

Application of Medical Imaging to the 3D Visualization of Astronomy Data

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ABSTRACT

As part of the Astronomical Medicine project at the Initiative in Innovative Computing at Harvard, whose goal is to address common areas of research for astronomical and medical imaging, 3D visualization and analytical techniques developed for medical imaging have been applied to astronomy data. Most astronomy visualization applications and tools are only for two dimensional data, and the few available for three dimensional visualization lack sophisticated graphics and rendering capabilities. In applying programs like 3D Slicer, a medical imaging tool developed at the Surgical Planning Lab at Brigham and Women's Hospital, to astronomy data we have demonstrated the usefulness of visualizing astronomy data in 3D. Using molecular line maps from the COMPLETE Survey of Star Forming Regions of the Perseus star-forming region, we have been able identify new outflows and shells from young stars, and understand the gas's hierarchical structure. The Astronomical Medicine project continues to apply new visualization and segmentation techniques to astronomy data, and integrate astronomy specific features into 3D Slicer paving the way for a general scientific visualization tool.

CR Categories and Subject Descriptors: J.2 [Physical Sciences and Engineering]: Astronomy; J.3 [Life and Medical Sciences]: Health; I.4.10 [Image Representation]: Multidimensional – Volumetric.

Additional Keywords: astronomy visualization

1 INTRODUCTION

Although astronomy is a scientific field fundamentally based on imaging, the visualization tools commonly used are for 2D imaging despite the existence of 3D data sets. The development of 3D visualization tools in astronomy has only begun over the past few years, and these tools generally lack usability and up-to-date graphic capabilities since they are based on astronomy toolkits developed for 2D visualization.

The Astronomical Medicine project [1] at the Initiative in Innovative Computing (IIC) at Harvard University was created to extend the state of the art of complex data understanding in astronomy and medical imaging using a broad-based approach to data exploration and analysis. In the same way physicians want to be able to visualize an MRI scan in 3D and segment out a tumor, astronomers want to be able to visualize data from a radio telescope in 3D and identify young stars. By combining the expertise of medical imaging and astronomy through shared software and professional collaboration, the Astronomical

Medicine project is developing tools and techniques that address the commonalities of research in the imaging sciences.

The project's current major collaboration involves visualizing data from the "COMPLETE" Survey of Star-Forming Regions [2] from the Harvard-Smithsonian Center for Astrophysics using medical image analysis software such as 3D Slicer [3] from the Surgical Planning Lab at Brigham and Women's Hospital, a teaching affiliate of Harvard Medical School. Introducing basic 3D visualization to the astronomy community is revolutionizing the way astronomers explore, visualize, and analyze their data.

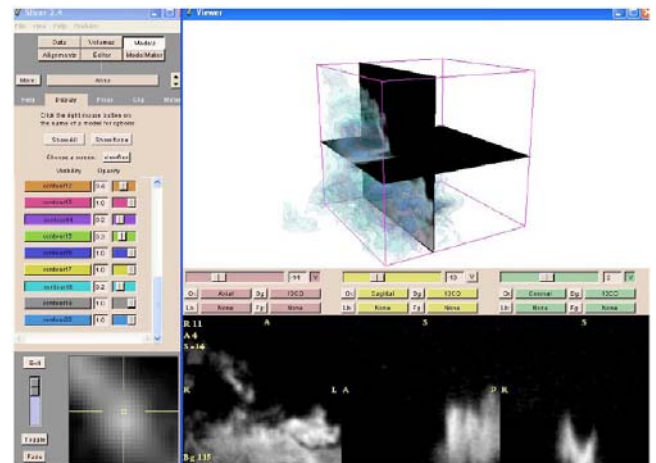


Figure 1. 3D Slicer displaying isosurfaces and slices of the star-forming region IC 348 in ^{13}CO .

2 VISUALIZATION TOOLS

The primary tool being used for visualization and being adapted for astronomical visualization as part of this project is 3D Slicer. 3D Slicer was originally developed as a medical imaging and visualization program. The application is built on top of the VTK (Visualization Toolkit) and ITK (Insight Segmentation and Registration Toolkit) toolkits, is cross platform, open source, and freely available. We have primarily utilized the isosurface rendering [4] capabilities for visualization and segmentation modules. 3D Slicer has volume rendering capabilities. However in the present version of the software the segmentation and surface generation pipelines are more mature. We also currently use OsiriX [5], another medical imaging program, for volume rendering. It is built on ITK and VTK, is open source, and built for Apple's Mac OS X operating system.

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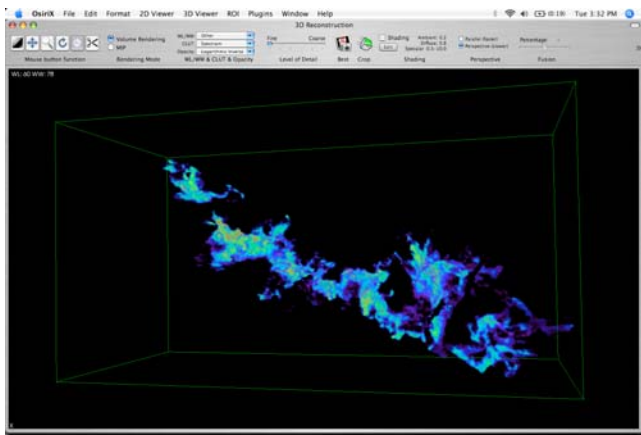


Figure 2. OsiriX displaying a volume rendering of the Perseus star-forming region in ^{12}CO .

3 ASTRONOMY UTILIZATION

The data currently being analyzed was collected during 2002-2006 at the FCRAO (Five College Radio Astronomy Observatory) radio telescope in central Massachusetts as part of the COMPLETE Survey. The Perseus molecular cloud complex (8 square degrees or $\sim 150,000$ pixels) was observed in ^{12}CO and ^{13}CO . Observing these molecules provides one with the structure of the cloud where ^{12}CO traces the “surface” and low density gas, while ^{13}CO reveals the inner gaseous structures. This spectral data (one spectrum per pixel in the map) can be converted from wavelength to velocity via the Doppler shift, thus the data can be represented in a cube as a series of intensity maps where each map in the series represents the gas emission’s intensity at a particular velocity. When this data is represented in 3D, one is visualizing the kinematics of the molecular gas in the cloud.

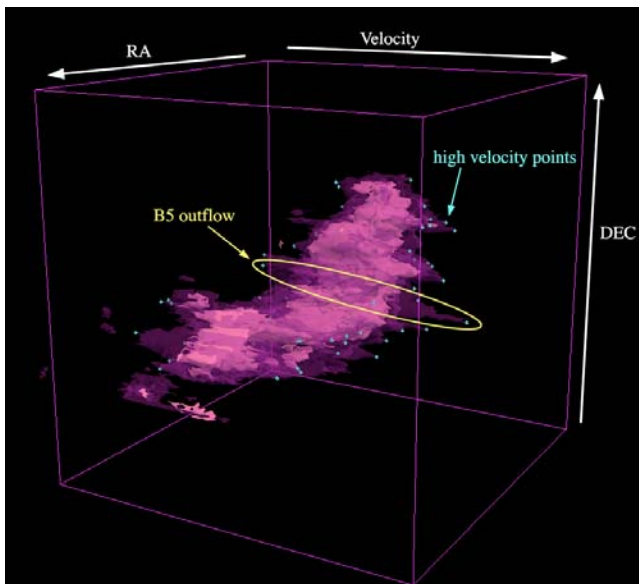


Figure 3. Isosurfaces representing the ^{12}CO (purple) and ^{13}CO (pink) emission in the B5 star-forming region of Perseus with high velocity points (teal) and the B5 outflow (yellow) marked.

Although the 3D models are not spatial, many spatial structures and properties can be studied including outflows or shells from

young stars, supernova, turbulence, dense cores and the hierarchical structure of gas in the cloud. These features are generally difficult to study and find in two dimensions since multiple features may lie along the same line of sight and be confused or obscured in a 2D projection. When represented in isosurfaces or volume rendered, however, these features are easily identifiable and disentangled. Volume rendering has proven an excellent exploratory tool revealing multiple intensity ranges at once.

One example where visualizing astronomy data in 3D has proven novel is in the search for outflows. Bipolar outflows of gas originate from young stars forming as gas collapses on them while spinning. This outflow phase is one that all young stars go through during their development, but it is a poorly understood phenomena and difficult to identify with conventional methods. The standard way to find outflows is by looking at individual spectra (an outflow lobe, depending on the telescope’s resolution, is only comprised of a few spectra), an integrated intensity (average emission over all velocity values) map, or individual maps over a range of velocities. These methods prove tedious and inefficient especially for large surveys like COMPLETE. When visualizing Perseus in ^{12}CO and ^{13}CO as a series of isosurfaces, the outflows are rapidly identified visually as “spikes” due to their extreme velocities observed along the line of sight. With this new outflow identification method, we have extended the known length of many outflows and discovered dozens of new outflows in the Perseus region shortening the feature identification process from months to minutes [6].

4 CONCLUSION AND FUTURE WORK

By applying 3D visualization techniques developed in the medical imaging community, we have been able to improve the way astronomers are able to study and visualize their 3D data sets. The Astronomical Medicine team is working in conjunction with the 3D Slicer development team to integrate astronomy-specific and jointly beneficial features. Future research includes further study of the Perseus star forming regions and comparison to others, comparing observational data with simulation output, and segmentation algorithms for the identification of astronomical objects like outflows. For more information about the Astronomical Medicine project, go to: <http://astromed.iic.harvard.edu>

5 ACKNOWLEDGMENTS

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