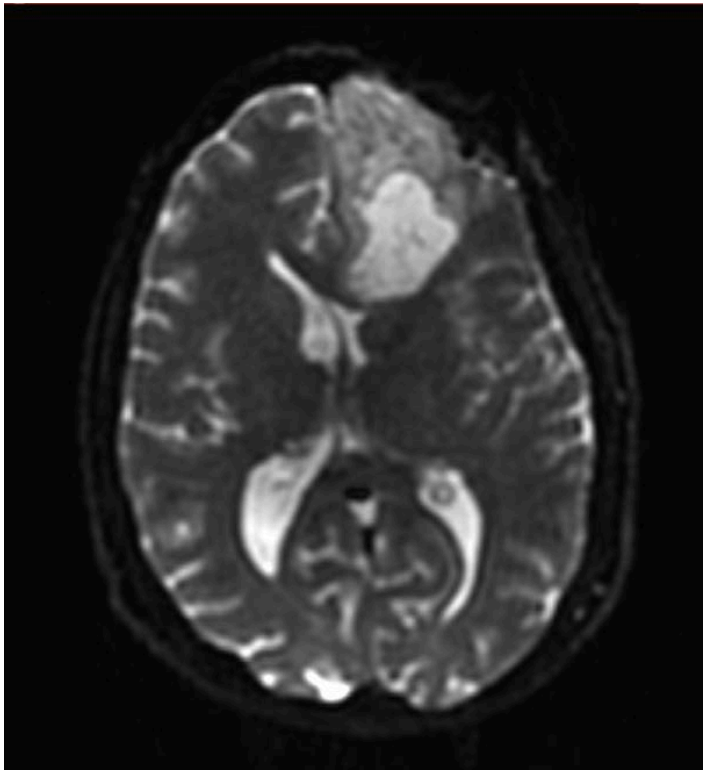
Exploring peritumoral white matter fibers for neurosurgical planning of brain tumor resection

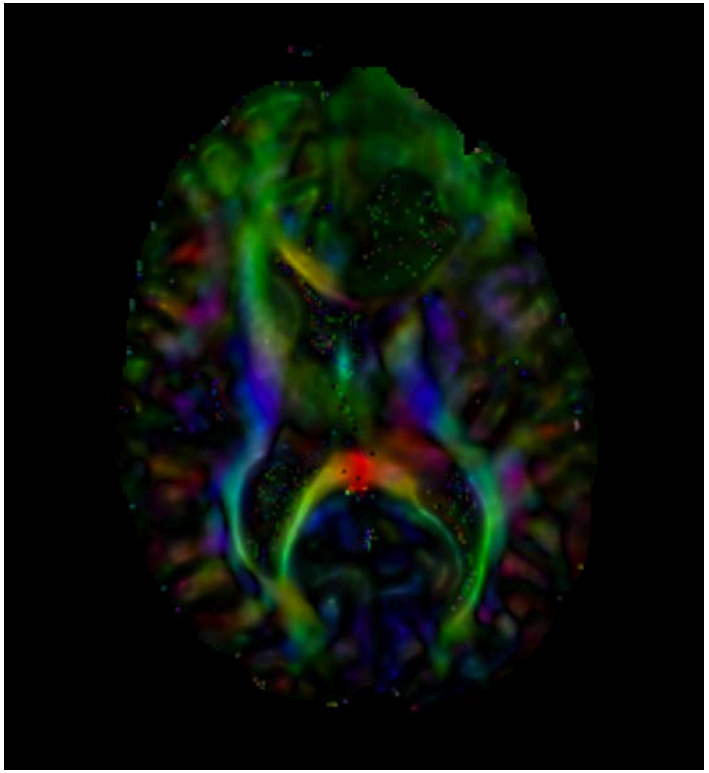
Sonia Pujol, Ph.D.
Assistant Professor of Radiology

Ron Kikinis, M.D.
Robert Greenes Director of Biomedical Informatics
Professor of Radiology

Brigham and Women's Hospital
Harvard Medical School

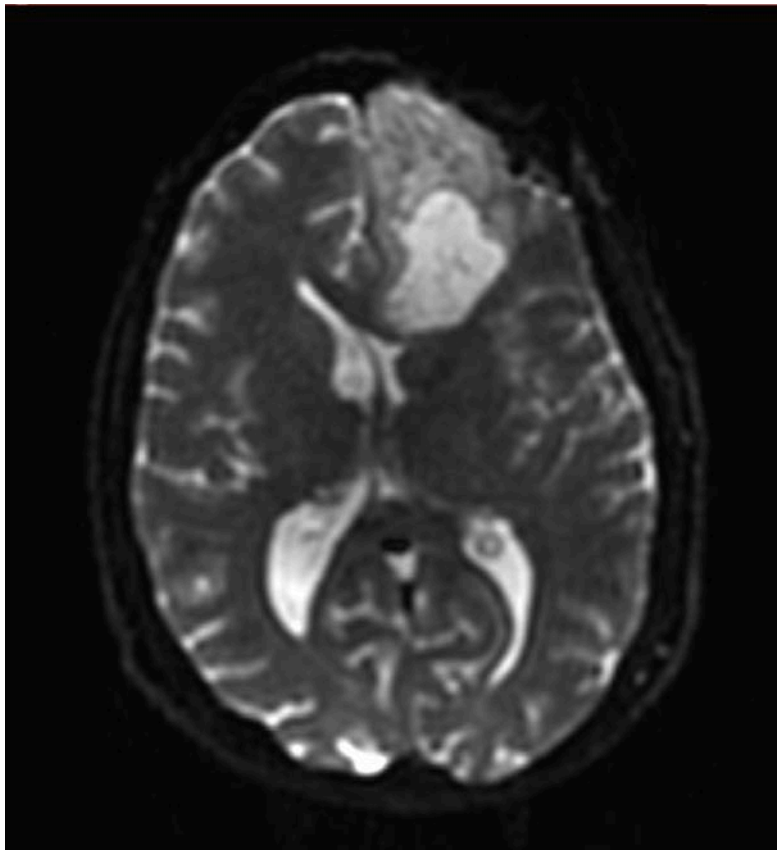
Clinical Case





35 y.o. patient presenting with a Glioblastoma Multiforme

Glioblastoma Multiforme



- Glioblastoma Multiforme (GBM) is a fast-growing high-grade primary gliomas
- Current treatment options combine surgery with radiotherapy and chemotherapy
- GBM spreads to critical areas associated with motor function, language or vision

GBM Surgery

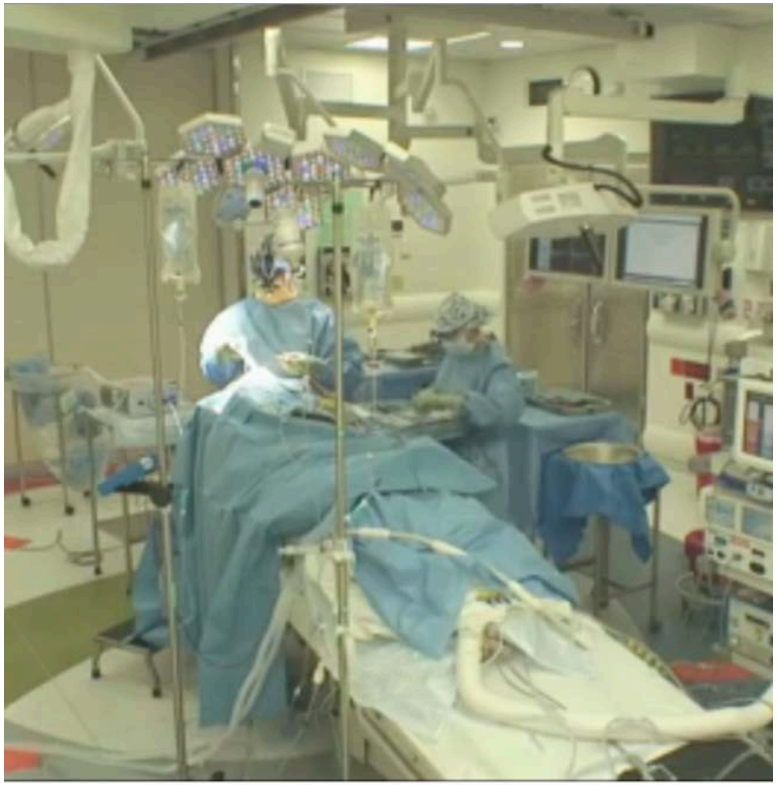
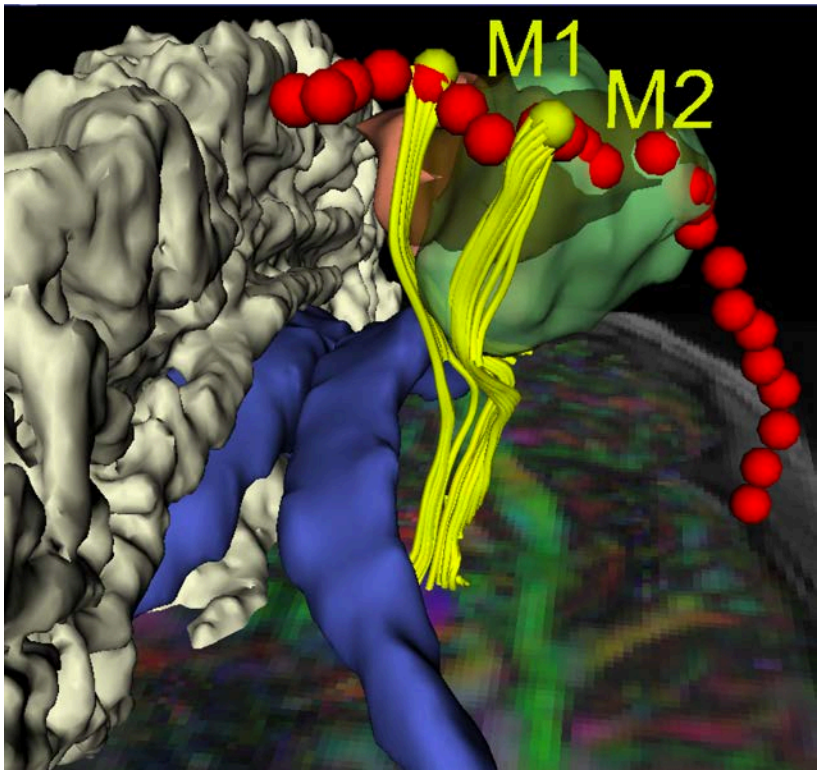


Image courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital

- Brain tumor surgery aims to maximize the extent of tumor resection while preserving critical white matter fibers

- Achieving complete resection in GBM surgery is a challenge due to tumor infiltration

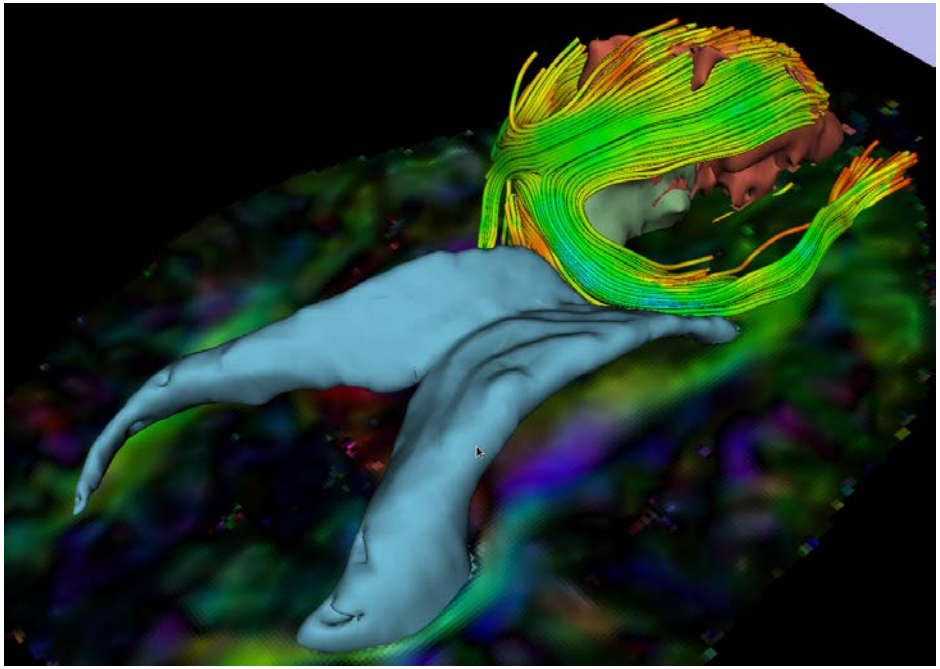
Diffusion MRI for brain surgery



Pujol S. *Imaging White Matter Anatomy for Surgical Planning of Brain Tumors*. Image-Guided Neurosurgery, First Edition. A. Golby Ed. Academic Press 2015

- Diffusion MRI enables non-invasive exploration of white matter anatomy
- Tractography techniques can bring clinically relevant information during surgical planning of brain tumor resection

Overall Objective



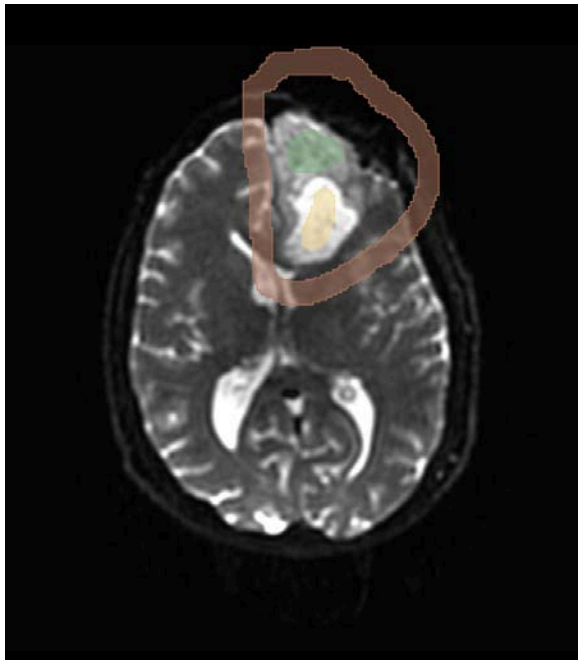
This tutorial provides an end-to-end solution for segmenting the contours of a tumor and generating white matter fiber tracts in the vicinity of the lesion

Disclaimer

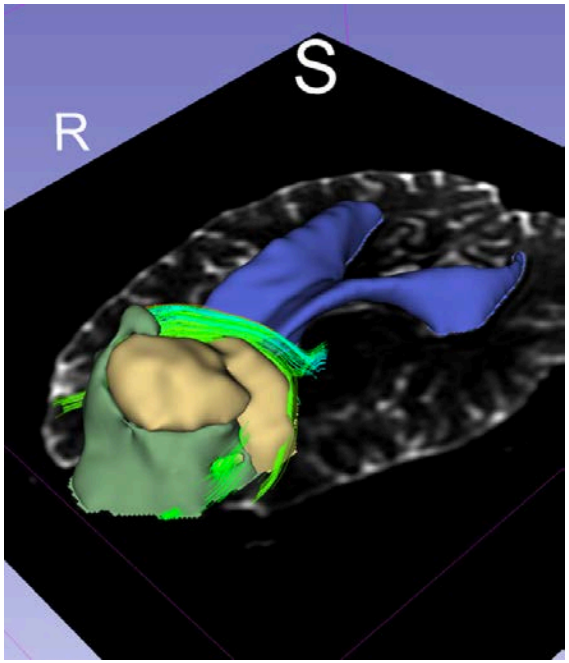
- 3D Slicer is a free open source software for medical image computing research distributed under a BDS style license.

- The software is not FDA approved or CE-Marked, and is for research use only.

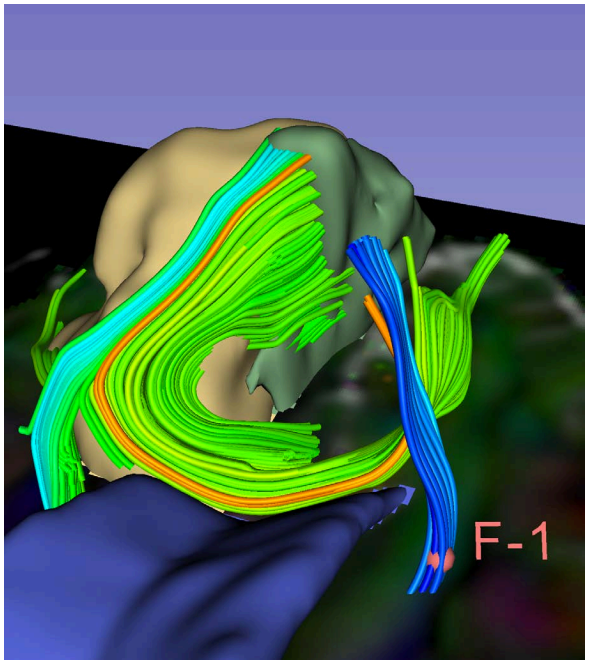
Workflow Overiew



Step 1: Tumor Segmentation



Step 2: Fiber Tracts Generation

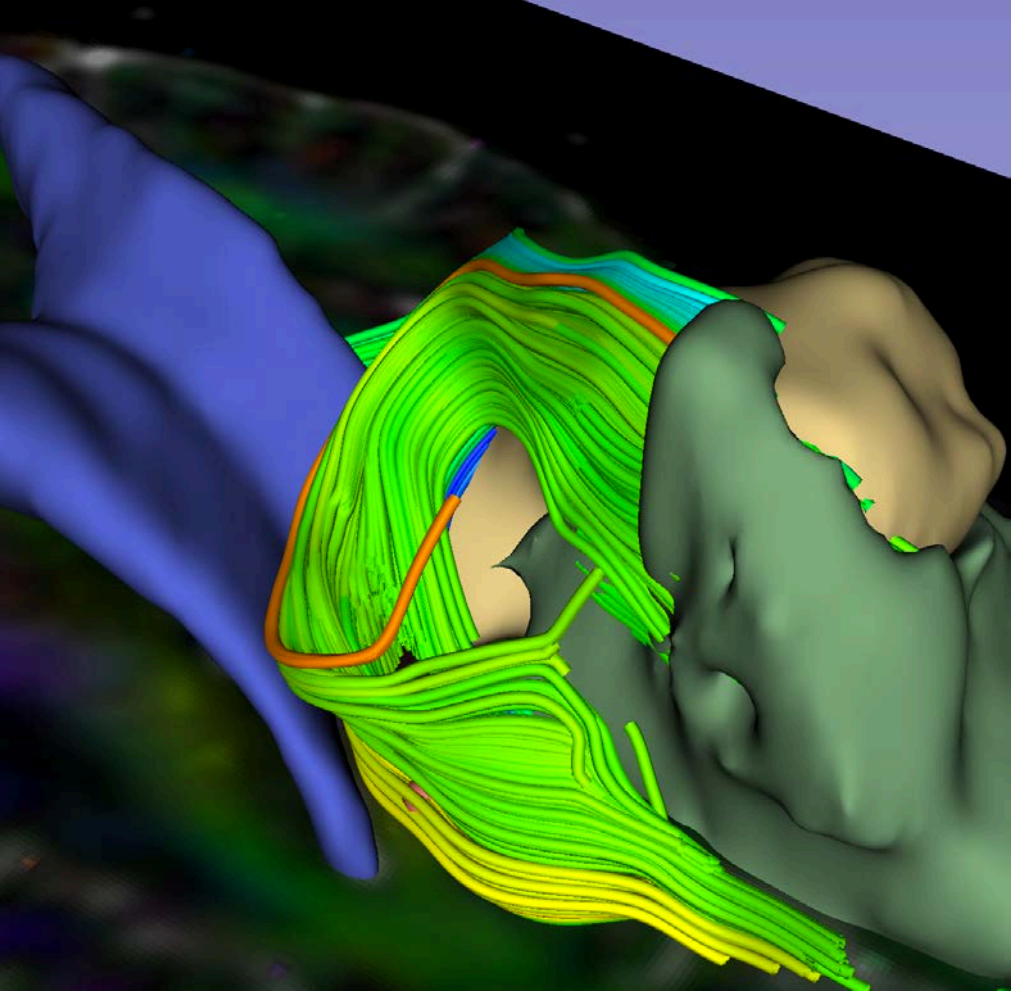


Step 3: Interactive Exploration

Image Processing Workflow

The image processing workflow described in this tutorial uses three algorithms:

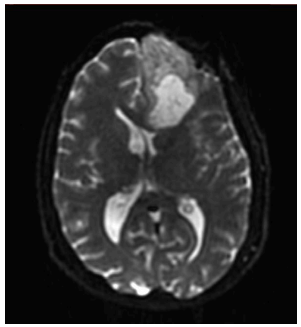
- **Grow Cut** algorithm for tumor segmentation
- **Marching Cube** algorithm for surface modeling
- **Single tensor streamline tractography** algorithm for fiber tract generation

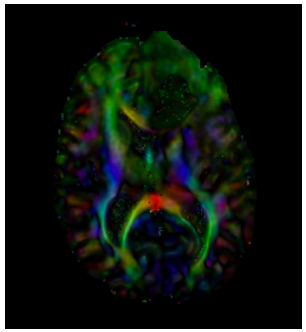


Overall Goal

This tutorial provides an end-to-end solution for segmenting the contours of a tumor and generating white matter fiber tracts in the vicinity of the lesion

Part 1: Tutorial Materials Installation



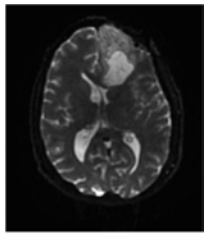


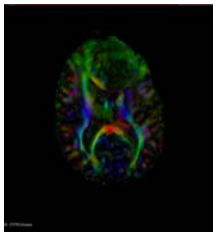
Tutorial materials

- 3D Slicer release version 4.10

- SlicerDMRI Extension

- White Matter Exploration dataset

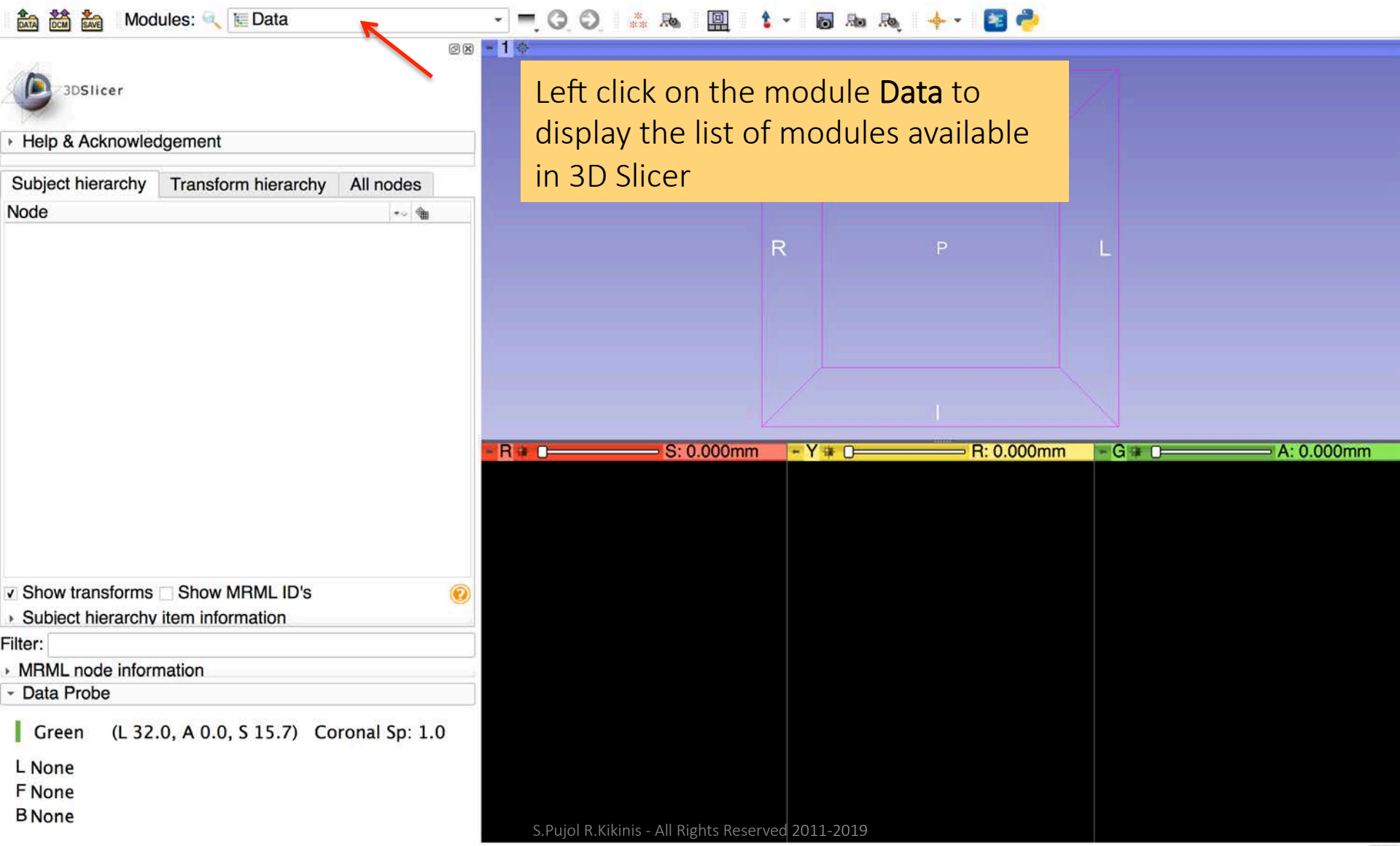




3D Slicer installation

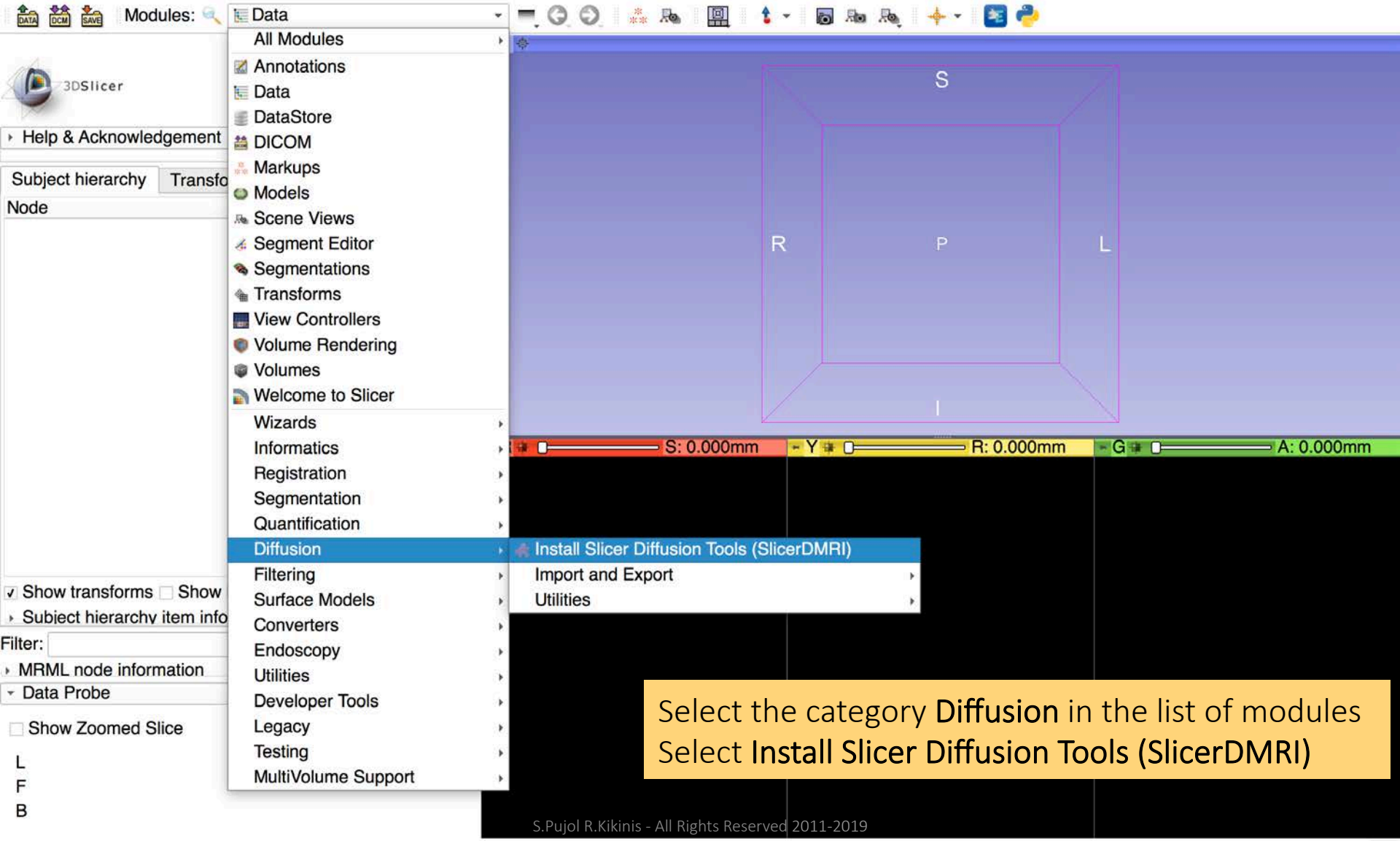
- To install and start the 3D Slicer software on your computer, follow the instructions of the **Quick Start Guide tutorial** available at https://www.slicer.org/wiki/Documentation/4.10/Training

SlicerDMRI Installation



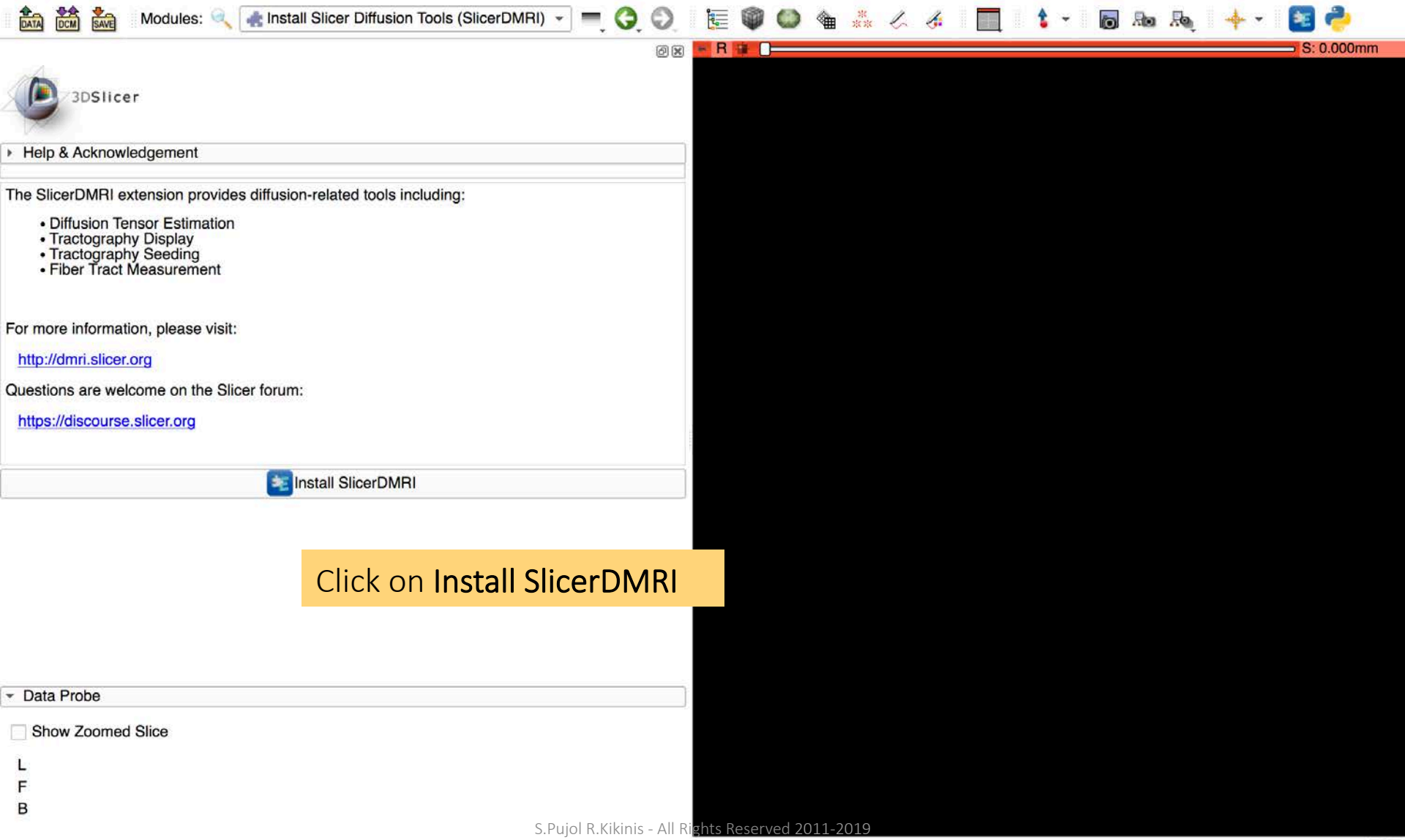
Left click on the module **Data** to display the list of modules available in 3D Slicer

SlicerDMRI Installation



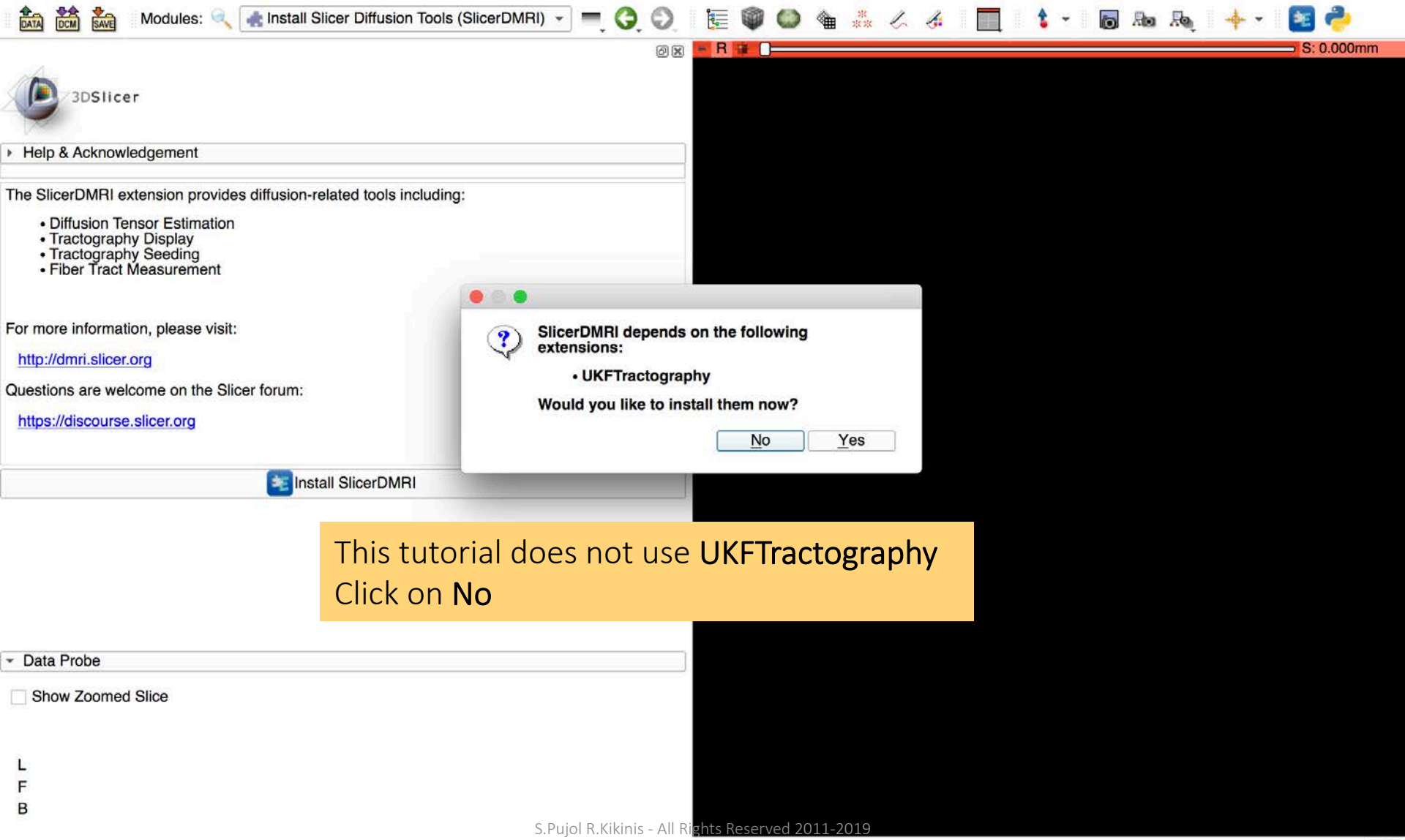
Select the category **Diffusion** in the list of modules
Select **Install Slicer Diffusion Tools (SlicerDMRI)**

SlicerDMRI Installation



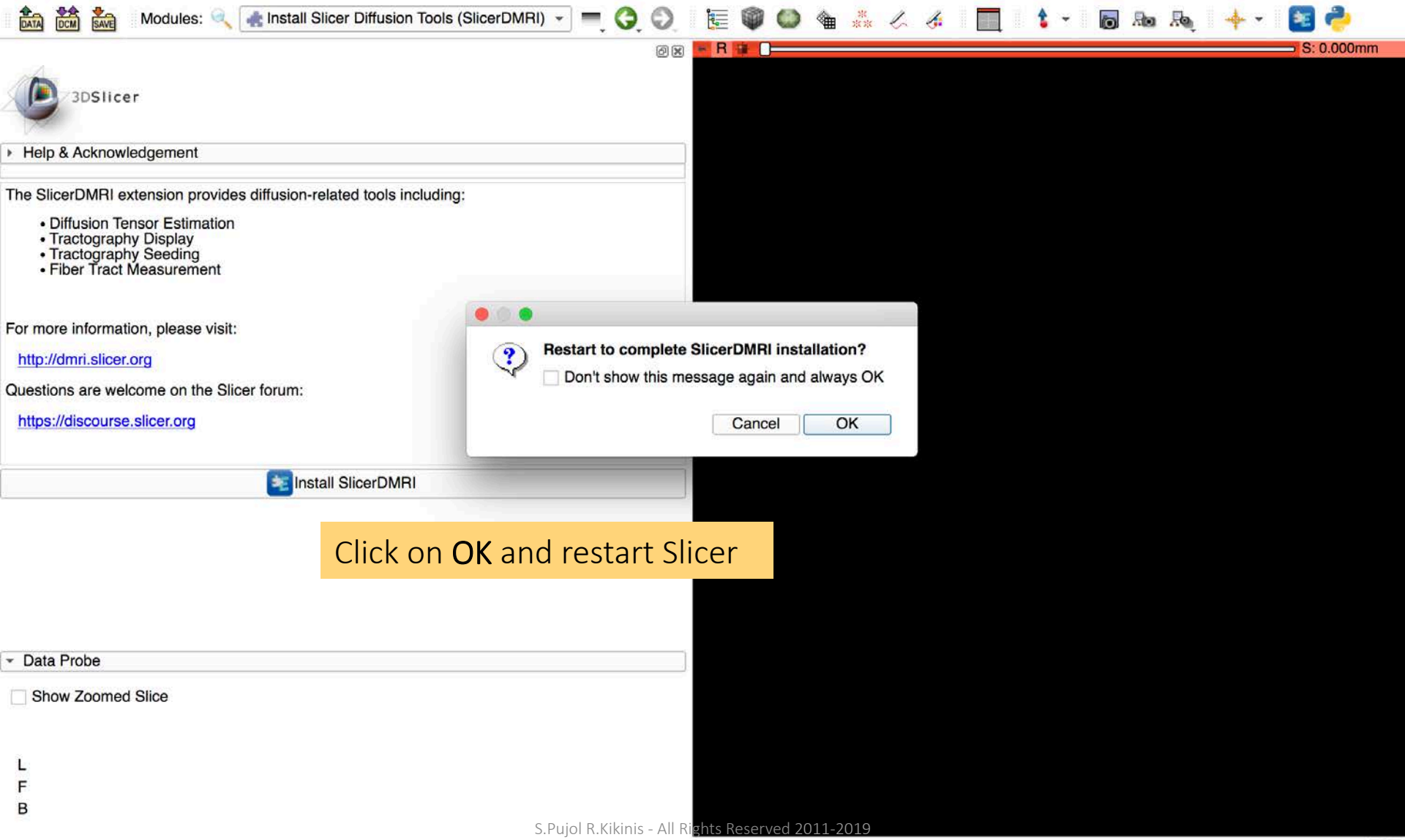
Click on **Install SlicerDMRI**

SlicerDMRI Installation



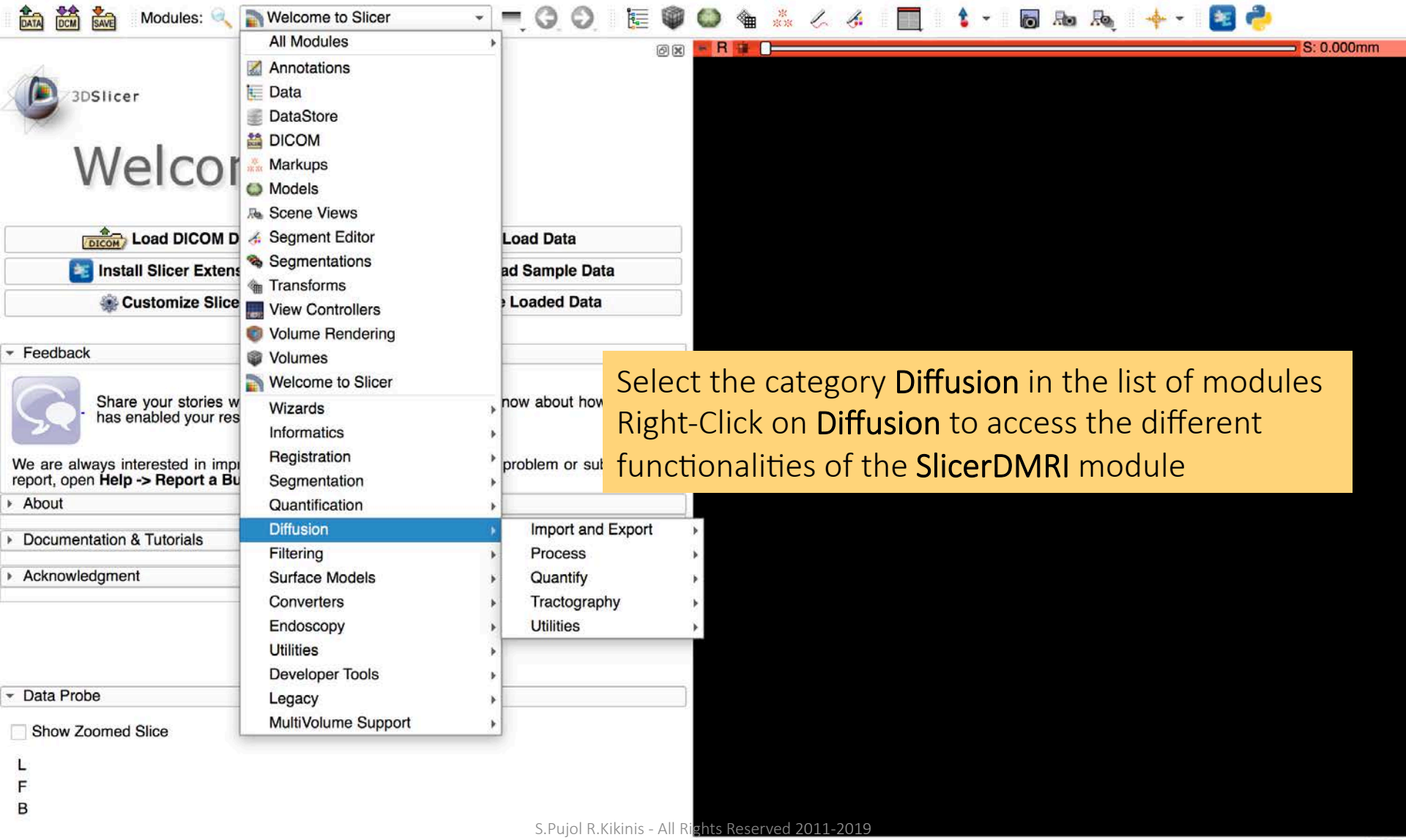
This tutorial does not use **UKFTractography**
Click on **No**

SlicerDMRI Installation



Click on **OK** and restart Slicer

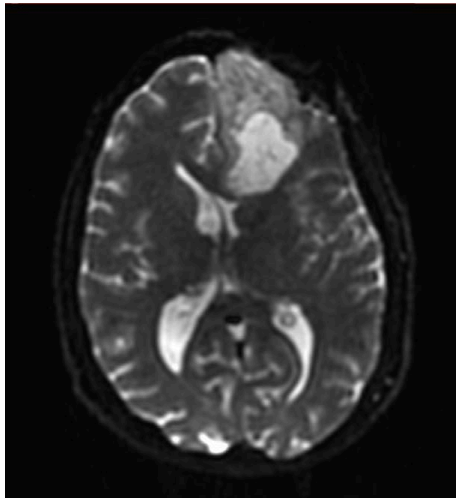
SlicerDMRI Installation

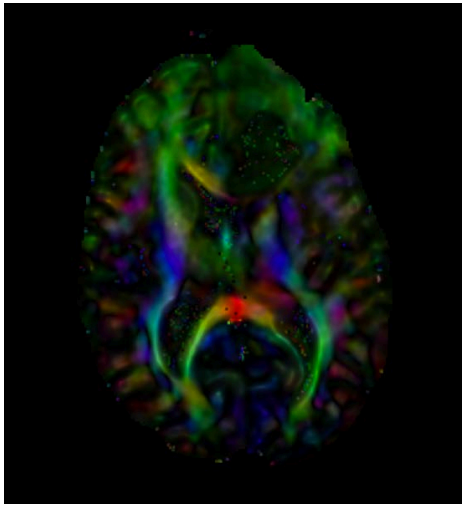


Select the category **Diffusion** in the list of modules
Right-Click on **Diffusion** to access the different functionalities of the **SlicerDMRI** module

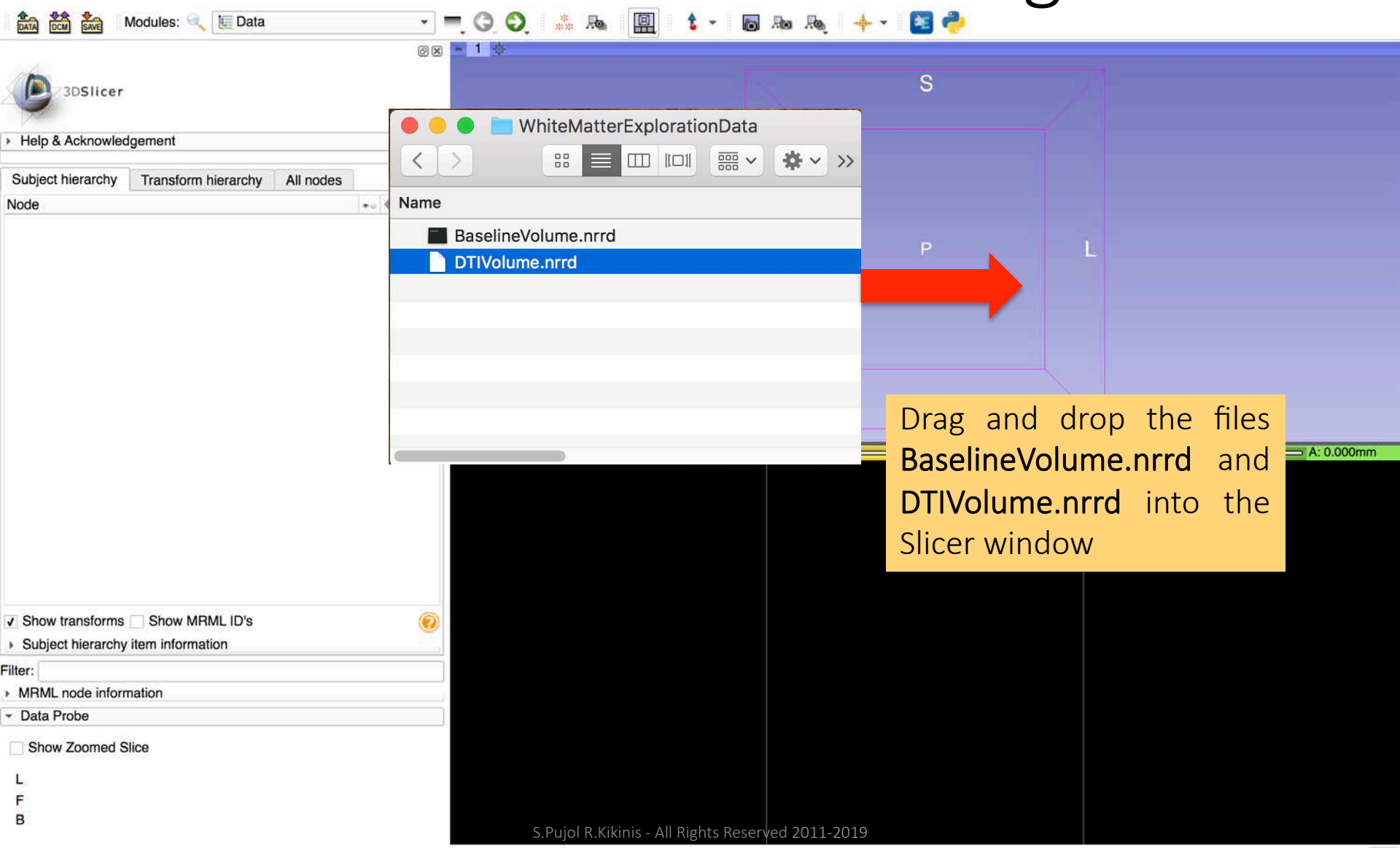
Tutorial Data

- The tutorial data include a baseline volume and a diffusion tensor imaging (DTI) volume



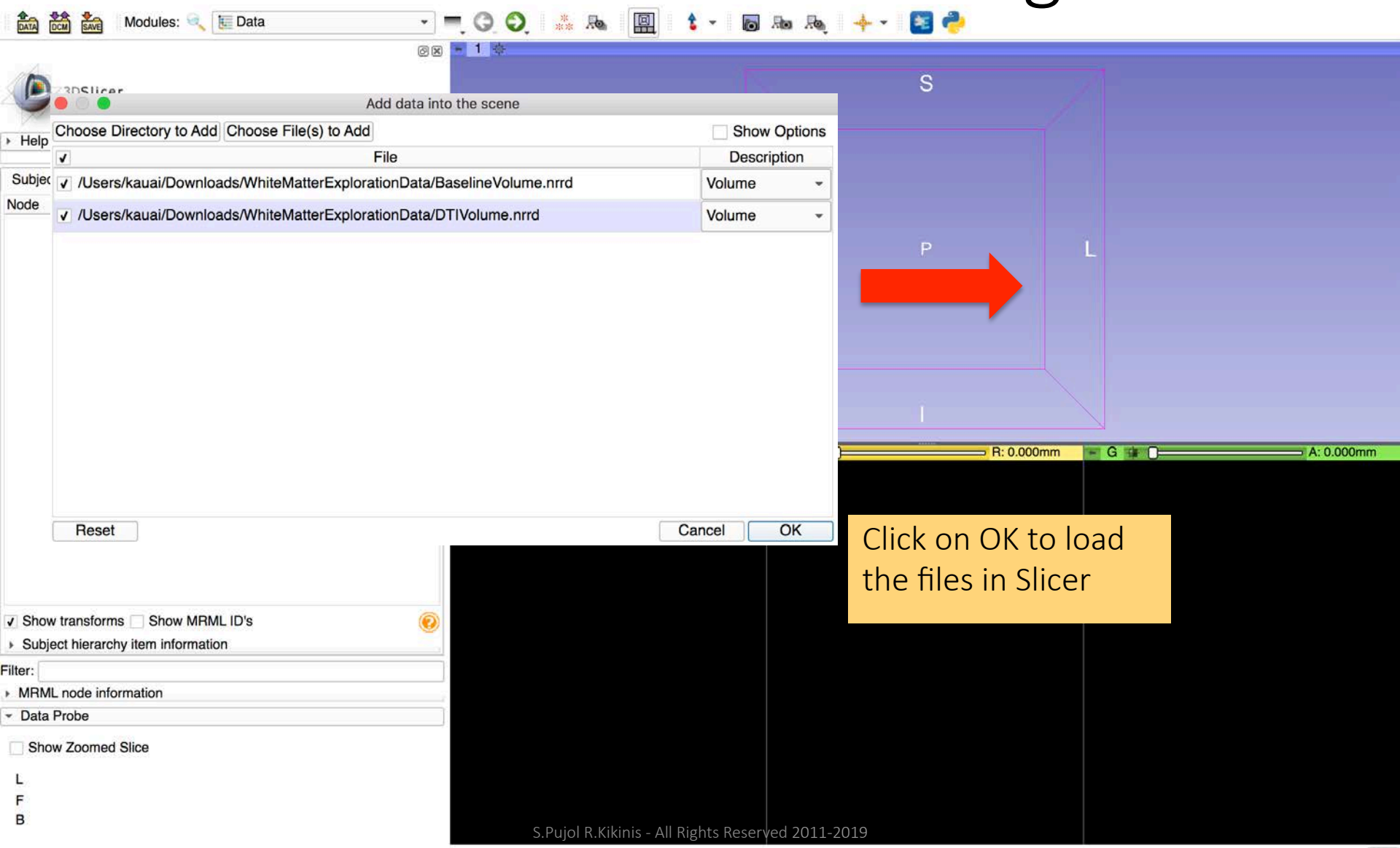


Tutorial Data Loading



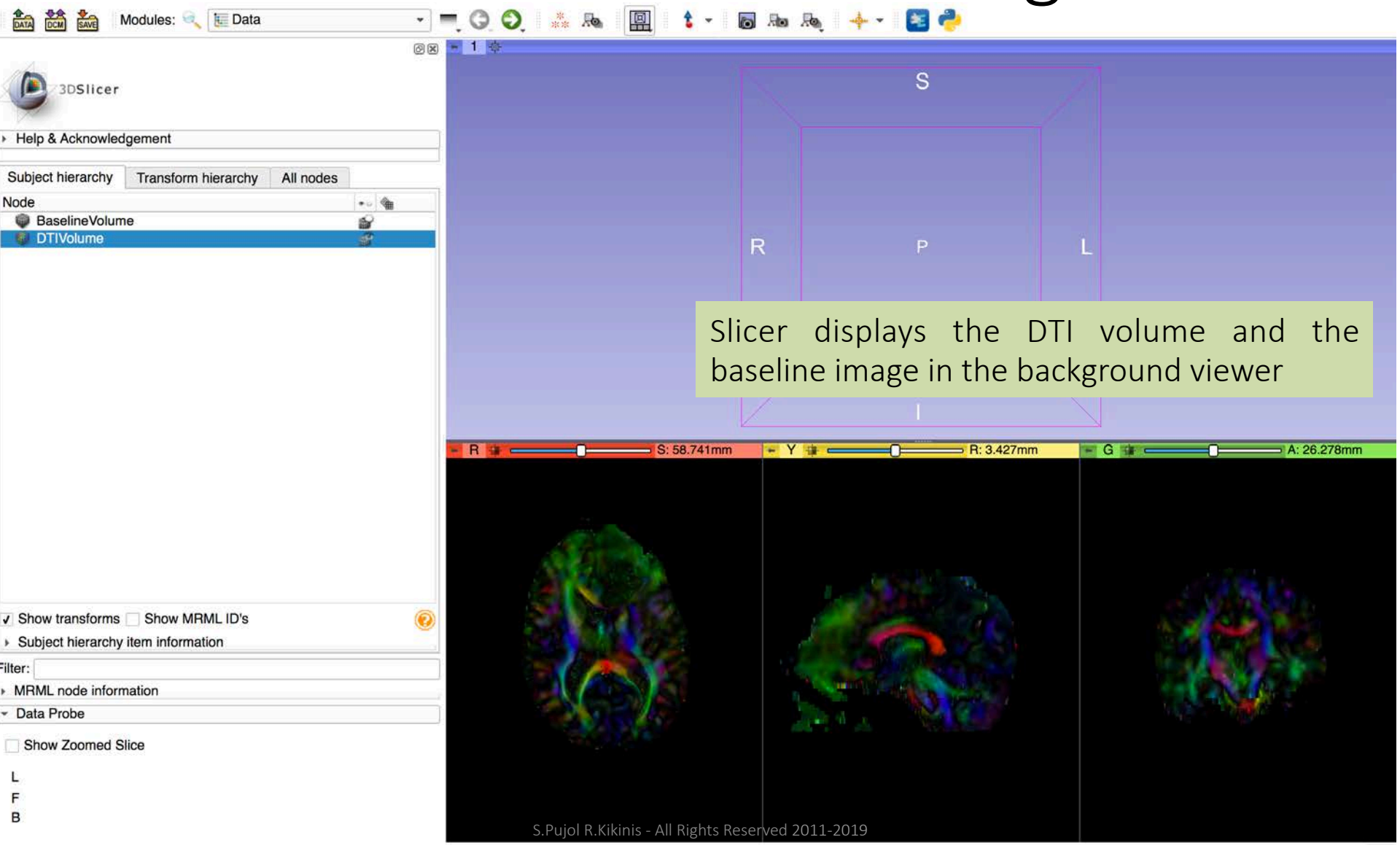
Drag and drop the files **BaselineVolume.nrrd** and **DTIVolume.nrrd** into the Slicer window

Tutorial Data Loading

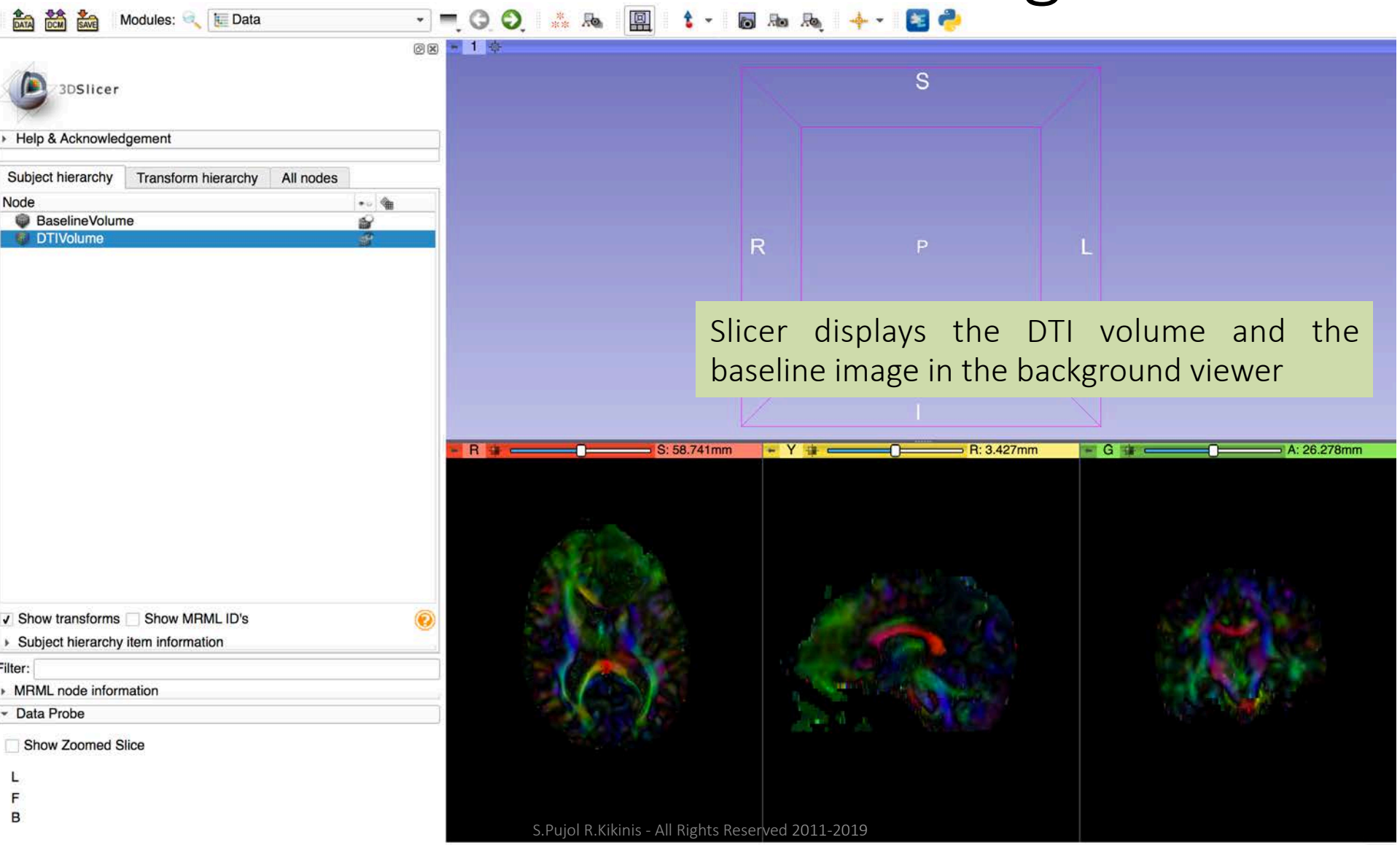


Click on OK to load the files in Slicer

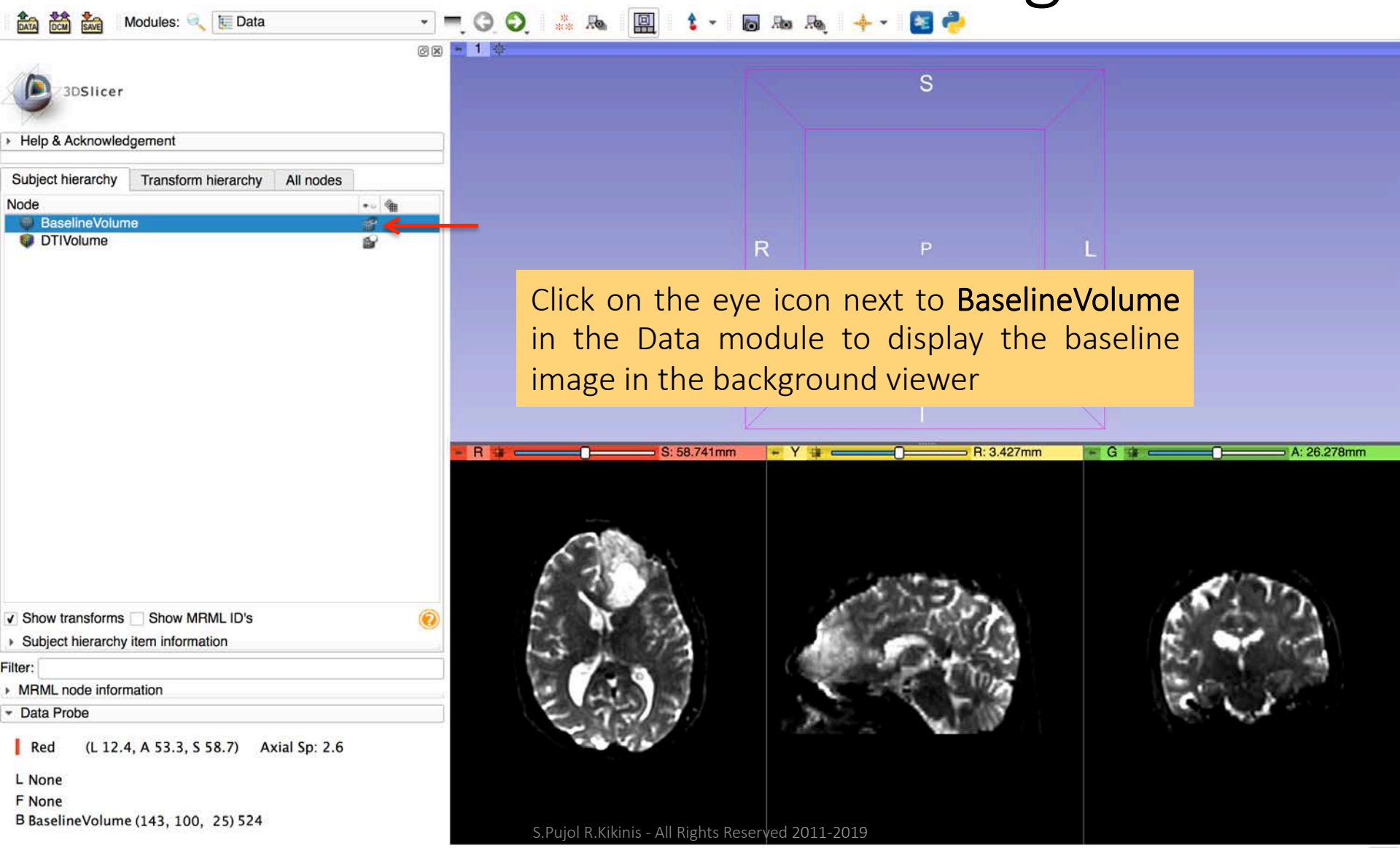
Tutorial Data Loading



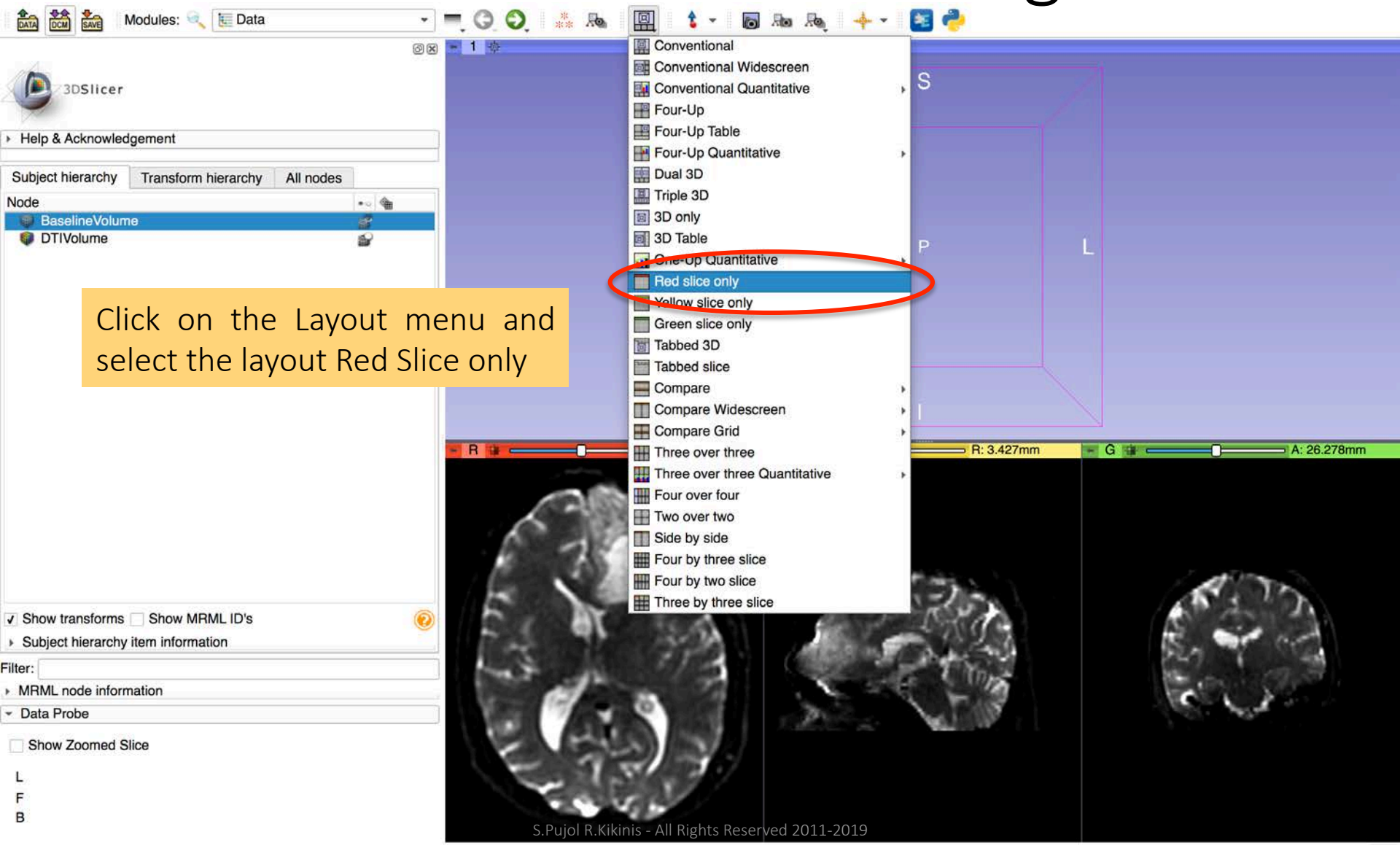
Tutorial Data Loading



Tutorial Data Loading

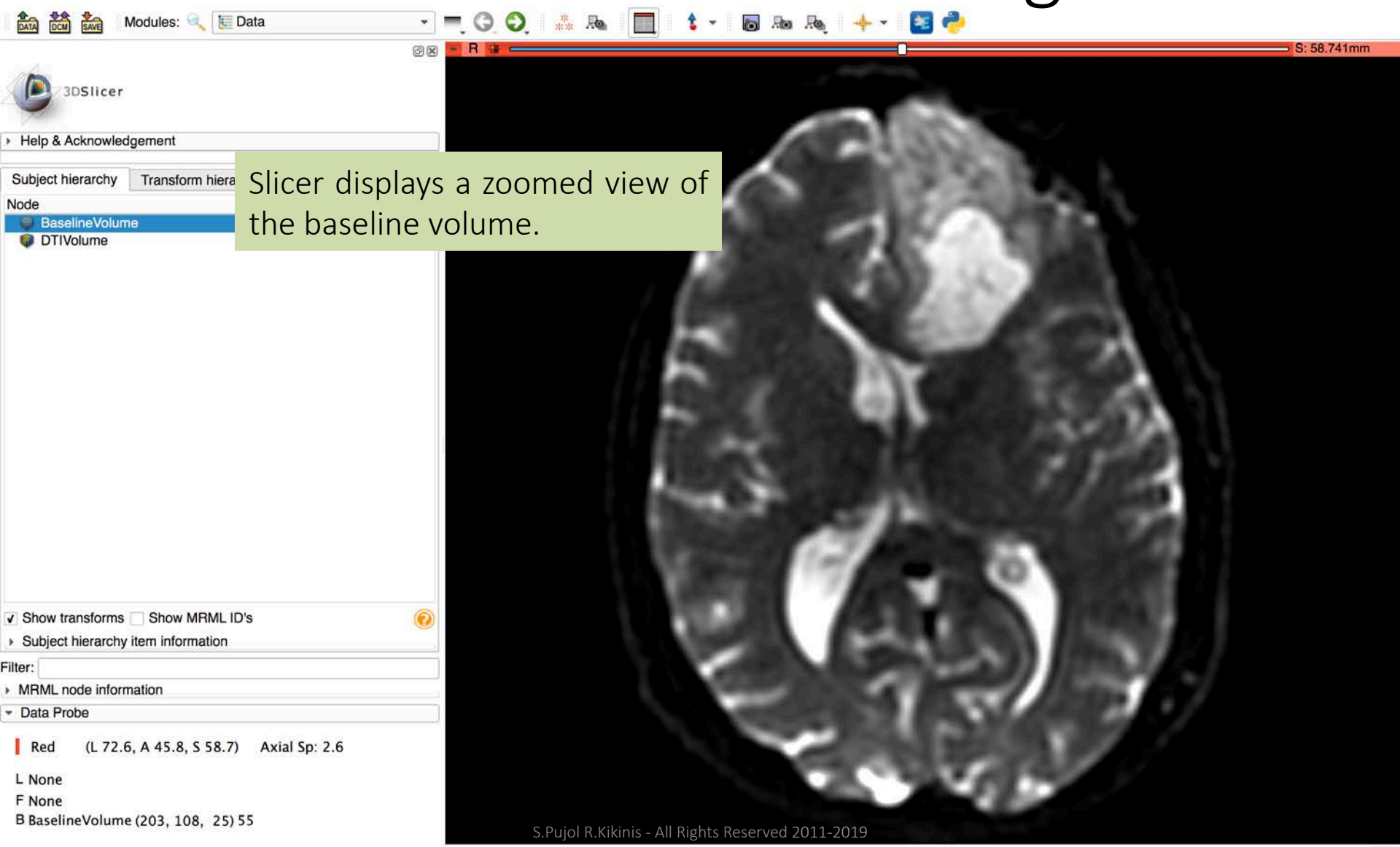


Tutorial Data Loading

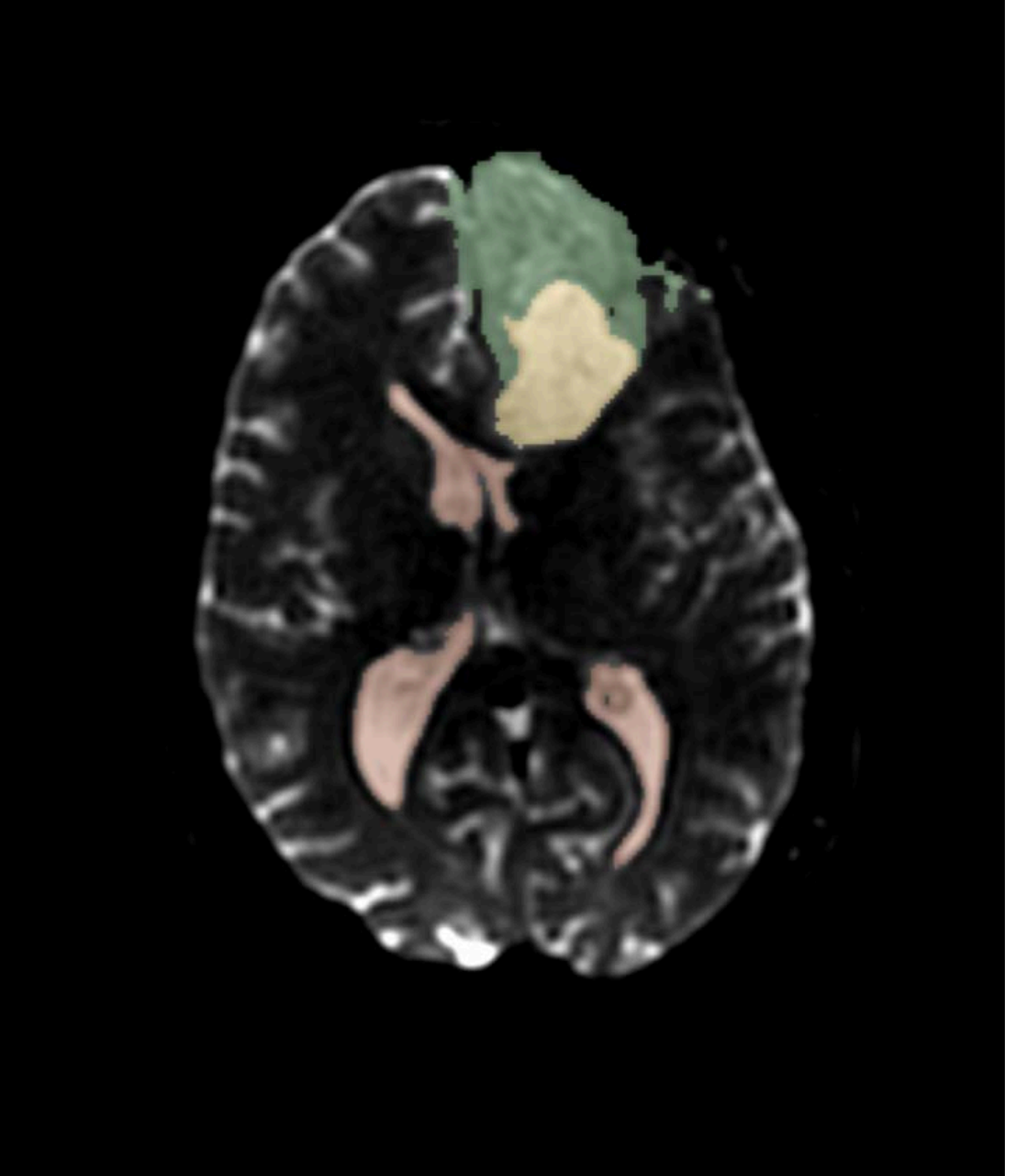


Click on the Layout menu and select the layout Red Slice only

Tutorial Data Loading

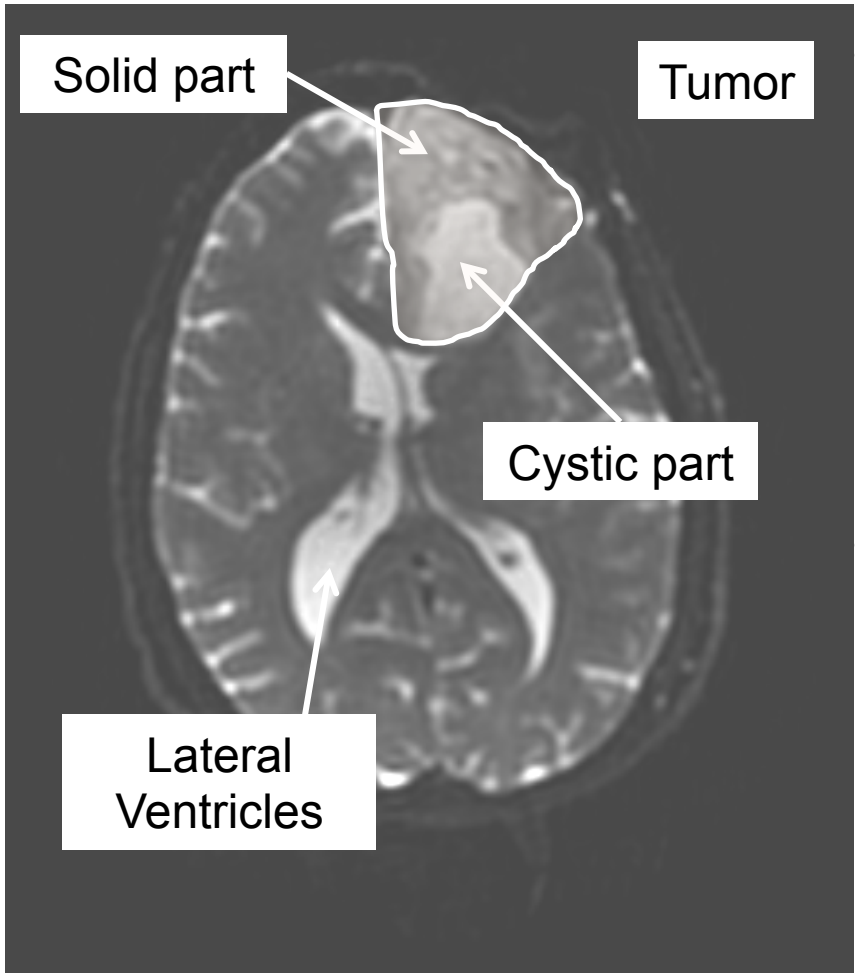


Slicer displays a zoomed view of the baseline volume.



Part 1: Segmentation of tumor and ventricles

Tumor segmentation



This section shows how to segment the solid and cystic components of the tumor using the **Grow from Seeds** tool of the Segment Editor module.

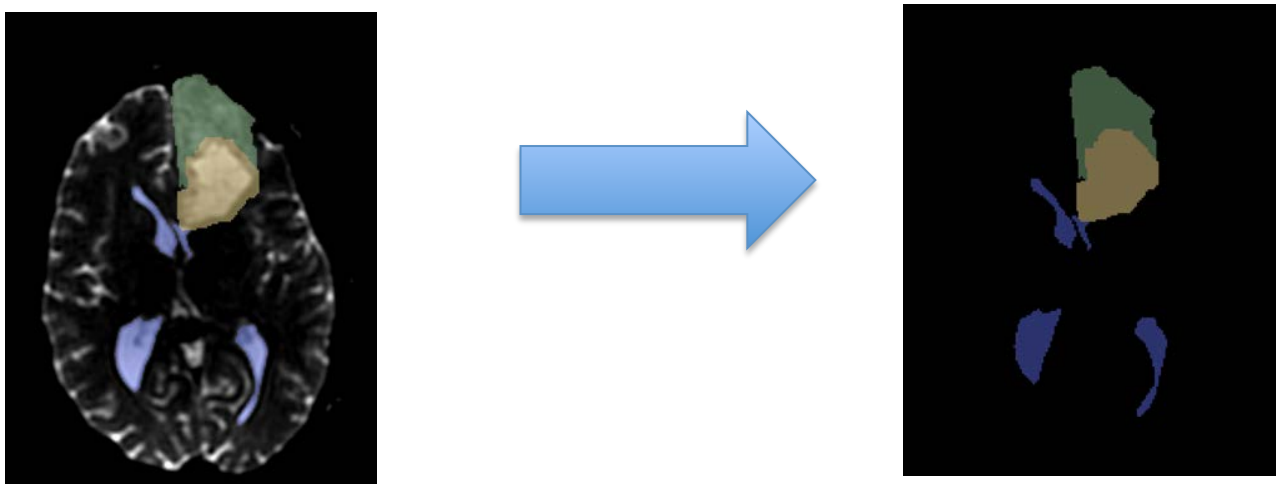
The section includes the segmentation of the lateral ventricles for anatomical reference.

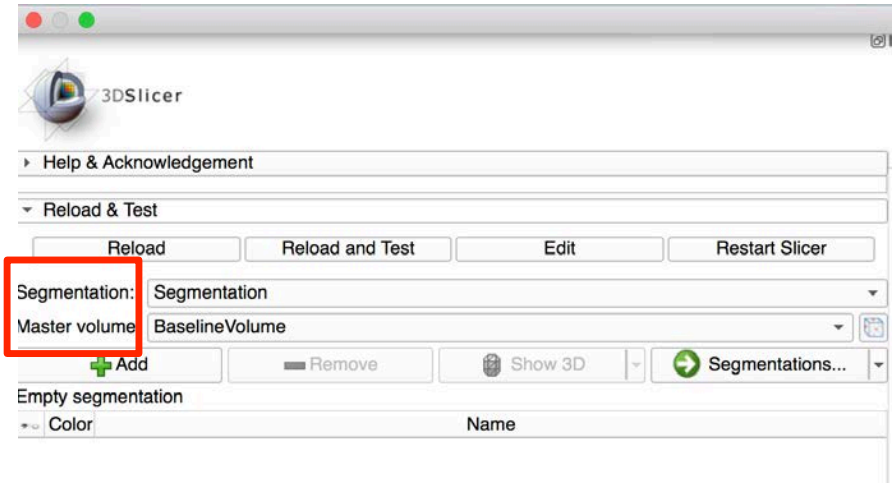
Segment Editor Module

- Segmentation is the process of identifying a structure of interest in imaging data

- The Segment Editor module of 3D Slicer provides powerful tools for manual and semi-automated segmentation

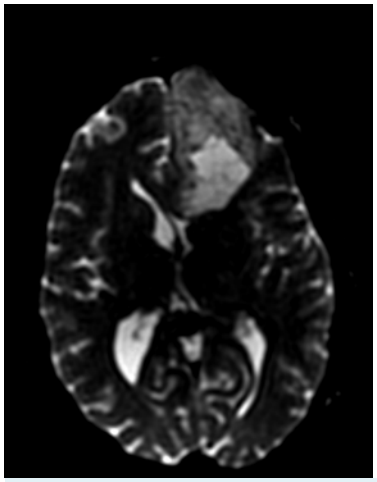
Basic Principle





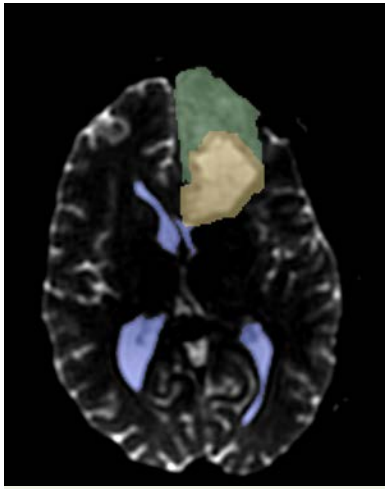
The Segment Editor module takes a reference image (**Master Volume**) as input and produces a segmented image (**Segmentation**) in output

Basic Principle



Master Volume

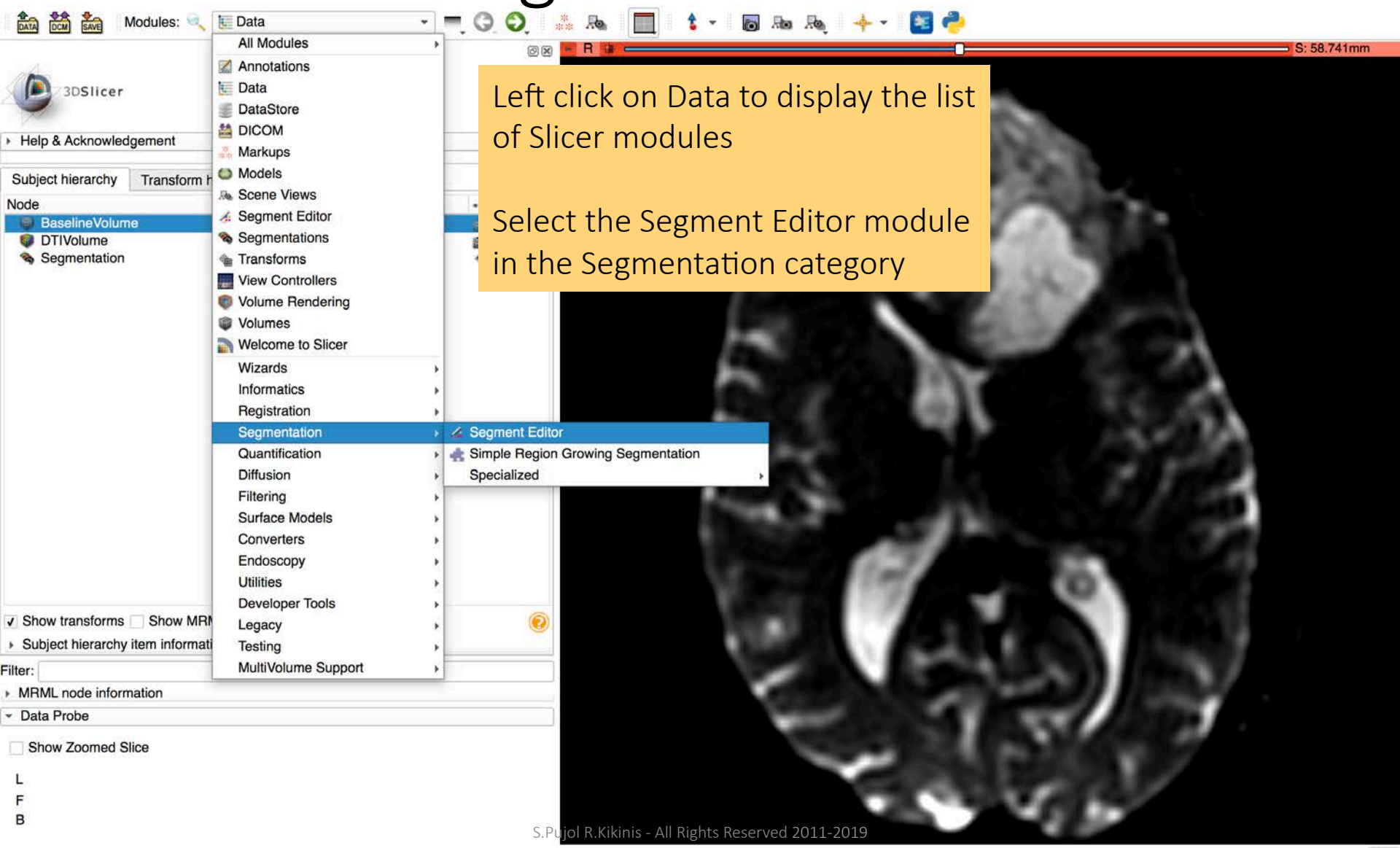
Segmentation



Master Volume + Segmentation

The Segmentation volume is a binary labelmap with the same origin and resolution as the Master Volume

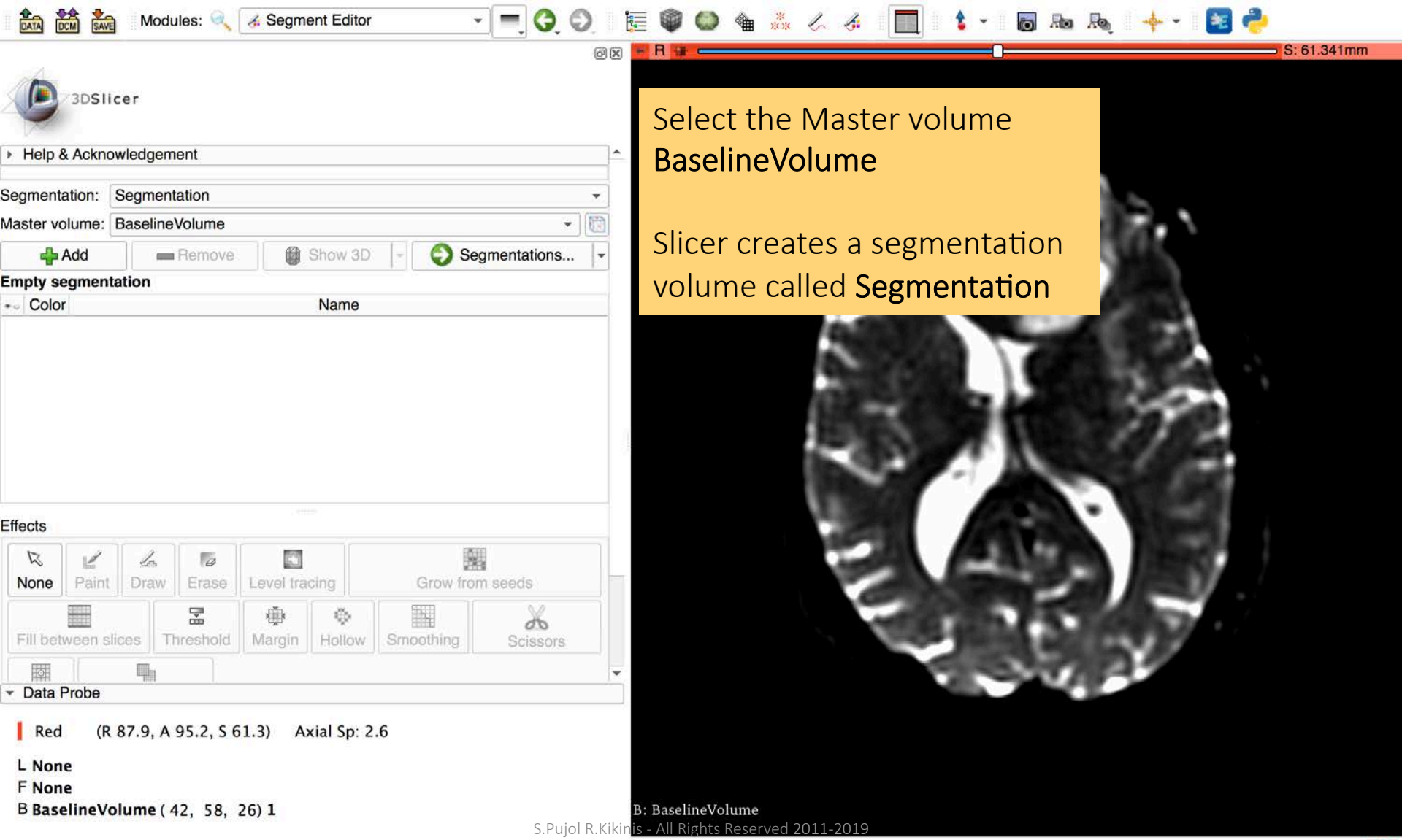
Segment Editor



Left click on Data to display the list of Slicer modules

Select the Segment Editor module in the Segmentation category

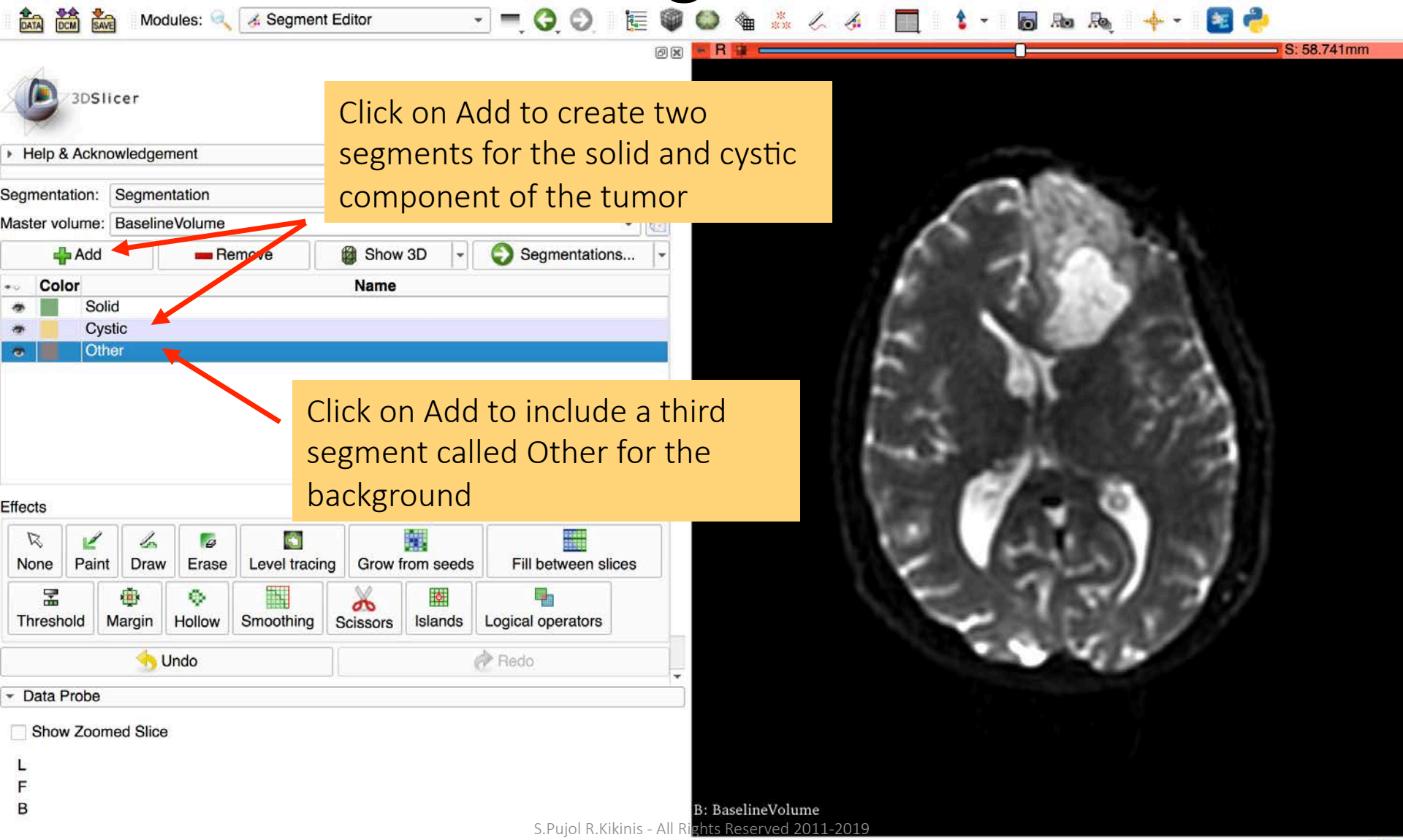
Tumor Segmentation



Select the Master volume **BaselineVolume**

Slicer creates a segmentation volume called **Segmentation**

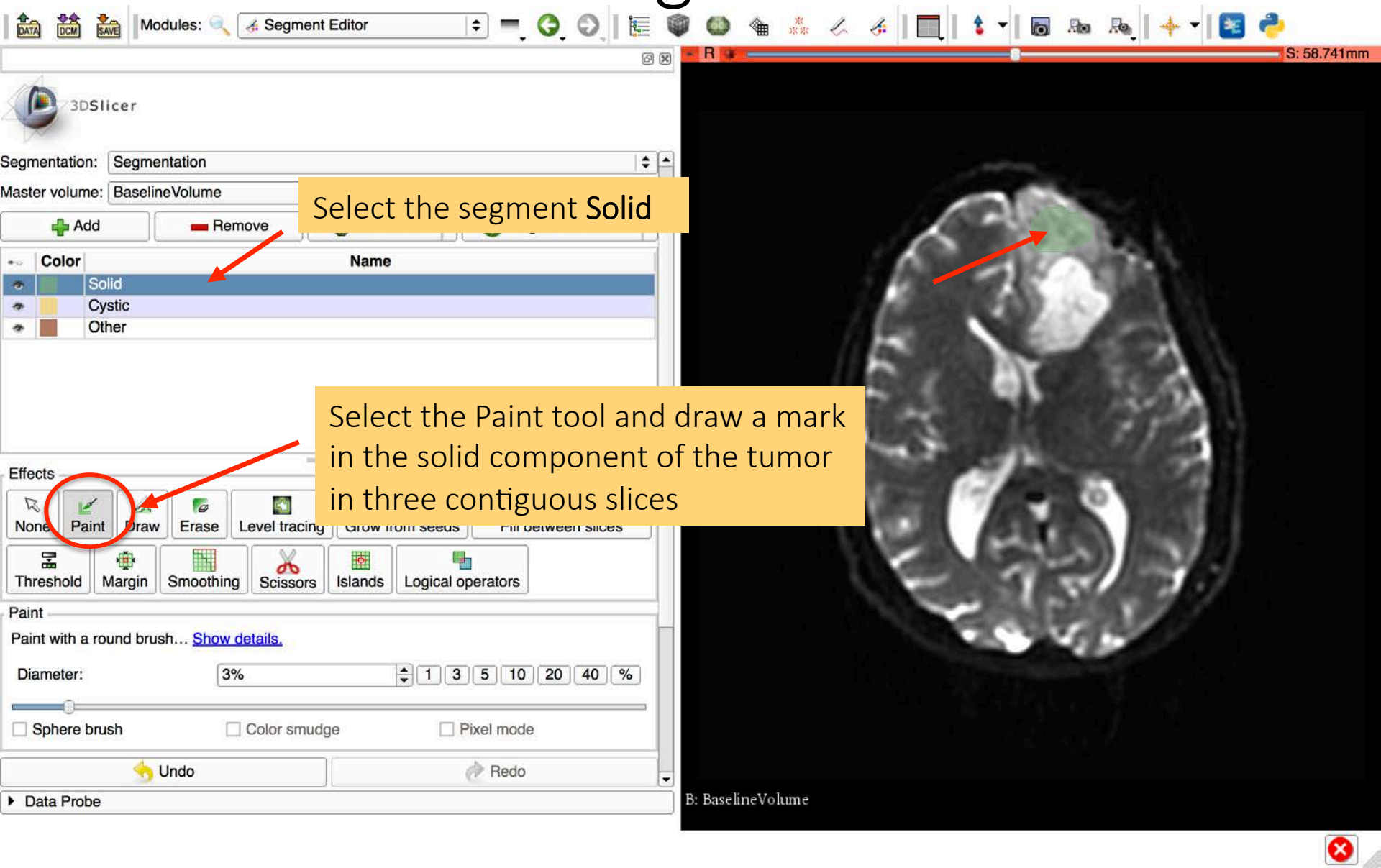
Tumor Segmentation



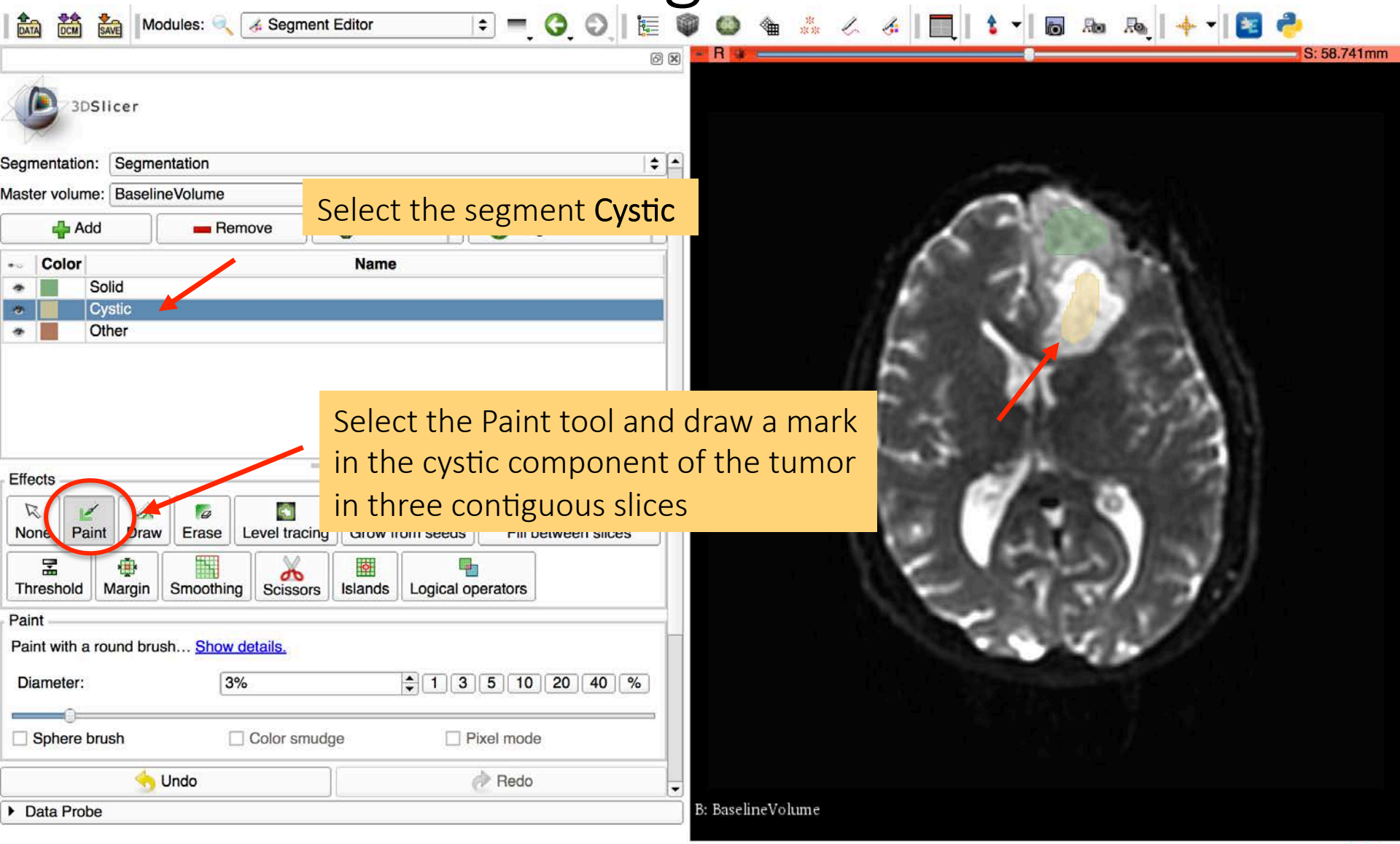
Click on Add to create two segments for the solid and cystic component of the tumor

Click on Add to include a third segment called Other for the background

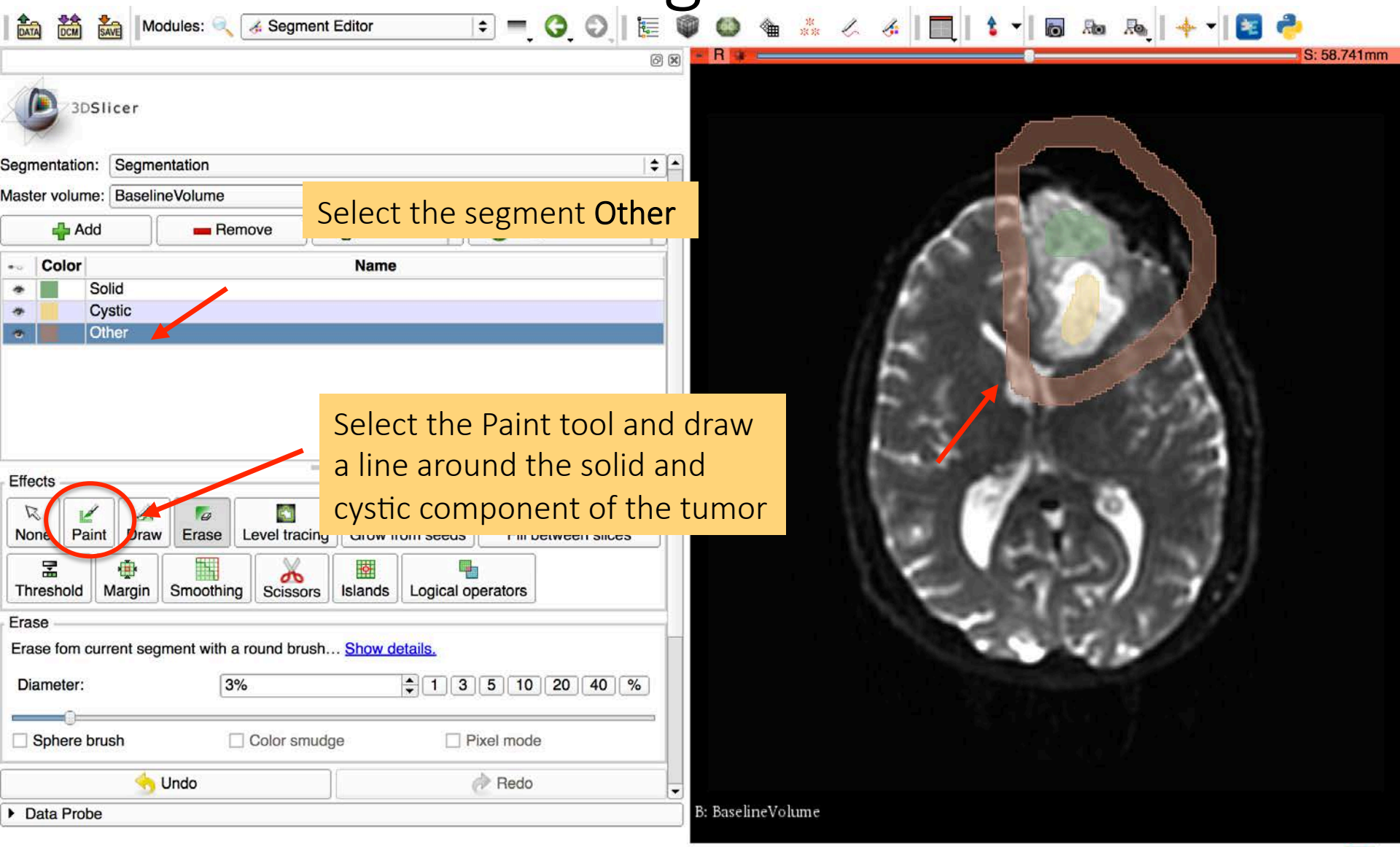
Tumor Segmentation



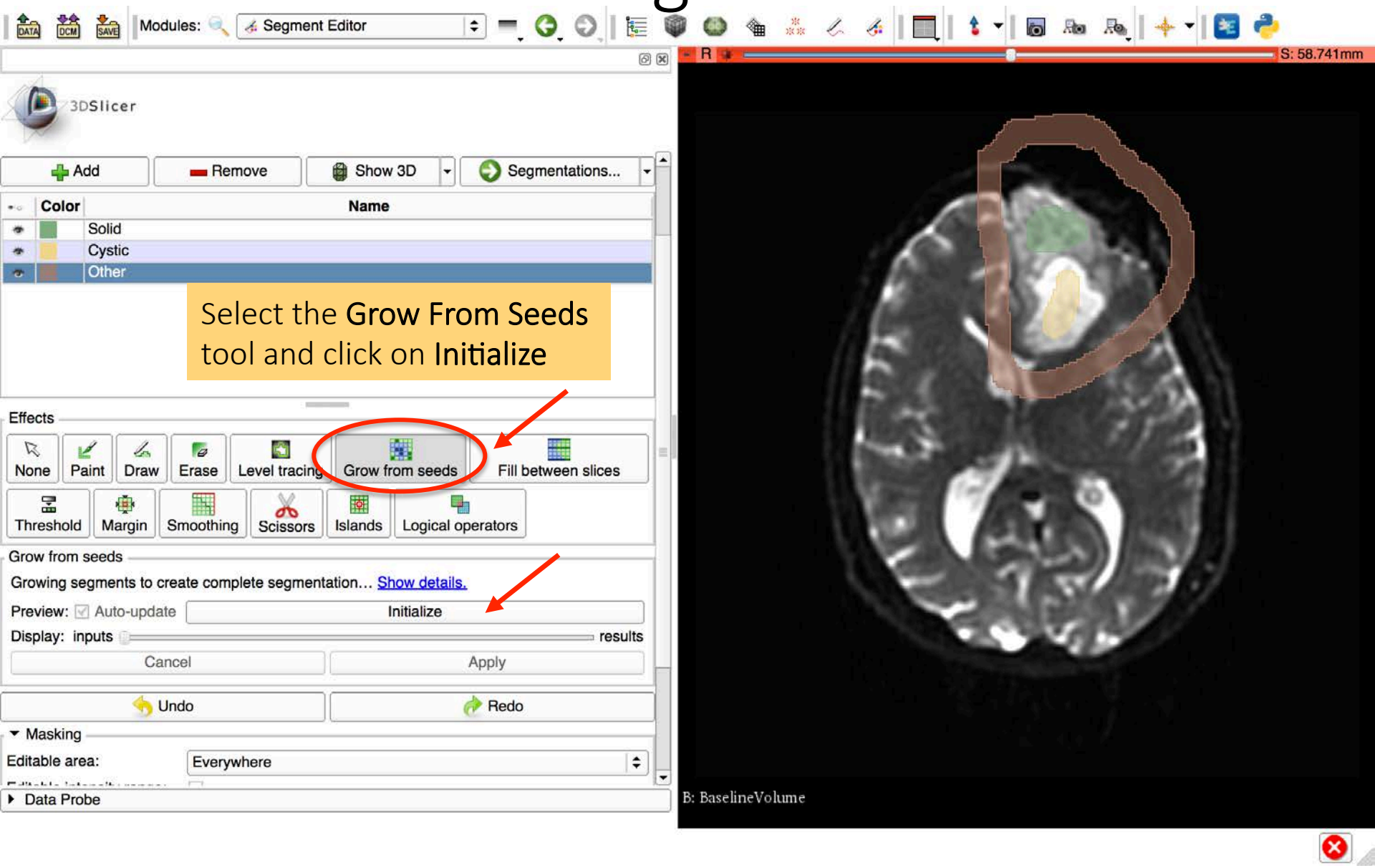
Tumor Segmentation



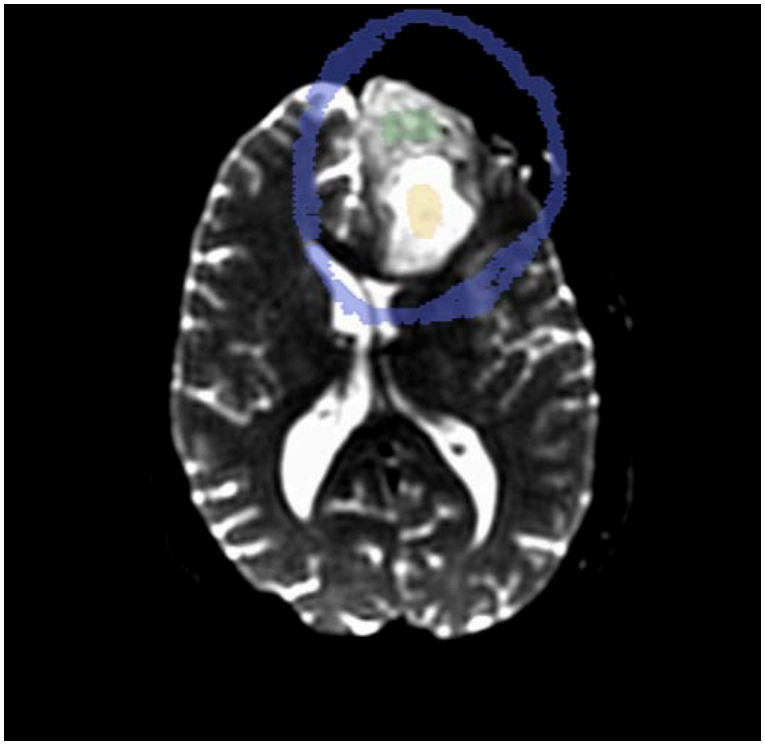
Tumor Segmentation



Tumor Segmentation



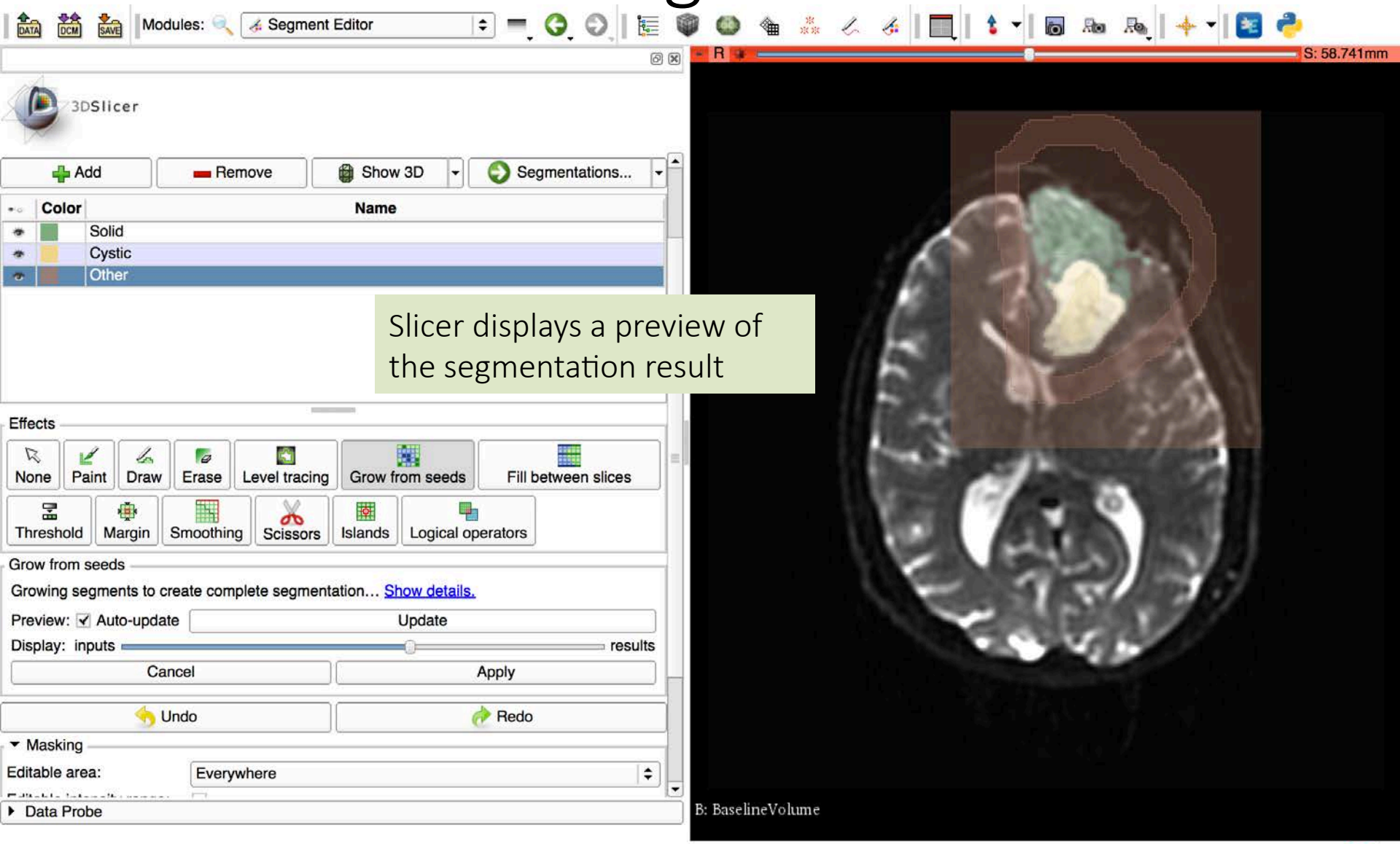
Grow from Seeds Algorithm



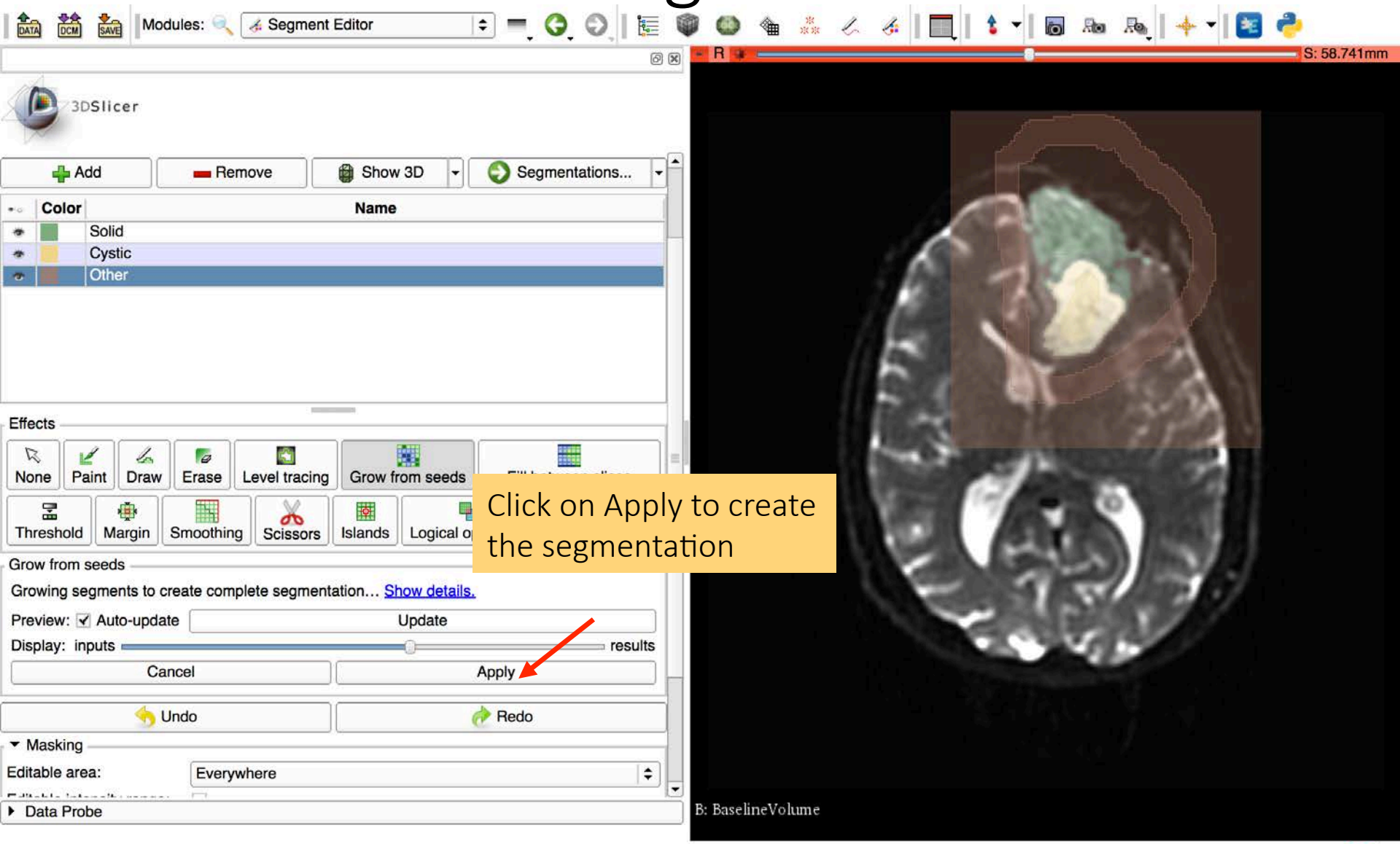
- The **Grow from Seeds** tool implements the **Grow Cut algorithm**, a competitive region growing algorithm using a Cellular Automata approach.
- The algorithm performs automated multi-label image segmentation using a set of user input scribbles.

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

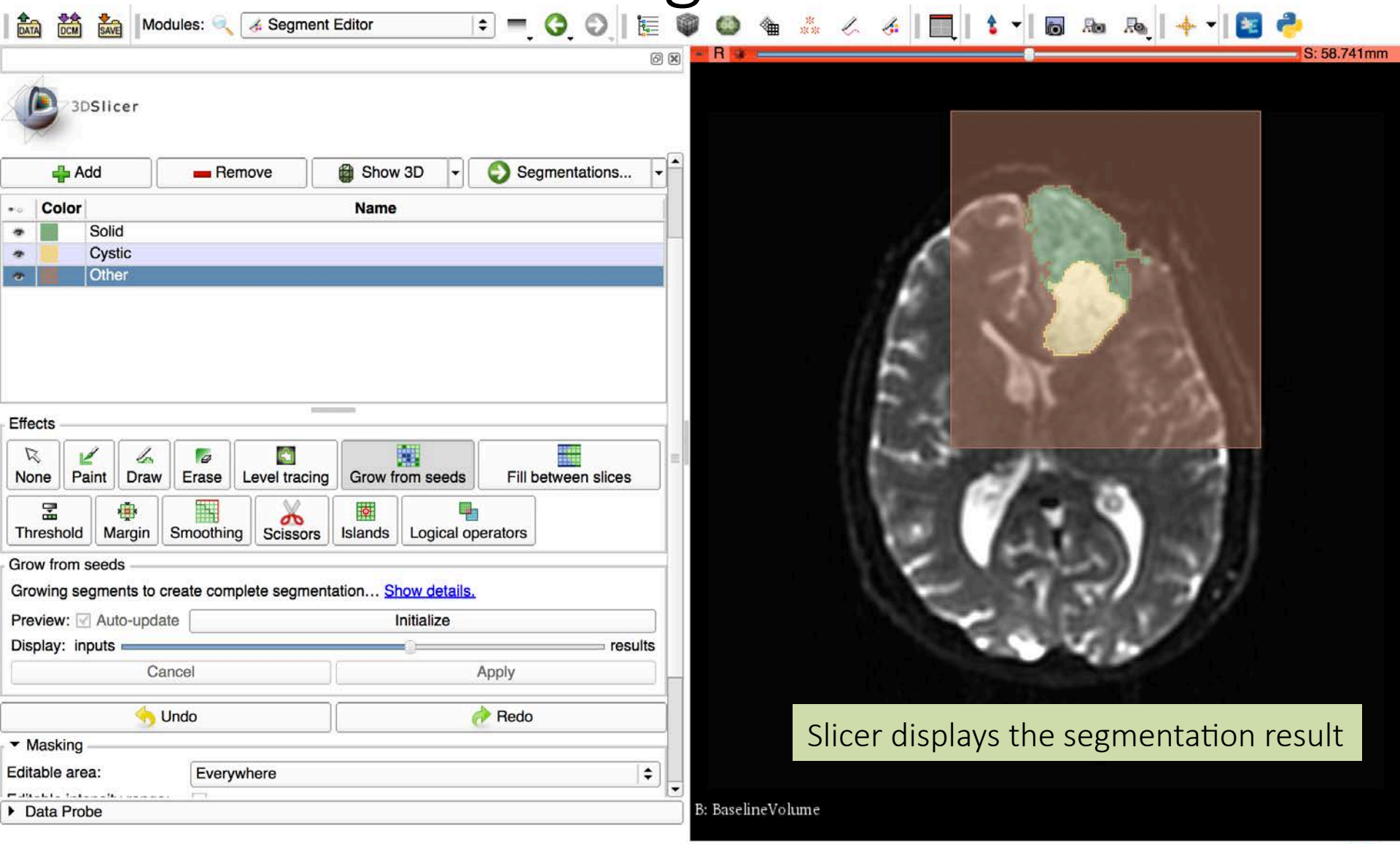
Tumor Segmentation



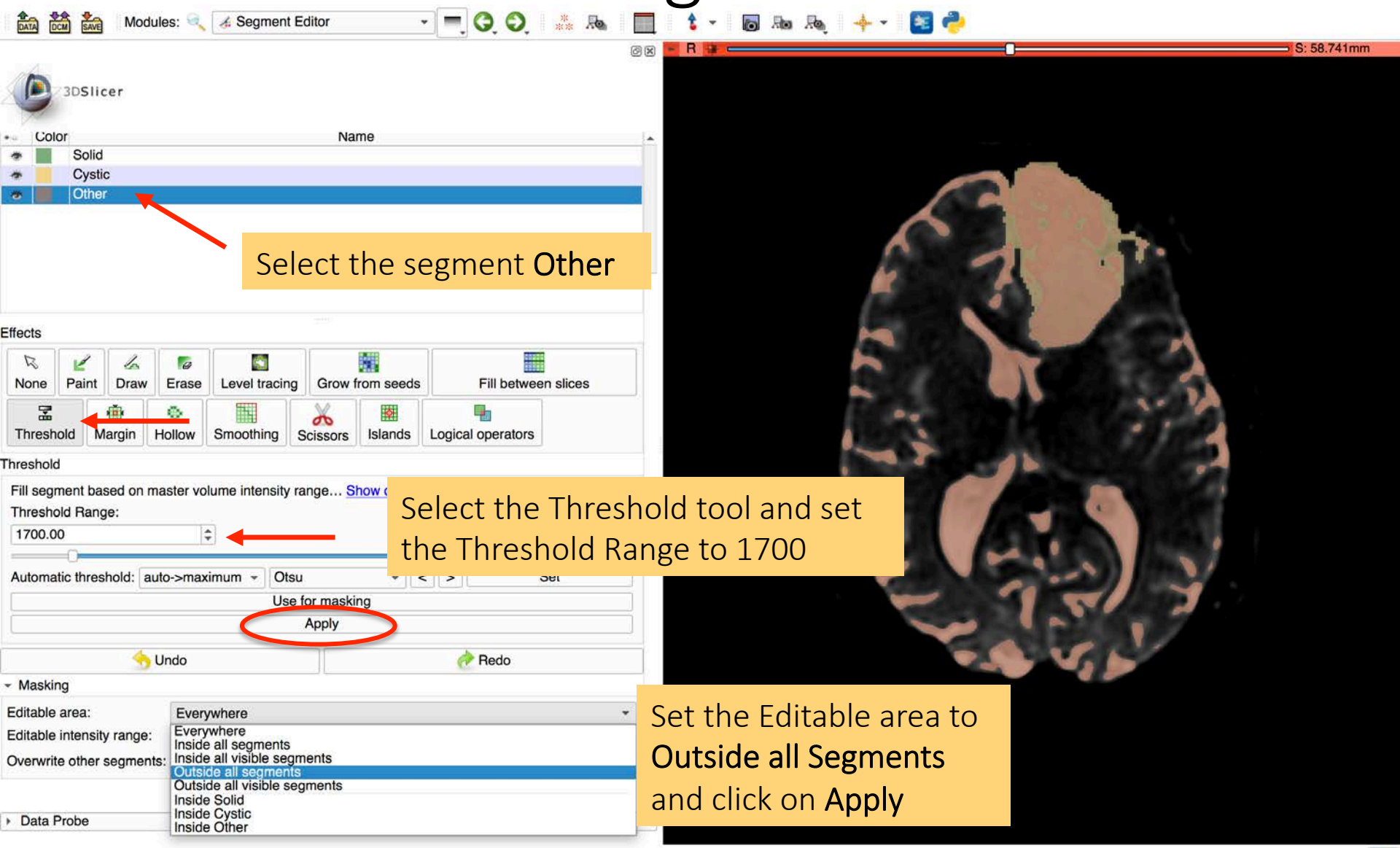
Tumor Segmentation



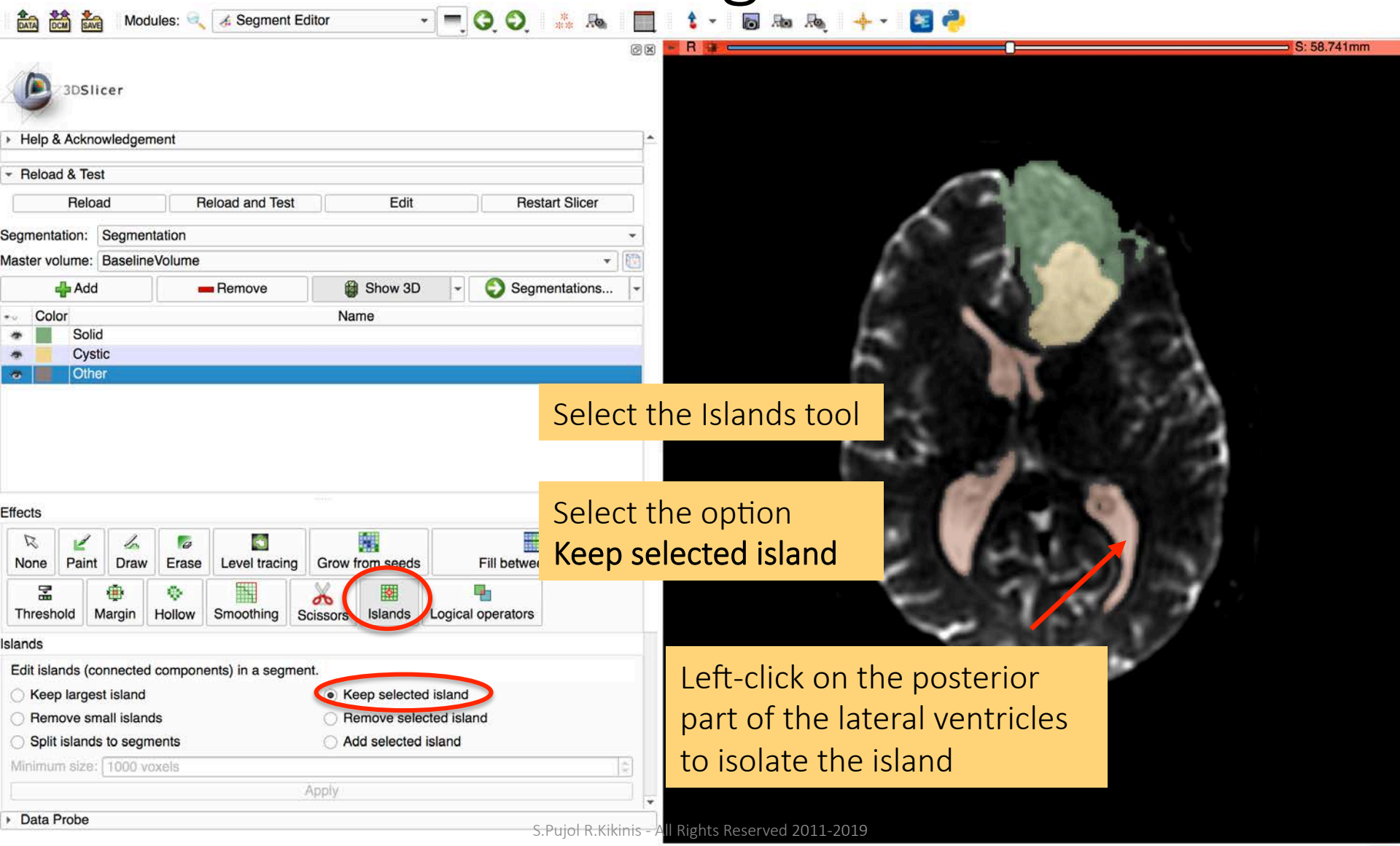
Tumor Segmentation



Tumor Segmentation



Ventricles Segmentation

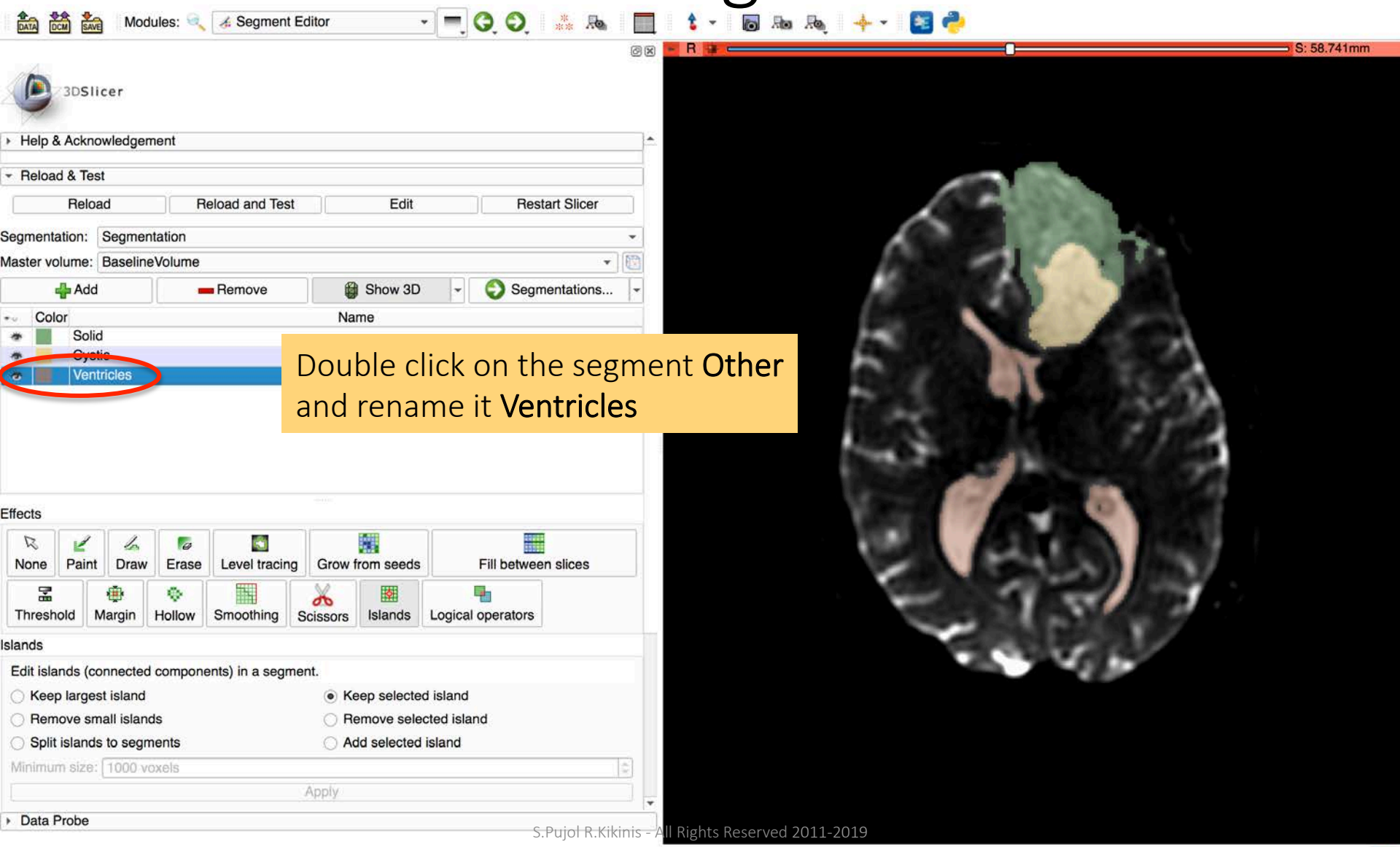


Select the Islands tool

Select the option
Keep selected island

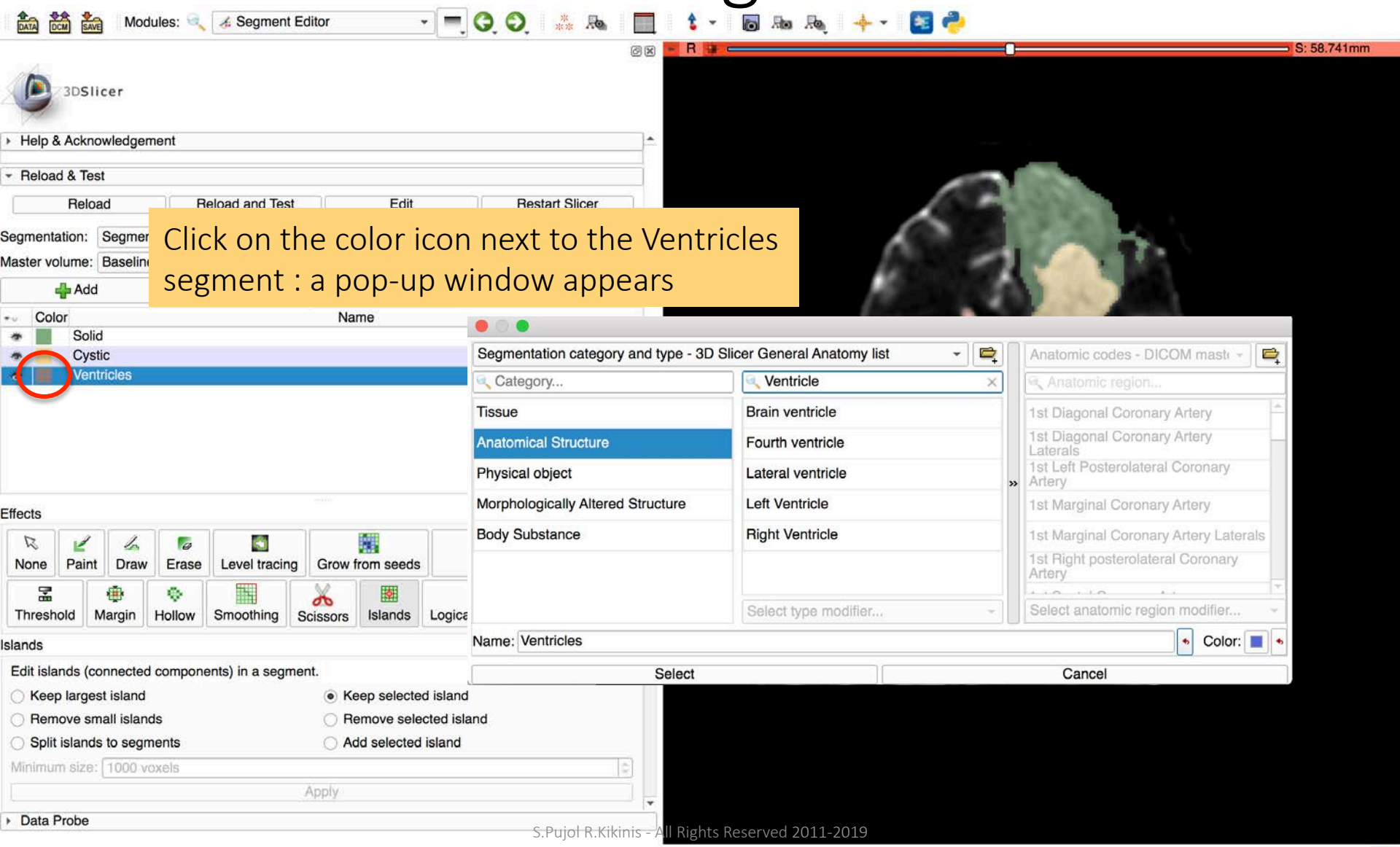
Left-click on the posterior part of the lateral ventricles to isolate the island

Ventricles Segmentation

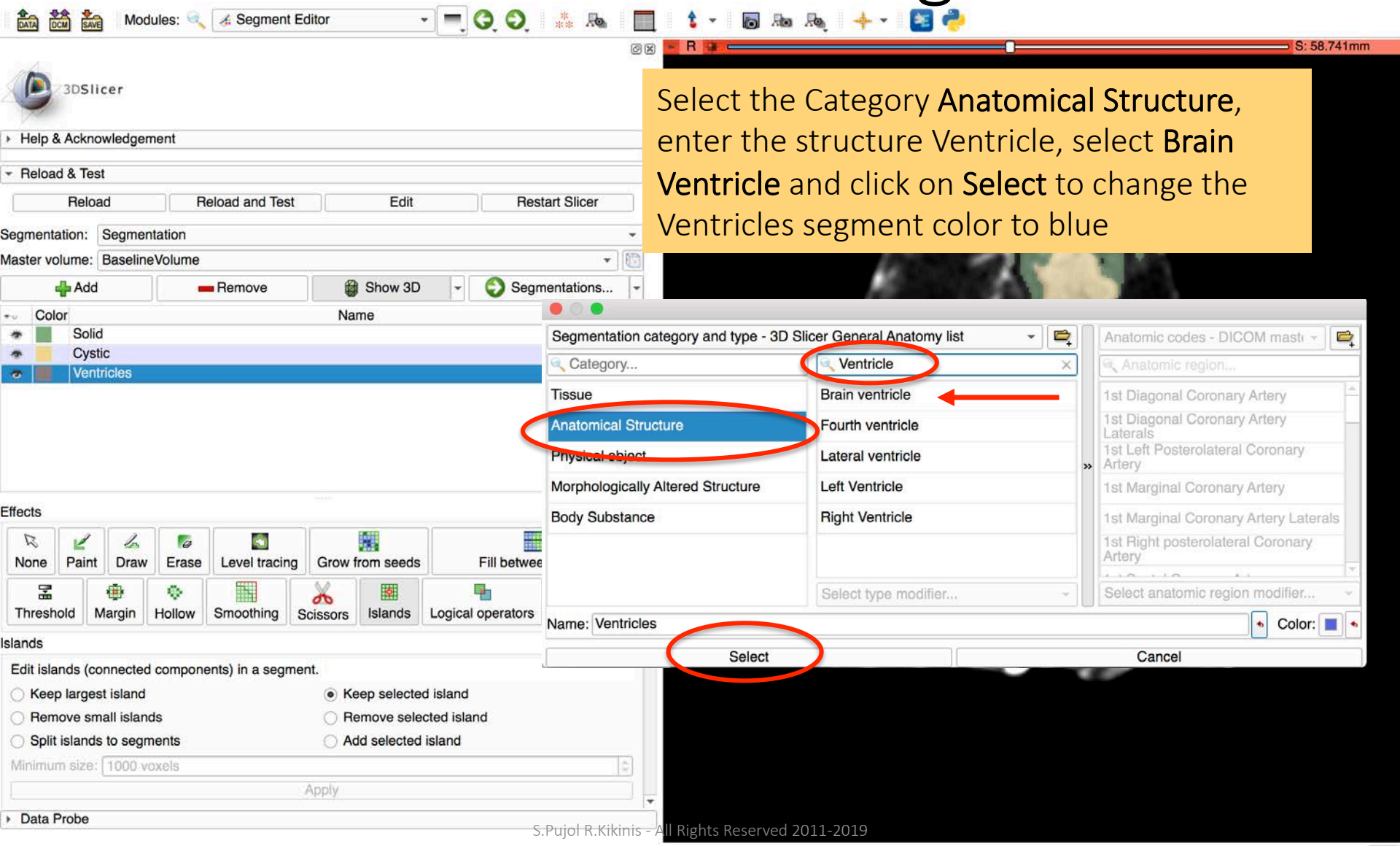


Double click on the segment **Other** and rename it **Ventricles**

Ventricles Segmentation

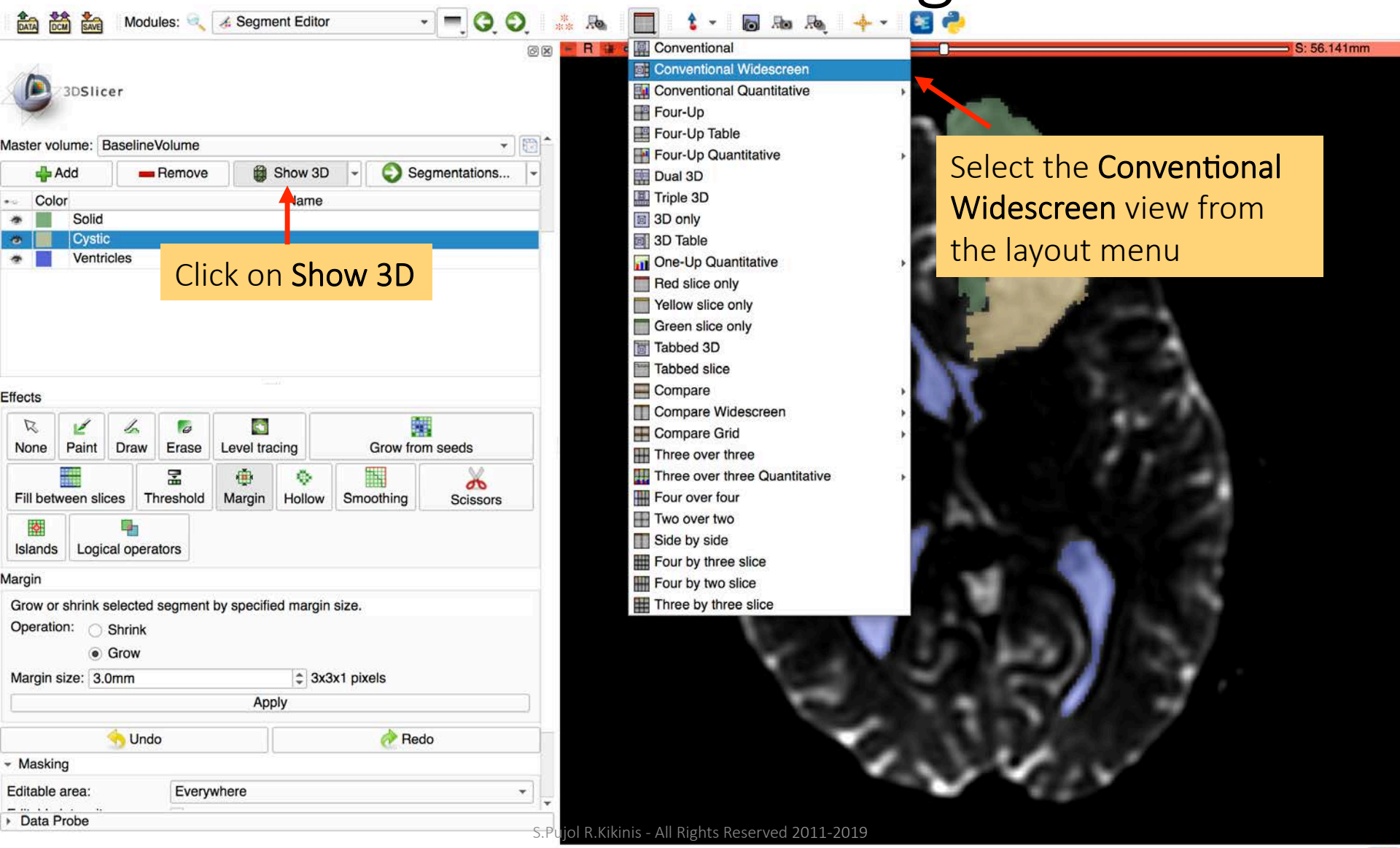


Tumor and Ventricles Segmentation

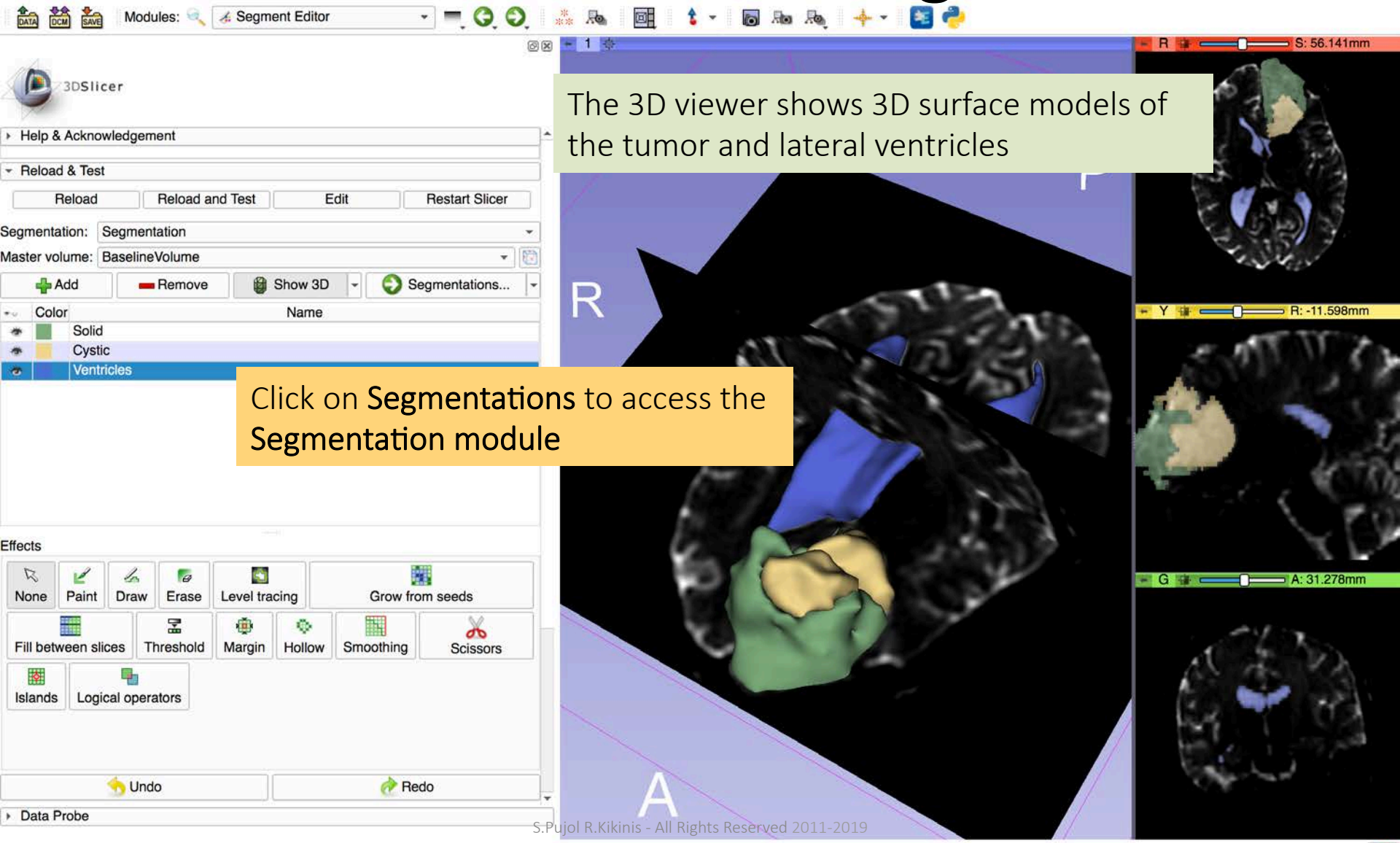


Select the Category **Anatomical Structure**, enter the structure Ventricle, select **Brain Ventricle** and click on **Select** to change the Ventricles segment color to blue

Tumor and Ventricles Segmentation

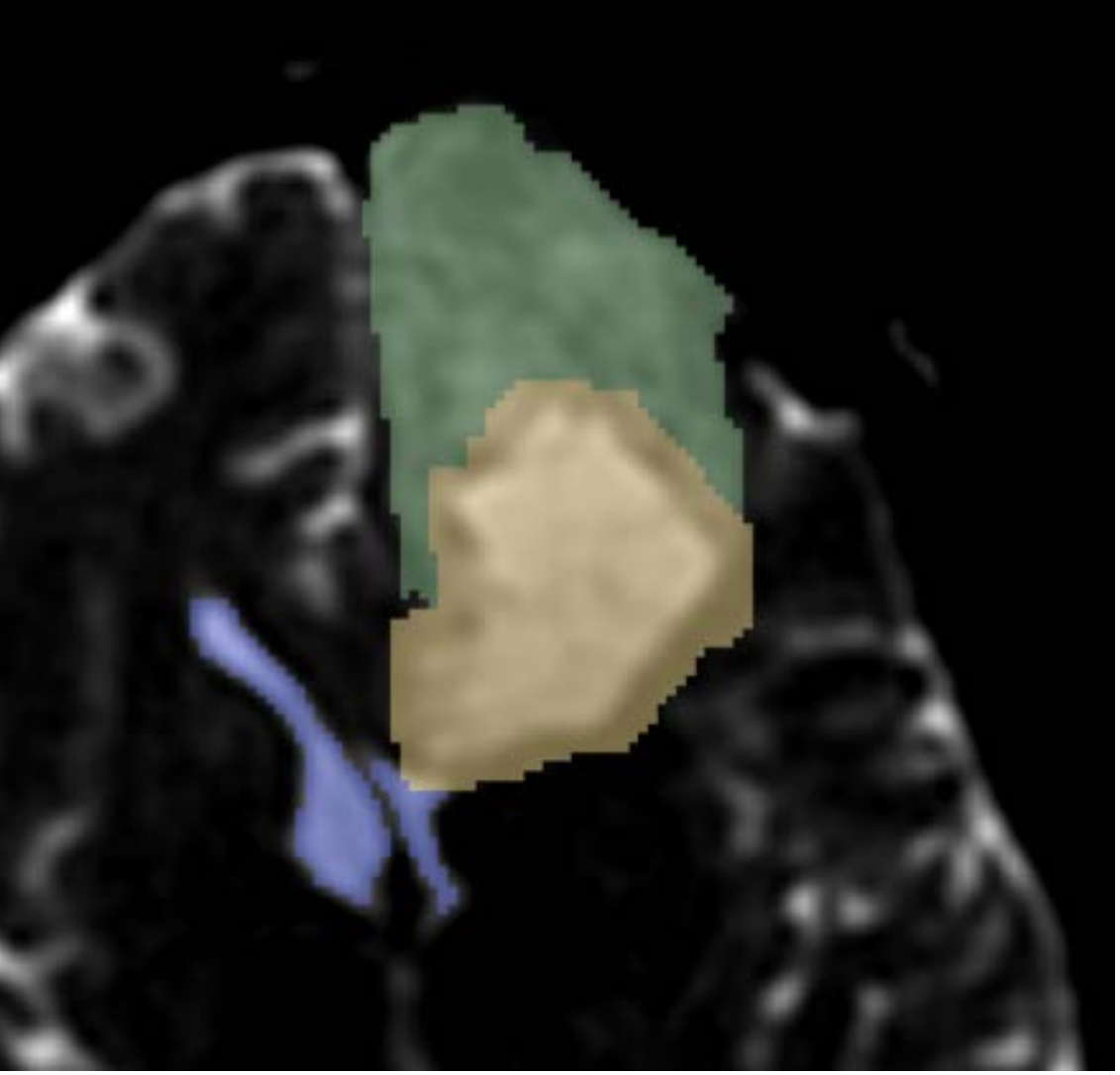


Tumor and Ventricles Segmentation



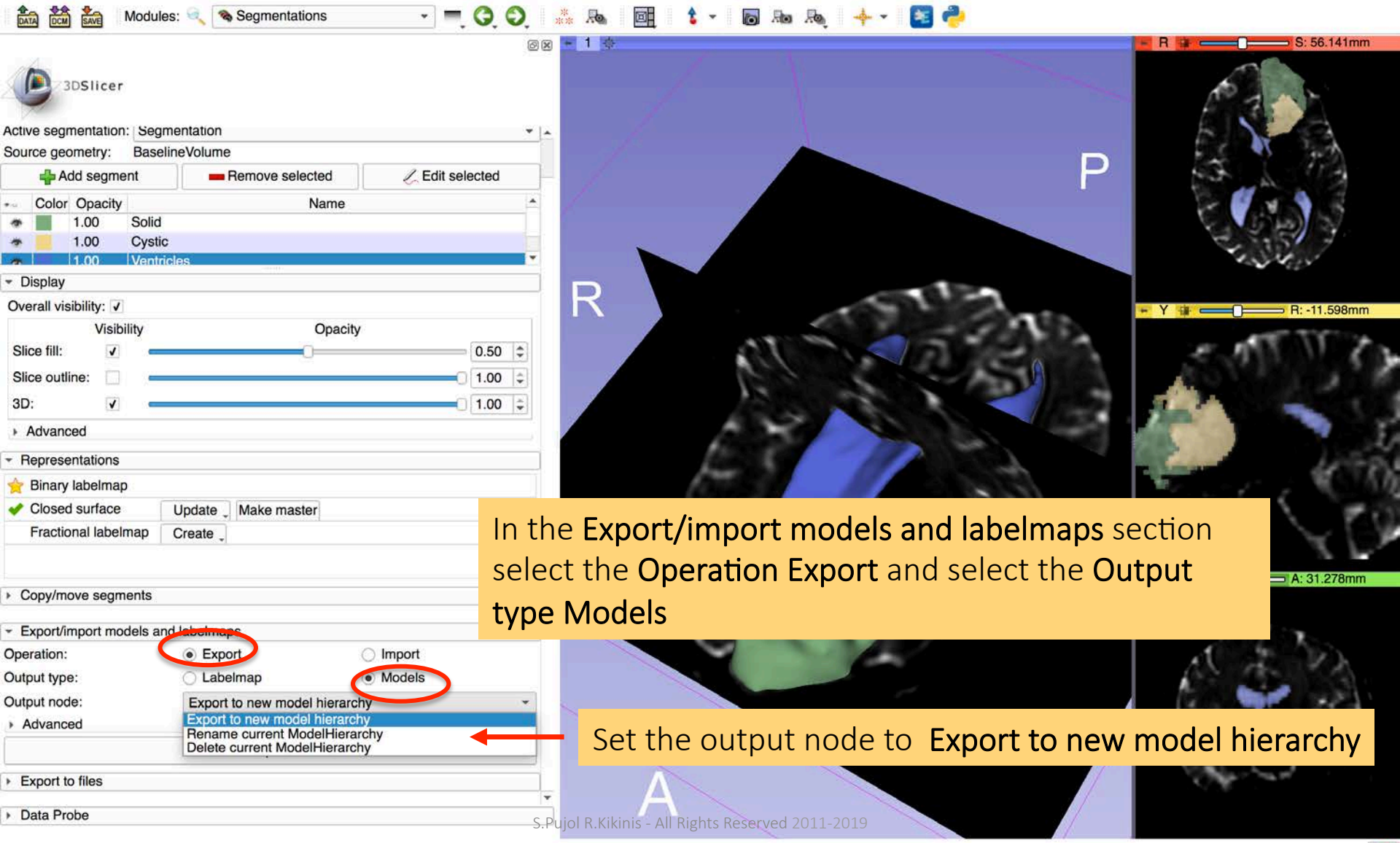
The 3D viewer shows 3D surface models of the tumor and lateral ventricles

Click on **Segmentations** to access the **Segmentation module**



Part 2: Peritumoral volume generation

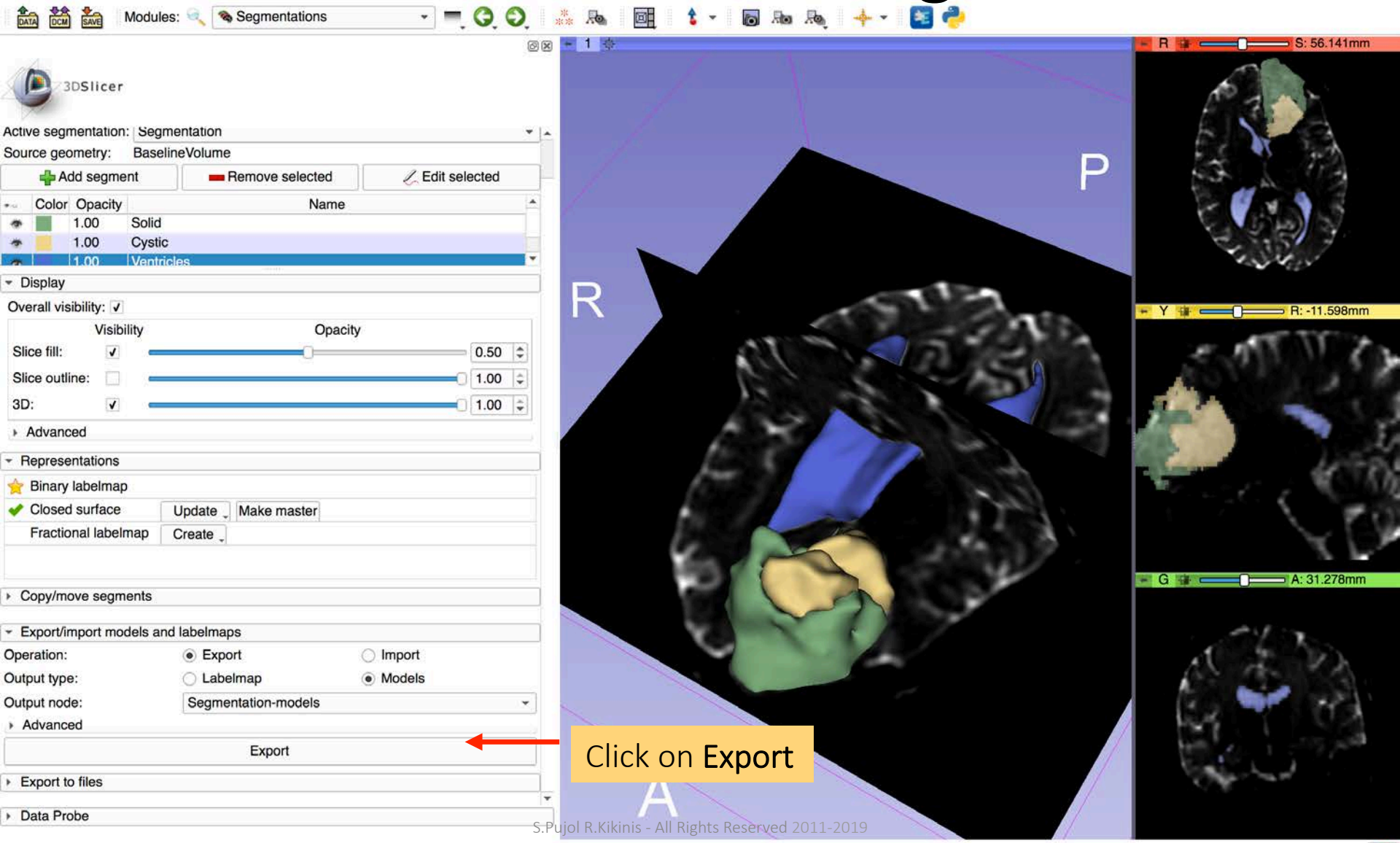
Tumor and Ventricles Segmentation



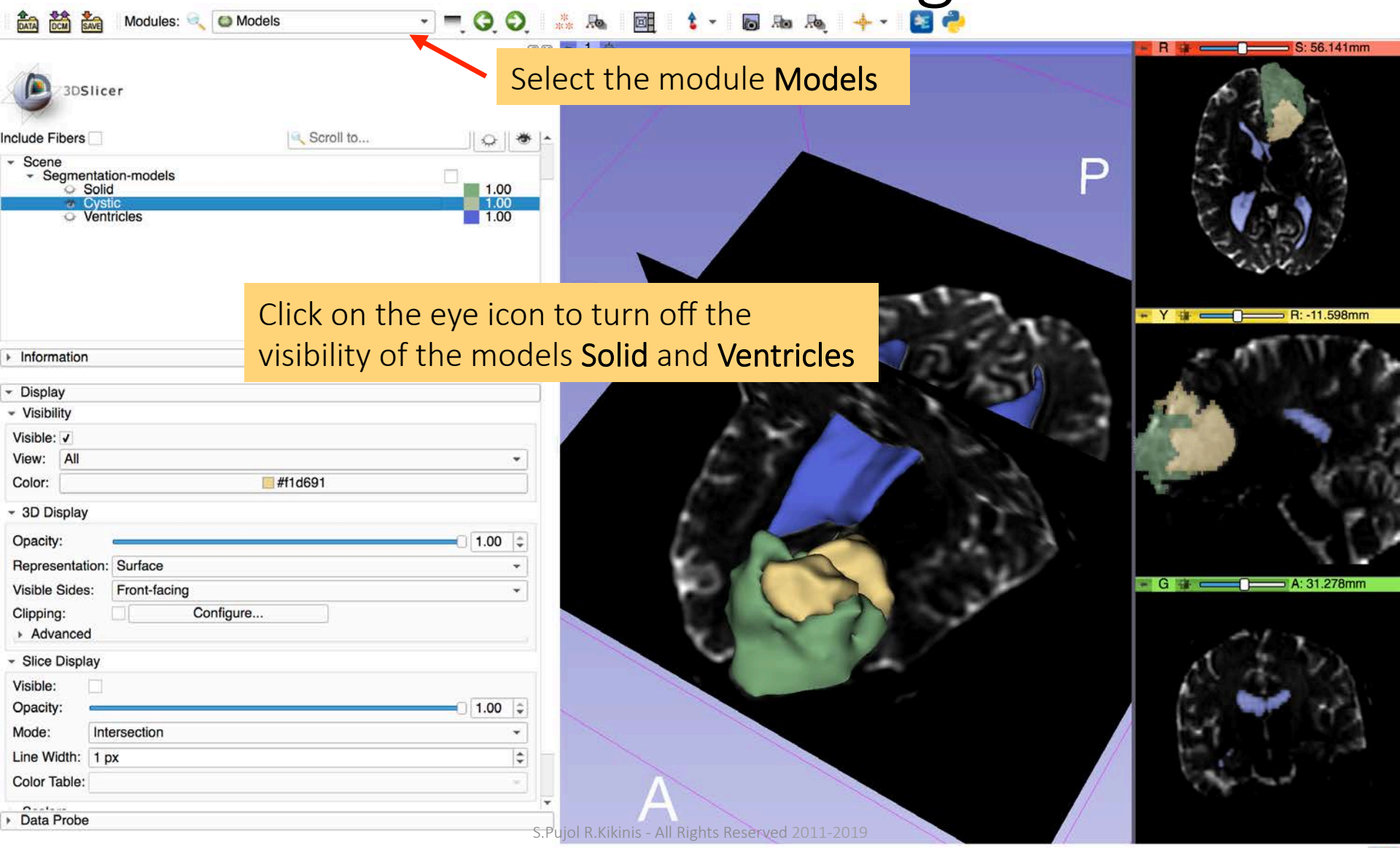
In the **Export/import models and labelmaps** section select the **Operation Export** and select the **Output type Models**

Set the output node to **Export to new model hierarchy**

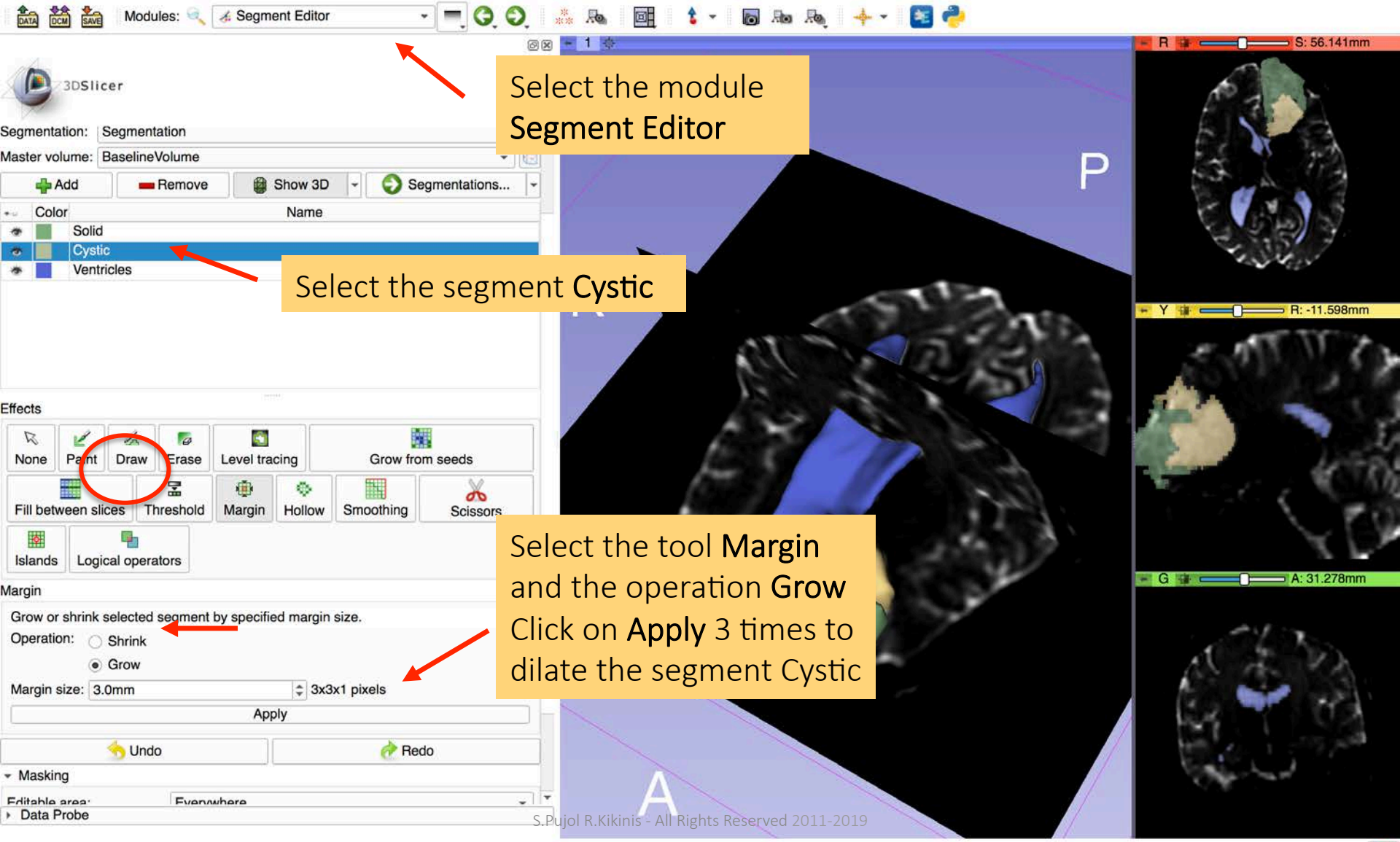
Tumor and Ventricles Segmentation



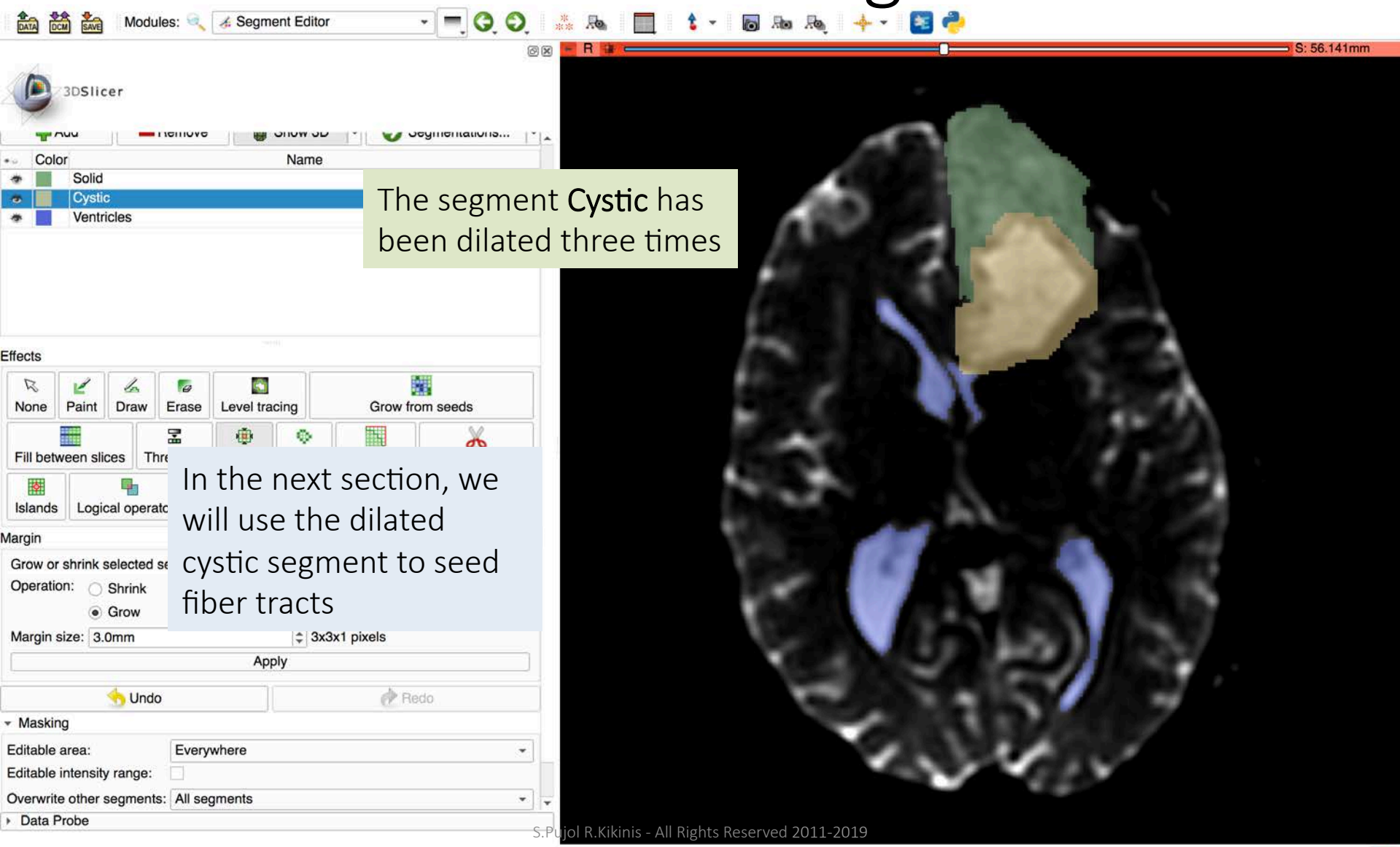
Tumor and Ventricles Segmentation



Peritumoral volume generation



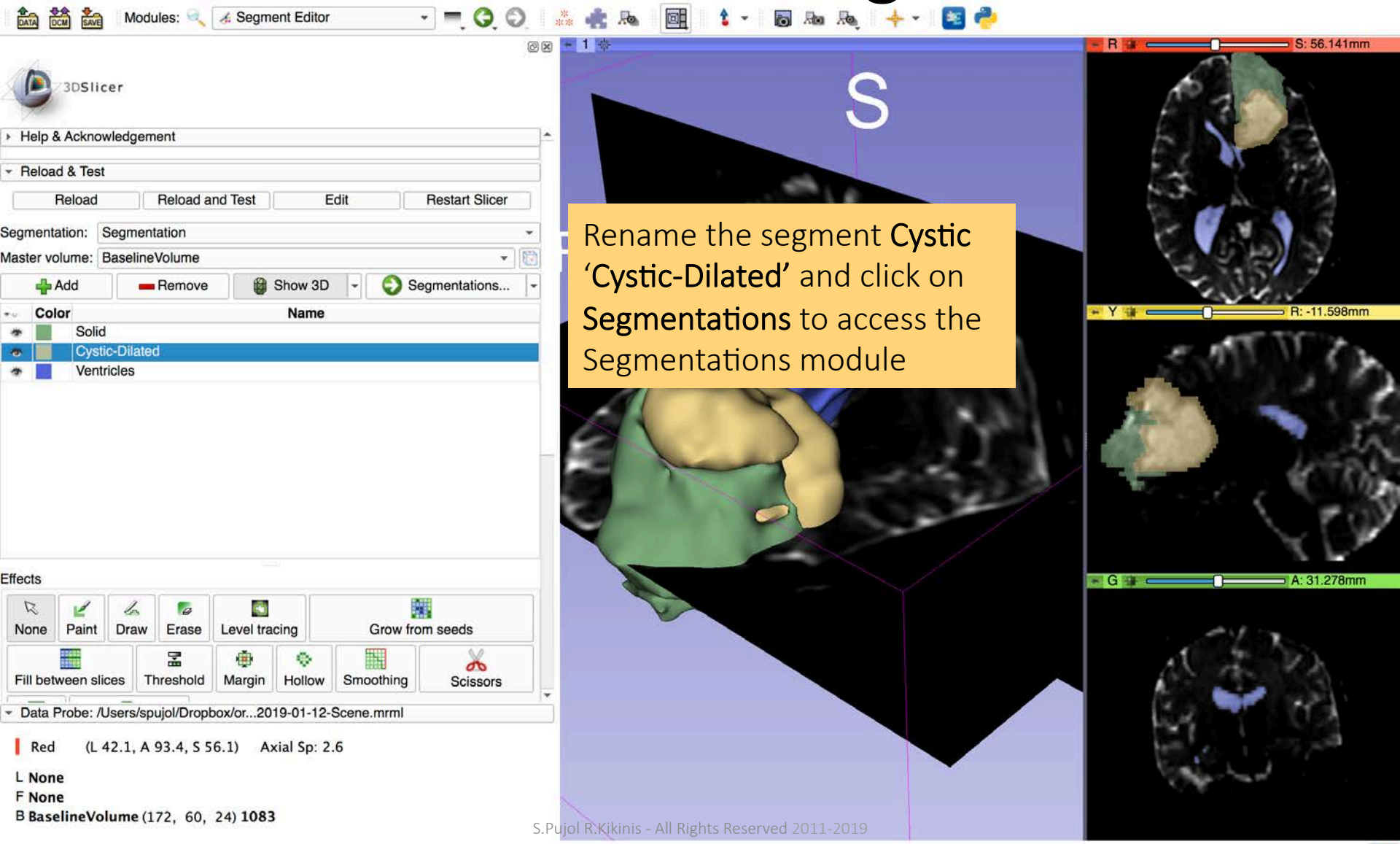
Peritumoral volume generation



The segment **Cystic** has been dilated three times

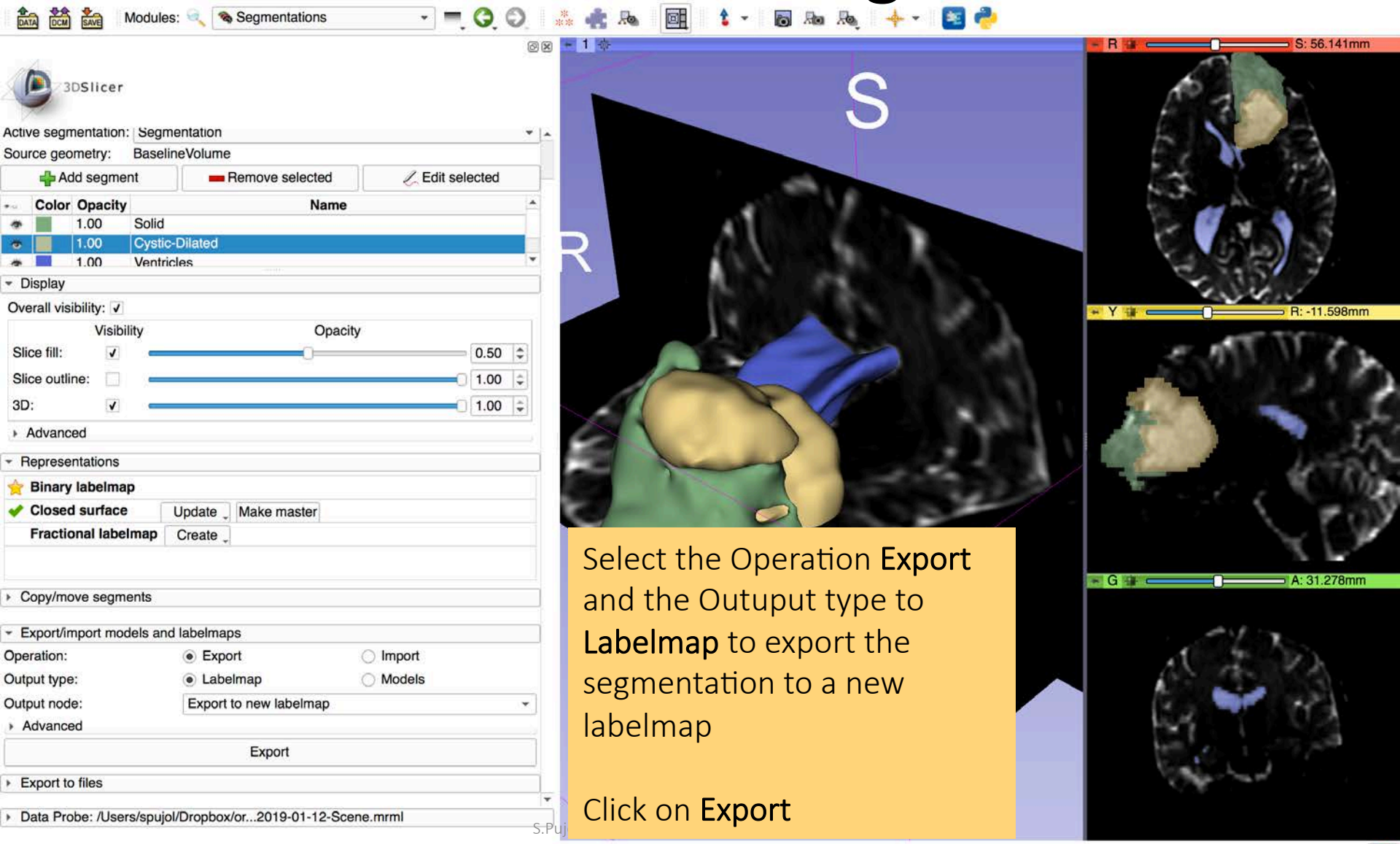
In the next section, we will use the dilated cystic segment to seed fiber tracts

Peritumoral volume generation



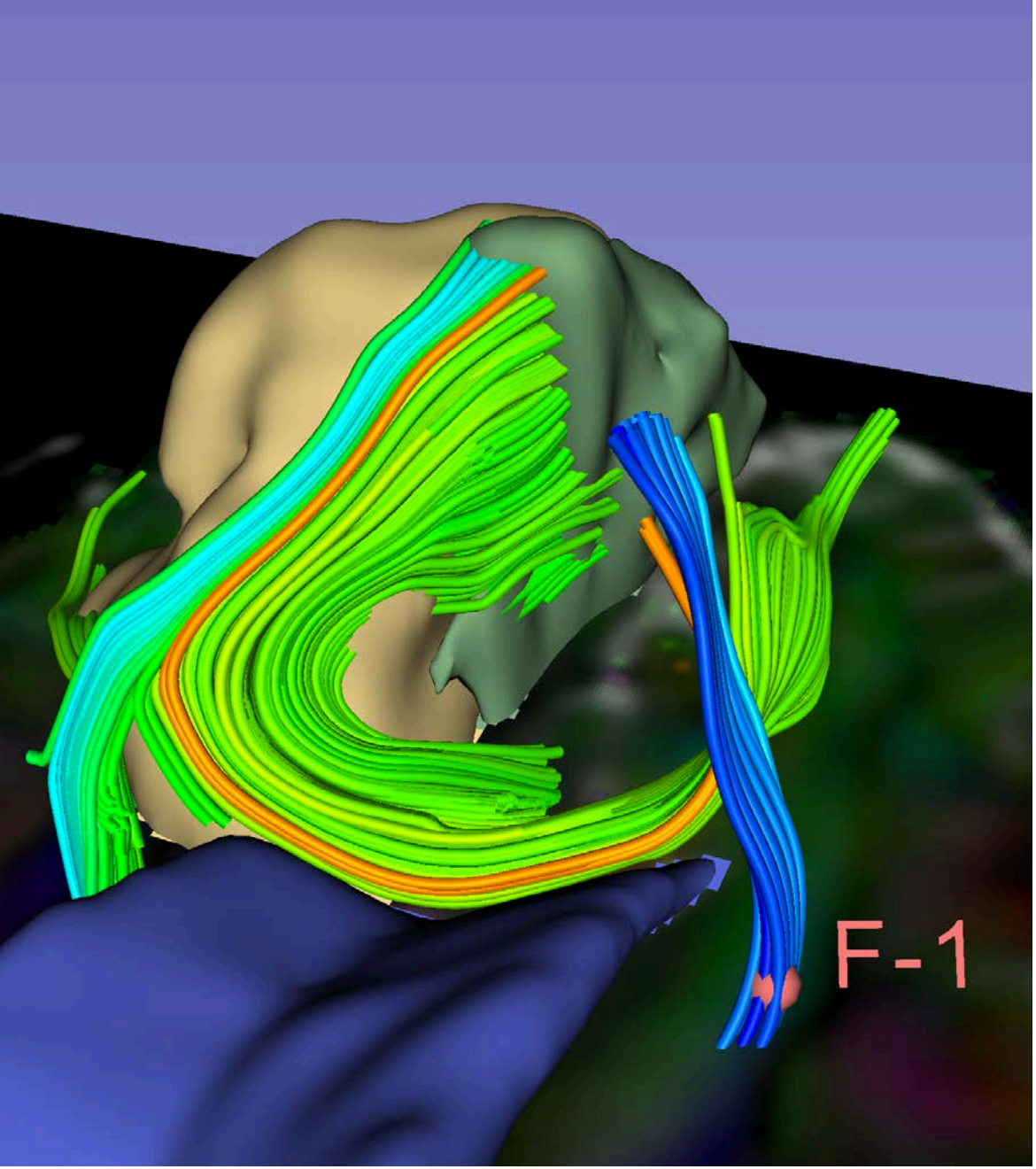
Rename the segment **Cystic** '**Cystic-Dilated**' and click on **Segmentations** to access the Segmentations module

Peritumoral volume generation



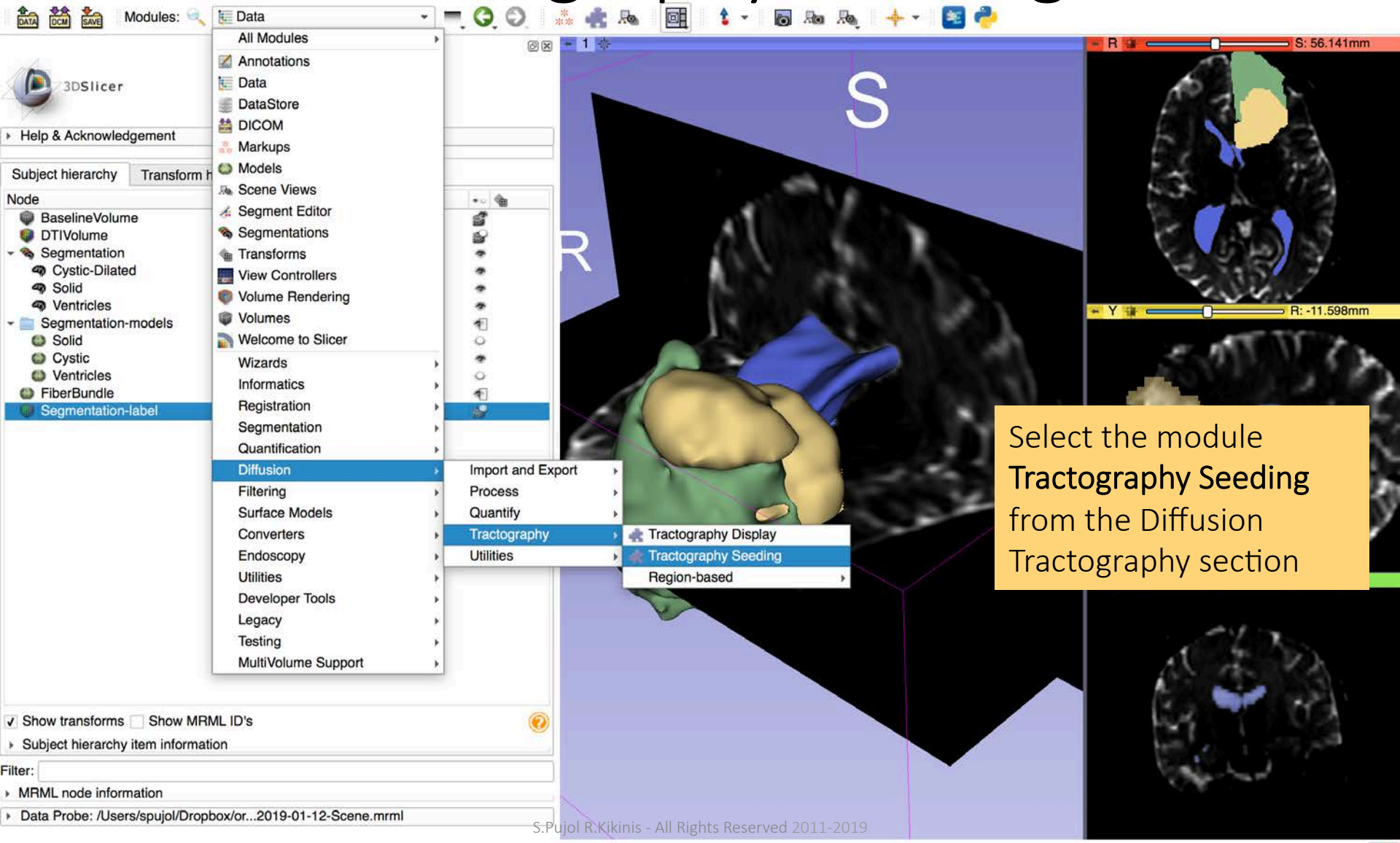
Select the Operation **Export** and the Outuput type to **Labelmap** to export the segmentation to a new labelmap

Click on **Export**



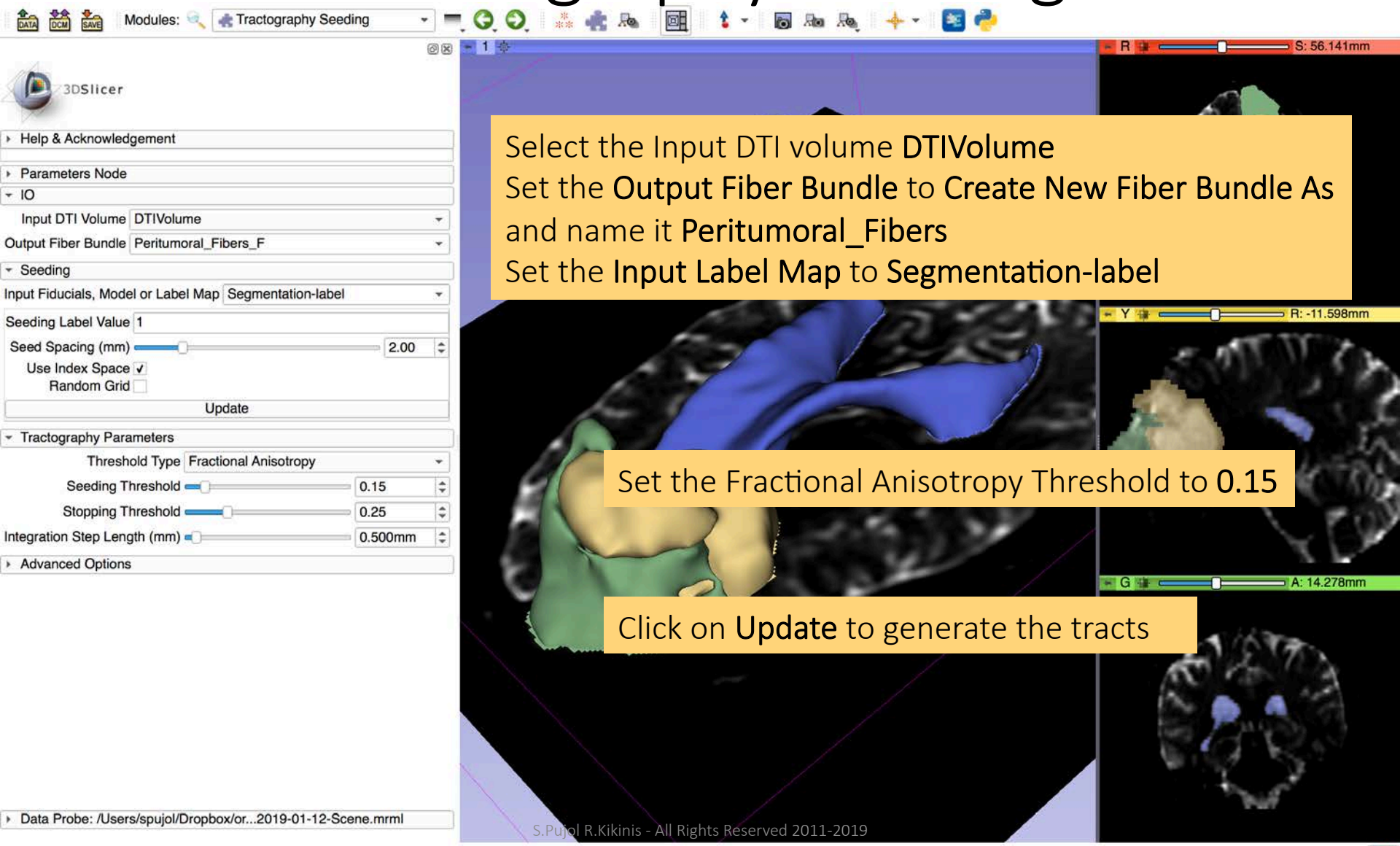
Part 3: Fiber Tracking in peritumoral area

Tractography Seeding

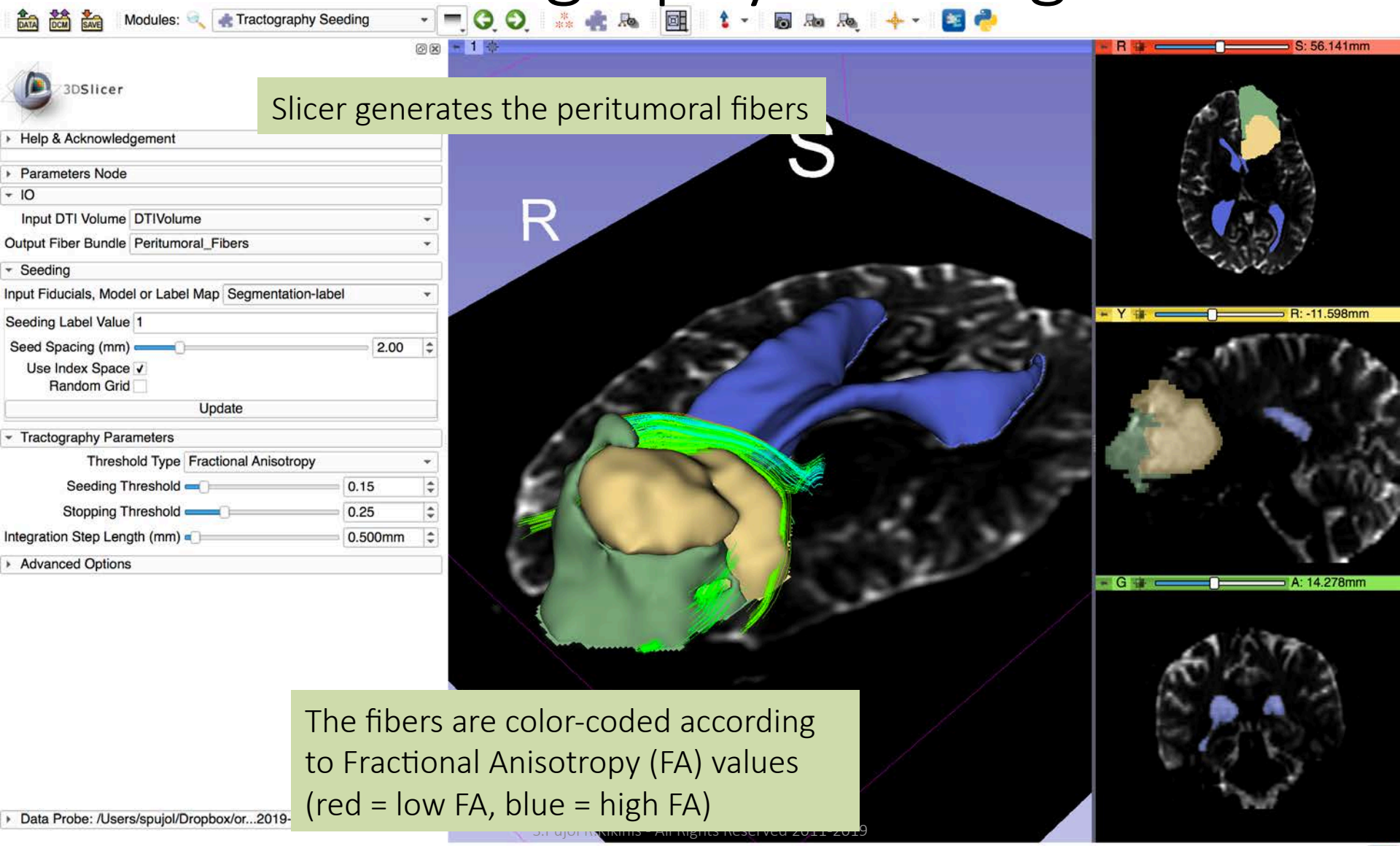


Select the module **Tractography Seeding** from the Diffusion Tractography section

Tractography Seeding



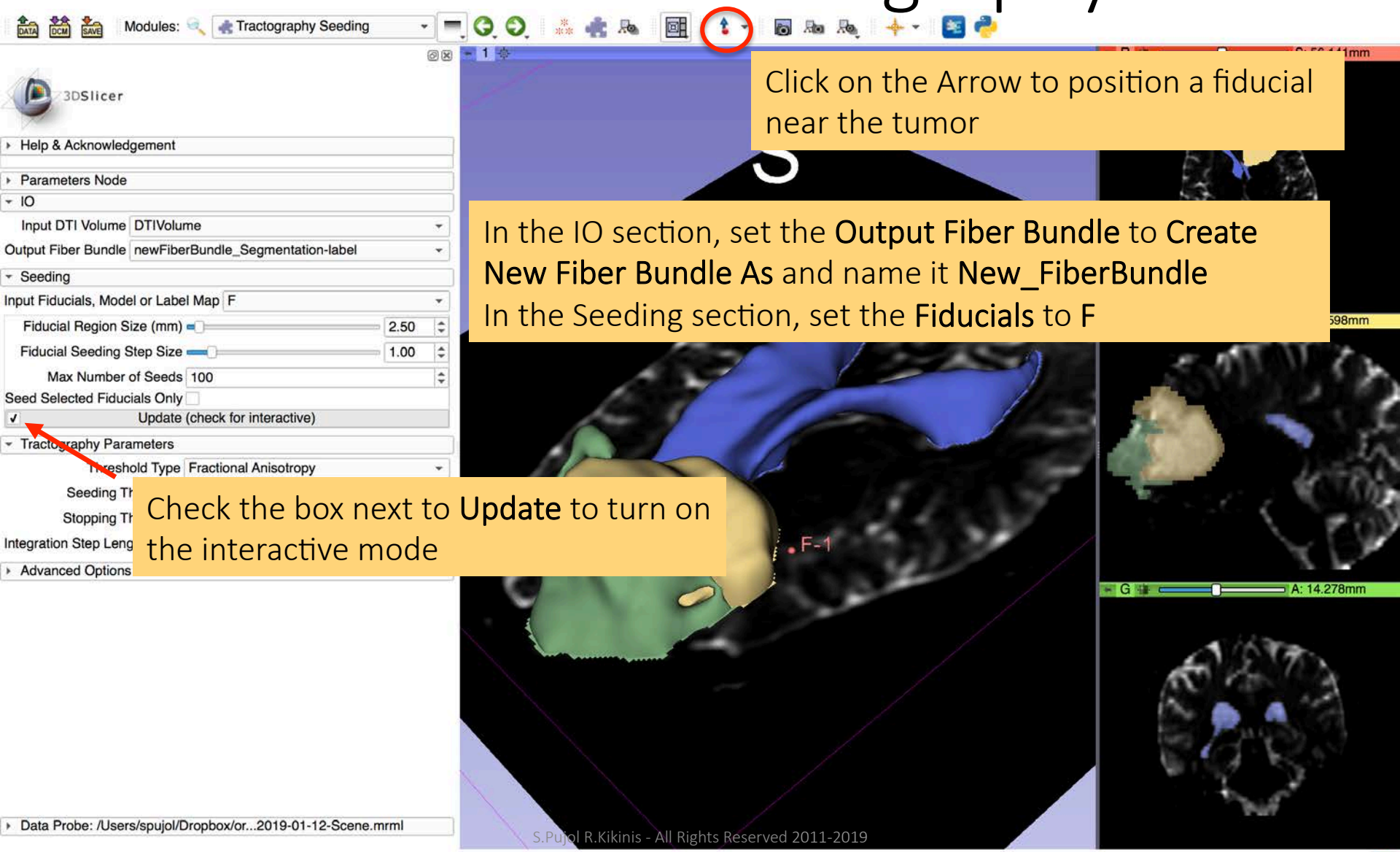
Tractography Seeding



Slicer generates the peritumoral fibers

The fibers are color-coded according to Fractional Anisotropy (FA) values (red = low FA, blue = high FA)

Interactive Tractography

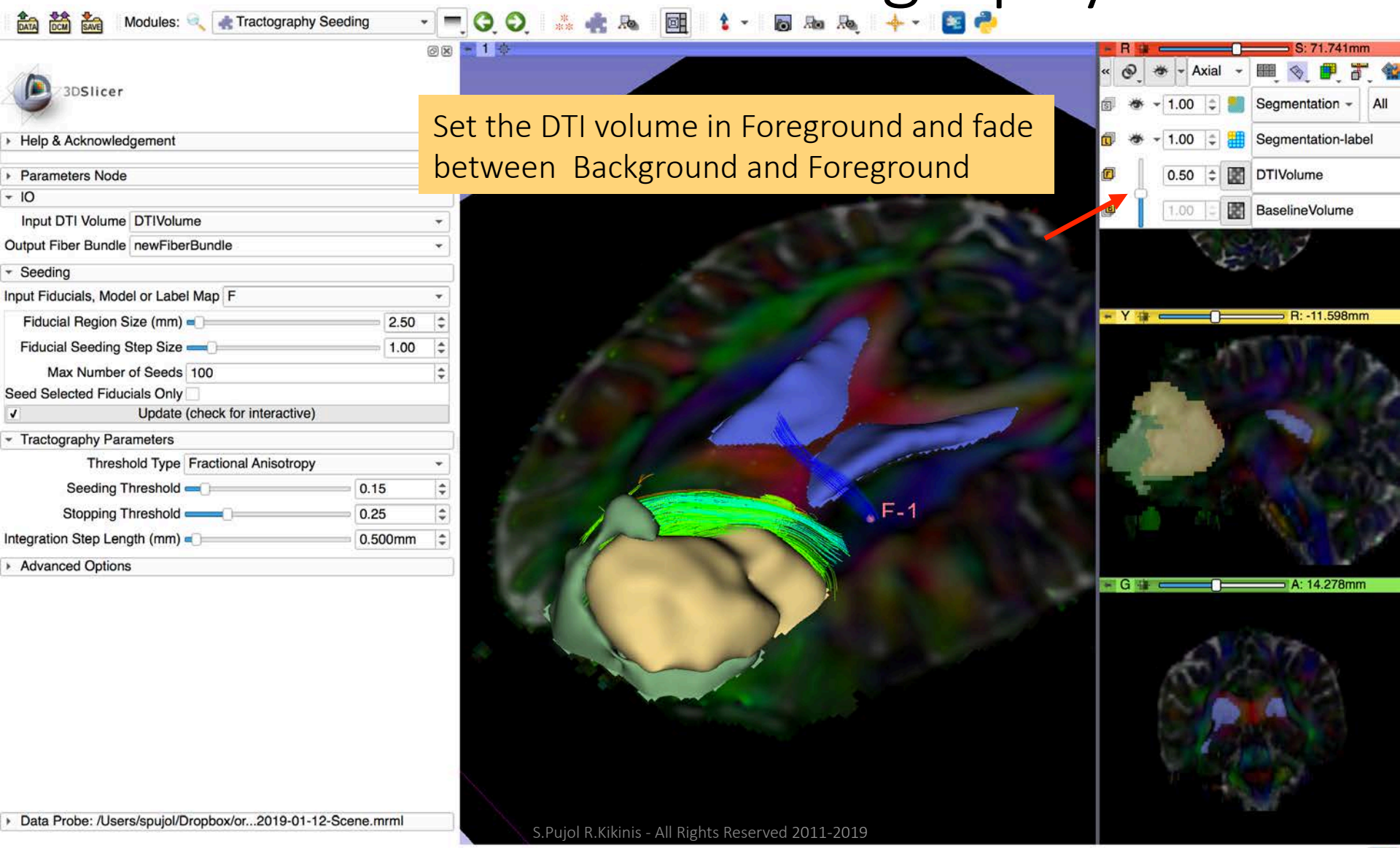


Click on the Arrow to position a fiducial near the tumor

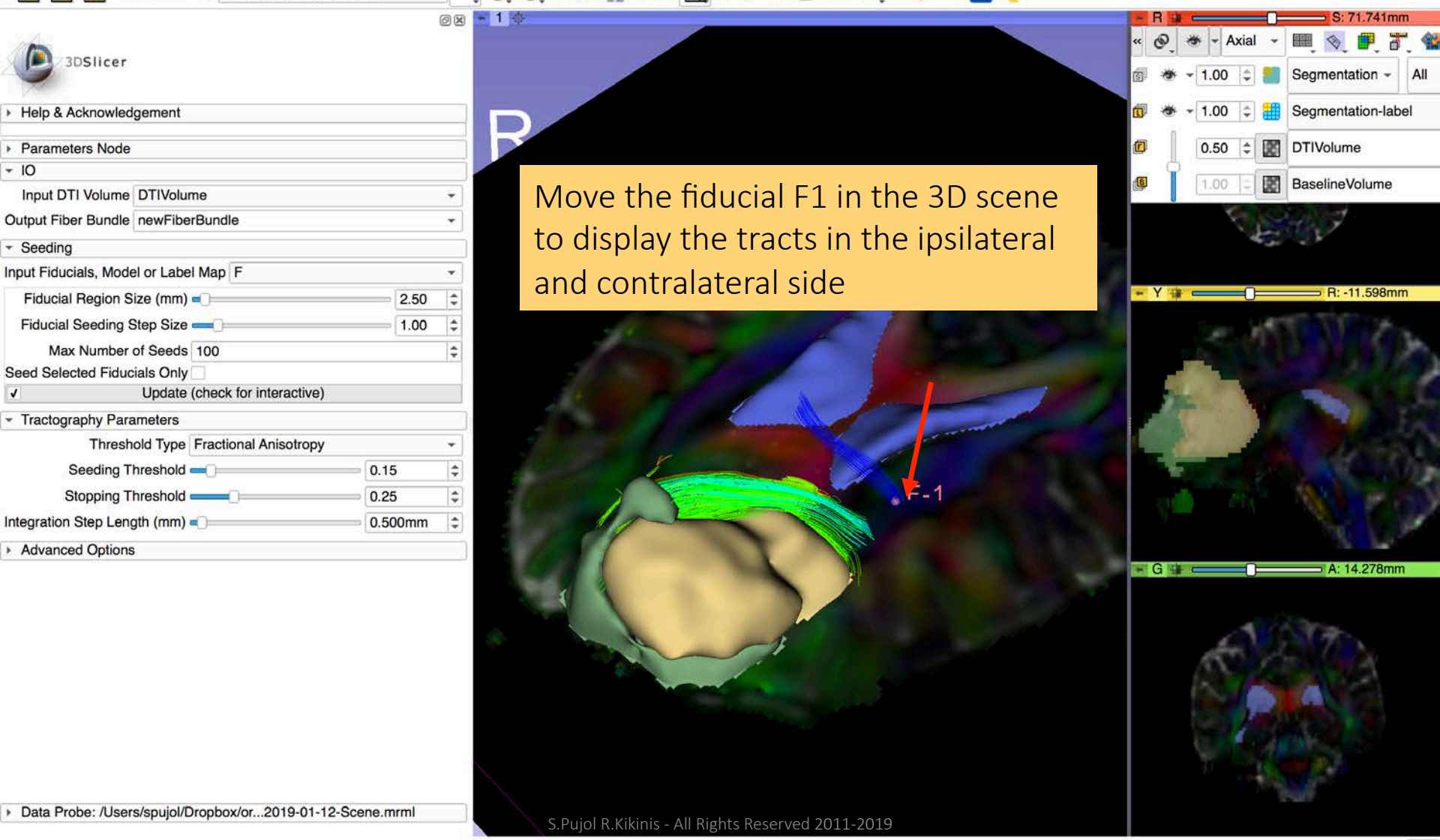
In the IO section, set the **Output Fiber Bundle** to **Create New Fiber Bundle As** and name it **New_FiberBundle**
In the Seeding section, set the **Fiducials** to **F**

Check the box next to **Update** to turn on the interactive mode

Interactive Tractography

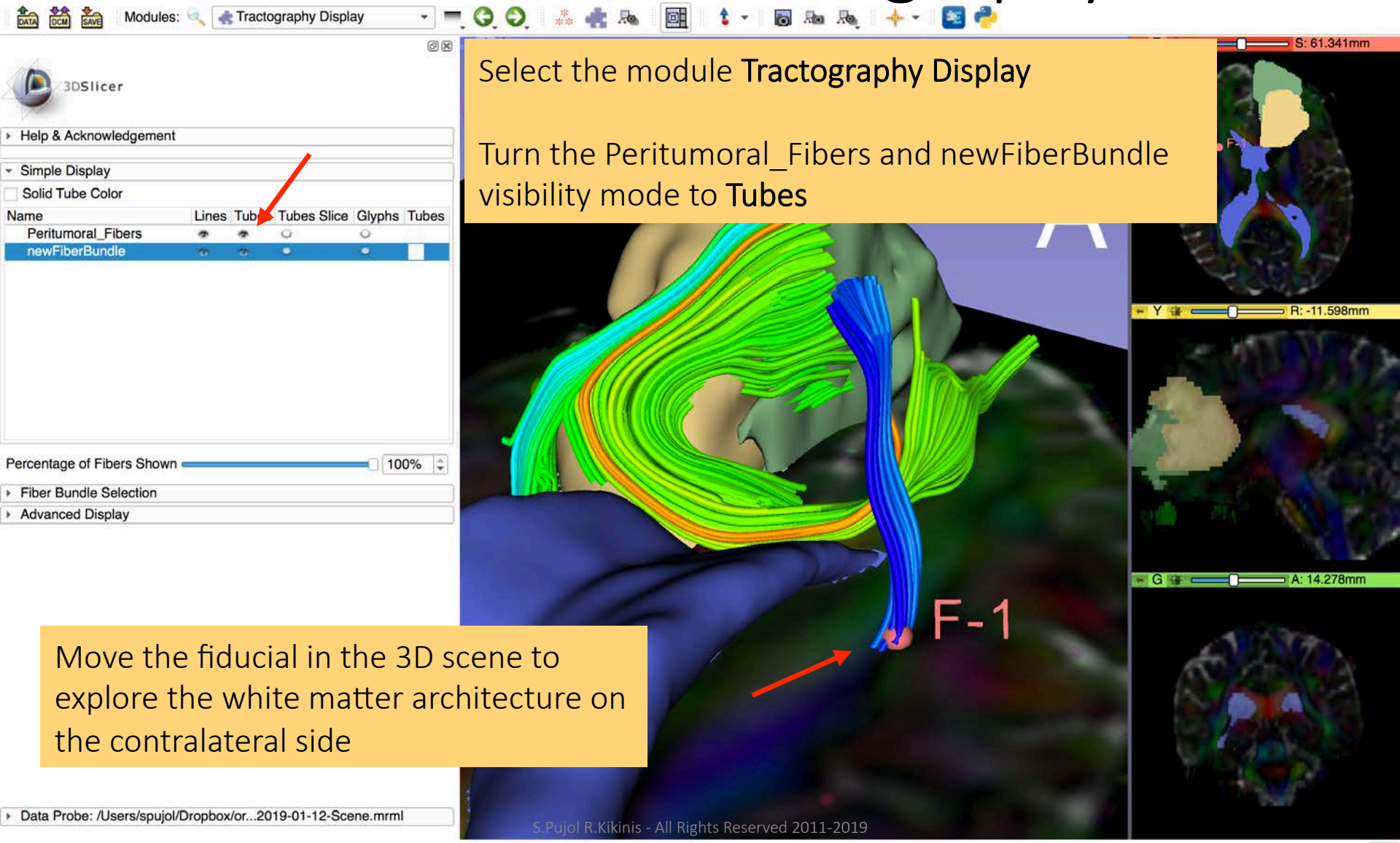


Interactive Tractography



Move the fiducial F1 in the 3D scene to display the tracts in the ipsilateral and contralateral side

Interactive Tractography



Summary

- **3D Slicer** enables interactive exploration of white matter fibers in the vicinity of a tumor:
  - The **Segment Editor** module provides tools for building 3D models of the tumoral region
  - The **SlicerDMRI solution** enables 3D interactive reconstruction of white matter fibers in the peripheral region

Acknoweldgments

- Neuroimage Analysis Center (NIH P41 EB015902)