



X-ray Binaries

Celebrating 50 Years
Since the Discovery of Sco X-1

2012 Chandra Science Workshop
Hosted by the Chandra X-ray Center

July 10-12, 2012

at the DoubleTree Guest Suites Boston, MA

Chandra
X-ray
Center

Smithsonian
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This Chandra science workshop is sponsored by the Chandra Directors Office (CDO) at the Chandra X-ray Center (CXC), part of the Smithsonian Astrophysical Observatory in Cambridge, MA.

Program

Tuesday July 10

I. THE DISCOVERY OF SCO X-1 AND THE DAWN OF EXTRASOLAR X-RAY ASTRONOMY

- 9:00 - 9:15 Paul Green and Harvey Tananbaum
Welcome
- 9:15 - 9:50 Riccardo Giacconi
Considerations on Method (1959-2012)
- 9:50 - 10:25 Ken Pounds
Observations of X-ray Binaries with Skylark and Ariel 5
- 10:25 - 11:00 Fred Seward
Rocket Observations of Sco X-1 and Other X-ray Sources 1965-1969
- 11:00 - 11:30 COFFEE AND POSTER VIEWING
- 11:30 - 12:00 POSTER MICROTALKS
- ### II. NEUTRON STAR EQUATION OF STATE
- 12:00 - 12:15 Nathalie Degenaar
Probing Fundamental Physics with Transiently Accreting Neutron Stars
- 12:15 - 12:30 Manuel Linares
Thermonuclear Bursts from Slowly and Rapidly Accreting Neutron Stars
- 12:30 - 12:45 Michael Zamfir
Distance Independent Constraints on Mass and Radius from Type I X-ray Bursts
- 12:45 - 1:00 Sebastien Guillot
Measurement of the Radius of Neutron Stars
- 1:00 - 2:15 LUNCH

III. JETS (1)

- 2:15 - 2:45 James Miller-Jones
Black Hole Accretion and Jet Ejection
- 2:45 - 3:15 Sera Markoff
Constraining the Role and Power of Jets in Black Hole Binaries
- 3:15 - 3:30 David Cseh
*Jet Ejection Events from the Intermediate Mass Black Hole ESO243-49
HLX-1*
- 3:30 - 3:45 David Russell
Constraints on X-ray Polarization of Synchrotron Jets from Stellar-Mass BHs
- 3:45 - 4:30 COFFEE AND POSTER VIEWING

IV. JETS (2) AND INDIVIDUAL SOURCES

- 4:30 - 4:45 Farid Rahoui
*An Optical/Infrared Spectroscopic View of the Cygnus X-1 and
GX 339-4 Jets*
- 4:45 - 5:00 Paul Sell
*Integral Field Spectroscopy and Chandra Observations of the
Cygnus X-1 Shell*
- 5:00 - 5:15 Angelo Varlotta
Multi-wavelength Observations of Cygnus X-3
- 5:15 - 5:30 Petri Savolainen
*Results from Observing Campaigns on Cygnus X-3 During 2010-
2011*

Wednesday July 11

V. X-RAY SPECTROSCOPY AND STATES

- 9:00 - 9:30 Joey Neilsen
New Results on Massive Winds and X-ray States in Black Hole X-ray Binaries
- 9:30 - 9:45 Jeroen Homan
A New Ranking Scheme for Neutron-Star Low-Mass X-ray Binaries
- 9:45 - 10:00 Oliwia Madej
Reflection in Carbon-Oxygen Dominated Accretion Discs of UCXB
- 10:00 - 10:15 Michael Nowak
Chandra-HETG Observations of LMC X-1
- 10:15 - 10:30 Norbert S. Schulz
Collisional Ionization in the X-Ray Spectrum of the Ultra-compact Binary 4U 162
- 10:30 - 11:00 COFFEE AND POSTER VIEWING
- ### VI. POPULATIONS AND ULXs (1)
- 11:00 - 11:30 Jeanette Gladstone
Observational Review of ULXs
- 11:30 - 12:00 G. Fabbiano
Extragalactic XRB Populations
- 12:00 - 12:15 Zhongli Zhang
Low-Mass X-ray Binaries in Elliptical Galaxies
- 12:15 - 12:30 Stefano Mineo
High-mass X-ray Binaries in Star-forming Galaxies
- 12:30 - 2:00 LUNCH

VII. POPULATIONS AND ULXs (2), THEORY (1)

- 2:00 - 2:15 Floyd Jackson
The Brightest X-ray Point Sources in M82
- 2:15 - 2:30 Marianne Heida
Discovering the Nature of Bright ULXs with Optical Spectroscopy
- 2:30 - 2:45 Tana Joseph
The X-ray Point Source Population of NGC 4472
- 2:45 - 3:00 Tassos Fragos
X-ray Binary Evolution Across Cosmic Time
- 3:00 - 3:45 COFFEE AND POSTER VIEWING

VIII. THEORY (2) AND INDIVIDUAL SOURCES

- 3:45 - 4:00 Michael Tremmel
Modeling the Redshift Evolution of the Normal Galaxy X-ray Luminosity Function
- 4:00 - 4:30 Will Farr
Mass Measurements of Black Holes in X-Ray Transients: is there a Mass Gap?
- 4:30 - 4:45 Akos Bogdan
The Formation Scenarios of Low-Mass X-ray Binaries
- 4:45 - 5:00 Tsing Wai Wong
Understanding Compact Object Formation and Natal Kicks
- 5:00 - 5:15 Diego Altamirano
IGR J17091-3624: the Little Sister of the Enigmatic Black Hole GRS 1915+105
- 5:30 - 7:00 RECEPTION WITH MUSIC AND CASH BAR

Thursday July 12

XI. THEORY (3) AND INDIVIDUAL SOURCES

- 9:00 - 9:30 Ken Oshuga
Overview of Recent Advances in Accretion Disk Theory
- 9:30 - 9:45 Michal Bursa
BHXR B Accretion Disks: Spectra Too Soft?
- 9:45 - 10:00 Michele M. Montgomery
SPH Simulation of Naturally Tilted Disks in Close Binary Systems
- 10:00 - 10:15 Ben Tofflemire
X-ray Grating Observations of Recurrent Nova T Pyx
- 10:15 - 10:30 Sven Wilbert
Chandra Follow-Up Analysis on HESS J1841-055
- 10:30 - 11:15 BREAK AND POSTER VIEWING

X. VARIABILITY AND INDIVIDUAL SOURCES

- 11:15 - 11:45 Poshak Gandhi
Optical/IR - X-ray Variability in X-ray Binaries
- 11:45 - 12:00 Paul A. Mason
High Speed Optical Photometry of LMXBs and CVs
- 12:00 - 12:15 Ricardo Heras
The Birth-Ultrafast-Magnetic-Field-Decay Model Applied to Isolated MSPs
- 12:15 - 12:30 Maithili Kalamkar
X-ray Variability Studies of the BHC SWIFT J1753.5 - 012 in Soft Band
- 12:30 POSTER REMOVAL, BAG LUNCH PROVIDED

Posters

- Christina Aragona - *LS 5039 and HD 259440: A Multiwavelength Approach*
- Tullio Bagnoli - *A Comprehensive Study of Recent Data on the Rapid Burster*
- Robin Barnard - *A Period Distribution for 12 M31 X-ray Transients from Chandra and HST*
- Paolo Bonfini - *The X-ray Point Sources in NGC4261 and Their Relation to the GC Population*
- Christopher Britt - *Variability of Optical Counterparts in the Galactic Bulge Survey*
- Mark Burke - *The X-ray Binaries of Centaurus A*
- Pablo Cassatella - *New Techniques for Spectral-Timing Variability Modelling in BHXRBs*
- Jan Cechura - *Probing the Environment of X-ray Binaries*
- Francesca Fornasini - *Searching for New High-Mass X-Ray Binaries in the Norma Spiral Arm*
- Cynthia Froning - *Far-Ultraviolet Spectroscopy of Low Mass X-ray Binaries with HST/COS*
- Robert Hynes - *Optical Observations of the Z Sources Sco X-1 and Sco X-2 (GX349+2)*
- Juthika Khargharia - *NIR Observations of Low Mass X-Ray Binaries*
- Laura Kreidberg - *Mass Measurements of Black Holes in X-Ray Transients: Is There a Mass Gap?*
- Denis Leahy - *New views of Hercules X-1 from Long Term Observations with RXTE*
- Dachen Lin - *The Spectral Evolution along the Z track of GX 17+2*

- Grigoris Maravelias - *Optical Spectroscopy of High-Mass X-ray Binaries in the Small Magellanic Cloud*
- Michael McCollough - *Cygnus X-3 and Its Little Friend: Stellar Endpoint Meets Stellar Beginning*
- Ivica Miskovicova - *Feeding the Monster: Wind Accretion in Cygnus X-1*
- Kumiko Morihana - *An X-Ray and Near-Infrared Study of the Galactic Ridge X-Ray Emission*
- Blagoy Rangelov - *High Mass X-ray Binaries in Nearby Star-forming Galaxies*
- Thomas Rauch - *How to Model Super-Soft X-ray Sources?*
- Serena Repetto - *Natal Kicks of Stellar-Mass Black Holes*
- Edward Robinson - *The Optical Orbital Light Curve of the LXMB V1408 Aquilae (= 4U 1957+115)*
- Joshua Schroeder - *Optical Detections of Black Widow Pulsar Counterparts*
- Malgosia Sobolewska - *X-ray Lightcurves of GRS 1915+105: a Tool to Determine Quasars' Accretion State*
- Lennart van Haften - *Variability and Populations of Low-Mass X-ray Binaries*
- Saeqa Vrtilik - *Putting X-ray Binaries in their Proper Place*
- Neven Vulic - *A Stacking Analysis of Star Clusters in M51: The Search for X-Ray Binaries*
- Natalie Webb - *Understanding Intermediate Mass Black Holes Through Study of ESO 243-49 HLX-1*

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Abstracts

IGR J17091-3624: THE LITTLE SISTER OF THE ENIGMATIC BLACK HOLE GRS 1915+105

Diego Altamirano
Anton Pannekoek Institute

IGR J17091-3624 is a black hole system which has very recently attracted the interest in the scientific community as it is the first system to show some of the bizarre, high-amplitude, highly-structured X-ray variability only seen before in the extremely energetic black hole system GRS 1915+105. In comparable states, IGR J17091-3624 X-ray flux can be between 30 and 50 times lower than that measured from GRS 1915+105, suggesting that either (i) all models requiring near Eddington luminosities for GRS 1915+105-like variability fail, (ii) IGR J17091-3624 is very far (> 20 kpc) or (iii) IGR J17091-3624 harbors one of the least massive black holes known ($< 3 M_{\odot}$). In this talk I will review what we have learn so far from IGR J17091-3624 and summarize how we can use this system to learn more about what happens at the brink of a black hole.

LS 5039 AND HD 259440: A MULTIWAVELENGTH APPROACH

Christina Aragona
Lehigh University

A handful of Galactic High Mass X-ray Binaries have been observed to emit radiation at very high energies (MeV-TeV), dubbed gamma-ray binaries. This poster will review the importance of multiwavelength observations for understanding two of these systems, HD 259440 and LS 5039. For HD 259440, detection of a nearby high-energy source instigated optical observations to search for evidence the system's binarity. For LS 5039, optically determined orbital and stellar parameters combined with constraints on the system inclination angle from X-ray, UV, and radio observations are bringing us closer to identifying the nature of the interaction region and the compact object. I am grateful for support from NSF grant AST-1109247 and Lehigh University.

A COMPREHENSIVE STUDY OF RECENT DATA ON THE RAPID BURSTER

Tullio Bagnoli
SRON (Netherlands Institute for Space Research)

We are studying all the RXTE (PCA and ASM), INTEGRAL (JEM-X) and Beppo SAX (WFC) data available for the Rapid Burster (RB). Our purpose is to find more clues of the nature of type II bursts and to characterize the type I bursting behavior of the RB. One of the classes of type I bursts we found, featuring a distinctively different shape, seems to mark the onset of an accretion instability triggering intense type II bursts trains. We also found a new class of type II bursts, consisting of very strong flares similar to those observed in only two other sources, the accreting black holes in GRS1915+105 and IGR J17901-3624. We investigate the possibility of a connection between the RB and these exceptional sources, which would give new insight in modeling both their variability and the RB itself.

A PERIOD DISTRIBUTION FOR 12 M31 X-RAY TRANSIENTS FROM CHANDRA AND HST

Robin Barnard
Harvard-Smithsonian Center for Astrophysics

Almost all Galactic black hole (BH) binaries with low mass donors are transient X-ray sources; we expect most of the X-ray transients (XRTs) observed in external galaxies to be BH binaries also. Obtaining period estimates for extra-galactic XRTs is challenging, but the resulting period distribution is an important tool for modeling the galaxy evolution. We have obtained periods, or upper limits, for 12 XRTs in M31, using a relation between the optical and X-ray luminosities. We have been monitoring the M31 center with Chandra, following up XRTs with HST; 4σ B magnitude limits for counterparts are $\sim 26 - 29$. We obtain period estimates for each XRT for both neutron star and BH accretors. These M31 XRTs appear to be somewhat skewed towards shorter periods than XRTs in the Milky Way.

THE FORMATION SCENARIOS OF LOW-MASS X-RAY BINARIES

Akos Bogdan
Smithsonian Astrophysical Observatory

NGC 4342 is a compact, very low stellar mass early-type galaxy, which has an extended, massive dark matter halo and presumably hosts a large population of globular clusters. Based on Chandra observations, we resolved ~ 17 bright excess X-ray sources beyond the optical extent of the galaxy, part of which are likely to be low-mass X-ray binaries (LMXBs) associated with the extended population of globular clusters. The unique combination of these properties allows us to address the debate about the formation scenarios of LMXBs, namely to directly assess the sources that were formed in globular clusters and expelled into the field. We will discuss current results and future prospects in resolving the debate about the formation scenarios of LMXBs.

THE X-RAY POINT SOURCES IN NGC 4261 AND THEIR RELATION TO THE GC POPULATION

Paolo Bonfini
SAO

We present a study of the Low Mass X-ray Binary (LMXB) sources of the elliptical galaxy NGC 4261 and its association with the Globular Cluster (GC) population, based on CHANDRA ACIS and HST WFPC2 data. We identified the GC counterparts of the LMXB sources and performed a spatial analysis in order to probe the azimuthal anisotropy revealed by Zezas et al. (2003) in the X-ray source distribution. The GC population shows significant asymmetry about a NE-SW axis, while the distribution of the X-ray sources shows less pronounced asymmetry in comparison to the previous data. We also measure the parameters of the X-ray luminosity function of the LMXBs, and we discuss these results in the context of similar results for other galaxies.

VARIABILITY OF OPTICAL COUNTERPARTS IN THE GALACTIC BULGE SURVEY

Christopher Britt
Louisiana State University

We present optical identification of counterparts in the Galactic Bulge Survey. Included are statistics concerning the proportion of sources showing variability and the periodicity of those sources. We summarize the properties of the population of variable counterparts to X-ray sources in the Galactic Bulge. We also highlight some particular sources with interesting optical counterparts.

THE X-RAY BINARIES OF CENTAURUS A

Mark Burke
University of Birmingham

We aim to distinguish between the different populations of X-ray binaries (XRBs), and, where possible, discover the nature of their compact objects. This work focusses on the detailed spectral modeling of XRBs from six 100 ks Chandra ACIS observations taken in 2007, and involves fitting absorbed disk blackbody and power law models to the spectra of the brightest sources. Spectral modeling is a valid approach for the brightest ~ 50 sources in these observations, down to a limiting L_X of $\sim 10^{37}$ erg/s, a population that is analogous to the XRBs typically found in the Milky Way. For the remaining XRBs with luminosity $< 10^{37}$ erg/s, of which there are > 330 sources across the 6 observations, further investigation using hardness ratios, colors, and variability tests are used in classification.

BHXR B ACCRETION DISKS: SPECTRA TOO SOFT?

Michal Bursa
ASU

In case of almost every black-hole X-ray binary where BH spin has been estimated using the method of fitting of X-ray continuum, the result shows a drop of the estimated spin with increasing luminosity after luminosity exceeds a threshold value of ~ 0.3 Eddington. This tells us that the accretion disk model that has been used (Novikov-Thorne thin disk) starts to have difficulties to accurately describe the real disk spectra, which are significantly softer than the one predicted by the model. However, it is not only the disk model which shapes the final spectrum. Equally important is the spectral hardening predicted by disk atmosphere models (e.g. BHSPEC). The talk will summarize processes that modify emergent spectrum of thermal disks and depart it from being blackbody. It will show the local (at each place in the disk) and global (after integration over the disk) spectral hardening factor, its dependence on luminosity and alpha-viscosity and implications for spectral fittings.

NEW TECHNIQUES FOR SPECTRAL-TIMING VARIABILITY MODELING IN BHXRBS

Pablo Cassatella
University of Southampton

The emission properties of Black Hole X-ray Binaries (BHXRBS) are commonly studied in terms of their energy spectrum or by characterizing their variability properties with e.g. power spectral densities. These products can be modeled and fitted using X-ray analysis packages. Self-consistent energy and frequency fits are however not very common and seldom retain intensity, variability and phase information at the same time. We discuss powerful novel techniques that self-consistently make use of Fourier-frequency and energy-dependent information and allow to fit all the above quantities simultaneously with user-made emission/variability models. We also show some potential applications as well as some earlier work.

PROBING THE ENVIRONMENT OF X-RAY BINARIES

Jan Cechura
Astronomical Institute of the ASCR

We combine a theoretical and observational approach to address the topic of matter distribution in the immediate vicinity of X-ray binaries and its structure. The results of a numerical model of a radiation-driven stellar wind, calculated by using the parameters appropriate for the high mass X-ray binary systems Cygnus X-1 and Cygnus X-3, are presented and discussed with regard to phase-resolved optical and infrared spectroscopic data, and Chandra HETG X-ray data. We use the indirect imaging method of Doppler tomography to probe the distribution of radiation emitting matter in these systems, in order to test the reliability of the numerical model as well as to set constraints on various physical parameters.

JET EJECTION EVENTS FROM THE INTERMEDIATE MASS BLACK HOLE ESO243-49 HLX-1

David Cseh
CEA Saclay

Ultraluminous X-ray sources (ULXs) are variable off-nuclear extragalactic X-ray sources with luminosities greatly exceeding the Eddington luminosity of a $20 M_{\odot}$ compact object, assuming isotropic emission. ULXs are binary systems containing a compact object that is either a stellar-mass black hole (StMBH) with beamed or super-Eddington emission; or an intermediate-mass black hole (IMBH). Jets have been observed from StMBHs as well as from supermassive black holes (SMBHs). Jets should also be produced by IMBHs, although evidence for this third class of black hole has until recently been weak. We report the radio detection of jet ejection events during the transition from hard to soft states of the best IMBH candidate ESO243-49 HLX-1. We show that despite the very diverse nature of ULXs, some might can bridge the gap between StMHBs and SMBHs.

PROBING FUNDAMENTAL PHYSICS WITH TRANSIENTLY ACCRETING NEUTRON STARS

Nathalie Degenaar
University of Michigan

In transient X-ray binaries, the crust of a neutron star becomes temporarily heated during accretion outbursts, while it subsequently cools in quiescence. This crustal cooling can be observed by studying the thermal X-ray emission from quiescent neutron stars with sensitive X-ray satellites. Comparing these observations with theoretical simulations provides a unique opportunity to gain insight into the heat production and thermal transport properties of the neutron star crust. In the past decade, it was possible to monitor the crust cooling curves of 4 neutron star X-ray binaries that were severely heated during prolonged accretion episodes of years. Recently, we have found evidence for crust cooling in a 11-Hz X-ray pulsar in the globular cluster Terzan 5, which experienced a much shorter outburst of only a few weeks. This has important implications for our understanding of the heat production inside neutron star crusts. Furthermore, these findings imply that a much larger sample of transiently accreting neutron stars can be used for crust cooling studies, which can greatly advance this research field. I will discuss the latest results on our quiescent monitoring of Terzan 5.

EXTRAGALACTIC XRB POPULATION

G. Fabbiano
CfA

XRB populations can be detected with Chandra in all types of galaxies. We can now study the energy distribution, variability, and luminosity function (XLF) of these sources, both to understand their nature and evolution in different stellar populations. XLFs differ for different types of XRBs: the HMXB XLF is a power-law extending to ULXs; the LMXB XLF presents breaks and different power-laws that can be related to the evolution of LMXBs (GC or field) and the age of the stellar population. Based on LMXB population studies in elliptical galaxies it appears that LMXBs are formed both in the field and in GCs and that a fraction of field LMXBs originates in GCs. More luminous, red, compact GCs are more likely to host X-ray sources. Spectral variability patterns of high L_X sources are reminiscent of BHBs, if BHBs, $M_{\text{BH}} \sim 5 - 15 M_{\odot}$. Transient high luminosity LMXBs are detected, prevalently in the field, but some are also present in GCs. There is increasing evidence of BH binaries in GCs. Finally, XRB detections with Chandra are not limited to stellar systems. Recently, a double supermassive black hole system, on its way to become a bound binary, has been detected in the Compton-thick AGN nucleus of the galaxy NGC 3393.

MASS MEASUREMENTS OF BLACK HOLES IN X-RAY TRANSIENTS: IS THERE A MASS GAP?

Will Farr
Northwestern University, CIERA

We explore possible systematic errors in the mass measurements of stellar mass black holes. We find that large errors can arise from the assumption of zero or constant emission from the accretion flow. For A0620-00 we show that typical data sets and analysis procedures can lead to underestimates of the inclination by ten degrees or more. Examining the data for 15 other systems suggests that this effect may reduce the black hole mass estimates in several other cases, notably GRO J0422+32. If this is correct, the “mass gap” can no longer exist. Nevertheless, we find that the black hole mass distribution in soft X-ray transients retains other previously identified characteristics: a peak around $8 M_{\odot}$, few sources with masses below $5 M_{\odot}$, and a sharp drop-off above $10 M_{\odot}$.

SEARCHING FOR NEW HIGH-MASS X-RAY BINARIES IN THE NORMA SPIRAL ARM

Francesca Fornasini
University of California, Berkeley

We conducted a survey of a 2° by 0.8° region of the Norma spiral arm with Chandra ACIS-I to study Galactic hard X-ray populations. A goal of this survey is to find new High-Mass X-ray Binaries (HMXBs) to further our understanding of HMXB evolution and their luminosity function, and to constrain estimates of NS/NS binaries to interpret future gravitational wave results. We selected this region because INTEGRAL imaging showed that, after the Galactic Center, it is the region most crowded with hard X-ray sources, and it contains several OB associations. We have found ~ 1400 sources in our field and have selected ~ 70 hard, bright, and/or variable sources for further study. We are identifying which sources have near-IR counterparts and will perform IR spectroscopic follow-up at CTIO in June 2012.

X-RAY BINARY EVOLUTION ACROSS COSMIC TIME

Tassos Fragos
Harvard-Smithsonian CfA

I will present results from a large scale population synthesis study that models the X-ray binary populations from the first galaxies of the universe until today. We use as input to our modeling the Millennium II Cosmological Simulation and the updated semi-analytic galaxy catalog by Guo et al. (2011) to self-consistently account for the star formation history and metallicity evolution of the universe. Our modeling, which is constrained by the observed X-ray properties of local galaxies, gives predictions about the global scaling of emission from X-ray binary populations with properties such as star-formation rate and stellar mass, and the evolution of these relations with redshift.

FAR-ULTRAVIOLET SPECTROSCOPY OF LOW MASS X-RAY BINARIES WITH HST/COS

Cynthia Froning
University of Colorado

We have obtained FUV spectroscopy of the X-ray binaries A0620-00, 4U0614+091, and MS1603.6+2600 using the Cosmic Origins Spectrograph on HST. The UV observations have been accompanied by contemporaneous multiwavelength X-ray, optical/NIR, and (for A0620-00) radio observations. The data provide constraints on the structure of the accretion disk and disk outflows, the evolutionary histories of the systems, and the physical properties of the accreting material. We will present the observations and analysis of the multiwavelength data.

OPTICAL/IR - X-RAY VARIABILITY IN X-RAY BINARIES

Poshak Gandhi
ISAS/JAXA

Following 50 years of X-ray studies, we are now beginning to harness the potential of optical and infrared (OIR) variability for the study of binaries. Well-sampled light curves across a broad range of timescales can now be observed, and OIR power-spectra can rival X-ray ones as a result of typically high photon count rates. I will review advances made in this field, concentrating on the fast timing (~ 0.1 s to 1 day) behavior of binaries in the hard state. Opening up of new observational parameter space in both wavelength and time resolution allows us to disentangle the contributions of the disc, hot flow and jet and measure key physical parameters such as magnetic field strength and jet size near its base.

X-RAY BINARIES IN EXTERNAL GALAXIES

Marat Gilfanov
MPA, Garching

Chandra revealed that populations of X-ray binaries in external galaxies scale with star-formation rate and stellar mass. Their luminosity distributions obey universal luminosity functions which are qualitatively different in young and old galaxies, reflecting the difference in the accretion regimes in high- and low-mass X-ray binaries. The numbers of HMXBs observed in star-forming galaxies indicate the high probability for a massive star to become an accretion powered X-ray source once upon its lifetime. This explains the relatively high contribution of X-ray binaries to the Cosmic X-ray background, $\sim 7 - 10\%$. I will also present the evidence that luminous X-ray sources may be formed in significant numbers in galactic nuclei, via tidal captures of low mass stars by stellar mass black holes.

ULTRALUMINOUS X-RAY SOURCES

Jeanette Gladstone
University of Alberta

The first black hole was observed almost 50 years ago, ~ 1 year after Sco X-1 (although its nature was not confirmed for ~ 11 years). Observations of black holes have been ongoing since then, falling in to two distinct categories; stellar-mass (sMBHs; $3 - 80 M_{\odot}$) and super-massive black holes ($10^6 - 10^9 M_{\odot}$). The missing link between these two types, intermediate mass black holes, has been the target of many searches due to their cosmological implications. Ultraluminous X-ray sources (ULXs) have been proposed to harbor such objects, but recent observational evidence has strongly suggested that the majority contain sMBHs. However, a handful of the brightest ULXs are so luminous that they defy this explanation. Here we will discuss the nature of both standard ULXs and this new bright subgroup of this population.

MEASUREMENT OF THE RADIUS OF NEUTRON STARS

Sebastien Guillot
McGill University

A physical understanding of the behavior of cold ultra dense matter – at and above nuclear density – can only be achieved by the study of neutron stars. The recent $1.97 \pm 0.04 M_{\odot}$ measurement for PSR 1614-2230 suggests that strange quark matter and hyperons/kaons condensate equations of state (EoSs) are disfavored, in favor of hadronic EoSs. Over much of the neutron star mass-radius parameter space, the latter EoSs produce lines of nearly constant radii (within about 10%). We present a simultaneous spectral analysis of several globular cluster quiescent low-mass X-ray binaries where we require the radius to be the same among all neutron stars analyzed. Our (preliminary) results suggest a neutron star radius much smaller than previously reported, in the range 7.5-10 km (90% confidence). The Markov-Chain Monte-Carlo method and the Bayesian approach developed in this analysis permits including uncertainties in the distance, in the hydrogen column density, and possible contributions to the spectra due to unmodeled spectrally hard components.

DISCOVERING THE NATURE OF BRIGHT ULXs WITH OPTICAL SPECTROSCOPY

Marianne Heida
SRON Netherlands Institute for Space Research

There are several scenarios for the nature of ultraluminous X-ray sources: some may be X-ray binaries accreting in the super-Eddington regime, while some of the brightest ULXs may be accreting intermediate mass black holes or recoiling supermassive black holes. Observational evidence for IMBHs and recoiling SMBHs is scarce, and finding these objects will provide new insights into galaxy evolution and black hole growth. Optical spectroscopy can help us distinguish between the different scenarios and weed out contaminants such as background AGN. We selected 5 ULXs from the catalog of Walton et al. (2012) with X-ray luminosities $> 10^{40}$ erg/s and clear optical counterparts and observed these with the FORS2 instrument on the VLT. We present the resulting spectra and our interpretation.

THE BIRTH-ULTRAFAST-MAGNETIC-FIELD-DECAY MODEL APPLIED TO ISOLATED MSP'S

Ricardo Heras
Preparatoria abierta de la SEP

The recently proposed birth-ultrafast-magnetic-field-decay model suggests that most neutron stars are born with magnetic fields typical of magnetars and periods typical of millisecond pulsars. The model uses energy conservation along with the idea that neutron stars experienced at birth an ultrafast decay of their magnetic fields (produced by magnetic instabilities) from their initial values to their current surface values. This model is applied here to isolated millisecond pulsars. It is shown that the low magnetic fields, the short periods and the relatively small transverse velocities of isolated millisecond pulsars are consistent with the idea that these pulsars experienced at birth a very large decay of their initial magnetic fields and a very small increase of their initial periods.

A NEW RANKING SCHEME FOR NEUTRON-STAR LOW-MASS X-RAY BINARIES

Jeroen Homan
MIT

During its 2006/2007 outburst XTE J1701-462 became the first neutron-star low-mass X-ray binary (NS-LMXB) to evolve through all known spectral sub-classes, thereby providing valuable information on the relation between these sub-classes and mass accretion rate. Here I present the results of a project that was inspired by these results and for which we analyzed data of more than 40 NS-LMXBs. We find that evolution similar to that seen in XTE J1701-462 can be identified in other sources, suggesting that the sequence of sub-classes shown by XTE J1701-462 is universal. We then use this sequence to rank, for the first time, 40+ NS-LMXBs in terms of relative mass accretion rate. I will discuss the implications of our ranking scheme and the opportunities it provides for further research.

OPTICAL OBSERVATIONS OF THE Z SOURCES SCO X-1 AND SCO X-2 (GX349+2)

Robert Hynes
Louisiana State University

We present photometric monitoring of the Z sources Sco X-1 and Sco X-2 (GX 349+2). Nine years of ASAS-3 data on Sco X-1 confirms the optical orbital period of Gottlieb et al (1975) exactly, but also finally rules out the one-year aliases. We confirm and refine a 22.45 hour orbital period for GX349+2, with a stable sinusoidal variation being seen over two seasons of SMARTS data. Comparison with RXTE/ASM dwells suggests that the modulation is very tightly traced during the flaring branch, but that the source fades optically during excursions to the normal branch. We also present Gemini-S/GMOS spectroscopy of GX349+2. We see the usual LMXB emission lines, including resolved Bowen Blend components, moving on the orbital period, and discuss their site of origin and the binary parameters.

THE BRIGHTEST X-RAY POINT SOURCES IN M82

Floyd Jackson
Harvard-Smithsonian Center for Astrophysics

Using data from ~ 0.5 Ms of Chandra observations, we have undertaken a study of the brightest X-ray point sources within the prototypical starburst galaxy M82. Among the sample of 8 sources are 3 previously studied ULXs, all of which display temporal variability and spectral characteristics consistent with previous observations. The remaining sources are heterogeneous, but all display X-ray properties typically observed in canonically accreting XRBs. A possible bi-modality is seen in spectral states between the brighter and fainter sources in this subset of our sample. Among these sources, we have discovered both a candidate transient and luminous accreting neutron star. This work demonstrates the rich potential for future studies of the diverse X-ray binary populations in nearby galaxies.

THE X-RAY POINT SOURCE POPULATION OF NGC 4472

Tana Joseph
University of Southampton

I discuss the X-ray point source population of the X-ray bright elliptical galaxy NGC 4472. We use a 380 ks Chandra data set and find 343 sources within the central $4.5'$ of the galaxy, down to $L_X = 2.3 \times 10^{37}$ erg/s (0.5–5 keV); 71 of these sources are in globular clusters. This is the largest sample of discrete X-ray sources in a galaxy. In addition to the properties of the ensemble, I will present data on interesting individual sources such as the globular cluster black hole XMMOU 122939.7+075333, showing that it continues to display large amplitude flaring activity and as a result probably did not turn off in 2010. I will show the results of spectral investigation into whether luminosity variability is due to intrinsic variability or changing absorption column from a disk wind.

X-RAY VARIABILITY STUDIES OF THE BHC SWIFT J1753.5 - 012 IN SOFT BAND

Maithili Kalamkar
University of Amsterdam

X-ray variability studies of black hole binaries have been carried out with RXTE for over a decade. Due to the limitation of a lower energy bound at 2 keV, the behavior of variability in the soft band remains mostly unexplored. Swift XRT, having an energy range 0.3–10 keV, provides a rare opportunity to explore the variability in the soft band which is dominated by the disk emission. This could help us directly address the question of the origin of variability. We present, for the first time, very detailed variability studies carried out with the Swift XRT in soft band. We study the outburst of the black hole binary SWIFT J1753.5 - 012, which has been speculated to have a disk even in the hard state (Miller et al. 2006), making it a very suitable candidate for this study. We observe strong variability in the soft band, which has been suggested to be intrinsic to the disk (Wilkinson et al. 2009). This challenges the truncated disk models. We will discuss the implications of our results on these models and the future scope of our work.

NIR OBSERVATIONS OF LOW MASS X-RAY BINARIES

Juthika Khargharia
University of Colorado

Compact object mass determination in low mass X-ray binaries is crucial to our understanding of accretion dynamics and physics in the strong gravity regime. Masses are typically measured at NIR wavelengths where the late type star dominates and flux from non-stellar sources (e.g the accretion disk) are assumed minimal. But this assumption is always questionable and frequently wrong. Unaccounted for extra flux tends to lower the binary inclination and overestimate the compact object mass. Here, I will present the results of an ongoing study undertaken to determine precise and unbiased compact object masses by properly accounting for non-stellar sources of light at NIR wavelengths applied to three LMXBs: V404 Cyg, Cen X-4 and XTE J1118+480.

MASS MEASUREMENTS OF BLACK HOLES IN X-RAY TRANSIENTS: IS THERE A MASS GAP?

Laura Kreidberg
University of Chicago

We explore possible systematic errors in the mass measurements of stellar mass black holes. We find significant errors can arise from the common assumption of zero or constant emission from the accretion flow. For the case of A0620-00, we find typical analysis procedures can lead to underestimates of the inclination by ten degrees or more. An examination of the available data for 15 other X-ray transients suggests this effect may significantly reduce several of their black hole mass estimates. With these revisions, our analysis of the mass distribution does not suggest a "mass gap" between the low end of the distribution and the maximum neutron star mass, as has been suggested. Nevertheless, we find the distribution retains other previously identified features, namely a peak near $8 M_{\odot}$.

NEW VIEWS OF HERCULES X-1 FROM LONG TERM OBSERVATIONS WITH RXTE

Denis Leahy
University of Calgary

The well-known X-ray binary Hercules X-1 displays a great variety of phenomena at different timescales, including pulsations at 1.24 s, eclipses at the orbital period of 1.7 days, and a 35-day cycle in the X-ray intensity. Yet the intrinsic properties of the system, including the accretion disk geometry and accretion stream are poorly understood. The 35-day cycle is understood as caused by a precessing accretion disk causing varying obscuration of X-rays from the neutron star, but the mechanisms of absorption dips and of the anomalous low state are not yet settled. Here, archival RXTE/PCA are analyzed to obtain a more detailed picture of the behavior of Her X-1 with orbital and 35-day phase than previously possible. The properties of the dips and anomalous low states are examined. In addition, models for the dips phenomena are discussed and an accretion stream model for dips is calculated and compared to the new observations.

THE SPECTRAL EVOLUTION ALONG THE Z TRACK OF GX 17+2

Dacheng Lin
IRAP

We analyze 68 observations of Sco-like Z source GX 17+2 taken in 1999 Oct by RXTE, covering a complete Z track. We fit color-resolved spectra with a model consisting of a thermal multicolor disk, a single-temperature-blackbody boundary layer and a weak Comptonized component. The Comptonization seed photons are tied to the thermal disk component and corrected for to recover the pre-Comptonized thermal disk emission. We find a constant \dot{M} into the disk along the entire Z track based on the thermal disk component. The branches are explained by three processes: increase of Comptonization up the horizontal branch, transition from a standard thin disk to a slim disk up the normal branch, and temporary fast decrease of the inner disk radius up the flaring branch. Our results also support identification of the upper kHz QPO frequency as the Keplerian frequency at the inner disk radius and close relation between the horizontal branch oscillation and the dynamics in the inner disk.

THERMONUCLEAR BURSTS FROM SLOWLY AND RAPIDLY ACCRETING NEUTRON STARS

Manuel Linares
MIT

Models of thermonuclear burning on accreting neutron stars predict different ignition regimes, depending mainly on the mass accretion rate per unit area. For more than three decades, testing these regimes observationally has met with only partial success. I will present recent results from the Fermi-GBM all-sky X-ray burst monitor, which is yielding robust measurements of recurrence time of rare and highly energetic thermonuclear bursts at the lowest mass accretion rates. I will also present RXTE observations of thermonuclear bursts at high mass accretion rates, including the discovery of millihertz quasi-periodic oscillations and several bursting regimes in a neutron star transient and 11 Hz X-ray pulsar. This unusual neutron star, with higher magnetic field and slower rotation than any other known burster, showed copious bursting activity when the mass accretion rate varied between 10% and 50% of the Eddington rate. I will discuss the role of fuel composition and neutron star spin in setting the burst properties of this system, and the possible implications for the rest of thermonuclear bursters.

REFLECTION IN CARBON-OXYGEN DOMINATED ACCRETION DISCS OF UCXB

Oliwia Madej
SRON

Ultracompact X-ray binaries (UCXB) are a subclass of LMXBs with orbital periods < 80 min. They consist of a neutron star/black hole accreting gas from a white dwarf. In the case of two UCXBs (4U0614+091, 4U1543-624) the donor star is most likely a CO WD. Theory predicts that in the case of oxygen-rich accretion disc the reflected photons give a spectrum in which OVIII Ly α is the strongest line. Hence a broad feature at ~ 0.7 keV discovered in the spectra of these two sources was interpreted as a relativistically broadened OVIII Ly α reflection line. Currently available reflection models do not take into account a possible overabundance of carbon and oxygen in the disc. We are therefore adapting the reflionx (Ross & Fabian 2005) model to this case and testing it on the spectra.

OPTICAL SPECTROSCOPY OF HIGH-MASS X-RAY BINARIES IN THE SMALL MAGELLANIC CLOUD

Grigoris Maravelias
SAO

We present results from optical spectroscopy of HMXBs in the SMC selected from Chandra and XMM-Newton surveys. We acquired 21 spectra for low-luminosity X-ray sources ($L_X < 10^{34}$ erg/s), well below the typical luminosities of outbursting BeXRBs. We find that their spectral types are in the B0-B9 range, with most objects being of later types. One of them is a new Supergiant X-ray binary, the second such system identified in the SMC. Its optical counterpart is the well-known SgB[e] (and probable LBV) star S-18. With this study we raise the sample of BeXRBs with available spectral types to 52 objects. While our results are in agreement with previous studies, we find systematically later spectral types. This might be the result of extending our sample of BeXRBs to fainter sources.

CONSTRAINING THE ROLE AND POWER OF JETS IN BLACK HOLE BINARIES

Sera Markoff
API, University of Amsterdam

Relativistic jets are launched in both steady and discrete ejecta forms from black hole X-ray binaries (BHBs), with enough similarities to AGN outflows to motivate quantitative comparisons. In particular, black hole spin is often invoked as a possible explanation for different observed jet powers in AGN populations, while jets come and go and change power in BHBs despite the spin not evolving over outburst timescales. I will discuss our current understanding of jets in BHBs, with a focus on the uncertainties both in spin determination as well as in constraining the radiative contribution of jets to the X-ray bands, which can help constrain power as well as jet launching scenarios.

HIGH SPEED OPTICAL PHOTOMETRY OF LMXBS AND CVs

Paul A. Mason
University of Texas at El Paso

Recent results of high speed (1–5 s) photometry of interacting binaries are presented. These include a study of 33 optically reprocessed X-ray bursts from UW CrB, revealing bursts at all orbital phases except during partial eclipses of the accretion disk. Ellipsoidal variations are observed in the LMXBs V1727 Cygni and J1118+480 providing multi-year ephemerides and, strong constraints on binary parameters and including X-ray heating derived from model fits. The rapid eclipse ingress and egress of the magnetic CV, FL Ceti is examined; confirming the existence of two highly localized accretion regions.

CYGNUS X-3 AND ITS LITTLE FRIEND: STELLAR ENDPOINT MEETS STELLAR BEGINNING

Michael McCollough
CXC/SAO/CfA

Using the unique X-ray imaging capabilities of the Chandra observatory, a study of Cygnus X-3 has provided insight into a singular feature associated with this well known microquasar. Extended emission, located $\sim 16''$ from Cygnus X-3, varies in phase and flux with Cygnus X-3, acting like a celestial X-ray “mirror”. The feature’s spectrum, flux and time variations allow us to determine the location, size, density, and mass of the scatterer. We find that the scatterer is a Bok globule located along our line of sight, and discuss its relationship to Cygnus X-3. This is the first time such a feature has been identified with the Chandra X-ray Observatory.

BLACK HOLE ACCRETION AND JET EJECTION

James Miller-Jones
ICRAR - Curtin University

The accretion of matter onto black holes is fundamentally linked to the ejection of relativistic jets. X-ray binaries provide an ideal laboratory to study this coupling between inflow and outflow, since they evolve through their entire outbursts on a typical timescale of a few months. I will provide an overview of our current understanding of the connection between accretion and ejection in black hole X-ray binaries, after which I will present some recent results from intensive, multiwavelength monitoring campaigns on a number of such systems. I will focus on the relation between the radio emission from the compact jets found in hard X-ray states and the corresponding X-ray emission from the accretion flow, and the appearance of transient, relativistic jets on transition to the soft X-ray spectral states.

HIGH-MASS X-RAY BINARIES IN STAR-FORMING GALAXIES

Stefano Mineo
CfA/SAO

Based on a homogeneous set of X-ray, infrared and ultraviolet observations from *Chandra*, *Spitzer*, *GALEX* and 2MASS archives, we studied the populations of high-mass X-ray binaries (HMXBs) in a sample of 29 nearby star-forming galaxies. We find that HMXBs are a good tracer of the recent star formation activity of the host galaxy. The luminosity function of HMXBs was derived and modeled with great statistical accuracy. It follows a power law with slope of 1.6 in the $\log(L_X) \sim 35 - 40$ luminosity range. We find evidence of a high-luminosity break at the Eddington luminosity of a $\sim 100 M_\odot$ black hole. We estimated that the fraction of compact objects that once upon their lifetime experienced an X-ray active phase powered by accretion from a high mass companion is $f_X \sim 0.2 \times (0.1 \text{ Myr}/\tau_X)$ (τ_X is the life time of the X-ray active phase).

FEEDING THE MONSTER: WIND ACCRETION IN CYGNUS X-1

Ivica Miskovicova
Remeis Observatory & ECAP

Stellar wind in HMXBs is highly structured: dense clumps of low temperatures are embedded in highly ionized material. We present analysis of the focused stellar wind in the hard state of Cygnus X-1 from high-resolution Chandra-HETGS observations at four distinct orbital phases: $\phi \sim 0$, ~ 0.2 , ~ 0.5 and ~ 0.75 . All light curves but the one at $\phi \sim 0.5$ show strong absorption dips that are believed to be caused by the clumps. We compare the spectral properties between dips and persistent flux: while the H-like and He-like absorption lines reveal the highly photoionized wind, the lines of lower ionization stages visible only in the dip spectra constrain the properties of the clumps. Comparison between different orbital phases allows us to study the complex structure and dynamics of the wind.

SPH SIMULATION OF NATURALLY TILTED DISKS IN CLOSE BINARY SYSTEMS

Michele M. Montgomery
UCF

Tilts and warps have long been suspected in a plethora of systems including X-ray binaries. Radiation from the central object and magnetic fields have been suggested as sources to disk tilt. We argue the accretion stream is also a viable source. Using SPH simulations, we show the stream remains normal to the host's spin and binary orbital angular momentum axes yet the disk's angular momentum axis tilts. We show where the disk warps after disk tilts and argue the source to the warp. As the only unknown in the numerical code is the artificial alpha viscosity, the results should be of interest to MHD modelers, among others.

AN X-RAY AND NEAR-INFRARED STUDY OF THE GALACTIC RIDGE X-RAY EMISSION

Kumiko Morihana
Institute of Physical and Chemical Research (RIKEN)

The Galactic Ridge X-ray Emission (GRXE) is an extended X-ray emission along the Galactic Plane, which has a thermal spectrum with Fe K line. The origin had been a mystery for a long time. Recently, it is elucidated that the GRXE is a sum of dim point sources by the deepest observation of Chandra. There are some candidates of the sources, but it is difficult to know the nature from X-rays alone due to a limited number of X-ray photons. Thus, we combined near-infrared with X-ray. As a result, the point sources are background AGNs, white dwarf binaries (WD), and late-type stars (flare/quiescence). We obtained fraction to the Fe K line as follows: AGNs ($\sim 33\%$), WD ($\sim 38\%$), and late-type stars on flare ($\sim 29\%$). Moreover, NIR observation indicates that WD are Cataclysmic Variables and Pre-Cataclysmic Variables. The latter has not been considered as the origin of the GRXE, but it is considered to contribute to the Fe K line of the GRXE.

NEW RESULTS ON MASSIVE WINDS AND X-RAY STATES IN BLACK HOLE X-RAY BINARIES

Joey Neilsen
MIT/Kavli Institute

In the last decade, high-resolution X-ray spectroscopy has revolutionized our understanding of the role of accretion disk winds in black hole X-ray binaries. Carrying away as much as 25x more matter than reaches the black hole, these ubiquitous, highly ionized outflows exert a powerful influence on the dynamics of the accretion flow: they may quench relativistic jets and may facilitate or even cause state transitions. I will review a few major developments from the last decade, and then I will present some brand new results from our multiwavelength observing campaigns on several X-ray binaries, which reveal some of the deepest iron absorption lines ever observed with Chandra, as well as some of the fastest line variability. Highlighting in particular the intricate links between the inner accretion flow, relativistic jets, and accretion disk winds, I will demonstrate how new Chandra observations continue to inform our understanding of black hole accretion states.

CHANDRA-HETG OBSERVATIONS OF LMC X-1

Michael Nowak
MIT-Kavli

The High Mass X-ray Binary, Black Hole Candidate (BHC) system LMC X-1 is among those BHC that has been claimed to exhibit evidence for being near maximal spin. However, compared to other systems, LMC X-1 is rather unusual in that it does show evidence for ever reaching a "stable" minimum effective area. In this presentation, we show a series of 9 Chandra-High Energy Transmission Gratings observations, totaling 150 ksec, that cover a number of different orbital phases. We find spectroscopic evidence for emission from the high mass companion's wind. Additionally, we explore whether there is orbital phase-dependent absorption by this wind, as has been previously suggested. Finally, we use Comptonization models to describe the continuum spectrum, and discuss those aspects of the fits that are driving the suggestion for maximal spin.

OVERVIEW OF RECENT ADVANCES IN ACCRETION DISK THEORY

Ken Ohsuga
NAOJ

The accretion disk theory, which is initiated in 1970, has made a success for understanding the powerful compact objects, XRBs, AGNs, and so on. Although one-dimensional accretion disk models (standard disk, slim disk, RIAF) were constructed based on the phenomenological α -viscosity prescription, multi-dimensional MHD/Radiation-MHD simulations are recently performed to resolve the disk structure and dynamics from the first principle. The time variations of the disk and the disk-jet connection are also investigated by the multi-dimensional study. We briefly summarize the disk models and introduce the recent advances of the numerical simulations of the black-hole accretion flows and outflows.

AN OPTICAL/INFRARED SPECTROSCOPIC VIEW OF THE CYGNUS X-1 AND GX 339-4 JETS

Farid Rahoui
Harvard University

We discuss the results of two multiwavelength spectroscopic studies of Cygnus X-1 and GX 339-4 that bring new constraints on their emission in the hard state. Over three epochs of observations, we quantify the changes in their X-ray and IR (Spitzer/IRS: 5–35 micron; ESO/ISAAC: 1–2.5 micron) spectroscopic properties as related to the contribution from the compact jets. In particular, we report the spectroscopic measurement of the break frequency in Cygnus X-1 and we argue that the jet accounts for its polarized gamma-ray emission. Likewise, we show that the rapidly variable near-IR continuum and emission lines of GX 339-4 exhibit different behaviors in the two observed hard states; this likely hints to either changes of the jet physics or the presence of another non-thermal component.

HIGH MASS X-RAY BINARIES IN NEARBY STAR-FORMING GALAXIES

Blagoy Rangelov
The University of Toledo

High Mass X-ray Binaries (HMXBs) often dominate the high-energy emission from nearby star-forming galaxies. These HMXBs are believed to form in star clusters, but subsequently become displaced from their parent clusters. By comparing observations of HMXBs from Chandra with observations of star clusters from Hubble, we find that approximately one-quarter of the HMXBs in a sample of galaxies still reside within their parent star clusters. We are also using the results of new N-body simulations to show that the vast majority of HMXBs that are found outside of clusters have neutron stars as the compact object. A second intriguing result suggests that up to ages of $\sim 20 - 30$ Myr, most HMXBs within parent clusters have black holes as the compact object.

HOW TO MODEL SUPER-SOFT X-RAY SOURCES?

Thomas Rauch
Eberhard Karls University Tübingen

During outbursts, the surface temperatures of white dwarfs in cataclysmic variables exceed by far half a million Kelvin. In this phase, they may become the brightest super-soft sources (SSS) in the sky. Time-series of high-resolution, high S/N X-ray spectra taken during rise, maximum, and decline of their X-ray luminosity provide insights into the processes following such outbursts as well as in the surface composition of the white dwarf. Their analysis requires adequate NLTE model atmospheres. The Tübingen Non-LTE Model-Atmosphere Package (TMAP) is a powerful tool for their calculation. We present the application of TMAP models to SSS spectra and discuss their validity.

NATAL KICKS OF STELLAR-MASS BLACK HOLES

Serena Repetto
Radboud University Nijmegen

We investigate whether stellar-mass black holes have to receive natal kicks in order to explain the observed distribution of Galactic low-mass X-ray binaries. We perform population synthesis calculations of these binaries, applying both kicks due to supernova mass-loss and natal kicks to the newly-formed black hole. We then integrate the trajectories of the binary systems within the Galactic potential. We find that natal kicks are in fact necessary to reach the large distances above the Galactic plane achieved by some binaries. Further, we find that the distribution of natal kicks would seem to be similar to that of neutron stars, rather than one where the kick velocities are reduced by the ratio of black hole to neutron-star mass (i.e. where the kicks have the same momentum).

THE OPTICAL ORBITAL LIGHT CURVE OF THE LXMB V1408 AQUILAE (= 4U 1957+115)

Edward Robinson
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V1408 Aql is an LXMB with an orbital period near 9.3 hours. The system shows an orbital photometric modulation at optical wavelengths. The mean modulation is nearly sinusoidal with a peak-to-peak amplitude that ranges from 18% to 23%. We show that the orbital light curve can be reproduced by a model in which the accretion disk around the compact star is thin, axisymmetric, and unclipped. The secondary star is heated by X-rays from the compact star and the accretion disk. The orbital modulation is produced by the changing aspect of the irradiated secondary star with orbital phase. The large amplitude of the orbital modulation favors models in which the secondary star is relatively large, which in turn favors mass ratios not far from 1.

CONSTRAINTS ON X-RAY POLARIZATION OF SYNCHROTRON JETS FROM STELLAR-MASS BHs

David Russell
Instituto de Astrofísica de Canarias (IAC)

Synchrotron emission from relativistic jets can be highly polarized. I demonstrate that the polarimetric signature of jets in X-ray binaries is detected in the infrared and is highly variable. This reveals the turbulent magnetic geometry in the compact jet. I present the first ever test for a correlation between optical polarization and X-ray flux of an XB (Sco X-1, 50 years after its discovery), using simultaneous data with sub-second time resolution. In two XBs, the evolution of their broadband spectra suggests synchrotron emission from the jet likely dominated both the infrared and X-ray flux during their hard state outburst decays. From these results, we predict that high, variable levels of X-ray polarization from XB jets will be detected by future spaceborne X-ray polarimeters.

RESULTS FROM OBSERVING CAMPAIGNS ON CYGNUS X-3 DURING 2010-2011

Petri Savolainen
Aalto University Metsähovi Radio Observatory

We present results from our modeling of Swift and RXTE X-ray spectra of Cygnus X-3, taken during 4/2010-4/2011, with radio context. During this year-long coverage, Cygnus X-3 went through all its known spectral states, including a > 12 Jy major radio flare. Our model includes a Comptonized disc blackbody, interstellar and local absorption, line features, and a very soft (~ 50 eV) component. Our dataset features the most extensive coverage of the 0.5–3 keV range from Cygnus X-3 ever observed, enabling us to characterize the soft component as modulated in phase and correlated with the main continuum, as well as having a temperature consistent with that of the photoionized Radiative Recombination Continua previously detected in the system, associated with the wind from the Wolf-Rayet donor.

OPTICAL DETECTIONS OF BLACK WIDOW PULSAR COUNTERPARTS

Joshua Schroeder
Columbia University

We report the detections of optical counterparts of black widow pulsars discovered by radio follow-up observations of unidentified Fermi LAT sources. Orbital phase-matched photometric light curves for two objects are measured and characterized according to the standard black widow pulsar model whereby a millisecond pulsar heats the nearside of the companion object resulting in a brightening and a dimming over an orbital period. Measurements of these light curves allow for constraints to be placed on the system's inclination and the temperature profile of the secondary.

COLLISIONAL IONIZATION IN THE X-RAY SPECTRUM OF THE ULTRACOMPACT BINARY 4U 162

Norbert S. Schulz
Massachusetts Institute of Technology

4U 1626-67 is an ultracompact binary pulsar with a pulse period of 7.7 sec and an orbital period of 40 min. Its X-ray spectrum exhibits strong Doppler line pairs from highly ionized Ne and O. The light curves show distinct differences after torque reversal episodes. We show while a photo-ionized plasma cannot fit the Doppler line emissions, a collisionally ionized plasma provides a better description of the data. Based on this new interpretation of the Doppler line emissions, we propose that magnetospheric accretion shocks and shocked matter moving towards the magnetospheric poles provide a more consistent description than the ionized disk paradigm. We also compare this spectrum to the more recent assessment of the Suzaku spectrum after torque reversal.

INTEGRAL FIELD SPECTROSCOPY AND CHANDRA OBSERVATIONS OF THE CYGNUS X-1 SHELL

Paul Sell
University of Wisconsin-Madison

I will report on X-ray (Chandra) and optical spectroscopic (WIYN) observations of the radio/H-alpha shell near the microquasar Cygnus X-1. The X-ray non-detection and the optical integral field spectra place upper limits on the velocity of the shock, the mass flow rate across the shock, and the temperature and density of the post-shock material, using robust line diagnostics and more sophisticated shock modeling. These limits enable us to derive a robust upper limit for the jet power. This work complements previous weaker limits from X-rays and narrow band imaging. The observations cannot rule out contributions from the O-star wind and radiation field to the evolution of the bubble, further limiting the jet power of Cygnus X-1.

X-RAY LIGHTCURVES OF GRS 1915+105: A TOOL TO DETERMINE QUASARS' ACCRETION STATE

Malgosia Sobolewska
SAO

We study lightcurves of a Galactic microquasar GRS 1915+105 and a powerful quasar 3C 273 at intrinsically comparable timescales. Due to black hole mass scaling of variability timescales, 10 sec in GRS correspond to ~ 20 yr in 3C 273. We use XTE/PCA sub-sec time resolution data to build GRS distributions of 10 sec normalized excess variances, σ_{nxs}^2 , in the soft (2–5 keV), medium (5–13 keV) and hard (13–60 keV) X-ray energy bands. We compare them with the 3C 273's σ_{nxs}^2 in B-band (~ 120 yr split in ~ 20 yr intervals) and X-rays (XTE/ASM, ~ 15 yr). We find a relatively good match between the variability of GRS in medium/hard bands and 3C 273 in X-rays. However, soft band GRS lightcurves in the accretion disk dominated spectral states differ from those of 3C 273 in B-band.

X-RAY GRATING OBSERVATIONS OF RECURRENT NOVA T PYX

Ben Tofflemire
University of Wisconsin - Madison

While Classical Novae are not believed to be the progenitors of Type Ia supernovae, the frequent and smaller outbursts of Recurrent Novae (RNe) may provide strong candidates for accretion above the Chandrasekhar mass. Of the few RNe observed in outburst with X-ray gratings, a large diversity exists among their spectral properties. We present X-ray grating observations of RN T Pyx during its 2011 outburst. X-ray observations of this kind provide a unique opportunity to study the highest ionization states of ejected material while potentially probing the White Dwarf atmosphere itself. We discuss the spectral properties and evolution of the T Pyx outburst and comment on its place in this unique group by comparing it with further RNe.

MODELING THE REDSHIFT EVOLUTION OF THE NORMAL GALAXY X-RAY LUMINOSITY FUNCTION

Michael Tremmel
University of Washington

Emission from X-ray binaries (XRBs) is believed to be a major component to the X-ray luminosity of normal galaxies. We present results from large-scale XRB population synthesis models in galaxies from $z = 0$ to $z \sim 20$, using the Millennium II Cosmological Simulation and the semi-analytic galaxy catalog by Guo et al. (2011) to account for star formation history and metallicity evolution. We show that the evolution of the normal galaxy X-ray luminosity function (XLF) is driven by late-type galaxies at high luminosities ($L_X > 1 \times 10^{40}$ erg/s) and early-types at lower luminosities. We find that late-type galaxies dominate the overall X-ray emission at $z < 2$, which however has non-negligible contribution from low mass XRBs. Finally, we make predictions for high redshift galaxy X-ray number counts.

VARIABILITY AND POPULATIONS OF LOW-MASS X-RAY BINARIES

Lennart van Haften
Radboud University Nijmegen

Using observations by the RXTE All-Sky Monitor, we studied the long-term luminosity behavior of Galactic low-mass X-ray binaries with special emphasis on ultracompact X-ray binaries (orbital period below one hour), and the relation between their behavior (persistent vs. transient) and orbital period. We use these results in a population synthesis study to predict the numbers and luminosities of observable populations of X-ray binaries. The goal is to construct X-ray luminosity functions for various environments, and improve our understanding of the features of these functions.

MULTIWAVELENGTH OBSERVATIONS OF CYGNUS X-3

Angelo Varlotta
Purdue Univ./SAO

Cygnus X-3 is a X-ray binary consisting of an accreting compact object orbiting a Wolf-Rayet star with collimated relativistic jets, placing it firmly in the category of microquasars. It has been detected at radio frequencies and up to the high-energy gamma rays (> 100 MeV) by the Fermi LAT. Many theoretical models envision very-high-energy (VHE) emission (> 100 GeV) when the source manifests relativistic persistent jets or transient ejections. In light of our multiwavelength studies of Cygnus X-3 in the radio, infra-red, soft X-ray, hard X-ray and gamma-ray (< 100 GeV) bands and with the aid of VERITAS, we believe we can cast light on the particular conditions which could trigger VHE emission. We argue this can help us understand the mechanisms that may trigger VHE gamma-ray emission, thus improving our knowledge of particle acceleration and radiative processes in the jets. The implications have far reaching consequences on the understanding of other microquasars and also of active galactic nuclei, which are in many ways similar to microquasars and are prominent VHE gamma-ray sources.

PUTTING X-RAY BINARIES IN THEIR PROPER PLACE

Saeqa Vrtilek
Harvard-Smithsonian Center for Astrophysics

The diverse behaviors displayed by X-ray binaries make it difficult to determine the nature of the underlying compact objects. In particular, identification of systems containing black holes is currently considered robust only if a dynamical mass ratio is obtained. However, we have recently developed a model-independent means of identifying the central bodies — neutron star or black hole — of most accreting binary systems. We find that different categories of object (black holes, pulsars, and non-pulsing neutron stars) occupy distinct regions in a 3-dimensional color-color-intensity (CCI) diagram. Assuming that this clustering effect is due to intrinsic properties of the sources (such as mass accretion rate, binary separation, mass ratio, magnetic field strength, etc.), we suggest possible physics that drives each object to its specific location in the CCI phase space; a surface in this space which separates systems that produce jets from those which do not and the use of CCI for identifying X-ray pulsars.

A STACKING ANALYSIS OF STAR CLUSTERS IN M51: THE SEARCH FOR X-RAY BINARIES

Neven Vulic
University of Western Ontario

We have used multiwavelength data from the *Chandra X-Ray Observatory* and the *Hubble Space Telescope* to investigate the faint population of XRBs in the grand-design spiral galaxy M51. A stacking analysis of the X-ray data at the positions of optically-identified star clusters was completed to probe low-luminosity X-ray sources. No cluster type had a significant detection in any X-ray energy band. An average globular cluster had the largest upper limit, 3.36×10^{35} erg s⁻¹, in the full-band (0.3–8 keV) while on average all clusters have the lowest upper limit, $\approx 9 \times 10^{33}$ erg s⁻¹ in the hard-band (2–8 keV). We conclude that the X-ray data is not deep enough to identify faint sources with a stacking analysis.

UNDERSTANDING INTERMEDIATE MASS BLACK HOLES THROUGH STUDY OF ESO 243-49 HLX-1

Natalie Webb
IRAP

The Ultra Luminous X-ray (ULX) source HLX-1 in the galaxy ESO 243-49 has a maximum X-ray luminosity of 1.3×10^{42} erg/s (0.2–10.0 keV). From the conservative assumption that this value exceeds the Eddington limit by at most a factor of 10, the minimum mass is then 500 solar masses. The X-ray luminosity varies by a factor of 50 with an apparent recurrence timescale of approximately one year. This X-ray variability is associated with spectral state transitions similar to those seen in black hole X-ray binaries. I will present our recent modeling of all of the X-ray data available for HLX-1 and show that it supports the idea that this ULX is powered by sub- and near Eddington accretion onto an intermediate mass black. I will show evidence for jets from this ULX and comment on the nature of the environment around HLX-1.

CHANDRA FOLLOW UP ANALYSIS ON HESS J1841-055

Sven Wilbert
ITPA University Wuerzburg

State of the art Imaging Atmospheric Cherenkov Telescopes (IACTs) like the Very Energetic Radiation Imaging Telescope Array System (VERITAS) and the High Energy Stereoscopic System (H.E.S.S) made surveys of the sky in order to discover new sources. The first and most famous is the H.E.S.S survey of the inner Galactic plane. So far more than 50 Galactic TeV Gamma-ray sources have been detected, a large number of which remain unidentified. HESS J1841-055 is one of the largest and most complex among these unidentified sources with an extension of approximately 1° . Follow up observations of the HESS J1841-055 region with Chandra, which is due to its high resolution good suited for searching for X-Ray counterparts and add-on analysis have revealed several X-ray sources spatially coincident with the multiple TeV emission peaks. The search for counterparts brought out the fact that not a single source itself but a bunch of sources of different nature, could be indeed the creators of this complex diffuse emission region; among them the SNR Kes 73, the pulsar within Kes 73, 1E 1841-45 and also the High Mass X-Ray Binary AX 184100.4-0536 and others.

UNDERSTANDING COMPACT OBJECT FORMATION AND NATAL KICKS

Tsing Wai Wong
Northwestern University

With plenty of well constrained observations on X-ray binaries, which are known to host black holes, it is possible to use them to study the formation of those black holes. Starting from the current observations, we uncover the past evolutionary history of a selected X-ray binary back to the formation of the black hole. We also trace the motion of the system in a Galactic potential backwards in time and derive constraints on the peculiar velocity when the black hole was just formed. Lastly, after knowing the binary configuration right after the black hole formation, we calculate the dynamics involved in the core collapse event and derive constraints on the mass of the black hole immediate progenitor and the possible natal kick velocity imparted to the black hole. We have applied this study to five systems: GRO J1655-40, XTE J1118+480, Cygnus X-1, IC 10 X-1 and M33 X-7.

DISTANCE INDEPENDENT CONSTRAINTS ON MASS AND RADIUS FROM TYPE I X-RAY BURSTS

Michael Zamfir
McGill University

Type I X-ray bursts from low mass X-ray binaries have, in the last few years, arisen as an important observational tool in the effort to constrain the ultra dense matter equation of state. Previous works have focused on using photospheric radius expansion (PRE) bursts to derive constraints on neutron star masses and radii, by either measuring the flux at "touchdown", or fitting the spectral cooling track in the burst tail. These efforts have highlighted and spurred debate about the systematic errors involved in these measurements. In this talk, I describe an approach to deriving constraints which minimizes the possible systematic errors. Particularly, the constraints we find have no dependence on the distance to the source or the burst emission anisotropy. Applying this to the regular bursting source GS 1826-24, we compare the observed light curves to a multi-zone burst simulation, and compare the spectrum of the burst in the tail to the latest atmosphere calculations by V. Suleimanov and J. Poutanen. From these, we find a distance and anisotropy independent upper limit on $R(1+z)$ of 10.8–15.1 km, depending on the atmosphere model, with a mass upper limit of 1.4–2.0 solar masses.

LOW-MASS X-RAY BINARIES IN ELLIPTICAL GALAXIES

Zhongli Zhang

Max Planck Institute for Astrophysics

We have studied the properties of populations of low-mass X-ray binaries (LMXBs) in early-type galaxies, focusing on their environmental dependence which reveals their formation and evolution histories. Our sample includes ~ 30 galaxies with Chandra observations, and ~ 2000 LMXBs were detected in total which cover the whole luminosity range (10^{35} to above 10^{39} erg/s). We found the luminosity distributions of LMXBs have a strong dependence on different stellar density (e.g. globular clusters, galactic nuclei vs. galaxy field), and velocity dispersion (globular clusters vs. galactic nuclei). And the number density of LMXBs depends on the age of the stellar population and the globular cluster content. We also found that young galaxies contain more ultraluminous X-ray sources (ULXs), which makes LMXBs the most popular explanation of ULXs found in early-type galaxies. Moreover, X-ray sources were found more extended to the outside of D25 radius of galaxies, which were assumed to be associated with globular clusters which trace the galaxy dark matter halo.

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