



The Chandra Source Catalog : Google Earth Interface



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Abstract

The Chandra Source Catalog (CSC) contains multi-resolution, exposure corrected, background subtracted, full-field images that are stored as individual FITS files and as three-color JPEG files. In this poster we discuss how we took these data and were able to, with relatively minimal effort, convert them for use with the Google Earth (GE) application in its *Sky* mode. We will highlight some of the challenges which include converting the data to the required Mercator projection, reworking the 3-color algorithm for pipeline processing, and ways to reduce the data volume through re-binning, using color-maps, and special Keyhole Markup Language (KML) tags to only load images on-demand. The result is a collection of some 11,000 3-color images that are available for all the individual observations in the CSC Release 1. We also have made available all ~4000 Field-of-View outlines (with per-chip regions), which are trivial to produce starting with a simple *dmlist* command.

In the first week of release, approximately 40% of the images have been accessed at least once through some 50,000 individual web hits which have served over 4Gb of data to roughly 750 users in 60+ countries.

We will also highlight some future directions we are exploring, including real-time catalog access to individual source properties and eventual access to file based products such as FITS images, spectra, and light-curves.

Google Sky Basics

Google Earth (GE) is a stand alone application available for Windows, Mac, and Linux. It provides a very intuitive pan & zoom GUI of the Earth to access vast amounts of geocentric data. Recent versions now include a *'Sky'* mode that turns the globe inside-out to allow presentation of celestial data.

Switching to Sky mode, users see DSS or SDSS mosaics of images as well as outlines of the Constellations and various 'points of interest.' GE allows users to render their own data via Keyhole Markup Language (KML). The data are drawn as different layers that can be enable/disable or made partially transparent. This allows one to visually check for spatial correlations.

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2"
hint="target=sky">
<GroundOverlay>
<Icon>
<href>acisf07433_000N001_4.png</href>
</Icon>
<LatLonBox>
<east>-135.034320686</east>
<west>-134.279565706</west>
<north>60.684718808</north>
<south>60.1495287469</south>
<rotation>0.0</rotation>
</LatLonBox>
</GroundOverlay>
</kml>
```

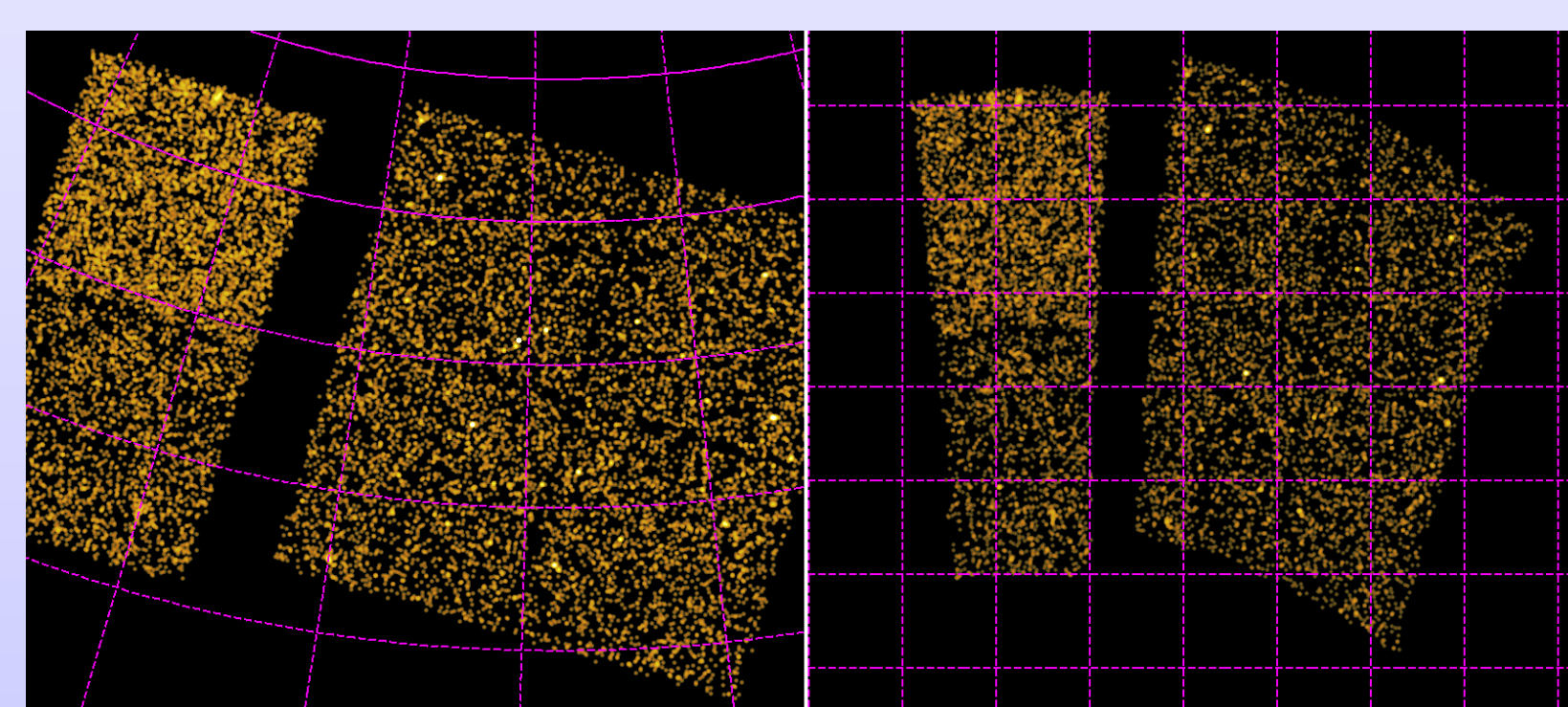
Here we see the elements of the GE GUI along with a simplified KML file used to overlay the image. We have made the logo partially transparent with the slider.

Mercator Projection

Google Earth assumes images are created using a Mercator projection: X and Y axes are constant Longitude and Latitude and fixed pixel sizes; note the use of the N-E-W-S cardinal directions in the KML example.

Given Chandra's relatively small field of view, the difference between the usual Tangent projection and the Mercator projection are hardly noticeable. However, there are obvious misalignments in fields away from the equator and for sources far off-axis at mid-range Declinations. Therefore we decided to reproject all the images using the required projection to get best alignment we could.

This figure shows ObsID 6431, an observation of Polaris near the North Pole. Left is the standard Tangent projection, right is the Mercator Projection. Data are displayed in *ds9* (grids are not the same); Google Earth renders poorly near the poles.

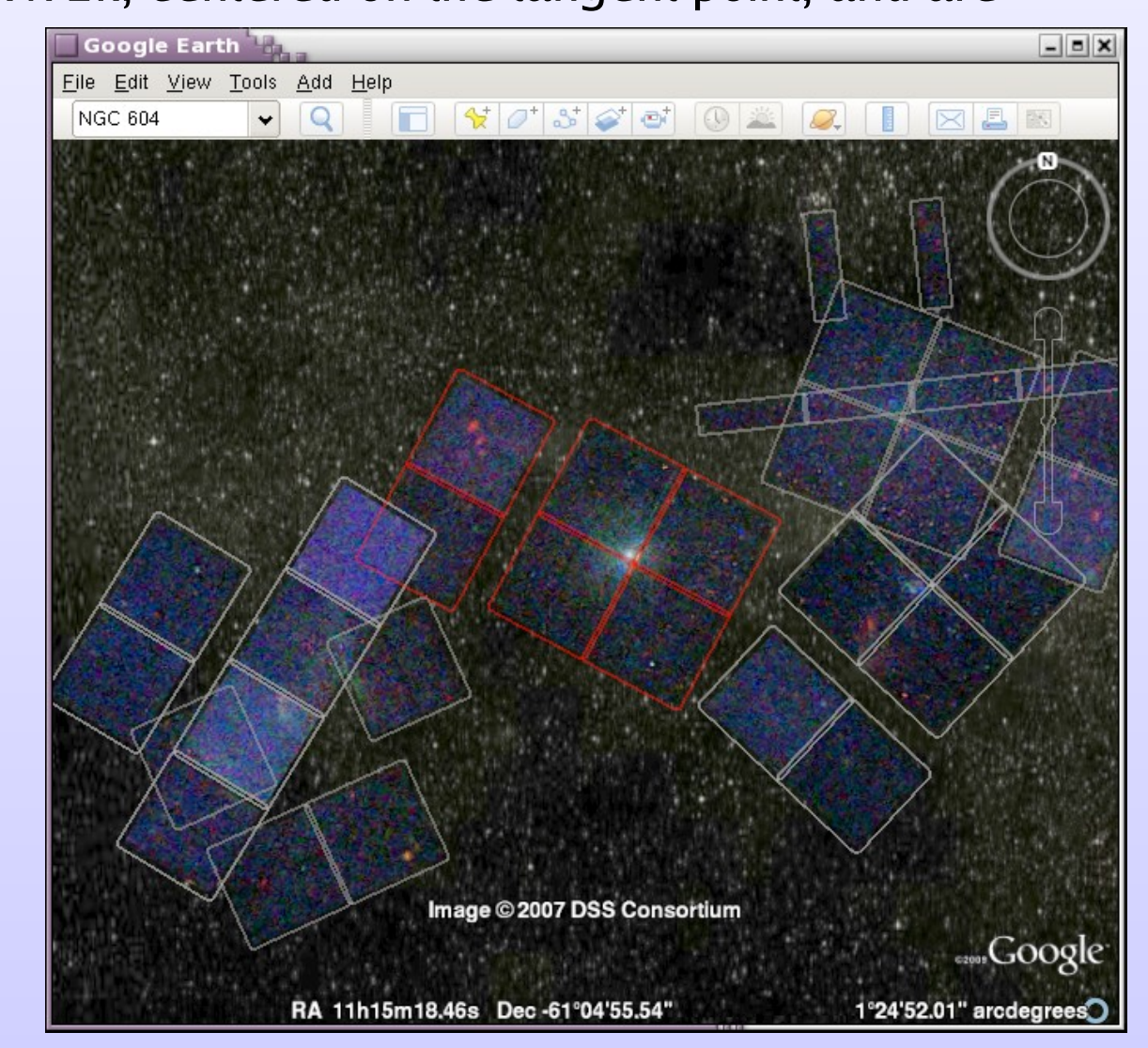


Multiple Resolution & Multiple Observations

In Release 1.0, every observation (OBI) was processed individually so we only have these individual images (not true mosaics). Somewhat unexpected was the number of overlapping OBIs. GE allows for images to overlap and provides a mechanism to order them via *drawOrder* tags. To automate the process we set the *drawOrder* to the exposure time of the OBI so that the longer observations were on-top.

The native images are all 2k x 2k, centered on the tangent point, and are created for blocking factors {1, 2, 4}.

The level-of-detail, *Lod*, tag was used to only load the images that would be visible. Block 4 images are loaded when they would cover 128 pixels, block 2 @ 256 pixels, and block 1 at 512 pixels; so users only load the largest file/finest detail when they have zoomed in closely.



Here we see the region around NGC 3603. The various observations and CCDs (including an OBI using a sub-array) are obvious.

Three Color Images

The CSC already includes a set of three-color images for each OBI that has been exposure corrected and background subtracted. These JPEG files are available along with their FITS counterparts as part of a CSC query and will be available via a VO SIAP request.

We realized that with the large number of overlapping OBIs that there was a significant problem with these files - JPEG format does not support transparency (alpha channel). Large parts of the sky were obscured by the black pixels representing the inactive parts of the images. Simple attempts to *convert* from JPEG to PNG and specify black as the transparent color failed due to the sparse nature of Chandra data.

As we had already decided to reproject the FITS data, we took on the extra task to convert the data to PNG format using the new imaging capabilities in *ChIPS* (which allows us to make pixels outside the FOV transparent.) This also gave us the opportunity to try to enhance the scaling of the 3-color images to bring out more detail.

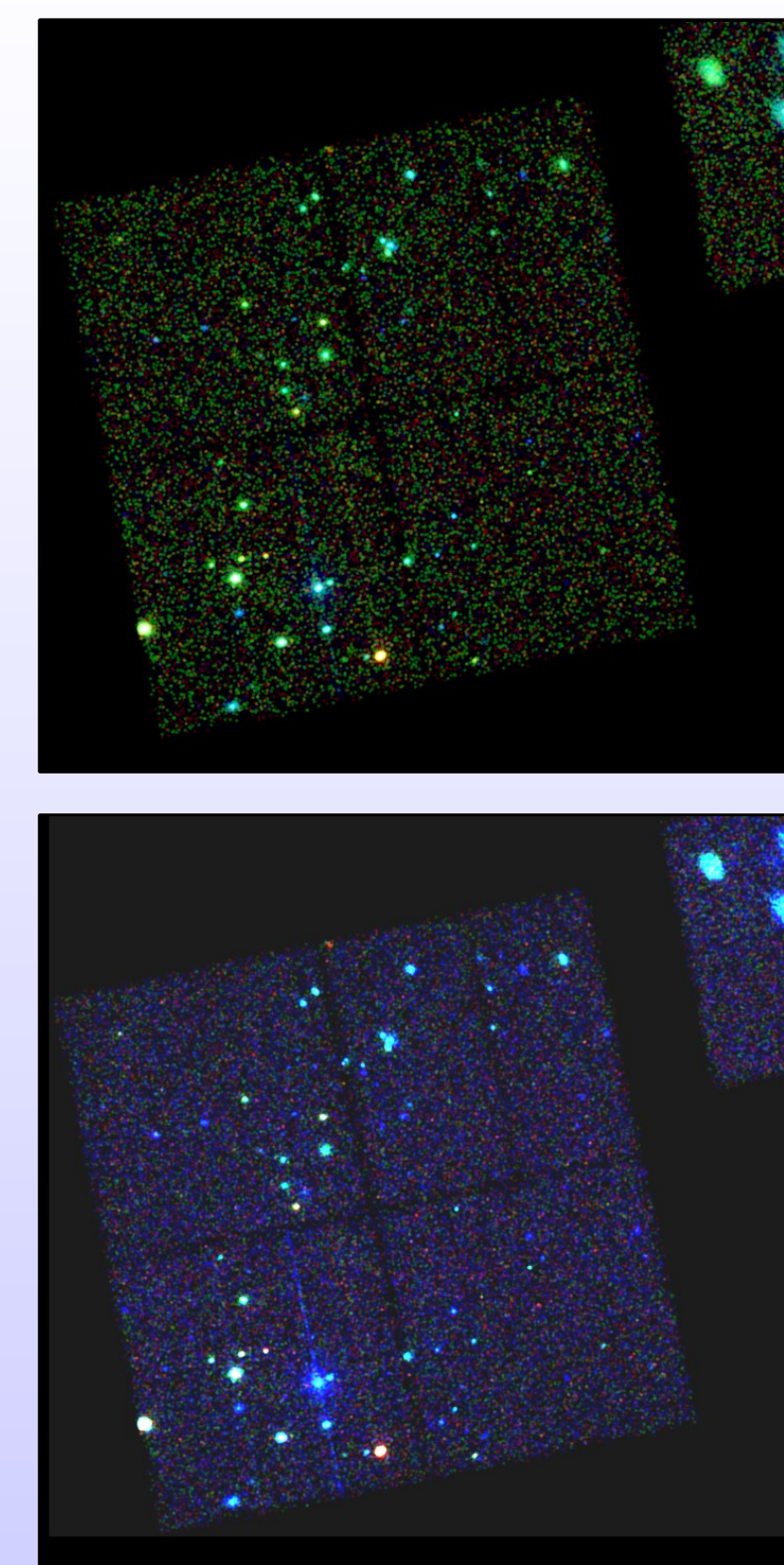
We applied at 15% max(Exposure) cutoff to remove artificially bright pixels at the edges and used a 0 cutoff to account for any background over-subtraction.

We are using the Lupton et al [arXiv:astro-ph/0312483v1] technique to create the 3-color images. This involves picking *Intensity* and *Scaling* functions. We are using the mean() of the R, G, and B images for the *intensity*. For the JPEG file we used *asinh(x)* for the *Scaling*; for the PNG conversion we found that compressing the scale using *asinh(x/10)* gave better results. The maximum pixel value was one of the critical parameters to adjust in the technique; we eventually found that using a 99.7% quantile of the pixel values as the upper limit gave us reasonable dynamic range over the wide variety of images being processed.

We then applied a 1 pixel sigma Gaussian smoothing to the images to remove the Moiré pattern that could be seen when GE regrid and renders the images.

Each step was done carefully to preserve the scientific validity of the data and still provide some aesthetic value. For example the Wang et al Galactic Center Survey is very blue in our images due to the on-orbit energy filter they used which filtered out low energies.

Shown to the right are 3-color images made with the same data. The figure on top is made by treating R, G, B independently. The figure on the bottom is made by scaling R, G, and B by the mean() and scaling them all together.

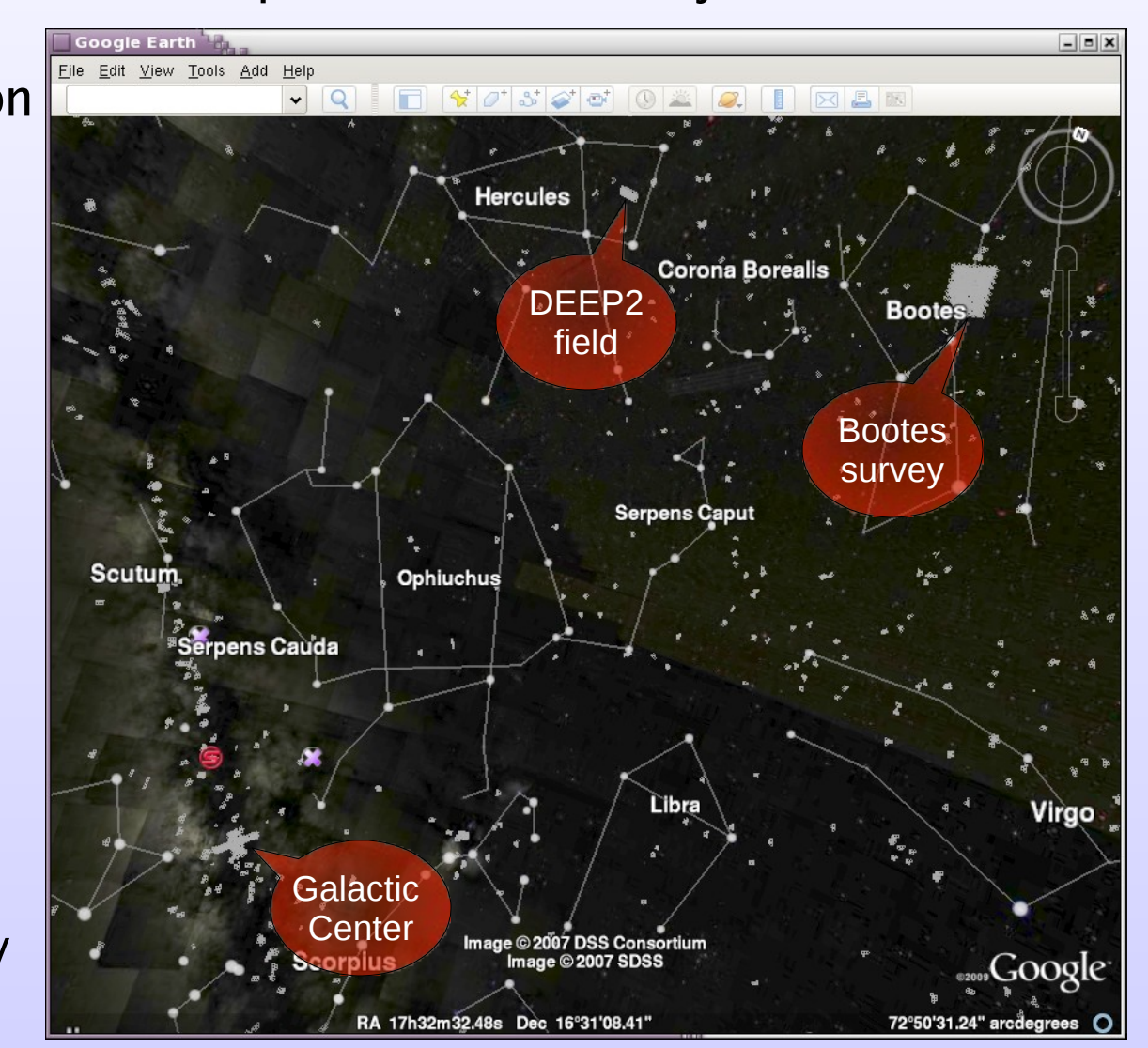


Field of Views

Every Chandra observation has a *field of view* (FOV) file that is part of the *primary* data package. These were regenerated for the Chandra Source Catalog to match the time range of the data as filtered in Level 3. We also excluded any chips that were dropped from processing due to extended emission. The FOVs are clickable and provide OBI and Object information.

To convert these FITS region files to KML format we start with a simple *dmlist* command to access the WCS as virtual columns to give us the celestial coordinates for the corners of all the active CCDs. Simple text processing tools (*sed*, *awk*, *grep*) were used to get into the proper format.

The FOVs make navigating the sphere easier especially when zoomed all the way out.



```
% dmlist "fov.fits[cols ra,dec,shape,component]" data,array
```

Data Volume and Usage

We have taken several steps to reduce the data volume needed to get started and to view simple fields (more complex mosaic regions are still bandwidth intensive). These steps include

- Using *Lod* tags to only load images when user is zoomed in enough to be meaningful.
- Using *Region* and *Link* tags to dynamically load (and subsequently parse) only the KML files needed for the part of the sky being viewed
- Rebinning the images to reduce data volume; highest resolution images blocked the least (x2) to maintain scientific usefulness; lowest resolution blocked more (x4) to give quick access to large areas at once.
- Converted block=1 images to use 8-bit (+alpha) color-maps to reduce file transfer and load times.

The data were publicly announced on 07 August 2009. There were some 11,000 hits¹ in the first 24 hours. The URL to the KML was also posted to the Google Earth Gallery where it was put into their list of Featured sites. Since then we have seen significant usage by the general public as well as from the scientific community.

Excluding one application that downloaded all the data files, all hits from internal developers and various search bots, over 60% of the images have now been accessed at least once which means users are not just going to the 'default' location in Orion. There have been hits from 80+ countries. The total access to date is over 260,000 hits to over 20 Gb of data. We are also seeing repeat usage; GE cache's data so we can see when it checks for updates and gets sent a 'hot modified' code.

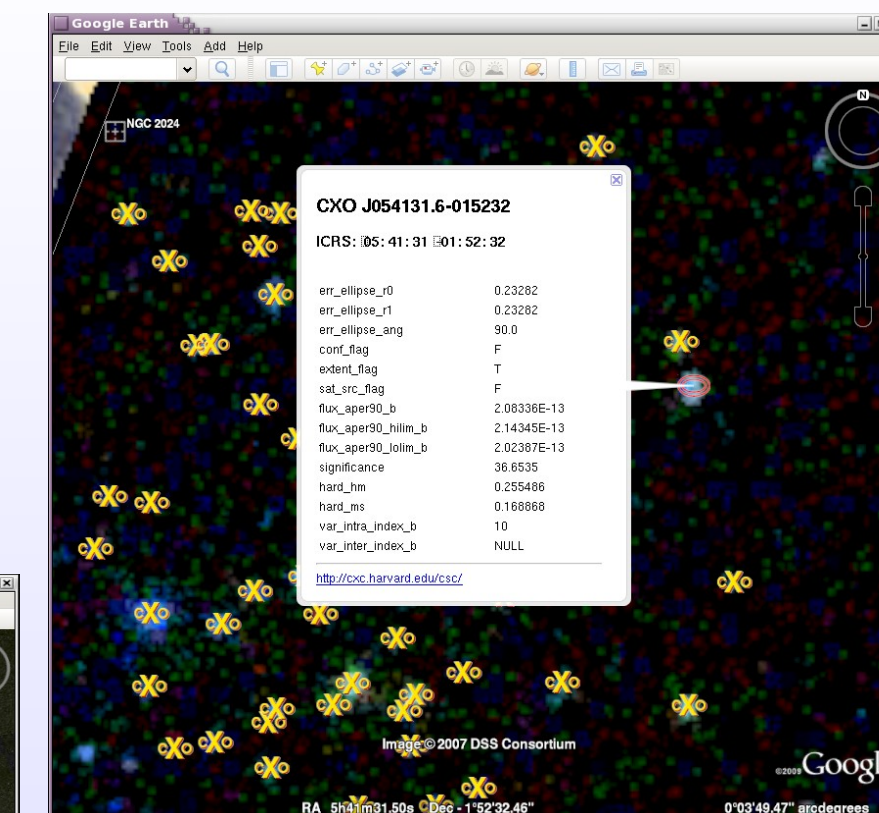
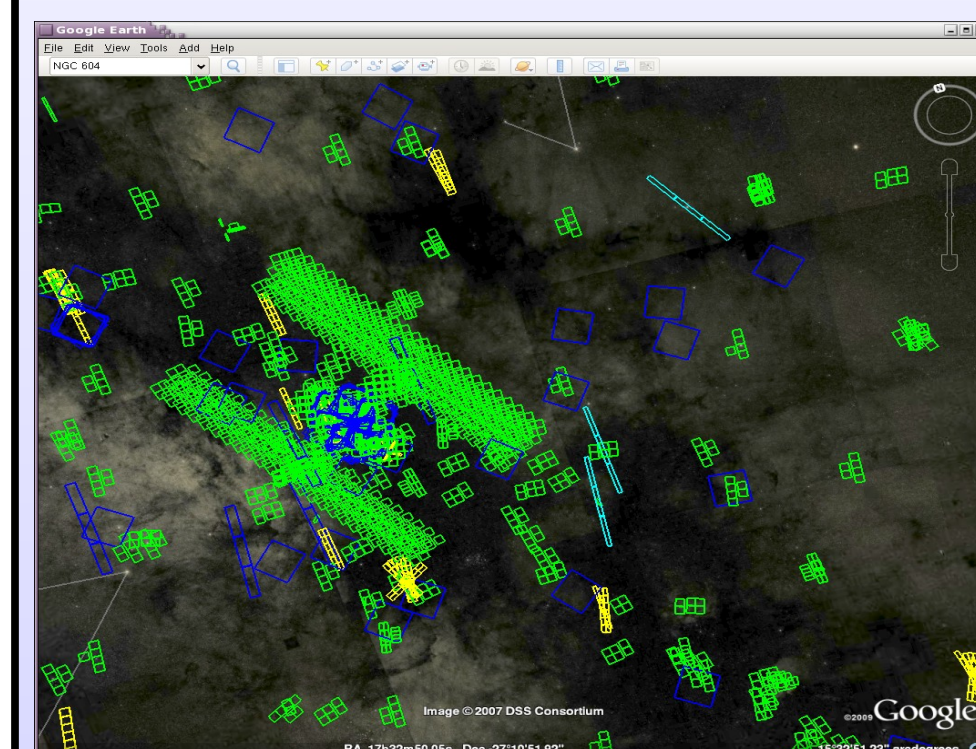


"Awesome: SAO's Chandra Source Catalog (CSC) data may now be visualized using the Sky in Google Earth interface"
- Carmen Iannacone - SLCTO

¹For these purposes, hit¹ refers to access to either the KML or the PNG files.

Future Enhancements

We will be providing access via 'pushpins' to all the Master sources in the CSC via a standard VO Cone Search service provided by the CXC. This returns not only the position but some key source properties such as significance, extent, variability, and colors (hardness ratios).



We will also be providing FOV's for all Chandra observations, not just those included in the CSC.

Longer term we hope to regenerate all the images such that the full-field is available at full resolution in sufficiently small file sizes to be useful. We are also looking at providing images of each source, plots of spectra and light-curves as well as links to additional file base products via additional VO protocols.

Additional interfaces such as *World Wide Telescope* may also be evaluated however its platform dependency makes it less desirable.

Conclusions

We have shown the simplicity and power of publishing a large percent of the *existing* Chandra data in GE. We have also shown some of the limitations of our data and things that we could do differently to provide even better data to the scientific community.

As we start to see more VO services come online we anticipate that they will be integrated into GE, much as the Microsoft World Wide Telescope application makes use of the VO registry and standard ConeSearch services.

- We envisage future usages such as
- Proposal planning to quickly see where Chandra has already observed with quick access to the observation parameters.
 - Authors creating tours to accompany their papers which may for example take referees to all the Clusters in their survey.
 - Non X-ray astronomers will be able to quickly see what data Chandra has available covering their favorite objects.
 - Continued interest from the public at large in the universe that Chandra sees.

Google Earth in Sky mode provides a very powerful *browser* for the sky. The ability to overlay multiple images from multiple wavelengths and to blend/link them together with user provided content makes it an application worthy of every professional astronomer. It has capabilities well beyond EPO; it just needs organizations and individuals to publish data to it.

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