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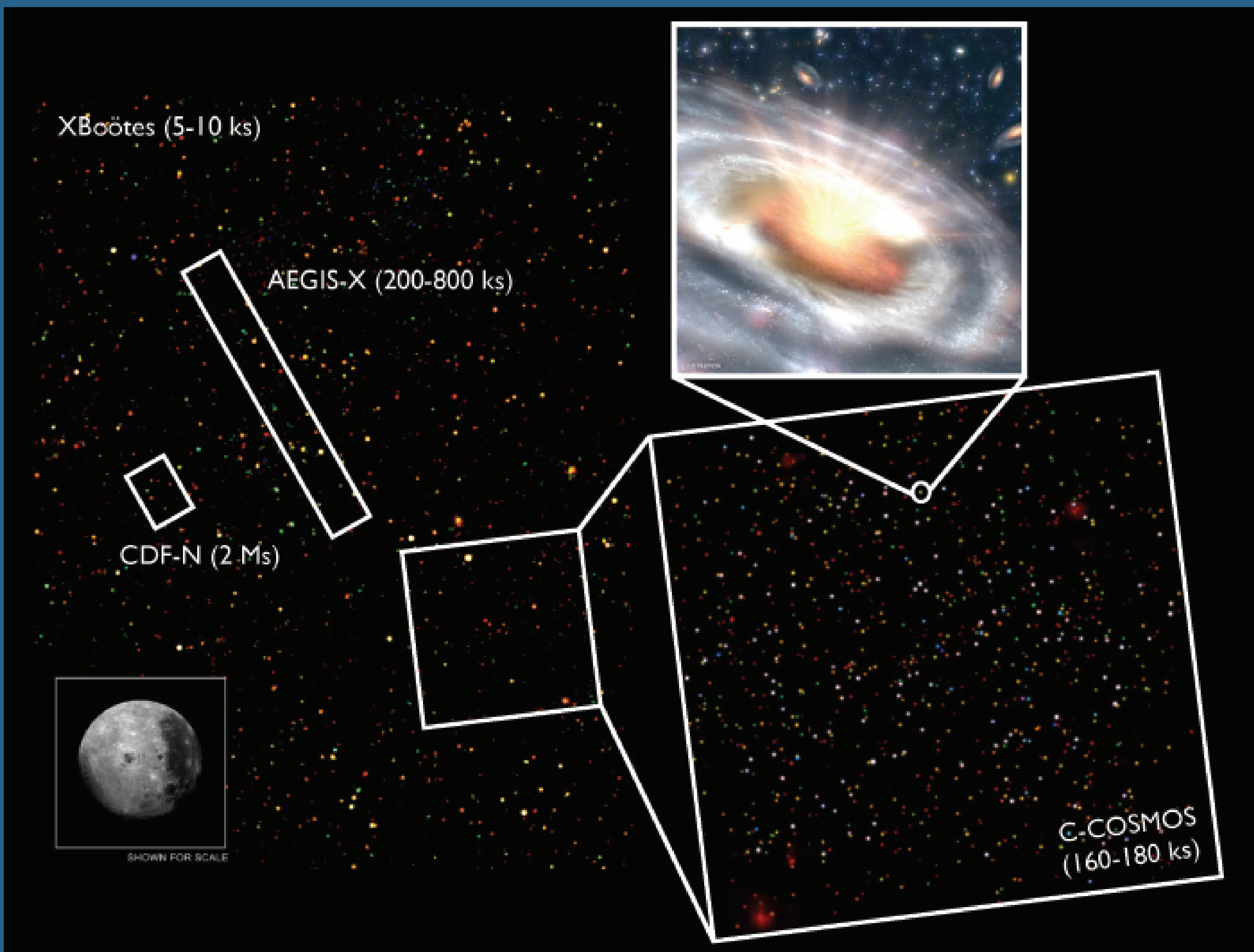
Black holes through cosmic time:

Exploring the distant X-ray Universe with extragalactic *Chandra* surveys

Ryan Hickox



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Ryan C. Hickox

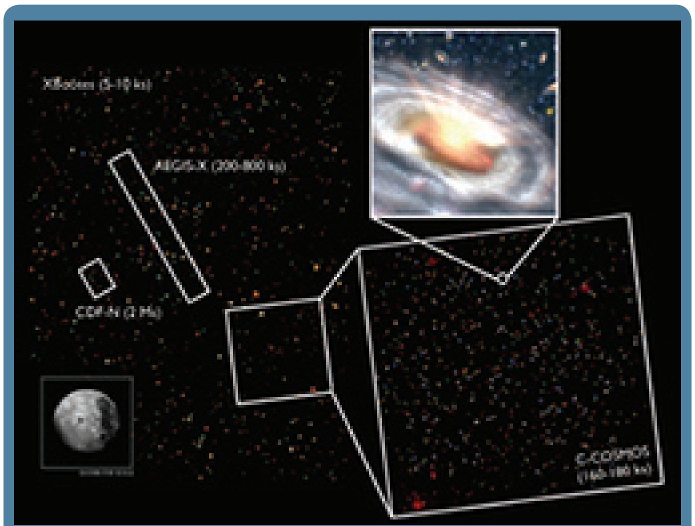

FIGURE 1 (full size image on cover): X-ray images and survey areas for a few representative *Chandra* surveys: XBoötes (Murray et al. 2005), C-COSMOS (Elvis et al. 2009), AEGIS-X (Nandra et al. 2005), and the *Chandra* Deep Field-North (Alexander et al. 2003). The relative areas of each field are superposed on the XBoötes image, and survey exposure times are shown. (The fields cover separate regions on the sky, and are shown together only for comparison.) The full C-COSMOS image is shown on an expanded scale. The inset illustration shows an active galactic nucleus; the vast majority of the X-ray sources detected in *Chandra* surveys are AGN. *(Figure prepared by the author, AGN illustration credit: NASA/JPL-Caltech/T.Pyle-SSC)*

In the last decade we have seen profound advances in our understanding of the composition and evolution of the Universe. Prominent among these is the discovery that essentially all galaxies with stellar bulges contain supermassive black holes (SMBH), which are believed to be the relics of accretion in active galactic nuclei (AGN). Further, the masses of SMBHs are tightly correlated to the properties of their host bulges, and the energy released by AGN may have a significant effect on the star formation history of galaxies. Thus it is increasingly clear that growth and evolution of black holes and galaxies are linked through cosmic time.

X-ray surveys are exceptionally powerful tools for studying the evolution of black holes and their host galaxies, by detecting large numbers of AGN over a wide range of redshifts and cosmic environments from voids to groups and clusters. With its superb angular resolution, low background, and sensitivity in the energy range 0.5–8 keV, *Chandra* has been at the forefront of recent extragalactic surveys. In this article we provide an overview of some of the leading *Chandra* surveys, and describe some recent results on the composition of the cosmic X-ray background (CXB), the evolution of black hole accretion, the nature of AGN populations, and links between AGN and their host galaxies and environments. This is an extremely active and exciting field, with many key contributions made by *XMM-Newton*, *Suzaku*, *INTEGRAL*, *Swift*, and other space and ground-based observatories; here we will focus on just a few representative results from *Chandra* surveys.

Breadth and depth in *Chandra* surveys

Chandra extragalactic surveys range from very deep and narrow to shallow and very wide, allowing us to study the broadest possible range in redshift and luminosity (Figure 1). The deepest existing X-ray surveys are the *Chandra* Deep Fields (CDFs) North (Alexander et al. 2003) and South (Luo et al. 2008), each with 2 Ms total exposure. Owing to *Chandra*'s unparalleled spatial resolution, these observations are not limited by confusion and probe to depths more than 6 times fainter than is accessible with any other X-ray observatory. The CDFs have yielded extraordinary progress in understanding faint X-ray populations and resolving the CXB. However, the X-ray luminosity density is dominated by more luminous X-ray sources that are rare in the CDFs, so *Chandra* also has undertaken several shallower surveys over wider areas to study these objects. These surveys include, in order of increasing area, ELAIS-N (Manners et al. 2003), the Extended CDF-S (Lehmer et al. 2005), AEGIS-X (Laird et al. 2009), CLASXS and CLANS (Trouille et al. 2008; CLANS is comprised of data from the SWIRE/Chandra survey; Wilkes et al. 2009), C-COSMOS (Elvis et al. 2009), XDEEP2 (Murray et al. 2008) and XBoötes (Murray et al. 2005). The areas and corresponding flux limits for these surveys are shown in Figure 2. Most surveys also have extensive multiwavelength coverage with *HST*, *Spitzer*, ground-based optical imaging and spectroscopy, radio, and other observations (Figure 3), allowing us to understand the detailed spectral energy distributions (SEDs) and environments of the X-ray sources. For a more detailed review of X-ray surveys with a focus on the deepest fields, see Brandt & Hasinger (2005).

In addition to dedicated *Chandra* observations in contiguous survey fields, the *Chandra* Multiwavelength Project

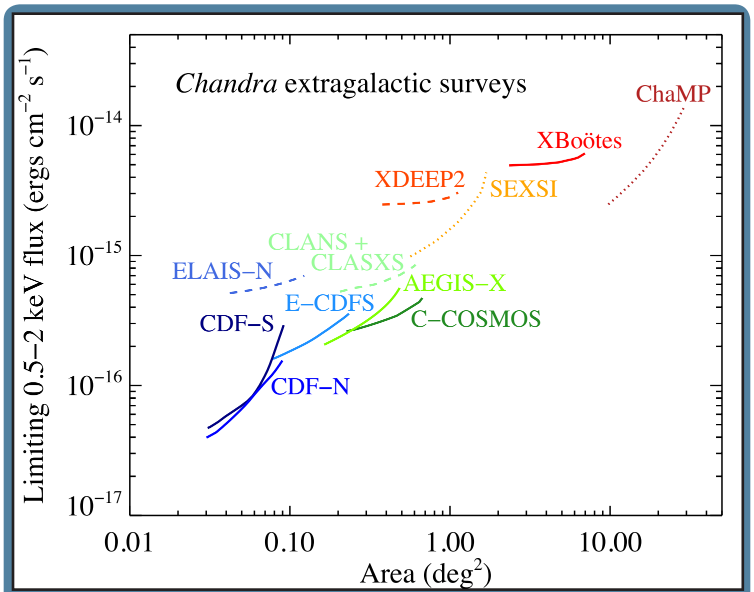

FIGURE **2:** *Chandra* surveys span a wide range of depths and areas, in order to probe the widest possible ranges in redshift, luminosity, and environment. The figure shows limiting 0.5–2 keV flux versus area for various *Chandra* blank-field and serendipitous extragalactic surveys (see text for references). Since sensitivity varies across *Chandra* fields, for a given survey the area increases with increasing flux limit. Lines show the sensitivity curves between 25% and 75% of the total area of each survey. Solid lines show contiguous surveys, dotted lines show serendipitous surveys, and dashed lines show surveys comprised of two or three separate fields with similar depths and multiwavelength coverage. Flux limits are defined somewhat differently for different surveys, but generally correspond to a ~50% completeness limit. For SEXSI (which is a hard X-ray selected serendipitous survey) the 2–10 keV limited fluxes were converted to 0.5–2 keV by dividing by 6.5, corresponding roughly to the relative on-axis flux limits of the CDF-N in the soft and hard bands. The AEGIS-X and XBoötes sensitivities correspond to the 200 ks and 5 ks surveys, respectively, while the sensitivity from the ≈10 ks XDEEP2 exposures are estimated from XBoötes.

(ChaMP) uses archival data for optical imaging and spectroscopic followup of serendipitous sources from 392 (non-contiguous) ACIS pointings (Green et al. 2004, Kim et al. 2007). The large samples allow removal of potentially biasing PI-targeted objects and provide large statistical subsamples immune to cosmic variance. Similar follow-up of serendipitous hard X-ray (2–10 keV) sources has been undertaken by the Serendipitous Extragalactic X-ray Source Identification (SEXSI) program (Harrison et al. 2003).

Resolving the cosmic X-ray background

Since its discovery in rocket flights at the dawn of X-ray astronomy (Giacconi et al. 1962), the origin of the diffuse extragalactic X-ray background has been one of the leading questions in high-energy astrophysics. With the exceptional sensitivity of the CDFs, it is now clear that almost all of the extragalactic CXB at energies <2 keV arises from X-ray point sources. The primary contributors are AGN, which dominate the radiative energy density of the Universe at X-ray wavelengths.

The precise fraction of the CXB that is resolved in X-rays has been the subject of numerous studies. Moretti et al. (2003) summed the X-ray emission from sources detected in a variety of *Chandra* and other surveys, and compared the total to an estimate of the total CXB, concluding that ≈90% of the CXB at $E < 2$ keV was resolved. Worsley et al. (2005) performed a similar analysis as a function of energy, and showed that the resolved fraction drops at energies >5 keV, indicating a "missing" population of hard sources, which may include AGN that are highly obscured by intervening gas (see below). Hickox & Markevitch (2006) took a complementary approach, measuring the absolute flux of the *unresolved* CXB in the CDFs, and showed that the resolved fraction of the 1–2 keV CXB is ≈80%.

Hickox & Markevitch (2007b) demonstrated that only 7% ± 3% of the 1–2 keV CXB remained unresolved after excluding HST sources in the GOODS field, in broad agreement with a stacking analysis by Worsley et al. (2006). By studying the distribution of X-ray counts at the HST source positions, Hickox & Markevitch (2007a) showed that the log*N*-log*S* for faint, unresolved X-ray galaxies in the CDFs is consistent with an extension of the observed population of faint star-forming galaxies, rather than AGN. These results indicate a large population of faint X-ray sources that may be accessible with deeper observations in the CDFs.

The cosmic evolution of black hole growth

A key question in black hole evolution is: where and when did black holes gain their mass? Unlike galaxies (for which we can determine ages for the stars), black holes have no "memory" of their formation history. Therefore, to determine the cosmic evolution of black hole growth we must observe that growth directly, by measuring how the space density of accreting black holes evolves with cosmic time. A number of authors have used the wealth of spectroscopic redshifts available in X-ray surveys to derive the X-ray luminosity function for AGN at a range of redshifts from the local Universe to $z > 4$ (e.g., Ueda et al. 2003; Barger et al. 2005; Hasinger et al. 2005; Silverman et al. 2008a). To cover the largest possible region in the luminosity-redshift plane, these studies combine data from narrow, deep and wide, shallow *Chandra* surveys, as well as data from *XMM-Newton*, *ASCA*, *Rosat,* and other missions.

These studies have shown that AGN activity has a relatively complex and interesting evolution with redshift. *Chandra* results favor a model of *luminosity-dependent density evolution (LDDE)*, in which the number density of AGN evolves differently for sources of varying luminosities. These results provide evidence for *downsizing*, in which the density of the most luminous AGN peaks earlier in cosmic time than for less luminous objects (e.g., Steffen et al. 2003; Hasinger et al. 2005, see Figure 4), which can be shown to imply that large black holes are formed earlier than their low-mass counterparts (e.g., Merloni & Heinz 2008; Shankar et al. 2009). Qualitatively similar downsizing has been observed for star formation in galaxies (e.g., Cowie et al. 1996), providing a circumstantial link between SMBH and galaxy evolution.

Understanding X-ray source populations

The large numbers of AGN detected in extragalactic surveys allows for robust statistical studies of AGN populations. Particular effort has been focused on measurements of X-ray spectra, which provide insights into the nature of AGN accretion. Tozzi et al. (2006) performed spectral fits for hundreds of sources in the CDF-S, while Green et al. (2009) measured the spectra for >1000 SDSS quasars in ChaMP, including 56 with $z > 3$. These studies show that in general, the unabsorbed spectra of AGN have remarkably uniform power-law continua. However, *Chandra* studies also have shown that X-ray spectra and X-ray to UV SEDs of AGN get harder with decreasing Eddington ratios[1] (e.g., Steffen et al. 2006; Kelly et al. 2008), similarly to black hole X-ray binaries (Remillard & McClintock 2006).

X-ray surveys also can constrain the numbers of AGN that are absorbed by intervening gas, which preferentially absorbs low-energy X-rays and so hardens the observed spectrum. The total spectrum of the CXB is harder than the emission from a typical unabsorbed AGN, indicating a significant contribution from absorbed sources. In the local Universe, 75% or more of optically selected Seyfert galaxies are obscured by dust (Maiolino & Rieke 1995), and *Chandra* surveys suggest a similar fraction are absorbed in X-rays. Further, there is evidence that the obscured fraction rises at lower luminosities and may increase at higher redshifts (e.g., Ueda et al. 2003; Steffen et al. 2003; Hasinger 2008), which may constrain models in which AGN provide radiation pressure feedback on surrounding gas. In addition, X-ray studies have confirmed the identification of obscured AGN detected in optical and IR observations (e.g., Hickox et al. 2007; Polletta et al. 2008; Donley et al. 2008; Alexander et al. 2008b).

Using the observed luminosity functions, spectral shapes, and absorbing columns derived from *Chandra* and other surveys, it has been possible to model the spectrum of the total cosmic X-ray background (e.g., Treister & Urry 2005; Gilli et al. 2007). While these models still have significant uncertainties (particularly in the number of highly obscured AGN), their success implies that we may be converging on a coherent picture for the cosmic evolution of black hole growth. One caveat however, is that the low numbers of X-ray counts in surveys make it difficult to distinguish absorption from intrinsically hard spectra for faint sources. If the X-ray spectra of AGN become harder at low Eddington ratio, this could produce a large number of low-luminosity, X-ray hard AGN that would be classified as "absorbed" in current analyses (Hopkins et al. 2009). Future deep surveys or detailed stacking of X-ray spectra may be able to break the degeneracy between intrinsic spectral shape and absorbing column.

Links between AGN and galaxy evolution

Finally, *Chandra* surveys have allowed for detailed examination of the host galaxies and environments of X-ray AGN, providing insight on the role of AGN in the evolution of galaxies. One powerful diagnostic is the color-luminosity distribution for the galaxies that host AGN. Galaxies are known to be divided into two types in color-magnitude space: the red sequence of luminous, passively evolving galaxies, and the blue cloud of less luminous, star-forming systems. Interestingly, a number of *Chandra* studies have found that at $z \lesssim 1$, luminous X-ray AGN (unlike radio, optical, or infrared-selected AGN) are preferentially found in

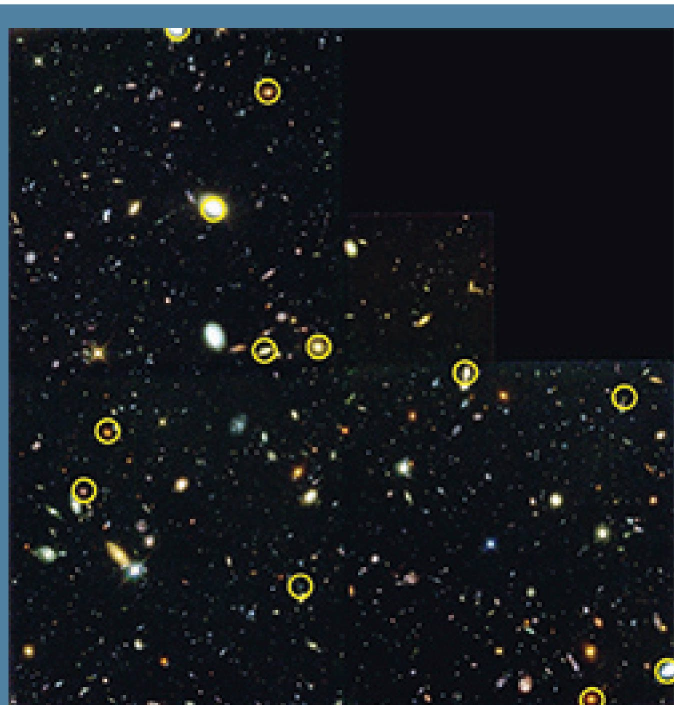

FIGURE 3: Optical counterparts of X-ray sources in the CDF-N as detected in the *Hubble* Deep Field (HDF). Shown is the full HDF image, and circles show objects matched with X-ray sources in the 2 Ms CDF-N. *(From Chandra press release; Credit: NASA/Penn State.)*

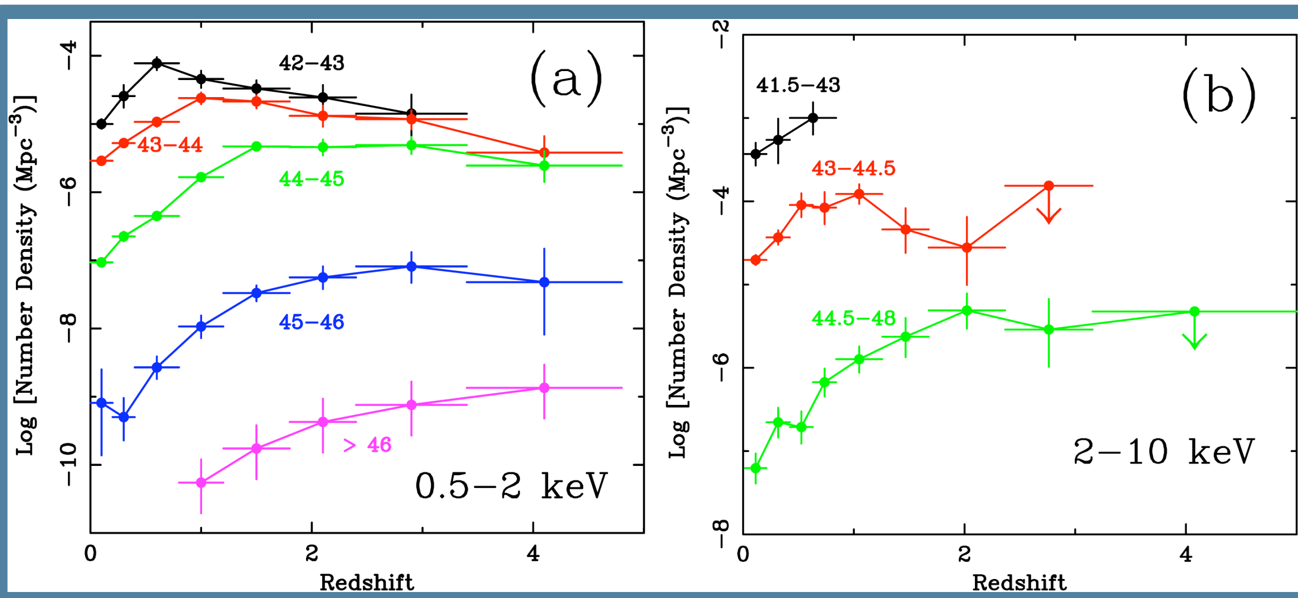

FIGURE 4: The comoving space density of X-ray AGN as a function of redshift, shown in the (a) 0.5–2 keV band (Hasinger et al. 2005) and (b) 2–10 keV band (Ueda et al. 2003). Lines show the evolution of AGN space density in different bins of luminosity. The data favor LDDE models, in which the space density of low-luminosity AGN peaks at a lower redshift compared to high-luminosity objects. Figure compiled by Brandt & Hasinger (2005).

the "green valley", with colors intermediate between blue and red galaxies (e.g., Nandra et al. 2007; Georgakakis et al. 2008; Silverman et al. 2008c; Hickox et al. 2009, see Figure 5), indicating that X-ray AGN may be associated with the transition of galaxies from the blue cloud to the red sequence, and may be responsible for quenching the star formation in galaxies through feedback (Bundy et al. 2008; Georgakakis et al. 2008). Further, studies of the environments and clustering of AGN find that *Chandra* X-ray AGN are preferentially found in overdense regions characteristic of galaxy groups (e.g., Yang et al. 2006; Georgakakis et al. 2007; Silverman et al. 2008b; Hickox et al. 2009; Coil et al. 2009). Models suggest it is these environments where star formation shuts off in massive galaxies; AGN may play a role in the initial quenching of star formation, or in subsequent heating that prevents gas from cooling and further forming stars (e.g., Croton et al. 2006; Bower et al. 2006; Hopkins et al. 2008).

Chandra surveys also have explored the presence of AGN associated with massive, vigorously star-forming galaxies in the distant Universe ($z \sim 2$). X-ray studies of starburst galaxies selected in the CDFs with observations in the submillimeter (e.g., Alexander et al. 2005) and infrared (Daddi et al. 2007; Fiore et al. 2008) have provided evidence for a large density of highly obscured AGN in galaxies co-eval with the formation of the bulk of their stellar mass. Alexander et al. (2008a) found that the AGN in submm galaxies have black hole masses that are roughly consistent with those expected from the local relation between black hole mass and bulge mass, indicating that there may be continuous feedback between star formation and accretion in these systems. While the precise nature of the AGN population associated with luminous starbursts is not yet clear, these studies point further towards important links between the growth of galaxies and their central SMBHs.

The future

Future X-ray surveys will provide more sensitive observations and larger AGN samples to study the characteristics and evolution of SMBH accretion in greater detail. One future prospect with *Chandra* is even deeper observations in the CDFs. *Chandra*'s high angular resolution will allow it to observe significantly deeper (up to 8 Ms or more) without reaching the confusion limit in the central regions (Alexander et al. 2003). This would allow the detection of a new population of extremely faint star-forming galaxies, as well as providing better photon statistics for the sources that have already been resolved. The upcoming NuSTAR[2] mission (to launch 2011) will provide an unprecedented all-sky survey at hard X-ray (6–80 keV) energies, while the eROSITA[3] instrument on the Spectrum X-Gamma observatory (scheduled for launch in 2011-2012) will survey the sky at 0.2–12 keV energies and will provide enormous samples of X-ray AGN. Among missions proposed for the future, Simbol-X[4] (target launch 2014) would provide high angular resolution (better than 30") and high sensitivity in the ~0.5-80 keV range, while EXIST[5] would conduct a large-area X-ray survey at the very hard (5-600 keV) energies. The Wide-Field X-ray Telescope[6] would provide an analog to SDSS in the X-ray band, detecting $>10^7$ X-ray

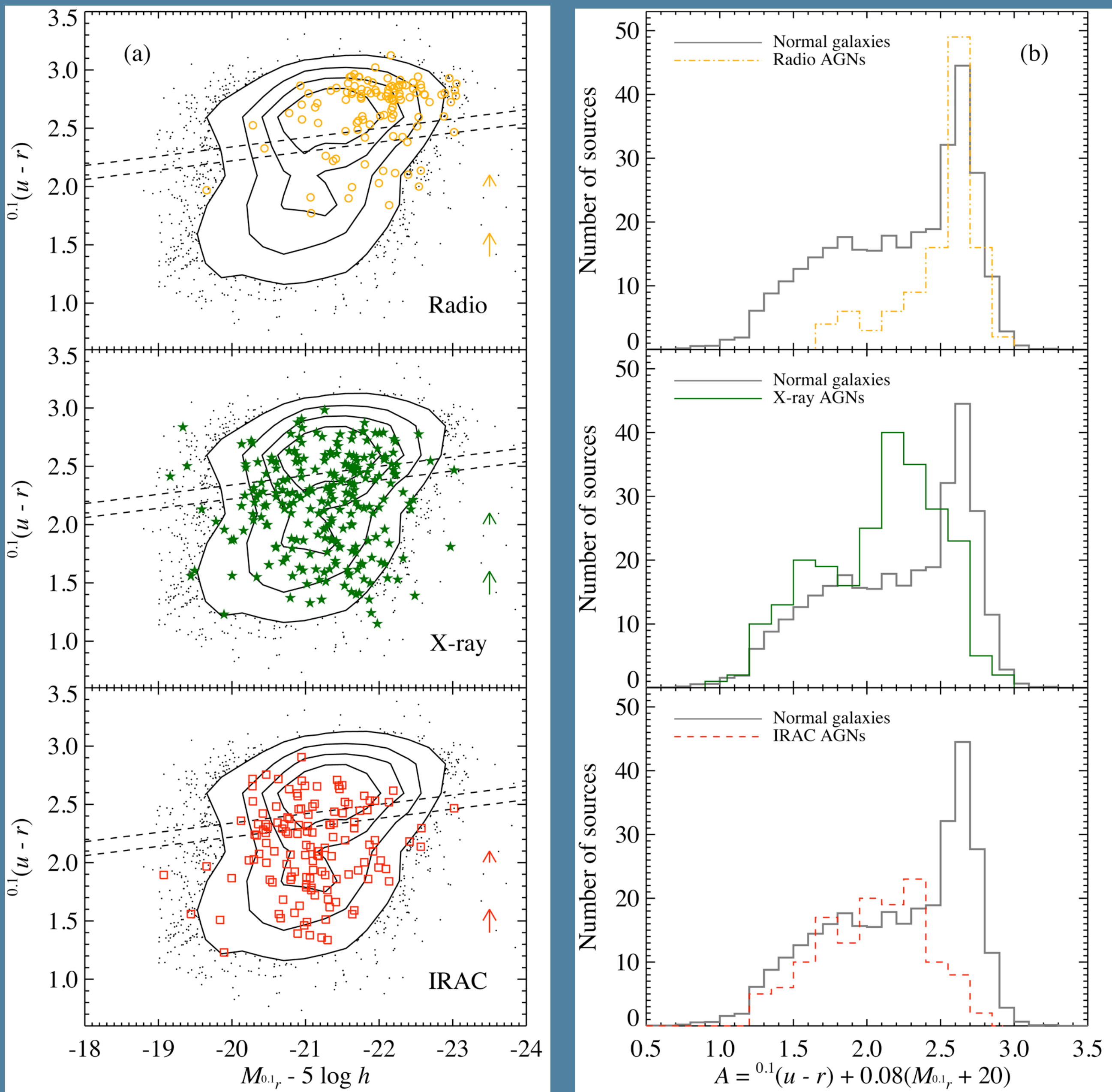

FIGURE 5: (a) Optical colors and absolute magnitudes of AGNs at 0.25<z<0.8 in the AGES redshift survey in Boötes (Hickox et al. 2009). Contours and black points show normal galaxies, and lines separate red and blue galaxies. The three panels show radio, X-ray, and IR-selected AGNs, respectively. (b) Distribution in rest-frame optical color for AGNs selected in the three wavebands, compared to normal galaxies at 0.25<z<0.8 (thick gray line). The radio AGN color distribution peaks along the red sequence, while X-ray AGNs are found preferentially in the "green valley" between the red sequence and the blue cloud. The distribution of IR AGNs is similar to that of X-ray AGNs, although they are typically found in somewhat less luminous galaxies, and show a less pronounced peak in the "green valley".

AGN over >10,000 deg[2] in the energy range 0.1–4 keV (possibly extending to 6 keV). Further, the enormous sensitivity of the International X-ray Observatory[7] would allow us to study in detail the spectra of large numbers of faint AGN. These future missions will be essential to build on our understanding of the growth of black holes and their place in the larger picture of galaxy and structure formation in the Universe.

Acknowledgements: Thanks to David Alexander, Francesca Civano, Bill Forman, Paul Green, Christine Jones, and Steve Murray for input, discussions, and comments on this article. ✩

FOOTNOTES

[1]The Eddington ratio is defined as the ratio of bolometric accretion luminosity to the Eddington limit, where $L_{Edd} = 1.3\times10^{38}(M_{BH}/M_{\odot})$ ergs s^{-1}.
[2] http://www.nustar.caltech.edu/
[3] http://www.mpe.mpg.de/projects.html#erosita
[4] http://smsc.cnes.fr/SIMBOLX/
[5]http://hea-www.harvard.edu/EXIST/
[6] http://wfxt.pha.jhu.edu/
[7] http://ixo.gsfc.nasa.gov/

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Project Scientist's Report

Martin C. Weisskopf, Stephen O'Dell

This year we celebrate *Chandra*'s 10th anniversary! On 1999 July 23, the space shuttle Columbia launched the *Chandra* X-ray Observatory. Then on 1999 August 12, *Chandra* obtained its first-light image of an x-ray source we dubbed "Leon X-1", in honor of Telescope Scientist Leon VanSpeybroeck. We fondly remember Leon and sincerely appreciate his contributions to the success of this mission. We also are grateful to the hundreds of scientists, engineers, technicians, support personnel, and even (sic) managers who contributed to the development and operation of *Chandra*.

On behalf of the *Chandra* Team, we invite you to join us in Boston, September 22-25, for the Symposium "Ten Years of Science with *Chandra*—*Chandra*'s First Decade of Discovery" (http://cxc.harvard.edu/symposium_2009).

Here's to another 10 years! ✩

CXC Project Manager's Report

Roger Brissenden

Chandra marked nine years of successful mission operations with continued excellent operational and scientific performance. Telescope time remained in high demand, with significant oversubscription in the Cycle 10 peer review held in June. In December 2008 the observing program transitioned on schedule from Cycle 9 to Cycle 10, and we look forward to the Cycle 11 peer review in June 2009.

NASA has decided to merge the *Chandra* and GLAST (now Fermi) fellowship programs, together with a number of additional fellowships, into a combined program called the Einstein Fellowships, which includes research areas related to the science goals of the Physics of the Cosmos program and its missions. NASA chose the CXC to solicit, evaluate and select proposals and administer the awards. In August the CXC issued a call for proposals for ten Einstein fellowships and received 156 proposals. (See the "Einstein Postdoctoral Fellowship Program" article).

The team worked hard to prepare for NASA's Senior Review of operating missions held in April. For the first time, the review included two large missions, *Chandra* and *Spitzer*. *Chandra* ranked second of the ten missions reviewed, with a score of 9.1 out of 10. The review committee's report said, "*Chandra* has recently produced - and is expected to continue to produce - results which change our view in areas as diverse as dark matter, dark energy, and clusters of galaxies." As a result of the ranking, *Chandra*'s funding level is expected to remain at approximately the present level for the next two years.

The CXC mission planning staff continued to maximize observing efficiency in spite of temperature constraints on spacecraft pointing. Competing thermal constraints continue to require some longer observations to be split into multiple short duration segments, to allow the spacecraft to cool at preferred attitudes. Following careful study and thermal modeling, mission planning complexity eased after an EPHIN radiation detector thermal constraint was relaxed in December 2006 and selected heaters on the ACIS instrument and the science instrument module were turned off in 2008 (see the "Instruments: ACIS" article). Overall the average observing efficiency in 2008 was 68%, compared with 67% in the prior year and a maximum possible efficiency of ~70%. Operational highlights over the past year included 9 requests to observe targets of opportunity that required the mission planning and flight teams to reschedule and interrupt the on-board command loads. The sun was quiet during the year, causing no observing interruptions due to solar activity. *Chandra* passed through the 2008 summer and winter eclipse seasons, as well as a brief lunar eclipse in February, with nominal power and thermal performance.

The mission continued without a significant anomaly and had no safe mode transitions in the last year. On three occasions the spacecraft transitioned to normal sun mode due, it is believed, to single event upsets in electronic circuits. In all cases the operations teams returned the spacecraft to normal status with no adverse consequences and minimal loss of observing time.

Both focal plane instruments, the ACIS (Advanced CCD Imaging Spectrometer) and the HRC (High Resolution Camera), have continued to operate well and have had no major problems. ACIS, along with the overall spacecraft, has continued to warm gradually. Following tests conducted during 2007 and 2008 to determine the effect of turning off the ACIS detector housing heater, the heater was turned off permanently in 2008, with an immediate beneficial reduction in the average ACIS focal plane temperature (see the "Instruments:ACIS" article).

All systems at the *Chandra* Operations Control Center continued to perform well in supporting flight operations.

Chandra data processing and distribution to observers continued smoothly, with the average time from observation to delivery of data averaging less than 2 days. The *Chandra* archive holdings grew by 1.6 TB to 6.6TB (compressed) and now contain 25 million files. 1.2 TB of the increase represents *Chandra* Source Catalog data products.

The Data System team released software updates to support the submission deadline for Cycle 10 observation proposals (March 2008), the Cycle 10 Peer Review (June) and the Cycle 11 Call for Proposals (December). In addition, the team released production versions of the *Chandra* Source Catalog (CSC) software and began processing data for the catalog in the Fall. Virtually all publicly available ACIS data representing compact sources have been processed, representing on the order of 100,000 sources, and will be available when the catalog is officially released in early 2009.

The Education and Public Outreach (EPO) group issued 11 *Chandra* press releases, 17 image releases, and 7 press postings and advisories during 2008. The EPO team organized two press conferences and two NASA media teleconferences, one accompanied by a separate briefing for NASA's Museum Alliance. The team continued to release *Chandra* podcasts through the CXC website, with 22 new standard definition and 20 high definition podcasts on science topics this year. They also released an audio podcast of the text of the multi-wavelength Braille book "Touch the Invisible Sky," and a video plus audio podcast of the Universe Forum's "Incredible Two Inch Universe" with American Sign Language translation. In addition, the *Chandra* podcasts were converted to the Adobe Media Player (AMP) format for the launch of the AMP channel on NASA's website. The team received a NASA ROSES grant to implement the International Year of Astronomy Cornerstone Project, "From Earth to the Universe" exhibits at two semi-permanent and six traveling sites around the United States (see the "*Chandra* in IYA2009" article).

We look forward to a new year of continued smooth operations and exciting science results. Please join us to celebrate *Chandra*'s discoveries at the seminar Ten Years of Science with *Chandra*, to be held in Boston in September, 2009. ✯

Instruments: ACIS

Paul Plucinsky, Catherine Grant, Joe DePasquale

The ACIS instrument continued to perform well over the past year with no failures or unexpected degradations. The charge-transfer inefficiency (CTI) of the FI and BI CCDs is increasing at the expected rate. The CIAO software and associated calibration files correct for this slow increase in CTI over time. The contamination layer continues to accumulate on the ACIS optical-blocking filter. Recent measurements indicate that a revision of the temporal model for the contaminant may be necessary. The CXC calibration group is investigating the issue and may release a revision later this year.

The only significant change in ACIS performance over the last year regards the thermal control of the ACIS focal plane (FP). As discussed in last year's newsletter article, a higher percentage of ACIS observations have been experiencing warmer than desired FP temperatures as the spacecraft ages and components inside the spacecraft get warmer in general. In response to this trend the ACIS Operations team turned off the ACIS Detector Housing (DH) heater on April 7, 2008. Before the DH heater was turned off, approximately 1/3 of observations had an average FP temperature of -119.2 C or warmer. After the DH heater was turned off, only about 2% of observations had an average FP temperature of -119.2 C or warmer. The desired FP temperature is -119.7 C. The FI CCDs have a narrower tolerance on the FP temperature than the BI CCDs. For the FI CCDs, the gain changes by 0.3% at 1.5 keV if the FP temperature warms to -119.2 C and for the BI CCDs, the gain changes by 0.3% if the FP temperature increases to -118.2 C. Figure 6 shows the average FP temperature from April 2007 until January 2009. The red line shows the FI CCD limit of -119.2 C and the blue line shows the BI CCD limit of -118.2 C. The figure clearly demonstrates the improvement in control of the ACIS FP temperature since the DH heater was turned off.

As a consequence of this change, the temperature of the ACIS Camera Body (CB) is no longer actively controlled. This created a complication for the aspect reconstruction since the ACIS fiducial lights are mounted on the ACIS CB. As the CB temperature increases/decreases the CB expands/contracts, producing an apparent motion in the fiducial lights. The CXC Aspect team has calibrated this motion by relating the brightness of the fiducial lights to the CB temperature and has modified the aspect reconstruction software to account for this effect. After applying this change, the Aspect team has confirmed that the aspect reconstruction is as accurate after the DH heater was turned off as it was before. ✯

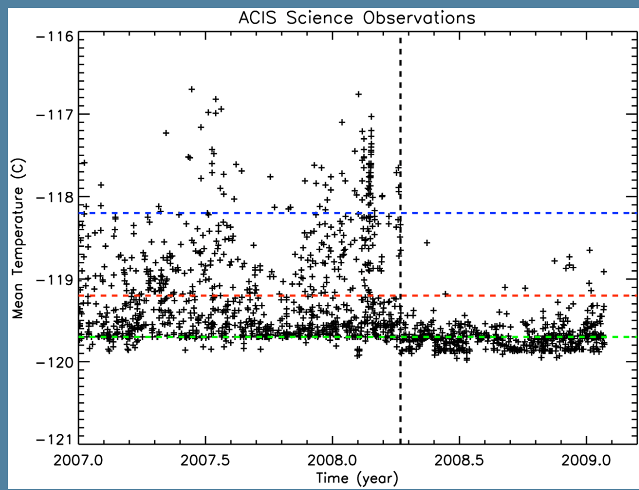

FIGURE 6: The average ACIS focal plane temperature for science observations from April 2007 until January 2009. The dashed vertical line at 2008.27 indicates the day on which the ACIS detector housing heater was turned off. The green dashed horizontal line indicates the desired FP temperature of -119.7 C. The red dashed line indicates the temperature (-119.2 C) at which the gain of the FI CCDs changes by 0.3% and the blue dashed line indicates the temperature (-118.2 C) at which the gain of the BI CCDs changes by 0.3% .

Instruments: HRC

Ralph Kraft, C.-Y. Ng

HRC operations continue smoothly with no major problems, anomalies, or interruptions. Routine monitoring observations show no significant charge extraction from the detectors. There may be some evidence of a decrease in the low energy (below 400 eV) QE of the HRC-S, probably indicative of the chemical evolution of the CsI photocathode. This is being monitored by the CXC Cal team and the HRC instrument team, but this phenomenon currently is not significant for scientific observations. There has been no significant change in the HRC-I quantum efficiency during the past year. One HRC observation was made using one of the shutters during the past year, an HRC+LETG observation of the Crab Nebula. The shutter was used to block the zeroth order image in order to reduce the overall instrument rate from this bright source below the telemetry limit. There were some anomalies in inserting and withdrawing the shutter in the past. Overall another quiet year from an HRC perspective.

A wide variety of scientific investigations have been carried out over the past year with the HRC instruments. This year we highlight an HRC-I observation of the Mouse nebula, a pulsar wind nebula, demonstrating the HRC's imaging and timing capabilities.

High Resolution X-ray Imaging of the Mouse

C.-Y. Ng, for the Mouse Team

Neutron stars lose a significant amount of their rotational energy through the relativistic winds. The consequent interactions with the surrounding materials result in broadband synchrotron emission, collectively referred to as pulsar wind nebulae (PWNe). The properties of PWNe depend strongly on the evolutionary state and environment. Since neutron stars are typically born with space velocities of a few hundred kilometers per second, they eventually escape the natal supernova remnants and travel supersonically through the interstellar medium. This results in bow shock nebulae, in which a pulsar's relativistic outflow is confined by the ram pressure. As compared to PWNe confined within supernova remnants, bow shocks are governed by a much simpler set of boundary conditions, offering ideal cases to refine our understanding of relativistic shocks and pulsar winds electrodynamics.

The best example of a bow shock PWN is G359.23-0.82

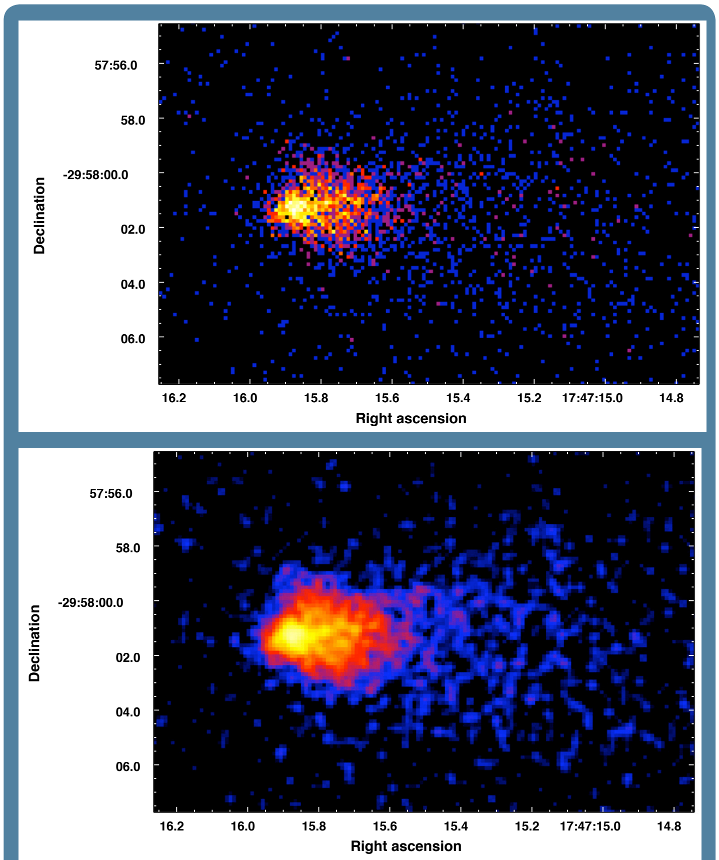

FIGURE 7: Raw (top) and smoothed (bottom) HRC-I images of the Mouse PWN.

('the Mouse') powered by the 0.1s period pulsar J1747-2958. This is the brightest bow shock system in X-rays, located near the direction of the Galactic center. Multi-wavelength studies show that the Mouse is well-modeled by a bright 'head' coincident with the pulsar, a 'tongue' corresponding to the surface of the wind termination shock, and an elongated 'tail' produced by material in the post-shock flow. We have recently obtained new HRC observations of this bow shock system, which offers the highest angular resolution images. Figure 7 shows the HRC image (raw and smoothed, respectively), demonstrating the unique capability of the HRC instrument. The new HRC observation suggests some hints of small-scale features, possibly a jet or knots, near the backward termination shock. The results will allow a comparison to detailed magnetohydrodynamic simulations. For comparison, an archival ACIS images of the same region is shown in Figure 8. For timing analysis, we have carried out simultaneous radio timing observations of the central pulsar in order to fold the HRC data. The lightcurve of the pulsar is shown in Figure 9 folded on the frequency of the radio pulsations (100 ms). We found no statistically significant X-ray pulsation at the radio pulse frequency. ✭

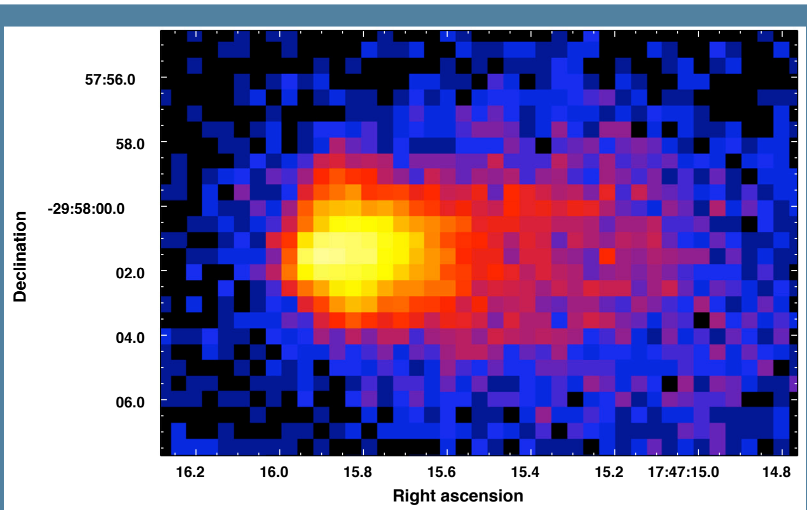

FIGURE 8: ACIS-S image of the Mouse PWN.

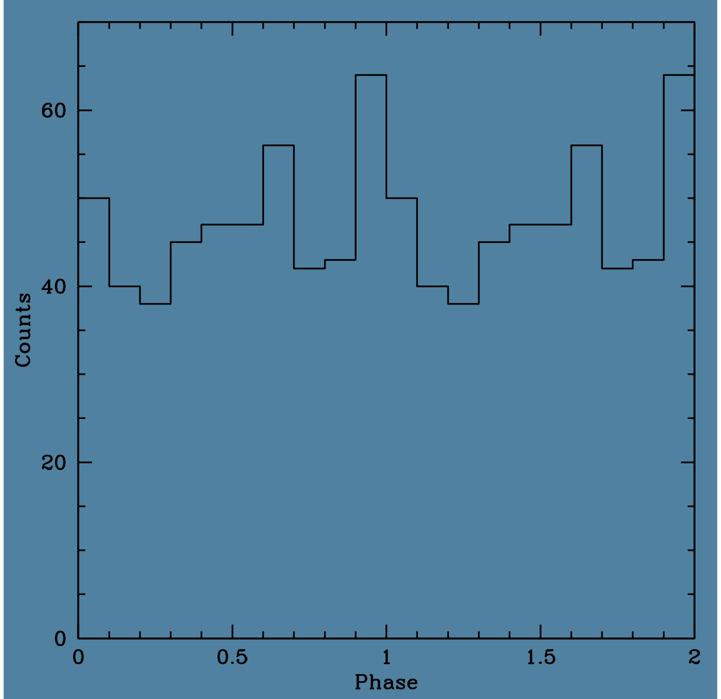

FIGURE 9: HRC-I lightcurve of the central pulsar of the Mouse PWN folded on the frequency of the radio pulsations.

Instruments: HETG

Dan Dewey

HETG Status and Calibration

The HETG continues to perform nominally with no specific issues. Of note in the past year are the efforts of the "International Astronomical Consortium for High Energy Calibration" (http://www.iachec.org/) to assess the cross-calibration of several current X-ray missions. HETG observations contributed to the low-energy results given in: "The SMC SNR 1E0102.2-7219 as a Calibration Standard for X-ray Astronomy in the 0.3-2.5 keV Bandpass" by Plucinsky et al. 2008. The missions (and instruments) included in this paper are: *XMM-Newton* (RGS1, MOS1, MOS2, pn), *Chandra* (HETG-MEG, ACIS-S3), *Suzaku* (XIS0, XIS1) and *Swift* (XRT). Relative flux measurements were compared at four low-energy spectral regions, corresponding to the bright lines of O VII, O VIII, Ne IX and Ne X (with rough energies of 0.57, 0.65, 0.92, and 1.02 keV.) These mid-2008 results demonstrate an absolute calibration agreement that is largely within ±10% across the instruments. The effort is on-going with yearly IACHEC meetings, the next is scheduled for the end of April 2009.

Be sure to also see the TGCat article in this Newsletter !

HETG Technique: "Look Ma! No Angstroms!"

HETG spectra are often presented in counts versus Angstrom space and plotted to emphasize narrow spectral features, and so they look very different when compared with X-ray spectra from CCD instruments (e.g., ACIS, EPIC, XIS). However, there is nothing about the HETG spectral products that prevents viewing them in the more familiar flux versus keV space. Likewise, as the following examples show, HETG observations can be used to: measure continuum sources, create light curves, generate hardness ratios, etc.

The broadband MEG spectrum of the Galactic X-ray binary 4U 1957+11 is shown in Figure 10; this binary includes what may be the most rapidly spinning black hole in the Galaxy. Here the data are fit with a model consisting of a disk blackbody plus a Comptonizing corona which contributes at higher energies. Besides studying black hole emission models through the broadband spectra, the data also allowed for a very accurate (and very low) determination of the N_H toward 4U 1957. Of course one can still zoom in on the spectrum and study narrow features that may be present. For example, here Ne IX absorption is seen at about 0.92 keV. The measured depth of this feature is consistent with the idea that most of the hot gas we see

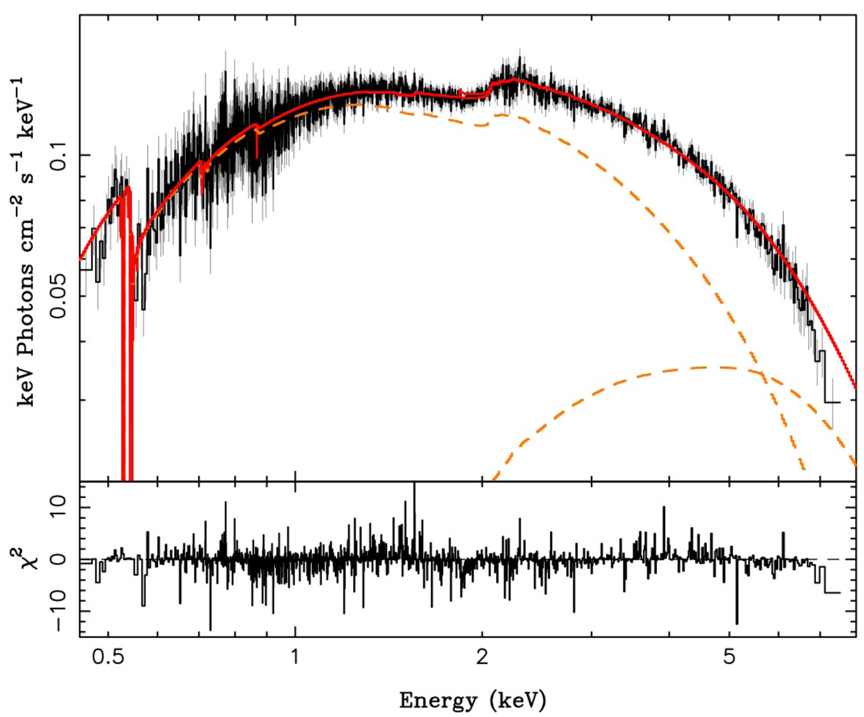

FIGURE 10: HETG spectrum of the low-mass X-ray binary 4U 1957+11. See text for discussion. (from Nowak et al. 2008)

along sightlines to distant objects (e.g., the AGN Mkn 421) is fairly local to, and above the disk of, our Galaxy.

In perhaps an even more uncommon presentation of HETG data, Figure 11 from Schulz et al. (2008) shows a light curve and color-color diagram from an observation of the neutron star X-ray binary Cyg X-2. Note that the count rate is equivalent to almost 0.5 Crab during the observations. To observe such a bright source, even given the reduced effective area and reduced pileup of the HETG instrument, it was necessary to operate the ACIS readout in the continuous clocking (CC) mode as well. The HETG spectral data in 500 s time intervals were coarsely binned in three spectral bands (soft: 0.5-2.5, medium: 2.5-4.5, and hard: 4.5-8 keV) to create the color ratios plotted (Hard Ratio = hard/medium, Soft Ratio = medium/soft). With the branches of the "Z-pattern" established, it was possible to measure variations of the flux of broad emission lines of Mg, Si, S, and Fe in the different "branches" of the Z-track, leading to an understanding of the parameters of the accretion disk corona in Cyg X-2.

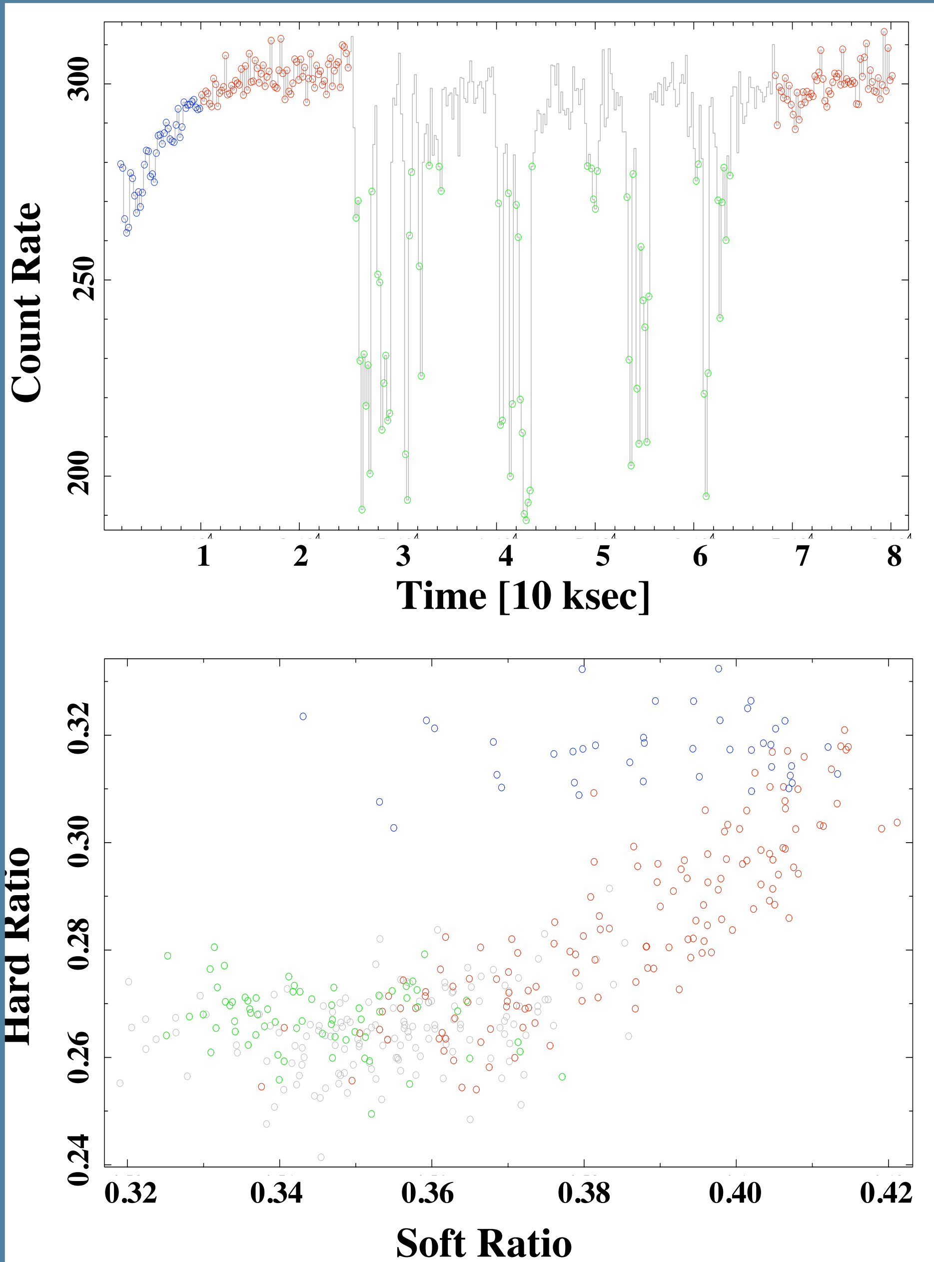

FIGURE 11: (Top) Light curve from an HETG observation of Cyg X-2. (Bottom) The light-curve points are plotted in a color-color diagram showing the horizontal branch (blue), normal branch (red), and flaring branch (green)(from Schulz et al. 2008).

HETG Science: "3D Clues in Nova Outbursts"

Black holes and neutron stars capture our imagination and interest partly because they are so "extreme". But the exciting phenomena surrounding their lives, accretion disks, jets, outbursts, and explosions, are also seen in more "vanilla" systems. Koerding et al. (2008) recently noted: "there may be a common disc/jet coupling in all accreting objects from young stellar objects (YSOs) to gamma ray bursts (GRBs)." This statement was made in the context of one example of such systems, the cataclysmic variables (CVs), binary systems consisting of a donor star and an accreting white dwarf (WD).

As artistically shown in Figure 12 (courtesy A. Beardmore, http://www.astro.keele.ac.uk/~apb/OGL_CV/), in a "dwarf nova" the material from the donor star accumulates in the cold outer region of an accretion disk around a non-magnetic WD. On occasion a viscous instability will trigger the matter to fall into the boundary layer around the WD, creating an optical outbust. In a recent paper,Okada et al. (2008) present the X-ray view of an outburst of SS Cyg using archival HETG data, Figure 13. Although the overall X-ray flux decreases during outburst, the fluxes of the emission lines increase by factors of 2 to 10.

Of particular interest is the broadening of the lines during the outburst. This broadening, likely due to Doppler velocities, gives clues to determine the geometry of the emitting material. Okada et al. consider material in a disk wind, a shell of matter falling onto the white dwarf, and/or azimuthal motion of the plasma around the white dwarf. They lean toward this latter mechanism based on fits to the set of bright K-alpha lines of O, Ne, Mg and Si.

A similar but more energetic system is RS Oph, a full fledged nova in which matter accretes from a red giant (RG) onto the surface of the WD where it explodes in a thermonuclear runaway, Figure 15 (left) (http://www.swift.ac.uk/RSOph.shtml). Observed with Director Discretionary Time in 2006, the HETG-measured line shapes, Figure 14 (Drake et al. 2009), encode not only aspects of the source geometry and velocities, but they are 'sculpted' by differential absorption which removes the red-shifted (positive velocity) side of the profiles. Amazingly, a detailed hydrodynamic model including X-ray emission synthesis, Figure 15 (right), produces asymmetric, blue-shifted line profiles remarkably similar to those observed by the HETG. To reproduce a comparable emssion-measure-versus-temperature curve as the data, the model includes an additional density enhancement in the equatorial plane of the binary system (consistent with non-X-ray observations). This enhancement combined with the collimation produced by the steep density variation in the RG's wind environment produces the highly asymmetric remnant.

Clearly, combining high-resolution X-ray observations over a wide wavelength range (i.e., the whole range of abundant ions: C, N, O, Ne, Mg, Si, S, Fe) with detailed 3D hydrodynamic simulations (and bigger computers) holds the promise of letting us 'see' the inner workings of X-ray sources with high fidelity in the years ahead. ✯

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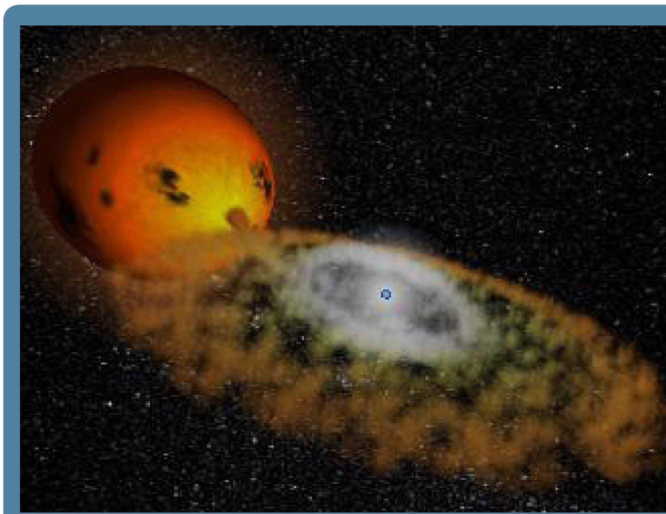

FIGURE 12: An artistic scientist's view of the dwarf nova SS Cyg (courtesy A. Beardmore, http://www.astro.keele.ac.uk/~apb/OGL_CV/).

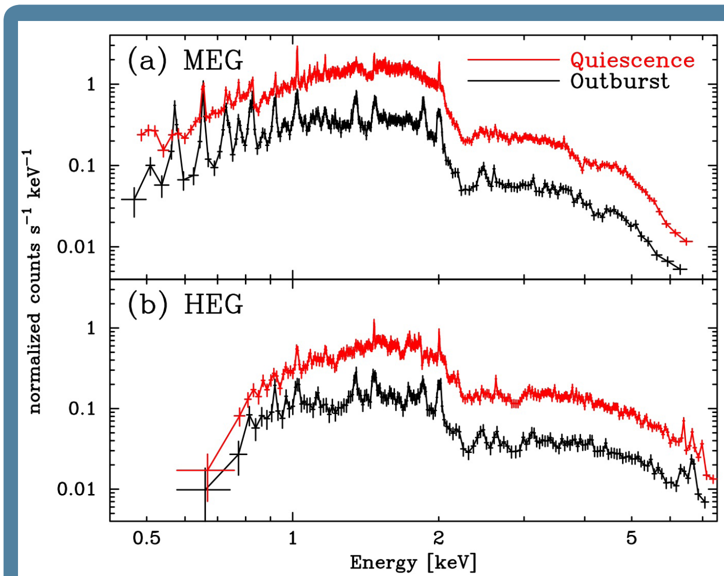

FIGURE 13: HETG spectra of SS Cyg in quiescence and in outburst (from Okada et al. 2008)

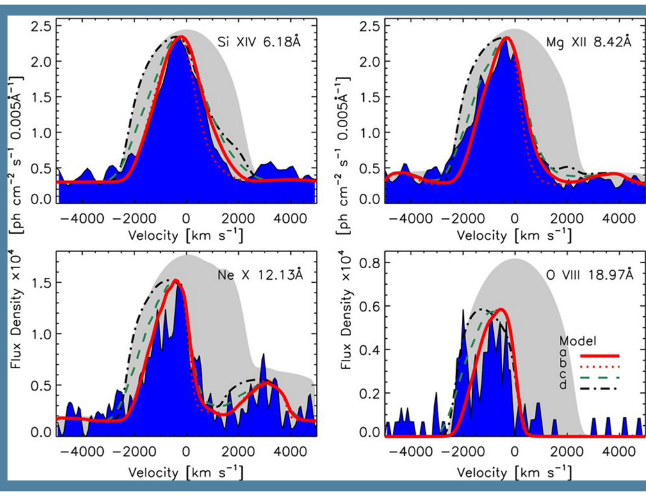

FIGURE 14: HETG-measured line profiles of RS Oph at 13.9 days into its February 2006 outburst; the data (blue) have a detailed structure differing from the simple spherical shell model (background gray; from Drake et al. 2009).

FIGURE 15: (left) An artists rendering shows the blastwave leaving the WD hours after the explosion (Credit: STFC/David Hardy). Because of the $1/r^2$ wind density profile around the red giant, the blast wave is far from spherical and will be effectively collimated away from the red giant. (above) A synthetic X-ray image of RSOph two weeks after explosion based on a detailed hydrodynamic model shows that the X-ray emission mainly originates from a (relatively) small region in the equatorial plane (from Orlando et al. 2009). Note the scale of this image: the WD and RG are the tiny white and red dots at far right!

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Instruments: LETG

Jeremy Drake

It was with a bittersweet tear of nostalgia in the corner of my eye that I watched my aging Linux box and its mountain of dusty whirring 9Gb appendages being unplugged and wheeled away, like a beloved institutionalized older relative at the end of visiting time. I didn't really mean it, of course, that time, or the other time, or that time either, and that other one, or ten, when I threatened to hurl it from the roof of the Center for Astrophysics during one of its senior moments of frustrating idiosyncratic X-dysfunction. So it was with some measure of guilt-ridden trepidation that I started to punch the keys of the new model: two rippling quad-cores of seductive, brushed aluminium-encased Mac Pro that seemed to whisper "try me..." It was for the good of the project, after all. We must be pragmatic. Sentimentality must be cast aside. *Chandra* needs it. It needs it because it has a new virtual mirror. Its new HRMA model makes it even better than it was before. It helps a lot of people understand their observations more easily. It improves the accuracy of our astrophysics. It silently eases unspoken international tensions with its European sibling *XMM-Newton*. It is progress. And it damn well breaks the whole of the LETGS calibration and we have to do it all over again.

I mention the new computer so the reader will have complete faith in our wherewithal to meet this slightly involved task: the reprocessing and analysis of about two score and ten different *Chandra* observations. Already I have got to grips with some powerful new spectral data analysis software on the Mac, and after only a few weeks we have made great progress. I haven't quite worked out the details of how to do all the spectral fitting and things like that—the cool street nomenclature of the Mac is quite different to what I'm used to and all the X-ray models and things have rather strange and sometimes colorful names—but I am confident I can work it all out soon. Even the software itself has an imaginative name: its called "Garage Band", or something like that—presumably a reference to the early years of AS&E.

Why does the LETGS have to be recalibrated? Unlike *Chandra*'s ACIS detector, the response of the primary detector for the LETG—the HRC-S—relies rather heavily on using cosmic sources of X-rays for calibration. At shorter wavelengths, $\lesssim$50Å or so, the supply of photons from the steady photospheres of white dwarfs that we use as standard candles[1] effectively runs out, and we have to turn to, shall we say, less well-understood X-ray sources. Nature has handed us one possible option in the form of BL Lac objects—perhaps not a poisoned chalice, but a rather unpleasant cocktail you would rather pour down the sink while no one is looking. (This might explain some of the behavior of our colleagues studying BL Lac's.)

BL Lac's beckon our calibration like sirens of the cosmos with their apparently silky smooth pure power-law continua, only to dash it on the rocks of spectral reality when we fail to notice the bit of curvature here or a break in index there, or that the thing has decided to lean at a completely different angle to when we looked at it last time. So in order to use bright BL Lac's for calibration, like the adopted *Chandra* standard PKS 2155-304, we need to know how they are behaving and what spectral model to attribute to them during our observations. As a reference we have used contemporaneous observations obtained with

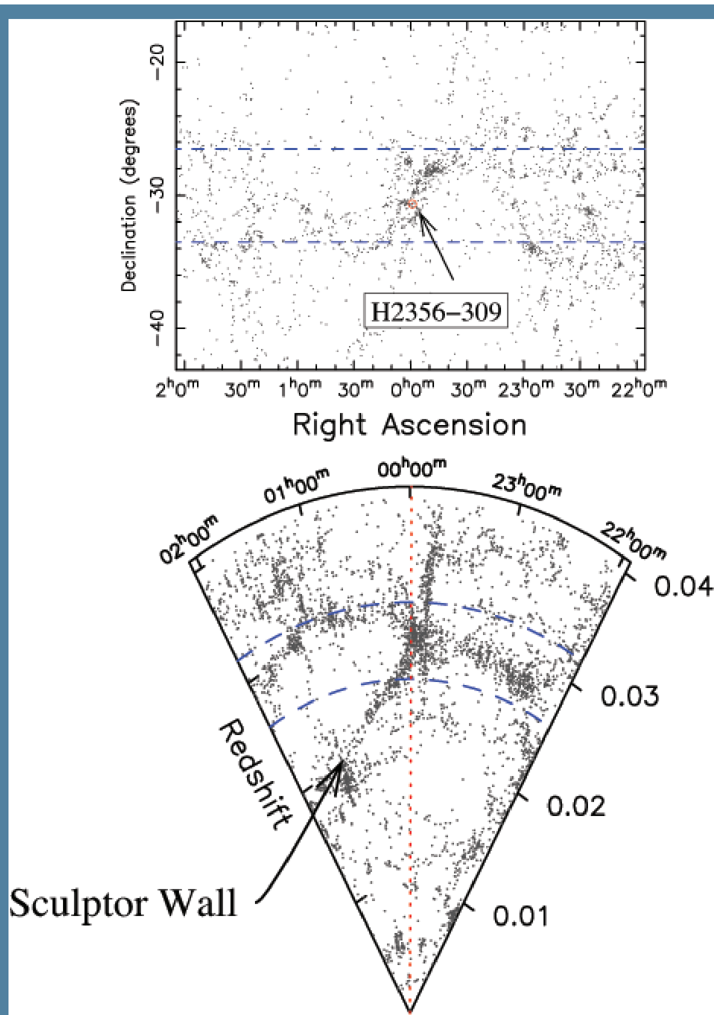

FIGURE 16: Sky map (top) and "wedge diagram" (bottom) of the region of the Sculptor Wall where the blazar H 2356-309 is located. Each dot correspond to a different galaxy. The blue dashed lines in the upper panel define the range of declination represented by the galaxies in the lower panel. The blue dashed lines in the lower panel show the red shift range of the galaxies in the top panel. The WHIM structure corresponding to these galaxies was detected in combined *Chandra* LETG and *XMM-Newton* RGS spectra. (From Buote et al. 2009).

the HETG+ACIS combination to constrain the models for the LETG. Since the HRMA model throughput has now changed, the models one derives from the HETG observations also change: all the data (HETG and LETG) have to be reanalyzed. This is of course where Garage Band and all its spectral models comes in. It appears that a combination of Urban models based on Vintage Funk and Electric Slap with γ=120 bpm provide a pretty good match to the data. Expect the revised LETG+HRC-S calibration release during the spring.

The Writing on the Sculptor Wall

Randall Smith once made the ingenious suggestion that the mysterious disappearance of socks experienced here on earth could account for the missing baryons in the universe.[2] While the details of the theory remain to be fleshed out, it is perhaps not too far-fetched in the realm of cosmology to hypothesise that socks are somehow evaporated from tumble driers into the intergalactic medium and form low density filamentary structures similar to those predicted by cosmological hydrodynamic simulations (e.g. Cen & Ostriker 2006 and references therein). If so, the sock-baryon theory might be tested by absorption spectroscopy of the warm-hot intergalactic medium (WHIM).

X-ray WHIM spectroscopy was pioneered by Fabrizio Nicastro and coworkers based on LETG spectra of bright background blazars (yes, that cocktail again! Nicastro et al. 2002, Nicastro et al. 2005). It is tricky because the absorption signatures are rather weak, and either an unusually bright background source or a very long exposure (and preferably both) is needed to see any convincing absorption features. In a recent study using both the *Chandra* LETG and RGS, Buote et al. (2009) have circumvented one of the major problems that greatly affects the sensitivity of the experiment. In searching for WHIM signatures at arbitrary red shift, a *blind* search must be done, testing for spectral features at all plausible red shifts from zero up to that of the background source. If, instead, the red shift of a particular WHIM feature is known, features can be sought at their expected wavelengths, thereby reducing the chance of coincidence with statistical fluctuations through the number of trials avoided in the corresponding blind search.

Buote et al. (2009) looked for WHIM absorption signatures in the spectra of the blazar H 2356-309 located behind a large structure in the Sculptor region of the southern sky containing a conglomeration of groups and clusters of galaxies known as the *Sculptor Wall*. This region and the line of sight to H 2356-309 is shown in Figure 16. The LETG and RGS spectra of H 2356-309 are illustrated in Figure 17, where features attributed to absorption by O VII at z=0, likely corresponding to local Galactic gas or the Local Group WHIM, and at z=0.032, corresponding to the expected Sculptor Wall red shift, are detected. Neither the *Chandra* or *XMM-Newton* observations provide significant detections alone, but when combined both lines attain a significance of ~ 3σ. The Buote et al. (2009) work provides strong evidence in support of the theoretical simulations that predict the "missing baryons" reside in the WHIM.

The most common constituent of socks—cotton—comprises mostly fibres of cellulose ($C_6H_{12}O_6$) with trace amounts of heavier elements such as Si, Ca and Al. Wool socks instead are made of more complex proteins from the keratin family and contain much more nitrogen. While the detection of O VII lines is perfectly consistent with highly ionized socks of any type, future deeper studies encompassing lines of C, N and O might also help constrain the different sock populations of the universe.

No Gain Map without Pain Map

In Newsletter 15, my good colleague Brad Wargelin bravely contravened the Writers Guild of America strike and penned an excellent report of the latest work toward defining a new gain map for use in shovelling out those background events that accumulate like snow in New England over the HRC-S during observations. In 2000 we implemented a background filter developed by Brad that removes background based on detector "pulse height"—essentially the strength of the electron cascade resulting from a photon or particle event on the illuminated side of the detector. Photon events on the HRC-S have a fairly nice, narrowly-peaked pulse height distribution whereas particle events giving rise to the snowy background are much more

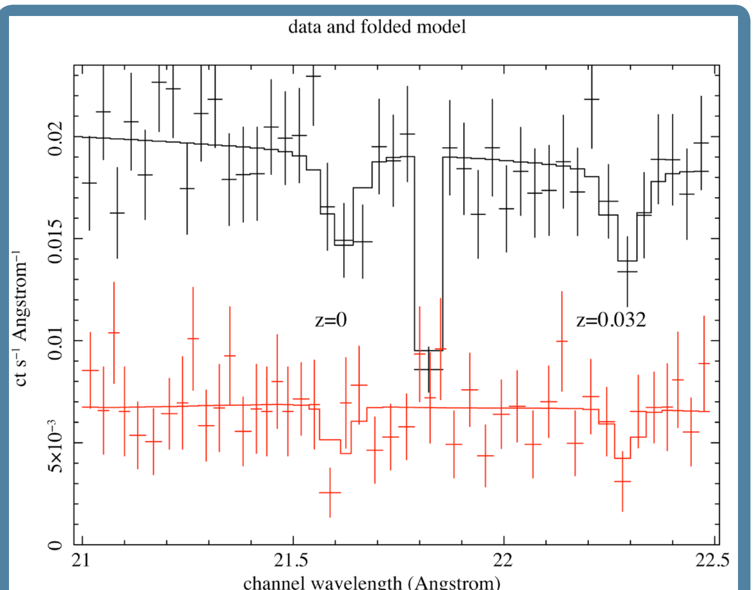

FIGURE 17: Background-subtracted *XMM-Newton* RGS (black) and *Chandra* LETG (red) spectra of blazar H 2356-309 in the 21–22.5 Å range. The solid curves illustrate spectral models comprising a power law continuum and absorption lines corresponding to the local WHIM and WHIM at the red shift of the Sculptor Wall. (From Buote et al. 2009).

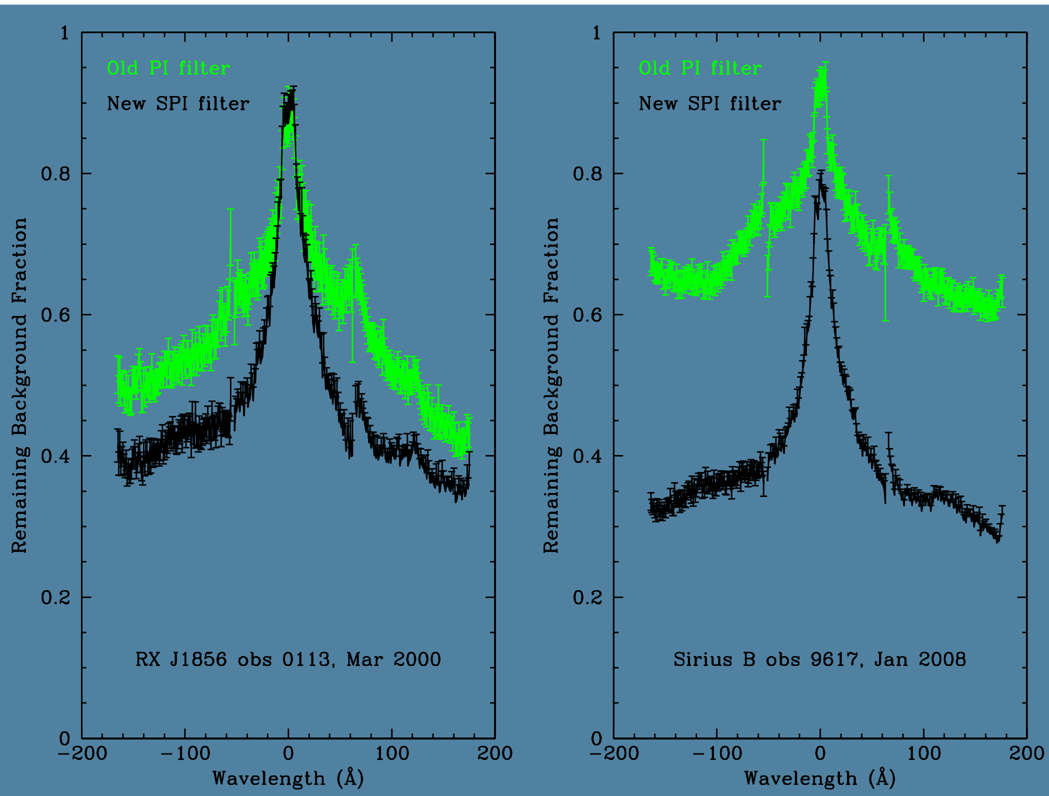

FIGURE 18: Comparison of the current and new filters, applied to data from 2000 and 2008. The old PI filter becomes less effective over time because it does not account for decreasing gain. Less background is removed at short wavelengths because the filtering threshold must be higher to avoid excluding X-ray events. The raw background rate is higher in 2008 than 2000 because of the solar cycle, but relatively more background is removed in 2008 because the BG pulse-height distribution has relatively more high-channel events. (From http://cxc.harvard.edu/contrib/letg/GainFilter/)

uniformly distributed. By drawing a line around the photon distribution and throwing out the events outside it we can exclude some of the background.

This filter is still quite effective and gets rid of about half the background with minimal X-ray event loss. However, two aspects of the detector performance prevent us drawing a general line around photon events as tightly as we would like to exclude the most background possible. Firstly, we had to allow some slop for a secular drop in the detector gain—and the peak of the X-ray pulse height distribution—that has continued since launch. Secondly, the detector pulse height response for a photon of a given energy strongly varies over the detector. To avoid these problems, Brad and Pete Ratzlaff went to great pains to devised a time-dependent gain map that utilizes the energy-dependent event position signals telemetered by the detector. Unlike simple pulse height, this "scaled SUMAMPS" parameter shows very little spatial variation over the detector. The result is a background filter that can cut around real photon events much more tightly and reject more background (Figure 18). The overall efficacy of the new filter is shown in Figure 19.

As you can gather from Figure 18, the improvement over the current filter is larger toward longer wavelengths. Anyone attempting to analyze spectra longward of ~50Å that are not completely source-dominated (and they rarely are) is urged to apply the new filtering algorithm in order to reduce the background. Even for $\lesssim$ 50Å these reprocessing steps should prove worthwhile. Since there really is no gain without pain, what is the catch? The algorithm has yet to be implemented in CIAO and its application is slightly less direct than the current approach. However, Pete Ratzlaff has whipped up a ripping Perl program that does the job and is easy to apply (though I have not yet worked out how to do this in Garage Band). The filter is more fully described with links to the filtering program and gain map on http://cxc.harvard.edu/contrib/letg/GainFilter/. A full CIAO implementation of the improved filter is expected later this year.

For the HRC-S Pain Map, see our faces at the upcoming Calibration Workshop. ✯

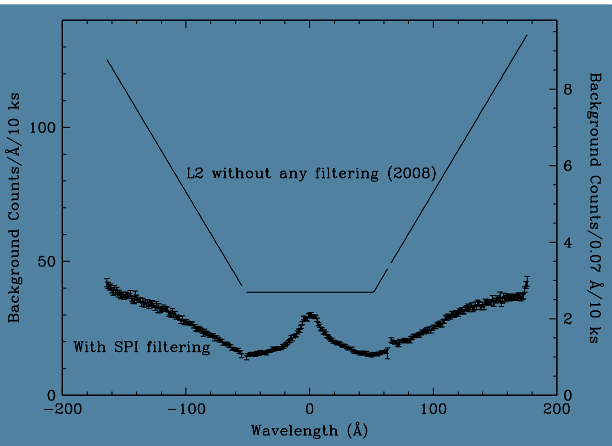

FIGURE 19: The 2008 LETG+HRC-S background rate with and without filtering, using the standard 'bow-tie' spectral extraction region. The right-hand axis units refer to the ~ 0.07Å FWHM resolution of the LETGS. (From http://cxc.harvard.edu/contrib/letg/GainFilter/)

FOOTNOTES

[1] e.g. Newsletter no. 13
[2] In a presentation to the Constellation-X Facility Science Team, 2006 December

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Chandra Calibration

Larry David

Update to the HRMA Effective Area

An updated version of the High Resolution Mirror Assembly (HRMA) effective area was released to the public in CALDB 4.1.1 on Jan. 21, 2009. This release was based on a re-analysis of ground-based calibration data taken at the X-ray Calibration Facility (XRCF) at the Marshall Space Flight Center (MSFC). The new HRMA effective area has the most significant affect on the spectroscopic analysis of hot clusters of galaxies (kT > 4 keV) and flux estimates for very soft sources. The new HRMA effective area was tested with a variety of astronomical sources (e.g., clusters of galaxies, AGNs, thermal supernova remnants, synchrotron dominated remnants and softer thermal sources) and the differences in the derived spectral parameters (e.g., temperatures and power-law indices) between the new and old HRMA effective areas are typically less than 3%, except for hot clusters of galaxies. For hot clusters, temperatures determined with the new HRMA effective area are up to 10% less compared to the temperatures derived with the previously released version of the HRMA effective area. While the spectral parameters of soft sources do not change significantly with the new HRMA effective area, fluxes derived with the new HRMA effective area can be up to 8% higher for very soft sources in the 0.5-2.0 keV energy band. This article gives a brief discussion of the recently released update to the HRMA effective area.

Chandra/XMM-Newton Cross-Calibration with Clusters of Galaxies

As part of an on-going *Chandra*/*XMM-Newton* cross-calibration project with the Astronomical International Council for High Energy Calibration (IACHEC), a sample of 12 X-ray bright clusters were chosen to compare gas temperatures obtained from ACIS, MOS and PN data. When this project began, revisions to the low energy response of the two MOS detectors were imminent, so the comparison was restricted to the 2.0-7.0 keV band pass. The resulting comparison showed that temperatures derived from ACIS and EPIC (MOS and PN) data were in good agreement for cool clusters (kT < 4 keV). For hotter clusters, ACIS temperatures were up to 10-15% higher than EPIC derived temperatures. Since it is impossible to determine from such a comparison whether the ACIS or EPIC derived temperatures are closer to the true temperatures, a study was undertaken to check the internal consistency of the ACIS calibration. This study showed that ACIS temperatures obtained by fitting the continuum emission in hot clusters from 2.0-6.0 keV were systematically higher than temperatures obtained from fitting a broad energy band from 0.5-7.0 keV and also the temperature calculated from the H-like to He-like Fe-kα line ratio.

HRMA Effective Area Calibration

Prior to this release, there have been two major adjustments to the effective area of the HRMA since the completion of ground-based calibration. The first was an empirical correction based on the results of extensive ground-based tests at the XRCF, which was incorporated in version 006 of the HRMA effective area. The second was the addition to the model of a contamination layer on the optics, based upon analyses of on-orbit grating spectra of blazars which exhibited residuals near the Ir-M edge, around 2 keV. The residuals could be reduced if the mirrors had a hydrocarbon contamination layer of thickness 22 Å. The addition of this layer led to release of version 007 of the HRMA effective area in CALDB 3.2.1 on Dec. 15, 2005.

Re-Analysis of the XRCF Data

A recent re-analysis of the XRCF data showed that the molecular contamination was already present on the mirrors during testing at the XRCF. The initial empirical XRCF correction essentially corrected for the gross effects of the molecular contamination, but had insufficient detail to resolve the Ir-M edge discrepancy. The addition of the explicit 22Å thick contamination layer provided the required detail to fix the Ir edge problems, but essentially doubled the contamination layer, over-correcting the gross features.

During XRCF testing, a system of shutters was placed behind the HRMA so that the response of the 4 shells could be measured independently. Two instruments were used at the focal plane; a flow proportional counter (FPC) and a solid state detector (SSD). A re-analysis of single-shell SSD measurements of a continuum source, this time including molecular contamination, led to estimates of the contamination layer depths on the individual shells (18-28A) which are in good agreement with the result derived from the on-orbit blazar gratings spectra. After incorporating this effect into the model, an additional gray correction was required to bring the model's prediction for the XRCF measured effective area in line with that measured. This correction is similar in purpose to the XRCF correction factor used in earlier models, but is derived from a different weighting of the FPC and SSD measurements. There are statistically significant differences between those measurements; the current method of weighting is, we believe, an improvement over the previous method. The resolution of the discrepancies between the two detectors is the subject of an ongoing investigation, which may lead to improvements in our understanding and subsequent improvements to the HRMA effective area.

The new version of the HRMA effective area (CALDB 4.1.1) is based on the predictions of the new model, including the as-measured contamination depths and the gray correction. Since the depth of the molecular contaminant varies from shell-to-shell, an updated version of the HETG efficiency was also released in CALDB 4.1.1 to maintain cross-calibration consistency between the HEG (which intercepts photons from the two smallest mirror shells) and MEG (which intercepts photons from the two largest mirror shells).

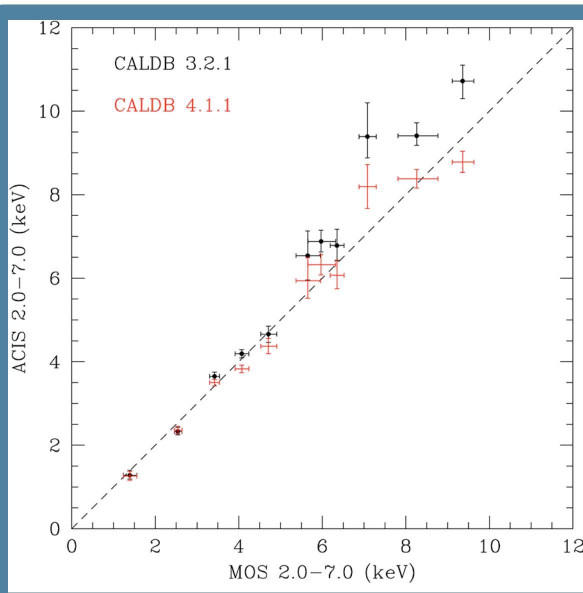


FIGURE 20: Comparison of cluster temperatures derived from the analysis of XMM-Newton MOS and *Chandra* ACIS data using two versions of the HRMA effective area. All temperatures were derived by fitting the data in the 2.0-7.0 keV energy band.

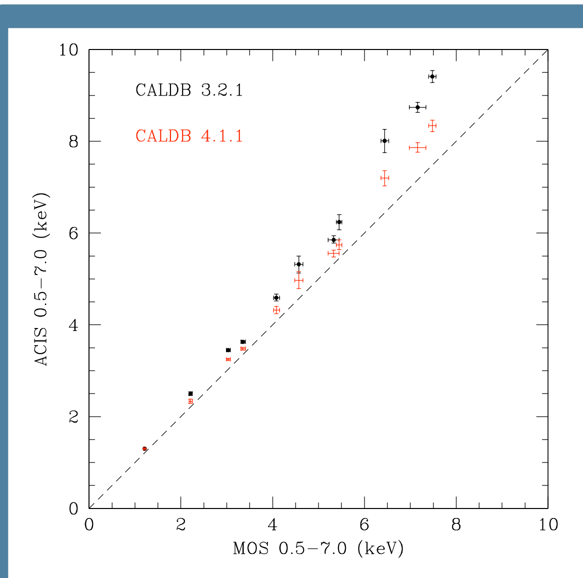


FIGURE 21: Comparison of cluster temperatures derived from the analysis of XMM-Newton MOS and *Chandra* ACIS data using two versions of the HRMA effective area. All temperatures were derived by fitting the data in the 0.5-7.0 keV energy band.

Comparison of Cluster Temperatures with Updated HRMA Effective Area

Figures 20 and 21 show a comparison of ACIS and MOS derived cluster temperatures with the old and new versions of the HRMA effective area. Temperatures were determined in both a hard (2.0-7.0 keV) and broad (0.5-7.0 keV) energy band. These figures show that there is now good agreement between ACIS and MOS derived temperatures in the hard energy band for all cluster temperatures. In the broader energy band, ACIS derived temperatures are slightly higher than MOS temperatures. This results from lower MOS temperatures derived in the broad energy band compared to the hard energy band. Our studies have also show that the MOS and PN produce consistent temperatures in both energy bands.

While the new HRMA effective area is a significant improvement over the previous version, the *Chandra* optics team is still investigating a few unresolved issues with the XRCF data which may lead to further improvements in the HRMA effective area. ✯

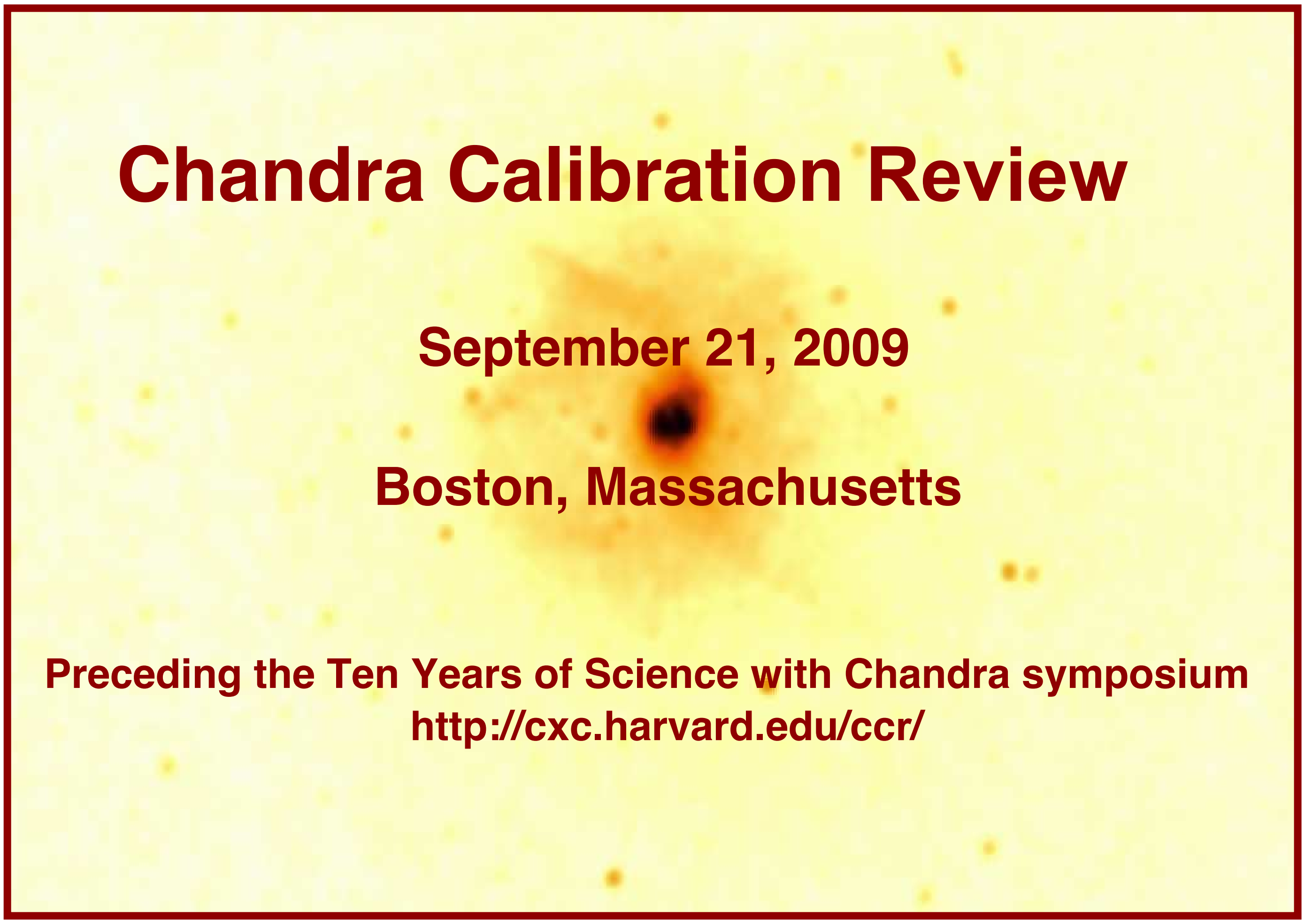
Chandra Calibration Review

Vinay Kashyap, Jennifer Posson-Brown

The *Chandra* Calibration Review (CCR) is held regularly for the dissemination and advancement of our understanding of the performance and capabilities of the *Chandra* X-ray Observatory. It is intended to share the *Chandra* teams' knowledge of the detectors, gratings, mirrors, and aspect system with the community while encouraging participation and feedback in the process of calibrating the observatory. Abstracts are solicited on calibration related issues.

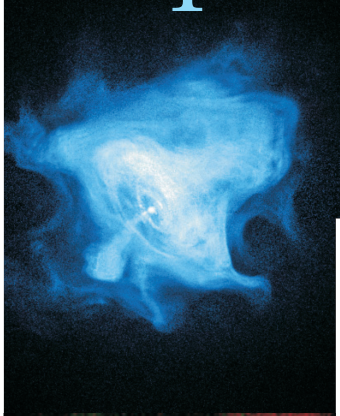
This year, we will again be holding the Calibration Review in conjunction with an anniversary symposium, the Ten Years of Science with *Chandra* Symposium in Boston, Massachusetts. Calibration talks will be presented on Monday September 21, prior to the Symposium. Calibration-related posters will be displayed throughout the Symposium, which runs from Tuesday, September 22 through Friday, September 25.

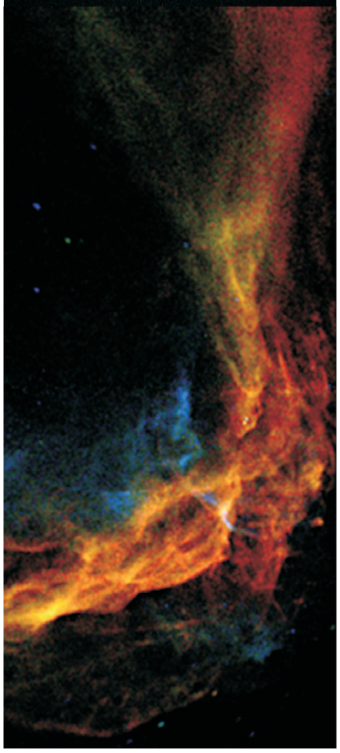
For more information, see http://cxc.harvard.edu/ccr/ ✯

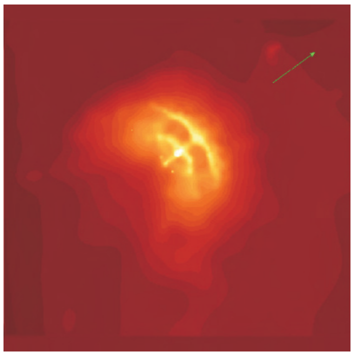



Chandra's First Decade of Discovery
Boston, Massachusetts
September 22 – 25, 2009

Supernova Remnants & Pulsar Wind Nebulae in the Chandra Era







Hosted by the Chandra X-ray Center
July 8-10, 2009
http://cxc.harvard.edu/cdo/snr09/
at the DoubleTree Guest Suites
Boston, MA

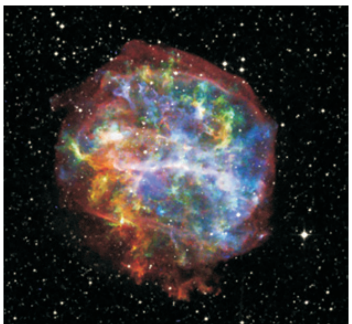
WORKSHOP ABSTRACT

X-ray observatories are advancing our understanding of a wide range of astrophysical processes, and profoundly so in the field of supernova remnants. The Chandra X-ray Observatory's superior spatial and spectral resolution, for example, are probing the structure and evolution of supernova remnant ejecta, diffusive shock acceleration processes, and interactions between supernova remnants and pulsar wind nebulae down to the sub-arcsecond level. This conference highlights both observational and theoretical studies of SNRs, emphasizing recent X-ray observations of Galactic SNRs. All aspects of SNR research will be explored including shock acceleration, electron/ion temperature equilibration, pulsar wind nebulae, connections between SNR ejecta and SN processes, and SNR interactions with the circumstellar and interstellar medium. The goals are to discuss outstanding problems in SNR research, and the most direct path forward in coming years.

DEADLINES *for registration and Abstract Submission*

Wednesday April 29, 2009
Contributed talks and poster presentations

Wednesday May 20, 2009
Final deadline, posters only



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Bringing Cosmology to the Public

Megan Watzke, Peter Edmonds

Timing for the publicity of science results can be challenging. There are many factors to juggle: acceptance of the paper into a journal, schedules of the main scientists, constraints from NASA, and others. We try to avoid holding press conferences near the holidays, since we don't want to hear that half of the world's science reporters are heading off for vacation instead of writing about our latest result. But, mid-December can work just fine, since for the second year in a row we have held a successful press conference at this time. Last year, the work on 3C321 by Dan Evans and others (which became known as the 'death star galaxy') was a big hit in the media. http://chandra.harvard.edu/photo/2007/3c321/. This year, a press conference was held on December 16th, 2008 to announce "Dark Energy Found Stifling Growth in Universe", work led by Alexey Vikhlinin at CfA. http://chandra.harvard.edu/chronicle/0408/darkenergy/. This press conference generated widespread press coverage, including the New York Times, the Washington Post, USA Today, NPR, the Associated Press, Reuters and the Economist, and many others.

Why did this result generate so much attention? There are several reasons. First, it represents a significant advance in astrophysics, and that is important to experienced science journalists. Also, several well-regarded astronomers who were not involved with the research gave positive supporting comments, and this helped reporters appreciate the significance of the findings. Alexey's work gives the best results so far from studying the effects of cosmic acceleration on the growth of large-scale structure, which is fundamentally different from studying cosmic acceleration itself. Not only does it allow important properties of dark energy to be independently determined, but it permits constraints on the behavior of gravity over large scales, when compared with distance measurements. In other words, this work was unlike anything else that reporters had heard before: a key to getting and keeping their attention.

It is worth noting that Alexey and his colleagues did not publish their cosmological constraints until their survey was complete and they had carried out detailed simulations and cross-checks of their results. This patience was rewarded with the recognition by cosmology experts that their results represented more than an incremental advance. This may not have been the case if the results had been allowed to trickle out. With this approach, there was a danger that the basic results would be "scooped" by a different team, for example a group using weak lensing as a probe of growth of structure, but a competitive result did not emerge.

Another important reason for the success of this story is that dark energy is now one of the hottest research fields in science, with new papers appearing almost every day on astro-ph. According to the Dark Energy Task Force, "nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration." As a result of this importance, an aggressive – and expensive – set of observational programs are either underway or planned to study dark energy in more detail. This has reached the level where there has even been a backlash with, for example, written and verbal debates between a prominent astronomer and physicist about whether such attention is good for the field of astronomy. These developments are familiar to many astronomers, of course, but they have also been noticed by science reporters.

Finally, and perhaps most importantly, cosmology is one of the most exciting and stimulating fields in all of science for the public. Questions like "What is the Universe made of?," "What did the Universe look like in the past?," and "What is the destiny of the Universe?" have been asked for millennia. If a result can give interesting new answers to any of these big questions, it is compelling to the public and to reporters. If it can address all of these questions, as the recent work does, that is even better. Also, studies of dark energy address intriguing questions about the nature of the vacuum, such as whether it is possible for nothing to weigh something.

Given the strength of this story, it did not matter that the *Chandra* images were not the most eye-catching ones we have ever released, or that the indirect effects of repulsive gravity were not trivial to explain, or that this result did not contain any major surprises. The advantages overwhelmed the disadvantages, resulting in the excellent press coverage.

Other *Chandra* results on cosmology have also received a significant amount of press coverage, including the work on the Bullet Cluster by Doug Clowe and collaborators in 2006, and independent work on dark energy by Steve Allen and collaborators in 2004. We continue to look for new results in this field to publicize. Maybe we'll do another mid- December press conference! ✯

CXC 2008 Science Press Releases

Megan Watzke

Date	PI	Objects	Title
January 9	Ralph Kraft (CfA)	Cen A	Jet Power and Black Hole Assortment Revealed in New *Chandra* Image
January 10	Rodrigo Nemmen (Penn State)	9 galaxies	*Chandra* Data Reveal Rapidly Whirling Black Holes
February 13	Rasmus Voss(MPE) Gijs Nelemans (Radboud Univ.)	SN 2007on	Possible Progenitor of Special Supernova Type Detected
March 20	Armin Rest (Harvard)	SNR 0509-67.5	Action Replay of Powerful Stellar Explosion
April 28	John Fregeau (Northwestern)	13 globular clusters	Oldest Known Objects May Be Surprisingly Immature
May 14	Steven Reynolds (North Carolina State)	G1.9+0.3	Discovery of Most Recent Supernova in Our Galaxy
June 18	Sera Markoff (Univ. Amsterdam)	M81	Black Holes Have Simple Feeding Habits
July 16	Philip Humphrey (Univ. California Irvine)	NGC 4649	A New Way to Weigh Giant Black Holes
September 25	Franz Bauer (Columbia)	SN 1996cr	Powerful Nearby Supernova Caught by Web
October 30	Gary Steigman (Ohio State)	Bullet Cluster	Searching for Primordial Antimatter
December 16	Alexey Vikhlinin (CfA)	86 galaxy clusters	Dark Energy Found Stifling Growth in the Universe

Useful Chandra Web Addresses

To Change Your Mailing Address:
http://cxc.harvard.edu/cdo/udb/userdat.html

CXC:
http://chandra.harvard.edu/

CXC Science Support:
http://cxc.harvard.edu/

CXC Education and Outreach:
http://chandra.harvard.edu/pub.html

ACIS: Penn State
http://www.astro.psu.edu/xray/axaf/

High Resolution Camera:
http://hea-www.harvard.edu/HRC/HomePage.html

HETG: MIT
http://space.mit.edu/HETG/

LETG: MPE
http://www.mpe.mpg.de/xray/wave/axaf/index.php

LETG: SRON
http://www.sron.nl/divisions/hea/chandra/

CIAO:
http://cxc.harvard.edu/ciao/

Chandra Calibration:
http://cxc.harvard.edu/cal/

MARX simulator
http://space.mit.edu/ASC/MARX/

MSFC: Project Science:
http://wwwastro.msfc.nasa.gov/xray/axafps.html

Chandra Science Publications

Paul Green, for CDO

Chandra is nearing a decade of robustly successful science observations. The number of *Chandra*-related science publications continues to grow strongly. The figure here shows the number of refereed *Chandra* Science Papers by publication year.

The *Chandra* Data Archive (CDA) Group at the CXC tracks such publications by a daily query to the ADS. All publications are scanned and reviewed by hand, categorized by several parameters and entered into the Bibliography Database. The website http://cxc.harvard.edu/cda/bibstats/ is updated monthly with fresh plots and data tables. A full list of the articles tallied is produced, with links to the ADS abstracts. The pages also contain detailed descriptions of the classifications we use, for instance, what do we define as a "Refereed *Chandra* Science Paper". The CXC also compiles statistics on *Chandra*-related PhD dissertations.

There is some unavoidable lag time for papers to appear in the ADS after they are published, and then the CXC Bibliography Database is updated within a couple of weeks of these new ADS entries. From experience, the asymptotic paper count for a given year is thus not available until about April of the year following, which explains why we mark the last bar differently in Figure 22.

Keep those papers coming! ✯

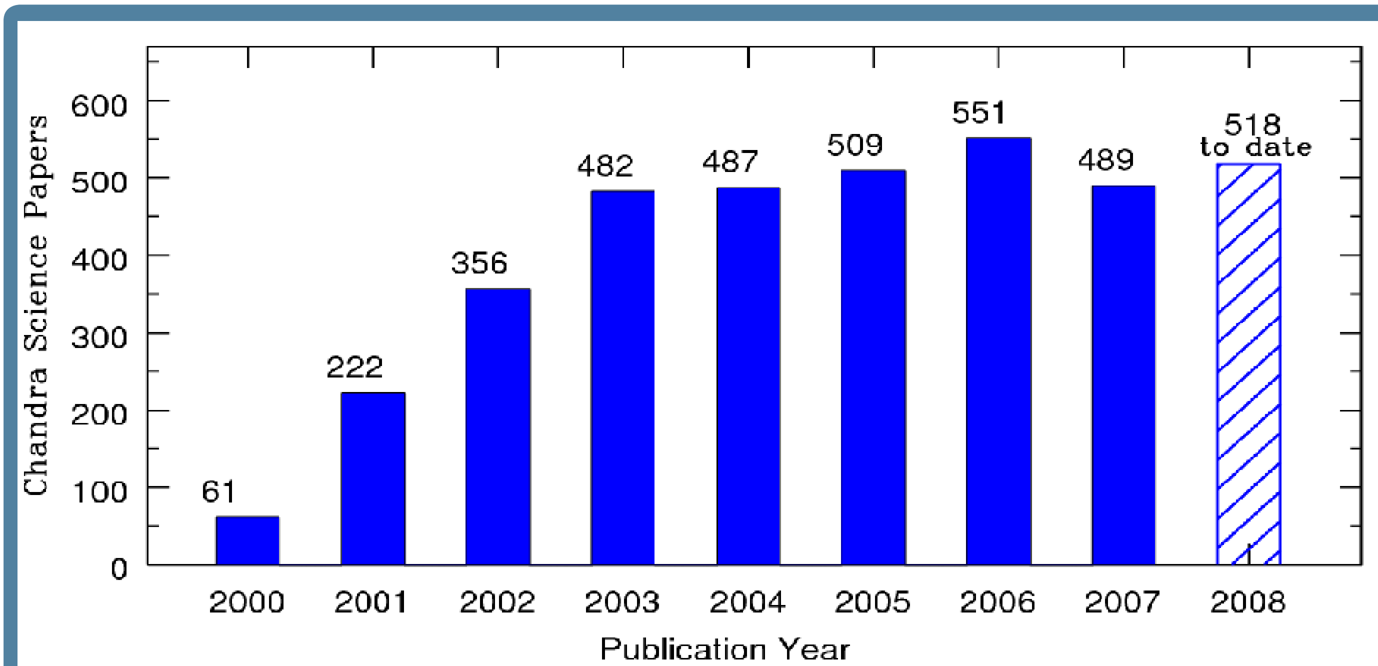

FIGURE 22: The number of refereed *Chandra* Science Papers by publication year. Based on experience, we expect that the full tally of 2008 papers will not be complete until sometime in Spring 2009.

CIAO 4.1: with a whole new Sherpa!

Antonella Fruscione, Douglas Burke and Aneta Siemiginowska for the CIAO team

Version 4.1 of the *Chandra* Interactive Analysis of Observation (CIAO) software was released in December 2008, followed immediately by a small patch 4.1.1 to include data files for proposal planning purposes.

CIAO 4.1 includes several improvements and bug fixes to some of the CIAO tools, libraries and GUIs (the release notes describe all these in detail and Figure 23 shows an example), but the main feature of this release is an all-new non-beta version of Sherpa, the CIAO modeling and fitting package. A re-designed, re-written Sherpa was released for the first time as beta version in December 2007. Now, the fully functional package is available for the community.

Sherpa supports forward fitting of 1-D X-ray spectra from *Chandra* and other X-ray missions, fitting of 1-D non-X-ray data, including ASCII data arrays, radial profiles, and lightcurves. The options for grating data analysis include fitting the spectrum with multiple response files required for example for overlapping orders in *Chandra* HRC/LETG observations. Modeling of 2-D spatial data is fully supported, including PSF and exposure maps effects.

The main new feature of the Sherpa redesign concerns the Sherpa's environment: it can be run in a S-Lang shell (http://www.s-lang.org/) or in Python (http://www.python.org/) with only very minor syntax differences. Users can select the language they prefer and in general will choose the language they have the most experience with, that their friends or colleagues use, or for which they can get the best support. In both cases they will gain scripting and programming capabilities, easier access to mathematical calculations, and access to other libraries written by the community. This new infrastructure greatly enhances the default Sherpa functions, and provides users with an environment for developing complex and sophisticated analysis.

Sherpa is designed to be used as a user-interactive application or in a batch mode. It is an importable module for the S-Lang and Python scripting and is available as a C/C++ library for software developers.

Sherpa internal data structures are exposed and fully accessible through high level user interface functions. This accessibility allows users to develop their own complex analysis routines. For example users can input their own models, can write specific analysis procedures not included in the current Sherpa package or run many simulations required for the planning of future observations.

One example of such a user package is “Deproject”, a Python module for X-ray clusters and other diffuse X-ray data that require 3D to 2D model deprojection. This Python extension module was developed by Tom Aldcroft and it is now available on the CXC contributed software web page: http://cxc.harvard.edu/contrib/deproject/

Possibly the main strength of Sherpa is its reliability in convergence. There are three optimization methods: “levmar”, a modification of the Levenberg-Marquardt algorithm which uses the LMDIF algorithm (More 1978); “neldermead”, A Nelder-Mead Simplex direct search (Nelder & Mead 1965); and “moncar”, a Monte Carlo method

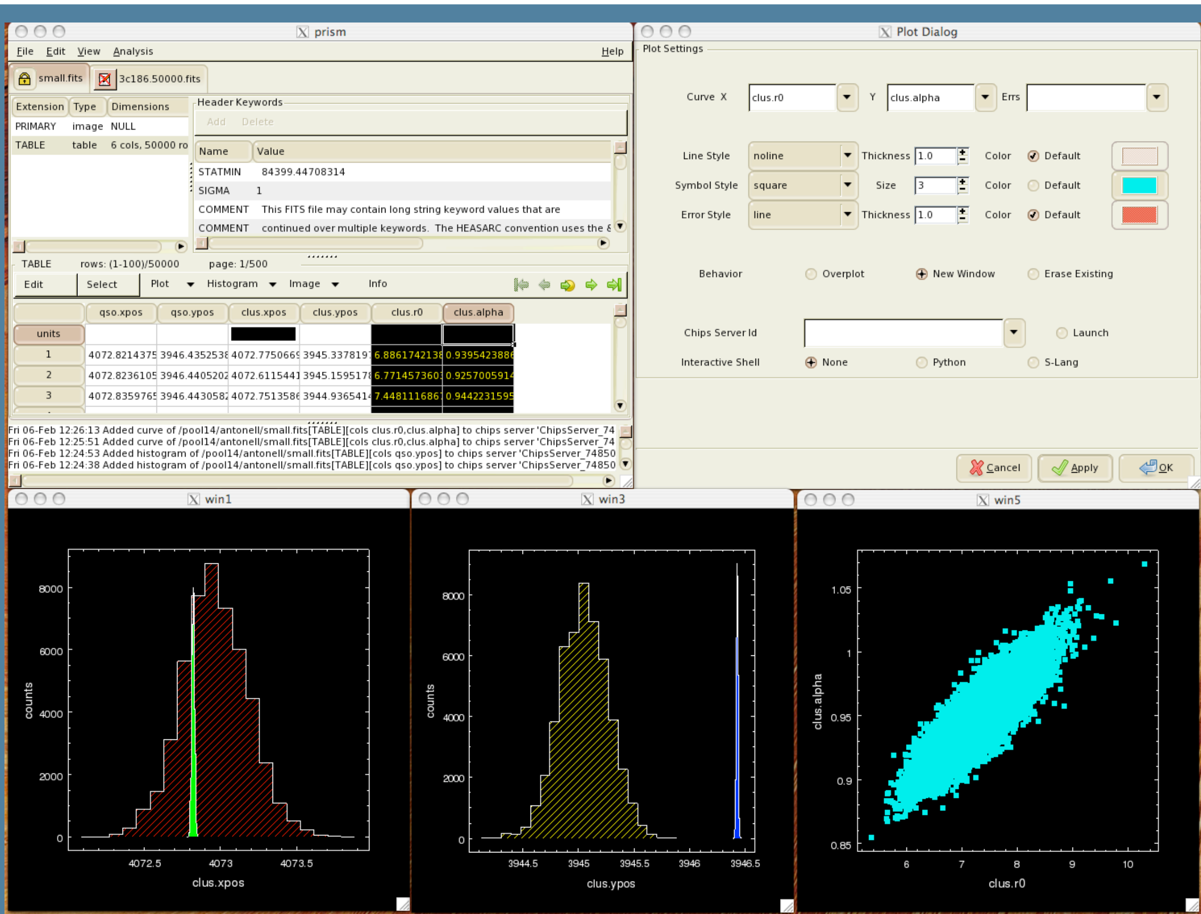

FIGURE 23: An example of thew new PRISM application and its interactive plotting/histogramming capabilities. The data file loaded into PRISM contains the results from 50,000 iterations of a Metropolis-Hastings sampler (see http://hea-www.harvard.edu/AstroStat/statjargon.html) used to evaluate the distribution of fit parameters for the best-fit model found by Sherpa. In this case the data is an image of a galaxy cluster with a bright point source close to the center. The data was fit with a gaussian2d component to represent the point source, a beta2d component for the cluster emission, and a flat background, all convolved with a PSF. Histograms of the cluster and point source center values have been overlaid using the “Interactive Histogram” option in PRISM; one window compares the X-axis values and one the Y-axis values. The window also allows the histogram properties (in this case the fill style and color) to be changed before plotting. As can be seen, although the x values are similar, the y values do not overlap which shows that the point source is offset from the cluster center. A third plot window shows a sample scatter plot of two fit parameters and was obtained with the “Interactive Plot” option in PRISM.

based on the paper by Storn and Price (1997). These more robust algorithms are a complete replacement of the Sherpa OPTIM routines in CIAO 3.4.

Several statistics are available in Sherpa including χ^2 with various "weight" options, C statistics and the maximum likelihood statistics as defined by Cash. Users need to note that some options of χ^2 statistics shows bias in fitting low count data, so they have a choice of appropriate statistics for low count Poisson X-ray data.

More information on CIAO can be found at http://cxc.harvard.edu/ciao/. Sherpa documentation and sample analysis thread are at http://cxc.harvard.edu/sherpa/ ✭

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New Functionality for Proposers: PRoVis and MaxExpo

Paul Green

The CXC announces the availability of PRoVis. PRoVis, at http://cxc.harvard.edu/soft/provis provides interactive plotting of *Chandra* spacecraft roll, pitch, and target visibility for a selected celestial target, using a recent projected *Chandra* ephemeris. PRoVis replaces the old WebVis tool, and adds interactive functionality, live cursor readout, revised and expanded output data format, and a plethora of plotting format choices. For instance, by default, hatched regions highlight the thermal restrictions imposed by the *Chandra* pitch ranges available for your celestial target.

Spacecraft thermal constraints translate into restrictions on the maximum uninterrupted exposure time for a target,

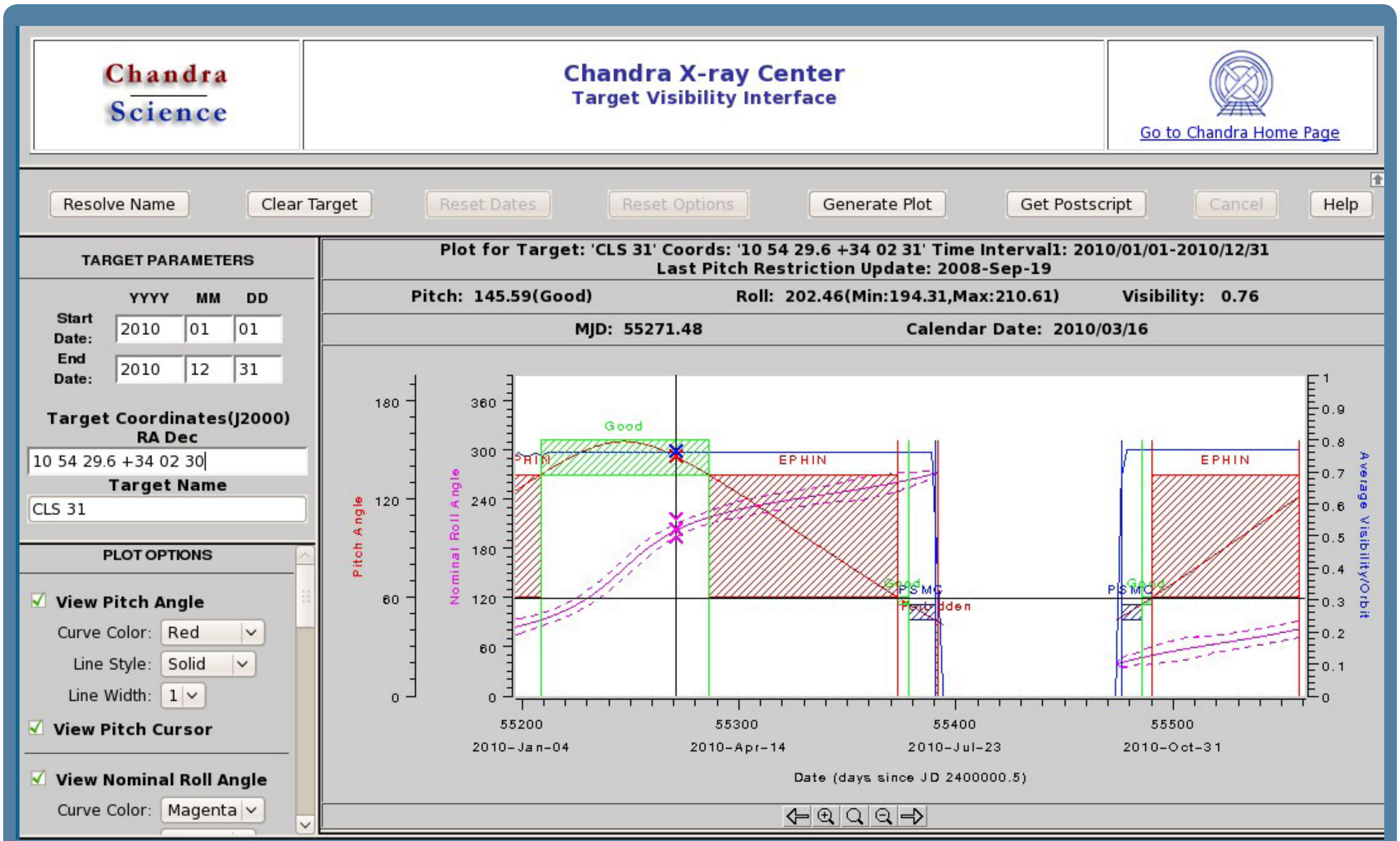


FIGURE 24: A snapshot of the PRoVis target visibility interface showing curves of roll, pitch, and target visibility for a target across the year 2010. The restrictive character of the pitch ranges are optionally shown by the hatched regions. The mouse cursor position creates a vertical line and intersecting curve points marked by Xs, whose values for roll, pitch and visibility are displayed above the plot.

depending on the available pitch angle and season. CXC now also provides the MaxExpo page http://cxc.harvard.edu/proposer/maxexpo.html with up-to-date static plots and tables showing the maximum *Chandra* dwell time as a function of pitch angle and season. The information here is most useful for proposers whose observations require constraints for scientific reasons, to determine the maximum uninterrupted exposure time for a given target, once its pitch angle is known, e.g., using PRoVis! ✯

The 6th *Chandra*/CIAO Workshop

Antonella Fruscione, for the CIAO group

After a pause of a few years (the 5th workshop occurred in 2003) and by popular demand, the *Chandra* X-Ray Center (CXC) resumed the *Chandra*/CIAO workshops with a 6th one during 3 days on October of 2008. The *Chandra*/CIAO workshops aim at helping users to work with the *Chandra* Interactive Analysis of Observations (CIAO) software.

The workshop included oral presentations by CXC "experts" and several hours of hands-on session where students could try to use CIAO "for real" with constant support from CIAO team members. Every presentation for this - and all previous - workshops can be found from http://cxc.harvard.edu/ciao/workshop/index.html In many cases these presentations are a very good starting point for new and old *Chandra*/CIAO users looking for a summary of a specific subject (e.g. Pileup Modelling, Source Detection, etc.).

About 30 people from all of the world and with a variety of backgrounds and expertise in X-ray data analysis attended the talks and the hands-on session, putting the CIAO tools and documentation to a real test!

A feedback survey distributed at the end showed us what we did well and where we could improve in the future. Many students expressed strong interest in an "Advanced CIAO Workshop" which we may try in the future. Everyone seemed to like the hands-on session and the availability of immediate on-site support. One survey answer for them all: "4. Did you get enough support during the hands-on session? That was simply perfect, and people were so nice!"

Thanks to all for coming and look out for the next announcement. ✯

FIGURE 25: Douglas Burke on "Merging *Chandra* Observations"

FIGURE 26: Workshop participants hard at work during the hands-on session

FIGURE 27: Helping students!

FIGURE 28: Even the DS9 expert was called in...

NEWS FROM THE *CHANDRA* DATA ARCHIVE

ARNOLD ROTS AND SHERRY WINKELMAN,
FOR THE ARCHIVE OPERATIONS TEAM

Chandra Deep Fields

In 2008 we released new custom processed datasets for *Chandra* Deep Fields, North and South. These data sets contain the merged 2Ms observations for CDFN and CDFS. The credit for the reprocessing of these data goes to all of CXC Data Systems. Descriptions of and access to the datasets can be found from our Contributed Dataset Pages

http://cxc.harvard.edu/cda/Contrib/CDFN.html
http://cxc.harvard.edu/cda/Contrib/CDFS.html

Bibliographic Database

Our *Chandra* Bibliography Database and classification system is undergoing a major overhaul and expansion. The database has been redesigned to be mission independent and to work with a new suite of tools for querying ADS, populating the database, downloading papers, and scanning papers for content in an automated fashion. Because of our improvements in scanning the content of papers, we now look at every astronomy paper in ADS, thus making our database much more complete. However, because of the high volume, we still limit physics and instrument papers to those which contain *Chandra* and its instruments in the title or abstract.

The new system also has a plug-in feature which gives a data center the opportunity to connect mission-specific information to paper content. We use this feature to flag instrument configuration information in the bibliography database from the *Chandra* Observation Catalog. The system also keeps a complete history of edits made to bibcodes and allows for multiple reviewers of papers which we use for quality assurance.

The expansion includes flagging observatories, catalogs, and surveys found in *Chandra*-related publications. We currently flag sixty-six observatories and sixty-nine catalogs and surveys and will be adding to these lists during our migration. A flag to an observatory, catalog, or survey also includes a flag to a wavelength, making multi-wavelength queries of papers more meaningful.

We have started migrating to the new system and plan to have it complete and accessible by the end of the year. During the migration process we will be studying the content of articles for more content-related flags and hope to work with ADS to make our content-related flags available to them. In the interim, you can continue to access the current database at

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

Finally, we have been collecting *Chandra*-related SPIE papers for a number of years and making them available online. This year we have collaborated with ADS allowing them to link to our repository from their pages.

We are excited about our expanded bibliography services and hope you will find them helpful.

Meet the Archive Operations Team (with a brief history)

The Archive Operations Team ("*arcops*", for short) is led by Arnold Rots who has been the Archive Astrophysicist since December 1997; he also provides the connections with outside entities, such as other data archives, the Virtual Observatory, the ADS, IAU commissions, FITS committees, ADASS, ADEC, and some of the digitization efforts at the Smithsonian Institution.

Michael McCollough is the second Archive Astrophysicist who has served as Arnold's deputy since April 2003; together they are involved in science support for the *Chandra* Source Catalog. Mike's predecessor was Stéphane Paltani who automated the provisional Data Distribution system, started the bibliography database, and provided an early design for the *Chandra* Source Catalog. Before Stéphane's arrival it was Tomas Girnius who provided during his brief tenure the original implementation of the Provisional Retrieval Interface.

Sherry Winkelman is the Chief Archive Specialist who directs the daily operations of the team, has designed (and implemented) the bibliography database, and, in general, oversees the software development needed for the team's operational activities. Sherry has been with the team since August 1998. She leads a team of three Archive Specialists who all joined the team in 2008; in order of arrival: Glenn Becker, Aaron Watry, and Joan Hagler. Their positions were held in the past by Jed Stamas, Michael Preciado, Emily Blecksmith, Kendra Michaud, Sarah Blecksmith, John Bright, Melissa Cirtain, and Alaine Duffy.

Finally, there is Padmanabhan Ramadurai (Durai for short) who is the database administrator and shares his time between *arcops* and the CXC Systems Group. ✯

Chandra Source Catalog

Ian Evans, for the *Chandra* Source Catalog project team

The first official release of the *Chandra* Source Catalog (CSC) is now fully available for use by the astronomical community. The release is accessible publicly through the catalog web site (http://cxc.harvard.edu/csc/), which also contains a wealth of supporting information for prospective catalog users. The catalog production database, which includes information about observations processed to-date during the production phase of the catalog, has been available since October 2008.

Release 1 of the CSC includes 94,688 sources detected in ACIS imaging observations released publicly prior to the start of 2009 (see Figure 29). Only point and compact sources, with observed spatial extents < ~30 arcsec, are included in this release; sources larger than this are not detected by the current catalog algorithms. In general, observations of fields containing highly extended sources are not included in this release. However, if the extended emission is isolated to a single ACIS CCD, then the remainder of the field covered by the other CCDs is included. Multiple observations of the same field are not co-added prior to performing source detection; instead, source detection is performed on each observation individually.

A subsequent release (1.1) is planned for later this year to extend the catalog to include public HRC-I imaging observations, and newly public ACIS observations, but will otherwise retain the same limitations as Release 1.

The CSC is capable of supporting many diverse scientific investigations. However, users should carefully review the “Caveats and Limitations” section of the catalog web site when assessing the efficacy of the catalog for their particular line of enquiry. Since the catalog is constructed from a subset of public pointed *Chandra* observations, users should be aware that there may be fundamental and significant selection effects that restrict the source content of the catalog and which therefore may limit scientific studies that require an unbiased source sample.

Catalog Contents

Release 1 of the CSC includes detected sources with fluxes that are at least 3 times greater than their estimated 1σ uncertainties (typically corresponding to about 10 net source counts on-axis and roughly 20–30 net source counts off-axis).

The catalog includes numerous raw measurements, as well as scientifically useful source properties derived from the data. These include estimates of the source position measured from each observation in which a source is detected, as well as raw source and PSF extents, and the deconvolved source extent, in several energy bands. Aperture photometry for sources detected in ACIS observations is provided for 5 energy bands — broad (0.5–7.0 keV), ultrasoft (0.2–0.5 keV), soft (0.5–1.2 keV), medium (1.2–2.0 keV), and hard (2.0–7.0 keV) — using several different methods. Band images and exposure maps in FITS format are provided for each source, together with a full-field limiting sensitivity map.

Cross-band (hard, medium, soft) spectral hardness ratios are reported for all detected sources, and absorbed power-law and black-body spectral fits are performed for sources with at least 150 net counts. Source pulse-invariant spectra and spectral response matrices are produced for sources detected in ACIS observations.

Several source variability measures are included, both within a single observation of a source and between multiple observations that include the same source. Intra-observation measures include Kolmogorov-Smirnov and Kuiper test probabilities, and a Gregory-Loredo odds ratio. An optimally binned light curve is produced for each source.

Catalog Statistical Properties

As part of the official catalog release, a characterization of the statistical properties of the catalog is provided. Preliminary analysis of both simulations and real datasets indicates that the statistical properties of the CSC may be characterized as follows:

- False source rates of << ~1 per observation for exposures $\lesssim$50 ks, and ~1 per observation for exposures $\gtrsim$120 ks;
- 50% completeness (see Figure 30) at broad-band fluxes of ~7×10^{-15} ergs cm^{-2} s^{-1} for a ~10 ks observation, improving to ~9×10^{-16} ergs cm^{-2} s^{-1} for a ~125 ks observation;
- Positional uncertainties (see Figure 31) of $\lesssim$1" (95% confidence) for sources with more than 10 counts, located within 3' of the optical axis, $\lesssim$2" for sources with more than 30 counts, within 10', and $\lesssim$5" for sources with more than 50 counts, within 15';
- Flux accuracies of better than ~35% (1σ) for sources with more than 30 counts, within 3' of the optical axis, ~30% for sources with more than 50 counts, within 10', and ~25% for sources with more than 100 counts, within 15'.

Data Access and User Documentation

The easiest way to query the CSC is via the CSCview web interface, on the catalog web site. CSCview enables

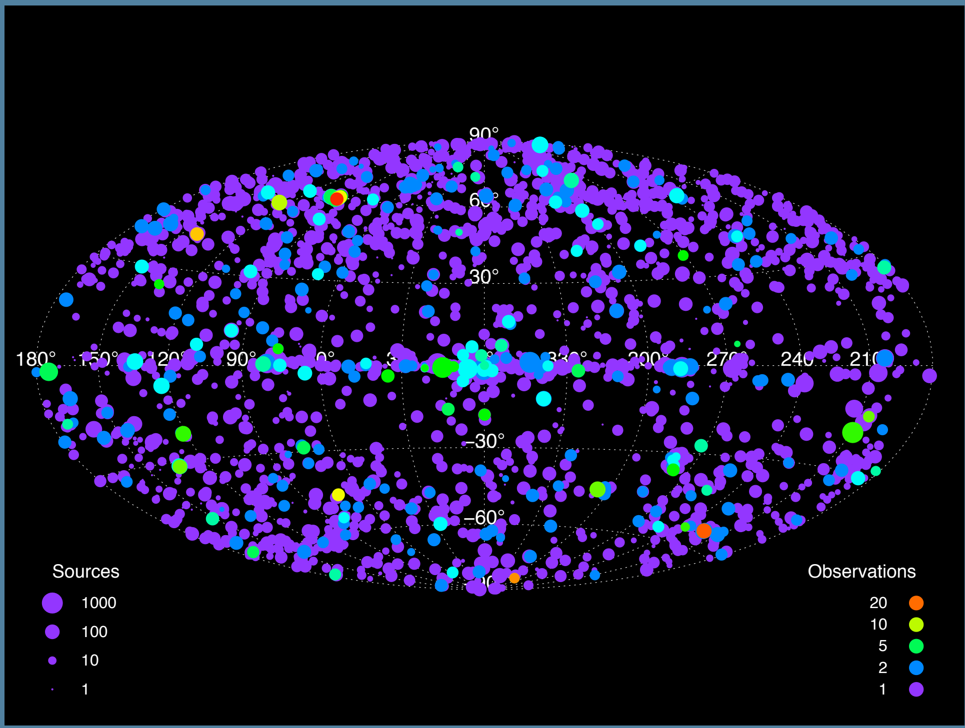
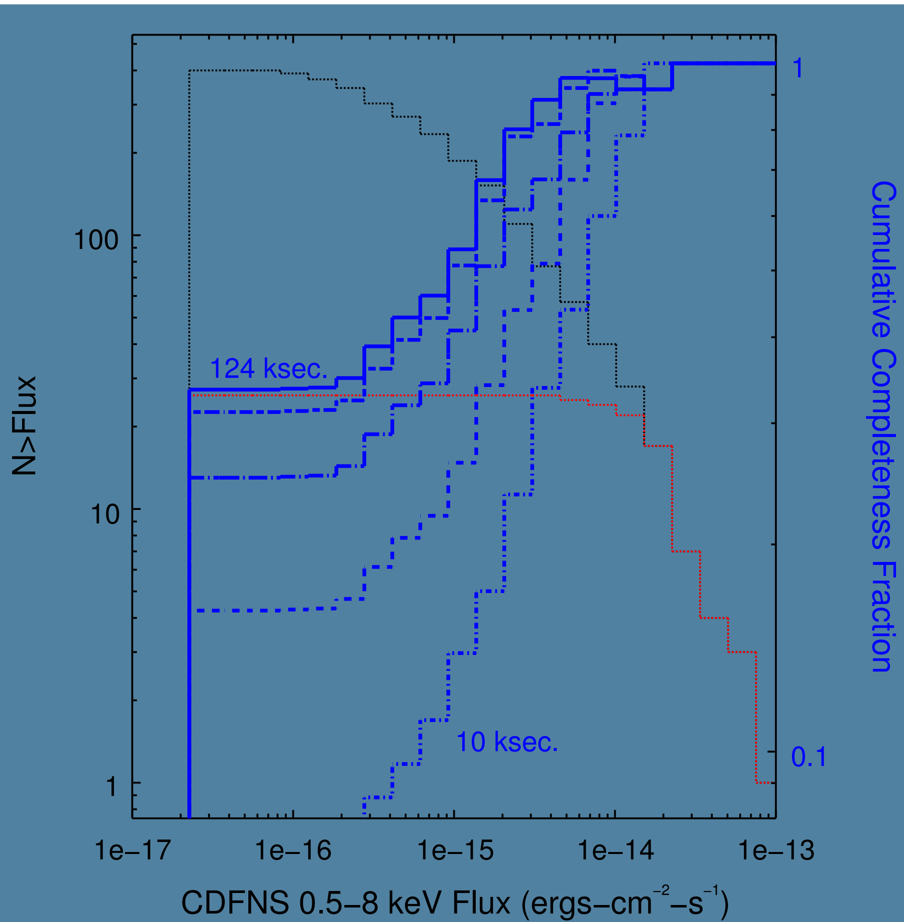


FIGURE 29: This figure shows the locations of observations included in the CSC (in Galactic coordinates). The size of each symbol is proportional to the logarithm of the number of sources detected in the observation (1 to ~1000 sources per field), while the color encodes the number of approximately co-located observations.

FIGURE 30: The black curve shows the cumulative flux distribution for all *Chandra* Deep Field (CDF) North and South sources. The red curve shows the corresponding distribution for CDF sources associated with CSC sources for a 10 ks observation. The ratios of the two distributions (blue curves) provide an estimate of the completeness fraction for the CSC. Completeness fractions for 10 and 124 ks observations are labeled. Fractions for intermediate exposures of 30, 60, and 95 ks are also plotted.



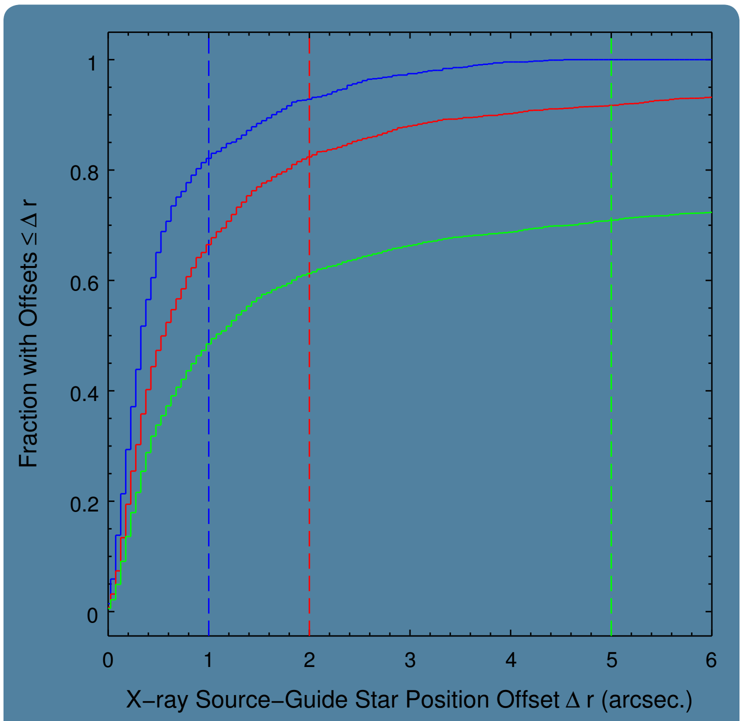


FIGURE 31: Astrometric uncertainty derived from comparison of CSC and AXAF (*Chandra*) Guide and Acquisition Star Catalog (AGASC) source positions. CSC and AGASC sources are considered to match if their positional offsets are less than 5 times the CSC position error. The cumulative distributions of offsets are displayed for 3 different subsets of CSC sources: sources with > 10 net ACIS "b" band counts and off-axis angle θ < 3' (blue), sources with > 30 net counts and θ < 10' (red), and sources with > 50 net counts and θ < 15' (green). Vertical dashed lines indicate 1σ catalog requirements for those sets.

the user to search for sources matching user-supplied constraints for any of the catalog properties, including searching by source position (cone search). The user can select which of the extensive set of catalog parameters they wish to display for matching sources, or can choose to see one of the pre-defined sets of parameters optimized for common queries. Besides displaying the results of a search on the screen, the user may choose to save the search results in a data table. CSCview also provides access for downloading any of the file-based data products that are included in the catalog.

The catalog website (http://cxc.harvard.edu/csc/) is also the place to look for a large bank of user documentation. Sections describe in detail the contents of the catalog, including important caveats and limitations; how to access the catalog; threads that include example catalog searches; and the statistical characterization of the catalog properties, and suggested language for acknowledging the use of the CSC in publications. The user documentation on the catalog website will continue to be improved and extended over the coming months. ✯

TGCat

David P. Huenemoerder, Arik Mitschang, Joy Nichols, Mike A. Nowak, Norbert S. Schulz, Dan Dewey

What is TGcat?

"TGCat" is a catalog and archive of *Chandra* data taken with a transmission grating spectrometer — the High Energy Transmission Grating (HETG) or the Low Energy Transmission Grating (LETG) — in conjunction with one of the spectroscopic readout arrays, ACIS-S or HRC-S. The catalog can be found at http://tgcat.mit.edu/.

Goals & Contents of the Catalog

Our intents are to

- Make grating observations more accessible and visible. There are over 800 observations to date of more than 300 distinct objects utilizing ACIS-S or HRC-S, with HETG or LETG;
- Provide summary products for easy assessment of the observation content and quality;
- Provide analysis-ready counts spectra and response files;
- Provide a web interface for searching, browsing, plotting, and downloading catalog products;
- Start with a simple catalog and enhance as per user requests;
- Provide scripts for easy reprocessing or customized extractions.

Heritage, Motivation:

There are a few other spectral catalogs of note which we examined for guidance:

- BiRD: XMM/RGS spectral browser (http://xmm.esac.esa.int/BiRD/)
- HotGas: database of Active Galactic Nuclei (http://hotgas.pha.jhu.edu)
- X-Atlas: HETGS stellar spectra (http://cxc.harvard.edu/XATLAS/). (Westbrook, et al. 2008, ApJS, 176, 218)

BiRD is browse-only simple and easy to use catalog providing plots of XMM/RGS spectra. X-Atlas and HotGas are research-topic oriented, with many model-dependent derived products. HotGas is AGN specific, uses CIAO standard products, has some modeling. X-atlas is quite

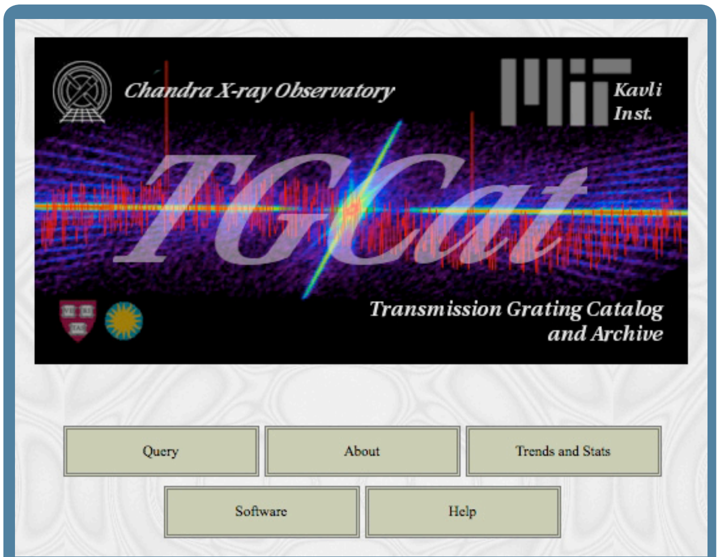


FIGURE 32: This is the front page of TGCat, at http://tg-cat.mit.edu. From here you can query the catalog, access the documentation, see overall statistics, or download software.

complex, with many derived quantities and both standard and custom products.

TGCat takes an intermediate approach by providing data and research-ready standard products (PHA, ARF, and RMF files), supporting graphical products for easy assessment and selection of data, and by supplying optional scripts for automated or custom reprocessing by users. TGCat does not provide any model-dependent analysis products.

Features of the Catalog

The catalog has a flexible web interface supporting queries by name (SIMBAD or observer-given), object type, coordinates, simple spectral properties (rates and fluxes), observation ID, or by various other criteria such as grating type, detector, or detector read-mode.

Searches can be done either from a table of observation ID's or through a table of unique targets categorized by SIMBAD names and types. The result is a list of basic information with links to summary plots. A very quick preview is given in a pop-up thumbnail spectrum as you move your cursor over the item. Columns are sortable by a click on the heading.

Pre-computed plots and images help you assess the observation; these products are also used to validate the processing. The summary plots include

- counts spectra (combined 1st orders);
- flux spectrum (if HETGS or LETG/ACIS-S; combined 1st orders);
- light curve (and background);
- central field images for zeroth order detail;
- full field image;
- spectral coordinates image, with extraction region;
- order-sorting image.

Further options allow customized plotting of single or multiple orders or of combined observations, with a wide variety of units. Selections may be packaged for download of standard products (PHA, ARF, RMF files). You may also generate and download an ASCII table of the custom plot.

We have taken care in determining the zeroth order centroid — the origin of the wavelength scale. For ACIS cases in which the zeroth order was distorted by CCD pileup or was intentionally excluded to reduce telemetry, we use the alternate method of "findzo" (http://space.mit.edu/cxc/analysis/findzo).

Intentionally Omitted Features

We have avoided producing any model-dependent products which rely on scientific judgement or interpretation: there is no modeling or fitting of spectra, no hardness ratios, no color-color plots, no galleries of spectra of similar objects. We have produced a table of count-rates or fluxes (if ACIS) because these can be reliably calculated. (Fluxes are not available for LETG/HRC-S because of the presence of overlapping orders.) Bands were chosen to overlap the *Chandra* Source Catalog ranges as well as interesting spectral regions.

Implementation

The *Chandra* archive is our primary data source; from the "cdaftp" site (ftp://cdaftp.harvard.edu/pub/science/), we download the minimum number of files required to create the basic spectral products.

Data are reprocessed using ISIS/S-Lang scripts which set up and run CIAO tools to make the standard products. ISIS scripts are also used to make the summary plots and tables.

The database management uses MySQL as its backbone. The web-based interactive plotting creates and runs ISIS scripts.

Detailed knowledge of ISIS, S-lang or MySQL are not required to use the catalog. However, the reprocessing scripts are available for users. A top-level function will perform end-to-end processing, starting with events, and ending with the spectrum, responses, and summary plots.

No proprietary software has been used for TGCat.

Example of Reprocessing Using the TGCat Scripts:

The following example set of commands using OBSID 16 will take about 30 minutes from download to data products and summary plots creation:

```
# slsh script - retrieves minimal set of files from the cdaftp site:
  > download_obsid 16

# shell script - sets up links required by TGCat ISIS scripts:
  > setup_obsdir obs_16

# Start ISIS in a ciao-configured shell, and load the processing package:
  > isis
  isis> require("tgcat");

% Run the pipeline using the configuration read from a header, use "findzo":
  isis>run_cfg( "obs_16", 1);
  isis> exit;

# review the summary plots:
  > display obs_16/summary*.ps &
```

Future Work

In a future release, we will provide combined data for single "observations" (defined by sequence number, but probably spanning multiple observation IDs). We will also add extractions for serendipitous sources and for isolated sources in crowded fields. We also intend to provide zeroth order spectra and responses.

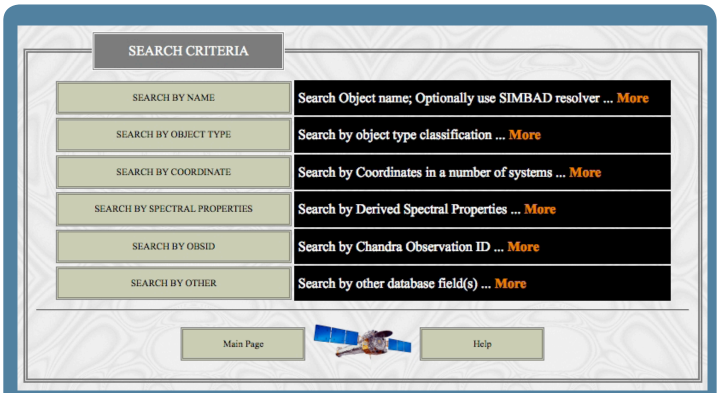


FIGURE 33: This is the main search page, which lets you select observations or objects using different criteria.

We will be adding more convenience functions to the processing scripts, such as to support easy time-slicing, or for customized regions.

We also encourage user-requests (email tgcat@space.mit.edu) and would especially like to hear of usage scenarios in your research.

Acknowledgements:

A number of people have been involved in TGCat since we started work in August 2007. First, thanks to Claude Canizares who suggested that we think about creating a grating catalog as a part of the *Chandra* legacy. And next, in alphabetical order, thanks to John E. Davis, John C. Houck, Herman L. Marshall, and Doug Morgan. ✫

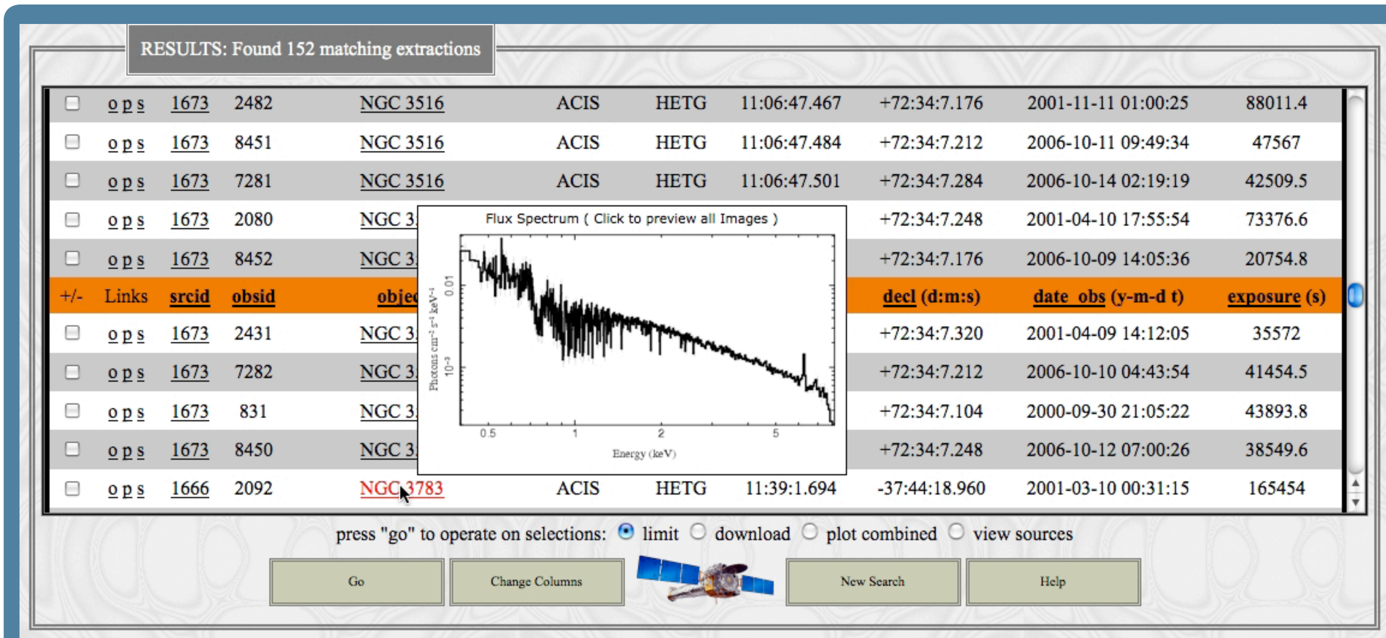


FIGURE 34: This is an example of search results. As the cursor moves over the links, a preview spectrum appears. With a click, you can access summary pages for an observation, SIMBAD information, *Chandra* OBSCAT information, or you can select observations for further operations, such as downloading or plotting combined observations.

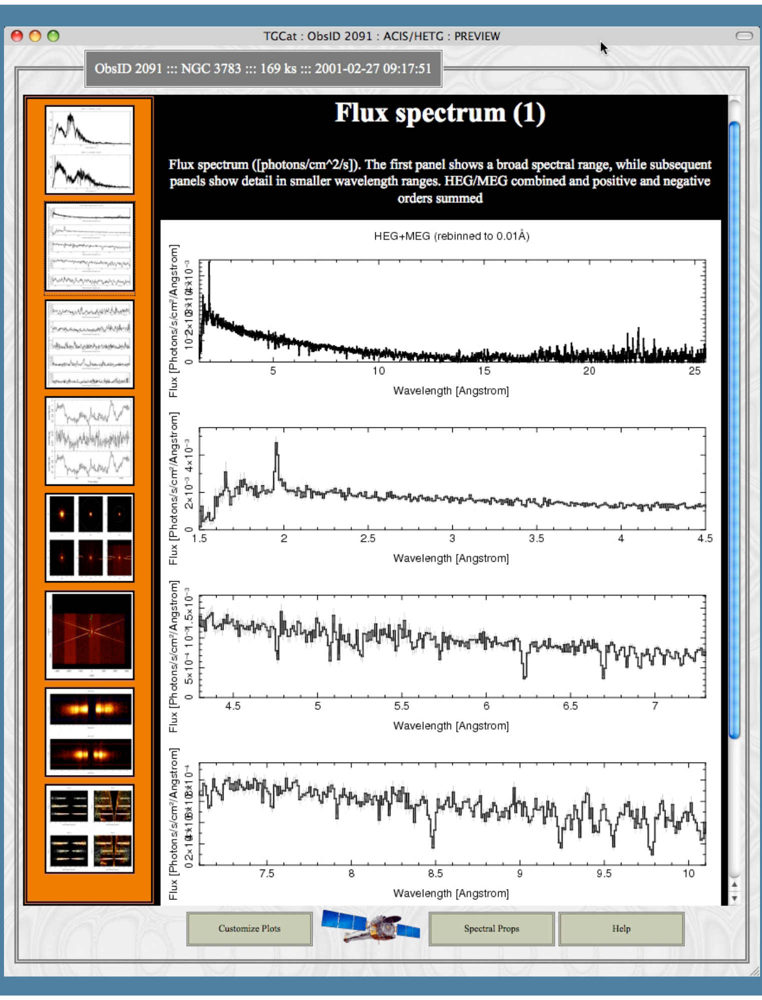


FIGURE 35: Here we see the graphical summary products. The thumbnails on the left are links which when clicked show the full size plot in the main window. Summary plots are from top-to-bottom counts (HEG and MEG), detailed fluxed spectrum (2 pages), light curves (total, background, and net), zeroth order region at six scales, the full field image, the spectral coordinates image, and an order-sorting image. (Plots differ slightly for the three grating/detector combinations.)

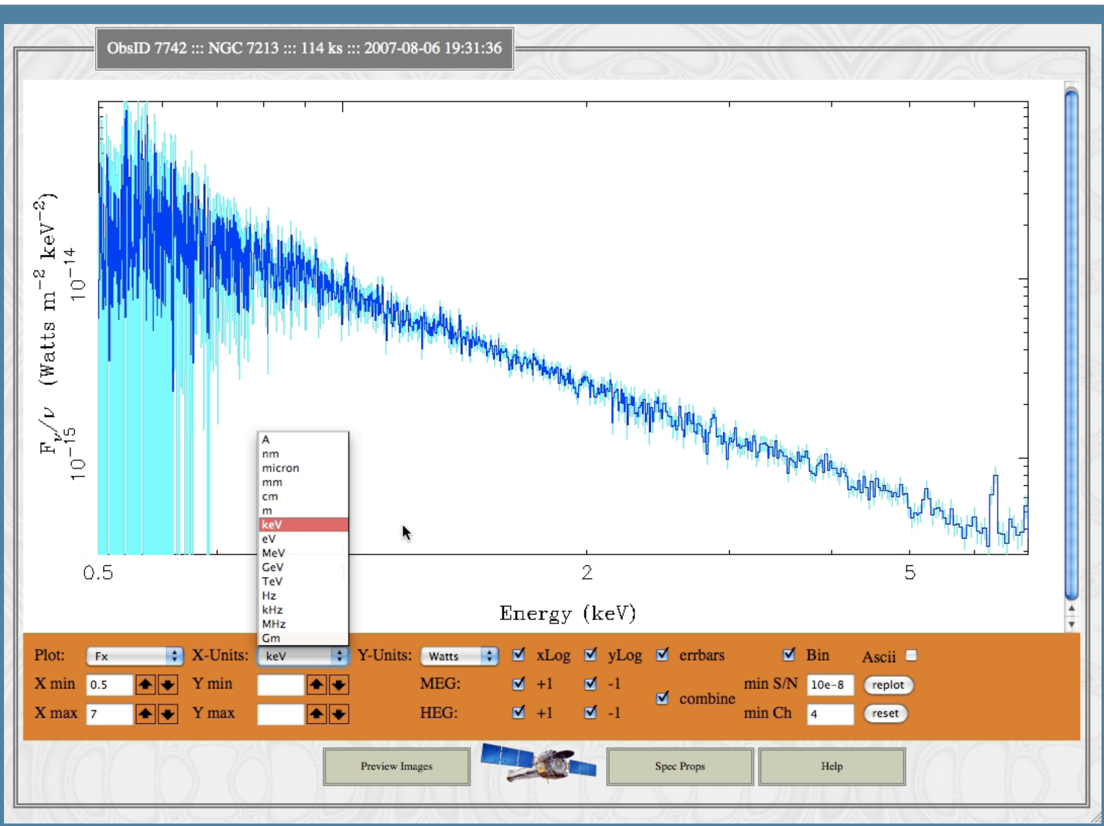


FIGURE 36: Here we show the custom-plot page. Drop-down menus allow a choice of units, and check-boxes control scales, binning, or data combination. Any plot displayed may be downloaded as an ASCII table.

Cycle 10 Peer Review

Belinda Wilkes

The observations approved for *Chandra*'s 10th observing cycle are now in full swing and the Cycle 11 Call for Proposals was released on 15 December 2008. Cycle 9 observations are very close to completion and Cycle 10 observations began in the Fall 2008. The substantial overlap of the two cycles allows us to efficiently fill the observing schedule.

The Cycle 10 observing and research program was selected as usual, following the recommendations of the peer review panels. The peer review was held 17-20 June 2008 at the Hilton Boston Logan Airport. More than 100 reviewers from all over the world attended the review, sitting on 14 panels to discuss 643 submitted proposals (Figure 37). The Target Lists and Schedules area of our website provides lists of the various types of approved programs, including abstracts. The peer review panel organization is shown in Table 1.

Table 1: Panel Organization

Topical Panels	
Galactic	
Panels 1, 2	Normal Stars, WD, Planetary Systems and Misc
Panels 3, 4	SN, SNR + Isolated NS
Panels 5,6,7	WD Binaries + CVs, BH and NS Binaries, Galaxies: Populations
Extragalactic	
Panels 8,9,10	Galaxies: Diffuse Emission, Clusters of Galaxies
Panels 11,12,13	AGN, Extragalactic Surveys
Big Project Panel	LP and VLP Proposals

The over-subscription rate in terms of observing time for Cycle 10 was 5.3, similar to that in previous cycles (Figure 38), with the total time request being ~ 89 Msecs, again similar to past cycles (Figure 39). As is our standard procedure, all proposals were reviewed and graded by the topical panels, based primarily upon their scientific merit, across all proposal types. The topical panels produced a rank-ordered list along with detailed recommendations for individual proposals where relevant. A report was drafted for each proposal by one/two members of a panel and reviewed by the Deputy panel chair before being delivered to the CXC. The topical panels were allotted *Chandra* time to cover the allocation of time for GO observing proposals based upon the demand for time in that panel. Other allocations made to each panel were: joint time, Fast and Very Fast TOOs, time constrained observations in each of 3 classes and money to fund archive and theory proposals. Many of these allocations are affected by small number statistics in individual panels so allocations were based on the full peer review over-subscription ratio. Panel allocations were modified, either in real time during the review or after its completion, transferring unused allocations from one panel to other panels which requested more.

Large (LP) and Very Large Projects (VLP) were discussed by the topical panels and ranked along with the other proposals. The topical panels' recommendations were recorded and passed to the Big Project Panel (BPP). The BPP discussed the LPs and VLPs and generated a rank-ordered list. BPP panelists updated review reports, as needed, both at the review and remotely over the following 2 weeks. The schedule for the BPP included time for reading and for meeting with appropriate panel members to allow coordination for each subject area. The BPP meeting extended into Friday morning to allow for additional discussion and a consensus on the final rank-ordered list to be reached.

The resulting observing and research program for Cycle 10 was posted on the CXC website three weeks later, 11 July 2008, following detailed checks by CXC staff and approval by the Selection Official (CXC Director). All peer review reports were reviewed by CXC staff for clarity and consistency with the recommended target list. Letters informing the PIs of the results, budget information (when appropriate) and providing a report from the peer review were e-mailed to each PI in August.

Joint Time Allocation

Chandra time was also allocated to several joint programs by the proposal review processes of Hubble and *XMM-Newton* (2 proposals in each case). The *Spitzer* joint program was not available in Cycle 10 due to the satellite's transition to the warm mission.

The *Chandra* review accepted joint proposals with time allocated on: *Hubble* (14), *XMM-Newton* (2), *NRAO* (7), *NOAO* (6) and *RXTE* (2).

Constrained Observations

As observers are aware, the biggest challenge to efficient scheduling of *Chandra* observations is in regulating the temperature of the various satellite components (see POG Section 3.3.3). In Cycle 9 we instituted a classification scheme for constrained observations which accounts for the difficulty of scheduling a given observation (CfP Section 5.2.8). Each class was allocated an annual quota based on our experience in previous cycles. The same classification scheme was used in Cycle 10. There was a large demand for constrained time so that not all passing-ranked

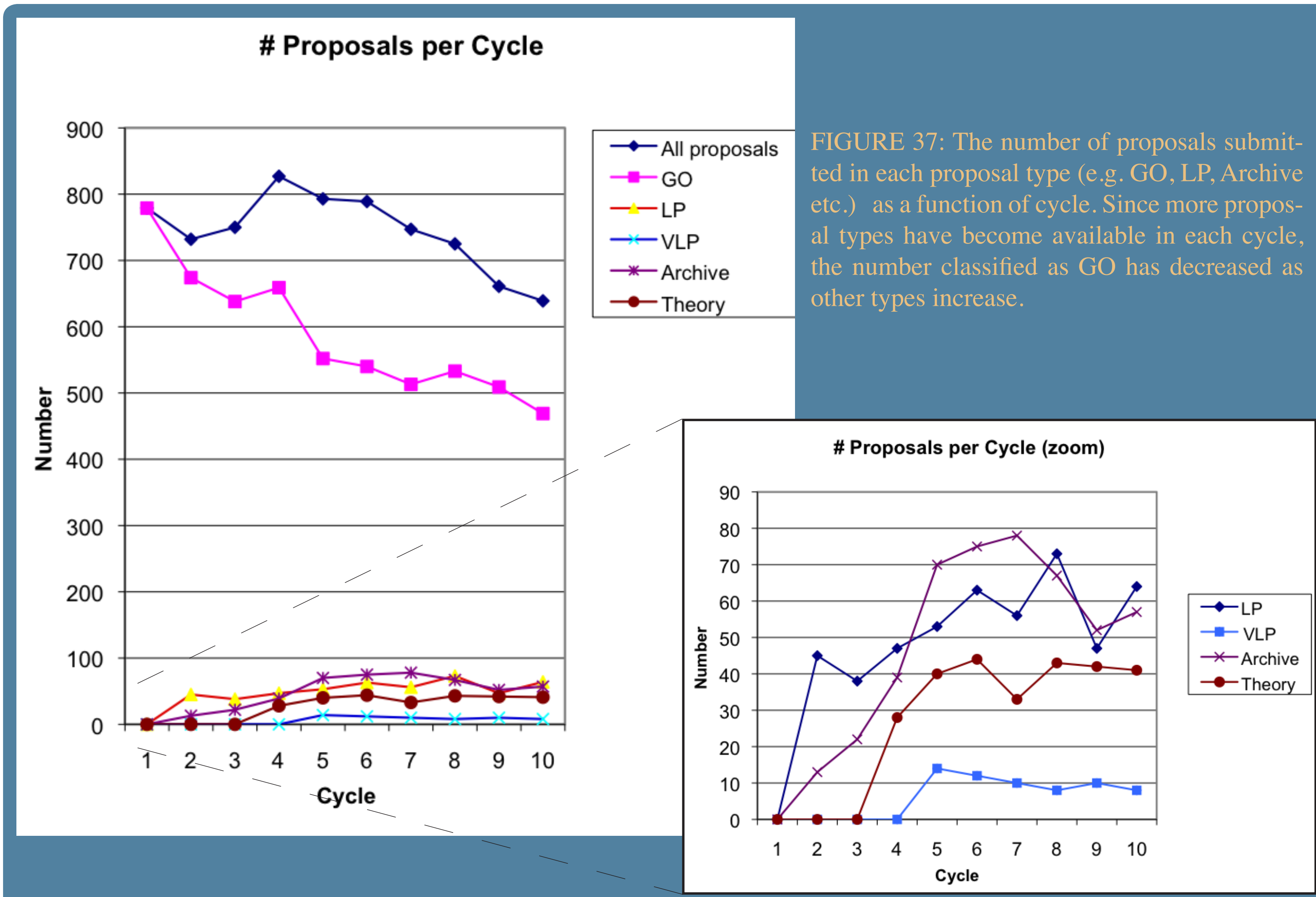


FIGURE 37: The number of proposals submitted in each proposal type (e.g. GO, LP, Archive etc.) as a function of cycle. Since more proposal types have become available in each cycle, the number classified as GO has decreased as other types increase.

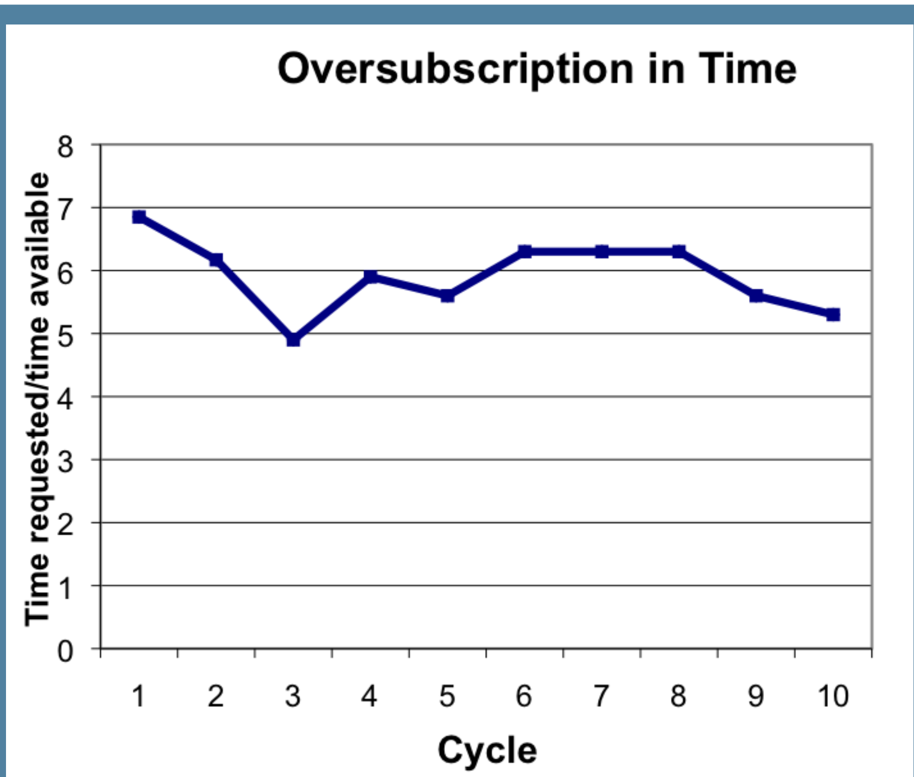


FIGURE 38: The over-subscription in observing time based on requested and allocated time in each cycle.

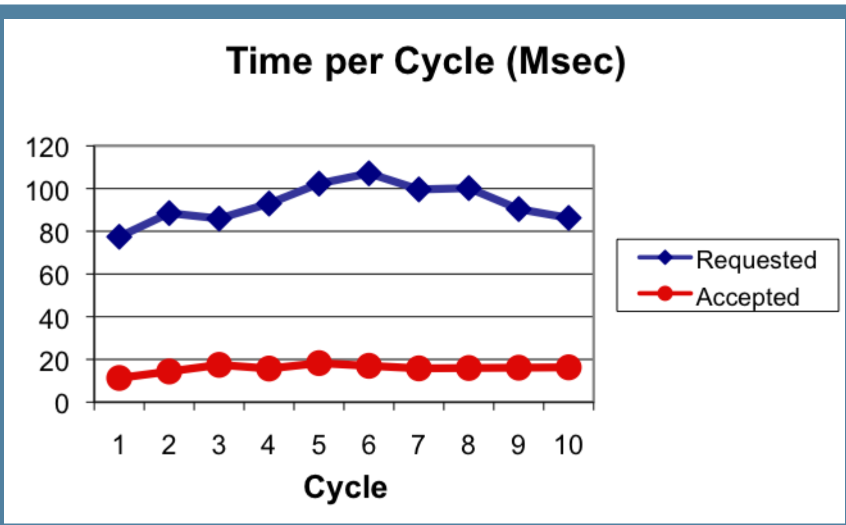


FIGURE 39: The requested and accepted observing time as a function of cycle in ksecs. This increased in the first few cycles, the largest effect being due to the introduction of VLPs in Cycle 5.

proposals which requested time constrained observations could be approved. Effort was made to ensure that the limited number of constrained observations were allocated to the highest-ranked proposals review-wide. Detailed discussions were carried out with panel chairs to record the priorities of their panels should more constrained observations become available. Any uncertainty concerning priorities encountered during the final decision process was discussed with the relevant panel chairs before the recommended target list was finalized. Please note that, as with Cycle 9, the most over-subscribed class was: "EASY" while "AVERAGE" was only marginally over-subscribed. In practice we combined these two classes in order to determine which observations should be allocated time. The same 3 classes will be retained so as to ensure a broad distribution in the requested constraints. *We urge proposers to specify their constraints as needed by the science rather than ensuring they are "EASY".*

Large and Very Large Projects

For the first time in Cycle 10, the full 6 Msecs of observing time available for Large and Very Large Projects (LPs, VLPs) was combined so that projects of both types competed for the full amount. In principle this allows projects requesting as much as 6 Msecs to be proposed, and approved. In practice the Big Project Panel recommended 15 LPs totalling 5.82 Msecs and no VLPs. The Large Project type has long been the most highly over-subscribed, a factor of >8 since Cycle 4 and close to 10 in Cycle 10. The combination of the two types results in an effective over-subscription of 6.5 for LPs, much closer to the review average of 5.3. The over-subscription for VLPs, though, is effectively infinite! In discussion with the *Chandra* Users' Committee, the process in which the two types are combined will be reviewed in advance of the release of the Cycle 12 Call for Proposals, based on the results of two peer reviews and experience with scheduling the resulting observing programs.

Cost Proposals

PIs of proposals with US collaborators were invited to submit a Cost Proposal, due in Sept. 2008 at SAO. As in past cycles, each project was allocated a "fair share" budget based on their observing program, as described in CfP Section 8.4. For the first time in Cycle 10, cost proposals requesting budgets at or lower than the allocated "fair share" budget were reviewed internally while those requesting more (8% of the cost proposals) were subject to an external review by a subset of the science peer reviewers. For these, final budgets were allocated based on the recommendations of the external review. The results were announced in early December, in good time for the official start of Cycle 10 on 1 Jan. 2009. Cycle 10 projects for which observations were started before mid-November 2008 were processed as early as possible, allowing their grants to be issued in a timely manner.

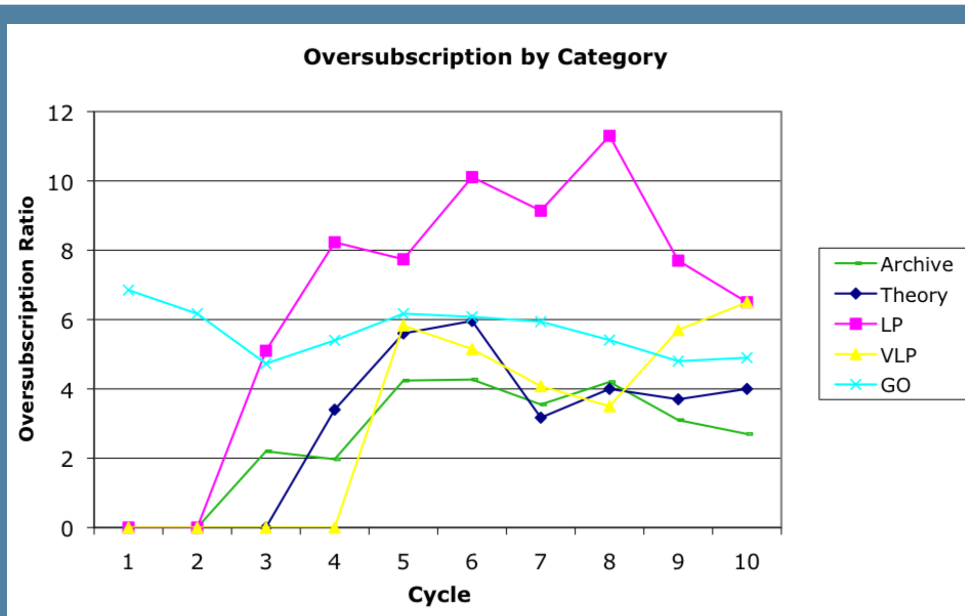


FIGURE 40: The effective oversubscription ratio in terms of observing time for each proposal type as a function of cycle. Please note that some of the fluctuations are due to small number statistics (e.g. Theory proposals).

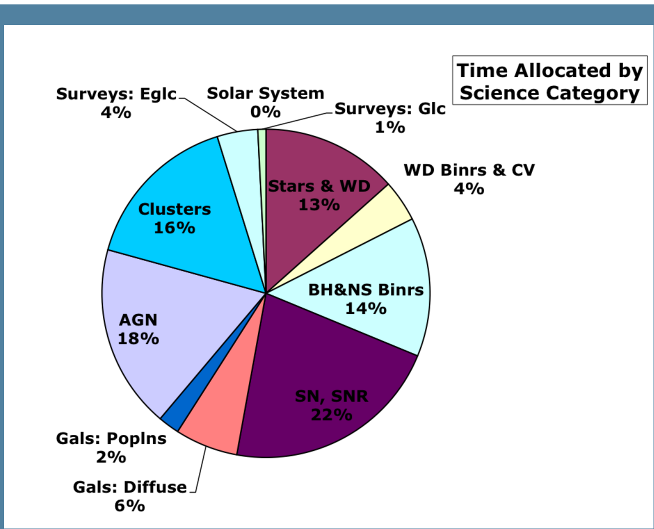


FIGURE 41: Pie chart indicating the percentage of *Chandra* time allocated in each science category. The time available for each category is determined by the demand.

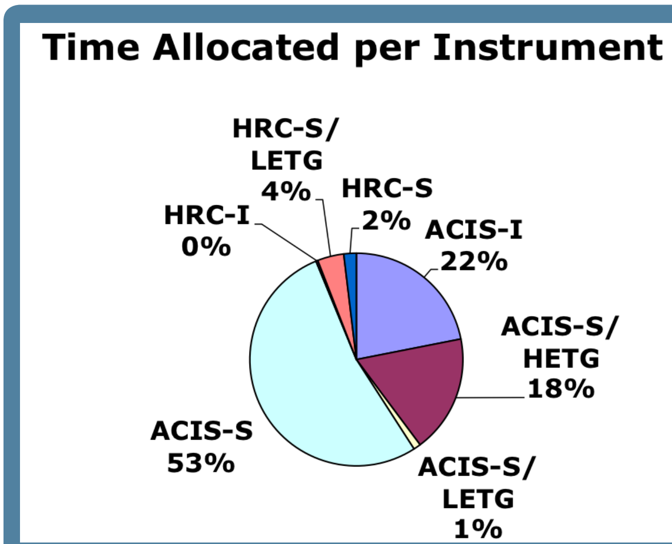


FIGURE 42: The percentage of *Chandra* time allocated to observations for each instrument configuration.

Proposal Statistics

Statistics on the results of the peer review can be found on our website: under "Target Lists and Schedules": select the "Statistics" link for a given cycle. We present a subset of these statistics here. Figure 40 displays the effective over-subscription rate for each proposal type as a function of cycle. Figures 41, 42 show the percentage of time allocated to each science category and to each instrument combination. Finally there is a list of proposals according to their country of origin. ✩

Table 2: Number of Requested proposals by Country

Country	Requested #Prop	Requested Time*(ksec)	Approved #Prop	Approved Time*(ksec)
USA	492	67173.60	151	13147.80
Foreign	151	22065.60	48	5085.70

Country	Requested #Prop	Requested Time(ksec)	Approved #Prop	Approved Time(ksec)
ARGENTINA	1	57.00		
AUSTRALIA	7	817.30	3	576.30
BELGIUM	2	270.00		
BRAZIL	1	60.00		
CANADA	13	3526.50	4	708.20
CHINA	1	50.00		
FRANCE	6	470.00	3	270.00
GERMANY	19	1841.00	5	240.00
GREECE	2	175.00		
INDIA	1	82.40		
ITALY	25	3459.00	8	820.00
JAPAN	9	1069.00	2	190.00
NETH	13	1314.00	7	674.00
POLAND	1	30.00		
RUSSIA	2	70.00		
SPAIN	7	770.00	1	20.00
SWITZ	4	427.30	1	60.00
TAIWAN	2	294.00		
UK	34	7083.10	14	1527.20
USA	492	67173.60	151	13147.80
VENEZUELA	1	200.00		
	643	89239.20	199	18233.50

*Note: Numbers quoted here do not allow for the probability of triggering TOOs

Upcoming *Chandra* Related Meetings

Check our website for details:
http://cxc.harvard.edu/

Workshop: Supernova Remnants and Pulsar Wind Nebulae
July 8-10, 2009
Cambridge MA
http://cxc.harvard.edu/cdo/snr09/

10 Years of *Chandra*
Sept. 22-25
Cambridge MA
http://cxc.harvard.edu/symposium_2009/

Chandra Calibration Review
Sept 21
Cambridge MA
http://cxc.harvard.edu/ccr/

Einstein Fellows Symposium
Fall, 2009
http://cxc.harvard.edu/fellows/

Einstein Postdoctoral Fellowship Program

Nancy R. Evans

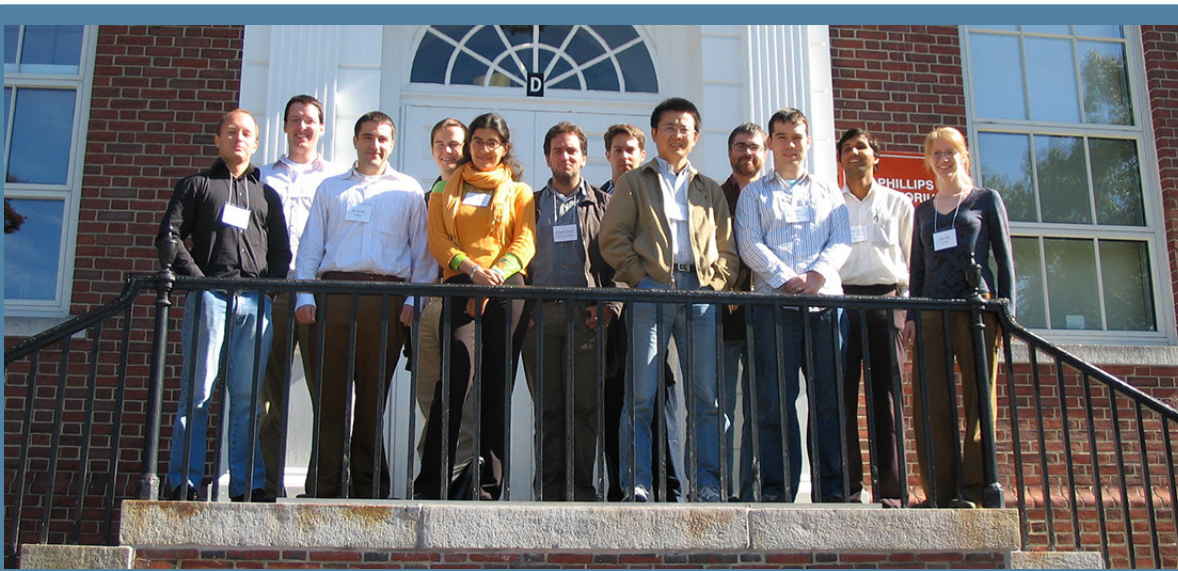


FIGURE 43: 2008 *Chandra* Fellows Symposium. Left to right: Jesper Rasmussen, Ed Cackett, Ian Parrish, Norbert Werner, Elena Rasia, Ezequiel Treister, Jon McKinney, Jifeng Liu, Carles Badenes, Shane Davis, Prateek Sharma, and Orly Gnat.

The *Chandra* Postdoctoral Fellowship program has now had 11 groups of Fellows: http://cxc.harvard.edu/fellows/fellowslist.html Many of the Newsletter readership may have enjoyed the exciting work they do by attending one of the annual *Chandra* Fellows Symposia.

Last summer, however, NASA reorganized its Postdoctoral Fellowship programs. The *Chandra* program was joined with the Fermi program to become the Einstein program, which was broadened to include science related to the Physics of the Cosmos program: http://nasascience.nasa.gov/programs/physics-of-the-cosmos In the call for proposals for the first Einstein Fellowship competition last fall, the missions were summarized as follows: "These include high energy astrophysics relevant to the *Chandra*, *Fermi* (formerly GLAST), *XMM-Newton*, INTEGRAL, and IXO (formerly Constellation-X) missions, cosmological investigations relevant to the Planck and JDEM missions, and gravitational astrophysics relevant to the LISA mission."

Ten Fellowships will now be given out for the Einstein program. In November, 2008 a record number of 156 applications were received for the first competition of the program. Once again, we invite you to enjoy the work of the Einstein Fellows at the first annual Einstein Fellows symposium in the fall 2009. ✫

Einstein Fellows 2009

	Host Institution	PhD Institution
Bogdanovic, Tamara	Maryland	Penn State
Fernandez, Rodrigo	IAS	Toronto
Kocsis, Bence	Harvard	Eotvos
Lehmer, Bret	Johns Hopkins	Penn State
McQuinn, Matthew	Berkeley	Harvard
Metzger, Brian	Princeton	Berkeley
Ofek, Eran	CalTech	Tel Aviv
Rozo, Eduardo	Chicago	Chicago
Schawinski, Kevin	Yale	Oxford
Simionescu, Aurora	Stanford	Munich

Education and Public Outreach Proposals Selected in Cycle 10

Kathy Lestition

The Cycle 10 *Chandra* EPO Peer Review, conducted by the CXC, was held in Cambridge MA on Dec. 3-5, 2008. A panel representing science, education, museum, Forum, and NASA mission and management perspectives reviewed 10 proposals. Seven individual and 3 institutional proposals were submitted. Three individual and 2 institutional proposals were selected for funding. An overview of the selected proposals by type follows, alphabetically in order of PI last name.

Individual Proposals

The Making of a Star and It's Entourage: A Planetarium Show About the Formation of Stars and Planetary Systems

Science PI: Prof. Jeffrey S. Bary, Colgate University, jbary@colgate.edu

EPO Co-I: Joe Eakin, Ho Tung Visualization Lab, Colgate University

Education Partner: Ho Tung Visualization Lab, Colgate University

In collaboration with a unique program at Colgate University which integrates the Visualization Lab into course content, this proposal will recruit approximately 20 Colgate University undergraduates from a variety of academic specialities (music, theater, graphic arts & design, physics & astronomy, history) to participate in aspects of the production of a high-quality planetarium show that align with their areas of academic expertise. The content is related to the PI's research. Topics will include the nature of the scientific endeavor and modern discovery, the processes by which planetary systems form, and our conception of our place in the universe. This rural area of central New York is underserved by NASA resources and the show will be an introduction to NASA science for students from the local school districts, other Colgate undergraduates, and the general public. This show will be the inaugural product for the recently opened, state of the art visualization lab and sound studio, and full-dome planetarium theater equipped with Digistar 3 projector. The EPO Co-I is an experienced content developer and oversees the Viz lab integration program. The show will be distributed to other planetaria.

Black Holes - A New Penn State Professional Development Workshop for Science Teachers

Science PI: Dr. William N. Brandt, Penn State University, niel@astro.psu.edu

EPO Co-I: Dr. Christopher Palma, Penn State University, cpalma@astro.psu.edu

Education Partner: Pennsylvania Space Grant Consortium

This proposal will fund the participation of teachers recruited from high poverty, underserved areas of both rural and urban Pennsylvania in a new professional development workshop focused on the topic of black holes. The workshop was developed based on focus group evaluations from participants of past workshops and the content was pilot tested and revised. In addition to the workshop, teachers will be offered a more sustained, long-term experience through a series of follow-up teleconferences in the school year following their summer participation. The workshop will utilize an available set of tested, standards-aligned NASA activities on black holes. The workshop is offered as a graduate credit-bearing course.

Addressing the Nature of Science Through a Telescope Loaner Program for Teachers

Science PI: Prof. Craig Sarazin, University of Virginia, sarazin@virginia.edu

EPO Co-I: Dr. Edward Murphy, University of Virginia, emurphy@virginia.edu

Education Partner: University of Virginia Astronomy Department

The goal of this program is to address the nature of science, astronomy, and the space science components of the Virginia Standards of Learning through a telescope loaner program and associated educational materials for teachers. The proposal builds on an earlier program utilizing these telescopes with teachers, developed by Co-I Murphy and Randy Bell, an Associate Professor at the U. VA Curry School of Education. Feedback indicated a lack of equipment at schools to enable the teachers to transmit their astronomy knowledge to students. This proposal utilizes 10 working Meade LX-10 8-inch Schmidt-Cassegrain telescopes recently retired by the University of Virginia Astronomy Department and made available to this program at no cost. After training, teachers will be able to check out a telescope for a period of one month to use at their school in night observing and daytime education activities. The science content will draw heavily from the research of NASA missions. Teachers will receive development credits for participation.

Team/Institutional Proposals

Building Partnerships Through "Kids Capture Their Universe"

Science PI: Dr. Deepto Chakrabarty, MIT Kavli Institute for Astrophysics and Space Research, deepto@space.mit.edu

EPO Co-I: Dr. Irene Porro, MIT Kavli Institute for Astrophysics and Space Research. iporro@mit.edu

Education Partners:
- Citizen Schools
- Science Education Department, Smithsonian Astrophysical Observatory (SAO)

The purpose of this proposal is to promote the dissemination and sustainability of the "Kids Capture Their Universe" (KCU) program. The KCU is at present successfully operating at 7 Citizen School sites. This proposal will add 10 additional out-of-school-time (OST) organizations across Massachusetts, particularly those serving populations underserved and underrepresented in STEM. The new OST organizations will develop partnerships with volunteers from local astronomy and space science communities to present an after-school program. The intent is to provide sustainability through the development of a pool of both astronomy content experts and OST centers with a common vision of the value of after-school science programs. The institutional team member scientists as well as other current volunteers are the core group of astronomy experts who will initiate partnerships with the new OST organizations and participate in the preparation of the training workshops. They will also be actively involved in recruitment of additional volunteer experts. The KCU curriculum utilizes the MicroObservatory robotic telescope network to provide concrete astronomy learning opportunities.

Touring a Universe of Black Holes: A WWT Educational Package

Science PI: Dr. Martin Elvis, Smithsonian Astrophysical Observatory, melvis@cfa.harvard.edu

EPO Co-I: Mary Dussault, Science Education Department, Harvard-Smithsonian Center for Astrophysics (CfA)

Education Partner: Science Education Department, CfA

With funding from NSF and NASA, the Science Education Department at the CfA is creating a national traveling exhibit, "Black Holes: Space Warps & Time Twists" that will tour the US for 3 years starting in June 2009. A cutting edge feature of the exhibit will be networked exhibit work stations where visitors will be able to create a personalized exhibit website through the use of swipe cards. The web content authoring system supports on-going visitor engagement beyond the walls of the museum, and connects the visitor experience to the immense reservoir of on-line resources. The newly emerged World Wide Telescope (WWT) technology is a logical extension of this forward-looking exhibit technology. This proposal will develop, as an integral part of the personalized exhibit web site option, an exhibit-specific accessible portal to the WWT that will allow visitors to extend their explorations of the exhibit content through the WWT's visualization software environment. The exhibit-tailored package within WWT will contain supplementary education materials that integrate WWT content with the exhibit museum education programs. The grant will also support direct educator and scientist involvement at the first 4 museum venues in the use of the science from the exhibit and the WWT in education programs. ✭

Chandra in IYA2009

Megan Watzke

The International Year of Astronomy 2009 (IYA2009) was conceived to honor the 400th anniversary of the first use of an astronomical telescope by Galileo Galilei in 1609, and has evolved into an extensive series of worldwide programs. Sponsored by the International Astronomical Union (IAU) and endorsed by the U.S. House of Representatives, UNESCO and the United Nations, IYA2009 aims to stimulate worldwide interest in astronomy and science, especially among young people and underserved populations. More than 135 countries and agencies are participating in this important global event. IYA2009's purpose is about more than just celebrating astronomy achievements during a single year: its goal is to build sustainable astronomy education and outreach programs and partnerships that will continue on into the future.

Chandra is heavily involved with several IYA2009 activities (for a full list of US and international activities, see www.astronomy2009.us and www.astronomy2009.org). Specifically, *Chandra* will be featured in the "100 Hours of Astronomy" webcast, "365 Days of Astronomy" podcasts, the Great Observatories image unveilings to museums, and more.

One of the IYA2009 efforts being led out of the *Chandra* X-ray Center is the “From Earth to the Universe” project (www.fromearthtotheuniverse.org). FETTU is a major

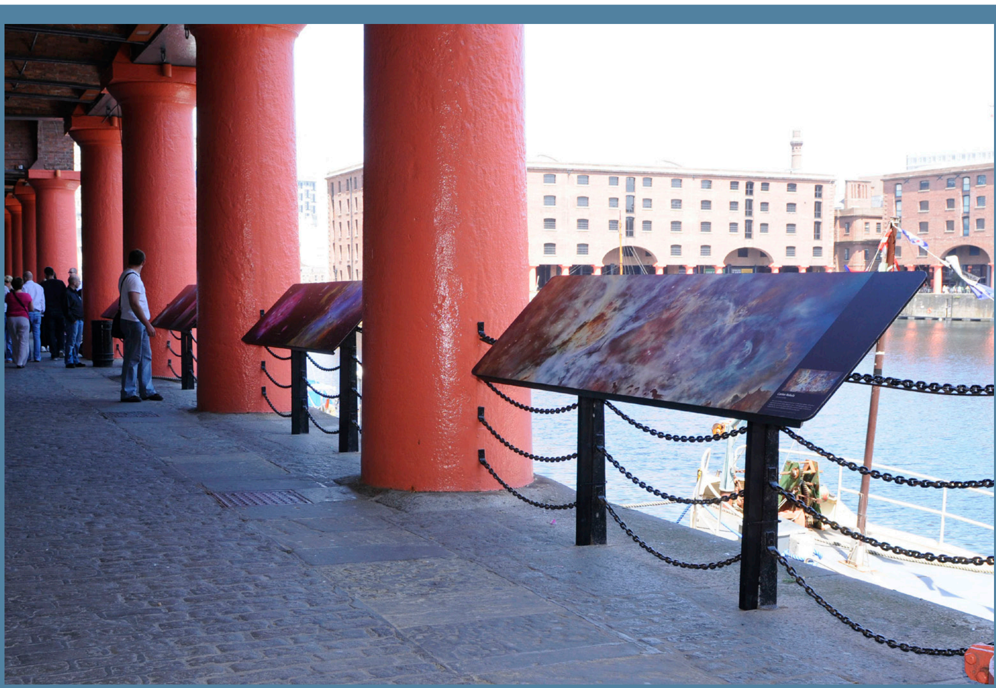


FIGURE 44: In June 2008, a prototype of FETTU was held at the Albert Dock area of Liverpool, England.

project of both the US and global efforts for the IYA2009. With images taken from both ground- and space-based telescopes (including *Chandra*, of course), FETTU showcases the incredible variety of astronomical objects that are known to exist: planets, comets, stars, nebulae, galaxies, clusters, and more.

FETTU will be shown in non-traditional public venues such as parks and gardens, shopping malls, metro stations and airports in major cities across the world. The FETTU images have been selected for their stunning beauty to engage members of the general public who might normally ignore or avoid astronomy. With short, but informative captions on each panel, the goal is introduce some basics of the science once an individual has been drawn to the image.

In the US, FETTU is being sponsored by NASA and will appear in semi-permanent installations in Atlanta and Chicago later this spring. A traveling version of FETTU will begin in the Tucson airport in late February before moving to Memphis in April. Several editions of FETTU will be appearing in the San Francisco area beginning in May, thanks to NASA's Lunar Science Institute, and the NASA Student Ambassador program is facilitating a FETTU exhibit in Madison, Wisc. More FETTU locations are being planned across the US and an enhanced schedule is being developed.

With NASA support, FETTU panels for the visually impaired are being prepared. The caption material for all of the images in the US collection of 50 images is available in both English and Spanish.

"It's great to see FETTU taking shape in the United States thanks, in large part, to NASA," said Kim Kowal Arcand of the *Chandra* X-ray Center and principal investigator for the NASA FETTU grant. "It's also amazing to see how it has taken off around the world."

With 2009 underway, FETTU is already being showcased in a variety of formats both physically and digitally in over 40 countries around the globe. These worldwide exhibits have been funded through a variety of local resources and are organized by each individual location. For a full list of known FETTU exhibits both in the US and internationally – visit http://www.fromearthtotheuniverse.org/table_events.php

While there is only one official year to celebrate astronomy, the goal is that the impact of FETTU and all of the other IYA2009 activities will extend far beyond that. By exposing the public to the wonders that *Chandra* and other telescopes have discovered, the hope is that it will create a lasting impression and generate further interest in astronomy and all science.

Enjoy 2 examples of the exhibits (Figures 44 and 45). ✮

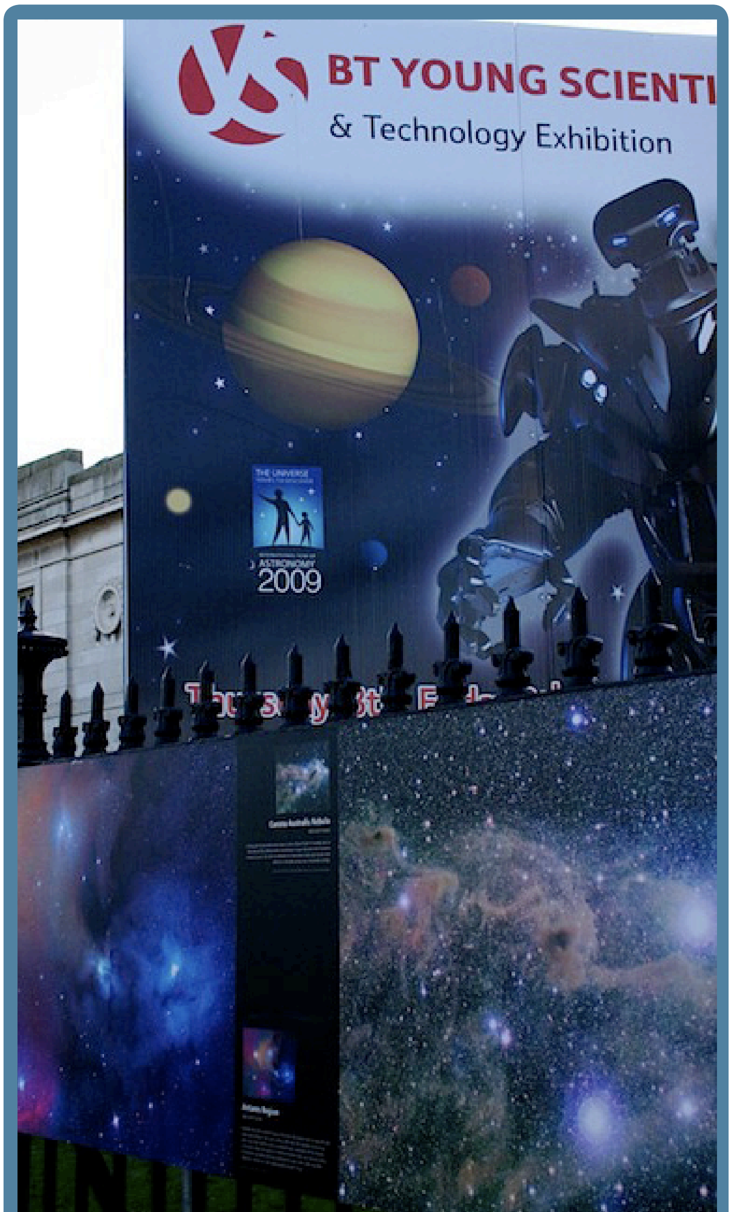


FIGURE 45: This is FETTU on display at the Royal Dublin Society Arena in Ireland.

International X-ray Observatory Update

Michael R. Garcia

As this newsletter article is being written, the IXO team, which includes many of you readers, is working on science white papers for the upcoming decadal survey. By the time you read this, those white papers will be completed and the Science Frontiers survey panel members will be reading and evaluating those papers. A big THANKS to all of you for your recent efforts on these papers, and for your help over the years in shaping the IXO into what it has become. The final submitted white papers build on the papers and presentations that you have crafted over the last several years.

The IXO team recently answered the 'notice of intent' request from the decadal, along with 171 other projects. The full list of projects can be seen on the ASTRO 2010 web site. The next stages of input into the decadal process are likely to be a town hall meeting in the Cambridge area in late March, followed by a submission from the project team on the observatory due April 1. As you can see from the rapid schedule, the decadal process is in full swing!

The first meeting of the combined IXO teams (formerly the Con-X and XEUS teams) was held in late August 2008 at GSFC, and was quickly followed in September 2008 by a meeting at MPE in Garching attended by over 150 people. The presentations from both meetings are posted on the revamped IXO web site, ixo.gsfc.nasa.gov. A key milestone described at both meetings was the technology assessments led separately by NASA and ESA, which converged on a consistent and robust mission design. This design retains the Con-X baseline instrument set (the calorimeter, gratings, and hard x-ray detector) but includes additional instruments from the XEUS baseline. The new instruments include a wide field imager (18 x 18 arcmin FOV), a polarimeter, and a high counting rate spectrometer. The next meeting of the IXO teams will also have occurred by the time you read this article, and is in late January in Cambridge, MA. Despite the likely chilly weather over 200 attendees have registered. This meeting will concentrate on the white papers to be submitted to the decadal science panels by Feb 15.

The IXO was well represented at several special sessions at the Jan. 2009 AAS meeting. The 40 posters at the special IXO poster sessions are now on line at the IXO web site. The special oral session in the main hall, which included presentations from IXO, EXIST, and Gen-X was also well attended.

Lastly, please join us in welcoming Randall Smith to the IXO team at SAO, and Rita Sambruna to the IXO team at GSFC. ✭

Chandra Users' Committee Membership List

The Users' Committee represents the larger astronomical community. If you have concerns about *Chandra*, contact one of the members listed below.

Name	Organization	Email
Steve Allen	Stanford	swa@stanford.edu
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Luisa Rebull	Spitzer Science Center	rebull@ipac.caltech.edu
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Ex Officio, Non-Voting

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CXC Coordinators

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DG Tau: Energetic Jets from a Budding Solar System

This article is reprinted with permission from http://chandra.harvard.edu/photo/2008/dgtau/

The young star, named DG Tau, is located in the Taurus star-forming region, about 450 light years from Earth. The bright source of X-rays in the middle of the image (Figure 46) is DG Tau and the jet runs from the top left to the bottom right, extending to about 70 billion miles away from the star, or about 700 times the Earth-Sun separation.

A detailed analysis of this image, led by Manuel Guedel of the Institute of Astronomy, ETH Zuerich in Switzerland, shows that the counter jet (top-left) has, on average, higher energy X-rays than the forward jet (bottom-right). The likely explanation is that some of the lower energy X-rays in the counter jet are absorbed by a disk around DG Tau, as shown in the accompanying illustration (right graphic), showing the star, disk and the inner regions of the jets.

Highly energetic X-rays are also detected from the young star, partially absorbed by streams of material flowing from the disk onto the star. The disk itself is much too cool to be detected by *Chandra*. Note that the faint vertical feature below the star does not show evidence for an additional jet, but is a chance alignment of four photons.

The effects of the jet on its surroundings may be significant. Other researchers have previously suggested that X-rays from a typical young star can significantly affect the properties of its surrounding disk, by heating it and creating charged particles by stripping electrons off atoms (a process called ionization). These X-rays will strike the disk at a low angle, mitigating their effects. In the case of the jets from DG Tau, the combined X-ray power in the jet is similar to that of a young star with relatively modest X-ray brightness, but X-rays from the jet have the advantage of striking the disk much more directly from above and below.

Guedel and colleagues argue that powerful X-ray jets might develop at some stage during the evolution of most young stars. They could, for example, have existed during the early stages of the solar system. DG Tau has about the same mass as the Sun, but is much younger with an age of about one million years, rather than about 4.5 billion years. Since it is surrounded by a disk where planets may be forming, this new *Chandra* image suggests that the early Earth and its environment may have been bathed in X-rays from a jet like DG Tau's. Although it is unknown if such X-rays would have had a significant impact on the forming Earth, it is possible that they did more good than harm. By ionizing the disk the X-rays may have generated turbulence, which could have had a substantial effect on the orbit of the young Earth, possibly helping to prevent it from making a disastrous plunge into the Sun. Furthermore, X-ray irradiation of disks may also be important in the production of complex molecules in the disk that will later end up on the forming planets.

The new X-ray observations of X-ray jets add new features to the already complex story of star and planet formation. The ionization and heating power of the X-rays from jets will have to be included in future model calculations that will help scientists understand the physical evolution and chemical processing of environments that eventually lead to planets like those in our solar system. ✯

Important Dates for *Chandra*

Proposals Due	March 17, 2009
Users' Committee Meeting	April 6, 2009
Cycle 11 Peer Review	June 23-26, 2009
Workshop (SNRs and Pulsar Wind Nebulae)	July 8-10, 2009
10 Years of *Chandra* Symposium	September 22-25, 2009
Cycle 11 Budgets Due	September 17, 2009
Cycle 11 EPO Proposals: Electronic	October 23, 2009
Cycle 11 EPO Proposals: Hardcopy	October 28, 2009
Einstein Fellows Symposium	Fall, 2009
Users' Committee Meeting	Fall, 2009
Einstein Fellowship Applications Due	Oct/Nov, 2009
Cycle 11 EPO Peer Review	December, 2009
Cycle 11 Observations Start	December, 2009
Cycle 12 Call for Proposals	December 2009

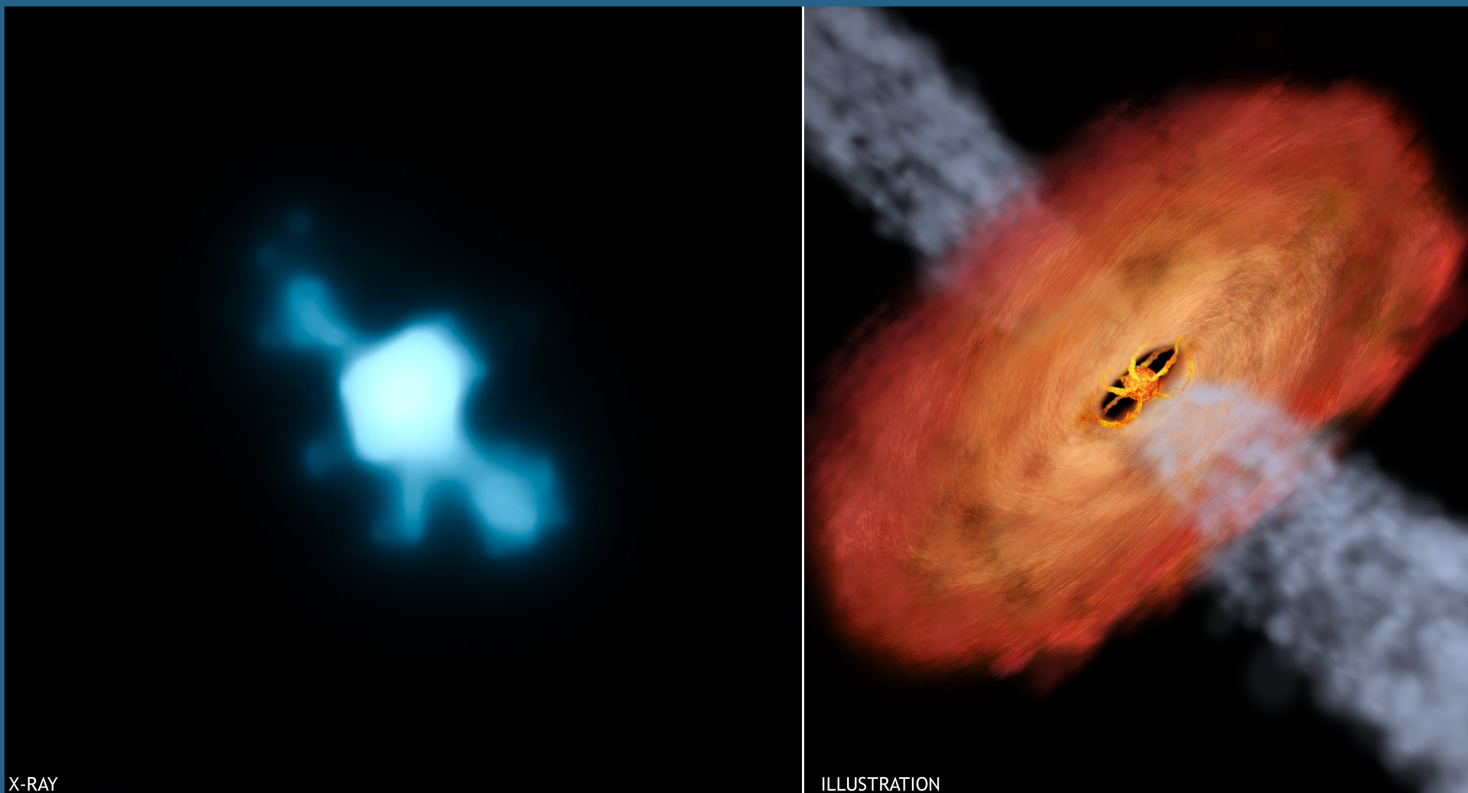

FIGURE 46: The image on the left from NASA's *Chandra* X-ray Observatory shows the first double-sided X-ray jet ever detected from a young star. A similar jet may have been launched from the young Sun and could have had a significant impact on the early solar system. (See article on page 47)

Credit: X-ray: NASA/CXC/ETH Zuerich/M.Guedel et al.; Illustration: NASA/CXC/M.Weiss

The** Chandra **Newsletter appears approximately once a year. We welcome contributions from readers.
Nancy Remage Evans edits "**Chandra **News", with editorial assistance and layout by Tara Gokas.
Comments on the newsletter and corrections and additions to the hardcopy mailing list should be sent to:
*chandra**news@head.cfa.harvard.edu**.*