The Extremes of Black Hole Accretion

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ABSTRACT BOOK

Oral Communications and Posters

Edited by
Jan-Uwe Ness

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Chapter 1

Invited Speakers

Ultraluminous X-ray sources - three exciting years

Matteo Bachetti[1]
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Ultraluminous X-ray sources are off-nuclear extragalactic sources with (apparent) luminosities exceeding the Eddington limit for a stellar-mass black hole. This naturally suggests an association with the elusive class of intermediate-mass black holes, or with super-Eddington accreting black holes. As it turns out, this peculiar class of sources is actually a variegated zoo, including both classes of accreting black holes mentioned above and, rather unexpectedly, neutron stars. In this talk I will overview the astrophysical properties of these objects, and give an update on the many breakthroughs appeared in the literature in the last three years.

Gravitational Lensing Size Scales for Quasars

George Chartas[1], Christopher Kochanek[2], Xinyu Dai[3], Christopher Morgan[4], Jeffrey Blackburne[2], Bin Chen[3], Ana Mosquera[2], Chelsea MacLeod[4,5]
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We review results from our monitoring observations of several lensed quasars performed in the optical, UV, and X-ray bands. Modeling of the multi-wavelength light curves provides constraints on the extent of the optical, UV and X-ray emission regions. One of the important results of our analysis is that the optical sizes as inferred from the microlesning analysis are significantly larger than those predicted by the theoretical-thin-disk estimate. In a few cases we also constrain the slope of the size-wavelength relation. Our size constraints of the soft and hard X-ray emission regions of quasars indicate that in some objects of our sample the hard emission region is more compact than the soft and in others the soft emission region is smaller. This difference may be the result of the relative strengths of the disk-reflected (harder and extended) versus corona-direct (softer and compact) components in the quasars of our sample. Finally, we present the analysis of several strong microlensing events where we detect an evolution of the relativistic Fe line profile as the magnification caustic traverses the accretion disk. These caustic crossings are used to provide independent estimates of the size of Fe K emission region.

Review of Relativistic Reflection Models

Thomas Dauser[1], Javier García[2], Jörn Wilms[1]
[1] *Dr. Karl Remeis-Observatory & ECAP, Bamberg, Germany*
[2] *Harvard-Smithsonian Center for Astrophysics, Cambridge, USA*

I will review the recent development of reflection models used to fit relativistic reflection features in GBHs and AGN. The increasing quality of X-ray data sets from long XMM-Newton observations combined with the extended energy range of NuSTAR challenges previous models. I will discuss the importance and advantages of employing the most updated physical models which implement the lamp post geometry and a correct calculation of the reflection fraction. Applying these advanced models indicates that a compact primary emitting source is responsible for the observed steep emissivities. The improved physics in the newest generation of reflection models allows for a self-consistent calculation of the ionization gradient along the radial direction of the accretion disk.

Winds in X-ray binaries

Maria Diaz Trigo[1]
[1] *ESO*

In the last decade there has been a wealth of discoveries of atmospheres and winds in X-ray binaries. Studies of such disc atmospheres and winds are of fundamental importance to understand accretion processes in these systems and possible feedback mechanisms to their environment.

I will review the current state of these studies, focusing on observational results and will discuss the possible wind launching mechanisms and compare the predictions of the models with the existent observations.

Patterns of disc-jet-wind coupling in black hole binaries

Rob Fender[1]
[1] *University of Oxford*

In this talk I will present the current state of the art in our understanding of the connection between accretion state and feedback in black hole X-ray binaries. In particular I will discuss how the X-ray accretion states, defined by their spectral and temporal properties, relate to phases of the production of relativistic (radio) jets and accretion disc winds. I will furthermore discuss how these patterns of behaviour contribute to the overall kinetic and radiative feedback during an outburst, and how comparable they may be to similar behaviour in neutron star X-ray binaries and supermassive black holes in active galactic nuclei.

Review of X-ray variability in black hole binaries

Adam Ingram[1]
[1] *University of Amsterdam, Amsterdam, The Netherlands*

The rapid X-ray variability displayed by accreting black hole binaries (BHBs) consists of aperiodic broad-band noise and quasi-periodic oscillations (QPOs). The properties of both correlate tightly with spectral state, which is seen to evolve over timescales of $\sim$ weeks to years. I will first review the phenomenological picture built up with the aid of 16 years of monitoring by the Rossi X-ray Timing Explorer (RXTE), before discussing a physical interpretation of all these data. I will summarise the growing body of evidence that the broad-band noise originates from propagating mass accretion rate fluctuations and present our recent results which provide evidence that low frequency QPOs are of geometric origin.

Spectral components in black hole binaries - disc, Comptonization, reflection and jets

Julien Malzac[1,2]
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[2] *CNRS, IRAP, Toulouse, France*

I will review the current models for the multi-wavelength emission of black hole binaries.

Quasi-periodic oscillations in black-hole binaries

Sara Elisa Motta[1]
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Fast time variability is an important characteristic of black hole (BH) binaries and a key ingredient in understanding the physical processes in these systems. Fast time variability is generally studied through the inspection of power density spectra, whose component are either broad distributed over several decades in frequency or fairly narrow, in the form of localised peak (quasi-periodic oscillations, QPOs).

It is now clear that QPOs are a common characteristic of accreting systems: they have been observed in accreting stellar mass BHs and neutron stars in X-ray binaries, in CVs, in ULXs and even in AGN. Even though their origin and nature is still debated, the study of QPOs provides a way to explore the inner accretion flow around accreting objects. Various models have been proposed to explain the origin of QPOs in black hole binaries, but only a few have been proved to be promising so far, having shown good agreement with observations. I will describe how timing is done in X-rays and how QPOs are usually studied. I will briefly review some of the proposed models and I will finally show the most recent results obtained on QPOs.

Unwrapping the X-ray Spectra of AGN

Christopher Reynolds[1,2]
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Active galactic nuclei (AGN) are complex phenomena. At the heart of an AGN is a relativistic accretion disk around the spinning supermassive black hole with a compact, probably pair-regulated, X-ray corona. On larger scales, the outer accretion disk and molecular torus act as the reservoirs of gas for the continuing AGN activity. And on all scales from the black hole outwards, powerful winds (and sometimes jets) are seen and can dominate the source energetics. As I shall review in this talk, each of these components imprints its own characteristic signature into the (time-variable) X-ray spectrum of the AGN. I shall then touch upon a few contemporary topics : (i) the use of new spectral timing techniques for aiding in the decomposition of the spectrum and for probing the geometry of the AGN central engine, (ii) the determination of supermassive black hole spin, (iii) direct confirmation of quasar-mode feedback in some luminous systems. The prospect of AGN observations with Astro-H will be discussed.

Accretion disk winds in active galactic nuclei: X-ray observations, models and feedback

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[2] *Department of Astronomy and CRESST, University of Maryland, College Park (MD), USA*

Powerful winds driven by active galactic nuclei (AGN) are often invoked to play a fundamental role in the evolution of both supermassive black holes (SMBHs) and their host galaxies, quenching star formation and explaining the tight SMBH-galaxy relations. A strong support of this quasar mode feedback came from the recent X-ray observation of a mildly relativistic accretion disk wind in an ultraluminous infrared galaxy and its connection with a large-scale molecular outflow, providing a direct link between the SMBH and the gas out of which stars form. Spectroscopic observations, especially in the X-ray band, show that such accretion disk winds may be common in local AGN and quasars. However, their origin and characteristics are still not fully understood. Detailed theoretical models and simulations focused on radiation, magnetohydrodynamic (MHD) or a combination of these two processes to investigate the possible acceleration mechanisms and dynamics of these winds. Some of these models have been directly compared to X-ray spectra, providing important insights into the wind physics. However, fundamental improvements on these studies will come only from the unprecedented energy resolution and sensitivity of the upcoming missions ASTRO-H (launch date early 2016) and Athena (2028).

Decoding black hole variability with spectral-timing

Phil Uttley[1]
[1] *Anton Pannekoek Institute, University of Amsterdam*

I will show how a combination of X-ray spectral and timing information can unlock new information about the innermost emitting regions of accreting black holes, focussing in particular on what we can learn about the nature of accretion flows and the origin of variability and introducing the methods used in the exciting new field of X-ray reverberation mapping.

An introduction to X-ray variability from black holes

Simon Vaughan[1]
[1] *University of Leicester, UK*

I will present an introduction and overview of some areas of the study of X-ray variability from black holes sources, including AGN, X-ray binaries and ULXs. I will first discuss the progress made understanding the red noise power spectrum of these sources over the past 15 years (since the launch of XMM-Newton), and in particular the study of correlations extending over the entire mass range from stellar mass X-ray binaries to AGN. I will then discuss the progress made identifying the accretion flow as the origin of the X-ray variations, with particular attention given to the rms-flux relation and associated phenomena. Time permitting, I will present some timing results from recent XMM-Newton observing campaigns, and discuss a few ideas for the future of this field.

Recent Highlights from the NuSTAR Mission

Dominic Walton[1], The NuSTAR Science Team[2]
[1] *JPL/Caltech*
[2] *Various*

Since its launch in 2012, the Nuclear Spectroscopic Telescope Array (NuSTAR) has been revolutionising our view of the hard X-ray sky, owing to its broad bandpass as well as its unprecedented hard X-ray sensitivity and imaging capabilities. Through a series of coordinated programs with XMM-Newton, providing simultaneous coverage in both the soft and hard X-ray regimes, NuSTAR has made significant contributions to our understanding of accretion in X-ray binaries, including providing the first robust high-energy view of the enigmatic ultraluminous X-ray source population, and active galactic nuclei. In this talk, I will review some of the recent highlights from the NuSTAR mission in these fields of black hole accretion.

Chapter 2

Spectral components (AGN)

Showing variability in AGN by principal component analysis (PCA)

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Principal component analysis (PCA) is a powerful tool for studying spectral variability. The technique consists of splitting relatively long exposures into a series of shorter-exposure spectra, and returns a minimal set of independent spectral shapes representing the variable components. If the initial spectra are made up of a linear sum of variable, uncorrelated and spectrally distinct physical components, the PCA will return detailed spectra of each variable component in a model independent way. This is a big advantage to analyze and study the origin of the observed variability without being limited by available spectral models (and by the systematic uncertainties that are inherent to any spectral analysis). We are applying the PCA analysis to several XMM-Newton observations from the brightest and most variable AGN with sufficiently long exposures. We shall present the most interesting results obtained so far.

A Variable-Density Absorption Event in NGC 3227 mapped with Suzaku and Swift

Tobias Beuchert[1], Alex Markowitz[2], Anna Lia Longinotti[3], Matteo Guainazzi[4], Giovanni Miniutti[5], Matthew Malkan[6], Jiri Svoboda[7], Javier García[8], Felicia Krauß[1], Jörn Wilms[1]
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[7] *Astronomical Institute of the Czech Academy of Sciences*
[8] *Harvard-Smithsonian Center for Astrophysics*

We present new time-resolved spectroscopy of the Seyfert galaxy NGC 3227. Observations of variable X-ray absorption over the past decade support the paradigm of clumpy circumnuclear gas. Eclipse events allow us to explore the properties of the clumps over a wide range of radial distances from the BLR to beyond the dust sublimation radius. The results on NGC 3227 showed an eclipse event from a Swift and Suzaku campaign over several weeks in 2008. We resolve the time dependent density profile to be highly irregular and variable, in contrast to a previous symmetric and centrally-peaked event mapped with RXTE. The data indicate a filamentary, moderately ionized cloud that nearly constantly covers $\sim 90\%$ of the line of sight to the central engine. For the first time our results show a variety of profile shapes within the same source and therefore provide an excellent opportunity to further test models describing the formation and dynamics of individual clouds or filaments as well as their distances from the supermassive black hole.

NuSTAR catches the unveiling nucleus of NGC 1068

Stefano Bianchi[1]
[1] *Università degli Studi Roma Tre, Rome, Italy*

We present a NuSTAR and XMM-Newton monitoring campaign in 2014/2015 of the Compton-thick Seyfert 2 galaxy, NGC 1068. We detect a clear high-energy excess above 15 keV during the observation performed on August 2014, which disappears in the following observation, in February 2015, reverting back to the spectrum observed by NuSTAR in 2012. We carry on a detailed broad band spectral analysis, using self-consistent models to reproduce all the emission components arising from the complex environment of this AGN. In this scenario, the observed high energy excess can be explained by a decrease of the column density of the obscuring material along the line of sight, which allows us for the first time to unveil the nuclear radiation of the archetypal AGN buried in NGC1068.

A hard X-ray view of the soft-excess in AGN

Rozenn Boissay[1], Stéphane Paltani[1], Claudio Ricci[2]
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[2] *Pontificia Universidad Catolica de Chile, Chile*

The origin of the soft-excess in many Seyfert 1-1.5s spectra remains debated, as several models have been suggested to explain it, including warm Comptonization and blurred ionized reflection. In order to constrain the origin of this component, we use the fact that these models predict different behaviors in the hard X-rays. Ionized reflection indeed covers a broad energy range, from the soft X-rays to the hard X-rays around a few tens of keV, while Comptonization from a warm plasma drops very quickly above a few keV. We present here the results of a study done on 102 Seyfert 1s (Sy 1.0, 1.2, 1.5, and NLSy1) from the Swift BAT 70-Month Hard X-ray Survey catalog. The joint spectral analysis of Swift/BAT and XMM-Newton PN and MOS data allows a hard X-ray view of the soft-excess that is present in about 80% of the objects of our sample. We discuss how the soft-excess strength is linked to the reflection at high energy and to the photon index of the primary continuum, and show that our results are in contradiction with those obtained from simulations of blurred ionized-reflection models.

How well can we measure black hole spin?

Kirsten Bonson[1], Luigi Gallo[1]
[1] *Saint Mary's University, Halifax, Canada*

Being one of only two fundamental properties black holes possess, the spin of supermassive black holes (SMBHs) is of great interest for understanding accretion processes and galaxy evolution. However, in these early days of spin measurements, we often struggle to obtain consistent spin values for the same object because of different modeling approaches. Here we examine various techniques and observing conditions to determine which yield the most accurate spin measurements. We have created and fit over 6500 simulated Seyfert 1 spectra, using both XMM-Newton and NuStar responses, in an effort to uncover any systematic "blind spots" and determine how best to approach measuring spin in AGN. With the next generation of high-energy observatories like
Astro-H and ATHENA, it is imperative that we understand just how well we are presently measuring spin and how we can maximize the potential of current and future missions.

Modelling the Extreme X-ray Spectrum of IRAS 13224-3809

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IRAS 13224-3809 is a narrow-line Seyfert 1 (NLS1) galaxy which shows many similarities with the extreme AGN 1H0707-495, including significant variability, frequency depended time lags, and strong Fe K line and Fe L features. We study the latest long 2011 XMM-Newton observation of IRAS 13224-3809 and carry out a series of analyses to probe the nature of the source, focusing in particular on the spectral variability exhibited. A self-consistent model that includes relativistic reflection from the inner accretion disc, a standard powerlaw AGN continuum, and a low-temperature blackbody which may originate in the accretion disc, explains the time-averaged spectrum well. We also undertake flux-resolved and time-resolved spectral analyses, which provide evidence of gravitational light-bending effects. This is the first work to probe spectral properties of extreme AGN in detail.

'Harder when Brighter' Spectral Variability in Low-Luminosity AGN

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[2] *Max-Planck-Institut fur Extraterrestrische Physik, Garching, DE*

We present X-ray spectral variability of four low accretion rate AGN - M81, NGC 1097, NGC 1052 and NGC 3998 - as observed by Swift and RXTE. All four objects were selected due to having spectra which hardened with increasing count rate, converse to the 'softer when brighter' behaviour normally observed in AGN with higher accretion rates. The spectra were summed in flux bins and fitted with a variety of models. A simple absorbed power law model was found to fit the spectra of M81, NGC 1097 and NGC 3998 well, whilst NGC 1052 required a partially covered power law model. In all four cases, the most likely main source of spectral variability is found to be luminosity-dependent changes in the photon index of the power law component. An anticorrelation between the photon index and the count rate is found in all of the sources. The anticorrelation is likely to be caused by accretion via a radiatively-inefficient accretion flow, expected in low-Eddington ratio systems such as these, and/or due to the presence of a jet. This behaviour is similar to that seen in the 'hard state' of X-ray binaries, implying that these LLAGN are in a similar state.

Using gravitational lenses to study the broad-band X-ray spectrum of distant QSOs; the case of B1422+321

Mauro Dadina[1], Massimo Cappi[1], George Chartas[2], Cristian Vignali[3], Margherita Giustini[4], Giorgio Lanzuisi[3], Barbara De Marco[5], Gabriele Ponti[5]
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[4] *SRON, Netherlands Institute for Space Research, Utrecht, the Netherlands*
[5] *Max Planck Institute for Extraterrestrial Physics, Garching, Germany*

The unique imaging capabilities of Chandra have been successfully used to perform microlensing studies of distant QSOs. The main aim was to infer the dimensions of their X-ray emitting regions. We started from the Chandra data to build-up a XMM-Newton program devoted to using the magnification due to gravitational lensing to characterize in detail the broad band spectra and variability of distant AGN. Here we present preliminary results of the XMM-Newton observation of z=3.62 QSO B1422+1233.

MUSE observations of the intermediate mass black hole ESO 243-49 HLX-1

Adrien Detoeuf[1], Natalie Webb[1]
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The formation of intermediate mass black holes is still poorly understood. With the discovery of the best intermediate mass black hole candidate, HLX-1 in the galaxy ESO 243-49, we can finally test some of the theories. Thanks to data taken with the Multi Unit Spectrograph Explorer (MUSE) on the VLT, which provides high-precision spectra in the visible and near infra-red domain (4750-9350 Angstroms), we are investigating both the intermediate mass black hole and its environment. We present preliminary results on the mass of the supermassive black hole in ESO 243-49 and constraints obtained on merger events in the galaxy.

Minimum X-ray source size for a lamppost corona in light-bending models for AGN

Michal Dovčiak[1], Chris Done[2]
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[2] *Durham University, United Kingdom*

The 'lamppost' model is often used to describe the X-ray source geometry in AGN, where an infinitesimal point source is located on the black hole spin axis. This is especially invoked for Narrow Line Seyfert 1 galaxies, where an extremely broad iron line seen in episodes of low X-ray flux can be explained by extremely strong relativistic effects as the source approaches the black hole horizon. However, the source must also be large enough to intercept sufficient seed photons from the disc to make the hard X-ray Compton continuum which produces the observed iron line/reflected spectrum. This size scale also sets the minimum height of the corona in order that the source can fit above the event horizon. We calculate this using a fully relativistic ray tracing code, and apply to the most extreme NLS1, 1H0707-495. The inferred source size is too big for it to be at a height of less than one gravitational radius above the horizon.

Origin of the Characteristic X-ray Spectral Variation of the Narrow Line Seyfert 1 Galaxies

Ken Ebisawa[1,2], Hiroki Yamasaki[1,2], Misaki Mizumoto[1,2], Hiroaki Sameshima[1]
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[2] *University of Tokyo*

We have proposed the Variable Double Partial Covering (VDPC) model to explain characteristic spectral variability of MCG-6-30-15 (Miyakawa et al. 2012), 1H0707−495 (Mizumoto, Ebisawa and Sameshima 2014) and other 20 Seyfert galaxies (Iso et al. 2015). In this model, observed flux/spectral variations below 10 keV within a ∼day are primarily caused by change of the partial covering fraction of the central X-ray source by patchy absorbing clouds with internal structure. Here, we found the VDPC model is also successful to explain spectral variations as well as Root Mean Square (RMS) spectra of IRAS 13224−3809, Mrk 335 and Ark 564 in the 0.5 –10 keV. In addition to the well-known significant drop in the iron K-band, we occasionally found such intriguing iron L-peaks in the RMS spectra of 1H0707−495 and IRAS 13224−3809, that appear when iron L-absorption edges are particularly deep. This feature is naturally explained with the VDPC model, where the fluxes of the direct component (without absorption edges) and the absorbed component (with absorption edges) exhibit anti-correlation while the sum is hardly variable. The fractional variation thus peaks at the energy where the flux separation between the two spectral components is the widest, corresponding to the iron L-edge.

Direct Observations of an Extragalactic Advection Dominated Accretion Flow

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We report the detection of central, unresolved continuum emission in NGC5044 that is likely emerging from an Advection Dominated Accretion Flow (ADAF). ADAFs are thought to power Radio-Mode feedback in galaxies and clusters, yet in super-massive black holes they are difficult to unambiguously detect against emission from other sources, such as dust and jets. Only the ADAF in Sgr-A* has previously been compellingly detected.

A surprisingly bright, 50mJy continuum source at 235 GHz was found in a Cycle-0 ALMA CO(2-1) observation of NGC5044. Having obtained multi-wavelength follow-up, we find that the shape of the mm-continuum and the narrow, 5-10 km s^{-1} width of the CO(2-1) absorption line are consistent with emission from a very compact central continuum source. Its continuum properties and energetics are consistent with self-absorbed synchrotron emission from an ADAF. Intriguingly, the spectral component associated with the ADAF is apparently varying by ∼20% on short (<1 month) timescales, implying that the accretion rate onto the AGN varies similarly. We will discuss the possibility that ADAFs in massive galaxies are fuelled by molecular gas, which has been recently discovered in NGC5044 and other systems.

Positive AGN feedback caught in action in NGC 2617

Margherita Giustini[1]
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A wealth of observational evidence has been recently collected supporting the presence of massive, high-velocity outflows coming from the very inner regions of AGN: such outflows are possibly able to influence the star formation and the evolution of the host galaxy by exerting significant "negative feedback". At the same time, very little is observationally known about inflows of matter in AGN. NGC 2617 (z$\sim$0.014) is an intriguing AGN that underwent a strong outburst during 2013/14, increasing its X-ray flux by one order of magnitude with respect to archival measurements. Concurrent optical spectroscopic observations revealed it to have switched from being a Seyfert 1.8 to be a Seyfert 1 sometimes during the past 10 years (Shappee et al. 2014). We report here on two follow-up XMM-Newton pointings that revealed the source to look like a typical bare Seyfert 1 in X-rays, with the addition of the extremely interesting detection of $\sim 30,000$ km/s redshifted Fe K absorption in both observations, taken one month apart. The occurrence of all these observational phenomena strongly suggests that we are witnessing an inflow of matter toward the central SMBH of NGC 2617, making it the best candidate where to investigate AGN "positive feedback" in action.

XMM-Newton Observations of the Super-Eddington Intermediate-Mass Black Hole: RX J1140.1+0307

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[2] *Department of Physics, Durham University, Durham, United Kingdom*

RX J1140.1+0307 is an intriguing IMBH. Last year we obtained data from two new observations of this source with XMM-Newton to study its spectral components and variability. Here we report the latest results from all three XMM-Newton observations of this source. We find the data show a strong soft X-ray component superimposed on a steep 2-10 keV power law, where the power law is more variable than the soft X-ray in high frequency. These properties are similar to a special group of NLS1s such as PG 1244+026 and RE J1034+396, making it natural to assume that the accretion flow in all these sources is at L$\sim$L$_{Edd}$. We tried various methods to constrain its black hole mass, and conformed M<1.E+6 Msun. With the mass being so small, the variable optical flux requires a mass accretion rate of L/L$_{Edd}$ $\sim$10 through the outer disk. Such high mass accretion rate would dramatically over-predicts the observed X-ray flux unless there is substantial energy loss through winds and/or advection, as is expected at such highly super-Eddington rates. But this is inconsistent with the X-ray spectral and variability properties, leaving us an unsolved puzzle about the formation mechanism of its X-ray spectra.

Monitoring the Dusty S-cluster object (DSO/G2) near the Galactic center black hole: model predictions for Br-gamma energy shift during the passage

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Dusty S-cluster Object (DSO/G2) had approached the supermassive black hole at the center of the Galaxy and its passage through the peribothron was monitored by the ESO VLT/SINFONI observations taken in the NIR band. The profile and the energy shift of Br-gamma spectral line can be employed to further constrain the nature of this event. We update and discuss the model predictions for different scenarios: a core-less cloud versus an enshrouded star with a partially disintegrating envelope.

Influence of stellar component on the conditions for thermal instability in the Galactic center Minispiral region

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Previously we demonstrated that collisions between clumps of gas in the Circum-Nuclear Disc can reduce their angular momentum and set some of the clumps on a plunging trajectory towards the supermassive black hole. If the central luminosity is determined by the gas accretion mechanism, then there exists a certain range of accretion rate and efficiency that allow the thermal instability to sustain the mass inflow through the two-temperature medium. Here we explore the stellar component of the nuclear star cluster which acts as an additional source of heating and contributes an additional energy input into the gaseous environment in the Galactic center Minispiral region. Under these conditions we discuss the values of relevant parameters that can support or suppress the thermal instability.

X-Ray Characteristics of Megamaser Galaxies

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Water-maser galaxies are a rare subclass of Active Galactic Nuclei (AGN). They play a key role in modern cosmology, providing a significant improvement for measuring geometrical distances with high precision. Therefore, megamaser studies presently measure H_0 to about 5%, and the goal of modern programs is to reach 3%, which would provide a powerful constraint on the equation of state of dark energy. An increasing number of independent measurements of water-masers is providing the statistics necessary to decrease the uncertainties. Studying these objects at X-ray energies yields important constraints on target-selection criteria for future maser surveys, leading to a higher detection rate. We have studied the X-ray properties of a unique and homogeneous sample of Type 2 AGN with water-maser activity observed by XMM-Newton to investigate the properties of megamaser-hosting galaxies compared to a control sample of non-maser galaxies, both analyzed in a uniform way. A comparison of the observed luminosity distribution confirms former studies, which showed that water-maser galaxies appear more luminous than non-maser sources. However, comparing the intrinsic luminosity distributions of both samples shows no significant difference. Our results indicate that the discrepancy can be solely explained by higher absorption and, hence, higher column densities in water-maser sources.

Relativistic Fe Kalpha line study in Seyfert 1 galaxies observed with SUZAKU

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Broad iron lines are expected, and observed, to be a widespread feature in bright AGN. However, a significant fraction of object misses a disk line component. We extracted from the sample of all Seyfert 1 galaxies the ones with no detection of a broad Fe Kalpha line, to investigate the physical reason for this absence. We analysed all archival Suzaku observations that, thanks to the broad energy band, allows us to investigate the connection between broad Fe Kalpha line and reflection continuum. I will start by presenting the detailed analysis on IC4329A, the brightest object of the sample. A relativistic Fe Kalpha line is detected with high significance only when all the observations are combined and the S/N ratio increases, demonstrating that high statistic is key to reveal broad Fe Kalpha lines. The data are also consistent with this feature being correlated to the emission at higher energies. I will also present the extension of this study to the sample: the relativistic Fe Kalpha line is primarily detected at the 95% of confidence level for those objects where the counts in the 5-7 keV energy band are greater than $2\text{x}10^5$.

The coronal parameters of local Seyfert galaxies

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One of the open problems for AGN is the nature of the primary X-ray emission: it is likely due to Comptonization of soft UV photons, but the optical depth and temperature of the emitting corona were largely unknown before the launch of NuSTAR. The Nuclear Spectroscopic Telescope Array (NuSTAR) is the first focusing X-ray telescope on orbit, $\sim$ 100 times more sensitive in the 10-80 keV band compared to previous observatories, enabling the study of AGN at high energies with high precision. We will present and discuss the results on the hot corona parameters of Active Galactic Nuclei that have been recently measured with NuSTAR (often in coordination with XMM-Newton or Suzaku) with unprecedented accuracy, in a number of local Seyfert galaxies.

Broad-band short term X-ray spectral variability of the quasar PDS 456

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We present an analysis of a recent 500 ks Suzaku observation, carried out in 2013, of the nearby (z=0.184) luminous ($L_{bol} \sim 10^{47}$ erg s^{-1}) quasar PDS 456 in which the X-ray flux was unusually low. Short term X-ray spectral variability has been detected, which may be caused by two variable coverers of column density log $(N_{H,1}/\mathrm{cm}^{-2})=22.3 \pm 0.1$ and log $(N_{H,2}/\mathrm{cm}^{-2})=23.2 \pm 0.1$ We find that the partial covering requires an outflow velocity of $\sim$ 0.25 c, coincident with the velocity of the highly ionised outflow at the 99.9 % confidence level. Therefore the partial covering clouds could be the denser clumpy part of an inhomogeneous wind. An obscuration event occurs 1250 ks into the observation, where the spectrum becomes totally opaque at Fe K. This implies that the size of the absorber and likewise the X-ray emitter, to be less than 20 Rg. We also analyse the flaring behaviour in the lightcurve. The behaviour of the soft and hard X-ray flux, suggested a corona characterised by an extended "warm" region of $\sim$ 20 Rg in size combined with more compact regions of "hot" electrons of $\sim$ 8 Rg in size.

A redshifted Kα line from the peculiar gamma-ray source PMN J1603-4904

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We present the latest results on the bright hard-spectrum gamma-ray source PMN J1603−4904, observed in the framework of the multiwavelength monitoring program TANAMI. High-resolution radio observations reveal a symmetric brightness distribution with the brightest, most compact component at the center of the emission region. Its broadband spectral energy distribution and other multiwavelength properties point to a very atypical blazar. Here, we focus on recent XMM-Newton and Suzaku observations. We detect a narrow iron line which allows for a first measurement of the redshift of the system ($z \sim 0.18$) and further challenges the earlier blazar classification. This result suggests that the source is observed at a larger angle to the line of sight than expected for blazars, and thus the source would add to the elusive class of gamma-ray loud misaligned-jet objects, possibly a gamma-ray bright young radio galaxy.

X-ray and UV Studies of the Central Engine in Seyfert NGC 3227 with Suzaku and Swift

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Accretion onto the supermassive black hole is considered to work as the central engine in an active galactic nucleus, efficiently generating radiation energy over broad frequencies, and kinetic energy in outflows and/or jets. However, the popular picture of the engine, described by just a corona and an accretion disk, is too simple, reflecting our insufficient understanding of its primary X-rays. Given this, we performed a model-independent and variability-assisted spectral decomposition (Noda+11,13) of the 2-45 keV Suzaku data of Seyfert NGC 3227. As a result, we discovered the simultaneous presence of at least two distinct primary continua, a fast-variable soft primary component (SPC) and slowly-varying hard primary component (HPC), reproduced by power-law functions with photon indices of 2.3 and 1.7, respectively (Noda+14). Furthermore, we compared the SPC and HPC intensities with the UV fluxes from the disk, measured simultaneously by Swift. Then, the HPC flux was found to tightly correlate with UV, while the SPC flux changes nearly independently. Thus, the engine in NGC 3227 is likely to consist of two coronae with distinct sizes and physical conditions. The one emitting the HPC is considered to have stronger positional and physical connections to the disk, than the other generating the SPC.

High-Resolution Spatially Resolved Spectroscopy of Sub-mm Galaxies at z∼2

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We have studied the properties of star forming regions of the sub-millimeter galaxies (SMGs) at redshift z∼2. Using SINFONI and adaptive optics integral field spectroscopy at the ESO VLT in Hα, we have determined the spatial distribution and kinematics of star forming regions in these galaxies at kilo parsec-scale. We identify in some sources evidence of galactic rotation and in others the Hα kinematics doesn't show evidence of ordered global motions, but rather large velocity offsets ($\sim$ few x 100 km s^{-1}). We also have spatially resolved clumps, where in some cases the star forming regions no match with the center of the galaxy. We found that SMGs display large Hα spatial extensions of 3-11 kpc, in contrast to the local environments. Our results indicate that the SMG in our sample have high surface densities of star formation activity, close to those found in local extreme environments, such as in circumnuclear starbursts and luminous infrared galaxies. However, considering the much greater spatial extents found for these SMGs ($\sim$ 8-11 kpc), the SMGs appear to be undergoing this intense activity on much larger spatial scales.

Measuring the Spin Parameter of the Supermassive Black Hole RXJ 1131-1231

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Attempts to constrain the spin parameter of a quasar are ongoing, yet the goal remains elusive. Recently, Reis et al. (2013) presented results from the analysis of Chandra spectra of the gravitationally-lensed quasar RXJ1131 and report to have constrained the spin of the supermassive black hole to be a= $0.87^{+0.08}_{-0.15}$ at the 3σ confidence level.

In our revised study we perform a detailed error analysis of the spin parameter that includes a search of the parameter space of spectral fits using an improved relativistic iron line model and a careful exclusion of data that have been corrupted by photon pile-up and/or microlensing. We conclude that when the data have been correctly screened for pile-up and microlensing no significant constrain can be placed on the spin parameter of the black hole of RXJ1131.

We use an independent approach of quasar microlensing to infer the inclination angle and size of the X-ray reflection region of RXJ1131.

Measurement of the black hole spin and the size of the X-ray source in AGNs with strong relativistic reflection

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I present an analysis of XMM-Newton and NuSTAR observations of the AGN in NGC 4051 and NGC 1365. In these two sources the strong relativistic bending produces a high equivalent width iron Kalpha line, and a reflection component dominating the emission at $\sim 20-30$ keV. I will discuss two results: (1) in these sources the presence of a relativistic reflection component is unavoidable based on physical arguments: alternative models, though acceptable statistically, lead to physical inconsistencies with the observations at other wavelengths, and imply highly super-Eddington luminosities; (2) a model reproducing an X-ray source with a size of a few gravitational radii is favored with respect to a lamp-post model. This is a first estimate of the size of the X-ray emitting corona based on X-ray spectroscopy.

Highly variable AGN in the XMM-Newton Slew Survey

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We investigate the properties of a variability-selected sample of AGN in order to identify the mechanisms which cause large amplitude X-ray variability on long time scales. A sample of 24 sources was constructed from AGN which varied in soft X-ray luminosity by more than one order of magnitude over 10–20 years between ROSAT observations and the XMM Slew Survey. Follow-up observations were obtained with the Swift satellite. We find that the sample has global properties which differ little from a non-varying control sample. A wide range of AGN types are present and the distribution of black hole masses is consistent with the non-varying sample. All the RQ sample have normal optical to X-ray ratios (alpha_OX) when at their peak but are X-ray weak during their lowest flux measurements. From this work, and previous studies on individual sources, we identify the variability mechanisms as: tidal disruption events (2), jet activity (2), change in absorption (3), thermal emission from the inner accretion disk (1) and variable accretion disk reflection (1). Little evidence for strong absorption is seen in the remainder of the sample and single-component absorption can be excluded as the mechanism for most sources.

The Seyfert that lost its big blue bump

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We present multi-epoch SEDs of the ″ultrasoft″, ROSAT WFC-detected Seyfert RE J2248-511. We used XMM-Newton, Swift, SAAO's 1.9m and Danish Telescope data to investigate the large big blue bump reported for this Seyfert. We found it to be strongly variable over the 7-year coverage, but our modelling suggests that this once intriguing object which fuelled debate about the NLS1/BLS1 distinction can be explained rather simply.

The continuum SED for the brightest epoch dataset is consistent with the mean SED of a standard quasar, and matches well to that from an XMM- SDSS sample of AGN with M/Msun $\sim 10^8$ and L/LEdd ~ 0.2: a normal BLS1. All the correlated optical and soft X-ray variability can be due entirely to a major absorption event. The only remarkable aspect of this AGN is that there is no measurable intrinsic X-ray absorption column in the brightest epoch dataset. The observed FUV flux is determined by the combination of this lack of intrinsic absorption and the fact that the source lies within a local absorption ″hole″.

RE J2248-511, which once defied classification, demonstrates that characterisation of such objects requires multi-epoch, multi-wavelength campaigns.

Laboratory measurements of K-shell transitions in highly charged iron ions

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Accurate atomic data of highly charged ions, especially of the iron K_α transitions, is needed to model and interpret the spectra of active galactic nuclei. However, most of this data is only known by theoretical calculations, thus testing them in laboratory measurements is crucial. We present our measurements of energies, natural linewidths [1], radiative and Auger decay rates [2] for K-shell transitions in He-like to F-like iron ions. In this experiments, an electron beam ion trap was used to create a target of highly charged ions, which were resonantly excited by monochromatic light from the PETRA III synchrotron radiation source. Fluorescence was observed while simultaneously detecting photoionization by the change in the ionic charge state. This method, combined with the high resolution of the monochromator used, yields uncertainties on the ppm-level for the excitation energies and below 10% for the linewidths and transition rates, thus providing a valuable benchmark for theory.

[1] J. K. Rudolph et al., Phys. Rev. Lett. 111, 103002 (2013)
[2] R. Steinbrügge et al., Phys. Rev. A 91, 032502 (2015)

X-ray reflection from black-hole accretion discs with a radially stratified ionisation

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Recent X-ray observations have suggested a very high compactness of coronae in Active Galactic Nuclei as well as in X-ray Binaries. The compactness of the source implies that the black-hole accretion disc irradiation is a strong function of radius. We will show how the X-ray spectra are modified assuming the radially stratified ionisation according to the illumination by a point-like source on the black-hole rotational axis. We will discuss how this affects the measurements of the other model parameters, such as spin and radial emissivity. We will show the application of this model to the recent XMM-Newton/NUSTAR data of an active galaxy MCG-6-30-15.

The NuSTAR X-ray spectrum of the low-luminosity AGN in NGC 7213

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In October 2014, NuSTAR performed a 100 ks observation of the low-luminosity, low accretion rate (0.1 per cent of the Eddington limit) active galactic nucleus (AGN) NGC 7213. We have analyzed its broadband (3-80 keV) X-ray spectrum to investigate the nature of the innermost region. In agreement with previous results we find a high-energy cut-off $Ec > 140$ keV, no evidence for a significant Compton reflection continuum and the presence of the three narrow iron K emission lines between 6.4 and 7 keV, possibly produced in the broad-line region. We analysed the time evolution of the iron lines on the time-scale of years by re-fitting archival observation of the source from XMM-Newton, Suzaku and Chandra. The analysis suggests a possible contribution from dusty gas. The fit with a Comptonization model indicates the presence of a hot corona with a temperature $kTe > 40$ keV and an optical depth $\tau < 1$. We compare our results with those found by NuSTAR in other low accreting AGN.

High-energy monitoring of Seyfert galaxies: the case of NGC 5548 and NGC 4593

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We discuss results of broad-band monitoring programs on the active galactic nuclei (AGNs) NGC 5548 and NGC 4593, focusing on the high-energy view with XMM, NuSTAR and INTEGRAL. NGC 5548 was the object of a successful multi-satellite campaign conducted from May 2013 to February 2014, during which the source appeared unusually obscured by a clumpy stream of ionized gas, causing strong absorption in the X-ray band and simultaneous deep, broad UV absorption troughs (Kaastra et al. 2014). A talk giving an overview of the campaign on NGC 5548 is also proposed at this conference (Cappi et al.). Concerning NGC 4593, it was the object of a monitoring program of 5×20 ks joint XMM/NuSTAR observations in January 2015, spaced by two days. In both cases, the availability of multiple, broad-band observations with a high signal-to-noise ratio allows us to disentangle the different spectral components present in the high-energy spectrum and properly study their variability. The use of realistic Comptonization models provides good constraints on the physical parameters of the hot corona responsible for the hard X-ray emission.

Driving Extreme Variability: Measurements of the changing coronae and evidence for jet launching

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Through analysis of the X-rays reflected from the accretion disc, it is possible to probe the innermost structures around accreting black holes and to measure the geometry and structure of the corona that produces the intense X-ray continuum.

We conducted detailed analysis of the narrow line Seyfert 1 galaxies 1H0707-495 and Markarian 335, over observations with XMM-Newton as well as Suzaku and NuSTAR spanning nearly a decade to measure the underlying changes in the structure of the X-ray emitting corona that gave rise to more than an order of magnitude variation in luminosity.

Underlying this long timescale variability lies much more complex patterns of behaviour on short timescales. We are, for the first time, able to measure the changes accompanying transient phenomena including a flare from Markarian 335 seen during a low flux state. This flaring event was found to mark a reconfiguration of the corona while there is evidence that the flare itself was caused by an aborted jet-launching event.

This gives us important insight into the processes by which energy is liberated from black hole accretion flows and allows observational constraints to be placed upon models of how jets are launched and how these extreme objects are powered.

Chapter 3

Spectral components (BHB)

Spectral analysis of the XMM-Newton data of GX 339-4 in the low/hard state during the outburst of 2013: Disk truncation radius and other issues

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We analyze three XMM-Newton observations of the black-hole binary source GX 339-4 taken during the decay phase of 2013 outburst when the source was in a low/hard state. Our analysis indicates a large truncation radius ($\sim 10 - 50 r_g$) for the three observations, which is in agreement with that obtained by Plant et al. (2014) for the same observations. We further extend the result in favour of the standard accretion scenario of the low/hard state. We find the reflection fraction to be small, which is consistent with the hot plasma filling the part of the source below the truncation radius. We further test our result against various models e.g., radius-dependent ionization and various ISM abundances. Finally, we try to find conditions of the inclination and the elemental abundance under which our fits are consistent with the mass function results of the source.

On the Optical - X-ray correlation from outburst to quiescence in Low Mass X-ray Binaries

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LMXBs show evidence of a global correlation between X-ray and optical luminosity. The origin of this correlation is debated. To unveil the mechanisms producing it, we study for the first time the optical – X-ray correlation of the black hole (BH) system V404 Cyg (V404) and the neutron star (NS) system Cen X-4 in outburst and in quiescence, over 6 orders of magnitude in X-ray luminosity. For Cen X-4 we find a power law correlation ($L_{opt} \propto L_X^{0.5}$) extending from outburst to quiescence. This is consistent with the optical emission being produced by X-ray reprocessing on the disc surface. We measure the same index for V404 in the hard state and quiescence. In outburst, at a given X-ray luminosity, V404 is 200 times optically brighter compared to Cen X-4. This difference is a factor 19 in quiescence, where the correlation breaks. The excess optical emission in V404 can be explained by the combination of three effects on the correlation. The BH has larger X-ray bolometric correction, mass and accretion disc size, and a strong jet contribution. These results have implications for the optical emission from LMXBs in general, as these two systems are representative of BH and NS systems, respectively.

Broad-band analysis of the spectral evolution of GX 339-4

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Black Hole X-ray binaries display large outbursts during which their spectral properties are strongly variable. Their high-energy emission includes the contribution of thermal and non-thermal components that are respectively attributed to the emission of an accretion disk and the one of a jet. How these structures form and evolve over time is still under investigation. The aim of our group is to provide the most up to date generic properties of these objects, as observed along the course of their outbursts, in order to constrain the theoretical models. Therefore, I will present the systematic broad-band analysis of the spectral properties of black hole binaries that we are currently developing, using the 2010 outburst of GX 339-4 as an example. I will give an overview of the results we obtained using observations at all wavelengths from proprietary radio data to hard X-rays.

Evidence for changes in the radiative efficiency of transient black hole X-ray binaries

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We present analysis of the decay into quiescence of outbursts from black hole X-ray binaries using pointed RXTE data. We find that the decay into quiescence consists of two distinct periods of exponential decay with different e-folding times. We consider the possible explanations for this and conclude that a switch to radiatively inefficient accretion at low luminosities best matches the results.

The complex accretion geometry of GX339-4 as seen by NuSTAR

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We present an in-depth spectral analysis of a failed outburst of GX 339-4 in 2013, as observed by NuSTAR and Swift. During this outburst, the source never left the low-hard state and our observations cover Eddington luminosity fractions between 0.9% and 6%. The high quality NuSTAR data allow us to study the weak reflection component in this state. We show that the source very likely has a complex coronal geometry, in which the parts illuminating the accretion disk have a significantly harder spectrum than the observed primary continuum. While we observe a relativistically broadened iron line, the complex corona makes it challenging to put stringent limits on the inner accretion disk radius. The measured values depend strongly on assumptions for the emissivity profile of the accretion disk and we discuss various scenarios. All models, however, clearly require inner disk radii smaller than 100 r_g. We compare these spectra to NuSTAR observations of a subsequent full outburst in 2015. We discuss differences in the continuum parameters possibly related to luminosity, which indicate changes in the accretion geometry.

Focused winds in high mass X-ray binaries: the case of Cyg X-1/HDE 226868

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As persistent sources, high mass X-ray binaries (HMXB) are ideal objects for observations aimed at deciphering properties of accretion and ejections flows. However, HMXBs are also strongly affected by the presence of strong, line-driven winds from the hot, massive companion stars. These winds drive the accretion towards the compact object, but also interact with both the radiation and the outflows produced in the inner regions, and have been suggested to majorly influence state transitions. The strongly variable absorption from the wind material has to be taken into account when analyzing HMXB observations.

Here we use ~ 5 Msec of RXTE observations of the HMXB Cygnus X-1 to constrain the orbital variability of the companion wind throughout different X-ray states. The variability can only be explained if we account for the presence of cold, dense clumps embedded in a tenuous hot gas. We put constraints on the porosity of such a two-component wind. We also show that even given the RXTE's limited coverage of the soft X-ray bandpass, we can only constrain the spectro-timing evolution of the source if we simultaneously account for the variable wind absorption.

X-ray Polarimetry Studies of Black Holes with the The Polarization Spectroscopic Telescope Array (PolSTAR)

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The proposed X-ray polarimetry mission, PolSTAR, will provide a new way to dissect the inner regions of accretion flows onto black holes and test General Relativity in the strong gravity regime. With the ability to make highly sensitive measurements over the broad range of energies from 2.5-70 keV it will allow for the opportunity to study the numerous phenomena observed in black holes. For example, polarization measurements of the thermal emission from stellar mass black holes can be used to fit to measure the spin and inclination of the inner disk with a high degree of accuracy, and to search for the polarization signatures of the Lense Thirring precession of the inner accretion disk. The polarimetric observations can furthermore be used to distinguish between different corona models for stellar mass and supermassive black holes. Last but not least, polarimetric observations can be used to reveal if helical magnetic fields play a role in the formation of the highly relativistic black hole outflows (jets).

Broadband X-ray Study of the Galactic Black Hole Binary 4U 1630–47 with Suzaku

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We present the results from an X-ray observation of the Galactic black hole binary 4U 1630–47 in the very high state performed with Suzaku in the 2012 September-October outburst. The continuum is well described with a multicolor disk and its Comptonized components by thermal and nonthermal electrons. The inner disk appears slightly truncated by comparison with a previous high/soft state of this source, even by taking into account energetic coupling between the disk and corona. Our X-ray spectra do not show the Doppler-shifted emission lines indicating baryonic jets that were seen four days previously in an XMM-Newton observation, despite the source being in a similar state. There are no significant absorption lines from highly ionized iron lines as were seen in the previous high/soft state data. We show that the increased source luminosity is not enough on its own to make the wind so highly ionized as to be undetectable, indicating that the disk wind has changed in terms of its launch radius and/or density compared to the high/soft state. We will also report the results of simultaneous Suzaku and NuSTAR observations of 4U 1630–47 made in an early epoch of the 2015 outburst.

Evidence for a variable accretion geometry in the black hole binary SWIFT J1753.5-0127

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The ongoing outburst of the black hole binary Swift J1753.5-0127 is providing a unique data-set to study accretion flows. Various investigations since the onset of its outburst from 2005 have not, however, led to converging conclusions regarding the accretion flow geometry, nor regarding the origin of the X-ray spectral components. In this poster we present the results from our spectral analysis of Swift J1753.5-0127 using quasi-simultaneous archived data from INTEGRAL/ISGRI, Swift/XRT, RXTE/PCA/HEXTE and MAXI. We find that during late outburst stages the X-ray spectral evolution is fully consistent with synchrotron self-Compton emission from the inner hot flow, and that the cold, optically thick accretion disc doesn't produce the seed photons for the Comptonised hard X/gamma-ray emission. The optically thick accretion disc likely never reaches the innermost stable circular orbit, except perhaps during the soft state transitions that manifest themselves as dips in the hard X-ray Swift/BAT light curve.

A New Characterization of the Compton Process in the ULX Spectra

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Ultra Luminous X-ray sources (ULXs) are unusually luminous point sources located at arms of spiral galaxies, and are candidates for the intermediate mass black holes (Makishima+2000). Their spectra make transition betweens power-law shapes (PL state) and convex shapes (disk-like state). The latter state can be explained with either the multi-color disk (MCD)+thermal Comptonization (THC) model or a Slim disk model (Watari+2000). We adopt the former modeling, because it generally gives physically more reasonable parameters (Miyawaki+2009).

To characterize the ULXs spectra with a unified way, we applied the MCD+THC model to several datasets of ULXs obtained by *Suzaku*, *XMM–Newton*, and *Nu–Star*. The model well explains all the spectra, in terms of cool disk ($T_{\rm in} \sim 0.2$ keV), and a cool thick ($T_{\rm e} \sim 2$ keV, $\tau \sim 10$) corona. The derived parameters can be characterized by two new parameters. One is $Q \equiv T_{\rm e}/T_{\rm in}$ which describes balance between the Compton cooling and gravitational heating of the corona, while the other is $f \equiv L_{\rm raw}/L_{\rm tot}$, namely, the directly-visible (without Comptonization) MCD luminosity. Then, the PL state spectra have been found to show $Q \sim 10$ and $f \sim 0.7$, while those of the disk-like state $Q \sim 3$ and $f \leq 0.01$. Thus, the two states are clearly separated in terms of Q and f.

Tracking a hard state radio-quiet to radio-loud transition in the black hole X-ray binary Swift J1753.5−0127

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A lot of effort has gone into trying to explain the two radio/X-ray correlation tracks seen in the low/hard state of black hole binaries in recent years. The standard correlation of the form $L_R \propto L_X^{0.6\pm0.1}$ is clearly paired with a lower, radio-quiet track with a slope of ∼1-1.4, although a generally accepted cause for this remains unclear.

We present simultaneous radio/X-ray observations of Swift J1753.5-0127, spanning over a year in time, which seem to confirm the steep-slope radio-quiet nature of the source. Our X-ray-faint sample complements previous higher luminosity observations, making Swift J1753 one of the best sampled sources in $L_X - L_R$. We find that the source shows possible signs of dual track behaviour, as it moves from the radio-quiet track towards the standard correlation track with decreasing X-ray flux. We discuss possible physical explanations for this behaviour, but find no obvious parameters to explain the observed transition.

Accretion flows govern black hole jet properties

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The process of jet formation in accreting black holes, and the conditions under which it occurs is currently hotly debated, with competing models predicting the jet power to be governed by black hole spin, the magnetic field strength, the location of the jet base, the mass accretion rate and/or the properties of the inner accretion flow. We present new results that show empirical correlations between the accretion flow properties and the spectral energy distribution of the jets launched from accreting black holes. The X-ray power law is directly related to the particle energy distribution in the hot accretion flow. We find that the photon index of this power law correlates with the characteristic break frequency in the jet spectrum emitted near the jet base, and the jet luminosity up to the break frequency. The observed correlations can be explained by the energy distribution of electrons in the hot accretion flow being subsequently channeled into the jet. These correlations represent a new inflow–outflow connection in accreting black holes, and demonstrate that the spectral properties of the jet rely most critically on the conditions in the inner accretion flow, rather than other parameters such as the black hole mass or spin.

Spectral state dependence of the high energy polarised emission in Cyg X-1 seen with INTEGRAL and link with the AMI-15 GHz radio data Jerome Rodriguez[1], Victoria Grinberg[2], Philippe Laurent[3], Marion Cadolle Bel[4], Katja Pottschmidt[5,6], Guy Pooley[7], Arash Bodaghee[8], Jörn Wilms[9], Christian Gouiffes[1]

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We present a spectral state resolved analysis of all the INTEGRAL/IBIS observations of Cyg X-1 obtained until December 2012, and study the radio behaviour of the source with the AMI/Ryle (15 GHz) radio data. The observations can be separated into hard, soft, and intermediate/transitional states. Radio emission from a compact jet is detected in the hard and intermediate states, but not in the soft.

The 10-400 keV INTEGRAL (JEM-X and IBIS) state resolved spectra are well modeled with thermal Comptonization and reflection components, and a hard tail component is present in the 0.4-2 MeV range for the hard state only.

Possible polarisation is detected only in the 400–2000 keV range in the hard state, with a fraction 75+-32 % and an angle $\sim 40°$. The likely detection of a > 400 keV polarized hard tail, together with the simultaneous presence of a radio jet in the hard state, reinforce the notion of a compact jet origin of the 400 keV emission.

Probing the black hole mass in supersoft ultra luminous X-ray source ULX-1 in NGC 5457 galaxy

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The mass value of compact object in ultra-luminous X-ray sources (ULXs) is crucial to understanding the nature of source (a stellar mass or intermediate mass black hole) powering ULX. The mass evaluation for the black hole (BH) in X-ray binaries is mainly provided by dynamical method, when the BH mass estimate bases on measuring the radial velocity of its companion. However, in case of ULX the X-ray accretion disk often dominates the optical emission, which complicates a reliable mass diagnostic. In contrast, here we suggest to apply the scaling technique for the mass determination of central object of ULX-1 in NGC5457 using X-ray band emission. We show that ULX-1 undergoes an X-ray spectral "transitions" from low to high states during Swift and Chandra observations. We show that the X-ray energy spectra during all spectral states are well tted by the Comptonization model with seed photon temperature of 40-100 eV. We have established the photon index (Γ) saturation level at about 2.8, in the Γ vs. mass accretion rate ($\dot{M}$) correlation. This $\Gamma\dot{M}$ correlation allows us to evaluate BH mass in NGC5457 ULX-1, $M_{BH} \geq 10^4 M_{\odot}$. This is robust observational evidence for the presence of a BH in M101 ULX-1.

The unusual accretion state of the black hole candidate Swift J1753.5-0127

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The transient Swift J1753.5-0127 (hereafter J1753) is a short-period, (candidate) black hole X-ray binary (BHB) in the Galactic halo. J1753 is unusual in that it did not return to quiescence after the initial outburst faded, instead it has remained in the low-hard state. A remarkable feature of J1753 is the presence of a number of extended X-ray dips in the Swift-BAT light curve, which appear to be related to a very short term spectral softening of the source. In March 2015, the Swift-BAT count rate dropped to 0.001 cts/s, indicative of another state transition. Swift XRT observations revealed a very soft spectrum, well constrained with a multicolor disc model plus an additional powerlaw component with photon index Γ=4.28. However, the inner disc temperature of $\sim$0.35keV was reminiscent of a hard-state disc, despite the 0.6-10keV flux being dominated by the soft (0.6-2keV) band. This is unlike any accretion state seen previously in BHBs. We present here the results of an extensive, multi-wavelength observing campaign of J1753 in this apparently new state, including contemporaneous XMM-Newton and NuSTAR pointings. This gives us unrivalled spectral coverage up to 79keV, providing us with the clearest picture yet of the accretion disc of this unusual source.

X-ray outburts from a candidate black hole binary in NGC 55

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We serendipitously discovered a X-ray transient source, XMMU J001446.81-391123.48, in the Magellanic-type, SB(s)m galaxy NGC 55. The X-ray transient was undetectable in the 2001 *XMM-Newton* and 2004 *Chandra* observations, but detected in a 127 ks long *XMM-Newton* observation at a significance level of 9σ in the 0.3 - 8 keV bandpass. The source spectrum is thermally dominated and well described by a 0.70 ± 0.06 keV disc blackbody, but is also consistent with a power law model with photon index of 3.17 ± 0.20. The strong short-term X-ray variability and the high observed luminosity ($\sim 10^{38}$ erg/s) strongly suggest an X-ray binary nature for the source. The source exhibited recurrent outbursts in the *Swift* X-ray Telescope (XRT) observations with period about a month. The spectra can be fitted with power law (with index $\sim 2.5 - 2.9$) or a disc blackbody ($kT_{in} \sim 0.8 - 1.0$ keV). In the *Swift* observations, the source changed its luminosity by an order of magnitude and reached the peak luminosity $\sim 2 \times 10^{39}$ erg/s, without significant change in the spectral parameters. The spectral and temporal properties of the source suggest that XMMU J001446.81-391123.48 is possibly a new transient black hole X-ray binary in NGC 55.

The X-ray spectra of the black hole candidate 4U 1630-47 during its 2012 outburst

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Diaz Trigo et al. (2013) reported the detection of three Doppler-shifted emission lines arising from baryonic matter in the jet of 4U 1630-47 during its 2012 outburst. Here we propose an alternative model that, without the need of the lines from the jet, and with less free parameters, fits the same data equally well. In our model we allow the abundances of S and Fe in the interstellar medium to vary; the best-fitting values are, respectively, 1.5 and 0.5 times solar, consistent with recent findings. Our model also includes a moderately broad emission line and a narrow absorption line due to highly ionised Fe. (These lines are also present in the other observations of this source during the 2012 outburst.) This model fits well all the XMM-Newton observations of this source, both in burst and timing mode. In addition to the components that we fitted to the burst-mode data, the timing-mode observations show several absorption features due to ionised Fe and Ni, which reveal the presence of a highly-ionised absorber close to the source. Our model also fits well the burst-mode data using the most recent calibration files (March 2015), whereas the model from Diaz Trigo et al. does not.

Accretion onto the intermediate mass black hole candidate ESO 243-49 HLX-1

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The mechanism for the formation of supermassive black holes is still unclear, but many of the theories proposed to explain their origin evoke lower mass seed black holes (intermediate mass black holes) as their progenitors. However, the observational evidence for these intermediate black holes has until recently been weak. Further, how such intermediate mass black holes can accrete sufficient matter to shine brightly has also posed problems. Here we present the best intermediate mass black hole candidate, ESO 243-49 HLX-1, which reaches X-ray luminosities in excess of 1e42 erg/s and discuss both the accretion and ejection mechanisms that have been proposed to explain this exceptional object. We also review the available observational evidence for the origin of this rare system.

Chapter 4

Spectral components (Theory)

High resolution cosmological zoom simulations of SMBHs at high redshift

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In recent years simulations of supermassive black holes in a cosmological context have been attempting to answer the question whether, given our current understanding of the process, we are able to grow SMBHs from stellar mass seeds to the quasars observed by redshift z=6. The emergent consensus points to the fact that there is in fact enough gas being funnelled from the ISM to the inner few parsecs of the galaxies to feed the black hole at its centre. However, whether enough of this gas is able to shed its angular momentum and reach scales on which an accretion disc starts to form is still open to debate. This poster will show results of new RAMSES simulations that are able to track the gas from intergalactic scales down to about 0.1 pc, greatly extending the range probed so far.

Constraining Key Coronal Parameters of Black Holes via X-ray Reflection Spectroscopy

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The fundamental parameters describing the coronal spectrum of an accreting black hole are the slope Γ of the power-law continuum and the energy E_{cut} at which it rolls over. Remarkably, these parameters can be accurately measured at energies of 1 MeV by modeling the spectrum of X-rays reflected from a black hole accretion disk at energies below 100 keV. This is possible because the details in the reflection spectrum, rich in fluorescent lines and other atomic features, is very sensitive to the spectral shape of the hardest coronal radiation illuminating the disk. By fitting simultaneous *XMM-Newton* and *NuSTAR* data using the most recent version of our reflection model `relxill`, we show that one can obtain reasonable constraints on E_{cut} at energies from tens of keV up to 1 MeV, for a source as faint as 1 mCrab in a 100 ks observation. The most crucial data are those provided by *XMM-Newton* at energies below a few keV. Importantly, our results indicate that the past practice of estimating the cutoff energy by fitting only the power-law continuum gives inaccurate and misleading results.

turbulent-convection accretion disk with super-critical accretion

Itzhak Goldman[1]
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The talk presents a selfconsistent model for an accretion disk in which the turbulent viscosity is due to turbulent convection and the vertical flux is the sum of the radiative and convective fluxes.

The model allows for both gas pressure dominated solution and radiation pressure dominated solution also for highly super-critical accretion. In this case the convective flux is much larger than the radiative flux.

Unlike in advection dominated disks, here the luminosity is emitted from the disk vertically and is highly super-critical enabling the acceleration of jets from the disk corona.

For a gas pressure dominated solution, the emitted spectrum is a black body while for the radiation pressure dominated solution it is a blackbody modified by electron scattering. These spectra are superposed with the bremsstrahlung spectrum from the disk corona.

Disk reprocessing in three dimensions - emerging spectra and polarization

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We present the latest results from our ongoing computation of a new X-ray reprocessing model for irradiated, ionized accretion disks observed e.g. in active galactic nuclei and X-ray binaries. Combining a semi-analytical radiative transfer method (TITAN) with Monte-Carlo simulations (STOKES), we obtain a grid of reprocessed intensity and polarization spectra across an energy range of 0.1–100 keV with sufficient energy resolution to be applied to NuSTAR and even Astro-H observations. The model includes all polar and, for the first time, also azimuthal dependencies of the local incident and emission angles. As it was shown previously, these dependencies matter once the observed spectrum at infinity is computed by a relativistic ray-tracing routine. The Monte-Carlo treatment of the disk reprocessing also allows us to investigate in detail the impact of thermal and turbulent velocity on the line transfer, which can affect the observed amount of soft X-ray emission. Finally, we explore the impact of the high and low energy cutoff of the irradiating spectrum on the reprocessing and we determine the timing response of the disk spectrum as a function of photon energy. We conduct a comparison of our results with existing X-ray reprocessing models.

Rotation curves and attractive forces in the Universe

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The hydrodynamic model of the motion of the cosmologic objects is proposed. The obtained solution gives the description of the rotation curves by the positive parts of the Bessel functions. The forms of rotation curves depend upon the parameter β (depending on the angular velocity, dimension and velocity of the progressive motion of the object). The case $\beta \gg 1$ corresponds to the rotation curves of the planets; the solution coincides with the Kepler-Newton law. In the case of parameters $\beta \leq 1$ we have different rotation curves of the galaxies without invoking dark matter hypothesis. In this model, the expression for the attractive force is derived. In the case of the planets, (when $\beta \gg 1$), the form of the attractive force coincides with the Newton law. In the case of the galaxies the attractive force differs sufficiently from the Newton law, the force propagates far from the edge of the galaxy.

Super-Eddington accretion in ultra-luminous neutron star binary

Maxim Lyutikov[1]
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We discuss properties of the ultra-luminous X-ray source in the galaxy M82, NuSTAR J095551+6940.8, containing an accreting neutron star. The neutron star has surface magnetic field BNS = 1.4 10 13 G; the accretion torque on the neutron star is reduce well below what is expected in a simple magnetospheric accretion due to effective penetration of the stellar magnetic field into the disk beyond the corotation radius. The neutron star is nearly an orthogonal rotator, with the angle between the rotation axis and the magnetic moment larger than 80 degrees. Accretion occurs through optically thick - geometrically thin and flat accretion curtain, which cuts across the polar cap. The X-ray luminosity (pulsed and persistent components) comes both from the neutron star surface as a hard X-ray component and as a soft component from reprocessing by the accretion disk.

Eclipsing the X–ray emitting regions in AGN

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Variable X–ray absorption has been observed in AGN on several timescales. Observations have allowed us to identify the absorber with clouds associated either with the clumpy torus (parsec scales, long timescales) or with the broad line region (short timescales). In the latter, the cloud size has been estimated to be of the order of few gravitational radii from the observed absorption variability. Such small cloud sizes are comparable to the X–ray emitting regions so that a detailed modeling of occultation events in AGN has the potential of enabling us to infer accurately the geometry of the system. We have developed a relativistic X–ray spectral model for occultation events and we present here theoretical predictions on the different observables that can be inferred by studying X–ray eclipses and occultation events in present and future X–ray data. These include the size of the continuum and of the X–ray soft excess emitting regions as well as more fundamental parameters such as black hole spin and system inclination. Moreover, we show the expected effects of such occultation events on the relativistic reflection component (and broad Fe line) that is often detected in the X–ray spectrum of AGN.

Chapter 5

Variability (Broadband)

Monitoring of the flaring activity of Galactic Center SMBH with ATCA

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The Galactic Center (GC) harbors a compact radio, infrared, and X-ray source which is associated with the 4 million solar mass SMBH, called Sagittarius A* (Sgr A*), located approximately 8 kpc away. Sgr A* is currently classified as inactive, although it is known to undergo regular flaring events, which suggests that it accretes matter sporadically. Its proximity allows us to study the immediate vicinity of a SMBH and compare its properties with nearby low luminosity active galactic nuclei.

We performed the monitoring observations of the Galactic Center to study the flux density variations at 3mm using the ATCA between 2010 and 2014. This makes it the largest database of observations of the GC at 3mm with 12 hrs of observation each day. We detect five instances of significant variability in the flux density of Sgr A*, with variations between 0.5 to 1.0 Jy, lasting for 1-2 hours. We use the adiabatically expanding plasmon model to explain the variations, and report the analysis of the results.

An Intermediate-Mass Black Hole candidate in M51

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We undertake a study of M51 ULX-7, using archival data from XMM-Newton, Chandra and NuSTAR, and optical and radio data from HST and VLA. The source has a consistently hard powerlaw X-ray spectrum with $\Gamma \sim 1.5$ and has high short-term variability, with all XMM-Newton observations having 30–40 percent rms. This is unusual variability behaviour for a ULX as we would expect highly variable ULXs to have soft spectra. The power spectrum features a break at $\sim 10^3$ Hz, from low frequency spectral index $\alpha = 0.1$ to high frequency spectral index $\alpha = 0.8$, analogous to the low frequency break found in power spectra of black holes accreting in the low/hard state. We do not observe a corresponding high frequency break, however taking the white noise level as frequency upper limit, we can calculate a black hole mass upper limit of 9.12×10^4 solar masses, assuming that the ULX is in the low/hard state. While there is no radio detection, we find a flux density upper limit of 87 μJy/beam. Using the X-ray/radio fundamental plane, we calculate a black hole mass upper limit of 1.95×10^5 solar masses. Therefore, this ULX is consistent with being an IMBH accreting in the low/hard state.

Swift/HST reverberation mapping of the accretion disk in NGC 5548: lessons for XMM?

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Swift/HST monitoring of NGC 5548 yielded the most intensive AGN continuum sampling ever obtained, covering seven UV/optical bands with a mean sampling rate <0.5-day over 125 days. The UV/optical light curves are strongly correlated ($r_{max} = 0.57 - 0.90$) with interband lags well-fit by a $\lambda^{4/3}$ wavelength dependence. This indicates an unexpectedly large disk size of $\sim 0.35 \pm 0.05$ lt-day at 1367Å, assuming a simple face-on model. The U-band shows a larger lag than expected, which could be due to Balmer continuum emission from the broad-line region as suggested by Korista and Goad. Combining this accretion disk size estimate with those estimated from microlensing studies suggests that AGN disk sizes scale approximately linearly with central black hole mass over a wide range of masses. Swift is capable of performing similar campaigns on a sample of AGN with BH masses $\sim 10^7 - 10^8 M_S$.

XMM could perform a similar experiment on lower-mass AGN ($< 10^6 M_S$), which would greatly extend the statistical leverage for determining how disk size depends on properties such as mass and Eddington ratio. I will outline how such an experiment could be designed. However this would require a change in the way the OM is used.

Power-Colours: Direct Power Spectral Comparison

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Variability observed from accreting compact objects, such as black hole X-ray binaries, uniquely allows us to directly probe timescales within the accretion disc. When variability features show comparable properties (i.e. peak frequencies) for different objects, we can infer that the structure of the accretion flow is similar and the sources are thus in the same state. I will explain how a simple method to identify observations with the same broad-band variability properties unlocks a new way to directly compare the emission from different black hole X-ray binaries. I will expand on how making comparisons between this one probe of the accretion flow structure and others, such as the reflection, can lead to a deeper understanding of how the flow evolves over the course of an outburst.

Long-term photometric monitoring of binary systems with neutron star components

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Long-term photometric variation of the selected X-ray binaries with neutron star components are studied. We obtained new BVRI data of the selected systems at TUBITAK National Observatory (TUG) with 60cm Robotic telescope. We present long and short magnitude variations of these systems.

Fast X-ray (and optical?) flashes; signs of a tidal disruption of a white dwarf by an IMBH?

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Tidal disruption events are our prime source of information on the large population of otherwise dormant black holes. We will highlight the recent results on tidal disruption flares by intermediate-mass black holes obtained from XMM and Chandra observations as well as perhaps recent results of the new Gaia satellite mission that recently started routine operations. We are part of Gaia's Data Analysis and Processing Consortium charged with allowing the rapid dissemination of inter-CCD variability detectable by Gaia. This inter-CCD variability of astronomical sources probes timescales related to TDEs of white dwarfs by an intermediate-mass black hole.

Long-term photometric monitoring of binary systems with black hole components

Dolunay Kocak[1], Kadri Yakut[1]
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In this study, we present long term BVRI monitoring of some selected X-ray binaries with black hole components. New observations obtained by using the 60cm Robotic telescope at the TUBITAK National Observatory (TUG). Multicolor photometric behavior of the selected systems will be discussed in this poster.

Looking inside jets: optical polarimetry as a probe of Gamma-Ray Bursts physics

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It is broadly accepted that gamma-ray bursts (GRBs) are powered by accretion of matter by black holes, formed during massive stellar collapse, which launch ultra-relativistic, collimated outflows or jets. The nature of the progenitor star, the structure of the jet, and thus the underlying mechanisms that drive the explosion and provide collimation, remain some of the key unanswered questions. To approach these problems, and in particular the role of magnetic fields in GRBs, early time-resolved polarimetry is the key, because it is the only direct probe of the magnetic fields structure. Using novel fast RINGO polarimeter developed for use on the 2-m robotic optical Liverpool Telescope, we have made the first measurements of optical linear polarization of the early optical afterglows of GRBs, finding linear percentage polarization as high as 30% and, for the first time, making time-resolved polarization measurements. I will present the past 8 years of RINGO observations, discuss how the results fit into the GRB theoretical picture, and highlight recent data, in particular high-time resolution multi-colour optical photometry performed during the prompt GRB phase, which also provides some limits on polarization.

The EXTraS project: Exploring the X-ray Transient and variable Sky

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Modern X-ray observatories can yield unique insights into time domain astrophysics. Indeed, a huge amount of information is already stored - and largely unexploited - in data archives. The EXTraS project harvests the hitherto unexplored temporal domain information buried in the serendipitous data collected by the European Photon Imaging Camera (EPIC) instrument onboard the ESA XMM-Newton mission since its launch. This includes a search for fast transients, missed by standard image analysis, and a search and characterization of variability (both periodic and aperiodic) in hundreds of thousands of sources spanning more than nine orders of magnitude in time scale (from less than 1 s to 10 yr) and six orders of magnitude in flux (from 10^{-9} to more than 10^{-15} erg cm^{-2} s^{-1} in 0.2-12 keV). X-ray results are to be complemented by multi-wavelength characterization of new discoveries. Phenomenological classification of variable sources will also be performed. Our final catalogue and results will be made available to the community, together with new analysis tools, at the end of the project (late 2016). EXTraS is funded within the EU/FP7-Cooperation Space framework and is carried out by a collaboration including INAF (Italy), IUSS (Italy), CNR/IMATI (Italy), University of Leicester (UK), MPE (Germany) and ECAP (Germany).

X-ray Timing Properties of the QSO, PG 1211+143

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I will present an analysis of the timing properties of the famous QSO PG 1211+143, based on a large $\sim$ 600 ks campaign with XMM-Newton. In particular, I will focus on the X-ray time lags, where, in addition to a high-frequency soft lag, we detect a significant low-frequency hard lag for the first time in this source with XMM. I will show that, similar to XRBs and lower-mass Seyferts, the hard lag in PG 1211+143 exhibits significant variability and energy-dependence, potentially with one of the longest time delays observed in an AGN to date. I will also present the results of simultaneous optical/UV monitoring with XMM-Newton's OM and a Swift ToO programme, where we find evidence for a correlation between the optical/UV flux and X-rays.

X-ray Spectral and Variability Properties of Low-Mass AGN

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We study the X-ray properties of a sample of 14 optically-selected low-mass AGN whose masses lie within the range $10^5 - 2 \times 10^6 M_\odot$ with *XMM-Newton*. Only six of these low-mass AGN have previously been studied with sufficient quality X-ray data, thus, we more than double the number of low-mass AGN observed by *XMM-Newton* with the addition of our sample. We analyze their X-ray spectral properties and variability and compare the results to their more massive counterparts. The low-mass AGN exhibit rapid, short-term variability (hundreds to thousands of seconds) as well as long-term variability (months to years). There is a well-known anti-correlation between black hole mass and variability amplitude. Comparing our sample of low-mass AGN with this relation we find that all of our sample lie below an extrapolation of the linear relation. Such a flattening of the relation at low masses (below $\sim 10^6$ $M_\odot$) is expected if the variability in all AGN follows the same shape power spectrum with a break frequency that is dependent on mass. Finally, we also found two objects that show significant absorption in their X-ray spectrum, indicative of type 2 objects, although they are classified as type 1 AGN based on optical spectra.

X-ray - UV/optical lag measurement in the very low mass AGN NGC4395 using the OM in sub-second readout mode: Implications for disc models

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The lag between the X-ray and UV/optical variations in AGN is a strong diagnostic of the emission processes in those bands; eg an X-ray lag means that seed photon variations drive X-ray variability but an X-ray lead means that the UV/optical variations result from reprocessing of X-rays by a surrounding accretion disc. Previous RXTE-based observations suggest that the UV/optical usually lags, although with large uncertainty. Recent Swift observations of NGC5548 (McHardy et al 2014; Edelson et al 2015), mass 4e7 solar, confirm a definite UV/optical lag, but the lag is larger than expected from a standard Shakura-Sunyaev disc model. To properly test our understanding of disc models it is vital to make similar lag observations of an AGN of very different mass. Here we report XMM-Newton observations of the low mass (3e5 solar) AGN, NGC4395. Using the OM in sub-second readout mode, we find that UVW1 lags the X-rays (EPIC) by ~ 450 s. We consider the implications of this result and of parallel ground based g-band observations, together with our previous Swift observations, for our understanding of accretion discs. To the best of our knowledge, these observations represent the first successful use of the OM fast-readout mode for AGN lag measurements.

Variabilities of the X-ray Broad Iron Spectral Features in Active Galactic Nuclei and Black-hole Binaries

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Active Galactic Nuclei (AGN) and black-hole binaries (BHB) often exhibit X-ray broad iron spectral features ("disk-line"), which may be explained either by the "relativistic disk reflection" scenario or the "partial covering" scenario. It is hardly possible to determine which models are valid from time-averaged spectral analysis, thus X-ray spectral variabilities have been investigated to constrain spectral models. To that end, it is crucial to study iron structure of BHBs in detail at short time-scales. This is made possible with the Suzaku XIS Parallel-sum clocking (P-sum) mode, which has the CCD energy-resolution as well as a time-resolution of 7.8 ms. We have carried out systematic calibration of the P-sum mode, and investigate spectral variabilities of GRS 1915+105. Consequently, we found that the spectral variabilities of GRS 1915+105 does not show iron features at sub-seconds. This is totally different from AGN variabilities, where the variability significantly drops at the iron energy band. This indicates that spectral variability timescales of AGN and BHB are not simply normalized by black-hole masses, which is naturally understood in the framework of the "partial covering" scenario.

Signatures of reverberation signals in the X-ray power-spectra of AGN

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Numerous X-ray "negative" time-lag measurements in AGN have been reported in the past five years using mainly XMM-Newton data in the 0.3-10 keV energy range. These time-lags are supposed to be caused by X-ray reverberation, i.e. they are believed to be due to the light travel time delays between the direct X-ray continuum emission and the reprocessed emission from the inner radii of the accretion disc. If X-ray reflection operates in the innermost parts of the disc then the X-ray reverberation signals should also affect the power spectra in energy bands where the X-ray reflection is expected to be strong, i.e. in the iron-line (5-7 keV) band, and at energies > 10 keV where the Compton reflection emission should be significant. We will present the predictions of these effects using fully relativistic transfer functions in the case of the "lamp-post" geometry. We will also present results from the comparison between the predictions and observed X-ray power spectra in the 5-7 and 10-20 keV bands, and the comparison with the time-lags measurements in the same objects.

Massive, long-duration, soft X-ray flares from galactic nuclei

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During the ROSAT and XMM-Newton sky surveys a very small number of giant (factor > 100), soft, X-ray flares have been seen in galactic nuclei. Their very rarity shows that they are not produced by a common AGN process. While they all tend to show similar decay curves, the rise and plateau sections of the flare vary considerably between sources. Flares which rise and decay on a timescale of weeks to months fit easily into the category of Tidal Disruption Events (TDE) where the black hole is temporarily fueled by stellar debris. But what about events, such as NGC 3599 and GSN 069 which have a peak flux lasting for years or IC 3599 where the flare repeated after 20 years ? The behavior of these three galaxies is similar to that of black hole binaries such as GRS 1915+105, where the flare is commonly attributed to an accretion disc instability, leading to an emptying and refilling of the inner disc. However, recent numerical simulations indicate that TDE occurring in galaxies with $M_{BH} < 6 \times 106$ solar masses, may also have light curves which take years to reach peak flux. We explore both of these possibilities in detail.

Completing the identifications of XMM-Newton Slew Survey sources

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We present a follow-up programme aimed at providing a step forward in completing the identifications of a substantial sample of XMM-Newton Slew Survey sources. 94 unidentified X-ray sources from the XMM Slew Survey were followed up with Swift, among which 29% were detected and subsequent optical spectroscopy at the WHT was carried out where possible. We identify 10 of these sources as stellar in nature, including one periodic variable, and 11 as AGN with redshifts spanning z = 0.2 - 0.9. Among the Swift-undetected objects, we suggest most if not all are extragalactic, though unlikely to be highly absorbed sources in the X-rays such as Compton thick AGN. Characterising the unidentified Slew population is important for understanding the nature of the transient sky and allowing flux-limited samples to be constructed.

Multi-epoch study of the gamma-ray emission within the M87 magnetosphere model

Stephane Vincent[1]
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M87 is a nearby radio galaxy that is detected at energies ranging from radio to very high energy (VHE) gamma rays. Its proximity and its jet, misaligned from our line of sight, enable detailed morphological studies. The detection of rapidly variable TeV emissions on timescale of days implies a source of a few Schwarzschild radii (Rsch). Gamma-ray telescopes cannot provide images with a sufficient resolution to localise the sites of the gamma-ray production. However, both X-ray and radio observations have shown evidence that charged particles are accelerated in the immediate vicinity of the black hole closer than 100 RSch. We propose that the non-thermal particle acceleration and the VHE emission processes may occur in a pair-starved region of the black hole (BH) magnetosphere. We produce a broadband spectral energy distribution (SED) of the resulting radiation and compare the model with the observed fluxes from the nucleus of M87 for the high gamma-ray activities.

Chapter 6

Variability (QPO)

The QPO-reverberation connection in AGN

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Quasi-periodic oscillations (QPOs) are coherent signals arising in the innermost regions of the accretion flow, providing information on the structure of the strongly-curved spacetime close to the event horizon. If accretion is scale invariant then QPOs should also be present in AGN. RE J1034+396 was the first NLS1 galaxy with a robust detection of a ~ 1 hr QPO in its X-ray light curve, but was believed to be a transient feature. Recently, we showed that the QPO is indeed still present at the same frequency in further *XMM-Newton* observations, allowing us study this phenomena in unprecedented detail. I will present recent work on the QPO phase resolved spectra and reverberation delays. I will also discuss the recent discovery of a QPO in the NLS1 galaxy, MS 2254.9-3712. This object shows similar spectral timing properties to RE J1034+396, including X-ray reverberation lags at the QPO frequency. I will also present new spectral-timing results from the recent 600 ks *XMM-Newton* campaign on PG 1244+026. I will discuss these results in the context of X-ray reverberation from the inner accretion flow and draw comparisons with certain accretion states observed in BHXRBs.

X-ray timing and spectral studies from Ultra-Luminous X-ray sources

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A unified characterization of the spectral evolution of black hole binaries has been done in the last 30 yrs. The study of the spectral and aperiodic variability characterizing the X-ray emission from stellar-mass black-hole binaries has revealed to be a very useful tool to understand the mass of the black hole and the physics of accretion onto these sources. Ultra-Luminous X-ray sources (ULXs) are accreting black holes that might represent strong evidence of the Intermediate Mass Black Holes (IMBH), proposed to exist by theoretical studies but with no firm detection (as a class) so far. Their X-ray properties have been seen to be different from the case of stellar-mass black hole binaries. I will present the results that we have obtained from two outstanding ULXs (NGC5408 X-1 and the ULXs in M82) and discuss on the properties that can be derived from the study of their X-ray emission.

The Complex Emission States of a near-Eddington Black Hole: IGR J17091-3624

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IGR J17091-3624 is an ultra-low mass black hole LMXB believed to be accreting at close to the Eddington Limit. This object displays a large number of complex and varied emission states, in a similar way to the well-studied BHC GRS 1915-105. These states are believed to be caused by instabilities in matter close to the inner edge of the accretion disk. Although a model-independent classification and analysis of the emission states of GRS 1915-105 has already been undertaken, no such study has been performed on IGR J17091-3624. Here I present the findings of the first model-independent classification of the emission states of IGR J17091-3624, using both colour and timing analysis methods. Particular attention is focused on the analysis of the phenomenology seen in this object, and a comparison to the behaviour of GRS 1915+105.

Fast multi-wavelength broad-band and QPO variability in a black hole X-ray binary: accretion flow and/or a jet origin?

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Fast variability in X-ray binaries has been studied for many decades, which is associated with accretion flows (in X-rays) and recently confirmed from jets (at least in the infra-red band). I will present results of observations of a black hole X-ray binary in hard state with simultaneous coverage in X-ray, optical and infra-red bands. A Quasi Periodic Oscillation (QPO) is detected for the first time in infra-red. Interestingly, the QPO is also detected in optical and the frequency in both these bands is half the frequency of the QPO in X-rays (classified as type-C) in the broad 0.3-60 keV range. The infra-red power spectrum also exhibits broad-band noise similar to the X-ray power spectrum and is correlated. Hence, we see strong correlated variability in the emission from the accretion disk, corona/hot flow and the jet. With the known origin of X-ray variability in accretion flows, I will discuss if this can manifest itself in jets providing a mechanism for jet variability in the framework of existing models (e.g., Ingram & Done 2011, Veledina et al. 2013, Drappeau et al. 2015). This will provide strong constraints on the structure and geometry of these systems and insight into their disk-jet coupling.

Chapter 7

Winds (AGN)

Modelling the Absorption Measurement Distribution (AMD) for Mrk 509

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Absorption Measurement Distribution (AMD) measures the distribution of absorbing column over a range of ionization parameters of the X-ray absorbers in Seyfert galaxies. In this work, we modeled the AMD in Mrk 509 using its recently published broad band Spectral Energy Distribution (SED). This SED is used as an input for radiative transfer computations with full photoionization treatment using the photoionization codes Titan and Cloudy. Assuming a photoionized medium with a uniform total pressure (gas+radiation), we reproduced the discontunity in the observed AMD distribution which is usually described as the region of thermal instability of the absorber. We also studied the structure and properties of the warm absorber in Mrk 509.

X-raying the gamma-ray sky

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We present the first results on the investigation of the X-ray counterparts on the Fermi sources. Given the well known connections between the radio and the gamma rays and between the infrared and the gamma rays, we aim to find a similar relation with the hard X rays. To achieve this goal we performed our analysis with the latest release of both the Swift-BAT and INTEGRAL catalogs. Optical spectra of several gamma-ray blazar candidates will be also presented to confirm the nature of several X-ray sources selected as potential counterparts of the unidentified gamma-ray objects.

Revealing the ionized wind in NGC1365

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In 2013, an XMM-Newton observation of NGC 1365 revealed a rapid uncovering of the source, when the $N_{\rm H}$ decreased from the typical $N_{\rm H} \sim 10^{23}\,{\rm cm}^{-2}$ down to $10^{22}\,{\rm cm}^{-2}$. Besides the presence of the Fe K outflow, the RGS data revealed the presence of several absorption features from a mildly ionized wind ($\log\xi \sim 2$ and $v \sim 1700\,{\rm km\ s}^{-1}$). We detected for the first time a possible P-Cygni profile of the MgXII Lyα line associated with this ionized absorber indicative of a wide angle outflowing wind. We suggest that this wind is a low ionization zone of the highly ionized wind present in NGC 1365, which is responsible for the Fe K absorption lines and is located within the variable X-ray absorber. This observation unveiled a possible variability of the highly ionized component of the disk wind.

Thus NGC 1365 can be classed not only as one of the most extreme examples of the changing look Seyferts but also one of the best example for the presence of a stratified and variable disk wind. Here we present the main results on the disk wind, obtained thanks to the wealth of XMM observations of this intriguing AGN that were carried in the last decade.

Anatomy of the AGN in NGC5548: Discovery of a fast and massive outflow - An overview

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After a very succesfull multi-satellite monitoring of Mrk 509 in 2009, we conducted a similar campaign on the nearby Seyfert galaxy NGC 5548 in 2013. Core of the campaign was a 14x50 ks monitoring by XMM-Newton, but we also collected multi-wavelength data (from 6 observations with HST/COS, 4 with NuSTAR, 4 with Integral, 3 with Chandra LETGs, ∼1 year Swift monitoring, and ground-based) to build one of the greatest dataset ever available for a nearby AGN.

To our great surprise (for such an archetypical type-1 Seyfert), we found the source to be strongly absorbed in the soft X-rays by a new, heavy, and variable absorber lasting during the entire (few months long) campaign. New deep, broad and high velocity (up to ∼5000 km/s) UV absorption troughs were also seen simultaneously. We argue for a broad picture in which we have witnessed the formation of a high velocity, long-lived stream of outflowing matter originating from the accretion disk.

In addition to this overview talk, companion/coordinated talks will present other important aspects of this campaign (Ursini et al.) and of the HST-reverberation campaign performed the following year (2014, Kriss et al. and Edelson et al.).

Discovery of a cold outflow in the radio-loud quasar 4C +74.26

Laura Di Gesu[1], Elisa Costantini[1]
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We present a detailed view of the X-ray absorption in the giant radio quasar 4C +74.26. Thanks to a joint RGS and Chandra-HETGS analysis, we could well characterize the extreme kinematics of the absorbers in this source. Besides showing a highly-ionized warm absorber, the spectrum is heavily obscured by a substantial column density of cold, neutral gas. This cold absorber produces a deep Fe I edge in the RGS spectrum, which is significantly blueshifted with respect to the systemic velocity (Di Gesu & Costantini, in prep.). We measured an outflow velocity of $\sim$16.000 $\mathrm{km\,s^{-1}}$ for the cold absorber. Some possible dust features at the same speed are also present. Such a fast cold outflow is an unprecedented case in X-ray spectroscopy of AGN. Because of the remarkably high velocity, this outflow is a strong candidate for producing an effective feedback in this source.

The AGN-star formation connection from the perspective of the gap paradigm for black holes

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We present elements of the gap paradigm for black hole accretion and jet formation, a phenomenological framework suggesting the inner regions of black hole accretion disks are essential in shaping the nature of AGN feedback and their evolution over cosmic time. In particular, we show how recent observations of enhanced star formation in radio loud quasars can be explained in the context of the paradigms time evolution.

Unveiling the X-ray/UV properties of AGN winds using Broad and mini-Broad Absorption Line Quasars

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BAL/mini-BALs are observed in the UV spectra of $\sim 20-30\%$ of optically selected AGN as broad absorption troughs blueshifted by several thousands km/s, indicative of powerful nuclear winds. They could be representative of the average AGN if their winds cover only 20-30% of the continuum source, and/or represent an evolutionary state analogous to the high-soft state of BHB, when the jet emission is quenched and strong X-ray absorbing equatorial disk winds are virtually ubiquitous. High-quality, possibly time-resolved X-ray/UV studies are crucial to assess the global amount and character of absorption in BAL/mini-BAL QSOs and to constrain the physical mechanism responsible for the launch and acceleration of their winds, therefore placing them in the broader context of AGN geometry and evolution. I will review here the known X-ray properties of BAL/mini-BAL QSOs, and present new results from a comprehensive X-ray spectral analysis of all the Palomar-Green BAL/mini-BAL QSOs with available XMM-Newton observations, for a total of 51 pointings of 14 different sources. These will include the most recent results from a high-quality simultaneous XMM/HST observational campaign on the mini-BAL QSO PG 1126-041, that unveiled with stunning details the X-ray/UV connection in action in an AGN disk wind through correlated X-ray/UV absorption variability.

Space Telescope and Optical Reverberation Mapping Project: Unraveling the Broad Line Region and the Intrinsic Absorption in NGC 5548

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The Space Telescope and Optical Reverberation Mapping (STORM) project monitored the Seyfert 1 galaxy NGC 5548 over a six-month period, obtaining 171 far-ultraviolet HST/COS spectra at approximately daily intervals. We find significant correlated variability in the continuum and broad emission lines, with amplitudes ranging from a factor of two in the emission lines to a factor of three in the continuum. The variations of all the strong emission lines lag behind those of the continuum, with He II lagging by ~ 2.5 days and Lyα, C IV, and Si IV lagging by 5 to 6 days. The broad UV absorption lines discovered by Kaastra et al. (2014) and associated with the new soft X-ray obscurer are continuously present in the STORM campaign COS spectra. Their strength varies with the degree of soft X-ray obscuration as revealed by the Swift X-ray spectra. The narrow absorption lines associated with the historical warm absorber varied in response to the changing UV flux on a daily basis with lags of 3 to 8 days. The ionization response allows precise determinations of the locations, mass flux, and kinetic luminosities of the absorbers.

New insights on the blazar phenomenon: low radio frequency observations of the unidentified gamma-ray sources

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About one third of the gamma-ray sources listed in the Fermi LAT catalogs have no firmly established counterpart at lower energies so being classified as unidentified gamma-ray sources (UGSs). We propose and present a new approach to find candidate counterparts for the UGSs based on the low frequency (i.e., below 1GHz) radio survey. First we investigate the low-frequency radio properties of blazars, the largest known population of gamma-ray sources; then we search for sources with similar radio properties within the gamma-ray positional uncertainties of the UGSs. The implications of our results in the contest of the blazars – radio galaxies connection to test the expectations of the unification scenario for radio-loud active galaxies will be also highlighted.

The cause of soft X-ray variability in AGN: variable absorption by obscuring winds or intrinsic continuum variability?

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A major difficulty hampering our understanding of the outflows and accretion-powered emission in AGN is the uncertain nature of the observed variability. For instance, changes in absorption by an obscuring disk wind can mimic continuum variability in the soft X-ray band. This problem can be overcome by combining (1) broadband (optical/UV/X-ray) spectral and timing analysis with (2) high-resolution UV and X-ray spectroscopy. This has been achieved for Seyfert-1 AGN NGC 5548, using data from a large multi-satellite campaign, including XMM-Newton, Swift, NuSTAR and HST. The obscuring disk wind discovered in this AGN is composed of weakly-ionised gas, causing significant X-ray absorption. By applying the two aforementioned techniques to the remarkably intensive Swift monitoring of this AGN over three years, we have disentangled the 'soft excess' component variability from that of the obscuring wind. We determine the soft X-ray variability is dominated by changes in the covering fraction of the obscuring wind. The less variable 'soft excess' component is found to be the high-energy tail of the optical/UV continuum, explained by inverse Comptonisation from a warm, optically-thick inner-disk corona. Lastly, we discuss the possible existence and variability of such obscuring disk winds in other AGN.

XMM-Newton view of the central degrees of the Milky Way: the energetic environment of an extremely faint SMBH

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The deepest XMM mosaic map (of over 100 observations) of the central 1.5 degrees of the Galaxy will be presented. New extended features, such as super-bubbles and X-ray filaments are discovered. The new XMM images show that SgrA's 20-pc scale bipolar lobes have sharp edges, suggesting they might be either the forward shock front of the explosion that created the recently discovered magnetar SGRJ1745-2900 or the consequence of a pressure-bounded outflow from the SgrA* region. On a larger scale, we discover the presence of a coherent soft X-ray emission filling the so called Arc-Bubble, mostly visible in the mid-IR, making it a solid super-bubble candidate, likely connected to the Quintuplet cluster. We also discover warm plasma having considerable extent in Galactic latitude showing, in its distribution, a sharp edge that correlates with the location of known radio/mid-IR features such as the "Galactic Center Lobe" formed by, e.g. the "Radio Arc" and the shock front centered on AFGL5376. These features might be associated with an inhomogeneous "atmosphere" over the central molecular zone or to continuous or episodic outflows of mass and energy from the Galactic center region.

A complex high velocity outflow in PG1211+143

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An extended XMM-Newton observation of the luminous narrow-line Seyfert galaxy PG1211+143 in 2014 has revealed a more complex high velocity outflow, with components distinguished in velocity, ionization and short-term variability.The new results will be presented and briefly discussed - as time allows - in relation to current views on the nature of AGN winds and galaxy feedback.

The Powerful Black Hole Wind in the Luminous Quasar PDS 456

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Broadband X-ray spectra of the luminous quasar PDS 456 are presented, as part of simultaneous campaign covering five XMM-Newton and NuSTAR observations during 2013-2014. The spectra show a persistent iron K-shell absorption profile in all of the observations, measured at 9 keV in the quasar rest frame, which demonstrates the presence of gas outflowing at about one third of the speed of light. Both the outflow emission and absorption components are spectrally resolved into a broad P-Cygni like profile, with the width of the profile corresponding to a FWHM velocity width of 35000 km/s. The wind profile and its response to the continuum makes it possible to measure the aperture and radial location of this wind, and thus to determine its total mass-loss rate and mechanical power. The observed wind stream starts at a radius of approximately 100 gravitational radii and spreads over a solid angle of at least 2 pi Steradian, and carries a kinetic power in excess of 10^{46} erg/s, enough to provide the feedback required by models of black hole and host galaxy co-evolution. The long term variability of the outflow is also discussed, comparing all the observations of PDS 456 over the last decade.

Constraining The Wind-Shield Scenario Of PG 2112+059

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The physical scenario describing the origin of quasar winds, still remains largely unsettled due to our failure to account for X-ray weak BALQSOs. Therefore, it is fundamental to study of the relation between the inner part of the wind which is likely to be shielding the X-ray emission and the UV winds characterized by broad absorption lines (BALs). To address this, we probe the shield-wind connection in the highly X-ray variable BALQSO PG 2112+059, which has exhibited periods of X-ray weakness and X-Ray normality in the past. A recent 20 ks *Chandra* observation (performed in Dec 2014) with a contemporaneous *Hubble* observation is compared with a nearly simultaneous archival *Chandra-Hubble* observation from 2002, affording us a unique opportunity to study the connection between the shield (which is thought to be responsible for the X-ray absorption) and the dynamics of the wind (observed as UV BAL features; e.g., C iv and O vi lines).

Timing the warm absorber in NGC4051

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In this work we have combined spectral and timing analysis in the characterization of highly ionized outflows in Seyfert galaxies, the so-called warm absorbers. Here, we present our results on the extensive $\sim$ 600ks of XMM-Newton archival observations of the bright and highly variable Seyfert 1 galaxy NGC4051, whose spectrum has revealed a complex multi-component wind. Working simultaneously with RGS and PN data, we have performed a detailed analysis using a time-dependent photoionization code in combination with spectral and Fourier timing techniques. This method allows us to study in detail the response of the gas due to variations in the ionizing flux of the central source. As a result, we will show the contribution of the recombining gas to the time delays of the most highly absorbed energy bands relative to the continuum (Silva, Uttley & Costantini in prep.), which is also vital information for interpreting the continuum lags associated with propagation and reverberation effects in the inner emitting regions. Furthermore, we will illustrate how this powerful method can be applied to other sources and warm-absorber configurations, allowing for a wide range of studies.

Chapter 8

Winds (BHB)

Magneto centrifugal winds from accretion discs around black hole binaries

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X-ray observations of black hole X-ray binaries (BHBs) suggest that disc winds occur in the softer (disk-dominated) states of the outburst and are less prominent or absent in the harder (power-law dominated) states, which are more characterized by radio-loud jets. We investigate the presence/absence and physical characteristics of disk winds in BHBs through the use of the magneto-hydrodynamic (MHD) solutions of Ferreira (1997). These models treat accretion and ejection self-consistently within a self-similar ansatz that allows to solve the full set of dynamical MHD equations without neglecting any term. As a consequence the ejection efficiency is not a free parameter but depends on the global structure of the disk. By testing different sets of solutions with varying disk aspect ratio and ejection efficiency, we attempt to reproduce the observed state dependent prevalence of the winds. With no a priori theoretical assumption about the state of the black hole, we recover this observed bias of the winds for the softer states. In this talk I shall detail the methods employed by us, followed by the results.

The evolution of the jet ejection of the ultraluminous X-ray source Holmberg II X-1

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Ultraluminous X-ray sources (ULXs) are extragalactic objects whose luminosity is in excess of a 20-M_sun black hole. Holmberg II X-1 lies in a nearby, metal-poor, dwarf irregular galaxy, where massive stellar-mass black holes (20-100 M_sun) might be expected to form. The source is associated with a radio and optical bubble that is indicative of the long-term feedback effect. Although, the exact mechanisms driving these bubbles are less clear. We have discovered a collimated jet structure and shown that it can inflate and sustain the radio bubble. From the radio and X-ray properties the source is inferred to be accreting near the Eddington-limit.

Here, we present follow-up radio and X-ray observations that reveal a large flux decay over 1.5 years of the central radio source. Also, a dynamical age of the jet ejection is estimated to be 2-13 years. We show that the evolution of the jet ejection can be explained by simple adiabatic expansion losses. Compared with the radiative feedback mode of AGNs, where no powerful radio jets are expected, sources like Holmberg II X-1 play odd. Super-Eddington sources might be expected to produce strong disk winds, however, the X-ray observational evidence is scarce. Do jets hinder detecting X-ray lines?

Wind Absorption in High Mass X-ray Binaries

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The black hole binary Cygnus X-1 is one of the best studied wind accreting high mass X-ray binaries (HMXBs). Its soft X-ray light curve shows strong dips where clumps in the highly photoionized, focused wind of the donor star HDE 226868 pass our line of sight. Chandra HETGS observations allow for an investigation of the wind's properties. We present the evolution of Si and S Kα spectra with four different dipping stages. As the inner part of the clumps is shielded from the X-rays, lower ionization stages appear during the deeper part of the dips.

We also present first results from a joint XMM/NuSTAR campaign on the strongly absorbed neutron star X-ray binary IGR J16318-4848. The source has an $N_{\rm H}$ exceeding $10^{24}\,{\rm cm}^{-2}$. Its X-ray spectrum below 10 keV is dominated by strong fluorescent Fe Kα emission, while the broad band 5–50 keV spectrum is dominated by Compton down scattering.

Formation and Evolution of the SS 433 Jets

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We present observations and modeling of the SS 433 relativistic jets based on contemporaneous X-ray (from the Chandra HETGS), optical, and VLBA observations. We expand upon previous models of the jets, inferring that the X-ray emission arises less than 2×10^{12} cm from the formation region and cools rapidly into clumps that travel ballistically beyond 10^{17} cm. Modeling the X-ray spectrum shows Ni to be overabundant by $\times10$ and n_e can be limited to the range 10^{10-13} cm^{-3} The jet Doppler shifts show a rapid change that could result from semi-relativistic shocks in interactions with local gas. We derive jet base density and temperature from the data using a radiative cooling model that includes free expansion and compute two relativistic shock scenarios entraining material from the accretion disk.

Connection between accretion state and FeK winds in neutron stars

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High resolution X-ray spectra of accreting stellar mass Black Holes (BH) reveal the presence of accretion disc winds, traced by high ionisation FeK lines. These winds appear to have an equatorial geometry and to be observed only during disc dominated states in which the radio jet is absent. Accreting Neutron Star (NS) systems also show equatorial high ionisation absorbers. However the presence of any correlation with the accretion state has not been previously tested. We have studied EXO0748-676 and AXJ1745.6-2901 the two high-inclination accreting NS with the best XMM-Chandra monitoring. Not one of twenty X-ray spectra obtained in the hard state revealed any significant Fe K absorption line. Intense Fexxv and Fexxvi are always clearly detected during the 10 soft state observations. The variability of the absorption features does not appear to be due to plasma over-ionisation in the hard state. This suggests that the connection between Fe K absorption and states (and anticorrelation between the presence of Fe K absorption and jets) is also valid for EXO0748-676 and AXJ1745.6-2901 and therefore it is not a unique property of BH systems but a more general characteristic of accreting sources.

ULX behaviour: the ultraluminous state, winds and interesting anomalies

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Recent evidence - in particular the hard X-ray spectra obtained by NuSTAR, and the large amplitude hard X-ray variability when ULXs show soft spectra - reveals that common ultraluminous X-ray source (ULX) behaviour is inconsistent with known sub-Eddington accretion modes, as would be expected for an intermediate-mass black hole (IMBH). Instead, it appears that the majority of ULXs are powered by super-Eddington accretion onto stellar-mass black holes. Here, we will delve deeper into ULX spectral-timing behaviour, demonstrating it remains consistent with the expectations of super-Eddington accretion. One critical missing piece from this picture is the direct detection of the massive, radiatively-driven winds expected from ULXs as atomic emission/absorption line features in ULX spectra; we will show it is very likely these have already been detected as residuals in the soft X-ray spectra of ULXs. Finally, we will discuss ULXs that do not appear to conform to the emerging ULX behaviour patterns. In particular we discuss the implications of the identification of a good IMBH candidate in IC 4320 as a background QSO; and the confirmation of an IMBH/ULX in the galaxy NGC 2276 via the radio/X-ray fundamental plane.

Optically thick disc wind in GRO J1655–40?

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Many disc winds observed in black hole binaries can be explained as thermally or radiation-pressure driven winds. An exceptional case is the disc wind of GRO J1655–40 detected with Chandra in 2005, whose launching radius was estimated to be much smaller than the Compton radius. Here we revisit the GRO J1655–40 wind, using RXTE X-ray data and simultaneous optical photometric data which trace the outer disc emission. We find that the optical flux was monotonically increasing around the Chandra epoch, while the X-ray flux started decreasing about 10 days before. The optical and X-ray spectral energy distribution at the Chandra epoch is well modelled by a disc emission and optically-thick Comptonisation, both of which are heavily absorbed. High frequency variability at the Chandra epoch was greatly reduced from the levels in the normal high/soft state, likely due to strong Compton scattering. These results suggest that the wind was optically thick to Compton scattering, and that the intrinsic X-rays are strongly scattered and absorbed by the wind. These effects, which have been ignored in previous studies, must be taken into account for accurate estimation of the wind launching radius and determination of the driving mechanism of the wind.

Tests of outflow as explanation for the spin fitting problem in continuum-fitting method

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The determination of the spins of black holes in some X-ray binaries for a range of luminosities done with the use of advanced fully relativistic disk models leads to a paradox: the spin of decreases with the rise in luminosity. Physically, any significant evolution of the spin during the set of observations is impossible. Therefore, the apparent decrease of the spin must be the artefact of the adopted model. We analyse whether this effect might be explained by an outflow from the innermost part of an accretion disk. We find that relatively smooth radial outflows, without explicit dependence on the Eddington ratio do not provide the requested effect. However, we can recover the observed trends with a simple model of an inner cut-off disk which depends on the luminosity. The position of the inner radius must increase linearly with the Eddington ratio. The physical interpretation of such a model is that either most of the material has to be removed from the disk in a form of a wind or a jet, or at least most of the energy has to be removed, leaving behind the cold non-radiating flow close to the black hole horizon.

Chapter 9

Winds (Theory)

Fast Ionized X-ray Absorbers in AGNs

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We present a study of X-ray ionization of MHD accretion-disk wind models in an effort to explain the highly-ionized ultra-fast outflows (UFOs) identified as X-ray absorbers recently detected in various sub-classes of Seyfert AGNs. Our primary focus is to show that magnetically-driven outflows are physically plausible candidates to account for the AGN X-ray spectroscopic observations. We calculate its X-ray ionization and the ensuing X-ray absorption line spectra in comparison with an XXM-Newton/EPIC spectrum of the narrow-line Seyfert AGN, PG 1211+143. We find, through identifying the detected features with Fe K transitions, that the absorber has a characteristic ionization parameter of log(xi[erg cm/s]) = 5-6 and a hydrogen-equivalent column density on the order of 1e23 cm-2, outflowing at a sub-relativistic velocity of v/c = 0.1-0.2. The best-fit model favors its radial location at R = 200 Rs (Rs is the Schwarzschild radius), with a disk inner truncation radius at Rt = 30Rs. The overall K-shell feature in data is suggested to be dominated by Fe XXV with very little contribution from Fe XXVI and weakly-ionized iron, which is in a good agreement with a series of earlier analysis of the UFOs in various AGNs including PG 1211+143.

Modelling the Spectra of Quasars: Clumpy Winds and X-ray Properties

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Broad, blue shifted absorption lines in the ultraviolet (UV) are seen in approximately 20% of quasi-stellar objects (QSOs), providing clear evidence that mass-loaded outflows are present in such systems (known as BALQSOs). These outflows may take the form of winds emanating from the accretion disk, which offer potential for a feedback mechanism with the host galaxy. Disk winds are also important in unification scenarios for QSOs and active galactic nuclei (AGN). We present Monte Carlo radiative transfer simulations using a simple biconical disk wind model which has already successfully reproduced BAL profiles. Previous models exhibited a well-documented 'over-ionization' problem- it is difficult to maintain an ionization state which produces significant line opacity in UV resonance species such as CIV, while remaining consistent with observed X-ray luminosities of QSOs. We attempt to address this problem by examining the effect of clumping and different mass-loss prescriptions on the ionization state and inferred X-ray properties. We also investigate the important emergent observable quantities as a function of viewing angle. We make comparisons to population studies of QSOs and AGN, and discuss our results with reference to ultra-fast outflows in AGN and potential super-Eddington accretion in ultra luminous X-ray sources (ULXs).

Chapter 10

New spectral-timing techniques

Revealing the inner accretion flow around black holes using frequency-resolved spectroscopy

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The geometry of the inner accretion flow of X-ray binaries is complex, with multiple regions contributing to the observed emission. Frequency-resolved spectroscopy is a powerful tool in breaking this spectral degeneracy. We have extracted the spectra of the strong low-frequency quasi-periodic oscillation (QPO) and its harmonic in GX339-4 and XTE J1550-564, and compare these to the time-averaged spectrum and the spectrum of the rapid (<0.1s) variability. Our results support the picture where the QPO arises from vertical (Lense-Thirring) precession of an inhomogeneous hot flow, softer at larger radii closer to the truncated disc and harder in the innermost parts where the rapid variability is produced. This coupling between variability and spectra allows us to constrain the soft Comptonization component, breaking the degeneracy plaguing the time-averaged spectrum and revealing the geometry of the accretion flow close to the black hole.

Modelling X-ray reverberation lags

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The recent detection of X-ray reverberation lags, especially in the Fe Kα line region, around Active Galactic Nuclei (AGN) has opened up the possibility of studying the time-resolved response (reflection) of hard X-rays from the accretion disk around supermassive black holes. More recently, there has been a hint of Fe Kα reverberation seen in a neutron star low-mass X-ray binary (LMXB) also. Here, we use general relativistic transfer functions for reflection of X-rays from a point source located at some height above the compact object to study the time lags expected as a function of frequency and energy in the Fe Kα line region. We explore the models and the dependence of the lags on key parameters such as the height of the X-ray source, accretion disk inclination, spin and mass. We apply these models to reverberation lags in AGN and neutron star LMXBs.

Spectral-timing modeling of the X-ray reverberation in Mrk 335

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We present a physical X-ray reverberation model to simultaneously fit the 2–10 keV spectrum and the frequency-dependent time lags of 2.5–4 vs. 4–6.5 keV bands in the high flux state of Mrk 335. The model consists of an axial point source that illuminates an accretion disc. The XILLVER model is used to produce a back-scattered, ionised reflection spectrum. The time lags are computed taking into account the relativistic and full-dilution effects. The best-fitting parameters are consistent with a black hole mass of $\approx 1.3 \times 10^7 M_\odot$, disc inclination of 45° and the photon index of the direct continuum of 2.4. The iron abundance is 0.5 and the ionisation parameter is 10^3 erg cm s^{-1} at the innermost part of the disc and decreases further out. The X-ray source height is very small, $\approx 2r_g$. Furthermore, we report systematic differences below 2 keV using the two reflection models, XILLVER and REFLIONX, which make simultaneous fitting the time-averaged spectrum and the softer-band lags (e.g. Fe-L lags) much more complicated. We also find that the measurements of the source height and the central mass significantly depend on the ionisation state of the disc and are possibly model-dependent.

Reverberation lags in black hole X-ray binaries

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Reprocessing of the primary X-ray continuum in the accretion disc is expected to cause reverberation lags which are powerful diagnostics of the geometry of the inner flow. X-ray reverberation lags are now commonly observed in supermassive accreting black hole systems (active galactic nuclei, AGN). These lags are also expected in smaller objects, where the accretor is a stellar mass black hole in a binary system (BHXRBs). However only one detection has been reported so far. I will present results obtained from a systematic analysis of X-ray lags in a sample of BHXRBs observed by XMM-Newton, with the main aim of assessing the presence of reverberation lags and study their evolution during the outburst. This study confirms the mass-scaling of the lag amplitude from supermassive down to stellar-mass black holes, supporting the hypothesis that reverberation lags are a characteristic feature of any accreting system. We find that the amplitude of the reverberation lag detected in BHXRBs scales also with the X-ray luminosity along the canonical hard state: shorter lags are observed during higher luminosity observations. This result implies that, while the source rises the hard state, reprocessing from disc radii progressively closer to the BH is observed.

The "iron-line/continuum" time-lags in AGN

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We have performed a detailed study of the statistical properties of traditional time-lag estimators, using extensive simulations in the case of constant delay, power-law and "reverberation"-like model time-lag spectra. Using the results from this study, as well as a large amount of archival *XMM-Newton* data, we have calculated the time-lag spectra between the "continuum" (i.e. $2-4\,\mathrm{keV}$) and "iron-line" (i.e. $5-7\,\mathrm{keV}$) energy bands for seven bright AGN, resulting in time-lag estimates with statistical properties suitable for traditional model-fitting techniques (i.e. estimates that are unbiased, normally distributed and with a known error). We used model transfer functions for an X-ray reverberation scenario in the case of the "lamp-post" geometry, which takes all relativistic effects into account, and fitted the resulting model time-lag spectra to the data. We also used archival *ASCA* and *Suzaku* data to determine the time-lag spectra at longer time-scales, and compared them with the best-fit model predictions in order to investigate the validity of the resulting best-fit models. We will discuss our results with those presented in the literature in the case of the "soft-excess/continuum" time-lags, and their implication regarding the innermost geometry (i.e. X-ray source distance from the disc and inner disc radius) in these AGN.

A global view of reverberation in bare Seyferts

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In recent years, X-ray reverberation has opened a new way to investigate the inner accretion flow around supermassive black holes. XMM-Newton and NuSTAR observations of the high-frequency variability have shown that the soft excess, broad iron K line and even the Compton hump lag behind the continuum emission, suggesting light travel distances of a few gravitational radii. In addition to high-frequency reverberation, there are also featureless low-frequency lags that have been observed commonly in AGN and black hole binaries for many years, and are often attributed the continuum emission. Through observations of individual sources, we are beginning to understand more about the low- and high-frequency X-ray lags, however, a systematic search is required to obtain a global view of reverberation in bare Seyferts. In particular, we need to understand how common iron K lags are, how the lags depend on the geometry of the accretion flow, and the effect of low-frequency absorption variability. In this talk, I will review some of the most recent XMM-Newton and NuSTAR observational results, and will also present results on a global look at reverberation in bare Seyferts.

Testing propagating mass accretion rate fluctuations model PROPFLUC on Black Hole X-ray Binaries

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Over the past 20 years, a consistent phenomenology has been established to describe the variability properties of black hole X-ray binaries. However, the physics behind the observational data is still poorly understood. The recently proposed model PROPFLUC assumes a truncated disc/hot inner flow geometry, with mass accretion rate fluctuations propagating through a precessing inner flow. These two processes give rise respectively to broad band variability and a quasi-periodic oscillation (QPO) on the precession frequency. We recently applied systematically for the first time PROPFLUC on a black hole candidate (MAXI J1543-564) in order to compare the results of phenomenological and physical modelling of the source power spectrum and to give a physical interpretation of the rising phase of the source outburst. I will present the results of this study and describe our work to go beyond power spectral fitting by also modelling the cross-spectral amplitudes and phase lags between different energy bands. We are testing the model by comparing with Swift data from the black hole binary MAXI J1659-152. In particular, we are exploiting the low energy coverage of Swift in order to test the hypothesis that fluctuations are generated in the disc before propagating into the inner flow.

Astro-H: science goals, development status, and European contribution

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The joint JAXA/NASA ASTRO-H mission is the sixth X-ray mission initiated by the Institute of Space and Astronautical Science (ISAS). ASTRO-H allows a combination of wide band X-ray spectroscopy (5-80 keV) provided by multilayer coating, focusing hard X-ray mirrors and hard X-ray imaging detectors, and high energy-resolution soft X-ray spectroscopy (0.3-12 keV) provided by thin-foil X-ray optics and a micro-calorimeter array. The mission will also carry a X-ray CCD camera as a focal plane detector for a soft X-ray telescope (0.4-12 keV) and a non-focusing soft gamma-ray detector (40-600 keV). ASTRO-H is expected to provide breakthrough results in the studies of the large-scale structure of the Universe and its evolution, the behaviour of matter in the strong gravitational field regime, providing time-resolved spectra from material approaching the event horizon of a black hole, the physical conditions in sites of cosmic-ray acceleration, and the distribution of dark matter in galaxy clusters at different redshifts. ASTRO-H will be launched into low-Earth orbit from the Tanegashima Space Center, Japan, by a JAXA H-IIA rocket.

A New Route to Phase-Resolved Spectroscopy of QPOs in X-ray Binaries

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I will present the application of a new spectral-timing technique for phase-resolved X-ray spectroscopy of low-frequency quasi-periodic oscillations (QPOs) from black hole X-ray binaries. These signals are thought to originate from near-periodic geometric changes in the inner accretion flow, possibly due to general relativistic Lense-Thirring precession. Our technique lets us study how the different spectral components change with QPO phase, providing a crucial test of the model and providing new insight into the geometry of the emitting region and accretion flow in the strong-field gravity regime close to black holes.

A comprehensive spectral-timing study of the 2014 outburst of H 1743–322

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Black hole transients during bright outbursts show distinct changes of their spectral and variability properties as they evolve during an outburst, that are interpreted as evidence for changes in the accretion flow and X-ray emitting regions. In September last year we obtained an anticipated XMM-Newton ToO observation of H 1743–322 during its early outburst phase, expecting to catch the start of the hard-to-soft transition. Here we present the results of a comprehensive spectral and variability study of this observation. The fact that neither the general shape of the observed power density spectrum nor the characteristic frequency show an energy dependence imply that the source was observed during another so-called 'failed outburst'. We investigated covariance spectra and ratios and found that the energy dependence of the ratio differs from the one observed in other sources. Conducting a comparable study of covariance ratios for a sample of black hole X-ray binaries, we discuss the possible dependence of the observed differences in the covariance ratio on the orbital inclination or the fact that H 1743–322 was observed during a failed outburst. Furthermore, we present the results of our study of the quasi-periodic pulse profile.

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