An Archive of Chandra Observations of Regions of Star Formation (ANCHORS)

Bradley D. Spitzbart[1], Scott J. Wolk[1], Natalya Bizunok[1], Angeliki T. Pollatou[2] and Fred M. Walter[2]

[1] Harvard-Smithsonian Center for Astrophysics (CfA), Cambridge, MA, USA

[2] SUNY - Stony Brook, Stony Brook, NY, USA

ANCHORS is a web based archive of all the point sources observed during Chandra observations of regions of star formation. It is designed to aid both the X-ray astronomer with a desire to compare X-ray datasets and the star formation astronomer wishing to compare stars across the spectrum. For some 50 Chandra fields, yielding 10,000+ sources, the database contains X-ray source properties including position, net count rates, flux, hardness ratios, lightcurve statistics and plots. Spectra are fit using several models, with final parameters and plots recorded in the archive. Multi-wavelength images and data are cross-linked to other archives such as 2MASS and SIMBAD. Many of the observations are of southern clusters and have no contemporary optical photometry. We are using time on the SMARTS telescopes to fill this void and will make the data available through the ANCHORS HTML/XML interface. The Chandra and SMARTS data are processed and compiled by separate automated pipelines. The pipelines ensure consistent analysis techniques for direct comparisons among clusters. We report on current status and availability to the community and prospects for expansion.

The *Chandra X-ray Observatory* was launched in July 1999 and has performed reliably since. Typical nuances and judgement calls in data analysis lead to many difficulties in comparing published data from different observers or from different observation dates. The data reduction and analysis software itself changes over time which can affect the final results even on the same dataset. In most cases different spectral models, parameter settings, and classification criteria will be applied based on the observer's preferences and familiarity. The goal of our catalog is to provide a uniform (not necessarily optimal) database for the comparison of data from different stellar clusters. This type of catalog provides added science return as well as convenient observatory health and performance metrics. The catalog will make it possible to treat science quantities in similar ways to how databased spacecraft temperatures and voltages are treated for monitoring and trending. The full benefit of ANCHORS will be realized in sorting and searching on any property (temperature, absorption, age, mass ...) across numerous stellar clusters.

Science Applications

The archive is designed to aid both the X-ray astronomer with a desire to compare X-ray datasets and the star formation astronomer wishing to compare stars across the spectrum. It brings together *Chandra* data on open clusters and other bright, variable, young stars for the study of the various physical mechanisms indicated by the x-ray emission. *Chandra's* superb spatial resolution allows the resolution of stars in crowded regions 2-3 kpc away. With good sensitivity between 2 and 8 keV, *Chandra* can penetrate star forming clouds to levels rivaling near-IR telescopes. These features allow novel investigations of star formation which is more massive, more embedded and more distant than previously possible. Using the point source database, one could follow the progression of luminosity and variability for various mass stars from the birthline to the present day without having to weigh the impact of the different analysis assumptions made by each team.

While much can be learned about stellar evolution from the study of individual clusters, science return is enhanced when the clusters are viewed as a group. As a pilot study, we examined brown dwarfs observed by Chandra during AO1-2. We found almost 70 candidate brown dwarfs had been detected by Chandra (Wolk 2003) (though only 8 bone-fide). Trends indicate that the younger brown dwarfs are hotter in X-rays than the field brown dwarfs, but the total X-ray luminosity of detected brown dwarfs are similar. Another study of a subset of objects was done by Feigelson et al. (2002). They examined only the 43 X-ray sources in the ONC between 0.7 and 1.4 solar masses in order to understand the mean properties of the young Sun at 0.5 Gyr. They conclude that the flares which occur during the protoplanetary phase can cause significant production of unusual nuclieds including Al-26. Using the point source database, one could follow the progression of luminosity and variability for sun-like stars from the birthline to the present day (with the inclusion of AO-4 target NGC~752) without having to weigh the impact of the different analysis assumptions made by each team. Similar studies can be performed on intermediate mass stars. These studies are particularly interesting since flares imply the presence of confined plasmas which should be absent in these stars.

Observatory Performance Metrics

Using PSF and spectral line measurements from all the best point sources observed (say, greater than 200 counts) gives a baseline than could not be available from a necessarily limited calibration campaign.

Note the elongation and rotation of sources far off-axis due to the cylindrical shape of *Chandra's* mirrors. The elongation and rotation as a function of chip position is an important quantity to measure and track over time, as any shifts must be explained. For sources combined from throughout the *Chandra* mission, filtering on time or energy we can detect shifts in this fit which indicate any mirror alignment problems. ANCHORS will aid in the calibration of aimpoint shifts.

Spectral characteristics can be used to monitor charge transfer inefficiency and to monitor for a systematic appearance of any new absorption features indicating contamination on the mirror or focal plane surfaces.

No thermal-induced image distortions are recognized to date. The point source catalog will confirm this result and provide a method of continued monitoring.

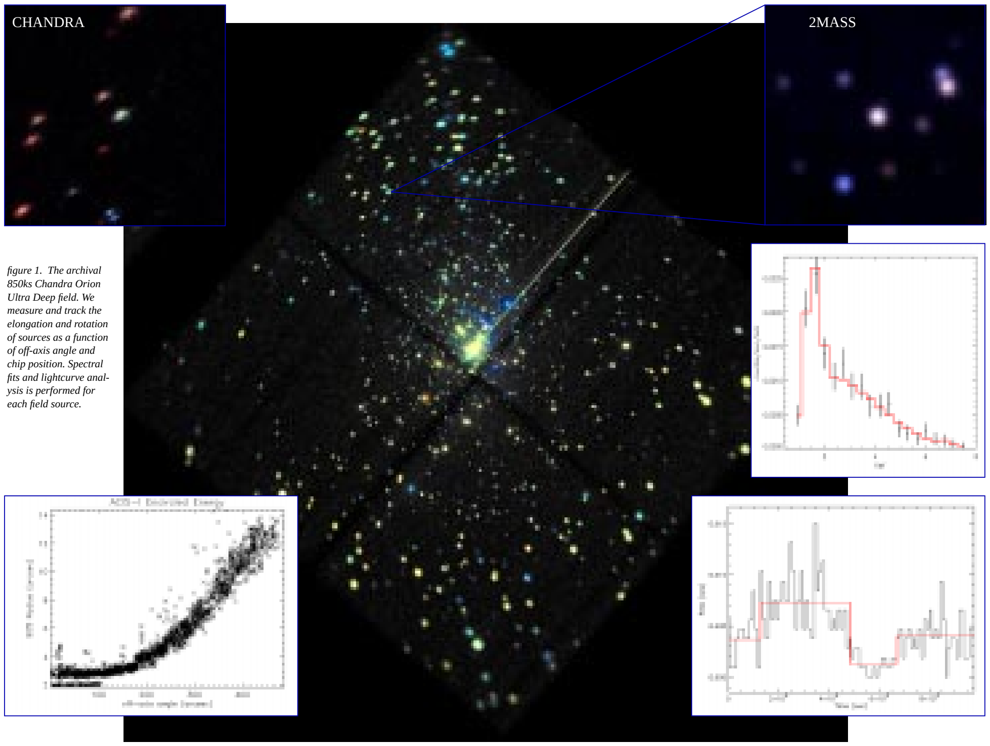

figure 1. The archival 850ks Chandra Orion Ultra Deep field. We measure and track the elongation and rotation of sources as a function of off-axis angle and chip position. Spectral fits and lightcurve analysis is performed for each field source.

ANCHORS Features

- Source detection by PWdetect, wavdetect.
- Automated processing by YAXX (Aldcroft, SAO).
- Spectral fits (mekal, apec, 2-temperature models) by Sherpa.
- Quantile analysis (Hong, SAO) and hardness ratios.
- Unabsorbed source fluxes.
- Bayesian block lightcurves (Scargle, NASA).
- Chandra, 2MASS, DSS images from SkyView.
- Downloadable data files.
- Links to query SIMBAD.
- Links to Chandra data archive.
- XML allows customized data formats and sorting/searching utilities.

Future Enhancements

- Import infrared/optical data from existing 2MASS, Spitzer, DSS, and USNO archives.
- Obtain new optical data through SMARTS.
- Provide distance, age, mass, references etc., from the literature when available and use to derive luminosities.
- Link to Vizier, Webda, ADS, etc. entries.
- Calculate additional temporal properties such as a K-S statistic.
- Add interactive plotting of user selected quantities.
- Allow on-line re-fitting using built-in or user defined models and parameters.
- Create advanced searching, sorting, and retrieval tools.

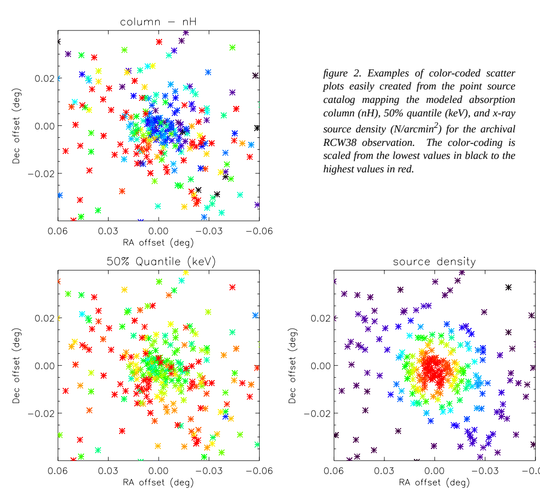

figure 2. Examples of color-coded scatter plots easily created from the point source catalog mapping the modeled absorption column (nH), 50% quantile (keV), and x-ray source density (N/arcmin^2) for the archival RCW38 observation. The color-coding is scaled from the lowest values in black to the highest values in red.

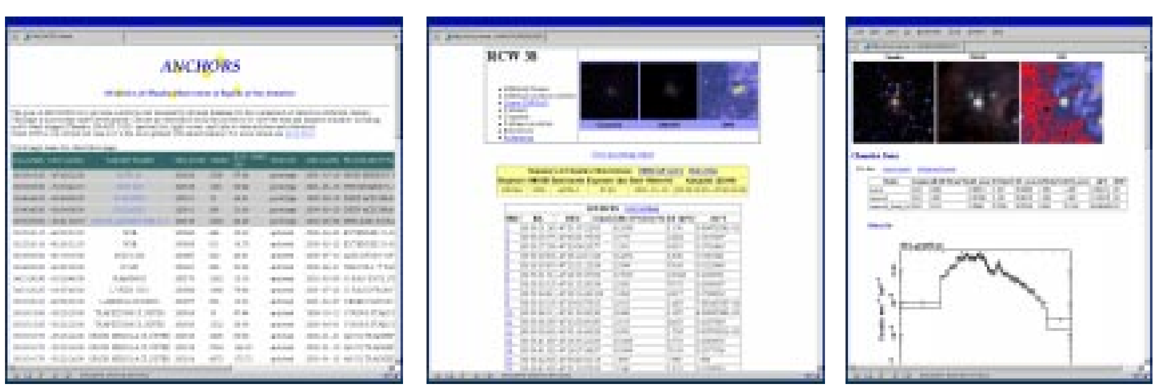

figure 3. The catalog's three main page types. Links and information about all available observations are listed on the top page (left). Each observation has its own sub-page (middle). And each source has its own page, showing multi-band images and data, spectral fit parameters and plots, and light curve plots and statistics (right).