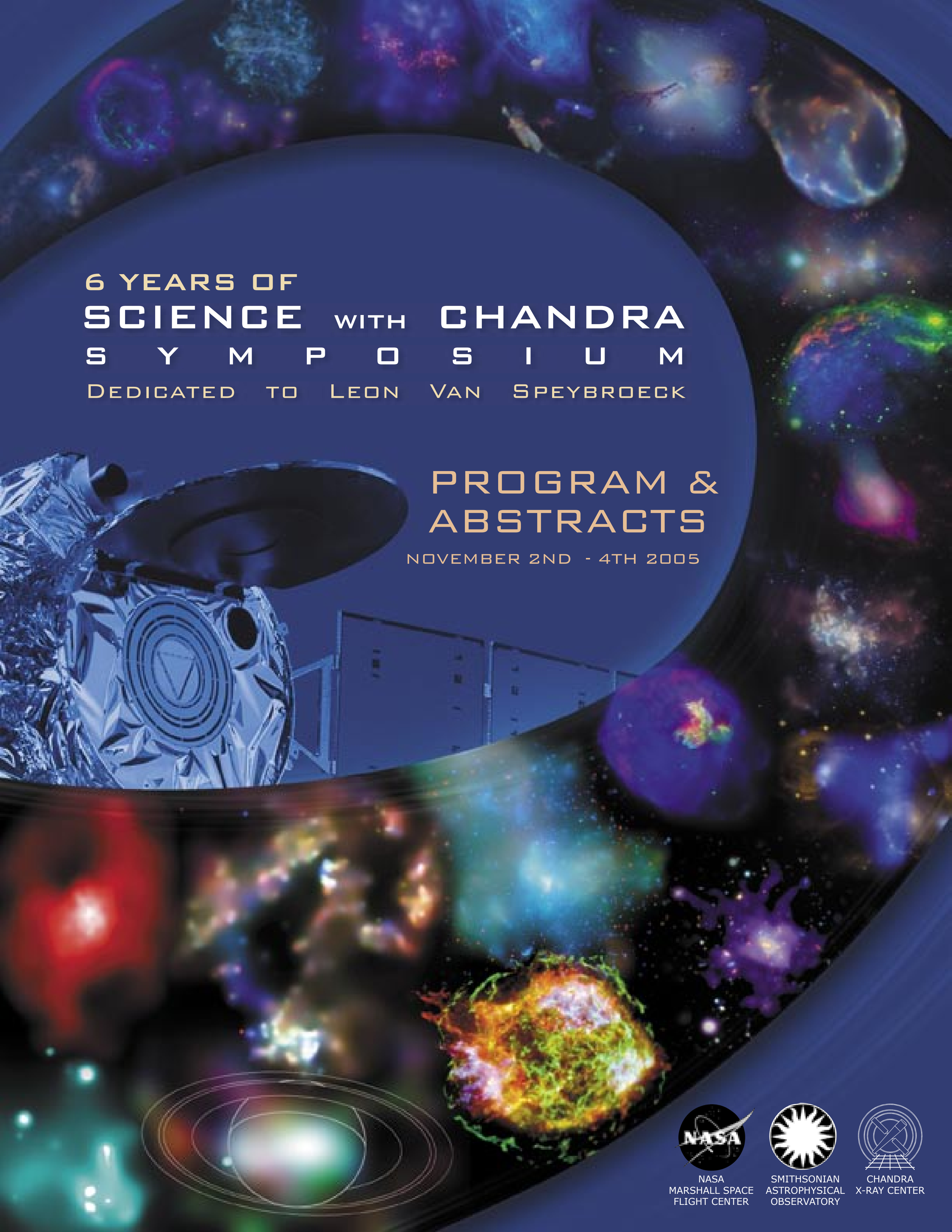
# 6 YEARS OF SCIENCE WITH CHANDRA SYMPOSIUM

## DEDICATED TO LEON VAN SPEYBROECK

# PROGRAM & ABSTRACTS

NOVEMBER 2ND - 4TH 2005



NASA MARSHALL SPACE FLIGHT CENTER

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

CHANDRA X-RAY CENTER

# Program Schedule

## Tuesday, November 1

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| 6:00 - 9:00 | Symposium Registration and Dinner Reception |

## Wednesday, November 2

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|---|---|
| 7:00 - 8:30 | Continental Breakfast, Registration and Poster Set-up |
| 8:30 - 8:45 | Harvey Tananbaum (SAO)<br>Welcome Remarks |

**Theme: Life Cycles of Stars**

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|---|---|
| 8:45 - 9:20 | Patrick Slane (SAO) [Invited]<br>A Detailed Study of the Pulsar Wind Nebula 3C 58 |
| 9:20 - 9:35 | Nat Butler (UC Berkeley)<br>X-ray Eyes on the Brightest Explosions in the Universe:<br>Probing the GRB Afterglow Emission Mechanism with Chandra |
| 9:35 - 9:50 | Michael Stage (Univ. of Massachusetts, Amherst)<br>Estimating the Rates of Electron Acceleration in SNR Shocks using Chandra |
| 9:50 - 10:20 | Break & Poster Viewing |
| 10:20 - 10:55 | Sangwook Park (Penn State Univ.) [Invited]<br>Supernova 1987A at the Age of 18: An On-Going Life Story by Chandra |
| 10:55 - 11:30 | Giuseppina Micela (INAF - Osservatorio Astr. di Palermo) [Invited]<br>The Chandra Orion Ultradeep Project (COUP) |
| 11:30 - 12:05 | Paul Reid (Harvard-Smithsonian Center for Astrophysics) [Invited]<br>X-Ray Optics: Past, Present and Future |
| 12:05 - 2:05 | Lunch Break |
| 12:50 - 1:50 | Special Session by the Chandra EPO Group:<br>Enhancing Chandra Images for Publication and Public Outreach |
| 2:05 - 2:20 | Jeremy Drake (SAO)<br>Neon and the Problem of the Sun and Stars, the Universe and Everything |
| 2:20 - 2:35 | Jeffrey L. Linsky (JILA/Univ. of Colorado and NIST)<br>Chandra and VLT Observations of Young Stellar Objects in the Eagle Nebula |
| 2:35 - 2:50 | Nancy Brickhouse (Harvard-Smithsonian Center for Astrophysics)<br>An Episodic Heating Model for Stellar Coronae:<br>Spectral Diagnostics of Non-Equilibrium Ionization |

## Wednesday, November 2, continued

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|---|---|
| 2:50 - 3:25 | Jürgen Schmitt (Hamburger Sternwarte) [Invited]<br>High Resolution X-ray Spectra of Classical T Tauri Stars |
| 3:25 - 3:40 | One-minute Oral Poster Presentations |
| 3:40 - 4:10 | Break & Poster Viewing |
| 4:10 - 4:25 | Joachim Krautter (Landessternwarte, Heidelberg)<br>Chandra Monitoring of Nova V4743 Sgr |
| 4:25 - 4:40 | Jeno Sokoloski (Harvard-Smithsonian CfA)<br>X-Ray Jets from White Dwarfs – Detection of the Collimated Outflow from CH Cygni with Chandra |
| 4:40 - 5:15 | Richard Kelley (NASA/GSFC) and Kazuhisa Mitsuda (ISAS/JAXA) [Invited]<br>The Suzaku X-Ray Observatory |
| 5:15 - 5:30 | One-minute Oral Poster Presentations |
| 5:30 - 8:00 | Poster Viewing with Cocktails |

## Thursday, November 3

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|---|---|
| 7:00 - 8:30 | Continental Breakfast & Poster Viewing |

**Theme: Energy Cycles and Outflows**

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|---|---|
| 8:30 - 9:05 | Jane Turner (UMBC/GSFC) [Invited]<br>Key Results in X-ray Spectroscopy of AGN |
| 9:05 - 9:20 | Martin Weisskopf (NASA/MSFC)<br>The First Chandra Field: The Discovery of "Leon X-1" |
| 9:20 - 9:35 | Jenny E. Greene (Harvard-Smithsonian CfA)<br>X-ray Properties of Intermediate-mass Black Holes in Active Galaxies |
| 9:35 - 9:50 | Sera Markoff (MIT Kavli Institute)<br>A Bridge from Sgr A* to LLAGN: Results from a 300ks Simultaneous Multiwavelength Campaign on M81* with the Chandra HETGS |
| 9:50 - 10:35 | Break & Poster Viewing |
| 10:35 - 11:10 | Diana Worrall (Univ. of Bristol) [Invited]<br>Radio Galaxies, Jets, and their Environments |
| 11:10 - 11:25 | Rita Sambruna (GFSC)<br>Deceleration in AGN jets |

## Thursday, November 3, continued

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|---|---|
| 11:25 - 11:40 | Aneta Siemiginowska (SAO/CXC)<br>Chandra Deep Imaging of a Large Scale Jet in the z=1 Quasar PKS 1127-145 |
| 11:40 - 11:55 | Nancy A. Levenson (Univ. of Kentucky)<br>Penetrating the Deep Cover of Compton Thick AGN |
| 11:55 - 12:10 | Christopher Reynolds (Univ. of Maryland, College Park)<br>Iron K-band Features in the 522ks Chandra/HETGS Spectrum of MCG-6-30-15: a Narrow View of the Broad Iron Line |
| 12:10 - 12:25 | Roberto Soria (SAO)<br>Why are they not AGN? |
| 12:25 - 1:45 | Lunch Break |
| 1:45 - 2:20 | Sarah Gallagher (UCLA) [Invited]<br>AGN Outflows: Agents of Galaxy Feedback |
| 2:20 - 2:35 | James Reeves (NASA/GSFC/JHU)<br>High Velocity Outflows in Near Eddington AGN |
| 2:35 - 2:50 | Farhad Yusef-Zadeh (Northwestern Univ.)<br>The Nature of Simultaneous near-IR and X-ray Flares from Sgr A* at the Galactic center |
| 2:50 - 3:05 | Saeqa Vrtilek (SAO)<br>The Chandra View of X-ray Binaries |
| 3:05 - 3:20 | Jon Miller (Univ. of Michigan)<br>Accretion Disk Winds in Black Hole X-ray Binaries |
| 3:20 - 3:35 | Herman Marshall (MIT Kavli Institute)<br>Modeling the Relativistic Jets in SS 433 Using Chandra X-ray Spectroscopy |
| 3:35 - 4:00 | Break & Poster Viewing |
| 4:00 - 4:35 | Christine Jones (SAO) [Invited]<br>Reflections of AGN Outbursts in the Hot Gas in Galaxies and Clusters |
| 4:35 - 4:50 | Steven Allen (KIPAC (Stanford/SLAC))<br>Dark Energy Studies with the Largest, Relaxed Galaxy Clusters |
| 4:50 - 5:05 | Alexey Vikhlinin (SAO)<br>Cosmology with the Chandra Cluster Data |
| 5:05 - 5:20 | Max Bonamente (UAH-NASA/NSSTC)<br>Measurement of the Cosmic Distance Scale from Chandra X-ray Imaging and Sunyaev-Zeldovich Effect Data of High Redshift Clusters of Galaxies |

## Thursday, November 3, continued

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|---|---|
| 5:20 - 5:35 | Michael Wise (MIT Kavli Institute)<br>Supercavities in the Hydra A Cluster: ICM Heating and the AGN Duty Cycle |
| 5:35 - 5:50 | Tracy Clarke (Naval Research Laboratory)<br>Ghost Cavities in Cluster Cores Viewed with Chandra and the VLA |
| 6:30 - 10:30<br>7:00 | Conference Dinner at the Museum of Science<br>Commemorative Remarks<br>at the Current Science and Technology Stage in the Blue Wing |

## Friday, November 4

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|---|---|
| 7:00 - 8:30 | Continental Breakfast & Poster Viewing |

**Theme: Energy Cycles and Outflows, continued**

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|---|---|
| 8:30 - 9:05 | Maxim Markevitch (SAO) [Invited]<br>Insights on Physics of Gas and Dark Matter from Cluster Mergers |
| 9:05 - 9:20 | Smita Mathur (The Ohio State Univ.)<br>Galactic Halo or Local Group Intergalactic Medium? |
| 9:20 - 9:35 | Fabrizio Nicastro (SAO/UNAM) - Presented by Martin Elvis (SAO)<br>Detections of the Warm Hot Intergalactic Medium |
| 9:35 - 9:50 | Andrzej Soltan (Copernicus Astronomical Center)<br>Study of the Soft X-ray Emission by Warm/Hot Intergalactic Medium |
| 9:50 - 10:05 | Joel Bregman (Univ. of Michigan)<br>Where are the Baryons in the Local Group? |
| 10:05 - 10:50 | Break & Poster Viewing |
| 10:50 - 11:05 | Yangsen Yao (MIT/UMASS)<br>X-raying the Multi-Phase ISM Along the Sightline to the Galactic Center |
| 11:05 - 11:20 | Q. Daniel Wang (Univ. of Massachusetts)<br>Chandra View of the Hot Interstellar Medium |
| 11:20 - 11:35 | David Ballantyne (CITA, Univ. of Arizona)<br>Connecting Galaxy Formation, Star Formation and the X-ray Background |
| 11:35 - 11:50 | Stephen Murray (Harvard-Smithsonian Center for Astrophysics)<br>Using AGN to Observe the Growth of the Cosmic Web |
| 11:50 - 12:05 | Anton Koekemoer (STScI)<br>First Results from the Extended Chandra Deep Field-South Survey |

## Friday, November 4, continued

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| 12:05 - 1:35 | Lunch Break<br>All posters that have not been taken down by noon will be discarded. |

**Theme: Populations in the High Energy Universe**

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|---|---|
| 1:35 - 2:10 | Douglas Swartz (USRA NASA/MSFC) [Invited]<br>Ultraluminous X-ray Sources in Nearby Galaxies |
| 2:10 - 2:25 | Pranab Ghosh (Tata Institute)<br>Cosmic Star Formation History and Chandra Deep Field Studies |
| 2:25 - 2:40 | Michael Garcia (SAO)<br>The Chandra M31 Campaign: Some Surprises and M31* |
| 2:40 - 2:55 | Marat Gilfanov (MPA, Garching)<br>Populations of Compact X-ray Sources in Galaxies |
| 2:55 - 3:30 | K. D. Kuntz (JHU/NASA-GSFC-LHEA) [Invited]<br>The M101 Ms |
| 3:30 - 4:00 | Break |
| 4:00 - 4:15 | Anil Bhardwaj (NASA/MSFC) - Presented by Ronald Elsner (NASA/MSFC)<br>X-Ray Emission from the Saturn System |
| 4:15 - 4:30 | Graziella Branduardi-Raymont (UCL Mullard Space Science Lab.)<br>XMM-Newton Observations of X-ray Emission from Jupiter |

# Invited Talks and Oral Presentations

Abstracts are listed in the order in which they will be presented.

## Wednesday, November 2

### A Detailed Study of the Pulsar Wind Nebula 3C 58

8:45 - 9:20 AM [Invited Talk]

Patrick Slane (SAO)

Recent Chandra observations of the X-ray emission from young neutron stars have revolutionized our picture of everything from the structure of their cores to the composition of their energetic winds. Measurements of the thermal emission from their surfaces provide constraints on their cooling properties while high resolution images of the compact structure surrounding the stars reveal jets, toroidal features associated emission downstream of the wind termination shock, and complex structures both near the neutron stars and in their extended wind-powered nebulae. 3C 58 is a wind nebula powered by one of the youngest neutron stars in the Galaxy. I will summarize the results of Chandra observations, including a Large Project, that provide evidence for nonstandard cooling processes in the neutron star interior, complex structures that may be associated with magnetic loops torn from the termination shock by kink instabilities, and a shell of shock-heated ejecta into which the nebula is expanding.

**Notes:**

## X-ray Eyes on the Brightest Explosions in the Universe: Probing the GRB Afterglow Emission Mechanism with Chandra

9:20 - 9:35 AM

Nat Butler (UC Berkeley), George Ricker, Peter Ford, Roland Vanderspek, Herman Marshall (MIT), Kevin Hurley, Garrett Jernigan (UC Berkeley), Don Lamb (U Chicago)

Chandra ACIS is an established and vital link in the network of space and ground-based observatories chasing after Gamma-ray burst (GRB) afterglows. More than 35 afterglows fields-of-view of short and long duration GRBs and X-ray Flashes (XRFs) have been observed to date, with several of the observations beginning less than 1 day after the GRB. Imaging observations probe the density profile and constrain the jet-structure of the emitting region. The X-rays are uniquely penetrating, and Chandra observations have enabled the detection of several events not seen in the optical/IR. We discuss how these observations link GRBs to supernovae and constrain the popular fireball model for GRBs, and we highlight interesting departures from the model which suggest, e.g., continued energy from the GRB. Chandra has also provided the highest signal to noise gratings spectra of GRB afterglows. We discuss early claims of low to moderate significance X-ray lines. The lines are strong diagnostics on the geometry, ionization state, and chemical composition of the circumburst emitting region. However, they have not been detected in the three most recent Chandra spectra.

**Notes:**

## Estimating the Rates of Electron Acceleration in SNR Shocks Using Chandra

9:35 - 9:50 AM

Michael Stage (Univ. of Massachusetts, Amherst), Glenn Allen, John Houck, John Davis (MIT Kavli Institute)

Over the last six years, the Advanced CCD Imaging Spectrometer (ACIS) on Chandra has captured the highest resolution X-ray images of several supernova remnants, the most spectacular example the Cassiopeia A megasecond observation from cycle 5. The observations of thermally dominated, young supernova remnants such as Cassiopeia A, Kepler, and Tycho show complex morphology often featuring narrow, filamentary, continuum dominated emission at the outer shocks. Young supernova remnants are believed to be possibly a source of and the main accelerator of Galactic cosmic rays. The emission from the filaments is believed to be synchrotron radiation associated with the acceleration of cosmic-ray electrons to TeV energies, rather than thermal bremsstrahulung associated with the ejecta emission. Using a combination of CIAO tools and a suite of specialized software utilizing the S-Lang scripting capabilities of ISIS, we have been able to analyze these extended sources using the full spatial and spectral information available from the ACIS data. Specifically, for Cas A, we have been able to identify, isolate, extract, and fit the spectra of the emission at each of about ten thousand locations along the filaments with a synchrotron model. We present maps at 1 arcsecond scale of the critical frequency associated with the exponential cut-off of the synchrotron spectrum as well as of the ratio of the electron diffusion coefficient to the Bohm coefficient, calculated from the critical frequency and shock velocity. At several locations, our maps indicate diffusion rates comparable to the Bohm limit-that is, that electrons are being accelerated about as fast as possible.

**Notes:**

## Supernova 1987A at the Age of 18: An On-Going Life Story by Chandra

10:20 - 10:55 AM [Invited Talk]

Sangwook Park (Penn State Univ.)

We present the morphological and spectral evolutions of SN/SNR 1987A from Chandra observations. We review the Chandra/ACIS observations of SNR 1987A performed since 1999, and report the latest results as of 2005 July. Brightening and expanding of the X-ray remnant as well as the softening of the X-ray spectrum continue. Remarkably, the latest soft X-ray flux increase rate turns up by significantly deviating from the model which successfully fits the earlier data covering over a decade. The high resolution X-ray spectrum observed with deep Chandra gratings observations reveals a disk-like structure and the kinematics of the X-ray emitting plasma.

**Notes:**

## The Chandra Orion Ultradeep Project (COUP)

10:55 - 11:30 AM [Invited Talk]

Giuseppina Micela (INAF - Oss. Astronomico. di Palermo), Eric Feigelson, COUP Collaboration (Penn State Univ.)

The 850 ksec Chandra observation of the Orion nebula region, obtained in January 2003, has provided an unprecedented dataset for the study of X-ray emission of very young stars. A wide range of studies involving a large international collaboration have been possible and others are in progress. Implications of the analysis and interpretation of data from COUP (http://www.astro.psu.edu/coup) are very important for the study of the formation and evolution of stellar coronae, their interplay with stellar structure and for the investigation of the possible role of the accretion in producing and/or regulating X-ray emission from young stellar objects (YSOs). The X-ray emission properties of very young stars and the variety of circumstellar environment present in Orion, allow us also to explore the influence of YSO high energy radiation on the circumstellar material in the first phases of stellar life. We review some results we already obtained along these lines as well as new ongoing work on the subject.

**Notes:**

## X-Ray Optics: Past, Present and Future

11:30 AM - 12:05 PM [Invited Talk]

Paul Reid (Harvard-Smithsonian Center for Astrophysics)

We discuss the development of x-ray optics for astronomy. Some of the technical problems, solutions, and lessons learned in fabricating the optics for the Einstein and Chandra Observatories are recounted. We also review new ideas aimed at developing x-ray telescopes with imaging resolution (and effective area) orders of magnitude better (and larger) than Chandra.

**Notes:**

### Neon and the Problem of the Sun and Stars, the Universe and Everything

2:05 - 2:20 PM

Jeremy Drake (SAO), Paola Testa (MIT Kavli Institute for Astrophysics and Space Research)

The demure element Neon has gained great notoriety in recent months as attention has been focussed on its possible role in a serious new problem with understanding how the Sun works. Solar models including recent downward revisions of the Sun's metal content are now inconsistent with helioseismology. While Chandra X-ray spectra of nearby stars indicate that a higher neon abundance could be a possible way out of the solar quandry, this route might require some unsustainable ravaging of old-growth astrophysics and will draw objections from conservationists. We will attempt to describe this new role of Neon, the newcomer, in these problems of the Sun and Stars, the Universe and Everything.

**Notes:**

## Chandra and VLT Observations of Young Stellar Objects in the Eagle Nebula

2:20 - 2:35 PM

Jeffrey L. Linsky (JILA/Univ. of Colorado and NIST), Marc Gagne, Anna Mytyk (West Chester Univ.), Mark J. McCaughrean (Exeter Univ.), Morten Andersen (Astro. Dept. Univ. Arizona)

We present the first X-ray images ever obtained of the Eagle Nebula star-forming region. On 2001 July 30 the Chandra X-ray Observatory obtained a 78-ks image of the Eagle nebula (M 16), that included the 2-Myr old star cluster NGC 6611 and the dark columns of dust and cold molecular gas known as the Pillars of Creation, the elephant trunks, or Columns. We find a total of 1103 X-ray sources in the 17 x 17 arcmin ACIS-I field of view. Most of the Chandra sources are associated with members of the 2-Myr old cluster NGC 6611 whose O stars ionize the nebula and are eroding the face of the adjacent molecular cloud. Only a small number of X-ray sources are associated with possibly younger stars just emerging from the molecular cloud. In particular, we detect no X-ray emission from the evaporating gaseous globules (EGGs) at the periphery of the Columns. We discuss the X-ray properties of two intermediate-mass YSOs at the heads of Columns 1 and 2, and of the bow shock of the Herbig-Haro object HH 216, and of some of the newly discovered YSOs. Comparing the X-ray luminosity function of NGC 6611 with the one in Orion, we estimate that NGC 6611 contains approximately 5300 cluster members. Although some stars appear to have formed in the last million years, the lion's share of star formation in M16 occurred some 2 Myr ago.

**Notes:**

## An Episodic Heating Model for Stellar Coronae: Spectral Diagnostics of Non-Equilibrium Ionization

2:35 - 2:50 PM

Nancy Brickhouse, Priya Desai, Andrea Dupree, Richard Edgar, Ronnie Hoogerwerf, John Raymond (Harvard-Smithsonian Center for Astrophysics), Randall Smith (NASA/GSFC)

Standard emission measure distribution analysis of Capella shows a strongly pronounced peak near 6 MK (Dupree et al. 1993; Canizares et al 2000), near the formation temperature of Fe XVIII and XIX; similar structures are observed on many active stars. Recently, the Chandra grating observations have revealed that the line ratios from these two ions are inconsistent, in the sense that the X-ray (11 to 17 A) lines are observed to be stronger than predicted by their EUV (90 to 120 A) counterparts (Desai et al. 2005). The discrepancies for the strongest lines are larger than expected from errors in the atomic data and calibration, and thus we consider an astrophysical explanation.

We construct a simple time-dependent heating model for active stellar coronae, following Sturrock et al. (1990), who suggested that the solar corona is heated by a distribution of short heating bursts, followed by radiative cooling. The Capella X-ray/EUV line ratios indicate temperatures above 10 MK, suggesting the presence of non-equilibrium ionization conditions. Thus, as in Raymond (1990) we follow the time-dependent ionization state of the gas and predict its EUV and X-ray spectrum. Parameters of the model are the maximum temperature, the heating time, and the electron density. We discuss the predicted iron line ratios, density, and charge state distribution in view of the observations.

**Notes:**

## High Resolution X-ray Spectra of Classical T Tauri Stars

2:50 - 3:25 PM [Invited Talk]

Jürgen Schmitt (Hamburger Sternwarte)

With the advent of Chandra and XMM-Newton high resolution spectroscopy of all classes of stars has become possible. I will present the available X-ray spectra of classical T Tauri stars and discuss the physical implications of these data. I will argue that all available spectra support an scenario where mass accretion is responsbile for soft X-ray emission. Mass accretion rates can be determined from the data. However, accretion alone cannot account for all the observed high energy phenomena.

**Notes:**

## Chandra Monitoring of Nova V4743 Sgr

4:10 - 4:25 PM

Joachim Krautter (Landessternwarte, Heidelberg), Jan-Uwe Ness (Dept. of Theoretical Physics, Oxford), Sumner Starrfield (ASU, Tempe), Alexander Petz, Peter Hauschildt (Hamburger Sternwarte), Jeremy Drake (Harvard-Smithsonian Center for Astrophysics)

The classical nova V4743 Sgr was observed five times with Chandra covering a time span of 16 months. Both lightcurve and spectra show strong temporal variations. An analysis of the lightcurve shows a stable period of about 1300 sec in all observations, but no stable amplitude. Also harmonic overtones were detected. During one epoch the X-ray countrate dropped to essentially zero over more than 5 ksec. Here only emission lines were observed while on all other occasions the spectra were dominated by a strong soft continuum with absorption lines. The cause of the pulsations, the decrease of the X-ray flux and the spectral properties will be discussed.

**Notes:**

## X-Ray Jets from White Dwarfs – Detection of the Collimated Outflow from CH Cygni with Chandra

4:25 - 4:40 PM

Jeno Sokoloski (Harvard-Smithsonian Center for Astrophysics), Duncan Galloway (Univ. of Melbourne)

Most symbiotic stars consist of a white dwarf accreting material from the wind of a red giant. A growing number of these objects have been found to produce jets. Analysis of archival Chandra data of the symbiotic system CH Cygni reveals faint extended X-ray emission to the south, aligned with the optical and radio jets seen in earlier HST and VLA observations. CH Cygni thus contains only the second known white dwarf with an X-ray jet, after R Aquarii. The jet was produced when CH Cygni transitioned from an optical low state to an optical high state – a behavior reminiscent of X-ray binaries, which can produce discrete ejections in association with X-ray state changes. We briefly compare the X-ray jets from symbiotic stars to the non-relativistic X-ray jets seen in several Herbig-Haro objects and the collimated outflows from the central stars or binaries in planetary nebulae.

**Notes:**

### The Suzaku X-Ray Observatory

4:40 - 5:15 PM [Invited Talk]

Richard Kelley (NASA/GSFC), Kazuhisa Mitsuda (ISAS/JAXA)

The Japan/US Suzaku (formerly Astro-E2) astrophysics mission has been successfully launched. Sensitive x-ray spectrometers have been designed to enable precise measurements of high-energy processes in stars, supernova remnants, galaxies, clusters of galaxies, and the environments around neutron stars and black holes. We will describe the current capabilities of Suzaku and present some of the early data from a number of celestial targets to illustrate the actual capabilities of the Observatory.

**Notes:**

# Thursday, November 3

### Key Results in X-ray Spectroscopy of AGN

8:30 - 9:05 AM [Invited Talk]

Jane Turner (UMBC/GSFC)

I review some of the important results gained from grating spectroscopy of AGN with Chandra and XMM. I focus on results that have provided new, and sometimes unexpected insight into the environs of supermassive black holes.

**Notes:**

## The First Chandra Field: The Discovery of "Leon X-1"

9:05 - 9:20 AM

Martin Weisskopf (NASA/MSFC), Thomas L. Aldcroft (SAO), Robert Cameron (SLAC), Poshak Gandhi, Cedric Foellmi (ESO), Ronald Elsner, Sandeep Patel (NASA/MSFC), Kinwah Wu (MSSLK, University College London), Stephen O'Dell (NASA/MSFC)

Before the official first-light images, the Chandra X-Ray Observatory obtained an X-ray image of the field to which its focal plane was first exposed. We describe this historic observation and report our study of the first Chandra field. Chandra's Advanced CCD Imaging Spectrometer (ACIS) detected 15 X-ray sources, the brightest being dubbed Leon X-1 to honor the Chandra Telescope Scientist, Leon Van Speybroeck. Based upon our analysis of the X-ray data and spectroscopy at the European Southern Observatory (ESO; La Silla, Chile), we find that Leon X-1 is a Type-1 (unobscured) active galactic nucleus (AGN) at a redshift z=0.3207. Leon X-1 exhibits strong Fe II emission and a broad-line Balmer decrement that is unusually flat for an AGN. Within the context of the Eigenvector-1 correlation space, these properties suggest that Leon X-1 may be a massive ($\geq 10^9\, M_\odot$) black hole, accreting at a rate approaching its Eddington limit.

**Notes:**

## X-ray Properties of Intermediate-mass Black Holes in Active Galaxies

9:20 - 9:35 AM

Jenny E. Greene (Harvard-Smithsonian Center for Astrophysics), Luis C. Ho (Carnegie Observatories)

We present Chandra observations of the only uniformly-selected sample of intermediate-mass ($< 10^6 \, M_\odot$) black holes (BHs) in active galactic nuclei (AGNs). This sample probes a new regime in BH mass, host galaxy morphology, and AGN demographics. The sample also currently provides the best observational constraints on the mass spectrum and spectral properties of primordial seed BHs. Remarkably, the objects appear to obey the M-sigma relation established locally for more massive systems, suggesting physical continuity over many orders of magnitude in BH mass. By selection, these systems radiate close to their Eddington luminosities, and thus we explicitly compare their properties to those of narrow-line Seyfert 1s. In conjunction with radio constraints from the VLA, the Chandra observations allow us to explore the broad spectral energy distributions for this unique sample.

**Notes:**

### A Bridge from Sgr A* to LLAGN: Results from a 300ks Simultaneous Multiwavelength Campaign on M81* with the Chandra HETGS

9:35 - 9:50 AM

Sera Markoff, Claude Canizares (MIT Kavli Institute), Geoff Bower (UC Berkeley), Poonam Chandra (TIFR), C. C. Cheung (MIT Kavli Institute), Sarah Gallagher (UCLA), Sebastian Heinz, Mario Jimenez-Garate, Herman Marshall (MIT Kavli Institute), Michael Muno (UCLA), Michael Nowak (MIT Kavli Institute), Alison Peck (Harvard-Smithsonian Center for Astrophysics), Alak Ray (TIFR), Rainer Schoedel (Uni Koeln), Andy Young (MIT Kavli Institute)

Sgr A* has been the focus of many fruitful multiwavelength campaigns using *Chandra* as well as several other instruments. It is the lowest luminosity (in Eddington units) black hole that we can currently study with high statistics, and is thus a valuable testbed for theories of black hole accretion. There are several unanswered questions regarding Sgr A* beyond its weak emission, such as what is the exact nature of its accretion flow, why does it show regular X-ray flares, and how does it relate to "normal" LLAGN? M81* offers itself as a unique bridge source: it is also the weak nucleus of a spiral galaxy, with a 20 times greater mass, and it shares very similar radio spectra and polarization properties with Sgr A*. Yet M81* is four orders of magnitude brighter in the radio, has significant nonthermal X-ray emission, and does have resolved jets. In this talk I will present some of the initial results from our 2005 campaign on M81*, using $\sim$300ks GTO time on the *Chandra HETGS*. We have obtained the first gratings-resolution X-ray spectrum of an isolated LLAGN nucleus to date, the details of which will be presented in another talk at this meeting. Here I will focus on the broadband continuum. The first 50ks were successfully coordinated with radio (GMRT, VLA), mm-submm (SMA, IRAM PdBI) and NIR (Lick w/laser guide star AO) and the rest had partial coverage by the GMRT, VLA/VLBA, SMA and PdBI. I will discuss both the long term variability and theoretical modeling, and compare it to what we see in Sgr A* and other LLAGN.

**Notes:**

## Radio Galaxies, Jets, and their Environments

10:35 - 11:10 AM [Invited Talk]

Diana Worrall (Univ. of Bristol)

Jet physics is again flourishing as a result of Chandra's ability to resolve high-energy emission from the radio-emitting structures of active galaxies and separate it from the X-ray-emitting thermal environments of the jets. I will review the progress that has been made in answering several important questions, including: Are the radio structures in a state of minimum energy? How fast are jets? What keeps them collimated? What type of plasma produces the jet structures we observe — electron-positron or electron proton? Where and how does particle acceleration occur? Which structures are dynamical and which have reached equilibrium? How is jet energy transferred to the surrounding medium?

**Notes:**

## Deceleration in AGN Jets

11:10 - 11:25 AM

Rita Sambruna (GFSC), M. Gliozzi, D. Donato (GMU), L. Maraschi (Oss Brera), F. Tavecchio (Oss Merate), C. C. Cheung (MIT), C. M. Urry (Yale), J. F. Wardle (Brandeis)

We present deep (70–80 ks) Chandra and multicolor HST ACS images of two jets hosted by the powerful quasars 1136–135 and 1150+497, together with new radio observations. The sources have an FRII morphology and were selected from our previous X-ray and optical jet survey for detailed follow up aimed at obtaining better constraints on the jet multiwavelength morphology and X-ray and optical spectra of individual knots, and to test emission models deriving physical parameters more accurately. All the X-ray and optical knots detected in our previous short exposures are confirmed, together with a few new faint features. The jet radial profiles show good correspondence between the knots at the various wavelengths; a few show offsets between the knots peaks of $<1$ arcsec. In 1150+497 the X-ray, optical, and radio profiles decrease in similar ways with distance from the core up to $\sim 7$ arcsec, after which the radio emission increases more than the X-ray one. No X-ray spectral variations are observed in 1150+497. In 1136–135 an interesting behavior is observed, whereby, downstream of the most prominent knot at $\sim 6.5$ arcsec from the core, the X-ray emission fades while the radio emission brightens. The X-ray spectrum also varies, with the X-ray photon index flattening from $\Gamma_x \sim 2$ in the inner part to $\Gamma_x \sim 1.7$ to the end of the jet. We intepret the jet behavior in 1136–135 in a scenario where the relativistic flow suffers systematic deceleration along the jet, and briefly discuss the major consequences of this scenario. Moreover, we find evidence for faint, soft intra-knot X-ray emission, and quantify its contribution to the X-ray flux of individual knots. The origin of this emission is addressed.

**Notes:**

## Chandra Deep Imaging of a Large Scale Jet in the z=1 Quasar PKS 1127-145

11:25 - 11:40 AM

Aneta Siemiginowska, Thomas L. Aldcroft (SAO/CXC), Jill Bechtold (Steward Observatory), Chi C. Cheung (MIT), Daniel E. Harris (SAO/CXC), Marek Sikora (CAMK, Warsaw), Lukasz Stawarz (Max-Planck Institut, Heidelberg)

The discovery of many X-ray jets associated with Active Galactic Nuclei (AGN) during the six years of the Chandra mission has changed the way we think about extragalactic jets. Although jets span distances of hundreds of kpc to Mpc and constitute the largest physical manifestation of the AGN phenomenon, before Chandra only a few were known to emit X-rays. The fact that X-ray emission originates so far away from AGN suggests low energy losses during the jet propagation, re-acceleration processes, and interaction with the environment at large distances. In May 2005 we obtained a deep Chandra ACIS-S image of the projected 300 kpc jet in the redshift 1.18 quasar PKS 1127-145, with the main goal of studying details of the jet X-ray morphology in the context of competing theoretical models. The X-ray jet extends $\sim$30 arcsec away from the quasar core, has distinct knots and diffuse jet emission. Here we present the new X-ray data together with new radio observations and discuss details of the jet broad-band morphology. The high quality of the Chandra data enable us to study spectral properties along the jet in the high redshift large scale X-ray jet for the first time. We also consider the implications of our observation on theoretical models of the large scale jet emission.

**Notes:**

## Penetrating the Deep Cover of Compton Thick AGN

11:40 - 11:55 AM

Nancy A. Levenson (Univ. Kentucky), T. M. Heckman (JHU), J. H. Krolik (JHU), K. A. Weaver (NASA/JHU), P. T. Zycki (Copernicus Astron. Ctr.)

We analyze observations of three active galaxies obtained with Chandra. All of these active galactic nuclei (AGN) suffer from Compton thick obscuration, with column densities in excess of $1.5 \times 10^{24}$ cm$^2$ along the lines of sight. We therefore view the powerful central engines only indirectly, even at X-ray energies. Approximately 1% of the continuum's intrinsic flux is detected in reflection in each case. The only hard X-ray feature is the prominent Fe K$\alpha$ fluorescence line, with equivalent width greater than 1 keV in all sources. In detail, the morphologies of the extended soft X-ray emission and optical line emission are similar, and line emission dominates the soft X-ray spectra. Thus, we interpret the soft X-ray emission as a consequence of photoionization by the central engines. Because the resulting spectra are complex and do not reveal the AGN directly, crude analysis techniques such as hardness ratios would mis-classify these galaxies as hosts of intrinsically weak, unabsorbed AGN and would fail to identify the luminous, absorbed nuclei that are present. The active nuclei produce most of the galaxies' total observed emission over a broad spectral range, and much of their light emerges at far-infrared wavelengths.

**Notes:**

### Iron K-band Features in the 522ks Chandra/HETGS Spectrum of MCG-6-30-15: a Narrow View of the Broad Iron Line

11:55 AM - 12:10 PM

Christopher Reynolds (Univ. of Maryland, College Park), Andrew Young (MIT), Andrew Fabian (Univ. of Cambridge), Julia Lee (Harvard), Claude Canizares (MIT), Robert Gibson (MIT)

We present results from a deep (522ks) Chandra HETG observation of the Seyfert 1.2 galaxy MCG-6-30-15, focusing on spectral features in the iron K-band and the robustness of the presence of a relativistically broadened iron emission line from the inner accretion disk. The combination of high signal-to-noise and high spectral resolution allows us to address in detail models in which a photoionized absorber mimics the highly broadened iron emission line by curving the spectrum in the 3-6keV. We can rule out these alternatives to the broad iron line; the very iron ions required to produce the observed curvature in a pure absorption model (via L-shell bound-free transitions) would also produce prominent K-shell absorption lines that are not observed. We also note FeXXV and FeXXVI absorption lines, revealing the presence of a highly ionized outflow from the nucleus of this AGN.

**Notes:**

### Why are they not AGN?

12:10 - 12:25 PM

Roberto Soria (Harvard-Smithsonian Center for Astrophysics/Univ. College London), Giuseppina Fabbiano (Harvard-Smithsonian Center for Astrophysics), Alister Graham (Australian National Univ.), Alessandro Baldi, Martin Elvis (Harvard-Smithsonian Center for Astrophysics), Helmut Jerjen (Australian National Univ.), Silvia Pellegrini (Univ. of Bologna), Aneta Siemiginowska (Harvard-Smithsonian Center for Astrophysics)

Why are most supermassive black holes (BHs) in the local universe so faint? Is it because of a lack of fuel, low radiative efficiency, or both? At what rate are they accreting today, and what fraction of the gas inflow gets re-ejected by outflows? Is accretion in a steady state, or is gas building up until the next outburst? To answer these questions, we have studied the nuclear activity in a sample of very faint elliptical/S0 galaxies with supermassive BHs. Their nuclei have typical X-ray luminosities $\sim 10^{38}$–$10^{39}$ erg/s ($\sim 10^{-8}$–$10^{-7} L_{\rm Edd}$), and are surrounded by X-ray-emitting hot gas. If this were the only source of fuel for the BH, the observed X-ray luminosities would be too faint for standard disk accretion, but brighter than predicted by radiatively-inefficient solutions (eg, ADAF). A second source of fuel, stellar mass losses from inside the sphere of influence, can be estimated from optical images. By adding the two components, we constrain the true accretion rate and efficiency. We show that a self-regulating, slow outflow, powered by the accretion luminosity (mechanical plus radiative), can remove all the gas that does not sink into the BH, using only a small fraction of the available power. The rest of the energy may be carried out in a jet or advected. Typical values consistent with the observations and with the condition of mass balance are that 90–99% of the injected gas is lost in outflows, 1–10% accretes onto the BH, and 0.01–0.1% may go in a relativistic jet.

**Notes:**

## AGN Outflows: Agents of Galaxy Feedback

1:45 - 2:20 PM [Invited Talk]

Sarah Gallagher (UCLA)

Theoretical modeling of structure formation in the early Universe overpredicts the masses of large galaxies unless some form of feedback is included. Recently, outflows from actively accreting black holes have emerged as the favored agents of this energy injection. The significant correlation of black-hole and host galaxy bulge masses in the local Universe is another indication of a connection between black holes and their hosts, and mass ejection accompanying mass accretion onto the black hole during its active accretion phase is probably important in mediating this relationship. While these theoretical considerations motivate the study of AGN outflows in the context of understanding massive galaxy formation, winds are also a fundamental product of accretion physics, particularly in luminous quasars. I will review the evidence on AGN outflows in the local Universe and at cosmologically interesting redshifts, focusing on the primary role that X-ray studies have played in detecting and constraining the most massive winds. These constraints are essential for estimating the kinetic power of AGNs and thus their impact on galaxy formation.

**Notes:**

### High Velocity Outflows in Near Eddington AGN

2:20 - 2:35 PM

James Reeves (NASA/GSFC/JHU), Ken Pounds (Univ. of Leicester)

We present evidence for ultra fast (0.1c) outflows in several AGN which are likely to be accreting at a high fraction of the Eddington limit. In particular we discuss the Chandra grating and XMM-Newton spectra of PG 1211+143 and PDS 456, both of which are high luminosity AGN likely to be accreting near the Eddington rate. The X-ray spectra of both sources exhibit deep absorption from high ionization material, in the form of ionized absorption lines and edges from Fe, O, Ne, Mg and S. The high column absorber appears to be outflowing with velocities near 0.1c in both sources, implying that the kinetic power of the fast outflows is a significant fraction of the quasar energy budget. We also present new Chandra observations of PG 1211+143, which shows evidence for variable, redshifted iron K absorption lines. The relativistic velocities measured (0.2-0.3c) imply that we are seeing the long sought-after evidence for infall of matter in the last few gravitational radii around a supermassive black hole.

**Notes:**

### The Nature of Simultaneous near-IR and X-ray Flares from Sgr A* at the Galactic center

2:35 - 2:50 PM

Farhad Yusef-Zadeh (Northwestern Univ.), Howard Bushouse (STScI), Craig Heinke (Northwestern Univ.), Mark Wardle (Macquarie Univ.), Darren Dowell (Cal Tech), Douglas Roberts (Northwestern/Adler), Stu Shapiro (UIUC)

Sgr A* is considered to be a massive black hole at the Galactic center and is known to be variable in radio, millimeter, near-IR and X-rays. However, the correlation of the variability across its spectrum has not been fully studied. Here I review highlights of the results of two observing campaigns in 2004, designed to investigate the correlation of flare activity from Sgr A* at high energies. We report the detection of a simultaneous X-ray and near-IR flare, as well as a sub-millimeter and near-IR flare using the NICMOS of HST, XMM-Newton and CSO. We explain the X-ray emission as arising from the population of near-IR-synchrotron-emitting relativistic particles, scattering sub-millimeter seed photons within the inner 10 horizon radii of Sgr A* up to X-rays and soft $\gamma$-rays, detected by INTEGRAL. Using the inverse Compton scattering picture, we explain the lack of one-to-one X-ray counterparts to near-IR flares by the variation of the magnetic field and the spectral index distributions of the nonthermal particles. We also describe a power spectrum analysis of the NICMOS data during which Sgr A* was active in near-IR wavelengths. Lastly, I will present Chandra results of X-ray emission from nonthermal radio filaments and diffuse features in the Galactic center and discuss their emission mechanism in X-rays.

**URL:** `http://apc-p7.org/APC_CS/Animation/HEP_GC/Conference/prog_conf.html`

**Notes:**

## The Chandra View of X-ray Binaries

2:50 - 3:05 PM

Saeqa Vrtilek (SAO)

This talk will present some highlights from the many remarkable studies of X-ray binary systems that have been conducted using Chandra. Chandra's unprecedented spatial resolution and sensitivity have enabled us to determine luminosity functions for entire classes of X-ray binaries as observed in other galaxies and in globular clusters within our own and nearby galaxies, and to measure and analyze scattering halos around X-ray binaries at an accuracy high enough to provide a new method for measuring cosmic distances. It has been used for identifications of sources through accurate x-ray positions, and to place constraints on the chemical state of interstellar matter by measuring absorption lines in X-ray binaries, to measure the speed of powerful X-ray winds with the first detections of X-ray P-Cygni features, and to determine the size and separation of the jet material in galactic microquasars by measuring X-ray line velocities to an accuracy comparable to that of optical spectroscopy.

**Notes:**

## Accretion Disk Winds in Black Hole X-ray Binaries

3:05 - 3:20 PM

Jon Miller (Univ. of Michigan)

The exact nature of warm absorbers in Seyfert AGN is unclear, but accretion disk winds provide a viable explanation. Chandra HETGS observations of black hole X-ray binaries in outburst have revealed variable, blue-shifted absorption lines which imply ionized outflows. These outflows also likely represent disk-driven winds, providing evidence that winds may be a generic property of accretion disks around compact objects. In this presentation, I will briefly review both recent and new Chandra results which establish ionized outflows in black hole binaries and discuss parallels with the warm absorbers inferred in Seyfert AGN.

**Notes:**

## Modeling the Relativistic Jets in SS 433 Using Chandra X-ray Spectroscopy

3:20 - 3:35 PM

Herman Marshall, Claude Canizares, Sebastian Heinz, Norbert Schulz, Michael Nowak (MIT Kavli Institute)

The unusual X-ray binary SS 433 has been observed with the *Chandra* X-ray observatory on four occasions at different orbital and precessional phases. These data have provided excellent views of the hottest parts of the oppositely directed jets. Emission line widths directly provide the opening angle of the jet, which varies by at least a factor of two between observations. We can also determine the composition, density, temperature, and ionization state of the jet gas from the X-ray spectra of the twin jets so that better models of the physical conditions in the jets can be constructed. In some observations, the soft X-ray emission lines are nearly absent, leading to a possible interpretation that jet cooling is predominantly radiative during these times. Observations during eclipse can be interpreted by blocking the cooler portions with the companion star, providing a measure of the size of the companion and the mass of the black hole. We will report on new, very long observations both in and out of eclipse using *Chandra* that were obtained in August, 2005 with simultaneous radio and optical coverage.

**Notes:**

## Reflections of AGN Outbursts in the Hot Gas in Galaxies and Clusters

4:00 - 4:35 PM [Invited Talk]

Christine Jones (SAO)

Chandra images show the presense of shocks, jets, cavities, and buoyant bubbles in the hot gas in galaxies, groups and clusters. These features all owe their origin to outbursts from the SMBH at the nucleus of the system. In this talk I will review recent results on AGN outbursts in the rich clusters MS0735.6+7421, Perseus, Hercules A, Hydra A and Virgo as well as the effects of outbursts and the X-ray luminosities of LLAGN in a sample of 160 early-type galaxies.

**Notes:**

## Dark Energy Studies with the Largest, Relaxed Galaxy Clusters

4:35 - 4:50 PM

Steven Allen (KIPAC (Stanford/SLAC)), Robert Schmidt (Heidelberg), David Rapetti (KIPAC (Stanford/SLAC)), Harald Ebeling (IfA, Hawaii), Andrew Fabian (IoA, Cambridge), Leon van Speybroeck (Harvard-Smithsonian Center for Astrophysics)

I will present the latest results on the mean matter density, dark energy density and dark energy equation of state from Chandra measurements of the X-ray gas mass fraction in the largest, dynamically relaxed clusters. This method, like supernovae studies, allows us to measure the acceleration of the Universe directly and leads to comparable, though entirely independent, constraints. I will highlight the remarkably complementary nature of X-ray, cosmic microwave background and supernovae studies and show how the combination of these data already provides interesting constraints on the evolution of dark energy, requiring only minimal priors.

**Notes:**

## Cosmology with the Chandra Cluster Data

4:50 - 5:05 PM

Alexey Vikhlinin (SAO) for the 400d Survey Team

We have serendipitously detected a large number of high-redshift galaxy clusters in ROSAT pointings covering over 400 square degrees of extragalactic sky. Each X-ray detection is optically confirmed and spectroscopic redshifts were obtained for all objects. The most massive distant clusters (43 objects at $z > 0.35$) were followed up with Chandra. This program is nearly completed. These observations provide the most accurate to-date measurement of the cluster number density evolution. We will present the cosmological constraints provided by the 400d distant cluster sample.

**Notes:**

## Measurement of the Cosmic Distance Scale from Chandra X-ray Imaging and Sunyaev-Zeldovich Effect Data of High Redshift Clusters of Galaxies

5:05 - 5:20 PM

Max Bonamente (UAH - NASA/NSSTC), Marshall Joy (NASA/MSFC), Samuel LaRoque, John Carlstrom (Univ. of Chicago), Erik Reese (Univ. of California, Berkeley)

Galaxy clusters are unique probes of the expansion of the universe. Their strong X-ray emission, along with radio observations measuring the scattering of the cosmic microwave background, affords an independent method to obtain distances based on the physics of ionized plasmas. We determine the distance to 37 clusters of galaxies in the redshift range 0.14<0.89 using Chandra X-ray data and interferometric radio observations using the Owens Valley Radio Observatory and the Berkeley-Illinois-Maryland Association interferometric arrays. We model the plasma and the dark matter distribution in clusters using a hydrostatic equilibrium model that accounts for radial variation in density, temperature and abundances, and use the cluster distances to measure the Hubble constant.

**Notes:**

## Supercavities in the Hydra A Cluster: ICM Heating and the AGN Duty Cycle

5:20 - 5:35 PM

Michael Wise (MIT Kavli Institute), Brian McNamara (Ohio Univ.), Paul Nulsen (Harvard-Smithsonian Center for Astrophysics), John Houck (MIT Kavli Institute), Larry David (Harvard-Smithsonian Center for Astrophysics)

We report on a new set of giant cavities recently discovered in a deep 200 ksec observation of the Hydra A cluster. These new cavities extend to a radius of 300 kpc from the central AGN with diameters of 250 kpc and 150 kpc for the northern and southern cavities, respectively, and appear to be connected to the previous smaller cavities seen in Hydra A. This connection suggests the the possibility that such supercavities represent merging bubbles generated by an ongoing series of outbursts from the central AGN. The mechanical energy necessary to inflate these supercavities is $\sim 10^{61}$ ergs and the buoyant rise time implies an age for the cavities of 100−−300 Myr. Taken together, these estimates imply a mechanical luminosity of $1 - - 3 \times 10^{45}$ erg $s^{-1}$ which is comparable to the luminosity associated with the cluster-scale shock in Hydra A discussed previously by Nulsen et al. (2005). As we demonstrate, the complete cavity system comprises 15−−30% of the total cluster volume inside 350 kpc, and this entire volume is filled with 330 MHz radio emission. In this work, we present images and temperature maps of these new cluster-scale cavities and an analysis of their physical properties. We will discuss the implications of such supercavities on the evolution of the ICM in Hydra A as well as their potential contribution to the excess entropy or preheating seen in cluster cores. Finally, studies of these cavity systems and large-scale shock fronts produced by radio jets advancing into the ICM are currently some of the most reliable and accurate diagnostics for determining the ages and energetics of AGN. Based on these observations, we discuss what limits we can place on the age, total energy output, and duty-cycle of activity for the central AGN in Hydra A.

**Notes:**

## Ghost Cavities in Cluster Cores Viewed with Chandra and the VLA

5:35 - 5:50 PM

Tracy Clarke (NRL), Craig Sarazin (UVa), Elizabeth Blanton (BU), Namir Kassim (NRL)

X-ray observations of the central regions of cooling core clusters have revealed a wealth of detail in the thermal gas. One of the most spectacular results is the profound effect that the central radio sources have on the structure of the thermal gas. X-ray data reveal depressions and filaments in the thermal gas which are connected to the active cluster-center radio galaxy. In addition, there are "ghost cavities" in several clusters which are located well beyond the currently active radio galaxy. The presence of numerous structures in cluster cores suggests that the central AGN may play a significant role in the energy budget of this region.

We present a study of the radio and X-ray interactions in the cores of two dense clusters. Our recent low frequency radio observations of these systems reveal low energy relativistic plasma which appears to connect the central radio source to the outer ghost cavities seen in Chandra images. We present details of the radio and X-ray observations of Abell 2597 which reveal several outburst episodes of the central AGN and provide the first suggestion of an X-ray tunnel which may be maintained over multiple outburst episodes. New radio observations of Abell 4059 reveal complex source morphology with the first evidence of emission extending into the southern ghost bubble.

**Notes:**

# Friday, November 4

## Insights on Physics of Gas and Dark Matter from Cluster Mergers

8:30 - 9:05 AM [Invited Talk]

Maxim Markevitch, Scott Randall (SAO), Douglas Clowe (Univ. of Arizona), Anthony H. Gonzalez (Univ. of Florida)

I will present constraints on the physical parameters of dark matter and intracluster plasma from the 500 ks Chandra observation of the bullet cluster 1E0657-56 as well as other merging cluster data. In particular, new constraints on the dark matter self-interaction cross-section derived from a combination of X-ray and weak lensing mapping of 1E0657-56 will be presented.

**Notes:**

## Galactic Halo or Local Group Intergalactic Medium?

9:05 - 9:20 AM

Smita Mathur (The Ohio State Univ.)

Cosmological hydrodynamic simulations predict that the low redshift universe comprises of a web of warm-hot intergalactic gas and galaxies, groups of galaxies and clusters form at dense knots in these filaments. Our own Galaxy being no exception is also expected to be surrounded by the warm-hot intergalactic medium, filling the Local Group. Some theoretical models also predict the existence of a hot halo of the Galaxy. With X-ray and FUV observations of extragalactic sources, we can probe the warm-hot gas through absorption lines of highly ionized elements. Indeed, Chandra, XMM and FUSE observations have detected z=0 absorption lines towards many sightlines. The debate that has emerged is over the interpretation of these observations: are the z=0 absorption systems from the halo of our Galaxy or from the extended Local Group environment? This has important implications for our understanding of the mass of the Local Group, the physical conditions in the intergalactic medium, the structure of the Galaxy and galaxy formation in general. I will present the current status of the debate and discuss our ongoing observing program aimed at understanding the z=0 absorption systems, with emphasis on an exceptionally high quality Chandra spectrum of the Mrk 421 sightline. I'll also outline a new theoretical model.

**Notes:**

### Detections of the Warm Hot Intergalactic Medium

9:20 - 9:35 AM

Fabrizio Nicastro (SAO, UNAM), Katrien Steenbrugge (SAO), Martin Elvis (**Presenter**, SAO), Smita Mathur, Rik Williams (OSU)

I will review the current observational evidence for the presence of a large amount of baryonic matter in a tenous and hot filamentary web of interagalactic medium in the local Universe. I will show detections of intervening highly ionized metal absorption lines in the Chandra and XMM spectra of a number of blazars spanning redshifts from z=0.03 (Mkn 421) to z=0.89 (3C 454.3), and will discuss the implications of this detections in terms of number density of WHIM filaments in the Universe, and of total cosmological mass density of WHIM. I will show that our measurements are consistent with predictions from hydrodynamical simulations for the formation of structure in the Universe, and with the total amount of "missing baryons."

**Notes:**

## Study of the Soft X-ray Emission by Warm/Hot Intergalactic Medium

9:35 - 9:50 AM

Andrzej Soltan (Copernicus Astronomical Center)

A positive detection of the soft X-ray emission generated by the Warm/Hot Intergalactic Medium (WHIM) at small separations from galaxies is reported. The signal strongly declines with the photon energy indicating the WHIM temperatures below kT = 1 keV. Systematic enhancements of the X-ray background (XRB) flux surrounding field galaxies are measured at scales of ~30 - 250 kpc. A technique is based on the correlation analysis of the XRB and the galaxy distribution. A large sample of the XMM-Newton observations is used in the investigation. The amplitude of the signal is in agreement with an extrapolation of our earlier measurements of the WHIM emission performed at larger scales. Preliminary assessments of the WHIM densities based on the observed emission are presented.

**Notes:**

### Where are the Baryons in the Local Group?

9:50 - 10:05 AM

Joel Bregman, Edward Lloyd-Davies (Univ. of Michigan)

The absorption by OVII and OVIII at zero redshift can be interpreted as a very extensive Local Group medium, whose baryonic mass is greater than that of the known galaxies. This result is model dependent, and for different assumptions, this gas could be a halo around the Milky Way, with a hot gas mass that is a fraction of the Milky Way mass. These two possibilities, the Local Group and the Milky Way halo models, make different predictions that can be tested by both absorption and emission studies. The Local Group picture would predict that the OVII absorption column be greatest along the Milky Way - M31 axis, but from XMM observations of OVII absorption, we see no such effect. Also, in the Local Group picture, the soft X-ray emission would extend to Mpc scale and could be shadowed by HI clouds in the Magellanic Stream (70 kpc), but from Chandra observations, no such shadows are detected. We conclude that the hot gas responsible for emission and absorption resides primarily in a Galactic halo of extent 50 kpc, rather than in a massive medium filling the Local Group. Support for this program was provided by NASA.

**Notes:**

## X-raying the Multi-Phase ISM Along the Sightline to the Galactic Center

10:50 - 11:05 AM

Yangsen Yao (MIT/UMASS), Q. Daniel Wang (UMASS)

We present an X-ray absorption line spectroscopy of the cold, warm, and hot phases of the ISM toward Galactic center region. The OI, OII, OIII, OVII, OVIII, and NeIX Kalpha absorption lines are clearly detected in the Chandra grating spectra of 4U 820-303 (Galactic coordinates l,b =2.79, 7.91 and distance = 7.6 kpc). The detection of these lines allows us for the first time to measure the column densities of these different ISM phases in the same line of sight through much of the Galaxy. A joint-analysis of OVII, OVIII, and NeIX lines also provides tight constraints on the velocity dispersion, temperature, and Ne/O abundance ratio of the hot phase. These measurements have strong implications for our understanding of the global ISM in the Galaxy. Complemented by the pulsar dispersion measure along the same sightline, we obtain the first direct observational constraint on the global filling factor of the hot phase. If these the warm and hot phases are in a rough thermal pressure balance, the hot gas filling factor would then be greater than 0.9. If a filling factor of the hot phase is significantly less than 0.8, the thermal pressure in the hot phase should then be at least 10 times higher than that in the warm phase (i.e., a condition similar to the Local ISM).

**Notes:**

## Chandra View of the Hot Interstellar Medium

11:05 - 11:20 AM

Q. Daniel Wang (Univ. of Massachusetts)

Diffuse hot gas is thought to play an essential role in shaping the interstellar medium, dispersing the energy and chemically-enriched materials produced by stars, and feedbacking to the intergalactic medium. I will review our recent work aimed to quantify these effects. Based on the Chandra detection of various interstellar X-ray and far-UV absorption lines, we characterize for the first time the global distribution and filling factor of the hot gas as well as its thermal, chemical, and kinematic properties. This Galactic study is complemented by a survey of diffuse hot gas in and around nearby normal galaxies, based on X-ray imaging and far-UV spectroscopic observations. The results are being compared with various theories and simulations, providing new insights into the heating, transportation, and cooling mechanisms of the hot gas as well as its role in the formation and evolution of galaxies.

**Notes:**

## Connecting Galaxy Formation, Star Formation and the X-ray Background

11:20 - 11:35 AM

David Ballantyne (CITA, Univ. of Arizona), John Everett, Norm Murray (CITA)

The AGN which contribute the majority of the cosmic X-ray background (CXRB) peak in redshift at $z \sim 0.7$. Since this redshift is similar to the peak in the cosmic star-formation rate, we propose that the obscuring material required for AGN unification is regulated by star-formation within the host galaxy. We test this idea by computing CXRB synthesis models with a ratio of Type 2/Type 1 AGN that is a function of both $z$ and 2-10 keV X-ray luminosity $L$. The model which simultaneously best accounts for the Type 1 AGN fractions of Barger et al. (2005), the CXRB spectrum and the X-ray number counts predicts a Type 2 AGN fraction which evolves as $(1+z)^{0.3}$. This evolution predicts that the deep X-ray surveys are missing about half the obscured AGN with $\log L > 44$. Overall, these calculations show that the current data strongly supports a change to the AGN unification scenario where the obscuration is initiated by star formation in the host galaxy rather than an unevolving molecular torus.

**Notes:**

## Using AGN to Observe the Growth of the Cosmic Web

11:35 - 11:50 AM

Stephen Murray, Christine Jones, Almus Kenter, William Forman, Maxim Markevitch, Alexey Vikhlinin (Harvard-Smithsonian Center for Astrophysics) Katherine Brand, Buell Jannuzi (NOAO), Christopher Kochanek (OSU), D. J. Eisenstein (Univ. of Arizona)

We present X-ray and optical observations of the contiguous 9.3 sq. deg. XBootes survey made with the ACIS instrument on Chandra. The X-ray survey consists of 126 5ksec pointings that achieve a sensitivity of about $4 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$ in the 0.5–7 keV band. At this sensitivity limit we detect 4642 X-ray sources. As part of the AGES galaxy survey in the Bootes region (Kochanek et al. 2005), we have obtained 1800 redshifts of the X-ray selected objects most of which are AGN, yielding a density of $\sim 150$ AGN per square degree. The mean AGN redshift is 1.3 with the distribution extending to $z > 4$.

We have analyzed the spatial distribution of the X-ray selected AGN and compared this to the distribution of the $\sim 20000$ AGES galaxies. To $z \sim 0.7$ (the limit of galaxy sample), the galaxies and AGN both trace the same structures and show the same web of voids and filaments. At larger redshifts, the X-ray AGN continue to show the characteristic structure of voids and filaments. Quantitatively, we computed the spatial 2-point correlation function for the X-ray selected AGN and find that the correlation length, $r_0 \simeq 6.4\, h^{-1}$ Mpc, and the exponent, $\gamma \simeq -1.7$, of the correlation function are similar to the canonical values derived for galaxies. In addition, we have compared the correlation function in several redshift intervals and find that the correlation length is approximately constant to $z \sim 1.5$.

**Notes:**

## First Results from the Extended Chandra Deep Field-South Survey

11:50 AM - 12:05 PM

Anton Koekemoer (STScI), E-CDF-S Team

The Extended Chandra Deep Field-South (E-CDF-S) survey has been designed to complement the Chandra Deep Fields by significantly increasing the solid angle of sky with coverage to very sensitive X-ray flux levels. It is composed of four contiguous 250 ks ACIS-I observations flanking the original Chandra Deep Field-South (CDF-S). These observations cover a region with superb and growing multiwavelength coverage (e.g., COMBO-17, GEMS, GOODS, UDF, Spitzer, VLT, VLA, ATCA, etc), and they have the sensitivity to detect the X-ray emission from moderate-luminosity active galactic nuclei (AGN) to z $\sim$ 4-6 as well as X-ray luminous starburst galaxies to z $\sim$ 1. All the Chandra observations have now been successfully obtained and analyzed, and nearly 1000 X-ray sources, mostly AGN, are detected in the E-CDF-S region, increasing the previously known number by an additional 600. Multiwavelength follow-up studies are underway to investigate topics including the cosmic evolution and luminosity dependence of AGN X-ray emission, the efficacy of X-ray versus optical AGN-selection techniques, AGN clustering, moderate-luminosity AGN in the high-redshift universe, and off-nuclear ultraluminous X-ray sources. I will review the first results from the E-CDF-S survey, with highlights on some recent results for off-nuclear X-ray sources, alpha_ox studies and high-redshift X-ray sources, and will also discuss other ongoing projects and future prospects.

**URL:** `http://www.stsci.edu/~koekemoe/`

**Notes:**

## Ultraluminous X-ray Sources in Nearby Galaxies

1:35 - 2:10 PM [Invited Talk]

Douglas Swartz (USRA NASA/MSFC)

Ultraluminous X-ray sources (ULXs) are non-nuclear point-like sources in external galaxies with apparent luminosities $> 10^{39}$ ergs/s. Their nature is still a mystery: If they are accreting sources at the distance of their host galaxies, then their high luminosities require either beamed emission geometries, or super-Eddington emission rates, or accretion onto compact objects more massive than predicted by stellar evolution models. I will present the evidence for and against a unique classification for ULXs, describe theoretical models for the formation of ULXs and their emission mechanisms, and demonstrate the importance of multi-wavelength campaigns to understanding the ULX phenomenon.

**Notes:**

## Cosmic Star Formation History and Chandra Deep Field Studies

2:10 - 2:25 PM

Pranab Ghosh (Tata Institute), Nicholas White (NASA/GSFC)

We discuss how recent CHANDRA deep-field surveys bear on the question of cosmic star-formation history. We show that our current understanding of the evolution of X-ray luminosities of normal/starburst and Lyman-break galaxies is qualitatively correct, while quantitative details need to be clarified. We explore the role of X-ray logN-logS plots in this context, which indicate that, while the power in the X-ray background is dominated by AGN, the number density of sources is dominated by normal/starburst galaxies at faint fluxes. We discuss various schemes currently employed to discriminate between AGN and normal/starburst galaxies, and we summarize the correlations between the emissions in the X-rays and in other wavebands — optical, IR, submm, and radio — which emphasize the diagnostic value of X-rays as a probe of star formation.

**Notes:**

## The Chandra M31 Campaign: Some Surprises and M31*

2:25 - 2:40 PM

Michael Garcia (SAO), Ben Williams (Penn State Univ.), Francis Primini (SAO), Lorant Sjouwerman (NRAO), Steve Murray (SAO)

Chandra has been monitoring M31 nearly monthly since A01, with a few interruptions. This nearly 6 year long dataset has allowed the X-ray variability of hundreds of sources in the bulge of this galaxy to be studied in unprecedented detail. In addition the summed exposure on the bulge is $\sim$0.5 Msec, allowing very faint sources to be studied. Here we will highlight some of the surprises that this study has revealed, which include an unexplained association between nebula and X-ray binaries. The nuclear supermassive black hole (M31*) has proven to be one of the most secure cases for a radiatively inefficient accretion flow, and bears striking differences to Sgr A*. Preliminary results from our AO6 campaign on M31* will be presented.

**Notes:**

**Populations of Compact X-ray Sources in Galaxies**

2:40 - 2:55 PM

Marat Gilfanov (MPA, Garching)

We will discuss several aspects of populations of compact X-ray sources in galaxies. Among other topics we will compare luminosity distributions of low- and high- mass X-ray binaries in nearby galaxies as observed by Chandra and XMM-Newton and discuss use of compact sources as proxies for the stellar mass and star formation rate of the host galaxy. We will also consider the dependence of the HMXB population on the stellar age and constrain parameters of the binary evolution based on observations of high mass X-ray binaries in other galaxies.

**Notes:**

### The M101 Ms

2:55 - 3:30 PM [Invited Talk]

K. D. Kuntz (JHU/NASA-GSFC-LHEA)

M101 is a nearby face-on Scd galaxy that is small enough in angular size to allow complete coverage with a limited number of Chandra observations. Thus, the campaign to accumulate a 1Ms exposure of M101 allows thorough study of the point source populations; the combination of depth and coverage allows a more detailed study of the luminosity function as well as a spatially resolved study of luminosity functions. I find that 1.) about a third of the sources have hardness ratios typical of thermal sources rather than X-ray binaries, 2.) the radial distribution is more centrally peaked for dimmer sources, suggesting that the brighter sources are more strongly correlated with the younger stellar populations, and 3.) the surface density of sources is correlated with the UV surface brightness.

**Notes:**

**X-Ray Emission from the Saturn System**

4:00 - 4:15 PM

Anil Bhardwaj (NASA Marshall Space Flight Center), Ronald F. Elsner (**Presenter**, NASA Marshall Space Flight Center), J. Hunter Waite Jr. (AOSS, Univ. of Michigan), G. Randall Gladstone (Southwest Research Institute), Graziella Branduardi-Raymont (MSSL, Univ. College London), Thomas E. Cravens (Dept. of Physics and Astronomy, Univ. of Kansas), Peter G. Ford (MIT)

Saturn was observed by the Advanced CCD Imaging Spectrometer on the Chandra observatory in two exposures on 20 and 26-27 January 2004 respectively; each continuous observation lasted for about one full Saturn rotation (about 10 hr). These Chandra observations have detected an X-ray flare from Saturn's disk seen in direct response to an M6-class solar X-ray flare emanating from a sunspot that was clearly visible from both Saturn and Earth. The observation showed that the Saturnian X-ray emission is highly variable: a factor of $\sim$3 variability in brightness over one week. The spectrum of Saturn disk X-rays is quite similar to that of Jupiter's equatorial emissions. In addition, there is a hint of auroral emission from Saturn's South pole. But unlike Jupiter, X-rays from Saturn's polar regions appear to have characteristics similar to those from its disk and vary in brightness inversely to the FUV aurora observed by the Hubble Space Telescope. These Chandra observations also discovered atomic oxygen $K\alpha$ X-rays from Saturn's rings. The X-ray spectrum of the rings is dominated by emission in a narrow ($\sim$130 eV wide) band centered on the atomic oxygen $K\alpha$ fluorescence line at 0.53 keV. These exciting results obtained from Chandra observations will be presented and their production mechanism will be discussed. XMM-Newton observed X-rays from Saturn during 2005 April 21-22, for about two Saturn rotations. Another observation, of similar duration, is scheduled for early November 2005. These observations are planned to take advantage of in-situ measurements being conducted simultaneously by the Cassini spacecraft. Preliminary results from the April XMM-Newton observations will also be presented and compared with the Chandra observations.

**Notes:**

### XMM-Newton Observations of X-ray Emission from Jupiter

4:15 - 4:30 PM

Graziella Branduardi-Raymont (Mullard Space Science Laboratory, Univ. College London), Anil Bhardwaj, Ronald F. Elsner (NASA Marshall Space Flight Center), G. Randall Gladstone (Southwest Research Institute), Gavin Ramsay (Mullard Space Science Laboratory, Univ. College London), Pedro Rodriguez (XMM-Newton SOC, Vilspa), Roberto Soria (Mullard Space Science Laboratory, Univ. College London), J. Hunter Waite Jr. (AOSS, Univ. of Michigan), Thomas E. Cravens (Univ. of Kansas),

Two XMM-Newton observations of Jupiter were carried out in 2003 for 100 and 250 ks (3 and 7 planet rotations) respectively.

X-ray images from the EPIC CCD cameras show bright emissions, modulated at the planet's rotation period, from Jupiter's auroral spots. Their spectra are well modelled by a combination of emission lines, including most prominently those of highly ionised oxygen (OVII and OVIII). Emission from the equatorial regions of the planet's disk is also observed: the spectrum, displaying FeXVII, Mg XI and SiXIII line emission, is consistent with that of solar X-rays scattered in the planet's upper atmosphere. Spectrally resolved EPIC images, using narrow bands centered on the brightest lines, clearly resolve the different emission areas. Remarkably, in November 2003, a large solar X-ray flare on the Sun's Jupiter-facing side is found to be associated with a corresponding feature in the Jovian X-ray lightcurve of the equatorial regions.

Jupiter's X-rays are further resolved spectrally with the RGS, which clearly separates the OVII triplet, the OVIII and FeXVII lines, the auroral emissions being mostly identified with the lower ionisation oxygen line.

Our findings suggest that the non-auroral X-ray emission from Jupiter is directly controlled by the Sun, while the auroral emissions are most likely due to capture and acceleration of energetic ions from the outer magnetosphere, or the solar wind, or both, followed by X-ray production by charge exchange.

**Notes:**

# Poster Abstracts

Poster abstracts are listed alphabetically by first author within each science category.

# 1 Active Galaxies and Quasars

## 1.1 Six Years of the BALQSO Pair UM425

Tom Aldcroft, Paul J. Green (Harvard-Smithsonian Center for Astrophysics), Leopoldo Infante (Universidad Catolica de Chile), Sebastian Lopez (Universidad de Chile), Joshua N. Winn (Harvard-Smithsonian Center for Astrophysics),

We now report the latest chapter in the saga of UM425, which started with a snapshot survey in Chandra cycle 1, built steam with a deep 110 ksec observation in cycle 3, and finally concludes (until the next episode) with recent VLT spectroscopy revealing a foreground cluster of galaxies in the UM425 field. UM425 is a pair of QSOs at $z = 1.47$ separated by 6.5 arcsec which show remarkably similar emission and broad absorption line (BAL) profiles in the optical/UV. We first observed this pair with Chandra during cycle 1, where we found that that high-ionization BAL QSOs appear in the X-rays to be normal QSOs with a moderate obscuring column of foreground gas. UM425A was seen to be one of the brightest known BAL QSOs in X-rays, so we proposed for a long 110 ksec followup observation in cycle 3. In addition to getting the best known X-ray spectrum of a BALQSO, we hoped to investigate this wide lens candidate by searching for foreground cluster emission. Despite deep searches, no lensing galaxy had been identified, leaving in doubt the lens interpretation. As hoped for, our deep observation revealed faint diffuse emission near the QSO pair, suggesting either the long-sought foreground lensing cluster or a high redshift cluster at the distance of UM425. Now from recent VLT spectroscopy we have discovered a foreground cluster of galaxies, and thereby interpret the diffuse X-ray emission as originating from $z = 0.77$, rather than the quasar redshift. The mass of the cluster is consistent with the theoretical mass required for gravitational lensing, but UM425 would be an unusual gravitational lens, by virtue of the absence of a bright primary lensing galaxy.

**Notes:**

## 1.2 X-ray Versus Optical Obscuration in AGNs: Hints from the XMM-BSS Sample

Valentina Braito (Johns Hopkins Univ.), Alessandro Caccianiga, Filomena Cocchia, Roberto Della Ceca, Tommaso Maccacaro, Paola Severgnini (INAF/Osservatorio Astronomico di Brera, Italy)

Extensive studies, in the 2-10 keV energy band, with Chandra and XMM-Newton have recently resolved the major part of CXB into discrete sources. Those studies have also shown the presence of exceptions to the widely accepted correlation between the optical obscuration and X-ray absorption, i.e. X-ray absorbed type 1 AGN. To investigate this issue we have selected, using the hardness ratio diagram, the sources of the 'XMM-Newton Bright Serendipitous Survey' sample that are located in regions in conflict with their optical classification. The good X-ray statistics, which characterize most of the sources in the XMM-BSS, combined with the relative brightness of their optical counterparts allows us to investigate the broad–band properties of these sources.

**Notes:**

## 1.3 The Role of Absorption and Reflection in the X-ray Spectrum of Active Galactic Nuclei

Loic Chevallier, Suzy Collin, Anne-Marie Dumont (LUTH/OPM), Bozena Czerny (CAMK), Martine Mouchet (LUTH/OPM), Anabela C. Gonçalves (LUTH/OPM and CAAUL/OAL), Rene Goosmann (LUTH/OPM)

In the 2-10 keV range, the AGN continuum is generally well represented by a single power law but at smaller energies it displays an excess with respect to the extrapolation of this power law, called the soft X-ray excess; the nature of this component is still under discussion. Until now the soft X-ray excess was attributed either to reflection of the hard X-rays on the accretion disk, or to the presence of an additional comptonizing medium. An alternative solution, proposed by Gierlinski and Done (2004), is that this feature would be due to the absorption of an intrinsically steep power law source (whose origin is not clear) by a medium with a very large dispersion velocity (as a relativistic wind). Understanding the nature of the soft X-ray excess is essential for our knowledge of both the Warm Absorber and the primary spectrum, with consequences on the understanding of the accretion flow process. We have therefore examined the pros and cons of the reflection and absorption models. We conclude that the observed soft X-ray spectra can be probably modeled by absorption (for a strong excess) or by reflection (for a weak excess).

**Notes:**

## 1.4 A 1 Hour Quasi-period in the Seyfert Galaxy 3C 273

Catherine Espaillat, Joel Bregman, Philip Hughes, Edward Lloyd-Davies (Univ. of Michigan)

Quasi-periodic signals (QPOs) have yielded important constraints on the masses of black holes in galactic X-ray binaries, and here we extend that to active galactic nuclei (AGN). We analyze 19 observations of 10 AGN obtained with the *XMM-Newton* EPIC PN camera, employing a continuous wavelet transform. We detect a statistically significant 3.1 ks quasi-period in the quasar 3C 273. If this period represents an orbital timescale originating near a last stable orbit of $3R_S$, it implies a central black hole mass of $6.8 \times 10^6$ $M_\odot$. For a maximally rotating black hole with a last stable orbit of $0.6R_S$ we obtain $7.6 \times 10^7$ $M_\odot$. A previous mass estimate obtained from reverberation mapping places the black hole mass of 3C 273 at $2.35 \times 10^8$ $M_\odot$, substantially higher than both of our estimates. Assuming that the reverberation mass is correct, the X-ray quasi-period must be caused by a higher order oscillatory mode of the disk.

**Notes:**

## 1.5 The Origin of X-ray Emission in Low-Redshift Radio-Galaxy Nuclei

Daniel Evans (Harvard-Smithsonian Center for Astrophysics), Diana Worrall (Univ. of Bristol), Martin Hardcastle (Univ. of Hertfordshire), Ralph Kraft (Harvard-Smithsonian Center for Astrophysics), Mark Birkinshaw (Univ. of Bristol)

The physical origin of continuum X-ray emission in the cores of radio galaxies is widely debated. We present spectral results from Chandra and XMM-Newton observations of a sample of low-redshift ($z < 0.1$) 3CRR radio galaxies, and consider whether the emission originates from the base of a relativistic jet, an accretion flow, or contains contributions from both. We find correlations between the unabsorbed X-ray, radio, and optical fluxes and luminosities of FRI-type radio galaxies, implying a common origin in the form of a jet. On the other hand, we find that the X-ray spectra of FRII-type radio galaxies is dominated by heavily absorbed emission which is likely to originate in an accretion flow. We discuss several models to account the differing nuclear properties of FRI- and FRII-type sources, and also demonstrate that both heavily obscured, accretion-related, and unobscured, jet-related components may be present at varying levels in all radio-galaxy nuclei.

**Notes:**

## 1.6 Nine Years in the X-Ray Life of NGC 4258

Antonella Fruscione, Lincoln J. Greenhill (Harvard-Smithsonian Center for Astrophysics), Alexei V. Filippenko (UCB), James M. Moran (Harvard-Smithsonian Center for Astrophysics), James R. Herrnstein (Rentec), Elizabeth Galle (Harvard-Smithsonian Center for Astrophysics)

We have analyzed X-ray (0.3-10 keV) observations of NGC 4258 obtained with the XMM-Newton and Chandra observatories. Including earlier observations by ASCA and Beppo-SAX, we present a new nine year time series of models fitted to the X-ray spectrum of NGC4258.

Our main conclusions are:

1. XMM and Chandra spectra are well fit by a multi-components model: a partially absorbed, hard (2 keV) power law, a soft thermal plasma, and a soft power law. The soft emission, some of which arises $<70$ pc from the central engine, does not vary appreciably from observation to observation.

2. XMM data indicate long-term time variability in the source count rate and absorbed flux over time scales of 6 months. No evidence of variability on individual $\sim$3 hour integrations.

3. From XMM data we detect a $\sim$60returning to a high level not reported since the ASCA observations in 1993, $NH$ $1.3x10^{23}$ cm-2.

4. Changes in NH and fX are not correlated, which indicates intrinsic variability of the central engine that is in one case 30(5-10 keV). We note that two of the largest estimates of unabsorbed luminosity are associated with the lowest estimates of NH, and we speculate that reductions in LX might affect the ionization state of the absorber.

5. The geometry and orientation of the accretion disk in NGC 4258 is well known from interferometric mapping of maser emission that arises in the accretion disk. The warped disk, a known source of H20 maser emission, is believed to cross the line of sight to the central engine. Assuming that the absorbing gas lies in the disk, we propose that the variations in NH arise from inhomogeneities sweeping across the line of sight in the rotating disk at the radius at which the disk crosses the line of sight. We estimate that the inhomogeneities are $\sim$ $10^{15}$ cm in size at the crossing radius of 0.29pc. This is the first direct confirmation that obscuration in

type 2 AGNs may, in some cases, arise in thin, warped accretion disk rather than geometrically thick tori.

6. We do not detect Fe Kalpha line emission in any of the XMM or Chandra epochs, thus extending the disappearance of the line from the last ASCA detection in May 1999 May to May 2002. The inferred line emission region is comparable in size to the maser disk. If the line arises from the disk (e.g., by fluorescence), then it is difficult to understand the variability because the maser emission has not changed substantially.

7. We do not observe evidence for absorption lines in any XMM or Chandra spectra.

**Notes:**

## 1.7 Highlights from a Chandra Survey of Quasar Jets

Jonathan M. Gelbord, Herman L. Marshall (MIT Kavli Institute), Dan A. Schwartz (Harvard-Smithsonian Center for Astrophysics), Diana M. Worrall, Mark Birkinshaw (Univ. of Bristol), Eric S. Perlman, Markos Georganopoulos (UMBC), Jim E. J. Lovell (CSIRO), Sebastian Jester (FNAL), Dave W. Murphy (JPL), Dave L. Jauncey, Leith Godfrey (CSIRO)

We are conducting a Chandra survey of quasars with extended radio structure. The majority of these are found to have X-ray bright jets. This emission is often interpreted as inverse Compton scattering of cosmic microwave background photons, but the expected redshift dependence of this mechanism is marginally excluded by our data.

From this sample we have selected a handful of interesting cases for multiwavelength followup study, to better understand the emission mechanisms and physical conditions at various points within these systems. Of particular interest is PKS 1421-490, in which we discovered an unusual feature 5.9 arcsec from the radio peak that appears to be a unique, optically-dominated jet knot. New, deeper Chandra observations coupled with HST and VLBI data provide new insight into this object. We also report recent Chandra and HST observations of PKS 1055+201. X-rays are found throughout the 23 arcsec (=170 kpc in the plane of the sky at z=1.11) length of the jet, making this one of the longest quasar jets seen in X-rays. Additionally, diffuse X-ray emission is detected surrounding the jet, which may be part of the jet structure or the effect of the jet upon the surrounding medium. Similar diffuse emission spans the gap between the core and the counter-lobe, provides direct evidence of an otherwise-unseen counter jet.

Partial support for this work was provided by the NASA through the SAO contract SV3-73016 to MIT for Support of the Chandra X-Ray Center, which is operated by SAO for and on behalf of NASA under contract NAS8-03060. Support has also come from SAO grant GO4-5124 and directly from NASA under contract NAS8-39073.

**URL:** `http://space.mit.edu/home/jonathan/jets/`

**Notes:**

## 1.8 A Constant Pressure Model for the Warm Absorber in NGC 3783

Anabela C. Gonçalves (LUTH/OPM and CAAUL/OAL), Suzy Collin, Anne-Marie Dumont (LUTH/OPM), Agata Rozanska (CAMK), Martine Mouchet, Loic Chevallier, Rene Goosmann (LUTH/OPM)

Many AGN exhibit X-ray absorption features caused by the presence of highly ionized gas located on the line of sight of the central continuum. Such a material is called Warm Absorber (WA) and should be stratified, displaying zones of different density, temperature and ionization. Our approach to the study of the WA relies on the assumption of pressure equilibrium, resulting in the natural stratification of the medium, which allows to explain the presence of lines from different ionization states in many AGN observed by Chandra and XMM-Newton. Among the best WA observations available are those of NGC 3783, which we have analyzed. We have used the TITAN code, developed by our team, to calculate a constant pressure grid of models dedicated to fit the WA in NGC 3783. Our study shows that the WA can be modelled under constant pressure conditions. Finally, this work provides a good example of the application of the TITAN code to the study of the Warm Absorber in AGN and opens perspectives for the future use of the code by a larger community, through a larger grid of models to be made available.

**Notes:**

## 1.9 Monitoring the M87 Jet for 4 years with Chandra: The Outburst of Knot HST-1

D. E. Harris (SAO), C. C. Cheung (NRAO; Stanford Univ.), J. A. Biretta, W. Sparks (STScI), W. Junor (LANL), E. S. Perlman, A. S. Wilson (Univ. of Maryland)

The X-ray intensity of knot HST-1, 0.85″ (65pc, projected) from the nucleus of the radio galaxy M87, has increased by more than a factor of 50 during the last 5 years. The optical increase is similar and our more limited radio data indicate a commensurate activity. We give the primary results of our Chandra X-ray Observatory monitoring program and consider some of the implications of this extreme variability in a relativistic jet. We find that the data support a modest beaming synchrotron model as indicated in our earlier papers. Based on this model, the decay of the X-ray lightcurve appears to be dominated by light travel time across the emitting region rather than the synchrotron loss timescales.

**Notes:**

## 1.10 Relationships Between the X-ray and UV properties of Radio-Quiet Quasars

Brandon Kelly, Jill Bechtold (Univ. of Arizona), Aneta Siemiginowska, Tom Aldcroft, Martin Elvis (Harvard-Smithsonian Center for Astrophysics), Malgorzata Sobolewska (Nicolaus Copernicus Astronomical Center),

We present results of our work comparing the X-ray properties with the UV properties using a sample of $\sim$ 75 radio-quiet, non-BAL quasars over a broad range in redshift and luminosity. All but 5 of the sources were detected by Chandra. I performed a multivariate regression analysis to compare $\alpha_X = 1 - \Gamma_X$ and $\alpha_{\rm ox}$ with $\log_{10} \lambda L_\lambda(2500\mathring{A}), \log_{10}(1+z), \alpha_{\rm uv}, \log_{10} EW_{\rm CIV}, \mu_{CIV}$ (the C IV line centroid), and $\log_{10} FWHM_{\rm CIV}$. Subset selection was carried out for both cases to select which set of the aforementioned non-X-ray parameters were related to $\alpha_X$ and $\alpha_{\rm ox}$. For $\alpha_X$, the best subset was selected using 10-fold cross-validation, and for $\alpha_{\rm ox}$ an approximation to the posterior probabilities of the models based on the Bayesian Information Criterion (BIC) was used. The best fit for $\alpha_X$ had $\alpha_X$ correlated with both UV luminosity and C IV $EW$, and anti-correlated with $\alpha_{\rm uv}$, although there is considerable model uncertainty. In addition, it is likely that $\alpha_X$ is related to $EW_{\rm CIV}$ and $\alpha_{\rm uv}$, and there is weak evidence that $\alpha_X$ is also related to UV luminosity. For the case of $\alpha_{\rm ox}$, the most probable model is that $\alpha_{\rm ox}$ is anti-correlated with UV luminosity, and correlated with C IV line centroid and redshift. This model is $\approx 3.5$ times more likely than the next most probable model. In addition, the posterior probabilities that $\alpha_{\rm ox}$ is related to UV luminosity, redshift, and $\mu_{\rm CIV}$ are 0.9999, 0.9668, and 0.9060, respectively. The data give weak evidence that $\alpha_{\rm ox}$ is unrelated to $\alpha_{\rm uv}$, $EW_{\rm CIV}$, and $FWHM_{CIV}$. These correlations cannot be explained as being the results of correlations among the non-X-ray parameters, as the multivariate regression already takes into account any collinearity among the covariates.

**Notes:**

## 1.11 X-ray Properties of the GigaHertz-Peaked and Compact Steep Spectrum Sources

Stephanie LaMassa, Aneta Siemiginowska, Thomas L. Aldcroft (Harvard-Smithsonian Center for Astrophysics), Matteo Guainazzi (European Space Astronomy Center of ESA), Jill Bechtold (Steward Observatory, Univ. of Arizona), Martin Elvis (Harvard-Smithsonian Center for Astrophysics)

Giga-Hertz Peaked Spectrum (GPS) radio sources are powerful radio and X-rays emitters. Their radio properties have been extensively studied leading to two possible explanations of the compact nature of the GPS sources: (1) *frustrated source* scenario in which the expansion of the radio source is confined by a dense environment; (2) *evolution scenario* in which the source is at an early stage of its expansion to a typical large scale radio source. Measurements of the expansion velocity of the radio components in several GPS sources (Compact Symmetric Objects) suggest that these sources are young, while there has been no evidence for a dense medium required for the source confinement. Here we consider a sample GPS sources, containing both galaxies and quasars, observed with *Chandra* and *XMM-Newton*. *Chandra* observations allow for detailed studies of the source morphology on arcsec scale and we discuss different types of observed X-ray morphology for our sample. Spectral modeling of *Chandra* and XMM-*Newton* data indicate that the GPS galaxies are more obscured than quasars. We discuss the implication of this finding on our understanding of the nature of GPS sources.

**Notes:**

## 1.12 Fe K Emission and Absorption in the Bright Seyfert IC 4329a

Alex Markowitz (NASA/GSFC), James Reeves (NASA/GSFC and JHU)

We present a re-analysis of the XMM-EPIC long-look of the X-ray bright Seyfert AGN IC 4329a, complementary to the RGS/EPIC analysis of Steenbrugge et al (2005). The Fe K bandpass is dominated by emission consistent with moderately-broadened Fe K alpha and beta. We detect, at high significance (confirmed with Monte Carlo simulations), a narrow absorption feature at 7.7 keV; one possible candidate for this feature's origin is highly blueshifted Fe K XXVI. Time-resolved spectrscopy of the XMM data as well as RXTE monitoring data, covering time scales from minutes to 2 years, show there is little variability in continuum flux or photon index on any time scale. There is no evidence for variability of the Fe K alpha line on any time scale, consistent with an origin far from the black hole (e.g., as discussed by previous works).

**Notes:**

## 1.13 X-ray Spectral Variability Study Using RXTE Active Galaxies

Barbara Mattson (UMD/NASA GSFC), Kimberly Weaver (NASA), Christopher Reynolds (UMD)

We report early results of a systematic X-ray spectral variability study of bright Seyfert galaxies observed by the Rossi X-Ray Timing Explorer (RXTE). The RXTE public archive contains data for 40 Seyfert galaxies with suitable temporal coverage to perform variability studies covering short (days/weeks) to long (years) timescales. We have developed a data pipeline to automate the data reduction. The pipeline produces a series of spectra for each source divided temporally in such a way that each has at least 125,000 net photons to ensure a good spectral fit. To fit the spectra, we have assumed an intrinsic powerlaw X-ray spectrum produced close to the central black hole that is reprocessed and absorbed by material around the black hole. We fit each X-ray spectrum with a model of this reflected emission, including fluorescent Fe K$\alpha$ emission, Compton reflection component and absorption. The goal of this research is first to build a database of spectral parameters for a large sample of AGN, and then to seek correlations between spectral parameters and those specific to various classes of AGN (e.g. Seyfert type or radio-loudness). The results will constrain the geometry of the nuclear region, providing tests for current reflection and unification models of AGN.

**Notes:**

## 1.14 Chandra and XMM Observations of Type II Quasars from the SDSS

Andrew Ptak (JHU), Nadia Zakamska, Michael Strauss (Princeton), Julian Krolik, Timothy Heckman (JHU), Donald Schneider (PSU), Jon Brinkmann (Apache Point Observatory)

We are carrying out sensitive X-ray observations with Chandra and XMM of type II quasars selected from the Sloan Digital Sky Survey based on their optical emission line properties. We present observations of four objects at redshifts $0.4 < z < 0.8$ and an analysis of the archival data for four additional objects in the same redshift range. Six of the eight were detected in X-rays; five of them have sufficient signal to derive spectral information. All of the detected sources have intrinsic luminosities L(2-10 keV) $> 5x10^{43}$ erg $s^{-1}$. The five with sufficient counts for spectral fitting show evidence for significant absorption ($N_H >\sim$ a few x $10^{22}$cm$^{-2}$). At least three of the objects likely have $N_H > 10^{23}$cm$^{-2}$; some may be Compton-thick ($N_H > 10^{24}$cm$^{-2}$). In the five objects for which we could fit spectra, the slopes tend to be significantly flatter than is typically observed in AGN; it is possible that this is due either to reprocessing of the nuclear emission or to a line of sight that passes through patchy absorption.

**Notes:**

## 1.15 Synchrotron-Loss Spectral Breaks in Jets and Pulsar-Wind Nebulae

Stephen Reynolds (North Carolina State Univ.)

Flows of synchrotron-emitting material can be found in several astrophysical contexts, including extragalactic jets and pulsar-wind nebulae. For X-ray synchrotron emission, flow times are often longer than electron radiative lifetimes, so the effective source size at a given X-ray energy is the distance electrons radiating at that energy can convect before they burn off. Since synchrotron losses vary strongly with electron energy, the source size drops with increasing X-ray energy, resulting in a steepening of the synchrotron spectrum. For homogeneous sources, this burnoff produces the well-known result of a steepening by 0.5 in the source's integrated spectral index. However, for inhomogeneous sources, different amounts of steepening are possible. I exhibit a simple phenomenological picture of an outflow, with transverse flow-tube radius, magnetic-field strength, matter density, and flow velocity all varying as different powers of distance from the injection point. For such a picture, I calculate the value of the spectral index above the break as a function of the power-law indices, and show the possible range of steepenings. I show that these simple calculations are confirmed by full integrations of source luminosity. In many cases, extragalactic jets show X-ray synchrotron emission steeper by more than 0.5 than the radio emission; the same phenomenon is exhibited by many pulsar-wind nebulae. It is possible that source inhomogeneities are responsible in at least some cases, so that the amount of spectral steepening becomes a diagnostic for source dynamical or geometrical properties.

**Notes:**

## 1.16 Revealing the Structure of the Absorber in NGC 1365 through Extreme X-ray Variability and Iron Absorption

G. Risaliti, M. Elvis, G. Fabbiano, A. Baldi, A. Zezas (Harvard-Smithsonian Center for Astrophysics), S. Bianchi, G. Matt

I present multiple XMM-Newton observations revealing extreme X-ray properties of the Seyfert Galaxy NGC 1365, which provide an unique opportunity to study the complex circumnuclear absorber. In particular, we observed (a) changes of the X-ray state from transmission-dominated to reflection dominated in time intervals as short as three weeks (b) changes of the column density of the cold absorber in transmission-dominated states, in time intervals of a few 10,000 sec; (c) the presence of four strong absorption lines in the 6.7-8.3 keV energy range, identified as FeXXV and FeXXVI $K\alpha$ and $K\beta$, implying the presence of a hot absorber with column density of the order of a few $10^{23}$ cm$^{-2}$. These observations suggest an extremely compact (of the order of the broad line region size) and composite structure of the circumnuclear absorber, consisting of at least two components, one cold and clumpy, and one extremely ionized.

**Notes:**

## 1.17 The Ionization Structure of the Wind in NGC 5548

Katrien Steenbrugge (Harvard-Smithsonian Center for Astrophysics), Jelle Kaastra (SRON), Mike Crenshaw (Department of Physics and Astronomy, Georgia State Univ.), Steve Kraemer (Catholic Univ. of America), Nahum Arav (CASA), Ian George (Joint Center for Astrophysics, Univ. of Maryland), Duane Liedahl (Physics Dept., Lawrence Livermore National Lab.), Frits Paerels (Columbia Univ.), Jane Turner (Joint Center for Astrophysics, Univ. of Maryland), Tahir Yaqoob (Laboratory for High Energy Astrophysics)

Combining the one week long Chandra and the 140 ks XMM-Newton observations of NGC 5548, we are able to study the velocity and ionization structure of the warm absorber. Using simultaneous HST STIS observations, we show that the X-ray and UV absorber have the same kinematics and have overlapping ionization parameters. In the X-ray spectra we detect a lower ionized component, which has a similar ionization parameter as the UV absorber. This component can not be in pressure equilibrium with the higher ionized components of the outflow, a requirement of most warm absorber theories. A continuous ionization parameter distribution, assuming a power-law function for the total hydrogen column density versus ionization parameter, equally well describes the data. We determine upper limits of the opening angle for such a outflow.

**Notes:**

## 1.18 The X-ray/Optical Properties of Active Galaxies Over Wide Luminosity and Redshift Ranges

Aaron Steffen, Iskra Strateva, Niel Brandt (Penn State), Dave Alexander (IoA), Anton Koekemoer (STScI), Bret Lehmer, Don Schneider (Penn State), John Silverman (Harvard-Smithsonian Center for Astrophysics), Christian Vignali (INAF),

We present the results of a partial correlation analysis testing the strength of the relationships between monochromatic 2500 Å and 2 keV luminosities ($l_{2500\ \text{Å}}$ and $l_{2\ \text{keV}}$, respectively), $\alpha_{\text{ox}}$, and redshift for optically-selected AGNs. We extend the work of Strateva et al. (2005) to include 54 moderate-luminosity, optically-selected AGNs from the COMBO-17 survey and corresponding X-ray observations from the Extended *Chandra* Deep Field-South. We also include recently published optical/X-ray observations of 18 high-redshift, optically-selected AGNs, and 46 luminous, low-redshift AGNs from the Bright Quasar Survey, which brings our total sample to 339 AGNs, 299 (88%) of which have X-ray detections. We confirm that $\alpha_{\text{ox}}$ is strongly anticorrelated with $l_{2500\ \text{Å}}$ ($11.8\sigma$), and find no significant correlation exists between $\alpha_{\text{ox}}$ and redshift ($0.2\sigma$). We take advantage of the high X-ray detection fraction of our sample to measure the correlation between $\alpha_{\text{ox}}$ and $l_{2\ \text{keV}}$. We find a moderately significant ($2.5\sigma$) anticorrelation between $\alpha_{\text{ox}}$ and $l_{2\ \text{keV}}$.

**Notes:**

## 1.19 A Chandra X-Ray Survey of Ultraluminous Infrared Galaxies

Stacy Teng, A. S. Wilson, S. Veilleux (Univ. of Maryland), A. J. Young (MIT), D. B. Sanders (IfA, Univ. Hawaii)

We present results from *Chandra* observations of 14 ultraluminous infrared galaxies (ULIRGs; $\log(L_{IR}/L_{\odot}) \geq 12$) with redshifts between 0.04 and 0.16. The goals of the observations were to investigate any correlation between infrared color or luminosity and the properties of the X-ray emission and to attempt to determine whether these objects are powered by starbursts or active galactic nuclei (AGNs). The sample contains approximately the same number of high and low luminosity objects and "warm" and "cool" ULIRGs. All 14 galaxies were detected by *Chandra*. Our analysis shows that the X-ray emission of the two Seyfert 1 galaxies in our sample are dominated by AGN. The remaining 12 sources are too faint for conventional spectral fitting to be applicable. Hardness ratios were used to estimate the spectral properties of these faint sources. The photon indices, $\Gamma$'s, for our sample plus the *Chandra*–observed sample from Ptak peak in the range of 1.0–1.5, consistent with expectations for X-ray binaries in a starburst, an absorbed AGN, or hot bremsstrahlung from a starburst or AGN. The values of $\Gamma$ for the objects in our sample classified as Seyferts (type 1 or 2) are larger than 2, while those classified as HII regions or LINERs tend to be less than 2. The hard X-ray to far-infrared ratios for the 12 weak sources are similar to those of starbursts, but we cannot rule out the possibility of absorbed, possibly Compton-thick, AGNs in some of these objects. Two of these faint sources were found to have X-ray counterparts to their double optical and infrared nuclei.

**Notes:**

## 1.20 A Chandra Search for Hidden AGN in H II Nuclei

Panayiotis Tzanavaris, Ioannis Georgantopoulos (National Observatory Athens), Antonis Georgakakis (Imperial College London)

We identified nine, early-type spirals, namely NGC 278, 891, 2146, 2782, 3310, 4102, 4217 and 4303, from the Palomar survey sample of Ho, Fillipenko and Sargent (1997), classified as normal, H II nuclei, which fall within archived Chandra ACIS-S fields. We carried out a detailed search of the Chandra fields to identify possible X-ray counterparts, and obtained the X-ray luminosity, $L_X$, hardness ratio, HR, and radial profiles of X-ray counterparts in order to search for hidden AGN. Our results suggest that two of the H II galaxies may harbour a low-luminosity AGN.

**Notes:**

## 1.21 The Extended Chandra Deep Field-South Survey: Optical & NIR Properties of X-ray Detected Sources

C. Megan Urry, Shanil Virani, Ezequiel Treister (Yale Univ.), Edward Taylor (Leiden), J. Van Duyne, Eric Gawiser, Pieter van Dokkum (Yale Univ.), MUSYC Collaboration

The Extended Chandra Deep Field-South survey consists of 4 Chandra ACIS-I pointings and covers ~1100 square arcminutes ($\sim 0.3deg^2$) surrounding the original CDF-S field, to a depth of approximately 228 ks. This is the largest Chandra survey ever conducted at such depth. In our X-ray catalog of this field (Virani et al. 2005, astro-ph/0506551), we detect 651 unique sources, of which 561 are detected in the full 0.5–8.0 keV band, 529 in the soft 0.5–2.0 keV band, and 335 in the hard 2.0–8.0 keV band. In this paper, we present the optical and near-IR counterparts to these X-ray detected sources obtained as part of the MUltiwavelength Survey by Yale/Chile (MUSYC; Gawiser et al. 2005, astro-ph/0509202). Of these 651 X-ray sources, ~75have optical and near-IR counterparts in deep MUSYC imaging of this field. We present the optical and near-infrared properties of these sources (ie, magnitude distributions and colors), as well as 7 new extreme X-ray-to-optical flux ratio objects (EXOs) found in the E-CDF-S field.

**URL:** `http://www.astro.yale.edu/svirani/ecdfs/`

**Notes:**

## 1.22 The 2MASS Red AGN: the Missing Link between Type 2 and Type 1 AGN?

Belinda Wilkes (SAO) Gary Schmidt, Paul Smith (Arizona), Ken Pounds (Leicester), Roc Cutri (IPAC), Kim Page (Leicester), Himel Ghosh (OSU), Dean Hines (Space Science Institute), Brant Nelson (IPAC), Joanna Kuraskiewicz (SAO)

The red active galactic nuclei (AGNs) being revealed by the Two Micron All Sky Survey (2MASS) have a surface density similar to, or greater than, previously known AGN, suggesting that a large fraction of the population has been missed by earlier surveys. Similar red AGN are being found in other IR and X-ray surveys, reinforcing this suggestion, although the size and diversity of the previously missed population(s) remain uncertain. The 2MASS red AGN sample includes broad, intermediate and narrow lined AGN with the latter in the minority by a factor of 3. Optical observations indicate high levels of polarisation suggesting a significant contribution from scattered light. Their emission lines have properties similar to normal, broad-lined or intermediate AGN but their optical-IR spectral energy distributions (SEDs) are unusually red. Chandra observations show that they are generally X-ray faint and have hard spectra. Although not directly related in individual AGN, both X-ray and optical-IR SEDs suggest absorption at the level, log Nh 21-23. Higher S/N XMM-Newton data show significant complexity in the X-ray spectra, indicating large uncertainty in the X-ray absorption levels deduced from low S/N data. The combination of all these properties combines to suggest that red AGN are viewed at an intermediate angle such that our line-of-sight passes through the surface of the absorbing material postulated by Unification models, perhaps the wind in the currently popular disk/wind models. They are also candidates for the absorbed AGN population required by models to explain the Cosmic X-ray Background (CXRB), reducing the need for a, so far largely undiscovered, type 2 quasar population. We estimate that their contribution to the CXRB may be as high as 30SEDs, their intrinsic X-ray flux and their evolution with redshift.

**Notes:**

## 1.23 Strong Gravity Effects in the High Luminosity Quasar E1821+643

Tahir Yaqoob (JHU/GSFC)

A narrow, redshifted absorption line superimposed on the red wing of a broad Fe K line was detected with the Chandra HETGS in the high luminosity quasar E1821+643 (z=0.297). We argue that the absorption line (at ∼6.2 keV in the quasar frame) could be due to gravitationally redshifted Fe XXV or Fe XXVI resonance absorption within ∼10-20 gravitational radii of the putative central black hole, although inflow is not ruled out (requiring velocities up to ∼0.1c). An interesting possibility is that the absorption line arises in a low-velocity outflow (∼0.0003-0.003c), as found in many Seyfert galaxies, but in this case much closer to the black hole. The structure and peak energy of the Fe K emission complex is variable, from a comparison with non-comptemoraneous ASCA and Chandra LETG observations. The full range of ionization states of Fe may be contributing to the line emission with variable relative strengths at different times. The line at ∼6.4 keV may arise in a relativistic accretion disk and its EW brings into question the validity of the so-called X-ray Baldwin effect, which would predict that a quasar with a luminosity as high as E1821+643 should have little or no Fe K line emission.

**Notes:**

## 1.24 A Chandra HETGS Study of the LLAGN M81*

Andrew Young, Claude Canizares, Teddy Cheung, Sebastian Heinz, Mario Jimenez-Garate, Sera Markoff, Herman Marshall, Mike Nowak (MIT)

The spiral galaxy M81 harbors a low luminosity active galactic nucleus (LLAGN), the luminosity of which is only a small fraction (less than one per cent) of the Eddington limit. Such low Eddington fraction accretion flows are thought to be qualitatively different to the higher Eddington fraction accretion flows found in more luminous active galactic nuclei (AGN), and are of considerable theoretical interest. We have obtained a deep (300 ksec) Chandra High Energy Transmission Grating Spectrometer (HETGS) observation of M81* to study the X-ray spectrum of the nucleus. The subarcsecond spatial resolution of Chandra isolates the nucleus from the surrounding point sources and diffuse gas. A number of emission lines are seen in the spectrum, including Si K alpha fluorescence, Si XIV, Si XIII (resonance and forbidden lines), Mg XII, Ne X and O VIII. Some of these lines are resolved, with FWHM of approximately 1700 km/s. Furthermore, we do not detect any narrow iron K alpha fluorescence lines from either neutral or ionized iron. The He-like ion triplets, broadened lines and lack of strong iron K alpha fluorescence provide important constraints for models of the accretion flow. A contemporaneous multi-waveband radio to X-ray spectrum of M81* and theoretical modeling of the accretion flow is the subject of a separate talk by Sera Markoff and collaborators.

**Notes:**

## 1.25 Probing the Extended Emission Surrounding Seyfert Galaxies

Jianning Zeng (JCA, UMBC), Ian George (JCA, UMBC & NASA/GSFC), Steven Kraemer (The CUA & NASA/GSFC), Tracey Turner (JCA, UMBC & NASA/GSFC), Henrique Schmitt (NRAO)

We are conducting a search for, and analysis of the extended diffuse X-ray emission surrounding nearby Seyfert nuclei using Chandra X-ray Observatory (CXO). Our primary motivation is to study and parameterize the X-ray emission on the smallest resolvable scale in order to investigate how it may be related to other AGN-related phenomena such as the NLR & other orientation indicators, the central mass/luminosity etc. Our ultimate goal is to test unification schemes. Here we present results for a sub-set nearby Seyfert galaxies observed using CXO ACIS-S3 chip. The spectroscopy of the extended X-ray emission will be modeled to illustrate and contrast the characteristics of the extended X-ray emission seen in our sample.

**Notes:**

# 2 Black Hole and Neutron Star Binaries

## 2.1 Optical Counterparts of Faint X-ray Sources in the SMC

Valsamo Antoniou (Harvard-Smithsonian Center for Astrophysics/Univ. of Crete, Greece), Andreas Zezas (Harvard-Smithsonian Center for Astrophysics), Despina Hatzidimitriou (Univ. of Crete, Greece), Jonathan C. McDowell (Harvard-Smithsonian Center for Astrophysics), Paul Taylor (Harvard-Smithsonian Center for Astrophysics/Boston College), Giuseppina Fabbiano (Harvard-Smithsonian Center for Astrophysics), Vicky Kalogera (Northwestern Univ.),

We present optical counterparts of the X-ray sources detected in our Chandra X-ray observations of the central region of the SMC. The survey yielded a total of 122 significant sources (at $3\sigma$ level) down to a luminosity limit of $4.3 \times 10^{33}$ erg s$^{-1}$. Comparisons were made with the OGLE-II and MCPS catalogs of stars in the SMC. We find secure optical counterparts for 40 sources of which 18 are early type stars suggesting that their associated X-ray sources are High Mass X-ray Binaries. We also identify potential counterparts for 63 additional sources. We further discuss the implications of these results for the observed overabundance of the X-ray binaries in the SMC.

**Notes:**

## 2.2 A Comparison of X-ray Spectral Properties of ULXs and Lower-Luminosity Point Sources in Nearby Galaxies

Ciprian T. Berghea (Catholic Univ. of America), Edward J. M. Colbert (Johns Hopkins Univ.), Timothy P. Roberts (Univ. of Leicester, UK), Kimberly A. Weaver (NASA)

We investigate the spectral properties of ultraluminous X-ray sources (ULXs) using the highest quality data available in the Chandra archive. This is defined as sources with at least 1000 observed counts, sufficient for reliable spectral analysis. We found 49 ULXs with X-ray luminosities $L_X \geq 10^{39.0}$ erg s$^{-1}$ in the energy range 0.3−8.0 keV that fulfill this criterion. We have also selected a comparison sample of 22 point-like X-ray sources with luminosities between $10^{38.3}$ erg s$^{-1}$ and $10^{39.0}$ erg s$^{-1}$ and a similar data quality. For our well-defined sample of ULXs and the comparison sample, we fitted the spectra with one-component models (cold absorption with power-law, and cold absorption with multi-colored disk blackbody) and two-component models (absorption with both a power-law and a multi-colored disk blackbody). The results are then used to determine if spectral properties of the ULXs are statistically distinct from those of the lower luminosity objects.

**Notes:**

## 2.3 High Resolution Fe Lyman and Balmer Band Spectroscopy of the Bursts in EXO 0748-676

Jean Cottam (NASA/GSFC), Frits Paerels, Gisela Telis, Marc Audard (Columbia Astrophysics Laboratory), Mariano Mendez (SRON), Thierry Lanz (Univ. of Maryland), Walter Lewin, Herman Marshall (MIT), Lars Bildsten, Phil Chang (UCSB)

We present the results of high resolution spectroscopy of the X-ray bursts in the LMXB EXO 0748-646. Early observations with XMM/RGS showed evidence for gravitationally redshifted absorption lines, which can be identified with the n=2-3 transitions in H- and He-like Fe arising in the stellar photosphere at z=0.35. We will discuss the results of spectroscopy of the Fe Lyman band with Chandra/HETGS, and a reobservation in the Fe Balmer band with XMM/RGS.

**Notes:**

## 2.4 Spectral Changes During Dipping in Low-mass X-ray Binaries due to Highly-ionized Absorbers

Maria Diaz Trigo, Arvind Parmar (ESTEC-ESA, The Netherlands), Laurence Boirin (Observatoire Astronomique de Strasbourg, France), Mariano Mendez, Jelle Kaastra (SRON, The Netherlands)

X-ray observations have revealed that many low-mass X-ray binaries (LMXBs) exhibit narrow absorption features identified with Fe XXV and Fe XXVI. We successfully model the changes in both the X-ray continuum and the Fe absorption features during dips from all the bright dipping LMXBs observed by XMM-Newton (EXO 0748-676, XB 1254-690, X 1624-490, MXB 1659-298, 4U 1746-371 and XB 1916-053) as resulting primarily from an increase in column density and a decrease in the ionization state of a highly-ionized absorber in a similar way as was done for XB 1323-619. This implies that complex spectral changes in the X-ray continua observed from the dip sources as a class can be most simply explained primarily by changes in the highly ionized absorbers present in these systems. We observe also small changes in the equivalent hydrogen column of neutral material, which may be related to the inclination of the system. Since the ionized plasma has a cylindrical geometry with a maximum column density close to the plane of the accretion disk and dipping sources are simply normal LMXBs viewed from close to the orbital plane this implies that ionized plasmas are a common feature of LMXBs.

**Notes:**

## 2.5 Evidence for Enhanced Neutrino Cooling from a NS SXT in Quiescence

Peter Jonker (SRON & Harvard-Smithsonian Center for Astrophysics) , Deepto Chakrabarty (MIT), Ed Brown (Michigan State Univ.), Gijs Nelemans (Nijmegen Univ.), Adrienne Juett (Univ of Virginia)

Observations of black hole and neutron star Soft X-ray Transients (SXTs) with Chandra and XMM-Newton turned out to have a profound impact on two important areas of high energy astrophysics. First of all, comparing the quiescent luminosity of neutron star SXTs with that of black hole SXTs it was found that black hole (BH) SXTs are systematically fainter in quiescence than neutron stars. This has been interpreted as evidence for advection of energy across a BH event horizon. Secondly, in observations of neutron star SXTs in quiescence which allow for a spectral study, the spectrum was found to be well-fit by a neutron star atmosphere model (NSA) sometimes supplemented with a power-law component. Well established theories about the time averaged mass accretion rates in neutron star SXTs, the pycnonuclear reactions taking place in the neutron star crust combined with neutron star cooling theory predictions, yield a neutron star core temperature. This hot neutron star core, moderated by the neutron star atmosphere, is thought to be observed during the quiescent phase of neutron star SXTs. In theory, a NSA-fit provides means to measure the mass and radius of the neutron star and hence constrain the equation of state (EoS) of matter at supranuclear densities. The description of the relations between pressure and density of matter (the EoS) under the extreme conditions encountered in neutron stars is one of the ultimate goals of the study of neutron stars. We recently observed the neutron star SXT 1H1905+000 in quiescence with ACIS-S. However, the source was not detected even though the distance and interstellar extinction are well known. This means that the source (thermal) luminosity in the 0.5-10 keV band is lower than $\sim 10^{31}$ erg s$^{-1}$. From this and from the fact that it is known from binary evolution theory that the time averaged mass accretion rate cannot be much less than $10^{-12}$ Msun per year, we conclude that the neutron star must have access to enhanced neutrino emission processes. Furthermore, the low luminosity puts these sources in the midst of the quiescent BH SXTs removing the evidence for the event horizon.

**Notes:**

## 2.6 Chandra HETG Observations of Fe K in Cygnus X-3

Michael McCollough (SAO), Norbert Schulz (MIT), Guy Pooley (MRAO)

We present an analysis of HETG Chandra observations of the Fe K region of the spectrum of Cygnus X-3. Cygnus X-3 is a HMXB which has two major states (hard/low and soft/high) and shows correlative activity in the radio. Chandra has observed Cygnus X-3 with the HETG on five occasions. These observations include a hard/low state (radio quiescent), soft/high (major radio flares), and a transitional period between these states. Lines of H-like, He-like and neutral Fe are observed. A discussion of the nature of these lines and how they vary as both a function of state and orbital phase will be given. Preliminary modeling of the data with XSTAR will be provided.

**Notes:**

## 2.7 The Broadband Spectrum of Centaurus X-4

Manuel Perez Torres, Michael Garcia, Jeffrey McClintock (Harvard-Smithsonian Center for Astrophysics), Ronald Remillard (MIT), Jon Miller (Univ. of Michigan),

We present the X-ray/UV/optical spectrum of the neutron star X-ray transient Centaurus X-4 in quiescence. HST/STIS and Magellan-Baade observations were performed simultaneously with Chandra/ACIS-S observations to avoid uncertainties in the broadband spectrum caused by short-term brightness variability. We show new results for the quiescent state, such as the first far-UV spectrum. This spectrum has sufficient signal-to-noise ratio to reveal broad emission lines of NV, SiIV, CIV and HeII superimposed on a flat continuum. The near-UV flux is a factor 2 lower than observed in a previous HST/STIS observation and proves UV variability. However, the centerpiece of this work is the quiescent multiwavelength spectrum of Centaurus X-4, which is discussed in terms of different spectral models.

**Notes:**

## 2.8 Clouds, Winds, and Jets in the Luminous X-ray Source Circinus X-1

Norbert S. Schulz (MIT), William N. Brandt (PSU), Duncan Galloway (Melbourne), Deepto Chakrabarty, Sebastian Heinz (MIT)

One of the early highlights of high resolution spectroscopy was the discovery of P Cygni lines in the highly variable and luminous X-ray source Circinus X-1 during the early days of the Chandra mission. By adapting the preceding paradigm established from ASCA observations that the accretion disk around the neutron star is viewed edge-on, the for the complex line structure was interpreted as a combination of accretion disk coronal line emission and absorption from a radiatively driven equatorial disk wind. The detection of ultra-relativistic radio jets at about the same time seemed to support the image of Circinus X-1 as a powerful microquasar, but also casted some doubt on the assumption that the source is viewed edge-on, but instead featured a face-on view. This not only challenges the current model for the observed X-ray emission, it could also force a complex scenario involving jets, winds and clouds that seems quite unique among accreting compact sources. Furthermore the X-ray emission of Circinus X-1 has undergone radical changes since then as it gradually slipped into a low intensity state which is even devoid of the typical outburst pattern with its binary orbit. We observed Circinus X-1 several times with the Chandra HETG spectrometer during this transition. These observations resulted not only in the first X-ray image of the source, they also show a unique pattern of changing X-ray continuum as well as line emission and absorption. We discuss the results in conjunction with its previous lightcurve and investigate possible connections of to the relativistic jet.

**Notes:**

## 2.9 High-speed Optical Observations of Black Hole X-ray Transients in Quiesence

Tariq Shahbaz (Instituto de Astrofisica de Canarias) Vik Dhillon (Sheffied University), Tom Marsh (Warwick University), Jorge Casares, Cristina Zurita (Instituto de Astrofisica de Canarias), Rob Hynes (Louisiana State University), Carole Haswell (Open University),

We present high time-resolution multicolour observations of the quiescent soft X-ray transients V404 Cyg and XTE J1118+480 obtained with ULTRACAM. The power density spectrum (PDS) of the V404 Cyg data shows a quasi-periodic oscillation (QPO) feature at 0.78 mHz (=21.5 min), whereas the PDS of the XTE J1118+480 data shows a 2 mHz break or QPO. We discuss the possible origins for the QPO feature and break-frequency in the context of the advection-dominated accretion flow model.

**Notes:**

## 2.10 Distance Determination Using Variability in X-ray Halos

Thomas Thompson, Richard Rothschild, John Tomsick (CASS, UCSD)

With the unprecedented angular resolution of the Chandra X-ray Observatory, it is now possible to geometrically determine the distance to variable galactic sources, based on the phenomenon that radiation scattered into the X-ray halo has to travel along a slightly longer path than the direct, unscattered radiation. By measuring the delayed variability, the source distance can be obtained if the halo brightness (scattering optical depth) is large enough to dominate the PSF and to provide sufficient statistics. In addition, the variability must be on time scales shorter than $\sim 10^4$ s, depending on the source distance, optical depth, and the halo angles investigated. Although this method is appealing, the accuracy of distances measured in this manner is limited, among other things, by knowledge of the dust distribution along the line of sight. Here we examine the applicability of this technique to two sources with different types of variability: (1) Gradual variability from the X-ray binary, Cyg X–3. Currently, this is the only source whose distance has been measured with this method. (2) Sharp variability from type I X-ray bursts from GS 1826–238.

**Notes:**

# 3 Clusters of Galaxies

## 3.1 Chandra Observation of the Cooling Flow Cluster A262

Loren Anderson, Elizabeth L. Blanton (BU), Tracy E. Clarke (NRL), Craig L. Sarazin (UVa)

We present a detailed study of the cooling flow cluster A262, including the projected and deprojected profiles of temperature and abundance as well as profiles of pressure, density, gas mass, total mass, and entropy. We find that the temperture drops by a factor of 3 from 2.7 to 0.9 keV in the center and that the abundance climbs steeply towards the center before falling in the very inner regions. We also present image analysis highlighting complex structure in the inner regions including a tunnel to the west and several interesting features surrounding the cluster center. We compare new low frequency (330 MHz) radio observations with the structure in the inner regions.

**Notes:**

## 3.2 The Chandra View of RXJ1716

Douglas Burke (SAO)

We present the results of a 50 ks Chandra observation of the $z = 0.809$ galaxy cluster RX J1716.9 + 6708. Previous X-ray and optical observations have shown that this system is not relaxed and that the large-scale structure in which the cluster is embedded exhibits the filamentary nature predicted by models of structure formation. The high spatial resolution of Chandra reveals that the core of the cluster X-ray emission shows signs of recent merger activity and is aligned with the NE-SW filament seen in the galaxy and mass distributions. On a larger scale, we detect— at a projected distance of 1 Mpc NE of the core— X-ray emission from a group of galaxies located in the NE-SW filament. It appears that we are observing RX J1716.9 + 6708 during its formation epoch.

**Notes:**

## 3.3 Chandra Observation of the Merging Cluster Abell 2065

Marios Chatzikos, Craig Sarazin (Univ. of Virginia)

We present analysis of a 41 ks observation of the merging cluster Abell 2065 with the ACIS-I detector. Previous observations with ROSAT and ASCA provided evidence for an ongoing merger, but also suggested that there were two surviving cooling cores, which were associated with the two cD galaxies in the center of the cluster. The Chandra observation reveals only one X-ray surface brightness peak, which is associated with the more luminous, southern cD galaxy. The gas related with that peak is cool and displaced from the position of the cD. The data suggest that this cool material has formed a cold front. On the other hand, in the higher spatial resolution Chandra image, the second feature to the north is not associated with the second cD, rather it appears to be a trail of gas behind the main cD. We argue that only one of the two cooling cores has survived the merger, which suggests that the cluster is undergoing an unequal merger. The data indicate that a shock front is propagating through the cluster's ICM, which we use to constrain the kinematics of the system.

**Notes:**

### 3.4 Chandra Observations of Abell 222/Abell 223

David Davis, Mark Henriksen (UMBC)

The formation of galaxy clusters and their subsequent evolution provide insight into not only how such large gravitationally bound objects are formed but also into cosmology. Simulations of large scale structure show that clusters are formed hierarchically and are formed from the aggregation of smaller structures. Identifying clusters in the early stages of a merger will provide observational constraints for the early stages of N-body/hydrodynamical simulations of merging clusters. Here we present the morphology and temperature for the double cluster Abell 222, Abell 223 derived from a 50 ksec Chandra ACIS-I observation.

**Notes:**

### 3.5 Chandra Observation of the Cluster Environment of a WAT Radio Source in Abell 1446

E. M. Douglass, Elizabeth L. Blanton (Boston Univ.), Tracy E. Clarke (NRL), Craig L. Sarazin (Univ. of Virginia), Michael W. Wise (MIT)

Wide-angle tail (WAT) radio sources are often found in the center of galaxy clusters where large scale flow of the ICM may bend the lobes into their characteristic C-shape. We present Chandra observations of the low redshift (z=0.1035), WAT containing galaxy cluster, Abell 1446. An infall of gas from the north appears to be bending one of the WAT radio lobes associated with the cluster's central elliptical galaxy. Further, a cavity within the X-ray gas appears coincident with the lobe. A temperature profile shows that the cluster is isothermal (kT= 4.1 keV) in a series of annuli reaching a radius of $\sim$350 kpc. There is no evidence of a cooling flow. In addition to images, profiles of temperature, abundance, surface brightness, pressure, density, mass, and a detailed temperature map will be presented.

**Notes:**

## 3.6 Analysis of X-MAS Images of a Simulated Cool Core Cluster

Alessandro Gardini, Alastair Sanderson (Univeristy of Illinois at Urbana-Champaign)

We show the results of the data analysis of simulated X-ray observations of a cool core cluster, in order to assess the robustness and reliability of results of analogous observations by Chandra. We generate simulated X-ray images using the X-MAS package of a cluster model in hydrostatic equilibrium resembling A2390. We consider different distances and exposure times, comparing surface brightness and temperature profiles to the results of deprojection analysis applied to the simulated observations. The effect of presence of bubbles of hot plasma in the cluster atmosphere is also taken in account.

**Notes:**

### 3.7 Finding Galaxy Groups in the Fields of Lensed Quasars

Catherine Grant, Mark Bautz (MIT)

Gravitationally lensed quasars can be used as an invaluable cosmological tool, however lens models often require a strong external shear in addition to the intrinsic eccentricity of the lensing galaxy to produce the observed asymmetry in the lensed images. The shear may be from a galaxy cluster or group associated with the lensing galaxy or otherwise along the line-of-sight to the quasar. We are searching for X-ray emission from groups in the fields of strong gravitational lenses using Chandra's resolving power to separate the bright quasar images from the much fainter diffuse emission. We present Chandra images and luminosities or luminosity limits for optically detected lensing groups associated with multiply imaged gravitationally lensed quasars. We also will discuss our search for extended X-ray emission in the fields of lensed quasars that are not yet known to contain a galaxy group.

**Notes:**

## 3.8 Limitations on Precision Cosmology Using Mass Measurements of Galaxy Clusters

Eric Hallman, Patrick Motl, Jack Burns, Michael Norman (Univ. of California, San Diego)

We critically analyze the role of clusters of galaxies as probes for precision cosmology. Using synthetic observations of numerically simulated clusters viewed through their X-ray emission and thermal Sunyaev-Zeldovich effect (SZE), we reduce the observations to attain measurements of the cluster gas mass. We utilize both parametric models such as the isothermal cluster model and non-parametric models that involve the geometric deprojection of the cluster emission assuming spherical symmetry. We are thus able to quantify the possible sources of uncertainty and systematic bias associated with the common simplifying assumptions used in reducing real cluster observations including isothermality and hydrostatic equilibrium.

**Notes:**

### 3.9 X-ray Observations of Galaxies in an Off-Center Region in Coma

Ann Hornschemeier (NASA GSFC), Bahram Mobasher (STScI), David Alexander (IoA Cambridge), Franz Bauer (Columbia), Mark Bautz (KIASR, MIT), Derek Hammer (JHU), Bianca Poggianti (Padova)

We have performed a pilot Chandra ACIS-I survey of a region in an off-center region of the Coma cluster to explore the X-ray properties and Luminosity Function of normal galaxies. We present results on 13 Chandra-detected galaxies with optical photometric matches, 9 of which are ascertained to be Coma members. We have taken the well-measured optical galaxy luminosity function in this region of the Coma cluster and translated it to an X-ray luminosity function. We use this XLF to find that the galaxies in the outskirts of Coma have very low X-ray-to-optical flux ratios. This confirms the Finoguenov et al. (2003) Coma result that the X-ray emission per unit optical flux per galaxy is suppressed in clusters of galaxies, but extends this work to a specific off-center environment of the Coma cluster. We also report on our work with the XMM Optical Monitor to classify galaxies in Coma based on their ultraviolet properties.

**Notes:**

## 3.10 X-ray Sources in Groups of Galaxies

Tesla Jeltema, Breanna Binder, John Mulchaey (OCIW),

We have undertaken an archival Chandra study to investigate the previously unknown AGN content of groups of galaxies. Our sample consists of 23 nearby groups with relatively long Chandra observations. Detected X-ray sources are matched to galaxies with known redshifts in NED to confirm group membership. While we generally find a couple of matches per group, we do not find a population of luminous AGN ($> 10^{41}$ ergs $s^{-1}$) outside of the group center. However, we do detect central X-ray point sources in most of the groups, and in several cases we detect diffuse emission from group galaxies.

**Notes:**

## 3.11 Chandra Observation of Abell 13: Understanding X-ray–Radio Interaction

Adrienne M. Juett, Craig L. Sarazin (Univ. of Virginia), Tracy Clarke (NRL), Yutaka Fujita (Nat. Astron. Obs. of Japan), Heinz Andernach (Univ. of Guanajuato), Matthias Ehle (XMM-Newton SOC), Joshua Kempner (Bowdoin College), Alan Roy (MPIfR), Larry Rudnick (Univ. of Minnesota)

We present results from the recent Chandra observation of Abell 13. This galaxy cluster also contains an unusual noncentral radio source, commonly referred to as a radio relic. We present a comparison of the properties of the hot X-ray gas derived from Chandra with those of the radio relic from VLA data, to study the interaction of the X-ray gas with the radio emitting electrons. Initial results suggest that the radio relic is associated with cooler gas in the cluster. We also present results on structure and temperature distributions of the gas in the cluster using the Chandra data, which suggest that a recent galaxy or group merger has occurred in the cluster.

**Notes:**

### 3.12 Cluster Samples with the Long Wavelength Array

Namir Kassim, Tracy Clarke, Emil Polisensky, Carl Gross, Aaron Cohen, Wendy Lane, Joseph Lazio (Naval Research Lab)

The Long Wavelength Array (LWA) will be a powerful new instrument that will open a new window of high resolution and sensitivity on the poorly explored region between 20 and 80 MHz. We will describe how the LWA will be an excellent instrument for studying clusters of galaxies and addressing key questions in Cosmology. The assembly of large-scale structures in the Universe is thought to proceed in a hierarchical manner, with smaller structures merging to form larger structures. At least a fraction of the most energetic mergers in the present-day Universe are marked by cluster halos and relics, which are characterized by diffuse, steep-spectrum radio emission not associated with any galaxy in the merging cluster. The current census of cluster halos and relics is considered incomplete due to the low sensitivity of existing long-wavelength instruments. The LWA will have sufficient sensitivity at long wavelengths to detect less energetic and more distant mergers, and it is estimated that there may be thousands of them. When compared with X-ray observations, a complete census of diffuse emission in merging clusters can be used to trace the formation of structure, measure the input of energy into the intracluster medium, and constrain the dark matter potentials that govern mergers. Additionally, the census would define a non-merging cluster sample which would provide the undisturbed systems necessary to study the dark energy equation of state through determination of the baryonic mass fraction in massive clusters. Basic research in radio astronomy at the Naval Research Laboratory is supported by the Office of Naval Research.

**Notes:**

## 3.13 Temperature and Metallicity in the Central Region of Cooling Flow Clusters of Galaxies

Naomi Kawano, Kengo Kawashima, Yasushi Fukazawa (Hiroshima Univ.)

Most cooling flow clusters show the temperature decline toward the center. The temperature in the central region reaches about a half of the outer region within 100−200 kpc, and widely scatters between galaxy clusters contrary to the prediction cooling flow model. On the other hand, the scale of the central cool region is consistent with the cooling radius, implying that the radiative cooling is surely occur and some heating mechanism to reduce it is necessary. Among the prevailing heating model, the hierarchical evolution with mergers provides better consistency with our results, and then seems to play an important role for heating in the intracluster medium (ICM).

The iron abundance increases in the central 100 kpc region, which is almost the same scale as the optical body of the cD galaxy. The mass of iron within the abundance-excess region is as much as that contained by stars in the elliptical galaxies. These results indicate that the cD galaxy can be a major source of metal supply into the ICM. If so, the Type Ia supernova and stellar mass loss are important processes to transport metals. Calculation of the amount of iron supply due to these process over the Hubble time shows that they are enough to provide the iron in the ICM. Thus, it appears certain that the cD galaxy can largely contribute to the metal in the ICM.

**Notes:**

## 3.14 Fake Source Experiment for Chandra ACIS Observations

Eunhyeuk Kim (Harvard-Smithsonian Center for Astrophysics) Paul Martini (The Ohio State Univ.), Minsun Kim, Dong-Woo Kim (Harvard-Smithsonian Center for Astrophysics)

High spatial resolution Chandra X-ray observations have resolved many point sources in both galaxies and clusters of galaxies. The observed spatial distribution of these points sources suffer from incompleteness due to source location, background variations, and brightness. The source counts may also suffer from inaccurate count measurements, particularly in high background regions such as clusters or diffuse emission from bright, nearby galaxies.

To investigate variations in completeness, we perform a large number of fake source experiments for Chandra ACIS observations using custom software called **XFAKE**. The detection probability is found to decrease with increasing off-axis angle(OAA), an angle measured from on-axis to the position of a source. For example, the detection probability for point sources with net counts $> 10$ and OAA $< 5$ arcmin is found to be greater than 95%, with a slight dependence on background variation.

We describe the simulation software **XFAKE** along with an accompanying software package **XPROCES** and discuss the detection probability and the count recovery rate for different background environments in detail.

**Notes:**

## 3.15 Synchronism of Events in Space Conditions

Dmitri Kirko (Dept. Plasma Phys., MEPI, Moscow, Russia)

The observed universe structure assume of some ordering of spatial and time characteristics of astronomical objects. At the supposition of presence of interaction between galaxy clusters of the universe in the present time range, it is expedient to allow the manifestation of information processes. We assume the existence of physical information interaction in the universe in the present time range or property as synchronism of events. The observed universe is compared with some event space of non-Euclidean (nonlinear) structure. Within that space information signals can move at a speed exceeding the speed of light. At each random moment of time transition from event space to Minkowski's space is established. Some laboratory and astrophysical experiments show the possibility on registration the images of stars (galaxies) within a time lag. In this work the correlation between synchronism of events, and the theory of relativity and the superstrings theory are assumed.

**Notes:**

### 3.16 Re-energizing a Cluster Cooling Core: the ICM/Radio Plasma Interaction in 3C 388

Ralph Kraft (SAO), Jaione Azcona (Observatiore de Paris-Meudon-Nancy and SAO), William Forman (SAO), Martin Hardcastle (Univ. of Hertfordshire), Christine Jones, Stephen Murray (SAO)

We present results from analyis of a 35 ks Chandra/ACIS-I observation of the hot ICM around the nearby (z=0.0908) FR II radio galaxy 3C 388. This radio galaxy resides in a cluster environment with a gas temperature of $\sim$3.5 keV. We detect cavities in the ICM coincident with the radio lobes and find no evidence for surface brightness discontinuities in the gas or hot rims around the lobes indicative of shocks. The lobes are therefore evolving at or below the sound speed of the ICM. The work done on the gas by the inflation of the lobes is $\sim 3\times10^{59}$ ergs, or $\sim$0.87 keV per particle out to the radius of the lobes. The radiative timescale for gas at the center of the cluster at the current temperature is a few Gyrs. The gas in the core was probably cooler and denser before the outburst, so the cooling time was considerably shorter in the past. Therefore, we suggest that gas cooling is being quenched by a radio galaxy outburst. The bubble enthalpy, $\sim 1.2\times10^{60}$ ergs, is sufficient to completely re-energize the cooling core if it is converted to thermal gas energy in or near the core. The mechanical power of the outburst is roughly two orders of magnitude larger than either the X-ray emission from the active nucleus or the radio emission from the lobes. The equipartition pressure of the radio lobes is more than an order of magnitude lower than that of the ambient medium, indicating that the pressure of the lobes is dominated by something other than the relativistic electrons radiating at GHz frequencies unless the lobe is far from equipartition.

**Notes:**

## 3.17 The Large AGN Population in Clusters of Galaxies

Paul Martini (Ohio State Univ.) Eunhyeuk Kim (Harvard-Smithsonian Center for Astrophysics), Dan Kelson, John Mulchaey (OCIW),

Chandra has revealed significant point source overdensities in the fields of many clusters of galaxies. We have spectroscopically observed eight clusters of galaxies at $z < 0.3$ and identified 40 cluster members with broad-band X-ray luminosities between $L_X = 8 \times 10^{40}$ and $4 \times 10^{43}$ erg/s and host galaxies more luminous than $M_R < -20$ mag. These cluster members make a sufficient contribution to the point source surface density to explain the higher densities observed in cluster fields. We compare the X-ray and visible-wavelength properties of these galaxies to observational datasets of galaxies with various X-ray emission mechanisms and conclude that most of these sources are AGN, although the X-ray emission from as many as a quarter of the least luminous sources may be due to other mechanisms, most notably LMXBs. This conclusion is in spite of the observation that only three of these 40 galaxies have obvious AGN signatures in our visible-wavelength spectra. We ascribe this significant difference between visible and X-ray identification to both obscuration of the visible-wavelength spectral signatures and their dilution by host galaxy emission.

**Notes:**

## 3.18 Chandra Observations of Distant Galaxy Clusters

Ben Maughan, Christine Jones, Bill Forman (SAO), Harald Ebeling (IfA, Hawaii), Leon Van Speybroeck (SAO)

We present the results of an analysis of 67 clusters of galaxies in the redshift range 0.1-0.9 (median=0.4). We give an overview of the sample, which includes a diverse array of galaxy clusters and discuss some of the interesting individual systems. The statistical properties of the sample are then investigated with an emphasis the scaling relations between cluster properties.

**Notes:**

## 3.19 X-ray Properties of a Mass-Selected Group Catalog

P. Mazzotta (SAO), R. Bower, M. Balogh, T. Ponman, T. Theuns, A. Edge, V. Eke, H. Bohringer, C. Collins, M. Colless, S. Maddox, J. Peacock

The observed X-ray luminosities of groups are inconsistent with a model in which the intragroup medium is shock-heated during the collapse. It is thought that a combination of pre-heating, gas cooling and energy injection removes low entropy gas, reducing the system's X-ray luminosity. However, the extent of this process is uncertain because the previous selection of group catalogs has been based on X-ray emission. To address this issue we have constructed a complete, mass-selected catalog of 18 groups from the 2dFGRS that we proposed for observation with both Chandra and XMM-Newton. To date twelve of these groups have been observed and here we present some preliminary results.

**Notes:**

## 3.20 Centroid Offsets in Simulated Clusters of Galaxies

Patrick Motl (Louisiana State Univ.), Michael Norman (Univ. of California, San Diego), Jack Burns, Eric Hallman (Univ. of Colorado)

Clusters of Galaxies are frequently used as cosmological probes and have been studied observationally through a variety of means; including the thermal Sunyaev-Zeldovich effect, through their X-ray emission as well as by weak gravitational lensing. These techniques sample, respectively, the projected thermal pressure of the ICM, the projected X-ray emissivity and the total surface density of the cluster material. In as much as clusters are dynamic systems, it is not clear that all three of these signals will have coincident maxima for a given cluster. Here, we investigate the frequency of centroid offsets (between thermal SZE, X-ray and total mass images) in a large catalog of simulated clusters of galaxies. We also investigate the role that centroid offsets may play in assessing the kinematic state of observed clusters as well as their interaction history.

**URL:** `http://charybdis.phys.lsu.edu/~patrickmotl/`

**Notes:**

## 3.21 Chandra and ROSAT Observations of the Hot X-ray Emitting Gas in NGC 5044 Group

Jelly Grace Nonesa (Hiroshima Univ., Univ. of Southern Mindanao), Yasushi Fukazawa, Takashi Ohsugi (Hiroshima Univ.)

We present a combined Chandra and ROSAT observations of the hot intragroup gas in one of the X-ray brightest galaxy groups, NGC 5044. A soft linear feature to the southeast has been observed in the X-ray image, indicating that the group has been slightly disturbed. Such feature is dramatically lying within the position of the prominent X-ray cavity, suggesting the existence of an active galactic nucleus (AGN). However, the absence of powerful radio emissions filling the cavities indicate a weak AGN. While within the inner central regions, the total mass profiles exhibit a bending feature, typical for groups containing a cD galaxy. Such feature have been observed in many clusters but the nature of such an interesting feature is not yet fully understood up to present. To investigate the origin of such feature, we performed various X-ray analyses using spatially resolved Chandra data. To constrain the mass distribution beyond the central regions, we simultaneously analyzed the Chandra data with the ROSAT data. With our joint analysis, we are able to constrain the dark matter distribution as well as many other important properties of this nearby group.

**Notes:**

## 3.22 Dark Matter Profile in Low-Redshift Galaxy Groups

Jelly Grace Nonesa, Yasushi Fukazawa, Takashi Ohsugi (Hiroshima Univ.)

We combine spatially resolved Chandra data with the ROSAT data to constrain the dark matter distribution in five low-redshift galaxy groups. Within the inner central regions, the total mass profiles exhibit a bending feature, typical for groups containing a cD galaxy. However, the nature of such an interesting feature is not yet fully understood up to present. Following previous works of mostly rich galaxy clusters, we made a detailed X-ray analysis on five nearby groups to investigate the dark matter distribution and the possible origin of such a feature. In the baryonic mass, the stars are dominant within the inner central regions. As such, we infer that this bending feature may be partly caused by the scale difference between stars and dark matter, not by dark matter alone. Consequently, this feature also signifies the likely interface between the cD galaxy and the surrounding group of galaxies. For these groups, the interface radius is found to be in the range 7-15 kpc from the peak of the X-ray emission. The total mass internal to each interface radius is found to be around $10^{10}$-$10^{11}$ $M_{\odot}$. Beyond this radius, the total mass profiles are apparently becoming DM-dominated. An NFW fit to the DM mass profiles yield results within reasonable scatter expected for CDM halos. While a power-law fit to the DM profiles give slopes comparable to that of rich galaxy clusters but is significantly larger than that of LSBs and self-interacting dark matter halos.

**Notes:**

## 3.23 The Dynamical State of Abell 1689

En-Hsin Peng, John Arabadjis, Eric Miller, Marshall Bautz (MIT)

We present projected temperature, electron density, plasma pressure, and entropy maps of the galaxy cluster Abell 1689 derived from Chandra ACIS observations using three different techniques. The morphology of the pressure and entropy maps suggests that the overall dynamical state of the cluster is consistent with hydrostatic equilibrium, although we confirm the presence of a hot substructure about 100 kpc (projected) from the cluster center. We provide an estimate its effect on the measurement of the mass profile.

**Notes:**

## 3.24 Constraining the Dark Matter Self-Interaction Cross-Section with Numerical Simulations of E1 0657-56

Scott Randall, Maxim Markevitch (Harvard-Smithsonian Center for Astrophysics)

We present results for constraining the self-interaction cross-section of dark matter by comparing X-ray and weak-lensing observations of the galaxy cluster 1E 0657-56 (the so-called bullet cluster) with results from N-body/hydrodynamical simulations. This cluster shows a high-velocity merger in the plane of the sky with a prominent bow shock that gives a subcluster velocity of roughly 4800 km s-1. A comparison of the X-ray image and weak-lensing mass map shows that the subcluster gas core lags the dark matter clump, which is coincident with the subcluster galaxies, indicating that the dark matter is not fluid-like. These observations allow for three independent methods for estimating the self-interaction cross-section of dark matter. Analytic estimates based on these methods have previously been determined. This work seeks to put tighter constraints on these results using a N-body/hydrodynamical code that is capable of simultaneously tracking gas particles and collisional dark matter particles. In this poster we present results from simulations with self-interacting dark matter and galaxies only.

**Notes:**

## 3.25 The Megasecond Chandra Observation of the Perseus Cluster

Jeremy Sanders, Andrew Fabian (Univ. of Cambridge), Gregory Taylor (Univ. of New Mexico), Steven Allen (Stanford Univ.), Carolin Crawford, Roderick Johnstone, Kazushi Iwasawa (Univ. of Cambridge)

We discuss the latest results from the Chandra megasecond observation of the Perseus cluster. This very deep observation of the X-ray brightest cluster in the sky reveals a wealth of structure in its core. We examine, by the use of extremely detailed temperature and pressure maps, the interaction of the radio source with the cluster. We show the evidence for the existence of further ancient radio bubbles in the cluster, highlighting the activity of this central source in the past. In addition we present results indicating the presence of X-ray cool gas in the central regions.

**Notes:**

### 3.26 Constraining the WHIM Mass Using XMM-Newton and Chandra Observations of 1ES1028+511

Katrien Steenbrugge, Martin Elvis, Fabrizio Nicastro (Harvard-Smithsonian Center for Astrophysics)

We report the discovery of redshifted Warm Hot Intergalactic Medium gas along the line of sight toward the medium redshift blazar 1ES1028+511. The spectra show absorption from one high column density, moderately ionized filament. The measured column density from this absorber and previous detected WHIM gas toward Mrk 421, allows us to better constrain the cosmological mass density. The calculated mass density compare well with the theoretical predicted value as well as the the number of missing baryons in the local universe, i.e. $z < 2$.

**Notes:**

## 3.27 Radio Galaxy Heating of Cooling Flow Clusters: Problems with Pure Hydrodynamic Models

John Vernaleo, Christopher Reynolds (Department of Astronomy, Univ. of Maryland)

Rich relaxed, clusters of galaxies cool, preferentially in the inner regions. Observationally however, there are strong limits to the amount of gas that could have cooled. Some form of heating (or some way to suppress cooling) is needed to reconcile these two observational facts. Energetic AGN are often viewed as a way to provide this heating. Most work indicates that they can provide enough energy to offset cooling. We have done a set of high resolution, three dimensional simulations that show that in the case of purely hydrodynamical AGN jets, although there is enough energy present, it is not spatially deposited in a way that can prevent catastrophic cooling of the cluster. We conclude that either some other physics (e.g., plasma transport processes or cosmic ray heating) is relevant for thermalizing the AGN energy output, or the role of AGN heating has been overestimated.

**Notes:**

# 4 Extragalactic Diffuse Emission and Surveys

## 4.1 LBG, LAE & AGN at z∼3 in MUSYC-ECDFS

Harold Francke (Universidad de Chile), Eric Gawiser, Shanil Virani, (Yale Univ.), Ezequiel Treister (Universidad de Chile), Meg Urry (Yale Univ.)

The E-CDFS field is the largest Chandra survey ever conducted at its depth (∼0.3 square degrees and 228 ks), and is also one of the 4 fields included in the MUltiwavelength Survey by Yale/Chile (MUSYC; Gawiser et al. 2005, astro-ph/0509202). The broad coverage of the survey (UBVRIzJHK+NB5000) is especially suited for selecting objects at specific redshifts. Using x-ray, UVR and BV+NB colors, we have selected AGN, LBG (Lyman Break Galaxies) and LAE (Lyman Alpha Emitters) at z∼3. We present results on the demographics of this set of protogalaxies, including estimates of the fraction of LBGs and LAEs that contain AGN, the joint x-ray and optical selection of AGN at this redshift, and the clustering amplitude of these sources.

**URL:** `http://www.astro.yale.edu/musyc/`

**Notes:**

## 4.2 Searching for Type-2 QSOs in Chandra/SDSS Fields

Ioannis Georgantopoulos, Athanasios Akylas (National Observatory of Athens)

We are searching for type-2 (narrow-line) QSO candidates among the Chandra XASSIST sources which have been spectroscopically identified in the Sloan Digital Sky Survey. Candidates are selected having a) column density $N_H > 10^{22} cm^{-2}$ as derived from the hardness ratios b) luminosity $L_x > 10^{44} erg\ s^{-1}$. Our sample consists of 23 type-2 QSO candidates. Detailed X-ray spectral analysis with XSPEC shows that only three sources present indeed high, $N_H > 10^{22} cm^{-2}$, column densities. All three have broad lines in their optical spectra and thus no source can be classified as a bona-fide type-2 QSO at least according to the strict optical classification. However, we cannot rule out the possibility that a number of type-2 QSO reside among fainter optical sources which have no SDSS optical spectroscopy.

**Notes:**

## 4.3 X-ray Luminous High Redshift Quasars from the ChaMP

Paul Green (SAO), John Silverman (MPE), Wayne Barkhouse (UIUC), Dong-Woo Kim, Minsun Kim, Belinda Wilkes, Amy Mossman (SAO), Harvey Tananbaum (SAO)

The space density of luminous optically-selected quasars peaked 2-3 Gyr after the Big Bang, but we know that much of accretion onto supermassive black holes is obscured, perhaps even more so in the early Universe. Both the intrinsic physical properties of high redshift quasars and their population statistics are of interest, but few X-ray-selected examples are known to date. The Chandra Multiwavelength Project provides a significant number of high redshift ($z>3$) X-ray selected quasars. We present new results on spectral energy distributions and evolution of these objects, including a revised X-ray luminosity function that maximizes the sample size using a large compilation of surveys. Since at low redshifts we know that low and high luminosity objects evolve very differently, we constrain luminosity-dependent density evolution models using maximum likelihood model fits.

**URL:** `http://hea-www.cfa.harvard.edu/CHAMP/`

**Notes:**

## 4.4 Intensity of the Unresolved Cosmic X-ray Background for 2–7 keV with Chandra

Ryan Hickox, Maxim Markevitch, Christine Jones (Harvard-Smithsonian Center for Astrophysics)

We will present results for the intensity of the unresolved cosmic X-ray background from 2 to 7 keV, using the *Chandra* Deep Fields (CDF) North and South. The X-ray surface brightness of these fields, excluding point and diffuse sources, is measured for observations over several epochs. We use detailed modeling of the ACIS-I instrumental background and careful flare removal to eliminate the non-sky components of the observed background. We calculate the resulting fraction of the XRB that remains unresolved at *Chandra* fluxes below $\sim 10^{-16}$ ergs cm$^{-2}$ s$^{-1}$.

**Notes:**

## 4.5 The Chandra/SWIRE Multi-wavelength Survey

Roy Kilgard, Belinda Wilkes (SAO), Alberto Franceschini (Universita di Padova), Dong-Woo Kim, Minsun Kim (SAO), Carol Lonsdale (Cal Tech), Frazer Owen (NRAO), Maria Polletta (Cal Tech), Brian Siana (Spitzer Science Center), Harding Smith (UCSD), Jason Surace (Cal Tech)

The Spitzer Wide-area Infrared Extra-galactic Survey (SWIRE) is designed to study the structure, evolution and environments of AGN, starbursts, and ellipsoids over the same spatial volume out to $z > 2.5$. We have completed medium depth (70 ksecs), Chandra ACIS-I, X-ray observations in the northern Lockman Hole SWIRE Field, covering 0.6 $deg^2$ for which deep observations are available in all seven Spitzer bands, optical and near-IR as well as extremely deep VLA 20cm data. We find 812 X-ray sources, of which 762 have counterparts in the Spitzer observations. 15 X-ray sources have sufficient counts to allow X-ray spectral fitting. We present preliminary results from this survey, including the multi-wavelength properties of the X-ray sources and resulting classifications and redshift estimation. We also discuss the highly obscured luminous AGN population, most of which show no detectable AGN characteristics in their optical spectra, and report the discovery of two high-redshift, luminous quasars with highly obscured X-ray and optical emission.

**Notes:**

## 4.6 ChaMP Normal Galaxies at Intermediate Redshift

Dong-Woo Kim, Wayne Barkhouse, Paul Green, Eric Schlegel (SAO), John Silverman (MPE) Harvey Tananbaum, Belinda Wilkes (SAO), Encarni Colmenero (SAAO), Minsun Kim, Tom Aldcroft, Craig Anderson (SAO) ChaMP Collaboration

We have investigated 136 Chandra extragalactic sources without broad emission lines, including 93 NELG and 43 ALG. Based on fX/fO, LX , X-ray spectral hardness and optical emission line diagnostics, we have conservatively classified 36 normal galaxies (20 spirals and 16 ellipticals) and 71 AGNs. Their redshift ranges from 0.01 to 1.2, while normal galaxies are at z=0.01-0.3. Our sample galaxies appear to share similar characteristics with local galaxies in terms of X-ray luminosities and spectral properties, as expected from the X-ray binary populations and the hot ISM. In conjunction with normal galaxies found in other surveys, we found no statistically significant evolution in LX/LB, within the limited z range (¡ 0.1). We have built our log(N)-log(S) relationship of normal galaxies in the flux range, $fX(0.5-8.0) = 10^{-15} - 10^{-13}$ erg s-1 cm-2, after correcting completeness by a series of simulations. The best-fit slope is -1.5 for both S and B energy bands, which is considerably steeper than that of AGN-dominated cosmic background sources at faint fluxes ($fX < 10^{-14}$ erg s-1 cm-2, i.e., below the break), but slightly flatter than the previous estimate, indicating normal galaxies will exceed in number over the AGN population at $fX < 10^{-18}$ erg s-1 cm-2 (an order of magnitude lower than the previous estimate). We have also built an X-ray luminosity function of normal galaxies in the luminosity range of $LX = 5x10^{39} - 10^{42}$ erg s-1, which is consistent with other survey results.

A group of NELGs (most of them with $fX/fO > 0.1$) appear to be heavily obscured in X-rays, i.e., a typical type 2 AGN. After correcting intrinsic absorption, their X-ray luminosities could be $LX > 10^{44}$ erg s-1, making them Type 2 quasar candidates. While most X-ray luminous ALGs (XBONG candidates) do not appear to be significantly absorbed, we found two heavily obscured objects, which could be as luminous as an unobscured broad-line quasar. Among 43 ALGs, we found two E+A galaxy candidates with strong Balmer absorption lines, but no [OII] line. The X-ray spectra of both galaxies are soft and one of them has a nearby close companion galaxy, supporting the merger/interaction scenario rather than the dusty starburst hypothesis.

**Notes:**

## 4.7 Chandra Multiwavelength Project (ChaMP) X-ray Point Source Catalog

Minsun Kim, Dong-Woo Kim (SAO), Wayne A. Barkhouse (UIUC), Nancy R. Evans, Paul J. Green, Eunhyeuk Kim (SAO), Myung Gyoon Lee (SNU), Amy E. Mossman (SAO), John D. Silverman (MPE), Harvey D. Tananbaum, Belinda J. Wilkes (SAO), ChaMP Collaboration

We present the Chandra Multiwavelength Projects (ChaMP) X-ray point source catalog with $\sim 6,800$ X-ray sources detected in 149 Chandra observations covering $\sim 10\ deg^2$.The exposure time of our sample ranges up to $\sim$ 120 ksec, corresponding to the X-ray flux limit of $f_{0.5-8.0} = 9 \times 10^{-16}\ erg\ cm^{-2}\ sec^{-1}$. The ChaMP catalog includes X-ray photometric data in 8 different energy bands as well as X-ray spectral hardness ratio and colors. To quantitatively assess those parameters, we have performed extensive simulations.We present a set of empirical equations in a few interesting confidence levels: the flux limit as a function of effective exposure time; the positional uncertainty and the false source detection rate as a function of source counts and off-axis angle.

**Notes:**

## 4.8 Chandra Multiwavelength Project (ChaMP) X-ray Point Source Number Counts Relations

Minsun Kim, Dong-Woo Kim (SAO), Wayne A. Barkhouse (UIUC), Nancy R. Evans, Paul J. Green, Eunhyeuk Kim (SAO), Myung Gyoon Lee (SNU), Amy E. Mossman (SAO), John D. Silverman (MPE), Harvey D. Tananbaum (SAO), Belinda J. Wilkes (SAO), ChaMP Collaboration

We present the ChaMP logN-logS relations in the multiple X-ray energy bands. We have used ∼5,500 X-ray sources detected from 130 ChaMP fields covering ∼9.3 $\mathrm{deg}^2$ in sky area. To correct the incompleteness and to determine sky coverage area, we have performed extensive simulations. The number count relations are fitted by a broken power law in differential number count spaces and fitting results agree with previous studies in 1 sigma error range. We also present the simultaneous fitting results of ChaMP and CDFs data. The best-fit parameters are $Gamma_{faint} = 1.50^{+0.05}_{-0.07}$, $Gamma_{bright} = 2.36^{+0.11}_{-0.12}$, and $S_b = 6.63 \times 10^{-15}{}^{+1.28}_{-1.59}$ in the 0.5-2.0 keV band. In the 2.0-8.0keV band, $Gamma_{faint} = 1.59^{+0.12}_{-0.08}$, $Gamma_{bright} = 2.51^{+0.28}_{-0.09}$, and $S_b = 12.62 \times 10^{-15}{}^{+7.01}_{-1.85}$. These number count relations cover very large flux ranges, $f_{0.5-2.0} = 3 \times 10^{-17}$ $10^{-12}$ and $f_{2.0-8.0} = 2 \times 10^{-16}$ $10^{-11}$ in cgs units, with the smallest statistical errors yet reported in any survey.

**Notes:**

## 4.9 Statistical Properties of Intermediate-redshift Off-nuclear X-ray Sources in the Chandra Deep Fields

Bret Lehmer, Niel Brandt (PSU), Ann Hornschemeier (Goddard), Franz Bauer (Columbia), Don Schneider, Aaron Steffen (PSU)

We statistically analyze a population of intermediate-redshift (z $\sim$ 0.05-0.3) off-nuclear X-ray sources located within the optical emission of optically-bright galaxies in the Great Observatories Origins Deep Survey and Galaxy Evolution from Morphology and SEDs fields. A total of 19 off-nuclear sources are classified using deep Chandra exposures from the Chandra Deep Field-North, Chandra Deep Field-South, and Extended Chandra Deep Field-South; ten of these sources are newly identified. This sample improves the source statistics for intermediate-redshift off-nuclear sources with 0.5-2.0 keV luminosities L(0.5-2.0 keV) $>\sim 10^{39.5}$ erg s-1, and significant new constraints are placed on the redshift evolution of the frequency of incidence for off-nuclear sources located in field galaxies. We find that the fraction of intermediate-redshift galaxies containing an off-nuclear source is statistically consistent with that observed for ultraluminous X-ray sources in the local universe over L(0.5-2.0 keV) $\sim 10^{39-40.5}$ erg s-1.

**Notes:**

## 4.10 Angular Structures of the X-ray Sources in the Extended Chandra Deep Field-South

Takamitsu Miyaji (Carnegie Mellon Univ.), Roberto Gilli (INAF-Osservatorio Astrofisico di Arcetri), Bret Lehmer, Niel Brandt (Penn State Univ.), Anton Koekemoer (STSCI), E-CDF-S Team

We report the first results on the angular structure on the Extended Chandra Deep Field-South, which consists of a mosaic of 2x2 ACIS-I fields centered at the original Chandra Deep Field-South. In this poster, we present angular auto-correlation functions ($w_{\rm xx}(\theta)$) of the X-ray sources published by our team (Lehmer et al. 2005; ApJS in press) as well as cross-correlation functions ($w_{\rm xg}(\theta)$) between the X-ray sources and galaxies in the COMBO-17 photometric redshift catalog (Wolf et al. 2004).

We were able to measure significant angular auto correlation ($w_{\rm xx}(\theta)$) down to 10 arcseconds separately for the X-ray sources detected in the 0.5-2.0 keV and 2-8 keV bands.

By further investigating the cross-correlation with galaxies, we can obtain 1) large number of pairs, giving high signal-to-noise ratios, and 2) thick cuts in the photometric redshift in the galaxy catalog. By doing so, we can roughly trace the redshift evolution of the clustering properties (large scale environments of the X-ray AGNs) even before full redshifts on the X-ray sources themselves are available. We have calculated $w_{\rm xg}(\theta)$ values between the X-ray sources detected in the 0.5-2.0 keV and 2-8 keV bands and galaxies in three thick photometric redshift ranges (0.1<0.3, 0.3<0.8, and 0.8<1.4). Our preliminary results show, in all photometric redshift ranges a positive correlation up to 10-100 arcseconds.

We also plan to report on the implied 3-D clusterings from both auto- and cross-correlations and their redshift dependences.

**Notes:**

## 4.11 The X-ray Luminosity Functions of Galaxies Derived from the GOODS

Andrew Ptak (JHU), Bahram Mobasher (STSci), Ann Hornschemeier (GSFC), Colin Norman (JHU)

We present soft X-ray luminosity functions (XLFs) derived from GOODS data, where for the first time XLFs are derived for early and late-type galaxies at $z \sim 0.25$ and $z \sim 0.75$. We derived XLFs both before and after selecting only normal/starburst galaxies from the GOODS data. The slopes of the early-type galaxy XLFs tend to be slightly flatter than the late-type galaxy XLFs. We find that the normal/starburst galaxy XLFs are significantly steeper at $z>0.5$ than at $z<0.5$. The XLF shape clearly differs from the Schechter function fits to the J-band luminosity functions, however our early-type galaxy XLFs have a similar overall normalization as the early-type galaxy J-band luminosity function rescaled to the X-ray band, consistent with both being tied to the older stellar population. The late-type XLFs derived from the normal/starburst sample agree well with rescaled local FIR luminosity functions assuming $(1+z)^3$ luminosity evolution, at both high and low redshift. This agreement is also not surprising since both samples should be dominated by star-forming galaxies.

**Notes:**

## 4.12 Searching for X-ray Luminous Star-forming Galaxies with Chandra, XMM and 2dFGRS

Panayiotis Tzanavaris, Ioannis Georgantopoulos (National Observatory Athens), Antonis Georgakakis (Imperical College London)

We cross-correlated the Chandra XASSIST and XMM-Newton Serendipitous Source Catalogs with the 2dF Galaxy Redshift Survey database (2dFGRS), looking for galaxies whose X-ray emission is not dominated by an AGN but by stellar processes ("normal" galaxies). We found 20 2dFGRS galaxies within 3 arcsec of a Chandra source, and 18 galaxies within 6 arcsec of an XMM-Newton source. We used the classification scheme of Ho et al. (1997) to classify six 2dFGRS spectra as H II nuclei, and two spectra as possible H II nuclei. The rest of the objects are absorption line galaxies, emission+absorption galaxies, AGN and LINERs. For all objects we calculated the X-ray luminosity, $L_X$, the logarithimic ratio of X-ray to optical fluxes, log $f_X/f_O$, and the hardness ratio, HR. Some of the "normal" galaxies found have log $f_X/f_O > -2$, although log $f_X/f_O < -2$ has often been used to separate "normal" galaxies from AGN. However, all "normal" galaxies have log $L_X < 42$. The implication of our results for X-ray surveys is that the empirical criterion log $L_X < 42$ is more reliable than log $f_X/f_O < -2$ for separating "normal" galaxies from AGN.

**Notes:**

## 4.13 The X-ray Luminosity Function and log N - log S of Normal Galaxies

Panayiotis Tzanavaris, Ioannis Georgantopoulos, Athanasios Akylas (National Observatory Athens), Antonis Georgakakis (Imperial College London), Andreas Zezas (Harvard-Smithsonian Center for Astrophysics)

By combining XMM-Newton and Chandra data (XMM-NHS, 1XMM, CDF-N, CDF-S and Chandra XASSIST/SDSS) we obtained the largest sample to-date ($\sim$ 200 objects) of X-ray selected, normal (non-AGN dominated) galaxies. We present the number count distribution, $\log N - \log S$, and the X-ray luminosity function of normal galaxies, separately for early and late-type galaxies.

**Notes:**

# 5 Galactic Diffuse Emission and Surveys

## 5.1 Deep Chandra Observations of the Arches and Quintuplet Clusters at the Galactic Center

Hui Dong, Q. Daniel Wang (Dept. of Astronomy, Univ. of Massachusetts, Amherst)

The Arches and Quintuplet clusters provide excellent local testbeds for our understanding of very young massive stellar systems and their interaction with galactic nuclear environment. We present an 100 ks on-axis ACIS-I observation of these two Galactic clusters. We detect several bright point-like sources that are clearly associated with the clusters. Some of the sources are positionally coincident with known radio sources with strong stellar winds. The sources also have similar X-ray spectra, which are dominantly thermal and show an unusually strong 6.7-keV emission line. The sources most likely represent the colliding wind close binaries of very massive stars. Diffuse X-ray emission is unambigously detected and extends at least to a distance of 2 pc from the cluster centers. In the cluster cores, the diffuse emission shows evidence of hot gas cavities around some massive stars and filamental structures. These substructures most likely represent the wind-wind interaction on cluster scales, providing potentially very useful diagnostics of collisionless shock dynamics and the formation of the cluster winds. The diffuse X-ray spectra also show remarkably different spectra from those point-like sources. In particular, the diffuse X-ray spectrum of the Arches clluster shows a strong 6.4-keV emission line and little evidence for the 6.7-keV line. But the bulk of the 6.4-keV emission line arises in regions away from the cluster core. The origin of this line emission is still uncertain. The understanding of the two clusters in our Galactic center will provide important hints about what might be happening in active starforming nuclear regions of other galaxies.

**Notes:**

## 5.2 A Search for Serendipitous Chandra Periodic and Transient Systems

Anna Hourihane (Univ. College Cork), Jeremy Drake (Harvard-Smithsonian Center for Astrophysics), Paul Callanan (Univ. College Cork), Dong-Woo Kim, Peter Ratzlaff (Harvard-Smithsonian Center for Astrophysics)

We present the results of a search for serendipitous X-ray sources in Chandra fields that show either strong variability or detectable periodicity in their X-ray emission. Our search concentrates on fields toward lower Galactic latitudes for which the exposure time exceeds 25ks. Sources bright enough for time-variability analysis are subject to FFT and Bayesian Blocks analysis to seek out promising candidates for more detailed study. We describe field selection criteria and data analysis methods, and present the findings of this initial phase of the study.

**Notes:**

## 5.3 A Non-equilibrium Ionization Code and its Applications

Li Ji, Q. Daniel Wang, John Kwan (UMass, Amherst)

We have developed a non-equilibrium ionization code based on updated atomic data. A version of the code has been optimized so that the calculation can be done efficiently and accurately enough for comparison with X-ray CCD spectra. We also self-consistently include recombination into highly excited levels, which is important in some non-equilibrium cases but has generally been ignored in the past. We will show example applications to illustrate the characteristics of the code and its combination with various models of gas dynamics. In particular, we will present results from an application to massive stellar cluster winds.

**Notes:**

## 5.4 ChESS: ChaMP Extended Stellar Survey

Vinay Kashyap, Nancy Evans, Deron Pease, Amy Mossman (SAO), Richard Gray (Appalachian State Univ.), Jeremy Drake, Belinda Wilkes, Paul Green, Dong-Woo Kim (SAO), ChaMP Collaboration

We present a catalog of stellar X-ray sources serendipitously detected in Chandra data from 1999-2001. We have searched for optical matches to X-ray sources from the Chandra Multi-wavelength Project (ChaMP) using the Tycho, SDSS, and ChaMP optical follow-up catalogs. We find over 250 stellar X-ray sources covering a magnitude range V = 10 - 19. This forms an X-ray selected, but otherwise unbiased, sample of field stars covering a wide range of spectral types, ages, metallicities, and rotation rates. We have classified the spectral types of those stars for which we have optical spectra, and use this set to calibrate the colors of the remainder of the sample. As expected, the majority of the sources are M type stars. We confront the observed sample with predictions from modeled Galactic populations, and discuss the X-ray properties of this sample.

This work was supported by NASA contract NAS8-39073 to the CXC.

**Notes:**

## 5.5 The Metal Abundance in the Interstellar Medium from XMM RGS Spectroscopy of AGN

Edward Lloyd-Davies, Joel Bregman (Univ. of Michigan)

The star formation history of the galaxy has left a substantial imprint on the interstellar medium in the form pollution from metals generated by supernovae. The abundance of metals in the ISM is an extremely important probe of past supernova activity. Optical measurements of metal abundance in the ISM can be uncertain due to corrections for ionization and dust. However absorption at X-ray wavelengths is relatively insensitive to these effects, in principle allowing much greater accuracy. We present the analysis of ISM absorption in XMM-Newton Reflection Grating Spectrometer observations of a sample of bright AGN. We find a systematic increase in measured absorption with observation date which we attribute to an undetermined instrumental problem (possibly analogous to the contamination build up on the Chandra ACIS). To minimize the corrections necessary for this effect we initially consider only sources with high absorption columns and derive O and Fe abundances for these sight-lines. We comment on the implication of these results for models of the star formation history in the Milky Way.

**Notes:**

## 5.6 BEHR: Bayesian Estimation of Hardness Ratios

Taeyoung Park (Harvard), Vinay Kashyap, Andreas Zezas, Aneta Siemiginowska (SAO), David van Dyk (UC Irvine), Alanna Connors (Eureka Scientific), Craig Heinke (Northwestern)

We present a generalized and statistically coherent scheme of computing hardness ratios and associated error bars. In this scheme, we model the observed counts as a non-homogeneous Poisson process and exploit sophisticated Bayesian approaches (e.g., Gibbs sampling) to calculate hardness ratios, accounting for local background contamination and effective area variations. We apply this scheme to the simple counts ratio [S/H] as well as its variants, colors [log(S/H)] and fractional difference hardness ratios [(H-S)/(H+S)]. We also perform simulations to compare the new Bayesian methods with the classical method, thereby illustrating that (a) the former provides more accurate estimates of the uncertainties, (b) the mode of the posterior probability distribution function (pdf) is a robust estimator of the hardness ratio, and (c) the pdfs of the colors are the best behaved in the low counts limit.

We apply this method to identify candidate qLMXB's in the globular cluster Terzan 5.

This project is part of the California-Harvard AstroStatistics Collaboration. The authors gratefully acknowledge funding for this project partially provided by NSF grant DMS-01-04129 and by NASA Contract NAS8-39073, and NASA grants NCC2-1350 and NAG5-13056.

**Notes:**

## 5.7 Chandra Observations of Dust Grains

Randall Smith (NASA GSFC/JHU)

Chandra observations of X-ray halos have begun to show the power of this technique to measure interstellar grain size distributions and their line of sight positions. I will discuss existing observations of halos around XRBs, including recent observation using the HRC-I, and what they can uniquely tell us about IS grains.

**Notes:**

## 5.8 Probing the Spatial Distribution of the Interstellar Dust Medium by High Angular Resolution X-Ray Halos of Point Sources

Jingen Xiang (Harvard-Smithsonian Center for Astrophysics/MSU),
Shuang Nan Zhang (Tsinghua THCA)

The excellent angular and good energy resolution coupled with broad energy coverage, the Chandra ACIS is so far the best instrument for studying the X-ray halos. But the direct images of bright sources obtained with ACIS usually suffer from severe pileup which prevents us from obtaining the halos in small angles. We first improve the method proposed by Yao et al to resolve the X-ray dust scattering halos of point sources from the zeroth order data in CC-mode or the first order data in TE mode with the Chandra HETG/ACIS. Using this method we studied the X-ray dust scattering halos around 17 bright X-ray point sources using Chandra data, including a re-analysis of Cygnus X-1. Using the interstellar grain models of WD01 model and MRN model to fit the halo profiles, we get the hydrogen column densities and the spatial distributions of the scattering dust grains along the line of sights (LOS) to these sources. We find there is a good linear correlation not only between the scattering hydrogen column density from WD01 model and the one from MRN model, but also between NH derived from spectral fits and the one derived from the grain models WD01 and MRN (except for GX 301-2 and Vela X-1). Finally we discuss the possibility of testing the model that the black hole can be formed from the direct collapse of a massive star without supernova using the statistical distribution of the dust density nearby the X-ray binaries.

**Notes:**

## 5.9 ChaMPlane Optical Survey

Ping Zhao, Jonathan Grindlay, JaeSub Hong, Silas Laycock, Xavier Koenig, Eric Schlegel, Maureen van den Berg (Harvard-Smithsonian Center for Astrophysics)

The Chandra Multiwavelength Plane (ChaMPlane) survey is a project to systematically identify and analyze the serendipitous X-ray sources in deep galactic plane fields imaged by the Chandra X-ray Observatory in order to determine the populations of accretion-powered binaries in the Galaxy. ChaMPlane consists of an X-ray survey and an optical survey, which is also one of NOAO's Long-term Survey Programs. We have successfully completed this 5-year ChaMPlane Optical Survey, using the NOAO 4-m telescopes with the Mosaic cameras and V, R, I and H$\alpha$ filters at CTIO and KPNO. These Mosaic images provide ground to identify Chandra optical counterparts for spectroscopic follow-up in order to determine the nature of the Chandra sources. The survey produced 65 Mosaic fields covering about 23 square degrees and 154 ACIS observations on 105 distinct Chandra fields in the Galactic plane during Chandra Cycles 1-6. Using 6 Mosaic pointings, we mapped out 2.2 square degrees around the Galactic center to cover 58 Chandra ACIS observations. This is so far the deepest optical survey towards the Galactic center.

**URL:** `http://hea-www.harvard.edu/ChaMPlane/`

**Notes:**

# 6 Normal galaxies: Diffuse Emission

## 6.1 Chemical Enrichment of the Complex Hot ISM of the Antennae Galaxies

Alessandro Baldi, John Raymond, Giuseppina Fabbiano, Andreas Zezas (SAO), Francois Schweizer (Carnegie Observatories), Andrew King (Theoretical Astrophysics Group, Univ. of Leicester), Trevor Ponman (School of Physics & Astronomy, Univ. of Birmingham), Arnold Rots (SAO)

We present an analysis of the properties of the hot ISM in the merging pair of galaxies known as The Antennae (NGC 4038/39), performed using the deep, coadded 411 ks Chandra ACIS-S data set. These deep X-ray observations and Chandra's high angular resolution allow us to investigate the properties of the hot ISM with unprecedented spatial and spectral resolution. Through a spatially resolved spectral analysis, we find a variety of temperatures (from 0.2 to 0.7 keV) and $N_H$ (from Galactic to $2x10^{21}$ cm$^{-2}$). Metal abundances for Ne, Mg, Si, and Fe vary dramatically throughout the ISM from sub-solar values ($\sim$0.2) up to several times solar. We also investigate in detail the physics of the hot emitting gas, deriving measures for the hot-gas mass ($\sim 10^7$ solar masses), cooling times ($10^7 - 10^8$ yr), and pressure ($3.5x10^{-11} - 2.8x10^{-10}$ dyne cm$^{-2}$). At least in one of the two nuclei (NGC 4038) the hot-gas pressure is significantly higher than the CO pressure, implying that shock waves may be driven into the CO clouds. Comparison of the metal abundances with the average stellar yields predicted by theoretical models of SN explosions points to SNe of Type II as the main contributors of metals to the hot ISM. There is no evidence of any correlation between radio-optical star-formation indicators and the measured metal abundances. Although due to uncertainties in the average gas density we cannot exclude that mixing may have played an important role, the short time required to produce the observed metal masses (<2 Myr) suggests that the correlations are unlikely to have been destroyed by efficient mixing. More likely, a significant fraction of SN II ejecta may be in a cool phase, in grains, or escaping in hot winds.

**Notes:**

## 6.2 Outflows, Edges, & Wakes: Probing Galaxy Evolution with Chandra and XMM-Newton

Marie Machacek, Christine Jones, William Forman, Paul Nulsen, Ralph Kraft (SAO)

An array of physical processes, often acting in concert, affect the evolution of galaxies and the intracluster medium (ICM) in groups and clusters. These processes include tidal interactions from galaxy collisions and mergers, ram pressure and turbulent viscous stripping of galaxy gas caused by the galaxy's motion through the ambient group/cluster gas, and outflows induced by star formation and/or AGN activity powered by accretion onto a central black hole within the galaxy. Each process imprints characteristic signatures, such as cavities, surface brightness edges, and wakes, on the hot gas in and near the galaxy. We use Chandra and XMM-Newton X-ray observations of nearby galaxies, spanning a range of galaxy types and environments, including spiral galaxies NGC 6872 in Pavo and NGC 2276 in the NGC 2300 group, and elliptical galaxies NGC 4552 in Virgo, NGC 7619 in Pegasus I, and the interacting pair NGC 4782/3, to investigate the physical processes at work in the evolution of these systems. This work was supported in part by the Smithsonian Institution, Chandra X-ray Center, and NASA grant GO3-4176A.

**Notes:**

## 6.3 Galaxy X-ray Coronae in Nearby Hot Clusters

Ming Sun (Harvard-Smithsonian Center for Astrophysics/MSU), Bill Forman, Christine Jones (SAO)

We present the first systematic investigation of X-ray thermal coronae of both early-type and late-type galaxies in hot clusters. About 130 galaxies in 16 nearby hot clusters were examined, based on the archival Chandra data (46 pointings with a total exposure of 1.5 Msec). Small cool X-ray coronae of early-type galaxies (1-4 kpc in radius, 0.5 - 1.5 keV), pressure confined in hot ($>$ 3 keV) clusters, are found to be very common, although their properties have been significantly modified by the dense ICM environment. Despite the effects of gas stripping, ICM evaporation, intense radiative cooling and AGN outbursts of the central SMBH, the common survival of these dense mini cooling cores puts interesting constraints on relevant physics, e.g., cooling, AGN feedbacks and transport processes. The detailed analysis for the $\sim$ 10 brightest coronae (temperature and pressure profiles etc.) will also be presented. Several coronae of late-type galaxies were also detected, with $L_X$ roughly scaled with the SF rate.

**Notes:**

## 6.4 Chandra Observations of Circumnuclear Star Formation in NGC 3351

Douglas Swartz (USRA NASA/MSFC), Mihoko Yukita (Univ. of Alabama in Huntsville), Roberto Soria (Harvard-Smithsonian Center for Astrophysics), Allyn Tennant (NASA/MSFC), Kajal Ghosh (USRA NASA/MSFC), Kinwah Wu (MSSL,Univ. College London)

The nearby SB(r)b galaxy NGC 3351 (M95) displays a $\sim$20 arcsec diameter star-forming nuclear ring fueled by gas accreted through a stellar bar. The X-ray emission from this region is composed of numerous point-like sources embedded in hot (kT=0.5 keV) nonuniform diffuse gas. Most of the point-like sources are themselves small ($\sim$50 pc) concentrations of hot gas though some are clearly hard and variable XRBs. The X-ray emission lies near the UV and Halpha hotspots but is, in general, not coincident with these star forming clusters. The X-ray morphology is basically ring-like, in particular the center of the galaxy lacks both large amounts of hot gas and any point-like source above an estimated X-ray luminosity of 1e37 erg/s in the 0.3–8.0 keV band. The X-ray and Halpha morphologies of the ring and surrounding regions can be explained by the evolution of localized star formation combined with outflows from the central regions of NGC 3351.

**Notes:**

## 6.5 Chemistry and Cavities in the Atmospheres of Elliptical Galaxies

Raymond White (Univ. of Alabama), David Davis (UMBC / NASA GSFC)

We describe the spatial distribution of chemical abundances in the atmospheres of three elliptical galaxies (NGC 1407, NGC 4125 and NGC 4552) and compare them to the stellar abundances in the same galaxies. The atmospheres of NGC 4125 and 4552 also contain multiple cavities likely caused by intermittent AGN activity, allowing us to constrain the AGN activity duty cycle. The association of low-mass X-ray binaries with globular cluster candidates in these three galaxies will also be described.

**Notes:**

# 7 Normal galaxies: X-Ray Populations

## 7.1 Three Distinct Classes of Ultraluminous X-Ray Sources

Hua Feng, Philip Kaaret (Univ. of Iowa)

We examined X-ray properties of ultraluminous X-ray sources (ULXs) in nearby galaxies in XMM-Newton archival data. There appear to be three distinct classes of spectra. One class shows emission from hot, diffuse plasma. This thermal emission is similar to that seen from recent supernovae; the temperatures are in the range 0.6–0.8 keV and the luminosities are the lowest in our sample, near $10^{39}$ erg/s. Three sources have spectra which are strongly curved at high energies and have the highest temperatures in our sample, 1.0–1.4 keV. These spectra are well fitted with a power-law plus multicolor disk blackbody model with the power-law dominant at low energies or a Comptonization model. The remainder of the sources are best fitted with a power-law plus multicolor disk blackbody model, as is commonly used to describe the spectra of accreting black holes. These sources have the lowest thermal component temperatures, 0.1–0.4 keV, and extend to the highest luminosities, above $10^{40}$ erg/s. This diversity of spectral shapes and the fact that the sources lie in three distinct temperature ranges suggests that the ULXs are a diverse population.

**Notes:**

## 7.2 Chandra - VLA-FIRST Ultraluminous X-ray Sources

Kajal Ghosh, Douglas Swartz (USRA, NASA/MSFC), Lakshmi Saripall (ATNF/CSIRO), Allyn Tennant (NASA/MSFC)

We have searched the VLA-FIRST catalog for potential radio counterparts to Ultraluminous X-ray source (ULX) candidates. Five radio sources (two in NGC 4490 and one each in NGC 4631, NGC 5194 and NGC 5775) with offsets between 0.4 and 4 arcsec from their Chandra positions were identified. Analysis of new and archival radio, infrared, optical, and X-ray observations of these sources are presented. We conclude the object in NGC 5775 and one of the objects in NGC 4490 are likely recent supernovae while the remaining three objects lack distinct optical counterparts and their nature remains uncertain.

**Notes:**

## 7.3 Chandra X-ray Survey Results of Galactic Center Fields

JaeSub Hong, Jonathan Grindlay, Maureen van den Berg, Silas Laycock, Xavier Koenig, Ping Zhao, Eric Schlegel (Harvard-Smithsonian Center for Astrophysics)

We present the X-ray survey results of the Galactic Center (GC) fields, which include deep Chandra observations of three low extinction windows (see paper by van den Berg et al. for a detailed description of these three fields) near the GC, and the Chandra archival data of Sgr A (750 ksec) and Sgr B2 field (100 ksec). The X-ray source populations in the GC fields may provide insights on the formation and evolution of the Galaxy, the Galactic Bulge and the supermassive blackhole in the center. The low extinction windows allow unique opportunities to study the bulge population directly without absorption through the molecular clouds. We classify the X-ray sources by quantile analysis, and drive logN-logS and spatial distributions according to the spectral types of the X-ray sources in order to understand their nature.

**URL:** `http://hea-www.harvard.edu/ChaMPlane/`

**Notes:**

## 7.4 Deep O/IR Survey of Chandra Galactic Bulge Fields

Silas Laycock, Jonathan Grindlay, Ping Zhao, Maureen van den Berg, JaeSub Hong , Xavier Koenig, Eric Schlegel (Harvard-Smithsonian Center for Astrophysics)

We report on progress in our deep infrared and optical survey of archival Chandra fields in the Galactic Bulge, which we are conducting as part of ChaMPlane (The Chandra Multiwavelength Plane Survey). From our analysis it appears that the extraordinary cluster of hard X-ray point sources in the inner Bulge (central 10x10 arcmin) are dominated by faint low-mass systems. Fewer than 10X-ray Binaries on statistical grounds. We will present preliminary results of a much larger survey of 1.5x0.5 degrees using the CTIO 4m telescope with ISPI and Mosaic imagers to conduct an O/IR counterpart search for Chandra X-ray sources in the Bulge as well as in the foreground Galactic Plane.

**Notes:**

## 7.5 ULXs in the Chandra Observations of the Interacting Galaxies NGC 7714/15

Michael Nowak (MIT-CXC), Beverly Smith (ETSU), Curt Struck (Iowa State Univ.)

We recently have obtained a 60 ksec Chandra observation of the interacting galaxy pair NGC 7714/7715 (Arp 284), which at only 37 Mpc ($H_0 = 75$km s$^{-1}$ Mpc$^{-1}$) is relatively nearby (significantly closer, for example, than the Cartwheel galaxy). In this paper, we concentrate on our results for the ultraluminious X-ray source (ULX) population. In addition to an unresolved starburst nucleus, we detect a variable, $L_{\rm x} \approx 10^{40}$ ergs s$^{-1}$ point source 270 pc to the northwest of the nucleus, coincident with a blue, extremely optically luminous ($M_V \approx -14.1$) point source on Hubble Space Telescope images. Eleven other candidate pointlike ULXs were also detected in the vicinity of NGC 7714/7715. Two of these exceed $10^{40}$ergs s$^{-1}$, and are among the brightest ULXs ever observed, and one of which, when compared to archival XMM observations, shows evidence of long term (month), large amplitude changes in flux. Additionally, one of the ULXs exhibits evidence for a short time scale (20 sec) flare. Ten of the ULXs appear to be associated with interaction-induced features, but interestingly only two are associated with currently active star formation regions. We then briefly discuss the X-ray emission associated with four extranuclear $H_{II}$ region complexes. In galaxies much more distant than NGC 7714, for example, the Cartwheel galaxy, similar $H_{II}$ region complexes would be unresolved by Chandra, and could mimic ULXs.

**Notes:**

## 7.6 Chandra Observations of the Nearby Face-on Sd Spiral Galaxy NGC 45

Thomas Pannuti (Spitzer Science Center/JPL/Caltech), Eric Schlegel (Univ. of Texas-San Antonio), Douglas Swartz (USRA/MSFC), Christina Lacey (Univ. of South Carolina)

We present the results of our Chandra observations fo the nearby face-on spiral Sd galaxy NGC 45. We have observed this galaxy as part of our study of supernova remnants in a sampe of nearby galaxies. The effective total exposure time of the observations was approximately 50 kiloseconds and we have detected approximately 20 discrete sources within the optical extent of the galaxy. We have searched for counterparts to the detected sources at multiple wavelengths: this search has included comparisons with known young star clusters and HII regions associated with this galaxy, foreground Galactic stars and background galaxies seen through the disk of NGC 45. We have also performed an analysis of the spectral properties of the brightest X-ray sources seen in this galaxy that were sampled by the observations. Initial results of this work will be presented and discussed.

**Notes:**

## 7.7 Chandra Observations of the X-Ray Point Source Population in NGC 4636

Jennifer Posson-Brown, Christine Jones, William Forman (SAO), R. Hank Donnelly (SAO/CNA), Somak Raychaudhury (Univ. of Birmingham), Stephen Murray (SAO)

We present results from four *Chandra X-ray Observatory* observations of the X-ray point source population in the nearby Virgo elliptical galaxy NGC 4636. These observations, totaling roughly 210 ks, were taken with the Advanced CCD Imaging Camera over a four year period. Using a wavelet decomposition detection algorithm, we detect over 200 individual point sources above a limiting luminosity of approximately $3 \cdot 10^{37}$ ergs $s^{-1}$ (outside the central bright core). Approximately 20% of sources in the common field of view were not detected in all observations, implying long-term variability or transience. We present a luminosity function for NGC 4636, as well as a radial source density profile, hardness ratios for the sources, and lightcurves for several sources which display short-term variability. We estimate the number of AGNs in the field based on *Chandra* Deep Field studies, and give optical identifications for sources associated with globular clusters.

This work was supported by NASA contract NAS8-39073, the CXC and the Smithsonian Institution.

**Notes:**

## 7.8 Multi-colored X-ray Sources in Spiral Galaxies

Andrea Prestwich, Roy Kilgard (SAO)

Spiral galaxies contain a multitude of X-ray sources. In this paper I show that the brightest sources can be classified according to X-ray color into two main categories: those that have X-ray colors characteristic of Low Mass X-ray Binaries and a population of softer sources that are clearly associated with star forming regions. The differential luminosity functions of these two populations are different. The "LMXB" sources have an X-ray Luminosity Function (XLF) very similar to the XLF of sources in elliptical galaxies, whereas the XLF of the "soft" sources is a single power law with a slope consistent with the cannonical value for High Mass X-ray Binaries. These latter sources are probably black hole/neutron star binaries with a high mass donor in a high/soft state.

**Notes:**

## 7.9 The Low-Mass X-ray Binary - Globular Connection in the HST ACS Virgo Cluster Survey

Gregory Sivakoff, Craig Sarazin (Univ. of Virginia), Andres Jordan (ESO / Oxford Univ.), Elizabeth Blanton (Boston Univ.), Patrick Cote, Laura Ferrarese (HIA / Rutgers Univ.), Jimmy Irwin (Univ. of Michigan), Adrienne Juett (Univ. of Virginia)

With the sub-arcsecond resolution of Chandra, a strong association between low-mass X-ray binaries (LMXBs) and globular clusters (GCs) has been established in early-type galaxies (20-70 GCs). Most of this association has been based on GC lists generated from ground-based observations, which can not resolve GCs at Virgo, or, HST-WFPC2 observations, which have small field-of-views. With the HST ACS Virgo Cluster Survey (VCS), a uniform sample of the GCs in the central 3 arcmin times 3 arcmin of 100 early-type galaxies has been created that contains not only positions and magnitudes, but also structural parameters. We present initial results of a study using this superior list of GCs and archival Chandra observations of LMXBS in a sub-sample of the HST ACS VCS to probe aspects of the LMXB-GC connection.

**Notes:**

## 7.10 The X-ray Transient Population of M31

Benjamin Williams, Michael Garcia, Jeffrey McClintock, Frank Primini, Stephen Murray (SAO)

Through an ongoing Chandra and HST snapshot campaign, we have been studying the X-ray transient population of M31. The observations have provided 5 years of X-ray variability information and high-resolution optical photometry coordinated with several bright transient events. Many Galactic X-ray binaries that exhibit outbursts similar to these events are known to contain black holes. These sources in M31 therefore offer an excellent opportunity to significantly expand the sample of known black hole binaries. The combined power of X-ray spectra and optical photometry provides new clues about the physical properties of the binary systems responsible for these outbursts in M31, and studies of the entire sample of M31 transient sources yield some of the first comparisons between the Galactic population and that of another galaxy with similar size and morphology.

**Notes:**

## 7.11 Chandra/HST Survey of Low-extinction Windows in the Galactic Bulge

Maureen van den Berg, Josh Grindlay, JaeSub Hong, Silas Laycock, Ping Zhao, Xavier Koenig (Harvard-Smithsonian Center for Astrophysics), Haldan Cohn, Phyllis Lugger (Indiana Univ.), Eric Schlegel (Univ. of Texas)

We present results of our deep, near-simultaneous Chandra/HST observations of three low-extinction windows in the Galactic Bulge. With positions progressively closer to the Galactic Center (GC), these windows are used to constrain the radial gradient of low-luminosity point sources towards the GC. We detect a group of hard sources - some with candidate optical counterparts - out to Baade's Window, and discuss this population in the context of our extensive optical/infrared survey to understand the nature of the numerous low-luminosity, hard sources in the GC region.

**Notes:**

## 7.12 X-ray Binary Populations in Nearby Star-forming Galaxies

Andreas Zezas, Giuseppina Fabbiano (Harvard-Smithsonian Center for Astrophysics), Francois Schweizer (OCIW), Vicky Kalogera (Northwestern University), Martin Ward (Univ. of Durham), Roy Kilgard (Harvard-Smithsonian Center for Astrophysics),

We present results from our Chandra monitoring campaign of the Antennae and M82 galaxies as well as a sample of nearby galaxies (NGC55, NGC1569, NGC4214 and NGC5253) spaning a range of star-formation histories. We discuss the spectral and temporal characteristics of the sources in these different galaxies, and their implications for the sources' nature. We find that the X-ray sources follow diverse spectral variability patterns suggesting that they belong to different populations or long term states. This diversity is also observed within the class of Ultra-luminous sources. The discrete sources are in their majority associated with young star clusters, indicating that they are High Mass X-ray binaries. Finally, we present the X-ray luminosity functions (XLF) of the discrete sources from the individual as well as the co-added observations and we discuss the effect of source variability on the shape of the luminosity function. By comparing the XLF of the Antennae, M82, and the sample of nearby galaxies spaning a range of star-formation histories (from young to post star-bursts), we discuss how the XLF depends on the stellar populations of different ages.

**Notes:**

# 8 SN, SNR and Isolated Neutron Stars

## 8.1 Evidence of an Inverse Compton Origin for the TeV Emission from G347.3-0.5

Glenn E. Allen, John C. Houck (MIT Kavli Institute), Thomas G. Pannuti (Caltech), Steven J. Sturner (USRA/NASA-GSFC)

Gamma-ray spectra of the supernova remnant G347.3-0.5 have been published by the CANGAROO and HESS collaborations. Several analyses of the CANGAROO data have been reported. Here we present the results of a joint spectral analysis of the HESS data, some XMM X-ray data and some ATCA radio data. The X-ray and radio data were fitted with a synchrotron radiation model. Inverse Compton scattering, nonthermal bremsstrahlung and neutral-pion decay models were fitted to the gamma-ray data. The results of these analyses suggest that the HESS spectrum is dominated by inverse Compton scattered photons.

**Notes:**

## 8.2 Fe-Rich Supernova Remnants DEM L238 and DEM L249: A Challenge for Standard Type Ia Explosion Models?

Kazimierz Borkowski (North Carolina State Univ.), Sean Hendrick (Millersville Univ.), Stephen Reynolds (North Carolina State Univ.)

We present observations of two Large Magellanic Cloud (LMC) supernova remnants (SNRs), DEM L238 and DEM L249, with CCD imaging detectors onboard Chandra and XMM-Newton X-ray satellites. Bright central emission, surrounded by a faint shell, is present in both remnants. Spectra of central emission are dominated by strong Fe L-shell lines, with the deduced Fe abundance far in excess of solar and not consistent with the LMC abundance. This Fe overabundance and a low observed O/Fe abundance ratio lead to the conclusion that DEM L238 and DEM L249 are remnants of thermonuclear (Type Ia) explosions. Elemental abundances in the shell are consistent with standard (0.4 solar) LMC abundances, and the shell emission originates in gas swept up and heated by the blast wave. The faint shells observed in these remnants are in stark contrast to the bright shells seen in the LMC remnants DEM L71 and SNR 0548-70.4 also known to be of Type Ia. A standard Sedov analysis implies about 50 solar masses in the swept-up shell, SNR ages between 10,000 and 15,000 yr, low ($< 0.05$ cm$^{-3}$) preshock densities, and subluminous explosions with energies of $3 \times 10^{50}$ ergs. By modeling the central Fe-rich emission with plane-parallel heavy-element shock models, we find very long ($\sim 10^{12}$ cm$^{-3}$ s) shock ionization ages. We performed 1-D hydrodynamical simulations of the interaction of 1.4 solar masses of supernova ejecta, assumed to consist of pure Fe and distributed in an exponential density profile, with a uniform ambient interstellar medium with densities as determined from the Sedov analysis. Thermal X-ray spectra have been calculated for these hydrodynamical models using nonequilibrium ionization spectral codes. The predicted Fe L-shell emission is much weaker (by an order of magnitude or more) than observed, and ionization ages are too short. This problem persists for more realistic Type Ia 1-D explosion models of Badenes et al. These standard Type Ia SNR models cannot explain strong Fe L-shell emission with long ionization ages present within faint shells of X-ray emitting swept-up ambient gas. We discuss possible solutions to this prob-

lem, including inhomogeneous clumpy ejecta and the hypothetical presence of dense circumstellar medium around Type Ia supernova progenitors.

**Notes:**

## 8.3 Images of a Moving Neutron Star

Andrea DeLuca, Patrizia Caraveo, Fabio Mattana, Alberto Pellizzoni (INAF, IASF-Milano-Italy), Giovanni Bignami (CESR, Toulouse-France),

A deep (100 ks) XMM-Newton observations of Geminga has shown two faint parallel tails of diffuse X-ray emission, extending for 2' behind the pulsar, well aligned with the proper motion (PM) direction. Such a structure is most likely due to electron synchrotron radiation in the bow-shock between the pulsar and the surrounding medium. We report here on the results of a recent 20 ks Chandra observation which enveil a new structure on a much smaller angular scale: a Trail of diffuse emission, 25" long and 5" thick, starting at the pulsar positionn and perfectly aligned with the PM direction, with a surface brightness 40 times higher than the Tails' one. The Trail has a remarkably hard spectrum (photon index $\sim 0.9 - 1.4$) and a luminosity of $\sim 5.5x10^{28}$ erg $s^{-1}$, comparable to the energetics of the larger Tails. Geminga is thus the first neutron star to show X-ray evidence of a large scale bow-shock as well as a jet-like, collimated short Trail.

**Notes:**

## 8.4 The Chandra/XMM-Newton View of the Eastern Cygnus Loop Supernova Remnant

Terrance Gaetz (SAO), William Blair (Johns Hopkins), Richard Edgar, Paul Plucinsky, Manami Sasaki, John Raymond (SAO)

The XA region in eastern Cygnus Loop supernova remnant is the site of an advanced cloud-shock interaction, including a range of shocks from radiative to partially radiative to nonradiative shocks. It has been well studied in the optical, UV, and IR, and is the target of upcoming *Spitzer* observations. It is also one of the brightest soft X-ray regions in the remnant, dominated by O VII and O VIII emission and even softer emission in places. We have imaged the region with *Chandra*, providing a deep, high spatial resolution image. We also observed it with the *XMM-Newton* RGS (and simultaneously with EPIC-MOS), providing low spatial resolution but high spectral resolution data. The *Chandra* data shows the structure of the bright, compact "XA" knot, and details of the the shock-cloud interaction. The RGS spectrum shows the distribution of C VI Ly$\alpha$ alpha emission, and partially resolves the O VII He-like triplet for the bright, compact X-ray knot. We analyze and compare these complementary datasets making use of the recent improvements in the calibration of the low energy responses.

This work was supported by NASA grants G01-2060X and NAG5-9978, and by NASA contract NAS8-03060.

**Notes:**

## 8.5 Chandra Observations of Several Radio Pulsars

Oleg Kargaltsev, George Pavlov, Gordon Garmire (Penn State Univ.), Divas Sanwal (Johns Hopkins Univ.)

X-ray observations of spin-powered pulsars (PSRs) provide valuable diagnostics of emission mechanisms and acceleration processes operating in pulsar magnetospheres and winds. We present the results from ACIS observations of several radio pulsars that belong to different categories of the diverse pulsar population. These include the 5-Myr-old "nulling" pulsar B1133+16, 200-kyr-old PSR J1825-1446, 20-kyr-old PSR B1800-21 with a pulsar-wind nebula (PWN), the famous 1-Gyr-old PSR B1257+12 with a planetary system, and a few others. The pulsars exhibit different X-ray spectral slopes suggesting that the contribution of polar cap thermal emission may become more important as pulsar ages. Although the pulsar X-ray luminosities generally correlate with the spin-down power $\dot{E}$, a strong scatter in the $L_x$ vs. $\dot{E}$ dependence suggests that other factors (e.g., the magnetic field geometry and orientation of magnetic and spin axes) are equally important. A compact 10"-size PWN around PSR B1800-21 shows a bow-shock-like morphology reminiscent of those found for several other PWNe. To provide a more complete picture, we compare our results with those from other Chandra observations of spin-powered pulsars.

**Notes:**

## 8.6 HETGS Observation of Cas A: Looking at the Trees in the Forest

Jasmina Lazendic, Daniel Dewey (MIT Kavli Institute)

Cas A is the largest supernova remnant (SNR) observed with the Chandra High Energy Transmission Grating Spectrometer (HETGS) to date. High resolution X-ray spectra extracted for many bright, narrow regions of Cas A provide unique insights into their kinematics and plasma state. From the dominant emission lines of H- and He-like silicon and sulfur we derived unambiguous, accurate Doppler shifts of up to 4000 km/s which agree well with transverse-velocity measurements (DeLaney 2004.) Plasma diagnostics of these regions indicate temperatures largely around 1 keV, which we model as O-rich reverse-shocked ejecta using as well the non-dispersed zeroth-order data. In this poster we present and discuss our results including some of the challenges we face in HETGS data reduction of such an extended, complex object.

**Notes:**

## 8.7 The Massive, Young, Galactic Star Cluster Westerlund 1

Michael Muno (UCLA) J. Simon Clark (Open University), Paul Crowther (Sheffield), Sean Dougherty (Dominion Radio Astr. Obs.), Richard de Grijs (Sheffield), Casey Law (Northwestern), Stephen McMillan (Drexel), Mark Morris (UCLA), Ignacio Negueruela (Universidad de Alicante), David Pooley (Berkeley), Simon Portegies Zwart (Astronomical Institute Anton Pannekoek), Farhad Yusef-Zadeh (Northwestern),

We report Chandra observations of the massive, young Galactic star cluster, Westerlund 1. First, we describe a slowly-rotating X-ray pulsar (period 10.6 s) that we discovered within the cluster. Optical spectroscopy reveals that the cluster contains main sequence stars with initial masses of 35 Msun, and that the cluster is no older than 5 Myr. At this age, only stars with initial masses $> 40$ Msun could have undergone supernova. Therefore, the progenitor to the neutron star was initially at least this massive. Second, describe a search for diffuse X-rays from recent supernovae, from shocks produced by the collective winds of the $> 25$ member WR stars, and from unresolved pre-main sequence stars with $M < 3$ Msun. Very little diffuse emission is seen, which suggests that the initial mass function of the cluster is truncated at low masses.

**Notes:**

## 8.8 Reverse Shock Processing of Ejecta in Cassiopeia A

Daniel Patnaude (Harvard-Smithsonian Center for Astrophysics),
Robert Fesen (Dartmouth College)

Cassiopeia A was observed with Chandra for 50 ksec in 2000 and 2002, and for 1 Msec in 2004. We note several X-ray knots located at the reverse shock which exhibit measurable intensity changes over the 4 years worth of observations. I will summarize the results from our spectral analyses of these regions and compare them to hydrodynamical models for reverse shock interactions with non-uniform ejecta.

**Notes:**

## 8.9 CHANDRA Observations of the Eastern Limb of the Vela Supernova Remnant

Paul Plucinsky (Harvard-Smithsonian Center for Astrophysics), Randall Smith (JHU/GSFC), Terrance Gaetz (Harvard-Smithsonian Center for Astrophysics), William Blair (Johns Hopkins Univ.), Patrick Slane, Richard Edgar (Harvard-Smithsonian Center for Astrophysics)

We present results from two Chandra/ACIS observations of the so-called Vela Bullet D region on the eastern limb of the Vela supernova remnant. The Bullet D region is a bright X-ray feature identified in the ROSAT All-Sky Survey, which protrudes beyond the blast wave on the eastern side of the remnant. It has been suggested that this feature is a fragment of supernova ejecta which is just now pushing beyond the position of the main blast wave. An alternate explanation is that the feature is a break-out of the shock in which inhomogeneities in the ambient medium cause the shock to be non-spherical. The Chandra image shows a fragmented, filamentary morphology within this region. The Chandra spectra show strong emission lines of O, Ne, and Mg. Equilibrium ionization models indicate that the O and Ne abundances are significantly enhanced compared to solar values. However, non-equilibrium ionization models can fit the data with solar O abundances and Ne abundances enhanced by only a factor of two. We will discuss the implications of the Chandra spectral results for these two possible explanations and compare to recent theoretical work on the structure and evolution of large fragments of ejecta.

**Notes:**

## 8.10 Chandra Observations of the Compact Shell Supernova Remnant G15.9+0.2

Stephen Reynolds, Kazimierz Borkowski (NC State Univ.), Ilana Harrus, Una Hwang, Robert Petre (NASA/GSFC)

We report a 30 ks *Chandra* observation of the compact shell supernova remnant G15.9+0.2. The morphology resembles that seen in radio. High absorption ($N_H \sim 4 \times 10^{22}$ cm$^{-2}$) suggests that the remnant is at least as distant as the Galactic Center, though no other distance information is available. The integrated spectrum shows very strong lines, and simple spectral models (single nonequilibrium-ionization component, plane shock, Sedov blast wave) all require elevated abundances, especially of sulfur, to describe the data. A plane-shock fit gives $kT = 0.9$ $(0.8, 1.0)$ keV, an ionization timescale $\tau = 6$ $(4, 9) \times 10^{10}$ cm$^{-3}$ s, and a sulfur abundance of 2.7 (1.7, 2.7) times solar. Solar sulfur is ruled out at a high level of confidence ($\Delta\chi^2 = 72$). This requirement for enhanced sulfur persists even at the outer remnant edge. The integrated spectrum is softer toward the interior of the shell, and in the faint emission to the north. We conjecture that strong mixing in the shell has brought ejecta to near the blast wave around much of the remnant periphery. The observed X-ray flux gives an estimate of the electron density, $n_e \sim 3$ cm$^{-3}$, which implies a remnant age of order 1000 yr. A point source in the remnant interior contains about 120 counts ($\Rightarrow$ a count rate of $\sim 4 \times 10^{-3}$ ct s$^{-1}$), none below 1 keV; a simple absorbed power-law fit shows absorption consistent with that of the shell, and a photon index of $\Gamma \sim 5$. An absorbed black-body has $kT \sim 0.4$ keV with similar absorption. The unabsorbed flux is $\sim 10^{-13}$ cm$^{-2}$ s$^{-1}$ between 2 and 9.5 keV, implying a low luminosity of about $10^{33}$ erg s$^{-1}$ for a distance of 8.5 kpc. For thermal emission from a neutron star, this would represent only $\sim 0.1\%$ of the surface area. We suggest that this point source may be a neutron star associated with the remnant, most likely a rotation-powered pulsar. It seems clear that G15.9+0.2 is among the dozen or so youngest remnants in the Galaxy.

**Notes:**

## 8.11 Chandra and CO Observations of the Shock-cloud Interaction in the Galactic SNR CTB 109

Manami Sasaki (Harvard-Smithsonian Center for Astrophysics), Roland Kothes (DRAO), Paul Plucinsky, Terrance Gaetz (Harvard-Smithsonian Center for Astrophysics), Christopher Brunt (Univ. of Massachusetts)

We report the detection of molecular clouds around the X-ray bright interior feature in the Galactic supernova remnant (SNR) CTB 109. This feature, called the Lobe, has been previously suggested to be the result of an interaction of the SNR shock wave with a molecular cloud and overlaps one of the CO clouds with significant 12CO emission located east of the Lobe. The velocity profiles of 12CO at various parts of the east cloud are well fit with a Gaussian. However, at the position where the CO cloud and the Lobe overlap, the velocity profile has an additional component towards higher negative velocities. The molecular hydrogen density in this part of the cloud is relatively high ($N_H 2 = 1.0 - 1.5e21$ cm-2), whereas the foreground absorption in X-rays ($N_H = 4.5e21$ cm-2), obtained from Chandra data, is lower than in other parts of the cloud and in other clouds. These results indicate that this cloud has been hit by the SNR blast wave on the western side, corroborating that the shock-cloud interaction caused the bright X-ray Lobe.

**Notes:**

## 8.12 Hydrodynamical Studies of the Shock-Shell Interaction in the Cygnus Loop

Jonathan Slavin, Terrance Gaetz (Harvard-Smithsonian Center for Astrophysics)

The Cygnus Loop supernova remnant has been studied extensively in X-rays and in several other wavebands. The X-ray and optical morphology of the remnant indicate that it is a cavity remnant, i.e. that the explosion occurred inside a low density bubble carved out of the interstellar medium by the progenitor star's stellar wind. Previous studies of particular regions of the remnant have used steady planar shock models to compare with the X-ray, optical and UV data, yet the relatively recent encounter of the shock with the cavity wall makes such models questionable. In an attempt to improve on these models, we use a numerical hydrodynamical code that includes cooling and non-equilibrium ionization to investigate the interaction of the SNR shock with the cavity walls. We produce X-ray spectra and compare with Chandra ACIS observations of shocks in the NE region of the SNR. This modeling will provide constraints on the shock speed and the morphology of the shell in the Cygnus Loop and give us insights into the shock-shell interaction. On a global level our study promises to improve our understanding of the coupling of supernova energy to the interstellar medium.

**Notes:**

## 8.13 Dust Destruction in Type Ia SNRs in the Large Magellanic Cloud

Brian Williams, Stephen Reynolds, Kazimierz Borkowski (North Carolina State Univ.), William Blair, Parviz Ghavamian, Ravi Sankrit (Johns Hopkins Univ.), Knox Long (STScI), John Raymond (Harvard-Smithsonian Center for Astrophysics), P. Frank Winkler (Middlebury College), R. Chris Smith, Sean Points (NOAO), Sean Hendrick (Millersville Univ.)

We present early results from an extensive survey of Magellanic Clouds supernova remnants (SNRs) with the Spitzer Space Telescope. We have obtained IR images of several type Ia SNRs in the Large Magellanic Cloud (LMC), with strong 24 micron detections of DEM L71, 0509-67.5, N103B, 0519-69.0, 0534-69.9, DEM L238, and 0548-70.4. A comparison of these images to Chandra broadband images shows a clear association with the blast wave, and not with internal X-ray emission associated with ejecta. Since emission for SNRs at these infrared wavelengths is primarily thermal radiation from dust heated by the plasma, we infer that no dust has formed in the SN ejecta; we are seeing ambient interstellar dust. We employ computer models for dust emission which use plasma parameters determined from X-ray analysis to predict fluxes at Spitzer wavelengths. We find that our models can only reproduce observed flux ratios from Spitzer's 24 and 70 micron cameras if dust grain destruction (sputtering) is included. Since grains are heated and sputtered by ions and electrons in the plasma, the plasma temperature and density must be determined from X-ray analysis, which, combined with the age of the remnant, give an estimate for the amount of dust sputtered. In DEM L71, for example, we find sputtering to reduce grain radii by $\sim$3-4 nm, destroying the smallest dust grains. Without sputtering, models overpredict our observed 24/70 micron flux ratios by factors of order 2. Absolute flux measurements at 24 microns also give us a total mass of dust in the remnant. For instance, in DEM L71, we find a total dust mass of about 0.03 solar masses, significantly lower than predictions assuming a constant dust/gas ratio in the LMC, consistent with the destruction of the smaller, more numerous grains. Substantial dust destruction has implications for gas-phase abundances, and we shall present X-ray spectral analyses for some of our remnants to investigate these implications.

We acknowledge support from NASA through Chandra and Spitzer grant programs.

**Notes:**

## 8.14 Mid-Life Crisis: New Chandra Results for Middle-Aged Supernova Remnants in the Magellanic Clouds

Rosa Williams, You-Hua Chu (University of Illinois, Urbana), Fred Seward (Harvard-Smithsonian Center for Astrophysics), John Dickel (University of Illinois, Urbana)

The Chandra Observatory represents a great leap forward in sensitivity and in spatial and spectral resolution. These advances have given unprecedented opportunities for detailed studies of the structure and composition of supernova remnants (SNRs) in the neighboring Magellanic Cloud galaxies. Notably, they have enabled the study of SNRs in their advanced evolutionary stages. We discuss our findings for a number of these middle-aged remnants, including key physical properties and probable progenitor types (Type Ia vs. Type II). In particular, we have discovered two candidate pulsar-wind nebulae (PWNe) and confirmed a third; in the latter case, we have also detected an X-ray point source associated with the PWN. Additionally, we have observed regions containing multiple SNRs, which allow us to witness their contributions to the multi-phase interstellar medium.

**Notes:**

## 8.15 Chandra Observations of RCW 89 at Two Epochs

Yoichi Yatsu, Nobuyuki Kawai, Jun Kataoka (Tokyo Institute of Technology), Keisuke Tamura (Nagoya Univ.), Wolfgang Brinkmann (Max-Planck-Institut fur Extraterrestische Physik)

We present two observation of the HII region RCW89 by Chandra in Aug 2000 and December 2004. RCW89 is part of the radio shell supernova remnant MSH15-52 which contains a 150 msec young pulsar PSR B1509-58. In X-ray band, RCW89 is composed of bright thermal knots embedded in tenuous non-thermal emission which extends from the pulsar wind nebula of PSR B1509-58. The location of the thermal knots at the terminus of the jet-like non-thermal feature suggests that these knots are powered by the jets from the pulsar. Based on the early Chandra observation, we found that the plasma clouds in RCW 89 aligned in a horse-shoe shape have temperatures and ionization parameters varying sequentially in clockwise direction, implying sequential heating.

We performed the second observation of RCW 89 with Chandra with RCW 89 at the aiming point, unlike the first one with RCW at 5 arcmin off-axis. The X-ray image which has higher spatial resolution and better photon statistics than the preceding observations allows us to discuss the morphology of the thermal plasma and the non-thermal emission more precisely. Furthermore, we study the dynamical evolution of the plasma clouds by comparison of the two images taken four years apart.

**Notes:**

# 9 Software and Calibration

## 9.1 On-orbit Performance of the Suzaku X-ray Imaging Spectrometer

Mark Bautz (MIT Kavli Institute) Suzaku XIS Team

The X-ray Imaging Spectrometer is the CCD imager aboard Suzaku, the X-ray obsevatory launched by the Institute of Space and Astrophysical Sciences of the Japan Aerospace Exploration Agency in July, 2005. We characterize the initial on-orbit performance of the instrument, compare its capabilities with those of Chandra and XMM/Newton, and present representative results from the early phase of mission.

**Notes:**

## 9.2 Error Analysis of HRC-I ECF Regions Applied to ACIS Data

Eli Beckerman, Diab Jerius (SAO)

In order to determine the errors associated with using HRC-I ECF tables on ACIS data, we raytrace a grid of off-axis observations with both HRC-I and ACIS-I at the aimpoint. We use two different approaches to determine the impact of using HRC-I ECFs on ACIS data. First, we compare the radii at which specific enclosed count fractions are reached on HRC and on ACIS. Second, we apply the HRC ECF regions to ACIS data and study the relative enclosed count fractions at those radii.

**Notes:**

## 9.3 New Features in ACIS Extract, a Semi-automated Package for ACIS Source Extraction and Spectral Fitting

Patrick Broos, Leisa Townsley, Konstantin Getman (Penn State Univ.)

We present examples of new features and facilities in ACIS Extract (AE), the IDL-based software package that helps to automate the extraction and spectral fitting of ACIS X-ray sources via calls to CIAO tools and to XSPEC. AE has been available to the Chandra community since February 2003. It has been used extensively within the ACIS team, for example on the Chandra Deep Fields, the Galactic Center, and on many star formation regions including the Chandra Orion Ultradeep Project.

In 2004 and 2005 development of AE has continued at a steady pace to support evolution in CIAO and to extend AE's capabilities. AE now supports extraction and fitting of diffuse emission regions, generating appropriately weighted ARFs and RMFs. It provides smart masking of point sources, choosing masks matched to source brightness to avoid unnecessary loss of any surrounding diffuse signal. Nominal extractions have been more fully automated, and recipes for complex extractions (including stacking for faint or undetected sources as well as annular extractions for piled up sources) have been provided. Support for the C-statistic in XSPEC has been added. Source characterization now includes a Maximum Likelihood image reconstruction of the neighborhood around each point source, adaptively smoothed light curves, median energy timeseries, and statistical errors on source positions. AE helps the observer decide which proposed point sources to accept by computing the probability that each source is a random fluctuation in the local background.

**URL:** `http://www.astro.psu.edu/xray/docs/TARA/ae_users_guide.html`

**Notes:**

## 9.4 A Software Tool for Analyzing ACIS Calibration Data

Gordon Garmire (The Pennsylvania State Univ.)

A JAVA-based software tool is commercially available that can be used analyze ACIS calibration data. The tool can be used to compute the gain and energy resolution for each CCD over preassigned areas of the CCD. The tool is available from Signostics, Inc. P. O. Box 780, Brookline, MA 02446-0006 and is called CCT & CCTA Version 2.0. Results from this software will be presented.

**Notes:**

## 9.5 An Improved HRC-I Degapping Correction

Michael Juda (CXC/SAO)

Event positions from the HRC are not telemetered to the ground rather, they must be reconstructed during ground processing using the telemetered data for each axis of: the number of the amplifie along the axis with the largest signal and the amplitude of the signal on that amplifier and the amplifiers on either side (the three-tap position algorithm). There is a loss of information in sampling the position this way that produces gaps in images where the event positions are calculated using the simplest centroiding algorithm: $X_{fine} = \frac{A_{i+1} - A_{i-1}}{A_{i-1} + A_i + A_{i+1}}$ These gaps are removed by applying additional corrections to the simple centroid. Recently the CXCDS changed the method for degapping the event positions from a fifth-order polynomial function of $X_{fine}$ to one based on a look-up table. This change was made to more easily be able to account for various non-ideal effects in the HRC electronics. The values in the look-up table can be populated using the polynomial functions however, improved degapping corrections can be determined in limited regions on the detector using observations of near-on-axis point sources. I will describe a method of determining degapping corrections by using the aspect solution to predict the source location on the detector surface and comparing this to the event position reconstructed with the simplest centroiding algorithm (RAW position). I will present an example of a HRC-I look-up table with improved degapping corrections over a limited region and demonstrate the improvement in the PSF of an on-axis source that results from its use.

**Notes:**

## 9.6 Recent ACIS CCD Irradiation Experiments

Beverly LaMarr, Marshall Bautz, Catherine Grant, Steve Kissel, Gregory Prigozhin (MIT), Steve Brown (GSFC)

We report results of recent ACIS CCD irradiation experiments aimed at understanding the effect of a possible future ACIS bakeout on detector performance. Six front-illuminated detectors were irradiated cold, and then subjected to simulated bakeouts. The CCDs were irradiated with protons ranging in energy from 100 keV to 400 keV and "baked out" at temperatures ranging from +0 C to +30C. After each irradiation and thermal cycle the CCDs were characterized at 5.9keV. We conclude that a future ACIS bakeout probably cause only a modest degradation in ACIS detector performance.

**Notes:**

## 9.7 Monitoring the Optical/UV Transmission of the HRC with Betelgeuse

Jennifer Posson-Brown, Vinay Kashyap (CXC/SAO)

We have carried out a comprehensive analysis of all Betelgeuse calibration observations obtained to date with the HRC. Betelgeuse is undetected in all of the individual observations as well as cumulatively. We find that the expected exposure time for detection is greater than 1 Ms for aimpoint observations for both HRC-I and HRC-S. We also find that the predicted count rate due to the UV/optical flux is sufficient to have already resulted in a detection for observations carried out over the thin filter regions at large off-axis angles of the HRC-S. The non-detections therefore suggest that the out-of-band response must be decreased, by a factor less than 0.3.

**Notes:**

## 9.8 The Chandra Bibliography Database

Arnold Rots, Sherry Winkelman, Sarah Blecksmith, Alaine Duffy, Melissa Cirtain (SAO)

The Chandra Data Archive (CDA) Operations team maintains a database of published articles related to the Chandra X-ray Observatory that we consider to be as nearly complete as practical. The records in the database are based on the holdings of the Astrophysics Data System (ADS). Where possible and applicable, articles are linked to specific observations. The database stores a variety of additional metadata on each publication, including the type of publication, whether or not refereed, publication date, association with particular spacecraft subsystems or software, a contents categorization, multi-wavelength information, and keywords associated with the article.

We will highlight five aspects of the database: - Its maintenance software - Access to Chandra data from the ADS - Access to ADS articles from the CDA - Integrated scientific searching of articles and observations through the database - Compilation of statistics

Since the beginning of 2005 the astronomical journals allow authors to insert direct links to archived observational data in manuscripts. As this feature gets more commonly used it will make maintenance of the bibliography database easier and it may allow limited inclusion of articles from astro-ph.

This work has been supported by NASA under contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the Chandra X-ray Center.

**URL:** `http://cxc.harvard.edu/cgi-gen/cda/bibliography`

**Notes:**

## 9.9 An Archive of Chandra Observations of Regions of Star Formation (ANCHORS)

Bradley Spitzbart, Natalya Bizunok, Scott Wolk (Harvard-Smithsonian Center for Astrophysics)

ANCHORS is a web based archive of point sources observed during Chandra observations of regions of star formation. It is designed to aid both the X-ray astronomer with a desire to compare X-ray datasets and the star formation astronomer wishing to compare stars across the spectrum. Automated pipeline processing ensures consistent analysis techniques for direct comparisons among clusters and observing epochs. Through cycle 5 the database contains about 60 Chandra fields yielding 10,000+ sources. The data consists of X-ray source properties including position, net count rates, flux, lightcurves and spectral fits using Raymond-Smith thermal plasma models. Multi-wavelength images and data are cross-linked to other archives such as 2MASS, Spitzer, SIMBAD, and ADS. Results are presented on-line with sorting, searching, and download functions via a HTML/XML interface. Scientifically, the range of star-forming regions available in ANCHORS advances our understanding of the progression of luminosity, variability, and flaring for various-mass stars. Additionally, the archive provides calibration metrics for monitoring the spacecraft and instrument performance during Chandra's lifetime. This project is supported by Chandra archival grant AR5-6002A and NASA contract NAS8-39073.

**URL:** `http://cxc.harvard.edu/ANCHORS/`

**Notes:**

## 9.10 The HRC-I Gain Map

Charles Wilton, Jennifer Posson-Brown, Michael Juda, Vinay Kashyap (CXC/SAO)

We have derived a gain map for the HRC-I based on laboratory and flight data. We use lab flat-field data at six energies to obtain median values of the gain, and combine to construct an average gain uniformity map. This gain map is then modified to match the on-axis PHA profile of AR Lac, using a raster of off-axis AR Lac calibration observations carried out at current flight voltage settings. The final gain correction map has been released and will be available in the Chandra CALDB.

**Notes:**

# 10 Solar System

## 10.1 Chandra X-ray Observatory Observations of the Jovian System

Ronald Elsner (NASA MSFC), Anil Bhardwaj (NRC-MSFC), Randy Gladstone (Southwest Research Institute), J. Hunter Waite (Univ. of Michigan), Tom Cravens (Univ. of Kansas), Peter Ford (MIT), Graziella Branduardi-Raymont, Gavin Ramsay (MSSL), Brian Ramsey (NASA MSFC)

Chandra X-ray Observatory (CXO) and XMM-Newton observations of x-rays from the Jovian system have answered questions that arose from early observations with the Einstein and Rosat X-ray Observatories, but in the process of vastly increasing our knowledge of x-ray emission from Jupiter and its environs they have also raised new questions and point to new opportunities for future studies. We will review recent x-ray results on the Jovian system, from the point of view of the CXO, and discuss various questions that have arisen in the course of our studies. We will discuss prospects for more observations in the immediate future, and how they might address open questions. Finally we will briefly descibe ways in which an imaging x-ray spectrometer in the vicinity of the Jovian system could provide a wealth of data and results concerning Jupiter's x-ray auroral and disk emission, elemental abundance measurements for the Galilean moons, and detailed studies of x-ray emission from the Io Plasma Torus.

**Notes:**

## 10.2 The Variable Compact Central Object in RCW103

Gordon Garmire, Audrey Garmire, George Pavlov (Penn State Univ.), Divas Sanwal (GSFC), David Burrows (Penn State Univ.), Vyacheslav Zavlin (Observatoire Astronomique, Strasbourg)

The Central Compact Object in the supernova remnant RCW103 has been observed since 1980 with a number of X-ray satellites and by Chandra since September 1999. A large outburst occurred between the first (1999 Sept 23) and second (2000 Feb 8) Chandra observation. The sources has slowly declined in intensity to near the preoutburst value with no evidence of a new brightening. The intensity was modulated by a 6.68 hour period and by a 1.67 hour period during a CC-mode observtion on 2002 March 3. The spectrum has remained relatively constant during the intensity changes. No high frequncy modulation of the intensity has been detected down to 0.2 ms. This appears to be a binary source with a low mass companion. No optical or IR counterpart has been detected so far.

**Notes:**

## 10.3 Detection of the Helium Focusing Cone in X-Rays

Bradford J. Wargelin, Jonathan D. Slavin, John C. Raymond, Paul P. Plucinsky, Vasili A. Kharchenko, Michael Juda, Richard J. Edgar, Alexander Dalgarno (Harvard-Smithsonian Center for Astrophysics), Ina P. Robertson, Mikhail V. Medvedev, Thomas E. Cravens (U. Kansas)

We have analyzed soft X-ray background (SXRB) data from seven Chandra observations of SN1999em in order to search for charge exchange (CX) emission from the helium focusing cone, a region on the downstream side of the Sun where the heliospheric neutral helium density is enhanced by gravitational focusing as the Sun moves through the Local Interstellar Cloud. Six of the observations looked through the heliospheric tail where neutral gas density is very low, but one of the observations looked through the helium cone while the Earth was positioned inside it. This last observation reveals enhanced SXRB emission (primarily from He-like and H-like oxygen) that arises from CX as highly charged solar wind ions collide with relatively dense neutral gas. From this we are able to measure the density of neutral helium in the cone, which is an important parameter in models of heliospheric CX and in estimates of its contribution to the SXRB.

This work is supported by NASA's Chandra X-ray Center (CXC) Archival Research Program under Grant AR4-5001X. BW, RE, MJ, and PP are also supported by NASA contract NAS8-39073 to the CXC.

**Notes:**

# 11 Stars and WD

## 11.1 Cataloging the Young Stars Around the Sigma Orionis Region

Nancy Adams, Scott Wolk (SAO), Fredrick Walter (SUNY at Stony Brook), William Sherry (NSO)

The Sigma Orionis region is a relatively nearby young star forming region. We have X-ray observations from Chandra and XMM, allowing us to study the X-ray luminosity of a well understood sample of pre-main sequence stars and detecting X-ray emission from known young brown dwarfs(BDs). The Sigma Ori cluster is uniquely suited to this study; it spans different stellar interior conditions, almost 3 orders of magnitude in mass, it is relatively close, almost dust free (5ONC), the proper angle to have a reasonable mix of stars with and without disks. Here we present the combined observations from the Chandra X-ray Observatory, XMM, and ground based photometry and spectra to study the probability of this area being a star formation cluster.

**Notes:**

## 11.2 Strip-mining the Coronal Graveyard

Thomas Ayres, Alexander Brown, Graham Harper (CASA)

In a series of *Chandra* programs, we have conducted High Resolution Camera (HRC-I) pointings on optically bright, but coronally dead, late-type giants and supergiants. So far, we have observed the red giants $\alpha$ Bootis (Arcturus: K1 III) and $\alpha$ Tauri (Aldebaran: K5 III), collecting 4 counts at the two detect circles combined (constituting a positive detection of the former, but not the latter); and (with more significant detections) the yellow supergiants $\alpha$ Aquarii (G2 Ib) and $\beta$ Aquarii (G0 Ib), members of the so-called hybrid chromosphere class. Previous *ROSAT* observations had been inconclusive: in the cases of $\alpha$ Boo and $\alpha$ Tau owing to lack of sensitivity; in the case of $\alpha$ Aqr due to a $38'$ mispointing; and for $\beta$ Aqr, because of a small positional discrepancy of the apparent source. The *Chandra* HRC-I, with its superior spatial resolution and sensitivity (and freedom from the CCD red leak), recorded positive detections of Arcturus (albeit only 3 counts) and $\alpha$ Aqr; and recovered faint emission at the location of $\beta$ Aqr, now well separated from the stronger source to the SE that dominated the earlier *ROSAT* image. The coronal $L_{\rm X}/L_{\rm C\ IV}$ luminosity ratios (or upper limit in the case of Aldebaran) of all four stars are extremely depressed relative to solar-type dwarfs, continuing the puzzling X-ray deficiency syndrome originally identified in late-F/early-G luminosity class III coronal giants of the Hertzsprung gap. One additional target—$\gamma$ Draconis (K5 III)—remains to be observed in the Cycle 6 part of the program; and new pointings on $\alpha$ Trianguli Australis (K2 I) and $\beta$ Indi (K1 II) are planned for Cycle 7.

**Notes:**

## 11.3 Close to the Dredge

Bill Ball, Jeremy Drake (SAO)

We present *Chandra* LETG measurements of the C/N abundance ratio in the corona of the giant in the active RS CVn binary $\lambda$ And (G8 III-IV +). We found a ratio by number $N(C)/N(N) \sim 3.1$, which is similar to its inferred original surface value and indicates that the products of main-sequence nuclear burning have not been significantly dredged-up. Comparison with evolutionary tracks indicate instead that the star, whose mass lies in the range $\sim$ 1.7-2.0$M_{\odot}$, is in a post dredge-up stage of evolution, near the base red giant branch. $\lambda$ And therefore poses a problem for standard stellar evolution predictions. We discuss this result in the context of C/N abundance ratios of other active binaries and possible implications for dredge-up theory, and speculate on mechanisms by which the $\lambda$ And giant might have avoided mixing its envelope with deeper processed layers as it evolved toward the cooler giant phase.

**Notes:**

## 11.4 Flare Analysis for Multiple Stellar Cluster Data from ANCHORS Database

Natalia Bizunok (Harvard-Smithsonian Center for Astrophysics), Megan Bruck (Williams College), Scott Wolk, Brad Spitzbart, Nancy Evans (Harvard-Smithsonian Center for Astrophysics)

We conduct a study of flares for multiple young stellar clusters using ANCHORS (An Archive of Chandra Observations of Regions of Star Formation) data and flare criteria derived previously from COUP (Chandra Orion Ultradeep Project). Stellar flares are strong disturbances in magnetic field structure in stellar atmospheres that result in violent outbursts of plasma and radiation. Understanding flares and identifying stars and young stellar objects that flare aids in understanding stellar magnetic field structures as well as evolution of protoplanetary disks and stellar environments. As a part of the ANCHORS database creation, we subject our sources' light curves to Bayesian Blocks analysis, which allows us to search for flaring behavior. While COUP presents a large catalog of stars with extensive variability sampling from the Orion Cloud region, ANCHORS data offers a complimentary sample from a variety of environments. We present the results of our study in a form of select light curves, detailed description of flaring detection algorithm, and a summary of flares found and some of their physical properties. The ANCHORS project is supported by Chandra archival grant AR5-6002A and NASA contract NAS8-39073.

**Notes:**

## 11.5 Simultaneous Chandra HETG and Radio Observations of the Decay of a Large Flare on the RS CVn Binary Sigma Gem

Alexander Brown, Thomas R. Ayres, Edmund Hodges-Kluck, Fonda Day (CASA, Univ. of Colorado), James E. Neff (College of Charleston), Rachel A. Osten (NRAO - Charlottesville)

During the period 2005 May 16-18 we obtained Chandra HETG spectra of the coronal emission from the 19.6 day orbital period RS CVn binary $\sigma$ Gem. Simultaneous with these X-ray observations we made a comprehensive set of radio observations using the VLA, VLBA, and MERLIN arrays and the Arecibo 305m telescope. The Chandra spectra were obtained in two 65 ksec segments and show the steady decay of a large X-ray flare. The most prominent spectral evolution is the decrease of a strong high temperature continuum, while the bulk of the dominant $10^7$ K plasma component maintains a nearly constant emission measure. We present a detailed description of the evolution of the coronal plasma during the two days of our Chandra observation. The radio observations show strong radio continuum emission at 3 and 20 cm varying independently from the X-ray emission with a strong radio flare, whose rapid onset occurs at 2005 May 17 16 hrs UT. Almost continuous radio monitoring was obtained using the VLA and MERLIN arrays. High time resolution 20 cm Arecibo observations were made during two 2.5 hour intervals, while the VLBA provided high spatial resolution imaging on both days of the Chandra observations. **Notes:**

### 11.6 X-ray Flares in Orion Low Mass Stars

Marilena Caramazza (Unversita‘ di Palermo), Ettore Flaccomio, Giusi Micela (INAF - Oss. Astronomico di Palermo), Fabio Reale (Unversita‘ di Palermo), Scott Wolk (SAO), Eric Feigelson (Penn State Univ.)

We present a study of X-ray variability of 250 COUP (Chandra Orion Ultradeep project) X-sources, associated with low mass stars (0.1-0.3 Msun). Using a method similar to that used by Wolk et al. (2005), we detect in these stars 270 flares and derive their frequency-intensity relation. Comparing this analysis with the results for solar type stars (0.9-1.2 Msun), we establish that, at $\sim$1Myr, low mass and solar type stars have very similar flares frequencies. The intensity distribution of flares for low mass stars is a power-law with index $\sim$2.2. We propose the following model/scenario: the light curves are entirely built by overlapping flares with a power-law intensity distribution, the intense ones are detected, the weak ones merge and form a pseudo-quiescent level, which we indicate as the characteristic level. Through several simulation set, we constrain the model parameters for every single light curve. The study of simulated light curves with the same analysis method used for real sources shows a good agreement between data and model.

**Notes:**

## 11.7 Eta Carinae: X-ray Line Variations during the 2003 X-ray Minimum

Michael Corcoran, Kenji Hamaguchi (USRA & XAL-NASA/GSFC), Kazunori Ishibashi (MIT), Ted Gull (NASA/GSFC), Augusto Daminel (IAGUSP), Julian Pittard (Leeds), Kris Davidson (UMN), Rob Petre (XAL-NASA/GSFC), Yousaf Butt (Harvard-Smithsonian Center for Astrophysics)

The nearby, superluminous star $\eta$ Carinae has been a mystery since its giant eruption in the 1840s. Based on periodic changes in the emission line spectrum, $\eta$ Car is now widely (but not universally) believed to be two stars bound in a long period, eccentric orbit. The presence of a companion star provides an in-situ probe of $\eta$ Car and may affect the atmosphere and perhaps even the evolution of the massive star. In mid-2003 $\eta$ Car underwent a minimum in its emission line spectrum, and in its X-ray emission. This event was observed by an unprecedentedly wide range of ground-based and space-based observatories, including 5 100-ksec HETGS observations, which arguably provide the most sensitive probe of this system. We describe the results of this campaign, focussing on the X-ray emission line changes, and show how these observations impact our understanding of the star and its evolutionary state.

**Notes:**

## 11.8 A Comparison of Fe XVIII and Fe XIX, EUV to X-Ray Line Ratios of Active Stars using Chandra Grating Observations

Priya Desai, Nancy Brickhouse, Andrea Dupree, Ronnie Hoogerwerf (Harvard-Smithsonian Center for Astrophysics)

Recent Fe XVIII and Fe XIX line observations of Capella (Desai et al. 2005) have shown significant discrepancies between modern theory and observations for the X-ray and EUV resonance lines. We investigate these lines further by analyzing a sampleof six active stars (Algol, AB Dor, Eps Eri, Capella, HR 1099, and Lambda And) also observed with the Low Energy Transmission Grating Spectrometer. The sample covers a range of coronal temperatures and will help shed light on these puzzling disagreements.

**Notes:**

## 11.9 X-ray Spectroscopic Signatures of the Extended Corona of FK Comae

Jeremy Drake, Sun Mi Chung, Vinay Kashyap (SAO), Heidi Korhonen (Astrophysikalisches Institut Potsdam), Adriaan Van Ballegooijen (SAO), Detlef Elstner (Astrophysikalisches Institut Potsdam)

High resolution *Chandra* X-ray spectra and surface Doppler images obtained from optical spectra of the rapidly rotating giant FK Com have been analysed in order to investigate links between coronal and surface magnetic structures. Net redshifts were detected at the $3\sigma$ level in the light of Ne X $\lambda 12.13$ amounting to $\sim 140$ km s$^{-1}$. Smaller shifts of $\sim 60$ km s$^{-1}$ at the $\sim 2\sigma$ level are seen in the X-ray spectrum as a whole, while the observed position of O VIII $\lambda 18.97$—the second strongest line in the spectrum after Ne X—is consistent with its rest wavelength. There is no statistical difference between redshifts during the first and second halves of the observation. Spectral line widths are most consistent with thermal broadening combined with rotational broadening at a scale height of $\sim 1R_\star$, though are also statistically consistent with surface rotational broadening. We interpret the results as indicative of pervasive emission at temperatures $<\sim 3 \times 10^6$ K, but with plasma at temperatures $>\sim 3 \times 10^6$ K residing predominantly in extended structures centred at phase $\phi = 0.75$ with a size similar to that of the star itself. The contemporaneous Doppler images of the surface of FK Com reveal active longitudes at phases $\phi \sim 0.6$ and 0.9. We speculate that extended coronal structures correspond to magnetic fields joining the two active longitudes which theoretical models predict are of opposite magnetic polarity. Such structures are supported by coronal potential field extrapolations of typical theoretical model surface magnetic field distributions.

**Notes:**

## 11.10 X-ray Evidence for a Pole-Dominated Corona on AB Dor

Jeremy Drake, Sun Mi Chung, Vinay Kashyap, David Garcia-Alvarez (SAO)

A fine analysis of spectral line widths and Doppler shifts employing Fourier transform and cross-correlation techniques has been applied to the *Chandra* HETG spectra of the rapidly rotating young star AB Doradus in order to investigate its coronal topology. We find no significant Doppler shifts that could be attributed to rotation of dominant coronal structures. Individual spectral line widths are statistically consistent with thermal broadening and formally require no rotational broadening, while the $1\sigma$ limit to rotational broadening corresponds to a compact corona restricted to latitudes $> 30$ deg. Fourier analysis suggests a small amount of additional rotational broadening is present consistent with a corona restricted to the poles, and excludes models with surface rotational broadening or greater. These results present direct spectroscopic evidence that the dominant coronal activity on rapidly-rotating active stars is associated with the dark polar spots commonly seen in photospheric Doppler images, and support models in which these spots are of mixed magnetic polarity.

**Notes:**

## 11.11 Chandra Observations of Open Cluster h Per

Nancy Remage Evans, Scott J. Wolk, Natalya Bizunok, Brad Spitzbart, Fred Seward, Scott Kenyon (SAO), Tom Barnes (Univ. of Texas), Jay Pasachoff (Williams)

We are analysing the 200 sources found in a 40 ksec observation of the open cluster h Per. The data are being processed with the ANCHORS pipeline which provides fluxes and low resolution X-ray spectra. For the stronger sources temperatures are derived from spectral fitting; for weaker sources interpretation is through quantiles. The luminosity distribution is discussed, including the effects of shallow sampling on the source population. The distribution of these properties on optical and infrared color magnitude diagrams is investigated for the cool pre-main sequence stars in this 10 Myr cluster.

**Notes:**

## 11.12 Chemical Composition and Geometry Diagnostics in High Resolution X-ray Spectra of T Tauri Stars

David Garcia-Alvarez, Jeremy Drake (Harvard-Smithsonian Center for Astrophysics), Paola Testa (MIT), Vinay Kashyap, Liwei Lin, Bill Ball (Harvard-Smithsonian Center for Astrophysics)

Chandra archival spectra of the weak-lined T Tauri Stars HDE 283572 and DoAr 21, and the classical T Tauri SU Aur have been analysed in order to investigate diagnostics of chemical composition and hot plasma geometry during flaring and quiescent states. Temperature-insensitive line ratios have been used to estimate the coronal abundance ratios Ne/O, Mg/Si, Si/S and Ca/Ar. Limits have been placed on plasma densities using transitions of He-like Mg. We also place limits on the strength of cold Fe fluorescence induced by X-ray irradiation of circumstellar disks. We discuss the results in the context of chemical fractionation, coronal structure and disk geometry in pre-main sequence stars.

**Notes:**

## 11.13 High Resolution Spectroscopy of the Super-saturated Contact Binary, VW Cep

David Huenemoerder, Paola Testa (MIT), Derek Buzasi (USAFA)

Short-period binaries represent extreme cases in the generation of stellar coronae via a rotational dynamo. Such stars are important for probing the origin and nature of coronae in the regimes of rapid rotation and activity saturation. VW Cep (P=0.28d) is relatively bright, partially eclipsing, and very active object. Light curves made from Chandra HETGS data show flaring and rotational modulation, but no obvious eclipses. Velocity modulation of emission lines indicates that the larger, more massive component dominates the X-ray emission. The emission measure is highly structured, having three peaks. Helium-like triplet lines give electron densities of about 3.0e+10 to 3.0e+11 /$cm^3$. The modulation, emission measure, and densities together suggest that the emitting structures are compact.

**Notes:**

## 11.14 New Spectral Models for Sirius B and HZ 43 and their Implication for the LETGS of Chandra

Jelle Kaastra (SRON), Thierry Lanz (Univ. of Maryland), Ivan Hubeny (Univ. of Arizona)

We have calculated new spectral models for the white dwarfs Sirius B and HZ 43. Both stars have been used widely as effective area calibration sources for soft X-ray missions, including the LETGS of Chandra. The new models take Compton scattering into account, a process that is unimportant for the global UV/optical spectrum but which diminishes the flux at the hardest X-rays significantly. Using these models together with the observed LETGS spectra of both stars allows us to refine the basic parameters of these stars as well as to re-calibrate the effective area of the LETGS. In particular at the longer wavelengths we find significant (¿20 percent) differences with the previously used effective area. In Sirius B, we find no evidence for significant amounts of helium in the atmosphere.

**Notes:**

## 11.15 High-resolution Imaging of the Mira AB Accreting System

Margarita Karovska, Eric Schlegel, John Raymond (Harvard-Smithsonian Center for Astrophysics) Warren Hack (STScI) Brian Wood (JILA)

Chandra's spatial and spectral resolution offers unprecedented opportunities for detailed studies of many astrophysical sources. Our recent observations of Mira AB demonstrate the power of Chandra's sub-arcsecond angular resolution by separating the components of this 0.6" interacting binary for the first time at X-ray wavelengths. Mira AB is the nearest symbiotic system composed of an evolved mass lossing AGB star (Mira A) and a wind accreting white dwarf.

In December 2003, Chandra ACIS observations detected a powerful soft X-ray outburst originating from the cool AGB star. This outburst is possibly associated with a jet-like activity, as evidenced by the extended structures in the X-ray and UV images of Mira A. Chandra also detected a bridge between the components showing that Mira B is accreting not only from the wind of the AGB star, but also via direct mass exchange. This was unexpected, because the components are separated by 70 AU and it has been assumed that the interaction between the components is only via wind accretion. We discuss the implications that these recent results have on our understanding of accretion processes in detached binaries and other wind accreting systems.

**Notes:**

## 11.16 X-ray Monitoring of the Rapid Pre-MS Accretion Episode of V1647 Ori

Joel Kastner (Rochester Inst. Technology), Nicolas Grosso (Lab Astrophys. Grenoble), Michael Richmond (Rochester Inst. Technology), David Weintraub (Vanderbilt Univ.), Ted Simon (Inst. for Astronomy, HI), Kenji Kamaguchi (NASA/GSFC), Hideki Ozawa (Lab Astrophys. Grenoble), Adam Frank (Univ. of Rochester)

Although it is widely accepted that low-mass, pre-main sequence (pre-MS) stars emit X-rays as a consequence of solar-like coronal activity (e.g., Preibisch et al. 2005, astro-ph/0506526), evidence is accumulating that X-ray emission also may be a direct result of mass accretion onto pre-MS stars (e.g., Kastner et al. 2002, ApJ, 567, 434; Schmitt et al. 2005, 432, L35). Perhaps the most striking example of such accretion-driven pre-MS X-ray emission is that of V1647 Ori. Chandra and XMM observations obtained before and shortly after this young stellar object underwent a spectacular, accretion-generated optical/IR outburst revealed a large, contemporaneous increase in X-ray flux (Kastner et al. 2004, Nature, 430, 429; Grosso et al. 2005, A&A, 438, 159). I describe the latest results from ongoing Chandra and XMM monitoring of V1647 Ori. These observations offer a unique opportunity to establish the timescale, variability, and spectral characteristics of accretion-enhanced X-ray emission from erupting YSOs, thereby probing star-disk interactions on size and temporal scales that are inaccessible to observations at longer wavelengths.

**Notes:**

## 11.17 The Darkest Bright Star: Chandra X-ray Observations of Vega

Deron Pease, Jeremy Drake, Vinay Kashyap (SAO)

We present X-ray observations of Vega obtained with the Chandra High Resolution Camera and Advanced CCD Imaging Spectrometer. After a total of 29 ks of observation with Chandra, X-rays from Vega remain undetected. We derive upper limits to the X-ray luminosity of Vega as a function of temperature over the range of $10^5 - 10^7$ K and find a 99.7upper limit as low as sim 2 times $10^{25}$ $ergs^{-1}$ at logT=6.2K. We also compare these new deeper observations with the limit derived from a re-analysis of *ROSAT* PSPC data. Our X-ray luminosity limit for Vega is still greater than predictions of post-Herbig Ae phase X-rays from the shear dynamo model proposed by Tout & Pringle for a Vega age of 350My. If the age of Vega is closer to 100Myr, as suggested by some indicators, our X-ray limit is then similar to Tout-Pringle model predictions. Current X-ray observations of Vega are therefore unable to discriminate between different scenarios explaining the X-ray activity of the convectively stable Herbig Ae/Be stars. Further progress is more likely achieved through X-ray observations of younger main sequence early-type A stars whose conjectured residual post-Herbig Ae phase X-ray activity would be significantly higher.

DOP, JJD, and VLK were supported by NASA contract NAS8-39073 to the Chandra X-ray Center during the course of this research.

**Notes:**

### 11.18 A New Paradigm for the X-ray Emission from the Winds of Hot Stars

Andy Pollock (European Space Agency XMM-SOC)

XMM-Newton observations of the O supergiant $\zeta$ Orionis have suggested a new framework for the interpretation of the X-ray spectra of hot stars. They probably originate far out in the wind in collisionless shocks behind which the exchange of energy between ions and electrons is so slow that electron heating does not take place. The observed plasma is not in equilibrium and an electron bremsstrahlung continuum is essentially absent. The excitation and ionization is more likely to be produced by protons whose thermalized post-shock velocities ensure appropriately high cross-sections. In general, the form of X-ray spectra in both single and binary stars is likely principally to be determined by the amount of post-shock electron heating: magnetically confined X-ray plasma in binary systems can evolve to high electron temperatures while in single stars this does not take place. The accumulated Chandra high-resolution data of hot stars are assessed in this new context.

**Notes:**

## 11.19 Invisible Giant: Chandra's Limits on X-rays from Betelgeuse

Jennifer Posson-Brown, Vinay Kashyap, Deron Pease, Jeremy Drake (SAO)

We have analyzed calibration observations of Betelgeuse ($\alpha$ Ori, M1 Iab, $m_V = 0.58$, 130 pc) performed by *Chandra* instruments. Betelgeuse is undetected in 8 ks of HRC-I, 8 ks of HRC-S, and 5 ks of ACIS-I data. We derive upper limits to its X-ray count rates for these observations by computing the counts necessary to obtain a $3\sigma$ detection in the presence of the observed background. We compute corresponding X-ray luminosity upper limits assuming isothermal coronal plasma over a range of temperatures, T = 0.3 - 10 MK. We place a limit as low as $L_x \sim 4 \cdot 10^{27}$ ergs $s^{-1} (L_x/L_{bol} \sim 4 \cdot 10^{-11})$ on the coronal luminosity of Betelgeuse, a limit roughly an order of magnitude lower than that obtained from ROSAT All-Sky Survey data.

This work was supported by NASA contract NAS8-39073 to the CXC.

**Notes:**

## 11.20 Chandra/HETGS Detection of Fluorescent X-ray Emission in the Flaring Single Giant HR 9024

Paola Testa, David Huenemoerder (MIT), David Garcia-Alvarez (SAO), Fabio Reale (Universita' di Palermo)

We present evidence of Fe 6.4 keV fluorescent emission in the Chandra/HETGS spectrum of the single G-type giant HR 9024 during a large flare. The unprecedented spectral resolution of Chandra/HETGS allows us to detect the weak fluorescent emission, and to distinguish it from the strong thermal Fe emission line complex near 6.7 keV. Constraints on geometry derived from the analysis of the fluorescent emission will be examined. The high flux provides us with line diagnostics at both high temporal and spectral resolution. Single line spectral diagnostics and lightcurves determine plasma temperature, emission measure, abundances, and density evolution during the flare. From this information, we can construct time-dependent hydrodynamic loop models to constrain loop morphology and heating.

**Notes:**

## 11.21 Chandra Observations of the Massive Stellar Cluster Trumpler 14 in Carina

Leisa Townsley, Patrick Broos, Eric Feigelson (Penn State Univ.)

We present the first high-spatial-resolution X-ray images and spectra of the massive cluster Trumpler 14, obtained in a single 57-ksec observation with *Chandra*/ACIS in March 2002. Tr 14 is an extremely rich, young ($\sim$1 My), compact OB cluster near the center of the Carina complex, containing at least 30 O and early B stars. This rich high-mass star-forming region reveals a complex mix of point source and diffuse X-ray emission. The OB association is resolved at the arcsecond level into more than 900 sources. HD 93129AB, a very early-type (O2I–O3.5V) binary, is resolved and the components are shown to possess very different X-ray spectra. Soft diffuse X-ray emission pervades the H II region and is resolved from the point source population. The extended emission that pervades Trumpler 14 is most likely from the fast O-star winds that thermalize and shock the surrounding media. We also see softer, bright diffuse emission in the off-axis CCDs of the ACIS array, far from any of the Carina massive clusters. A spectral fit to this diffuse emission requires high abundances of O, Ne, Si, and Fe; this is evidence that the emission may be from an old cavity supernova remnant that exploded inside the Carina superbubble.

**Notes:**

### 11.22 A Chandra HETGS Survey of O-Stars

Wayne Waldron (L-3 Communications GSI), Joy Nichols (SAO), Joseph Cassinelli (Univ. of Wisconsin), Nathan Miller (Univ. of Wisc. - Eau Claire), Nancy Evans (SAO), Nolan Walborn (STScI), Alex Fullerton (JHU), Pete Mendygral (SAO)

The high energy resolution capabilities of the Chandra HETGS are particularly useful for studies of X-ray emission from O-stars. The X-rays are believed to arise from within and/or below a moderately ionized, high density, rapidly expanding plasma flow. Model calculations predicted that the X-ray line profiles would be very broad, asymmetric, and highly blue-shifted. Although the line broadness is observed in several O-stars (typical HWHM $\sim$ 1000 km/s), the line profiles are found to be symmetric and to have minimal blue-shifts in essentially every O-star that has been observed, with one exception, the early O-star, Zeta Puppis. To understand these discrepancies between model predictions and observations, we were granted a Chandra Very Large Project to obtain HETGS data for several other early O-stars. Our O-star survey targets along with the HETGS archival data will provide complete coverage of the O-star domain in the H-R diagram. The collection will allow us to search for morphological trends in the emission lines as a function of stellar and wind parameters. These trends will guide the development of improved models to explain the behavior of the X-ray emission lines of O-type stars. In this poster, we present our preliminary results for the HETGS observations of three early O-stars (9 Sgr, HD93250, and HD93129AB), and we discuss the trends that are emerging from the data. We also address the question, is Zeta Puppis still the only O-star to display highly asymmetric and blue-shifted X-ray line profiles?

**Notes:**

## 11.23 Chandra Observation of Massive Star-Forming Complex NGC6357: the HII Region G353.2+0.9 and the Massive Open Cluster Pismis 24

Junfeng Wang, Leisa Townsley, Eric Feigelson, Gordon Garmire (Penn State Univ.)

We present the first high-spatial-resolution X-ray image of the massive star forming complex NGC 6357 at a distance of 2.5 kpc, obtained in a 40-ksec observation using the Advanced CCD Imaging Spectrometer (ACIS) on board Chandra. The OB association illuminating this HII region, Pismis 24, is one of the richest star clusters in the galaxy with eight O stars including two of the O3 stars. The cluster is resolved at the arcsecond level, ~800 point sources are detected, and more than half of them have optical/IR counterparts. X-ray emission was detected from ~20 O-type and early B-type stars, including two O3 stars and a Wolf-Rayet/O6 binary HD 157504, and from hundreds of pre-main-sequence stars. Given the exposure time and typical spectra (e.g., $\theta^1$ Ori C), Chandra can detect $10^{33}$ ergs/s O stars through heavy absorption (Av 50 mag). The nondetection of embedded O stars supports models where the HII region is ionized by the unobscured O stars in Pismis 24. One of the X-ray sources arises from a very young low-mass star, an evaporating gaseous globule (EGG) lying at the tip of an evaporating elephant trunk molecular structure.

Support for this work was provided to Gordon Garmire, the ACIS Principal Investigator, by the National Aeronautics and Space Administration (NASA) through NASA Contract NAS8-38252 and Chandra Contract SV4-74018 issued by the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of NASA under contract NAS8-03060.

**Notes:**

## 11.24 Chandra Observations of the RCW 108 Star Forming Region

Scott Wolk, Bradley Spitzbart, Tyler Bourke (SAO)

We present our recent Chandra observations of the embedded star forming region RCW 108. RCW 108 contains a deeply embedded young cluster lying in a dark cloud to the west of the young open cluster NGC 6193 (excited by two early O stars). Our motivation for this obsrvation was to followup on our discovery of diffuse X-ray emission in the older less embedded RCW 38. If the diffuse emission seen in RCW 38 is the result of plasma being trapped within the star forming region by overlaying molecular material, then RCW 108 should contain even more trapped plasma.

At 8-20 $\mu$m microns, the Midcourse Space Experiment Galactic Plane Survey data shows a ridge of warm dust passing through the eastern edge of the emission peak parallel to but west of an optical ridge. Our SEST mm continuum observations show a cold component to this dust ridge peaking strongly at the cluster. The far infrared luminosity suggests that there is more than one significant heating source, i.e., OB stars and/or intermediate mass protostars. The extended infrared nebulosity to the east of the main cluster is due to emission and not reflection, suggesting a break-out of radiation in this direction.

We detected 339 sources divided into 3 groups: A) $\sim$ 3 Myr Stars associated with the older star forming region, B) Stars still forming and C) background sources. Over 80 sources exceed 100 counts. 53 Sources are variable. ABout 175 have IR counterparts bright than K of 15.

The goals of the observations are to: 1) Study triggered star formation. 2) Investigate the origin and nature of diffuse X-ray emission within regions of massive star formation. 3) Identify deeply embedded PMS stars via their X–ray emission and derive an IMF and XLF. 4) Investigate the X–ray properties of the embedded sources.

**Notes:**

### 11.25 Star Formation in the Era of the Three Great Observatories: A White Paper

Scott J. Wolk (SAO), SOC and Attendees of the Workshop on Star Formation

At the behest of the Chandra Director's Office, a workshop was held 13-15 July 2005 entitled Star Formation in the Era of Three Great Observatories (http://cxc.harvard.edu/stars05). The goal of the workshop, which was co-sponsored by the Spitzer Science Center, was to develop a white paper which could serve as a roadmap for the field. We sought to review topics in star-formation which are inherently multiwavelength, and define both the current state of our knowledge and the points of current controversy where new observations are most needed. We focused on topics for which the Great Observatories (HST, Chandra and Spitzer) have the most to contribute during this unique period of simultaneous operation. We also considered observations from other facilities including radio and ground based optical in addition to theoretical work. We covered star formation in both galactic and local-group star forming regions. One of the goals we define for star formation is to understand how stars and their associated accretion disks are assembled from molecular material. We identified the following key areas of physics which highlight the complimentary aspects of the great observatories: 1)Stellar populations. 2)The formation and evolution of disk systems. 3)Rotation and dynamos.

**Notes:**

## 11.26 Chandra Spectroscopy of the 70 Oph and 36 Oph Binaries

Brian Wood, Jeffrey Linsky (JILA, Univ. of Colorado)

Last year Chandra resolved the nearby 70 Oph (K0 V+K5 V) and 36 Oph (K1 V+K1 V) binary systems for the first time in X-rays. The LETG/HRC-S spectra of all four of these stars are presented and compared with a higher S/N archival LETG spectrum of another K dwarf, Epsilon Eri. One particularly surprising finding concerns the relative coronal abundances of the two 70 Oph stars. The coronae and winds of the Sun and many solar-like stars have been found to have a curious abundance pattern where the abundances of elements with low first ionization potential (FIP) are enhanced relative to high FIP elements. Surprisingly, 70 Oph A shows a significantly stronger FIP bias than does 70 Oph B, despite these stars being nearly identical in almost all respects. They have the same age, the same rotation period (20 days), nearly identical coronal X-ray fluxes, and very similar spectral types. Any theoretical explanation for the FIP effect will have to explain how two stars so similar in all other respects can have coronae with different degrees of FIP bias.

**Notes:**

# 12 WD Binaries and CV

## 12.1 X-ray Binaries in Terzan 5

C. O. Heinke (Northwestern Univ.), R. Wijnands (Univ. of Amsterdam), J. E. Grindlay (Harvard Univ.), H. N. Cohn, P. M. Lugger (Indiana Univ.), P. D. Edmonds (Harvard Univ.), D. Pooley (UC Berkeley), W. H. G. Lewin (MIT)

Terzan 5 is a dense metal-rich globular cluster, containing a transient LMXB and large numbers of millisecond pulsars and low-luminosity X-ray binaries. We present results from a Chandra survey of this globular cluster, focusing on the implications for the physical nature of the X-ray sources.

**Notes:**

## 12.2 Time-Resolved X-Ray Spectroscopy of EX Hydrae

Ronnie Hoogerwerf, Nancy Brickhouse (Harvard-Smithsonian Center for Astrophysics), Chris Mauche (LLNL)

EX Hydrae is the brightest Intermediate Polar type cataclysmic variable in the sky. The 60 ks DDT HETG observation of EX Hya yielded a high signal-to-noise spectrum that made it possible to measure the first x-ray radial velocity curve for a white dwarf and determine its mass independently from an accretion model. Furthermore, light curves versus the binary (97 min) and white dwarf (68 min) period revealed new features. The binary light curves require absorption by an ionized absorber whose charge state changes with binary phase. We rule out photoionization and interpret this charge state change as a temperature gradient in the accretion disk, perhaps from shocks. The white dwarf light curves for individual spectral lines formed at low temperatures (i.e. in the cool, low part of the accretion column) show sharp spikes. Using the standard model, we can derive the height above the white dwarf surface at which these lines are formed. These results demonstrate that, given sufficient signal-to-noise, X-ray spectroscopy will allow us to map the temperature and density structure of magnetic accretion columns.

**Notes:**

## 12.3 Comparison of Chandra and XMM-Newton Observations of R Aqr

Edwin Kellogg, Craig Anderson, Joseph DePasquale, Kelly Korreck, Joy Nichols (SAO), Jeffrey Pedelty (NASA-GSFC), Jennifer Sokoloski (SAO)

X-ray and VLA radio observations of R Aqr over the past several years have revealed a rich variety of phenomena, in addition to observations spanning decades in radio, optical and IR. These observations argue more and more strongly for a binary system with a compact companion, with an accretion disk, producing jets along the symmetry axis of the compact object or accretion disk. Chandra observations at epochs 2000.7 and 2004.0 show bright regions of $10^6$ K thermal x-ray emission 1400-5000 AU out from the center, aligned with a bipolar axis extending from the star at PA $\sim$145/325. In the Chandra observations there is Fe K line emission, consistent with an unresolved source at the star, its compact companion, or an accretion disk. A recent XMM-Newton observation of R Aqr was taken in 2005.5. We report on further evolution of the jets and Fe K lines. We also report on XMM RGS high resolution grating spectroscopy, resolving $\sim 10^6$ K line emission in the jets. We also see evidence for emission at higher energies in the 7.5-12 keV range for the first time.

**Notes:**

## 12.4 Chandra Observations of R Aquarii's Non-Relativistic Outer Jets

Kelly Korreck, Edwin Kellogg, Craig Anderson, Joe DePasquale, Joy Nichols, Jennifer Sokoloski (Harvard-Smithsonian Center for Astrophysics)

Two epochs of Chandra X-Ray observations of R Aquarii, combined with VLA radio data, reveal non-relativistic, evolving outer jets. The multi-wavelength spectral energy distribution indicates that the X-rays from the outer jet are thermal, in contrast with the inner jets, which are non-thermal (see Nichols et al, this conference). The outer-jet emission from both the northeast (NE) and southwest (SW) jets is compatible with shock heating of material ejected from the compact object in R Aquarii. The X-ray-bright region of the NE jet is moving outward with an apparent bulk velocity of 600 km/s, which is faster than the 150 km/s motion of the radio-bright portion of the jet. The jet in the NE is still a strong source of X-rays in the second epoch (2004.0), whereas the X-ray emission from the SW jet faded between 1999.8 and 2004.0. The disappearance of the southern outer X-ray jet is consistent with adiabatic expansion and cooling,implying a low density environment in the SW. New Chandra x-ray observations of the system will reveal greater details of the processes and environment driving the evolution of the outer jets.

**Notes:**

## 12.5 Chandra Observations of the Core and Inner Jet of R Aqr

J. Nichols, J. Sokoloski, E. Kellogg, C. Anderson, J. DePasquale
(Harvard-Smithsonian Center for Astrophysics)

R Aqr is a nearby jet-producing symbiotic binary-star system. Chandra spectra of the core of R Aqr reveal changes in the soft continuum, hard continuum, and Fe K lines on a time scale of years. The data also suggest possible rapid variability with a period of about 1700 sec in the Fe K lines. Such rapid variability must originate from very close to the wind-accreting white dwarf. The X-ray data also suggest that the accretion rate on the white dwarf in this system is variable. A new infant X-ray jet is identified in the Chandra data, and the power-law X-ray spectrum indicates that the emission from this new inner jet is non-thermal.

**Notes:**

## 12.6 Long and Short Term Time Variability in Supersoft X-ray Sources

Marina Orio (INAF-Torino, Italy and Univ. of Wisconsin), Elia Leibowitz (Tel Aviv Univ., Israel), Alon Retter (Penn State Univ.), Emre Tepedelenlioglu (Physics Dept., Univ. of Wisconsin), Paola Mucciarelli (Dept. of Astronomy, Univ. of Padova, Italy)

Supersoft X-ray sources, likely progenitors of type Ia SN, are an intriguing class of objects but they are still poorly understood. They are often variable on time scales of years, months, hours and even seconds. In the framework of a funded Chandra archival program we searched the whole data base of X-ray observations of these sources. Long term variability may be due to three different types of evolutionary phenomena: a) thermonuclear flashes, b) a wind originated when more mass is accreted than the rate for stable hydrogen burning, or c) irradiation effects triggering variations in mass transfer rate from the secondary. Short term variability, typically on many-minutes time scales, may be due to non radial oscillations of the white dwarf, or to its spin. We classified the variability of the different systems in order to find clues to their physical nature.

**Notes:**

# NESSIE Poster Abstracts

The New England Space Science Initiative in Education (NESSIE) posters will be displayed at the Museum of Science during the Symposium Dinner on Thursday evening.

# 13 NESSIE Posters

### Chandra in Out-of-School Time: Science Learning Opportunities for Urban Underrepresented Youth

Irene Porro, Mark Hartman (MIT Kavli Institute for Astrophysics and Space Research)

In the last five years the Education and Public Outreach office at the MIT Kavli Institute (MKI) (formerly MIT Center for Space Research) has been developing a comprehensive strategy to reach out to youth from groups underrepresented in STEM. Our overall goal is to first generate large-scale interest for astronomy and science among urban youth and then support the most motivated among them in the pursuit of STEM related learning and careers. The strategy we developed is the product of the experience and lessons learned from a series of after-school and summer programs funded through several Chandra EPO grants. Two complementary programs are the pivotal elements of the MKI EPO strategy: the After-School Astronomy Project (ASAP) and the Chandra Astrophysics Institute (CAI).

ASAP is a comprehensive initiative designed to promote the pursuit of science learning among underrepresented youth. ASAP makes use of a modular curriculum consisting of a combination of hands-on activities and youth-led explorations of the night sky using MicroObservatory, a network of educational telescopes that can be controlled over the Internet. Through project-based investigations youth reinforce learning in astronomy and develop an understanding of science as inquiry, while also improving communication and computer skills. Through the professional development of qualified after-school workers we also contribute to building the capacity of urban community-based centers to deliver innovative science out-of-school programming to their youth.

CAI is a yearlong research program in x-ray astrophysics for extremely motivated high school students and their science and math teachers. The goal of the program is to enable students and teachers to use their own observations to engage in model building, testing and revising like practicing scientists. To this end CAI participants attend a 4-week summer institute at the MKI where they are introduced to relevant elements of physics and astrophysics and to the use of software tools for the analysis of x-ray data. The summer training enables students and teachers to work on actual research projects in x-ray astrophysics. The projects are then carried out during after-school time at their schools during the following school year, and results are presented at a community-wide science symposium.

**Notes:**

## Big Explosions, Strong Gravity: Making Girl Scouts ACEs of Space through Chandra E/PO Outreach

Ann Hornschemeier (NASA Goddard Space Flight Center)

Thanks to two years of Chandra E/PO funding we have carried out a number of successful activities with the Girl Scouts of Central Maryland, focusing on girls in the 11-17 year age range. Our reasons for targeting this age range include the general decline in interest in math and science that occurs at or after children reach this critical age (meaning that we reach them early enough to have a positive effect). Also, much of the relevant astrophysics is much better suited to grades 7-12 rather than grades K-6. We initially target girls due to their under-representation in science, but the activities are all gender-neutral and highly adaptable to other groups.

The program includes two components, in collaboration with Girl Scouts of Central Maryland. The first component is a well-established one-day Girl Scout patch activity entitled Big Explosions and Strong Gravity (BESG) where the girls earn a patch for their badge sash. The four BESG activities, mostly adapted from existing E/PO material, are available on the World Wide Web for use by others. The activities cover the electromagnetic spectrum as a tool for astronomy, the cosmic abundance of the elements and the supernova origin of many of the elements, black holes and their detection, and supernova explosions/stellar evolution. Thus far approximately 200 girls and their parents have participated in BESG and it has now become part of the council culture. The second activity is new and is part of the relatively new Girl Scout Studio 2B program, which is a girl-led program for the 11-17 year age range. Based on several meetings with small groups of girls and adults, we have formed a Studio 2B "club" called the ACE of Space Club (Astronomical Cosmic Exploration). We'll describe our experiences interacting with the Girl Scouts in this girl-led program.

**Notes:**

## The Penn State In-Service Workshops in Astronomy (PSIWA)

Christopher Palma, Niel Brandt, Eric Feigelson (Pennsylvania State Univ.)

The Department of Astronomy & Astrophysics at the Pennsylvania State University offered two workshops for upper elementary through high school science teachers during the summer of 2005. These workshops are part of the Penn State In-Service Workshops in Astronomy (PSIWA) program, which just completed its tenth year of providing teacher training workshops.

In collaboration with partners at the Pennsylvania Space Grant Consortium, faculty members Niel Brandt, Christopher Palma, and Eric Feigelson delivered workshops with the broad themes of Galaxies & Cosmology and Stars & Planets. The curriculum for the workshops is a mix of sessions designed to present modern astronomy content and inquiry-based activities for presenting that content in a classroom. An important addition to the program this year came from Pennsbury High School teacher and PSIWA alumnus Glenn Goldsborough. Glenn has attended both workshops in the past and incorporates much of the material that he learned into his own high school astronomy course. During our 2005 PSIWA program, Glenn returned to Penn State and worked with Brandt and Palma to present sessions on incorporating PSIWA content into a high school curriculum. Ten guest speakers, including Penn State Astronomy & Physics faculty, postdocs, and students as well as a scientist from NASA Goddard Space Flight Center also contributed their time to the workshop program.

Evaluation has played an important role in the history of the PSIWA program. Each year we have made changes to the program in response to the feedback from the educators who attend. In collaboration with a student from the PSU College of Education, a thorough evaluation of the program was conducted after the summer of 2004, which led to many changes for 2005. Based on a preliminary analysis of the 2005 evaluations, the overall ranking of the program improved based on these changes.

In this poster, an overview of the PSIWA program is presented. We acknowledge the support of the program from the Chandra and the Swift Education and Public Outreach programs as well as the Lockheed Martin Corporation.

**Notes:**

# Index