

## Visualization with SDvision of ASH Stellar MHD Simulations

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**Abstract.** Numerical simulations are playing a leading role in the study of astrophysical objects. The ASH program is used to perform high-resolution three-dimensional simulations of the MHD processes occurring in the convection zone of the Sun and other stars. The size and complexity of the data produced in these simulations require to use special software tools at the post-treatment, visualization and analysis stages. The SDvision graphical interface is developed to provide an interactive and immersive visualization of such data. In this paper, we describe the different rendering capabilities provided by this program.

### 1 Introduction

With the increasing computing power offered by massively parallel mainframes, simulation has become a major tool in the investigation of complex physical phenomena. The ASH program (Clune et al. 1999, Brun et al. 2004) is used to perform high-resolution three-dimensional simulations on parallel computers with up to several thousands processors, with a special emphasis on the MHD processes occurring in the solar convection zone. The need for interactive and immersive visualization of such data has motivated the development of the SDvision graphical interface.

### 2 ASH Simulations of Stellar Magnetohydrodynamics

The Anelastic Spherical Harmonic (ASH) code solves the 3D anelastic equations of motion in a rotating spherical shell using a pseudo-spectral method (Clune et al. 1999). The thermodynamic variables, the mass flux, and the magnetic field are expanded in spherical harmonics to resolve their horizontal structures and in Chebyshev polynomials to resolve their radial structures.

The ASH code is used to simulate turbulent convection within deep spherical shells of the solar convection zone (Brun et al. 2004, Jouve & Brun 2009). Simulations involving increasingly nonlinear flows are performed on uniform grids in the spherical coordinate system with typically  $10^6$  to  $2 \times 10^9$  cells.

In this paper, we use simulations produced in the context of the STARS2 Project<sup>1</sup> funded by the European Research Council<sup>2</sup>, aiming at understanding

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<sup>1</sup> <http://www.stars2.eu>

<sup>2</sup> <http://erc.europa.eu>

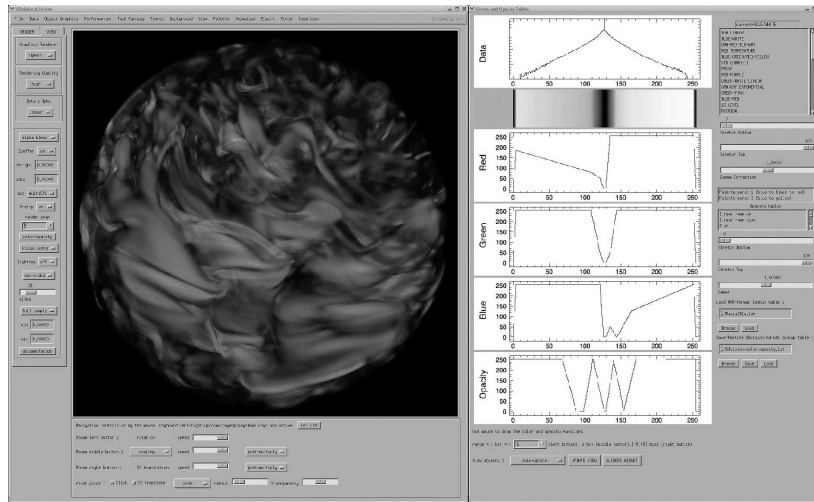


Figure 1. The SDvision graphical interface used here to visualize the azimuthal component of the magnetic field in the solar convection zone. The rendering is obtained with the ray-casting technique with alpha-blending compositing. The colors and opacity lookup tables are fine-tuned against the data distribution in the right-hand side widget.

the nonlinear interactions between convection, turbulence, shear, rotation and magnetic fields in stars.

### 3 Visualization with SDvision

The SDvision visualization tool (Pomarède et al. 2007) is developed as part of the COAST Project dedicated to Computational Astrophysics<sup>3</sup>. The code is deployed in the environment of the IDL data analysis and visualization platform<sup>4</sup>. It relies on the use of the Object Graphics, a collection of pre-defined object classes, each of which is designed to encapsulate a particular visual representation and supports OpenGL-based hardware accelerated graphics. A snapshot of the SDvision widget configuration is displayed in Figure 1.

Several ways to visualize the scalar and vector fields produced in the ASH simulations are proposed. Scalar fields are visualized through either ray-casting volume rendering, isosurface reconstruction, stacking of texture maps, or through volume slicing.

In the volume rendering implementation, rays are cast through the data cube and the contributions of each voxel in terms of color and opacity are integrated along each line. Several compositing functions are available, including alpha-blending and maximum intensity projection. The RGB colors and opacity

<sup>3</sup> <http://irfu.cea.fr/Projets/COAST/>

<sup>4</sup> <http://www.itvis.com/idl/>

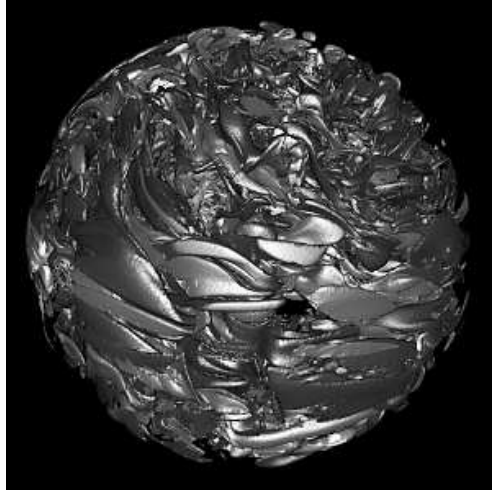


Figure 2. Isosurfaces of the azimuthal component of the magnetic field.

lookup tables can be tuned interactively to enhance the visualization of the turbulent structures that characterize these data. An example of volume rendering is shown in Figure 1.

In the isosurface rendering implementation, a surface which represents points of a constant value of a dataset is reconstructed using the marching cubes algorithm. Multiple isosurfaces can thus be visualized, as illustrated in Figure 2. The reconstructed surfaces are Gouraud-shaded and various sources of illumination can be played with to enhance the three-dimensional rendering. In the textures rendering implementation, a stack of two-dimensional textures each mapping a given slice of the data cube, are piled-up in the direction closest to the viewing axis, as shown in the example of Figure 3. The rendering of the volume is achieved by tuning the transparencies in order to reveal its structuration along the third dimension.

Vector fields are visualized by hedgehog displays or by streamlines. These can be seeded either on spherical grids, such as in the example of Figure 3, or interactively by clicking in the scene, as illustrated in Figure 4.

The SDvision tool has the capability to interact with the IDL framework where the analysis of the data is performed and where new variables can be created for visualization. It is used to produce stereo rendering of the data distribution, with a module producing the input to the new generation of autostereoscopic high-definition screens.

#### 4 Conclusions and Perspectives

The SDvision software is a versatile tool offering numerous ways to visualize the results of the ASH simulations. New simulations performed in the context of the STARS2 Project will provide multi-billion cells datasets, a challenge for interactive visualization.

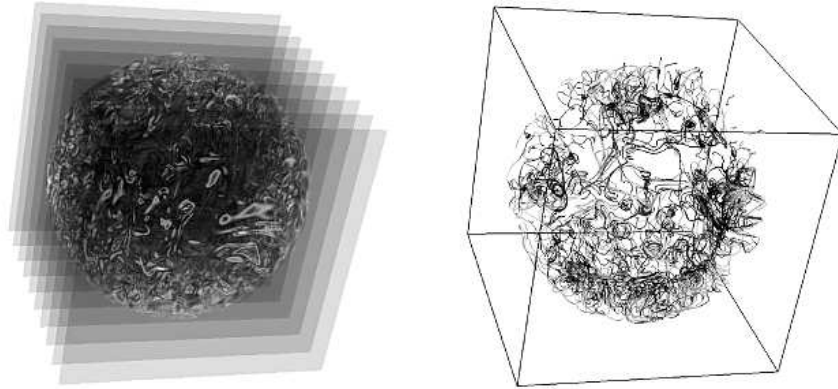


Figure 3. Volume rendering using a stack of textures (left). Visualization of velocity streamlines seeded on a spherical grid and color-coded using the vector norm (right).

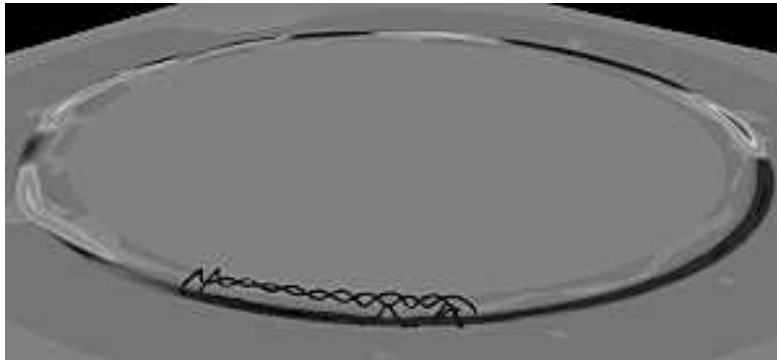


Figure 4. Visualization of a magnetic field line seeded interactively in the scene, together with a slice of the magnetic energy field.

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