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AstroVirgil: A Chandra Data Analysis Tool for the General Public

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Abstract. This paper reviews AstroVirgil, a user friendly program for the analysis of Chandra event files. AstroVirgil integrates photon filtering and visualization into a single GIU based tool. Photons can be filtered using custom GUI panels based on spatial position (in multiple coordinate systems), photon energy level (using multiple measures) or time of arrival. Filtered photons can be displayed as images, spectrums or lightcurves. This paper also reviews some of the performance and memory consequences of performing non-disk file based processing.

AstroVirgil is a GPLed pure Java program. It is built on top of JSky, a collection of reusable Java components developed at ESO and first described at ADASS'99. AstroVirgil is available from: www.SiliconSpaceships.com.

1. A Step Back

The web is full of scientific data sets that are used to discover the nature of the universe. Our goal is to empower non-scientists so they can also use this data as a vehicle for exploration. This paper reviews AstroVigil. It is an X-ray analysis tool designed for high school students and amateur astronomers. It is not intended for scientists; they already have their own tools. Instead it is intended to make the Chandra archive usable and relevant to the general public.

Before discussing the details of AstroVirgil, we need to step back and consider the earlier days of astronomy. By the year 1611, astronomical research using a telescope was open to a large number of people. Since the only resources a would-be astronomer needed was glass and grit, they were only limited by their talent and their time. Those with an interest in astronomy could contribute to the field and join the quest for knowledge or at least closely follow the field as it advanced.

But those welcoming conditions never last. Over time, resources become the limiting factor. Doing significant work requires larger and more expensive telescopes. Those without funding are left out of the game. No matter how great their interest or talent, the work done by researchers becomes more remote and the unfunded general public become more alienated. We are now in a world where orbital telescopes are very important, but most people don't live in a

country that can launch one. And for citizens of the developing nations, orbital telescopes and their data simply aren't relevant. The forefront of a field even as well loved as astronomy becomes more and more distant.

Can this change? Over the last 20 years, the processing power in the average home or classroom has gone from nothing to astonishing. During this same time, scientific instruments have left the analog world and been swept up by the digital revolution. Archives of these digital data sets have made their way onto the world wide web where they are available and free to anyone. Are we still in a world where resources present a huge barrier? The very best data and vast computational resources are plentiful. Is it possible to return to the days of 1611 when people were only limited by their talent and their time? If we build an X-ray analysis tool for the masses, will they come? We have built it, so soon we will find out if they care.

2. AstroVirgil Overview

AstroVirgil is a X-ray analysis tool designed for people who aren't astronomers such as students or amateur astronomers. It is for those with an interest in high energy astronomy, but a limited background. It was built on top of JSky, an open source pure Java application from ESO. AstroVirgil was built with the help of several graduate students at the University of Massachusetts Boston. More information on the program, as well as screen shots and download information, is available at www.SiliconSpaceships.com.

AstroVirgil is not intended to replace any existing Chandra tools. It lacks an awful lot of important features. It currently does not support: forward folding, PSF, ARF, RDF, CALDB, HRC, HETG, LEGT or scripting. If you are fluent in Chandra-speak, you can see there are many very important things missing. It is hoped that even with these limitations amateurs can still work on projects they find interesting.

2.1. Memory Based Processing

Existing X-ray data analysis tools such as CIAO or funtools typically operate by reading in a FITS event file, performing some operation and writing out a FITS file. This approach works well with both their command line interface and their scripting interface. However, AstroVirgil needs to be a much more novice user friendly program. Therefore, it implements a Graphical User Interface. The user controls factors such as the coordinate system and display parameters via menus and buttons. To see what the possible options are the user need not refer to a manual, but just looks at what the menus have to offer.

Typically, Chandra event files are under 100 MB. Most are small enough that can comfortably be loaded into RAM where they can be manipulated more quickly. Files of this size can contain data on roughly a million individual photons. Responding to the user's request to filter and display this many photons takes less than a second. For those Chandra files that are too large to fit in memory, AstroVirgil won't work. Since it is a tool for amateurs, it is not required to handle all Chandra data. AstroVirgil need only solve the simpler problems needed to engage the amateur community.

2.2. Photon Filtering

When using the Advanced CCD Imaging Spectrometer (ACIS), the sky position, approximate energy and time of arrival for each photon is recorded in the FITS event file. From this data cube, AstroVirgil can create either an image, a spectrum or a light curve. AstroVirgil also supports filtering of photons based on sky position, energy level or time of arrival. This provides the user with an amount of flexibility not possible with data from optical or radio telescopes. Detectors in lower energy astronomy do not register every photon. Instead, they integrate photons over time until a detectable signal has been accumulated. To answer specific questions, the choice of which photon to integrate is made before the observation by placing filters or prisms in front of the sensor. The Chandra X-ray Telescope need not employ filters. That is done during data analysis.

With AstroVirgil, the user can create a spatial filter by drawing a polygon on the image. Photons can either be excluded because they are inside or outside the polygon. Once the spatial filter has been created, spectra and light curves can be created that only use a subset of the photons in the original observation.

With AstroVirgil, the user can create an energy filter by selecting the region of interest by clicking on the graph of the spectrum. The images and light curves then display only the photons in the defined energy range.

With AstroVirgil, the user can filter photons based on their time of arrival. The user selects the desired time by picking points on a graph of the light curve. Then, the image and spectrum displays only use the photons with the right arrival times based on their time stamps.

These filters can be combined in many ways. Images can be made from just the hard or just the soft photons. Spectra can be made from just the photons when the source is brightest. Lightcurves can be created from just a small region of the image. Since all of these filters are created by clicking on images and graphs, the user need not understand the internal representation of information. Analysis tools for scientists expect the user to understand the units energy is expressed in, how Chandra keeps track of time and its spatial coordinate systems. While this does not present a challenge for astronomers, it does present barriers for beginners. By eliminating these barriers, we reduce what the user needs to learn. If the things to learn can be reduced enough, a threshold will be crossed and X-ray astronomy will be available to new communities.

3. Science with AstroVirgil

By filtering photons and analyzing images, spectra and lightcurves users can gain an understanding of astronomical objects. For many reasonably bright sources, the user may measure its temperature. For non-point sources the user can explore whether they are isothermal and if there are variations in heavy element ratios. For sources that show a variable light curve, the user can see if the image or spectrum vary over the same intervals.

The user can ask these questions and others for any non-grating ACIS observation in the Chandra archive. In the near future, we hope to support grating observations by reading Chandra 'pha2' files.

A group of students at Somerville High School is currently working on Science Fair projects using AstroVirgil and Chandra data. With help from scientists at the Harvard-Smithsonian Center for Astrophysics, these students will measure the rate of cooling of supernova remnants, survey the X-ray sources near the galactic center and compute the geometry of eclipsing X-ray binary star systems.

4. Future Plans

AstroVirgil is currently available on the web at www.SiliconSpaceships.com. It is downloaded by someone every day. We will continue to change and extend AstroVirgil based on suggestions from astronomers and users. Over time, we hope it will become a much more complete and powerful tool.

The Chandra Calibration Database (CALDB) is large, consuming roughly 1 GB of disk space. Even if this were made available to amateurs, it is doubtful they would want to give up that much disk space. We hope to develop a 10 MB mini-calibration database that contains information of the frequency-based varying response of the telescope at a coarse resolution.

Much interesting work can be done with grating observations. In the near future, we plan to extend AstroVirgil so it can read and display the processed pha2 files available from the archive. We have no plans to display grating observations based on event files.

We welcome suggestions for extending AstroVirgil or including other data sets that might engage students and the amateur community.

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