ACIS Update

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The Advanced CCD Imaging Spectrometer (ACIS) is in good health and continues to produce spectacular results approaching its twentieth year in orbit. All ten CCDs are operating nominally, the electronics are functioning well without any failures or degradations, and the flight software (SW) continues to function well without any issues.

ACIS continues to be the workhorse for *Chandra* observations, conducting over 90% of the science observations. One of the first images that ACIS acquired after launch was that of the Galactic supernova remnant(SNR) Cassiopeia A (Cas A). In that "first light" image, *Chandra*/ACIS revealed the complex morphology of this SNR and it also discovered a point source close to the center of the remnant (Tananbaum 1999). This point source turned out to be the remains of the exploded star, a particular type of neutron star known as a "Compact Central Object" (CCO, Pavlov et al. 2000, Heinke & Ho 2010, and references therein). *Chandra* has continued to observe Cas A over the years, accumulating a rich data set that allows detailed studies of the X-ray emitting plasma on small spatial scales and the temporal evolution of the emission (see Patnaude & Fesen 2007, Patnaude & Fesen 2009, and Patnaude et al. 2011). The CXC Press Office produced this image of Cas A which is not only beautiful but visually demonstrates the power of spatially-resolved spectroscopy on arcsecond scales. The different colors in the image represent emission from narrow energy bands centered on prominent lines from the dominant elements, with Si in red, S in yellow, Ca in green and Fe in purple. The dark blue represents the high-energy continuum emission. The complex structures of the different elements in this remnant are readily apparent in this image showing that the distribution of ejecta from the supernova (SN) explosion and the interaction with the reverse shock is highly asymmetric (see Hughes et al. 2000 and Hwang et al. 2004 and references therein). The amount of each element produced in the SN explosion can be estimated from these data, thus providing constraints on the explosion mechanism and the nucleosynthesis models (Laming & Hwang 2003 and Hwang & Laming 2012). The location of the forward shock is also clearly seen in this image as delineated by the dark blue emission (Gotthelf et al. 2001). Also apparent in this image is a region in which some high velocity ejecta have apparently propagated beyond the forward shock. All of these results are possible because the combination of the arcsecond angular resolution of the High Resolution Mirror Assembly (HRMA) and the spectral resolution of the ACIS CCDs allows the fine-scale structure of this SNR to be studied in exquisite detail. Our understanding of SNRs such as Cas A and the physics of SN explosions and shock interactions with interstellar material have greatly advanced because of deep *Chandra* observations such as those of Cas A.

The ACIS hardware is in excellent shape, all equipment is operating on the primary side after nearly twenty years in orbit. The charge transfer inefficiency (CTI) of the CCDs continues to increase at a low rate (dCTI/dt = 2×10^{-6} yr^{-1} for the FI CCDs and dCTI/dt = 1×10^{-6} yr^{-1} for the BI CCDs) such that the scientific performance will not change significantly for many years. The ACIS flight SW has been patched six times since orbital activation and checkout to provide enhancements and a seventh patch is under development to allow ACIS to monitor its electronics temperatures and to send a signal to the *Chandra* on-board computer (OBC) to cease science observations if the temperatures exceed limits. In addition, the *Chandra* operations team has been verifying the EEPROM version of the flight software monthly since 2016 and the data indicate no corruptions in this memory after nearly twenty years in orbit.

The contamination layer continues to accumulate on the ACIS optical blocking filters (OBFs), however there have been significant changes over the last several years. The contamination is behaving differently on the ACIS-I filter compared to the ACIS-S filter. The accumulation rate at the center of the ACIS-I OBF from 2017 to 2019 is more than 5 times lower than it was from 2015 to 2017. While the accumulation rate at the center of the ACIS-S OBF has been roughly constant over the same period, with perhaps a small decrease in the accumulation rate in the 2017 to 2019

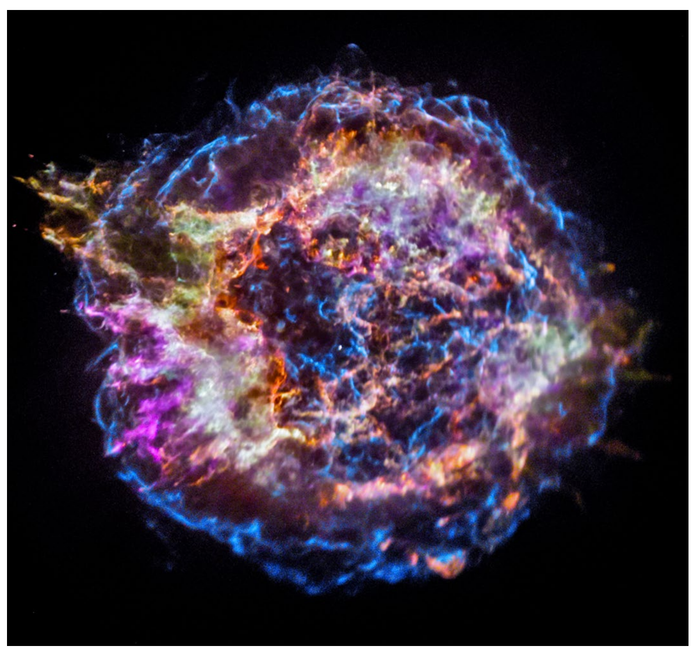

Figure 1: ACIS-S3 image of Cassiopeia A based on over 1.3 Ms of archival observations. The different colors represent narrow energy bands around prominent emission lines of the following elements: Si(red), S(yellow),Ca(green), and Fe(purple). The dark blue indicates the high-energy continuum. The CCO is visible as the white point source near the center.

period. The contaminant had accumulated faster at the center of the ACIS-I OBF than at the center of the ACIS-S OBF prior to 2017, with the the current ACIS-I thickness about 5% larger than the current ACIS-S thickness. One possible explanation is that the contaminant accumulated faster on the ACIS-I OBF because that filter has a larger view factor to the *Chandra* Optical Bench Assembly (the presumed source of the contamination) and now the contaminant is redistributing amongst the two filters as the center of the ACIS-I OBF is most likely slighty warmer than the center of the ACIS-S OBF. The details of the analysis are presented in an SPIE paper, Plucinsky, Bogdan, & Marshall 2018. Future observations will be crucial to monitor the behavior of the contamination layer. The CXC will continue to acquire calibration observations of A1795, E0102 and Mkn 421 to characterize the contaminant and to produce updated contamination files. Over the last year, the CXC has released two updates to the contamination file: N0011 in CALDB 4.7.9 with an updated ACIS-I model and N0012 in CALDB 4.8.1 with an updated ACIS-S model.

ACIS was properly safed during the 2018 October safe mode and there were no adverse effects on the instrument. The ACIS Operations Team (AOT) took advantage of the time available during the safe mode recovery to collect calibration data from the external calibration source (ECS) at a variety of focal plane (FP) temperatures. The ECS is a radioactive ^{55}Fe source with a half life of 2.73 years, meaning the flux is less than 1% of what it was at the start of the mission. Therefore, any additional ECS data are a significant benefit toward maintaining the calibration of ACIS. The AOT executed four realtime procedures during the recovery that resulted in a total of 315 ks of data at a range of temperatures from -119.7 C to -109.0 C. A large fraction of the data were acquired at FP temperatures near -114.0 to -115.0 C which will be particularly useful to calibrate the current response of the CCDs at those temperatures. The calibration team had been considering dedicated measurements at these temperatures and those new measurements may not be necessary now.

The thermal properties of the spacecraft and ACIS continue to be a major concern for the AOT as the observatory ages. The AOT team spends a substantial fraction of its time developing and maintaining thermal models that are used to predict the ACIS electronics and FP temperatures for a given week of observations. Observers are advised to read sections 6.20 and 6.22 of the Proposers Observatory Guide for the details that might affect their observations. The most significant change, which was implemented in Cycle 20, is that proposers may request up to 4 CCDs as required CCDs at the time of proposal submission. If a 5th and 6th CCD are desired, they must be requested as optional at the time a proposal is submitted. ACIS can still execute observations in any part of the sky that is currently visible with careful planning, but proposers should be aware that the uninterrupted durations of those observations may be limited depending on the spacecraft thermal environment at that time.

As with any project that spans two decades, the *Chandra* project has had it share of key personnel that have moved on to other projects or have retired. The ACIS team will celebrate Richard Edgar's many contributions to the *Chandra* project as he plans to retire this year. Richard started on the *Chandra* project as a member of the Mission Support Team that was integral in designing the measurements and analyzing the calibration data of the HRMA's properties at the X-ray Calibration Facility (XRCF) at MSFC. After launch, he transitioned to the calibration team within the CXC where he continued working on the HRMA calibration and began to work on calibration issues for ACIS. In particular, he was deeply involved in the creation of the maps of the charge traps in the CCDs that are a critical part of the CTI correction software. In 2013, Richard transitioned to the AOT and has been a valuable contributor ever since. He is an expert in Solar weather and has become critical in the development of thermal models for ACIS. Richard has over twenty years experience with different aspects of the *Chandra* mission and his expertise will be sorely missed. We wish him the best in retirement and look forward to any new novels he might write. The ACIS team will also celebrate the partial retirement of two key members from the instrument team at MIT. Robert Goeke, the ACIS Project Engineer, and Peter Ford, the ACIS Flight SW Manager, are both working part-time. Both Robert and Peter continue to make significant contributions to the current operation of ACIS and we are grateful that they are still available to answer questions and work on urgent issues.

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