FROM WINDS TO JETS: THE ROLE OF OUTFLOWS IN COMPACT BINARIES

ABSTRACTS

Richard Plotkin
University of Nevada

Radio observations of black hole jets

I will provide a review of relativistic jets from black hole X-ray binaries, focusing on how jets evolve with the state of the underlying accretion flow. I will pay particular attention to how the jet may (or may not) change as black holes transition between the hard state (Lx>~1e-5 Ledd) and quiescence (Lx<~1e-5 Ledd). Understanding jets from hard state and quiescent black hole X-ray binaries has a wide range of applications, including placing constraints on how to use radio emission to search for new populations of black holes in our Milky Way, to refining applications of the black hole fundamental plane to discover and study accretion within low-luminosity and quiescent active galactic nuclei.

Maria Cristina Baglio
New York University of Abu Dabi

Searching for jet signatures in X-ray binaries: a NIR/optical perspective

In this talk I will review some of the most relevant aspects and properties of jets in X-ray binaries at optical and near infrared (NIR) frequencies. Jets are one of the most intriguing phenomena linked to relativistic accreting objects. Studying jets in X-ray binaries in particular offers a great opportunity, since on short timescales (~years) a stellar massive black hole or a neutron star in a transient binary system typically undergoes accretion in a number of different modes, showing significant changes in the possible outflows. In the last decades, this allowed to deepen the knowledge of the accretion-ejection coupling in X-ray binaries, which is at the moment established in the case of black hole (BH) binaries, while lots of steps still have to be performed in the case of neutron star (NS) systems. The emission of jets is thought do be dominant in the radio band, while at higher frequencies it is expected to be diluted by the emission coming from other components (the accretion disc, the companion star, etc.). Evidence for the emission of jets can however be found also in the optical and NIR. In particular, in both BHs and NSs systems, a typical signature of the emission of a jet at NIR frequencies is the observation of an excess in the spectral energy distribution, which indicates that a further component (i.e. the jet) with respect to the accretion disc and the companion star has to be invoked to explain the observations. I will present here some relevant examples for this, for both BHs and NSs systems, also showing how this NIR excess might change (together with the position of the jet-break frequency, i.e. where the jet spectrum goes from optically thick to optically thin) depending on the X-ray spectral state in which the sources linger, enforcing the accretion-ejection coupling paradigm. Another intriguing (and less investigated) signature of jets emission is the observation of linearly polarized radiation emitted from the systems, especially at NIR frequencies. In fact, the emission mechanisms of jets is almost certainly synchrotron due to relativistic electrons that spiral in the strong magnetic fields in these systems, and synchrotron radiation is known to be intrinsically linearly polarized up to tens of per cent. Despite this, only a few optical-NIR polarimetric studies have been performed to date on X-ray binaries to establish the emission of jets, and mainly in case of BHs, which are normally brighter than NSs, and therefore better candidates for polarimetric studies, that require very high levels of signal to noise. I will present here the state of the art of these findings, together with some new results, for both NSs and BHs systems.
Compact, continuously launched jets in black hole X-ray binaries (BHXBs) produce radio to optical–infrared (OIR) synchrotron emission. These jets are launched in the hard X-ray state, and are quenched in the soft state. They are not spatially resolved except in a few cases using VLBI radio observations. One of the basic properties of these jets is the bulk Lorentz factor, which defines how fast and how relativistic these jets are. The bulk Lorentz factor is notoriously difficult to measure, with to date only weak constraints for a few BHXBs. Here, we adopt simple models to constrain the Lorentz factor of the compact jets in several BHXBs using the amplitude of the jet fade and recovery at infrared (IR) wavelengths over state transitions. We investigate why some BHXBs have prominent IR excesses and some do not, quantified by the amplitude of the IR quenching or recovery over the transition from/to the hard state. Using the amplitude of the IR fade/recovery, known orbital parameters and simple Bayesian analysis, we constrain for the first time the Lorentz factor of compact jets in several BHXBs. We also find that the very high amplitude IR fade/recovery seen repeatedly in GX 339–4 requires a much lower inclination angle than previously expected. Our results are strongly supportive of the IR excess being produced by synchrotron emission in a relativistic outflow, and demonstrates how useful OIR monitoring of BHXB is for studying jet properties.

Chiara Ceccobello
Chalmers Institute of Technology

Stellar-mass black hole jets: a theoretical view

Astrophysical jets are collimated flows of matter associated with accretion in systems of different kinds. While jets from the nuclei of active galaxies have been discovered a century ago, only in the last two decades the same phenomenon has been observed in stellar-mass black hole systems. Black hole binaries are the perfect laboratories to study the evolution of jets due to the relatively short timescale of their outburst cycle. Since their discovery, multi-wavelength observations with increased time and frequency coverage have been revealing a rather complex and diverse behaviour of jets during state transitions. Driven by the challenge provided by the mounting observational results, the theoretical modelling of jets has been rapidly evolving. This growing effort is providing crucial insight to understand the physics underlying the jet phenomenon. In this review talk, I will present the state-of-the-art of the theory of jets from stellar-mass black holes, summarise what we have learned so far and discuss the open questions that need to be addressed in the near future.
Radio observations of neutron star jets

Jets are ubiquitous phenomena in our universe, linked to a wide range of objects, from young stars to compact objects. Of all the systems that launch jets, X-ray binaries are particularly excellent testbeds for studying jet phenomena, as their rapid evolutionary timescales provide a real-time view of jet behaviour. However, after decades of X-ray binary research, while we know there exists a fundamental connection between the accretion flow (probed by spectral and variability properties of the X-ray emission) and the jet (probed by radio emission) in these systems, our current knowledge of the physics that governs this connection and the behaviour of these jets is still limited. Analyzing and quantifying the similarities and differences between jet behaviour in X-ray binaries that house different types of compact objects (namely black holes vs neutron stars), presents an unique opportunity to pinpoint the role of key properties that may affect the jet production process (e.g., mass, spin, magnetic field, existence of a surface or event horizon). However, sampling neutron star systems tends to be very observationally challenging, as neutron stars evolve quickly and are faint at radio frequencies. With today’s more sensitive interferometric arrays and improved coordination capabilities, we are increasingly able to obtain more of these valuable radio data sets of neutron star systems. In this talk, I will review our current understanding of neutron star jets, highlighting recent advances from photometric and imaging studies, and providing an in step comparison to black hole jets. Additionally, I will discuss future prospects for obtaining more of these invaluable neutron star data sets, and the critical role that next generation instruments (such as the ngVLA and ALMA-2030) will play in driving new discoveries through this science.

On the evolution of the disk and corona in accreting black hole binaries

During an outburst, accreting black hole binaries (BHB) cycle between quiescence to their Eddington luminosity exhibiting a rich phenomenology that includes thermal and non-thermal X-ray emission, ionized reflection, relativistic jets, quasi-periodic oscillations, and disk winds. The current paradigm dictates that the accretion disk is highly truncated during the jet-dominated hard state, while in the soft state the jet is quenched and the inner-disk is stable at the inner-most circular orbit (ISCO) radius. I will present recent spectroscopy analysis that contradicts this picture. We have found evidence for strong X-ray reflection originated very close to the black hole, suggesting that the disk has reached the ISCO radius at the early phases of the outburst, while the non-thermal coronal emission shows clear signs of evolution in both its electron temperature and optical depth. The implications of these observational findings are discussed in the context of state transitions of several BHBs.
Deanne Coppejans  
Northwestern University  

*Radio observations of white dwarf jets*

Jets are found in a number of accreting white dwarf classes such as Super Soft Sources, Novae and Symbiotics. In Cataclysmic Variables (CVs, binaries wherein a white dwarf accretes from a low-mass main sequence star via Roche-lobe overflow), there is strong evidence indicating the presence of jets, but the issue is not yet settled. The key argument for jets in CVs is that the accretion-outflow cycle in X-ray Binaries (XRBs) can be mapped to CVs, and that multi-wavelength observations of the exemplar system SS Cyg have spectacularly met key predictions of this model. In particular, SS Cyg consistently shows a bright radio flare on the rise to outburst (analogous to an XRB crossing the jet line). Current radio observations of other (fainter) CVs are consistent with this behaviour, but with one clear exception. Conclusively establishing whether CVs launch jets is important to understanding jet-launching in compact accretors: they would provide a non-relativistic environment to study jet physics. I will review the case for jets in CVs and talk about the impact that MeerKAT/MeerLICHT observations will play.

Kyle Parfrey  
NASA Goddard Space Flight Centre  

*Jets from Neutron Stars — Theory and Simulations*

Radio emission indicating the presence of relativistic jets has been detected from most classes of neutron stars in binary systems. Reliable stellar rotation frequencies and approximate magnetic field strengths are known in a subset of cases, providing more constraints on the launching physics than is often possible for black holes. This represents an opportunity to leverage both compact-object types to understand viable jet production mechanisms. I will review theoretical ideas for describing neutron-star jets and the simulations which have been performed to test them, with a particular focus on recent 2D and 3D relativistic MHD simulations.
In the last decade, a new class of “transitional” millisecond pulsars (tMSPs) has been identified. These sources switch on multi-year timescales between rotation-powered radio millisecond pulsars and accreting or disk-dominated low-mass X-ray binaries. The (quasi-)simultaneous combination of X-ray and radio observations of tMSPs is a powerful way to probe the pulsar recycling process and jet-like outflows because it traces both the inflow of material (inner accretion disk and matter transfer onto the neutron star) as well as outflows (compact jet or propelling of material). Recently, such X-ray/radio observations of tMSPs have shown that these objects exhibit much brighter radio emission than expected when undergoing accretion, and that this emission is highly variable on the short timescales and mirrors discrete X-ray brightness modes in the low-luminosity accretion state. Do all tMSPs show similar radio emission behaviour? In my talk I will present our progress in the multi-wavelength study of tMSP candidates 3FGL J1544-1125 and IGR J17591-2342, both sharing many similarities with the three well-established tMSPs. With 3FGL J1544-1125 we performed strictly simultaneous VLA and Chandra observations, where we studied the correlation between low and high X-ray luminosity modes and radio brightness on a short timescale (minutes). With IGR J17591-2342 we performed quasi-simultaneous VLA/ATCA and Swift-XRT observations throughout its first observed outburst, and as it was fading to quiescence, thereby studying the X-ray/radio emission correlation over a few orders of magnitude in luminosity.

The black hole X-ray binary candidate MAXI J1820+070/ASASSN-18ey has been the subject of intensive, multi-wavelength, monitoring since its outburst began in early 2018. I will present some initial results from our observing campaign on MAXI J1820+070 at radio frequencies. During the hard X-ray state the radio emission was strongly correlated with the X-ray emission, on the 'radio loud' branch, which was previously dominated by the black hole GX 339-4. Uniquely for a black hole transient, MAXI J1820 was detected at every single one of ~50 epochs during 3 months in the soft state during monitoring with the Arcminute Microkelvin Imager Large Array at 15 GHz. Imaging observations with eMERLIN, MeerKAT and the JVLA have revealed the origin of this radio emission during the soft state to be large scale superluminal jets, which have been tracked from the core to separations of ~10 arc seconds from the black hole. These observations provide insight into the orientation of the system, structure and speed of the ejecta, as well as the connection between transient jet launching and accretion state through comparison with X-ray observations of the source.
An Observational View of Disc Physics and Disc Winds

From planets and newborn stars to the evolution of entire galaxies, many astrophysical objects grow and evolve by accumulating mass through a disc. For these objects to grow, matter must both lose angular momentum to flow inward, and avoid being removed from the system via different types of outflows. However, despite decades of research, our understanding of the detailed physics governing angular momentum (and mass) transport in, and the physical mechanisms that drive outflowing matter from, such discs remains fragmented due to the limits of theoretical work and missing observational constraints. Recurring outbursts associated with matter flowing onto compact stellar remnants (black holes, neutron stars and white dwarfs) in compact binaries provide strong test beds for constraining key aspects of this poorly understood accretion process. In this talk I will review (i) our current understanding of compact binary outbursts according to the disc-instability model, (ii) how the fundamental predictions of this model can be tested using observations, and (iii) recent work demonstrating how the multi-wavelength light-curves of these bright outbursts can act as powerful diagnostics to probe the mechanisms driving mass inflow and outflow in these systems. I will conclude by presenting new results demonstrating that, through a combination of accretion theory and observations, outburst light-curves can be used to: test for signatures of, compute mass loss rates in, and put constraints on the driving mechanism(s) behind, disc outflows in compact binary systems.

Radiation hydrodynamic simulations of disk winds.

Disk winds appear to be a ubiquitous feature of accreting compact objects across the entire size scale from stellar mass black holes/neutron stars up to quasars. Several driving mechanisms have been proposed, including magneto-centrifugal driving, radiation driving and thermal driving, but it is still not clear which mechanism is dominant in which systems. Thermal driving is an attractive idea, since the physics is compellingly simple. Indeed one would expect this process to drive winds in almost all systems where gas is strongly heated. Here we discuss the physics behind thermal driving of disk winds in low-mass X-ray binaries (XRBs). We demonstrate that for physically reasonable system parameters, we would expect strong disk winds to be produced. Such winds can carry away most of the mass that is injected into the accretion disk, and we show simulated observational signatures similar to those seen in edge-on XRBs in the high/soft state. We also show that the dependence of outflow rate on luminosity predicted by thermal disk winds is similar to that observed in XRBs.
Karri Koljonen  
Finnish Centre for Astronomy with ESO  

*X-ray winds in Cyg X-3, V404 Cyg and V4641 Sgr*

Cyg X-3, V404 Cyg and V4641 Sgr are unique sources even in the fairly non-homogenous group of X-ray binaries. They are all very powerful X-ray emitters, exhibiting luminous outbursts where the X-ray luminosity can exceed the Eddington luminosity for a ten solar mass black hole. More importantly, they are all thought to be surrounded by dense material that affects the X-ray spectral properties either during the outburst in form of a disk wind or from a stellar wind of the companion star. In this presentation, I will discuss the striking similarity of their X-ray spectra and show that it most likely arises from our obscured view of the sources through a wind.

Maria Diaz Trigo  
ESO  

*X-ray observations of X-ray binary disk winds*

Absorption lines in the X-ray spectra of X-ray binaries were first detected more than two decades ago with ASCA and identified with a highly ionised plasma from the accretion disk surrounding the compact object (a black hole or neutron star). The timely launch of the X-ray observatories Chandra and XMM-Newton, equipped with high energy gratings, enabled to discover such lines in additional sources and to determine that these lines were blueshifted in a very high fraction of the black hole X-ray binaries, indicating the presence of winds. In this talk, I will review the past observations and what we have learnt from them and the challenges of the more recent observations to answer the still standing questions related to this topic such as the launching mechanism of the winds.

Teo Muñoz-Darias  
Instituto de Astrofisica de Canarias  

*Optical/nIR observations of X-ray binary disc winds*

X-ray and radio observations performed during the last few decades have provided a rich data base on Low Mass X-ray Binaries (LMXBs). A strong coupling between the properties of the accretion flow and the presence of outflows, such as radio-jets and hot X-ray winds, has been found to be a fundamental characteristic of black hole systems, and to a great extend of LMXBs in general. In addition to this, and particularly since the spectacular case of the 2015 outburst of V404 Cygni, optical accretion disc winds are being found in several systems, suggesting that these are also an important ingredient in the LMXB accretion picture. I will review the state-of-the-art of this young field, with emphasis on the studies that are currently being carried out. I will show that cold (optical/nIR) winds with terminal velocities above 1000 km/s are most likely a common feature in LMXBs. I will discuss the possible nature of these winds as well as their impact on the accretion process.
**Chris Done**  
University of Durham

*Thermal wind models*

The pioneering work of Begelman McKee & Shields 1983 laid the foundations of thermal wind models in binaries. However, these have been sidelined of late, in favour of magnetic wind models to explain the observed anti-correlation of the wind (high/soft state) and jet (low/hard state) by a reconfiguration of the magnetic field topology. I will review the thermal wind models and show how they predict the disappearance of the wind in the low/hard state. Done et al (2018) suggested that this was due to the response of the wind launch radius to the changing ionising spectrum. However, a more important issue is described by Begelman & McKee 1983. The static corona over the inner disc goes optically thick in the radial direction along the disc plane, blocking direct irradiation until the disc curvature lifts it out of the shadow. The increase in scale height of this inner attenuation zone after the transition to the low/hard state dramatically increases the extent of the shadow, so that the outer disc is completely shielded from coronal irradiation, suppressing the wind. I will show full radiation hydrodynamic simulations which show that thermal winds (helped by radiation pressure) can explain all of the observed wind features in all states of 1H1743.

**James Matthews**  
University of Oxford

*Disc Winds in Accreting White Dwarfs*

Disc winds, and outflows generally, are a remarkably ubiquitous phenomenon in accreting systems. In this talk, I will review what we know about disc winds in accreting white dwarfs using a combination of theory and observations. I will discuss direct observational evidence for outflows - blue-shifted, broad absorption lines - but I will also talk about the indirect effects winds can have on the observed spectrum, specifically involving single-peaked emission lines, eclipse mapping and the observed continuum. Informed by stellar winds, as well as hydrodynamic and radiative transfer simulations, I will discuss possible driving mechanisms for the outflow with particular focus on radiative "line-driving". Finally I will explore how AWDs can inform the study of quasars and other compact binaries.
Outflows in the quiescent state of DNe and LMXBs

Dwarf novae (DNe) and low-mass X-ray binaries (LMXBs) are accreting compact binaries. Both systems show eruptions which are thought to be due to a thermal-viscous instability in the accretion disk. In the disk instability model, transport is traditionally supposed to be turbulent and modeled as an effective viscosity. However, transport of angular momentum could also be driven by MHD outflows. I will review our current knowledge on outflows in DNe and LMXBs with a particular emphasis on the quiescent state. Unlike the eruptive state, winds in quiescence cannot be driven by radiation pressure or thermal effects and must be, in some extent, MHD driven winds. I will show, using a new disk instability model including the wind torque, how these MHD winds impact the dynamics of accretion and shape the light curves of DNe, and possibly those of LMXBs. The impact of MHD winds cannot be reduced to a mass loss in the wind. Angular momentum and energy are also extracted from the disk, leading to enhanced accretion and less energy deposited in the disk. MHD wind-dominated disk could provide the key to understand some unexplained observational features of DNe and LMXBs in the context of turbulent accretion disks. The strong impact of MHD winds on the dynamics of the disk could also provide some indirect evidence of their presence in quiescence.

Peter Kosec
University of Cambridge

Disc winds in Her X-1

Hercules X-1 is one of the best studied accreting neutron star X-ray binaries with a wealth of archival X-ray data. It is well-known for the various time periods in its system: a 35-day period of high, low and short-on flux states, likely caused by a precessing warped accretion disc, a 1.7 day orbital period and a 1.2 sec pulsation period of a neutron star with a \( \sim 10^{12} \) G magnetic field. I will present the discovery of a highly ionised disc wind in the X-ray spectrum of Her X-1 when the source is in the high state. The wind detection is statistically significant in nearly all the archival XMM-Newton observations, with velocities ranging from 300 to 900 km/s. Observed features in the iron K band can be explained by both a forest of iron emission lines or by wind absorption. However, we also detect neon and oxygen absorption lines at the same systematic velocity in the high-resolution RGS grating spectra. The very high ionisation degree of the outflowing material (log (\( \xi/\) erg cm s\(^{-1}\)) = 3.7\(-4.6\)) suggests that we are seeing the wind close to its launching point in the accretion disk, and we deduce that the mass outflow rate can be of the same order as the mass accretion rate onto the neutron star. This outflow could be the progenitor of the UV absorption features observed at comparable velocities, but the latter likely originate at much larger distances from the compact object. Possible launching mechanisms will be discussed.
Among the most important and debatable problems in astrophysics and cosmology is the formation of supermassive black holes. The detection of fully-grown supermassive black holes in active galactic nuclei at high redshift, when the Universe was young, challenges the theories of black holes growth, requiring long periods of high accretion, most likely above the Eddington limit. This is a focus of the next generation large missions, such as JWST and ATHENA, but the most distant supermassive black holes will be difficult to probe even with these advanced observatories. Ultraluminous X-ray sources (ULXs) are bright objects with X-ray luminosities between $10^{39}$-$10^{41}$ erg/s and can be found in nearby galaxies. Today we know that the vast majority of this complex class consists of stellar-mass black holes or neutron stars accreting at or above the Eddington limit. This was made possible by the discovery of coherent pulsations and cyclotron lines in some ULXs, indicating that at least a fraction of them hosts neutron stars as compact objects and, finally, the discovery of powerful winds as predicted by theoretical models of super-Eddington accreting black holes and neutron stars. In particular, the presence of both pulsations and winds in a pulsating ULX supports the existence of hybrid configurations where thick disks and radiatively-driven winds survive despite the opponent strong magnetic pressure. ULX winds carry a huge amount of power owing to their mildly relativistic speeds ($\sim 0.2c$) and are able to significantly affect the surrounding medium such as regulating the ionization state and brightness of ULX super bubbles. The winds substantially limit the amount of matter that can reach the central accretor, which slows down its growth and extends its lifetime - in the case of an accreting neutron star. The study of ULX winds is therefore quintessential to understand 1) how much and how fast can matter be accreted by black holes and 2) how strong is their feedback onto the surrounding medium in the regime of high accretion rate such as for quasars and supermassive black holes at their peak of growth. In this talk I will provide an overview on this vast phenomenology and its state-of-art, focusing on recent discoveries of outflows in ULXs and their characteristics.

Accretion of matter onto a magnetic, rotating object can be strongly affected by the interaction with its magnetic field. This occurs in a variety of astrophysical settings involving young stellar objects, white dwarfs, and neutron stars. As matter is endowed with angular momentum, its inflow toward the star is often mediated by an accretion disc. The pressure of matter and that originating from the stellar magnetic field balance at the magnetospheric radius. When centrifugal forces takes over we enter the propeller regime, resulting in a characteristic reduction of the accretion luminosity. The onset of this mechanism has been widely adopted to interpret a distinctive knee in the decaying phase of the light curve of several transiently accreting X-ray pulsar systems. By comparing the observed luminosity at the knee for different classes of objects with the value predicted by accretion theory on the basis of the independently measured magnetic field, spin period, mass, and radius of the star, we disclose here a general relation for the onset of the propeller which spans about eight orders of magnitude in spin period and ten in magnetic moment. The parameter-dependence and normalisation constant that we determine are in agreement with basic accretion theory.
**Alexander Mushtukov**  
Leiden Observatory

*Theory of propeller accretion*

Interaction between the magnetic field of rotating neutron star and accretion flow at low mass accretion rates results in so-called “propeller regime” of accretion, when the material cannot penetrate through the centrifugal barrier set up by the rotating magnetosphere. The propeller state was investigated theoretically over a few decades. The recent progress in observational studies of the propeller state throughs light on the details of its onset and helps to understand a behaviour of accreting neutron stars at extremely low mass accretion rates. I will review the theoretical background of propeller accretion and discuss it in the context of the very recent observational results.

**Jonatan Jacquemin Ide**  
Université Grenoble Alpes

*Magnetically-driven jets and winds from MRI-active accretion disks*

Semi-analytical models of disk outflows have successfully described magnetically-driven, self-confined super-Alfvenic jets from near Keplerian accretion disks (Ferreira 1997). These Jet Emitting disks (JED) are possible for high levels of magnetization, close to the equipartition, leading to supersonic accretion and deeply affecting the emitted spectrum (see eg. Marcel et al 2018). However, these solutions prove difficult to compare with cutting edge numerical simulations, for the reason that numerical simulations show wind-like outflows but in the domain of small magnetization.In this work, we present for the first time self-similar solutions for accretion-ejection structures at small magnetization. We will elucidate the role of the magneto-rotational instability in the acceleration processes that drive this new type of solutions. The generalized parameter space and the astrophysical consequences will then be discussed. We believe that these new solutions could be a stepping stone in understanding the way astrophysical disks drive either winds or jets.

**Jeroen Homan**  
Eureka Scientific

*Observations of outflows from Z-sources*

Z sources are a class of neutron-star low-mass X-ray binaries (NS LMXBs) with near/super-Eddington luminosities. All Z sources produce radio jets and some produce (simultaneous) disk winds as well. Before discussing these outflows in detail, I will briefly summarize how NS LMXB phenomenology evolves as luminosities reach near/super-Eddington values. This is followed by an observational overview of both types of outflows in Z sources. Finally, I will discuss if properties that set the Z sources apart from the lower luminosity NS LMXBs, such as strong radiation pressure, play a role in the launch of jets and winds in Z sources.
**Chris Fragile**  
College of Charleston

*Interactions of Type I X-ray Bursts with Accretion Disks*

An interesting diagnostic for studying accretion states around neutron stars is to carefully monitor the response of the accretion disk during Type I (thermonuclear) X-ray bursts occurring on the star’s surface. This has been done in both the hard state, where the hard X-ray flux of the disk is seen to be inversely correlated with the soft X-ray flux of the burst, and the soft state, where there is evidence for a retreat of the inner edge of the accretion disk beyond its non-burst location. We have now done general relativistic, viscous, radiation hydrodynamic simulations of the interaction of realistic burst radiative profiles with accretion disks in both the hard and soft states. In this talk, I will summarize our main results, including discussion about the role (or lack thereof) of winds/outflows.

**Sara Elisa Motta**  
University of Oxford

*Simultaneous X-ray and radio observations of Sco X-1*

The nearby accreting neutron star binary Sco X-1 is the closest example of ongoing relativistic jet production at high Eddington ratios. Previous radio studies have revealed that alongside mildly relativistic, radio-emitting ejecta, there is at times a much faster transfer of energy from the region of the accretion flow along the jet. The nature of this ultrarelativistic flow remains unclear and while there is some evidence for a similar phenomenon in other systems which might contain neutron stars, it has never been observed in a confirmed black hole system. We have compared these previous radio observations with a new analysis of simultaneous X-ray observations which were performed with the RXTE mission. We find that the ejection of the ultra-relativistic flow seems to be associated with the simultaneous appearance of two particular types of quasi-periodic oscillations in the X-ray power spectrum. In contrast, the mildly relativistic, radio-emitting outflows may be associated with flat-topped broad band noise in the X-ray power spectrum. This is the first time a link, albeit tentative, has been found between these mysterious unseen flows and the accretion flow from which they are launched.

**Tiziana Di Salvo**  
University of Palermo

*Observational evidence for non-conservative mass transfer in X-ray binaries*

We are collecting growing evidences of non-conservative mass transfer in Low Mass X-ray Binary (LMXB) systems. These come from measurements of large orbital period derivatives in Accreting Millisecond Pulsars (AMSPs) as well as in LMXBs at high inclination, in which the orbital period and its long-term derivative are inferred from the presence of periodic dips and eclipses. Together with a more or less constant parabolic trend, these sources sometimes show puzzling behaviors of the residuals that we try to interpret and discuss. Other evidences come from the observation of the averaged accretion rate in X-ray transients as compared to the zero-order mass transfer rate inferred from the orbital evolution of these systems driven by Gravitational Radiation (GR) and/or magnetic braking. This non-conservative mass transfer may be connected to the presence of large outflows from these systems in the form of jets and winds and to the presence of circumbinary matter in these systems. I will finally discuss possible causes of what appears to be an ubiquitous behavior among LMXBs.
Stephen Justham
University of Amsterdam

Impact of Outflows

Understanding outflows from compact binaries is important for predicting the future evolution of such binary systems, and may even be important on much larger scales: for understanding galaxy evolution. Most clearly, the extent to which outflows carry away mass and angular momentum can make the difference between a shrinking orbital separation and a widening one, i.e., leading to qualitatively different evolutionary outcomes. Not only are these outflows certainly significant for the systems themselves, it seems plausible that they can be significant on galactic scales. Supernova feedback is widely recognised as a significant process in regulating star formation and heating the ISM, and for reasonable assumptions the integrated energy input from X-ray binaries could be at least comparable to that supernova energy input. Given the current evidence that most stellar core-collapse events leading to black holes form relatively silently, X-ray binary feedback may also often precede supernova feedback, and can also extend far longer than input from core-collapse SNe. Classical novae have also been discussed as potentially significant for understanding present-day globular clusters and dwarf spheroidals. I will review the literature, and hope to encourage more connections between short-timescale observations and evolutionary-timescale modelling.

Alexey Bobrick
Lund University

Hydrodynamic simulations of mass transfer in white dwarf-neutron star binaries

We perform hydrodynamic simulations of the onset of mass transfer in white dwarf-neutron star binaries. Most such binaries evolve through a phase when the mass transfer rate exceeds the Eddington rate by many orders of magnitude, which results in significant outflows. These outflows efficiently remove angular momentum from the binary orbit. We use the angular momentum loss rates measured in our simulations to construct a long-term evolution model for white dwarf-neutron star binaries. The angular momentum loss rates are found to be much larger than assumed in standard population synthesis models where all the material is assumed to be removed entirely through a collimated jet. As a result, more systems experience a dynamically unstable outcome where the white dwarf is tidally shredded by the neutron star than previously thought. In particular, all the binaries with CO donors and the binaries with He white dwarf donors more massive than about 0.2 solar masses result in a dynamically unstable outcome. We show that this helps us to better explain the observed inspiral rates of detached binaries and the formation rates of the ultra-compact X-ray binaries and the faint supernovae likely resulting from inspirals of these systems.
V341 Ara - The Nova-like variable that has it all

Non-magnetic nova-likes are cataclysmic variables with mass-transfer rates high enough to keep the accretion disk in a permanent high state. These systems are therefore great test beds for our understanding of steady-state accretion disks. V341 Arae is an 11th magnitude blue object embedded in a large (8' x 10') emission line nebula. [O III] images suggest a parabolic bow-shock shape for the nebula, with V341 near the apex. The ionized mass of the nebula is very low compared to the canonical PN, though is inline with the spected form an old nova shell. The source was long misclassified as a Cepheid variable and first revealed as a nova-like CV by Samus, Pastukhova & Durlevich (2007) and Frew (2008) independently. Even since then, it has remained surprisingly unnoticed by the CV community. Remarkably, even though V341 Ara is one of the brightest nova-likes known, only the orbital period of the system is known. Here, we present results from a spectroscopic campaign we have been carrying out with the SAAO 1.9m telescope and time resolved spectroscopy carried out with the integral field unit WiFeS at SSO. This is supplemented by archival data obtained with the CTIO 1.5m and new observations gather with SALT. We also present the results from long-term photometric light curves obtained by the ASAS-SN and KELT surveys, which reveal long-term (10 day) super-orbital (quasi-)periodicities. With this data we will constrain the binary parameters, and discuss the origin of the nebula and its evolutionary stage of this peculiar source. In addition we present new UV and X-Ray spectroscopic observation carried out with SWIFT which allow us to study the interaction of the accretion disk with the circumstellar medium and help us to construct a full SED of the source.