



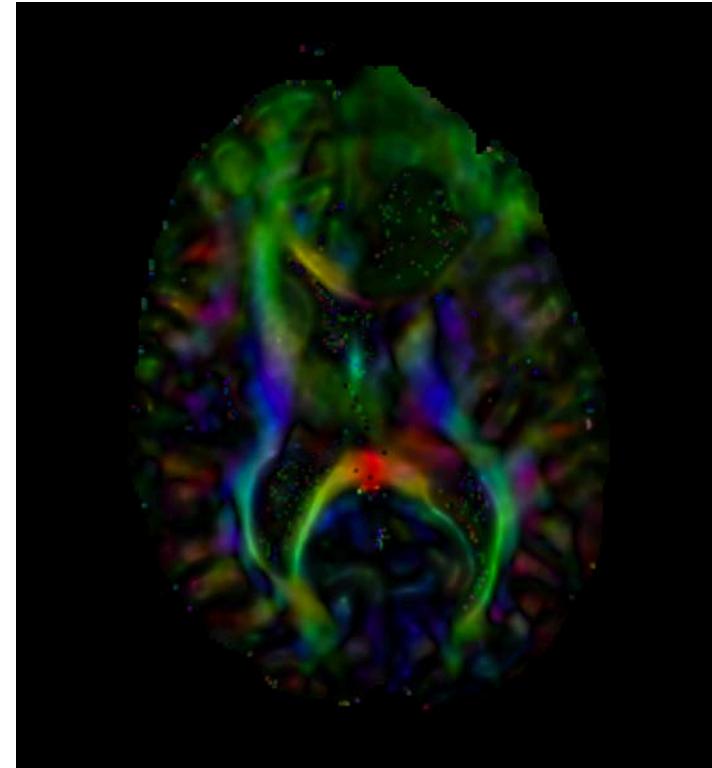
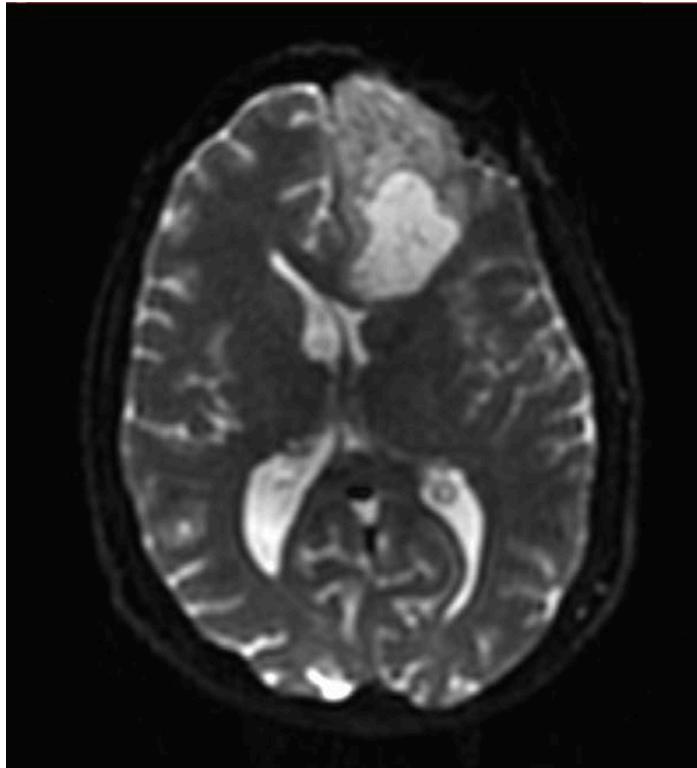
Exploring peritumoral white matter fibers for neurosurgical planning of brain tumor resection

Sonia Pujol, Ph.D.
Assistant Professor of Radiology

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

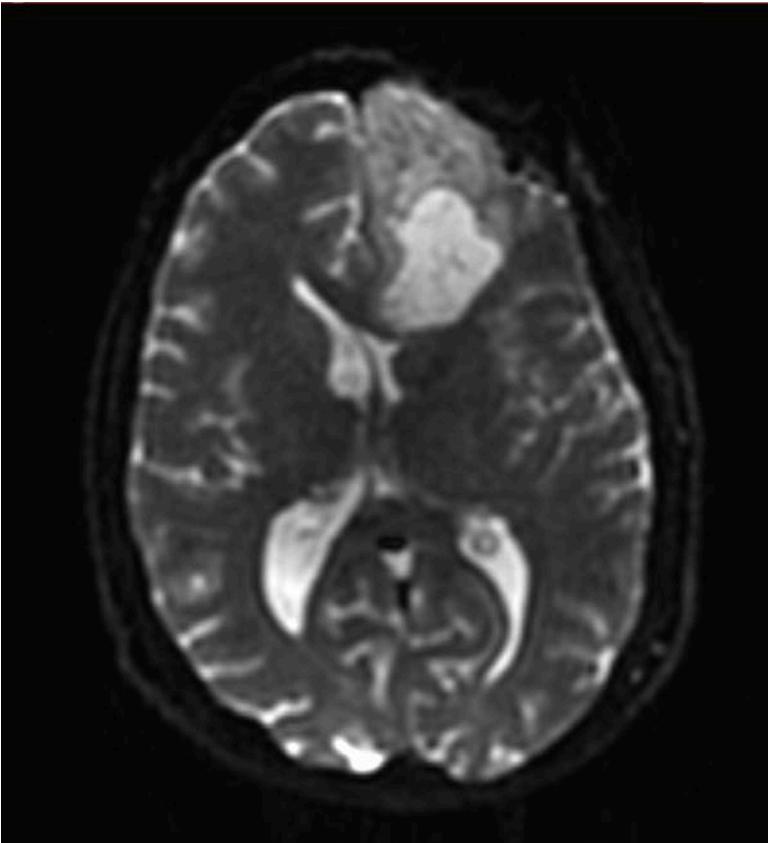
Brigham and Women's Hospital
Harvard Medical School

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

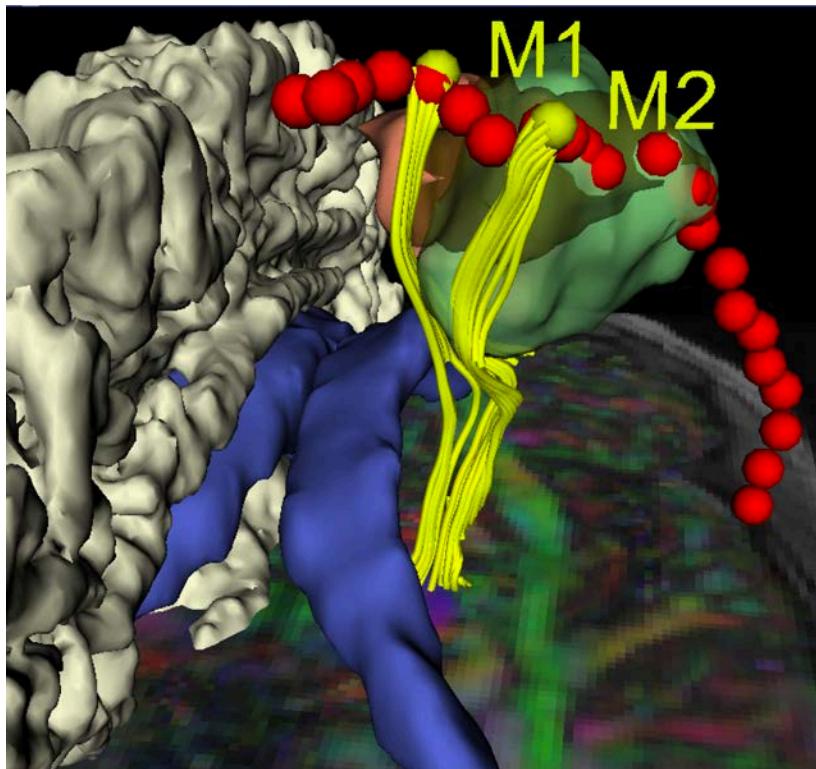
GBM Surgery

- 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



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

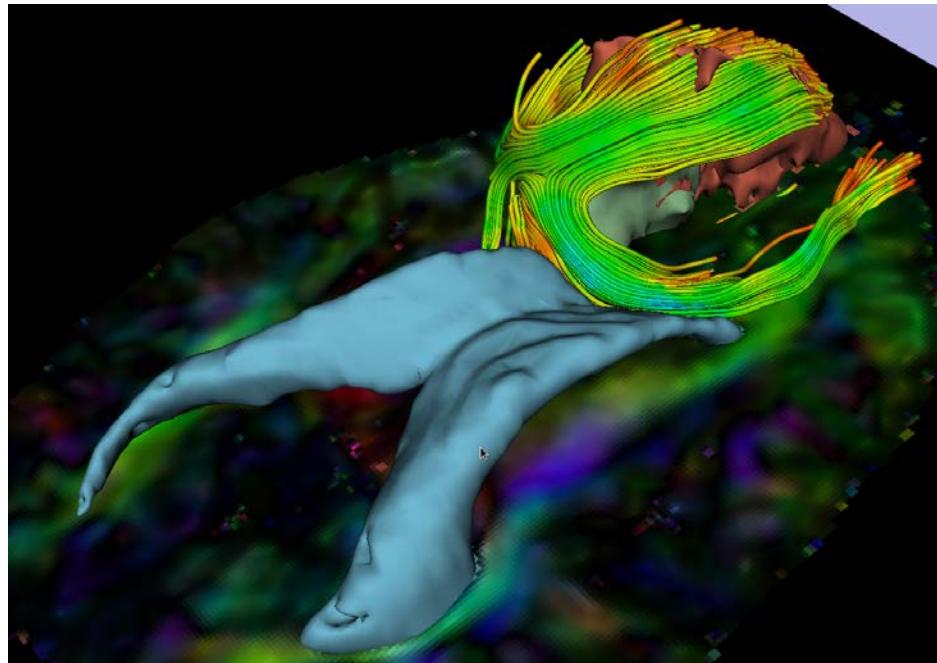
Diffusion MRI for brain surgery



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

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

Overall Objective

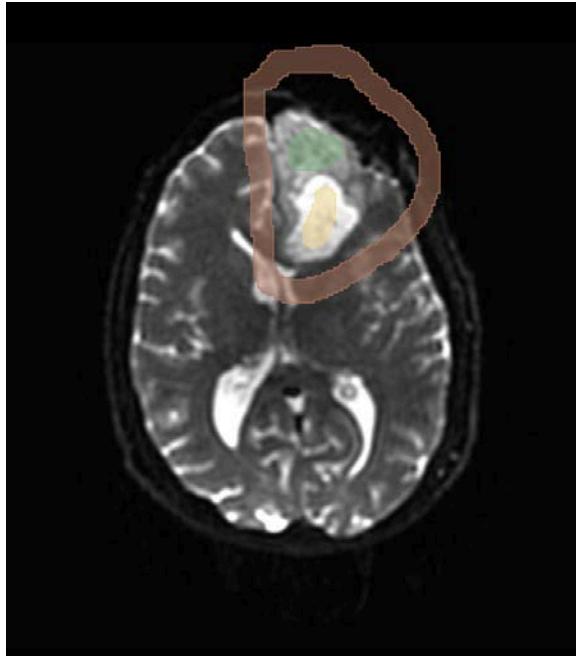


This tutorial provides an end-to-end solution for segmenting the contours of a tumor and generating white matter fiber tracts in the vicinity of the lesion

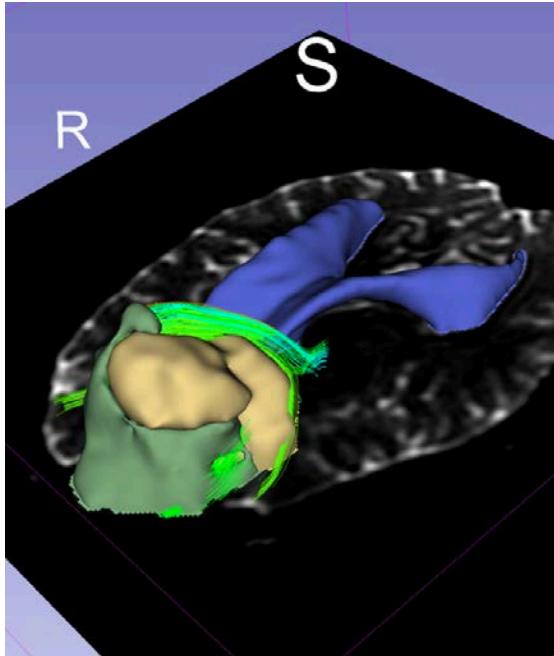
Disclaimer

- 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.

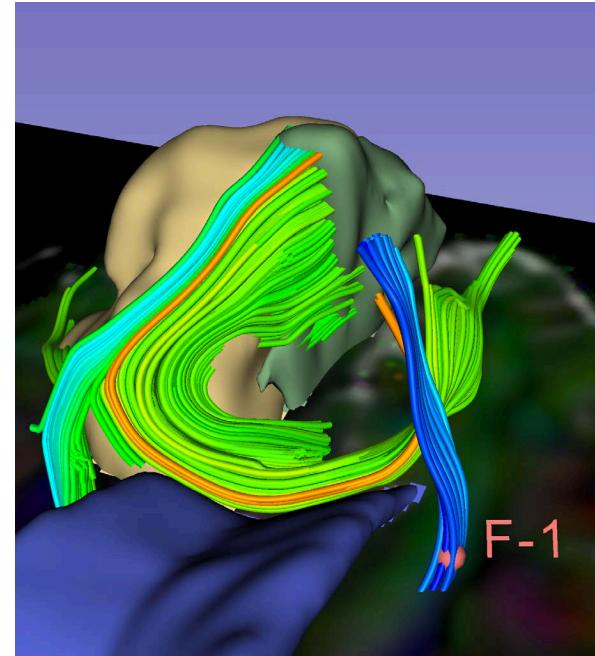
Workflow Overview



Step 1: Tumor
Segmentation



Step 2: Fiber Tracts
Generation

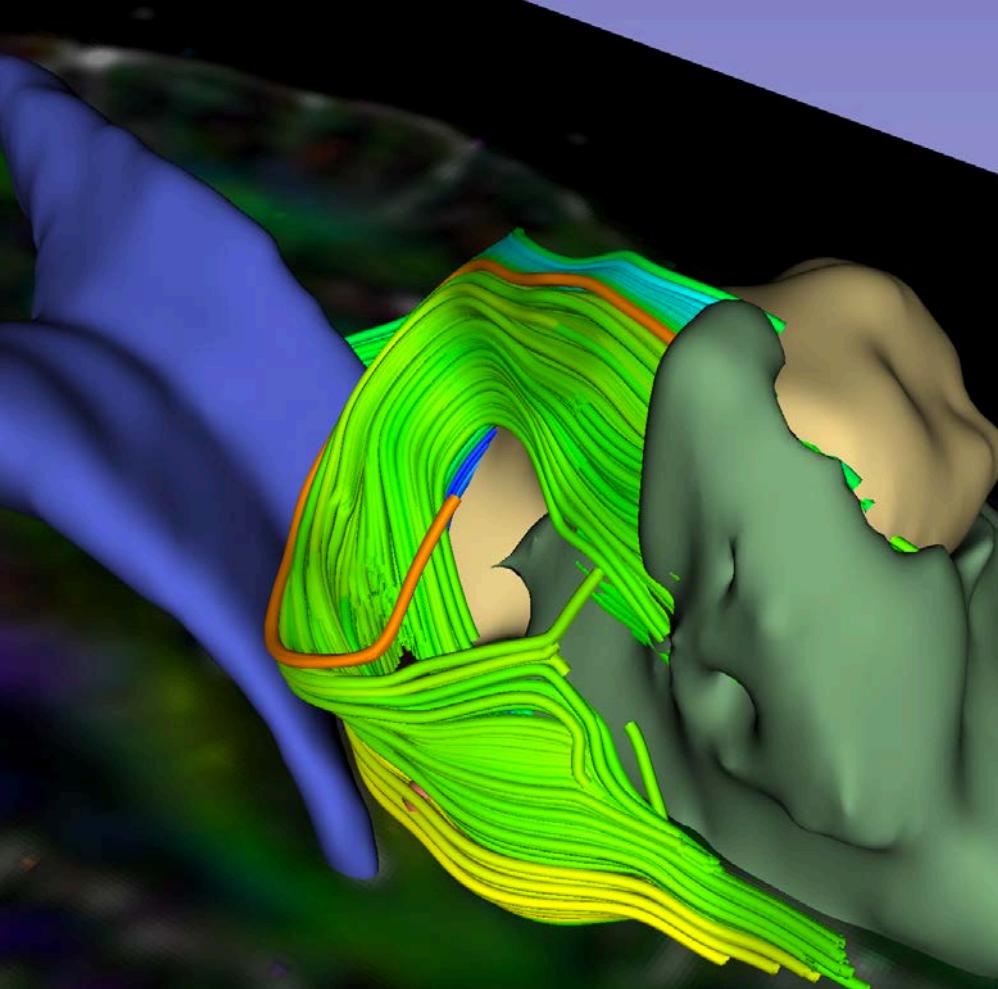


Step 3: Interactive
Exploration

Image Processing Workflow

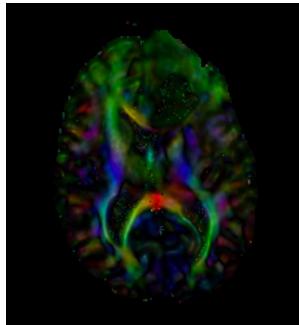
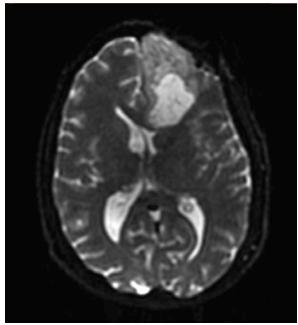
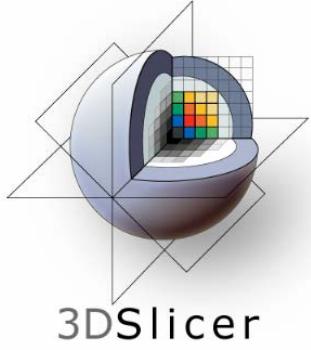
The image processing workflow described in this tutorial uses three algorithms:

- **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

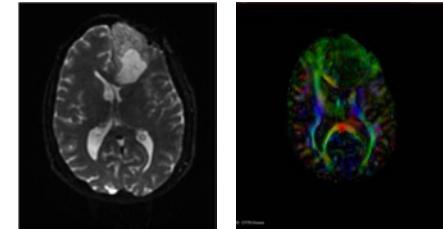


3DSlicer

- SlicerDMRI Extension



- White Matter Exploration dataset

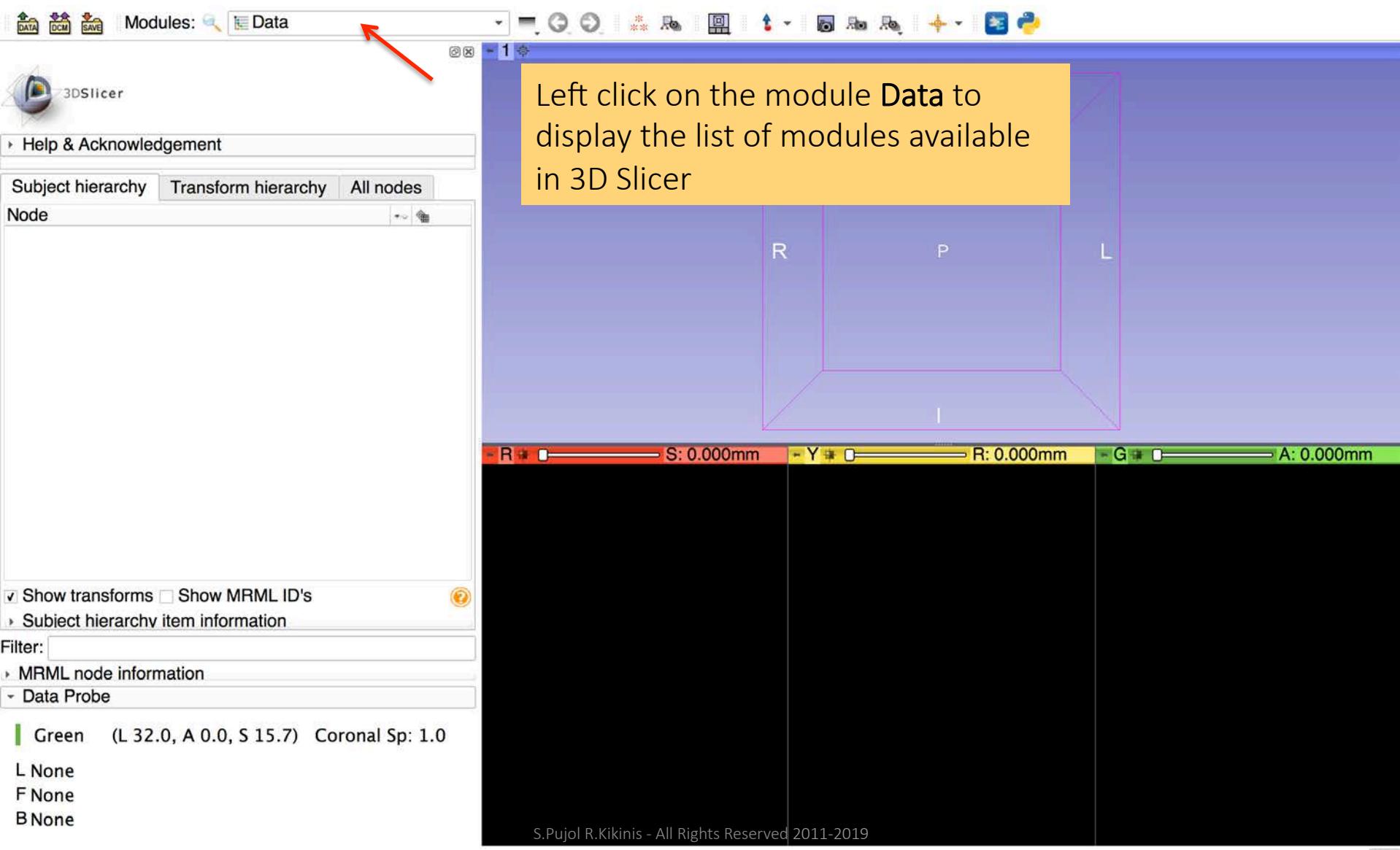


3D Slicer installation

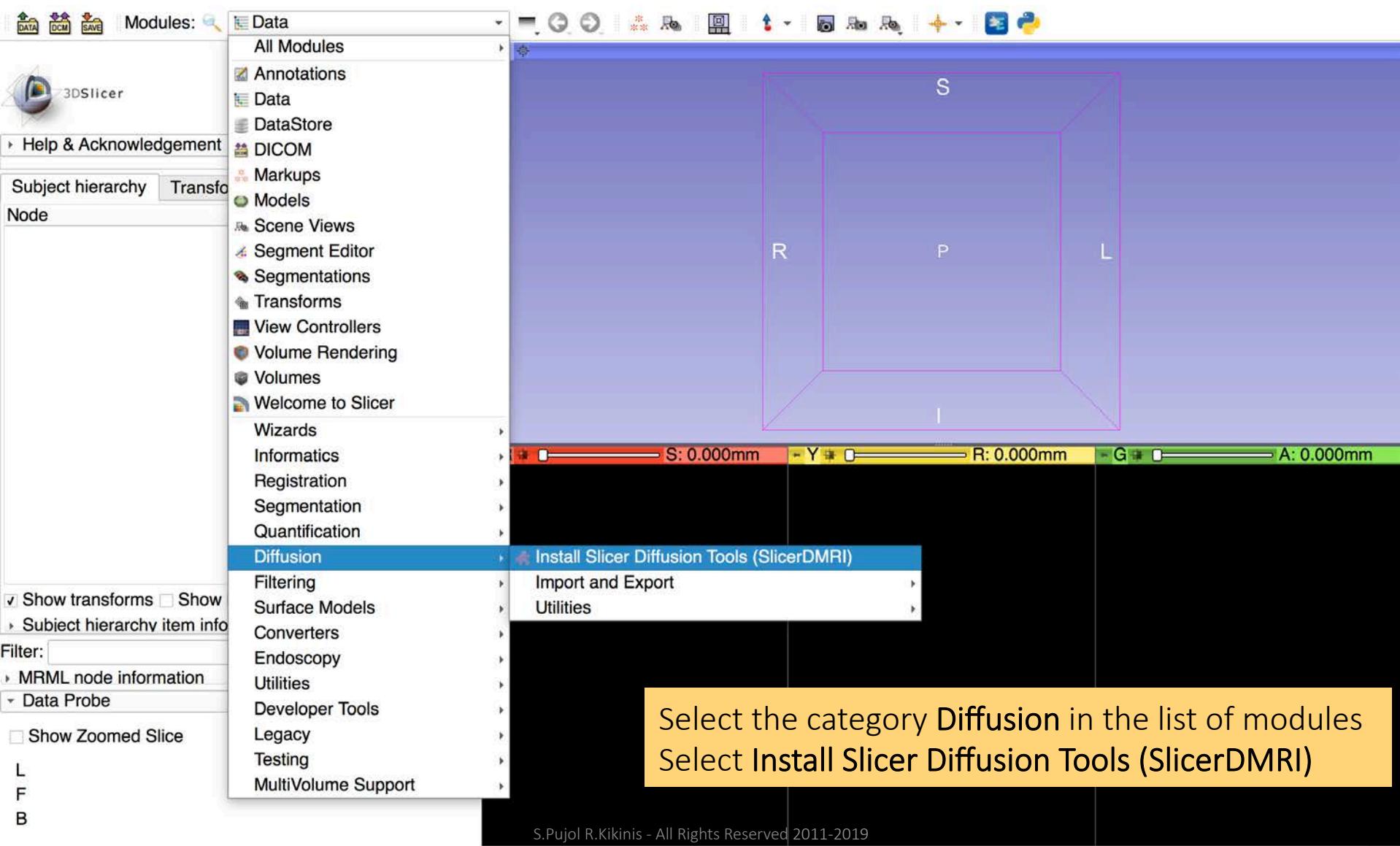
- To install and start the 3D Slicer software on your computer, follow the instructions of the **Quick Start Guide** tutorial available at
[https://www.slicer.org/wiki/Documentation/4.10/
Training](https://www.slicer.org/wiki/Documentation/4.10/Training)

	Windows	Mac OS X	Linux
Stable Release <small>older releases</small>	version 4.10.0 revision 27501 built 2018-10-19	version 4.10.0 revision 27501 built 2018-11-01	version 4.10.0 revision 27501 built 2018-10-19

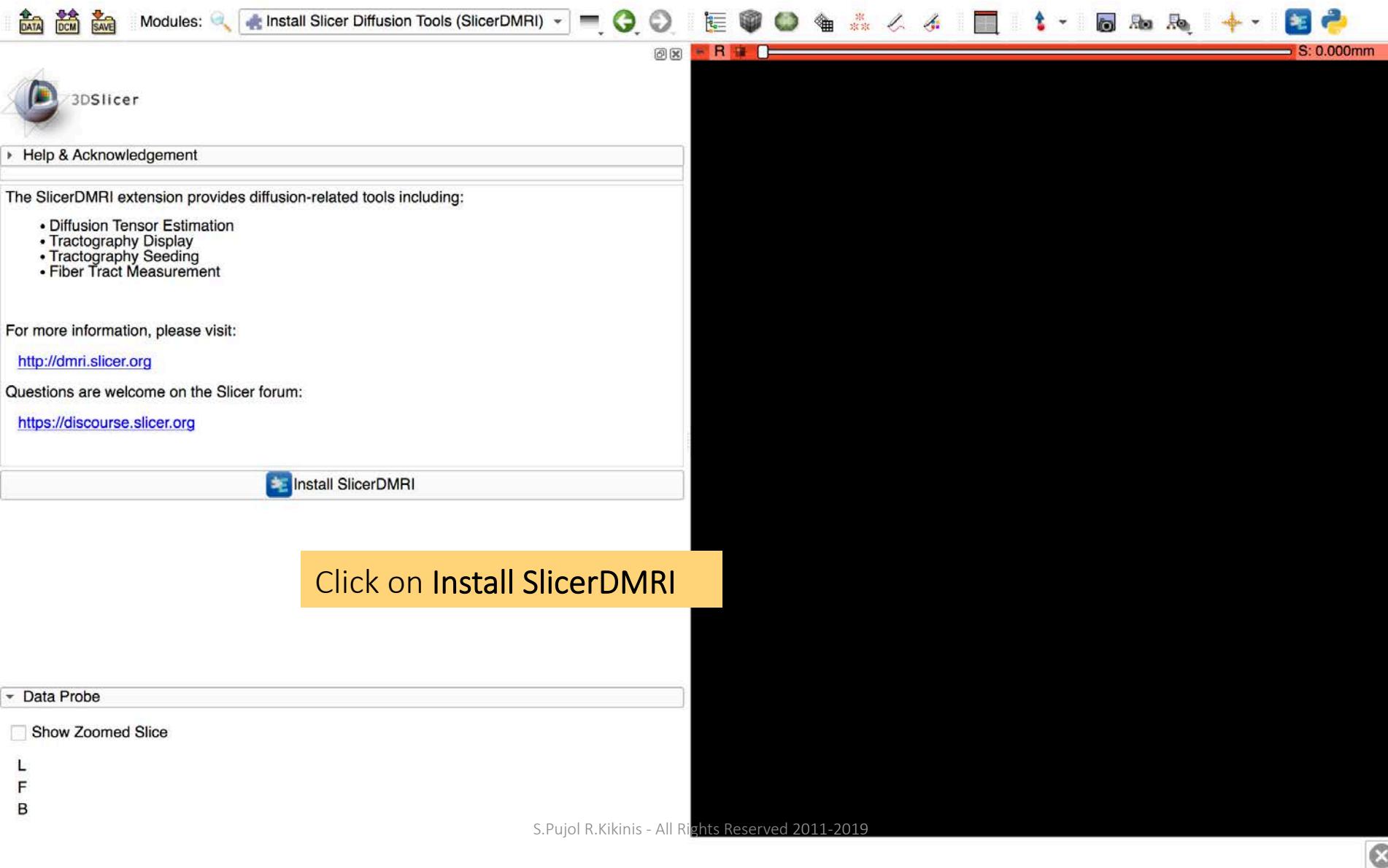
SlicerDMRI Installation



SlicerDMRI Installation



SlicerDMRI Installation



SlicerDMRI Installation

The SlicerDMRI extension provides diffusion-related tools including:

- Diffusion Tensor Estimation
- Tractography Display
- Tractography Seeding
- Fiber Tract Measurement

For more information, please visit:
<http://dmri.slicer.org>

Questions are welcome on the Slicer forum:
<https://discourse.slicer.org>

SlicerDMRI depends on the following extensions:

- UKFTractography

Would you like to install them now?

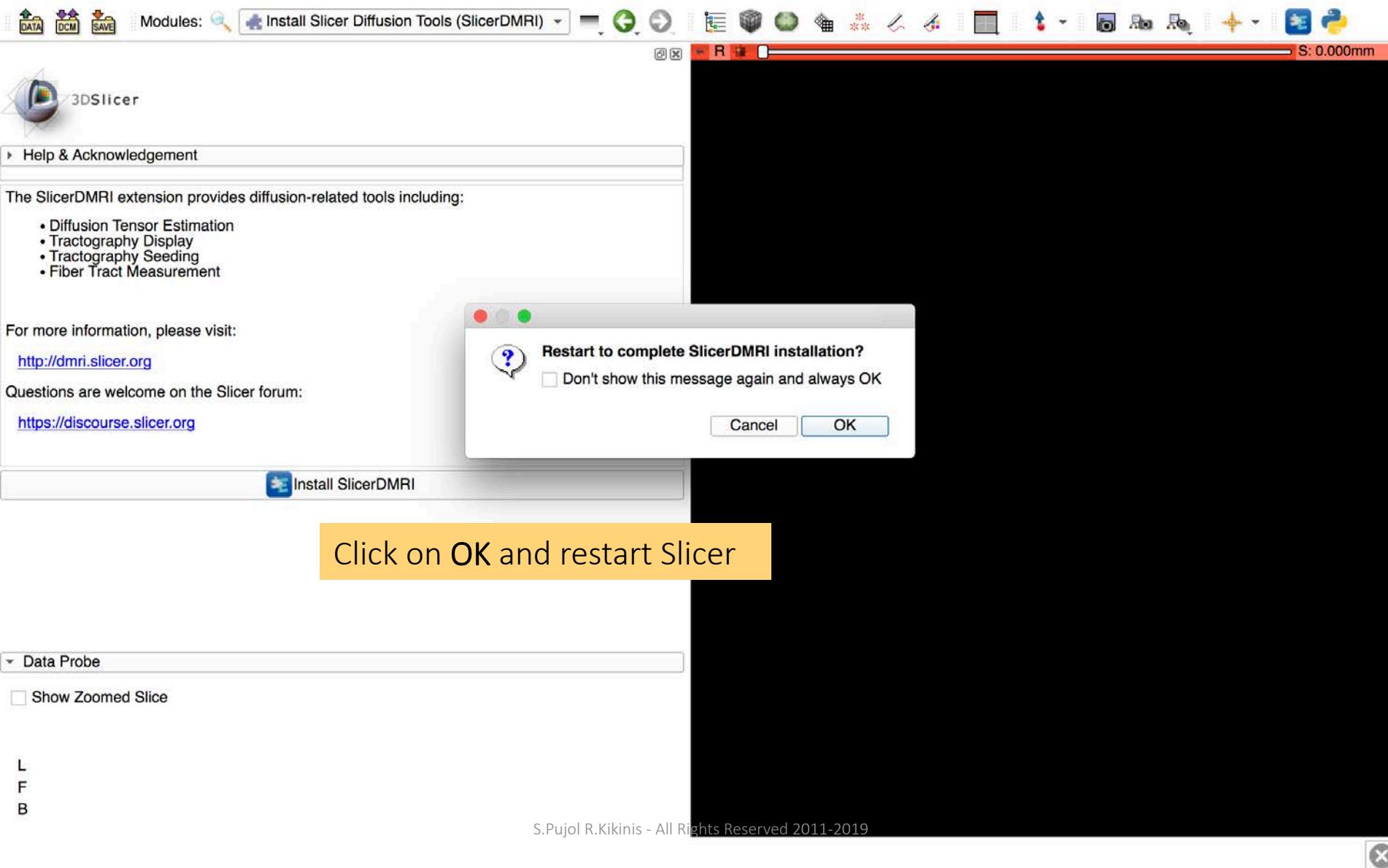
No **Yes**

This tutorial does not use UKFTractography
Click on No

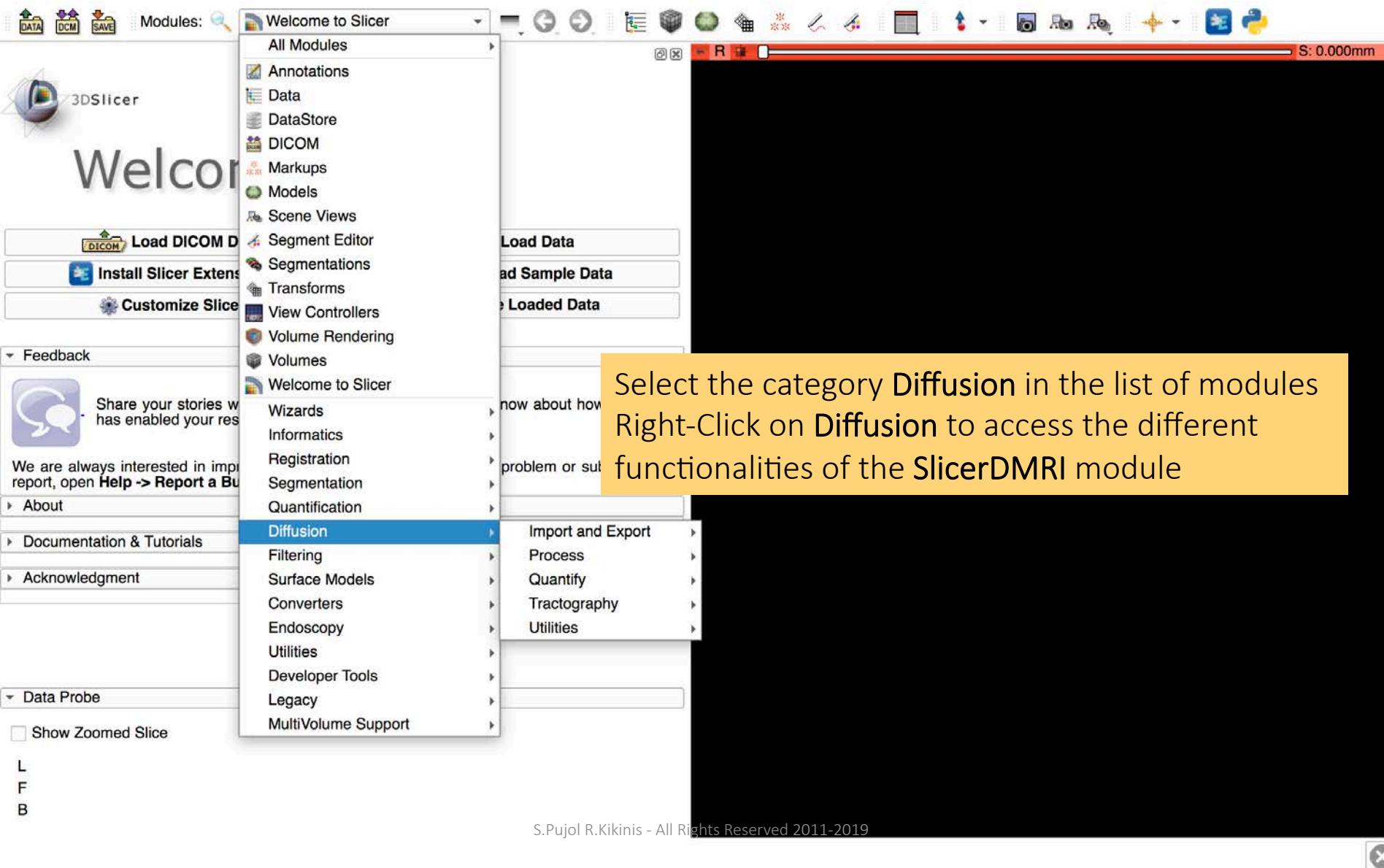
L
F
B

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SlicerDMRI Installation

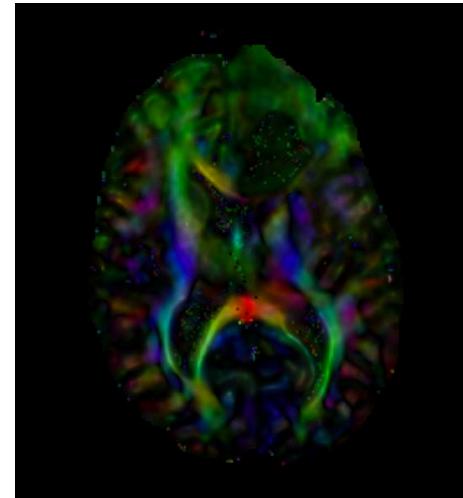
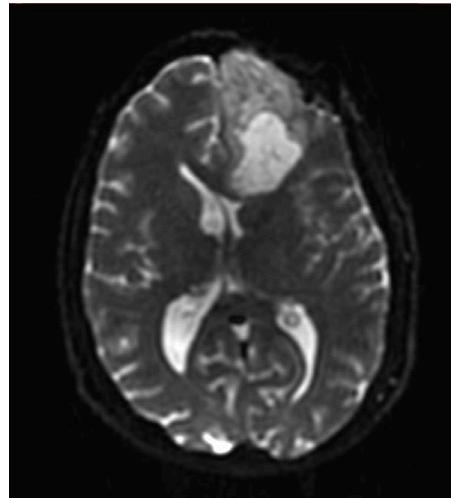


SlicerDMRI Installation

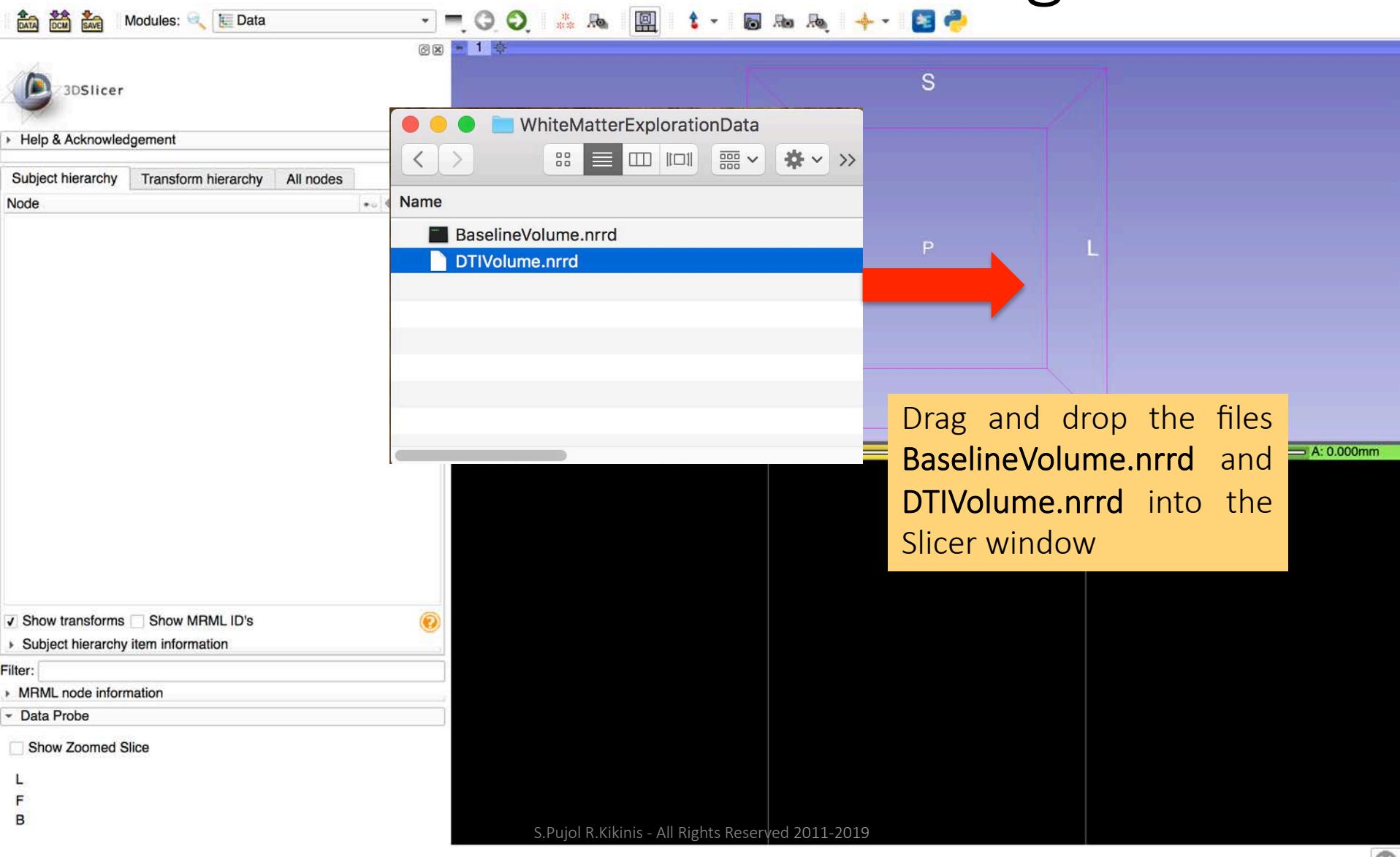


Tutorial Data

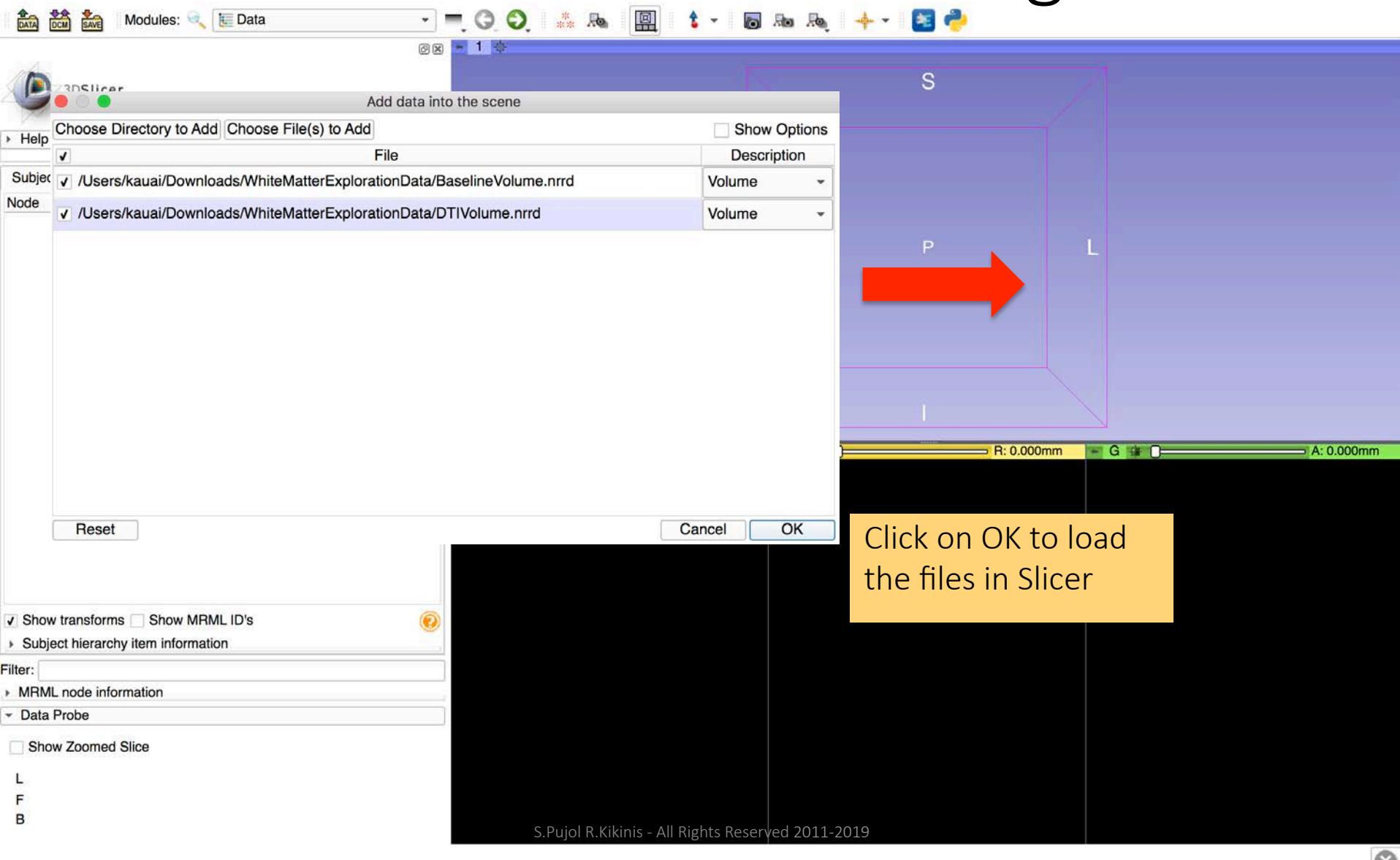
- The tutorial data include a baseline volume and a diffusion tensor imaging (DTI) volume



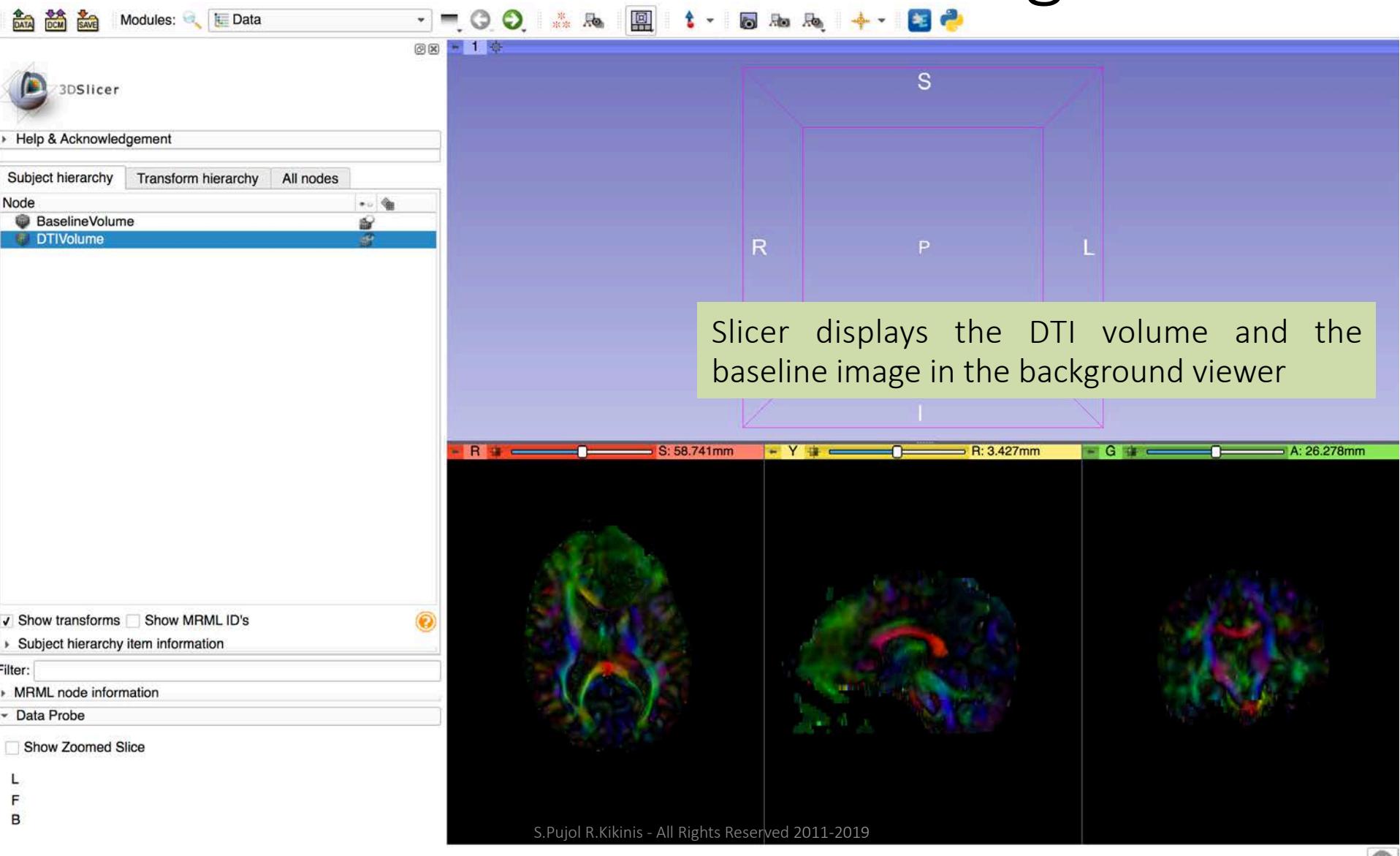
Tutorial Data Loading



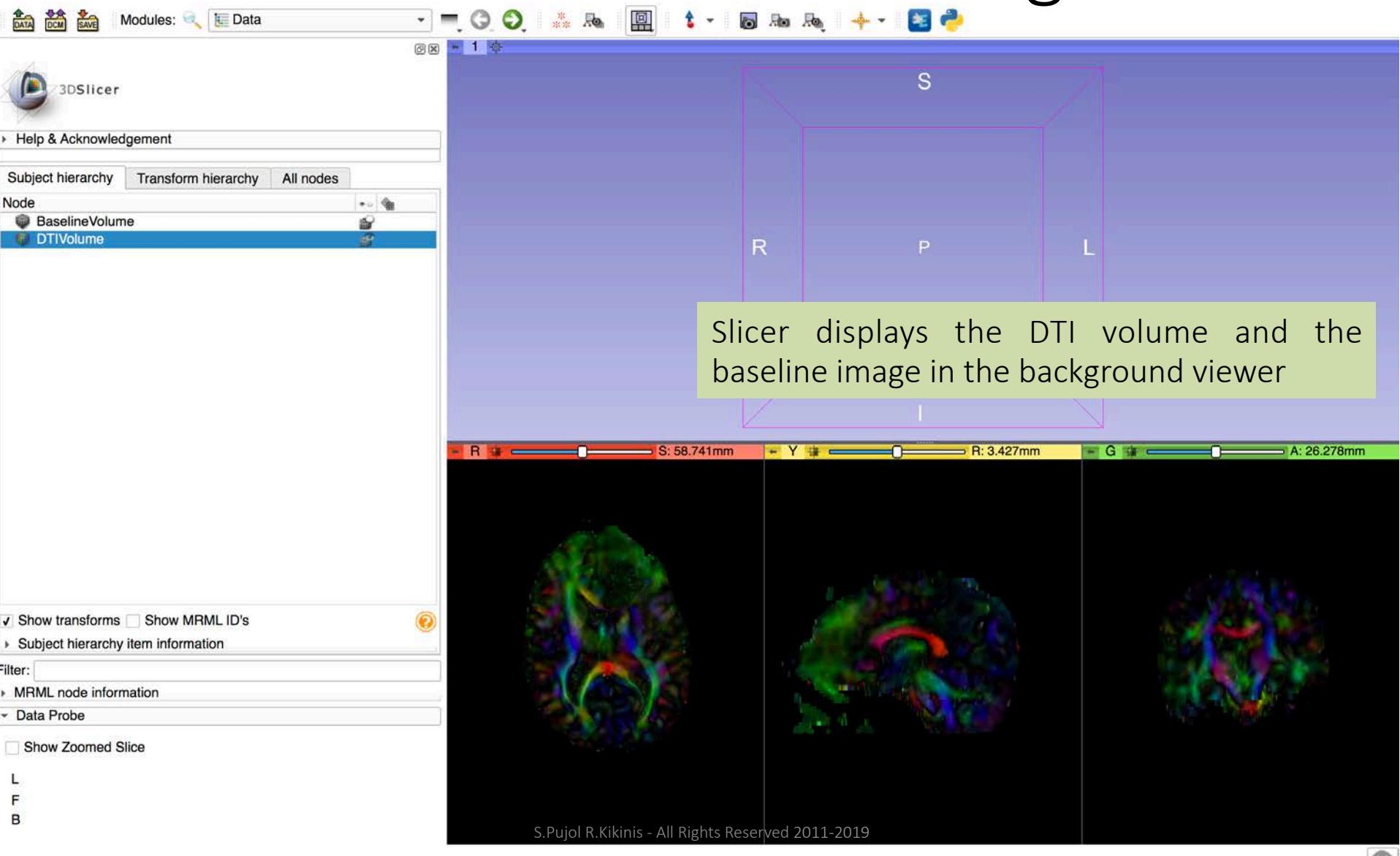
Tutorial Data Loading



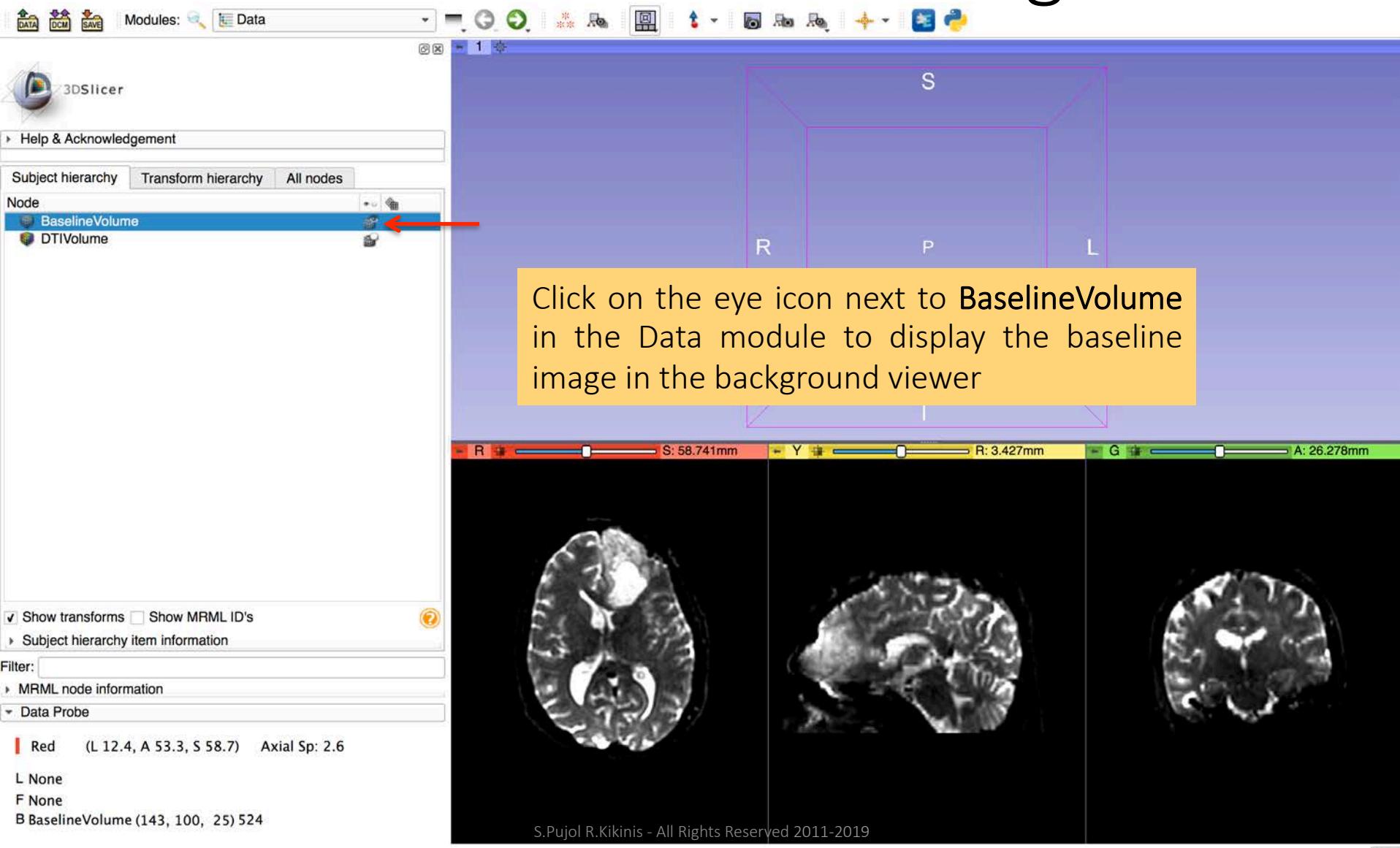
Tutorial Data Loading



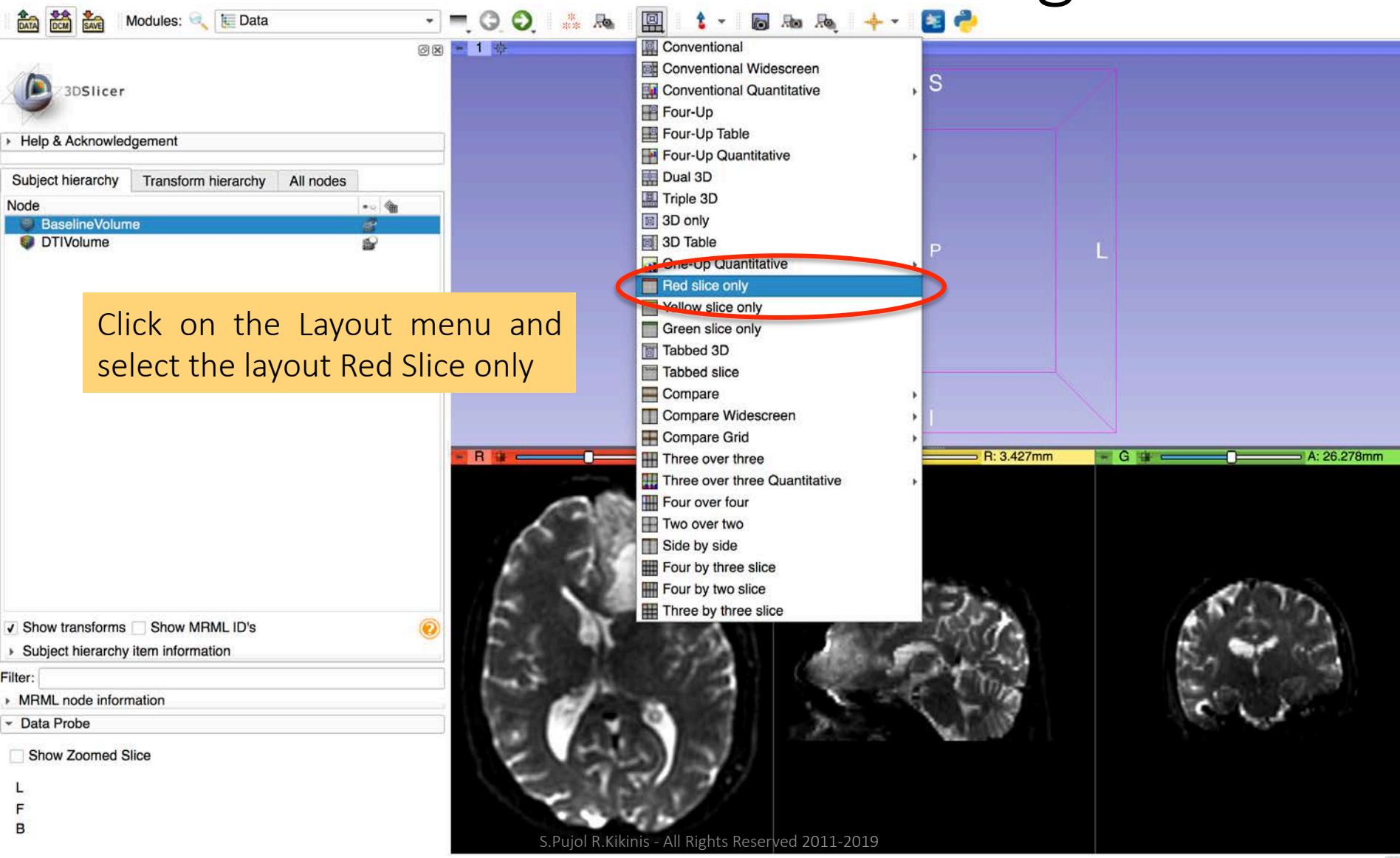
Tutorial Data Loading



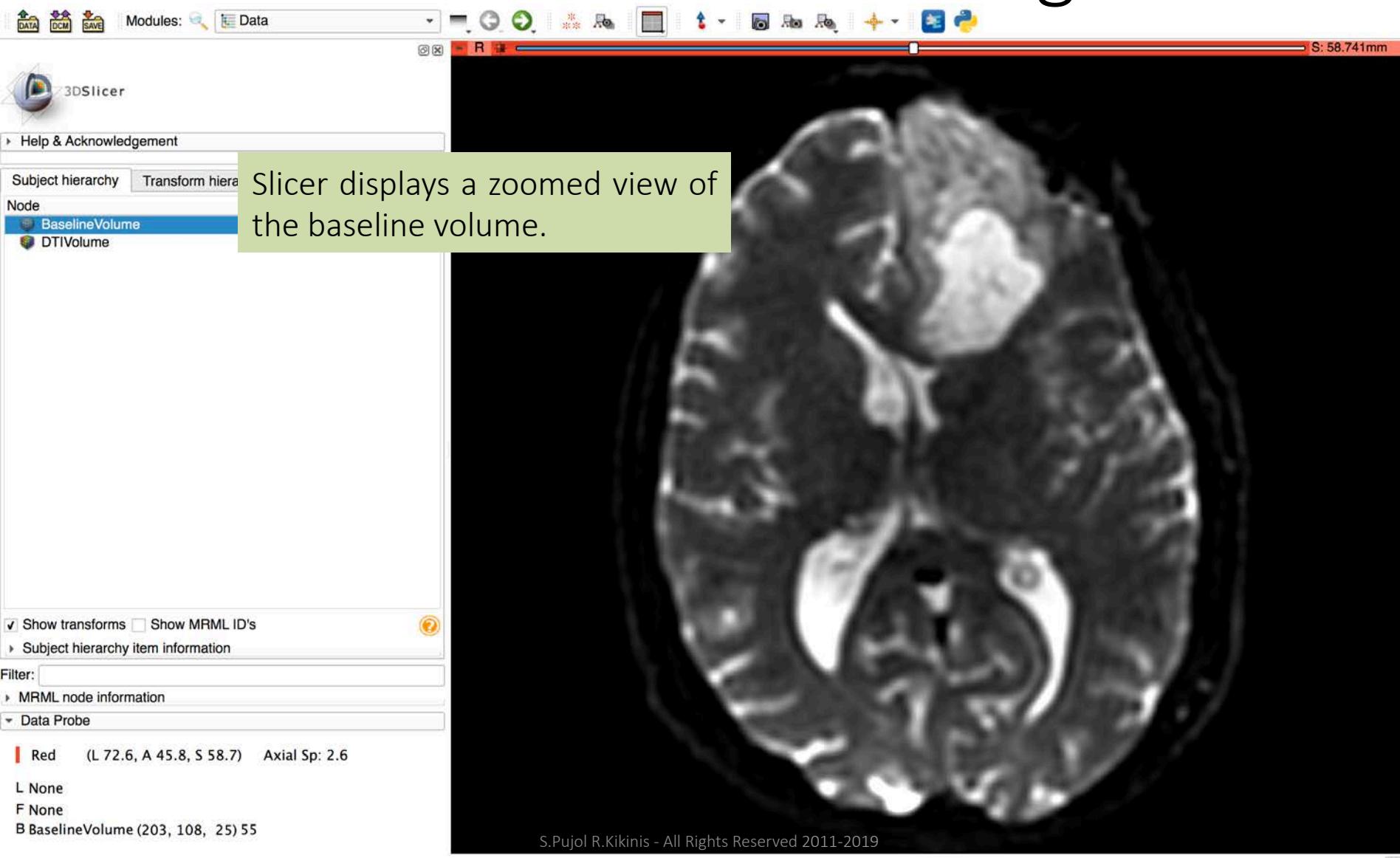
Tutorial Data Loading

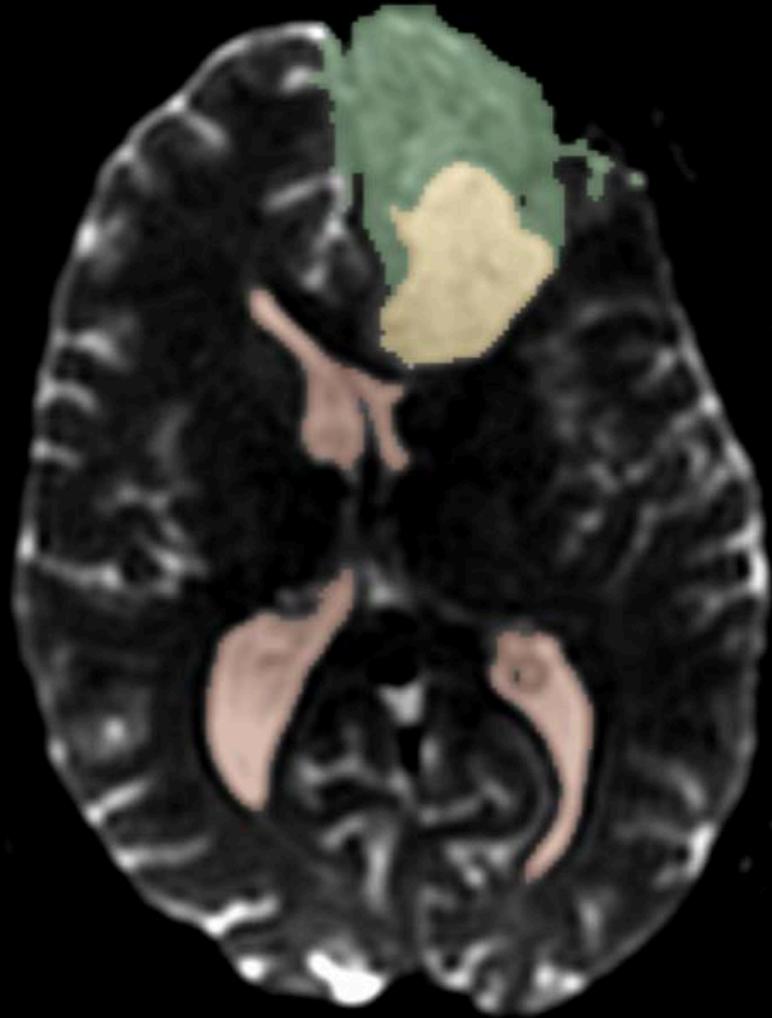


Tutorial Data Loading



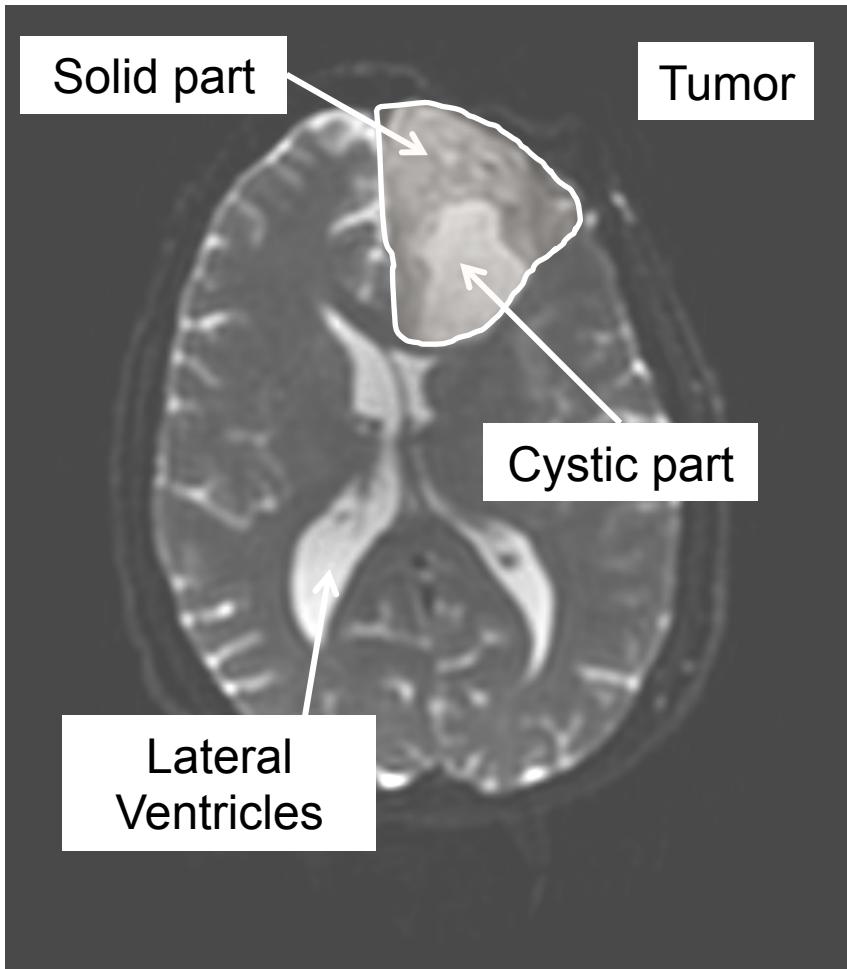
Tutorial Data Loading





Part 1:
Segmentation
of tumor and
ventricles

Tumor segmentation



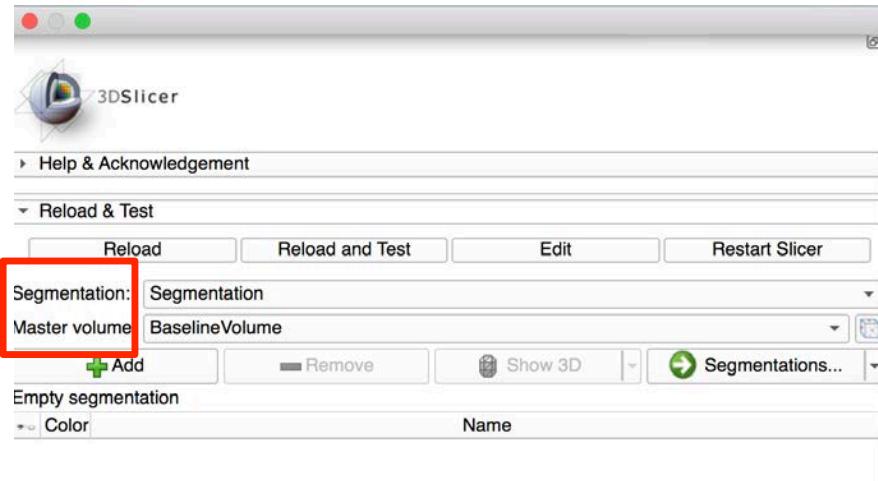
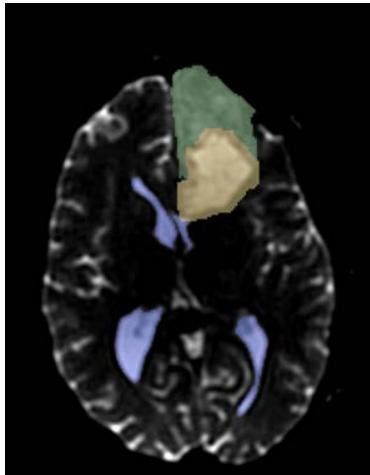
This section shows how to segment the solid and cystic components of the tumor using the **Grow from Seeds** tool of the Segment Editor module.

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

Segment Editor Module

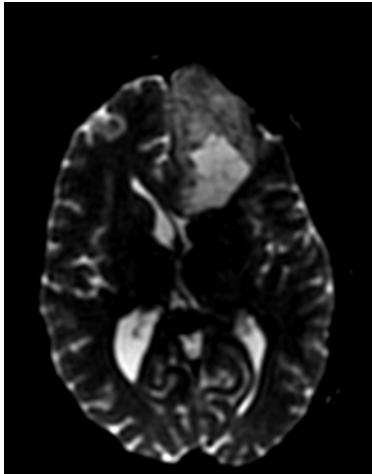
- Segmentation is the process of identifying a structure of interest in imaging data
- The Segment Editor module of 3D Slicer provides powerful tools for manual and semi-automated segmentation

Basic Principle



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

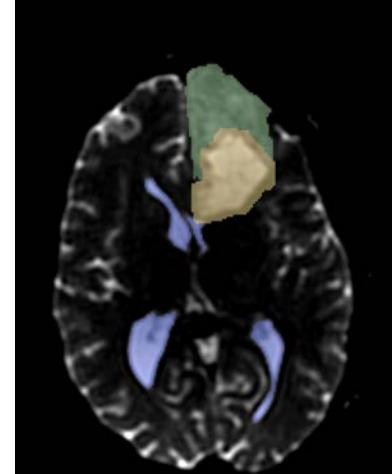
Basic Principle



Master Volume



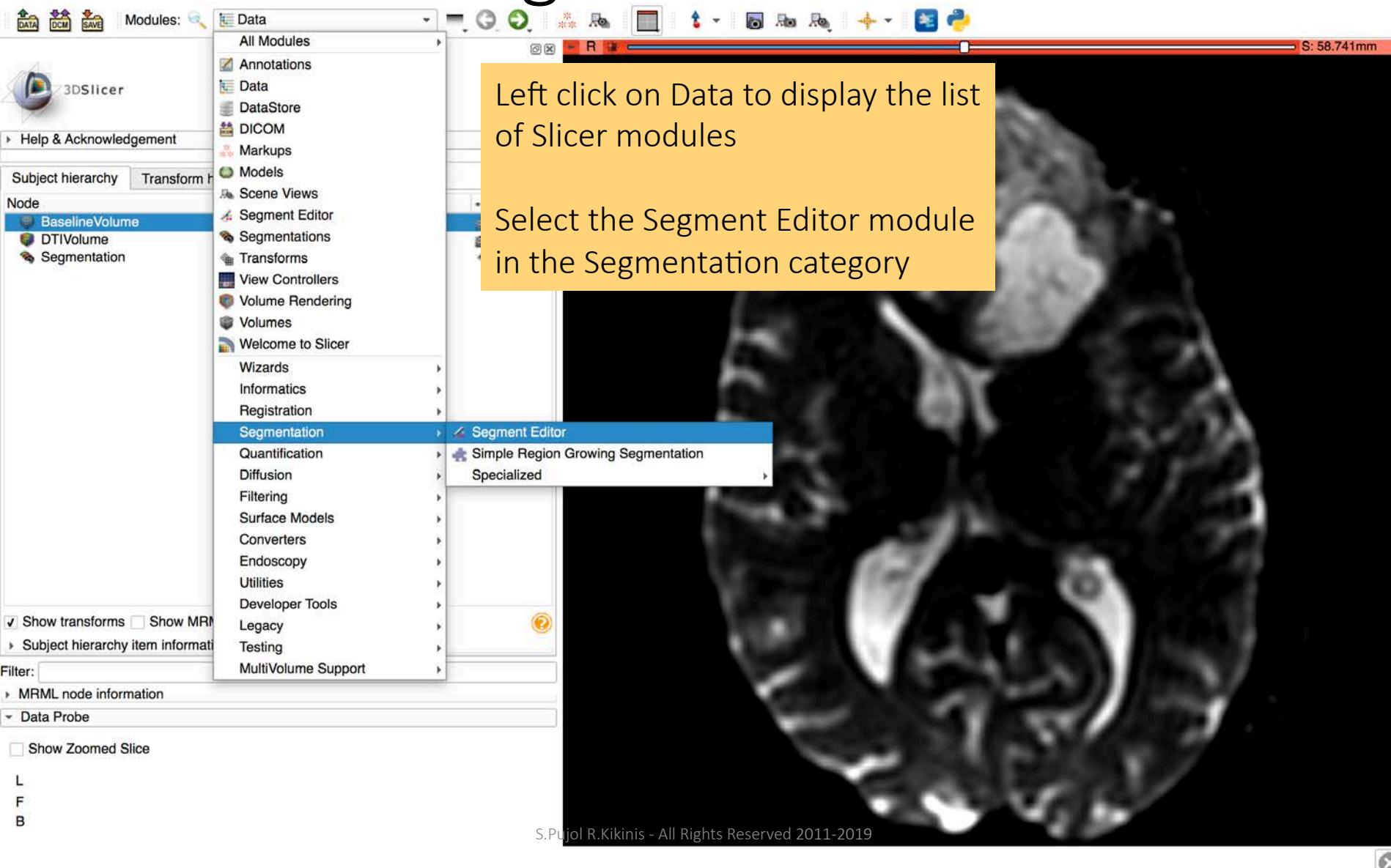
Segmentation



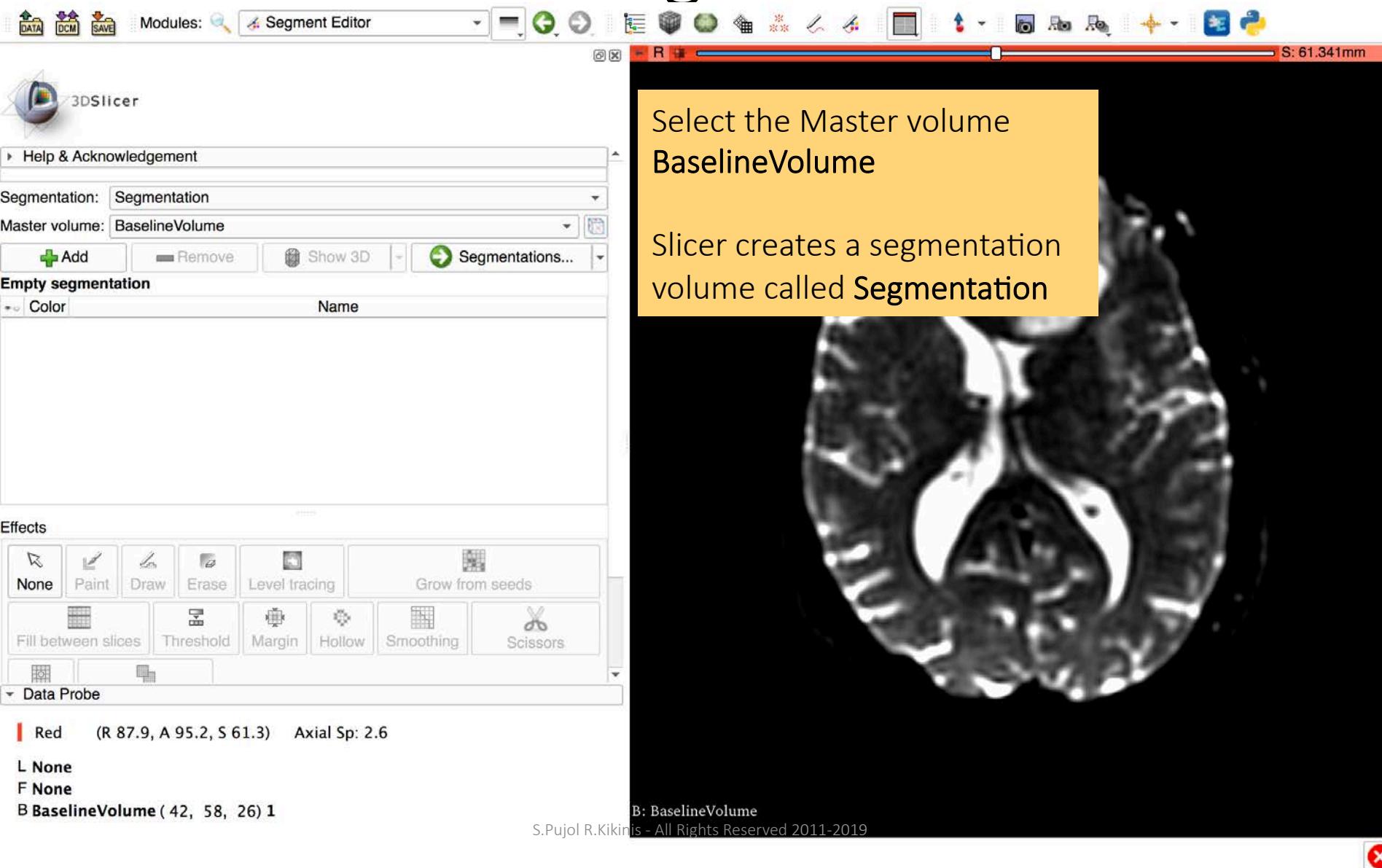
Master Volume +
Segmentation

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

Segment Editor



Tumor Segmentation



Tumor Segmentation

3DSlicer

Modules: Segment Editor

S: 58.741mm

Help & Acknowledgement

Segmentation: Segmentation

Master volume: BaselineVolume

Add Remove Show 3D Segmentations...

Color Name

- Solid
- Cystic
- Other

Effects

- None Paint Draw Erase Level tracing Grow from seeds Fill between slices
- Threshold Margin Hollow Smoothing Scissors Islands Logical operators

Undo Redo

Show Zoomed Slice

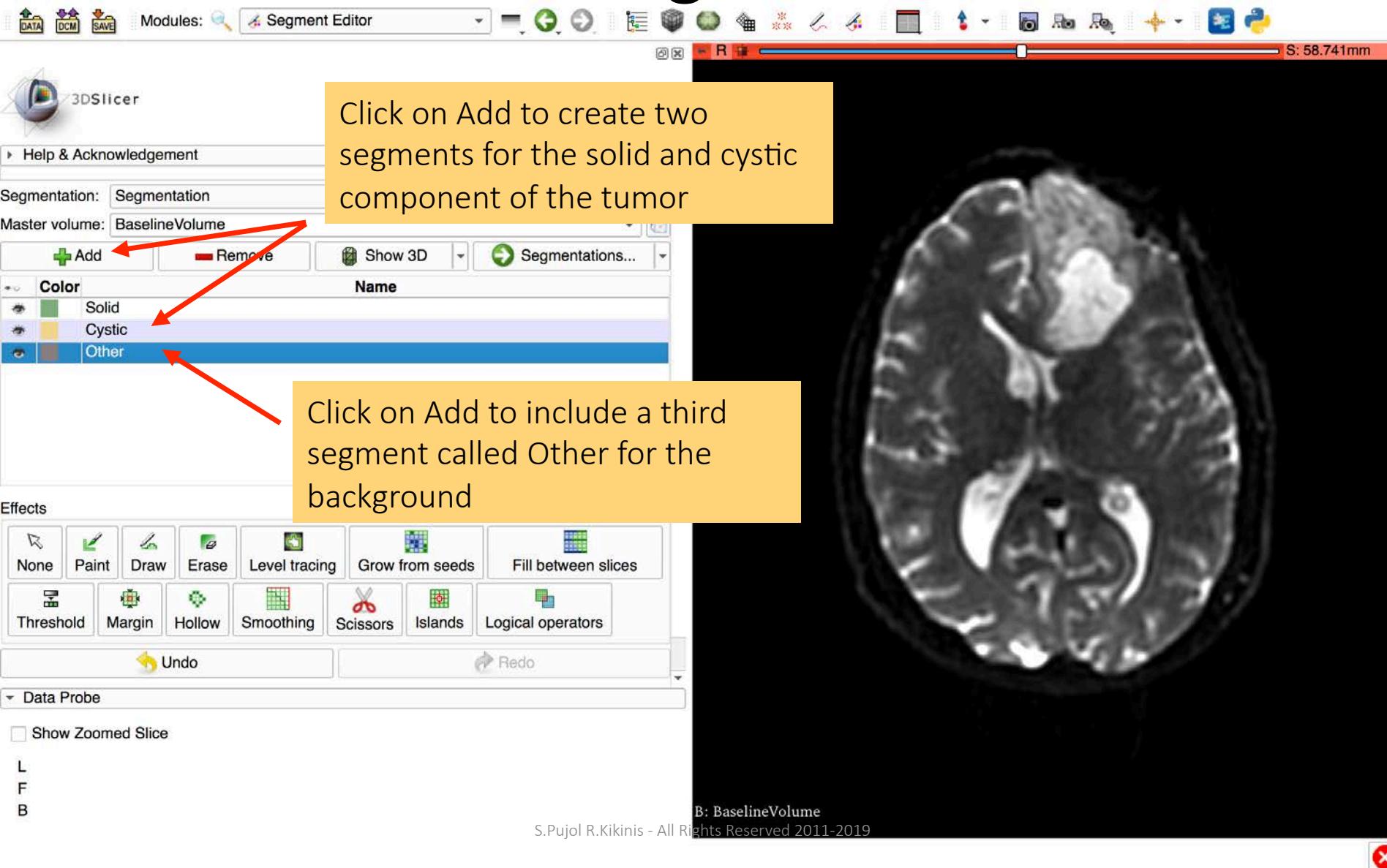
L F B

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

B: BaselineVolume

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Tumor Segmentation

3DSlicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove

Color	Name
Green	Solid
Yellow	Cystic
Brown	Other

Select the segment Solid

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Paint

Paint with a round brush... [Show details.](#)

Diameter: 3% 1 3 5 10 20 40 %

Sphere brush Color smudge Pixel mode

Undo Redo

B: BaselineVolume

Select the Paint tool and draw a mark in the solid component of the tumor in three contiguous slices

Tumor Segmentation

3DSlicer

Segmentation: Segmentation

Master volume: BaselineVolume

+ Add - Remove

Color	Name
Solid	Solid
Cystic	Cystic
Other	Other

Select the segment Cystic

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Paint

Paint with a round brush... [Show details.](#)

Diameter: 3% 1 3 5 10 20 40 %

Sphere brush Color smudge Pixel mode

Undo Redo

B: BaselineVolume

Select the segment Cystic

Select the Paint tool and draw a mark in the cystic component of the tumor in three contiguous slices

B: BaselineVolume

Tumor Segmentation

3DSlicer

Segmentation: Segmentation

Master volume: BaselineVolume

Add Remove

Color Name

- Solid
- Cystic
- Other

Select the segment Other

Effects

- None
- Paint**
- Draw
- Erase
- Level tracing
- Grow from seeds
- Fill between slices

Paint tool selected.

Select the Paint tool and draw a line around the solid and cystic component of the tumor

Threshold Margin Smoothing Scissors Islands Logical operators

Erase

Erase from current segment with a round brush... [Show details.](#)

Diameter: 3% 1 3 5 10 20 40 %

Sphere brush Color smudge Pixel mode

Undo Redo

Data Probe

R S: 58.741mm

B: BaselineVolume

The image shows a 3D Slicer interface for tumor segmentation. On the left, the 'Segment Editor' module is active, displaying a color palette with 'Solid' (green), 'Cystic' (yellow), and 'Other' (brown) segments. A red arrow points to the 'Other' segment. Below the palette is the 'Effects' toolbar, where the 'Paint' tool is highlighted with a red circle. A second red arrow points to the 'Paint' tool icon. A callout box with the text 'Select the segment Other' is positioned over the color palette. Another callout box with the text 'Select the Paint tool and draw a line around the solid and cystic component of the tumor' is positioned over the effects toolbar. On the right, a grayscale MRI slice of a brain shows a tumor. The tumor is segmented and outlined with a brown line, representing the 'Other' segment. A red arrow points to this brown outline on the image.

Tumor Segmentation

3DSlicer

Modules: Segment Editor

Add Remove Show 3D Segmentations...

Color Name

- Solid
- Cystic
- Other

Select the Grow From Seeds tool and click on Initialize

Effects

None Paint Draw Erase Level tracing **Grow from seeds** Fill between slices

Threshold Margin Smoothing Scissors Islands Logical operators

Grow from seeds

Growing segments to create complete segmentation... [Show details.](#)

Preview: Auto-update **Initialize**

Display: inputs results

Cancel Apply

Undo Redo

Masking

Editable area: Everywhere

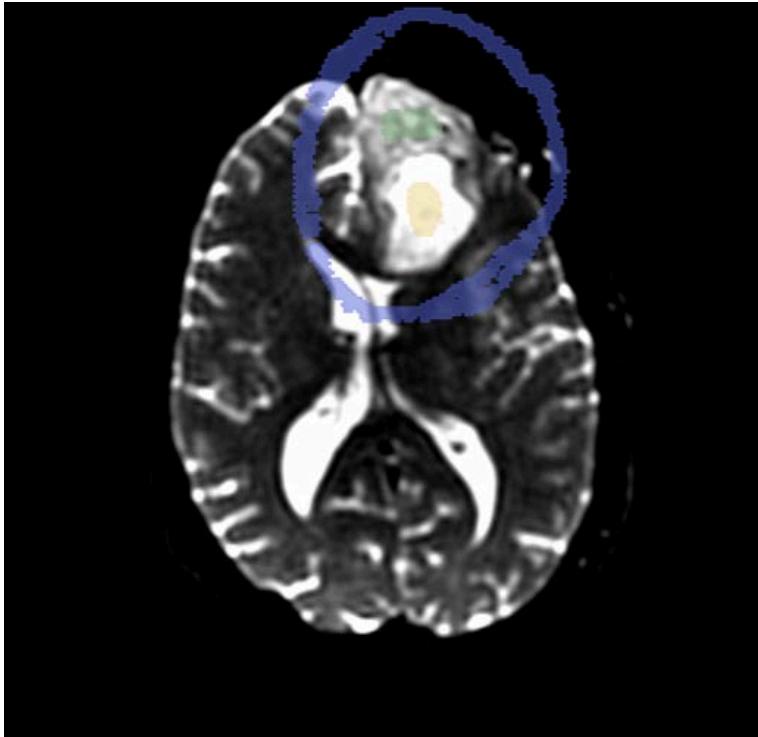
Data Probe

R S: 58.741mm

B: BaselineVolume

The image shows the 3DSlicer interface with a brain MRI slice. A tumor is segmented and highlighted with a green core and a yellow shell. The left panel displays the 'Segment Editor' tools, including the 'Grow from seeds' tool which is circled in red. A second red arrow points to the 'Initialize' button in the 'Grow from seeds' dialog box. A yellow callout box contains the text 'Select the Grow From Seeds tool and click on Initialize'.

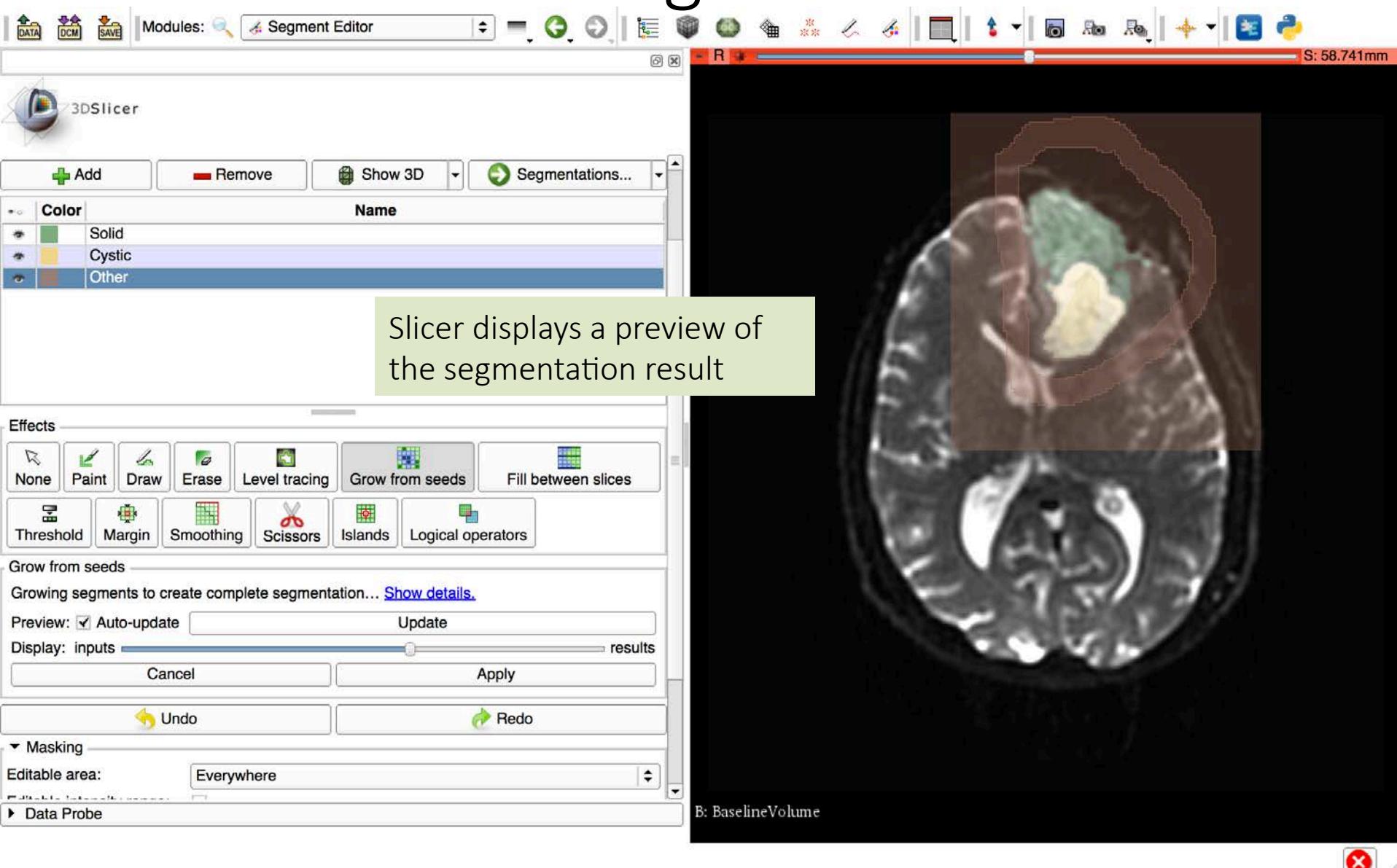
Grow from Seeds Algorithm



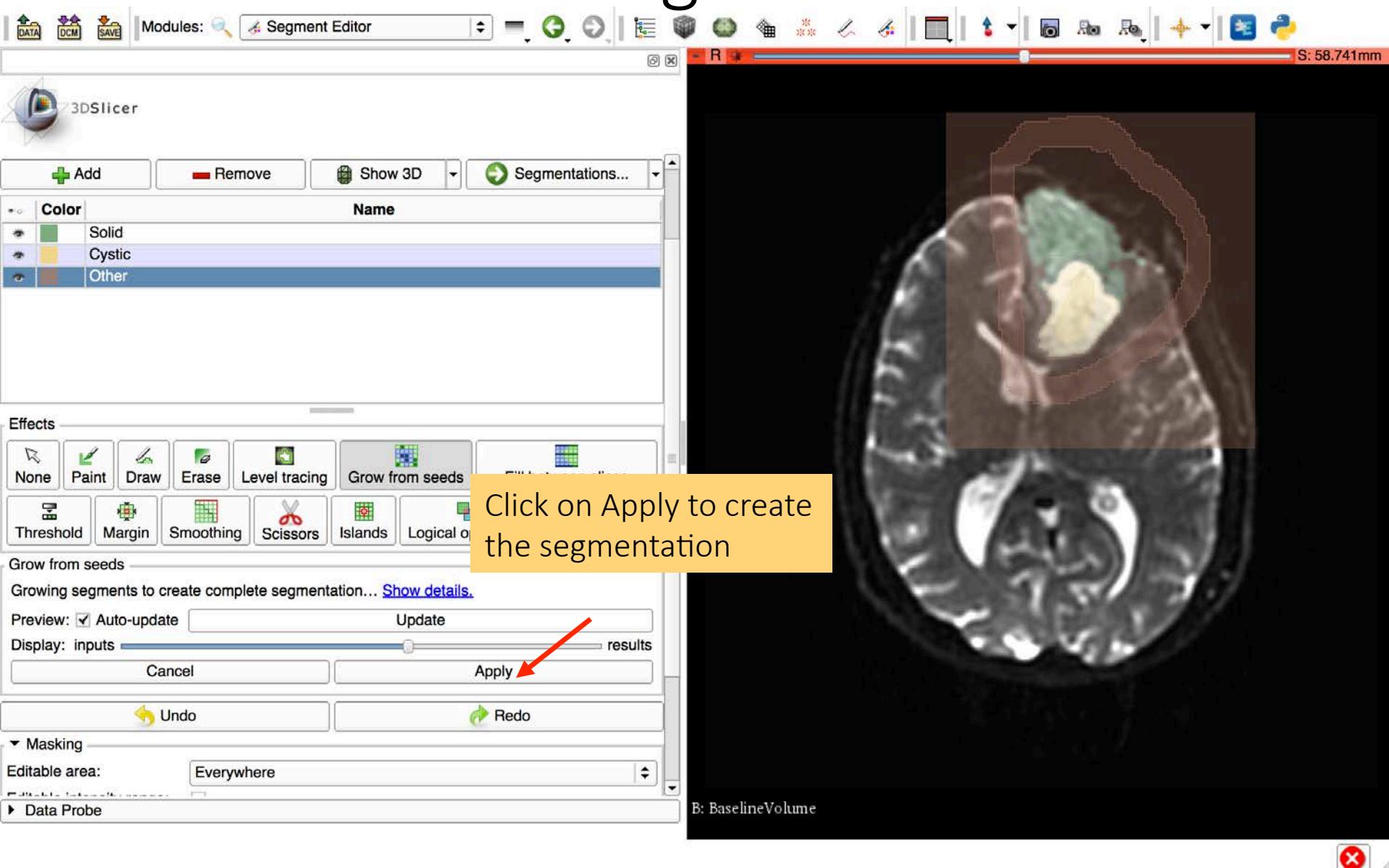
- The **Grow from Seeds** tool implements the **Grow Cut algorithm**, a competitive region growing algorithm using a Cellular Automata approach.
- The algorithm performs automated multi-label image segmentation using a set of user input scribbles.

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

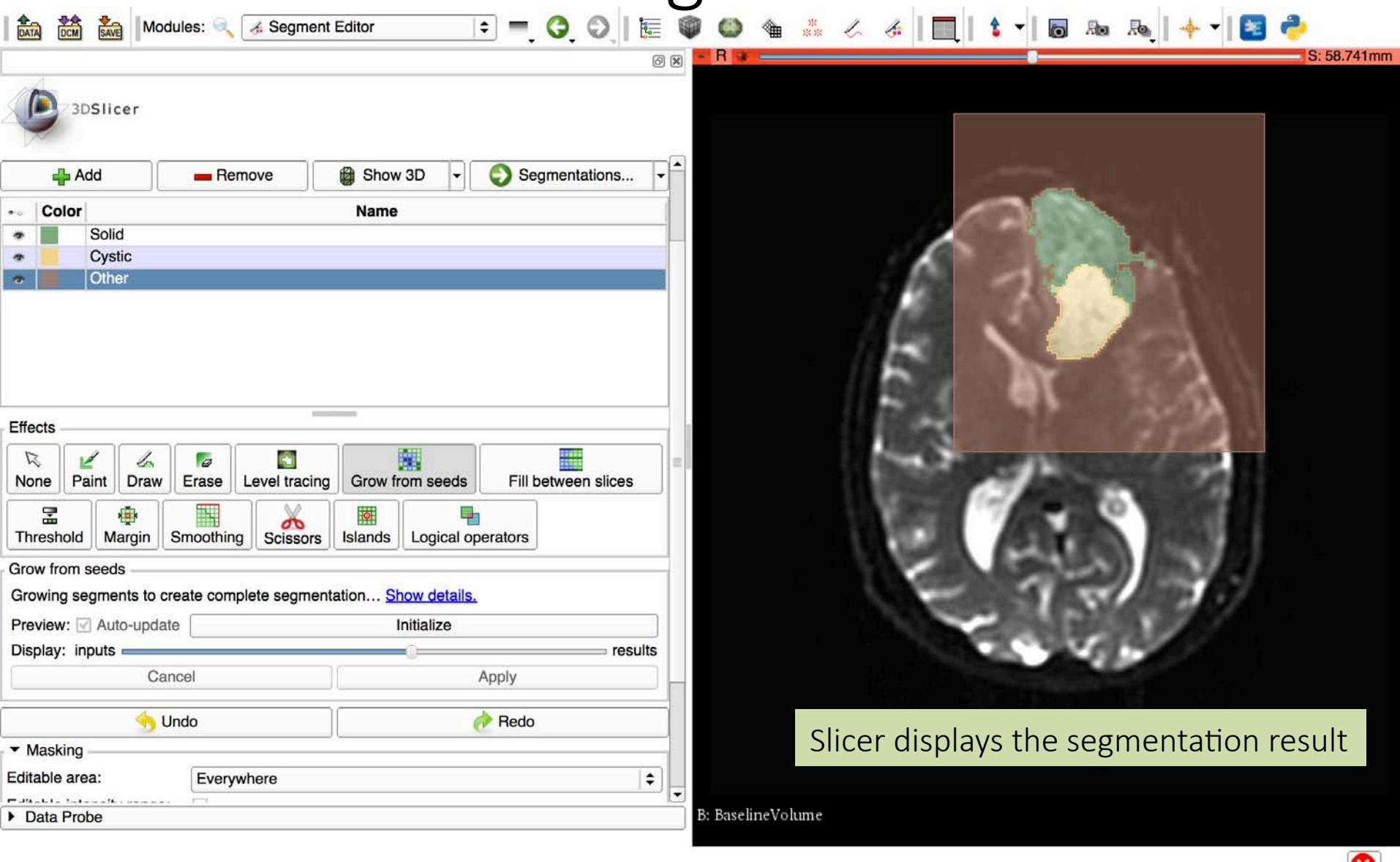
Tumor Segmentation



Tumor Segmentation



Tumor Segmentation



Tumor Segmentation

The screenshot shows the 3DSlicer software interface with the 'Segment Editor' module active. The top menu bar includes 'DATA', 'DCM', 'SAVE', 'Modules: Segment Editor', and various tool icons. The main window displays a 3D brain volume with segmented regions. A legend on the left identifies segments: 'Solid' (green), 'Cystic' (yellow), and 'Other' (blue). A red arrow points to the 'Other' segment in the color palette.

Select the segment Other

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between slices

Threshold Margin Hollow Smoothing Scissors Islands Logical operators

Fill segment based on master volume intensity range... Show [Color Map](#)

Threshold Range: 1700.00

Automatic threshold: auto->maximum Otsu Use for masking Set

Apply

Undo Redo

Masking

Editable area: Everywhere Everywhere Inside all segments Inside all visible segments Outside all segments Outside all visible segments Inside Solid Inside Cystic Inside Other

Data Probe

A yellow callout box with a red arrow points to the 'Threshold' button in the effects toolbar. Another yellow callout box with a red arrow points to the 'Threshold Range' input field, which is set to 1700.00. A third yellow callout box with a red circle around the 'Apply' button is located in the 'Threshold' section of the controls.

Select the Threshold tool and set the Threshold Range to 1700

Set the Editable area to Outside all Segments and click on Apply

Ventricles Segmentation

The screenshot shows the 3DSlicer software interface with the "Segment Editor" module active. On the left, the "Effects" panel contains various tools like Paint, Draw, Erase, and Islands. The "Islands" tool is highlighted with a red circle. Below it, the "Edit islands" section has a radio button for "Keep selected island" which is also circled in red. The main window displays a grayscale brain scan with a green and yellow segmented region representing the lateral ventricles. A red arrow points from the text "Left-click on the posterior part of the lateral ventricles to isolate the island" towards the green segment.

Select the Islands tool

Select the option
Keep selected island

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

DATA DCM SAVE Modules: Segment Editor R S: 58.741mm

3DSlicer

Help & Acknowledgement

Reload & Test

Reload Reload and Test Edit Restart Slicer

Segmentation: Segmentation

Master volume: BaselineVolume

Add Remove Show 3D Segments...

Color Name

- Solid
- Cystic
- Other

Effects

None Paint Draw Erase Level tracing Grow from seeds Fill between

Threshold Margin Hollow Smoothing Scissors Islands Logical operators

Islands

Edit islands (connected components) in a segment.

Keep selected island

Remove small islands

Split islands to segments

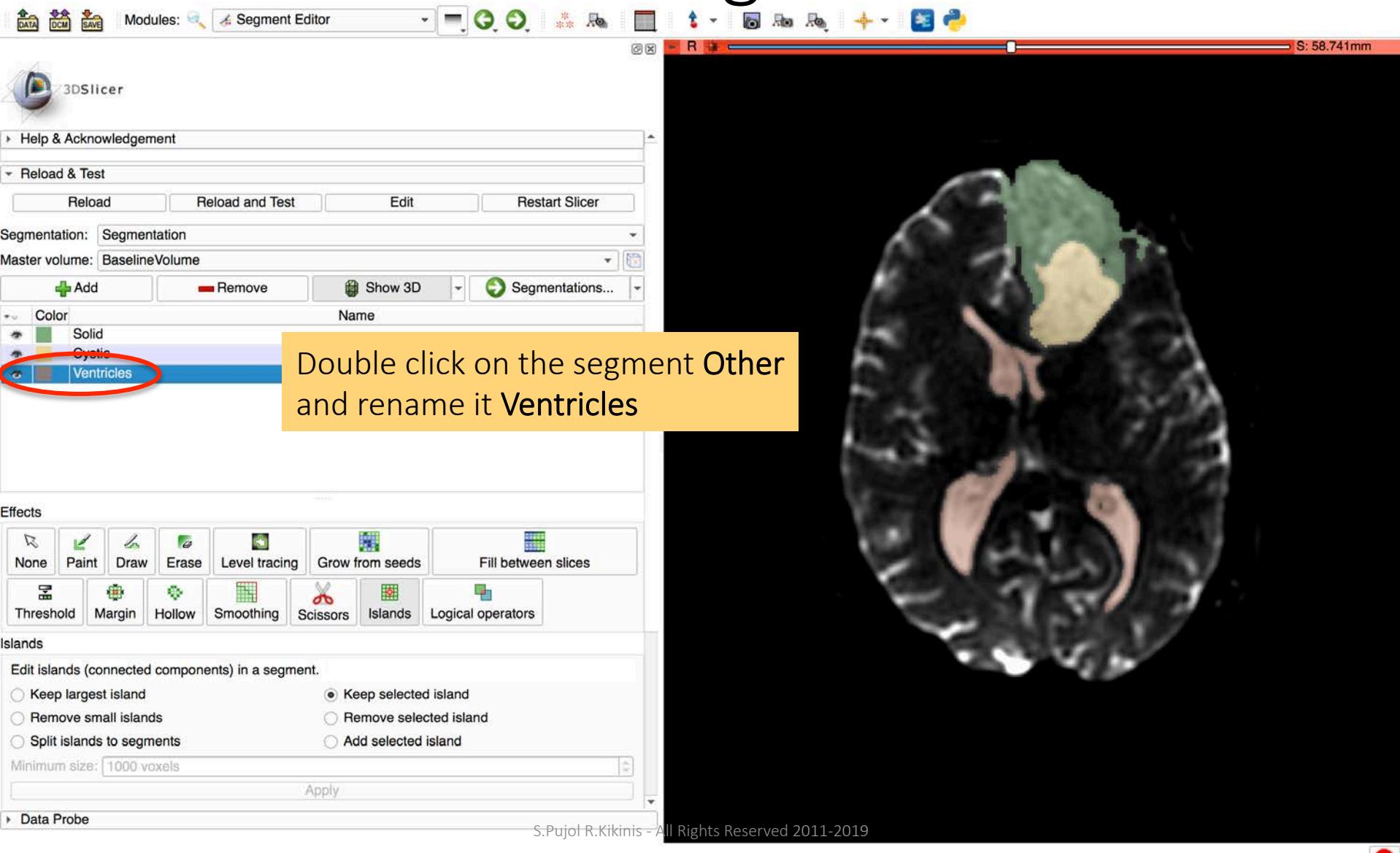
Minimum size: 1000 voxels

Apply

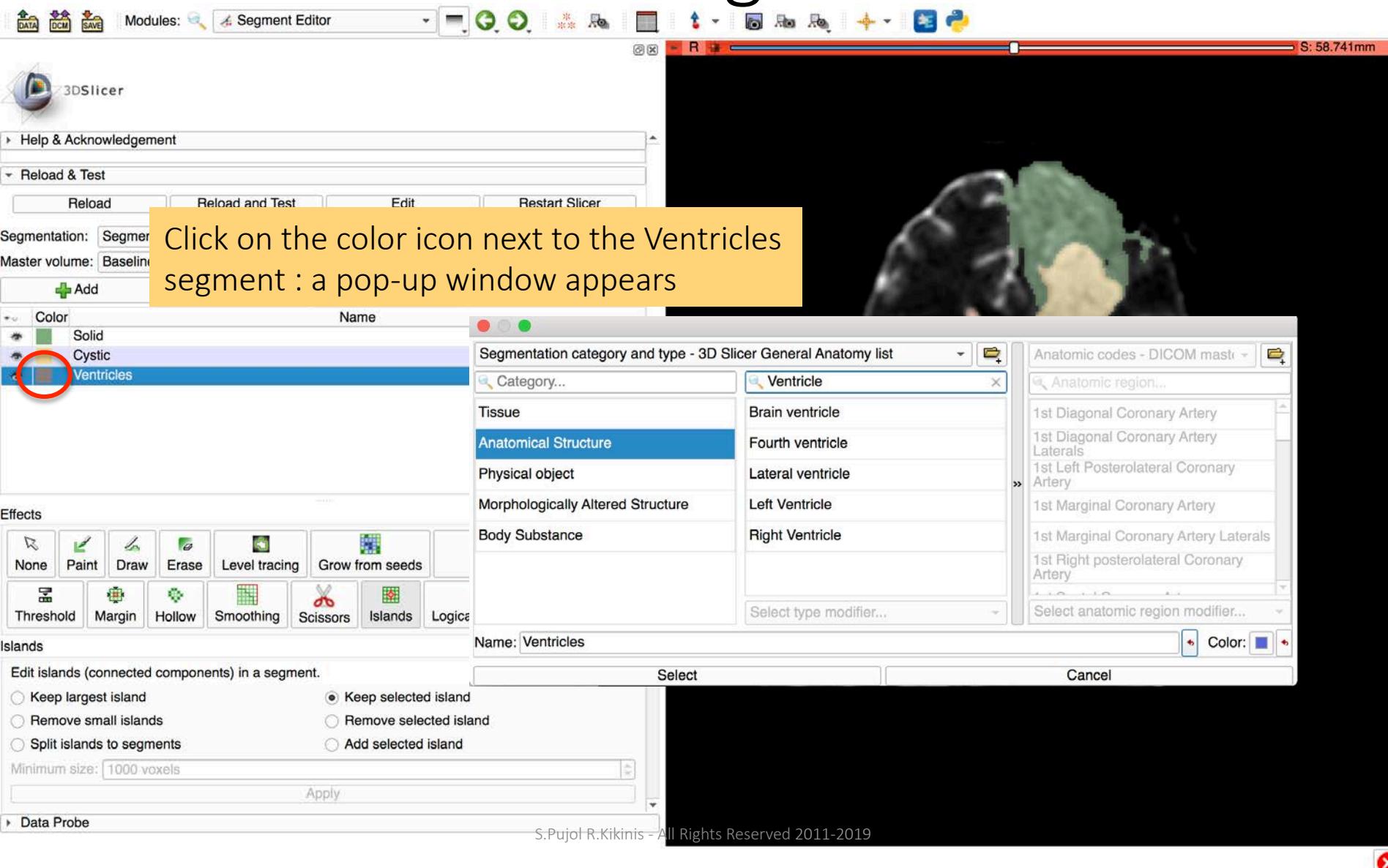
Data Probe

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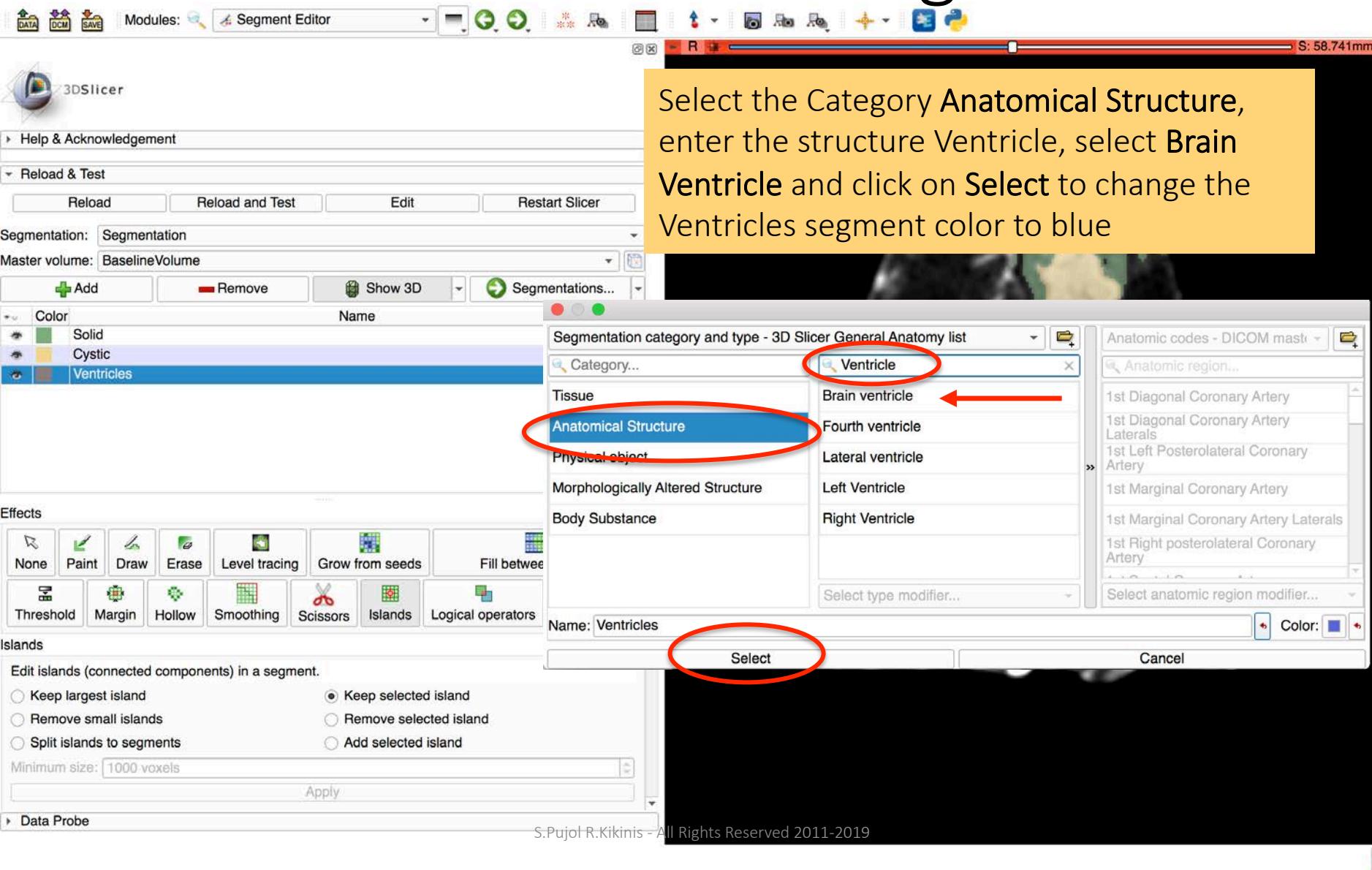
Ventricles Segmentation



Ventricles Segmentation



Tumor and Ventricle Segmentation

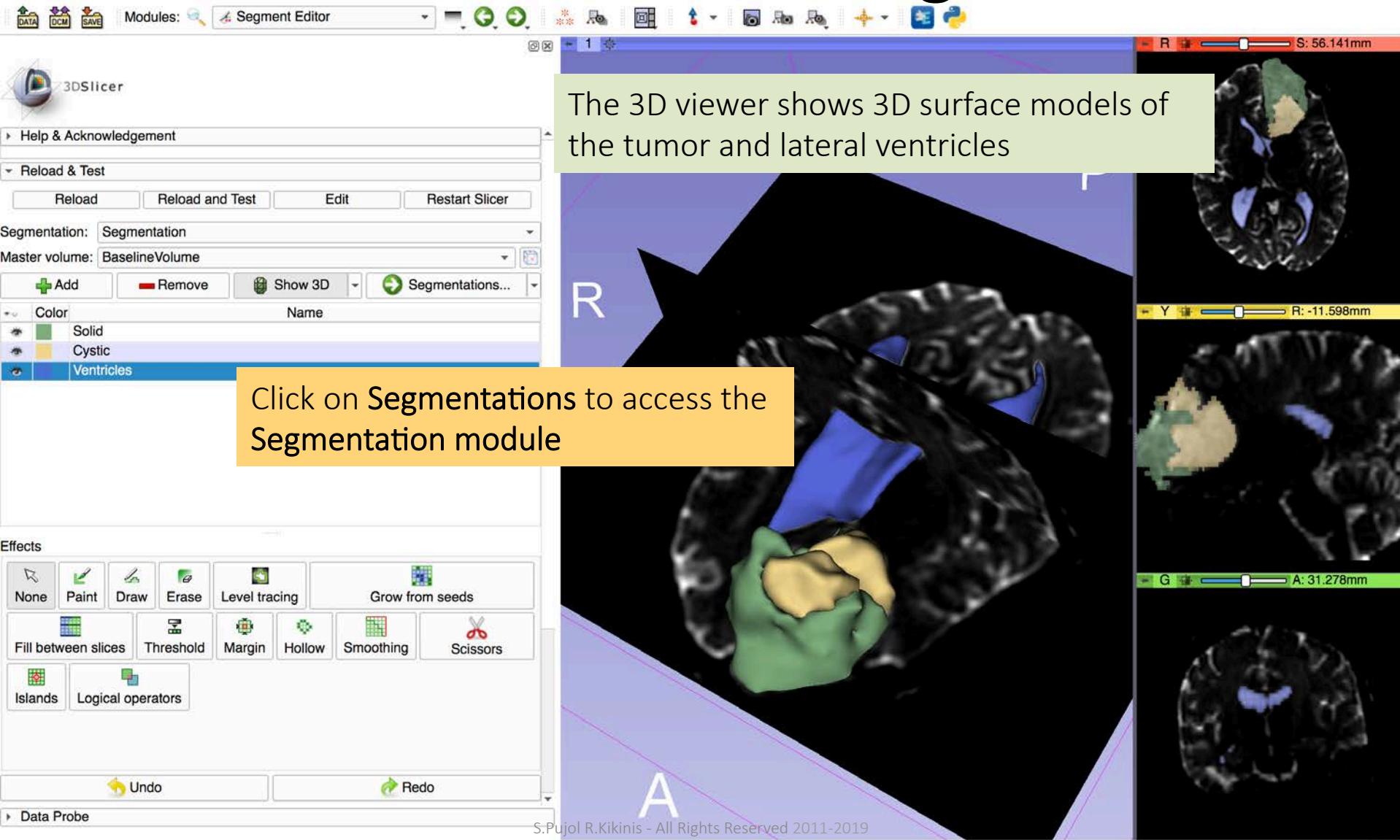


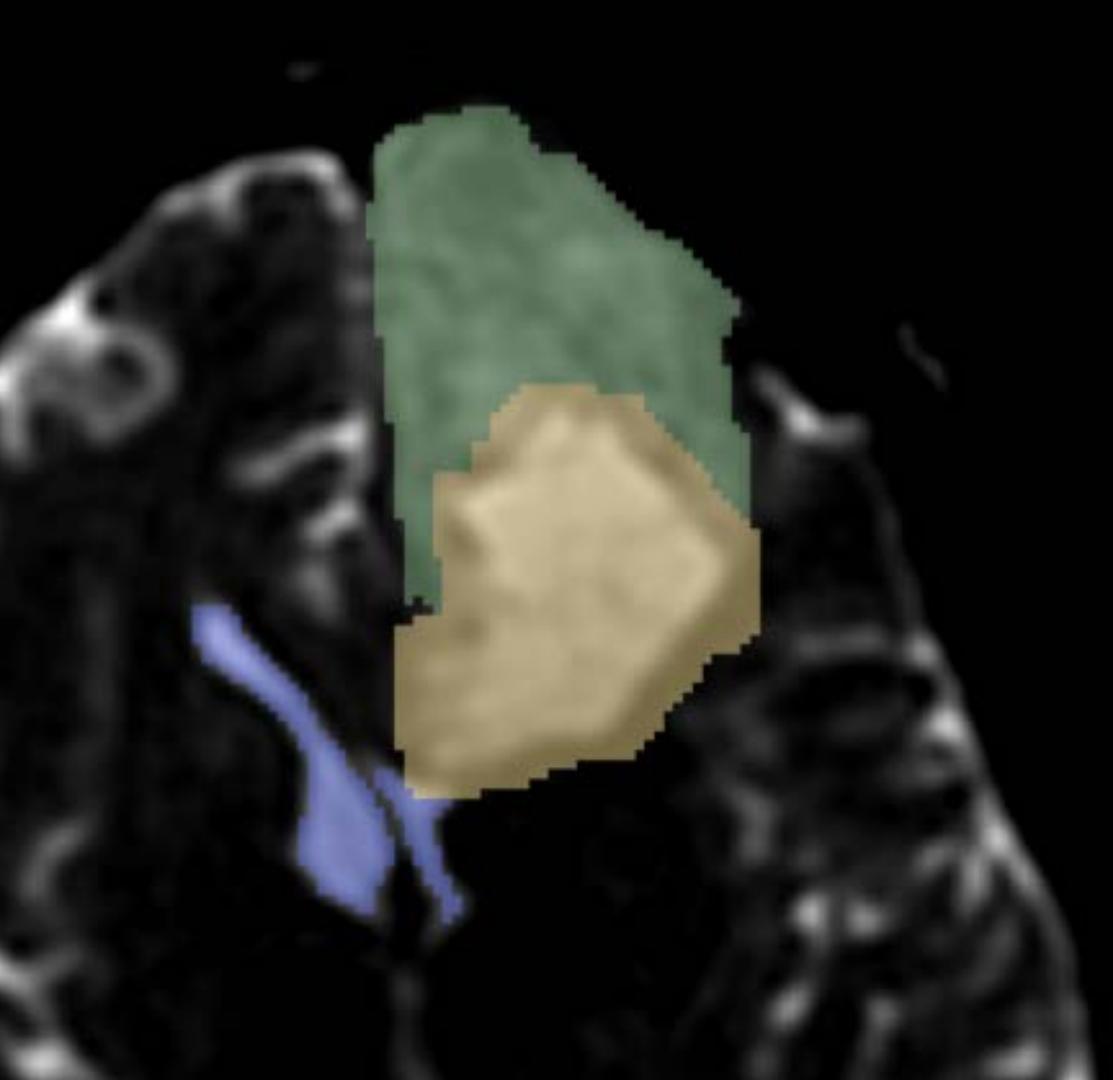
Tumor and Ventricle Segmentation

The screenshot shows the 3DSlicer interface with several panels:

- Segment Editor Panel:** Shows a list of segments: BaselineVolume, Solid, Cystic, and Ventricles. A red arrow points to the "Show 3D" button.
- Effects Panel:** Contains various segmentation tools like Paint, Draw, Erase, Level tracing, Grow from seeds, Fill between slices, Threshold, Margin, Hollow, Smoothing, Scissors, Islands, and Logical operators.
- Margin Panel:** Allows shrinking or growing selected segments by a specified margin size (3.0mm, 3x3x1 pixels).
- Masking Panel:** Sets the Editable area to Everywhere.
- Layout Menu:** A dropdown menu showing various 3D view options. The "Conventional Widescreen" option is highlighted with a blue selection bar, and a red arrow points to it from the right.
- 3D Volume Rendering:** A large 3D volume rendering of a brain, colored to distinguish different tissue types (e.g., white matter in blue).
- Text Overlay:** An orange callout box contains the text: "Select the Conventional Widescreen view from the layout menu".

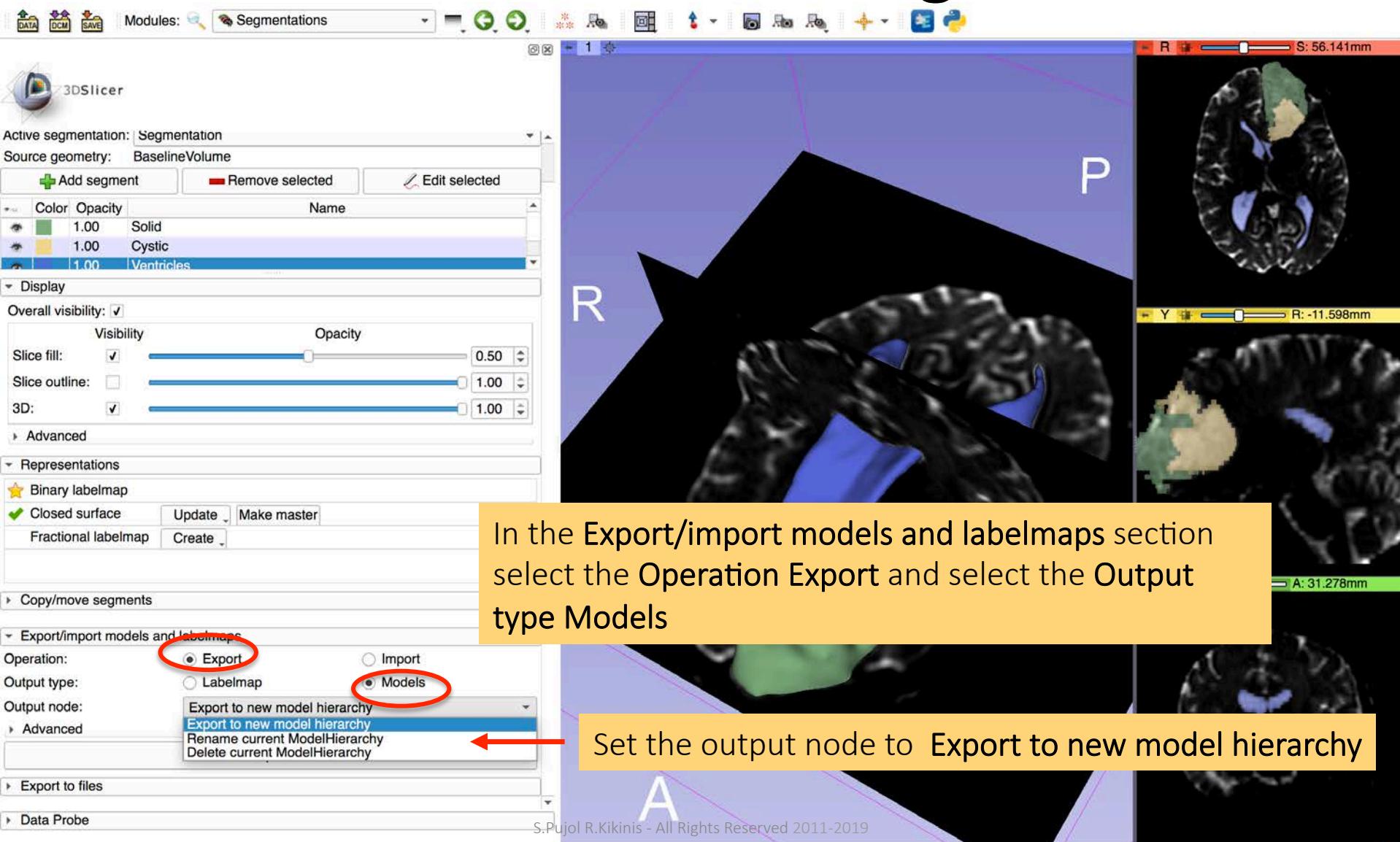
Tumor and Ventricles Segmentation



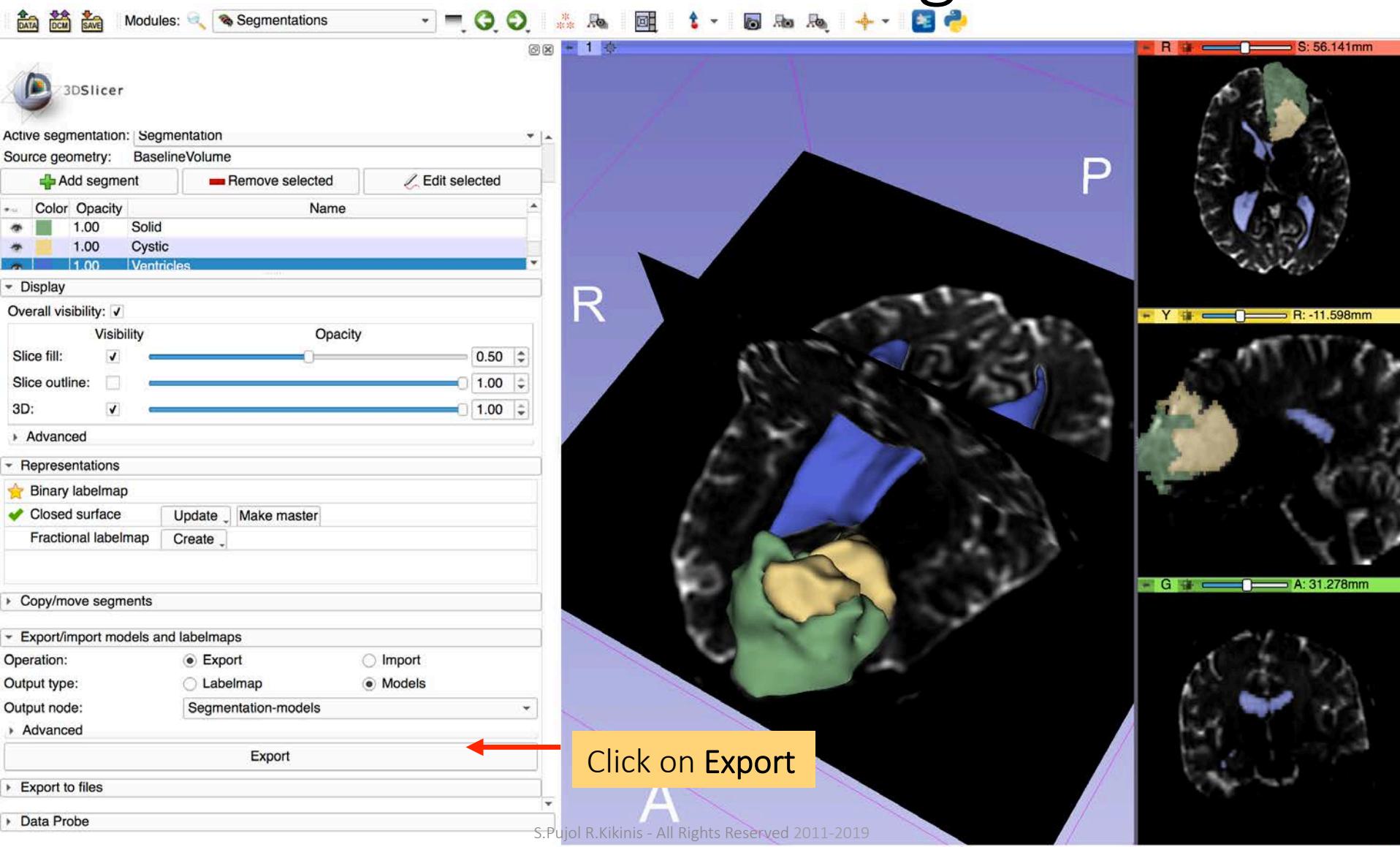


Part 2: Peritumoral volume generation

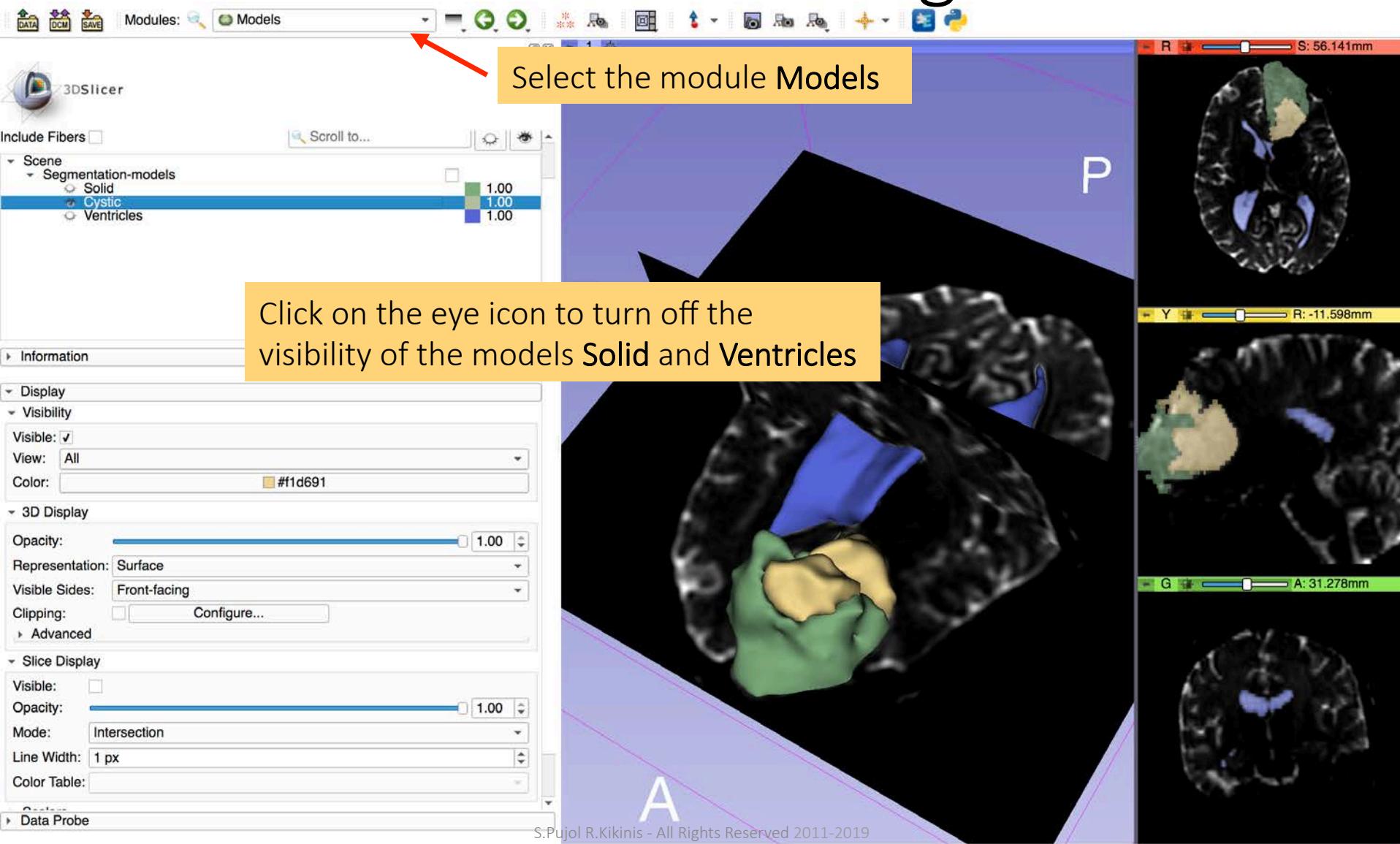
Tumor and Ventricle Segmentation



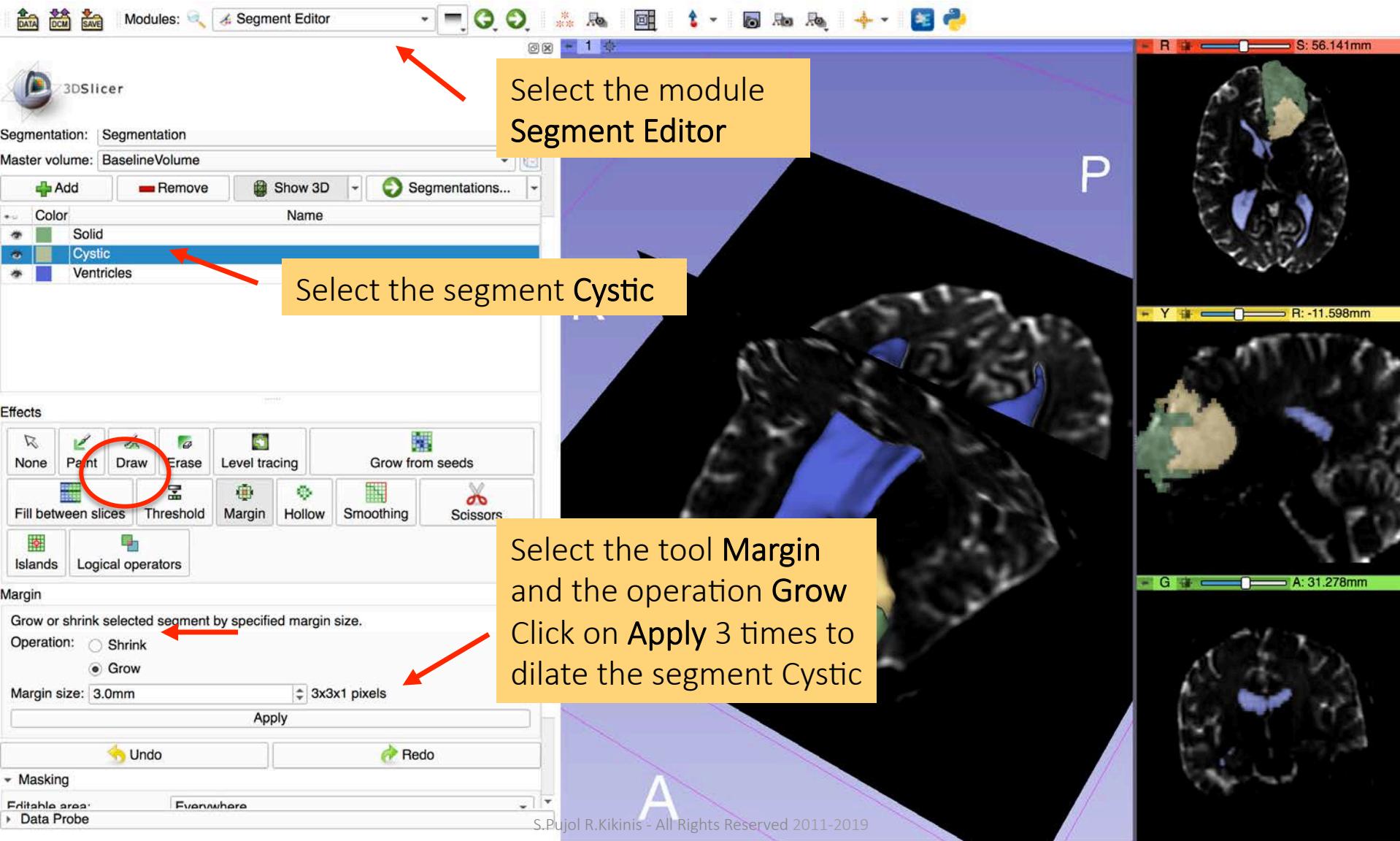
Tumor and Ventricle Segmentation



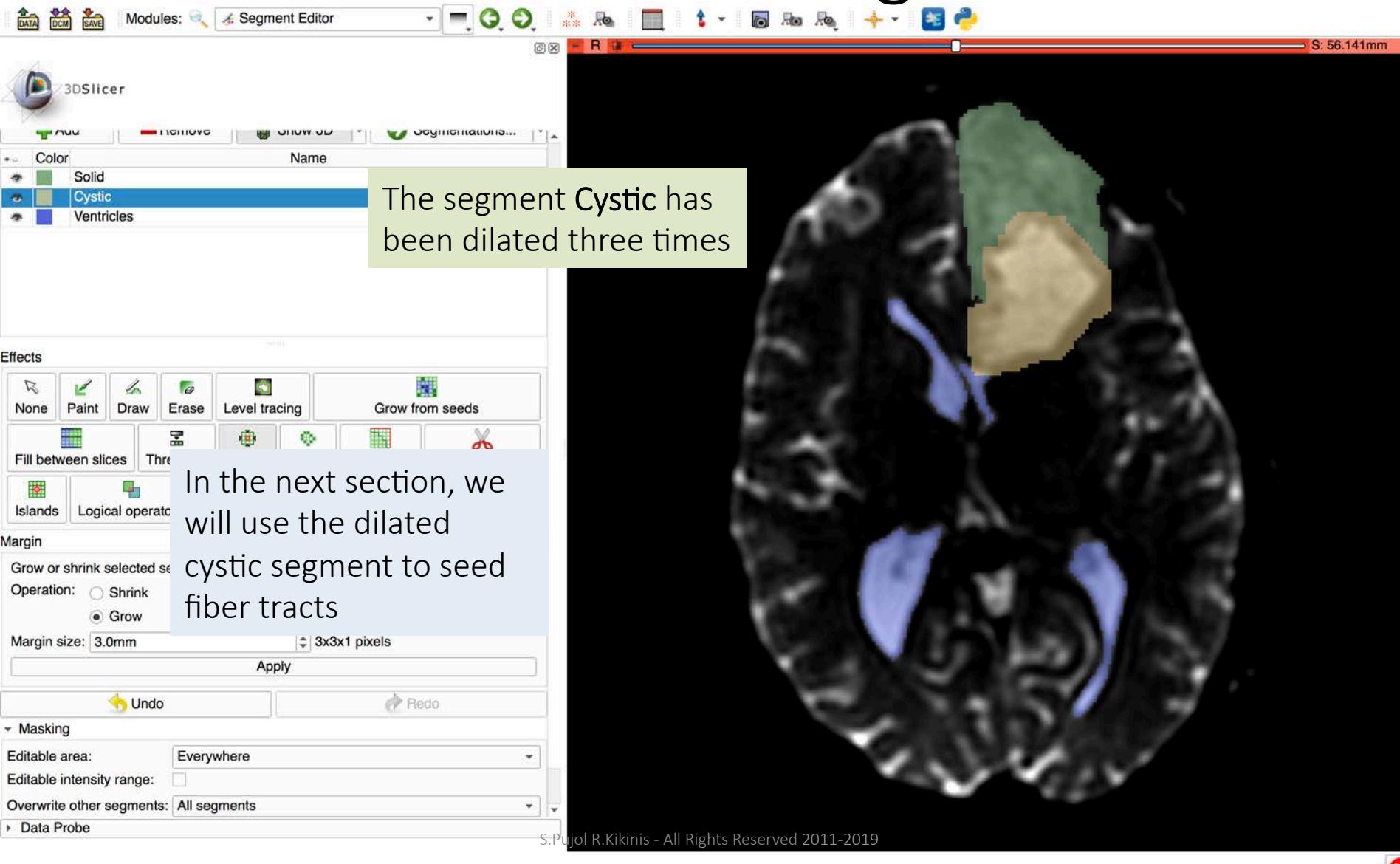
Tumor and Ventricles Segmentation



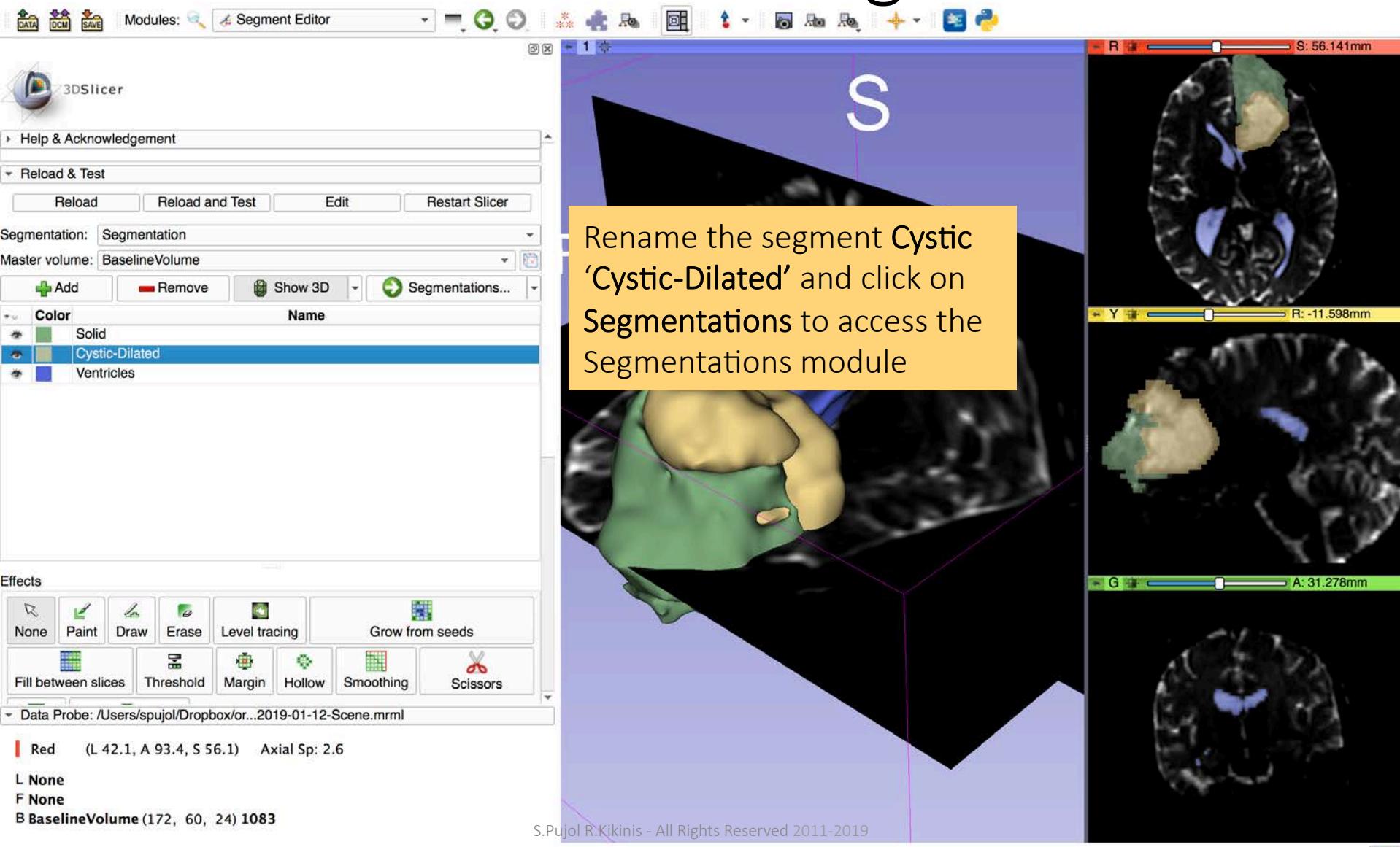
Peritumoral volume generation



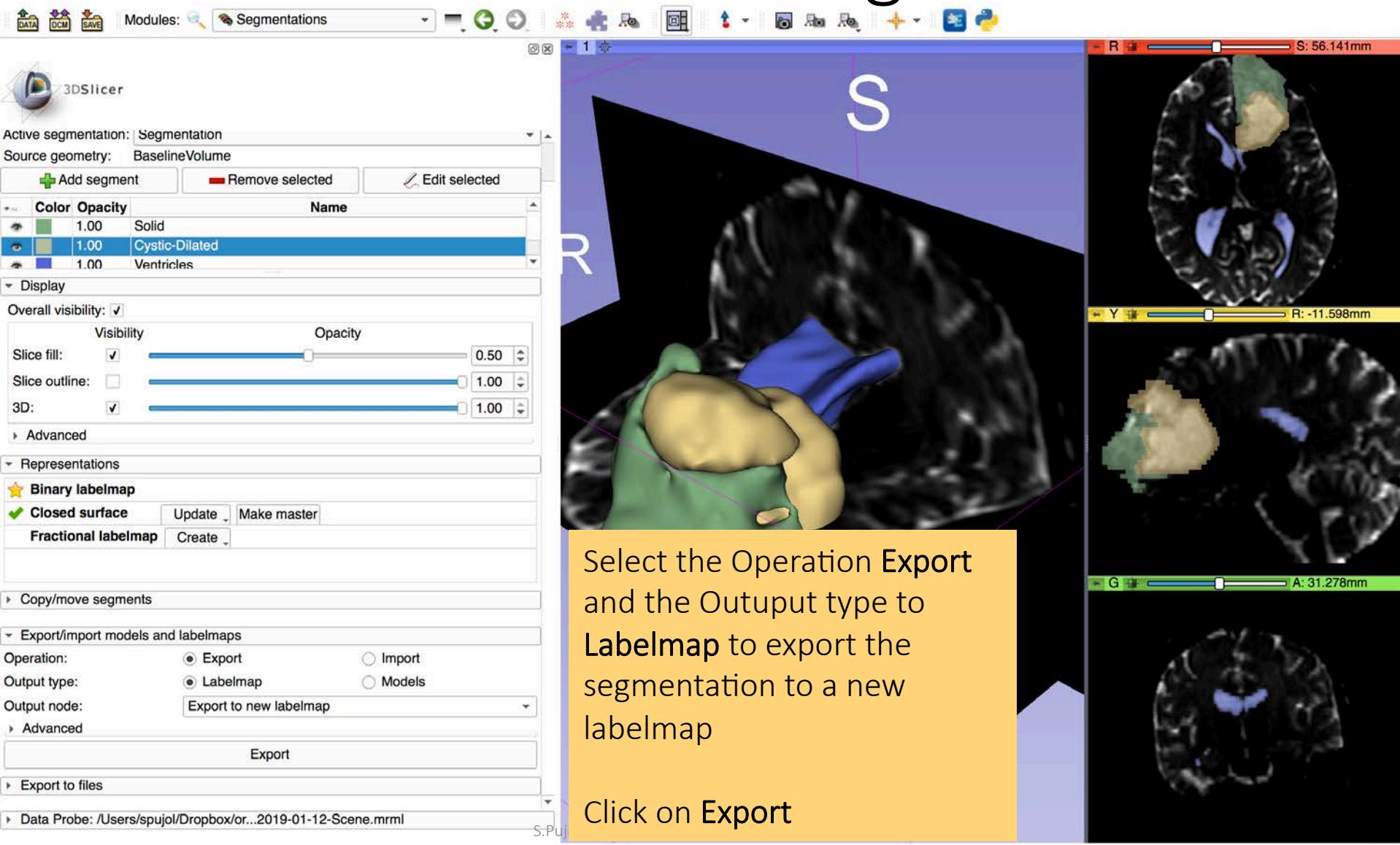
Peritumoral volume generation

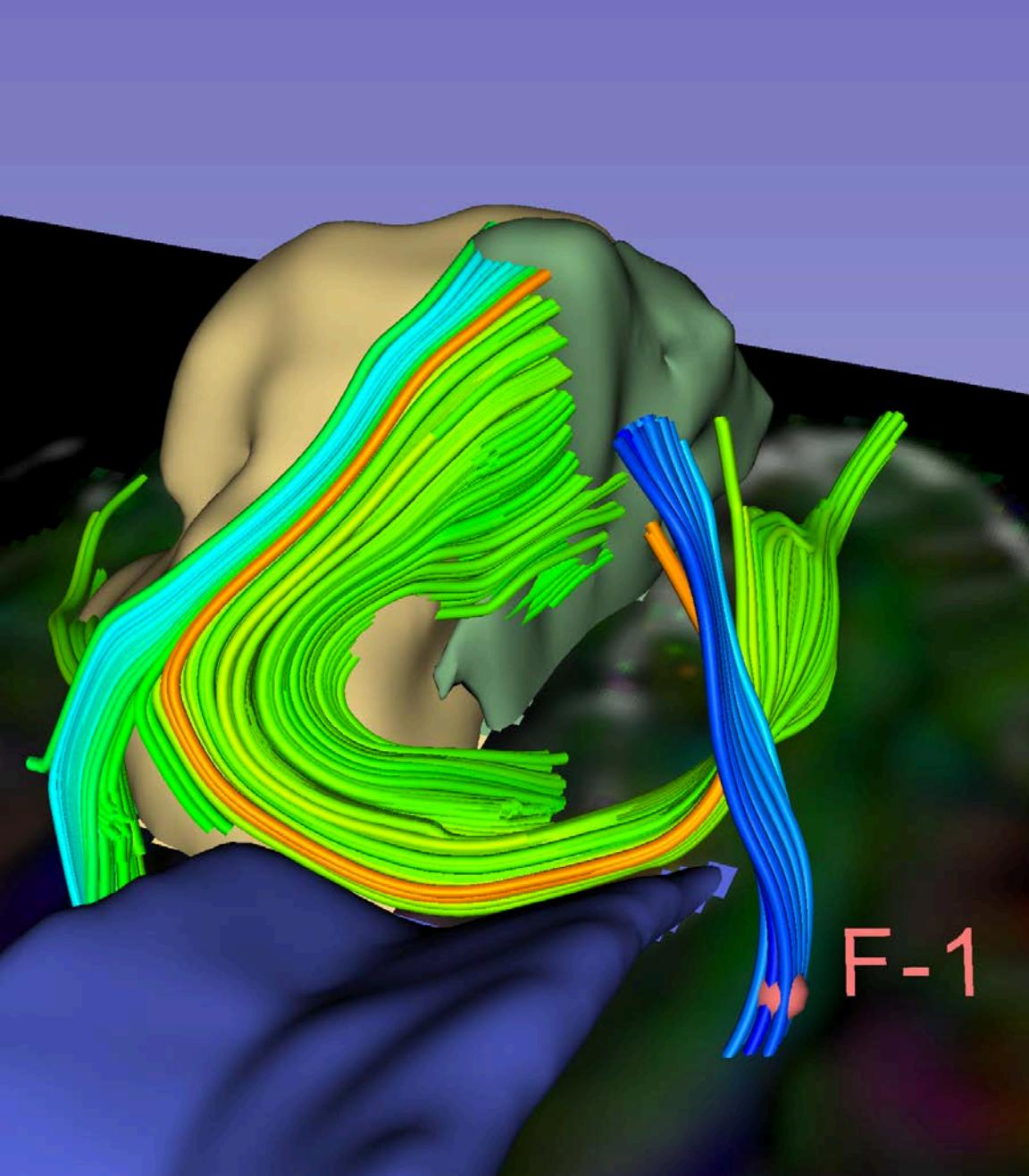


Peritumoral volume generation



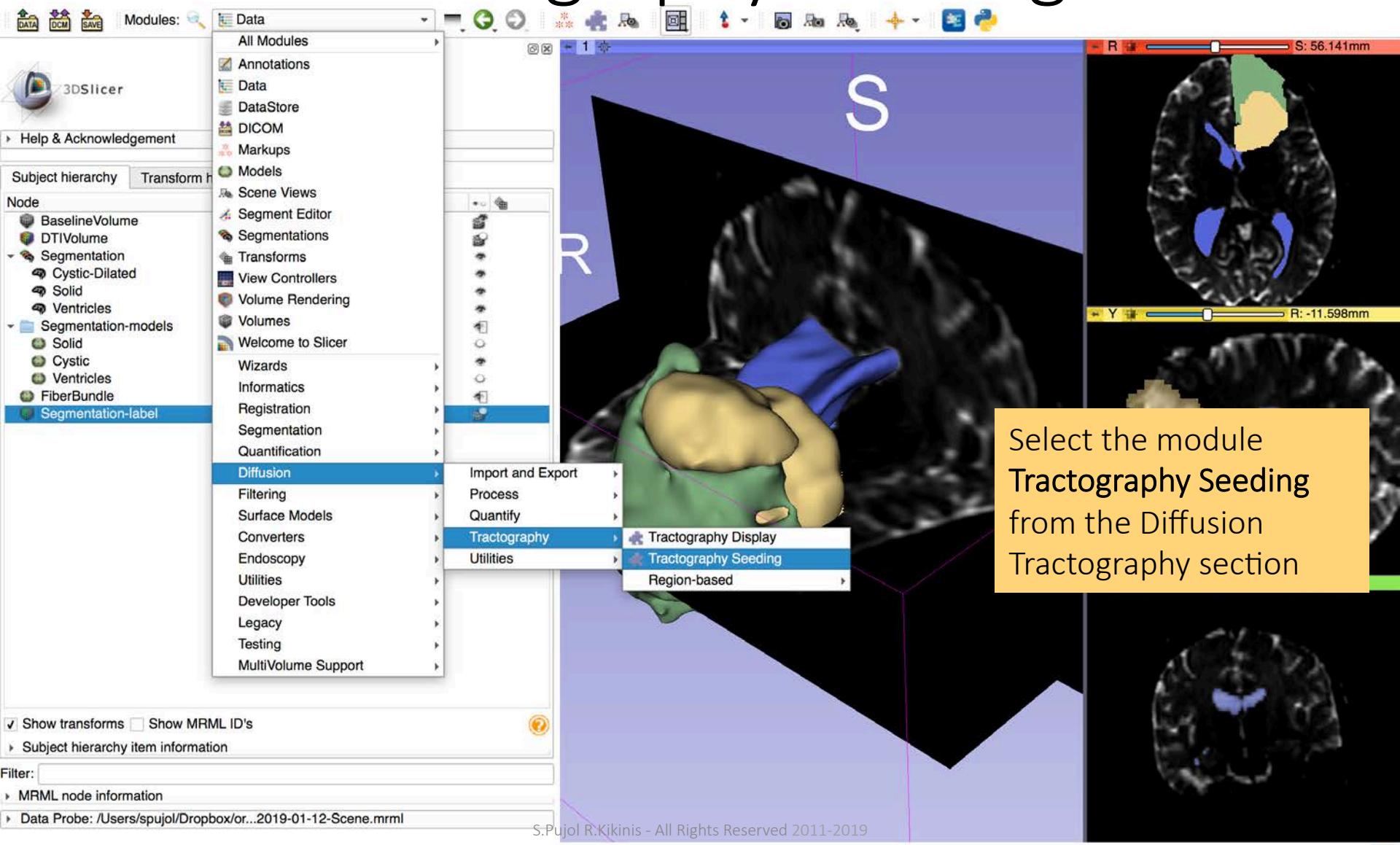
Peritumoral volume generation



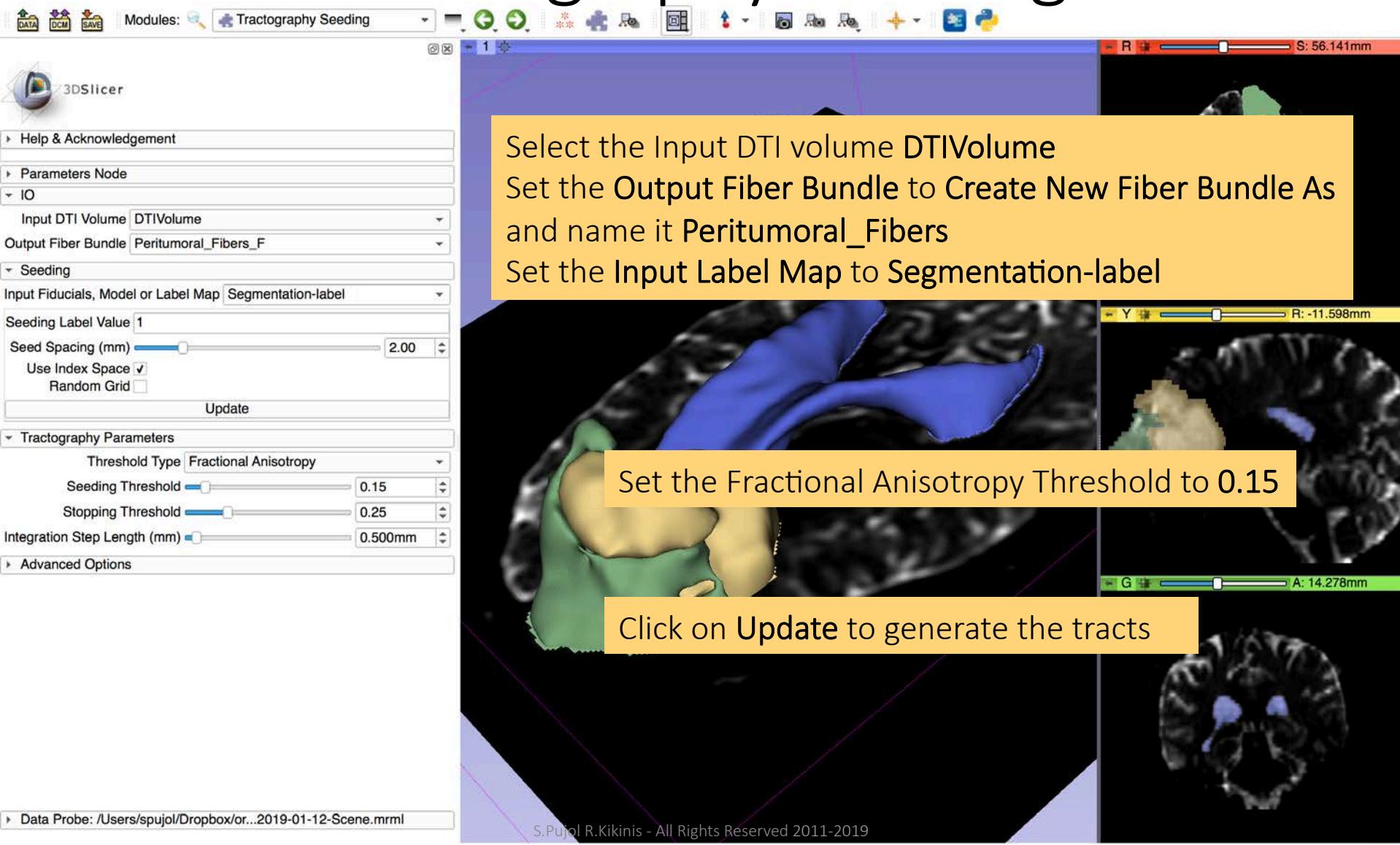


Part 3: Fiber Tracking in peritumoral area

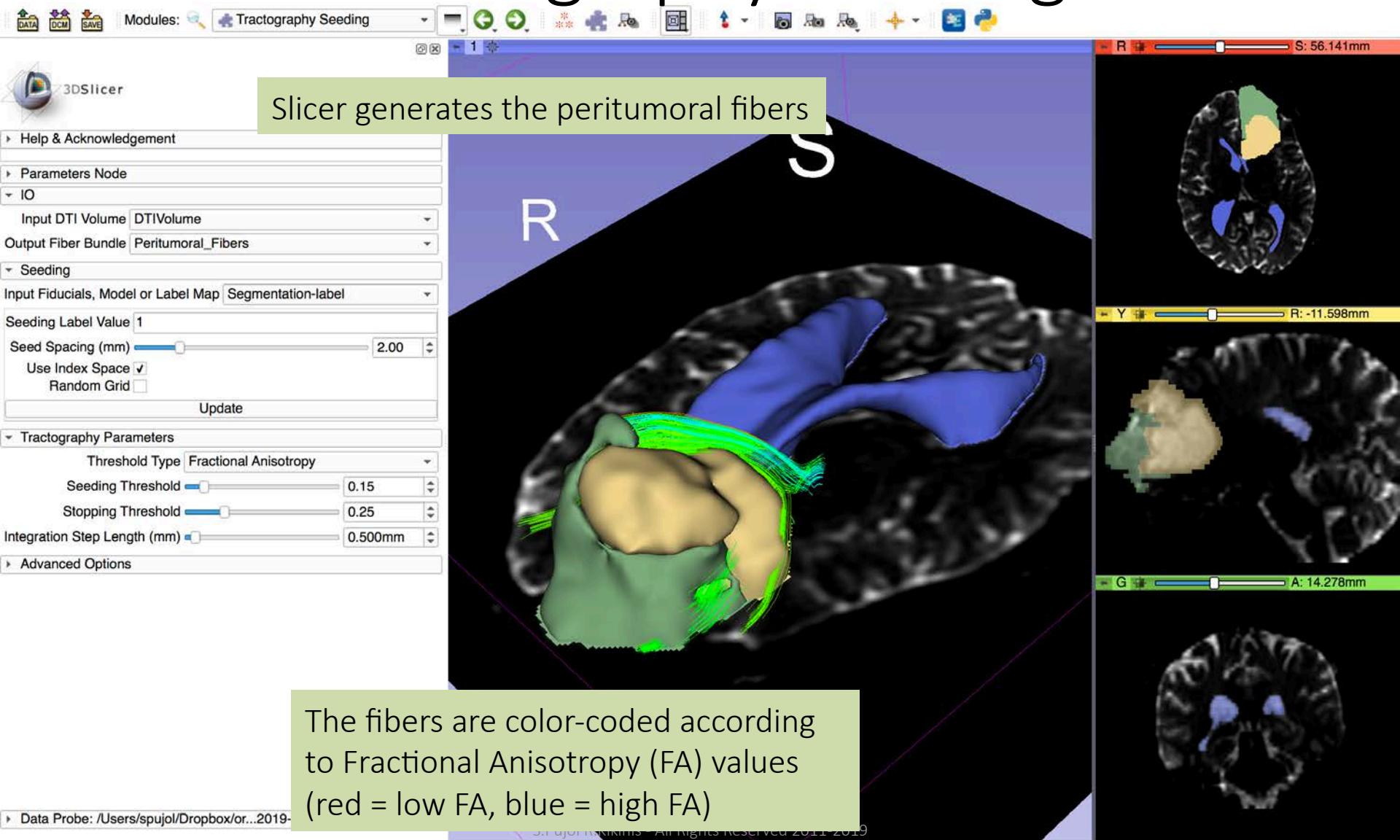
Tractography Seeding



Tractography Seeding



Tractography Seeding



Interactive Tractography

3DSlicer

Modules: **Tractography Seeding**

DATA DCM SAVE

Help & Acknowledgement

Parameters Node

- IO

Input DTI Volume: DTIVolume

Output Fiber Bundle: newFiberBundle_Segmentation-label

- Seeding

Input Fiducials, Model or Label Map: F

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Max Number of Seeds: 100

Seed Selected Fiducials Only

Update (check for interactive)

- Tractography Parameters

Threshold Type: Fractional Anisotropy

Seeding Th

Stopping Th

Integration Step Length

Advanced Options

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

Click on the Arrow to position a fiducial near the tumor

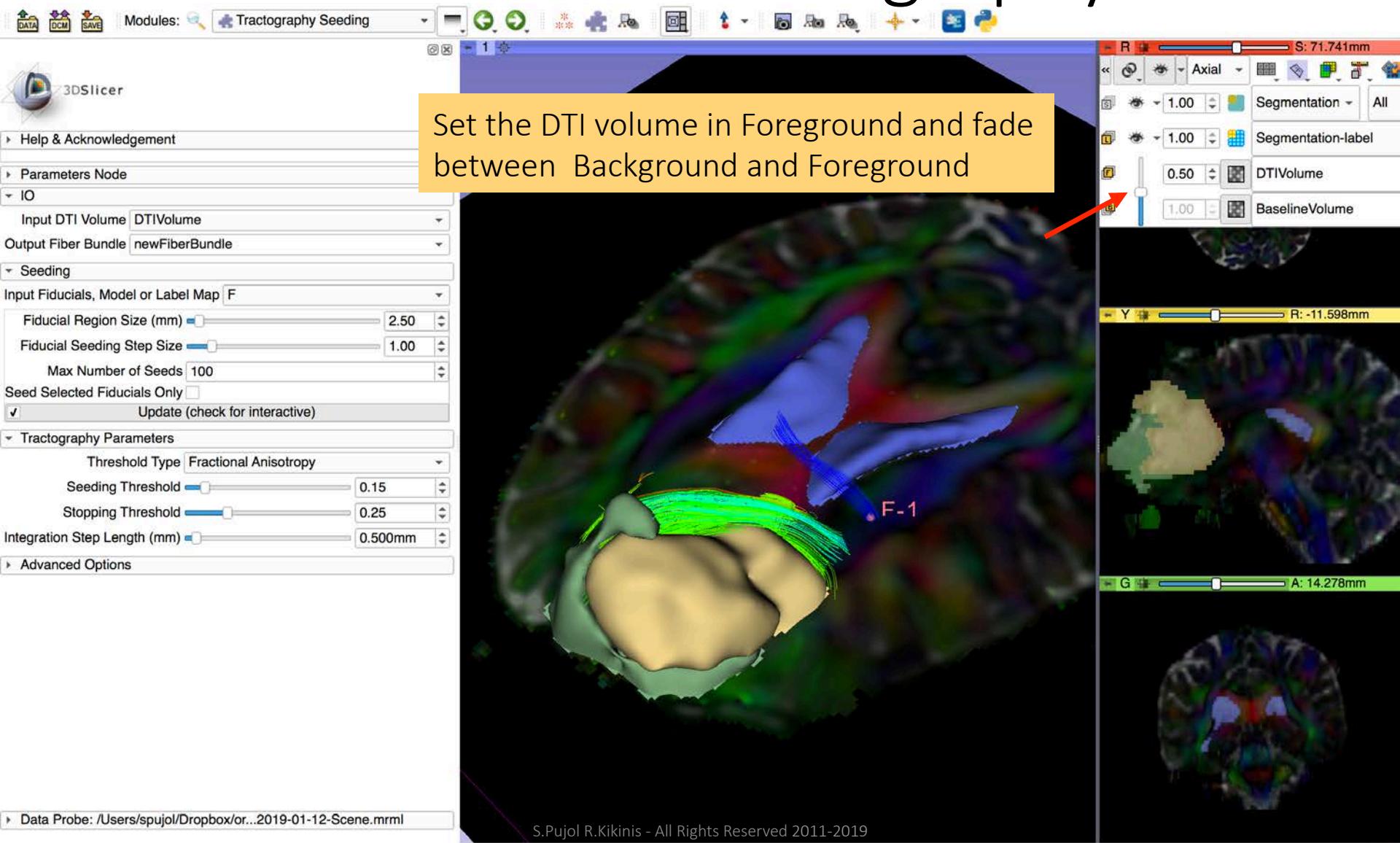
In the IO section, set the Output Fiber Bundle to Create New Fiber Bundle As and name it New_FiberBundle

In the Seeding section, set the Fiducials to F

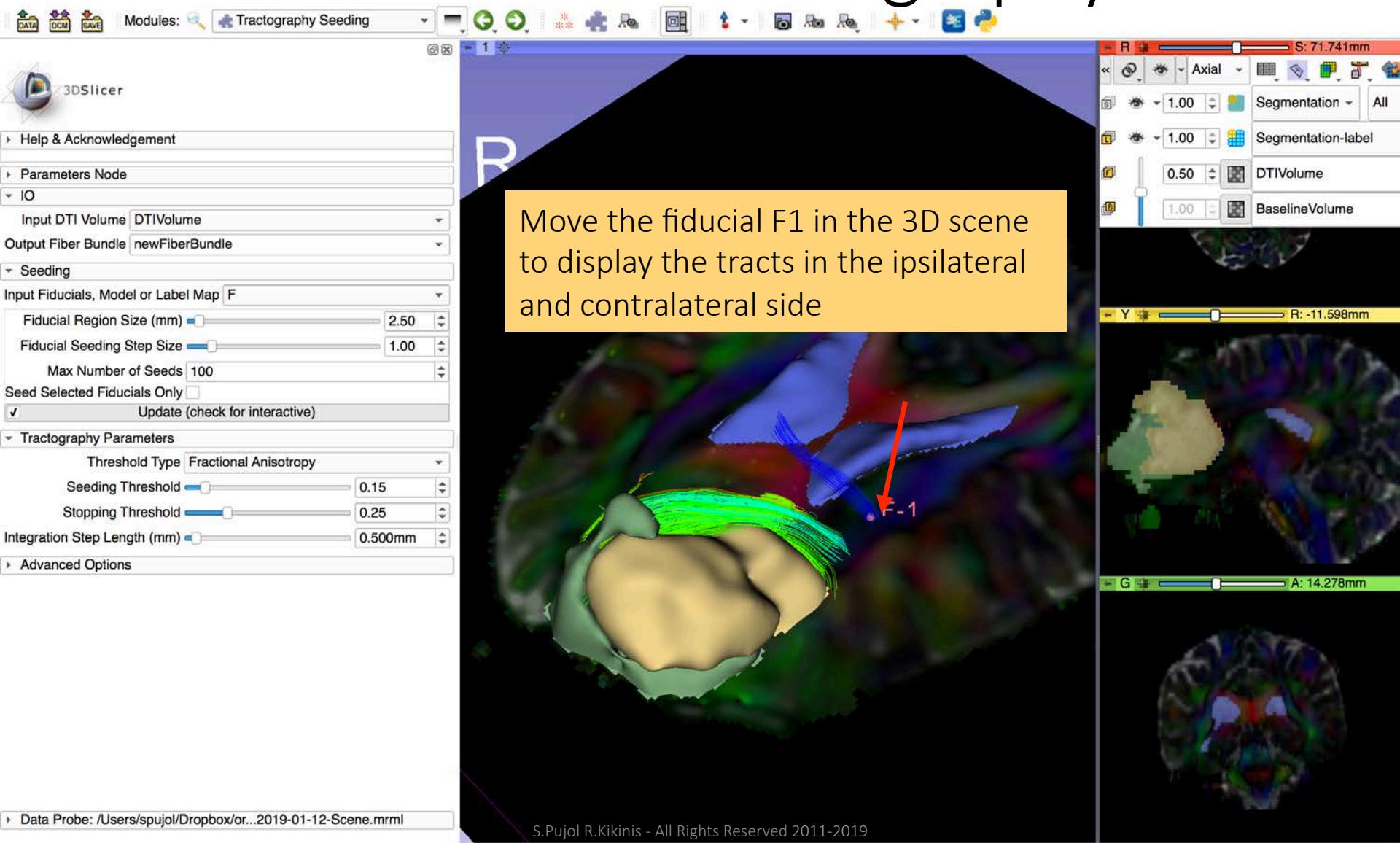
Check the box next to Update to turn on the interactive mode

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Interactive Tractography



Interactive Tractography



Interactive Tractography

3DSlicer

Modules: **Tractography Display**

Select the module **Tractography Display**

Turn the Peritumoral_Fibers and newFiberBundle visibility mode to Tubes

Move the fiducial in the 3D scene to explore the white matter architecture on the contralateral side

F-1

Data Probe: /Users/spujol/Dropbox/or...2019-01-12-Scene.mrml

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The image shows the 3DSlicer software interface. On the left, the 'Tractography Display' module is selected. The main 3D view shows a brain with numerous colored fiber tracts. A red arrow points to the 'Tubes' button in the display settings for the 'Peritumoral_Fibers' module. To the right are three 2D axial slices showing tumor segmentation and fiber density. A red arrow also points to a fiducial marker labeled 'F-1' on the 3D brain model. The bottom left shows the data probe path and copyright information.

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

Acknowledgments

- Neuroimage Analysis Center (NIH P41 EB015902)