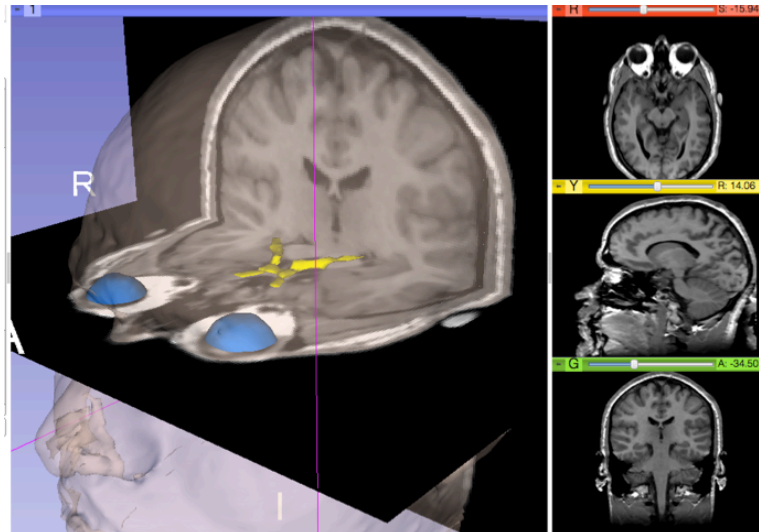# The 3D Slicer open-source platform for image analysis and 3D visualization

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

Sonia Pujol, Ph.D.

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

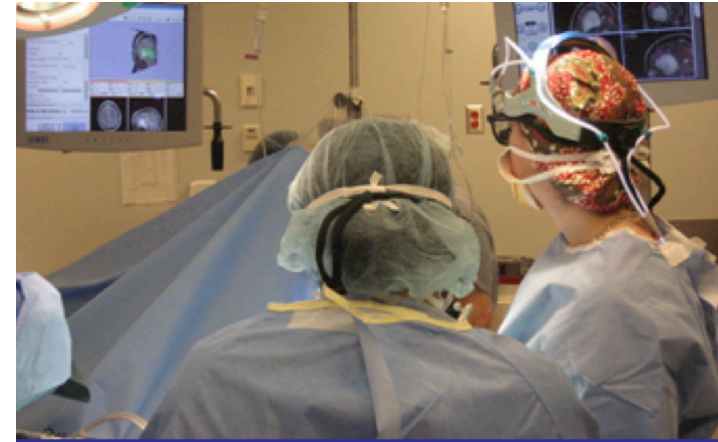# Part I – From algorithms to tools: the 3D Slicer software for translational research

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
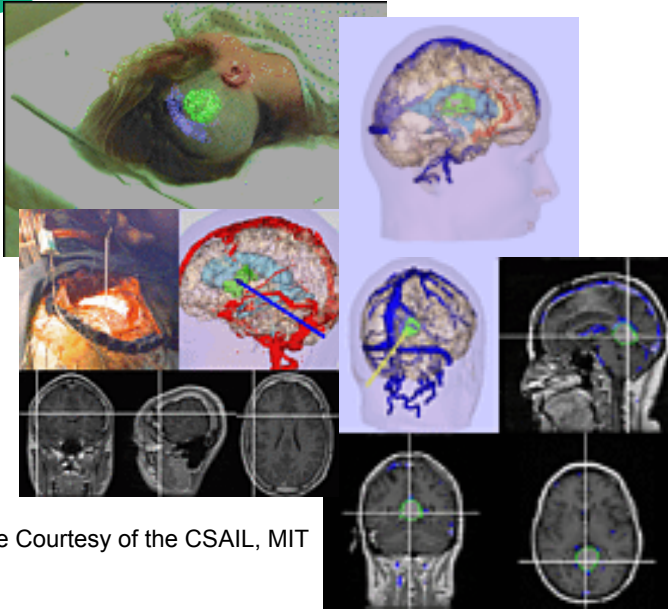
Slicer 16th year Anniversary

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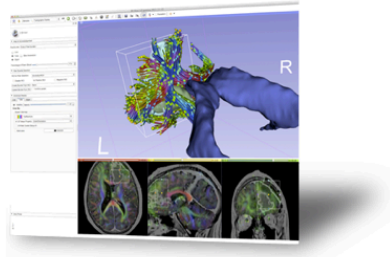
P.I. Prof. Ron Kikinis, BWH, Harvard

3D Slicer in practice

- 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
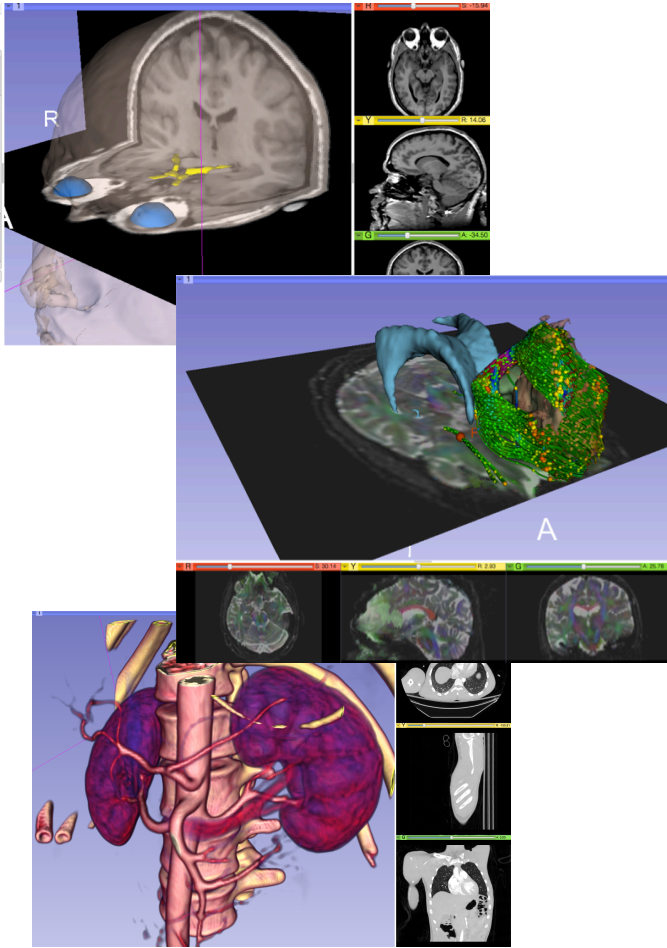
Madrid 2012

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

SPL

3DSlicer

Slicer 4 download statistics

| Download location | By Country | By Filename | By Month |

Total matching downloads:
62948

Date range:
forever

Release type:
any

Browser type:
desktop

Update

Map | Satellite

Google — Map data ©2013 MapLink, Tele Atlas - Terms of Use

A Multi-institution Effort

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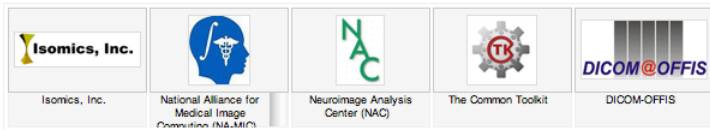
End-user Documentation

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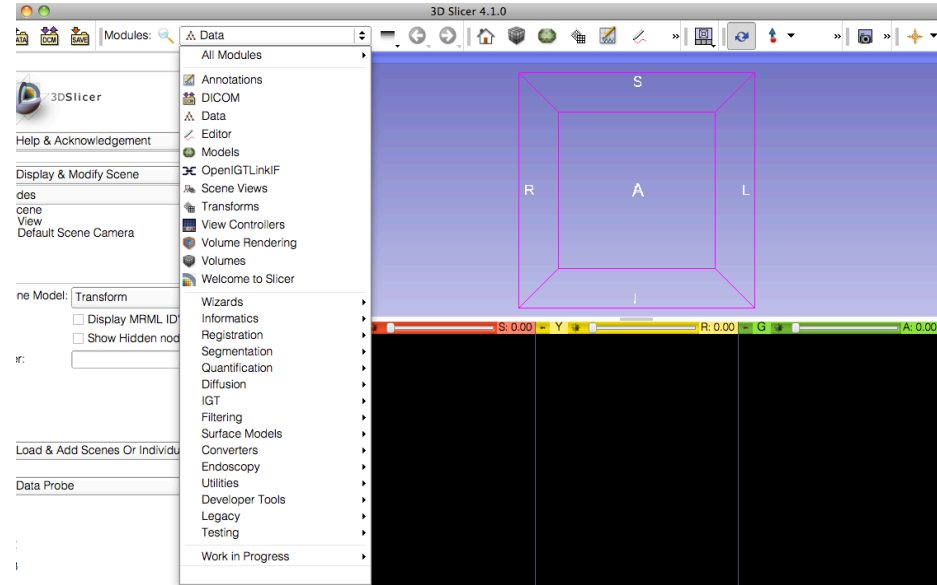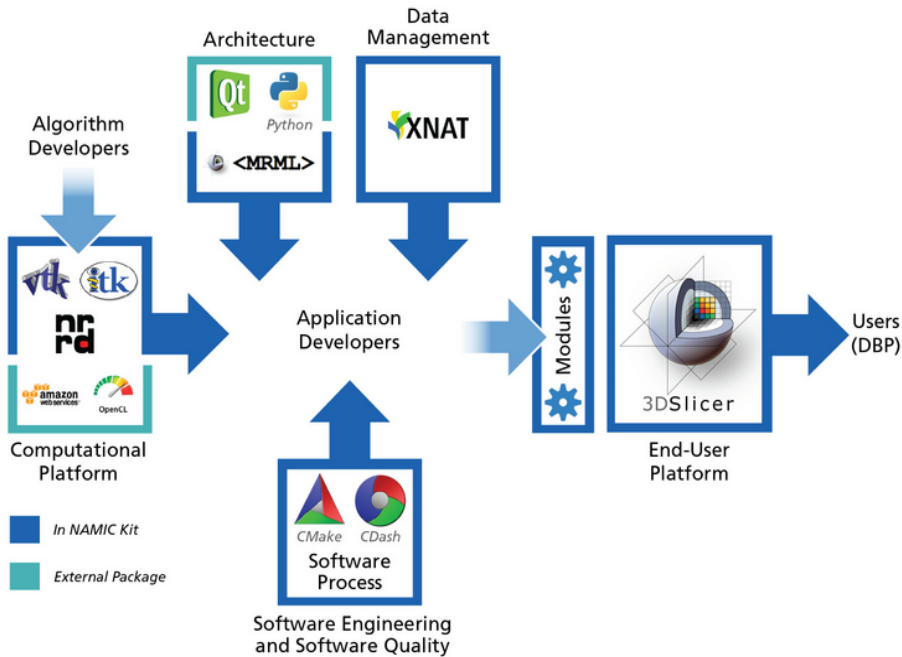
Core Functionalities
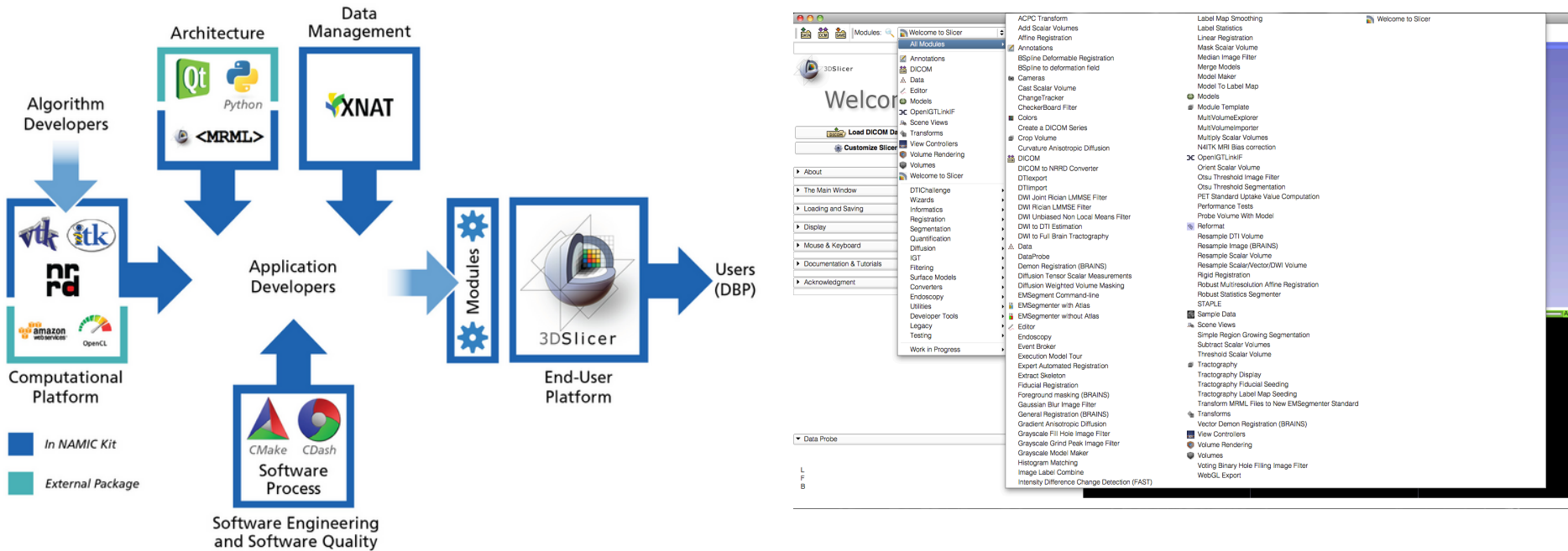
Slicer4 core functionalities include 108 modules, and represent 700,000 lines of code

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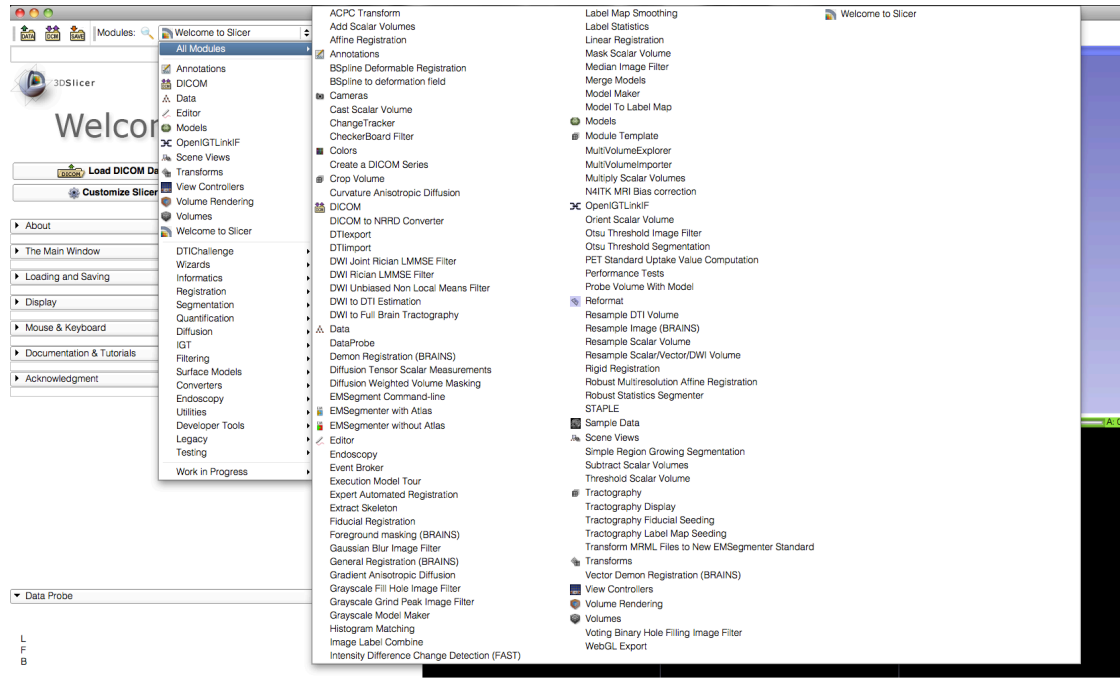
- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification
- Reporting

Core Functionalities
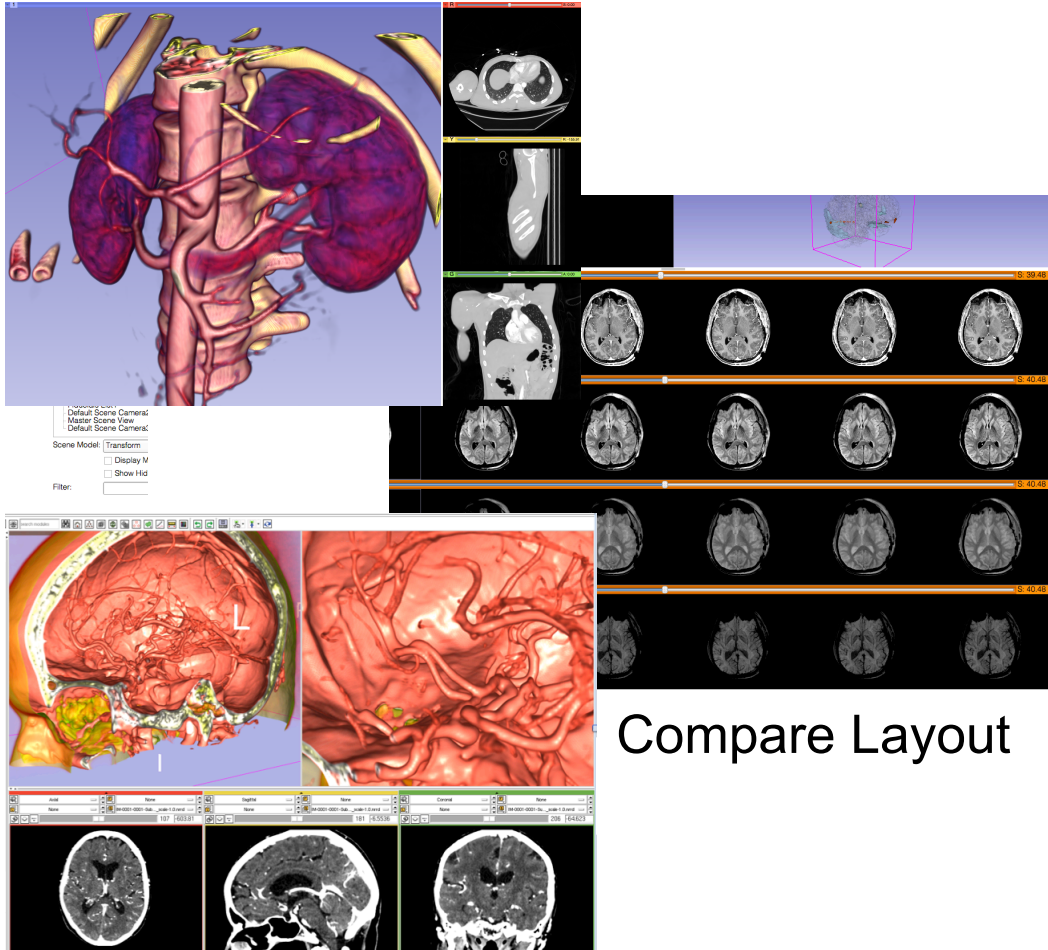
Compare Layout

Volume Rendering

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

Core Functionalities
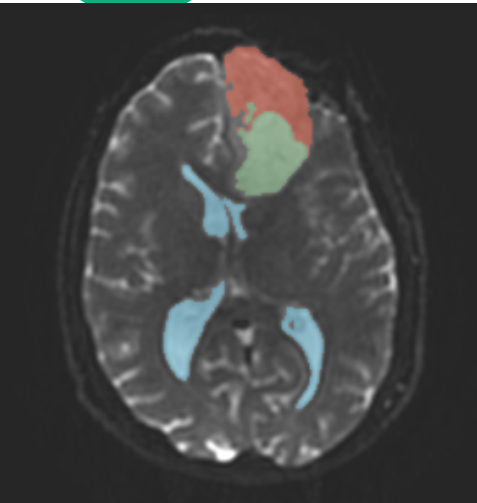
Editor
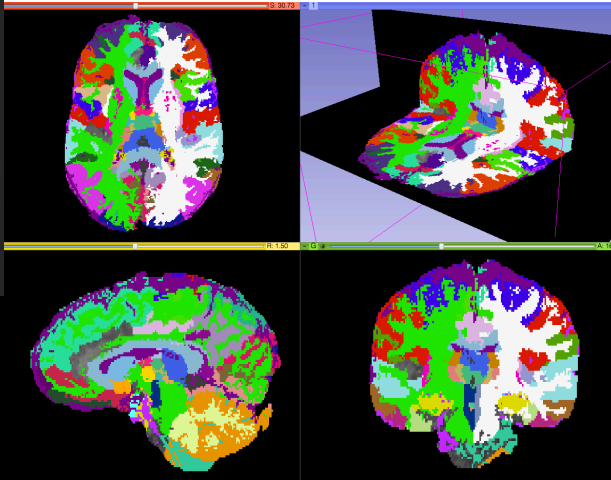
EMSegmenter
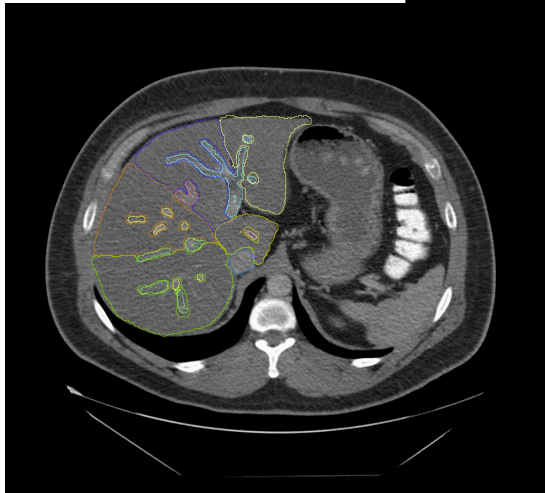
- Visualization
- **Segmentation**
- Registration
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

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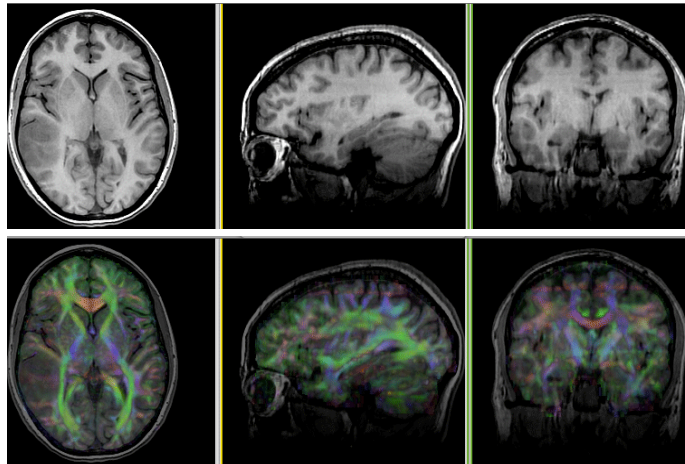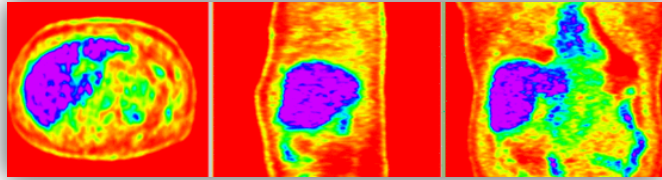
- Visualization
- Segmentation
- **Registration**
- Reconstruction
- Diffusion
- Image Guided Therapy
- Quantification

Core Functionalities
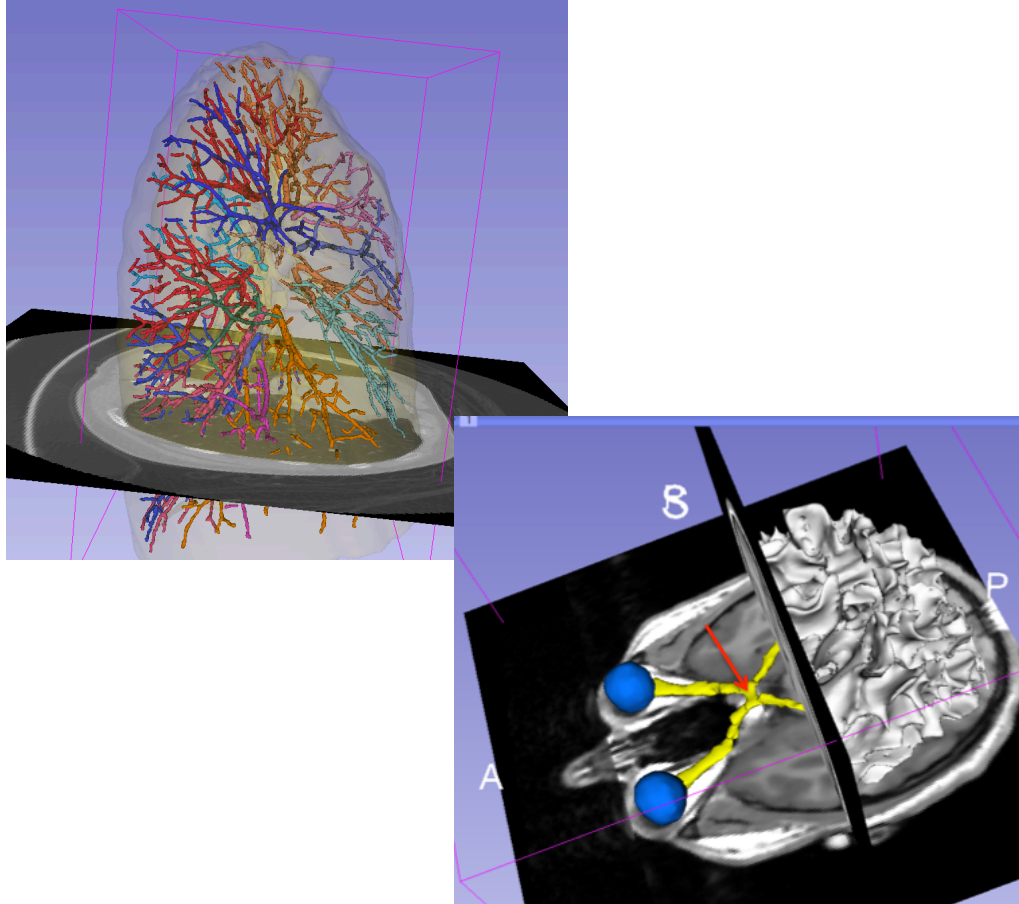
- Visualization
- Segmentation
- Registration
- **Surface Reconstruction**
- Diffusion
- Image Guided Therapy
- Quantification

Model Maker

Core Functionalities
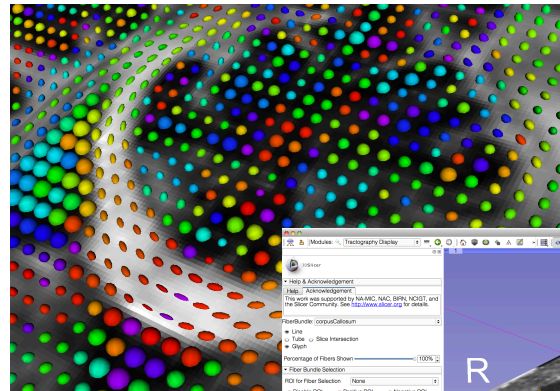
DWI To DTI Estimation

Labelmap Seeding

Interactive Seeding

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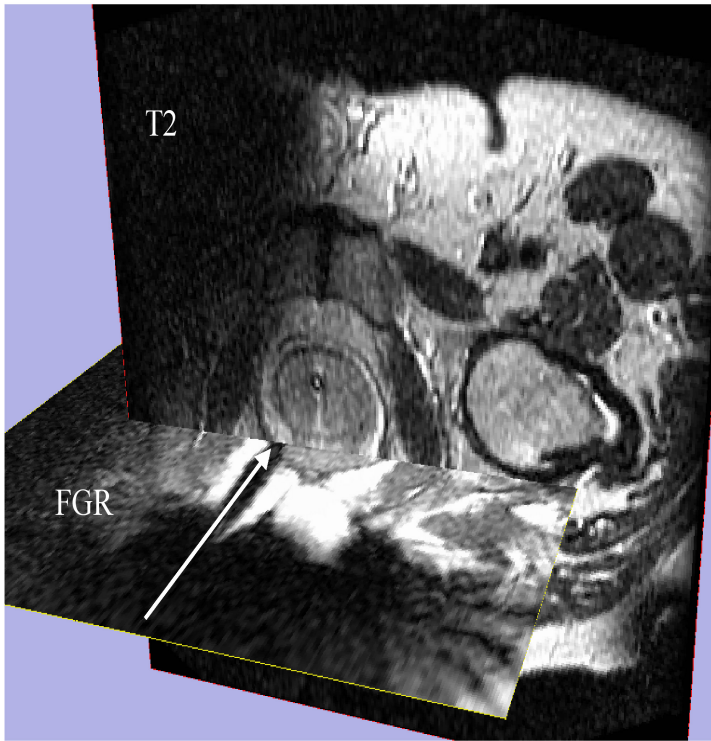
Core Functionalities

T2

FGR

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

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

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

Here Junichi feel free to replace this image by one of your papers

Core Functionalities
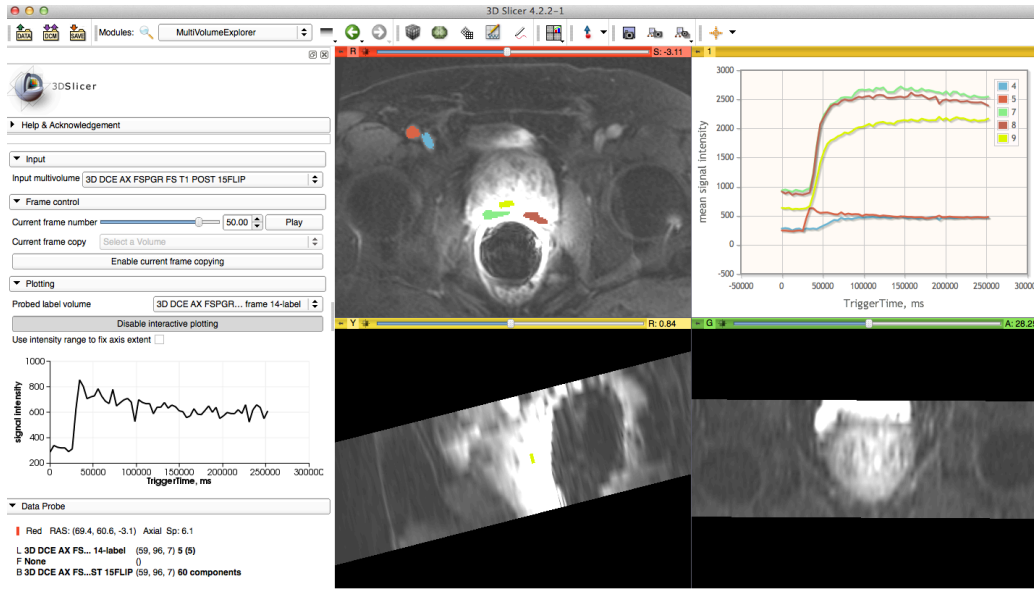
Prostate DCE-MRI analysis.

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

MutiVolumeExplorer

Slicer use in clinical research environment

Improving Patient Care with AMIGO
Advanced Multimodality Image Guided Operating Suite

- AMIGO, BWH, Boston

Neurosurgery applications

Interactive exploration of peritumoral white matter anatomy neurosurgical planning using DTI tractography
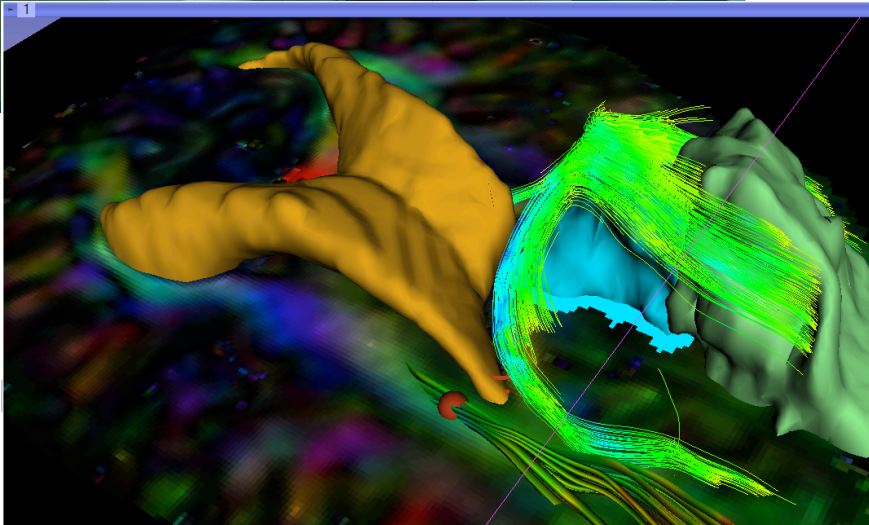
SlicerRT for radiation therapy

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/
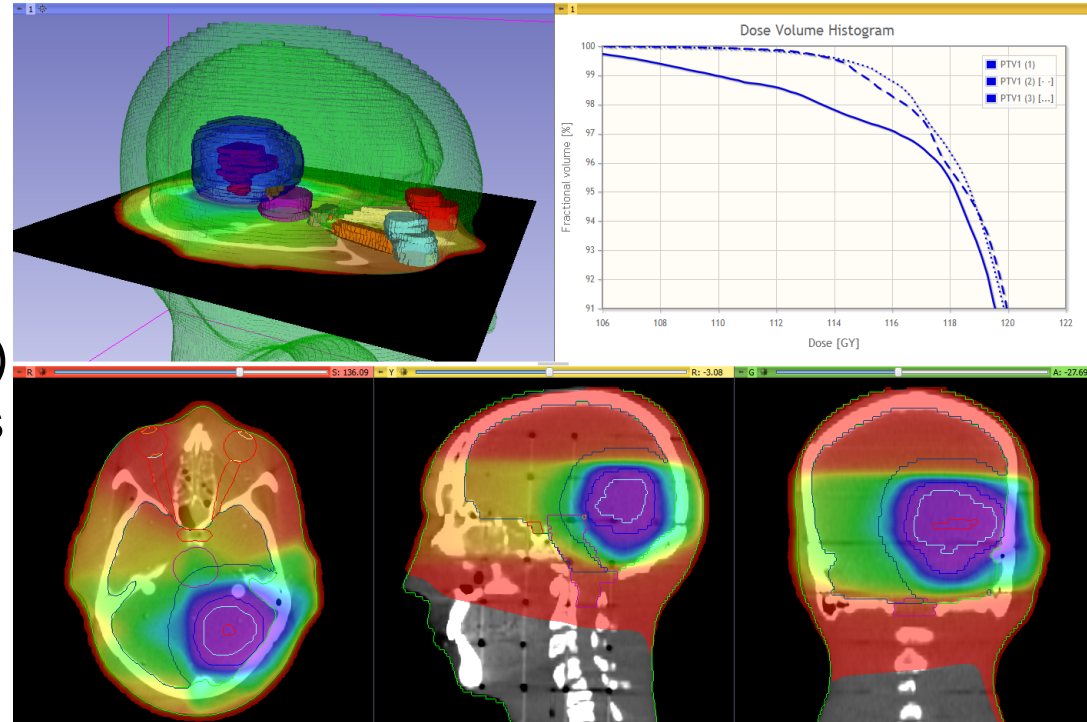
Slide courtesy
G.Fichtinger and
C.Pinter

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

Programming in Slicer4

Sonia Pujol, Ph.D.
Surgical Planning Laboratory,
Harvard Medical School

Steve Pieper, Ph.D.
Isomics Inc.

Paul Cézanne, Moulin sur la Couleuvre à Pontoise, 1881, Staatliche
Museen zu Berlin, Nationalgalerie

Course Overview

- Part A: Exploring Slicer via Python

- Part B: Integration of the HelloPython.py program into Slicer4

- Part C: Implementation of the Laplace operator in the HelloPython module

- Part D: Image Sharpening using the Laplace operator

Course Material

Unzip the HelloPython.zip archive
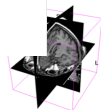
spgr.nhdr spgr.raw.gz
(124 SPGR images)

HelloPython.py
HelloLaplace.py
HelloSharpen.py

Manipulating Arrays

Run the following code in the Python console,
(indent each new line with 2 spaces)

```
def toggle():
    n = slicer.util.getNode('spgr')
    a = slicer.util.array('spgr')
    a[:] = a.max()/2. - a
    n.GetImageData().Modified()
    print('Toggled')

toggle()
```
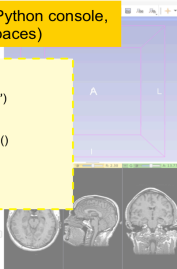
- Slicer Module development

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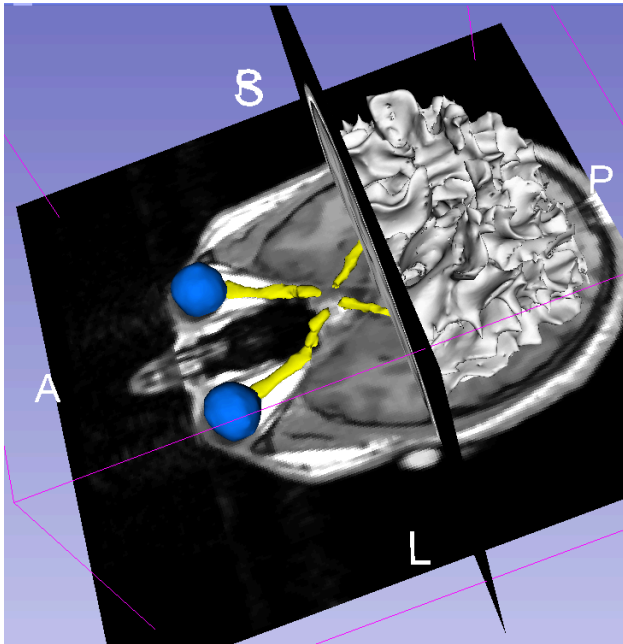
Part II – Hands-on session:
Slicer4 Minute tutorial on data loading and 3D Visualization

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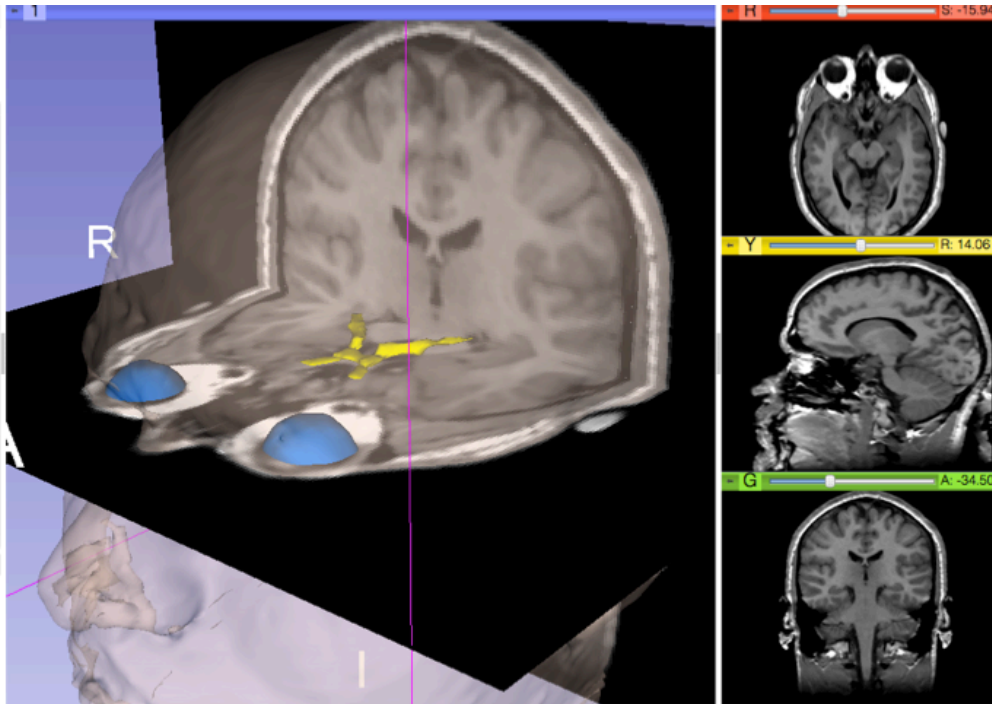
This tutorial is an introduction to the 3D visualization capabilities of the Slicer4 software for medical image analysis.

3DSlicer version 4

Start Slicer on your computer: the Welcome module is the default start-up module.
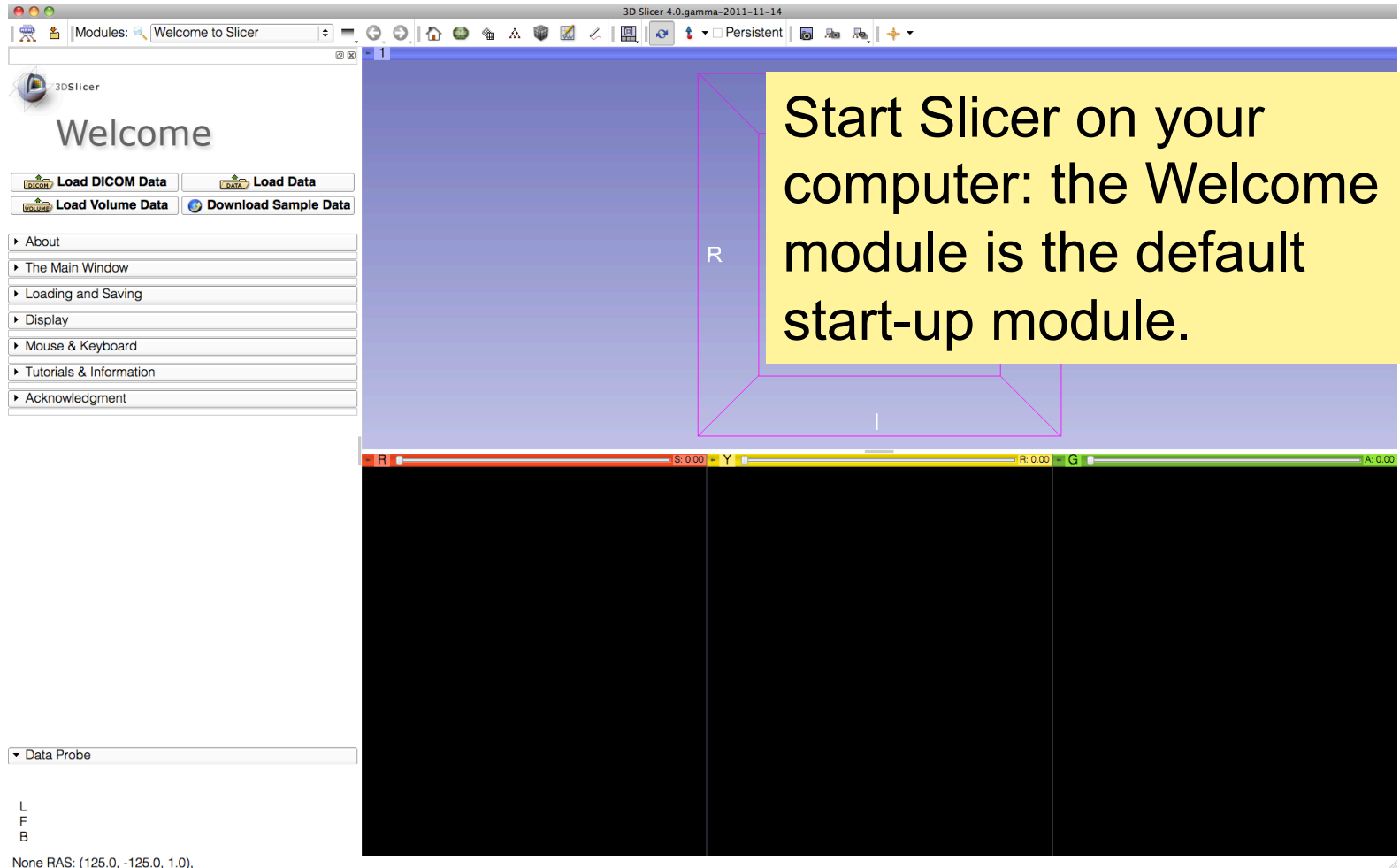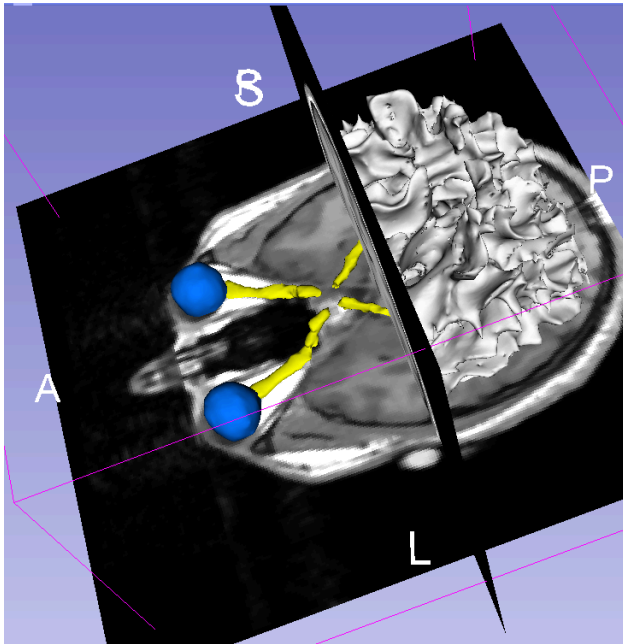
3D Slicer Scene

- 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→ Load Scene** from the main menu, and load the scene slicer4minute.mrml
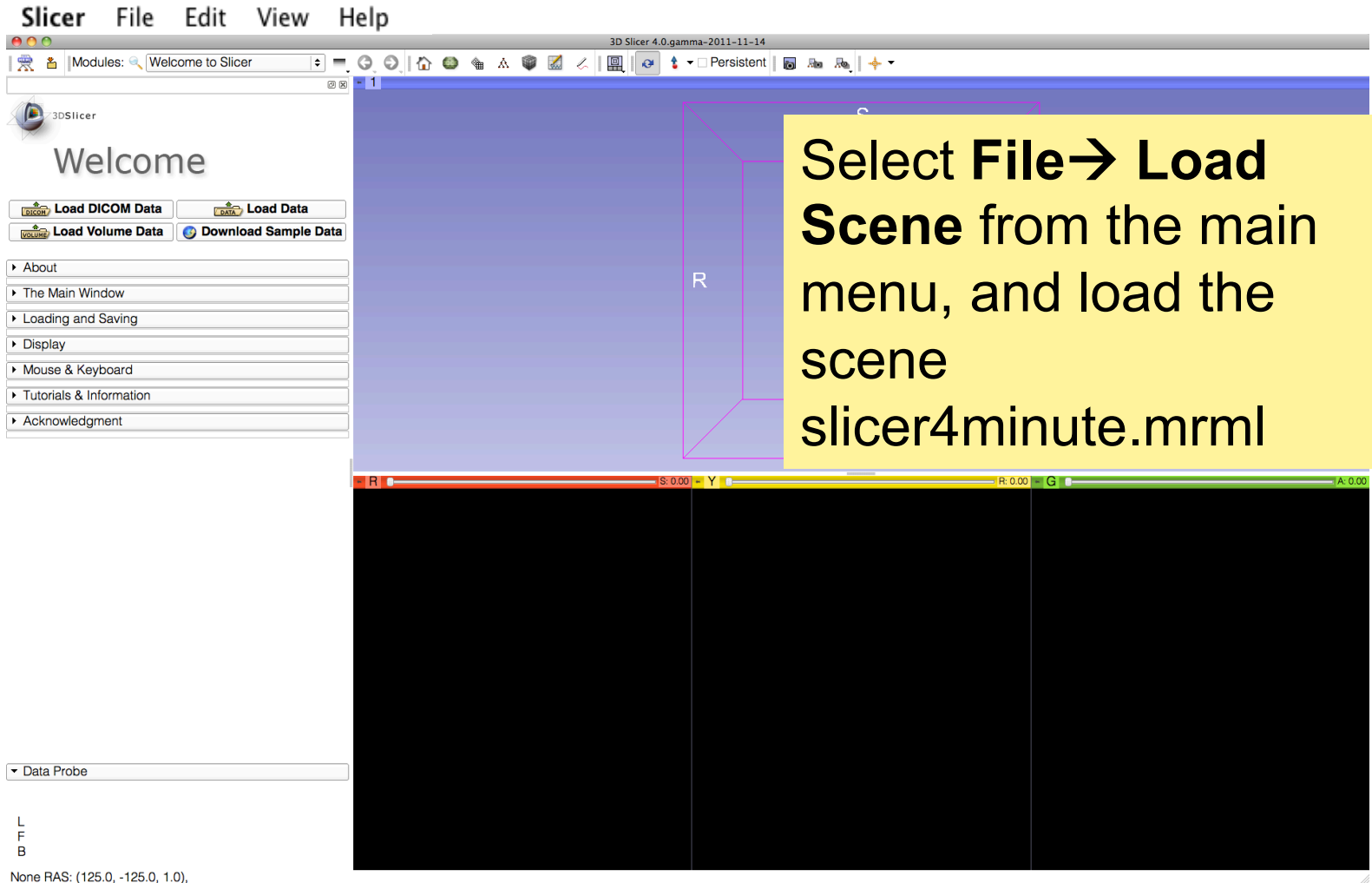
Slicer4 minute Scene
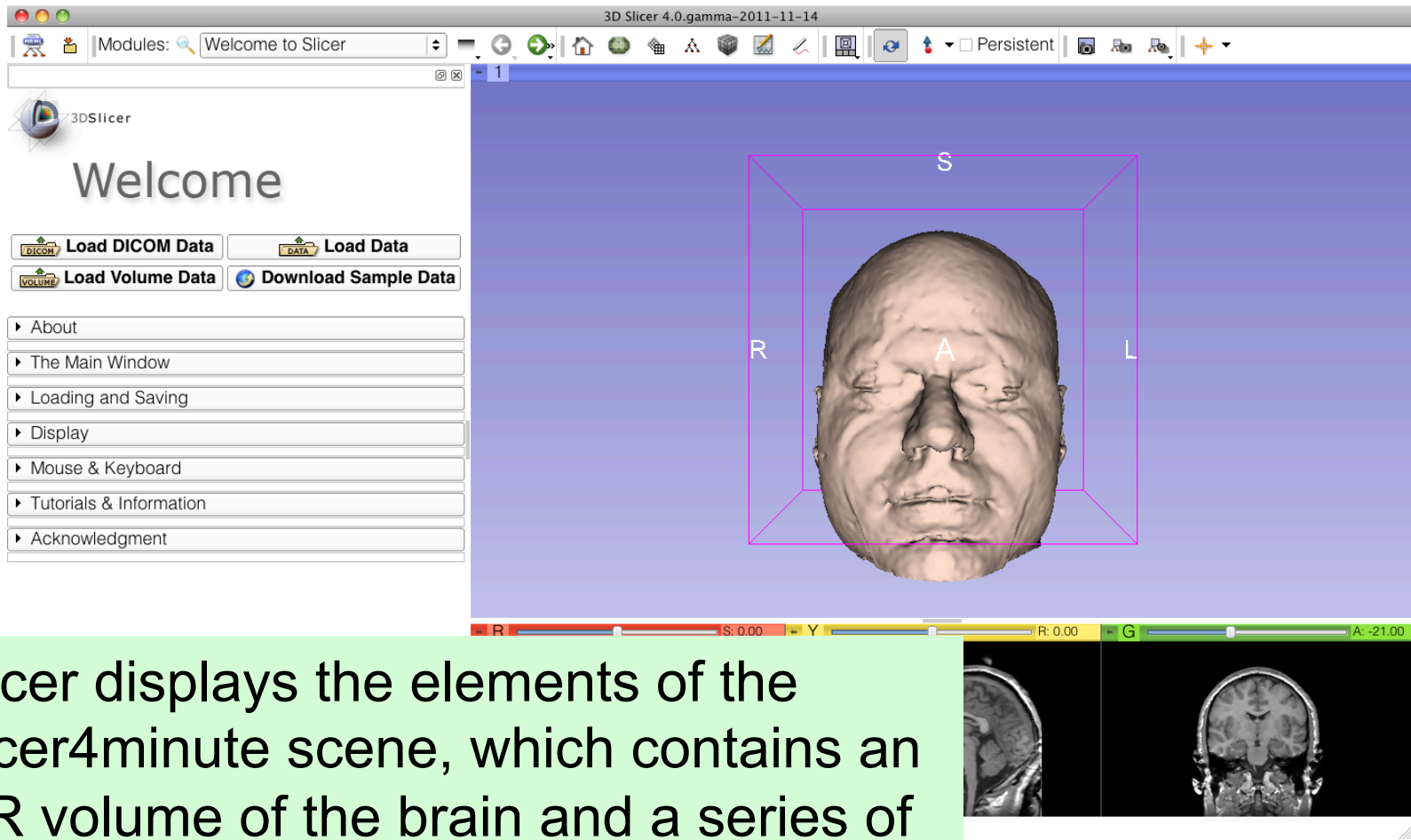
Slicer displays the elements of the slicer4minute scene, which contains an MR volume of the brain and a series of 3D surface models.

Slice4 minute scene

Select the mode 'Conventional Widescreen' from the viewing mode menu

Slicer4minute Scene

Select the module **Models** from the Modules menu
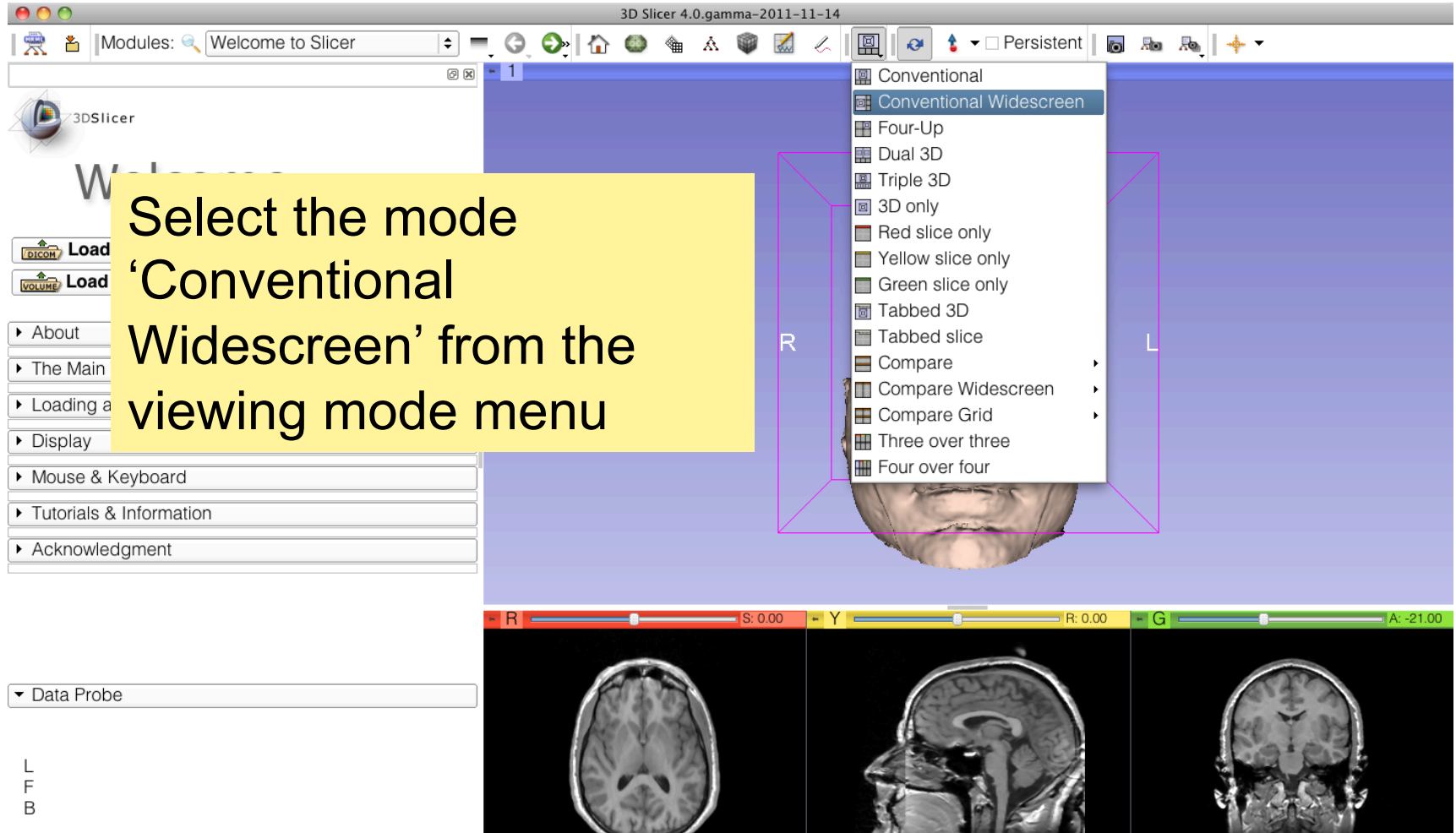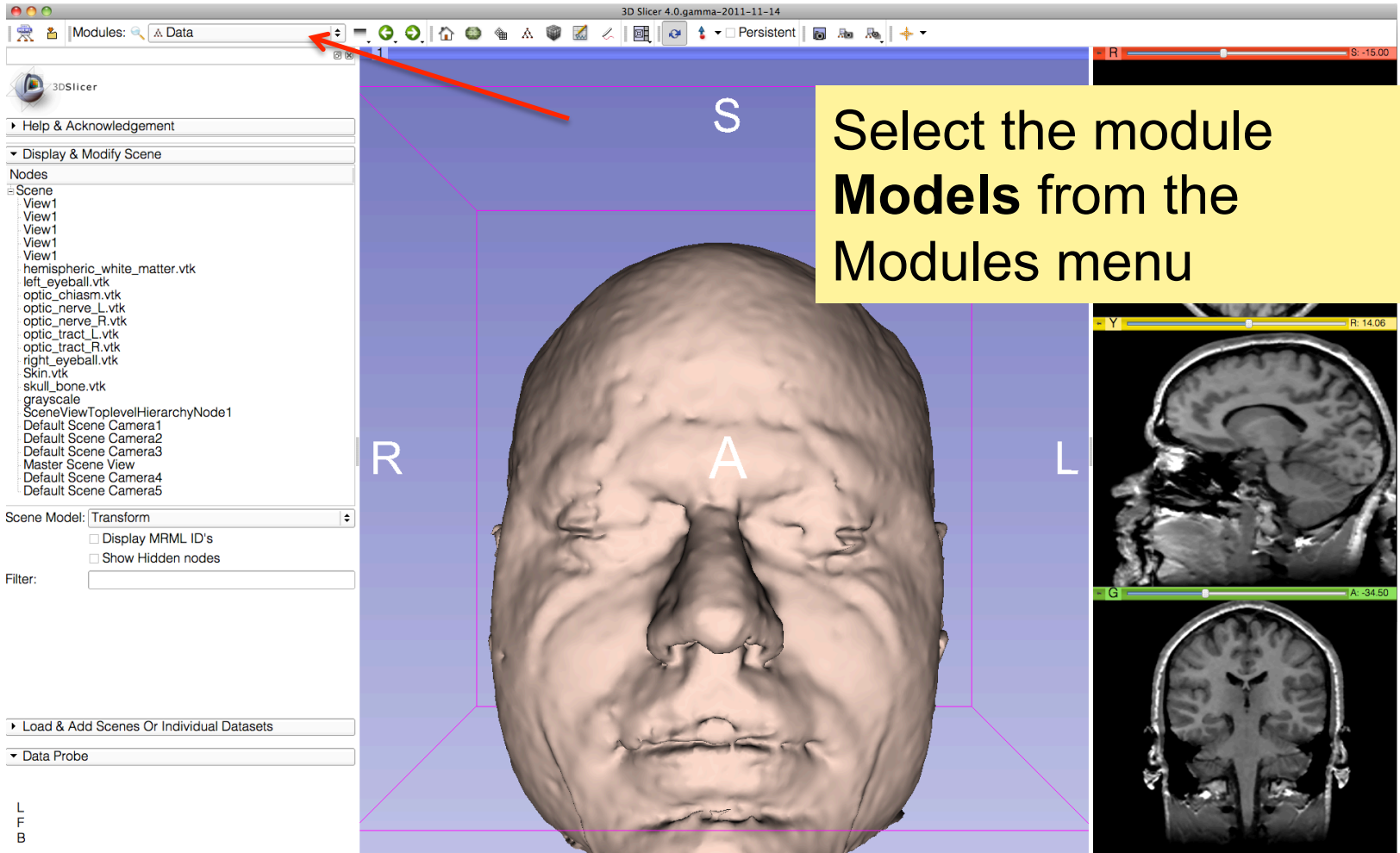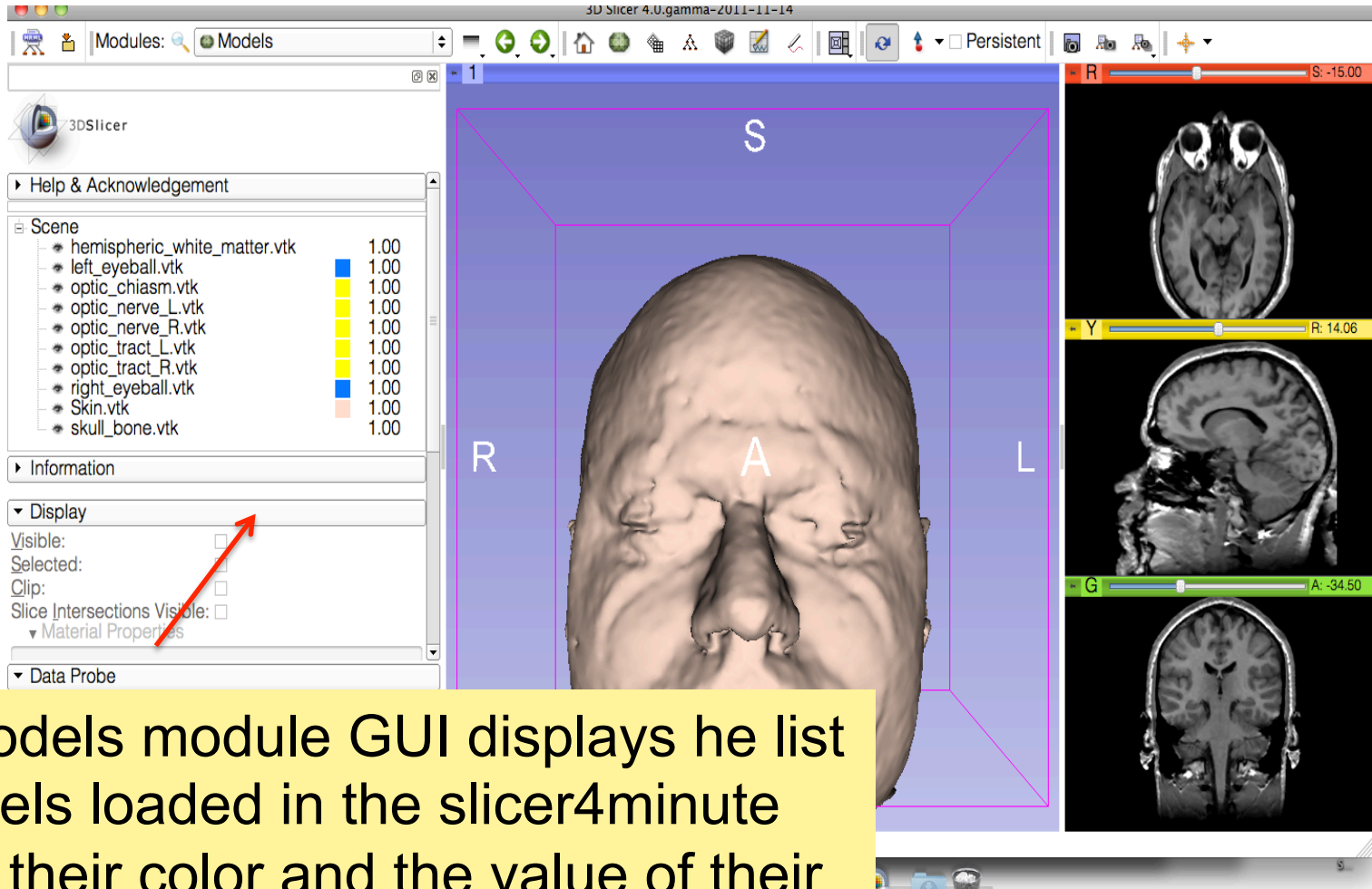
3D Visualization

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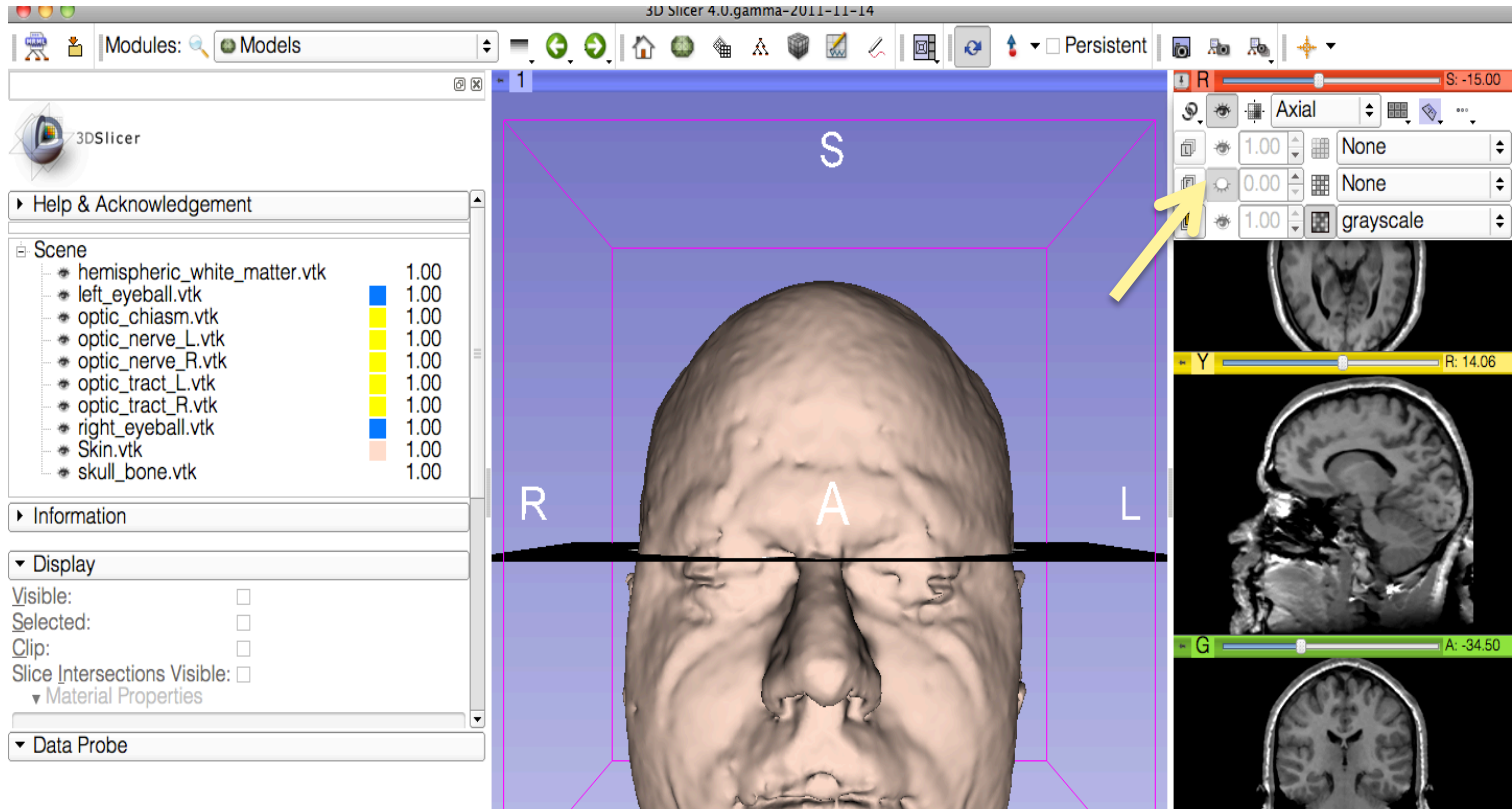
Click on the pin icon on the top left corner of the red slice to display the slice viewer menu.
Click on the eye icon to display the axial slice in the 3D Viewer

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
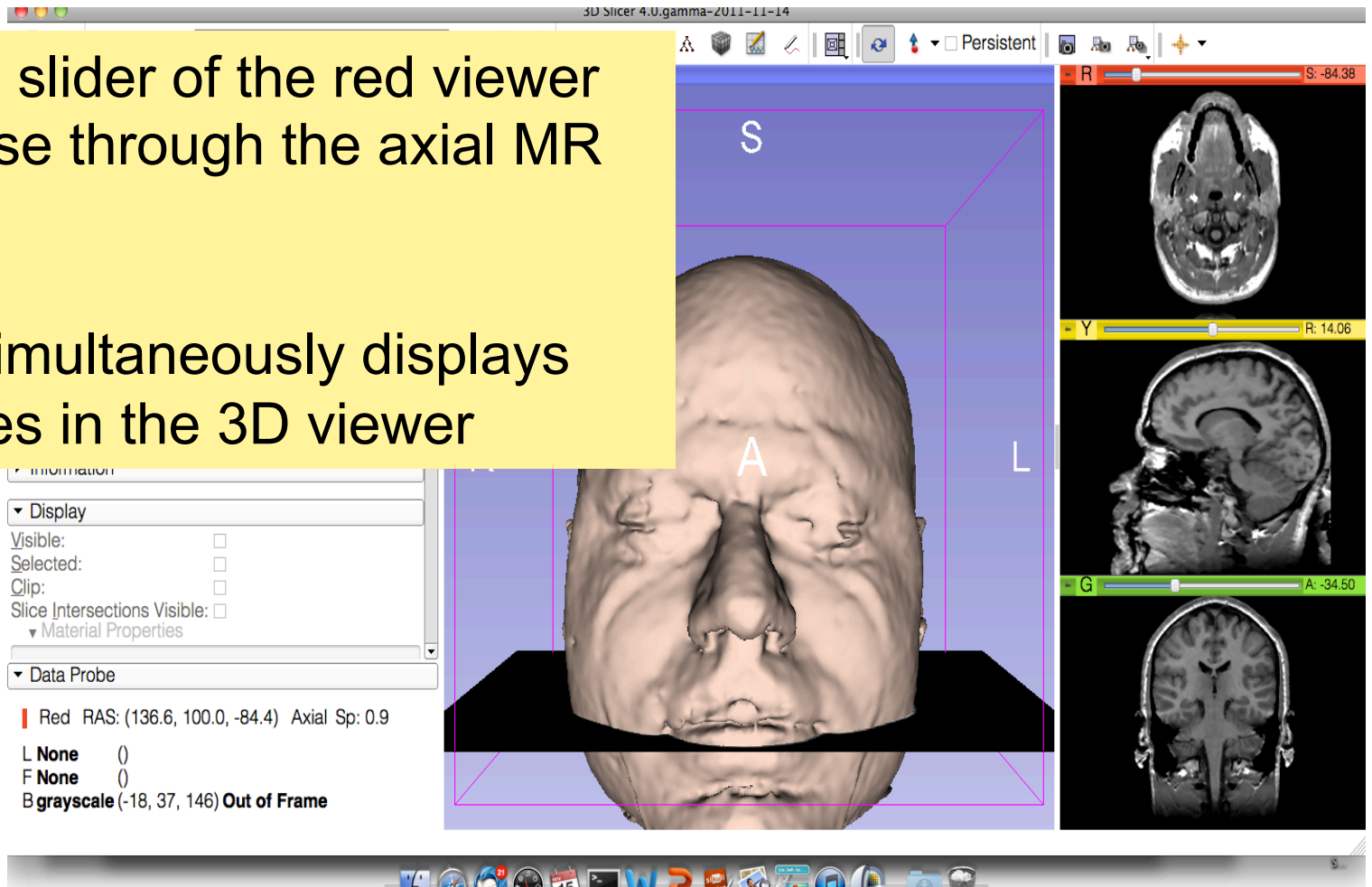
3D Visualization

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
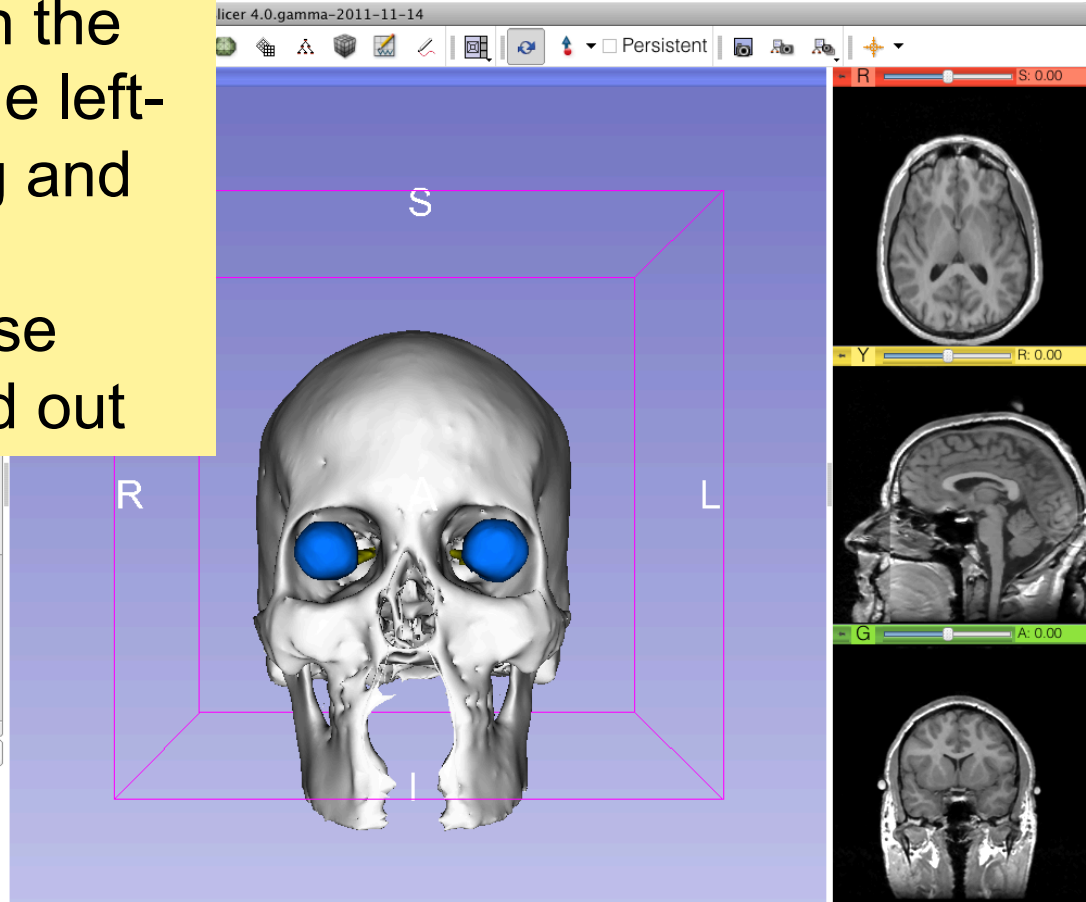
Anatomical Views

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.
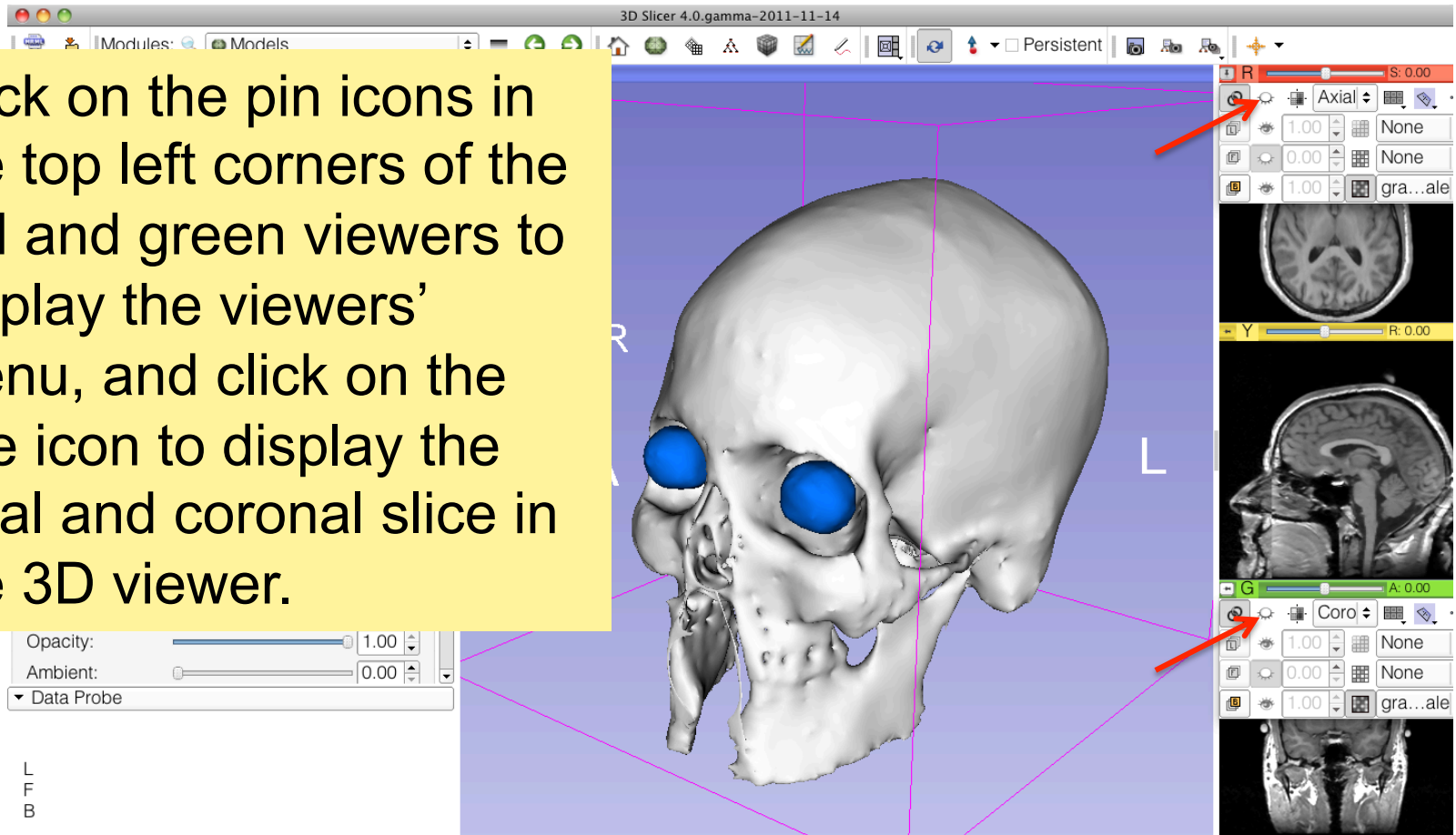
3D Visualization

Turn off the visibility of the skull to display the brain white matter model
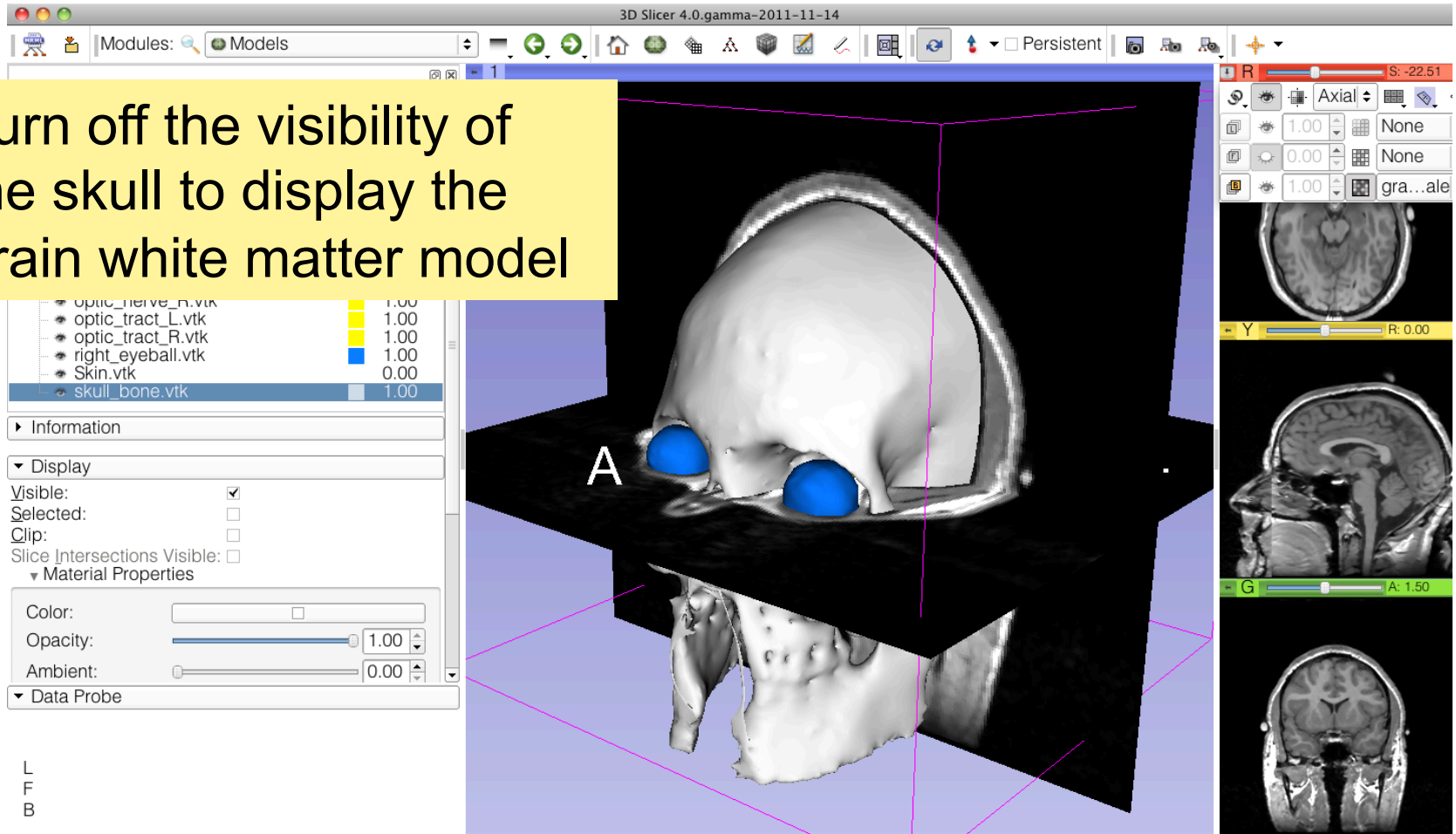
3D Visualization

The white matter surface, as well as the left and right optic nerves, appear in the viewer
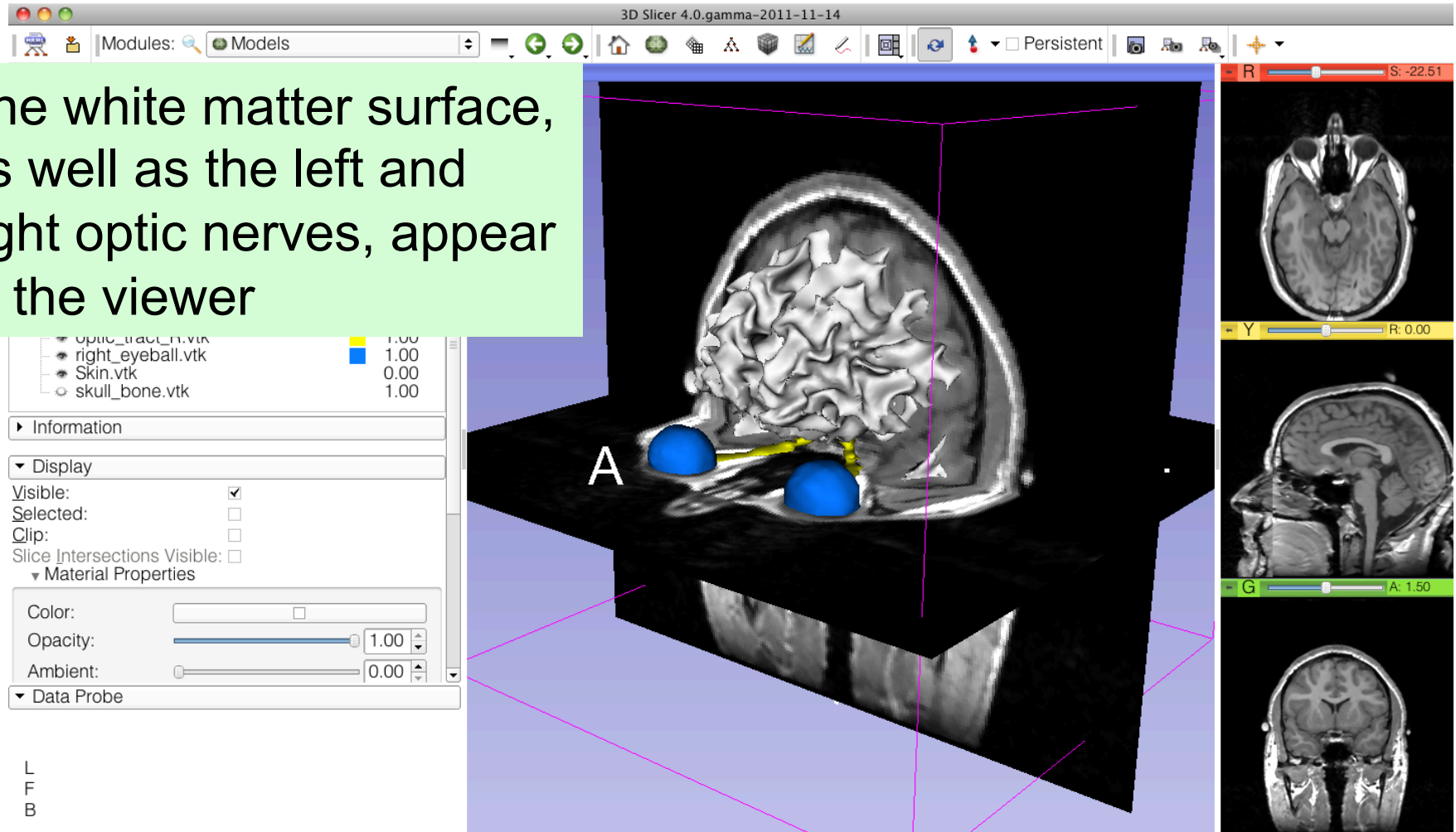
3D Visualization

Select the **hemispheric_white matter.vtk** model, and check Clip in the Display options tab.

3D Visualization

Use the coronal slider (green) to expose the optic chiasm.
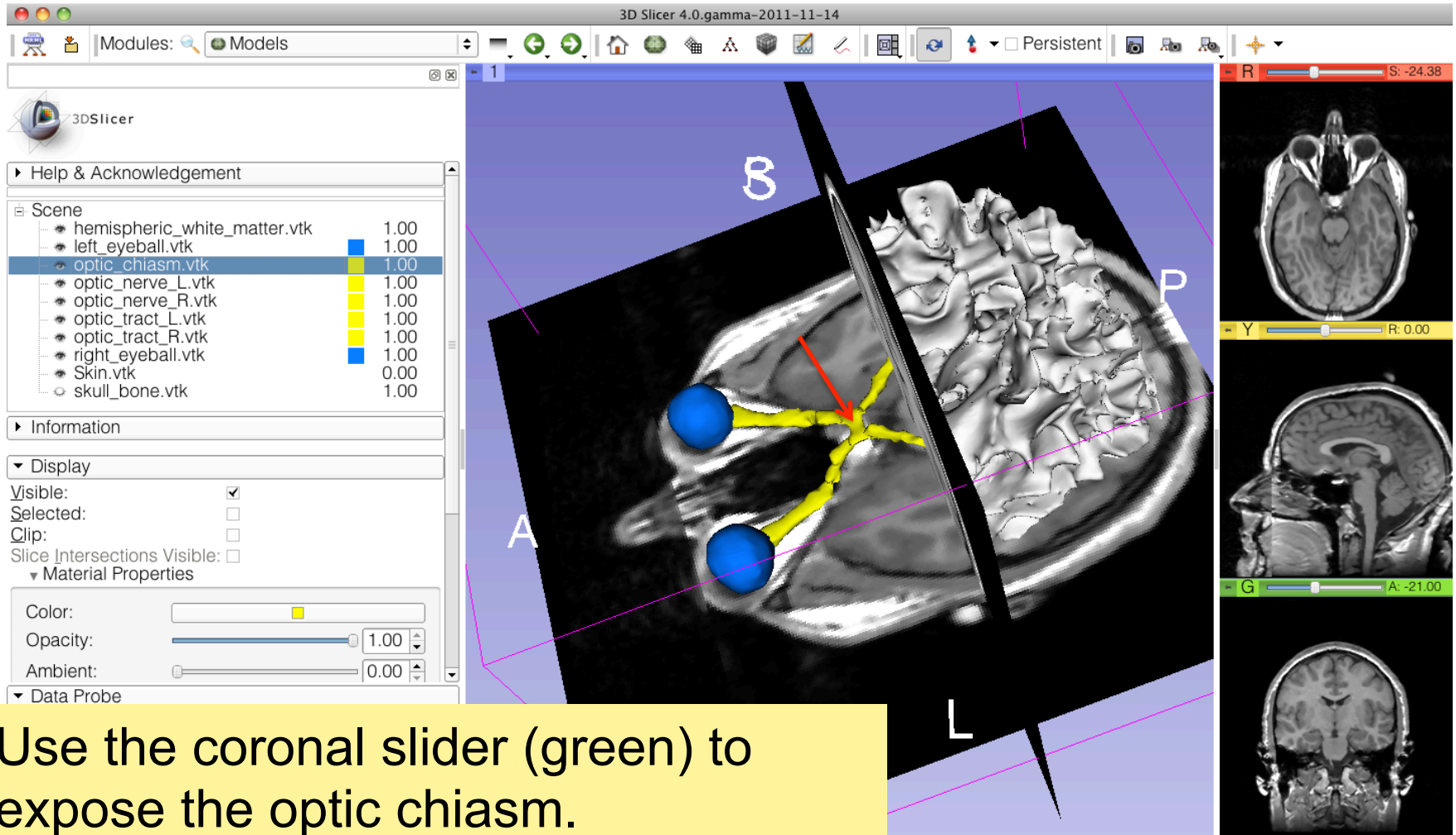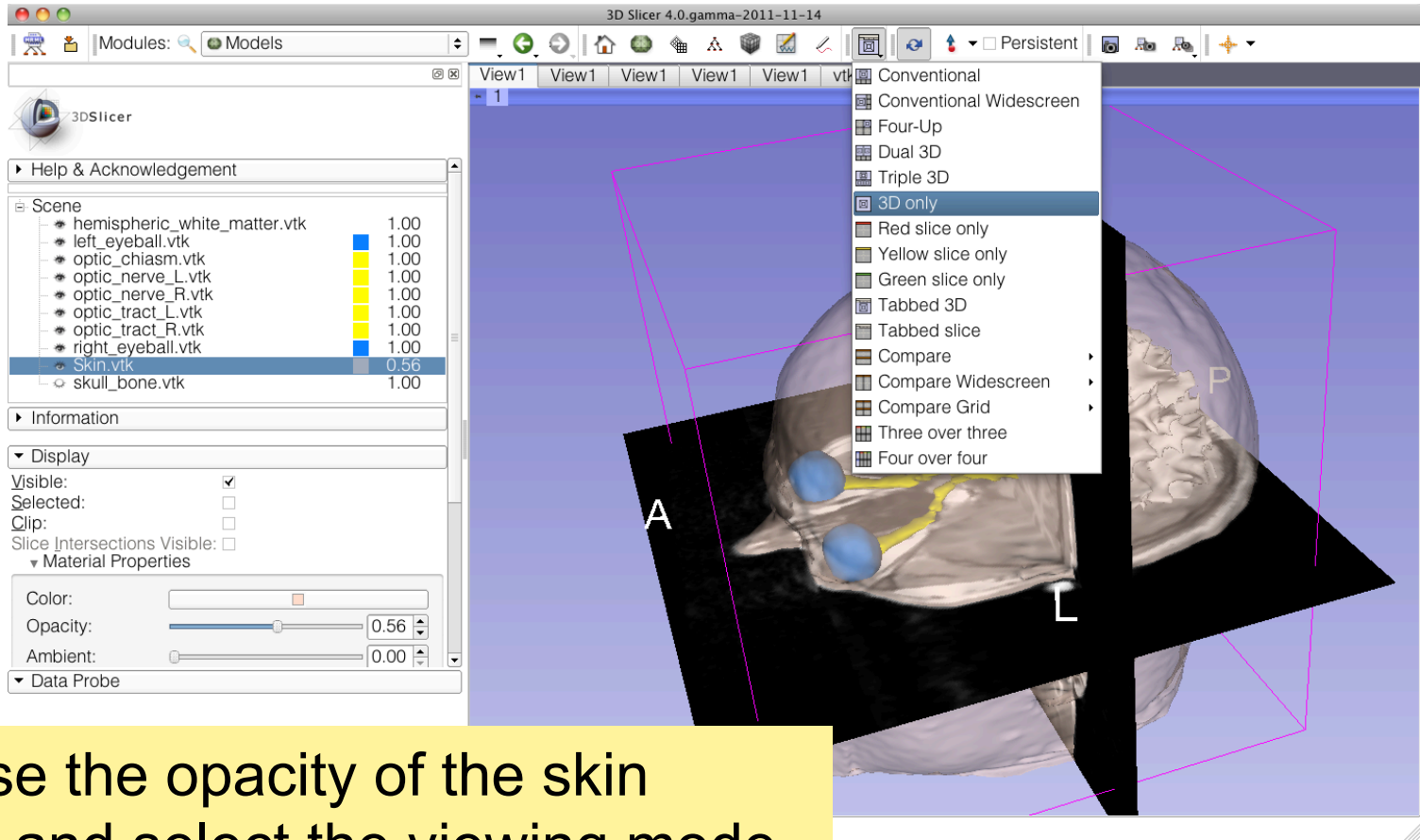
3D Visualization

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

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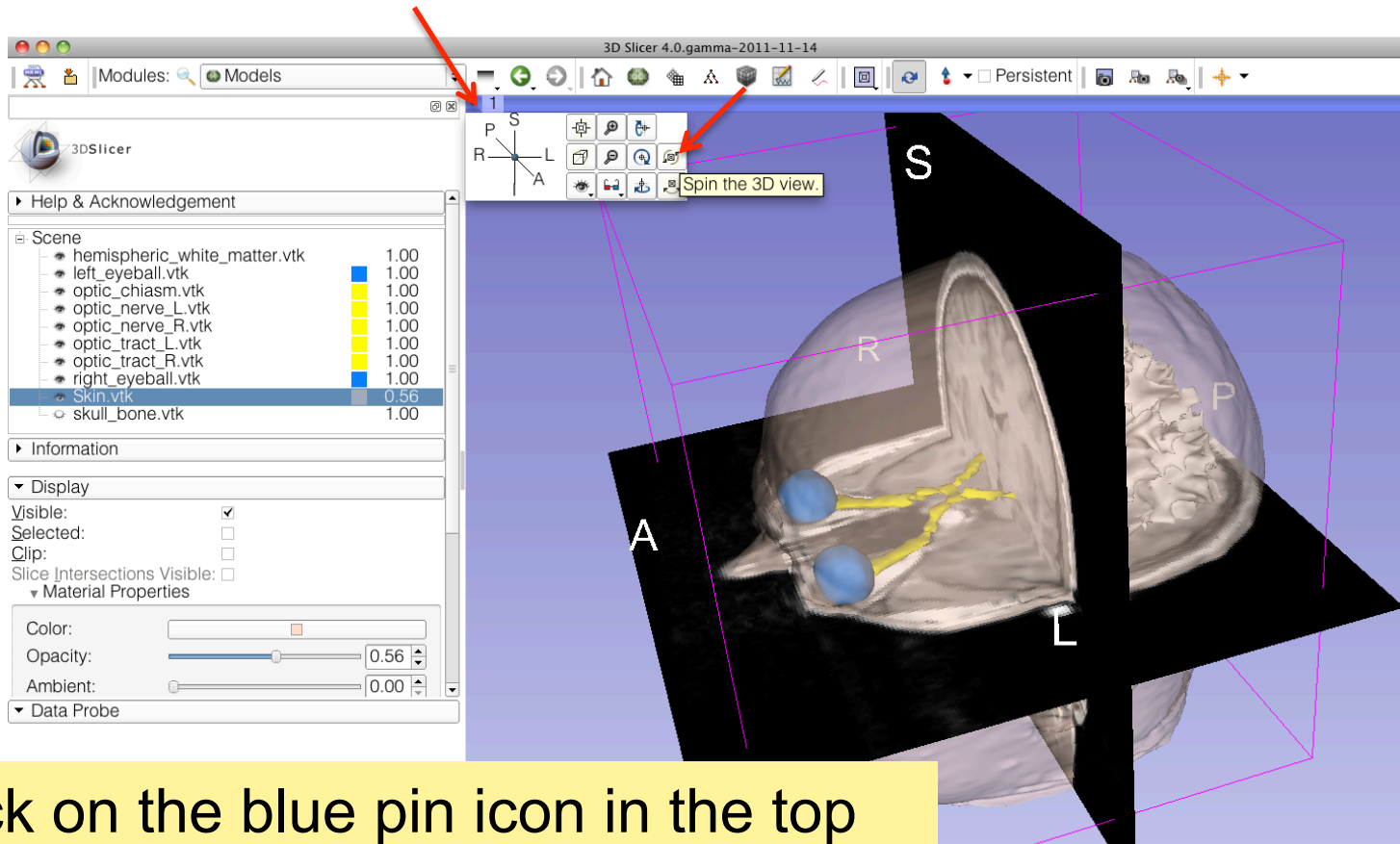
Click on the blue pin icon in the top left corner of the 3D viewer, and click on the Spin icon.

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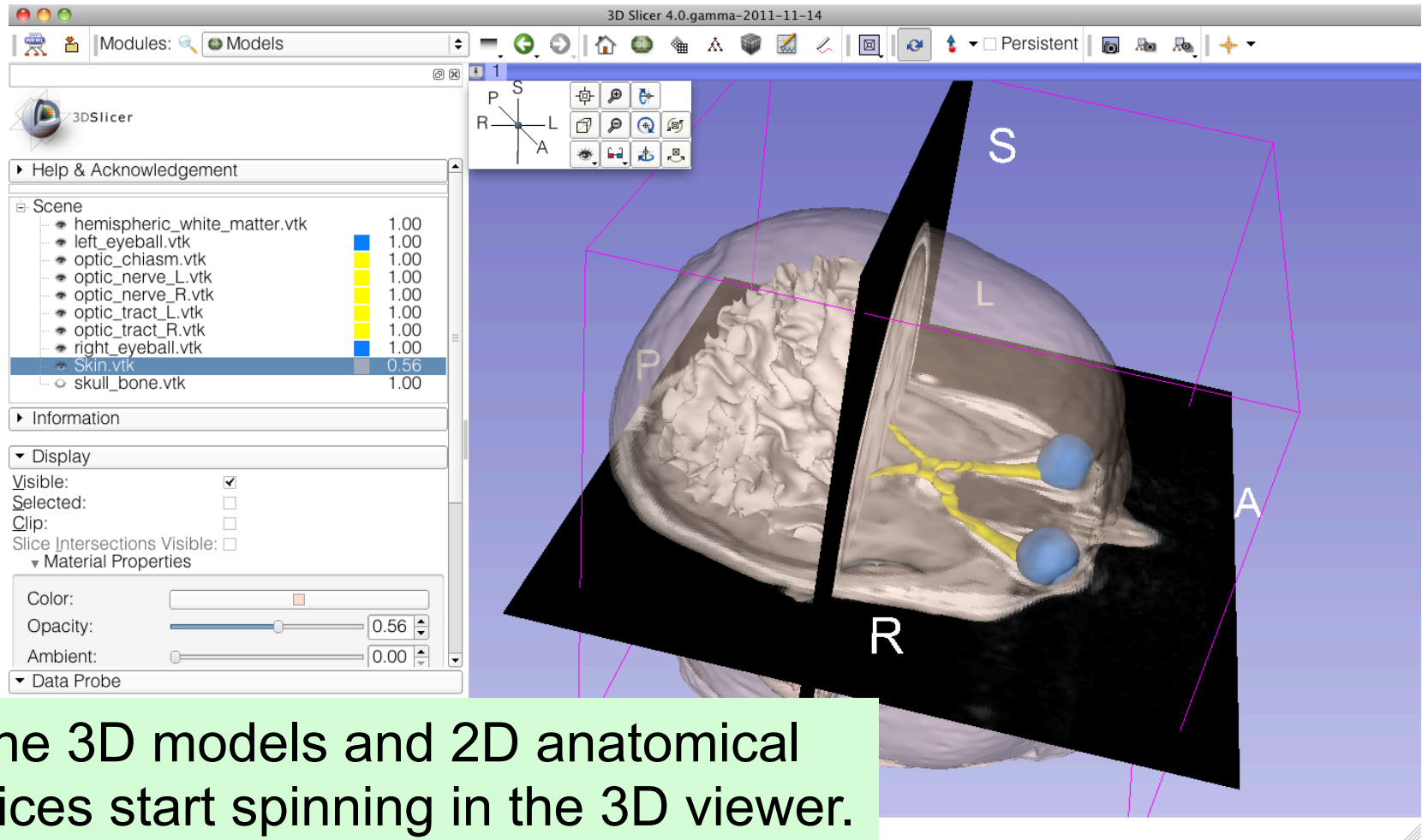
The 3D models and 2D anatomical slices start spinning in the 3D viewer. Click a second time on the spin icon to stop the models from spinning.

Slicer4 minute tutorial
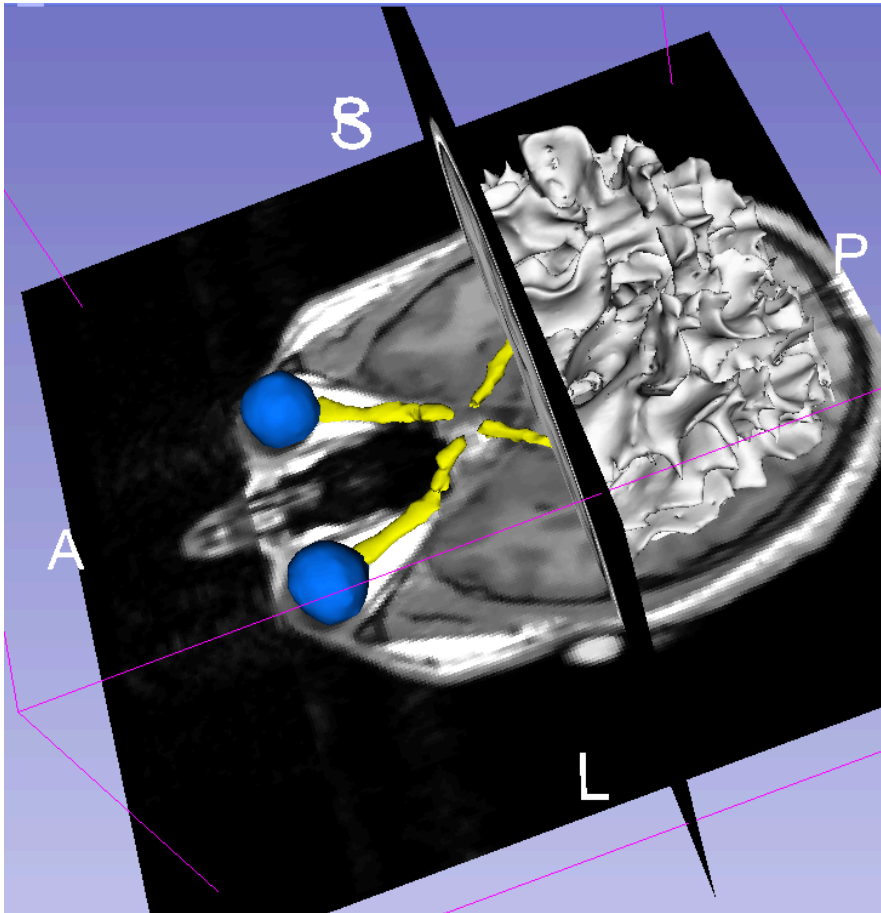
This tutorial was a short introduction to the 3D visualization capabilities of Slicer.

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

www.slicer.org
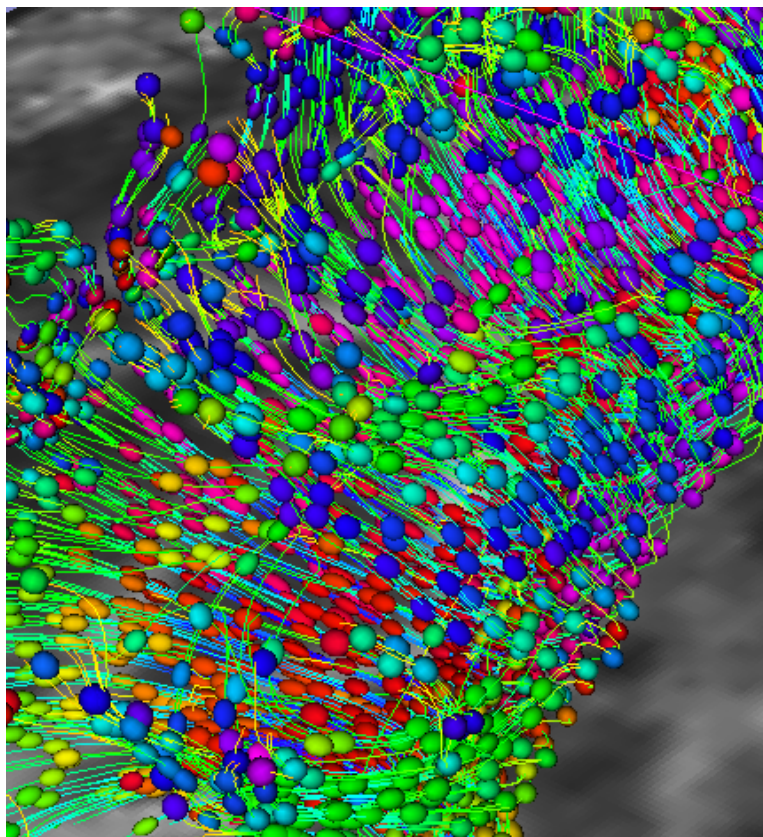
Part III:
3D Slicer DTI demo
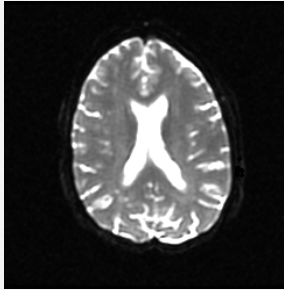
DWI
Acquisition
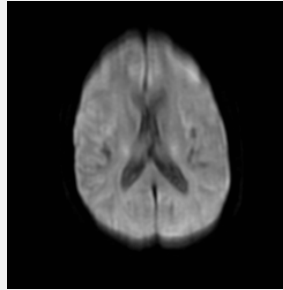
Tensor
Calculation
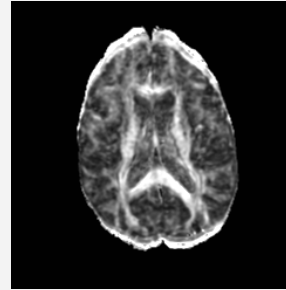
Scalar
Maps

3D
Visualization

Diffusion MRI Analysis – Sonia Pujol, Ph.D.
NA-MIC ARR 2012

Loading the DTI Scene

Select File→ Add Data on **'Choose File to Add'**

Select the 'dti_Scene.mrml' file located in SlicerData/DTI
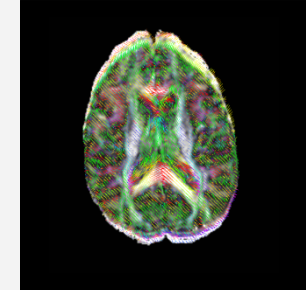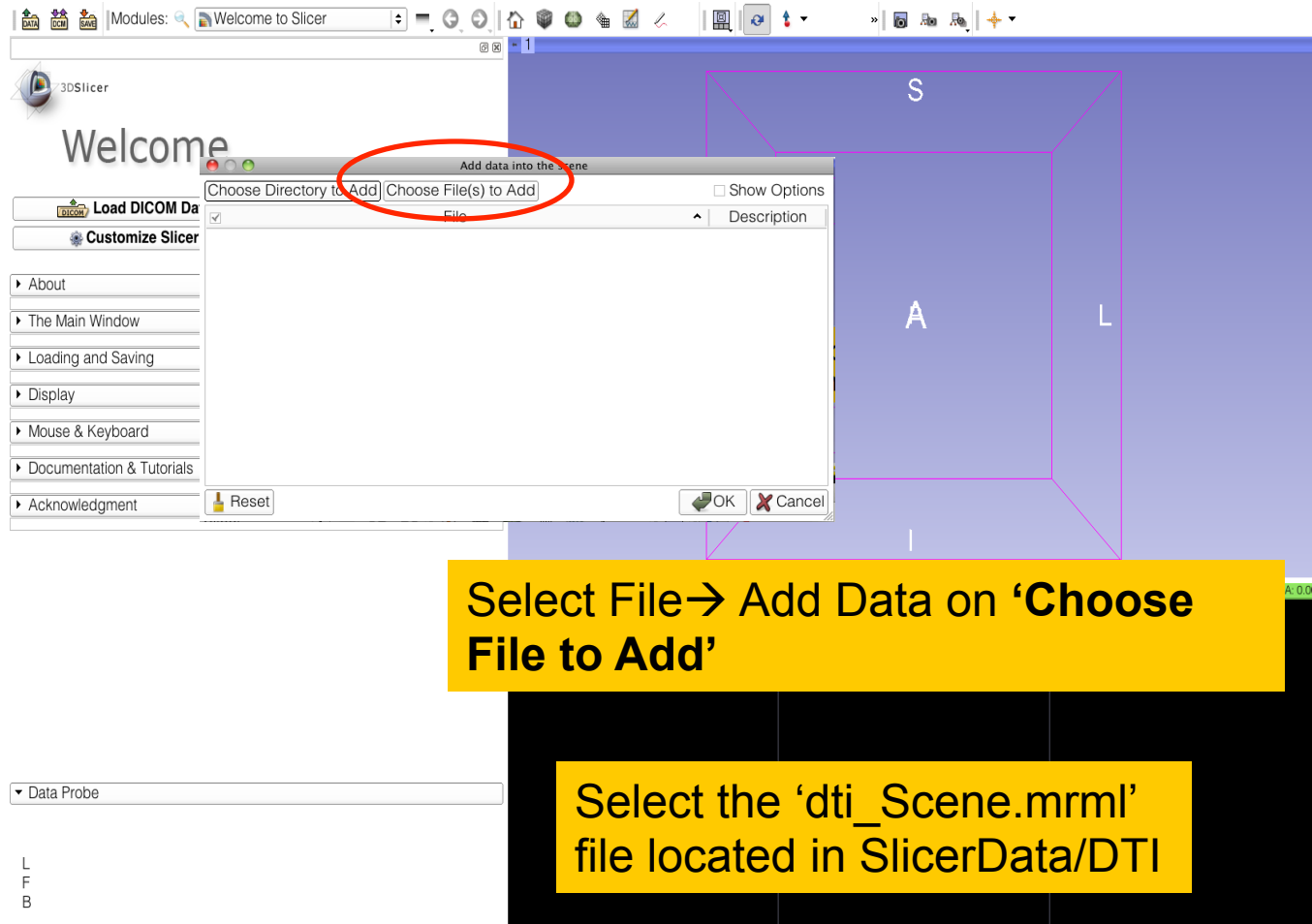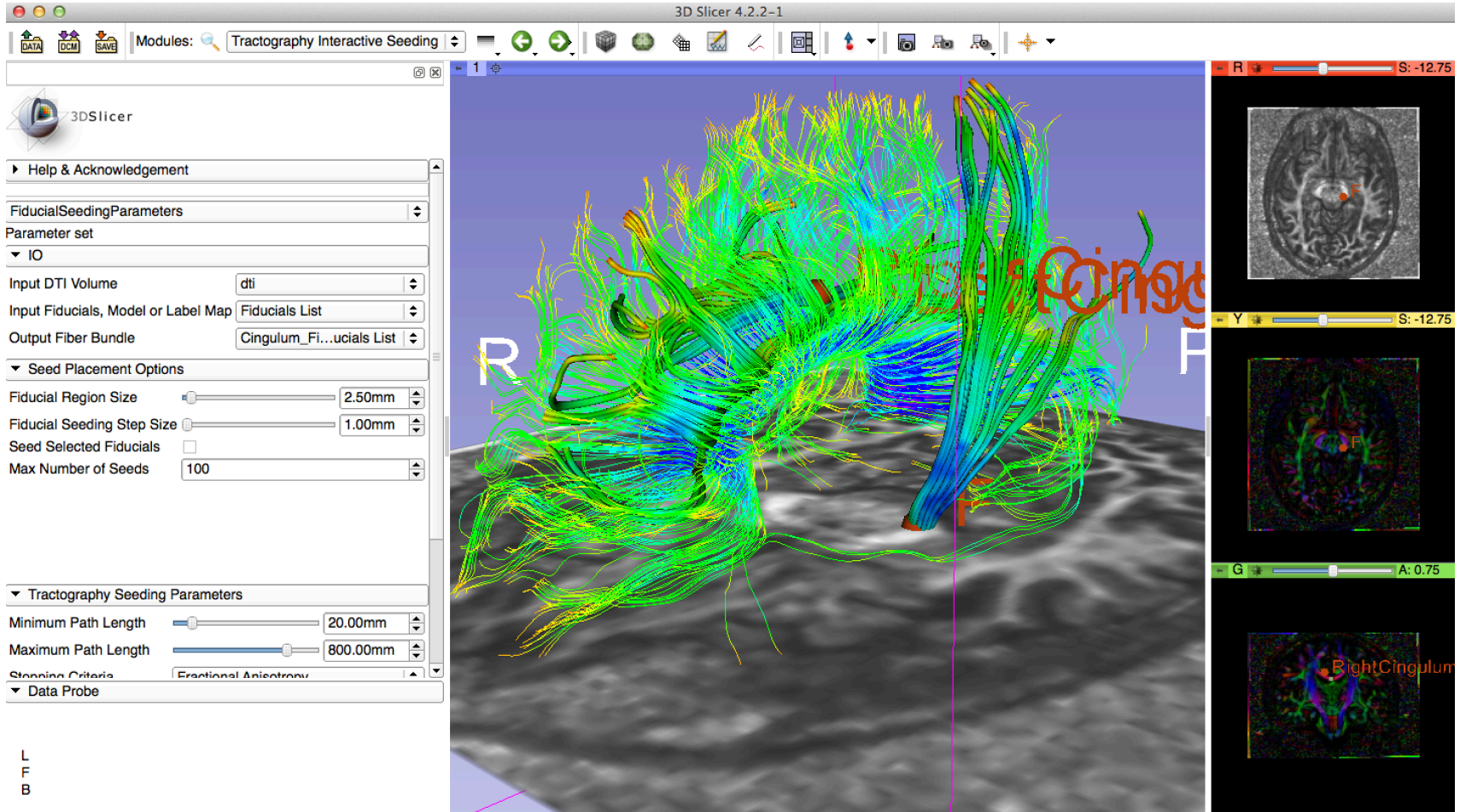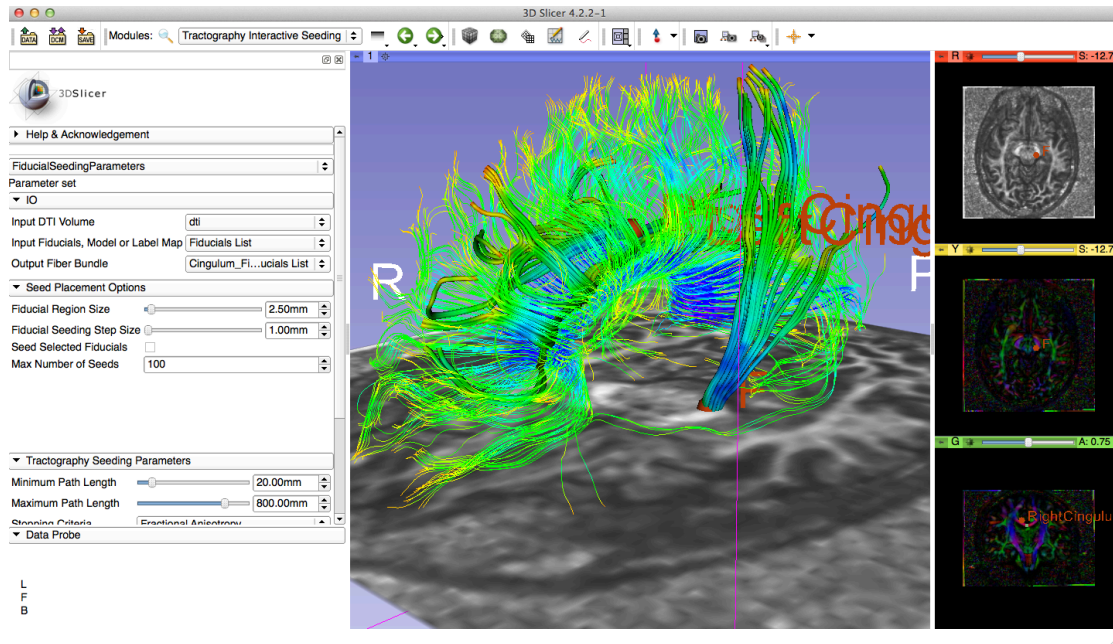
DTI Scene

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
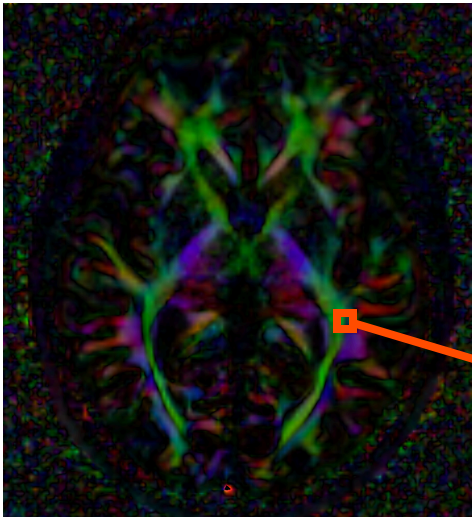
$$S_i = S_0 e^{-b\hat{g}i^T \underline{D}\hat{g}_i}$$

Stejskal-Tanner equation (1965)

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

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

Diffusion MRI Analysis – Sonia Pujol, Ph.D.
NA-MIC ARR 2012

Diffusion Tensor

- The diffusion tensor <u>D</u> 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 $\lambda 1$, $\lambda 2$, $\lambda 3$ to characterize the size and shape of the diffusion tensor.

Diffusion MRI Analysis – Sonia Pujol, Ph.D.
NA-MIC ARR 2012
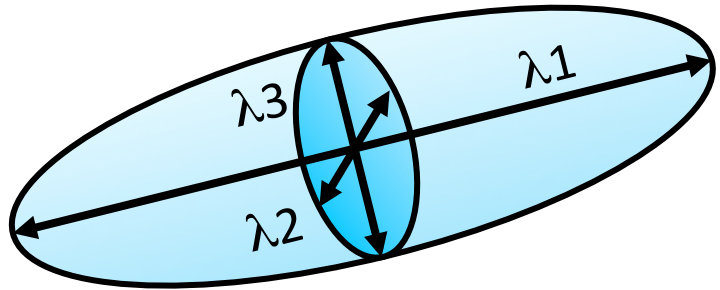
Diffusion Tensor Shape

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

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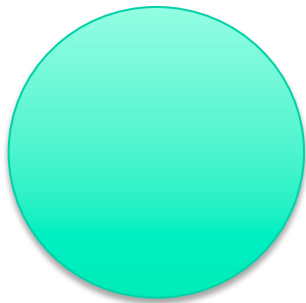
$\lambda 1 \sim \lambda 2 >> \lambda 3$

Isotropic media
(CSF, gray matter)
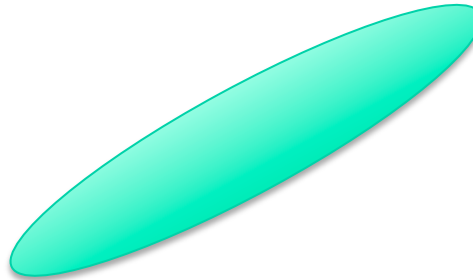
Anisotropic media
(white matter)

Diffusion MRI Analysis – Sonia Pujol, Ph.D.
NA-MIC ARR 2012

Diffusion MRI tractography
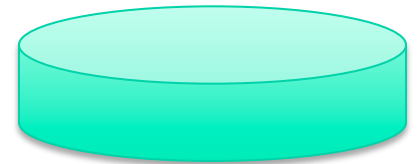
- Tractography can be defined as the virtual reconstruction of the trajectory of water molecules along white matter bundles.

- 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.

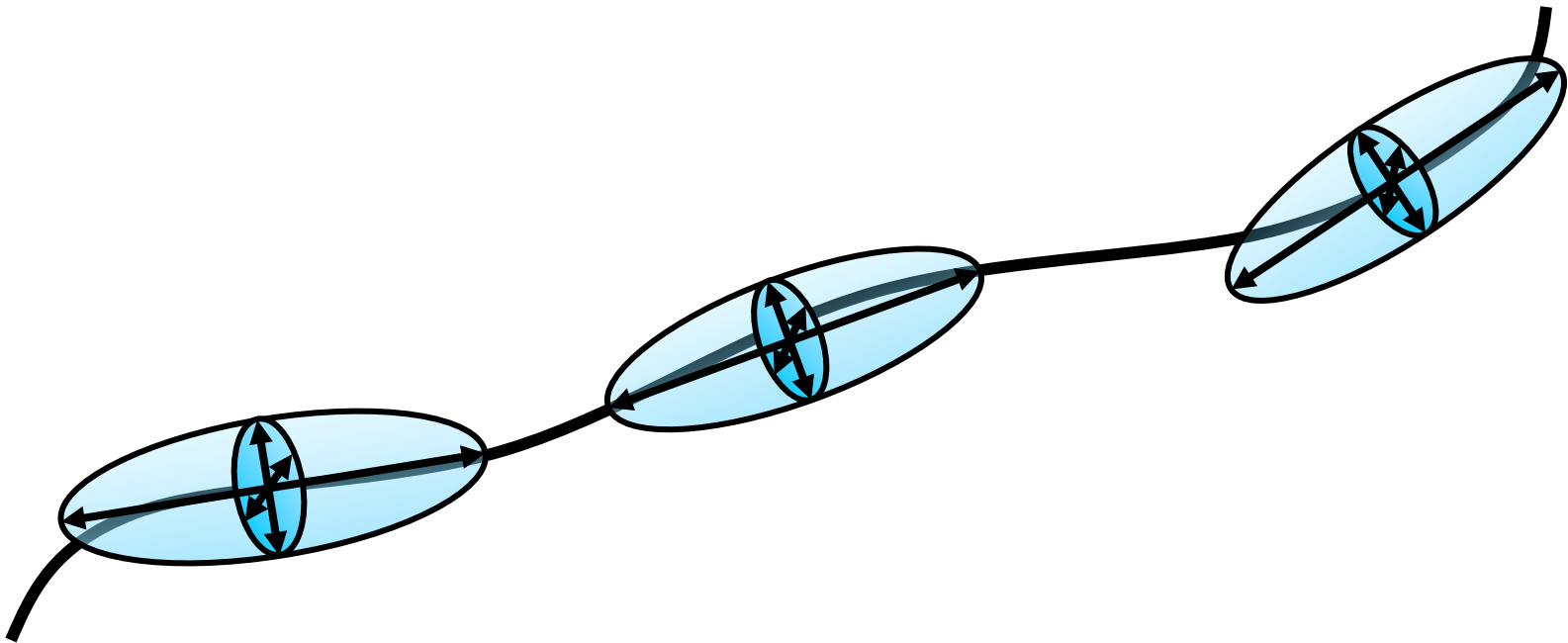Underlying Assumption: the orientation of the fibers is collinear with the direction of the principal eigenvector

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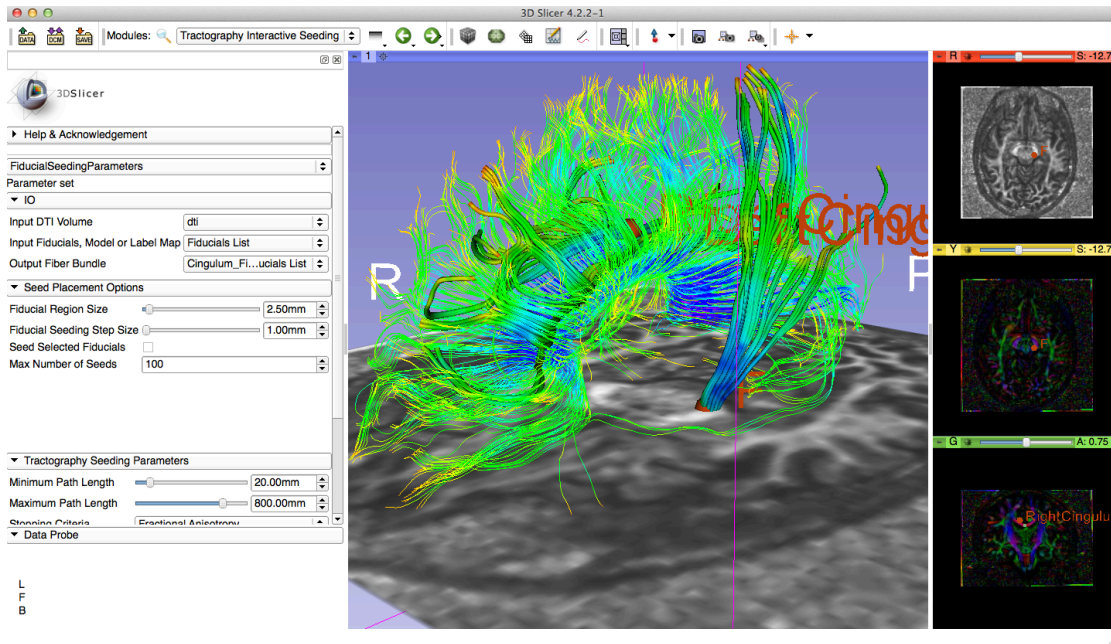
In this example, the tractography reconstruction of the corpus callosum has been generated using the **LabelMap Seeding module**;

LabelMap Seeding Module

DTI Scene
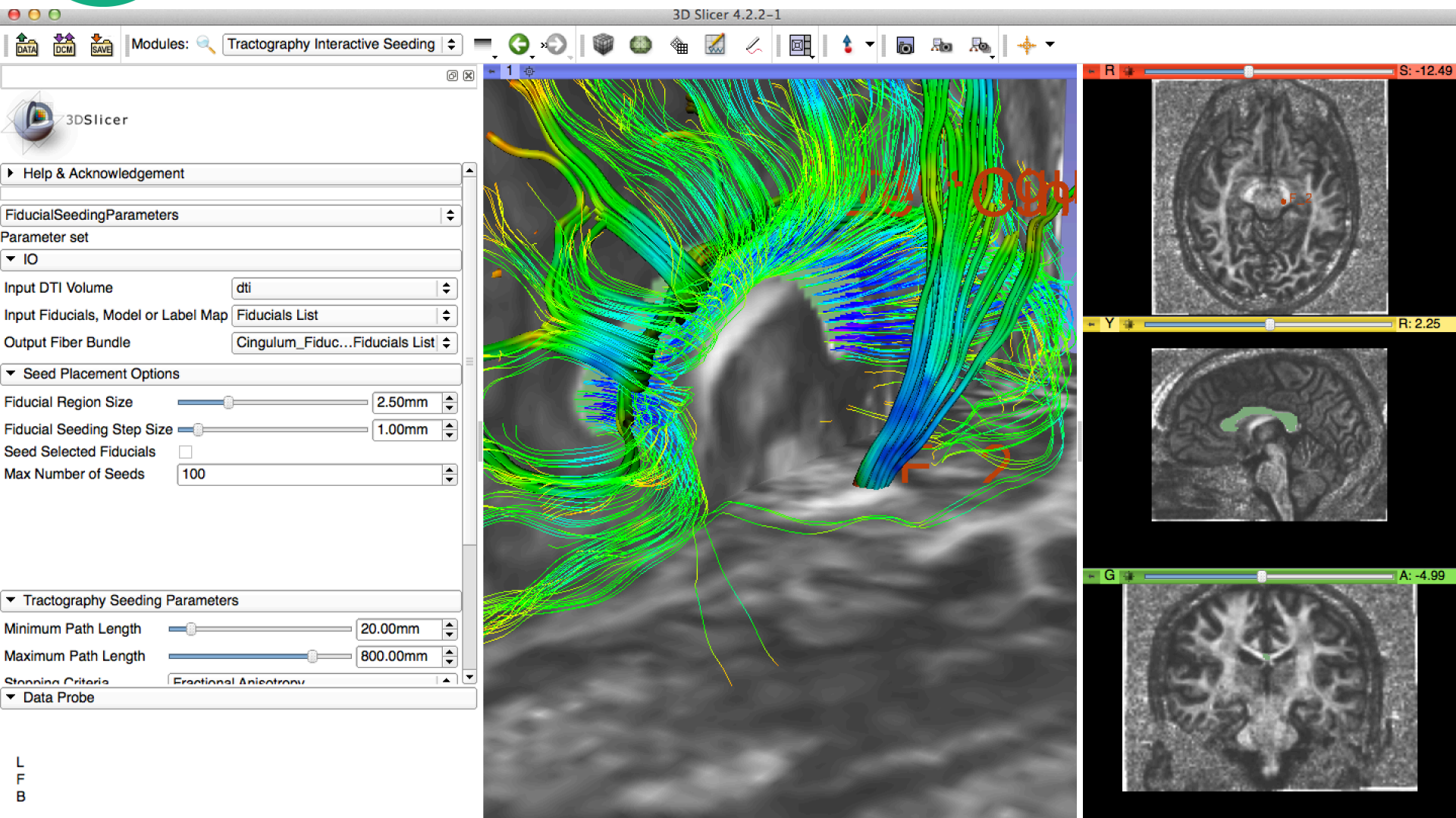

In this example, the tractography reconstruction of the the cingulum has been generated using the **Interactive Tractography Seeding** module.

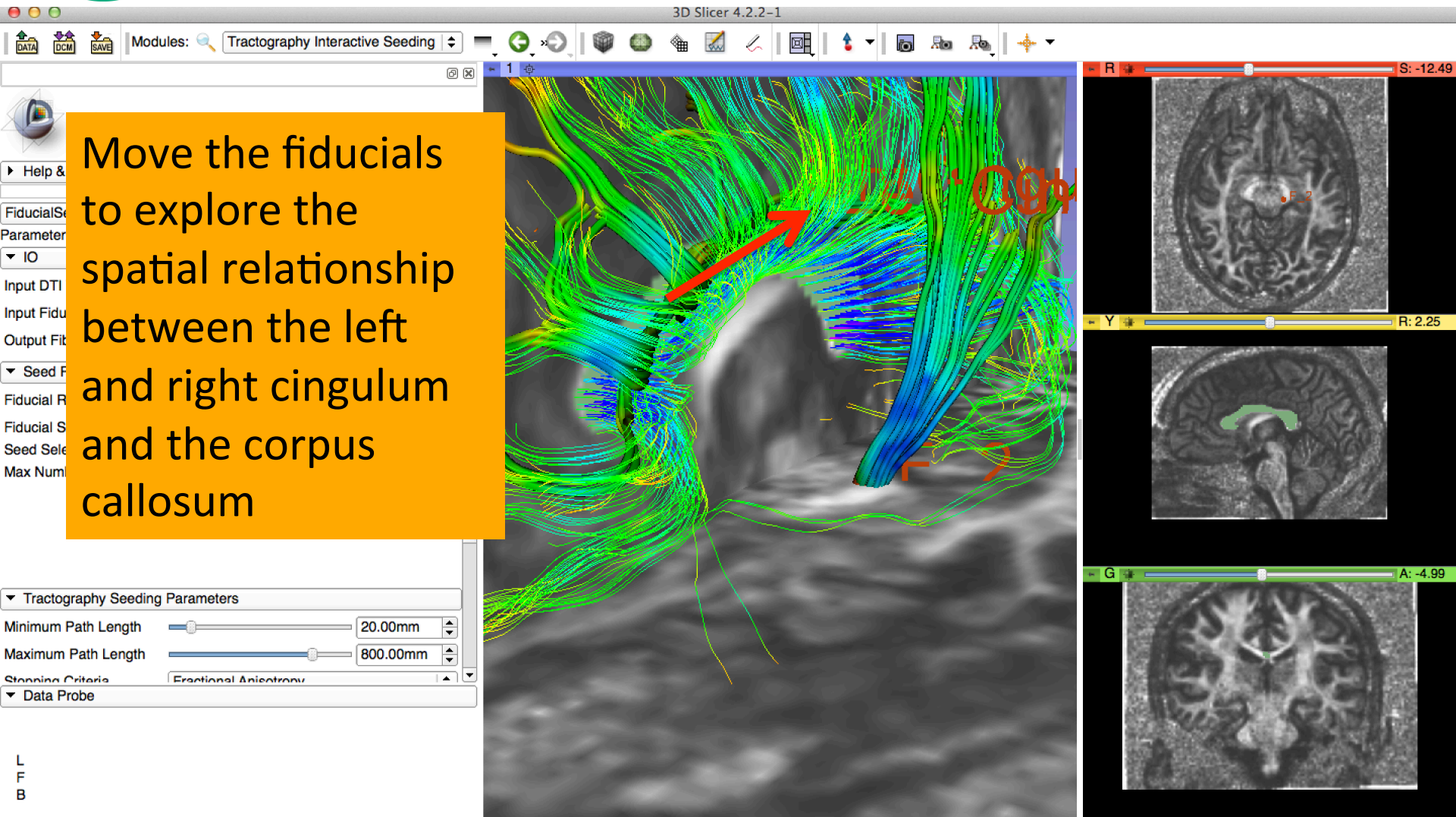# Interactive Tractography Seeding

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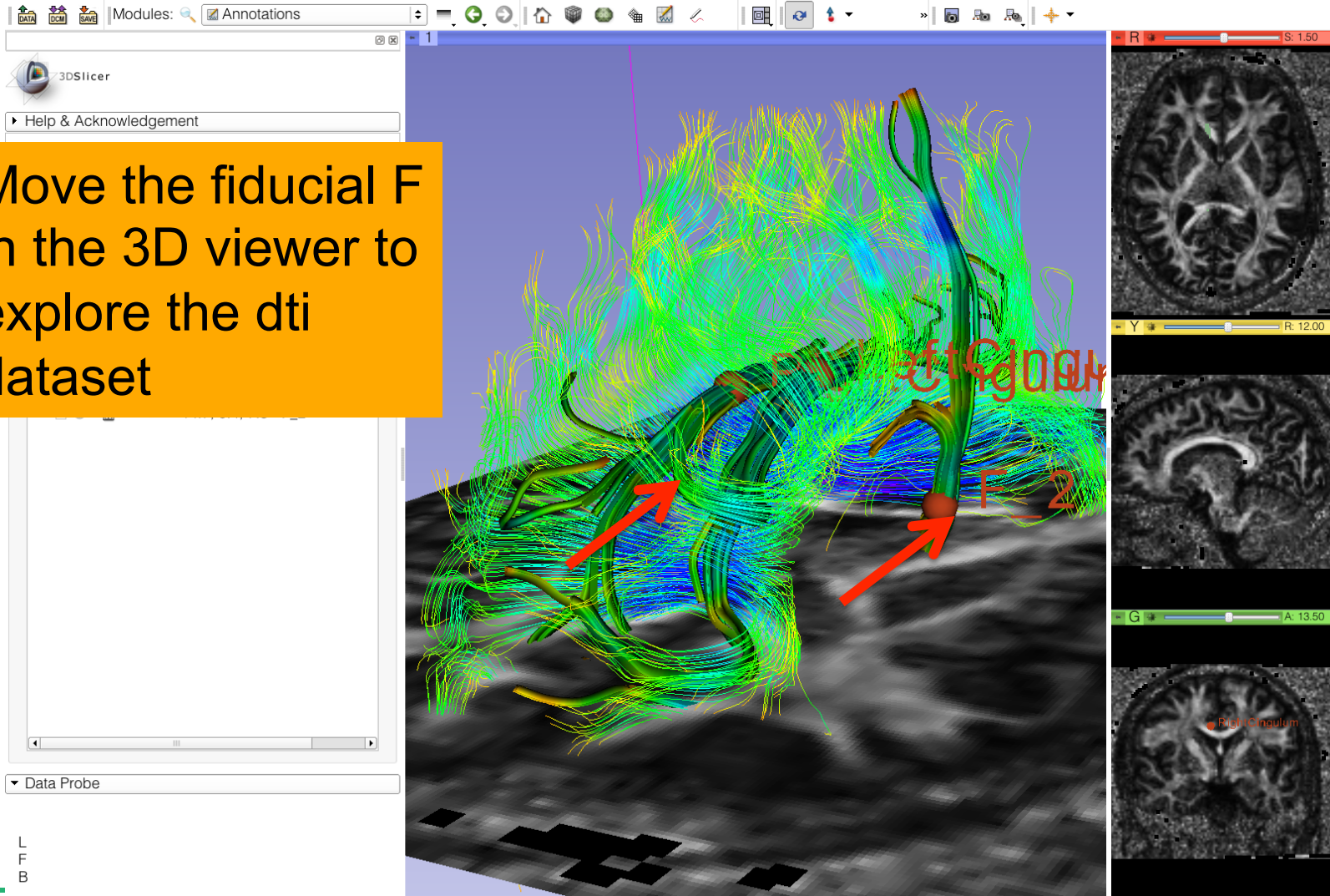
Interactive Tractography Seeding

Move the fiducials to explore the spatial relationship between the left and right cingulum and the corpus callosum
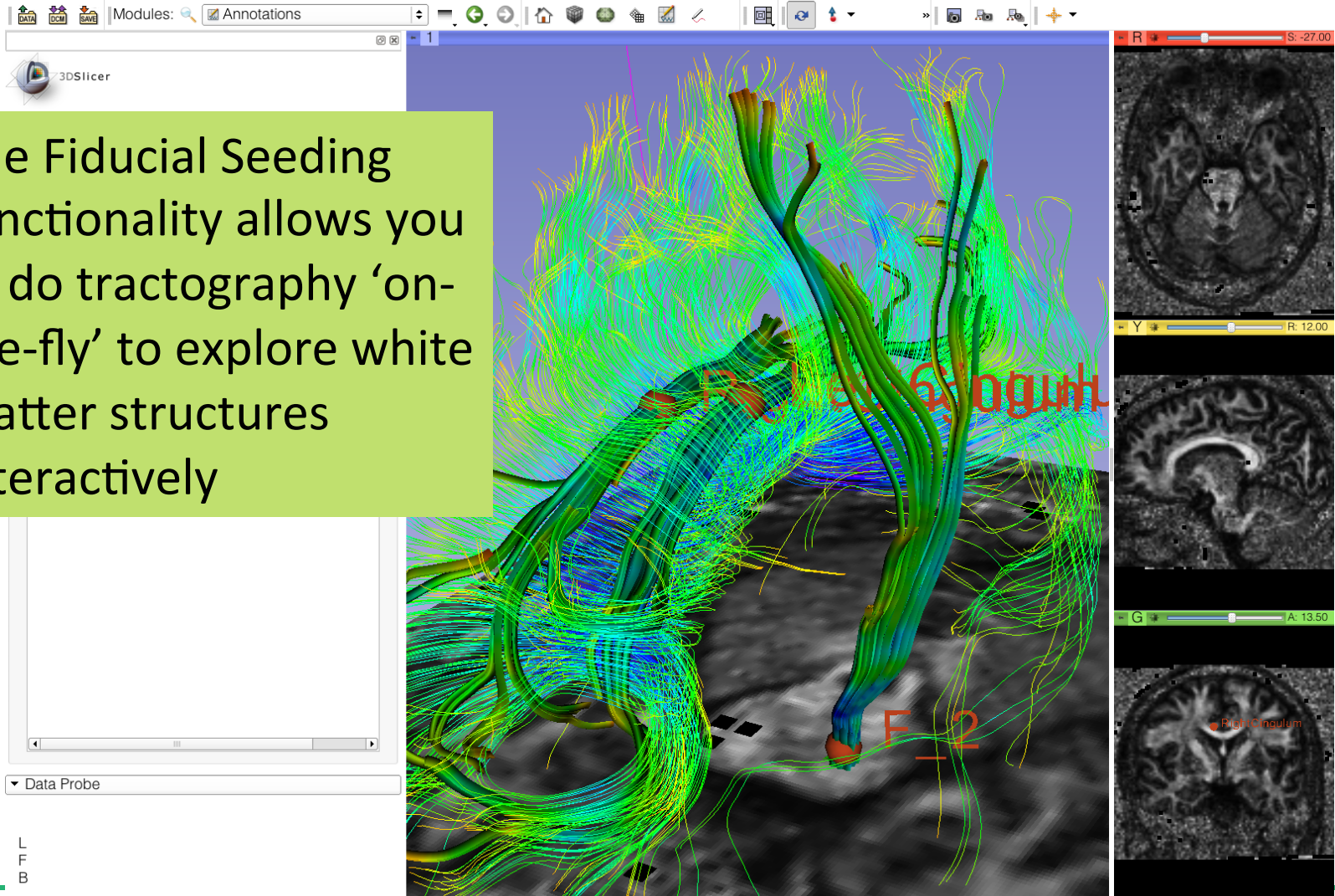
Fiducial Seeding

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

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Tractography 'on-the-fly'

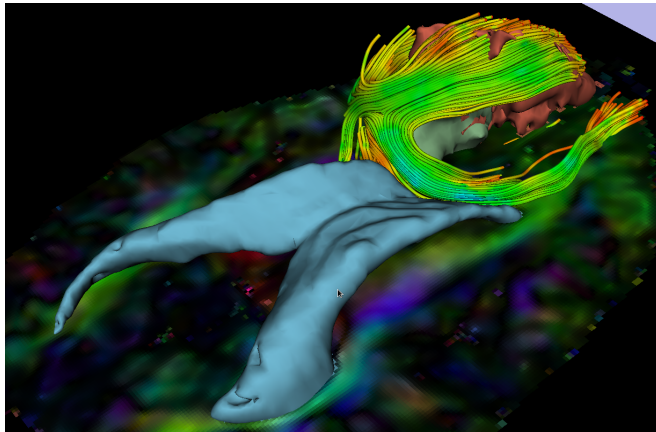The Fiducial Seeding functionality allows you to do tractography 'on-the-fly' to explore white matter structures interactively

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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
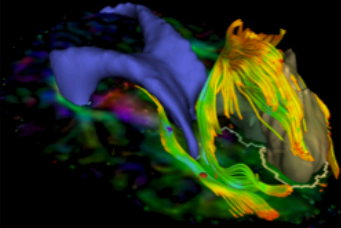
DTI training tutorials in Slicer4:
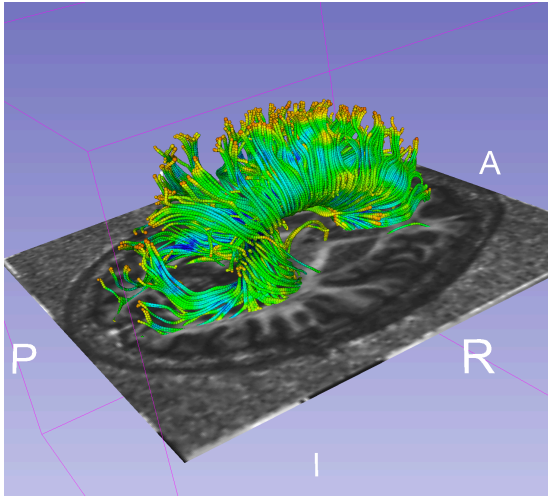
- Diffusion MR Imaging tutorial

- Exploring White Matter peritumoral fibers for exploration for neurosurgical planning

- Tutorials and datasets available at www.slicer.org

Acknowledgments

National Alliance for Medical Image Computing
NIH U54EB005149

Neuroimage Analysis Center
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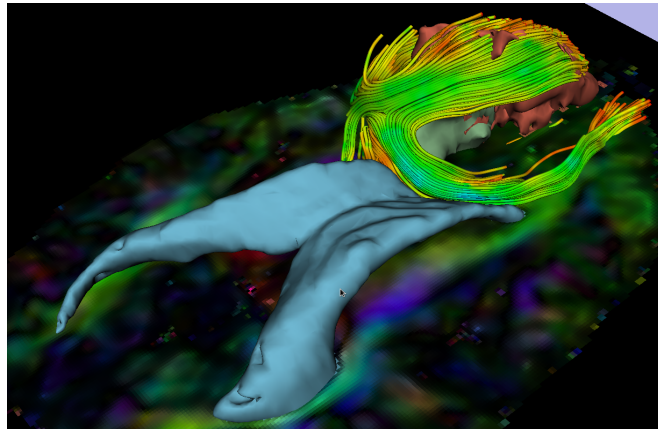
Slicer Community

- www.slicer.org

- Mailing lists:

slicer-user@bwh.harvard.edu

slicer-devel@bwh.harvard.edu

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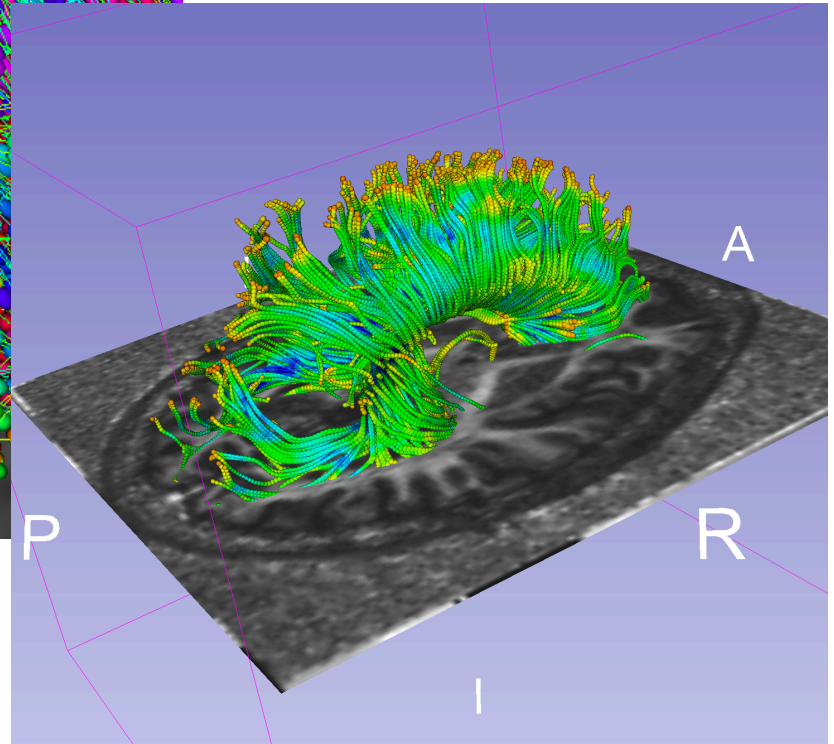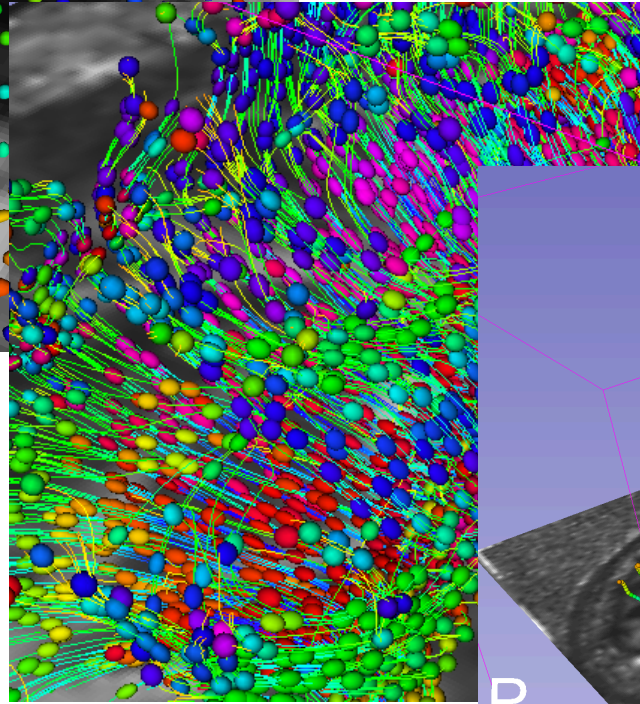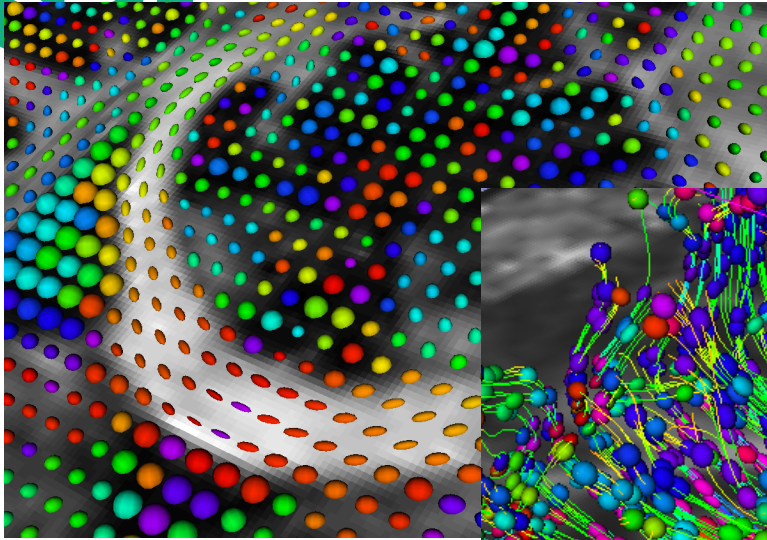
Contact:
spujol@bwh.harvard.edu

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

3DSlicer

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