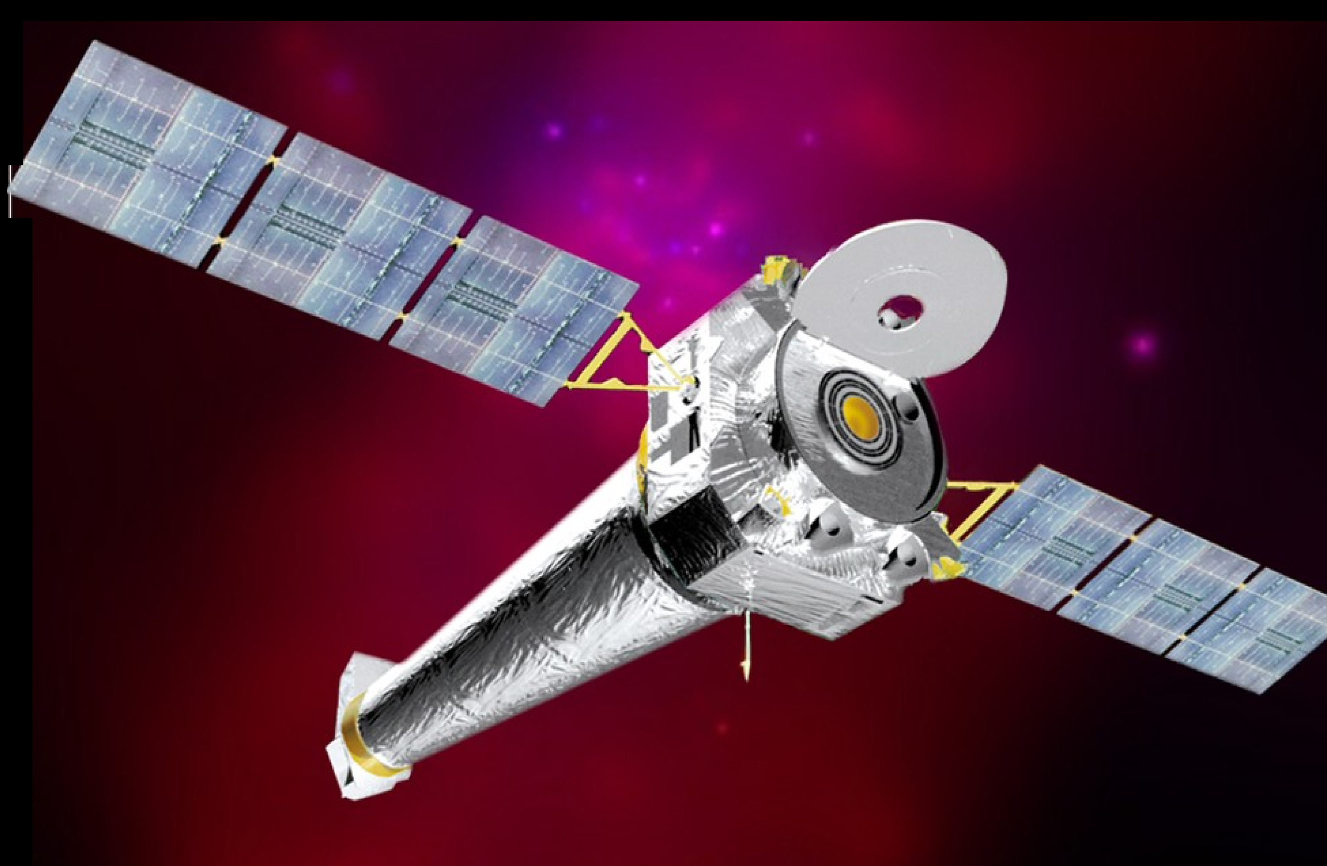
Mica: data-mining the Chandra archive for satellite operations

Jean Connelly and Tom Aldcroft
(Harvard / Smithsonian Center for Astrophysics and Chandra X-ray Center)

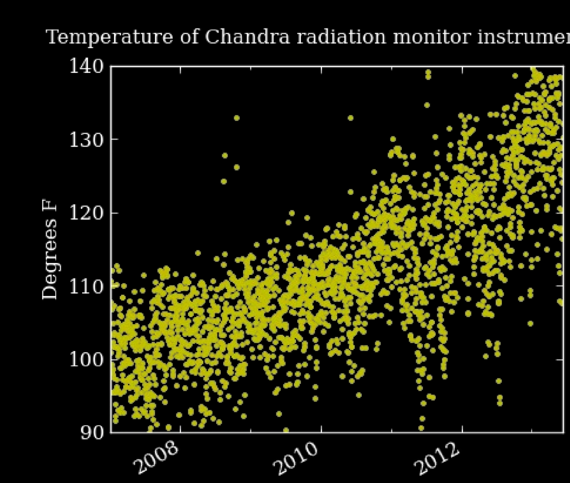
The Chandra X-ray Observatory was launched in July 1999 and continues to make a wide range of astronomical discoveries. A unique capability of Chandra is the extraordinary spatial resolution of of the X-ray images, made possible by the X-ray optics and a sophisticated attitude determination system that reconstructs the detected photons into a sharp image.

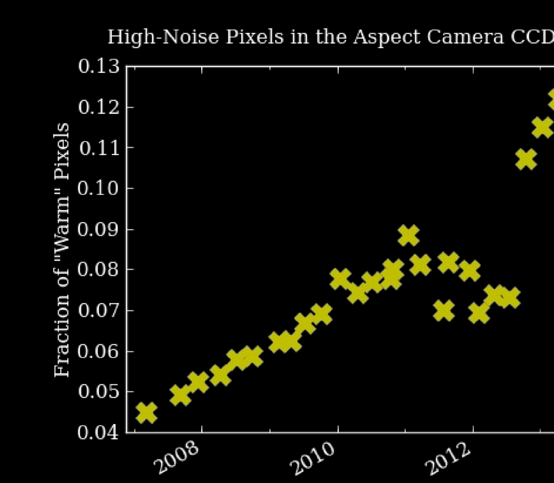
In order to fully track the performance of the attitude system, the operations team at the Chandra X-ray Center has developed a Python-based infrastructure named Mica. Mica includes a component which aggregates diverse engineering and science data products, and a component which provides tools to mine these aggregated data to assist in data trending and visualization as well as anomaly investigation.

In this poster we will discuss some of the issues facing the Chandra satellite as it nears its 14th birthday, and then describe the architecture of Mica and show examples of how it has been used in practice.



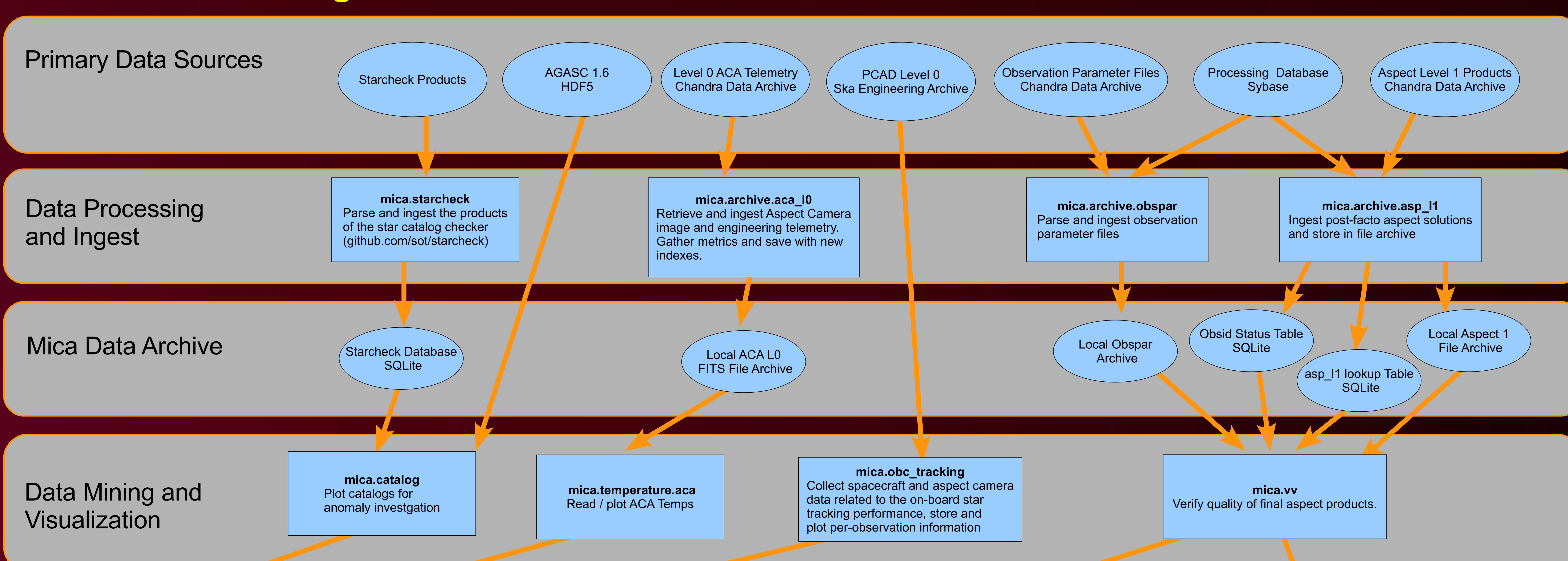
Mitigating attitude control issues as the spacecraft gets hotter





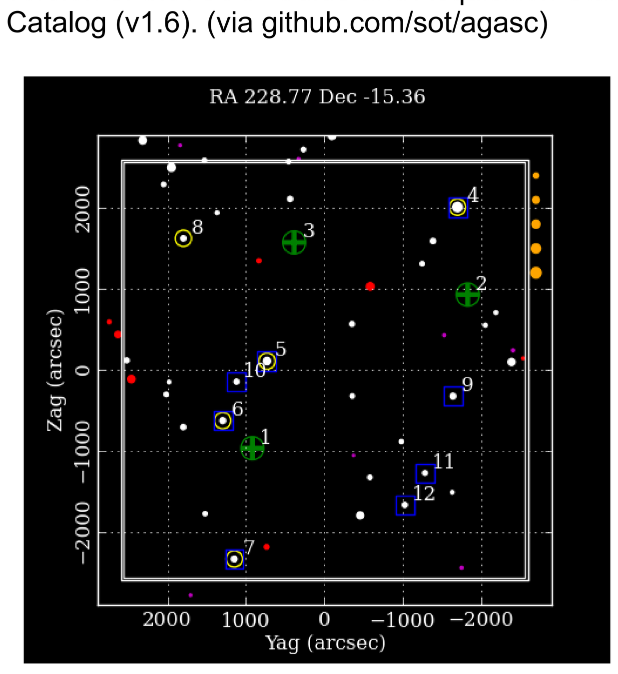
- Many parts of the Chandra spacecraft, including the camera used for star tracking, are getting warmer as the spacecraft ages.
- As the Aspect Camera CCD temperature increases, CCD “dark current” increases.
- This increase presents challenges to the onboard star tracking algorithm and to the post-facto attitude determination system.
- Tools to monitor onboard performance and post-facto accuracy help the operations team to evaluate mitigation strategies so that we can ensure the highest quality data and maximize the mission science return.

Mica Processing Architecture

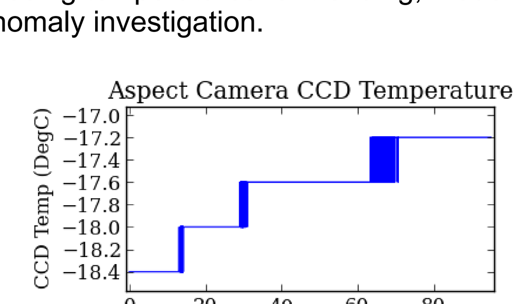


The aspect camera tracks 5 to 8 stars during observations. During observation planning and in anomaly investigation, it is helpful to visualize the selected stars in the star field. Mica and matplotlib make construction of these plots trivial.

Star positions are read from an indexed HDF5 version of the AXAF Guide and Acquisition Star Catalog (v1.6). (via github.com/sot/agasc)



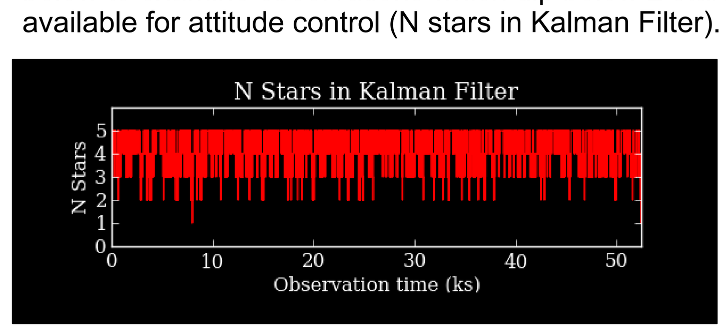
Mica provides access to the camera CCD and housing temperatures for trending, modeling, and anomaly investigation.



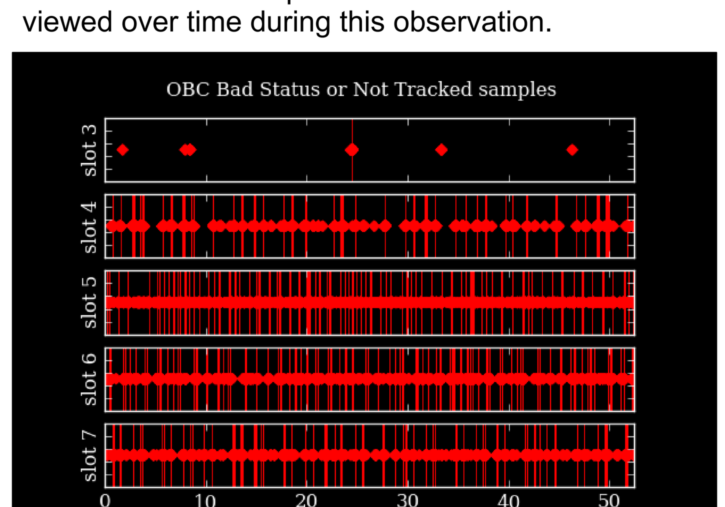
During an observation, the spacecraft determines its attitude using an algorithm that includes the centroid positions of a set of stars read out every 2 or 4 seconds (depending on the tracking mode). If the aspect camera is unable to track a star or if a star is flagged 'bad' during a position readout, that star's position is excluded.

When fewer than 2 stars are available for attitude determination for several consecutive readouts, the spacecraft may be forced to execute a safing action which halts science observations and changes the onboard attitude control law to no longer rely on star tracker data. Such a safing action results in the loss of science.

Mica assists in operations by generating plots like those below to examine observations which dip below 2 stars available for attitude control (N stars in Kalman Filter).

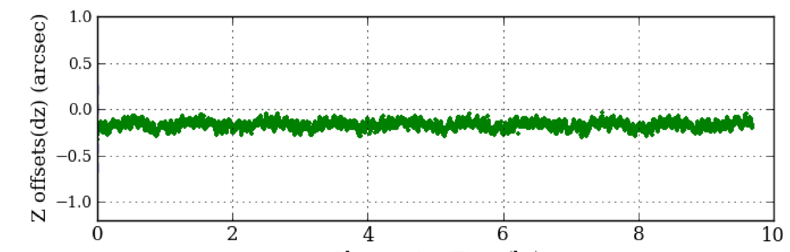


Here the the overall pattern of stars marked 'bad' can be viewed over time during this observation.

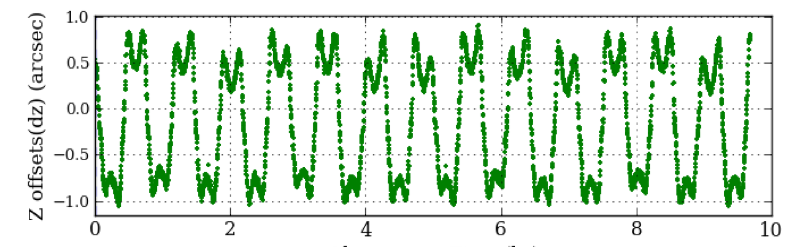


After an observation, an aspect solution is determined in ground processing. The aspect team uses mica to check the quality of these aspect solutions. These checks verify that the aspect determination system, from onboard aspect determination, to telemetry downlink and decommutation, through ground aspect processing, produces a highly precise and accurate solution.

One way that we evaluate precision is to use the ground aspect solution to calculate the expected position of each star at each sample and then compare the actual individual star positions with those calculated positions. Here is an example of the individual star residuals for a well-tracked star.

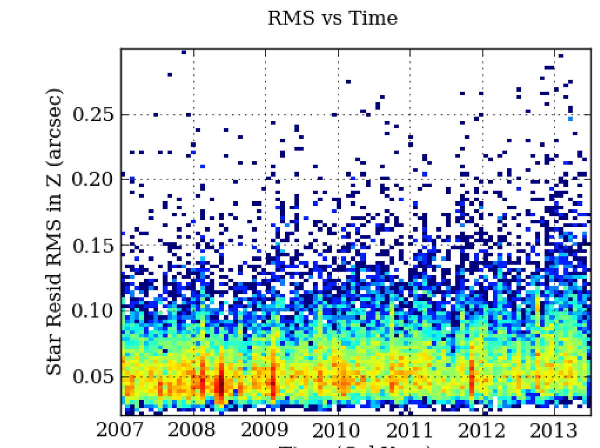


Here is an example of a star which has centroids that are pulled away from the expected pattern by a pixel on the CCD detector with a high dark current. The observed frequency of these residuals is determined by the frequency of the spacecraft's dither pattern. The aspect solution for this observation was recalculated without this star.



The verification and validation system is also used to mine the per-observation V&V outputs for long term trending. This figure shows is a 2d histogram used to visualize the RMS of the star residuals for each star in each observation over the last 6 years.

This is a key example of how we visualize the reduced data to follow trends and also shows that the aspect reconstruction performance has been largely unchanged over the plotted interval.



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