Searching for the Power Source in a Low Metallicity Dwarf-Dwarf Merger

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While there have been myriad deep multi-wavelength studies of nearby dwarf galaxies, uncovering extreme stellar populations and intermediate mass black hole (IMBH) driven active galactic nuclei (AGN), there has been limited targeted study into the interactions between these galaxies. This is particularly true in the low metallicity regime, despite these systems potentially representing the local analogues of the earliest galaxies undergoing their first interactions. The Dwarf GIMLI (Dwarf Galaxies Interactive and Merging with Low Intrinsic metallicity) survey is a multi-wavelength project to improve our understanding of these systems and their implications for the interpretation of data from higher redshifts. Here we focus on a specific pilot target from the survey. J1148+2149 is a local ($z=0.027$), low metallicity dwarf-dwarf merger with WISE colors typically indicative of activity, whether by active star formation or an AGN, which has significant multi-wavelength data across the X-ray, optical, and near-infrared. Here we present our initial results, including a discussion of unusual features that could indicate multiple sources for potential AGN or star formation activity due to the merger. Finally, we discuss the implications of these results to the larger picture of dwarf galaxies and the earliest epochs of galaxy formation and evolution.

Low luminosity BeXRB spectral shape and its correlation with magnetic field strength

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The X-ray spectra of neutron stars with moderate magnetic fields ($B \sim 10^{12}\text{G}$) in high-mass X-ray binaries at low luminosities are well described by a double humped shape. The spectral shape is understood to be the result of spectral redistribution and Landau excitation within the two-temperature magnetized neutron star atmosphere. The spectrum is dominated by thermal emission below 10keV, while the hard X-ray emission consists of upscattered thermal photons and redistributed cyclotron photons. The hard X-ray emission is thought to be related to the magnetic field strength of the neutron star.

We perform spectral analysis of archival NuSTAR observations of Galactic BeXRBs at low luminosities using empirical models to determine the relative position between the two spectral components.

We identify the intersection point of the two cutoff powerlaws as a descriptor of the relative position of the two spectral components. For four BeXRBs with NuSTAR observations and known CRSF energy the intersection energy is positively correlated with the magnetic field strength. We obtain a similar positive correlation from our study of simulated spectra based on a physical self-consistent of the polar cap.

The effect of the magnetic field on spectral formation results in a correlation between the field strength and spectral shape.

The elusive cyclotron line in 4U 1901+03: hidden, yet present

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Cyclotron resonant scattering features (CRSFs) in accreting X-ray pulsars can be difficult to detect when shallow. I present a spectral–timing analysis of four NuSTAR observations obtained during the 2019 giant outburst of the HMXB 4U 1901+03, sampling different accretion states and focusing on the 30–40 keV band, where previous analyses yielded conflicting evidence for a CRSF and its properties. To probe the link between spectral features and pulse morphology, we combine harmonic decomposition of energy-resolved pulse profiles, cross-correlation analysis, energy–phase maps, pulsed-fraction spectra and Bayesian spectral modelling. We detect significant luminosity-dependent variability within this energy range, which increases at lower levels of luminosity. In particular, a clear drop in the pulsed fraction around $\approx 35\text{ keV}$ emerges in the lowest accretion state and in the first harmonic of one intermediate state. Using an informative Bayesian framework, we find evidence for a cyclotron line at $\approx 32\text{ keV}$ with limited centroid variability ($\approx 1.6\%$). Although marginal in one phase-averaged spectrum, the timing analysis consistently reveals a coherent signature at the same energy. This demonstrates that spectral–timing methods enhance the detectability of shallow CRSFs and trace changes in emission geometry and accretion structure.

Spectro-polarimetric modelling of XrB observations in the JED-SAD/MONK framework

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The Jet Emitting Disk–Standard Accretion Disk (JED–SAD) model provides a self-consistent framework to describe accretion and ejection in X-ray binaries. It assumes a large-scale magnetic field threading the accretion flow, dividing it into two regions: an inner, highly magnetized Jet Emitting Disk (JED) that launches jets, and an outer, weakly magnetized Standard Accretion Disk (SAD). Because the jet torque efficiently extracts angular momentum, the JED structure and energetics differ significantly from those of the SAD. The model successfully reproduces the spectral energy distributions (SEDs) of X-ray binaries throughout their outbursts. We apply this framework to Swift J1727.8–1613, which entered outburst in August 2023 and was observed by SWIFT, IXPE, NICER, NuSTAR, and INTEGRAL. We focus on two hard states: a bright state during the rise and a dim state during the decay. Spectral fits reveal distinct dominant radiative processes due to a two-order-of-magnitude difference in accretion rate: Bremsstrahlung Self-Compton in the bright state and Synchrotron Self-Compton in the dim state. Using the MONK Monte Carlo code, we compute polarization properties and compare them with IXPE data. We also explore the impact of additional components, including disk reflection and non thermal particles.

Spectro-polarimetric properties of neutron star low-mass X-ray binaries with IXPE, NuSTAR and NICER

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We discuss the X-ray spectro-polarimetric properties of low-mass X-ray binaries hosting weakly magnetized neutron stars through recent observations. We focus in particular on IXPE polarimetric measurements, which reveal significant X-ray polarization in most sources and across different spectral states, and provide direct constraints on the geometry of the inner accretion flow. Comptonization generally represents the dominant contribution to the X-ray emission and observed polarization in the 2–8 keV band. However, the polarization is often higher than expected for a standard accretion disk plus boundary-layer scenario, pointing to more complex geometries and a substantial role for scattering. We discuss possible physical interpretations based on spectro-polarimetric modeling, and outline how future observations and improved theoretical models may further constrain the geometry of neutron star accretion flows.

Exploring BeXRBs Major Outbursts: Insights from X-ray and Optical Variability

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X-ray pulsars are powered by the transfer of matter from a companion to a rapidly rotating neutron star (NS), and are mainly found in young massive binaries. The Magellanic Clouds (MCs) provide an unparalleled laboratory for studying high-mass X-ray binaries (HMXBs) due to their moderate, well-constrained distances and relative isolation from the Galactic plane. Among these systems, Be X-ray binaries (BeXRBs) – featuring Be-type stars as donor companions – stand out for their remarkable variability, including prominent outbursts in both X-ray and optical wavelengths. Systems in the MCs are particularly valuable for investigating super-Eddington accretion during major X-ray outbursts, as similarly bright events are perhaps only seen in Galactic BeXRB pulsar Swift J0243.6+6124.

Recent advances, enabled by extensive monitoring through X-ray observatories such as Swift and the optical OGLE survey, have provided unique datasets for analyzing major outbursts over the past decade. In this talk, I will present findings on the super-Eddington regime in BeXRBs, and in particular I will examine the relationship between X-ray and optical variability observed during major outbursts caused by X-ray irradiation of the Be Star and its surrounding decretion disk, offering new insights into the mechanisms driving the extreme behavior of these remarkable astrophysical systems.

The Jet Emitting Disk model: where do we stand?

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The presence of a large-scale magnetic field is likely unavoidable in jetted systems such as X-ray binaries, playing a crucial role in extracting accretion flow angular momentum and allowing matter to reach sonic speeds. These ingredients form the basis of the JED-SAD model, which radially couples an inner Jet Emitting Disk (JED), described by a self-consistent magnetohydrodynamic accretion-ejection solution, with an outer Standard Accretion Disk (SAD). The interplay between gravitational energy release, disk heating, and radiative cooling processes shapes the disk's thermal structure and emitted spectrum. The model predicts hot radiative solutions capable of reproducing the hard X-ray states of X-ray binaries, even at high accretion rates approaching the Eddington limit. Over the past decade, JED-SAD has successfully explained the spectral evolution of several sources during outbursts. Coupled with the MONK Monte Carlo code, it now predicts X-ray polarimetric signatures that can be compared to IXPE observations. The computation of wind signatures and the implementation of time variability is also on-going. I will recall the main properties of the JED-SAD model, present the main results obtained in the last 10 years and their implications in our understanding of these objects, and discuss the future developments.

Investigation of a luminous and variable source ULX 5 in the vicinity of Circinus galaxy using XMM-Newton & NuSTAR observation

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Circinus ULX 5, located in the outskirts of the Circinus Galaxy, is among the most luminous and variable ultra-luminous X-ray (ULX) sources, reaching peak luminosities $> 10^{40}$ erg/s and exhibiting pronounced broadband spectral curvature. Previous observations with NuSTAR revealed a clear high-energy cutoff and suggested spectral evolution analogous to the broadened-disk and hard ultra-luminous states. We report on an ongoing broadband spectral-timing study combining new 2025 coordinated observations from XMM-Newton and NuSTAR with archival datasets spanning multiple luminosity epochs. In newer observation, it has been caught in a brighter state with luminosity $\sim 2 \times 10^{40}$ erg/s. The joint 0.3-30 keV coverage provides a powerful diagnostic of spectral curvature, high-energy rollover evolution, and disk-corona coupling. We apply physically motivated models incorporating multi-temperature accretion disks and thermal Comptonization to track variations in coronal temperature, optical depth, and inner disk structure across flux states. Timing analysis, including energy-resolved variability and hardness-intensity evolution, is used to probe state transitions and constrain changes in accretion geometry. This work aims to place Circinus ULX5 within the broader phenomenology of super-Eddington accretion and assess whether its behavior favours extreme stellar-mass accretion or alternative scenarios. Results from this analysis will be presented at the conference.

ULXs and HLXs Revisited: Synchrotron Radiation from Accreting Neutron Stars

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Ultraluminous X-ray sources (ULXs) serve as important probes of extreme accretion physics, exhibiting luminosities that surpass the expected limits of standard stellar-mass black hole systems. While these sources were traditionally interpreted as hosting intermediate-mass black holes (IMBHs), recent observations, including the detection of neutron stars in several ULXs and advances in broadband X-ray spectroscopy, support super-Eddington accretion onto compact stellar remnants as a viable alternative. Hyperluminous X-ray sources (HLXs), typically exceeding 10^{41} erg/sec luminosity, have likewise been regarded as strong IMBH candidates; however, emerging evidence suggests that neutron stars may also power some of these extreme systems. In this work, I investigate the spectral properties of ULXs and HLXs using a newly developed physically motivated model that favors neutron stars as the dominant accretors. Particular focus is given to NGC 470 HLX1, whose strong variability, soft thermal emission, and possible high-energy synchrotron component are consistent with a neutron-star-driven origin. I also examine particle acceleration mechanisms in accreting neutron star environments, emphasizing the roles of magnetic field configuration, accretion geometry, and magnetospheric or shock-related processes. Future studies of HLX samples can test whether super-Eddington neutron stars power their luminosities, challenging the IMBH paradigm and supporting a ULX-like neutron star origin.

Unveiling the Nature and distributions of X-ray populations in the Galactic Center: A Concentration of Hard X-ray Sources in the Nuclear Stellar Disk

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The Galactic center (GC) hosts the highest known concentration of exotic X-ray sources in the Milky Way, including cataclysmic variables (CVs) and low-mass X-ray binaries (LMXBs), along with thousands of faint X-ray sources whose physical nature remains uncertain. Despite their importance for understanding galaxy evolution, compact binary formation, and other cosmological processes, the classification of most GC X-ray sources has remained elusive. Leveraging a wide, groundbreaking survey conducted with XMM-Newton, we perform a comprehensive study of the properties and distributions of the X-ray source populations within the central $20^\circ \times 2^\circ$ of the Galactic disk. Our results reveal a pronounced concentration of hard X-ray sources within the nuclear stellar disk (NSD). We find that distinct GC source populations occupy different spatial scales along the central parsec, the nuclear star cluster, and the NSD, hinting at multiple formation pathways and even evolutionary histories.

How LMC star-formation history formed its current population of HMXBs

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The Magellanic Clouds are our closest star-forming galaxies with low Galactic foreground absorption. This makes them a unique laboratory to study the population of high-energy sources. The SMC hosts a large population of Be/X-ray binaries associated with high star formation activity ~ 25 -40 Myr ago. It has been proposed that the HMXB population in the LMC is associated with more recent star formation. However, due to the large angular extent and resulting insufficient coverage of the LMC, this association with SFR is not well established yet. An essential asset for studying the HMXB population in the entire LMC was the launch of eROSITA. Due to the vicinity to the south-ecliptic pole, sources in the LMC were monitored for up to several weeks during each all-sky survey, leading to a total exposure of up to ~ 50 ks. This allowed us to discover several new HMXBs, verify candidate HMXBs and publish a catalogue, complete down to a few 10^{34} erg/s. During my presentation, I will first focus on the classification scheme we adopted using multi-wavelength properties of all objects in the catalogue. Then I will discuss HMXB population properties in the LMC with a focus on the tight connection to star-formation history.

The First X-Ray Polarimetry of GRS 1739-278 Reveals Its Rapidly Spinning Black Hole

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I will present an analysis of the recent *IXPE* observation of the black hole X-ray binary GRS 1739–278 during its 2025 mini-outburst. The 2–8 keV spectrum is dominated by thermal disc emission with a contribution of thermal reflection component interpreted as caused by the disc self-irradiation. The hard Comptonized contribution is found to be negligible. The *IXPE* data show an averaged polarization degree of $PD = (2.3 \pm 0.4)\%$ and polarization angle of $PA = 62^\circ \pm 5^\circ$ in the 2–8 keV range. The model-independent PCUBE analysis reveals that PD increases from $\sim 2\%$ at 2 keV to $\sim 10\%$ in the highest 6–8 keV bin, while PA remains constant across the *IXPE* band within statistical uncertainties. Modelling with Novikov-Thorne standard disc including the disc self-irradiation indicates that high-spin configurations enhance the contribution of the reflected returning thermal radiation, which dominates the observed polarization properties. We infer an extreme black hole spin of $a \simeq 0.994$ and a system inclination of $\theta \simeq 54^\circ$. Owing to the large contribution from the reflected returning radiation, the observed polarization direction is nearly parallel to the projected system axis, the position angle of which is predicted to be at $\simeq 58^\circ$ east of north.

A Systematic Meta-Analysis of Iron Abundances from X-ray Reflection Spectroscopy

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Studies of accreting black hole sources with X-ray reflection spectroscopy frequently report iron abundances significantly larger than the Solar (expected) value, raising questions about whether these values are physical or model artifacts. We present a comprehensive meta-analysis of the complete RELXILL literature, encompassing 650+ refereed papers and more than 2,000 individual spectral fits. Using a standardized AI scheme, we harvest all available literature and analyze published results for both X-ray black hole binaries and active galactic nuclei. We find a global median iron abundance of ~ 2 Solar, with 25% of measurements reaching or exceeding 5 times this value. Our analysis highlights the role of community priors, finding that in $\sim 25\%$ of the studies the value of A.Fe was assumed to be known (fixed in the spectral fits). This sample also underscores the impact of hard X-ray missions like NuSTAR, which contributes to half of the studies. This census provides a robust statistical baseline for distinguishing systematic modeling effects from genuine chemical enrichment across stellar-mass and supermassive black holes.

Probing accretion disk plasmas in LMXBs with XRISM

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Low mass X-ray binaries (LMXBs) are systems composed of a compact object (black hole or neutron star) and a low mass ($\lesssim 1$ mSun) star. The compact object accretes matter from its companion, forming an accretion disk. The gas in the disk gets ionized by the X-ray emission, photoionizing the plasmas. Characterizing their properties is essential for understanding the accretion disk of LMXBs. X-ray dipping provides an excellent opportunity to study these accretion disk plasmas. The dipping phenomenon consists of drops in flux that result from interaction between the stream of accreted matter from the companion star and the impact region of the disk. This phenomenon has been observed in two dozen systems, however, specifics of the structure and plasma properties in this impact region of the accretion disk are not yet understood. Building on the XMM-Newton study of the dipping behavior of the LMXB 4U1624-490, I will present XRISM Resolve results, showcasing a newly discovered wind and the analysis of the X-ray dips, now studied for the first time with high spectral resolution. We aim to provide insight into the dipping phenomenon, find any connection to disk winds, and get a comprehensive picture of plasmas in the accretion disk of LMXBs.

A Direct Test of Super-Orbital Precession in NGC5907 ULX-1: Lense-Thirring versus Free Precession

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NGC5907 ULX-1, the most luminous ultraluminous X-ray pulsar known ($L_{X,\text{peak}} \sim 10^{41}$ erg s⁻¹; ~ 500 times the neutron star Eddington limit), exhibits a ~ 78 -day super-orbital periodicity. An extended low-flux/quiescent state (mid-2017–mid-2020), likely associated with the propeller regime, separates two epochs of high-flux activity, enabling a direct test of whether the super-orbital modulation is driven by Lense-Thirring precession of the super-Eddington disc or by neutron star free precession. We present results from more than a decade of Swift XRT monitoring (2014–2025). Using Bayesian mixture models to marginalise over intermediate-flux states that dilute the periodic signal in the recent epoch, we recover a tightly constrained period ($P = 78.06 \pm 0.05$ d) and find evidence for phase coherence across the ~ 14 -cycle quiescent gap. This, together with the period stability despite substantial changes in both accretion rate and spin period, challenges Lense-Thirring precession and instead favours free precession of a magnetically deformed neutron star. With the super-orbital ephemeris established, we perform phase-resolved spectroscopy to track spectral evolution over the precession cycle, constraining the relative contributions of the inner disc, wind photosphere, and accretion column at different viewing angles.

Unbinned Constraints on Black Hole Spin from Energy-Dependent Polarization Rotation

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Energy-dependent polarization rotation (EDPR) is a predicted signature of general-relativistic photon transport in disk-dominated black hole X-ray binaries (BHXBs). Because photons of different energies originate at different disk radii and follow distinct spacetime trajectories, the X-ray polarization angle (PA) is expected to vary with energy, with an amplitude set by black hole spin, luminosity, and viewing geometry. Detecting this effect with the Imaging X-ray Polarimetry Explorer (IXPE) is challenging using traditional energy-binned analyses, which assume a constant PA within each bin and can smear out energy-dependent changes, reducing sensitivity—especially at high energies where counts are sparse. We present an unbinned Bayesian framework QUEEN-BEE that uses an event-level likelihood based on per-event Stokes parameters, avoiding depolarization biases from binning. We implement a continuous EDPR parameterization and perform Bayesian model comparison between linear-rotation, constant-PA, and unpolarized models, using Bayes factors to quantify evidence for each. Applied to disk-dominated BHXBs like LMC X-3, QUEEN-BEE robustly recovers polarization and find no significant EDPR, placing stringent upper limits on rotation across 2–8 keV. Interpreted within thin-disk relativistic transport models, these limits provide direct constraints on black hole spin and demonstrate EDPR as a model-independent probe of relativistic disk physics.

Two recent novae observed with the XMM-Newton and Chandra gratings

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Nova Cen 2025 (V1935 Cen) was observed with the XMM-Newton RGS during its decline from the supersoft state when the continuum of the white dwarf was dominating the X-ray spectrum. We observed the still hot, but cooling white dwarf with overimposed emission lines due to shocked material. Nova Sco 2024 (V1723 Sco) was observed with XMM-Newton and with the Chandra HETG grating when it exhibited only a spectrum of thermal plasma due to shocks, before the onset of the supersoft X-ray source (later monitored with Swift and NICER). Reaching collisional ionization equilibrium took several months, and the spectrum was quite "hard" until the white dwarf became observable. I will discuss the intriguing spectra of these two novae in the framework of the general nova evolution and of some exciting discoveries recently made with X-ray high spectral resolution.

Investigating the Fe K fluorescence complex in GX 301-2 with XRISM

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The X-ray spectrum of the neutron star High-Mass X-ray binary GX 301–2 is characterized by obscuration with line-of-sight column densities of the order of 10^{24} cm^{-2} and very strong, near neutral fluorescence lines, most prominent from Fe, but also from S, Ar, Ca, Cr, and Ni. The Fe $K\alpha$ complex further shows a pronounced Compton shoulder, originating from subsequent scattering of line photons in the ambient medium. Two XRISM observations of GX 301–2 during its periodic per-periastron flare, one in February and one December 2025, allow us to resolve the Fe K region in unprecedented detail, in particular the exact profile of the near-neutral Fe $K\alpha$ and $K\beta$ lines, the Compton shoulder, as well as the Fe K absorption edge. In this talk we will present plasma diagnostics of the stellar wind of the B-hypergiant companion through Monte-Carlo-based radiative transfer modeling of the Compton shoulder and photoionized plasma models of the Fe $K\alpha$ and $K\beta$ lines and K edge. We will further discuss the variability of these spectral features over the course of the pre-periastron flare.

Search for X-ray counterparts of optical mHz variability detected in nova-like cataclysmic variables by TESS.

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We studied the flickering of nova-like cataclysmic variables in the X-ray band using observations from XMM-Newton and Chandra. We were interested in the mHz variability previously detected in high optical state using TESS data. The typical shape of the power density spectrum in the optical light is red noise, but some objects also show a frequency break. This frequency clusters around 1 mHz. Detection of the same frequency also in the X-rays is key for interpretation. While the presence of this break only in the optical radiation points to a geometrically thin disk, detection of the same break in the X-rays suggests that the source of the variability is a boundary layer or a central geometrically thick optically thin disk, the corona. The number of detected break frequencies in X-rays is extremely low. This is mainly due to short X-ray observations typical of cataclysmic variables. Therefore, the final picture of the accretion geometry is unclear. So far, it appears that systems showing only red noise in X-rays also show red noise in optical. The same applies to several break frequency detections, which may be inconsistent with dwarf novae in the high optical state.

From Spectral Properties to X-ray Reprocessing in ULXPs/ULXs: A Comparative Study with Galactic X-ray Binaries

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Ultra-luminous X-ray sources (ULXs) are off-nuclear X-ray sources whose luminosities exceed the Eddington limit for stellar-mass compact objects. The discovery of coherent X-ray pulsations has established a subset as accreting neutron stars (ULX pulsars; ULXPs), requiring super-Eddington accretion onto magnetized neutron stars. We present a broadband spectral analysis of five ULXPs using simultaneous XMM-Newton and NuSTAR observations. The spectral continua are well described by models commonly applied to Galactic accreting X-ray pulsars, consisting of a high-energy cut-off power law with a soft excess and relatively low absorption. We detect no significant Fe $K\alpha$ emission, with only marginal evidence or low upper limits on its equivalent width, distinguishing ULX pulsars from local accreting X-ray pulsars. We further investigate X-ray reprocessing signatures by examining the presence of Fe $K\alpha$ emission in bright ULXs and ULXPs, hardness ratio variations during eclipse transitions, and eclipse-to-out-of-eclipse (OOE) flux ratios in eclipsing ULXs. We obtain stringent upper limits (11–20 eV) on Fe equivalent widths, detect no significant hardness ratio changes during eclipse transitions, and find that higher eclipse-to-OOE flux ratios than in Galactic X-ray binaries. These findings suggest ULXs reside in metal-poor or highly ionized environments that suppress reprocessed emission features.

X-Ray Characterization of the Post-Nova Stage of V2487 Ophiuchi

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V2487 Oph is a recurrent nova that underwent a fast and luminous eruption in 1998. The host system consists of a massive white dwarf (1.35 Msun) and a donor star (0.21 Msun), with the binary exhibiting an orbital period of 0.753 days (18.1 hours). Previous X-ray observations conducted 2.7 and 3.2 years after the outburst have been interpreted to support the resumption of accretion. In this study, we present the X-ray analysis of five observations of V2487 Oph, obtained with XMM-Newton and Suzaku over a 12 year span following the 1998 outburst, to characterize its X-ray emission and investigate signs of resumed accretion in the post-nova phase.

XMM-Newton confirms the persistent nature of the Be X-ray binary pulsar 4U 0728-25

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In the persistent Be X-ray binaries (BeXRBs) a slowly rotating neutron star (with $P_{\text{spin}} > 100$ s) is in a wide ($P_{\text{orb}} > 30$ d) and almost circular orbit around a Be star. Due to the orbit and spin properties, the matter accretion occurs at a low and almost constant rate: therefore, these sources are characterized by persistent low X-ray luminosities, with $L_X \simeq 10^{34-35}$ erg s⁻¹.

Here we report the results obtained with a recent XMM-Newton observation of the poorly known X-ray binary pulsar 4U 0728-25, which allowed us to investigate its spectrum at an unprecedented detail level. It is characterized by a significant thermal excess over the main power-law component, which can be described with a blackbody model of high temperature ($kT_{\text{bb}} \simeq 1.5$ keV) and reduced size ($R_{\text{bb}} \simeq 240$ m); it contributes for about 25 % to the total source flux and varies along the pulse phase. The estimated luminosity was about 9×10^{34} erg s⁻¹. These spectral properties, together with the long spin ($P_{\text{spin}} = 103.3$ s) and orbital ($P_{\text{orb}} = 34.5$ d) periods, strongly suggest that 4U 0728-25 is a new member of the persistent BeXRBs.

Towards a Volume Limited Sample of CVs

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Accreting compact binaries (ACB) are among the most luminous X-ray sources within the Galaxy. By incorporating machine learning techniques, we have identified roughly 11,000 potential ACB candidates in the eROSITA data sample. Optical spectroscopic observations are, however, now required to determine whether these candidates are true ACBs. For this project we are, therefore, conducting follow-up optical spectroscopic observations of these candidate systems using various instruments, primarily from SDSS, ESO and SAAO. However, identification spectra are not enough to classify an ACB. Therefore, following the positive identification of an ACB, time-resolved photometric observations are obtained, primarily using the SPECULOOS-south telescopes, to determine the orbital period, which would enable further sub-classification. The ultimate goal of these observations is to obtain a complete 500pc volume-limited sample of all ACBs. Having these complete volume-limited samples will enable us to better understand the evolution of close binary systems, as well as constrain the contribution of ACBs to the total high-energy output of the Galaxy. All of these observations are ongoing, and has already yielded several hundred new ACB systems. In this presentation I will give an overview of these observations, talk about some of the results, and discuss the future prospects of this project.

Discovery of a 0.8-mHz quasi-periodic oscillation in the transient X-ray pulsar SXP31.0 and associated timing transitions

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We report the discovery of a quasi-periodic oscillation (QPO) from the Be/X-ray pulsar SXP31.0 at 0.8 ± 0.1 mHz, detected at a bolometric luminosity of 2.5×10^{38} erg s⁻¹. SXP31.0 is the fourth known super-Eddington pulsar exhibiting an mHz QPO and the first such source outside the ultraluminous X-ray pulsar population.

The QPO coincides with a low pulsed fraction in soft X-rays, consistent with values observed in these systems, but rises sharply above 20 keV, reaching 35%. Thanks to broad-band coverage and detailed timing analysis, this is the first time such a pronounced increase in pulsed fraction has been observed at hard X-rays in a super-Eddington pulsar with an mHz QPO.

The QPO disappears in all subsequent observations, accompanied by a marked increase in pulsed fraction and a distinct change in pulse profile shape. We constrain the timescale of this transition to less than 14 days, providing the first such limit for this phenomenon. Interestingly, the QPO is not observed in any follow-up observations at luminosities above or below its initial detection, suggesting it is a transient phenomenon.

We discuss these results in the context of other super-Eddington pulsars exhibiting mHz QPOs, including M51 ULX-7, NGC 7793 P13, and M82 X-2.

The Be/X-ray Binary A0538-66: A laboratory for extreme X-ray accretion physics

Lorenzo Ducci¹

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The Be/X-ray binary A0538-66 in the Large Magellanic Cloud has been challenging our understanding of accretion physics since its discovery nearly 50 years ago. It hosts the fastest-known pulsar in its class (69 ms) in a remarkably short (16.6 d) and eccentric ($e \sim 0.7$) orbit. A0538-66 shows extraordinary multiwavelength variability, including seconds-long X-ray flares with a dynamic range >1000 and peak luminosities exceeding $1E38$ erg/s, which are correlated with bright, fast optical flares. Recently, it also displayed an outburst reaching luminosities typical of ultraluminous X-ray sources. The combination of extreme properties shown by this source is unmatched among accreting pulsars. I will present the most recent results on this binary system from multiwavelength data, with a focus on the X-ray band. Finally, I will discuss how these findings constrain the physical mechanisms, such as magnetic field geometry and accretion flow dynamics, responsible for its unique variability.

Hide and seek in NGC 4631: discovery of a new ultra-luminous X-ray pulsar with a rapid spin-up rate

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Using recent data from the XMM-Newton telescope, we have found a new ultraluminous X-ray source in the galaxy NGC 4631. This source, called X-8, shows strong periodic pulsations every 9.6652 seconds. Its spin is increasing at one of the fastest rates ever observed. The high luminosity and fast spin-up show that the object is a neutron star, making X-8 a new member of the class of pulsating ultraluminous X-ray sources. The X-ray emission can be explained by models often used for such sources. We consider two explanations for the rapid spin-up: the orbital motion of the neutron star or the torque from accreting material. This discovery adds an important example to the small group of known pulsating ultraluminous X-ray sources, which will help us understand how they produce such high luminosity.

XMM-Newton follow-up of eROSITA-discovered cataclysmic variables

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With its exceptional sensitivity, the eROSITA telescope array onboard the Spektrum-Roentgen-Gamma (SRG) mission has enabled the discovery of new cataclysmic variable (CV) candidates, later confirmed through multi-wavelength follow-up observations. Robustly classifying CVs into different subtypes is key to constraining their space densities and to improving our understanding of close binary evolution, with broader implications for the evolution of the Galaxy. In this talk, I will present a multi-wavelength characterisation of three eROSITA-discovered CVs using XMM-Newton X-ray data together with optical observations. We classify SRGt 062340.2-265751 as a nova-like system. However, it shows multiple periodicities that are more typical of intermediate polars, which suggests it may represent a new CV type. For eFEDS J090344.3-0133 and eFEDS J084413.5-0128, two AM CVn systems identified through optical spectroscopy, I will present our search for their orbital periods.

Variability of the emission lines during the eclipse-egress and out-of-eclipse in Cen X-3 with RGS

José Joaquín Rodes-Roca¹, José Miguel Torrejón Vázquez¹, Graciela Sanjurjo-Ferrín¹, Jessica Planelles Villalva¹

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The eclipse-egress and the out-of-eclipse light curves show a distinctive structure and has been divided into three and two intervals, respectively. The high-resolution spectra obtained from the reflection grating spectrometer on board XMM-Newton were extracted according to these segments. Pure photoionisation-dominated, collisional-dominated and phenomenological models were explored in SPEX and ISIS, for which we studied the properties of emitting and absorbing matter depending on the emission and absorption lines identified in the spectra. Emission lines from Si v, Mg xii, Mg xi, and Ne x were detected in the spectra; in particular hydrogen-like lines of Mg and Ne with a significance at a 5σ level in the eclipse-egress spectrum and at a 3σ level in the out-of-eclipse spectrum. The maximum emissivity temperature of the emission lines points to the presence of two different plasmas with different temperatures. The variability of the line parameters, fluxes and equivalent widths, suggest stellar wind structures emerging from the eclipse, most likely associated with the disc and the Lagrangian point after the emergence of the accretion stream.

Cen X-3: States and Transitions

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Cen X-3 is a disc-fed high-mass X-ray binary composed of an O6–8 II donor star and a neutron star in a 2.1-day orbit. The system exhibits high-soft and low-hard states. In the low-hard state, the eclipse-egress light curve is highly structured, suggesting the emergence of multiple structures from behind the donor star, such as the accretion disc, the accretion stream, or material near the Lagrangian point. In the high-soft state, by contrast, the egress is sharp. Dips have also been observed in the light curve, likely related to interactions between the neutron star and its magnetosphere. The transition from low-hard to high-soft has been observed with Chandra, with evidence pointing to the ingestion of a train of clumps as a possible trigger. During this transition, Doppler modulations of Fe XXV, consistent with a ballistic orbit around the neutron star, were detected. To perform this analysis, methods such as automatic dip detection with autoencoders and orbital-modulation fitting with particle-swarm optimization were developed and made publicly available to improve reproducibility and facilitate their application to other sources by the community.

Multiwavelength Study of Three ULXs in NGC 1792: Identification of a New Transient ULX and Constraints on Donor Stars

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This study investigates the X-ray, optical, and infrared properties of three ultraluminous X-ray sources (ULXs) in NGC 1792. We report the discovery of a new transient source (ULX-3), which reaches a peak luminosity of 5.5×10^{39} erg s⁻¹ based on archival Chandra observations. In addition, we reanalyze two previously known ULXs using Chandra data that had not been examined before, allowing us to better constrain their X-ray properties. We investigate the optical and infrared counterparts of all three ULXs using archival Hubble Space Telescope and James Webb Space Telescope data. Counterparts are identified through precise astrometric alignment between the X-ray and imaging datasets. To constrain the nature of the donor stars, we perform photometric analyses including variability studies, spectral energy distribution modeling, and color-magnitude diagram (CMD) comparisons. A unique optical counterpart is identified for ULX-3, while multiple optical and infrared candidate counterparts are found for the other two ULXs. Estimates of donor star masses and ages derived from CMD analysis suggest that, if the optical emission is dominated by the donor stars, these systems are consistent with high-mass X-ray binaries.

X-ray Periodicities in the Gamma Cas Analogues

Robbie Webb¹, Natalie Webb¹

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The mechanism for X-ray generation in the Gamma Cas analogues, a small group of highly variable Oe/Be stars, has been a mystery for several decades. They are characterised by their hard X-ray spectra, often including strong Fe fluorescence lines, and X-ray luminosities in the gap between those seen in similar stars and the more luminous Be/X-ray Binaries. They have also been observed to be highly variable on a range of timescales, from seconds up to several years. Competing theories for the mechanism for X-ray production include magnetic interactions between the star and its descretion disk or accretion onto a white dwarf (WD) companion. Until now the missing evidence in favour of these sources being a new population of Be+WD binaries has been the absence of persistent significant periodicities associated with potential WD companions.

We will present the results of a comprehensive review of intra-observation variability in a large sample of 89 XMM-Newton and 45 Chandra observations, using both Fourier- and time-domain techniques to search for periodicities. We will identify those sources which appear to show periodicities across several observations, and outline how the periodicities in these sources might resolve the doubt over the nature of these exotic sources.

Charting CVs in the eROSITA sky: A Machine learning boosted Bayesian Framework for CV identification and characterization in all-sky X-ray surveys

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Cataclysmic Variables (CVs) are unparalleled laboratories for studying accretion physics and binary evolution. Historically, all-sky X-ray surveys have revolutionized the discovery of CVs, with ROSAT expanding the known population dramatically. eROSITA advances this legacy with its multiple all-sky surveys. With each scan five times deeper than ROSAT, eROSITA offers an unprecedented spatial and spectral resolution. Thousands of CVs across sub-types are forecasted in the eROSITA sky, promising the largest, unbiased sample of CVs to date. A key challenge, however, lies in robustly identifying the CV content in all-sky X-ray surveys such as eROSITA. We present a machine learning-enhanced Bayesian framework for the accurate identification and characterization of CVs in eROSITA data and the results of its implementation on the deepest eROSITA catalogue, eRASS:5. The results demonstrate that this framework facilitates the discovery of unbiased, complete samples of CVs enabling volume-limited studies with GAIA. We also discuss large-scale follow-up campaigns undertaken to confirm the CV nature of the predicted candidates and the current prospects for probing unresolved questions in CV evolution and their contribution to the Galactic Ridge X-ray emission.

Solving the Soft X-ray Puzzle Using XMM-Newton Observation of the Highest Field Polar AR UMa

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Canonical models of accretion in magnetic cataclysmic variables (MCVs) predict that half of the hard X-ray radiation emitted by the shock-heated plasma should be reprocessed into a soft X-ray blackbody component. Contrary to this expectation, several polar MCVs show an excess of soft component, a ROSAT-era observation known as ‘Soft X-ray Puzzle’. The soft excess is currently understood as a deficiency in hard X-ray, often attributed to ‘blobby accretion’ in which the accretion stream, discretised into dense blobs, penetrate deep into the white dwarf photosphere during the accretion shock. The cause of blobby accretion, however, remains unclear, with potential drivers including the magnetic field strength, the location of the threading region, etc. In this contribution, we revisit the soft X-ray puzzle using the high-state XMM observation of AR UMa, the highest field polar (230 MG). AR UMa, which has long escaped high-state X-ray observations, was captured in its 2023 high-state by a triggered XMM-Newton observation. Utilizing the broad spectral coverage enabled by OM and EPIC instruments, we derive a comprehensive energy budget for the source. By quantifying the energy-balance of polars at the magnetic extreme, we provide a critical benchmark for understanding the origin of soft X-ray excess in MCVs.

Outburst from the slowest rotating X-ray pulsar AX J1910.7+0917 detected by XRISM/Xtend

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XRISM/Xtend Transient Search (XTS) project aims to search for X-ray transient sources within the Xtend field-of-view (FoV) during a pointing observation. In a XRISM PV observation of the supernova remnant W49B, XTS detected an outburst from the high-mass X-ray binary AX J1910.7+0917. AX J1910.7+0917 is known as the slowest rotating X-ray pulsar, with a pulsation period of 10 hours. However, the details of the accretion process associated with this slow rotation remain unclear. We present a detailed analysis based on Xtend data with the longest exposure time of 550 ks for this source. We detected drastic flares with a peak luminosity of $1 \times 10^{36} \text{ erg s}^{-1}$, and the averaged spectrum during the outburst is reproduced by an absorbed power-law with a Fe emission line ($\sim 6.5 \text{ keV}$). Additionally, we determined the pulsation period to be $\sim 38 \text{ ks}$, which is slower than that reported in previous observations. The observed flaring activity and slow rotation indicate that the system is driven by quasi-spherical settling accretion. We discuss the accretion geometry of the slowly rotating pulsar based on the spectral and timing features.

Flip-Flops and QPO switching in GX 339–4 during the 2021 and 2024 Nicer outbursts

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GX 339–4 is a low-mass X-ray binary often used as an archetype, showing typical outburst behaviour. The source undergoes a full outburst every 2–3 years, passing through all known accretion states. We used NICER data to study the spectral-timing properties of the 2024 outburst of GX 339–4 and to compare them with the 2021 outburst. In particular we focused on rapid “flip-flop” transitions, i.e. step-like changes in X-ray flux that often come with changes in the timing properties. We used Monte Carlo simulations to assess the statistical significance of candidate QPO peaks in the power spectra, testing for the short-timescale appearance and disappearance of Type-B QPO signatures. We used this statistically defined classification to compare variability across flip-flop levels, to extract energy spectra for intervals with and without QPO signatures, and to study relations between QPO peak frequency and other variability properties. We will present detailed results and their implications.

The Chandra-HETG spectrum of 4U 1746-37: hints for red- and blue-shifted high-velocity FeXXV and XXVI Absorption

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4U 1746-37 is a bright (F(2-10 keV) = 50 mCrab), persistent Low-Mass X-ray binary, lying in the globular cluster NGC 6441 at 11 kpc from us, behind the Galactic center. In this poster we present the Chandra-HETG spectrum of 4U 1746-37, whose 6-9 keV portion shows hints for up to 5 He- and H-like iron absorption components, at velocities comprised between -0.2c and +0.1c. The equivalent H column densities of these absorbers spans the range $\log N_H(\text{cm}^{-2}) \sim (21 - 23)$. Given the target location in the Galaxy, these could be due to either absorption by far- (receding) and near-side (approaching) shells of a hot and energetic central Galactic bi-conical outflow X-rayed by the binary continuum on its way to us, or to inflowing and outflowing highly ionized gas intrinsic to the binary system and intercepting our line of sight at different radial distances from the central source (e.g. an accretion disk fountain). We show that the Chandra-HETG spectrum cannot distinguish between these two scenarios, but anticipate that our approved 60 ks XRISM-Resolve observation of the target will unambiguously confirm or invalidate the detection of all kinematics components hinted-at by the Chandra spectrum, and disentangle between the two possibilities.

Energy shifts of iron K-shell emission lines in the intermediate polar EX Hydrae observed with XRISM

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Measuring white dwarf (WD) masses in accreting systems constrains accretion physics, binary evolution, and their potential link to Type Ia supernovae. The new era of high-resolution X-ray spectroscopy opened by XRISM enables the most precise measurements of line centroid energies in the Fe K band. We present the XRISM observation of the intermediate polar EX Hydrae in July 2025 with a total exposure of 83 ks. The XRISM/Resolve spectrum clearly resolves the Fe K α and K β fluorescence lines, as well as He-like triplet and H-like Ly α lines. We perform orbital-phase-resolved spectroscopy and detect a sinusoidal modulation in the centroid energies of Fe K α fluorescence, Fe XXV z, and Fe XXV w lines. The modulation amplitude is ~ 1 eV ($\sim 50 \text{ km s}^{-1}$), and can be attributed to Doppler shifts from the WD's orbital motion. The best-fit baselines differ among the lines, with Fe K α fluorescence showing a higher baseline than Fe XXV z and Fe XXV w, implying distinct emission regions. In this presentation, we will also discuss the energy shifts of the Fe K α and K β fluorescence lines and combine them with the orbital modulation to constrain the WD mass and the geometry of the accretion column.

A 20-Year X-ray Spectral Analysis of the Ultraluminous X-ray Pulsar NGC 5907 ULX-1

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XMM-Newton observations of NGC 5907 ULX-1 offer a unique opportunity to investigate the spectral evolution of a pulsating ultraluminous X-ray source over a long period with X-ray luminosities varying by up to one order of magnitude. NGC 5907 ULX-1 is the most luminous ultraluminous X-ray pulsar known to date and one of the ULX pulsars that exhibits spin-down during its low flux states. Benefiting from the long-term monitoring of the source between 2003-2024, we present the results of a systematic search for the best physically motivated model to fit the continuum of the X-ray spectrum with the help of different emission models and modeling procedures. Such an approach also serves to resolve degeneracies between thermal and non-thermal emission at low and high energies. As a natural outcome of our analysis, we study the correlation between the thermal and non-thermal model parameters such as the inner disk temperature, the photon index, and the electron temperature for Comptonization with respect to the spin observability and the X-ray luminosity of NGC 5907 ULX-1.

Super-orbital period evolution of Hercules X-1

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Hercules X-1 is an intermediate (or low) mass X-ray binary pulsar that exhibits a ~ 35 -day super-orbital modulation whose origin-disc precession or neutron-star free precession remains debated. Earlier work reported stochastic variations without a clear long-term trend. Using ~ 50 years of data from CGRO/BATSE, RXTE/ASM, Swift/BAT, Fermi/GBM, and MAXI/GSC supplemented with archival measurements, we studied the long-term evolution of this modulation. Three methods are applied: epoch-folding searches for constant periods, χ^2 maximisation in the period-period-derivative space, and timing of main-on peaks via an Observed-minus-Calculated analysis. All approaches consistently show a long term decrease in the super-orbital period at a rate of $\sim 10^{-5} \text{ s s}^{-1}$, with additional short-timescale variabilities superposed on this trend. The possible mechanisms for the observed decay of the super-orbital period will be discussed.

Flux-dependent behavior of the “10 keV feature” of 4U 0115+63

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The Be X-ray binary system 4U0115+63 has one of the highest numbers of detected harmonics of its cyclotron resonant scattering features (CRSFs), a pronounced spectral component known as the “10 keV feature,” and strong quasiperiodic oscillations (QPOs).

NuSTAR observations of 4U0115+63, taken during the decay of a Type II outburst in 2015, showed that the source flux varies by a factor of 2 during the QPOs (approximately 500s long). We present our results from flux-resolved analysis of the “10 keV feature,” aiming to disentangle it from the broadband continuum and CRSFs and investigate its origin.

Comparing the flux-resolved spectra of a given observation with the respective total dataset revealed a distinct change in overall spectral shape at the position of the “10 keV feature” but no comparable deviation at the energies of the harmonic CRSFs. We find indications for an anticorrelation between the continuum flux and the ratio of the “10 keV feature” flux to the continuum flux within each observation.

We present evidence that the “10 keV feature” shows independence from the remaining features, as it seems to have a different formation mechanism than the continuum emission, while still originating from the same physical environment.

Resolved extreme ionization around Holmberg II X-1: a new view on ULX radiative feedback

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We present spatially resolved JWST NIRSpec and MIRI integral-field spectroscopy of the nebula surrounding the ultraluminous X-ray source Holmberg II X-1, providing the first direct view of high-ionization infrared emission on scales of only tens of parsecs in this system. By combining emission-line surface-brightness maps, diagnostic line ratios, and kinematic profiles, we detect intense [Ne V] and [Ne VI] emission that is strongly confined to a localized sector of the nebula, in contrast to the more extended hydrogen recombination and low-ionization emission. All detected transitions exhibit narrow velocity dispersions, with no evidence for broad wings or systematic velocity shifts, ruling out fast radiative shocks as the dominant excitation mechanism. The highest-ionization gas is aligned with previously identified radio structures, suggesting directional escape of hard photons from the accretion flow. Comparisons with other low-metallicity galaxies hosting ULXs show that similar high-ionization luminosities can arise in very different star-formation environments, pointing to the dominance of compact accretion as a source of hard ionizing radiation. These results demonstrate that anisotropic hard-photon feedback from compact objects can imprint observable signatures on the interstellar medium, providing a resolved laboratory for studying the coupling between accretion power and nebular ionization in extreme environments.

Low luminosity behaviour of BeXRBS: a systematic study using eROSITA

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Be X-ray binaries (BeXRBS), where neutron stars orbit and accrete from a Be star were long considered transient sources owing to their massive outbursts ($\sim 10^{36}$ – 10^{38}) at periastron. Their behaviour outside of outburst has been a longstanding question, with early research suggesting predicting the propeller effect at low mass-accretion rate. Recent NuSTAR observations have however shown that several Galactic BeXRBS indicate signs of accretion at low luminosities ($\sim 10^{33}$ – 10^{34}). We use the eROSITA all-sky survey to probe the prevalence of this behaviour on a systematic level, since eROSITA allows a uniform study of the entire population of BeXRBS, at least in the Western hemisphere. The question of prevalence of the propeller regime has implications for both the study of accretion onto highly magnetised neutron stars, and the low end of the HMXB luminosity function, which is a key probe for Galactic star formation rate. We show using eROSITA that this effect is marginal for the Galaxy, with only a few systems hinting at this behaviour. We further depict the eROSITA luminosity of each source over spin period, to verify the prevalent cold disk accretion scenario, put forth to explain stable accretion at low luminosity. Archival XMM-Newton data help complement our findings.

New intermediate-mass black hole candidates in extragalactic globular clusters

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Intermediate-mass black holes are the missing link between stellar-mass and supermassive black holes. Their demographics and environments inform black hole seeding pathways from population III stars, direct collapses or from runaway cluster growth. Only a few good examples of such exotic intermediate-mass black holes exist. Using the Euclid early release observations and the XMM-Newton and Chandra X-ray data archives, we have identified 6 new candidate globular clusters that host Ultra-Luminous X-ray sources (ULX) in the Fornax cluster of galaxies. Since globular clusters consist of only old stellar systems that are not expected to reach ULX luminosities, these globular-cluster-ULXs are good candidates for IMBHs that have disrupted or captured a star. Alternatively, the candidates could be background quasars that have been mis-identified as globular cluster systems by our detection algorithms. To discern between the alternatives, we were awarded observations with the Gemini South telescope to spectroscopically confirm the two most promising candidates. One system was indeed a new globular-cluster-ULX near NGC 1387, while the other turned out to be a background quasar at a redshift of $z=1.56$. We expect to detect many more of these systems in the forthcoming Euclid data releases.

The Role of X-ray Irradiation in the Variability of Unstable Black hole Accretion disks.

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X-ray binaries hosting compact objects frequently exhibit characteristic lightcurve variability at high accretion rates, often attributed to thermoviscous instabilities within their accretion disks. A primary driver of this behavior is the radiation pressure instability (RPI), which triggers limit-cycle oscillations in the inner disk regions. Building upon the global disk instability model and alpha-viscosity prescription established by Janiuk et al. (2002), this work investigates the influence of irradiation from the central compact source on the time-evolution of such unstable disks.

As highlighted by Dubus et al. (1999), irradiation is a critical factor in disk evolution, whether originating from a black hole's hot corona or a neutron star's boundary layer. We utilize the "GLADIS" code to calculate a 1D vertically averaged global hydrodynamical model, modifying the energetics to include irradiating flux based on accretion rate and system geometry. Our model incorporates a shielding region in the inner disk to regulate variability of amplitude and examines how irradiation dictates the morphology of outburst patterns. Furthermore, we explore the role of disk winds in regulating RPI in black hole X-ray binaries. As a case study, we model the "heartbeat" feature observed in 4U 1630-47 by Fan et al. 2025.

Energy-Dependent Pulse Profile Diagnostics in Ultra-Luminous X-ray Pulsars

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The emission properties of pulsating Ultra-Luminous X-ray sources (PULXs) are governed by extreme accretion onto magnetized neutron stars. Following the methodology of Ferrigno (2023), we employ a novel spectro-timing approach that integrates spectral behavior with energy-dependent pulse profile analysis, providing a robust diagnostic of the emission geometry often hidden in phase-averaged spectra. In this presentation, I focus on the energy-dependent Pulsed Fraction (PF) of the PULX NGC 7793 P13. By utilizing all available NuSTAR data to achieve the highest possible S/N, we have obtained a robust determination of the Pulsed Fraction Spectra (PFS). We specifically investigate potential discontinuities in the energy-resolved pulse profile shapes, as these have been identified in sub-Eddington Galactic pulsars as indicators of cyclotron absorption lines. This work aims to place the PFS characteristics of NGC 7793 P13 into the broader context of these Galactic sources, exploring whether similar physical mechanisms—such as cyclotron resonance or beam pattern transitions—are at play in the supercritical regime. While our primary focus remains on the hard X-ray timing signatures from NuSTAR, we also consider the soft X-ray context provided by XMM-Newton.

Broadband X-ray study of low luminosity Intermediate Polars (LLIPs)

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Intermediate Polars (IPs) are a subtype of magnetic Cataclysmic Variables (mCVs) that serve as important laboratories for studying accretion onto magnetized white dwarfs (WDs). As the accreting material impacts the WD surface, a standing shock forms, heating the plasma to tens of keV and producing strong X-ray emission. Their broadband spectra typically display multi-temperature thermal plasma emission, complex intrinsic absorption, a prominent 6.4 keV Fe fluorescence line, and a Compton reflection hump. Only a few IPs are known with an orbital period below two hours, where the mCVs population is dominated by another subclass known as Polars. These short-period IPs have lower accretion rates and therefore exhibit reduced X-ray luminosities ($L_X < 10^{33}$ erg/s) and thus belong to the low-luminosity class of intermediate polars (LLIPs). In this talk, I will discuss results from our recent X-ray observations of short-period LLIPs CC Sculptoris, DW Cancri, and V1025 Centauri, obtained with XMM-Newton and NuSTAR. Through detailed timing and spectral analysis, our study provides critical insights into the temperature distribution, absorption, and reflection properties, offering a comprehensive view of accretion processes in this atypical, less explored population of IPs.

Long-term X-ray variability of eROSITA ULXs

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Ultraluminous X-ray sources (ULXs), defined by their extreme X-ray luminosities, were historically interpreted as accreting intermediate-mass black holes. It is now well established that a significant fraction of these systems are instead powered by super-Eddington accreting neutron stars. Distinguishing between these populations remains challenging but is crucial for understanding accretion physics in extreme regimes. Recent studies suggest that enhanced long-term X-ray variability may be preferentially associated with neutron-star ULXs. In this talk, I will present the long-term flux evolution of a sample of known ULXs, for which we exploit data from the first eROSITA all-sky survey (eRASS1) to probe variability on multi-year timescales. I will discuss the bulk variability properties of the sample and highlight individual sources exhibiting the most extreme variability amplitudes, which represent strong candidates for super-Eddington accretors.

Characterizing ULX Donor Stars in NGC 5643 through Photometry and Stellar Evolution Models

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We investigated the X-ray and multiwavelength properties of the ultraluminous X-ray sources (ULXs) in NGC 5643 using archival data from the Chandra, Hubble Space Telescope (HST), and the James Webb Space Telescope (JWST). ULXs are defined as non-nuclear, point-like sources with isotropic X-ray luminosities $L_X \geq 10^{39}$ erg s⁻¹, which exceed the Eddington limit for stellar-mass black holes.

Two ULXs (X-1 and X-2) are catalogued in this galaxy. The long-term X-ray light curves show no variability for these two ULXs over a timescale of 13 years. Since only X-1 ($L_X \approx 10^{40}$ erg s⁻¹) falls within the HST field of view, we searched for its counterparts in HST/WFC3 and JWST/NIRCam images.

Following the application of relative astrometric corrections, we identified three optical/infrared candidate counterparts within a 0.3" error radius (95

An SRG/eROSITA Study of BeXRBs in Quiescence

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We performed a comprehensive analysis of BeXRBs in low luminosity state with eROSITA first all-sky survey (eRASS1) data. BeXRBs are mostly transient X-ray binaries with a Be star as their optical companion and usually a neutron star as the compact object. They are usually present in quiescence, but often studied during outbursts. A quiescence study is useful for probing the emission mechanism of BeXRBs at low mass accretion rates. The X-ray luminosity for eROSITA spectral fit ranges in $\sim 10^{32-36}$ ergs s⁻¹ and fits similarly for both absorbed powerlaw and blackbody models for most cases. For the absorbed blackbody model, the emission seems to come from a fraction of the neutron star's surface for most sources. We determine upper limits on flux for undetected BeXRBs from eROSITA observations, assuming a spectral shape for counts observed at the source position. We also conduct an extensive literature survey of BeXRBs in quiescence across multiple X-ray observatories. The BeXRB luminosity may be used to distinguish between possible accretion models at a low mass accretion rate, like accretion in the propeller regime or from a cold accretion disc. Similarly, upper limits on flux for a sky coordinate may be used to rule out accretion models.

A Census of X-ray Binaries in the Grand-Design Spiral NGC 2336

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We present a comprehensive study of the X-ray source population in the nearby grand-design spiral galaxy NGC 2336 based on nine Chandra observations spanning seven months. We detect 32 X-ray sources down to a limiting luminosity of $L_X \sim 1.4 \times 10^{38}$ erg/s (0.5-7 keV). Five sources exceed 10^{39} erg/s in the co-added 190 ks dataset and are classified as ultra-luminous X-ray sources (ULXs). Using hardness ratios, we identified six hard sources, while variability analysis revealed 13 variable sources over the full baseline. Eight sources varied in Period 1 (Dec 2020) and nine in Period 2 (Jul 2021). All five ULXs show long-term variability, and two exhibit mid-term variability. We also identified two candidate transients: one active in both individual periods and the combined dataset, and another detected only in the combined dataset. Cross-matching with 78 UV-bright star-forming knots identified in ASTROSAT/UVIT data, and accounting for chance coincidences using Monte Carlo simulations, yields nine robust associations. Two associated sources have hard spectra and are identified as candidate high-mass X-ray binaries (HMXBs). None of the ULXs are confidently linked to UV knots, pointing to a low-mass X-ray binary (LMXB) origin. Notably, we identify a candidate transient ULX-LMXB system, a rare object warranting further study.

Ultraluminous X-ray Sources in Globular Clusters

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Ultraluminous X-ray sources (ULXs) are compact objects with X-ray luminosities exceeding 10^{39} erg/s, which remain among the most puzzling phenomena in high-energy astrophysics. While most known ULXs reside in star-forming field environments, a growing population has been identified in extragalactic globular clusters (GCs), offering a unique window into binary evolution under extreme dynamical conditions. Our results demonstrate that cluster dynamics profoundly shapes ULX demographics. Non-tidally filling clusters produce ULX rates up to an order of magnitude higher than tidally filling ones, driven by enhanced binary hardening and exchange interactions. ULX formation peaks sharply in the first 300 Myr, naturally explaining the observed scarcity of ULXs in the predominantly old Galactic GC population. These findings offer testable observational predictions: young, dense clusters should show elevated ULX rates, and field ULX populations in elliptical galaxies may carry a non-negligible dynamical imprint.

Chapter 5

(Ultra) Higher-Energy Transients, GRBs

Fast X-ray transients in NuSTAR data

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Fast X-ray transients (FXTs) are flashes of X-rays that last for a few hundreds of seconds to a few hours. An enigmatic population of these transients that did not have a clear origin has been known for several decades, mostly found serendipitously in soft X-ray imaging observations. Recent progress in this field by Einstein Probe has found that many FXTs are associated with gamma-ray bursts and the collapse of massive stars. Motivated by this, we searched the NuSTAR archive in the harder 3–79 keV band for ~ 1000 s duration transients. From 204 Ms of exposure we present five candidate FXTs, four of which are spectrally hard, with power-law indices $-3 < \Gamma < 0$, standing them apart from FXTs discovered in the soft band. Three have potential associations with galaxies at $z = 0.1 - 2$, implying 3–79 keV luminosities of 10^{43} to 10^{48} erg s⁻¹ and volumetric event rates of 125–2900 Gpc⁻³ yr⁻¹. The properties of these NuSTAR FXTs most resemble low-luminosity gamma-ray bursts, and would be much more common than their higher-luminosity counterparts in this redshift range.

Accurate distances of the Galactic spiral arms from dust-scattered X-ray emission of gamma-ray bursts

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Gamma-ray bursts (GRBs) provide bright, short-lived X-ray sources that can be exploited as powerful probes of the Milky Way interstellar medium. In particular, X-ray dust scattering rings produced by Galactic clouds in response to GRB X-ray emission enable direct, model-independent measurements of cloud distances with percent-level precision, even in the outer regions of the Galaxy.

We present a systematic analysis of all available XMM-Newton and Chandra follow-up observations of three low-Galactic-latitude GRBs—GRB 031203, GRB 160623A, and GRB 221009A—sampling three distinct lines of sight through the Milky Way. The detected X-ray rings trace dust clouds located beyond 5 kpc and can be associated with the Perseus, Outer, and Outer Scutum–Centaurus spiral arms, providing direct distance measurements to these large-scale Galactic structures.

Our analysis identifies two dust scattering rings toward GRB 160623A at distances of 6.91 ± 0.06 kpc and 9.9 ± 0.6 kpc, confirms the presence of a dust cloud at 9.7 ± 0.4 kpc toward GRB 031203 through an independent observation, and measures dust cloud distances out to 19.0 ± 0.2 kpc in the direction of GRB 221009A. These high-precision GRB-based measurements place strong constraints on the geometry of the outer Milky Way and reveal significant discrepancies with spiral arm models relying on kinematic distance estimates.

X-ray signatures of time-dependent photoionisation in GRB circumburst media

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The 1-100 pc region embedding long-duration gamma-ray bursts (LGRBs) has been hitherto unexplored, as extremely high ionisation by the GRB prevents application of optical absorption spectroscopy on such distances. We show that the GRB ionising flux imprints a unique time- and spatially-dependent ionisation structure on the gas, which can be probed by X-ray absorption. Application of this model to a selected sample of 7 bright GRB X-ray afterglow spectra observed by *XMM-Newton* EPIC-pn enables an independent, quantitative estimation of the density ($\log(n) \sim 2-4$) and distances (5-100 pc) of the ionised absorber directly from the GRB X-ray spectrum, thereby allowing us to locate the absorbing medium of this representative sample of long GRBs in the region of the density-size diagram populated by star-forming regions versus other gravitationally bound objects in the Universe. Our results provide one of the most direct links between LGRBs and star formation and open the potential of high-resolution X-ray spectroscopy as a powerful probe of star-forming regions that embed GRBs up to the highest redshifts.

Ultra-long MeV transient from a relativistic jet: a tidal disruption event candidate

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Gamma-ray bursts (GRBs) are extragalactic MeV transients lasting from fractions of a second to several minutes, typically associated with compact object mergers or the collapse of massive stars. On 2 July 2025, Fermi GBM detected three emission episodes with overlapping sky localisations, collectively designated GRB250702B. Together, the emission lasted more than 3 hours, making it the longest MeV transient ever observed. Follow-up observations with Swift XRT and NuSTAR revealed a rapidly decaying soft X-ray counterpart over the next ten days.

Time-resolved spectral analysis of the prompt emission shows that gamma-ray spectra are harder than those of long GRBs and well described by a single power law extending from 10 keV to 40 MeV, with evidence for a break above 50 MeV.

The extreme duration, spectral properties, and X-ray evolution suggest GRB250702B likely originates from a relativistic jet launched during the tidal disruption of a star by a compact object. From $\gamma\gamma$ opacity constraints, we derive a lower limit on the jet bulk Lorentz factor of $\Gamma > 10$. The inferred luminosity and energetics are consistent with previously reported relativistic tidal disruption events. The MeV spectra disfavour inverse Compton scenarios and are naturally explained by synchrotron emission from sub-TeV electrons.

EP250905a and EP241021a: Multi-wavelength Insights into Fast X-ray Transients

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The Einstein Probe (EP) mission is rapidly transforming our understanding of extragalactic fast X-ray transients (FXTs), uncovering a diverse population of short-lived, luminous high-energy events. I present results on two EP-discovered FXTs, EP241021a and EP250905a, illustrating how rapid multi-wavelength follow-up constrains their physical nature. EP241021a exhibited a fast and unique prompt optical emission (multi-peak evolution). Its luminous, rapidly evolving optical counterpart places it among the brightest FXTs, bridging the parameter space between long gamma-ray bursts (GRBs), luminous fast blue optical transients (LFBOTs), and other relativistic explosions. Its properties highlight the difficulty of associating FXTs with a single progenitor channel. EP250905a also shows a fading optical counterpart (~ 23.2 at 0.62 days). Spectroscopy of two candidate host galaxies yields possible redshifts of $z=0.374$ and $z=2.714$. At the lower redshift, late-time limits rule out SNe, LFBOTs, and jetted TDEs, favoring a short GRB origin. At the higher redshift, the event reaches ~ -22 AB mag and is consistent with long GRBs and several FXTs. Together, these events demonstrate the growing diversity of the FXT population across cosmic time.

Probing GRB Afterglow and X-ray Flare Microphysics through Broadband X-ray to GeV Emission and Implications for Very-High-Energy Radiation.

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The early X-ray afterglows of Gamma-Ray Bursts (GRBs), observed with the Swift X-ray Telescope (XRT; 0.3–10 keV) onboard the Neil Gehrels Swift Observatory, have revealed distinct temporal features beyond those predicted by the standard forward shock afterglow model. Components in the XRT light curve, such as flares, suggest more complex afterglow physics. These observations highlight the need for a multi-wavelength, systematic study of the early afterglow's temporal and spectral evolution. In this study, we analyzed GRB afterglows across a wide energy range, from 0.3 keV to 100 GeV, using data from Swift/XRT, Swift/BAT (15–150 keV), and the Fermi Large Area Telescope (LAT; 30 MeV–300 GeV). Our analysis reveals that the broadband GRB spectral evolution exhibits double-peaked spectral energy distributions. We discuss the implications for the microphysics of X-ray and GeV emission production sites and the underlying forward shock in the synchrotron self-Compton scenario. These results also emphasize the importance of very-high-energy (VHE; > 100 GeV) gamma-ray observations for understanding the GRB emission mechanisms behind these anomalies and for determining whether VHE GRBs are unique. By integrating multi-wavelength datasets and focusing on the VHE regime, our research contributes to the broader effort of understanding the complex physics of GRBs.

Accelerating SED Modeling Using Neural Networks

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Modeling the spectral energy distributions (SEDs) of astrophysical sources with physically motivated radiation models is computationally demanding. These models require solving coupled integro-differential equations across high-dimensional parameter spaces, rendering traditional inference techniques—such as Markov Chain Monte Carlo (MCMC) and nested sampling—computationally expensive and often impractical.

Prominent examples include emission from relativistic jets in blazars powered by supermassive black holes in Active Galactic Nuclei (AGN), as well as prompt and afterglow emission in Gamma-ray bursts (GRBs). In both cases, complex radiative processes and rapid variability introduce additional challenges for robust parameter estimation.

To overcome these limitations, we employ machine learning techniques to accelerate SED model evaluations and enable efficient Bayesian inference. We generate training datasets using publicly available radiative transfer codes and train neural networks (NNs) to emulate the computationally intensive radiation calculations. Our results demonstrate that the NN surrogate models accurately reproduce the original code outputs while achieving orders-of-magnitude speed improvements.

We present an NN-based framework tailored to GRB SED modeling, establishing a pathway toward fast, scalable, and statistically rigorous exploration of large parameter spaces in high-energy astrophysics.

Chapter 6

Supernovae, SNRs, Isolated Neutron Stars & Diffuse Emission

Expanding the population of distant X-ray thermally emitting isolated neutron stars

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X-ray thermally emitting isolated neutron stars (XINSs) provide crucial insights into neutron star cooling and Galactic demographics. Using over two decades of data from XMM-Newton, we searched the fourth-generation serendipitous source catalogues for absorbed XINS candidates, focusing on sources with soft X-ray spectra and no optical/infrared counterparts. The brightest candidates were followed up with XMM-Newton fulfil programmes, Chandra snapshot observations, deep imaging with Gemini, and radio searches with FAST. Our analysis revealed five sources with stable, moderately absorbed X-ray emission, consistent with distant XINSs at distances up to 7 kpc. These sources are primarily located in the Galactic plane, with possible associations to open clusters and a SNR/PWN system. Population synthesis models suggest that many softer, more absorbed, and distant XINSs are still hidden below our selection threshold. These sources are likely present in the 4XMM-DR12 catalogue but are difficult to identify due to source confusion and catalogue cross-matching limitations. Ongoing and future follow-up will enable the detailed study of these faint, distant populations.

Latest dense matter constraints from millisecond pulsars with NICER

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The Neutron Star Interior Composition ExploreR (NICER) was built to study the dense matter inside the core of millisecond pulsars (MSPs). By fitting the X-ray energy-resolved pulse profile from NICER with detailed physical models of surface emissions of MSPs, we can measure their masses and radii. These observables strongly inform the Equation of State (EoS) of the dense matter in the core of neutron stars.

This method, named Pulse Profile Modeling (PPM), works noticeably well for MSPs with prior constraints on mass and inclination from radio timing. In addition, jointly fitting NICER data with phase-averaged XMM spectra is necessary, as it breaks degeneracies between the background and source spectra in the NICER data.

In this talk, I will present the application and results of PPM on MSP data, which bring the number of exploitable mass-radius measurements to five. I will focus on the two latest additions, PSR J0614-3329 and PSR J1614-2230, both having precise mass and inclination prior constraints from radio timing. These provide valuable insights on both the EoS of dense matter, and on the magnetic field configurations of MSPs. They also allow us to assess the consistency of constraints from PPM across different sources.

New Insights into Galactic Energy Feedback with SRG/eROSITA: A systematic study of the Orion-Eridanus Superbubble

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Superbubbles created by star-forming activity play a key role in transporting energy and matter from the Galactic disk to the halo. The Orion-Eridanus Superbubble (OES), extending from (l, b) = (180 deg, -30 deg) to (200 deg, -50 deg), is the nearest superbubble and a key target for studying galactic feedback. However, previous X-ray observations (ROSAT, Suzaku, HaloSat) had narrow fields of view or limited spectral coverage, preventing a coherent study of its full structure.

Using eROSITA all-sky survey data (eRASS1), we present the first spatially continuous and spectroscopically uniform analysis of the entire OES. We derive plasma properties across the structure with unprecedented sensitivity. The emission is well described by a two-temperature thermal plasma model with kT about 0.18 keV and 0.9 keV. We report, for the first time, a statistically significant temperature increase in the OES shell, indicating localized heating at the bubble boundary. Combining these results with H-alpha data, we find pressure equilibrium between the hot interior plasma and the shell. The total thermal energy supports a multiple-supernova origin.

This study provides the first complete physical map of a nearby superbubble and new constraints on disk-halo energy transport revealed by SRG/eROSITA.

Archival Optical Counterpart Search for Extragalactic Fast X-Ray Transients Discovered by Einstein Probe

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Extragalactic fast X-ray transients (eFXTs) are an emerging class of high-energy phenomena whose physical origins remain largely uncertain. The wide-field, high-sensitivity monitoring capability of *Einstein Probe* (EP) has significantly increased the discovery rate of these events.

We present an ongoing program aimed at identifying optical counterparts to EP-detected eFXT candidates through a systematic search of publicly available optical survey data and transient databases, including the Zwicky Transient Facility (ZTF) and the Transient Name Server (TNS). We report the first results of this effort, focusing on EP240506a, which we associate with the UV/optical transient AT 2024ofs. Combining archival survey data with early-time multiwavelength observations, we find that both the luminosity and light-curve evolution of AT 2024ofs are consistent with a core-collapse supernova origin. We also quantified the probability of chance coincidence for systematic searching.

These results highlight EP's unique capability to uncover prompt high-energy emission from core-collapse supernovae and emphasize the critical importance of rapid follow-up observations for future eFXT discoveries. They also demonstrate the strong potential for maximizing the scientific return through coordinated multi-wavelength wide-field survey efforts, such as WFST and LSST.

Spectral portrait of Cassiopeia A with XRISM/Resolve: a Bayesian analysis via UltraSPEX

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XRISM/Resolve has enabled high-resolution X-ray spectroscopy of extended sources. Fully exploiting microcalorimeter data requires improved atomic databases, spectral modeling, and rigorous statistical inference. To meet this need, we developed UltraSPEX, a Bayesian nested-sampling extension to SPEX.

We apply UltraSPEX to deep XRISM/Resolve observations of Cassiopeia A, the youngest known galactic core-collapse supernova remnant, producing the first comprehensive microcalorimeter-based plasma parameter maps of a supernova remnant. We disentangle emission from intermediate-mass-element (IME)-rich ejecta, iron-group-element (IGE)-rich ejecta, and non-thermal components, robustly constraining their physical properties. Enhanced Ar/Si, Ca/Si, and Ni/Fe ratios appear near the base of the Si-rich jet in the northeastern region. IGE-rich ejecta have higher Doppler velocities and broader lines than IME-rich ejecta; Ca shows faster kinematics in southeastern regions. The ionization timescale and electron temperature show a surprising anti-correlation, suggesting significant ejecta clumping (overdensities of ~ 10 for IGEs, ~ 100 for IMEs) and reduced historical reverse-shock velocities, contrasting most semi-analytical models. Non-thermal emission contributes $> 47\%$ of the 4–6 keV flux, dominating in the western regions.

These findings show how microcalorimeter spectroscopy reveals the physical and chemical structure of this archetypal remnant and sheds light on its asymmetric explosion.

Magnetically-driven volcanic and seismic activities in magnetars

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Magnetars form a subclass of neutron stars, characterized by ultra-strong magnetic fields from 1E14-1E15 G at their surface up to potentially 1E18 G in their interior. These extreme fields power the richest phenomenology among isolated neutron stars, driving persistent and transient activities including some of the most energetic events in the Universe. Magnetars are particularly prominent in the X-ray band, where intense outbursts have been observed, with flux enhancements of several orders of magnitude lasting from weeks to years. They have also been proposed as possible sources of ultraluminous X-rays, long gamma-ray bursts, and fast radio bursts. Beyond their radiative behavior, magnetars also exhibit sudden spin frequency variations known as (anti-)glitches, sometimes accompanied by unusual radio emission suggesting internal processes as their likely origin. In this talk, I will discuss the plausibility of magnetically-driven volcanic and seismic activities in magnetar crusts for explaining the observed (anti-)glitches and their electromagnetic counterparts.

Extreme anisotropies in deep layers of an exploding star: overabundance of Cr in the northeastern jet of Cassiopeia A

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Core-collapse supernovae drive nucleosynthesis under extreme thermodynamic conditions, transporting heavy elements from the deep stellar interior to the outer layers. We present spatially resolved X-ray spectroscopy of Cassiopeia A (Cas A)'s northeastern (NE) jet based on archival 1 Ms *Chandra*/ACIS observations, focusing on three prominent fingers. We measure the highest Cr/Fe mass ratio ever reported in Cas A (Cr/Fe ~ 0.14), localized in a compact region of the southernmost finger. Comparison with nucleosynthesis models indicates that the NE jet material originated near the boundary between the complete and incomplete Si-burning layers, and that mixing between different burning layers is required to reproduce the observed abundances. We find significant physical and chemical differences among the three fingers. The southernmost finger appears to originate from a slightly more external region of the explosion and differs kinematically: while the northern and central fingers lie close to the plane of the sky, the southernmost finger shows a line-of-sight velocity of $\sim 2100 \text{ km s}^{-1}$ toward the observer, corresponding to a tilt angle of $\sim 16^\circ$. These results emphasize the NE jet's role in ejecting material from deep explosive-burning layers and provide new constraints on explosion asymmetries in core-collapse supernovae.

Measuring stolen energy of the SNR shock by particle accelerations with XRISM/Resolve

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We measure the stolen energy of the shock by cosmic rays in several supernova remnants (SNRs), utilizing high spatial or spectral resolution observations. We show that electron/ion temperatures of the shock with the velocity below 4000 km/s, such as Tycho's SNR and Cygnus Loop, are consistent with the thermal structure of an adiabatic ideal gas. This indicates that the particle acceleration is not efficient enough to affect the thermal environment near the shock front in these cases. In contrast, the electron temperature on the shocks with the velocity larger than 7000 km/s shows a significant decrease from the temperature estimated from the Coulomb relaxation. The amount of the stolen energy reaches at most 57%, indicating that the injection rates of the particles is greater than 0.001 in significant fast shock environment.

Magnetar fraction in Core-Collapse Supernovae

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Understanding the birthrate of magnetars, highly magnetized neutron stars, is essential for constraining their role as engines of high-energy transients such as gamma-ray bursts and fast radio bursts. However, the fraction of neutron stars born as magnetars remains uncertain, partly because magnetars may be evolutionarily linked to other neutron star classes. In this talk, we estimate the magnetar birth fraction in core-collapse supernovae using pulsar population synthesis that includes all isolated neutron star classes in the Galaxy and self-consistently accounts for Galactic dynamics and magneto-rotational evolution. We focus on the young Galactic neutron star population, where 24 objects are currently detected. Only 10 (41 %) are classical rotation-powered pulsars, while the remaining 59 % are magnetars or central compact objects. We further compare these results with the nearby volume-limited population of X-ray Dim Isolated Neutron Stars, interpreted as evolved magnetars. Our analysis shows that the observed Galactic population can be reproduced only if the core-collapse supernova rate exceeds two per century and the magnetar fraction is significantly higher than previously inferred. Assuming a bimodal magnetic-field distribution at birth, magnetars peak at $B_0 \sim (1-2.5) \times 10^{14}$ G and represent on average about 50 % of the neutron star population.

Exploring the cosmic dust chemistry in the X-rays

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Interstellar dust plays a vital role in galactic evolution: it cools interstellar clouds, enabling star formation; provides surfaces for complex chemical reactions; and serves as a fundamental building block for new planets. Yet, the dust grain properties remain open questions in astrophysics. High-resolution X-ray spectroscopy offers a powerful means to probe interstellar dust. The X-ray band is particularly sensitive to absorption from K- and L-shell electrons of abundant interstellar elements such as C, N, O, Ne, Si, Mg, and Fe. Spectral features of dust appear near the photoelectric absorption edges and reveal the dust grain chemical composition, physical size and lattice structure. Here, I will present our efforts to understand dust grain properties in both the diffuse and dense interstellar medium using high-resolution X-ray spectroscopy. I will highlight recent results from the diffuse interstellar medium (Psaradaki et al. 2020, 2023), based on XMM-Newton and Chandra data from dedicated observing and laboratory campaigns. I will then present new results on dust grain chemistry in dense interstellar environments from recent XRISM observations of the bright X-ray binary GX 340+0 (Psaradaki et al., in prep.). Finally, I will summarize our current understanding of dust grain composition in various Galactic environments using X-ray observations.

Hot Bubbles in Planetary Nebulae: The Role of Wolf-Rayet-Type Winds in Shaping X-ray Emission

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Some planetary nebulae (PNe) exhibit extended soft X-ray emission produced by hot bubbles inflated by the fast stellar winds of their central stars. Observations reveal plasma temperatures of $T_X \approx (1-3) \times 10^6$ K and X-ray luminosities reaching $L_\odot$. These hot bubbles are frequently associated with PNe hosting H-deficient Wolf-Rayet ([WR]) central stars, yet most existing theoretical models have focused on H-rich post-AGB winds and do not explicitly account for the properties of [WR] stars. We present radiation-hydrodynamical simulations performed with the PLUTO code that investigate the impact of [WR] winds on the formation and evolution of X-ray-emitting hot bubbles. We follow the evolution of systems with different initial stellar masses and compute their synthetic X-ray emissivities. Our results show that [WR] winds inject significantly larger mechanical power than H-rich winds; however, enhanced radiative cooling associated with their C-rich composition strongly influences the early development of the hot bubble. Consistent with previous studies, we find that turbulent mixing between shocked wind material and the ionized nebula regulates the observed X-ray temperatures and luminosities. The simulations successfully reproduce the X-ray properties of PNe hosting both [WR] and H-rich central stars, providing a unified framework for interpreting hot-bubble emission in planetary nebulae.

Different radio and X-ray polarization properties revealed in the young supernova remnant SN 1006

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We report the detection of a spatial variation of X-ray polarization in the southwestern (SW) shell of supernova remnant SN 1006 (SN 1006 SW) using the Imaging X-ray Polarimetry Explorer (IXPE). The shell has an average X-ray polarization degree (PD) of $21.6\% \pm 4.5\%$ and polarization angle of $-48 \text{ deg} \pm 5 \text{ deg}$ in the 2-4keV energy band, similar to those in the northeastern shell. The PD varies along SN 1006 SW, with a peak PD = $40\% \pm 8\%$ in the south and a significantly lower PD $j = 27\%$ (99% upper limit) in the west, where the shell has been proposed to be interacting with an interstellar cloud. The correlation between the PD, which reflects the magnetic orderliness, and the preshock density provides observational evidence that magnetic turbulence and amplification are environment-dependent. The high PD detected in the southern region of the shell constrains the magnetic turbulence scale to $j = 0.1 \text{ pc}$. Moreover, by comparing the IXPE X-ray and MeerKAT radio polarization measurements for SN 1006 SW, we found that magnetic fields traced by X-ray polarization are nearly radially distributed, whereas those traced by radio polarization tend to follow a direction parallel to the Galactic plane. This suggests that the X-ray polarization probes freshly amplified magnetic fields from small-scale structures in the immediate postshock region, while the radio traces more extended regions influenced by the preexisting ambient magnetic fields.

Revealing the Three-Dimensional Dynamics of Tycho supernova remnant with XRISM

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Supernova remnants (SNRs) are key laboratories for constraining the physics of stellar explosions. X-ray CCD telescopes have long enabled measurements of elemental abundances and their spatial distribution, providing diagnostics of Type Ia explosion models. With the advent of XRISM and its high spectral resolution, we can now directly probe the full three-dimensional dynamics for individual elements of the ejecta. Measuring element velocity stratification and 3D asymmetries offer crucial diagnostics of both explosion mechanism and progenitor system, as demonstrated by 3D numerical simulations from supernovae to SNRs. Tycho's SNR is an ideal Type Ia remnant for this purpose. We present results from five XRISM/Resolve observations to map, at pixel-level, velocities and fluxes from the front and back sides of the remnant for various elements (Si, S, Ar, Ca, Fe). We detect significant asymmetries in both velocity and emission, in the plane of the sky and along the line of sight. These measurements provide new constraints on the structure of the outer Si/S-rich layers and the inner Fe-rich ejecta. We interpret these results in the context of Type Ia explosion scenarios and possible effects of an asymmetric ambient medium.

Origin of magnetar magnetic fields: Insights from 3D magneto-thermal simulations

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Magnetars, the most strongly magnetized class of the isolated neutron star population, are characterized by large-scale dipolar magnetic fields of order 10^{14} G, which are responsible for their rapid spin-down. The origin of such intense dipolar fields remains an open problem. In this talk, I will discuss the role of the chiral magnetic effect, arising from the chiral anomaly, which enables mutual conversion between magnetic helicity and electron chiral asymmetry. We present results for scenarios with both nonzero and vanishing net magnetic helicity, the latter being more representative of realistic birth conditions in proto-neutron stars. Using three-dimensional magneto-thermal simulations, we demonstrate that the chiral magnetic effect transfers magnetic energy from small-scale fields—expected at birth—to large-scale dipolar structures without requiring any external energy input. This mechanism provides a physical explanation for the formation of the large-scale dipolar structure observed in magnetars.

Verification of Cas A Neutron Star Cooling Rate Using Chandra HRC-S Observations

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The young neutron star (NS) in the Cassiopeia A (Cas A) supernova remnant provides a unique test of NS cooling theories. Chandra observations have indicated that its surface temperature is declining rapidly, at a rate of about 2% per decade over 20 years, assuming a uniform temperature carbon atmosphere. This rapid decline may be caused by neutrons in the NS core transitioning from a normal to a superfluid state. However, most Cas A NS observations were performed with the Chandra ACIS detectors, which suffer from complicated systematic effects.

Here, we test the cooling of the Cas A NS using Chandra HRC data spanning 25 years. The HRC detector has independent systematics and therefore provides an important cross-check. We infer a cooling rate of $1.11^{+0.25}_{-0.28}\%$ ($0.57^{+0.26}_{-0.27}\%$) per decade, assuming a fixed (variable) hydrogen column density (N_H). We also verify a decline in the absorbed flux at the $> 3\sigma$ level, measuring $4.7\% \pm 1.5\%$ over 10 years with an independent instrument. The inferred cooling rate can be explained by reduced neutrino emission efficiency associated with the Cooper pair breaking and formation process.

Asymmetric Fe-K Kinematics in Kepler's SNR with XRISM/Resolve

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Type Ia supernovae are major sources of iron-peak elements, but their progenitor channels and explosion geometries remain debated. Two leading progenitor scenarios are single-degenerate (SD; accretion from a non-degenerate companion) and double-degenerate (DD; white-dwarf merger). Kepler's SNR, the most recent confirmed Galactic Type Ia remnant, has been discussed as suggestive of an SD progenitor (Katsuda et al. 2015). Here we use the high energy resolution of XRISM/Resolve to measure the line-of-sight kinematics of Fe-rich ejecta in Kepler's SNR. We fit Fe-K spectra pixel-by-pixel with a two-component non-equilibrium ionization model that separates red- and blue-shifted Fe K α emission, and use the resulting component flux maps and spectral-shape maps to define two representative regions (central and northwestern rim). Using spectra extracted from these regions, we quantify the components and find a clear segregation: the center is dominated by the redshifted component, whereas the northwestern rim is enhanced in the blueshifted component. This pattern is difficult to reconcile with simple spherical expansion and is suggestive of a ring-like structure with an axis inclined to the line of sight, reminiscent of the double-ring morphology discussed for N103B (Yamaguchi et al. 2021).

The soft X-ray all-sky map observed with the lobster-eye focusing wide field telescope onboard Einstein Probe

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The Einstein Probe Wide-Field Telescope (WXT), leveraging lobster-eye optics, reinvigorates the second generation of soft X-ray imaging all-sky surveys. With an angular resolution of 5 arcmin and nearly one order of magnitude improvement in GRASP (effective area x FOV) compared to earlier all-sky survey missions, WXT is an efficient instrument for observing the X-ray sky and mapping large-scale diffuse structures. We will present an overview of intriguing, large-scale structures identified through narrow-band and hardness ratio maps, including the diffuse X-ray background, the soft shell near the eROSITA bubble, superbubbles, supernova remnants, and giant unidentified structures – several of which are newly discovered by WXT. We observe a global anti-correlation between soft X-ray and HI emission, which may result either from shadowing of X-ray emission by cold foreground atomic gas or from interactions between hot and cold phases. The EP-WXT all-sky maps demonstrate the unique potential of lobster-eye optics, promising a legacy survey of the X-ray-emitting hot Universe.

Chlorine and potassium enrichment in Cassiopeia A

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Phosphorus (P), chlorine (Cl), and potassium (K) are essential for life, yet their cosmic origins remain poorly understood. Current galactic chemical evolution models underestimate the production of Cl and K by up to an order of magnitude (e.g., Kobayashi et al. 2020). These light odd-Z elements have never been detected at their production sites, hindering a comprehensive understanding of their formation. XRISM/Resolve is uniquely suited to address this issue. We present XRISM observations of the core-collapse supernova remnant Cassiopeia A, where, for the first time in the X-ray band, we detect Cl, K, and a signature of P alongside comparable even-Z elements (XRISM Collaboration 2025). Notably, we measure a K/Ar abundance ratio 1.2–1.3 times the solar value, indicating efficient production of odd-Z elements in this event. These yields are thought to depend on stellar parameters such as rotation (Limongi et al. 2018), as well as dynamic processes in the stellar evolution paths like shell mergers (Ritter et al. 2018, Issa et al. 2026). In this presentation, we will discuss these observational results and their implications for understanding the origin of the odd-Z elements in Cassiopeia A.

Supernova Remnants in the Large Magellanic Cloud

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A statistical study of supernova remnants (SNRs) inside a galaxy is important for the understanding of the chemical enrichment and the energy budget inside a galaxy. The complete coverage of the Large Magellanic Cloud (LMC) and its surroundings provided by eROSITA allows us to investigate the SNR candidates proposed in radio and optical and to detect new SNR candidates never observed by another X-ray telescope before. Of particular interest is the increasing population of SNRs detected in the outskirts of the LMC. We present the most updated catalog of SNRs in the LMC. We compare the X-ray luminosity function (XLF) of the SNRs in the LMC with the XLF in the Local Group galaxies. Furthermore, we perform a morphology study on the X-ray SNRs in the LMC finding indications of a sub-sample of elongated SNRs.

Dead Men Do Tell Tales: What Supernova Remnants Say about Type Ia Supernova Progenitors

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Despite sustained advances in both theory and observations over the last few decades, the identity of the stellar progenitors of Type Ia Supernovae remains unclear. Nearby X-ray bright Supernova Remnants in the Milky Way and the Magellanic Clouds offer an excellent opportunity to examine aspects of the SN Ia phenomenon that are not accessible to optical observations of extragalactic SNe. I will summarize the results of an ongoing project to model the imprint of mass loss from the SN Ia progenitor on the bulk properties and X-ray spectra of Supernova Remnants. A systematic comparison between these models and the best observed Type Ia SNRs yields interesting conclusions. While many (perhaps most) SN Ia progenitors do not substantially modify their surroundings on pc scales, some SNRs are clearly expanding into a modified circumstellar medium, either high density material likely associated with slow progenitor outflows, or large, low-density cavities that must have been excavated by high velocity progenitor outflows.

The Explosion Dynamics and Three Dimensional Structure of SNR G292.0+1.8

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The composition and dynamics of supernova remnants inform us on the explosion mechanism of the supernova and the evolution of the progenitor. The Galactic remnant G292.0+1.8 is an evolved remnant rich in emission from shocked ejecta and circumstellar material. It is also bright in [OIII] emission. Here, I discuss progress on a joint XMM-Newton/Chandra/HST Large Program aimed at mapping the three dimensional structure of the ejecta in the SNR. The data are combined with existing ground based optical spectra of the entire SNR, as well as recent XRISM observations. I compare the dynamics of the X-ray bright ejecta to that of the optical knots and the motion of the neutron star. The dynamics of the ejecta and three dimensional morphology of the remnant provides strong evidence for asymmetric neutrino emission during core collapse as well as a highly asymmetric supernova event.

Fitting spectral changes across extended X-ray sources with SUSHI

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It is challenging to determine the changes of spectral parameters across an image of an extended X-ray source, particularly in cases where different spectral components have distinct spatial distributions. This often either involves heavily rebinning the image to obtain enough counts per region, or results in independent spectral fits that do not take smoother variations of spectral parameters across the image into account. SUSHI is a new method for performing spatial spectral fits, which tackles all of these challenges by minimising the log likelihood plus a spatial regularisation term. In this talk, I will present the method, and how it can be applied to X-ray images of supernova remnants, AGN jets, pulsar wind nebulae and their filaments. I will show how it can reveal new trends that have previously remained hidden in the data, and what we can learn about all of these sources with SUSHI.

XRISM Observations of Cassiopeia A: Overview, Atomic Data, and Spectral Models

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Cassiopeia A is the youngest known core-collapse supernova remnant (SNR) in the Galaxy. Cas A was observed at two different locations during the XRISM PV phase. We present maps of the “spatial-spectral mixing” effect due to the fact that the XRISM point-spread function is larger than a pixel in the Resolve calorimeter array. We analyze spectra from two bright, on-axis regions such that the effects of spatial-spectral mixing are minimized. We fit these spectra with a semi-empirical model consisting of two thermal components, a nonthermal component, and a background model. We find that it is critical to include redshifts/blueshifts and broadening in the two thermal components. We fit the spectra with two versions of the AtomDB atomic database (3.0.9 and 3.1.0) and two versions of the SPEX (3.08.00 and 3.08.01) spectral fitting software. Overall we find good agreement between AtomDB 3.1.0 and SPEX 3.08.01 for the adopted spectral models. The most significant difference is the Ni abundance, with the new atomic data favoring a considerably lower Ni abundance. We find that the abundance ratios of Ti/Fe, Mn/Fe, & Ni/Fe are significantly lower in the NW than the SE, with the Ti/Fe and Mn/Fe ratios consistent with zero in the NW.

Chandra and XMM-Newton's X-ray Study on the Core-collapse Supernova Remnant N63A Embedded in an H II Region

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N63A is one of the brightest supernova remnants (SNRs) in the Large Magellanic Cloud and provides an excellent laboratory for studying SNR evolution in an H II region. We present a detailed X-ray analysis of N63A using *Chandra* and XMM-*Newton* observations, combining both imaging and high-resolution spectroscopy. Our global spectral fitting reveals three distinct thermal plasma components with temperatures $kT \sim 0.26$, 0.73 , and 1.54 keV. Spatially-resolved spectroscopy with *Chandra* shows substantial variations in physical parameters across the remnant, with the eastern lobes of the optical nebula exhibiting significantly higher ionization timescales than the western region. These multi-temperature plasma components indicate that N63A is evolving in a cloudy interstellar medium: the low-temperature component arises from evaporated dense cloudlets that are engulfed by the blast wave, the intermediate-temperature component represents shocked inter-cloud medium, and the highest-temperature component likely results from the shocks reflected by the clouds. We estimate a Sedov age of approximately 4.5 kyr and an explosion energy of about 4×10^{51} erg. Comparison of the observed abundance ratios and masses of metal elements with the nucleosynthesis models constrains the progenitor mass to approximately $\sim 20 M_{\odot}$, supporting a single-star core-collapse origin for N63A.

A Complete X-ray View of Supernova Remnant W28 with Einstein Probe: Spatial distribution of parameters and origin of the thermal composite morphology

Yi-Heng Chi¹

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It has been an unsolved question what leads a supernova remnant (SNR) to a thermal composite rather than a typical shell-like morphology, and what causes recombining plasma inside it. With the 13-ks observation of the Following-up X-ray Telescope onboard Einstein Probe, we give an overall X-ray picture of W28, one of the prototypical thermal composite SNRs. The observation revealed shell-like structures west of W28, which may revise the known extent of the SNR to $72' \times 45'$. Spectral analysis explicitly maps the special relationship where the plasma experiences recombination in the interior of the remnant, spatially coincident with $H\alpha$ emissions, while in the other regions, the plasma is ionization-dominated. We found that W28 is generally isobaric from its center to the newly discovered shell, and even isothermal with a temperature of ~ 0.6 – 0.7 keV in the center before the cooling of the plasma. Saturated thermal conduction and cloud evaporation may cool down the plasma within ~ 3 kyr, the estimated recombination timescale. We revised the SNR dynamical age to ~ 8 kyr, much younger than previous estimates. The complex structure and complex ionization state distribution may suggest that centrally filled and shell-like morphologies coexist in W28. This state may depend on the environment in which the SNR evolves.

Disentangling the Galactic centre X-ray reflection signal using XMM-Newton data

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The Galactic Centre (GC) is an environment of very energetic phenomena (i.e. the flaring activity of Sgr A*, supernova explosions, emission of stellar origin) that result in the emission of soft ($<4\text{keV}$) as well as hard X-rays ($>4\text{keV}$). This environment makes the GC region rich in (apparently) diffuse X-ray emission. In this work, we focus on the 6.4 keV fluorescent line of neutral or weakly ionised iron, a key tracer of X-ray reflection. Using a deep (6Msec) XMM-Newton mosaic covering the GC and inner Galactic disc, together with the stellar mass distribution of our Galaxy, we combine spatial and spectral information to disentangle the reflection signal from other physical X-ray components. We interpret the resulting residual 6.4 keV emission map as the cleanest current estimate of the large-scale reflection signal across the GC. This map provides a valuable framework for future studies, such as low-energy cosmic-ray and polarisation analyses in the Central Molecular Zone.

Growing the population of thermally emitting isolated neutron stars with SRG/eROSITA

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Making use of the wide survey area and unprecedented sensitivity at soft X-ray energies, searches in the SRG/eROSITA All-Sky Survey allow to significantly grow the population of thermally emitting isolated neutron stars (INSs). This will not only give insights into the intrinsic and population properties of still rare INS types, like the class of X-ray dim isolated neutron stars, but is likewise important to constrain the composition and evolution of the overall Galactic INS population. In this talk, we will review the applied search strategy, describe the resulting candidate sample of 33 promising sources, and give an update on the results of an ongoing dedicated follow-up campaign that targets the selected candidates from radio to gamma-rays with the goal to place them among the population of Galactic INSs.

The X-ray luminosity function of stars observed with SRG/eROSITA

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Background diffuse X-ray emission is contributed in large part by the emission of point sources not individually resolved. While this is established since decades for the contribution of quasars to the diffuse emission above 1 keV energies, the possible contribution of undetected stars in the Milky Way to the softer band (0.5-1 keV) background emission is still poorly constrained. The overall unresolved X-ray flux from the stars is the product between the stellar spatial distribution in the Milky Way and the underlying X-ray luminosity function (XLF). In this work, we build the XLF of the stars and study its structure with respect to a set of main-sequence spectral types (F, G, K, M). We build the XLF in volume-limited subsamples of increasing maximum distance and corresponding minimum X-ray luminosity, using the HamStar catalog of X-ray emitting stars detected in the Western Galactic hemisphere by SRG/eROSITA. The obtained XLF is then used to estimate the unresolved contribution from the stars to the soft X-ray background of the Milky Way in a flux-limited XMM survey of the inner 2x20 deg towards the Galactic Center.

PSR J1740+1000, its X-ray PWN, and Pevatron 1LHAASO J1740+0948u: pulsar tail versus pulsar filament

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We analyzed Chandra and XMM-Newton observations of the region of 1LHAASO J1740+0948u. We find no plausible counterparts except for the strongly offset pulsar PSR J1740+1000. The pulsar is accompanied by diffuse X-ray emission extending toward 1LHAASO J1740+0948u. This could be pulsar tail (pulsar wind confined by the ram pressure due to supersonic motion of the pulsar) or it could be pulsar filament (escaped PWN particles propagating along the ISM magnetic field). In either case this represents the first detection of such a feature in TeV. We discuss both scenarios and constraints they impose on pulsar wind properties and particle transport as well as implications for other similar objects.

The Lighthouse pulsar wind nebula: an extremely energetic electron/positron beam interacting with ISM

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The remarkable Lighthouse nebula offers a rare opportunity to study how the most energetic pulsar wind particles escape into the ambient ISM near the apex of the bow shock ahead of the highly supersonic pulsar. The 7'-long pulsar filament, by far the brightest among its peers, has been observed by the Chandra X-ray observatory for more than 800 ks. ACIS images reveal the intricate details of internal structure, enable informative spatially-resolved spectroscopy constraining the injected particle SED and its evolution with distance from the pulsar, and shed light on leptonic cosmic ray propagation in the ISM. The 20+ yr time span of the Chandra observations also allows a very accurate measurement of pulsar velocity, which solidifies association with the SNR MSH 11-61A and provides a reliable measurement of the pulsar and SNR ages.

Diffuse Hot Gas in Star-forming Galaxies and (U)LIRGs: Scaling Relation and the Role of Stellar Feedback

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Using archival Chandra data, we investigate diffuse hot interstellar gas in two galaxy samples: 23 nearby star-forming galaxies and 78 (ultra)luminous infrared galaxies ((U)LIRGs). In star-forming galaxies, surface brightness profiles reveal a break at 0.3–2.2 kpc, separating central regions from disks. We find evidence indicating more efficient X-ray production per unit star formation in central regions. This slope decreases with increasing spatial scale, converging to the global linear relation. For (U)LIRGs with $\text{SFR} > 50 M_{\odot}/\text{yr}$, we also find a superlinear relation identical to that in normal galaxy centers, suggesting mergers deliver gas that fuels widespread star formation, enhancing global hot gas emission. AGN activity and unresolved compact sources in these samples contribute only at low level to the soft X-ray emission. These results demonstrate that stellar feedback dominates hot gas production, with galactic centers exhibiting enhanced X-ray radiation efficiency.

**From stellar birth to stellar death: tracing high energy processes in
Sh2-284/G213.0-0.6 complex**

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G213.0-0.6 is a Galactic supernova remnant previously estimated to lie at a distance of ~ 1 kpc, with a reported angular extent of $\sim 2.3^\circ \times 2.7^\circ$, and a debated interaction with nearby molecular material, namely the Sh2-284 HII region. Using eROSITA observations, we detect thermal X-ray emission across most of the remnant and revise its extent to $2.6^\circ \times 4.0^\circ$. X-ray spectral analysis indicates significant absorption ($N_{\text{H}} = 2.4 - 4.6 \times 10^{21} \text{ cm}^{-2}$), implying a distance of 1.7-3.9 kpc, significantly larger than previously assumed. At this revised distance, the angular extent implies a physical size exceeding 100 pc, placing G213.0-0.6 among the largest known Galactic supernova remnants. Analysis of Fermi-LAT data reveals gamma-ray emission from the remnant area, with particularly enhanced emission from the region between its northwestern boundary and the adjacent HII region Sh2-284. The combined X-ray morphology, absorption-derived distance, and gamma-ray spatial distribution disfavor a cosmic-ray illumination scenario for the gamma emission near the northwestern boundary, instead supporting an origin associated with active star formation embedded within the HII region.

Chapter 7

Active Galactic Nuclei, Tidal Disruption Events and QPEs

Catching the launch of ultrafast wind in NGC 3783

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Supermassive black holes are messy eaters, ejecting vast amounts of material and energy back into their host galaxies. While we know they do launch powerful ultrafast outflows (UFOs) that might eventually reshape their environments, the actual mechanism how these winds are launched against gravity remains a major open question. Are these winds driven by the intense radiation and thermal pressure of the accretion disk, or by magnetic forces?

In this talk, I will present results from X-ray spectroscopy data on AGN NGC 3783, obtained with a 10-day campaign led by XRISM and XMM-Newton. We caught this black hole in the act: a sudden soft X-ray flare followed immediately by the ejection of a highly ionized wind moving at nearly 20% the speed of light. This is a highly transient UFO that lasted for only half a day. By analyzing the timing of the flare, we found signatures of magnetic reconnection, which is the same process that drives solar flares. I will explain why this challenges the view that the quasar winds are mostly driven by radiation pressure and suggests that magnetic eruptions might play an important role at the innermost region close to the supermassive blackhole.

The energy dependence of the X-ray power spectrum in Seyferts.

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Power spectrum analysis (PSD) is a common tool used to characterise the observed variability in AGN. X-ray power spectra of radio-quiet AGN are typically well described by a bending power-law model with a slope of -1 at low frequencies, which steepens to a slope of -2 (or steeper) above a bending frequency. The dependence of the bending frequency on black hole mass and accretion rate has been investigated in detail, and the PSD amplitude appears to be similar in all objects, irrespective of their black hole mass and accretion rate. However, the dependence of the power spectrum characteristics on photon energy has not been systematically explored in the past. We have started a systematic investigation of the energy dependence of the power spectrum parameters for many X-ray bright and variable AGN. We used archival data from XMM-Newton, Suzaku and NuSTAR, computed power spectra over a broad frequency range in six energy bands from 0.3 to 20 keV, and fitted them with a bending power-law model. I will present the results regarding the energy dependence of the power spectrum parameters and discuss the significant constraints our results impose on current models of X-ray variability on compact accreting objects.

Probing sub-kiloparsec X-ray structure in high-redshift AGN with strong gravitational lensing.

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Strong gravitational lensing of AGN offers a powerful telescope to probe sub-kiloparsec structures at early cosmic epochs when spatial offsets and mergers are expected to be abundant, yet unresolvable by direct imaging with current and future instruments. I will present an innovative solution to this conundrum, combining lens mass modeling in the optical with spatially resolved Chandra X-ray imaging of lensed AGN. Chandra's sub-arcsecond angular resolution is critical for resolving individual lensed images in the X-rays. By performing a maximum-likelihood analysis, we recover the relative spatial origin of the X-ray emission with respect to the optical, achieving milliarcsecond relative astrometry using Gaia observations. I will showcase recent results from Chandra-Gaia observations of three lensed quasars: J0659 ($z = 3.1$), J1433 ($z = 2.74$), and the first zig-zag lens J1721 ($z = 2.37$), highlighting sensitivity to structure at tens-to-hundreds of parsecs expected from low- z AGN studies. I will then discuss prospects for identifying dual AGN at sub-kpc separations at high- z – critical predictions in galaxy formation, yet observationally elusive. Finally, I will describe how the caustic method will scale to the thousands of new lensed AGN expected from Euclid, LSST, and other discovery engines, leveraging machine-learning-optimized lens modeling for sample-level analyses.

A Review of Ultrafast AGN Outflows with XRISM

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The XRISM observatory is providing meaningful new insights into the nature of ultra fast outflows. These winds with velocities of $0.1c$ and higher were discovered with XMM-Newton. Nonetheless, XRISM's combination of unprecedented high spectral resolution above 6 keV, along with its high collecting efficiency at these energies has revealed the outflows to be both clumpy and transient in nature. The talk will describe the observations, the uniqueness of the data, how they shed new light on the X-ray corona, as well as change our understanding of the launching mechanism and impact of these powerful winds.

Extreme X-ray variability in extragalactic sources: statistics from the eROSITA all-sky survey

Mirko Krumpe¹, the eROSITA.DE team¹

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We present the results of our study on long-term X-ray variability in extragalactic sources based on data from the eROSITA all-sky survey (eRASS). The survey consists of repeated scans separated by six months. By comparing fluxes across different epochs, we identify the most strongly variable objects over timescales of 6, 12, 18, and 24 months. These variable events include active galactic nuclei (AGN), tidal disruption events (TDEs), and other SMBH-related transients.

We focus on extreme variability events and present the statistical distribution of flux changes in this regime. In particular, we distinguish between brightening and fading events, examining their respective amplitudes, temporal behavior, and relative occurrence rates. We compare the variability characteristics of these two populations to identify potential asymmetries in their physical drivers and evolution.

Furthermore, we derive the likelihood of variability as a function of the magnitude of the flux change, defined as the fraction of variable sources (in a given range of flux change) relative to the parent sample. The combined study of flux and spectral variability provides new constraints on the physical mechanisms that govern long-term accretion variability in active extragalactic sources.

Unveiling AGN Wind Dynamics: From Real-Time Acceleration to Advanced Relativistic Modeling

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Ultra-fast outflows (UFOs) are critical drivers of AGN feedback, yet their launching mechanisms remain debated. IRAS 13224-3809, a highly variable Narrow-Line Seyfert 1 galaxy, provides an ideal laboratory for studying these processes at high accretion rates. We present a systematic, time- and flux-resolved re-analysis of 1.5 Ms XMM-Newton and 500 ks NuSTAR observations from 2016, employing equal-count spectral selections. Our analysis unambiguously confirms a strong, variable UFO with velocities reaching $0.38c$. By tracking the wind's evolution, we report direct evidence of rapid acceleration (a 50 m/s^2) in response to an X-ray flare. This prompt coupling between the radiation field and outflow velocity suggests magnetic driving mechanisms may be required alongside radiative acceleration. To support current and future high-resolution spectroscopy (e.g., XRISM, NewAthena), we present updates to the Wind in the Ionized Nuclear Environment (WINE) code. Substantially optimized for speed and accuracy, WINE incorporates full special-relativistic modeling of absorption and emission within flexible biconical geometries. This framework enables robust constraints on wind parameters and mass/energy outflow rates, breaking degeneracies to provide the necessary modeling for the high-resolution era of black hole winds.

The Photon index-Eddington ratio relation in AGN

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The existence of a tight connection between the accretion disc and the corona in AGN is supported by many observations, like the correlated variability between X-ray and UV emission or the tight L_X - L_{UV} relation. Still, it is unclear what accretion disc parameter governs the coronal physics. A reported result is a positive correlation between the X-ray photon index (Γ) and the Eddington ratio (λ), suggesting that objects accreting closer to the Eddington limit produce steeper X-ray spectra. Yet, these results have been obtained with sparse and/or inhomogeneous samples. I will present a systematic study of the Γ - λ relation using the largest sample assembled for this purpose (some thousands AGN), built by cross-matching SDSS and XMM-Newton catalogues. We adopted state-of-the-art methods to obtain reliable Γ estimates and explored different approaches to measuring λ . We find no evidence for a Γ - λ ratio on the overall population. However, when focusing on objects with multiple XMM-Newton observations, we find a clear evidence for an intrinsic (on a source-by-source basis) Γ - λ relation. I will discuss how these results update our understanding of the disc-corona interplay and how to interpret the role of the Eddington ratio as a driver of AGN X-ray spectral properties.

Revisiting the X-ray-to-UV relation of quasars in the era of all-sky surveys

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The X-ray-to-UV relation of active galactic nuclei (AGNs), commonly parametrized by the monochromatic luminosities at 2500 Å and 2 keV, probes the energetic coupling between the accretion disc and the X-ray-emitting corona. While previous studies suggest that disc-dominated emission becomes more prominent at higher optical luminosities, the redshift evolution of this relation remains debated, and a predicted dependence on Eddington ratio is still observationally unconstrained. We revisit this relation using a large, nearly all-sky quasar sample constructed by combining the SDSS DR16Q catalogue with X-ray data from *XMM-Newton* and the *SRG/eROSITA* all-sky survey DR1, yielding 136,745 QSOs at $0.5 \leq z < 3.0$. We introduce a hierarchical Bayesian framework that treats X-ray detections and upper limits consistently, allowing robust inference from both parametric and non-parametric models. We confirm a tight, sublinear $\log L_X(2 \text{ keV}) - \log L_\nu(2500 \text{ Å})$ correlation, but with a normalization lower than most previous estimates. We detect mild redshift evolution, with the relation flattening and its intrinsic scatter decreasing toward higher redshift. This trend may indicate enhanced energy transfer to the corona and evolution in the X-ray bolometric correction. We find no significant dependence on Eddington ratio.

The first eROSITA AGN X-ray luminosity function

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The Data Release 2 of the eROSITA mission will deliver a soft X-ray (0.2–2.3 keV) all-sky survey 10 times deeper than ROSAT. Containing over 2 million active galactic nuclei (AGN) in half of the sky, it enables an unprecedented statistical characterisation of supermassive black hole (SMBH) growth up to redshift 6, thanks to spectroscopic follow-up with SDSS-V. In this talk, I present the first measurement of the eROSITA X-ray luminosity function (XLF) of AGN, spanning nearly six orders of magnitude in luminosity. Unlike previous patchworks of pencil-beam surveys, eROSITA provides a controlled selection function, enabling robust constraints on evolutionary models. The resulting XLF provides stringent constraints on SMBH growth through the Soltan argument, probing also the rare, extremely luminous population, particularly at high redshift. We explore the link between the observed accretion luminosity density, the buildup of the integrated SMBH mass density, and the star formation history over cosmic time. Finally, at redshifts greater than 3, eROSITA is also sensitive to obscured X-ray-emitting AGN in the hard X-ray band (2–10 keV). We compare UV-selected AGN and quantify the contribution of the obscured population to the overall accretion budget.

Observational evidence of feeding and feedback in the low-luminosity Active Galactic Nuclei

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The majority of galaxies in the local Universe are quiescent or in low-luminosity states. The central supermassive black holes of them are powered by the hot, advection-dominated accretion flow (ADAF) at the Eddington ratio below 1%. Numerical simulations predicted that such hot ADAFs can launch energetic hot winds as powerful as jets, making low-luminosity active galactic nuclei (LLAGN) as potential candidates for AGN feedback. Direct observational evidence for these hot winds has been detected through Doppler shifts of highly ionized iron emission lines in several prototypical LLAGN with high-resolution X-ray spectroscopic data from Chandra HETG and XMM-Newton RGS. These hot winds exhibit characteristic temperature of larger than 10 keV and velocity of several 10^3 km s^{-1} , with kinetic energy accounting for $\sim 10 - 15\%$ of the total bolometric luminosity. Potential signatures for accretion feeding inflows and shocked circumnuclear interstellar medium (ISM) have also been identified in some of these sources. With the help of customized numerical simulations, we propose that these hot LLAGN winds not only help keep the inner circumnuclear region hot, but also effectively impede ISM infalling toward the central black hole, providing strong evidence for energy and momentum feedback in LLAGN.

Revealing the Dynamic Heart of NGC 3783: A Multi-Wavelength Campaign Unveiling Outflows and Fe K α Emission

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A large campaign on the Seyfert galaxy NGC 3783 was conducted in late July 2024, involving XRISM, XMM, Chandra, NuSTAR, and HST. Known for its signature warm absorber spectrum observed with HETGS in 2000-2001, NGC 3783 is now revisited with XRISM. The high-resolution spectra, spanning UV to X-ray, reveal rich absorption and emission features, providing a comprehensive view of outflowing and accretion structures. Three key aspects are highlighted:

Warm absorber variability: While warm absorbers are often considered quasi-steady, our observations reveal significant variability. The column density of the intermediate ionized component, contributing to the Fe unresolved transition array at the L-shell, has doubled over 24 years.

Mapping Fe K α lines: We resolved three emission components, with modeling indicating a moderately to rapidly spinning black hole in NGC 3783.

X-ray BLR variability: For the first time, we detected X-ray BLR variability using high-resolution spectroscopy. The delay between light curve variations and BLR Fe K α emission suggests the emitting region is at approximately 1500 gravitational radii.

Detection of a Stellar-Like Magnetic Reconnection Event in an AGN Corona With XRISM

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The X-ray source around supermassive black holes in active galactic nuclei (AGN) has been dubbed the corona by analogy to stellar coronae. The coronal activity in the Sun and cool stars is studied in detail and has been shown to be driven by magnetic energy converted into heat through the process of magnetic reconnection. While it has been theorized that AGN corona are also magnetically driven, the driving mechanism of AGN coronal activity has not been directly observed. A smoking gun of magnetic reconnection is when a coronal flare's temporal evolution in hard and soft X-rays follows the Neupert Effect, in which the hard X-ray light curve correlates with the time derivative of the soft X-ray light curve. These flares result in both a solar coronal mass ejection, and energetic particles streaming down along magnetic field lines to the photosphere. The talk will report the detection of the Neupert Effect in the XRISM observation of the Seyfert galaxy NGC 3783, providing the first direct evidence for magnetic reconnection in AGN. Our measurements indicate a magnetic field strength of 20,000G, magnetic loop height of up to 30 R_g, and distance of 400 R_g between the corona and the UV emitting accretion disk.

Properties of an X-ray selected sample of dual AGN and AGN pairs with XMM-Newton and Chandra

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Dual Active Galactic Nuclei (AGN) and AGN in pairs are fascinating laboratories for studying how galaxies and their central supermassive black holes co-evolve. In this talk, I will present an X-ray selected sample of AGN in pairs with projected spatial separation between the nuclei $1 \leq r_p \leq 100$ kpc at $z \leq 0.1$, using XMM-Newton and Chandra data. Our findings show that 10% of AGN reside in pairs, with 4% of AGN pairing with another AGN. Through an X-ray and optical analysis, we found that about 55% of these AGN are Compton-thin, while 6% are heavily obscured (Compton-thick). Interestingly, we found that AGN in late-stage mergers ($r_p \leq 30$ kpc) are significantly more obscured than those in the early stage of interaction. Furthermore, as the distance between the nuclei decreases, we observe an increase of the excess of AGN pairs with respect to a control sample of inactive galaxy pairs, and a clear increase of both the bolometric luminosity and the Eddington ratio of the less massive black hole in the pair. These results suggest that galaxy mergers may play a decisive role in triggering AGN accretion and activity.

A Dual AGN in a Narrow-Line Seyfert 1 Green Pea Galaxy

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We report the discovery and X-ray characterization of a dual active galactic nucleus (AGN) in the narrow-line Seyfert 1 Green Pea galaxy SDSS J1622+3521 at $z=0.266$. Deep Chandra imaging resolves two hard X-ray nuclei separated by $1.9''$ (8.4 kpc), each coincident with distinct optical peaks in a compact, low-metallicity starburst host. Both X-ray spectra are described by absorbed power laws with photon indices $\Gamma=1.8$, consistent with radiatively efficient accretion. The line-of-sight column densities are $\log N_H = 22.9$ and 23.6 , indicating moderate-to-heavy obscuration. The intrinsic 2–10 keV luminosities are $\log L_{2-10\text{ keV}} = 43.9$ and 43.6 erg/s, placing both components at the luminous end of dual AGN in low-mass galaxies. The projected separation and high luminosities indicate a pre-coalescence merger phase with simultaneous rapid black hole growth. As extreme, compact star-forming systems, Green Peas are nearby analogs of high-redshift galaxies. This system offers a spatially resolved view of merger-driven SMBH growth under conditions resembling those in the early Universe.

A fast powerful X-ray transient from possible tidal disruption of a white dwarf

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More than 100 tidal disruption events (TDEs) have been observed, most involving invariably normal gaseous stars, sustaining the flares over years. White dwarfs (WDs), which are the most prevalent compact stars and a million times denser—and tougher—than gaseous stars, can only be disrupted by intermediate-mass black holes (IMBHs). WD-TDEs are considered to generate more powerful and short-lived flares, but their evidence has been lacking. Here we report observations of a fast and luminous X-ray transient EP250702a detected by Einstein Probe. Its one-day-long X-ray peak as luminous as 10^{47} – 10^{49} erg/s showed strong recurrent flares with hard spectra extending to several tens of MeV gamma-rays, indicating relativistic jet emission. The jet's X-rays dropped sharply from 3×10^{49} erg/s to around 10^{44} erg/s within 20 days (10 days in the source rest frame). These characteristics are inconsistent with any previously known transient phenomena. We suggest that this fast-evolving event over the unprecedentedly short timescale arises likely from disruption of a WD by an IMBH. At late times, a soft component progressively dominates the X-ray spectrum, reaching a luminosity as high as 10^{44} erg/s, which is consistent with being extreme super-Eddington emission from an accretion disk expected to form in an IMBH-WD TDE.

The WISSHFUL XMM Heritage Program: probing accretion and ejection in luminous QSOs at Cosmic Noon

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Ultra-Fast Outflows (UFOs) are believed to be the nuclear drivers of AGN feedback, yet their properties at the peak of SMBH growth ($z \sim 2 - 4$) remain largely unconstrained. WISSHFUL is a 2.3 Ms XMM-Newton Multi-year Heritage Program targeting 15 luminous ($L_{bol} > 10^{47}$ erg/s), non-lensed QSOs selected from the WISSH sample, complemented by coordinated NuSTAR Large Programs and rest-frame UV spectroscopic campaigns. I will present the first-year results from this program. In the super-Eddington QSO WISSH J0900+4215 ($z = 3.29$), we report the detection of a two-component UFO at $v_{out} \sim 0.1c$ and $\sim 0.3c$ - the highest-redshift UFO discovered in a non-lensed QSO - with stratified variability and extreme energetics (E_{kin} up $\sim 10\%$ L_{bol}). The broadband XMM-Newton+NuSTAR analysis of the full year-1 sample (7 sources) reveals uniformly low high-energy cutoffs ($E_{cut} < 70$ keV), pointing to cold coronae across the highly accreting regime and extending the Temperature- λ_{Edd} relation to unexplored luminosities. I will also discuss emerging connections between UV absorbers (BALs/NALs) and X-ray UFOs, offering a unified view of multi-phase nuclear winds at Cosmic Noon.

Quasi-periodic eruptions with an unprecedented crest of narrow flares

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Quasi-periodic eruptions (QPEs) are recently discovered short-duration X-ray flares originating from galactic nuclei. They repeat every few hours/days, and their temporal and spectral properties point to an origin in stellar-mass objects orbiting a supermassive black hole, impacting a newly formed accretion disk resulting from a tidal disruption event (TDE). We present the discovery of QPEs with unprecedented phenomenology, as reported in Baldini+2026, coming from the nucleus of eRASS1 J234402.9-352640, an eROSITA-discovered TDE. Through XMM-Newton and Einstein Probe observations, we revealed broad, thermal flares recurring every ~ 12 hours, consistent with QPEs, but uniquely accompanied by a “crest” of hotter, faster flares, with durations as short as 5 minutes. These narrow flares predominantly appear on the rising phase of each eruption and show a potential colder-when-brighter evolution, a behaviour unprecedented among known QPEs. This new discovery expands the diversity of QPE phenomenology and strongly challenges current theoretical models, potentially suggesting the need to invoke additional ingredients to explain the nature of these sources.

Unveiling BLR Scale Outflows: Models for the Era of High Resolution X-ray Spectroscopy

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XRISM has provided an unprecedented view of the emission and absorption lines in the X-ray. Notably, early results showed significant complexity to the Fe-Kalpha line profile in AGN, with clear contributions from at least three emitting structures: an inner disc, intermediary broad line region (BLR), and an outer torus. This poses a new challenge for the modelling of the emission lines, which will only become more prominent with NewAthena. While fast sophisticated models exist for the disc line-profiles, large scale-height material is typically much more complex. In this talk I will present an analytic, yet physically motivated, approach for the emission line profiles from outflowing BLR scale material, motivated on reverberation and Gravity+ studies which suggest at times an outflowing BLR. I will show that this gives a physically motivated, yet computationally fast, model for the intermediary component to Fe-Kalpha seen in the XRISM data, and demonstrate its application using the XRISM observations of NGC 4151. I will finish by discussing the future outlook, and how this approach can be extended for NewAthena to map not only the line profile but also its variability.

First Constraints on QSO X-ray Timing Properties from Hours to Years Across the Black Hole Mass-Accretion Rate Plane.

Amie-Louise Doherty¹

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The stochastic variability of AGN provides key information about the structure and dynamics of accretion flows onto supermassive black holes. This has motivated observational programmes to characterise the Power Spectral Density (PSD) across different wavelengths and as a function of black hole mass and Eddington ratio. However, direct PSD measurements are currently limited to a small number of nearby Seyferts with high-quality timing data, probing only a narrow region of parameter space.

Ensemble variability studies overcome this limitation by combining timing data from large QSO samples, enabling constraints on the average variability properties of the population despite the low signal-to-noise of individual sources. Until recently, such studies were largely confined to the UV/optical regime. The eROSITA X-ray telescope has transformed time-domain X-ray astronomy by providing light curves spanning hours to years for unprecedentedly large QSO samples.

I present an ensemble statistical analysis of eROSITA QSO light curves from the SDSS and DESI surveys. Using novel tools accounting for Poissonian X-ray data, I measure the normalised excess variance from hours-to-years timescales, providing the first constraints on the typical X-ray PSD across a broad range of black hole masses and Eddington ratios and revealing the properties of the innermost accretion flow.

Uncovering Collisionally Ionized, Relativistic, and BAL-like Outflows in MCG-6-30-15 with Chandra HETG, XRISM, and Bayesian Framework

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Highly ionized outflows near radiatively efficient black holes are a promising candidate for Active Galactic Nuclei (AGN) feedback. Studying them relies on challenging high-resolution spectral measurements of blueshifted X-ray absorption lines, which are typically all assumed to be photoionized. However, recent studies suggest that many winds may be collisionally ionized, or that additional kinematic components can be detected using novel methods, yielding potentially major changes in their inferred mechanisms and power. Leveraging legacy-class X-ray grating archival data, Bayesian analysis, and high-performance computing, we have developed a framework to systematically identify all statistically significant collisionally and photoionized winds. In this work, we showcase this approach with MCG-6-30-15. Using the 0.65 Ms archival 2000 and 2004 deep Chandra High Energy Transmission Grating (HETG) spectra, we uncover a highly ionized, relativistic ultra-fast outflow (UFO) component previously undetected in HETG, independently observed in XRISM, and tentative cool UFOs. We also reveal a more detailed view of the slower warm absorbing systems, detecting collisional absorbers and confirming the presence of dust. Finally, we uniformly trace how these winds evolved over 25 years, the longest possible timeline using XRISM Resolve, and emphasize the arrival of a new era in high spectral resolution X-ray astrophysics.

Hidden BLR in Centaurus A: Resolving the Nuclear Structure with XRISM and NuSTAR

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High-resolution spectroscopy with XRISM/Resolve, combined with NuSTAR's broadband coverage, allows for a detailed decomposition of the nuclear structure in Centaurus A. In contrast to the phenomenological approach of Bogensberger et al. (2025), this study adopts self-consistent physical models for the clumpy torus and X-ray Broad Line Region (xBLR) calculated with the SKIRT radiative transfer code (Vander Meulen et al. 2023). Our spectral analysis identifies a multi-component Fe K α profile, requiring a broad component (FWHM ~ 6000 km s⁻¹) and two narrower torus components with velocity widths of ~ 320 km s⁻¹ and ~ 1900 km s⁻¹. We find abundance ratios of Ca/Fe (1.3 ± 0.4) and Ni/Fe (1.2 ± 0.2) consistent with the ISM composition of the host galaxy, distinct from the abundance patterns observed in the Circinus galaxy (XRISM collaboration 2026). Furthermore, we characterize the xBLR as a localized, thin shell at ~ 6000 gravitational radii with a high covering factor (> 0.18) and an inferred mass of 1-5 solar masses. This suggests that a robust formation mechanism for the BLR operates even in the low-luminosity AGN phase. We discuss the implications of these results for the nuclear structure of Centaurus A.

The search for long-lived, ultraviolet-bright, tidal disruption events

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The tidal disruption and subsequent accretion of a stellar object by a supermassive black hole in the nucleus of a galaxy, creates an event (TDE) which can be observed at many wavelengths. Powerful X-ray emission, generated from the inner parts of the newly-formed accretion disc and corona, fades away after 2-3 years in most events, as the disc cools and the corona dissipates. Ultraviolet emission from the disc, on the contrary, can continue to outshine that of the host galaxy, for many years, or decades, leaving a so-called Zombie TDE which can give valuable constraints on system parameters, complementing findings from the X-ray band. A census of such objects would allow us to constrain the overall event rate and investigate the persistence of mass-limited discs.

In this talk we describe a general purpose, publically-available tool which we have written to generate long-term UV light curves using data from IUE (1978-1996), GALEX (2003-2012), XMM-OM (2000-date) and Swift-UVOT (2005-date). Using this resource we have searched for galaxies which have shown an increase in UV flux. After carefully removing potential AGN and known supernovae we are left with an initial list of candidate TDEs, whose characteristics are presented here.

Radio-Quiet, unobscured AGN: 4 years of IXPE observations

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The Imaging X-ray Polarimetry Explorer (IXPE) observed several radio-quiet, unobscured AGN to date (including NGC 4151, IC 4329A, MCG-05-23-16, NGC 2110 and NGC 5506), yielding important, though still partial, results. Here we present the X-ray polarimetric analyses of these sources, combined with simultaneous XMM-Newton and NuSTAR observations (essential for constraining the physical properties and geometry of the hot corona), along with a tentative interpretation of the IXPE results collected to date. We also report outcomes from extensive Monte Carlo simulations designed to model different coronal geometries, comparing them with the observed polarization signatures to identify favored scenarios. Finally, we outline future prospects for X-ray polarimetry, including new IXPE campaigns and advances in theoretical modeling. We also discuss the role of forthcoming polarimeters, whose greater sensitivity will allow more definitive characterization of coronal geometry.

The Correlation of Iron Abundance Indicators in Active Galactic Nuclei from X-ray and Optical/UV Spectroscopy

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X-ray reflection spectroscopy is a powerful tool for constraining the black hole mass and spin in Active Galactic Nuclei (AGN), by modeling the reflection of coronal emission from the accretion disc. This method often requires super-solar iron abundances in the disc to reproduce the observed AGN spectra. In this talk, I will discuss possible mechanisms that could enhance the iron abundance in the disc. I will present our recent finding of a correlation between the disc iron abundance inferred from X-ray reflection spectroscopy, and the metallicity of the broad-line region derived from optical/UV spectroscopy, based on a sample of AGN. Mass transfer between the broad-line region and the accretion disc may account for this correlation. Our results also support the reliability of probing disc iron abundance using X-ray reflection spectroscopy.

Constraining Disk-to-Corona Power Transfer Fraction, Soft X-ray Excess Origin, and Black Hole Spin Population of Type-1 AGN across Mass Scales

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Unveiling the nature of the accretion disk, its interplay with the X-ray corona, and assessing black hole spin demographics are some open challenges in astrophysics. To address these issues, we systematically modeled broadband *XMM-Newton* and *NuSTAR* spectra of a sample of Type-1 active galactic nuclei (AGN) across mass scales. In this talk, I will present the key results from our spectral modeling, discuss the implications of relativistic disk reflection and warm Comptonization for the origin of the soft X-ray excess, the predictions of the standard alpha-disk model, and how we can compute the disk-to-corona power transfer fraction in accreting objects. Our first-ever calculation of the disk-to-corona power transfer fraction reveals that the fraction of power released from the accretion disk into the hot corona spans a wide range, with a sample median of about 0.7. Finally, through both hard X-ray (3–78 keV) and broadband (0.3–78 keV) relativistic reflection spectroscopy, we systematically constrain the black hole spin parameter across the mass scales of $\log(M_{\text{BH}}/M_{\odot}) \sim 5.5 - 9.0$. This increases or refines available spin measurements in the AGN population by about 20%.

Black hole accretion across the mass scale

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We use the unparalleled four-pass eROSITA All-Sky Survey (eRASS:4) to compute the X-ray AGN incidence as a function of the specific black hole accretion rate ($\lambda_{\text{SAR}} \propto \text{X-ray luminosity}/\text{stellar mass}$) across the mass scale: from dwarf to massive galaxies (at low redshift). This data set includes the largest sample of X-ray AGN in low-mass galaxies ($\log M^*/M_{\odot} < 10$) to date, which are of particular interest considering that these local low-mass galaxies could be analogues to the first galaxies that formed in the early Universe. Using X-ray data from 5.3 million parent galaxies, we constrain the specific accretion rate distribution over a wide range of λ_{SAR} , revealing a second-order mass-dependence and a robust detection of a high- λ_{SAR} break, possibly indicating Eddington-limited black hole growth. Integrating the incidence distributions, we find an intriguing peak in the cumulative AGN fraction as a function of stellar mass around $\log M^*/M_{\odot} \sim 10 - 10.5$ for moderately- and highly-accreting AGN. This could not only highlight changes in fuelling efficiency of AGN across the mass scale, but as the peak is in the mass regime where star-formation efficiency is also maximal, it could point to a common physical condition that is responsible for AGN accretion and star-formation.

The X-rays strikes back: Unlocking the formation of SMBHs in quasars at early cosmic times

Alessia Tortosa¹

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Understanding how the first SMBHs assembled within the first Gyr of cosmic time remains a major open problem. We investigate hyperluminous QSOs at $z > 6$ observed with XMM-Newton, leveraging the dataset from the Multi-Year Heritage Programme HYPERION, complemented by archival data. We find very steep spectral shapes and a strong relation between the X-ray photon index and the velocity of CIV winds, providing direct evidence for coupling between the accretion-disk corona system and radiatively driven outflows in early luminous QSOs. This relations suggests that SMBHs of the first QSOs may have reached their masses through very rapid accretion. Thanks to new observations from a dedicated XMM Large Programme, designed to extend the parameter space of early SMBH growth to test whether steep X-ray continua are a general feature of rapid assembly SMBHs or specific to extreme systems, we find that X-ray spectra remain systematically steep indicating that soft coronal emission is a robust and possibly ubiquitous property of rapidly growing SMBHs at high- z . The persistence of steep X-ray spectra also has important implications for the design and interpretation of future high- z X-ray surveys, as non-canonical spectral shapes can significantly affect detectability, inferred luminosities, and survey completeness for next-generation missions.

Chandra spectroscopy confirms the tightest-separation dual AGN in a gravitationally lensed radio-loud system at $z = 3.23$.

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Strong gravitational lensing acts as a cosmic probe, magnifying the flux and spatially resolving emission regions in cosmologically distant sources. I will present definitive evidence for a dual AGN in the radio-loud lensed system MG B2016 + 112 at $z = 3.23$ enabled by a new 175 ks Chandra observation. Previously, lens modeling suggested that the lensed radio source features two AGN at a projected separation of just 175 parsecs. However, neither multi-epoch VLBI data nor a previous 7 ks Chandra observation could discard the interpretation of a single AGN with a complex radio jet. Our new Chandra observation allows separate spectral analyses of the brightest images of the quadruply imaged source inside the caustic (magnification= 350) and of the doubly imaged source outside the caustic. Our analysis reveals strong intrinsic absorption at $z = 3.23$ for the inner source, whose AGN nature is thus confirmed, while prior optical data demonstrated the outer source is an AGN. Therefore, we confirm the closest-separation dual AGN yet identified at high redshift. I will discuss how our discovery challenges hierarchical structure formation theories predicting low galaxy merger rates and suggests enhanced lensing probabilities - hypotheses which can be tested with forthcoming lensing surveys.

Soft X-rays from tidal disruptions onto IMBHs

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Off-nuclear tidal disruption events (TDEs) are one of the processes that reveal the presence of intermediate mass black holes (IMBHs) in the outskirts of larger galaxies, perhaps remnants of accreted satellite dwarfs. Theoretical arguments suggest that such IMBH TDEs peak in the soft X-ray band. We will revisit the multiband properties of the soft X-ray transient ESO243-49 HLX-1 (often considered the template for accreting IMBHs), and show that they are consistent with the late-time evolution of a TDE. Its X-ray flaring behaviour was previously interpreted as a partial TDE from a companion star on a highly eccentric orbit; however, we will argue that luminosity oscillations are the expected behaviour during the decline of the large-scale accretion rate after a full TDE, and do not require multiple periastron stripping of a surviving companion star. Finally, we will illustrate the multiband properties and light-curve evolution of a few other soft X-ray transients discovered by Einstein Probe and Chandra, also consistent with IMBH TDEs.

High resolution X-ray spectroscopy of outflow in Radio Galaxy

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We present an analysis of the high-resolution XRISM/Resolve spectrum of the radio galaxies (e.g., Centaurus A, 3C 111). In Cen A, the ionized Fe-K emission lines are detected in the 6.5-6.9 keV band. There are two ionized Fe-K components. One of which is a broad (with a width of 3000 km/s) and redshifted (+3400 km/s), and the other is a narrow (with a width of 600 km/s) and blueshifted (-1500 km/s). The photoionized model fits the broader component, while either the photoionized model or the collisional ionization model explains the narrower component. Assuming a free-fall inflow, the position of the broader component was calculated to be $\sim 5e3$ Rs, which is consistent with the distance to the central engine inferred from the ionization parameters. In addition, there are two absorption line features at 7.1 keV and 10.6 keV. These absorption lines can be explained by ultra-fast outflows (UFOs) with velocities of approximately 0.06c and 0.43c, respectively. This 0.4c component is also detected in 3C 111. We will report the physical properties of and ionized Fe-K line features found in XRISM observed Radio Galaxies.

The physical origin of the mm radio emission in Radio-Quiet AGN

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The physical origin of radio emission in radio-quiet active galactic nuclei (RQ AGN) remains uncertain, likely arising from a combination of synchrotron processes linked to star-forming regions, weak or small-scale jets, and compact optically thick regions near the supermassive black hole. Increasing evidence supports this latter component: several RQ AGN exhibit flat or inverted GHz spectra and a millimeter (mm) excess consistent with self-absorbed synchrotron emission from a compact spherical region. Rapid mm variability, on daily to even hourly timescales, together with indications of correlation with X-ray emission, further points to a small emitting region physically connected to the X-ray corona. To investigate this link, we have conducted a dedicated program of simultaneous mm observations with NOEMA and X-ray observations with XMM-Newton or NuSTAR. A key result came from MCG+08-11-11 in 2021, where both mm and X-ray fluxes increased during a 12-hour observation, with hour-scale mm variability constraining the emitting region to within ~ 1300 gravitational radii. I will review the recent simultaneous mm/X-ray observations we did in this project, and discuss our conclusion concerning the origin of the mm emission and its relation to the X-ray corona.

An update on X-ray quasi-periodic eruptions in GSN 069

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X-ray quasi-periodic eruptions (QPEs) are luminous soft X-ray flares that recur on timescales of hours to weeks and have so far been detected in roughly a dozen low-mass galaxies. Observations suggest that QPEs primarily occur in tidal disruption events with a delay of months to years with respect to the outburst peak. Although their origin is still uncertain, leading models for QPEs invoke interactions between an orbiting low-mass companion and the newly formed accretion disc in an extreme mass ratio inspiral (EMRI) system. In this scenario, QPEs might represent the electromagnetic counterpart (or precursor) of gravitational wave sources to be detected by future space-based interferometers. QPEs were first identified in the nucleus of the galaxy GSN 069 and extensive follow-up observations make it the best-monitored QPE-emitting galactic nucleus thus far. I review the X-ray history of GSN 069 in the past 15 years including the appearance and disappearance of QPEs as a function of accretion flow properties, and I discuss the lessons learned and the prospects for elucidating the underlying physical mechanism(s) at play.

Tidal Disruption Events with eROSITA and XMM

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I will present the results of a systematic search for Tidal Disruption Events (TDEs) in the German half of the eROSITA all-sky survey. Thanks to its unprecedented combination of sensitivity and all-sky coverage, eROSITA has enabled the first comprehensive study of the X-ray-selected TDE population. This work reveals remarkable diversity in their observational properties, particularly in their temporal evolution. I will highlight key discoveries for individual sources, many of which were further characterised through dedicated follow-up observations with XMM-Newton. These findings provide new insights into the demographics and physical mechanisms of stellar TDEs by supermassive black holes.

Constraining the Physical Properties of Lensed AGN using Optical-to-X-Ray Data

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Gravitational lensing of luminous AGN can be used as a natural telescope to zoom in on their inner structures, which are otherwise difficult to resolve. With the increasing number of lensed AGN being discovered, it is crucial to conduct a homogeneous study focused on constraining their key physical properties, particularly the bolometric luminosity. The primary limitation of such a study is the availability of observations for a representative sample of lensed AGN in at least the optical, UV, and X-ray bands, where most of the AGN emission is concentrated.

In my research, I carried out one of the largest multiwavelength studies of lensed AGN with the aim of accurately measuring some of the fundamental quantities, such as their bolometric luminosities, black hole masses, and Eddington ratios. I compiled photometric and spectroscopic data in the optical/UV and X-rays for a sample of 27 quadruply lensed AGN to construct and model their broadband spectral energy distributions. In this talk, I will present an overview of the physical properties of optically selected lensed AGN and how they compare with non-lensed AGN. Additionally, I will discuss the reliability of widely used X-ray bolometric corrections in predicting the bolometric luminosities of lensed AGN.

Probing the Inner Environment of Mrk 509: Insights from XRISM, NuSTAR, and XMM-Newton Observations

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Nearby AGN offer unique laboratories for testing feedback models that aim to explain the observed correlations between supermassive black holes (SMBHs) and their host galaxies. The nearby, X-ray bright Seyfert 1 galaxy Mrk 509 stands out in this context, as previous observations revealed the presence of a prominent FeK α emission line complex, including both a narrow, neutral and stable core component, and a broad and variable component. In addition blue- and red-shifted absorption lines have been reported, suggesting the presence of out/inflow material.

Using XMM, NuSTAR and XRISM/Resolve data, we investigated not only the Fe K complex, but also the origin of the X-ray soft excess, to disentangle the contribution of the warm corona and of the relativistic reflection. Reflection from both the innermost accretion disc and colder material (outer disc, torus and/or BLR) is also invoked to describe the multicomponent FeK α emission line, that dominates the broadband spectrum. Partial covering absorption of the two comptonizing coronae provide a good description of the data, suggesting the presence of discrete inner BLR clouds along the line of sight that produce strong complex absorption in the broadband X-ray spectrum.

Black hole growth at the heart of a Green Pea galaxy uncovered by XMM-Newton

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²*California Institute of Technology*

Green Pea galaxies are compact, low-mass, low-metallicity star-forming galaxies in the nearby universe. They are believed to be analogues of the high-redshift galaxies that re-ionised the universe and, indeed, the James Webb Space Telescope (JWST) is now uncovering such populations at record redshifts. Intriguingly, JWST finds evidence suggestive of active galactic nuclei (AGN) in many of these distant galaxies, including elusive Little Red Dots, that broadly lack any detectable X-ray counterparts. Intuitively, one would expect to detect an AGN in their low-redshift analogues with X-rays, yet no study to date has identified an X-ray AGN within a Green Pea galaxy. I will present the deepest X-ray campaign of a Green Pea galaxy performed by XMM-Newton to discern the presence of a low-luminosity AGN. I will show that with detailed X-ray spectral modelling, we find for the first time evidence of soft X-ray variability over a 6.2 year baseline to $\geq 99.8\%$ confidence. By combining the X-ray spectral properties with a detailed multi-wavelength analysis, we prove that the source cannot be explained without an AGN that appears to share traits with JWST-detected AGN. I will conclude with prospects for next-generation studies of local analogues to the high-redshift universe with NewAthena/WFI.

Indirect probes of early black hole growth with nearby analogues

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An ongoing challenge re-invigorated by the James Webb Space Telescope is to understand the formation, growth and evolution of the earliest supermassive black holes (SMBHs). Regardless of cosmic epoch, most SMBH growth in active galactic nuclei (AGN) is expected to be heavily obscured by gas and dust. However, the challenge to select the most obscured AGN with approximately equal efficacy as the less-obscured population remains. I will first present NuLANDS — one of the largest NuSTAR legacy surveys ever performed in tandem with XMM-Newton and Swift, dedicated to constructing an obscuration-unbiased census of AGN in the local universe with combined infrared and broadband X-ray constraints. We find the fraction of obscured AGN in NuLANDS is fully consistent with expectations from the Cosmic X-ray Background, for the first time devoid of bias corrections. I will then discuss efforts to understand the growth of nearby obscured AGN in analogy to early SMBH growth. I will present our discovery of the first Compton-thick AGN with an intrinsically-soft X-ray spectrum, providing a unique window into the rapid growth of obscured AGN. I will conclude by advocating for further detailed studies of nearby Compton-thick AGN as a means to put the high-redshift universe in context.

Phase resolved X-ray spectral analysis of RE J1034+396

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We performed detailed phase resolved X-ray spectral analysis using the recent mega-second data from nine XMM-Newton observations for RE J1034+396. We confirm that a QPO signal is detected in all the nine observations in the hard band (1-4 keV) and is also detected at high significance (about 3σ) in six out of the nine observations in the soft X-ray band (0.3-0.5 keV). We utilised a novel band pass filtering method to filter out the QPO signals, which enables us to construct averaged phase-resolved X-ray spectra using the measured QPO frequency in different energy bands for each observation. We also constructed phase-resolved spectra based on the time-lag between the hard and soft band. These phase resolved X-ray spectra were fitted with phenomenological (broken power-law) and physical models (e.g. Comptonisation model). We find strong correlations between key parameters, e.g. photon index of power-law and gamma of the Comptonisation component, and QPO phases. Further more, the soft X-ray component shows phase shifts relative to the hard component that corresponds to the time-lag. Our findings strongly suggest that the QPO signal is intrinsically linked to the hard X-ray band, i.e., the Comptonisation component.

General relativistic effects at the heart of accreting Sgr A* light curve asymmetry

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While the supermassive black hole Sgr A* is currently underluminous, it is known to exhibit transient flares, presumably caused by episodes of material inflow that give rise to spots or self-crossing shocks, possibly originating from tidal disruption events. Understanding the physical origin of rapid high-energy variability therefore requires disentangling intrinsic emission timescales from propagation and relativistic effects, as flare overlap and relativistic modulation can produce asymmetric profiles that complicate physical interpretation.

We model the light curve by incorporating relativistic magnification and investigate the structure functions of both observed and mock X-ray light curves as a direct imprint of general relativistic effects on the signal. Key parameters include those describing the intrinsic flare profile, as well as the black hole spin and the observer's inclination angle. Through forward modeling of the intrinsic emission and inclusion of Doppler boosting and gravitational lensing associated with orbital motion, we quantify how relativistic effects reshape observed flare morphology and systematically bias the inferred rise and decay timescales of Sgr A* events.

We analyse a sample of archival X-ray light curves to characterise these asymmetries and then compare the July 2019 flare with contemporaneous infrared observations from Spitzer.

Absorption and emission under extreme conditions: the case of Mrk 766

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General relativity and MHD simulations suggest a strong link between accretion rate and the ejection of Ultra-Fast Outflows (UFOs) from AGN disks. If these outflows carry more than 0.55% of the bolometric luminosity, they can impact the host galaxy via AGN feedback, removing gas and dust and regulating star formation. High-Eddington disks are predicted to launch clumpy winds, producing both UFOs and slower, equatorial Warm Absorbers (WAs), but the connection between these outflows remains unclear. The nearby, highly accreting ($L/L_{\text{Edd}}=1.92$) NLSy1 Mrk 766 is an ideal laboratory to study emission and absorption under extreme conditions. Previous observations reveal a multi-component disk wind, including a variable WA, a highly ionized absorber (HIA), and a transient UFO. These features vary with flux, indicating a direct connection to disk activity. Fe K α emission is complex, with narrow and broad components, and ionized emission lines are present around 6-7keV. In June 2024, Mrk 766 was observed with XRISM, NuSTAR, and XMM-Newton. Despite a temporary anomaly with XRISM's Resolve filter wheel affecting half of the observation, the data were successfully analyzed. Here, we report results on the Fe K emission region, reflection, and the interplay between different ionized gas phases and disk activity.

Changes in SMBH Accretion Flow Structure from Rapid AGN Variability

Claudio Ricci¹, Arghajit Jana²

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Accreting supermassive black holes are known to be variable, changing in brightness across all wavelengths and on a wide range of timescales. In recent years, a remarkable subset of these AGN has been discovered to exhibit extreme spectral variability. These changing-state events can be driven by extreme and rapid changes in the black hole accretion rate, defying the expected accretion timescales for black holes with masses of millions to billions of solar masses. Such rapid variations provide a unique opportunity to gain insight into the accretion process in massive black holes.

In my talk will present new results from a study of approximately 1,000 optical/UV/X-ray observations of several nearby changing-state AGN, illustrating clear variations in their AGN spectral energy distributions as a function of the mass-normalised accretion rate. I will also discuss the impact of these SED changes on the close environments of accreting SMBHs.

X-ray reverberation mapping of active galactic nuclei with XMM-Newton

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The X-ray reverberation mapping emerged as a powerful technique that uses echoes of light from the immediate vicinity of the black hole, providing insights into the structure and kinematics of the inner accretion flow and geometrical arrangement of the disc-corona system. In this talk, I will present the recent results of the X-ray reverberation lag measurements with XMM-Newton, with a focus on the detection of the relativistic Fe-K X-ray lag in the Narrow-line Seyfert 1 (NLS1) galaxies Ton S180 and NGC 4395. The discussion will continue for the detection of Compton hump reverberation lag in the bright NLS1 IC 4329A. I will also discuss results of the general relativistic (GR) transfer function modelling of the reverberating lines performed in all three sources, which places constraints on the black hole mass concurrently with the spin and the coronal height. Lastly, I will address the future perspective of X-ray lags with the upcoming eXTP.

Nuclear and galactic ionized winds in a massive quiescent galaxy KUG 1208+386 hosting an obscured AGN

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Outflows are considered a key mechanism for active galactic nuclei (AGN) feedback, potentially linking the growth of supermassive black holes (SMBHs) to the evolution of their host galaxies. We present a multi-wavelength study of the nearby obscured Seyfert galaxy KUG 1208+386 ($z=0.023$), integrating archival X-ray observations from XMM-Newton, NuSTAR, and Swift with optical spectroscopy from DESI and multi-band UV-to-MIR photometry. XMM-Newton observations reveal the first detection of a highly ionized ultra-fast outflow (UFO) in this source, with a velocity of $v \sim 0.09c$. Simultaneously, DESI spectra identify galactic-scale warm ionized [O III] winds with a velocity dispersion of $\sim 320 \text{ km/s}$. Notably, our UV-optical-MIR spectral energy distribution (SED) fitting uncovers a quiescent star formation history, positioning the host galaxy in a likely post-feedback phase. By comparing the energetics of the nuclear UFO and large-scale winds, we discuss whether these multi-phase outflows are sufficient to drive the observed quenching of star formation, providing a complete picture of AGN feedback in a single system.

Cold, Bright, and Breaking the Rules: Finding Common Ground Between Cold Quasars and Typical AGN

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Active galactic nuclei (AGN) have played a major role in the X-ray Universe as they are known to be one of the brightest objects to be observed in the X-ray. They also have been shown to play a vital role in the evolution of their host galaxy such that there is a coevolution between the growths of both the supermassive black hole and the galaxy. However, a recently defined population of AGN, cold quasars, has begun to question the AGN's role. Cold quasars seem to break classical models of AGN evolution in that they are X-ray luminous and have broad lines in their optical spectra but are also IR luminous having a significant excess of cold gas in the line of sight producing extreme amounts of star formation ($1000+ M_{\odot}/\text{year}$) along with overmassive black holes. These cold quasars have been identified over three large X-ray surveys (Stripe82X, XMM-XXL, eFEDS). I aim to merge the three datasets and make direct comparisons of these sources to the cold quasars to paint an intricate picture of AGN evolution and determine whether cold quasars are a unique population or part of a short-lived phase experienced by all AGN in their evolution.

Mass Outflow in QSO2s: The Role of the X-ray Wind in Mrk 34

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Feedback in the form of AGN-driven winds is likely responsible for the co-evolution of supermassive black holes and galactic stellar bulges. Our *HST* study of QSO2s found evidence for interaction between [O III]-emitting gas and X-ray winds. To probe the role of the X-ray winds we obtained a 200 ksec XMM observation of Mrk 34, the nearest non-merging QSO2. It possesses an extended NLR region, both in X-rays and in the optical, and a massive optical wind. The Chandra/ACIS data revealed structure in the Fe K band which may be associated with UFOs. I will present the new XMM data, which has provided new insight into the structure and dynamics of these AGN driven winds.

Complex Nuclear Structure in Seyfert 2 Galaxy NGC 4388 Revealed by XRISM Observation

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We report results from the simultaneous XRISM (183 ks) and NuSTAR (62 ks) observations of the Seyfert-2 galaxy NGC 4388. This AGN has the brightest Fe K α line among Compton-thin, obscured sources. The profile of the neutral Fe-K fluorescent line is well described as the sum of three components convolved with Gaussians with FWHM values of ~ 290 km s $^{-1}$, ~ 1470 km s $^{-1}$, and ~ 11100 km s $^{-1}$. These line widths correspond to radii of 1.5 pc, 0.060 pc, and 1.0×10^{-3} pc by assuming Keplerian motion, which we interpret as the dusty torus, its inner edge region, and the BLR, respectively. The data suggest that the Fe K α BLR component is larger than that of H α (FWHM of 4500 km s $^{-1}$) in the polarized optical spectrum, implying that the velocity field of the BLR is dominated by that parallel to the equatorial plane. In addition, Fe XXVI Ly α and Fe XXV absorption lines are detected, characterized by $\log \xi \sim 3.50$ erg cm s $^{-1}$, $\log N_{\text{H}} \sim 22.1$ cm $^{-2}$, $v_{\text{out}} \sim 40$ km s $^{-1}$, and $\sigma_v \sim 160$ km s $^{-1}$. We infer that the absorber is gravitationally bound and is possibly associated with a failed wind, consistent with a radiation-driven fountain flow.

Spectral-timing modelling of the energy-dependent X-ray variability in Mrk 335

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The X-ray spectrum of the NLS1 galaxy Mrk 335 could be explained by multiple physical models, including partial covering absorption, warm-hot coronal emission and relativistically blurred reflection, leading to model degeneracies in purely spectral analyses. Using observations from XMM-Newton, we investigate whether energy-dependent variability can break this degeneracy. We develop a spectral-timing modelling technique that predicts the fractional rms spectrum resulting from correlated variations of spectral parameters and compare these predictions with the observed variability on 3 ks and 6 ks time scales. We find that at least two varying parameters are required in all scenarios. The partial covering and two-corona models reproduce the observed non-monotonic rms behaviour through physically plausible parameter correlations. In contrast, the blurred reflection model requires different parameter combinations for different timescales, suggesting a more complex variability and yields extreme spectral parameter values, indicating that it might not be a plausible explanation for the observation under consideration. Our results highlight the power of energy-resolved variability modelling as a characteristic tool for distinguishing emission scenarios in active galactic nuclei and demonstrate its wider applicability to XMM-Newton datasets.

A Universal X-ray–He II Correlation from Star-forming Galaxies to AGN

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He II emission traces ionizing photons above 54 eV and probes hard radiation fields in galaxies. In active galactic nuclei (AGN), high-ionization lines trace intrinsic power, yet standard diagnostics such as [O III] can be affected by star formation and host-galaxy contamination. We present a statistical study of the connection between He II 4686 emission and X-ray output based on a large sample of He II emitters cross-matched with archival Chandra observations. We find a tight linear correlation between X-ray and He II luminosities spanning more than seven orders of magnitude and holding across both AGN and star-forming galaxies, with lower scatter than correlations involving metallicity or star-formation rate. The persistence of the L_X–L_{HeII} relation across AGN and star-forming galaxies indicates that accreting X-ray sources—supermassive black holes in AGN and X-ray binaries in star-forming systems—provide the hard ionizing photons required for He II excitation. This makes He II a valuable diagnostic of intrinsic high-energy power in sources of ambiguous or composite classification, where traditional optical indicators may be diluted or obscured by host-galaxy emission. He II emission therefore emerges as a robust probe of intrinsic high-energy radiation in AGN and galaxies across cosmic time.

Probing the Geometry of Low-Ionization Ultra-Fast Outflows in PDS 456 through Soft X-ray Variability with XRISM and NuSTAR

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Ultra-fast outflows (UFOs), launched from accretion disks at relativistic speeds, are thought to play a key role in the co-evolution of galaxies and black holes (BHs), yet their acceleration mechanism —whether radiation-driven or magnetohydrodynamic-driven— remains unclear. Here we present XRISM and NuSTAR observations of the quasar PDS 456, focusing on its low-ionization UFO component. The soft X-ray spectrum (0.5–5 keV) shows strong absorption explained by a low-ionization UFO with an ionization parameter of $\xi \sim 10^3$, an outflow velocity of $0.3c$, and a partial covering fraction of ~ 0.9 . We detect significant variability in the covering factor, changing from 0.88 to 0.93 over the observation. This variability is interpreted as the absorber crossing our line of sight, implying a transverse velocity of approximately 1500 km/s. Assuming conservation of angular momentum between the launching and observation points, we estimate that the low-ionization UFO is located at distances greater than $3000 R_g$ from the BH. This result indicates a stratified wind geometry, in which the low-ionization component lies outside the previously reported high-ionization UFO at 200–600 R_g , while sharing the same outflow velocity. This geometry, in which both components share the same velocity at different distances, favors a radiation-driven origin.

Machine learning methods for spectral-timing of AGN outflows

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Ionized outflows in active galactic nuclei (AGN) act as a link between the central supermassive black hole and the host galaxy, possibly influencing galactic evolution and the self-sustenance of the nucleus. Spectral-timing techniques allow us to extract information on the physical properties of these outflows by exploiting density-dependent delays in the gas response (Juranova et al., 2022). In this context, we present an overview of the inner workings of simulations based on non-equilibrium gas evolution models, focusing on their optimization through the implementation of neural network-based emulators. In particular, we show how simulation runtimes reduction and thorough parameter space exploration made possible by the machine learning approach can facilitate placing constraints on the location and energetics of AGN outflows, bringing us closer to an application of spectral-timing methods to non-simulated observational data.

The X-ray spectral changes in highly variable AGNs

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Stellar-mass black holes (BHs) exhibit spectral state transitions governed by mass accretion rate, producing distinct X-ray spectral properties in each state. In contrast, only a small fraction of active galactic nuclei (AGNs) show X-ray variability exceeding an order of magnitude, and analogous transitions are rarely observed. We analyzed AGNs showing soft X-ray flux variability by a factor ≥ 10 selected from the XMM-Newton stacked catalogue 4XMM-DR14s. We identified 31 sources displaying large-amplitude variability in soft X-rays on multi-year timescales. Among them, 25 objects exhibit spectral evolution characterized by changes in absorption, photon index, blackbody temperature, or combinations thereof, while the remaining six show little spectral change. Several sources show pronounced spectral variability. For example, J0047 exhibits an apparent transition from a very high state to a low/hard-like state, while its UV flux remains nearly constant. Its spectral variation is explained by an increase in the column density of ionized absorber rather than intrinsic accretion rate variation. We also identify J0054 as a candidate tidal disruption event or supersoft AGN, with a spectrum dominated by a blackbody component and an extremely weak power law continuum.

Physical Origin and Variability of AGN Ultra-Fast Outflows Observed with XRISM

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AGN winds are observed in UV and X-ray spectra as absorption features, the fastest and most energetic of which are the Ultra-Fast Outflows (UFOs). With velocity measured up to $0.4c$, UFOs are mainly identified by highly ionized Fe K-alpha absorption lines above 7 keV, where they are the only ions not fully ionized. The Resolve spectrometer on board XRISM has been particularly efficient at detecting UFOs featuring higher energy resolution and sensitivity in the Fe-K band than previous instruments. UFOs were by now reported in several AGNs demonstrating their clumpiness. These results are based on the full observations, lasting more than 400 ks. Time variation examination of the observations however indicates a shifting behavior on shorter time frames of 10-100 ks. Our results show a transient behavior of the absorption lines, in two AGNs observed by XRISM PDS 456 and PG 1211+143. Our analysis further links the transient nature of the UFOs to the emission process of individual wind clumps.

Probing Highly Accreting AGN in the Quasar Main Sequence Through Soft X-ray Excess and Bayesian Analysis

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We present a comprehensive Bayesian analysis of the X-ray spectral properties and soft excess emission in 207 type 1 AGN distributed along the Quasar Main Sequence (MS), spanning over five orders of magnitude in luminosity (10^{43} – $10^{47.5}$ erg s^{−1}). Within the 4D Eigenvector 1 framework, primarily driven by the Eddington ratio, quasars are organized into distinct populations with different accretion properties and broad-line region kinematics. Using high-quality 0.3–10 keV spectra from XMM-Newton (4XMM-DR12), we modelled each source with four spectral prescriptions, including power-law and soft-excess components, applying Bayesian X-ray Analysis (BXA) tools to characterize posterior parameter distributions.

We find statistically significant differences between Population A and B quasars in the hard X-ray photon index (Γ_{hard}), with higher accretors (Population A, especially extreme accretors A2–A4) showing systematically steeper spectra. These differences become more pronounced when soft emission is included. The soft excess strength, quantified via the blackbody-to-power-law luminosity ratio ($L_{\text{bb}}/L_{\text{pl}}$), is enhanced in extreme accretors and weakest in Population B sources. Additionally, we identify a clear correlation between the optical Fe II strength (R_{FeII}) and the X-ray photon index, linking X-ray spectral properties directly to accretion physics onto supermassive black holes.

X-ray and optical polarization of BL Lac objects with IXPE and Kanata telescope

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Polarimetric observations of blazars have been performed mainly in the radio and optical band. Recently IXPE enables us to perform X-ray polarimetric observations. BL lac objects among blazars show a Synchrotron radiation up to X-ray band and thus IXPE gives us an important information on higher energy electrons emitting Synchrotron radiation. We have performed the optical polarimetric observations of BL Lac objects simultaneously with IXPE. Here we report the systematic analysis of BL Lac polarization in the optical and X-ray band. . Systematic comparison between X-ray and optical polarization for several BL Lac objects showed that the X-ray polarization degree is higher than that of the optical and the polarization degree is different between two X-ray and optical. This is consistent with the above indication of localized emitting region of higher-energy electrons and further indicates that the optical emission comes from relatively larger region and thus is depolarized. We compare the X-ray polarization angle with the radio jet direction and found the tendency that the X-ray polarization direction is along or perpendicular to the jet direction.

Chapter 8

Groups of Galaxies, Clusters of Galaxies & Cosmology

Unveiling Gas Kinematics in the Perseus Cluster with XRISM: AGN Feedback, Sloshing, and More

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In this talk, I will highlight a series of groundbreaking results from XRISM observations of the Perseus cluster. Using four PV-phase pointings, we have mapped the gas kinematic distribution of Perseus beyond its cool-core radius. Perseus remains the only cluster target to date that enables us to probe a broad range of dynamical scales while simultaneously achieving sufficient spatial resolution.

The data provide direct evidence for the presence of at least two dominant gas motion drivers, with a transition occurring at a radius of ~ 60 kpc. These are associated with AGN feedback and mergers (i.e., the cosmological environment), respectively. The inner, small-scale driver sustains a heating rate at least an order of magnitude higher than that of the outer, large-scale driver, highlighting the significant role of AGN-powered turbulence in offsetting radiative cooling losses.

Together with recent calibration and GO1 pointings, we have extended our velocity mapping of Perseus to radii beyond 400 kpc. We detect significant gas bulk motions driven by sloshing, which place constraints on the merger configuration of Perseus. I will present our latest progress on constraining turbulence properties using the velocity structure function.

The hot circumgalactic medium in X-ray absorption and emission spectroscopy

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The hot circumgalactic medium (CGM), a reservoir of missing baryons, metals, and energy, plays a key role in our understanding of galaxy evolution. However, extraordinary observational challenges make the hot CGM one of the least understood components of galaxies. I will discuss three snippets of our recent efforts using grating and CCD data for absorption and emission spectroscopy. 1) Using novel spectroscopic techniques, we have detected the volume-average extended CGM emission of spiral galaxies and showed that the CGM is fainter than the ISM due to lower density and not lower temperature, as opposed to common assumptions made in imaging analyses. 2) Anchoring at the redshift known from O_VI absorption, we have detected O_VII absorption in the CGM at $\lesssim 100$ kpc impact parameter. 3) Going beyond the oxygen-only analysis and employing a multi-ion multi-metal approach, we are unveiling thermal, chemical, and kinematic anomalies in the CGM of the Milky Way. I will briefly discuss how next-generation missions like NewAthena (and AXIS) will enable us to scale these achievements up and help conduct statistically complete surveys of individual galaxies in emission and X-ray bright quasars to probe intervening absorption.

Constraints and prospects with XRISM on rotation and turbulence of the intracluster medium

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Bulk and turbulent motions of the intracluster medium (ICM) are expected at velocities of a few hundreds km/s. Detecting these motions in X-ray is key to quantifying the non-thermal energy budget of the ICM, which contributes to systematic uncertainties in cluster-based cosmological studies.

I will present constraints on the rotation and turbulent support of the ICM in a sample of nearby, massive galaxy clusters (X-COP) obtained by jointly fitting, within a Bayesian inference framework, hydrodynamical-equilibrium models to a combination of the state-of-the-art X-ray datasets. For the first time, we demonstrate the accuracy of our rotation and turbulence constraints by comparing our predictions with the observed X-ray spectra at high-resolution obtained with XRISM for the galaxy cluster A2029. I will conclude by presenting the velocity measurements in the new XRISM pointing of A2029, approved in the XRISM AO-2 program, and by highlighting the implications of our results for cluster-based cosmological studies.

The fate of hot gas in galaxy groups

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Thanks to their shallow gravitational potential, galaxy groups are a sensitive probe of AGN feedback. However, accurate comparison between observations and models are hindered by selection effects and measurement systematics. We constrain feedback models by comparing thermodynamic observables of galaxy groups from the XMM-Newton Group AGN Project (X-GAP) with FLAMINGO simulations, accounting for observational selection and X-ray measurement process. We select X-GAP analogues using our calibrated selection function. We forward model the XMM-Newton observation folding instrumental response. We compare to X-GAP using the observables measured on the mocks with the same pipeline as the real data. In this contribution, I will show that our framework is able to properly recover true input quantities. I will focus on the combinations of observables that discriminate between FLAMINGO flavours: the variant calibrated to lower gas fractions provides the best agreement with X-GAP over weaker and stronger models (preferred by stacked kSZ analysis and cluster gas mass fractions). This tension is also relevant for cosmology: the redistribution of baryons due to feedback has an impact on the suppression of the matter power spectrum. Our end-to-end forward model provides a stringent test on the fate of hot gas in $1e13$ - $1e14$ Msun haloes.

Tracing the hot gas budget at the outskirts of galaxy groups with eROSITA

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Active galactic nuclei feedback is the favoured scenario for ejecting gas outside the virial regions of galaxy groups, ultimately reshaping the matter distribution of the Universe on small scales. Gas fraction measurements at R_{200} remain scarce due to the limited sensitivity of X-ray instruments, while the predictions of cosmological hydrodynamical simulations reveal notable discrepancies traceable to their different feedback implementations. We confront this picture by using eROSITA data to study the properties of hot gas beyond R_{500} of a sample of 25 X-ray selected galaxy groups, detected in eRASS1 and confirmed via the 2MRS spectroscopic catalogue. In doing so, we account for the aperture-covariance effect between quantities with shared integration radii. We find sub-cosmic gas fractions at our median mass of $f_{\text{gas},500} = 4.5 \pm 0.42\%$ and $f_{\text{gas},200} = 6.1 \pm 0.7\%$. Our $f_{\text{gas}} - M$ and $L_X - M$ relations are consistent with the predictions of BAHAMAS, SIMBA, and fiducial FLAMINGO simulations, while significantly deviating from FLAMINGO's strong feedback variations. Our constraint on the suppression of the matter power spectrum implied by our $f_{\text{baryon}} - M$ relation is consistent with simulations at $k < 1 \, h \, \text{Mpc}^{-1}$ but reveals a growing tension with strong feedback variants on smaller scales.

FornaX: the XMM-Euclid Heritage Deep Survey

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²<https://fornax.cosmostat.org/list-of-members/>

In 2023, one thousand hours of XMM time were allocated to cover the Euclid Deep Field Fornax, as part of the XMM multi-year Heritage programme. The XMM observations started in 2024 and will be completed in 2027 to achieve a uniform 40 ks coverage over 10 deg², along with extensive deep observations across the entire electromagnetic spectrum. Several hundred galaxy clusters and several thousand AGNs will be discovered. The Fornax collaboration gathers some 60 scientists closely involved in the XMM and Euclid data analysis. I present the scientific goals of the survey, the current status of the XMM observations and our first scientific results. One of the main aim of the Fornax project is to uncover the faint cluster population that will not be seen by the Euclid Wide survey. While being a science topic on its own, this also is a key issue for the subsequent Euclid cosmological analysis based on cluster number counts; I thus describe our joint XMM-Euclid simulation programme that aims at quantifying the systematic uncertainties in the cluster selection procedures. Finally, I explain our plans to deliver deep catalogues of the XMM Fornax sources, along with their multi-lambda counterparts, ensuring a long-lasting Heritage data set.

The role of turbulence in galaxy clusters: A XRISM perspective

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The high-resolution X-ray spectral capability of the recently launched XRISM telescope has enabled us to measure gas motions in galaxy clusters. I will briefly present recent results on gas motions in Cygnus A, Hydra A. In Cygnus A, XRISM has detected a velocity dispersion of 261 ± 13 km/s, along with a cooler gas phase that has an even broader velocity dispersion of 440 ± 130 km/s. The total energy due to the kinetic motion is 5.1×10^{60} erg, consistent with the energy of the central radio source. We therefore suggest that such large dispersions are mainly due to the expanding cocoon shock driven by the radio source. Hydra A, on the other hand, has a lower velocity dispersion of 160 km/s over the whole field of view, but the dispersion is asymmetric (ranging from 80 - 260 km/s) when the field of view is divided. Furthermore, we find velocity dispersion to be nearly constant (140-160 km/s) with respect to radius toward the Northern direction, where giant bubbles exist. Such a result is not consistent with pure Kolmogorov turbulence. I will then discuss implications regarding mechanisms by which turbulence may heat cluster cores using simple buoyancy models.

Probing hot baryon beyond virial radius of massive halos

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The hot gas in the outskirts of galaxy cluster-sized halos, extending around and beyond the virial radius into nearby accretion regions, remains among one of the least explored baryon components of large-scale cosmic structure. In this talk, I will present recent progress from the eROSITA All Sky Survey in probing the hot gas in these low-density regions. The stacking of 680 galaxy clusters in the low-redshift Universe greatly expands understanding of gas distribution in and beyond halo outskirts. The stacked surface brightness profile reveals significant X-ray emission out to $2 \times r_{200m}$ (about 4.5 Mpc). The subsequent modeling discloses the position of the cluster boundary as well as the gas density and gas fraction out to r_{200m} . Meanwhile, the density profile and its slope indicate that feedback processes have played an important role in shaping the outer atmospheres of massive halos.

Calibrating Group Masses and AGN Feedback with a Self-Consistent Bayesian Framework

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X-ray observations of galaxy groups open a rich discovery space, serving as critical laboratories where the feedback energy from AGN is comparable to the gravitational binding energy of the gas (Eckert+2024). We present a self-consistent calibration of scaling relations for the XMM-Newton Group AGN Project (X-GAP) using a comprehensive hierarchical Bayesian framework. By simultaneously fitting L_x , T , M_{gas} , Y_x , V_{disp} and M_{tot} , we provide a unified analysis that rigorously accounts for the X-GAP selection function (Seppi+2025), mass function, and both intrinsic and measurement covariances. By anchoring the mass scale with V_{disp} , our work addresses the historical challenge of group mass calibration and enables robust constraints on the hydrostatic mass bias at the group scale. The fitted relations, particularly the L_x - T relation, serve as a key diagnostic for AGN feedback efficiency (e.g., see Eckert+2025). To interpret our findings, we compare the calibrated relations with the predictions of simulations featuring various feedback implementations and parameterizations to identify the sub-grid physics required to reproduce the measured group properties. This work provides the unbiased mass calibration and feedback constraints for the low-mass haloes that are necessary to transform galaxy groups into robust probes for galaxy evolution and, eventually, cosmology.

The SRG/eROSITA view of the Fornax galaxy cluster

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The Fornax cluster is one of the nearest X-ray-bright galaxy clusters, allowing high-resolution studies. Previous observations of its intracluster medium were limited to within $R500$. We use five eROSITA all-sky surveys to extend the X-ray view of Fornax and search for surface-brightness features beyond $R500$ linked to the cluster's gravitational growth. We perform one- and two-dimensional analyses, tracing hot gas from kiloparsec to megaparsec scales with a single instrument. We compare our results to the SLOW simulation of the local Universe and correlate the X-ray morphology with other tracers, including member galaxies, ultra-compact dwarfs, intracluster globular clusters, and HI-tail galaxies. We detect emission well beyond the virial radius ($R100=2.2\text{deg}$). Inside $R500$, known structures such as a spiral-shaped edge are confirmed, but we find no clear evidence for the previously predicted bow shock south of the center. Instead, we discover “emission fingers” beyond $R500$ and excesses extending past the virial radius. Their alignment with galaxy and globular-cluster distributions favors warm-hot gas infall along filaments. We also find a faint X-ray bridge toward Fornax A, coincident with enhanced Faraday depth. Spatial-spectral analysis reveals the 1keV extended Fornax A emission to be dominated by thermal emission and not by inverse Compton.

Galaxy cluster count cosmology with simulation-based inference

Manon Regamey¹, Dominique Eckert¹

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Recent measurements of cosmological parameters highlight possible tensions between values determined by CMB measurements and late-epoch observations, particularly for the clumpiness parameter σ_8 . Galaxy cluster surveys provide a sensitive way of investigating the σ_8 tension and probing the Λ CDM framework thanks to the strong dependency of the halo mass function on the Universe’s matter distribution. Here, I will present recent papers introducing a simulation-based inference pipeline to retrieve cosmological information from galaxy cluster counts. The implemented pipeline generates samples of galaxy clusters from the halo mass function, incorporates complex observational effects, and applies the survey selection function exactly. We test our method on mock samples through various validation steps before applying it to the XXL survey data. We demonstrate that simulation-based inference is a promising avenue for future cosmological studies from galaxy cluster surveys such as eROSITA and Euclid, as it provides a natural framework to jointly model all the available observables in a coherent manner.

Resolving AGN Feedback in Cluster Cores with XRISM and Chandra

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Identifying how active galactic nuclei (AGN) couple to galaxy cluster atmospheres is central to understanding the regulation of star formation in massive halos. I present a comprehensive view of AGN feedback using complementary imaging and spectroscopic diagnostics. First, I introduce an imaging technique, “X-arithmetic,” which decomposes perturbations in feedback-dominated regions of 15 galaxy groups and clusters into components dominated by (1) weak shocks and sound waves, (2) jet-inflated bubbles, or (3) isobaric perturbations associated with cooling and slow gas motions. This approach efficiently identifies the origin of feedback-driven structures in Chandra images without requiring spatially resolved spectroscopy, confirming known features while revealing previously unidentified ones. Second, I present new high-resolution spectroscopic constraints from XRISM/Resolve, which directly probe intracluster medium kinematics on kiloparsec scales. Focusing on M87 in the Virgo Cluster, we measure a velocity dispersion peak of 260 km/s within 5 kpc of the central black hole, declining rapidly to 60 km/s at larger radii. Comparisons with other feedback-active clusters observed by XRISM/Resolve place these results in context. Together, these results provide clues to how AGN impact cluster cores, laying the groundwork for future investigations and numerical models.

**KINETIC: Unveiling the gas motions in the intracluster medium using
XMM-Newton and XRISM**

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Galaxy clusters are key laboratories for studying structure formation, yet the dynamical state of the intracluster medium (ICM) remains only partially constrained. I present results from KINETIC (Kinematics of the Intracluster Medium), a program aimed at measuring and interpreting gas motions in clusters using X-ray observations and simulations. Using deep XMM-Newton data, we characterize bulk motions, turbulence, and chemical structure in the ICM through spatially resolved spectroscopy. These measurements are combined with recent XRISM results to place gas dynamics within the broader context of cluster assembly and large-scale structure. To interpret these observations, we perform consistent comparisons with state-of-the-art hydrodynamical simulations, generating synthetic X-ray observables that are analyzed in the same manner as the real data. This approach allows us to track down the merger history, AGN feedback, and non-thermal pressure support. These results demonstrate how current and upcoming X-ray missions are opening a new window onto the dynamical evolution of galaxy clusters.

From Clusters to Milky Way-Type Groups: Extending X-ray Scaling Relations with eROSITA

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Low-mass galaxy groups are the most common environments for galaxies and serve as a key bridge between cosmological structure formation and galaxy evolution. Yet, their hot gas and baryonic content remain poorly characterized, largely due to their low surface brightness in X-rays. In this talk, I will show how spectral stacking of eROSITA data offers a powerful method to uncover the X-ray properties of galaxy groups and clusters identified through large spectroscopic surveys, including SDSS, GAMA, and DESI. Focusing on eRASS1 results, I will present stacked X-ray spectra for these systems and compare them with mock observations based on Magnetium hydrodynamical simulations. This technique allows us to trace the intra-group medium from massive clusters down to group scales comparable to the Local Group, extending and validating key X-ray scaling relations into the low-mass regime. In doing so, we also probe the impact of AGN feedback on baryon content and distribution, offering new insights into the thermodynamics and internal structure of galaxy groups. These results open new pathways to connecting observations and theory across the full mass spectrum of cosmic structures, even for systems undetected from the individual X-ray data.

A robust spectroscopic detection of pure WHIM and the missing baryons throughout a pristine cosmic filament

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The "missing baryon" problem refers to a significant fraction of the baryons in the late Universe that remains undetected. These missing baryons are believed to reside in cosmic filaments as the warm-hot intergalactic medium (WHIM). The latter is especially challenging to detect observationally due to its diffuse, faint X-ray emission. We applied a novel and powerful method to detect WHIM emission in filaments and report the first-ever spectroscopic detection of pure WHIM throughout a 7 Mpc pristine cosmic filament via its X-ray emission. The filament lies in the Shapley supercluster, connecting the quadruple cluster system A3530/32-A3528N/S, with a 53-degree angle to the sky's plane. Employing deep Suzaku and XMM-Newton data, we study the axial and radial surface brightness profiles of the filament, and we detect the WHIM emission to be $\approx 20\%$ above the background level at 6 sigma. Performing a careful and novel spectroscopic analysis, we measure the filament gas temperature and baryon overdensity to be ~ 1 keV and ~ 35 , respectively. This is the first time that consistency between observations and Λ CDM simulations is found regarding WHIM properties for a single filament. Finally, we demonstrate how undetected filaments can bias the mass estimates of the local cosmic web.

Exploring cosmic expansion anomalies with galaxy clusters

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The isotropy of cosmic expansion and the dissipation of bulk flows at large scales are crucial assumptions of Λ CDM. As such, they should be thoroughly scrutinized observationally. Galaxy clusters and their multiwavelength scaling relations are excellent probes of such expansion anomalies. In the past, we used scaling relations between X-ray, millimeter, and optical cluster properties to detect a 9% dipole variation in the Hubble constant that could be attributed to an 800 km/s bulk flow of galaxy clusters extending to 500 Mpc. Both of these scenarios constitute a $\sim 4 - 5\sigma$ tension for Λ CDM in the local Universe. I will present new, independent results derived from X-ray data of > 5000 newly discovered eROSITA clusters, as well as from new XMM-Newton and optical data, that independently support the existence of a cosmological anomaly, pinpointing its origin in the local ($z \lesssim 0.2$) Universe rather than suggesting a global anisotropy. I will also present new results from the FLAMINGO cosmological simulations that demonstrate that cosmic variance and cluster noise only mildly reduce the tension between cluster data and Λ CDM Universe to a 3.5σ level. Finally, I will discuss the promising future of cosmic anisotropy tests with galaxy clusters.

XRISM/Resolve and NuSTAR Constraints on Non-thermal Emission in the Arms of M87

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M87, the central dominant galaxy of the Virgo Cluster, is a nearby laboratory for studying the co-evolution of active galactic nuclei (AGN) feedback and the surrounding intracluster medium (ICM). Hosting a supermassive black hole and powerful relativistic jets, M87 is expected to exhibit both thermal X-ray emission from the ICM and possible non-thermal components associated with jet-driven particle acceleration. Identifying and characterizing this non-thermal emission is critical for understanding energy transport, particle populations, and feedback processes in cool-core clusters, in addition to putting strong constraint on the ICM observables. In this work, we combine high-resolution soft X-ray spectroscopy from XRISM/Resolve with hard X-ray imaging spectroscopy from NuSTAR to disentangle thermal and non-thermal contributions to M87's X-ray spectrum. Resolve's spectral resolution enables precise modeling of line-rich thermal plasma, while NuSTAR extends sensitivity to hard X-ray excesses indicative of inverse Compton emission. Through joint spectral analysis of the core and jet regions with XRISM/Resolve and NuSTAR data, we place new constraints on high-energy electron population and the mechanisms powering M87's X-ray emission.

Electron-Ion Equilibration in the Merging Galaxy Cluster A665

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Galaxy cluster mergers drive powerful shocks that redistribute $\sim 10^{64}$ ergs of energy in the intracluster medium (ICM), heating the plasma and accelerating particles. Hosting one of the strongest known shocks ($M \sim 3$), Abell 665 provides a unique opportunity to study how quickly electrons and ions reach thermal equilibrium in a merger. Using ~ 200 ks of NuSTAR observations, we measure the temperature distribution across the shock to distinguish between two heating scenarios: an (1) instant, collisionless model where electrons and ions are immediately heated at the shock, or a (2) delayed, collisional model where electrons are initially, adiabatically compressed and subsequently equilibrate with ions over ~ 100 Myr. Our measurements favor delayed equilibration, with the post-shock temperature profile more consistent with a Coulomb collisional time scale than with immediate electron heating. These results inform our understanding of the microphysics of low density astrophysical plasmas, and imply that electron temperatures may systematically lag behind ion temperatures in cluster mergers. Such effects influence our interpretation of X-ray based cluster temperature measurements, which directly impact cluster mass estimates and their use as cosmological probes, while adding to our understanding of particle acceleration and energy partition in the ICM.

Constraining the Multiphase ICM in Cool-Core Clusters with Joint XMM-Newton RGS and EPIC Spectroscopy

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The multiphase ICM in cool-core clusters is a key probe of the interplay between ICM thermodynamics, star formation in the central galaxy, and feedback from the central supermassive black hole. However, the cool X-ray-emitting phase (< 1 keV) remains difficult to quantify due to current instrumental limitations, including the limited spectral resolution of CCD detectors and the complicated continuum in grating spectra. We address this with a joint analysis of XMM-Newton EPIC and RGS spectra for 10 nearby cool-core clusters and groups within their central 30 kpc. Using a three-component spectral model that separates central cool gas, central hot gas, and surrounding hot gas projected into the RGS extraction region, we reduce biases inherent to single-instrument fits. Assuming pressure equilibrium, we find the cool-phase ICM typically contributes $\sim 5\%$ of the total gas mass within 30 kpc, corresponding to 10^8 – 10^{10} $M_{\odot}$, comparable to mass range of molecular gas reservoirs reported for cool-core clusters. The cool-gas mass shows no correlation with 1.4 GHz radio luminosity but a weak anti-correlation with AGN cavity power, consistent with a cumulative feedback effect on gas cooling. Additionally, we find elemental abundance ratios of O, Ne, Mg, Fe consistent with dust depletion of metals in cool-cores.

Einstein Probe's complete view of the stripping of the M86 Virgo subgroup

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The M86 subgroup is plunging into the centre of the Virgo cluster at a velocity of greater than 1550 km/s. It is one of the nearest and best examples of a group being stripped as it merges with a cluster. We present deep new observations of the group taken as part of the Einstein Probe (EP) performance verification programme. With the wide field of view and soft band sensitivity of the FXT telescopes, we map a complete view spanning a degree across of M86 and its neighbouring galaxies. These data show a detailed network of stripped material, as these galaxies interact with the main cluster. Using spatially resolved spectroscopy, we map the thermodynamics of the material around M86 and also map the metallicity of the stripped gas. These data, combined with multiwavelength observations, provide insights into the merging process and how the gas is stripped from the subgroup, and highlight the capabilities of EP for general observatory science.

X-ray Temperature Discrepancies and the Effect on Cluster Mass Estimates

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X-ray telescopes are ideal for measuring temperature and density of the intracluster medium (ICM)—and thus mass—of galaxy clusters. The cluster mass function can be used as a sensitive probe of cosmological parameters, provided the mass can be estimated accurately. However, different X-ray telescopes measure different temperatures. This discrepancy has been present for decades, and is believed to be a calibration issue. Previous work has shown large temperature discrepancies, in hotter clusters especially, between Chandra and XMM-Newton, and NuSTAR temperatures cooler than those from Chandra.

We have measured the temperature profiles of 6 cool-core galaxy clusters in identical regions with Chandra, NuSTAR, and XMM-Newton, and find that, on average, Chandra measures hotter temperatures than both NuSTAR and XMM-Newton in hotter clusters, and temperatures that are more in agreement with NuSTAR and XMM-Newton in cooler clusters. We use these profiles to estimate the hydrostatic cluster mass, and find that the differences in cluster mass are proportional to the differences in temperature on average. We have also compared the Chandra, NuSTAR, XMM-Newton, Suzaku, and XRISM temperatures of the Coma cluster and find that agreement is greatly improved when fits are restricted to the overlapping bandpass of 3 to 9 keV.

Measurement of bulk velocity in the Centaurus cluster adopting new energy scale calibration using the XRISM/Xtend CCD

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Galaxy clusters are significant objects in cosmology. The distribution of hot plasma gas (ICM) throughout the clusters is believed to be important for cluster evolution. The Centaurus cluster is the nearest neighboring cool-core galaxy cluster. It has minimal AGN activity, making it an ideal ICM study target. XRISM/Resolve's excellent energy resolution has revealed the bulk velocity of the ICM in the "Core" of the Centaurus cluster as $v_{\text{bulk}} = -128 \pm 6 \text{ km/s}$ (XRISM Collaboration et al. 2025a). Meanwhile, XRISM/Xtend is the best CCD camera for large-scale ICM velocity measurements, thanks to its ability to take long exposures and its wide field of view. Therefore, we calculated the bulk velocity of the Centaurus cluster from the ICM emission's redshift using energy calibration with the NXB(AuL α) lines of XRISM/Xtend. An attempt was made to enhance energy calibration by utilizing Xtend Night Earth (NTE) and Day Earth (DYE) events. The bulk velocity of the ICM outside the Resolve FOV was measured to within $\pm 120 \text{ km/s}$. This presentation will discuss the velocity structure of the Centaurus cluster's ICM, with a particular focus on the results obtained from Xtend and Resolve.

Low Turbulent Broadening in the Massive Merging Galaxy Cluster Abell 2163

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Abell 2163 is the hottest, most massive low redshift cluster in the universe. It is actively merging in the plane of the sky, with a Bullet-like cool core driving a potentially turbulence-generating shock front ahead of it that has accelerated one of the most powerful radio halos known—a property that should correlate with higher turbulent velocity dispersion. We present a 220 ks XRISM observation of its bright core, containing both the disrupted cool core and ambient post-shock gas within the Resolve FOV, supported by XMM-Newton, NuSTAR, and Chandra archival data. Detailed measurements of the H and He-like Fe lines reveal a lack of significant radial velocities—confirming its plane-of-sky orientation—and a surprisingly low velocity dispersion—corresponding to a non-thermal pressure fraction of only 3%—similar to that found in the center of the Coma cluster. Dividing the Resolve FOV into quadrants, 9 keV and 16 keV components are found with $< 200 \text{ km/s}$ dispersion, with one intermediate temperature region suggestive of high dispersion at $\sim 450 \text{ km/s}$, indicative of turbulent or bulk eddies in that direction. We place these results in the context of the larger-scale merger scenario apparent from XMM-Newton and NuSTAR-revealed dynamics and compare continuum and line-based temperatures across observatories.

X-raying the Redistribution of Baryons in the Universe

Silvano Molendi¹

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Understanding how baryons are redistributed across cosmic structures remains a central challenge in astrophysics. In this talk, I will present recent work combining semi-analytical modeling with key observational constraints to explore processes driving the transition from galaxy groups to clusters.

I argue that this transition can be viewed as a large-scale reorganization of the dominant baryonic component: the hot gas. While this phase is directly observed as the intracluster medium (ICM) in clusters, a significant fraction remains elusive in groups. In these lower-mass systems, a substantial possibly dominant fraction of the gas that ultimately becomes part of the ICM exists in an unvirialized warm-hot phase.

I will show that the stochastic nature of feedback processes, operating mostly near the characteristic mass scale of $10^{13}M_{\odot}$ marking the boundary between galaxies and groups, produces large system-to-system variations in hot gas content. This naturally explains the observed diversity in X-ray properties and affects detectability across wavelengths.

Finally, I will discuss the implication that most of the baryons in the local Universe, although not fully virialized, may already be sufficiently hot to emit in X-rays, provided their metallicity is comparable to that measured in the ICM, as suggested by recently derived constraints.

Revealing kpc-scale bulk motions in a giant elliptical: the deepest XMM-Newton RGS view of NGC 5813

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A key missing piece in our understanding of AGN feedback and the evolution of the largest galaxies is the velocity structure within their hot gaseous halos. In this talk I will present our new results based on the deepest-to-date XMM-Newton RGS observation of a group-central galaxy, the 700ks program on NGC 5813. We use a novel method which utilizes the first and second order grating spectra to disentangle the redshifts of two temperature components present in the gas from their spatial offsets (a systematic that typically limits velocity measurements). We obtain, for the first time, measurements of bulk velocities of multiple gas temperature components in a galaxy halo, opening a new window into gas dynamics and AGN feedback with RGS. Until NewAthena, RGS remains the only instrument with sufficient spectral and spatial resolution to probe hot gas motions on the relevant, kpc scales.

The XRISM view of the core of A2142

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XRISM Resolve is transforming our understanding of galaxy cluster dynamics by providing the first high spectral resolution measurements of gas motions within the Intracluster Medium (ICM). By analyzing the broadening and Doppler shifts of the Fe K α line complex, consistently low turbulent velocities have been found across diverse systems. Whether examining dynamically relaxed Cool Core clusters influenced by AGN feedback (e.g., Perseus) or disturbed Non-Cool Core clusters shaped by mergers (e.g., Coma), results indicate turbulent velocities of only 100-200 km/s. This accounts for a surprisingly small 2-4% of the total thermal pressure. We will report on the AO1 observation obtained through ESA time of the intermediate-state cluster A2142 showing low turbulence levels of 170 +/- 10 km/s. Given its unique state of large-scale sloshing without AGN feedback, A2142 provides a crucial benchmark for determining the nature of turbulent motions across the broader cluster population.

Direct Measurement of Quasar-mode Feedback on Cluster Scales

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Quasars are extremely luminous supermassive black holes powered by rapid mass accretion. They are believed to impact cosmological evolution primarily through energetic winds, known as quasar-mode feedback. However, the efficiency and spatial extent of quasar-mode feedback beyond galactic scales have long been elusive in all wavelengths. Here, we present XRISM observations of quasar-host clusters, offering a rare opportunity to directly prove quasar-mode feedback on the surrounding intracluster medium (ICM). Our analysis reveals exceptionally broadened Fe XXV emission lines, with velocity dispersions significantly exceeding those typically observed in nearby clusters. Spatially resolved spectroscopy with XRISM and Chandra strongly constrains the spatial extent of the broadened Fe XXV emission, indicating that the quasar injects substantial kinetic energy into the ICM beyond galactic scales. The first strong constraints on the energy injection rate and feedback efficiency suggest strong feedback on cluster-core scales, consistent with the latest cosmological simulations. Our finding of the vigorous turbulence, a new tracer of quasar activity, indicating that powerful quasar-mode feedback plays a central role in regulating galaxy and cluster evolution at high redshift (Yamada, Ueda, Noda, Fujita+, under review).

XMM-Newton and Euclid observation of Galaxy Clusters in the Euclid Deep Fornax Field

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As the largest gravitationally bound structures in the Universe, galaxy clusters are powerful probes in constraining cosmological models and physical processes shaping the evolution and growth of these systems. The intracluster medium (ICM) dominates a cluster's baryon content, and its X-ray emission enables precise measurements of ICM properties (such as their temperature, mass and luminosity). However, cluster catalogues selected by the X-ray emission can lead to significant statistical biases on those properties. For instance, at a given mass, X-ray bright clusters are more likely to be included in a sample, producing samples skewed towards higher luminosities. The FornaX project leverages deep XMM-Newton observations covering the 10deg² Euclid Deep Fornax Field to study the populations of clusters selected both in X-ray and optically by Euclid. We apply forced X-ray aperture photometry to measure the luminosities of Euclid-selected clusters, independently of their X-ray emission. This will enable us to investigate the deviations from theoretical scaling relations (such as the correlation between X-ray luminosity and mass), and quantify how X-ray and optical selection effects shape the observed cluster population.

Hot Gas in Normal Galaxies

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Using the Chandra X-ray-selected normal galaxies with multi-wavelength data, we delve into the characteristics of hot gas and its evolution to $z=0.5$ (look back time of 5 Gyr). Incorporating the Chandra Source Catalog v2.1, we have expanded the X-ray-selected normal galaxy sample from the earlier sample in Kim et al. 2023. We also applied an AI-assisted classification scheme to ascertain the likelihood of galaxies being early or late-type. Pursuing the earlier study of the luminosity evolution of hot gas (Kim & Fabbiano 2024), we find that the X-ray luminosity function evolves differently in early and late type galaxies. We discuss the implications of our results.

Kim, D.-W., Cassity, A., Bhatt, B. et al. 2023, ApJS, 268, 17

Kim, D.-W. & Fabbiano, G. 2024, ApJ, 976, 112

The Sloshing Core of Abell 496

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The Abell 496 cluster is a bright, nearby ($z=0.0328$), and hot system. At first glance, it appears to be a regular, undisturbed cluster with a strong cool core (Hudson et al. 2010). However, detailed studies of the core with Chandra and XMM-Newton have identified multiple sloshing cold fronts and a northwest extension that coincides with a region of galaxy overdensity. In XRISM AO1, we were granted a 26-ks observation of A496. Our high-quality Resolve spectrum reveals prominent emission lines, including Fe XXV He α and Fe XXVI Ly α . Spectral fitting yields a gas temperature of 3.24 ± 0.09 keV and a metallicity of $0.67 \pm 0.04 Z_{\text{solar}}$. Remarkably, we find a very small 1D turbulent velocity of 79 ± 17 km/s and a bulk line-of-sight velocity of only -49 km/s relative to the BCG, despite the presence of a central AGN and a clear sloshing pattern. This indicates an unexpectedly quiescent dynamical state in the core, in contrast to the SLOW constrained Universe simulation (Dolag et al. 2023), which predicts a higher 1D velocity dispersion of 150 km/s specifically in this XRISM FoV. This highlights XRISM's potential to reveal subtle gas motions that would be difficult to detect with previous instruments.

Deep Dive into the Dancing Ghosts Cluster

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The recent Evolutionary Map of the Universe pilot survey by the Australian Square Kilometre Array Pathfinder (Norris et al. 2021) and MeerKAT observations of the Abell 3785 cluster (Velović et al. 2023) have revealed intricate details of extended radio emission in the core of the cluster. The complex morphology of this extended radio emission, which has been named the “Dancing Ghosts”, is thought to have originated from the intertwining of radio lobes hosted by two active galactic nuclei (AGNs). These wide-angle tail radio sources are at least 2.2 arcmin offset from the X-ray center and pointing away from each other, indicating their movement relative to the ICM in opposite directions. To assess the ICM morphology and core property of A3785, we constructed an X-ray surface brightness profile out to the R_{500} using the eRASS data and fit a β -model to it. We obtained $\beta = 0.56 \pm 0.16$ and core radius $r_c = 4.89 \pm 1.69$ arcmin. The large r_c (43% of R_{500}) is untypical for a relaxed cluster. The origin of this, either gas expansion by radio bubbles or recent merger activity, is to be determined with deeper XMM-Newton data.

Chemical enrichment in ram-pressure stripped galaxies

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Chemical enrichment studies have shown that the hot gas pervading cluster-member galaxies and galaxy groups exhibits Solar relative abundance ratios, similar to the intracluster medium (ICM). However, in cases where strong ram-pressure stripping is active, this hot atmosphere may be depleted, allowing a new generation of hot gas to be replenished through stellar mass-loss products that show super-Solar abundance ratios. In this study, we present O/Fe, Ne/Fe, Mg/Fe, Si/Fe, and S/Fe ratios as diagnostics to reveal the origin of the hot gas: whether it is the primordial ICM-like gas or replenished stellar material. Using XMM-Newton and Chandra data, we examine and compare the cores of four Virgo Cluster galaxies experiencing ram-pressure stripping and exhibiting varying radio-mechanical AGN activity: M84, M89, and M49 (with AGN); and M86 (without AGN activity).

The Outskirts of A3266: Infalling Groups, Filaments, and a Pre-Merger Cold Front

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The galaxy cluster Abell 3266 is a well-known merging system, embedded in a dense environment of galaxy groups and clusters at a similar redshift. This work investigates the far outskirts of A3266 out to $3R_{100}$, using the *SRG/eROSITA* all-sky survey 1-5. We report the 3.6σ detection of an X-ray emission filament connecting A3266 to its closest neighboring group in the north-west. The group exhibits cool-core properties and is embedded within the filament. The filament temperature is $T = (1.4^{+0.8}_{-0.2})$ keV, its density $n_e = 8^{+1}_{-2} \times 10^{-5} \text{ cm}^{-3}$, and an upper limit on the metallicity of $Z < 0.16 Z_{\odot}$ is derived. Our findings reveal a coherent network of galaxy groups in the outskirts of A3266, tracing the ongoing assembly of the cluster along large-scale structure. The detected filament is hotter and denser than expected for pristine WHIM, consistent with gas that has been processed in the cluster environment and further affected by the infall of the north-west group.

Uncovering the Giants in the Sky - Semantic Segmentation of Galaxy Clusters in Astrophysical Surveys

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We present a deep-learning approach for galaxy cluster detection in X-ray survey data using the eROSITA all-sky survey. A U-Net-based convolutional neural network is trained to perform semantic segmentation of extended galaxy cluster emission. Compared to standard segmentation tasks, this problem poses additional challenges, including Poisson-dominated noise, incomplete and uncertain ground truth labels, diffuse and poorly defined object boundaries, and the need to distinguish clusters from morphologically similar sources such as active galactic nuclei. The model is trained on both real eROSITA observations and mock images to assess robustness against false labels, achieving dice scores of 95% on simulated data and 92% on real survey data. This work forms a basis for leveraging additional multi-wavelength survey data to further improve galaxy cluster detection and classification.

Observations of the Prototypical Cold Front in Abell 3667

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Cold fronts (CFs) in merging clusters provide a direct connection between bulk flows, magnetic draping, and non-thermal emission. We present XRISM/Resolve results for Abell 3667 from three pointings (**CF_IN**, **Center**, **North**). Resolve shows that the CF vicinity is shifted by $\simeq 400 \text{ km, s}^{-1}$ relative to **Center** and reveals a 566 km, s^{-1} line-of-sight velocity jump across the CF boundary. These kinematics support an offset-merger geometry with the rotation within line-of-sight: the cool core rotates/sloshes, producing strong shear at the interface. Chandra/XMM-Newton images show no Kelvin-Helmholtz roll-ups, implying that the instability is suppressed. If magnetic draping stabilizes the interface, the observed shear requires $B \geq 7.2 \pm 2.0 \mu\text{G}$ along the front. We compare the gas motions with the radio emission. The velocity dispersion is $\sigma_v \simeq 420 \text{ km, s}^{-1}$ in the innermost CF region, drops to $\simeq 100 \text{ km, s}^{-1}$ at 200–400 kpc from the CF, and rises to $\simeq 200 \text{ km, s}^{-1}$ at $\simeq 500 \text{ kpc}$, while the GHz radio emission is weak at the CF and brightens into the wake. A comparison with Abell 2319 and Abell 754 suggests a similar downstream offset between gas motions and radio brightening, despite differing merger geometries and substantial line-of-sight complexity across these benchmark systems.

RGS analysis of cool-core galaxy cluster RXCJ 1539.5-8335

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We present an XMM-Newton study of cool-core galaxy cluster RXCJ 1539.5-8335 ($z = 0.076$), previously reported to host a massive reservoir of diffuse molecular gas. Using 60 ks of clean exposure, we analyzed the high-resolution Reflection Grating Spectrometer (RGS) spectrum extracted from the cool-core region to search for cool X-ray emitting gas. We find that, in addition to Galactic hydrogen absorption, modeling with a partially covered intrinsic absorption component at the cluster's redshift improves fitting statistics in various multi-temperature configurations. Using a three-temperature model (including the hot ICM surrounding the cool core), we find intrinsic absorption component's column density of $\sim 3 \times 10^{21} \text{ cm}^{-2}$ and partial covering factor of $\sim 60\%$, which is consistent with molecular gas surface density in literature implied by CO measurements. Similar intrinsic absorption values were also found in a model configuration with truncated cooling flow down to $\sim 0.6 \text{ keV}$ at a rate of $\sim 50 \text{ Msun/yr}$. These results support a scenario in which patchy cold material in the cluster core can make measurable impact on soft X-ray emission of cool cores.

Are the effective iron yields in groups and clusters a real conundrum?

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The distribution of baryons in the extended atmospheres of galaxy groups and clusters (IGrM/ICM) plays a fundamental role in understanding AGN feedback and galaxy evolution. Early on, the effective Fe yield has been introduced as a useful descriptor of the amount of Fe present in the gas and stars of those systems. However, many recent studies indicate that galaxy clusters have significantly larger amounts of Fe in the ICM than it would be physically possible for their stars to produce. As a result the measured Fe yields challenge our understanding of both stellar and AGN physics. In this work, we compare the intrinsic effective Fe yields of groups and clusters from the IllustrisTNG simulation suite and the inferred ones, by analysing mock XMM-Newton observations. Our results indicate that the current tension between observations and expectations arise largely from observational effects. We will also provide key insights on the nature of these biases and how these systematic uncertainties can inflate the inferred amount of Fe in these halos.

Testing AGN Feedback Models using the Mass Content of eRASS1 Galaxy Groups and Clusters

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AGN feedback redistributes and expels gas from the halos, suppresses the matter power spectrum, and influences the formation and evolution of cosmic structures. Owing to their shallower gravitational potential, galaxy groups are more sensitive to the feedback processes than massive clusters.

In this work, we investigate the hot gas mass content of galaxy groups and clusters to constrain the mass dependence of AGN feedback strength. We construct a high-purity eRASS1 sample spanning systems from galaxy groups to massive clusters over a wide redshift range and quantify how baryon depletion varies from groups to clusters. Using the deepest eRASS:5 survey data, we stack X-ray images of thousands of sources and forward model the stacked surface brightness profiles to derive electron density and gas mass fraction profiles from the core to the outskirts.

We compare our measurements with state-of-the-art hydrodynamic simulations to test several well-motivated feedback models. Our results reveal a clear mass dependence, in agreement with recent observational studies, and indicate that gas removal in low-mass halos is more efficient than predicted by some current simulations.

Chapter 9

Future missions

What does the NewAthena Community Office offer to the X-ray Astronomy Community?

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Athena/NewAthena will be the largest X-ray observatory ever constructed. It is designed to investigate the Universe's most energetic and extreme phenomena with unprecedented accuracy and depth. The observatory will provide spatially resolved X-ray spectroscopy and deep, wide-field X-ray spectral imaging, offering capabilities that will far exceed those of existing X-ray observatories.

The NewAthena Community unites more than 1,000 researchers from 309 institutions worldwide. These members are organised into five scientific working groups, guided by the NewAthena Science Study Team, and coordinated by the NewAthena Community Office (ACO), led by the Instituto de Física de Cantabria (CSIC-UC) and in collaboration with IRAP, MPE and Geneva University.

The ACO's responsibilities fall into five main categories:(a)Managing the scientific community, including coordinating calls and keeping members informed about project developments;(b)Supporting the search for synergy between the mission and other astronomical infrastructures operating in the same era; (c)Promoting the mission's science, such as organising monthly seminars and coordinating workshops and conferences;(d)Supporting the design and development of simulations, including open-source software tools;(e)Promoting and supporting open outreach activities.

In this talk, we will present an overview of the main ACO tasks relevant to the X-ray Astronomy Community.

Online Data Analysis Platforms and the Future of X-ray Analysis

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In the past few years both ESA and NASA have dedicated resources towards developing online data analysis platforms to aid astronomers in performing X-ray analysis. Archival datasets in the petabyte scale present unique opportunities and challenges for experienced X-ray astronomers. For new and early career X-ray astronomers one barrier to entry has been the difficulty in installing and updating, along with the various dependencies, the specialized software needed to perform X-ray analysis. To overcome this, online platforms such as Datalabs (ESA), SciServer (Johns Hopkins University/NASA), and Fornax (NASA) have been developed to provide compute containers with the necessary simulation and analysis software pre-installed along with server-side connections to data archives. These compute containers utilize JupyterLab environments along with terminal interfaces to allow users to run code from a command prompt. These online platforms provide essential opportunities for collaborative development of existing and new analysis codes, tutorials, and documentation, along with broadening access and reproducibility for those with limited local resources. These systems are a testbed for the development of the future of X-ray analysis.

The cosmological evolution of normal galaxy X-ray emission up to cosmic noon and beyond with the NewAthena mission

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The NewAthena mission opens a new window to the cosmological evolution of galaxies by allowing the detection of large numbers of normal galaxies even at cosmic noon and beyond. This allows us to accurately measure the evolution of their X-ray luminosity. We will discuss how based on the available multi-wavelength data we can discriminate between AGN and normal galaxies, and measure their metallicity and stellar population parameters (SFR, stellar mass, and in some cases star-formation history). We will discuss the populations of normal galaxies that are expected to be detected in the NewAthena surveys as a function of redshift, and how they can constrain the redshift evolution of their X-ray luminosity scaling relations with SFR, stellar mass and metallicity, and their X-ray luminosity function. Understanding the cosmological evolution of the X-ray emission of galaxies is critical for constraining binary evolution models in higher redshifts (relevant for progenitors of compact object mergers), the contribution of X-ray binaries in the high-energy budget of galaxies as a function of redshift and their impact on providing high energy photons relevant to reionization of the early Universe by preheating the IGM and to potentially powering the high-ionization emission lines observed in high- z galaxies.

The X-ray Universe at ultra-high resolution: simulating the X-ray Interferometric Space Telescope

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While astronomical imaging at most wavelengths operates near the diffraction limit, X-ray telescopes remain orders of magnitude away. By leveraging a compact, single-spacecraft design, X-ray Interferometry (XRI) can achieve an *EHT*-like spatial resolution of tens of microarcseconds. This enormous leap in resolution allows for direct imaging of stellar coronae from tens of parsecs, resolving X-ray binaries throughout our galaxy, and tracing AGN accretion disks and supermassive black hole binaries across the visible universe. We are developing a mission concept to unlock this remarkable potential: *XRIstel*, the X-ray Interferometric Space Telescope. Beyond the development of advanced technologies, which I will briefly describe, realizing an X-ray interferometer necessitates a new type of science simulator that is crucial to develop a detailed science case, set mission requirements, and empower the future XRI community. This new software, which will be publicly released shortly, enables users to generate and analyse X-ray interferometric data for simulated sources conforming to the SIMPUT file format. Here, I will introduce the simulator and present initial case studies for *XRIstel*.

The X-ray Universe at ultra-high resolution: the X-ray Interferometric Space Telescope

Philipp Stoecker¹, Phil Uttley¹, Roland den Hartog²

¹*Anton Pannekoek Institute, University of Amsterdam, Amsterdam, The Netherlands*

²*SRON Space Research Organisation Netherlands, Leiden, The Netherlands*

Current and planned X-ray telescopes have imaging resolutions on the order of arcseconds or worse, which lies above the theoretical diffraction limit by four orders of magnitude. By leveraging a compact, single-spacecraft design, X-ray Interferometry can achieve an *EHT*-like spatial resolution of tens of microarcseconds. This enormous leap in resolution allows for direct imaging of stellar coronae from tens of parsecs, resolving X-ray binaries throughout our galaxy, and tracing AGN accretion disks and supermassive black hole binaries across the visible universe. We are developing a mission concept to unlock this remarkable potential: *XRIstel*, the X-ray Interferometric Space Telescope. With this poster we provide an overview of *XRIstel*, present initial science cases, and showcase enabling technology developments.

probing the potential of NewAthena for demographic studies of the obscured AGN population

Angel Ruiz¹, Antonis Georgakakis¹, Ioannis Georgantopoulos¹

¹*National Observatory of Athens (NOA)*

We will present the results of a study, aiming to investigate the capabilities of a NewAthena/WFI survey to study the demographics of the obscured AGN population up to the epoch of reionization ($z \sim 8$). We generate a mock AGN sample based on an assumed X-ray luminosity and absorption function, and simulate WFI spectra for each source. Spectra corresponding to sources above a given detection probability threshold are analyzed using Bayesian X-ray spectral fitting. The resulting spectral parameters are then used to reconstruct the X-ray luminosity function through both parametric and non-parametric methods. Our methodology enables a quantitative evaluation of how accurately the input luminosity function can be recovered, and to explore the impact of various observational factors —such as survey configuration (area and depth), redshift accuracy (e.g., impact of photometric redshifts), use of complementary infrared data, or contamination from spurious detections—on the final results.

NinjaSat-2: X-ray Monitoring of the Galactic Plane with an 8U Scanning CubeSat

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By around 2028, X-ray monitoring of the densely populated central region of the Galactic plane is expected to become severely limited due to the absence of dedicated missions. NinjaSat-2 is a fully funded 8U CubeSat mission designed to fill this gap, with launch planned for late 2028. NinjaSat-2 will carry two identical gas detectors operating in the 2–50 keV band, equipped with a 0.5 deg x 10 deg crisscross collimator that enables scanning observations of the X-ray sky. By conducting Galactic plane surveys for approximately half of each year, the mission aims to enable systematic monitoring of X-ray binaries, discover and characterize several new X-ray transients annually, and perform rapid follow-up observations of newly detected sources down to mCrab-level sensitivity. In the absence of dedicated missions, NinjaSat-2 will provide unique 2–50 keV X-ray monitoring of the central region of the Galactic plane in the late 2020s. NinjaSat-2 builds upon the flight-proven heritage of the 6U X-ray CubeSat NinjaSat, launched in November 2023 and successfully operated until September 2025. We will present the mission concept and expected performance of NinjaSat-2 based on NinjaSat’s demonstrated achievements.

A Forecast of HUBS Observations of Inter-Cluster Filaments

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Cosmological simulations indicate that a large fraction of baryons in the nearby Universe reside in cosmic filaments as warm-hot intergalactic medium (WHIM). Although soft X-ray excesses associated with filaments have been reported, the physical state of WHIM in individual systems remains poorly constrained because current soft X-ray instruments lack adequate spectral resolution. The Hot Universe Baryon Surveyor (HUBS), with eV-level energy resolution over 0.1–2.0 keV and a 1 square-degree field of view, will enable detailed WHIM spectroscopy and mapping. Using the eRASS1 supercluster catalog, we compiled 1577 inter-cluster filaments and modeled their soft X-ray emission, selecting four as the most promising HUBS targets. Mock observations show that 200 ks per target can recover filament properties with high precision: temperature to 0.01 keV, metallicity to 0.03 solar, and density to better than 10%. Independent measurements of O, Ne, Mg, and Fe abundances will provide new constraints on the chemical enrichment history of filament gas. We also demonstrated that direct mapping of the WHIM distribution is promising with narrowband imaging of the O viii line.

Chapter 10

Theory & Simulations

The Radio-X-ray Correlation of High-Redshift AGN Jets

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In the early universe, Active Galactic Nuclei (AGN) strongly influence galaxy evolution through relativistic jet feedback. At high redshift, inverse compton scattering of the dense Cosmic Microwave Background (CMB) photons by jet-accelerated electrons enhances X-ray emission and accelerating radiative cooling, which in turn modifies radio properties such as low-frequency spectral turnovers and steep spectra.

We investigate these effects using 3D relativistic magnetohydrodynamic simulations performed with the PLUTO code, adopting a hybrid Eulerian–Lagrangian framework, incorporating a newly developed IC/CMB radiation module to examine the effects of varying CMB radiation density with redshift.

We find that the radio emission decreases weakly with redshift, while the X-ray emission initially declines and then increases rapidly at high redshift, following the expected $(1+z)^4$ scaling. This behavior indicates that the X-ray enhancement of high-redshift AGN jets is dominated by the IC/CMB process. Both X-ray and radio emission also depend strongly on jet propagation timescales and ambient density. In addition, the radio spectral index shows a strong redshift dependence, with jets exhibiting progressively steeper radio spectra toward high redshift. Overall, this work provides a unified simulation-based framework for interpreting the radiative signatures of AGN jet feedback across cosmic time.

From Sky to Detector: XMM-Newton Simulations with SIXTE

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The SIXTE simulator provides realistic end-to-end simulations of X-ray detectors required by current and next-generation missions, supporting mission design, calibration, and data analysis validation. SIXTE is based on a Monte Carlo approach that propagates single photons through the instrument (including interactions such as pile-up), starting from astrophysical source models described via SIMPUT. Telescope optics and mirror effects are simulated using either PSF-based models or ray tracing (with support for Wolter and Lobster-Eye telescopes), enabling the assessment of non-ideal optical behaviour as part of instrument validation prior to the application of detector-specific effects. With its modular, instrument-agnostic approach, SIXTE can be easily modified for different detector physics. Its focus on realistic detector effects helps close the gap between astrophysical source models and detector-level data products, supporting ground segment and instrument development. In this talk, we will present the newly added XMM-Newton EPIC instrument support and the inclusion of bad pixel effects, and demonstrate how it can be used to improve the modelling of NewAthena’s WFI instrument. We will further demonstrate the scientific outlook of SIXTE through simulations of galaxy cluster emissions, showcasing its applicability for high-energy research.

Improving Transient Identification With Swift-XRT

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The Living Swift-XRT Point Source Catalogue (LSXPS) is a unique facility: it is updated in near real-time, enabling a sensitive, “live” search for new high-energy transients. This opens a new region of transient phase space for exploration, as demonstrated by the LSXPS discovery of the enigmatic event Swift J0230. However, most transient candidates detected are faint and classified as “low significance.” Determining which of these are truly transient—especially near the XRT detection limit, where Eddington bias systematically inflates the apparent brightness of faint sources—remains a major challenge.

We present a simulation-based approach that yields confidence intervals on source flux, corrected for Eddington bias and accounting for the increasing number density of sources at lower fluxes. This enables more reliable identification of genuine transients and rejection of those whose apparent flux enhancement is purely statistical.

Applying our bias-corrected Bayesian framework to LSXPS data, we recover more than 500 transients above the historical 3σ upper limit—an eight-fold increase over the original 64 confirmed events. Our approach therefore substantially boosts the yield and reliability of real-time Swift-XRT transient detection. This technique will soon be integrated into LSXPS’s real-time analysis, enhancing detection rates and advancing high-energy transient astronomy in the TDAMM era.

Hot Off The Stacks: Physical Drivers of Simulated X-ray Brightness in Romulus25

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In this talk, I will discuss the physical drivers of X-ray surface brightness and total luminosity in the circumgalactic medium (CGM) of simulated galaxies. Using a sample of 600 galaxies from the smooth particle hydrodynamic cosmological volume, Romulus25, we explore the multi-phase properties of the CGM in galaxies across stellar masses from $\log M_* = 10 - 11.5$. We compare surface brightness measurements from our simulated galaxies to surface brightness profile stacks from the eRosita X-ray instrument on the SRG mission. Furthermore, we compare total luminosity, $L_{X,CGM}$, measurements from each of our galaxies to measurements from the eRosita and ROSAT all-sky surveys. Our study connects the impact of feedback energy to X-ray brightness in the CGM of local galaxies and characterizes the physics impacting measurements of X-rays in the soft band.

A Benchmark Study of Line-Driven Winds Based on 3D Hydrodynamics and Monte Carlo Radiative Transfer in the Era of High-Resolution X-ray Spectroscopy

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Line-driven winds are a common acceleration mechanism in the universe. The line-driven force must account for the effects of X-ray radiation fields in optically-thick photoionized plasmas, which are common in Active Galactic Nuclei (AGNs) and X-ray binaries, but current treatments remain insufficient. To investigate this, we present a benchmark study coupling hydrodynamics with radiative transfer, focusing on the high-mass X-ray Binary (HMXB) Cen X-3. We analyzed data covering an entire orbit of Cen X-3 obtained with the XRISM/Resolve instrument, which provided velocity-resolved high-resolution X-ray spectra. We performed 3D hydrodynamic (HD) simulations incorporating gravity, orbital forces, and radiative processes. The line-driven force in these HD simulations is based on Monte Carlo Radiative Transfer (MCRT) simulations with SKIRT in optically-thick photoionized plasmas. Using the density and velocity fields from the HD results, we synthesized orbital-phase-dependent X-ray spectra via MCRT simulations with SKIRT. In this presentation, we will report on the comparison between the observed and simulated line profiles.

Fe K α equivalent-width mapping with 3D radiative transfer calculation for the microcalorimeter era

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The Fe K α fluorescence line at 6.4 keV is a widely used geometric diagnostic in systems where an X-ray source photoionizes surrounding cold material. With the advent of X-ray microcalorimeter XRISM/Resolve, Fe K α lines with equivalent widths down to ~ 5 eV are now detectable, and even non-detections provide upper limits of a few eV, making non-detections themselves valuable for constraining the geometry. Motivated by this new microcalorimeter era, we present Fe K α equivalent-width maps computed with the three-dimensional Monte Carlo radiative-transfer code SKIRT for a generalized configuration: a spherical reflector of radius R_* and a point source located at height h above the surface. The maps show two characteristic behaviors: (1) an increase toward the disk center within the limb and (2) an overall decrease with increasing h/R_* . As an application, we compare these maps with XRISM/Resolve spectra of three RS CVn-type stars (GT Mus, σ Gem, and HR 1099) and constrain the locations of coronal X-ray sources. Owing to the generalized point-source–spherical-reflector setup, the maps are readily applicable to other objects, including X-ray binaries and cataclysmic variables.

The effectively optically thin accretion flow and its potential applications

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Black holes in active galactic nuclei (AGNs), tidal disruption events (TDEs) and X-ray binaries (XRBs) are observed in a wide range of Eddington ratio. Aiming at a general description of various accretion flows, we present generalized equations, where the entropy advection, the radiation pressure, and the photon trapping effect are all included self-consistently. Based on this generalized solution, we found a long-ignored solution—the effectively optically thin accretion flow. It mainly occurs in supermassive black holes for accretion rates around the Eddington value, bridging the standard thin disk at low accretion rates and the slim disk at high rates, where the radiation-pressure puffs up the inner disk, suppressing the density, bremsstrahlung and its self-absorption. The gas is heated to sufficiently high temperatures so that Comptonization plays a role in cooling. This effectively optically thin region is thermally stable and is characterized by moderate temperature and large scattering optical depth, producing a multicolour Wien spectrum. It could provide an alternative origin of soft X-ray excess in AGNs. Our results show that the Wien spectrum is sensitive to the viscosity parameter. We also discussed constraining the viscosity parameter in AGNs, TDEs and XRBs by comparing the predictions and observed spectra.

The effects of multipolar magnetic fields on magnetar activity

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Magnetars are isolated neutron stars hosting the strongest magnetic fields known in the Universe. Several lines of evidence indicate that these fields are far more complex than the dipole that is measurable through spin-down, but exhibit multipolar, tangled structures that shape their observable properties. On long timescales, magnetic energy dissipation heats the crust anisotropically through coupled magneto-thermal evolution, sustaining high thermal X-ray luminosities. On shorter timescales, magnetic field reconfiguration drives a rich phenomenology of bursts and outbursts. Understanding magnetars therefore requires modelling not only the field strength, but also its topology. I will present a set of three-dimensional coupled magneto-thermal simulations with complex magnetic geometries and follow their impact on surface temperature anisotropies and emergent X-ray spectra, assessing the observables with realistic instrumental responses. I will further show that magnetic stresses build up in a strongly non-uniform manner within the crust, concentrating within regions determined by the field structure. This leads to the crust failing preferentially in these topologically selected zones, triggering fractures whose location, recurrence, and energetics are set by the evolving field structure, linking the internal magnetic complexity to the observed transient activity.

Viscous or Turbulent? The XRISM Puzzle of Coma

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The evolution of galaxy clusters is strongly shaped by the physics of the intracluster medium (ICM), where processes such as turbulence, mixing, and galaxy-ICM interactions drive much of the cluster's dynamical state. One key ingredient in this picture is viscosity, which regulates how efficiently turbulence cascades, how density fluctuations develop, and how magnetic fields evolve. Yet, despite its importance, the level of viscosity in the ICM remains uncertain.

In this talk, I will present results from high-resolution cosmological simulations that explicitly include viscosity, with a particular focus on the Coma cluster. I will show how viscosity affects the cluster morphology, turbulence, and ICM fluctuations compared to inviscid cases, and discuss how these signatures can be connected to observations. I will explore how simulations can help us interpret these results and provide indirect constraints on the effective viscosity of the ICM, particularly comparing with Coma observations. This study is expected to enhance our understanding of ICM dynamics and contribute to our knowledge of galaxy cluster evolution.

Detection of warm-hot intergalactic absorbers in EAGLE through X-IFU observations of GRB afterglows and blazars

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The NewAthena mission aims to detect and characterise the warm-hot intergalactic medium (WHIM), which is predicted to contain the missing baryonic content in the local Universe. Here we present the findings of end-to-end advanced simulations of X-ray absorption features (CV, CVII, NVI, NVII, OVII, OVIII, NeXI, FeXVII) from the WHIM using the EAGLE cosmological simulation suite and the SIXTE framework for all simulated observations. We consider both Gamma-ray Burst (GRB) afterglows and Blazars as candidates to provide a background X-ray beacon to study these ions in absorption. For target of opportunity observations of GRB afterglows, we assume an observation beginning 11 hours after the initial burst, and utilise randomly selected spectral and temporal parameters from the Swift sample to model their decaying nature. In the case of Blazars, we defined a sample based on their sky location, to minimise the effect that galactic absorption can have on our ability to detect these absorption lines, and their observational properties. This allows us to quantify how the various blazar states (flaring, quiescence, hard, soft) can influence the ability of NewAthena to probe the WHIM.

Bridging simulations and observations: advancing X-ray reflection models with GRMHD

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X-ray reflection spectroscopy has developed as one of the leading techniques to infer the properties of black holes and accreting material. However, the data analysis models used for measurement rely on theoretical assumptions based on simplified analytical prescriptions. General relativistic magnetohydrodynamic (GRMHD) simulations provide a more realistic picture of the accretion process arising from first principles. We use GRMHD simulations to model the X-ray reflection emissions from accreting black hole systems. These simulated spectra are then used to test the capability of current models in recovering the input parameters given an instrument response. This reveals the underlying systematic uncertainties in the models as well as highlight the need to upgrade the models with richer physics as we anticipate for advanced observatories.

TIME to Study Mass Transfer: the New 3D Horizon for Binary Evolution

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X-ray binaries are often only detectable through their X-ray output. However, this luminosity is the end result of interdependent feedback processes spanning the entire binary system. Only by tackling system dynamics across evolutionary timescales can we truly understand the sources that power the X-ray universe.

In this talk, I will describe my novel approach to track mass transfer hydrodynamics across system evolution. All system regimes are collectively evolved through the new method of Time-Incremented Multiscale Evolution (TIME), achieving variable time resolution by looped feedback between 3D hydrodynamics and 1D binary evolution codes.

This model is capable of translating a 1D profile accounting for tidal deformations into a 3D stellar envelope while retaining hydrostatic equilibrium. It is now possible to model long evolutionary timescales while fitting 3D sub-orbital timescale dynamics, in a new milestone for stellar evolution.

I conclude that the wind Roche lobe overflow mode can persist at higher filling factors than previously thought ($f > 1$). On the opposite end, I identify binary mass transfer more than 10% overflowing ($f > 1.1$) to be necessarily brief (< 100 years).

Finally, I will plot the course for future developments in binary models towards high-resolution 3D models of nuclear-timescale mass transfer in the next few years.

Modeling XMM-Newton and eROSITA photon pile-up with a normalizing flow

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The dynamic range of imaging detectors flown on-board X-ray observatories often only covers a limited flux range of extrasolar X-ray sources. The analysis of bright X-ray sources is complicated by so-called pile-up, which results from high incident photon flux. This nonlinear effect distorts the measured spectrum, resulting in biases in the inferred physical parameters, and can even lead to a complete signal loss in extreme cases. Pile-up affects a non negligible fraction of detections in XMM-Newton and eROSITA observations. For photometric, spectroscopic, and time-domain analysis, piled-up data are commonly discarded due to resulting intractability of the likelihood. As a result, a large number of archival observations remain under explored. We present a machine learning solution to this problem, using a simulation-based inference framework that allows us to estimate posterior distributions of physical source parameters from piled-up XMM-Newton and eROSITA data. We show that a normalizing flow produces better-constrained posterior densities for the spectral fit parameters over a range of canonical spectral models, compared to traditional mitigation techniques, as more data can be leveraged. We consider model- and calibration-dependent uncertainties and apply the method to archival XMM-Newton catalog detections, demonstrating improvement in the determination of their spectral parameters.

Exploring Viscosity Effects in Accretion Disk Simulations: A Code Comparison Between FLASH and Athena

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Accretion disks around black holes power many X-ray-emitting systems, including active galactic nuclei, X-ray binaries, and tidal disruption events. Interpreting X-ray observations of these sources relies on numerical models of disk evolution, in which angular momentum transport is commonly described using an effective viscosity prescription. However, different hydrodynamical simulation codes implement viscous processes using distinct numerical schemes, raising questions about the robustness of simulated accretion behaviour. We investigate the impact of viscosity on black hole accretion disk evolution through a systematic code comparison between the FLASH and Athena frameworks. By varying the viscosity parameter while keeping the physical setup otherwise identical, we isolate its influence on global disk properties. We focus on the time evolution of the mass accretion rate, a key quantity linking simulations to observable X-ray luminosity. Across a range of viscosity values, we find near-identical temporal behaviour of the accretion rate in both codes, indicating strong agreement despite differences in numerical implementation. These results suggest that, for the configurations studied, viscous disk evolution relevant to X-ray-emitting accretion flows is robust across codes. We discuss implications for modelling X-ray sources and highlight the importance of extending code-comparison studies to include additional physics such as magnetohydrodynamics and radiative processes.

Optimizing eRASS source detection for XDINS: towards a new eROSITA soft X-ray catalog

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The Magnificent Seven (M7) are X-ray dim isolated neutron stars (XDINS) known for their soft blackbody-like spectra without signs of non-thermal emission, and with X-ray-to-optical flux ratios in excess of 10^3 . Discovered with ROSAT, they were classified as rather nearby (within 1 kpc) neutron stars powered predominantly by cooling. Compared to ROSAT, eROSITA onboard the “Spectrum-Roentgen-Gamma” (SRG) mission provides a much improved sensitivity, better spatial and spectral resolution which have boosted the number of detected X-ray sources by a factor of ~ 25 compared to ROSAT. The current source detection scheme for eRASS in the 0.2–2.3 keV band is optimized to detect mildly hard X-ray sources as completely as possible and with least possible contamination of spurious sources. It misses, however, extremely soft sources. The new approach presented here is based on extensive X-ray simulations, aimed at optimizing the energy bands for detecting XDINS sources and other (super-) soft sources. The eRASS data is reprocessed using these optimised energy bands to develop a new catalog of eROSITA soft sources that have so far been undetected in the standard processing. Various source classes will benefit from the super-soft catalog: XDINS, white dwarfs, cataclysmic variables, and NLS1 AGN.

Chapter 11

Calibration & Operations

Introducing The SHell misAlignment Detection for straylight Estimation (SHADE) algorithm: the case of XMM-Newton

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When performing X-ray observations with a Wolter-I telescope, the presence of bright off-axis sources can introduce unfocused rays, known as straylight, which contaminate the detector and compromise the scientific analysis. Among the different components of straylight, single reflections off the hyperboloid section of the mirror shells often produce arc-like patterns on the detector. These arcs depend not only on the off-axis angle of the source but also on the geometrical alignment of the individual shells. We introduced the SHell misAlignment Detection for straylight Estimation (SHADE) algorithm, a novel and flexible tool designed to infer the misalignment parameters of individual shells, reproduce the geometry of straylight arcs and predict its pattern on the detector. SHADE allows us to model each shell displacement with two parameters: (γ, ξ) that represents the tilt amplitude and direction. While the algorithm is general and applicable to any Wolter-like telescope, we demonstrate its effectiveness using a set of XMM-Newton observations. As a proof of concept, we recover the best-fit misalignment parameters for a selected shell, obtaining a direct measure for these parameters.. SHADE represents a new approach to diagnosing mirror misalignments from straylight patterns and can support both pre and post-launch calibration efforts and future telescope designs.

XMM-Newton: more than 26 years in space and counting, how to get ready for the next decade.

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XMM-Newton was launched on 10th December 1999 as part of ESA’s Horizon 2000 program, with the purpose of observing the hot X-ray universe, including objects such as neutron stars, black holes, and active galaxies. The original design anticipated a maximum operational lifetime of 10 years, but after 26 years the spacecraft is still providing excellent scientific results. The flight control team continues to monitor potential life-limiting factors and strives to find solutions to extend the satellite’s life as much as possible. This talk will cover all the methods that have been applied to counteract one of the major limiting factors: fuel availability. It will first introduce the principle by which XMM began using four reaction wheels to maintain stable pointing, rather than three, and how this results in reduced fuel consumption. Then, it will explain the concept of fuel migration and the onboard automatic safe mode avoidance strategy. It will give a brief overview of the new safe mode concept, based on reaction wheels rather than propellant and the Z-flip method may be proposed to continue performing scientific observations even after the fuel is exhausted. The final purpose is to provide to the community many more years of XMM-Newton data.

Overview of the XRISM/Xtend Transient Search

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X-Ray Imaging and Spectroscopy Mission (XRISM) carries two X-ray telescope systems: Resolve, the soft X-ray spectrometer, and Xtend, the soft X-ray imager. The latter has one of the largest field-of-view (FOV) of 38.5 square arcmin among pointing X-ray satellites. To maximize the scientific value of Xtend, we promote an extended activity in the science operation, the XRISM/Xtend Transient Search (XTS). XTS searches for X-ray transients within the Xtend FOV and reports them to the world to encourage multi-wavelength follow-up observations. The search is performed every day for the quick-look data as soon as possible after the data downlink. Automatic analysis is performed for each detected source: timing analysis, catalogue collation, spectral fitting, and flux measurement. Once a transient source is verified and confirmed to be worth reporting, XTS team members report it on the Astronomer’s telegram. XTS started in March 2024 and reported 55 transients (ATels) by February 2026, which consist of stellar/protostellar flares (dominant), outbursts of X-ray binaries, transients of AGNs, and a GRB candidate. In this presentation, we report on the overview of XTS, current results, and development of the follow-up observation networks.

Calibration observations of RXJ1856 with eROSITA and other X-ray observatories

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The isolated neutron star RXJ1856.6-3754, the closest and brightest member of the “Magnificent Seven” (M7), has been used as a standard candle for spectral calibration for major X-ray missions. Due to its featureless and stable thermal spectrum, this source has been observed regularly as a calibration target by several X-ray instruments, resulting in a large set of data, spanning over 20 years. High quality spectral data from both grating and CCD based instruments, as well as coordinated simultaneous observations, make this source an ideal target for cross-calibration across instruments and missions. We present a detailed spectroscopic analysis of the three deep eROSITA performance verification observations totaling 200 ks of net exposure. The new eROSITA data are examined in the context of the long-term archival record from major X-ray observatories. We additionally analyze a set of coordinated simultaneous observations obtained in 2019 with three different observatories: eROSITA, Chandra, and XMM-Newton. As part of the broader cross-calibration effort, simultaneous eROSITA and XMM-Newton observations of 1RXS J072025.1-312554 and PSR B0656+14 are also analysed. Using this multi-mission dataset, we assess both the cross-calibration consistency among current X-ray instruments and the continued suitability of RXJ1856.6-3754 as a calibration standard

The second eROSITA Data Release: A Catalogue from the first three All-Sky Surveys

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The German eROSITA collaboration presents the second SRG/eROSITA data release (DR2) from the first 18 months of all-sky observations. The data release comprises catalogues derived from the first three eROSITA all-sky surveys (eRASS:3) and covers the galactic Western Hemisphere, where the data rights lie with the German eROSITA consortium. We release a main catalogue in the 0.2-2.3 keV band and a hard catalogue in the 2.3-5 keV band. With more than 1.9 million detections, the main catalogue is about twice as deep as the eROSITA DR1 catalogue from the first all-sky survey. The hard catalogue contains 16000 detections. The data release also comprises catalogues of counterparts in the near-infrared and optical bands from Bayesian cross-matching, including machine-learning classifications and photometric redshifts for the X-ray point source content of the eROSITA catalogues. More than 300 000 spectra of AGN candidates, cluster galaxies, and galactic sources have been taken by SDSS-V in an effort to classify sources from eRASS:3.

Cross-Calibration of XRISM Xtend and Resolve with NuSTAR: Effects on Temperature Measurements in Abell 2029

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Galaxy clusters are the most massive structures held together by gravity in the Universe, and their evolution over cosmic time provides a powerful probe of cosmology. Reliable cosmological measurements from clusters require precise mass estimates, which in turn depend on accurate X-ray temperature measurements. However, systematic differences between X-ray observatories in their measured temperatures pose a significant challenge for precise cluster cosmology studies. In this work, we investigate the temperature structure of the galaxy cluster Abell 2029, focusing on calibration differences between XRISM/Xtend, XRISM/Resolve, and NuSTAR, and we present possible strategies to mitigate them. We extract spectra from identical regions of the cluster and analyze them using a uniform procedure across all instruments, enabling direct comparisons of temperatures and fluxes while isolating the impact of instrumental differences. In particular, we find an excess of approximately 20% below 3 keV in the Resolve on-axis observations relative to Xtend, highlighting instrument-specific calibration characteristics. By quantifying the impact of such calibration differences on the derived properties of the intracluster gas, we aim to improve the robustness of multi-instrument analyses and provide a methodological framework for future joint studies of galaxy clusters.

Introducing the new XMM Science Archive — Getting ready for 20 more years of operations

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The XMM Science Archive, XSA, is at the core of the XMM-Newton mission because it provides near-real time access to the data. XMM has been in orbit since 1999 and the XSA was built and maintained with technologies that were available. To prepare for another 20 years of operations, we have rebuilt from scratch the frontend using modern technologies shared across the newest science archives maintained by the ESDC at ESAC. In this talk we will give a sneak preview of this new version of the XSA planned for release in late 2026.

The SRG/eROSITA upper limits of the Galactic Western hemisphere

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We implemented the first half-sky SRG/eROSITA upper limit database to provide X-ray photometric data and flux upper limit to every position in the Western Galactic hemisphere. The eROSITA flux upper limits can be crucial for understanding the physical and statistical properties of variable objects, transients, and even large numbers of sources detected at wavelengths other than X-rays. I will describe the process for retrieving SRG/eROSITA upper limits, the eROSITA data required for the calculation, the X-ray aperture photometry procedure, the upper limit calculation via a Bayesian approach, and the final data products. I will also highlight the legacy value of future eROSITA data releases and the corresponding upper limits.

Spectrum-based source detection for XMM-Newton and beyond

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Source detection in EPIC images from XMM-Newton uses a maximum-likelihood fit and Cash statistics. It simultaneously fits source position, extent, and the counts under the point-spread function in each energy-resolved image. The method has performed reliably on meanwhile more than 14,000 pointed observations with XMM-Newton. When stacking many overlapping observations, though, it becomes mathematically constrained in the low-count regime: The degrees of freedom scale with the number of observations, limiting the detection sensitivity. To become even more sensitive towards faint sources, we have introduced a spectrum-based PSF-fitting approach, in which source position, extent and spectrum are fitted, independently of the number of observations involved. The talk will outline the power of this approach, its validation both on real and artificial EPIC data, and its application in the newest XMM-Newton Serendipitous Source Catalogue, 5XMM-DR15.

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