

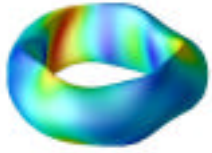
Three Dimensional Visualization of High Beta Compact Stellarator Configurations

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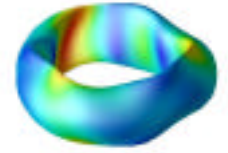
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S. P. Hirshman, D. A. Spong

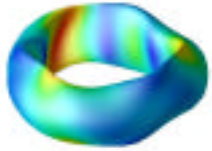
Oak Ridge National Laboratory



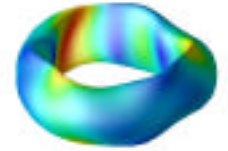
Abstract



Compact stellarator configurations with good neoclassical confinement and stability properties which allow access to second stable ballooning regime have been obtained. In order to improve our understanding of these and other stellarator configurations, we are developing a set of three-dimensional visualization techniques for stellarators. We have chosen the OpenDX visualization program [<http://www.opendx.org>] (formerly IBM's Visualization Data Explorer) as the platform for the visualization package. OpenDX is a powerful visualization tool that is now available on many different platforms. One of the important features of the high beta configurations is the structure of $|B|$ in Boozer coordinates. These visualization techniques allow us to explore the magnetic field structure in both toroidal and Boozer coordinates.

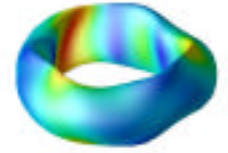
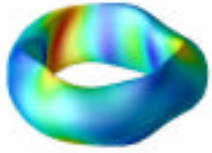


I. Introduction

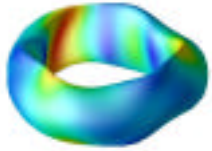


Numerical Data to 3-D Visualization

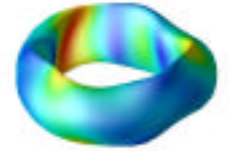
- We solve for equilibria using VMEC (Variational Moments Equilibrium Code)
 - Results in a numerical file containing information about the magnetic field structure
- Want to develop programs that allow us to visualize the magnetic field structure
 - Use software called OpenDX
 - Development done on UNIX platform, but potential portability to Mac and/or Windows



- Programs must be functional
 - Give the user maximum control over the visualization process
 - Keep controls simple, user-friendly
- Programs must be “universal”
 - Require little or no DX experience to use
 - Shareable, useful in ongoing research



II. What is OpenDX?



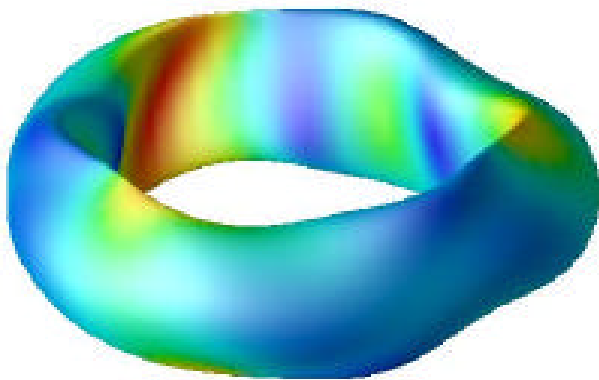
- Formerly IBM's Visualization Data Explorer
 - Originally a commercially developed, technically supported software
 - Changed to an “open source” format
- OpenDX is a flexible visualization software
 - Imports a variety of formats
 - Has a graphical interface consisting of modules with preset functions
 - User creates the visualization process by combining, manipulating modules into a network

III. Development Process

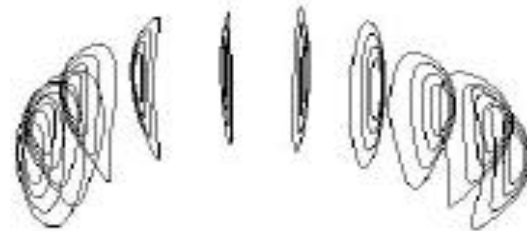
What can we visualize?

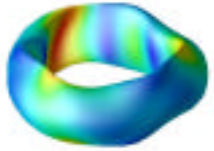
- With the output from VMEC, we can visualize different field properties

Shape and field strength of an entire flux surface

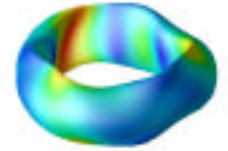


Cross sectional view of nested flux surfaces

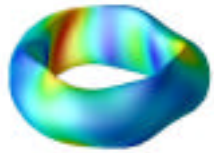




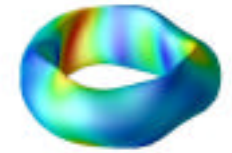
Specific Visualization Goals



- Create programs that allow for an effective visualization of both the entire flux surface and the nested surfaces
- Two distinct programs are needed
 - Goal #1: A fully interactive program, giving the user real-time control of the visualization
 - Goal #2: A user defined automated sequence which creates a movie illustrating important aspects of the field structure



Goal #1:

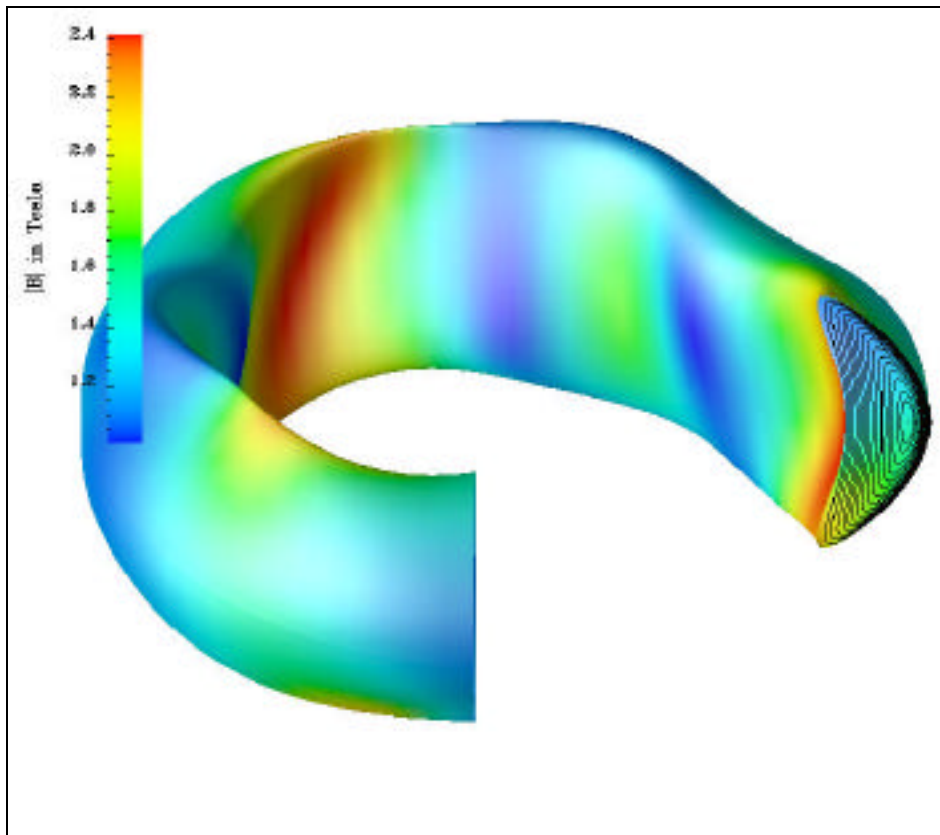


Interactive Visualization

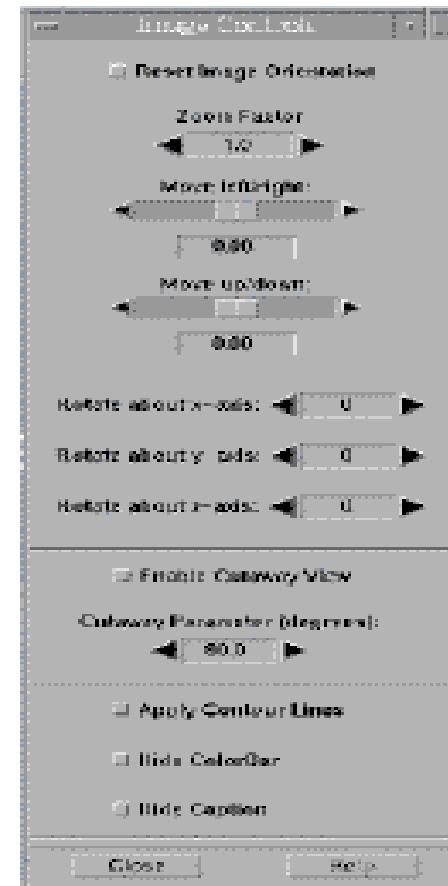
- Created a program called **SCR-Interact**
 - SCR: Surface, Contours, Rotation
 - *Interactive, user-controlled environment
 - *Displays flux surface, color coded to indicate $|B|$
 - *Allows for complete control of image orientation, with rotation, zoom, and translation capabilities
 - *Optional cutaway view exposes an end of the surface
 - *Adjustable cutaway angle in two-degree increments
 - *Option to view contour lines of corresponding nested surfaces

Illustration of the SCR-Interact screen layout

The image is continually updated in the Image window



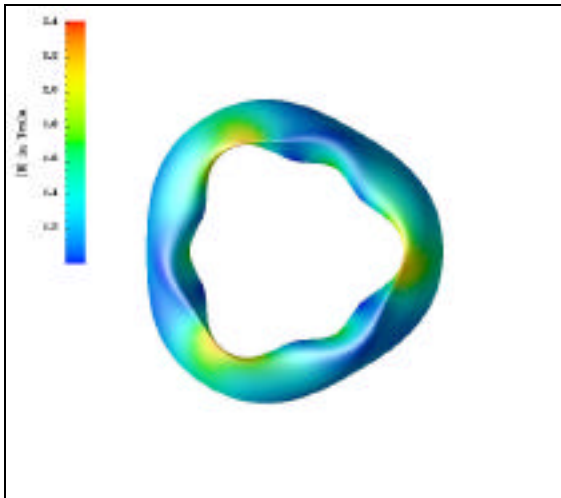
All visualization controls are found on the Image Controls control panel



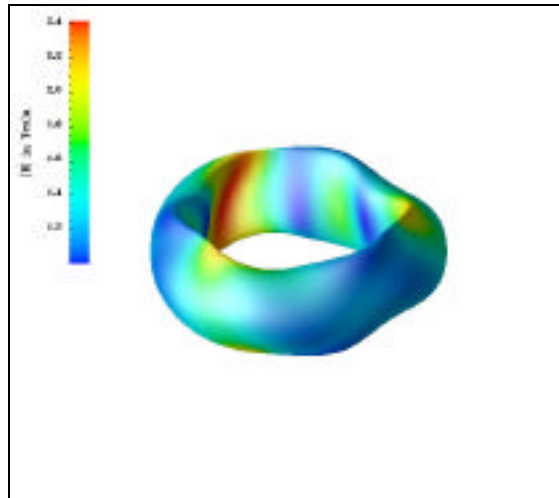
Sample Viewing Procedure

Following is a sequence of images that demonstrates the interactive capabilities of SCR-Interact. Note that when actually using the program, the view is continually updated with every adjustment, resulting in a true interactive process.

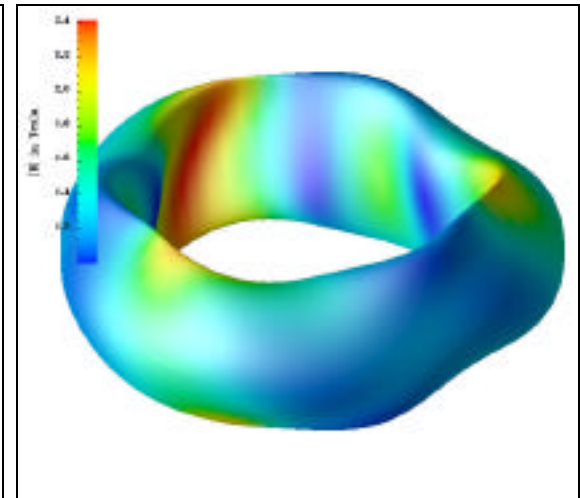
Default view of magnetic flux surface



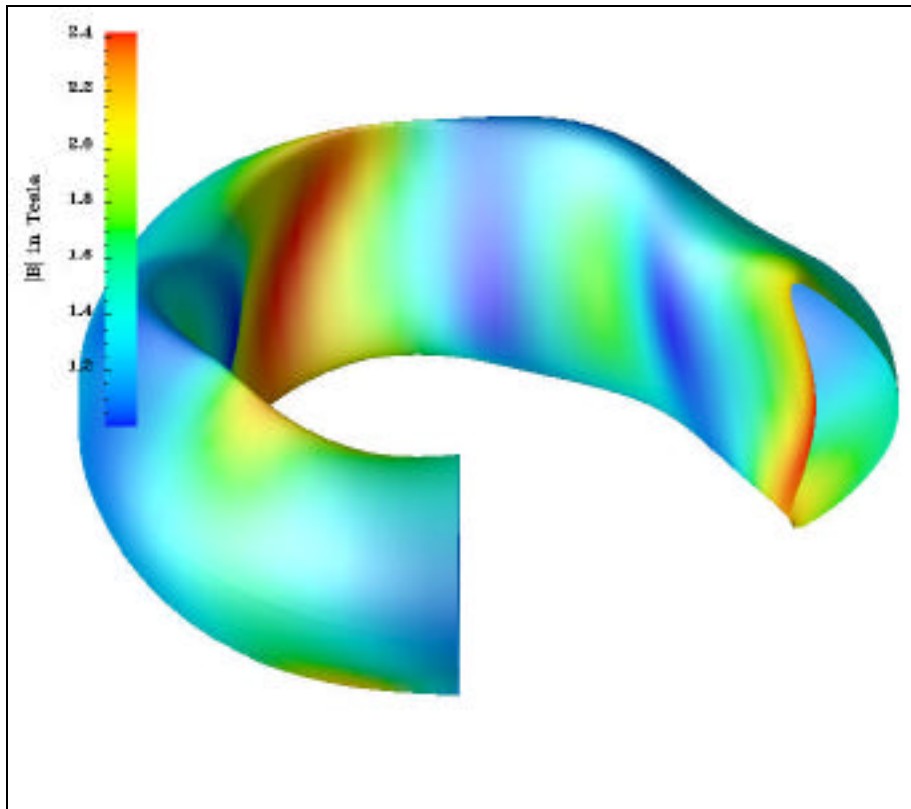
Rotate about x-axis for better perspective



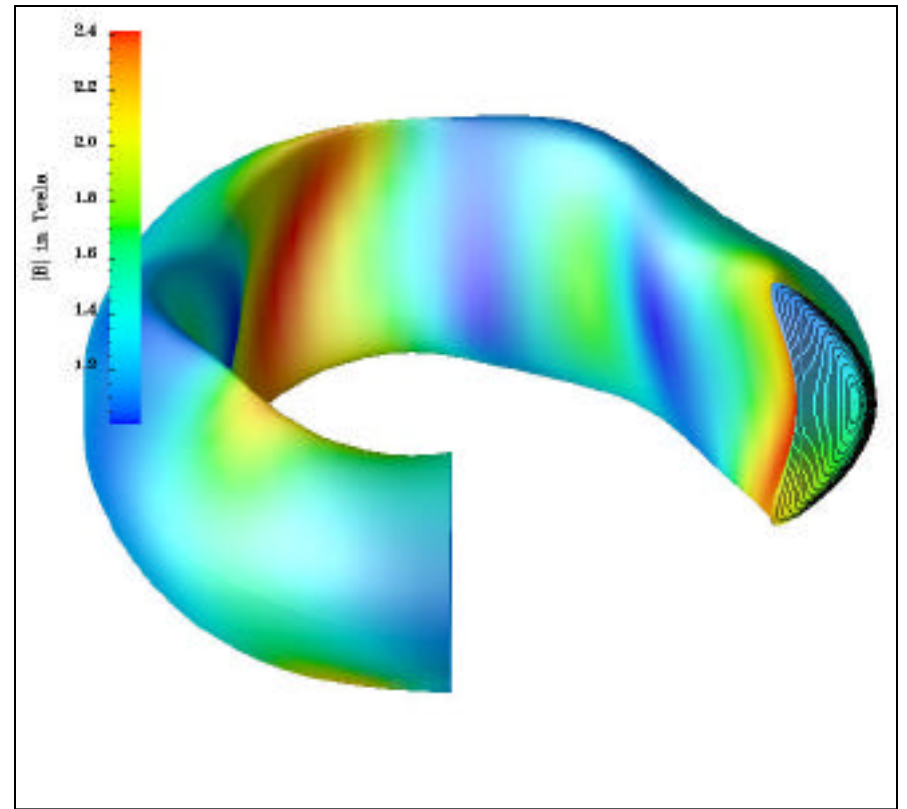
Zoom in for a closer look



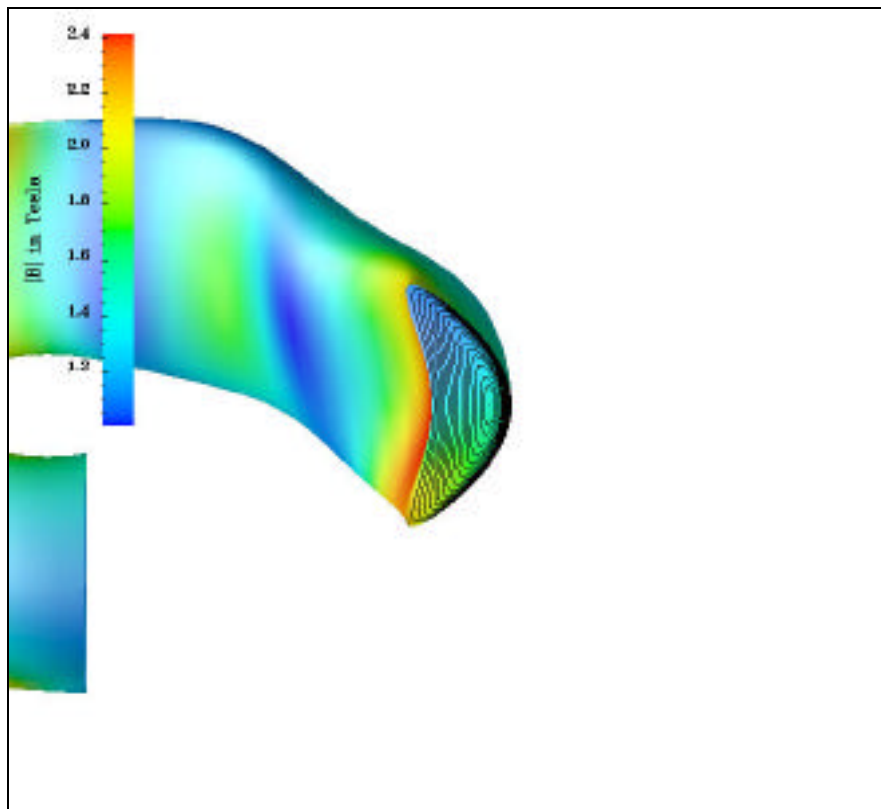
Cut away a portion of the surface to expose an end



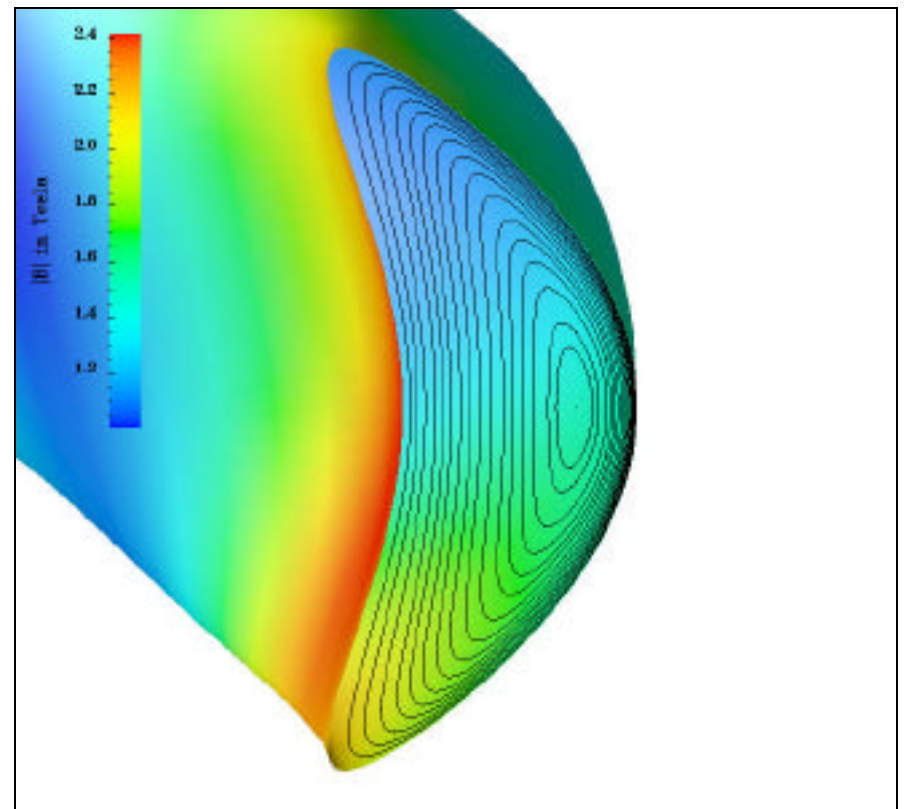
Apply the corresponding contour lines to see the shape of nested flux surfaces

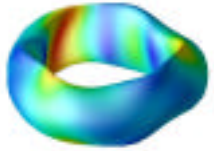


Move image laterally to center the desired portion in the image window

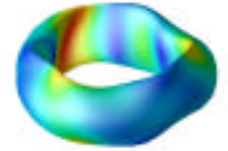


Zoom in on the center of the image window to see a detailed view

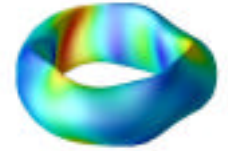
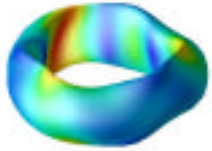




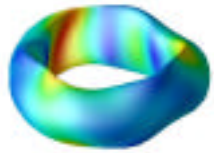
Simple Program Execution



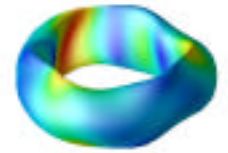
- No DX experience necessary
 - Product we can easily share with others for ongoing research
 - Only requires that the user has OpenDX
- For program to work properly, the correct input files must be created and accessed
 - File containing data for outer flux surface
 - File containing data for contours
 - Both derived from the VMEC output file



- Entire process automated with use of a shell script
 - User enters a simple command at the UNIX terminal
 - Correct input files are automatically created and inserted into program
 - Directory is created for all related files

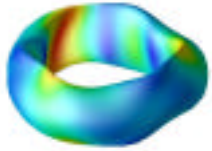


Goal #2:

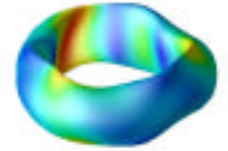


Automated Visualization

- Created a program called **SCR-Movie**
 - Utilizes the same functions and visualization procedures as SCR-Interact
 - Automates the functions to create a visualization sequence
 - Sequence can be saved and viewed as a movie



User-Defined Sequence



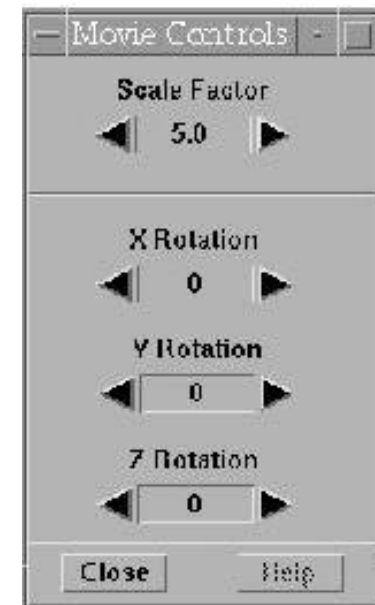
- User has control of the visualization sequence
 - Sequence is made up of two distinct segments:
 - ***Segment 1** -- scaling and rotations, both of which are specified by the user
 - ***Segment 2** -- pre-defined cutaway sequence
- Sequence controls are easy to use
 - Parameters for the user-defined segment are set using a simple control panel
 - Sequence is played using VCR-like controls

Illustration of the SCR-Movie screen layout

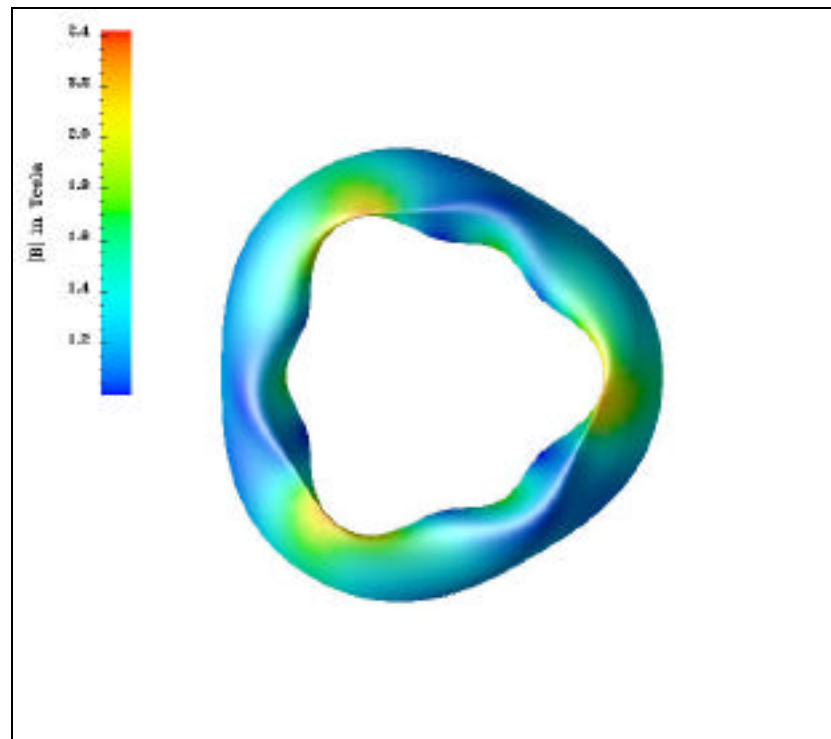
Sequence is played using VCR-like controls

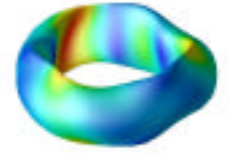
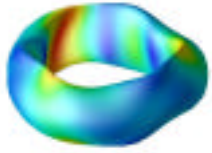


Movie Controls control panel lets the user specify scaling and rotation for the first portion of the movie



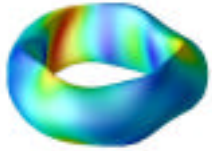
Sequence is displayed in the Image window



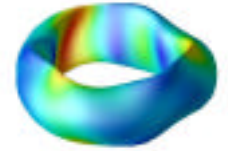


Simple Program Execution

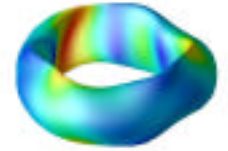
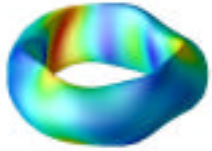
- Requires no DX experience
 - Program is shareable and useful in ongoing research
- SCR-Movie runs by creating and accessing the same files as SCR-Interact
- Process is automated using shell script
 - Executed with a simple UNIX command
 - File creation and import occurs automatically



IV. Conclusions



- Using OpenDX, we were able to develop flexible, user-friendly programs for interactive 3-D visualization of stellarator configurations
- Two distinct programs were developed
- **SCR-Interact** is fully interactive, giving the user complete control over the visualization process
- **SCR-Movie** automates the functions of SCR-Interact to create a user-defined automated sequence



- Both programs require little or no DX experience, and are designed to run with a simple UNIX command
- Programs are shareable, and will be useful in ongoing confinement research
- Development of programs is ongoing