Putting Accretion Theory to the Test

Program Booklet

Loews Annapolis Hotel
November 4 - 6, 2013
Annapolis, MD

Putting Accretion Theory to the Test

Annapolis, Maryland
November 4-6, 2013

Monday, November 4

7:30 **Breakfast and Registration Begin**

9:00 **Welcome** (Chris Reynolds, Chair of the SOC, & Cole Miller, Director of JSI)

Keynote Address

9:05 **Steven Balbus** (Oxford University) and **John Hawley** (University of Virginia)
Accretion and the Insidious Effects of Weak Magnetic Fields

Turbulence in accretion disks is probably regulated by the magnetorotational instability, but that is only one of innumerable important dynamical processes introduced by seemingly weak magnetic fields. In this talk I will give an overview of some outstanding issues associated with MHD disk turbulence, with focus upon magnetic Prandtl number effects. I will also discuss important thermal processes engendered in dilute astrophysical plasmas that may have important consequences for our understanding of heating, cooling, and convective turbulence.

Session I: Turbulence and Angular Momentum

10:05 **Omer Blaes** (University of California-Santa Barbara)
Issues of Thermal Equilibrium, Stability, and Radiation Spectra In MRI Turbulence (25+5)

Recent progress in cosmic ray observations have sharpened the observed features in the overall spectrum over a large range in energy and have revealed unexpected composition changes. Combined with recent gamma-ray and neutrino data, these observations have narrowed down possible Galactic and Extragalactic sources. I will review the current state of cosmic ray observations and their implications for proposed acceleration models and secondary astroparticle fluxes. A clear resolution of the origin of cosmic rays calls for much larger statistics than the reach of current observatories.

10:35 **Coffee Break / Poster Viewing**

11:00 **J.-P. Lasota** (Institut d'Astrophysique de Paris)
Observational Constraints on Alpha (25+5)

After a very short review of observations and a concise presentation of the thermal-viscous model of dwarf-nova outbursts I will show how their combination constrains the value of the viscosity parameter alpha. I will put stress on model-independent aspects of the argument.

Monday, November 4

11:30 **Jacob Simon** (Southwest Research Institute)
The Importance of Vertical Magnetic Fields in Protoplanetary Disks (15+5)

I will present a series of disk simulations that model the outer regions (30 AU and beyond) of proptolanetary disks where ambipolar diffusion strongly damps magnetohydrodynamic turbulence driven by the magnetorotational instability (MRI). These simulations include an ionization structure based on recent models in which FUV photons ionize very thin surface layers of the disk. We find that in the absence of a vertical magnetic field threading our domain, MRI turbulence is very weak and only exists within these small surface layers; the resulting accretion rates are far too low to account for observational constraints. Including a vertical magnetic field however, drastically improves the situation by activating the MRI in the low ionization mid-plane region as well as by driving a magnetocentrifugal wind. Depending on the strength of this field, the disk can either be turbulent or completely laminar. In both cases, estimated accretion rates agree well with observations. If magnetic fields are indeed responsible for accretion in protoplanetary disks, a large-scale vertical magnetic field threading the disk is necessary to drive this accretion at appreciable rates.

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11:50 **Matthew Kunz** (Princeton University)
Magnetic Self-Organization in Hall-Dominated Magnetorotational Turbulence (15+5)

The magnetorotational instability (MRI) is the most promising mechanism by which angular momentum is efficiently transported outwards in astrophysical discs. However, its application to protoplanetary discs remains problematic. These discs are so poorly ionized that they may not support magnetorotational turbulence in regions referred to as “dead zones”. It has recently been suggested that the Hall effect, a non-ideal magnetohydrodynamic (MHD) effect, could revive these dead zones by enhancing the magnetically active column density by an order of magnitude or more. We investigate this idea by performing local, three-dimensional, resistive Hall-MHD simulations of the MRI in situations where the Hall effect dominates over Ohmic dissipation. As expected from linear stability analysis, we find an exponentially growing instability in regimes otherwise linearly stable in resistive MHD. However, instead of vigorous and sustained magnetorotational turbulence, we find that the MRI saturates by producing large-scale, long-lived, axisymmetric structures in the magnetic and velocity fields. We refer to these structures as zonal fields and zonal flows, respectively. Their emergence causes a steep reduction in turbulent transport by at least two orders of magnitude from extrapolations based upon resistive MHD, a result that calls into question contemporary models of layered accretion. We construct a rigorous mean-field theory to explain this new behaviour and to predict when it should occur. Implications for protoplanetary disc structure and evolution, as well as for theories of planet formation, are briefly discussed.

Monday, November 4

12:10 **Oleg Kirillov** (Helmholtz-Zentrum Dresden-Rossendorf)
Inductionless Magnetorotational Instabilities: From Lab Tests To Accretion Disks (15+5)

How stars and black holes are able to form from rotating matter is one of the big questions of astrophysics. What is known is that magnetic fields figure prominently into the picture via the mechanism of magnetorotational instability (MRI). However, the current understanding is that it only works if matter is electrically well conductive – but in rotating disks this is not always the case. In areas of low conductivity like the dead zones of protoplanetary disks or the far-off regions of accretion disks that surround supermassive black holes, the MRI's effect is numerically difficult to comprehend and is thus a matter of dispute. Simulation of the MRI in a liquid metal experiment with an exclusively vertically oriented magnetic field requires that this field has to be rather strong. At the same time, since the rotational speed has to be very high, these types of experiments are extremely involved and thus far success has eluded them. By adding a circular magnetic field to a vertical one it became possible to observe the helical MRI at substantially smaller magnetic fields and rotational speeds. Very recently, the azimuthal MRI with m=1 has also been observed in the PROMISE facility in Dresden. However, one of the blemishes of these inductionless versions of MRI is the fact that they only act to destabilize rotational profiles that are relatively precipitous towards the periphery, which for now did not include rotation profiles obeying Kepler's law. In this talk we present a theoretical study of the stability of rotational flows in the presence of a constant vertical magnetic field and an azimuthal magnetic field with a general radial dependence characterized by an appropriate magnetic Rossby number. Employing the short-wavelength approximation we develop a unified framework for the investigation of the standard, the helical, and the azimuthal version of the magnetorotational instability, as well as of current-driven kink-type instabilities. Considering the viscous and resistive case, our main focus is on the limit of small magnetic Prandtl numbers which applies, e.g., to liquid metal experiments but also to the colder parts of accretion disks. We rigorously demonstrate that the inductionless versions of MRI extend well to the Keplerian case if only the azimuthal field slightly deviates from its field-free profile.

*** * * 12:30 - 2:00 Lunch * * ***

Monday, November 4

Session II: Outflows and Jets

2:00 **Elena Gallo** (University of Michigan-Ann Arbor)
Outflows and the Disk-jet Connection (25+5)

Relativistic jets are increasingly being recognized as a crucial ingredient for understanding the process of accretion onto black holes as whole. In this talk, I will focus on recent discoveries that complement our long-standing paradigm for the so called 'jet-accretion coupling' in black hole X-ray binary systems, including the ubiquity of winds in the thermal-dominant state, the existence of two tracks in the radio/X-ray domain of hard and quiescent state sources, and recent (contradictory) results on the relation between black hole spin and the power of transient radio ejections.

2:30 **Mitchell Begelman** (JILA, University of Colorado-Boulder)
Hyperaccretion from ADIOS to ZEBRA (25+5)

To maintain a disk-like configuration while remaining bound, radiatively inefficient accretion flows require a mean specific angular momentum close to the Keplerian value. Some flows with potentially hyper-Eddington accretion rates, such as tidal disruption events (TDEs), collapsars and quasistars, may not possess enough angular momentum to remain disk-like. I will argue that such flows "close up" toward the rotational axis as they approach a state of "ZEro-BeRnoulli Accretion" (ZEBRA). Flows in such a state have steep density profiles, and no feedback mechanism capable of regulating the accretion power to a value that can be radiated away in a steady state. Instead, the liberated energy must drive unsteady, dynamical mass loss or escape as a pair of hyper-Eddington jets along the rotational axis. The jets from the super-Eddington TDE Swift J1644+57, and GRB jets from collapsars in general, may be examples of this phenomenon.

3:00 **Jon Miller** (University of Michigan-Ann Arbor)
X-ray Disk Winds in Black Holes (25+5)

X-ray spectroscopy of stellar-mass black holes has revealed equatorial disk winds in soft, disk-dominated phases. The most extreme cases may remove a substantial fraction of the accreting material, and thereby affect the growth of the black hole and evolution of the binary. There are different means by which such winds may be powered, but magnetic driving is an interesting possibility in some cases. Existing data suggest that winds and jets may be driven by a common mechanism, and governed in a simple fashion that extends across the mass scale. This talk will review recent developments and give a picture of how observations with Astro-H might improve our understanding of outflows.

3:30 **Coffee Break / Poster Viewing**

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4:00 **Shinji Koide** (Kumamoto University)
Causal Extraction of Rotational Energy from Spinning Black Hole By Electromagnetic Fields (15+5)

Recent general relativistic MHD simulations have suggested that relativistic jets from active galactic nuclei (AGNs) have been powered with the rotational energy of the central black holes. Some mechanisms of extraction of black hole rotational energy had been proposed, like Penrose process, Blandford-Znajek mechanism, MHD/magnetic Penrose process etc. It is believed that the Blandford-Znajek mechanism is most promising mechanism of the engines of the relativistic jets from AGNs. However, an interpretation of the mechanism within causality is not clarified yet. In this talk, I will show its explanation in a general point of view.

4:20 **Francesco Tombesi** (University of Maryland-College Park)
X-ray Observations of Accretion Disk Winds in Active Galactic Nuclei (15+5)

X-ray evidence for massive, highly ionized, ultra-fast outflows (UFOs) has been recently reported in a number of AGNs through the detection of blue-shifted Fe XXV/XXVI absorption lines. We present the results of a comprehensive spectral analysis of a large sample of 42 local Seyferts and 5 radio galaxies. Their outflow velocities are mildly-relativistic, up to values of ~0.3c, and their observed location at sub-pc scales is consistent with that of accretion disk winds. Importantly, their mass outflow rate and mechanical power are high enough to influence the surrounding environment through AGN feedback and also limit the supply of matter to the black hole. The wind acceleration mechanism is still not clear, but it is probably a combination of radiation pressure and/or MHD. A comparison with the less ionized/slower warm absorbers (WAs) in the same sources show, for the first time, significant correlations among these X-ray absorbers, supporting the interpretation as a large-scale, stratified outflow observed from the vicinity of the black hole up to the outskirts of these galaxies. Such winds have been observed also in some radio-loud AGNs, suggesting a possible relation with the radio jet activity. Therefore, these X-ray observations can provide important clues for the development of theoretical models of accretion/ejection processes in AGNs.

4:40 **Tracey Jane Turner** (University of Maryland-Baltimore County)
The Importance of Nuclear Winds in Shaping the X-ray Properties Of AGN (15+5)

Feature-rich X-ray spectra of AGN trace the circumnuclear reprocessing gas, which spans a wide range of column density and ionization state in the local population. Combining spectral information with X-ray time lag signatures indicates that the nuclear regions have a high covering fraction of absorbing, Compton-scattering gas existing on scales of light-hours. Grating spectroscopy indicates that the X-ray reprocessor is part of a nuclear outflow, whose details are key to understanding the accretion process, and the influence of the nuclear black hole upon its host galaxy.

Monday, November 4

5:00 **William N. Brandt** (Penn State University)
Exceptional X-ray Weak Quasars and their Implications for Accretion Disks, Coronae, and Winds (15+5)

Efficiently accreting supermassive black holes are found, nearly universally, to create luminous X-ray emission in the innermost parts of their accretion disks. However, there are notable exceptions to this rule that provide unique insights into accretion physics, including PHL 1811 analogs and some weak-line quasars. We have been systematically studying such X-ray weak quasars with Chandra, XMM-Newton, and NuSTAR observations, based largely on samples selected from the vast Sloan Digital Sky Survey spectroscopic database. We will report our results and their implications for models of the accretion disk/corona, quasar winds, and emission-line formation. First, our results establish that there is indeed a population of luminous type 1 quasars that produce X-rays at a level of 10-80 times less than nominal expectations; we have established the basic demographics of this population. Second, we have used the (remarkable) basic X-ray spectral and variability properties of these objects to assess models for their innermost accretion regions. Third, we have established relations between X-ray weakness and UV/optical emission-line properties that allow the efficient selection of optically bright examples of X-ray weak quasars for study. Finally, NuSTAR observations are now providing evidence that a significant fraction of Broad Absorption Line Quasars are likely intrinsically X-ray weak, in line with expectations that X-ray weak objects should be inherently effective at driving strong accretion-disk winds.

*** * * Reception – 5:30 pm – 7:30 pm * * ***

Tuesday, November 5

8:00 **Breakfast Begins**

Session III: Global Structure of Accretion Flows I

9:00 **Julian Krolik** (Johns Hopkins University)
The Bardeen-Petterson Effect in MHD (25+5)

Nearly forty years ago, Bardeen and Petterson predicted that Lense-Thirring torques exerted by a spinning black hole on a surrounding misaligned disk should ultimately result in aligning the disk at small radii, while leaving it misaligned and precessing at larger radii. Warped disks like these create radial pressure gradients, and therefore radial fluid motions; it is these motions that transport misaligned angular momentum, and therefore determine the shape of the disk. For the past thirty years, almost all analyses of this process have assumed that the radial flows are controlled by an isotropic viscosity identified with the stress driving accretion, even though for the past twenty years it has been understood that accretion stress is actually due to anisotropic MHD turbulence. In this talk I will report on the first numerical simulation employing MHD (and no assumed viscosity) in which the alignment process can be observed and analyzed quantitatively. A simple model for the propagation speed of the alignment front fits the simulation data very well. The simulation data further show that magnetic stresses acting on the radial flows do not act in a manner consistent with an isotropic viscosity. Our results also have implications for spin alignment in binary black hole systems.

9:30 **Andrew King** (University of Leicester)
How Do Supermassive Black Holes Grow? (25+5)

Almost all galaxies host supermassive black holes, but how the holes grow to these masses is still ill-understood. The hole's gravity is insignificant on scales larger than a few parsecs, and angular momentum is a severe barrier to accretion. In this talk I will discuss possible ways out of these difficulties.

10:00 **Meredith Hughes** (Wesleyan University)
Observational Constraints on Turbulence in Protoplanetary Disks (25+5)

Turbulence is a central aspect of planet formation theory, yet there are very few observational constraints on its magnitude and spatial distribution. Furthermore, the geometry of magnetic fields remains elusive. I will discuss recent observational work at millimeter wavelengths that begins to untangle these issues. Millimeter-wavelength polarimetry is uniquely suited for measuring magnetic field morphologies independent of disk geometry, while high-resolution molecular line spectroscopy is providing some of the first observational constraints on nonthermal linewidths in protoplanetary disks. I will discuss the implications of these recent observations, and emphasize the breakthroughs on the horizon with ALMA.

10:30 **Coffee Break / Poster Viewing**

Tuesday, November 5

11:00 **Zhaohuan Zhu** (Princeton University)
How Do Young Planets Interact with Accretion Disks? (15+5)

We use numerical simulations to perform a systematic study on the dynamics of dust particles in protoplanetary disks under the influence of a planet in disks. Dust particles in viscous disks (representing turbulent regions in disks) and inviscid hydro disks ("dead zone") have been simulated separately using our newly developed Two-Fluids FARGO and ATHENA Particle codes. For inviscid 3-D disks, we found that a low mass planet ($8\ M_{\oplus}$) open almost unnoticeable gaps in gas which can still lead to significant dust piling up at gap edges. Sharp gap edges carved out by a massive planet are unstable to the formation of vortices, which can efficiently trap particles with a wide range of sizes (at least 4 orders of magnitude in our cases). Thus gaps and vortices in particle disks should be very common if there are planets in the "dead zones". For viscous disks, the dust features are significantly smoothed out by the parameterized turbulent diffusion, and small dust particles can follow the accreting gas flowing to the inner disk. Thus, the so-called "dust filtration" mechanism by the gap edges can differentiate big and small dust particles. MHD simulations are developed to understand the gap opening and particle concentration in realistic turbulent disks.

11:20 **Jason Dexter** (University of California-Berkeley)
A Model of the Spectra and High-Frequency QPOs in Black Hole X-ray Binaries (15+5)

High-frequency quasi-periodic oscillations (HFQPOs) in black hole X-ray binaries have frequencies comparable to the orbital frequency at the innermost stable circular orbit, and therefore may encode information about strong gravity. However, the origin of the oscillations and the associated steep power law X-ray spectra are poorly understood. I will discuss a new model for these spectra, which also acts as a filter to produce QPOs from local disk oscillations. The model uses the fact that at high luminosities, radiation pressure dominated accretion disks are expected to become effectively optically thin. The gas temperature therefore rises sharply inwards, producing local saturated Compton spectra with rapidly increasing peak energy. These spectra sum together to form a steep power law tail to the spectrum. A given photon energy on this tail corresponds to a narrow range in radius, providing a filter to produce HFQPOs from local disk oscillations in the hard X-ray band. The two lowest order modes have a robust frequency ratio of ~1.53. This model explains the appearance of steep power law spectra and HFQPOs at high luminosity, the 3:2 HFQPO frequency ratios, and their association with the power law spectral component. It makes several testable predictions with archival X-ray data, and can in principle be used to measure black hole spin.

Tuesday, November 5

11:40 **Nathalie Degenaar** (University of Michigan-Ann Arbor)
Multi-wavelength View of the Black Hole Swift J1910.2-0546:
A New Perspective on Accretion Flows (15+5)

Coordinated multi-wavelength observations offer powerful means to study the accretion flow around compact objects. We recently employed Swift and SMARTS to densely monitor the newly discovered candidate black hole X-ray binary Swift J1910.2-0546 during its 2012 outburst in X-ray, UV, optical and near-infrared. This has revealed two interesting aspects. Firstly, we observed an intensity dip that is initially detected at near-infrared wavelengths and then propagates through the optical, UV and finally X-ray bands. This provides a unique measurement of the viscous time scale in the disk. Secondly, we initially detected the source in a hard X-ray state where it showed a significant positive correlation between the UV and X-ray emission. However, when the source subsequently goes through a soft X-ray state and returns to the hard state, the UV and X-ray emission are strongly anti-correlated. This offers an intriguing new perspective on the physical properties of the accretion flow around compact objects.

12:00 **Javier Garcia** (Harvard-Smithsonian CfA)
New Generation of X-ray Reflection Models from Ionized Accretion Disks Around Black Holes (15+5)

Reflection models from accretion disks are a key component in the interpretation of the X-ray spectra from compact accreting sources. These are used to constrain important physical information about the disk itself, such as the degree of ionization of the material, elemental abundances, and inner radius, which can ultimately be used to derive the spin of the black hole. I will present a new and complete library of synthetic spectra to model the reprocessed and reflected X-ray radiation from illuminated accretion disks, using our reflection code XILLVER. I will discuss the current state of these models and their implication in the analysis of X-ray observations. I will also report on current and future efforts on the integration of these models with the general relativistic blurring code RELCONV in order to provide a complete and self-consistent numerical model for the distribution of the reflected X-ray spectra from ionized accretion disks around black holes.

12:20 **Bob Wagoner** (Stanford University)
Theories of QPOs (Diskoseismology, …) Confront Black Hole Spin (15+5)

We compare the determinations of the angular momentum of stellar mass black holes via the continuum and line methods with those from models which attempt to generate the QPOs (quasi–periodic oscillations) observed in many sources. Within diskoseismology, the most robust and visible normal mode of oscillation of the accretion disk is the fundamental g–mode. The comparisons are most consistent with the second highest frequency QPO being produced by this g–mode, but are not consistent with any model in which one QPO frequency is close to that of the innermost stable circular orbit. We also include a recent result from numerical simulations of McKinney et al. in which QPO frequencies are proportional to the angular velocity of the black hole. The fact that the ratio of the two highest observed frequencies is close to 3/2 remains a mystery that we are investigating.

*** * * 12:40 - 2:00 Lunch * * ***

Tuesday, November 5

Session IV: Transient and Impulsive Phenomena

2:00 **Brian Metzger** (Columbia University)
Delayed Outflows from Accretion Tori Following Neutron Star Binary Mergers (25+5)

The coalescence of neutron star binaries are the chief source for the direct detection of gravitational waves by Advanced LIGO within the next few years. A promising electromagnetic counterpart to the merger is a supernova-like IR/optical transient powered by the radioactive decay of heavy elements synthesized in the merger ejecta (a 'kilonova'). I will present axisymmetric hydrodynamical simulations of the long-term (many viscous time) evolution of the remnant accretion disks formed in compact object mergers, including the effects of weak interactions, nuclear recombination, and a simplified accounting of neutrino self-irradiation. I will show that the disk generically undergoes a late time 'evaporation' powered by the formation of heavy elements, which unbinds ~10 per cent of the initial disk mass. Implications for the kilonova emission from mergers, and for the (unknown) astrophysical source of heavy r-process elements, will be discussed. Due to its effect on the outflow composition, the presence and lifetime of a hyper-massive massive neutron star remnant may be directly imprinted in the transient light curves and color.

2:30 **James Guillochon** (Harvard University-ITC)
Comparing and Contrasting Two Near-Eddington Tidal Disruption Events (25+5)

The full disruption of a star by a supermassive black hole can result in mass accretion rates that exceed the Eddington limit by a couple orders of magnitude. In such events, the black hole is likely incapable of accepting the full dose of mass provided by the disrupted star, and thus may eject a significant fraction of this mass through a wind. While the tidal disruption event (TDE) PS1-10jh appears to have no significant absorption features, a second TDE (PS1-11af) shows clear evidence of metal-line absorption features with blue-shifted velocities in excess of 10,000 km/s near peak luminosity. We show that the multiband light curves of both events are well-modeled as an elliptical debris disk with a reprocessing zone, and argue that the absorption features of PS1-11af are likely associated with a wind that developed when the accretion rate exceeded Eddington for a brief period. Such an interpretation suggests that PS1-11af is an important transition TDE, whose behavior may help us understand the conditions under which winds may be generated by accreting supermassive black holes.

3:00 **Davide Donato** (CRESST/UMCP, NASA/GSFC)
A Tidal Disruption Event in a Nearby Galaxy Hosting an Intermediate Mass Black Hole (15+5)

We report the serendipitous discovery of a bright point source flare in the Abell cluster 1795 with archival EUVE and Chandra observations. Assuming the EUVE emission is associated with the Chandra source, the X-ray 0.5–7 keV flux declined by a factor of ~2300 over a time span of 6 years, following a power-law decay with index -2.44±0.40. The Chandra data alone vary by a factor of ~20. The spectrum is well fit by a blackbody with a constant temperature of kT ~ 0.09 keV (~10^6 K). The flare is spatially coincident with the nuclear region of a faint, inactive galaxy with a photometric redshift consistent at the one sigma level with the cluster (z = 0.062476). We argue that these properties are indicative of a tidal disruption of a star by a black hole with $\log(M_{BH}/M_\odot)$ ~ 5.5±0.5. If so, such a discovery indicates that tidal disruption flares may be used to probe black holes in the intermediate mass range, which are very difficult to study by other means.

Tuesday, November 5

3:20 **Coffee Break / Poster Viewing**

4:00 **Ashley King** (University of Michigan-Ann Arbor)
A Radio Flare in the Low Luminosity AGN, M81* (15+5)

We present broadband coverage of the 2011 radio flare in M81* with the VLA, VLBA, SMA, Swift and Suzaku. We clearly resolve the jet at 22 GHz with the VLBA, noting opposing lobe structures to the NW and SE of the core. These stationary structures are detected in all of our four epochs, with a distance of approximately 13000 R_G from the core. The VLA broad spectral coverage detects a fairly constant flux density at low radio frequency, and a rising flux density at high radio frequency, indicating an optically thick emitting region. We also find that the contemporaneous X-ray flux shows a striking decrease in flux approximately the same time the radio flux density decreases, suggesting that the X-ray may be a continuation of the synchrotron radiation detected in the radio frequencies. We will discuss this in terms of disk-jet connections and low-Eddington accretion flows.

4:20 **Anne Lohfink** (University of Maryland-College Park)
The Fast UV Variability in Fairall 9 (15+5)

Most of our knowledge regarding the UV/optical AGN variability was obtained by the AGN Watch Consortium in the 1990s. It laid the foundations for the currently accepted emission mechanisms of AGN in the optical/UV as well as in the X-ray band. Both long- and short-term UV/optical continuum variability were detected in all their targets with a larger variability towards the UV bands. While we understand that on long time scales the variability stems from fluctuations in the accretion rate, our knowledge diminishes towards shorter timescales. The origin of the microvariability which can be studied within one night is mostly unknown. However, the data quality in the 1990s was limited relying to mostly on ground based observations and/or the poor PSF of the IUE satellite, which limited the host galaxy subtraction. Here, we present the results from a Swift monitoring of the bare Seyfert 1 galaxy Fairall 9. The better instruments on Swift allowed us to unambiguously detect a previously undetected 4-day time scale variability. Using the simultaneous X-ray and UV data from Swift we also study the UV--X-ray correlation in the object. Previous X-ray analysis indicate that the soft excess in Fairall 9 could originate from a broad band component (such as Comptonization). We confirm these X-ray results by detecting a weak UV--X-ray correlation. To see whether this correlation also holds on shorter time scales, we investigated the UV--X-ray correlation within an XMM-Newton observation. Surprisingly, we find an anti-correlation on these time scales. We will discuss implications from this discovery for the nature of the fast UV variability and the emission mechanisms involved.

4:40 **Juri Poutanen** (University of Oulu)
On the Origin of Optical/Infrared Flares in the Low Hard State Of Black Hole Binaries (15+5)

Optical/infrared (OIR) emission of black hole binaries (BHBs) often shows signatures of a power-law-like spectra or strong infrared excesses above the thermal emission of the irradiated accretion disc. It became customary to associate this emission with the jet. Some BHBs in the outbursts also show strong OIR flares during the low hard states. There have been claims that these flares are also related to the jet activity. Here we show that the power-law OIR spectra are naturally produced by synchrotron emission from the inhomogeneous hot accretion flow if a small fraction of the electrons in the flow have nonthermal distribution. Detailed analysis of the 2000 outburst of XTE J1550-564 shows that the OIR flare starts with a rather hard spectrum clearly inconsistent with the optically thin jet emission, but consistent with the hard self-absorbed synchrotron spectrum from the hot flow. By extension, all OIR flares in BHBs are thus probably produced by the hot flow. Presence of a significant nonthermal electron population gives us clues about the processes operating in hot plasmas of the accretion flow. Spectral evolution of the flare emission puts strong constraints on the distribution of the magnetic field and the optical depth with distance from the black hole that can be compared with the theoretical dependences of various versions of the hot flow model.

5:00 **Wenfei Yu** (Shanghai Astronomical Observatory)
Spectral State Transitions in X-ray Binaries: Challenges to Current Accretion Theory (15+5)

Two major X-ray spectral states, namely the hard state and the soft state are seen in black hole binaries as well as neutron star low-mass X-ray binaries in which the magnetic field of the neutron star is probably weak. The soft state corresponds to an optically thick, geometrically thin disk flow, while the hard state corresponds to a hot accretion flow, the nature of which is not well-understood. We show the large range of the transition luminosity between the hard and the soft state put stringent challenge to current theory in the following aspects: 1) observations do not show a significant difference between the transition luminosity of black hole systems and neutron star systems, while the popular ADAF model predicts that the hard-to-soft transitions in neutron star systems should occur at a luminosity about an order of magnitude lower in luminosity than those in black hole systems; 2) the hard-to-soft transition luminosity has been seen to reach or close to the Eddington luminosity, which is much higher (e.g. ten times) than theoretical predictions. We show the X-ray observations of more than 20 bright X-ray binaries and more than 110 transient outbursts in the past 1-2 decades, as well as the observations of a few transient ULXs in nearby galaxies of a LMXB nature actually requires theorists to develop non-stationary models to explain the bright hard state regimes and spectral transitions in X-ray binaries.

5:20 **Gregory Sivakoff** (University of Alberta)
VLBI Parallax Distance to the Cataclysmic Variable SS Cygni Vindicates the Disk Instability Model (15+5)

Dwarf novae are white dwarfs accreting matter from a nearby red dwarf companion. Their regular outbursts are explained by a thermal-viscous instability in the accretion disc, described by the disc instability model that has since been successfully extended to other accreting systems. However, the prototypical dwarf nova, SS Cygni, presents a major challenge to our understanding of accretion disc theory. At the distance of 159 ± 12 parsecs measured by the Hubble Space Telescope, it is too luminous to be undergoing the observed regular outbursts. Using very long baseline interferometric radio observations, we report an accurate, model-independent distance to SS Cygni that places the source substantially closer at 114 ± 2 parsecs. This reconciles the source behavior with our understanding of accretion disc theory in accreting compact objects.

5:40 **Poster Viewing**

*** * * Banquet – 6 – 8 pm * * ***

Wednesday, November 6

8:00 **Breakfast Begins**

Session V: Global Structure of Accretion Flows II

9:00 **Charles Gammie** (University of Illinois at Urbana-Champaign)
Conduction in Low Luminosity Accretion Flows (25+5)

Black holes accreting far below the Eddington rate are expected to have nearly collisionless accretion flows. The mean free path is much larger than GM/c^2, and thermal conduction can play a role in reshaping the accretion flow. I will describe early results from a program to dynamically model black holes with thermal conduction.

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9:30 **Roman Shcherbakov** (University of Maryland-College Park)
Feeding and Accretion in Low-luminosity AGNs (25+5)

Most galaxies in the Universe host low-luminosity AGNs. These systems exhibit a vast range of dynamical and radiative effects, which require high sensitivity and high angular resolution to study. The closest objects with the largest central supermassive black holes are revealing their secrets with the improvement of instrumentation. I will review recent progress on (1) observing with Chandra and modeling of the accretion flow onset in Sgr A* and NGC3115, (2) observing with EHT and modeling of the inner accretion flow onto the Milky Way central black hole, (3) observing with VLT and Keck and modeling of the G2 object falling towards the Galactic Center.

10:00 **Laura Blecha** (University of Maryland-College Park)
Signatures of Single and Dual AGN Fueling in Mergers (15+5)

It is well-established that merging galaxies have a higher incidence of nuclear activity than their isolated counterparts. Single or dual active galactic nuclei (AGN) observed at various stages of galaxy merging provide valuable evidence of this supermassive black hole (SMBH) fueling mechanism, in addition to placing indirect constraints on the rate of SMBH mergers. Recent progress in spectroscopic searches for dual AGN has created, for the first time, a statistical sample of candidates. We describe efforts to characterize the signatures of AGN in mergers, focusing especially on their narrow-line profiles. Our previous work indicates that double-peaked narrow-lines, which are used as a selection criterion for dual AGN candidates, can arise from a variety of gas kinematic effects, as well as from dual SMBH motion during mergers. By combining hydrodynamic simulations with dust radiative transfer calculations, including our model for the narrow-line region, we are able to characterize the spectral signatures of single and dual AGN during galaxy mergers. In particular, we describe the substantial effects of dust scattering and obscuration in gas-rich mergers, as well as the contribution of stellar photoionization in the nuclear region to the narrow-line profiles. We discuss the implications of this modeling for future follow-up studies of candidate dual AGN.

10:20 **Coffee Break / Poster Viewing**

Wednesday, November 6

10:40 **Abderahmen Zoghbi** (University of Maryland-College Park)
Probing Black Hole Accretion with X-ray Reverberation (15+5)

The effects of strong gravity is imprinted in the observed spectra stellar and supermassive black holes. These are generally manifested in the broadening and distortion of reflection spectra emitted in the vicinity of the black hole. The reflection emission is also seen to lag the continuum illuminating continuum seen directly. This reverberation delays provide a powerful tool that directly probes the inner regions of accreting black holes. In this work, I will discuss X-ray reverberation in active galaxies, concentrating on Iron K reverberation. I will present results from XMM observations as well as new results from Suzaku and NuSTAR.

11:00 **Koji Mukai** (CRESST/UMBC, NASA/GSFC)
Inner Accretion Flow of Quiescent Dwarf Nova, V893 Sco, Inferred Form XMM-Newton Data (15+5)

It is well known that the simplest version of the disk instability model (DIM) cannot explain the X-ray observations of quiescent dwarf novae (DNe), starting with the problem that they are observed to be moderately bright X-ray sources, even though DIM predicts little accretion onto the white dwarf during quiescence. Here I present the results of XMM-Newton X-ray and UV observations of the eclipsing dwarf nova, V893 Sco, in quiescence. The X-ray spectrum requires the presence of intrinsic absorber. The energy dependence of the eclipse profile then requires the intrinsic absorber to be located close to the white dwarf and be confined to the orbital plane. This disk-like structure of cold matter, however, contains much less mass than a standard alpha-disk would. A sub-Keplerian disk with radial drift velocity of order 10% of the Keplerian velocity would match the observed properties of the X-ray emission from V893 Sco.

11:20 **Bin Luo** (Penn State University)
Energy Budget of AGNs with Disk-Like Emission Lines and its Implications for Accretion Disks (15+5)

In a small subset of active galactic nuclei (AGNs) the broad, optical emission lines have profiles that can be well described by models that attribute the emission to the surface of a Keplerian accretion disk. The most striking of the disk-like profiles are double peaked. Disk-like lines in AGNs have motivated the development of disk emission models to describe their profiles, and we can use these lines as tools to gain insights into the physical properties of accretion disks and the broad-line regions. We present X-ray and multiwavelength studies of a sample of eight high-luminosity disk-like emitters. The IR-to-UV spectral energy distributions (SEDs) of these sources are similar to the mean SEDs of typical quasars with a UV “bump"', suggestive of standard accretion disks radiating with high efficiency, which differs from low-luminosity disk-like emitters. Energy budget analysis suggests that for disk-like emitters in general, the inner disk must illuminate and ionize the outer disk efficiently (~15% of the nuclear ionizing radiation is required) via direct illumination and/or scattering. Warped accretion disks are probably needed for direct illumination to work in high-luminosity objects, as their geometrically thin inner disks decrease the amount of direct illumination possible for a flat disk. We have also discovered a broad absorption line quasar among our disk-like emitters.

11:40 **Ranjan Vasudevan** (University of Maryland-College Park)
The Hard X-ray Perspective on the Soft X-ray Excess in AGN (15+5)

The X-ray spectra of many active galactic nuclei (AGN) exhibit a `soft excess' below 1 keV; however its physical origin remains unclear. Diverse models have been suggested to account for it, including ionised reflection of X-rays from the inner part of the accretion disc, ionised winds/absorbers, Comptonisation and other processes. The ionised reflection model suggests a natural link between the prominence of the soft excess and the strength of the Compton reflection hump above 10 keV (the `hard excess' over a power-law), but it has not been clear until now what signatures, if any, the other candidate models would exhibit in the hard X-ray regime. Additionally, it has not been possible until recently to obtain high-quality simultaneous measurements of both soft and hard X-ray emission, but upcoming joint XMM-NUSTAR programmes provide precisely this opportunity. I will present an analysis of extensive simulations of candidate soft excess models as they would be observed by XMM and NUSTAR, to determine whether such campaigns can disambiguate between these different candidate models by using both hard and soft X-ray observations in tandem. A new diagnostic diagram will allow the soft excess production mechanism to be determined in individual sources and samples using the next generation of hard X-ray enabled observatories, without requiring long observations or complex model fits. Determining the soft excess production mechanism will have profound implications for our understanding of AGN accretion.

*** * * 12:00 - 1:30 Lunch * * ***

1:30 **Philip Hopkins** (Caltech)
How Does Gas Get from Galaxies to Black Holes? (25+5)

Super-massive black holes (SMBHs) and AGN are of fundamental interest both in their own right and to cosmology and galaxy formation. However, the physics of angular momentum transport from galactic scales to an accretion disk is one of the outstanding problems in our understanding of the formation and evolution of SMBHs. New, multi-scale hydrodynamic simulations can probe these scales. On large scales, a mix of galaxy mergers and violent events, together with stochastic encounters between black holes and molecular clouds, drives fuel into galactic nuclei. Gravitational instabilities then drive inflow down into the viscous accretion disk. The last stage of this instability takes the form of a lopsided eccentric nuclear disk, which may also explain many properties of the putative AGN torus. A wide range of observations also suggest there are changes to the dominant mechanisms driving inflow at certain characteristic luminosity thresholds, and these are closely related to a number of puzzles that make Seyferts not exactly analogous to quasars. I'll also discuss the implications of these processes for AGN host galaxies, the cosmological evolution of accretion, and feedback from black holes on their host galaxies.

Wednesday, November 6

2:00 **Mateusz Ruszkowski** (University of Michigan-Ann Arbor)
Chaotic Cold Accretion onto Supermassive Black Holes (15+5)

Using 3D adaptive mesh refinement simulations with the dynamical range of 10 million, linking the 50 kpc to sub-pc scales, we systematically relax the classic assumptions of the Bondi accretion in a typical galaxy hosting a supermassive black hole. In the more realistic scenario, where the hot gas is cooling, while heated and stirred by subsonic turbulence on large scales, the accretion rate is boosted up to two orders of magnitude compared with the Bondi prediction. The cause for the rapid accretion is the non-linear growth of thermal instabilities, leading to the condensation of cold gas clouds and filaments when $t_{cool}/t_{freefall}$ falls below ~10. These clouds decouple from the hot gas and “rain” onto the center. The recurrent collisions between clouds, filaments, and the central clumpy rotating torus promote angular momentum cancellation and dramatically boost accretion. On sub-pc scales the clouds are channelled to the very center via a funnel. A good approximation to the accretion rate is the cooling rate, which can be used as subgrid model, physically reproducing the boost factor of 100 required by cosmological simulations. Since our modelling is fairly general, chaotic cold accretion may be common in many systems, such as hot galactic haloes, groups, and clusters. In this mode, the black hole can quickly react to the state of the entire host galaxy, leading to efficient self-regulated AGN feedback and the symbiotic Magorrian relation. Chaotic accretion can generate high-velocity clouds, likely leading to strong variations in the AGN luminosity, and the deflection or mass-loading of jets. During phases of overheating, the hot mode becomes the single channel of accretion, though strongly suppressed by turbulence. High-resolution data could determine the current mode of accretion: assuming quiescent feedback, the cold mode results in a quasi-flat-temperature core as opposed to the cuspy profile of the hot mode.

Session VI: Wrap-up

2:20 **Andy Fabian** (University of Cambridge)
Summary and Some Visions of the Future (25+5)

Posters

The Structure of Magnetized Accreting Disks

Yann Boehler (CRyA, UNAM), Susan Lizano (CRyA, UNAM), Carlos Tapia (CRyA, UNAM), and Paola D'Alessio (CRyA, UNAM)

Protoplanetary disks are the birthplace of planets; to know their structure is essential to understand how their formation can occur. Our main purpose is to evaluate the effects of the diffusive processes on protoplanetary disk, and more specifically of the resistive heating which has never been taken into account until now.

For this purpose, we built a model based on equations of Shu (2008) to evaluate the vertical structure in temperature, local density, etc. of such a accreting magnetized disk.. Inside, we consider the accretion process in a disk with magnetic fields. The two main sources of diffuses process (intern heating) are taking into account in the system: (1) “viscous” torques exerted by turbulent and magnetic stresses, and (2) “resistive” redistribution of mass with respect to the magnetic flux arising from the imperfect conduction of current. Irradiation coming from the star is also included as an external source of the system.

An XMM-Newton View of 3C 411

Allison Bostrom (University of Maryland), Chris Reynolds (University of Maryland), and Francesco Tombesi (University of Maryland)

We present XMM-Newton observations of the broad-line radio galaxy 3C 411. After fitting various spectral models, an absorbed double-power law model is found to be the most plausible description of the data. While the softer power-law component is entirely consistent with that found in Seyfert galaxies (and hence likely originates from a disk corona), the additional power law component is very hard; amongst the AGN zoo, only flat-spectrum radio quasars have such hard spectra. Together with the very flat radio-spectrum displayed by this source, we suggest that it should be classified as a FSRQ. This leads to potential discrepancies regarding the jet inclination angle, with the radio morphology suggesting a large jet inclination but the FSRQ classification suggesting small inclinations.

Implications for Models of Coupled Disk-ADAF Flows from Specific Tests Against Observed Variability

Hal Cambier (UCSC) and David M. Smith (UCSC)

The evolving thermal and power-law components in black hole binary X-ray spectra have long been explained with a thermalized disk and some hot, Comptonizing medium, which in some pictures is an advective 'halo' flow interior to and possibly sandwiching the disk. In the latter case, coupling of the flows through electron thermal conduction leads to mass exchange and variability behavior including hysteresis. Previously, we studied this mechanism among others in the case of LMC X-3 where it lent itself to explaining observations of sudden drops in disk accretion rates that recover and recur on long viscous disk timescales; the mass exchange can accelerate and amplify variability at the boundary. However, we also found it necessary to suppress re-condensation of the hot flow at small radii as sustained, simultaneous increases in disk and halo accretion rates predicted by the model conflicted with the data. We examine potential physical explanations, including saturated conduction flux, as well as differing models in the literature with a greatly refined method, and discuss the implications for more common systems like the transient black-hole binaries.

Irradiation of an Accretion Disk by a Jet: Implications for Spin Measurements of Black Holes

Thomas Dauser (Dr. Karl Remeis Observatory & ECAP), Javier Garcia (Harvard-Smithsonian CfA), Jörn Wilms (Dr. Karl Remeis Observatory & ECAP), Moritz Böck (MPI für Radioastronomie), Refiz Duro (Dr. Karl Remeis Observatory & ECAP), Maurizio Falanga (ISSI), Keigo Fukumura (NASA/GSFC), Christopher S. Reynolds (University of Maryland)

X-ray irradiation of an accretion disk around a black hole leads to strong fluorescent reflection features, which are then broadened and distorted by relativistic effects. Analyzing the shape of this reflection spectrum allows us to determine the spin of the black hole. Generally, broad reflection features are identified with rapidly spinning black holes. As the shape also depends on the location and size of the irradiating source, we study how different irradiation geometries affect the determination of the spin. We find that broad reflection features are produced only for compact irradiating sources situated close to the black hole. This is the only case where the black hole spin can be determined unambiguously. In all other cases the line shape is narrower, which could either be explained by a low spin or an elongated irradiating source. Hence, for those cases no unique solution for the spin exists and therefore only a lower limit of the spin value can be given.

AGN Obscuration from Parsec Scale Winds and Accretion

Anton Dorodnitsyn (NASA/GSFC & University of Maryland), Tim Kallman (NASA/GSFC), and G. Bisnovatyi-Kogan (Space Research Institute-Moscow)

Observational properties of active galactic nuclei are essentially influenced by their winds. I will present the results from the multidimensional, flux-limited diffusion radiation hydrodynamics simulations of the dusty obscuring flows in AGN. Simulations show that the illumination of a parsec-scale, dusty accretion disk by X-rays, and UV, forces the disk to become geometrically thick due to pressure of the reprocessed IR radiation on dust. If AGN luminosity exceeds 0.1Ledd the outer part of the disk develops a rigorous IR-driven wind. This dense wind provides most of the obscuration making an AGN to appear as Type-2. The inner hot and photoionized part of the same large scale wind has properties similar to those of a warm absorber flow. At luminosities =0.1Ledd episodes of the outflow are followed by periods when the wind switches to slow accretion.

Constraining MHD Disk-Winds with X-ray Absorbers in AGNs

Keigo Fukumura (James Madison University), Demos Kazanas (NASA/GSFC), Francesco Tombesi (University of Maryland & NASA/GSFC), Chris Shrader (NASA/GSFC), Ioannis Contopoulos (Academy of Athens, Greece), Ehud Behar (Technion, Israel)

From the state-of-the-art spectroscopic observations of AGNs, the robust features of warm absorbers (WAs) have been often detected in soft X-rays (2 keV). While the identified WAs are often mildly blueshifted to yield line-of-sight velocities up to ~100-3,000 km/sec in typical X-ray-bright Seyfert 1 AGNs, a fraction of Seyfert galaxies such as PG 1211143 exhibits even faster absorbers (v/c~0.1-0.2) called ultra-fast outflows (UFOs) whose physical condition is more extreme compared with the WAs. Motivated by these recent X-ray data we show that the magnetically- driven accretion-disk wind model is a plausible scenario to explain the characteristic property of these X-ray absorbers. As a preliminary case study we demonstrate that the wind model parameters (e.g. launching radius and wind density among others) can be constrained by XMM-Newton data from PG 1211143 with chi-squared spectral analysis.

Lyman Edges in Supemassive Black Hole Binaries

Aleksey Generozov (Columbia University) and Zoltan Haiman (Columbia University)

In the hierarchical picture of structure supermassive black hole binaries (SMBHBs) are expected to be a common byproduct of galaxy mergers. However, we have only one clear example at parsec separations. One explanation for the paucity of observational evidence is that detection is hindered by our poor understanding of emission from material around a SMBHB. With this in mind, I propose a new EM signature for SMBHBs: a sharp, orders of magnitude drop in flux at the Lyman limit region of the spectrum due to absorption by neutral hydrogen in the circumbinary disk. This would be a distinctive feature never seen observationally in AGN. I explain why SMBHBs could have this feature, while AGN would not.

Propagating Fluctuations In A Global Accretion Disk Simulation

J. Drew Hogg (University of Maryland), Christopher Reynolds (University of Maryland), and Sean O'Neill (University of Colorado-Boulder)

We present an analysis of “propagating fluctuations” in a long, global magnetohydrodynamic (MHD) simulation of the magnetorotational instability (MRI) around a black hole. Viscosity in the standard Shakura and Sunyaev accretion disk (alpha-disk) model is believed to be stochastically generated by turbulence from the MRI, which causes fluctuations in the accretion rate that combine as they propagate to smaller radii. Signatures of propagating fluctuations are thought to have been found in X-ray observations of stellar mass black holes and Kepler observations of AGN, but simulated disks have yet to reproduce this behavior. We find the distribution of accretion rate becomes progressively more skewed at smaller radii and is log-normal at the ISCO in our simulation, and that the coherence of accretion rate fluctuations between two radii is regulated by the viscous time.

Global MHD simulation of Cataclysmic Variable (CV) Accretion Disks

Wenhua Ju (Princeton University) and James. M. Stone (Princeton University)

Magneto-rotational instability (MRI) has been recognized as the mechanism to drive angular momentum transport in most accretion disks (Balbus & Hawley 1998). One of the major challenges nowadays for accretion theory is to understand the behaviors of MRI on global scales. Accretion disks in close mass-transferring binary star systems (which appear as cataclysmic variables in observations) are ideal laboratories for this problem due to their richness in observational data and relatively narrow range of spatial and temporal scales. We perform 3D global MHD simulations of CV disks with the Athena code to study how MRI acts on the structure, evolution and angular momentum transport of the disks. In CV disks, both spiral shocks excited by the binary potential and MRI turbulence contribute in driving angular momentum transport. With our preliminary results, we found the effective $\alpha_R \sim$ 0.02 - 0.05 (Reynolds stress / gas pressure) due to spiral shocks in pure hydro disks without MRI. The α_M (Maxwell stress / gas pressure) in MHD disks are going to be reported recently with our ongoing simulations. We will compare the alpha from simulations with the observed values in Dwarf Novae.

Poynting-Robertson battery and the accretion disk - jet connection in X-ray Binaries

Demos Kazanas (NASA/GSFC), N. Kylafis (University of Crete), I. Contopoulos (Academy of Athens), and D. Christodoulou (University of Massachusetts-Lowell)

Significant phenomenology has been developed to describe the spectral states of neutron-star and black-hole X-Ray Binaries (XRBs), and there is general agreement about the type of the accretion disk around the compact object in the various spectral states. We investigate whether the phenomenology describing the X-ray emission on one hand and the jet appearance and disappearance on the other can be put together in a consistent physical picture. We show consideration the so-called Poynting-Robertson cosmic battery (PRCB), which has been shown to explain in a natural way the formation of magnetic fields in the disks of AGN, can provide a consistent picture of the relation between spectral state and jet presence also in XRBs, including also the relevant time scales. As such it argues for the significant influence of this process in the structure and dynamics of accretion disks in general.

Quasar Accretion-Disk Structure and Microlensing-Induced Changes of the Fe K \alpha Line

Lukas Ledvina (Charles University in Prague), David Heyrovsky (Charles University in Prague), and Michal Dovciak (Astronomical Institute, Academy of Sciences of the Czech Republic)

In quasar microlensing the flux from a quasar is modulated by the gravitational lensing effect of individual stars in a galaxy lying in the foreground along the line of sight. The stars form a network of caustics that scan the surface of the quasar accretion disk passing in the background. Here we illustrate the effects of microlensing on the iron K_\alpha line emitted from the innermost disk. Changes in the line profile were most clearly observed by Chartas et al. (2012) in the lensed quasar RX J1131-1231. We use a fully relativistic Kerr metric thin disk model (Dovciak et al. 2004) to demonstrate the connection between features of the line profile and the caustic position on the emission map of the quasar. In the future this method may prove to be a very powerful technique for spatially resolving the X-ray emission from the innermost accretion disk.

Size Measurements of the Quasar X-Ray Continuum Emission Region from Microlensing

Chelsea MacLeod (US Naval Academy), Christopher Morgan (US Naval Academy), Ana Mosquera (The Ohio State University), Christopher Kochanek (The Ohio State University), Malte Tewes (EPFL), Frédéric Courbin (EPFL), and Georges Meylan (EPFL)

Microlensing offers a unique way to constrain the physical extent of different emission regions in a lensed quasar, putting to test various accretion and continuum emission models. We perform a joint microlensing analysis using six Chandra observations (spanning six years) of the lensed quasar SDSS 09240219, in which X-ray microlensing variability is detected with high confidence, and high-cadence r-band monitoring (spanning eight years). Our joint microlensing analysis provides robust constraints on the extent of the X-ray continuum emission region and the accretion disk radius, disfavoring models involving an extended X-ray corona.

Evidence for Large Temperature Fluctuations in Quasar Accretion Disks from Spectral Variability

John J. Ruan (University of Washington), Scott F. Anderson (University of Washington), Eric Agol (University of Washington), and Jason Dexter (UC-Berkeley)

The well-known bluer-when-brighter trend observed in quasar variability is a signature of the complex processes in the accretion disk, and can be a probe of the quasar variability mechanism. Using a sample of 604 variable quasars with repeat spectra in SDSS-I/II, we construct difference spectra to investigate the physical causes of this bluer-when-brighter trend. The continuum of our composite difference spectrum is well-fit by a power-law, with a spectral index in excellent agreement with previous results. We measure the spectral variability relative to the underlying spectra of the quasars, which is independent of any extinction, and compare to model predictions. We show that our SDSS spectral variability results cannot be produced by global accretion rate fluctuations in a thin disk alone. However, we find that a simple model of a inhomogeneous disk with localized temperature fluctuations will produce power-law spectral variability over optical wavelengths. We show that the inhomogeneous disk will provide good fits to our observed spectral variability if the disk has large temperature fluctuations in many independently varying zones, in excellent agreement with independent constraints from quasar microlensing disk sizes, their strong UV spectral continuum, and single-band variability amplitudes. Our results provide an independent constraint on quasar variability models, and adds to the mounting evidence that quasar accretion disks have large localized temperature fluctuations.

Spectral Hardening in Black Hole X-ray Binaries

Greg Salvesen (JILA, University of Colorado-Boulder), Jon M. Miller (University of Michigan-Ann Arbor), Rubens C. Reis (University of Michigan-Ann Arbor), and Mitchell C. Begelman (JILA, University of Colorado-Boulder)

A multi-color disk blackbody model adequately fits observations of X-ray binary accretion disks with only two parameters: the disk temperature and flux normalization. The flux normalization combines intrinsic parameters (distance, inclination), the inner disk radius, and the color correction factor, which phenomenologically accounts for hardening of the seed disk spectrum due to physical effects such as Comptonization and the disk vertical structure. Here, we present two main results on the role of the color correction factor in spectral hardening in black hole X-ray binaries. (1) A variable color correction factor is a viable alternative to disk truncation to explain the observed disk evolution in black hole state transitions. (2) The color correction factor is dependent on the disk inclination; therefore, caution should be exercised before assuming a constant canonical value. We will discuss the implications of these results on black hole state transitions, accretion disk temperature measurements, and black hole spin measurements.

Simulated X-ray Spectra from Stellar-mass Black Holes

Jeremy Schnittman (NASA/GSFC), Julian Krolik (Johns Hopkins University), and Scott Noble (RIT)

We combine global magneto-hydrodynamical (MHD) simulations of accreting black holes with a fully relativistic radiation transport code to generate simulated spectra of stellar-mass black holes. We explore the effects of black hole spin and accretion rate, and are able to reproduce many well-known features in the X-ray spectrum, including a thermal peak, power-law tail, and iron fluorescent line. For the thermal-dominated spectra, we find that the MHD simulations systematically predict greater radiative efficiency and harder spectra than expected when using a simple thin disk model with an inner edge at the ISCO. This corresponds to a systematic under-estimate of the black hole spin when using conventional fitting tools.

Effects of Local Dissipation Profiles on Magnetized Accretion Disk Spectra

Ted Tao (St. Mary's College of Maryland) and Omer Blaes (UC-Santa Barbara)

We present spectral calculations of non-LTE accretion disk models appropriate for high luminosity stellar mass black hole X-ray binary systems. We first use a dissipation profile based on scaling the results of shearing box simulations of Hirose, Krolik & Blaes (2009) to a range of annuli parameters. We simultaneously scale the effective temperature, orbital frequency and surface density with luminosity and radius according to the standard alpha-model (Shakura & Sunyaev 1973). This naturally brings increased dissipation to the disk surface layers (around the photospheres) at small radii and high luminosities. We find that the local spectrum transitions directly from a modified black body to a saturated Compton scattering spectrum as we increase the effective temperature and orbital frequency while decreasing mid-plane surface density. Next, we construct annuli models based on the parameters of a 0.8 Eddington disk orbiting a 6.62 solar mass black hole using two modified dissipation profiles that explicitly put more dissipation per unit mass near the disk surface. The new dissipation profiles are qualitatively similar to the one found by Hirose, Krolik & Blaes (2009), but produce strong near power-law spectral tails. Our models also include physically motivated magnetic acceleration support based once again on scaling the Hirose, Krolik & Blaes (2009) results. We present three full-disk spectra each based on one of the dissipation prescriptions. Our most aggressive dissipation profile results in a disk spectrum that is in approximate quantitative agreement with certain observations of the steep power law (SPL) spectral states from some black hole X-ray binaries.

On the Nature of Correlated Optical and X-ray Variability of Black Hole Binaries

Alexandra Veledina (University of Oulu), Juri Poutanen (University of Oulu), Indrek Vurm (Columbia University), and Adam Ingram (University of Amsterdam)

The X-ray radiation of accreting black hole binaries (BHB) shows variations on a wide range of timescales, from the week-long spectral transitions down to millisecond flares. Among the most prominent features commonly observed in BHBs are low-frequency quasi-periodic oscillations (QPOs). QPOs at the same frequency have also been detected in the optical and UV in a number of low-mass BHB. In addition, the complex shape of the optical/X-ray cross-correlation function suggests that the optical emission drops before the X-ray flares, rises sharply at the time of the X-ray flares and has a peak after that. Moreover, the width of the auto-correlation functions implies that the optical varies on shorter timescales than the X-rays. Such a behavior cannot be understood in terms of the standard optical candidates: the irradiated accretion disk or the jet. We propose the first physical model capable of explaining the mysterious optical/X-ray connection along with their common QPO features. It is based on the hot accretion flow scenario, where the broad-band, optical to the X-ray spectrum is formed by the synchrotron self-Compton emission in hybrid thermal/nonthermal plasmas. The complex shape of the cross-correlation function is naturally explained by a combination of the dip, because of the spectral pivoting, with a shifted peak because of the X-ray reprocessing in the outer disk. The simultaneous optical/X-ray QPOs are produced by the Lense-Thirring, solid-body precession of the whole hot flow if the black hole spin is misaligned from the orbital axis. Unlike many other purely kinematic QPO models, our hot flow scenario is also consistent with the broadband spectral properties.

Seeing to the Event Horizon Through Energy-resolved X-ray Reverberation

Dan Wilkins (St Mary's University)

The extreme variability in the X-ray emission from accreting black holes, most notably the measurement of reverberation time lags between variability in the X-ray continuum emission from the corona and reflection of this emission from the accretion disc has added a further dimension to the study of accreting black holes. Reverberation time lags correspond to the light travel times over just a few gravitational radii, indicating they are probing in the innermost regions, right down to the innermost stable orbit and the event horizon, complimenting measurements of X-ray spectra and gravitational redshifts which probe the geometry of the spacetime around the black hole.

I will discuss how, through the combination of timing and spectral analysis of X-ray data and a theoretical understanding of X-ray reflection and reverberation in the Kerr spacetime around black holes gained from systematic and versatile ray tracing simulations, the innermost structure of accreting black hole systems and the physics of accretion flows and the X-ray emission process can be understood in detail. Such analyses of the AGN 1H0707-495 and IRAS 13224-3809 with XMM Newton have revealed an unprecedented amount of information about not only the location and extent of the X-ray emitting corona but has also given an insight into the mean by which fluctuations in luminosity propagate through the corona.

Future generations of X-ray observatory will provide exciting advances in probing accreting black holes. Larger effective areas and improved energy resolution will mean that while, until now, X-ray energy spectra and variability have typically been analyzed separately, true energy-dependent variability analysis will be possible. I will discuss how energy-resolved analysis of timing data can be understood and developed into an observational tool analogous to present-day spectral analysis to truly exploit X-ray observations and place more detailed constraints on models of X-ray emission and the underlying accretion flow, advancing our understanding of these extreme objects.