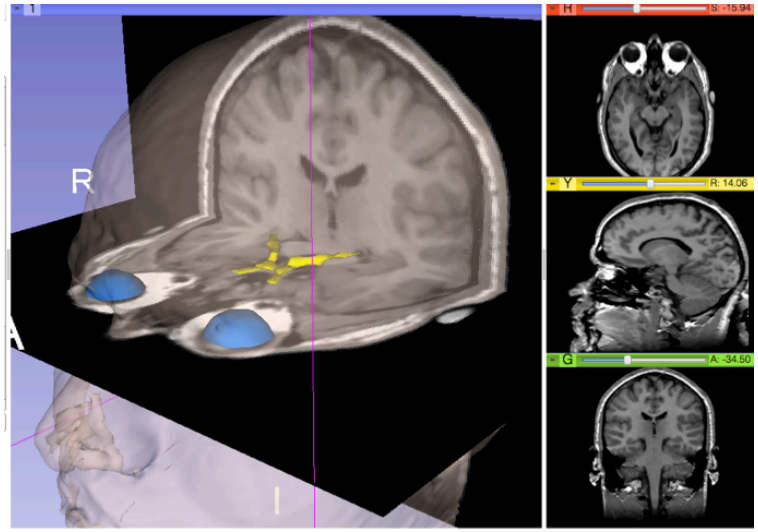
The 3D Slicer open-source platform for image analysis and 3D visualization

Junichi Tokuda, Ph.D., Nicole Aucoin, M.S. (Presenters)

Sonia Pujol, Ph.D.

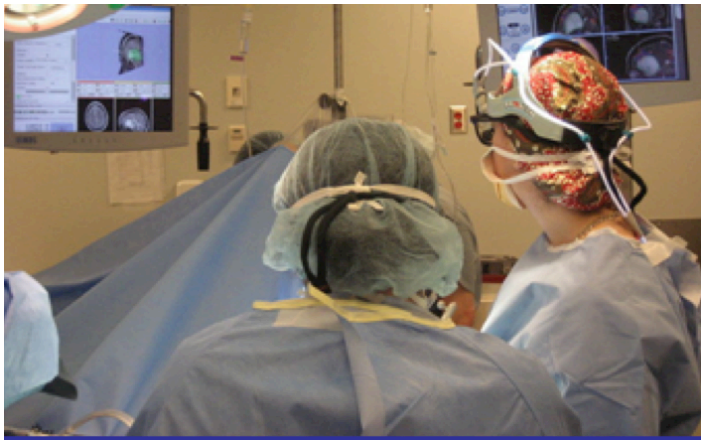
Surgical Planning Laboratoy,
Brigham and Women's Hospital, Harvard Medical School



Part I – From algorithms to tools: the 3D Slicer software for translational research

Translational research

An open-source environment
for software developers



An end-user application
for clinical investigators
and scientists

3D Slicer: an open-source platform for
translating innovative algorithms into
clinical research applications

Slicer 16th year Anniversary

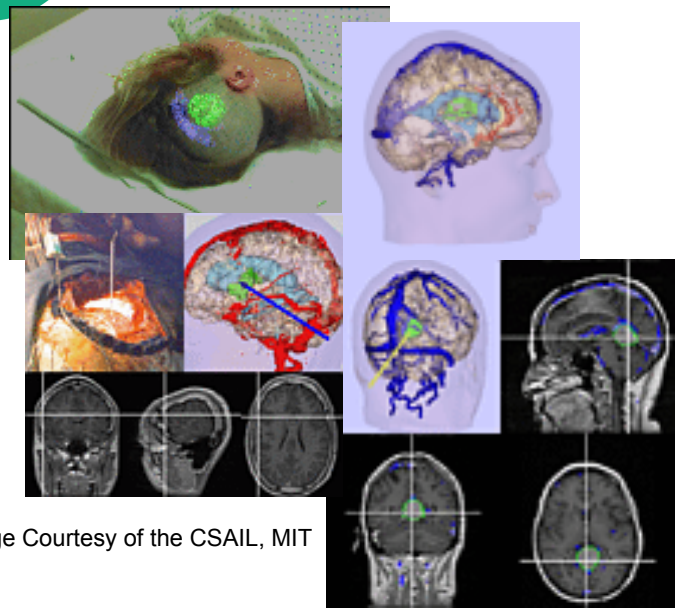
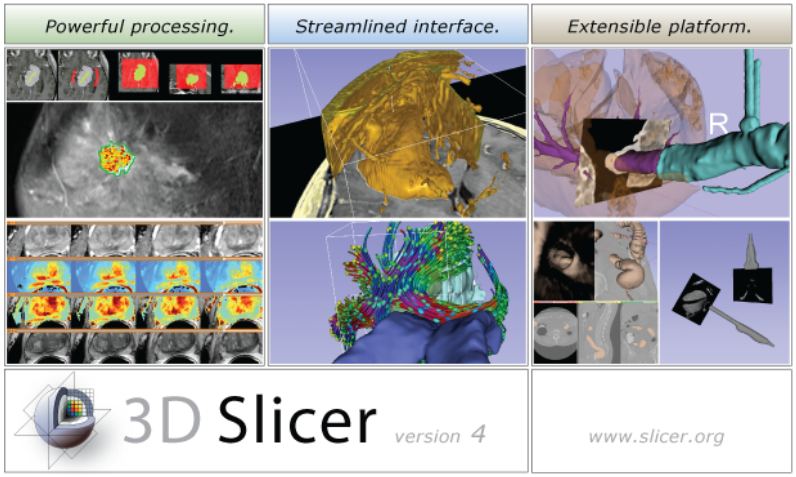


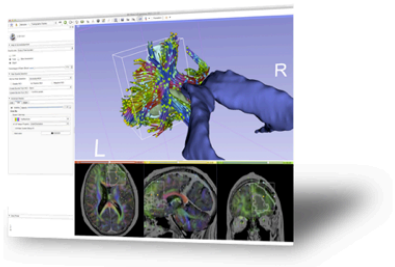
Image Courtesy of the CSAIL, MIT



- 1997: Slicer started as a Master's thesis between the Surgical Planning Lab (Harvard) and the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL)
- 2013: International open-source platform developed through a multi-institution effort

P.I. Prof. Ron Kikinis, BWH, Harvard

3D Slicer in practice



Get Slicer 4.

Slicer 4 is the latest stable version of 3D Slicer, a free, comprehensive software platform for medical image analysis and visualization developed with NIH support.

3D Slicer is distributed under a permissive BSD-style open source license. It has a thriving user and developer community.

Pre-compiled binaries

		Windows	Mac OS X	Linux
stable release	64 bit	4.1.0 64 bit installer 2012-04-11 r19886 (159.6MB)	4.1.0 64 bit installer 2012-04-11 r19886 (236.9MB)	4.1.0 64 bit archive 2012-04-11 r19886 (251.5MB)
	32 bit	4.1.0 32 bit installer 2012-04-11 r19886 (153.3MB)		
nightly build	64 bit	nightly 64 bit installer 2012-04-29 r19953 (160.4MB)	nightly 64 bit installer 2012-04-27 r19951 (237.4MB)	nightly 64 bit archive 2012-04-29 r19953 (252.0MB)
	32 bit	nightly 32 bit installer 2012-04-29 r19953 (154.0MB)		

System requirements

Slicer requires 1GB of RAM absolute minimum, with more highly recommended. Common data sets may require 4GB or more RAM for processing. A fast graphics card or GPU that supports OpenGL is also recommended.

Slicer is built and tested on many hardware and software platforms. 3D Slicer runs on Microsoft Windows XP, Vista, and Windows 7; Mac OS X versions 10.5 (Leopard), 10.6 (Snow Leopard), and 10.7 (Lion); and a variety of Linux distributions.

- Slicer is free
- Slicer is open-source
- Slicer works on Windows, Linux, and Mac
- Slicer is distributed under a BSD-style license agreement with no restriction on use

Slicer Is Open

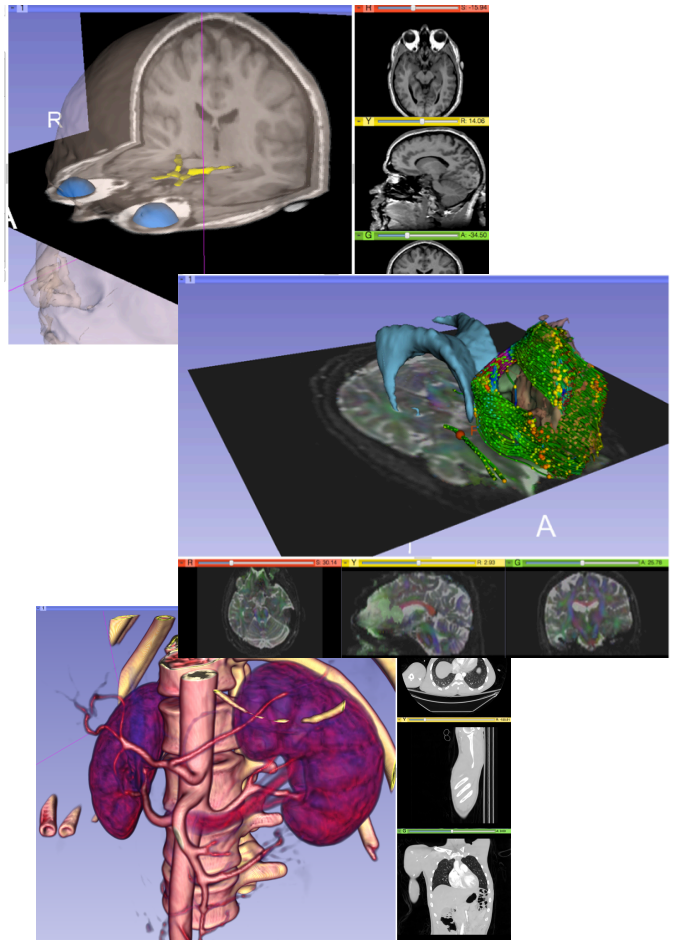
- Open Science
  =
  Open Source
  +
  Open Data
  +
  Open Community

Madrid 2012

Iowa City, USA 2012

Courtesy R. Kikinis

Slicer Open Community



- 80 authorized developers contributing to the source code of Slicer
- Over 700 subscribers on Slicer user and Slicer developer mailing list

Nov.2011-March.2013 Downloads

Slicer 4 download statistics

Total matching downloads:
62948

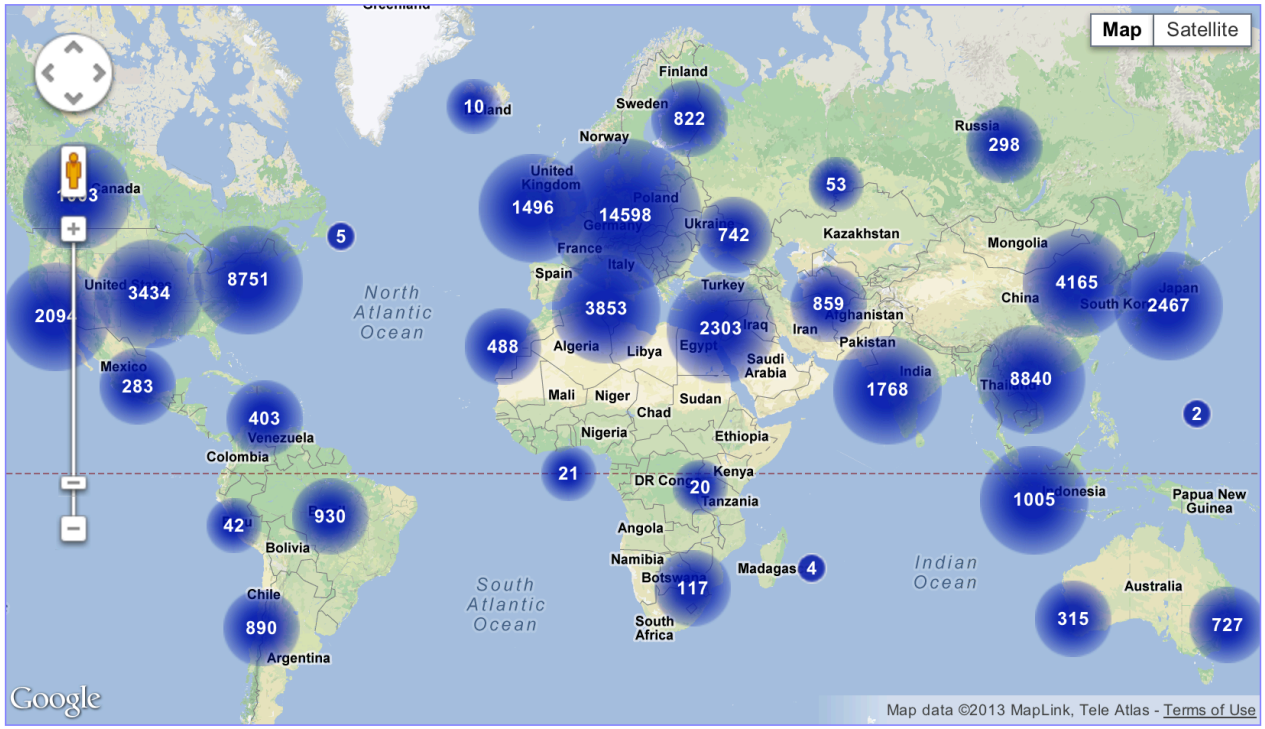
Date range: forever

Release type: any

Browser type: desktop

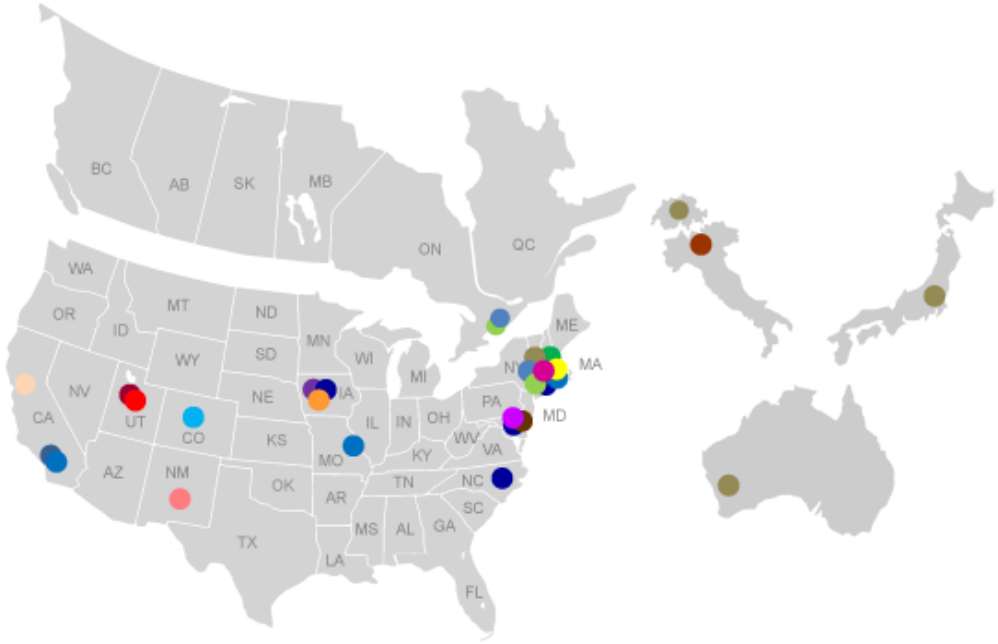
Update

Download location | By Country | By Filename | By Month



A Multi-institution Effort

- Autism
- Brain Cancer
- Depression
- Head and Neck Cancer
- Huntington's Disease
- Lupus
- Schizophrenia
- Traumatic Brain Injury
- VCFS
- Neuroimage Analysis
- Lung Disease
- Atrial Fibrillation
- Cardiovascular Disease
- Liver Cancer
- Colon Cancer
- Prostate Cancer
- Orthopedic Injury
- Neuromuscular Dynamics
- Image Informatics



Active

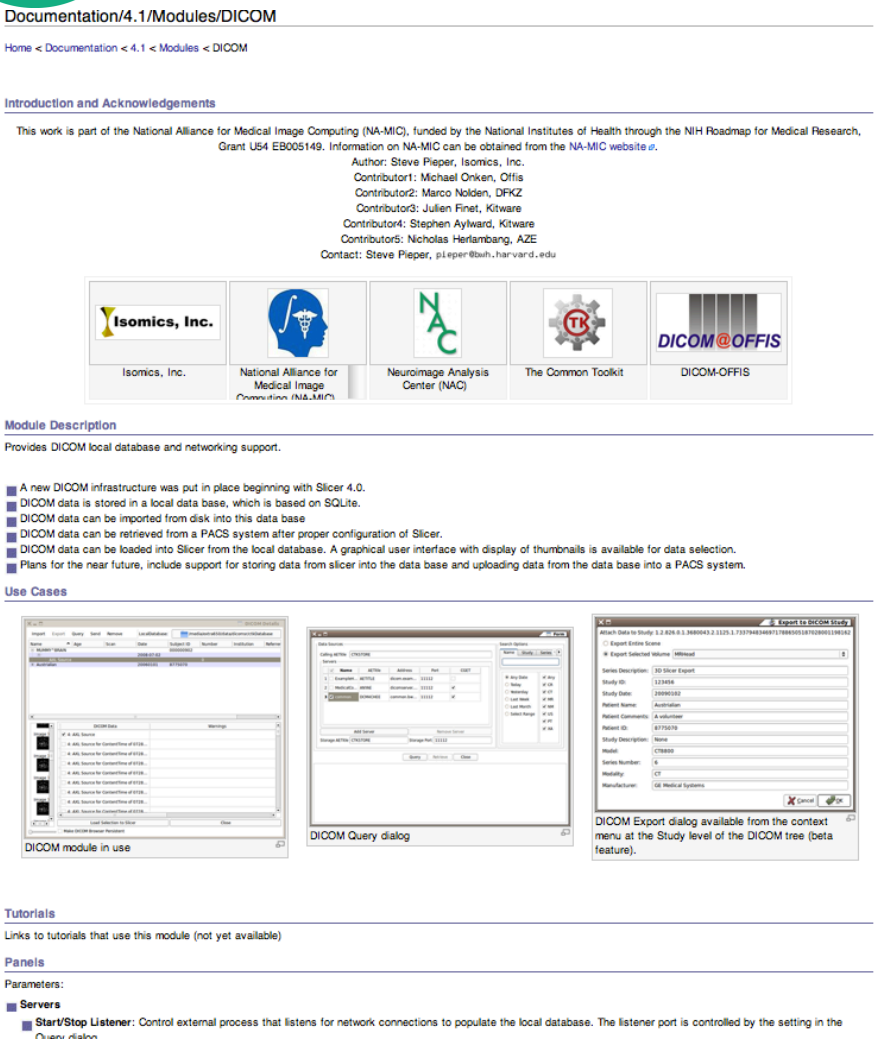
R01MH084795, U41RR019703, NSF CCF-0916526, R01EB008171, U01HL089897, R01CA124377, R01CA131718, R01CA11128
R01EB005973, U54EB005149-05S2, U54GM072970, P41RR013218, R01EB006733, R01NS050568, R21EB009900, U54EB005149-05S3
UL1RR025758, U54LM008748, U24RR025736, U24RR021992, U24RR021382, U24RR026057, AIST, Japan, UWA, Australia
Mario Negri Institute, Italy, CO-ME, Switzerland, OCAIRO, Canada

Completed

U54EB005149-04S1

- Infrastructure grants fund the platform
- Collaborative projects (e.g. Canada, Japan, Australia, Italy) fund the application packages

End-user Documentation



Documentation/4.1/Modules/DICOM

Home < Documentation < 4.1 < Modules < DICOM

Introduction and Acknowledgements

This work is part of the National Alliance for Medical Image Computing (NA-MIC), funded by the National Institutes of Health through the NIH Roadmap for Medical Research, Grant U54 EB005149. Information on NA-MIC can be obtained from the NA-MIC website.

Author: Steve Pieper, Isomics, Inc.
Contributor1: Michael Onken, Offis
Contributor2: Marco Nolden, DFKZ
Contributor3: Julien Finet, Kitware
Contributor4: Stephen Aylward, Kitware
Contributor5: Nicholas Herlambang, AZE
Contact: Steve Pieper, pieper@bwh.harvard.edu

Isomics, Inc. | National Alliance for Medical Image Computing (NA-MIC) | Neuroimage Analysis Center (NAC) | The Common Toolkit | DICOM-OFFIS

Module Description

Provides DICOM local database and networking support.

- A new DICOM infrastructure was put in place beginning with Slicer 4.0.
- DICOM data is stored in a local data base, which is based on SQLite.
- DICOM data can be imported from disk into this data base
- DICOM data can be retrieved from a PACS system after proper configuration of Slicer.
- DICOM data can be loaded into Slicer from the local database. A graphical user interface with display of thumbnails is available for data selection.
- Plans for the near future, include support for storing data from slicer into the data base and uploading data from the data base into a PACS system.

Use Cases

DICOM module in use

DICOM Query dialog

DICOM Export dialog available from the context menu at the Study level of the DICOM tree (beta feature).

Tutorials

Links to tutorials that use this module (not yet available)

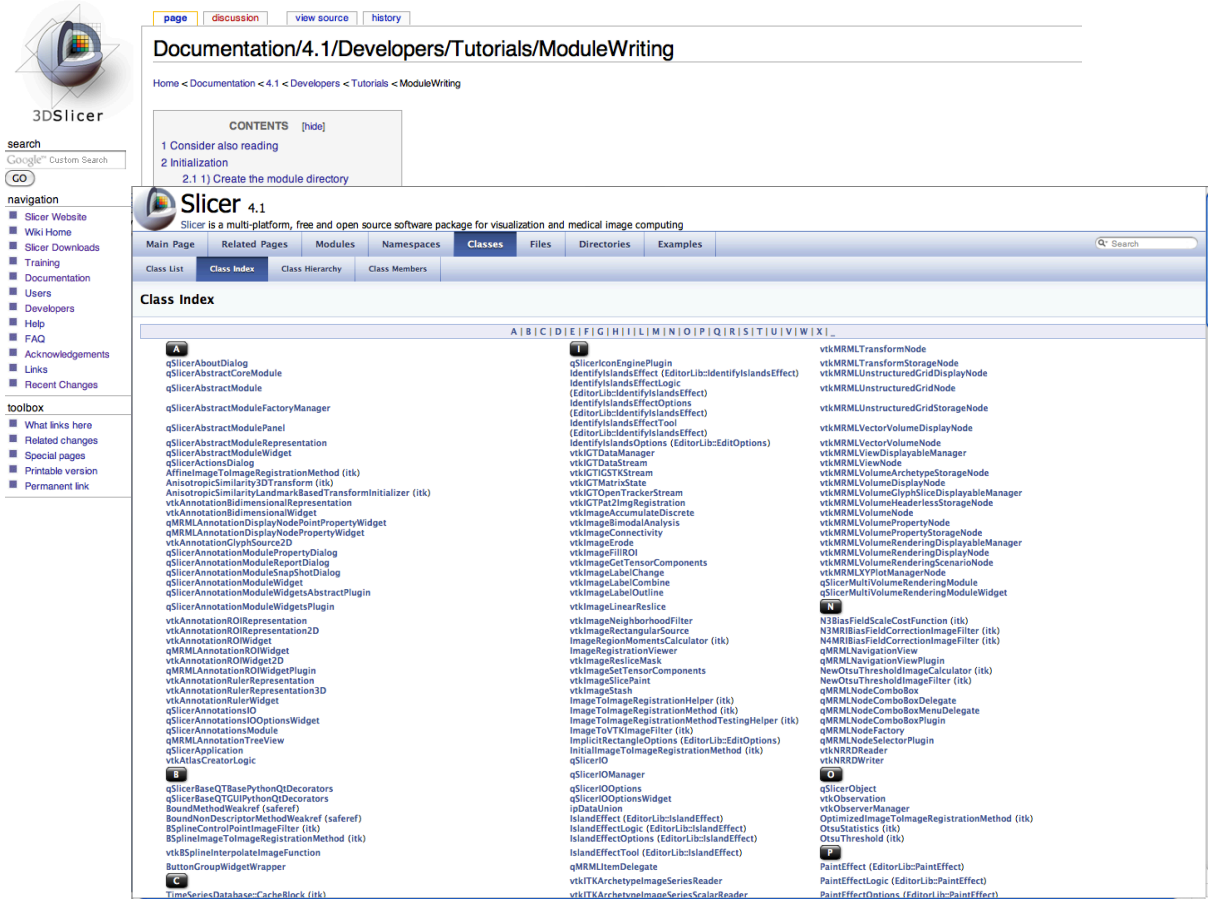
Panels

Parameters:

- **Servers**
  - **Start/Stop Listener**: Control external process that listens for network connections to populate the local database. The listener port is controlled by the setting in the Query dialog

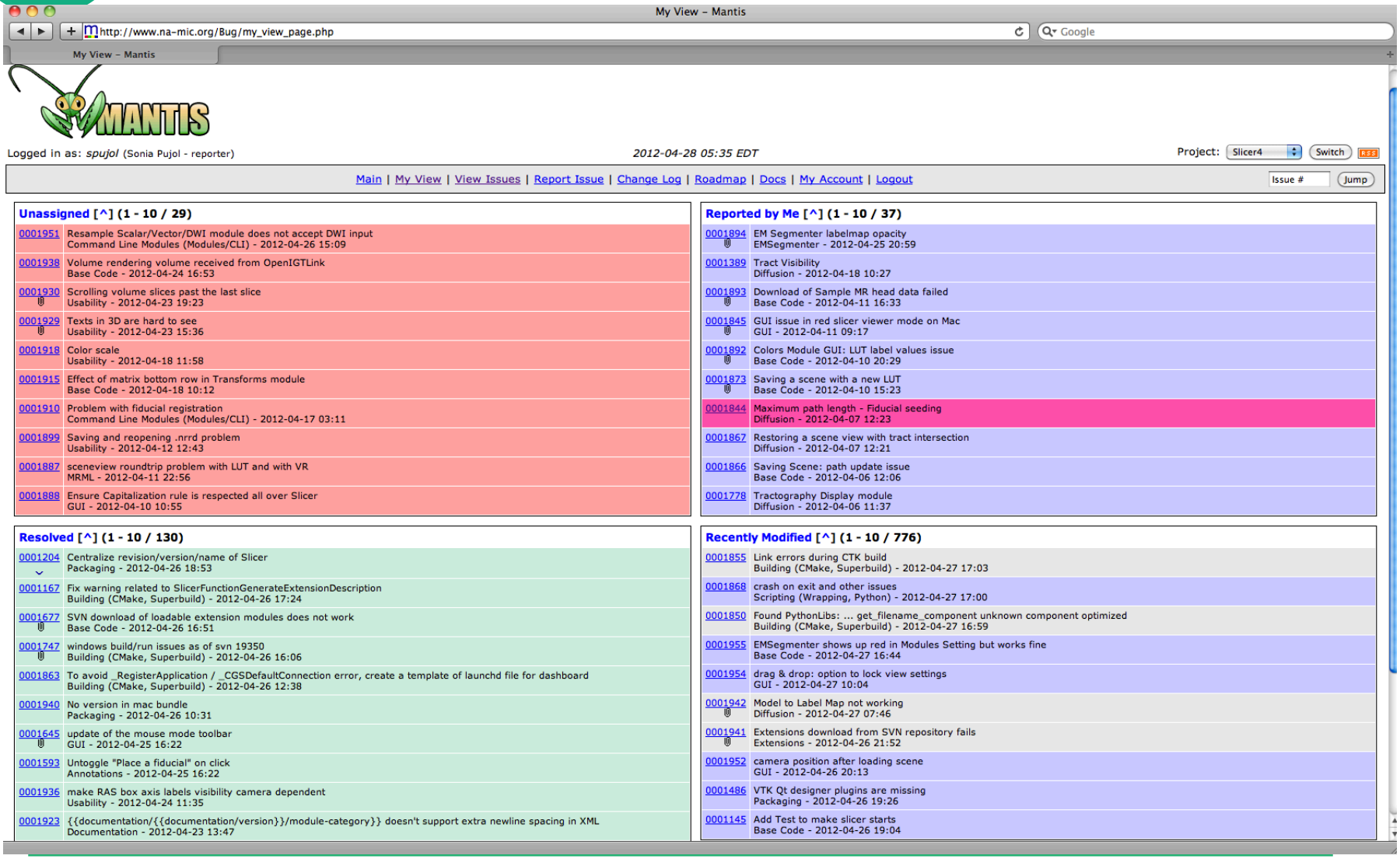
- Wiki-based web pages accompany every module of Slicer and provide reference documentation of functionality and usage examples.

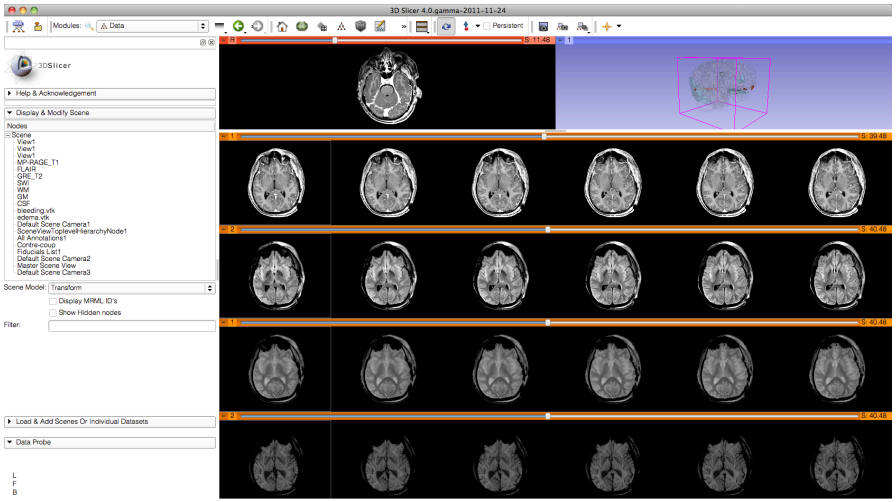
Developer Documentation



Code examples and Doxygen source code API documentation

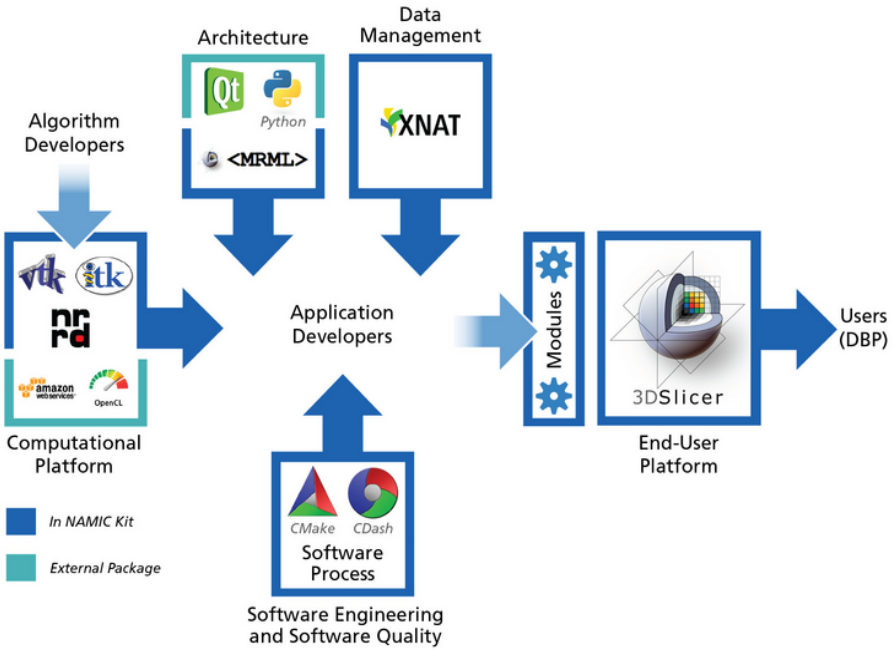
Slicer Bug Tracker

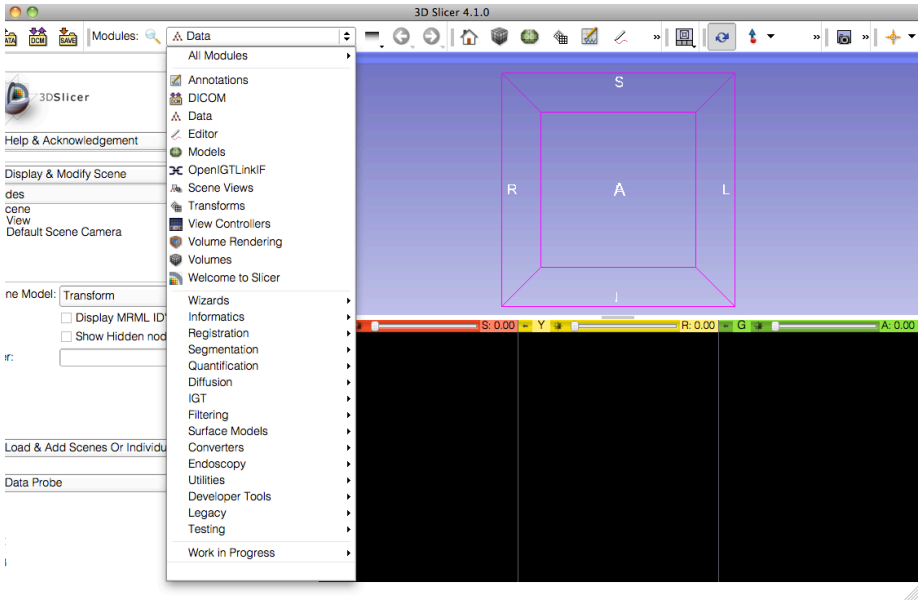




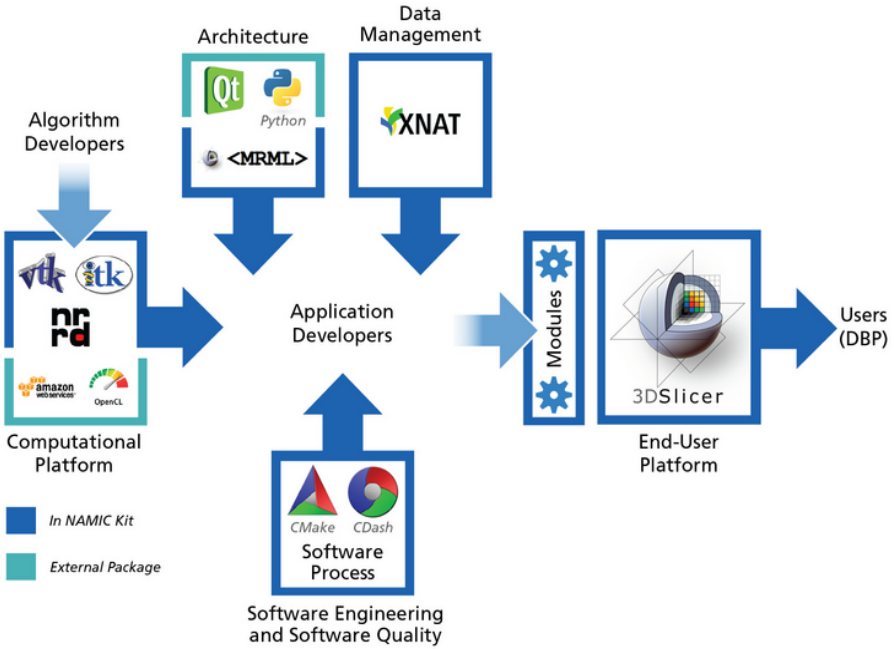
SLICER FUNCTIONALITIES

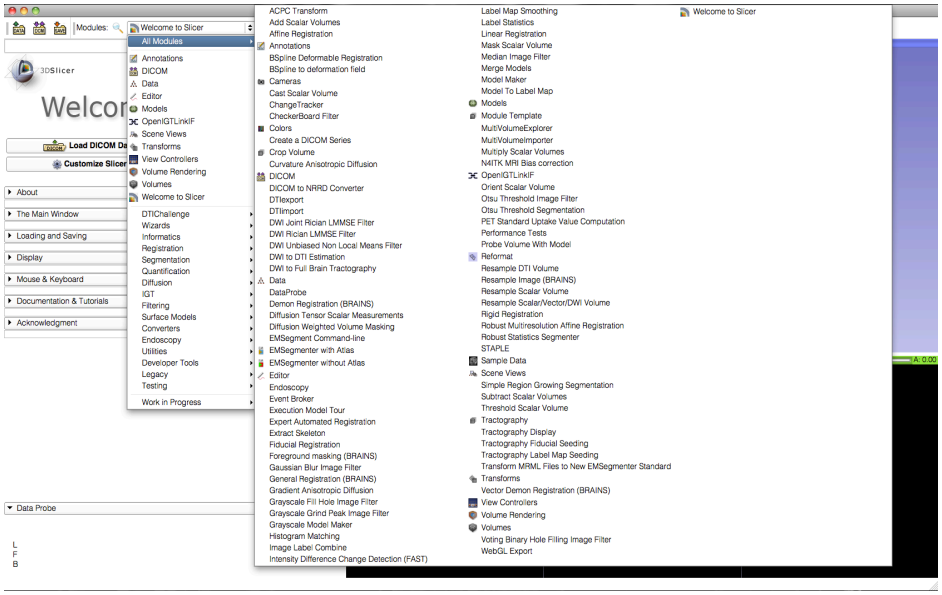
Core Functionalities





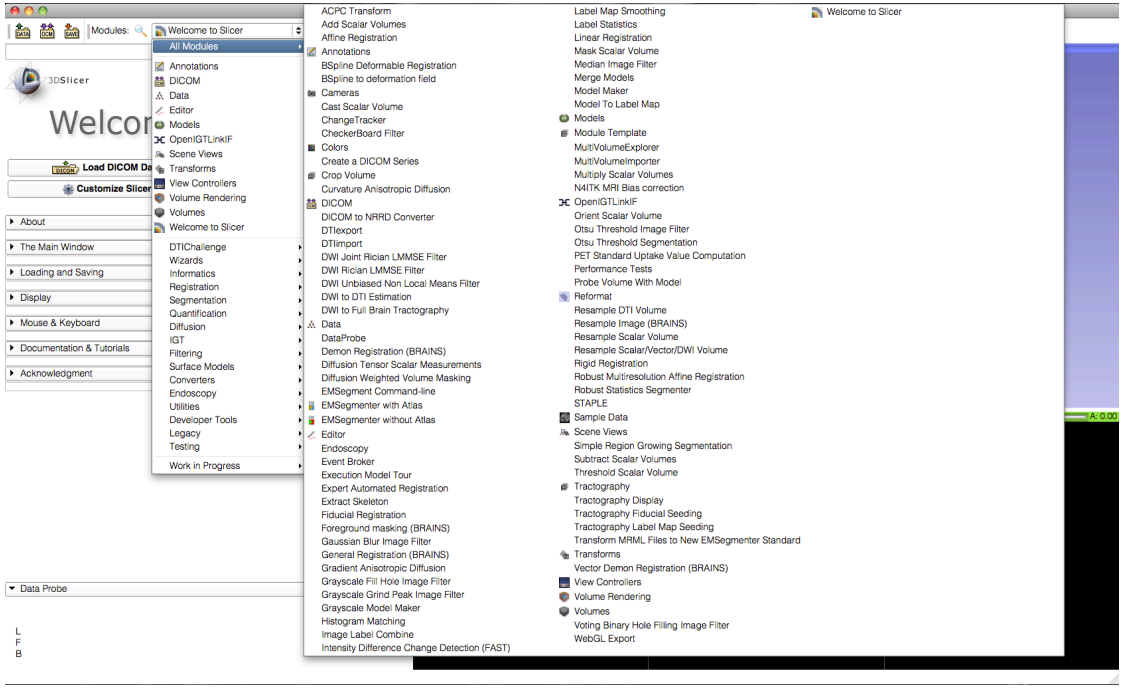
Core Functionalities





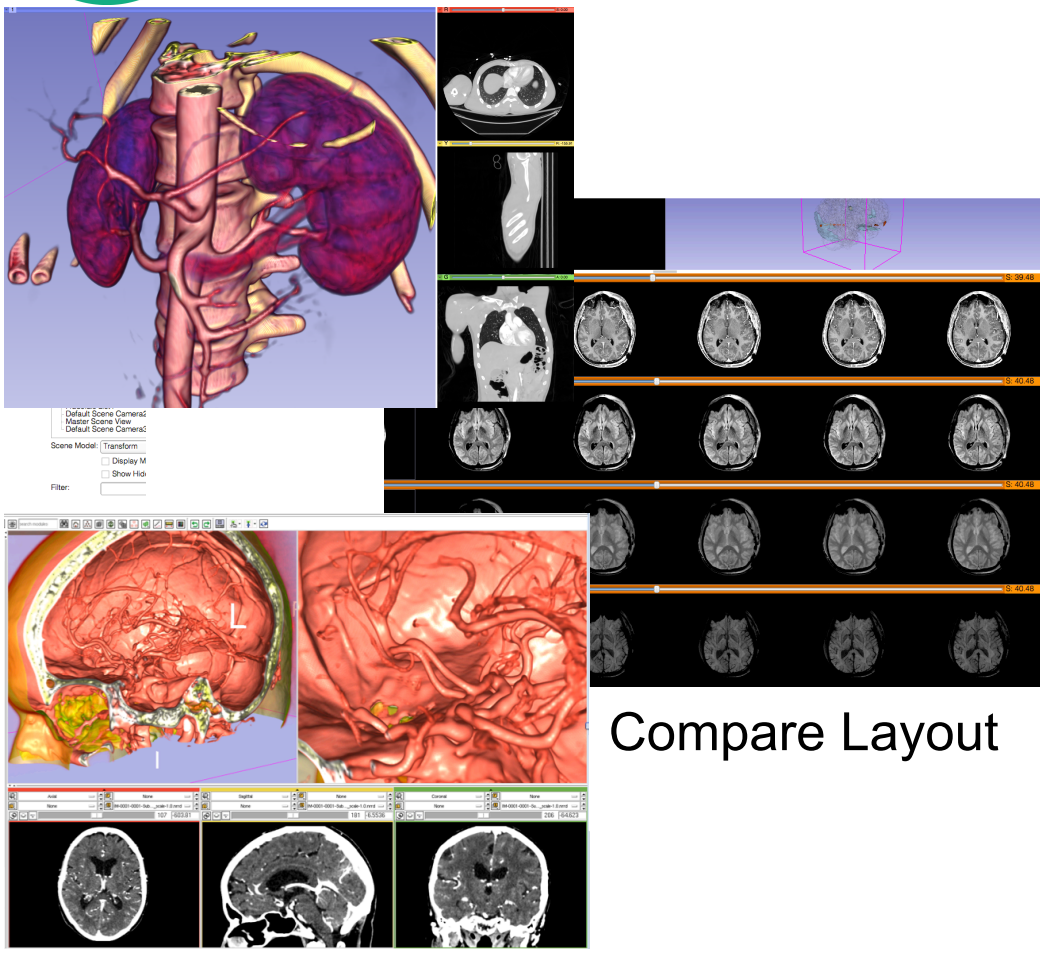
Slicer4 core functionalities include 108 modules, and represent 700,000 lines of code

Core Functionalities



- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification
- Reporting

Core Functionalities

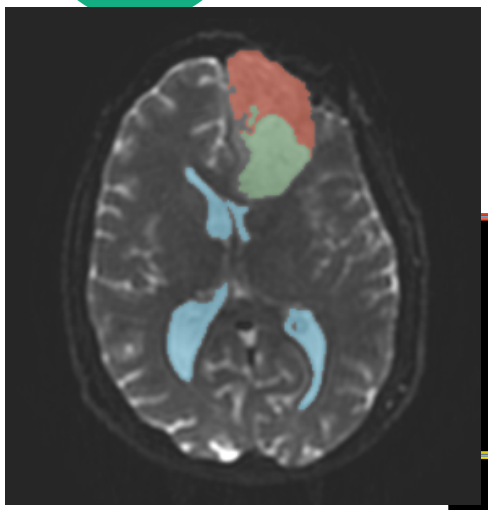


Volume Rendering

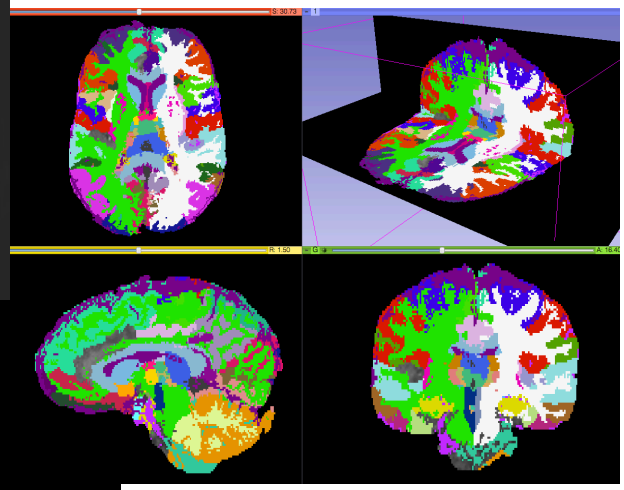
Compare Layout

- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

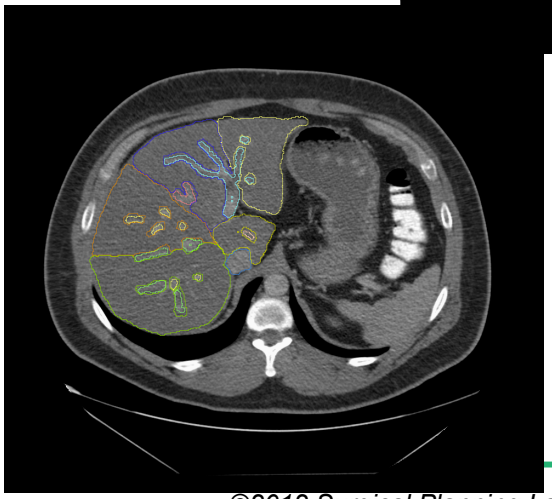
Core Functionalities



Editor

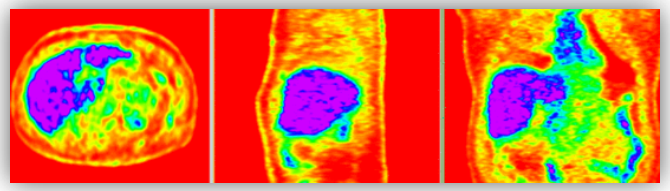


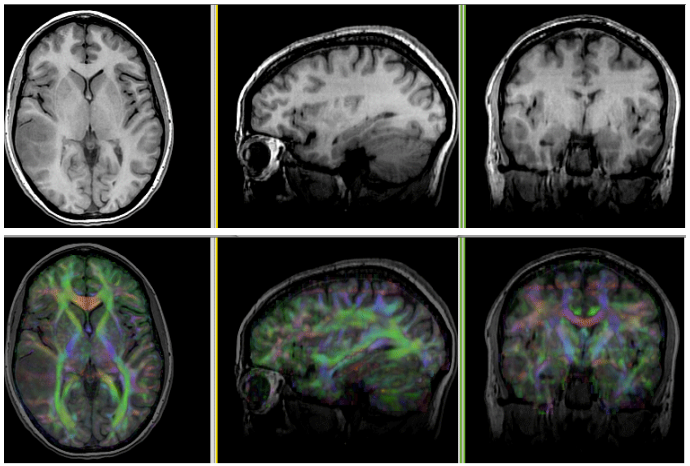
EMSegmenter



- Visualization
- **Segmentation**
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

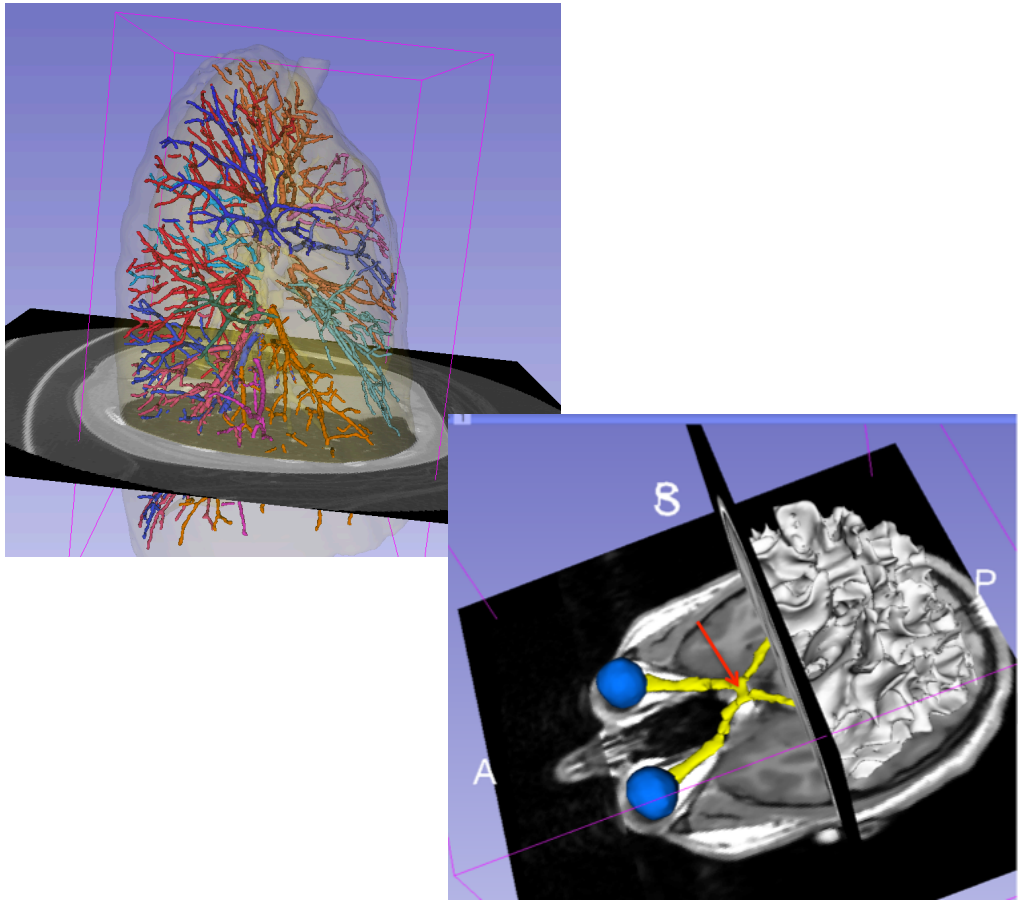
Core Functionalities





- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

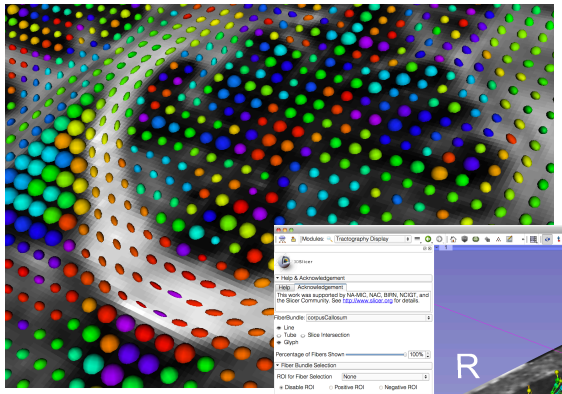
Core Functionalities



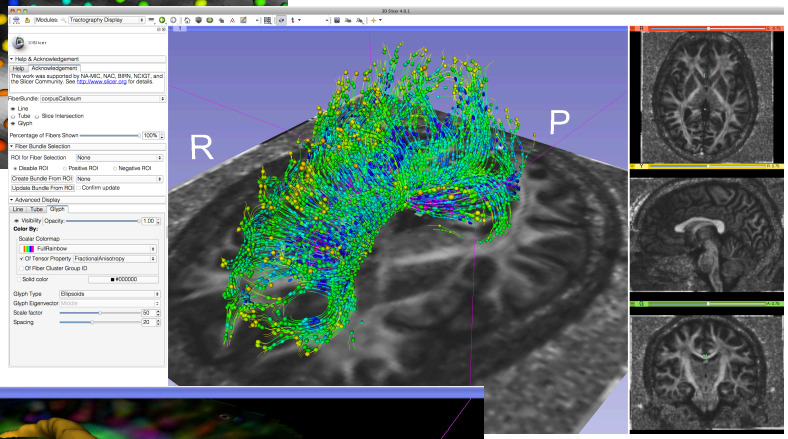
- Visualization
- Segmentation
- Registration
- Surface Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

Model Maker

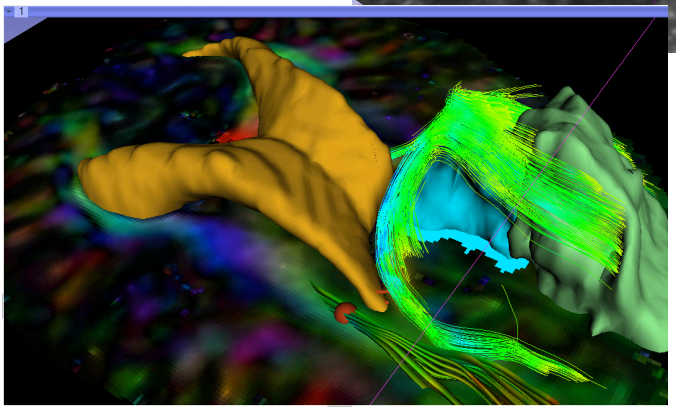
Core Functionalities



DWI To DTI Estimation



Labelmap Seeding



Interactive Seeding

- Visualization
- Segmentation
- Registration
- Reconstruction
- **Diffusion MRI**
- Image Guided Therapy
- Quantification

Core Functionalities

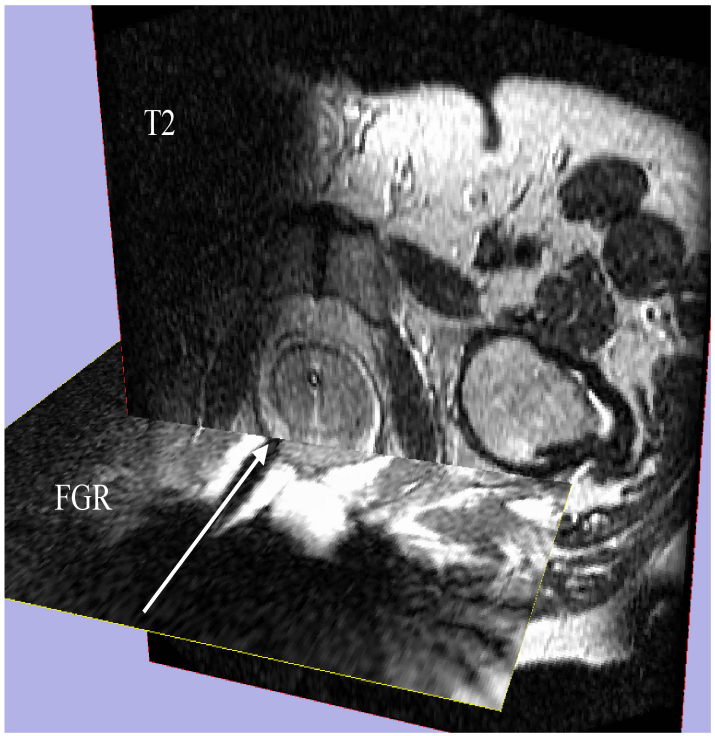
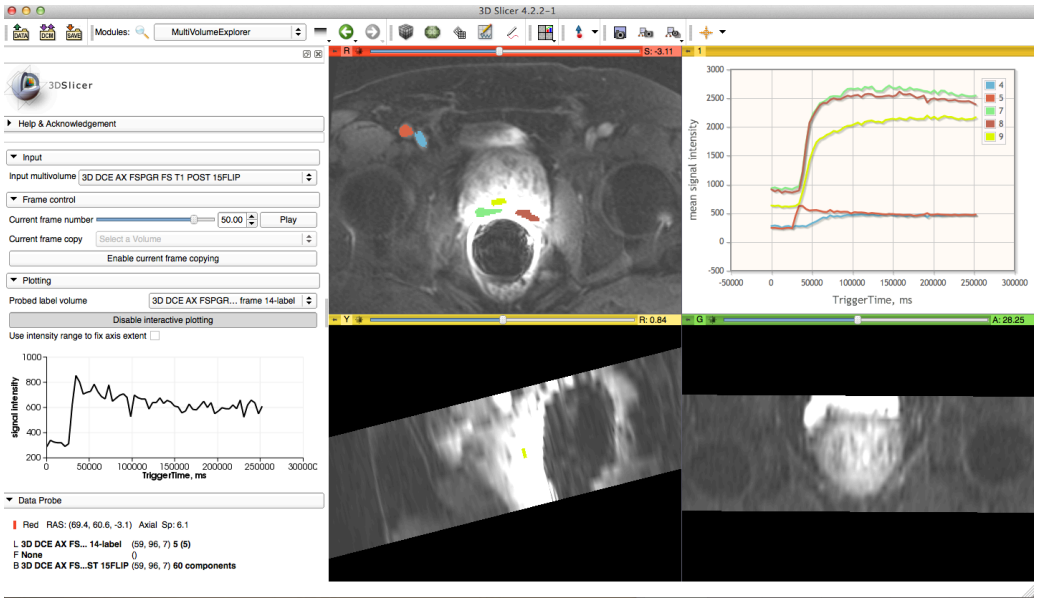


Image Courtesy of Steven Haker, PhD and Clare Tempany, MD

Image-guided therapy for prostate interventions:
- Brachytherapy Planning
- Navigation for Biopsy

- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Filtering
- Image Guided Therapy
- Quantification

Core Functionalities



- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Filtering
- Image Guided Therapy
- Quantification

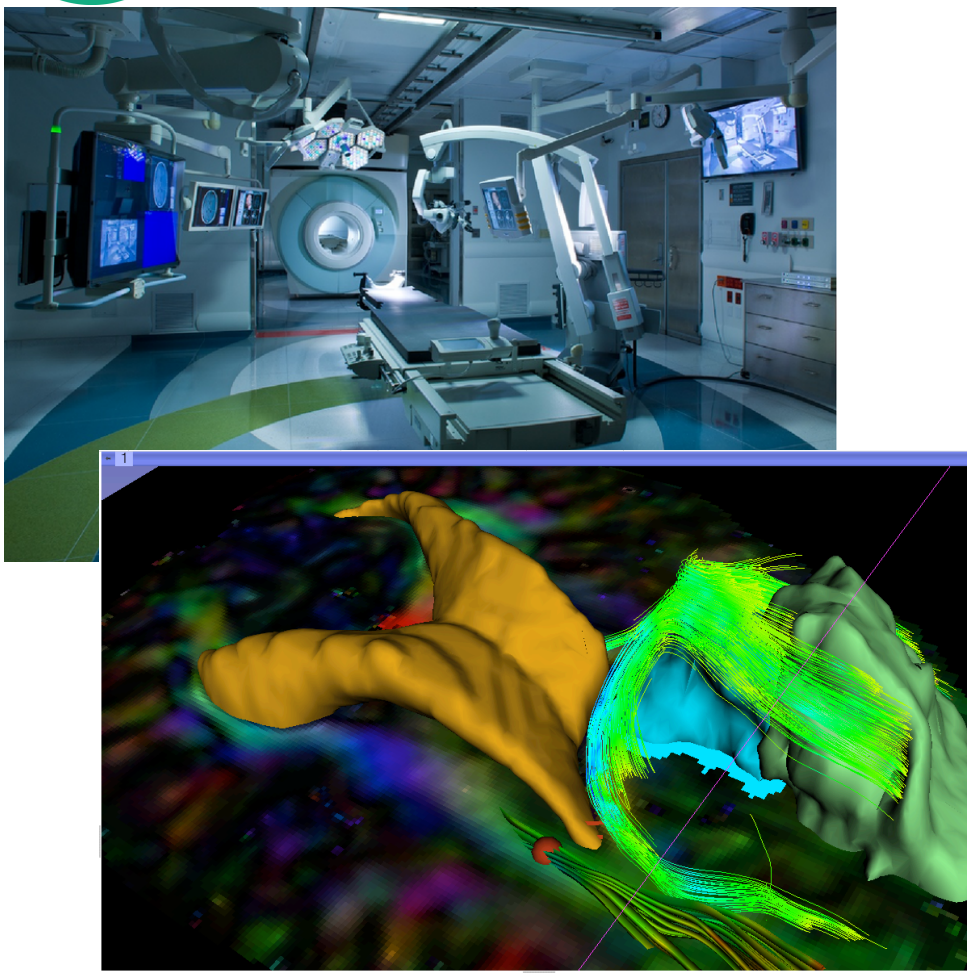
Prostate DCE-MRI analysis.

MutiVolumeExplorer

Slicer use in clinical research environment

- AMIGO, BWH, Boston

Neurosurgery applications

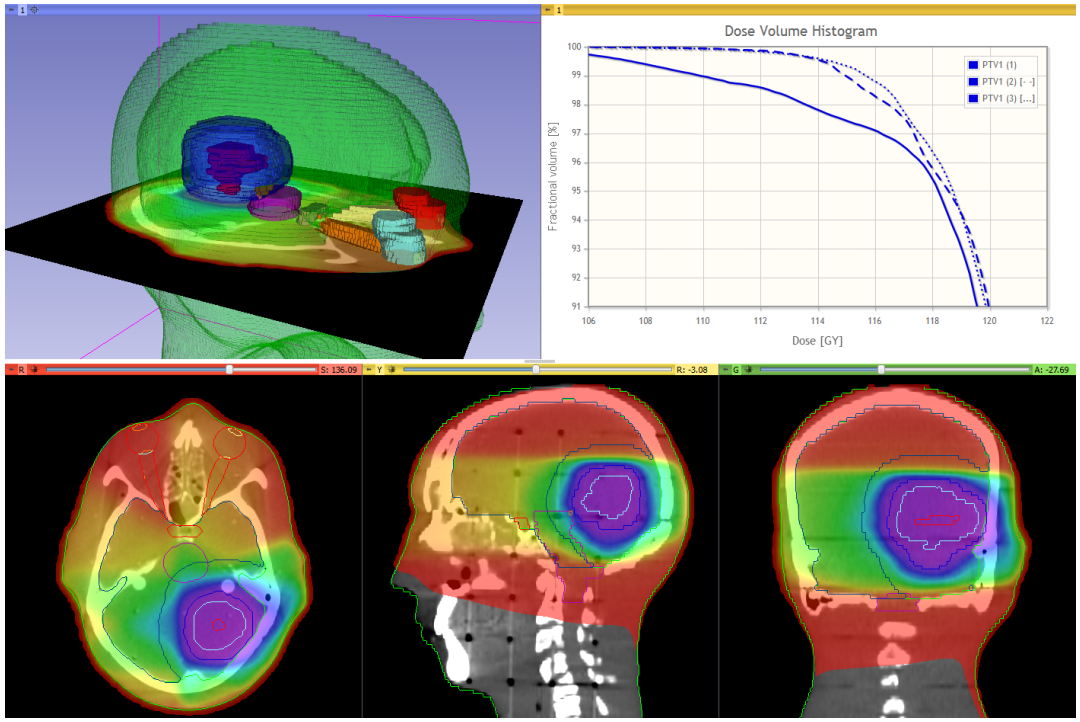


Interactive exploration of peritumoral white matter anatomy neurosurgical planning using DTI tractography

SlicerRT for radiation therapy

SlicerRT extension

- DICOM-RT import
- RT-specific analysis:
  Dose Accumulation
  Dose Comparison (gamma)
  Isodose contours / surfaces
  Contour Comparison
  Contour Morphology
- Plastimatch
  BSpline registration
  Landwarp registration



- Project homepage: https://www.assembla.com/spaces/slicerrt/

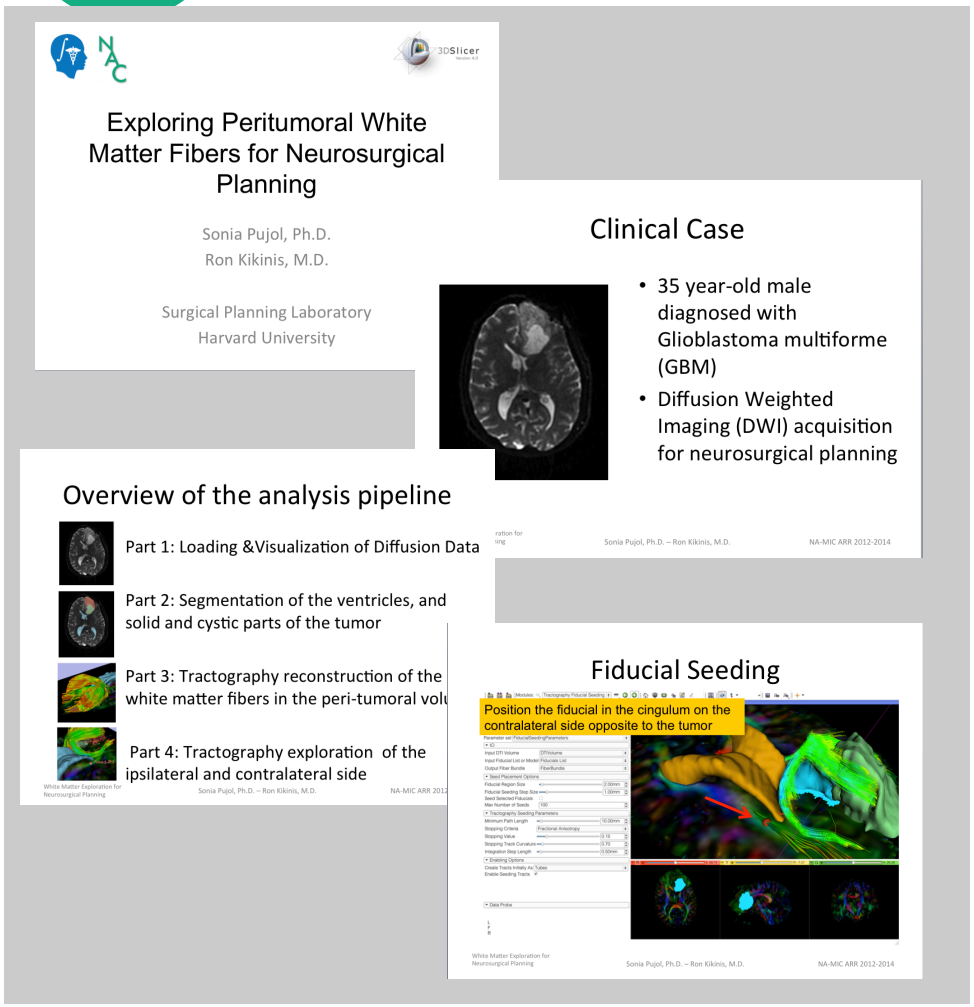
Slide courtesy
G.Fichtinger and
C.Pinter

3DSLICER: TRAINING

Slicer Trainees

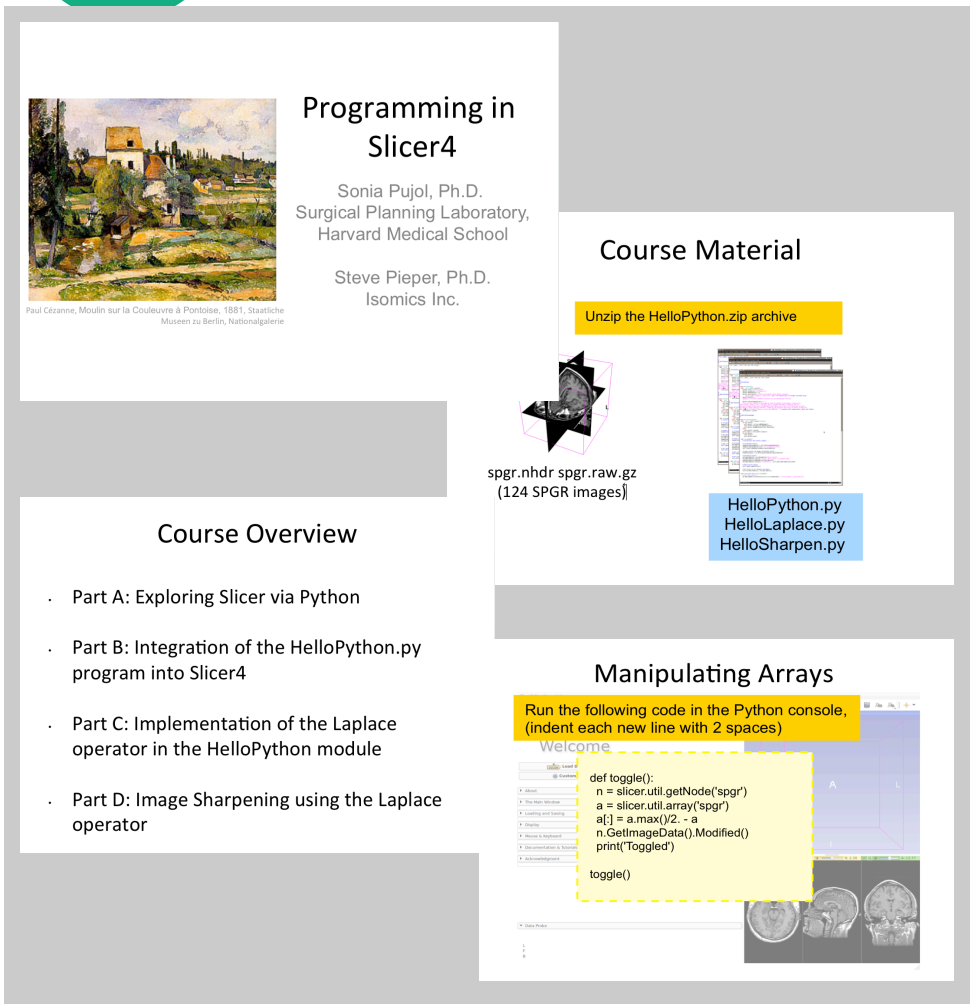
- Clinical investigators
- Senior scientists
- Postdoctoral fellows
- Programmers
- Undergraduate and graduate students
- Staff researchers

Slicer Tutorials: for Users



- Clinically driven goal
- Pre-computed anonymized datasets
- Image-analysis pipeline with step-by-step instructions

Slicer Tutorials: for developers



- Slicer Module development
- Pre-computed exemplar source code
- Programming pipeline with step-by-step instructions

Slicer Training Workshops

Hands-on courses at major international conferences

(e.g.RSNA, SfN, SPIE, CARS, etc..)

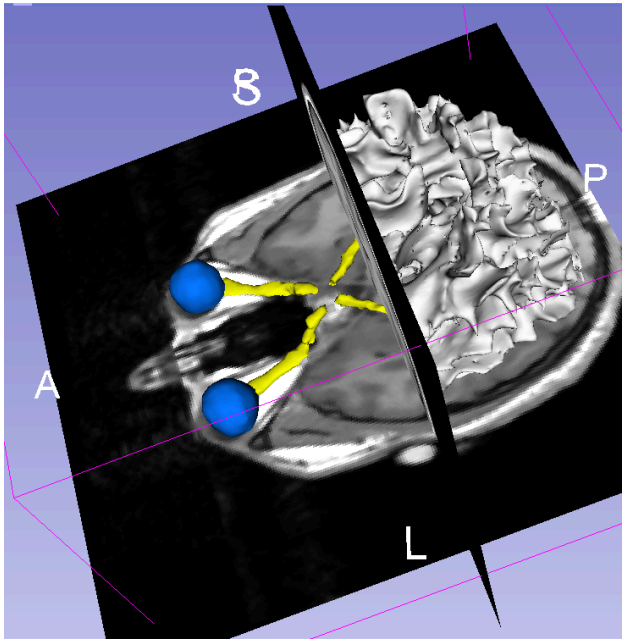
Invited workshops at international universities

(April 2013: Iwate Medical Center, Japan)

Slicer Project Weeks

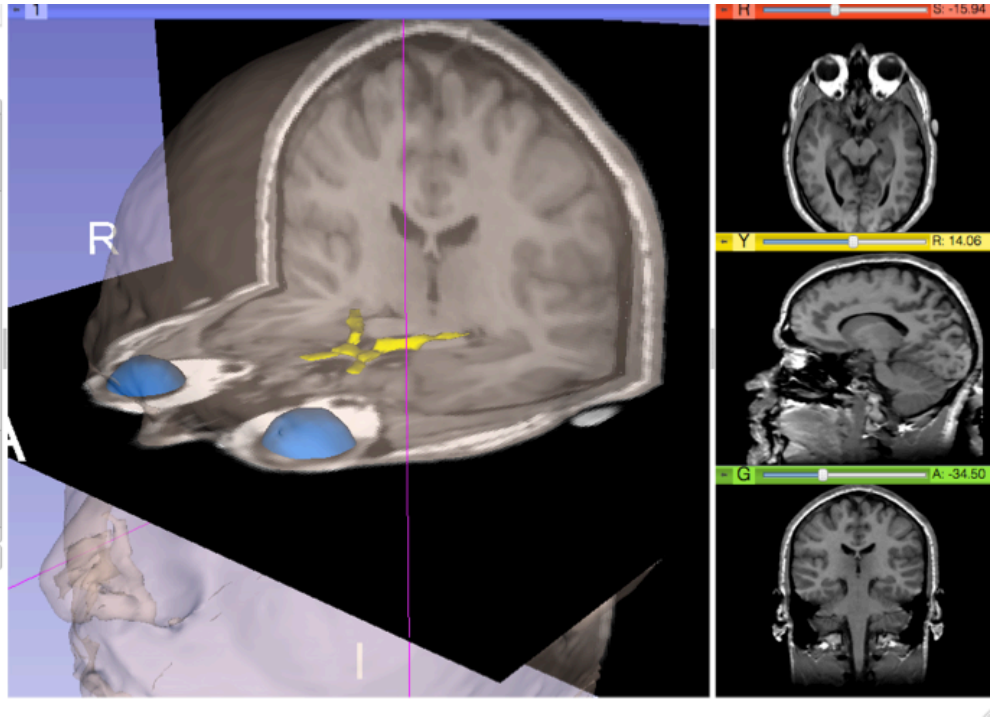
- Bi-annual week of hands-on programming (Winter: Salt Lake City, Summer: MIT)
- Practical exchange of idea and experience
- 17 project weeks since 2005
- Next Project Week:

June 17-21, 2013, MIT



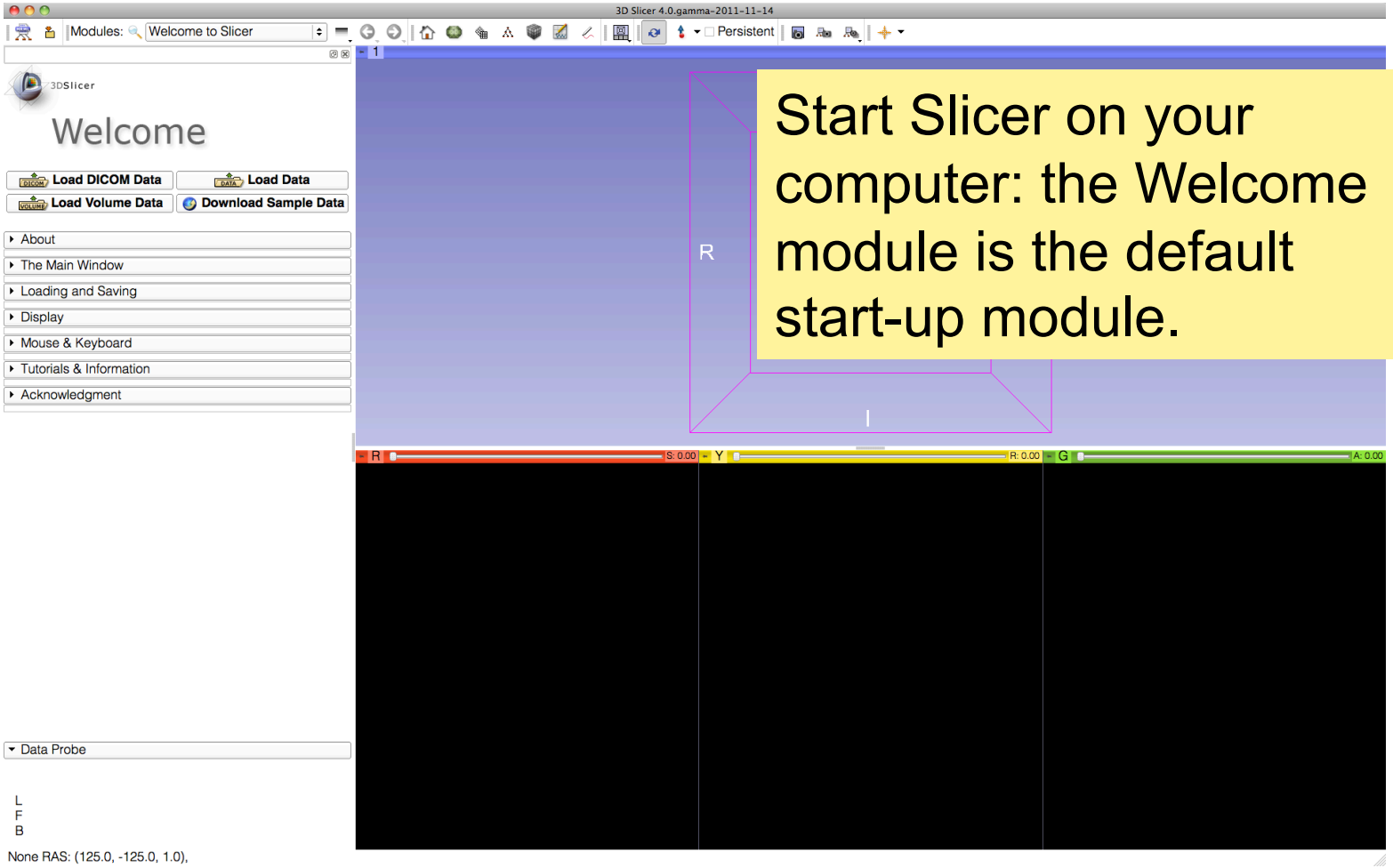
Part II – Hands-on session: Slicer4 Minute tutorial on data loading and 3D Visualization

Slicer4 minute tutorial



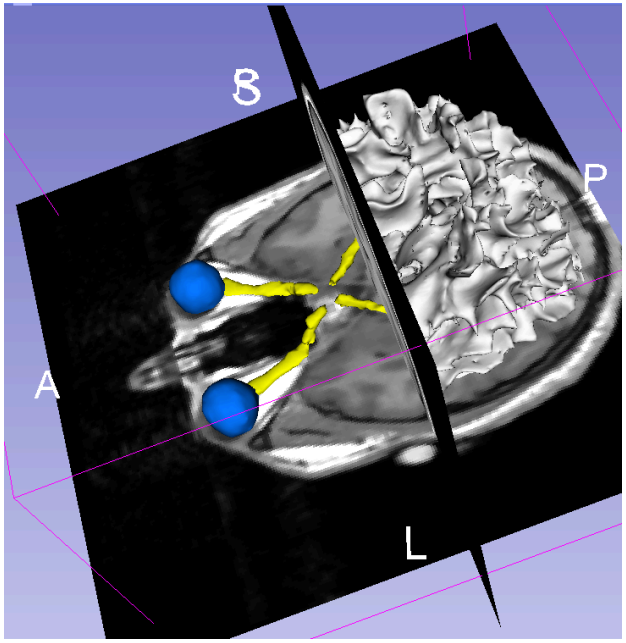
This tutorial is an introduction to the 3D visualization capabilities of the Slicer4 software for medical image analysis.

3DSlicer version 4



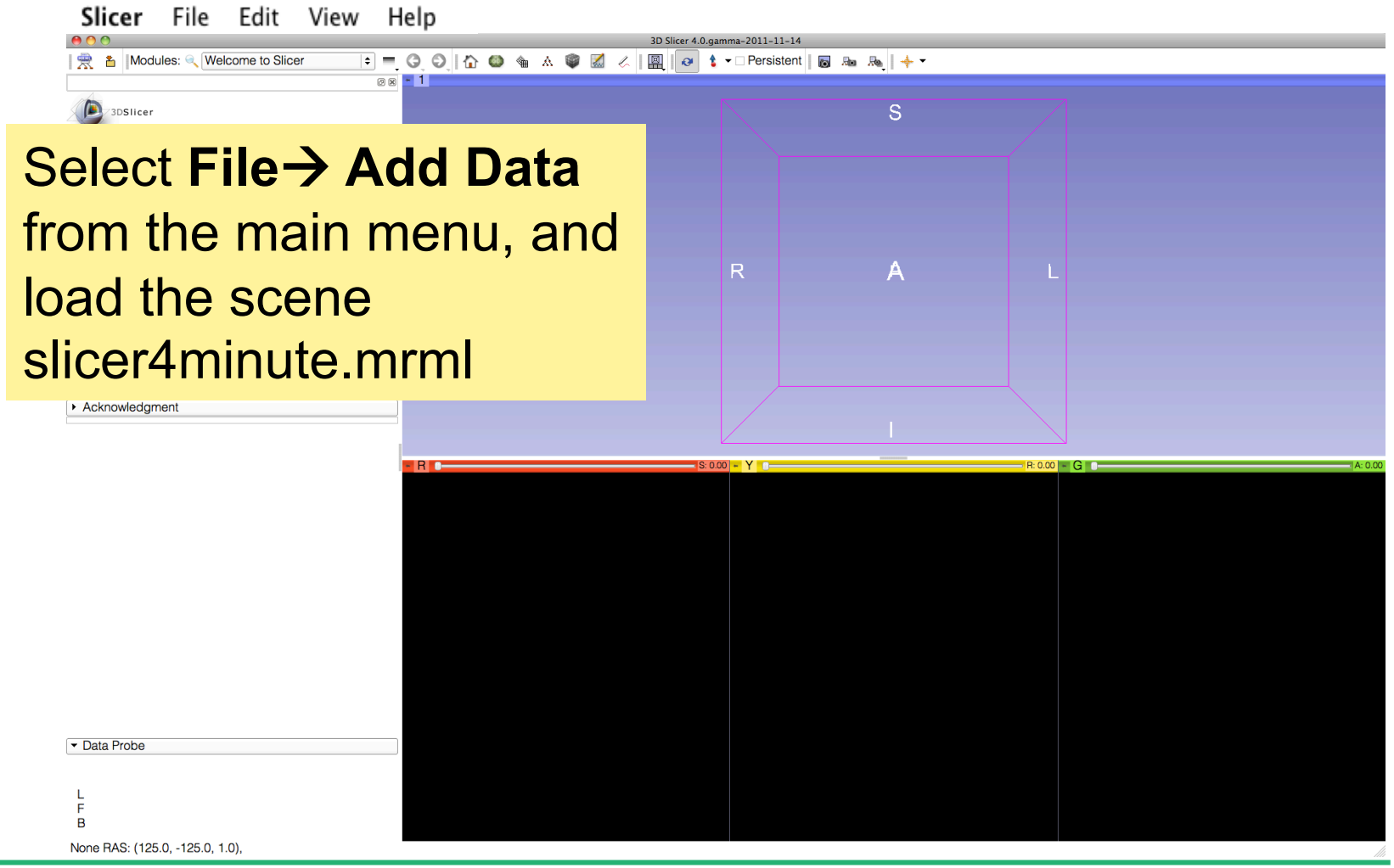
Start Slicer on your computer: the Welcome module is the default start-up module.

3D Slicer Scene



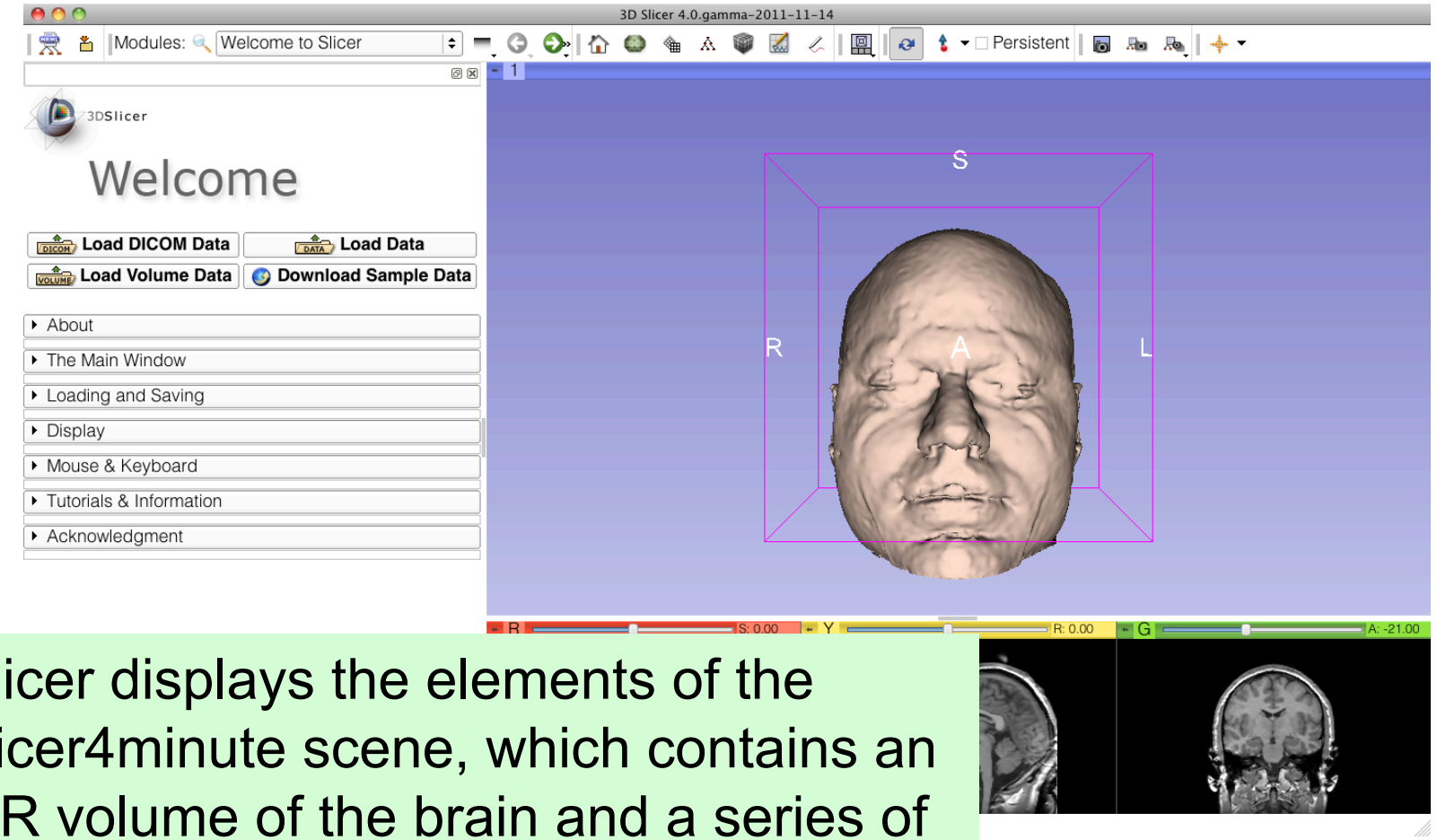
- A Slicer scene is a MRML file which contains the list of elements loaded into Slicer (volumes, models, fiducials…)
- The following example uses a 3D Scene which contains images and 3D surface models of the head from the SPL-PNL Brain Atlas.

3DSlicer version 4



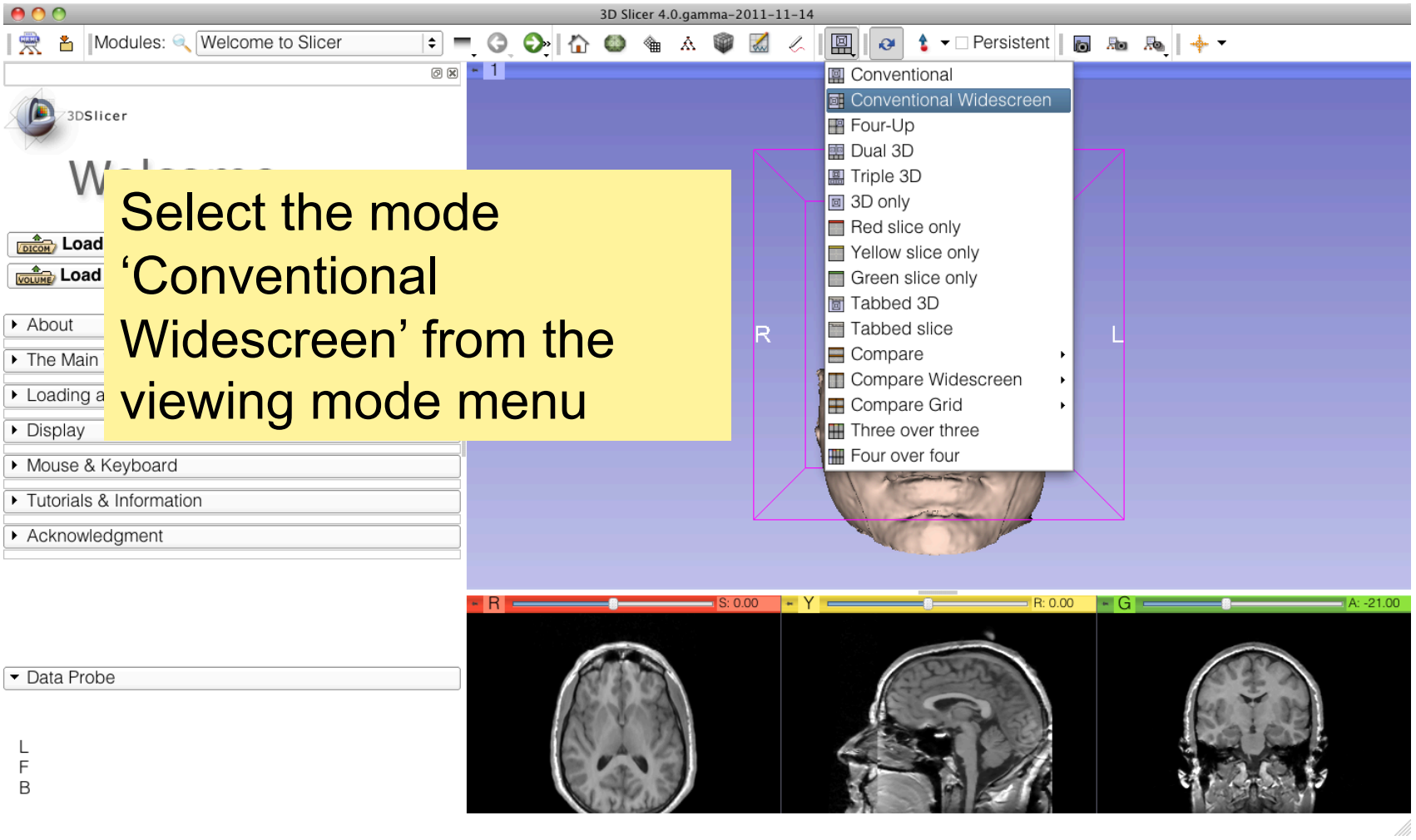
Select **File→ Add Data** from the main menu, and load the scene slicer4minute.mrml

Slicer4 minute Scene



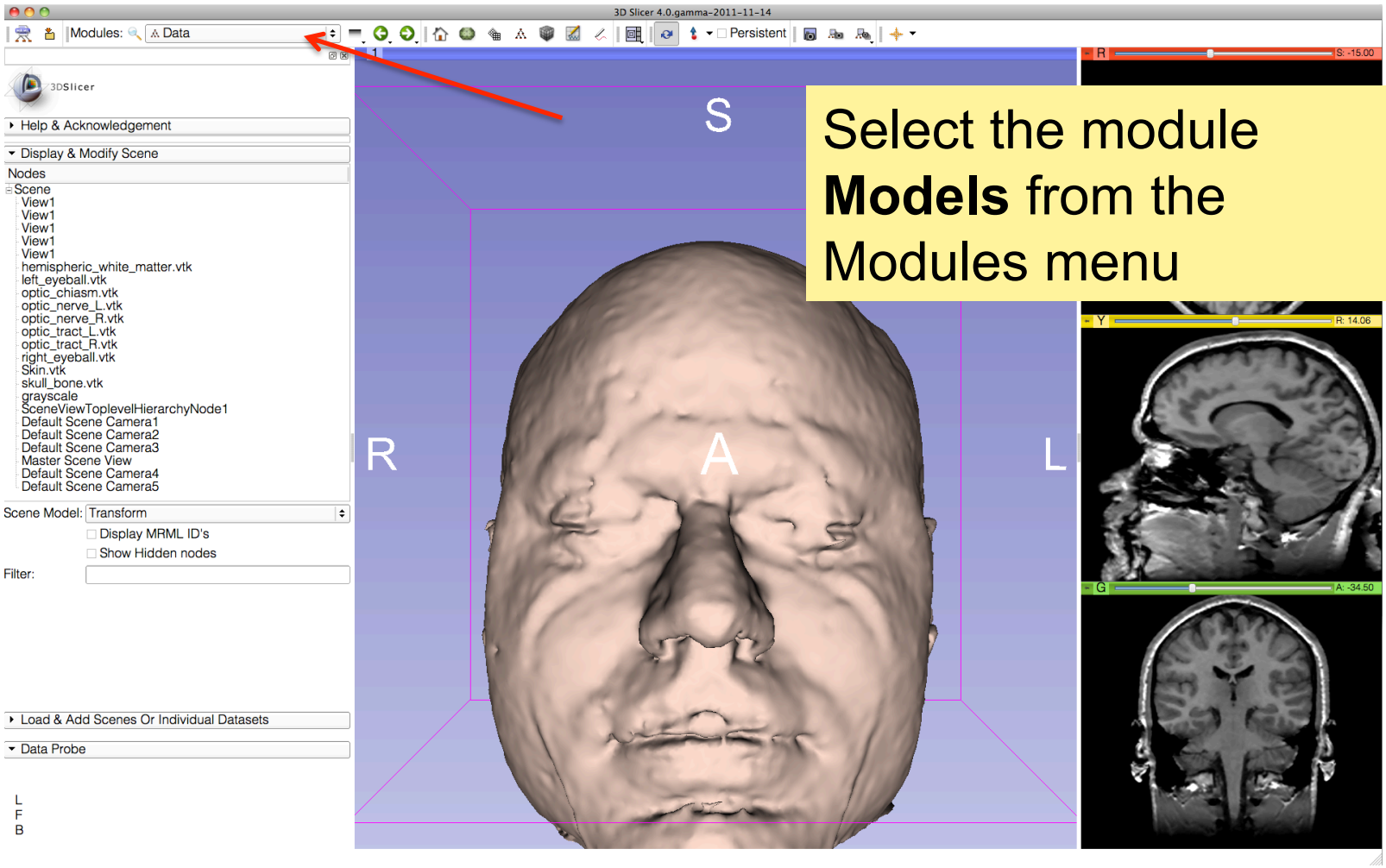
Slicer displays the elements of the slicer4minute scene, which contains an MR volume of the brain and a series of 3D surface models.

Slice4 minute scene



Select the mode ‘Conventional Widescreen’ from the viewing mode menu

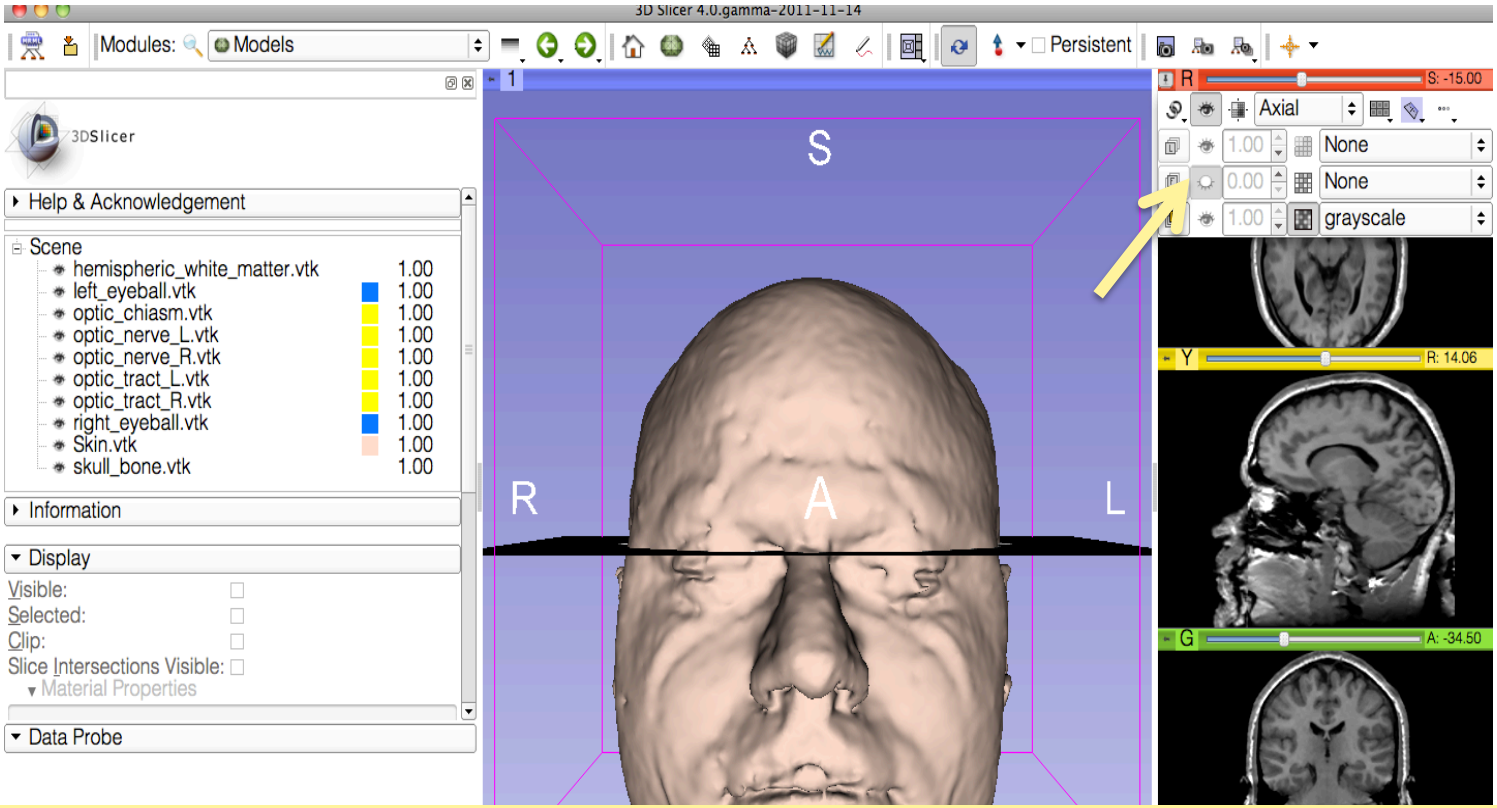
Slicer4minute Scene



3D Visualization

The Models module GUI displays he list of models loaded in the slicer4minute scene, their color and the value of their opacity (between 0.0 an 1.0)

3D Visualization

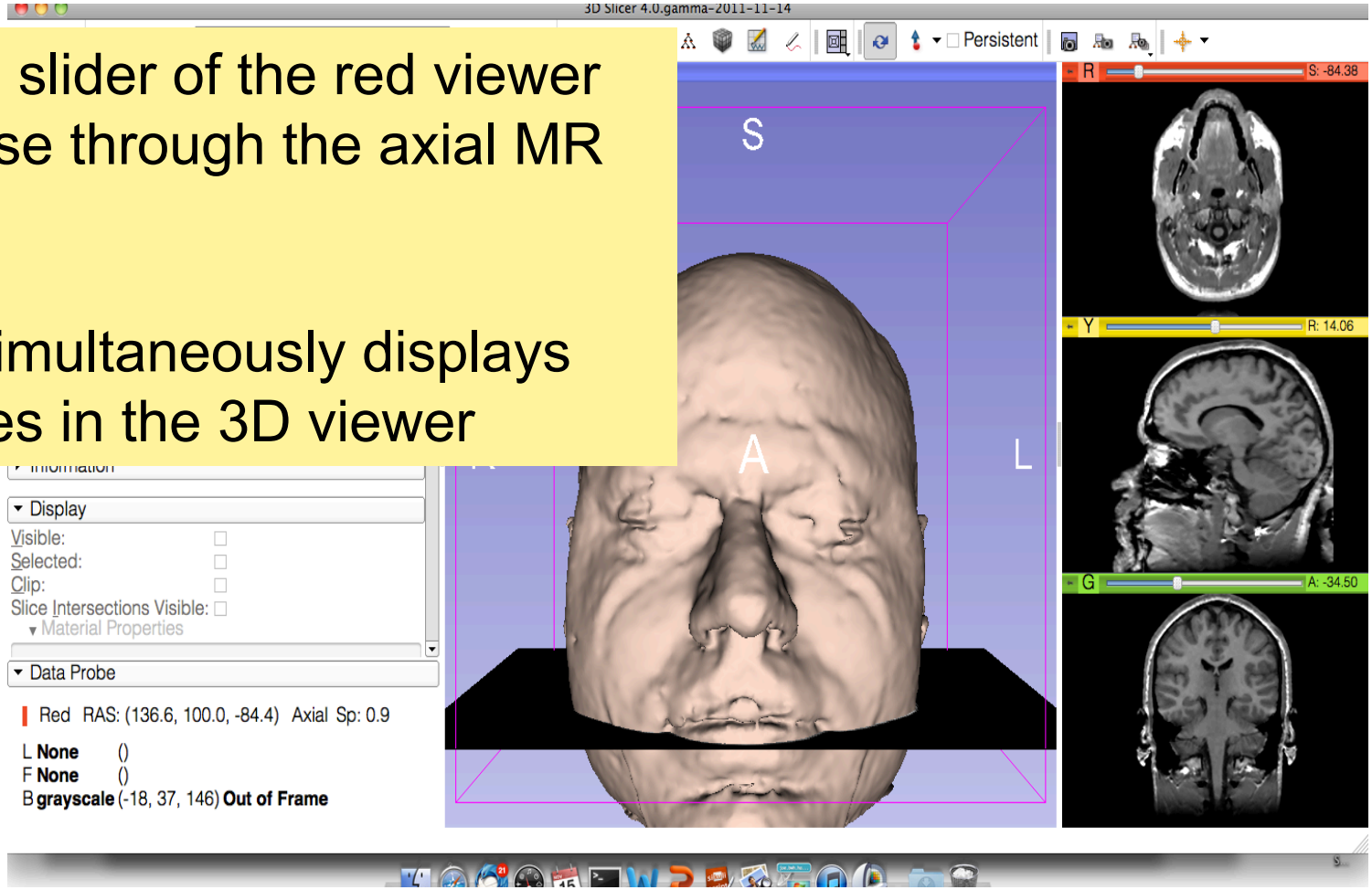


Click on the pin icon on the top left corner of the red slice to display the slice viewer menu.
Click on the eye icon to display the axial slice in the 3D Viewer

3D Visualization

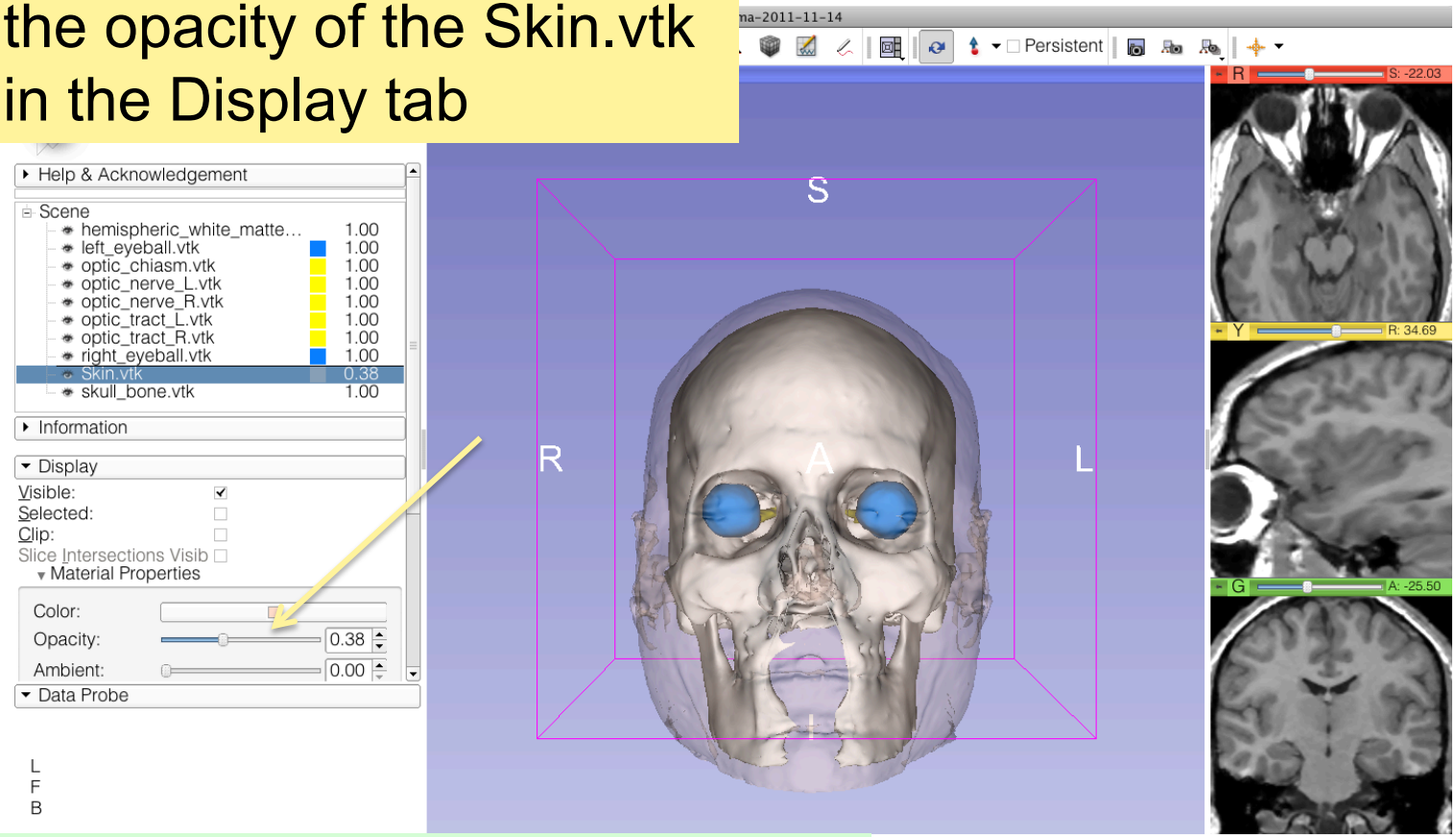
Use the slider of the red viewer to browse through the axial MR slices.

Slicer simultaneously displays the slices in the 3D viewer



3D Visualization

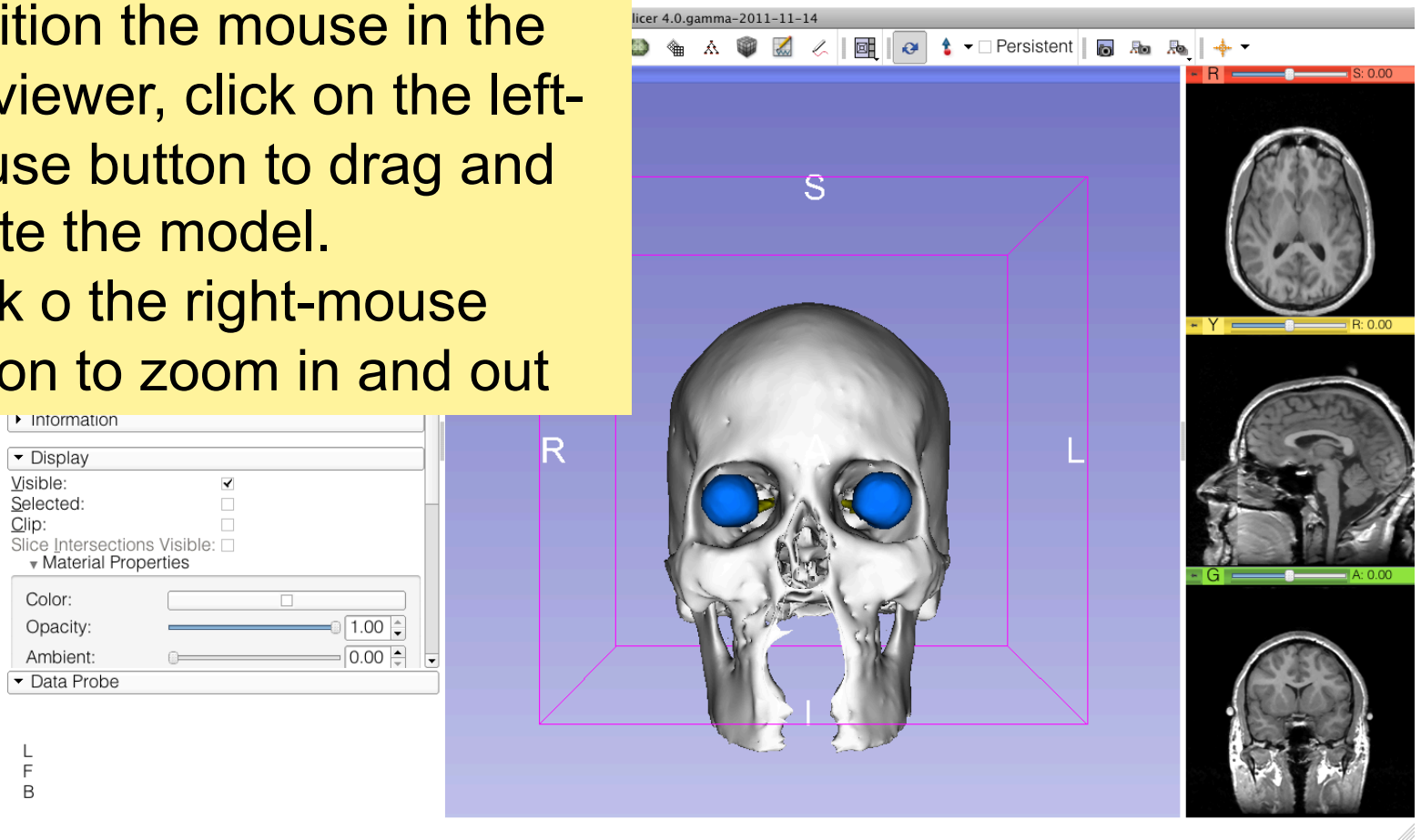
Lower the opacity of the Skin.vtk model in the Display tab



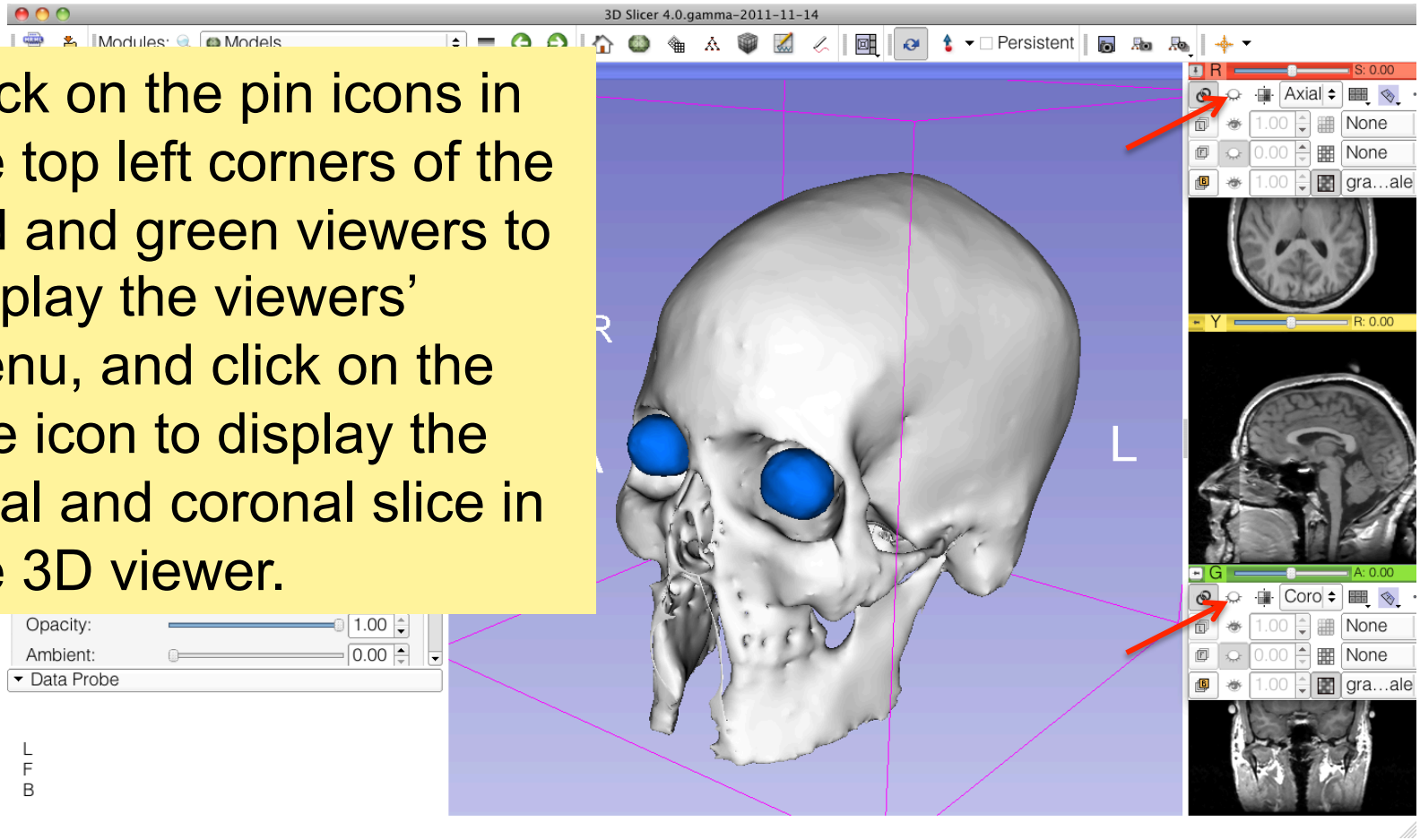
The skull_bone.vtk model appears through the skin.

3D Visualization

Position the mouse in the 3D viewer, click on the left-mouse button to drag and rotate the model.
Click o the right-mouse button to zoom in and out



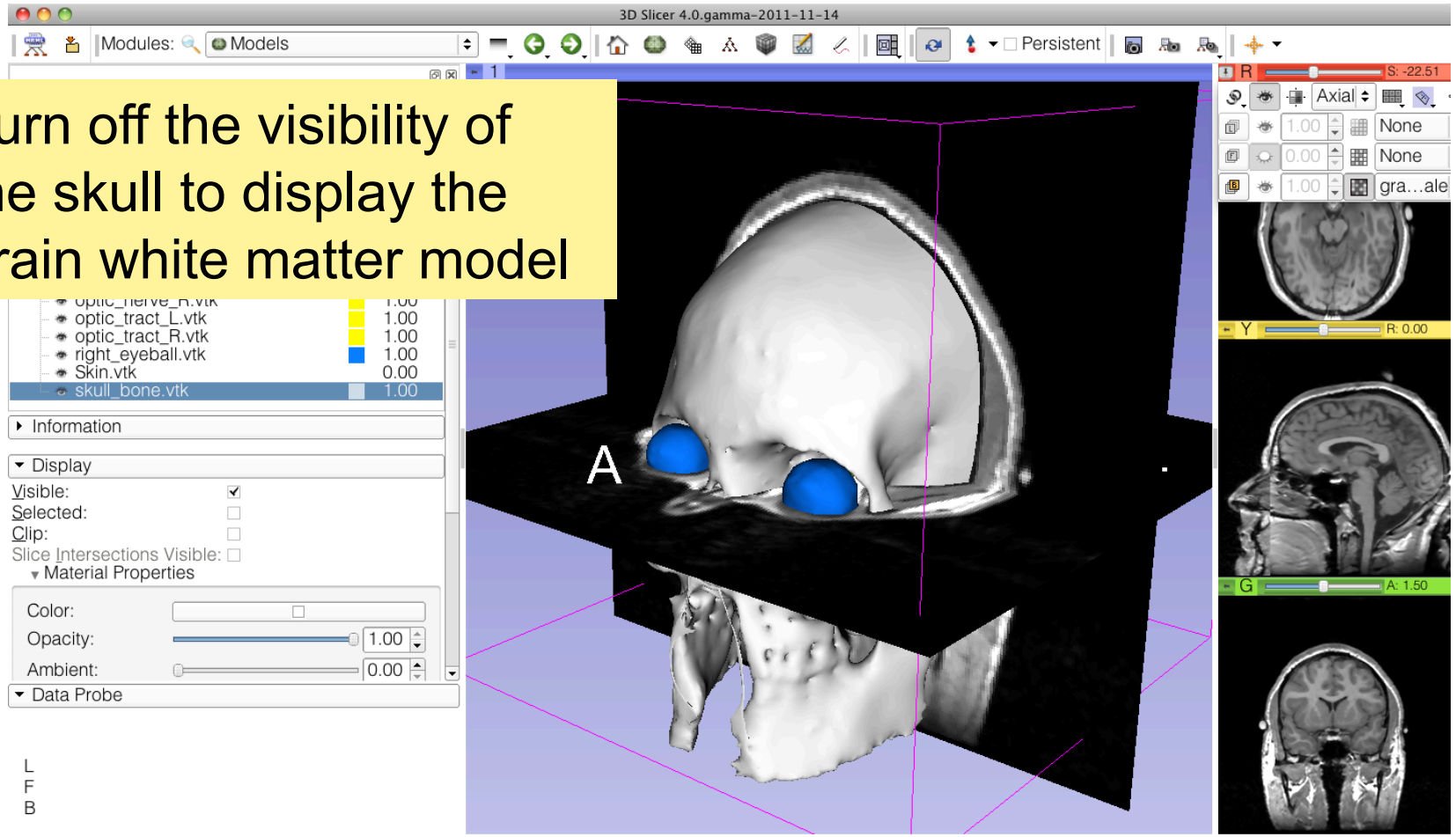
Anatomical Views



Click on the pin icons in the top left corners of the red and green viewers to display the viewers' menu, and click on the eye icon to display the axial and coronal slice in the 3D viewer.

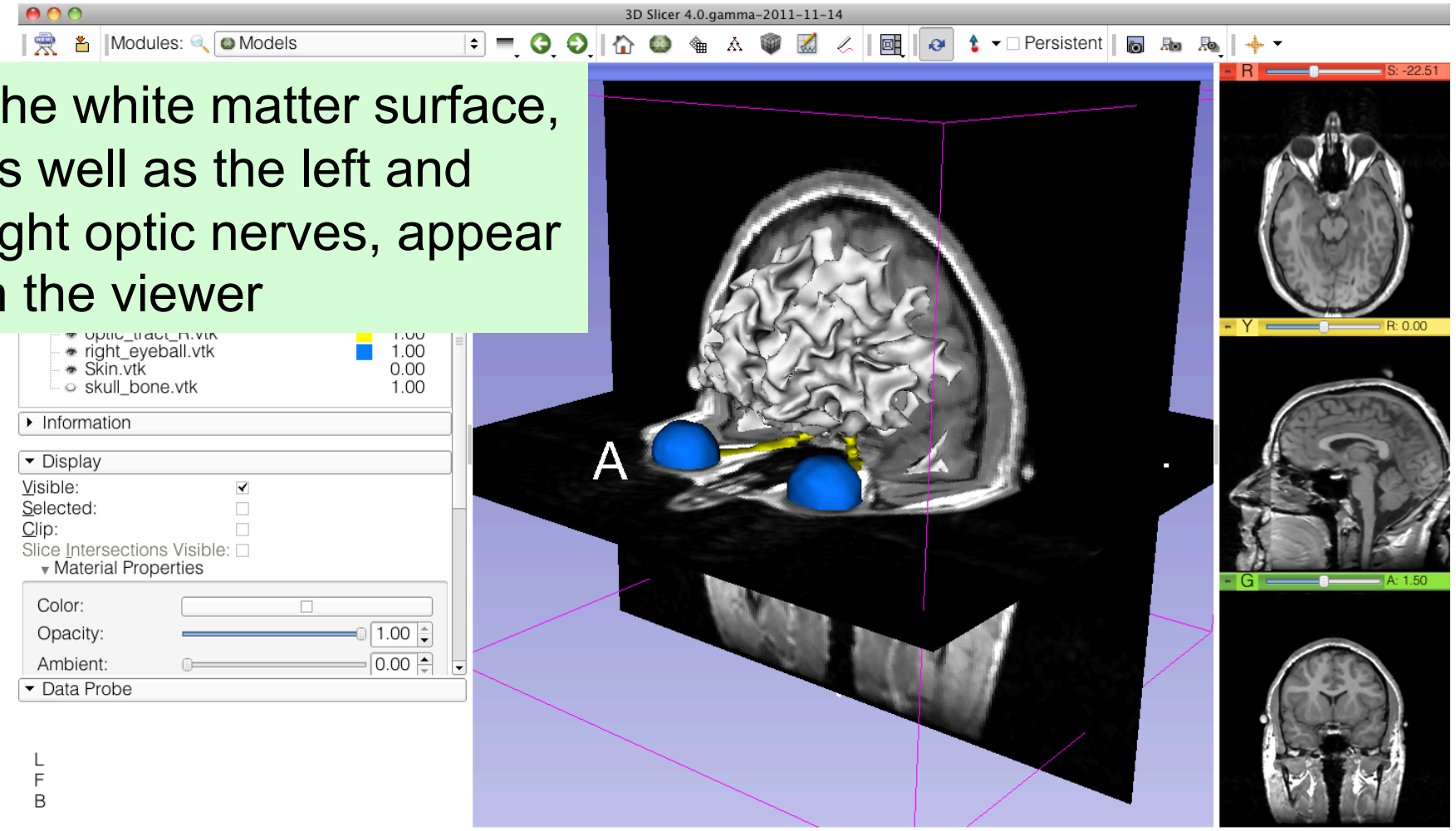
3D Visualization

Turn off the visibility of the skull to display the brain white matter model

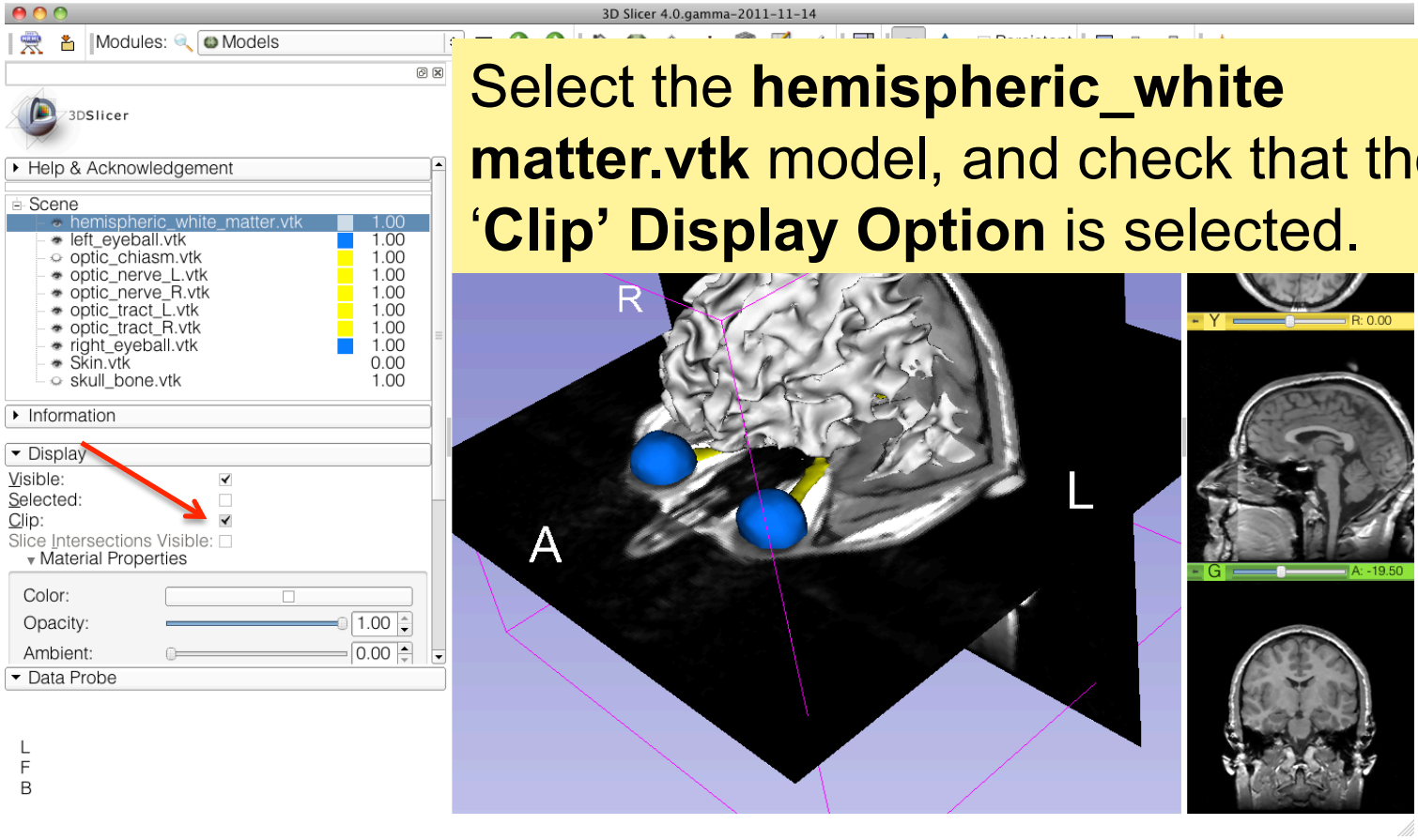


3D Visualization

The white matter surface, as well as the left and right optic nerves, appear in the viewer

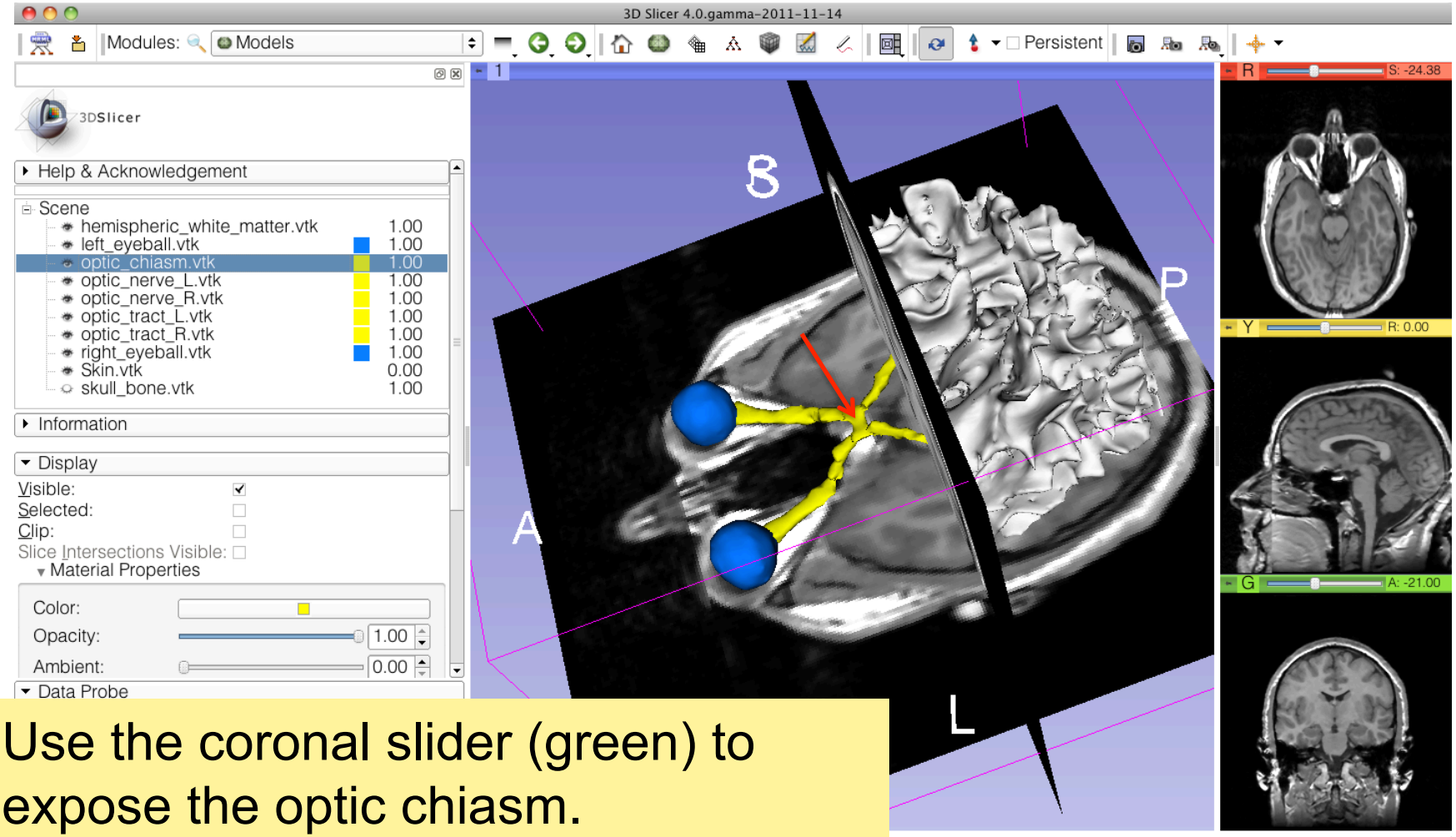


3D Visualization



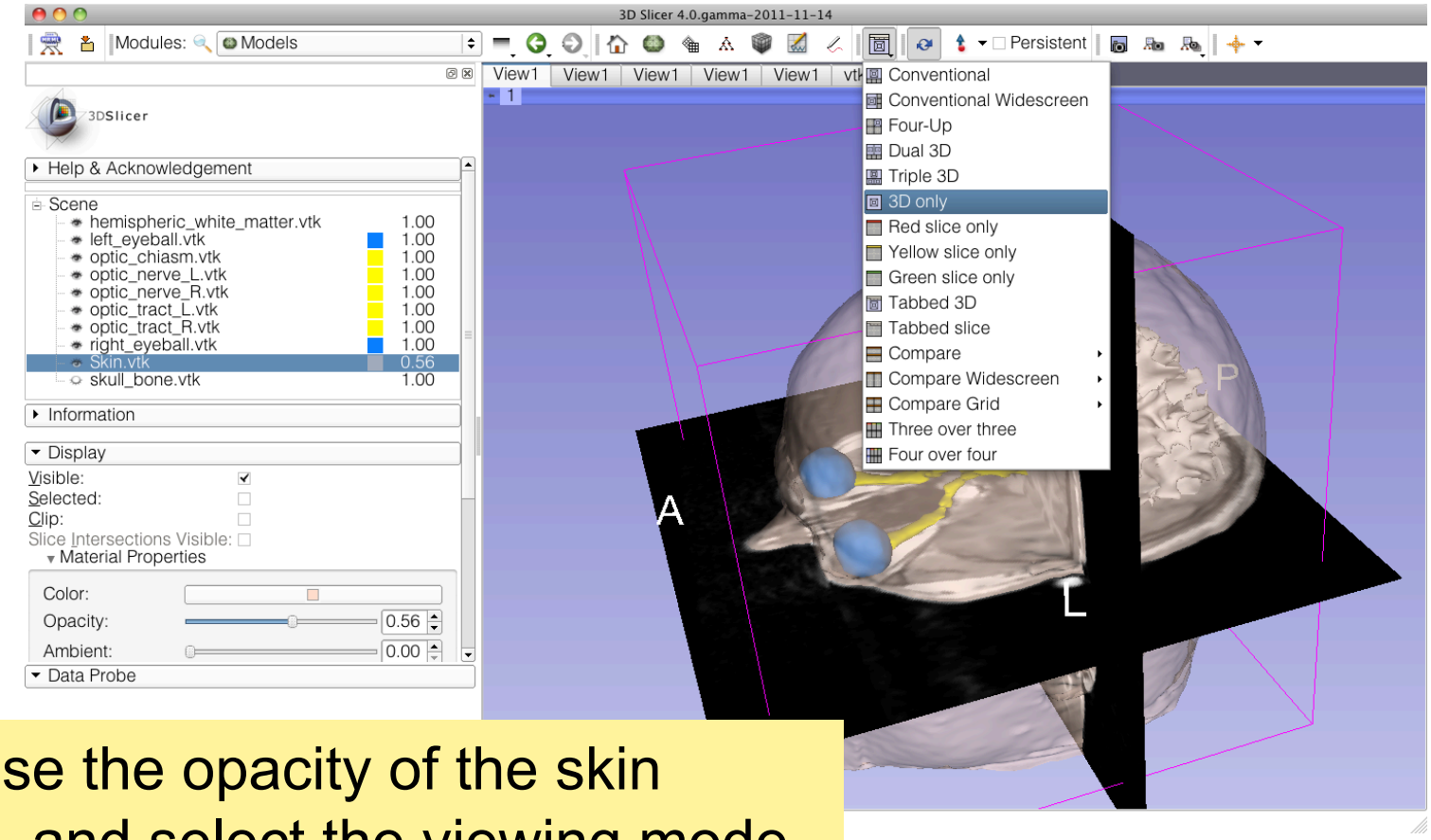
Select the **hemispheric_white matter.vtk** model, and check that the '**Clip' Display Option** is selected.

3D Visualization



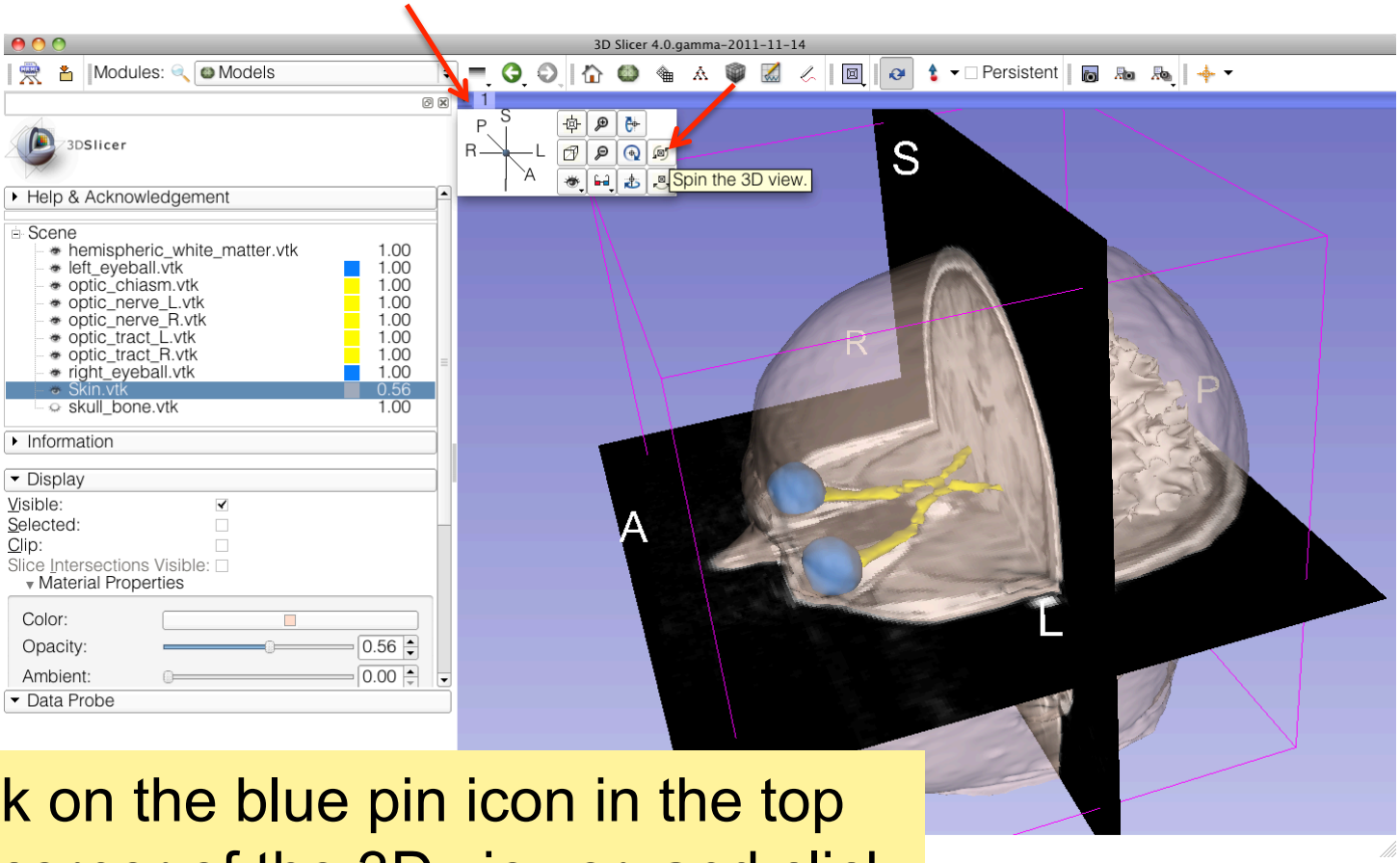
Use the coronal slider (green) to expose the optic chiasm.

3D Visualization



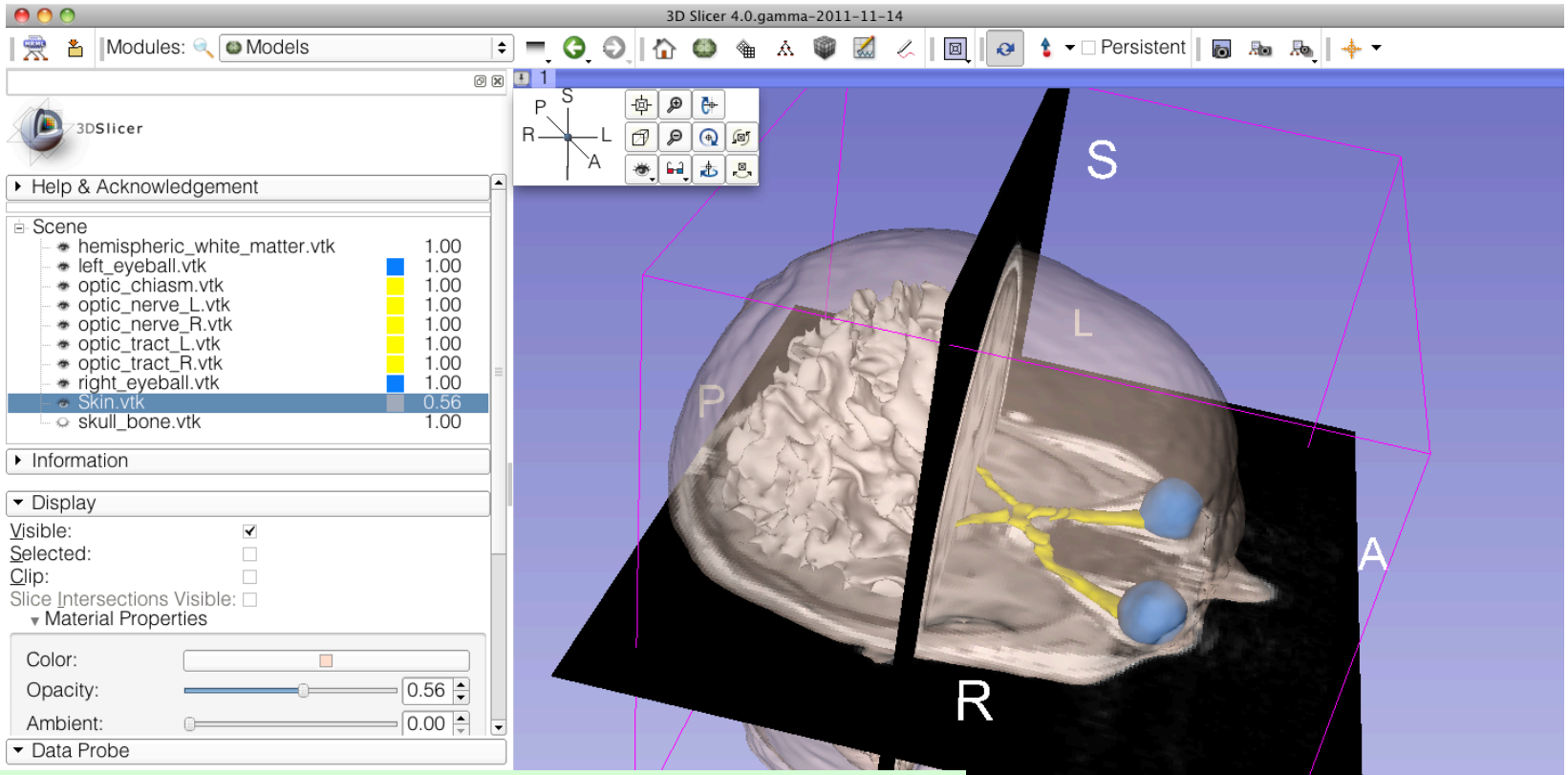
Increase the opacity of the skin model, and select the viewing mode '3D only'

3D Visualization



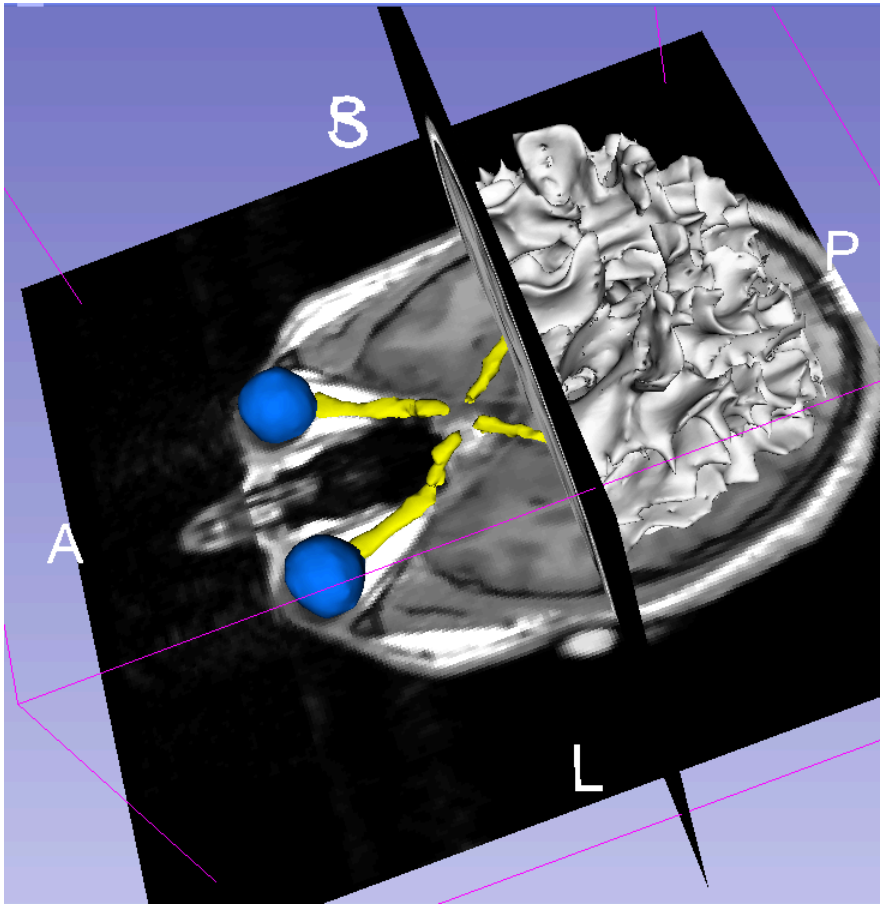
Click on the blue pin icon in the top left corner of the 3D viewer, and click on the Spin icon.

3D Visualization



The 3D models and 2D anatomical slices start spinning in the 3D viewer. Click a second time on the spin icon to stop the models from spinning.

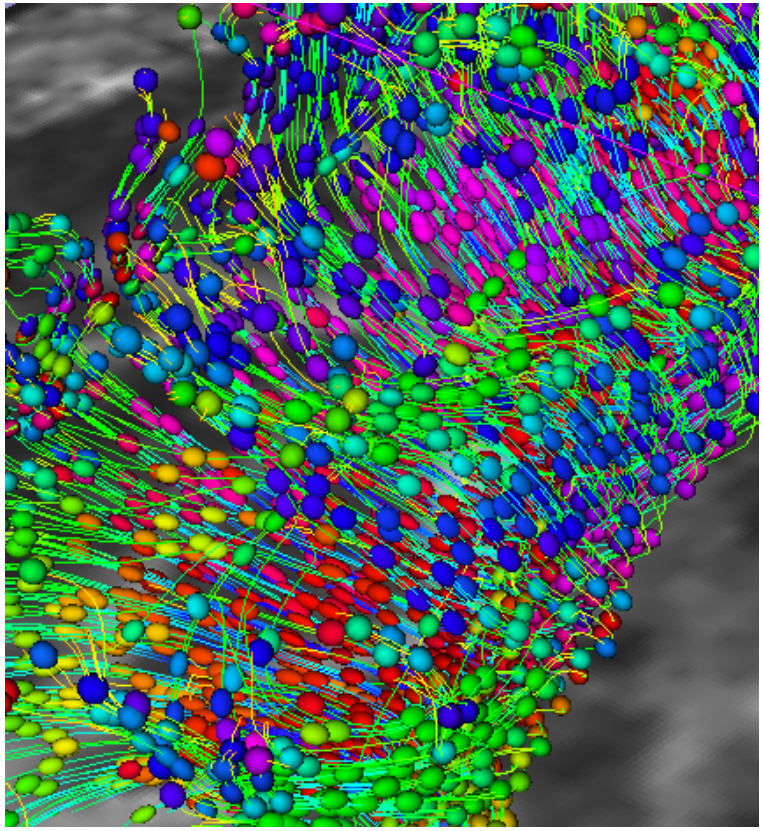
Slicer4 minute tutorial



This tutorial was a short introduction to the 3D visualization capabilities of Slicer.

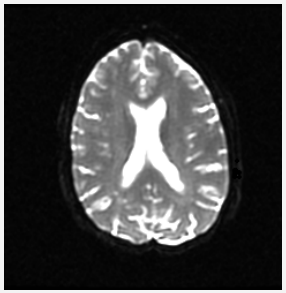
Please visit the Slicer4 training compendium for more information on the software

www.slicer.org

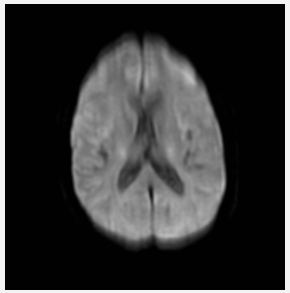


Part III:
3D Slicer DTI demo

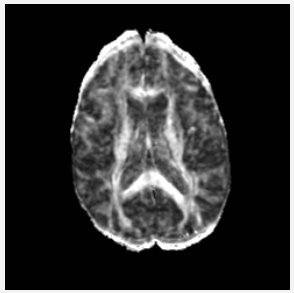
MR Diffusion Analysis Pipeline



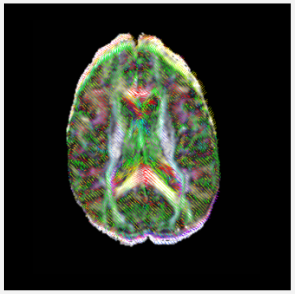
DWI
Acquisition



Tensor
Calculation

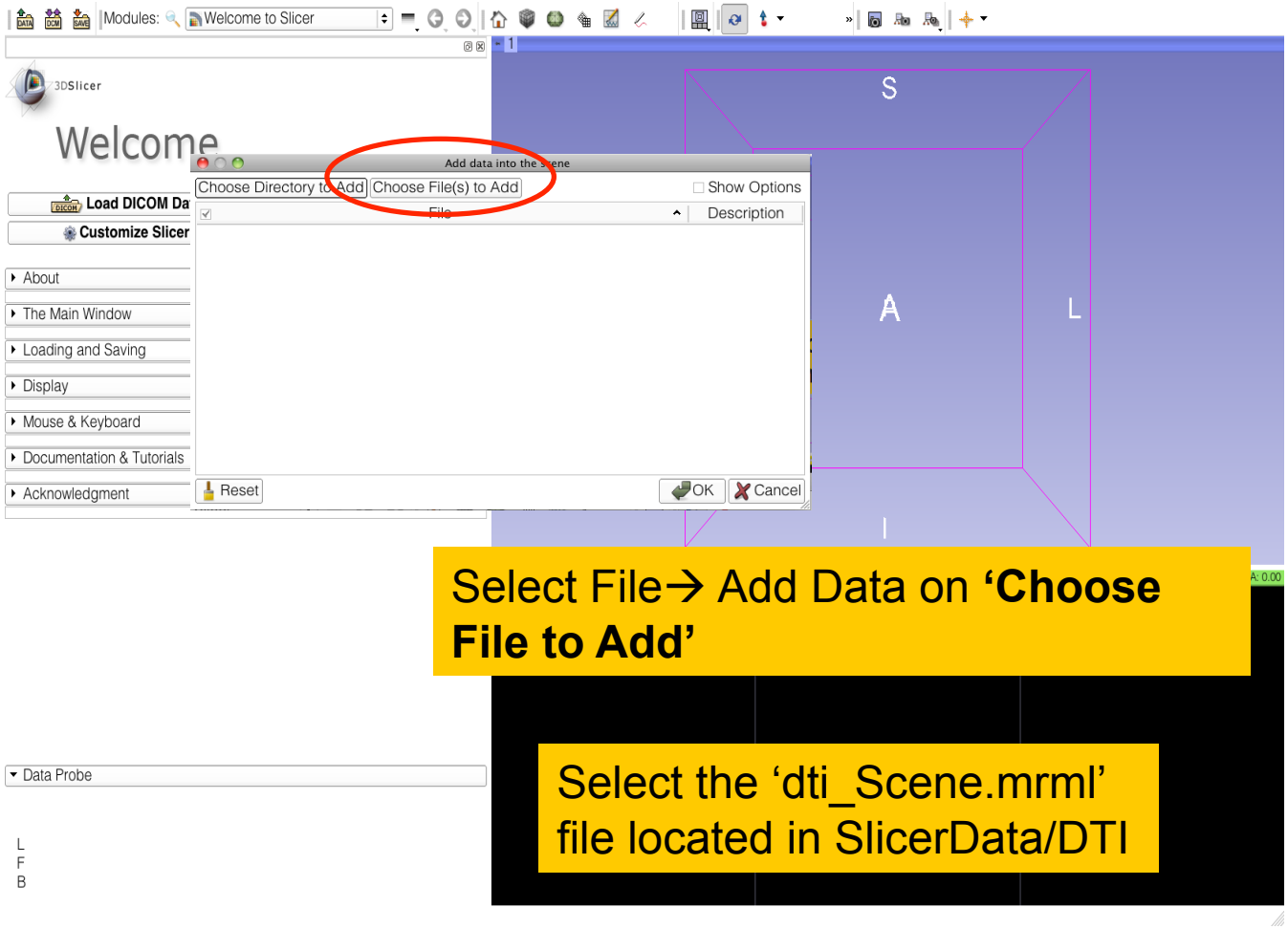


Scalar
Maps

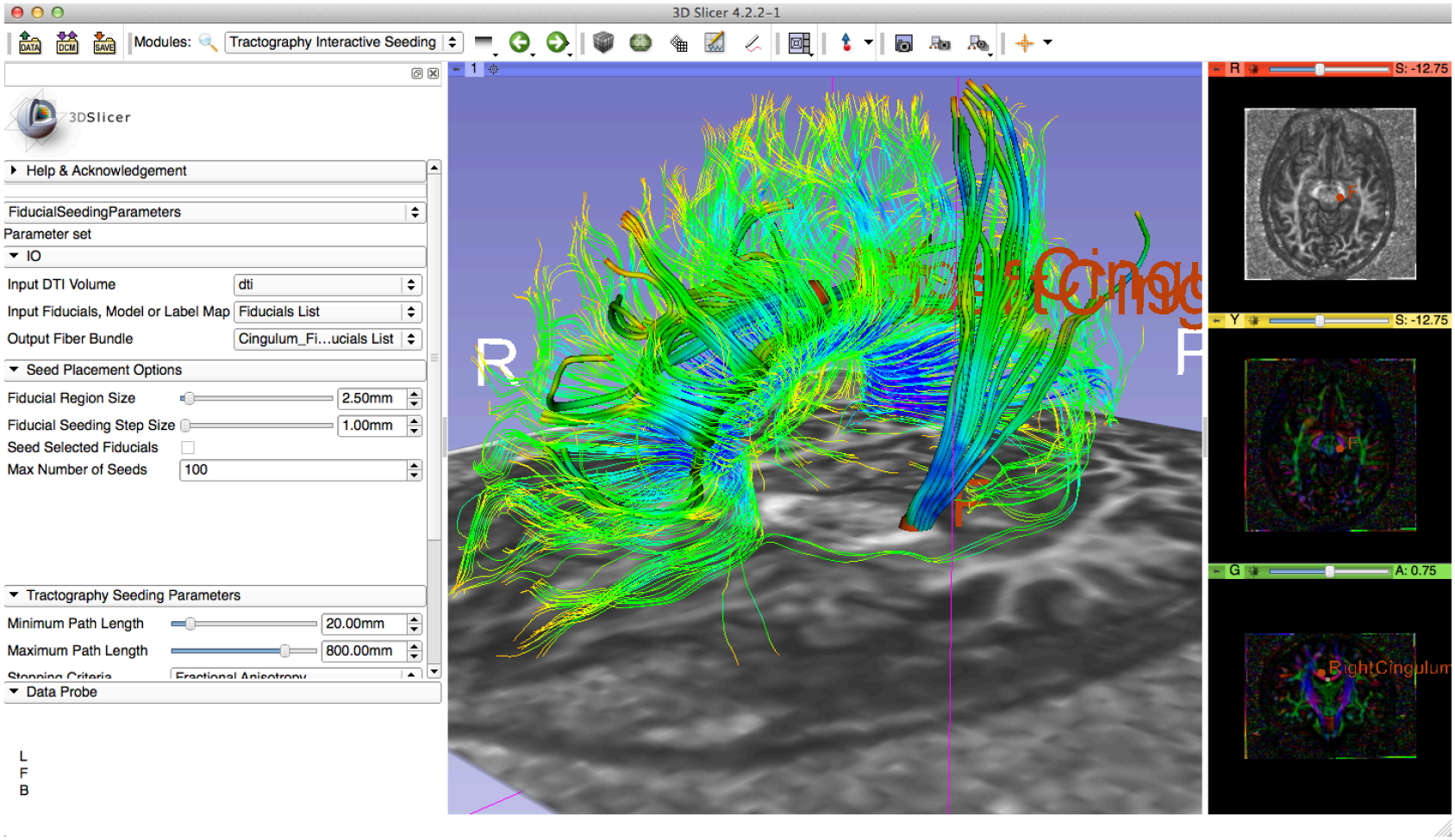


3D
Visualization

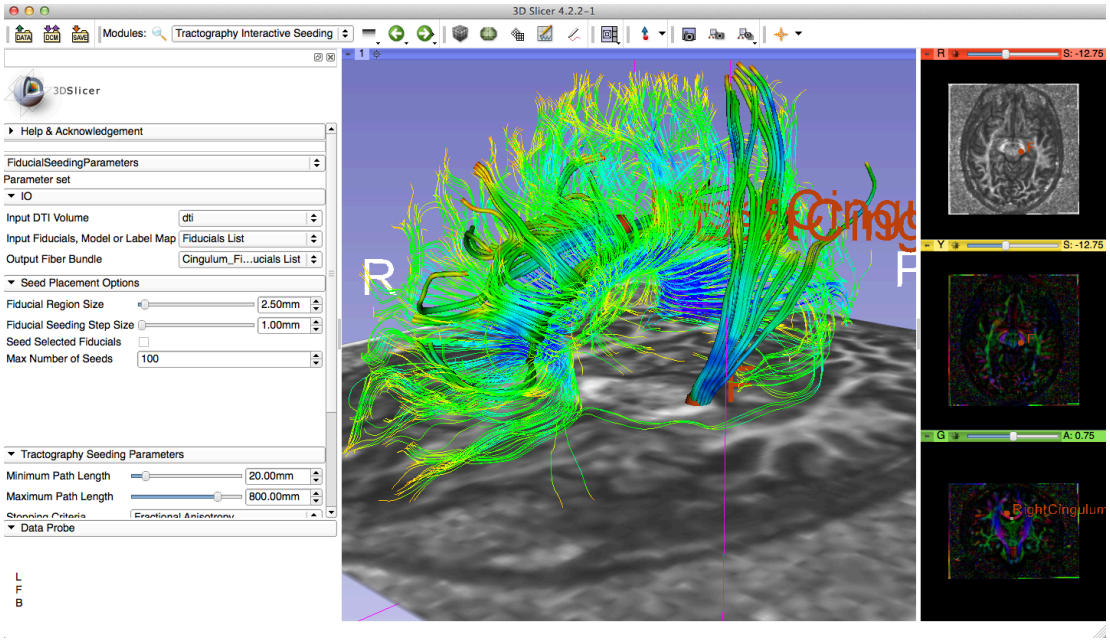
Loading the DTI Scene



DTI Scene

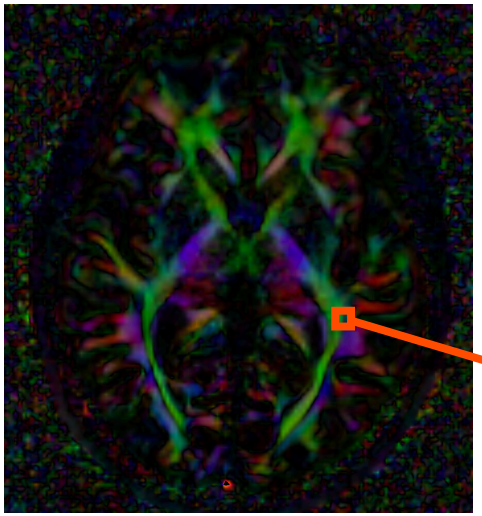

3D Slicer 4.2.2-1
Modules:
Tractography Interactive Seeding
3DSlicer
Help & Acknowledgement
FiducialSeedingParameters
Parameter set
IO
Input DTI Volume
dti
Input Fiducials, Model or Label Map
Fiducials List
Output Fiber Bundle
Cingulum_Fi...ucials List
Seed Placement Options
Fiducial Region Size
2.50mm
Fiducial Seeding Step Size
1.00mm
Seed Selected Fiducials
Max Number of Seeds
100
Tractography Seeding Parameters
Minimum Path Length
20.00mm
Maximum Path Length
800.00mm
Data Probe
L
F
B
R
S: -12.75
Y
S: -12.75
G
A: 0.75

DTI Scene



The DTI Scene contains a pre-computed DTI volume and corresponding FA map.
Slicer displays the tractography reconstructions of part of the corpus callosum, left and right cingulum.

Diffusion Tensor Data



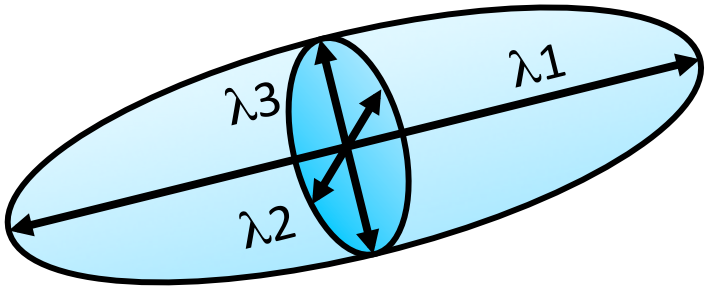
Stejskal-Tanner equation (1965)

$$\underline{D} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$

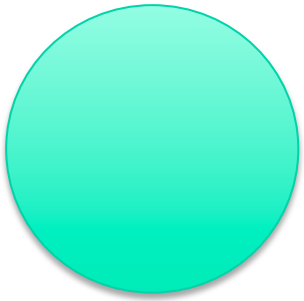
The diffusion tensor $\underline{D}$ in the voxel (I,J,K) is a 3x3 symmetric matrix.

Diffusion Tensor

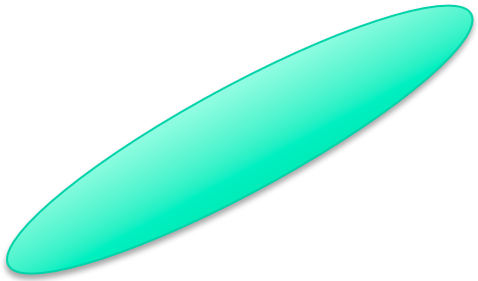
- The diffusion tensor $\underline{D}$ in the voxel (I,J,K) can be visualized as an ellipsoid, with the eigenvectors indicating the directions of the principal axes, and the square root of the eigenvalues defining the ellipsoidal radii.
- Scalar maps can be derived from the rotationally invariant eigenvalues λ1, λ2, λ3 to characterize the size and shape of the diffusion tensor.



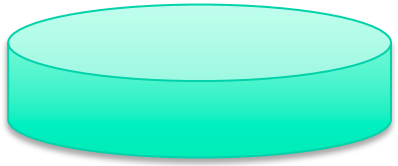
Diffusion Tensor Shape



$\lambda 1 = \lambda 2 = \lambda 3$



$\lambda 1 >> \lambda 2, \lambda 3$



$\lambda 1 \sim \lambda 2 >> \lambda 3$

Isotropic media
(CSF, gray matter)

Anisotropic media
(white matter)

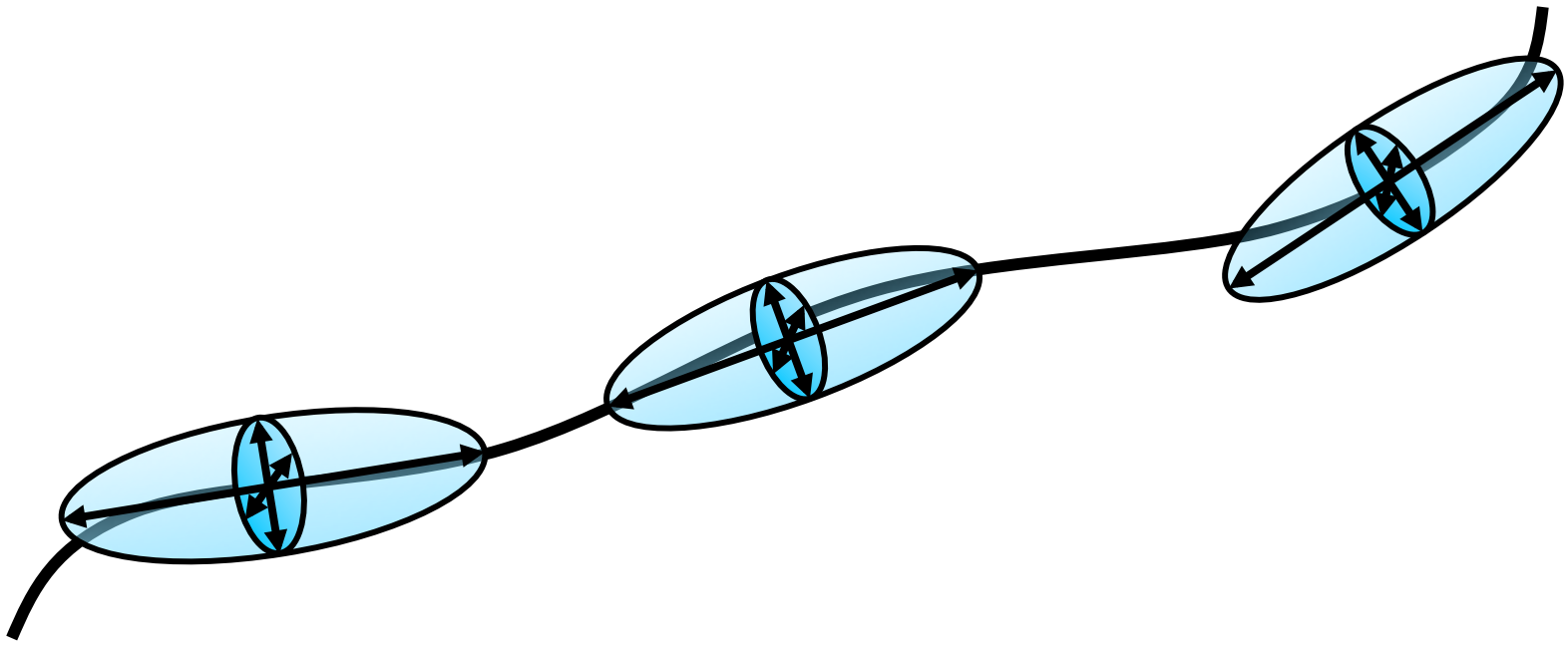
Diffusion MRI tractography

- Tractography can be defined as the virtual reconstruction of the trajectory of water molecules along white matter bundles.
- DTI tracts provide a mathematical representation of the underlying white matter anatomy.
- Each voxel contains hundreds of thousands of axon fibers: size of a voxel ~ 1-5 mm; diameter of an axon~0.1-10 µm

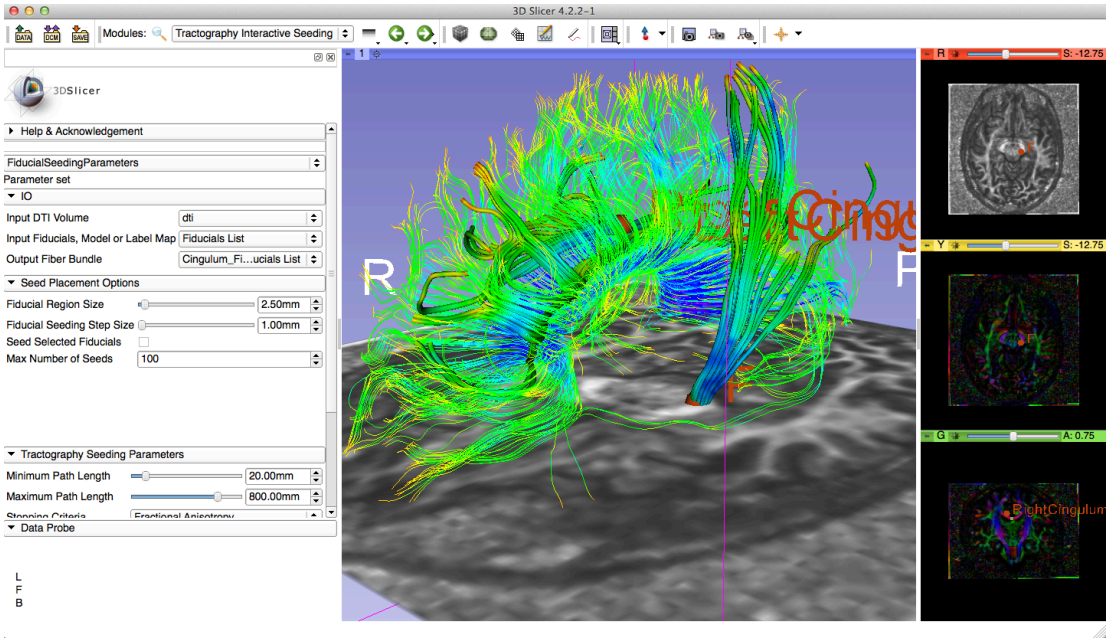
→ A DTI tract is not equivalent to a real fiber.

Streamline tractography

Underlying Assumption: the orientation of the fibers is collinear with the direction of the principal eigenvector

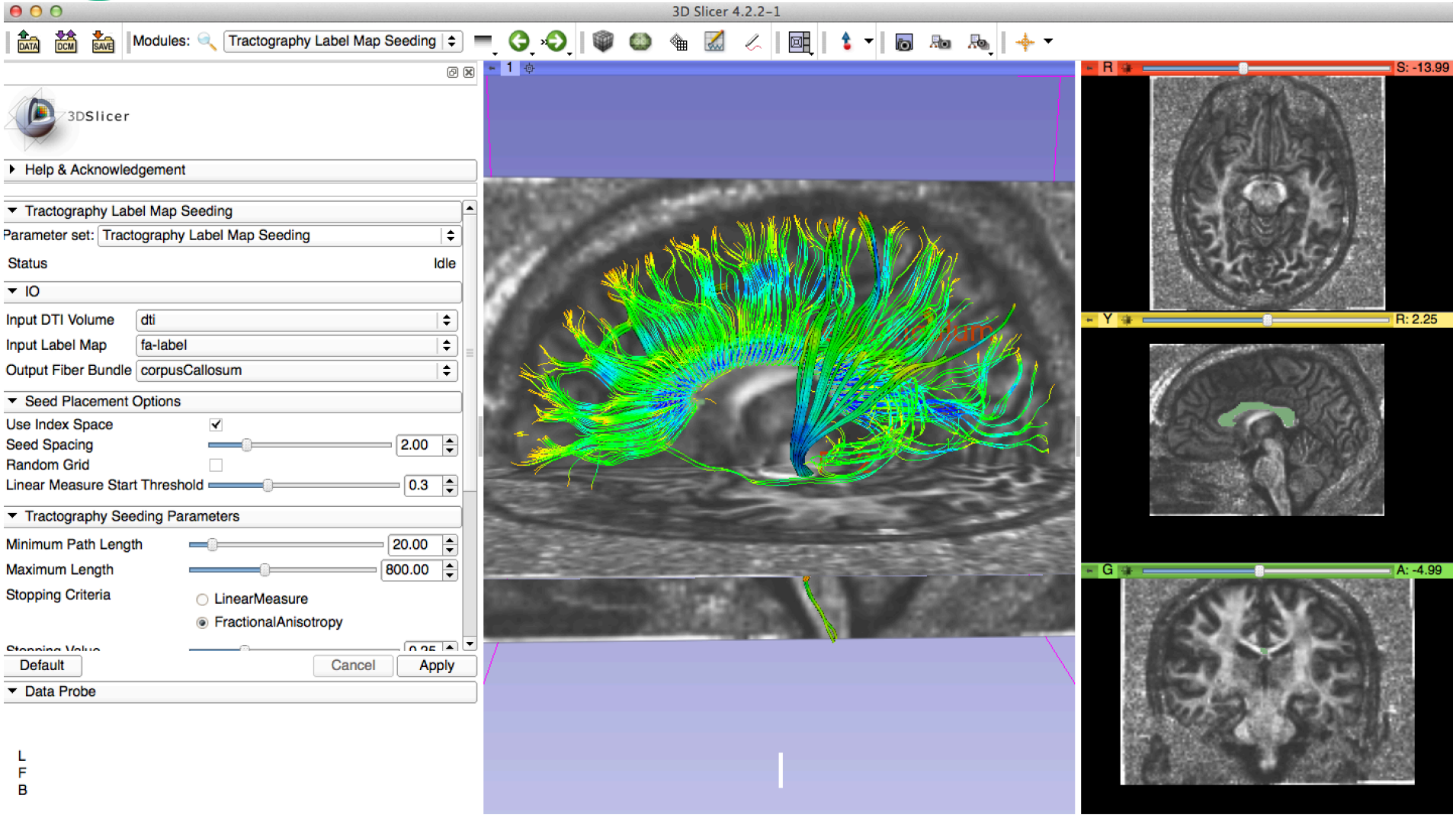


DTI Scene

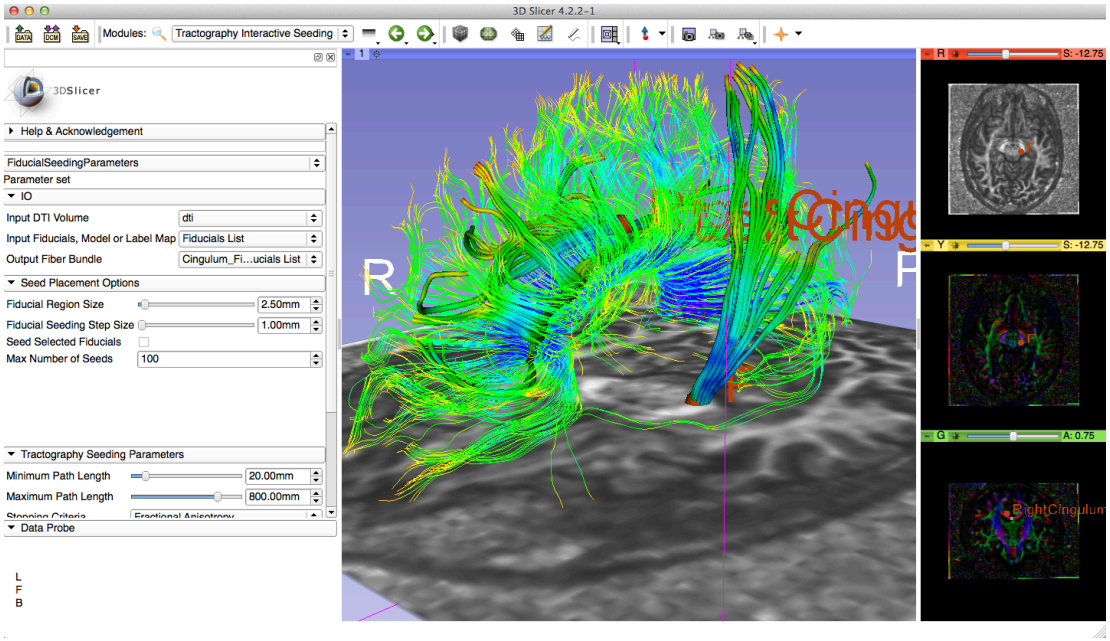


In this example, the tractography reconstruction of the corpus callosum has been generated using the **LabelMap Seeding module**;

LabelMap Seeding Module

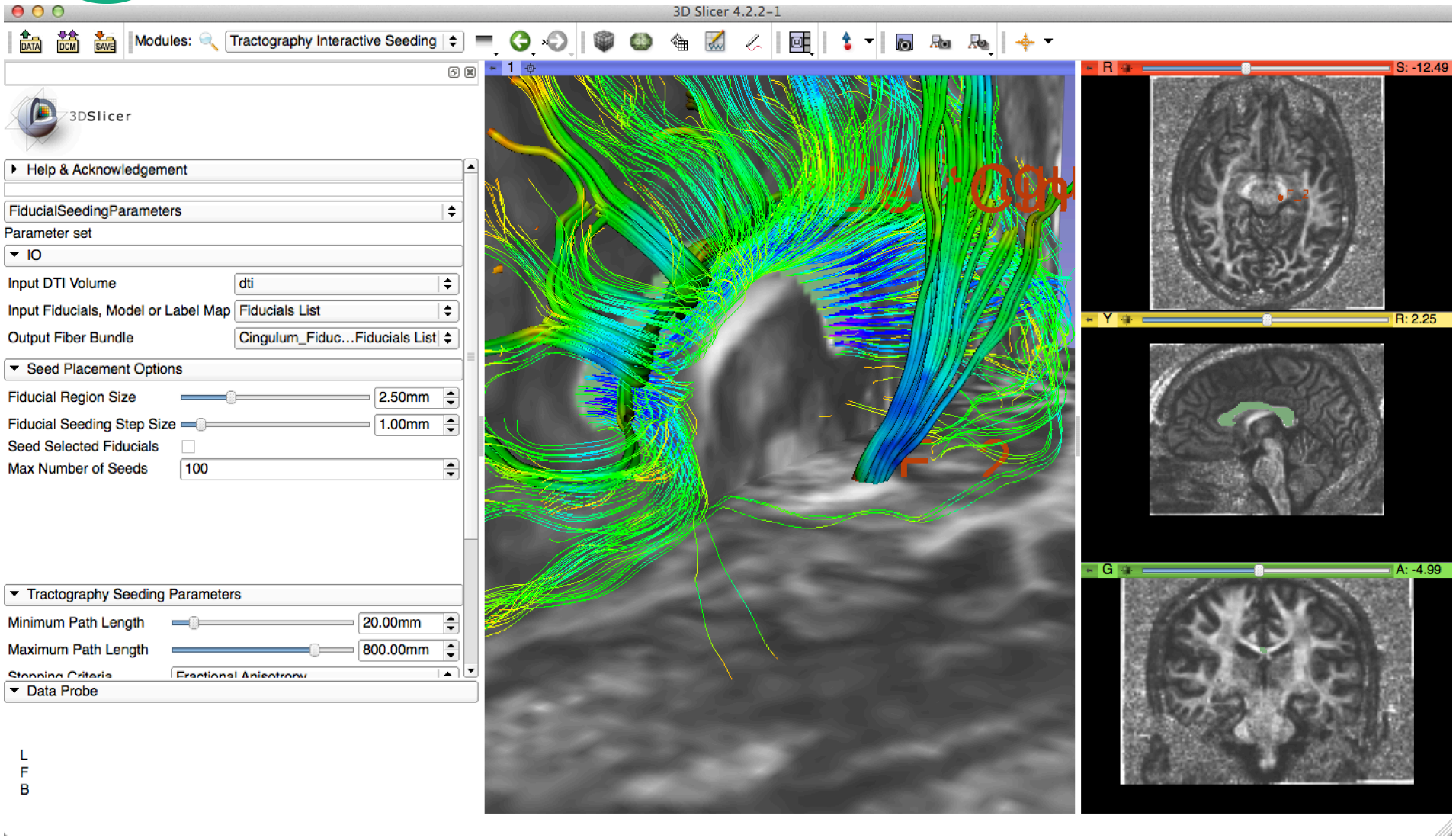


DTI Scene

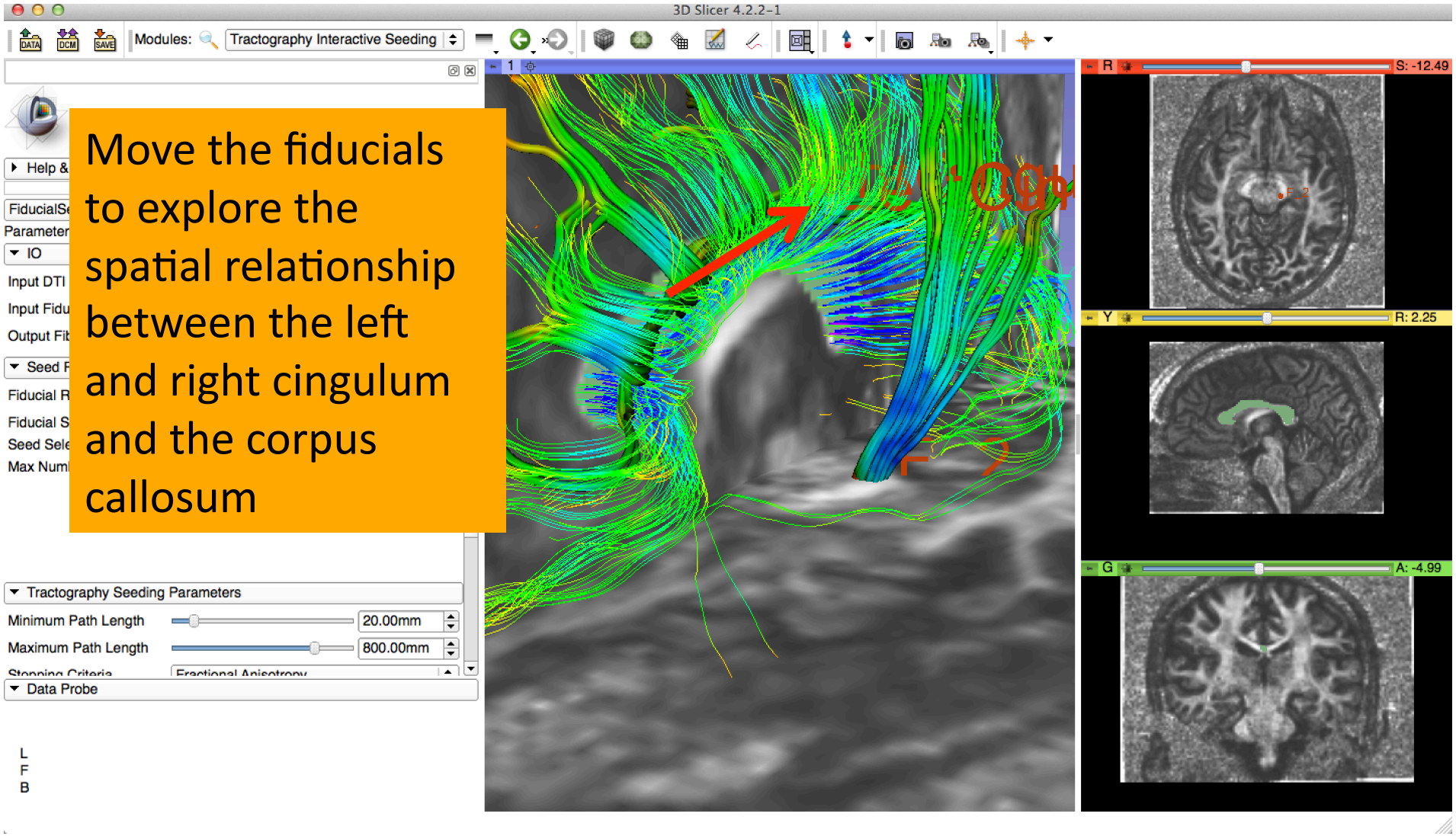


In this example, the tractography reconstruction of the the cingulum has been generated using the **Interactive Tractography Seeding** module.

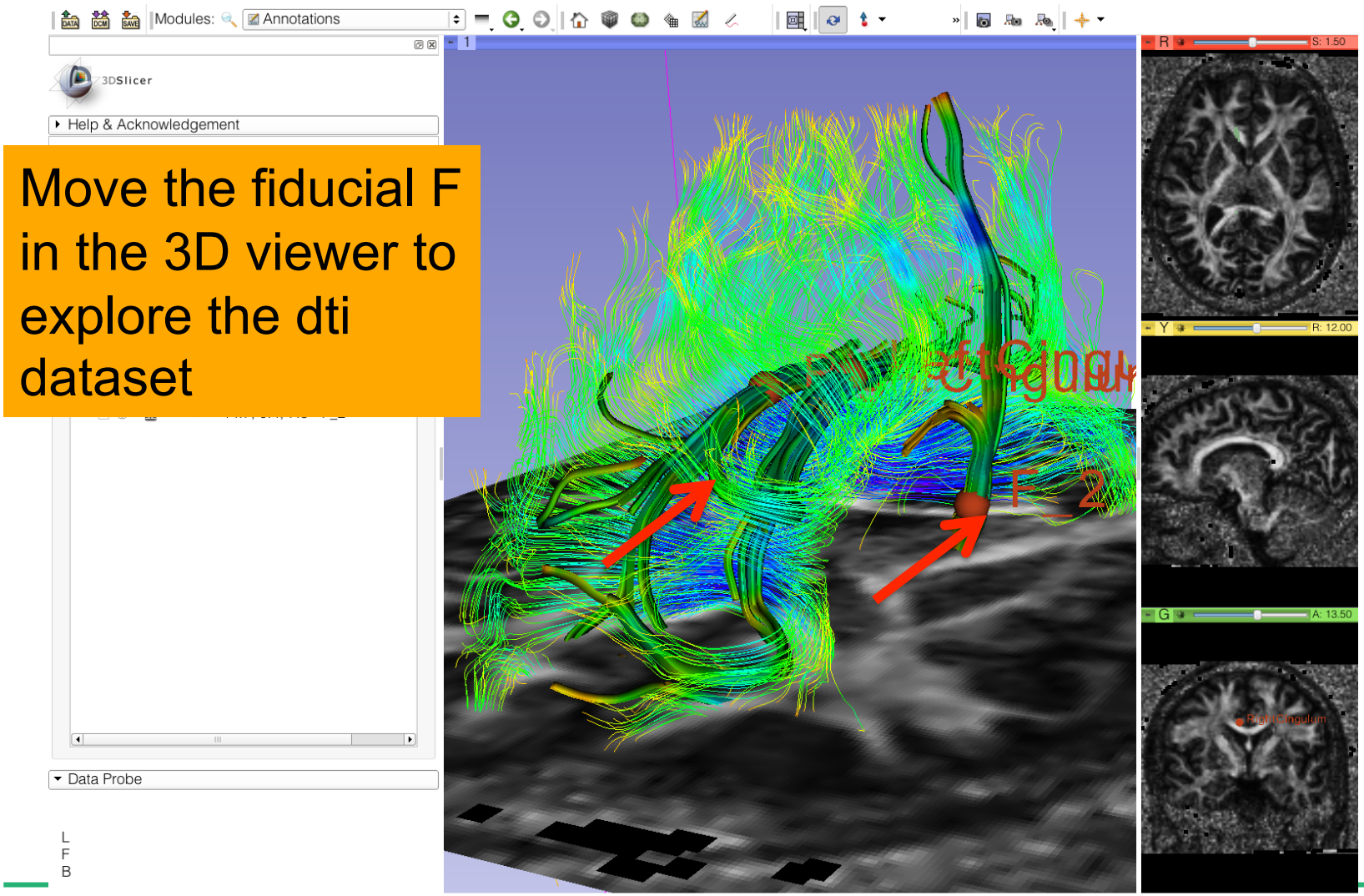
Interactive Tractography Seeding



Interactive Tractography Seeding



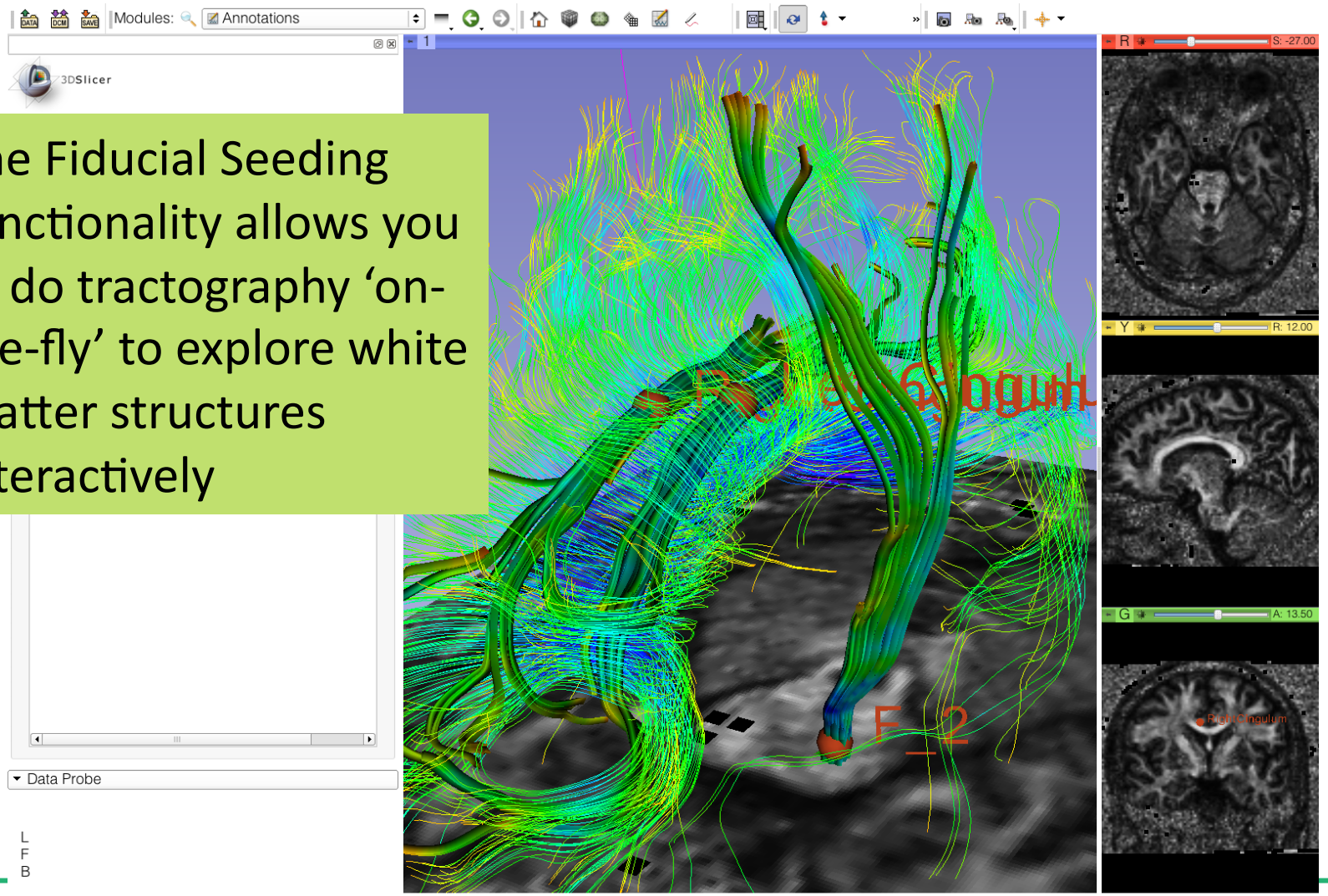
Fiducial Seeding



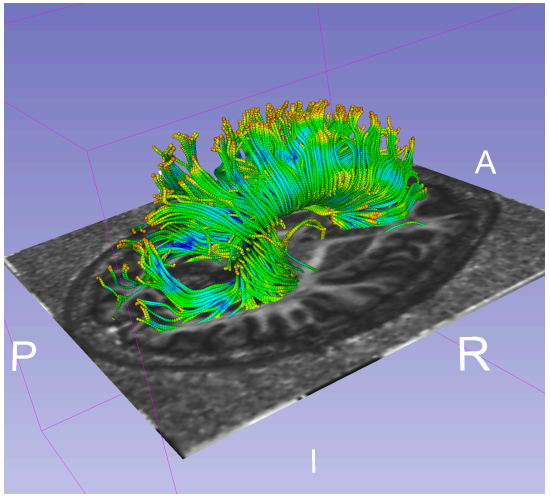
Move the fiducial F in the 3D viewer to explore the dti dataset

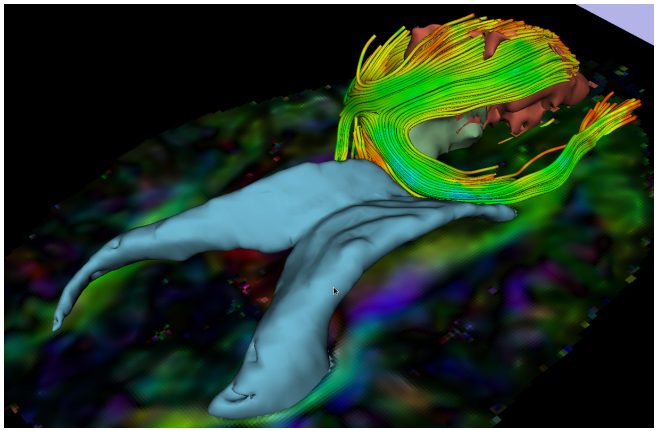
Tractography ‘on-the-fly’

The Fiducial Seeding functionality allows you to do tractography ‘on-the-fly’ to explore white matter structures interactively



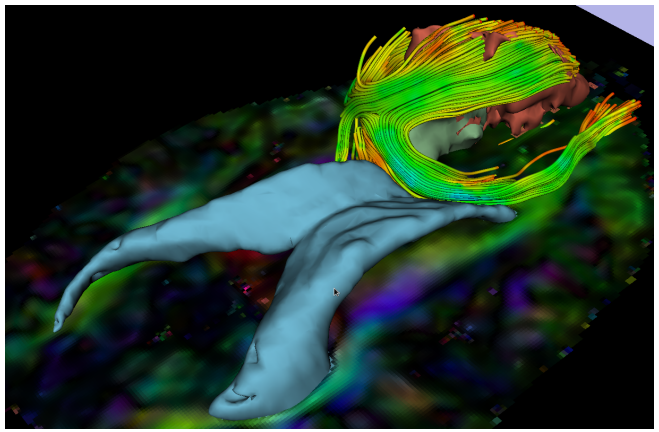
DTI training tutorials in Slicer4:





- Diffusion MR Imaging tutorial
- Exploring White Matter peritumoral fibers for exploration for neurosurgical planning
- Tutorials and datasets available at www.slicer.org

Going Further

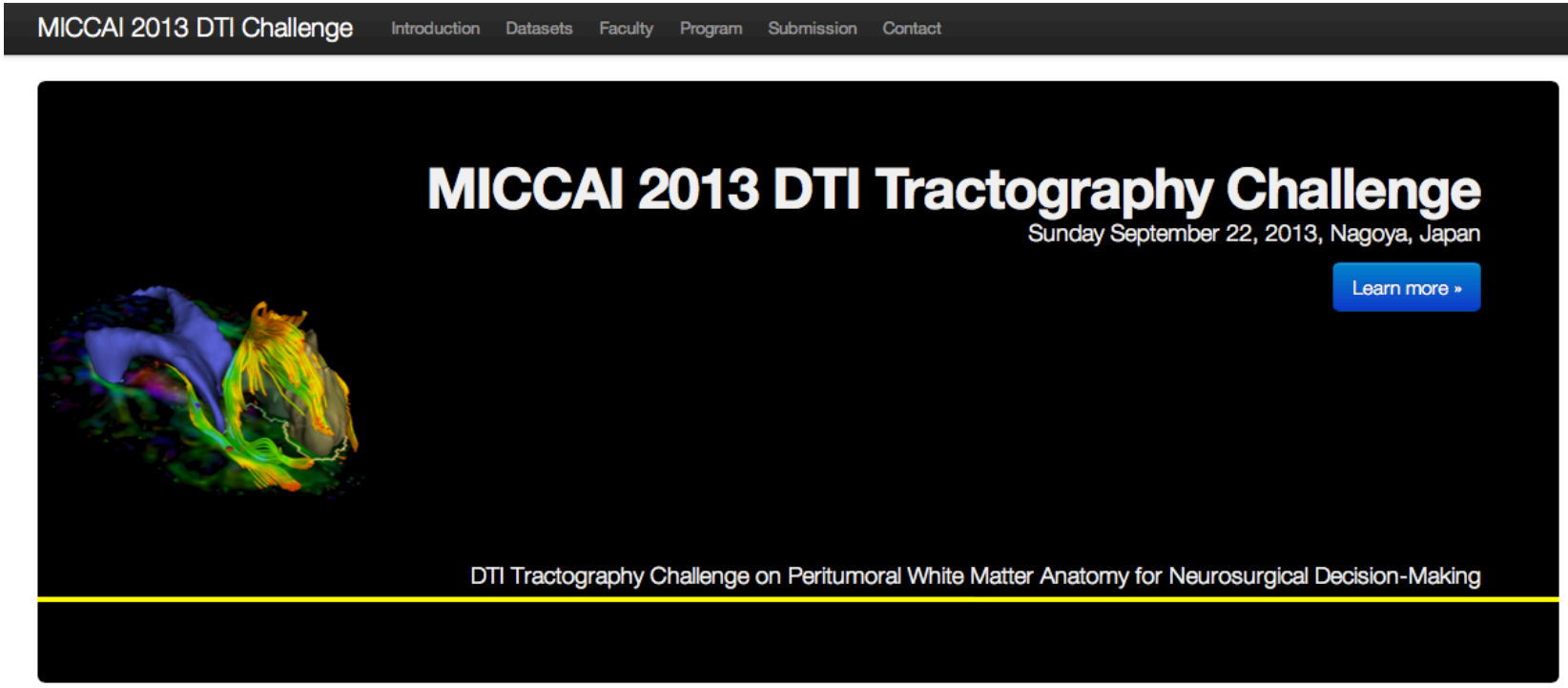


- DTI tractography can be used to guide resection of tumor located in eloquent areas
- However, validation of DTI findings in clinical settings has yet to be establish

MICCAI DTI Challenge

- International collaborative effort on the validation of DTI tractography for neurosurgical planning
- Standardized comparison of tractography methods on patient data
- Working group of DTI Experts, Practicising neurosurgeons, tractography algorithms developers and neuroradiologists
- http://dti-challenge.org

Third edition: Sept 22, 2013, Nagoya, Japan



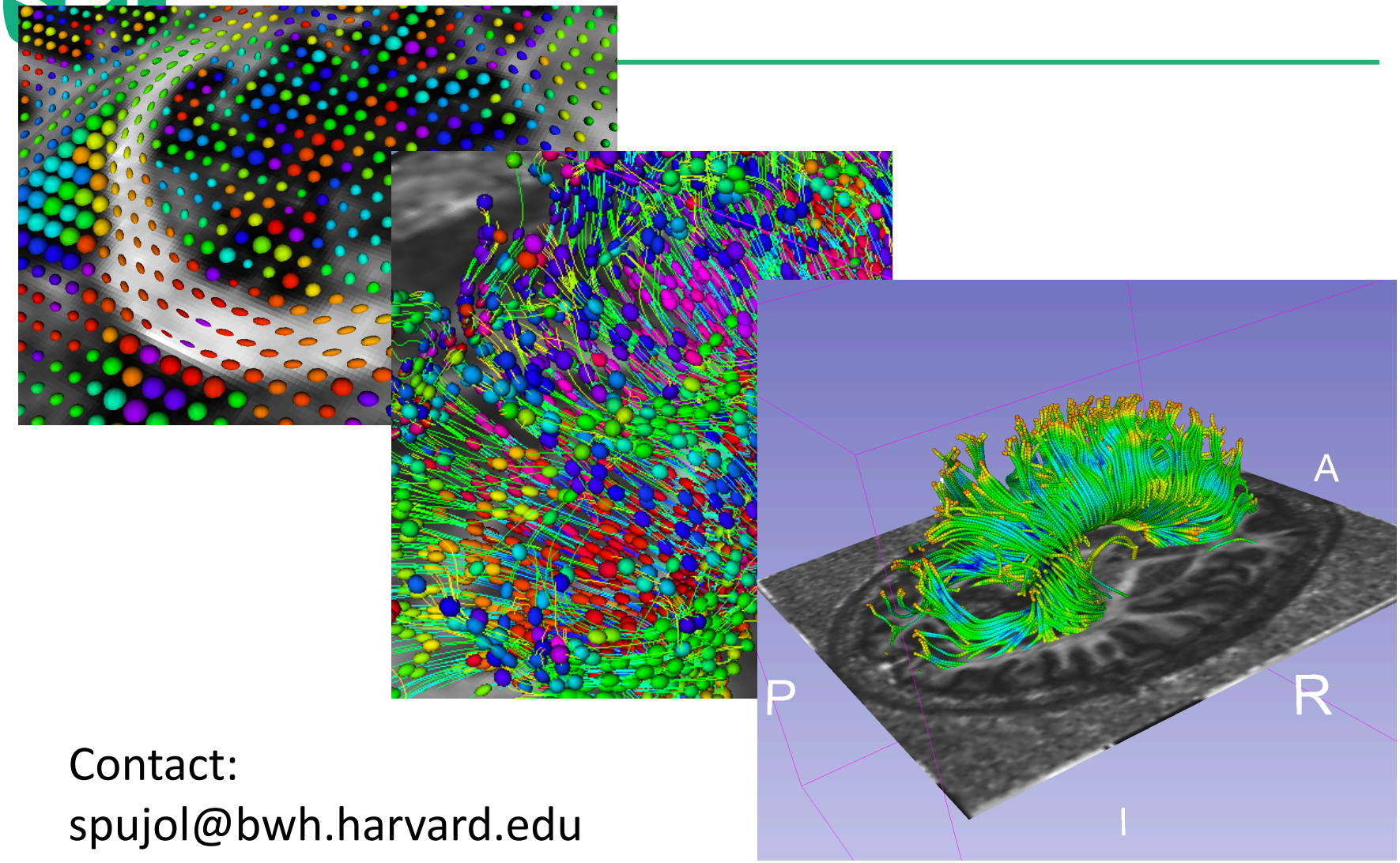
Slicer Community

- www.slicer.org

- Mailing lists:

slicer-user@bwh.harvard.edu

slicer-devel@bwh.harvard.edu



Contact:
spujol@bwh.harvard.edu

Conclusion

- Slicer is an open-source research platform for the rapid development of biomedical image analysis tools.
- Slicer community is open with contributors from all over the world
- Slicer is a versatile platform for translational research and subject specific analysis of biomedical ima data

Acknowledgments

National Alliance for Medical Image Computing

NIH U54EB005149

Neuroimage Analysis Center

NIH P41RR013218