



Diffusion MRI Analysis

Sonia Pujol, Ph.D.

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Brigham and Women's Hospital
Harvard Medical School

Brain Anatomy



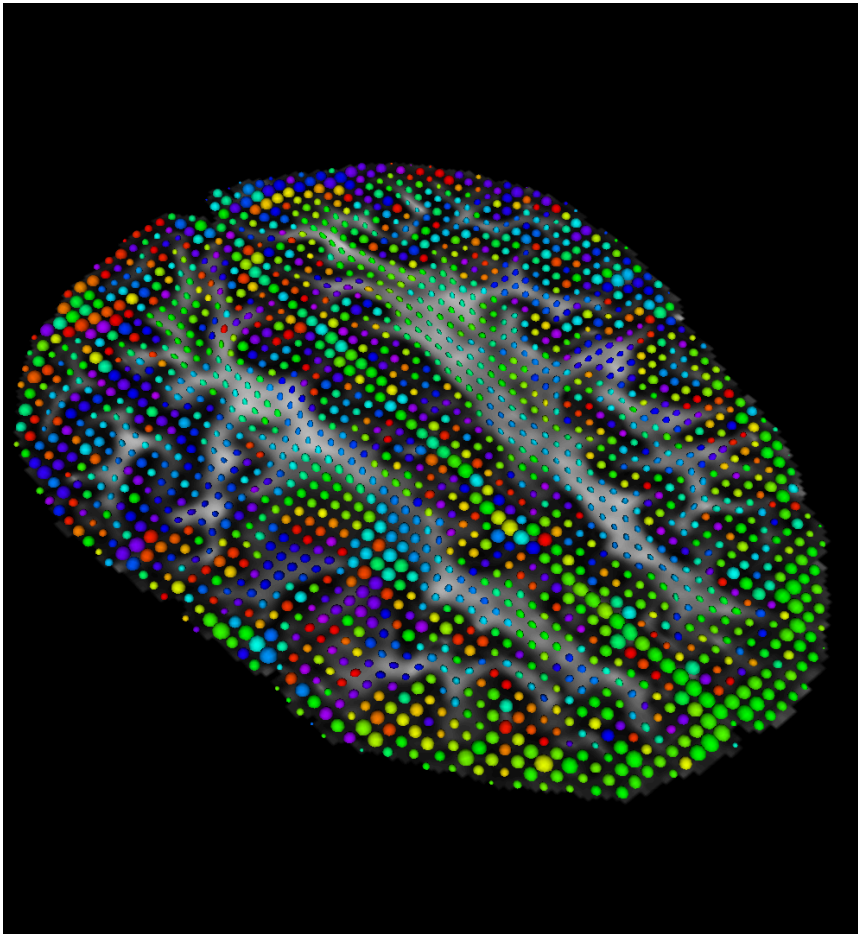
- White matter ~45% of the brain
- Myelinated nerve fibers (~ 10 μm axon diameter)

White Matter Exploration



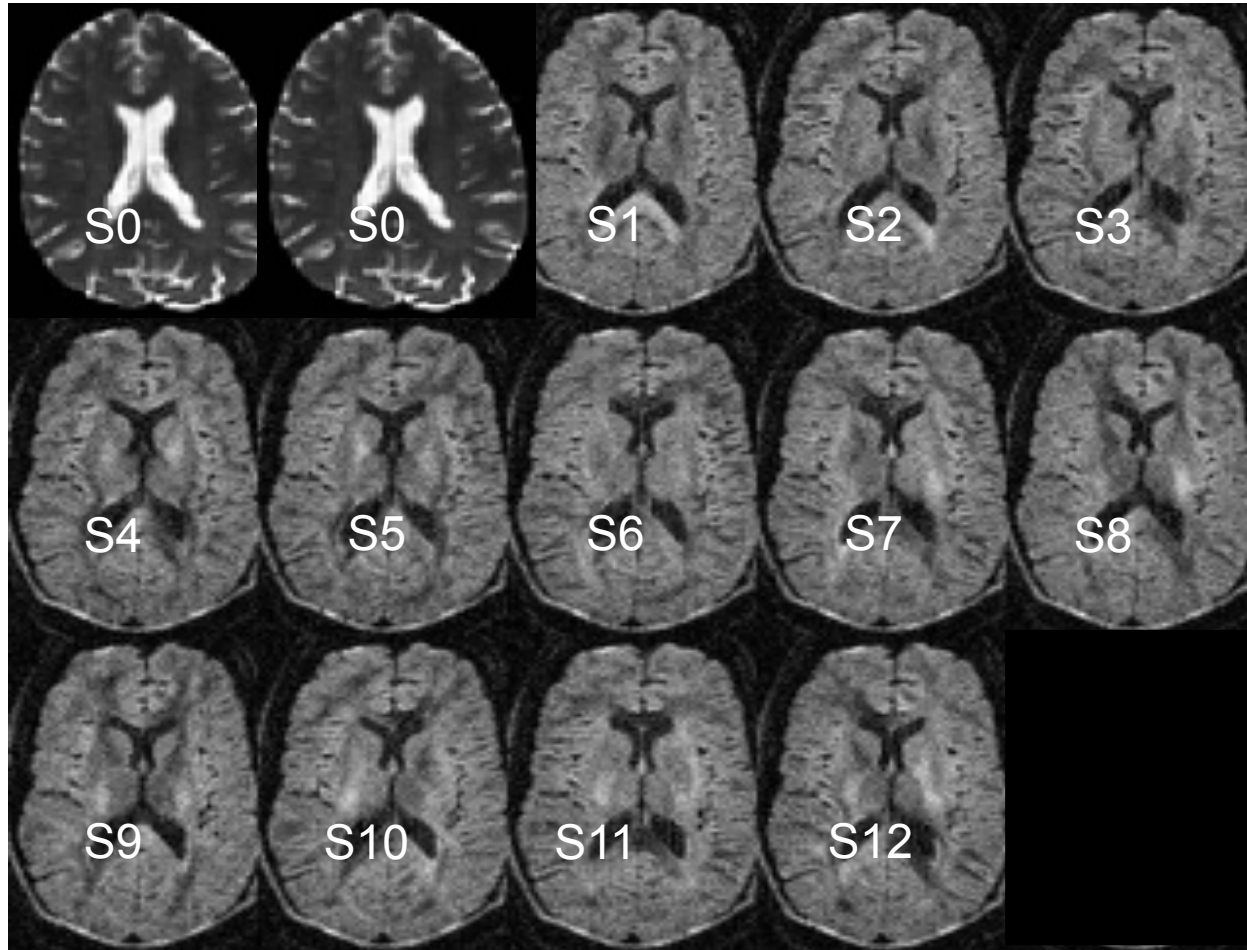
Jules Joseph and Augusta Dejerine (*Anatomie des centres nerveux* (Paris, 1890-1901)): Neuroanatomy atlas based on myelin stained preparation

Diffusion Tensor Imaging (DTI)



- First non-invasive window on white matter anatomy
- Measurement of the motion of water molecules using MRI techniques.
- Three-dimensional reconstruction of the trajectory of white matter bundles

Diffusion Weighted Imaging (DWI)

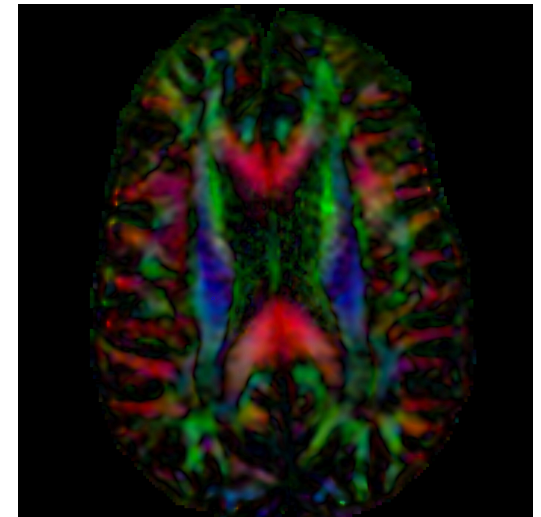
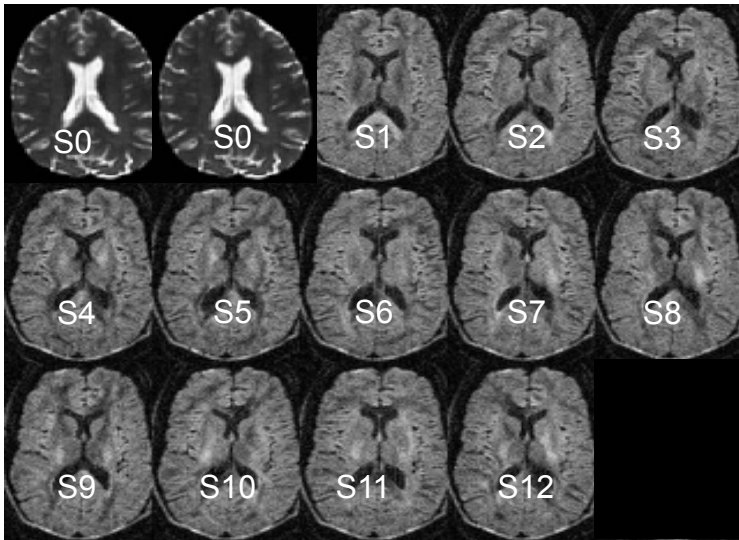


In this example, the DWI scan was acquired with 12 diffusion sensitizing gradient directions (S1-S12) and 2 non-diffusion sensitizing gradients (S0)

From DWI to DTI

DWI

DTI



DWI dataset

DTI dataset

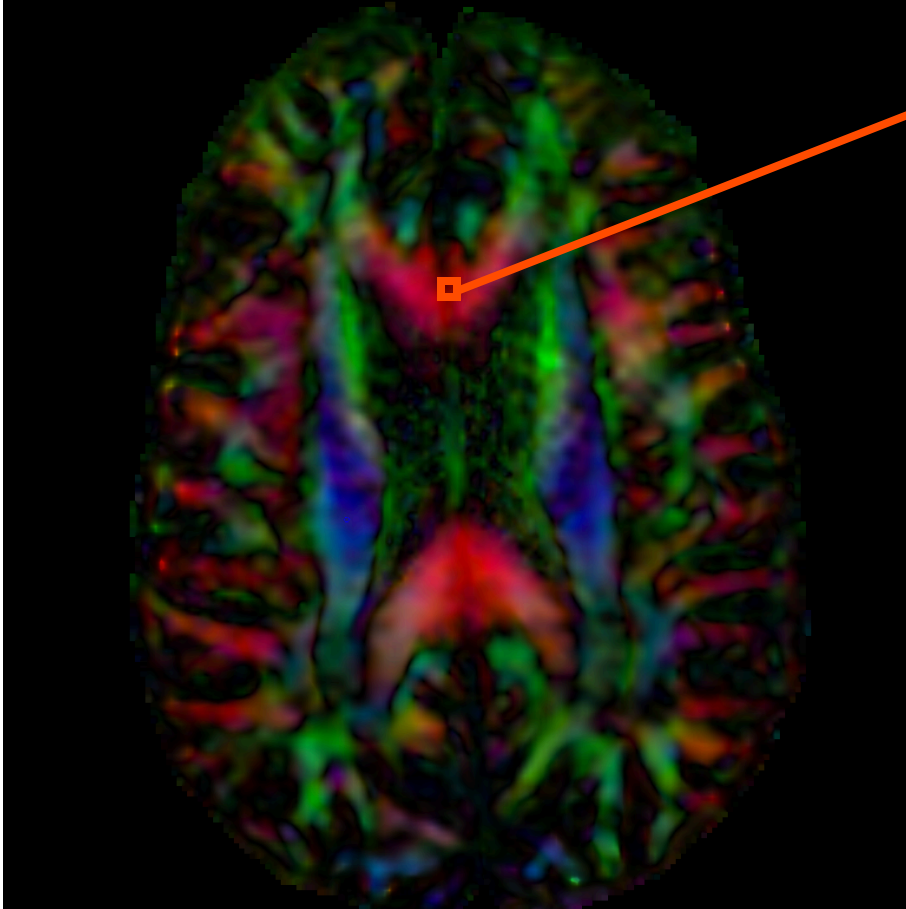
$$S_i = S_0 e^{-b \hat{g}_i^T \underline{D} \hat{g}_i}$$

Stejskal-Tanner (1965)

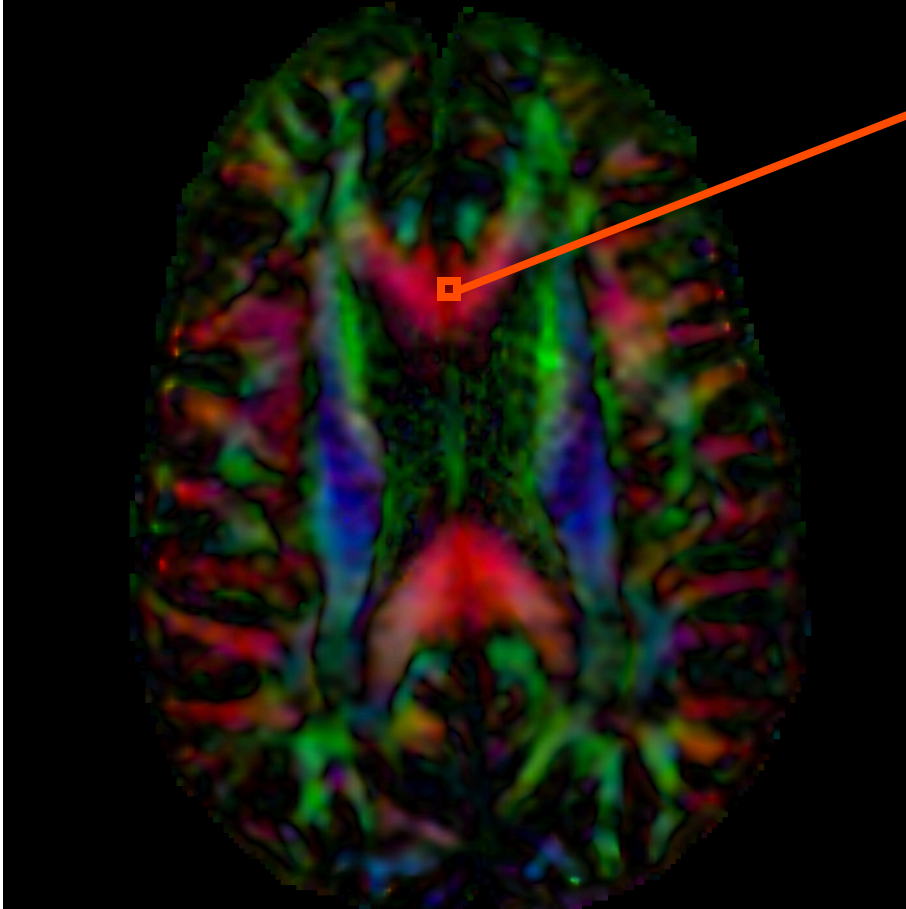
S_i : DWI volume acquired with
 i th gradient
 S_0 : Baseline volume

Diffusion Tensor Imaging

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



Diffusion Tensor Imaging

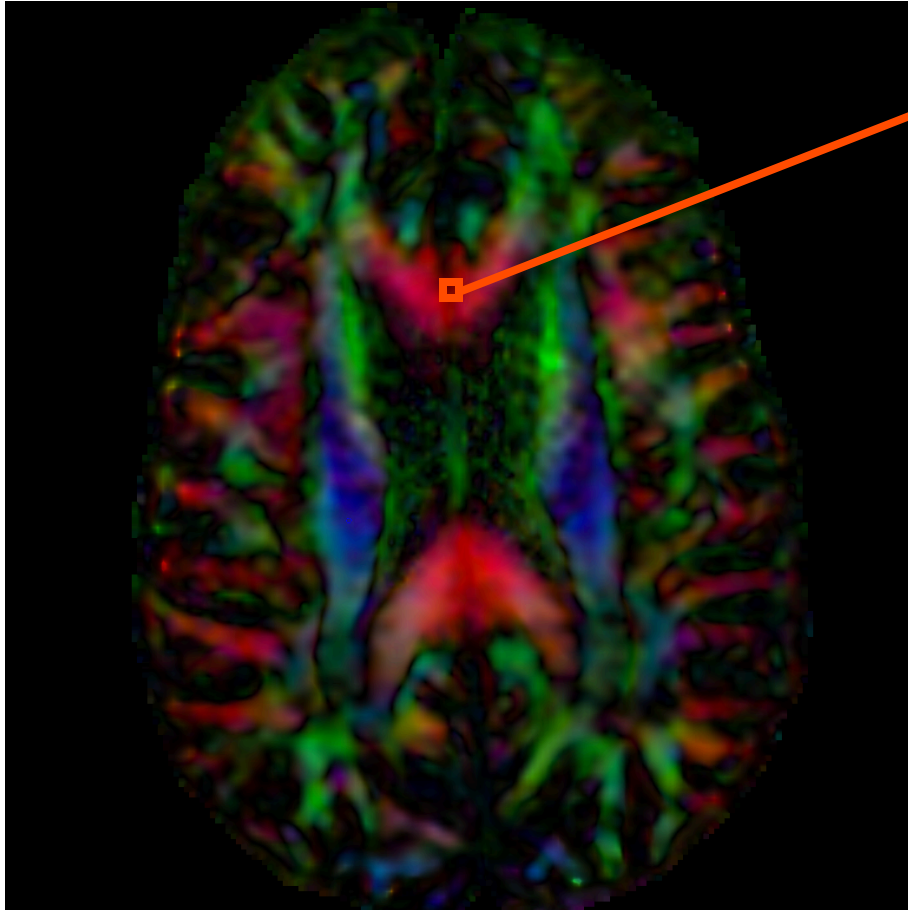


$$S_i = S_0 e^{-b \hat{g}_i^T \underline{D} \hat{g}_i}$$



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

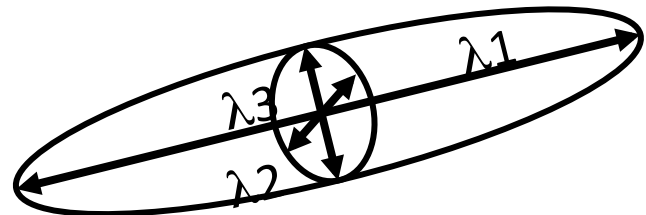
Diffusion Tensor Imaging



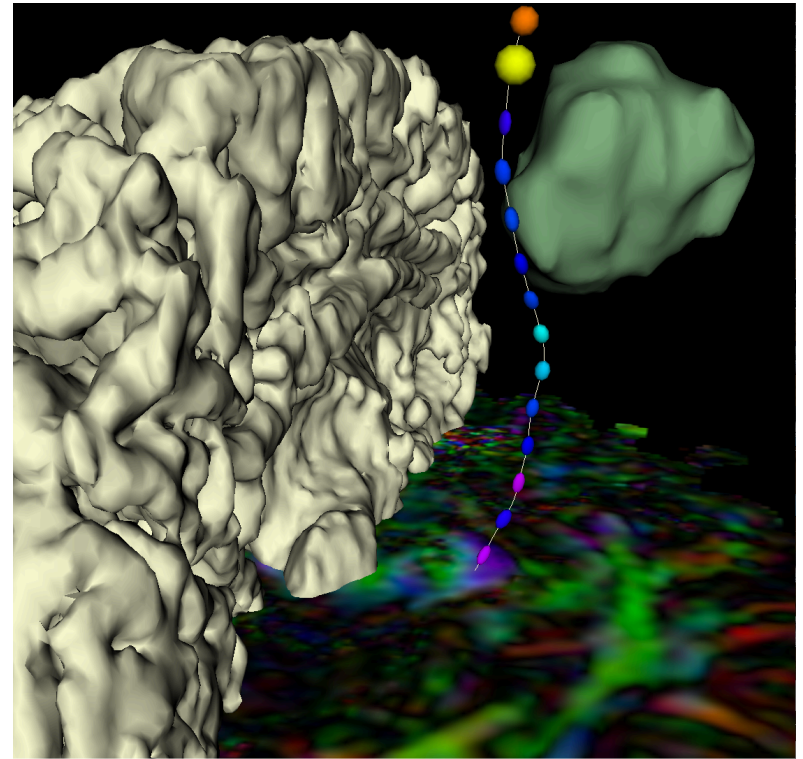
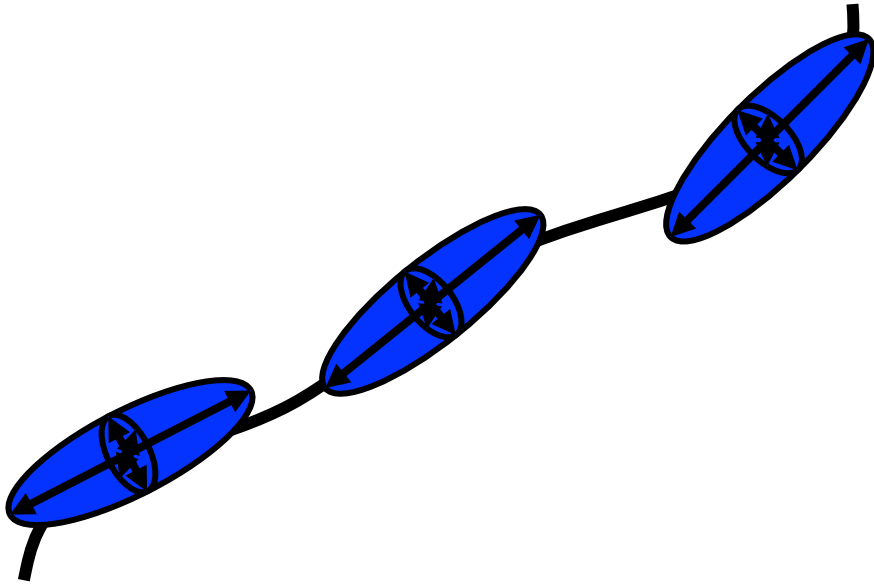
$$S_i = S_0 e^{-b\hat{g}_i^T \underline{D} \hat{g}_i}$$



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



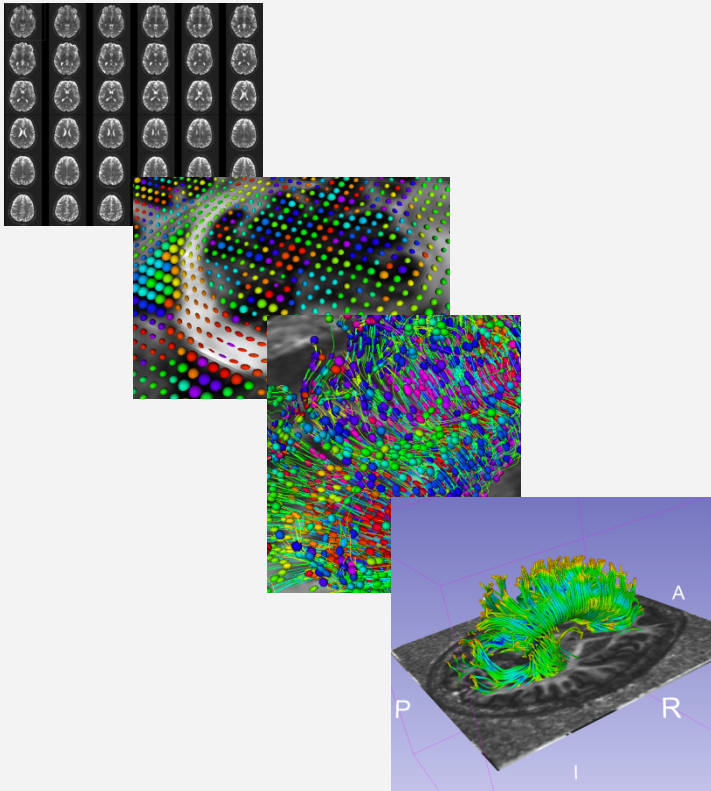
Tractography



DTI tractography provides 3D reconstruction of the trajectory of white matter pathways

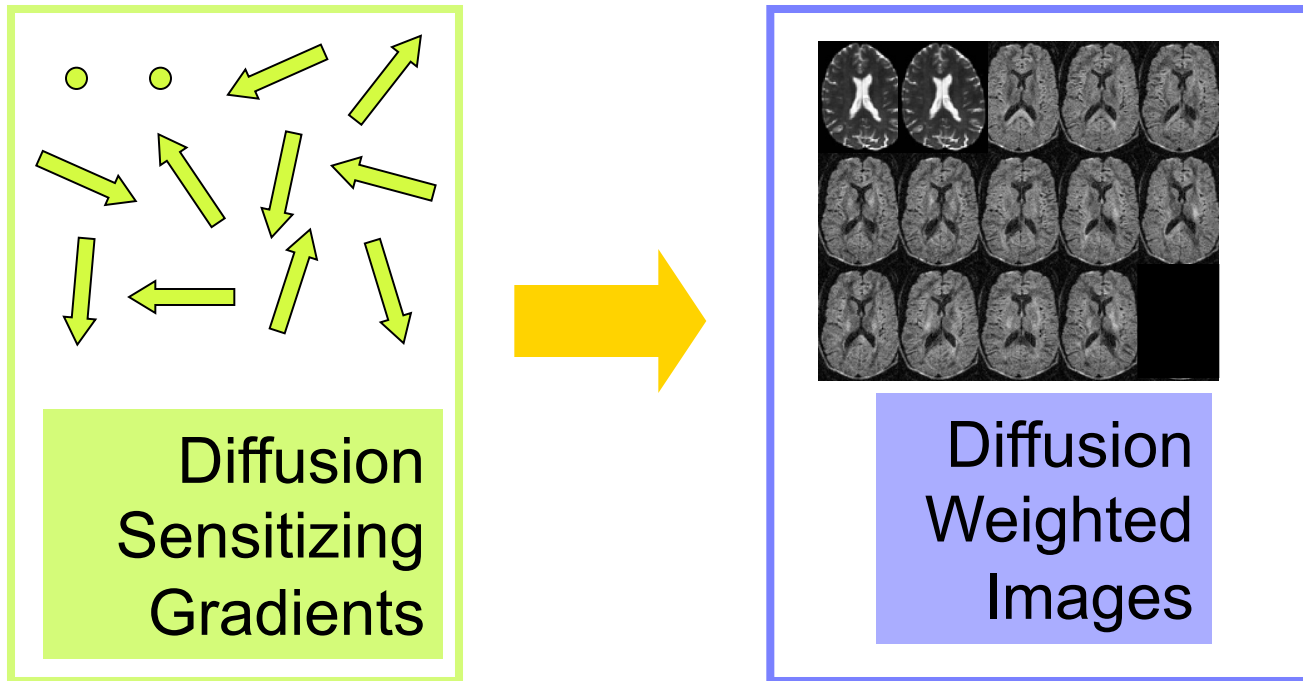
Tutorial Outline

This tutorial is an introduction to the fundamentals of Diffusion MRI analysis, from the estimation of diffusion tensors to the interactive 3D visualization of tracts.



Tutorial Dataset

The tutorial dataset is a Diffusion Weighted MR scan of the brain acquired with 41 diffusion sensitizing gradient directions and 7 baseline.



Tutorial Software

The tutorial was created using the 3D Slicer (Version 4.5) available at:

<http://download.slicer.org>

Please note that the **Diffusion Weighted Volume Masking** module has been updated in 2016. In this tutorial, we use a Slicer nightly build (Slicer4.5.0-2016-02-23). If you plan to use the Diffusion Weighted Volume Mask module, we recommend you download a Slicer nightly build version posterior to 02-23-2016.

Disclaimer

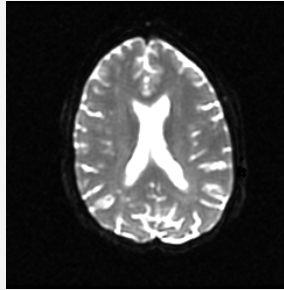
It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules. Slicer is a tool for research, and is not FDA approved.

Learning Objectives

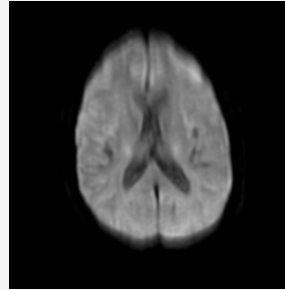
Following this tutorial, you'll be able to

- 1) Estimate a tensor volume from a set of Diffusion Weighted Images
- 2) Understand the shape and size of the diffusion ellipsoid
- 3) Reconstruct DTI tracts from a pre-defined region of interest
- 4) Interactively visualize DTI tracts seeded from a fiducial

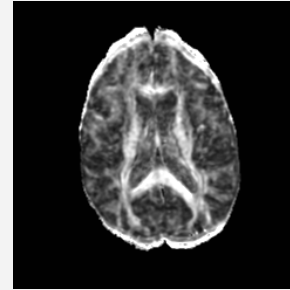
MR Diffusion Analysis Pipeline



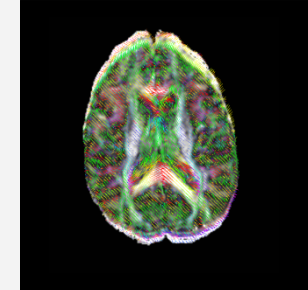
DWI
Acquisition



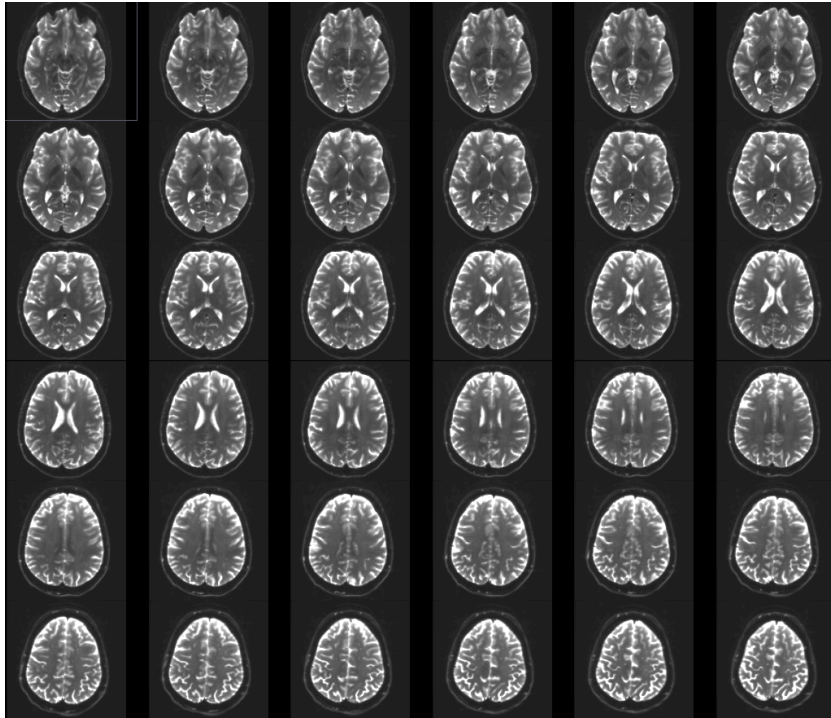
Tensor
Calculation



Scalar
Maps

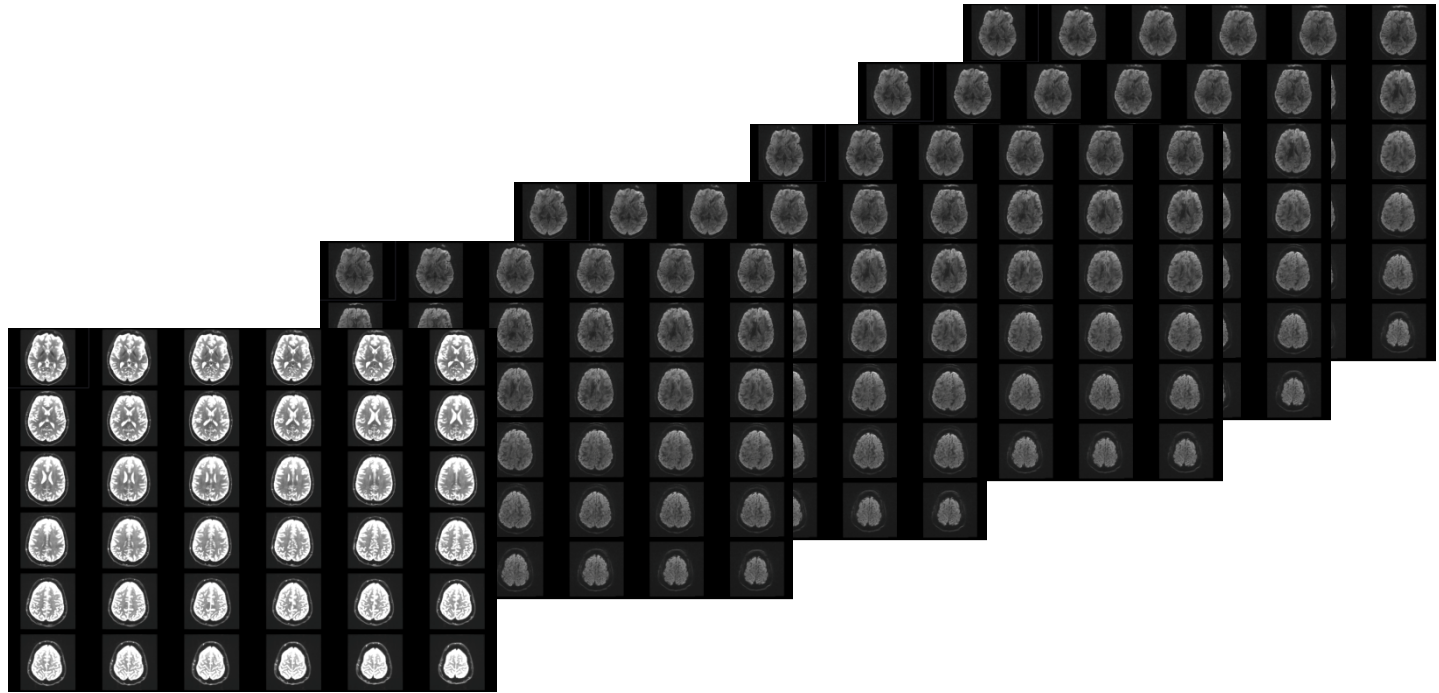


3D
Visualization



Part 1: From DWI images to Tensors

Understanding the DWI Dataset



The Diffusion Weighted Imaging (DWI) dataset is composed of 48 volumes acquired with 41 different diffusion-sensitizing gradient directions, and 7 baseline image acquired without diffusion weighting.

Loading the DWI Dataset

The image shows the 3D Slicer 4.5.0-2016-02-23 interface. The left sidebar contains a 'Welcome' section with buttons for 'Load DICOM Data', 'Load Data', 'Customize Slicer', and 'Download Sample Data'. Below this is a 'Feedback' section with a message: 'Share your stories with us and let us know about how 3D Slicer enabled your research. We are always interested in improving 3D Slicer, and every submission will be carefully read. See more at <http://goo.gl/6BvcHm>.' A 'Data Probe' section is also visible with a 'Show Zoomed Slice' checkbox and labels 'L', 'F', 'B'. The main 3D view shows a blue brain slice with a purple wireframe box. The axes are labeled 'S' (Superior-Inferior), 'R' (Right-Left), 'P' (Posterior-Anterior), and 'L' (Left-Right). The bottom status bar shows 'R: 0.000mm', 'Y: 0.000mm', 'G: 0.000mm', and 'A: 0.000mm'. A yellow text box is overlaid on the 3D view with the text 'First, start Slicer4'. At the bottom of the slide, there is a footer with 'Diffusion MRI Analysis', 'Sonia Pujol, Ph.D.', and 'NA-MIC ARR 2012-2016'.

3D Slicer 4.5.0-2016-02-23

Modules: Welcome to Slicer

3DSlicer

Welcome

Load DICOM Data **Load Data**

Customize Slicer **Download Sample Data**

Feedback

Share your stories with us and let us know about how 3D Slicer enabled your research.

We are always interested in improving 3D Slicer, and every submission will be carefully read.

See more at <http://goo.gl/6BvcHm>.

About

The Main Window

Loading and Saving

Display

Mouse & Keyboard

Data Probe

Show Zoomed Slice

L
F
B

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

First, start Slicer4

Loading the DWI Dataset

3DSlicer

Welcome

Load DICOM Data Load Data Customize Slicer Download Sample Data

Feedback

Share your stories with us and let us help you enable your research.

We are always interested in improving 3D Slicer. Please carefully read.

See more at <http://go.slicer.org>

About

- The Main Window
- Loading and Saving
- Display
- Mouse & Keyboard
- Data Probe

Show Zoomed Slice

L
F
B

dti_tutorial_dataset

Name	Date Modified	Size	Kind
dwi.nrrd	3 Jun 2015 5:15 pm	85 MB	Document

In your files archive, locate the file **dwi.nrrd** in the dataset folder for this tutorial



Loading the DWI Dataset

The screenshot shows the 3D Slicer application interface. The main window displays a 'Welcome' message with buttons for 'Load DICOM Data', 'Load Data', 'Customize Slicer', and 'Download Sample Data'. A file explorer window is open, showing a folder named 'dti_tutorial_dataset' containing a file named 'dwi.nrrd' (85 MB, Document). A red arrow points from the 'dwi.nrrd' file to the 'L' label on the 3D viewer, which is part of a coordinate system (R, P, L, S). A yellow callout box contains the text: 'Drag and drop the file **dwi.nrrd** onto the viewer of the Slicer4 application'.

Drag and drop the file **dwi.nrrd** onto the viewer of the Slicer4 application



Loading the DWI Dataset

3DSlicer

Welcome

Load DICOM Data

Customize Slicer

Feedback

Share your stories with us and enabled your research.

We are always interested in improving carefully read.

See more at <http://>

About

The Main Window

Loading and Saving

Diffusion MRI Analysis

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5 cm

5 cm

5 cm

1

S

L

R: 0.000mm G A: 0.000mm

Add data into the scene

Choose Directory to Add Choose File(s) to Add Show Options

File	Description
✓ ...fan/Dropbox_usyd/Dropbox/Fan/data/dti_tutorial_dataset/dwi.nrrd	Volume

Reset OK Cancel

Exit the archive folders window, and click **OK** to load the dataset to Slicer

Loading the DWI Dataset

3DSlicer

Welcome

Load DICOM Data **Load Data**

Customize Slicer **Download Sample Data**

Feedback

Slicer displays DWI volume of the brain

See more at <http://goo.gl/6BvcHm>.

- About
- The Main Window
- Loading and Saving
- Display
- Mouse & Keyboard
- Data Probe

Show Zoomed Slice

L
F
B

1

S
R P L
I

R S: 0.000mm Y R: 1.500mm G A: 1.500mm

B: dwi B: dwi B: dwi

5 cm 5 cm 5 cm



Loading the DWI Dataset

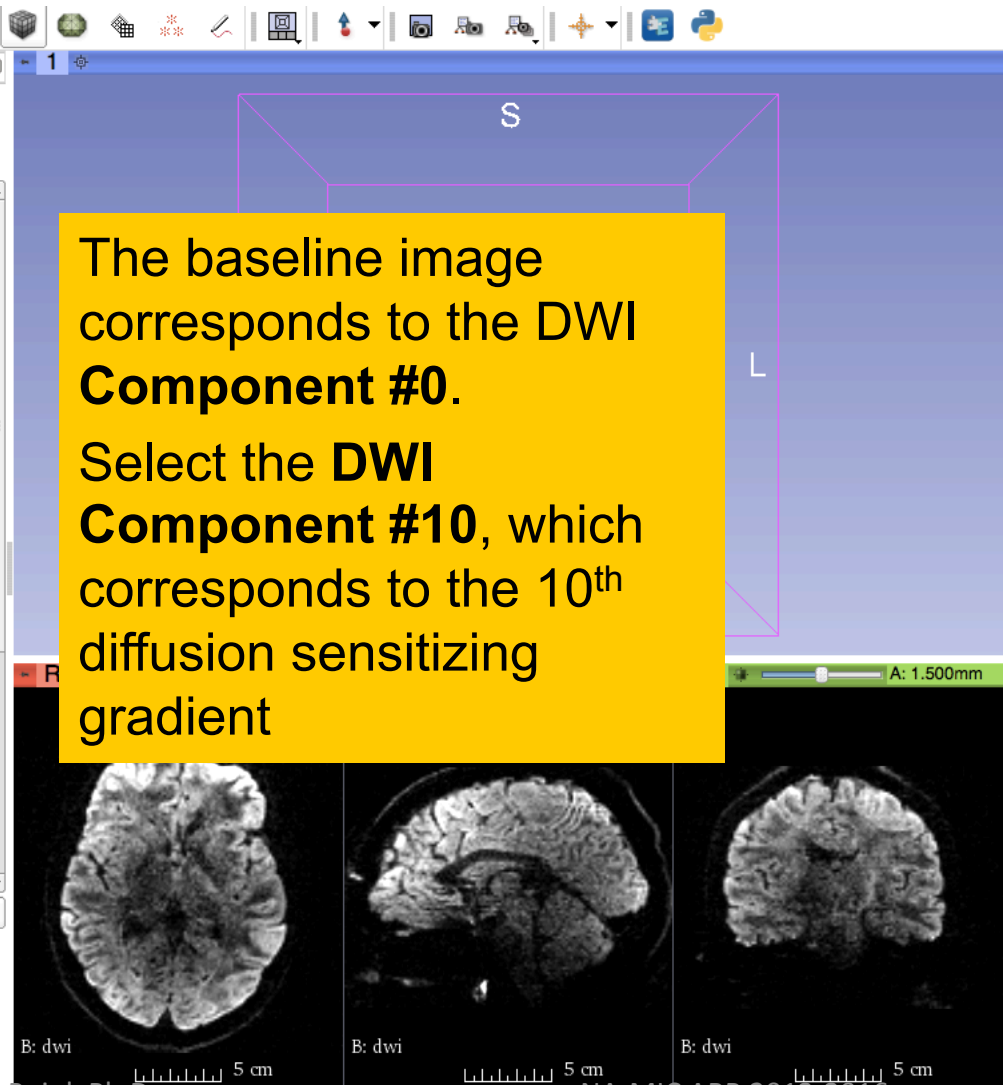
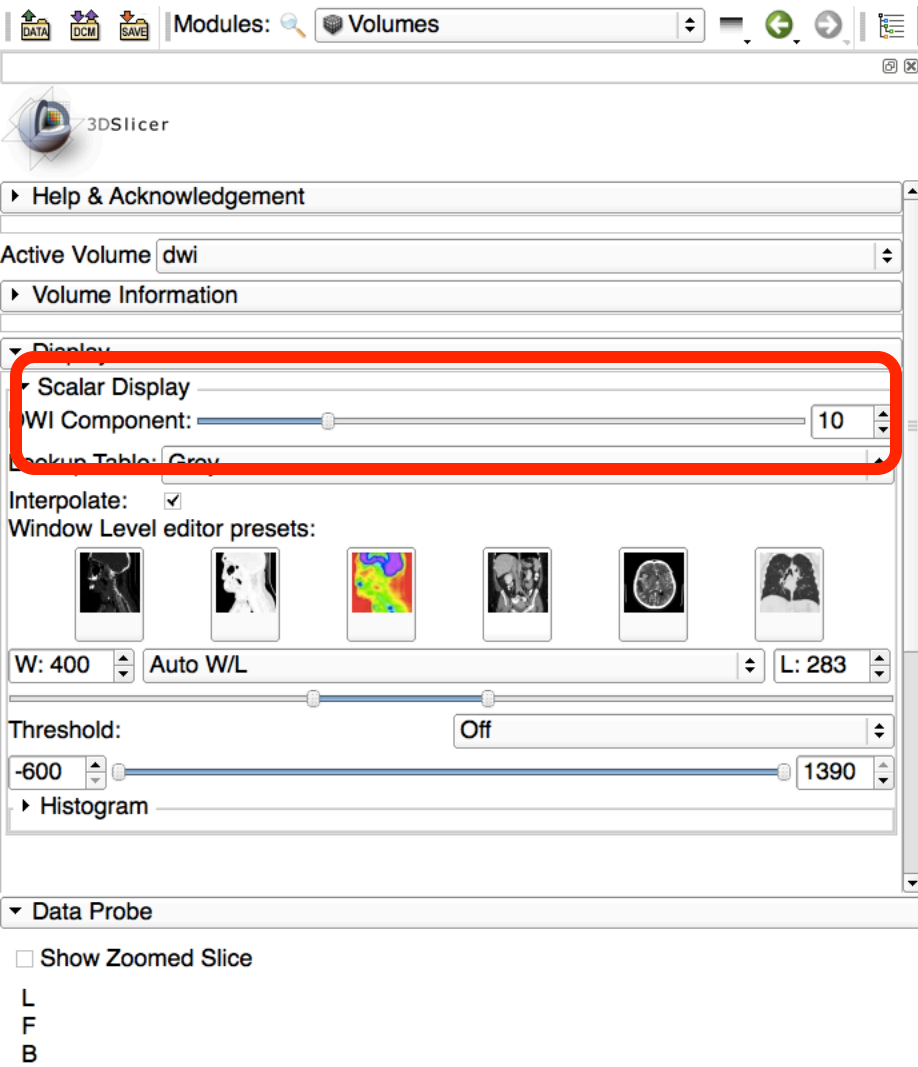
Click on the **Modules** menu and select the module **Volumes**

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Loading the DWI Dataset



The baseline image corresponds to the DWI **Component #0**.

Select the **DWI Component #10**, which corresponds to the 10th diffusion sensitizing gradient



Loading the DWI Dataset

Adjust the **Window Level editor presets** with the **Volume** module menu

W: 450 Manual W/L L: 288

Diffusion MRI Analysis

Loading the DWI Dataset

The screenshot displays the 3D Slicer software interface. On the left, the 'Volumes' module is active, showing the 'Display' section with 'Scalar Display' set to 'DWI Component' (value 10) and 'Look up Table' set to 'Grey'. Below this, the 'Window Level editor presets' are visible, including icons for different image types. The 'W: 450' and 'L: 288' sliders are also present. A red arrow points from the 'Link' icon in the bottom toolbar to the 'Fit Image to Window' icon. Another red arrow points from the 'Fit Image to Window' icon to the 'Image' icon in the bottom toolbar. A yellow text box with a red border contains the instruction: 'Position your mouse over the pin icon, then click on the link icon and the fit image to window icon'. The main 3D view shows a brain slice with a purple bounding box and a white 'S' label. The bottom toolbar shows the 'R' (Right) view selected, with 'S: 0.000mm', 'Y' (Superior-Inferior) view, 'R: 1.500mm', 'G' (Grayscale) view, and 'A: 1.500mm'. The bottom right corner shows three brain slices in different views (Axial, Sagittal, Coronal) with a 5 cm scale bar.

Position your mouse over the pin icon, then click on the link icon and the fit image to window icon



Loading the DWI Dataset

The screenshot displays the 3DSlicer software interface. On the left, the 'Display' panel is visible, showing 'Active Volume: dwi' and 'DWI Component: 10'. A yellow callout box with black text is overlaid on the interface, pointing to the layout menu. The callout text reads: 'Click on the Slicer layout menu and select the Red slice only layout'. The layout menu is open, showing various options such as 'Conventional', 'Four-Up', and 'Red slice only', which is currently selected. The background shows a 3D view of a brain slice with a purple wireframe box and a red arrow pointing to the 'Red slice only' option in the menu.

Click on the Slicer layout menu and select the **Red slice only** layout



Loading the DWI Dataset

3DSlicer

Modules: Volumes

Active Volume: dwi

Volume Information

Disp

Sca

DWI C

Looku

Interp

Window Level editor presets:

W: 450 Manual W/L L: 288

Threshold: Off

-600 1390

Histogram

Data Probe

Red RAS: (32.5, 43.5, -0.8) Axial Sp: 1.5

L None

F None

B dwi (42, 35, 47) 49 components

Diffusion MRI Analysis

Slicer displays only the Axial anatomical slice in the Viewer

B: dwi

5 cm

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Creating a brain mask

The image shows the 3D Slicer software interface. On the left, the 'Modules' menu is open, listing various tools. The 'Diffusion' category is expanded, and 'Diffusion Weighted Volume Masking' is highlighted. A yellow callout box with a red arrow points to this option. The main window displays a brain MRI slice with a red 'R' marker and a scale of -0.750mm. The bottom of the screen features a footer with the text 'Diffusion MRI Analysis', 'Sonia Pujol, Ph.D.', and 'NA-MIC ARR 2012-2016'.

Click on the Modules menu and select the module **Diffusion Weighted Volume Masking**

Diffusion MRI Analysis

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Creating a brain mask

The screenshot shows the 3DSlicer software interface with the 'Diffusion Weighted Volume Masking' module selected. The 'IO' section is highlighted with a red box, showing the following settings:

- Input DWI Volume: dwi
- Output Baseline Volume: baseline
- Otsu Threshold Mask: dwi_mask

Below the IO section, the 'Baseline B-Value Threshold Parameter' is set to 100.00, and the 'Remove Islands in Threshold Mask' checkbox is checked. The status bar at the bottom indicates 'Status: Idle' and 'RAS: (115.5, -8.6, 13.2) Axial Sp: 1.5'.

- Select the Input DWI volume 'dwi'
- Select Output Baseline Volume 'Create and Rename New Volume', and rename it 'baseline'
- Select Output Threshold Volume 'Create and Rename new Volume', and rename it 'dwi_mask'
- set Baseline B-Value Threshold Parameter to 100
- Check Remove Islands in Threshold Mask
- Click on **Apply**.

Note: This version of the Diffusion Weighted Volume Masking module is available in the Slicer4.5 nightly build posterior to Feb.23, 2016

Creating a brain mask

The screenshot displays the 3DSlicer software interface. The top toolbar shows the 'Diffusion Weighted Volume Masking' module selected. The left sidebar contains the 'Diffusion Weighted Volume Masking' parameter set, with the following settings:

- Input DWI Volume: dwi
- Output Baseline Volume: baseline
- Otsu Threshold Mask: dwi_mask
- Baseline B-Value Threshold Parameter: 100.00
- Remove Islands in Threshold Mask:

A green callout box with the text "Slicer displays the brain mask" is overlaid on the interface. The main window shows a brain slice with a blue mask applied to the brain tissue. The status bar at the bottom indicates "Status: Completed" and "100%".

Estimating the tensor

The image shows the 3DSlicer software interface. On the left, the 'Modules' menu is open, showing a list of categories. The 'Diffusion' category is selected, and its sub-menu is displayed. In this sub-menu, 'Diffusion Weighted Images' is selected, and its sub-menu is also open, showing 'DWI to DTI Estimation' as the selected option. A yellow callout box with a red arrow points to this option. The background shows a brain MRI slice with a red 'R' marker and a scale bar of 5 cm. The bottom of the screen contains text: 'Diffusion MRI Analysis', 'Sonia Pujol, Ph.D.', and 'NA-MIC ARR 2012-2016'.

Click on the Modules menu and select the module **DWI to DTI Estimation**

Diffusion MRI Analysis

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Estimating the tensor

3DSlicer

Modules: **DWI to DTI Estimation**

Parameter set: **DWI to DTI Estimation**

IO

Input DWI Volume:

Diffusion Tensor Mask:

Output DTI Volume:

Output Baseline Volume:

Estimation Parameters

Estimation Parameters: LS **WLS**

Shift Negative Eigenvalues:

Status: Idle

- Select the module **DWI to DTI Estimation** in the modules menu:
- Set the **Input DWI volume** to 'dwi'
- Set the **Diffusion Tensor Mask** to 'dwi_mask'
- Select **Output DTI Volume 'Create and Rename New Volume'**, and rename it 'dti'
- Set **Output Baseline Volume** to 'baseline'
- Select the **Estimation Parameters 'WLS'** (Weighted Least Squares) and click on **Apply**.

Estimating the tensor

Position your mouse over the **pin icon** and select the volume **dti**

Modules: **DWI to DTI Estimation**

3DSlicer

Help & Acknowledgments

DWI to DTI Estimation

Parameter set: DWI to DTI Estimation

IO

Input DWI Volume: **dwi**

Diffusion Tensor Mask: **dwi_mask**

Output DTI Volume: **dti**

Output Baseline Volume: **baseline**

Estimation Parameters

Estimation Parameters: LS WLS

Shift Negative Eigenvalues:

Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Volumes: **dti**

None
dwi
Output Baseline Volume
baseline
dwi_mask
dti
Rename current volume: DiffusionTensorVolume

B: baseline

5 cm

L
F
B

Diffusion MRI Analysis

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Exploring the DWI Dataset

3DSlicer

Modules: DWI to DTI Estimation

Help & Acknowledgement

DWI to DTI Estimation

Parameter Settings

IO

Input DWI Volume

Diffusion Tensor

Output DTI Volume

Output Basis

Estimation

Estimation Method

Shift Negative

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

L
F
B

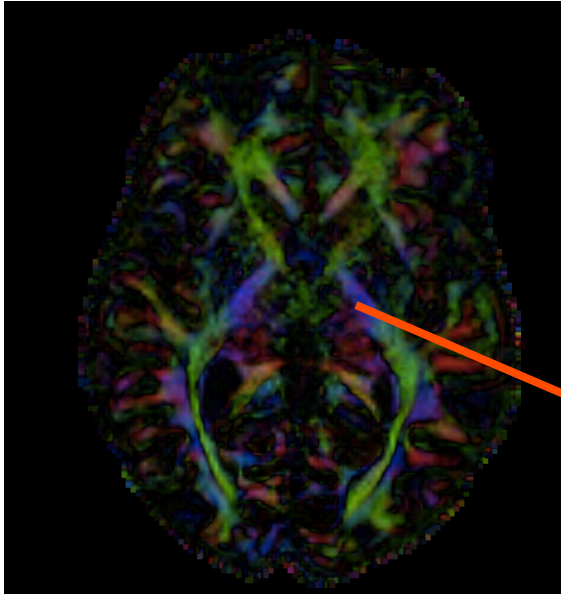
B: dti

5 cm

S: 0.000mm



Diffusion Tensor Data



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

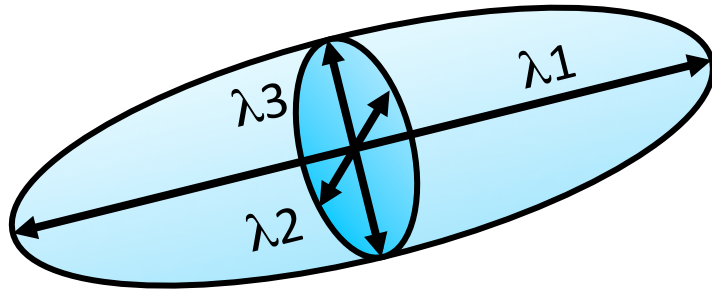
Stejskal-Tanner equation (1965)

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

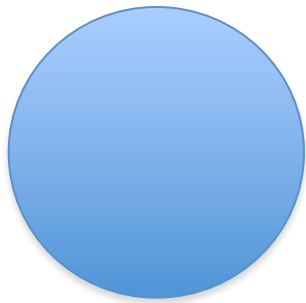
The diffusion tensor $\underline{\mathbf{D}}$ in the voxel (I,J,K) is a 3x3 symmetric matrix.

Diffusion Tensor

- The diffusion tensor \underline{D} in each voxel can be visualized as a diffusion ellipsoid, with the eigenvectors indicating the directions of the principal axes, and the ellipsoidal proportional to the square root of the eigenvalues defining the
- Scalar maps can be derived from the rotationally invariant eigenvalues λ_1 , λ_2 , λ_3 to characterize the size and shape of the diffusion tensor.

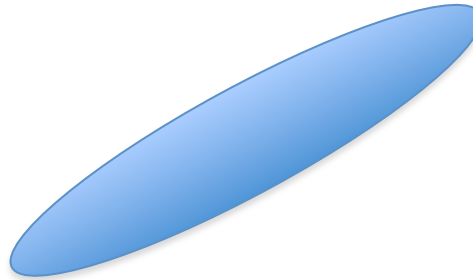


Diffusion Tensor Shape



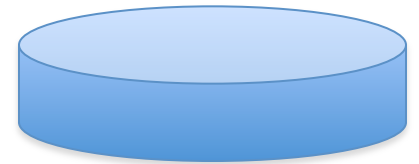
$$\lambda_1 = \lambda_2 = \lambda_3$$

Isotropic media
(Cerebrospinal
Fluid, gray matter)



$$\lambda_1 \gg \lambda_2, \lambda_3$$

Anisotropic media
(white matter)



$$\lambda_1 \sim \lambda_2 \gg \lambda_3$$

Exploring the DWI Dataset

3DSlicer

Modules: **DWI to DTI Estimation**

Help & Acknowledgement

DWI to DTI Estimation

Parameter set: DWI to DTI Estimation

IO

Input DWI Volume: dwi

Diffusion Tensor Mask: dwi_mask

Output DTI Volume: dti

Output Baseline Volume: baseline

Estimation Parameters

Estimation Parameters: LS DTI

Shift Negative Eigenvalues:

Status: Completed

100%

Restore Defaults | AutoRun | Cancel | Apply

Data Probe

L
F
B

B: dti

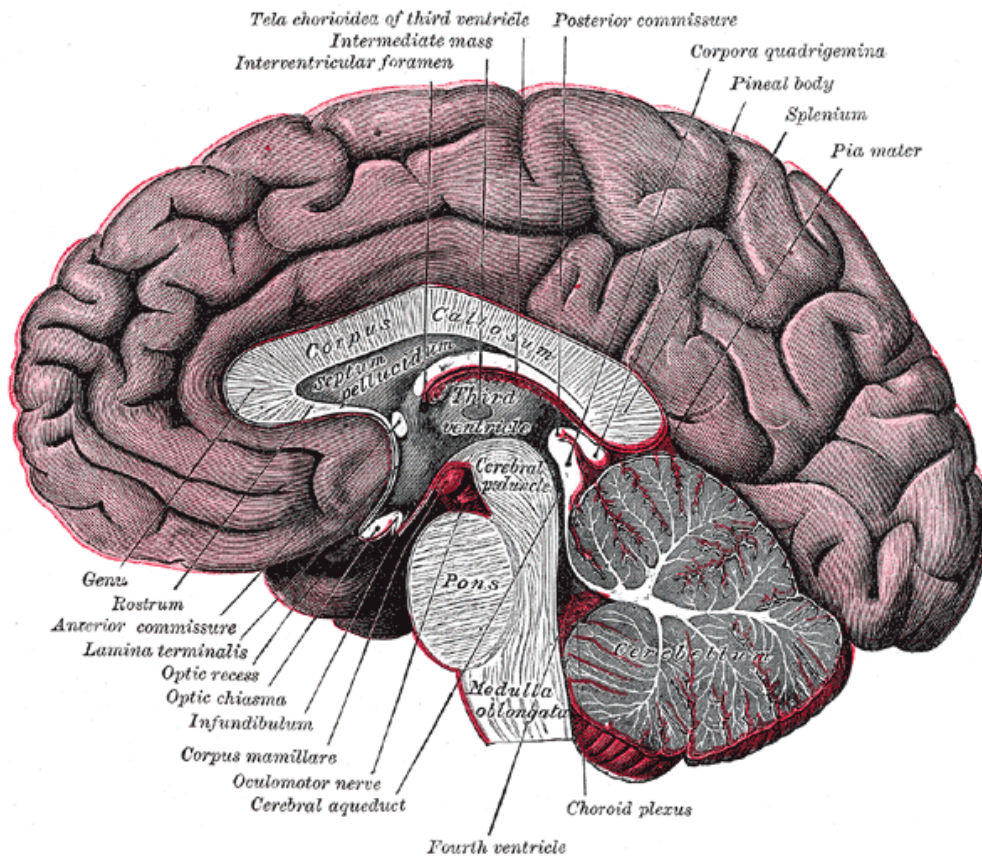
5 cm

S: 0.000mm

Use the slider to browse through the dti volume, and try to locate the **Corpus Callosum**



Corpus Callosum



The corpus callosum is a broad thick bundle of dense myelinated fibers that connect the left and right hemisphere. It is the largest white matter structure in the brain

Image from Gray's Anatomy

Corpus Callosum

3DSlicer

Modules: DWI to DTI Estimation

Help & Acknowledgement

DWI to DTI Estimation

Parameter set: DWI to DTI Estimation

IO

Input DWI Volume: dwi

Diffusion Tensor Mask: dwi_mask

Output DTI Volume: dti

Output Baseline Volume: baseline

Estimation Parameters

Estimation Parameters: LS WLS

Shift Negative Eigenvalues:

Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

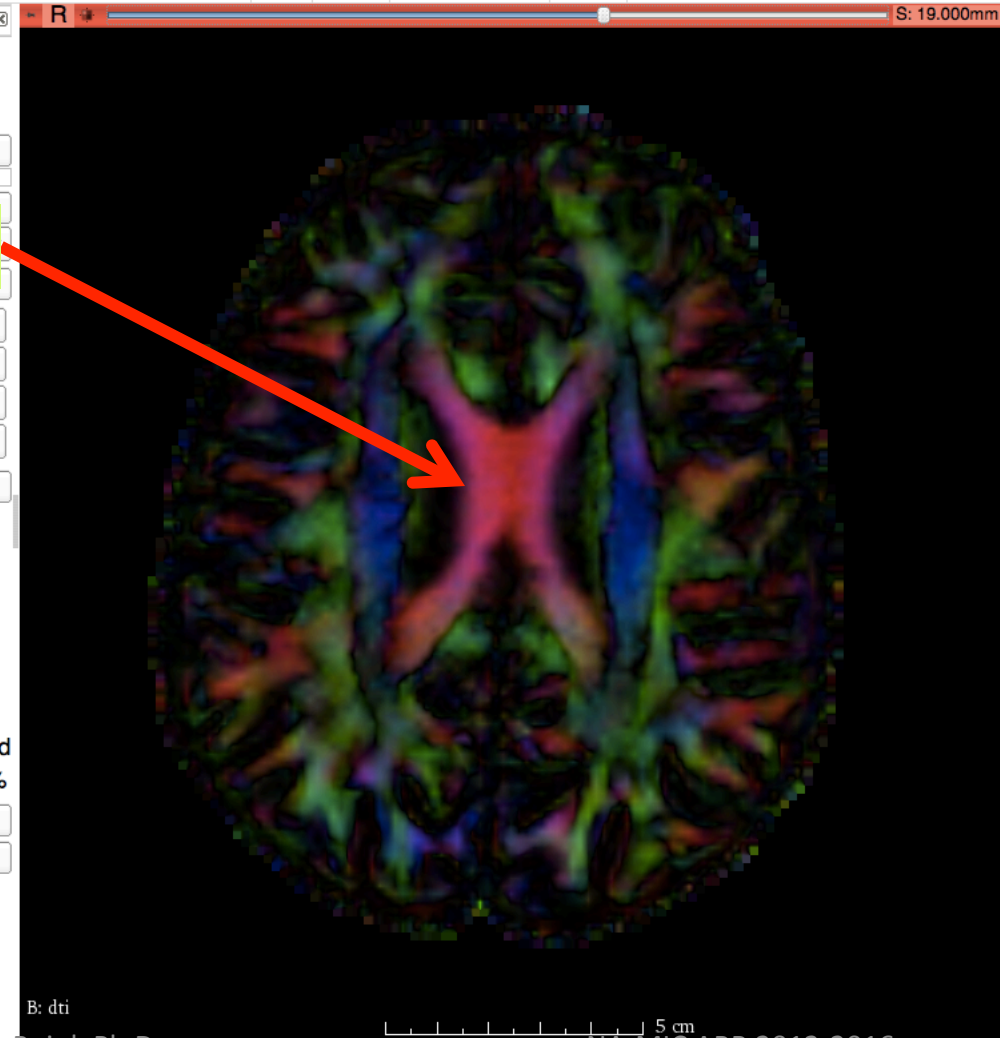
Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Corpus Callosum



L
F
B



Characterizing the Size of the tensor: Trace

$$\text{Trace}(D) = \lambda_1 + \lambda_2 + \lambda_3$$

- Trace(D) is intrinsic to the tissue and is independent of fiber orientation, and diffusion sensitizing gradient directions
- Trace(D) is a clinically relevant parameter for monitoring stroke and neurological condition (degree of structural coherence in tissue)
- Trace(D) is useful to characterize the size of the diffusion ellipsoid

Trace

Click on the Modules menu and select the module **Diffusion Tensor Scalar Measurements**

3DSlicer

Modules: DWI to DTI Estimation

All Modules

- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer

Wizards

- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion**
 - DWI to Full Brain Tractography
 - Tractography Display
 - Diffusion Data Conversion
 - Diffusion Tensor Images**
 - Diffusion Tensor Scalar Measurements**
 - Resample DTI Volume
 - Tractography Interactive Seeding
 - Tractography Label Map Seeding
 - Diffusion Weighted Images
 - Tractography
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support
- Unspecified
- BRAINS

Help & Acknowledgement

DWI to DTI Estimation

Parameter set: DWI to DTI Estimation

IO

Input DWI Volume: dwi

Diffusion Tensor Mask: dwi

Output DTI Volume: dti

Output Baseline Volume: baseline

Estimation Parameters

Estimation Parameters

Shift Negative Eigenvalues

Restore Defaults AutoRun

Data Probe

L
F
B

Diffusion MRI Analysis

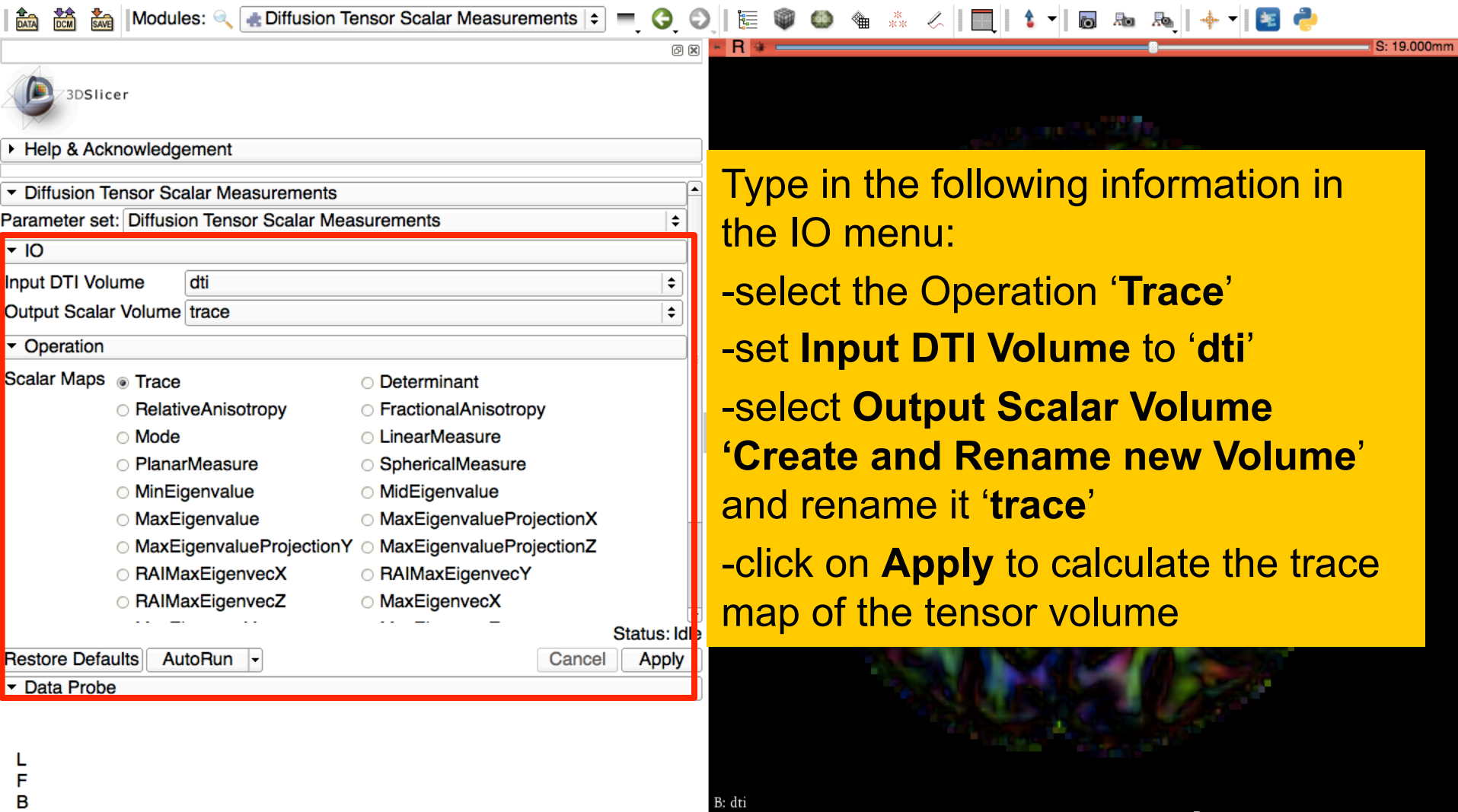
S: 19.000mm

B: dti

5 cm

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Trace



Type in the following information in the IO menu:

- select the Operation '**Trace**'
- set **Input DTI Volume** to '**dti**'
- select **Output Scalar Volume** '**Create and Rename new Volume**' and rename it '**trace**'
- click on **Apply** to calculate the trace map of the tensor volume



Trace

3DSlicer

Modules: Diffusion Tensor Scalar Measurements

Help & Acknowledgement

Diffu

Param

IO

Input D

Output Scalar Volume trace

Operation

Scalar Maps

- Trace
- Determinant
- RelativeAnisotropy
- FractionalAnisotropy
- Mode
- LinearMeasure
- PlanarMeasure
- SphericalMeasure
- MinEigenvalue
- MidEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionY
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecX
- RAIMaxEigenvecY

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

L
F
B

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

B: trace

5 cm

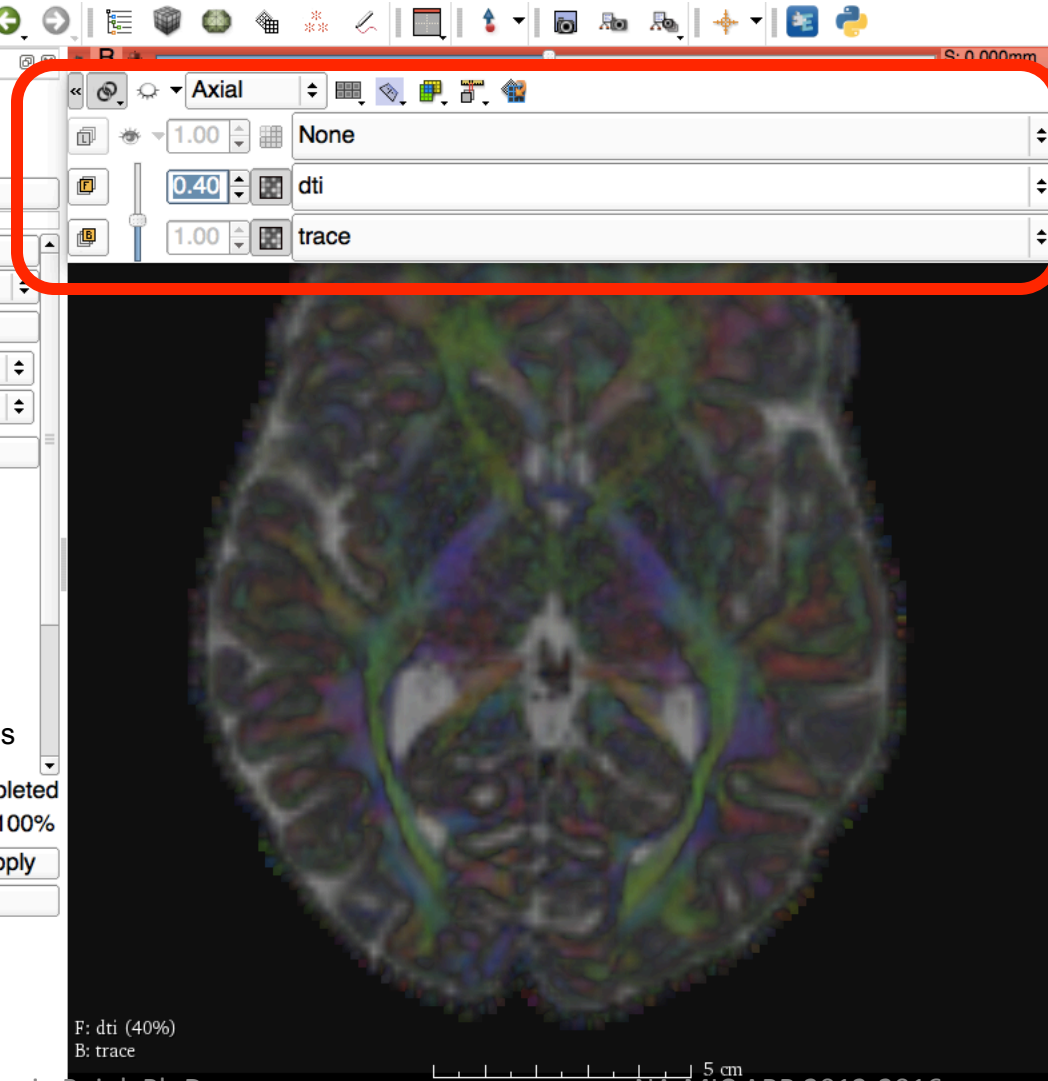
S: 0.000mm

Trace

Position your mouse over the **pin icon** and then select the **'>>'** icon to display this table and fill in the following information:

- Select the volume **'trace'** in the Background viewer
- Select the volume **'dti'** in the Foreground viewer

Set the **opacity** of the **dti** volume to **0.40**



Trace

Position your mouse within the region of the Corpus Callosum and observe the trace values in the **Data Probe**

Parameter set: Diffusion Tensor Scalar Measurements

IO

Input DTI Volume: dti

Output Scalar Volume: trace

Operation

Scalar Maps

- Trace
- Determinant
- RelativeAnisotropy
- FractionalAnisotropy
- Mode
- LinearMeasure
- PlanarMeasure
- SphericalMeasure
- MinEigenvalue
- MidEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionY
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecX
- RAIMaxEigenvecY

Status: Completed

100%

Restore Defaults Auto Run Cancel Apply

Data Probe

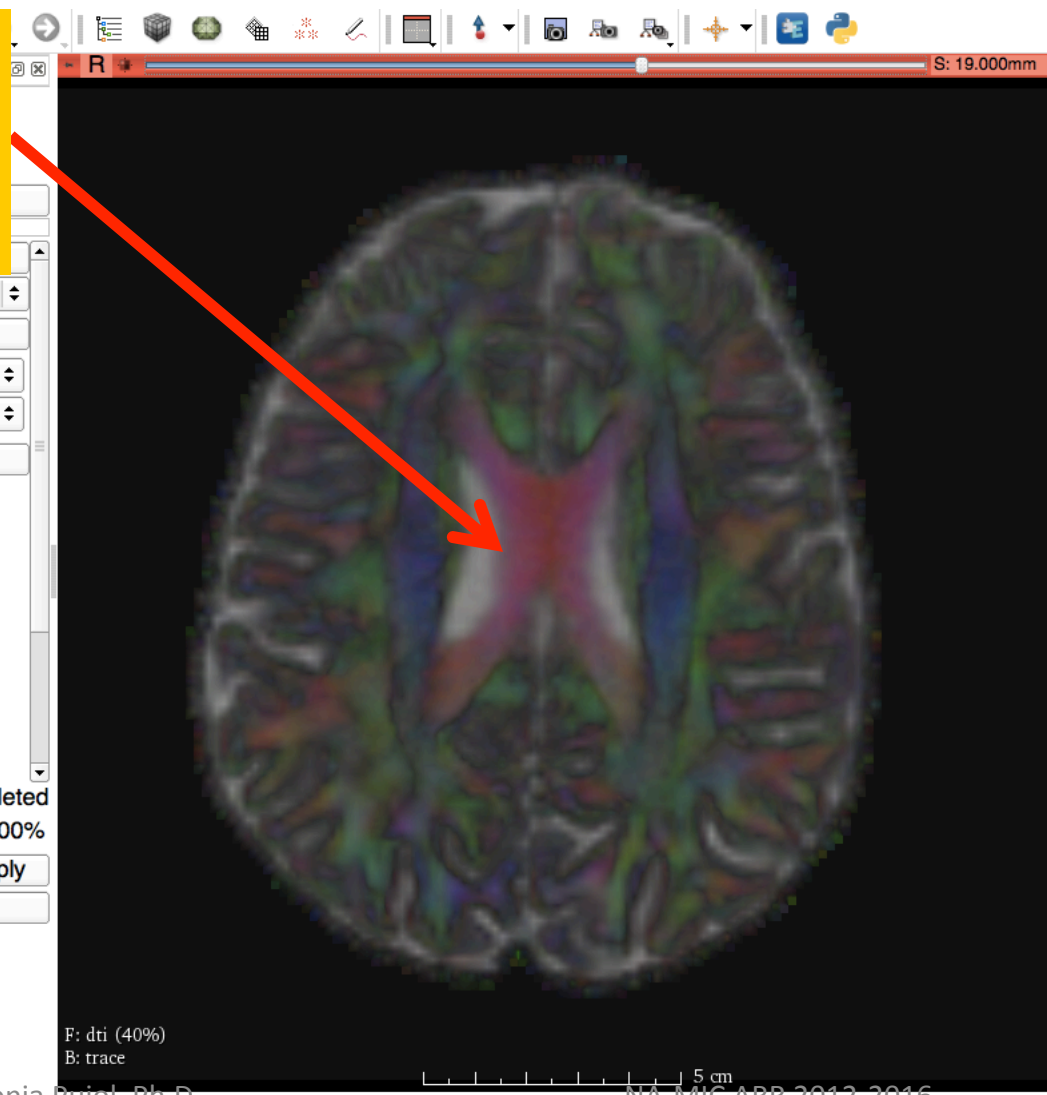
Red RAS: (6.2, 6.7, 19.0) Axial Sp: 1.5

L None

F dti (60, 60, 60) ColorOrientation 0

B trace (60, 60, 60) 0.002111

Diffusion MRI Analysis



Trace

Modules: Diffusion Tensor Scalar Measurements

Note how the Trace values are fairly uniform in both white and gray matter, even if the tissues are different in structure.

Input DTI Volume: dti
Output Scalar Volume: trace

Operation

Scalar Maps

- Trace
- Determinant
- RelativeAnisotropy
- FractionalAnisotropy
- Mode
- LinearMeasure
- PlanarMeasure
- SphericalMeasure
- MinEigenvalue
- MidEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionY
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecX
- RAIMaxEigenvecY

Status: Completed
100%

Cancel Apply

Data Probe

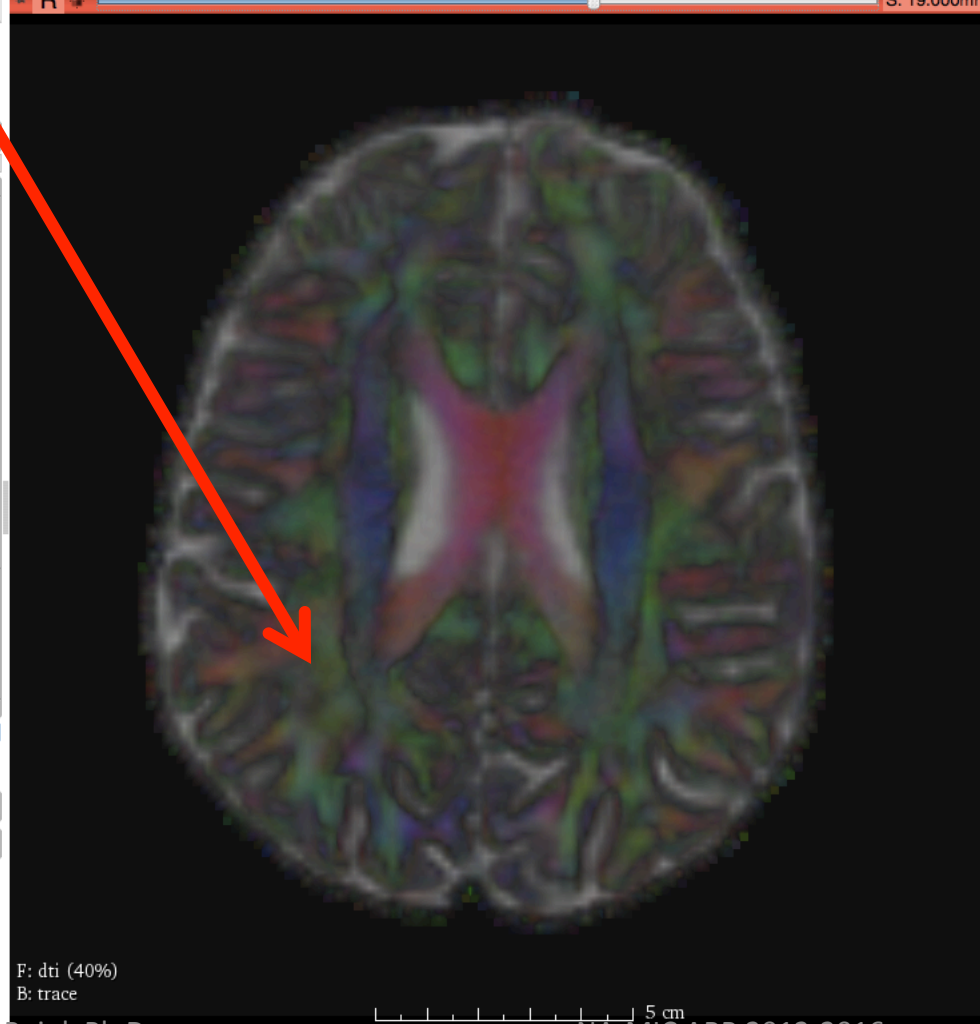
Red RAS: (38.0, -21.2, 19.0) Axial Sp: 1.5

L None

F dti (39, 78, 60) ColorOrientation 0

B trace (39, 78, 60) 0.002008

Diffusion MRI Analysis






F: dti (40%)
B: trace

5 cm

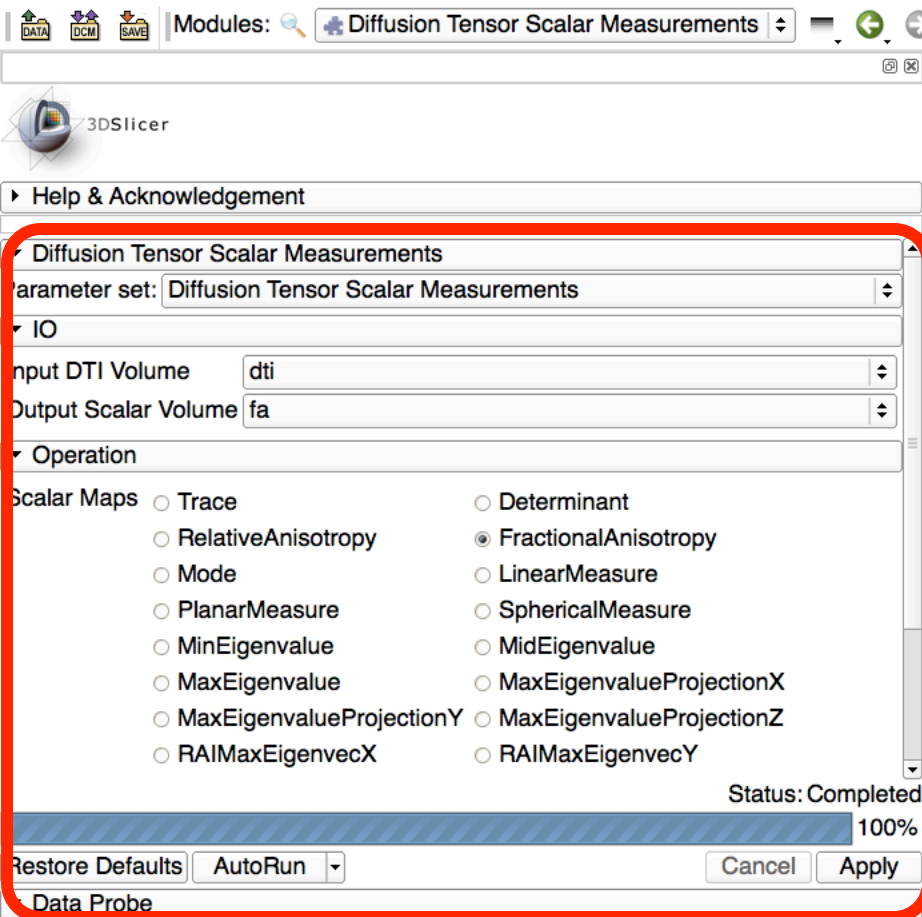
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Scalar Maps: Fractional Anisotropy

$$FA(D) = \frac{\sqrt{(\lambda_1 - \lambda_2)^2 + (\lambda_1 - \lambda_3)^2 + (\lambda_2 - \lambda_3)^2}}{\sqrt{2} \sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}}$$

- FA(D) is intrinsic to the tissue and is independent of fiber orientation, and diffusion sensitizing gradient directions
- FA(D) is useful to characterize the shape (degree of 'out-of-roundness') of the diffusion ellipsoid
- Low FA:   High FA: 

Fractional Anisotropy



Modules: Diffusion Tensor Scalar Measurements

3DSlicer

Help & Acknowledgement

Diffusion Tensor Scalar Measurements

Parameter set: Diffusion Tensor Scalar Measurements

IO

Input DTI Volume: dti

Output Scalar Volume: fa

Operation

Scalar Maps

- Trace
- RelativeAnisotropy
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionY
- RAI_MaxEigenvecX
- Determinant
- FractionalAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionZ
- RAI_MaxEigenvecY

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Fill in the following information:

- Set **Input DTI Volume** to 'dti'
- Select **Output Scalar Volume** 'Create new Volume' and rename it 'fa'
- Select the Operation '**Fractional Anisotropy**'
- Click on **Apply** to calculate the Fractional Anisotropy map of the tensor volume

F: dti (40%)
B: trace

Fractional Anisotropy

3DSlicer

Modules: Diffusion Tensor Scalar Measurements

Help & Acknowledgement

Diffu

Param

IO

Input D

Output Scalar Volume fa

Operation

Scalar Maps

- Trace
- RelativeAnisotropy
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionY
- RAIMaxEigenvecX
- Determinant
- FractionalAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecY

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

L
F
B

B: fa

5 cm

S: 0.000mm

Fractional Anisotropy

3DSlicer

Modules: Diffusion Tensor Scalar Measurements

Diffusion Tensor Scalar Measurements

Parameter set: Diffusion Tensor Scalar Measurements

Input DTI Volume: dti

Output Scalar Volume: fa

Layer Control Panel (highlighted in red):

- Background: None
- Foreground: dti (Opacity: 0.40)
- Background: fa (Opacity: 1.00)

Position your mouse over the **pin icon** and click the **'>>'** icon to display this table. Set the background volume to **'fa'** and be sure the foreground volume is still set to **'dti'** with **opacity at 0.40**

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

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5 cm

F: dti (40%)
B: fa



Fractional Anisotropy

Explore the FA values in the Corpus Callosum and in adjacent gray matter areas. Note how the FA values are high in the white matter areas, and low in gray matter regions

Output Scalar Volume **fa**

Operation

Scalar Maps

- Trace
- RelativeAnisotropy
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionY
- RAIMaxEigenvecX
- Determinant
- FractionalAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecY

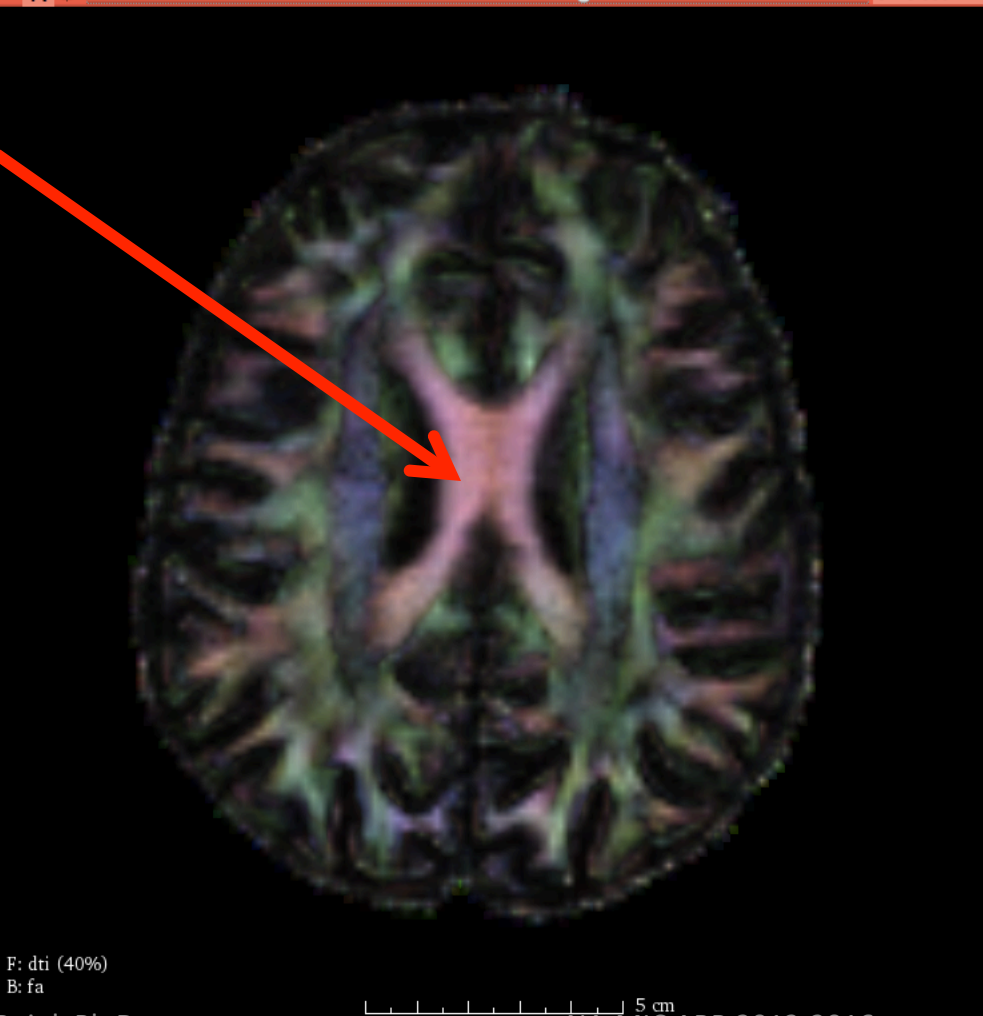
Status: Completed

100%

Cancel Apply

Data Probe

- Red RAS: (7.7, 8.8, 19.0) Axial Sp: 1.5
- L None
- F dti (59, 58, 60) ColorOrientation 0
- B fa (59, 58, 60) 0.890284



F: dti (40%)
B: fa

5 cm

S: 19.000mm

Diffusion MRI Analysis

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Fractional Anisotropy

Modules: Diffusion Tensor Scalar Measurements

Change to Conventional view

Help & Acknowledgement

Diffusion Tensor Scalar Measurements

Parameter set: Diffusion Tensor Scalar Measurements

IO

Input DTI Volume: dti

Output Scalar Volume: fa

Operation

Scalar Maps

- Trace
- RelativeAnisotropy
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- MaxEigenvalueProjectionY
- RAIMaxEigenvecX
- Determinant
- FractionalAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- MaxEigenvalueProjectionX
- MaxEigenvalueProjectionZ
- RAIMaxEigenvecY

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

L
F
B

Diffusion MRI Analysis

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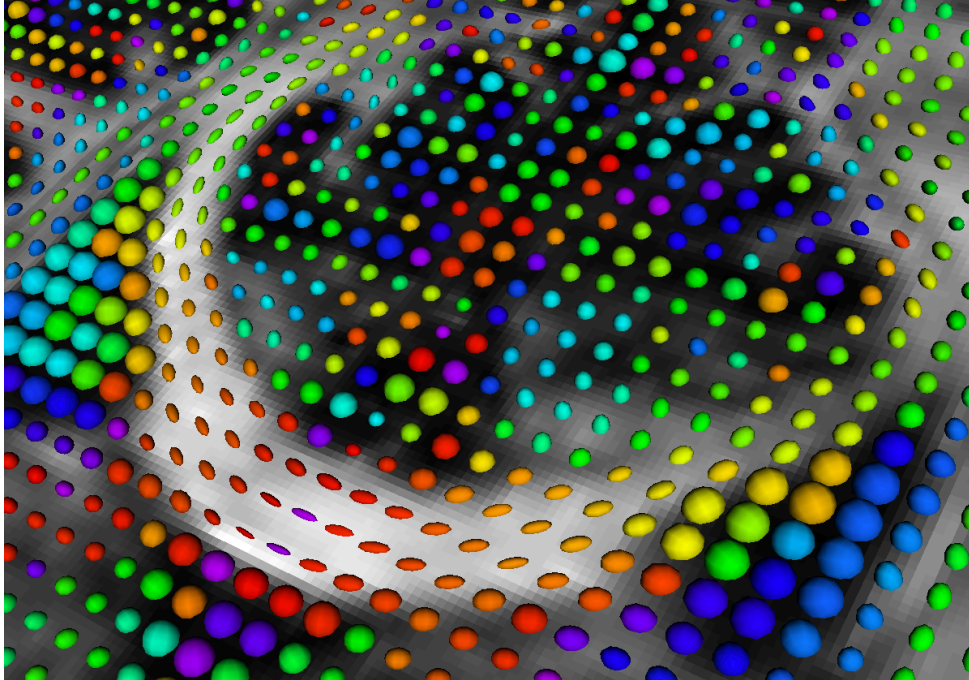
5 cm

F: dti (40%)
B: fa

S: 19.000mm

Conventional

- Conventional Widescreen
- Conventional Quantitative
- Four-Up
- Four-Up Quantitative
- Dual 3D
- Triple 3D
- 3D only
- One-Up Quantitative
- Red slice only
- Yellow slice only
- Green slice only
- Tabbed 3D
- Tabbed slice
- Compare
- Compare Widescreen
- Compare Grid
- Three over three
- Three Over Three Quantitative
- Four over four
- Two over Two
- Side by side
- Four by three slice
- Four by two slice
- Three by three slice



Part 2: Visualizing the tensor data

3D Visualization: Glyphs

Click on the Modules menu and select the module **Volumes**

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

3DSlicer

Modules: Diffusion Tensor Scalar Measurements

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes**
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support
- Unspecified
- BRAINS

Parameter set: Diffusion Tens

Input DTI Volume dti

Output Scalar Volume fa

Operation

Scalar Maps

- Trace
- RelativeAnis
- Mode
- PlanarMeasu
- MinEigenva
- MaxEigenva
- MaxEigenva
- RAIMaxEige

Restore Defaults AutoRun

Data Probe

L
F
B

Completed 100%

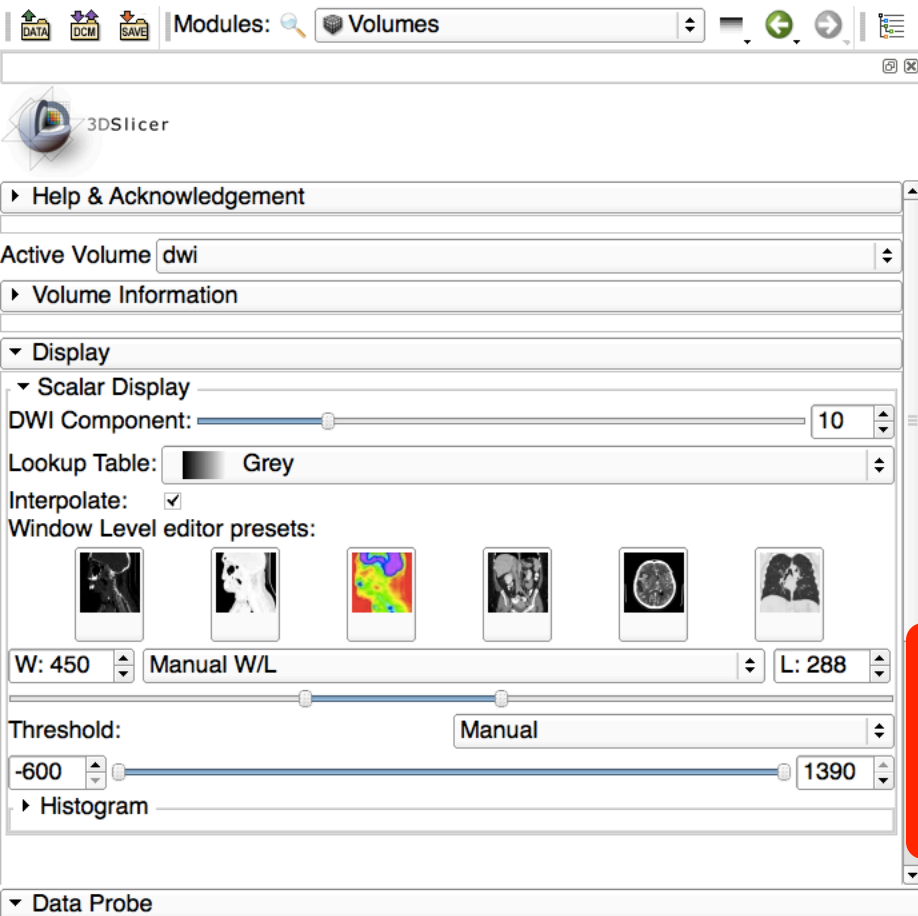
Apply

S: 19.000mm Y R: 1.500mm G A: 1.500mm

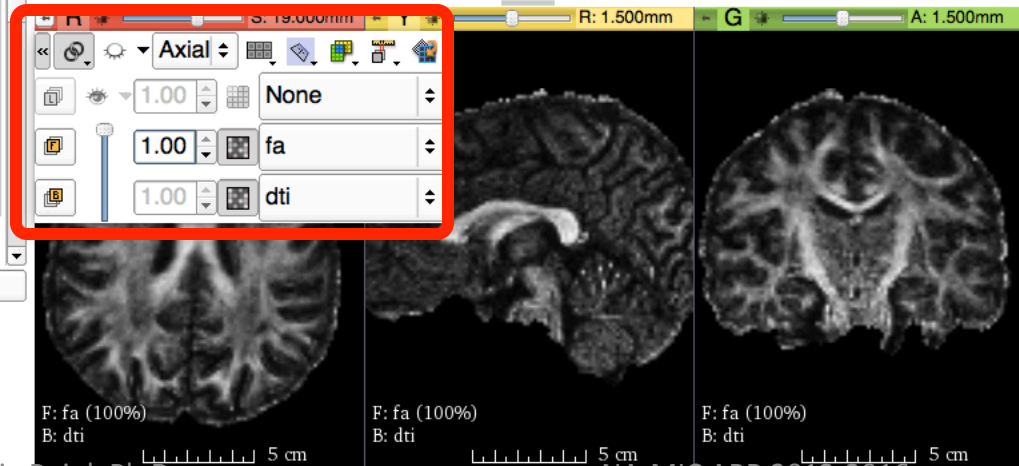
F: dti (40%)
B: fa

5 cm

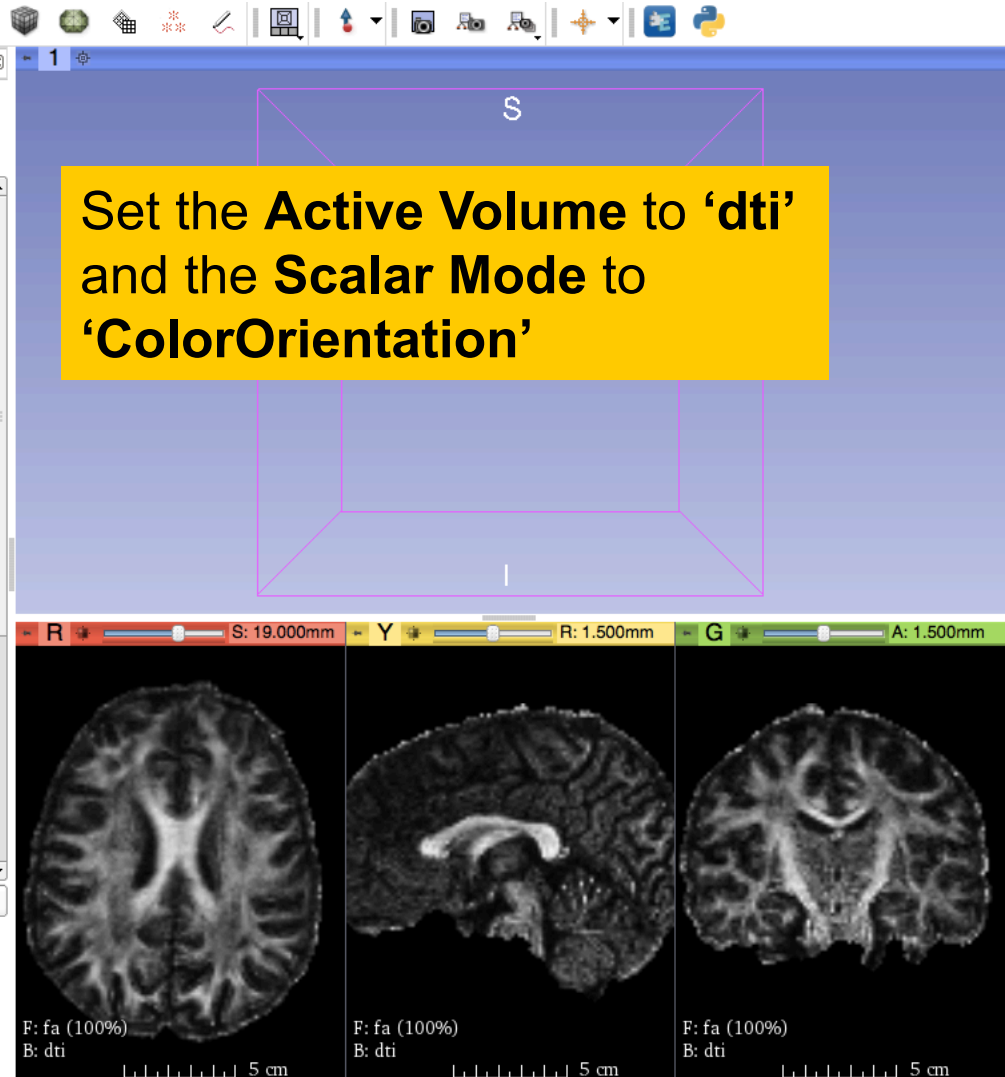
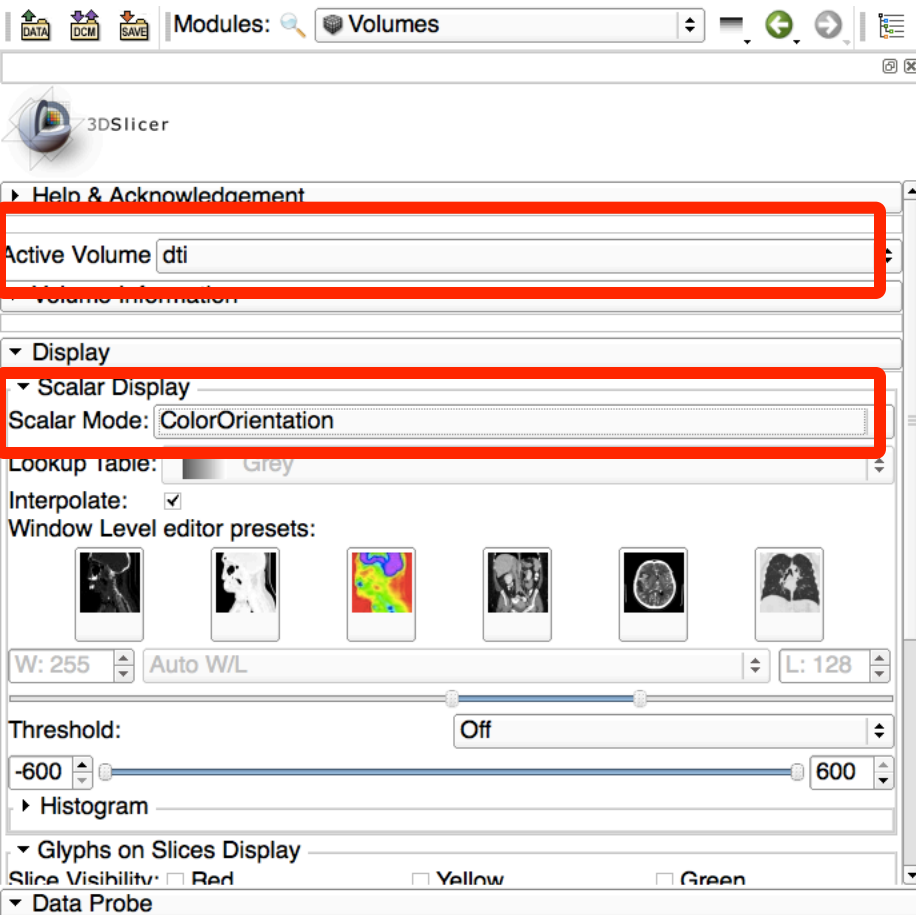
3D Visualization: Glyphs



Position the mouse over the **pin icon** and select the '<<' icon to display the axial slice toolbar. Set the **Foreground** to 'fa' and the **Background** to 'dti', with the **Foreground** opacity set to **1.00**



3D Visualization: Glyphs

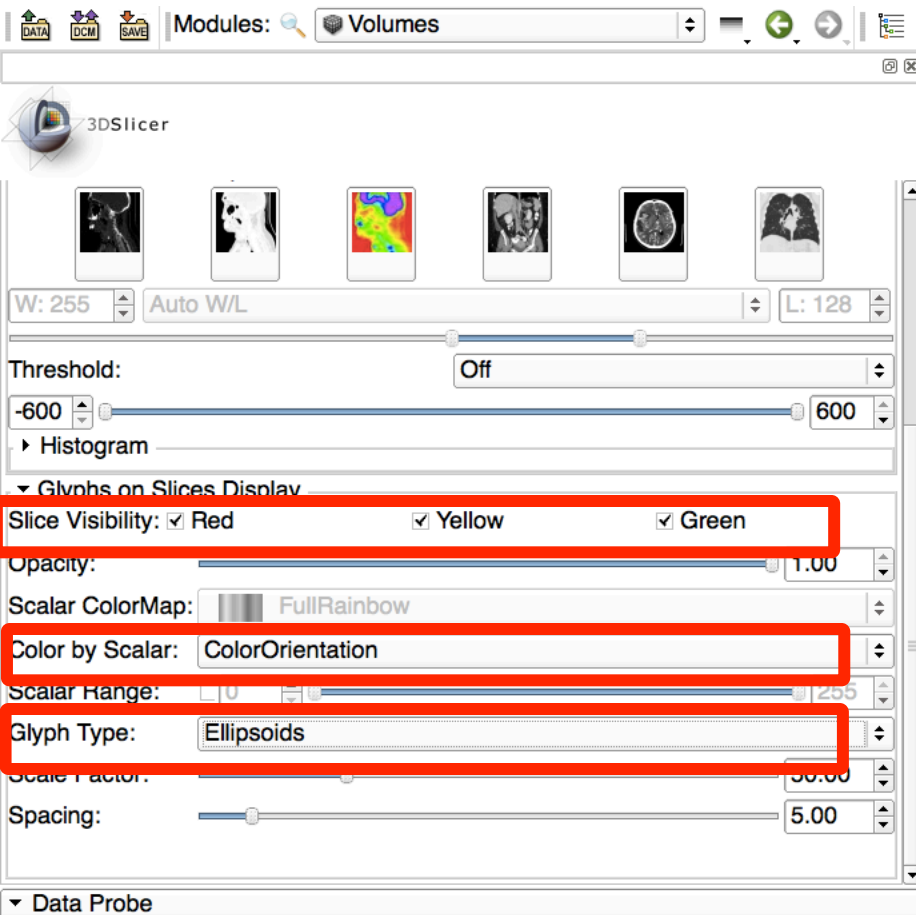


Set the **Active Volume** to 'dti' and the **Scalar Mode** to 'ColorOrientation'

L
F
B



3D Visualization: Glyphs

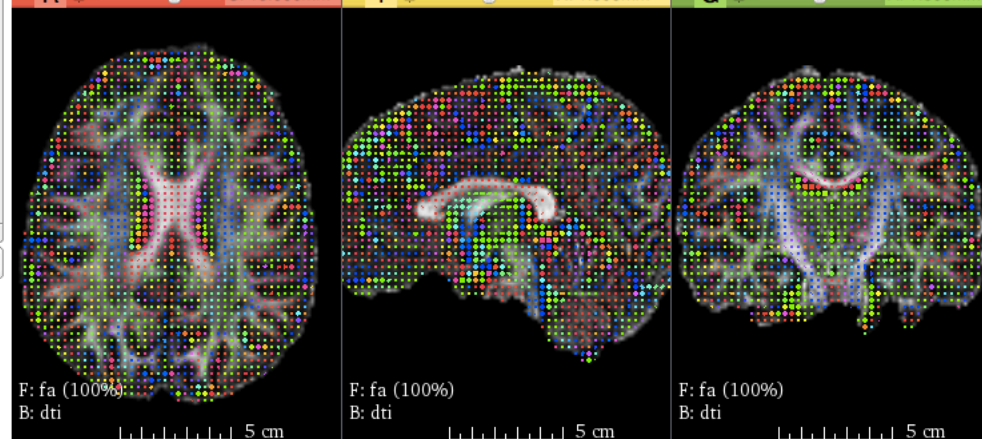


Scroll down the module panel and:

- Check off the option for **Red, Yellow, and Green Slice Visibility**

- Set the **Color by Scalar** parameter to **'ColorOrientation'**

- Set the **Glyph Type** to **'Ellipsoids'**

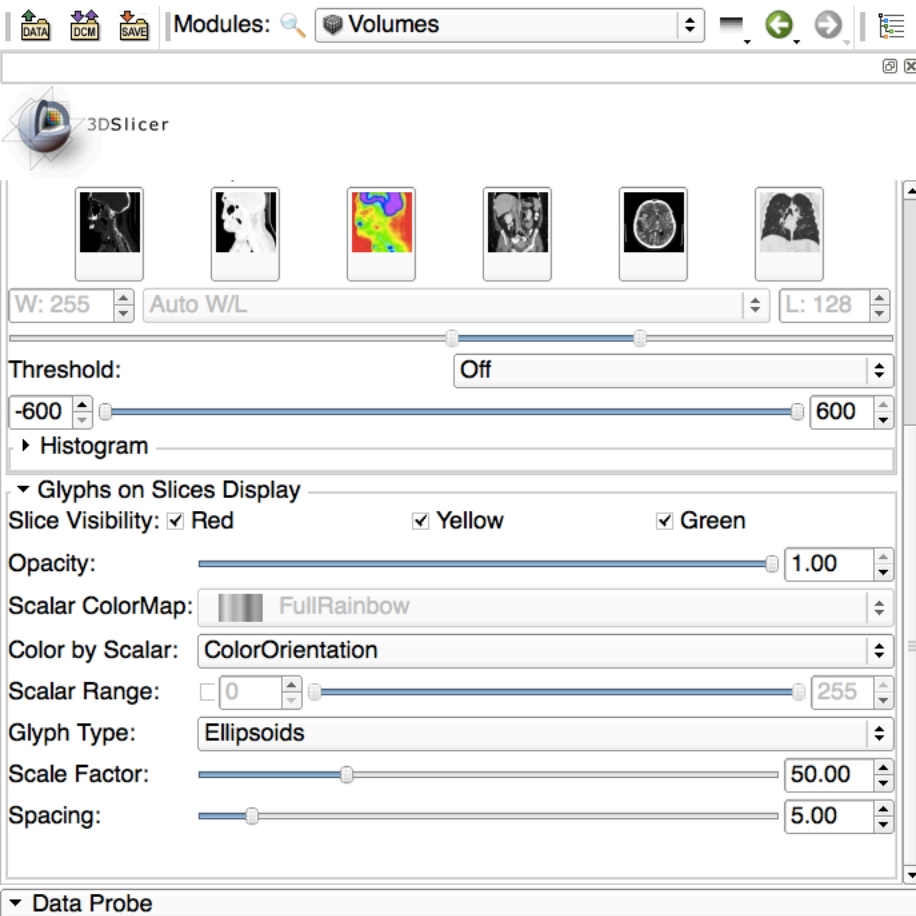


3D Visualization: Glyphs

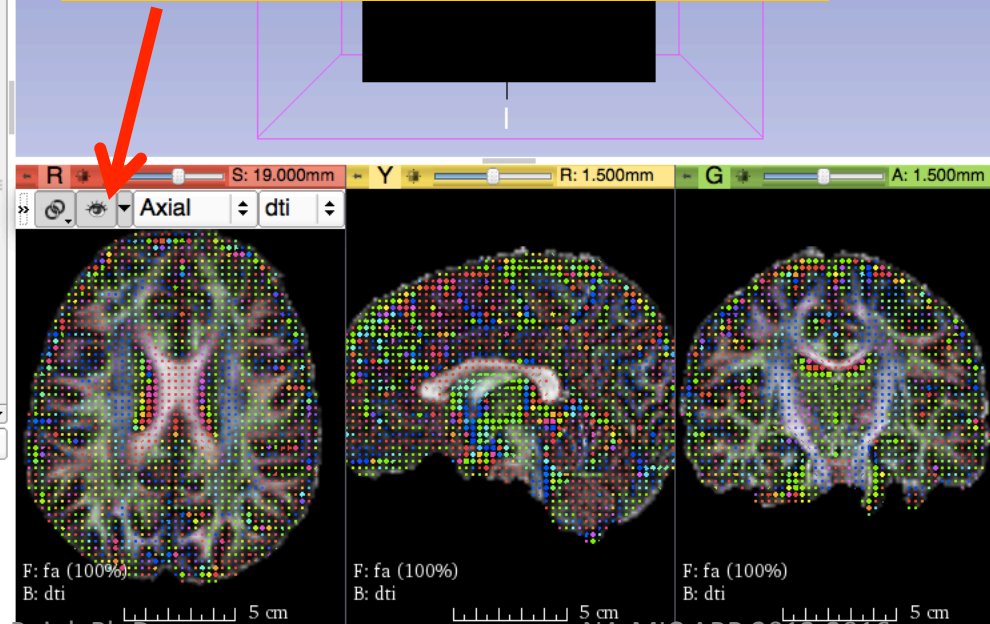
The image shows the 3D Slicer software interface for Diffusion MRI Analysis. The left sidebar contains the 'Volumes' panel with a list of image thumbnails. Below this is a control panel for the selected volume, including a 'Threshold' slider set to 'Off' with values from -600 to 600, a 'Histogram' button, and a 'Glyphs on Slices Display' section. The 'Glyphs on Slices Display' section includes 'Slice Visibility' checkboxes for Red, Yellow, and Green (all checked), an 'Opacity' slider at 1.00, a 'Scalar ColorMap' set to 'FullRainbow', 'Color by Scalar' set to 'ColorOrientation', 'Scalar Range' from 0 to 255, 'Glyph Type' set to 'Ellipsoids', 'Scale Factor' at 50.00, and 'Spacing' at 5.00. The 'Data Probe' section is also visible.

The main 3D view shows a brain slice with a grid of glyphs (small colored ellipsoids) overlaid on it. A yellow text box with the text 'The glyphs appear in all 3 slice viewers' is overlaid on the 3D view. Below the 3D view are three slice viewers (axial, sagittal, and coronal) showing the glyphs in different orientations. Each slice viewer has a 5 cm scale bar and labels 'F: fa (100%)' and 'B: dti'. The bottom of the interface shows the 'Diffusion MRI Analysis' title bar and the name 'Sonia Raju, Ph.D.'.

3D Visualization: Glyphs



Position your mouse over the **pin icon** select the **eye icon** to display the axial, coronal, and sagittal slices in the 3D viewer



3D Visualization: Glyphs

The screenshot displays the Slicer software interface. On the left, a control panel for 'Glyphs on Slices Display' is visible, featuring various sliders and checkboxes. A green text box highlights the text 'Slicer displays the anatomical slices in the 3D viewer'. The main 3D view shows a brain model with three intersecting planes (Axial, Sagittal, Coronal) and a dense field of multi-colored glyphs. Below the 3D view, three 2D slice windows are shown, each displaying a different view of the brain with glyphs. The slice windows are labeled 'R', 'Y', and 'G' at the top, and 'F: fa (100%)' and 'B: dti' at the bottom. A 5 cm scale bar is present in each slice window.

Slicer displays the anatomical slices in the 3D viewer

W: 255 Auto W/L L: 128

Threshold: Off

-600 600

► Histogram

▼ Glyphs on Slices Display

Slice Visibility: Red Yellow Green

Opacity: 1.00

Scalar ColorMap: FullRainbow

Color by Scalar: ColorOrientation

Scalar Range: 0 255

Glyph Type: Ellipsoids

Scale Factor: 50.00

Spacing: 5.00

▼ Data Probe

L
F
B

R S: 19.000mm Y R: 1.500mm G A: -0.500mm

F: fa (100%)
B: dti 5 cm

F: fa (100%)
B: dti 5 cm

F: fa (100%)
B: dti 5 cm



3D Visualization: Glyphs

Zoom in to observe the glyphs.
The ellipsoids represent the principal direction of diffusion (main eigenvector)

Modules: Volumes

Threshold: 0

► Histogram

▼ Glyphs on Slices Display

Slice Visibility: Red Yellow Green

Opacity: 1.00

Scalar ColorMap: FullRainbow

Color by Scalar: ColorOrientation

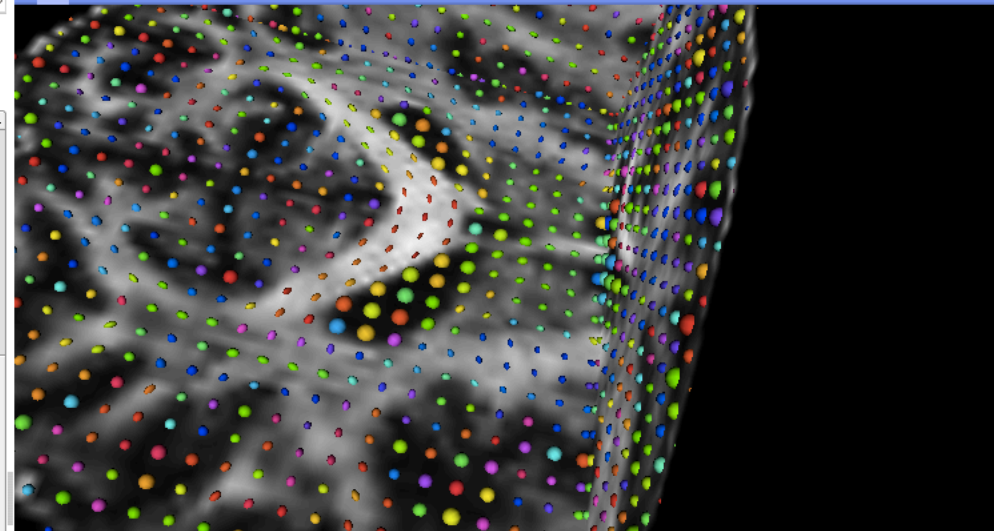
Scalar Range: 0 255

Glyph Type: Ellipsoids

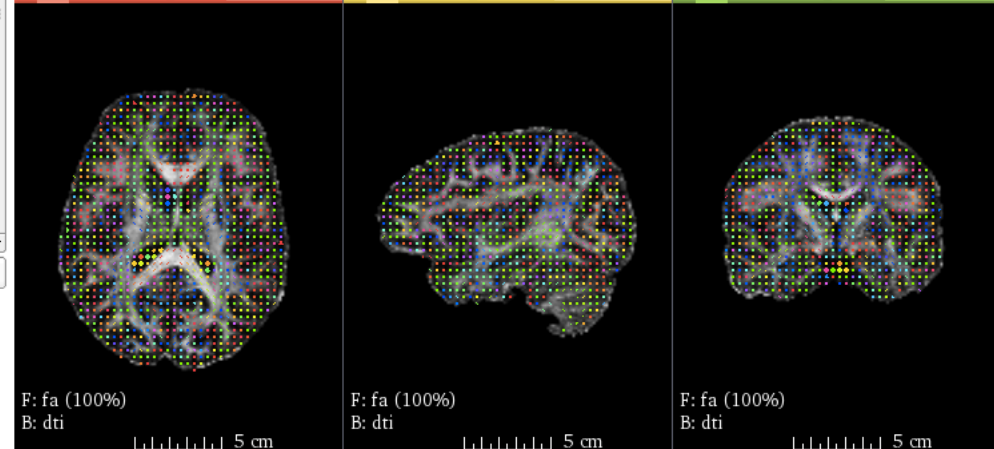
Scale Factor: 50.00

Spacing: 5.00

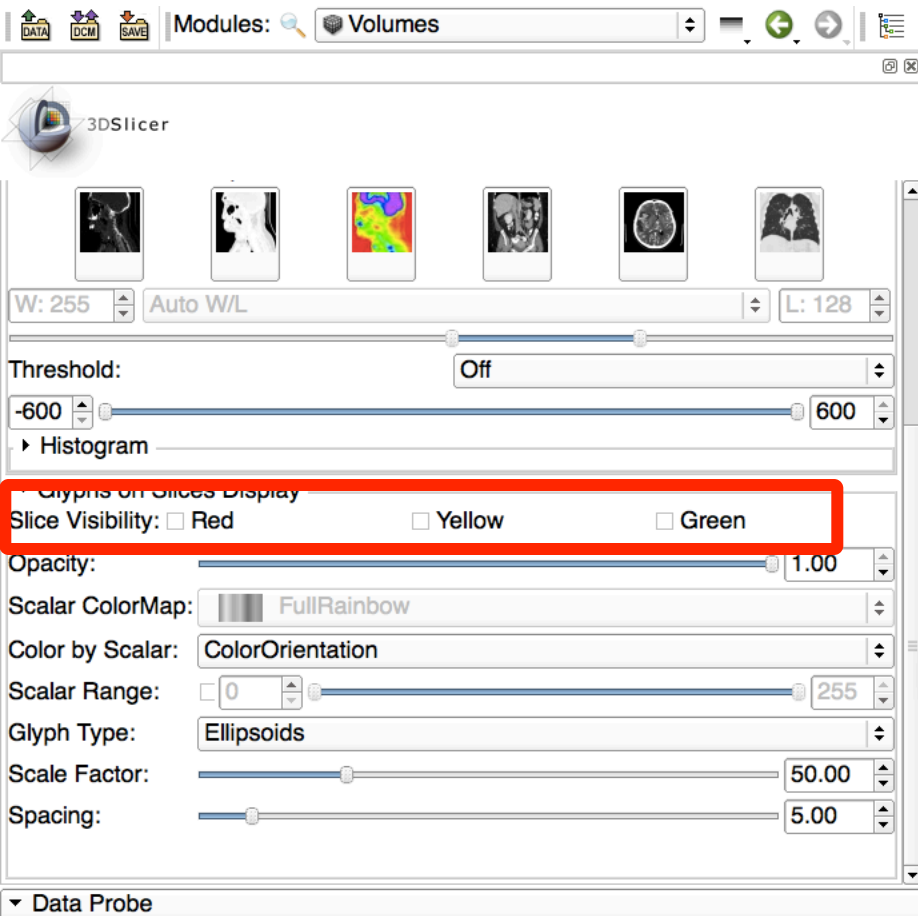
▼ Data Probe



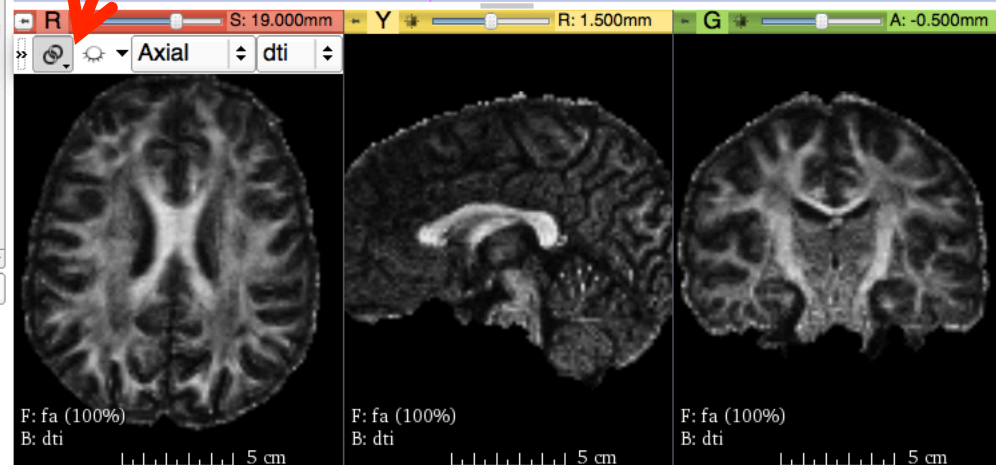
R S: 10.500mm Y R: -31.500mm G A: 13.500mm



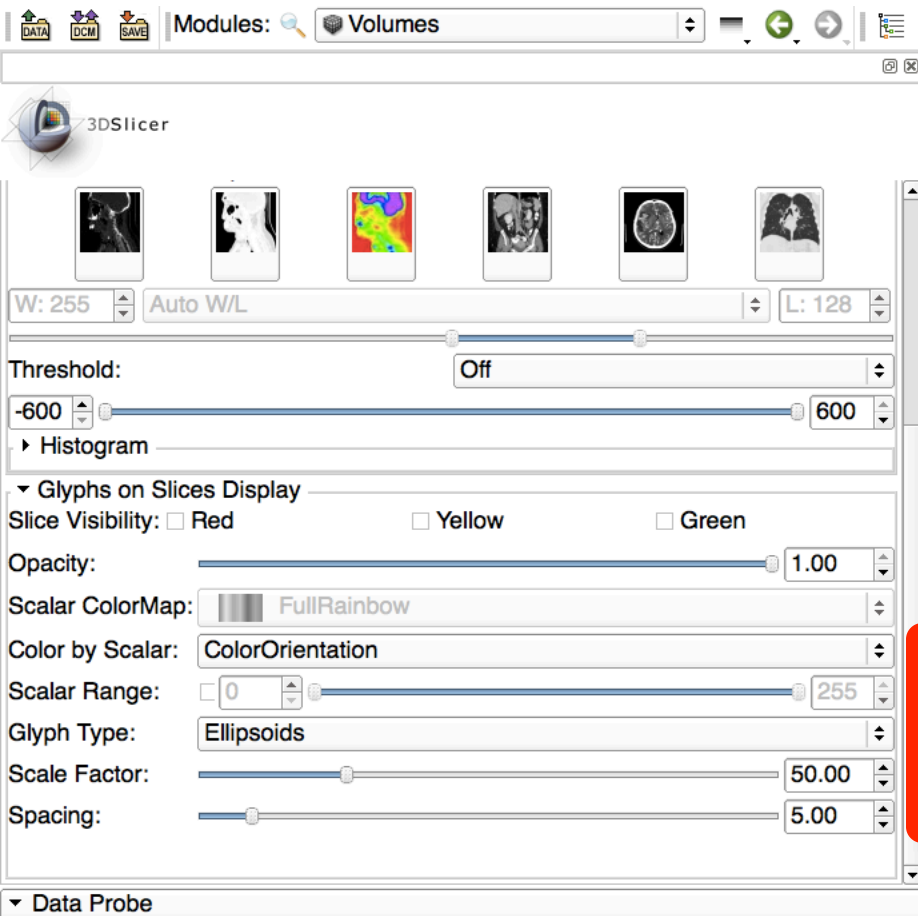
Diffusion MRI tractography



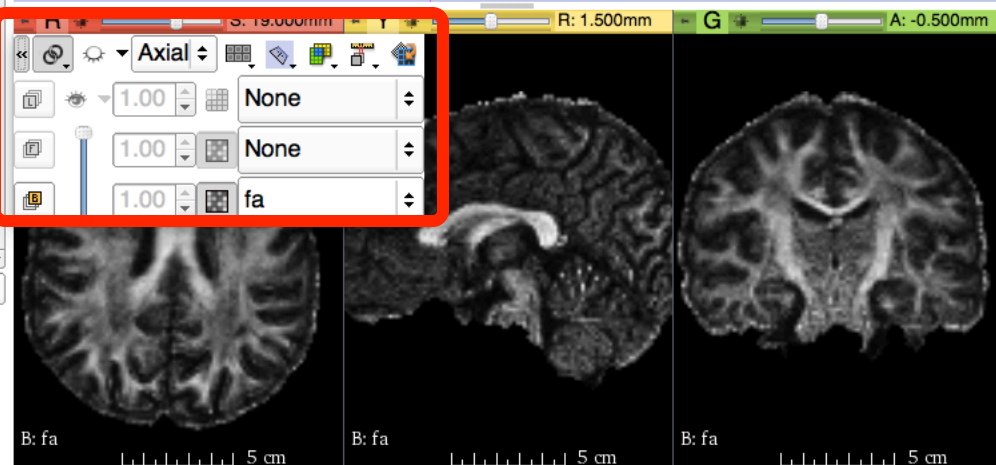
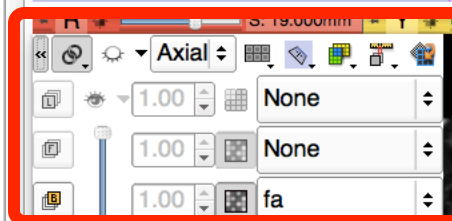
Deselect the option for Red, Yellow, and Green Slice Visibility, and deselect the eye icon

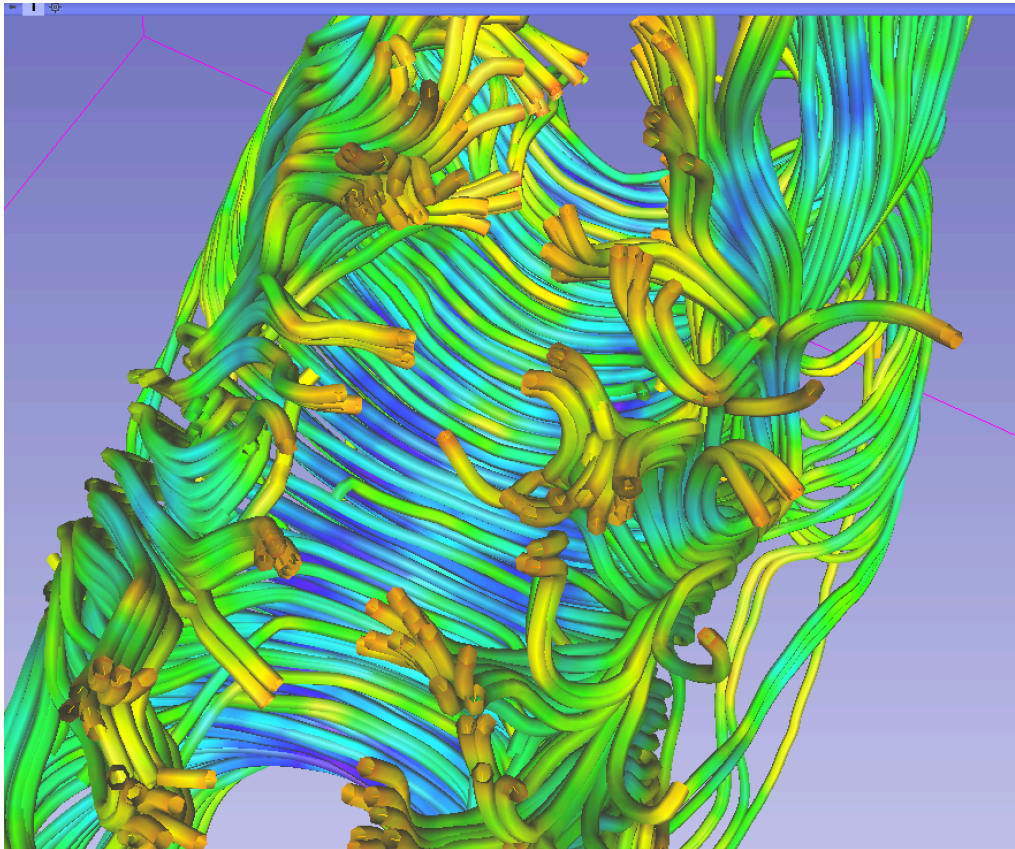


Diffusion MRI tractography



Position your mouse over the pin icon and change the **Foreground** to 'None' and the **background** to 'fa'





Part 3: From tensors to tracts

DTI tractography

- Definition of a region of interest (ROI) for seeding tract in an FA map (Editor module)
- Single-tensor tractography (Tractography Interactive Seeding module)
- Fiducial-seeding tractography (Tractography Interactive Seeding module)

Diffusion MRI tractography

3DSlicer

Modules: Volumes

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor**
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support
- Unspecified
- BRAINS

W: 255 Auto W/L

Threshold: -600

► Histogram

▼ Glyphs on Slices Display

Slice Visibility: Red

Opacity: [Slider]

Scalar ColorMap: [ColorMap]

Color by Scalar: ColorOriented

Scalar Range: [0]

Glyph Type: Ellipsoids

Scale Factor: [Slider]

Spacing: [Slider]

▼ Data Probe

L
F
B

Select the module **Editor**

1

R S: 19.000mm Y R: 1.500mm G A: -0.500mm

B: fa 5 cm B: fa 5 cm B: fa 5 cm

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Diffusion MRI tractography

The screenshot displays the 3DSlicer software interface. The top toolbar includes icons for DATA, DCM, SAVE, and various editing tools. The 'Modules' dropdown is set to 'Editor'. The left sidebar shows a menu with 'Help & Acknowledgement', 'Create and Select Label Maps', and 'Edit Selected Label Map'. The 'Master Volume' is set to 'fa'. A dialog box is open in the center, titled 'Create a merge label map for selected master volume fa. New volume will be fa-label. Select the color table node that will be used for segmentation labels.' The dialog shows a color table dropdown set to 'GenericAnatomyColors' and 'Apply' and 'Cancel' buttons. A yellow box with the text 'Click on Apply' and a red arrow points to the 'Apply' button. The bottom of the interface shows three orthogonal views of a brain slice with a 5 cm scale bar and labels 'B: fa'. The status bar at the bottom indicates 'R: 0.750mm', 'G', and 'A: 0.750mm'. The left side of the status bar shows 'L', 'F', 'B' orientation markers.



Diffusion MRI tractography

The screenshot displays a software interface for Diffusion MRI analysis. On the left, there are panels for 'Create and Select Label Maps' and 'Edit Selected Label Map'. The 'Create and Select Label Maps' panel includes fields for 'Master Volume: fa' and 'Merge Volume: fa-label', along with a 'Set...' button. The 'Edit Selected Label Map' panel features a toolbar with various icons and an 'Undo/Redo' section. Below these panels, the 'Active Tool' is set to 'DefaultTool', and the 'Label' is 'tissue' with a value of '1'. The main window shows a 3D view of a brain slice with a red arrow pointing to a menu. The menu lists various layout options, with 'Yellow slice only' highlighted. The bottom of the interface shows three axial brain slices with labels 'L: fa-l...00%' and 'B: fa' and a 5 cm scale bar.

Select the **Yellow slice only** layout

- Conventional
- Conventional Widescreen
- Conventional Quantitative
- Four-Up
- Four-Up Quantitative
- Dual 3D
- Triple 3D
- 3D only
- One-Up Quantitative
- Red slice only
- Yellow slice only**
- Green slice only
- Tabbed 3D
- Tabbed slice
- Compare
- Compare Widescreen
- Compare Grid
- Three over three
- Three Over Three Quantitative
- Four over four
- Two over Two
- Side by side
- Four by three slice
- Four by two slice
- Three by three slice

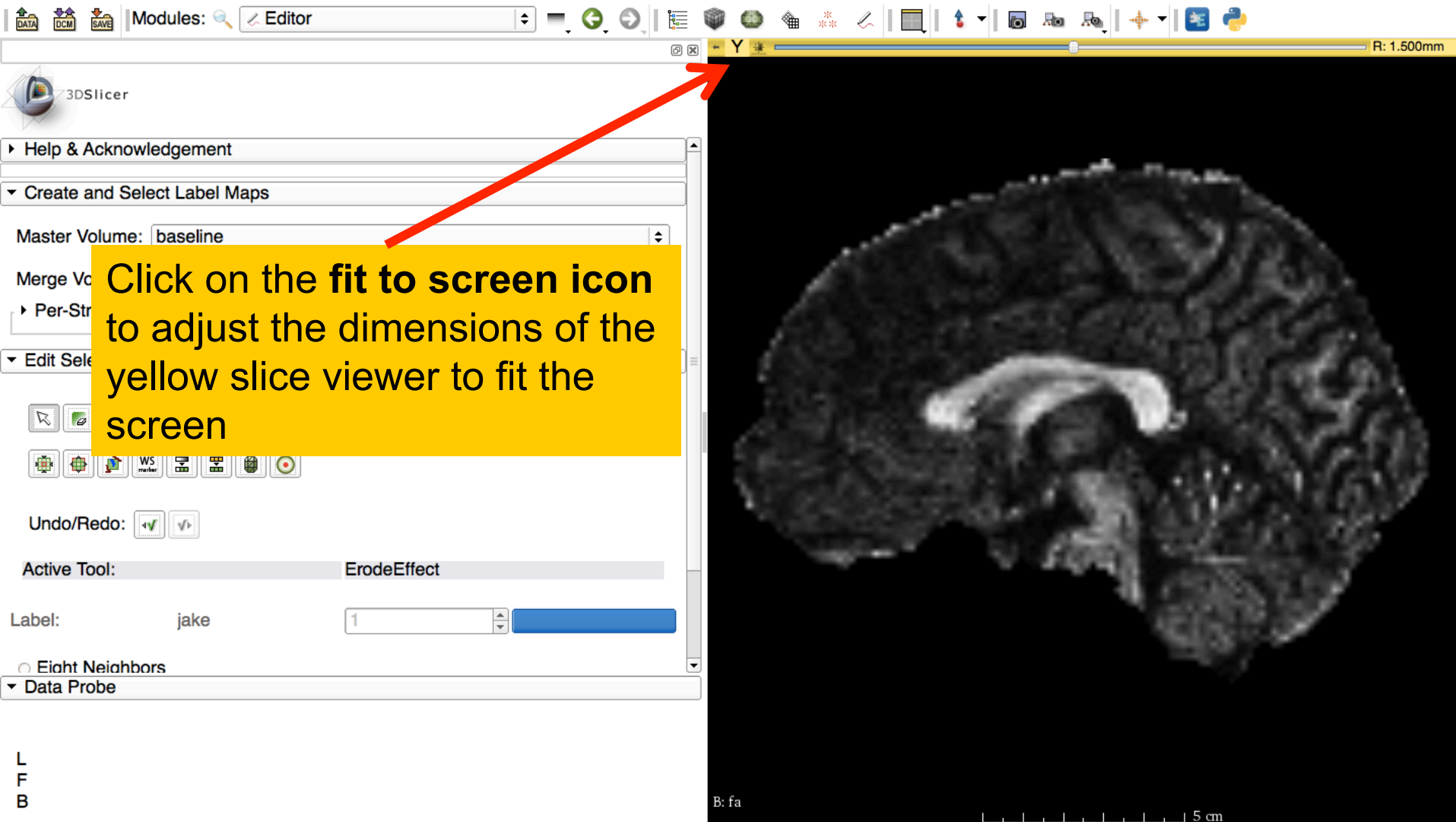
L
F
B

Diffusion MRI Analysis

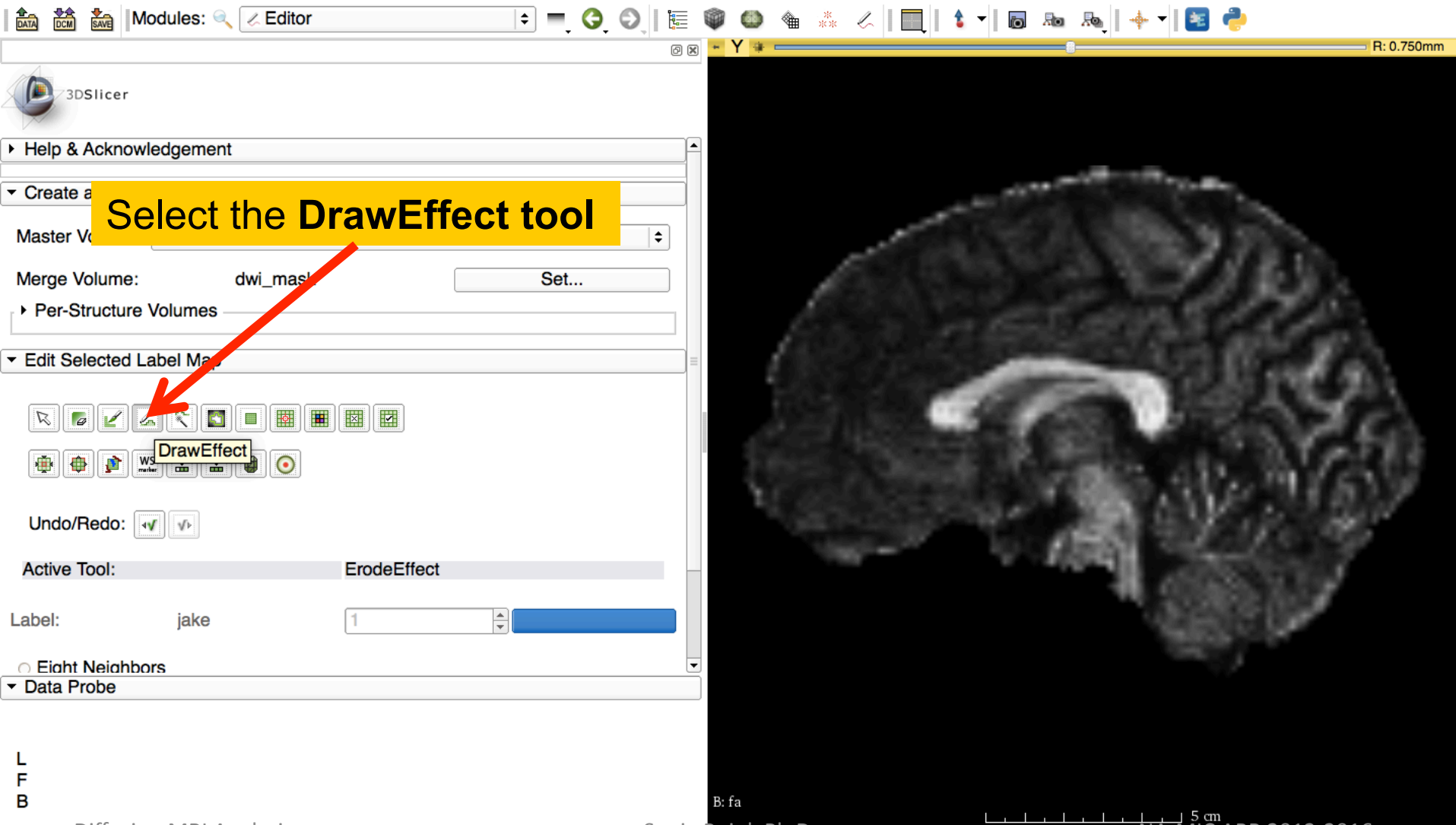
Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

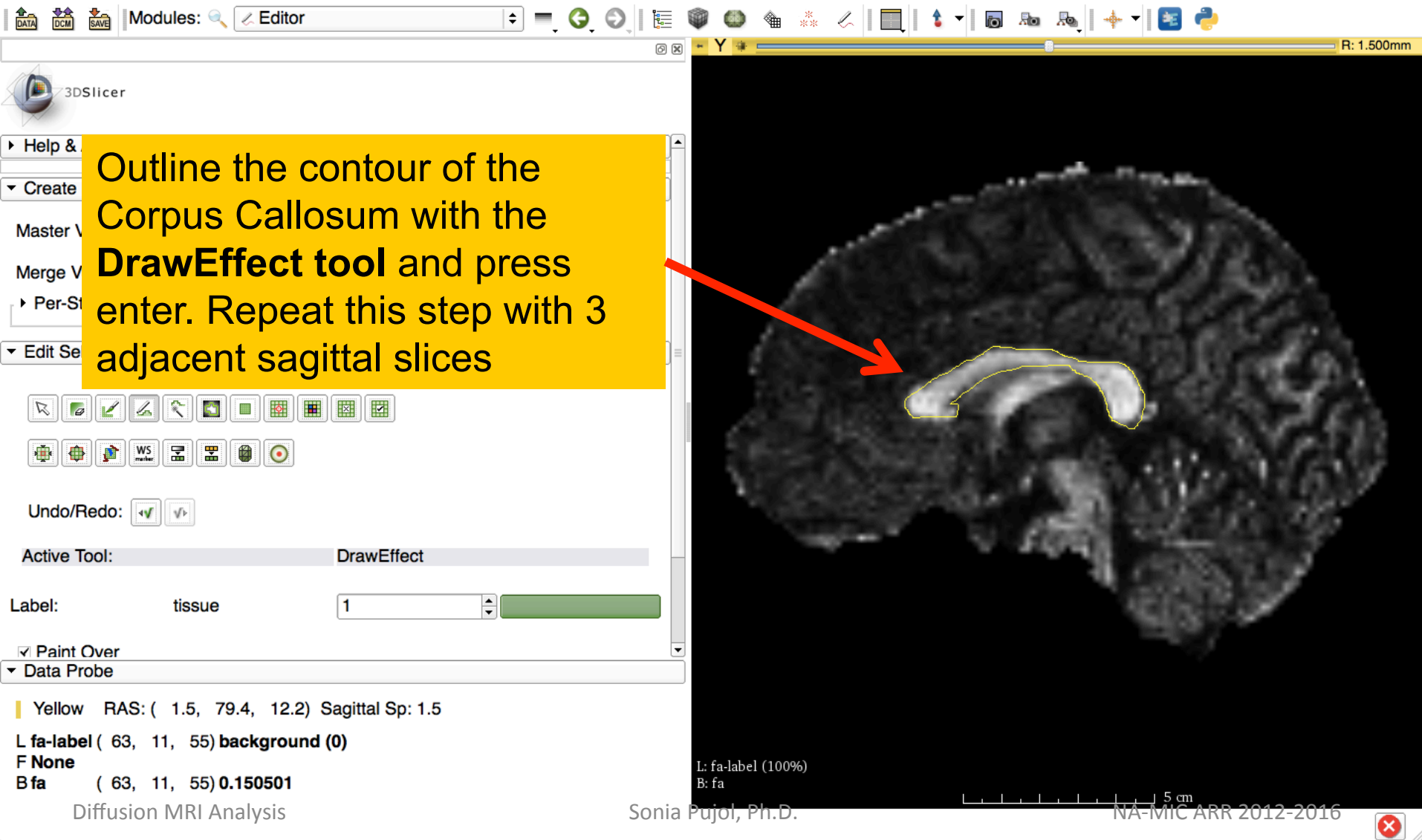
Diffusion MRI tractography



Diffusion MRI tractography



Diffusion MRI tractography



Modules: Editor

3DSlicer

Help &
Create
Master V
Merge V
Per-St
Edit Se

Outline the contour of the Corpus Callosum with the **DrawEffect tool** and press enter. Repeat this step with 3 adjacent sagittal slices

Active Tool: DrawEffect

Label: tissue 1

Paint Over
Data Probe

Yellow RAS: (1.5, 79.4, 12.2) Sagittal Sp: 1.5
L fa-label (63, 11, 55) background (0)
F None
B fa (63, 11, 55) 0.150501

Diffusion MRI Analysis

R: 1.500mm

L: fa-label (100%)
B: fa

5 cm

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Diffusion MRI tractography

The screenshot shows the 3D Slicer software interface. The top toolbar contains various icons for file operations (DATA, DCM, SAVE), navigation (back, forward, home), and visualization (layers, volume rendering, camera). The left sidebar has a menu with the following items: Help & Acknowledgement, Create and Select Label Maps, Master Volume: fa, Merge, Per, Edit, and Data Probe. A text box is overlaid on the sidebar with the text: "In the next section, we will seed tracts from this anatomical region of interest." The main viewing area shows a brain MRI slice with a green region of interest highlighted. The bottom left corner of the interface shows the orientation: L (Left), F (Frontal), B (Bottom). The bottom right corner shows a scale bar: 5 cm. The bottom center shows the text: "Diffusion MRI Analysis". The bottom right corner also shows the text: "NA-MIC ARR 2012-2016".

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Master Volume: fa

Merge

Per

Edit

Undo/Redo: [Undo] [Redo]

Active Tool: DrawEffect

Label: tissue 1

Paint Over

Data Probe

L
F
B

5 cm

L: fa-label (100%)
B: fa

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Diffusion MRI tractography

The image shows the 3DSlicer software interface. On the left, the 'Modules' panel is open, showing a tree view of available modules. The 'Diffusion' module is selected, and its sub-menu is displayed, with 'Diffusion Tensor Images' selected. A yellow callout box with a red arrow points to the 'Tractography Interactive Seeding' option in the sub-menu. The main window displays a brain MRI slice with a green region of interest. The bottom status bar shows 'L: fa-label (100%)' and 'B: fa'. A scale bar at the bottom right indicates 5 cm.

3DSlicer

Help & Acknowledgement

Create and Select Label Map

Master Volume: fa

Merge Volume:

Per-Structure Volumes

Edit Selected Label Map

Undo/Redo:

Active Tool:

Label: tissue

Paint Over

Data Probe

Modules:

Editor

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
 - Informatics
 - Registration
 - Segmentation
 - Quantification
- Diffusion
 - DWI to Full Brain Tractography
 - Tractography Display
 - Diffusion Data Conversion
 - Diffusion Tensor Images
 - Diffusion Tensor Scalar Measurements
 - Resample DTI Volume
 - Tractography Interactive Seeding
 - Tractography Label Map Seeding
 - Diffusion Weighted Images
 - Tractography
- IGT
- Filtering
- Surface Models
- Converters
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support
- Unspecified
- BRAINS

Select the module
Tractography
Interactive Seeding

L: fa-label (100%)
B: fa

5 cm

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Labelmap Seeding: Step1: I/O

Change to **Conventional** view

Input DTI Volume: dti
Input Fiducials, Model or Label Map: fa-label
Output Fiber Bundle: corpusCallosum
Enable Seeding Tracts:

- Set the **Input DTI Volume** to 'dti'
- Set the **Input Label Map** to 'fa-label'
- Set **Output Fiber Bundle** to 'Create and Rename New Fiber Bundle' and rename it 'corpusCallosum'
- Uncheck **Enable Seeding Tracks**

Labelmap Seeding: Step 2: Seeding parameters

3DSlicer

Modules: Tractography Interactive Seeding

Enable Seeding Tracts

Label Map Options

Use index Space

Seed Spacing 2.00

Random Grid

Linear Measure Start Threshold 0.30

ROI Labels 1

Write Fibers To Disk

Output Directory /Applications

File Prefix

Tractography Seeding Parameters

Minimum Path Length 20.000mm

Maximum Path Length 500.000mm

Stopping Criteria Fractional Anisotropy

Stopping Value 0.15

Stopping Track Curvature 0.70

Integration Step Length 0.500mm

Enabling Options

Data Probe

R S: 0.000mm Y R: 1.500mm G A: 1.500mm

5 cm 5 cm 5 cm

Select the default Tractography Seeding parameters:

- Check Use index Space
- Stopping Criteria: FractionalAnistropy
- Stopping Value: 0.15



Labelmap Seeding: Step 3: Generate Tracts

3DSlicer

Modules: Tractography Interactive Seeding

Help & Acknowledgement

IO

Parameters: FiducialSeedingParameters

Presets: Slicer4 Interactive Seeding Defaults

IO

Input DTI Volume: dti

Input Fiducials, Model or Label Map: fa-label

Output Fiber Bundle: corpusCallosum

Enable Seeding Tracts

Label Map Options

Use index Space

Seed Spacing: 2.00

Random Grid

Linear Measure Start Threshold: 0.30

File Prefix

Data Probe

L
F
B

Diffusion MRI Analysis

S: 0.000mm V: R: 1.500mm G: A: 1.500mm

L: fa-l...00%)
B: fa

L: fa-l...00%)
B: fa

L: fa-l...00%)
B: fa

5 cm

5 cm

5 cm

The tracts generated in the corpus callosum area appear in the 3D viewer.

Labelmap Seeding: Step 4: Undesirable track removal

Click on the Modules menu and select the module **Tractography Display**

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Labelmap Seeding: Step 4: Undesirable track removal

The screenshot displays the 3D Slicer interface. The top toolbar includes icons for DATA, DCM, SAVE, and Modules, with 'Tractography Display' selected. The main 3D view shows a brain with fiber tractography in green and yellow, with anatomical planes labeled R (Right), P (Posterior), and A (Anterior). A yellow callout box with a red arrow pointing to the 'ROI for Fiber Selection' dropdown menu contains the text: 'Set ROI for Fiber Select to 'ROI node''. The 'Fiber Bundle Selection' panel is expanded, showing 'ROI for Fiber Selection' set to 'ROI Node'. Other options include 'Disable ROI' (selected), 'Positive ROI', and 'Negative ROI'. Below these are 'Interactive ROI', 'Extract Bundle From ROI', 'Update corpusCallosum From ROI' (checked), and 'Enable Interactive Edit'. The bottom of the interface shows three axial, sagittal, and coronal slices of the brain with a 5 cm scale bar. The status bar at the bottom indicates 'L: fa-...0%)', 'B: fa', and '5 cm' for each slice.

Set ROI for Fiber Select to 'ROI node'



Labelmap Seeding: Step 4: Undesirable track removal

The screenshot displays the 3D Slicer interface with the Tractography Display module active. The main 3D view shows a bundle of fiber tracts in green and blue, with a white rectangular ROI box positioned around a section of the bundle. A red arrow points from a yellow text box to this ROI box. The left sidebar contains several panels: 'Help & Acknowledgement', 'Simple Display' (with 'Solid Tube Color' unchecked), 'Name' (containing 'corpusCallosum'), 'Percentage of Fibers Shown' (set to 100%), 'Fiber Bundle Selection' (with 'ROI for Fiber Selection' set to 'ROI Node'), and 'Advanced Display'. The 'Fiber Bundle Selection' panel includes options for 'Disable ROI', 'Positive ROI', and 'Negative ROI', along with 'Interactive ROI', 'ROI Visibility', 'Extract Bundle From ROI', and 'Update corpusCallosum From ROI'. The bottom of the interface shows three orthogonal axial, sagittal, and coronal views of the brain with the ROI box visible in each. A status bar at the bottom indicates coordinates: S: 0.000mm, Y: 1.500mm, G: 1.500mm.

Adjust the ROI frame to include the undesirable tracks

3DSlicer

Modules: Tractography Display

Help & Acknowledgement

Simple Display

Solid Tube Color

Name

corpusCallosum

Percentage of Fibers Shown 100%

Fiber Bundle Selection

ROI for Fiber Selection ROI Node

Disable ROI Positive ROI Negative ROI

Interactive ROI ROI Visibility

Extract Bundle From ROI None

Update corpusCallosum From ROI Confirm update

Enable Interactive Edit

Advanced Display

Data Probe

L
F
B

R S: 0.000mm Y: 1.500mm G: 1.500mm A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm



Labelmap Seeding: Step 4: Undesirable track removal

3DSlicer

Modules: Tractography Display

Help & Acknowledgem

Simple Display

Solid Tube Color

Name	Lines	Tubes	Tubes Slice	Glyphs	Tubes
corpusCallosum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Percentage of Fibers Shown: 100%

Fiber Bundle Selection

ROI for Fiber Selection: ROI Node

Disable ROI Positive ROI Negative ROI

Interactive ROI ROI Visibility

Extract Bundle From ROI: None

Update corpusCallosum From ROI: Confirm update

Enable Interactive Edit

Advanced Display

Data Probe

L
F
B

R S: 0.000mm Y R: 1.500mm G A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm



Labelmap Seeding: Step 4: Undesirable track removal

3DSlicer

Modules: Tractography Display

Help & Acknowledgem

Simple Display

Uncheck ROI Visibility

ROI Visibility

Percentage of Fibers Shown 100%

Fiber Bundle Selection

ROI for Fiber Selection ROI Mode

Disable ROI Positive ROI Negative ROI

Interactive ROI ROI Visibility

Extract Bundle From ROI None

Update corpusCallosum From ROI Confirm update

Enable Interactive Edit

Advanced Display

Data Probe

L
F
B

R S: 0.000mm Y R: 1.500mm G A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm



Labelmap Seeding: Tracts

The image shows the 3D Slicer software interface. On the left, the 'Modules' panel is open, displaying a list of modules. The 'Diffusion' module is selected, and its sub-menu is open, showing 'Tractography Interactive Seeding' as the selected option. A yellow callout box with a red arrow points to this option. The main 3D view shows a brain with green and yellow fiber tracts. Below the 3D view, there are three axial slices of the brain, each with a 5 cm scale bar. The top toolbar contains various icons for navigation and manipulation. The bottom status bar shows the current slice position: S: 0.000mm, R: 1.500mm, G: 1.500mm, A: 1.500mm.

3DSlicer

Help & Acknowledgement

Simple Display

Solid Tube Color

Name

corpusCallosum

Percentage of Fibers Shown

Fiber Bundle Selection

ROI for Fiber Selection

Disable ROI

Interactive ROI

Extract Bundle From ROI

Update corpusCallosum From

Enable Interactive Edit

Advanced Display

Data Probe

L

F

B

Tractography Display

All Modules

Annotations

Data

DataStore

DICOM

Editor

Markups

Models

Scene Views

Subject Hierarchy

Transforms

View Controllers

Volume Rendering

Volumes

Welcome to Slicer

Wizards

Informatics

Registration

Segmentation

Quantification

Diffusion

IGT

Filtering

Surface Models

Converters

Endoscopy

Utilities

Developer Tools

Legacy

MultiVolume Support

Unspecified

BRAINS

Tubes Slice Glyphs Tube

100%

Negative ROI

DWI to Full Brain Tractography

Tractography Display

Diffusion Data Conversion

Diffusion Tensor Images

Diffusion Weighted Images

Tractography

Diffusion Tensor Scalar Measurements

Resample DTI Volume

Tractography Interactive Seeding

Tractography Label Map Seeding

Select the module
Tractography
Interactive Seeding

R

P

A

R

S: 0.000mm

R: 1.500mm

G

A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm

5 cm

5 cm

Tractography Results

Position the mouse over the **pin icon** and click on the **eye icon** to display the axial slice in the 3D viewer

Uncheck **Enable Seeing Tracks**

The screenshot displays the Slicer software interface. At the top, the 'Modules' menu is set to 'Tractography Interactive Seeding'. The main 3D viewer shows a brain slice with green and yellow fiber-like tractography results. Below the viewer, a control panel is visible with the following settings:

- Parameters: FiducialSeedingParameters
- Presets: Slicer4 Interactive Seeding Defaults
- Input DTI Volume: dti
- Input Fiducials, Model or Label Map: fa-label
- Output Fiber Bundle: corpusCallosum
- Enable Seeding Tracks: (unchecked)
- Label Map Options: Use index Space
- ROI Labels: 1
- Write Fibers To Disk:
- Output Directory: /Applications
- File Prefix: (empty)
- Data Probe: (empty)

A red arrow points from the 'Enable Seeding Tracks' checkbox to the 'eye icon' in the 3D viewer's control panel. A yellow tooltip over the 'eye icon' reads 'Toggle slice visibility in 3D view'. The 3D viewer also shows a coordinate system (S: 22.500mm, Y: 1.500mm, R: 1.500mm, G: 1.500mm, A: 1.500mm) and a scale bar of 5 cm.



Fiducial Seeding

Select the module Markups

3DSlicer

Help & Acknowledgement

IO

Parameters: FiducialSeeding

Presets: Slicer4 Interactive

IO

Input DTI Volume

Input Fiducials, Model or Lab

Output Fiber Bundle

Enable Seeding Tracts

Label Map Options

Use index Space

Seed Spacing

Random Grid

Linear Measure Start Thresh

ROI Labels

Write Fibers To Disk

Output Directory

File Prefix

Data Probe

Tractography Interactive Seeding

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups**
- Models
- Scene Views
- Subject Hierarchy
- Transforms
- View Controllers
- Volume Rendering
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Endoscopy

Utilities

Developer Tools

Legacy

MultiVolume Support

Unspecified

BRAINS

2.00

0.30

ns

R

S: 0.000mm

Y

R: 1.500mm

G

A: 1.500mm

L: fa-...0%

B: fa

5 cm

L: fa-...0%

B: fa

5 cm

L: fa-...0%

B: fa

5 cm

L

F

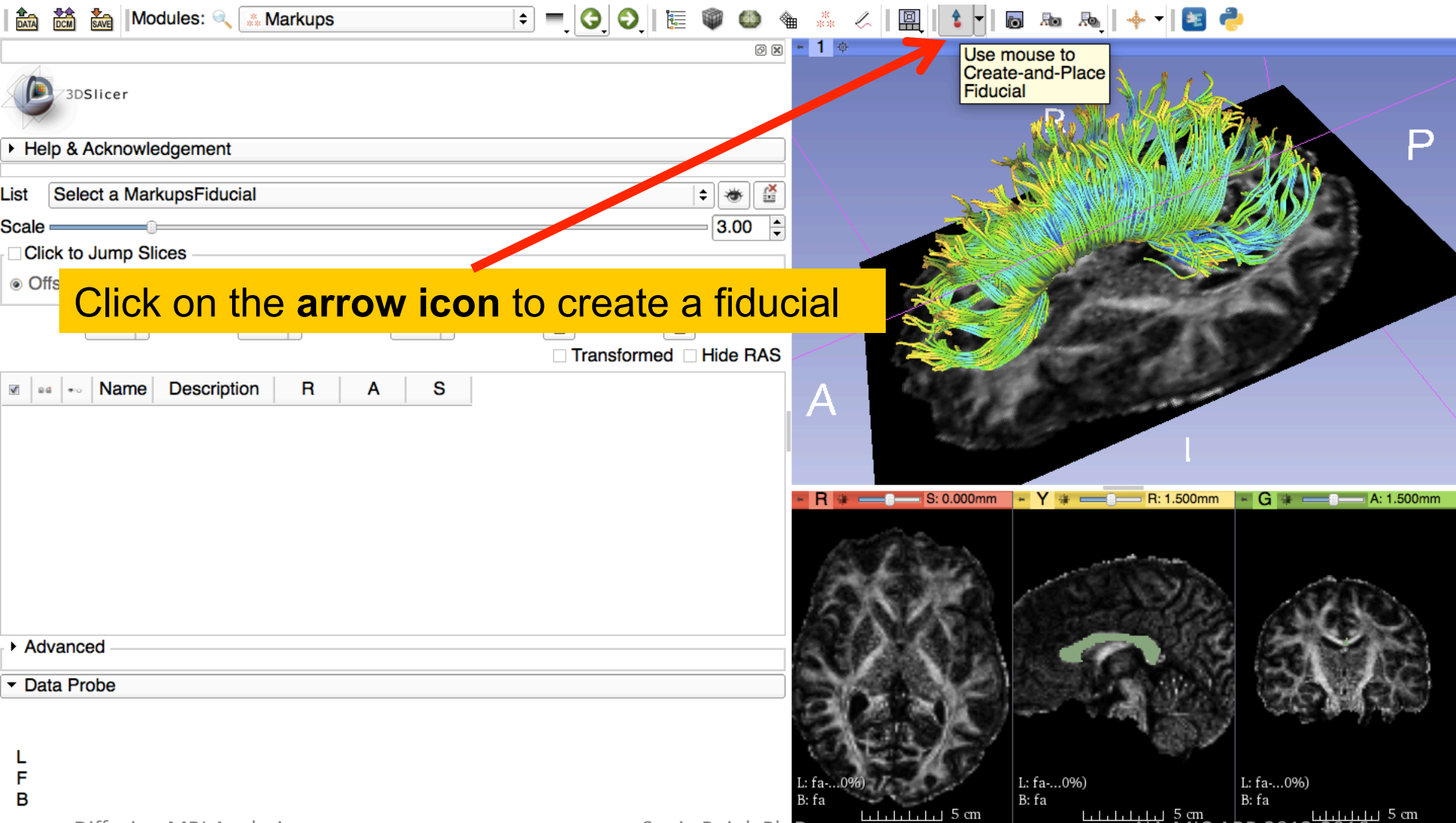
B

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Fiducial Seeding



Fiducial Seeding

Position the fiducial in the left cingulum of the coronal slice

	Name	Description	R	A	S
1	F-1		-3.137	1.500	23.736

Diffusion MRI Analysis

Sonia Pujol, Ph.D.



Fiducial Seeding

3DSlicer

Modules: Markups

Help & Acknowledgement

List F

Sc

Double click on the fiducial and change the name to **LeftCingulum**

Transformed Hide RAS

Name	Description	R	A	S
1	LeftCingulum	-3.137	1.500	23.736

Advanced

Data Probe

L
F
B

R S: 22.500mm Y R: 1.500mm G A: 1.500mm

L: fa...0%)
B: fa

L: fa...0%)
B: fa

L: fa...0%)
B: fa

5 cm 5 cm 5 cm



Fiducial Seeding

The screenshot shows the 3D Slicer software interface. The 'Modules' dropdown menu is set to 'Tractography Interactive Seeding'. The 'Parameters' section is set to 'FiducialSeedingParameters'. The 'Presets' section is set to 'Slicer4 Interactive Seeding Defaults'. The 'IO' section is highlighted with a red box and contains the following settings: 'Input DTI Volume' is 'dti', 'Input Fiducials, Model or Label Map' is 'F', 'Output Fiber Bundle' is 'Cingulum', and 'Enable Seeding Tracks' is checked. The 'Seed Placement Options' section shows 'Fiducial Region Size' at 2.50mm and 'Fiducial Seeding Step Size' at 1.00mm. The 'Data Probe' section is empty. The main 3D view shows a brain slice with a green and yellow fiber bundle. A yellow text box on the right contains instructions: 'Select the module Tractography Interactive Seeding', 'Set the Input DTI volume to 'dti'', 'Set the Input Fiducials, Model or Label Map to 'F'', 'Select the Output Fiber Bundle 'Create New Fiber Bundle' and rename it 'Cingulum'', and 'Check Enable Seeding Tracks'. The bottom of the screen shows the 'Diffusion MRI Analysis' window with a scale bar of 5 cm and the name 'Sonia Pujol, Ph.D.'.

Modules: Tractography Interactive Seeding

3DSlicer

Help & Acknowledgement

IO

Parameters: FiducialSeedingParameters

Presets: Slicer4 Interactive Seeding Defaults

IO

Input DTI Volume: dti

Input Fiducials, Model or Label Map: F

Output Fiber Bundle: Cingulum

Enable Seeding Tracks:

Seed Placement Options

Fiducial Region Size: 2.50mm

Fiducial Seeding Step Size: 1.00mm

Seed Selected Fiducials:

Max Number of Seeds: 100

Data Probe

L
F
B

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

5 cm

5 cm

5 cm

NA-MIC ARR 2012-2016

right cingulum

right cingulum

right cingulum

Fiducial Seeding

The screenshot displays the 3D Slicer interface. At the top, the 'Modules' menu is set to 'Tractography Interactive Seeding'. The main 3D viewer shows a brain slice with a dense bundle of green and blue streamlines representing white matter tracts. A red dot labeled 'Cingulum' is placed on the left side of the bundle. A green rectangular box is overlaid on the left side of the interface, containing the following text:

Part of the left cingulum appears in the 3D viewer.
Move the Left Cingulum fiducial to explore the spatial relationship between the left cingulum and the corpus callosum

Below the 3D viewer, there are three orthogonal views: Axial (top), Sagittal (middle), and Coronal (bottom). The Axial view shows the corpus callosum in green. The Sagittal view shows the cingulum in green. The Coronal view shows the cingulum in green. The bottom right corner of the interface shows a scale bar of 5 cm and a small red 'X' icon.

Fiducial Seeding

Go to the Markups module

Diffusion MRI Analysis

Sonia Pujol, Ph.D.

NA-MIC ARR 2012-2016

Fiducial Seeding

3DSlicer

Modules: Markups

Help & Acknowledgement

List: F

Scale: 3.00

Click to Jump Slices

Offset Centered Show Slice Intersections

Transformed Hide RAS

	✓	✗	👁	Name	Description	R	A	S
1	✓	✗	👁	LeftCingulum		-4.691	1.500	
2	✓	✗	👁	RightCingulum		10.855	1.500	

Double click on the Name and change it to **RightCingulum**

R: 1.500mm G A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm



Fiducial Seeding

3DSlicer

Modules: Markups

Help & Acknowledgement

List F

Scale

Click to Jump Slices

Offset Centered

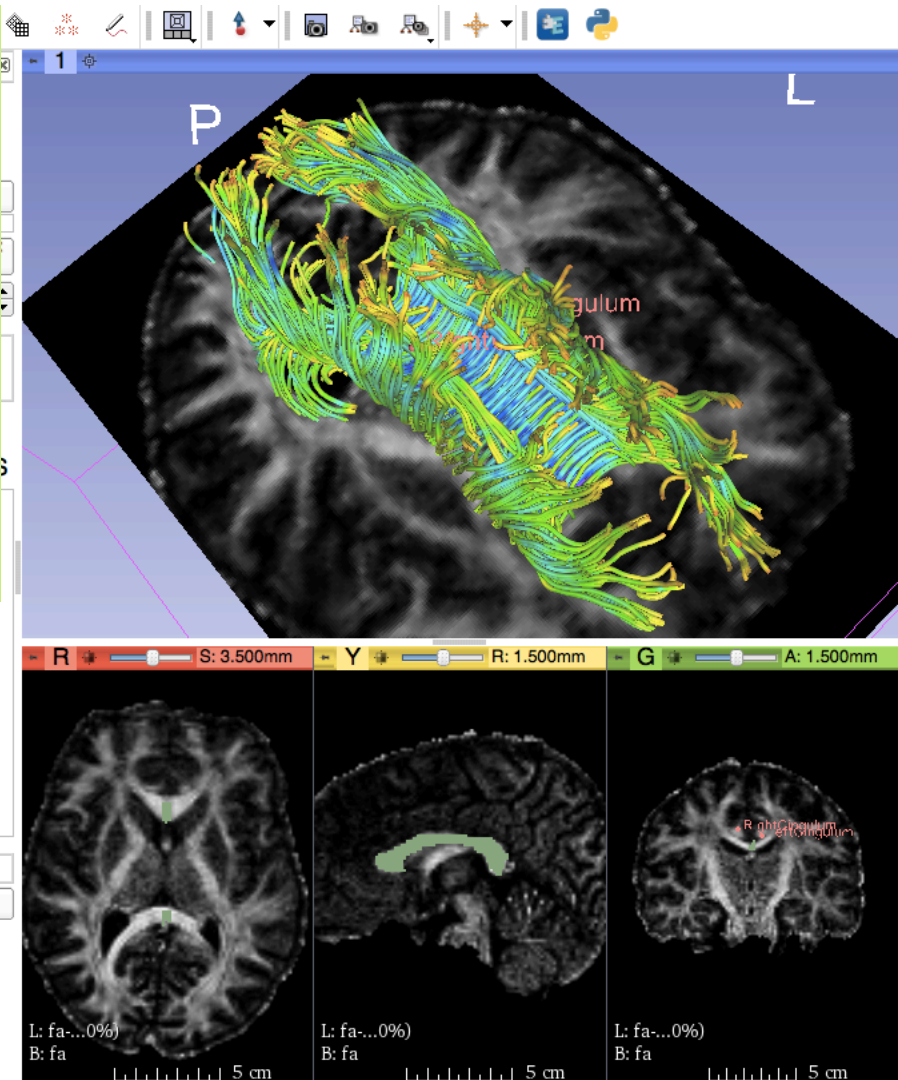
	Name	Description
1	LeftCingulum	
2	RightCingulum	

Advanced

Data Probe

Part of the left and right cingulum appear in the 3D viewer.

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



Fiducial Seeding

Click on the arrow icon to create a new fiducial, and position it in the 3D viewer

	Name	Description	R	A	S
1	LeftCingulum		-4.691	1.500	24.513
2	RightCingulum		9.301	1.500	27.622
3	F-3		36.616	-6.073	-5.171

Advanced
Data Probe

L
F
B

R S: -16.500mm Y R: 1.500mm G A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm



Fiducial Seeding

3DSlicer

Modules:

Help & Acknowledgement

List

Scale

Click to Jump Slices

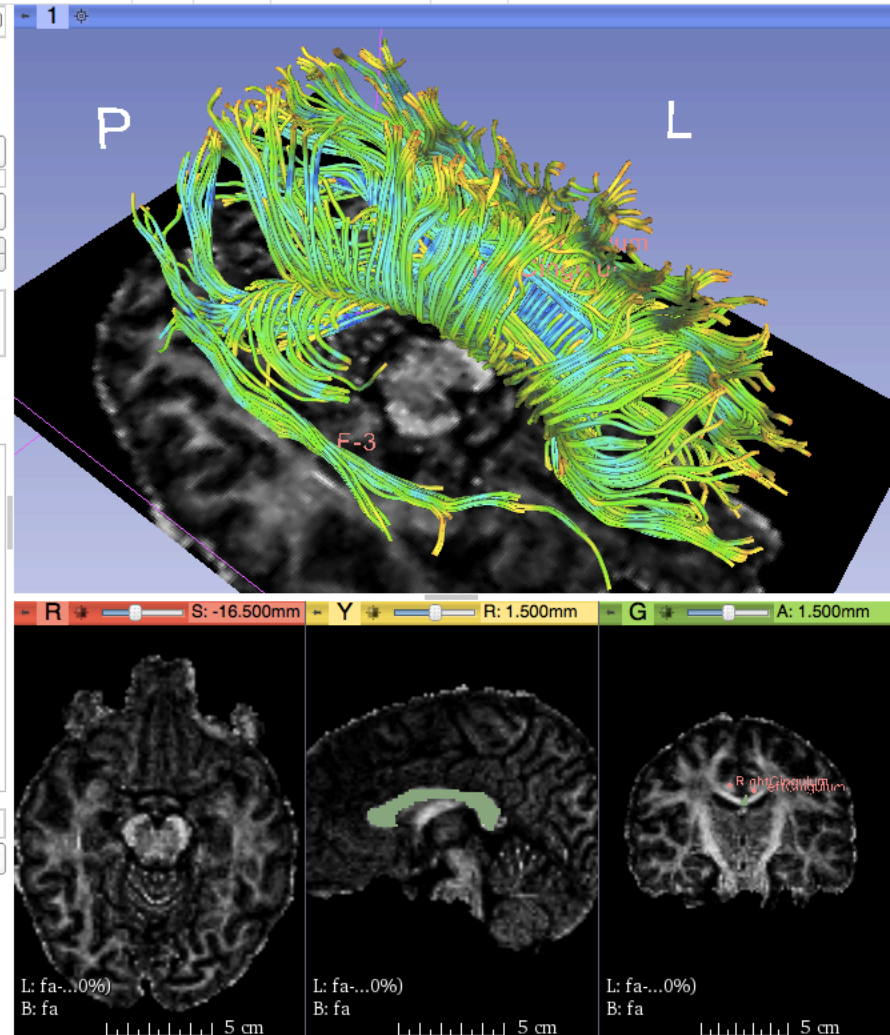
Offset Centered Show Slice Intersections

Transformed Hide RAS

	<input checked="" type="checkbox"/>			Name	Description	R	A	S
1	<input checked="" type="checkbox"/>			LeftCingulum		-4.691	1.500	24.513
2	<input checked="" type="checkbox"/>			RightCingulum		9.301	1.500	27.622
3	<input checked="" type="checkbox"/>			F-3				-6.937

Advanced

Data Probe



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



Tractography 'on-the-fly'

3DSlicer

Help & Acknowledgement

List F

Scale 3.00

Click to Jump Slices

Offset Centered Show Slice Intersections

Transformed Hide RAS

	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Name	Description	R	A	S
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	LeftCingulum		-4.691	1.500	24.513
2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	RightCingulum		9.301	1.500	27.622
3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	F-3		35.306	-3.916	-5.110

Advanced

Data Probe

L
F
B

nm G A: 1.500mm

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm 5 cm 5 cm

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



DTI Analysis

3DSlicer

Modules: Data

Help & Acknowledgement

Display & Modify Scene

Nodes

- Scene
 - View1
 - Red
 - Yellow
 - Green
 - Default Scene Camera
 - dwi
 - baseline
 - dwi_mask
 - dti
 - fa
 - trace
 - fa-label
 - All Annotations
 - ROI Node
 - ROI List
 - corpusCallosum
 - F
 - Cingulum

Scene Model: Transform

- Display MRML ID's
- Show Hidden nodes

Data Probe

Volume

P L

R S: -16.500mm Y R: 1.500mm G A: 1.500mm

L: fa-...0%)
B: fa

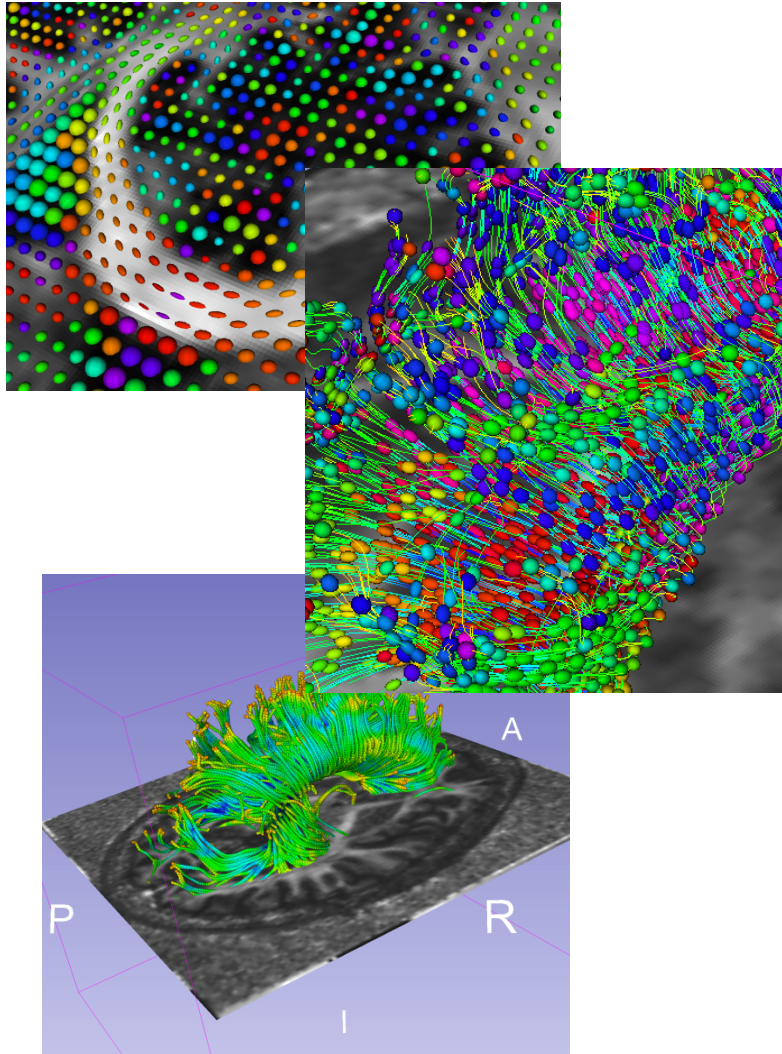
L: fa-...0%)
B: fa

L: fa-...0%)
B: fa

5 cm



Conclusion



This tutorial guided you through the different steps of a Diffusion MR analysis pipeline, from tensor estimation to 3D tracts visualization, for exploring and studying the 3D architecture of the brain white matter.

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