Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

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Harvard University

Clinical Goal

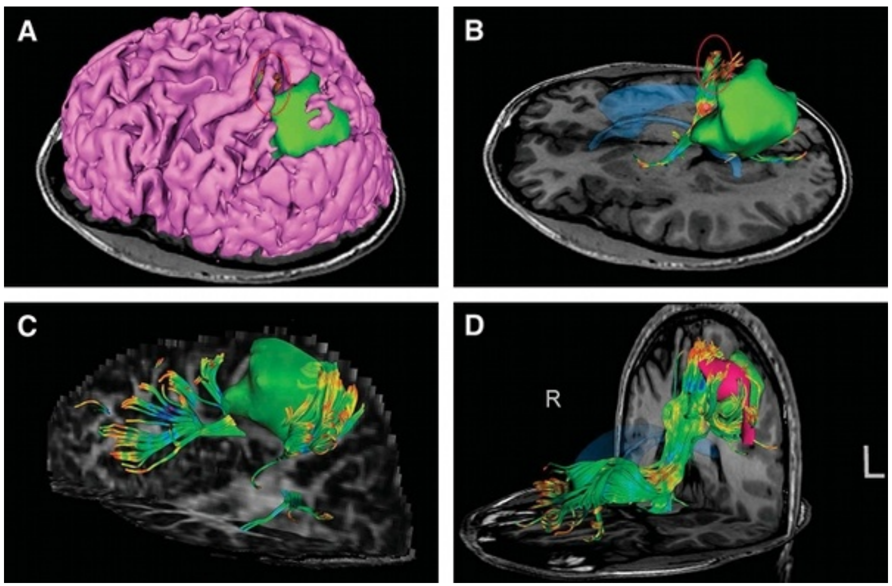
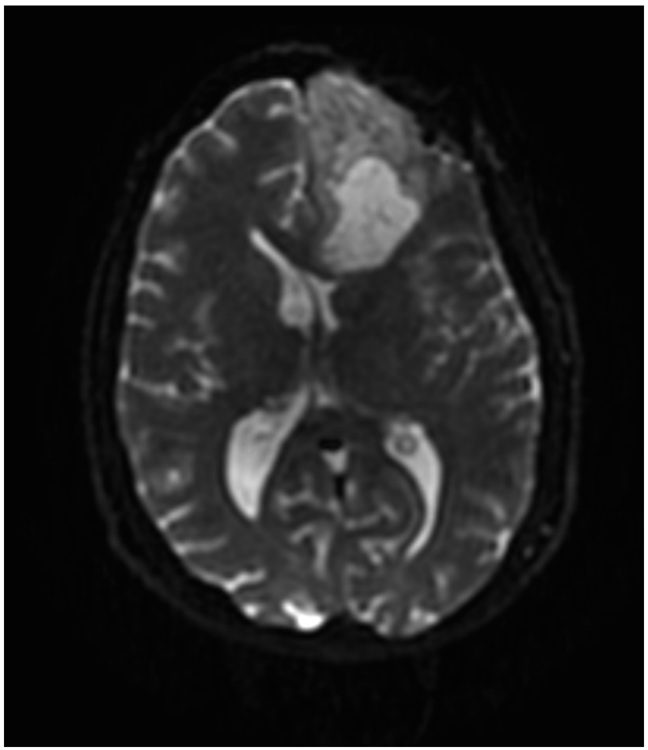


Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

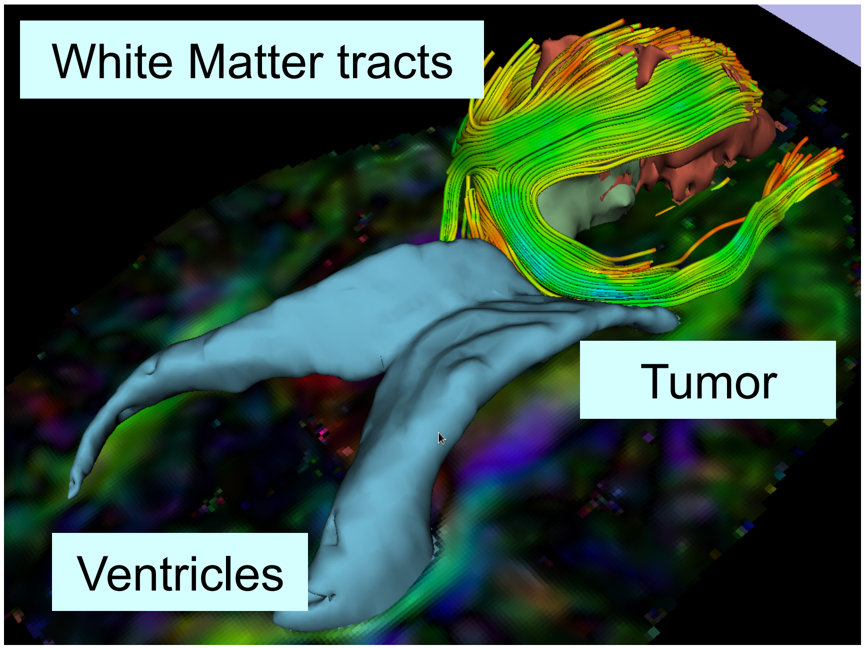
Diffusion Tensor Imaging (DTI) Tractography has the potential to bring valuable spatial information on tumor infiltration and tract displacement for neurosurgical planning of tumor resection.

Clinical Case



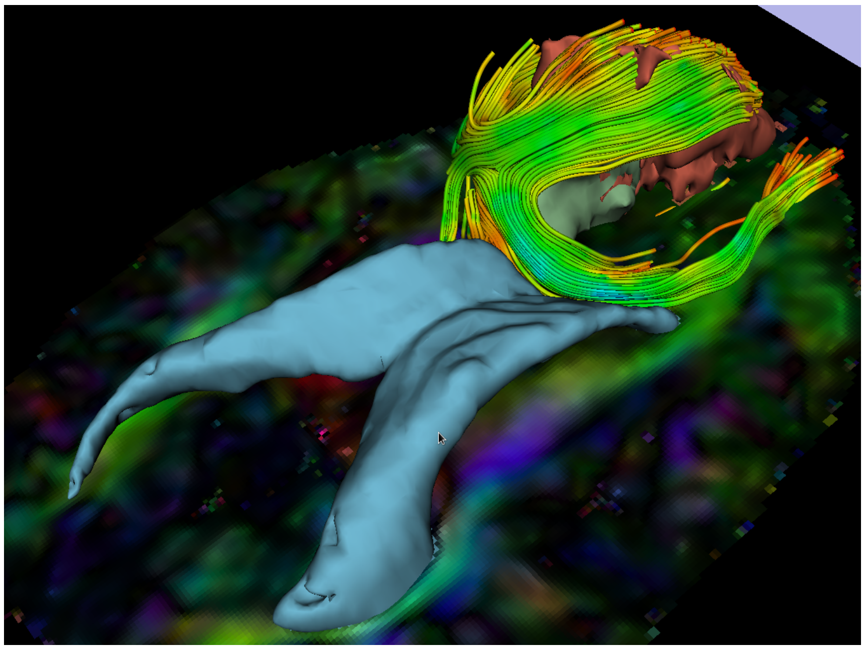
- 35 year-old male diagnosed with Glioblastoma multiforme
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal



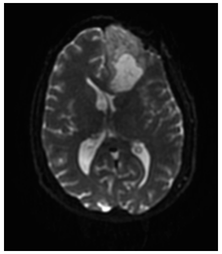
The goal of this tutorial is to explore white matter fibers surrounding a tumor using Diffusion Tensor Imaging (DTI) Tractography.

Image Analysis Pipeline

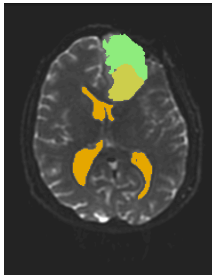


The image analysis pipeline described in this tutorial uses three different algorithms: the "Grow Cut" algorithm for segmentation of the tumor parts, the Marching Cube algorithm for surface modeling, and the single tensor streamline tractography algorithm for tract generation.

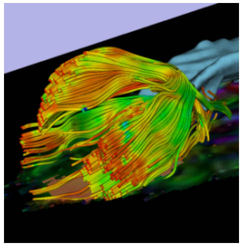
Overview of the analysis pipeline



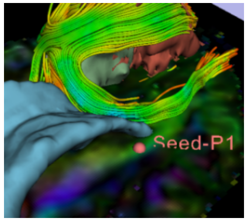
Part 1: Loading &Visualization of Diffusion Data



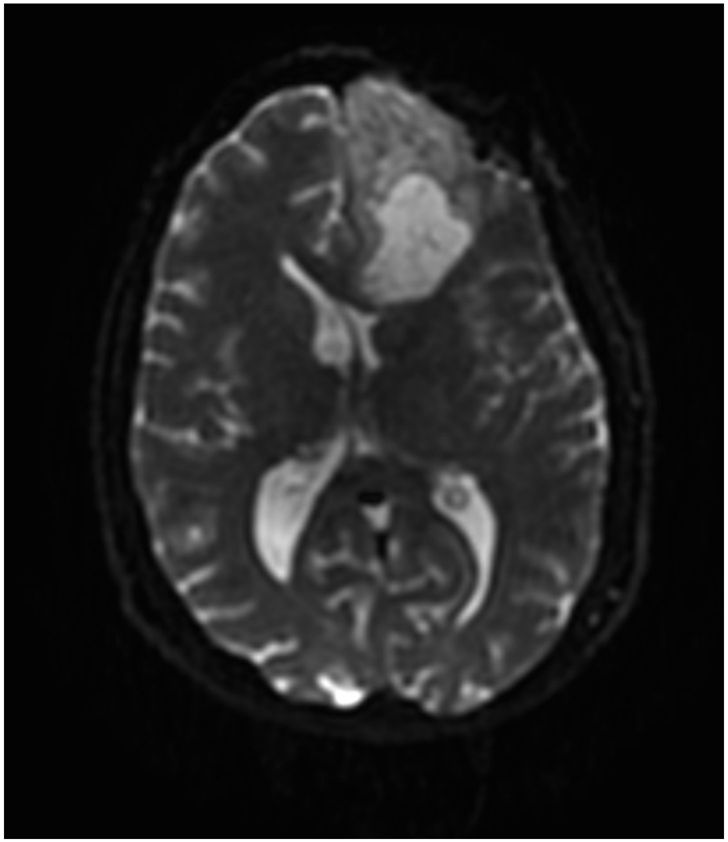
Part 2: Segmentation of the ventricles, and solid and cystic parts of the tumor



Part 3: Tractography reconstruction of the white matter fibers in the peri-tumoral volume

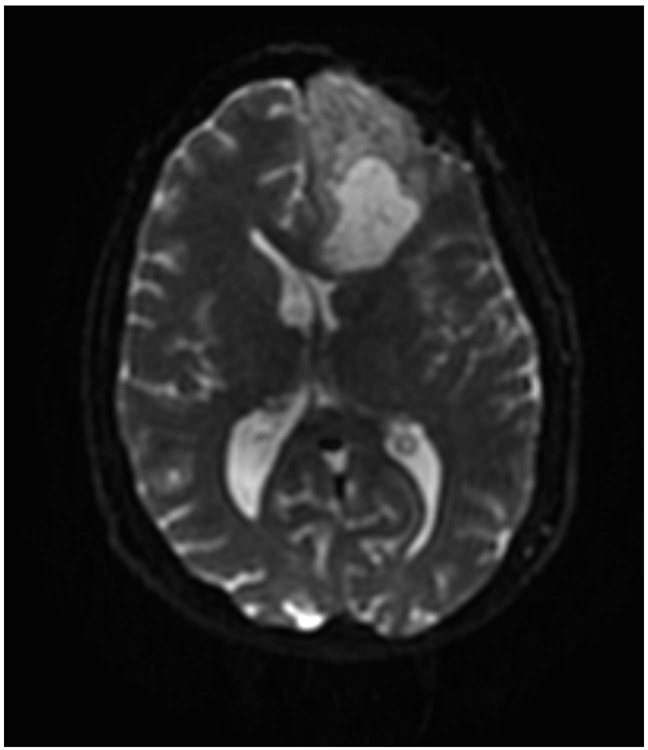


Part 4: Tractography exploration of the ipsilateral and contralateral side



Part 1: Loading and Visualization of Diffusion Data

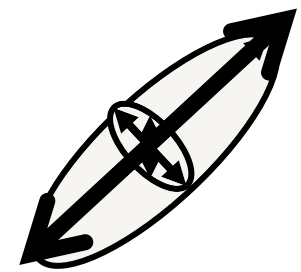
Diffusion Tensor Imaging



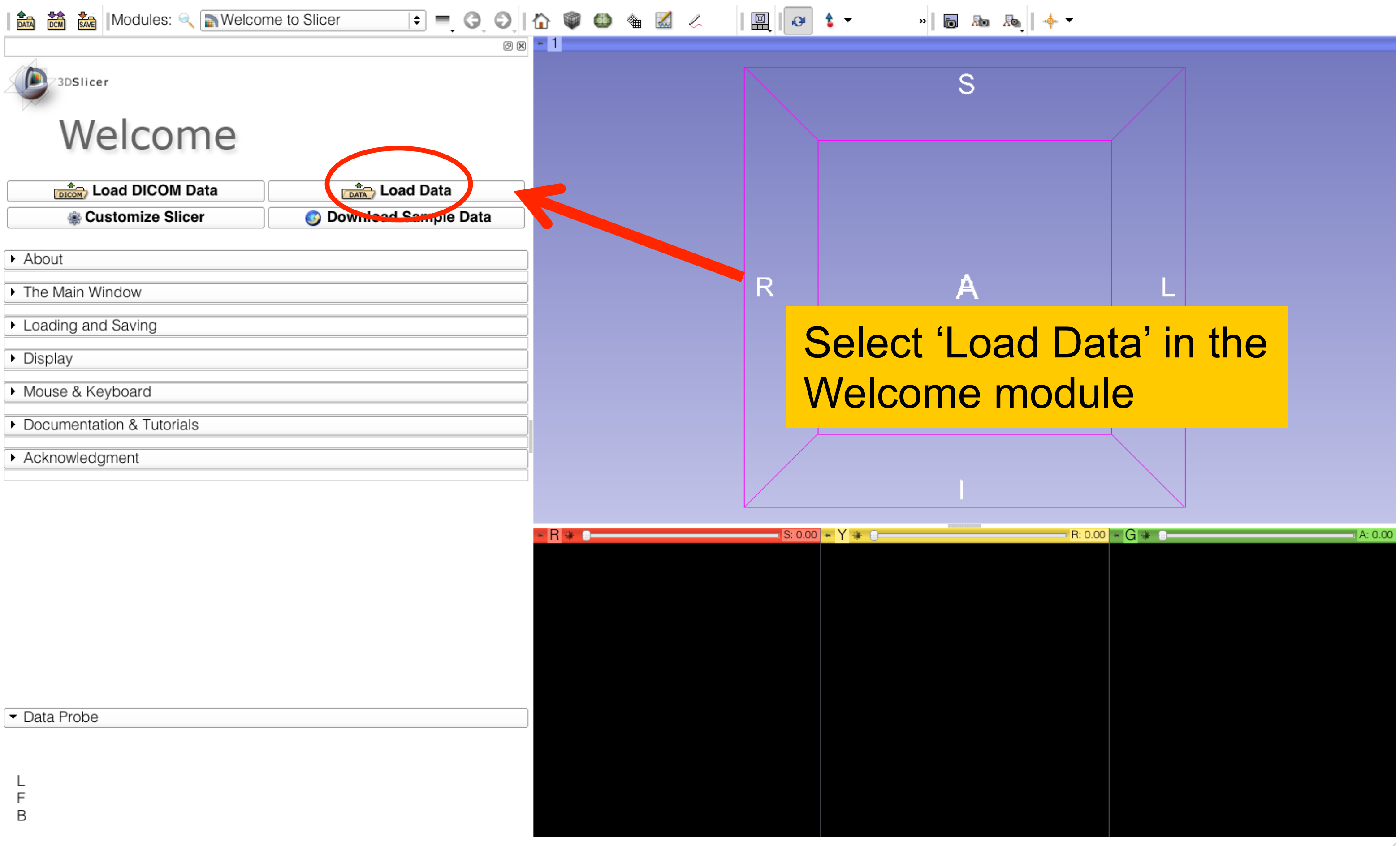
$$S_i = S_0 e^{-b\hat{g}_i^T \underline{D} \hat{g}_i}$$

(Stejskal and Tanner 1965, Basser 1994)

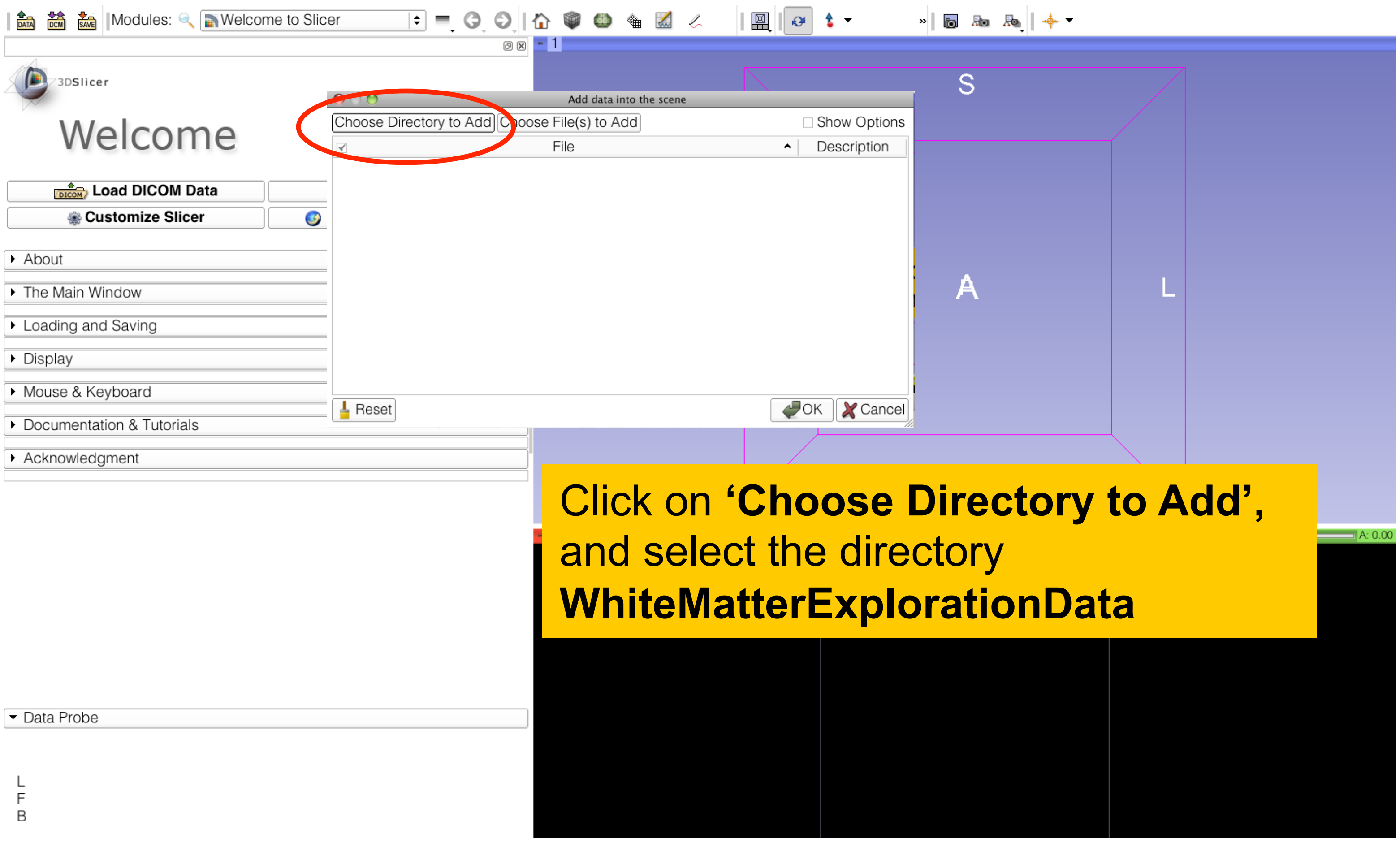
$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$



Loading DTI and Baseline Data

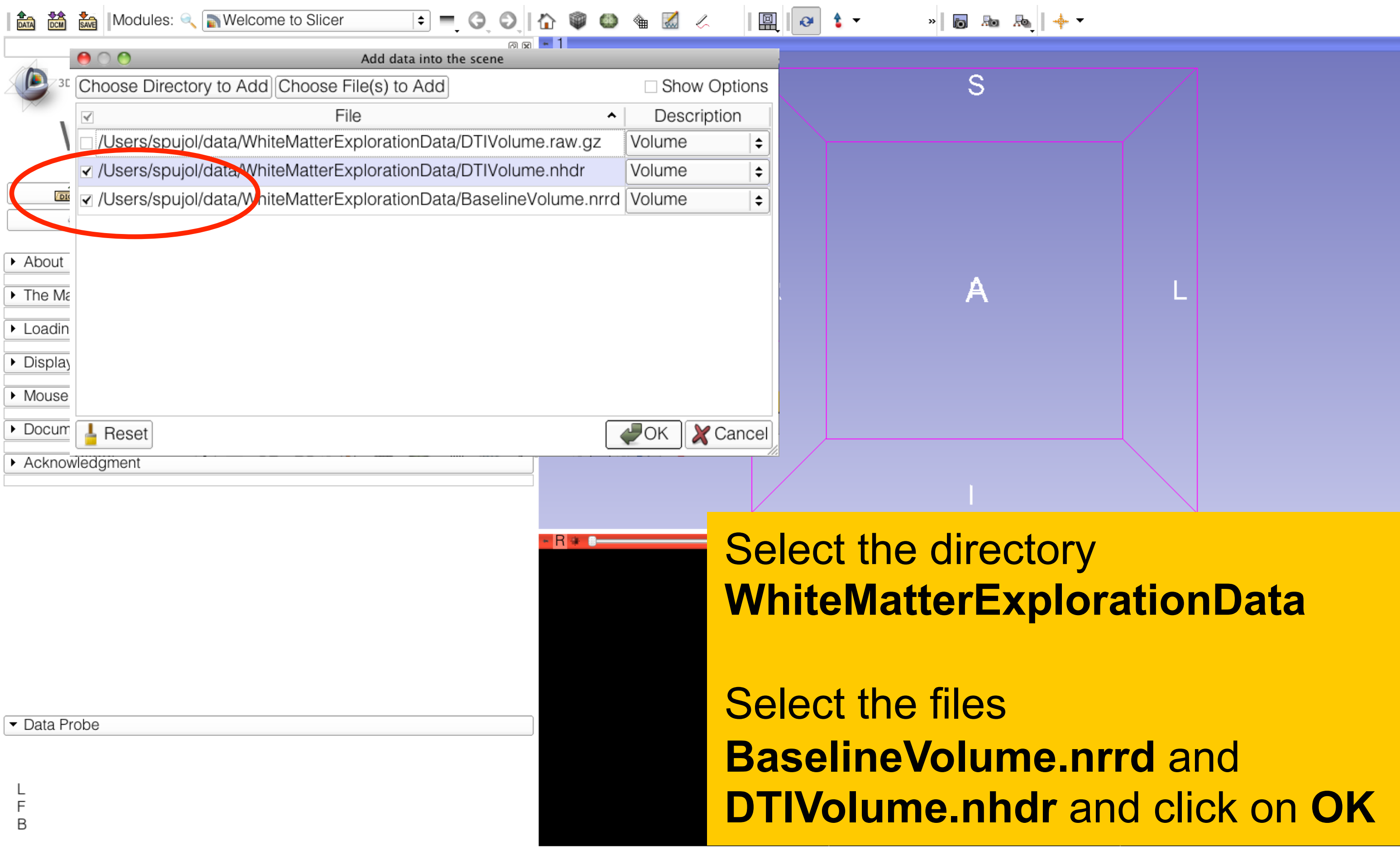


Loading DTI and Baseline Data



Click on **'Choose Directory to Add'**, and select the directory **WhiteMatterExplorationData**

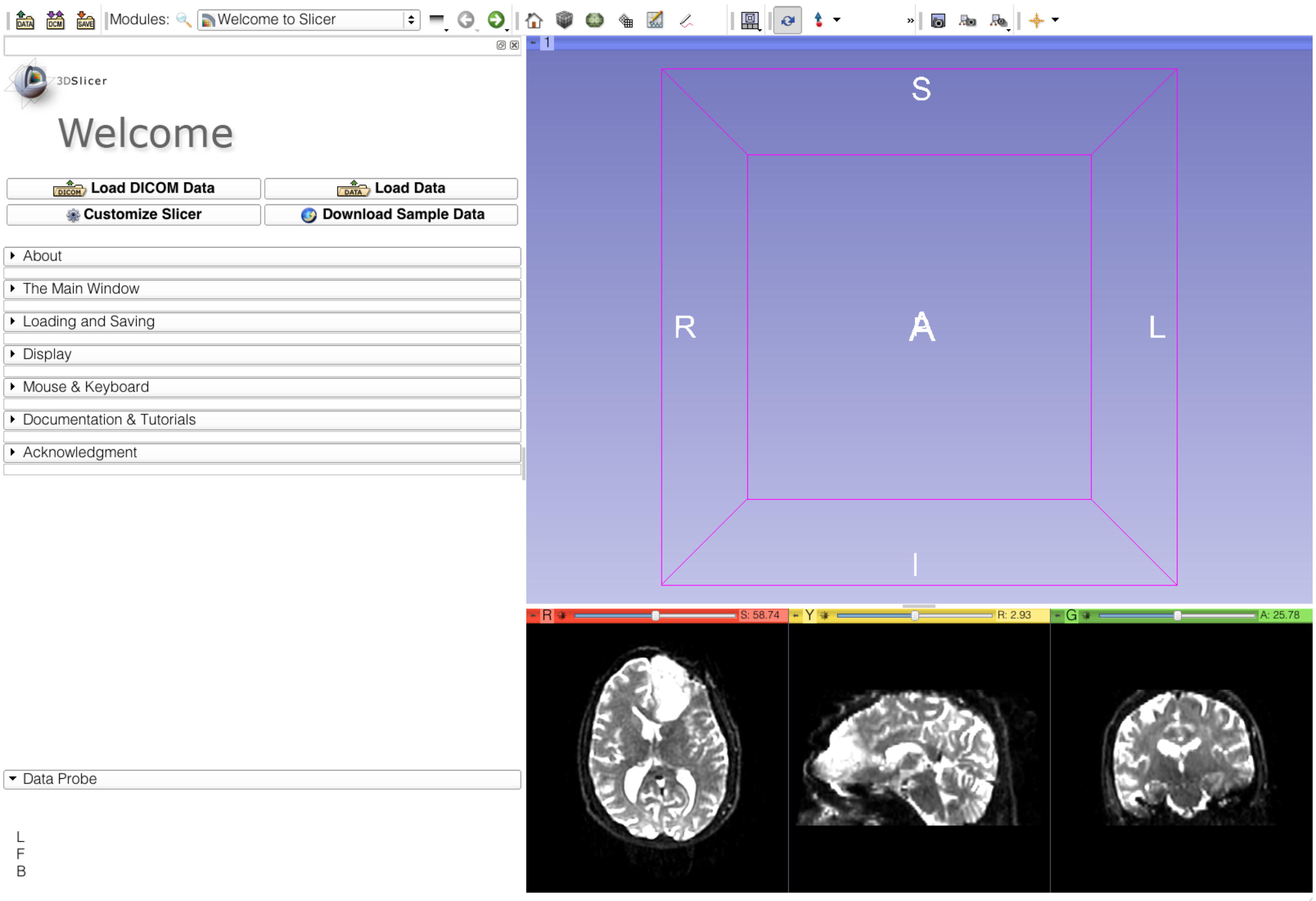
Loading DTI and Baseline Data



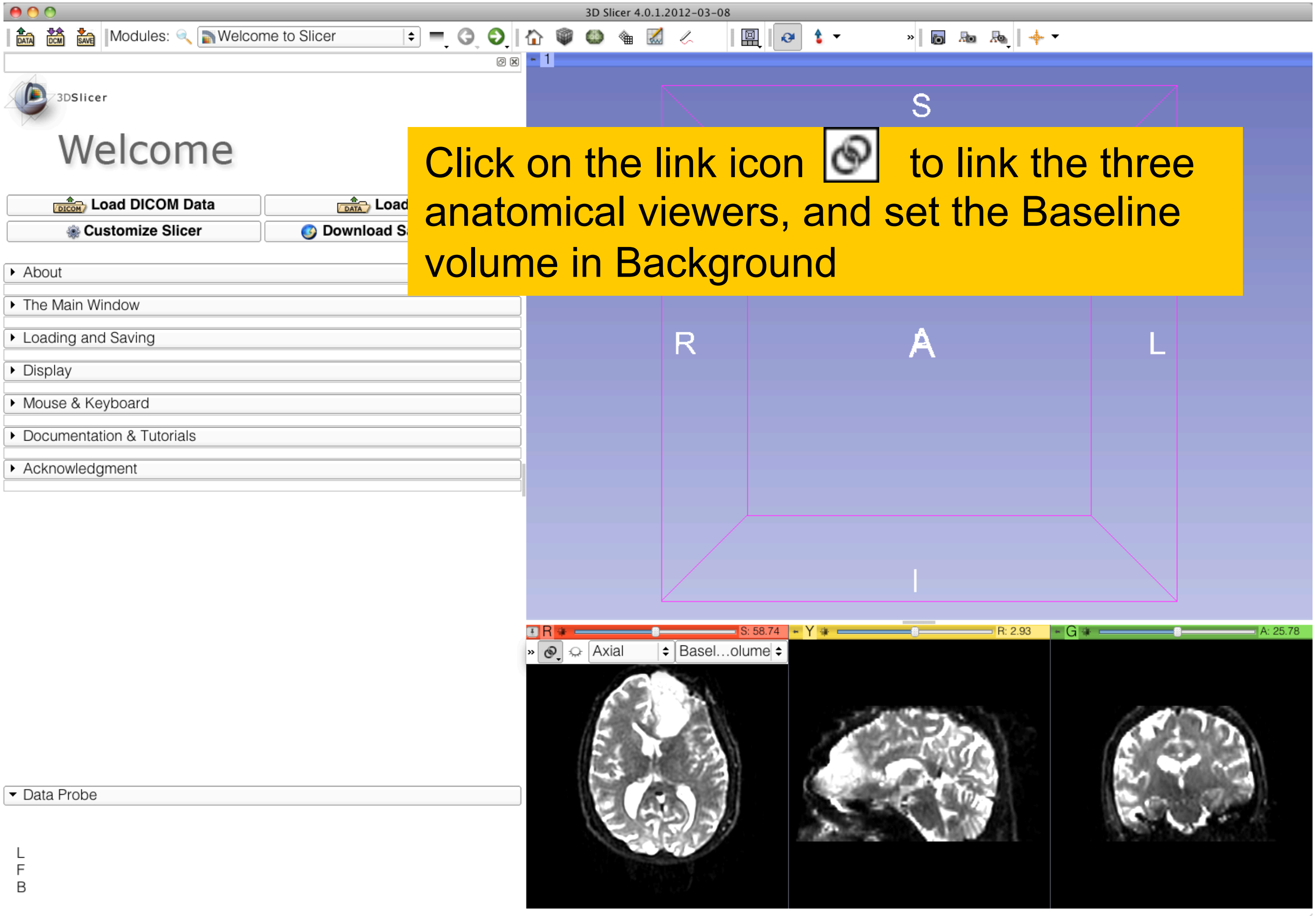
Select the directory **WhiteMatterExplorationData**

Select the files **BaselineVolume.nrrd** and **DTIVolume.nhdr** and click on **OK**

Loading DTI and Baseline Data

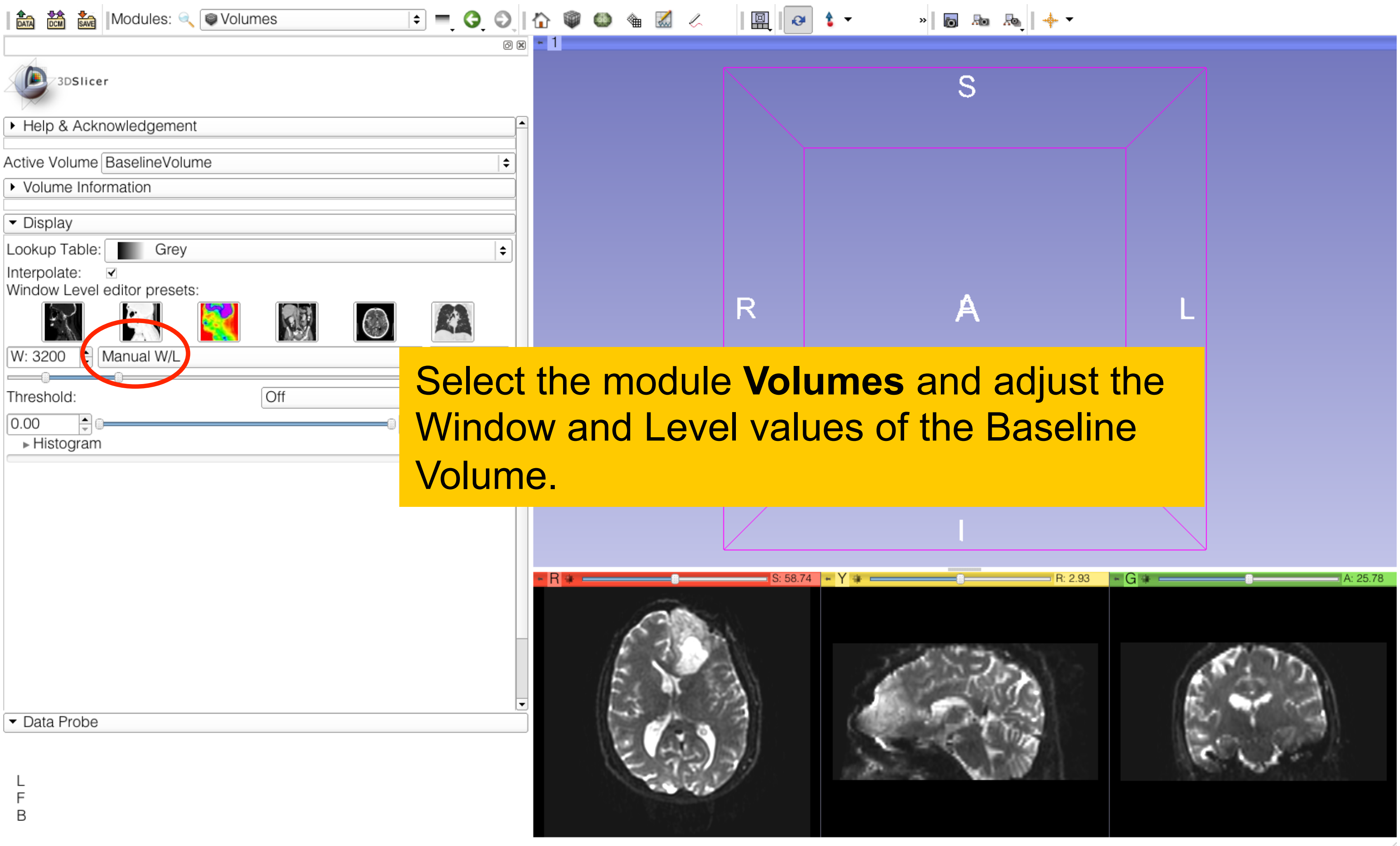


Loading DTI and Baseline Data



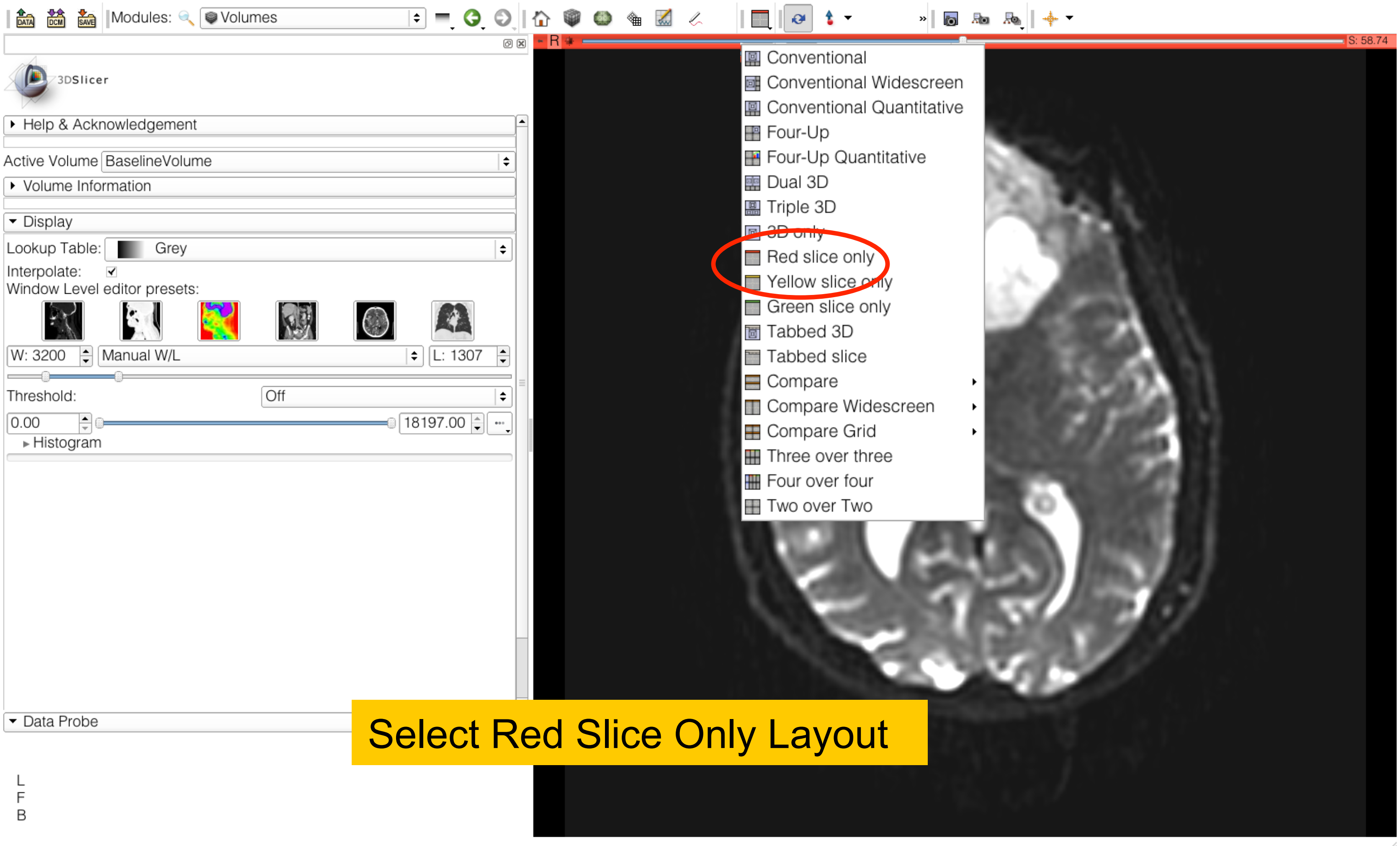
Click on the link icon [link icon] to link the three anatomical viewers, and set the Baseline volume in Background

Loading DTI and Baseline Data

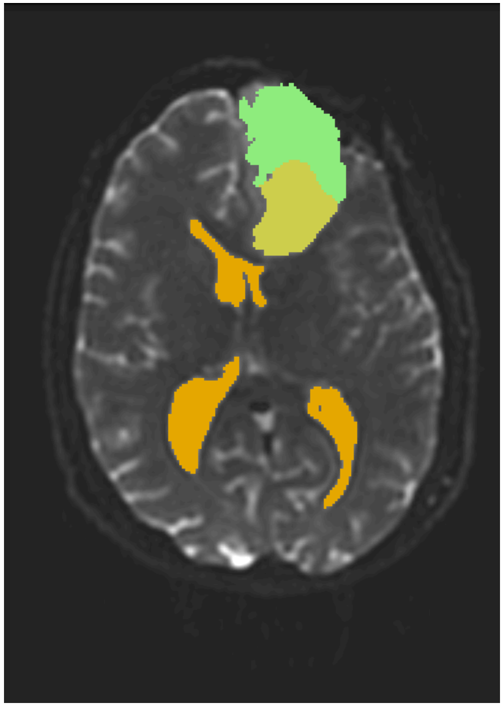


Select the module **Volumes** and adjust the Window and Level values of the Baseline Volume.

Loading DTI and Baseline Data

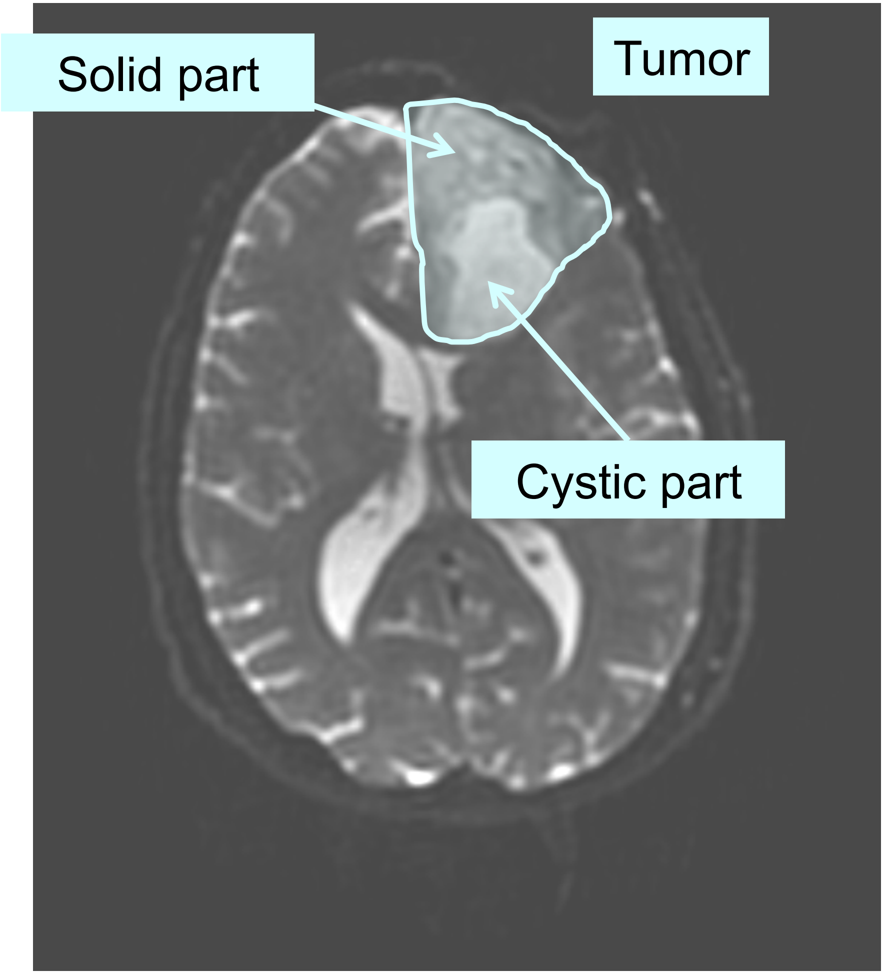


Select Red Slice Only Layout



Part 1: Segmenting the tumor and ventricles

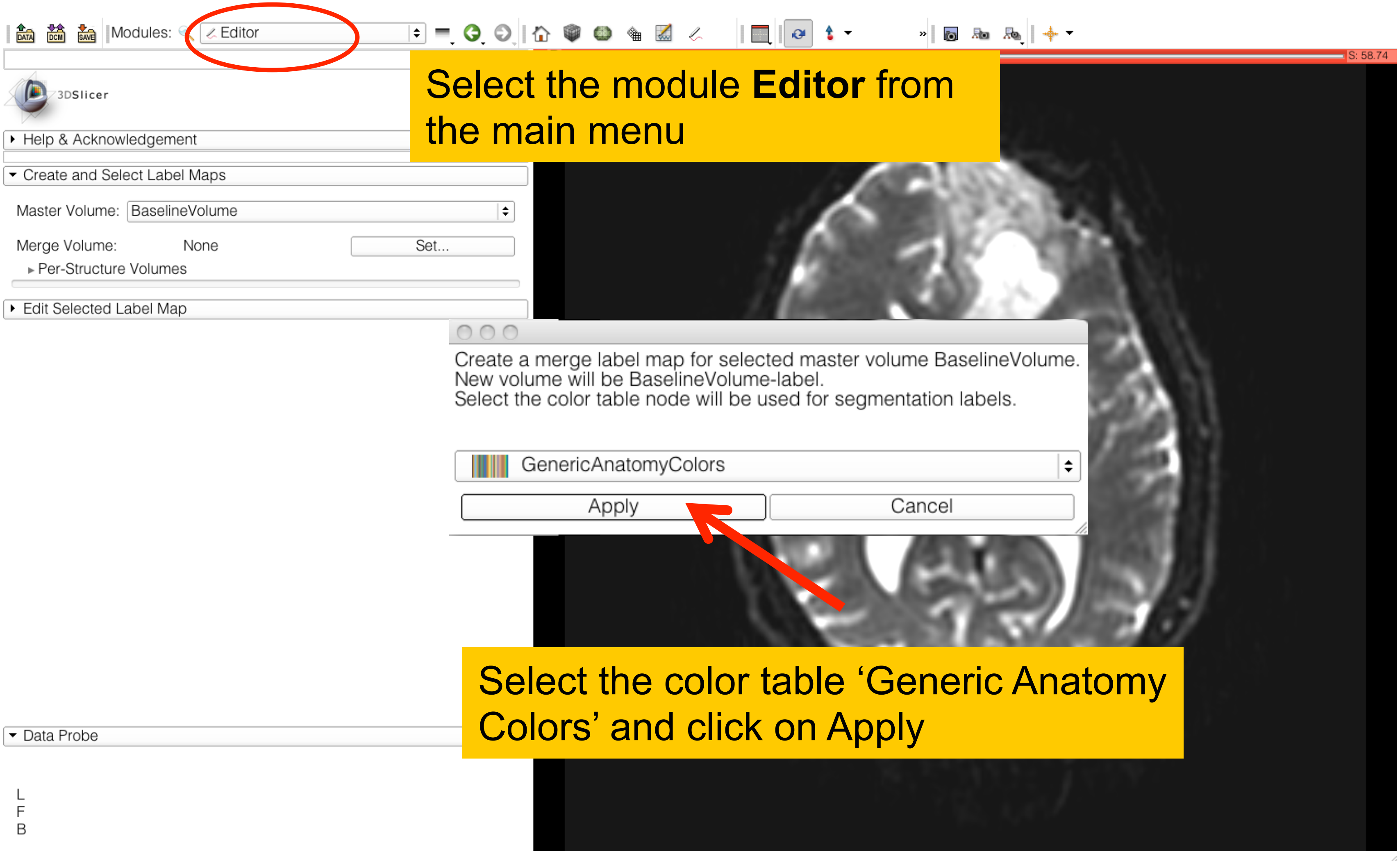
Tumor Segmentation



The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

In this section, we will segment the different parts of the tumor using a Grow Cut Segmentation algorithm.

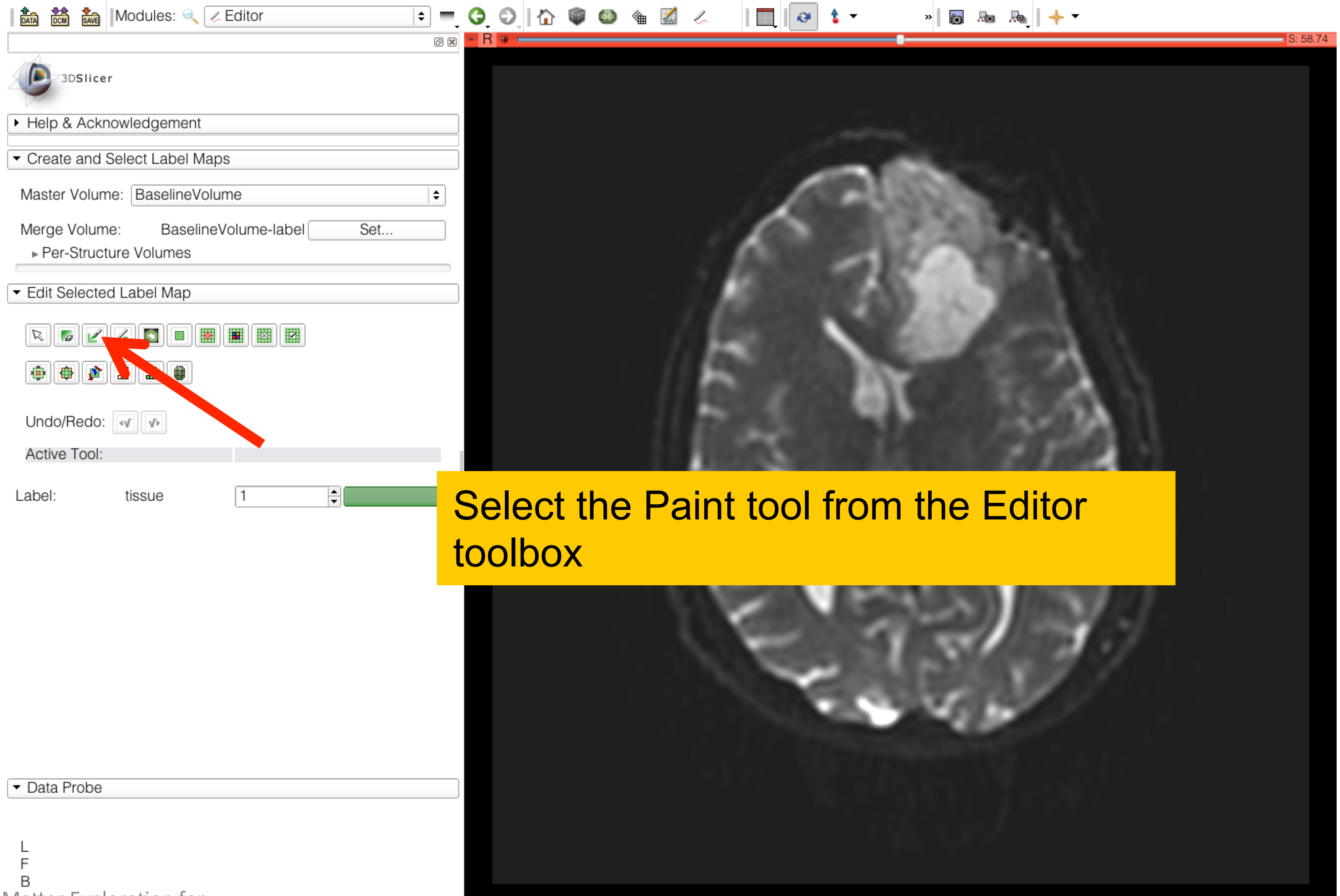
Tumor Segmentation



Select the module **Editor** from the main menu

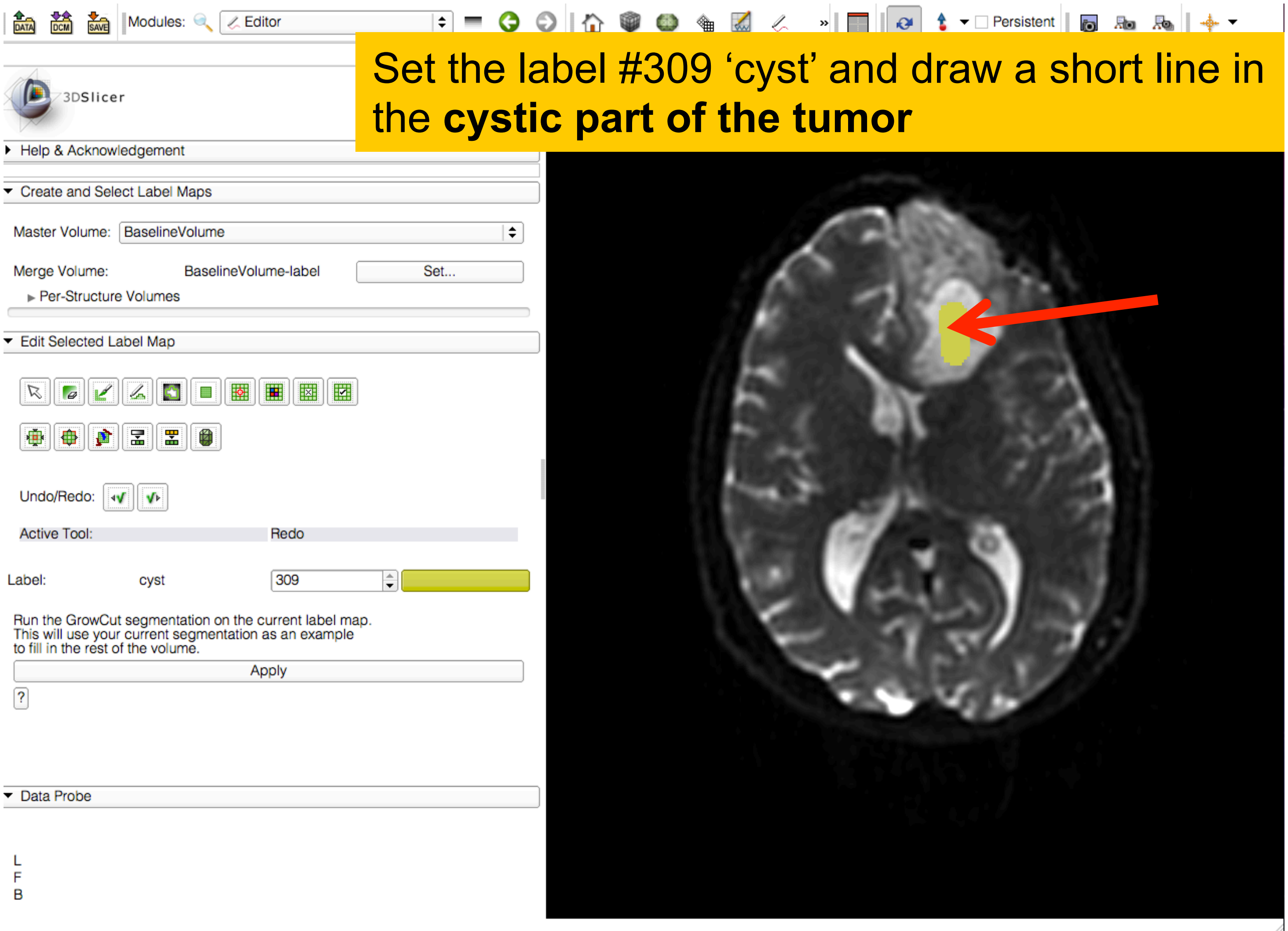
Select the color table 'Generic Anatomy Colors' and click on Apply

Tumor Segmentation

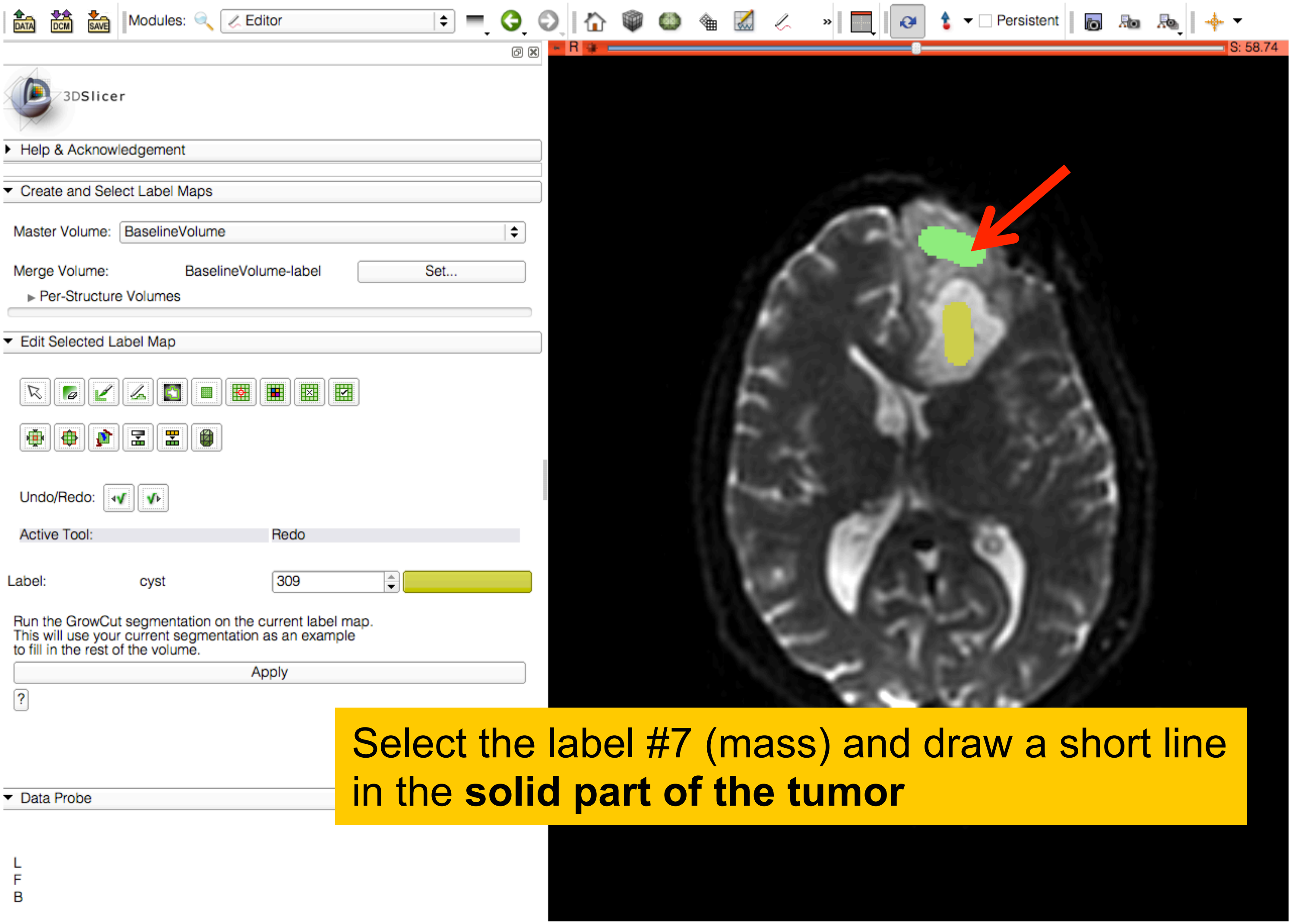


Select the Paint tool from the Editor toolbox

Tumor Segmentation

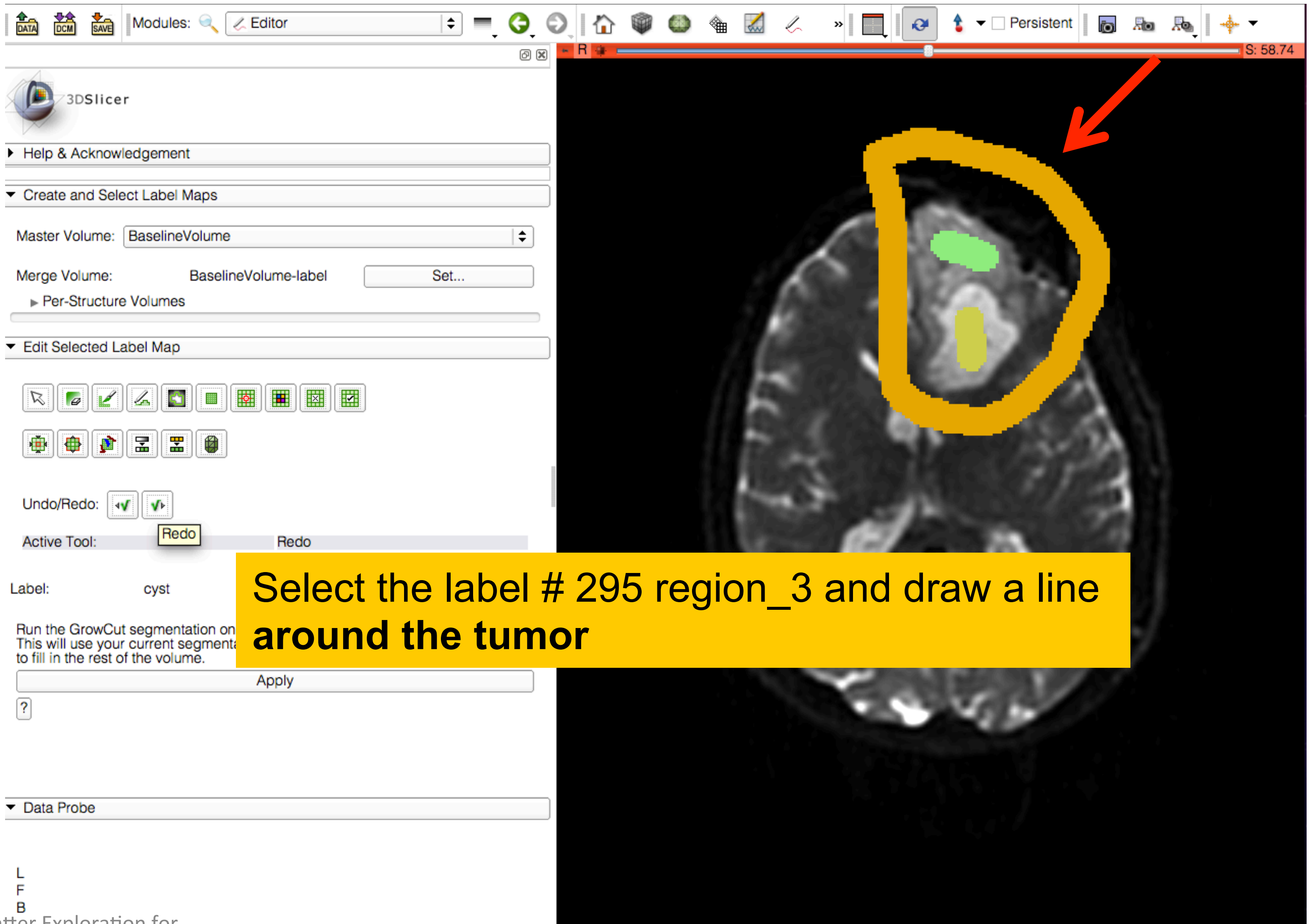


Tumor Segmentation



Select the label #7 (mass) and draw a short line in the **solid part of the tumor**

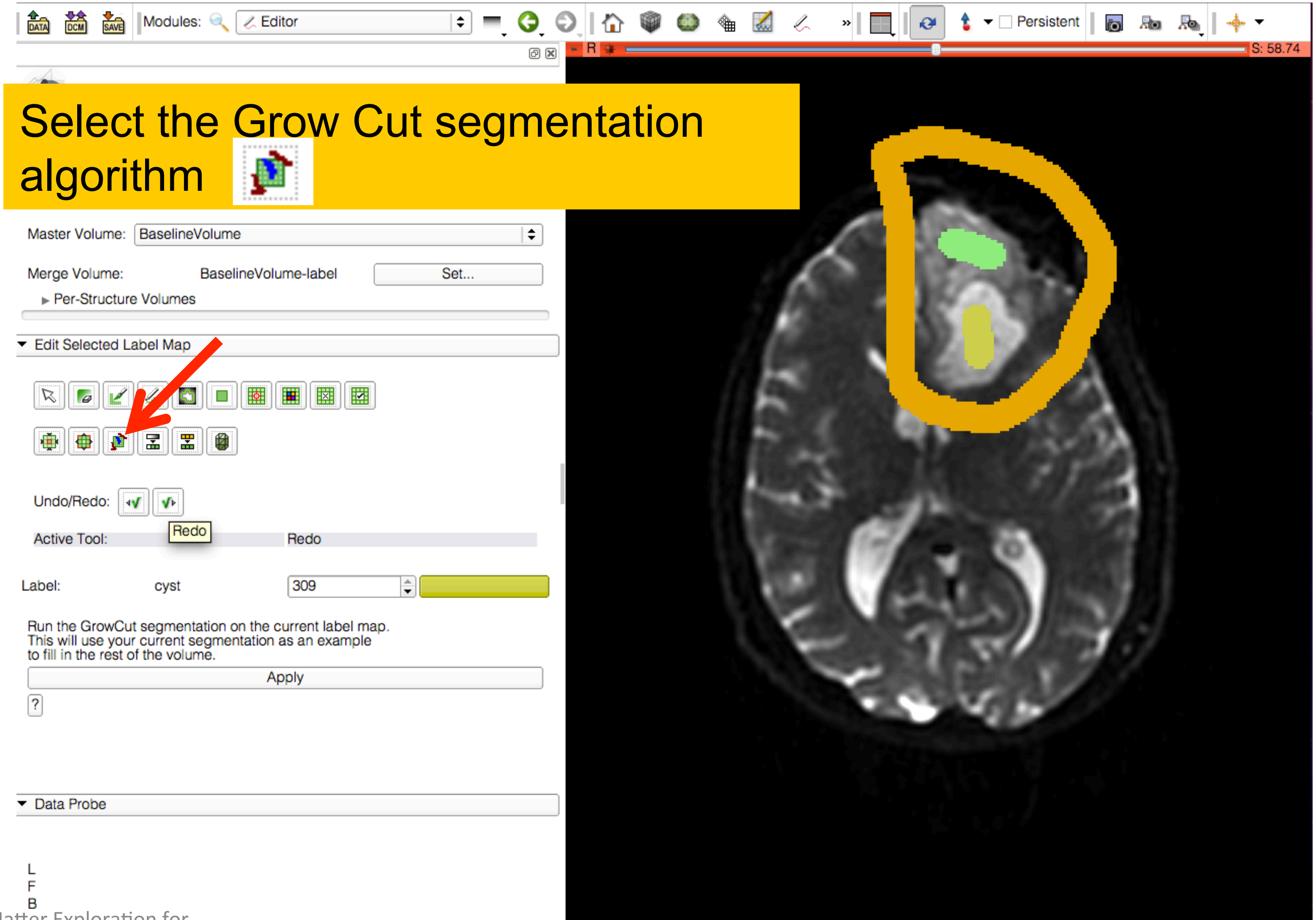
Tumor Segmentation



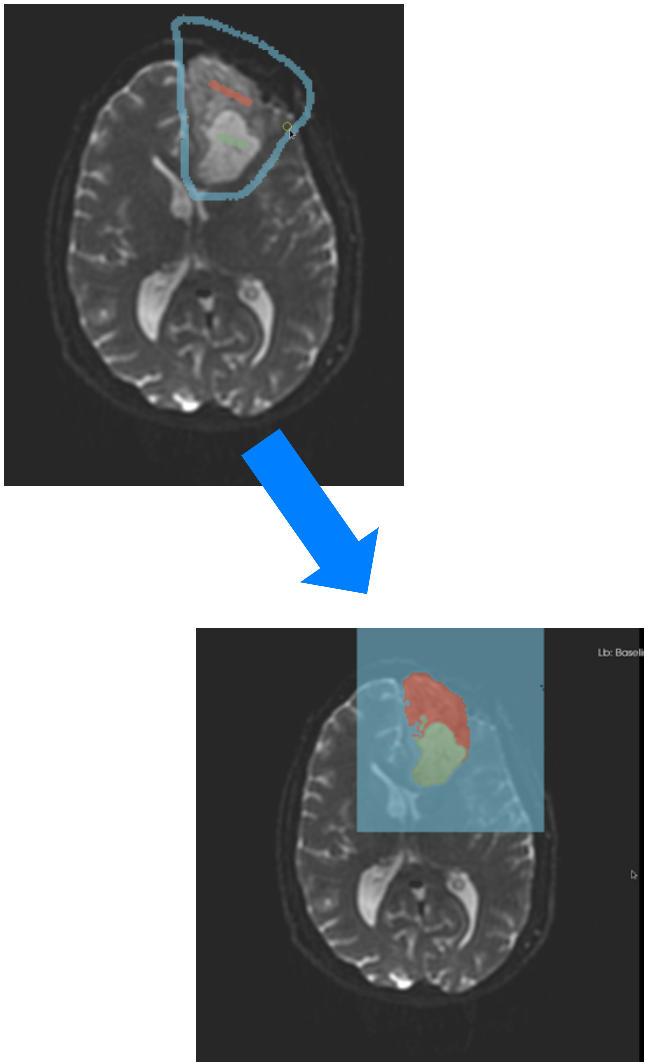
Select the label # 295 region_3 and draw a line **around the tumor**

Tumor Segmentation

Select the Grow Cut segmentation algorithm



Grow Cut Segmentation



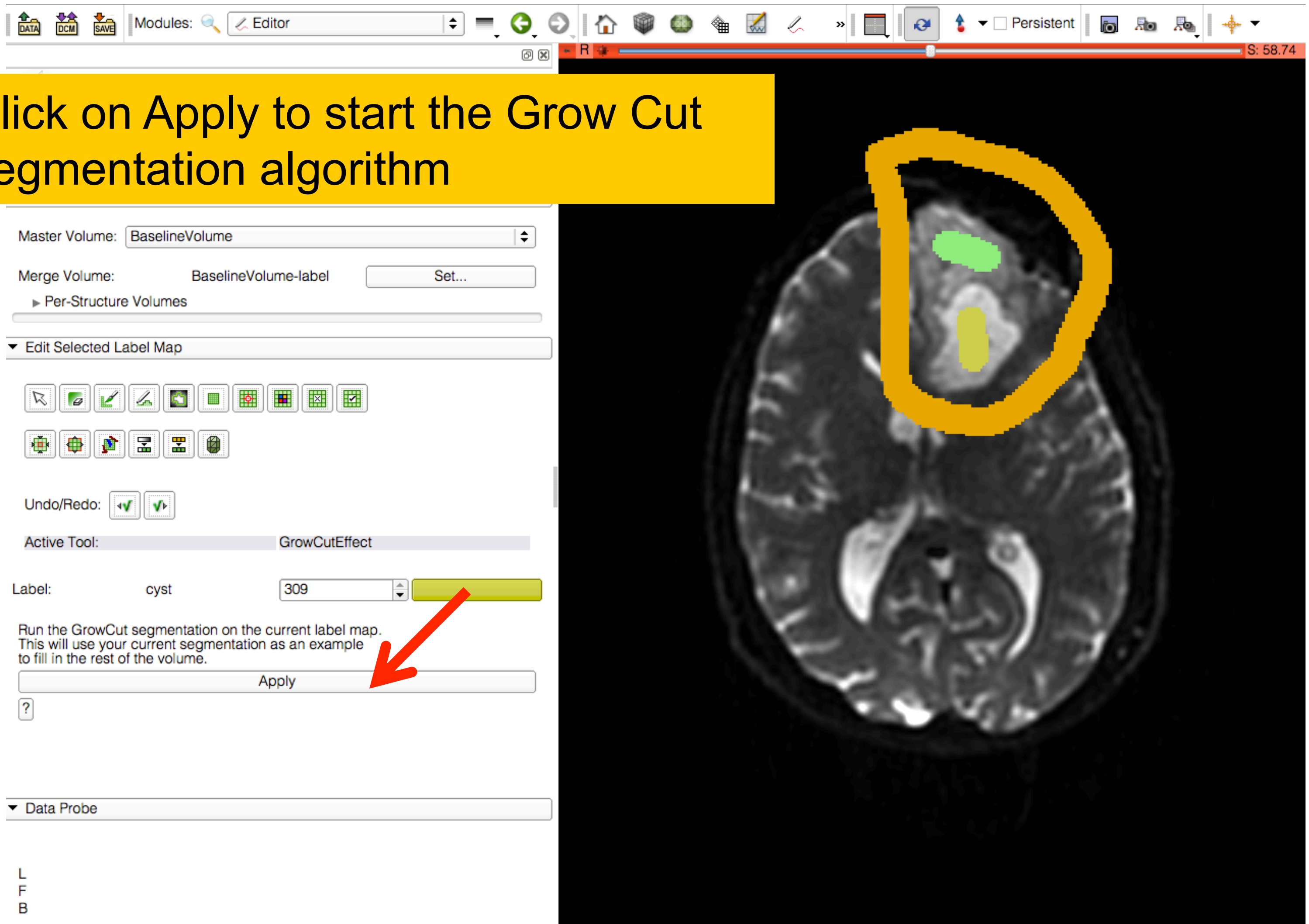
- The **Grow Cut Segmentation method** is a competitive region growing algorithm using Cellular Automata.

- The algorithm performs multi-label image segmentation using a set of user input scribbles.

- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". *Proc. Graphicon*. 2005 . pp. 150–156.

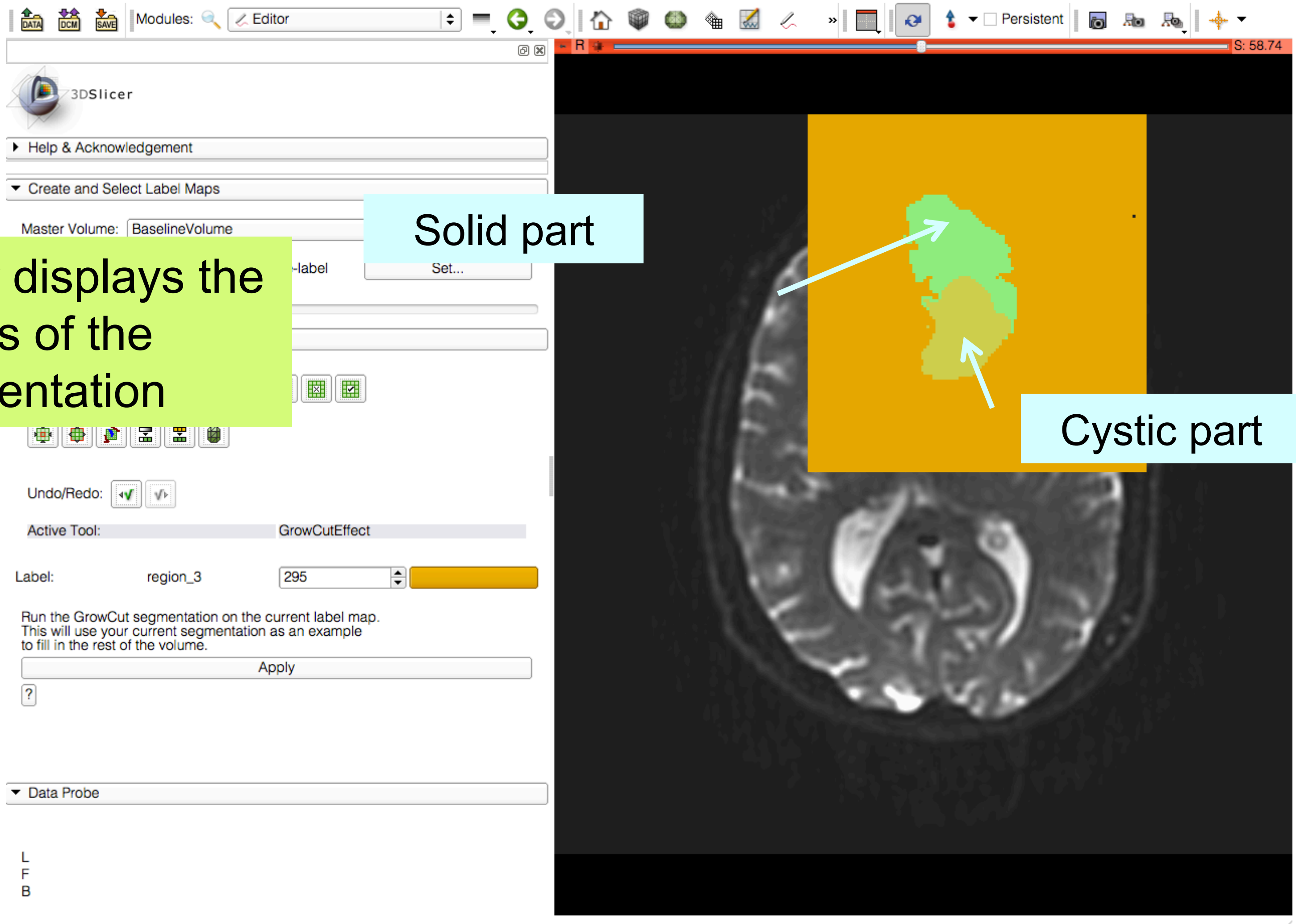
Tumor Segmentation

Click on Apply to start the Grow Cut segmentation algorithm

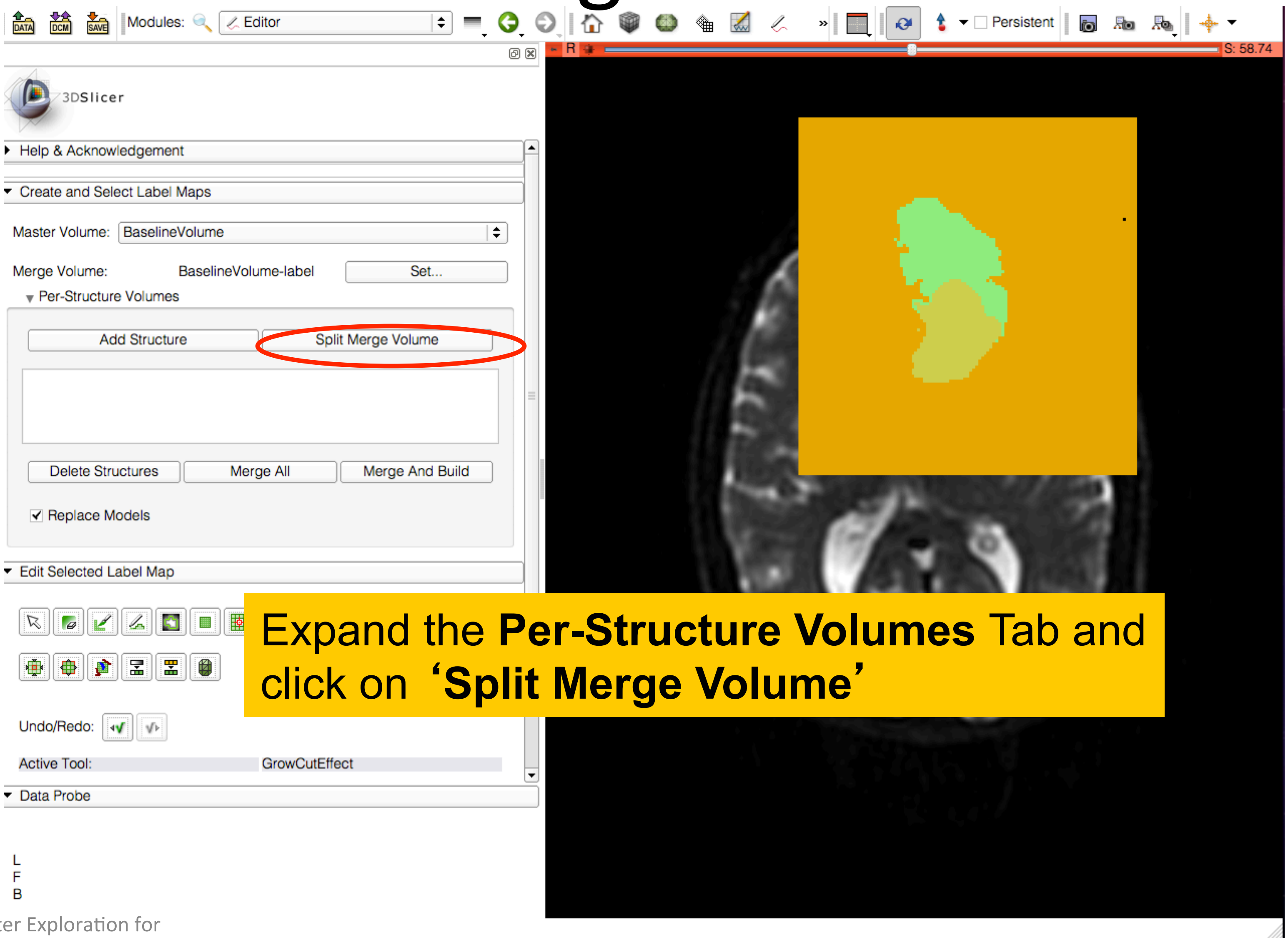


Tumor Segmentation

Slicer displays the results of the segmentation

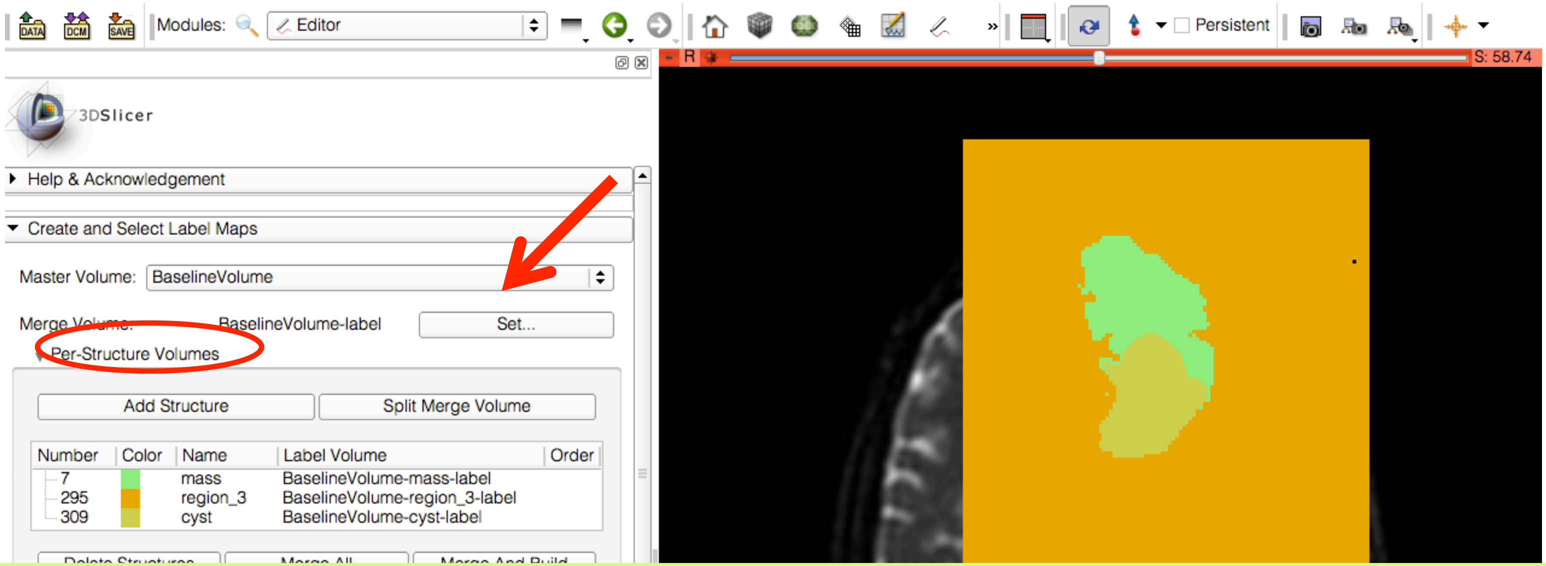


Tumor Segmentation



Expand the **Per-Structure Volumes** Tab and click on **'Split Merge Volume'**

Tumor Segmentation



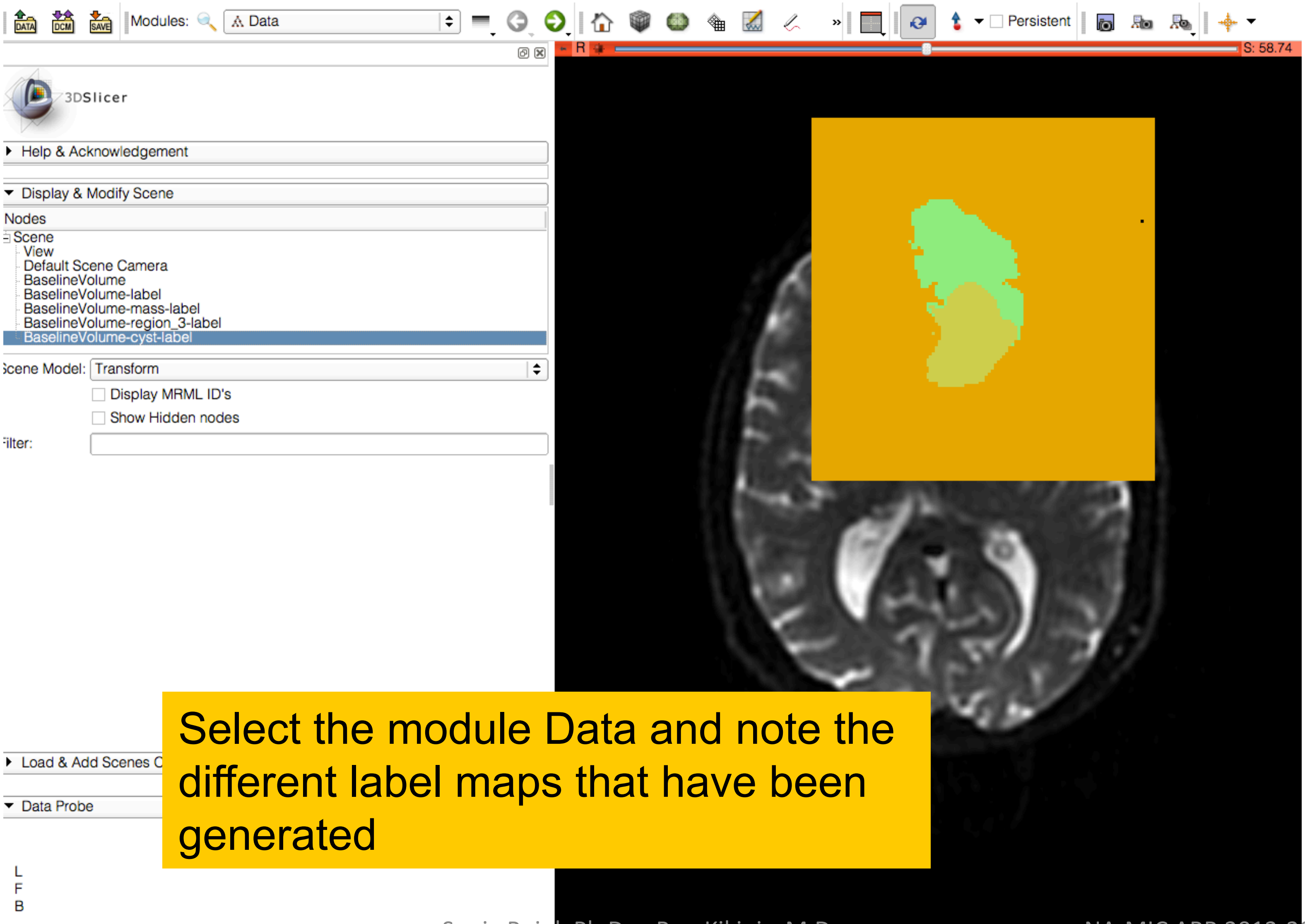
The label map **BaselineVolume-label** has been split into three volumes:

-**BaselineVolume-mass-label**: solid part of the tumor

-**BaselineVolume-cyst-label**: cystic part of the tumor

-**BaselineVolume-region_3-label**: surrounding structures

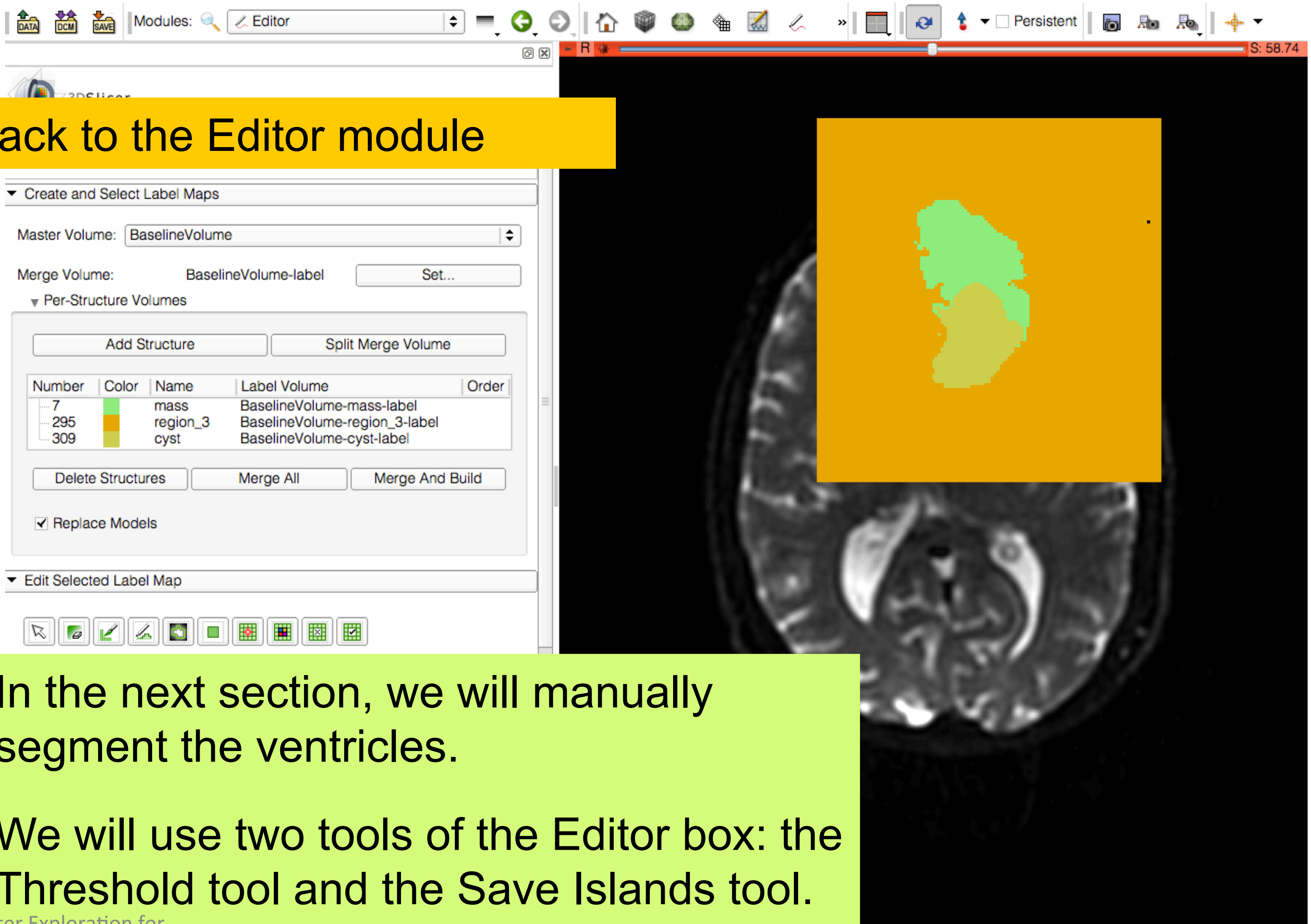
Tumor Segmentation



Select the module Data and note the different label maps that have been generated

Ventricles Segmentation

Go back to the Editor module

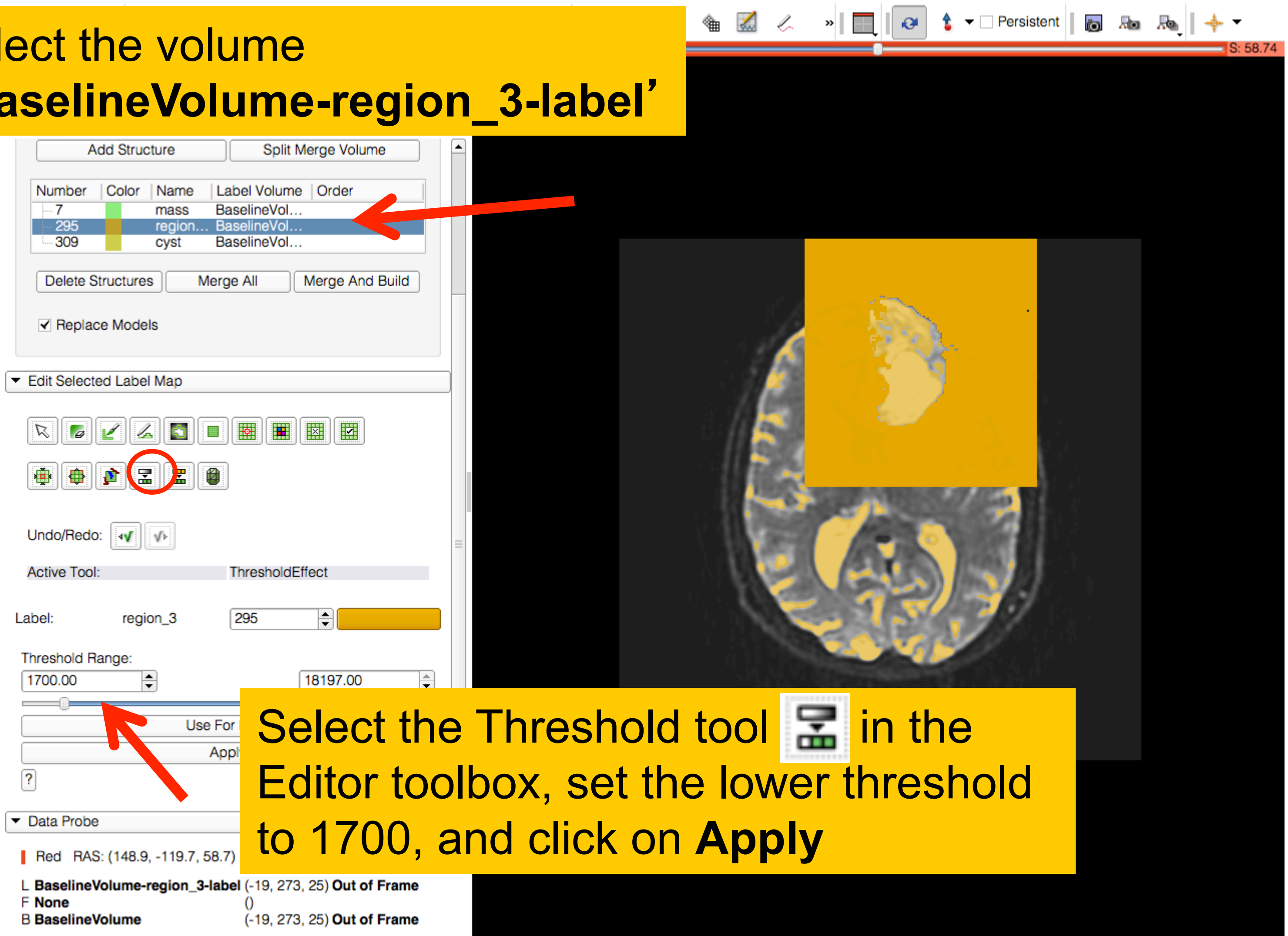


In the next section, we will manually segment the ventricles.

We will use two tools of the Editor box: the Threshold tool and the Save Islands tool.

Ventricles Segmentation

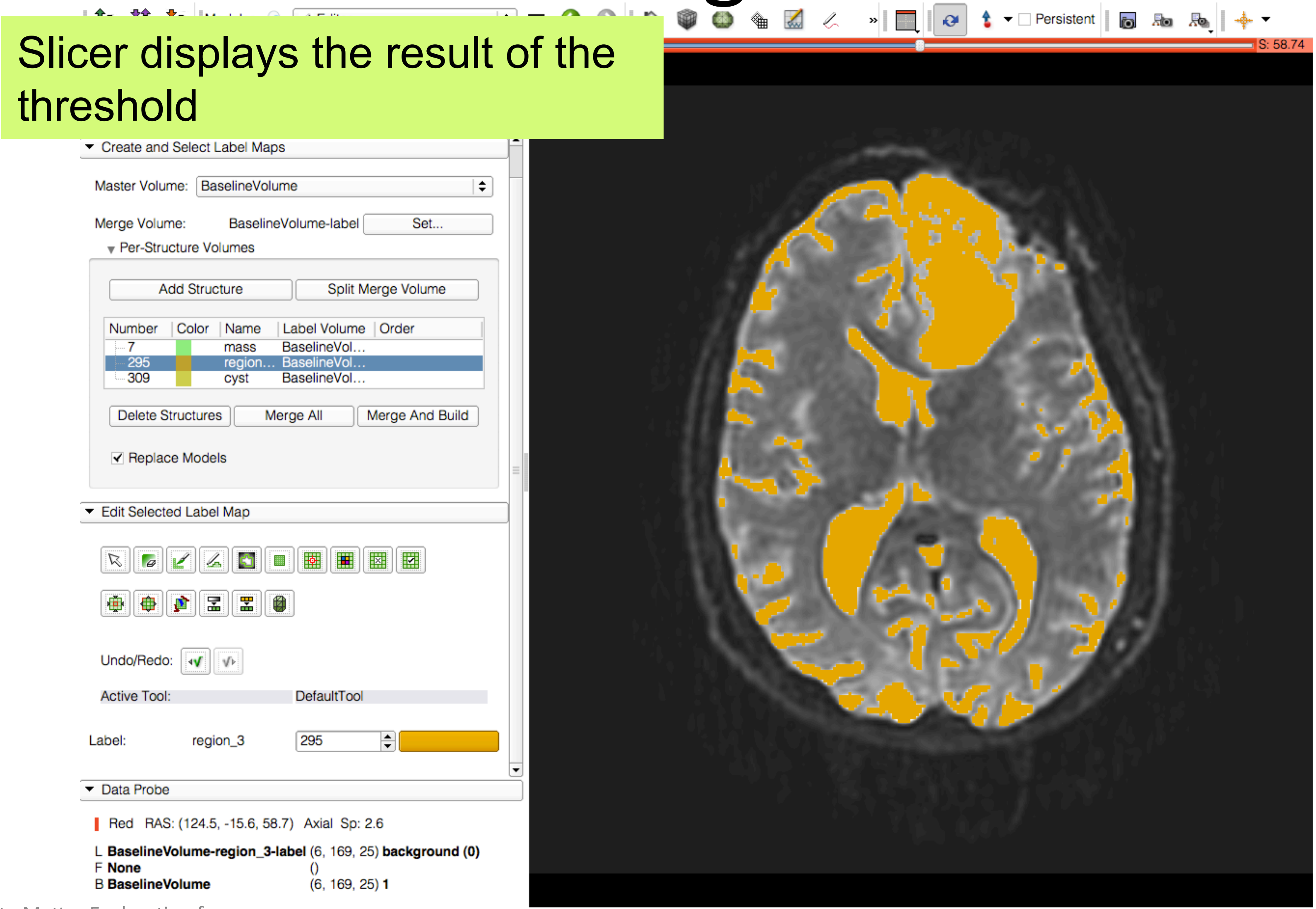
Select the volume
'BaselineVolume-region_3-label'



Select the Threshold tool in the Editor toolbox, set the lower threshold to 1700, and click on **Apply**

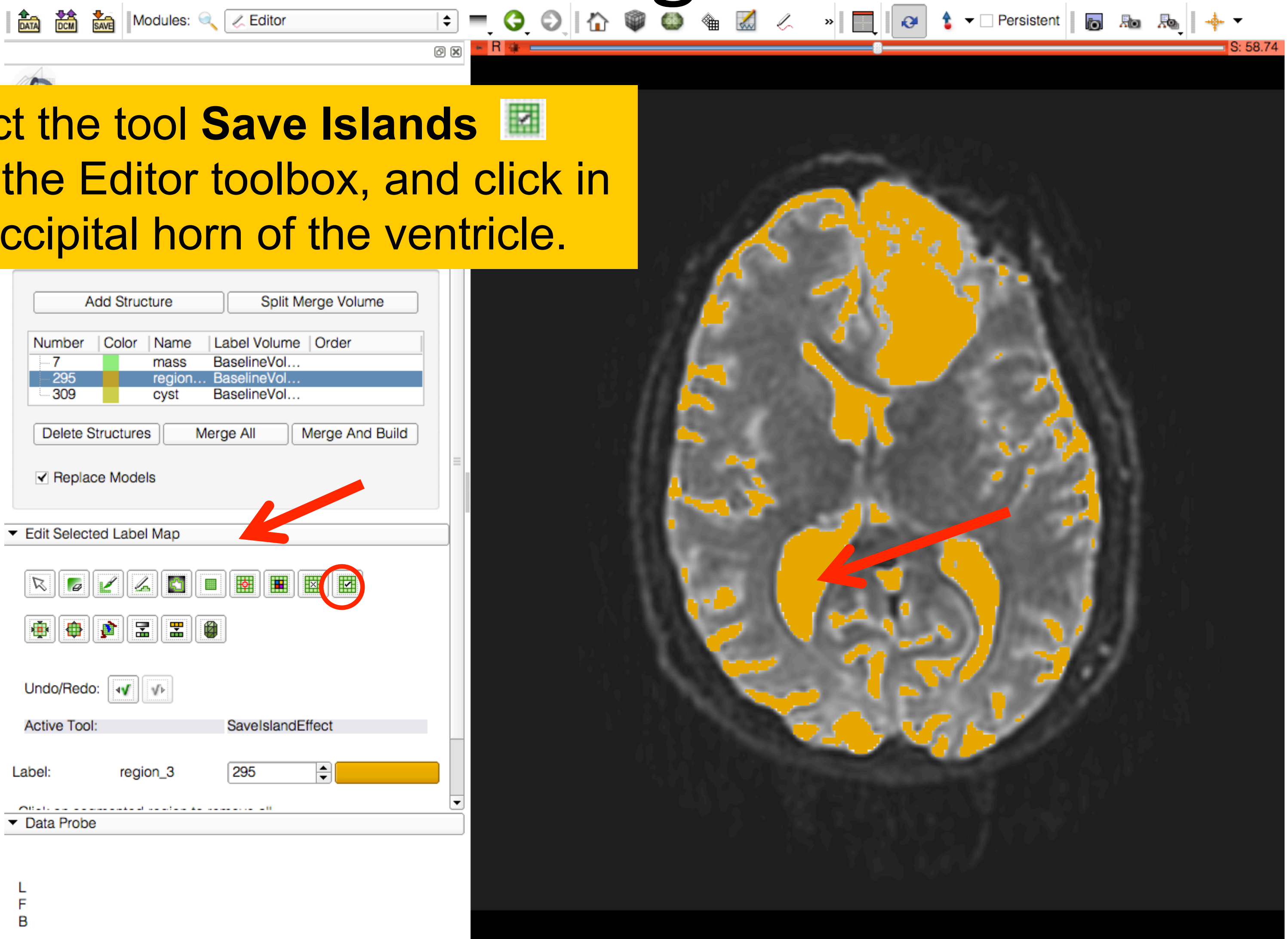
Ventricles Segmentation

Slicer displays the result of the threshold

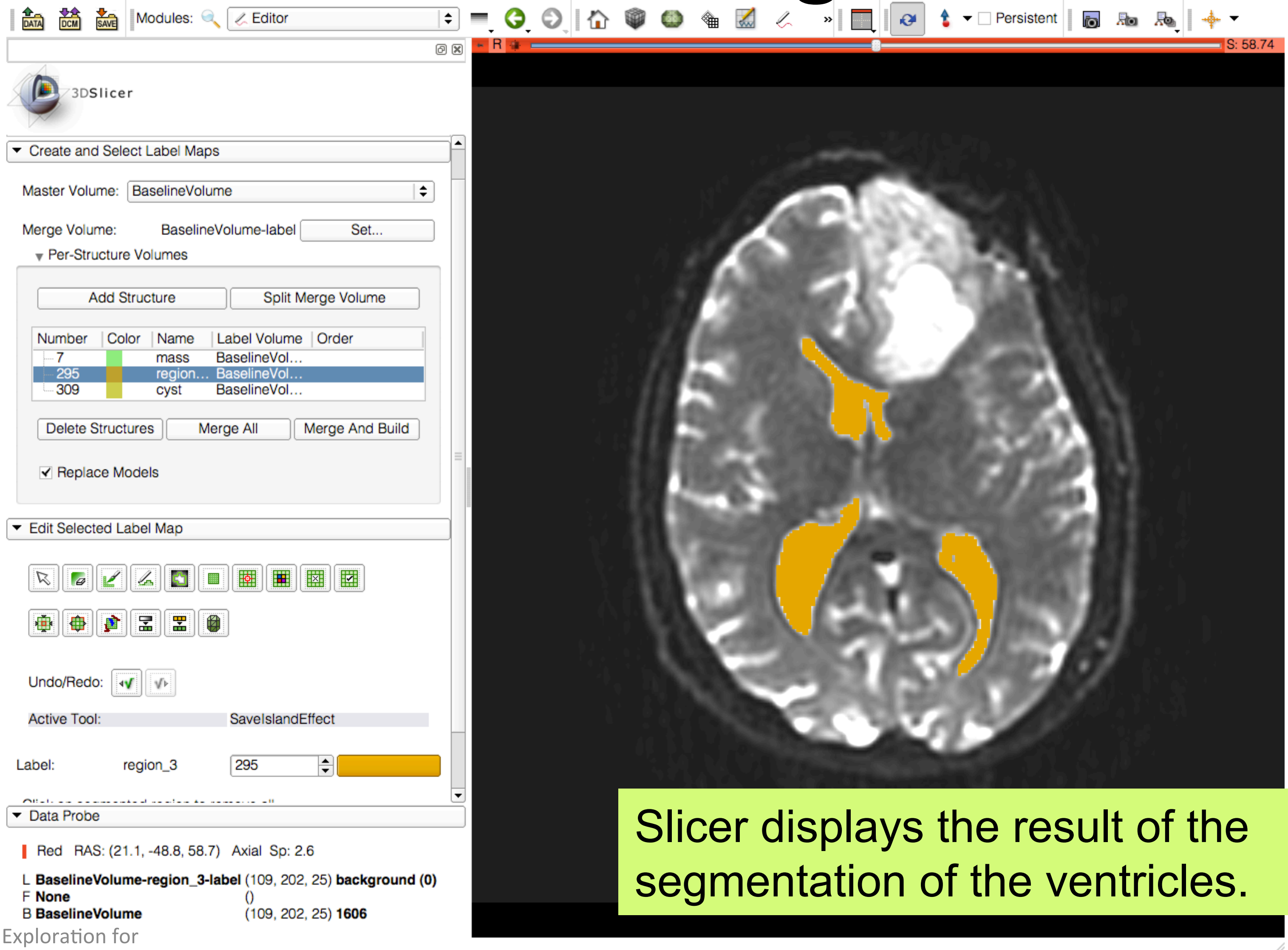


Ventricles Segmentation

Select the tool **Save Islands** from the Editor toolbox, and click in the occipital horn of the ventricle.

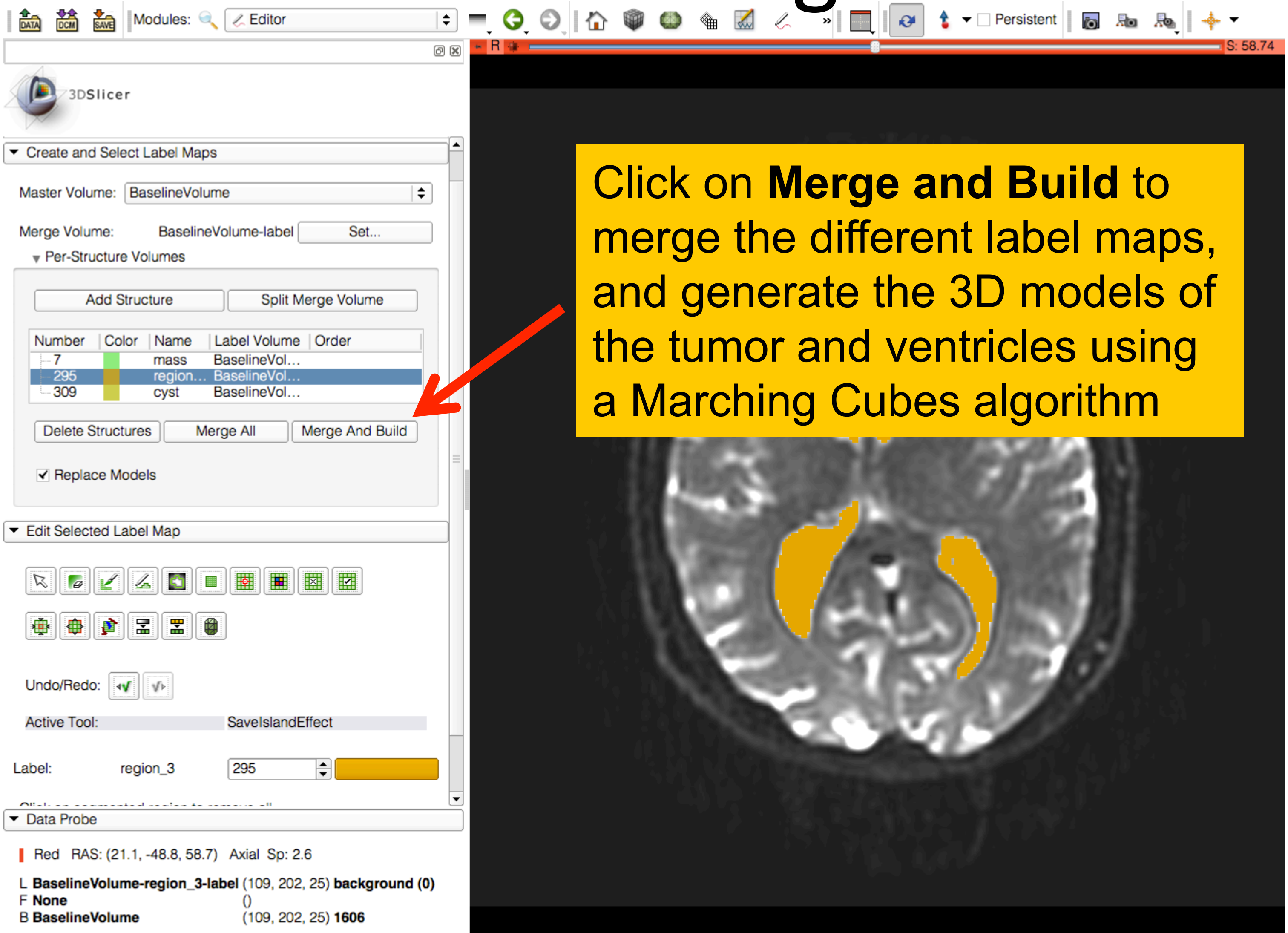


Final Result of the Segmentation



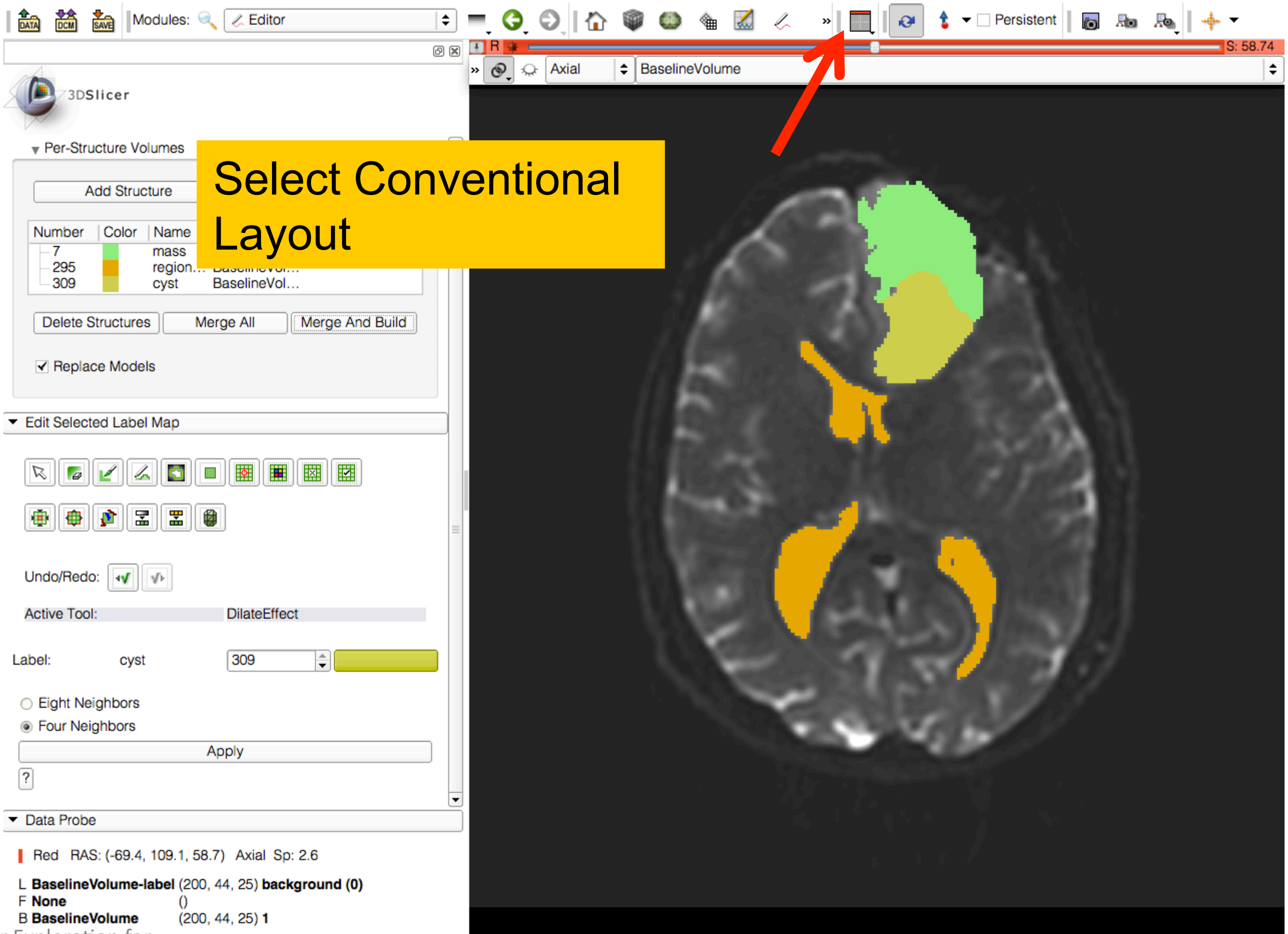
Slicer displays the result of the segmentation of the ventricles.

Final Result of the Segmentation

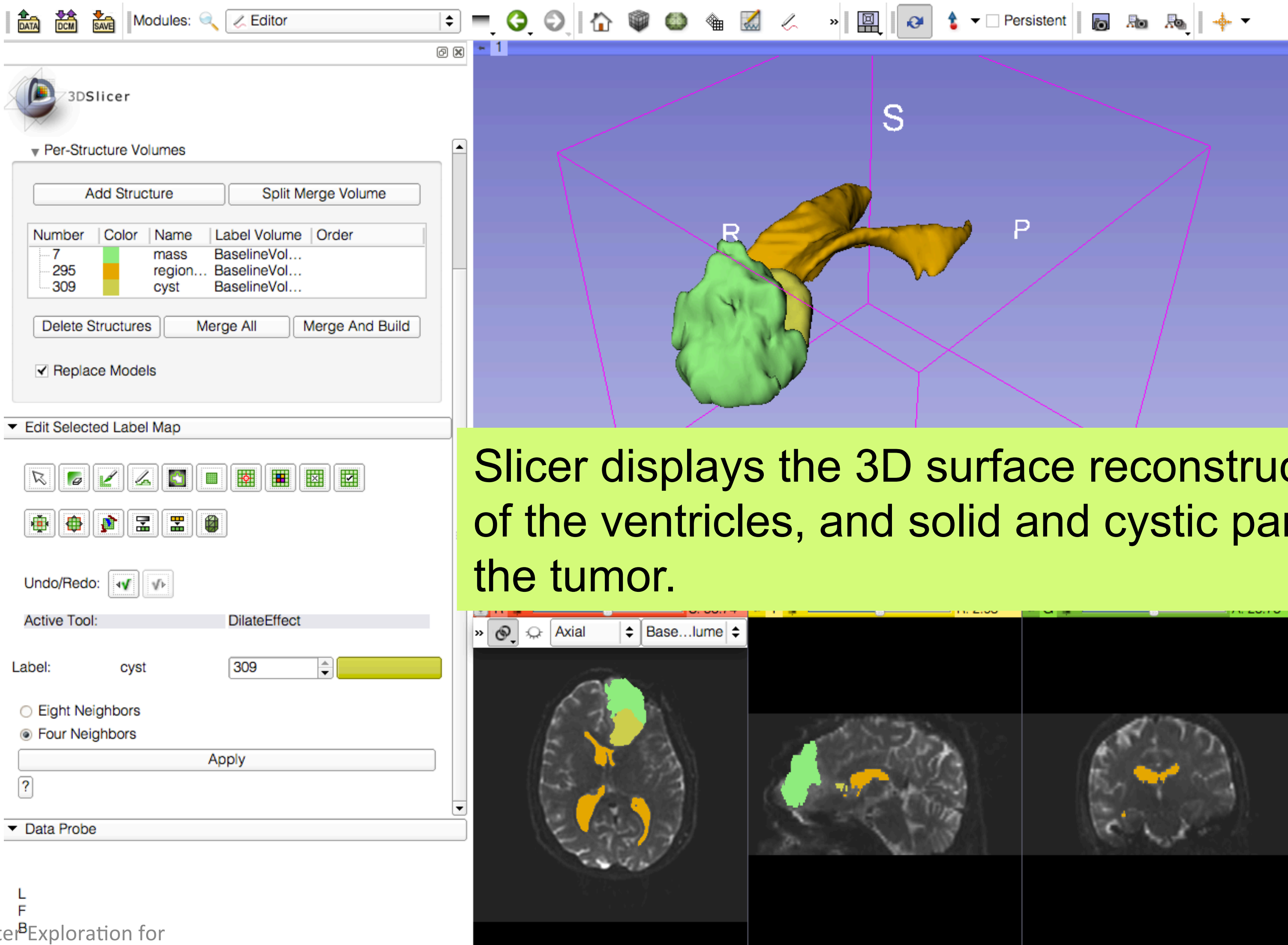


Click on **Merge and Build** to merge the different label maps, and generate the 3D models of the tumor and ventricles using a Marching Cubes algorithm

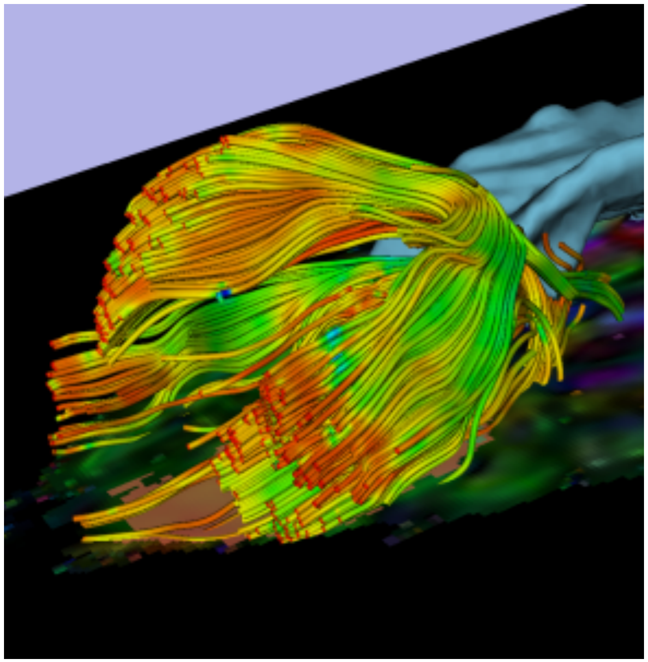
Final Result of the Segmentation



Final Result of the Segmentation



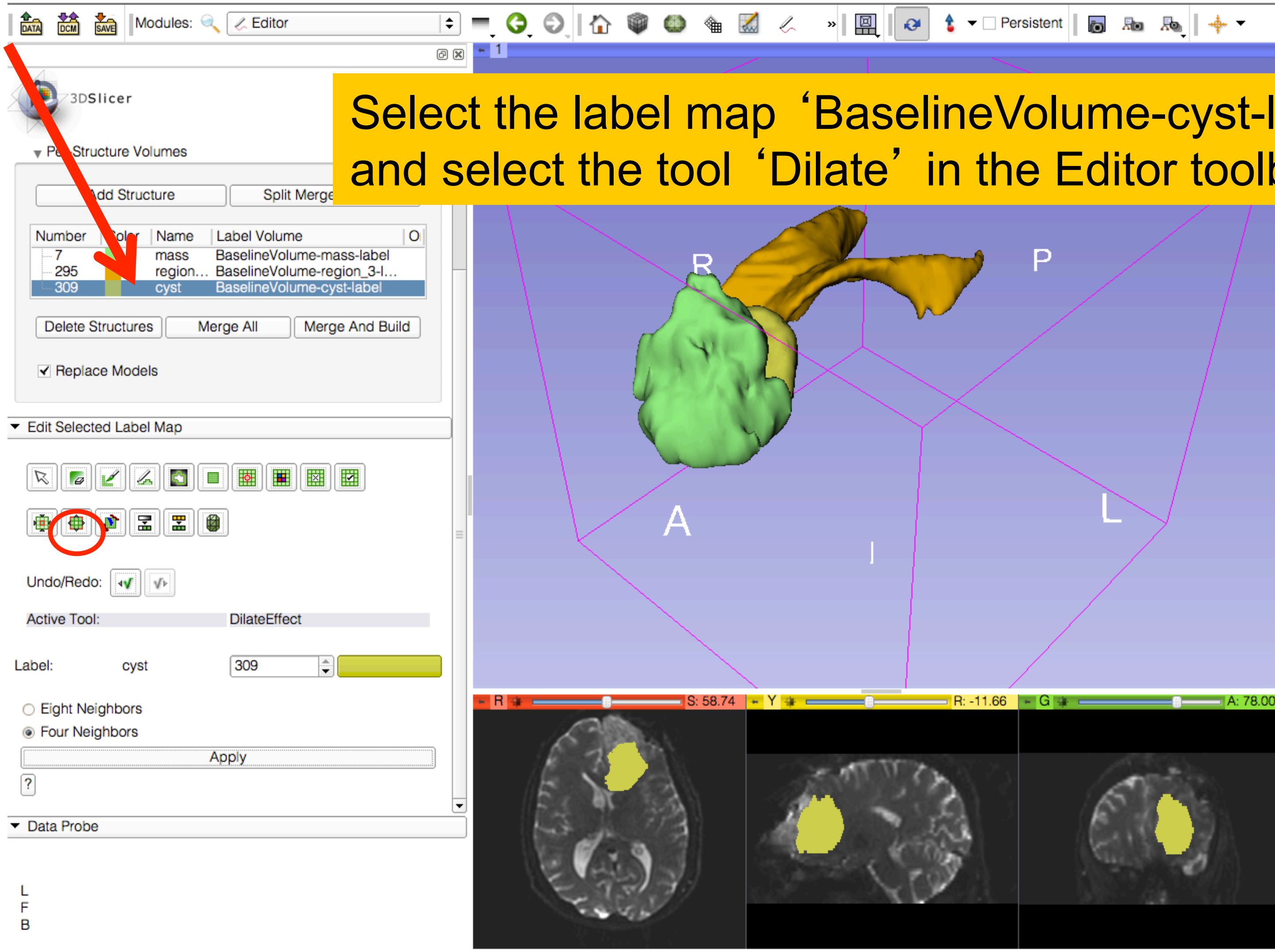
Slicer displays the 3D surface reconstructions of the ventricles, and solid and cystic parts of the tumor.



Part 2: Tractography exploration of peri-tumoral white matter fibers

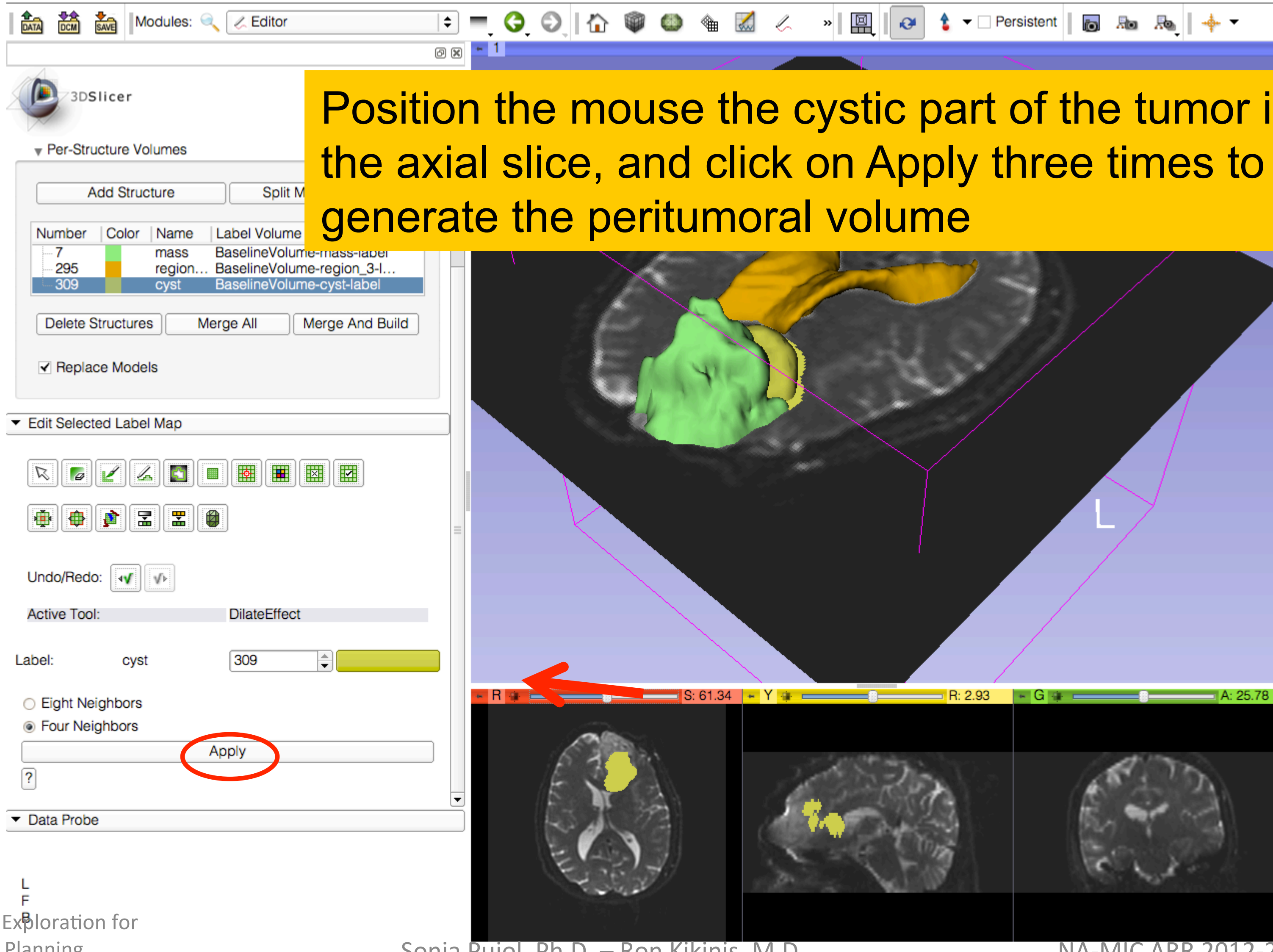
Definition of the peri-tumoral volume

Select the label map ‘BaselineVolume-cyst-label, and select the tool ‘Dilate’ in the Editor toolbox

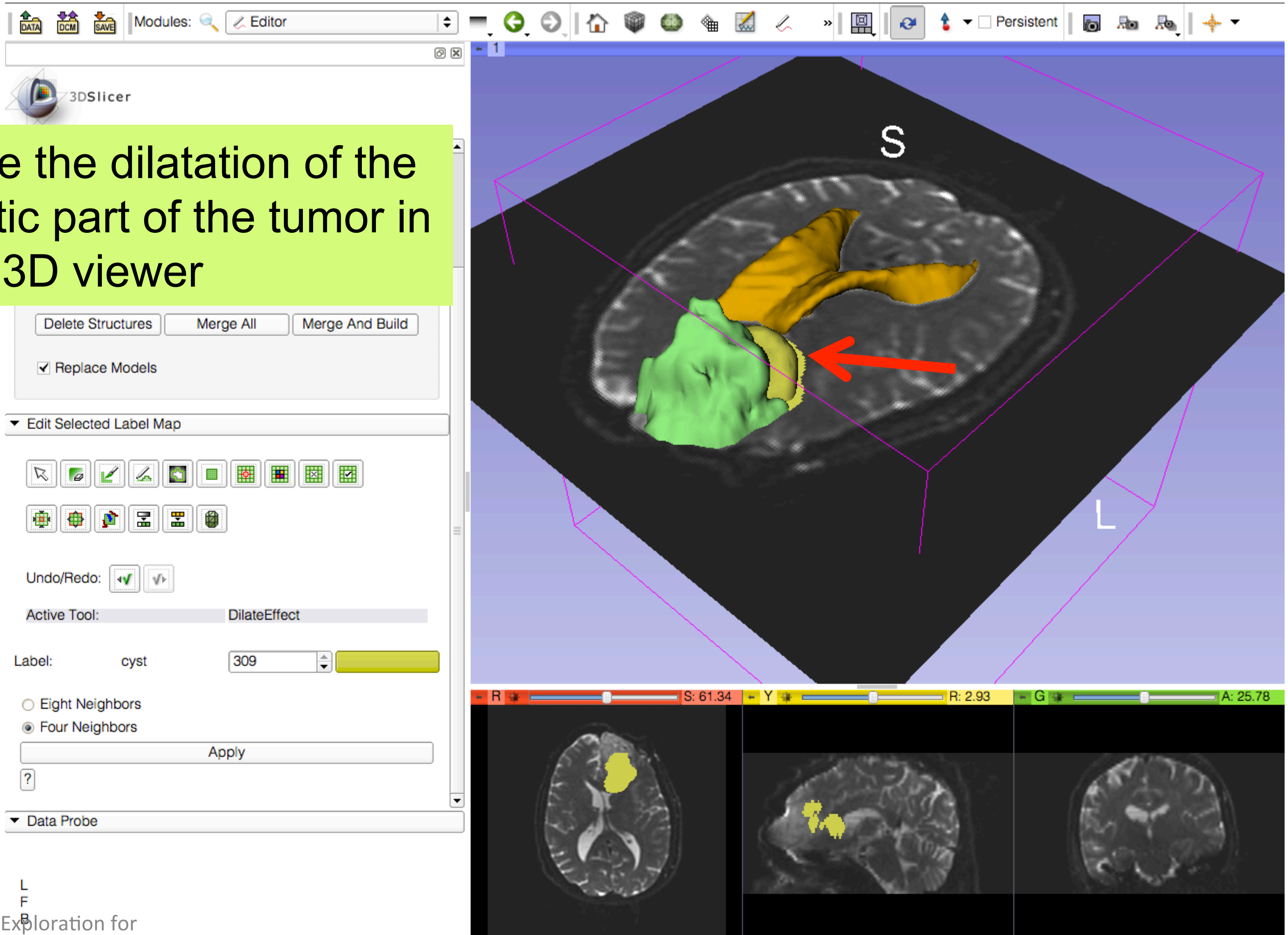


Definition of the peri-tumoral volume

Position the mouse the cystic part of the tumor in the axial slice, and click on Apply three times to generate the peritumoral volume

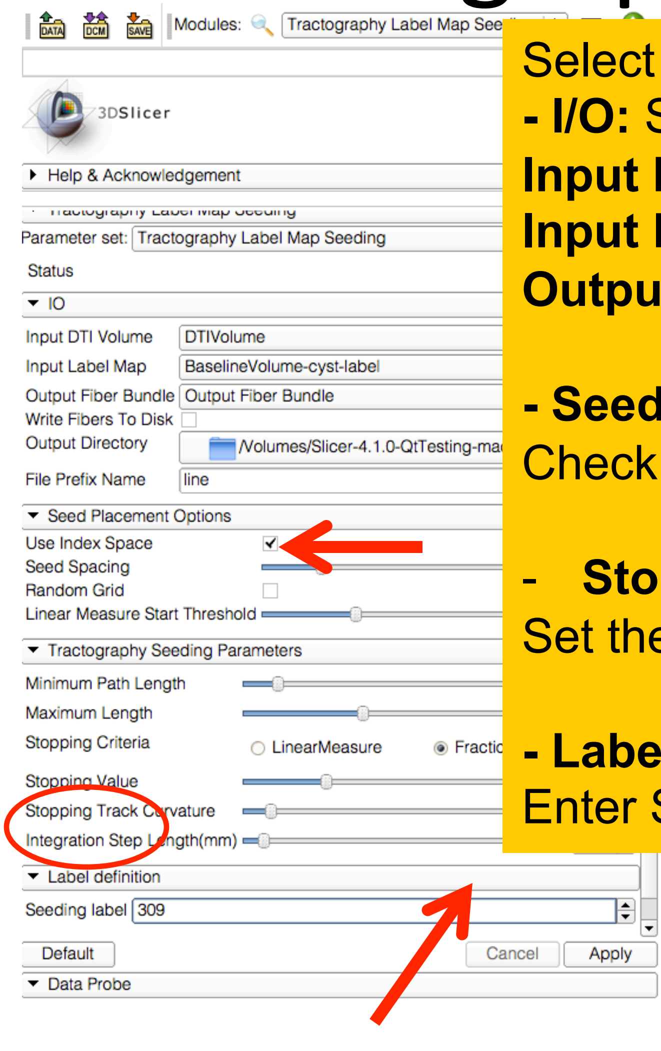


Visualization of the DTI Volume



Note the dilatation of the cystic part of the tumor in the 3D viewer

Tractography Parameters



Select the module **Tractography Label Map Seeding** ‘

- I/O: Set the following input and output volume:

Input DTI Volume: DTIVolume

Input Label Map: BaselineVolume-cyst-label

Output Fiber Bundle: Create NewFiberBundle

- Seed Placement Options:

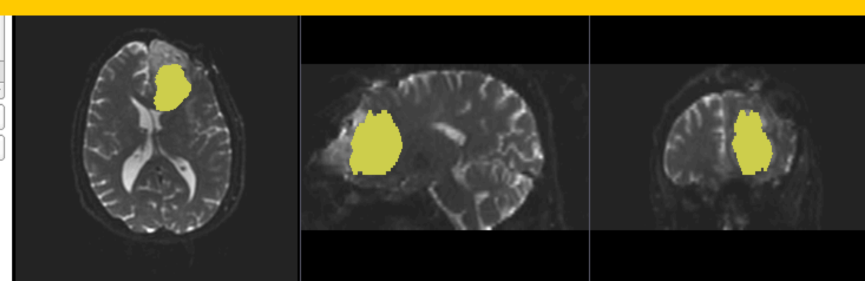
Check **Use Index Space**

- **Stopping Value**

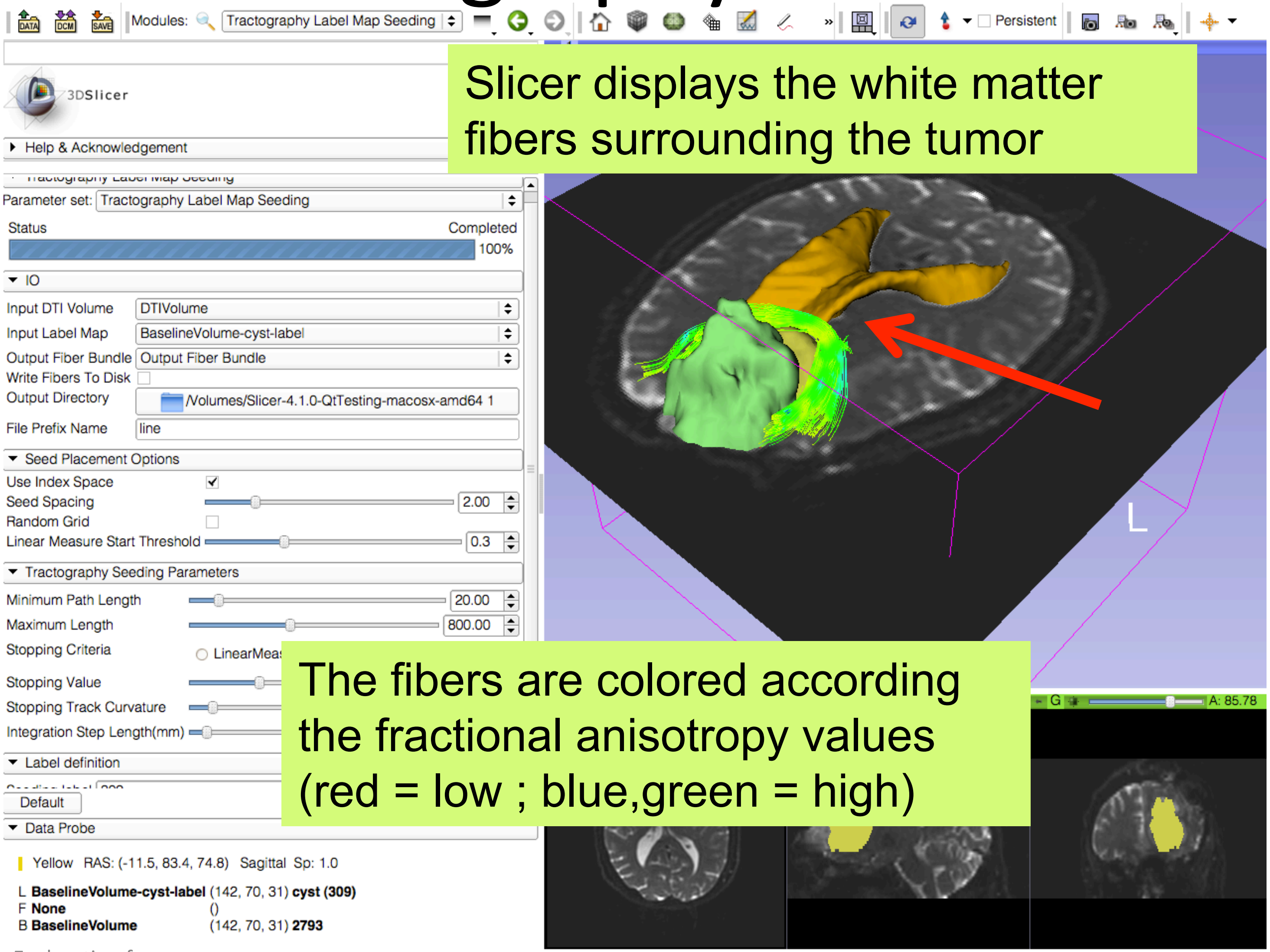
Set the FA threshold to 0.15

- Label Definition:

Enter Seeding Label **293**, and Click on **Apply**

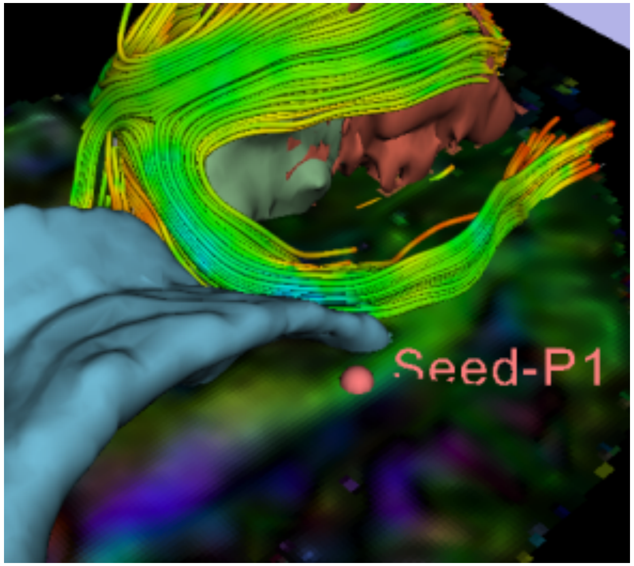


Tractography Results



Slicer displays the white matter fibers surrounding the tumor

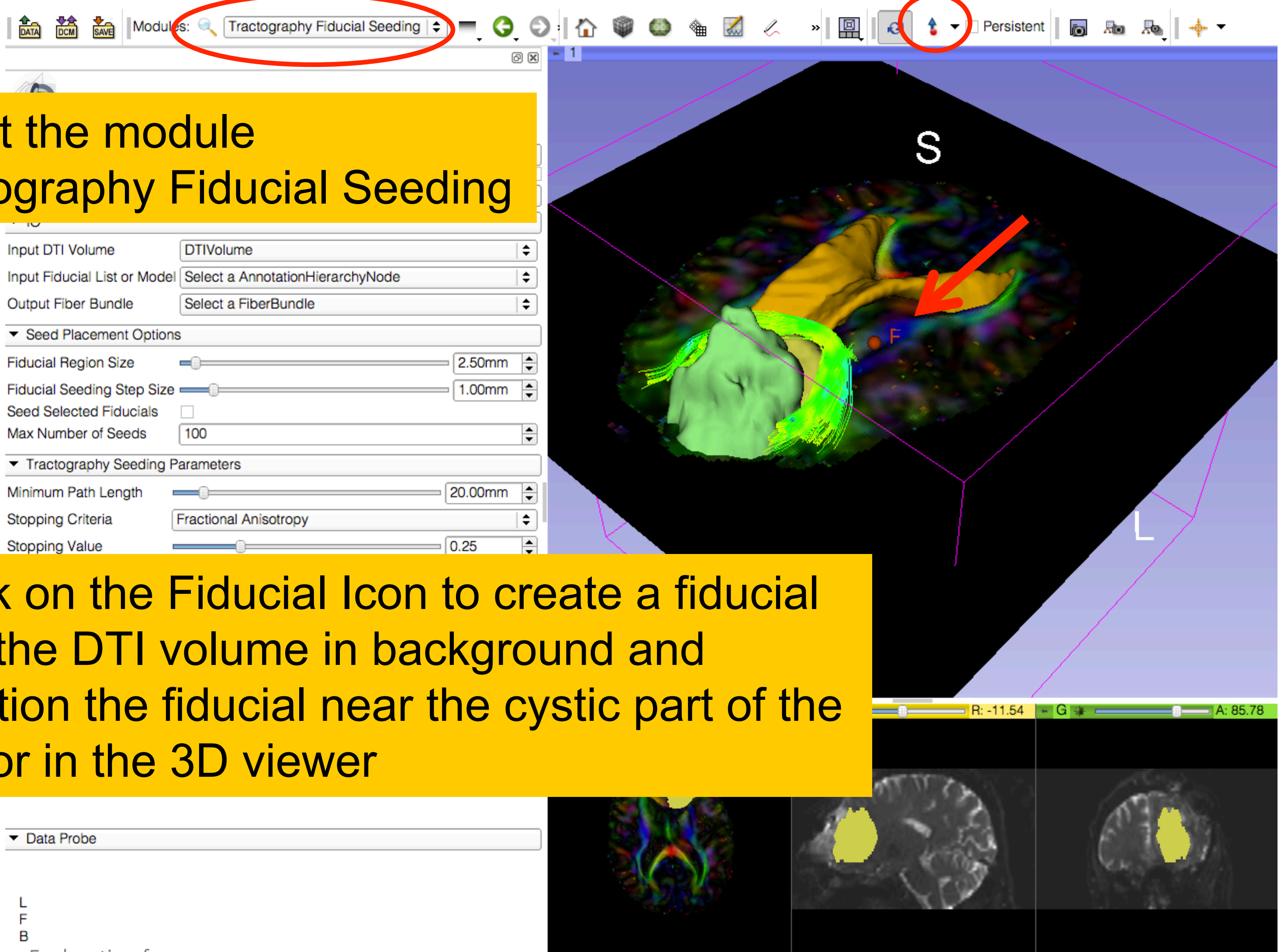
The fibers are colored according the fractional anisotropy values (red = low ; blue,green = high)



Part 4: Tractography exploration of the ipsilateral and contralateral side

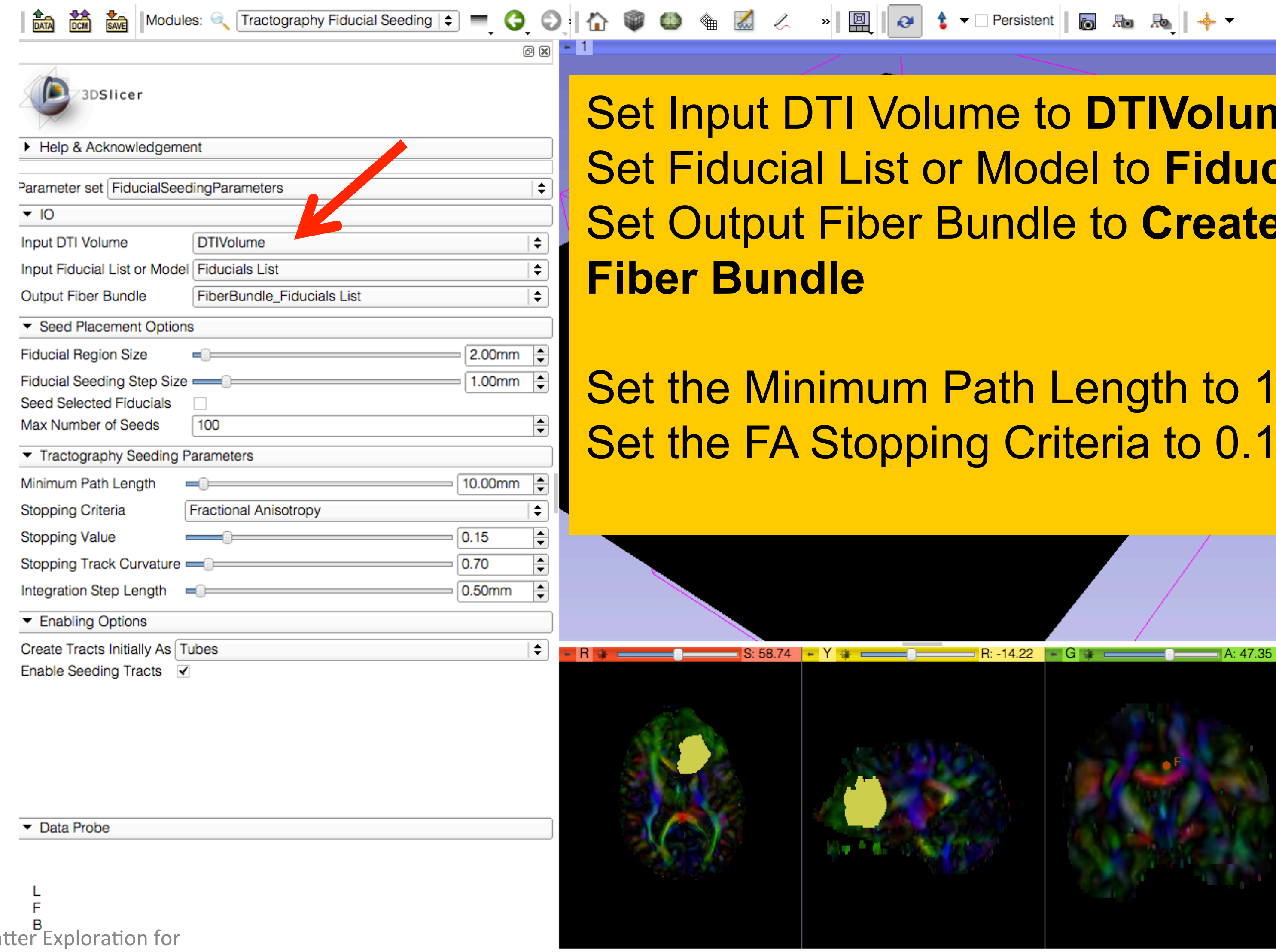
Tractography on-the-fly

Select the module
Tractography Fiducial Seeding



Click on the Fiducial Icon to create a fiducial
Set the DTI volume in background and
position the fiducial near the cystic part of the
tumor in the 3D viewer

Tractography on-the-fly

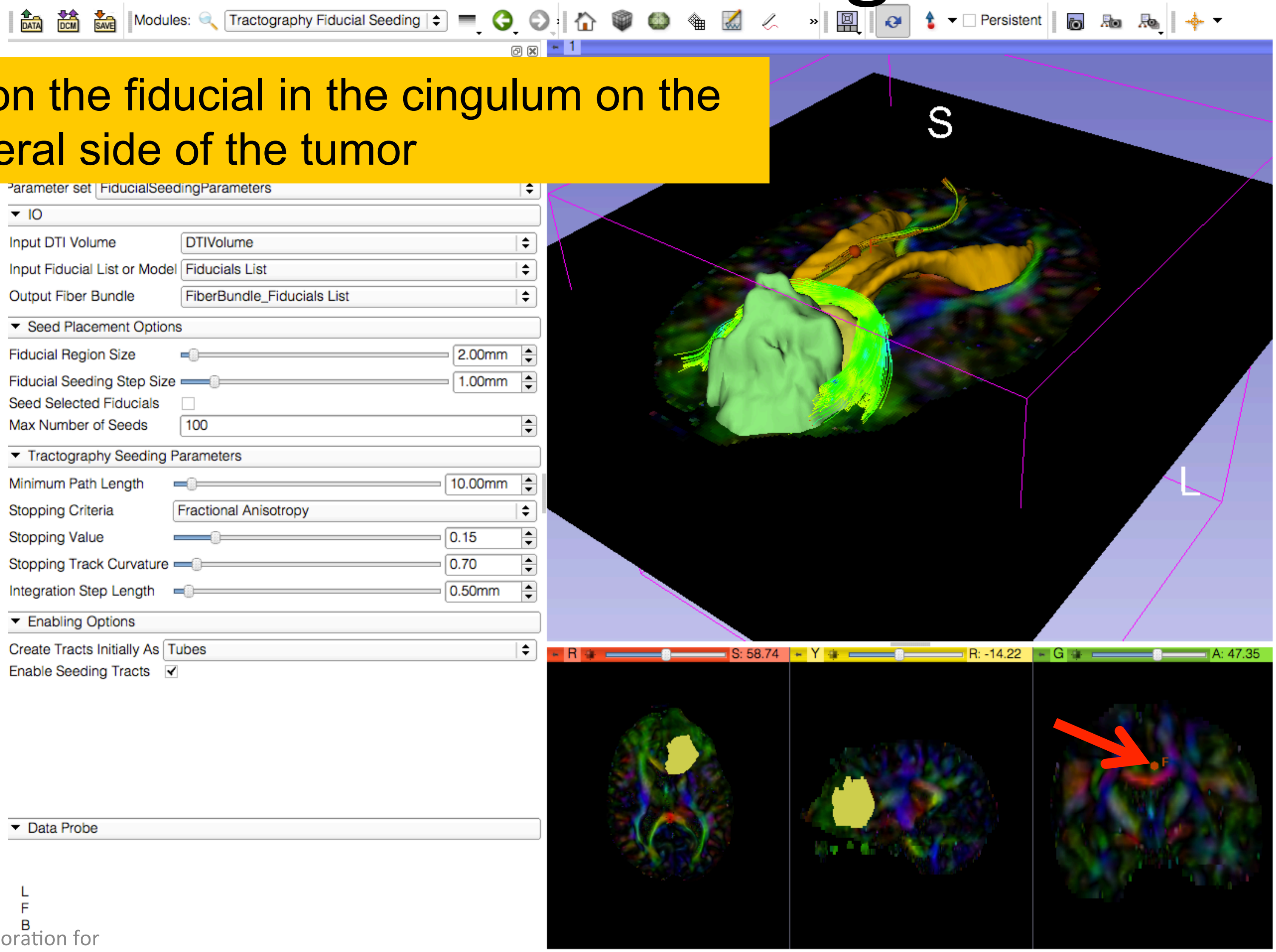


Set Input DTI Volume to **DTIVolume**
Set Fiducial List or Model to **FiducialsList**
Set Output Fiber Bundle to **Create new Fiber Bundle**

Set the Minimum Path Length to 10 mm
Set the FA Stopping Criteria to 0.15

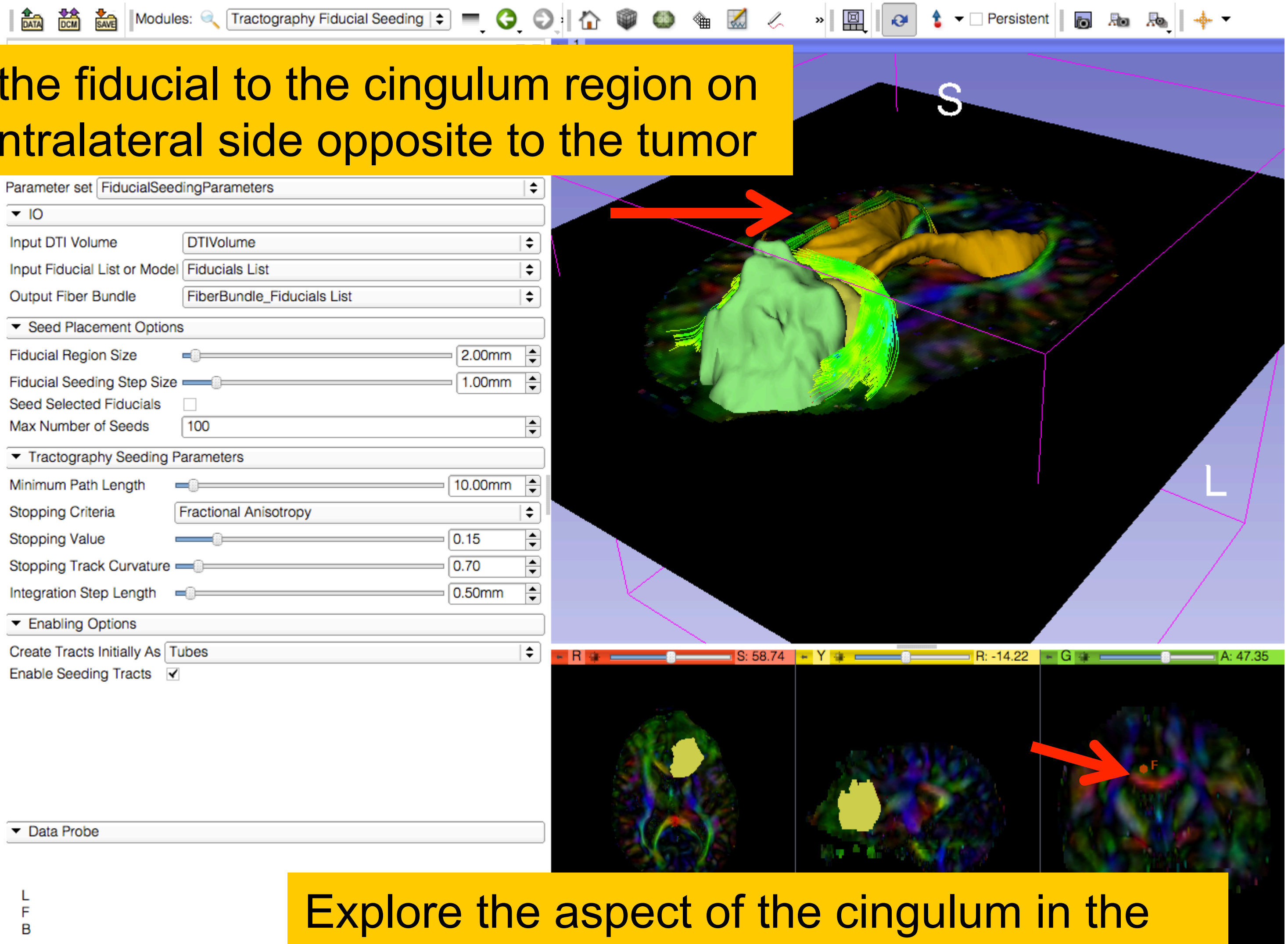
Fiducial Seeding

Position the fiducial in the cingulum on the ipsilateral side of the tumor



Fiducial Seeding

Move the fiducial to the cingulum region on the contralateral side opposite to the tumor

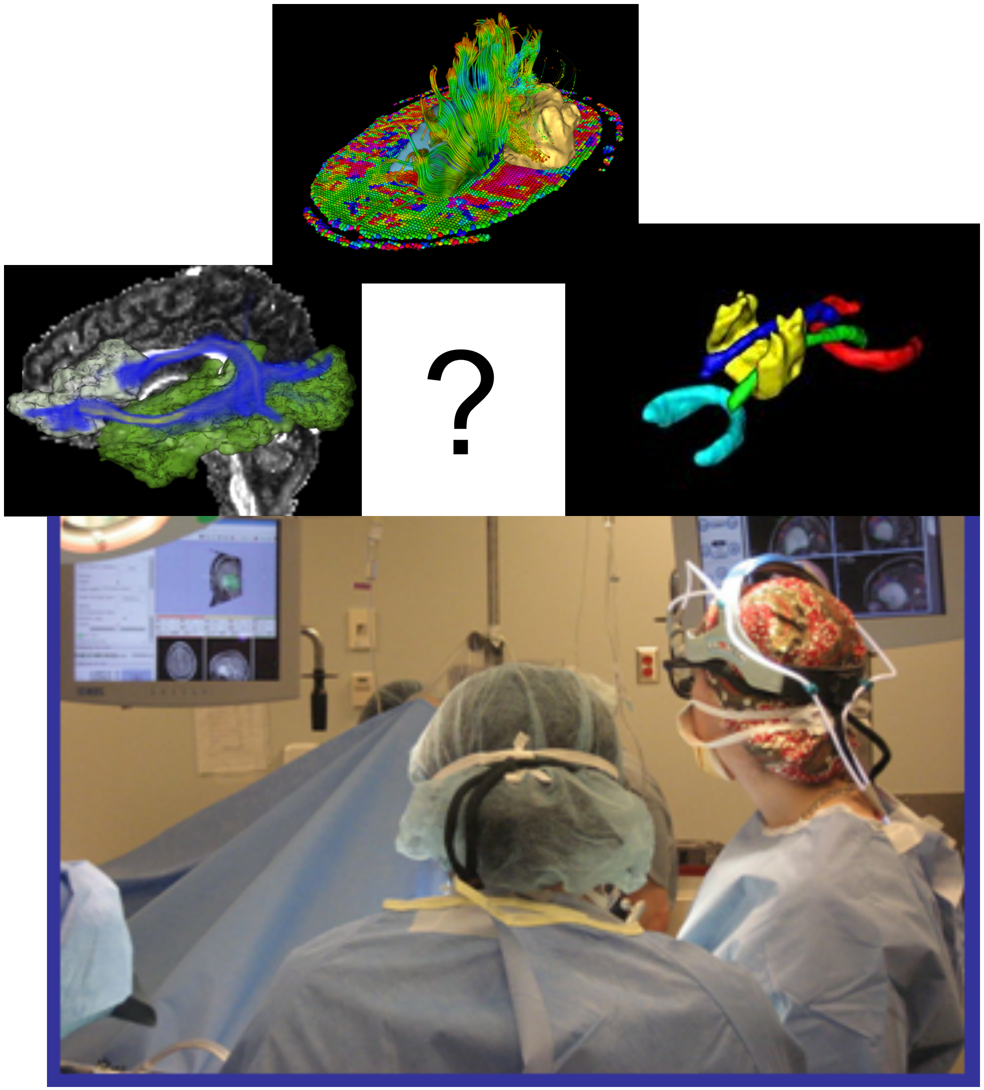


Explore the aspect of the cingulum in the contralateral and ipsilateral sides

Conclusion

- Fully integrated pipeline for semi-automated tumor segmentation and white matter tract reconstruction
- 3D interactive exploration of the white matter
- tracts surrounding a tumor (peri-tumoral tracts) for neurosurgical planning

Going Further: How to choose ?

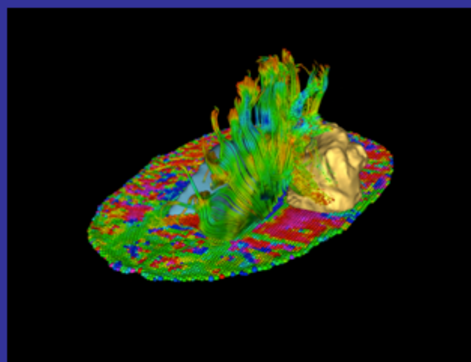


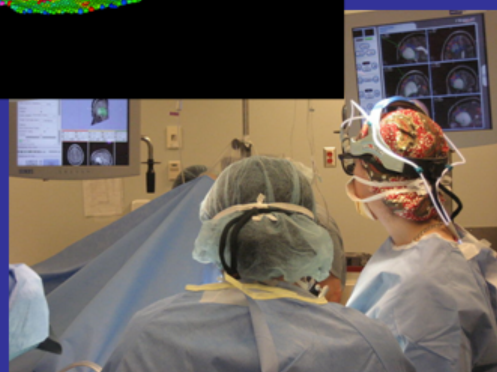
Neurosurgeons face the challenge of selecting the appropriate tractography method and tract selection strategy

Need for validation to accelerate clinical use of DT-MRI findings

MICCAI 2011 DTI Challenge

14th International Conference on Medical Image Computing and Computer Assisted Intervention





DTI Tractography for Neurosurgical Planning: A Grand Challenge

MICCAI 2011 Workshop
Sunday September 18, 9am-6pm
Westin Harbour Castle
Toronto, Canada

Workshop Faculty

Sonia Pujol, PhD, Surgical Planning Laboratory, Harvard Medical School
Ron Kikinis, MD, Surgical Planning Laboratory, Harvard Medical School
Alexandra Golby, MD, Brigham and Women's Hospital, Harvard Medical School
Guido Gerig, PhD, The Scientific Computing and Imaging Institute, University of Utah
Martin Styner, PhD, Neuroimage Research and Analysis Laboratory, University of North Carolina
William Wells, PhD, Surgical Planning Laboratory, Harvard Medical School
Carl-Fredrik Westin, PhD, Laboratory of Mathematics in Imaging, Harvard Medical School
Sylvain Gouttard, MSc, The Scientific Computing and Imaging Institute, University of Utah

National Alliance for Medical Image Computing

http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

MICCAI 2011 Workshop

- 8 international teams
- 10-hour long workshop
- 25 participants
- 352 corticospinal tracts generated
- 6,600 visits on challenge webpage

http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

Neurosurgical Planning Workshop, October 1st, 2012 – Nice, France

MICCAI 2012 DTI Tractography Challenge
Second Edition

INTRODUCTION THE CHALLENGE FACULTY KEYNOTE SPEAKER DATA LOGISTICS CONTACT

Welcome to the 2nd edition of the MICCAI DTI Tractography Challenge. The workshop will be held on Monday October 1st, 2012 as part of the 15th International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI 2012).

DTI Tractography for Neurosurgical Planning: A Grand Challenge

MICCAI 2012 Conference
Acropolis Convention Center
Nice, France
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