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Quantitative Analysis and Visualization with 3D Slicer

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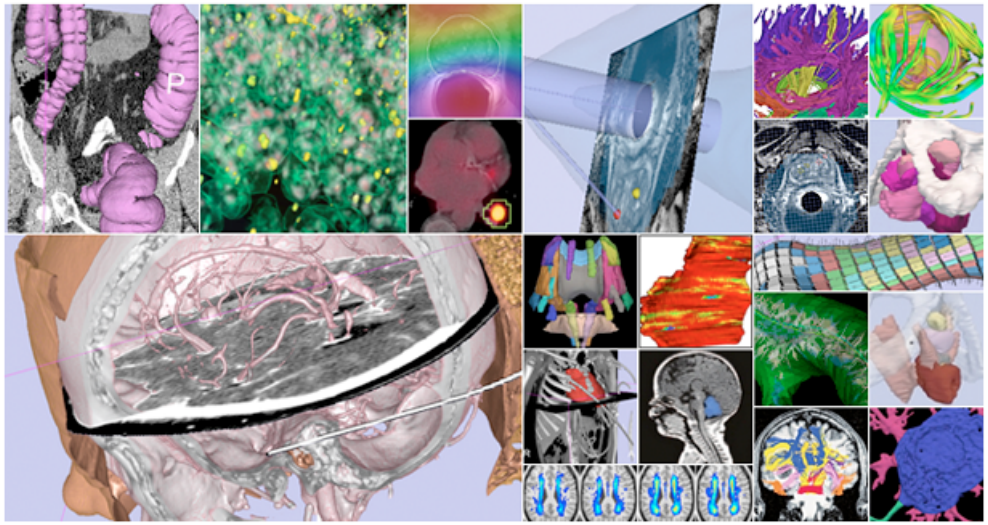
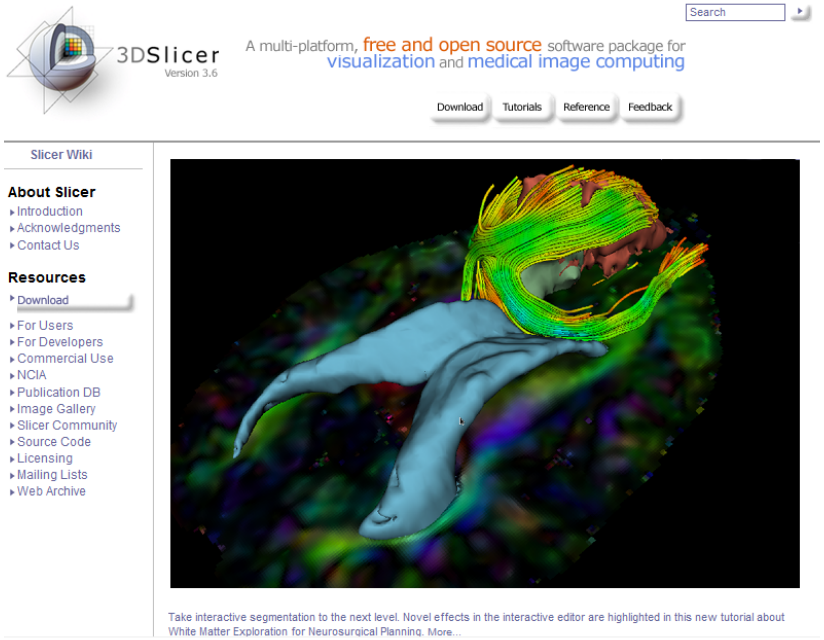
3D Slicer is…

- An end-user application for image analysis and visualization
- An open-source environment for software development
- A software platform that is both easy to use for clinical researchers and easy to extend for programmers



www.slicer.org

3DSlicer version 4 is a multi-platform software running on **Windows, Linux, and Mac OSX**.

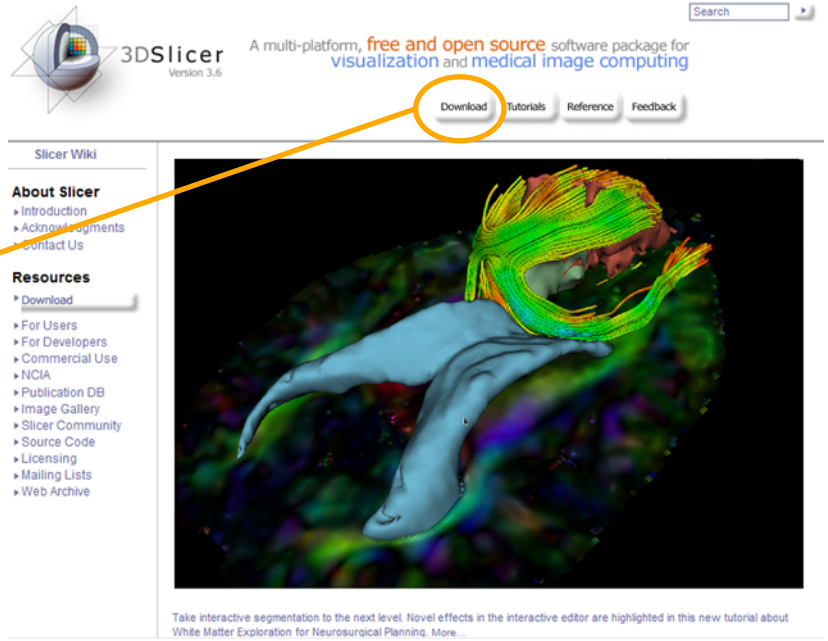


Disclaimer

It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules.
Slicer is a tool for research, and is not FDA approved.

www.slicer.org

- This workshop uses a new pre-release of 3D Slicer version 4
- Visit the **Slicer download page** for Slicer 4 official release, or Slicer nightly builds.

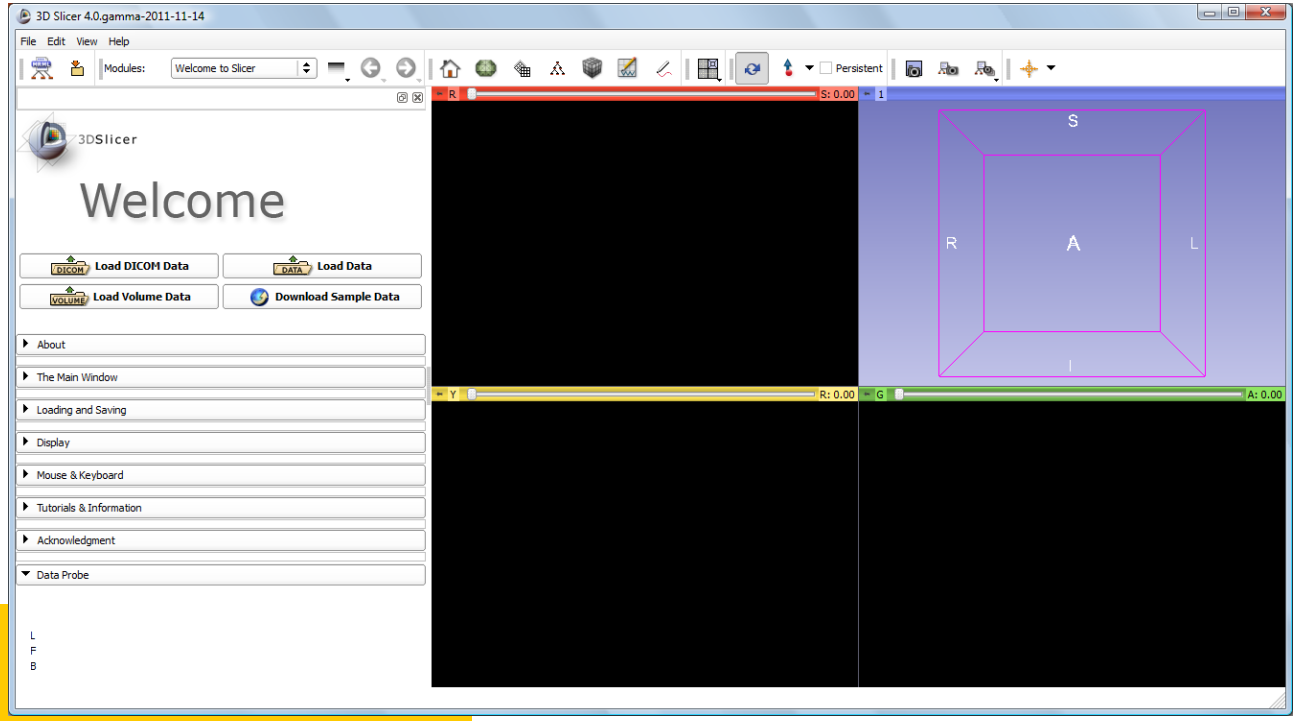


Tutorial Overview

- Getting Started: **Slicer4 Minute Tutorial**
- Quantitative Measurements for Functional Imaging: **PETCT Fusion Tutorial**
- Quantitative Measurement of Volumetric Change: **Change Tracker Tutorial**

All Tutorial datasets are located in C:\Documents and Settings\Administrator\Desktop Slicer_data 2011

Launch the Application



Windows users:

Start -> All programs -> Slicer4 -> Slicer

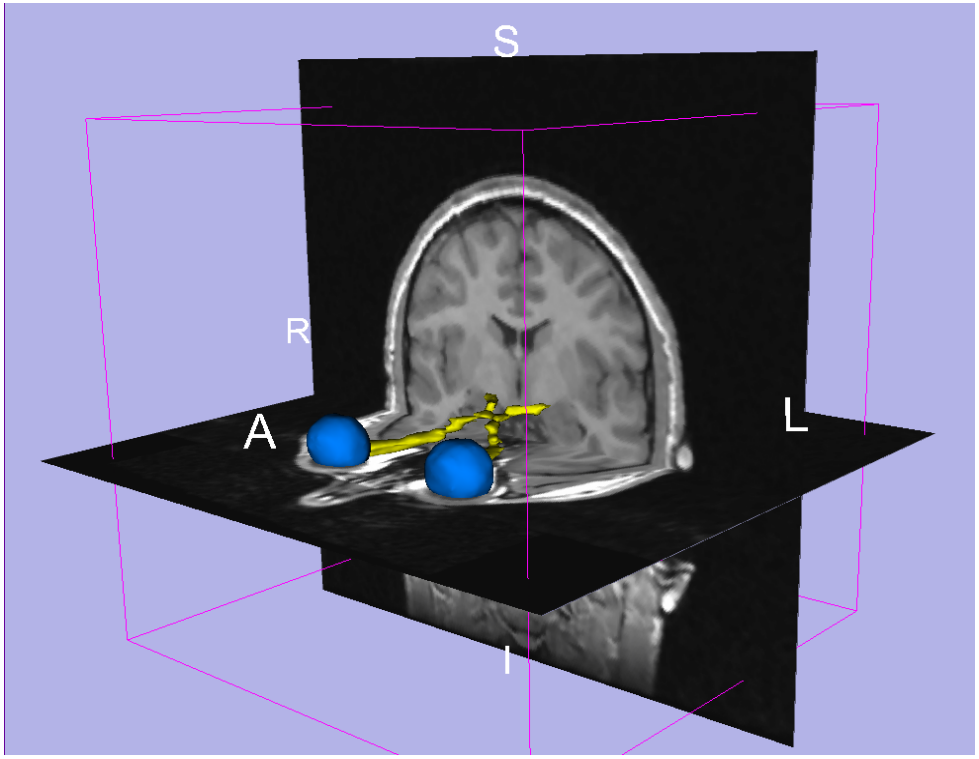
Slicer4 Minute Tutorial

Part I: Slicer4 Minute Tutorial

Sonia Pujol, PhD
Wendy Plesniak, PhD

This tutorial is a short introduction to the advanced **3D visualization capabilities** of the Slicer4 software for medical image analysis.

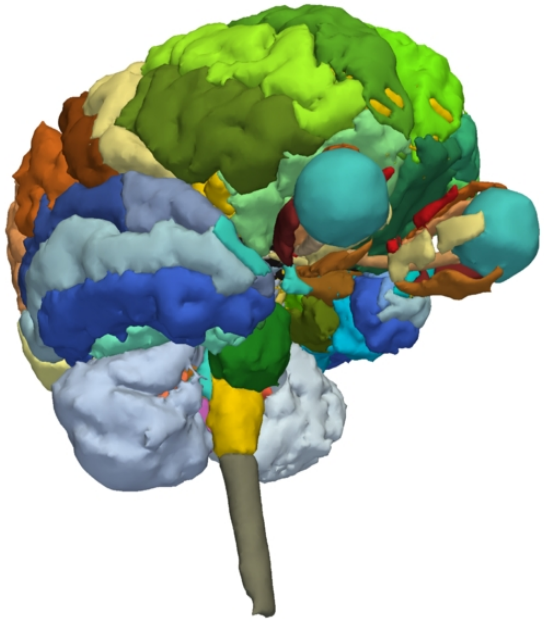
It is designed to **quickly build a basic level of comfort** with the Slicer software.



Slicer4 Minute Tutorial

The Slicer4 Minute dataset is composed of
An MR scan of the brain and 3D surface
Reconstructions of anatomical structures.

The data are part of the SPL-PNL Brain Atlas
Developed by Talos *et al.* The atlas is available at:

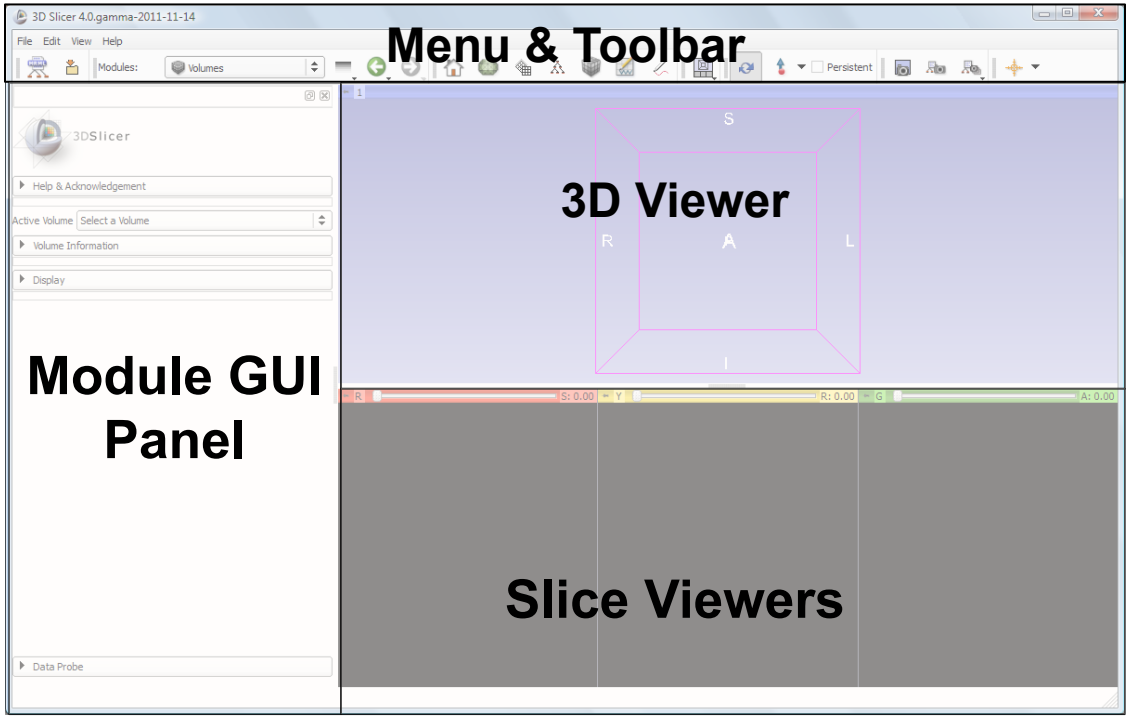


http://www.spl.harvard.edu/publications/item/view/1265

Slicer4 Minute Tutorial: Navigating the Application GUI

The Graphic User Interface (GUI) of Slicer4 integrates **four components:**

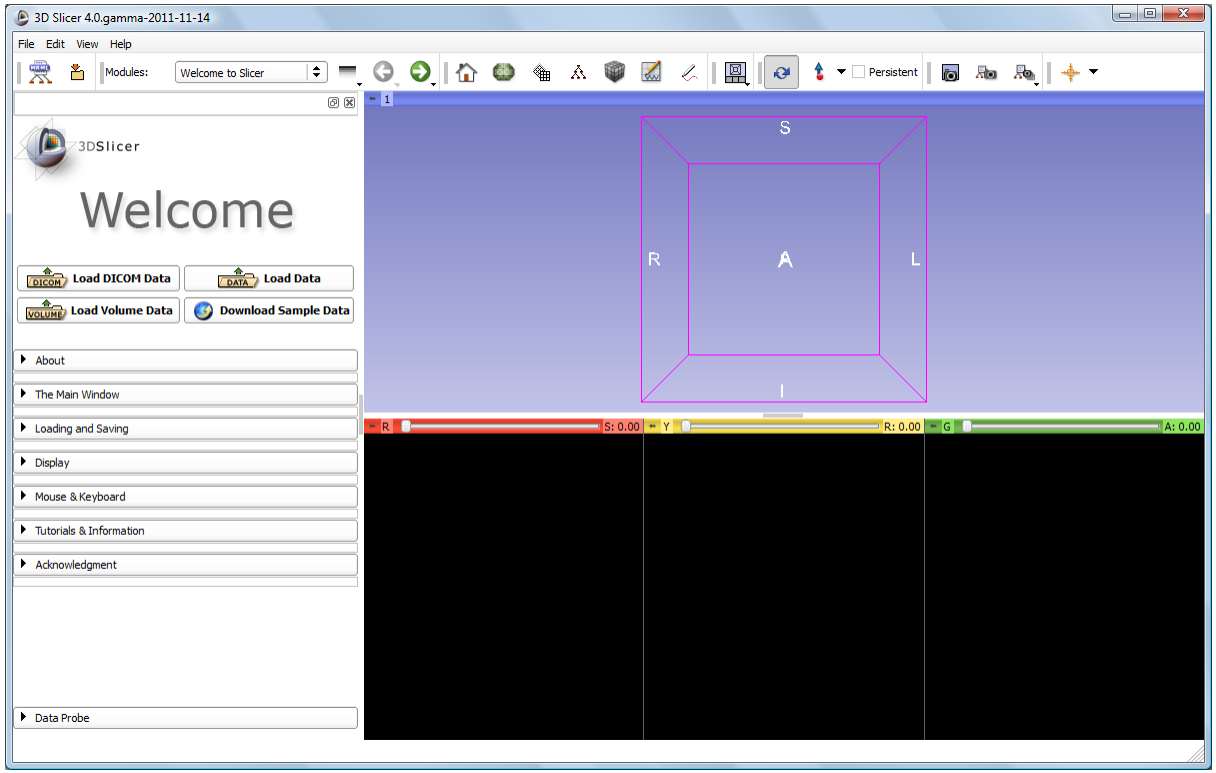
- the Menu Toolbar
- the Module GUI Panel
- the 3D Viewer
- the Slice Viewer



Slicer4 Minute Tutorial: Welcome Module

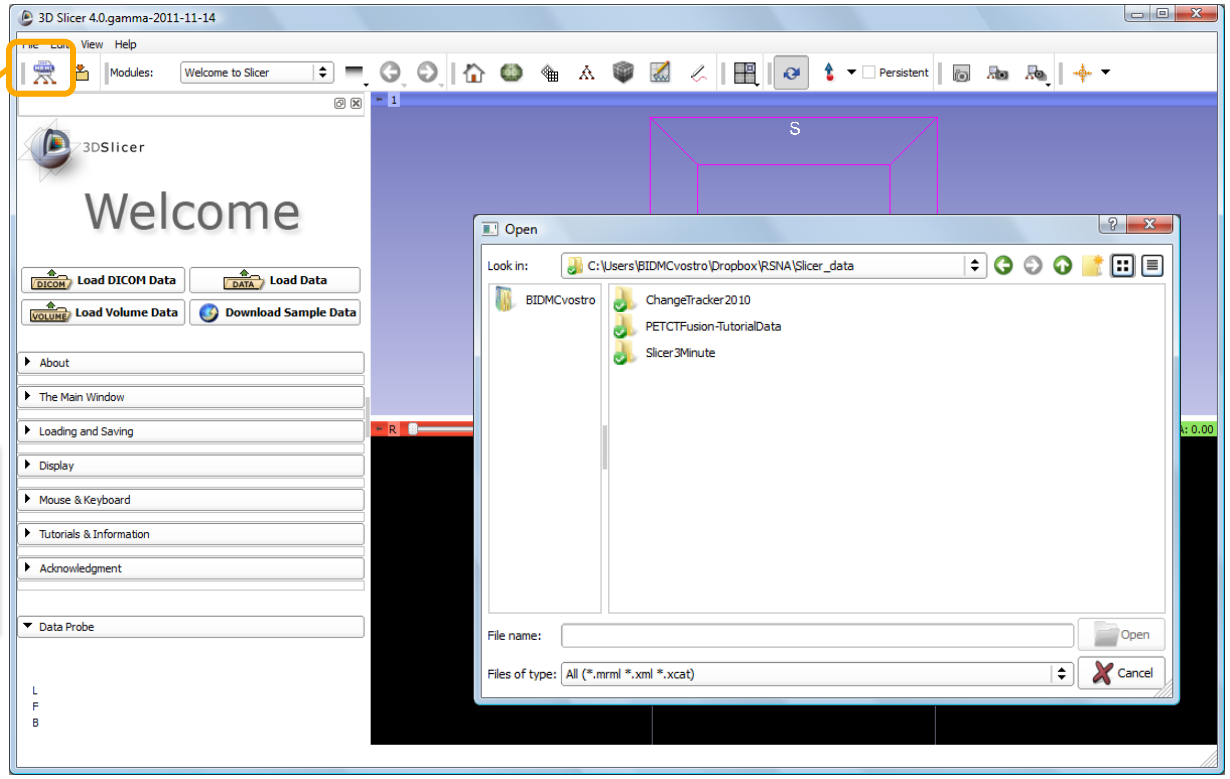
The **SlicerWelcome** module is the module displayed by default.

This module gives an overview of the GUI of Slicer4, and **data loading & saving functionalities.**



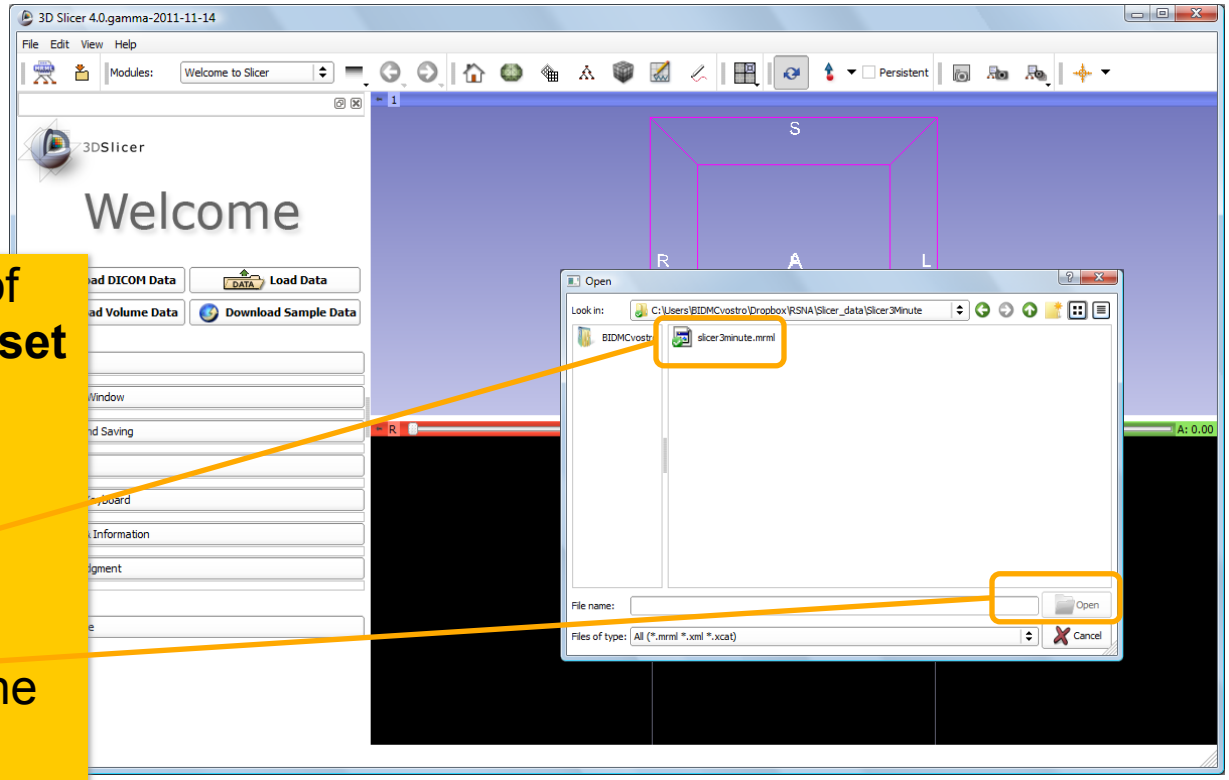
Slicer4 Minute Tutorial: Load a Scene

Click on the **Load Scene** icon



Browse to the location of the **Slicer_data** directory.

Slicer4 Minute Tutorial: Load a Scene



Browse to the location of the **Slicer3Minute dataset** directory.

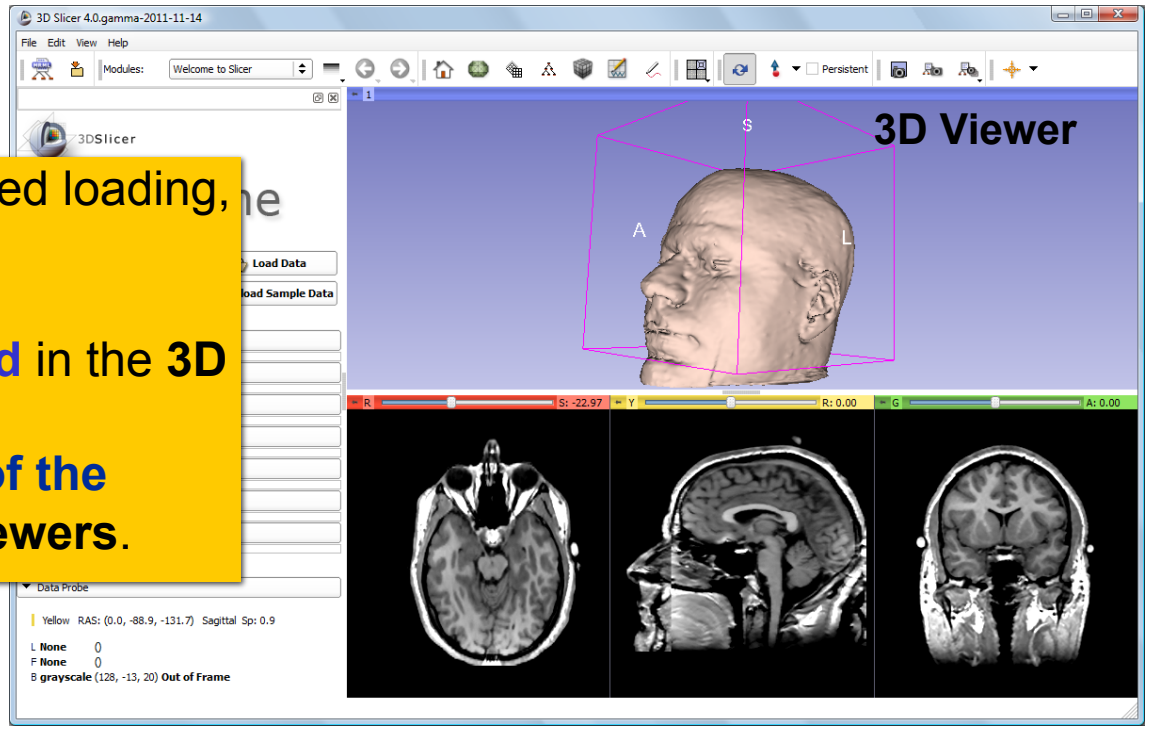
Select the scene file **slicer3minute.mrml**

Click on **Open** to load the scene

Slicer4 Minute Tutorial: Viewing the Scene

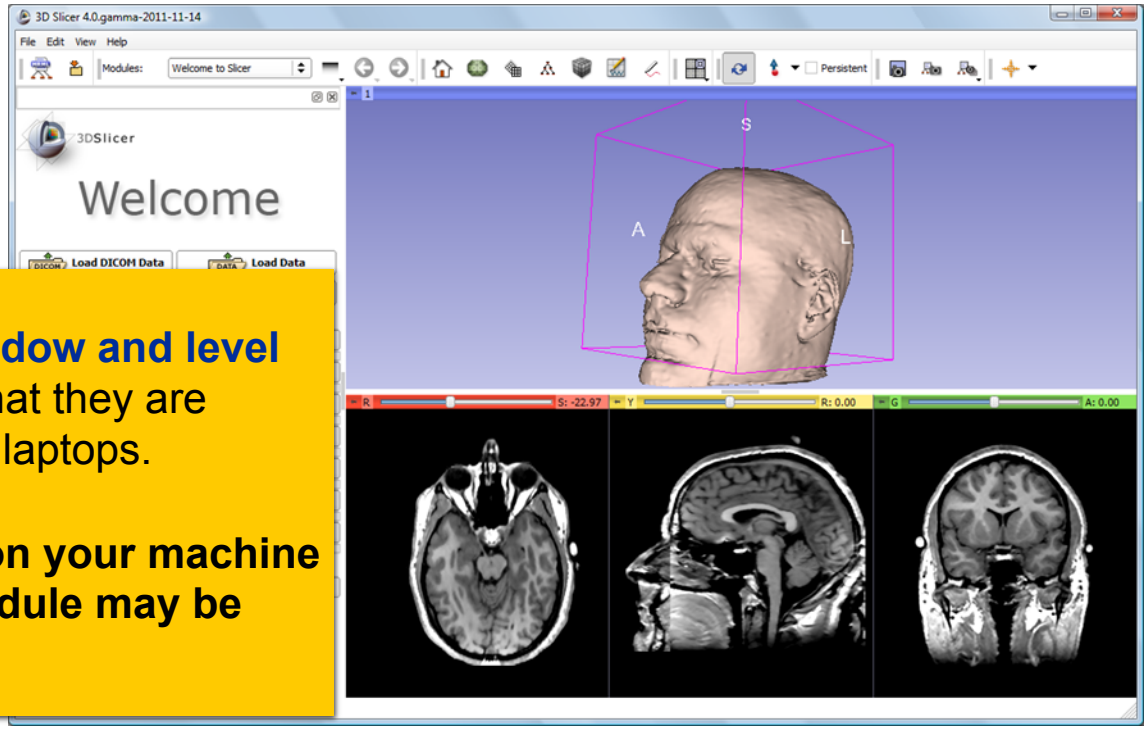
When the scene is finished loading, Slicer displays:

- a **3D model of the head** in the **3D Viewer**, and
- anatomical **MR slices of the brain** in the **2D Slice Viewers**.



2D Slice Viewers

Slicer4 Minute Tutorial: Viewing the Scene



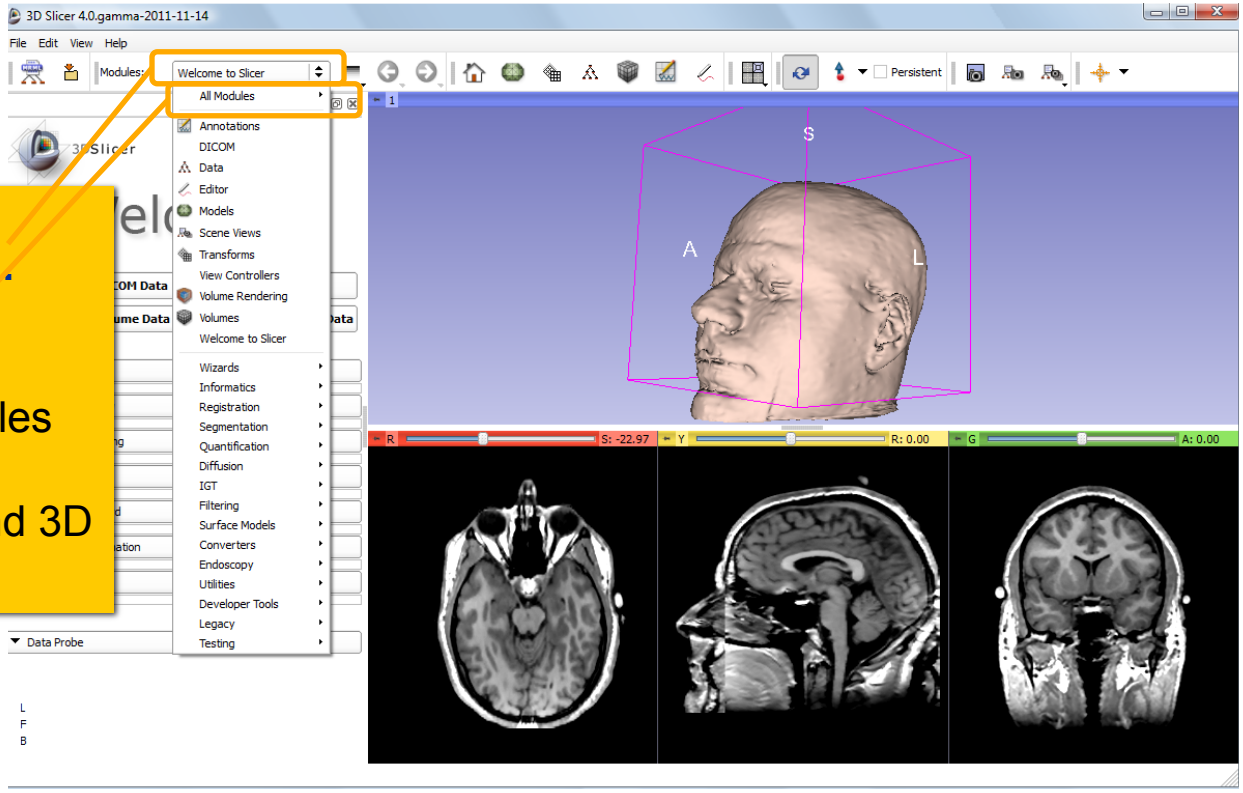
Note:
We have **pre-adjusted the window and level** settings for these volumes so that they are appropriate for display on most laptops.

If display is not satisfactory on your machine or projector, the Volumes Module may be used to refine these settings.

Slicer4 Minute Tutorial: Exploring Slicer's functionality

Left click and hold the **Modules menu button.**

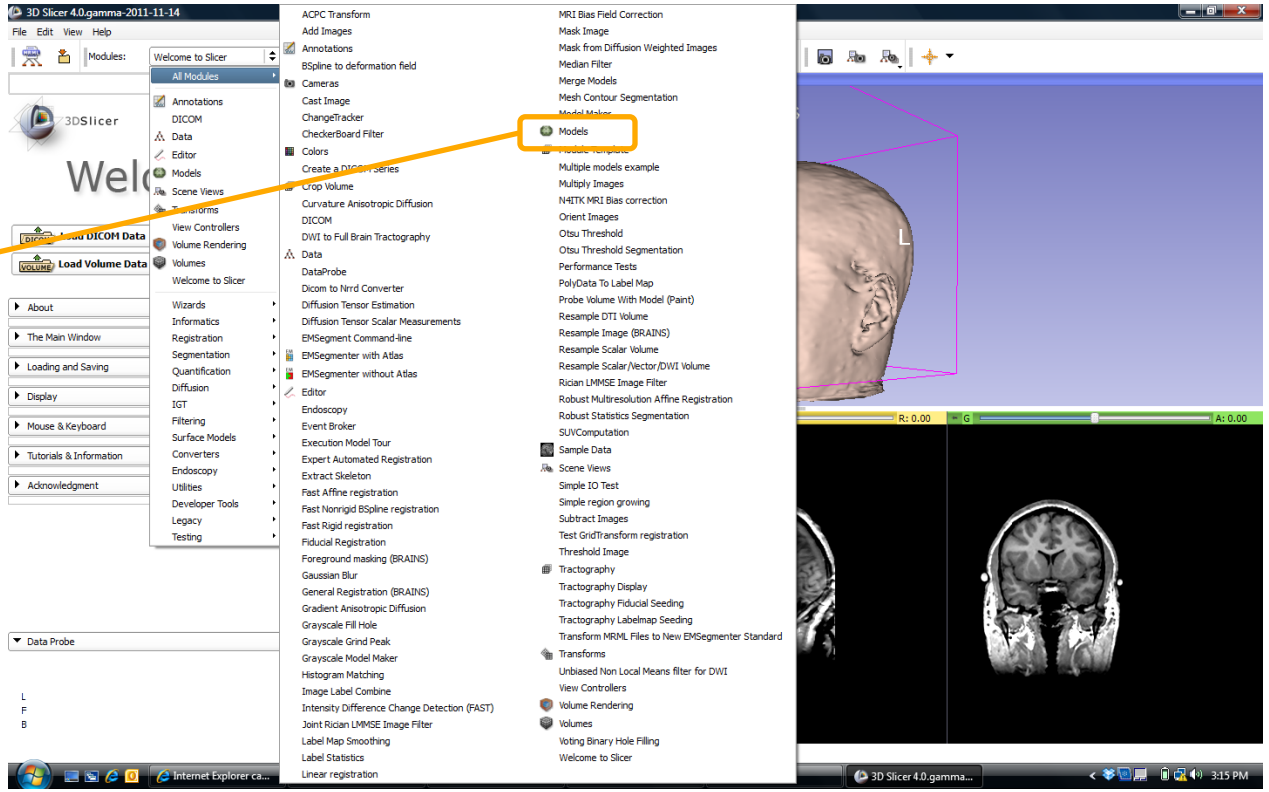
Select **All Modules** to display the many modules available for image processing, analysis and 3D visualization.



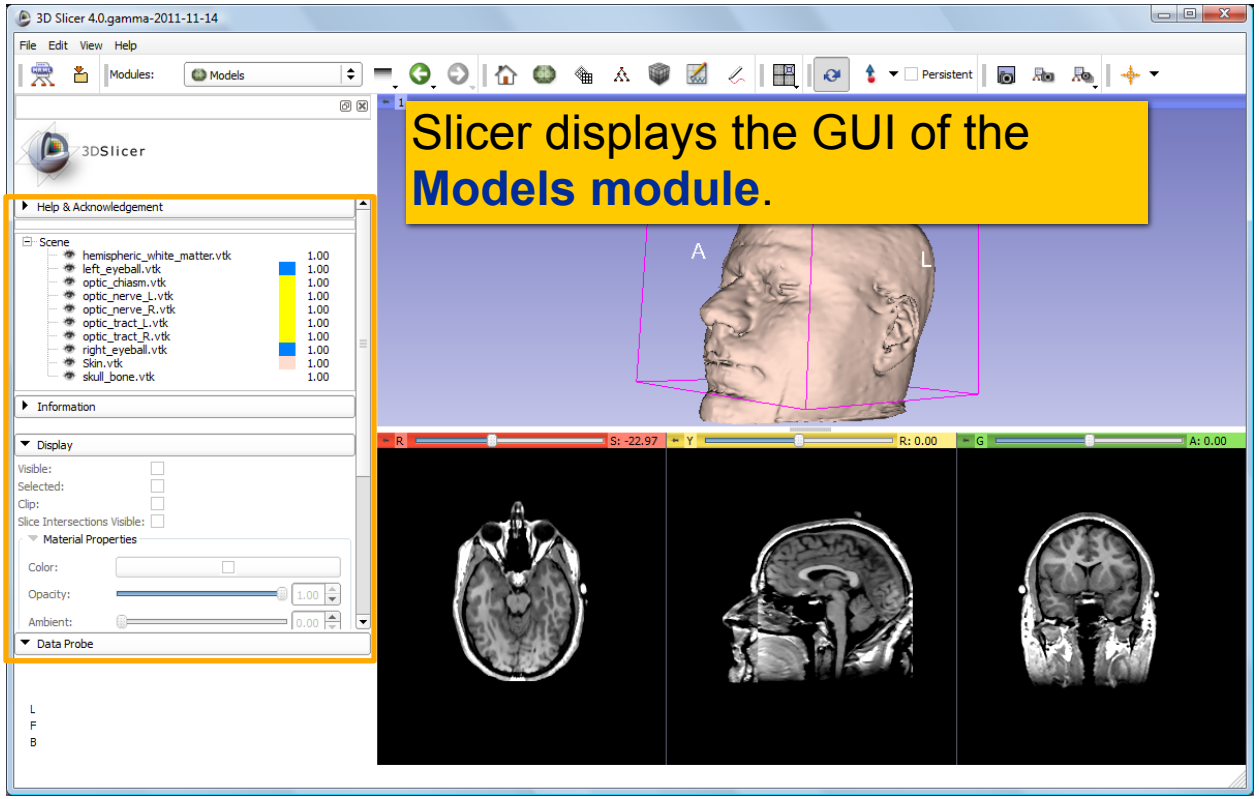
Slicer4 Minute Tutorial: Exploring Slicer's functionality

To access the **Models module**, browse through the list of modules...

...or click on the **models icon** in the toolbar



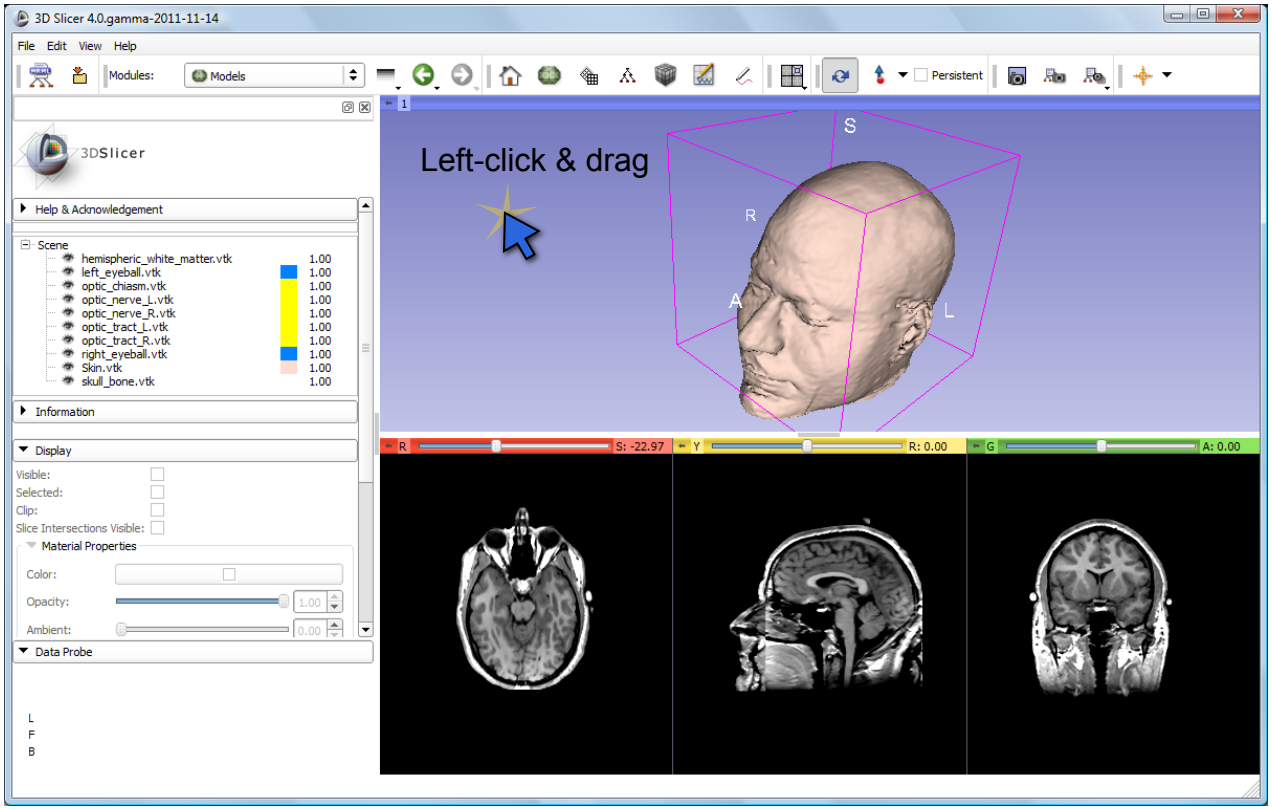
Slicer4 Minute Tutorial: Switching to the Models Module



Slicer4 Minute Tutorial: Basic 3D Interaction

Position the mouse in the 3D Viewer.

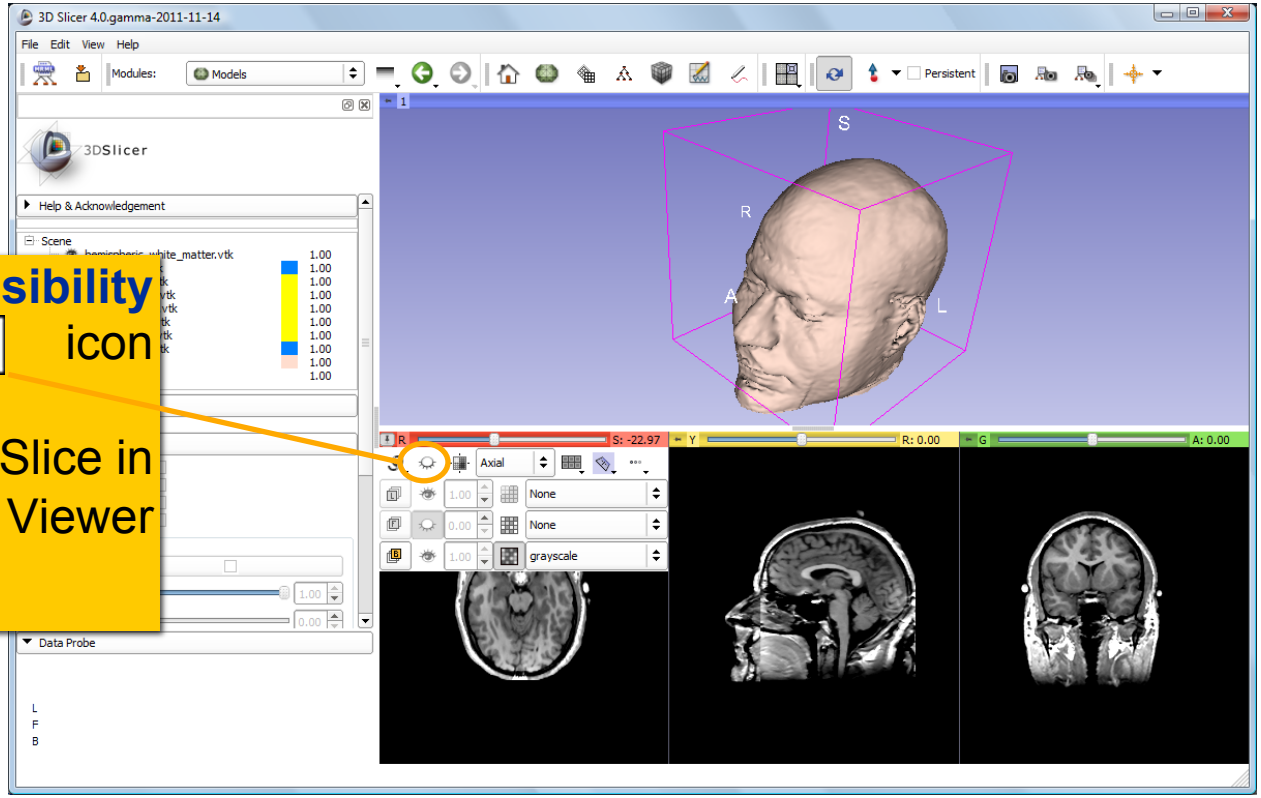
Hold down the **left mouse button** and **drag to rotate** the model.



Slicer4 Minute Tutorial: Viewing Slices in the 3D Viewer

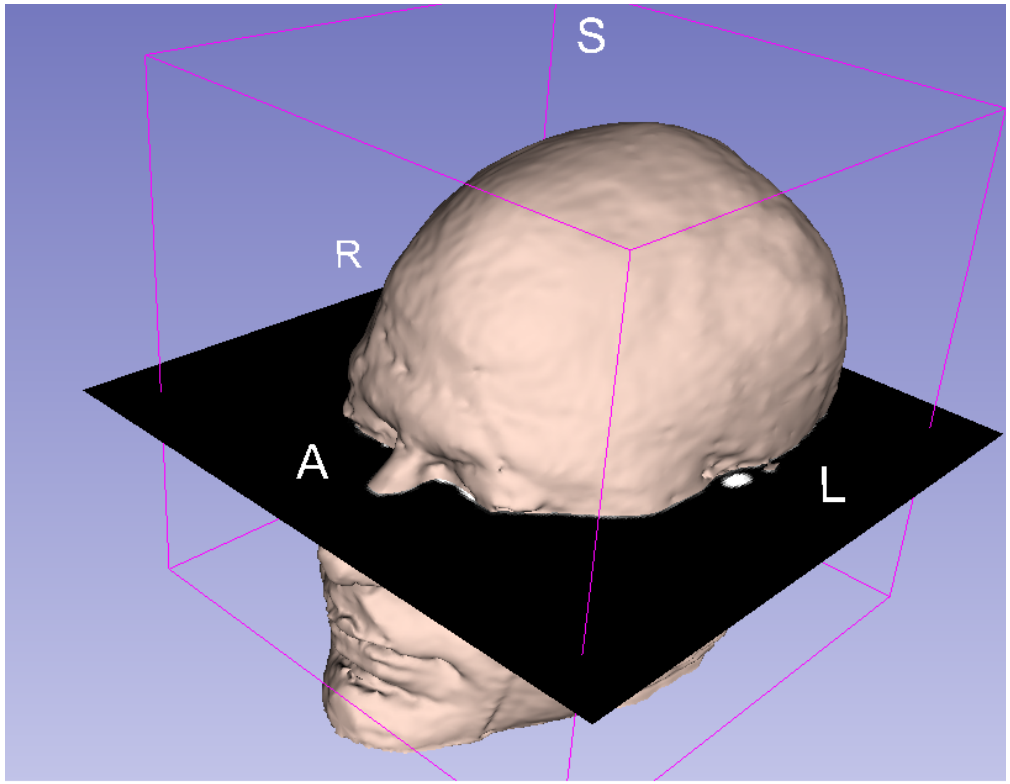
Click on the **Slice Visibility** icon

to display the Axial Slice in the 3D Viewer



Slicer4 Minute Tutorial: 3D Visualization

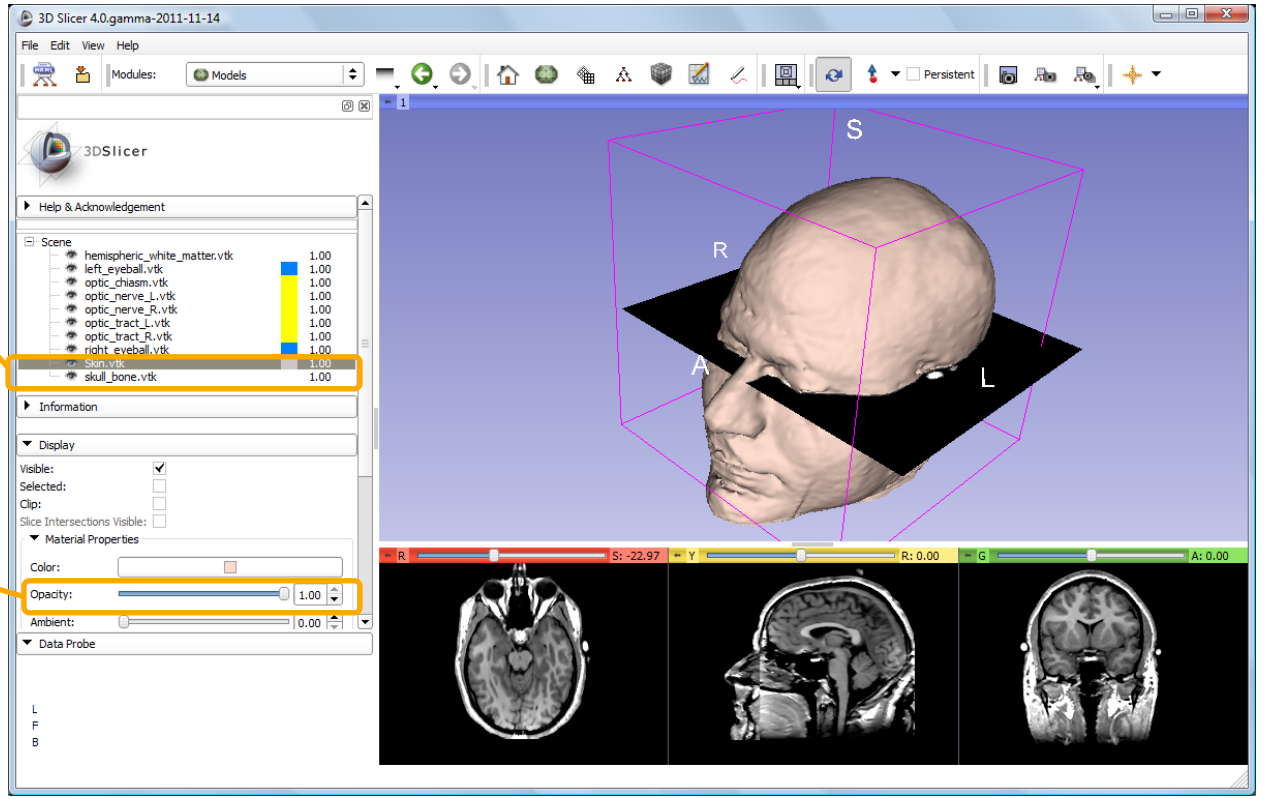
Slicer adds a view of the **Axial slice** in the 3D View.



Slicer4 Minute Tutorial: 3D Visualization

Select the **Skin model**.

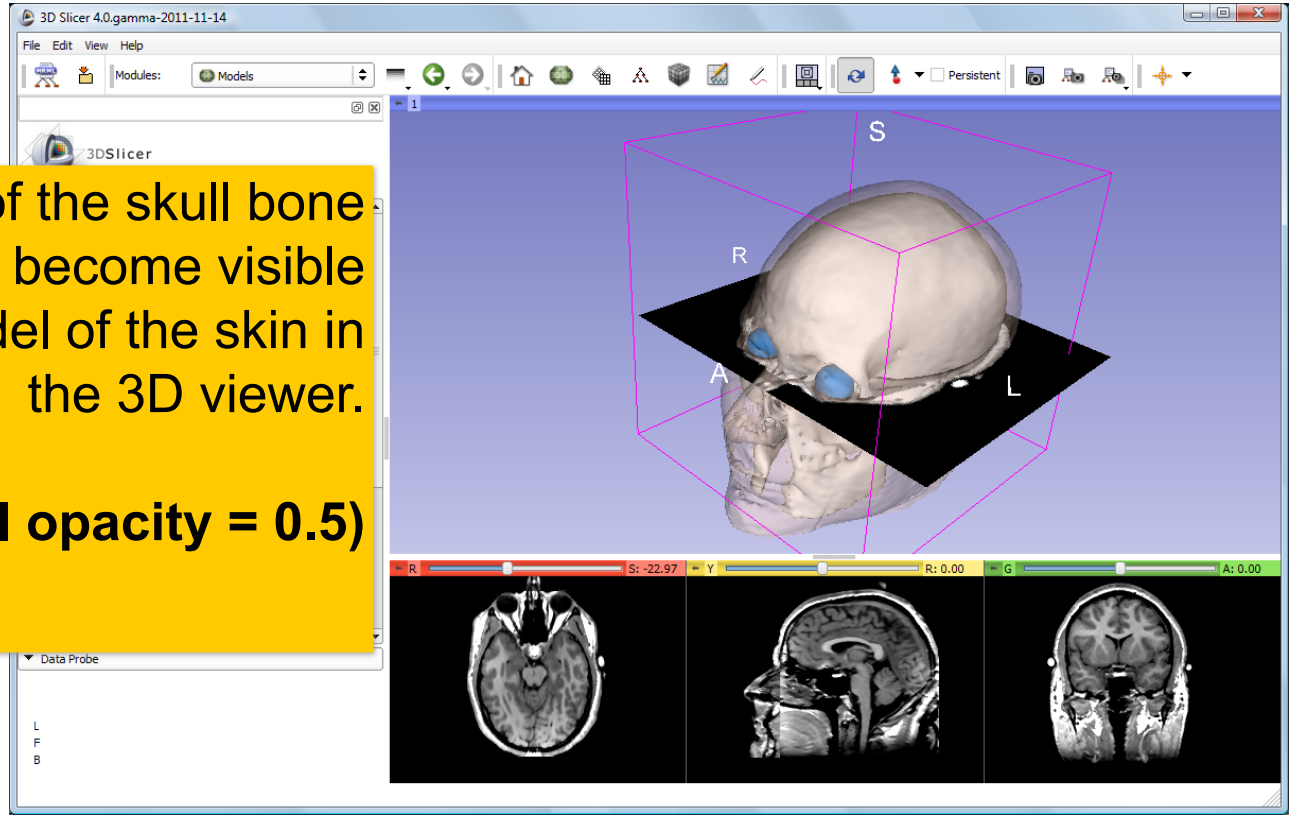
Change the opacity of the model from **1.0** to **0.0**.



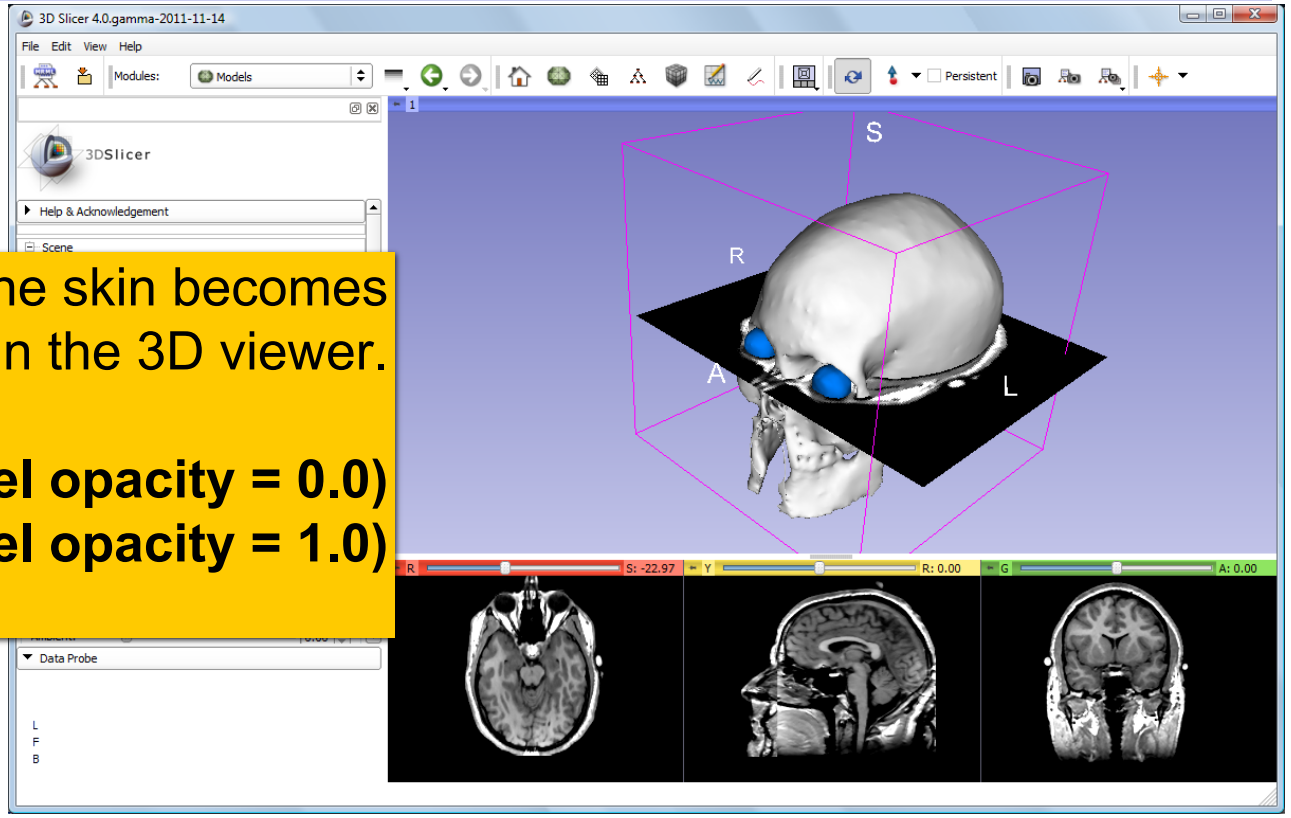
Slicer4 Minute Tutorial: 3D Visualization

The model of the skull bone and eyeballs become visible through the model of the skin in the 3D viewer.

(skin model opacity = 0.5)



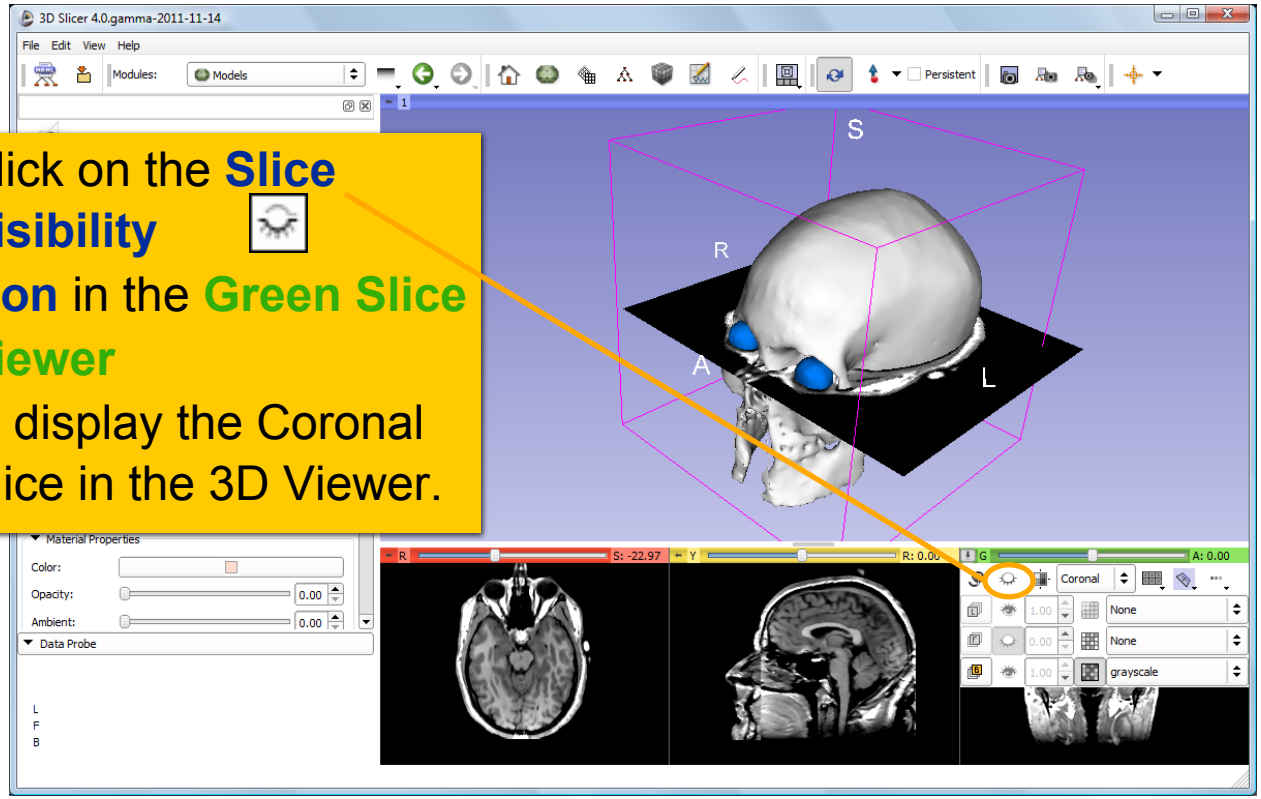
Slicer4 Minute Tutorial: 3D Visualization



The model of the skin becomes invisible in the 3D viewer.

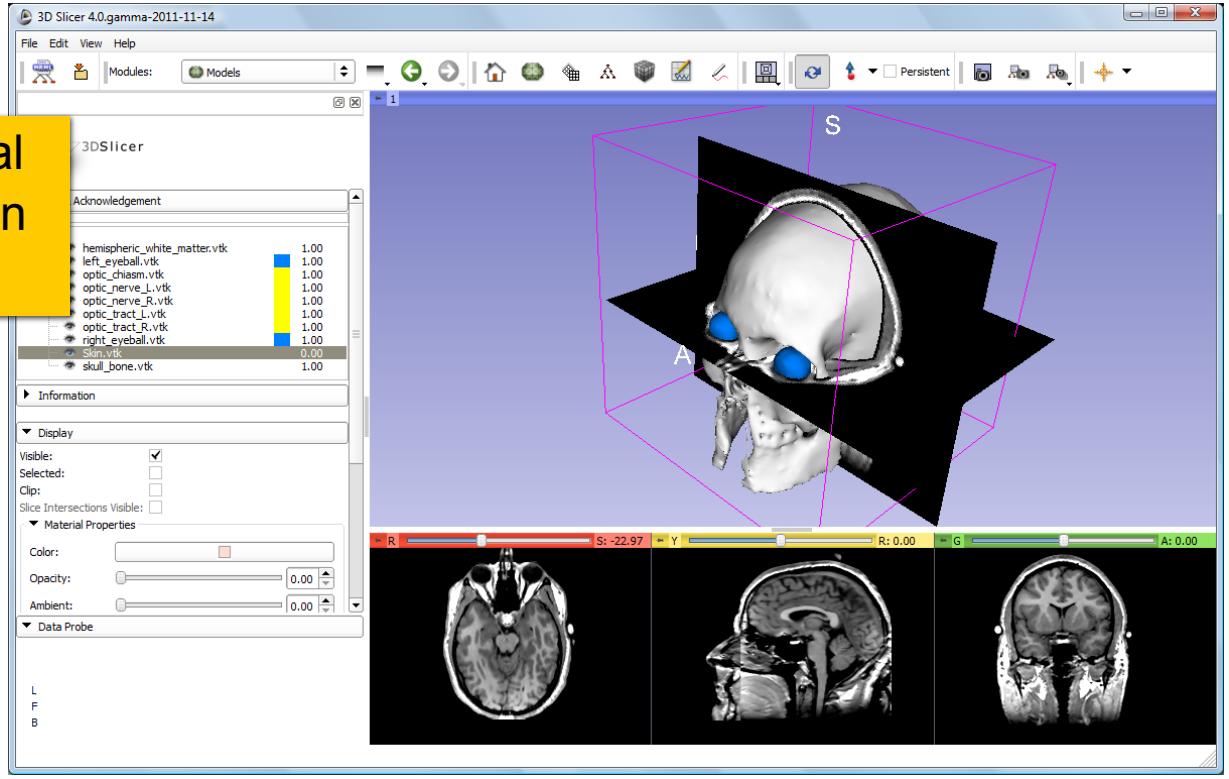
(skin model opacity = 0.0)
(skull model opacity = 1.0)

Slicer4 Minute Tutorial: 3D Visualization



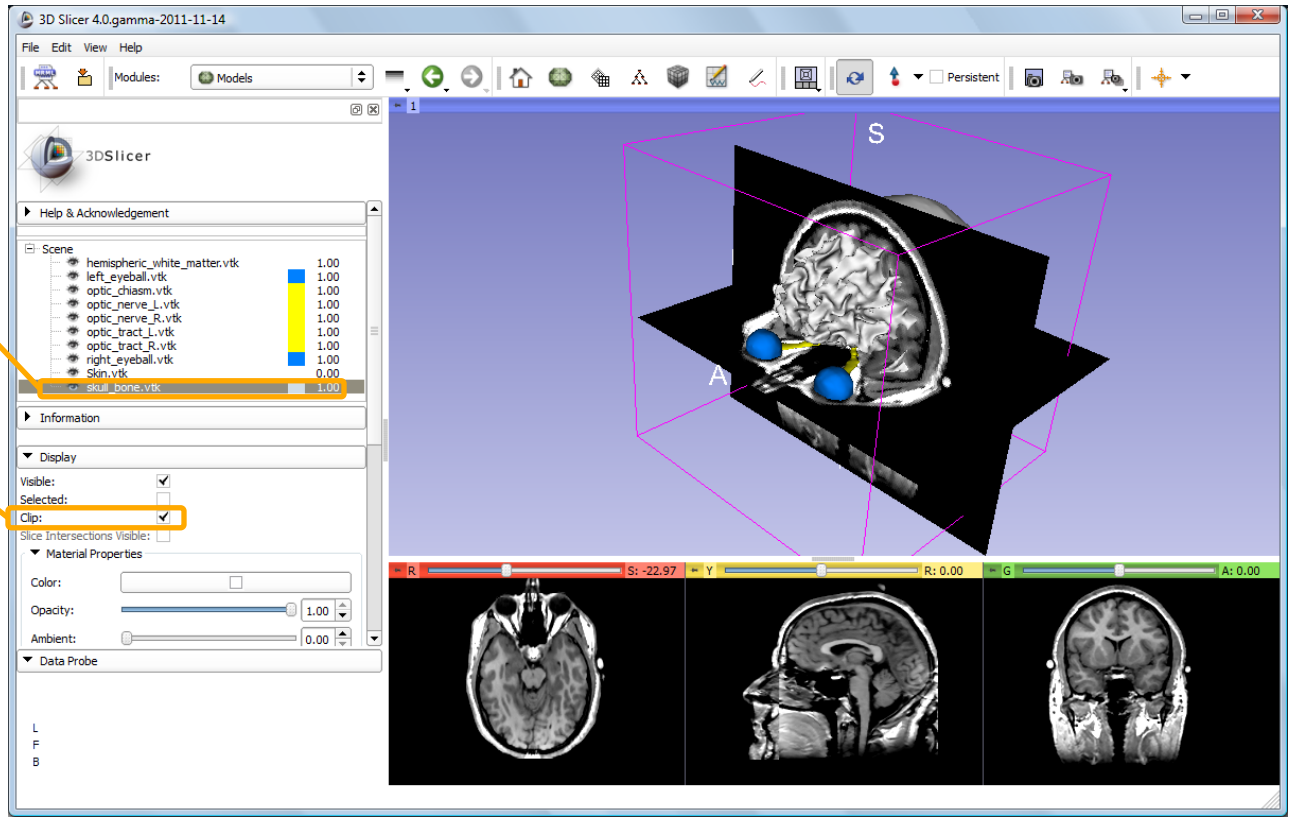
Slicer4 Minute Tutorial: 3D Visualization

The Axial and Coronal Slices are displayed in the 3D Viewer.

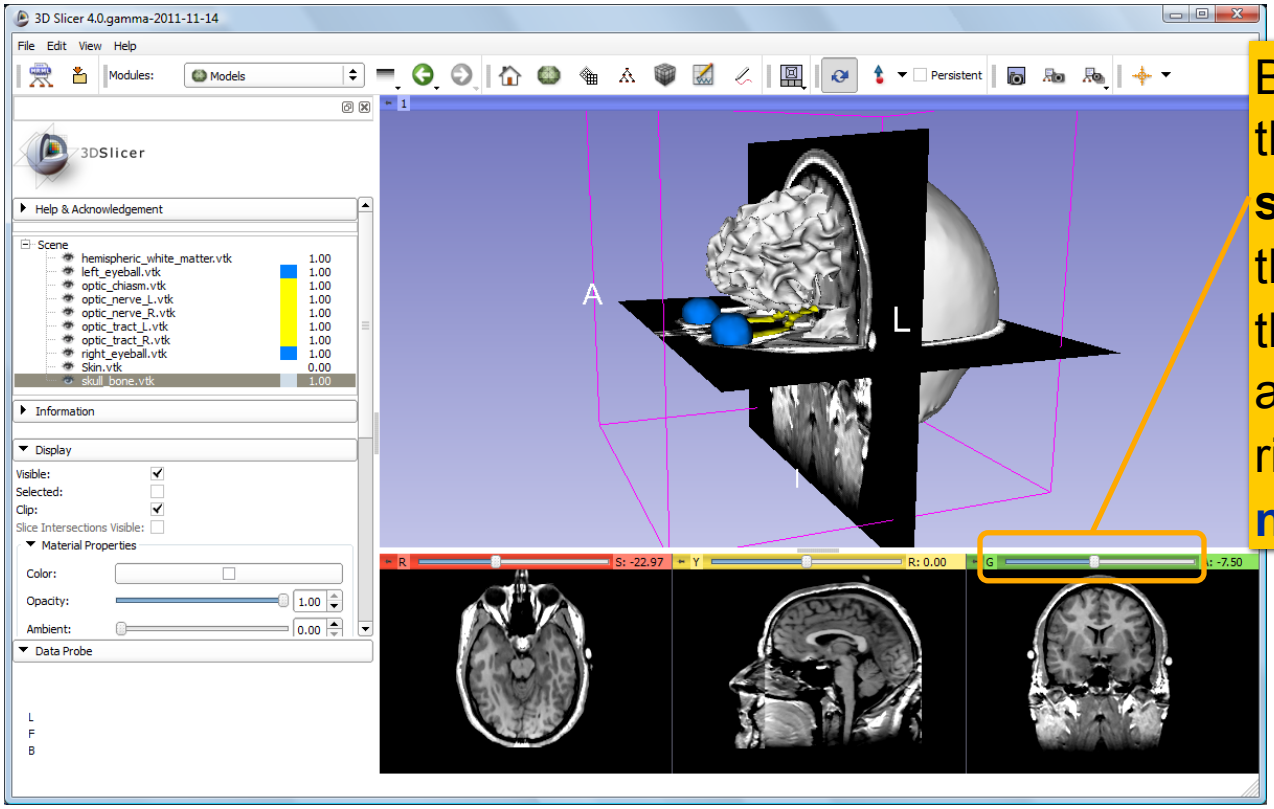


Slicer4 Minute Tutorial: 3D Visualization

Select the 3D model **skull_bone.vtk** in the Model Hierarchy and turn on the **Clipping option.**



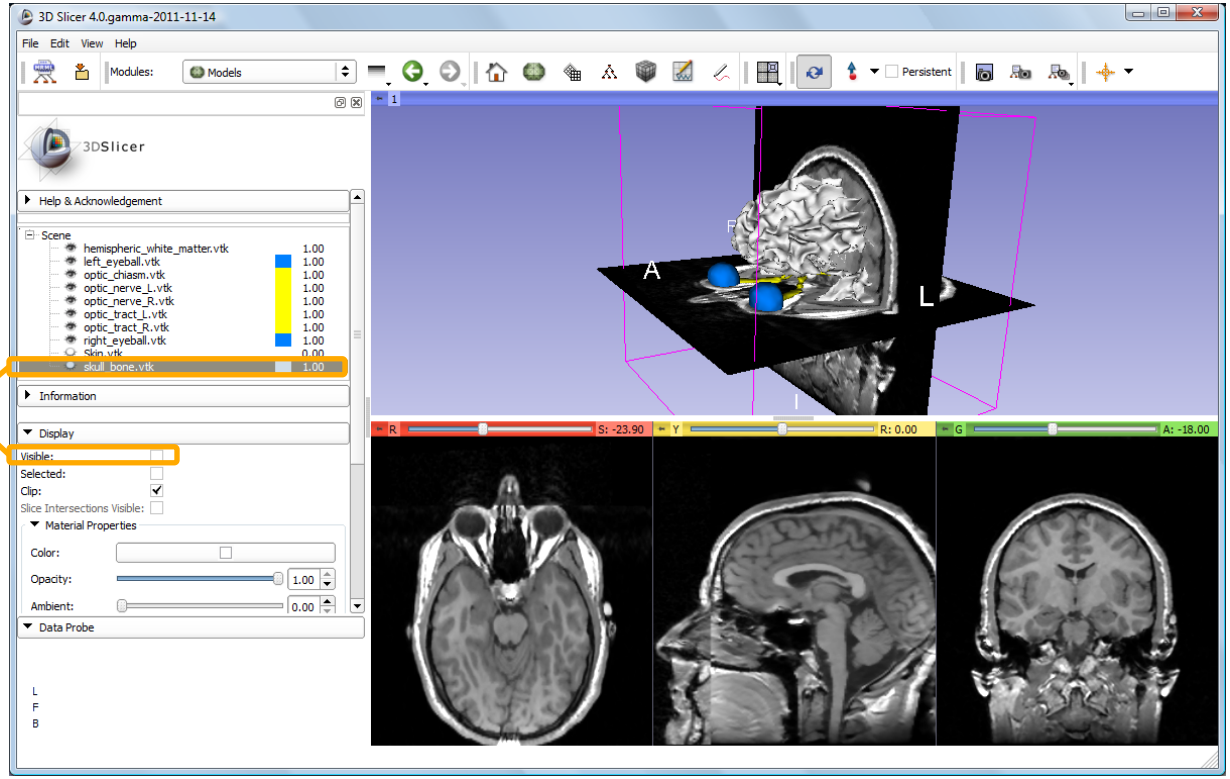
Slicer4 Minute Tutorial: 3D Visualization



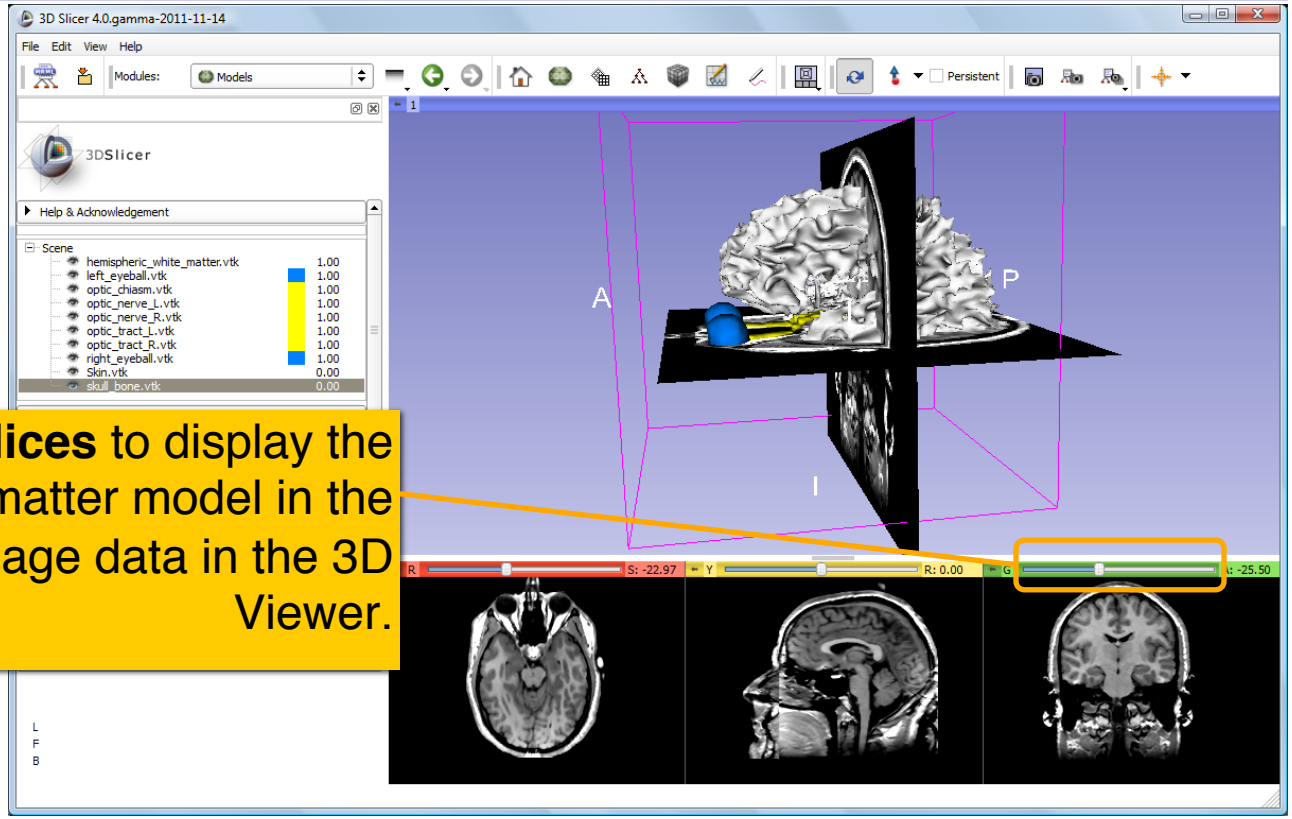
Browse through the **coronal slices** to expose the 3D model of the **white matter**, and the left and right **optic nerves**.

Slicer4 Minute Tutorial: 3D Visualization

Now **make the skull invisible.**



Slicer4 Minute Tutorial: 3D Visualization

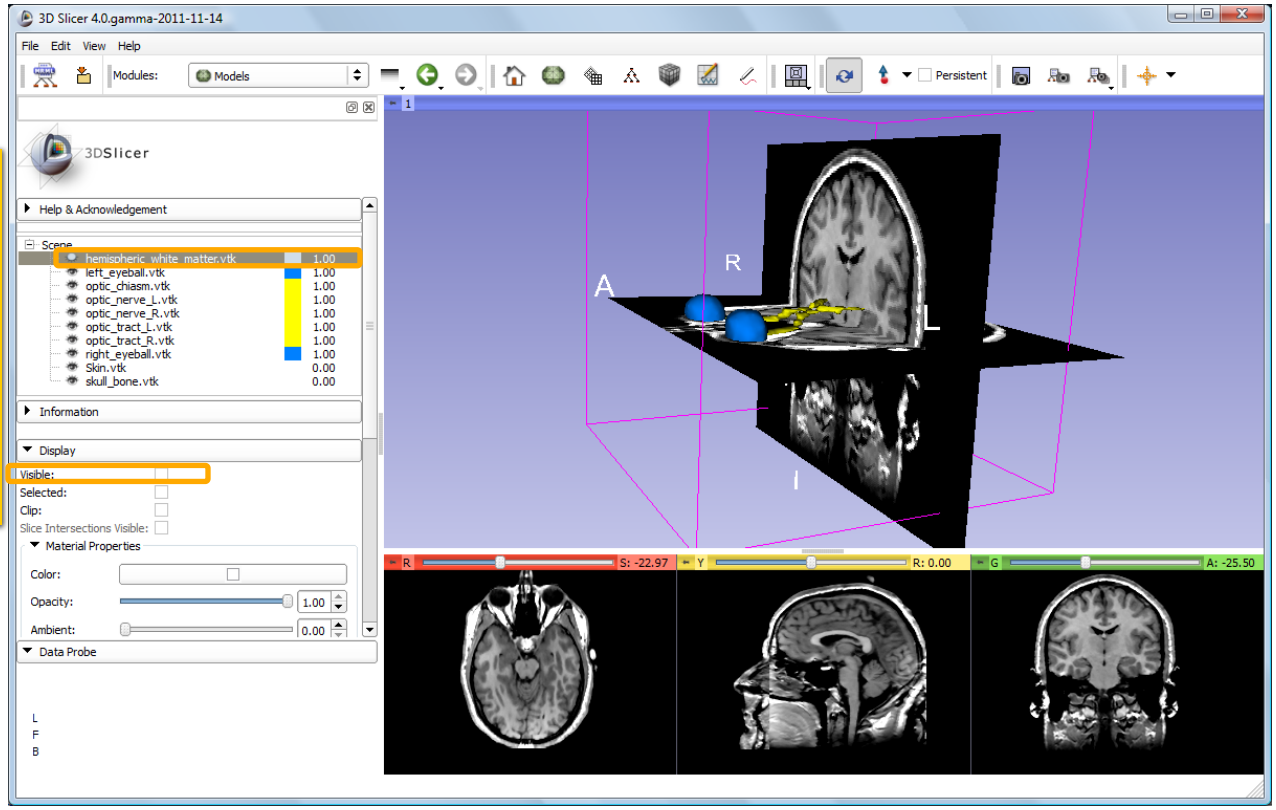


Scroll the **Coronal Slices** to display the hemispheric white matter model in the context of the image data in the 3D Viewer.

Slicer4 Minute Tutorial: 3D Visualization

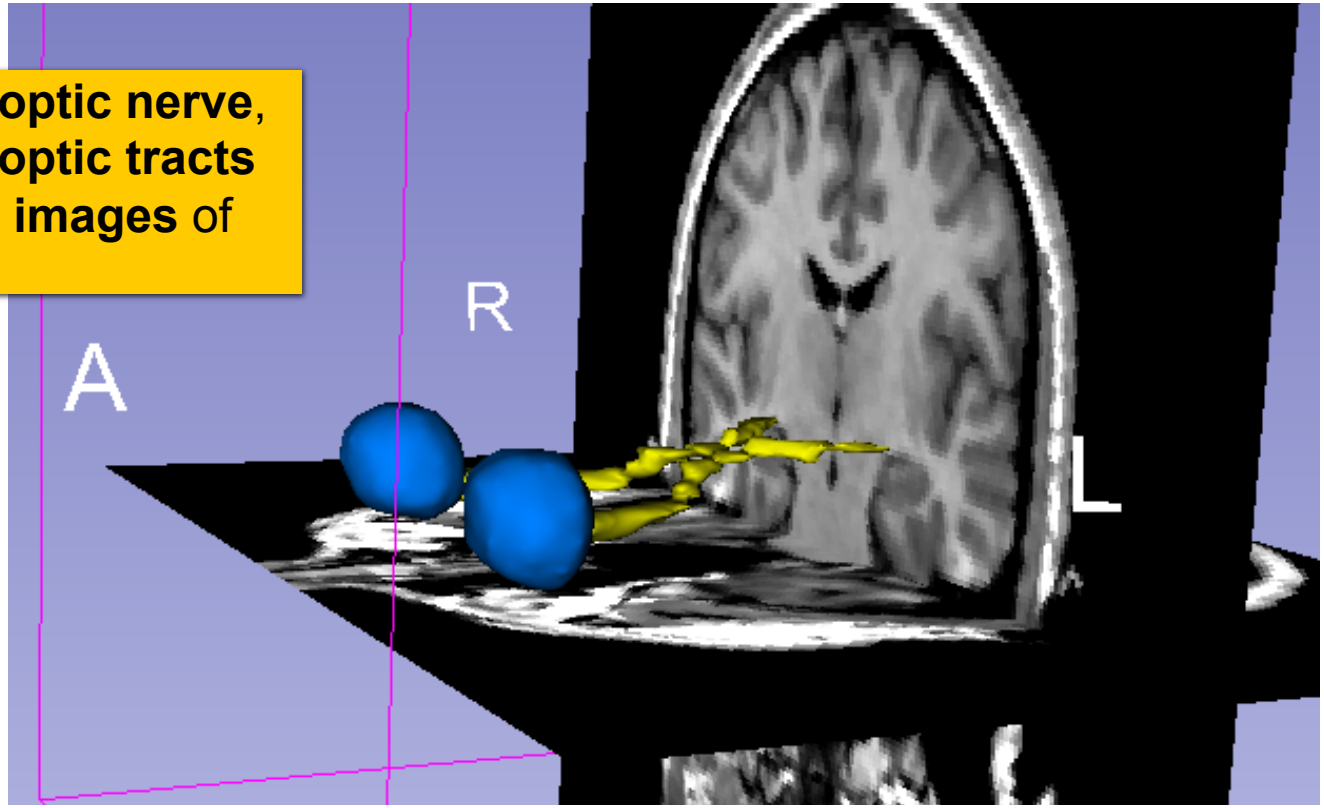
Select the hemispheric white matter model called **hemispheric_white_matter.vtk**

Turn off its **visibility**.



Slicer4 Minute Tutorial: 3D Visualization

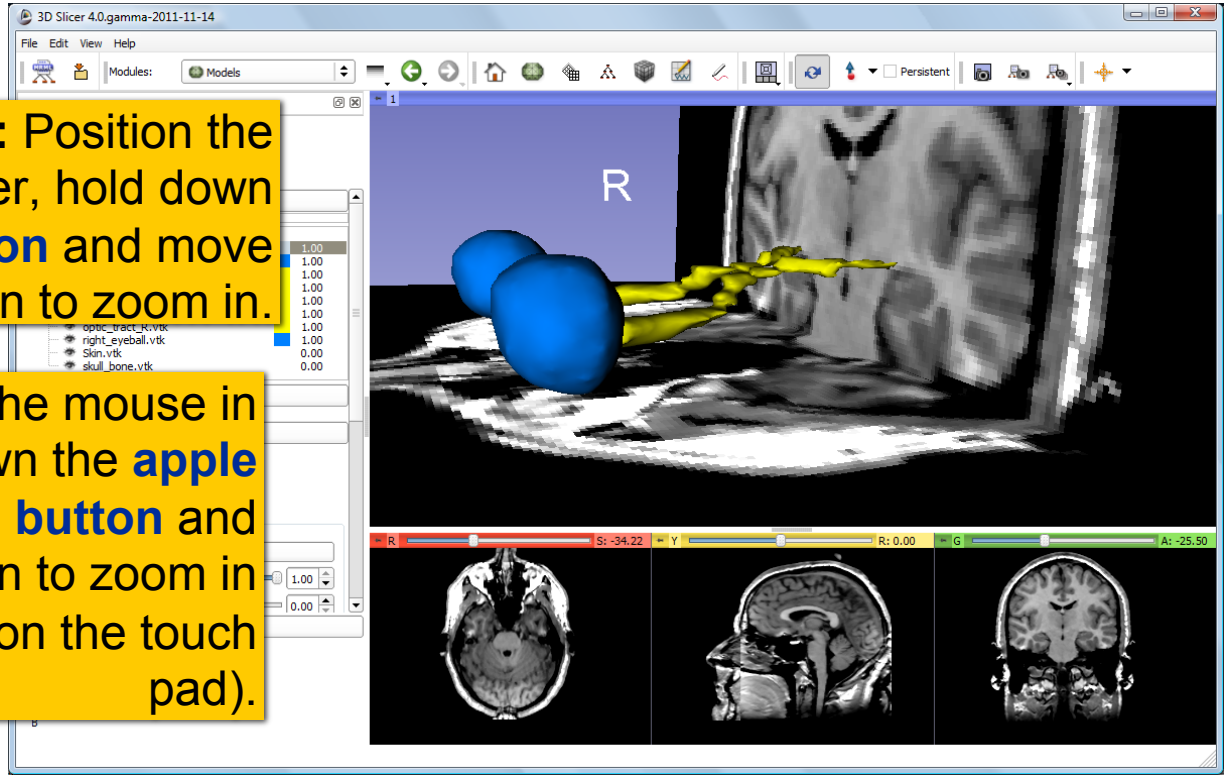
Slicer displays the **optic nerve**, **optic chiasm** and **optic tracts** overlaid on the **MR images** of the brain.



Slicer4 Minute Tutorial: 3D Visualization: Zoom the view

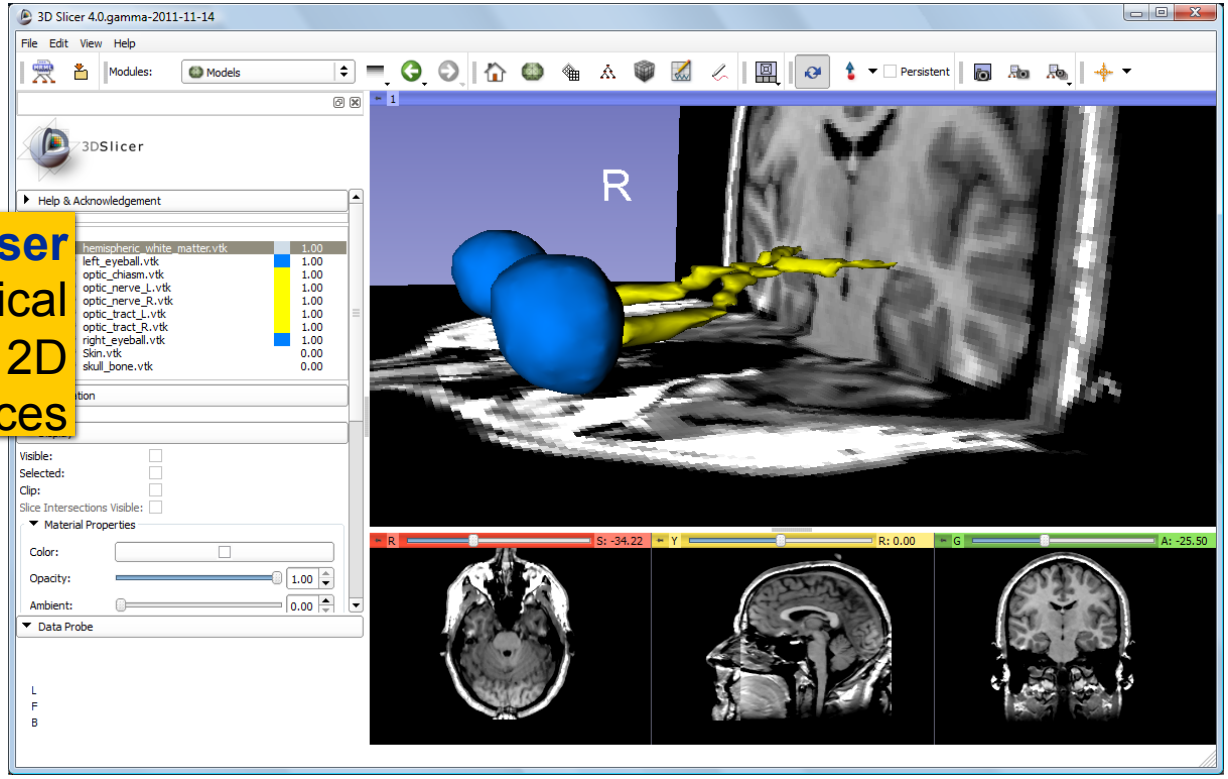
Windows/Linux users: Position the mouse in the 3D Viewer, hold down the **right mouse button** and move the mouse down to zoom in.

Mac users: Position the mouse in the 3D Viewer, hold down the **apple button and the mouse button** and move the mouse down to zoom in (or use two fingers on the touch pad).



Slicer4 Minute Tutorial: 3D Visualization: Zoom the view

Slicer displays a **closer view** of 3D anatomical structures overlaid on 2D MR slices



Slicer4 Minute Tutorial: Summary

This tutorial has demonstrated:

- Basic description of the Slicer4 Application Interface
- How to load a scene containing volumes and models
- How to visualize these different datasets together

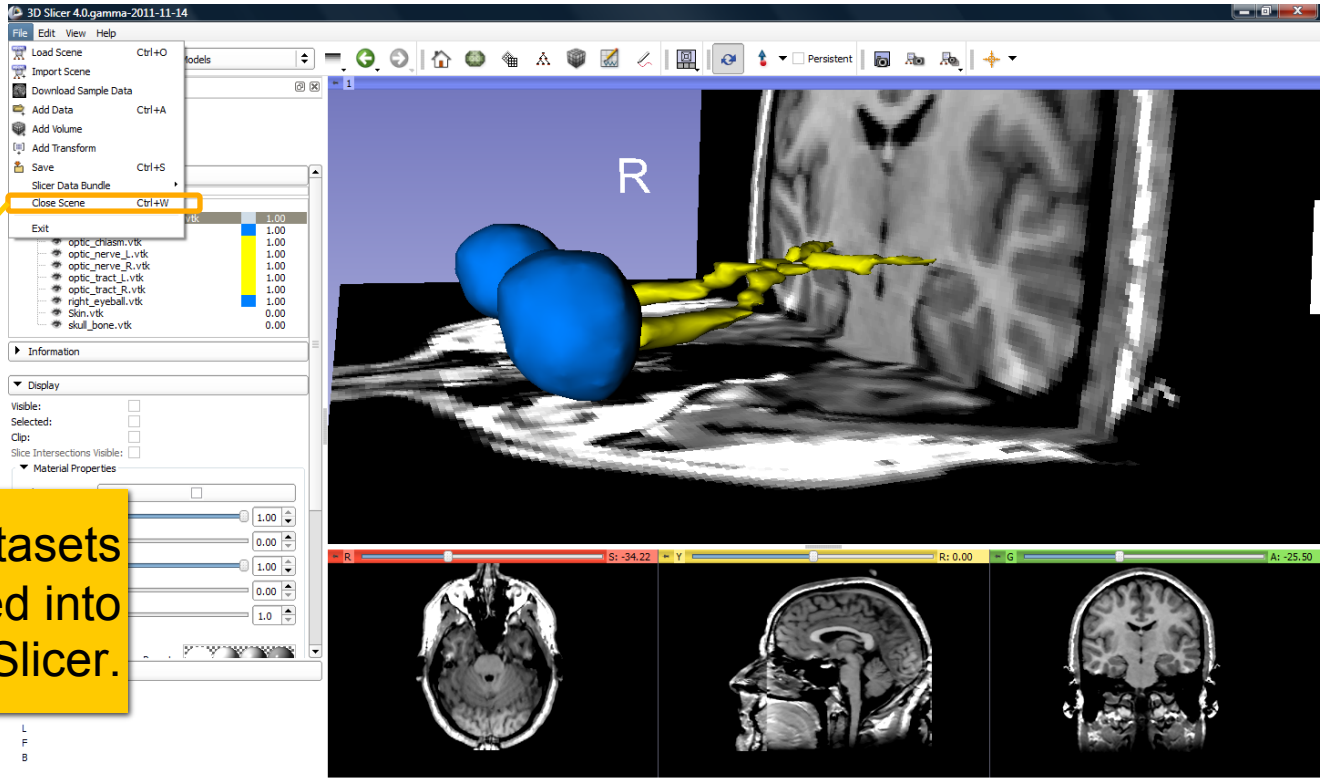
Next, we will use these building blocks to perform image analysis and visualize quantitative results

Close the existing scene and all its data

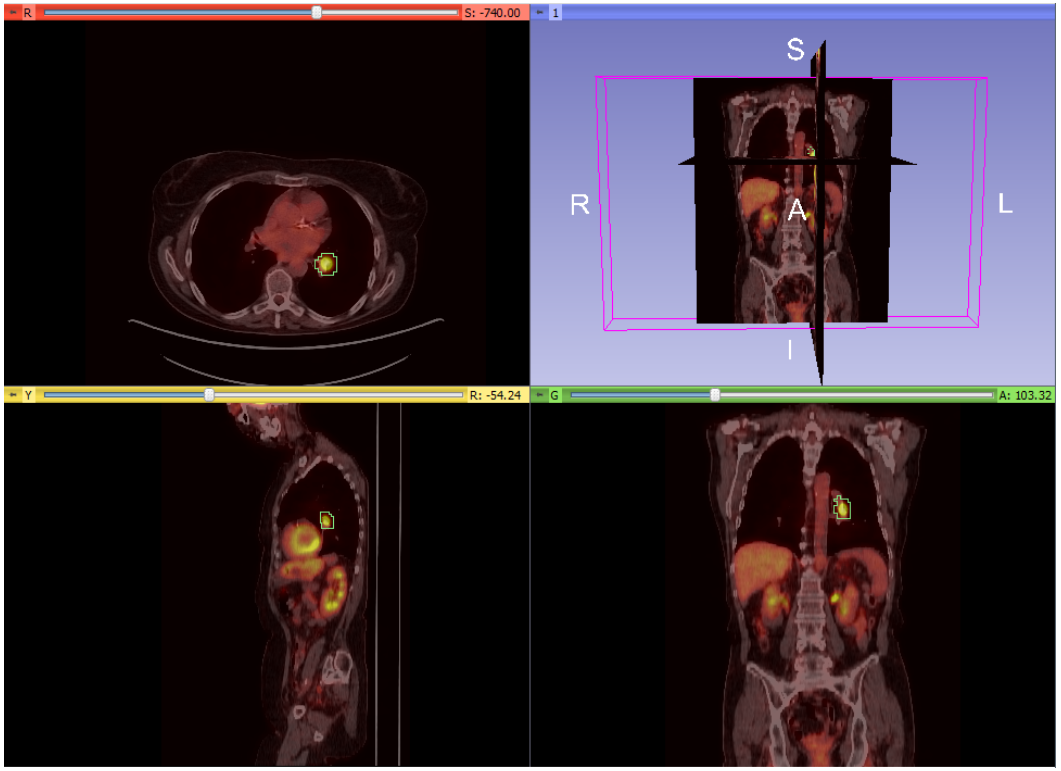
Clear the previous scene.

Select **File->Close Scene**

This removes any datasets previously loaded into Slicer.



PET/CT Visualization and Analysis



Part II: *PET/CT Analysis using 3D Slicer*

Jeffrey Yap PhD
Ron Kikinis MD
Wendy Plesniak PhD
Nicole Aucoin BSc
Valerie Humblet PhD

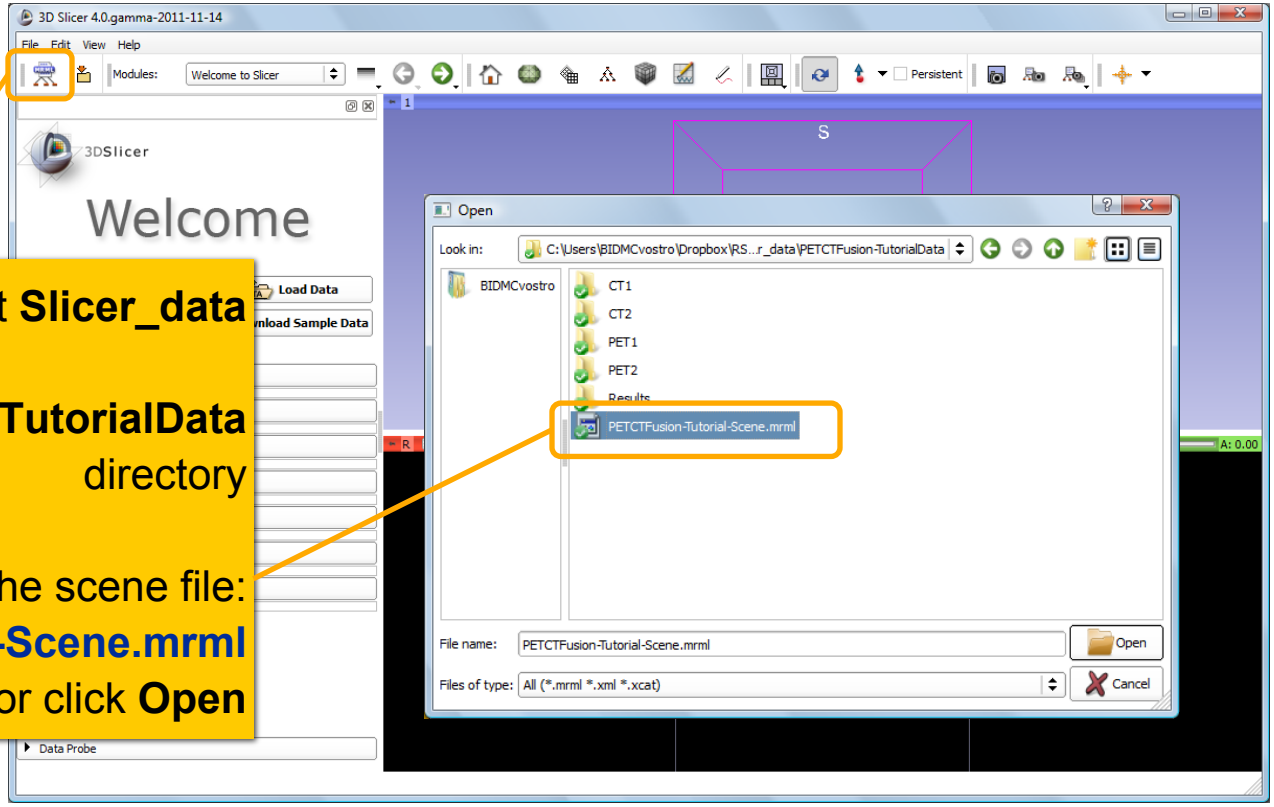
PET/CT Visualization and Analysis: Load the new scene

Click on the **Load Scene** icon

Select **Slicer_data**

Select the **PETCTfusion-TutorialData** directory

And select the scene file: **PETCTFusion-Tutorial-Scene.mrml** double click the file, or click **Open**



PET/CT Visualization and Analysis: About the data

- **Non small cell lung cancer patient**
- **Two PET studies**: **baseline** acquired before treatment, and **follow-up** acquired 1 month after chemotherapy
- Two non-diagnostic CT images are acquired without the use of contrast
- FDG-PET scans acquired 60 minutes after intravenous injection of approximately 20 mCi of 18FDG
- **Two VOIs** have been created using Slicer's Editor Module.

PET/CT Visualization and Analysis: About the data

Standardized Uptake Value

$$\text{SUV (time)} = \frac{\text{Radioactive Concentration} \times \text{Weight}}{\text{Injected Activity}}$$

- Under certain circumstances, ^{18}FDG SUV correlates with metabolic rate of glucose and/or the number of viable tumor cells
- Simplified semi-quantitative measure that can be routinely performed in clinical PET studies
- Adjusts for differences in patient size and injected activity

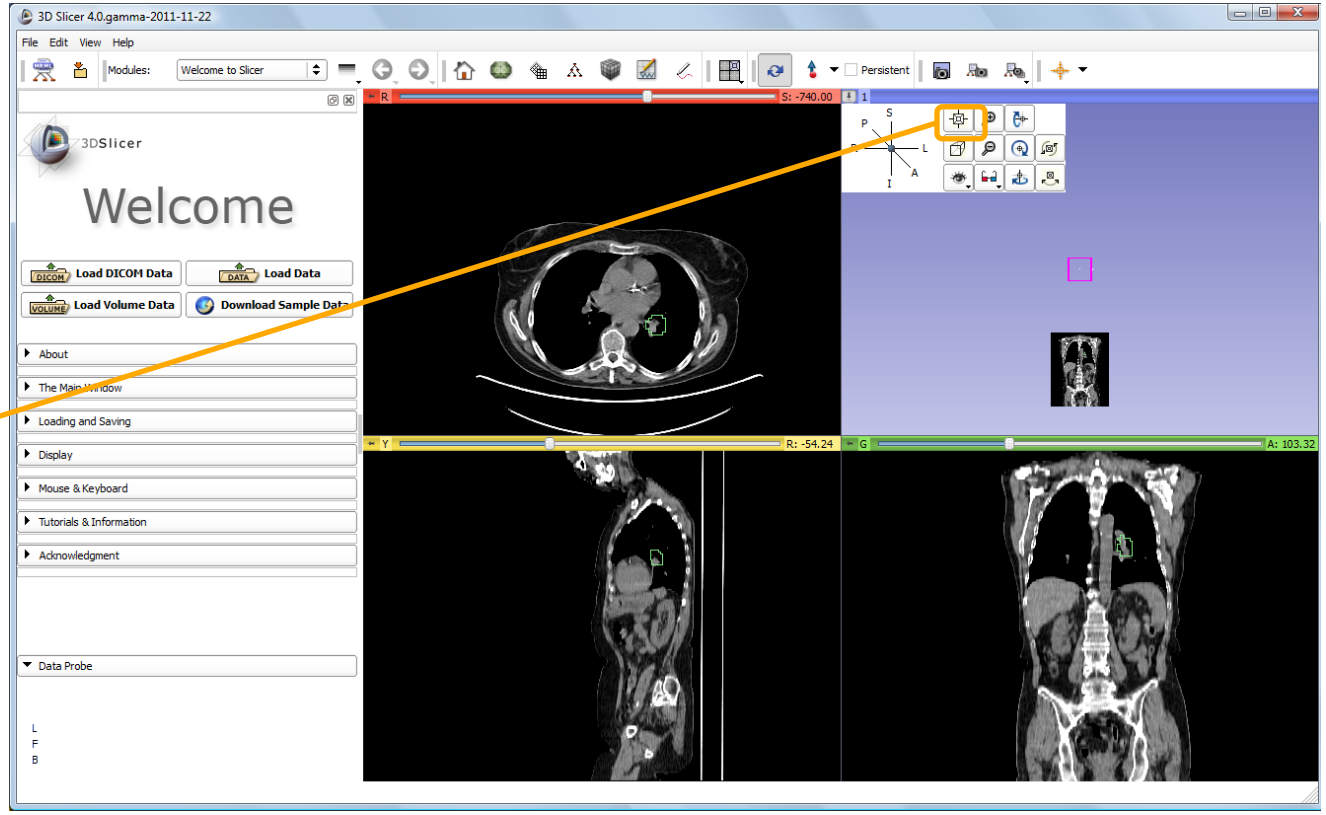
PET/CT Visualization and Analysis: About the data

Response criteria

- Complete response (CR): Complete resolution of all lesions
- Partial Response (PR): >= 25% decrease in SUVmax
- Stable Disease (SD): < 25% change
- Progressive Disease (PD): >= 25% increase in SUVmax

PET/CT Visualization and Analysis: view the scene

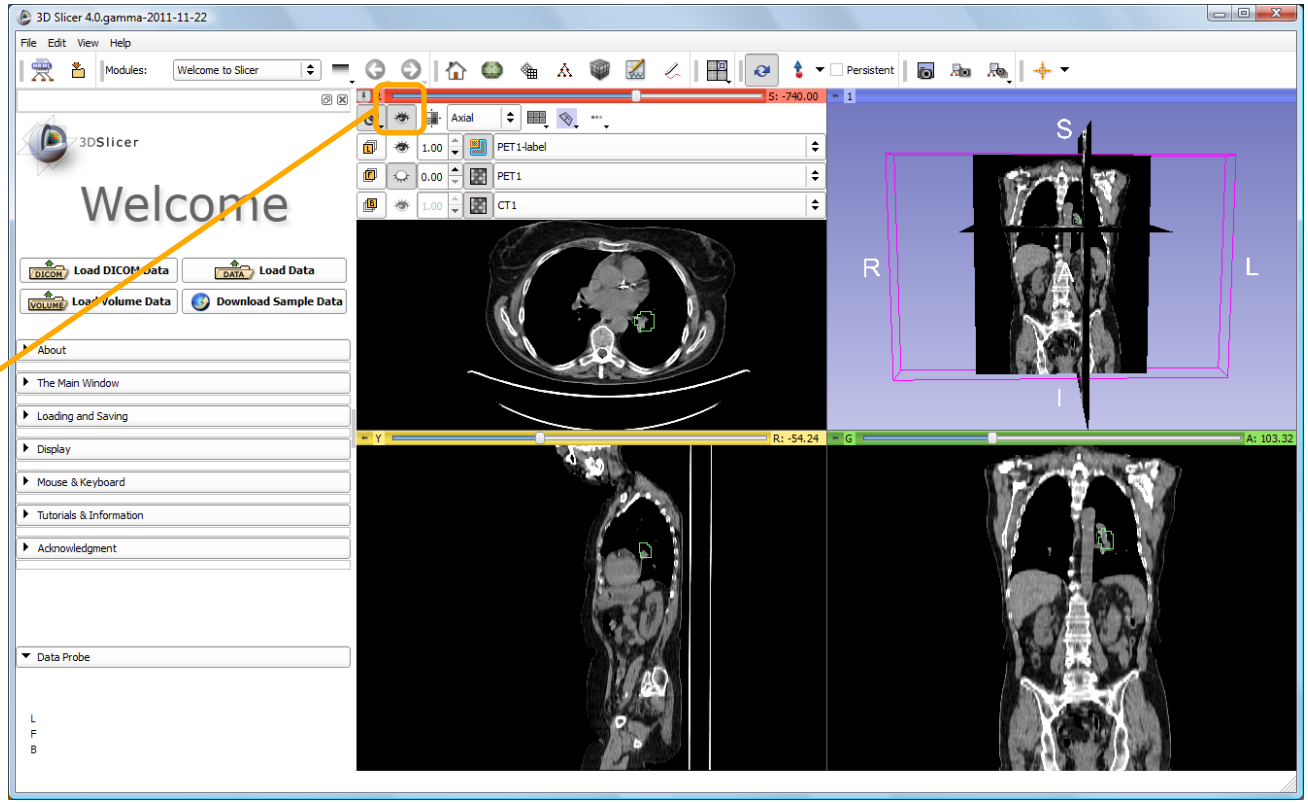
To view the slices in the 3D viewer, click on **center the 3D view on scene** icon 



PET/CT Visualization and Analysis: Open the Volume Module

Zoom (right mouse button)

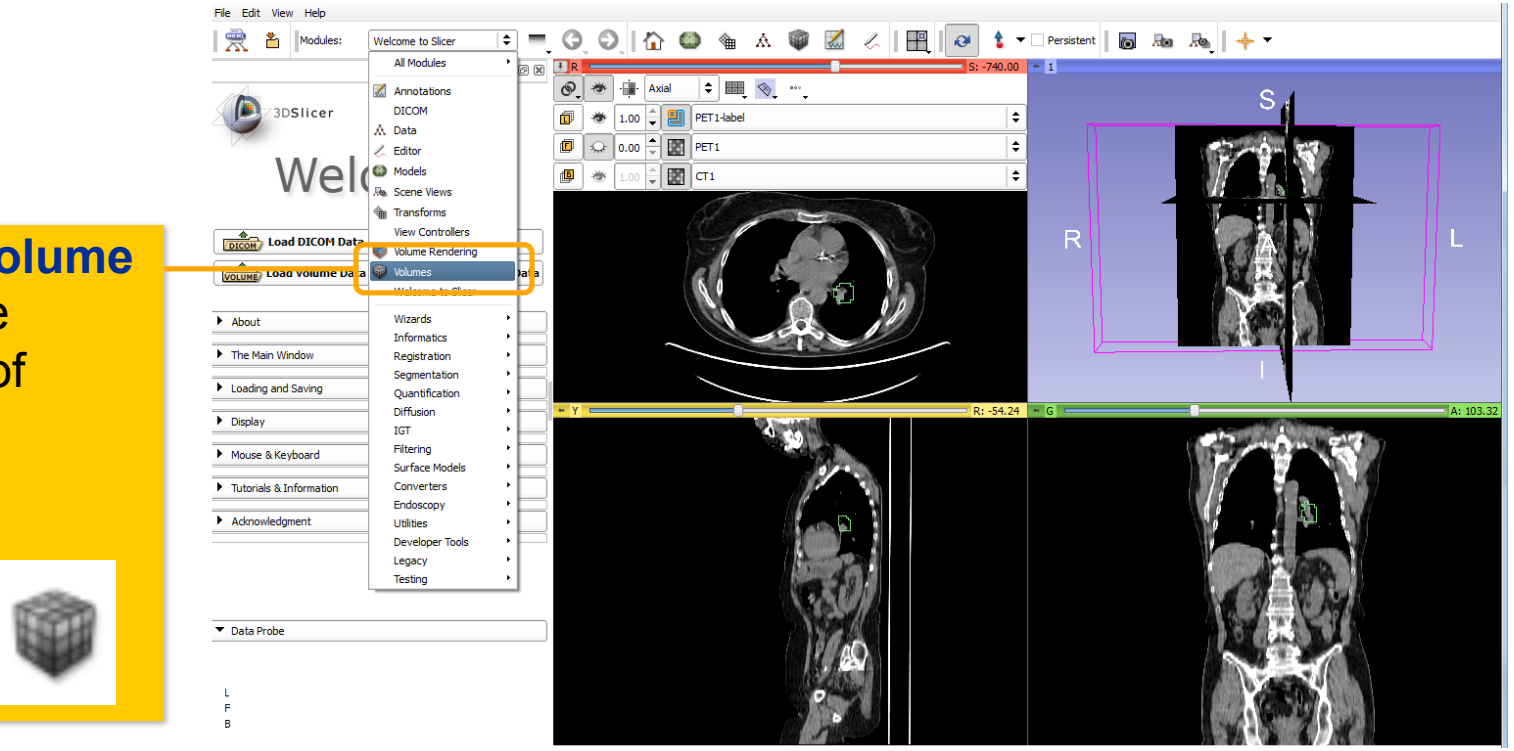
Then click on the **Slice Visibility** icon to display the Axial and Sagittal Slices in the 3D Viewer



PET/CT Visualization and Analysis: Open the Volume Module

To access the **Volume module**, browse through the list of modules...

...or click on the **volume icon** in the toolbar

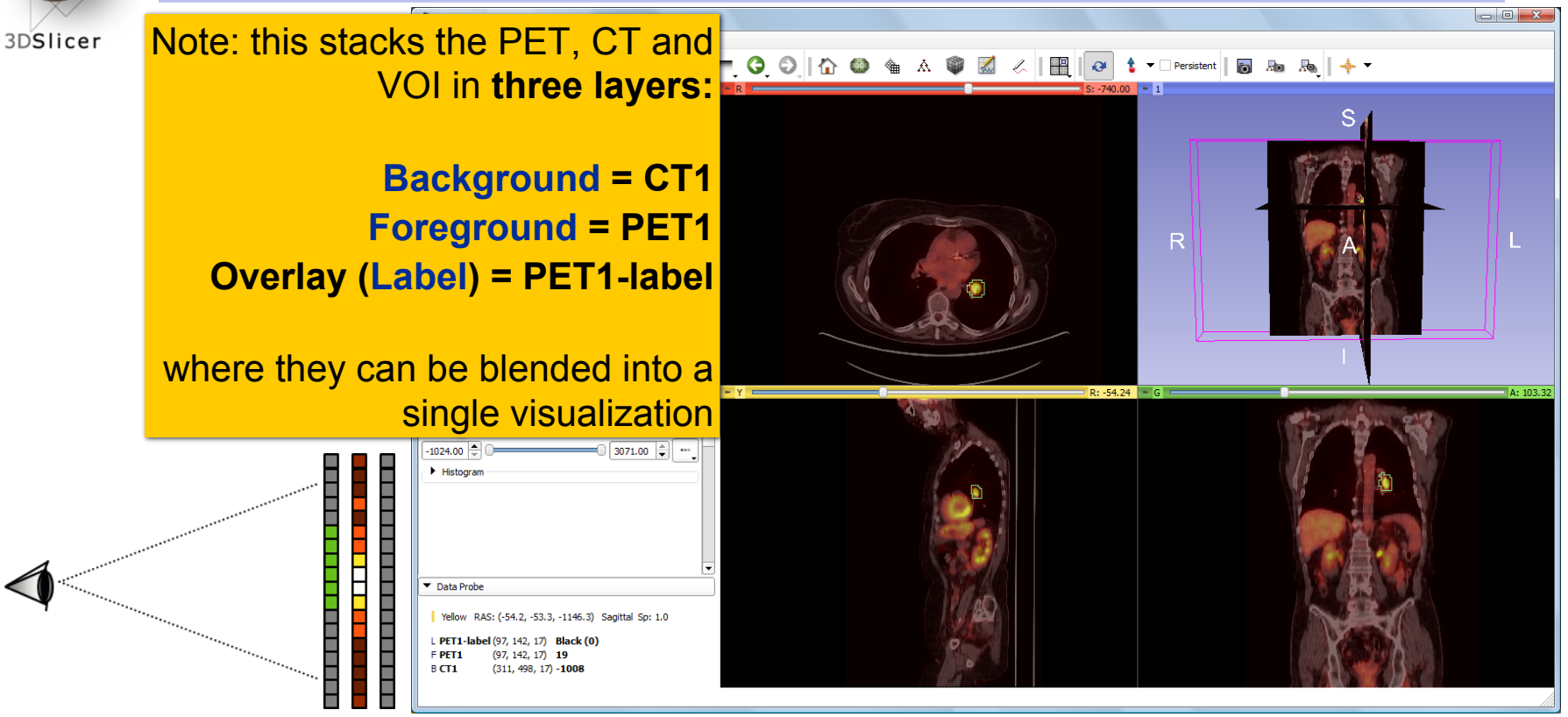


PET/CT Visualization and Analysis: Information displayed in "Layers"

Note: this stacks the PET, CT and VOI in **three layers:**

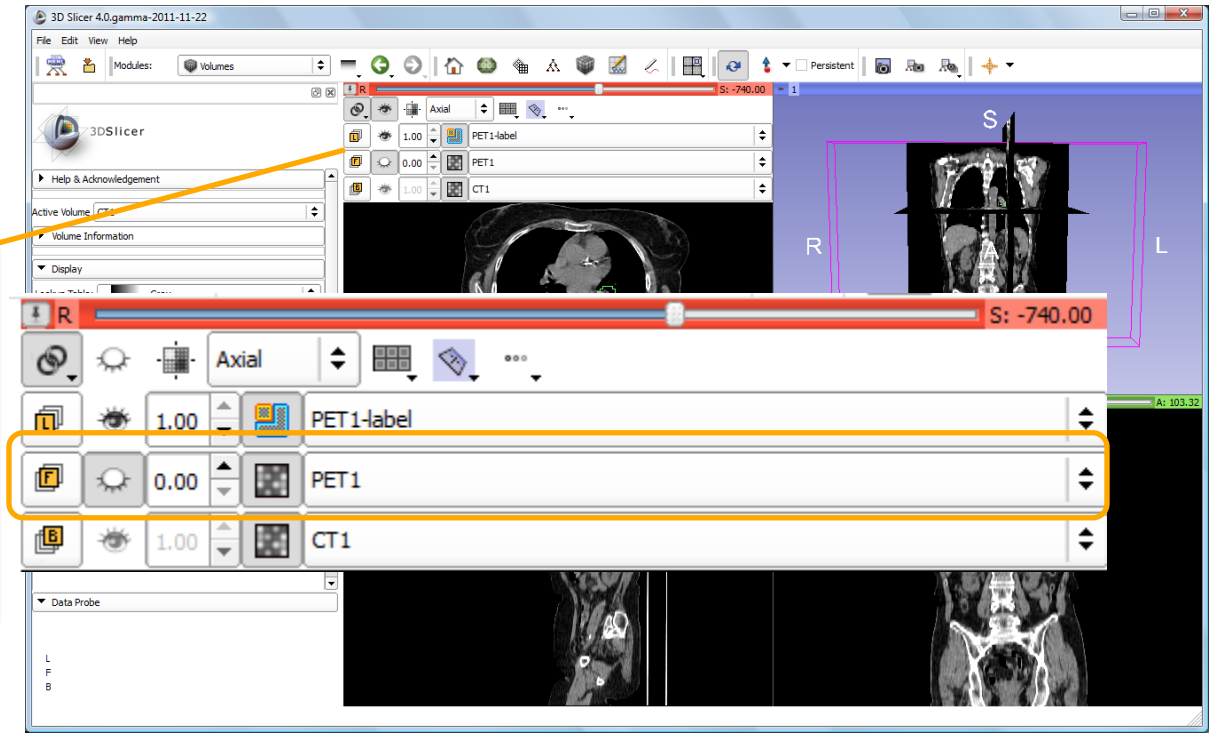
Background = CT1
Foreground = PET1
Overlay (Label) = PET1-label

where they can be blended into a single visualization



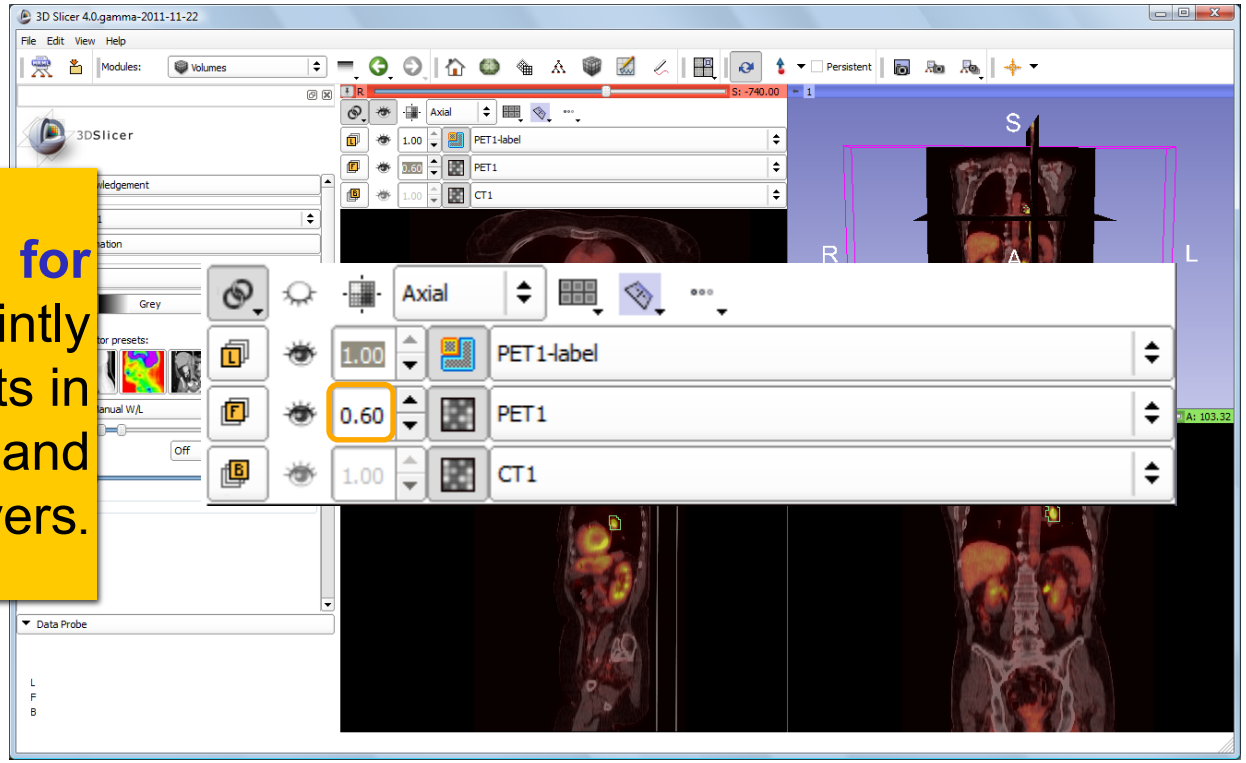
PET/CT Visualization and Analysis: Adjust display of baseline study

Click on the **Visibility** icon
to display the PET1 image
in the Slice Viewers



PET/CT Visualization and Analysis: Adjust display of baseline study

Adjust the **level for PET1** volume to jointly display the datasets in the foreground and background layers.

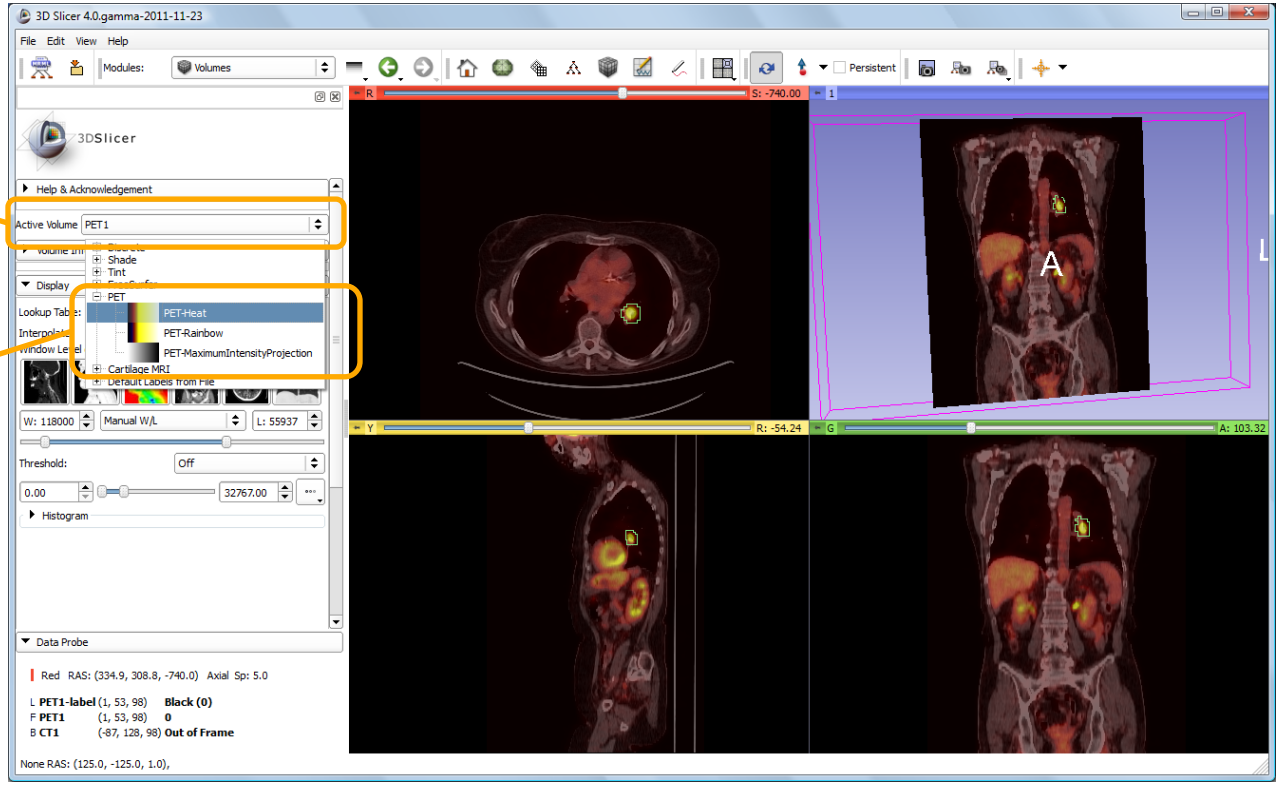


PET/CT Visualization and Analysis: Adjust display of baseline study

Choose PET1 as **Active Volume**

In the Display Panel, **choose a colorization option** for the PET volume from among **Heat, Rainbow or MPI**.

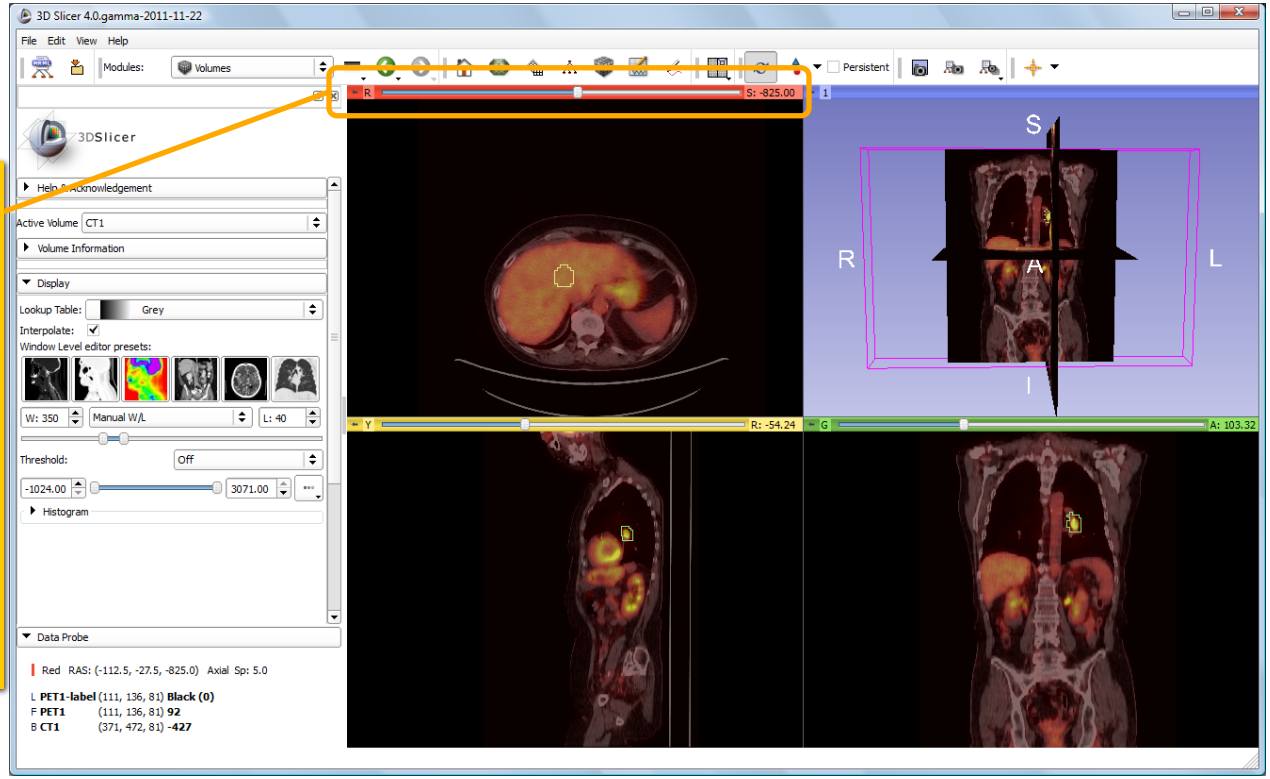
.



PET/CT Visualization and Analysis: Explore the visualization

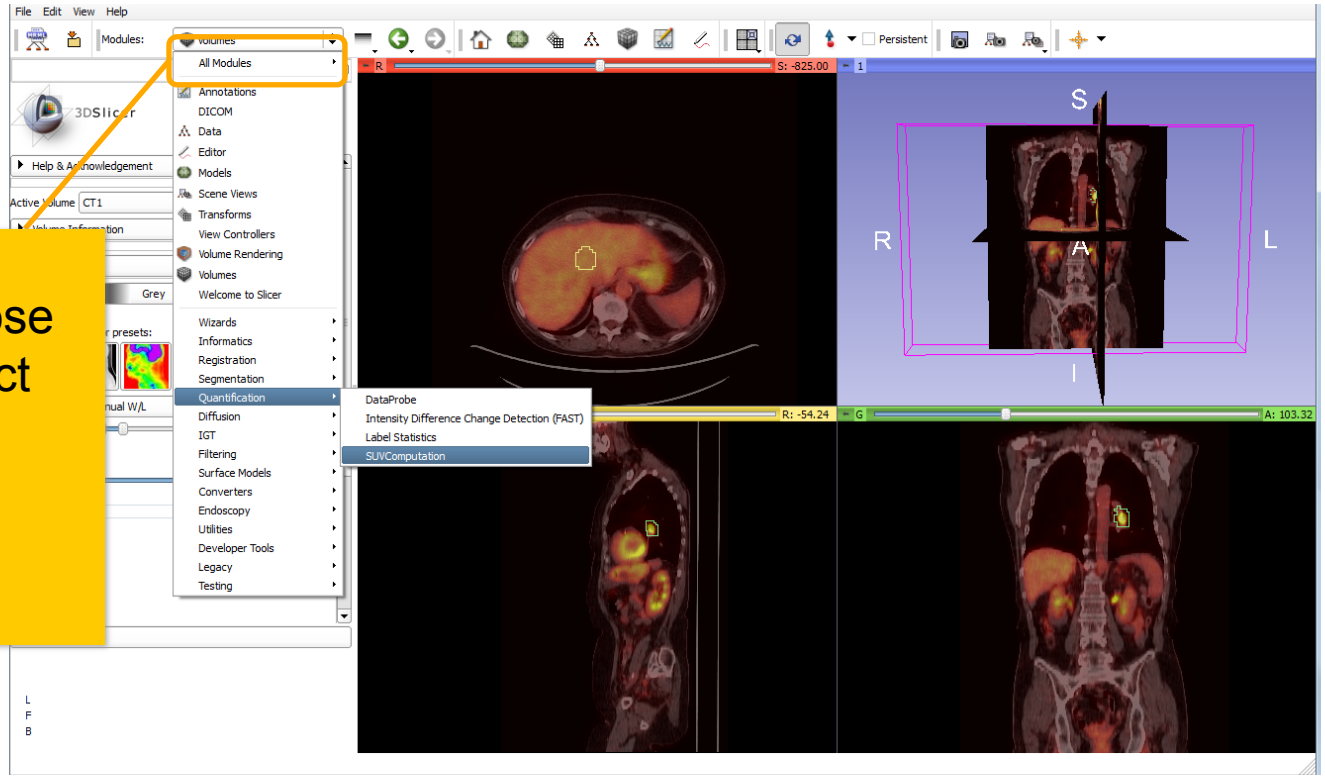
Explore:
in the Slice Viewers, **scroll through the slices** to locate the green **Tumor label** and the yellow **Liver label.**

Note: (the yellow label is used only to demonstrate multiple-VOI functionality).



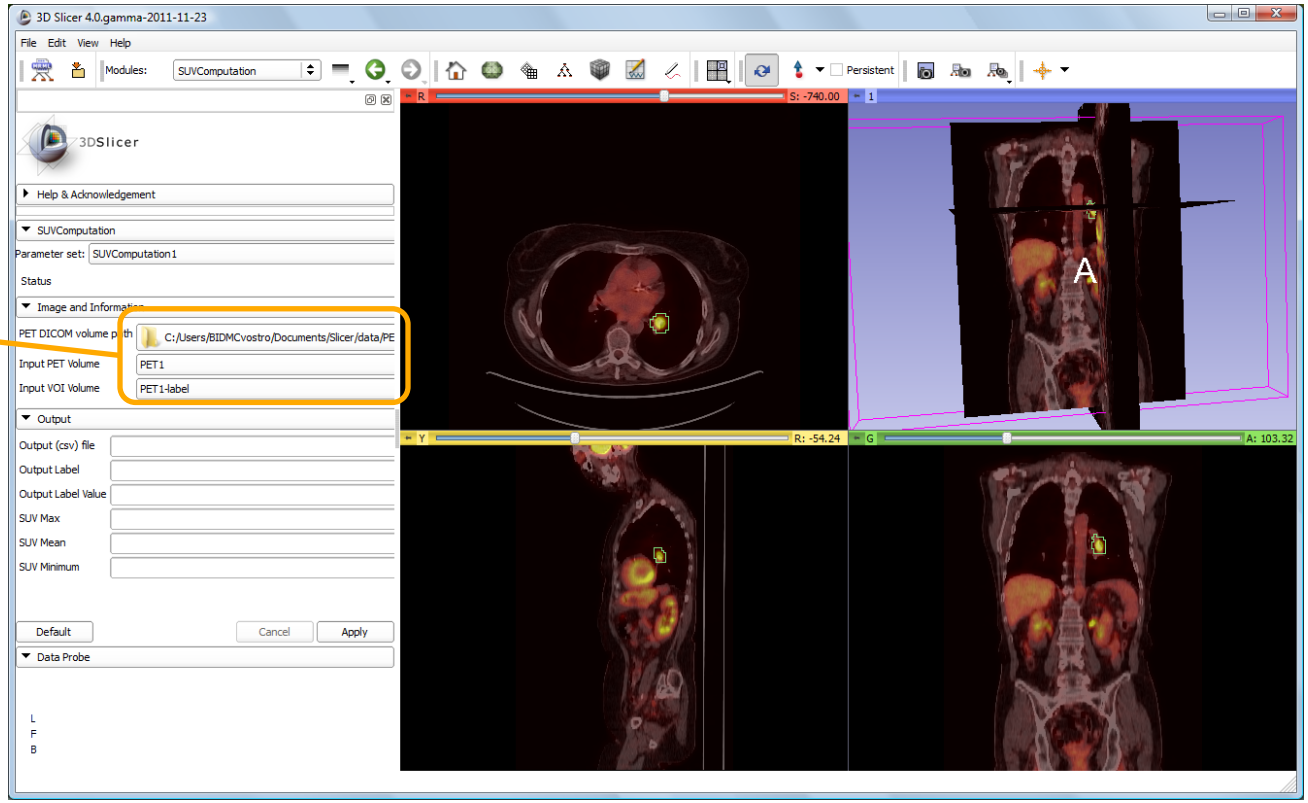
PET/CT Visualization and Analysis: Compute SUV for all VOIs in baseline

Using the **Module Menubutton**, expose the menu and select **SUV computation** under the **Quantification** category



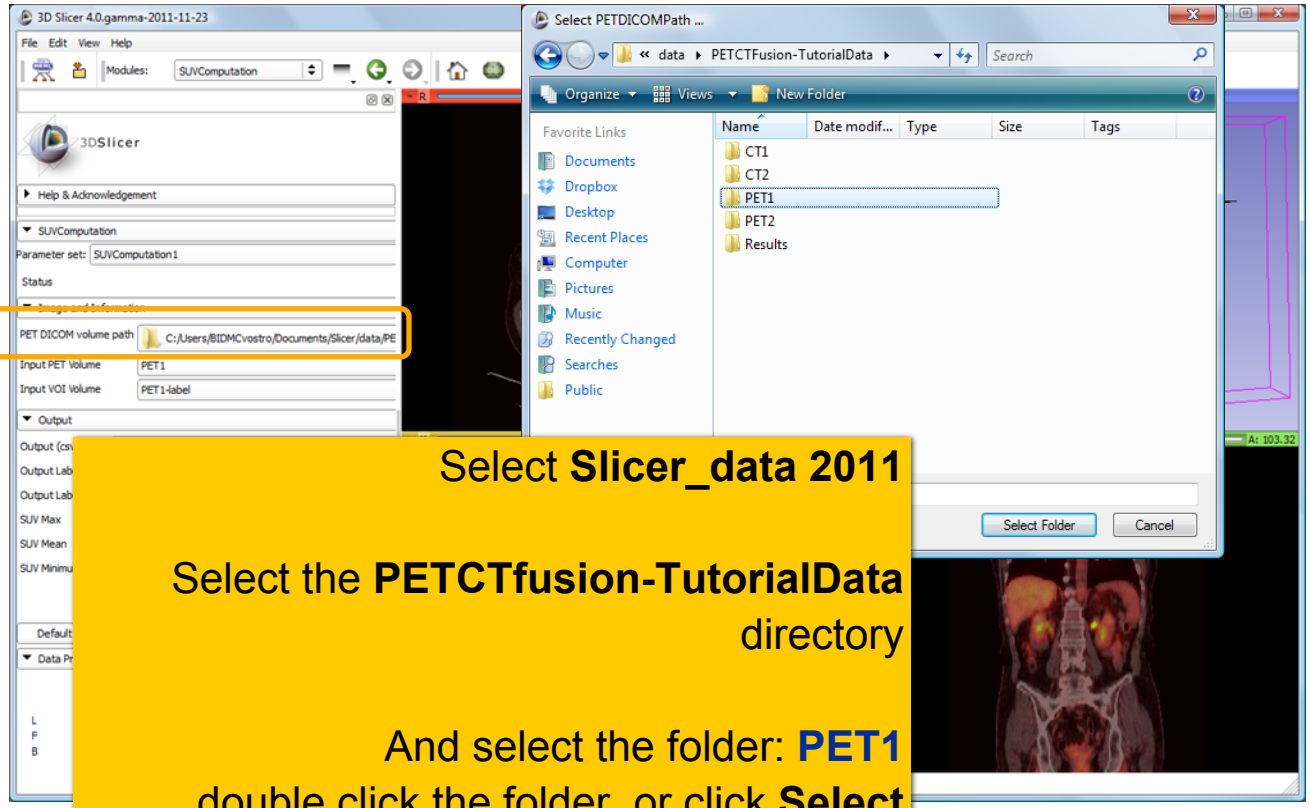
PET/CT Visualization and Analysis: Compute SUV for all VOIs in baseline

In **Image and Information**, select the PET and VOI volume (for example PET1 and PET1-label)



PET/CT Visualization and Analysis: Compute SUV for all VOIs in baseline

PET DICOM volume path: Input the path to a directory containing a DICOM header with information for SUV computation

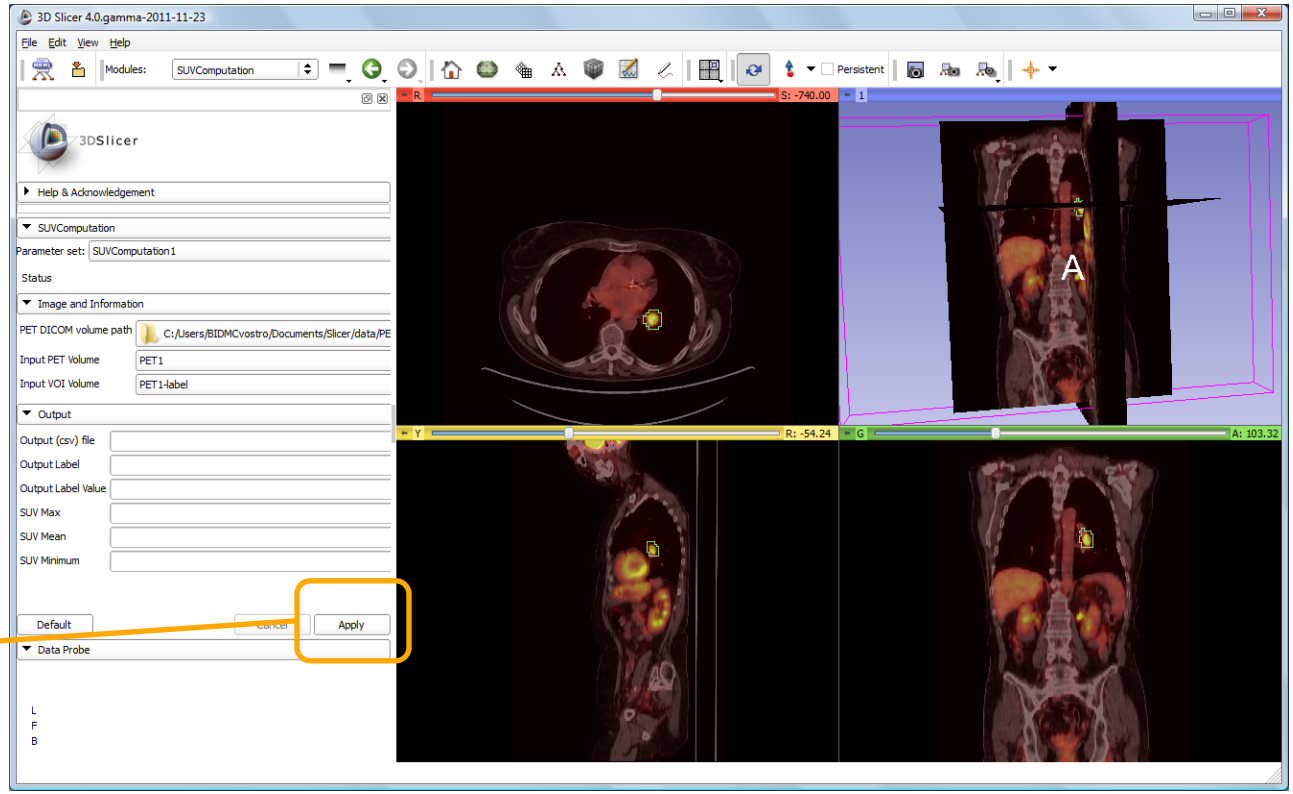


Select **Slicer_data 2011**

Select the **PETCTfusion-TutorialData** directory

And select the folder: **PET1**
double click the folder, or click **Select**

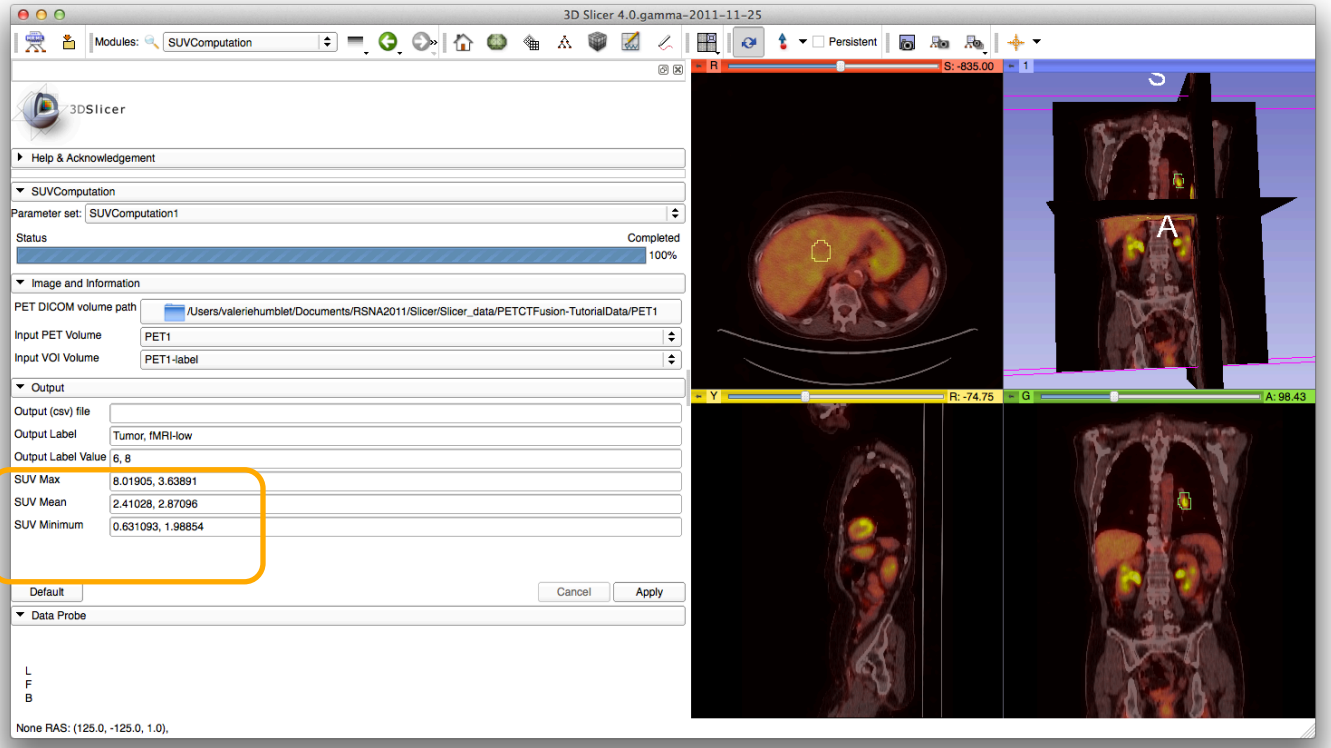
PET/CT Visualization and Analysis: Compute SUV for all VOIs in baseline



To start the SUV computation, click **Apply**

PET/CT Visualization and Analysis: Compute SUV for all VOIs in baseline

SUVmax, SUVmean and **SUVmin** for each VOI (represented by a different color in the label map) are displayed.

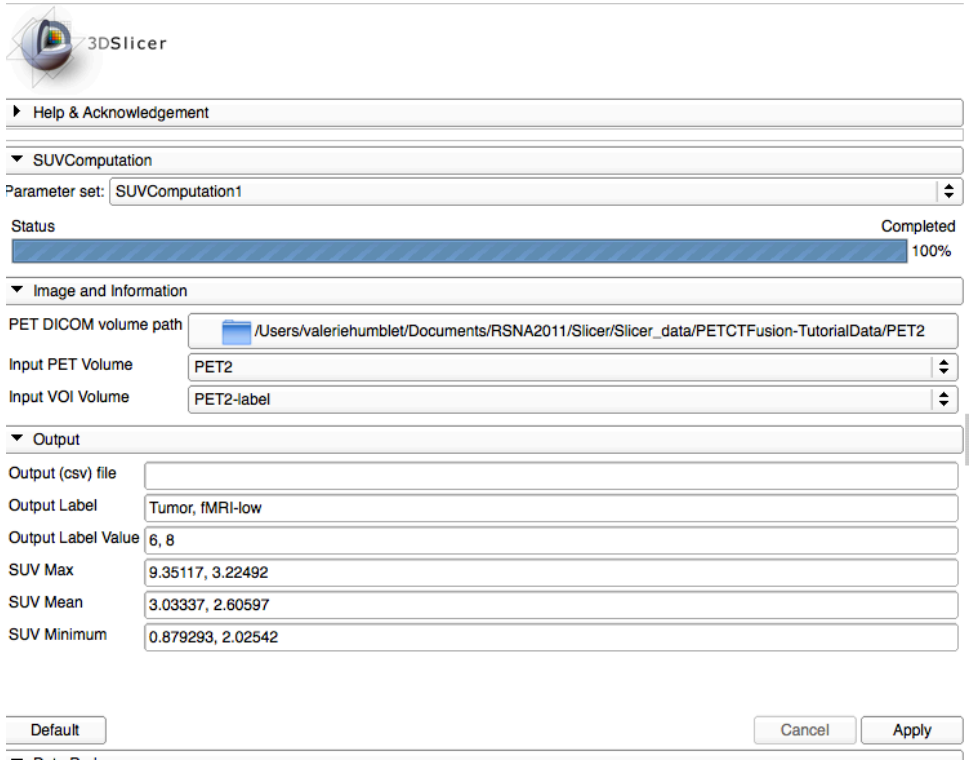


PET/CT Visualization and Analysis: Compute SUV for follow-up study

Look for **response to treatment** in the follow-up study:

In the Image and Information panel, set:
PET DICOM= **PET2**,
PET volume = **PET2** and
VOI volume= **PET2-label**.

This dataset contains two **VOIs** that correspond to the segmentations the baseline study.



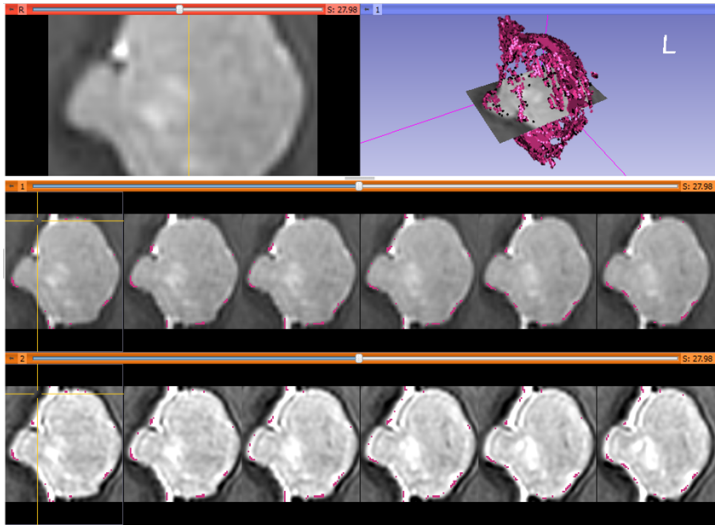
PET/CT Visualization and Analysis: Assess response

Pre-Treatment Max SUVbw = 8.0 g/ml

Post-Treatment Max SUVbw = 9.4 g/ml

+16.61% (Stable Disease)

ChangeTracker: exploring small volumetric changes



Part III: *Analyzing Small Volumetric Changes using the ChangeTracker Module*

Kilian M Pohl, PhD
Ender Konukoglu, PhD
Andriy Fedorov, PhD

The module described in this tutorial was tested on Axial 3D SPGR T1 post Gadolinium scans (Voxel dimension: 0.94mm x 0.94mm x 1.20mm, FOV: 240mm, Matrix: 256 x 256)

ChangeTracker: Conventional measures of tumor response

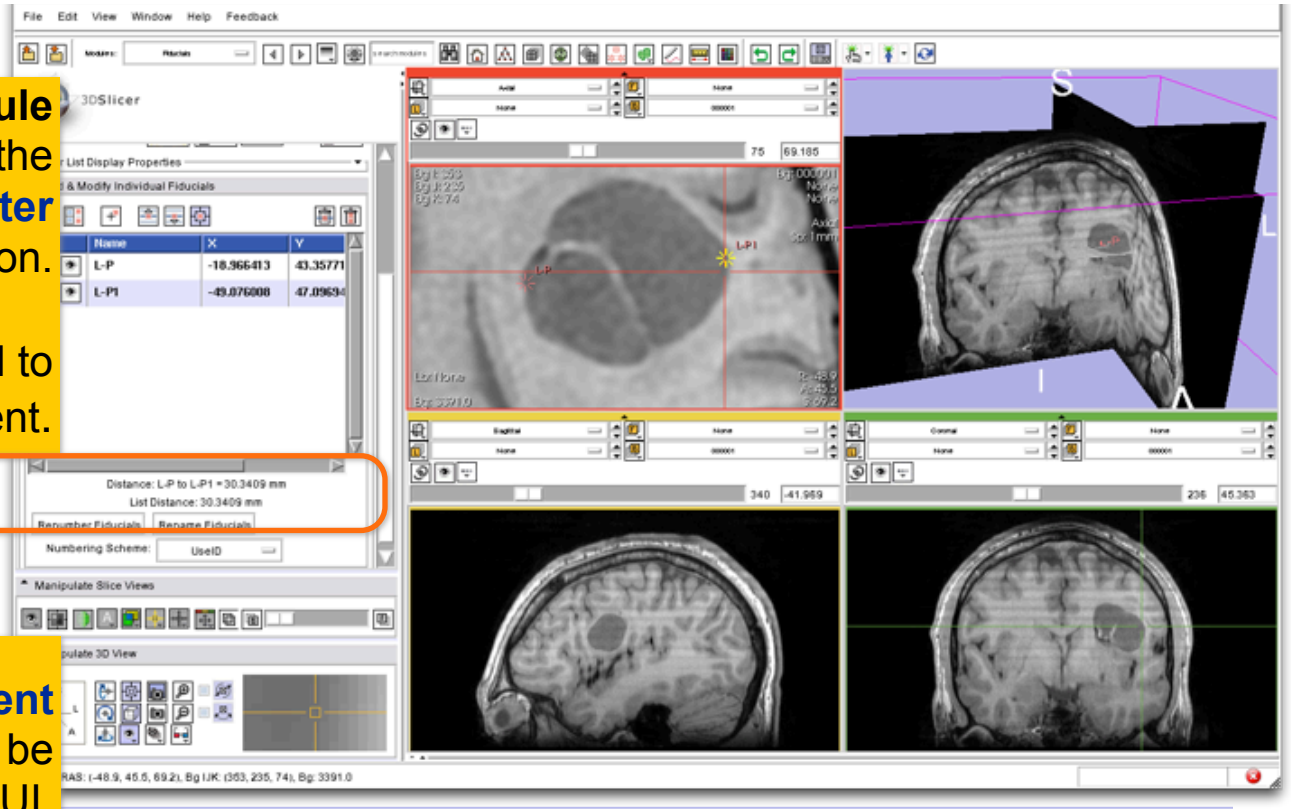
- Conventional anatomic imaging using CT or MRI are often used to evaluate tumor size and shape
- Most clinical trials that evaluate new chemotherapeutic drugs use changes in uni-dimensional or bi-dimensional measurements to assess response (*e.g.* RECIST)
- Slicer has several tools for applying RECIST methodologies

Quantifying tumor change: Conventional measures of tumor response

3D Slicer's **Fiducials Module** can be used to measure the **longest diameter** in a tumor cross section.

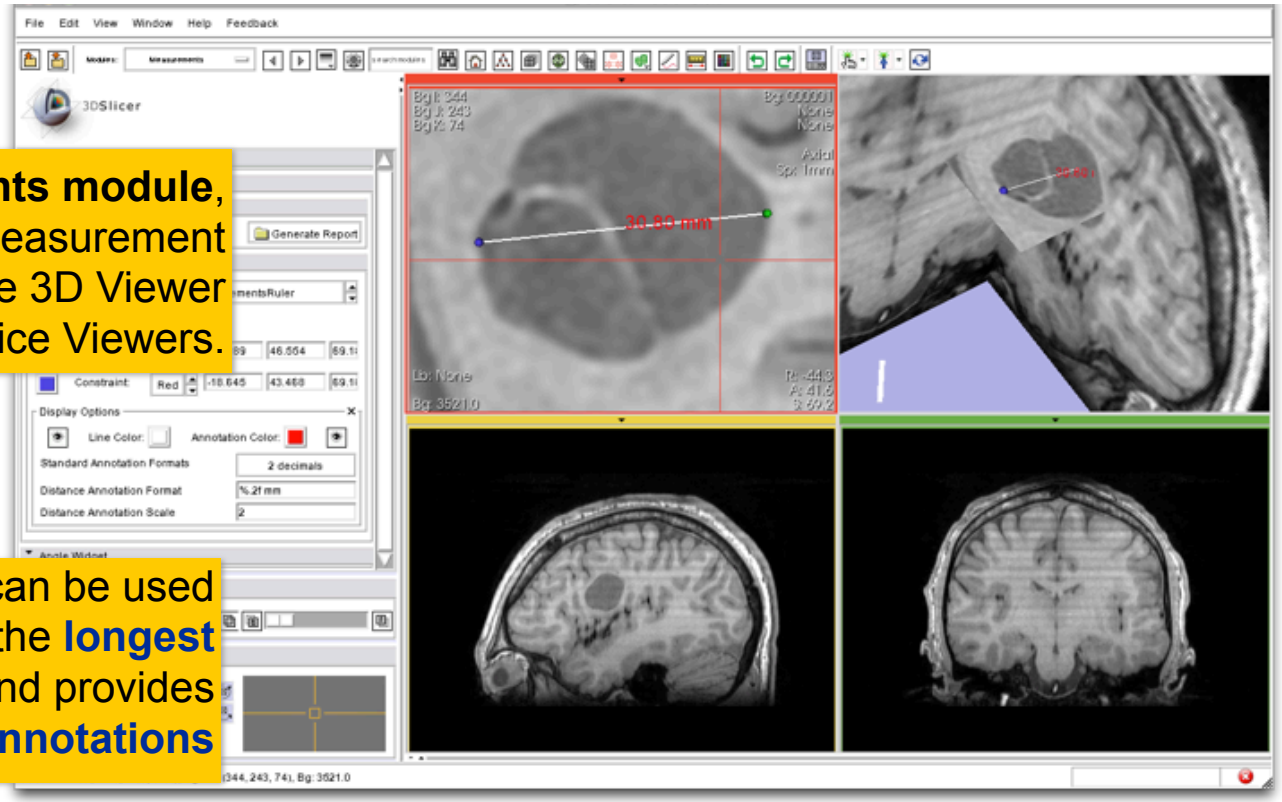
Two fiducials may be used to mark the tumor's extent.

The **distance measurement** (mm) between fiducials will be updated in the Fiducial's GUI.



Quantifying tumor change: Conventional measures of tumor response

3D Slicer's **Measurements module**, provides interactive measurement tools that operate in the 3D Viewer and the Slice Viewers.

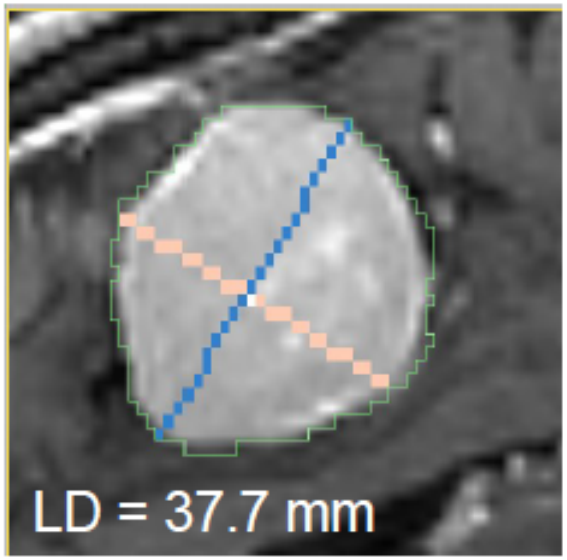


Interactive ruler can be used to measure the **longest diameter** and provides numerical **annotations**

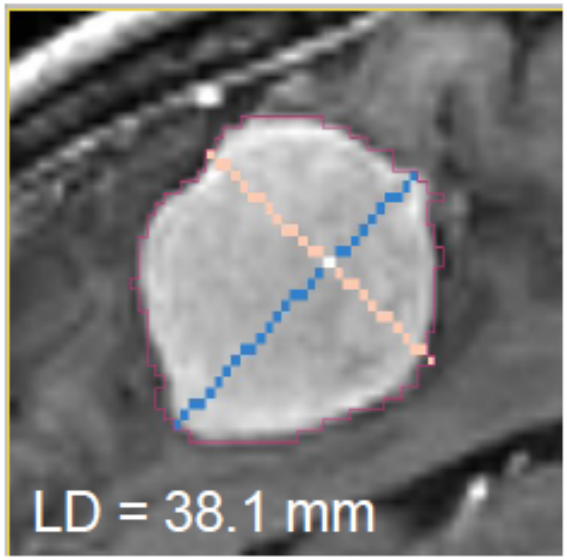
Quantifying tumor change: Conventional measures of tumor response

3D Slicer's **LabelDiameterEstimation (extension) module** will automatically compute the largest tumor diameter and **orthogonal** dimension.

This analysis requires an **initial segmentation (VOI)**.



Baseline: June 2006



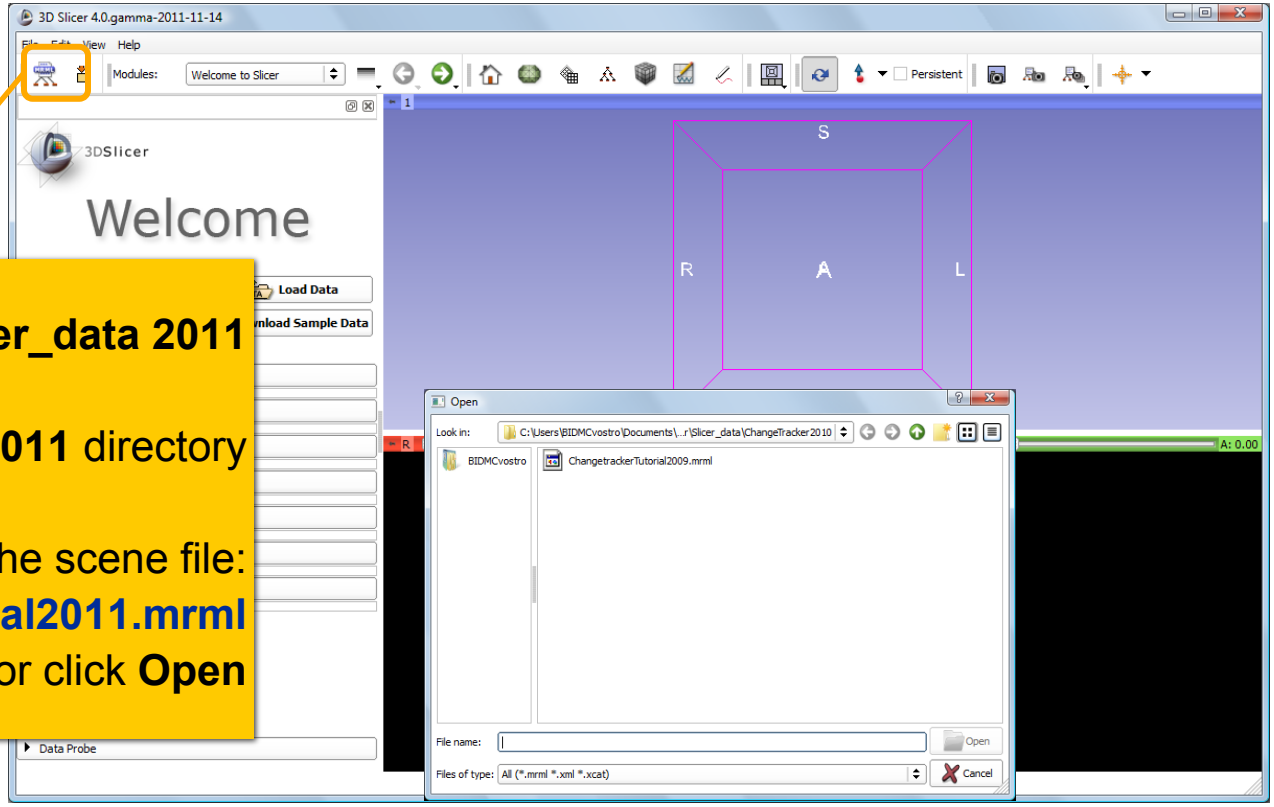
Follow-up: June 2007

ChangeTracker: rationale for new approaches

- However, more accurate and precise methods for understanding volume changes may be useful when:
- **benign tumor change** is being monitored, or
- where **small changes may be clinically significant** but difficult to assess with RECIST
    - **ChangeTracker Module** is a tool to measure **volumetric change at the voxel level**.

ChangeTracker: Load the dataset

Click on the **Load Scene** icon



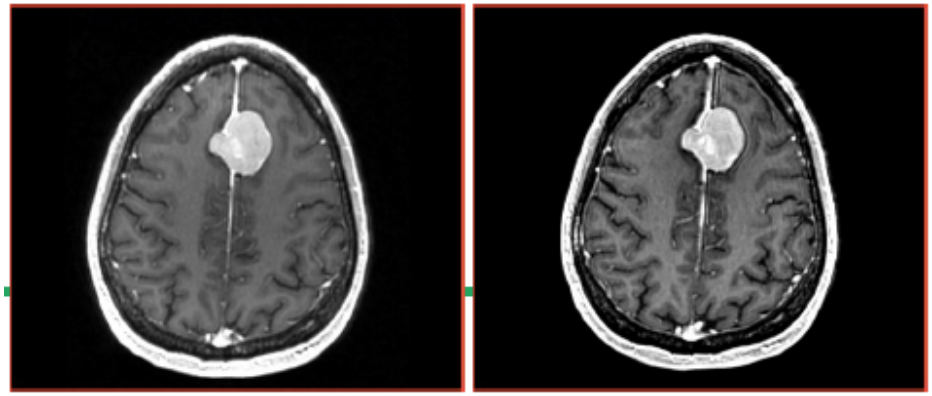
Select **Slicer_data 2011**

Select the **ChangeTracker2011** directory

And select the scene file:
ChangetrackerTutorial2011.mrml
double click the file, or click **Open**

ChangeTracker: about the data…

This course is built upon two scans of a patient with meningioma:

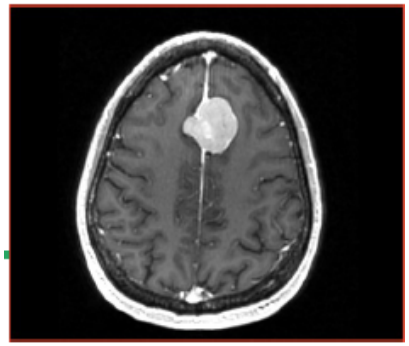


MR Scan 1 MR Scan 2

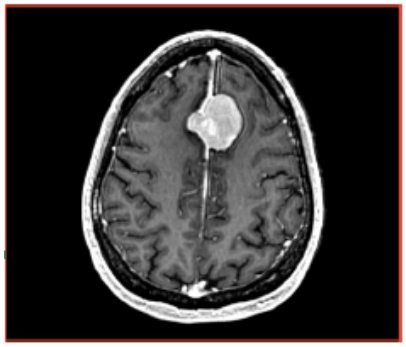
Please note: we have **pre-adjusted the window and level settings** for these volumes so that they are appropriate for display on most laptops. If display is not satisfactory on your machine or projector, the Volumes Module may be used to refine these settings.

ChangeTracker: Clinical context

SCAN1
Baseline:
June 2006



SCAN2
Follow-up:
June 2007



Meningioma

- Usually benign slow-growing tumors

Baseline radiologist's clinical impression:

- large falcine lesion is identified.
- measures 3.1 cm anteroposteriorly, 3.05 cm from side-to-side, 3.5 cm in height.
- enhances moderately on post gadolinium imaging.

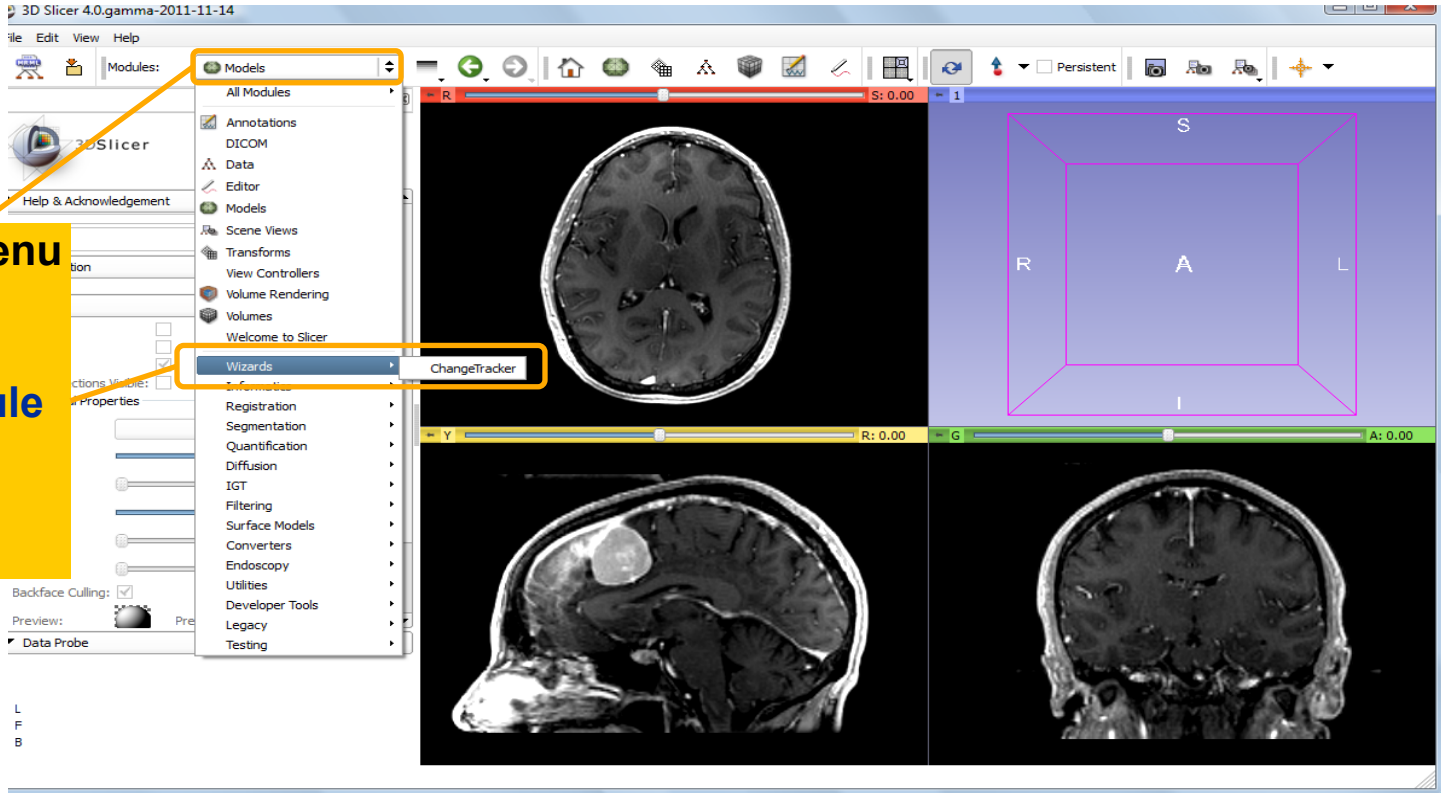
Follow-up radiologist's clinical impression:

- left frontal lobe mass appears unchanged on all series.
- measures 3.3 x 3.2 cm in maximum dimension.
- enhances moderately on post gadolinium imaging.

How has the tumor changed?

ChangeTracker: exploring small volumetric changes

Using the **Modules Menu button**,
Select the **ChangeTracker Module** from the **Wizards** category.



ChangeTracker: a note about the Workflow wizard

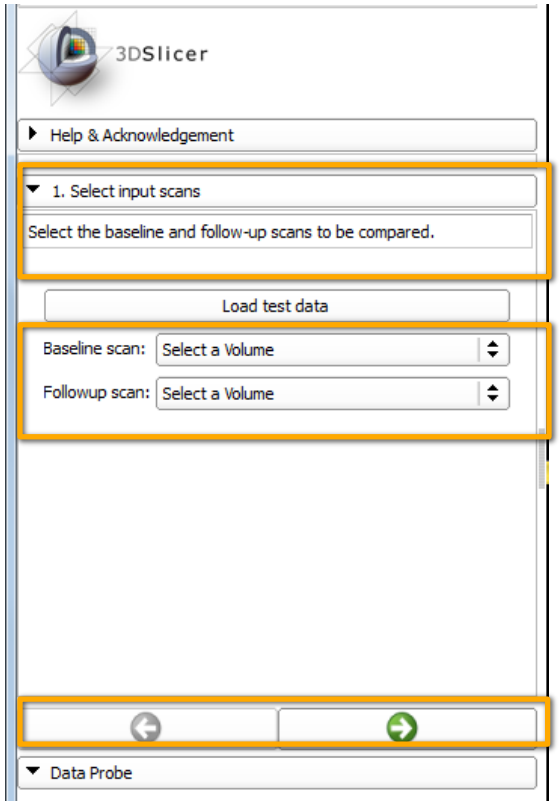
A **Workflow Wizard** guides the user through a sequence of steps and has the following components:

- the Step Panel
- the User Panel
- the Navigation Panel

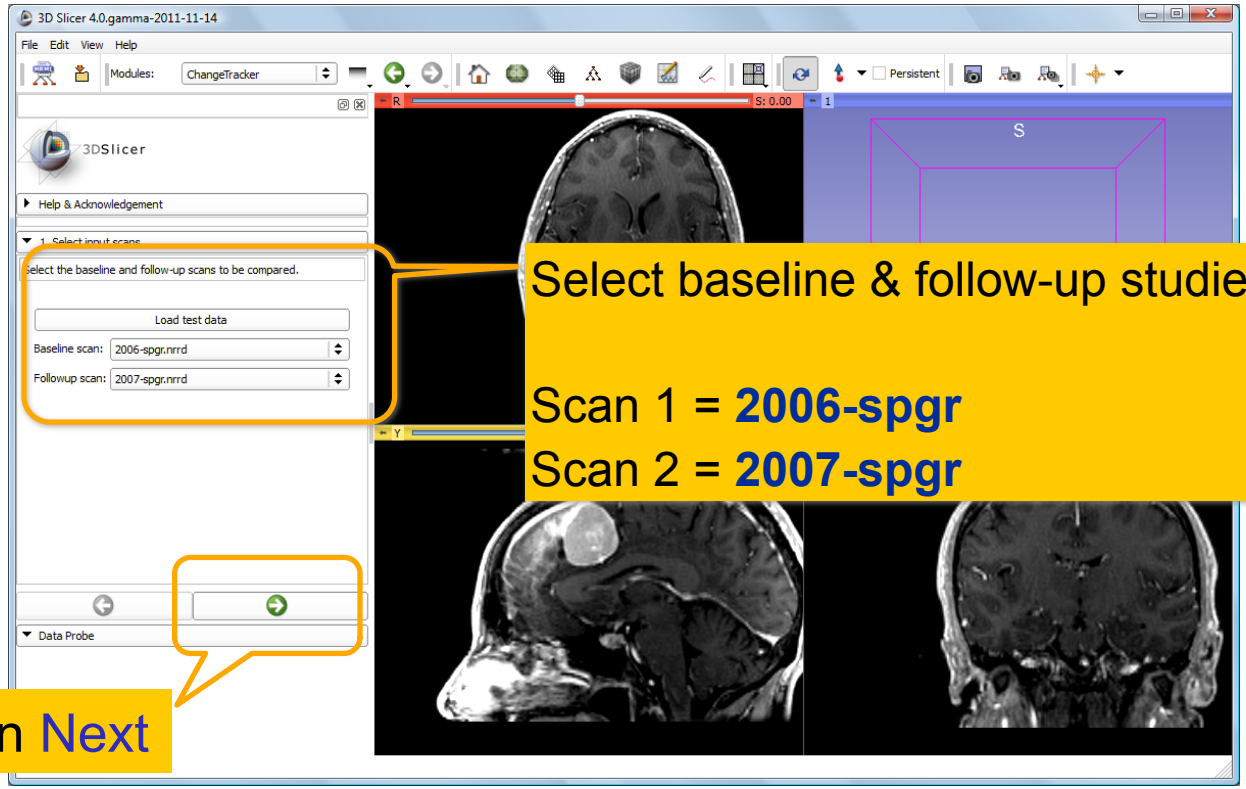
Step Panel--

User Panel--

Navigation Panel--



ChangeTracker: First step: select scans

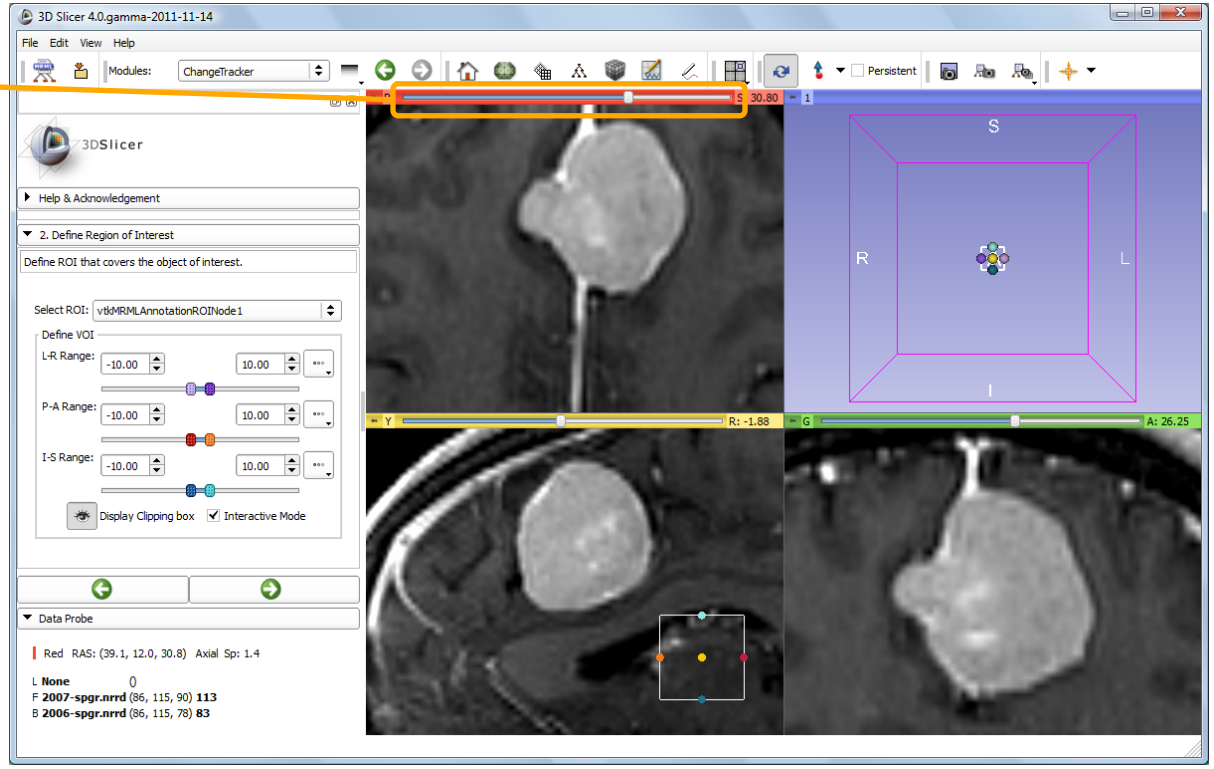


ChangeTracker: inspect the tumor

Move sliders in Slice Viewer Control panels to get a **close-up view** of tumor in Axial, Sagittal and Coronal slice viewers.

Zoom (Right mouse down and push/pull).

Pan (Middle mouse down and move)

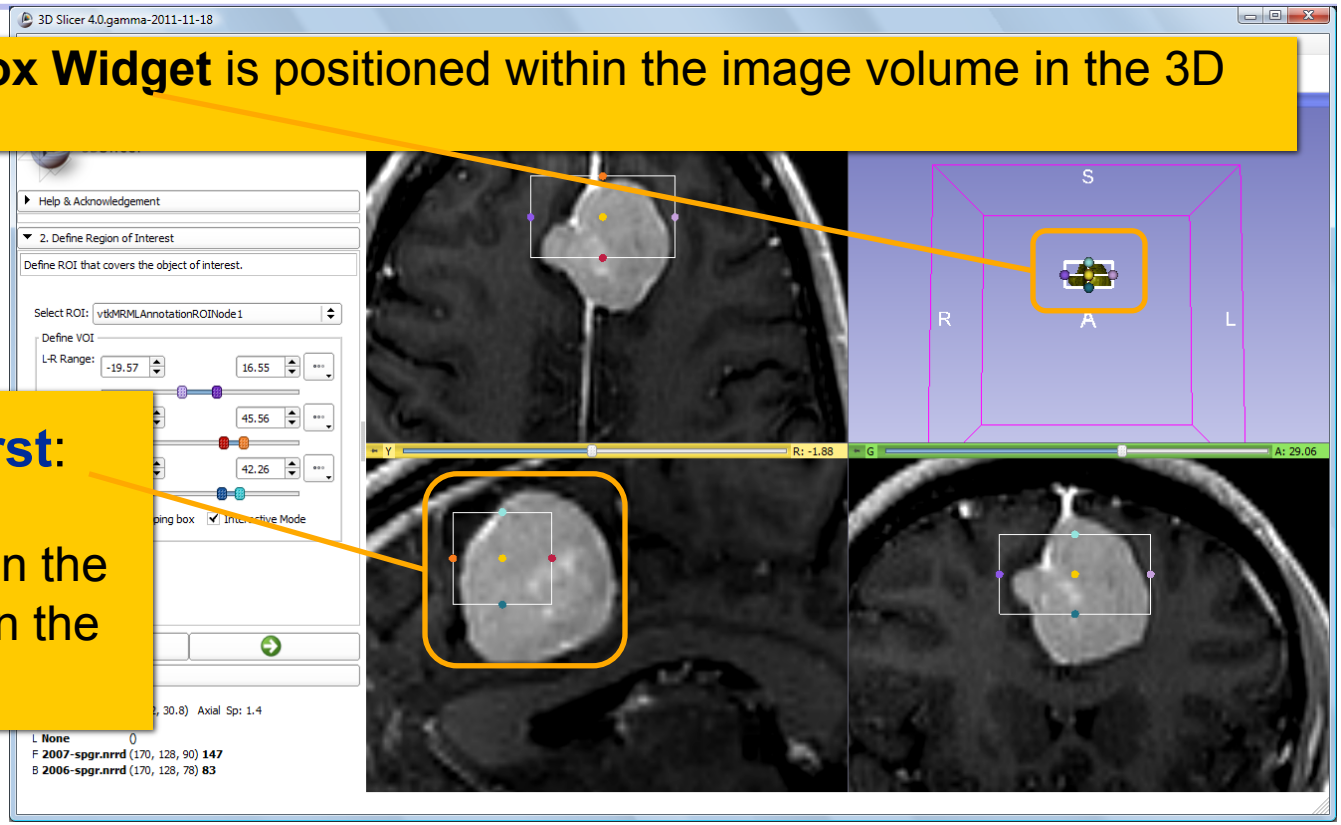


ChangeTracker: Step 2: Define a volume of interest

A **VOI Box Widget** is positioned within the image volume in the 3D viewer

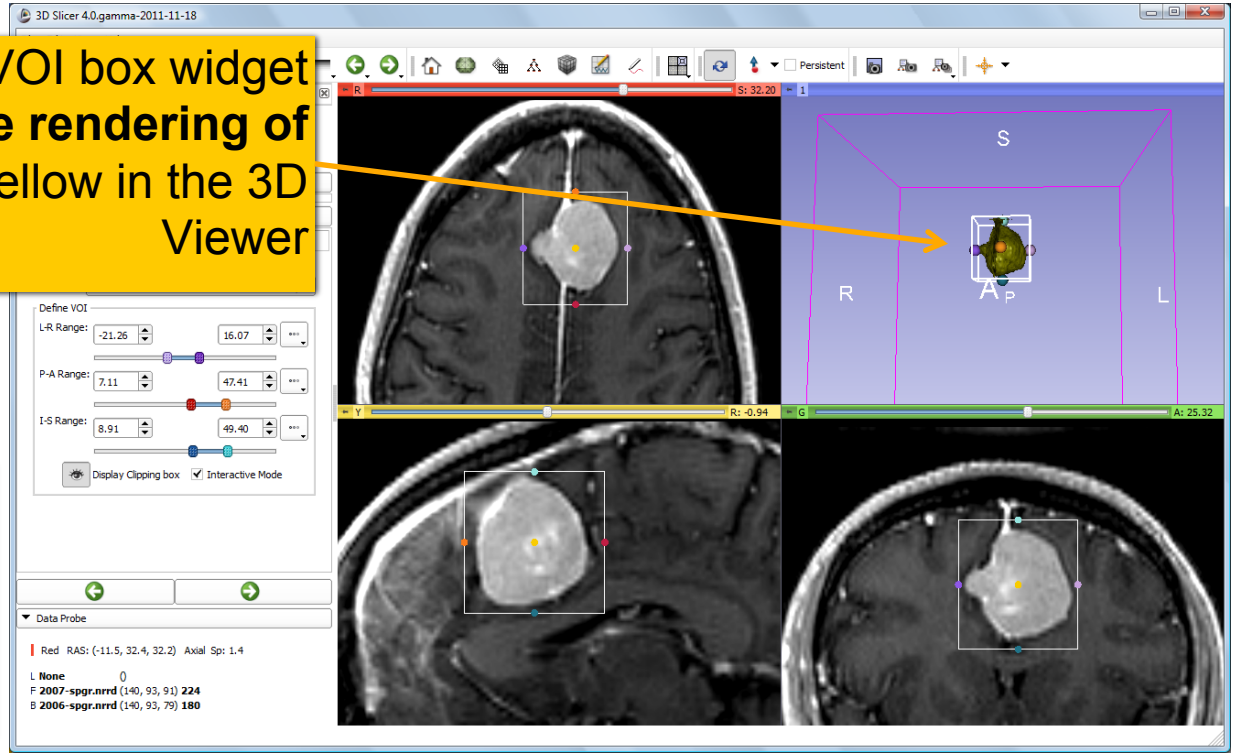
Center the VOI first:

Position the square in the center of the tumor in the slice viewer.



ChangeTracker: Step 2: Define a volume of interest

View the VOI box widget and **volume rendering of tumor** in yellow in the 3D Viewer

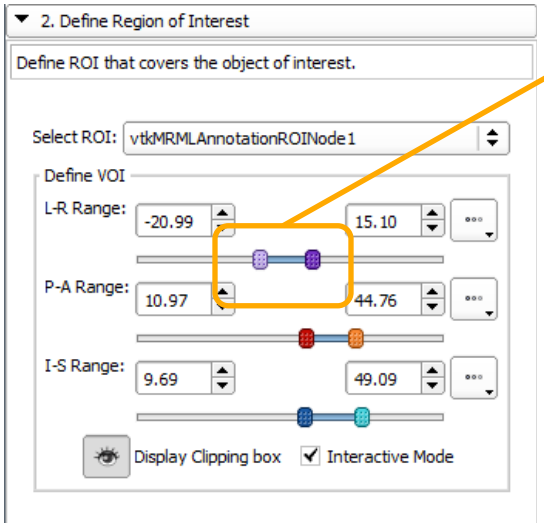


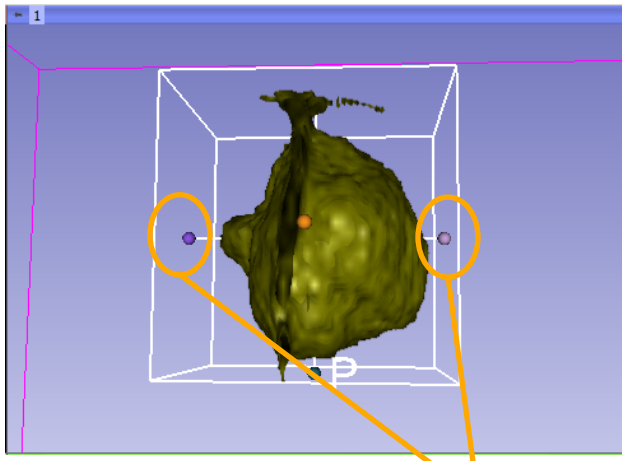
Next, resize the VOI:

Use the colored handles to change the VOI extent

ChangeTracker: Step 2: Define a volume of interest

Fine-tune the VOI using the VOI Widget **range sliders** or by moving the VOI Widget handles in 3D view



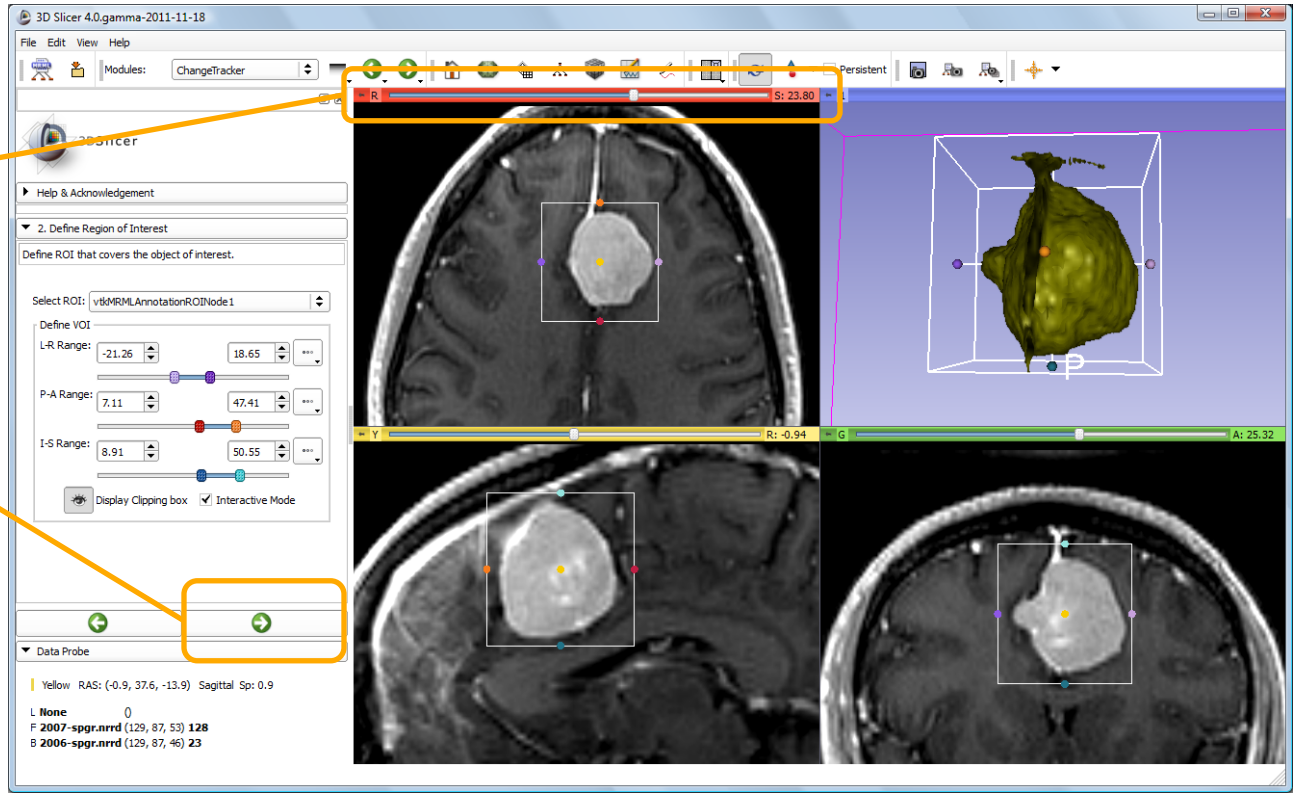


Note: VOI Widget range sliders are **color-coded** to match VOI box Widget **handles** in 3D Viewer

ChangeTracker: Step 2: Define a volume of interest

Scroll through slices to ensure that tumor boundaries are included in the VOI.

Click Next

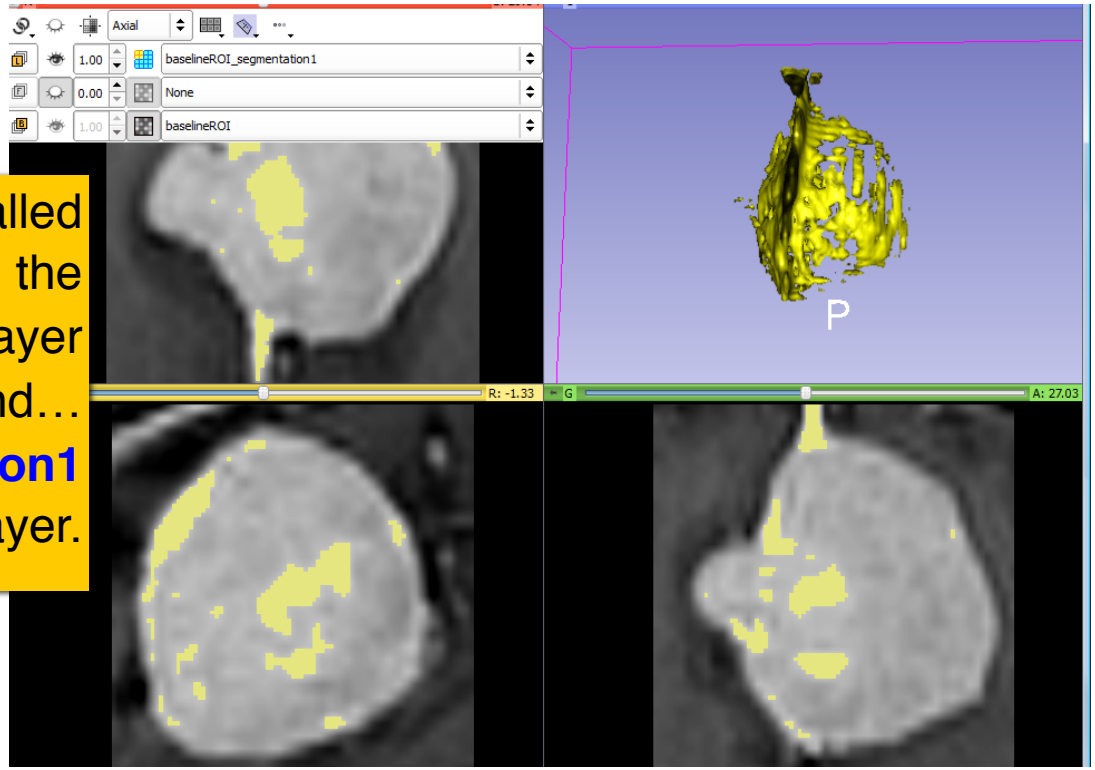


ChangeTracker: Step 2: Define a volume of interest

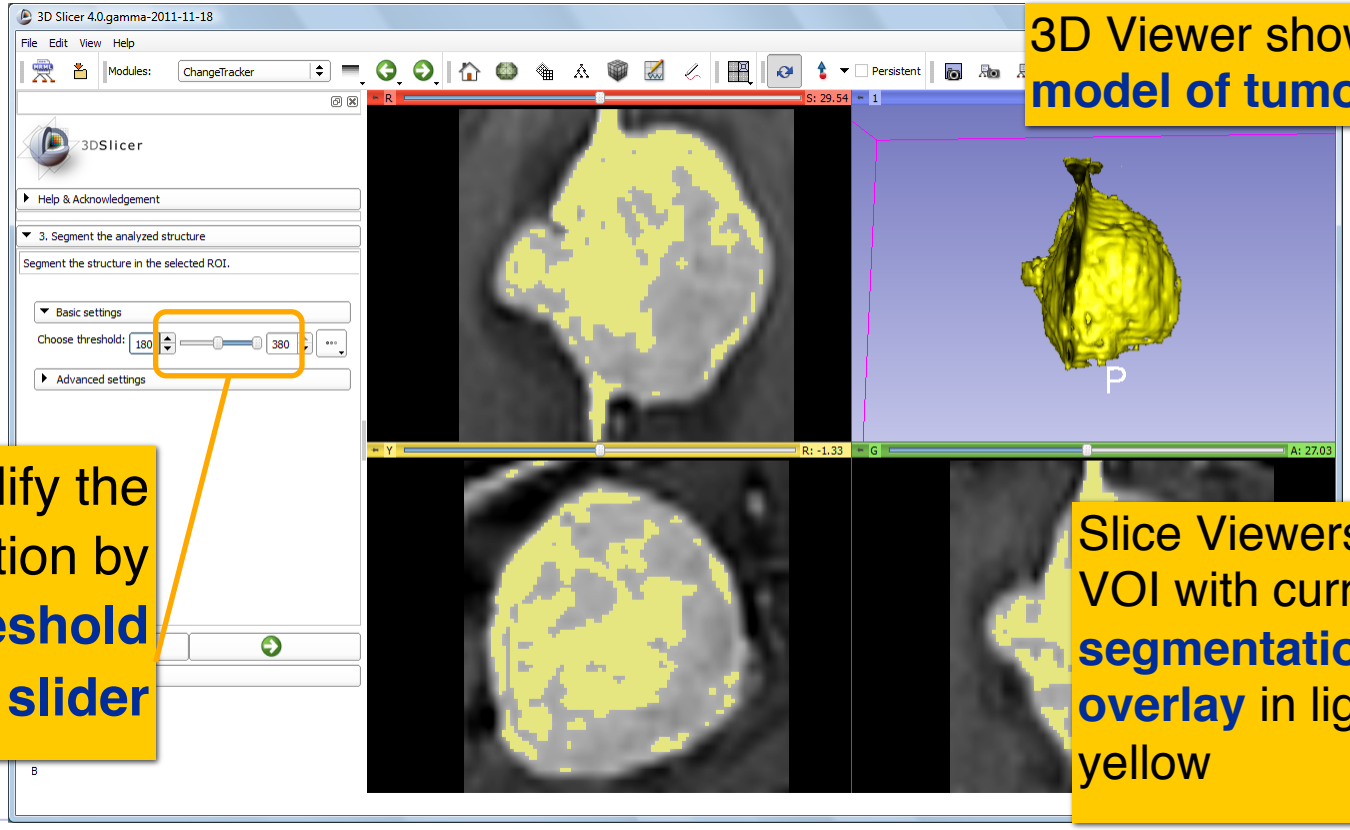
You should see a volume called **a Baseline ROI** selected in the **background** layer

...and…

a BaselineROI_segmentation1 selected in the **label** layer.



ChangeTracker: Step 3: Segment the tumor



3D Viewer shows **model of tumor**

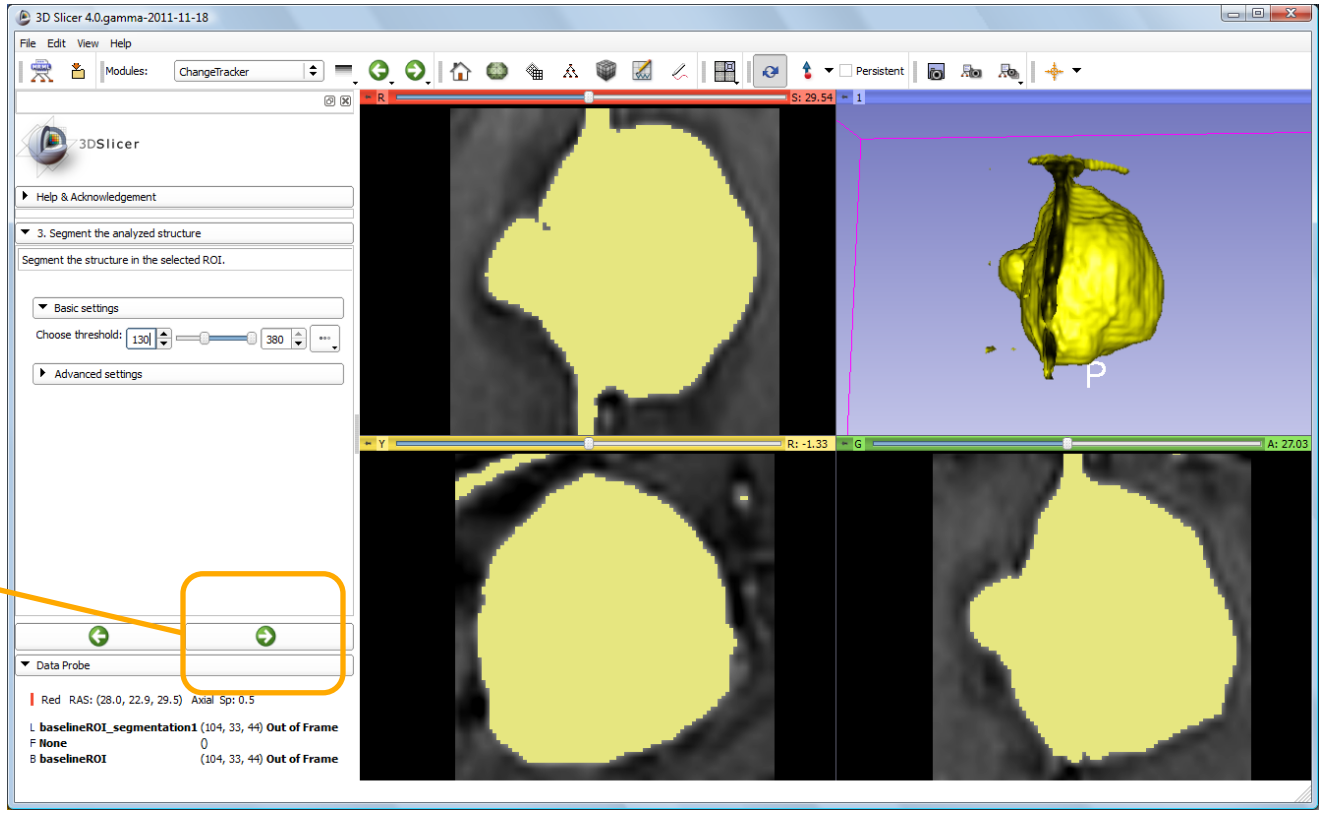
Modify the segmentation by moving **threshold range slider**

Slice Viewers show VOI with current **segmentation overlay** in light yellow

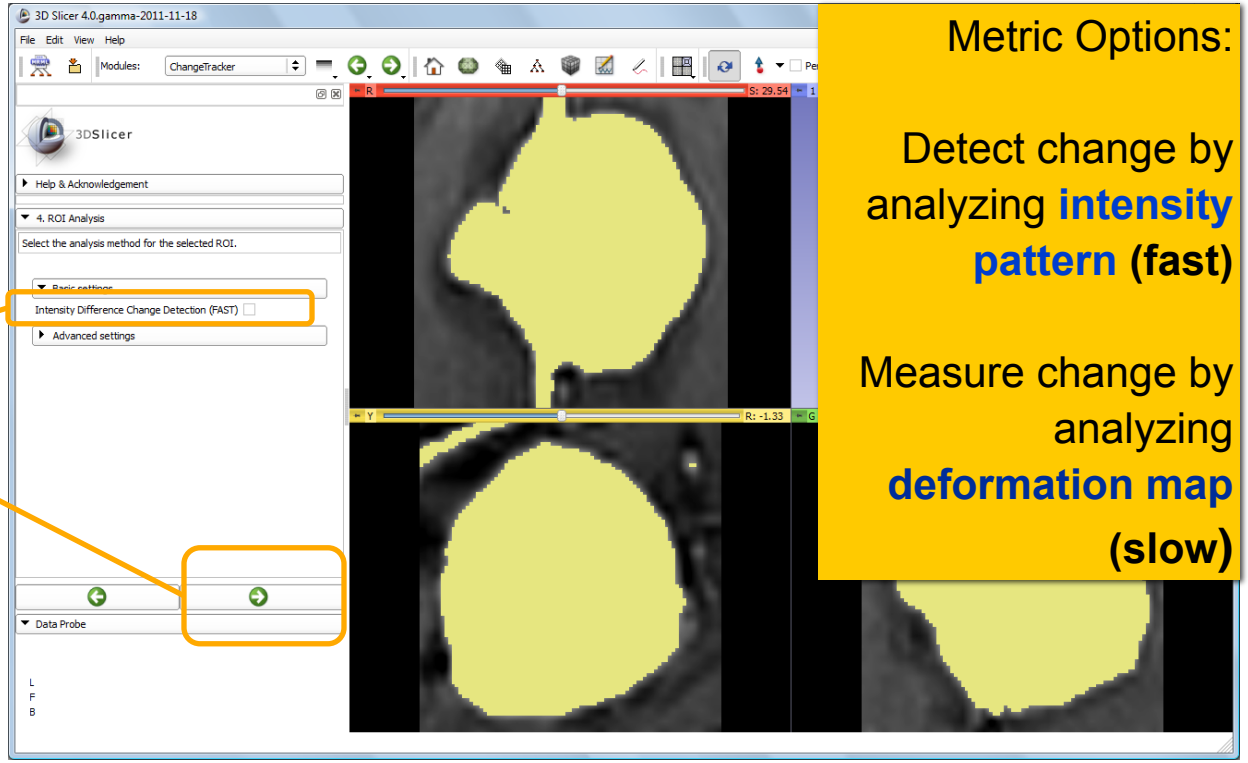
ChangeTracker: Step 3: Segment the tumor

Scroll through the slices until the segmentation appears optimal.

Press **Next**.



ChangeTracker: Final step: Select Metric



Select **fast** and press **Next**

Metric Options:

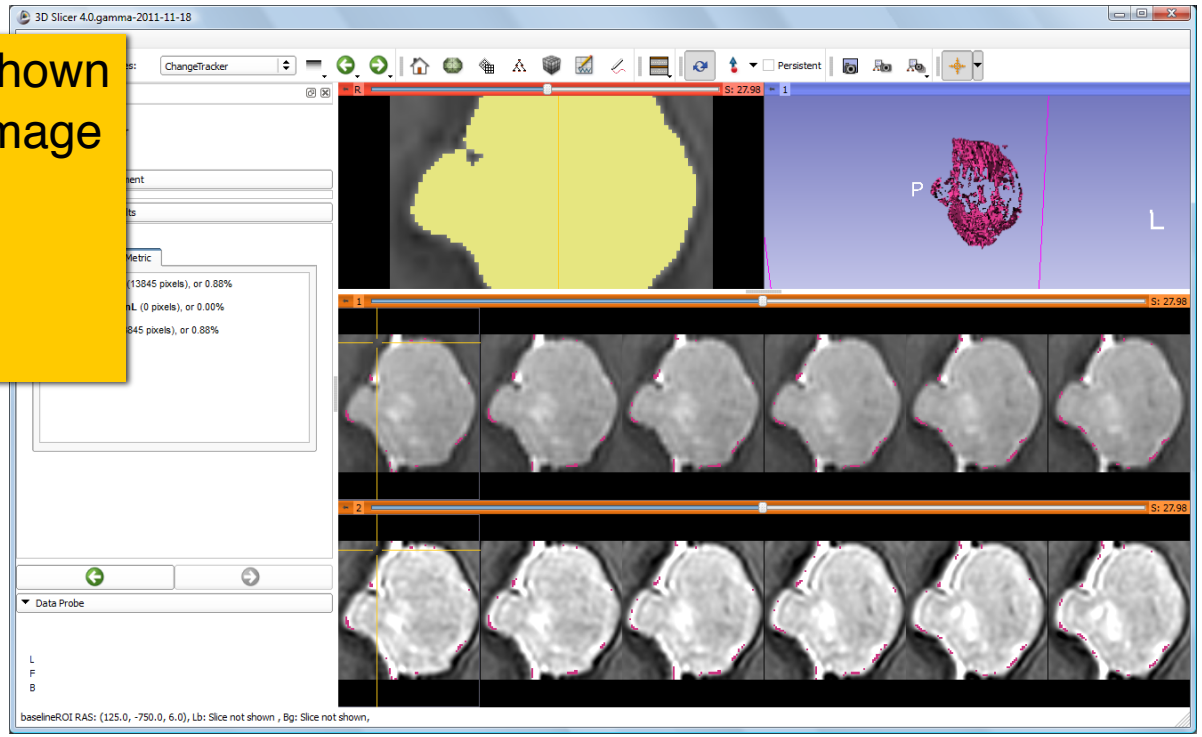
Detect change by analyzing **intensity pattern** **(fast)**

Measure change by analyzing **deformation map** **(slow)**

ChangeTracker: Results: change in pathology

Change in volume is shown overlaying the tumor image and in the 3D Viewer:
magenta = growth
green = shrinkage

Note: Analysis is displayed in the **"Compare View"** layout with linked control for the compare Viewers.



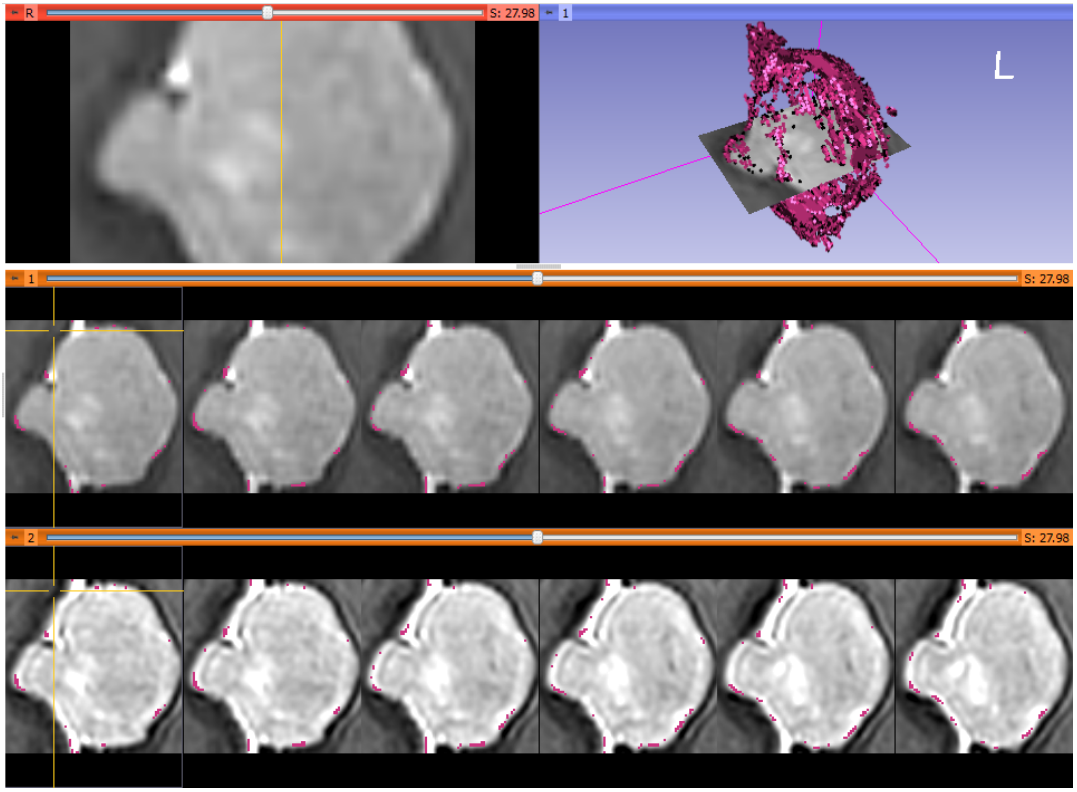
ChangeTracker: Results: change in pathology

Select **visibility icon**  to **show axial slice** in the 3D Viewer.

ChangeTracker: Results: change in pathology

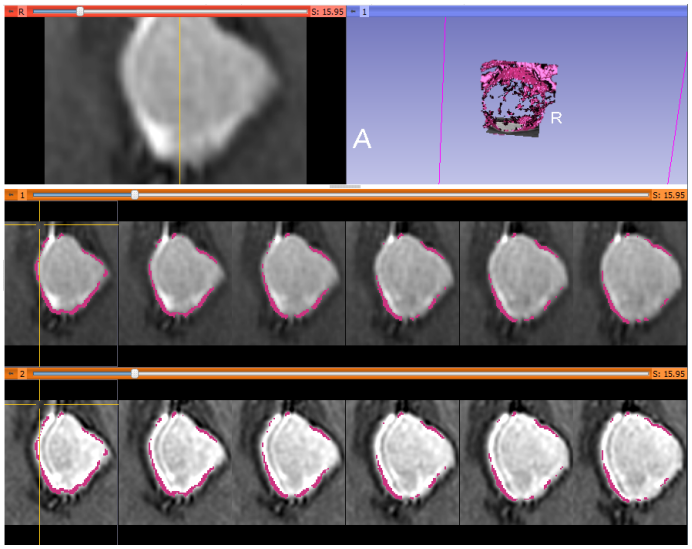
"Compare View" layout displays:

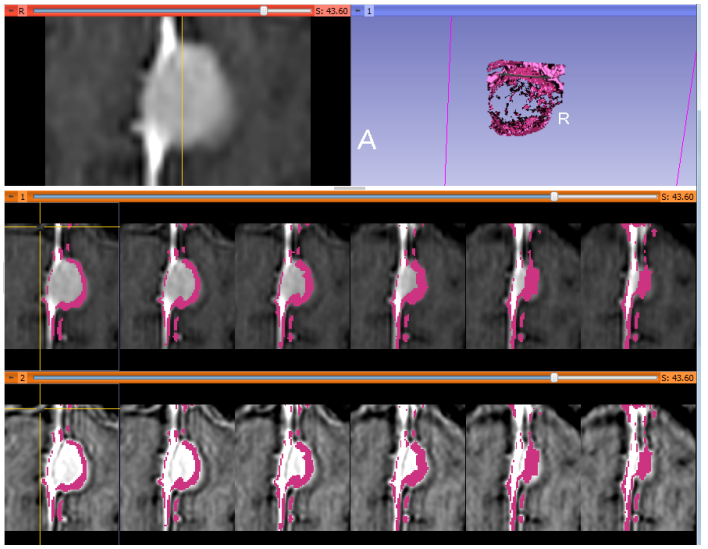
- Axial slice & 3D View
- Five corresponding consecutive slices for the VOI in Scan1 **(top row)**, and
- in the Scan2 **(bottom row).**



ChangeTracker: Results: change in pathology

Crosshairs in Compare View show corresponding voxels in **Scan1** and **Scan2** for voxel-wise comparison.





ChangeTracker: Exploring small volumetric changes

Tested on Axial 3D SPGR T1 post Gadolinium scans (Voxel dimension: 0.94mm x 0.94mm x 1.20mm, FOV: 240mm, Matrix: 256 x 256).

Tumor boundary should be clear.

Only for contrast enhanced images.

Need homogenous enhancement across time points.

Not tested for tumors with changing necrosis.

Correspondence between Intensity-based and deformation mapping-based analyses should be checked.

ChangeTracker: Exploring small volumetric changes

This tutorial demonstrated:

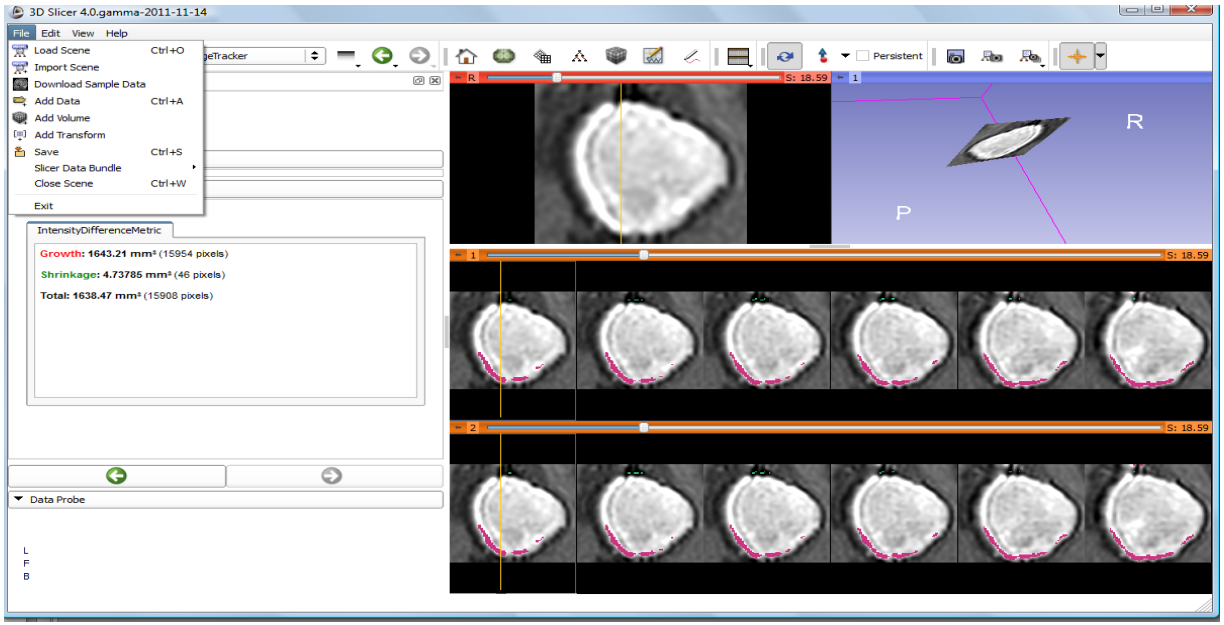
- a method to quantify small volumetric changes in pathology.
- visualization of these changes in the anatomical context
- use of Slicer's "**Compare Viewer**" to simultaneously explore baseline and follow-up studies.

Clear the scene and its data

Clear the previous scene.

Select **File->Close Scene**

This removes any datasets previously loaded into Slicer.



Workshop summary

- **This workshop has demonstrated:**

- Basic scene loading and visualization using 3D Slicer

- Workflow to make quantitative measurements of SUV (body weight) in Slicer

- Use of Slicer's ChangeTracker module to assess small changes in tumor size

Thank you and more information

- **Thank you for your attendance!**
- Tutorial Slides and Data:
  www.na-mic.org/Wiki/index.php/RSNA_2011
- Tutorial Software:
  www.slicer.org/Downloads
- More Information: http://www.slicer.org

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Harvard Clinical and Translational Science Center