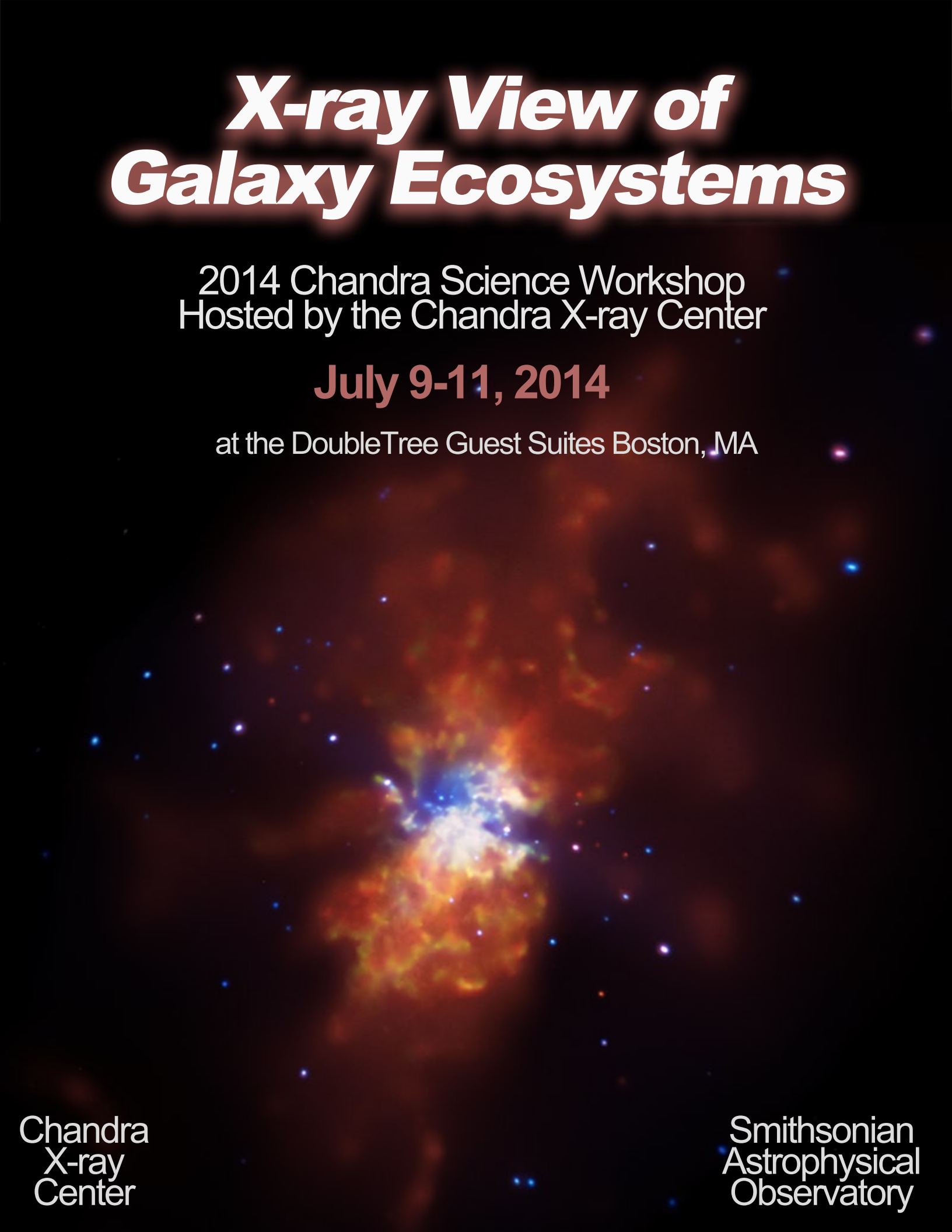
X-ray View of Galaxy Ecosystems

2014 Chandra Science Workshop
Hosted by the Chandra X-ray Center

July 9-11, 2014

at the DoubleTree Guest Suites Boston, MA



Chandra X-ray Center

Smithsonian Astrophysical Observatory

Scientific Organizing Committee:

SOC Chair: Dong-Woo Kim (SAO)
Giuseppina Fabbiano (SAO)
Ann Hornshemeier (GSFC)
John Mulchaey (Carnegie Observatories)
Kentaro Nagamine (UNLV / Osaka Univ)
Jerry Ostriker (Princeton)
Silvia Pellegrini (Univ of Bologna)
Andy Ptak (GSFC)
Craig Sarazin (Univ of Virginia)
Daniel Wang (Univ of Mass)

Local Organizing Committee:

Chair: Paul Green
Michelle Henson
Lisa Paton
Katy Wyman
Evan Tingle

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

Program

Wednesday, July 9

Opening Session

9:00 - 9:15 Paul Green and Belinda Wilkes
Welcome

9:15-9:45 Giuseppina Fabbiano
X-ray Insight into Galaxy Evolution

X-ray View of Ecosystem in Early Type Galaxies I

9:45 - 10:15 Craig Sarazin
The Physical State of the Hot and Cool Gas in Elliptical and BCG Galaxies

10:15 - 10:30 Ginevra Trinchieri
IR to UV to X-rays in Early-type galaxies

10:30 - 11:00 Break

X-ray View of Ecosystem in Early Type Galaxies II

11:00 - 11:30 Scott Randall
The X-ray View of AGN Feedback in Early Type Galaxies

11:30 - 11:45 Norbert Werner
The origin of cold gas in giant ellipticals and its role in fueling AGN feedback

11:45 - 12:00 Laurence David
The Fate of the X-ray Emitting Gas in the Early-Type Galaxy NGC 5044

12:00 - 12:15 Silvia Pellegrini
X-ray haloes and galaxy structure

12:15 - 12:30 Dong-Woo Kim
X-ray Scaling Relations of Early-Type Galaxies

12:30 - 2:00 Lunch

AGN Feedback

2:00 - 2:30 Jeremiah Ostriker
The Role of Hot ISM in Galaxy Formation and Evolution

2:30 - 2:45 William Forman
AGN Feedback in Normal Early-type Galaxies

2:45 - 3:00 Paul Nulsen
A critical role for viscosity in the AGN feedback cycle

3:00 - 3:15 Christine Jones
X-ray and Radio Emission from Supermassive Black Holes in Early-type Galaxies

3:15 - 3:30 Alessandro Paggi
AGN Feedback in the Hot Halo of NGC 4649

3:30 - 4:00 Break

4:00 - 4:30 Poster Microtalks

Galaxies at High Z

4:30 - 5:00 Bret Lehmer
X-ray Evolution of Galaxies Through the Eons: Insight From the Deep Fields

5:00 - 5:15 John Silverman
Environmental impact on the growth of supermassive black holes up to z 1

5:15 - 5:30 Shannon Patel
The Stellar to Halo Mass Relation of X-ray Groups at 0.5

Thursday, July 10

X-ray View of Ecosystems in Late Type Galaxies I

9:00 - 9:30 Q. Daniel Wang
Diffuse X-ray emission of Disk galaxies

9:30 - 9:45 Edmund Hodges-Kluck
The Gaseous Halo of NGC 891

9:45 - 10:00 Mihoko Yukita
The central 1 kpc starburst region of M82 with Chandra

10:00 - 10:15 Natthias Ehle
NGC 6946: the interplay of hot gas and galactic magnetic fields

10:15 - 10:30 Jennifer Schober
Using Chandra for Exploring the Evolution of Galactic Magnetic Fields

10:30 - 11:00 Break

X-ray View of Ecosystems in Late Type Galaxies II

11:00 - 11:30 K.D. Kuntz
Diffuse Emission in Normal Spiral Galaxies

11:30 - 11:45 Andrew Ptak
A Hard X-ray Look at Starburst Galaxies with NuSTAR

11:45 - 12:00 Matthew Miller
Analyzing the Milky Way's Hot Gas Halo with OVII and OVIII Emission Lines

12:00 - 12:15 Vallia Antoniou
A Chandra XVP Program of a Low-Metallicity Star-Forming Galaxy: First Results

12:15 - 12:30 David Henley
XMM-Newton Observations of a High-Velocity Cloud in the Magellanic Stream

12:30 - 2:00 Lunch

Stellar Feedback

2:00 - 2:30 Timothy Heckman
X-Raying Galactic Winds

2:30 - 2:45 Paul Sell
Constraints on AGN Activity in Massive Compact Galaxies with Ultrafast Outflows

2:45 - 3:00 Douglas Swartz
Testing the Steller Feedback Paradigm in Dwarf Irregulars

3:00 - 3:30 Break

AGN-Host Galaxy Connection

3:30 - 4:00 Elena Gallo
X-ray constraints on the local SMBH occupation fraction

4:00 - 4:15 Ana Mosquera
First quantitative limits in quasars' X-ray emitting regions using microlensing

4:15 - 4:30 Rik Williams
Probing hot galactic environments with X-ray quasars

4:30 - 4:45 Junfeng Wang
Disentangling AGN-Host Galaxy Interactions From An X-ray Perspective

4:45 - 5:00 Andy Goulding
Evolution of galaxies and their black holes throughout the last 9 Gyrs

Friday, July 11

Galaxies in Groups and Clusters I

9:00 - 9:30 Ming Sun
The Galaxy / Cluster Ecosystem

9:30 - 9:45 Electra Panagoulia
Entropy profiles and cavity dynamics of nearby X-ray groups and galaxies

9:45 - 10:00 Rebecca Canning
On the triggering of X-ray AGN in clusters

10:00 - 10:15 Panayiotis Tzanavaris
Many weak AGNs in Compact Groups of Galaxies with Chandra and Swift?

10:15 - 10:45 Break

Galaxies in Groups and Clusters II

10:45 - 11:00 Elke Roediger
Measuring hot plasma transport coefficients with stripped cluster galaxies

11:00 - 11:15 Ewan O'Sullivan
Building the Hot Intra-Group Medium in Spiral-Rich Compact Groups

11:15 - 11:30 Rukmani Vijayaraghavan
The Dynamical Removal of Gas from Group and Cluster Galaxies

11:30 Summary and Panel Discussions

12:30 Poster Removal, Bag Lunch Provided

Participants

- Charles Alcock - SAO - *calcock@cfa.harvard.edu*
- Vallia Antoniou - SAO - *vantoniou@cfa.harvard.edu*
- Elizabeth Blanton - Boston University - *eblanton@bu.edu*
- Akos Bogdan - SAO - *abogdan@cfa.harvard.edu*
- Douglas Burke - SAO - *dburke@cfa.harvard.edu*
- Rebecca Canning - Stanford University - *rcanning@stanford.edu*
- Raffaele D'Abrusco - SAO - *dabrusco@gmail.com*
- Laurence David - SAO - *ldavid@cfa.harvard.edu*
- Matthias Ehle - ESA-ESAC, XMM-Newton SOC - *Matthias.Ehle@sciops.esa.int*
- Giuseppina Fabbiano - SAO - *pepi@cfa.harvard.edu*
- William Forman - SAO - *wforman@cfa.harvard.edu*
- Terrance Gaetz - SAO - *tgaetz@cfa.harvard.edu*
- Elena Gallo - University of Michigan - *egallo@umich.edu*
- Audrey Garmire - Huntingdon Institute for X-ray Astronomy - *agarmire@astro.psu.edu*
- Gordon Garmire - Huntingdon Institute for X-ray Astronomy - *g2p3g4@gmail.com*
- Kristen Garofali - University of Washington - *kgarofali@gmail.com*
- Andy Goulding - SAO - *agoulding@cfa.harvard.edu*
- Paul Green - SAO - *pgreen@cfa.harvard.edu*
- Timothy Heckman - Johns Hopkins University - *heckman@pha.jhu.edu*
- David Henley - University of Georgia - *dbh@physast.uga.edu*
- Edmund Hodges-Kluck - University of Michigan - *hodgeskl@umich.edu*
- Diab Jerius - SAO - *djerius@cfa.harvard.edu*
- Christine Jones - SAO - *cjones@cfa.harvard.edu*

- Dong-Woo Kim - SAO - *dkim@cfa.harvard.edu*
- K.D. Kuntz - JHU - *kuntz@pha.jhu.edu*
- Dharam Lal - National Centre for Radio Astrophysics - *dharam@ncra.tifr.res.in*
- Bret Lehmer - Johns Hopkins University - *blehmer@pha.jhu.edu*
- Marie Machacek - SAO - *mmachacek@cfa.harvard.edu*
- Matthew Miller - University of Michigan - *mjmil@umich.edu*
- Ana Mosquera - The Ohio State University - *mosquera@astronomy.ohio-state.edu*
- Susan Neff - NASA Goddard Space Flight Center - *susan.g.neff@nasa.gov*
- Paul Nulsen - Harvard-Smithsonian Center for Astrophysics - *pnulsen@cfa.harvard.edu*
- Jeremiah Ostriker - Princeton - *ostriker@princeton.edu*
- Ewan O'Sullivan - SAO - *eosullivan@cfa.harvard.edu*
- Alessandro Paggi - SAO - *apaggi@cfa.harvard.edu*
- Electra Panagoulia - Institute of Astronomy - *epanagoulia@ast.cam.ac.uk*
- Shannon Patel - Carnegie Observatories - *patel@obs.carnegiescience.edu*
- Silvia Pellegrini - Dept. of Physics and Astronomy, Bologna University - *silvia.pellegrini@unibo.it*
- Paul Plucinsky - SAO - *pplucinsky@cfa.harvard.edu*
- Andrew Ptak - NASA/GSFC - *andrew.f.ptak@nasa.gov*
- Scott Randall - SAO - *srandall@cfa.harvard.edu*
- Shawn Roberts - UMass-Amherst - *srrobert@astro.umass.edu*
- Elke Roediger - Hamburg University Observatory - *eroediger@hs.uni-hamburg.de*
- Craig Sarazin - University of Virginia - *sarazin@virginia.edu*
- Eric Schlegel - Univ of Texas at San Antonio - *eric.schlegel@utsa.edu*

- Jennifer Schober - Center for Astronomy Heidelberg - *Schober@stud.uni-heidelberg.de*
- Paul Sell - Texas Tech University - *paul.sell@ttu.edu*
- Jaejin Shin - Seoul National University, Republic of Korea - *jjshin@astro.snu.ac.kr*
- Aneta Siemiginowska - CfA/SAO - *asiemiginowska@cfa.harvard.edu*
- John Silverman - Kavli IPMU - *john.silverman@ipmu.jp*
- Ming Sun - University of Alabama in Huntsville - *ms0071@uah.edu*
- Douglas Swartz - NASA/MSFC - *doug.swartz@nasa.gov*
- Ginevra Trinchieri - INAF-OABrera - *ginevra.trinchieri@brera.inaf.it*
- Panayiotis Tzanavaris - NASA/GSFC/UMBC - *panayiotis.tzanavaris-1@nasa.gov*
- Eugenio Ursino - University of Miami - *ursino@physics.miami.edu*
- Laura Vega - University of Texas at San Antonio - *laura.daniela.vega@gmail.com*
- Rukmani Vijayaraghavan - University of Illinois at Urbana-Champaign - *vijayar2@illinois.edu*
- Jan Vrtilek - SAO - *jvrtilek@cfa.harvard.edu*
- Junfeng Wang - Xiamen University - *jfwang@xmu.edu.cn*
- Q. Daniel Wang - University of Massachusetts - *wqd@astro.umass.edu*
- Belinda Wilkes - SAO *bwilkes@cfa.harvard.edu*
- Rik Williams - Carnegie Observatories - *williams@obs.carnegiescience.edu*
- Mihoko Yukita - JHU - *myukita1@pha.jhu.edu*
- Dong Zhang - The Ohio State University - *dzhang@astronomy.ohio-state.edu*

Abstracts
Poster and Oral

A Chandra XVP Program of a Low-Metallicity Star-Forming Galaxy: First Results

Vallia Antoniou
SAO

The 1.1 Ms Chandra Deep Survey of the SMC aims to identify the nature of X-ray sources detected down to few times 10^{32} erg/s in fields with young (< 100 Myr) stellar populations of different ages. With these data we will a) derive the deepest X-ray luminosity functions for X-ray binaries (XRBs) in a low metallicity ($0.2Z_{\odot}$) star-forming galaxy, b) study how accreting XRBs form and evolve, and c) provide observational constraints on their mass-transfer mechanisms. We detect 50-90 X-ray sources in each field and measure their X-ray photometric/spectroscopic parameters. Analysis of their light-curves is used to identify accreting pulsars and flaring objects. Based on their multi-wavelength properties, we identify high-mass XRBs and study their clustering with star-forming regions.

The asynchronous growth of bulges and black holes in two early-type galaxies

Akos Bogdan
SAO

According to the theoretical paradigm, supermassive black holes (BHs) and galaxy bulges are believed to co-evolve. The black hole-to-bulge mass ratios of NGC4342 and NGC4291 are about 6.9% and 1.9%, which significantly exceed the typical observed ratio of about 0.2%. Based on Chandra X-ray observations, we show the presence of extended dark matter halos around NGC4342 and NGC4291, thereby demonstrating that the observed low bulge masses are not due to tidal stripping. We thus conclude that the BHs and the bulges did not co-evolve, as opposed to current theoretical models. The presence of massive dark matter halos around NGC4342 and NGC4291 implies that dark matter halos may play a fundamental role in regulating the BH growth.

Chandra Galaxy Atlas

Douglas Burke
SAO

The hot ISM in early type galaxies plays a crucial role for understanding their formation and evolution. Structural features of the hot ISM identified by Chandra (including jets, cavities, cold fronts, filaments and tails) point to key evolutionary mechanisms, e.g., AGN feedback, merging history, accretion/stripping and star formation and its quenching. In our new project, Chandra Galaxy Atlas, we will systematically analyze the archival Chandra data of 137 ETGs to study the hot ISM. Taking full advantage of the Chandra capabilities, we will derive uniform data products of spatially resolved dataset with additional spectral information. We will make these products publicly available and use them for our focused science goals.

On the triggering of X-ray AGN in clusters

Rebecca Canning
Stanford University

Studies of the triggering of X-ray AGN in clusters have to date been hindered by small sample sizes. To address this we have undertaken a survey of 11,000 X-ray AGN in the fields of 135 of the most massive clusters known, where the high galaxy and gas densities offer a unique opportunity to examine the impact of environment. We find the number density of cluster AGN at a given radius, relative to the field, scales inversely with the cluster mass in a similar way to the predicted galaxy merger rate, suggesting that galaxy mergers and interactions are important for the triggering of cluster AGN. The redshift evolution of the cluster AGN is consistent with that of the field. Even larger datasets extending to higher redshifts will be required to investigate this further.

The Motif of Low-Mass X-ray Binaries and Globular Clusters in Ellipticals

Raffaele D'Abrusco
SAO

I will present inhomogeneities in the projected 2D spatial distributions of Low Mass X-Ray Binaries observed in NGC4649 and NGC4278, two massive elliptical galaxies with extensive Chandra coverage. I will compare the LMXBs overdensities with the density structures found in the distribution of Globular Clusters extracted from HST observation of the same galaxies. This comparison can shed light on the origins of the LMXBs structures in the context of different evolution mechanisms of the host galaxies. Finally, I will describe an ongoing project aimed at determining how common these structures are using a larger sample of galaxies with Chandra and HST partial coverage, and will discuss what we can learn from this investigation about how the LMXBs population and their host galaxies evolve.

The Fate of the X-ray Emitting Gas in the Early-Type Galaxy NGC 5044

Laurence David
SAO

The early-type galaxy NGC 5044 resides at the center of the X-ray brightest group in the sky. Chandra observations show that the central region of NGC 5044 has been repeatedly perturbed by AGN outbursts. Low frequency radio observations have detected several distinct AGN outbursts and an ALMA observation shows that the AGN is bright at 230 GHz, probably due a recent accretion event. While the hot gas in NGC 5044 is likely subject to AGN feedback, the presence of Hα filaments, [CII] line emission and numerous molecular structures indicate that some gas is able to condense out of the X-ray emitting phase. By combining the wealth of multi-frequency data for NGC 5044 we can discuss the history of gas in a cooling flow from the hot phase through to molecular cloud formation.

NGC 6946: the interplay of hot gas and galactic magnetic fields

Matthias Ehle
ESA-ESAC, XMM-Newton SOC

The grand-design spiral galaxy NGC 6946 is remarkable due to its high star formation activity, its massive northern spiral arm and the "magnetic arms," visible in radio continuum polarization and located between the optical arms. Strong Faraday depolarization of the polarized radio emission from the disk indicates an extended halo of ionized gas around NGC 6946. We use X-ray observations of NGC 6946 performed with XMM-Newton to disentangle and characterize emission from point-like sources and extended hot gas from the disk, the "magnetic arms" and the halo. We study relations between thermal and magnetic energy densities in different regions, allowing us to start mapping the distribution of the energy budget of NGC 6946.

X-ray insight into galaxy evolution

Giuseppina Fabbiano
SAO

With Chandra we have been able to identify and characterize the major emission components of galaxies in the near universe, as well as detect galaxies at high-z. These observations are providing unique insight into the evolution of the ISM, XRBs, and the interaction of AGN with the ISM, which are relevant for our understanding of crucial ingredients of current evolutionary scenarios: merging evolution and of feedback. This talk will discuss some of these Chandra results.

AGN Feedback in Normal Early-type Galaxies

William Forman
SAO

We present Chandra observations of a large sample of early type galaxies with a focus on accretion and feedback. We find that 30% of the most luminous galaxies show cavities produced by AGN outbursts. For these systems, we determine bubble inflation times and energies. We compare the mechanical power to the coronal X-ray luminosity and find that the mechanical energy can supply the heat lost through radiation. We also discuss the broad range of X-ray coronal emission at fixed galaxy optical luminosities. We present evidence for the termination of star formation at early epochs that drives some galaxies away from the "standard" correlation of stellar bulge mass with SMBH mass, and address how future X-ray missions can explore the evolution of hot coronae and SMBHs from $z \sim 6$ to the present.

X-ray constraints on the local SMBH occupation fraction

Elena Gallo
University of Michigan

Models of black hole growth in the context of galaxy mergers indicate that central supermassive black holes (SMBHs) will be more often present even in smaller galaxies when seeds are generated from the remnants of the first massive stars rather than via direct gas collapse. Consequently, measurement of the local occupation fraction provides an observational discriminator between seed formation models. I will present recent results from two large Chandra X-ray Telescope programs targeting a sample of 200 nearby early type galaxies, and discuss how we can use the measured active fraction to provide the first quantitative constraints on how the first black holes formed at high redshifts.

The X-ray Source Population of M33 as seen by XMM-Newton

Kristen Garofali
University of Washington

We present results from a deep XMM-Newton survey of M33 consisting of 8 pointings extending beyond the D25 isophote sensitive to L(0.2-4.5 keV) $> 4 \times 10^{34}$ erg/s. The large area coupled with the XMM soft response complement the deep Chandra Survey of M33. Cross-correlation of the surveys allows us to identify variable sources and previously undetected soft sources. Our coverage reveals many new sources including at least one previously unclassified SNR. The radial coverage provides high-quality background statistics, including a radial density distribution of sources that suggests roughly 15% ($\sim$60) of sources with inferred L $> 3.6 \times 10^{35}$ erg/s are in M33. Our background-corrected log(N)–log(S) reveals a relatively flat power law index (0.3-0.7) consistent with a substantial population of HMXBs.

Evolution of galaxies and their black holes throughout the last 9 Gyrs

Andy Goulding
SAO

Many theoretical models require a close link between the growth of the BH and that of the galaxy through feedback processes. Indeed, active galactic nuclei (AGN) are capable of releasing enormous quantities of energy over their lifetimes, often comparable to the host galaxy binding energy. I will present our population analysis of AGN host galaxies, showing that radiatively efficient (X-ray/IR) and mechanically-dominated AGN (exhibiting radio-emitting jets) are typically hosted in separate galaxy populations at all times in the last 9 Gyrs. Furthermore, galaxies with AGN have evolved along the same path as galaxies that are not hosting AGN, with little evidence for distinctly separate evolution, suggesting that galaxy evolution may proceed similarly with or without the inclusion of an AGN.

X-Raying Galactic Winds

Timothy Heckman
Johns Hopkins University

I will summarize our current understanding of starburst-driven galactic winds, with an emphasis on the hot phase of the winds that is probed with X-ray observations.

XMM-Newton Observations of a High-Velocity Cloud in the Magellanic Stream

David Henley
University of Georgia

The interactions between high-velocity clouds (HVCs) and their Galactic halo environment can result in X-ray emission. We present our analysis of 2 XMM-Newton observations of a constituent HVC of the Magellanic Stream, which exhibits soft X-ray emission near the densest part of the cloud. Neither shock heating nor charge exchange can account for the observed X-ray emission. We find that magnetic reconnection could plausibly power the emission; if this is the case, the observed X-ray emission could potentially constrain the halo magnetic field in the vicinity of the Magellanic Stream. We will conclude by discussing the possible importance of reconnection powering X-ray emission on larger (i.e., galactic) scales.

The Gaseous Halo of NGC 891

Edmund Hodges-Kluck
University of Michigan

The halos of disk galaxies contain a substantial mass of diffuse gas whose properties (temperature, density, structure, and metallicity) are important to understanding how the intergalactic medium was enriched and the long-term star-formation potential of the galaxy. However, we still do not know whether most of the halo material was expelled from the galaxy in a 'galactic fountain' or is fresh infall from the circum/intergalactic medium. NGC 891 is a nearby (D=10 Mpc), edge-on Milky Way analog whose halo has been intensively studied. I will present our recent work in the X-ray and UV bands aimed at trying to determine the origin of the hot and cool components of the halo gas by measuring their metal content, and discuss whether results from NGC 891 can be generalized to other galaxies.

X-ray and Radio Emission from Supermassive Black Holes in Early-type Galaxies

Christine Jones
SAO

Using Chandra observations of a large sample of normal (quiescent) early-type galaxies, we compare the X-ray luminosities of their central supermassive black holes with their radio luminosities. We also compare the X-ray and radio luminosities with the masses of the black holes, the stellar masses of the host galaxies, and the presence and luminosities of hot gaseous coronae. For galaxies in this sample, we find very small values for the ratio of the observed nuclear luminosity to the Eddington luminosity, implying ADAF-like accretion. We compare the results from our sample of normal (quiescent) galaxies to those found for samples of active galactic nuclei.

X-ray Scaling Relations of Early-Type Galaxies

Dong-Woo Kim
SAO

The scaling relations of early-type galaxies are key observables which can be directly compared with theoretical models to better understand the formation and evolution of ETGs. We revisit the scaling relations, using high spatial resolution Chandra observations of multi-wavelength selected galaxies (Atlas 3D sample), including a large fraction of gas-poor galaxies. Cross-correlating the X-ray properties (e.g., hot gas luminosity and temperature and other waveband properties (e.g., stellar luminosity and age, kinematical and structural parameters, cold HI and H2 gas, environment, dark matter) of ETGs, we address the implications of our results in terms of theoretical predictions of the dynamical states of hot halos.

Diffuse Emission in Normal Spiral Galaxies

K.D. Kuntz
JHU

The diffuse X-ray emission traces the most energetic phases of the ISM which have important implications for the global structure of the ISM. However, even with Chandra's angular resolution, one cannot study nearby galaxies except on relatively large scales, integrating over many different environments, and thus weakening the link between the spectrum and the physical conditions of the gas. Nevertheless, global spectra of galaxies suggest interesting trends with Hubble type, and multi-wavelength correlations within galaxies link the X-ray emission closely to star-formation, but in neither case is the physical cause of the correlations clear. I will report on some work in progress that suggests that X-ray structures in Chandra images present a strongly biased view of the hot ISM.

Radio galaxy with a twist: On the interaction of the BCG with the C4 3289 group

Dharam Lal
National Centre for Radio Astrophysics

Here we present the analysis of multi-frequency data gathered for the B085902.5+521533, an FRI, Z-symmetric radio galaxy, hosted in the brightest group galaxy of SDSS-C4 3289. The galaxy provides us an extremely rare opportunity to study the rotational dynamics of the group gas. We find evidence for the hot gas being surrounded by cooler gas, and the comparison of Chandra and radio images shows the propogating radio jets probably bend at the location of the shock-heated shell of X-ray gas. We will present preliminary results using Chandra and radio data for this system.

X-ray Evolution of Galaxies Through the Eons: Insight From the Deep Fields

Bret Lehmer
Johns Hopkins University

The Chandra Deep Fields have provided a new view of the X-ray Universe spanning the vast majority of cosmic history. At its limits, the majority of the 4 Ms CDF-S detected sources are associated with normal galaxies not powered by AGN, a regime only reached by this ultra-deep survey. X-rays from normal galaxies arise from hot gas and X-ray binaries. I will present new constraints from the CDFs on how X-ray emission from galaxy populations evolved from z ∼0-4 in response to changes in galaxy properties (star-formation activity, metallicity, aging of stellar populations). I will discuss recent efforts to put these constraints into a self-consistent cosmological framework, covering reionization from the first X-ray emitting galaxies to hot gas heating in ellipticals at z<1.

Hot Gas in Merging Subgroups; Probing the Early Stages of Structure Formation

Marie Machacek
SAO

To fully understand the growth of large scale structure in hierarchical cosmological models, we must first understand how their building blocks, low mass galaxy subgroups, evolve through mergers. These galaxy subgroups are X-ray faint and difficult to observe at high redshift. The study of near-by subgroup mergers may be used as templates to gain insight into the dominant dynamical processes that are at work in the early universe. We use Chandra observations of edges, tails and wings in a sample of near-by galaxy groups (Pavo, Telescopium, Pegasus, NGC7618/UGC12491) to measure the properties of the diffuse gas, merger velocities, shocks and non-hydrostatic gas 'sloshing', as their common ICM envelopes evolves.

Analyzing the Milky Way's Hot Gas Halo with OVII and OVIII Emission Lines

Matthew Miller
University of Michigan

We present an analysis of the Milky Way's hot gas halo using archival XMM-Newton observations of OVII and OVIII line emission. These lines are excellent tracers of gas at $\sim 10^6$ K, which is characteristic of the Milky Way's halo gas as well as estimates for the Local Bubble. Our model consists of a spherical β-model for the halo gas and a constant density Local Bubble. We find an acceptable fit to the OVIII observations by modeling the emission lines with an optically thin β-model with a normalization of $n_o(r_c)^{3\beta} = 1.3 \pm 0.4 \times 10^{-2}\ cm^{-3} kpc^{3\beta}$ and $\beta = 0.49 \pm 0.05$. We compare our OVIII fitting results to similar studies analyzing the Milky Way's hot gas halo using X-ray absorption lines and find our results are generally consistent with the absorption line results.

First quantitative limits in quasars' X-ray emitting regions using microlensing

Ana Mosquera
The Ohio State University

One of the defining characteristics of AGNs is their X-ray emission, but the origin and spatial extent of this emission is still unknown, in large part because we have lacked the means to resolve the central engine. However, microlensing in multiply imaged gravitationally lensed quasars allows us to zoom in on the structure of AGN and explore their physics in more detail. Quantitative microlensing X-ray size constraints exist for 5 systems, setting the first upper limits for these emitting regions. In my talk I will describe the methodology, the results from our CXO monitoring program, and the next frontier of exploring possible correlations of the X-rays sizes with black hole mass and spectral index, as well as to set constraints on the scaling of the size with X-ray energy.

What Energizes the Northern Transition Region of Centarus A?

Susan Neff
NASA Goddard Space Flight Center

We present deep ultraviolet, H-alpha, and radio images of the inner ∼40kpc Centaurus A. We find no evidence for a collimated flow extending beyond ∼6kpc from the active nucleus. The possible "large-scale jet" identified by Morganti et al. (1999) is part of narrow ridge of emission embedded within the broader radio-loud region. Overpressured radio knots appear to be related to similar X-ray knots reported by Kraft et al (2009). The radio ridge is associated with a ribbon of ultraviolet and H-alpha emission extending at least 35kpc from the galaxy center, and including previously known, bright, emission-line filaments. We suggest that the transition region is currently energized by a superwind from the starburst in the central disk.

A critical role for viscosity in the AGN feedback cycle

Paul Nulsen
Harvard-Smithsonian Center for Astrophysics

For giant elliptical galaxies with extended hot atmospheres, the origin of the gas that fuels AGN activity is a key issue for the AGN feedback cycle. One possible fuel source is cooled hot gas, but pressure supported hot gas only cools via thermal instability if its cooling time is less than about ten free-fall times. This condition is relaxed if the hot gas is partially supported by rotation, so that randomly injected angular momentum promotes thermal instability if the viscous stresses in the hot gas are small. The conditions for this form of thermal instability will be presented. For samples of giant elliptical galaxies, Chandra data show that they are met in all of the systems that contain cold gas and/or young stars, arguing that cooled hot gas is a likely AGN fuel source.

The Role of Hot ISM in Galaxy Formation and Evolution

Jeremiah P. Ostriker
Princeton

The cooling rate for hot gas in and around galaxies has a critical importance both in physically setting the basic mass scale for these massive, self-gravitating systems and as an observational tool for assessing formation models, by enabling the comparison between predicted and observed X-ray luminosities. Three classic papers in 1977 showed that it would be difficult for galaxies above a certain mass to cool on a dynamical timescale. That mass scale, in terms of fundamental physics is as follows:

$$\mathcal{M} \simeq \Big[\Big(\frac{Gm_p^2}{\hbar c}\Big)^{-2}\Big(\frac{e^2}{\hbar c}\Big)^{5}\Big(\frac{m_p}{m_e}\Big)^{1/2}\Big]m_p \tag{1}$$

or roughly 10^{12} solar masses. Galaxies above this mass tend to be enveloped in the hot, X-ray emitting, gaseous halos familiar to Chandra observers and their predecessors. The outer parts of these gaseous halos are easily kept hot by SNI, dynamical in-fall of satellites and other processes, but the inner parts will repeatedly collapse into cooling flows, starbursts and AGN flare-ups. The thermal X-ray emission will be highly variable with this providing an important diagnostic for these physical processes.

Also, normal cosmological inflow of gas onto massive galaxies can be shown to produce (absent feedback) more X-rays emission than is observed – providing yet another argument for feedback processes, which would reduce the ambient hot gas density. Finally, several postulated physical scenarios, such as gas rich (wet) binary spiral mergers or thermal AGN feedback would produce X-ray emission far in excess of observational limits, again showing the power of X-ray observations as a critical diagnostic tool.

Building the Hot Intra-Group Medium in Spiral-Rich Compact Groups

Ewan O'Sullivan
SAO

Galaxy groups provide a natural laboratory for studying the co-evolution of galaxies and their environment, from spiral-dominated, cold-gas-rich groups to elliptical-dominated systems with a hot intra-group medium (IGM). We have studied this transition in several groups, including the well known compact groups Stephan's Quintet (HCG92) and HCG16, using deep Chandra X-ray and GMRT radio observations. We will present evidence from these groups that starburst winds and shock-heating of stripped HI may play an important role in the early stages of IGM formation, and discuss the likely impact of the group environment in driving gas stripping, enhanced star formation and nuclear activity in the group member galaxies.

AGN Feedback in the Hot Halo of NGC 4649

Alessandro Paggi
SAO

Using the deepest available Chandra observations of NGC 4649 we find strong evidences of cavities, ripples and ring like structures in the hot ISM, morphologically related with the central radio emission. These structures show no significant temperature variations in correspondence with higher pressure regions. On the same spatial scale, the discrepancy between the mass profiles obtained from stellar dynamic and Chandra data yields evidence of a significant non-thermal pressure component in the hot gas, related to the radio jet and lobes. The nucleus of NGC 4649 appears to be extremely radiatively inefficient, with highly sub-Bondi accretion flow. Comparing the jet power to radio and nuclear X-ray luminosity the cavities show similar behavior to those of other giant elliptical galaxies.

Entropy profiles and cavity dynamics of nearby X-ray groups and galaxies

Electra Panagoulia
Institute of Astronomy

We study the overall entropy profile and cavity dynamics of a volume- and L_x-limited sample of 101 X-ray groups and clusters. We find that the overall entropy profile does not flatten out at small radii. Rather, it seems to resemble a broken power-law in shape. We searched the sources in our sample for cavities, detecting cavities in 30 sources, all of which have a central cooling time of <3 Gyr. We focus on the subset of sources with a central cooling time of <3 Gyr, and estimate the AGN duty cycle at 61 and 80 percent for sources with a central cooling time of < 3 Gyr and < 0.5 Gyr, respectively. Our results suggest that the AGN "bubbling mode" has to be continuous in order to offset cooling. We show that the detection of entropy floors, cool cores and cavities depends on data quality.

The Stellar to Halo Mass Relation of X-ray Groups at 0.5<z<1 in CDFS with CSI

Shannon Patel
Carnegie Observatories

Combining the deepest X-ray imaging to date in the CDFS with the Carnegie-Spitzer-IMACS (CSI) spectroscopic redshift survey, we study the aggregate stellar mass content in bonafide low mass group halos (down to $M_h \sim 10^{13}\ M_\odot$) at $0.5 < z < 1$ - an important halo mass regime and epoch that have not been previously probed. We find that the stellar to total mass ratio gradually decreases toward higher group masses, bridging the trend seen in the local universe between more efficient L* halos and massive, cluster halos. We compare our findings to various models and show how our measurements provide important constraints over an epoch when groups undergo substantial growth in number density, contribute toward the quenching of star formation, and serve as the building blocks of present day clusters.

X-ray haloes and galaxy structure

Silvia Pellegrini
Dept. of Physics and Astronomy, Bologna University

We present high resolution 2D hydrodynamical simulations to investigate the effects of galaxy shape and rotation on the X-ray haloes of early-type galaxies. With a Jeans code written on purpose we built a large set of realistic galaxy models, with different optical and dark mass, intrinsic flattening, internal kinematics. Flattening and rotation are important in determining the hot gas luminosity and temperature, but their effect is a function of galactic mass: in lower mass galaxies global winds are favoured, in higher mass ones conservation of angular momentum reduces L_X and T_X with respect to spherical models. The ISM rotation field is similar to that of the stellar component, with low values for the thermalization of the relative ordered motion.

XMM and Chandra Spectroscopy of the Brightest Supernova Remnants in M33

Paul Plucinsky
SAO

We present a spectral analysis of the X-ray brightest Supernova Remnants (SNRs) in the nearby, spiral galaxy M33 from our deep XMM-Newton survey (see poster by Garofali et al. this conference) that complements our previous survey with Chandra (ChASeM33). We have simultaneously fit the XMM and Chandra spectra to constrain the temperature and abundances. We do not find any young (t<1,000 yr) SNRs that could be analogs of Cas A or the Crab, but we find several SNRs older than 1,000 yr that show evidence of enhanced abundances. The X-ray detected SNRs appear to occur preferentially in regions with a higher than average density of the Interstellar Medium. We present the first detailed spectral analysis of the third most luminous X-ray SNR in M33 that was outside the ChASeM33 survey area.

A Hard X-ray Look at Starburst Galaxies with NuSTAR

Andrew Ptak
NASA/GSFC

NuSTAR opens up the possibility to not only detect starburst galaxies above 10 keV for the first time but also characterize their hard X-ray properties. Here we present an overview of a NuSTAR program to survey a sample of normal/starburst galaxies: NGC 253, M82, M83, NGC 3256, NGC 3310 and Arp 299, half of which have been observed so far. The main goals are: 1) characterize the typical starburst spectrum above 10 keV 2) identify the nature of individually-detected X-ray sources (neutron star HMXB vs. black hole candidate) 3) look for short-term (hours to weeks) variability and establish a baseline for long-term variability studies and 4) characterization of the unresolved contribution to the NuSTAR flux (unresolved X-ray binaries and inverse-Compton scattering off of cosmic rays).

The X-ray View of AGN Feedback in Early Type Galaxies

Scott Randall
SAO

Recent studies have confirmed an empirical relationship between the evolution of galaxies and the growth of their central supermassive black holes (SMBH). This relationship is likely mediated by AGN feedback, where diffuse gas cools and is accreted onto the central SMBH, driving AGN outbursts which in turn heat the surrounding gas, slowing cooling and affecting star formation. I will summarize the current understanding of AGN feedback, focusing on results from X-ray studies of early type galaxies at the centers of galaxy groups and clusters. X-ray and other observations of some key systems will be presented, including recent results from deep Chandra observations of the central galaxy in the galaxy group NGC 5813.

Evidence for X-ray emitting charge exchange in the Cygnus Loop SNR

Shawn Roberts
UMass-Amherst

The Cygnus Loop has been the focus of substantial debate concerning the contribution of charge exchange (CX) to SNR emission. We take advantage of a distinct feature of CX, enhanced K-alpha forbidden line emission, and employ the OVII Kα triplet as a probe of physical conditions. We find that enhanced forbidden to resonance line emission exists throughout much of the rim of the SNR and this enhancement azimuthally correlates with non-radiative Hα filaments, a tracer of strong neutral-ion interaction in the optical. We also show that alternative mechanisms cannot explain the enhancement observed. These results support the need for CX modelling within the emission of SNRs, particularly in the outer regions where the sightline has a long path through the neutral-ion interface.

Measuring hot plasma transport coefficients with stripped cluster galaxies

Elke Roediger
Hamburg University Observatory

Cluster galaxies are gas-stripped during their motion through the cluster gas. Thermal conductivity and viscosity of the hot gas -or plasma- in and around these galaxies affect the stripping mechanisms, and in particular the multiphase nature of the tails of stripped gas and star formation in tails of the spirals. However, the effective transport coefficients are still ill-constrained. Current deep X-ray observations of stripped nearby cluster ellipticals show the details of the plasma flows around them. We aim at measuring the effective plasma transport coefficients by means of one-to-one comparisons to viscous hydro-simulations tailored to each galaxy. We report first evidence for a highly suppressed viscosity around Virgo and Fornax cluster ellipticals and discuss future observations.

The Physical State of the Hot and Cool Gas in Elliptical and BCG Galaxies

Craig Sarazin
University of Virginia

Theoretical models, and Chandra and other X-ray observations of the physical state of the hot, X-ray emitting gas and cooler phases in elliptical galaxies and in the BCGs will be reviewed. The connections with feedback from AGN and star formation will also be reviewed.

Diffuse Hot Gas in M51

Eric Schlegel
Univ of Texas at San Antonio

X-ray observations of face-on spiral galaxies reveal diffuse emission across the face of nearby galaxies. Whether that emission represents hot gas or unresolved point sources remains to be determined. We present two examples of our pursuit of an answer. First, a Chandra observation of M51 reveals a difference in the soft X-ray emission of the arms. The fitted spectra exhibit similar temperatures for the model components, but different abundances, particularly for Mg. Second, we compare the X-ray emission of M51 with data at other wavelengths via 'pixel statistics'. We adaptively bin the X-ray image and apply the resulting mask to data at other wavelengths to search for pixel correlations. We report on our results and inferences to date.

Using Chandra for Exploring the Evolution of Galactic Magnetic Fields

Jennifer Schober
Center for Astronomy Heidelberg

The origin of strong magnetic fields in galaxies is still not fully understood. Theoretically the turbulent dynamo can amplify weak seed fields up to several μG already in young galaxies. As the dynamo is driven by shocks from supernovae, we expect a correlation between the field strength and the star formation rate. Observations of magnetic fields can be made by emission of cosmic rays. In highly redshifted galaxies and starburst galaxies they lose their energy mostly by inverse Compton scattering, resulting in X-ray emission. In these environments one can estimate the cosmic ray energy and the magnetic field strength from the X-ray flux with a model of the galaxy. Hence Chandra data of young and starburst galaxies can help us to understand the evolution of galactic magnetic fields.

Constraints on AGN Activity in Massive Compact Galaxies with Ultrafast Outflows

Paul Sell
Texas Tech University

We investigate the process of rapid star formation quenching in a sample of 12 massive galaxies at intermediate redshift ($z \sim 0.6$) with high-velocity outflows ($v > 1000\ km/s$). Common attributes of these galaxies include diffuse tidal features and bright, extraordinarily compact cores indicative of recent, highly dissipative mergers. For 9/12 galaxies, we rule out a substantial AGN contribution to the nuclear light. While we find some evidence of AGN activity in half the sample, we argue that it accounts for only a small fraction ($< 10\%$) of the total bolometric luminosity. We find no correlation between AGN activity and outflow velocity, and we conclude that the fast outflows in our galaxies are not powered by on-going AGN activity, but rather by recent, extremely compact starbursts.

A systematic study of X-ray cavities in various galaxy environments

Jaejin Shin
Seoul National University, Republic of Korea

AGN feedback is considered as one of the key phenomena in understanding the interaction between black holes and galaxies. In particular, X-ray cavity is useful for studying AGN feedback over 10 kpc scales. For a comprehensive study of X-ray cavities, we collect all available diffuse X-ray data of various galaxy environments, ranging from field galaxies to galaxy clusters, using the Chandra X-ray data archive. We build up a sample of 87 targets to perform the X-ray cavity detection analysis. We detected X-ray cavities and estimated their physical properties for 49 objects. Also, we measured X-ray gas temperature to understand the growth of the cavities and compared them with cavity properties. Here, we will discuss the physical properties of the X-ray cavity and the environmental effects.

Jet-ISM Interactions and Outflow in a Nearby Radio Galaxy 4C+29.30

Aneta Siemiginowska
CfA/SAO

We present results of a deep Chandra observation of a low-z radio galaxy where the complexity of interactions between the radio plasma and ISM is uniquely displayed. The Chandra image shows regions of enhanced X-ray emission correlated with radio structures along the jet axis. Additionally, there is larger scale X-ray diffuse emission outside the radio source which correlates with the morphology of known optical line-emitting regions. We measure the temperature of the ISM and identify regions heated by weak shocks with the Mach number of 1.6. The X-ray emitting gas is most likely heated by the radio source expanding within this galaxy. The multi-band data supply a complex view of the source, signaling feedback processes closely associated with the central active nucleus.

Environmental impact on the growth of supermassive black holes up to $z \sim 1$

John Silverman
Kavli IPMU

There has been a lack of understanding what physical mechanisms are responsible for the mass buildup of supermassive black holes. The challenge lies with determining whether internal influences, within the host galaxy, are in response to external factors (e.g., galaxy mergers). Multi-wavelength surveys, with large spectroscopic efforts and Chandra coverage such as COSMOS, now enable us to construct statistical galaxy and AGN samples up to $z \sim 1$ with environmental information to disentangle various factors relevant for triggering accretion. We will discuss that a scale-dependent modulation of black hole growth is in effect with mergers playing a key role. Our results are likely indicative of the importance of the gas reservoir for fueling both AGN activity and concurrent star formation.

The Galaxy / Cluster Ecosystem

Ming Sun
University of Alabama in Huntsville

Most baryons in galaxy clusters are in the hot ICM. Together with cluster galaxies, they form the cluster ecosystem and their mutual interaction has significant impact on their evolution. In this talk, we summarize the observational results of thermal X-ray components for both early-type galaxies and late-type galaxies in galaxy clusters, as well as the related results in other bands and the implications. For cluster early-type galaxies, the survival of small X-ray coronae for most massive galaxies provide constraints on gas stripping, microscopic transport, and radio-mode feedback processes. For cluster late-type galaxies, ram pressure stripped tails have been detected in multiple wavelengths and star formation in the stripped gas is a common process.

Testing the Steller Feedback Paradigm in Dwarf Irregulars

Douglas Swartz
NASA/MSFC

We test whether or not the role of stellar feedback in the low densities and pressures of Dwarf Irregular (dIrr) galaxies is fundamentally different than in the dense environments of massive spirals, classical starbursts, and luminous infrared galaxies. By comparing X-ray surface brightness and temperature profiles to radial stellar mass surface density and star formation history profiles, we determine if heating through stellar feedback is efficient in driving shells and generating large bubbles in dIrr galaxies or, as in dense environments, cooling times are short and energy input from stellar winds and SNe is quickly radiated away.

IR to Uv to X-rays in Early-type galaxies

Ginevra Trinchieri
INAF-OABrera

We report on the results from SWIFT and XMM-Newton observations of 10 early-type galaxies, originally selected from a sample of galaxies observed by Spitzer and by GALEX in an attempt to establish an evolutionary sequence based on the UV-to-IR properties of early-type galaxies. The data are complemented by the multiband optical-UV observations available from the SWIFT-UVOT instrument, and are interpreted with the aid of SPH chemo-photometric simulations.

Many weak AGNs in Compact Groups of Galaxies with Chandra and Swift?

Panayiotis Tzanavaris
NASA/GSFC/UMBC

Compact groups of galaxies (CGs) experience prolonged galaxy-galaxy interactions, directly affecting the state of the gas, and thus star formation, AGN activity and galaxy evolution. We present a census of the nature of nuclear activity in 9 Hickson CGs (37 galaxies), involving detailed point source detection and characterization with Chandra/ACIS and Swift/UVOT. X-ray and UV luminosities and estimates for the "optical-to-X-ray" spectral slope, α_{OX}, suggest CG galaxies are more likely to harbor LLAGN and/or star-formation, but AGN *numbers* are at least as high as in galaxy clusters. We discuss the need for an evolutionary paradigm that will link the evolution of star formation and AGN activity in CGs, as well as the levels of diffuse emission from hot gas.

Probing the Galactic Halo with Shadow Observations

Eugenio Ursino
University of Miami

We use shadow observations to investigate the sources of the Galactic components of the Diffuse Soft X-ray Background (DXB), in particular the Galactic Halo (GH). Shadow observations are a powerful technique to disentangle the very local components of the DXB (like the Local Bubble and the Solar Wind Charge Exchange) from the non-local components, like the GH and unresolved point sources. The GH is made of highly ionized gas at $T \sim 3 * 10^6 K$, although little is known about its spatial properties. By combining new and archival results we are mapping the X-ray emission from the GH testing the existing models. In particular, the observations towards MBM16 and MBM20 show dramatic differences in the X-ray contribution, suggesting that the GH has a very patchy distribution.

The Dynamical Removal of Gas from Group and Cluster Galaxies

Rukmani Vijayaraghavan
University of Illinois at Urbana-Champaign

Galaxies in group and cluster environments are gas-poor and have low star formation rates compared to field galaxies. We investigate the mechanisms of gas removal in these environments using idealized high-resolution simulations of populations of galaxies evolving in groups and clusters. We quantify the effects of tidal and ram-pressure stripping as well as galaxy-galaxy interactions on removing gas bound to galaxies. We study these effects in both isolated and merging groups and clusters, and investigate pre-processing of galaxies in group environments before cluster infall. Additionally, we generate mock Chandra X-ray observations from our simulations, and probe the properties of the intra-cluster and intra-group medium using the known properties of ram-pressure stripped galaxy wakes.

Disentangling AGN-Host Galaxy Interactions From An X-ray Perspective

Junfeng Wang
Xiamen University

The circum-nuclear region in active galaxies is often complex with presence of high excitation gas, collimated radio outflow, and star forming regions, besides the active nucleus. In studies of a number of archetypal Seyfert galaxies (for example, NGC4151 and NGC 1068), we were able to evaluate the mass outflow and shock heating by radio jet. For galaxies in the throes of a violent merging event such as NGC6240, we were able to resolve 70MK hot gas surrounding the double nuclei and discovered a large scale soft X-ray halo. The unique resolving power of Chandra also enables more discovery of such dual AGN systems.

Diffuse X-ray emission of Disk galaxies

Q. Daniel Wang
University of Massachusetts

Disk galaxies are the dynamic ecosystem of many species. I will review recent X-ray observations that reveal an otherwise hidden species and its energetic interplay with other components of such galaxies. I will focus on answering three questions: 1. How do X-ray properties vary among galaxies? 2. Does the X-ray emission trace the accretion or feedback of galaxies? 3. What is the nature of the X-ray emission?

The origin of cold gas in giant ellipticals and its role in fueling AGN feedback

Norbert Werner
Stanford University/KIPAC

I will present a multi-wavelength study of the nature and origin of the multi-phase medium in giant ellipticals at the centers of low mass groups of galaxies. All systems with extended Hα emission in our sample contain significant amounts of cold gas, which is co-spatial with the line emitting nebulae and the lowest entropy X-ray emitting plasma. I will show that while the hot atmospheres of the cold-gas-poor galaxies are thermally stable outside of their innermost cores, the atmospheres of the cold-gas-rich systems are prone to cooling instabilities. This indicates that cold gas in giant ellipticals is produced chiefly by cooling from the hot phase. I will also show that cooling instabilities may develop more easily in rotating systems and discuss the role of cold gas in AGN feedback.

Probing hot galactic environments with X-ray quasars

Rik Williams
Carnegie Observatories

Chandra has made numerous advances in absorption-line spectroscopy of hot gas, including detections of several candidate metal absorption lines from the warm-hot intergalactic medium (WHIM). Some of these appear to be isolated while others are associated with large-scale galaxy walls and filaments. Using both public galaxy survey data and deep Magellan multi-object spectroscopy, we revisit the deepest Chandra quasar sightlines to better determine the origin of this gas. Most intergalactic X-ray absorbers in fact appear to lie within the virial radii of individual galaxies or groups, indicating that these bound structures are surrounded by the 10^6 gas predicted by theory.
Previously-reported WHIM absorbers may thus trace the hot, metal-enriched circumgalactic (or circumgroup) medium.

The central 1 kpc starburst region of M82 with Chandra

Mihoko Yukita
JHU

Galactic winds are one of the most dramatic forms of stellar feedback in the local universe, and an important ingredient of galaxy evolution. These kpc-scale outflows are driven by high-pressure hot gas ($10^7 - 10^8$ K) originating in supernova explosions and stellar winds from powerful starbursts. We present a detailed spectral analysis of the central 1 kpc region of M82 using 500 ks of Chandra ACIS-S observations. We have constructed high spatial resolution (1"-10") thermodynamic maps. We will discuss the spatial correlations of these parameter values with star-forming activity, as well as warm and cold gas. We also discuss the detection and origin of the Fe K emission lines (K alpha, He-like and Ly alpha).

Hot Galactic Winds Constrained by the X-Ray Luminosities of Galaxies

Dong Zhang
The Ohio State University

Galactic superwinds may be driven by very hot outflows generated by supernovae within the host galaxy. We use the Chevalier & Clegg (CC85) wind model and the observed correlation between galactic X-ray luminosities and their SFRs to constrain the mass loss rates across a wide range of SFRs. We constrain the mass-loading and thermalization efficiency of hot galactic winds. For SFR $\gtrsim 10 M_{sun}/yr$ we find that $\dot{M}_{hot}/SFR \lesssim 1$, significantly lower than required by integrated constraints on the efficiency of stellar feedback in galaxies, and potentially too low to explain observations of winds from rapidly star-forming galaxies. In addition, we highlight the fact that heavily mass-loaded winds cannot be described by the adiabatic CC85 model because they become strongly radiative.

Notes

Notes

Notes