'Accretion and Outflows Across the Spectrum (AccrOutflo)' Abstracts

Talks

Unmasking r-process Signatures in Hyper-accreting Black Hole Outflows

Authors

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Abstract

Hyper-accreting black holes in super-collapsars represent some of the most extreme accretion environments in the universe. While neutron star mergers are confirmed nucleosynthetic sites, the "missing gold" problem suggests that these massive black hole accretion disks may be prolific r-process element factories. These engines launch massive, stratified outflows consisting of an inner radioactive Ni-56 core shrouded by immense layers of r-process material. To date, the characteristic light curve signatures of these outflows remain largely unmodelled. In this work, we employ a high-resolution N-shell radiative diffusion model to resolve the stratified layers of the ejecta. We show that capturing the signature of the innermost regions critically depends on numerical resolution, by using $N > 500$ shells, we reveal hidden features within the outflow. Through a survey of 1,000 synthetic light curves, we define the specific parameter space under which signatures from the innermost regions become observable. While these transients are likely to be rare, our modelling provides a framework for identifying them. We find that approximately 30% of our sampled population exhibits a distinct double-peaked light curve, providing a new template for identifying super-collapsar candidates. I will discuss how our N-shell radiative diffusion model offers a vital tool for interpreting upcoming high-cadence surveys, such as the Vera Rubin Observatory, and highlight how high-resolution modelling can peel back the layers of these massive radioactive outflows.

Nuclear energy generation in super-Eddington neutron star accretion disks drives disk dynamics and titanium-44 production

Authors

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Abstract

During common envelope evolution between a neutron star and a companion star, the neutron star can accrete material from the companion's stellar envelope at super-Eddington accretion rates. The accreting material has angular momentum and so hangs up in an accretion disk. The dynamics of the accretion disk allow for significant nuclear energy generation through fusion of hydrogen and helium. In extreme scenarios, the accretion disk can become a nuclear dominated accretion flow (NuDAF). In a NuDAF, nuclear energy can drive increased outflows at the radius in the disk where nuclear energy is generated while preventing material from moving further inwards on the accretion disk.

Through nuclear post processing of semianalytical trajectories from an α-disk model, we find scenarios in which the neutron star accretion disk can become nuclear energy dominated. This occurs at outer regions of the disk. The composition of the outflow can be enriched in 44Ti created in the outer regions of the neutron star accretion disk but deficient in 56Ni which would be created in the inner parts of the disk not accessed due to the increased outflow. At the end of the common envelope phase, this 44Ti can be ejected into the interstellar medium.

We will discuss scenarios in which our semianalytical models of the neutron star disk become nuclear energy dominated. We will discuss outflow compositions from sections of the accretion disk in which outflows may be significant due to nuclear energy generation. We will present hypothetical lightcurves and potential gamma-ray line profiles from a neutron star common envelope given this 44Ti enrichment. We will place these results into the context of common envelope evolution: discussing the neutron star common envelope scenarios in which NuDAFs may appear and how the binary population synthesis model STARTRACK informs the potential occurrence of NuDAF disks.

Dynamic shocks powered by a wide relativistic outflow from an accreting neutron star

Authors

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Abstract

X-ray binary systems can launch powerful outflows which create observable parsec scale structures where they interact with and deposit energy in the surrounding medium. Measuring these large scale structures at radio and other wavelengths allows them to be used to measure physical properties of the outflows and the surrounding medium, and in particular they serve as accurate calorimeters. Only a handful of X-ray binary systems have associated large scale structures and all are consistent with being formed by collimated jet-like outflows over timescales of 1000s of years. We present new MeerKAT radio observations of the only neutron star X-ray binary with associated large scale structure, Circinus X-1. When combined with archival radio observations going back over 2 decades we discover decelerating dynamic relativistic shocks in the system which show proper motion and morphological evolution over time. We show these shocks are likely powered by a hidden wide-angle conical relativistic (> 0.3c) outflow launched in the mid-20th century, in stark contrast to other structures around X-ray binaries. Using the shocks we are able to constrain the powering outflow to be significantly super-Eddington. Furthermore, the high linear polarisation of the shocks reveals the presence of an ordered magnetic field, and we show that these structures are potential PeVatrons, capable of accelerating electrons and protons to PeV scale energies. In light of this, and the recent detection of very high energy gamma ray emission from some X-ray binaries, we predict that the next generation of gamma-ray facilities may be able to detect hadronic signatures from the dynamic shocks of Cir X-1.

Epic Fail! A Multi-Wavelength Summary of the Surprisingly Short 2024/25 Outburst from EXO 0748-676

Authors

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Abstract

After sixteen years in quiescence, EXO 0748-676 unexpectedly signalled its return to outburst in June 2024 with a bright X-ray burst, having been increasing in brightness since March 2024. However, in stark contrast to its previous outburst (1985 - 2008), EXO 0748-676 returned to quiescence in January 2025, after only ~10 months in outburst. In this talk, I will present a multi-wavelength summary of this surprisingly short outburst, utilising data from eleven detectors, covering wavelengths from radio to X-ray. Unlike the 1985 outburst, both the rise and decay are fully captured at X-ray and optical wavelengths. The outburst light curve does not exhibit the hallmarks of a typical transient low-mass X-ray binary outburst, and the short outburst duration creates additional tension with EXO 0748-676's previous `persistent' classification. Our optical monitoring reveals a skewed optical phase curve, peaking at ~0.7 and a cooling phase dominated by an inside-out recession of the ionised disc, where the inner thermal regions fade first, and the outer disc area remains constant. X-ray observations by XMM-Newton and NICER from June 2024 revealed that EXO 0748-676 was heavily obscured, with measured 0.5- 10 keV count rates around a factor of 10 lower than those measured from the 1985 outburst. A spectral model that includes a clumpy, high-density absorber can describe the strong obscuration, consistent with the false widow sub-classification of EXO 0748-676. The X-ray colours show that EXO 0748-676 spent a large portion of the ~10 month outburst in a faint, hard state. EXO 0748-676 increased marginally in brightness towards the end of the outburst, but never entered a soft spectral state. This behaviour is strongly indicative of a failed outburst, a reflare or the onset of a transitional evolutionary phase.

Illuminating the disc and corona: geometric models of the unobscured X-ray binary MAXI J1348-630

Authors

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Abstract

The geometry of the corona in active galactic nuclei and X-ray binaries remains an unanswered question. Recent polarimetry studies have pointed strongly towards an extended corona parallel to the accretion disk. The exact shape however remains unknown even from current polarimetry capabilities. The X-ray binary MAXI J1348-630 presents an ideal test case for what observable effect different geometries may have on X-ray spectra as it has an almost unobscured view to the inner regions of its black hole. We will present several models of coronal geometry fitted to observations of MAXI J1348-630 using NuSTAR. These models use disc emissivity, line profiles and corresponding reflection spectra generated by the relativistic raytracing software Gradus.jl. These models can be used to explore the degeneracies between the different corona models and how future observations could help break these degeneracies.

Long-term evolution of the helium nova V445 Puppis and the emergence of the underlying binary

Authors

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Abstract

Novae are among the most explosive outcomes of accretion in compact binaries, and are the result of runaway hydrogen burning on the surface of white dwarfs. An important exception is the class of helium novae, where it is hydrogen-poor material that is instead accreted. These events remain poorly understood, despite being a potential channel for compact binary evolution to Type Ia supernovae. As such, V445 Puppis is a fascinating object: it is the only Galactic helium nova observed to date and is surrounded by an expanding bipolar outflow with an equatorial dust disc. Whilst the evolving ejecta have provided important insights, including an expansion parallax, the dust has hampered efforts to characterise the underlying binary and thus test the viability of the helium nova pathway to Type Ia supernovae. Recent observations, decades after the nova eruption, indicate that the obscuration is lifting, making this an opportune moment to revisit this system. I present previously unpublished NACO and HST imaging of the bipolar shell. These reveal an oxygen-rich outflow and provide conclusive evidence that the central binary is re-emerging. These findings are corroborated by long-term spectral monitoring of V445 Puppis using SALT. Additionally, the spectra confirm the total absence of hydrogen and reveal strong He emission lines. These lines, HeII in particular, suggest that V445 Puppis is now in an active accretion state. Furthermore, photometry from TESS and other sources imply an orbital period of 3.7 days instead of the advocated 1.87 day period. Modelling of the light curve folded on this period supports the scenario of a Roche-lobe filling He-star feeding a hot white dwarf. I discuss these results in the wider context of compact binary evolution along hydrogen-poor accretion pathways.

Pulsed X-rays from the ultra-massive magnetic white dwarf merger remnant ZTF J1901+1458

Authors

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Abstract

Double-degenerate white-dwarf merger remnants can host extreme magnetic fields and minute spin periods, but their high-energy emission remains poorly characterised. ZTF J1901+1458 is an ultra-massive (1.3 Msun), rapidly rotating (6.94 min), highly magnetised (>800MG), and isolated white-dwarf merger remnant whose recently discovered X-ray emission offers a rare window into this problem. I will present a joint timing and spectral analysis of Chandra/ACIS-I and new XMM-Newton/EPIC observations, placed in the context of the source's multiwavelength light curve. Our re-analysis of the Chandra data strengthens the detection and is independently confirmed by XMM. The source has an X-ray luminosity of about 1.3 × 10^27 erg s^-1 and a soft spectrum well described by a steep power law (Gamma=2.9). Using newly developed magnetic atmosphere models together with HST UV spectroscopy and optical/IR constraints, we show that the white-dwarf photosphere is too cool (Teff=27500 K) to account for the observed X-rays, while the infrared data rule out a stellar or brown-dwarf companion as the power source. The X-ray light curve is strongly modulated on the spin period, directly linking the high-energy emission to the star and its immediate environment. I will discuss possible origins, including weak accretion of fallback or planetary debris and magnetospheric interaction with circumstellar material, and argue that J1901 may define a new class of magnetic white-dwarf merger remnants.

Simulating the Plunging Region: Testing Analytic Models and the Spin-Stress Relation

Authors

Jake Rule (1)

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Abstract

Robust measurements of black hole spins across the mass spectrum provide important insights into their growth and formation at a population level. In black hole X-ray binaries, continuum fitting measurements rely on accurate modelling of the soft state accretion disc. The plunging region between the ISCO and the event horizon is commonly neglected in such models, which impose a vanishing-stress boundary condition at the ISCO, sharply truncating the thermodynamic profiles. However, GRMHD simulations consistently find a non-zero ISCO stress, as well as rich plunging region thermodynamics. Including the plunging fluid and setting a finite ISCO stress are critical for accurately estimating the spin: a low-spin black hole with a non-zero ISCO stress may be mistaken for a rapidly spinning black hole with no emission from the plunging region. This can produce the apparent tension between the inferred spins of black holes detected via gravitational-wave or electromagnetic observations. Recent analytic solutions for the plunging region thermodynamics have been incorporated into a full disc model extending down to the horizon, thereby correcting the spin measurement bias. We show that these solutions agree well with our GRMHD results across the spin range, particularly for low-spin black holes. Moreover, we use our survey of GRMHD simulations to study the physical origin of the ISCO stress and its dependence on the spin, demonstrating that the measurement degeneracy between these quantities can be broken.

Probing Accretion and Ejection Physics through sub-second multi-wavelength observations (Invited)

Authors

Federico Vincentelli (1)

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Abstract

Accretion onto compact objects is one of the most fundamental phenomena in the astrophysics, powering some of the most luminous objects in the sky. Along with this, accretion has also a key impact on the evolution of the Universe, through the launch of powerful outflows that affect the surrounding medium. In the last years sub-second optical-infrared observations of accreting X-ray binaries have opened a new window in the study of inflow-outflow connection, discovering a wide range of previously unknown phenomena. In this talk I will review the recent results regarding multi-wavelength variability studies of both black holes and neutron stars which allowed to place unprecedented constraints on these systems. Finally I will discuss what are the future direction of this exciting field in the near future.

Spin-dependent tidal disruption and fallback of white dwarf binaries by intermediate-mass black holes

Authors

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Abstract

We investigate tidal encounters between close identical white dwarf binaries and spinning intermediate-mass black holes, where the binary center of mass follows a parabolic orbit. Such interactions involve a complex interplay between the binary's internal spin angular momentum, orbital angular momentum, and the black hole spin, leading to rich tidal dynamics and distinctive observational signatures.

We first analyze the corresponding three-body problem in the point-particle approximation to identify the key dynamical regimes. Building on this, we perform a suite of smoothed particle hydrodynamics (SPH) simulations to capture the full tidal interaction and debris evolution. In our framework, the geodesic motion around the spinning black hole is treated relativistically, while the hydrodynamics and the self- and mutual gravity of the white dwarfs are modeled in the Newtonian limit, an approach justified for the chosen system parameters.

We explore a range of initial configurations, including equatorial and off-equatorial center-of-mass trajectories, as well as different initial inclinations between the binary spin angular momentum and the orbital angular momentum. Our results show that black hole spin leaves clear imprints on the tidal disruption dynamics of both stars. The mass fallback rate, a key observable in tidal disruption events, is found to depend sensitively on the initial spin-orbit misalignment.

We demonstrate that the influence of black hole spin manifests differently across encounter geometries and alignment configurations. In particular, within the Hills mechanism regime, interactions between the tidal debris streams of the two white dwarfs can produce a distinctive three-hump structure in the fallback rate. These results highlight new signatures of binary tidal disruptions by spinning black holes and may help interpret future transient observations.

Exploring the impact of density contrast on jet morphology across the mass range

Authors

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Abstract

Astrophysical jets are ubiquitous among accreting objects in our universe. Black holes in particular are unique laboratories for these powerful outflows and their connection to the underlying accretion flow. In this talk I will present a suite of relativistic hydrodynamical simulations using the PLUTO code, which explore jets across the black hole mass range, such as X-ray binary (XRB), tidal disruption event (TDE) and active galactic nucleus (AGN) jets. While these systems likely share similar jet launching mechanisms, the jets are likely to have different mass densities and to evolve within different ambient environments. At distances of thousands to millions of gravitational radii the jets interact with media whose properties differ substantially: the interstellar, the circumnuclear or the circumgalactic medium. Using the same jet simulation prescription we explore how the impact of a changing jet to ambient density contrast across the mass range can lead to differences in observed luminosities, morphology, jet life time and spatial extent in these different black hole systems. We explore the regime of steady hard-state jets, which is underexplored in XRB simulation literature currently and aim to compare our simulations to spatially resolved hard state jets observed in systems such as Swift J1727.8-1613. We are able to draw comparisons between jet populations across the mass range and investigate how some of the observed differences in XRB, TDE, and AGN jets can be explained within a unified jet model propagating into different media.

Posters

Radio Emissions from Ultra-compact White Dwarfs

Authors

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Abstract

Recent discoveries of long-period radio transients (LPTs) confirmed to host white dwarfs have increased the number of classes of radio-emitting white dwarf binaries, including cataclysmic variables (CVs), white dwarf pulsars, and AM CVn systems. However, key questions remain about accretion and outflow processes in these, particularly in AM CVns, where a white dwarf accretes from a white dwarf or evolved helium star. To date, only one radio detection of an AM CVn exists, and both its validity and emission mechanism remain uncertain. Using observations from the Karl G. Jansky Very Large Array (VLA) and MeerKAT, this study presents the deepest radio luminosity constraints for three AM CVns: AM CVn, HP Lib, and ASASSN-14mv. These data are combined with large survey catalogues, including LOFAR, RACS, and VLASS, to constrain the AM CVn population for the first time. By comparing radio and optical luminosities alongside orbital periods, we explore potential emission mechanisms. Statistical analysis of detected systems allows us to investigate how binary configuration influences radio luminosity. With this poster, I will discuss how this work contributes to our understanding of radio emission processes in compact binaries.

From spherical cows to asymmetric dinosaurs: astrophysical jets and a new numerical approach to modelling their emissions.

Authors

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Abstract

The modelling of astrophysical jets has traditionally taken one of two approaches: macroscopic or microscopic. The former examines the large-scale structure and dynamics (e.g. GRMHD), while the latter focuses on the small scales of particle interactions (e.g. one-/multi-zone models). Each approach captures only part of the picture, but both perspectives are required to fully describe how these jets are formed, launched, and emit the multi-messenger signals through which we observe them. To bridge these two approaches, I will present DIPLODOCUS, a framework for general particle transport and emission modelling of astrophysical sources, capable of the self-consistent inclusion of large-scale spatial structure and small-scale anisotropic particle interactions. This will include an overview of the framework and its associated open-source code implementation, Diplodocus.jl; verification of its capability through relevant tests and code comparisons; and an exploration of its use in studying particle creation, acceleration, and emission within the acceleration region of an AGN jet.

Equatorially Asymmetric Magnetic Fields and Their Impact on Black Hole Accretion Dynamics

Authors
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Abstract
We investigate the impact of equatorial asymmetry in the magnetic field geometry on accretion dynamics around a spinning black hole using axisymmetric general relativistic magnetohydrodynamic simulations. We consider a Fishbone--Moncrief torus orbiting a Kerr black hole with spin parameter $a = 0.9375$, threaded by large-scale magnetic fields that are asymmetric about the equatorial plane. The degree of equatorial asymmetry in the magnetic field is parametrized by an angle, with values of 30°, 45°, and 60°. We examine how this equatorially asymmetric initial magnetic field configuration influences the magnetic field structure, accretion flow morphology, and angular momentum transport across a range of initial plasma beta values ($\beta = 0.007, 0.005, 0.001$). We find that such deformation in the magnetic field leads to noticeable changes in the inner disk structure, asymmetric outflow patterns in the poloidal plane, and time-dependent variations in accretion rates. These effects are generally more pronounced at lower beta values, where magnetic pressure dominates; in particular, the 30° case at $\beta = 0.001$ exhibits strong and persistent asymmetric inflows and outflows. Our results demonstrate that equatorially asymmetric magnetic field configurations can significantly influence the structure and variability of relativistic accretion flows. These findings motivate future extensions to full three-dimensional studies, where black hole magnetosphere can be explored in a more general setting.

Revisiting the spin–orbit landscape of magnetic cataclysmic variables with an expanded multi-catalogue dataset

Authors

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Abstract

Cataclysmic variables (CVs) are semi-detached, close contact binary systems in which a white dwarf (WD) is accreting mass from a low-mass donor via Roche lobe overflow. They can be broadly classified to be magnetic or non-magnetic, with the accretion flow in non-magnetic systems forming an accretion disc around the WD. Due to the loss of angular momentum, mass is transported through the disc to the WD surface. Those containing a WD with a significantly strong magnetic field, known as magnetic CVs (mCVs), channel the accretion flow to restricted areas of the WD surface. In polars (AM Herculis systems, or AMs), field strengths of 10–240 MG are sufficient to prevent the formation of an accretion disc. Instead, material is channelled directly from the accretion stream along field lines to the magnetic poles. In intermediate polars (IPs), weaker fields (~1–10 MG) allow a truncated accretion disc to form. These mCVs can be characterised observationally by their orbital rotation period, Porb, and the WD spin period, Pspin, which, together, reveal much about the accretion flow types dominating them.

The Ritter & Kolb catalogue (RKcat) remains the most often cited and comprehensive CV catalogue to date. It contains 1429 CVs of various classifications. In addition to Pspin and Porb, it contains many other parameters, including minimum and maximum magnitudes, whether the system is eclipsing, spectral type of the donor, and length of superoutbursts. RKcat was last updated in 2015. Since then, many more CVs have been discovered through a plethora of sky surveys and missions. Although several new catalogues have been released, these contain a limited data set, or limited parameters within. We have compiled a new catalogue, using data from RKcat, IP Catalogue, PolarCat, and SDSS, containing ~1780 distinct systems, cross-identified using coordinates from Gaia, ROSAT, CRTS, LAMOST, and 2MASS, and deduplicated. Each duplicate system's subtype classification was verified or corrected through literature research, and non-CV objects were removed.

Norton, Wynn & Somerscales (2004) plotted Pspin against Porb for 111 mCVs: 72 AMs and 39 IPs. This demonstrated the parameter space where rotational equilibrium occurs and commented on different accretion flow type (disc-fed, stream-fed, disc-overflow, propellor). The new catalogue has provided data for 15 additional mCVs. Here we present an updated Pspin–Porb plot of 126 mCVs, comprising 99 IP or IP candidates, 25 AM or AM candidates, and 2 systems where the IP versus AM nature is uncertain, all with confirmed Pspin. Statistical tests confirm the AM and IP populations span distinct states, and further structure within the IPs. We aim to further constrain the boundaries of the orbital period gap, reveal insights into the types of accretion flow operating within these systems, and identify shared physical properties across the mCV population.