Winter 2008

Chandra News

Published by the Chandra X-ray Center (CXC) Issue number 15

HETG Observations of Hot Stars: From Predicted to Bizarre

Norbert S. Schulz, Paola Testa, David P. Huenemoerder, Claude R. Canizares

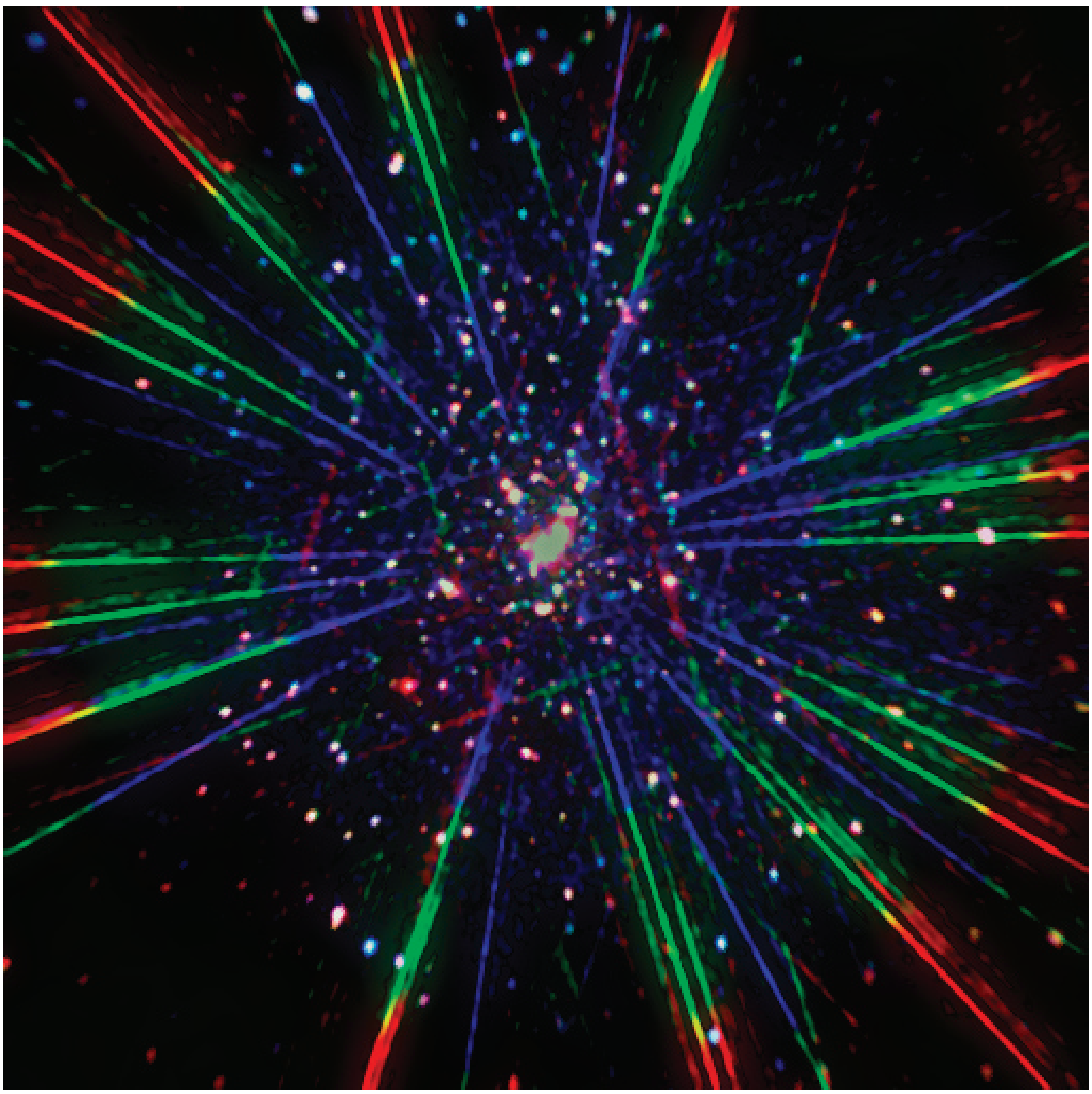


FIGURE 1: Cumulative images of 8 HETG exposures of the central region of the Orion Trapezium Cluster with aligned zero orders centered on θ^1 Ori C for a total exposure of approximately 300 ks and with a logarithmic intensity scale. The radial features are the dispersed HETG spectra, color coded according to first order CCD energy. Most streaks are from the X-ray brightest stars θ^1 Ori A, C, and E (article p.3).

CONTENTS

HETG Observations of Hot Stars (cont. from p.1)

The impact of broadband high resolution X-ray spectroscopy on stellar astronomy since the launch of *Chandra* and XMM-Newton has been outstanding. Specifically our understanding of the X-ray production in hot stars has made significant advances. Moreover, many of the observed X-ray spectral properties did not match predictions from standard models and previously analyzed low resolution spectra. Even today interpretations are incomplete at best and highly debated. In this respect young massive stars seem to behave particularly oddly and long HETG exposures of young embedded clusters cores (Figure 1) have now become available. This article summarizes advances made from *Chandra* HETG spectra. A comprehensive atlas of HETG spectra of hot stars in the *Chandra* data archive can be found under *http://cxc.harvard.edu/XATLAS* and by Westbrook et al. (2007).

X-Ray Emission from Radiation Driven Winds

The *Chandra* archive currently contains many HETG observations of OB stars, which have been re-analyzed and discussed with respect to their nature as main sequence stars, giants, and supergiants (Waldron & Cassinelli 2007). They range from types B0.5V (β Cru) to O4If (ζ Pup) and surface temperatures from 28000 K to 45000 K. HETG spectra of most stars indicate plasma temperatures in the range between about 2 to 25 MK and contain strong lines from He- and H-like ions from N, O, Ne, Mg, Si, and S. X-ray plasmas of temperatures well beyond 25 MK contain lines from highly ionized Ar, Ca, and Fe ions. The line fluxes are generally very strong. Figure 2 shows plasma temperature distributions from several OB stars. Most O stars in the *Chandra* archive sample show standard distributions generally lying within the gray area, B stars are up to an order of magnitude lower. Enhanced winds, i.e. through magnetic activity such as observed in θ^1 Ori C and τ Sco (see below), show unusually hot distributions. Within the standard sample some differences between main sequence stars, giants, and supergiants have now been detected as well (Waldron & Cassinelli 2007).

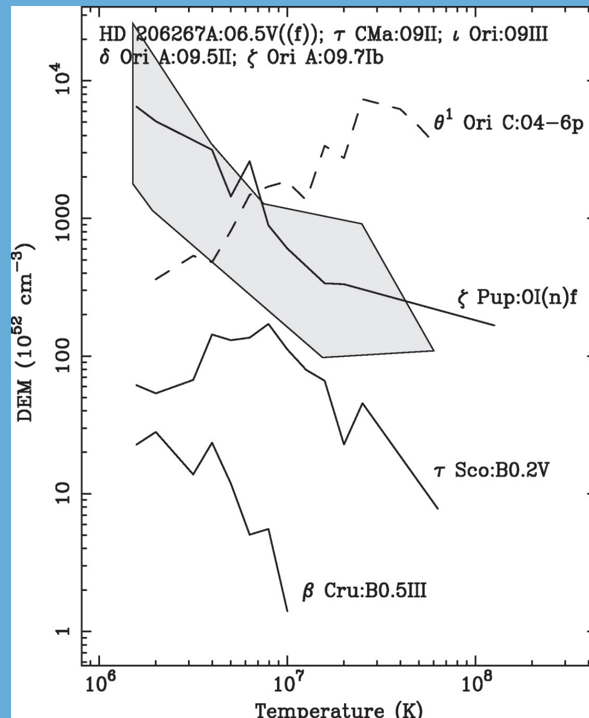


FIGURE 2: Emission measure or plasma temperature distributions of a variety of hot stars as compiled by Wojdowski & Schulz (2005). The grey area indicated the location of O-stars following the standard picture.

The Standard Picture

Early X-ray observations with EINSTEIN and ROSAT led to the development of a basic shock model in which line-driven instabilities accelerate wind plasmas to high velocities. Models today are diverse in detail but despite their differences predict soft X-ray emissivities up to only a few ten MK, broad and asymmetric lines, and in some cases measurable blueshifts. The prototype for such a behavior was seen in the very early supergiant ζ Pup with evidence that the X-ray sources are shocks embedded in the wind (Cassinelli et al. 2001). However, even this prototype star did not live up to expectations and as encountered in many other stars where line profiles remained fairly symmetric and without measurable blueshifts (see Figure 3), interpretations remain problematic (Waldron & Cassinelli 2007). Statistics show that in many cases the line widths are substantial with a trend to be somewhat narrow-

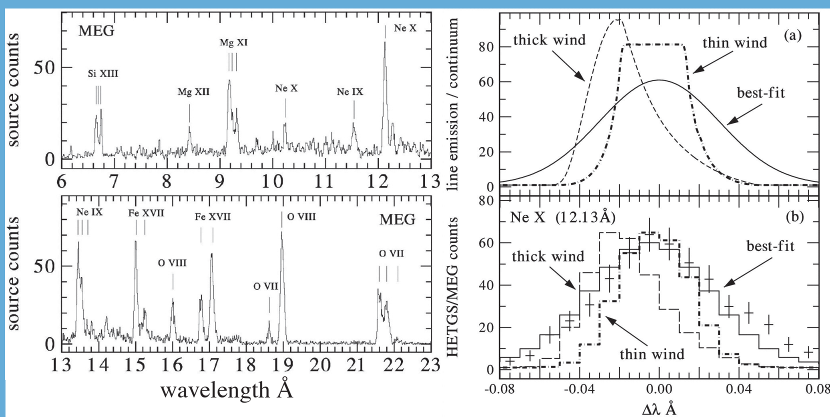


FIGURE 3: X-ray spectrum and line profiles from HETG data of an early *Chandra* observation ζ Ori (Waldron & Cassinelli 2001). Plasma temperatures were determined to about 2 - 10 MK and many lines showed Doppler broadening of the order of 900±200 km/s. A Si XIII line formation region near the stellar surface suggested that these Doppler velocities were too small to produce the shock jumps required in the standard picture.

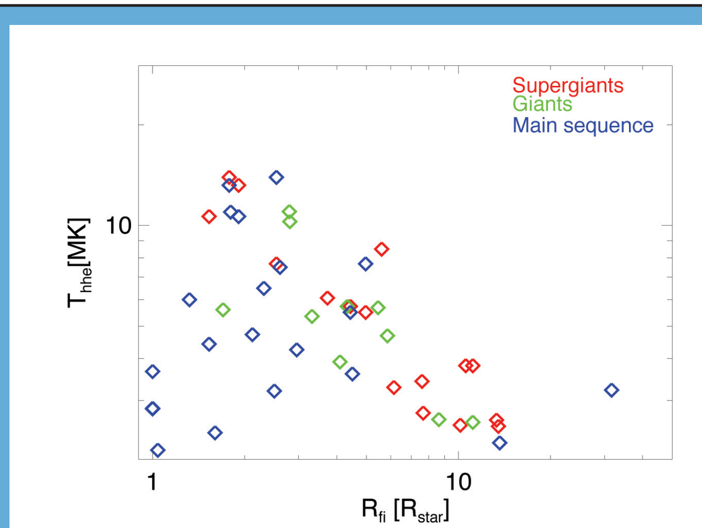
er in main sequence stars with respect to giants and supergiants. While some line shifts are seen in the latter, they remain undetected in most stars.

The Power of Line Ratios

The diagnostic of the metastable line components in He-like line triplets has been one of the powerhouses in the analysis of cool star spectra. The interpretation of line ratios in hot stars is dramatically different as they are heavily affected by the radiation field of the high temperature stellar surface. In this case the value of the forbidden (f) over intercombination (i) line ratio has shifted from an important density diagnostic to a measure of distance of the formation region from the hot stellar surface. For UV excited lines longward of the Lyman limit such as O VII, Ne IX, and Mg XI the photoexciting photons are unattenuated, for EUV excited lines such as Si XIII and S XV the f/i ratios are predicted by model atmospheres. Details clearly remain problematic, specifically with respect to the question of whether the X-ray formation range for a specific ion is local (Leutenegger et al. 2006) or more distributed in the wind (see Waldron & Cassinelli 2007 for a more detailed discussion).

Figure 4 shows the dependence of the X-ray temperature determined from the H- to He-like resonance line flux ratio to the inferred f/i line formation distance from the stellar surface. It shows that there is a well defined radial-dependent maximum X-ray temperature in all stellar types. For supergiants the

FIGURE 4: Distribution of temperatures from resonance line ratios versus the radial distance from the stellar surface from the f/i ratios (ratios from Waldron & Cassinelli 2007). The blue diamonds are from main sequence stars, the green ones from giants, the red ones from supergiants.



inner radii are missing due to absorption effects.

Strange Spectra

Besides a general discussion that has emerged in recent years about wind porosity, possibly reduced mass outflow rates in general, and our better understanding of wind opacity effects, there are some outstanding examples where the standard picture of X-ray production clearly fails. Two stars, τ Sco and θ^1 Ori C, are known to exhibit magnetic fields and were intensively studied with HETG (Cohen et al. 2003, Schulz et al. 2003). θ^1 Ori C specifically came under early scrutiny because its emissivity distribution (see Figure 2) not only differed by showing extremely high temperatures incompatible with the standard shock model, but also its line widths appeared low but resolved for most of the bandwidth and much larger in the soft band. Gagne et al. (2005) successfully modeled several HETG spectra of θ^1 Ori C with a magnetic rotator and a confined wind model involving turbulence accounting for the resolved line widths. The broader soft lines are likely due to a normal, unconfined wind component (Schulz et al. 2003). Figure 5 shows a more recent high definition HETG spectrum of this star from the ongoing HETG Orion Legacy Project. This spectrum not only allows us to study this extraordinary star in more detail, but due to its hardness is a benchmark for extremely hot collisionally ionized plasmas.

Other strange spectra involving hot stars have emerged recently and stirred quite some controversy in the community. These involve hot emission line OB stars such as γ Cas (Smith et al. 2004), HD 119682 (Rakowski et al. 2006), and HD 110432 (Lopez de Oliveira et al. 2007). Spectra here appear hot and thermal with at least one soft (< 10 MK) and one extremely hard (> 100 MK) X-ray component. The ongoing controversy stems from the fact that γ Cas also contains a compact white dwarf secondary and low resolution spectra in part are reminiscent of some cataclysmic variables. However, other OBe stars show no evidence for such binarity, leaving the possibility for presumably magnetic interactions between the fast rotation surface of the star and its disk (see also Li et al. 2008). *Chandra* will revisit HD 119682 in Cycle 9 with the HETG and allow further studies of the phenomenon.

Effects due to Multiplicity

The X-ray production scenarios discussed so far involved radiation driven winds of isolated OB

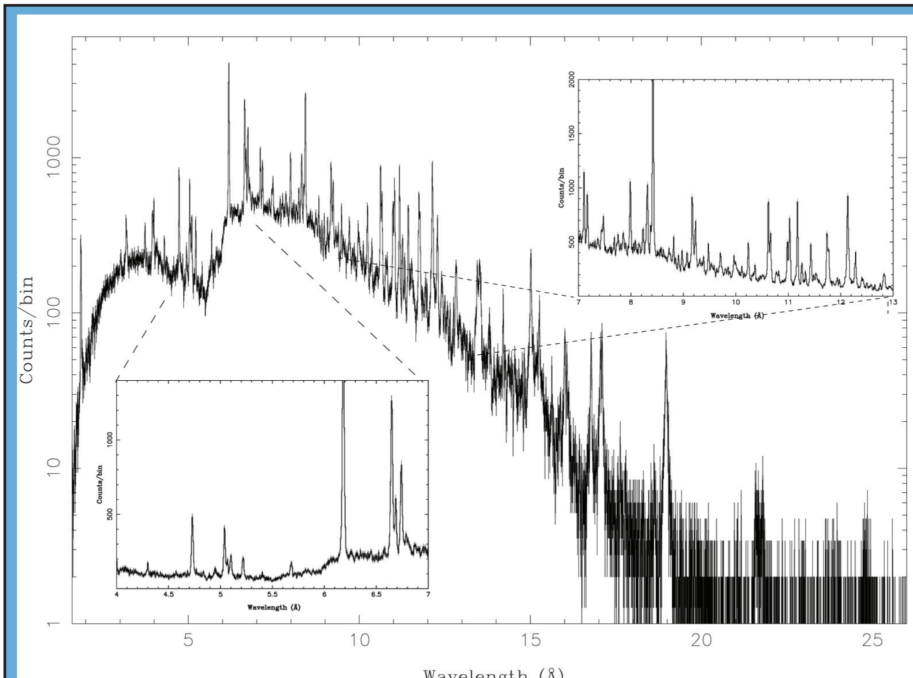


FIGURE 5: The HETG Orion Legacy Project so far collected 485 ks exposure of the young O5.5V star θ^1 Ori C. The long exposure allows us to generate a high definition X-ray spectrum of a collisionally ionized plasma with temperatures well beyond 50 MK. The left inset shows the resolved S XV and Si XIII triplets at 5.06 Å and 6.68 Å. The right inset shows the Fe XXIV dominated line region of the hot plasma (see also Schulz et al. 2003).

stars. There are at least two more mechanisms in the literature involving OB stars, colliding winds and binary induced magnetic reconnection. In a general sense, accretion phenomena involving compact objects such as in high-mass X-ray binaries may be considered as well, but here the OB component is not the primary X-ray source. When dealing with X-rays from massive stars, on the other hand, one has to consider the possibility of substantial emission due to known or unseen young companions.

Interactive Events

X-rays from colliding winds have been proposed since the launch of EINSTEIN and mostly involved binary systems involving very strong winds as provided by Wolf-Rayet (WR) stars. Perhaps the prototype of such a system is WR 140 which was observed with the HETG during its periastron passage and where the interplay of the vast collisionless shock interaction zone of the two winds between the pre-shock and the absorbed post-shock gas was monitored (Pollock et al. 2005). One of the outstanding examples is supermassive η Carina, which exhibits variable and hard X-ray mission through collisions of its dense wind with a less dense, but faster moving wind from a hidden companion surrounded by an expanding bipolar nebula. η Carina has seen intense coverage by HETG over its 5.53 yr orbital period which has been a highlight of a previous *Chandra* Newsletter (Corcoran et al. 2005).

Many other close binaries exhibiting effects of wind collisions involving very early type giants and supergiants have been observed, though not with HETG but with gratings onboard XMM-Newton (see Sana et al. 2004). However, not all binaries involving OB stars are bound to exhibit colliding winds. Two classic cases were HD 206267 and ι Ori. They were candidate targets for colliding winds during the EINSTEIN and ROSAT missions. *Chandra* HETG observations did not find any evidence for wind collisions, and the absence of such events are important clues that help constrain the conditions for such interactive events.

Another candidate for a colliding wind system in Orion is the massive triplet θ^2 Ori A, a O9.5V primary with two intermediate mass companions. *Chandra* observed two giant outbursts of this system, which appeared related to the periastron passage of the primary and the spectroscopic secondary (Schulz et al. 2006). Sporadic outbursts of this magnitude are inconsistent with any known processes involving hot star winds, but also rule out colliding wind scenarios. The total energy in the outburst observed with the HETG is larger than any stellar flare observed in Orion so far (see Figure 6). Energetic considerations in this case deem induced magnetic reconnection events as more likely, specifically under the assumption that the unusually hot non-outburst spectrum is due to magnetic confinement of the primary wind.

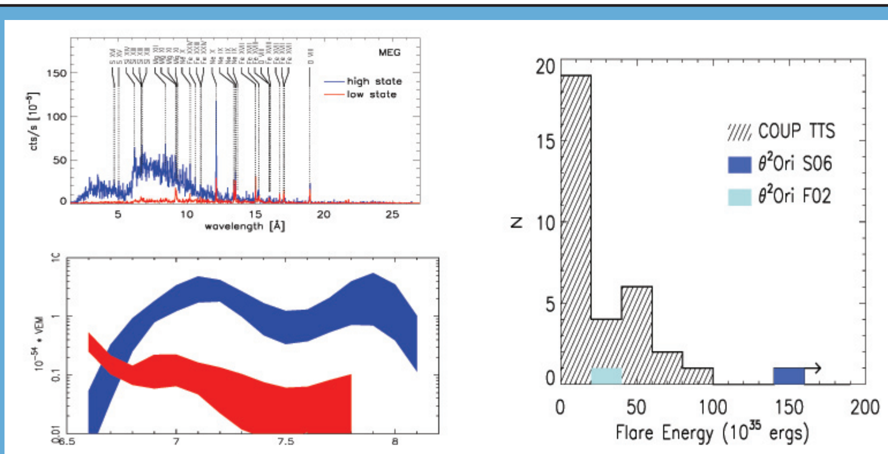


FIGURE 6: The second most massive star system θ^2 Ori A showed two giant outbursts during *Chandra* observations. In 2005 *Chandra* HETG observed an outburst that produced the hottest X-ray spectrum of a massive star system. The blue spectrum (top left) and deduced temperature distribution (bottom left) show the outburst, the red indicates the behavior during quiescence (for line identifications in the upper left, see Fig 4 in Schulz, et. al, 2006). The right panel compares the energy of these outbursts to the brightest T Tauri X-ray flares observed in Orion (F02: Feigelson et al. 2002 ACIS-I, S06: Schulz et al. 2006, HETG).

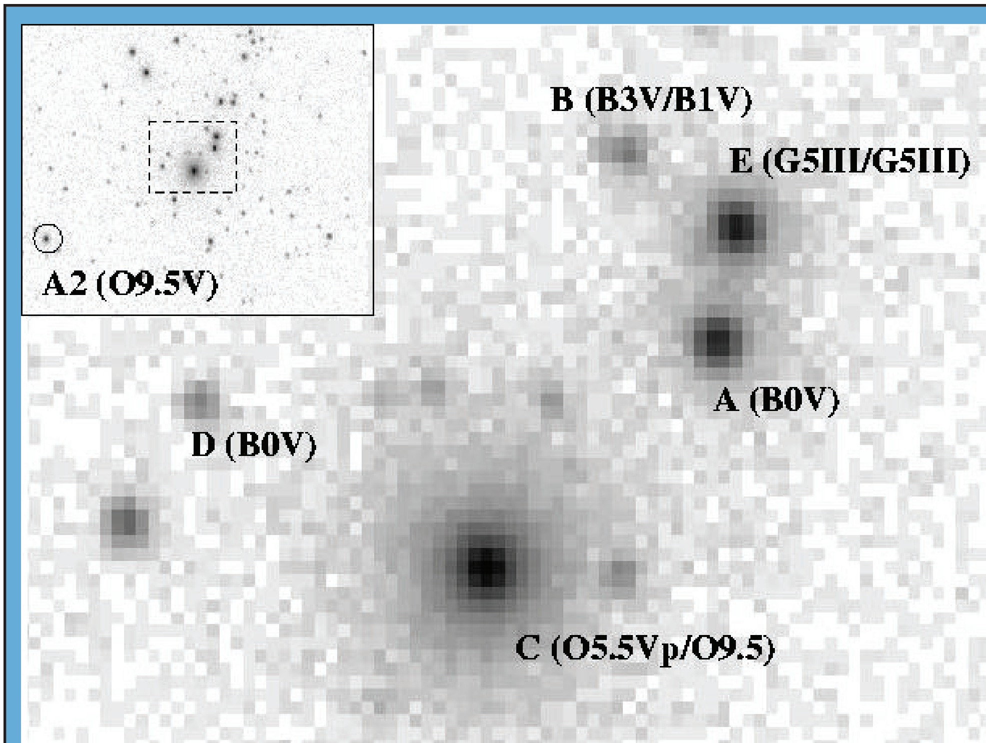


FIGURE. 7: The zero order image of the 580 ks exposure of the Orion Trapezium from the HETG Orion Legacy Project. The main stars are from θ^1 Ori; A2 in the inset is θ^2 Ori A, further from the cluster center.

Massive Orion Trapezium Stars

The HETG Orion Legacy Project, performed to a large extent within the HETG Guaranteed Time Observation program at MIT and designed to study high resolution X-ray spectra of over a dozen pre-main sequence stars in the Orion Trapezium Cluster (OTC), has accumulated over 580 ks so far (Figure 7, see also Figure 1), which, once unfavorable roll angles are eliminated, also provide substantial HETG exposures for the other massive constituents. Several puzzling trends are already evident. One conclusion that is emerging is that X-ray emission of these very young massive stars is soft and surprisingly weak unless enhanced by additional interactions.

The cases of θ^1 Ori C and θ^2 Ori A already demonstrated that X-ray emissions from young (< 1 Myr) massive stars in the Orion Trapezium have extraordinary properties. Three of the five X-ray production mechanisms mentioned above are at work in this young cluster, which besides the standard shock model are magnetically confined winds, and binary induced magnetic interactions. Colliding winds are so far excluded and as there are no classical emission line stars in the cluster. The example of θ^1 Ori C shows that even though the HETG spectrum is dominated by emissions from magnetically confined wind plasma, it also exhibits weak and soft wind shock emission (see above). This is an important clue as it indicates that all the massive θ^1 Ori stars are likely to show this emission.

The prime example in this respect is θ^1 Ori D, which is so weak and cool that even with the large exposure, no significant HETG spectra can be extracted. Optically, on the other hand, it is classified as a B0V star (Simon-Diaz et al. 2006), just like θ^1 Ori A which is X-ray bright and hot. Its similarity to θ^1 Ori C could invoke magnetic properties as the difference, but this so far remains to be modeled. θ^1 Ori E is now classified as a young intermediate binary (Herbig and Griffin 2005) and has a similarly bright and hot X-ray spectrum (Schulz et al. 2003). There are still many open questions and future studies of hot stars in the OTC with the HETG promise to be very fruitful.

References

Cassinelli, J. P., Miller, N. A., Waldron, W. L., et al. 2001, ApJ, 554, 55

Corcoran, M. F., Seward, F. D., Henley, D. B., Hamaguchi, K. 2005, *Chandra* Newsletter, Issue 12

Cohen, D. H., de Messieres, G. E., MacFarlane, J. J. et al. 2003, ApJ, 586, 495

Feigelson, E. D., Broos, P., Gaffney, J. A. 2002, ApJ, 574, 258

Herbig, G. H., Griffin, R. F. 2005, AJ, 132, 1763

Leutenegger, M. A., Paerels, F. B., Kahn, S. M., Cohen, D. H. 2006, ApJ, 650, 1096

Li, Q., Cassinelli, J. P., Brown, J. C. et al. 2008, ApJ, 672, 1174

Lopez de Oliveira, R., Motch C., Smith, M. A. et al. 2007, A&A, 474, 983

Pollock, A. M. T., Corcoran, M. F., Stevens, I. R., Williams, P. M. 2005, ApJ, 629, 482

Rakowski, C. E., Schulz, N. S., Wolk, S. J., Testa, P. 2006, ApJ, 649, L111

Sana, H., Stevens, I. R., Gosset, E., Rauw, G., Vreux, J.-M. 2004, MNRAS, 350, 809

Schulz, N. S., Testa, P., Huenemoerder, D. P., Ishibashi, K., Canizares, C. R. 2006, ApJ, 653, 636

Schulz, N. S., Canizares, C. R., Huenemoerder, D. P., Tibbets, K. 2003, ApJ, 595, 365

Simon-Diaz, S., Herrero, A., Esteban, C., Najarro, F. 2006, A&A, 448, 351

Smith, M. A., Cohen, D. H., Gu, M. F. et al. 2004, ApJ, 600, 972

Waldron, W. L. & Cassinelli, J. P. 2007, ApJ, 668, 456

Waldron, W. L. & Cassinelli, J. P. 2001, ApJ, 548, L45

Westbrook, O. W., Remage Evans, N., Wolk, S. J. et al. 2007, arXiv: 0712.0610

Project Scientist's Report

Martin C. Weisskopf, Stephen O'Dell

The major highlight of this period was the Symposium "Eight Years of Science with *Chandra*", hosted by NASA Marshall Space Flight Center and the *Chandra* X-ray Center on 2007 October 23-25, in Huntsville, Alabama.

Steve O'Dell (MSFC) and Dan Schwartz (SAO) co-chaired the Science Organizing Committee.

Other committee members were:
Max Bonamente (UAH),
Graziella Branduardi-Raymont (MSSL),
Annalisa Celotti (SISSA/ISAS),
Larry David (SAO),
Ron Elsner (MSFC),
Dan Evans (Harvard),
Kathy Flanagan (STScI),
Mike Garcia (SAO),
Ann Hornschemeier (GSFC),
Margarita Karovska (SAO),
Vicky Kaspi (McGill),
Chryssa Kouveliotou (NASA/MSFC),
Kazuhisa Mitsuda (ISAS/JAXA),
Dan Patnaude (SAO),
Peter Predehl (MPE),
Andrea Prestwich (SAO),
Leisa Townsley (Penn State U.), and
Meg Urry (Yale).

Susan Tuttle (SAO) did an outstanding job chairing the Local Organizing Committee. Having the food catered for the breaks and lunch was an excellent idea, fostering active interactions amongst participants.

This fourth biennial symposium included a keynote talk by Jon Morse (Director of NASA's Astrophysics Division, see Figure 8), 11 invited talks, 38 contributed talks, and 56 poster presentations. For on-line proceedings of the Symposium, please visit *http://cxc.harvard.edu/symposium_2007/proceedings/* .

The *Chandra* Calibration Workshop, organized by Vinay Kashyap (SAO), immediately followed the Symposium. For proceedings of the Workshop, please visit *http://cxc.harvard.edu/ccw/proceedings/07_proc/* .

FIGURE 8: Pictures from the "Eight Years of Science with *Chandra*" Conference including Martin Weisskopf (bottom left), Jon Morse (upper right), and the audience.

Chandra will be assessed in the next Senior Review of Operating Missions. The proposal is due March 12, 2008 and the Review will take place April 22-25. *Chandra* will be represented by Martin C. Weisskopf (Project scientist), Harvey Tananbaum (CXC Director), Roger Brissenden (CXC Manager), Keith Hefner (Program Manager), and Belinda Wilkes (CXC Assistant Director). ✯

CXC Project Manager's Report

Roger Brissenden

Chandra marked eight years of successful operations with continued excellent operational and scientific performance, and with a seminar "8 Years of Science with *Chandra*," held in Huntsville, Alabama, in October 2007. Telescope time remained in high demand, with significant oversubscription (Figures 34 and 36) in the Cycle 9 peer review held in June. In December 2007 the observing program transitioned on schedule from Cycle 8 to Cycle 9, and we look forward to the Cycle 10 peer review in June 2008. The competition for *Chandra* Fellows positions remained fierce this year, with 99 applications for the 5 new awards.

The CXC mission planning staff continued to maximize observing efficiency in spite of temperature constraints on spacecraft pointing. Competing thermal constraints require some longer observations to be split into multiple short duration segments, to allow the spacecraft to cool at preferred attitudes. However constraints were eased when ongoing efforts relaxed the EPHIN thermal constraints. Overall the average observing efficiency in the last year was 67%, compared to 64% in the prior year, and with a maximum possible of ~70%.

Operational highlights over the past year included 9 fast turn-around observing requests that required the mission planning and flight teams to reschedule and interrupt the on-board command loads. The sun was exceptionally quiet this year, causing no observing interruptions due to high levels of solar activity. *Chandra* passed through the 2007 summer and winter eclipse seasons with nominal power and thermal performance, and handled lunar eclipses in March and October without incident. Perhaps most important, the mission continued without a significant anomaly and had no safe mode transitions this year.

In addition to the routine training simulations conducted for the Flight Operations Team (FOT), members of the CXC's management staff, science teams and FOT responded to a surprise operations simulation in December. The simulation was initiated by the *Chandra* program office at Marshall Space Flight Center and prepared and carried out by a select team at the OCC, who modified actual *Chandra* telemetry from an early safe mode for the exercise. The simulation, which began after midnight, tested the team's response to a perceived spacecraft emergency. The staff performed well, investigating the anomaly and making appropriate decisions. As a result of the experience, actions were identified to improve procedures and responses in the event of future spacecraft problems.

The FOT marked a year of outstanding operations and the seventh continuous year without a safe mode. To understand *Chandra*'s long-term operational capabilities, the FOT calculated *Chandra*'s orbit through 15 years following launch and examined the orbit's effect on mission planning and operations. The study found no significant limit on *Chandra*'s ability to operate at the current level of observing efficiency over a 15-year mission. The FOT also continued its preparation for recompiling the spacecraft's software. This major effort will make it easier in the future to generate, verify and control changes to the flight software.

Both focal plane instruments, the Advanced CCD Imaging Spectrometer and the High Resolution Camera, have continued to operate well and have had no major problems. ACIS experienced two minor anomalies: its Front End Processor spontaneously reset in April, resulting in loss of data from three chips for one observation, and its side-B power supply turned off in December, resulting in loss of data from one observation. Such anomalies have been rare and do not significantly affect the mission. Mission planners rescheduled the affected observations at later dates.

Because ACIS, along with the overall spacecraft, has continued to warm gradually, it was decided in 2006 to ask observers to identify ACIS chips that could be turned off during observations. Each powered-off chip provides approximately 5 deg C of temperature margin, adding flexibility to mission planning. The capability for ACIS chip selection was introduced this year in the proposal planning software for Cycle 9. As another means of mitigating ACIS warming, tests were conducted during 2007 to determine the effect of turning off the ACIS detector housing heater. As a result the heater is being turned off during perigee passages with particular spacecraft attitudes, and further tests are planned.

Following successful functional tests during 2006, the HRC +Y shutter was partially inserted to support a December, 2007, observation of the Crab nebula. The shutter operated properly during the observation.

All systems at the *Chandra* Operations Control Center continued to perform well in supporting flight operations. The ground system staff and the systems engineering team successfully completed a major external IT (information technology) security audit. The team updated the online software system to implement a small number of changes required by the audit, and in September NASA headquarters signed the OCC's formal Authority to Operate for the next 3 years. The OCC replaced its aging data storage system and installed a redundant server string in an off-site location to provide a minimum backup operations capability for use in the event of a major anomaly at the OCC.

Chandra data processing and distribution to observers continued smoothly, with the time from observation to delivery of data averaging less than 2 days. The *Chandra* archive holdings grew by 0.8 TB to 4.9 TB (compressed) and now consist of 17.4 million files. The large increase is due in part to the third full reprocessing of *Chandra* data, which was completed in 2007. The reprocessed data incorporate the most recent instrument calibrations.

Work is progressing well on the *Chandra* source catalog. The CXC Data System programming team released several versions of the source catalog processing software to the CXC during the year for evaluation and testing, and the team expects to release a full version in summer 2008, with processing to follow.

The Data System team also released software updates to support the submission deadline for Cycle 9 observation proposals (March 2007), the Cycle 9 Peer Review (June), and the Cycle 10 Call for Proposals(December) and issued a major release of CIAO (December).

The Education and Public Outreach group issued 14 *Chandra* press releases and 18 image releases during 2007. The EPO team held two press conferences, a NASA Media Teleconference, and a NASA Science Update. The EPO team received the prestigious Pirelli *Internet*ional award, an international multimedia competition for the communication of science & technology, for its innovative *Chandra* podcasts. The team continued to release *Chandra* podcasts through the CXC website, with 12 new podcasts this year.

We look forward to a new year of continued smooth operations and exciting science results. ✭

Instruments: ACIS

Controlling the ACIS Focal Plane Temperature

Paul P. Plucinsky

Over the course of the mission, the ACIS focal plane (FP) temperature has been warming above the desired temperature of -119.7 C when the spacecraft is in an orientation in which the Sun is on the back of the Science Instrument Module (SIM). Warming of the FP temperature has been observed for pitch angles larger than 130 degrees. The amount of warming depends of course on how long the satellite spends in an orientation with pitch angles larger than 130 degrees and how cold the various components were at the start of the observation. The warming occurs because the insulating layers on the outside of the SIM are degrading with time and more heat is propagating into the interior of the SIM. The FI CCDs are more sensitive to deviations in the FP temperature than the BI CCDs. For deviations of less than 1.0 degree, *Chandra* GOs should not notice any difference in the calibration of the FI CCDs. The comparable limit for the BI CCDs is 3.0 degrees.

In order to partially counteract this effect, the ACIS instrument team has been conducting tests in which the Detector Housing (DH) heater is turned off. The DH heater has been used to keep the Camera Body at a steady temperature of about -60 C (the Camera Body is essentially the box which encloses the volume containing the FP). If the DH heater is turned off, the camera body temperature will fluctuate between -65 C and -72 C. These lower temperatures would reduce the heat load on the FP and make it more likely that a temperature of -119.7 C could be maintained for tail-Sun orientations. Please note that the FP temperature is regulated by a different circuit and turning off the DH heater does not affect the regulation of the FP temperature.

It is desirable to have a constant camera body temperature because the ACIS fiducial lights are mounted on the camera body. If the camera body temperature is fluctuating, the camera body will be contracting or expanding and the position of the fiducial lights will be changing relative to the Aspect system. The CXC has been conducting tests in which the DH heater is turned off to determine how the positions of the fiducial lights change over the course of an observation. These tests show that the motion of the fiducial lights is small and can be corrected such that there is no impact on the aspect reconstruction for the observations. The CXC Data System is incorporating this correction into the standard processing pipelines. In addition, the ACIS instrument team is conducting additional tests with the DH heater off when the satellite is in forward-Sun orientations since the thermal models indicate this will be the coldest orientation for the camera body. When these tests are completed and the SW

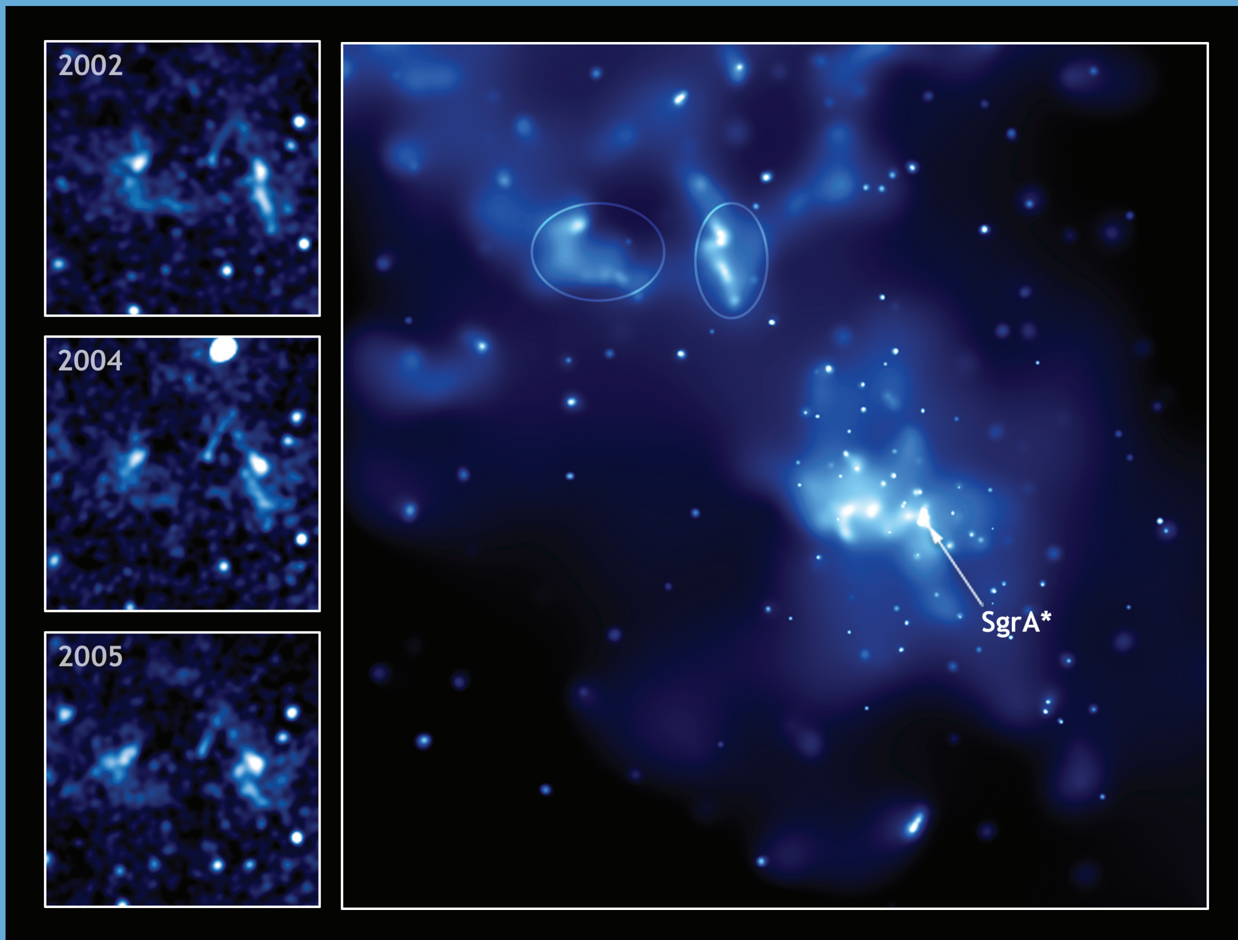


FIGURE 9: NASA/CXC/Caltech/M.Muno et al.

has been modified to account for the motion of the fiducial lights, the ACIS instrument team expects to turn off the DH heater permanently. The CXC anticipates that this will be some time in Spring 2008. Hopefully after the DH heater is turned off, the ACIS FP temperature will maintain -119.7 C for a larger fraction of the observations.

A Light Echo from the Milky Way's Black Hole

Peter Edmonds

A popular activity for news magazines is to list the top news stories of the year. As a member of the Education and Public Outreach group, I enjoy these articles because they can give a second round of publicity to *Chandra* press releases that we put out months earlier. These publicity "echoes" often reach a different audience from the one that saw the original stories.

In their January 2008 issue, Discover magazine lists their hundred top science stories of 2007. Coming in at number 41 is the discovery of evidence for a different type of echo, a light echo generated by the Milky Way's supermassive black hole, Sagittarius A*. This result, announced by Mike Muno of Caltech at the 2007 American Astronomical Society meeting in Seattle, suggests that a mass equivalent to the planet Mercury was devoured by the black hole about 50 years earlier, causing an X-ray outburst which then reflected off gas clouds near Sagittarius A*.

The large image (see Figure 9) shows a *Chandra* view, using ACIS, of the middle of the Milky Way, with Sagittarius A* labeled. The smaller images show close-ups of the region marked with ellipses. Clear changes in the shapes and brightness of the gas clouds are seen between the 3 different observations in 2002, 2004 and 2005. This behavior agrees with theoretical predictions for a light echo produced by Sagittarius A* and helps rule out other interpretations. While the primary X-rays from the outburst would have reached Earth about 50 years ago, before X-ray observatories were in place to see it, the reflected X-rays took a longer path and arrived in time to be recorded by *Chandra*.

Studying this light echo gives a crucial history of activity from Sagittarius A*, and it illuminates and probes the poorly understood gas clouds near the center of the galaxy. It also gives an excellent example of the innovative science enabled by *Chandra*'s ACIS camera and the scientific advances that are possible with observations spread out over several years.

Instruments: HRC

Ralph Kraft, Almus Kenter, for the HRC team

At the expense of sounding like a broken record, the HRC continues to operate well with no anomalies or interruptions. There has been a measurable but, for most observations, insignificant amount of charge extracted from the MCPs to date. The potential impact of extracted charge on LETG observations is discussed in the section Instruments: LETG. Any increase in the MCP high voltage and therefore gain is at least several years away. Ongoing monitoring/calibration observation show no change in the HRC UV sensitivity (potentially indicative of problems with the UVIS) and a small decrease in the X-ray QE due to extracted charge. One HRC shutter was used for an observation of the Crab Nebula during the past year. The shutter performed nominally, although it is not expected that either will be used again. It has been another quiet, routine year for HRC operations.

A wide range of science observations, both GO and GTO, have been made over the past year with the HRC-I, the HRC-S in timing mode, and the HRC-S/LETG combination. The next two sections present some science highlights from the last year, including HRC-I and HRC-S/LETG observations of α Cen A, and HRC-I observations of unidentified ASCA sources in the Galactic plane.

The Fainting of α Cen A, Resolved

Thomas R. Ayres (University of Colorado), Philip G. Judge (High Altitude Observatory), Steven H. Saar (CfA), & Jürgen H. M. M. Schmitt (Hamburger Sternwarte)

XMM-Newton snapshots of the famous α Centauri binary at six month intervals recorded an abrupt disappearance of the primary's X-ray corona in early 2005. The "fainting" of α Cen A was contrary to the previous two decades of X-ray monitoring of the system, which had found only modest coronal variability of the Sun-like star (although its cooler K-type companion was considerably more erratic). To be sure, the solar corona varies by factors of hundreds in hard kilovolt X-rays over the 11-year activity cycle, but even at sunspot minimum there still is a pervasive soft 1 MK "quiet corona" that always is present. Thus, the "fainting" of the α Cen A X-rays was unexpected and puzzling. At the same time, the A–B orbit has been closing rapidly over the past decade, leaving the companions badly blended in the *XMM*-Newton MOS1 images; only *Chandra* now can cleanly separate them.

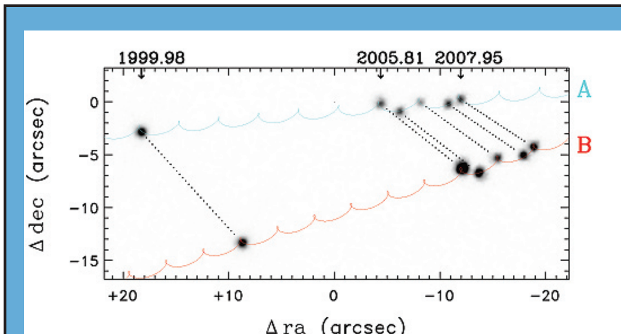


FIGURE 10: The positions of the A (blue) and B (red) components of α Centauri. The size of the spot is proportional to the count rate. The looping curves are the combined orbital, parallactic, and proper motions. The subarcsecond imaging resolution of HRC-I and aspect reconstruction tracks the parallax of the binary.

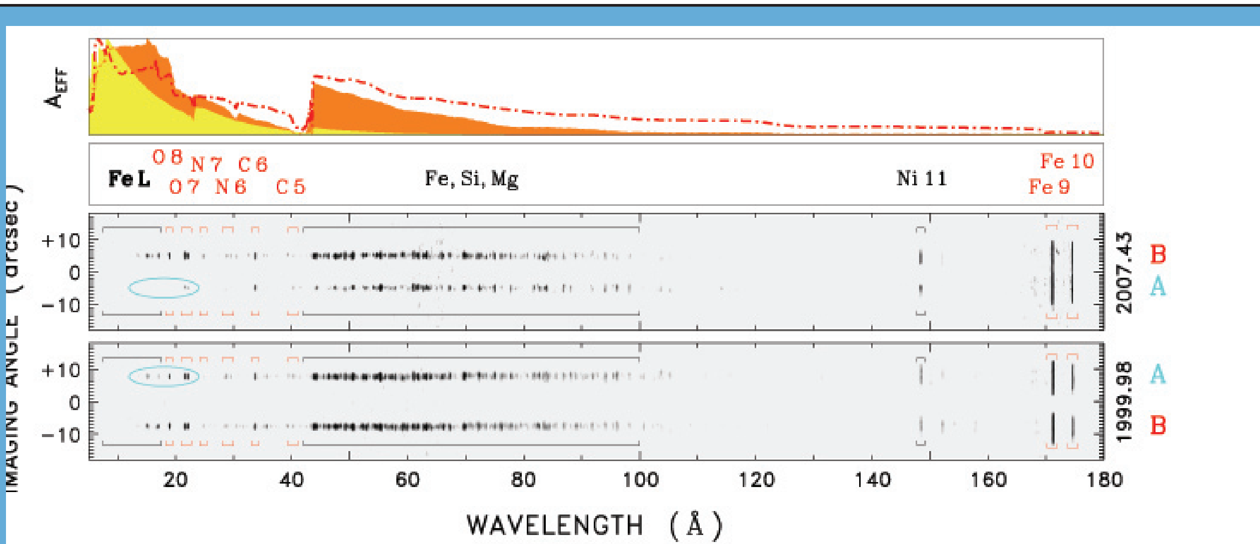


FIGURE 11: *Chandra* LETGS spectra of α Cen taken 7.5 years apart. The bottom two panels illustrate the spatially resolved LETGS events, binned into an image combining the plus and minus grating arms. The A component is the lower stripe in the upper spectrum, and the upper stripe in the lower one. The A and B spectra in the earlier observation (1999.98) are quite similar to one another, and to the 2007.43 trace of the B component. The new A spectrum, however, displays a striking lack of emission below 30 Å (highlighted by blue ovals in both epochs). The upper panel compares normalized effective area curves of MOS,1 (with thick blocking filter: yellow shaded), HRC-I (orange shaded), and LETGS 0th-order (red dot-dashed). The bands of XMM-Newton and HRC-S/LETG are quite different, and the decrease in flux of the hot component from the A component is the cause of the low XMM-Newton/MOS count rate and the apparent 'fainting'.

Thanks to a initial grant of *Chandra* Director's Discretionary Time, our team began acquiring pointings on α Centauri in late 2005. We used the HRC-I camera: the optical brightness of the binary precluded ACIS (with its red leak). HRC-I also has good soft response. Figure 10 shows the results to date. In each epoch, the A component (the Sun-like star) is uppermost; the B component (the K dwarf) is below and to the right; and the size of the spot is proportional to the X-ray count rate. The leftmost pair is a 0th-order image from a late-1999 LETGS/HRC-S exposure (scaled to HRC-I sensitivity); the middle three are HRC-I's from the initial DDT allocation; and the rightmost two are from a follow-up Cycle 8 GO program. The most recent pointing was in December 2007. Looping curves are the combined orbital, parallactic, and proper motions: *Chandra*'s subarcsecond aspect reconstruction easily tracks the *parallax* of the nearby binary.

Although α Cen A had faded a factor of 50 in the MOS1 frames of early 2005, we see that the primary is clearly visible in HRC-I, and at flux levels not very different from the 1990's, when the system was monitored on a regular basis by *ROSAT*. Had α Cen A suddenly recovered from its deep X-ray lull of only a few months prior, or was something else going on? Fortunately, an LETGS spectrum taken this past June 2007 fully resolved the mystery. And while diehard X-ray spectroscopists baldly assert that spectra are superior to pure imaging for gleaning physical insight, in this case we actually were right.

Figure 11 depicts *Chandra* LETGS spectra of α Cen taken 7.5 years apart. The main panels illustrate the spatially resolved LETGS events, binned into an image combining the plus and minus grating arms. Owing to vignetting, the spectral stripes bloom toward longer wavelengths, and become slightly blended in the more recent LETGS exposure. Nevertheless, the shortwavelength portions of both spectra are cleanly resolved. The A component is the lower stripe in the upper spectrum, and the upper stripe in the lower one, owing to opposite roll angles in the different epochs. He-like and H-like CNO emissions are conspicuous in the 20–40

Å interval, while Fe L-shell features below 20 Å are weak in these relatively cool (1–2 MK) coronal sources. Si, Mg, and Fe M-shell emissions crowd the 40–100 Å interval, and the isolated Fe IX and Fe X lines near 170 Å are very bright. The A and B spectra in the earlier observation (1999.98) are quite similar to one another, and to the 2007.43 trace of the B component. The new A spectrum, however, displays a striking lack of emission below 30 Å (highlighted by blue ovals in both epochs). The upper panel compares normalized effective area curves of MOS,1 (with thick blocking filter: yellow shaded), HRC-I (orange shaded), and LETGS 0th-order (red dot-dashed). Apparently, a sharp decline in the hottest components (>2 MK) of the solar twin's corona had substantially depleted the line spectrum where the *XMM*-Newton response peaks (λ < 30 Å), but the overall coronal luminosity, dominated by longer wavelength ~1 MK emissions, had declined only slightly. In hindsight, this same behavior is seen over the solar magnetic cycle: sunspot maximum is dominated by hot 2–3 MK active regions scattered across the disk, whereas at minimum all that remains is the ubiquitous cool 1 MK basal corona. However, our appreciation of the solar effect in the 0.2–2 kev MOS1 bandpass had been subverted by lack of routine X-ray measurements of the Sun at ~0.5 keV. This is an excellent example of the dark side of the solar-stellar connection informing our understanding of our own star; as well as a specific illustration of the power of spectroscopy to answer riddles posed by low energy resolution imaging; all made possible, of course, by the unique capabilities of *Chandra* itself.

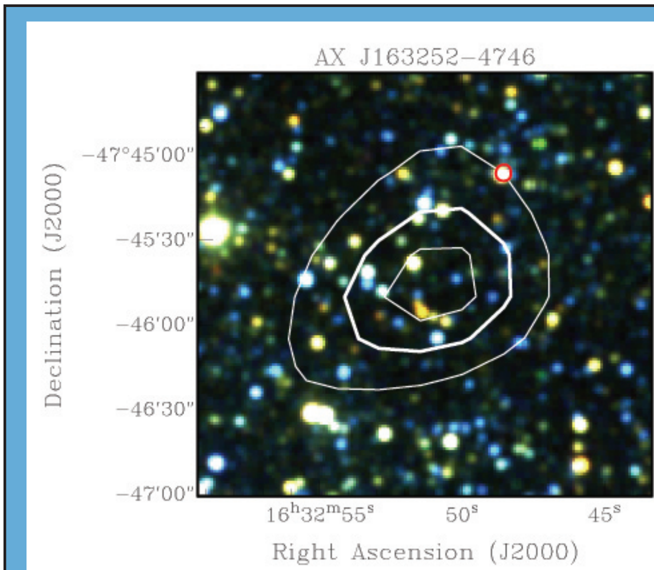


FIGURE 12: Three band 2MASS image (J: blue, H: green, and K: red) of AXJ163751-4656 field with ASCA X-ray contours overlaid. The position of the HRC is shown with the red contours.

ChIcAGO: Chasing the Identification of ASCA Galactic Objects

Gemma Anderson, Bryan Gaensler (University of Sydney), for the ChIcAGO Team

ASCA has surveyed 40 deg^2 of the Galactic plane in the flux range 10^{13} to 10^{11} erg cm^{-2} s^{-1} (Sugizaki et al. 2001), resulting in a catalog of 163 sources. This yields a useful logN - log S distribution of Galactic X-ray sources, but the poor spatial resolution of ASCA (> 1 arcmin positional uncertainty) has left two-thirds of these sources unidentified. For the last few years, we have been using new and archival data to improve this situation, with considerable success. Our recent work has demonstrated that unidentified ASCA sources represent a whole range of interesting objects, including massive stars, magnetars, young supernova remnants (SNRs), pulsar wind nebulae (PWNe) and high mass X-ray binaries (HMXBs). To go beyond this initial sample, we have conceived the ChIcAGO project (Chasing the Identification of ASCA Galactic Objects), in which we are using the sub-arcsecond resolution of the HRC-I and ACIS instruments on *Chandra* to identify >100 unidentified low-latitude ASCA sources caught between the bright and faint distributions that have been the focus of previous investigations. Combined with these existing studies, ChIcAGO will allow us to derive the lifetimes, birth-rates, and spatial distributions of the young populations associated with the life and death of massive stars in the Milky Way.

Beyond the initial X-ray analysis, the key to source identifications is an extensive multi-wavelength campaign. Many of our targets should be readily identifiable with stellar counterparts in DSS, 2MASS and GLIMPSE data. For those sources with optical and infrared counterparts that are obscured or too faint to be seen in the above shallow surveys

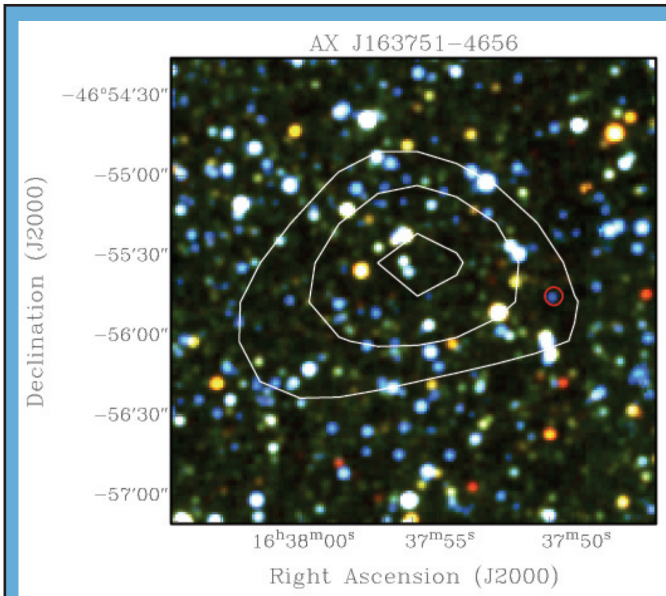


FIGURE 13: Three band 2MASS image (J: blue, H: green, and K: red) of AXJ163751-4656 field with ASCA X-ray contours overlaid. The position of the HRC is shown with the red contours.

we are using Magellan to deeply image the field and obtain spectra, allowing us to identify the X-ray sources.

The technique described above is demonstrated in Figures 12 and 13 for two of the ChIcAGO sources, AX J163751-4656 and AX J163252-4746. The images show 2MASS data (J: blue; H: green; K: red), overlaid with smoothed ASCA GIS observations. The red contours show the one HRC-I source detected in each observation. The exposure times for the observations of AX J163751-4656 and AX J163252-4746 were 1.49 and 2.67 ks respectively, resulting in 100 counts each. These were calculated based on the count rates published in Sugizaki et al. (2001) for each of the 163 sources detected in the ASCA Galactic Plane Survey. It can be seen in both examples that the HRC-I positions are coincident with an infrared counterpart. In both cases the 2MASS data demonstrates how crowded the fields are and how the sub-arcsecond localization capabilities of *Chandra* are necessary to pinpoint the counterpart. Using large telescopes like Magellan we will be able to obtain spectra of the counterparts, ultimately allowing us to identify these ChIcAGO X-ray sources.

Instruments: HETG

David Huenemoerder, for the HETG team

The High Energy Transmission Grating Spectrometer continues to collect wonderful spectra. The cover article of this Newsletter reviews the contributions of HETGS spectra to advances in hot-star astrophysics. Two Cycle 8 large projects - 500ks each - on TW Hya and EX Hya (no relation) are now available in the public archive. Figure 14 shows some of the cumulative combined plus and minus first order spectrum for HEG (black) and MEG (inset, blue). Some prominent lines have been labeled. At the shortest wavelengths (1.4-2.0 Å, or approximately 6-8 keV), we see the H- and He-like lines of iron, as well as cold Fe K fluorescence.

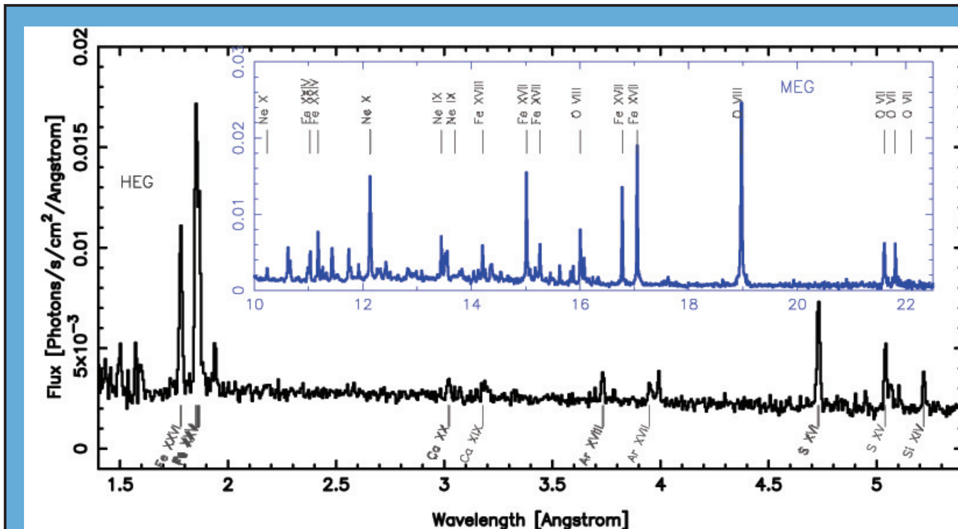


FIGURE 14: The spectrum of EX Hya.

There are no calibration issues with HETGS itself, but there are currently efforts on improved calibration of ACIS when operated in graded and CC modes of data collection. Such improvements will greatly aid analysis of existing X-ray binary spectra. The ACIS contamination continues to be monitored and modeled using, in part, HETGS spectra. Cross-calibration efforts with XMM also continue. Details were presented at the 2007 *Chandra* Calibration Workshop *(http://cxc.harvard.edu/ccw/proceedings/07_proc/index.html)*.

The CXC organized a workshop on "X-ray Grating Spectroscopy" in July, 2007 (*http://cxc.harvard.edu/xgratings07/*). The HETG/CXC team, with substantial input from members of the community, initiated the organization of a special HEAD meeting session on "Science Impacts of High Resolution X-ray Spectroscopy" in March-April, 2008 *(http://www.confcon.com/head2008/)*.

The CXC/HETG team has also begun a project to develop a catalog and archive of all *Chandra* grating data, using experience gained from other catalogs such as the "X-atlas" *(http://cxc.harvard.edu/XATLAS/)* or the XMM/RGS browser, "BiRD" *(http://xmm.esac.esa.int/BiRD/)*. The CXC catalog, "TGCat", will include data taken with HETG/ACIS-S, LETG/HRC-S, and LETG/ACIS-S, will include CC-mode data, and provide responses ("ARFs" and "RMFs") light-curves, background spectra for LETGS, as well as the counts spectra. The web interface will make it easy to browse the observations and spectra, to make it easy to assess data quality and suitability for detailed analysis or for proposal planning. In addition, the portable scripts we used to generate the catalog (using CIAO and S-Lang programs) will be provided to users for custom reprocessing. These scripts will download observations, reprocess events into binned spectra, and also generate responses, light curves, and summary plots, all with minimal interaction (for standard cases). Some "complicated" data sets will be custom processed and made available in the archive, such as combined extractions of multiple observations (like Capella or some Orion stars) or of extended sources. An important part of the on-line catalog will be community feedback, and we welcome suggestions and criticism. A URL and contact scientist will be distributed when the baseline catalog is available (tentatively, Summer 2008). ✭

Instruments: LETG

Brad Wargelin, for the LETG Team

(The author wishes to acknowledge his status as a poor last-minute stand-in for the usual LETG composer, Jeremy Drake, who will return in the next issue. This has nothing to do, so far as I know, with the recent and equally lamented Writers Guild of America strike.)

As noted in previous newsletters, the HRC-S gain has been slowly but steadily decreasing over the past several years. So far, this has had no detectable effect on detector quantum efficiency (QE), although there is an unrelated and energy independent decrease of about 5% in QE since launch caused by charge extraction, mostly from background events which comprise the vast majority of detected events.

The gain decline does, however, have some impact on LETG performance via pulse height filtering. Although the intrinsic energy resolution of the HRC-S is quite poor (a difference of less than 40% in signal strength for X-rays differing by a factor of 10 in energy), it is sufficient to provide significant discrimination between X-ray and background events, particularly at long wavelengths. In order to characterize X-ray pulse height distributions and measure detector gain as a function of position, laboratory data were collected by the HRC instrument team at several X-ray energies ranging from B-K (183 eV) to Fe-K (6.4 keV) before launch. These data later allowed the construction of a gain map for the HRC-S and an associated pulse-height filter for the LETG/HRC-S combination, based on the expected pulse height for a grating-dispersed (known-energy) X-ray event. Background reductions of 50-65% are obtained with the loss of less than 1% of valid X-ray events.

The first gain map and filter were created in 2000, when the flight gain of the HRC-S was about 10% higher than the lab gain. Since then the gain has decreased to roughly 30% lower than the lab gain (see Figure 15). Because of the conservative tuning of the filter, there's been negligible change in background rejection efficiency and X-ray loss

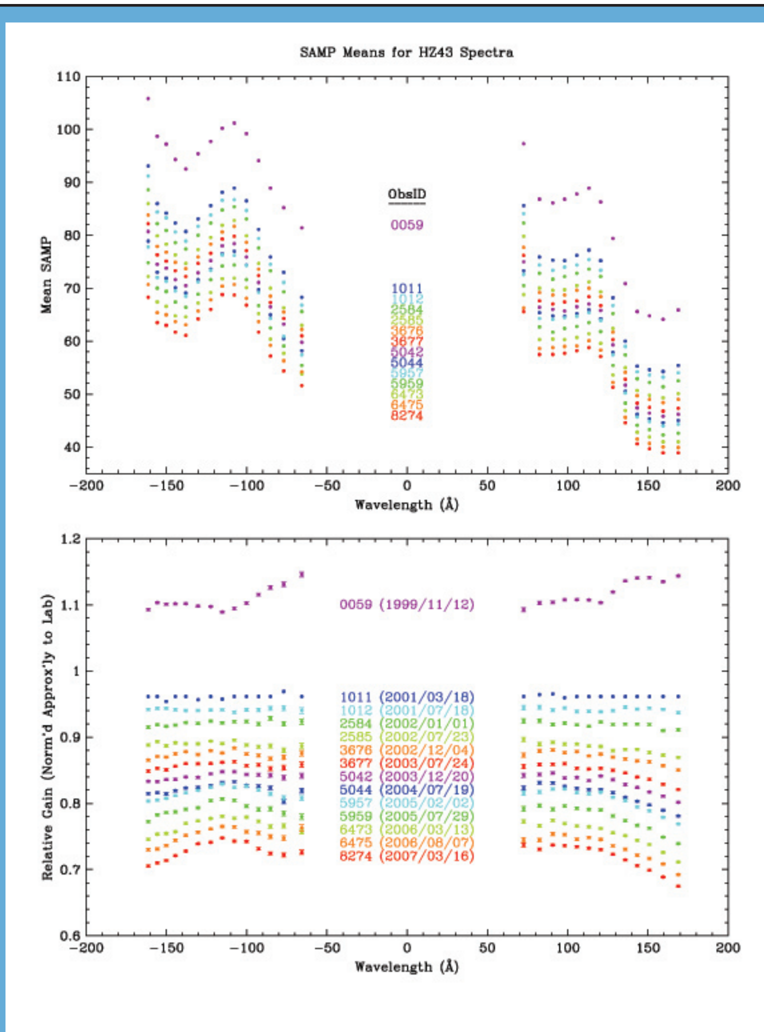


FIGURE 15: Mean pulse-height values (SAMP) from wavelength intervals of HZ43 spectra observed by LETG/HRC-S. Data from PKS2155-304 are being analyzed to calibrate the time dependence of HRC-S gain on the central plate. Top panel illustrates the large variation in gain across the detector. Results in the bottom panel have been roughly normalized to the laboratory gain.

fraction, but the desirability of an updated gain map and filter has been growing, particularly given improvements in our understanding of HRC-S event pulse heights.

Work on the new gain map and filter, both of which will be time dependent, is well underway. The first step was to reanalyze the lab data on finer spatial scales and using a different pulse-height metric. The usual measure of an event's signal strength is its Pulse Height Amplitude (PHA), but the original PHA-based gain map has large variations on small scales (up to 25% in 1/2-tap steps). A different measure is the "scaled SUMAMPS" amplitude, which sums the six position signals (au1-au3 and av1-av3 in the .evt1 file) and scales that by a factor based on the event amplitude scaling factor (amp_sf) value.

The result is called "SAMP"; "SCAMP" seemed a little too cute, but we can still be swayed by public opinion. The intrinsic SAMP signal strength is about 90% that of PHA, and because it is based on electrical signals from only the 6 taps surrounding an event instead of signals from the entire plate that is triggered by the event (as for PHA), it excludes most of the noise that seems to be affecting the PHA signal. Comparisons of lab results based on PHA and SAMP are shown in Figure 16. As can be seen, the SAMP results are much smoother and give a better indication of the true gain of the detector, which should permit more effective filtering.

Based on the lab results (collected at 4 or 8 energies, depending on which plate), the SAMP mean is approximately proportional to the log of the X-ray energy. After applying some relatively small semi-empirical adjustments to account for secondary electron yield, we can therefore model the SAMP mean position as a continuous function of photon energy.

The next step is to adapt the laboratory gain map

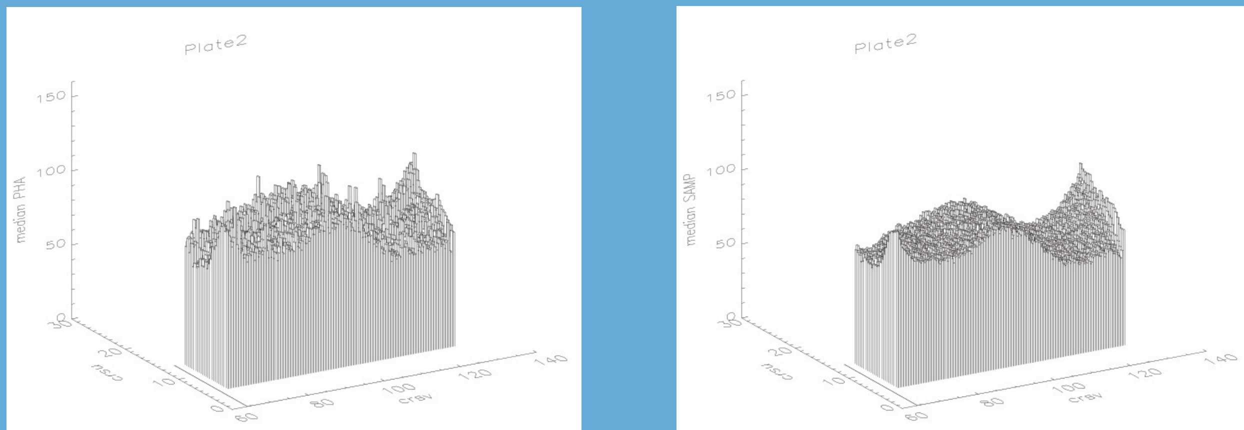


FIGURE 16: Surface plots for the HRC-S center plate comparing mean PHA and SAMP values from the C-K laboratory data, with 1/3-tap grid. The SAMP results vary much more smoothly and will allow better gain calibration and more effective pulse-height filtering of LETG/HRC-S data.

to reflect the gain of the HRC-S in orbit as a function of time. LETG/HRC-S data from monitoring observations of HZ43, a white dwarf and supremely stable soft X-ray source, have been analyzed to calibrate relative gain at long wavelengths (on the two outer plates). Data from the blazar, PKS2155-304, a harder and not-too-wildly varying source, are being analyzed to cover the central plate, with some overlap on the outer plates.

The final step is to apply the resulting time-dependent gain maps to flight data (again, mostly from HZ43 and PKS2155, with spot checks from bright line sources such as Capella and RS Oph in outburst) and determine the range of SAMP values as a function of dispersed wavelength that optimizes LETG spectral filtering. With a better behaved pulse-height metric, and calibrated time dependence of the gain, our goal is to obtain 75% background rejection at wavelengths longer than 100 Å (and at least 60% at shorter wavelengths) with less than a 2% loss of the X-ray signal. "When?!" you ask, with barely contained excitement. With a little luck, this summer. If not, Jeremy will be happy to explain why in the next newsletter. ✭

Chandra-Related Meetings Planned for This Year

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

Radio Galaxies in the *Chandra* Era
8-11 July, 2008
Cambridge, MA
http://cxc.harvard.edu/radiogals08/

Chandra Fellows Symposium
October 17, 2008
Cambridge, MA
http://cxc.harvard.edu/fellows/

Chandra Calibration

Larry David

ACIS

A complete set of cti-corrected calibration products for all 10 ACIS chips was released in CALDB 3.3 on Dec. 18, 2006. These products only apply to data taken in timed event (TE) mode with a telemetry format of faint (F) or very faint (VF) and with a focal plane temperature of -120 C (the ACIS operating temperature since Jan. 2000). These data account for the bulk of ACIS data taken since launch.

Since the release of CALDB 3.3, most of the ACIS calibration efforts have centered on developing a set of cti-corrected calibration products for data taken in TE graded mode and continuous clocking (CC) mode. Data taken in graded mode cannot be cti-corrected in the same manor as data taken in F or VF mode, since only the flight event grade is telemetered and not the 3 by 3 (in F mode) or 5 by 5 (in VF mode) distribution of charge around each event. The flight event grades run from 1 to 256 which are binned into the 7 ASCA grades during pipe-line processing.

The analysis of a large set of ground calibration and in-flight data showed that the flight grades are actually a very good proxy for the 3 by 3 charge distribution around an event. Thus, the flight grade alone can be used to accurately estimate the charge distribution around an event and the data can then be cti-corrected in the same manor as F or VF data. A newly developed cti-correction algorithm for graded mode data has been extensively tested with data from the ACIS external calibration source as well as several astronomical sources, in particular, the oxygen rich supernova remnant E0102-72. The 1 σ residuals in the gain of cti-corrected TE graded mode data are 0.3%, and are nearly independent of location on the chips, date of the observation and photon energy.

With the addition of these new calibration products, the 1 σ residuals in the gain of cti-corrected data taken in TE mode and any telemetry format are now 0.3%. The gain on all ACIS chips continues to be calibrated in 3 month intervals by co-adding data from the ACIS external calibration source which is acquired before and after each perigee pass. No changes to the ACIS QE have been made over the past year. The application of the TE graded mode cti-corrected calibration products to ACIS data requires some modifications to the CIAO task acis_process_events which are under development.

In addition, the set of ACIS blank sky observations were reprocessed with the latest calibration products (i.e., the cti-corrected products for TE mode data taken in V or VF telemetry format) in May 2007 and released to the public in CALDB 3.4.1.

HRC

An HRC-I raster scan of ArLac is carried out every six months to a year to monitor the gain of the HRC-I. These raster scans show that the HRC-I gain has decreased by about 20% since launch at the aim point and by lesser amounts farther off-axis. An updated set of gain correction files for the HRC-I (one for each year) was released in CALDB 3.4 in May 2007. For data acquired since May 2007, the pipe-line processing automatically applies the appropriate gain corrections. For data processed earlier than May 2007, users can apply the updated gain corrections using the CIAO tool hrc_process_events. After applying the time-dependent gain corrections, users can then generate energy-invariant hardness ratio images for any HRC-I observation. The HRC-I gain corrections are discussed in more detail in Posson-Brown & Kashyap (2007,Proc. SPIE, V6686, 66860V). A set of finer spatial scale time-dependent gain correction files (one for each year) is under development for the HRC-S. These calibration products will improve background filtering of LETG/HRC-S data.

Two HRC-I raster scans of Capella have been carried out over the past two years for a total of 40 pointings. These data have been used to update the HRC-I de-gap table, which is used for image reconstruction. The updated de-gap table was released in 3.4.1 in Sept., 2007. The use of the new-gap table improves the astrometry on the outer regions of the HRC-I. These raster scans of Capella also show that the QE uniformity (QEU) map of the HRC-I is presently calibrated to within 2% across the entire detector. There is also an on-going study to cross-calibrate the HRC-I and HRC-S. The initial results of this study show that the absolute effective areas of these two detectors agree to within 10%.

Chandra Calibration Workshop

Vinay Kashyap, Jennifer Posson-Brown

Chandra has a justified reputation as one of the best calibrated telescopes around. In many subsystems, the design goals have been met, and sometimes exceeded (*http://cxc.harvard.edu/cal/*). And the continuing accumulation of flight data, coupled with the treasure trove of ground calibration data, has allowed us to understand *Chandra*'s detectors and mirrors better than ever before. This understanding is publicized via the web pages of the Calibration group as well as through updates to the CALDB (*http://cxc.harvard.edu/caldb/*).

In addition, the *Chandra* Calibration Workshops (CCW) provide a venue for sharing the latest information on ongoing investigations with the high-energy astrophysics community. For the past couple of cycles, the CCW has been paired with the biennial *Chandra* Symposia, so that the dissemination of calibration information is maximized. This time, it was held at Huntsville, AL, at the conclusion of the Eight Years of *Chandra* symposium, on 25 Oct 2007. All CCW presenters were offered the opportunity to further publicize their work as posters during the Symposium, and more than 90% availed themselves of it. We believe that it is perhaps safe to suggest that perchance it was possibly a somewhat popular scheme, maybe. Yeah. We thank the organizers of the Symposium for all the help they gave us, and which led to a seamless integration of the CCW with the Symposium.

The workshop was well attended, and went off without a hitch. A standing room only crowd listened with rapt attention through a poster haiku session and two long session of talks. Topics covered ranged from ACIS (bias maps, CTI corrections, effective areas, CC mode, contamination), to HRC (gain maps, background, QE uniformity), to XMM cross-calibration, and to the somewhat meta topic of how to figure out the error on the errors of fit parameters.

The presentations are available online now at the CCW web site: *http://cxc.harvard.edu/ccw/proceedings/07_proc/* . Proceedings from earlier workshops are also available at the same place. In order to make the site more accessible, we are tagging all presentations and generating a tagging index, available at: *http://cxc.harvard.edu/ccw/tags/* . If you have suggestions for specific tags for any presentation, please send us an email. When complete, we fully expect this supercalifragilisticexplicatedocial tagged index to completely outshine Google.

Prospects and Perspective: *Chandra* in the Future

Sabina Bucher

As *Chandra* approaches nine years of successful science operations the Flight Operations Team is looking to the future. The team has completed a detailed study of the factors that will influence the capability of the spacecraft to support a 15-year mission. The principal contributing factors are *Chandra*'s orbit, the vehicle health and the science-return from the mission. In this article, we present a summary of the findings of the 15-year study in each of these areas.

Orbit

Chandra's orbit is always evolving. During the first seven years of the mission the inclination of the orbit increased, tipping the orbit up toward the poles, the eccentricity decreased, making the orbit more circular, and the altitude at perigee increased. While the inclination will continue to increase through 2015, the eccentricity and altitude of perigee have turned around. Through 2012 the orbit will grow increasingly elongated and the altitude at perigee will decrease (see Figure 17), crossing the lowest value experienced to date in 2010. Changes in the orbit will not prevent a 15-year *Chandra* mission; they will, however, bring some challenges.

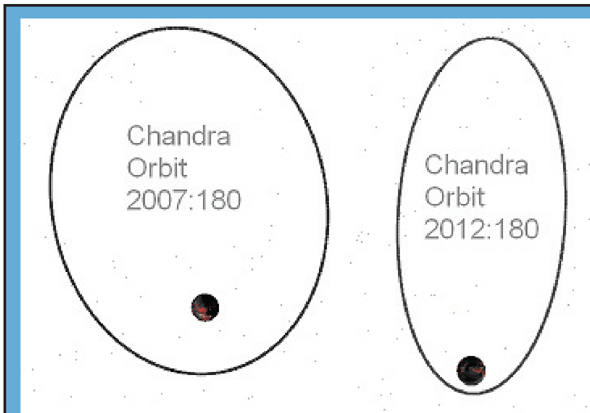


FIGURE 17: Changing shape of the *Chandra* orbit

A summary of findings from analysis of the 15-year orbit is provided below:

- **Eclipse Times**
  - * All eclipses will be well within the capabilities of the vehicle
  - * Eclipse seasons will get longer, but will not impact observing time
- **Communications**
  - * Largely unchanged, no observing impact
  - * Some reduction in redundancy of coverage
- **Radiation Zones**
  - * Low perigee altitude and increasing inclination will change radiation environment in the radiation zone
  - * Potential to gain science time every orbit
- **Perigee Attitude Planning**
  - * Low perigee altitude will cause increased gravity gradient torques, which, unaccounted for, can lead to high system angular momentum. Mitigation plans are underway and *Chandra*'s safing system will prevent hardware damage, should the momentum reach elevated levels.
  - * Low perigee altitude and changing radiation zones will reduce flexibility in attitude selection through perigee
  - * Reduced flexibility through radiation zones may reduce ability to prepare for some types of observations. Benefits from constraint management activities (see Science Return section) should mitigate this potential impact.

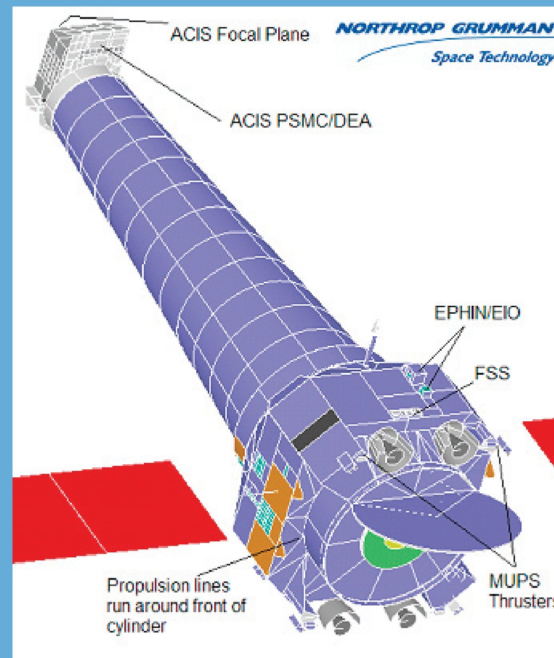


FIGURE 18: Schematic of the *Chandra* spacecraft showing units with thermal constraints or concerns

Vehicle Health

The *Chandra* spacecraft is in remarkably good condition for a vehicle eight years into its mission. To date, there have been no unit failures that impact the capabilities of the mission. On vendor recommendation, one gyro was powered down to preserve its functionality for contingency operations; however, multiple layers of redundancy remain. There are no current hardware issues that pose undue risk to the prospects of a fifteen year mission.

The remaining spacecraft health issues relate to thermal conditions and trends. The protective thermal surfaces on the -Z-side (sun side) of the spacecraft have been slowly degrading over the mission. Such degradation was anticipated pre-launch, but the rate has been higher than expected. It is expected that the degradation will continue, but that the rate will slow.

As the passive thermal controls degrade, components on the sun side of the vehicle are increasingly impacted by solar heating. Scheduling constraints have been imposed to reduce the exposure of certain

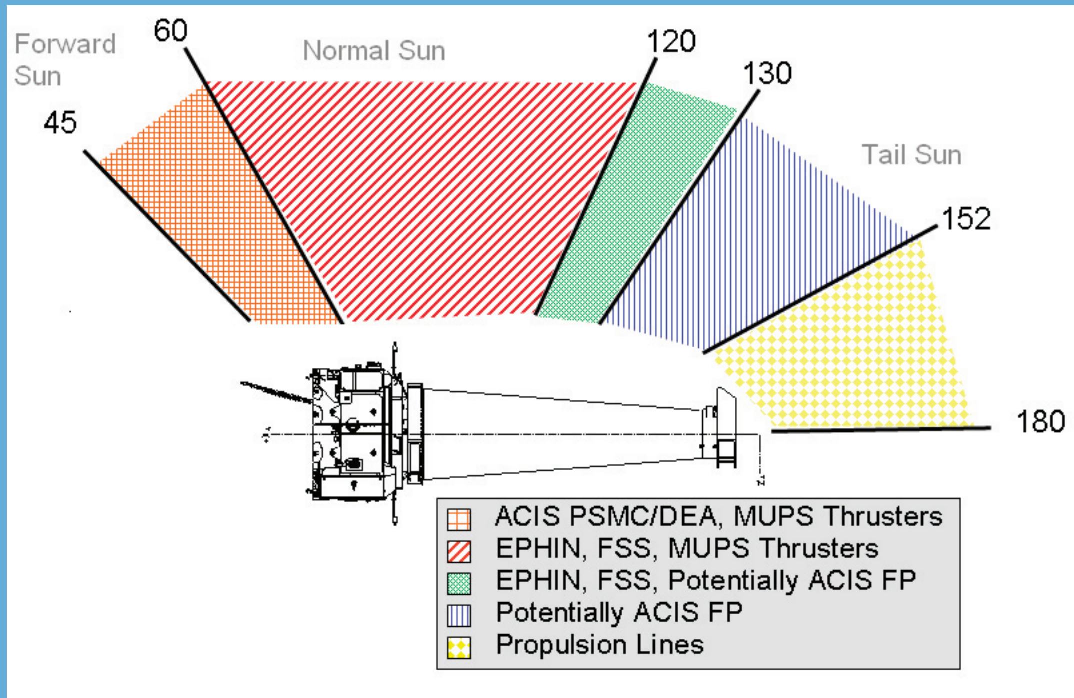


Figure 19: Summary of thermal constraints and concerns by pitch region

units to extreme temperatures. Figures 18 and 19 show the components that have current thermal concerns and the pitch regions impacted by them. It is anticipated that scheduling constraints will continue to mitigate most -Z-side heating effects. There are three notable exceptions: (1) the time constant of the Fine Sun Sensor (FSS), used only in safing modes, is too fast for scheduling constraints to feasibly limit temperatures; (2) the temperature of the ACIS Focal Plane could be mitigated through scheduling constraints, but alternative mitigations are being investigated first; (3) the restrictions required to keep the temperatures of the EPHIN radiation detector and its electronics (EIO) within limits have been relaxed to increase scheduling flexibility. Based on vendor input, it is fully expected that the FSS will operate above the currently established operational limits. However, since it is part of the spacecraft safing system, preparations for increased performance monitoring and for operations without it are underway. EPHIN is currently operating acceptably at elevated temperatures, but some performance impacts have been observed when the unit is at high temperatures. The Flight Software has been modified such that, in the event that EPHIN fails, the HRC can be used as a radiation detector. Losing EPHIN would not be without cost, but the mission can continue successfully without it. Thermal issues will continue to impact scheduling and engineering effort, but there are currently no vehicle health concerns that jeopardize the on-going mission.

Science Return

There are many factors that influence the science return of the mission, too many to discuss in a single article. However, one, the ability to schedule observations, is a direct result of the orbit and vehicle health. Observation scheduling is governed by a set of constraints, which are used to protect the vehicle and to ensure each observation is scheduled for maximum science quality. Constraints come from three sources, the design of the vehicle, observation requests, and vehicle aging. With multiple sources for constraints, it is not hard to imagine that the scheduling problem could become over-constrained. This occurred in late 2004, when efforts to protect EPHIN and the propulsion lines forced splitting observations into pieces with large maneuvers between them.

There are two metrics used to measure scheduling ability: (1) the ability to schedule any one observation (target availability); (2) the percentage of time used for science observations (scheduling efficiency). Both suffered in late 2004. The decline in scheduling ability prompted cross-team analysis and discussion, which led to relaxation of the EPHIN temperature limits, which, in turn, allowed scheduling ability to recover. The cross-team group that led the EPHIN constraint relaxation was a precursor to a new constraint management working group, whose mission is to minimize the impact of constraints while protecting the safety of the vehicle. Since 2005, the group has been actively and effectively managing constraints and optimizing scheduling, which has kept scheduling efficiency near early mission values.

As part of the on-going constraint management effort, models were used to predict impacts of constraints through 2015. Figure 20 shows the maximum allowed dwell times by pitch angle over time, assuming current trends. The allowed dwell time is the maximum allowed duration for any observation or series of observations. Notice that the bowl around 90 degrees pitch gets deeper and wider, which will force splitting observations into pieces, driving down both target availability and schedule efficiency. The decrease in allowable dwell time can be mitigated through relaxing the EPHIN constraint further. Under the watch of the constraint working group, a relaxation plan has been put into motion. Figures 21 and 22 show the allowed dwell times with

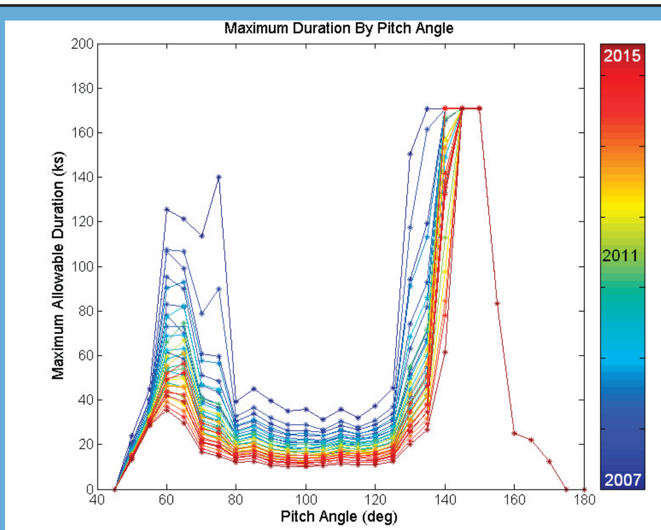


FIGURE 20: Maximum allowed duration for observations or series of observations at a given pitch angle. Assumes best case starting conditions for every attitude, no constraint relaxations through 2015 and 6 ACIS chips clocking.

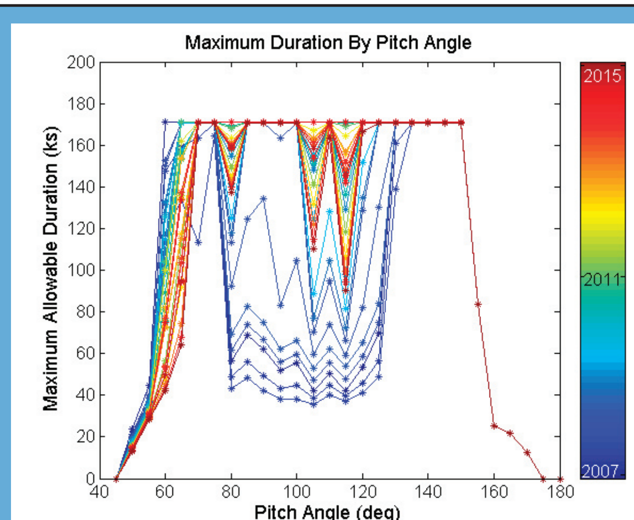


FIGURE 21: Maximum allowed duration for observations or series of observations at a given pitch angle. Assumes best case starting conditions for every attitude, relaxation of the EPHIN constraint by 2 deg F every 3 months, to a maximum of 140 deg F, and 6 ACIS chips clocking.

the EPHIN constraint relaxation plan in place. While there will continue to be duration limits during the hot season, the impact of thermal constraints will be dramatically reduced over the coming years.

Summary

The *Chandra* orbit, the spacecraft health and observation scheduling ability are all well positioned to support a 15-year mission. The spacecraft hardware is in remarkably good condition, with no current failures that impact capability. Orbital changes and evolving constraints will bring challenges and operational changes, but are not expected to significantly impact a 15-year mission. Finally, reduced time in the radiation zones and active constraint management are expected to improve scheduling capabilities as *Chandra* continues its scientific mission in future years.

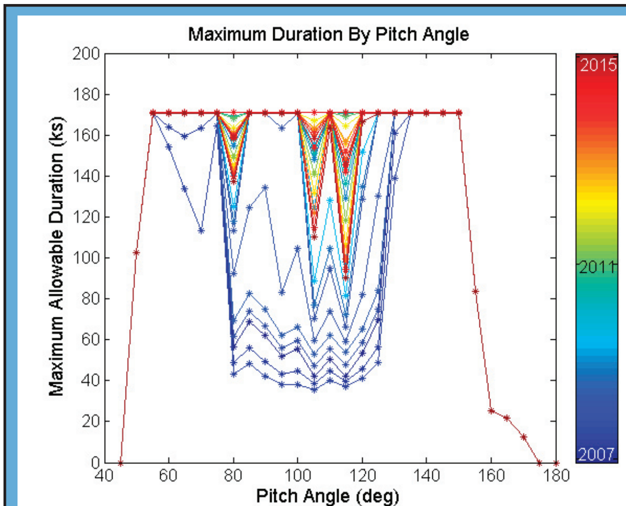


FIGURE 22: Maximum allowed duration for observations or series of observations at a given pitch angle. Assumes best case starting conditions for every attitude, relaxation of the EPHIN constraint by 2 deg F every 3 months, to a maximum of 140 deg F, and 4 or fewer ACIS chips clocking.

Chandra Important Dates 2008

Cycle 10 Proposals Due
March 20, 2008
Users' Committee Meeting
April 9-10, 2008
Cycle 10 Peer Review
June 17-20, 2008
Workshop: Radio Galaxies in the *Chandra* Era
July 8-11, 2008
Cycle 10 Budgets Due
September 18, 2008
Cycle 10 EPO Electronic Deadline
October 24, 2008
Cycle 10 EPO Hardcopy Deadline
October 29, 2008
Chandra Fellows Symposium
October 17, 2008
User's Committee Meeting
Fall, 2008
Chandra Fellowship Applications Due
Oct/Nov, 2008
Cycle 10 EPO Review
December, 2008
Cycle 10 Observations Start
December, 2008
Cycle 11 Call for Proposals
December 2008

New ObsVis Functionality!

Paul Green

The ObsVis tool for high-fidelity flexible display of *Chandra* instrument fields-of-view (FoVs) on sky images has been significantly revised and upgraded, and its integration with the ds9 image display tool improved. ObsVis allows for the manipulation of the FoVs in a variety of ways, including adjusting the roll angle, adjusting the X, Y and SIM-Z offsets, and grouping FoVs together. The initial ObsVIs release in CIAO4 was superceded in February 2008 by a release CIAO4.0.1 that also generates grids of FoVs for planning of "mosaic" or "raster" observations designed to cover large contiguous sky regions. A simple grid example is shown in this DSSII (R band) sky image of M31 (Fig. 23). The grid was generated (Fig. 24) simply by typing M31 into the ObsVis Target Name box, and specifying a 2x3 grid of ACIS-I at Roll Angle 45deg and default spacing 15arcmin. Grid FoVs are grouped by default, and the grid ensemble can moved or rotated, or individual FoVs within the grid can also be manipulated. The FoVs can be saved for later reload into ObsVis.

Please note that the nominal roll/visibility/pitch plots for a given target position that were once packaged as part of ObsVis are now found only at http://obsvis.harvard.edu.

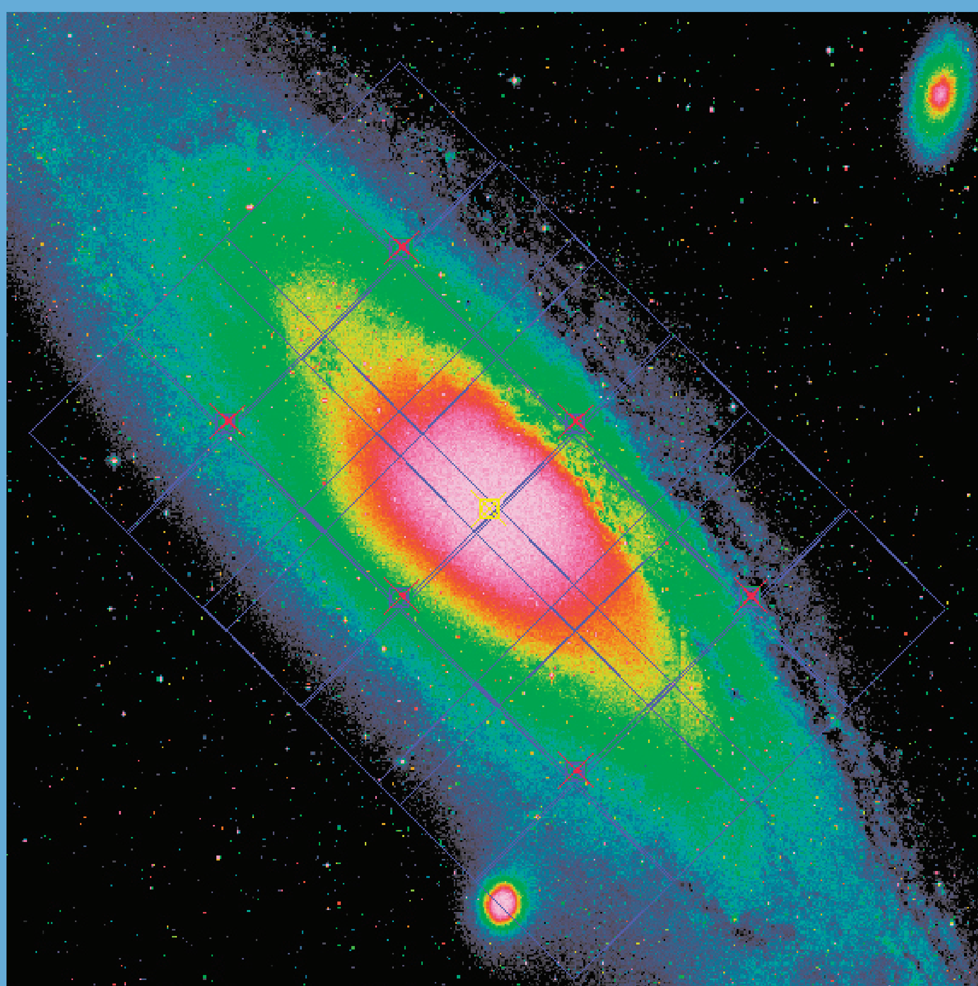


FIGURE 23: A simple ObsVis example of a grid is shown in this DSSII (R band) sky image of M31.

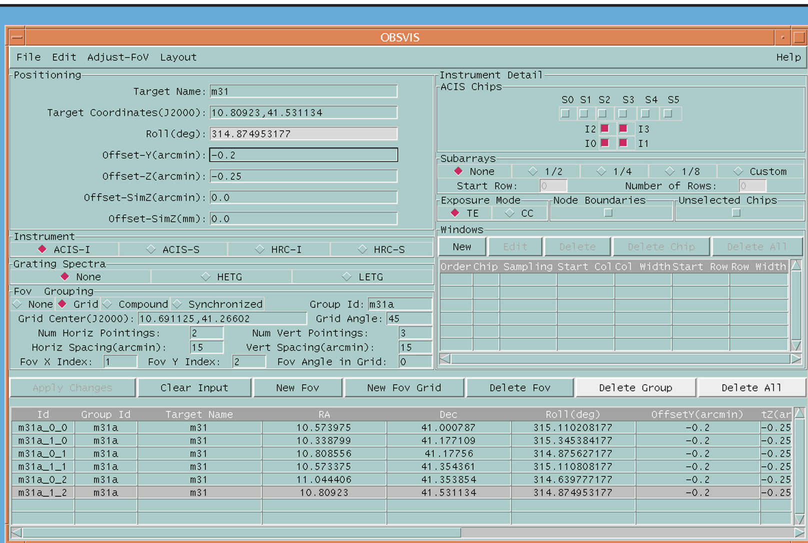


FIGURE 24: Providing input to the ObsVis Target Name box

CXC 2007 *Science* Press Releases

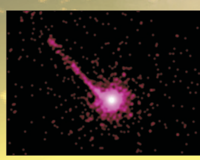
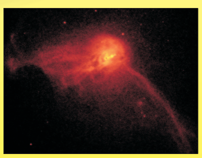
Megan Watzke

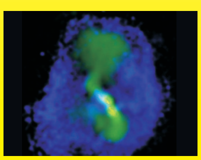
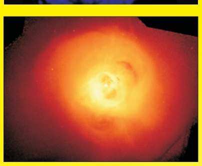
Date	PI	Objects	Title
01-04-2007	Kazimierz Borkowski	DEM L238, DEM L249	X-ray Evidence Supports Possible New Class of Supernova
01-10-2007	Michael Muno	Sgr A*	*Chandra* Discovers Light Echo from Milky Way's Black Hole
03-12-2007	Ryan Hickox	Bootes Field	New Panorama Reveals More Than a Thousand Black Holes
04-12-2007	Guido Risaliti	NGC 1365	*Chandra* Sees Remarkable Eclipse of Black Hole
05-07-2007	Nathan Smith	SN 2006gy	NASA's *Chandra* Sees Brightest Supernova Ever
05-30-2007	Ralph Kraft	3C438	Galaxy Cluster Takes It to the Extreme
06-27-2007	Sebastian Heinz	Circinus X-1	Neutron Star Joins the Black Hole Set
07-24-2007	Jason Eastman	CL 0542-4100, CL 0848.6+4453	*Chandra* Catches Piranha Black Holes
08-16-2007	Andisheh Mahdavi	Abell 520	Dark Matter Mystery Deepens in Cosmic Train Wreck
09-20-2007	Ming Sun	Abell 3627	Orphan Stars Found in Long Galaxy Tail
10-17-2007	Jerome Orosz	M33 X-7	Heaviest Stellar Black Hole Discovered in Nearby Galaxy
10-23-2007	Sangwook Park	G292.0+1.8	Stellar Forensics with Striking Image from *Chandra*
11-28-2007	Frank Winkler	Puppis A	*Chandra* Discovers Cosmic Cannonball
12-17-2007	Dan Evans	3C321	Black Hole Fires at Neighboring Galaxy

Radio Galaxies in the Chandra Era

Hosted by the Chandra X-ray Center
Cambridge, Massachusetts July 8-11, 2008

Registration and Abstract Submission Deadline:
April 30 (talks and posters)
May 21 (posters only)


Workshop Goals:

Chandra has profoundly influenced our understanding of a wide range of astrophysical phenomena, but one area in which Chandra's influence has arguably been the greatest is in the study of radio galaxies and radio loud quasars.

The superb angular resolution of Chandra permits the multicomponent emission from radio galaxies to be spatially separated and has given us insights into the accretion and outflow processes. In many cases, however, the wealth of new data has provoked more questions than answers. This conference will highlight both theoretical and observational studies of all aspects of radio galaxies including nuclei, jets, lobes, hot spots, and interactions with the ambient medium.

The goals are to bring together a diverse group of researchers to present the latest results and discuss the outstanding problems in radio galaxy physics, and best decide how to use the unique capabilities of Chandra going forward to resolve the outstanding issues.

Scientific Organizing Committee:

Chairs: Ralph Kraft and Aneta Siemiginowska
Elizabeth Blanton (BU)
Geoff Bicknell (Stromlo)
Annalisa Celotti (SISSA)
Jean Eilek (NRAO/NMIMT)
Dan Evans (Harvard)
Heino Falcke (Radboud)
Paul Green (SAO)
Martin Hardcastle (Hertfordshire)
Dan Harris (SAO)
Sebastian Heinz (UWisc)
Jun Kataoka (TokyoTech)
Herman Marshall (MIT)
Paul Nulsen (SAO)
Chris Reynolds (UMd)
Jeremy Sanders (IoA)
Dan Schwartz (SAO)
Marek Sikora (CAMK, Warsaw)

Local Organizing Committee
Paul Green (Chair)
Kathlyne Jean, Cathy Oskin,
Lisa Paton, Su Tuttle

Contact: radiogals08@cfa.harvard.edu

http://cxc.harvard.edu/radiogals08

CIAO 4.0 Overview

Elizabeth Galle
for the CIAO development team

The *Chandra* X-Ray Center introduced version 4.0 of the *Chandra* Interactive Analysis of Observations (CIAO) software package on 14 December 2007. A small patch version 4.0.1 was released on February 22, 2008.

CALDB version 3.4.2 was also released on 14 December 2007. CALDB 3.4.0 or higher is required for the proper operation of CIAO 4.0.

Everything is available for download from the CIAO website: *http://cxc.harvard.edu/ciao/download/* . The CXC is committed to helping users transition to new syntax as smoothly as possible. If you have existing ChiPS or Sherpa scripts or save files, submit them to us via the CXC Helpdesk as we will provide the CIAO 4.0 syntax to you.

Overview

CIAO 4.0 is a full installation of the CIAO software. It contains all the enhancements and bug fixes since CIAO 3.4, including those which were made available in the 4.0 Beta releases.

Since CIAO 4.0 is a major release with several new packages and applications, the CXC will continue to support CIAO 3.4 for the near future. *We suggest that users who install CIAO 4.0 keep the CIAO 3.4 installation available as well.*

Read the "Why should I keep the CIAO 3.4 installation on my system now that CIAO 4.0 is released?" page for more information: *http://cxc.harvard.edu/ciao/faq/keep_ciao34.html*. In brief, both ChIPS and Sherpa have been re-written, which means that the syntax and the language have changed since CIAO 3.4. Some time and effort will be required by users to learn the new system.

ACIS Dead Area Calibration

The most notable change to the CIAO tools in version 4.0 is that the ACIS dead area correction is turned on by default. For complete details on the dead area correction, read the ACIS Dead Area Correction why topic: *http://cxc.harvard.edu/ciao/why/acisdeadarea.html*.

The following CIAO response tools and scripts can apply the dead area correction: mkarf, mkinstmap, mkgarf, mkwarf, specextract, fullgarf, psextract, and acisspec. This change requires the use of an additional data product, the parameter block file (pbk0.fits), when running these tools.

If you have an analysis in progress and do not want to apply the dead area correction, it is possible to "turn off" the correction. To do so, set the dafile parameter to "NONE" and leave the pbkfile parameter blank. For example:

```
unix% pset mkgarf pbkfile="" dafile=NONE
```

Tools and Data Model

There is a new version of tgextract - named tgextract2 - which provides similar functionality, but allows large and asymmetric regions for better determination of background counts. Significant work has been done on the tool wavdetect, which has two new parameters. The sso_freeze tool has been enhanced so that it can create object-centered aspect solutions which allows an object-centered exposure map to be generated. A number of bug fixes to the Data Model library and several CIAO tools are also included.

The Data Model library now supports an ASCII kernel. This kernel allows users to generate ASCII format files for use within Data Model enabled tools (e.g. dmlist, dmcopy), and apply the suite of Data Model capabilities to those files via its extended filename syntax. The ASCII kernel is considered beta for this release. The "Using ASCII Files in CIAO" thread gives an introduction to the new functionality: *http://cxc.harvard.edu/ciao/threads/dmascii_basic/* .

Parameter Files

The CIAO 4.0 software establishes a separate local parameter file directory, ~/cxcds_param4. This allows users to run both CIAO 3.4 and CIAO 4.0 without having to worry about parameter file conflicts.

ChIPS: the CIAO plotting package

The CIAO 4.0 release includes a new, more powerful version of ChIPS, the CIAO plotting pack-

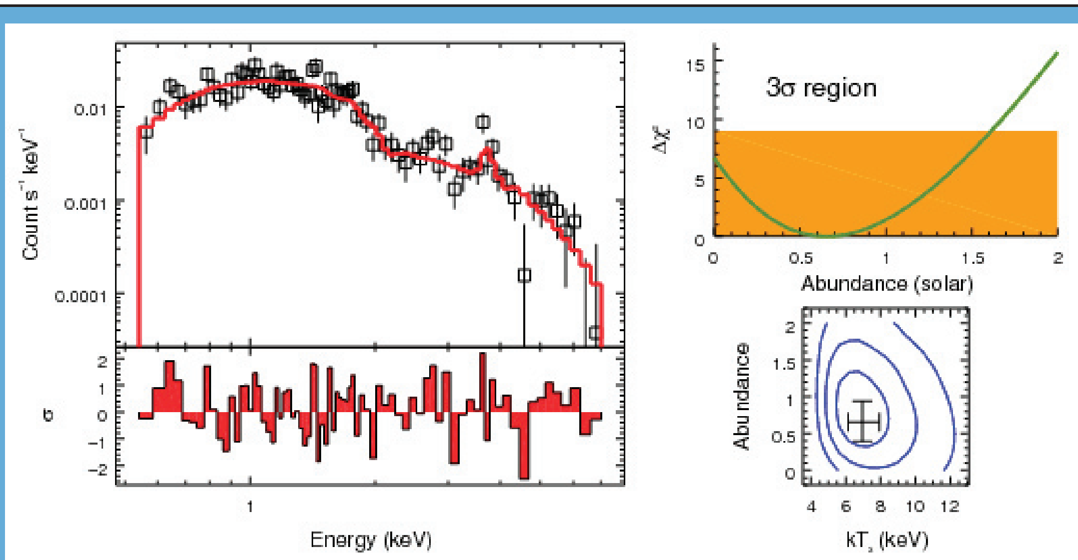


FIGURE 25: Some examples from the new ChIPS plotting package.

age. It can be used during data analysis - e.g. to plot a lightcurve - and to create publication-quality figures. Details and documentation on the new system is available from the ChIPS website: *http://cxc.harvard.edu/chips/* . Examples are provided in Figure 25.

Sherpa: the CIAO modeling and fitting package

This release also features an experimental (beta) version of the new Sherpa, the CIAO modeling and fitting package. Sherpa enables the user to construct complex models from simple definitions and fit those models to data, using a variety of statistics and optimization methods.

Sherpa is designed for use in a variety of modes: as a user-interactive application and in batch mode. Sherpa is an importable module for scripting languages (Python or S-Lang) and is available as a C/C++ library for software developers. In addition, users may write their own Python and S-Lang scripts for use in Sherpa.

Details and documentation on the new system are available from the Sherpa website: *http://cxc.harvard.edu/sherpabeta/* .

Since this is the initial phase of the Sherpa redesign, not all of the functionality of the CIAO 3.4 version is implemented yet. The "About the Sherpa Beta Release" page outlines new features and provides a summary of missing items: *http://cxc.harvard.edu/sherpabeta/about.html*.

Infrastructure

For information on CIAO 4.0 infrastructure changes, see the article "CIAO 4 Infrastructure - Moving in a Modular Direction" in this issue.

CIAO 4 Infrastructure – Moving in a Modular Direction

Janet DePonte Evans, Mark Cresitello-Dittmar, Stephen Doe, Ian N. Evans, Gregg Germain, Kenny Glotfelty, James Overly

Introduction

In December 2007, we released the CIAO (*Chandra* Interactive Analysis of Observations) version 4.0 software package. The CIAO package includes tools and applications for users to further analyze data received from standard data processing (SDP) or downloaded from the *Chandra* Data Archive.

CIAO 4.0 is ported to several Unix-based platforms: Sun/Solaris, several flavors of Linux, and Mac OS X (PPC and Intel). The package consists of approximately 85 individual tools for scientific calibration and data analysis, user libraries, and 4 major software applications that include Sherpa (a spectral and spatial fitting package), ChIPS (a plotting package), Prism (a data access and display application), and ObsVis (an observation visualizer for proposal planning).

Major features include a calibration database interface library, coordinate system and regions libraries, and the Data Model (DM) library. The latter provides an abstract description of a generic astronomical dataset that gives the application writer a file-format independent interface to the data, and provides the user with advanced virtual file and filtering operations.

The New Face of CIAO

With a strong functional base for *Chandra* data analysis, CIAO 4.0 plans centered on infrastructure upgrades as the focus of the release. GNU Public License (GPL) compliance, scripting interface improvements, package independence, upgraded off-the-shelf (OTS) packages, updated operating system support, and performance enhancements were included in the list of drivers. Our aim was to build a cohesive, independent, and more modern system.

One of the major updates included in CIAO 4.0 is a new, substantially more capable version of the ChIPS plotting package. We have replaced the proprietary plotting engine with the Visualization Toolkit (VTK). Users have fine control over the graphical display, including setting colors, changing font styles, and repositioning objects. Object attributes can be changed at any time during the session, and the change is immediately visible. The ChIPS session can be saved into a platform-independent state file, and restored at any time. Other enhancements include the capability to produce camera ready plots, and undo and redo commands that allow the user to easily step forward and backward through previous commands. ChIPS is designed using a client-server model and coded in C++. Python wrappers support scripting in that language, and a S-Lang interface is provided through the use of the PySL interface layer (see Fig. 27).

CIAO 4.0 also includes a modernized implementation of the Sherpa fitting and modeling application (Fig. 28). Written primarily in Python and C++, with some third party legacy science functions in Fortran, the new application aims to be more robust, and easily extensible through user written scripts. The design is modular and flexible, with the goal of packaging many models, fitting methods, and statistics for data analysis. The application structure comprises 3 layers: base, application, and user interface (UI). The base layer consists of modules that provide a set of functions (models, optimization functions, statistics, and astronomy-specific functions) that are needed by the application. C++ or Fortran functions are wrapped in Python for access by higher layers. The application layer is implemented as a set of Python classes and contains the logic needed for Sherpa to fit models to data. The UI layer contains master lists of all of the loaded data sets, models, optimization, and fitted data, and provides high-level functions to simplify user access for reading data, creating, assigning, and fitting models, and visualizing results.

A new Observation Visualizer application is also be part of our CIAO 4.0 release (Fig. 26). Since this is a GUI application, it does not share the same scripting interface as ChIPS and Sherpa. Upgraded functionality includes several new features requested for proposal planning. We have partitioned the application so that it is available as a standalone package, and upgraded our interface to take advantage of a new library interface available from the

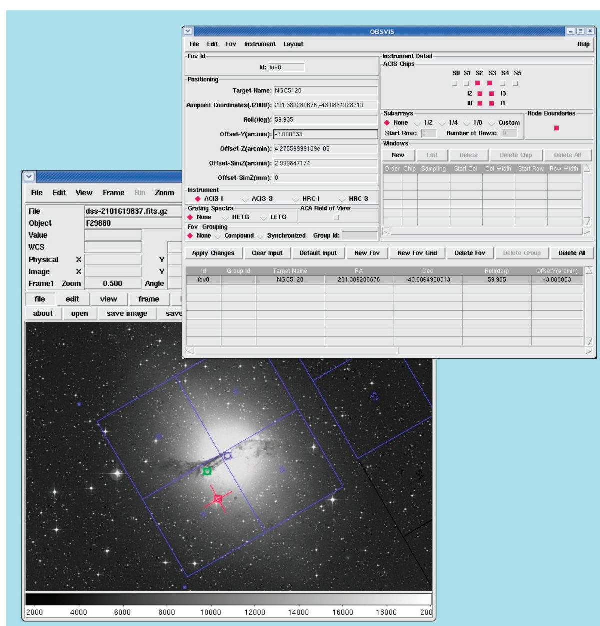


FIGURE 26: ObsVis: The screen and the output.

***CIAO* Python Session**	***CIAO* S-Lang Session**
Import Sherpa and ChIPS modules	
from sherpa.astro.ui import * from pychips import *	require("sherpa"); require("chips");
Read data, set data range 0.1–6.0 keV, subtract background	

load_pha("3c273.pi")
 notice_id(1, 0.5, 6.0)
 subtract()
	load_pha("3c273.pi");
	 notice_id(1, 0.5, 6.0);
	 subtract();

Choose model; set one of the model parameters and freeze it	

set_model(xsphabs.abs1 * powlaw1d.p1)
 abs1.nH = 0.07
 freeze(abs1.nH)
	set_model(xsphabs.abs1 * powlaw1d.p1);
	 abs1.nH = 0.07;
	 freeze(abs1.nH);

Fit data; get 90% (1.6 sigma) confidence limit projection on it	

fit()
 get_proj().sigma = 1.6
 proj()
	fit();
	 get_proj().sigma = 1.6;
	 proj();

Plot results	
plot_fit()	plot_fit();
Use ChIPS functions directly to change plot to log-log	
log_scale(X_AXIS) log_scale(Y_AXIS)	log_scale(X_AXIS); log_scale(Y_AXIS);
Use ChIPS function to print to fit.png in PNG format	
print_window("fit", "format=png")	print_window("fit", "format=png");

FIGURE 27: Comparison of CIAO Python and S-Lang Sessions

ds9 imager that allows rapid development and interaction in TCL/Tk. We also provide an interface to the calibration data for pertinent spacecraft quantities to keep them separate from the application.

Since much of the system infrastructure has fundamentally changed, and since source availability is required for GPL compliance, we have provided new user regression tests ("Smoketests") as part of the package. The scripts execute the CIAO tools and applications and compare the results to packaged data to verify a clean installation and setup of the CIAO.

I/O Environment

Following the lead of many astronomical packages, we are now offering Python as user scripting environment in CIAO 4.0, along with S-Lang. Scripting languages offer the power of self-contained environments to manage and manipulate data. CIAO extends those languages by adding our modules and applications.

The glue layer for CIAO 4.0 is Crates. This library consists of a general set of classes and methods that allow a user or application to easily access and manipulate general data files, as well as specialized classes designed to handle specific types of data products. The Crates module also provides convenient access to metadata information, such as DM subspace information which may be associated with a table column or image. A Transform module provides a high-level interface for performing world coordinate system transformations on the data. The core Crates and Transform libraries are written in

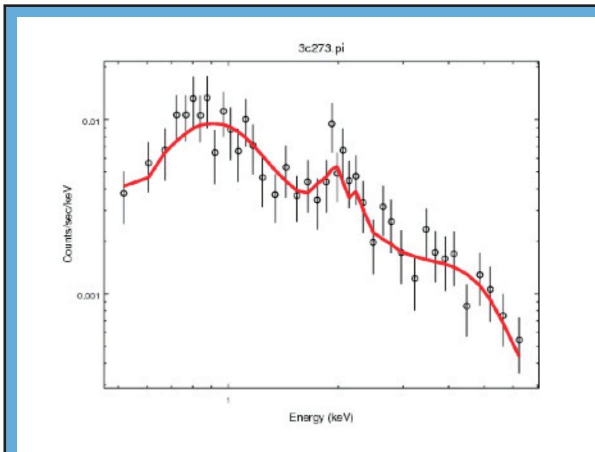


FIGURE 28: An example of a SHERPA fit.

C++, with Python and S-Lang wrappers available. CIAO applications that need to use these functions call them directly.

The integration of Python and S-Lang has been carefully designed to provide a high-level, user-friendly interactive interface for users, together with scripting capabilities that have access to data structures. The syntax of high-level commands are closely matched between the Python and S-Lang environments to provide ease of use and low maintenance for the system.

Package Independence

In CIAO 4.0 we have worked to achieve independence between applications. The major partitions are tools, ChIPS, Sherpa, and ObsVis. Users will be able to choose to download predefined subsets of CIAO as their needs dictate, for example, downloading the *Chandra* tool set without any of the applications. From the maintenance perspective, partitioning the system allows us to manage smaller releases that involve less resources and risk to the system as a whole. If we need to release tools because of a mission priority, then a small tool release can be updated, tested, and released on a relatively short timescale.

When used within CIAO, Sherpa automatically imports the Python modules that are interfaces to Crates/Transform, ChIPS, and ds9. However, Sherpa can be built and used without other CIAO components, in which case the user may substitute PyFITS for Crates and matplotlib for ChIPS.

The infrastructure is currently in place to support independent downloads in CIAO 4.0. The last step of packaging the separate releases for users is a task that is currently in progress.

Conclusion

In order to manage a system release of the magnitude of CIAO 4.0 given our limited resources, we devised a roll-out plan of 3 Beta releases through 2007 culminating with release of CIAO 4.0 in December. In the Beta 1 release, the tools and new infrastructure were the focus of our efforts. We included new OTS, platforms, smoketests, and packaging along with a tool set which was, for the most part, stable with a few bug-fixes and enhancements. In the Beta 2 release, the focus was the new application ChIPS. The release included Python for the first time along with the extra OTS software required by ChIPS. The tools and other infrastructure updates were re-released. In the Beta3 release, the new application Sherpa was the focus of our efforts. Sherpa is the most complicated of our interactive applications and required the extra development time in the schedule. At the same time, it is layered on top of the framework laid out in the previous Beta releases and utilizes ChIPS for its plotting.

It is our hope that this new more powerful version of CIAO will meet our users needs and lead to more manageable development and release of the software. ✭

Status of the *Chandra* Source Catalog Project

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

The *Chandra* Source Catalog project has recently moved from a development phase into an operational testing phase. With few exceptions, the science, software, and infrastructure tasks needed to commence production of the first release of the catalog are either completed or nearly complete. The remaining tasks will be completed during the next few months leading up to an anticipated start of production in late Spring.

Over the past year, development has continued at a rapid pace. We have completed design, development, and testing of several key algorithms. These include a new background algorithm that combines a low-spatial frequency Poisson mean with a high spatial-frequency streak map in order to suppress false source detections on ACIS read-out streaks associated with bright sources. Aperture photometry of detected sources is performed using Bayesian estimators that have been developed to derive source fluxes and their associated confidence limits in several energy bands. Limiting sensitivity information is derived for each location in the field-of-view, using source and background apertures appropriate for that location, and local background estimates derived from the above-mentioned background maps. Several temporal analysis tools statistically evaluate source variability, both within a single observation and between multiple observations of the same source. Currently, source extent estimators are being implemented, and the algorithms that perform source matching between multiple observations that include the same region of the sky are being refined.

The progress that has been made with the catalog science pipelines has been mirrored in other areas needed to support catalog production and data management. Development of the catalog databases and interfaces, and enhancements to the *Chandra* data archive to support the new file-based data products, is largely complete, as are the extensions to the processing system infrastructure to support the distributed, Beowulf cluster-based processing architecture for catalog production.

We recently completed an end-to-end test on our second "Operational Testbed" catalog software release. The test was designed to provide an integrated dataset to evaluate the science pipelines and verify processing and archive performance projections. Five hundred ACIS observations completed processing in just under two weeks on our test hardware, generating roughly 22,000 sources that met the minimum flux significance criterion discussed below and also satisfied all quality assurance criteria. The production hardware should be at least a factor of two faster.

Catalog Contents

The catalog will include detected sources whose flux estimates are at least 3 times their estimated 1 σ uncertainties, typically corresponding to about 10 net source counts on-axis and roughly 20–30 net source counts off-axis. In the first release, multiple observations of the same field will be linked together with a single source name but will not be combined prior to source detection. Therefore the flux cutoff applies to each observation separately.

For each detected source and observation, we anticipate that the catalog will include the following tabulated properties (for all sources except where otherwise noted):

- Source position and errors,
- Aperture photometry fluxes and confidence intervals in several energy bands,
- Spectral hardness ratios,
- Power-law and thermal black-body spectral fits for bright (> 250 counts) sources,
- Source variability measures (Gregory-Loredo, K-S, and Kuiper tests),
- Estimate of the source extent compared to the local point spread function.

In addition, a number of file-based data products will be produced for each source individually in formats suitable for further analysis in CIAO. These include:

- Source region, background, and local point spread function images,
- Source region photon event list,
- Limiting sensitivity map,
- Auxiliary Response File (ARF),
- Source and background light-curves,
- Pulse invariant (PI) spectrum and Redistribution Matrix File (RMF) [for ACIS observations].

For a detailed description of the planned catalog contents, users are presently referred to the *Chandra* Source Catalog Requirements document, which is available on the catalog website.

Catalog Access and Organization

User access to the catalog will be through a web-based browser interface in the first instance. Catalog users will be able to query the tabulated source properties, and retrieve associated file-based data products for further analysis.

The first stable release of the catalog will be accompanied by a detailed statistical characterization, and is expected to be completed in the fall of this year. However, users will be able to access the "catalog database," including observations and sources processed to-date, starting roughly one month after the start of catalog production. The catalog database will be updated continually as observations are released publicly, and sources are processed. Unlike the official catalog release, the statistical properties of the catalog database are not guaranteed.

Each identified distinct X-ray source on the sky will be represented in the catalog by a single "master" catalog entry and one or more "source-by-observation" entries (one for each observation in which the source was detected). The master catalog entry records the best-estimates of the tabulated properties for a source, based on the data extracted from the set of observations in which the source was detected. The source-by-observation entries record all of the tabulated properties about a detection extracted from a single observation, as well as the file-based data products, which are observation-specific.

All of the tabulated properties included in both the master catalog and the source-by-observation catalog entries will be searchable via the user interface. Links within the database maintain the connections between the master catalog entries and associated source-by-observation entries, so that users can access all observations of a single source seamlessly.

Information about the *Chandra* Source Catalog project, including the catalog requirements and associated documents, is now available on the CXC web site at the following URL: *http://cxc.cfa.harvard.edu/csc*. The catalog web site will be updated regularly as we approach catalog production and release.

Getting More From Your Multicore: Exploiting OpenMP for Astronomy

Michael S. Noble

(This article on parallel computing and the use of the OpenMP application program interface in the reduction of Chandra high resolution spectra was presented at a recent ADASS (Astronomical Data Analysis Software and Systems) meeting.

Reprinted by permission from Astronomical Data Analysis Software and Systems XVII, ASP Conference Series, eds. J. Lewis, R. Argyle, P. Bunclark, D. Evans, & E. Gonzalez-Solares)

Abstract

Motivated by the emergence of multicore architectures, and the reality that parallelism is rarely used for analysis in observational astronomy, we demonstrate how general users may employ tightly-coupled multiprocessors in scriptable research calculations while requiring no special knowledge of parallel programming. Our method rests on the observation that much of the appeal of high-level vec-

CXC Contact Personnel

Director:	Harvey Tananbaum	Calibration:	Christine Jones
Associate Director:	Claude Canizares	Development and Operations:	Dan Schwartz
Manager:	Roger Brissenden	Mission Planning:	Pat Slane
Systems Engineering:	Jeff Holmes	Science Data Systems:	Jonathan McDowell
		Deputy:	Mike Nowak
Data Systems:	Pepi Fabbiano	Director's Office:	Belinda Wilkes
Education & Outreach:	Kathy Lestition	Media Relations:	Megan Watzke

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

torized languages like IDL or MatLab stems from relatively simple internal loops over regular array structures, and that these loops are highly amenable to automatic parallelization with OpenMP. We discuss how ISIS, an open-source astrophysical analysis system embedding the S-lang numerical language, was easily adapted to exploit this pattern. Drawing from a common astrophysical problem, model fitting, we present beneficial speedups for several machine and compiler configurations. These results complement our previous efforts with PVM, and together lead us to believe that ISIS is the only general purpose spectroscopy system in which such a range of parallelism – from single processors on multiple machines to multiple processors on single machines – has been demonstrated.

Problem: Underpowered Analysis

As noted in Noble et al (2006), parallel computation is barely used in astronomical analysis. For example, models in XSPEC (Arnaud 1996), the de facto standard X-ray spectral analysis tool, still run serially on my dual-CPU desktop. In this situation scientists tend to either turn away from models which are expensive to compute or just accept that they will run slowly. Analysis systems which do not embrace parallelism can process at most the workload of only 1 CPU, resulting in a dramatic *1/n* underutilization of resources as more CPU cores are added. At the same time, however, astronomers are well versed in scripting, particularly with very high-level, array-oriented numerical packages like IDL, PDL, and S-Lang, to name a few. They combine easy manipulation of mathematical structures of arbitrary dimension with most of the performance of compiled code, with the latter due largely to moving array traversals from the interpreted layer into lower-level code like this C fragment

```
case SLANG_TIMES:
        for (n = 0; n $<$ na; n++)
              c[n] = a[n] * b[n];
```

which provides vectorized multiplication in \slang. This suggests that much of the strength and appeal of numerical scripting stems from relatively simple loops over regular structures. Having such loops in lower-level compiled codes also makes them ripe for parallelization with OpenMP on shared memory multiprocessors. Proponents contend that conceptual simplicity makes OpenMP more approachable than other parallel programming models, e.g. message-passing in MPI or PVM, and emphasize the added benefit of allowing single bodies of code to be used for both serial and parallel execution. For instance, preceding the above loop with **#pragma omp parallel for** parallelizes the S-Lang multiplication operator; the pragma is simply ignored by a non-conforming compiler, resulting in a sequential program.

Parallelizing ISIS by way of OpenMP

ISIS (Houck, 2002) was conceived to support analysis of high-resolution *Chandra* X-Ray gratings spectra, then quickly grew into a general-purpose analysis system; it is essentially a superset of XSPEC, combining all of its models and more with the S-Lang scripting language, whose mathematical capabilities rival commercial packages such as MatLab or IDL. One of several distinguishing features possessed by ISIS is its ability to bring the aggregate power of workstation clusters, through a fault-tolerant PVM interface, to bear on general problems in spectroscopic analysis (Noble et al 2006). This paper complements that work by discussing two ways in which OpenMP has been used to enable shared-memory parallelism in ISIS. Like our PVM work, we believe this is another first for general-purpose X-ray spectroscopy, and is of added significance in that adapting ISIS for parallelism – both distributed and shared-memory – no modifications to its architecture or internal codebase were required.

The first manner in which ISIS was endowed with multicore capability involved loading a module of parallelized wrappers for C functions such as **exp** and **hypot** (Fig. 29). These bindings were created by SLIRP, which is distinguished by its ability to auto-generate vectorized wrappers such as

```
static void sl_atof (void)
{
   ...
   for (_viter=0; _viter < vs.num_iters; _viter++)
              retval[_viter] = atof((char*)*arg1);
   ...
}
```

that allow functions which ordinarily accept only scalar inputs to also be used with array semantics. Adapting SLIRP to enable these vectorized wrappers

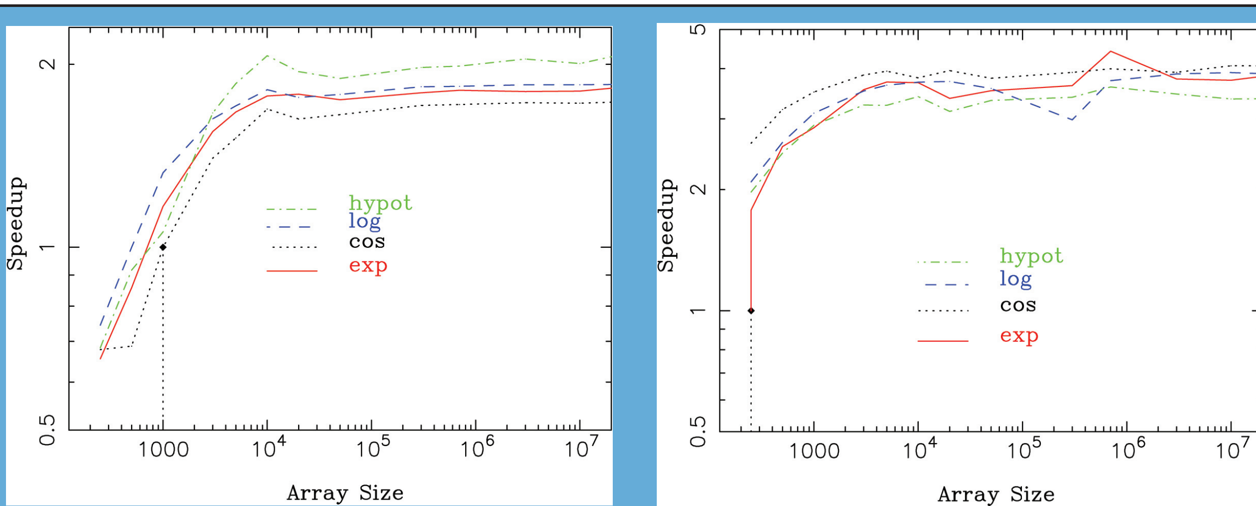


FIGURE 29: Speedups after replacing selected S-Lang math intrinsics with parallelized versions generated by SLIRP. Left: 2 CPUs on Linux (Linux2). Right: 4 CPUs on Solaris (Solaris4). The dotted vertical lines mark the inflection points where parallel performance begins to overtake serial.

to run in parallel was as simple as having it prefix the vectorization loop with an OpenMP **#pragma** as detailed above. This enables S-Lang intrinsics, all of which execute serially, to be replaced with parallel versions of the same name, transparently parallelizing the replaced functions. Our second multicore tactic involved minimizing the effects of Amdahl's law by parallelizing a number of S-Lang operators (and part of the **where()** function), through the addition of **#pragma** omp parallel for if (size > omp_min_elements) to the corresponding loops within the S-Lang interpreter source. The **if** clause in these directives was used to tune performance for small arrays, where the cost of threads outweighs the serial execution time

The speedup plots in Figs. 29 and 30 demonstrate significant performance gains from the use of shared-memory parallelism in ISIS. Our numbers represent measurements of prerelease GCC 4.2 -O2 builds on 2 CPUs running Debian Linux (Linux2) and Sun Studio 9 -xO3 builds on 4 CPUs running Solaris (Solaris4), with position independent compilation. Performance of the parallelized functions approaches the theoretical maximum of linear speedup as array sizes increase (Fig. 29), and the inflection points in the size of the arrays needed for nominal speedup from multithreading (represented by the dotted vertical lines) are relatively small, ca. 1000 elements on Linux2 and 250 elements on Solaris4 (More performance numbers and discussion, as well as the code for the Weibull function discussed herein, are given in the arXiv e-print at *http://arxiv.org/abs/0706.4048*.

Case Study: Weibull Model in ISIS

While ISIS supports custom user models in Fortran and C/C++, it can be faster to code them directly in S-Lang and avoid compilation steps during experimental tuning. In this section we discuss how one such function, a 4-parameter Weibull model coded for serial execution and taken directly from an active research project at MIT, parallelized using the techniques detailed above. Fig. 30 shows realized speedups converging on ca. 150% for Linux2 and 300% for Solaris4. These are sizable performance increases, and especially significant in that end-users need to do nothing – in terms of learning parallelism or recoding sequential algorithms – to obtain them; the same top-level model script can be used for both parallel and serial execution. Furthermore, recall that these models are used in the context of an iterative fitting process. Fits do not converge after just one iteration, and generating accurate confidence intervals – an absolute necessity for credible modeling – can require that tens or hundreds of thousands of fits be performed at each point on a parameter space grid. In such cases the speedups given here accumulate to significant differences in the overall runtime of an analysis sequence.

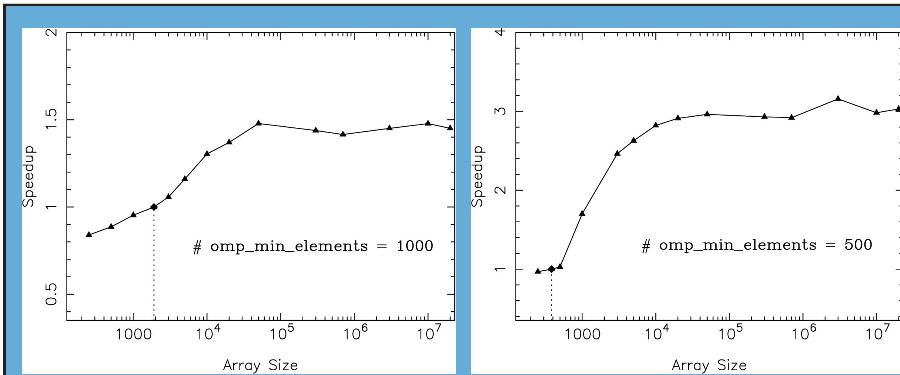


FIGURE 30: Aggregate speedup of the Weibull fit function due to the parallelized operators and functions discussed above. Left: LINT, with inflection point at 1907 elements. Right: Solaris4, with inflection point at 384 elements.

Conclusion: Transparently Parallel Scripting

We are witnessing the arrival of serious multi-processing capability on the desktop: multicore chip designs are making it possible for general users to access many processors. At the granularity of the operating system it will be relatively easy to make use of these extra cores, say by assigning whole programs to separate CPUs. As noted with increasing frequency of late, though, it is not as straightforward to exploit this concurrency *within* individual desktop applications. In this paper we demonstrated how we have helped our research colleagues prepare for this eventuality. We have enhanced the vectorization capabilities of SLIRP, a module generator for the S-Lang numerical scripting language, so that wrappers may be annotated for automatic parallelization with OpenMP. This lets S-Lang intrinsic functions be replaced with parallelized versions, at runtime, without modifying a single line of internal S-Lang source. We have shown how S-Lang operators may also be parallelized with relative ease, by identifying key loops within the interpreter source, tagging them with OpenMP directives and recompiling. These simple adaptations, which did not require any changes to the ISIS architecture or codebase, have yielded beneficial speedups for computations actively used in astrophysical research, and allow the same numerical scripts to be used for both serial and parallel execution – minimizing two traditional barriers to the use of parallelism by non-specialists: learning how to program for concurrency and recasting sequential algorithms in parallel form. By transparently using OpenMP to effect greater multiprocessor utilization we gain the freedom to explore on the desktop more challenging problems that other researchers might avoid for their prohibitive cost of computation. The OpenMP support now available in GCC makes the techniques espoused here a viable option for many open source numerical packages, opening the door to wider adoption of parallel computing by general practitioners. ✭

Acknowledgments

This work was supported by NASA through the Hydra AISRP grant NNG06GE58G, and by contract SV-1-61010 from the Smithsonian Institution.

References

Arnaud, K. A. 1996 ADASS V

Houck, J. C. 2002, ISIS: The Interactive Spectral Interpretation System, High Resolution X-ray Spectroscopy with XMM-Newton and *Chandra*

Noble, M. S., Houck, J. C., Davis, J. E., Young, A., Nowak, M. 2006, Using the Parallel Virtual Machine for Everyday Analysis, ADASS V, 481

Chandra Deep Field South: Merged Datasets for the 2000 and 2007 Observations

CXC Data Systems

The old 2000 and the new 2007 data from the *Chandra* Deep Field South have been custom processed to register all 21 individual observations astrometrically. For more information, see: *http://cxc.harvard.edu/cda/whatsnew.html#CDFS2000-2007*

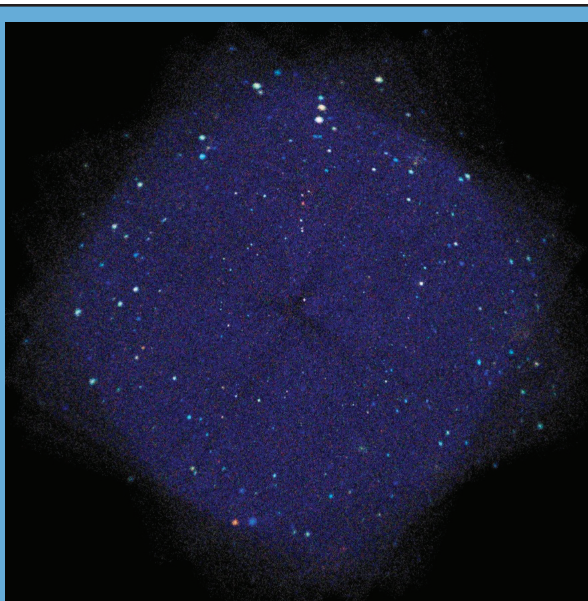


FIGURE 31: The combined CDFS image.

The *Chandra* Deep Field South is centered on:
RA(ICRS) = $03^{h}32^{m}28.2^{s}$ Dec(ICRS) = -27°48′ 36″

We offer these types of products for download:

- Merged tar file containing the merged event file, exposure map, and image
- By-ObsId tar file containing the event list and aspect solution for each of the individual ObsIds
- Full resolution linear three-color image of merged datasets
- Full resolution enhanced three-color image of merged datasets
- Smoothed enhanced three-color image of merged datasets; see Fig. 31

To deliver user-friendly, combined data products, we have merged:

A. 12 CDF-S observations taken during Sep. - Nov. 2007 (ObsId = 8591, 8592, 8593, 8594, 8595, 8596, 8597, 9578, 9593, 9596, 9718, 9575) .
Total exposure: 980 ks.

B. 9 CDF-S observations taken during May - Dec. 2000 (ObsId = 441, 582, 1672, 2239, 2312, 2313, 2405, 2406, 2409) . Note that we excluded two observations (ObsId = 581, 1431) taken in 1999 with CCD temperature = -110˚C, because of the problem in the corresponding calibration data. We will regenerate the combined data set with all 11 observations after reliable calibration data are available.
Total exposure: 855 ks.

C. All 21 CDF-S observations including 2000 and 2007 data. Again two 1999 observations (ObsId = 581, 1431) are excluded. See Figure 31.
Total exposure: 1835 ks.

We have removed cosmic-ray afterglows (using the CIAO tool acis_detect_afterglow), refined astrometry based on the matched source positions and reprojected onto a common tangent plane (using a CIAO tool, reproject_aspect). The relative offsets (from ObsId 9575) for individual observations are listed in the README file for reference. We then regenerated Level-2 event files (using CXC pipelines), and merged individual evt2 files (using the CIAO tool merge_all). ✯

News from the *Chandra* Data Archive

Arnold Rots,
for the Archive Operations Team

In previous issues of the *Chandra* Newsletter we explained the use of Dataset Identifiers in manuscripts, allowing authors to create direct links to the data of specific observations in the archive. These links may either be to single ObsIds or to larger groups of ObsIds. We encourage all users of *Chandra* data to include Dataset Identifiers in their manuscripts; it makes our task much easier and it ensures the accuracy of the links.

In 2007 we have added one more service to this: authors who have processed images or other pertinent and valuable datasets that are essential to their papers may submit such sets for permanent storage at the *Chandra* Data Archive site and refer to them in the manuscript through a custom Dataset Identifier. The first example is a dataset submitted by Ben Maughan that can be accessed at:
http://cxc.harvard.edu/cda/Contrib/2007/MAUG1

Requests for storing these special datasets may be submitted to arcops@head.cfa.harvard.edu. We ask that users provide a justification and submit a tarfile containing an index.html file and a subdirectory with the actual data files. The index file should provide an explanation of the dataset and all access to the dataset's files need to go through the index file. In other words, it should be a self-contained web tree that we can just drop into a directory on our web server; see the example mentioned above.

We are excited about the opportunity to collect valuable analysis products and hope you will find this service helpful.

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/chandra/

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

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

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

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

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

X-Ray Astronomy School

Aneta Siemiginowska,
Elizabeth Galle

The 5th International X-ray Astronomy School, sponsored by the *Chandra* X-ray Center and NASA Goddard Space Flight Center, was held at The George Washington University in Washington, DC on August 6-10, 2007. The X-ray Astronomy school is organized every other year and is intended for graduate students and recent postdocs who want to understand the intricacies of X-ray astronomy. Emphasis is placed on the foundations of X-ray astronomy rather than on any particular software tools. The lectures presented at the recent school covered a broad range of X-ray astronomy topics including characteristics of X-ray detectors, techniques used to analyze the data and recent advances in several fields of X-ray astronomy, e.g. stars, galaxies, AGNs and clusters of galaxies.

Twenty-five students attended the school, representing such countries as Germany, Italy, England, Finland, Switzerland and Canada, as well as several universities across the United States. Morning sessions were devoted to classes and lectures, while the afternoons were hands-on sessions with the computer to work with real data. The students were given several projects to work on during the week of school and they gave a short presentation on the final day of the school.

The students were very attentive and participated with great interest in the entire program. They attended the lectures, asked plenty of questions and - as was clear from their final presentations - worked hard both on their analysis projects and on improving their understanding of X-ray data analysis. In the evenings, students had a chance to get to know their colleagues with informal group dinners, social time, and the traditional reading of "Copenhagen", a play dramatizing a meeting between the physicists Niels Bohr and Werner Heisenberg that took place in 1941.

Many thanks to the instructors who worked on their lectures, the administration and computer groups for their support, and to the computer specialists for their help at the hands-on sessions.

FIGURE 32: Images from the X-ray Astronomy School.

The next X-ray School will be in Summer, 2009.

The school web page contains the details of the program and posts lectures on-line: *http://xrayschool.gsfc.nasa.gov/docs/xrayschool/index.html*

email: xrayschool@milkyway.gsfc.nasa.gov

The Results of the Cycle 9 Peer Review

Belinda Wilkes

Chandra is now in its 9th observing cycle. Cycle 8 observations are very close to completion and Cycle 9 observations started in the Fall 2007. The substantial overlap of the two cycles allows us to efficiently fill the observing schedule.

The Cycle 9 observing and research program was selected as usual, following the recommendations of the peer review panels. The peer review was held 18-22 June 2007 at the Hilton Boston Logan Airport. 100 reviewers from all over the world attended the review, sitting on 13 panels to discuss 663 submitted proposals (Figure 33).

In addition *Chandra* time was also allocated to several joint programs by the proposal review processes of Hubble, XMM-Newton, and Spitzer (2,3,3 proposals respectively). The *Chandra* review accepted joint proposals with time allocated on: Hubble (9), XMM-Newton (5), Spitzer (6), VLA (12, 1 with VLBA), NOAO (6) and RXTE (2). The Target Lists and Schedules area of our website lists the various approved programs, including abstracts. The panel organization is shown in Table 1.

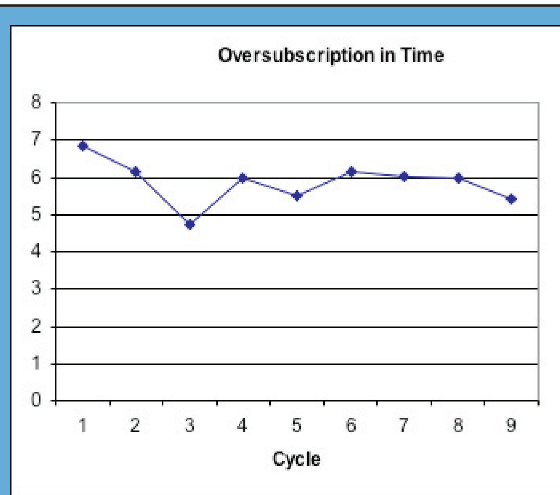


FIGURE 34: The over-subscription in observing time based on requested and allocated time in each cycle. The numbers are remarkably constant.

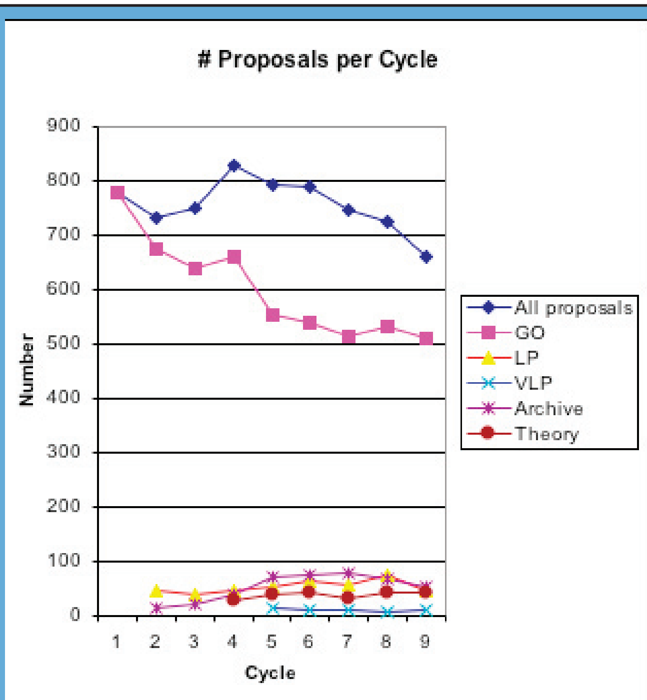


FIGURE 33: The number of proposals submitted in each proposal type (e.g. GO, LP, Archive etc.) as a function of cycle. Since more proposal types have become available in each cycle, the number classified as GO has decreased as other types increase.

The over-subscription rate in terms of observing time for Cycle 9 was 5.4, similar to that in previous cycles (Figure 34), with the total time request being again similar to past cycles (Figure 35). As is our standard procedure, all proposals were reviewed and graded by the topical panels, based primarily upon their scientific merit, across all proposal types. The topical panels produced a rank-ordered list along with detailed recommendations for individual proposals where relevant. A report was drafted for each proposal by one/two members of a panel and reviewed by the Deputy panel chair before being delivered to the CXC. The topical panels were allotted *Chandra* time to cover the allocation of time for GO observing proposals based upon the demand for time in that panel. Other allocations made to each panel were: joint time (for those facilities which were over-subscribed), Fast and Very Fast TOOs, time constrained observations in each of 3 categories and money to fund archive and theory proposals. Many of these allocations are affected by small number statistics in individual panels so allocations were based on the full peer review over-subscription ratio. In some cases panel allocations were modified

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

Table 1: Panel Organization

in real time during the review as some panels did not use all their allocation while others requested more.

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

The resulting observing and research program for Cycle 9 was posted on the CXC website three weeks later, 13 July 2007, following detailed checks by CXC staff and approval by the selection official (the CXC director). All peer review reports were reviewed by CXC staff for clarity and consistency with the recommended target list. Letters informing the PIs of the results and providing a report from the peer review were e-mailed to each PI in early August. PIs of proposals with US collaborators were invited to submit a Cost Proposals, due in Sept 2007 at SAO. The cost proposals were reviewed by a subset of the science peer reviewers and the results were announced in late November, in good time for the official start of Cycle 9 on 1 Jan 2008.

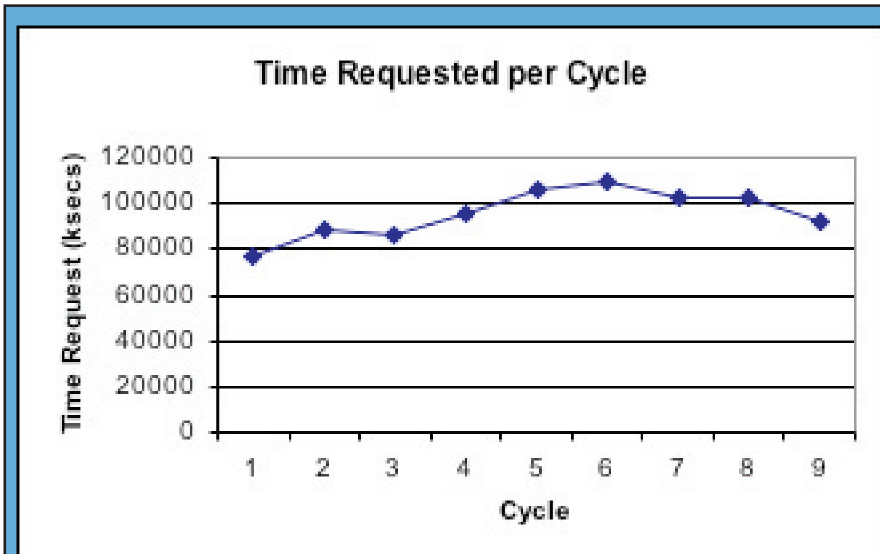


Figure 35: The requested time as a function of cycle in ksecs. This increased in the first few cycles, the largest effect being due to the introduction of VLPs in Cycle 5.

Constrained Observations

As observers are aware, the biggest challenge to efficient scheduling of *Chandra* observations is in regulating the temperature of the various satellite components (see POG Section 3.3.3). In Cycle 9 we instituted a classification scheme for constrained observations which accounts for the difficulty of scheduling a given observation (CfP Section 5.2.8). Each class was allocated an an-

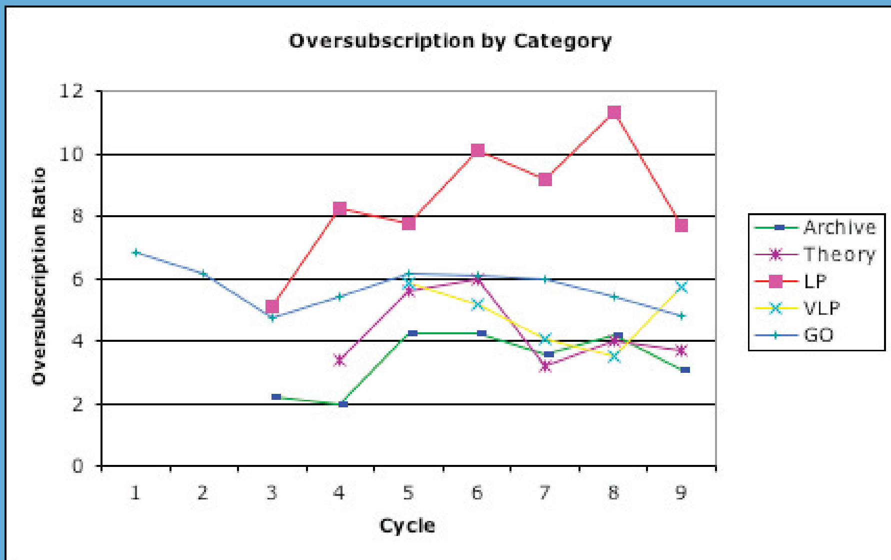


Figure 36: The over-subscription ratio for each category as a function of cycle. Please note that some of the fluctuations are due to small number statistics (e.g. Theory proposals).

nual quota based on our experience in previous cycles. The same classification scheme will be used in Cycle 10. There was a large demand for constrained time so that not all passing-ranked proposals which requested time constrained observations could be approved. Effort was made to ensure that the limited number of constrained observations were allocated to the highest-ranked proposals review-wide. All post-review decisions were discussed with the relevant panel chairs before the recommended target list was posted. We note that the most over-subscribed class was: "EASY" while "AVERAGE" was under-subscribed. In practice we combined these two categories in order to determine which observations should be allocated time. We urge proposers to specify their constraints as needed by the science rather than ensuring they are "EASY".

Proposal Statistics

Statistics on the results of the peer review can be found on our website: under "Target Lists and Schedules" select the "Statistics" link for a given cycle. We present a subset of these statistics here. Figure 36 displays the over-subscription ratio in each category as a function of cycle. Figures 37, 38 show the percentage of time allocated to each science category and to each instrument combination respectively. Following this is a list of proposal numbers according to their country of origin.

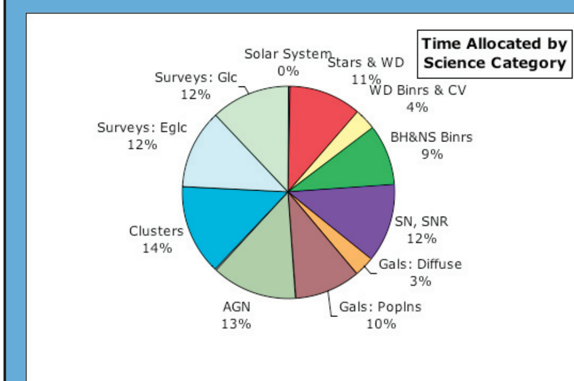
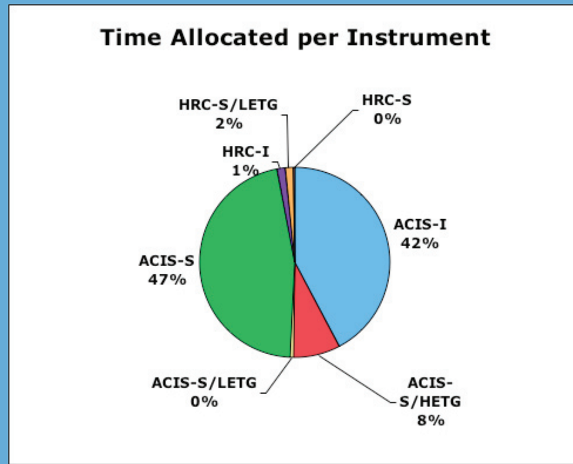


Figure 37: Pie chart indicating the percentage of *Chandra* time allocated in each science category. But note that the time available for each category is determined by the demand.

Figure 38 : A pie chart, shows the percentage of *Chandra* time allocated to observations for each instrument configuration.



Country	#Prop	Requested Time(ksec)	#Prop	Approved Time(ksec)
USA	502	69473.25	131	11763.20
Foreign	161	23356.20	47	5433.00

AUSTRALIA	5	804.70	1	60.00
BELGIUM	2	310.00		
BRAZIL	1	90.00		
CANADA	6	643.00	1	80.00
CHILE	1	25.00		
CHINA	1	40.00	1	20.00
FRANCE	7	445.00	3	210.00
GERMANY	18	2504.80	7	1060.00
GREECE	2	2025.00		
INDIA	2	90.70		
ISRAEL	1	200.00		
ITALY	26	2797.00	6	430.00
JAPAN	13	1942.00	4	230.00
NETH	15	961.00	9	461.00
POLAND	1	5.00	1	5.00
RUSSIA	3	150.00		
SPAIN	9	1051.00	2	100.00
SWITZ	7	1117.00	3	137.00
UK	41	8155.00	9	2640.00
USA	502	69473.25	131	11763.20
	663	92829.45	178	17196.20

TABLE 2: Number of Requested and Accepted Proposals and Observing time by Country

Education and Public Outreach Proposals Selected in Cycle 9

Kathleen Lestition
Education & Outreach Coordinator

The Cycle 9 *Chandra* EPO Peer Review, conducted by the CXC, was held in Cambridge MA on Dec. 5-7, 2007. A panel representing science, education, museum, Forum, and NASA mission and management perspectives reviewed 12 proposals. Three individual and 9 institutional proposals were submitted. Two individual and 5 institutional proposals were selected for funding. An overview of the selected proposals by type follows, alphabetically in order of PI last name.

Individual Proposals

1) *The Extreme Universe Video Conference Field Trips for Grades 6-10*
Science PI: Dr. Mark Voit/Michigan State University, voit@pa.msu.edu
EPO Co-I: Judy Smyth/MSU Museum, smythjud@msu.edu
Education Partner
- Michigan State University Museum

The proposal will develop and provide science content around the theme of "The Extreme Universe" for an on-going teleconferencing project (Learning and Developing Distance Education Resources - LADDERS) being carried out by the MSU museum for remote middle schools in Michigan under a grant from the Institute of Museum and Library Services. The content is presented as virtual field trips that include inquiry-based, hands-on classroom activities. The content will address National Education standards for grades 5-10 as well as Project 2061 goals to advance literacy in science. In addition to serving Michigan schools, the program will be offered to classrooms across the country through LADDERS' partnerships with national distance learning web sites and listservs. MSU's Virtual Outreach Website will connect participants to additional NASA resources and will utilize NASA materials. With an existing infrastructure and in-place program staff as well as participant schools, the program will remain in existence beyond the term of this grant.

2) *Creating a Tour of the Center of the Galaxy in the World Wide Telescope*
Science PI: Dr. Farhad Yusef-Zadeh/Northwestern University, zadeh@northwestern.edu
EPO-Co-I: Doug Roberts/Adler Planetarium, doug-roberts@northwestern.edu
Education Partner
- Adler Planetarium and Astronomy Museum, Chicago, IL

This proposal will use data from NASA's Great Observatories to create a story-driven "tour" of the center of the Milky Way Galaxy in multi-wavelength for the World Wide Telescope (WWT) interactive visualization system. The WWT enables users to actively explore the sky with targeted images. Captions and an audio option (to be provided in English and Spanish) make the tour accessible. Some data from each of NASA's Great Observatories has already been incorporated into the WWT, and this proposal will expand the offerings. Two versions of the tour will be created: one aimed at middle school children, one aimed at adults with a high school education or above. The system will be developed and tested with target audiences at the Adler. The finished products will be available through MicroSoft's release of the WWT and also deployed at Adler's Space Visualization Lab and the CyberSpace installation, ensuring longevity beyond the term of this grant. Adler staff will develop outreach presentations in the form of Informal public interpretation programs as well as video-conferenced field trips. The adult version of the tour will be used in an Adler adult education astronomy class.

Team/Institutional Proposals

1) *Rooftop Variables*
Science PI: Dr. Marcel Agueros/Columbia University, marcel@astro.columbia.edu
Education Partners
- Summer Research Program for Teachers (SRP), Columbia University
- American Association of Variable Star Observers (AAVSO), Cambridge, MA

This program leverages the existing Summer Research Program at Columbia University which has provided ~200 New York City teachers with professional development programs in the sciences since 1990. Teachers gain hands-on experience by becoming integral participants in their mentors' labs for two consecutive summers. To date there has been no formal astronomy opportunity, which this program addresses. Initially 4-6 teachers will be competitively selected to learn observational and data reduction techniques on amateur observing targets suggested by the AAVSO, under the guidance of mentors from the Columbia astronomy department. The AAVSO monitors sources which can become targets of opportunity for telescopes such as *Chandra* and participants will be expected to contribute data to the AAVSO data base. Teachers will also be presented with astronomy teaching resources and opportunities to develop their own astronomy-related materials, and have access to department sponsored observing nights and dark-sky field trips. The ultimate goal of the program is the establishment of on-going astronomy clubs at each of the participants schools under continued mentorship from the Columbia astronomy department.

2) *Chandra Astrophysics Institute*
Science PI: Dr. Deepto Chakrabarty/MIT Kavli Institute for Astrophysics and Space Research (MKI), deepto@space.mit.edu
EPO Co-I: Dr. Irene Porro/MKI,iporro@mit.edu
Education Partners

- Lynn Public School District, Lynn MA
- Urban Science Academy, West Roxbury MA
- The Engineering School, Hyde Park MA
- New Mission High School, Boston MA
- Community Charter School of Cambridge, Cambridge MA

This program continues the previously funded CAI. The goal of the CAI is to provide underserved students with effective learning opportunities in science. Through CAI, students build the background skills and knowledge necessary to understand how research science is done, by actually doing it. Students participate in an intensive, 5 week summer session at MIT, and then apply their skills during the next full year to undertake investigative projects in X-ray astronomy developed in collaboration with mentors from MKI. Several new schools have been added, and contact time with participating students has been increased. A pilot outreach component, working with math/science/technology clubs at participating schools will be implemented. In addition to the traditional public presentations, a portfolio of the final product of the student investigations will be created for public dissemination via a public web site.

3) *Adding Loops To The STEM Pipeline: Mentoring and After-School Activities for Girls Scouts*
Science PI: Dr. Ann Hornschemeier/Goddard Space Flight Center,
Ann.Hornschemeier@nasa.gov
EPO Co-I: Christine Lamgerton/Teen Program Specialist, Girl Scouts of
Central Maryland, CLamgerton@gscm.org
Education Partners

- Girl Scouts of Central Maryland (GSCM), Baltimore MD
- GSFC Astrophysics (ASD) EPO, Baltimore MD
- GSFC Heliophysics (HSD) EPO, Baltimore MD

The program will transfer existing activities from the Big Explosions/Strong Gravity (BESG) program (previously funded by *Chandra* and now in a national expansion phase with ROSES funding), as well as new content to be developed and adapted from EPO programs in the GSFC ASD, HSD and Solar Dynamics Lab, to the 8-week after school "feeder" program that engages younger, inner city girls to graduate into the Girls Scouts' ACE mentoring program. This program (as well as the earlier BESG) combines STEM content with a mentoring experience provided by a scientist volunteer network including GSFC, JHU, UMd, CUA and STScI. This grant will fund the preparation of a core group of GSCM staff to train the mentors, as well as the start up funds for four after school programs utilizing the NASA content to be held during the 2008-2009 school year.

4) *Connecting Kids to the Universe with the Beyond Einstein Explorers Program*
Science PI: Dong Lai/Cornell University, dong@astro.cornell.edu
EPO Co-I: Nancy Schaff/Center for Radiophysics and Space Research, Cornell University, nancys@astro.cornell.edu
Education Partner
• Cornell Cooperative Extension 4-H Youth Development

This program will leverage NASA's Beyond Einstein Explorers Program (BEEP) by funding the development of teaching kits, and the implementation of a regional training workshop in collaboration with the 4-H Youth Development program in New York State to extend the geographical reach of the BEEP program and materials. The 4-H education partner will particularly seek to reach underrepresented and underserved youth. The trained leaders will develop the capacity to implement the project with youth as well as train other leaders. The resource kits will be available for loan on a regional level. The participants intend to use this pilot program as a development opportunity to develop a working paradigm for expansion. They plan seek additional funding to expand the program through other 4-H groups on a wider geographical basis.

5) *The Nature of Science: A Planetarium Show on Globular Clusters at the Science Museum of Virgina*
Science PI: Dr. Craig Sarazin/Univeristy of Virginia, sarazin@virginia.edu
EPO Co-I: Dr. Edward Murphy/University of Virgina,emurphy@virginia.edu
Education Partner
• The Science Museum of Virgina, Richmond VA

The purpose of this program is to introduce students and the public to the nature of science through the development and production of a planetarium show on globular clusters at the Science Museum of Virginia. The focus of the show will be to demonstrate how scientists know basic properties of globular clusters through the nature of science and the scientific method. The factual content of what scientists know will be introduced incidentally to discussing how scientists work. Throughout the show, the differences between facts, hypotheses, theories and laws will be emphasized. In addition to the PI and EPO Co-I, the development team includes experienced staff at the planetarium of the Science Museum of Virginia who will oversee the production of the show and define and manage production of the associated study guide.

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
Mark Dickinson	NOAO	med@noao.edu
Ken Ebisawa	ISAS	ebisawa@isas.jaxa.jp
Matthias Ehle	ESA	Matthias.Ehle@sciops.esa.int
Henry Ferguson	STScI	ferguson@stsci.edu
Martin Laming	1NRL	j.laming@nrl.navy.mi
Smita Mathur	OSU	smita@astronomy.ohio-state.edu
Chris Mauche	LLNL	mauche@cygnus.llnl.gov
Jon Miller	U. Michigan	jonmm@umich.edu
Chris Reynolds (chair)	U. Maryland	chris@astro.umd.edu
Randall Smith	GSFC	rsmith@milkyway.gsfc.nasa.gov
Lisa Storrie-Lombardi	Spitzer Science Center	lisa@ipac.caltech.edu
Leisa Townsley	PSU	townsley@astro.psu.edu

Ex Officio, Non-Voting

Alan Smale	NASA HQ	Alan.P.Smale@hq.nasa.gov
Wilt Sanders	NASA HQ	wsanders@hq.nasa.gov
Allyn Tennant	NASA/MSFC	allyn.tennant@msfc.nasa.gov
Martin Weisskopf	NASA/MSFC	martin@smoker.msfc.nasa.gov

CXC Coordinator

Belinda Wilkes	CXC Director's Office	belinda@head.cfa.harvard.edu

FIGURE 39: *Chandra* Fellows Symposium, 2007. Fellows l to r: Shane Davis, Jifeng Liu, Masahiro Tsujimoto, Jonathan McKinney, Jesper Rasmussen, Ian Parrish, Jan-Uwe Ness, Elena Gallo, Elena Rossi, Carles Badenes, Elena Rasia, Jeremy Schnittman, and John Fregeau. Missing: David Sand.

Chandra Fellows for 2008

Nancy Remage Evans

As always, the applicants for *Chandra* Postdoctoral Fellowships were impressive. The list of *Chandra* Fellows for 2008 has just been finalized and is provided to the right.

Keep an eye on our web pages for information about the *Chandra* Fellows Symposium (October 17, 2008) and the annual Fellowship competition (October-November 2008).

	PhD Institution	*Host Institution*
Edward Cackett	St. Andrews	U Michigan
Orly Gnat	Tel Aviv	CalTech
Prateek Sharma	Princeton	Berkeley
Ezequiel Treister	Chile	Hawaii
Norbert Werner	Utrecht	Stanford

Table 3: 2008 *Chandra* Fellows

They Might Be Giants: X-ray Secrets of Saturn and Jupiter

This article is taken from the Chandra Chronicles. Text and images can be found here: http://chandra.harvard.edu/chronicle/0107/giants/ .

-Editor

When NASA's New Horizons spacecraft made its closest approach to Jupiter on February 28, 2007, the *Chandra* X-ray Observatory was watching the giant planet. This flyby gave scientists an opportunity to study Jupiter using the instruments that New Horizons will eventually use to observe Pluto. But it also allowed astronomers to synchronize these data with from an armada of both space- and ground-based telescopes, including *Chandra*.

Chandra's involvement in studying Jupiter may be surprising for those who can't imagine that X-rays could come from a planet. And, for good reason too. X-rays are a kind of light associated with some of the hottest things in the Universe, such as neutron stars, supernova remnants and black holes. Planets in our Solar System are typically very cold. Even Mercury, the closest planet to our Sun, only gets to around a few hundred degrees Celsius. While that is certainly hotter than we would find comfortable, it is much less than the millions of degrees necessary to generate X-rays. Since Jupiter and Saturn are much colder than Mercury or the Earth, what chance do astronomers have of detecting X-rays from them? The answer turns out to be: a very good one.

Chandra observations of Saturn show that Saturn's atmosphere acts like a massive fuzzy mirror. Saturn reflects X-rays emitted by the Sun back to the Earth, just as it reflects sunlight back to us that we see in the

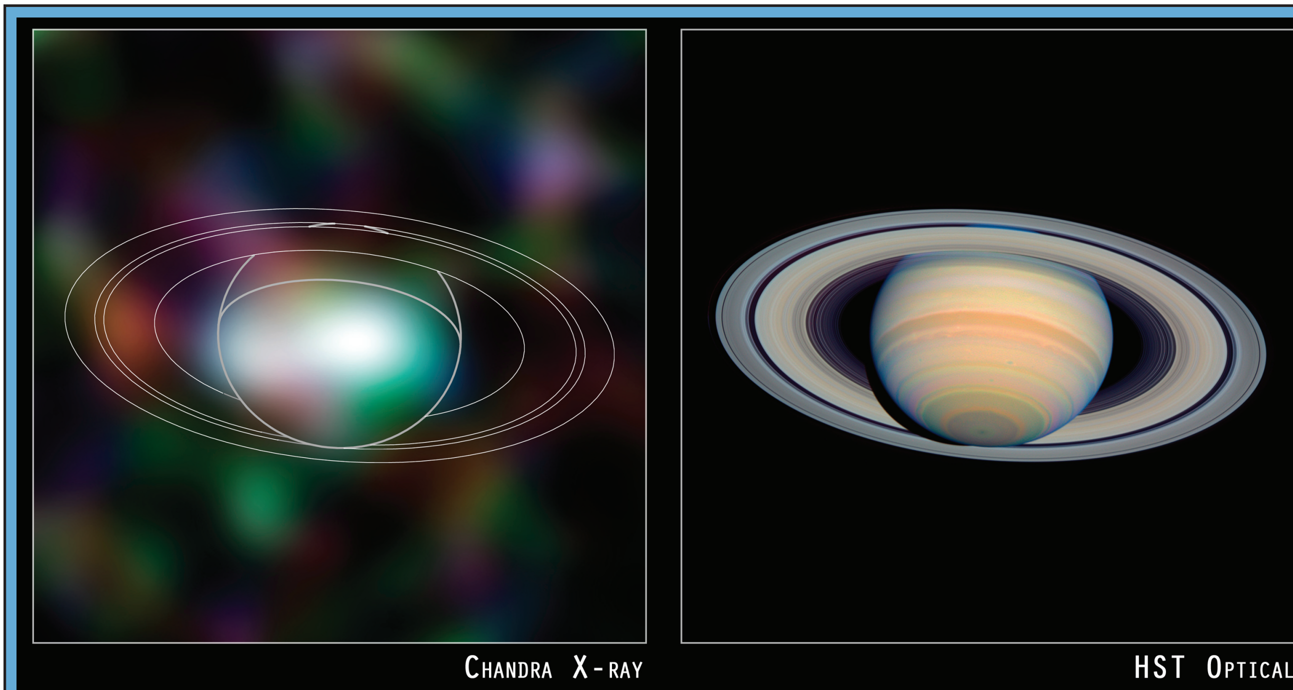


FIGURE 40: Images of Saturn (from: *http://chandra.harvard.edu/photo/2004/saturn/*) Credit: X-ray: NASA/U. Hamburg/J.Ness et al;Optical: NASA/STScI

night sky. Astronomers were able to gather evidence for this when they saw the Sun flare on January 20, 2004, getting hundreds of times brighter. Luckily, *Chandra* was observing Saturn during this flare. Two hours and 14 minutes later, exactly the amount of time it takes light to go to Saturn and back to Earth, astronomers saw Saturn get brighter in X-rays. Discovering that Saturn can act as an X-ray mirror could help scientists know when the far side of the Sun flares. This could help future astronauts traveling deep in the solar system who would be affected by the radiation these flares produce.

Astronomers were also able to use *Chandra* in a different way to study Saturn's moon, Titan. On January 5, 2003, a rare alignment caused Titan to cross in front of the Crab Nebula, which is a very strong X-ray source. Because the Crab pulsar and the surrounding areas are so bright in X-rays, this effectively provided scientists with a "medical" X-ray of Titan. In other words, Titan was illuminated from the back, just as a strong X-ray beam is placed behind a broken bone in the doctor's office. The X-ray shadow cast by Titan allowed astronomers to make the first X-ray measurement of the extent of its atmosphere, revealing that it is thicker than previously thought. Titan is Saturn's largest moon and the only moon in the Solar System with a thick atmosphere.

Like Saturn, Jupiter can also reflect X-rays. But, because Jupiter has a strong magnetic field, things can become much more interesting. For example, charged particles, possibly from the Sun or from material sputtered off the moon Io, can get captured by the magnetic field of Jupiter and driven towards the million-volt environment above the planet's poles. The source of the charged particles is ambiguous because the X-rays are seen in a region on Jupiter that can't obviously be linked to either the Sun or Io. Therefore, there's some new astrophysics to be learned before the answer is known. Scientists hope that the New Horizons flyby will help. Combining the New Horizons data with the simultaneous *Chandra* observations of the whole planet's magnetic field, astronomers may find new insight into this complicated planetary system.

While spacecraft have been sent out to study the outer Solar System, certain secrets may only be revealed through the X-rays that *Chandra* can detect. Scientists will continue to use the observatory to unlock the mysteries of our planetary neighbors.

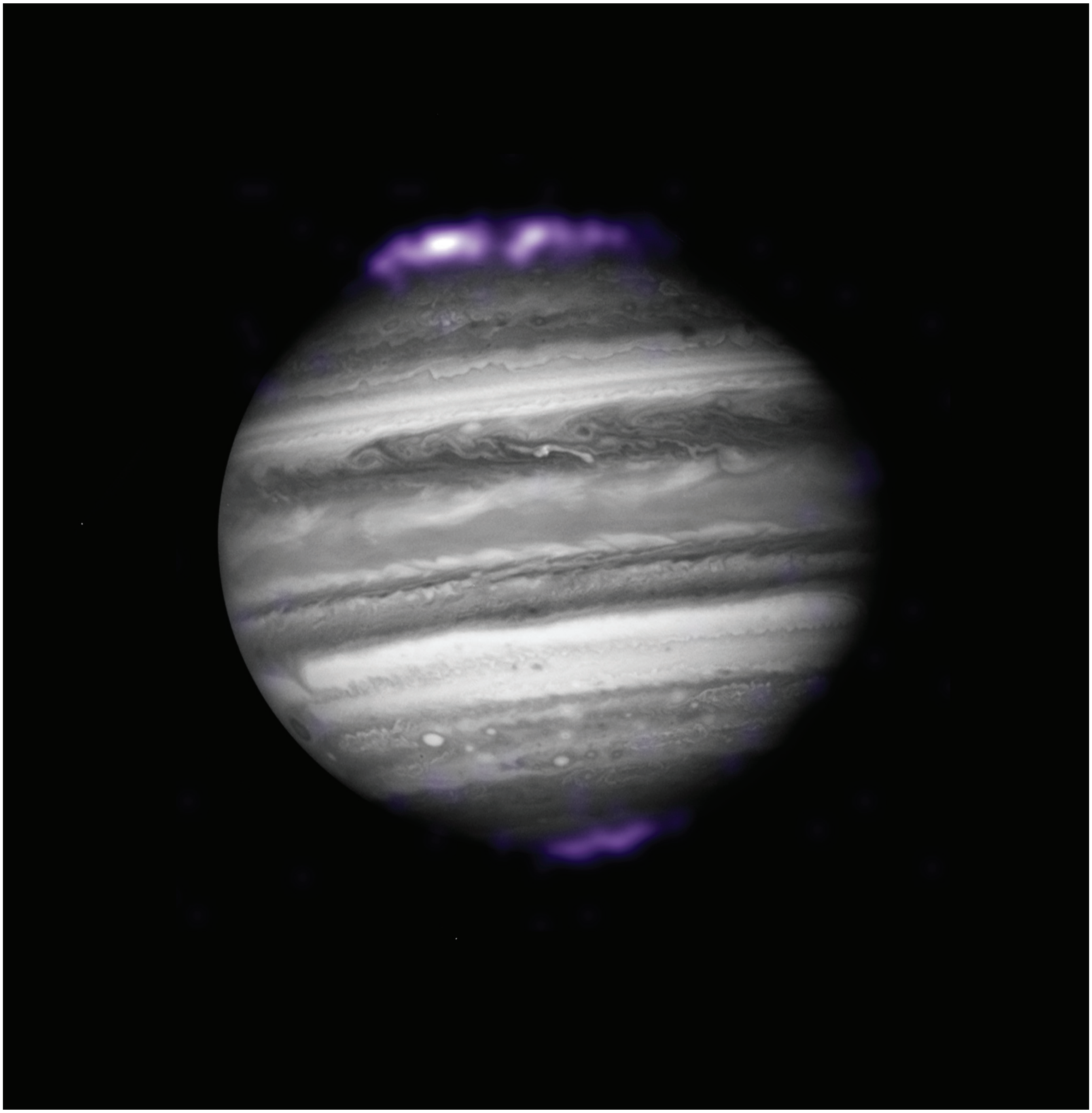


FIGURE 41: X-ray/Optical Image of Jupiter (See article on page 50)

Credit: X-ray: NASA/CXC/SwRI/R.Gladstone et al.; Optical: NASA/ESA/Hubble Heritage (AURA/STScI)

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