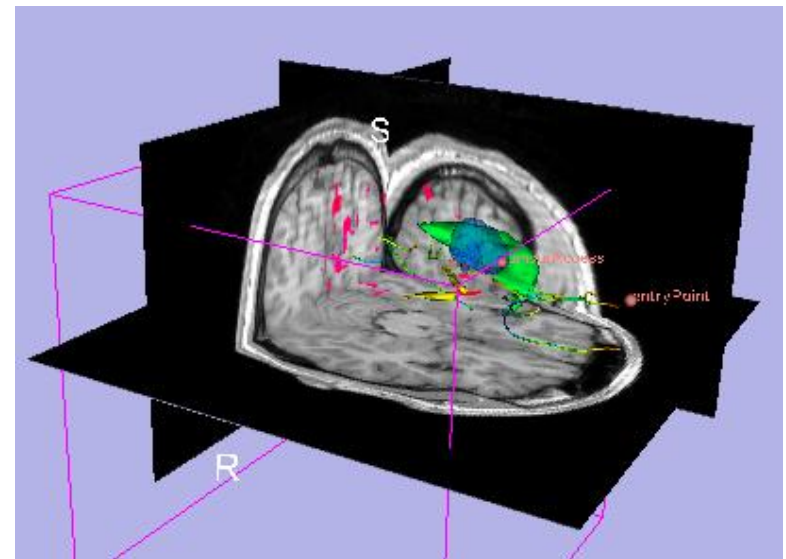




Image Guided Therapy in Slicer3

Planning for Image Guided
Neurosurgery

Nobuhiko Hata, Ph.D.





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Kiyoo Chinzei



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created by:

- Danielle Pace
- Isaiah Norton
- Haiying Liu

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 - **Ron Kikinis, M.D.**, Surgical Planning Laboratory, Brigham and Women's Hospital
- for images and valuable inputs.

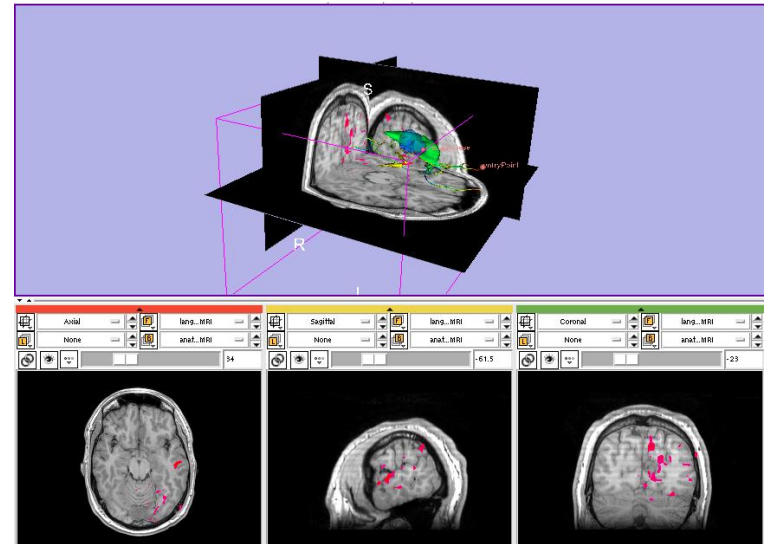


Learning objectives

Following this tutorial, you will be able to perform many common Image Guided Therapy tasks using Slicer3, including:

- Manual tumor segmentation
- Model making
- DTI tractography

using the example of preoperative planning for image guided neurosurgery





Material

This course requires the installation of the Slicer3 version 3.6 (rev. June 10, 2010) and the training datasets accessible at the following locations:

- Slicer3 version 3.6 software:

<http://www.slicer.org/pages/Special:SlicerDownloads>

- Training datasets:

http://www.slicer.org/slicerWiki/index.php/Slicer_3.6:Training

Disclaimer

It is the responsibility of the user of 3D Slicer to comply with both the terms of the license and with the applicable laws, regulations and rules.



Prerequisites

The learners are required to take the following tutorials for Slicer 3.6 as prerequisite to this tutorial.

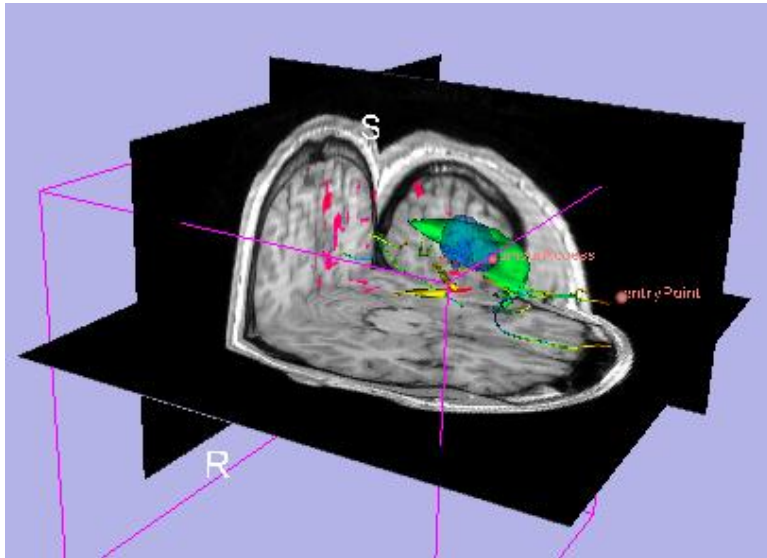
- [Slicer3Minute Tutorial](#)
- [Slicer3Visualization Tutorial](#)
- [Editor](#)
- [Manual Registration](#)
- [Diffusion MRI Tutorial](#)

These tutorials are available at:

http://www.slicer.org/slicerWiki/index.php/Slicer_3.6:Training



The goal of neurosurgical planning



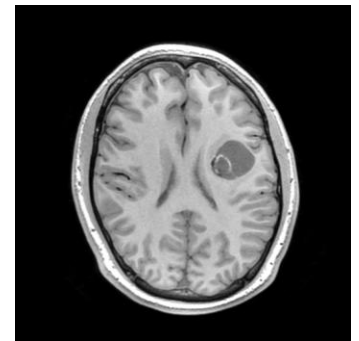
- Prior to surgery:
 - Integrate image information from multiple sources, including anatomical MRI, functional MRI and diffusion tensor imaging
 - Highlight structures of interest
 - Determine the best surgical approach



Clinical Case - brain tumour resection

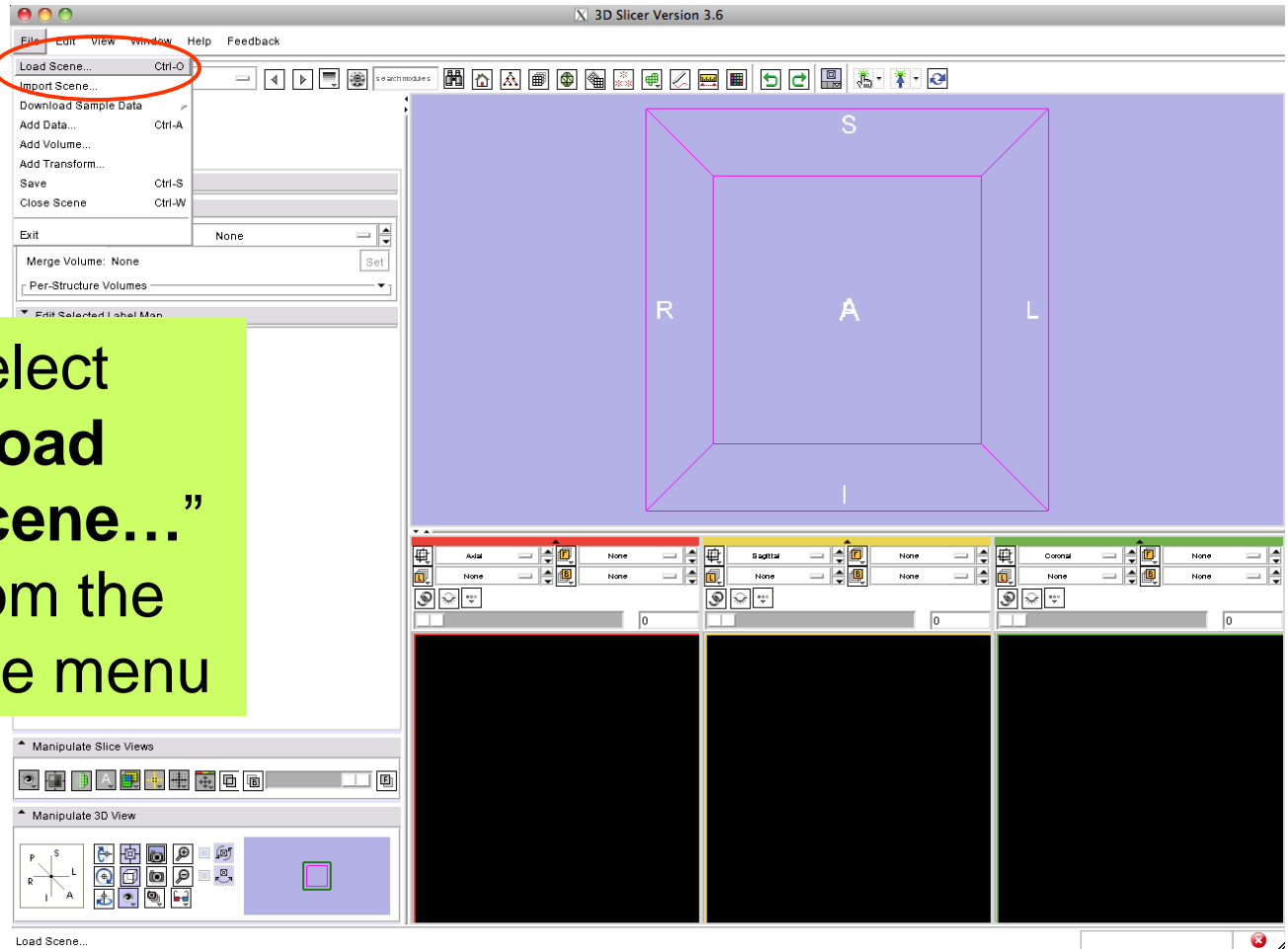
- Imaging showed a large lesion in the left frontal region of the brain, predicted to be a glioma (brain tumour originating from glial cells)
- Preoperative imaging included 3D SPGR MRI, T2-weighted MRI and FLAIR MRI, language and motor functional MRI (fMRI) imaging, and diffusion tensor imaging (DTI)
- fMRI showed speech areas close to the lesion
- Surgical procedure: left frontal craniotomy and tumour resection

See the `clinical_background` file within the patient dataset for more information





Load the Scene file



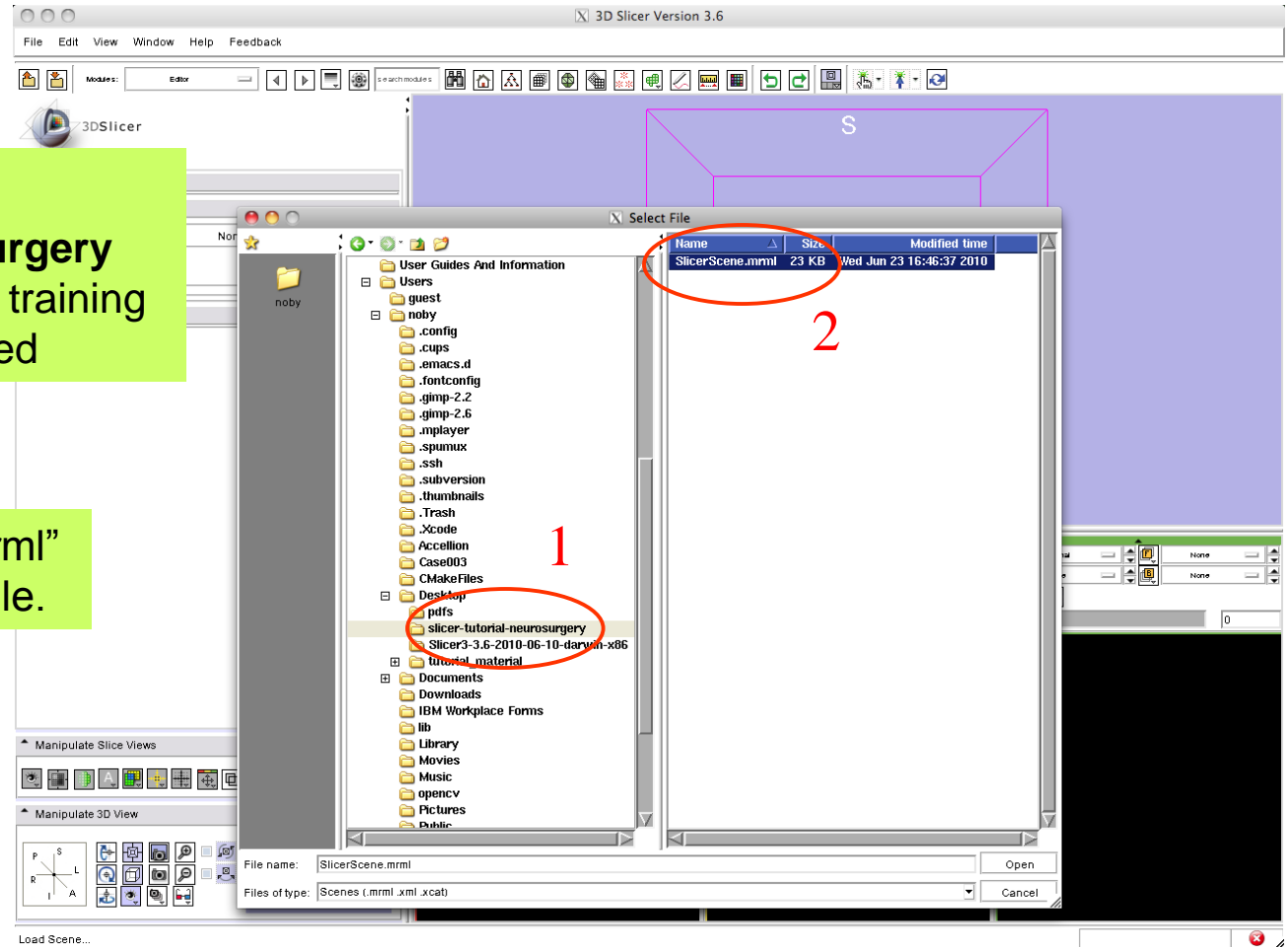
Select
“Load
Scene...”
from the
File menu



Load the anatomical MRI data

1. Select the **slicer-tutorial-neurosurgery** directory containing the training datasets you downloaded

2. Choose “Baseline.mrml” and “Open” the scene file.





Load the anatomical MRI data

Open the Data module

3D Slicer Version 3.6.1

File Edit View Window Help Feedback

MRML Tree

- Scene
- View1
- Default Scene Camera
- SPGR
- DWI-baseline
- fMRI
- fMRI_language

MRML Node Inspector

Load & Add Scenes Or Individual Datasets

- Load new scene (close current)
- Add a scene (to current)
- Add data or a data directory

Manipulate Slice Views

Manipulate 3D View

fMRI_language RAS: (151.4, 34.6, 135.0), Bg IJK: (-47, 257, 140), Fg: Out of Frame, Bg: Out of Frame.



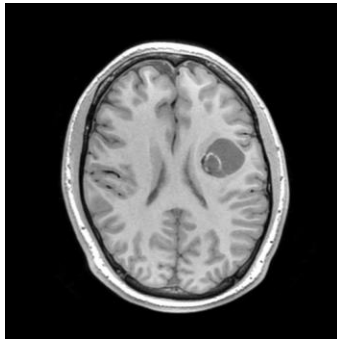
Load the anatomical MRI data

The screenshot displays the 3D Slicer Version 3.6.1 interface. On the left, the MRML Tree panel is visible, with a red circle highlighting the following nodes: Scene, View1, Default Scene Camera, SPGR, DWI-baseline, fMRI, and fMRI_language. The main 3D view area shows a brain slice with a green text box containing the text: "Observe that the name of the nodes in the MRML tree". Below the 3D view, there are three slice view panels: Axial, Sagittal, and Coronal. The status bar at the bottom indicates: fMRI_language RAS: (151.4, 34.6, 135.0), Bg IJK: (-47, 257, 140), Fg: Out of Frame, Bg: Out of Frame.

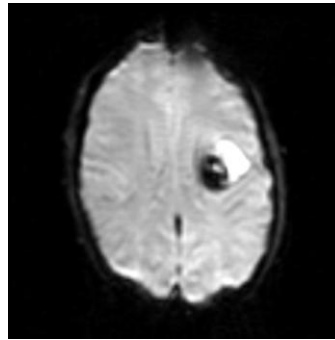


Images in the scene

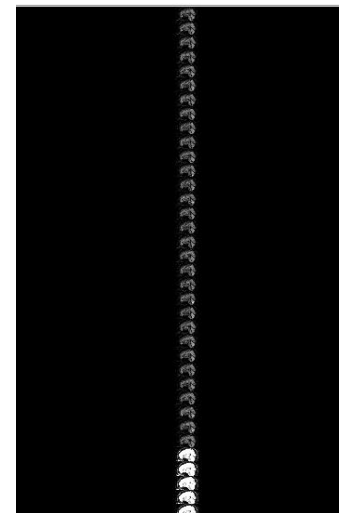
- Three clinical datasets from a single patient with a large tumour in the left frontal region



SPGR MRI
(*SPGR*)



Language fMRI
(*fMRI, and
fMRI_language*)



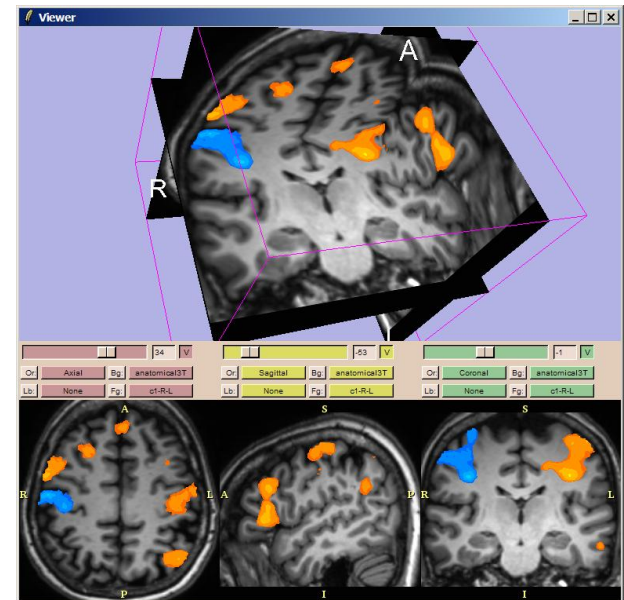
**Diffusion Weighted
Images (*DWI, baseline
only*)**



Functional MRI (fMRI)

- **fMRI:**

- Measures the blood oxygen level in each part of the brain while the patient performs a task, such as a speech or motor task
- Statistical techniques are used determine which brain regions are active during the task
- This statistical pre-processing has already been done using SPM



SPM

<http://www.fil.ion.ucl.ac.uk/spm/>



Functional MRI (fMRI)

- **Utility of functional MRI in IGT:**
 - Damage to regions of the brain important for language or movement could result in problems with speech, reading or movement
 - Knowing where these regions are allows us to modify our surgical plan so that we avoid them (as much as possible)



Functional MRI (fMRI)

- **Steps involved in this section:**

Identify language fMRI
from patient dataset

Identify language fMRI
registered to SPGR

Threshold registered language
fMRI to display regions with
high activation



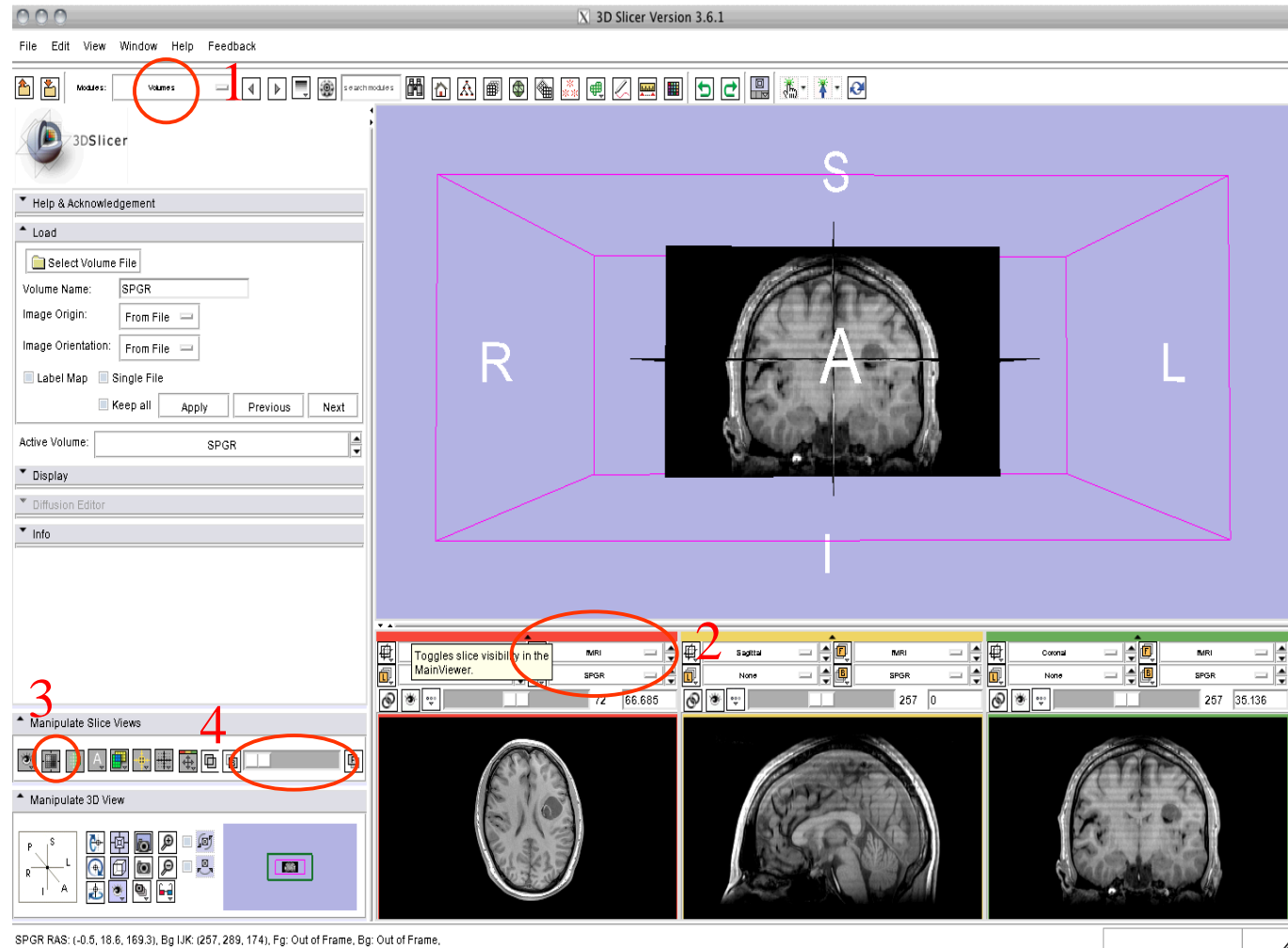
fMRI registration to SPGR

1. Open the **Volumes** module

2. Set the foreground to fMRI and the background to SPGR

3. Click on the **fit to window** button

4. Change blending ratio to appreciate fMRI registered to SPGR



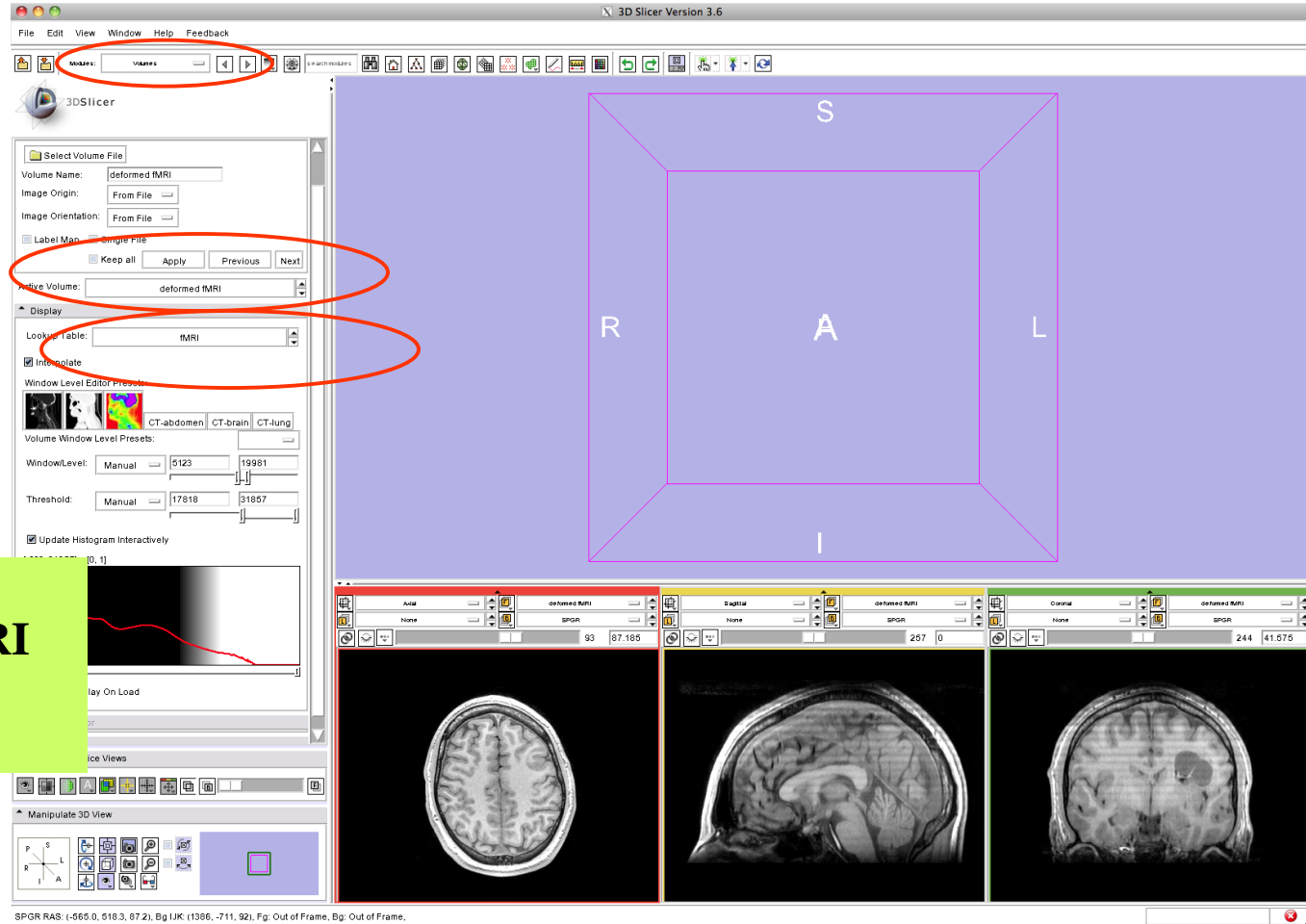


Threshold image intensity

Move to **Volume** window

Choose
“**fMRI_language**”
as the active volume

Choose **Discrete-->fMRI**
in the Lookup Table

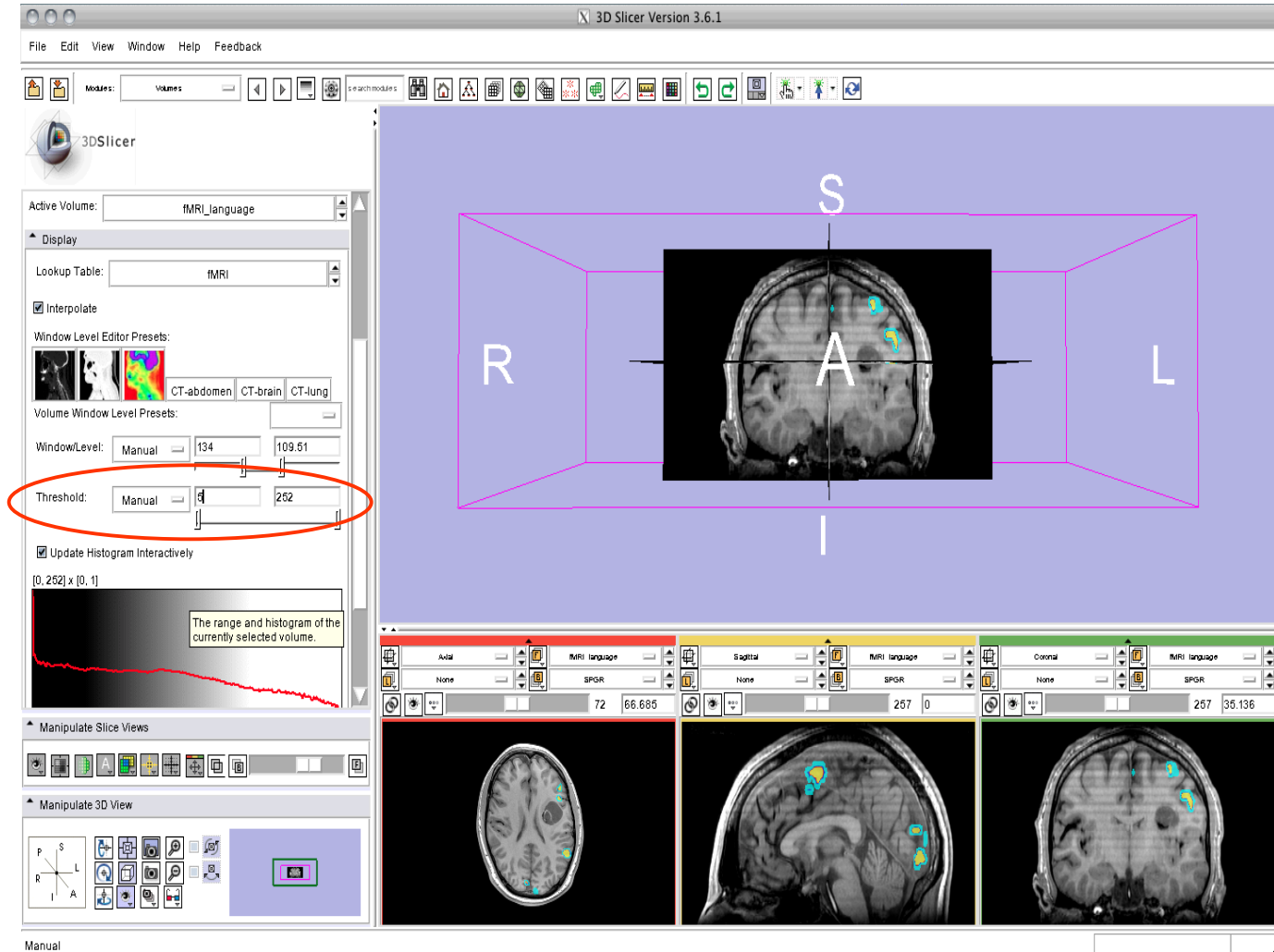




Threshold image intensity

Set the threshold to **Manual** and set lower threshold to 5

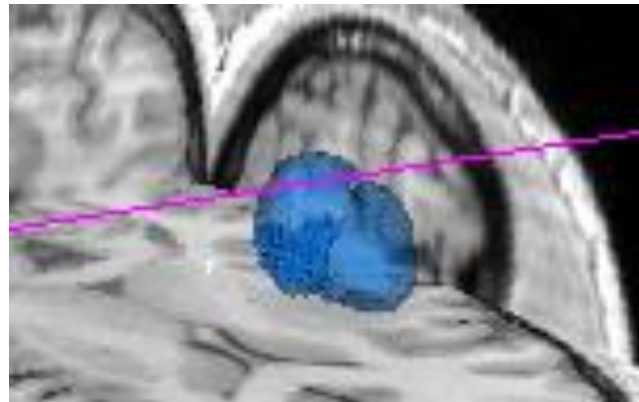
Note that there are speech activation regions close to the tumour





Model Making in Slicer3

- **Utility of model making in IGT:**
 - View the structure as a complete unit (instead of slice by slice)
 - Perform measurements, such as volume measurements, that can be difficult to perform on the image volume itself





Model Making in Slicer3

- **Steps involved in this section:**

Segment the tumour volume in the anatomical MRI

Create the tumour model using Slicer3's ModelMaker

Change the tumour model's appearance

Save the tumour model



Display SPGR images

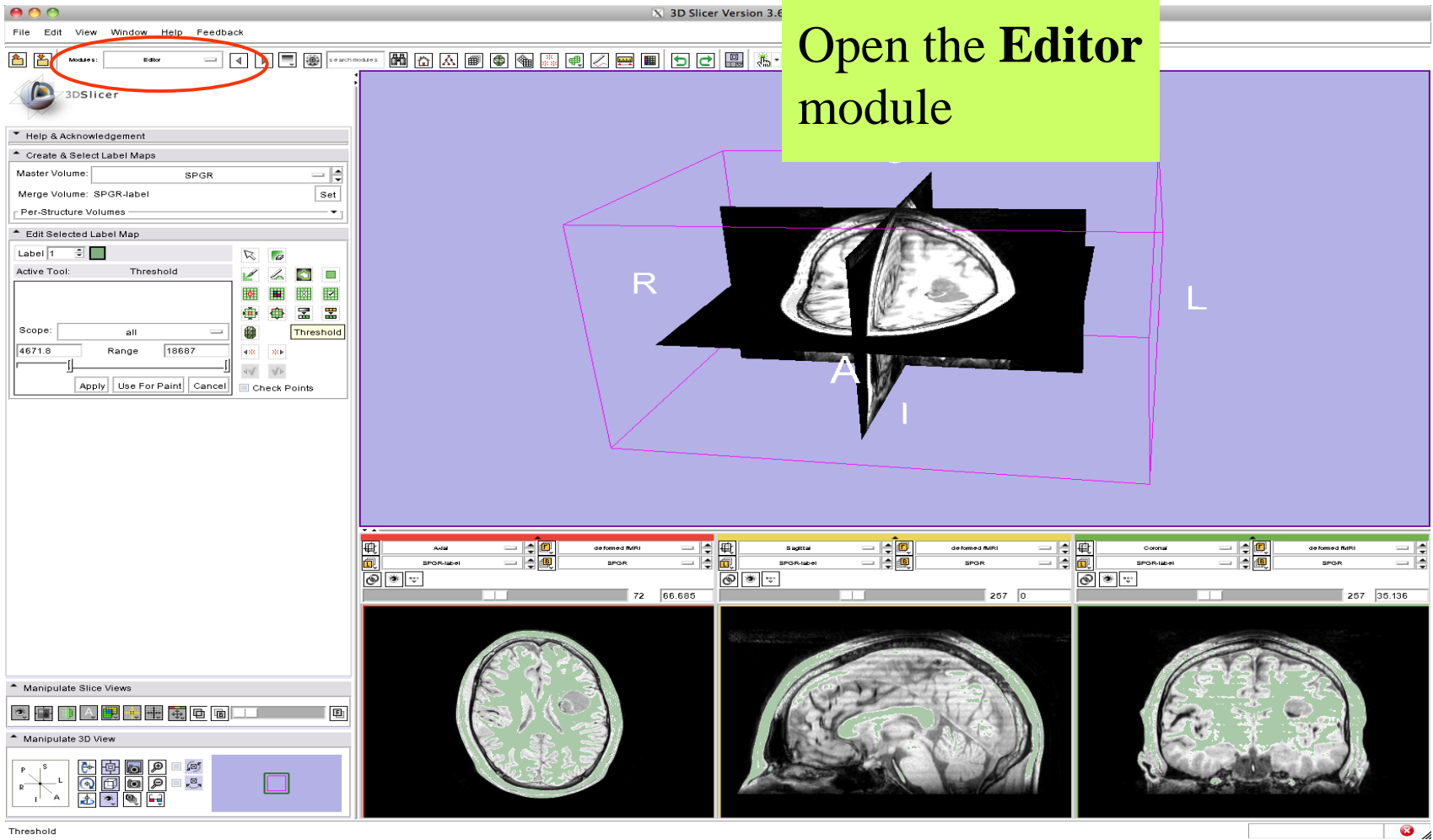
Chose SPGR as Background image





Segment the tumour volume

Open the **Editor** module

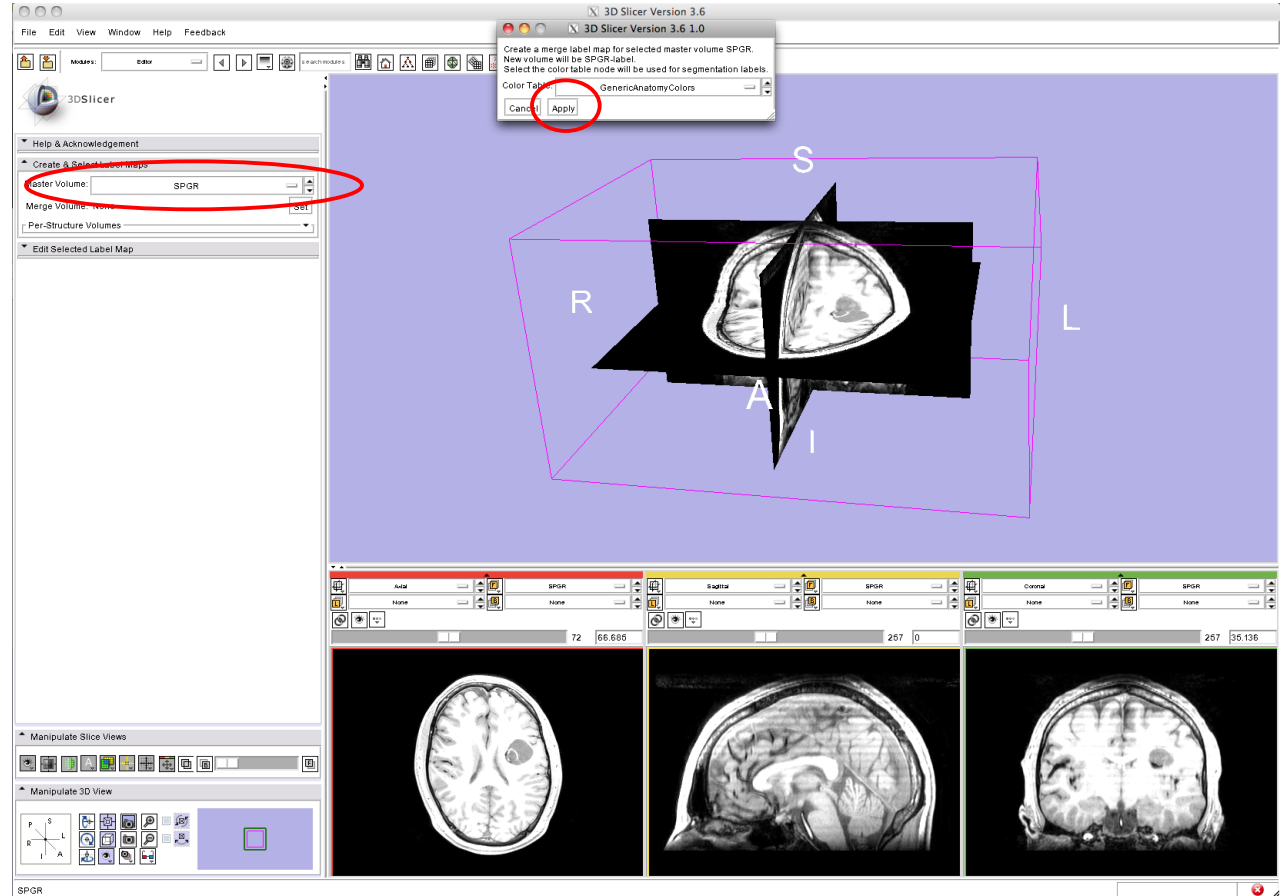




Segment the tumour volume

Set the Master Volume to **SPGR**

When “Color Table” option window pop up, press **Apply** button.



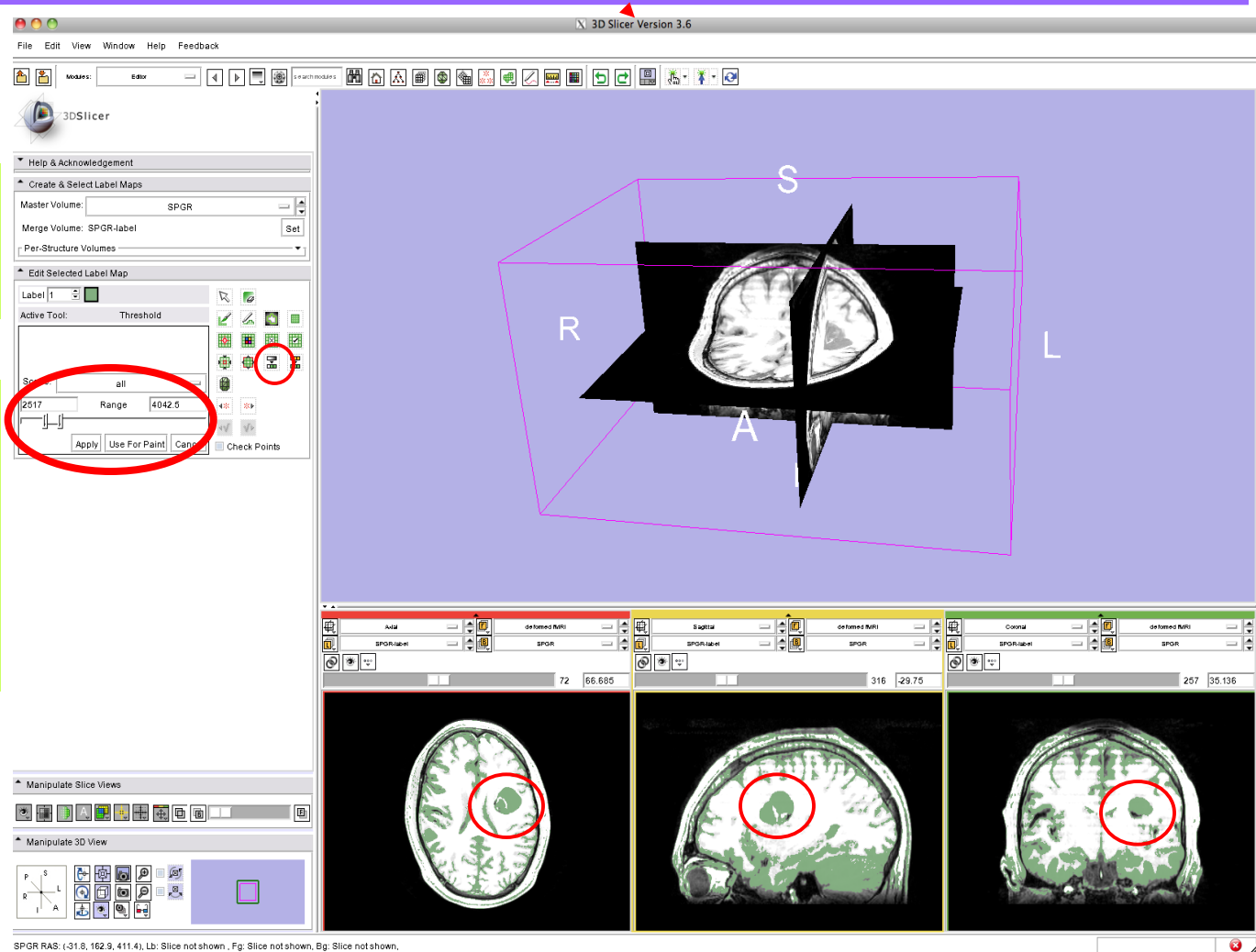


Segment the tumour volume

Choose **Threshold** editor.

Put 2517 and 4042 in the entry box, or move the slider till you can see isolated tumour lesion.

Hit **Apply** button



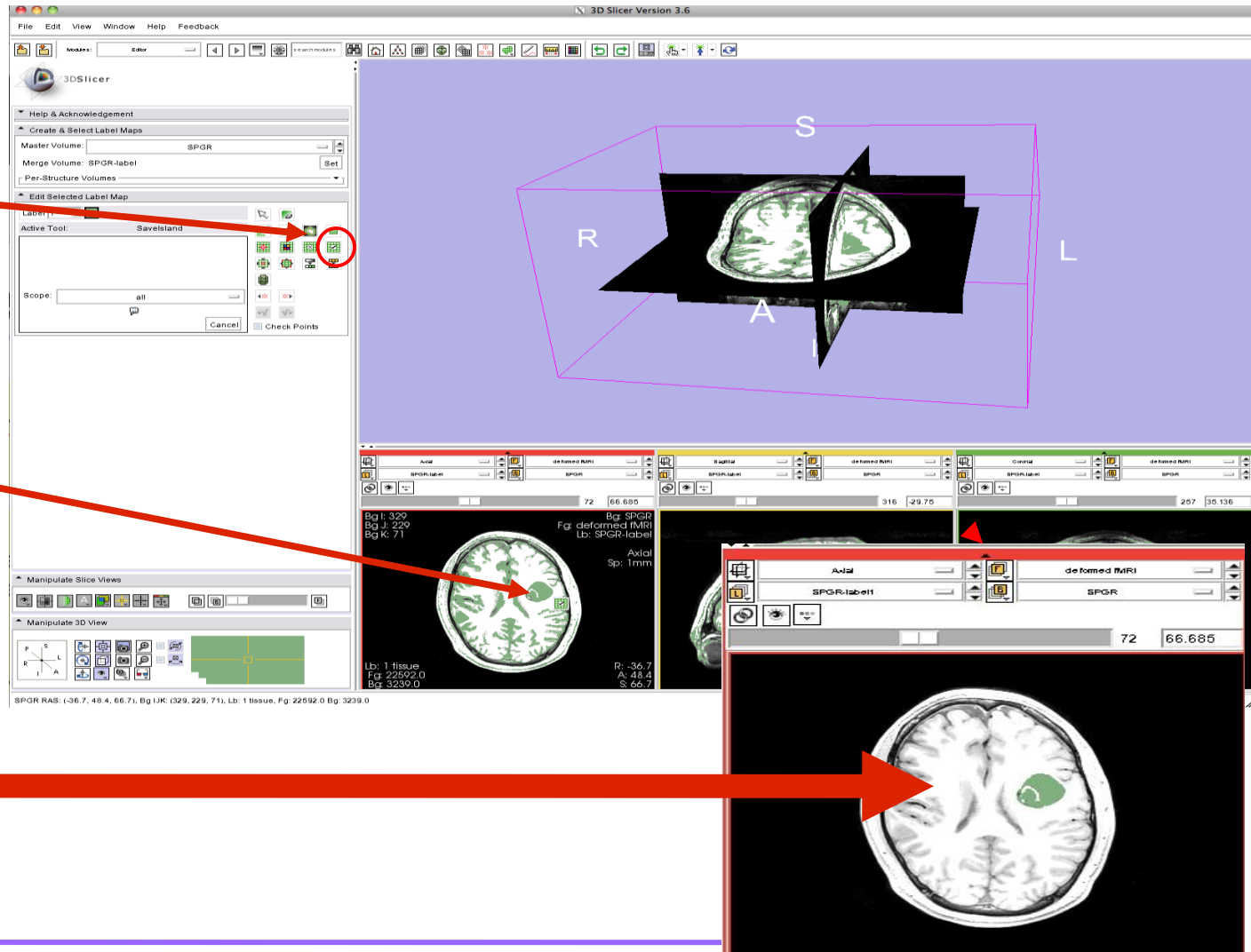


Save Island

Choose **Save Island** option

Click on the tumor lesion

Confirm that only tumor lesion remains painted green

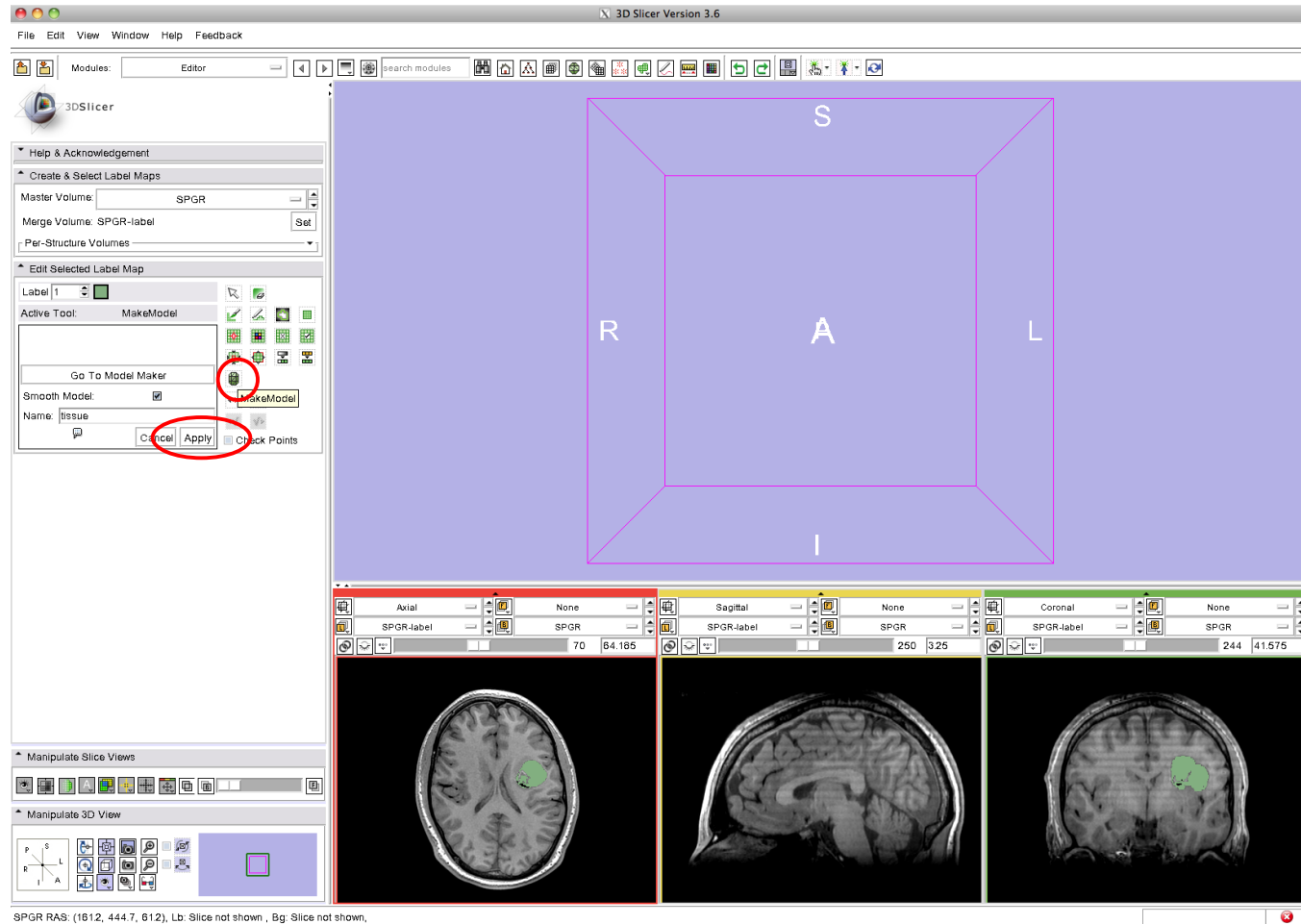




Create the tumour model

Choose **Model Maker** in the Editor module

Click **Apply**

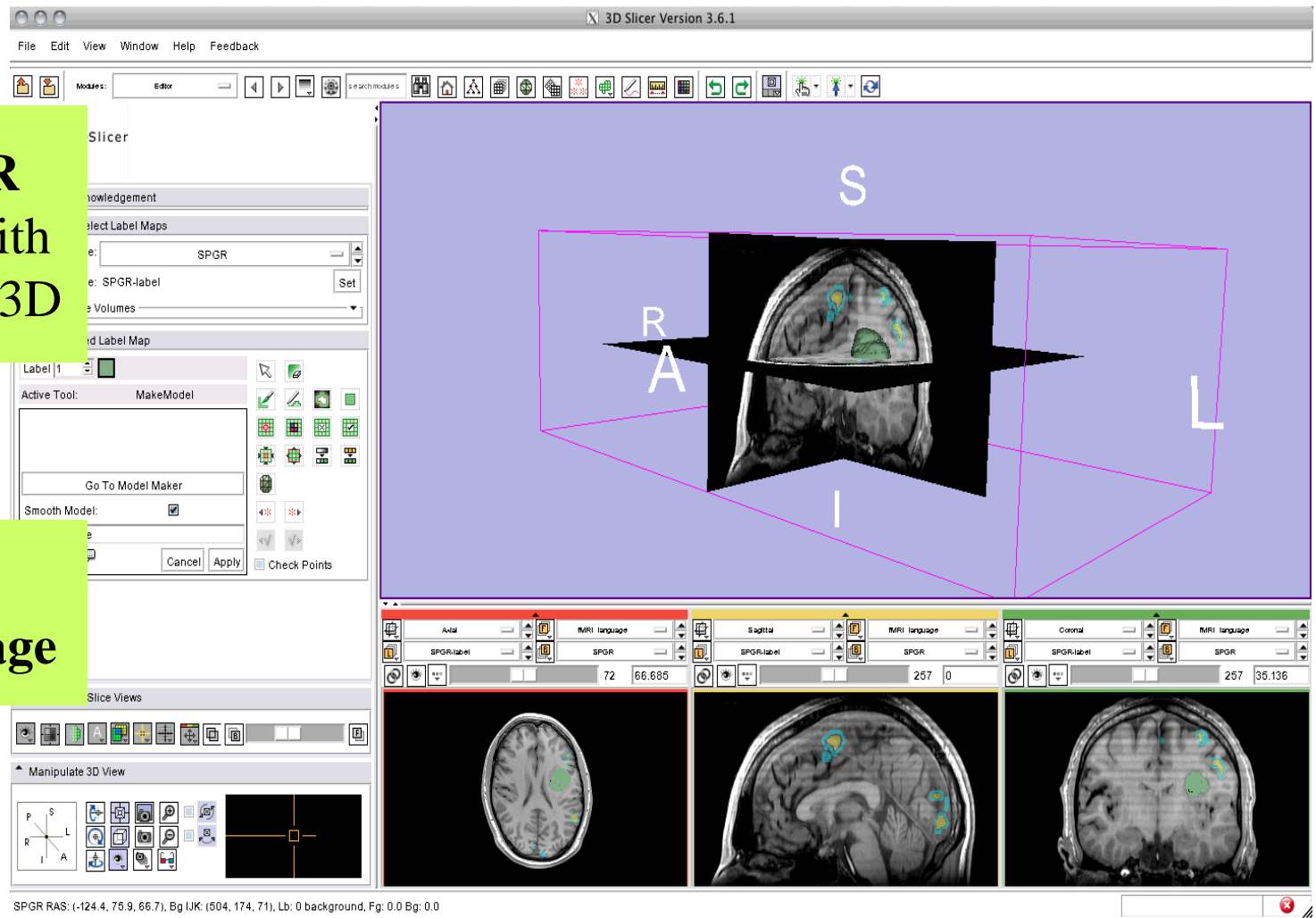




View the anatomical MRI, fMRI and tumour model

Display **SPGR** in 3D View with the generated 3D

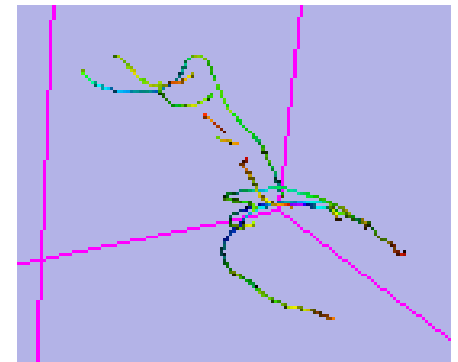
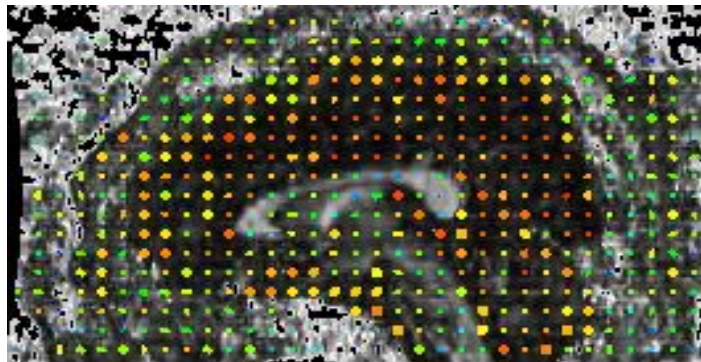
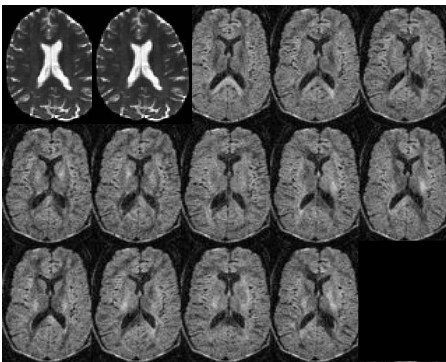
Display **fMRI_language**





Diffusion Tensor Imaging (DTI)

- Acquire diffusion weighted images (DWI) and baseline images
- Estimate a tensor at each voxel to create a Diffusion Tensor Image (DTI)
- Calculate a scalar “diffusion anisotropy index”, such as fractional anisotropy, to quantify the diffusion’s anisotropy
- Perform tractography (fiber tracking)





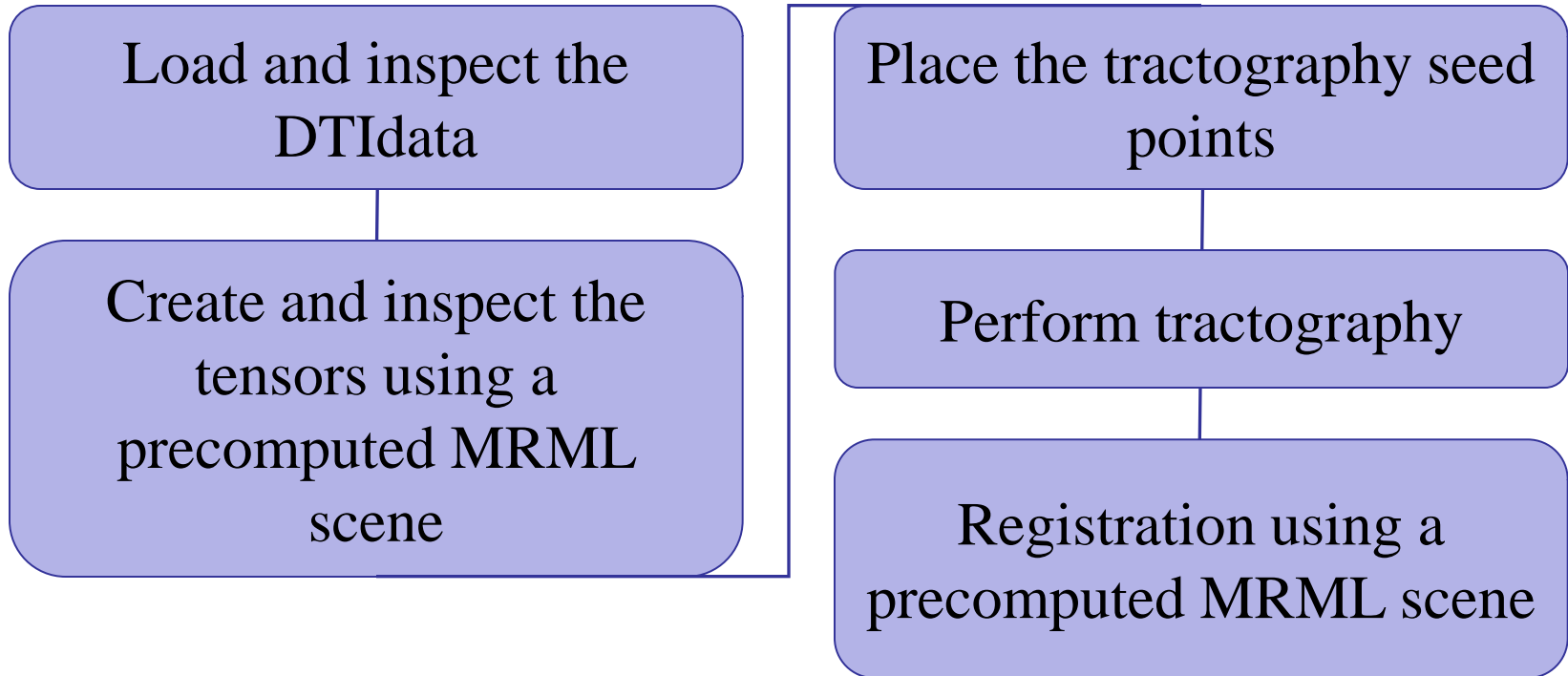
Diffusion Tensor Imaging (DTI)

- **Utility of Diffusion Tensor Imaging in IGT:**
 - Major tracts that run between functionally important regions of the brain must remain intact to prevent adverse effects for the patient
 - Knowing where these tracts are allows us to modify our surgical plan so that we avoid them (as much as possible)



Diffusion Tensor Imaging (DTI)

- **Steps involved in this section:**

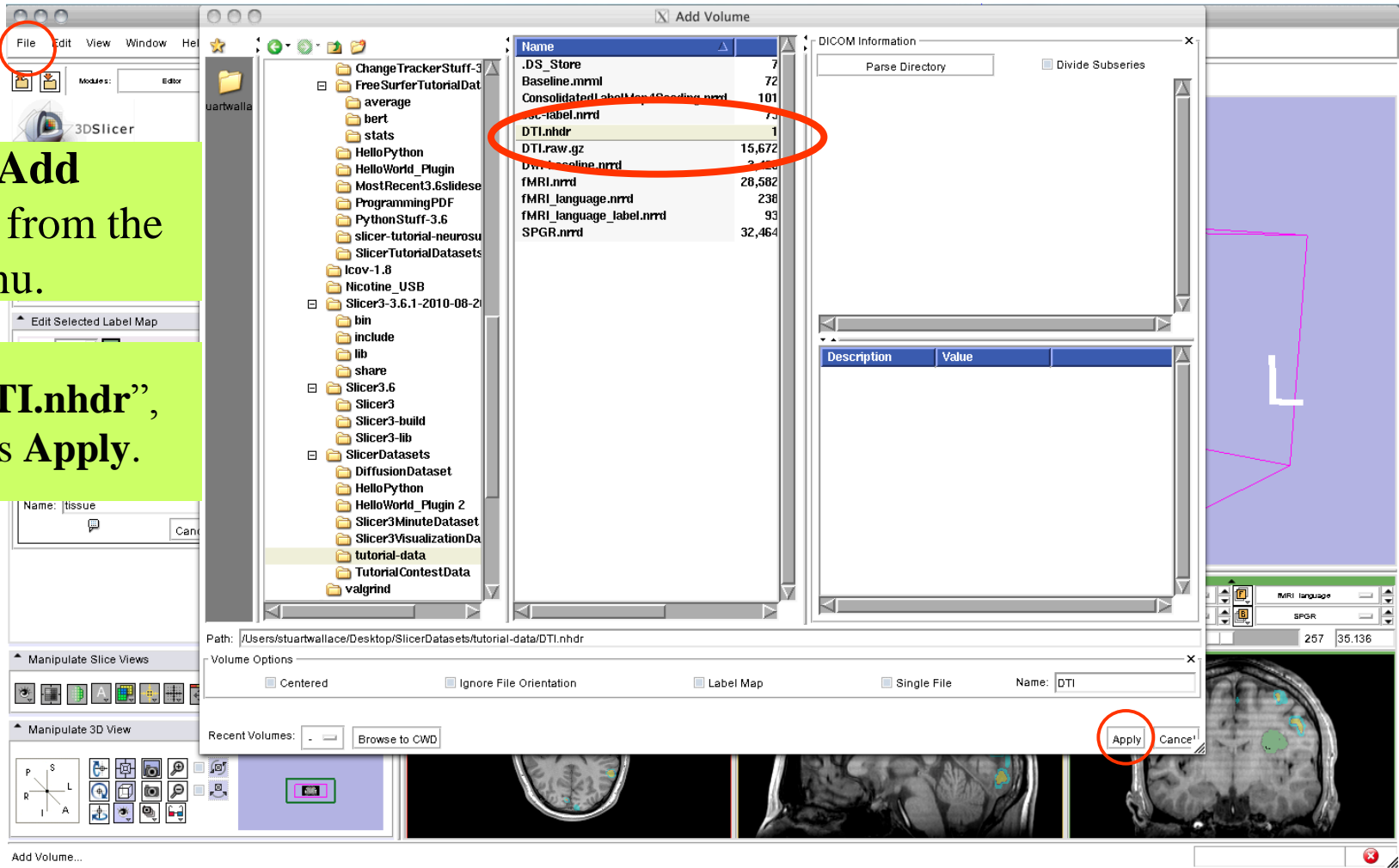




Load the DTI data

Choose **Add Volume** from the **File** menu.

Load **“DTI.nhdr”**, then press **Apply**.



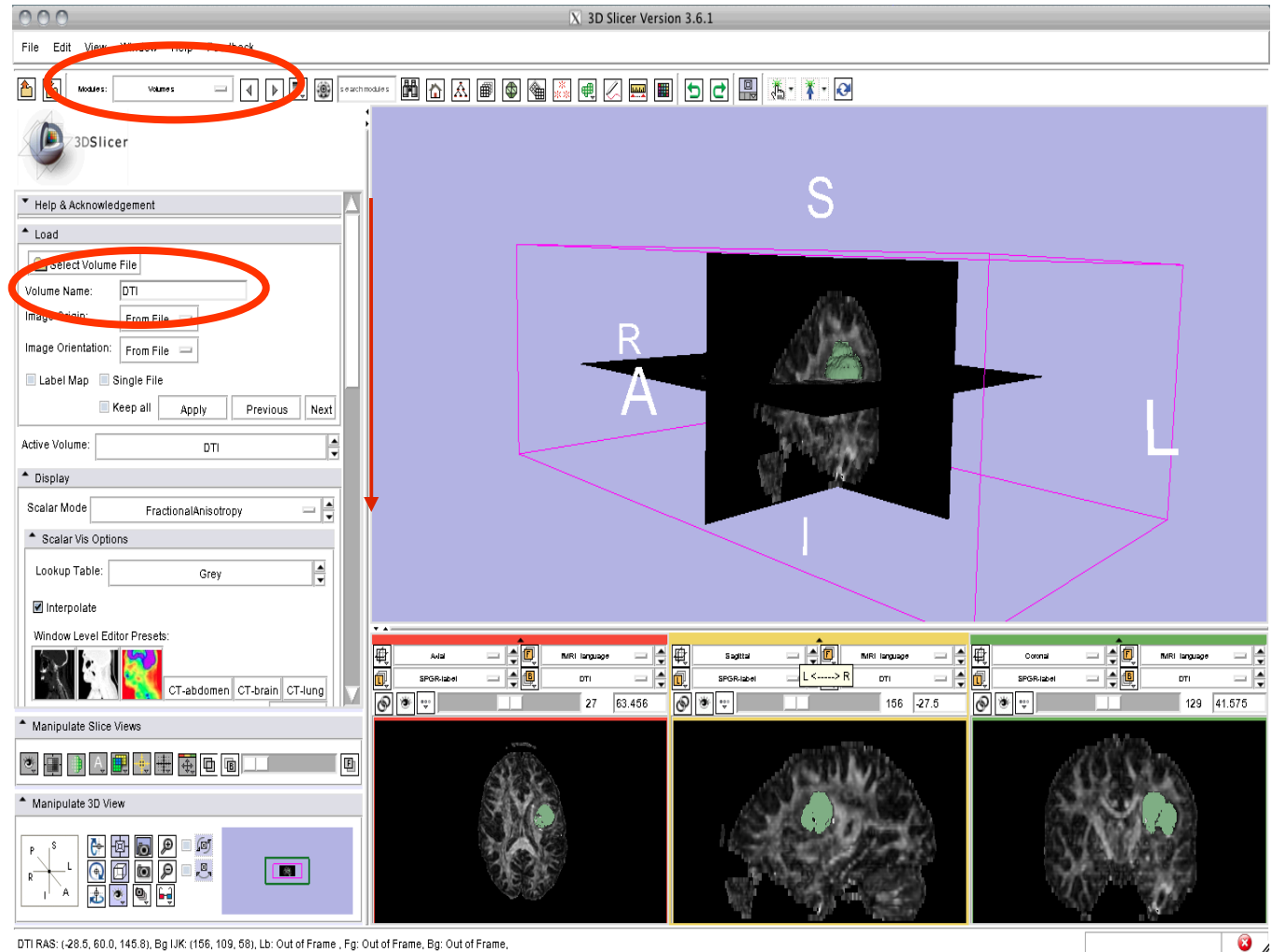


Inspect the DTI data

Go to **Volume**

Choose **DTI** as the **Active Volume**

Pull down the **slider....**

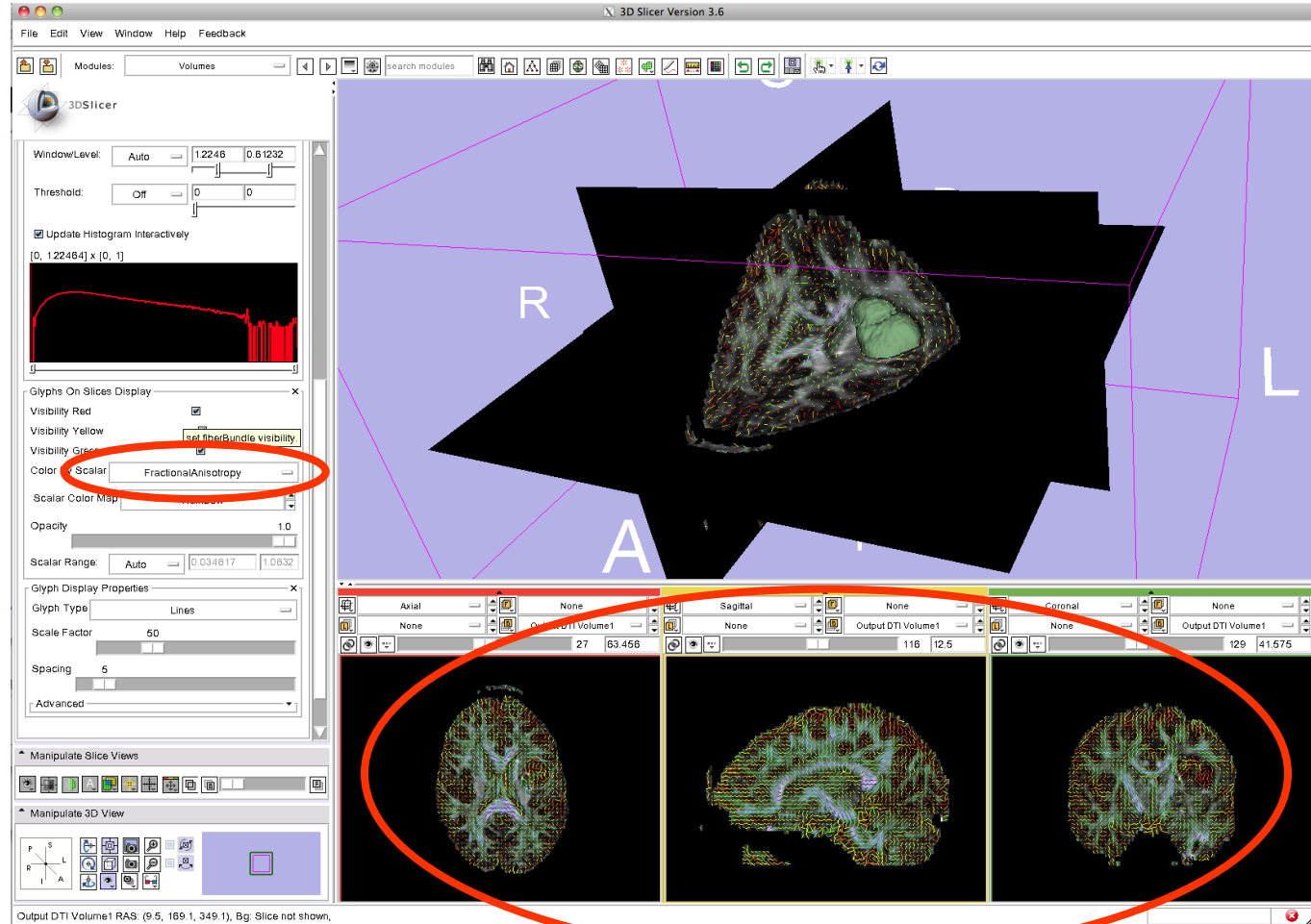




Inspect the DTI data

Toggle on
“Visibility Red”
“Visibility Yellow”
and “Visibility
Green”

See **Fractional
Anisotropy** are
visualized as lines

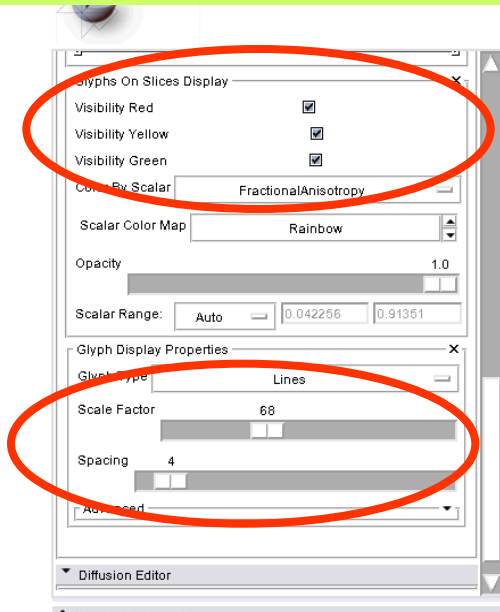




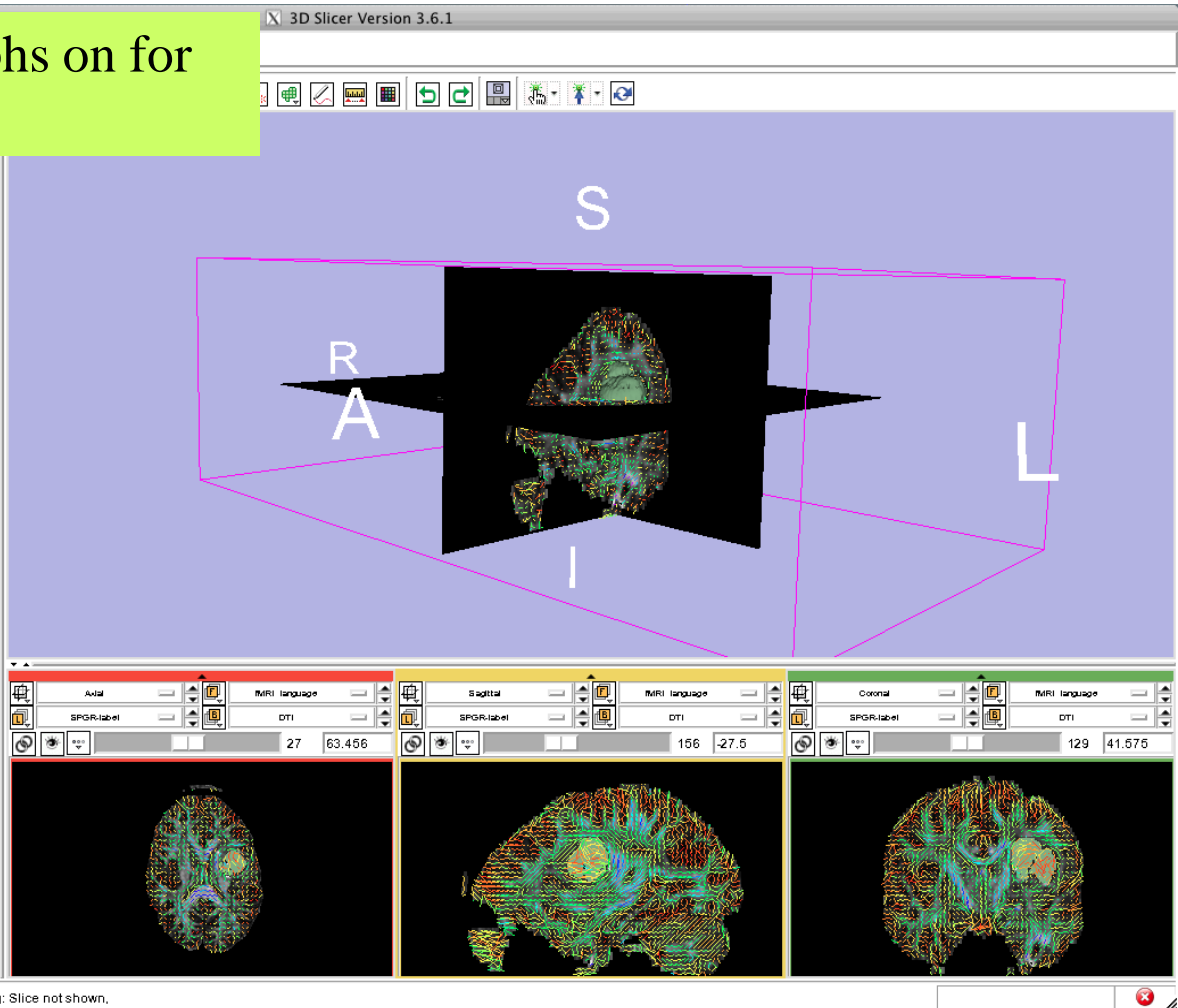
3DSlicer

View the tensors

Scroll down and turn the glyphs on for all three views



Adjust the scale factor and the spacing



DTI RAS: (-31.5, 169.1, 385.0), Lb: Slice not shown, Fg: Slice not shown, Bg: Slice not shown.

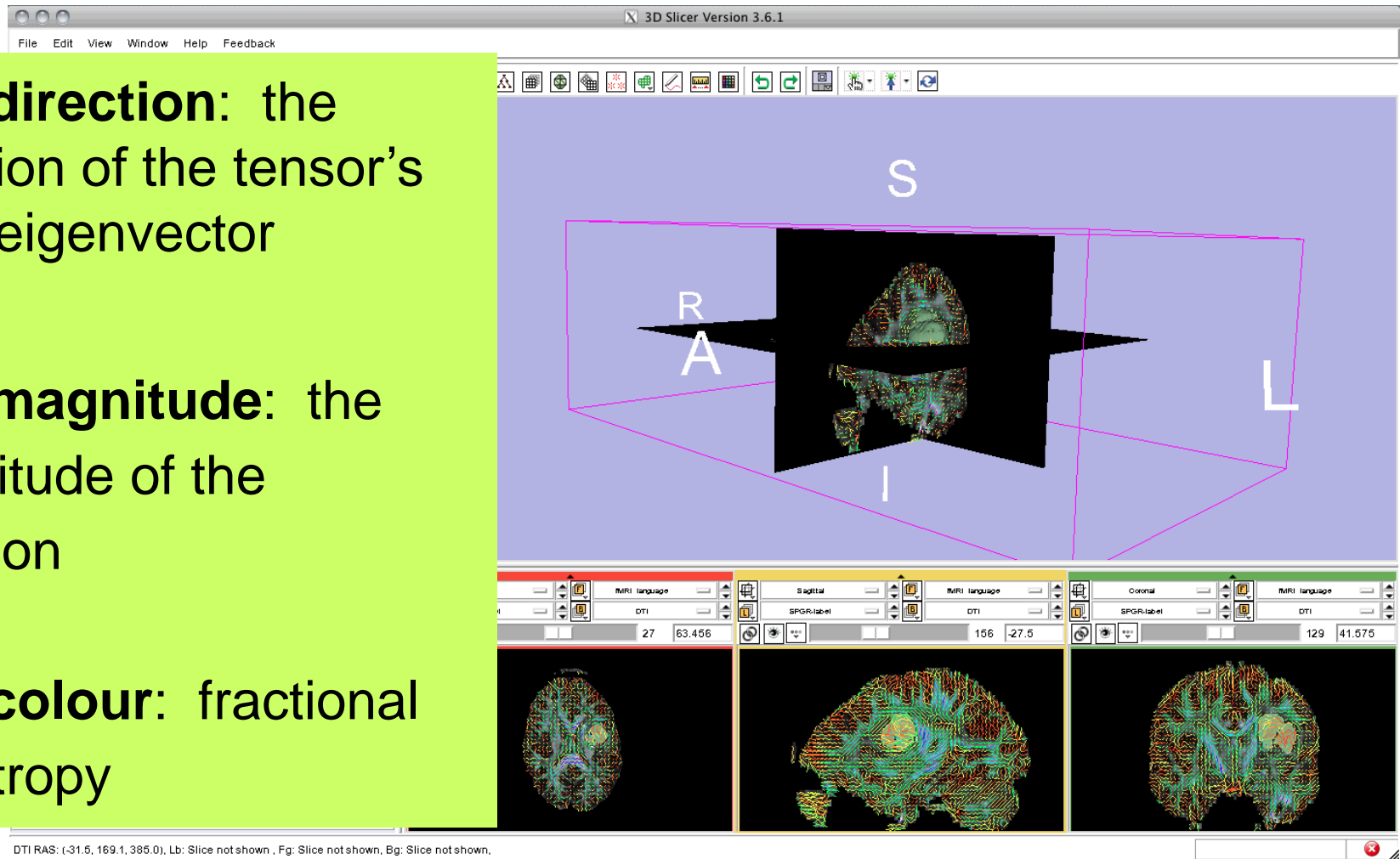


View the tensors

Line direction: the direction of the tensor's main eigenvector

Line magnitude: the magnitude of the diffusion

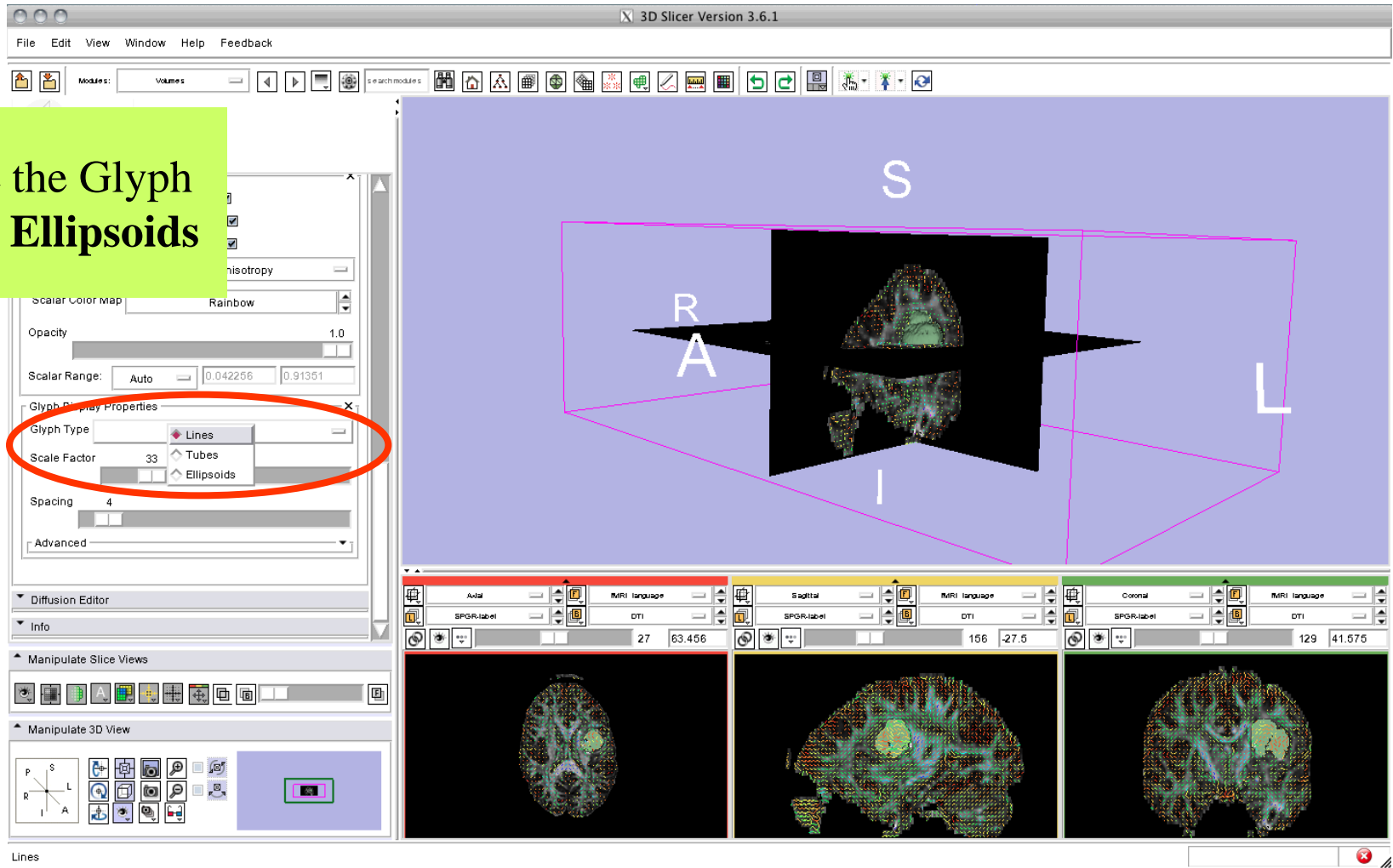
Line colour: fractional anisotropy





View the tensors

Change the Glyph
Type to **Ellipsoids**





View the tensors

Change the Glyph
Type back to
Lines

3D Slicer Version 3.6.1

File Edit View Window Help Feedback

Modules: Volumes

Scalar Color Map: Rainbow

Opacity: 1.0

Scalar Range: Auto 0.042256 0.91351

Glyph Display Properties

Glyph Type: Lines

Scale Factor: 68

Spacing: 4

Diffusion Editor

Manipulate Slice Views

Manipulate 3D View

DTI RAS: (-31.5, 169.1, 385.0), Lb: Slice not shown, Fg: Slice not shown, Bg: Slice not shown.



Placing tractography seed points

The screenshot shows the 3D Slicer Version 3.6.1 interface. The 'Fiducials' module is selected in the top toolbar. The 'Fiducial List' dropdown menu is open, showing 'FiducialList'. A green box highlights the 'Fiducials' module name in the toolbar. Another green box highlights the 'Fiducial List' dropdown menu. The main 3D view shows a brain scan with a green seed point and a purple wireframe box. The axes are labeled S (Superior), I (Inferior), R (Right), and L (Left). The bottom panel shows three slice views: Axial, Sagittal, and Coronal. The status bar at the bottom indicates DTI RAS coordinates: (-31.5, 169.1, 392.5).

Open the
Fiducials
module

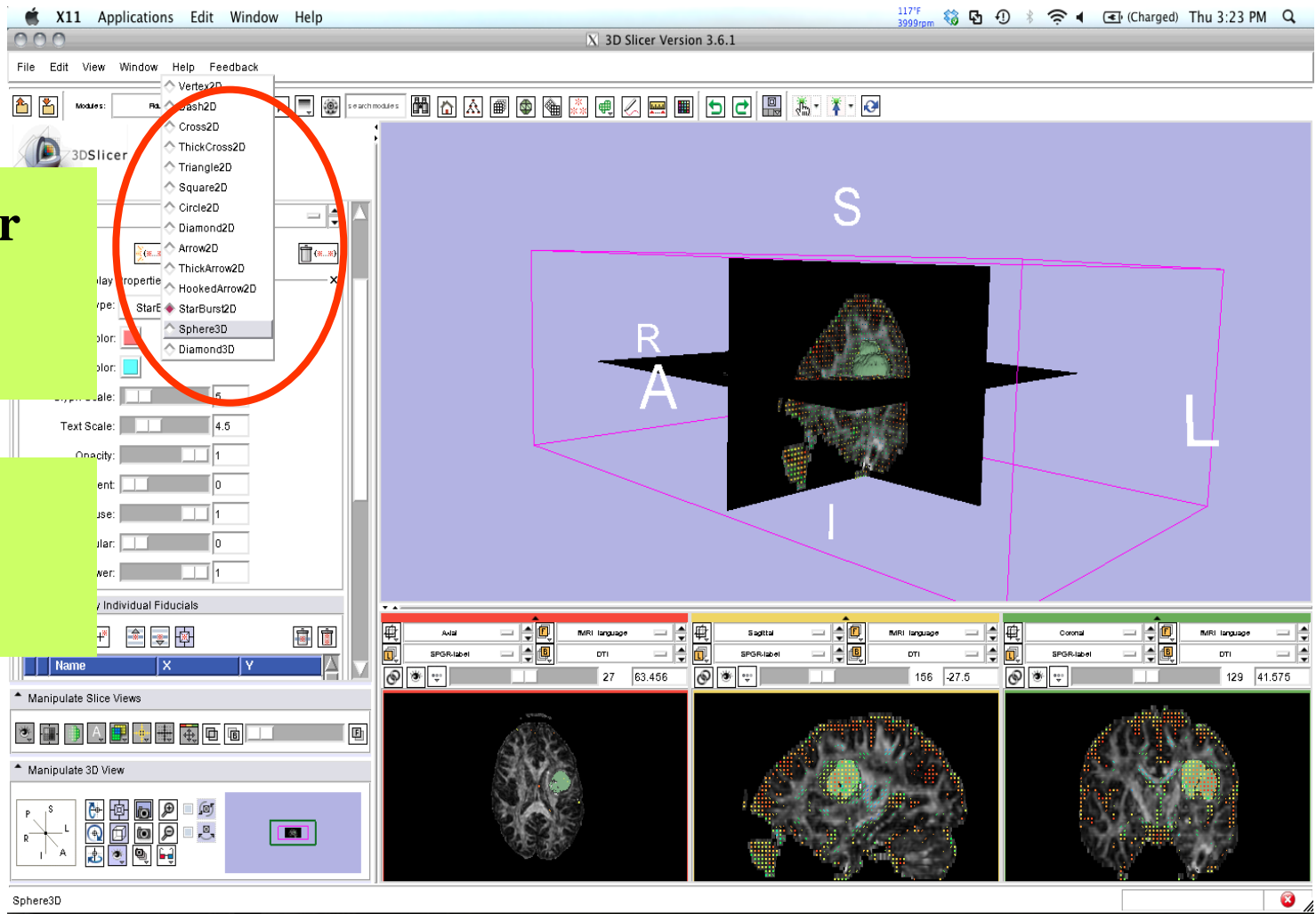
Create a new
Fiducial List



Placing tractography seed points

Expand Other Display List Properties.

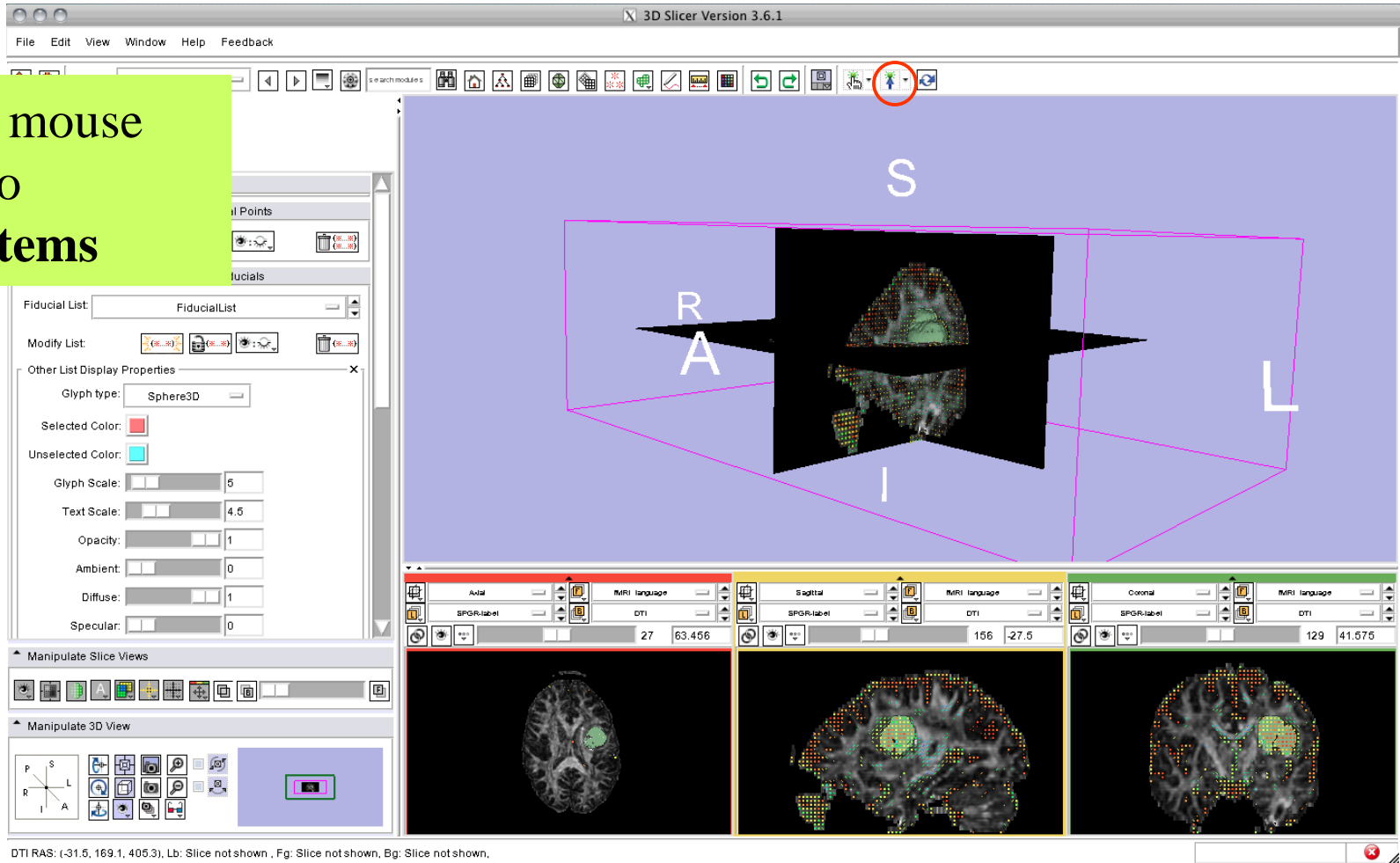
Set the glyph type to Sphere3D





Placing tractography seed points

Set the mouse mode to place items

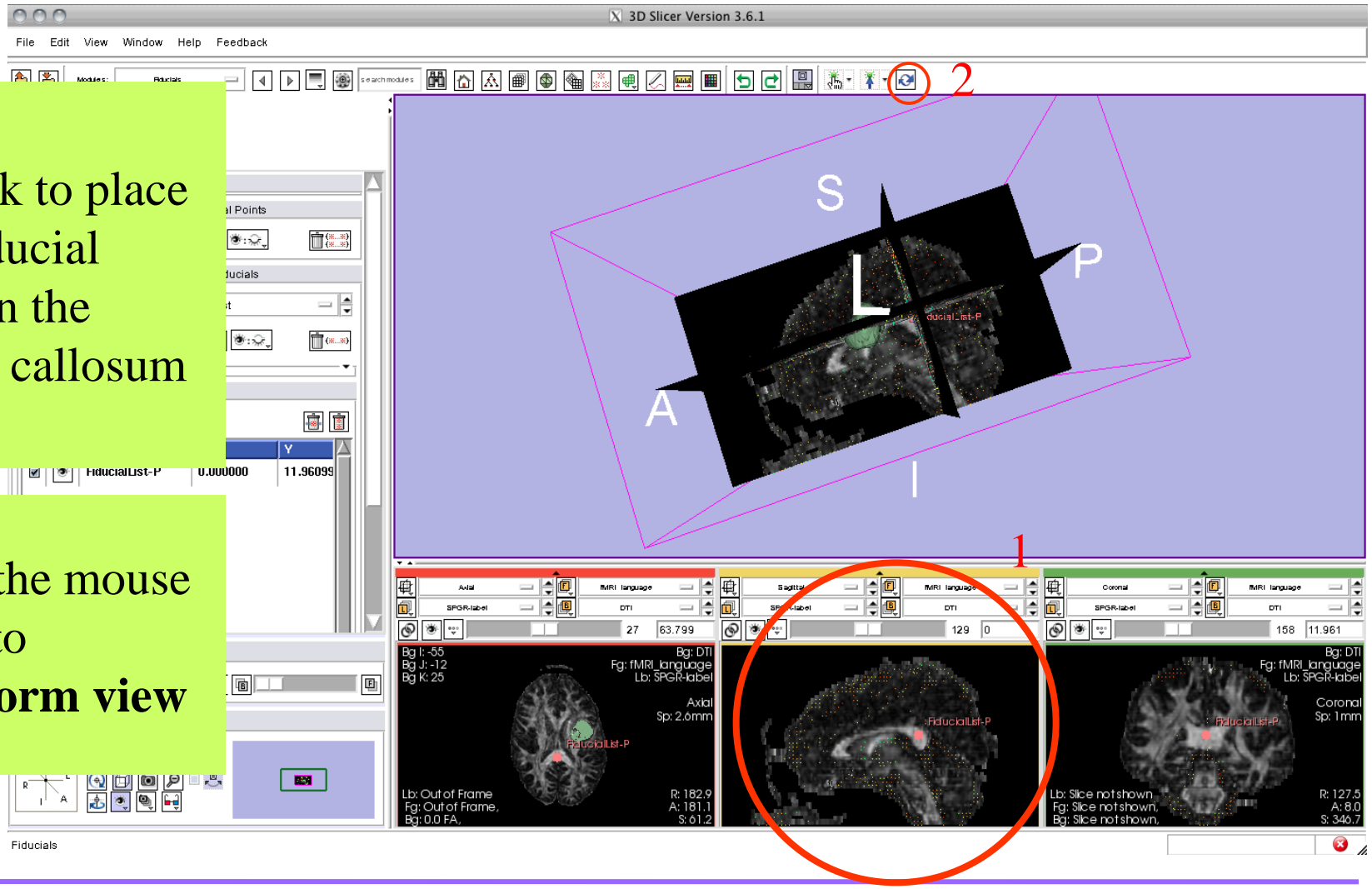




Placing tractography seed points

1. Click to place one fiducial point in the corpus callosum

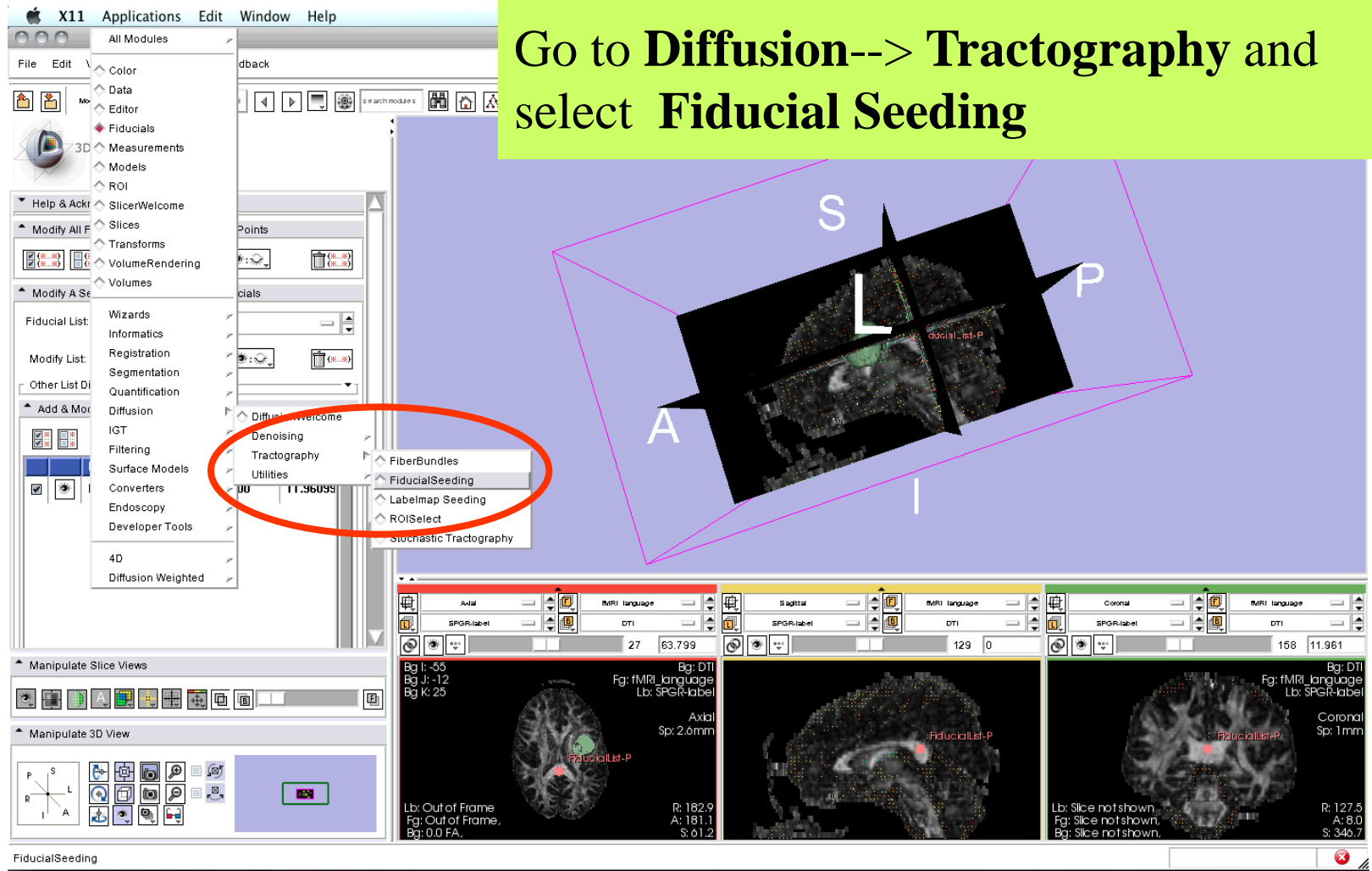
2. Set the mouse mode to transform view





Perform tractography (fiber tracking)

Go to **Diffusion--> Tractography** and select **Fiducial Seeding**





Perform tractography (fiber tracking)

3DSlicer Version 3.6.1

File Edit View Window Help Feedback

Modules: Fiducial Seeding

Help & Acknowledgement

Tractography: Seeding From Fiducial

- Parameters: Parameters
- Select DTI Volume: DTI
- Select FiducialList or Model: FiducialList
- Output FiberBundleNode: s
- Stopping Mode: Fractional Anisotropy
- Stopping Value: 0.25
- Stopping Track Curvature: 0.7
- Integration Step Length (mm): 0.5
- Minimum Path Length (mm): 20
- Fiducial Seeding Region Size (mm): 5.0
- Fiducial Seeding Step Size (mm): 1.5

Manipulate Slice Views

Manipulate 3D View

File

- **DTI volume**= DTI
- **Fiducial list** = FiducialList
- **Output FiberBundle Node** = Create New Fiber Bundle
- **Stopping Mode** = Fractional Anisotropy

158 11.961

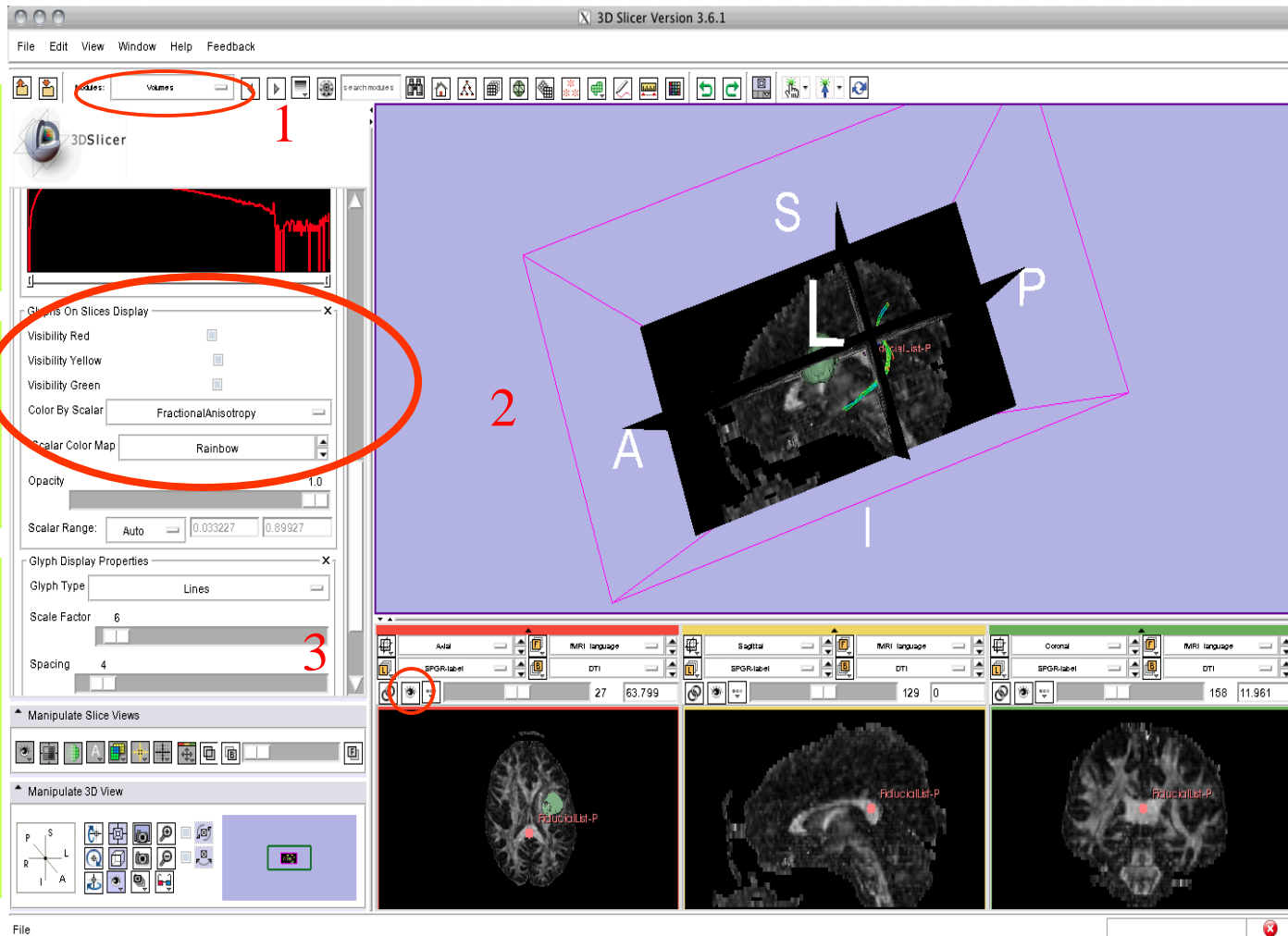


Perform tractography (fiber tracking)

1. Open the Volumes module

Turn the glyphs off for all three views

3. Click on the visibility button to turn off the slice visibility



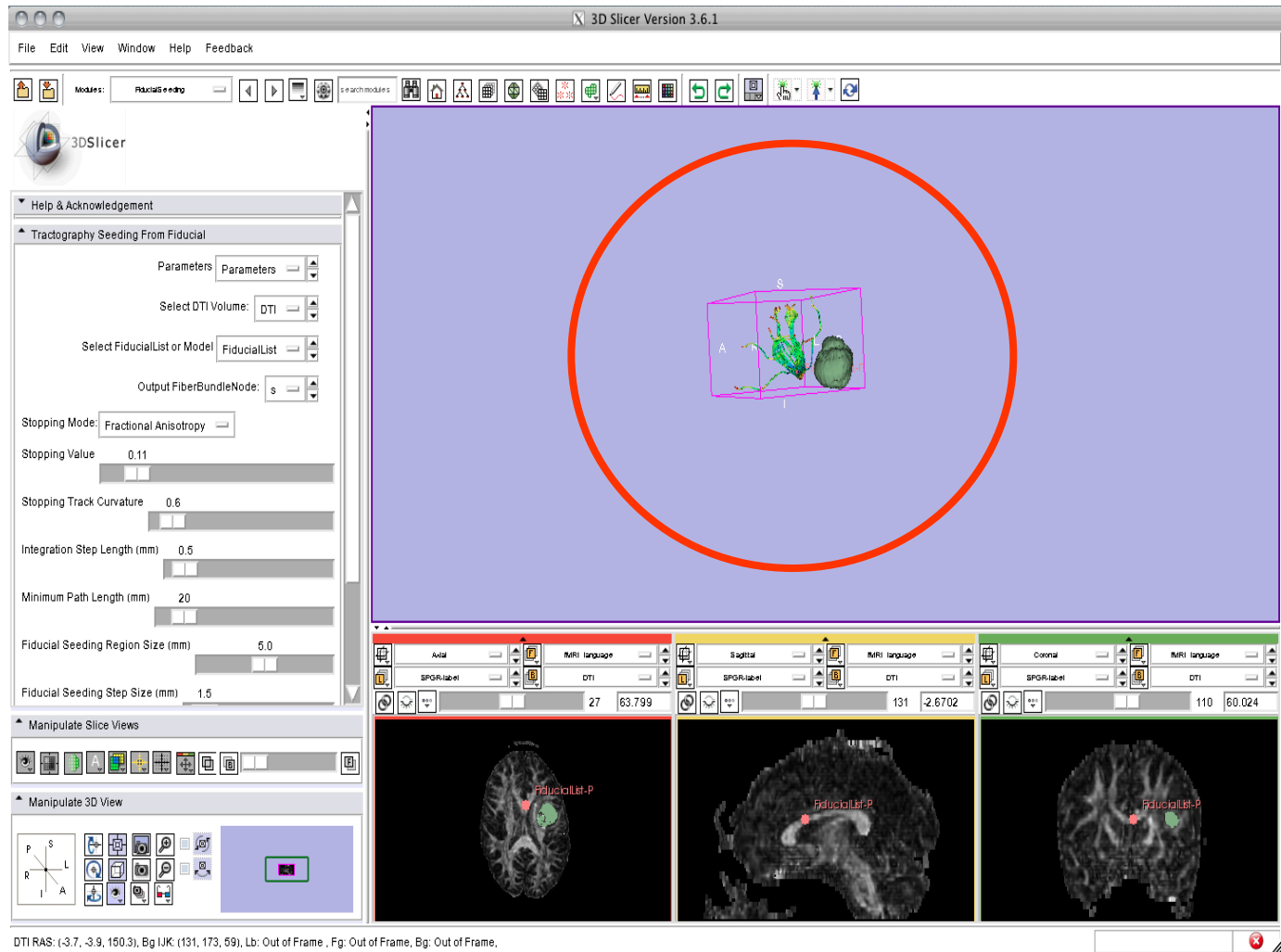


Perform tractography (fiber tracking)

One tract is generated for each fiducial

The tract colour is the fractional anisotropy by default.

Click and drag the pin sphere in 3D view to interactively select tracts.





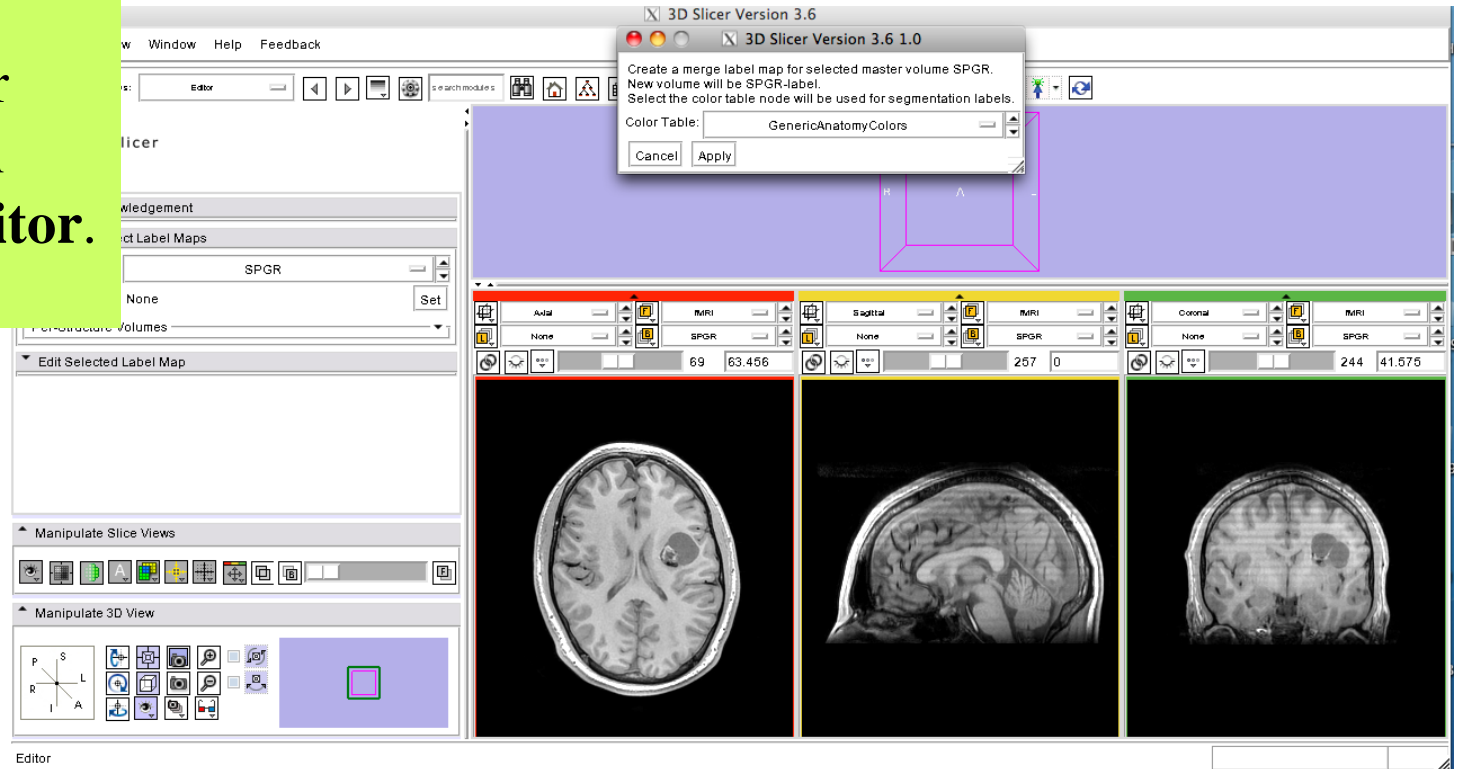
Tasks

- Examine how neural fibers are running in or around the tumor.
- Examine if the fiber infiltrate into the tumor.



Segment the tumor volume

Repeat tumor segmentation using the **Editor**.





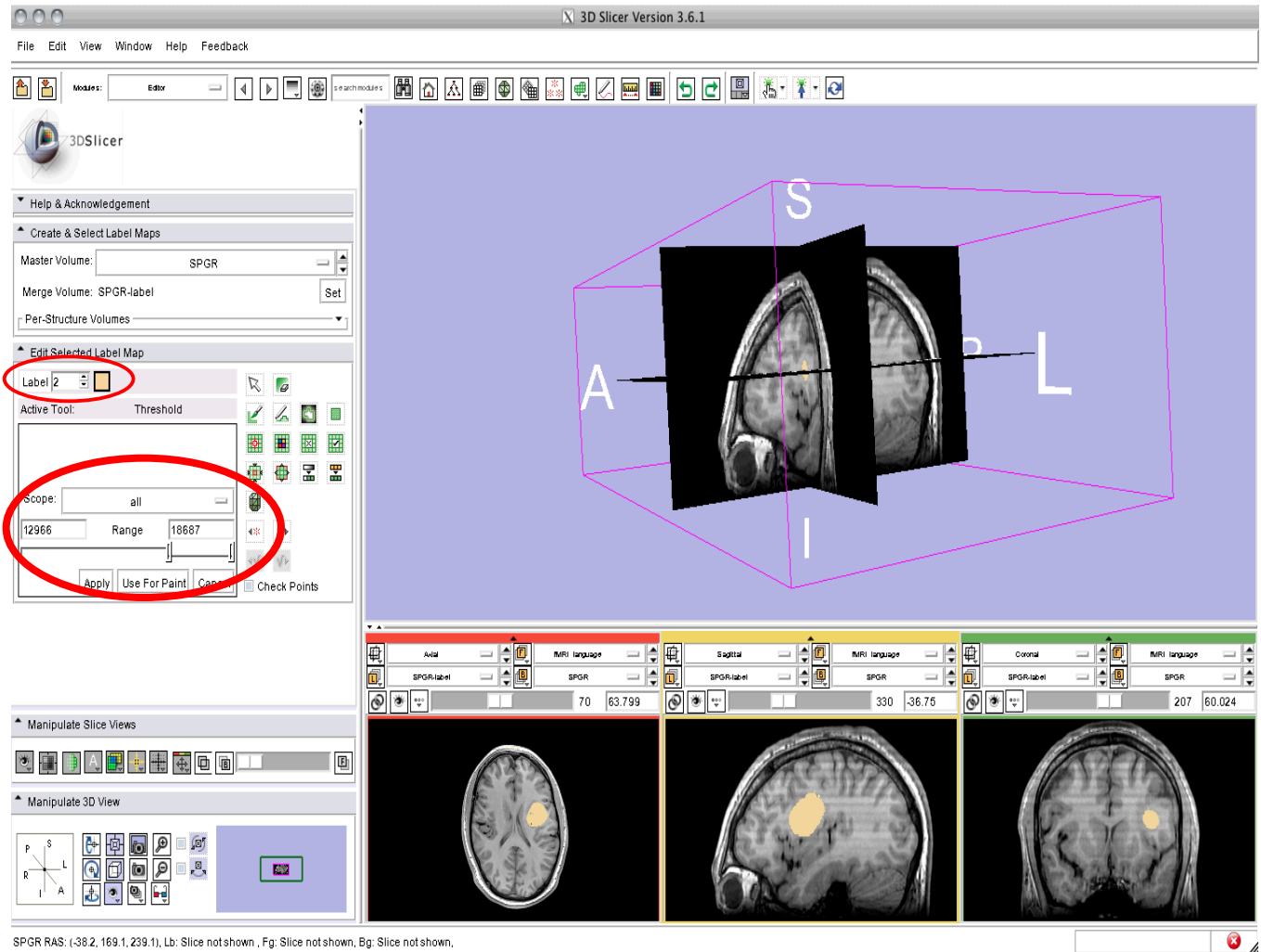
Segment the tumour volume

Choose label value
“2”

Choose Threshold
editor.

Put 1894 and 3977
in the entry box, or
move the slider till
you can see isolated
tumor lesion.

Hit **Apply**



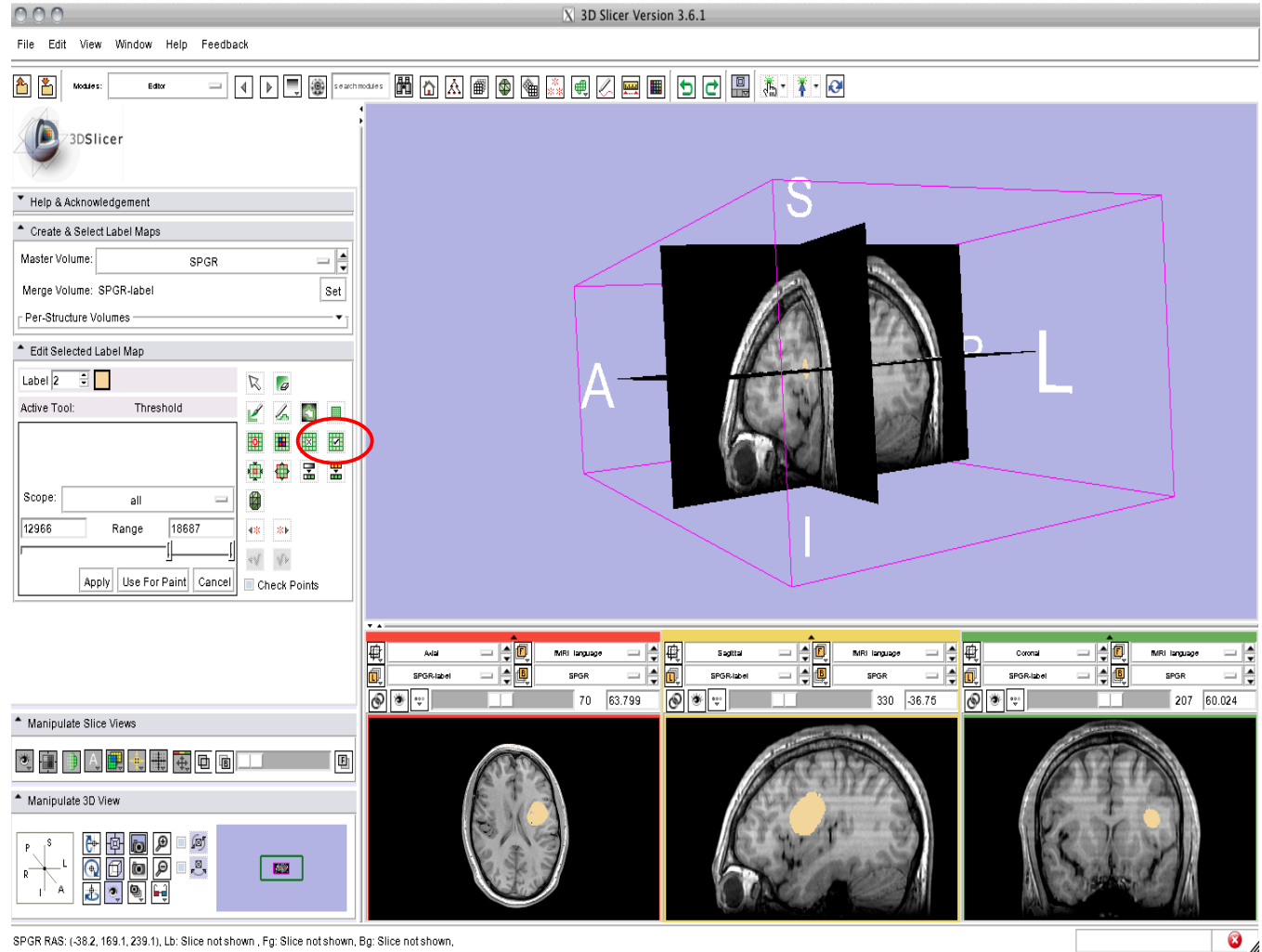


Save Island

Choose **Save Island** option

Click on the tumor lesion

Confirm that only tumor lesion remains painted



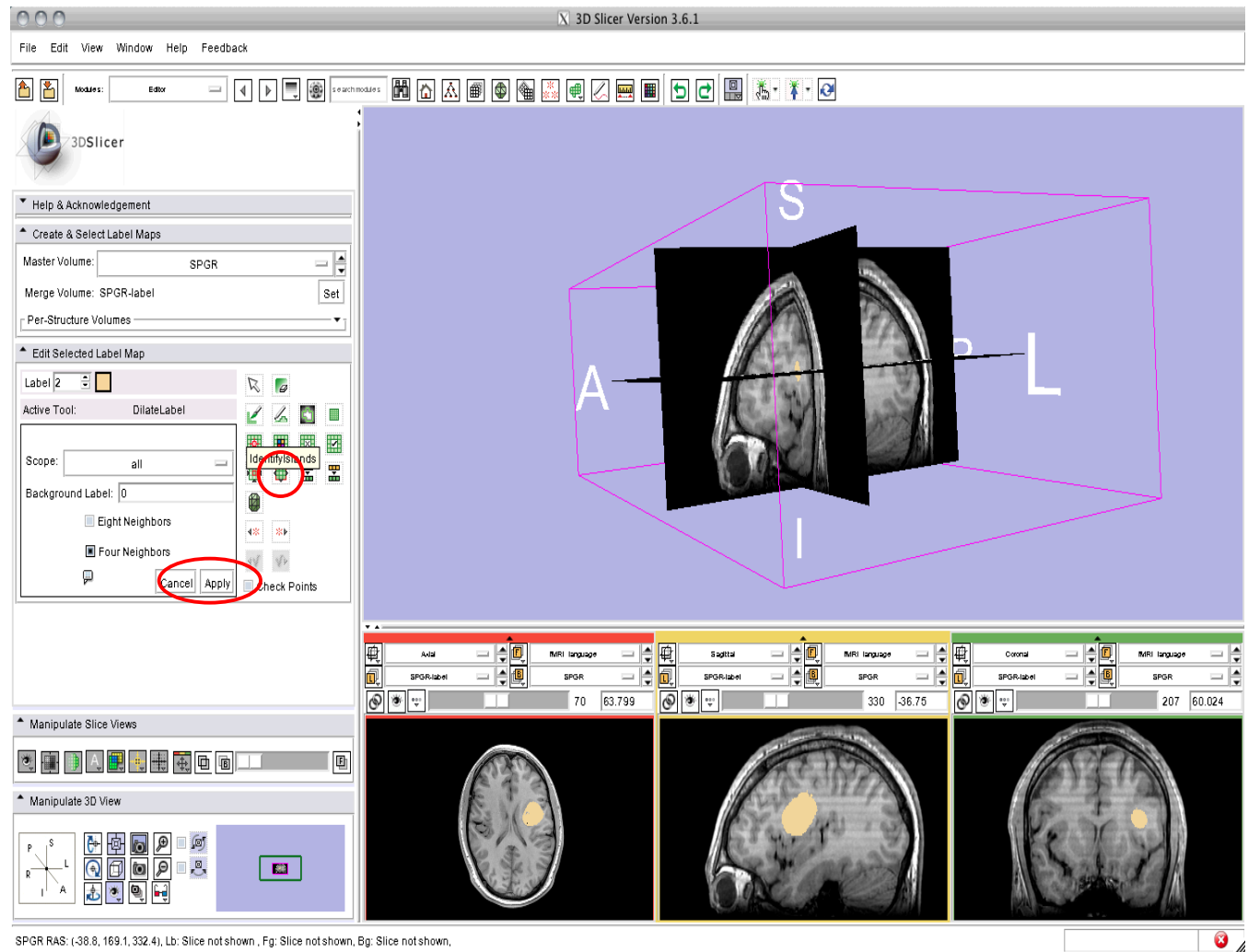


Dilate the label map to include neighboring pixels

Choose **Dilate** Label option

Click **Apply** multiple times (5-8 times)

Observe the segmented lesion dilates.





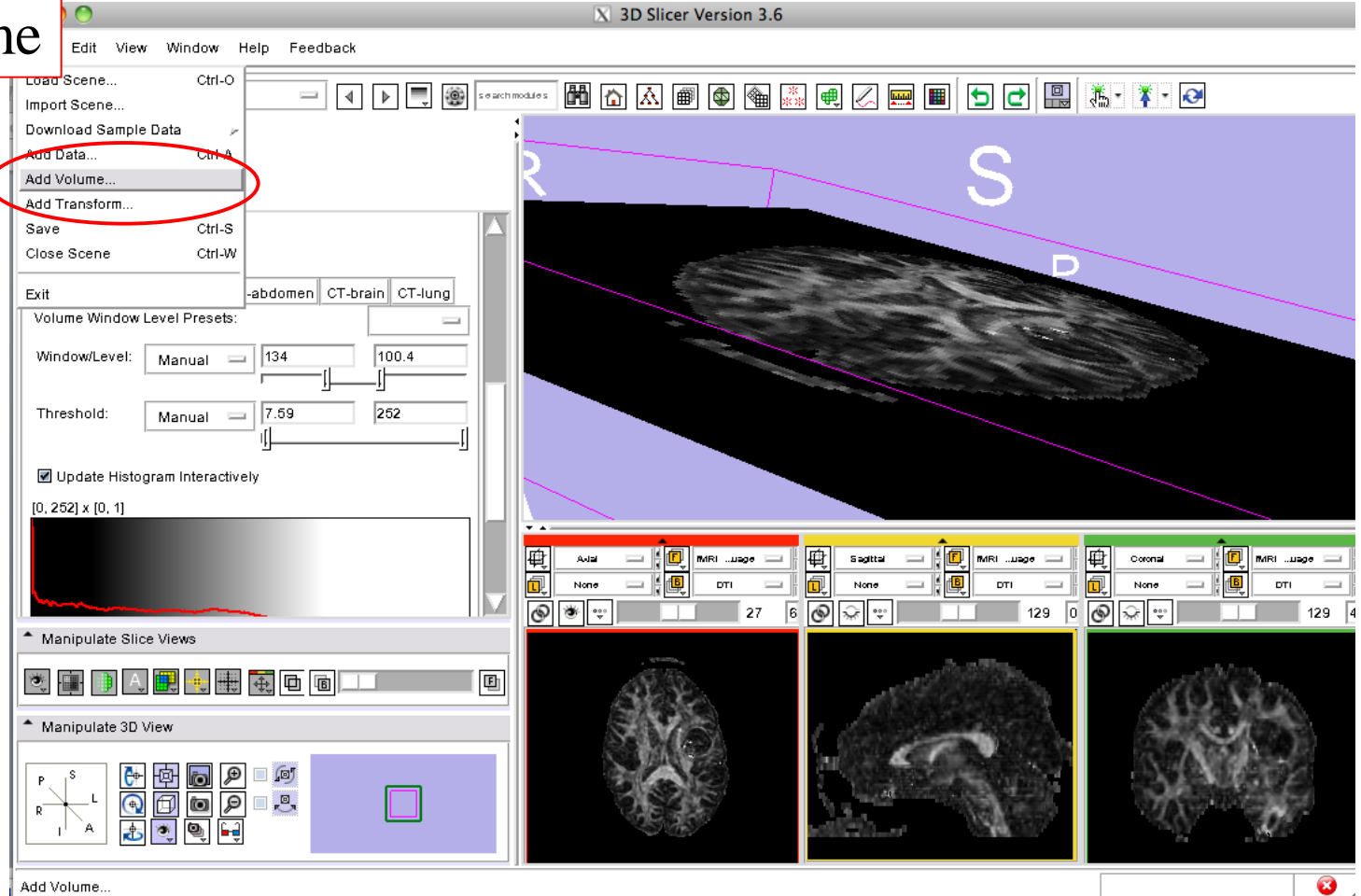
Task

Use label map seeding effectively to visualize the fiber in the proximity of the tumor.



Load label map

Add Volume





Load label map

Select “ConsolidatedLabelmap4Seeding.nrrd”

The screenshot shows the 3DSlicer interface with the following components:

- File Browser:** A tree view on the left showing the file system structure. The file `ConsolidatedLabelMap4Seeding.nrrd` is selected in the right pane.
- Table:** A table listing files and their sizes. The selected file is highlighted in blue.
- DICOM Information:** A panel on the right showing options like `Parse Directory` and `Divide Subseries`.
- Volume Options:** A panel at the bottom with the `Label Map` checkbox checked and circled in red.
- 3D Viewport:** A 3D view of a brain slice with a purple and pink overlay.
- 2D Viewport:** A 2D view of a brain slice at the bottom right.

Name	Size
.DS_Store	7
Baseline.mrml	72
ConsolidatedLabelMap4Seeding.nrrd	101
csc-label.nrrd	73
DTI.nhdr	1
DTI.raw.gz	15,672
DWI-baseline.nrrd	3,428
fMRI.nrrd	28,582
fMRI_language.nrrd	238
fMRI_language_label.nrrd	93
SPGR.nrrd	32,464

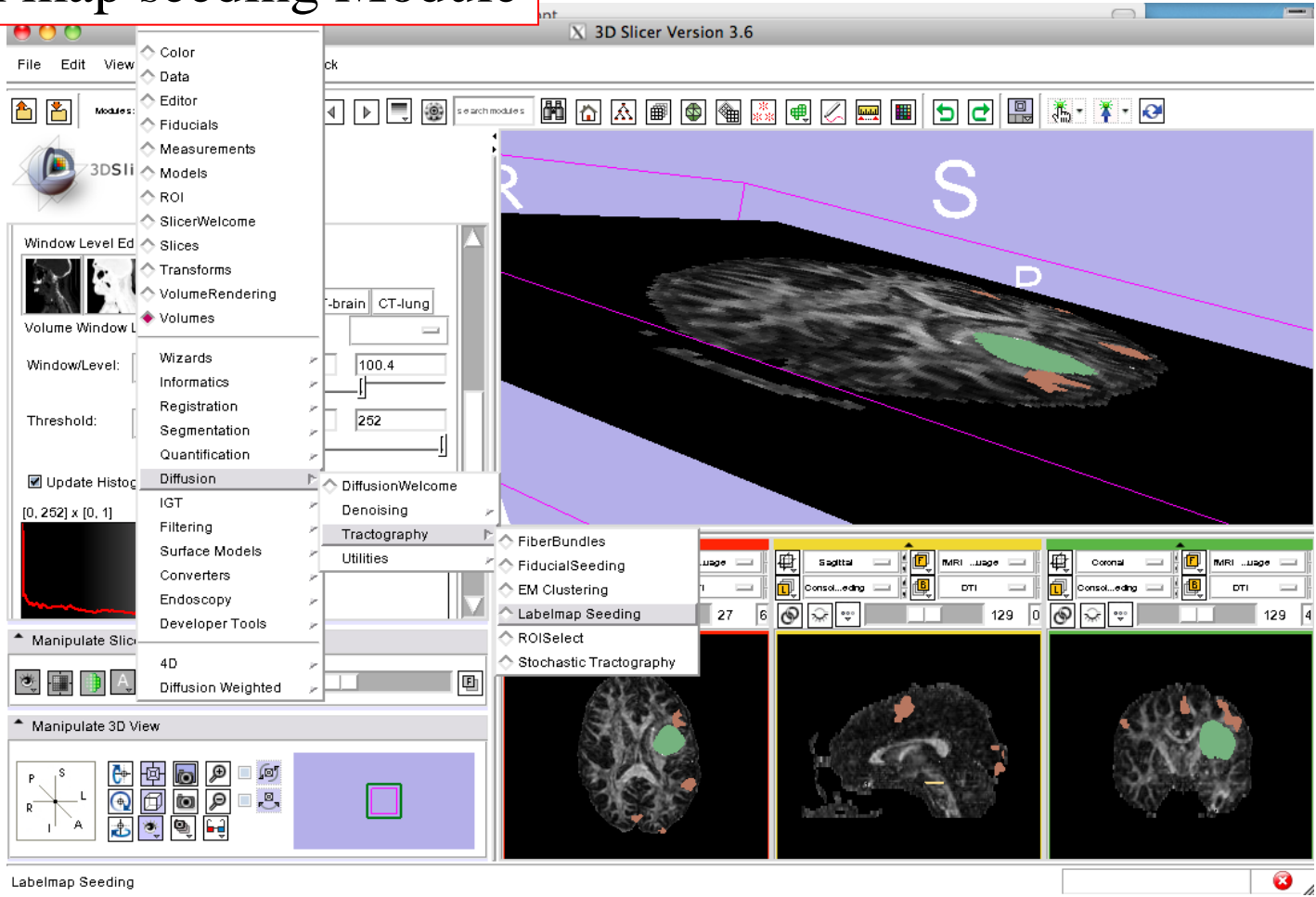
Volume Options: Centered Ignore File Orientation Label Map Single File Name: ConsolidatedLabelMap4S

Turn on “Label Map” option



Label map seeding

Open Label map seeding Module





Apply the following values:

I/O Tab:

Input DTI Volume: **DTI**

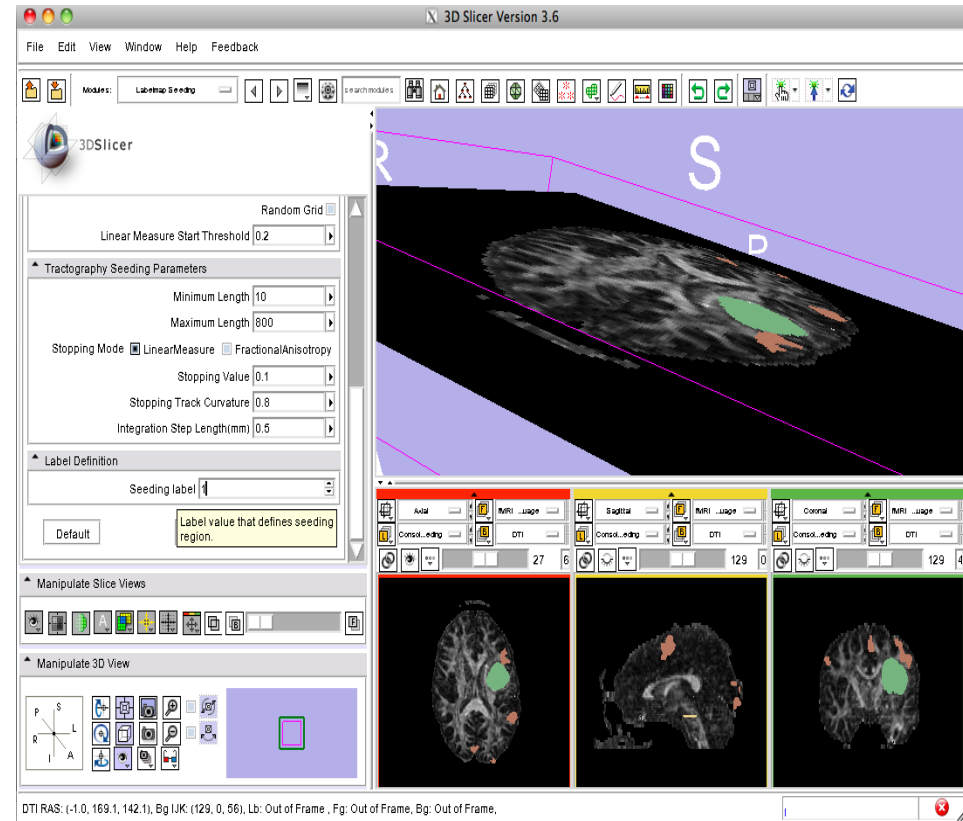
Input Label Map:

ConsolidatedLabelMap4Seeding

Output Fiber bundle: **Create New
FiberBundle**

Tractography Seeding Parameters Tab:

Stopping Mode: **FractionalAnisotropy**

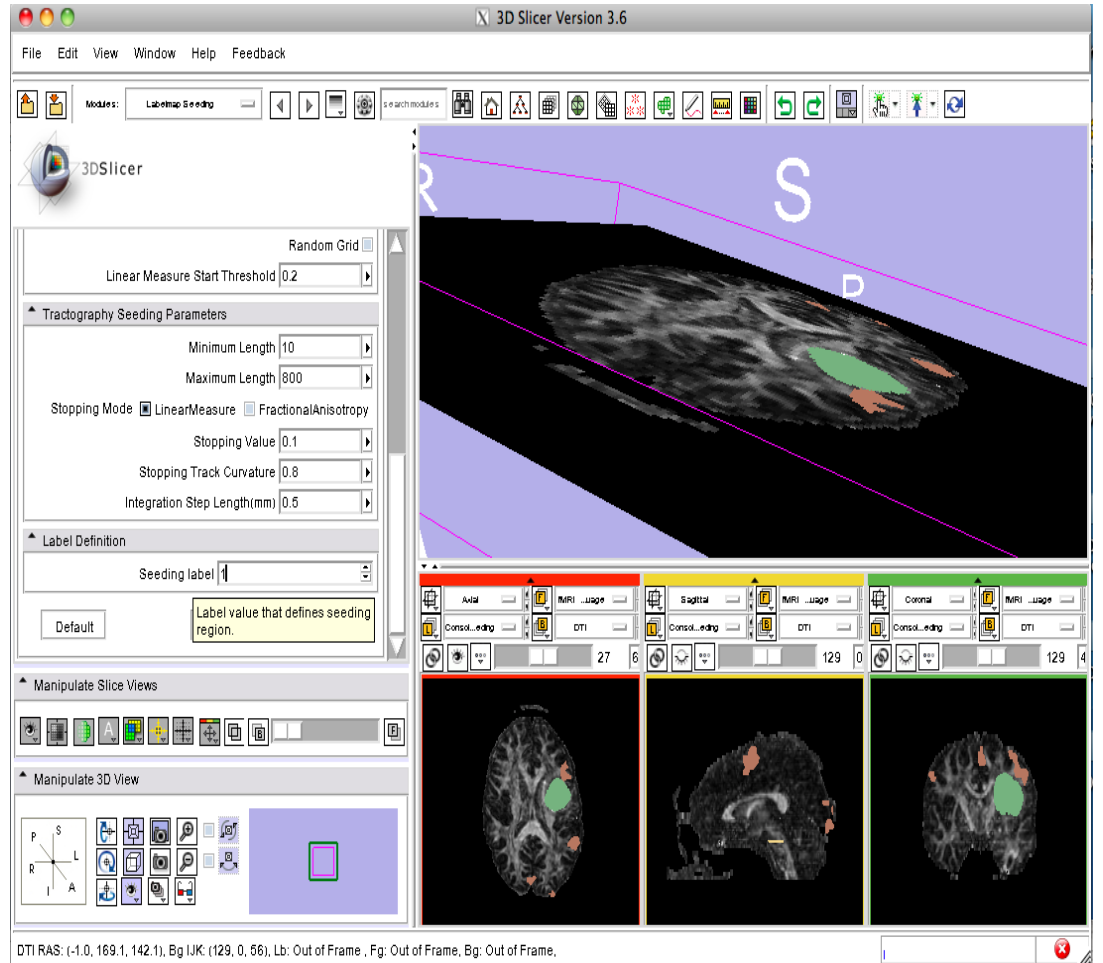




Perform labelmap seeding by using the Label value for:

- Tumor : 1
- Cortical Spinal Cord : 2
- Language fMRI : 3

Control density of fibers by changing seed spacing.





Tasks

- Examine the relationship between the tumor and the fibers.
- Assess if the fiber infiltrates in to the tumor.
- Assess which part of the tumor has to handled carefully during the surgery due to its proximity to the critical fiber running nearby.



Overview

- **In this tutorial, you learned how to**
 - Register image volumes together
 - Segment and build models of structures of interest
 - Load diffusion weighted images, calculate tensors and perform fiber tractography
- in order to build a preoperative neurosurgical plan incorporating**
- anatomical MRI
 - functional MRI
 - a model of the tumour
 - brain structure models from a registered atlas
 - fiber tractography
 - annotated fiducial points
-



Conclusions

- Slicer3 has extensive support for Image Guided Therapy
- Slicer3 is free open-source software that allows IGT researchers to share algorithms and work within a common framework