The AIPSview Astronomy Visualization Tools

Richard M. Crutcher[1,2], M. Pauline Baker[1], George Baxter[1], John Pixton[1] and Harold Ravlin[1,2]

Abstract. AIPSview is a set of two new software tools for visual data analysis being developed by the radio astronomy group at the University of Illinois as part of the AIPS++ project. The tools provide a wide range of functionality for the display and analysis of 2D and 3D astronomical data sets. In this paper we describe how to obtain further information about AIPSview on the WWW including how to obtain executable and source code, and discuss the current functionality of AIPSview and future development plans.

1. Introduction

AIPSview is a set of two visualization tools built in C++ at the National Center for Supercomputing Applications, with support from the University of Illinois Astronomy Department and the NSF/ARPA Grand Challenge project in Radio Astronomy Imaging. It will be the principal visualization and analysis system for the AIPS++ software system which is now under development. Other partners in the AIPS++ project, including especially the group at the Australia Telescope, will begin contributing to AIPSview in the near future.

Our goal in producing AIPSview is to improve the ability of astronomers to visualize and analyze image data, particularly three dimensional (spectroscopic) images. AIPSview includes a number of techniques for the visualization of 3D data sets, including slicing and dicing along any of the three axes, sweeping through the third dimension of a data set as a movie, isosurface rendering, and volume rendering. A unique feature of AIPSview is the ability to present synchronized visualization of multiple images of the same area of sky (obtained for example at different wavelengths or in multiple spectral lines). It is possible to blink any frame from two (or more) image cubes, to run a synchronized sweep or movie through the third dimension of two (or more) data cubes with the same world coordinate frame of each of the data cubes displayed simultaneously, to read out world coordinates, intensity values, and line profile plots for multiple data cubes simultaneously, and to display multiple data sets simultaneously in the same visualization as slices, contours, isosurfaces, and/or volumes.

Our AIPSview development work is really on two tools, one (hereinafter called AIPSview) that runs on Unix workstations without special graphics li-

[1]National Center for Supercomputing Applications, University of Illinois, Urbana, IL 61801

[2]Astronomy Department, University of Illinois, Urbana, IL 61801

brary support and one (hereinafter called Inventor AIPSview) that requires OpenGL and OpenInventor. AIPSview itself is a tool for two-dimensional visualization and relies on Motif and Xlib for its user interface and drawing capabilities; it has been released to the astronomy community. Inventor AIPSview allows us to take advantage of the powerful features in the OpenGL and OpenInventor libraries in order to support full three-dimensional visualization of data, including multiple slice display, isosurface representation, block and brick excavation, and direct volume rendering. Inventor AIPSview is both a development tool for techniques which might migrate later into AIPSview and a system for three dimensional visualization using the highest end graphics workstations, including virtual reality systems.

In this paper we describe how to obtain the AIPSview code and discuss its features. We then describe Inventor AIPSview, and our plans for the future.

2. WWW information about AIPSview

The AIPSview WWW home page is http://monet.ncsa.uiuc.edu/Aipsview. The page contains contains an html version of the AIPSview UserGuide, an interactive tour of many of AIPSview's features and functions, and instructions for downloading the AIPSview C++ source code and the AIPSview executables for each of the six Unix workstation architectures available to us: Sun under SunOS4.1.3, Sun under Solaris 2.4, IBM RS/6000 under AIX 3.2.5, DEC Alpha under OSF/1 V2.0, HP under HP-UX A.09.05, and SGI under IRIX 5.3.

3. Description of AIPSview features

3.1. File formats and user interface

AIPSview can read image files in a wide variety of FITS formats (both scaled integer and floating point data formats are supported). Floating point numbers blanked with NaN (not a number) or integer values equal to the value of the "BLANK" keyword in the FITS header are treated as blanked values. To the extent possible, FITS image files are not read into main memory (i.e., such files are memory-mapped), enabling large files to be displayed and explored. However, AIPSview's operations and graphics do require a reasonably sized machine, with "reasonable" amounts of memory and swap space. AIPSview can also read single-SDS files written in the HDF format.

The AIPSview user interface is designed to be easy to use and intuitive. It is a Motif based graphical user interface, so users familiar with the Motif GUI will be familiar with interface operations. Files are loaded into AIPSview with the standard Motif file selection window. Figure 1 shows the resulting AIPS View display window after the FITS file IRC10216.CN has been loaded. Information about the data set, such as axis labels, number of dimensions and length of each dimension, is read from the FITS header and is used to define what appears in this display. For example, for a 2D data set the "Slice along" part of this window would not appear since there is no option to be selected. In figure 1 the slice along VELO button has been pressed, which results (by default) in a raster image display of the middle velocity plane of the data cube, scaled to a 256 x

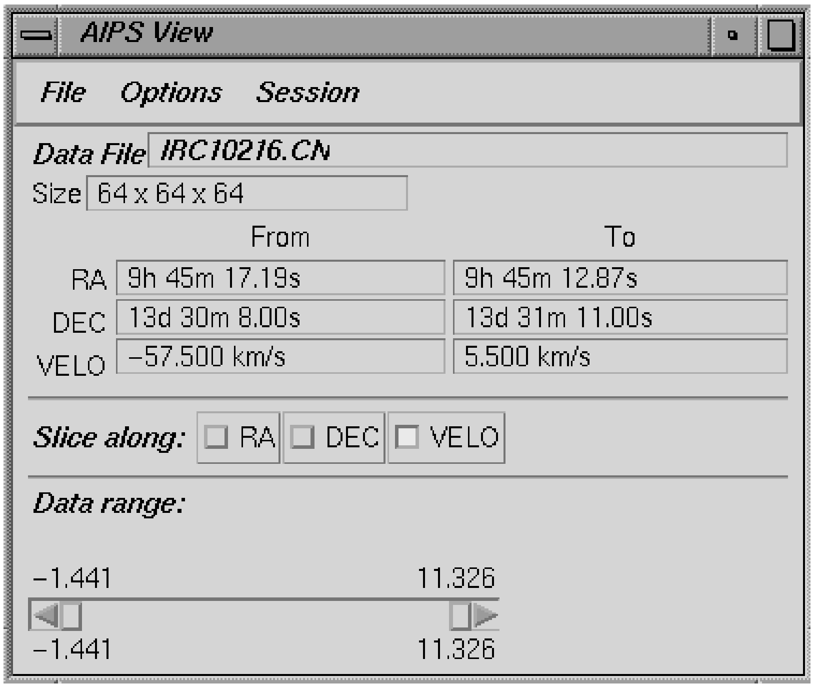

Figure 1. AIPSview window with information about the FITS file IRC10216.CN.

256 screen display. This 64 x 64 image has been expanded to 256 x 256 by pixel replication. Images larger than 256 x 256 are subsampled. At the bottom of the window the minimum and maximum of the intensity values in the full data cube are shown at the ends of the slider; one may limit the range that is displayed with this slider. If multiple data sets have been loaded into AIPSview, each is listed under the "Session" menu. Selecting a particular data set from this menu will display information about that data set (figure 1). Data sets may be deleted from a session.

3.2. Display of 2D images

AIPSview can display as a raster image a 2D image or any orthogonal 2D slice from a 3D image cube (e.g., display of RA vs. Dec for a given Velocity, display of RA vs. Velocity for a fixed Dec, etc.). To produce a RA vs. Velocity slice, one would push the Slice along DEC button (see figure 1). Multiple representations (both an RA-DEC and an RA-VELO) may be displayed simultaneously, as shown in figure 2. Pixel values corresponding to blanked values are displayed as black. With the default colormap and the initial data range, any black in the image will be blanked data. The scaling of the image display may be changed with the "Scale" menu; the images in figure 2 have been rescaled from the default 400% (the 64 x 64 data set displayed in 256 x 256 screen pixels) to 500%.

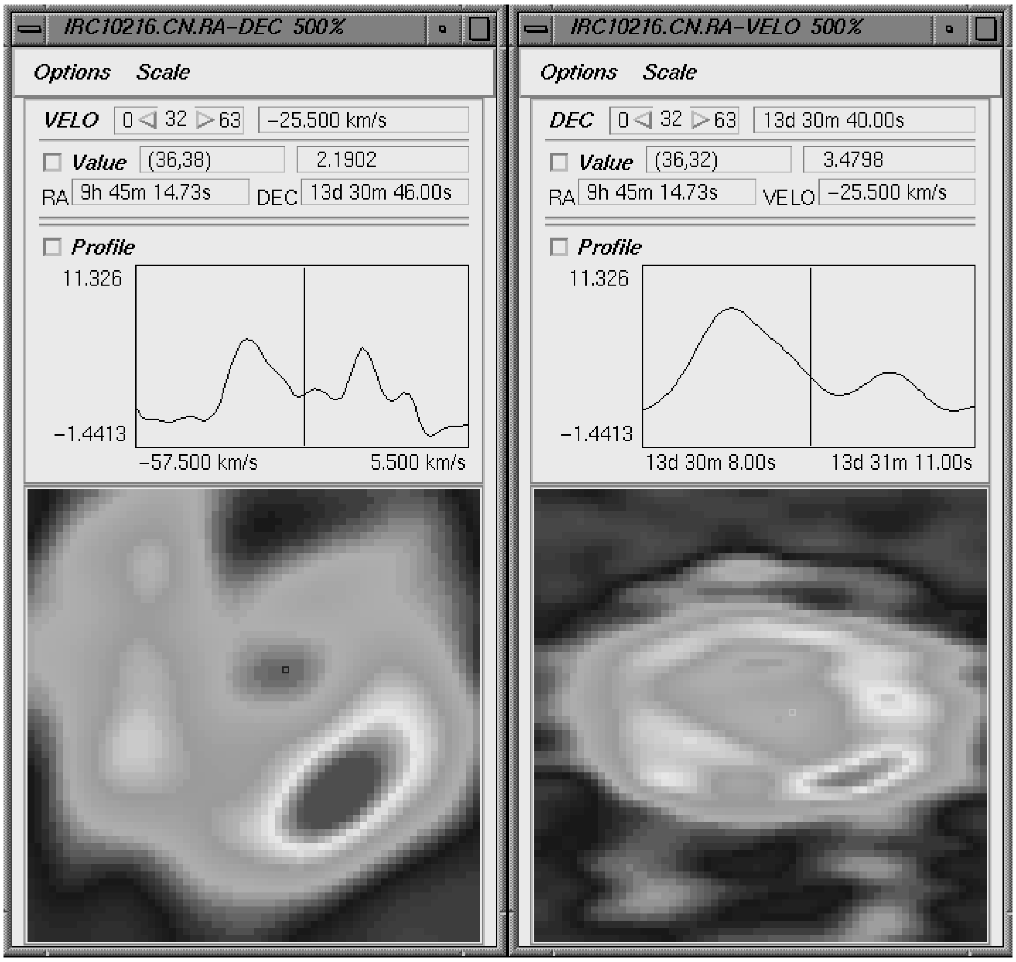

Figure 2. AIPSview raster display windows showing the middle velocity plane (left) and middle RA plane (right) of the IRC10216.CN data set.

3.3. Data set information

The area above the raster images in figure 2 shows information about the data set. The Value, Region (not shown here, see figure 3), and Profile display options are each turned on and off from the Options menu item. The Value button has been turned on, so the pixel coordinates, world coordinates, and data value are displayed when the mouse pointer is in the image display window and the left button is clicked. When the value button is on, there is a box drawn around the selected pixel in the image window to indicate the current position. The value information is continually updated as the mouse pointer roams the display window with the left button held down. A blanked pixel will cause the word "Blanked" to appear rather than an intensity number.

Region information shows the region which has been selected, which by default is the entire region. Region was not turned on in figure 2, but was in figure 3 (discussed more fully below). Pressing the left mouse button at a pixel in the image display, dragging to another pixel, and releasing the mouse button defines a new region, which is displayed as a rectangle in the display window. The pixel and world values of the subregion will be displayed in this area of the window. By pushing the Display Region button, one can get a new Display window showing only the selected region.

For 3D data sets, there is a Profile area of the window. By clicking on the Profile button, you get a profile plot when the mouse pointer is in the Display window and the left button is clicked. A vertical line marks the plane currently being displayed; this line will move through the profile if a movie (see below) is being run. This profile is continually updated as the mouse pointer roams the display window with the left button held down. If the display is of a VELO plane of a 3D data set, the profile is the usual spectral line plot. If an RA-VELO slice is being displayed, the profile display would be a data value versus DEC profile (as shown in figure 2). The intensity range displayed is by default the entire range present in the data; this may be changed by use of the slider at the bottom of the AIPS View window (figure 1). If some spectral channels are blanked, the blanked channels will be "shown" as gaps in the displayed spectrum.

3.4. Animation (movie and blink) display

In order to examine the images in the third dimension of a data cube, there are movie display capabilities, which sweep through the planes along the third dimension, displaying each in sequence. There is a speed control slider to control the rate of sweeping. It is possible to animate once through and stop, animate continuously from front to back to front, et cetera, or to animate continuously from front to back. A frame number control slider changes automatically during the sweeping. An animation may be stopped at any point, and the movie controlled manually with the frame number slide control. If there is sufficient RAM available, animations are loaded into pixmap RAM memory of the display computer in order to maximize the speed of animation.

There is also a blink function which will open a new window and run an animation through all of the selected display frames; more than two images may be blinked. Any plane from a 3D data cube may be blinked with the single plane of a 2D data set, or any plane of a different 3D data set.

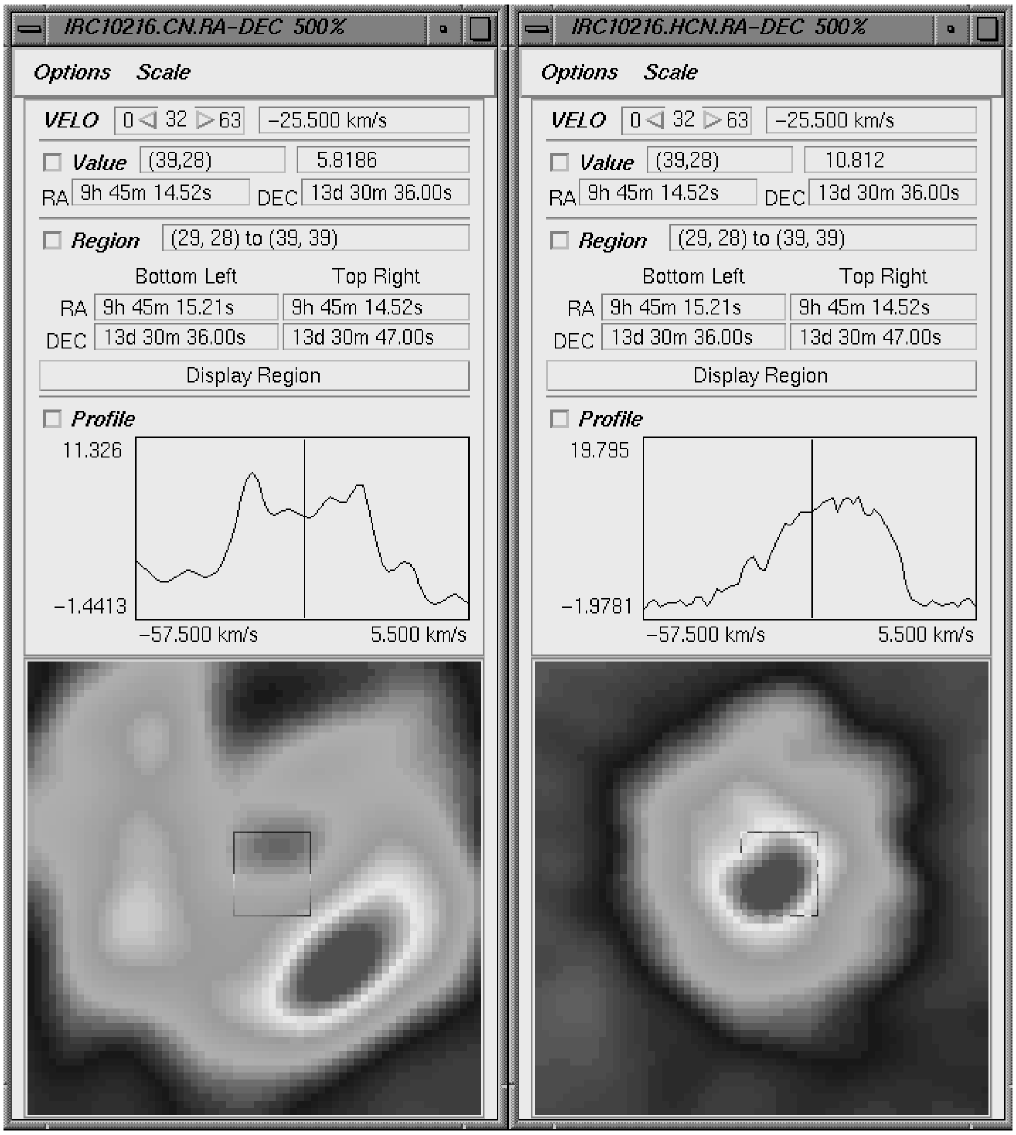

Figure 3. Display window with two IRC10216 files (CN left and HCN right) displayed.

3.5. Synchronized display of multiple data sets

Multiple data sets may be displayed simultaneously in AIPSview, whether or not they are related to one another. A unique feature of AIPSview is the *synchronized* display of multiple data sets. Figure 3 shows an example of the synchronized display of two IRC10216 data sets, one a CN and the other a HCN spectral line data cube. One example of the use of this feature is to display a time synchronized, simultaneous set of movies of two (or more) data cubes of the same area of sky (for RA-DEC displays, the same velocity of each data cube is displayed as the two movies are run). Synchronized "picking" is also available. If there are two (or more) images which at least partially overlap in world coordinate (RA-DEC-VELO) space, including them synchs them together for the purpose of interactive display of intensities, profiles and/or for region selection at the same world coordinates. For example, suppose you have CN and HCN data cubes and an infrared 2D image of the same object (they need not be the same size in either RA-DEC-VELO or pixels, since the synchronization is based on world coordinates and not pixel coordinates). By "including" all three data sets, when one displays intensity values by using the mouse to point at one image, the intensity value of the other image at the same position will be displayed. When one displays CN line profiles by interactively roaming the mouse pointer around the CN image, the HCN line profile at the same spatial position will also be displayed. If one does a subregion selection on the CN image, the same subregion will be selected on the HCN and infrared image. In figure 3 the two data sets have been synched, so intensity values and line profiles are for the same sky position and the subregions which have been defined are the same.

3.6. Glish

Glish is an interprocess communication system used extensively by AIPS++. AIPSview can be controlled by glish events, so that another process can use AIPSview for display. Also, glish will be used to send information obtained from a visualization of a data set (the definition of a subregion, for example) to separate image analysis tasks (gaussian line profile fitting, for example).

3.7. ColorMap Editor

The ColorMap Editor (figure 4) is used to carry out a wide range of color fiddling and editing. Just below the menu buttons is a display of the color look up table that is in use. The zero point and contrast of the color LUT may be interactively adjusted by placing the mouse pointer within this display and moving the mouse both horizontally and vertically while holding down the left mouse button. Colormaps are remembered by AIPSview as "palettes"; these palettes may be saved to files for reloading later. The ColorMap Editor allows loading predefined palettes such as greyscale, rainbow, logarithmic, or pseudocolor.

Palettes may be created and edited using drawing tools in the ColorMap Editor. The Editor shows a palette as graphs of the RedGreenBlue (or HueSaturationValue) color values across the range of colors available to AIPSview. One can switch between RGB and HSV representation of the same palette for editing purposes. At the top of each graph is a series of buttons which are used to select the kind of function to create. The functions available are, from left to right, Draw (freehand draw the graph with the mouse), Constant, Linear,

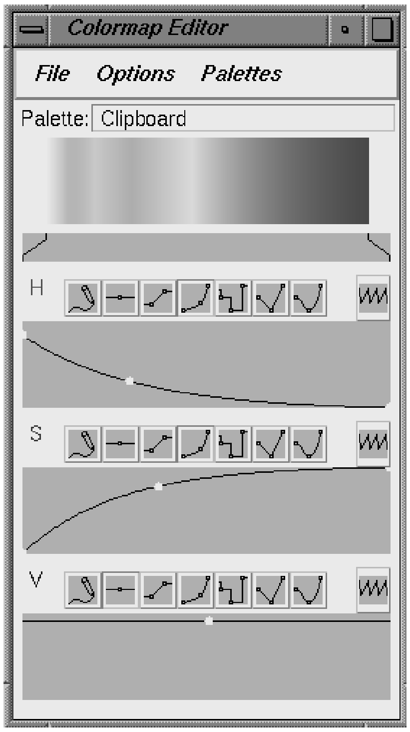

Figure 4. ColorMap Editor used to edit and fiddle color palettes.

Log/Exponential, Piece-wise Constant or Stairstep, Piece-wise Linear, Spline, and Repeat. Repeat is a function used to repeat a function between the first and last control points to the rest of the graph. For example, a sawtooth function is created by Repeat-ing the linear function. More complex repeating functions are possible by applying Repeat with other modes. In all modes expect Draw, control points are moved by "grabbing" them with the mouse and dragging them to a new place. Control points can be added to the StairStep, Piece-wise Linear, or Spline modes by pressing the left mouse button far enough (5 pixels or so) away from any existing control points. In these modes, control points are deleted when they have the same X value. Simply put, the control point being moved absorbs any others within its horizontal motion.

4. Inventor AIPSview

The above discussion has been almost entirely about the Xlib/Motif AIPSview which is now in beta release to astronomers. We have also done considerable work on a separate visualization tool which depends on the OpenInventor and OpenGL libraries to support true 3D visualizations. Inventor AIPSview (figure 5 shows an examply display) supports the following 3D visualization techniques:

- Slicing, which can show rendered slices along all three dimensions simultaneously and allows sweeping of the slice planes through the data cube.

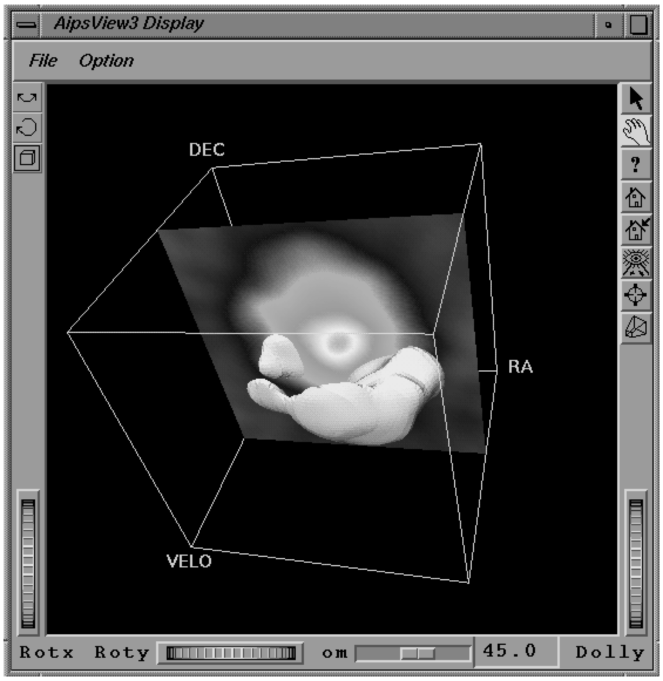

Figure 5. Simultaneous display of isosurface of the IRC10216.CN data cube with a velocity slice of the IRC10216.HCN data cube.

• Contouring of a plane of a data set plotted onto another representation (such as a rendered slice) of itself or onto display of a different data set.

• Surface display, where for example the intensity of a plane of a data cube may be shown as the height of a surface.

• Isosurfaces. This is the 3D analog to the 2D technique of contouring. Throughout the 3D data cube, a surface at a constant value of the intensity in the data is generated. Inventor AIPSview allows one to generate multiple isosurfaces at different intensity values of the same data set and display them simultaneously (with different colors and transparencies).

• Volume rendering. This is the 3D analog to the 2D technique of raster image display. The entire three dimensional data cube is rendered so that all of the data may be seen simultaneously. The transparency of the rendered volume may be varied so that (with low transparency) one can focus on low intensity parts of the data cube, or (with high transparency) one can look through the low intensity parts of the data cube and see the high intensity regions. An example of a volume rendered display of the IRC10216.CN data set is shown in .

Labeled axes for data cubes are drawn, as shown in figure 5. Inventor provides a number of functions for very flexible simultaneous display of data cubes with any of the above techniques and for rotating the 3D displays, changing the illumination, zooming, et cetera. Inventor AIPSview can also be used to produce VRML files for inclusion in WWW documents.

5. Future plans

We are currently working on several major enhancements to AIPSview. One is to add a much more extensive vector graphics capability. This will include the ability to put a gridded box around a raster image display with coordinate labels, to overlay contours on raster images or to plot them separately, and to provide much more flexible xy line plotting capabilities. A second enhancement will be providing for postscript hard copy output. We will also significantly enhance glish support. Finally, in close collaboration with AIPS++ workers at the Australian Telescope, we will add volume rendering functionality to the Xlib/Motif AIPSview. Additional enhancements will be driven by user requirements.

Although Inventor AIPSview has not yet been released to the astronomy community, we expect to do so within the coming year. Inventor AIPSview will serve as the software for astronomy visualization in the virtual environments being developed at NCSA, including the Immersadesk, the PowerWall, and the CAVE. These hardware and software systems will enable astronomers to examine and analyze complicated three dimensional data sets in a highly physically immersive, stereoscopic environment. Useful visualization techniques developed in Inventor AIPSview will be migrated to AIPSview as software and hardware technologies permit.

Acknowledgments. We gratefully acknowledge financial support for radio astronomy visualization, high performance computing, and digital library work from the NSF and ARPA under grant NSF ASC 92-17384, from NASA under grant NCC5-106, from the National Center for Supercomputing Applications, and from the University of Illinois Astronomy Department through its participation in the Berkeley-Illinois-Maryland Array. The BIMA IRC10216 data sets used here to illustrate some of the functions of AIPSview were obtained from the Astronomy Digital Image Library at NCSA; we thank A. Dayal and J. H. Bieging for depositing these FITS files in the library.