



Diffusion MRI Analysis

Sonia Pujol, Ph.D.

Surgical Planning Laboratory

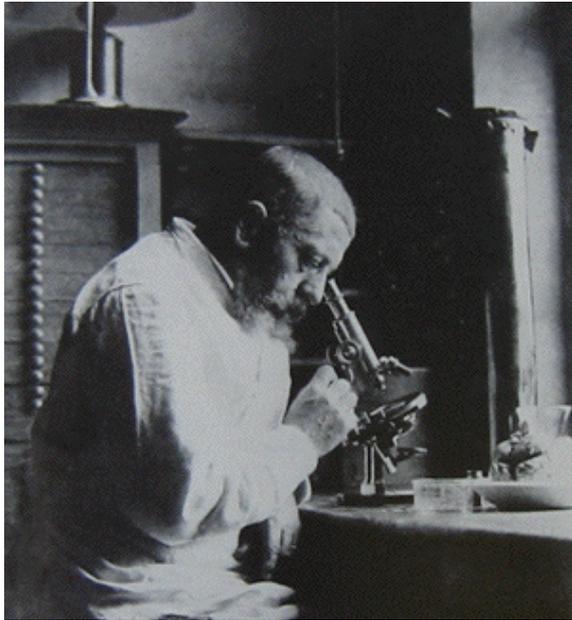
Harvard University

Brain Anatomy



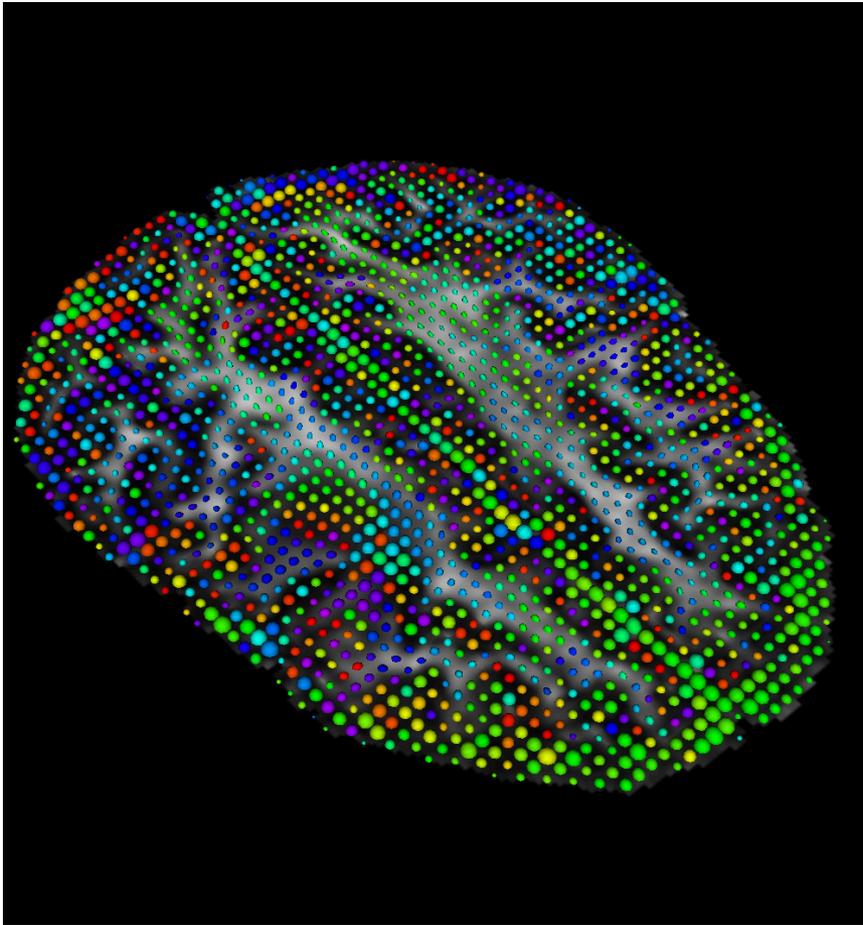
- White matter ~45% of the brain
- Myelinated nerve fibers (~ 10 μm axon diameter)

White Matter Exploration



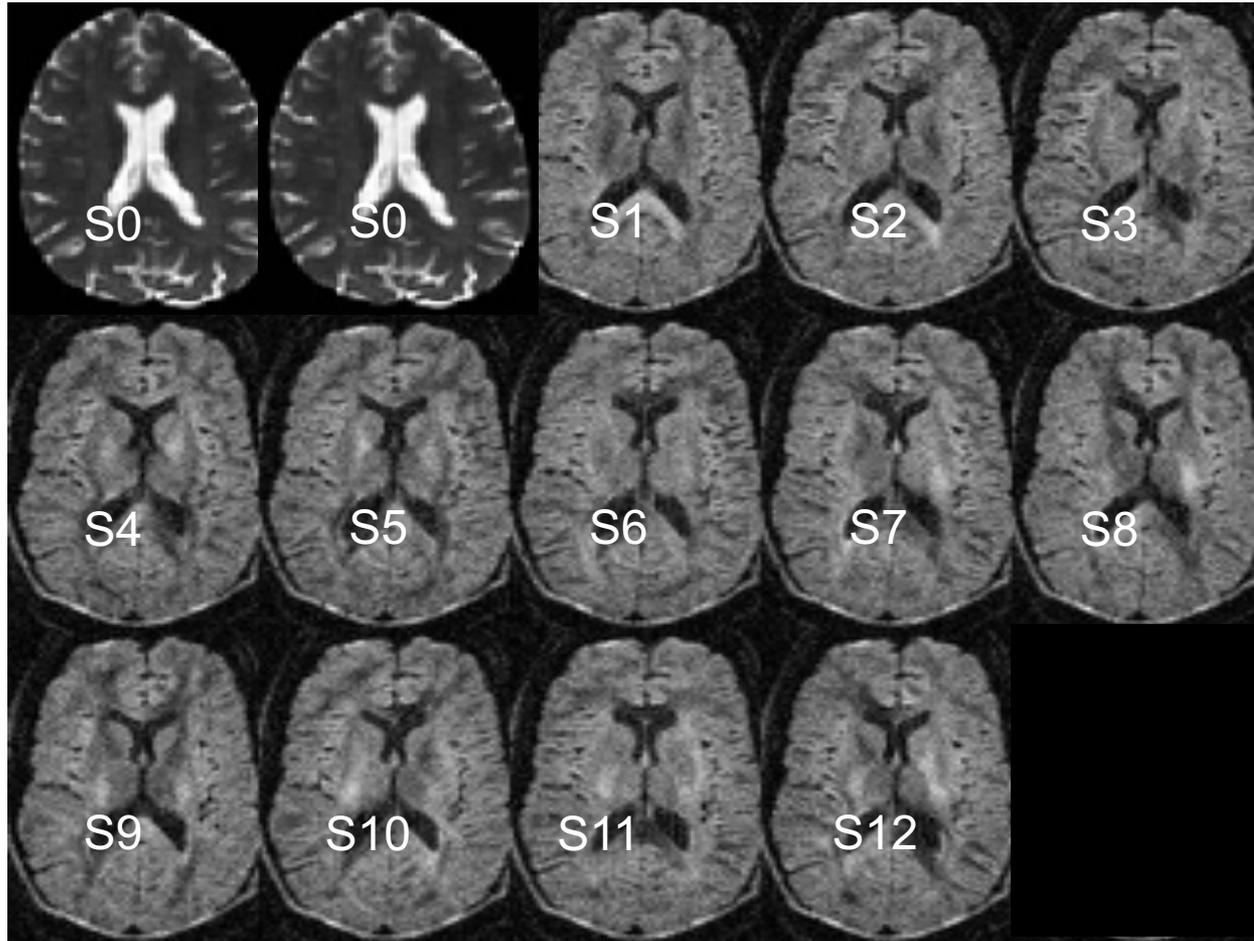
Jules Joseph Dejerine
(*Anatomie des centres
nerveux* (Paris, 1890-1901):
Atlas of Neuroanatomy based
on myelin stained preparation

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)

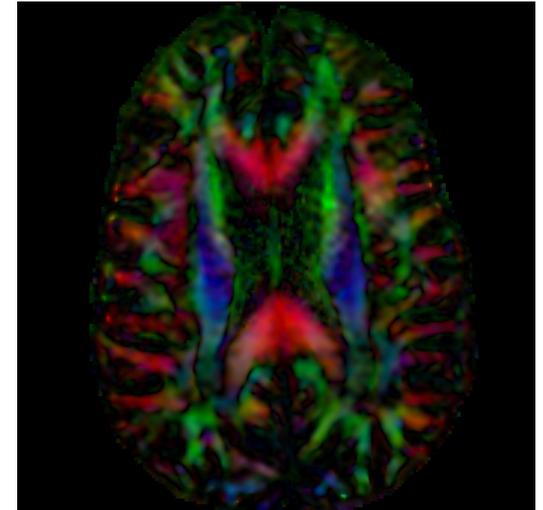
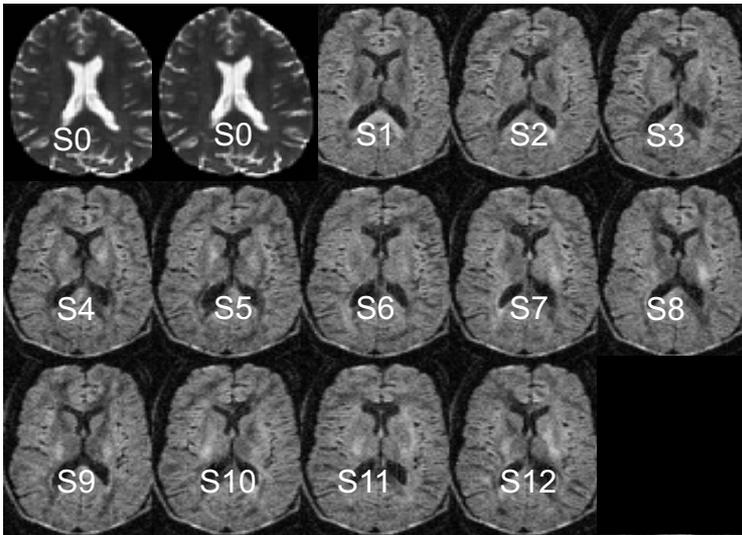


In this example, the DWI scan was acquired with 12 diffusion sensitizing gradient directions (S1-S12) and 2 non-diffusion sensitizing gradients (S0)

From DWI to DTI

DWI

DTI



DWI dataset acquired with 12 gradient and 2 baseline

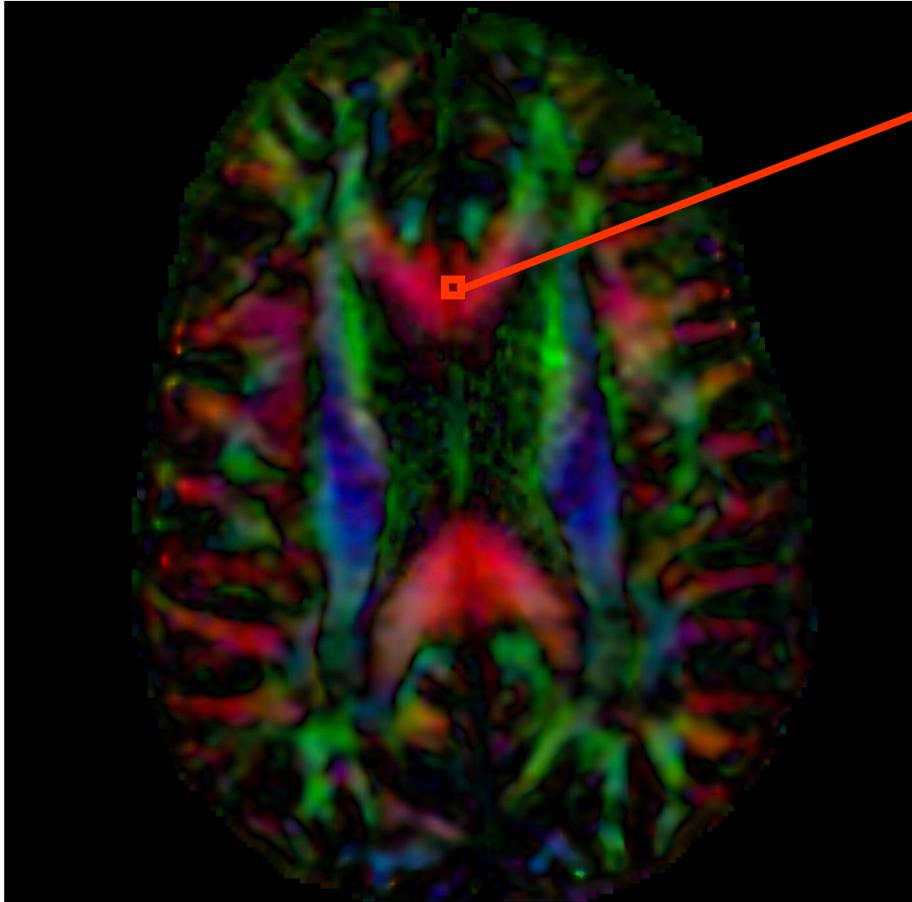
DTI dataset

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

Stejskal-Tanner (1965)

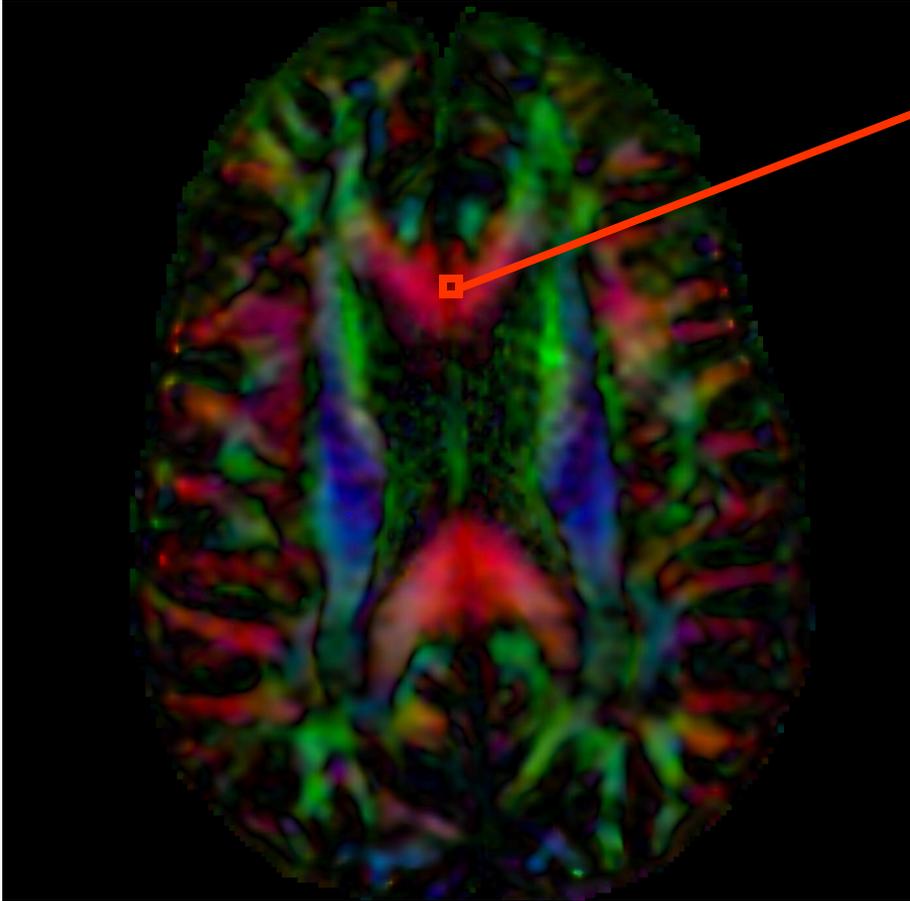
S_i : DWI volume acquired with i th gradient
 S_0 : Baseline volume

Diffusion Tensor Imaging



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

Diffusion Tensor Imaging

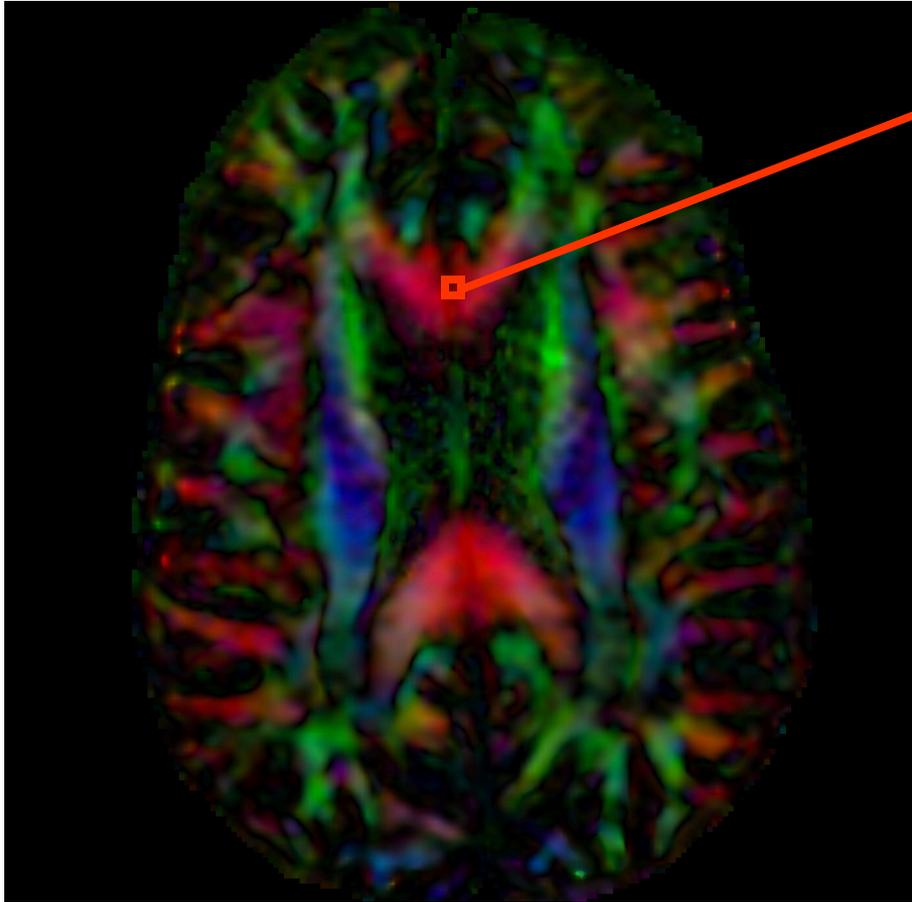


$$S_i = S_0 e^{-b \hat{g}_i^T \underline{D} \hat{g}_i}$$



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

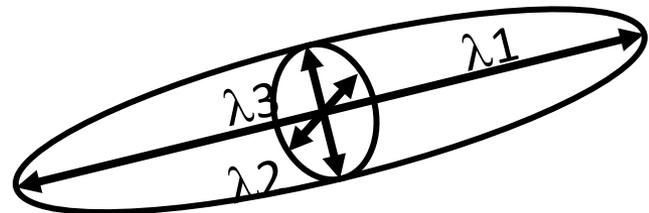
Diffusion Tensor Imaging



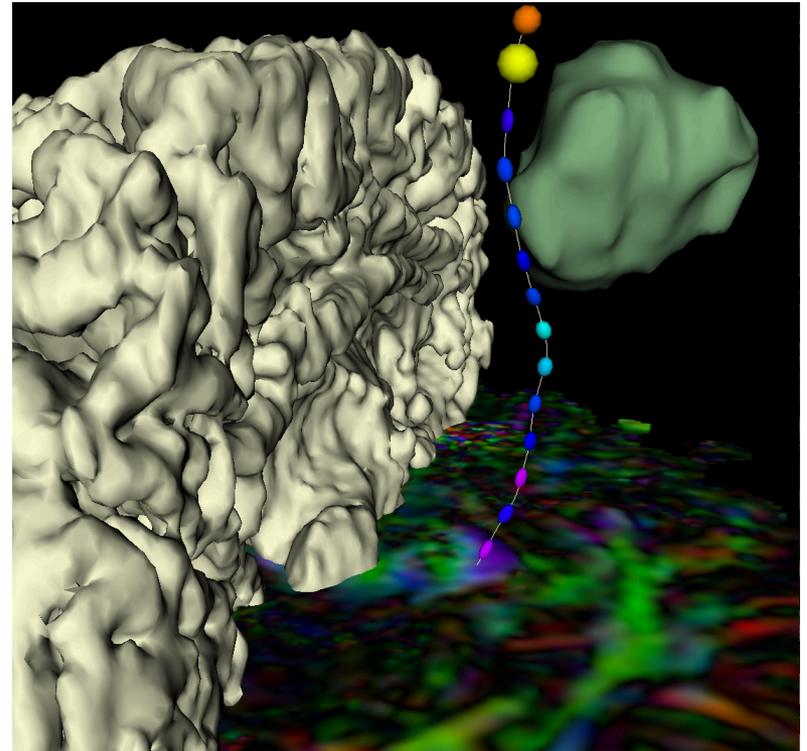
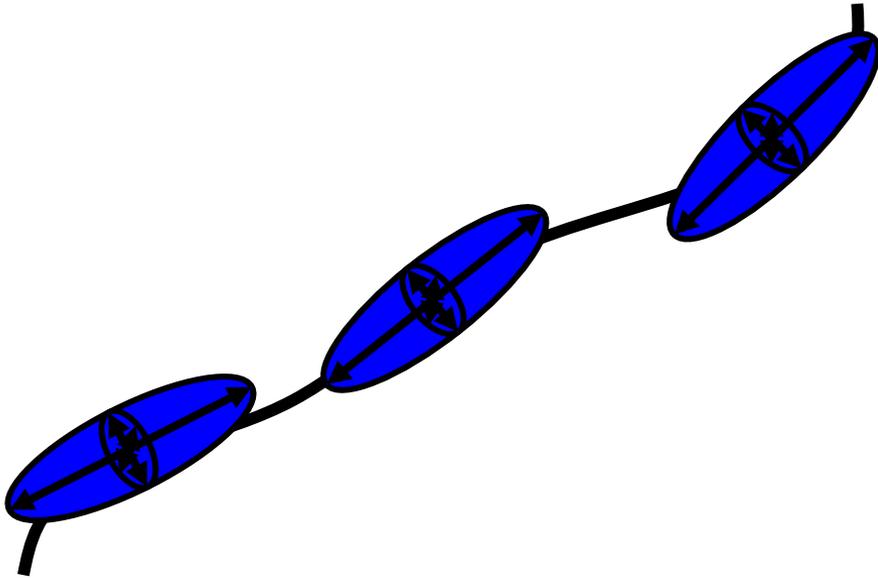
$$S_i = S_0 e^{-b \hat{g}_i^T \underline{D} \hat{g}_i}$$



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



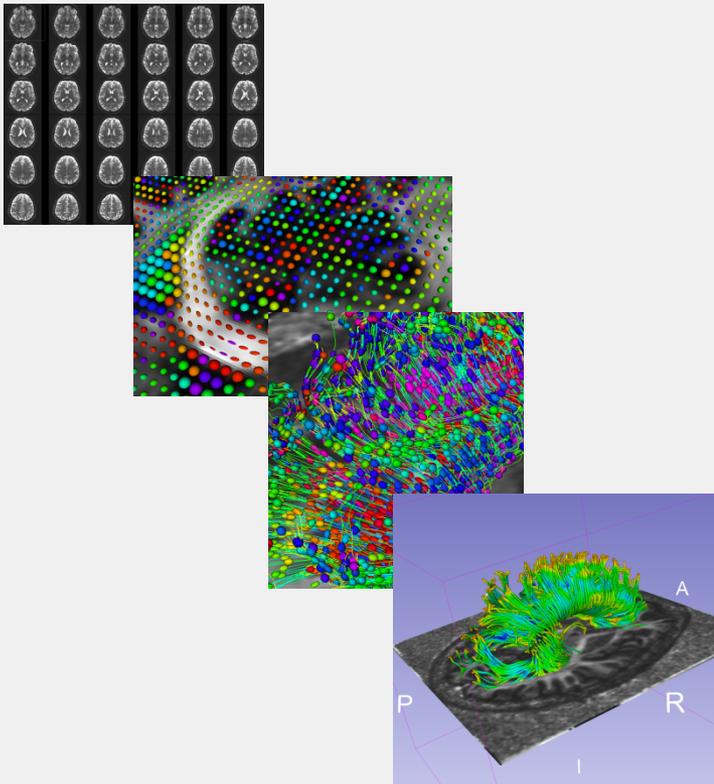
Tractography



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

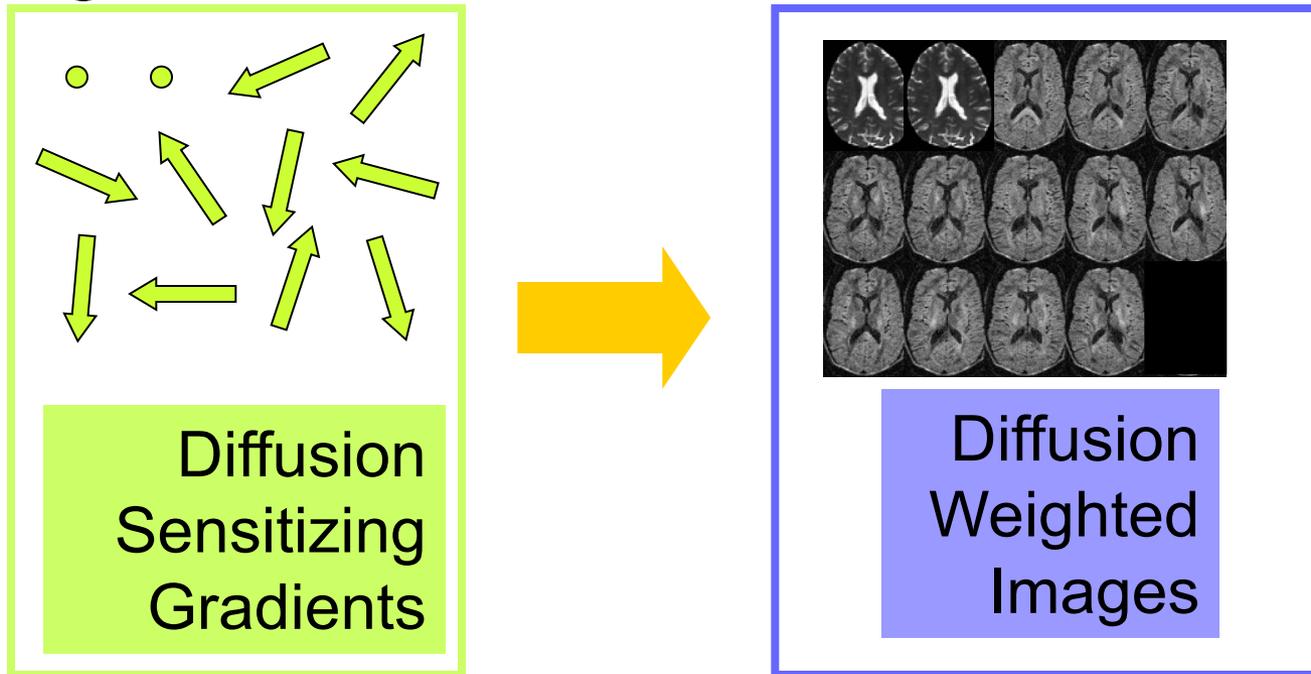
Tutorial Outline

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



Tutorial Dataset

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



Download the dataset at:

https://www.slicer.org/w/images/e/e6/Dti_tutorial_data.zip

3D Slicer

The tutorial uses the 3D Slicer (Version 4.8.1, revision 26813, Stable Release) software available at:

<http://download.slicer.org>

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.

SlicerDMRI

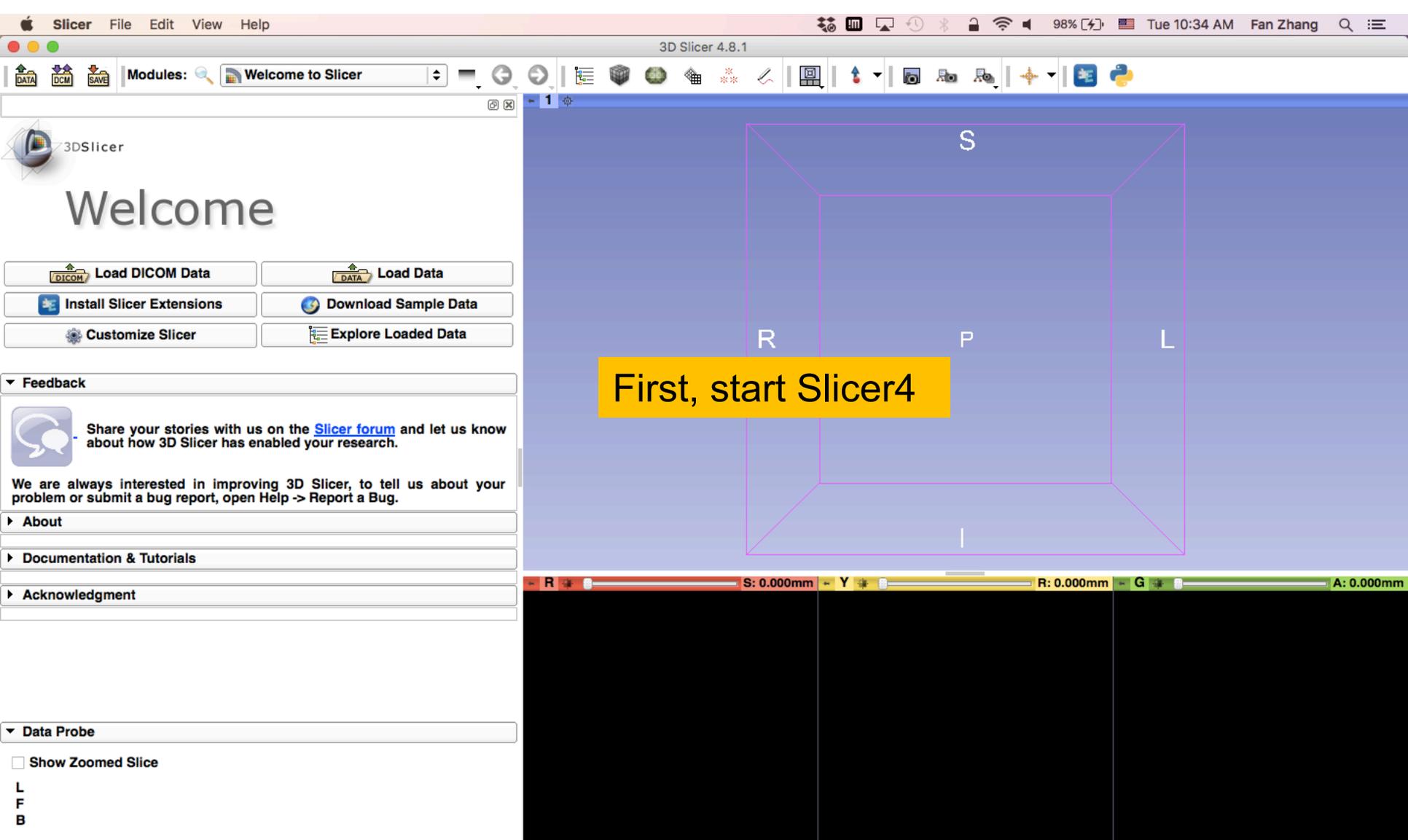
An open-source project to improve and extend diffusion magnetic resonance imaging software in 3D Slicer:

<http://dmri.slicer.org>

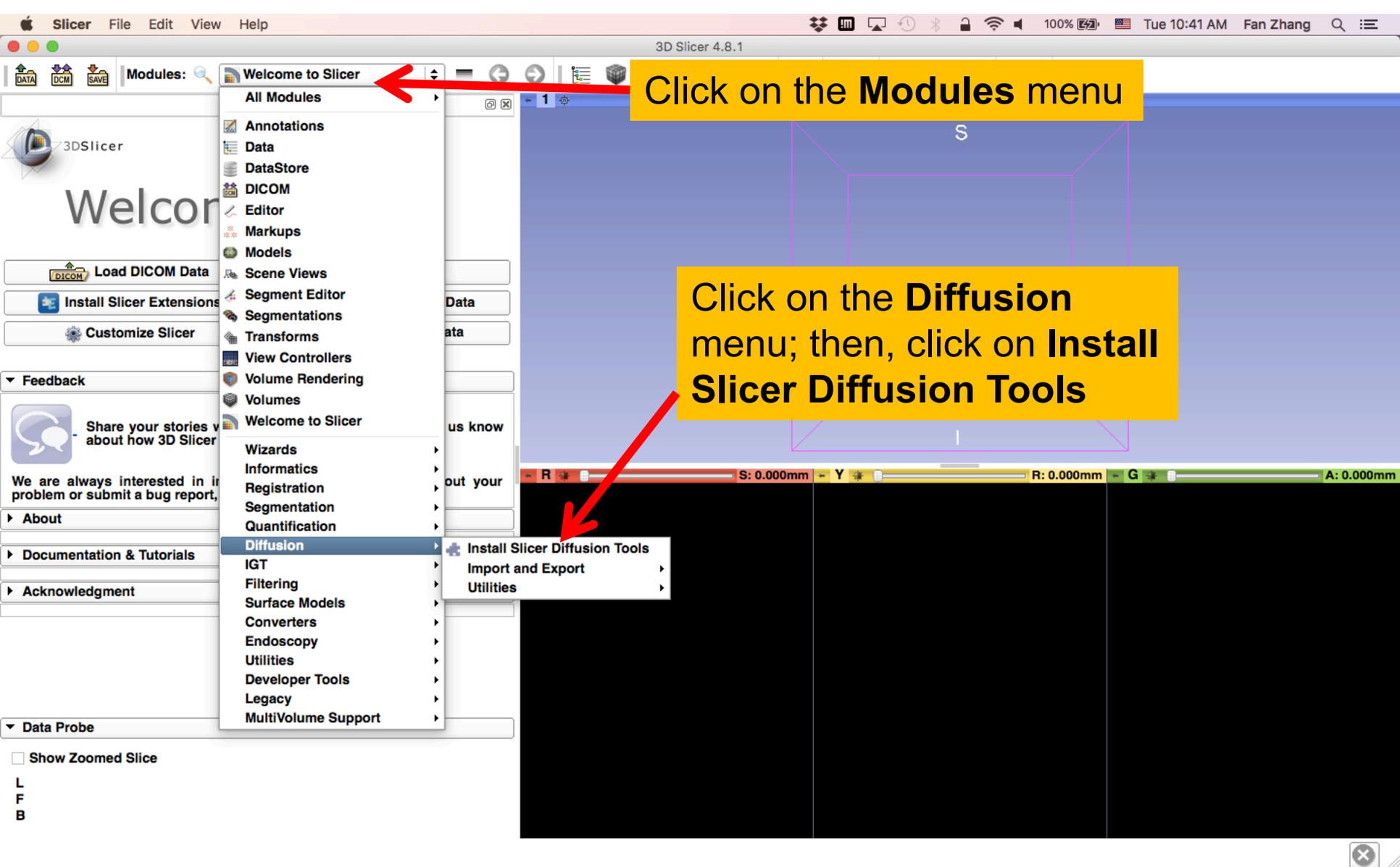
Disclaimer

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.

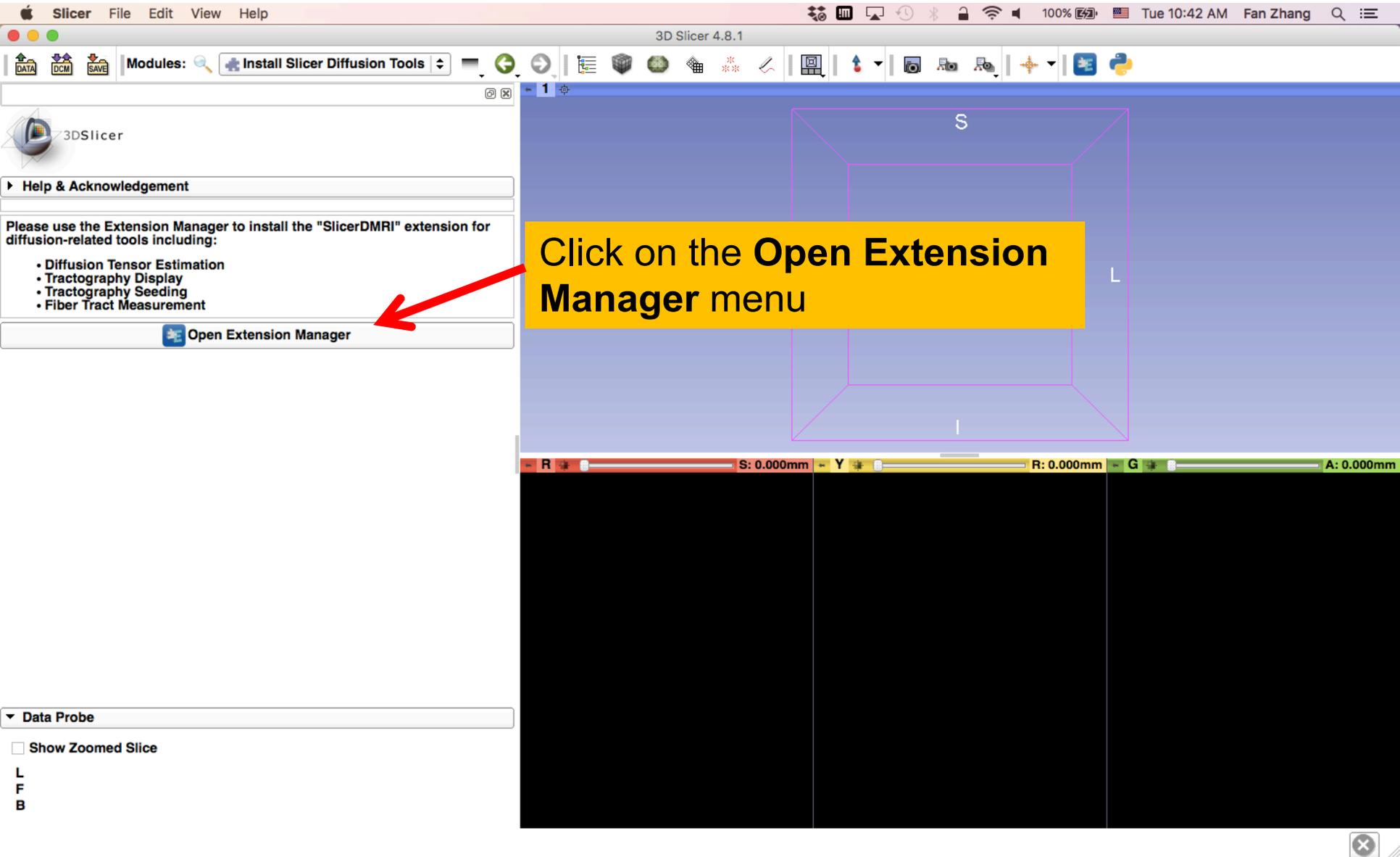
Install SlicerDMRI



Install SlicerDMRI



Install SlicerDMRI



Install SlicerDMRI

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer' and system icons. The main toolbar has 'Install Slicer Diffusion Tools' selected. The 'Extensions Manager' window is open, displaying a search for 'SlicerDMRI'. The search results show a single extension card for 'SlicerDMRI' by 'Isaiah Norton, Lauren ...' with a blue 'INSTALL' button. A red arrow points from the search bar to the extension card, and another red arrow points from the extension card to the 'INSTALL' button. A yellow callout box with black text says 'Search for SlicerDMRI in Extension Manager' with an arrow pointing to the search bar. Another yellow callout box with black text says 'Click on SlicerDMRI to install' with an arrow pointing to the extension card. The bottom of the window has 'Restart' and 'Close' buttons. The background shows a 3D brain model and various toolbars.

3D Slicer 4.8.1

Modules: Install Slicer Diffusion Tools

Extensions Manager

Search: SlicerDMRI

Slicer Extensions

Categories

- All
- Diffusion (1)

SlicerDMRI
Isaiah Norton, Lauren ...
★★★★★ (0)

INSTALL

Search for **SlicerDMRI** in Extension Manager

Click on **SlicerDMRI** to install

Restart Close

Install SlicerDMRI

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', system icons, and the date/time 'Tue 10:43 AM Fan Zhang'. The main toolbar has 'Install Slicer Diffusion Tools' selected. The 'Extensions Manager' window is open, displaying 'Slicer Extensions' with a search for 'SlicerDMRI'. A dialog box is overlaid on the window, asking: 'SlicerDMRI depends on the following extensions: UKFTractography. Would you like to install them now?'. The 'Yes' button is highlighted with a red arrow. A yellow banner at the bottom of the dialog area reads 'Click Yes to install UKFTractography'. The background shows a 3D model of a brain slice and various toolbars.

3D Slicer 4.8.1

Modules: Install Slicer Diffusion Tools

Extensions Manager

Manage Extensions (0) Install Extensions

SlicerDMRI

Slicer Extensions

Categories

- All
- Diffusion (1)

SlicerDMRI depends on the following extensions:

- UKFTractography

Would you like to install them now?

Yes No

Click Yes to install UKFTractography

Restart Close

Install SlicerDMRI

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer' and system icons. The main toolbar has 'Install Slicer Diffusion Tools'. The 'Extensions Manager' window is open, displaying 'Slicer Extensions'. The search bar contains 'SlicerDMRI'. The 'Diffusion (1)' category is selected, showing the 'SlicerDMRI' extension by 'Isalah Norton, Lauren ...' with a 'UNINSTALL' button. A yellow box highlights the text 'Restart Slicer to finish installation'. At the bottom of the window, a red asterisk indicates '* Restart requested' and buttons for 'Restart' and 'Close' are visible. A red arrow points from the yellow box to the 'Restart' button.

3D Slicer 4.8.1

Modules: Install Slicer Diffusion Tools

Extensions Manager

Manage Extensions (2) Install Extensions

SlicerDMRI

Slicer Extensions

Categories

- All
- Diffusion (1)

SlicerDMRI
Isalah Norton, Lauren ...
★★★★★ (0)
UNINSTALL

Installed extension UKFTractography (201759) revision a89ac6c

Downloading extension [itemid: 329717]

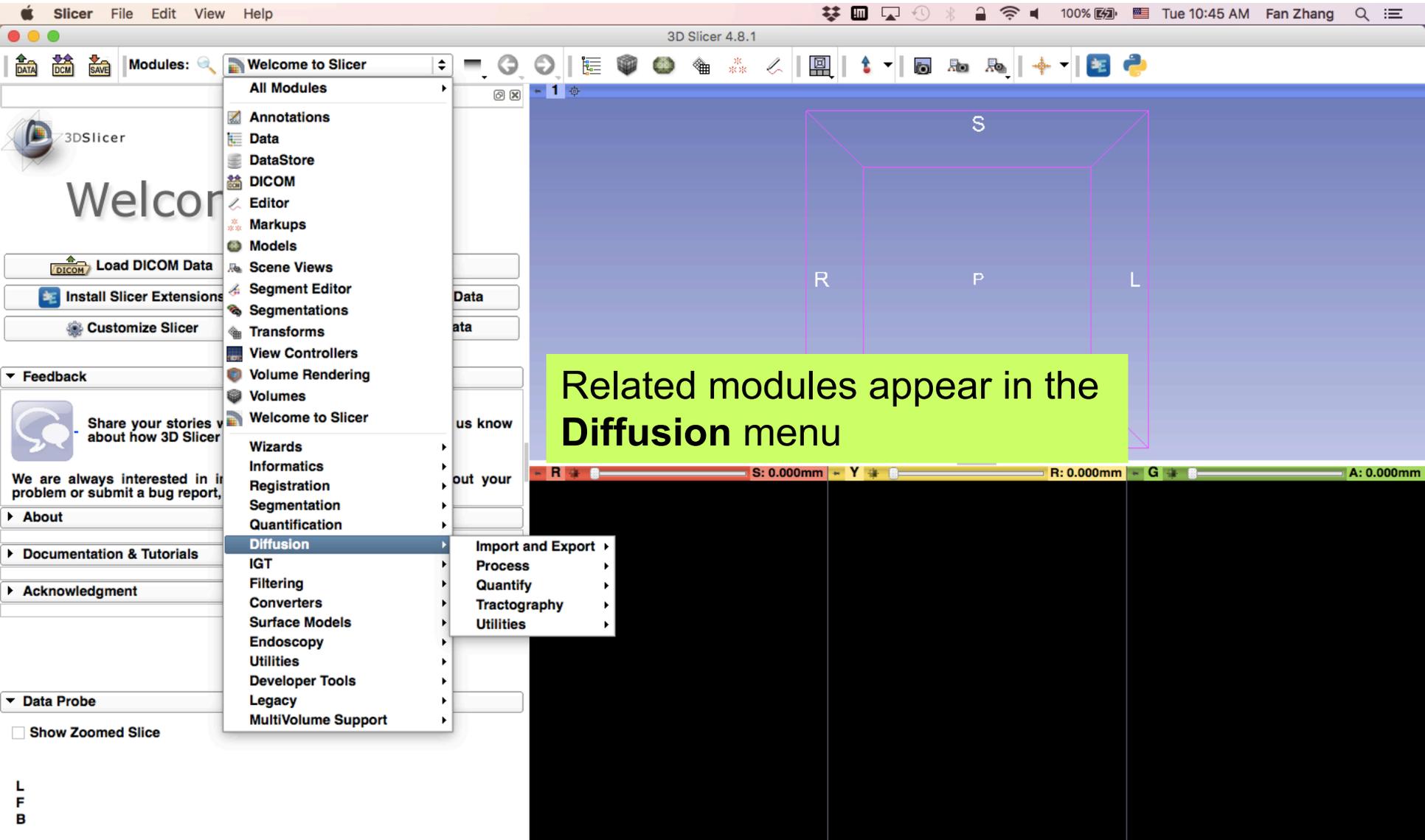
Installed extension SlicerDMRI (201755) revision 3ae6094

Restart Slicer to finish installation

* Restart requested

Restart Close

Install SlicerDMRI

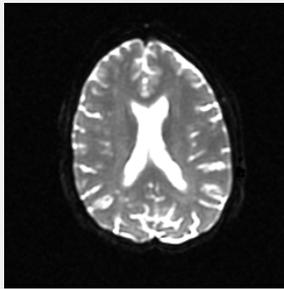


Learning Objectives

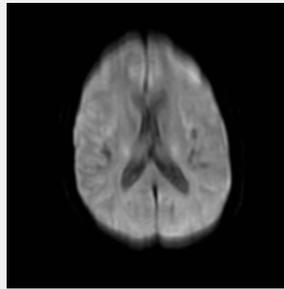
Following this tutorial, you'll be able to

- 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

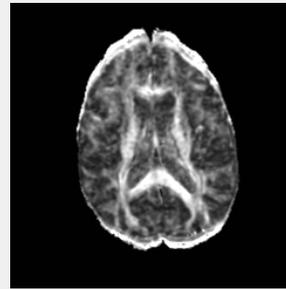
MR Diffusion Analysis Pipeline



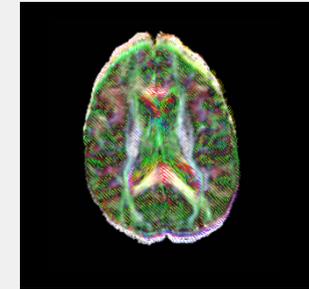
DWI
Acquisition



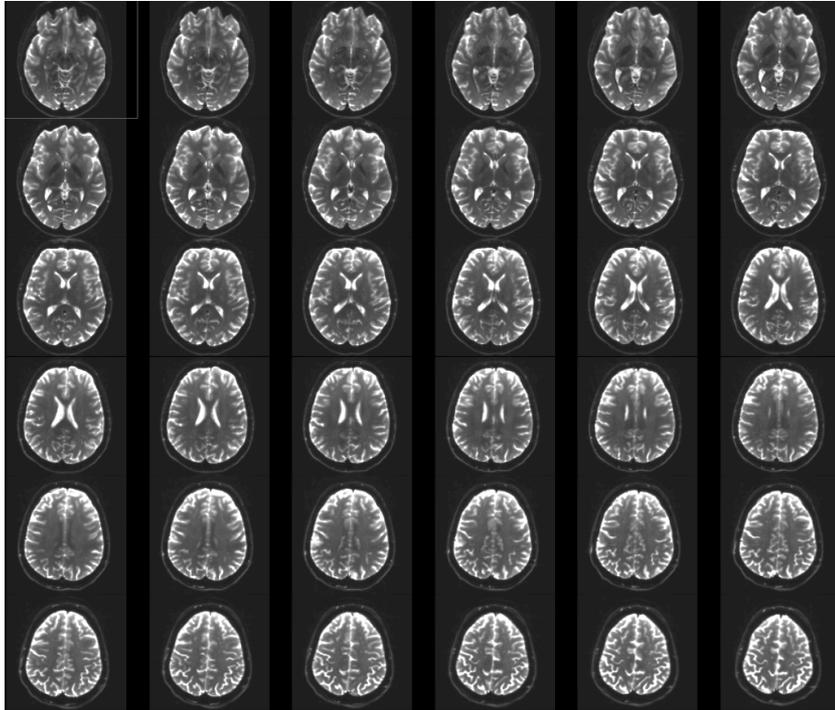
Tensor
Calculation



Scalar
Maps

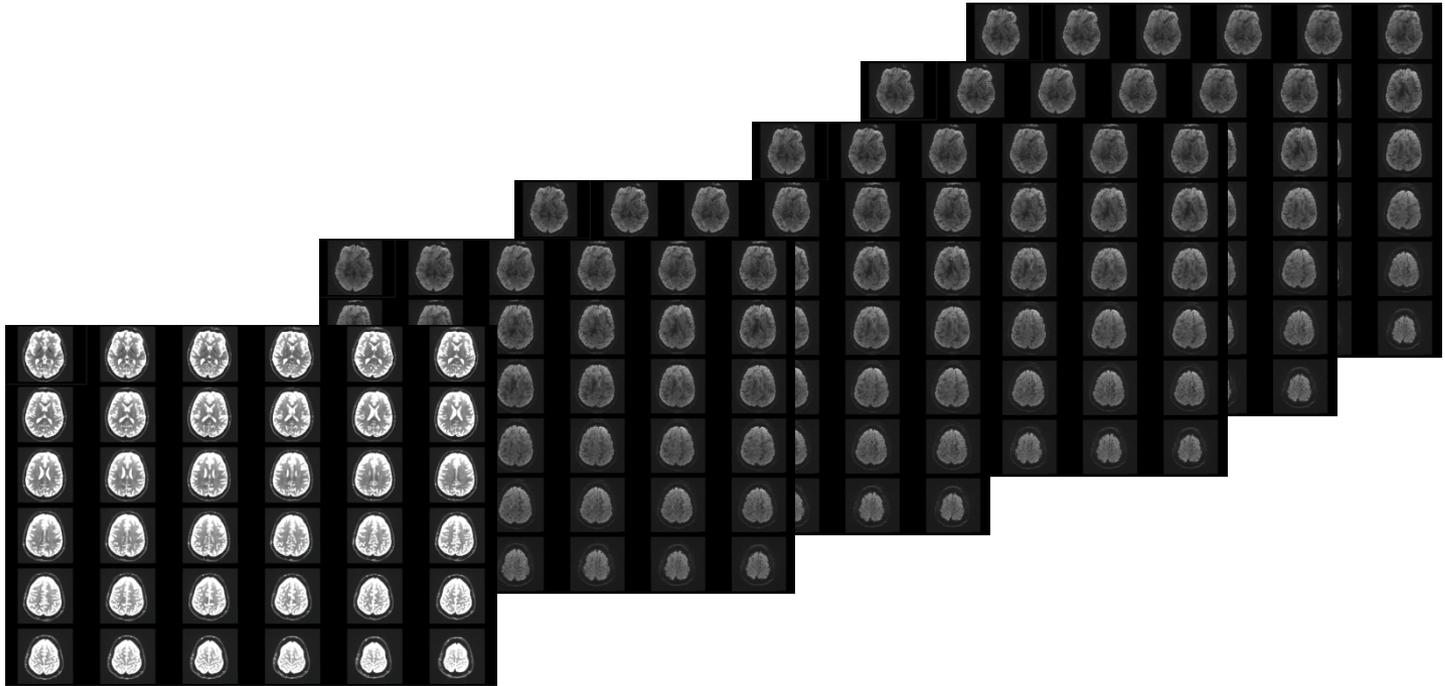


3D
Visualization



Part 1: From DWI images to Tensors

Understanding the DWI Dataset



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

Loading the DWI Dataset

The image shows the 3D Slicer 4.8.1 application window. The top menu bar includes 'Finder', 'File', 'Edit', 'View', 'Go', 'Window', and 'Help'. The main interface has a 'Welcome' message and a 'Modules' dropdown. A yellow text box with a red arrow pointing to the file 'dwi.nrrd' in a Finder window says: 'In your files archive, locate the file **dwi.nrrd** in the dataset folder for this tutorial'. The Finder window shows a table with columns 'Name', 'Date Modified', 'Size', and 'Kind'. The file 'dwi.nrrd' is highlighted, with a date of 'Jun 3, 2015, 5:15 PM' and a size of '85 MB'. A second yellow text box with a red arrow pointing to the 3D viewer area says: 'Drag and drop the file **dwi.nrrd** onto the viewer of the Slicer application'. The 3D viewer shows a blue background with a purple wireframe box and axes labeled 'S', 'L', 'R', 'G', and 'A'. The bottom status bar shows 'R: 0.000mm', 'G', and 'A: 0.000mm'. The left sidebar contains options like 'Load DICOM Data', 'Install Slicer Extensions', 'Customize Slicer', 'Feedback', and 'Data Probe'.

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

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

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

Loading the DWI Dataset

The screenshot shows the 3D Slicer 4.8.1 application window. The main interface includes a top toolbar, a central 3D view area with a purple wireframe box, and a left sidebar with a 'Welcome' message and various tool buttons. A dialog box titled 'Add data into the scene' is open in the foreground. The dialog has two tabs: 'Choose Directory to Add' and 'Choose File(s) to Add'. The 'Choose File(s) to Add' tab is active, showing a table with one file selected:

File	Description
<input checked="" type="checkbox"/> /Users/fan/Dropbox (Partners HealthCare)/WROK/tutorials/dti_tutorial_data/dwi.nrrd	Volume

At the bottom of the dialog, there are 'Reset', 'OK', and 'Cancel' buttons. A red arrow points from a yellow text box to the 'OK' button.

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

Loading the DWI Dataset

The screenshot shows the 3D Slicer 4.8.1 application window. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The title bar indicates '3D Slicer 4.8.1' and the system tray shows the time as 'Tue 10:47 AM' and the user as 'Fan Zhang'. The main interface is divided into a left sidebar and a central 3D view.

Left Sidebar:

- 3DSlicer logo
- Welcome message
- Buttons: Load DICOM Data, Load Data, Install Slicer Extensions, Download Sample Data, Customize Slicer, Explore Loaded Data
- Feedback section with a message: 'Share your stories with us on the [Slicer forum](#) and let us know about how 3D Slicer has enabled your research.'
- Buttons: Report a Bug, About, Documentation & Tutorials, Acknowledgment
- Data Probe section showing: Red (L 59.5, A 79.5, S 0.0) Axial Sp: 1.5, L None, F None, B dwi (104, 11, 47) 49 components

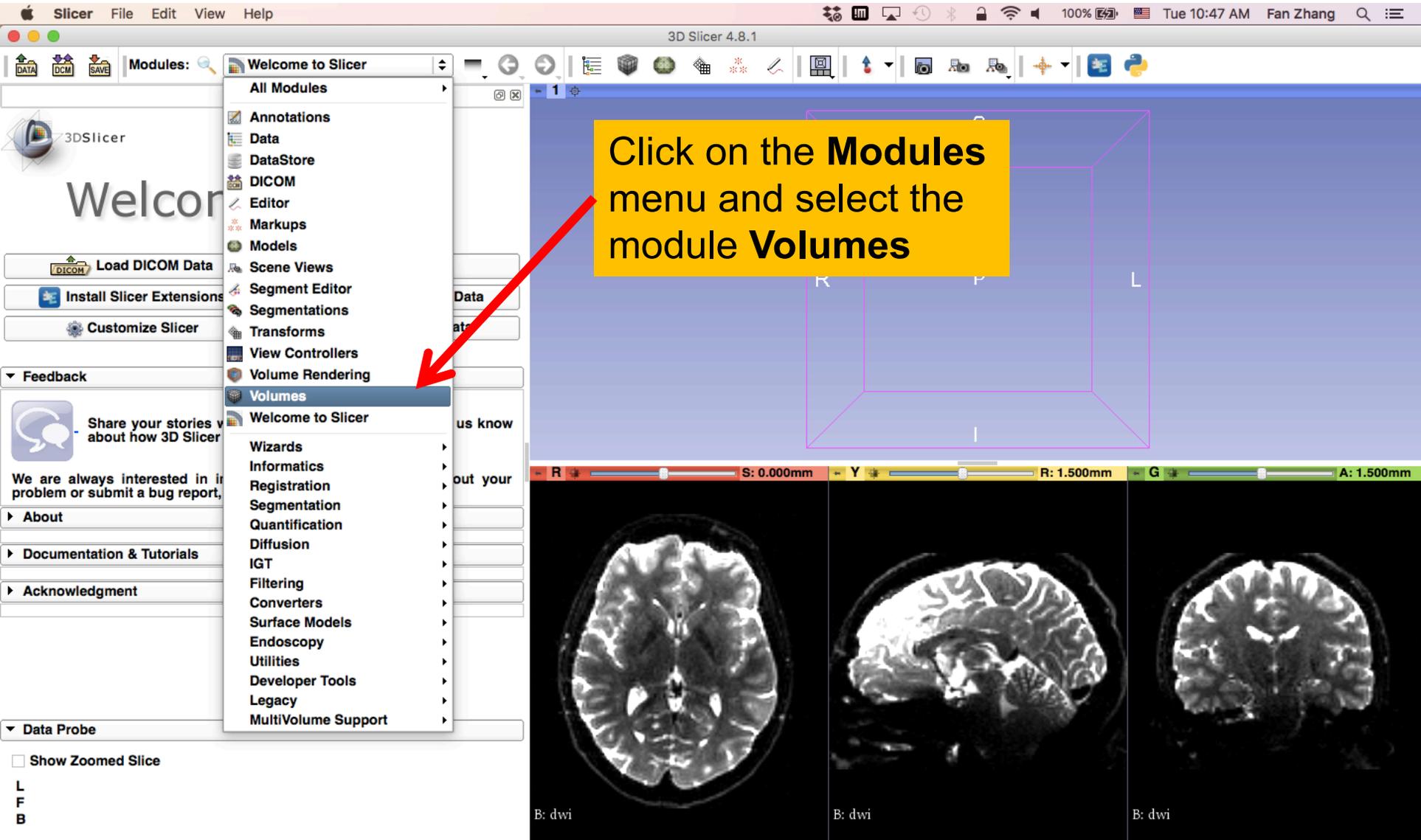
Central 3D View:

- A large purple wireframe box is overlaid on the 3D view, with axes labeled S (Superior), I (Inferior), P (Posterior), and L (Lateral).
- A green text box in the center of the wireframe reads: 'Slicer displays DWI volume of the brain'.
- Below the 3D view is a control bar with sliders for R (Red), Y (Yellow), G (Green), and A (Alpha). The values are: S: 0.000mm, R: 1.500mm, A: 1.500mm.

Bottom Panel:

- Three orthogonal views of the DWI volume are shown: Axial (left), Sagittal (middle), and Coronal (right).
- Each view is labeled 'B: dwi' at the bottom.

Loading the DWI Dataset



Loading the DWI Dataset

The screenshot displays the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The status bar shows '3D Slicer 4.8.1', 'Tue 10:48 AM', and 'Fan Zhang'. The 'Modules' panel on the left shows 'Volumes' selected. The 'Active Volume' is 'dwi'. The 'Volume Information' panel is visible. The 'Scalar Display' panel is highlighted with a red box, showing 'DWI Component: 10' and 'Lookup Table: Grey'. The 'Window/Level' panel shows 'W: 400', 'Auto W/L', 'L: 283', and 'Threshold: Off'. The 'Data Probe' panel is at the bottom left. The main 3D view shows a brain slice with a purple bounding box. The bottom right shows three axial brain slices labeled 'B: dwi'.

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

The screenshot displays the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The status bar shows '3D Slicer 4.8.1', '100%' zoom, and the user 'Fan Zhang' at 'Tue 10:49 AM'. The 'Modules' panel on the left shows 'Volumes' selected. The 'Active Volume' is 'dwi'. The 'Volume Information' panel is visible. The 'Display' panel is expanded to 'Scalar Display', showing 'DWI Component: 10', 'Lookup Table: Grey', 'Interpolate: checked', and 'Window/Level: [W: 400, L: 283]'. A red box highlights the 'Window/Level' controls, including a 'Threshold: Off' dropdown and a slider from -600 to 1390. The main 3D view shows a brain slice with axes 'S', 'R', 'P', 'L', and 'I'. Below the 3D view are three 2D slice views labeled 'B: dwi'. The bottom status bar shows 'R: 1.500mm', 'Y: 0.000mm', 'G: 1.500mm', and 'A: 1.500mm'.

For image contrast adjustment, you may use the Manual W/L slider.

Loading the DWI Dataset

The screenshot displays the 3D Slicer 4.8.1 interface. On the left is the 'Volumes' module panel, showing 'Active Volume: dwi' and various display settings like 'Scalar Display', 'Lookup Table: Grey', and 'Window/Level'. The main 3D view area is currently empty, with a yellow text box overlaid that reads: 'Position your mouse over the pin icon, then click on the link icon and the fit image to window icon'. A red arrow points from this text box to the 'pin' icon in the bottom toolbar. Below the toolbar, three image thumbnails are visible, each labeled 'B: dwi'. A second red arrow points from the 'fit image to window' icon in the toolbar to the first thumbnail. The top status bar shows '3D Slicer 4.8.1' and system information like 'Tue 10:49 AM Fan Zhang'.

Loading the DWI Dataset

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The main window displays a DWI dataset with three orthogonal views (axial, sagittal, and coronal). A red arrow points from a yellow text box to the 'Red slice only' option in the layout menu. The menu is open, showing various layout options such as 'Conventional', 'Four-Up', 'Dual 3D', and 'Red slice only'. The 'Red slice only' option is highlighted in blue. The interface also shows a 'Modules' panel on the left with 'Volumes' selected, and a 'Data Probe' panel at the bottom left.

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

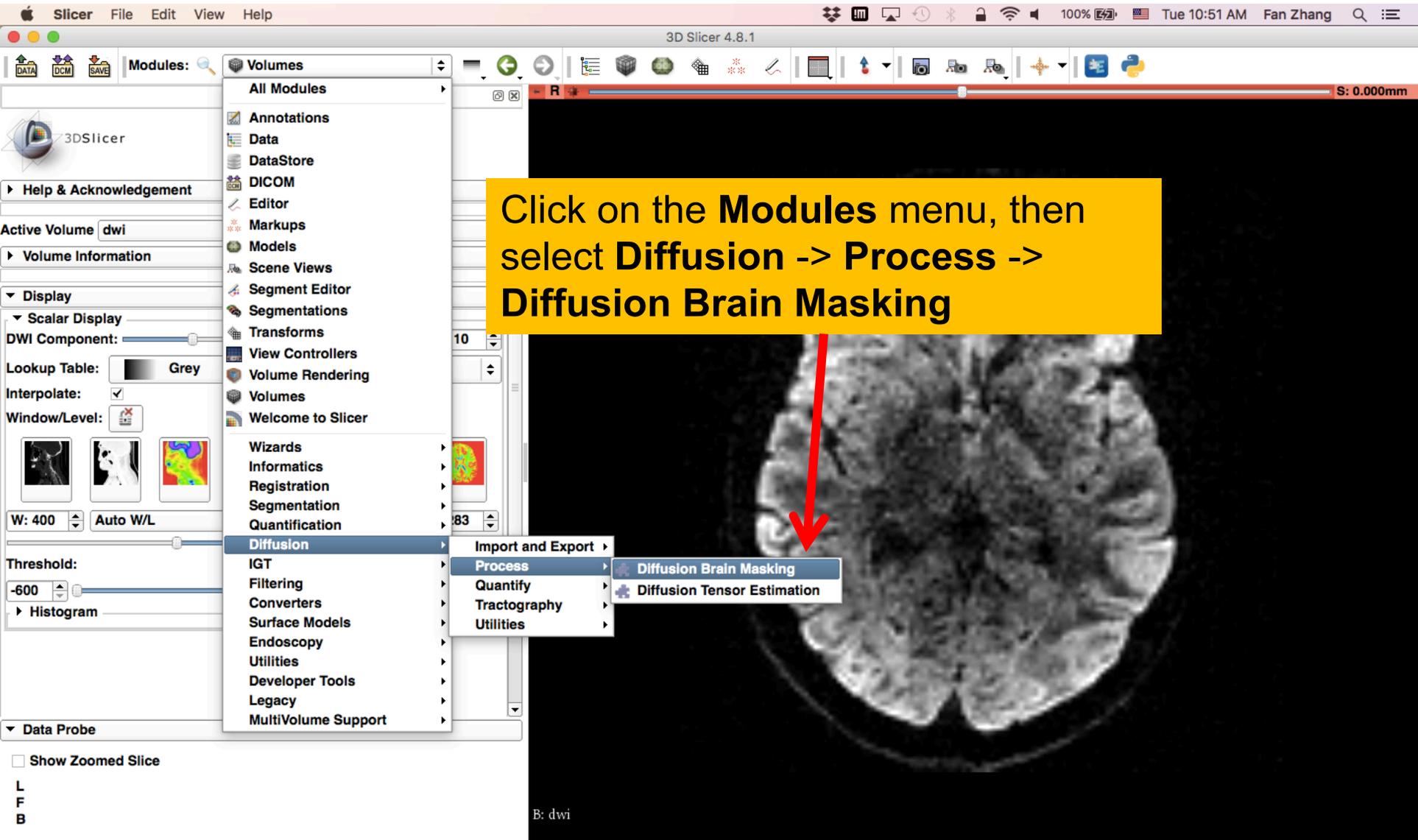
Loading the DWI Dataset

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes Apple logo, Slicer, File, Edit, View, and Help. The system tray shows various icons and the time 'Tue 10:50 AM' and name 'Fan Zhang'. The main toolbar contains icons for DATA, DCM, SAVE, and Volumes. The left sidebar has a 3DSlicer logo and a 'Help & Acknowledgement' section. The 'Active Volume' is set to 'dwi'. The 'Volume Information' section is expanded, showing 'Display' and 'Scale' options. A green text box is overlaid on this section with the text: 'Slicer displays only the Axial anatomical slice in the Viewer'. Below this, there are window level controls with a 'Threshold' set to 'Off' and a range from -600 to 1390. A 'Histogram' section is also visible. The 'Data Probe' section at the bottom left shows: 'Red (R 62.3, P 26.7, S 0.0) Axial Sp: 1.5', 'L None', 'F None', and 'B dwi (22, 82, 47) 49 components'. The main viewer area shows an axial slice of a brain with a red 'R' marker on the left side. The status bar at the bottom right of the viewer shows 'S: 0.000mm' and 'B: dwi'.

Slicer displays only the Axial anatomical slice in the Viewer

Red (R 62.3, P 26.7, S 0.0) Axial Sp: 1.5
L None
F None
B dwi (22, 82, 47) 49 components

Creating a brain mask



Creating a brain mask

3D Slicer 4.8.1

Modules: Diffusion Brain Masking

3DSlicer

Help & Acknowledgement

Diffusion Brain Masking

Parameter set: Diffusion Brain Masking

IO

Input DWI Volume: dwi

Output Baseline Volume: baseline

Output Diffusion Brain Mask: brain_mask

Mask Settings

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

B: dwi

S: 0.000mm

-select the Input DWI volume 'dwi'
-select Output Baseline Volume 'Create new Volume as...', and name it 'baseline'
-select Output Diffusion Brain Mask 'Create new LabelMapVolume as...', and name it 'brain_mask'
-click on Apply.

Creating a brain mask

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The top status bar shows '3D Slicer 4.8.1', 'Tue 10:52 AM', and 'Fan Zhang'. The 'Modules' panel on the left is set to 'Diffusion Brain Masking'. The parameter set is 'Diffusion Brain Masking'. The IO section shows 'Input DWI Volume' set to 'dwi', 'Output Baseline Volume' set to 'baseline', and 'Output Diffusion Brain Mask' set to 'brain_mask'. The 'Mask Settings' section is expanded. The main view shows a brain slice with a blue brain mask and a black baseline. The status bar at the bottom indicates 'Status: Completed' and '100%'. The 'Data Probe' section shows 'Show Zoomed Slice' checked. The bottom left corner shows 'L: brain_mask (100%)' and 'B: baseline'.

Slicer displays the edited brain mask

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

L: brain_mask (100%)
B: baseline

Creating a brain mask

3D Slicer 4.8.1

Modules: Diffusion Brain Masking

Parameter set: Diffusion Brain Masking

IO

Input DWI Volume: dwi

Output Baseline Volume: base

Output Diffusion Brain Mask: brain

Mask Settings

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

L: brain_mask (100%)
B: baseline

Change the label layer to **None** to make the mask invisible

Estimating the tensor

The screenshot shows the 3D Slicer 4.8.1 interface. The 'Modules' menu is open, and the path 'Diffusion -> Process -> Diffusion Tensor Estimation' is highlighted. A red arrow points from a yellow text box to the 'Diffusion Tensor Estimation' option. The background shows a brain MRI slice with 'B: baseline' text at the bottom left.

Click on the **Modules** menu, then select **Diffusion** -> **Process** -> **Diffusion Tensor Estimation**

3D Slicer 4.8.1

Modules: Diffusion Brain Masking

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Segment Editor
- Segmentations
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion**
 - Import and Export
 - Process**
 - Diffusion Brain Masking**
 - Diffusion Tensor Estimation**
 - Quantify
 - Tractography
 - Utilities
- IGT
- Filtering
- Converters
- Surface Models
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support

Parameter set: Diffusion Brain Masking

IO

Input DWI Volume: dwi

Output Baseline Volume: bas

Output Diffusion Brain Mask: bra

Mask Settings

Restore Defaults AutoRun

Data Probe

Show Zoomed Slice

L
F
B

B: baseline

S: 0.000mm

Estimating the tensor

3D Slicer 4.8.1

Modules: Diffusion Tensor Estimation

3DSlicer

Help & Acknowledgement

Diffusion Tensor Estimation

Parameter set: Diffusion Tensor Estimation

IO

Input DWI Volume: dwi

Input Brain Mask: brain_mask

Output DTI Volume: dti

Output Baseline Volume: baseline

Advanced Settings

Fitting Method ([Weighted] Least Squares) LS WLS

Shift Negative Eigenvalues

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

B: baseline

S: 0.000mm

- Set the Input DWI volume to 'dwi'
- Set the Input Brain Mask to 'brain_mask'
- Select Output DTI Volume 'Create DiffusionTensorVolume as ...', and name it 'dti'
- Set Output Baseline Volume to 'baseline'
- Under 'Advanced Settings', set Fitting Methods to 'WLS' (Weighted Least Squares)
- Click on **Apply**.

Estimating the tensor

3D Slicer 4.8.1

Modules: Diffusion Tensor Estimation

Parameter set: Diffusion Tensor Estimation

IO

Input DWI Volume: dwi

Input Brain Mask: brain_mask

Output DTI Volume: dti

Output Baseline Volume: baseline

Advanced

Fitting Method: dti

Shift Negative: none

None
dwi
baseline
brain_mask
dti

Rename current Volume

Position your mouse over the pin icon, click on the double arrow and select the dti in the B field, set the F and L to none.

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

L: brain_mask (100%)
B: dti

Exploring the DWI Dataset

Slicer File Edit View Help

3D Slicer 4.8.1

Modules: Diffusion Tensor Estimation

3DSlicer

Help & Acknowledgement

Diffusion Tensor Estimation

Parameter

IO

Input E

Input E

Output

Output

Adv

Fitting

Shift N

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

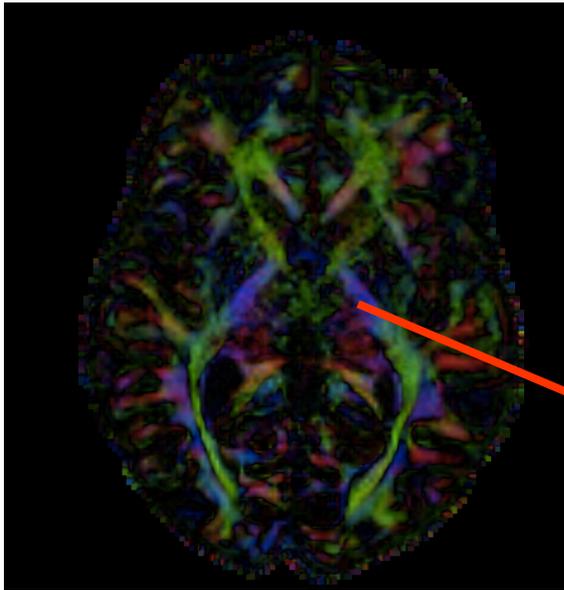
B: dti

S: 0.000mm

Slicer displays the DTI volume in color by orientation mode:

- Red: right-left
- Green: anterior-posterior
- Blue: inferior-superior

Diffusion Tensor Data



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

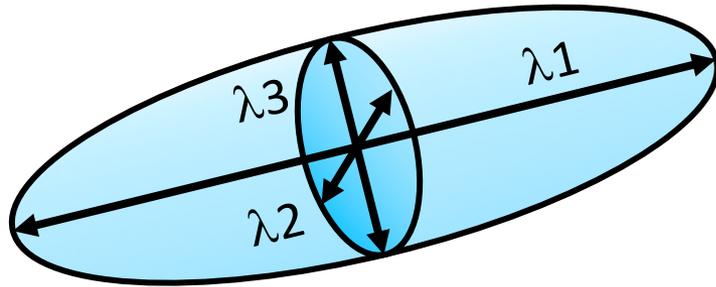
Stejskal-Tanner equation (1965)

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

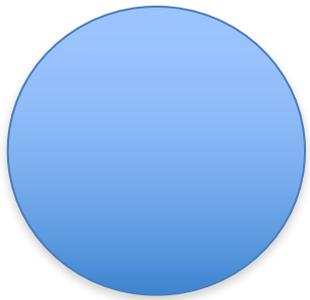
The diffusion tensor $\underline{\mathbf{D}}$ in the voxel (I,J,K) is a 3x3 symmetric matrix.

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.

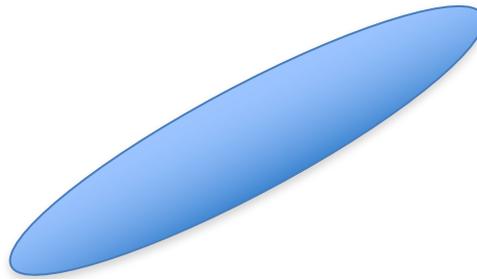


Diffusion Tensor Shape



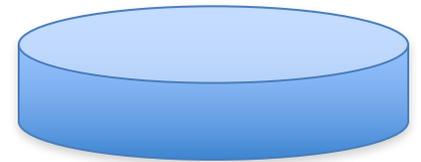
$$\lambda_1 = \lambda_2 = \lambda_3$$

Isotropic media
(Cerebrospinal
Fluid, gray matter)



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

Anisotropic media
(white matter)



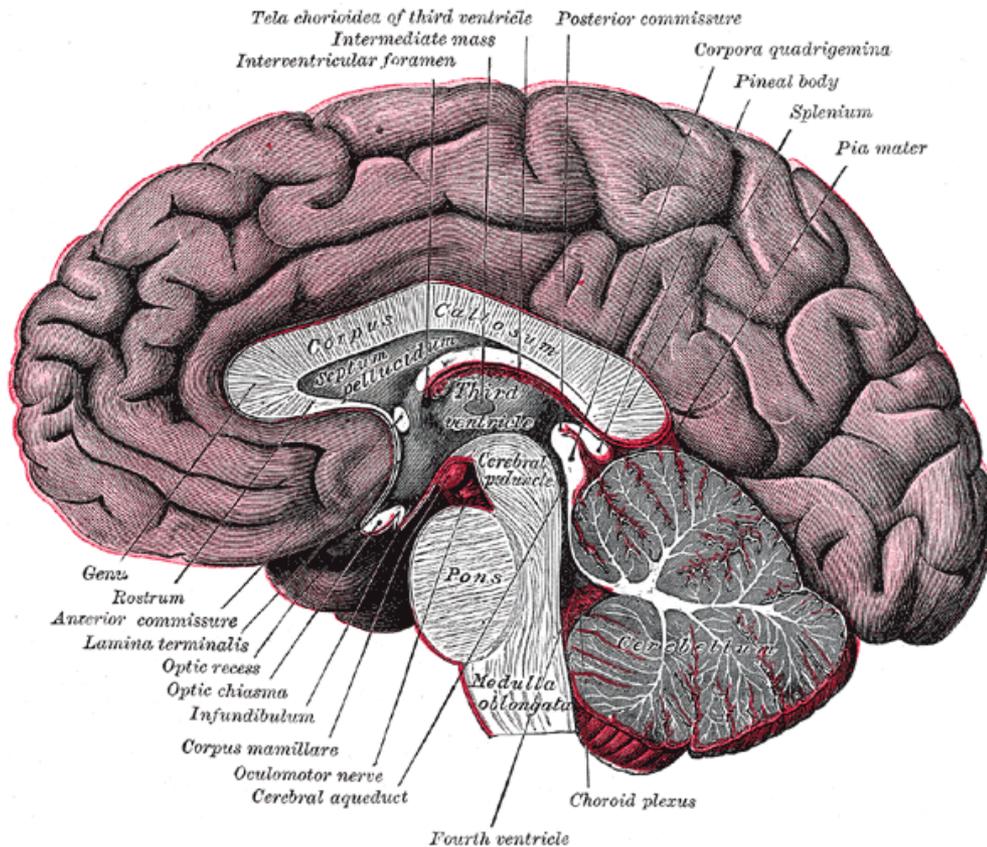
$$\lambda_1 \sim \lambda_2 \gg \lambda_3$$

Exploring the DWI Dataset

The screenshot displays the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The main toolbar shows various icons for file operations and viewing. The 'Modules' panel on the left is set to 'Diffusion Tensor Estimation'. The parameter set is 'Diffusion Tensor Estimation'. Under the 'IO' section, the input DWI volume is 'dwi', the input brain mask is 'brain_mask', the output DTI volume is 'dti', and the output baseline volume is 'baseline'. The 'Advanced Settings' section shows the fitting method as 'WLS' (Weighted Least Squares) and the 'Shift Negative Eigenvalues' checkbox is unchecked. A red arrow points from a yellow text box to the layout menu in the top right corner. The layout menu is open, showing various options such as 'Conventional', 'Conventional Widescreen', 'Conventional Quantitative', 'Four-Up', 'Four-Up Table', 'Four-Up Quantitative', 'Dual 3D', 'Triple 3D', '3D only', '3D Table', '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', and 'Two over two'. The 'Yellow slice only' option is highlighted. The background shows a 3D visualization of a brain slice with a color-coded DTI map. The status bar at the bottom indicates 'S: 0.000mm' and 'B: dti'.

Click on the Slicer layout menu and select the **Yellow slice only** layout.

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

The image shows the 3D Slicer 4.8.1 interface. The main window displays a brain slice with a red arrow pointing to the Corpus Callosum. The left sidebar contains the following settings:

- Modules: Diffusion Tensor Estimation
- Parameter set: Diffusion Tensor Estimation
- IO
 - Input DWI Volume: dwi
 - Input Brain Mask: brain_mask
 - Output DTI Volume: dti
 - Output Baseline Volume: baseline
- Advanced Settings
 - Fitting Method ([Weighted] Least Squares): LS WLS
 - Shift Negative Eigenvalues:

The status bar at the bottom indicates "Status: Completed" with a 100% progress bar. The Data Probe shows the following information for the Corpus Callosum:

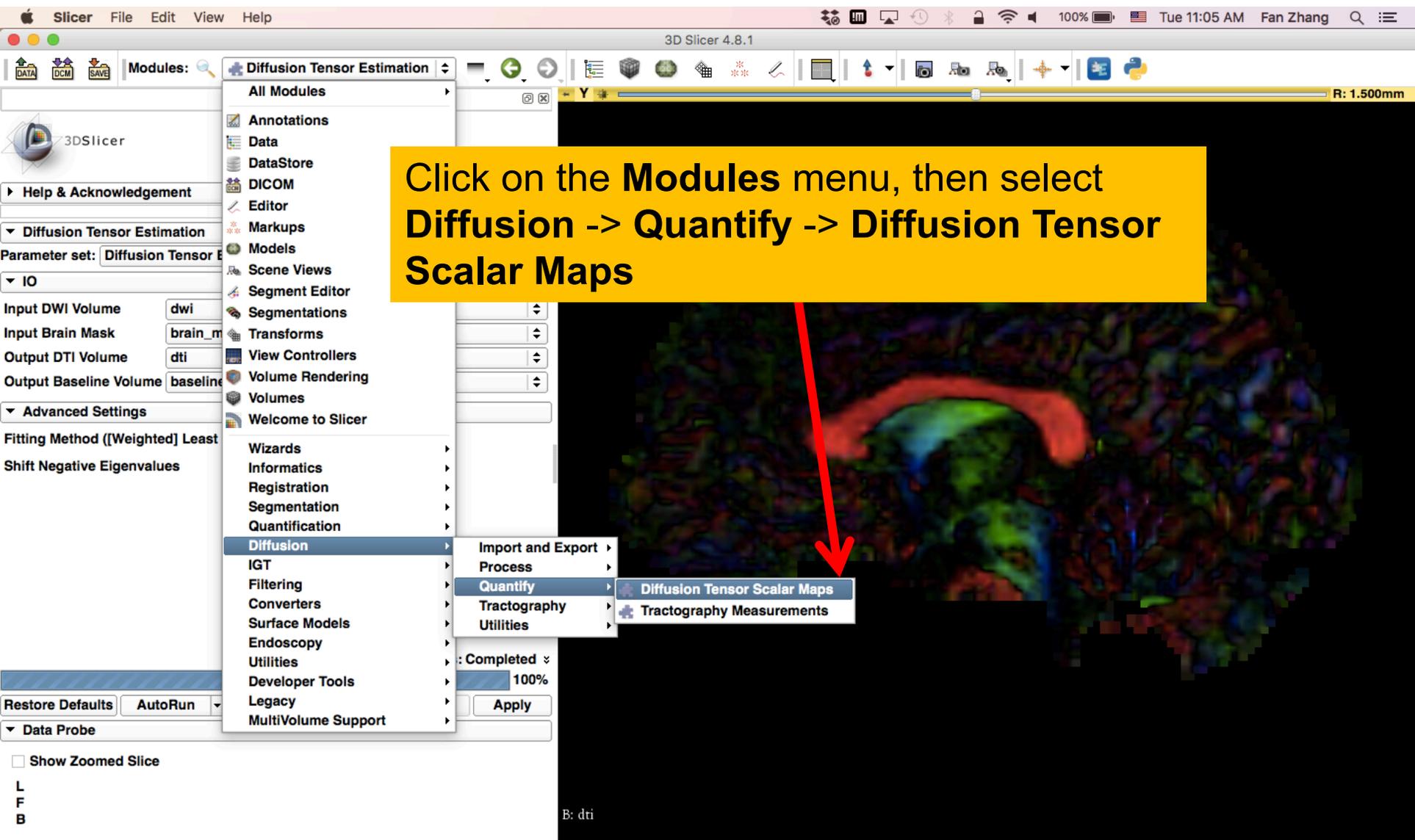
- Yellow (R 1.5, A 64.2, S 39.1) Sagittal Sp: 1.5
- L None
- F None
- B dti (63, 21, 73) ColorOrientation 0

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



Trace

The screenshot shows the 3D Slicer 4.8.1 interface. The 'Diffusion Tensor Scalar Maps' module is active. The 'Settings' section is expanded, showing the following configuration:

- Input DTI Volume: dti
- Output Volume: trace
- Scalar Measurement: Trace, MeanDiffusivity, Mode, PlanarMeasure, MinEigenvalue, MaxEigenvalue, PerpendicularDiffusivity, FractionalAnisotropy, Determinant, RelativeAnisotropy, LinearMeasure, SphericalMeasure, MidEigenvalue, ParallelDiffusivity

At the bottom of the settings panel, there are buttons for 'Restore Defaults', 'AutoRun', 'Cancel', and 'Apply'. The status is 'Idle'. The 'Data Probe' section is also visible, with 'Show Zoomed Slice' unchecked and axes L, F, B shown.

Type in the following information in the IO menu:

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

Trace

3D Slicer 4.8.1

Modules: Diffusion Tensor Scalar Maps

R: 1.500mm

Sagittal

None

0.00 None

1.00 trace

Set L as none.

Help & Acknowledgement

Diffusion Tensor Scalar Maps

Parameter set: Diffusion Tensor Scalar Maps

Settings

Input DTI Volume: dti

Output Volume: trace

Scalar Measurement: Trace, FractionalAnisotropy, Determinant, MeanDiffusivity

The trace image appears in the yellow viewer

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

B: trace

Trace

Apple Slicer File Edit View Help

3D Slicer 4.8.1

Modules: Diffusion Tensor Scalar Maps

3DSlicer

Help & Acknowledgement

Diffusion Tensor Scalar Maps

Parameter set: Di

Settings

Input DTI Volume

Output Volume

Scalar Measurem

Adjust window level by right-dragging up and down.

- RelativeAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- ParallelDiffusivity
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- PerpendicularDiffusivity

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Yellow (L 1.5, A 2.3, I 12.1) Sagittal Sp: 1.5

L None

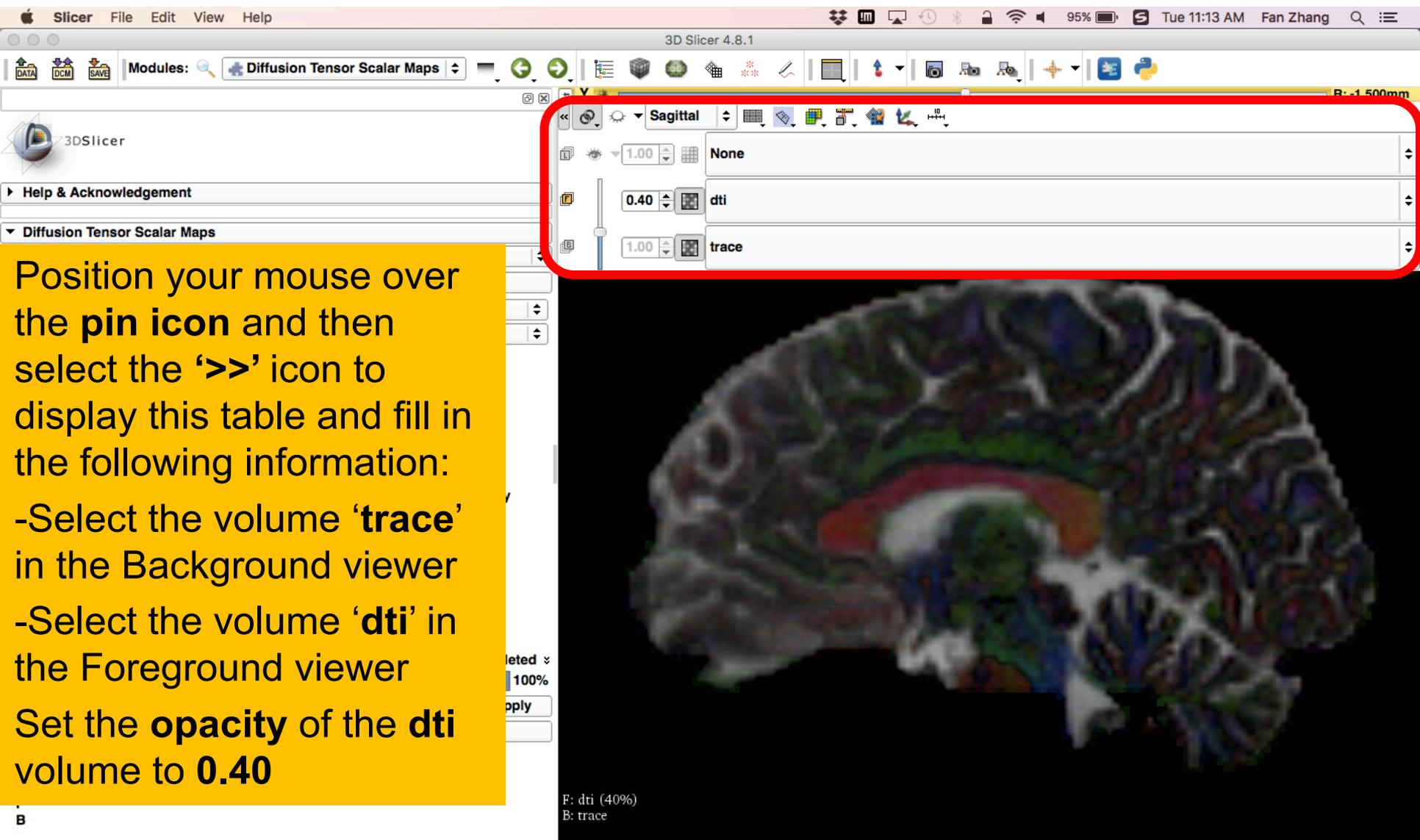
F None

B trace (65, 62, 39) 0.001984

R: -1.500mm

B: trace

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**

Volume Name	Opacity	Background
None	1.00	None
dti	0.40	dti
trace	1.00	trace

F: dti (40%)
B: trace

Trace

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

The screenshot displays the 3D Slicer 4.8.1 interface. The main window shows a sagittal view of a brain with DTI scalar maps. A red arrow points to a region in the Corpus Callosum. The left sidebar shows the 'Diffusion Tensor Scalar Maps' parameter set with 'Trace' selected. The bottom right corner shows a 'Data Probe' window with the following information:

Status: Completed 100%

Restore Defaults | AutoRun | Cancel | Apply

Data Probe

Yellow (L 1.5, A 33.9, S 8.4) Sagittal Sp: 1.5

L None

F dti (65, 41, 53) ColorOrientation 0

B trace (65, 41, 53) 0.001909

F: dti (40%)
B: trace

Trace



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 Volume: trace

Scalar Measurement

- FractionalAnisotropy
- Trace
- Determinant
- MeanDiffusivity
- RelativeAnisotropy
- Mode
- LinearMeasure
- PlanarMeasure
- SphericalMeasure
- MinEigenvalue
- MidEigenvalue
- MaxEigenvalue
- ParallelDiffusivity
- PerpendicularDiffusivity

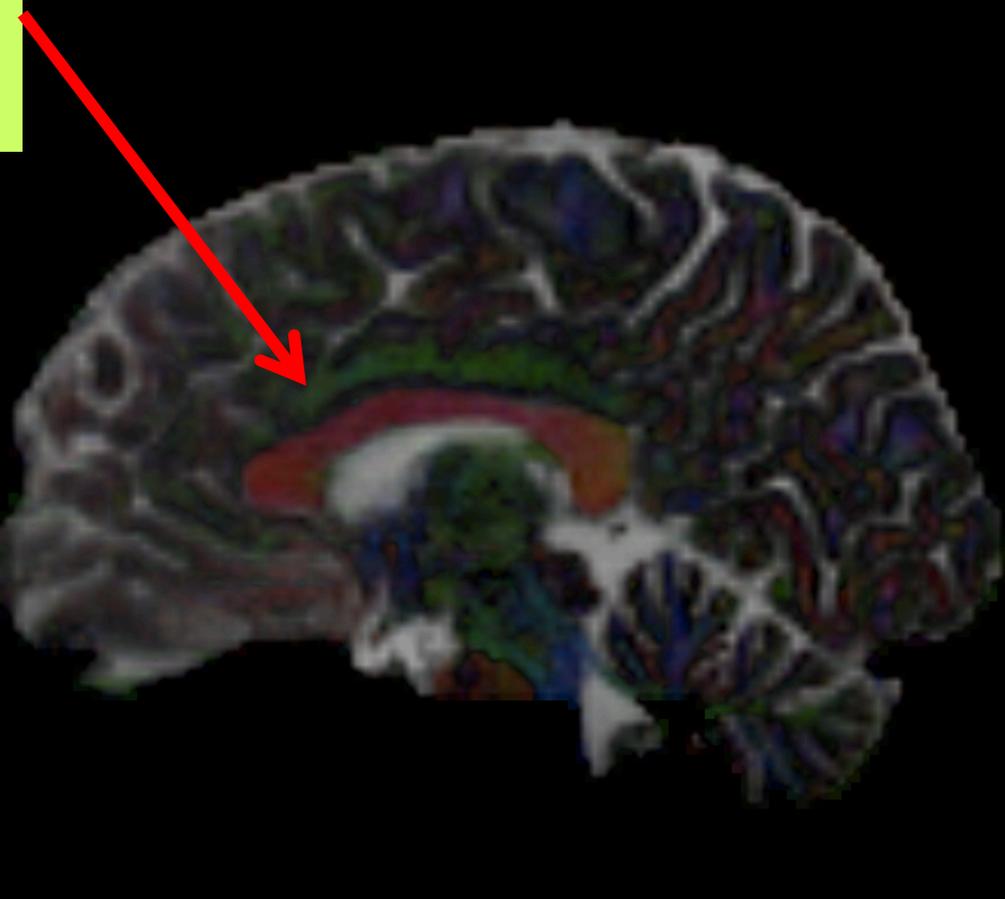
Status: Completed 100%

Restore Defaults AutoRun [dropdown] Cancel Apply

Data Probe

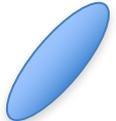
Yellow (L 1.5, A 31.3, S 19.1) Sagittal Sp: 1.5

L None
F dti (65, 43, 60) ColorOrientation 0
B trace (65, 43, 60) 0.002775



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

3D Slicer 4.8.1

Modules: Diffusion Tensor Scalar Maps

Help & Acknowledgement

Diffusion Tensor Scalar Maps

Parameter set: Diffusion Tensor Scalar Maps

Settings

Input DTI Volume: dti

Output Volume: fa

Scalar Measurement

- FractionalAnisotropy
- Determinant
- RelativeAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- ParallelDiffusivity
- Trace
- MeanDiffusivity
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- PerpendicularDiffusivity

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

F: dti (40%)
B: trace

Fill in the following information:

-Set **Input DTI Volume** to 'dti'

-Select **Output Scalar Volume**
'Create new Volume as ...' and name it 'fa'

-In '**Scalar Measurement**', select '**Fractional Anisotropy**'

-Click on **Apply** to calculate the Fractional Anisotropy map of the tensor volume

Fractional Anisotropy

3D Slicer 4.8.1

Modules: Diffusion Tensor Scalar Maps

R: 1.500mm

Sagittal

None

0.40

None

1.00

fa

Set L as none.

The FA image appears in the yellow viewer

- RelativeAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- ParallelDiffusivity
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- PerpendicularDiffusivity

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

B: fa

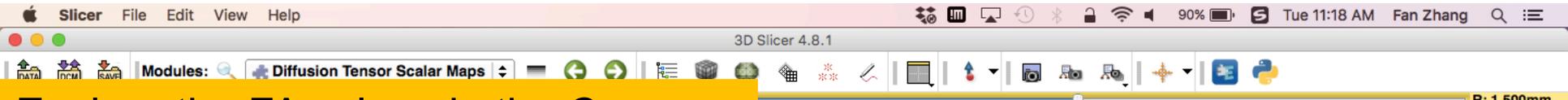
Fractional Anisotropy

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

Volume Name	Opacity
None	1.00
dti	0.40
fa	1.00

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 Volume: fa

Scalar Measurement

- FractionalAnisotropy
- Determinant
- RelativeAnisotropy
- LinearMeasure
- SphericalMeasure
- MidEigenvalue
- ParallelDiffusivity
- Trace
- MeanDiffusivity
- Mode
- PlanarMeasure
- MinEigenvalue
- MaxEigenvalue
- PerpendicularDiffusivity

Fractional Anisotropy

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Yellow (R 1.5, A 35.0, S 6.8) Sagittal Sp: 1.5

L None

F dti (63, 41, 52) ColorOrientation 0

B fa (63, 41, 52) 0.703706

F: dti (40%)
B: fa



Fractional Anisotropy

The screenshot displays the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The main toolbar shows various icons for data, DCM, save, and navigation. The 'Diffusion Tensor Scalar Maps' module is active, with a settings panel on the left. A yellow box highlights the text 'Change to Conventional view' with a red arrow pointing to the 'Conventional' option in the view menu. The view menu is open, showing a list of view options including 'Conventional', 'Conventional Widescreen', 'Conventional Quantitative', 'Four-Up', 'Four-Up Table', 'Four-Up Quantitative', 'Dual 3D', 'Triple 3D', '3D only', '3D Table', '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', and 'Three by three slice'. The settings panel on the left includes 'Input DTI Volume' (dti), 'Output Volume' (fa), and 'Scalar Measurement' options: FractionalAnisotropy (selected), Trace, Determinant, MeanDiffusivity, RelativeAnisotropy, Mode, LinearMeasure, PlanarMeasure, SphericalMeasure, MinEigenvalue, MidEigenvalue, MaxEigenvalue, ParallelDiffusivity, and PerpendicularDiffusivity. The status bar at the bottom indicates 'Status: Completed' and '100%'. The bottom left corner shows 'L', 'F', and 'B' orientation markers. The bottom right corner shows 'F: dti (40%)' and 'B: fa'.

3D Slicer 4.8.1

Modules: Diffusion Tensor Scalar Maps

3DSlicer

Help & Acknowledgement

Change to Conventional view

Parameter set: Diffusion Tensor Scalar maps

Settings

Input DTI Volume: dti

Output Volume: fa

Scalar Measurement

- FractionalAnisotropy
- Trace
- Determinant
- MeanDiffusivity
- RelativeAnisotropy
- Mode
- LinearMeasure
- PlanarMeasure
- SphericalMeasure
- MinEigenvalue
- MidEigenvalue
- MaxEigenvalue
- ParallelDiffusivity
- PerpendicularDiffusivity

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

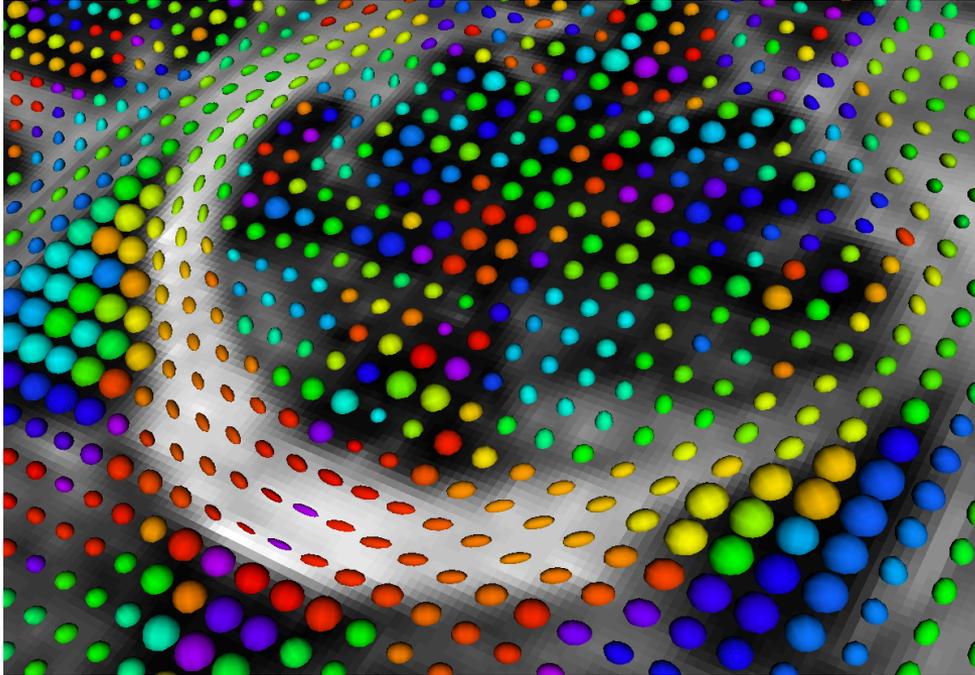
Data Probe

Show Zoomed Slice

L
F
B

F: dti (40%)
B: fa

R: 1.500mm



Part 2: Visualizing the tensor data

3D Visualization: Glyphs

The screenshot shows the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The main toolbar contains various icons for file operations and viewing. The left sidebar shows the 'Volumes' module with settings for 'Active Volume' (trace), 'Volume Information', 'Display', 'Lookup Table' (Grey), 'Interpolate' (checked), 'Window/Level' (W: 0.0076, L: 0.0050), 'Threshold' (Off), and 'Histogram'. A yellow box with black text provides instructions: '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'. Below the yellow box, the 'Axial' toolbar is visible, with a red box highlighting the 'pin' icon and the '<<' icon. The main view area shows three axial slices of a brain, with the foreground set to 'fa' and the background to 'dti'. The bottom status bar shows 'F: fa (100%) B: dti' for each slice.

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

3D Slicer 4.8.1

Modules: Volumes

Active Volume: dti

Volume Information

Display

Scalar Display

Scalar Mode: ColorOrientation

Lookup Table:

Interpolate:

Window/Level:

W: 255 Auto W/L L: 128

Threshold: Off

-600 600

Glyphs on Slices Display

Slice Visibility: Red Yellow Green

Opacity: 1.00

Scalar ColorMap: Rainbow

Data Probe

Show Zoomed Slice

L
F
B

S

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

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

F: fa (100%)
B: dti

F: fa (100%)
B: dti

F: fa (100%)
B: dti

3D Visualization: Glyphs

3D Slicer 4.8.1

Modules: Volumes

Scalar Mode: ColorOrientation

Lookup Table:

Interpolate:

Window/Level:

W: 255 Auto W/L L: 128

Threshold: Off

-600 600

▼ Glyphs on Slices Display

Slice Visibility: Red Yellow Green

Scalar ColorMap: FullRainbow

Color by Scalar: ColorOrientation

Glyph Type: Ellipsoids

Scale Factor: 50.00

Spacing: 5.00

▼ Data Probe

Show Zoomed Slice

L
F
B

Scroll down the module panel and in the **Glyphs on Slices Display** section:

- 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'**

F: fa (100%)
B: dti

F: fa (100%)
B: dti

F: fa (100%)
B: dti

3D Visualization: Glyphs

The image shows the 3D Slicer 4.8.1 interface. The main window displays a brain with glyphs (small colored dots) overlaid on it. A yellow callout box points to the glyphs with the text: "The glyphs appear in all 3 slice viewers". The interface includes a menu bar (File, Edit, View, Help), a toolbar, and a sidebar with various modules and settings. The 'Volumes' module is active, showing a list of volumes: Red (L 37.8, A 56.2, S 0.0), L None, F fa (89, 27, 47) 0.394249, and B dti (89, 27, 47) ColorOrientation 0. The 'Glyphs on Slices Display' section is expanded, showing 'Slice Visibility' checked for Red, Yellow, and Green, and 'Glyph Type' set to 'Ellipsoids'. The 'Data Probe' section shows the current volume selected: Red (L 37.8, A 56.2, S 0.0) Axial Sp: 1.5.

Scalar Mode: ColorOrientation
Lookup Table:
Interpolate:
Window/Level:
W: 255 Auto W/L L: 128
Threshold: Off
-600 600
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
Red (L 37.8, A 56.2, S 0.0) Axial Sp: 1.5
L None
F fa (89, 27, 47) 0.394249
B dti (89, 27, 47) ColorOrientation 0

The glyphs appear in all 3 slice viewers

R L I

F: fa (100%)
B: dti

F: fa (100%)
B: dti

F: fa (100%)
B: dti

3D Visualization: Glyphs

The image shows the 3D Slicer 4.8.1 interface. On the left is the 'Volumes' module panel with various settings for glyphs on slices. On the right is the 3D viewer showing a brain scan with glyphs overlaid. A yellow callout box with a red arrow points to the eye icon in the viewer's toolbar.

Scalar Mode: ColorOrientation
Lookup Table:
Interpolate:
Window/Level: [Icons]
W: 255 | Auto W/L | L: 128
Threshold: Off
-600 | 600
▼ 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
 Show Zoomed Slice
L F B | 3D Visualization: Glyphs

3D Viewer:
R | S: 0.000mm | Y | R: 1.500mm | G | A: 1.500mm
Eye icon highlighted by a red arrow and yellow callout box.
Viewer content: Three panels showing brain slices with glyphs. Labels: F: fa (100%) B: dti.

Callout Box:
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 3D Slicer 4.8.1 interface. The main 3D view shows a brain volume with glyphs (small colored ellipsoids) overlaid on it. The glyphs are color-coded by scalar values, ranging from red to green. The 3D view is rotated to show the brain from an oblique perspective. The axes are labeled R (Right), S (Superior), Y (Anterior), G (Posterior), and A (Inferior). The slice views at the bottom show the brain in three different orientations: axial (left), sagittal (middle), and coronal (right). Each slice view shows the glyphs in a different orientation, corresponding to the slice plane. The glyphs are color-coded by scalar values, ranging from red to green. The slice views are labeled with 'F: fa (100%)' and 'B: dti'.

Slicer displays the anatomical slices in the 3D viewer

Scalar Map
Lookup table:
Interpolate:
Window/Level:
W: 255 Auto W/L L: 128
Threshold: Off
-600 600
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
 Show Zoomed Slice
L
F
B

R S: 0.000mm Y R: 1.500mm G A: 1.500mm
F: fa (100%)
B: dti
F: fa (100%)
B: dti
F: fa (100%)
B: dti

3D Visualization: Glyphs

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

W: 255 Auto W/L L: 128

Threshold: Off

Scalar Range: -600 600

▼ 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

Spacing: 5.00

▼ Data Probe

Show Zoomed Slice

L
F
B

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

F: fa (100%)
B: dti

F: fa (100%)
B: dti

F: fa (100%)
B: dti

Diffusion MRI tractography

The image shows the 3D Slicer 4.8.1 interface. On the left is the 'Volumes' module panel. A red box highlights the 'Glyphs on Slices Display' section, which includes 'Slice Visibility' with checkboxes for 'Red', 'Yellow', and 'Green', and an 'Opacity' slider set to 1.00. A yellow callout box with black text is overlaid on the main 3D view, containing the instruction: 'Deselect the option for Red, Yellow, and Green Slice Visibility, and deselect the eye icon'. A red arrow points from this callout to the 'Eye' icon in the slice view toolbar. The main 3D view shows a brain with white fiber-like tractography. Below the 3D view are three slice views: Axial, Sagittal, and Coronal. The Axial slice view is currently selected. The slice view toolbar shows 'R' (Red), 'Y' (Yellow), and 'G' (Green) slice visibility indicators, and 'A: 1.500mm' for the axial slice. The slice view panels show 'F: fa (100%)' and 'B: dti' for each view.

Scalar Mode: ColorOrientation
Lookup Table:
Interpolate:
Window/Level:
W: 255 Auto W/L L: 128
Threshold: Off
-600 600
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
 Show Zoomed Slice
L
F
B

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

R S: 0.000mm Y R: 1.500mm G A: 1.500mm
Axial
None
1.00
fa
1.00
dti
F: fa (100%)
B: dti
F: fa (100%)
B: dti
F: fa (100%)
B: dti

Diffusion MRI tractography

The image shows the 3D Slicer 4.8.1 interface. On the left is the 'Volumes' module panel with various settings. The main 3D view area is currently empty, with a coordinate system (P, S, R, L, A) and a toolbar. A red arrow points to the 'L' icon in the toolbar. A yellow box contains the text: 'Click L to reset the 3D view to left'. Another yellow box contains the text: 'Position your mouse over the pin icon and change the Foreground to 'None' and the background to 'fa''. Below this, a red box highlights a toolbar with a pin icon and a dropdown menu. The dropdown menu has three options: 'None', 'None', and 'fa'. The bottom of the screen shows three 2D slice views (Axial, Sagittal, Coronal) with 'B: fa' labels.

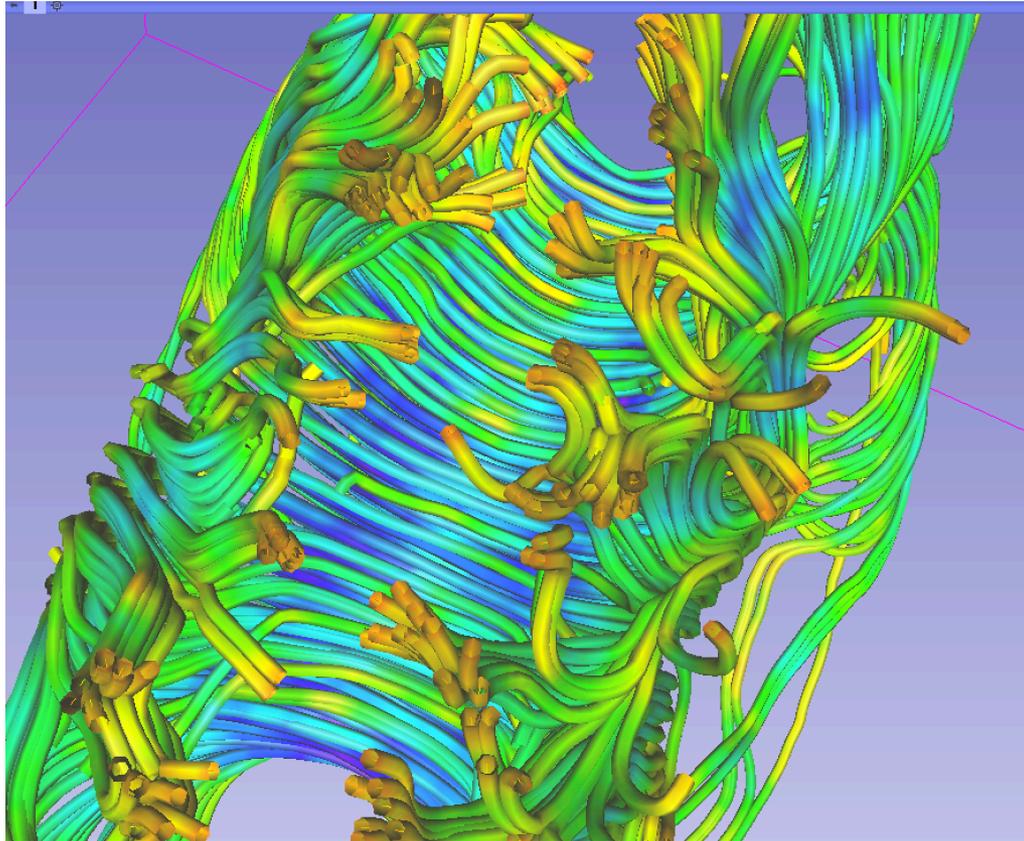
3D Slicer 4.8.1

Click L to reset the 3D view to left

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

None
None
fa

B: fa B: fa B: fa

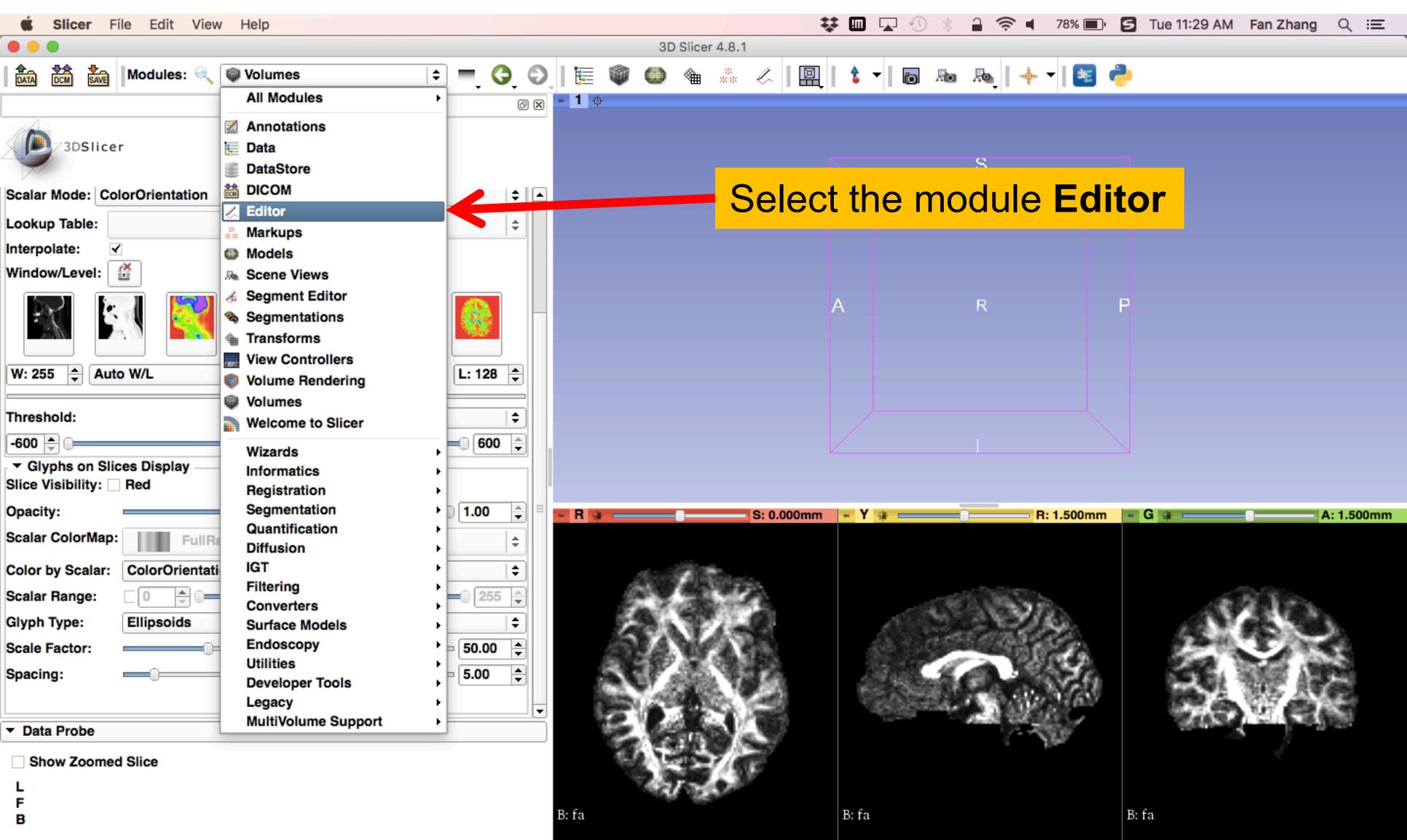


Part 3: From tensors to tracts

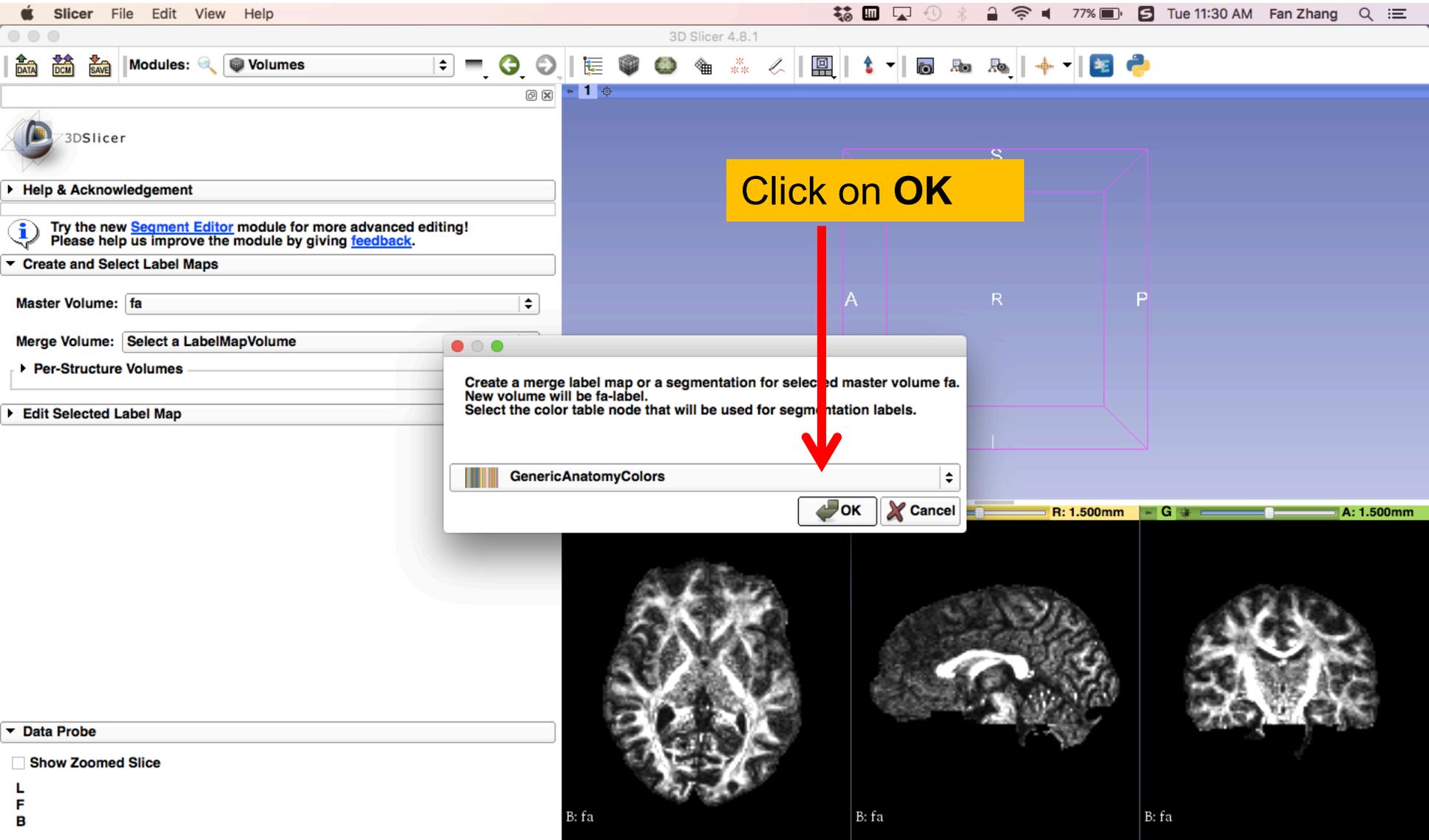
DTI tractography

- 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



Diffusion MRI tractography



Diffusion MRI tractography

The image shows the 3D Slicer 4.8.1 software interface. A yellow callout box with the text "Select the Yellow slice only layout" has a red arrow pointing to the "Yellow slice only" option in the View menu. The menu is open, showing various layout options. The "Yellow slice only" option is highlighted. The interface includes a top menu bar (Slicer, File, Edit, View, Help), a toolbar, and a left sidebar with panels for "Help & Acknowledgement", "Create and Select Label Maps", and "Edit Selected Label Map". The main view area shows a 3D brain model with a yellow slice selected. The bottom of the interface displays three 2D slices: a coronal slice (R), a sagittal slice (S), and an axial slice (A). The labels for these slices are "L: fa-la...100%" and "B: fa".

Select the Yellow slice only layout

- Conventional
- Conventional Widescreen
- Conventional Quantitative
- Four-Up
- Four-Up Table
- Four-Up Quantitative
- Dual 3D
- Triple 3D
- 3D only
- 3D Table
- 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

Help & Acknowledgement

Try the new [Segment Editor](#) module for more advanced editing! Please help us improve the module by giving [feedback](#).

Create and Select Label Maps

Master Volume: fa

Merge Volume: fa-label

Per-Structure Volumes

Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: DefaultTool

Label: tissue 1

Diffusion MRI tractography

Data Probe

Show Zoomed Slice

L
F
B

R S: 0.00 G A: 1.500mm

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Diffusion MRI tractography

The screenshot displays the 3D Slicer 4.8.1 interface. The top menu bar includes 'Slicer', 'File', 'Edit', 'View', and 'Help'. The status bar shows '3D Slicer 4.8.1' and system information like 'Tue 11:31 AM' and 'Fan Zhang'. The 'Modules' panel on the left is set to 'Editor'. The main 3D view shows a coronal slice of a brain with a white tractography line. The left sidebar contains several panels: 'Help & Acknowledgement', 'Create and Manage Labels' (with 'Master Volume: fa' and 'Merge Volume: fa-label'), and 'Edit Selected Label Map'. A yellow callout box with the text 'Select the DrawEffect tool' has a red arrow pointing to the 'DrawEffect' icon in the 'Edit Selected Label Map' panel. Below this panel, the 'Active Tool' is set to 'DrawEffect', and the 'Label' is 'tissue' with a value of '1'. The 'Data Probe' panel is also visible.

3D Slicer 4.8.1

Modules: Editor

3DSlicer

Help & Acknowledgement

Try the Please

Select the DrawEffect tool

Create and Manage Labels

Master Volume: fa

Merge Volume: fa-label

Per-Structure Volumes

Edit Selected Label Map

DrawEffect

Undo/Redo: [Undo] [Redo]

Active Tool: DrawEffect

Label: tissue 1

Paint Over

Data Probe

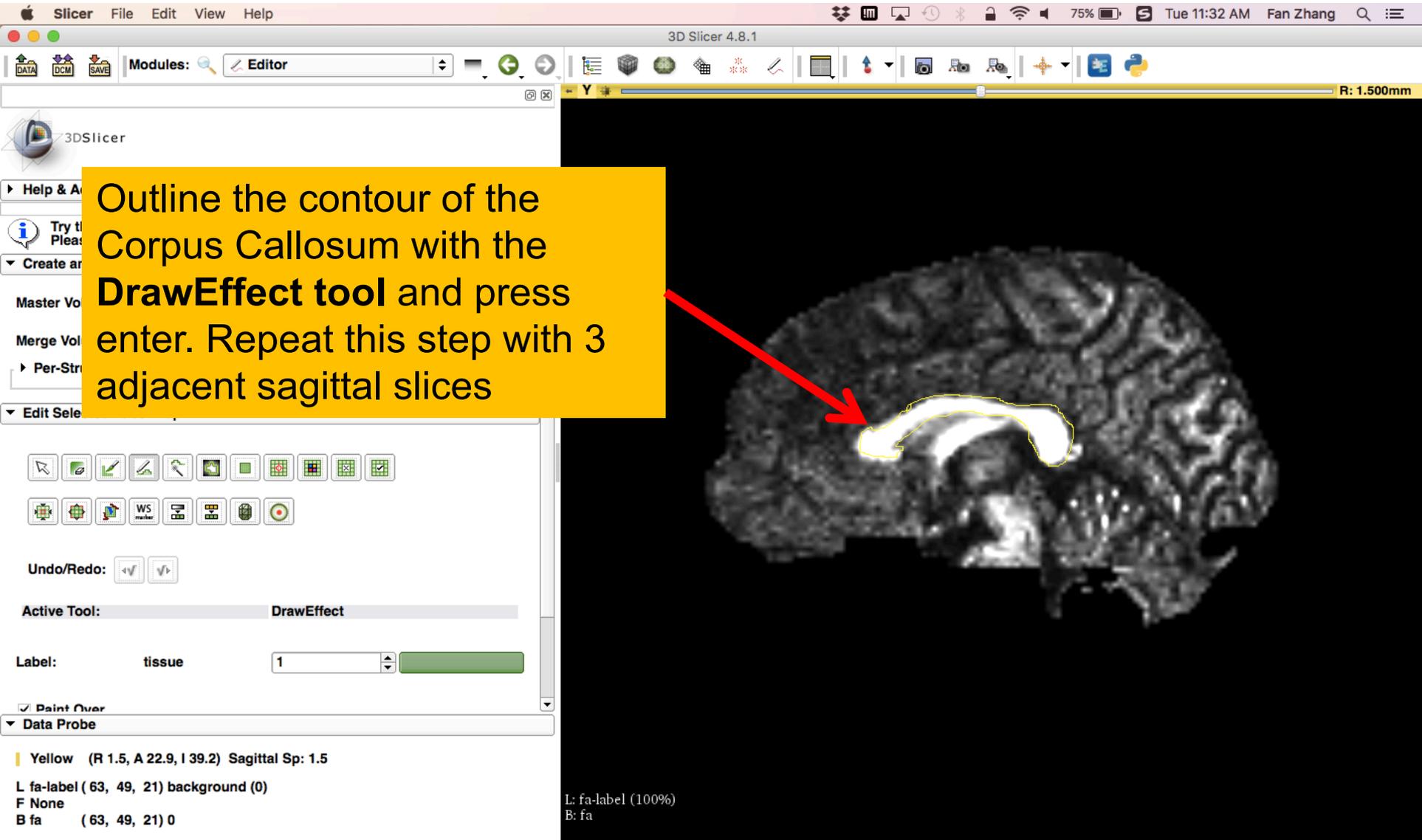
Show Zoomed Slice

L
F
B

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

R: 1.500mm

Diffusion MRI tractography



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 (R 1.5, A 22.9, I 39.2) Sagittal Sp: 1.5

L: fa-label (63, 49, 21) background (0)

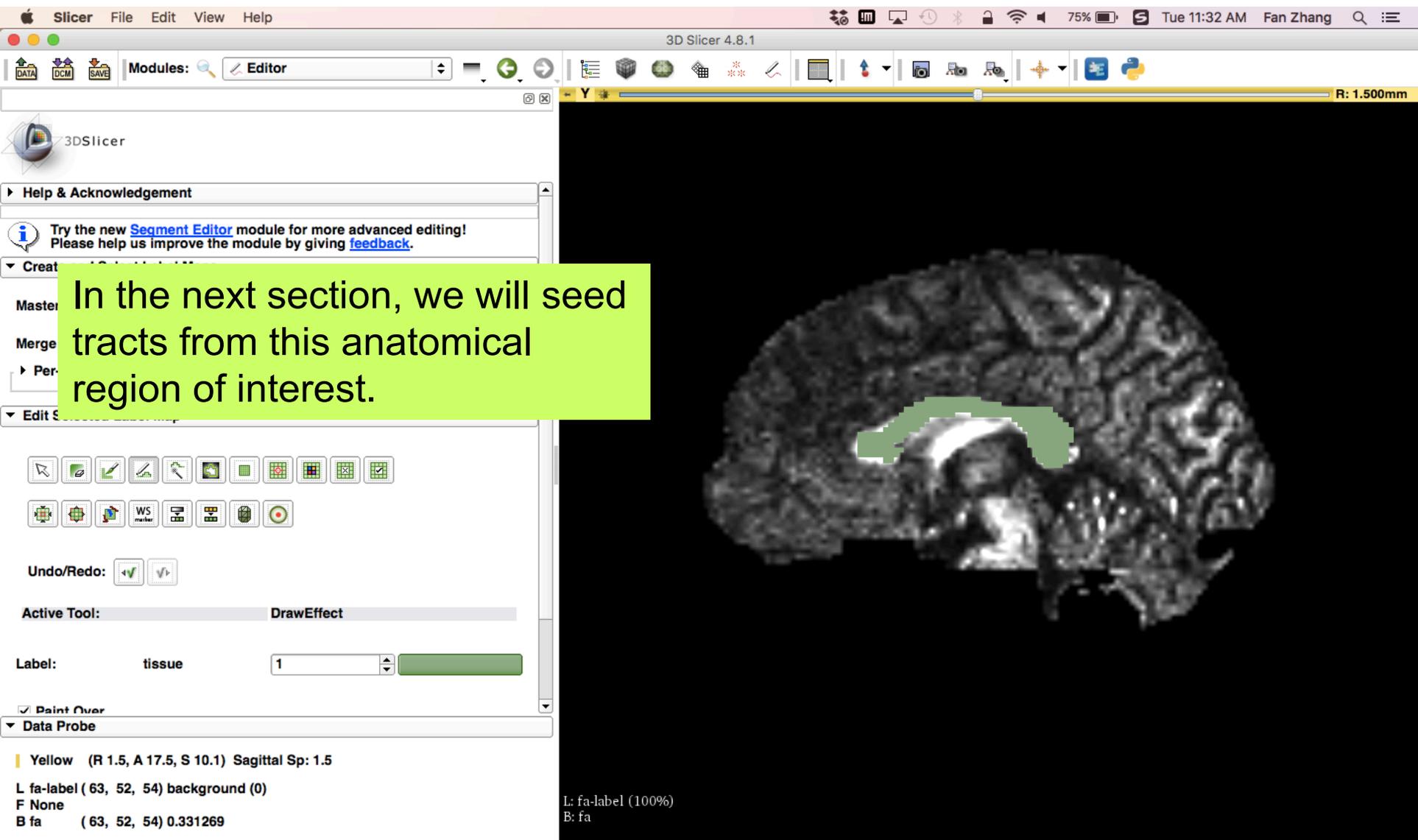
F None

B fa (63, 49, 21) 0

L: fa-label (100%)

B: fa

Diffusion MRI tractography



The screenshot displays the 3D Slicer 4.8.1 interface. The main window shows a sagittal MRI scan of a brain with a green region of interest (ROI) highlighted in the white matter. The interface includes a menu bar (Slicer, File, Edit, View, Help), a toolbar with various icons, and a sidebar on the left with modules like DATA, DCM, SAVE, and Editor. A green text box is overlaid on the left side of the image, containing the text: "In the next section, we will seed tracts from this anatomical region of interest." The bottom of the interface shows a status bar with the following information: "Yellow (R 1.5, A 17.5, S 10.1) Sagittal Sp: 1.5", "L fa-label (63, 52, 54) background (0)", "F None", "B fa (63, 52, 54) 0.331269".

In the next section, we will seed tracts from this anatomical region of interest.

Yellow (R 1.5, A 17.5, S 10.1) Sagittal Sp: 1.5
L fa-label (63, 52, 54) background (0)
F None
B fa (63, 52, 54) 0.331269

Diffusion MRI tractography

The image shows the 3D Slicer 4.8.1 software interface. The 'Modules' panel on the left is open, and the 'Diffusion' module is selected. A red arrow points from a yellow instruction box to the 'Tractography Seeding' option in the 'Diffusion' module's sub-menu. The main 3D view shows a brain slice with a green highlighted region, representing the seeding area for tractography. The status bar at the bottom indicates 'L: fa-label (100%)' and 'B: fa'.

Click on the Modules and then select Diffusion -> Tractography->Tractography Seeding.

3D Slicer 4.8.1

Modules:

- All Modules
- Annotations
- Data
- DataStore
- DICOM
- Editor
- Markups
- Models
- Scene Views
- Segment Editor
- Segmentations
- Transforms
- View Controllers
- Volume Rendering
- Volumes
- Welcome to Slicer
- Wizards
- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion**
 - Import and Export
 - Process
 - Quantify
 - Tractography**
 - Tractography Display
 - Tractography Seeding**
 - UKF Tractography Region-based
 - Utilities
- IGT
- Filtering
- Converters
- Surface Models
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support

- Informatics
- Registration
- Segmentation
- Quantification
- Diffusion
- IGT
- Filtering
- Converters
- Surface Models
- Endoscopy
- Utilities
- Developer Tools
- Legacy
- MultiVolume Support

Master Volume: fa

Merge Volume: fa-label

Per-Structure Volumes

Edit Selected Label Map

Undo/Redo:

Active Tool:

Label: tissue

Paint Over

Data Probe

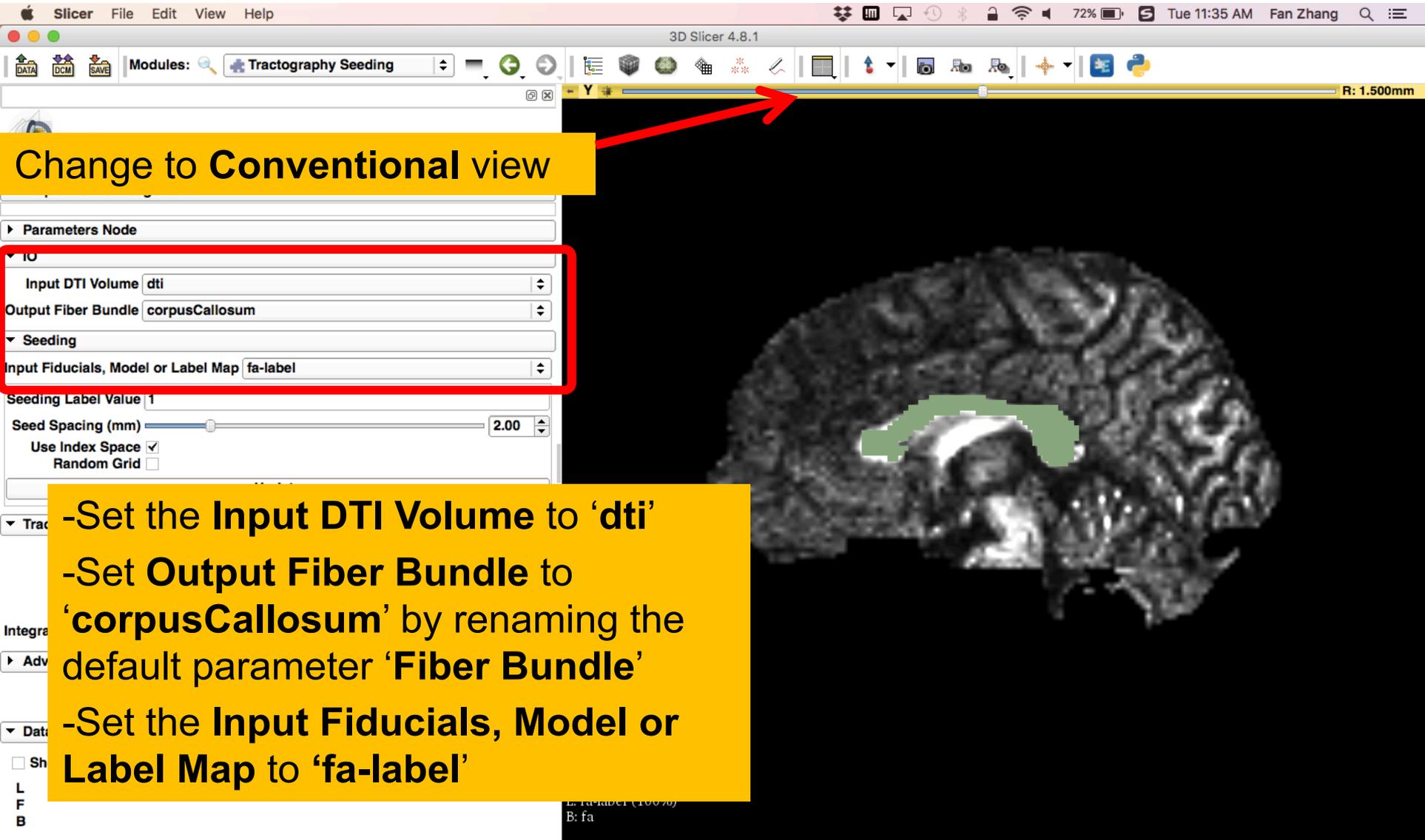
Show Zoomed Slice

L
F
B

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

R: 1.500mm

Step1: I/O



Change to **Conventional** view

IO

- Input DTI Volume: dti
- Output Fiber Bundle: corpusCallosum

Seeding

- Input Fiducials, Model or Label Map: fa-label
- Seeding Label Value: 1
- Seed Spacing (mm): 2.00
- Use Index Space:
- Random Grid:

- Set the **Input DTI Volume** to 'dti'
- Set **Output Fiber Bundle** to 'corpusCallosum' by renaming the default parameter 'Fiber Bundle'
- Set the **Input Fiducials, Model or Label Map** to 'fa-label'

Step 2: Seeding parameters

3D Slicer 4.8.1

Modules: Tractography Seeding

Input DTI Volume: dti

Output Fiber Bundle: corpusCallosum

Input Fiducials, Model or Label Map: fa-label

Seeding Label Value: 1

Seed Spacing (mm): [Slider]

Use Index Space:

Random Grid:

Update

Tractography Parameters

Threshold Type	Fractional Anisotropy
Seeding Threshold	0.30
Stopping Threshold	0.25
Integration Step Length (mm)	0.500mm

Advanced Options

Data Probe

Show Zoomed Slice:

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

R: 1.500mm

Select the default Tractography Seeding parameters:

- Threshold Type: FractionalAnistropy
- Seeding Threshold:0.30
- Stopping Threshold: 0.25

Click **Update** to generate tractography

Step 3: Generate Tracts

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

3D Slicer 4.8.1

Modules: Tractography Seeding

Seeding Label Value: 1

Seed Spacing (mm): 2.00

Use Index Space: Random Grid:

Update

Tractography Parameters

Threshold Type: Fractional Anisotropy

Seeding Threshold: 0.30

Stopping Threshold: 0.25

Integration Step Length (mm): 0.500 mm

Advanced Options

Data Probe

Show Zoomed Slice:

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

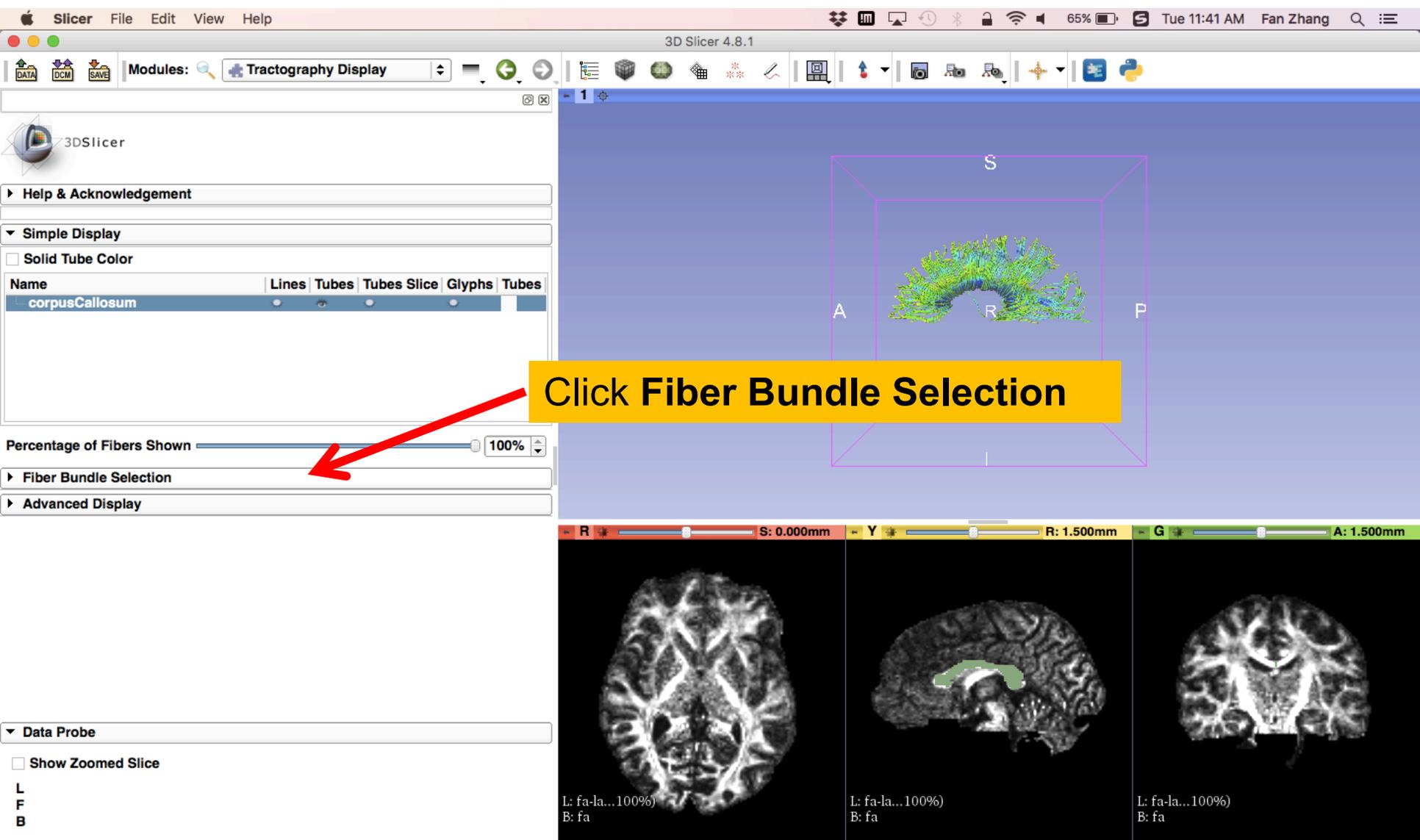
L: fa-la...100%)
B: fa

Step 4: Undesirable track removal

The screenshot shows the 3D Slicer 4.8.1 interface. The 'Modules' menu is open, and the 'Diffusion' sub-menu is selected. Within the 'Diffusion' sub-menu, the 'Tractography' option is highlighted, and its sub-menu is open, showing 'Tractography Display' as the selected option. A yellow callout box with a red arrow points to the 'Tractography Display' option. The main 3D view shows a brain slice with a green tract highlighted. The bottom of the interface shows three panels: a top-down view, a sagittal view, and an axial view, each with a green tract highlighted. The bottom-left panel has labels 'L: fa-la...100%' and 'B: fa'. The bottom-middle and bottom-right panels also have labels 'L: fa-la...100%' and 'B: fa'. The top of the interface shows the menu bar (Slicer, File, Edit, View, Help) and the system tray (3D Slicer 4.8.1, Tue 11:40 AM, Fan Zhang).

Click on the **Modules** menu, then select **Diffusion** -> **Tractography** -> **Tractography Display**

Step 4: Undesirable track removal



Step 4: Undesirable track removal

3D Slicer 4.8.1

Modules: Tractography Display

3DSlicer

Help & Acknowledgement

Simple Display

Solid Tube Color

Name	Lines	Tubes	Tubes Slice	Glyphs	Tubes
corpusCallosum	<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 Updates ROI Visibility

Extract Bundle From ROI: None

Update corpusCallosum From ROI: Confirm update

Enable Interactive Edit

Advanced Display

Step 4: Undesirable track removal

Data Probe

Show Zoomed Slice

L
F
B

In 'Fiber Bundle Selection', under ROI for Fiber Select, create a new AnnotationROI as 'ROI node' and select Disable ROI.

A: 1.500mm

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Step 4: Undesirable track removal

Adjust the ROI frame to include the undesirable tracks, using the colorful spheres provided.

3D Slicer 4.8.1

Modules: Tractography Display

Percentage of Fibers Shown: 100%

Fiber Bundle Selection

ROI for Fiber Selection: ROI Node

Disable ROI Positive ROI Negative ROI

Interactive ROI Updates ROI Visibility

Extract Bundle From ROI: None

Update corpusCallosum From ROI: Confirm update

Enable Interactive Edit

Advanced Display

Data Probe

Show Zoomed Slice

L
F
B

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

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Step 4: Undesirable track removal

The screenshot displays the 3D Slicer 4.8.1 interface. The main window shows a 3D view of fiber tractography with a white cube ROI. A red arrow points from the 'Negative ROI' option in the 'Fiber Bundle Selection' panel to the cube. A yellow callout box contains the text 'Click on Negative ROI to finish'. The 'Fiber Bundle Selection' panel includes options for 'ROI for Fiber Selection' (ROI Node), 'Disable ROI', 'Positive ROI', and 'Negative ROI' (selected). Other options include 'Interactive ROI Updates', 'ROI Visibility', 'Extract Bundle From ROI', 'Update corpusCallosum From ROI', and 'Confirm update'. The 'Advanced Display' and 'Data Probe' panels are also visible. The bottom of the interface shows three orthogonal views (axial, sagittal, and coronal) of the brain with the ROI and fiber tracks overlaid. The status bar at the bottom indicates 'Step 4: Undesirable track removal'.

Click on Negative ROI to finish

ROI for Fiber Selection: ROI Node

Disable ROI Positive ROI Negative ROI

Interactive ROI Updates ROI Visibility

Extract Bundle From ROI: None

Update corpusCallosum From ROI: Confirm update

Enable Interactive Edit

Step 4: Undesirable track removal

Step 4: Undesirable track removal

3D Slicer 4.8.1

Modules: Tractography Display

Help & Acknowledgement

Simple Display

Solid Tube Color

Name	Lines	Tubes	Tubes Slice	Glyphs	Tubes
corpusCallosum	<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 Updates ROI Visibility

Extract Bundle From ROI: None

Update corpusCallosum From ROI: Confirm update

Enable Interactive Edit

Advanced Display

Data Probe

Show Zoomed Slice

L
F
B

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

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Fiducial Seeding

3D Slicer 4.8.1

Modules: **Tractography Display**

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

Diffusion

- Import and Export
- Process
- Quantify
- Tractography**
- Utilities

Tractography

- Tractography Display**
- Tractography Seeding**
- UKF Tractography
- Region-based

Tractography Seeding

Click on the **Modules** and then select **Diffusion** -> **Tractography**->**Tractography Seeding**.

ROI: 100%

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

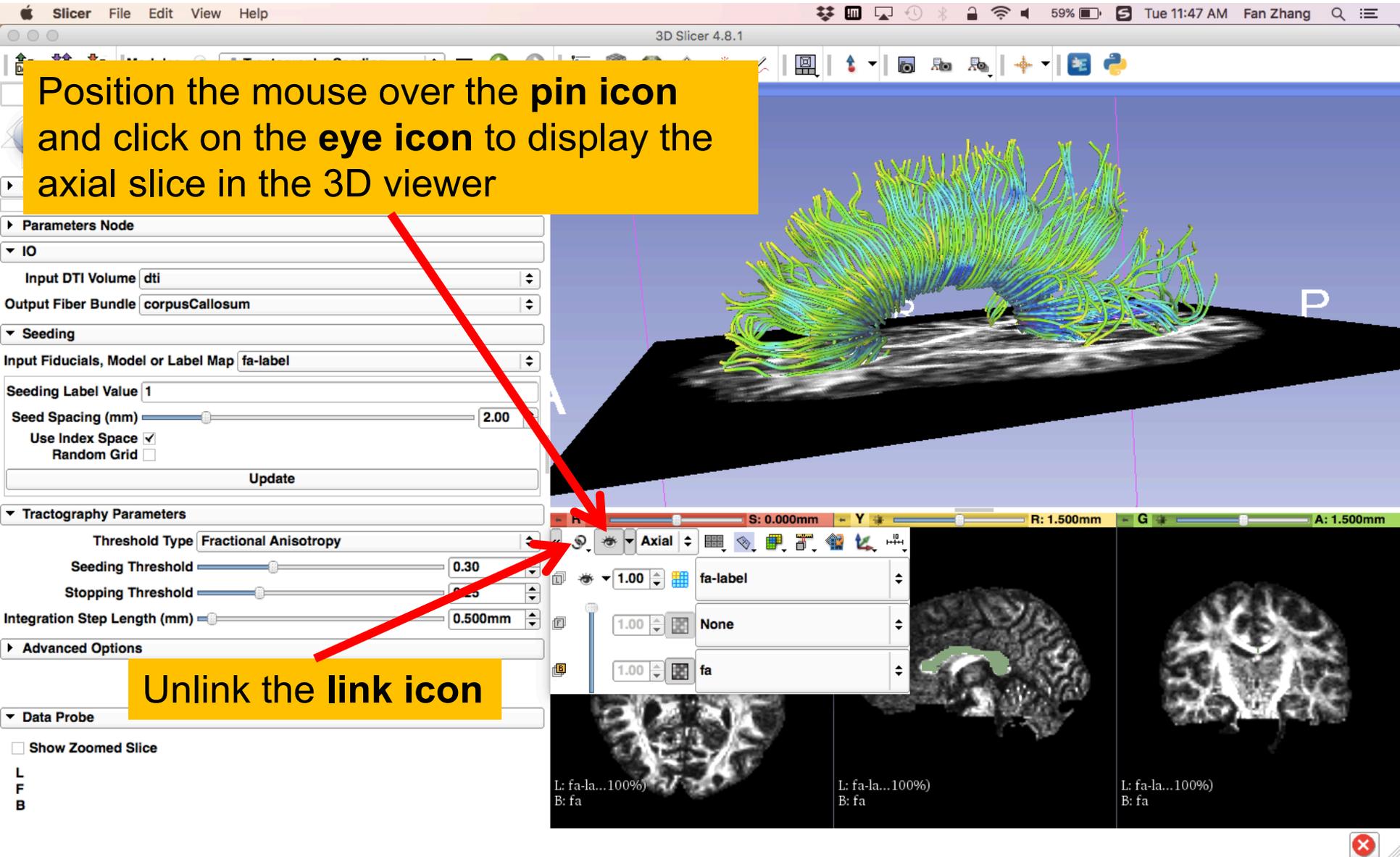
L: fa-la...100%) B: fa

L: fa-la...100%) B: fa

L: fa-la...100%) B: fa

Fiducial Seeding

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



Unlink the link icon

Fiducial Seeding

Select the module Markups

Tractography Seeding

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

Input DTI Volume: dti
Output Fiber Bundle: corpusCalli

Seeding Label Value: 1
Seed Spacing (mm): 2.00
Use Index Space:
Random Grid:

Fiducial Seeding

Tractography Parameters

- Threshold Type: Fractional Anisotropy
- Seeding Threshold: 0.30
- Stopping Threshold: 0.25
- Integration Step Length (mm): 0.500mm

Advanced Options

Data Probe

Show Zoomed Slice:

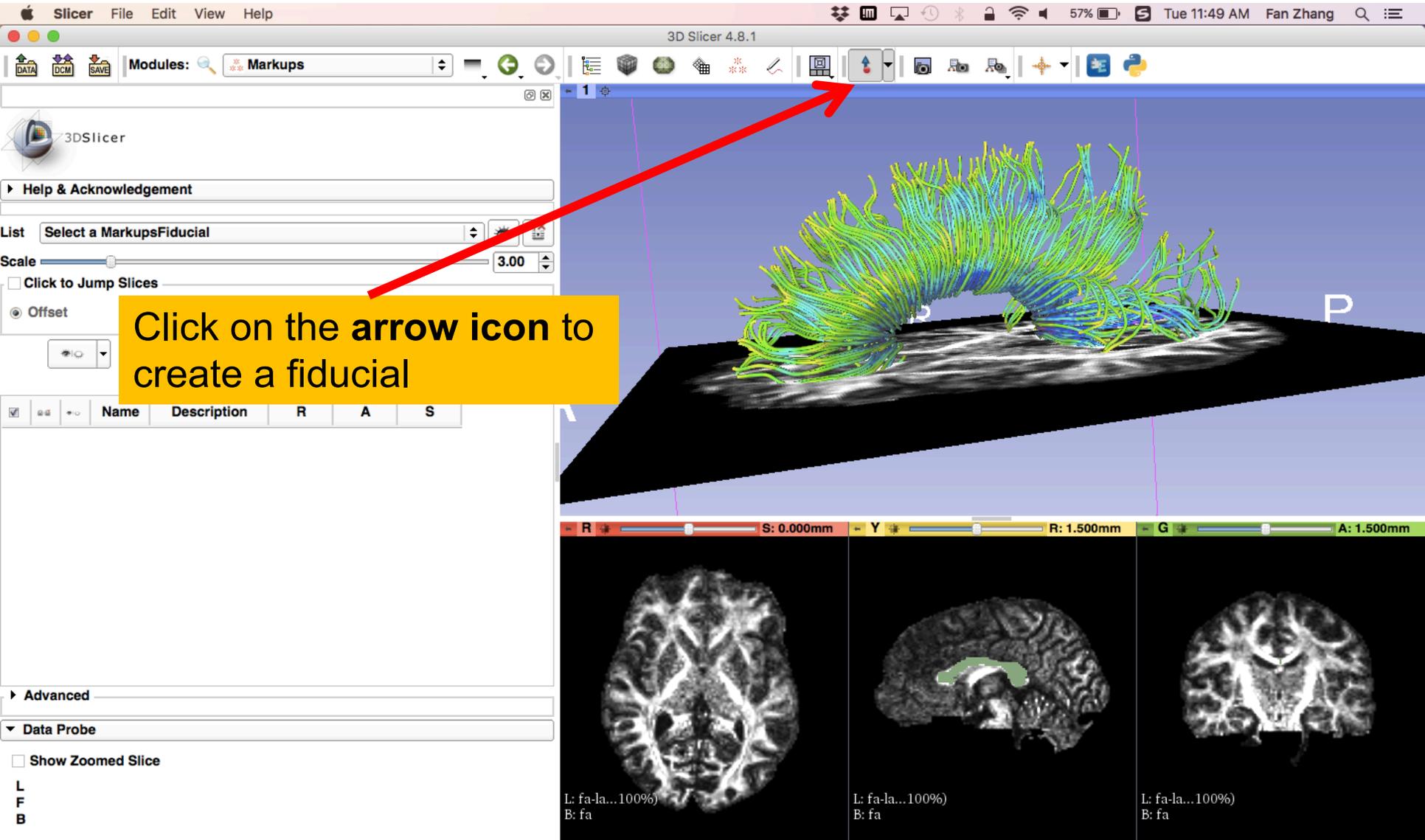
L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

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

Fiducial Seeding



Fiducial Seeding

3D Slicer 4.8.1

Modules: Markups

Position the fiducial in the left cingulum of the coronal slice

Name	Description	R	A	S
F-1		10.317	1.500	25.642

Advanced

Data Probe

Red (R 6.4, A 67.4, S 0.0) Axial Sp: 1.5

L fa-label (60, 19, 47) background (0)

F None

B fa (60, 19, 47) 0.109656

R: 15.000mm Y: R: 1.500mm G: A: 1.500mm

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Fiducial Seeding

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

	Name	Description	R	A	S
1	LeftCingulum		10.317	1.500	25.642

Advanced

Data Probe

Show Zoomed Slice

L
F
B

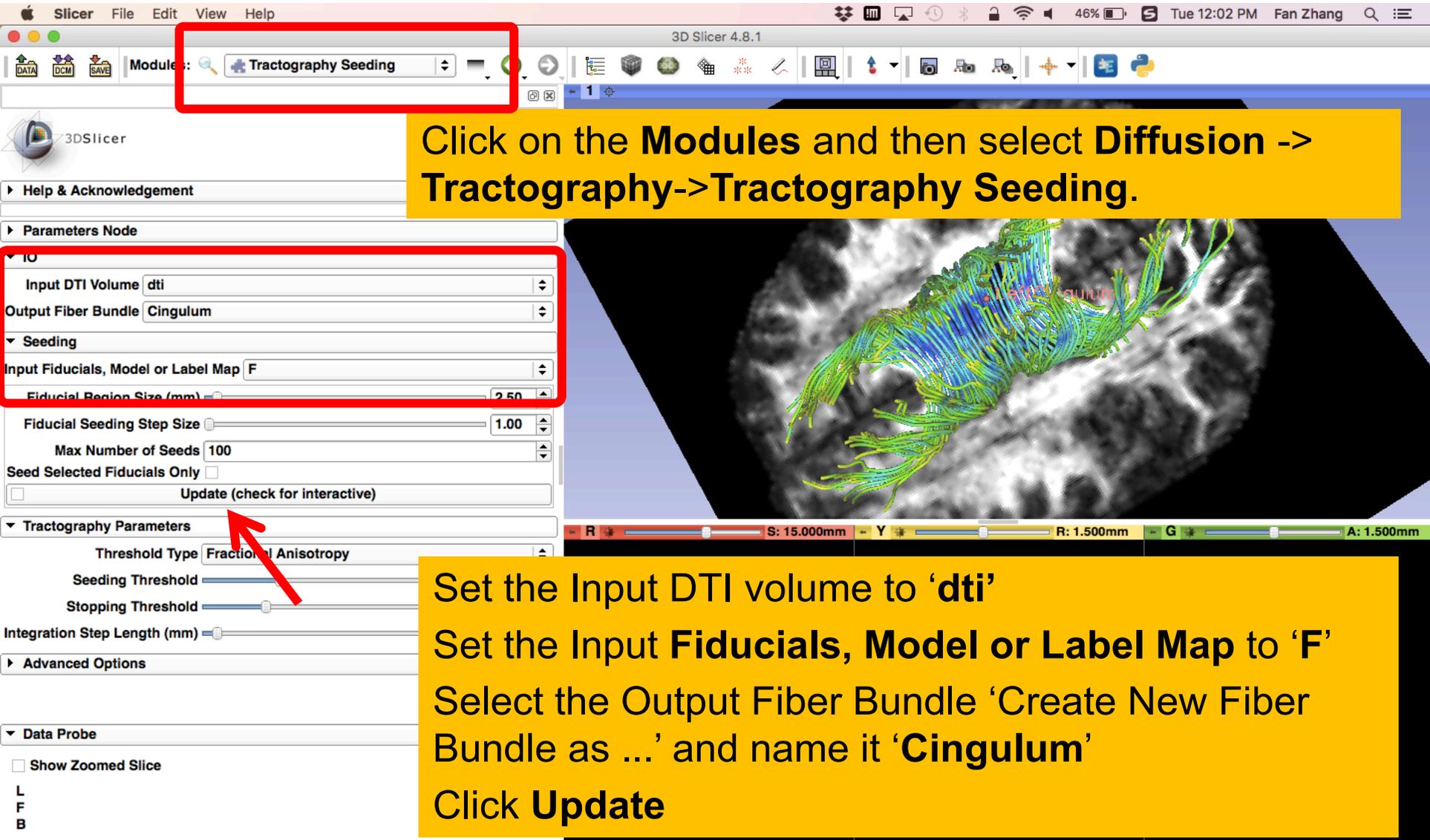
R S: 15.000mm Y R: 1.000mm G A: 1.500mm

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Fiducial Seeding



The screenshot shows the 3D Slicer 4.8.1 interface. The 'Modules' dropdown menu is highlighted with a red box, showing 'Tractography Seeding' selected. The 'Parameters Node' is expanded to show the 'IO' section, which is also highlighted with a red box. The 'Input DTI Volume' is set to 'dti', the 'Output Fiber Bundle' is 'Cingulum', and the 'Input Fiducials, Model or Label Map' is 'F'. The 'Fiducial Region Size (mm)' is 2.50, 'Fiducial Seeding Step Size' is 1.00, and 'Max Number of Seeds' is 100. The 'Tractography Parameters' section is also visible, with 'Threshold Type' set to 'Fractional Anisotropy'. A red arrow points to the 'Update (check for interactive)' button. The 3D visualization shows a brain slice with fiber bundles colored in green and blue, labeled 'Cingulum'.

Click on the **Modules** and then select **Diffusion -> Tractography->Tractography 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 as ...' and name it '**Cingulum**'
Click **Update**

Fiducial Seeding

Part of the left cingulum appears in the 3D viewer.

Move the fiducial and update the Left Cingulum fiducial to explore the spatial relationship between the left cingulum and the corpus callosum

3D Slicer 4.8.1

Modules: Tractography Seeding

Help & Acknowledgement

3DSlicer

R S: 15.000mm Y R: 1.500mm G A: 1.500mm

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Left Cingulum

P

Tractography 'on-the-fly'

The image shows a screenshot of the 3D Slicer software interface. The main window displays a brain MRI slice with a 3D tractography visualization of fiber bundles in green and blue. A yellow callout box with a red arrow points to the 'Markups' module in the 'All Modules' list on the left sidebar. The sidebar also shows various other modules and parameters for the 'Tractography Seeding' module.

Select the module Markups

3D Slicer 4.8.1

Modules: Tractography Seeding

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

Input DTI Volume: dti

Output Fiber Bundle: Cingulum

Seeding

Input Fiducials, Model or Label Map

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Max Number of Seeds: 10

Seed Selected Fiducials Only:

Update

Tractography Parameters

Threshold Type: Fractional Anisotropy

Seeding Threshold: 0.30

Stopping Threshold: 0.25

Integration Step Length (mm): 0.500mm

Advanced Options

Data Probe

Show Zoomed Slice:

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

L: fa-la...100%)
B: fa

Left Cingulum

R: 15.000mm - Y: 1.500mm - G: 1.500mm

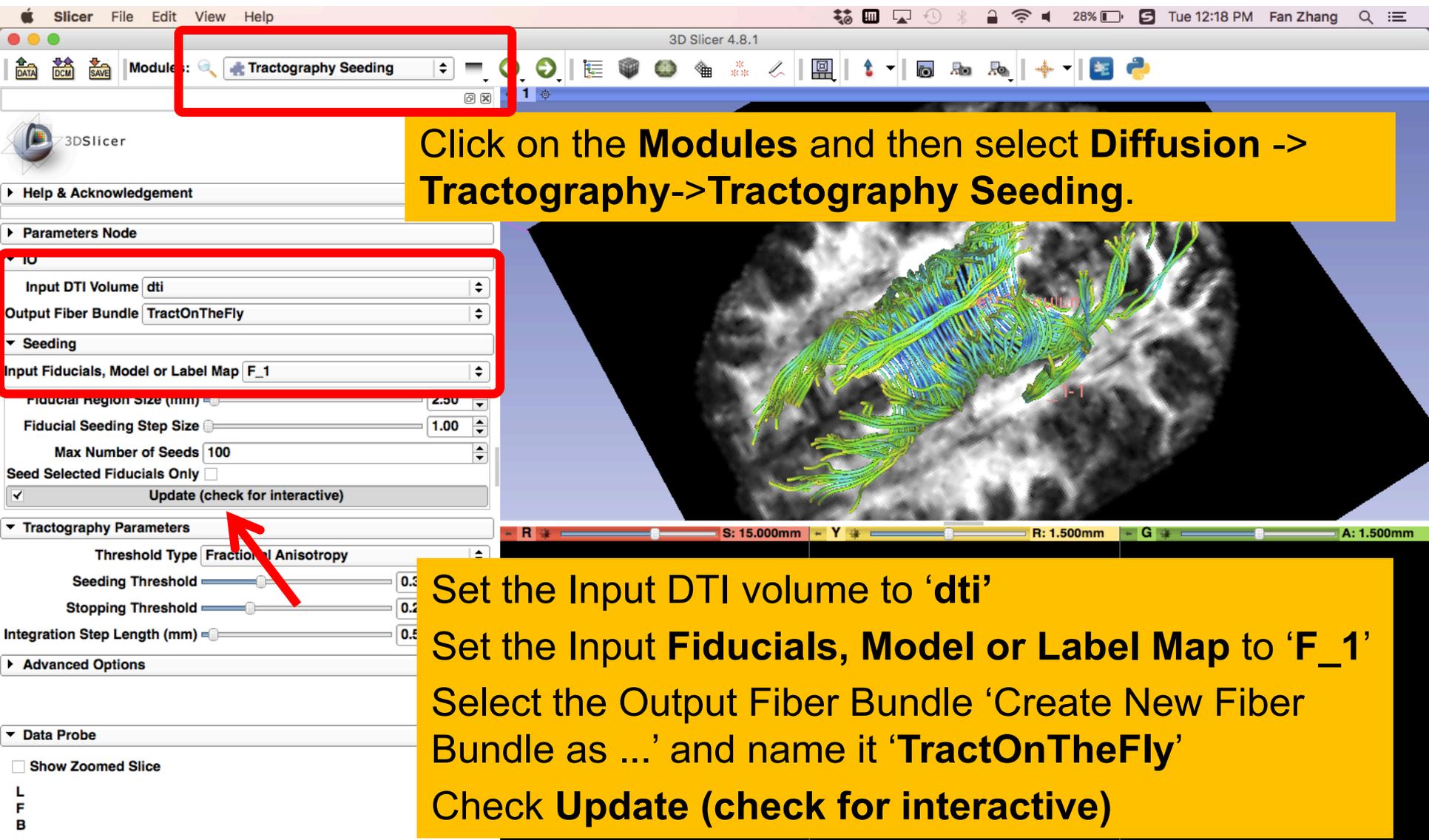
Tractography 'on-the-fly'

The screenshot displays the 3D Slicer 4.8.1 interface. The main 3D viewer shows a brain slice with green and blue fiber-like tractography. A red arrow points to a fiducial marker labeled 'F_1-1' on the tractography. A yellow callout box above the 3D viewer contains the text: 'Select the List 'Create new MarkupsFiducial''. Below the 3D viewer, a yellow callout box contains the text: 'Click on the arrow icon to create a new fiducial, and position it in the 3D viewer'. The left sidebar shows the 'Markups' module with a list of fiducials. The table below is a representation of this list:

	Name	Description	R	A	
1	F_1-1		-22.760	-2.741	1

At the bottom, three orthogonal views (axial, sagittal, and coronal) are shown, each displaying the tractography and the fiducial marker. The bottom status bar shows coordinates: S: 15.000mm, Y: 1.500mm, R: 1.500mm, G: 1.500mm, A: 1.500mm. The bottom left corner shows the legend: L: fa-label (100%), B: fa.

Tractography 'on-the-fly'



Click on the **Modules** and then select **Diffusion** -> **Tractography**->**Tractography Seeding**.

Set the Input DTI volume to 'dti'
Set the Input **Fiducials, Model or Label Map** to 'F_1'
Select the Output Fiber Bundle 'Create New Fiber Bundle as ...' and name it 'TractOnTheFly'
Check **Update (check for interactive)**

Tractography 'on-the-fly'

3D Slicer 4.8.1

Modules: Tractography Seeding

3DSlicer

Help & Acknowledgement

Parameters Node

IO

Input DTI Volume: dti

Output Fiber Bundle: TractOnTheFly

Seeding

Input Fiducials, Model or Label Map: F_1

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Max Number of Seeds: 100

Seed Selected Fiducials Only:

Move the fiducial F_1-1 in the 3D viewer to explore the dti dataset

Advanced Options

Data Probe

Show Zoomed Slice:

L
F
B

A

P

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

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

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

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

Left Caudate

Tractography 'on-the-fly'

3D Slicer 4.8.1

Modules: Tractography Seeding

3DSlicer

Help & Acknowledgement

Parameters Node

IO

Input DTI Volume: dti

Output Fiber Bundle: TractOnTheFly

Seeding

Input Fiducials, Model or Label Map: F_1

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Max Number of Seeds: 100

Seed Selected Fiducials Only:

Update (check for interactive)

Tractography Parameters

Threshold Type: Fractional Anisotropy

Seeding Threshold: 0.30

Stopping Threshold: 0.25

Integration Step Length (mm): 0.500mm

Advanced Options

Data Probe

Show Zoomed Slice

L
F
B

A

P

R

A: 1.500mm

Left Hemisphere

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

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

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

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

DTI Analysis

Select the module **Data** to display the list of elements that have been generated in this tutorial

Subject hierarchy

- Node
 - dwi
 - baseline
 - brain_mask
 - dti
 - corpusCallosum
 - Cingulum
 - TractOnTheFly
 - trace
 - fa
 - fa-label
 - All Annotations
 - ROI List
 - ROI Node
 - F
 - F_1

Filter:

MRML node information

Data Probe

Show Zoomed Slice

L
F
B

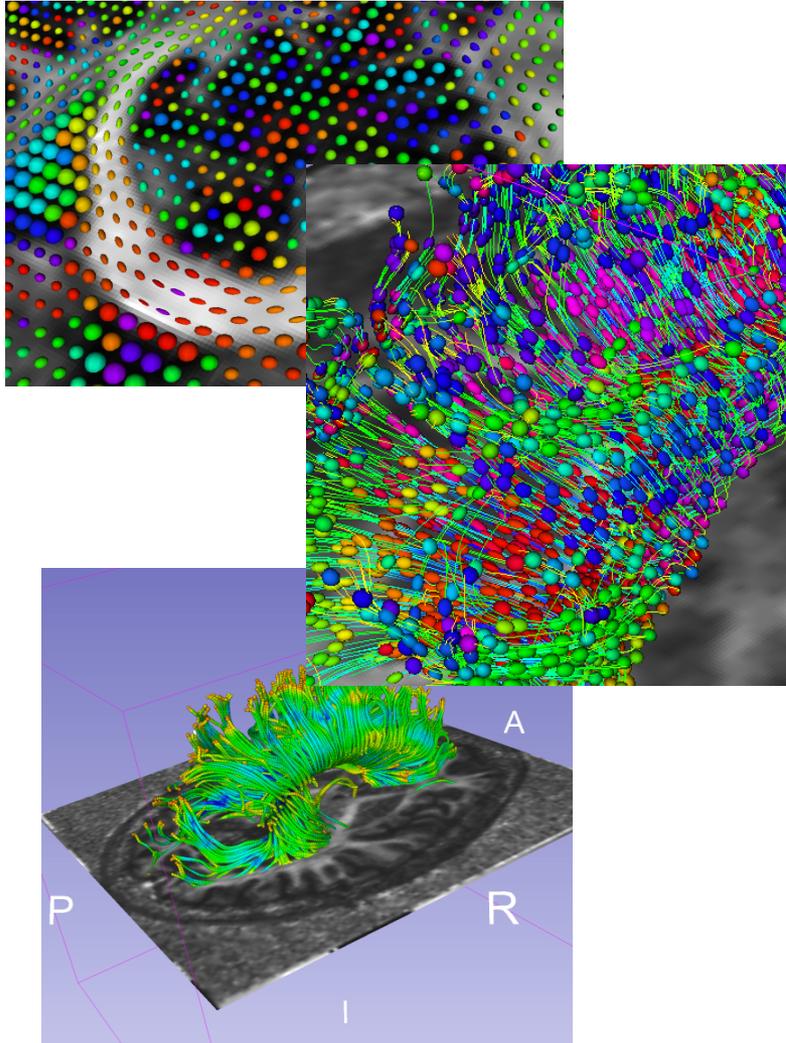
L: fa-label (100%)
B: fa

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

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

Left Cingulum

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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- **Fan Zhang, Ph.D.**
Brigham and Women's Hospital, Harvard Medical School