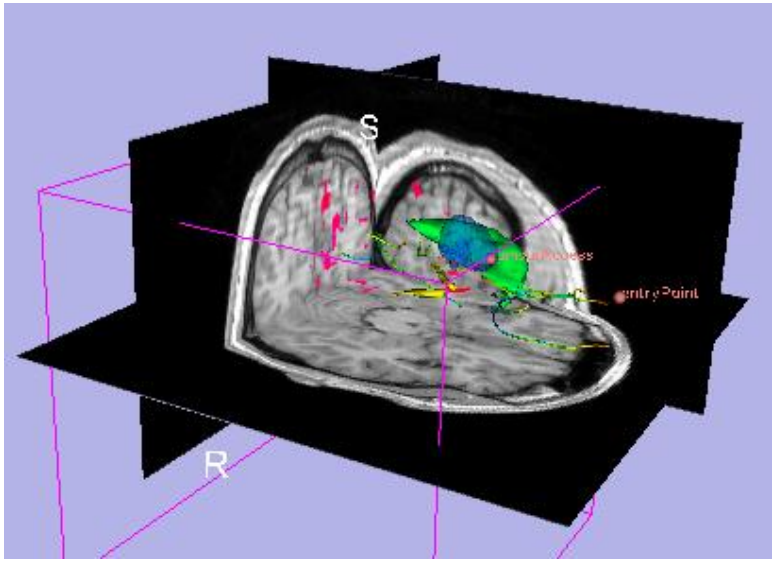
Image Guided Therapy in Slicer3

Planning for Image Guided Neurosurgery

Nobuhiko Hata, Ph.D.



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Nobuhiko Hata, Steve Pieper, Ron Kikinis, Haiying Liu, Sonia Pujol, Randy Gollub, Rodrigo de Luis Garcia, Carl-Fredrik Westin

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- 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.

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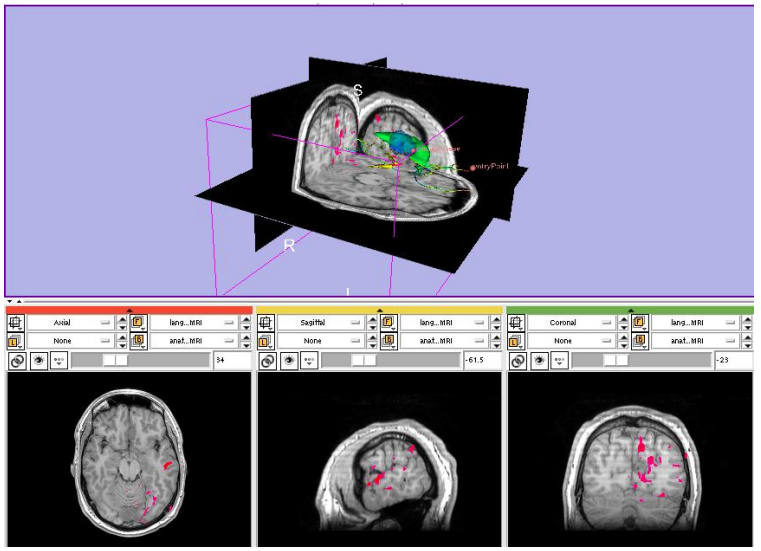
Learning objectives

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



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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.

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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

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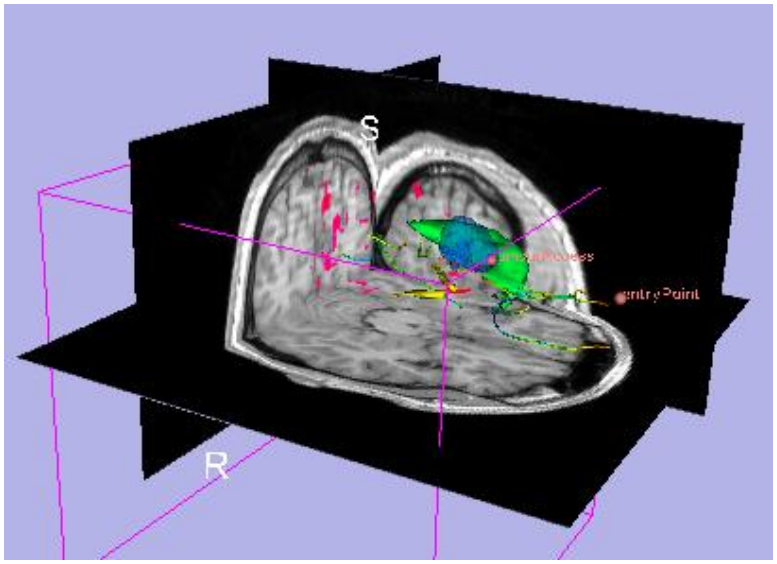
The goal of neurosurgical planning



- 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

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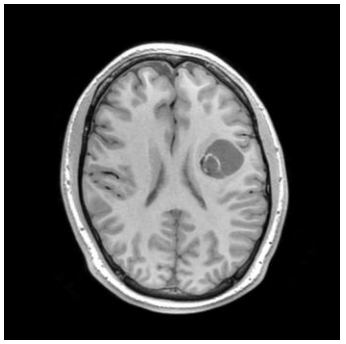
Clinical Case - brain tumour resection

- 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

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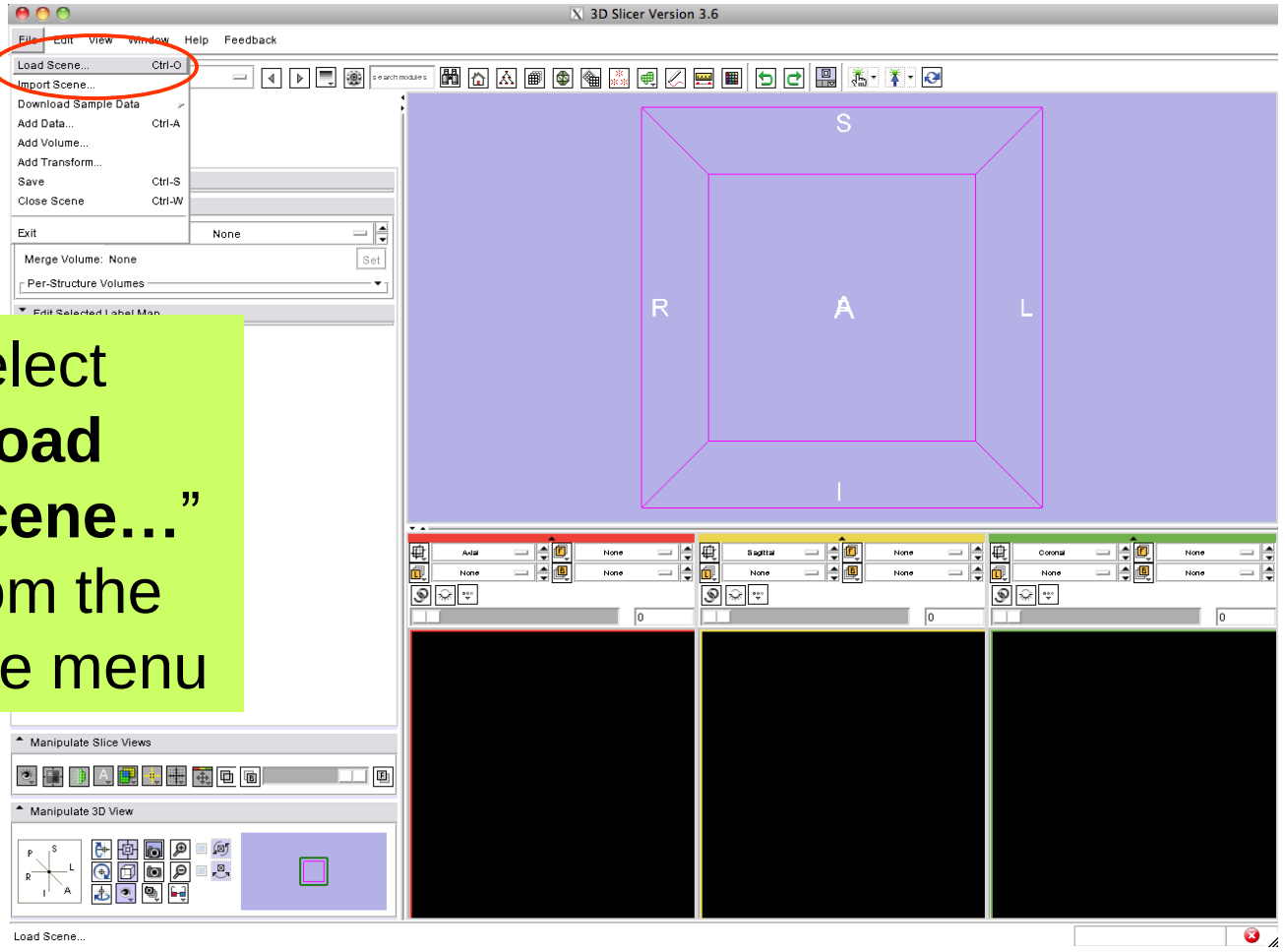
Load the Scene file



Select "**Load Scene…**" from the File menu

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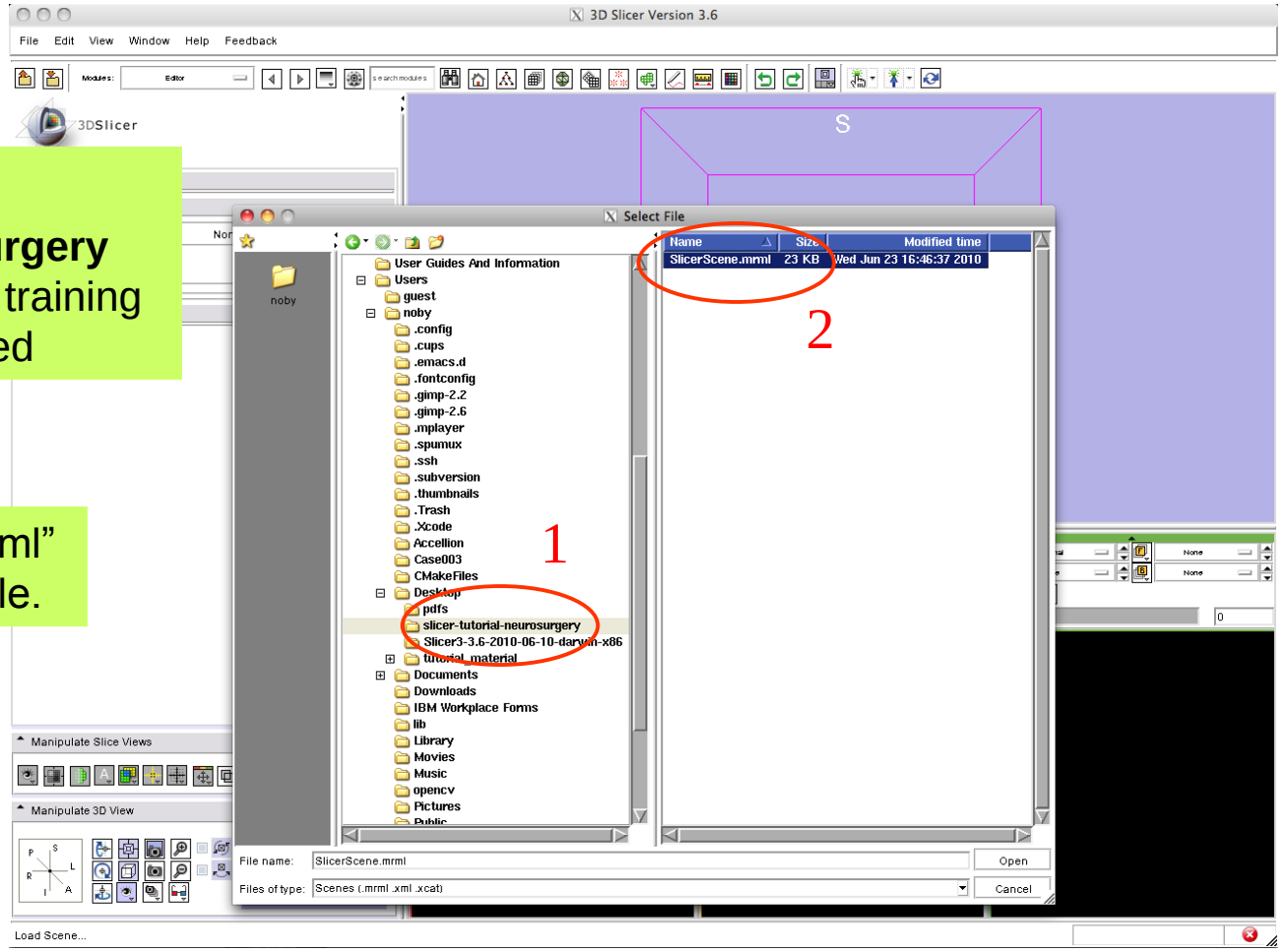
Load the anatomical MRI data

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

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



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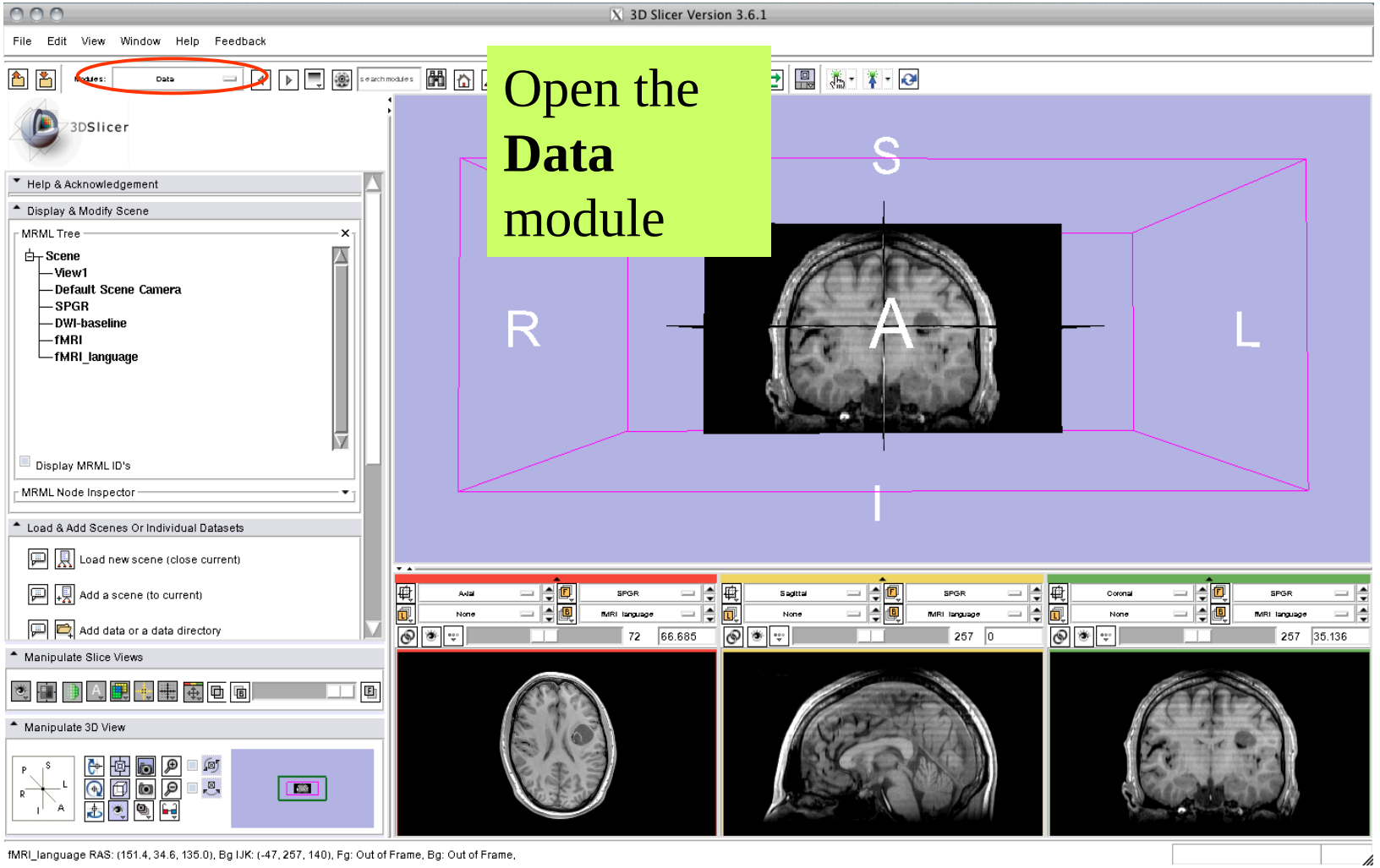
Load the anatomical MRI data



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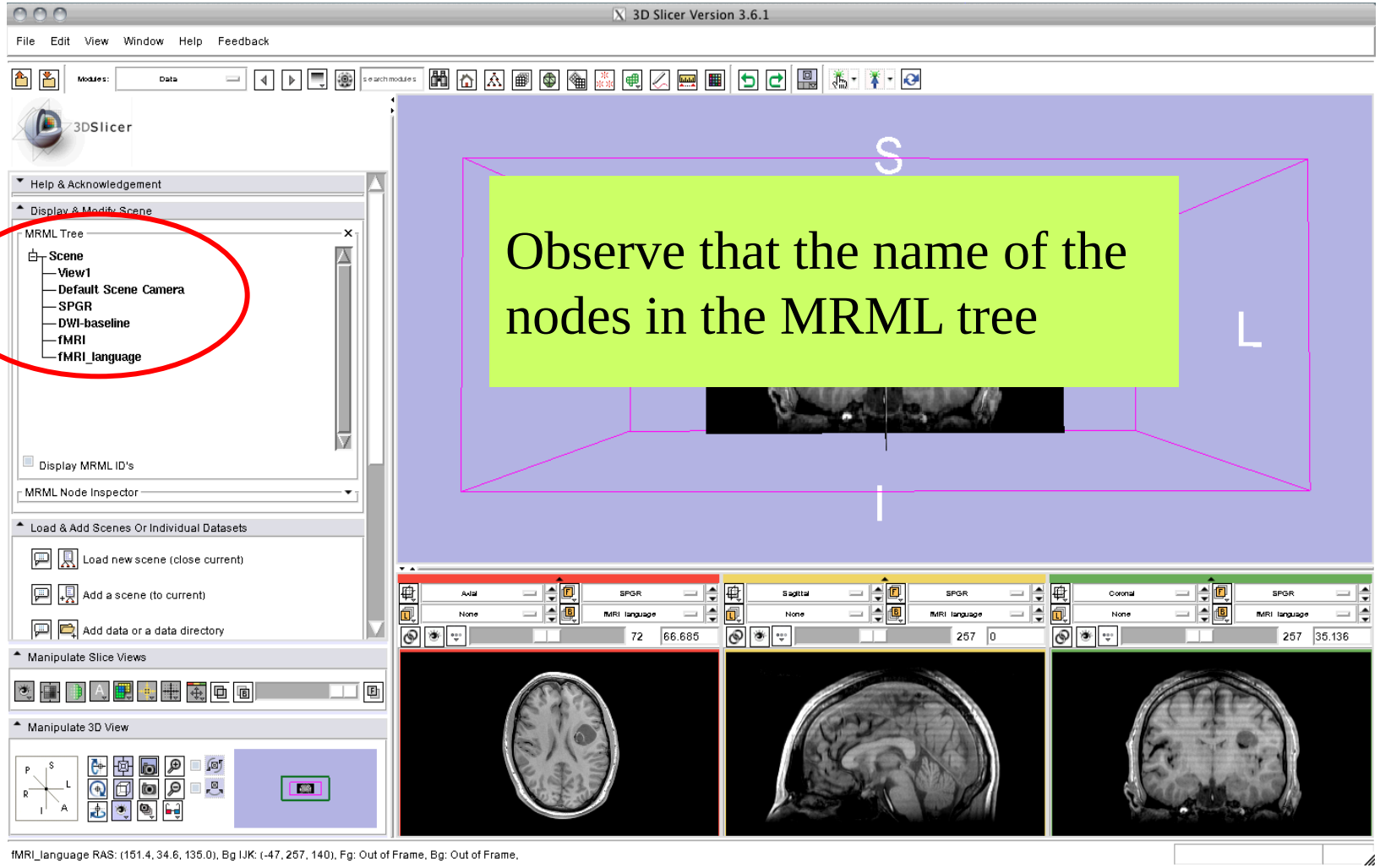
Load the anatomical MRI data



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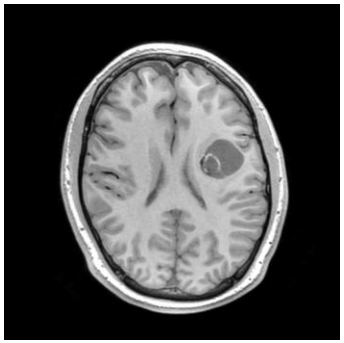
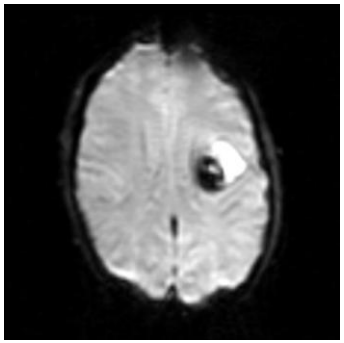
Images in the scene

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

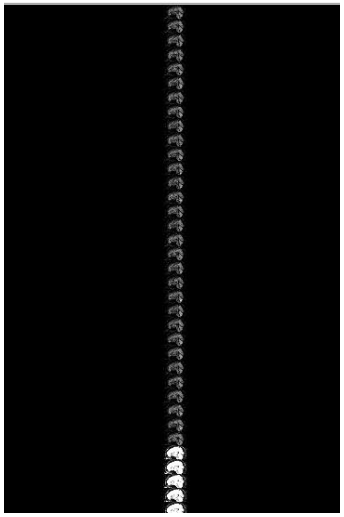


SPGR MRI (*SPGR*)



Language fMRI

(*fMRI, and fMRI_language*)



Diffusion Weighted Images (*DWI, baseline only*)

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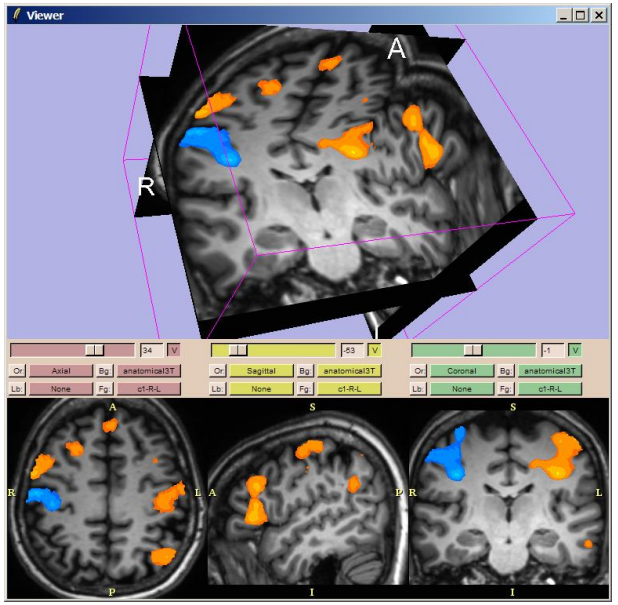
Functional MRI (fMRI)

- **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

(http://www.fil.ion.ucl.ac.uk/spm/)



SPM

Courtesy S. Pujol, W. Plesniak and R. Gollub

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)

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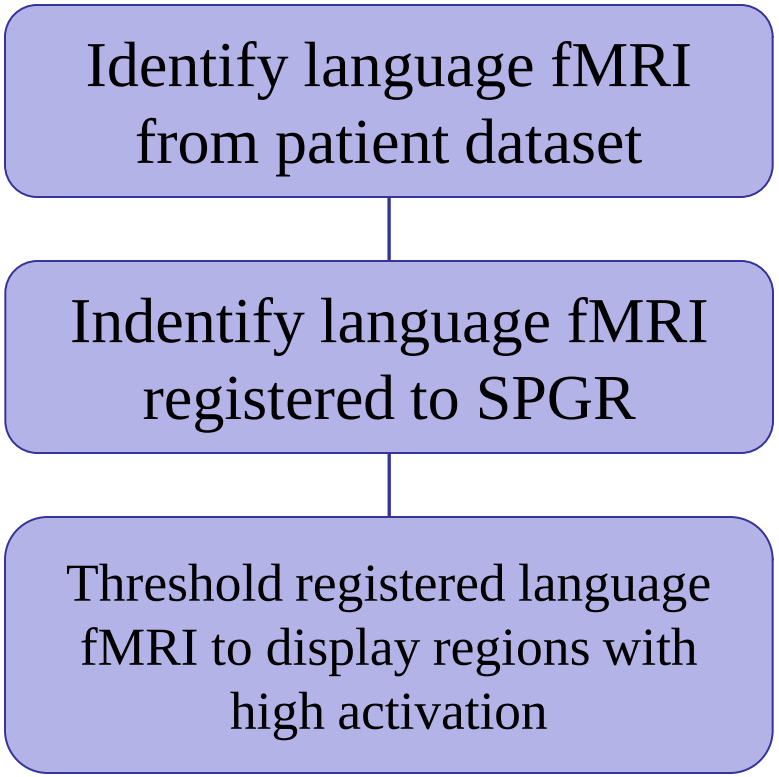
Functional MRI (fMRI)

- **Steps involved in this section:**



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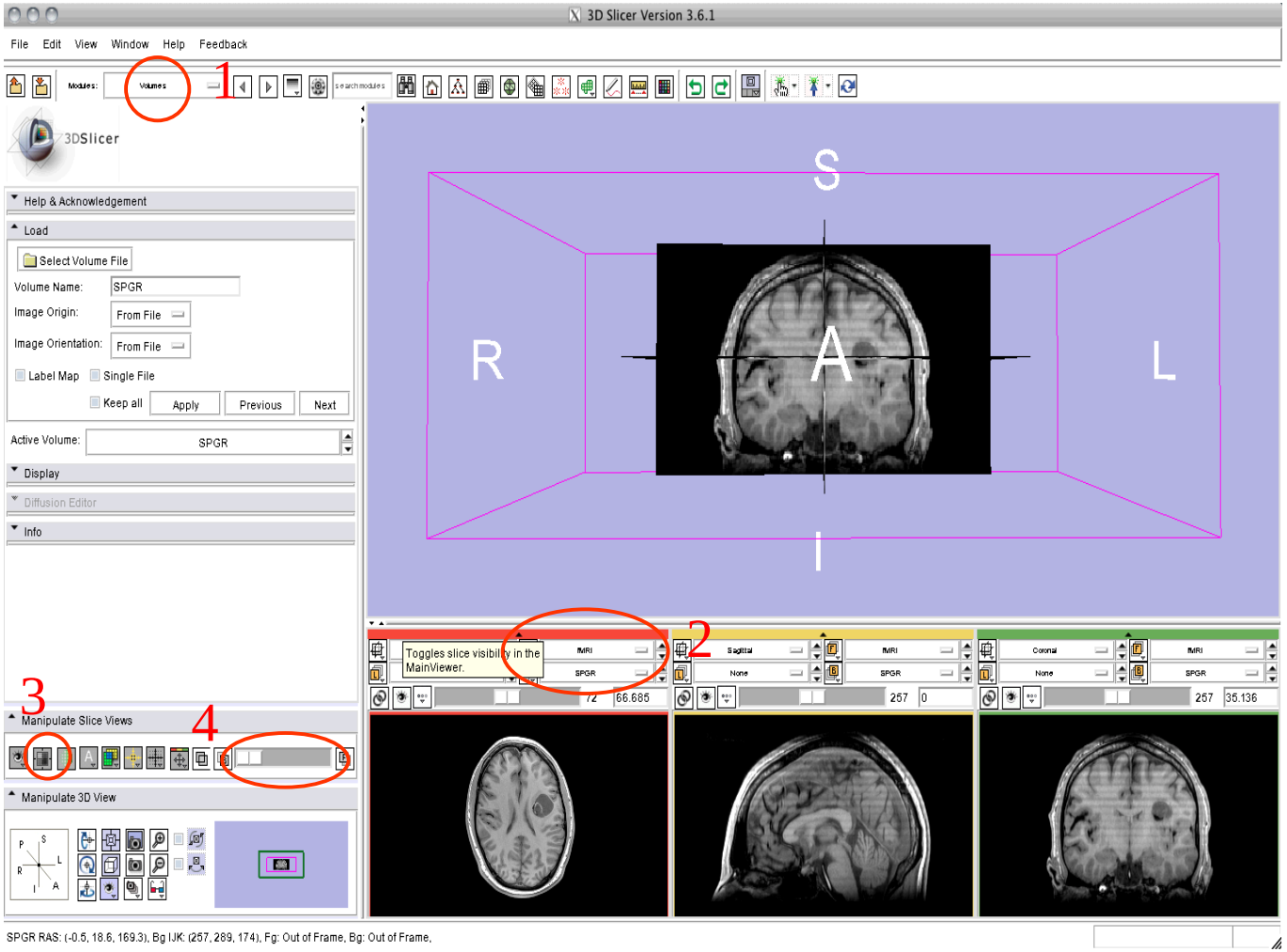
fMRI registration to SPGR

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



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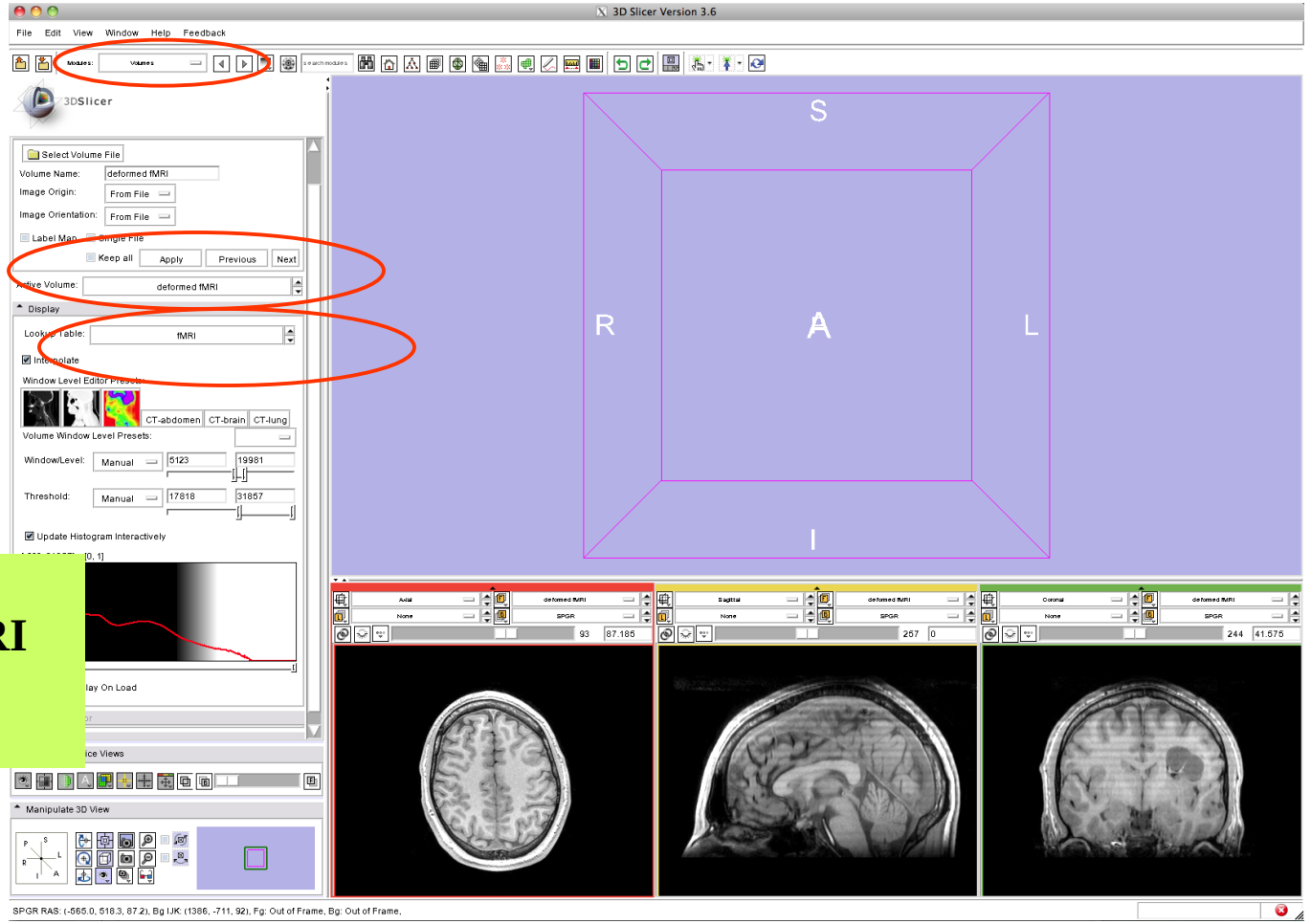
Threshold image intensity

Move to **Volume** window

Choose "**fMRI_language**" as the active volume

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



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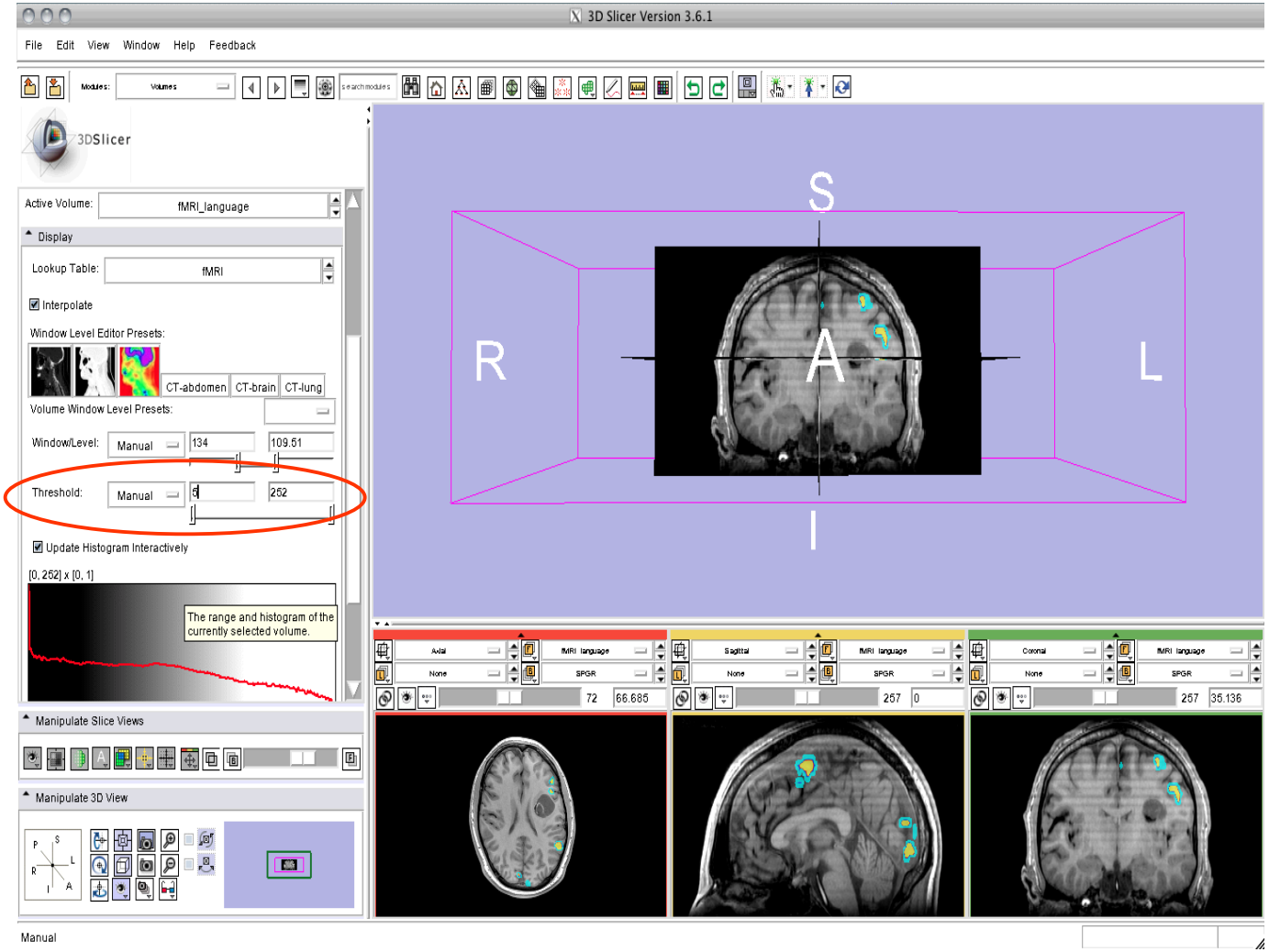
Threshold image intensity

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

Note that there are speech activation regions close to the tumour



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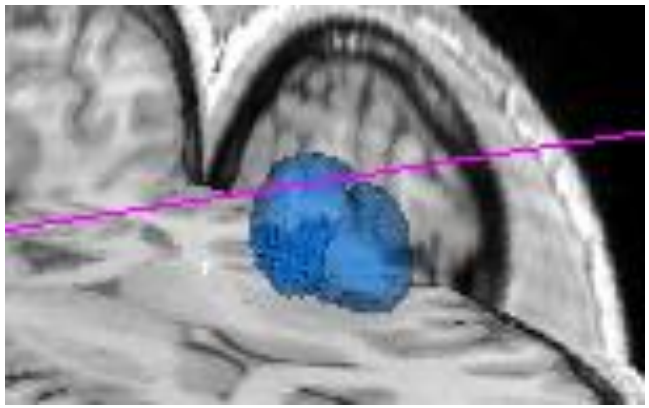
Model Making in Slicer3

- **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



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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

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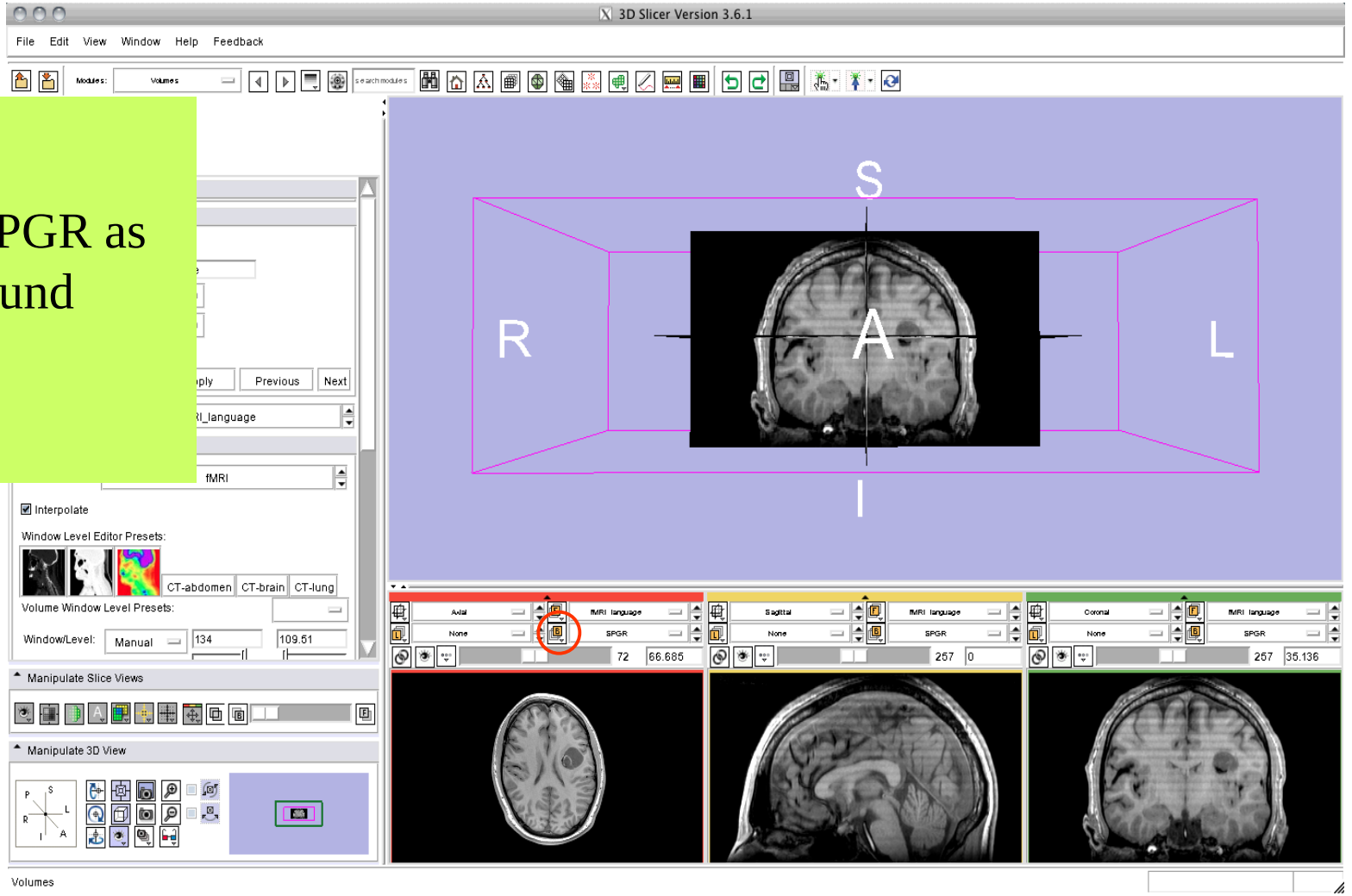
Display SPGR images

Chose SPGR as Background image



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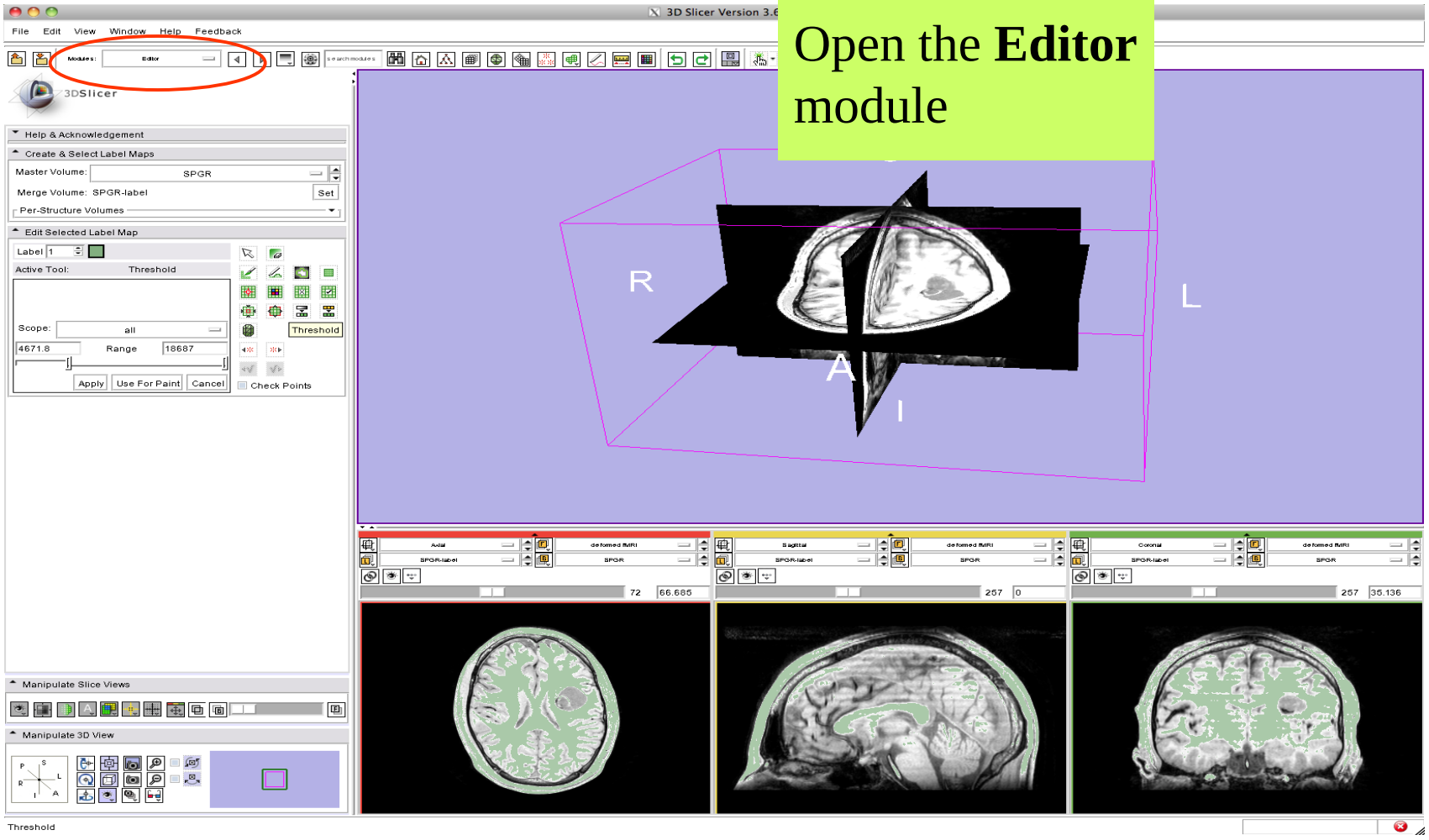
Segment the tumour volume



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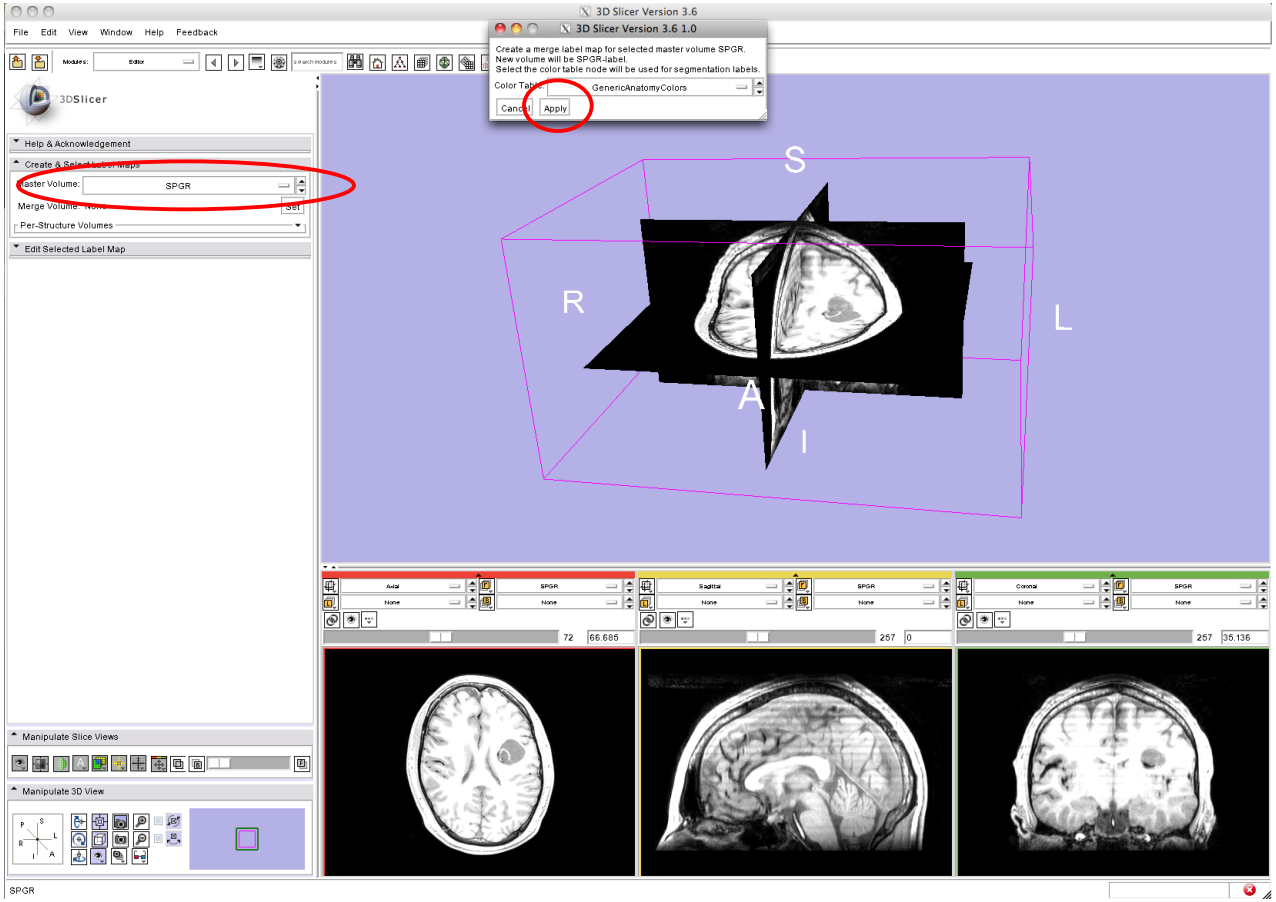
Segment the tumour volume

Set the Master Volume to **SPGR**

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



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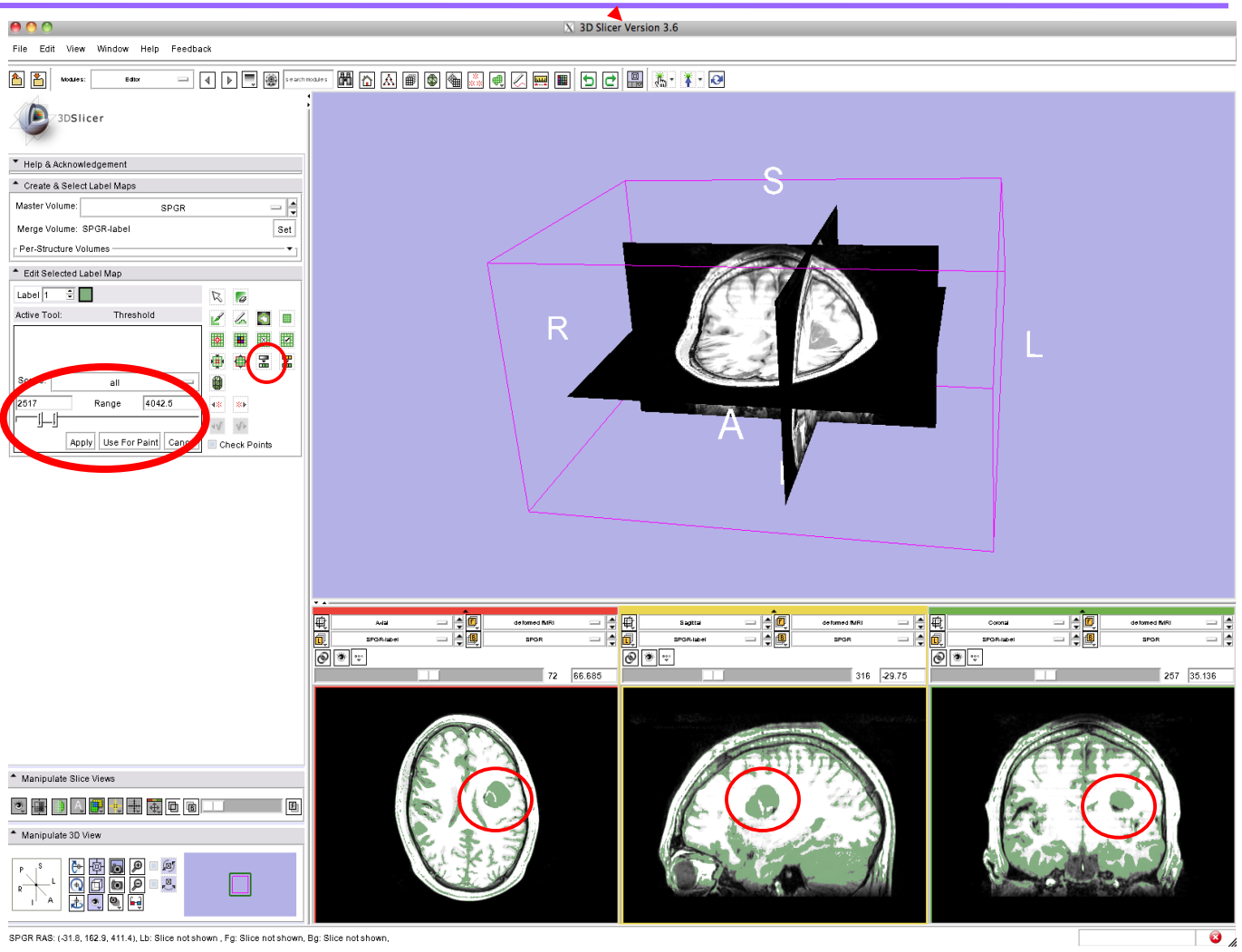
Segment the tumour volume

Choose **Threshold** editor.

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

Hit **Apply** button



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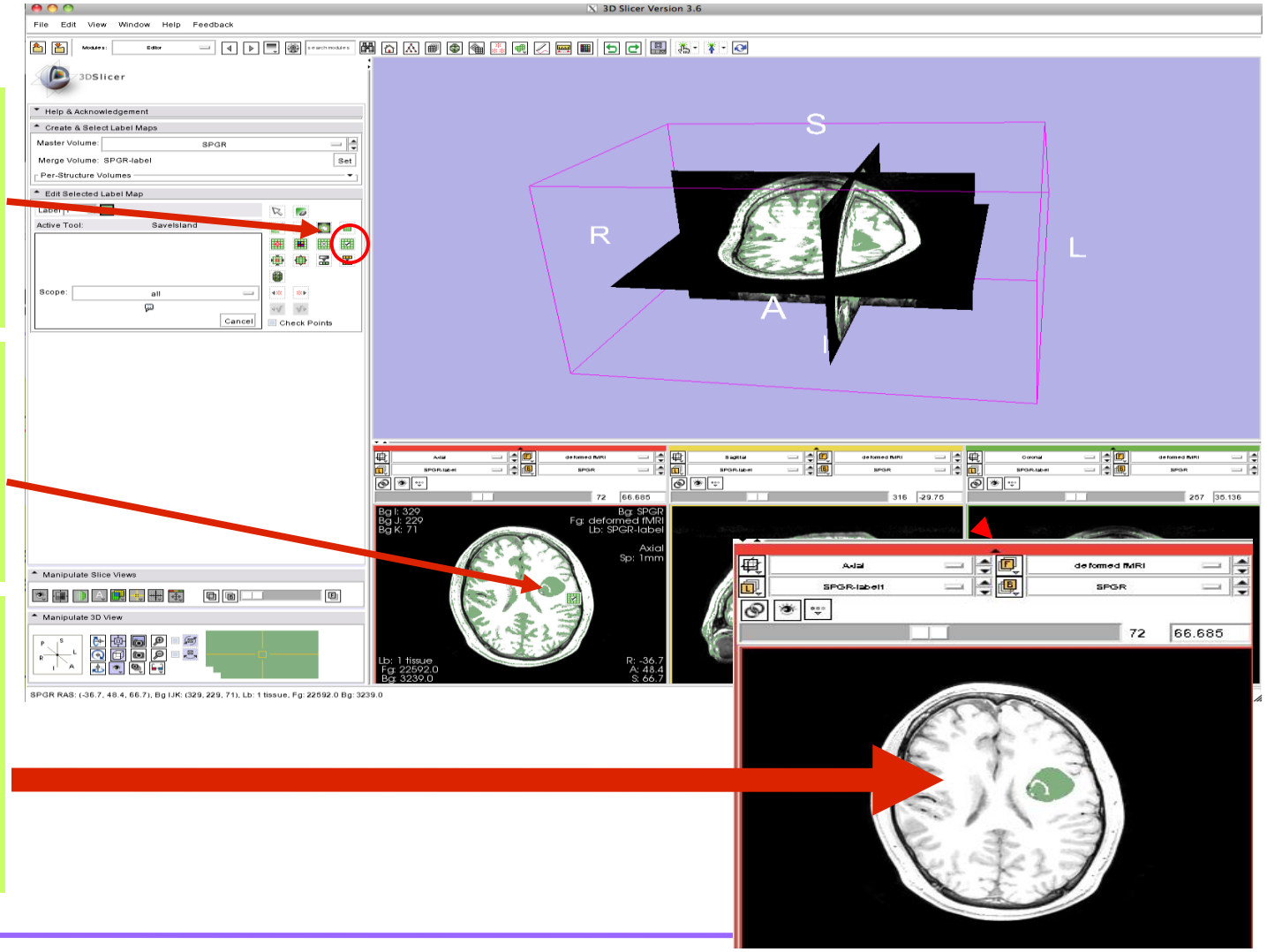
Save Island

Choose **Save Island** option

Click on the tumor lesion

Confirm that only tumor lesion remains painted green



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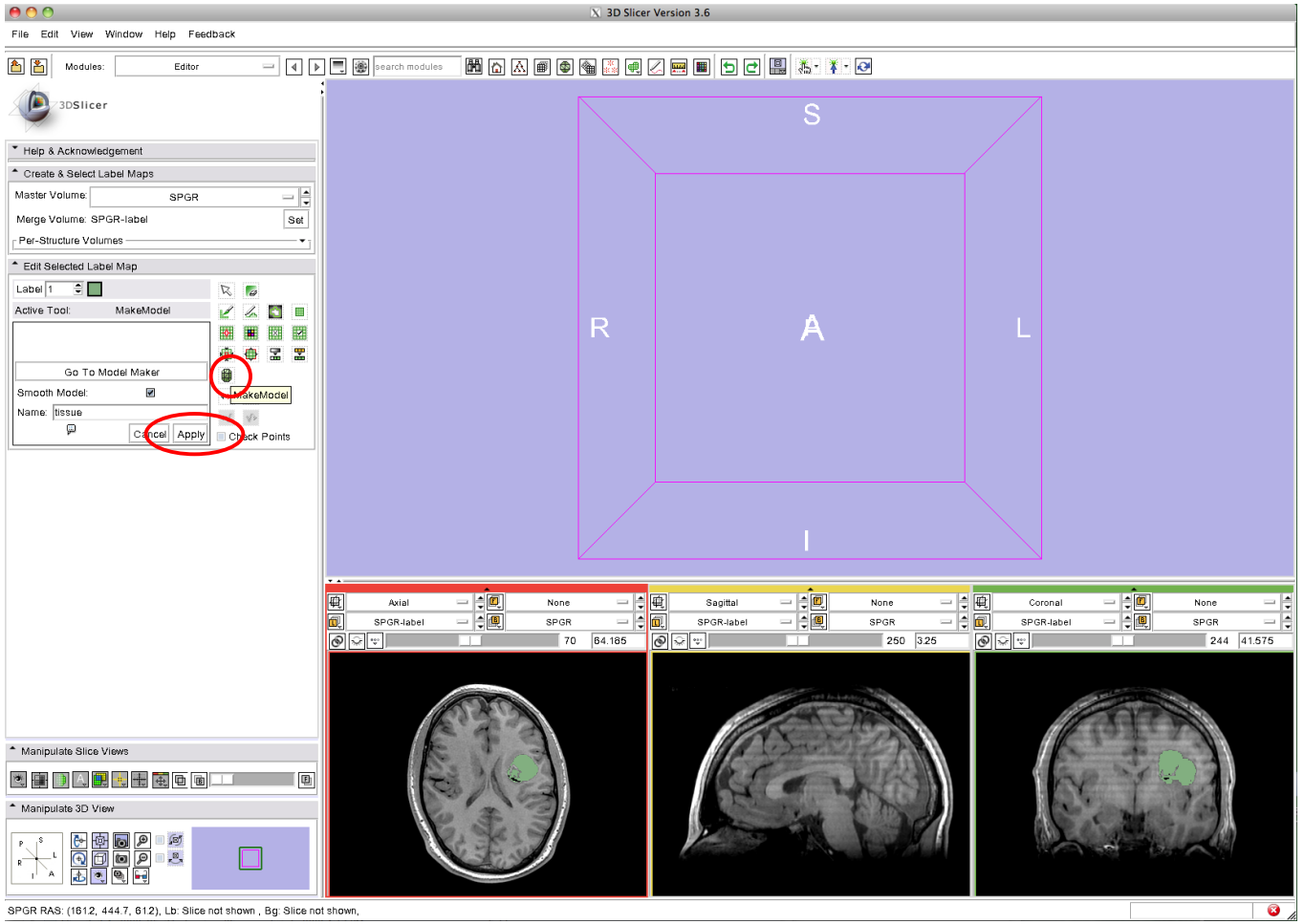
Create the tumour model

Choose **Model Maker** in the Editor module

Click **Apply**



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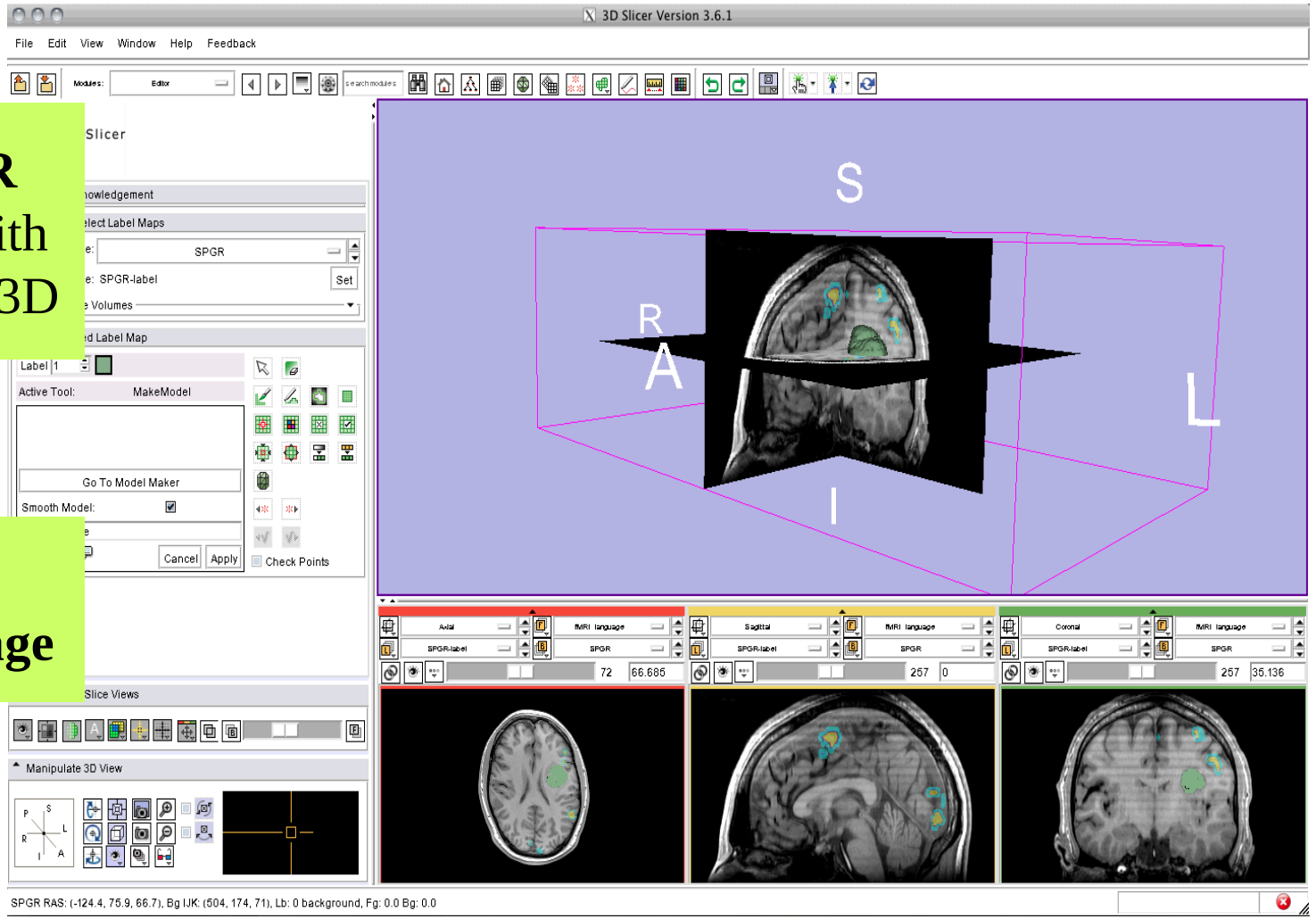
View the anatomical MRI, fMRI and tumour model

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

Display **fMRI_language**



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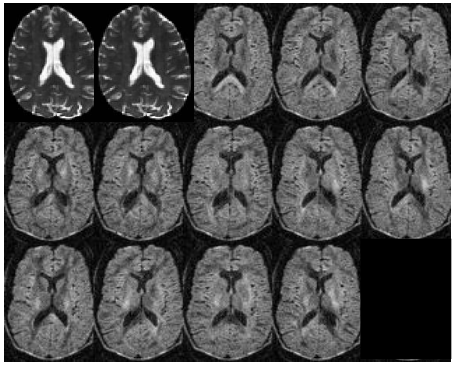
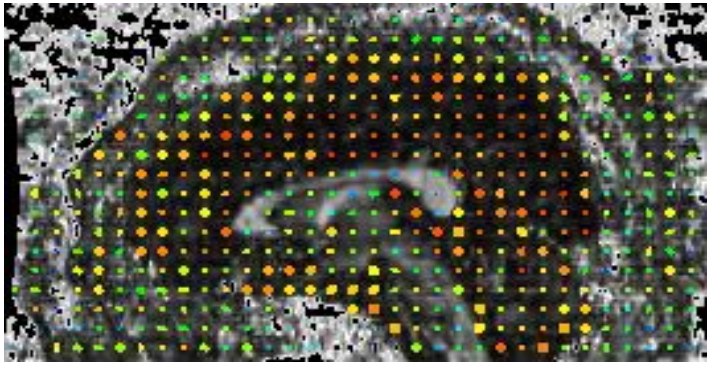
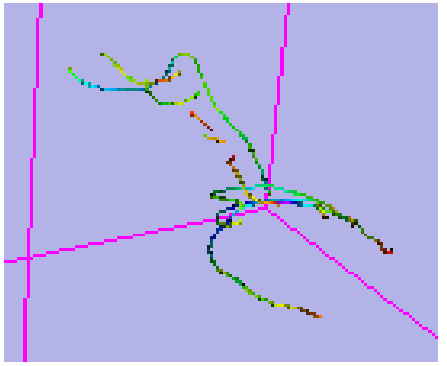
Diffusion Tensor Imaging (DTI)

- 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)







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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)

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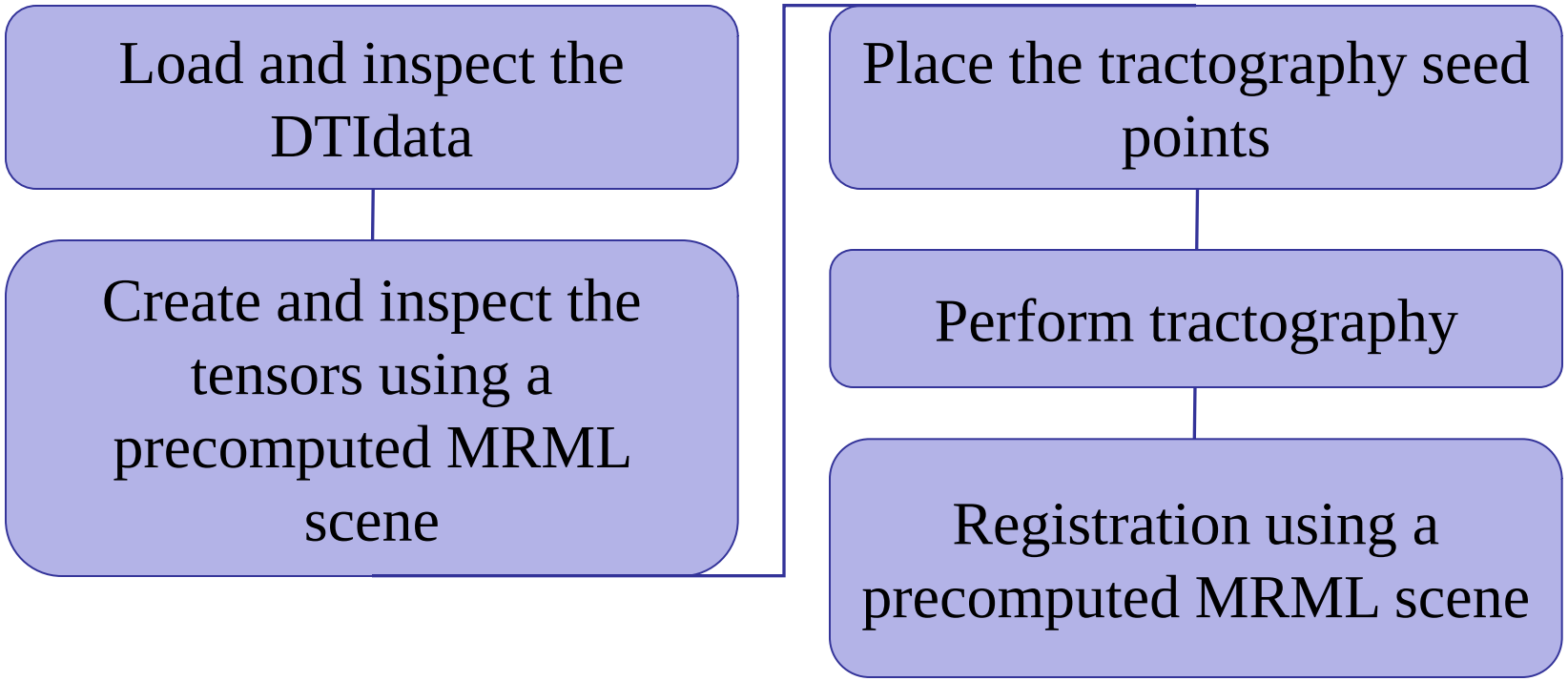
Diffusion Tensor Imaging (DTI)

- **Steps involved in this section:**



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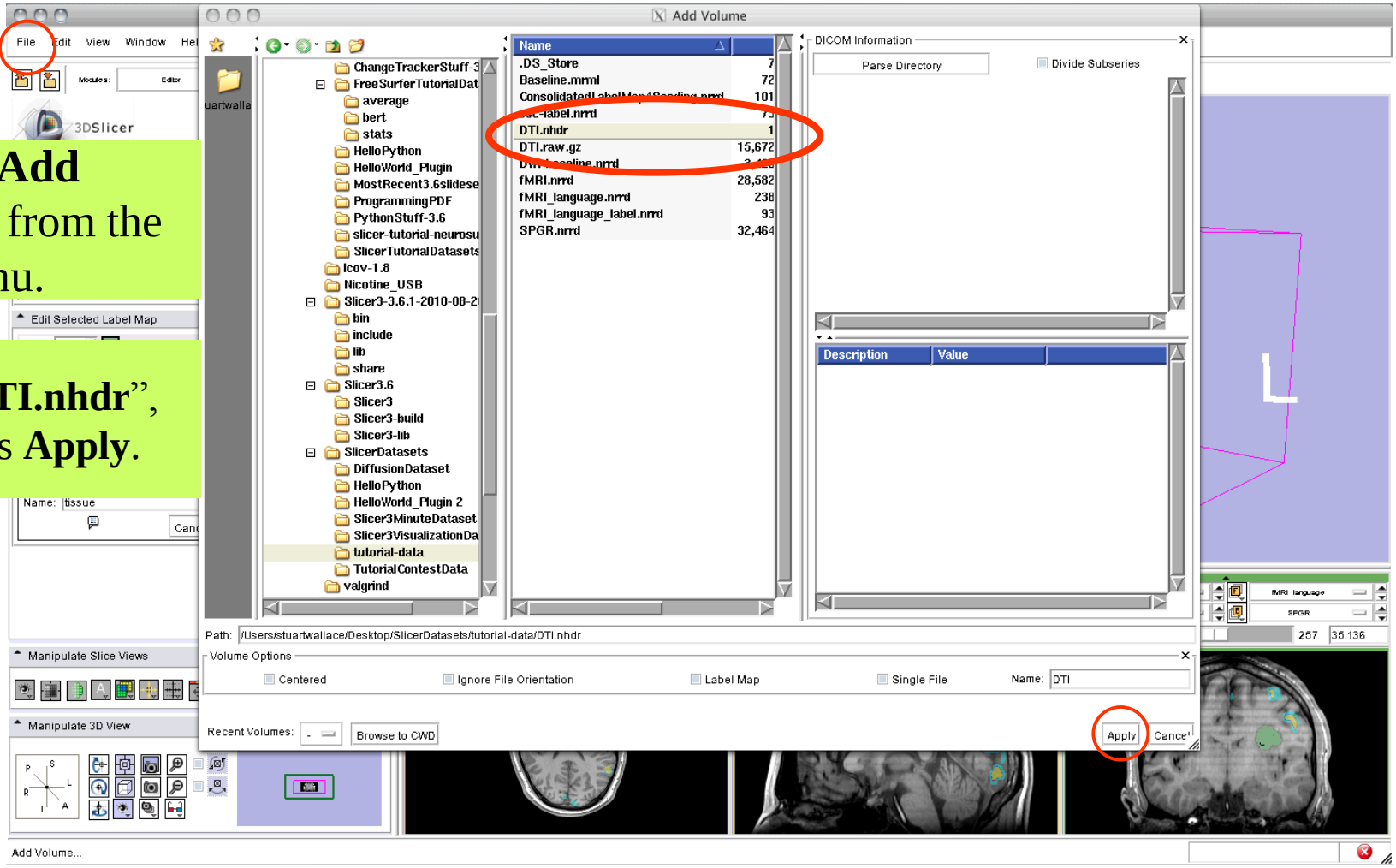
Load the DTI data

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

Load "**DTI.nhdr**", then press **Apply**.



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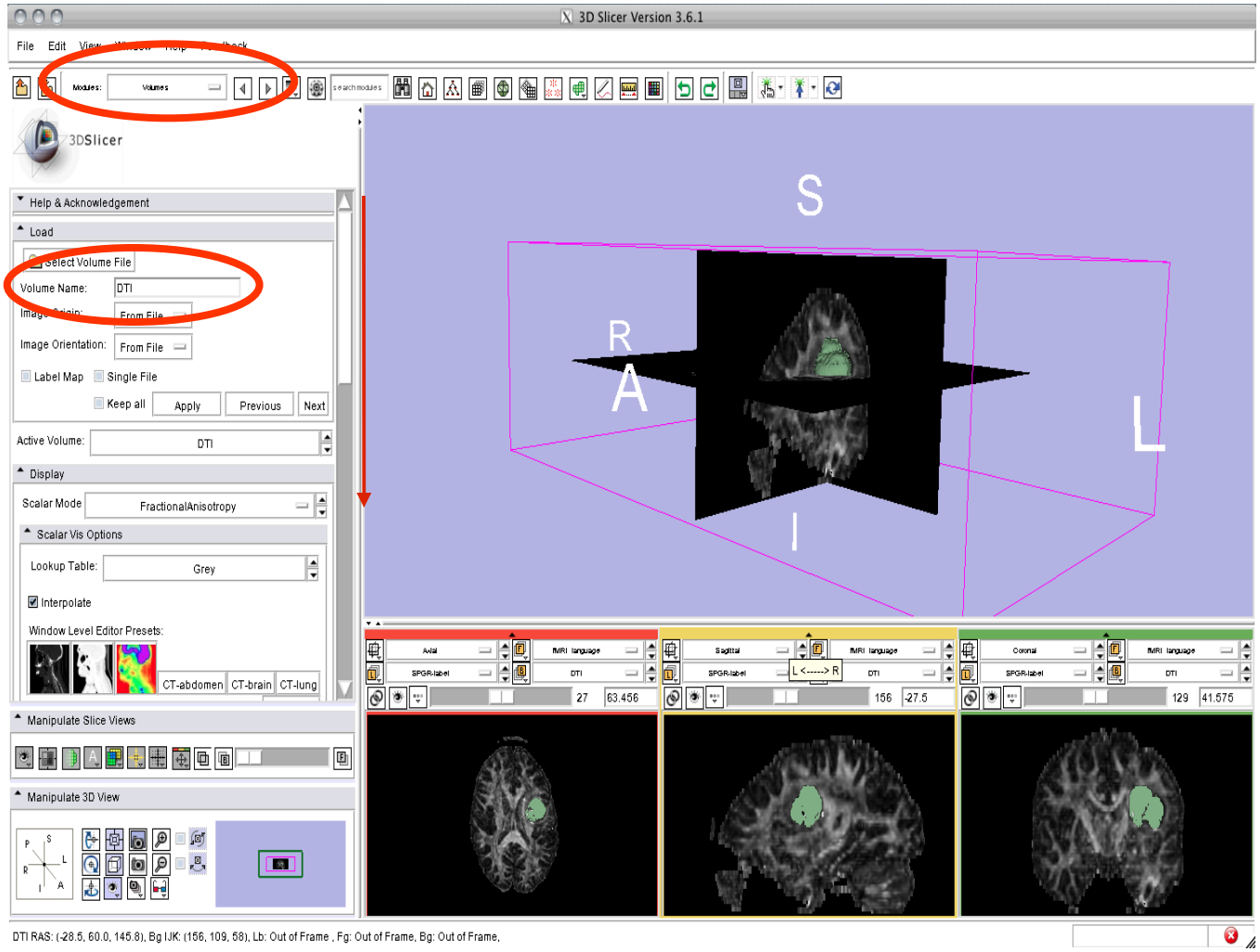
Inspect the DTI data

Go to **Volume**

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

Pull down the slider….



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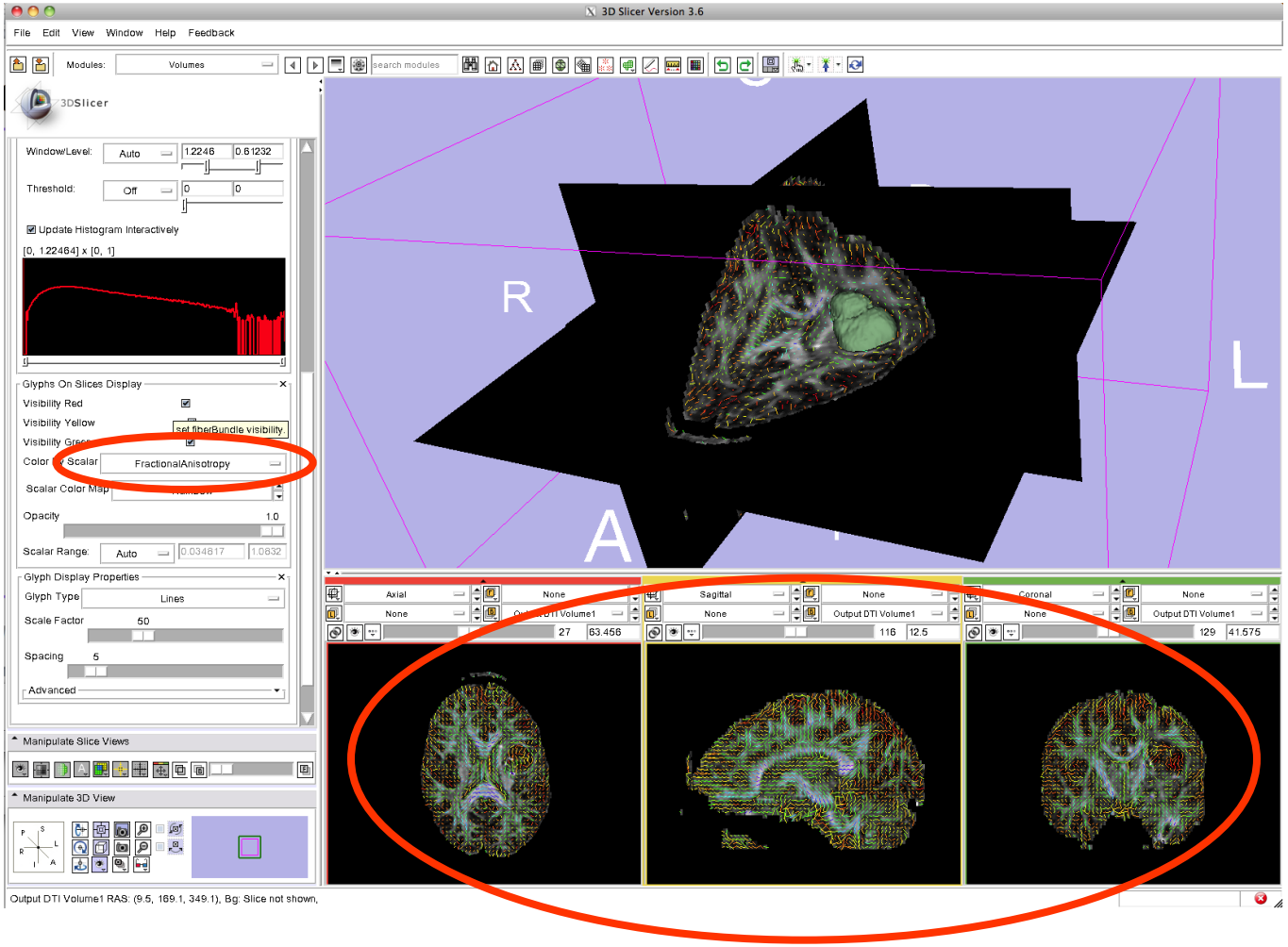
Inspect the DTI data

Toggle on "Visibility Red" "Visibility Yellow" and "Visibility Green"

See **Fractional Anisotropy** are visualized as lines



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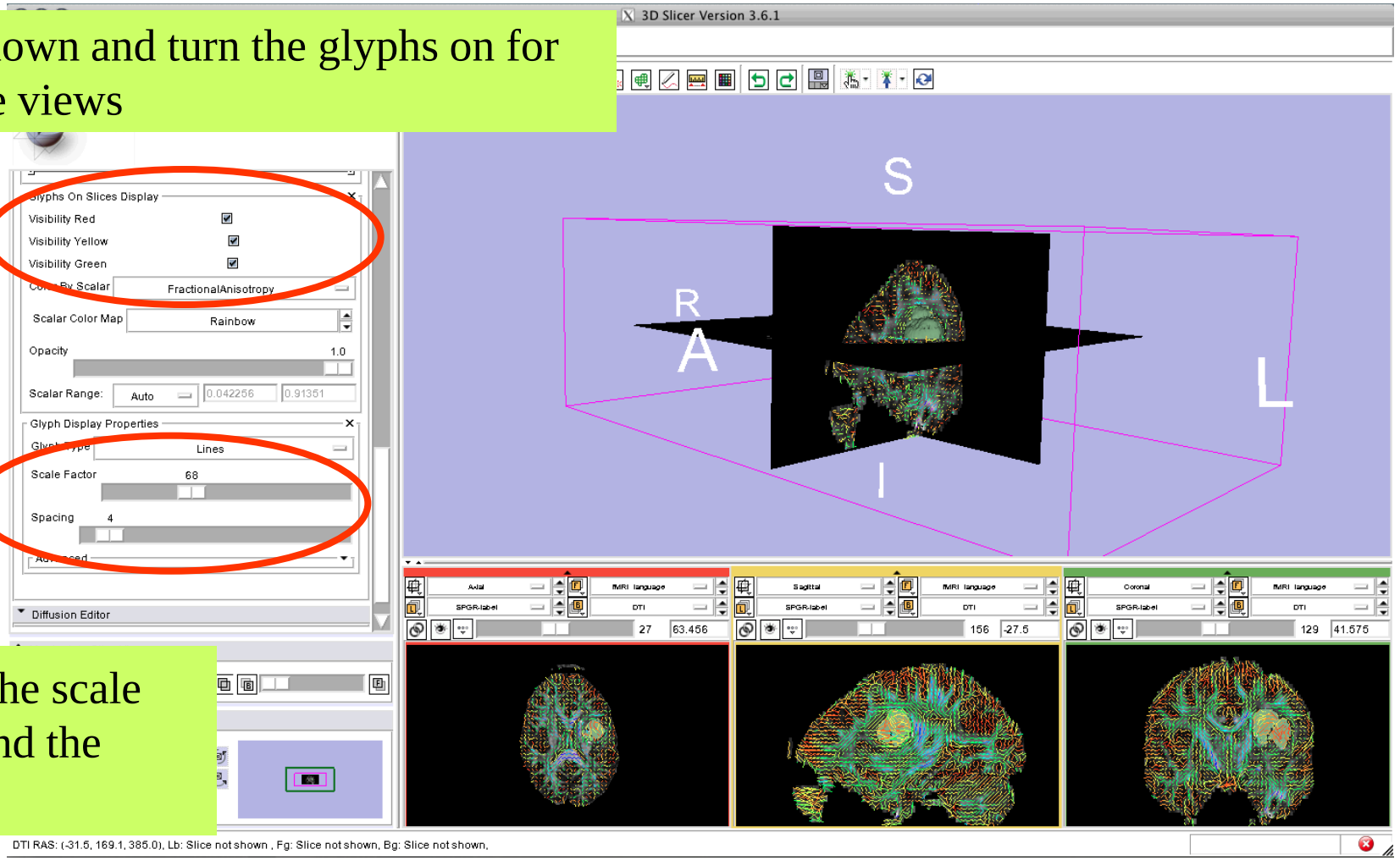
View the tensors

Scroll down and turn the glyphs on for all three views



Adjust the scale factor and the spacing

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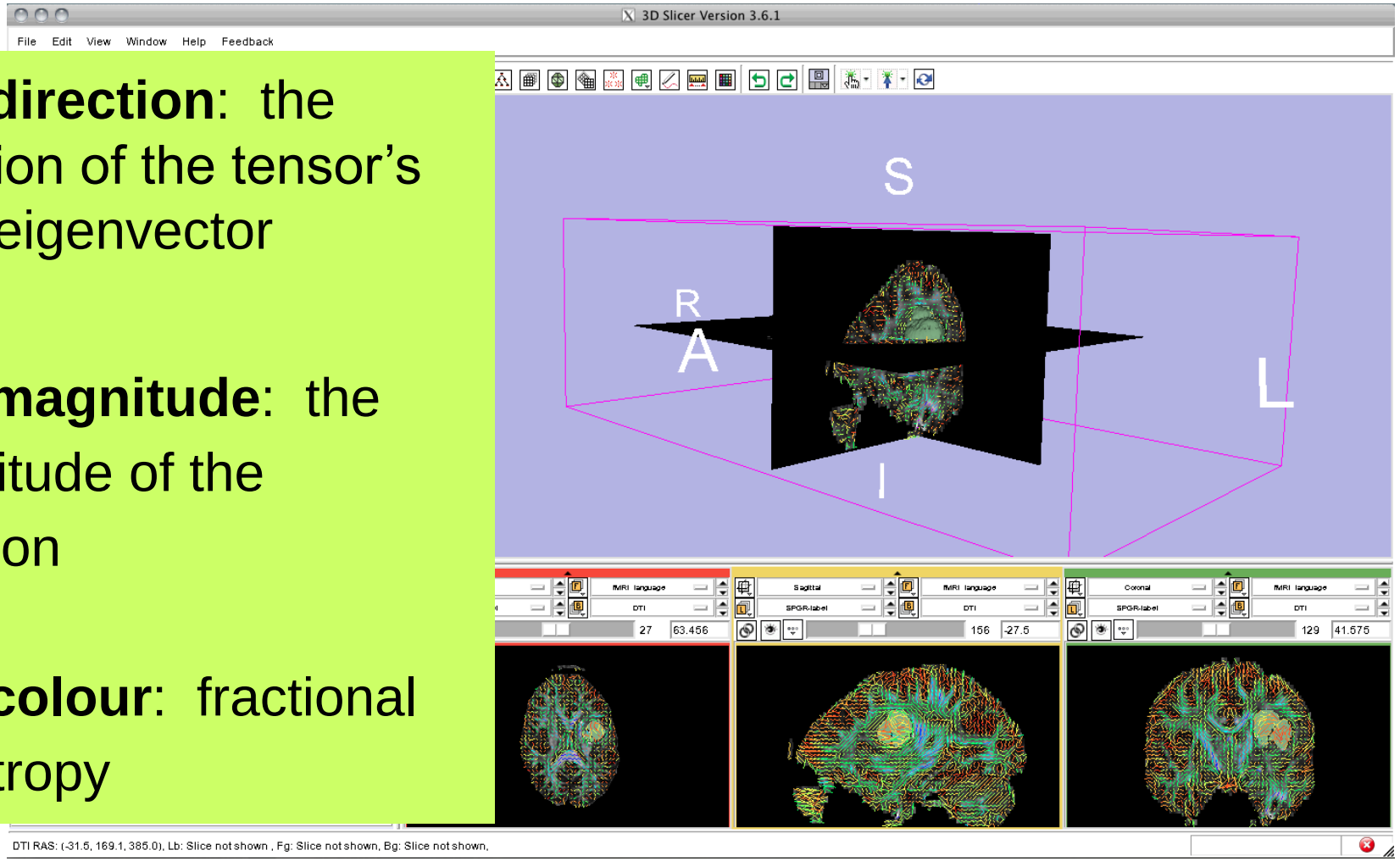
View the tensors

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

Line magnitude: the magnitude of the diffusion

Line colour: fractional anisotropy



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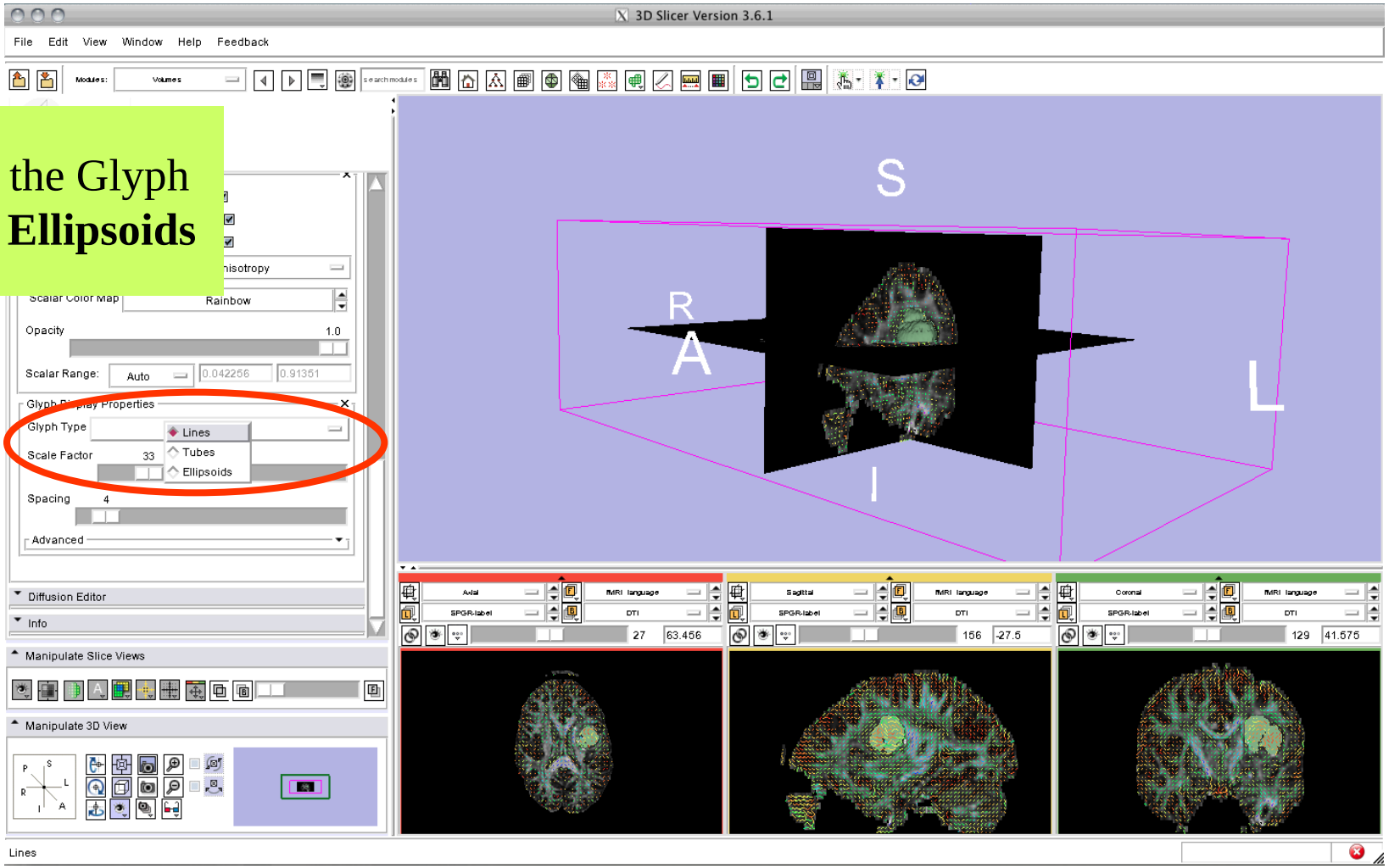
View the tensors

Change the Glyph Type to **Ellipsoids**



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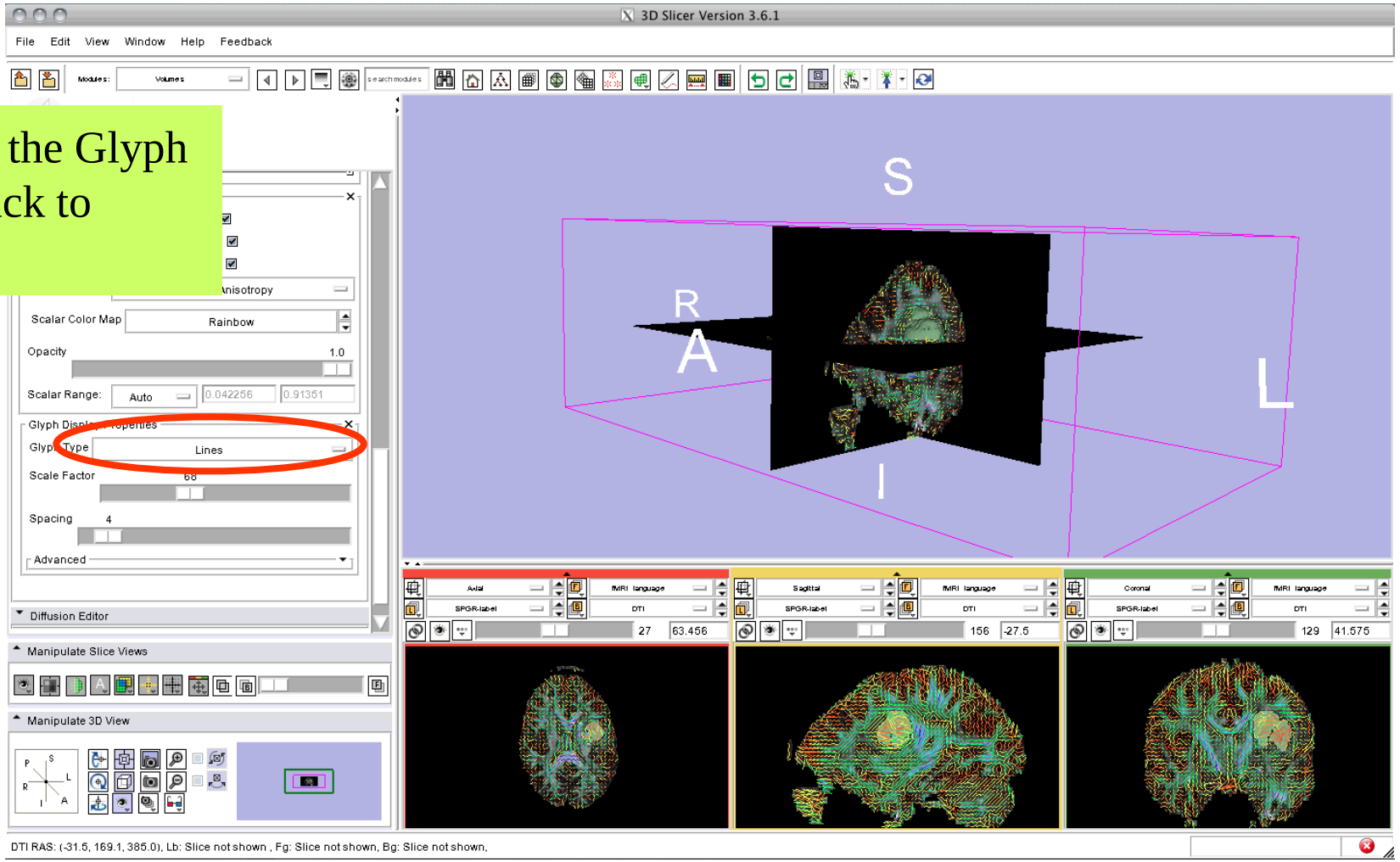
View the tensors

Change the Glyph Type back to **Lines**



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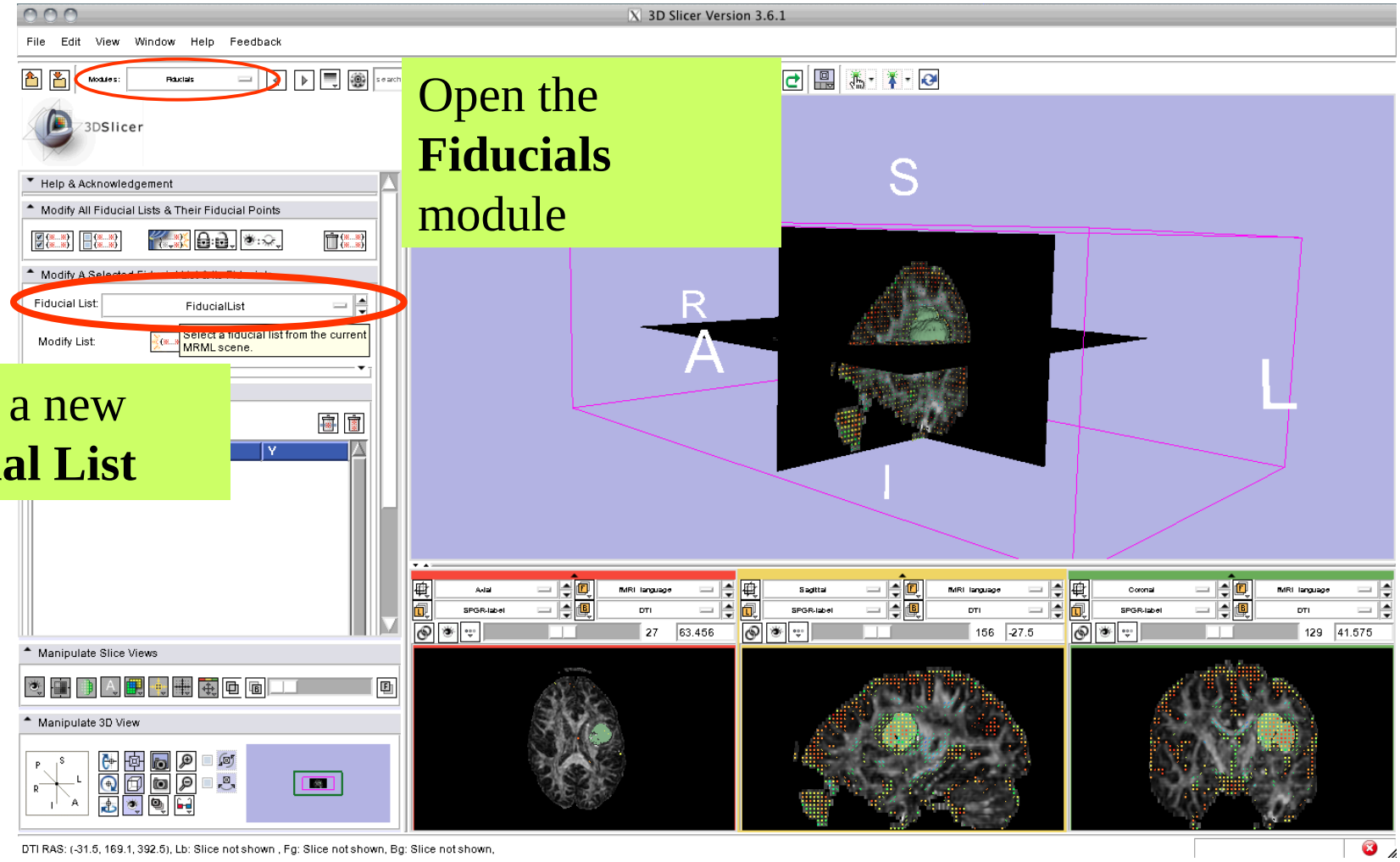
Placing tractography seed points



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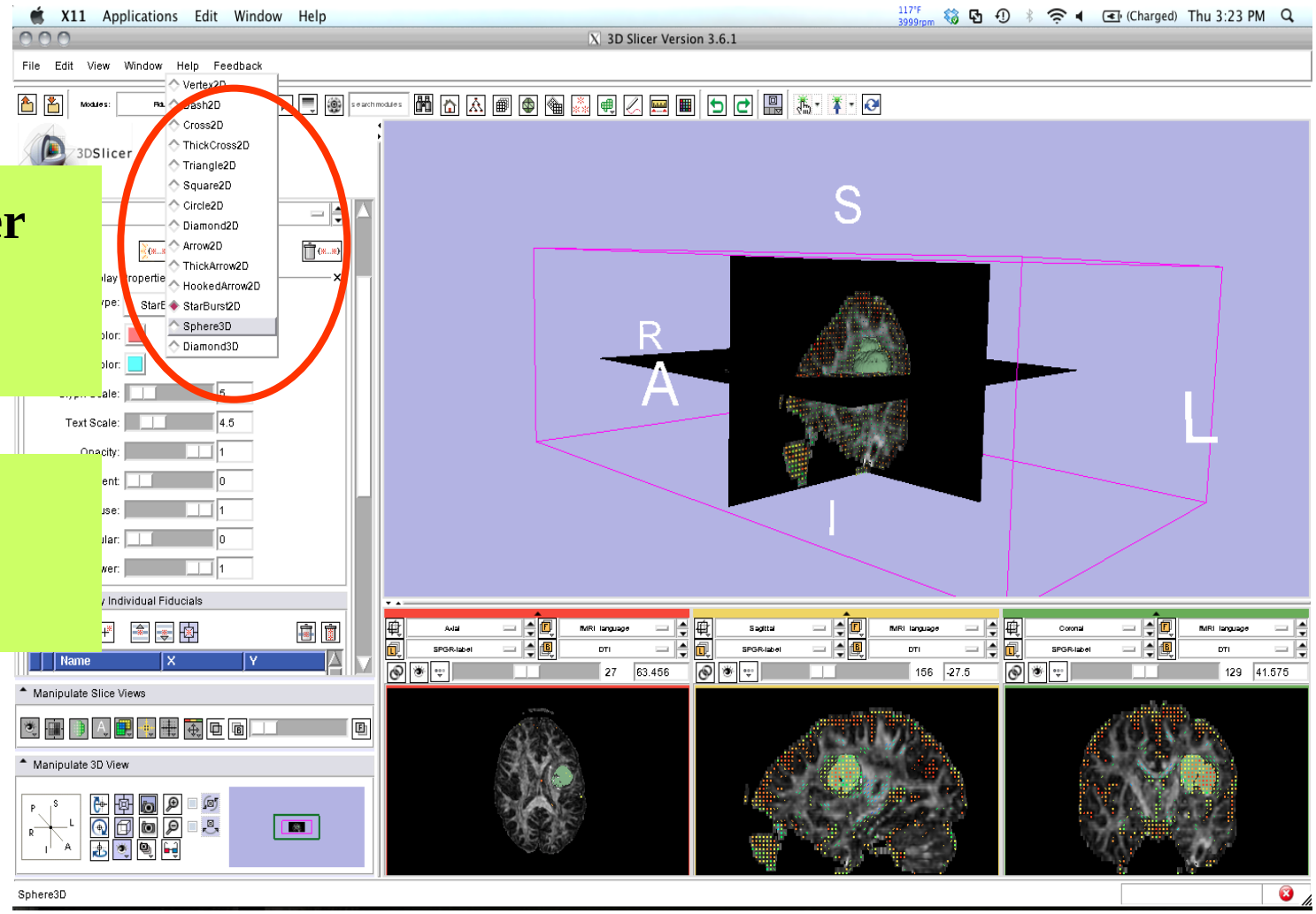
Placing tractography seed points

Expand **Other Display List Properties.**

Set the glyph type to Sphere3D



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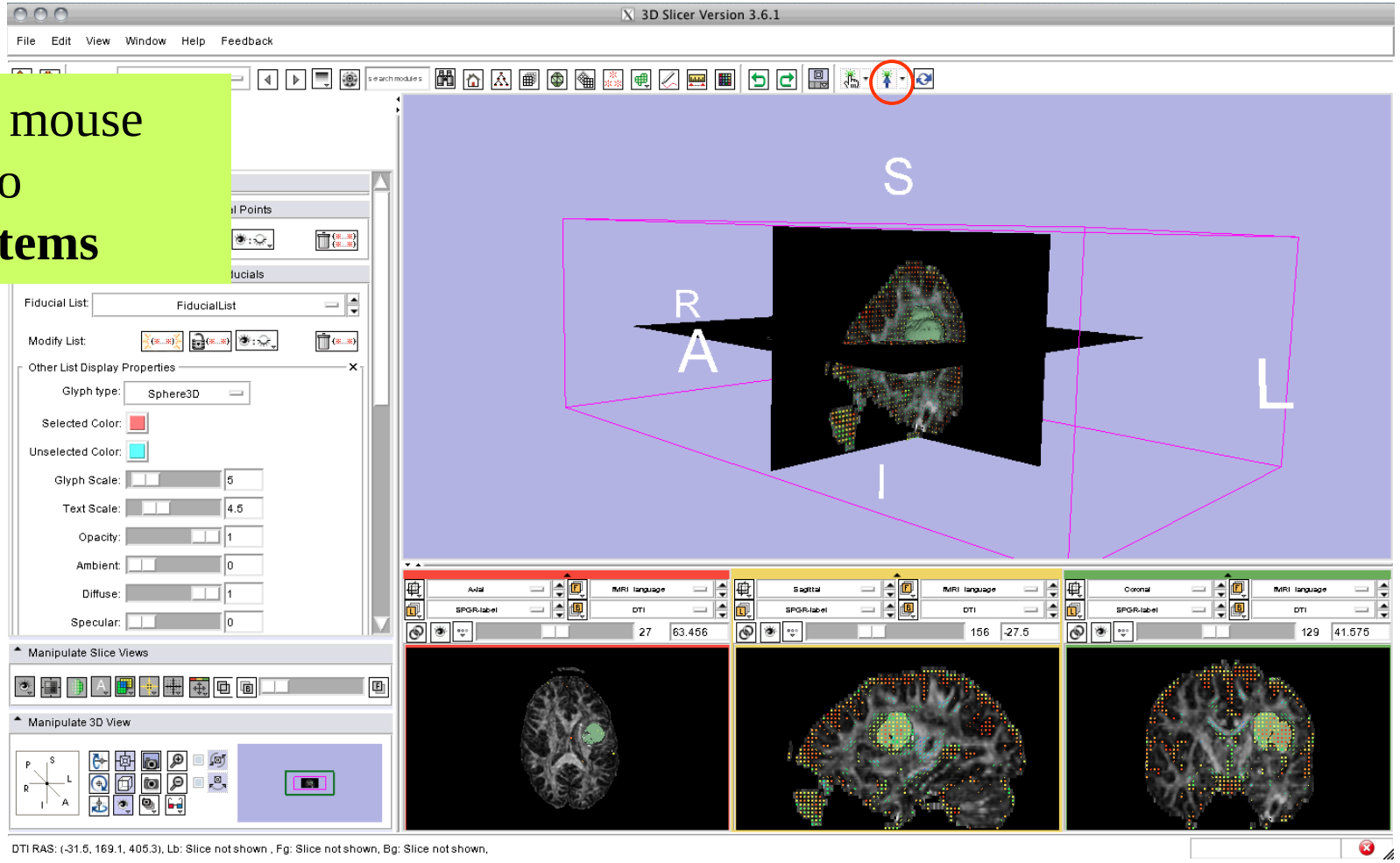
Placing tractography seed points

Set the mouse mode to **place items**



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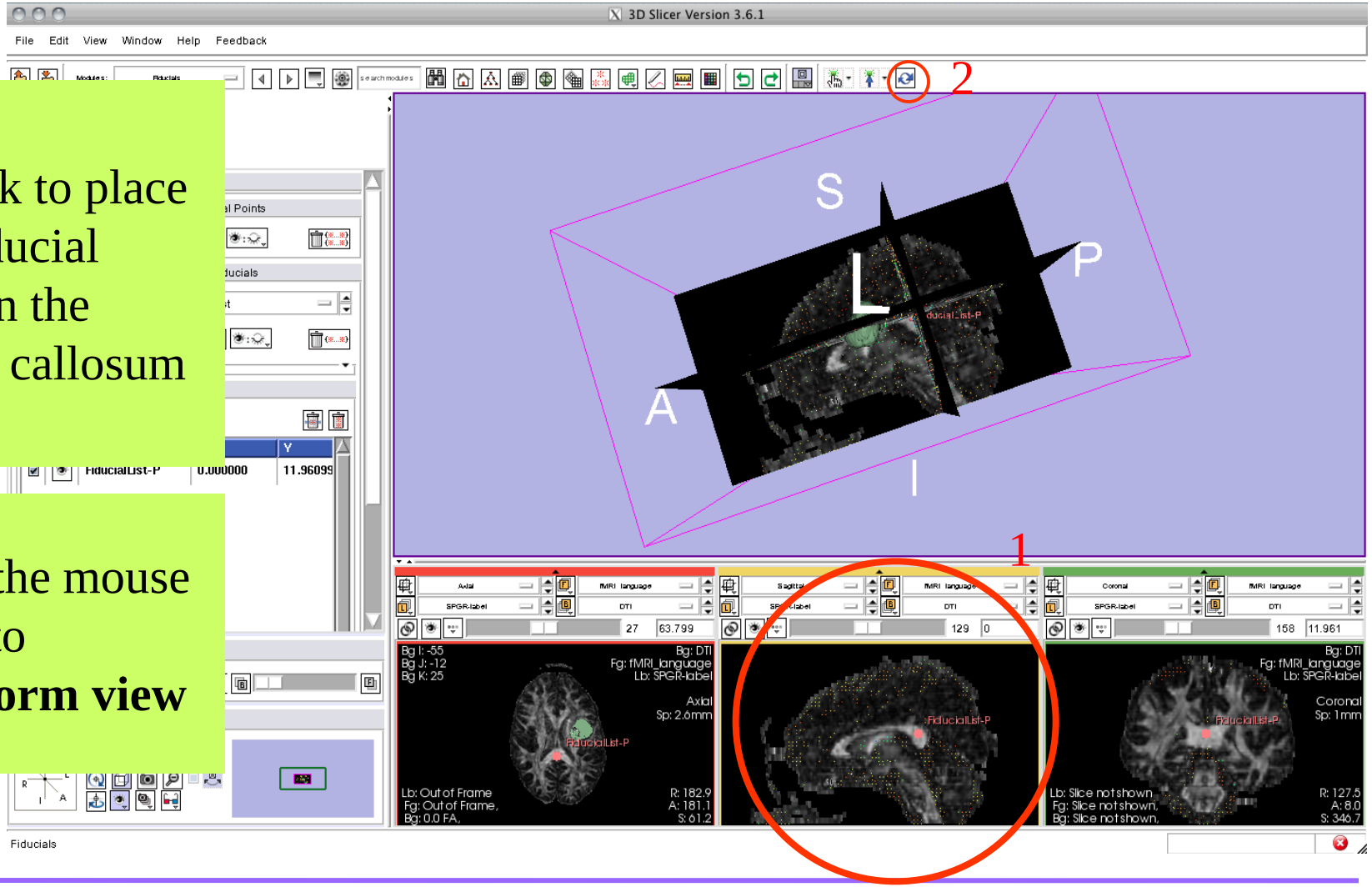
Placing tractography seed points

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

2. Set the mouse mode to **transform view**



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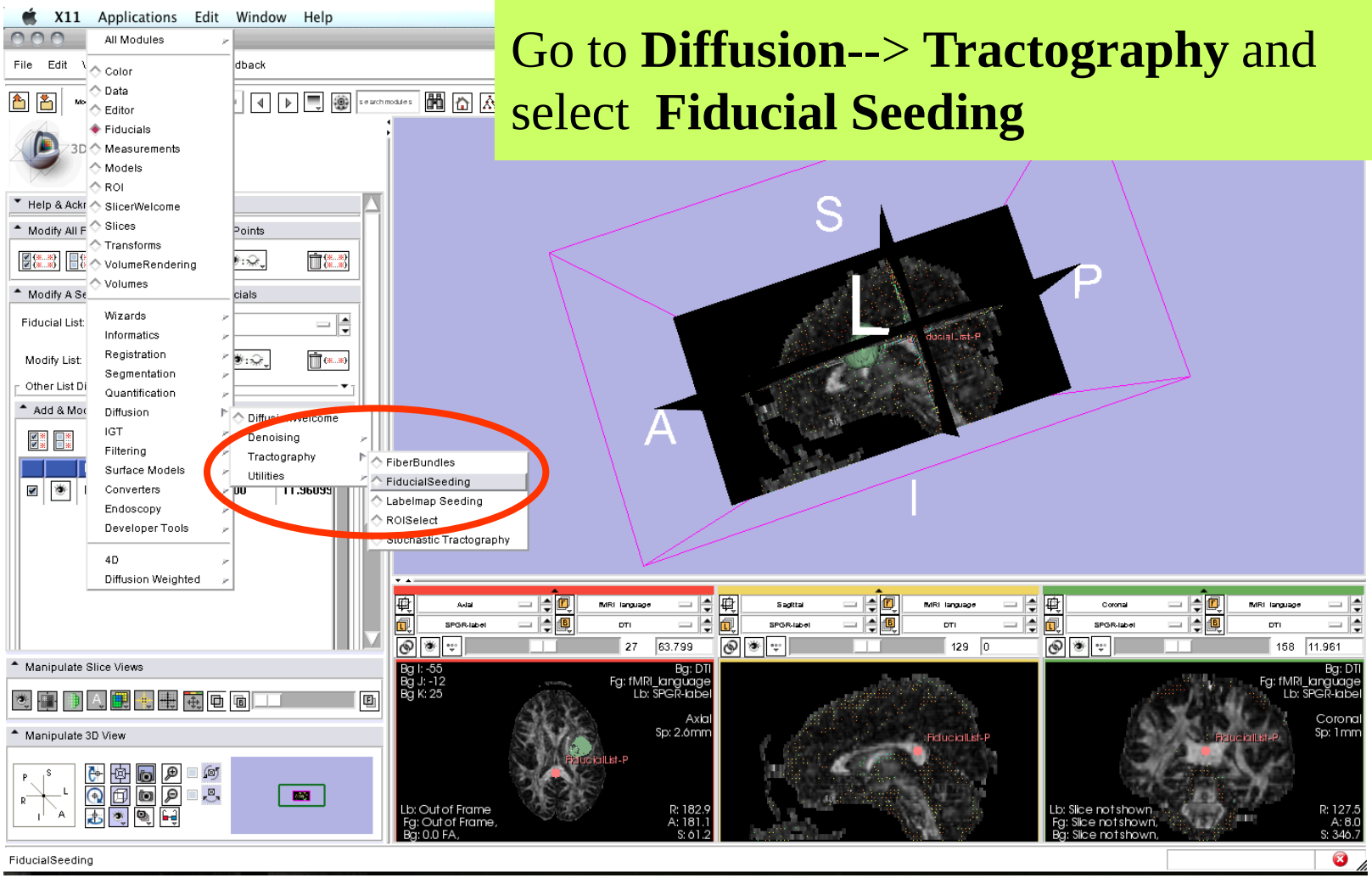
Perform tractography (fiber tracking)

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



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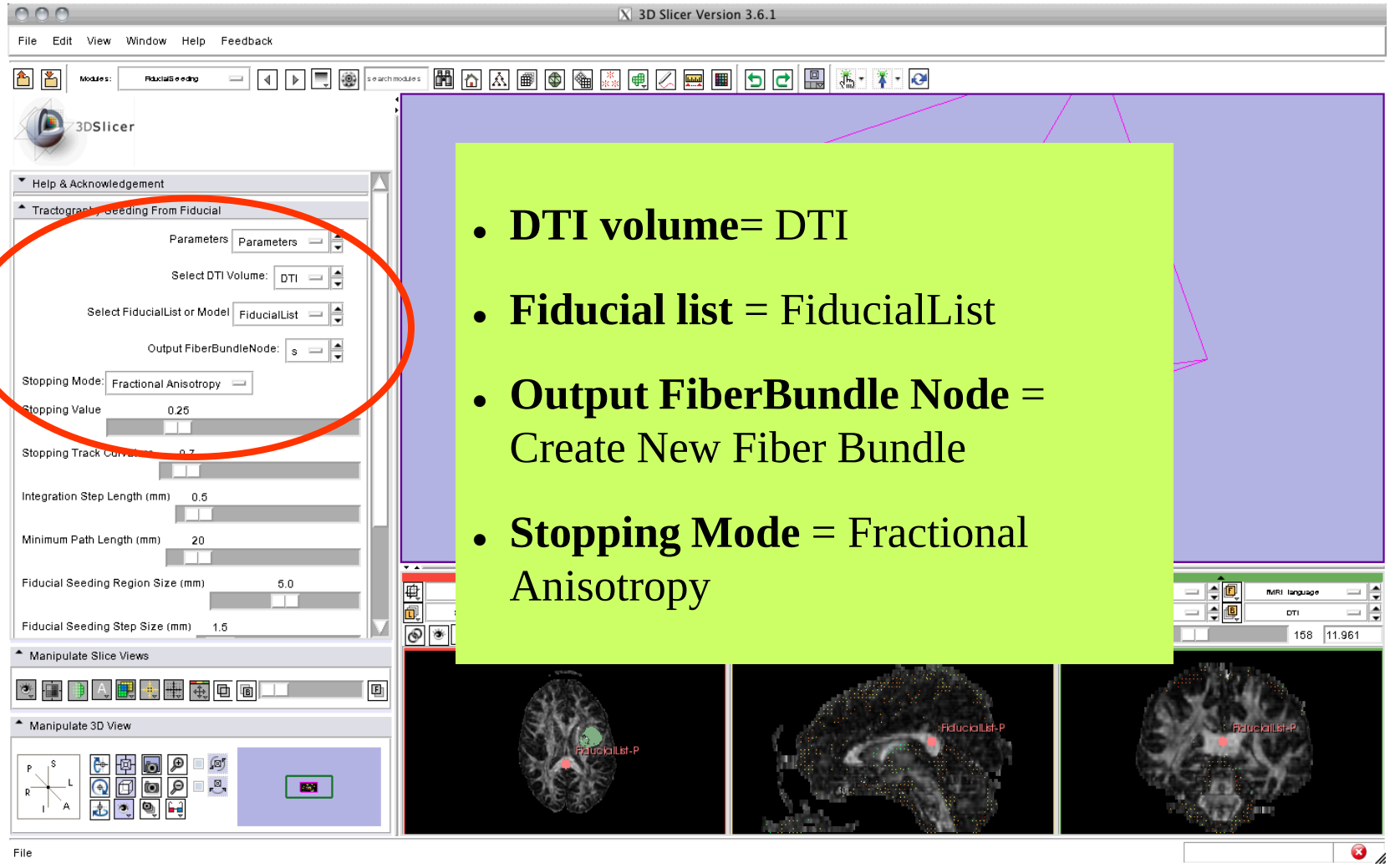
Perform tractography (fiber tracking)



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

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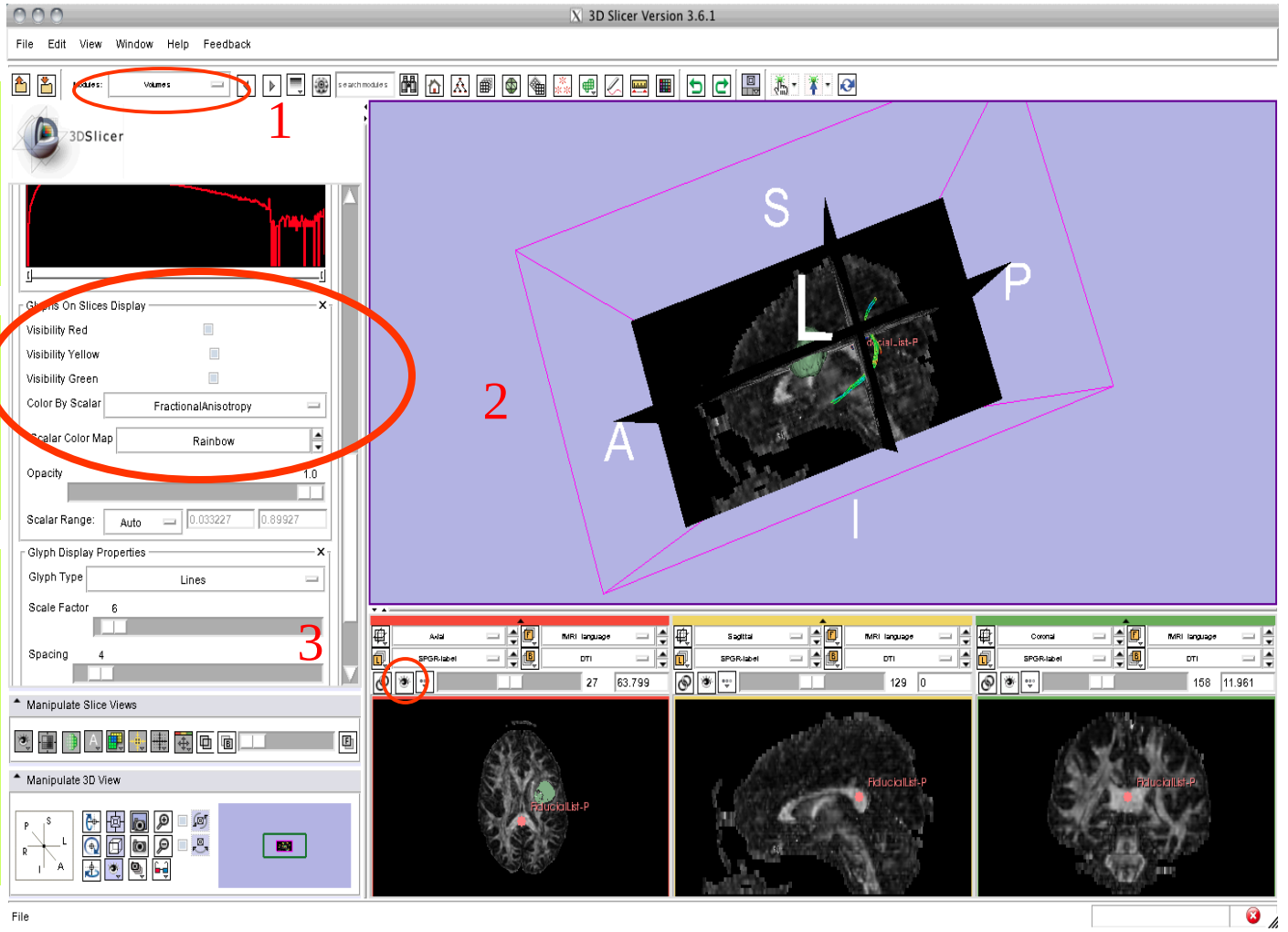
Perform tractography (fiber tracking)

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



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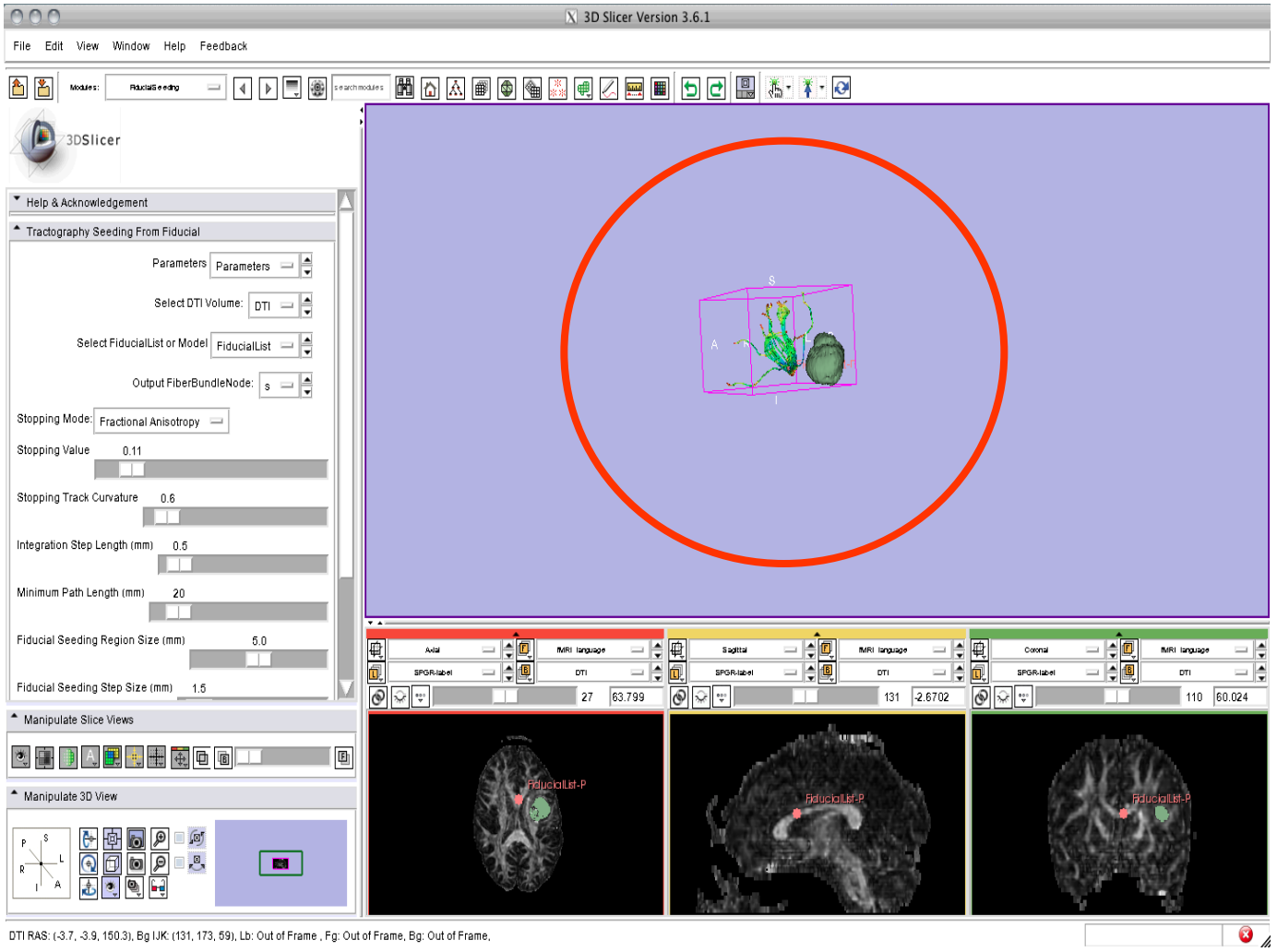
Perform tractography (fiber tracking)

One tract is generated for each fiducial

The tract colour is the fractional anisotrophy by default.

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



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Tasks

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

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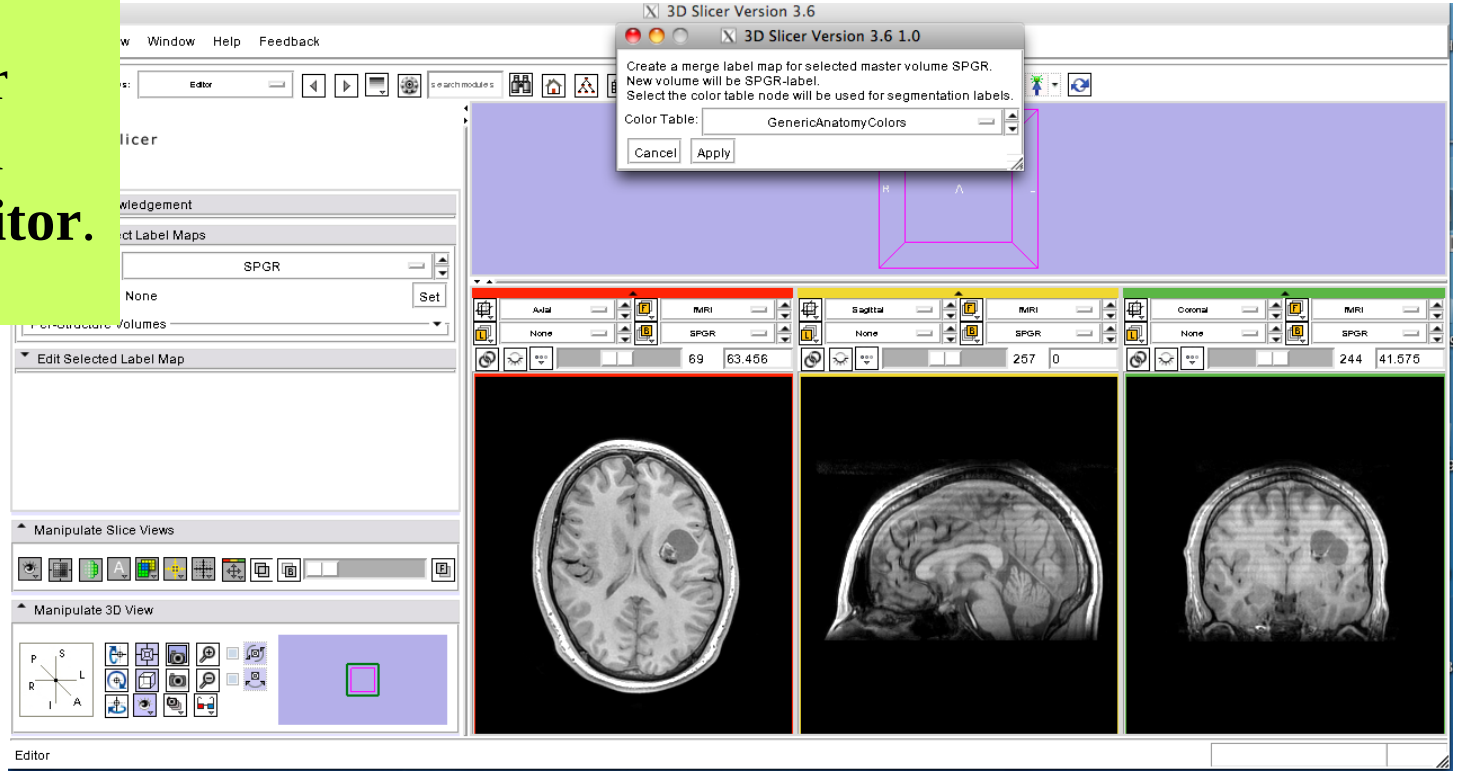
Segment the tumor volume

Repeat tumor segmentation using the **Editor**.



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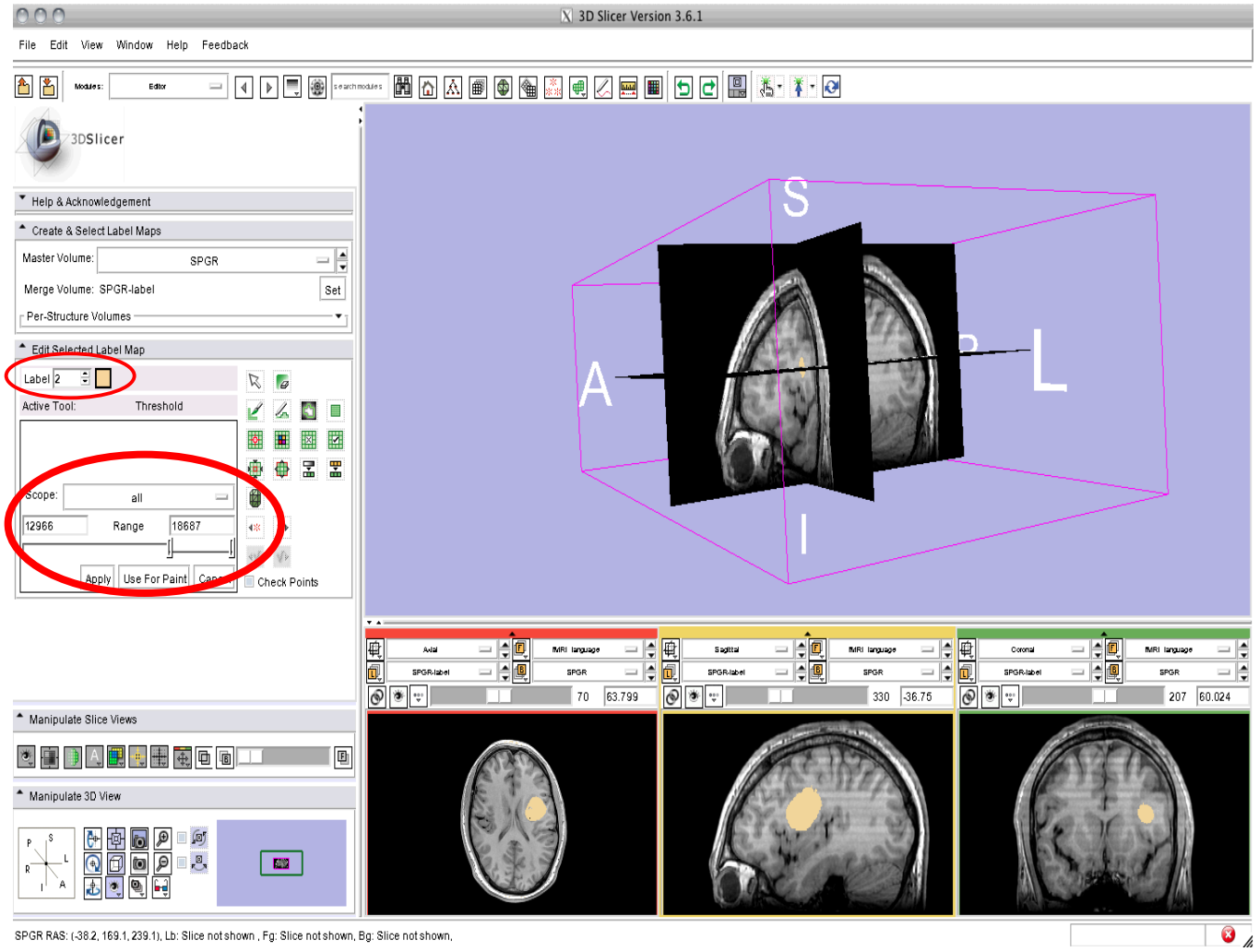
Segment the tumour volume

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**



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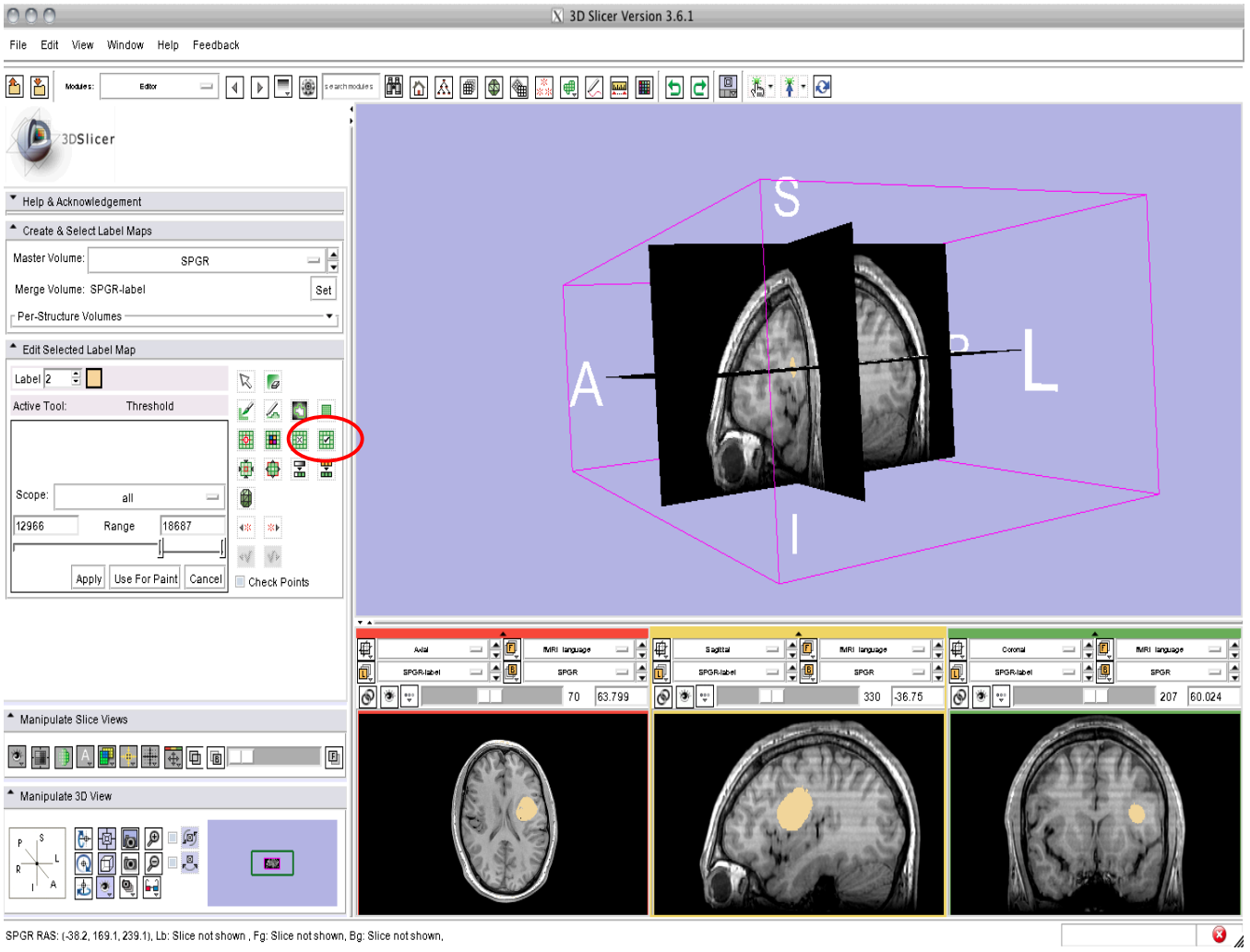
Save Island

Choose **Save Island** option

Click on the tumor lesion

Confirm that only tumor lesion remains painted



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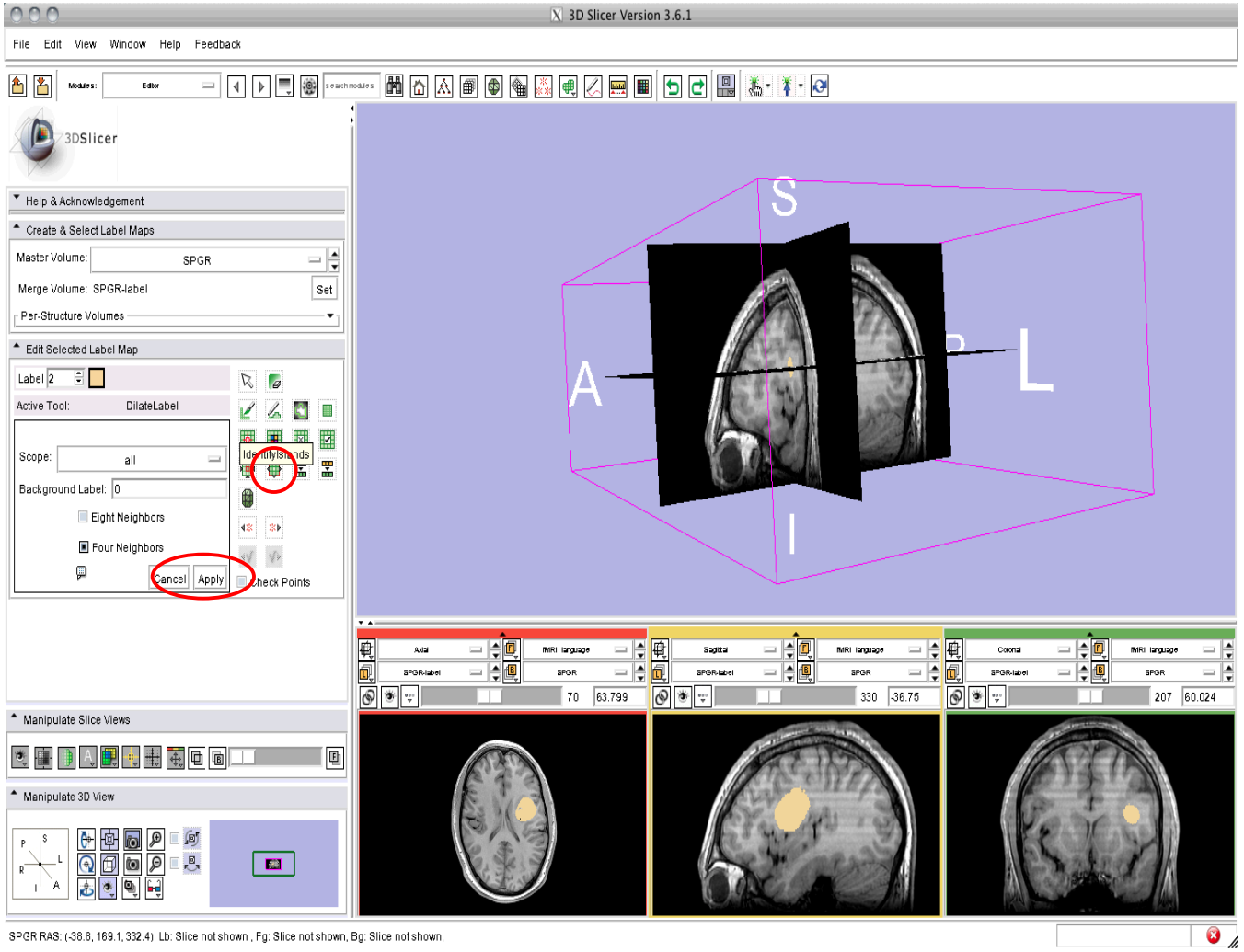
Dilate the label map to include neighboring pixels

Choose **Dilate Label** option

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

Observe the segmented lesion dilates.



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Task

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

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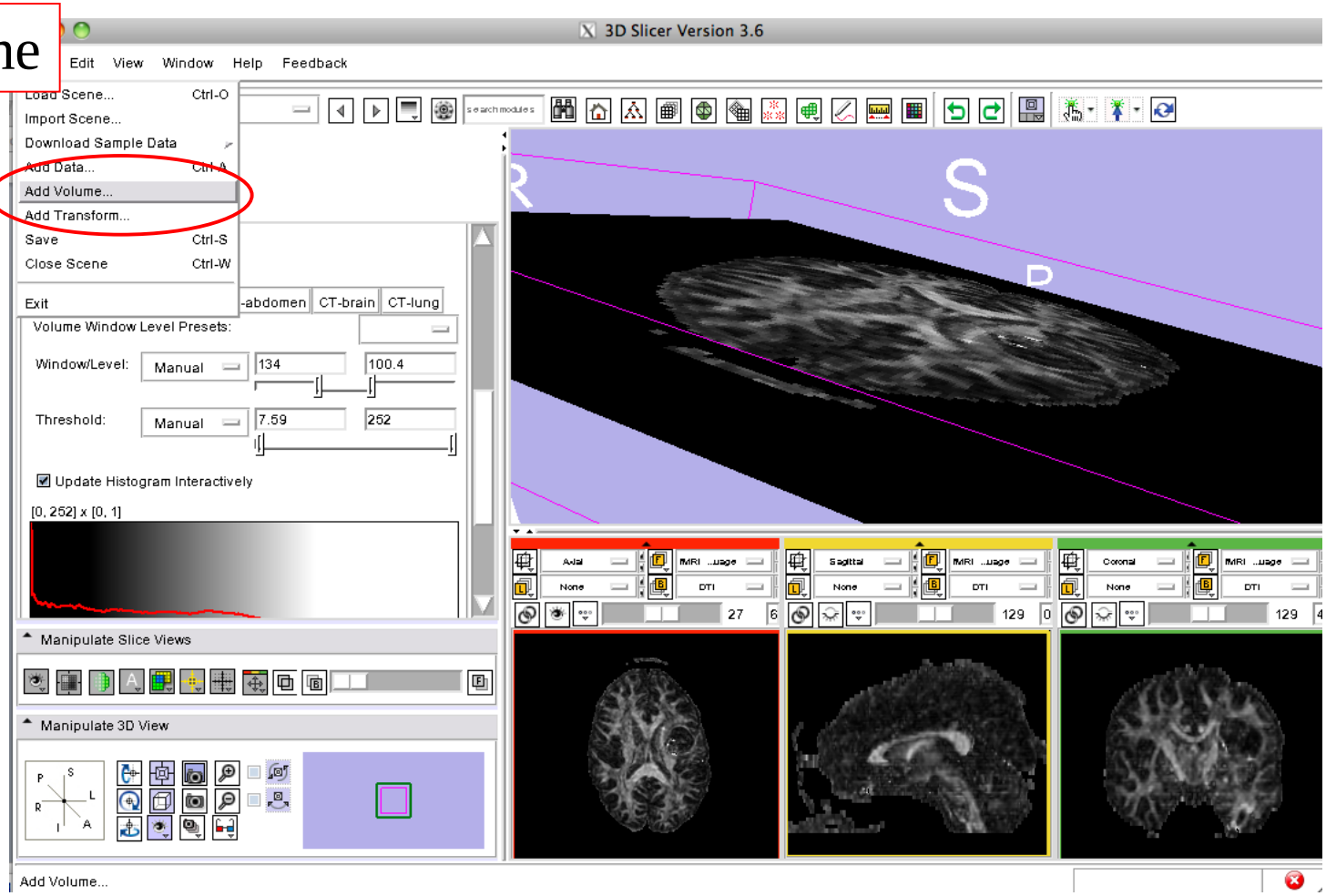
Load label map

Add Volume



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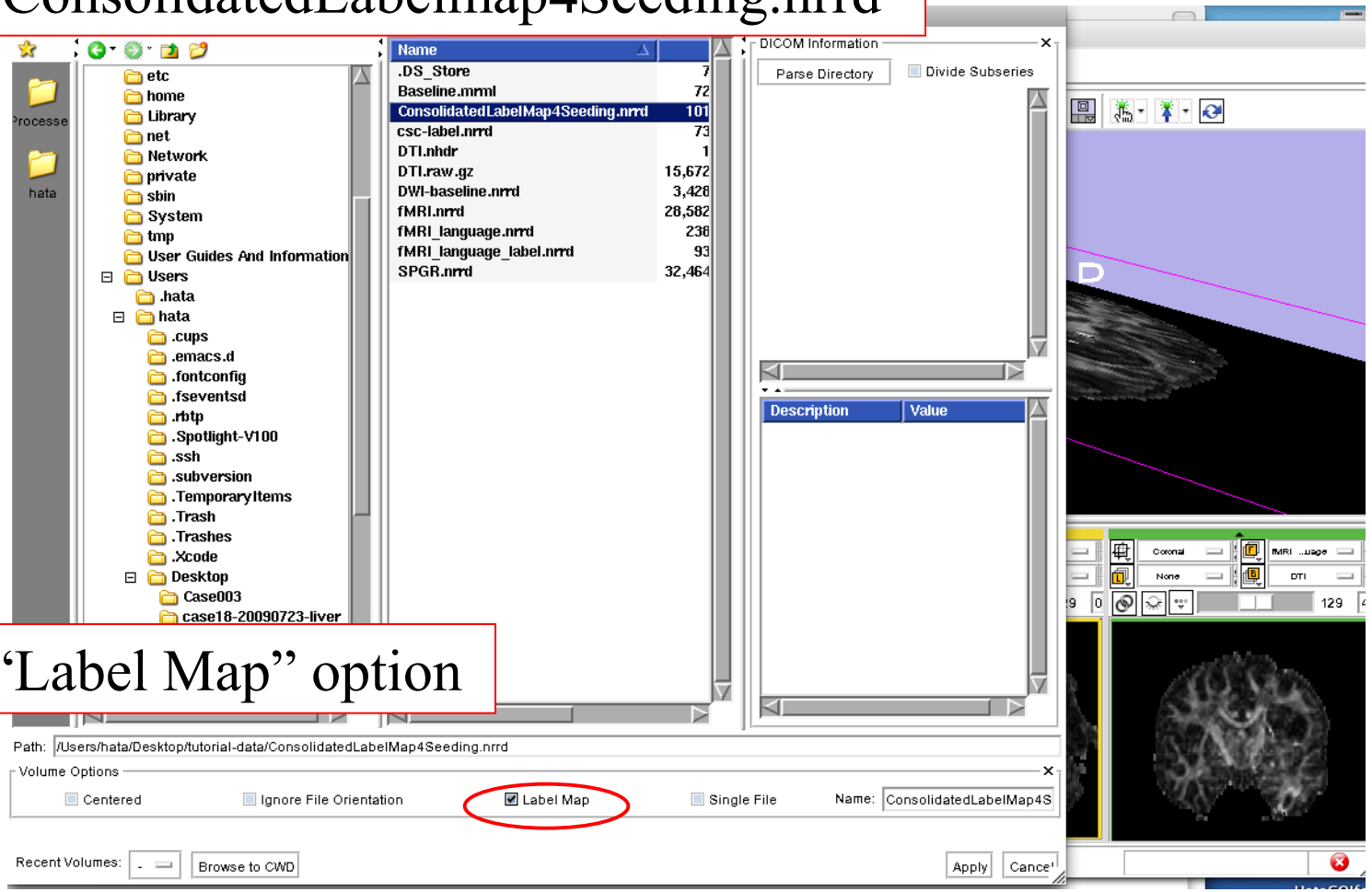
Load label map

Select “ConsolidatedLabelmap4Seeding.nrrd”



Turn on “Label Map” option

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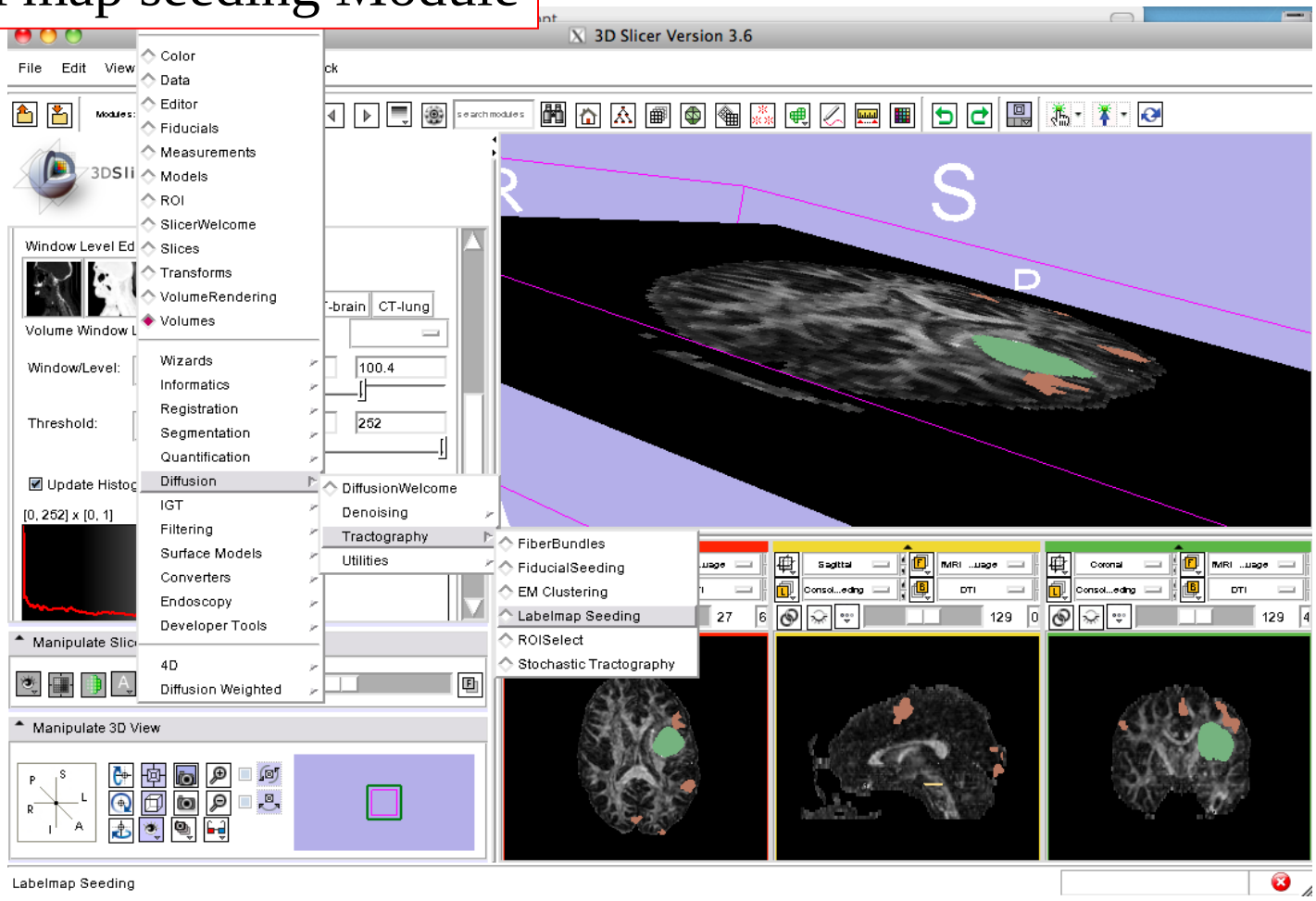
Label map seeding

Open Label map seeding Module



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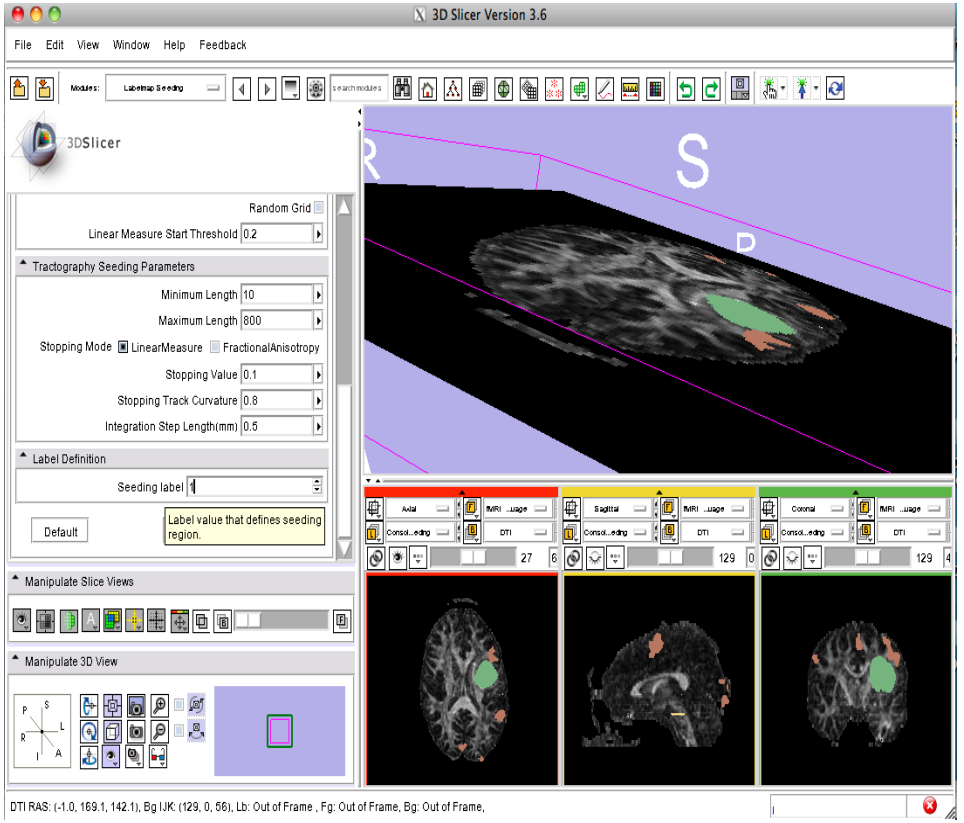
Apply the following values:



I/O Tab:

Input DTI Volume: **DTI**

Input Label Map: **ConsolidatedLabelMap4Seeding**

Output Fiber bundle: **Create New FiberBundle**

Tractography Seeding Parameters Tab:

Stopping Mode: **FractionalAnisotropy**

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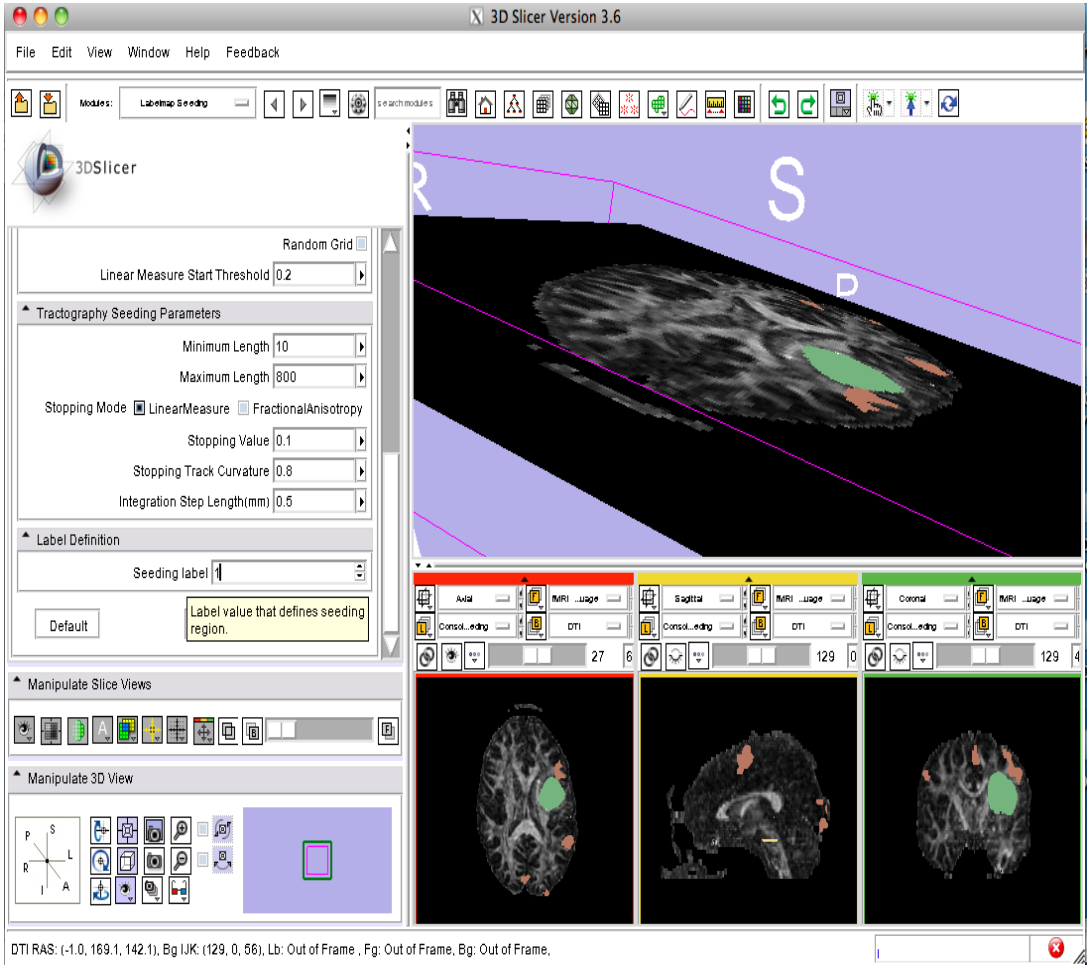
Perform labelmap seeding by using the Label value for:

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

Control density of fibers by changing seed spacing.



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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.

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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

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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

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