# Visualizing and Analyzing Massive Astronomical Datasets with Partiview

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**Abstract.** Partiview is an advanced, real-time visualization tool for multi-dimensional datasets. Developed at NCSA, Partiview has cross-platform compatibility that allows its use in environments ranging from laptops to the 21-meter-diameter Hayden Planetarium dome, on scales varying from the solar neighborhood to large-scale structure. Current applications of Partiview include the simultaneous, fully interactive visualization of multiple datasets, including both observed and simulated data. The software is available at no cost from `www.haydenplanetarium.org` along with our Digital Universe data archive. A major priority of the ongoing development of Partiview is its integration as an analysis and visualization component of an International Virtual Observatory.

## 1 Introduction

In 2000, the American Museum of Natural History (AMNH) completed the Rose Center for Earth and Space which included a rebuilt Hayden Planetarium. As part of this renovation, AMNH/Hayden created one of the largest immersive theaters in the world serving not only as an education/outreach facility, but also as a scientific tool for visualization. With our 21-meter dome and through our web site, we have brought complex scientific visualizations and our three dimensional atlas, the Digital Universe, to millions of visitors.

The Digital Universe is a multi-dimensional atlas of the universe that one can use for data analysis or to simply explore the Milky Way or the extra-galactic universe interactively. The software that allows the display of this atlas, Partiview, has been developed at the National Center for Supercomputing Applications (NCSA) and runs on a personal computer. Since April 2002, we have been distributing Partiview and our data to the public at no cost via our web site (`www.haydenplanetarium.org`) and have served over 10,000 downloads of our Milky Way Atlas. This paper will focus on these two interrelated projects, discussing their potential as an education/public outreach resource and scientific analysis tool for a Virtual Observatory.

## 2 The Partiview Visualization Software

Partiview is a software package that was designed to provide real-time, interactive data visualization for three dimensional particle data. Developed at the

National Center for Supercomputing Applications (NCSA), Partiview is actually the desktop version of a more versatile program called Virtual Director. These programs were designed to interactively record, edit, and play back a flight path through massive data sets inside a virtual environment like the CAVE.

In 2002, the Department of Astrophysics and Hayden Planetarium at AMNH was given a grant from the NCSA Alliance to distribute and help develop Partiview to aid in scientific visualization. We have contributed to the distribution, documentation, and data collection for Partiview. We are also making contributions to the software itself, which will eventually be open source.

Partiview differs from other data visualization programs in its ability to display and interleave multiple data sets at once. Seeing many data groups simultaneously, or even blinking one data set as you navigate in real-time among other data, provides a unique 3-D view that scientists often do not have access to. Partiview also differs from other visualization tools in the ease by which data are imported. There is no new programming syntax to learn, just a simple, concise command structure that tailors the display to your needs. Figure 1 shows Partiview with the 2dF galaxy and Sloan quasar surveys displayed.

Currently, Partiview runs on Linux, IRIX, Windows, and Mac OSX. The graphics output is OpenGL while the graphical user interface is written in FLTK. The efficiency of data rendering in Partiview depends on the graphics support as well as the complexity of the data. With our off-the-shelf laptop computer, we are able to display hundreds of thousands of particles and render them in real-time without any performance problems.

Time evolving data are also supported in Partiview. Namely, time evolving, three dimensional stellar dynamics codes have been accommodated for display and analysis in Partiview. Furthermore, Partiview can display other particle simulations such as galaxy collisions as well as polygonal surface models. Partiview, then, is not just a static particle viewer, but can accommodate dynamic simulations and theoretical computations, making this software an ideal tool for both theoretical and observational astronomers and scientists of all disciplines.

## 3 A Digital Universe

As part of the rebuilt Hayden Planetarium and newly-formed Department of Astrophysics, the American Museum of Natural History endeavored to create a Digital Universe that would not only take visitors on guided tours of the three dimensional universe but, more importantly, be a resource for the scientific community. Initially funded by NASA in 1998, our first goal was to build a Digital Milky Way Galaxy. We achieved this goal, building a statistical galaxy with over 800 million stars and other objects integrated with observed data sets.

Since then, we have expanded our interests to include the entire observable universe. We are collecting data on all scales and from many scientific disciplines. Additionally, many scientists have offered their data for use and distribution in the Digital Universe so that the scientific and education communities can share these data and view them within Partiview. We intend for the Digital Universe

to be a Partiview data node for the Virtual Observatory, shared by and accessible to scientists, educators, and the general public.

## 4 Integration Into a Virtual Observatory

We see great potential for both Partiview and the Digital Universe to be integral components of a Virtual Observatory. The main benefits that are available right now include:

- **Data Visualization** Currently, Partiview is mature enough to be used as a robust tool for visualizing data in real-time. While there are many paths of development that will enhance its functionality in the future, as it stands now Partiview is more than capable of providing an interactive, multi-dimensional visualization of existing observed and theoretical particle data.
- **Data Distribution** We are currently distributing data for use in Partiview. These data are mainly targeted at education and outreach organizations. With our Milky Way Atlas and Extragalactic Atlas, we provide everyone, from student to scientist, a rare view of our universe. Most of these data sets are derived from publicly-available data that exist in archives, however, others are from direct contact with project scientists. While the means of data distribution are primitive right now, we intend to integrate data standards that will be updated as those of the Virtual Observatory evolve.
- **Education/Public Outreach Node** Although we are a research institution, the American Museum of Natural History has a strong commitment to education and public outreach. We provide complex scientific visualizations to millions of visitors per year—our outreach potential is among the best of any scientific institution. We are tapping this potential for our distribution of the Digital Universe and Partiview. As these become more strongly coupled with the Virtual Observatory, we will be ideally placed to bring complex data sets to a public audience in understandable ways.

While there are many improvements to be made, we feel Partiview is ready for integration into a Virtual Observatory right now. These improvements, which we discuss in the following section, will enhance the functionality of Partiview as well as improve access to an expanded Digital Universe data archive.

## 5 Future Enhancements

In the future, we intend to enhance both the Partiview software as well as the Digital Universe archive. These changes will take place in conjunction with development by other scientific groups who are also adding features to Partiview.

We will concentrate our enhancements to Partiview in several areas. One major area for improvement is the user interface. Currently, much of the functionality in Partiview is accessed via commands, while some of the more common tasks are found in a small graphical user interface (GUI). We plan to add functions

and commands to the GUI which will make Partiview easier and more natural to use. We will also make improvements to the remote conferencing and collaborative modes of Partiview so that one Partiview could talk to many other instances of Partiview, broadcasting the view of multiple data sets over the Internet. In addition, we will provide more sophisticated data access capabilities into Partiview, allowing for on-line data access, conversion, and display. Finally, we will continue to update and improve the documentation and distribution methods for Partiview.

The Digital Universe, being less technically sophisticated, will require more development. We hope to first provide our data in sensible ways over the Internet. Currently, these are offered as ASCII files; however, once data standards are set, be it XML or some other data standard, we intend to integrate these standards so that our Digital Universe archive will be compatible with other standardized archives. We will also make data importation a smoother process, creating routines to convert data into the Partiview format. This will open up the possibility of on-the-fly, over the Internet visualization by loading and displaying data interactively.

We believe these enhancements will insure that Partiview and the Digital Universe, as part of a Virtual Observatory, will be a powerful visualization tool for scientists and a valuable outreach resource for transmitting science to a broad audience.

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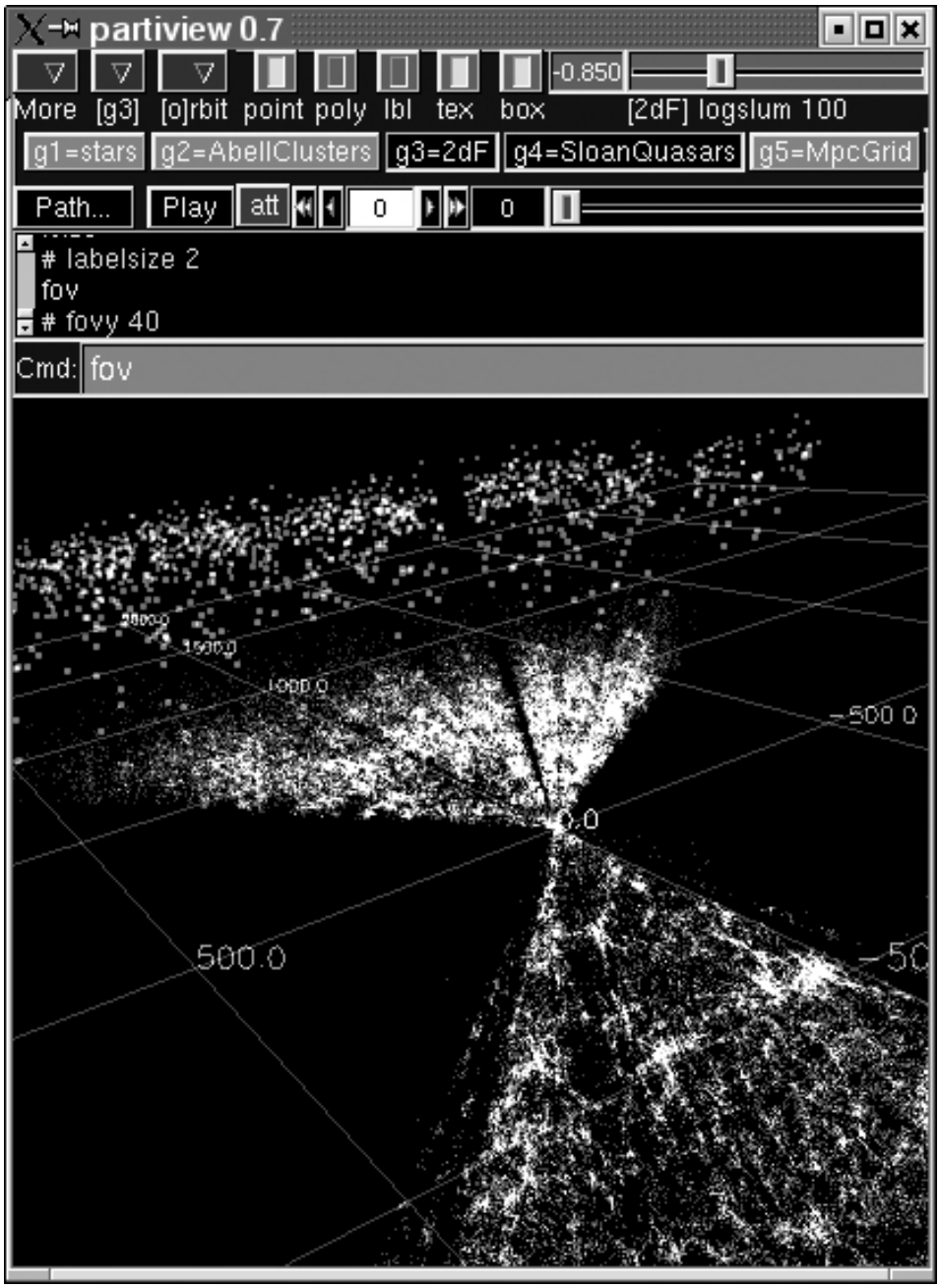


**Fig. 1.** A screen shot of Partiview. Shown (in glorious black and white) are the 2dF galaxy survey (white points) and the Sloan Quasar Survey (gray points). Our vantage point is such that the flat, fan-like portion of data extending out from the Earth (toward the top of the viewing area) is at a low angle of inclination while the opposite side (at bottom) is inclined at a higher angle, thereby revealing the structure of these data. The megaparsec grid is in the same plane as the data in the top of the viewing area. It should be noted that static images cannot capture the 3-D view, particularly when you are in motion.