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CHANDRA NEWS

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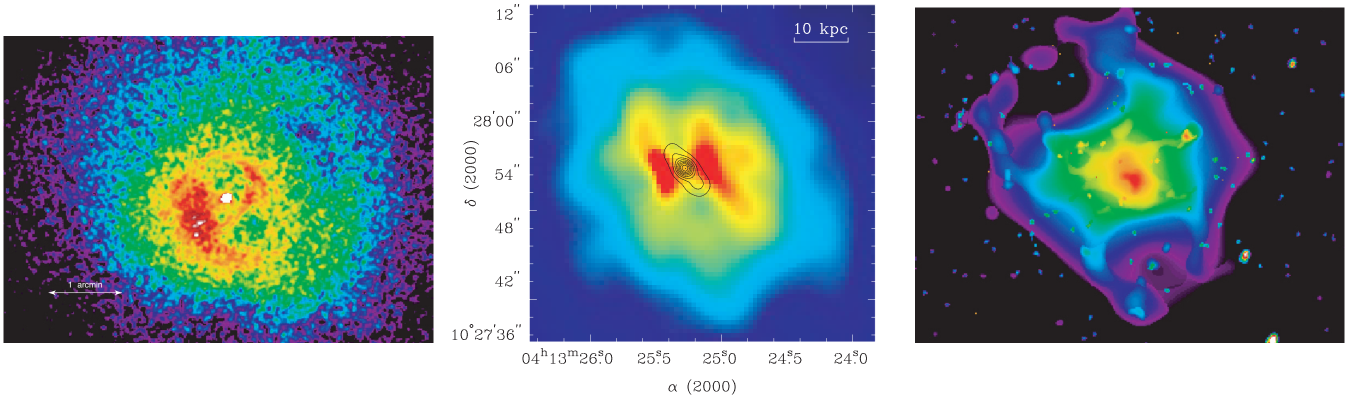

FIGURE 1: Chandra images of the Perseus (left) and Abell 478 (middle) clusters along with the group HCG62 (right). Colors indicate brightness. Each shows a bright central region with symmetrical X-ray cavities. The black contours on the A478 image show the radio emission.

CHANDRA LOOKS AT CLUSTERS OF GALAXIES

Clusters of galaxies are complex, multi-component systems with hundreds of galaxies, a hot (10^7 to 10^8 K) intracluster medium (ICM), and dark matter evolving in tightly coupled ways. Clusters are unique because of their size. As the most massive bound objects, clusters are the ultimate manifestations of cosmic structure building. A massive, rich cluster with $M_{total} \sim 10^{15} M_{\odot}$ forms from a density perturbation of radius ~15 Mpc. On these huge scales, most of the mass is dark. Only a few percent of the mass in clusters lies in the optical galaxies. In rich clusters, most of the luminous baryonic mass is in the hot ICM, which comprises about one fifth of the total mass. Since clusters form from such large volumes of space, their mass composition is thought to be representative of the universe.

Since most of the luminous matter in clusters is hot gas, X-ray observations provide unique insights into the physics of clusters. For example, while in relaxed clusters, the hot ICM traces the total cluster mass, in merging systems, the gas maps the often complex structure and provides information on gas heating through shocks. In the centers of clusters, cooling gas may fuel AGN, which in turn can reheat most of the cooling gas. And finally, since the evolution of cosmic structure depends strongly on the cosmology of the Universe, X-ray observations of samples of clusters can constrain cosmological parameters.

The sensitivity and exquisite angular resolution in the Chandra images has led to quantitative changes in our understanding of how clusters grow and evolve. This article touches on only a few examples of the insights Chandra observations provide. First, we illustrate the small scale structures seen in cluster cores and generally associated with relativistic plasma produced in active nuclei, second, the effects of subsonic or supersonic mergers and finally, comment on cluster evolution.

The Complex Centers of Clusters

The high gas density and cooler temperatures in the centers of clusters led to the "standard" cooling flow model in which large quantities of gas (hundreds to thousands of solar masses each year) cool in the cluster core (e.g. Fabian 1994). However, one of the first surprises from the XMM-Newton gratings and Chandra was the lack of cool gas in the centers of cooling flow clusters (e.g. Kaastra et al 2001, David et al. 2001). In some clusters, the observations limit the amount of cool gas to below 10% of that predicted by the standard cooling flow model. While these observations are difficult to reconcile theoretically, the amounts of cool gas detected in the X-ray observations are in close agreement with the observed star formation rates in these systems and with the amount of cool material detected at other wavelengths.

One of the basic assumptions in the standard cooling flow model is the lack of a heat source that could resupply the heat lost by radiative cooling. Chandra images have shown evidence of heat sources. In particular, Chandra images (see examples in Fig. 1) showed complex structures in cluster cores often in the form of X-ray cavities associated with radio lobes.

One of the clearest examples of the effect of plasma bubbles on the hot intracluster medium is in the Perseus cluster around the active central galaxy NGC1275 (see Fig. 1). First studied in detail with ROSAT (Bohringer et al. 1993), Chandra showed that the X-ray cavities that coincide with radio lobes have cool bright rims (Fabian et al. 2000). In addition to these inner bubbles, Perseus has outer "holes" in its surface brightness. These outer holes, as well as the X-ray cavities seen in a few other groups and clusters, do not coincide with radio lobes. The presence of these ghost cavities suggests that they may have been inflated during an earlier nuclear outburst and

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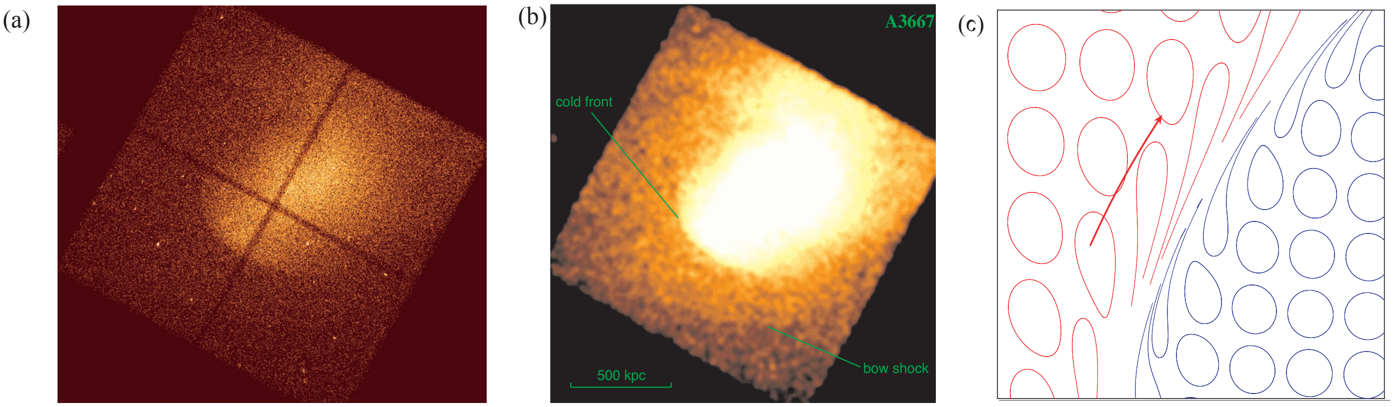

FIGURE 2: The Chandra image of the merging cluster A3667 (Fig. 2a) shows the sharpness of the cold front. On the smoothed image (Fig. 2b), the locations of the cold front and bow shock are marked. Fig. 2c is an illustration of how a magnetic layer could form along the cold front as the initially tangled magnetic fields are stretched along the surface of the subcluster by the motion of the gas.

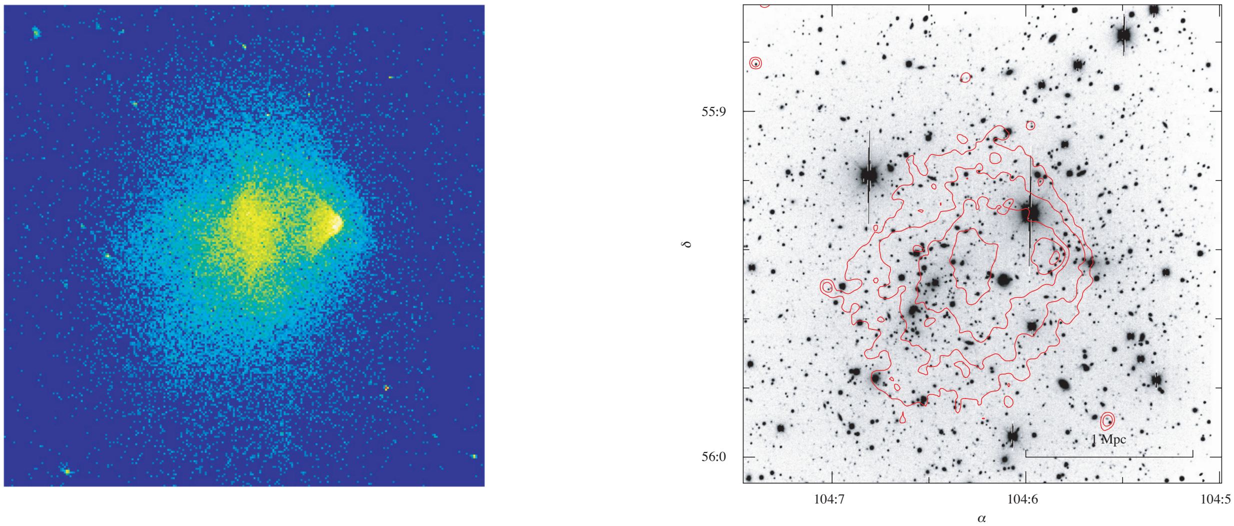

FIGURE 3: The Chandra image (left) shows the bullet subcluster as it exits the core of the cluster 1E0657-56. On the right, contours of the X-ray emission are superposed on an optical image showing the cluster galaxies.

synchrotron losses have now depleted the high-energy radio emitting electrons. Lower frequency radio observations are required to determine if the ghost cavities are filled with less energetic electrons.

While Chandra has shown that nuclear outbursts have a major impact on the X-ray morphology of cluster centers, the energetic consequences of these outbursts are still unclear.

The fact that the rims of the X-ray cavities are cool implies that they were inflated too slowly to shock heat the gas. Although the bubbles do not appear to drive shocks into the surrounding gas, they can still provide a significant means for redistributing the energy within cluster cores. In particular, the low gas density found in the cavities compared to the ambient cluster gas means that these bubbles will rise buoyantly. As the buoyant bubbles rise, they will dredge up ("entrain") cooler gas from the cluster center and deposit it at large radii, where it will eventually mix with the hotter gas (for details see Churazov et al. 2002 and references therein). Since any gas that is shock heated during the nuclear outburst will be convectively unstable, the heat resulting from the radio outburst will be redistributed throughout the center of the cluster. Both of these processes will reduce the accumulation of cool gas. Outside the central region, the conduction of heat from the hot ICM into the cooling gas also may be a source of reheating (e.g. Zakamska and Narayan 2003). It may be that convection at the very centers of clusters and conduction at large radii are both required to replenish the energy radiated away in the cooling flow and thereby reconcile the predictions of the "standard" cooling flow model with the new X-ray observations.

Cluster Evolution and Mergers

Our best current understanding of the formation of clusters is that they form hierarchically from smaller groups and subclusters and that, even today, matter continues to rain onto clusters, preferentially along the directions of large scale filaments that intersect at nodes defined by rich clusters. While relatively rare, major mergers of a large subcluster with a rich cluster dissipate a significant fraction of the subcluster's kinetic energy through gas dynamic shocks that heat the intracluster gas. These mergers also may accelerate high-energy particles, producing halo radio sources. As shown through two examples described below, Chandra observations of such mergers are providing new insights into cluster formation processes.

Prior to Chandra, the cluster A3667 was known to have a sharp gas density discontinuity, which was expected to be a shock front resulting from an on-going merger. But Chandra images (Fig 2) showed this was not a shock, but instead was a cold front, the boundary between a dense cold cloud associated with a merging subcluster and the hot cluster (Vikhlinin et al. 2001 a, b). Precise measurements of the gas density, temperature and pressure yield the subcluster velocity. The factor of two difference in pressure across the front implies a Mach number for the subcluster of ~ 1 (a velocity of about 1400 km sec^{-1}). The sharpness of the front, less than 3.5" on the sky or only 5 kpc in physical units, requires that the gas dynamic instabilities at this boundary be suppressed, probably by magnetic fields. If these instabilities were not suppressed, the edge should be broader, since the electron Coulomb mean free path is ~ 13 kpc. In the subcluster, the dark matter halo moves in front of the cold gas and pulls it along, maintaining the global stability of the front and suppressing the small-scale Rayleigh-Taylor instabilities. The observed velocity of the gas flow implies that the sharp front would be destroyed by the Kelvin-Helmholtz instability. However, the generation of a magnetic field surface tension along the front, as shown schematically in Figure 2c can suppress this instability. For the subcluster in A3667, a gas layer with an ~ 10 μG magnetic field is required to lie along the cold front. South of the front, Figure 2b shows a second weaker surface brightness discontinuity that is probably associated with the bow shock in front of the cold cloud, implying that the velocity of the front is slightly supersonic.

The best example of a supersonic merger is the hot (~ 15 keV), distant (z=0.3) cluster 1E0657-56, also known for reasons that will soon become clear as the bullet cluster (Markevitch et al. 2002). Fig 3 shows the recent, deep Chandra

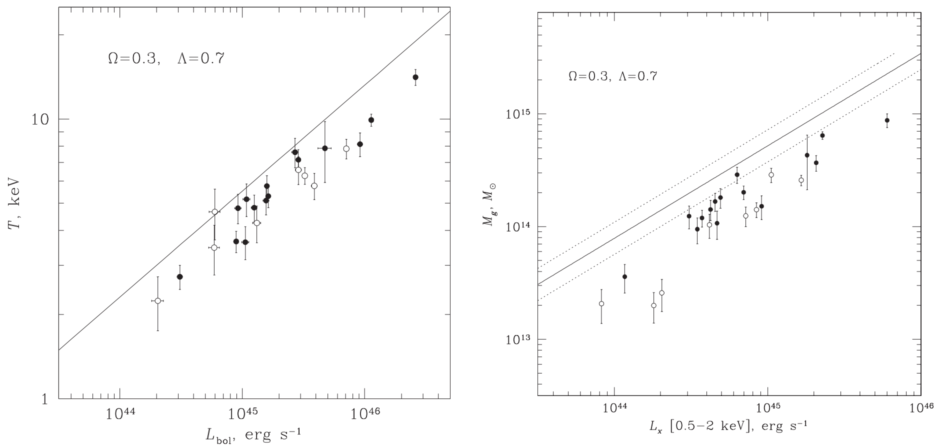

FIGURE 4: On the left, the solid line shows the correlation between luminosity and temperature for low redshift clusters for comparison to the Chandra measurements for high redshift clusters. Filled and open symbols correspond to different redshift ranges. Similarly, on the right, the correlation of gas mass and luminosity shifts with cluster redshift.

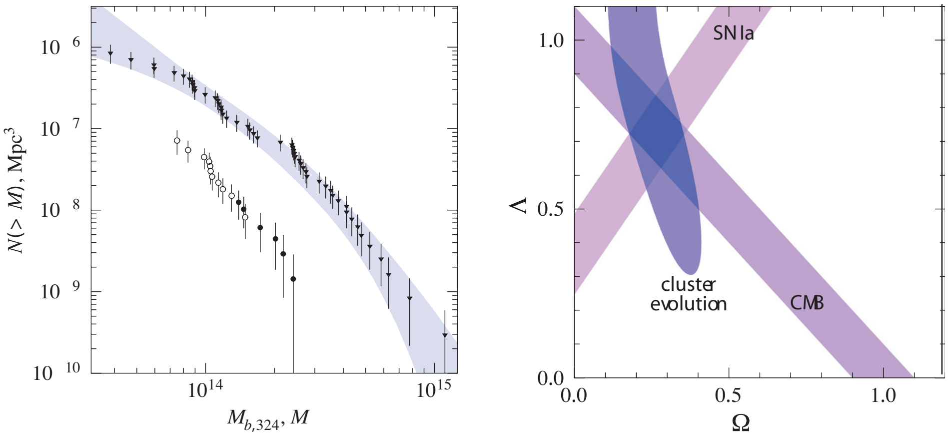

FIGURE 5: The graph on the left shows the change in the baryon mass function for distant clusters compared to that for nearby clusters (in the shaded band indicating the 68% uncertainty interval). A comparison of the 68% confidence intervals for Ω and Λ derived from cluster evolution, Type Ia supernova, and the CMB is shown on the right.

image of this cluster, along with the isointensity X-ray contours superposed on an optical R-band image. The X-ray image shows the "bullet" subcluster just exiting the cluster core and traveling west. In front of the bullet is a bow shock. The jumps in temperature and density across this front require supersonic motions, with a Mach number of 2-3. The 3000-4000 km sec^{-1} velocity of the bullet implies that the subcluster passed through the core of the main cluster only about 0.1 Gyr ago. The shuttlecock shape of the bullet shows that the subcluster continues to be actively destroyed by gas dynamic instabilities. As seen in Fig 3 (right), its gas lags behind the subcluster galaxies due to the ram pressure of the cluster gas that retards the gas in the bullet subcluster. The unique characteristics of the shock and supersonic subcluster allow several interesting measurements, including a possible opportunity to constrain the collisional nature of dark matter. In particular a comparison of the dark matter distribution (as measured by weak lensing) to the location of the subcluster galaxies and the lagging gas would determine if the dark matter is collisionless (like the galaxies) or if it undergoes an analog of ram pressure (like the gas).

Evolution and Cosmology

In theory, cluster evolution is simple, being driven by the gravity of the underlying mass field of the Universe and the collisionless collapse of dark matter. The growth of large scale structure is sensitive to the value of Ω the density parameter, but only weakly dependent on the cosmological constant Λ. However while observations of cluster evolution should provide a robust measure of the evolution of cosmic structure and constraints on the cosmology, the amount of evolution has been in contention.

The high X-ray luminosity of clusters allows them to be studied at great distances. Large samples of distant clusters were observed by Einstein, notably in the EMSS, and by ROSAT. These studies showed the first and best evidence for evolution in the luminosities of clusters. In particular, these studies found a dearth of high luminosity clusters at high redshifts (Henry et al. 1992, Gioia et al 2001, Vikhlinin et al. 1998).

While many distant clusters have been studied in detail with Chandra, the analysis of the global X-ray properties for samples of distant clusters has recently provided more evidence for cluster evolution as well as constraints on the underlying cosmology. In particular Chandra observations of 22 distant ($z > 0.4$) clusters show that the correlations between gas temperature, X-ray luminosity and gas mass all evolve between $z > 0.4$ and the present (Vikhlinin et al. 2002). Fig 4 shows the L-T and L-gas mass relation for the distant clusters compared to that found for present epoch systems. These observations show that high redshift clusters are systematically denser than clusters are today, and also hotter and more luminous for a given mass. Chandra observations of distant clusters also show a strong evolution in the baryon mass function which provides new constraints on the cosmology (Vikhlinin et al. 2003). The baryon mass function is used as a proxy for the total mass function since both observations and theory argue that the baryon fraction in rich clusters is constant. Figure 5 (left) shows the change in the baryon mass function for the distant clusters compared to a present epoch sample. Figure 5 (right) shows the constraints placed on cosmological parameters Ω and Λ from the cluster evolution compared to the constraints from the distant supernovae and the Cosmic Microwave Background (CMB). All three very different methods show very good agreement with both the supernovae and cluster results requiring a non-zero value for Λ.

In this article, we have touched briefly on several areas of cluster research that illustrate some of the new science that Chandra has produced.

Christine Jones, Larry David, Bill Forman, Maxim Markevitch, Steve Murray, Leon Van Speybroeck, & Alexey Vikhlinin

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RICCARDO GIACCONI AND THE ORIGINS OF THE CHANDRA PROGRAM

Many people are aware that we have worked on Chandra (originally AXAF) for more than 20 years, tracing back to an unsolicited proposal submitted to NASA in 1976, by Riccardo Giacconi (PI), myself (Co-PI) and Paul Gorenstein, Rick Harnden, Pat Henry, Ed Kellogg, Steve Murray, Herb Schnopper, and Leon VanSpeybroeck - all Co-Is and all members of our team at the Harvard-Smithsonian Center for Astrophysics. Martin Weisskopf came on-board in 1977 at MSFC as the Project Scientist. What some readers may not know is that the "roots" for this mission trace all the way back to 1963.

Just one year after the discovery of the first extra-solar X-ray source, Sco X-1, and the all-sky X-ray background (see article in this Newsletter about award of 2002 Nobel Prize to Riccardo Giacconi for leading this effort), Riccardo and his team at American Science and Engineering described their ideas to NASA for a long-range program of X-ray observations over the next decade. This 1963 plan described an ongoing rocket program, instruments to be flown on the OSO-4 spacecraft, an Explorer to do an all-sky survey (later built and flown as the UHURU satellite), a small X-ray telescope on an OAO spacecraft, and a 4ft diameter, 30ft focal length, arcsec class grazing incidence telescope.

The diameter and focal length of this telescope described in 1963 are essentially identical to the Chandra parameters. The suggested collecting area in 1963 was 400 sq cm, with the concept for nesting the optics not yet in vogue. The advertised angular resolution was characterized as order of seconds of arc - no doubt ambitious for a mirror design which had never been built, and only a bit less precise than the resolution achieved with Chandra nearly 40 years later. With detections for just Sco X-1, the Crab, and a few other fainter sources plus the all-sky background, Riccardo and his group already anticipated using such a telescope "for detailed study of the structure of galactic and extra-galactic sources". I think it is fair to say that Chandra has fulfilled that vision.

"And now you know the rest of the story" - or at least some of it.

Harvey Tananbaum

X-ray Astronomy Pioneer, Leon Van Speybroeck, 1935-2002

FIGURE 6: Leon van Speybroeck

Leon van Speybroeck, widely recognized as the premier X-ray telescope mirror designer, died on December 25, 2002 in Newton, Massachusetts at the age of 67.

As the Telescope Scientist for NASA's Chandra X-ray Observatory, van Speybroeck was intimately involved in every phase of the design and development of the High Resolution Mirror Assembly. His work with scores of engineers and scientists at the Center for Astrophysics, NASA's Marshall Space Flight Center, TRW, Inc., Hughes-Danbury (now BF Goodrich Aerospace), Optical Coating Laboratories, Inc. and Eastman-Kodak over a period of two decades was critical to the success that Chandra now enjoys.

"Leon was one of the best instrumentalists I ever knew and a dear colleague and friend," said Nobel Physics laureate Riccardo Giacconi of Associated Universities, Inc. in Washington, DC, who established and led the team that built the first X-ray telescopes. "Together with Giuseppe Vaiana he perfected the X-ray telescopes which were used for solar research in the late 60's and early 70's. He was directly responsible for the development of the Einstein and Chandra X-ray telescopes. Leon's contributions were essential to the achievement of Chandra's angular X-ray resolution, the highest yet obtained in X-ray astronomy. Many of the outstanding scientific results from Chandra could not have been obtained without it. He brought to his work complete intellectual integrity and a search for excellence. We all feel his loss as a colleague and a friend."

"A giant of X-ray astronomy has passed from our midst," said Irwin Shapiro, director of the Center for Astrophysics, where van Speybroeck spent most of his career. "Leon was also a wonderful person, always modest, unfailingly helpful to anyone in need, and ever precise and accurate in his statements."

Van Speybroeck, a native of Wichita, Kansas, graduated in 1957 from the Massachusetts Institute of Technology, where he received a Ph. D. in nuclear physics in 1965. After graduating, he joined Giacconi's X-ray astronomy group at American Science & Engineering where he became involved in the design of the X-ray mirrors on Skylab. After moving to the Center for Astrophysics in 1973, he had primary responsibility for designing and developing the mirrors for the Einstein X-ray Observatory, the predecessor to Chandra.

In recognition of his contributions to X-ray optics, van Speybroeck was awarded the 2002 Bruno Rossi Prize of the High Energy Astrophysics Division of the American Astronomical Society. On learning of this honor, he commented, "Many, many other people made essential contributions to the Chandra program, and hopefully some of them will receive proper recognition. I am thoroughly enjoying my days in the sun, but am quite humbled by the list of past recipients."

One of our favorite memories of Leon is the wonder and elation he would express when he viewed early Chandra images. Although he had labored heroically for years in the face of formidable technical challenges and never wavered in his conviction that an X-ray telescope could be built to produce high-resolution images, he beamed with excitement every time he saw the fruits of his efforts.

Leon truly loved his family, his friends and colleagues, and his work.

We will miss him dearly and will think of him often as exciting new Chandra results appear.

Harvey Tananbaum, Wallace & Karen Tucker

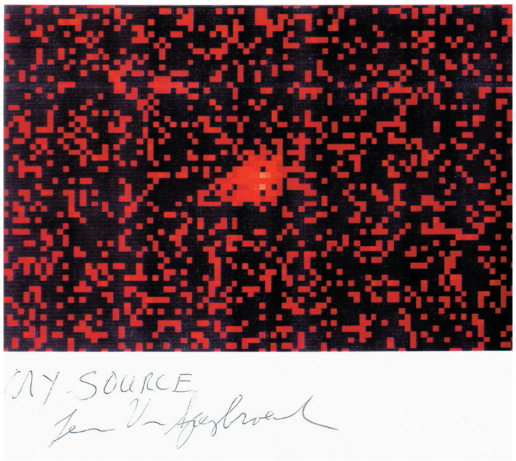

FIGURE 7: The first image received from Chandra, showing that the mirrors and the rest of the instrument were doing their job. Bystanders in the control room dubbed the source Leon X-1.

Space Shuttle Columbia

Chandra was launched by the Space Shuttle Columbia. We are reminded again of the courage and dedication of the astronauts who make space observatories possible. Everyone at the Chandra X-ray Center extends their deepest sympathies to the family, friends and colleagues of the lost crew of the Space Shuttle Columbia.

REPORT FROM THE PROJECT SCIENTIST

What a time! The contrasting highs and lows in the history of this Great Observatory have never been more extreme than with the announcement of Riccardo Giacconi's Nobel Prize and the sad, sad news of the passing of Leon van Speybroeck, just before he was to formally receive his Rossi prize. We are extremely fortunate that these individuals have played such vital roles in the conception, design, and development of the Chandra Observatory. We owe them both enormous debts of gratitude.

On other fronts, Project Science together with the CXC, particularly the calibration team, and members of the ACIS team, has been concentrating their technical efforts on measuring the composition and rate of build up of molecular contamination on the very cold ACIS-filters. The ACIS experiment, and the Observatory venting system, had, of course, been designed to allow for heating the instrument and boiling off contaminants.

Unfortunately, we have discovered, on-orbit, that heating also has the negative consequence of most likely increasing the charge transfer inefficiency of the front-illuminated CCDs. Thus, we are examining non-standard approaches to the heating and the possible consequences. Damaging the prime instrument on the Observatory is not a consequence that we can tolerate, so we are proceeding to study the situation very carefully before recommending solutions, if any.

We are pleased to announce the second conference highlighting science with NASA's Chandra X-ray Observatory to be held on Sept 16-18, 2003 in Huntsville, AL. Please reserve the date on your calendars. More details will be posted at the CXC web site.

Martin Weisskopf

CXC PROJECT MANAGER'S REPORT

The last year was once more an outstanding one for the Chandra X-ray Center from both a science and operations perspective. We celebrated Chandra's 1000th day in orbit on April 18 and 3rd birthday on July 23.

The scheduled viewing efficiency averaged 67% during the last year, allowing the observing program to transition from Cycle 3 to Cycle 4 in November. The average was approximately 3% lower than expected, mostly due to 10 interruptions of the observing schedule caused by high levels of solar activity. Once again this year, the science and mission operations teams worked hard to perform rapid re-plans and ensure a highly efficient return to the science time-line after these events. There is some indication (at last) of a decline in solar activity following solar maximum.

Observers were active in both the Target Of Opportunity (TOO) and Director's Discretionary Time (DDT) programs. Thirteen TOO targets with 18 observations and 27 DDT targets with 45 observations were accepted. Of these targets, 14 were fast response requests and required a mission schedule interruption and re-plan.

The Education and Public Outreach group have had a banner year with an increased focus on press releases and NASA Space Science Updates. Additional staff have been added to the group to aid in the production of animations and graphics, and in researching and developing science stories. Twenty science press releases and multiple other image releases were made during the year, and 4 Space Science Updates were made through NASA HQ.

The spacecraft and Science Instruments have continued to operate well and with no major anomalies. An investigation is underway to determine the cause of a decreased efficiency in the output of one of the Momentum Unloading Propulsion System (MUPS) thrusters following a longer than predicted momentum unload in December. The flight team has worked creatively to ensure no impact to the science schedule during the investigation.

A series of on-orbit tests were completed with the Aspect Camera to determine how close to the bright earth limb the camera could acquire and track stars. The results allowed for a reduction in the 20 degree limitation to 10 degrees and will ease scheduling of attitudes near the earth both during perigee passage and for science observing.

There were no safe modes during the year, but one safing action occurred when the spacecraft transitioned to bright star hold following a long maneuver in January. The cause was traced to a slightly inaccurate on-board gyro scale-factor and alignment matrix. A newly calibrated set of values was uplinked in May to mitigate against similar cases in the future.

Also of operational note was the nominal performance of the Observatory though two eclipse seasons, and a lunar eclipse in May.

The Science Processing team maintained an excellent record for throughput of data from observation to release to the Observer with an average time of 6 days. The Chandra archive holdings are now 1.6 TB (6M files compressed), with a total of 64.6K files corresponding to 2.5 TB retrieved last year

The Data System team completed a major port of the system to Solaris 8 in July and made releases of an interface to the Chandra Ray Tracer software (ChaRT) and an update to WebChaSer in December. CIAO 2.3 was released in November and includes a new tool that can be used to apply the CTI (charge transfer inefficiency) adjustment procedure. This correction restores some of the resolution lost due to radiation damage to the ACIS detectors early in the mission.

We look forward to continued smooth operations and exciting science results in 2003-2004.

Roger Brissenden

INSTRUMENTS: ACIS

Calibration: Response Matrix Products and CTI Correction

A great deal of work was done in calendar year 2002 on the development of response matrix products for use with the CXC CTI (charge transfer inefficiency) corrector. This software, an option in acis_process_events, corrects some of the effects of the radiation damage the front-illuminated (FI) ACIS devices experienced in the first two months of the Chandra mission. This damage produced a large CTI, which means that both the mean charge collected and the energy resolution of ACIS is reduced, in an approximately linear function of the number of rows in the imaging array through which a given packet must be clocked in order to reach the readout register.

The CTI corrector is able to very nearly restore the mean of the charge distribution (the "gain" of the detector), and to restore approximately half of the resolution degradation. There is a stochastic component to the degradation that cannot be completely corrected after the fact.

This new, better, performance of the ACIS imaging chips (the I array and S2) then needed to be calibrated. We have developed a new FEF (FITS Encoded Function) file, released in early November 2002 (with a small correction to be released in March 2003). We have run of order 10^8 photons through the MIT CCD simulator, and degraded the pulse heights of the simulated events in a manner analogous to the hardware. The undegraded events at each energy were fit to a function consisting of a handful of Gaussian parameters (two for the main peak, one each for Si K escape and fluorescence, and one for low-pulse-height noise), plus some broad functions to model the continuum "tail" produced by partial charge collection. The CTI degradation was modeled for each energy in a "CTI scatter matrix" consisting of two Gaussian parameters. This was then convolved analytically with the Gaussian portions of the undegraded response function. The resulting coefficients are stored in the FEF file. A small upgrade to the FEF file function set was needed for this work; it was incorporated into the CIAO mkrmf tool.

The resulting FEF files were tested against data taken in spring, 2000, from the on board external calibration source, which has strong lines at 1.49, 4.51, and 5.90 keV. Energy scales were adjusted such that a match was found within 0.3% for all chip regions for all three energies. The resulting FEF files were also used to fit the SMC supernova remnant 1E0102-72.3 ("E0102"), which has a particularly simple spectrum (He- and H-like lines from oxygen and neon, with little to no iron) and a high surface brightness. Good agreement (of order 0.5%) was found in the energy scales at these energies (down to about 0.55 keV). Further testing against various grating data taken in non-standard modes (with the source off axis, and falling on the ACIS-I array) is in progress to assess the precision of the low-energy portion of the response.

We are also beginning to test the FEF files to look for time dependent effects as the CTI increases at expected rates over the life of the mission. The current mean I-array parallel CTI is about 1.31 x 10^{-4}, while that of S3 is 1.7 x 10^{-5}. These numbers are increasing at a rate consistent with our expectations: 3.6 x 10^{-6} / yr for the mean I-array and 1.2 x 10^{-6} / yr for S3.

Calibration: Degradation of the Low-Energy (E < 1 keV or so) QE of ACIS

Another effect discovered this year is that the quantum efficiency (QE) of ACIS is decreasing with time for energies less than about 1 keV. The effect is consistent with slow buildup of a contaminant(s) on the ACIS Optical Blocking Filter (OBF), an aluminized polyimide film designed to reject optical light. Thanks to the HETG and LETG, we have obtained high signal-to-noise spectra of the contaminant (or mixture of contaminants) in absorption against a variety of astrophysical continuum sources. Work is proceeding to obtain the composition of the substance(s). We observe a strong carbon K edge, a clear oxygen K edge, and a weak fluorine K edge, leading to the tentative conclusion that it may be related to lubricants used in the translation stage of the Chandra science instrument module. The (model) spectrum of the degradation is given in Figure 8, for four epochs (as a function of wavelength for the MEG first order): 2000.0, 2001.5, 2003.0, and a projection for 2004.5, the middle of the AO-5 observing period.

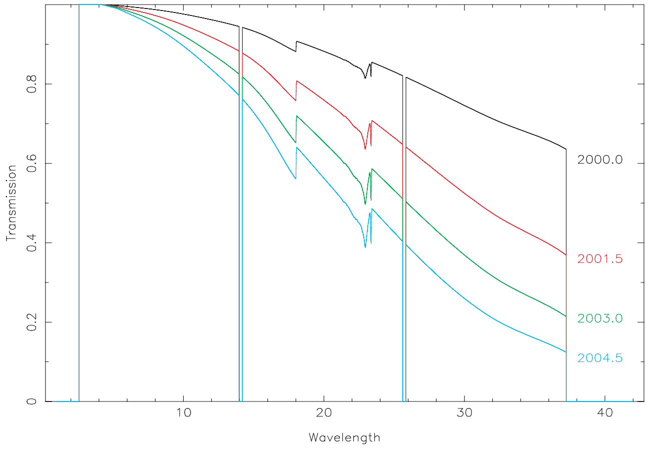

FIGURE 8: A model of the filter transmission at various epochs

If the particular substance identified proves to be sufficiently volatile, we may attempt to evaporate it, by temporarily raising the temperature of ACIS and/or the OBF. The prime contractor for Chandra (Northrup-Grumman, formerly TRW) is carrying out studies to assess the temperature and duration of such a bakeout, and to predict how effectively material might be removed from the vicinity of the ACIS. A risk assessment for such an option is in progress as of this writing (January 2003). In the meantime, users can correct for the effect using one of a variety of tools. One, called corrarf (G. Chartas), designed to correct the Ancillary Response Function (ARF file), accepts as inputs a standard ARF file and a time since launch. Another called contamarf (D. Huenemoerder) is high resolution, suitable for gratings as well as images. Two time dependency functions are under study (linear and exponentially decaying buildup), and either can be selected. These tools are available from :

http://www.astro.psu.edu/users/chartas/xcontdir/xcont.html
http://cxc.harvard.edu/cgi-gen/cont-soft/soft-list.cgi

Another tool is an xspec- or sherpa-usable model component which the user can multiply by an astrophysical model. This allows for some flexibility in the composition of the contaminant and the rate of buildup (via the time parameter). These models are available here:

http://www.astro.psu.edu/users/chartas/xcontdir/xcont.html
(for the xspec model)
http://cxc.harvard.edu/ciao/threads/sherpa_acisabs
(for the sherpa version)

Calibration Workshop, November 2002

Elsewhere in this newsletter, Hank Donnelly describes the first annual Calibration Workshop, held in Cambridge in November 2002. Many talks were given detailing various aspects of the calibration of the observatory, and most of these presentations are available on the web.
This excellent resource should be a standard place to go when calibration questions arise in the course of data analysis.

Backgrounds

In 2002 a long (53 ks) observation was taken in a novel mode. The translation table was moved to put ACIS between the on-board external calibration source and the optical bench, so that ACIS could see neither the cal source nor the sky. This put the focal point of the telescope on the HRC-I. A target was selected and an exposure of the neutron star RXJ 1856.5-3754, useful for calibration of the point spread function far off-axis (27.33 arcmin) was obtained using a small window (to minimize bandwidth) on the HRC-I.

The ACIS data are useful as backgrounds, since they include a charged particle environment very similar to that at the focal point of Chandra, and no sky-looking x-ray photons. The resulting spectra are described at (web page http://cxc.harvard.edu/contrib/maxim/stowed/), and the event list files are available (see links in the above memo). The spectra are quite comparable to backgrounds obtained in less desirable modes (dark moon observations, or histogram mode ACIS data taken when HRC-I is at the focal point).

Operations

ACIS continues to operate smoothly. We continue to obtain a great deal of on-board calibration source data when the observatory is in the near-earth radiation belts. These data are used to monitor the performance of the ACIS devices. Users may find it useful to obtain on board calibration source data taken near in time to their GO data, for comparison purposes. The observatory was shut down from time to time due to radiation events associated with solar Coronal Mass Ejections, as the sun comes down from its period maximum activity.

Richard Edgar, on behalf of the extended ACIS Instrument, Operations, and Calibration Teams.

INSTRUMENTS: HRC

Ongoing Calibration Issues

At the recent Chandra Calibration Workshop, the LETG team presented HRC-S/LETG data which show that positions of the positive and negative orders of spectral lines are not always symmetric on the detector. In addition, some of these lines do not appear to fall at their "proper" theoretical locations on the detector given the nominal LETG dispersion relation (independently verified with ACIS/LETG observations on-orbit). As an example of this phenomenon, the first and third positive orders of an Fe XVII line from the spectrum of the RS CVn star Capella are plotted in Figure 9 along with the predicted line profile. There is a clear offset between the observed and predicted position of the third order line. By analyzing many spectral lines from a compendium of sources, it is found that these offsets are not systematic, but vary in a complex manner across the detector. This variation across the detector is shown graphically in Figure 10. Typical magnitudes of these discrepancies are from 0.02 Å to 0.05 Å, with a maximum excursion of up to 0.1 Å. These non-linearities are near the performance level of detectors of this type and may require pixel-by-pixel calibration. This is also discussed in the LETG article below.

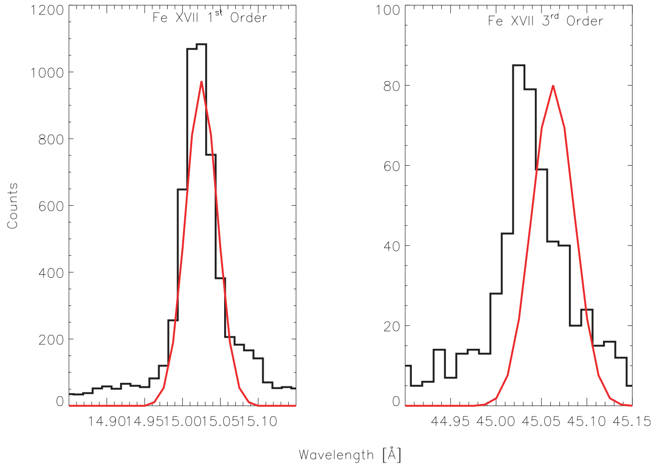

FIGURE 9: Spectral lines of the RS CVn star Capella obtained with HRC-S LETG observation. Note the detected and expected lines do not agree for the higher order line. Figure courtesy of Vinay Kashyap.

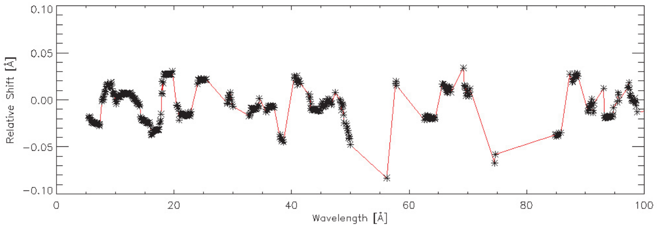

FIGURE 10: Discrepancy between positive and negative orders from a compendium of observations with HRC-S LETG. Plot shows deviations in Å.

Evidence suggests that these systematic uncertainties are due to small-scale spatial non-linearities in the HRC-S detector. We are investigating this issue in order to maximize the scientific gain. The HRC IPI team is presently examining ways to reduce or entirely eliminate these small position offsets by mapping out the HRC spatial non-linearities at the highest level of possible detail. Measurements of the small-scale spatial non-linearities will be made in the HRC laboratory with the HRC instrument Proof-of-Concept (POC) detector and a system of translation stages, position encoders and nickel etched pinhole masks. The results of this measurement campaign will be analyzed and the findings will be used to understand and model the non-linearities in order to reduce these position errors in the in-flight HRC detectors. We are also continuing to analyze in-flight data and to investigate whether additional in-flight observations can shed light on this issue.

In an independent investigation, the HRC IPI team is conducting a feasibility study on the use of the HRC anti-coincidence shield as a monitor of the *Chandra* radiation background. This function is currently being performed by the EPHIN, but the recent upward trend in the EPHIN temperature has raised the possibility that its performance may degrade with time. Apart from being a scientific instrument in its own right, the EPHIN serves the very practical function of monitoring the Chandra spacecraft radiation environment and aids mission operations by determining when to prepare the spacecraft and the scientific instruments for high radiation environments. Because of the steady rise in temperature of the EPHIN, an alternative method may eventually have to be developed to monitor the spacecraft radiation environment.

Fortunately, the HRC anti-coincidence shield may be able to fill the space environment monitoring role of the EPHIN. The HRC anti-coincidence shield consists of a box made of plastic scintillator and two photomultiplier tubes surrounding the HRC detectors. The primary purpose of this shield is to veto charged particle events that pass through the shield and are simultaneously detected by one of the HRC detectors. Preliminary results indicate that the anti-coincidence shield should be capable of monitoring the local radiation environment.

A plot of the quiescent EPHIN rate versus anti-coincidence shield rate is shown in Figure 11. It is apparent that the HRC shield rate correlates well to the EPHIN integral channel flux, at least over a limited range shown in the figure.

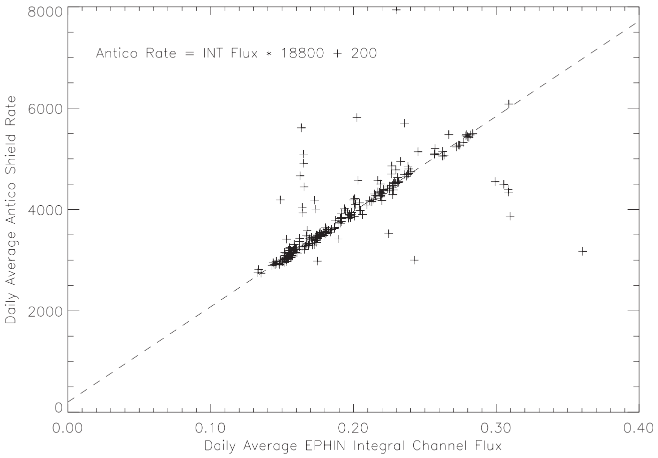

FIGURE 11: Correlation of quiescent EPHIN integral channel rate and HRC anticoincidence rate. Courtesy of Michael Juda

HRC Science

Long Term Monitoring of M31

As part of the HRC GTO program, Mike Garcia and Benjamin Williams continue to observe M31 with the HRC-I as part of a multi-year survey. The larger FOV of the HRC (as compared to ACIS) allows them to cover the entire disk of M31 with only 5 pointings. Bright XRBs in M31 are visible in short HRC exposures, so the lower QE of the HRC (as compared to ACIS) is not a limitation in the study of variability of these sources.

Through this program, they have obtained 16 epochs of Chandra-HRC snapshot images covering a total baseline of ~2.5 years and containing a mean total exposure of 17 ks. They have measured the mean fluxes and long-term lightcurves for 172 objects detected in these data. One representative lightcurve is shown in Figure 12. They find that M31 contains a dynamic X-ray source population. Measurements show that at least 30% of the sources vary significantly on ~1 year timescales. Over a dozen new transient sources were found, the majority in the bulge and therefore likely containing black holes. A comparison of the number of these objects versus the persistent bulge sources (likely containing neutron stars) indicates the relative numbers of black holes versus neutron stars, modulo the duty cycle of the transients.

They have also searched through published X-ray, optical and radio catalogs, as well as new optical data, searching for previous detections and counterparts for these X-ray sources. Via comparison to the Local Group Survey (Massey et al. 2001) data, they were able to find several new optical counterparts. Many of these have the colors of foreground stars, but several have colors/magnitudes typical of M31 upper main sequence and supergiants: 2 (B=21.46, V=20.45), 14 (B=21.14, V=21.23), and 171 (B=17.88, V=17.15). Typically, foreground stars in the M31 field have colors of B-V~0.5 to B-V~1.5. Object 2 has a color and magnitude appropriate for an M31 red giant. Object 14 is the color of an M31 upper main sequence star, and 171 has the color and magnitude of an M31 red supergiant. Follow-up spectra may provide positive identifications for these stars.

ULX Identification

In a separate study using the HRC, Kris Eriksen and Pat Slane have observed the enigmatic X-ray source 1E0953.8+6918, located in the M81 group dwarf irregular galaxy Holmberg IX (Ho IX). 1E0953.8+6918 is one of the nearest and most luminous members of the class of "Ultra-Luminous" X-ray sources (ULXs); objects whose X-ray luminosities ($L_x > 10^{39}$ erg s^{-1}, assuming isotropic emission) greatly exceed the Eddington luminosity for a neutron star. As such, the most luminous ULXs may either contain accreting "intermediate mass" (~100 solar mass) black holes, or are beamed and may be related to Galactic microquasars. Most ULXs are observed in galaxies that are vigorously forming stars and are thus thought to be associated

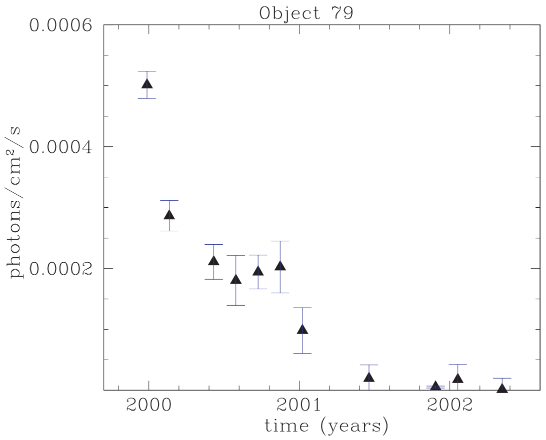

FIGURE 12: Time variability of one of the M31 x-ray sources.

with massive stars. 1E0953+69 is particularly interesting in that Ho IX has very little current star formation (UV observations show that Ho IX has no main sequence stars earlier than B0). While previous X-ray observations of 1E0953+69 had sufficient resolution to indicate that the source is roughly coincident with a bright optical emission line shell, a high resolution HRC observation, combined with images from the Vatican Advanced Technology Telescope (shown in Figure 13), clearly establish that the optical counterpart is a stellar association located near the center of the shell.

Preliminary analysis of MMT optical spectroscopy indicates that the shell was shock heated by a recent energetic event equivalent to 10-100 supernovae, providing insight into the possible origin of ULXs.

Acknowledgements

Vinay Kashyap, Mike Garcia, Ben Williams, Michael Juda, Kris Eriksen, and Pat Slane have contributed to this article.

Almus Kenter and Ralph Kraft , for the HRC team

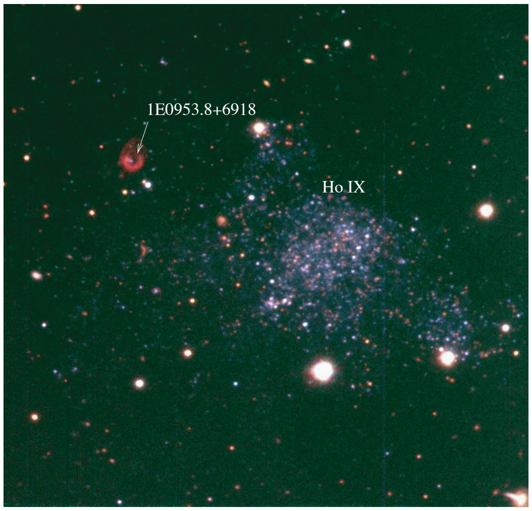

FIGURE 13: Vatican Advanced Technology B,V+[O III],R+Hα+[N II] composite of Ho IX. The ULX is located inside the bright emission-line shell in the northeast (upper-left) of the image. Figure courtesy of Kris Eriksen.

INSTRUMENTS: HETG

HETG Calibration

The Chandra Calibration Workshop held in early November 2002 provided a useful forum for discussing Chandra calibration issues and included a session on the Chandra gratings [1]. Some items of note with respect to HETG are summarized here.

A growing contamination layer on ACIS reduces the HETG long wavelength effective area; representative modeled transmission curves are plotted in Figure 8 (Fig in ACIS article) for the MEG wavelength range. Edges in the contaminant spectrum have been identified and include Fluorine (~18Å), Oxygen (~23Å), and Carbon (~43Å, not shown). This time-dependant contamination layer is an additional term that needs to be included in HETG ARF files. This will be transparent to the user when a new version of the mk[g]arf tool and appropriate CALDB files are released in the future. In the meantime, software is available through the CXC to correct for or include knowledge of this contamination in analyses. For more information, see the Calibration Workshop[1] presentations by Plucinsky; Chartas; and Marshall.

Another "ARF" effect is the likely reduction of front-illuminated (FI) CCD effective quantum efficiency (QE) due to random and occasional cosmic ray events, which deposit a large amount of charge in the device. This effectively "splotches out" a fraction of the active area for one or more frames. In the process, any real X-rays that may have interacted in the region are not detected. More quantitative details will be coming, but roughly expect an energy-independent factor of 0.92 to 0.95 to be applied to the QE of FI CCDs. This is relevant to HETG because both back-illuminated (BI) and FI CCDs are used in the ACIS-S grating readout and resulting grating ARFs. At present, without the correction, slight discontinuities and plus-side versus minus-side differences may be expected where statistics allow.

Finally, more accurate grating RMFs (line spread functions) can be created by using mkgrmf. These new custom-created RMFs are made up of two Gaussian and two Lorentzian components based on high-count MARX grating simulations. For more details see the calibration workshop poster by Ishibashi[1].

Calibration progress will continue, so please refer to the CXC and Calibration web pages for the latest information and calibration products.

HETG Science: Ne and Fe

A "dispersion fest" of sorts was held in October 2002 at the Mullard Space Science Laboratory (MSSL) in the UK --- more formally known as the "High Resolution X-ray Spectroscopy with XMM-Newton and Chandra" workshop. Quite a range of topics was covered and many of the contributions are available on the web[2]. A few, containing information about the Ne and Fe lines, are mentioned here (numbered references are to talks on the two websites below).

Plasma diagnostics using the forbidden to intercombination lines of He-like triplets are common: the f/i ratio can indicate the plasma density. For the Ne triplet around 13.5 Å, however, lines of Fe can blend with the Ne lines, complicating measurements. Ness[1,2] compares the HEG, MEG, LETG, and RGS views of this spectral region, finding that the spectra are consistent given the underlying high-resolution view provided by the HEG.

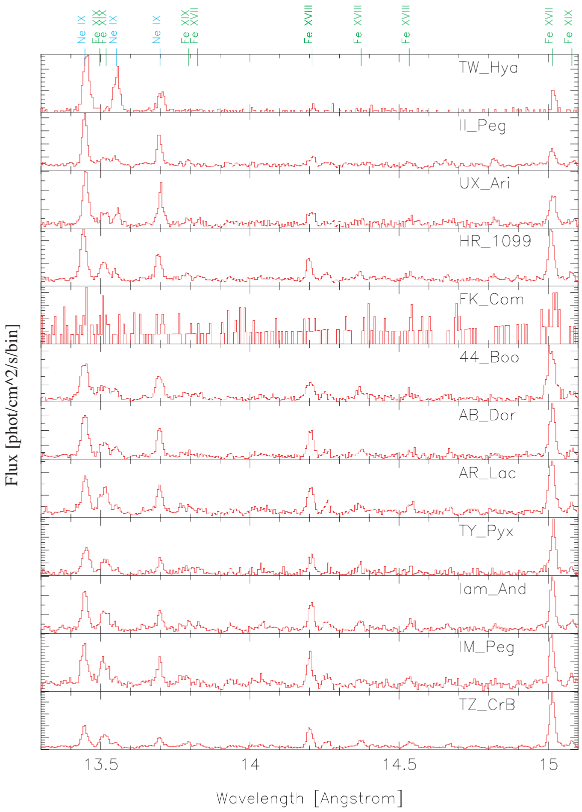

FIGURE 14: Gallery of spectra for a very diverse collection of cool stars. The Ne IX triplet lines (13.44, 13.55, 13.70 Å) are at the left, and Fe XVII, which has a similar emissivity distribution with temperature is at the right (15.02 Å). Spectra have been ordered by relative strength of Ne IX to Fe XVII, a mainly abundance-dependent ratio.

Ne and Fe emission from stellar coronae are summarized in Figure 14 taken from Huenemoerder[2]. The Ne triplet lines are on the left, and a variety of Fe lines are indicated from the triplet to the Fe XVII line at 15 Å. The stars are arranged here in order of their Ne IX to Fe XVII flux, which depends largely on the Ne/Fe abundance ratio. The flux observed is averaged over the whole star and all emitting regions. In his presentation, Guedel[2] noted that there are a range of volumes of different density in a corona. If the distribution of these densities goes as a power law, then the global f/i ratio, which we measure in data such as these, is more a measure of the power-law index than the average emission density.

Supernova remnants also show various amounts of Ne and Fe. Four SNR observed with the HETGS are shown in Figure 15, from Dewey[2]. Note that for E0102 there is little Fe emission and so Ne X (and Ne IX just to its right) is clearly visible against weaker lines and continuum. In the case of N103B and N132D, however, there is significant Fe emission, which fills in the range between Si XIII and O VIII and swamps the Ne emission. Note that because of its large size, the image of Cas A is shown here only in Si line emission.

Dan Dewey , for the HETG Team

References

[1] Chandra Calibration Workshop:
http://cxc.harvard.edu/ccw/proceedings/index.html

[2] High Resolution X-ray Spectroscopy with XMM-Newton and Chandra:
http://www.mssl.ucl.ac.uk/~gbr/rgs_workshop/

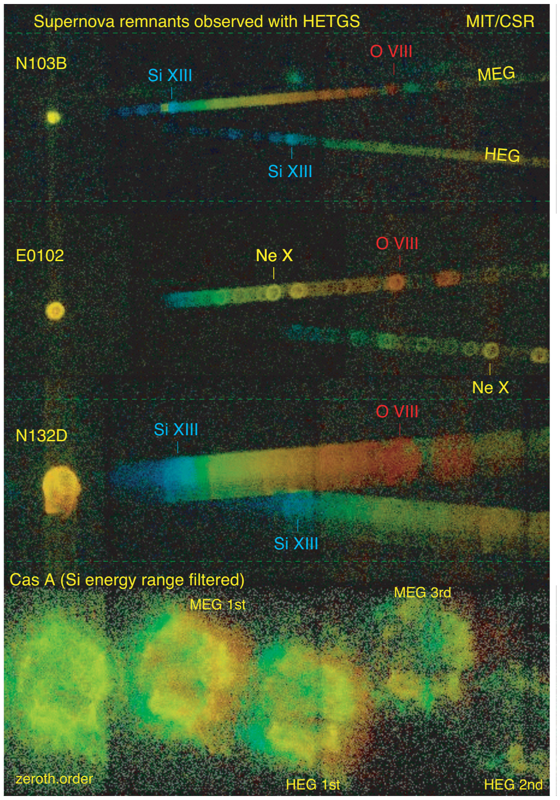

FIGURE 15: Supernova remnants as observed in the HETG GTO program are shown on the same scale.

INSTRUMENTS: LETG

The LETGS operated normally during 2002 with no significant instrument anomalies or problems. Observations were undertaken for a range of different types of X-ray sources: late-type stars, novae, AGN, X-ray binaries, and one γ-ray burst source. A spectacular Fast TOO was pulled off for the blazar Mkn 421 in 2000 October (P.I. F. Nicastro), catching the source in a very bright state. The resulting LETG+ACIS spectrum has about 4.2 million counts and clearly illuminates the different orders of the LETG perpendicular support structure diffraction (Figure 27).

Calibration activities have concentrated on attempting to understand and reduce the most important uncertainties in our current description of the instrument performance. Some of these activities are described below.

Higher Order Diffraction Efficiencies

One of the largest remaining sources of uncertainty in the effective area calibration of the LETGS lies in the efficiency of higher order throughput. The LETG diffraction efficiencies are based on optical constants for gold, in combination with an analytical diffraction model that assumes the individual gold grating bars have rhomboidal cross-sections. The parameters describing the rhomboids influence the predicted diffraction efficiency in the higher orders much more than they do for first or 0th order diffraction.

In the current diffraction model, each of the 540 circular grating elements making up the LETG assembly have their own set of rhomboidal parameters. In this way, the diffraction efficiency for the ensemble is an average of the efficiencies of all the different grating elements (weighted as a function of energy by their respective mirror shell effective areas). The initial set of rhomboidal parameters used prior to launch in the diffraction model of each grating element, together with the mean period and period variance, were determined using laboratory infrared measurements. The resulting grating model met its first major X-ray challenge during end-to-end calibration activities at the MSFC X-ray Calibration Facility. Analysis of tests designed to probe the efficiency of diffraction in the various orders indicated generally good agreement between observation and model for first order—to 10-15% or so-though with some much larger discrepancies in the wavelength range ~ 6-12 Å (1-2 keV), shortward of the gold M edges, where the diffraction efficiencies are changing fairly rapidly.

Prompted by the observed discrepancies, post-XRCF activities of the MPE and SRON groups included tests of diffraction efficiencies of spare grating elements at the German PANTER facility. The MPE team lead by Peter Predehl analyzed these data and concluded that, while a single set of rhomboidal parameters for a given grating element could match the observed diffraction efficiency in any one order reasonably well, no set of parameters could be found that simultaneously matched observed efficiencies in all the orders. The current LETG diffraction model uses different parameters for different spectral orders—a fudge.

Why is the model failing? Electron microscope pictures of grating bars for this and similar gratings suggest to the eye that for any given bar the rhomboid is not a bad approximation. However, the approximation of the same rhomboidal shape is likely not so good for *all* the bars of a single LETG facet, and dependency of diffraction efficiency on rhomboidal parameters for different spectral orders is non-linear. While it would be technically feasible (though non-trivial) to construct a new analytical model that allows for a more general description of grating bars, it is not immediately obvious that such an effort would be worthwhile: data likely do not exist to constrain uniquely any additional parameters.

The LETG group at CXC has recently completed an extensive and detailed re-analysis of XRCF diffraction efficiency tests and we find the current grating model in agreement with the data to a level of typically 10% or better for first order. In higher orders, we have indications of larger discrepancies. These discrepancies are backed up by analyses of in-flight observations of bright, narrow spectral lines seen in multiple orders, supporting the general conclusion that we need to modify the efficiencies for 2nd and 3rd orders by as much as 30% or so at wavelengths above ~12 Å (1 keV) or so. At shorter wavelengths, 2nd and 3rd orders tend to agree better with the model. A comprehensive analysis of on-orbit LETG+ACIS-S spectra, including that from the recent Mrk421 observation, is in progress. Improved higher order efficiencies are expected to be available later this summer.

Further details on higher order diffraction efficiencies can be found at the web page listed at the end of this article.

Gain Sag?

Measurements of the flux from HZ 43 in the longest wavelengths of the LETG+HRC-S (~ 150Å; 0.08 keV) have revealed a trend of very slowly decreasing count rate over the time since the first post-launch observation. The total change since launch so far is at a level of about 4% or less. Since this is much smaller than the estimated absolute calibration accuracy of 15-20% at these wavelengths, this is not a significant source of additional error. While analysis is still ongoing, it appears that the gradual decrease in count rate is due to gain sag in the HRC-S detector. Some small fraction of the lowest energy photon events are then lost because their pulse heights fall below a threshold limit used to reject "bad" events. Such a drop in gain is common in microchannel plate detectors after some time in the radiation and operating environment of orbital satellites. The detector voltages that control gain can be adjusted to compensate for this and we will be monitoring the general trends of gain and effective low energy quantum efficiency to determine if and when such a voltage change might be worthwhile.

Numerics and the Dispersion Relation

Shortly after launch, analysis of LETG+HRC-S spectra of Capella and other coronally-active late-type stars revealed a puzzle in the dispersion relation. It appeared as though the outer plates of the HRC-S detector had a different dispersion relation than that of the central plate, in the sense that the outer plates needed a larger Rowland diameter. This obviously could not be caused by the grating, and so all aspects concerning the detector that might enter into the effective dispersion relation were carefully examined; no plausible source for the effect was found. As simulation tools improved and we were able to process accurate grating ray trace experiments through the Chandra pipe, it became apparent that the dispersion problem could also be found in simulations. As we improved the simulations and tried different detector and grating combinations, the same effect was seen in HETG tests. This pointed the finger unambiguously in the direction of software. It was John Davis from the CXC group at MIT who discovered that a string of numerical operations in the computation of diffraction angle accumulated an increasingly large systematic error going toward longer wavelengths. A fix for this bug has been tested and will be implemented in the next software release.

Detectors and the Dispersion Relation

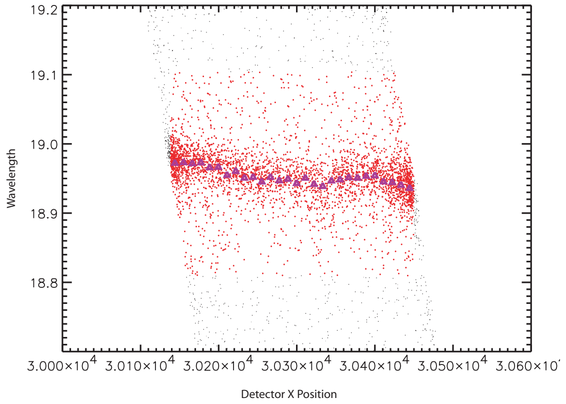

FIGURE 16: The observed wavelengths of photon events in the vicinity of the O VIII Ly α doublet seen in the LETG+HRC-S spectrum of Capella plotted as a function of detector x (pixels) position. The spread of events in the horizontal direction is due to the spacecraft dither and corresponds to 40 arcsec on the sky, and approximately 2mm in detector space. The triangles mark the measured centroids of the line events when divided into bins in the x direction. The “wobble” in the line centroid as a function of detector x is caused by imaging non-linearities in the detector that can amount to several hundredths of an Ångstrom.

While absolved from causing systematic errors in the dispersion relation, the HRC-S detector was strongly suspected as the cause of small-scale non-linearities. While no hints of non-linearities were found in XRCF or pre-flight laboratory tests, such effects were seen soon after launch in the spectra of coronal sources with narrow spectral lines. Study during the ensuing year or two concentrated on attempting to quantify the effects—very difficult for the majority of the LETG+HRC-S range because of a lack of very bright sources at longer wavelengths with bright spectral lines—which turned out to be more widespread on the detector than previously thought. See Figures 9 and 10 in the HRC section for examples of our analysis. An example is illustrated in Figure 16, where the computed wavelengths for photon events for the bright O VIII Ly α doublet in the spectrum of Capella are shown as a function of detector x (dispersion axis) position. The spread in detector x is caused by the component of spacecraft dither along the axis of dispersion. If the detector were behaving perfectly linearly, all the events should fall along a straight line. Instead, significant “wobble” is seen. Methods for correcting for this effect are being investigated and mapping of the distortions is ongoing. Observers need to be aware that such effects can shift the apparent wavelengths of spectral lines by a few hundredths of an Angstrom from their true positions, and that spectral line widths can be larger than predicted by raytrace and other “ideal” models of the instrument response.

HRC-S or ACIS-S for Cycle 5?

The accumulation of a contaminating layer on the ACIS instrument that reduces its effective quantum efficiency at longer wavelengths (≥ 12 Å) is an important issue to consider when choosing a detector for cycle 5 LETG proposals. Proposers are encouraged to consult the POG to see comparisons of effective areas for both LETG+HRC-S and LETG+ACIS-S combinations. The HRC-S currently offers a significantly larger effective area for wavelengths ≥ 20Å (≤ 0.6 keV) or so.

Observer and proposer information and news on the performance of the Chandra LETGS can be found on the instruments and calibration page:
http://cxc.harvard.edu/cal/Links/Letg/User/
Calibration Workshop Presentations are at:
http://cxc.harvard.edu/ccw/proceedings/index.html#grating
Including a discussion of higher order diffraction efficiencies at:
http://cxc.harvard.edu/ccw/proceedings/presentations/bradw/letg/index.html

Jeremy Drake, for the LETG Team

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://wave.xray.mpe.mpg.de/axaf/
LETG: SRON:	http://www.sron.nl/missions/Chandra/
MARX simulator:	http://space.mit.edu/ASC/MARX/
MSFC: Project Science:	http://wwwastro.msfc.nasa.gov/xray/axafps.html

THE CHANDRA CALIBRATION PROGRAM

The present calibration of the Chandra Observatory is indebted to the work of many teams of scientists, engineers, and computer specialists within the Chandra project who have analyzed vast amounts of data over the past decade. Chandra calibration began many years before launch with the development, assembly, and testing of the individual scientific instruments. Commencing in December 1996, and continuing for 6 months, the assembled components of the Chandra Observatory (i.e., mirrors, gratings, and detectors) were extensively calibrated at the X-Ray Calibration Facility (XRCF) at MSFC, (see Newsletters #3, #4, #5, and #6 for discussions of prelaunch calibration). Ground testing is essential for absolute calibration, since only on the ground can we measure with certainty the flux and spectra of the incident radiation on the telescope.

There are, however, some characteristics of the observatory that can only be measured in-flight. For example, the X-ray source at XRCF was located 1700 feet from the mirrors. In-flight, the sources are essentially at infinity and the focal length is about 7 inches shorter. During the Orbital Activation and Calibration phase (OAC), which spanned the first three months after launch, the health of the instruments was checked along with measurements of many critical elements that could only be measured in-flight. Determining the focal point of the four onboard detectors was one of the first tasks completed after launch. The shorter focal length also necessitated in-flight measurements of the detector plate scales. In addition, the optical axis of the mirrors had to be located since the instruments were not assembled in the spacecraft in exactly the same manner as they were in the vacuum chamber at the XRCF.

During OAC we also established the framework for our monitoring program of the Chandra Observatory. We established a set of standard X-ray candles that we have periodically observed since launch. In addition to monitoring the Chandra instruments, these candles have helped cross calibration efforts with other X-ray observatories, in particular XMM-Newton. While there have been some deletions and additions to our yearly calibration plans, our set of standard candles has remained intact. The two most significant adjustments to our plan resulted from the radiation damage incurred by the front illuminated CCDs shortly after launch and the build-up of contamination on ACIS. In addition to observing cosmic sources, ACIS acquires data from its internal "55Fe" calibration source before and after every radiation belt passage. These data have been very helpful in monitoring the charge transfer inefficiency (CTI) of the CCDs, but the 55Fe source does not produce spectral lines below 1.5 keV. To monitor the ACIS gain at lower energies, we perform a raster scan of the oxygen rich supernova remnant E0102-72 every 6 months. Starting last spring, we added grating observations of PKS2155-304 at six month intervals to monitor the build-up of the contaminant on ACIS and determine its chemical composition.

The table below lists the targets we have repeatedly observed throughout the Chandra mission and the primary objectives of these observations. All calibration observations are immediately ingested into the public archive. These observations can be a valuable asset to observers in the analysis of their own Chandra observations.

Larry David, for the Chandra Calibration Team

Calibration Targets

Target	Detector	Objectives
Cas A	ACIS and HRC	Monitor the gain and spectral resolution of the CCDs. Monitor the QE and QE uniformity of the HRC. Cross-calibration between the focal plane detectors.
G21.5-09	ACIS and HRC	Monitor the QE and QE uniformity of the detectors. Cross-calibration between the focal plane detectors and other X-ray telescopes.
E0102-72	ACIS	Measure the effects of increasing CTI on gain and spectral resolution. Monitor the degradation in low energy QE.
HZ43	LETG/HRC-I LETG/HRC-S	Monitor the HRC-I low energy QE and the throughput of LETG/HRC-S at low energies.
Coma	HRC-I	Monitor the QE, QE uniformity and degap map.
AR Lac	HRC	Measure small scale gain variations across the detectors.
Betelgeuse Vega	ACIS, HRC	Monitor the optical/UV transmission of the detector filters.
Capella	LETG/HRC-S HETG/ACIS-S	Monitor the gratings dispersion relation and LSF.
PKS2155-304	LETG/ACIS-S HETG/ACIS-S LETG/HRC-S	Cross-calibration. Monitor the build-up of contaminant on ACIS and the HRC-S QE uniformity.
3C273	LETG/ACIS-S HETG/ACIS-S	Cross-calibration and monitoring the low energy absorption on ACIS.

Newly Updated and Searchable Guide Star Catalog for Chandra

The AXAF (Chandra) Guide and Acquisition Star Catalog (AGASC) has recently been updated to include the best available positions, proper motions and colors for stars across the sky for use by Chandra's Aspect Camera Assembly (ACA). The new AGASC 1.5 also includes information on how well isolated each star is, to facilitate a high acquisition rate. The updated catalog can also now be searched on the web:

http://cxc.harvard.edu/agasc

The ACA (Ball Aerospace & Technologies Corp) is a 4-inch defocused telescope with 5" pixels and a 2 deg field of view, which provides about 0.1" centroids for single stars down to a magnitude of ≤ 10.2 in its own red (unfiltered CCD) bandpass. Chandra observations typically use up to 8 acquisition stars and 5 guide stars for every pointing. After the data reach the ground, the guide star observations are used for aspect reconstruction – to assemble the dithered X-ray events into a final high spatial resolution X-ray image. If the ACA magnitude estimates in AGASC are good, a high fraction of stars are acquired. If the star positions in the AGASC are accurate, the spatial resolution and astrometric accuracy of reconstructed X-ray images are optimized. With the latest updates to the AGASC, more than 95% of stars are acquired, and the aspect reconstruction achieves excellent (< 1") relative and absolute astrometry. For most Chandra observers, the full thread of acquisition and guide star selection and aspect reconstruction is completely transparent, and the full aspect solution is provided by the CXC as a standard data product.

The AGASC was originally based on the Hubble Space Telescope Guide Star Catalog v1.1, containing 19 million stars. In 2002 the Chandra X-ray Center (CXC) completed a major upgrade of AGASC. We merged data from three catalogs---Tycho-2, GSC-ACT, and 2MASS. The Tycho-2 data substantially improve the photometric and astrometric measurements of stars as faint as V=12. The GSC-ACT data merge decreases by about half the systematic astrometric errors down to the catalog limit of about V=14.5. The 2MASS data identify 41855 galaxies down to J=12.5. All these new data enhance the value of AGASC for scientific as well as operational purposes.

Specifically for Chandra's operational use of AGASC, we recalibrated the estimated ACA magnitudes based on Chandra on-orbit measurements, and implemented a more sophisticated calculation of the effect of nearby stars on the best-fit centroid of a guide star. We also flag any known multiple or variable stars, as well as those within $3r_{20}$ of a 2MASS galaxy. (r_{20} is the K-band 20 mag/arcsec^2 isophotal elliptical radius in arcseconds.)

AGASC 1.5 currently represents the only available catalog that *combines* high quality astrometry on the ICRS system down to 14.5 mag with detailed color and proper motion information down to about 12th. In addition, a unique feature are the "spoiler codes" that indicate the likely perturbation any stellar centroid might suffer from nearby objects. These properties make AGASC1.5 a potentially important catalog for guide star selection for other space- and ground-based telescopes (e.g., for telescope guiding or Adaptive Optics). AGASC1.5 should also prove useful for a variety of scientific purposes. More information about the catalog, its constituents and construction are available on the web.

Paul Green and Dennis Schmidt

Lies, True Lies, and AstroStatistics

Since infancy (or the first year of grad school, whichever comes first), astronomers are taught one basic rule: "If it takes statistics to prove it, you can't believe it". A laudable attitude, wisdom distilled and passed along from advisor to student over the generations, and one guaranteed to ensure that referees don't snicker at your manuscripts. On the other hand, the same capricious referee will refuse to let you publish a result if you don't put an error bar around it. And nowadays, in these trying times when we don't live in the Gaussian regime, it is all too easy to put the wrong error bar on a critical result. Life isn't fair (±0.314?). We have all experienced those sources at the edge of detectability, jets that look like fluctuations, spectral lines that *ought* to be there, pulsing signals that are clearly evident to the naked eye and yet remain tantalizingly consistent with zero; and conversely, absorption features that turn out to be Poisson fluctuations, and abundance anomalies due to a misplaced continuum, and so on, and so forth. Now, Chandra data are pushing the envelope on how far astronomers can go without having to care about the underlying statistics. We can no longer turn the crank on that black box and afford to blindly trust the results that pop out.

In an effort to coherently address these issues, the CXC has established a collaboration with the Statistics Department at Harvard University, led by David van Dyk (Harvard University) and Aneta Siemiginowska (CXC)1. The AstroStatistics Working group maintains a WWW site that contains details of the group's activities, including preprints and journal articles2.

It took a while for us to get past: (1) the language difficulties: *"λ ... umm.. you mean wavelength?" ``NO! That is the Poisson model intensity!*"; (2) the horror of the statisticians at how the Typical Astronomer wields the statistical axe: a search through ApJ's of the past 5 years revealed that the vast majority of the 170-odd papers that used the F-test for model comparison did so improperly, inappropriately, incorrectly, or to put it another way, erroneously (see Protassov et al. 2002, ApJ, 571, 545); (3) and the obstinacy of the astronomers looking for a quick fix: *``Why can't we use the $\chi^2$? It worked fine yesterday!" and ``Takes 5 minutes to run that program? -- That is NO GOOD. Should run in 5 seconds. 10, tops!"*. The collaboration is now working smoothly, dealing with problems ranging from spectral fitting in the low-counts case to handling pileup in

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1 Other members of the AstroStat Working Group include Alanna Connors (Wellesley), Peter Freeman (CXC), Vinay Kashyap (CXC), Andreas Zezas (SAO), Margarita Karovska (CXC), Eric Kolaczyk (Boston University), and numerous grad and undergrad students at Harvard University: Rostislav Protassov, David Esch, Yaming Yu, Hosung Kang, Epaminondas Sourlas, et al.

2 http://www.people.fas.harvard.edu/~vandyk/astrostat.html

intense sources, to image deconvolution (with error-bars), as well as incorporating atomic data errors in spectral fitting, modeling log(N)-log(S) curves at very low sensitivities, etc.

Recently, we organized a workshop on Current Challenges in Multi-Scale Analysis on Jan 15-16, 2003 at Cambridge, MA, following up on a similar themed Special Session at AAS 201 (Principled ``Model Free Deconvolution" via Multi-scale Methods). This event was sparked by an unusual confluence: the AAS speakers, their collaborators, and local multi-scale and deconvolution experts from several disciplines were in the Boston area following the AAS and we took this opportunity to have two days of in-depth talks by key speakers, commentaries by visiting experts, and discussions by all. The goals of the workshop included:

- Presenting the cutting edge of Poisson ``deconvolution" techniques using new multi-scale methods;
- Hammering out the current understandings, problems, and future challenges for Poisson multi-scale methods across astronomy, medicine, engineering, and statistics;
- Drafting a list of questions, practical problems, challenges and new successes;
- Providing a "gateway" for researchers new to these methods;
- Laying the groundwork for new collaborations and new lines of research; and
- Reporting back to the wider astronomical community.

About 50 participants ranging from students to seasoned researchers attended the workshop. The talks were intended to present the analysis challenges from both the astronomers' and statisticians' perspectives. We heard about the challenges in the current X-ray data analysis (e.g., Chandra, XMM-Newton, Integral and TRACE) and those expected in future missions (e.g., GLAST, SPIDR, STEREO). The Statistics talks were related to the details of the multi-scale methods (wavelet techniques, multi-scale factorization including Bayesian Blocks, platelets and multi-scale geometric analysis) with immediate applications to the X-ray data. There was plenty of time for questions and discussions and the participants had a chance to ask their favorite questions, which they did in great abundance. Overall, the workshop was a good experience for all of the participants and we hope that it started a few future collaborations. We plan to make the workshop presentations available online.

Vinay Kashyap & Aneta Siemiginowska

HelpDesk

Questions can be sent to the CXC by using the HelpDesk facility. The HelpDesk is reached from a link on the header of the CXC web pages (i.e., at http://cxc.harvard.edu). The information entered into the form is passed into our HelpDesk Archive; we can easily track pending items with this tool. An introduction to the HelpDesk system is available from this same link. Questions can also be sent to the HelpDesk staff using email (cxchelp@head-cfa.harvard.edu), but we prefer submissions through the web.

THE CHANDRA CALIBRATION WORKSHOP

October 28-29, 2002

Discussing the bleeding edge of calibration of an instrument, although a necessarily messy proposition, is potentially useful in order to determine if the oddity in your data is an astrophysically interesting phenomenon or just an instrumental artifact. To this end, a diverse group of 85 participants spanning a wide range of representation both "inside" and "outside" of the Chandra project gathered last November in Cambridge to discuss the state of the art in the calibration of Chandra.

For two days, the audiences were regaled with detailed discussions about FEF's, QEU's and other esoterica related to all elements of the observatory. The emphasis was a frank discussion of not only what is known, but also what was still in need of attention. Those who attended seemed enthusiastically pleased with the event and what they learned from it. In order to preserve and propagate the information discussed at the workshop, the presentations, both oral and poster, can be found online at the workshop website: http://cxc.harvard.edu/ccw/proceedings/index.html. These have been further augmented by including (much) of the question and answer period following each oral talk.

We are currently in the early planning stages for the next workshop, which will be held October 27 and 28 somewhere in the Cambridge/Boston area. Please keep your eye on our site: http://cxc.harvard.edu/ccw, as well as the International Meetings website: http://cadcwww.dao.nrc.ca/meetings/meetings.html for more updates. The meeting will again be open to the entire astronomical community and we are especially keen to have even more Chandra users in attendance. See you this fall!

Hank Donnelly

CHANDRA-RELATED MEETINGS PLANNED FOR THE NEXT YEAR

Keep an eye on the Chandra Webpage:
http://cxc.harvard.edu for further information

X-ray Astronomy School	May 12-16, 2003	Wallops Island, VA
Four Years of Chandra Observations: A Tribute to Riccardo Giacconi	Sept 16-18, 2003	Huntsville, AL
CIAO Workshop	Sept. 2003	CfA
Chandra Fellows Symposium	Oct. 2003	CfA
Calibration Workshop	Oct. 27-28, 2003	CfA

CXC 2002 Science Press Releases

See http://chandra.harvard.edu/press/press_release.html for details

Date	PI	Objects	Title
18 Dec 02	Wolk	RCW 38	Young Star Cluster Found Aglow with Mysterious X-Ray Cloud
10 Dec 02	Migliari	SS 433	Chandra Reveals Pileup on Cosmic Speedway
19 Nov 02	Komossa	NGC 6240	Never Before Seen: Two Supermassive Black Holes in Same Galaxy
22 Oct 02	Buote	NGC 720	Dark Matter Reality Check: Chandra Casts Cloud on Alternative Theory
03 Oct 02	Corbel Tomsick Kaaret	XTE J1550-564	From Cradle to Grave: Chandra Discovers the History of Black Hole X-Ray Jets
19 Sep 02	Martini	Abell 2104	Chandra Finds Surprising Black Hole Activity in Galaxy Cluster
07 Aug 02	Karovska	Centaurus A	X-ray Arcs Tell the Tale of Giant Eruption
31 Jul 02	Nicastro, Canizares Mathur Bregman	PKS 2155-304 H1821+643 NGC 891	Chandra Discovers Rivers of Gravity that Define Cosmic Landscape
23 Jul 02	Martin	NGC 1569	Dwarf Galaxy Gives Universe a Breath of Fresh Oxygen
25 Jun 02	Lu	SNR G54.1+0.	Energetic Ring Shows Way to Discovery of Pulsar Bulls-Eye
06 Jun 02	Pavlov	1E 1207.4-5209	Astronomers Use X-Rays to Probe Gravitational Field of a Neutron Star
04 Jun 02	Sarazin	NGC 4697 NGC 4649 NGC 1553	Black Holes in Distant Galaxies Point to Wild Youth
19 Apr 02	Clements	Arp 220	When Worlds Collide: Chandra Observes Titanic Merger
10 Apr 02	Drake Helfand	RX J1856.5-3754 3C58	Cosmic X-rays Reveal Evidence for New Form of Matter
28 Mar 02	Brandt Mathur Bechtold	SDSS 1306+0356 0836+0054 1030+0524	Chandra Finds Well-Established Black Holes in Distant Quasars
13 Mar 02	Green	Q2345+007 A, B	Twin Quasars Tango and it's No Mirage
27 Feb 02	Gladstone	Jupiter	Jupiter Hot Spot Makes Trouble for Theory
06 Feb 02	Siemiginowska Bechtold	PKS 1127-145	Chandra Scores a Double Bonus with a Distant Quasar
09 Jan 02	Wang	Galactic Center	Chandra Takes in the Bright Lights, Big City of the Milky Way
08 Jan 02	McNamara	Abell 2597	Chandra Finds Ghosts of Eruption in Galaxy Cluster

Megan Watzke

X-RAY BINARIES IN THE CHANDRA AND XMM-NEWTON ERA (WITH AN EMPHASIS ON TARGETS OF OPPORTUNITY)

Nov. 14-15, 2002

On Nov 14 and 15 2002, the CXC sponsored a workshop on X-ray Binaries, with ‘an Emphasis on Targets of Opportunity’. The workshop was initially conceived as a small (~50 people) local workshop, but quickly grew to ~100 attendees from all over the world. One of the main aims of the workshop was to focus discussion on how to obtain the best science from the limited number of TOO observations possible with Chandra. To that end, the results of past Chandra and XMM TOO observations of XRB were presented, and the opportunities for future observations with these (and other) observatories were discussed.

The proceedings of the workshop, in the form of the viewgraphs from the talks and posters, are being published on the CXC web site and ingested into ADS. See: “http://cxc.harvard.edu/xrbconf/proceedings.html” for the contributions.

Michael Garcia

HIGH ENERGY ASTROPHYSICS DATA CENTERS COORDINATION (HEADCC) MEETING

November 13, 2002

The HEADCC meeting took place in Cambridge on November 13, 2002, under the auspices of the CXC. Participants included representatives of the CXC, SAO, the HEASARC, the XMM-Newton European Data Center, Leicester University, the Japanese ISAS, and other interested astronomers.

The purpose of this meeting was to look at our different software systems, identify areas of collaboration, identify areas of similar efforts that could be merged or streamlined, and set priorities for future collaborations. Representatives of the Data Centers each gave a brief status of their projects:

Bill Pence (HEASARC) reported on the HEADAS software, including new FTOOLS, CALDB and CFITSIO developments.

Martin Elvis (CXC) presented news on CIAO updates and plans for CIAO 3.0, which will include S-Lang access to tools, giving CIAO a programable/scriptable capability; also discussed were the release of ChaRT (a GUI interface to the Chandra raytrace software), Webguide (a web interface to the APED/APEC atomic transition database, that allows the user identification of spectral lines), and significant upgrades in documentation.

Fred Jansen (XMM-Newton) discussed the status of the SAS software, which produces calibrated processed data, on which any other software tool may be used. The upcoming Version 6 will fix some keyword problems, as well as introducing missing functionality and GUIs.

Plans for new missions included Astro-E2, discussed by Koji Mukai (at NASA-GCFC) and Dr. Ueda (ISAS); Swift (Alan Smale, GSFC); GLAST (David Band, GSFC), and INTEGRAL (Ken Ebisawa, GSFC). The need for working towards inter-operability with FTOOLS and CIAO was discussed.

Bill Joye (SAO) presented new developments in the DS9 visualizer, which now includes support for the Virtual Observatory, allowing analysis of data on a remote site, and full WCS (World Coordinate System) support.

These presentations were followed by group discussions on selected topics. The aim of these discussions was to highlight the path towards a more complete inter-operability of the various data analysis tools.

The discussion of FITS conventions was led by Jonathan McDowell (CXC). By making the keywords of data products from different observatories mutually compatible, different data sets will be accessible by a wider range of software. This work is a data model effort for the high energy astrophysics data, and fits in well with the effort of the astrophysical community towards a more general seamless access to different data archives (the Virtual Observatory). The action was assigned to Jonathan to lead a pilot effort using Chandra and XMM data and software.

Keith Arnaud (HEASARC) led the discussion of the need to standardize the conventions for regions files, and Bill Pence (HEASARC) addressed issues of software compatibility. A more seamless interplay between FTOOLS and CIAO was advocated and will be pursued.

A discussion of the Calibration Data (Mike Corcoran, HEASARC; Dale Graessle, CXC) identified the need for an extension of the CALDB system to accommodate the complexity of the Chandra data. Work has already begun to resolve this need.

The meeting was concluded with a discussion of image display and line graphics programs, and it was concluded that DS9 should be extended towards a fuller support of line graphics.

This was a very fruitful meeting and we look forward to the improvements in our capability of handling data from different missions within a similar user environment.

Giuseppina Fabbiano

IMPORTANT DATES

Next Users’ Committee Meeting	June, 2003
Guest Observer Proposals Due Cycle 5	March 14, 2003 7 pm EST
Peer Review Cycle 5	June 24-26, 2003
Chandra Cycle 4 Ends	~ November, 2003
Call for Proposals Cycle 6	~ December, 2003

CIAO "WHY? TOPICS" AND "ANALYSIS GUIDES": A DEEPER AND WIDER PERSPECTIVE

Since the release of CIAO 2.0 in December 2000, the primary goal of the documentation team has been to create new analysis threads. Each thread is a step-by-step "recipe" that illustrates how to perform tasks common to analyzing Chandra data. They cover a wide range of abilities, from beginner (e.g. how to create datamodel filters) to advanced (e.g. calculating k-corrections using S-Lang and Sherpa).

There are currently over 100 threads available from the CIAO web pages (106 at the writing of this article). The threads simply show how to perform a certain task, often without explaining why it is important or where it falls into the larger analysis session. To address these issues we are working on building inter-connected web pages. Two new types of documents have been created: *analysis guides* and *why? topics.*

Looking at the large amount of documentation online, it can be difficult for a new CIAO user (or even an experienced one!) to know where to start. The analysis guides serve as a "roadmap" through the threads. Each guide takes a certain instrument configuration (e.g. ACIS) or type of analysis (e.g. extended sources) and lists the relevant threads. Along with the listing is a brief explanation of the purpose of each task, as well as the specific order in which they should be run, if any. The goal is to help the user to complete the analysis without requiring that every CIAO thread be read. Three analysis guides are now available, and several more are planned for the near future.

On the other hand, the threads sometimes do not contain enough information for the scientist interested in the details. Just as the analysis guides create a layer above the threads, the why? topics are intended to dig deeper. Some of the topics describe aspects of the Chandra Observatory and data obtained with it, while others provide information on why certain science decisions are made.

There are six why? topics online at the moment and over a dozen more have been requested.

All of this information combined - the guides, threads, and why? topics - enable the user to tailor the analysis to a particular dataset or scientific goal.

At present, the analysis guides and why? topics are largely available only from their respective index pages. The infrastructure of the threads is being modified and improved for the CIAO 3.0 release (scheduled for Summer 2003) to incorporate all of these references. At that time, there will also be a major effort to include links to relevant Proposers' Observatory Guide sections from the threads.

The documentation team is always interested to receive feedback from the users on what information is particularly useful and which areas are lacking. We encourage you to send comments and suggestions for improvement via the CXC Helpdesk.

Related online references:

The main CIAO webpage
http://cxc.harvard.edu/ciao/
http://ledas-cxc.star.le.ac.uk/ciao/ (UK mirror site)

Threads
http://cxc.harvard.edu/ciao/threads/

Analysis guides
http://cxc.harvard.edu/ciao/guides/

Why? topics
http://cxc.harvard.edu/ciao/why/

Please send questions and comments on CIAO and the documentation to the CXC Helpdesk
http://cxc.harvard.edu/helpdesk/

Elizabeth Galle and Antonella Fruscione, for the CIAO documentation team

SIMULATING CHANDRA PSFS WITH CHART

ChaRT (Chandra Ray Tracer) is a user-friendly web interface that allows the user to simulate High Resolution Mirror Assembly (HRMA) Point Spread Functions (PSFs) at any off-axis angle and for any energy or spectrum. Realistic PSFs including instrument effects can be simulated using the ChaRT ray files as an input in MARX (Wise *et al.* 1997).

ChaRT can be accessed from the following web page:
http://cxc.harvard.edu/chart/.

Chandra produces sharper images than any other X-ray telescope to date and therefore provides an opportunity for high-angular and spectral resolution studies of X-ray sources. Crucial to these studies is the knowledge of the characteristics of the PSF. The blurring of the Chandra images is introduced by the HRMA PSF, the aspect solution, the limited size of detector pixels and detector effects. Simulating the HRMA PSF is the first and most important step in obtaining a good model of the Chandra PSF for a given observation. The shape and size of the HRMA PSFs vary significantly with source location in the telescope field of view, as well as with the spectral energy distribution of the source. Therefore, in order to carry out spatial analysis of *Chandra* data, each PSF must be simulated individually.

Until recently, the HRMA PSF models were available via standard PSF library files consisting of 2-D simulated monochromatic PSF images, "postage stamps" (Karovska *et al.* 2000). These PSF images were made only for 5 monochromatic energies (ranging from 0.277 keV to 8.6 keV). They are stored in multi-dimensional FITS hypercubes with azimuth and elevation steps of either 1 arcminute or 5 arcminutes. The usage of the standard PSFs libraries for a detailed spatial/spectral analysis has limitations including interpolation over the coarse energy and spatial grids (especially for large off-axis angles), fixed number of photons and energies, and lack of instrument (detector) effects.

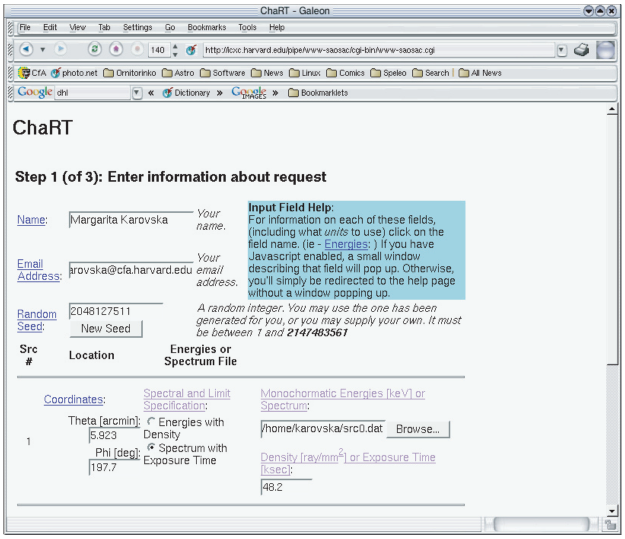
ChaRT provides the user with access to the best available mirror model, including many of the details of the HRMA's physical construction and a detailed model of the reflective properties of the mirror surface. ChaRT software runs remotely the *SAOsac* set of routines (used internally at the CXC for studies and calibration of the HRMA optics, see Jerius *at al* 1995). The software verifies and submits the user's simulation parameters and notifies the user when his/her files are available to download via FTP. More details about the software and imlementation are available in Carter *et al.* 2003.

The output of ChaRT is a FITS table containing a collection of rays. In order to create a model PSF image, it is necessary to project the rays onto the detector and take account of detector effects. The output from ChaRT can be fed through the MARX software package (http://space.mit.edu/CXC/MARX/) that contains detailed models for the focal plane geometries of the various Chandra detectors. Standard CXC FITS files can be created from the output for subsequent processing with *CIAO* or other software.

A set of ChaRT threads were designed to guide the user and can be accessed from the ChaRT page: http://cxc.harvard.edu/chart/threads.

With the combination of ChaRT and MARX, users may easily perform detailed simulations of the Chandra PSFs. However, ChaRT and MARX have their limitations of which users should remain aware. The ChaRT web pages describe these limitations and caveats in detail.

Margarita Karovska and the ChaRT Team



http://cxc.harvard.edu/pipe/www-saosac/cgi-bin/www-saosac.cgi

ChaRT

Step 1 (of 3): Enter information about request

Name: Margarita Karovska *Your name.*

Email Address: arovska@cfa.harvard.edu *Your email address.*

Input Field Help: For information on each of these fields, (including what *units* to use) click on the field name. (ie - Energies:) If you have Javascript enabled, a small window describing that field will pop up. Otherwise, you'll simply be redirected to the help page without a window popping up.

Random Seed: 2048127511 *A random integer. You may use the one has been generated for you, or you may supply your own. It must be between 1 and* ***2147483561***

Src #	Location	Energies or Spectrum File	
	Coordinates:	Spectral and Limit Specification:	Monochormatic Energies [keV] or Spectrum:
1	Theta [arcmin]: 5.923 Phi [deg]: 197.7	○ Energies with Density ● Spectrum with Exposure Time	/home/karovska/src0.dat Density [ray/mm^2] or Exposure Time [ksec]: 48.2

Figure 17: The sample web page shows an example of a ChaRT parameter interface for a simulation of a PSF at 6 arcminutes off-axis with a spectrum file provided by the user. The off-axis location in the sample web input page is Theta=5.923 arcminutes, Phi=197.7 degrees. The exposure time is 48.2 ksec. and an ascii spectrum file src0.dat, (output from Sherpa), was provided by the user.

References

Carter *et al.* 2003, in in ASP Conf. Ser., ADASS XII in press.

Jerius, D. *et al.* 1995, in ASP Conf. Ser. Vol. 77, ADASS IV, ed. R.A. Shaw, H. E. Payne, & J.J.E. Hayes (San Francisco: ASP)

Karovska, *M. et al.* 2000, in ASP Conf. Ser. Vol. 238, ADASS X, eds. F.R. Harnden, Jr., F.A. Primini, & H.E. Payne (San Francisco: ASP)

Wise, M. *et al.* 1997, in ASP Conf. Ser. Vol. 125, ADASS VI, eds. G. Hunt & H.E. Payne (San Francisco: ASP)

THE CHANDRA ARCHIVE: WEBCHASER

The CXC has released a new version of the web search and retrieval interface to the Chandra Data Archive, known as WebChaSeR.

The URL has remained the same and it is linked to the same pages as before, e.g., the CDA home page:
http://cxc.harvard.edu/cda/.

There are a large number of improvements and new features - more (and more flexible) search options and access to much detailed information about observations, including quick-look images and literature links. As such, it includes a number of features that used to be only available in ChaSeR, the application. WebChaSeR downloads are still restricted to primary and/or secondary data products packages.

Please give it a try; it is not the old WebChaSeR that you knew!

WebChaSeR does allow downloading of proprietary data, using authorized archive accounts. The account information, for PI accounts as well as proposal accounts, was e-mailed in December to AO-4 PIs.

Arnold Rots, CDA Operations

CHANDRA FELLOWS FOR 2003

The Chandra Fellows for 2003 have just been announced. Keep an eye on our web pages for information about the Chandra Fellows Symposium (October, 2003), and the annual Fellowship competition (November, 2003).

2003 CHANDRA FELLOWS

Name	PhD Institution	Host Institution
Taotao Fang	MIT	Berkeley
Sebastian Heinz	Colorado	MIT
Peter Jonker	Amsterdam	CfA
Enrico Ramirez-Ruiz	Cambridge	Inst. for Advanced Study
Mateusz Ruszkowski	Cambridge	Colorado

Nancy Remage Evans

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
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Systems Engineering:	Jeff Holmes	Science Data Systems:	Martin Elvis
Data Systems:	Pepi Fabbiano	Director's Office:	Fred Seward and Belinda Wilkes
Education & Outreach:	Kathy Lestition	Media Relations:	Megan Watzke

Note: E-mail address is usually of the form: <first-initial-lastname>@cxc.harvard.edu
(addresses you may already know for nodes head-cfa.harvard.edu or cfa.harvard.edu should work also)

EDUCATION AND PUBLIC OUTREACH

Cycle 4 Peer Review

The Cycle 4 Chandra Education and Public Outreach (EPO) Peer Review, conducted jointly by NASA and CXC, was held in Cambridge MA on Oct. 23-24, 2002. A seven-member panel representing science, education, museum, Forum, NASA mission and NASA management perspectives reviewed 19 proposals. Twelve individual PI proposals and 7 institutional proposals were submitted, a record for Chandra EPO (Education and Public Outreach) submissions. The overall quality of the proposals was high, which made the selection process quite competitive. Four individual proposals and three institutional proposals were selected for funding. A list of the selected PI's and institutions follows. Additional summary information about each selected proposal can be found on the Chandra EPO web site at:

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

Individual PI Proposals

- **Bright Lights Big City: Massive Galaxies & Supermassive Black Holes**
  Science PI: Dr. Wil van Breugel, Lawrence Livermore Lab
  Education PI: Stan Hitomi, Exec. Dir., Edward Teller Education Center
  Education Partners: Edward Teller Education Center, Science & Technology Education Program (STEP)
  Contact: Stan Hitomi, hitomi@llnl.gov

- **A Star in Our Neighborhood**
  Science PI: Prof. Joseph P. Cassinelli, Univ. of Wisconsin
  Education Co-I: Dr. Jim Lattis, U. Wisconsin Space Place
  Education Partner: U. Wisconsin Space Place
  Contact: James Lattis, lattis@sal.wisc.edu

- **The Chandra Student Research Program at the Pisgah Astronomical Instititue**
  Science Co-I/EPO PI: Dr. Jonathan Keohane, North Carolina School of Science & Mathematics
  Education Partner: Pisgah Astronomical Research Institute
  Contact: Jonathan Keohane, keohane@ncssm.edu

- **Black Holes, Seeing the Unseeable: A Planetarium Show at the Science Museum of Virginia**
  Science PI: Prof. Craig Sarazin, University of Virginia
  Education Co-I: Dr. Edward Murphy
  Education Partner: Science Museum of Virginia
  Contact: Edward Murphy, emurphy@virginia.edu

Institutional Proposals

- **Gear Up and Look Up with Chandra**
  Institutional PI: Prof. Deepto Chakbaraty, MIT
  EPO Co-I: Dr. Irene Porro
  Education Partners: GEAR UP in Boston, Boston Museum of Science
  Contact: Irene Porro, iporro@space.mit.edu

- **Creating Agents for Science**
  Institutional PI: Dr. Ronald Elsner, NASA/Marshall Space Flight Center
  EPO Co-I: Mitzi Adams, MSFC
  Education Partners: U. of AL, Huntsville, Institute of Science Education (ISEd),
  Huntsville Housing Authority Cultural Art Conservancy,
  Huntsville Weed and Seed (US Dept. of Justice),
  Chandra X-ray Center (CXC)
  Contact: Mitzi Adams, mitzi.adams@msfc.nasa.gov

- **New and Improved: the Future of the Penn State Inservice Workshops in Astronomy**
  Institutional PI: Dr. Eric Feigelson, Pennsylvania State University
  EPO Co-I: Dr. Christopher Palma
  Contact: Christopher Palma, cpalma@astro.psu.edu

Cycle 5 EPO and Peer Review

The CXC has responsibility for issuing the Call for Proposals (CfP) for EPO proposals as well as organizing and carrying out the Peer Review. PIs interested in submitting EPO proposals should read the EPO section of the Cycle 5 CfP. Supplementary EPO proposals may be submitted by PIs of selected science proposals who are US citizens. Additional information and specific links for proposal submission will be posted to the CXC proposer site at:

http://cxc.harvard.edu/proposer/.

Deadline for Cycle 5 EPO proposals is September 15, 2003

Note that the deadline for Cycle 5 EPO proposals has been decoupled from the due date of the science budget to enable EPO proposers to concentrate fully on their EPO submission.

CXC Education & Public Outreach Resources

- New! 8 new postcards showing a Chandra image with multi-wavelength comparisons. Selection includes CAS A, 30 Doradus, Cen A, M82, Eta Carinae, Crab Nebula, M51, and a collection (all in X-ray) of supernova remnants.

- See http://chandra.harvard.edu/edu/epo/epo_resources.html for an on-line order form to request printed outreach materials

- A reminder that we maintain an on-line resource section on chandra.harvard.edu that includes all Chandra images that have been released on our Press and Photo Album pages.

  We maintain multiple formats:
  - Printing & incorporation into digital/film products (http://chandra.harvard.edu/resources/images.html)
  - PowerPoint slides (ppt version) (http://chandra.harvard.edu/resources/ppt/index.html)
  - Printing as viewgraphs (PDF version) (http://chandra.harvard.edu/resources/ppt/index.html)
  - Basic PowerPoint presentations (http://chandra.harvard.edu/resources/pptshows/index.html)
  - Animations & video (http://chandra.harvard.edu/resources/animations)

We encourage you to use this section as a resource for talks and public presentations or to create other outreach materials.

Kathy Lestition

CHOOSING CHANDRA TARGETS

The following article is reprinted from the Chandra Chronicles (http://chandra.harvard.edu/chronicle/0103/peer_review/index.html). Editor

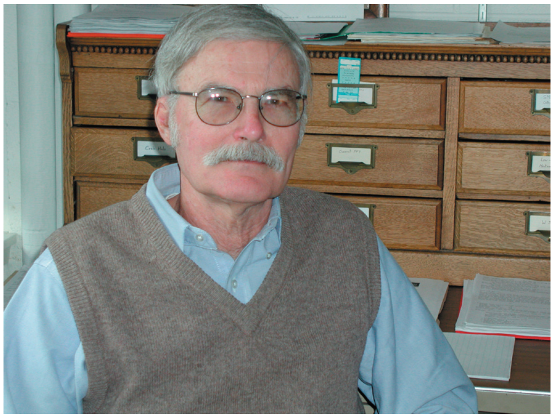

Figure 18: Fred Seward

Over the course of 3-and-a-half years, the Chandra X-ray Observatory has made more than a thousand observations of cosmic objects such as comets, planets, normal stars, neutron stars, black holes, supernova remnants, galaxies, and clusters of galaxies. A frequently asked question is: who decides what Chandra will observe? To answer that question we asked Dr. Fred Seward, Assistant Director of the Observatory, to describe the process.

Q: **How are the Chandra targets selected?**
Fred Seward (FS): Observing time is awarded through the proposal process. Since Chandra is a national facility, built and supported with taxpayer money, anyone can propose for time. All proposals are evaluated in the same way, under the same rules.

Q: **Can a proposal be made at any time, or is there a special time to submit the proposals?**
FS: There is a special time. Every year a call for new proposals goes out in mid-December. Proposers are allowed 3 months to write the proposals and the deadline for receipt is in mid-March - the Ides of March!

Q: **Who submits the proposals?**
FS: Scientists from all over the world. In the last proposal cycle, 71 percent were from the United States, followed by Japan and the United Kingdom with 7 percent each, Germany and Italy with 5 percent each and the remaining 5 percent spread among 15 other countries.

Q: **Is there some system or information available to aid proposers?**
FS: Yes. A Proposers' Guide gives information about the observatory and instruments and is available as hard copy or over the Internet. A catalog of past and planned observations is available with a search engine so proposers can know if particular objects have been observed or not. A program to calculate instrument count rates from target information can be used via a web interface. Detailed instructions for preparation of proposals are on the Internet. An observing proposal consists of target information, a detailed set of instrument settings, and a 4-page science justification.

Q: **Do scientists get their proposals in early, or do they procrastinate, like everyone else?**
FS: Considering that most proposers are experienced professional astronomers, and that the proposals can be submitted electronically using the Remote Proposal Submission software, the submission process is somewhat bizarre. We receive a total of about 800 proposals. Four hundred are sent during the last day of the 3-month submission period and about 100 during the last hour!

Q: **Who reviews the proposals?**
FS: Proposals are divided among 12 panels according to topics, for example, normal stars, supernova remnants, black holes, etc. Each review panel has 8 reviewers; so about 100 peer reviewers are needed. These reviewers are from universities and research institutions, large and small, US and foreign, and are all experts in some field of astronomy. Each reviewer must read the 60-70 proposals to be evaluated by his/her panel and is responsible for a detailed understanding of 20. This is a big job and reviewers are not compensated for their time. We are fortunate that so many talented people are willing to be reviewers. Every year the panels have worked diligently to select the most interesting observations and the results have been outstanding.

Q: **How long does the review process take?**
FS: About 3 months are needed for the CXC to process the proposals and to arrange a mid-June review. Reading proposals and attending the review take about 2 weeks of time, which reviewers are expected to donate to the general good of the scientific community. The review itself is conducted in a Boston hotel where the reviewers are confined for 2 days during which they discuss and grade all the proposals. On the third day, a merging panel meets to blend the results of the 12 topical panels and to evaluate proposals for very long observing times.

Q: **Are reviewers allowed to propose?**
FS: Yes, but they are not allowed to review their own proposals or those from others at their institution. Most reviewers have submitted proposals that have been placed in other panels. Reviewers are very conscientious about being fair and often leave the room when a proposal from a good friend (or enemy) is being considered.

Q: **What if two people propose to look at the same object?**
FS: If several high-ranking proposals include a common target, the peer review will recommend which proposal to accept. Reports are written to return to the proposers giving results of the review and, if a proposal is not accepted, reasons why it was not ranked higher.

Q: **It sounds like an exhaustive and exhausting process.**
FS: It is, but it doesn't end there for the CXC staff. They must check the results, understand and fix any discrepancies, and put the new targets, ranging from the nearest planets to the most-distant quasars, in the observing program. Then it is time to solicit cost proposals, arrange the cost proposal review, and, incidentally, start preparing for the next cycle! It takes half the time of six CXC staff members to plan and implement the process.

Q: **How many proposals were accepted?**
FS: In the last cycle, 239 proposals to look at more than 500 different targets were selected.

Q: **What was the most popular type of target?**
FS: Black holes, especially the supermassive black holes that reside in the centers of active galaxies and quasars were the most popular, but all categories were included.

Q: **What advice would you give to a proposer?**
FS: The goal of the observing program is to maximize the science resulting from Chandra observations. Observing proposals therefore must convince the reviewer that the result will be scientifically interesting. That is, it should add to our knowledge, answer a question, or determine parameters of a model. The proposal must show that Chandra's unique capability - for example its high spatial resolution - is necessary. It must also demonstrate that the observation is feasible - for example, that the source is expected to be strong enough to detect with the proposed observation. Remember that some reviewers will not be knowledgeable about all the details of your specialty. Part of the proposal should be written for a general audience. Start early! Follow instructions. If your project is not accepted, read the report, improve the proposal, and submit it again next year.

Wallace and Karen Tucker

NOBEL DAYS AND NIGHTS IN STOCKHOLM: FROM BLACK HOLES TO WHITE TIES

The following article is reprinted from the Chandra Chronicles (http://chandra.harvard.edu/chronicle/0103/nobel/index.html). Editor

January 6, 2003: In October 2002, we learned that Riccardo Giacconi had been awarded one half of the 2002 Nobel Prize for Physics for his pioneering work leading to the discovery of cosmic x-ray sources. Riccardo was cited for the detection of the first extra-solar x-ray source - Sco X-1 and the discovery of the all-sky x-ray background in a 1962 rocket flight. The Nobel press release also noted Riccardo's efforts to develop the first x-ray telescopes, so essential for the advancement of the field.

Each Nobel winner is permitted to invite fifteen official guests for the festivities in Stockholm, and I was very excited when Riccardo called me (in Dallas where I was visiting my children and grandsons Kyle and Jason) to ask if I would like to take a winter break in Stockholm. Since our family has traditionally traveled from Boston to Buffalo for the winter holidays, Stockholm was right up our alley.

There followed a series of e-mails with particulars about the various activities being arranged, including a detailed form to be completed in metric units to arrange for the formal (tails and white tie) garb required for the Awards Ceremony and Banquet. Lucky for me that I knew how many cm per inch and how many kg per pound - one never knows when all of that formal training in physics and math may be needed.

In addition to Riccardo's wife Mirella, his daughters Guia and Anna and their husbands Jonathan (Trutter) and Ed (Baize) and Riccardo's grandchildren Colburn (Colbe) and Alexandra (Nicki) represented the Giacconi family. Long

FIGURE 19: Grand Hotel, Stockholm

FIGURE 20: Rona and Harvey Tananbaum and Anna and Ed Baize (left to right) Anticipate Riccardo's Lecture

FIGURE 21: UHURU data for Her X-1, Cyg X-3, and Cyg X-1

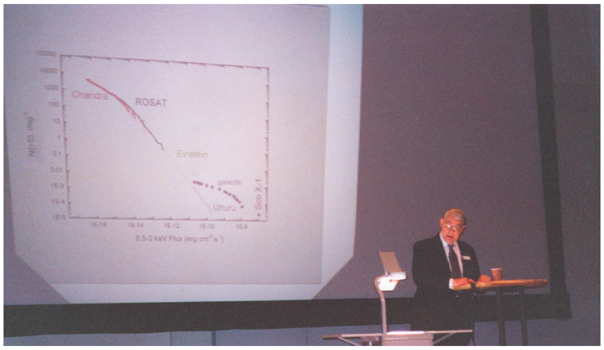

FIGURE 22: Graph showing increasing numbers of x-ray sources as one goes fainter and fainter with better telescopes.

time collaborators, Herb Gursky, Ethan Schreier, and myself, along with our wives Flora, Janet, and Rona, respectively, and Giacconi family friends Marvin and Joan Cornblath comprised the rest of Riccardo's guest list.

Herb Gursky had actually been at the test range and conducted the discovery rocket flight in 1962. Ethan and I had worked with Riccardo on UHURU (the first x-ray satellite) and Einstein (the first x-ray telescope for extra-solar studies), and Riccardo and I had written a 1976 proposal, which effectively began the Chandra program.

Riccardo left the Harvard-Smithsonian Center for Astrophysics in 1981 to become the first Director of the Hubble Space Telescope Science Institute, and subsequently served as Director General of the European Southern Observatory. He is now President of Associated Universities Inc.

Family and friends arrived in twos (and fours) in Stockholm with all of us staying at the magnificent Grand Hotel right on the water (Fig. 19). Stockholm is a series of islands surrounded by rivers and seas. Rona and I arrived in the afternoon on the 7th just in time to be transported to a reception hosted by the Royal Swedish Academy of Sciences at Stockholm University.

At the reception, we met Professors Per Olaf Lindblad and Bengt Guftafsson who were very excited over the fact that this year's Prize recognized work done in Astrophysics. The science staff at the University had downloaded information covering the time from the initial rocket flight to the present Chandra data and had superb displays of the instrumentation and science highlights. Riccardo did engage us all in an animated discussion when he noted a statement that future x-ray missions might prove the existence of black holes, since he and most of us involved in X-ray astronomy feel that the case has already been made. A lively dialog ensued, which we all enjoyed.

On Sunday morning, we rose early and left the Grand Hotel (by tourbus) for the Nobel Lectures in Physics, again at Stockholm University. The first two lectures involved neutrino research done by Raymond Davis and Masatoshi Koshiba. Ray Davis was able to attend, but due to health reasons his lecture was presented by his son. Having arrived early, we had primo seats for this event (Fig. 20).

Riccardo delivered a magnificent presentation starting from the discovery of Sco X-1 and the X-ray background in 1962 and describing the chase to understanding these mysterious findings. He presented data from the UHURU satellite showing how work by him, Ethan Schreier, myself and others had led to the discovery of rapid variability in several sources including Cen X-3, Her X-1, and Cyg X-1 (Fig. 21). In the case of the first two sources, regular pulsations were seen, establishing the presence of a neutron star. Regular changes in the pulse period and x-ray eclipses showed that the X-ray sources were in binary systems. Along with the speed-up of the pulse period these data pinned down the energy source as gravitational energy released when matter from the "normal" star falls onto the neutron star, just as energy is released when a book drops on the floor under the force of gravity.

For Cygnus X-1, the intensity changes were more rapid and irregular, and radio and optical observations soon led to the realization that the x-ray source was several times heavier than our Sun, too massive to be a neutron star and therefore a black hole.

Riccardo went on to explain that observations with X-ray telescopes on the Einstein, ROSAT, ASCA, and Chandra missions have detected many fainter X-ray sources mostly associated with supermassive black holes at the centers of quasars and other active galaxies (Fig. 22). The collected output from these faint sources explains most of the X-ray background discovered in 1962.

After this marvelous lecture (during which Riccardo generously shared credit with many of those who had contributed to the development of the field), Riccardo invited us all to lunch at a local Italian restaurant. There we enjoyed a delightful lunch while remembering many "war stories" from the early days of X-ray astronomy (Fig. 23).

Later, while the Giacconis were attending numerous official lunches and dinners, the rest of us had time to visit

FIGURE23: Giacconi family and friends at lunch

several of the fantastic museums in Stockholm and to enjoy some amazing cuisine - Ethan made sure that we really enjoyed this portion of our visit. We also caught up with former SAO team members Joe Schwarz and Ginevra Trinchieri who were in Stockholm as guests of their longtime friend Bob Horvitz, co-winner of the 2002 Prize for Physiology or Medicine.

On Tuesday, December 10 the big events were at hand. Formal gowns and tails and the like were rolled out, and we rode the tourbus to the Stockholm Concert Hall. We had an excellent view of the Prize Award Ceremony (first row, center in Second Balcony - akin to the Fenway Park bleachers in some ways, but certainly with a better-dressed crowd). Riccardo and the others received their awards, shaking hands with the King and making sure that all of the protocols were followed. Citations were read in Swedish and attendees were provided with English translations (Fig. 24).

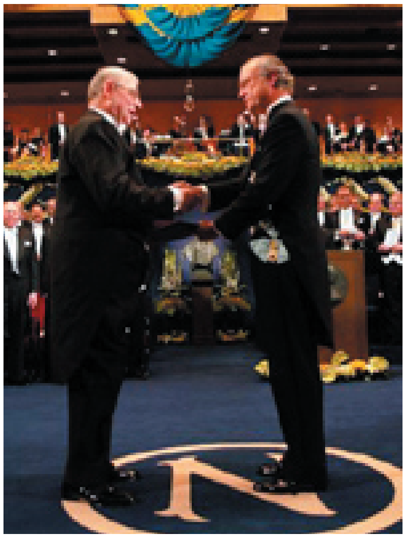

FIGURE 24: Riccardo Receiving Award From the King
(Photo: Hans Mehlin, Nobel e-Museum)

Then we were transported to Stockholm City Hall, where the Banquet was held in the Blue Hall, which looks a bit like a medieval castle. We found our assigned seats and then watched as the Royal Family and the Prize Winners marched into the Hall. Dinner was magnificent - with venison as the main course and wonderful first dishes and dessert, along with a series of superb wines. Entertainment was provided between courses by a circus troupe who were able to do some amazing dances and acrobatics in the Hall which is not normally equipped for such activity. After dinner there was dancing in the Gold Room with more time to socialize (Fig. 25).

FIGURE 25: Ethan, Herb, Riccardo, Harvey and Riccardo's Grandchildren, Colbe and Nicki

After the formal banquet our group (and those with the other Prize Winners) were invited to an after-the-party party (Nobel Nightcap) hosted by the graduate students in economics this year. Most of us were able to make this party, and Ethan, Janet, Rona, and yours truly even made the party after the after-the-party party. Twas a long day (actually short day and long night) and a fun time (Fig. 26)!!

On Wednesday we slept late and met the Giacconis for lunch. Then Riccardo was off to transact business (make arrangements for his half of the Prize Award). Riccardo and Mirella had dinner with the King and Queen again that evening while Ethan found another splendid restaurant for us. While there was another official (white tie, tails, and gowns) dinner on Friday, called the Lucia Dinner and hosted by the Student Union of Stockholm University, Rona and I headed home on Thursday Dec 12, which just happened to be the anniversary date for the launch of UHURU.

On a personal note, I am delighted that Riccardo's pioneering work and vision have been rewarded with this Prize. Those of us working on Chandra and in the field are incredibly pleased to see X-ray astronomy recognized through the Nobel Prize. Stockholm was indeed wonderful (and essentially snow-free during our visit) and this was truly a memorable event.

Harvey Tananbaum

FIGURE 26: Rona and I with two of Santa's Helpers

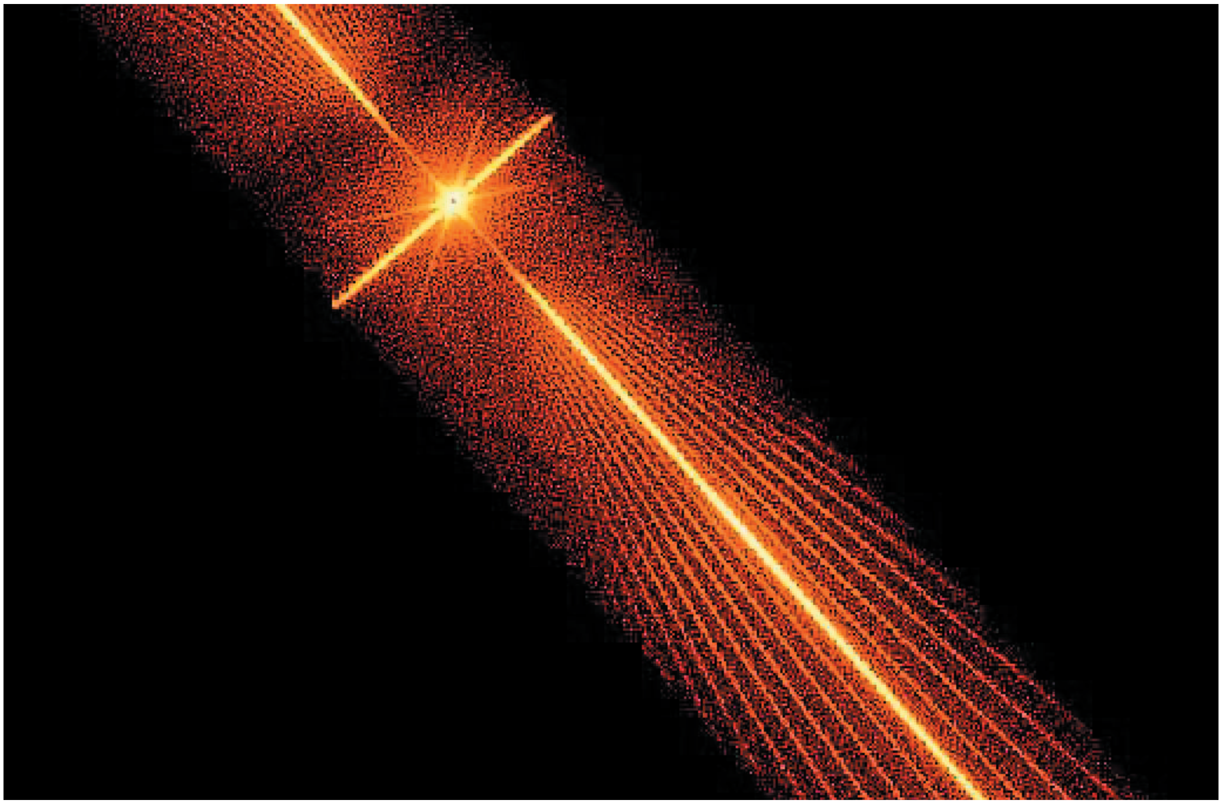

Figure 27: Chandra LETG spectrum of Mrk 421

MKN 421

This spectacular Chandra image shows the dispersed LETG spectrum of the nearby blazar Mkn 421 in an outburst giving the highest signal-to-noise spectrum taken so far with the LETG - a remarkable achievement for an extragalactic source. The spectrum lets us study the warm intergalactic medium in unprecedented detail. The seemingly complex image also contains the 0th-order image of the point-like source in the center of the crosses. The dispersed spectrum is seen in the two very bright lines which form a diagonal from the upper left to the bottom right, the positive and negative orders. The "fan of rays" around both the 0th-order image and the dispersed spectrum are an instrumental artifact due to diffraction of the X-ray photons off the instrument support. The lack of photons (i.e. the "hole") in the very center of the 0th-order source image is due to an exceptionally high degree of "pile-up" (multiple photons counted as one) in the CCD detector. Finally the luminous strip centered on the 0th-order image perpendicular to the dispersed spectrum contains 0th-order photons primarily diffracted from the LETG fine support structure, with a contribution deposited during read-out along the CCD read-out axis. This is because the source photon rate is much faster than the CCD read-out rate.

Chandra observed Mkn 421 on 2002 October 26-27, as a pre-approved Target of Opportunity (TOO). The source was caught at a luminosity > 100 times its normal, quiescent value making it by far the brightest AGN in the sky. This spectrum contains more than 4 million counts in the dispersed 1st-order alone. In the OVII Kα region (from 21.6 Å - the OVII Kα rest wavelength - up to 22.3 Å - the OVII Kα wavelength at the source redshift) this allows detections of OVII absorption column densities down to 10^{15} cm^{-2} at a 3-σ significance level. With this we can probe for the first time the existence of an intervening "X-ray Forest" of absorption lines from highly ionized intergalactic gas outside our own Local Group. This previously unseen baryonic component contains the majority of the matter in the local Universe (more than twice that concentrated in visible stars and galaxies) and can be used to track the dark matter concentrations in the Universe.

Fabrizio Nicastro

The Chandra Newsletter currently appears approximately once a year. We welcome contributions from readers. Nancy Remage Evans edits "Chandra News", with assistance from Mihoko Yukita and Tara Gokas. Comments on the newsletter and corrections and additions to the hardcopy mailing list should be sent to: chandranews@cxc.harvard.edu.