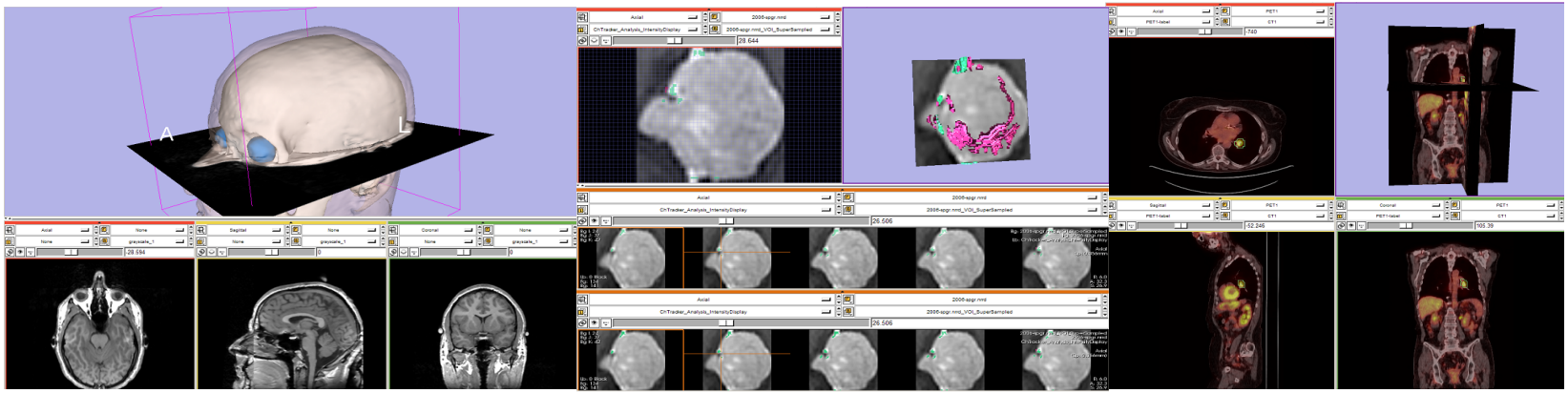
Quantitative Analysis and Visualization with 3D Slicer



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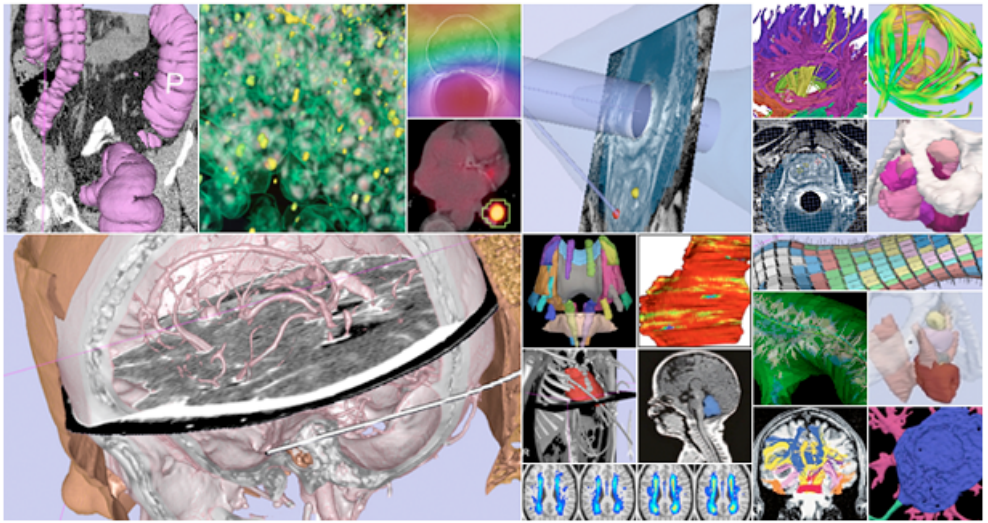
Andriy Fedorov, Ph.D.

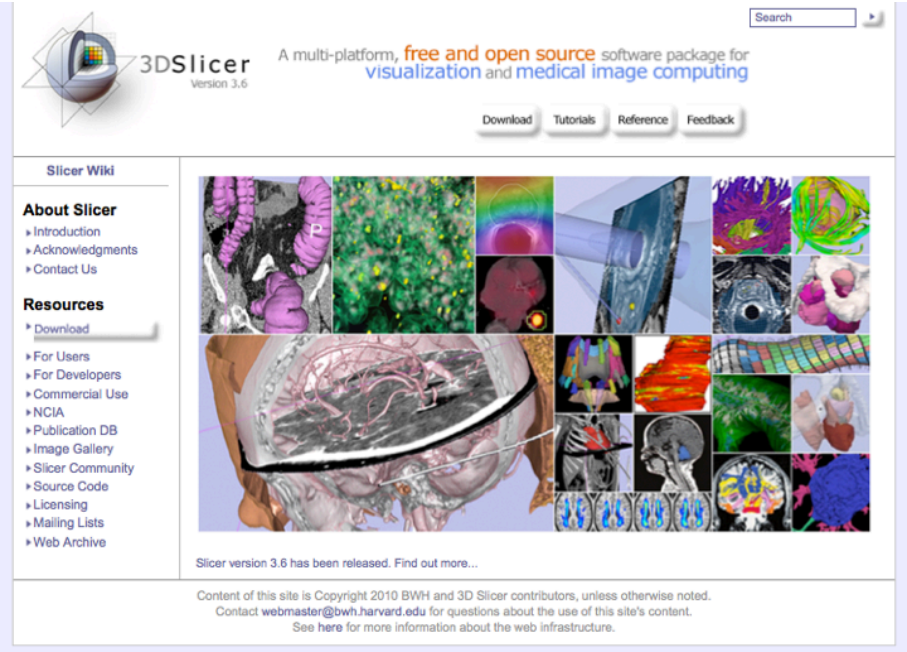
3DSlicer

- 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



3DSlicer

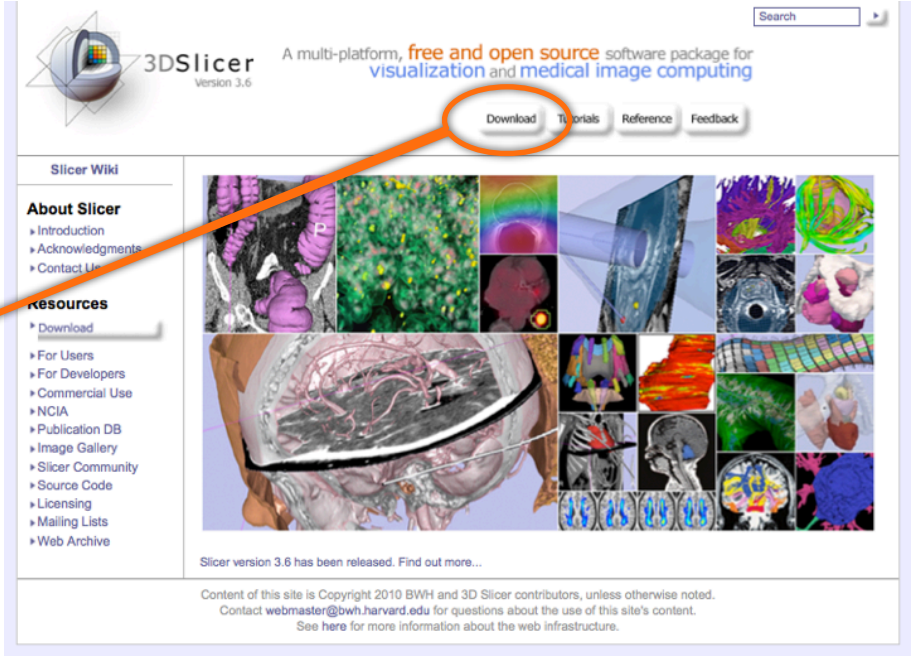
3D Slicer version 3 is a multi-platform software running on Windows, Linux, and Mac OSX.



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.

- This workshop uses the newest release of 3D Slicer (version 3.6.2).
- Visit the **Slicer download page** for Slicer 3.6 stable release, or for Slicer nightly builds.



Tutorial Overview

- Getting Started: **Slicer3 Minute Tutorial**
- Quantitative Measurement of Volumetric Change: **ChangeTracker Tutorial**
- Quantitative Measurements for Functional Imaging: **PETCTFusion Tutorial**

All Tutorial Datasets are located in C:\slicer_data

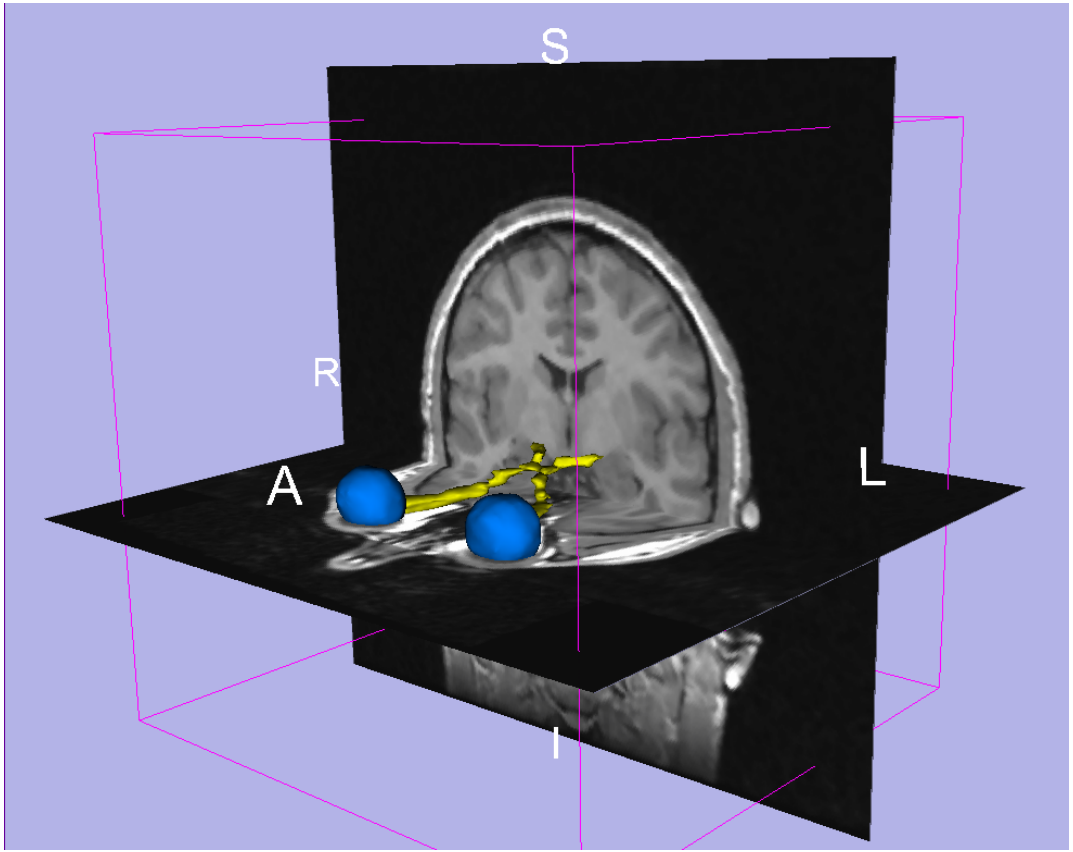
Slicer3 Minute Tutorial

Part I: Slicer3 Minute Tutorial

Sonia Pujol, PhD
Wendy Plesniak, PhD

This tutorial is a short introduction to the advanced 3D visualization capabilities of the Slicer3 software for medical image analysis.

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



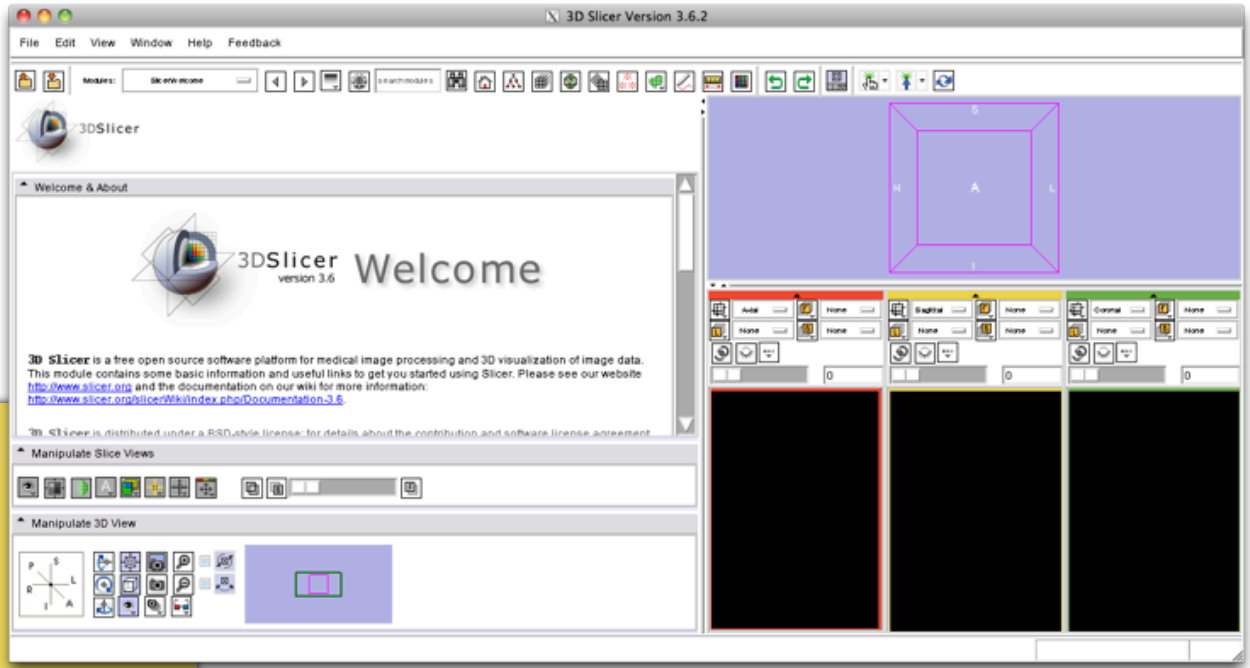
Slicer3 Minute Tutorial

- The Slicer3minute 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

Slicer3 Minute Tutorial: Launch the Application



Windows users:

Double-Click the Shortcut to **Slicer3.exe** on the Desktop

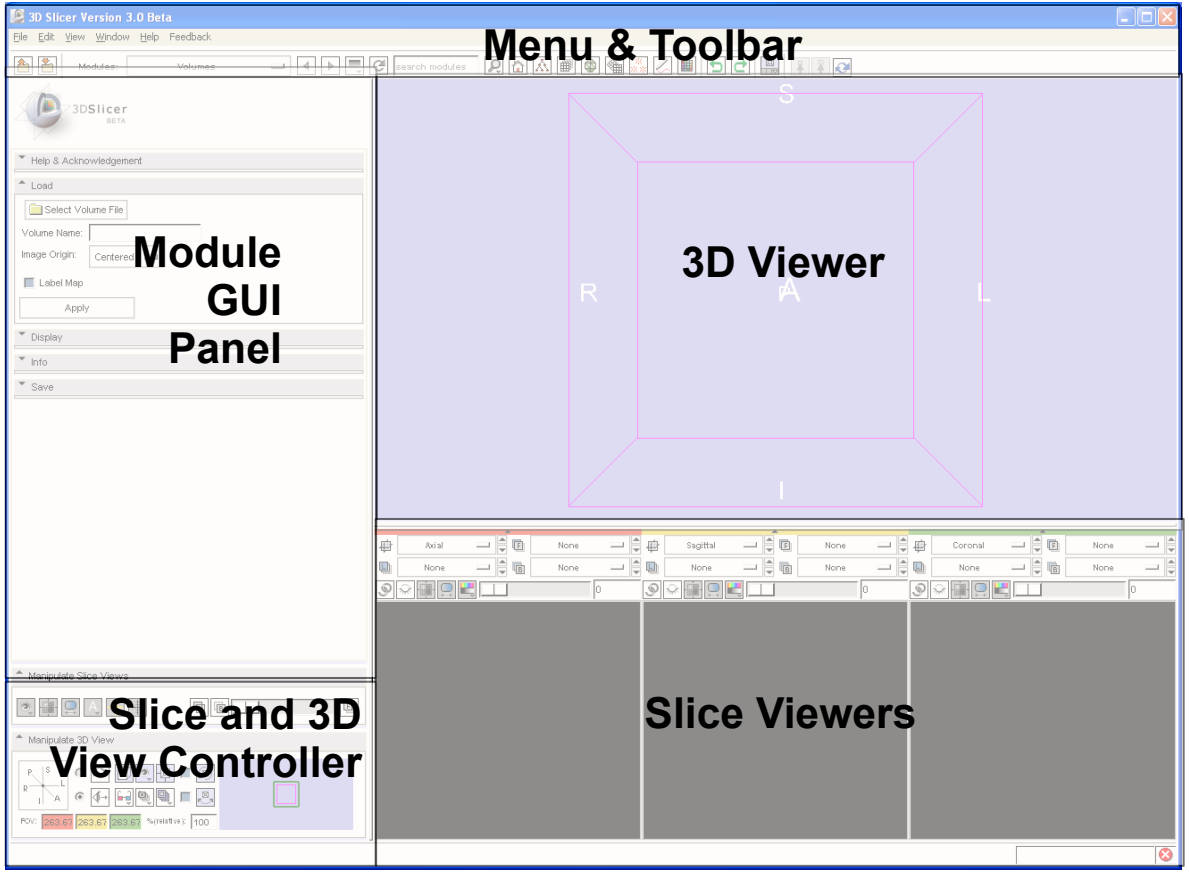
or Select

Start ->All Programs ->Slicer3 3.5.2009-11-06->Slicer

Slicer3 Minute Tutorial: Navigating the Application GUI

The Graphical User Interface (GUI) of Slicer3 integrates five components:

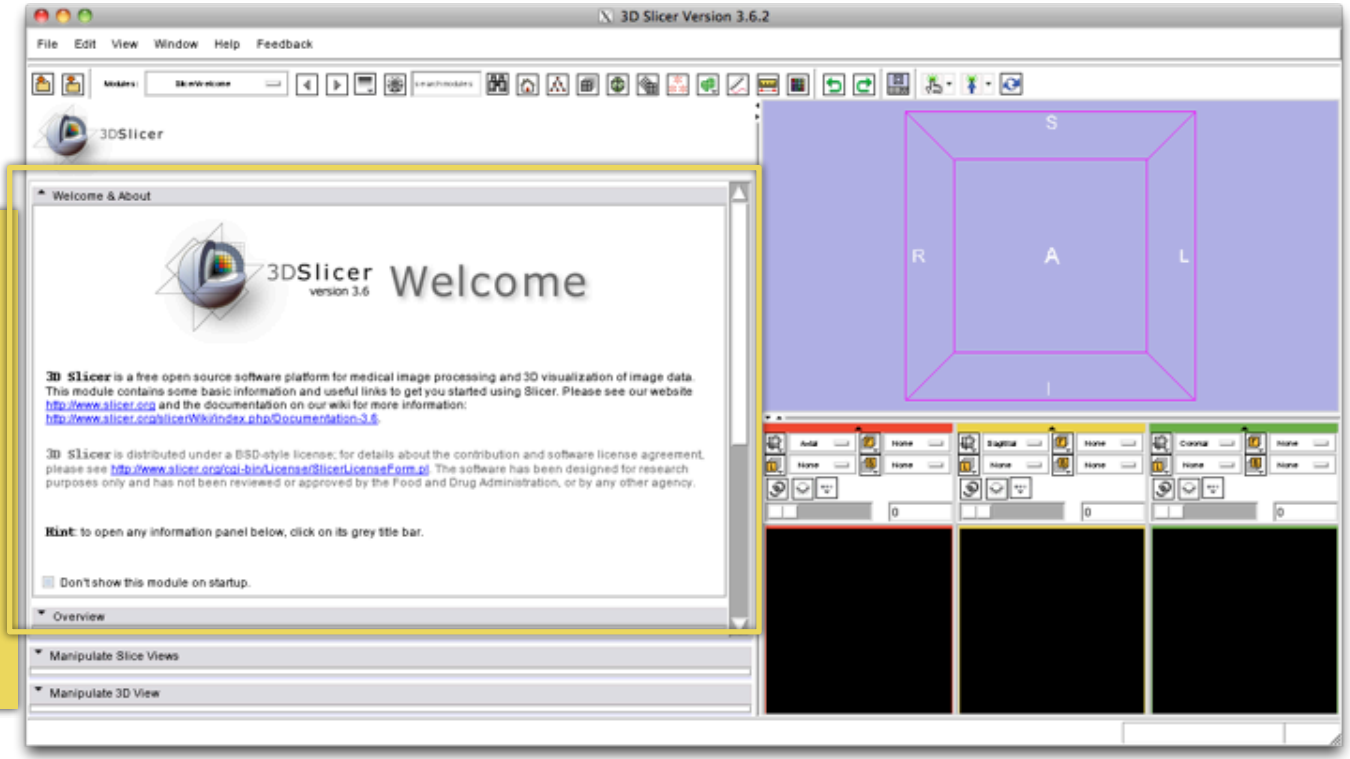
- the Menu Toolbar
- the Module GUI Panel
- the 3D Viewer
- the Slice Viewer
- the Slice and 3D View Controller



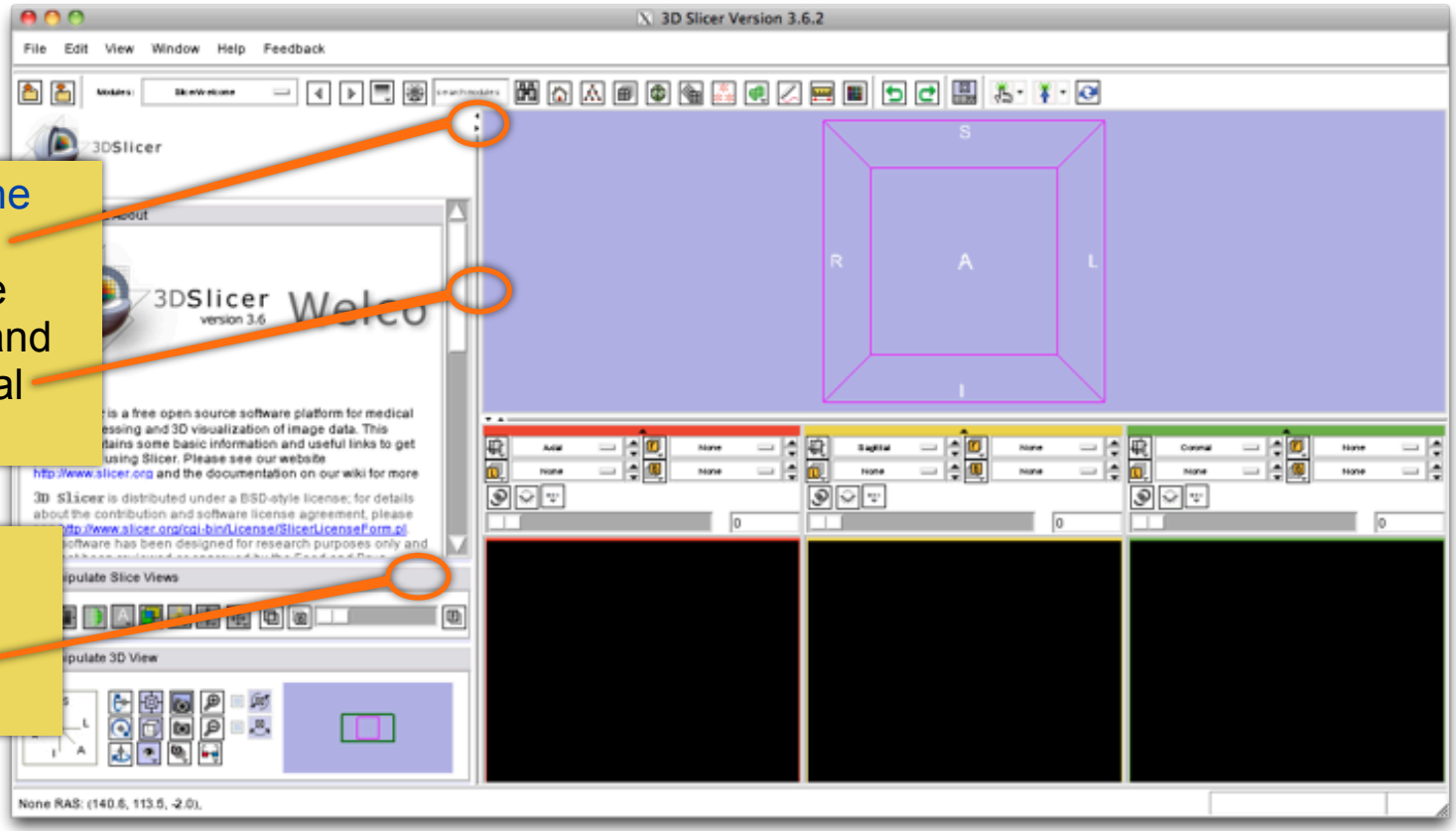
Slicer3 Minute Tutorial: Welcome Module

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

This module gives an overview of the GUI of Slicer3, and data loading & saving functionalities.



Slicer3 Minute Tutorial: GUI Basics



Expand or shrink the GUI panel with the arrows at the frame top, or by clicking and dragging the vertical separator

Expand or collapse any sub-panel by clicking on its grey title bar.

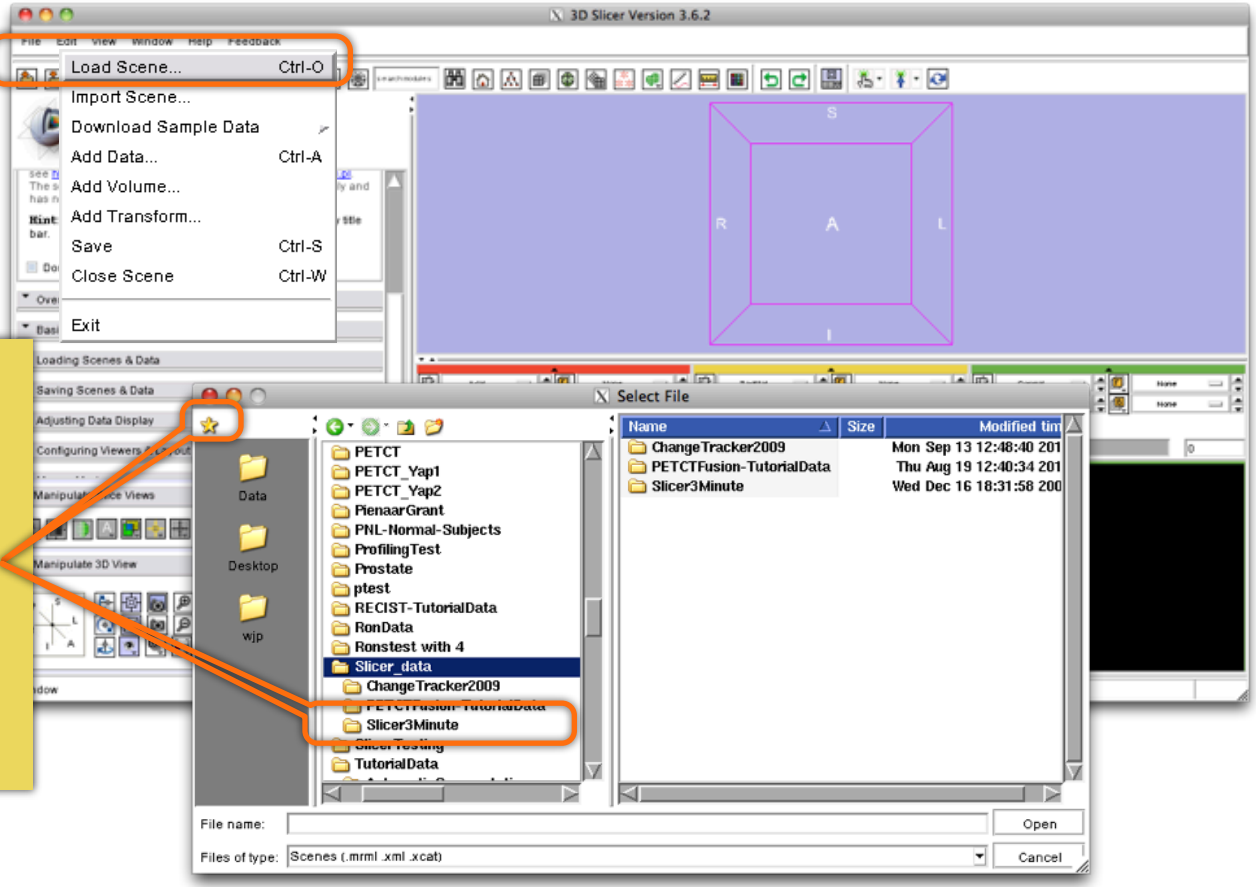
Slicer3 Minute Tutorial: Load A Scene

Select **File-> Load Scene** from the File menu

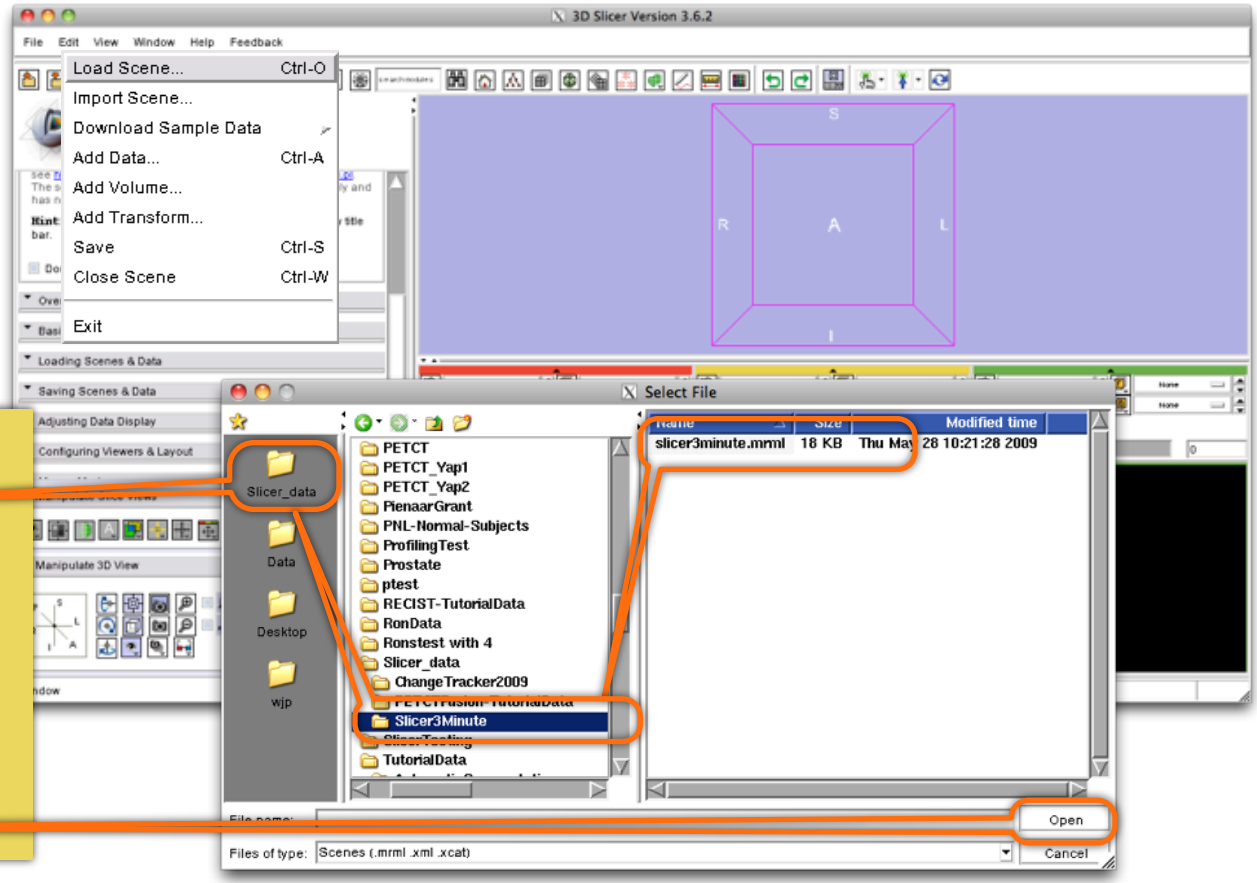
Browse to the location of the **Slicer_data** directory.

Select that directory and select the **Add To Favorites** icon

This will make the directory easier to find later...



Slicer3 Minute Tutorial: Load A Scene



Browse to the location of the **Slicer3MinuteDataset** directory.

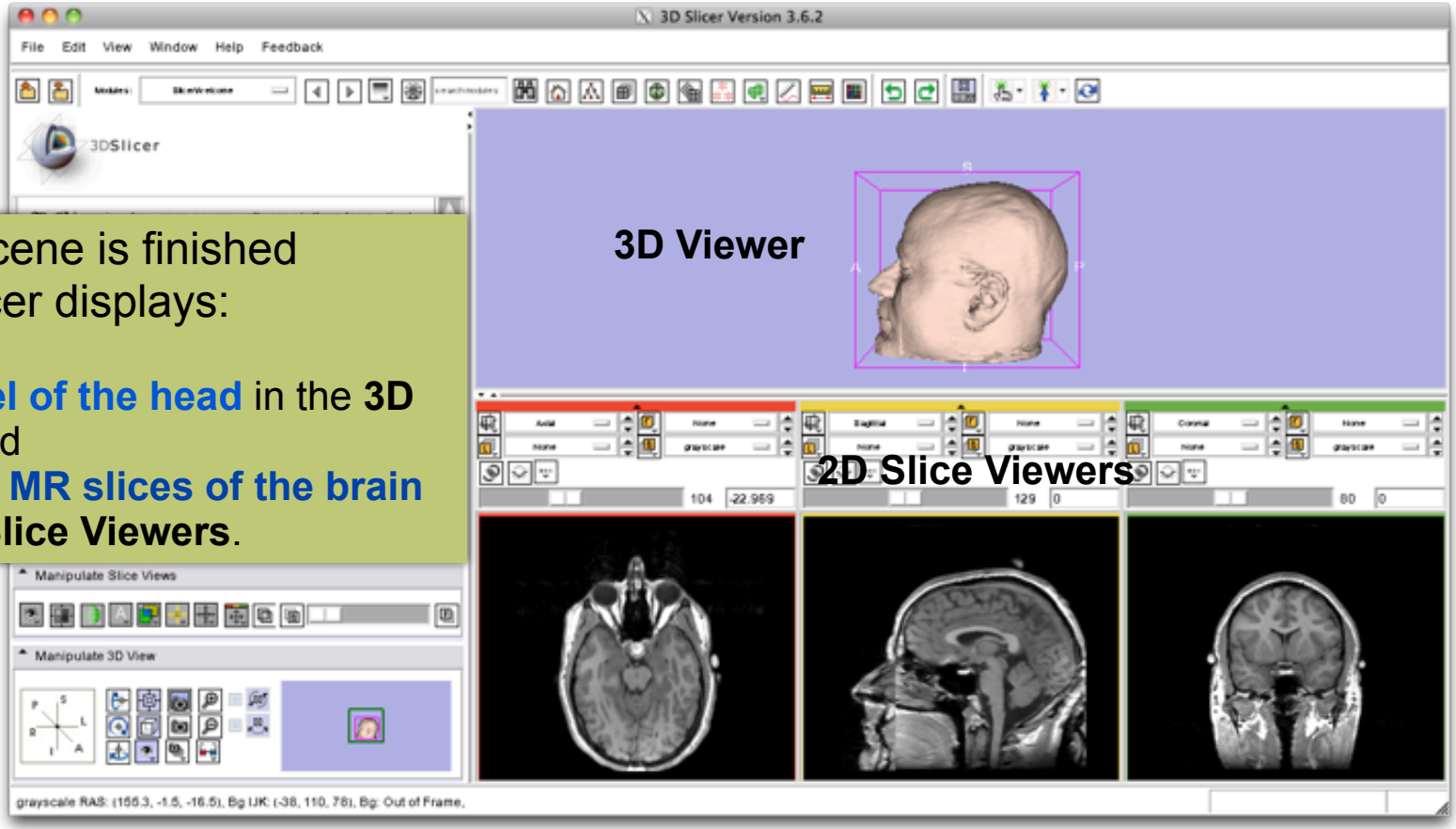
Select the scene file **slicer3minute.mrml**

Click on **Open** to load the scene

Slicer3 Minute Tutorial: Viewing the Scene

When the scene is finished loading, Slicer displays:

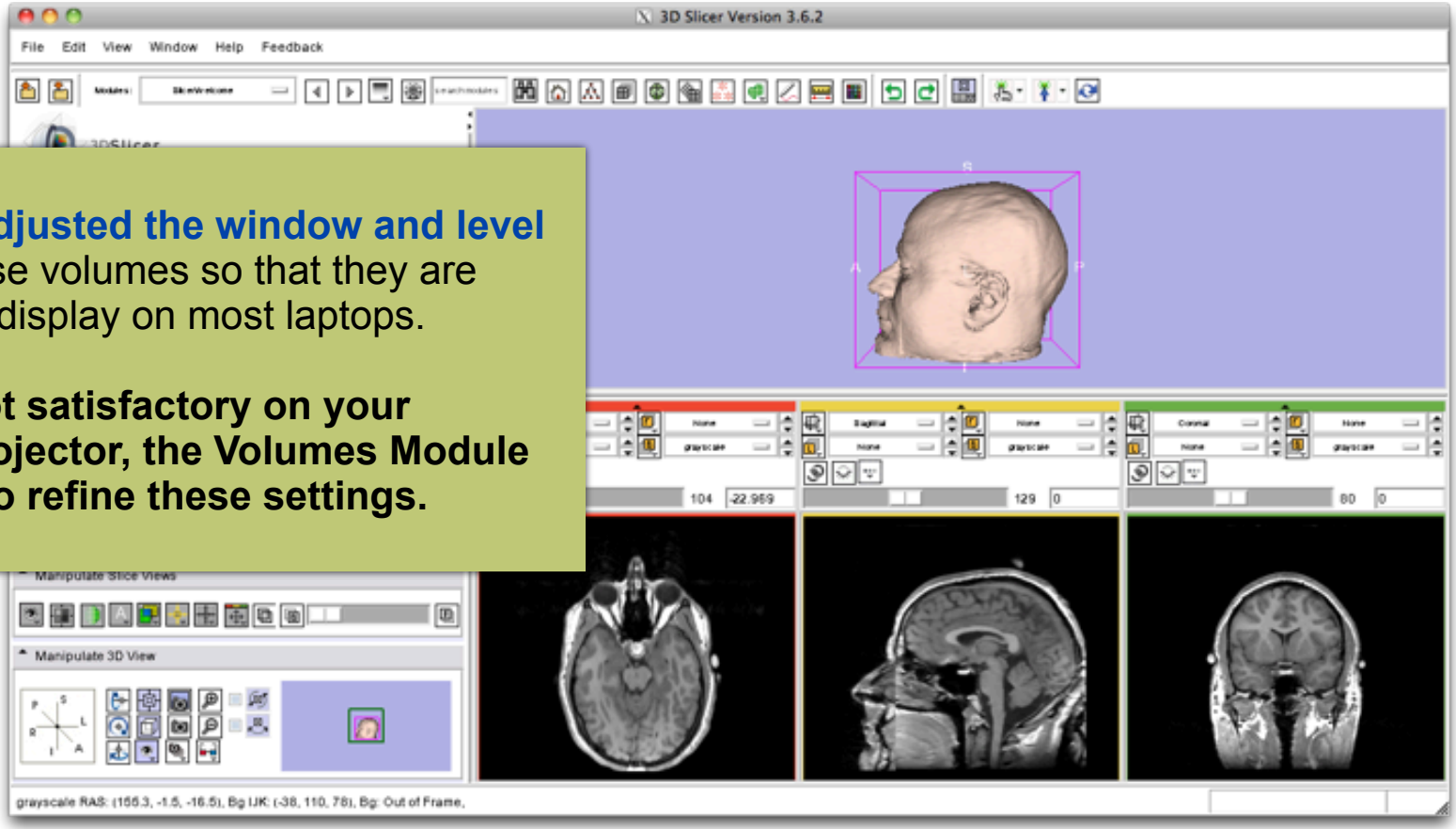
- a **3D model of the head** in the **3D Viewer**, and
- anatomical **MR slices of the brain** in the **2D Slice Viewers**.



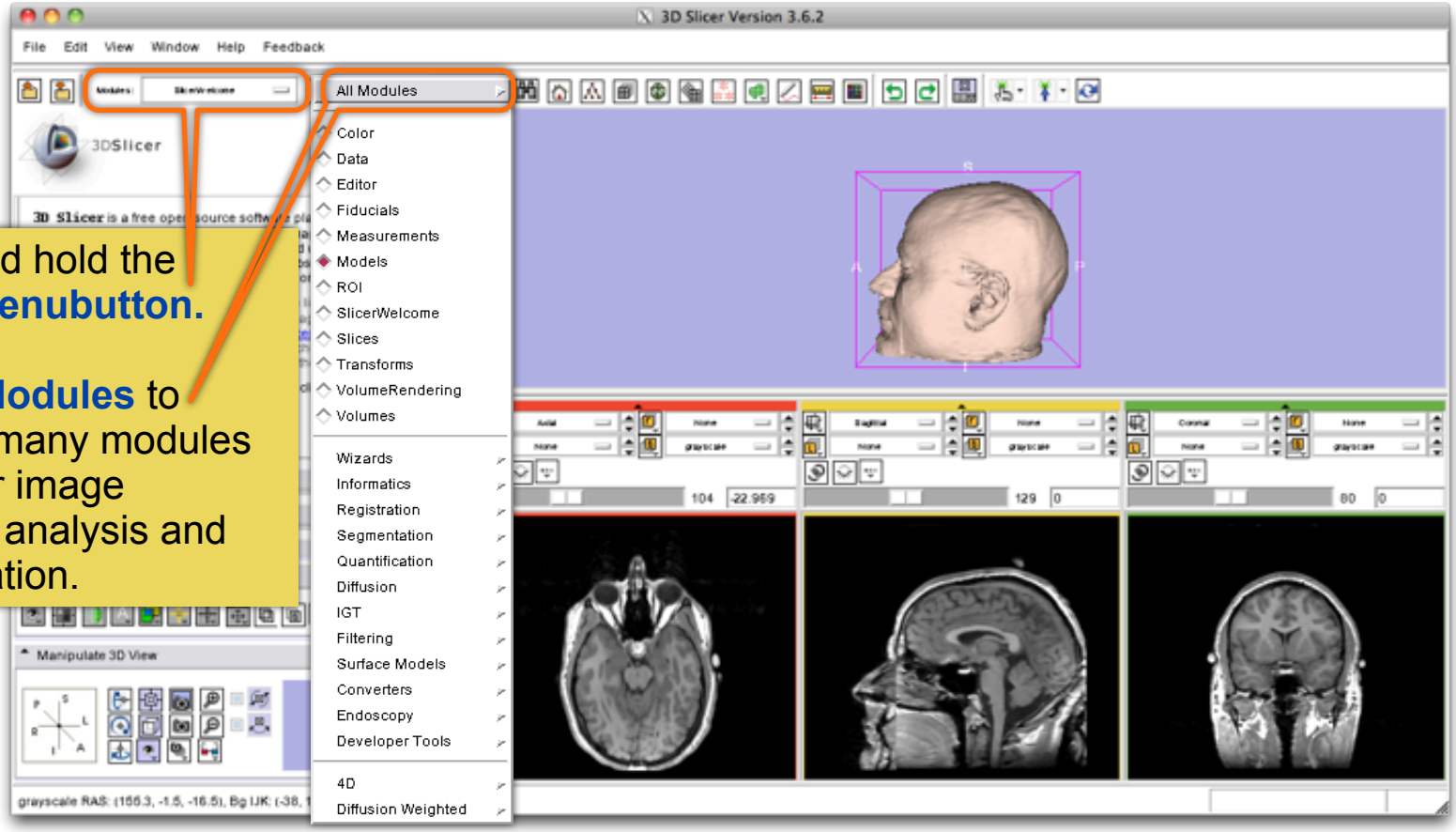
Slicer3 Minute Tutorial: Viewing the Scene

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.



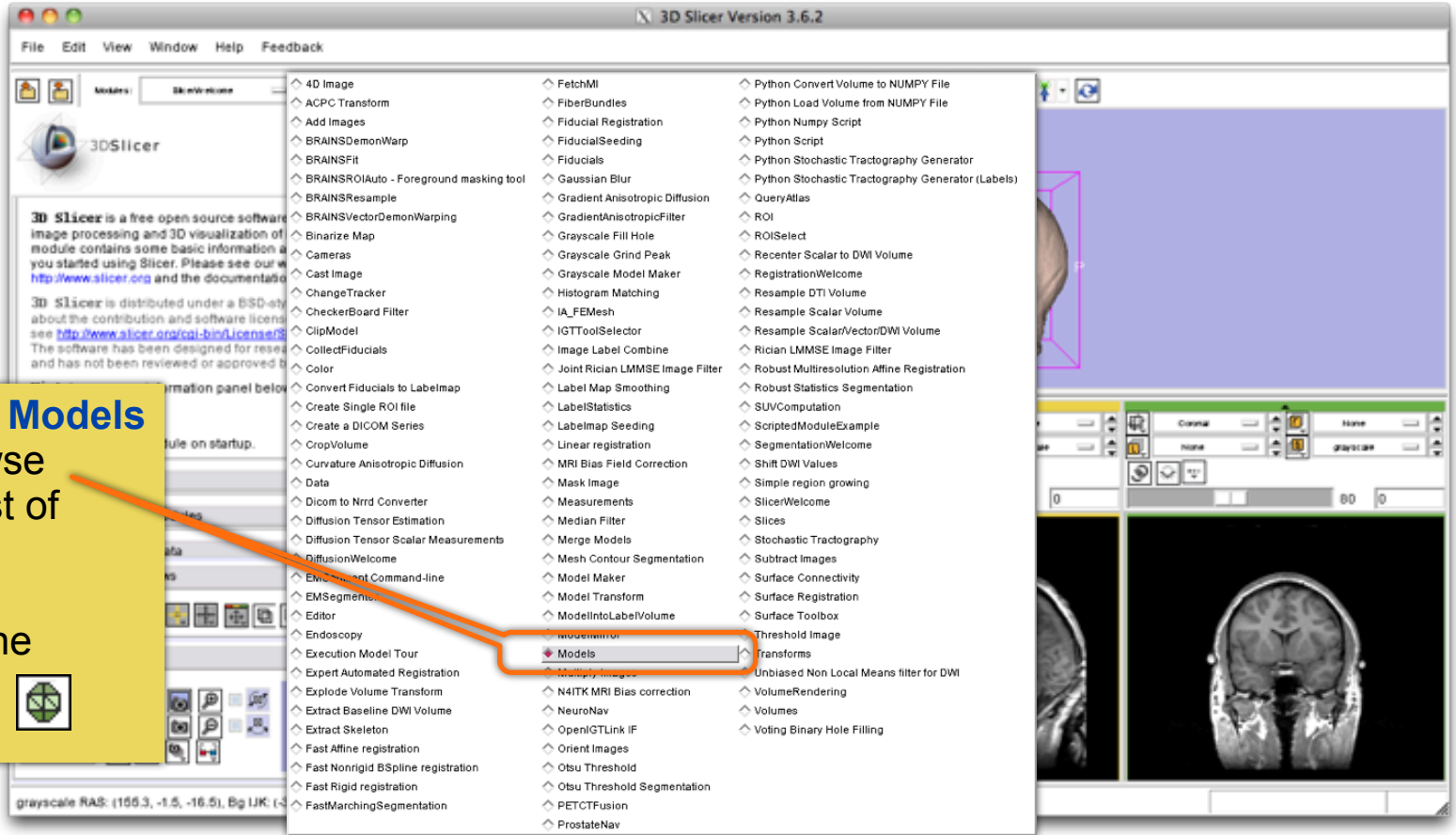
Slicer3 Minute Tutorial: Exploring Slicer's functionality



Left click and hold the **Modules menubutton.**

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

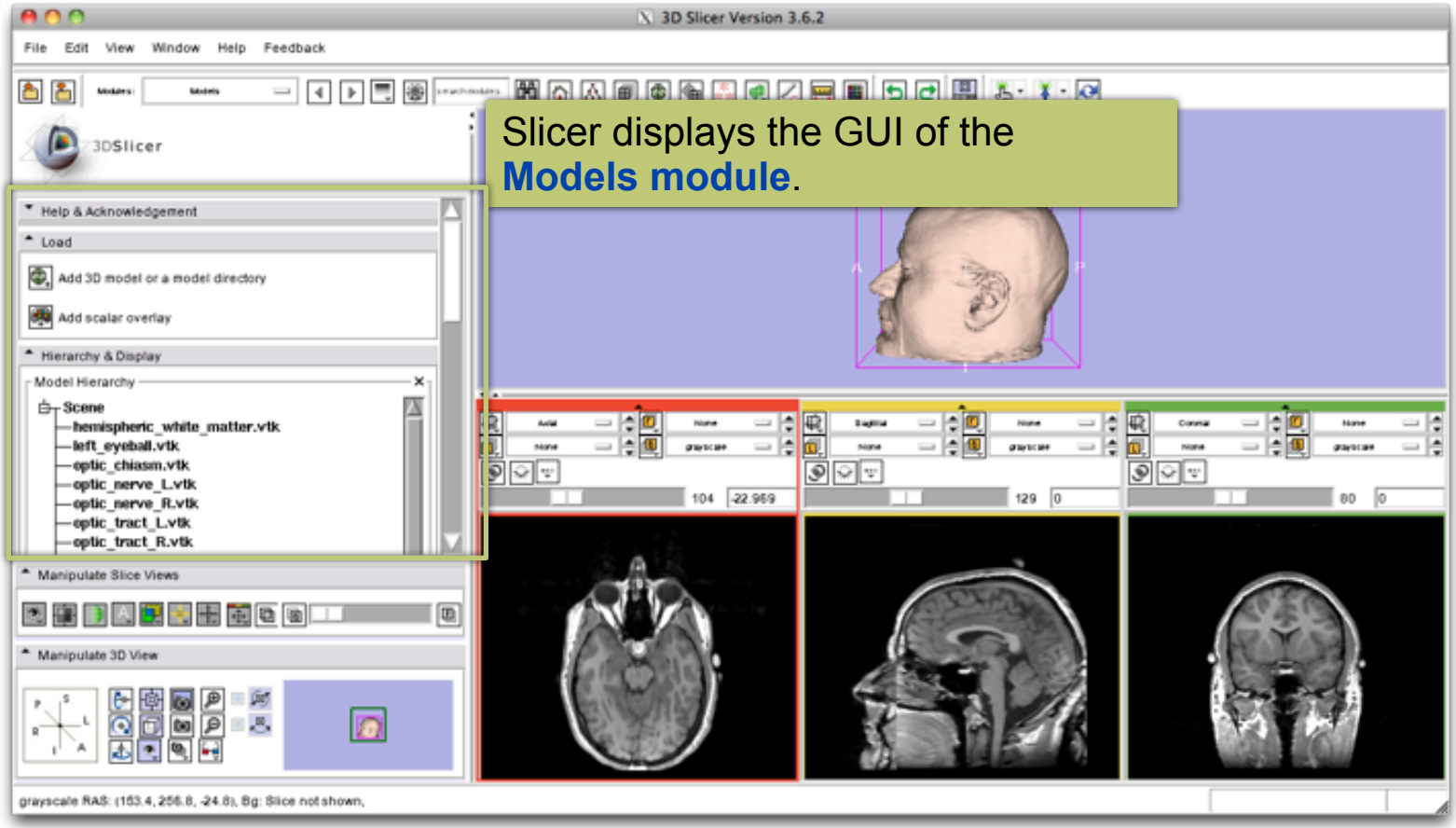
Slicer3 Minute Tutorial: Exploring Slicer's functionality



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

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

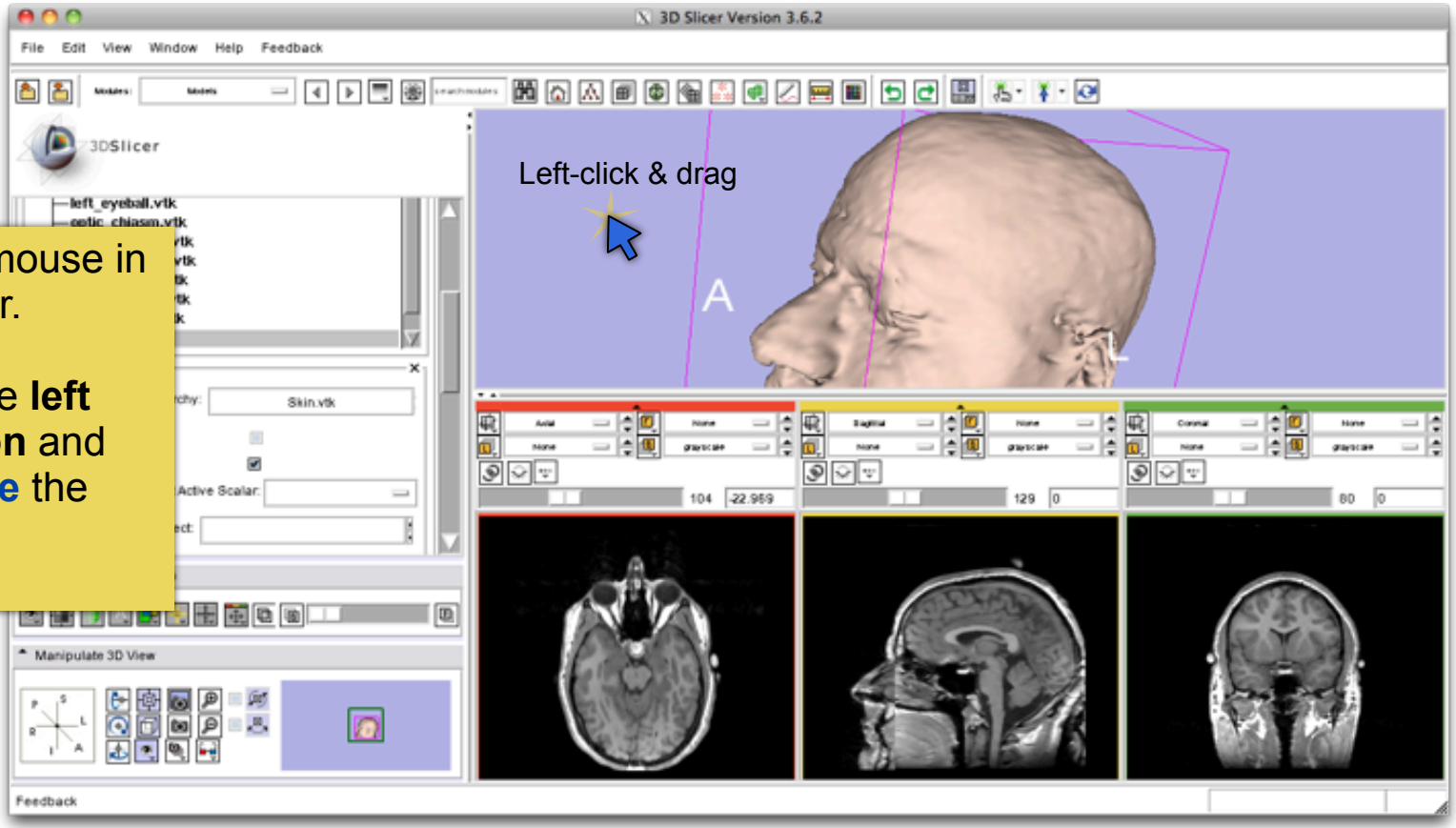
Slicer3 Minute Tutorial: Switching to the Models Module



Slicer3 Minute Tutorial: Basic 3D Interaction

Position the mouse in the 3D Viewer.

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

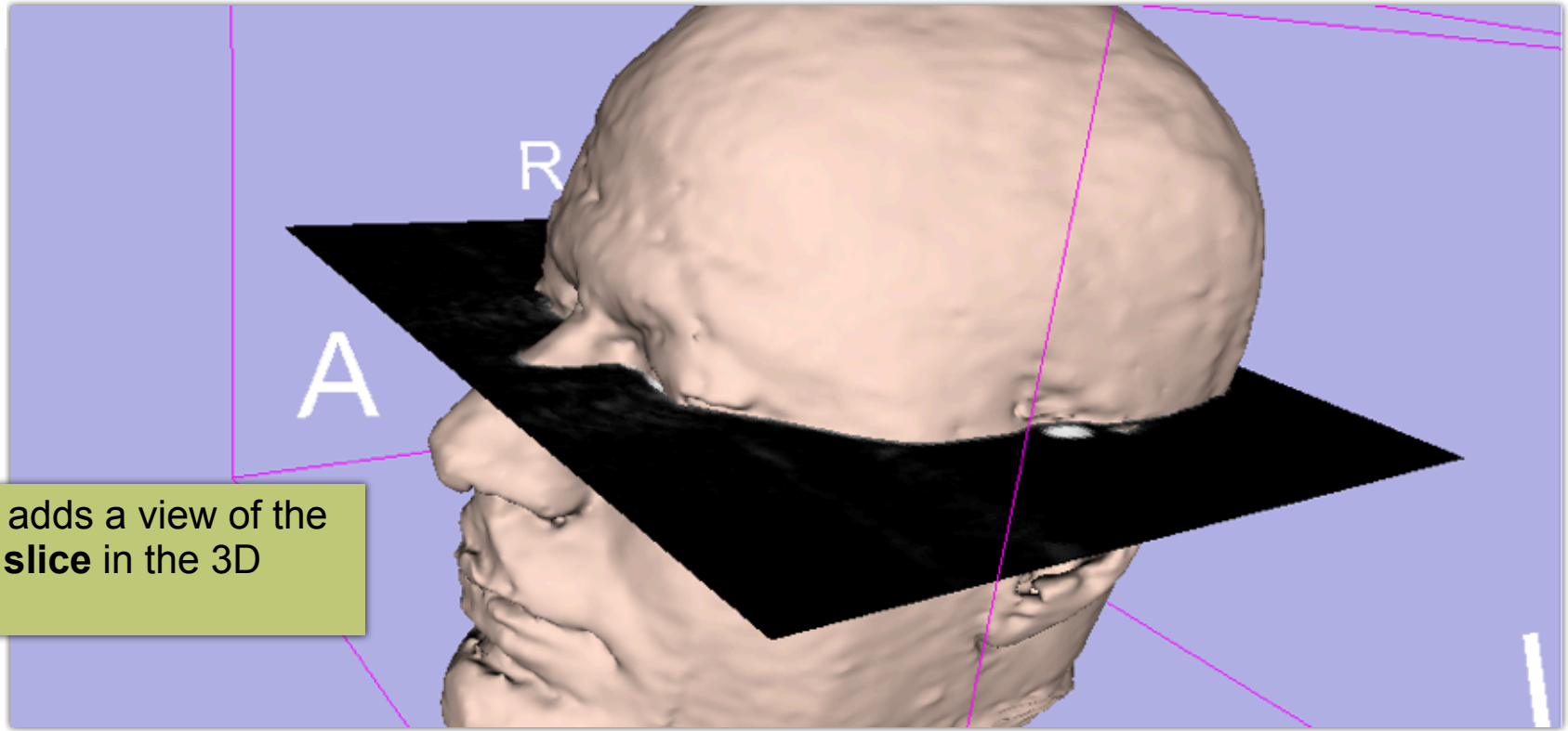


Slicer3 Minute Tutorial: Viewing Slices in the 3D Viewer

Click on the **Slice Visibility** icon

to display the Axial Slice in the 3D Viewer

Slicer3 Minute Tutorial: 3D Visualization

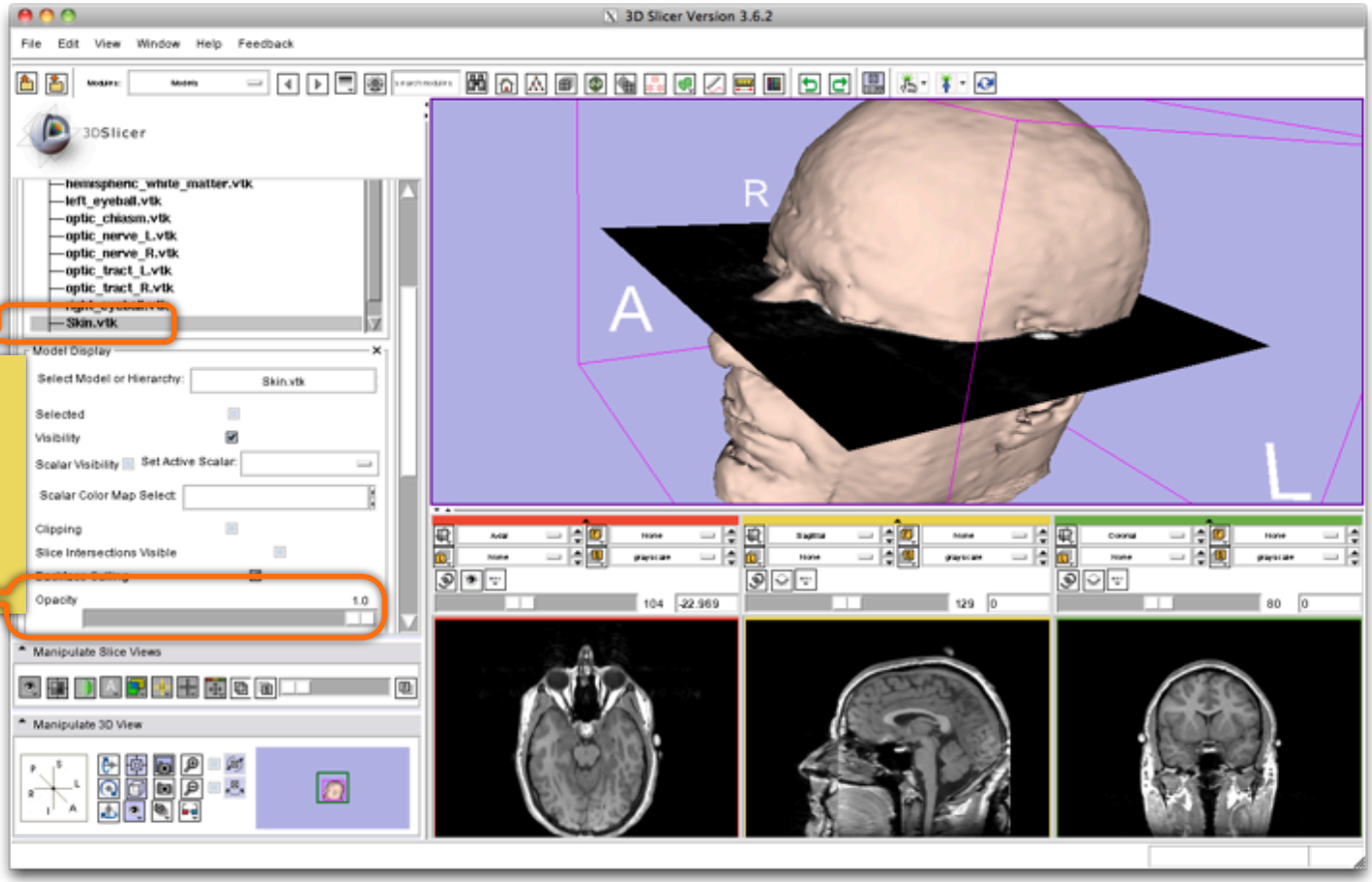


Slicer adds a view of the **Axial slice** in the 3D View.

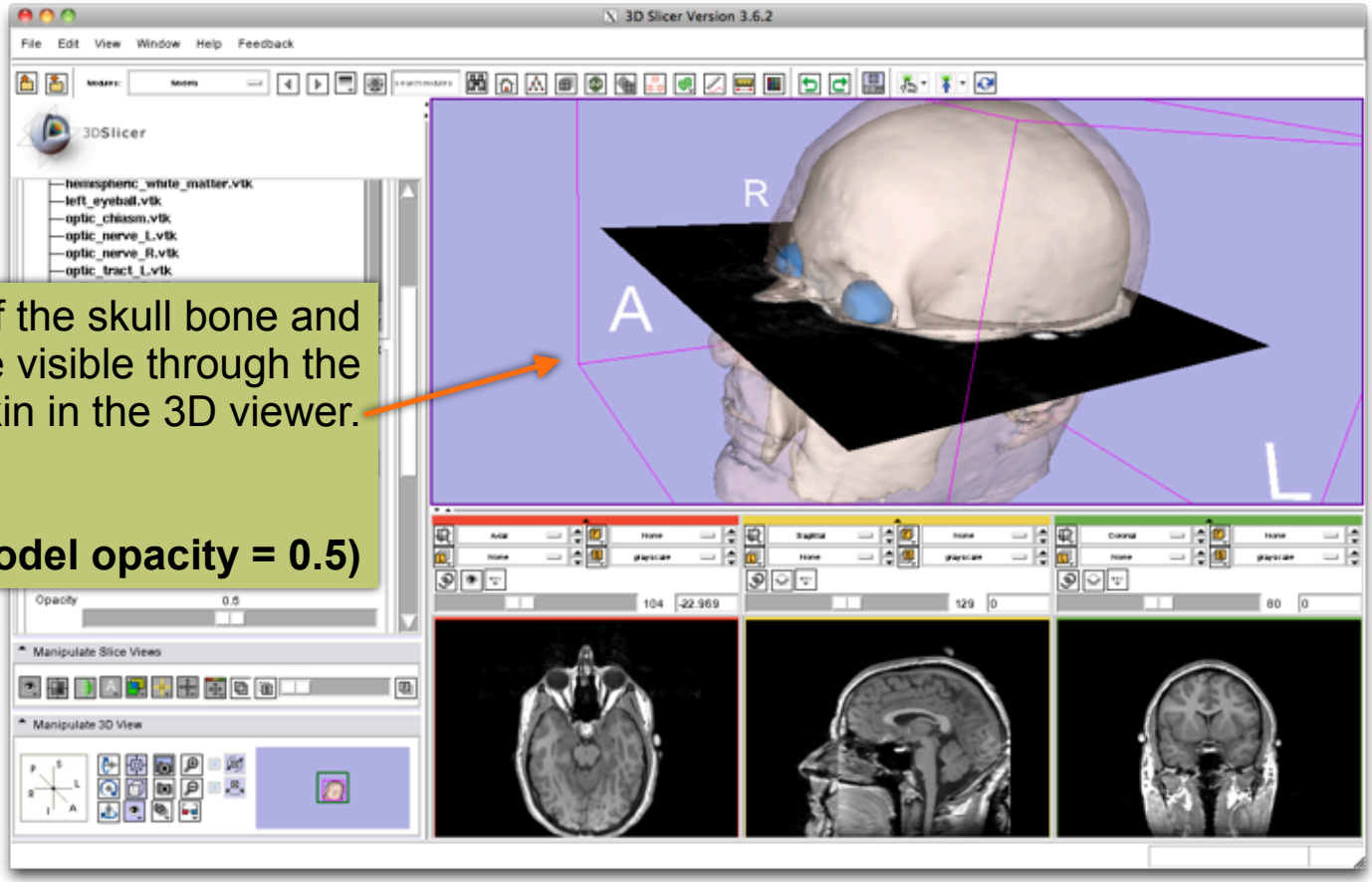
Slicer3 Minute Tutorial: 3D Visualization

Select the **Skin model**.

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



Slicer3 Minute Tutorial: 3D Visualization



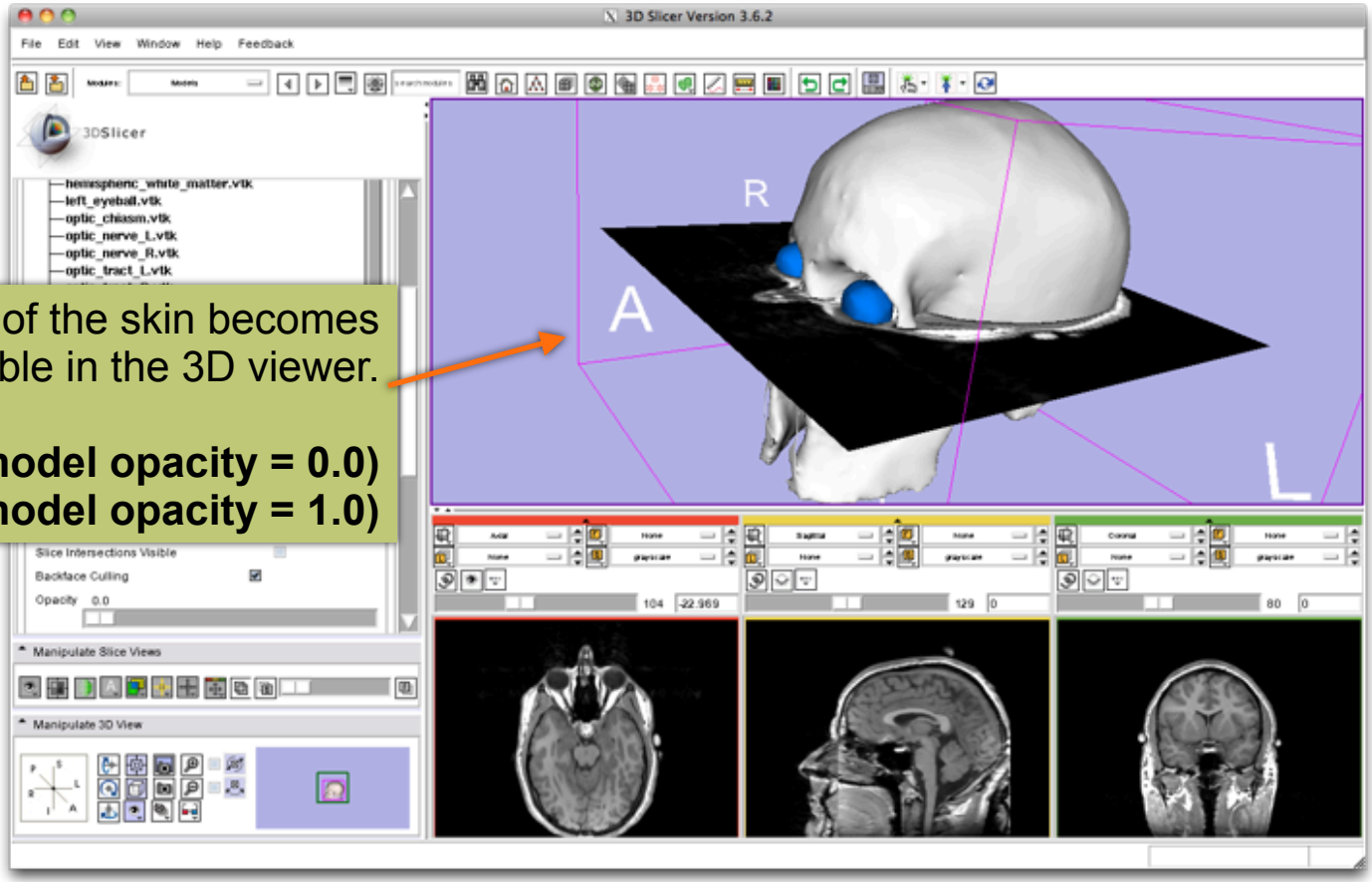
The model of the skull bone and eyeballs become visible through the model of the skin in the 3D viewer.

(skin model opacity = 0.5)

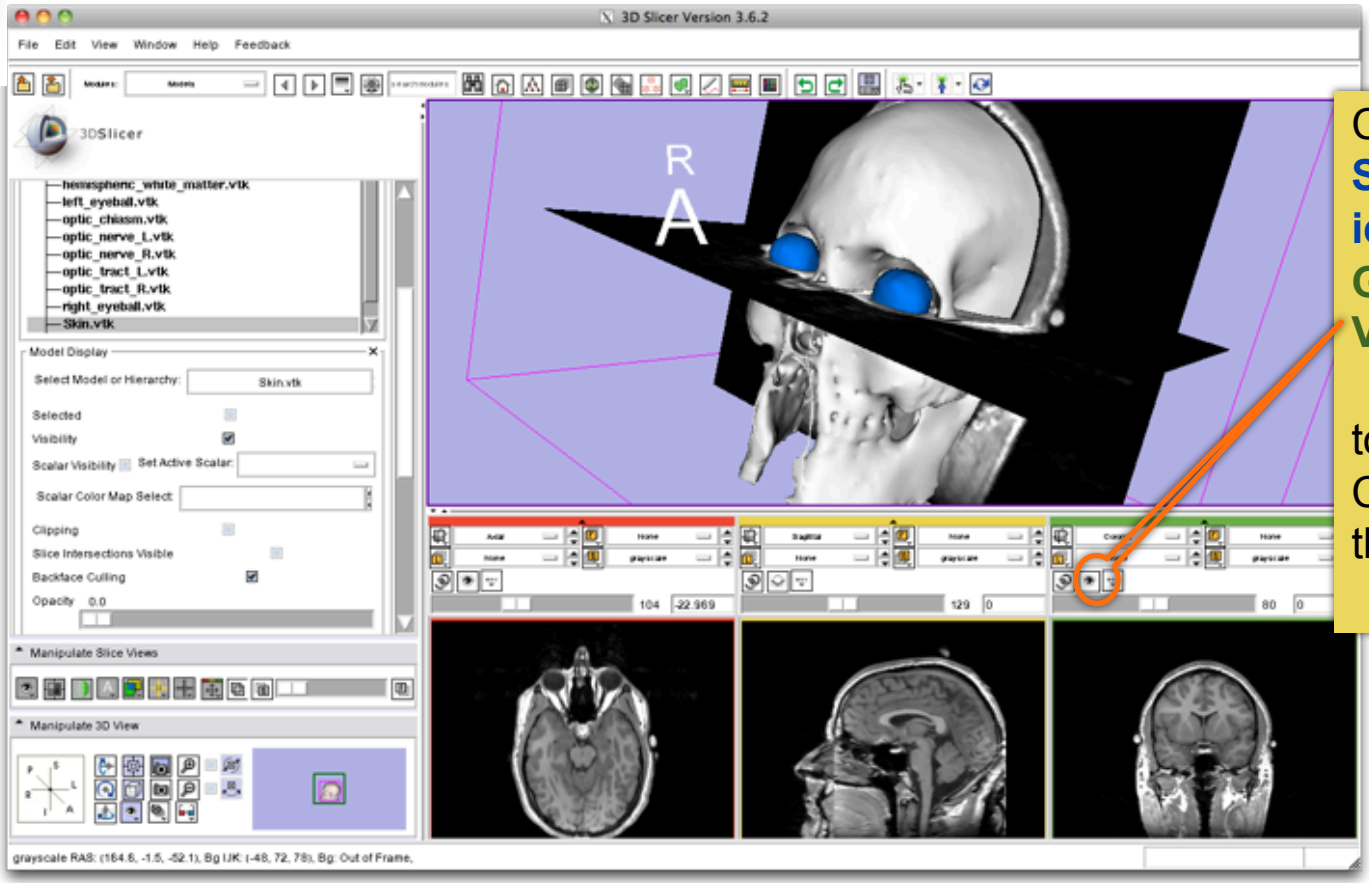
Slicer3 Minute Tutorial: 3D Visualization

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

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



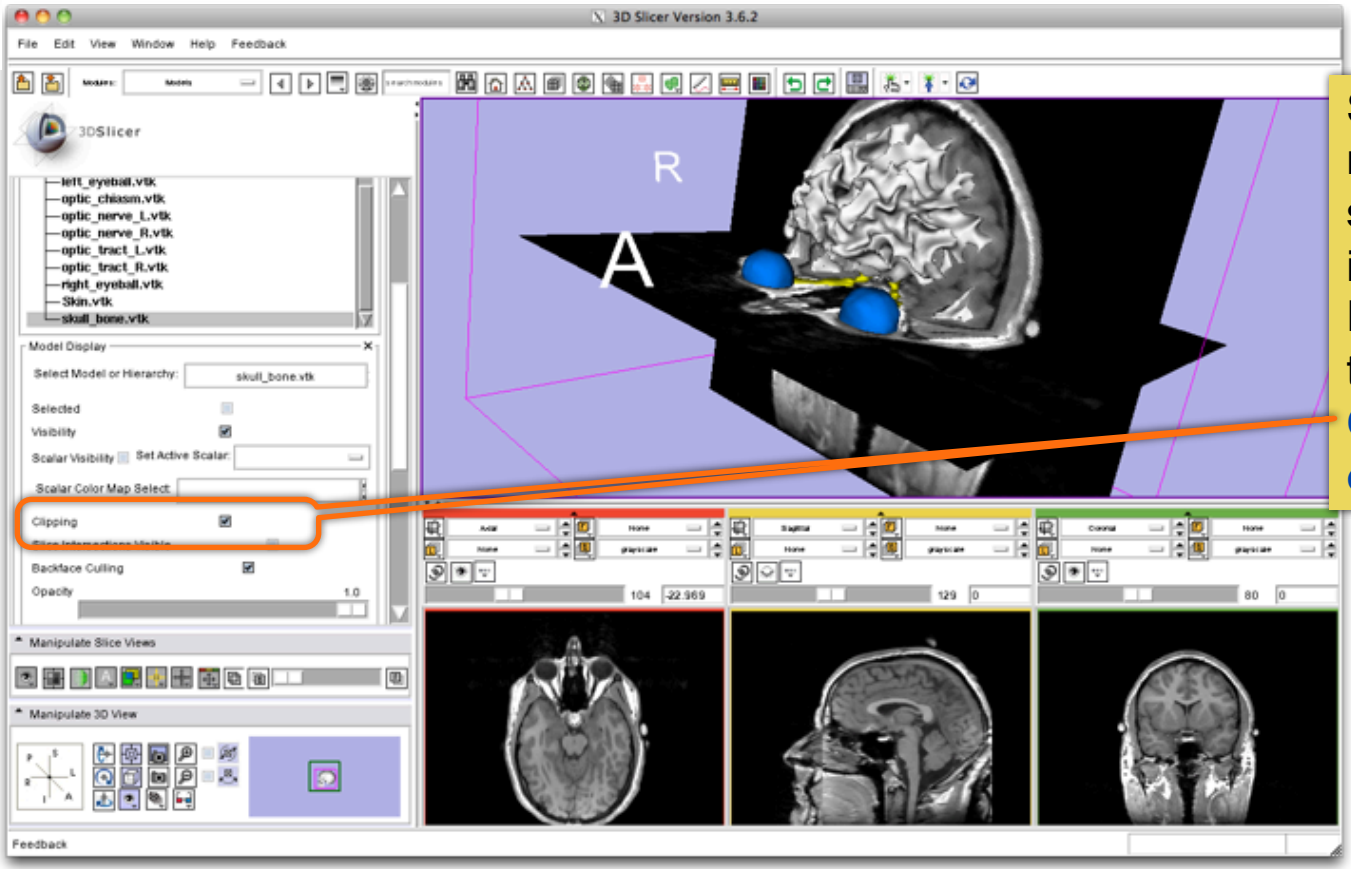
Slicer3 Minute Tutorial: 3D Visualization



Click on the **Slice Visibility icon** in the **Green Slice Viewer**

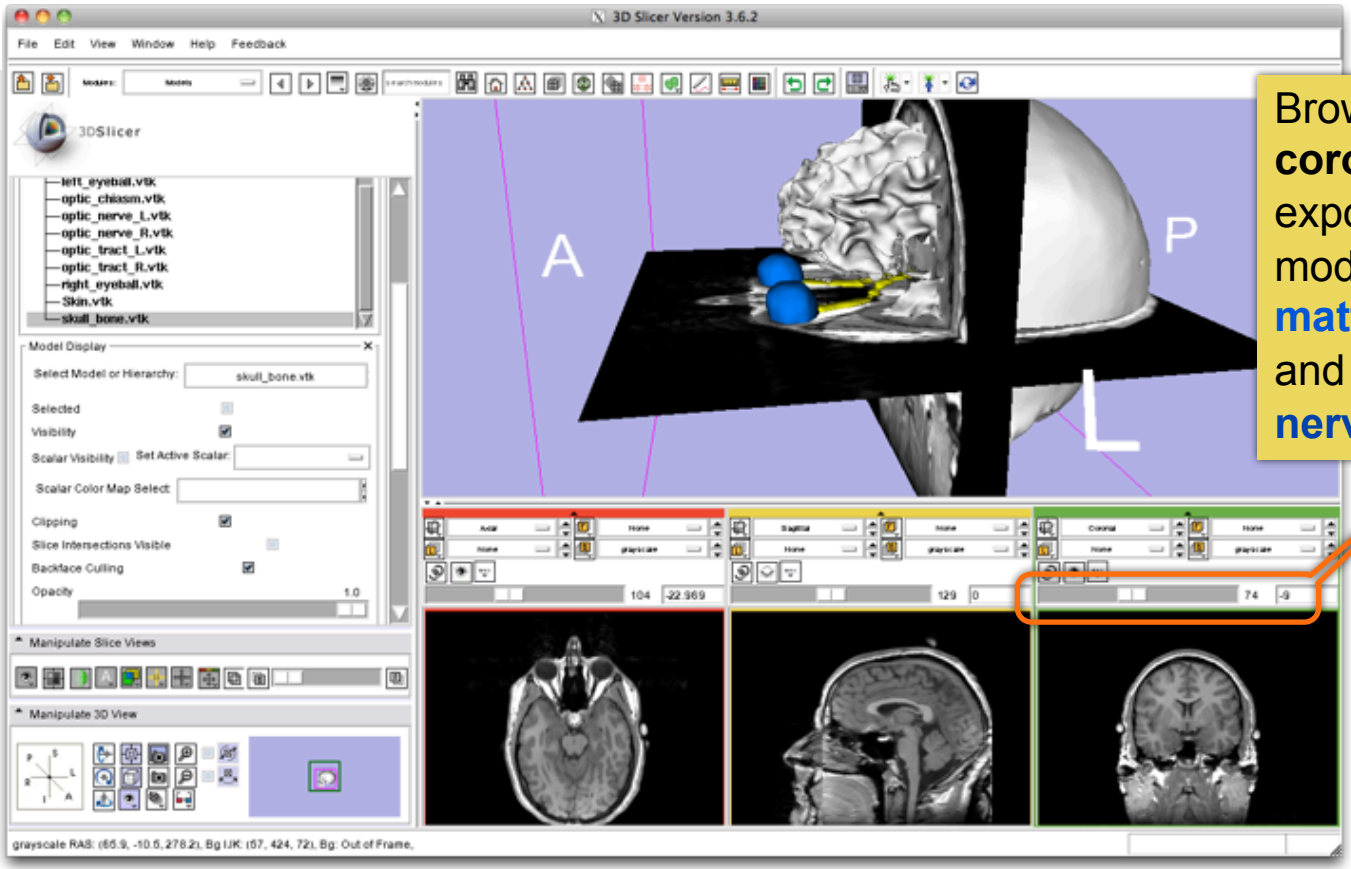
to display the Coronal Slice in the 3D Viewer.

Slicer3 Minute Tutorial: 3D Visualization



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

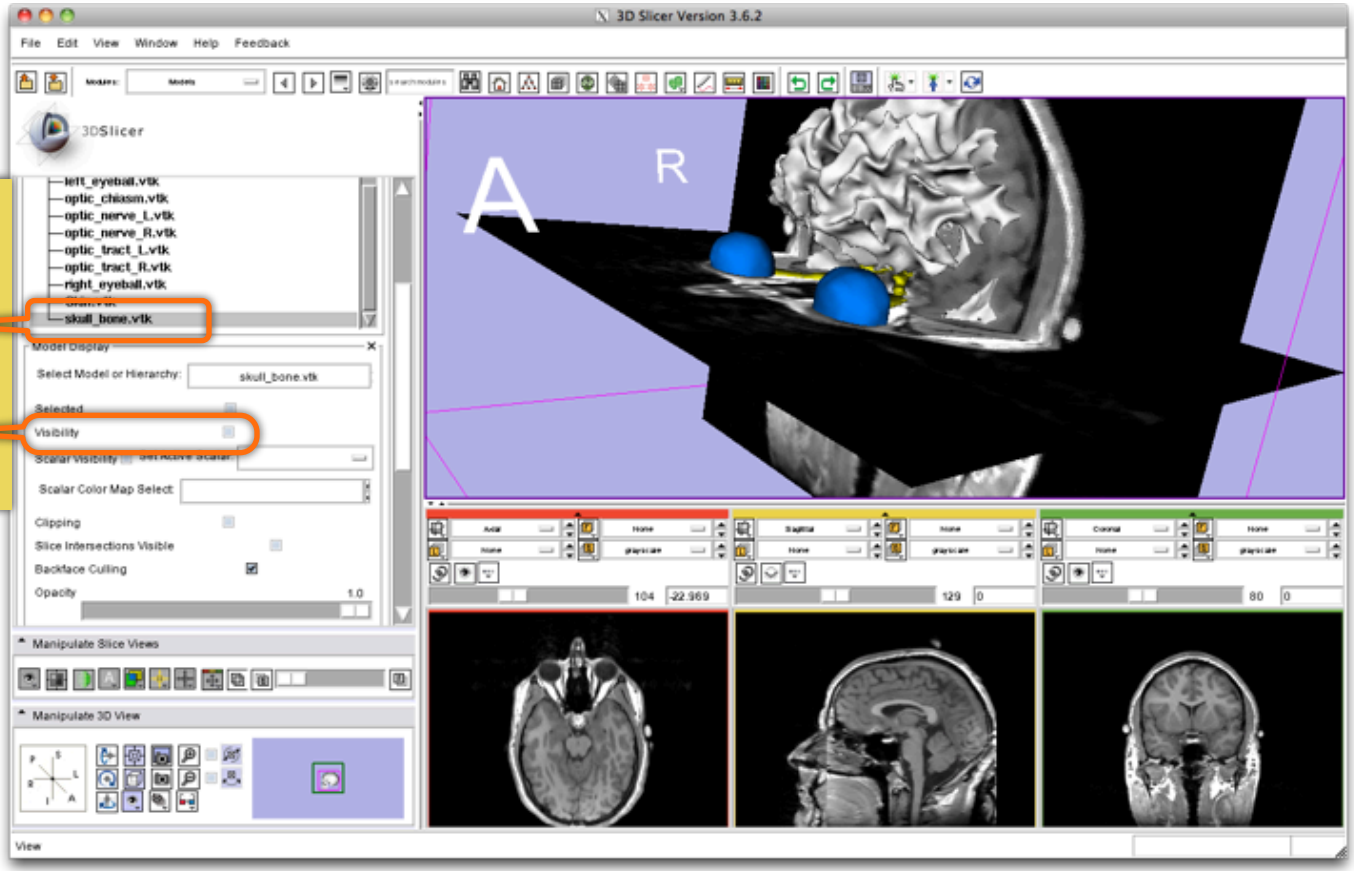
Slicer3 Minute Tutorial: 3D Visualization



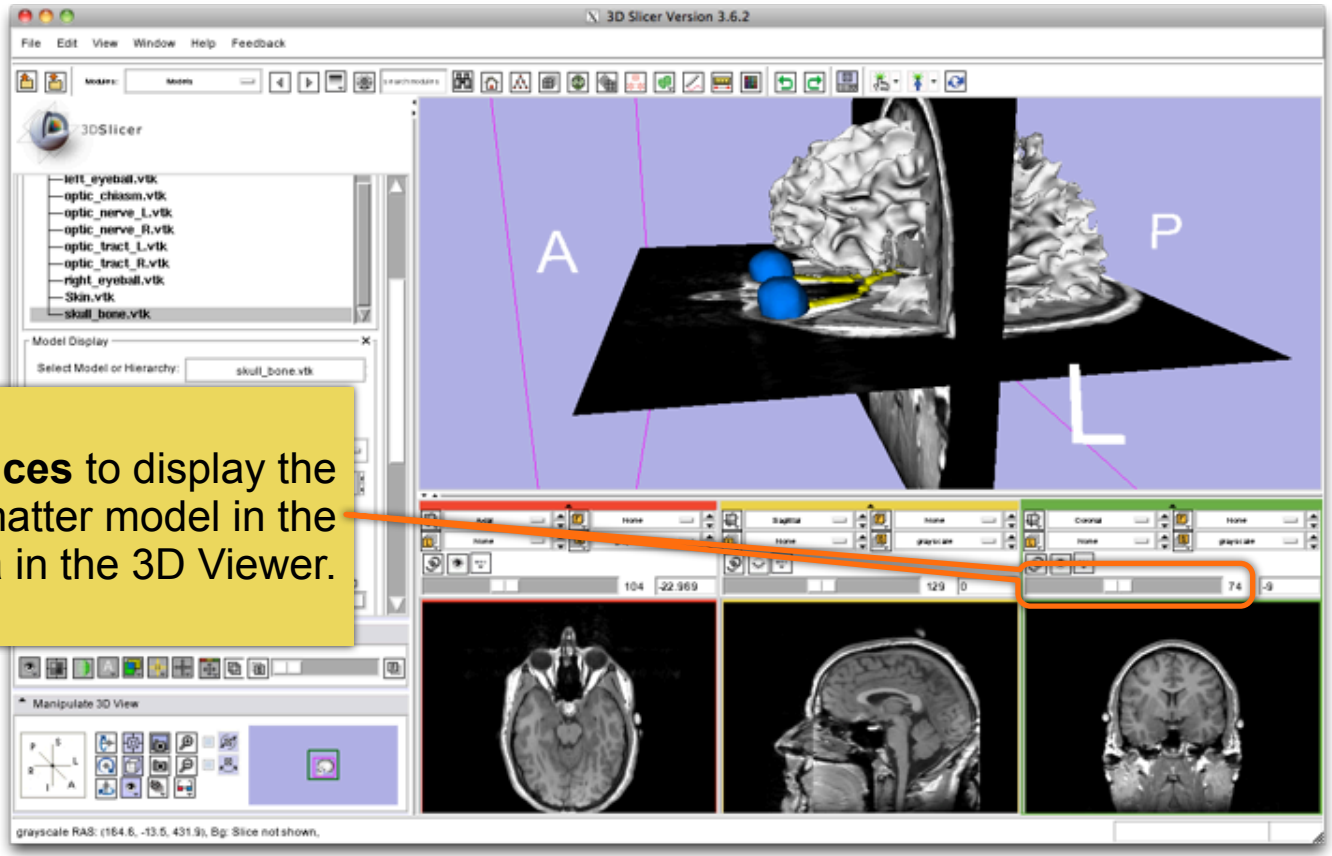
Browse through the **coronal slices** to expose the 3D model of the **white matter**, and the left and right **optic nerves**.

Slicer3 Minute Tutorial: 3D Visualization

Select the 3D model "**skull_bone**" in the **Model Hierarchy**, and **turn off its Visibility**

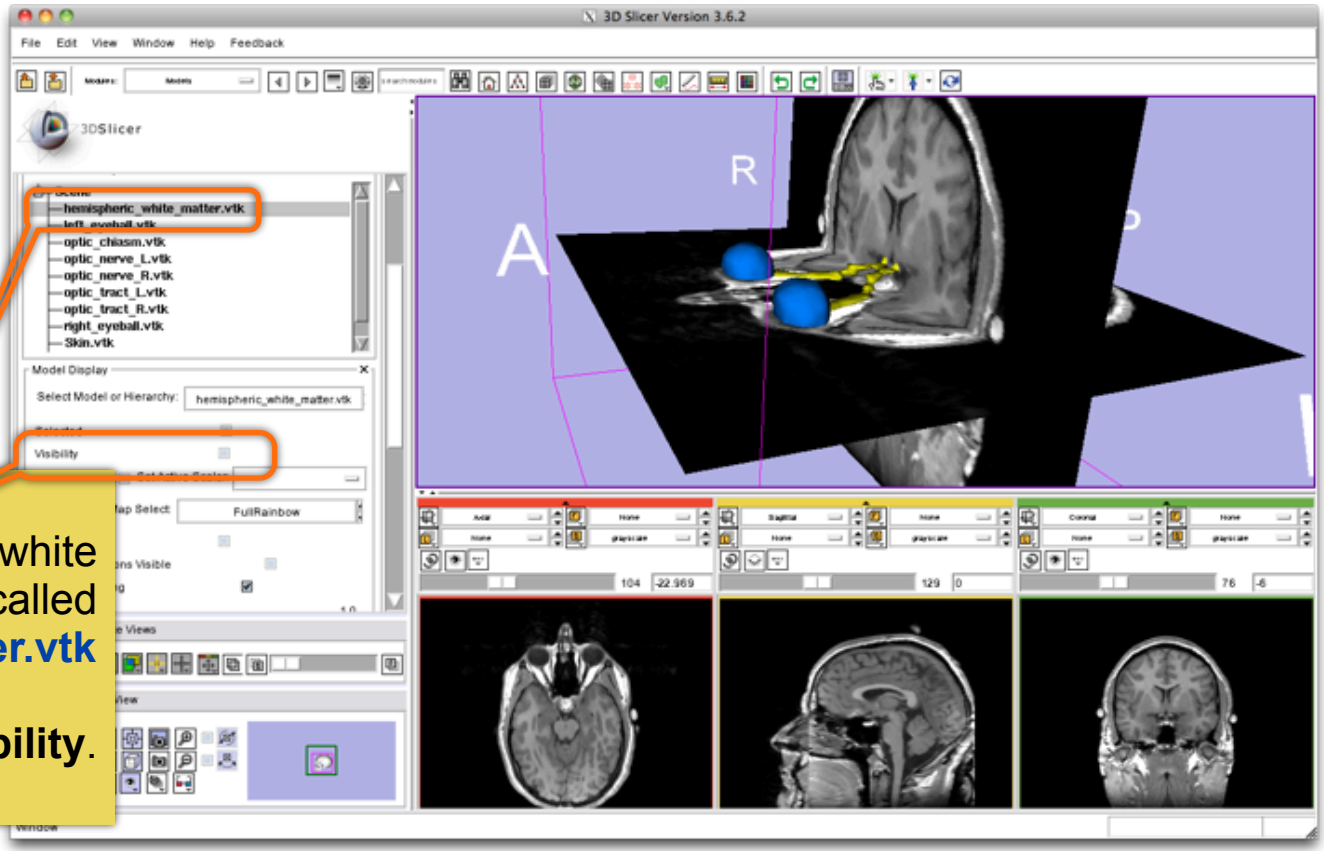


Slicer3 Minute Tutorial: 3D Visualization



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

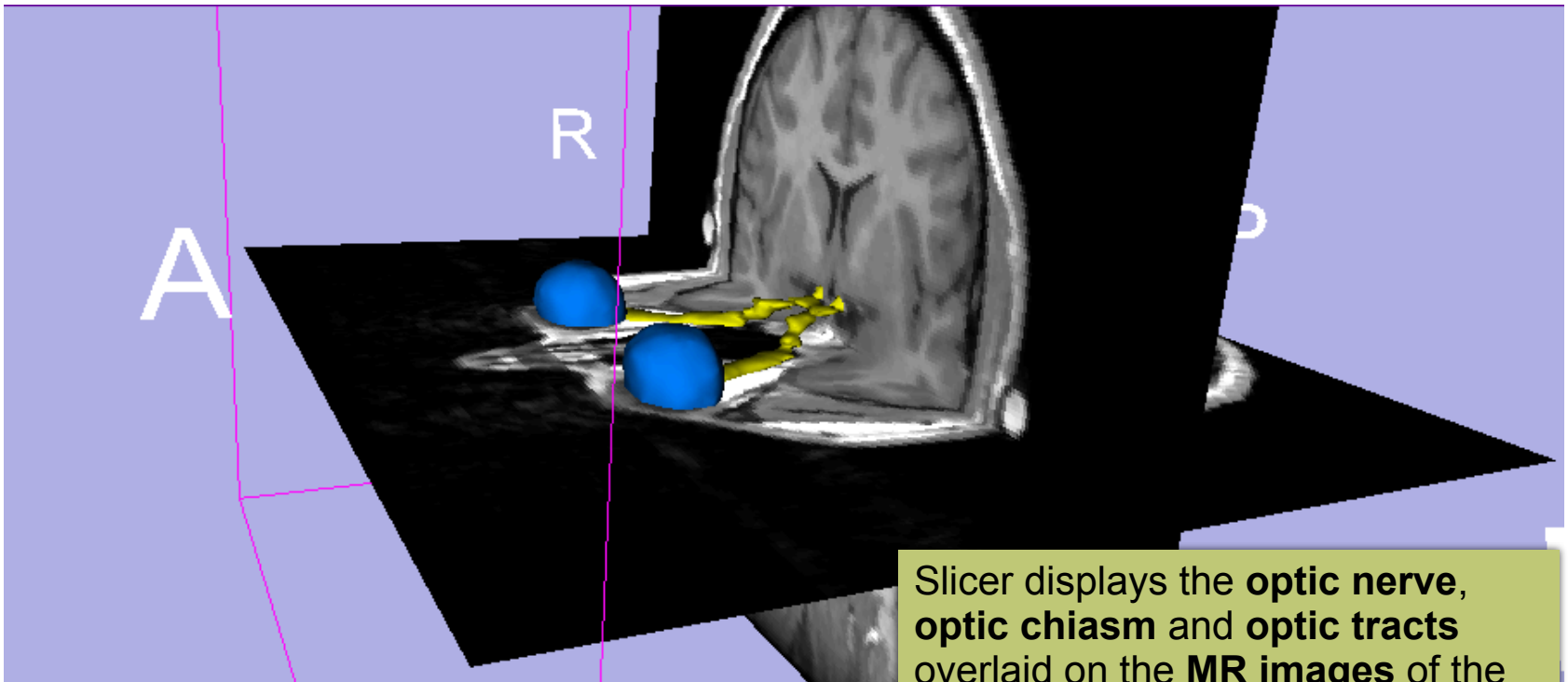
Slicer3 Minute Tutorial: 3D Visualization



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

Turn off its **visibility**.

Slicer3 Minute Tutorial: 3D Visualization

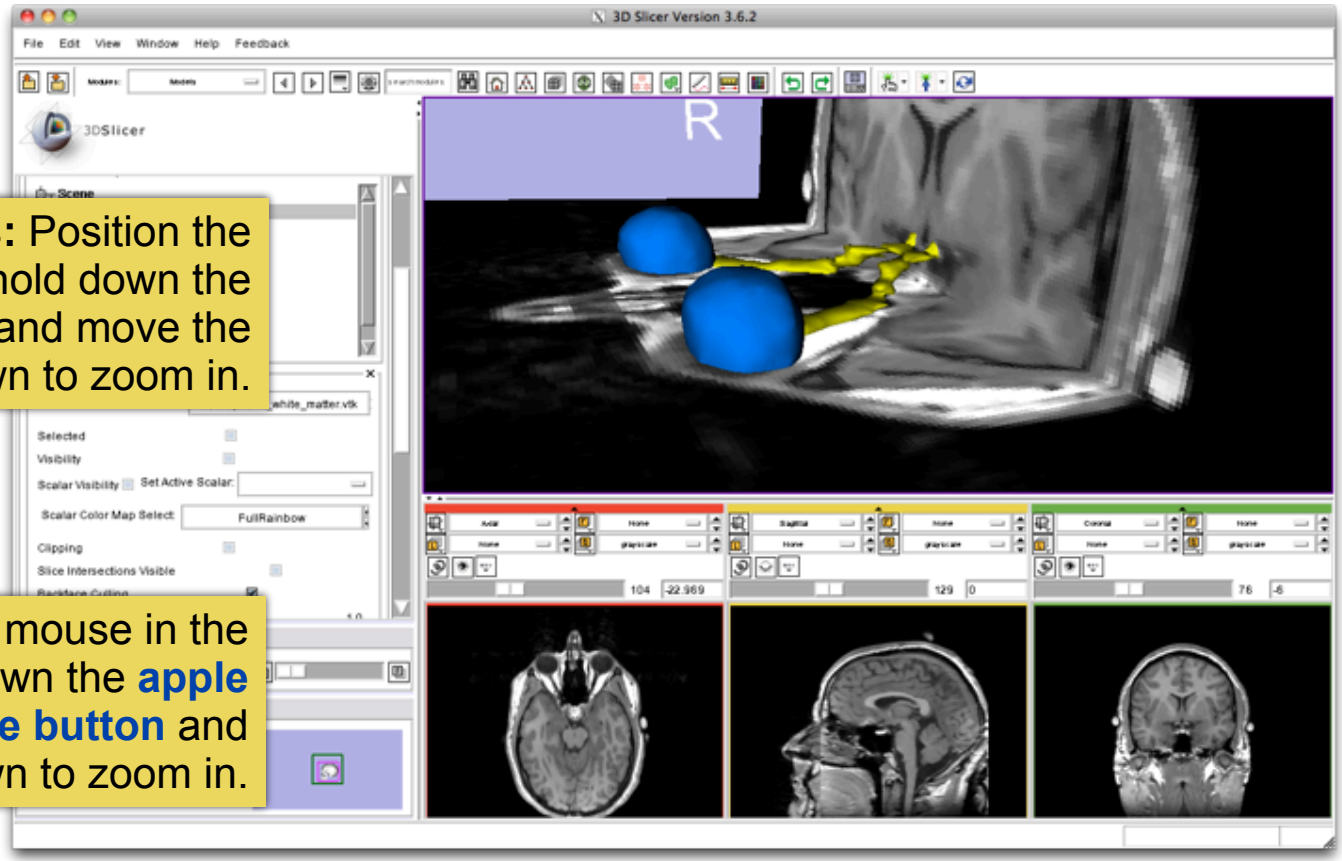


Slicer displays the **optic nerve**, **optic chiasm** and **optic tracts** overlaid on the **MR images** of the brain.

Slicer3 Minute Tutorial: 3D Visualization: Zoom the view

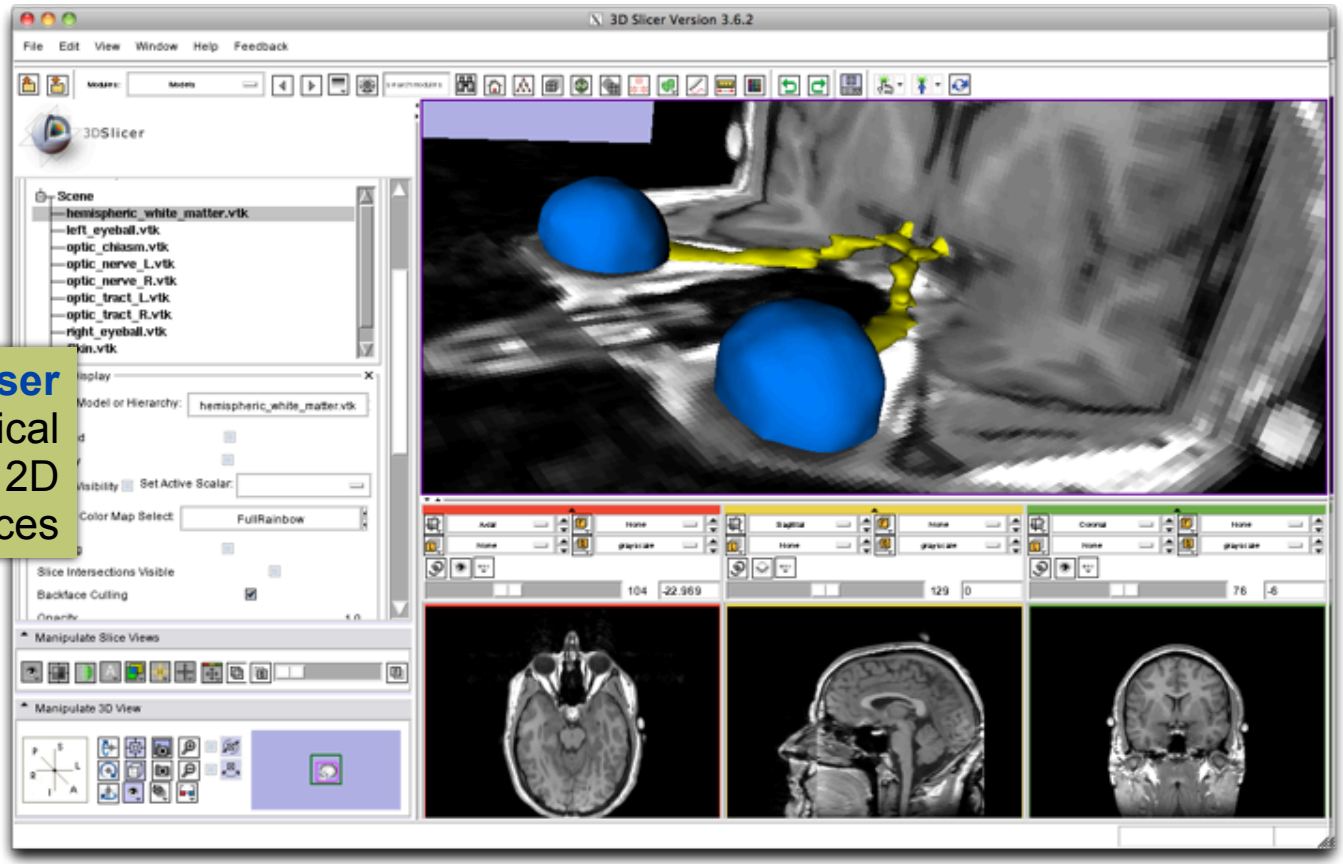
Windows/Linux users: Position the mouse in the 3D Viewer, hold down the **right mouse button** and move the mouse down to zoom in.

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.



Slicer3 Minute Tutorial: 3D Visualization

Slicer3 displays a **closer view** of 3D anatomical structures overlaid on 2D MR slices



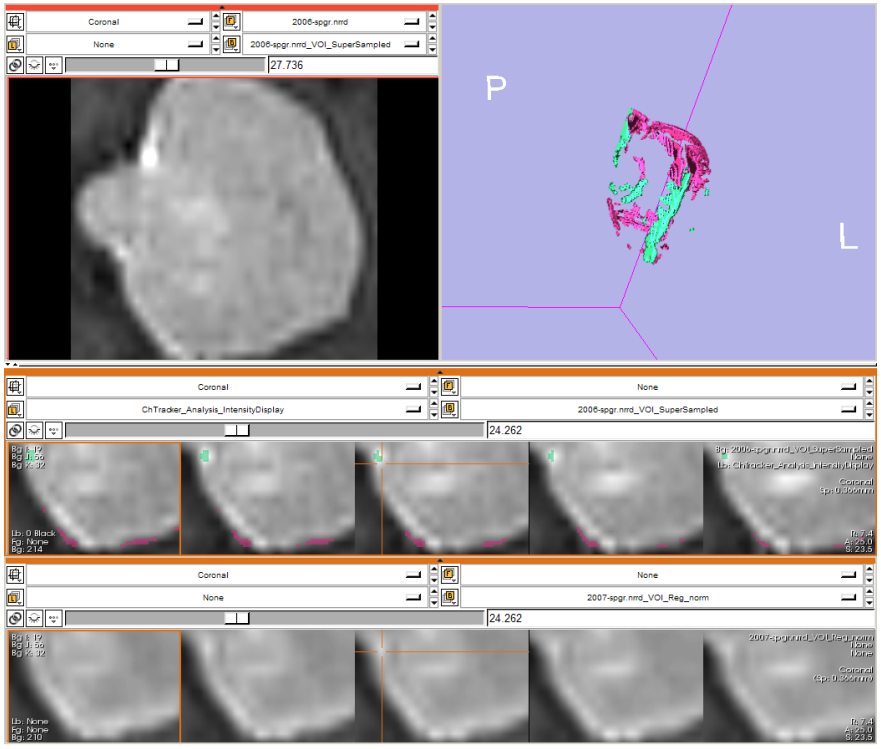
Slicer3 Minute Tutorial: Summary

This tutorial has demonstrated:

- Basic description of the Slicer3 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.

ChangeTracker: exploring small volumetric changes



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)

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

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

ChangeTracker: Conventional measures of tumor response

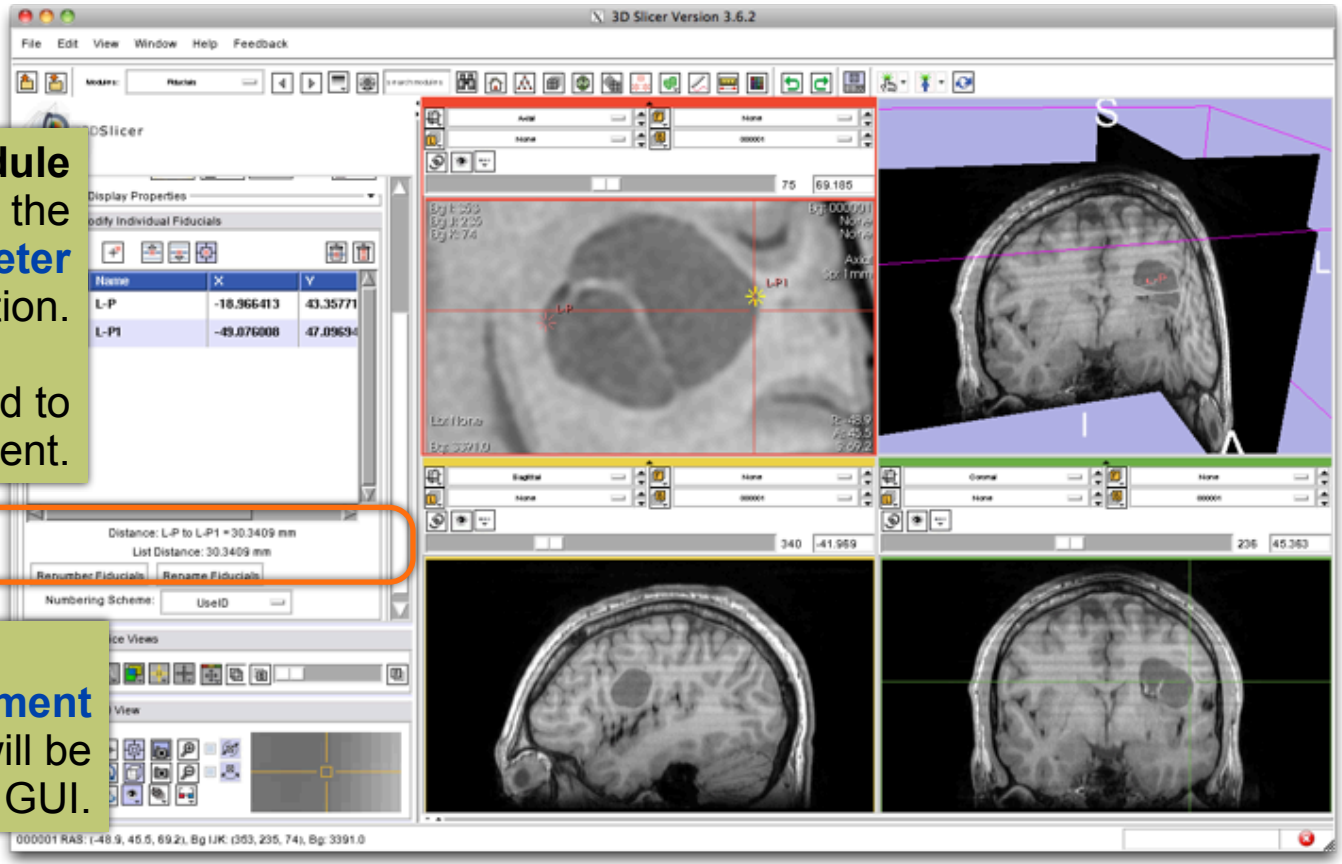
- Conventional anatomic imaging using CT or MRI are often used to evaluate tumor size and shape
- Most clinical trials that evaluate new chemotherapeutic drugs use changes in uni-dimensional or bi-dimensional measurements to assess response (*e.g.* RECIST)
- Slicer has several tools for applying RECIST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

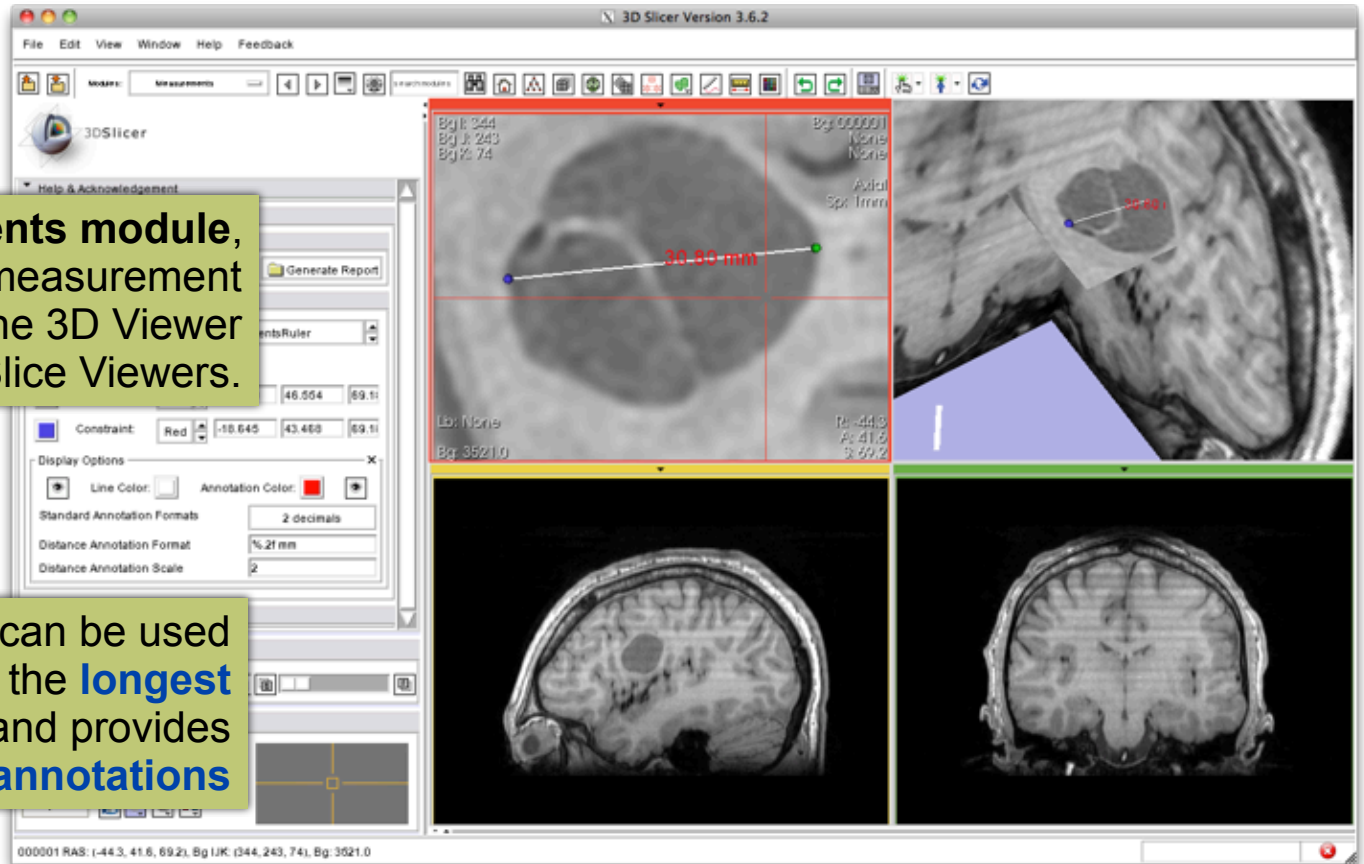
The **distance measurement** (mm) between fiducials will be updated in the Fiducial's GUI.



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**

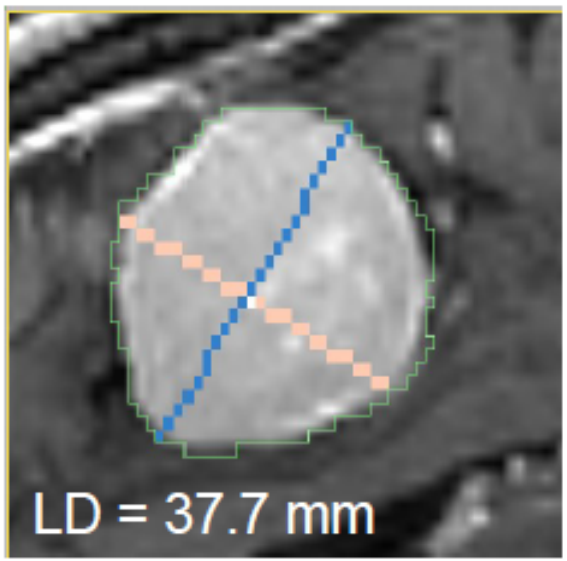


Quantifying tumor change: Conventional measures of tumor response

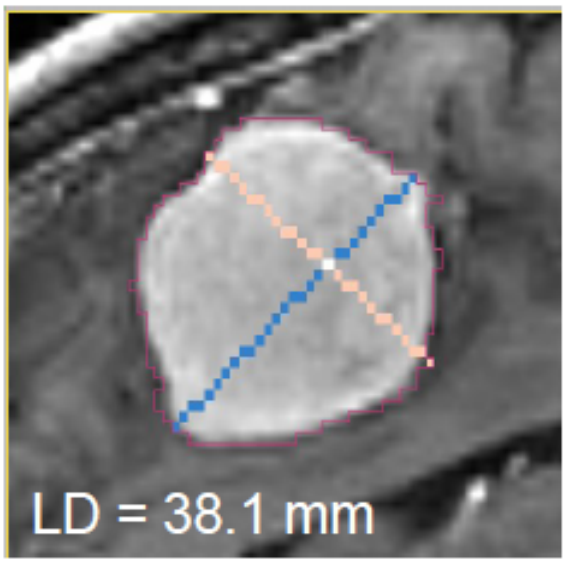
3DSlicer

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 s**mall changes may be clinically significant** but difficult to assess with RECIST

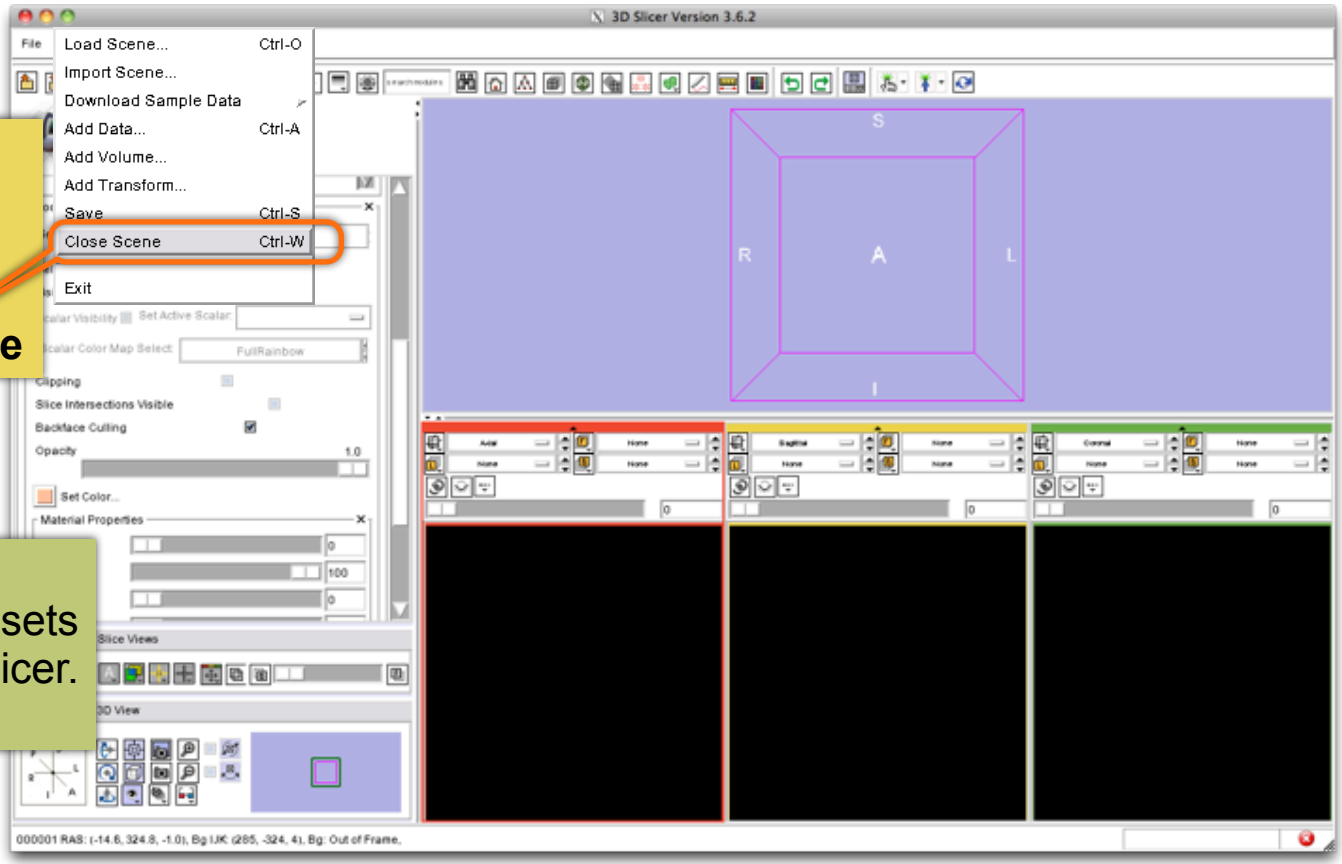
- **ChangeTracker Module** is a tool to measure **volumetric change at the voxel level**.

ChangeTracker: exploring small volumetric changes

First, close any previous scene.

Select **File->Close Scene**

This removes any datasets previously loaded into Slicer.



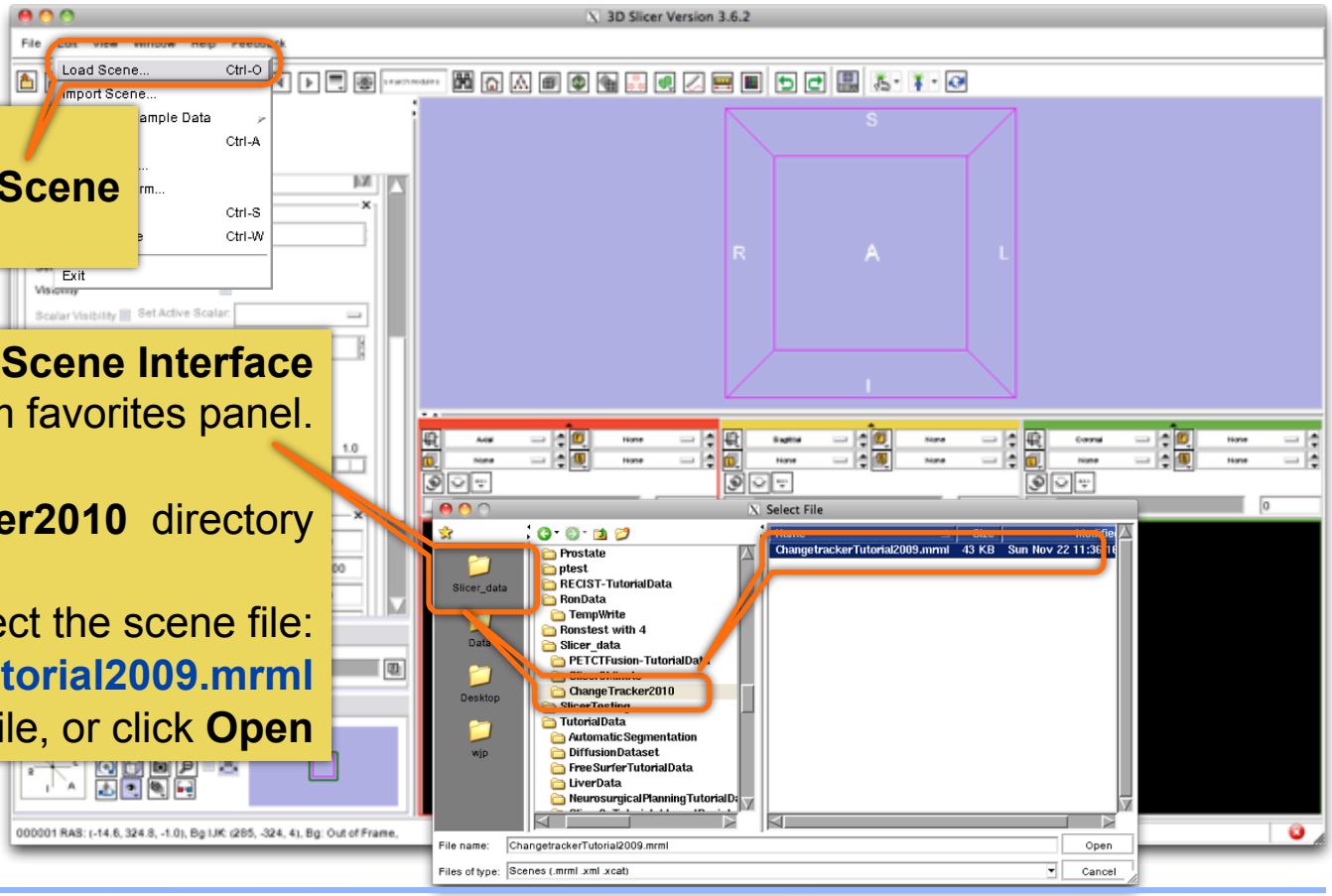
ChangeTracker: Load the training dataset

Select **File->Load Scene**

This raises the **Load Scene Interface**
Select **Slicer_data** from favorites panel.

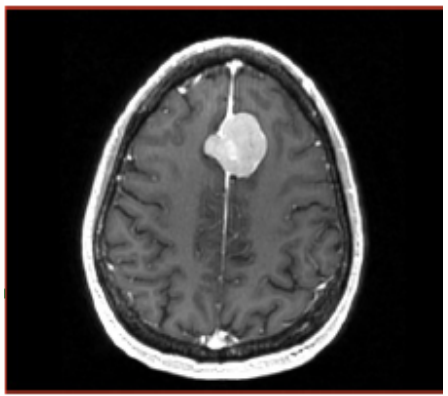
Select the **ChangeTracker2010** directory

And select the scene file:
ChangetrackerTutorial2009.mrml
double click the file, or click **Open**

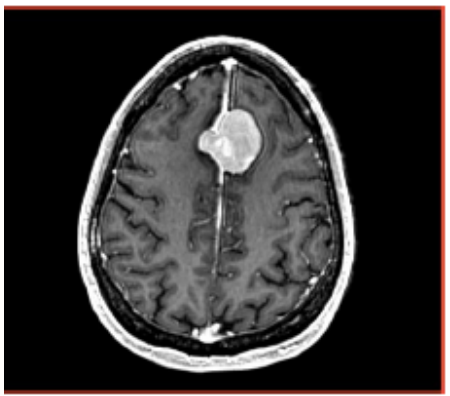


ChangeTracker: about the data...

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



MR Scan 1

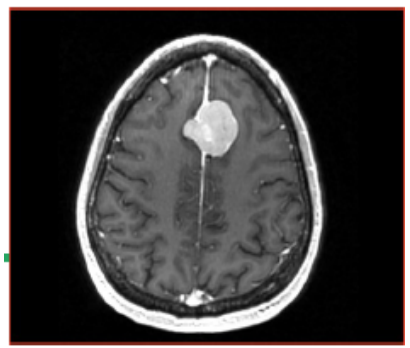


MR Scan 2

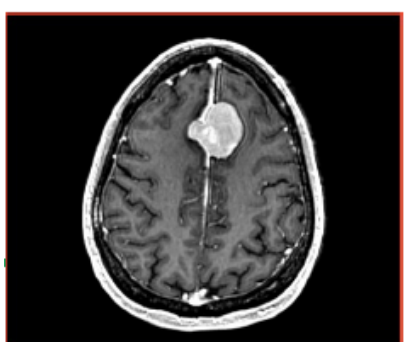
Please note: we have **pre-adjusted the window and level settings** for these volumes so that they are appropriate for display on most laptops. If display is not satisfactory on your machine or projector, the Volumes Module may be used to refine these settings.

ChangeTracker: Clinical context

Baseline:
June 2006



Follow-up:
June 2007



Meningoma
- 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.

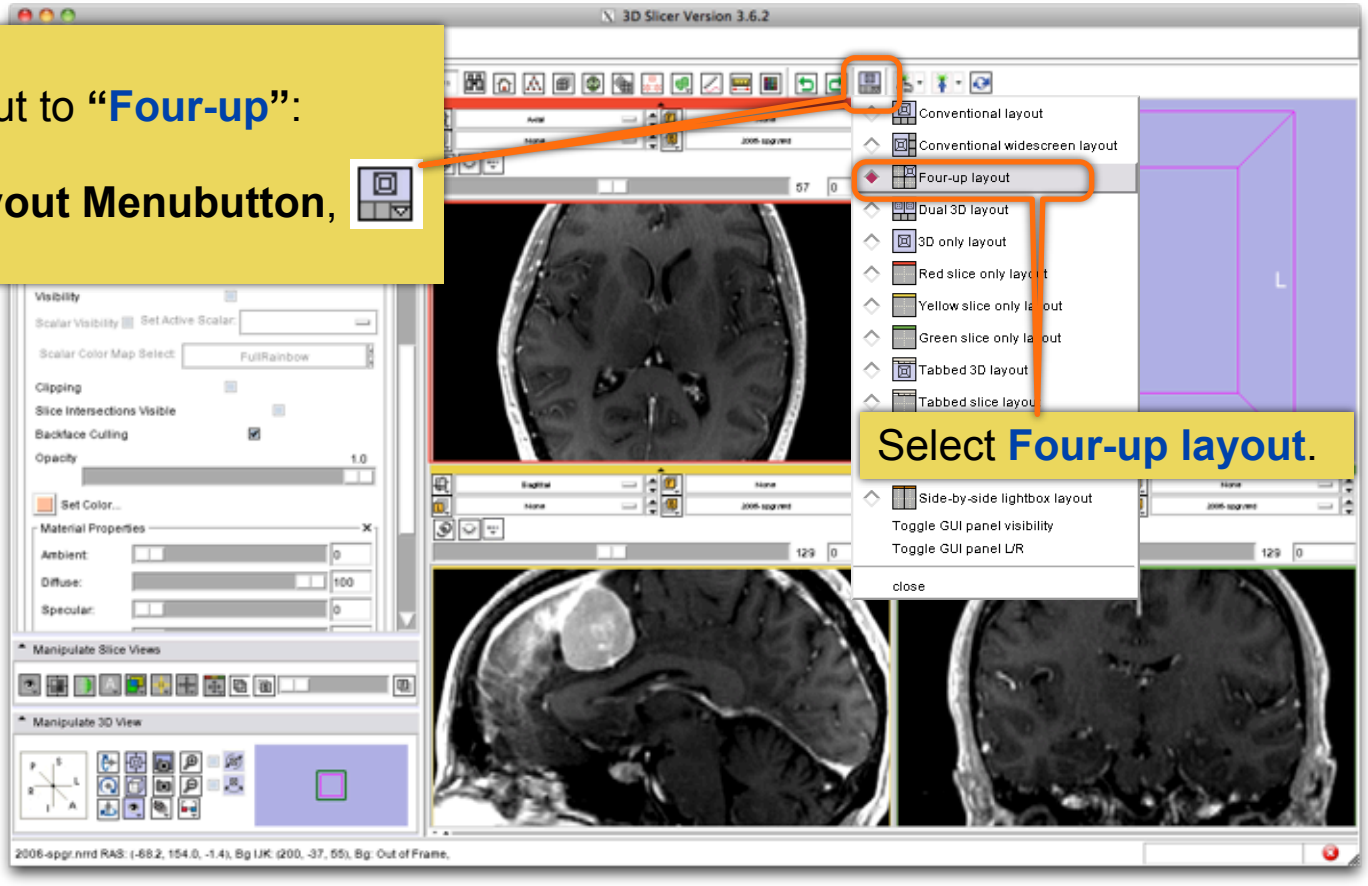
Follow-up radiologist's clinical impression:
- left frontal lobe mass appears unchanged on all series.
- measures 3.3 x 3.2 cm in maximum dimension.
- enhances moderately on post gadolinium imaging.

How has the tumor changed?

ChangeTracker: exploring small volumetric changes

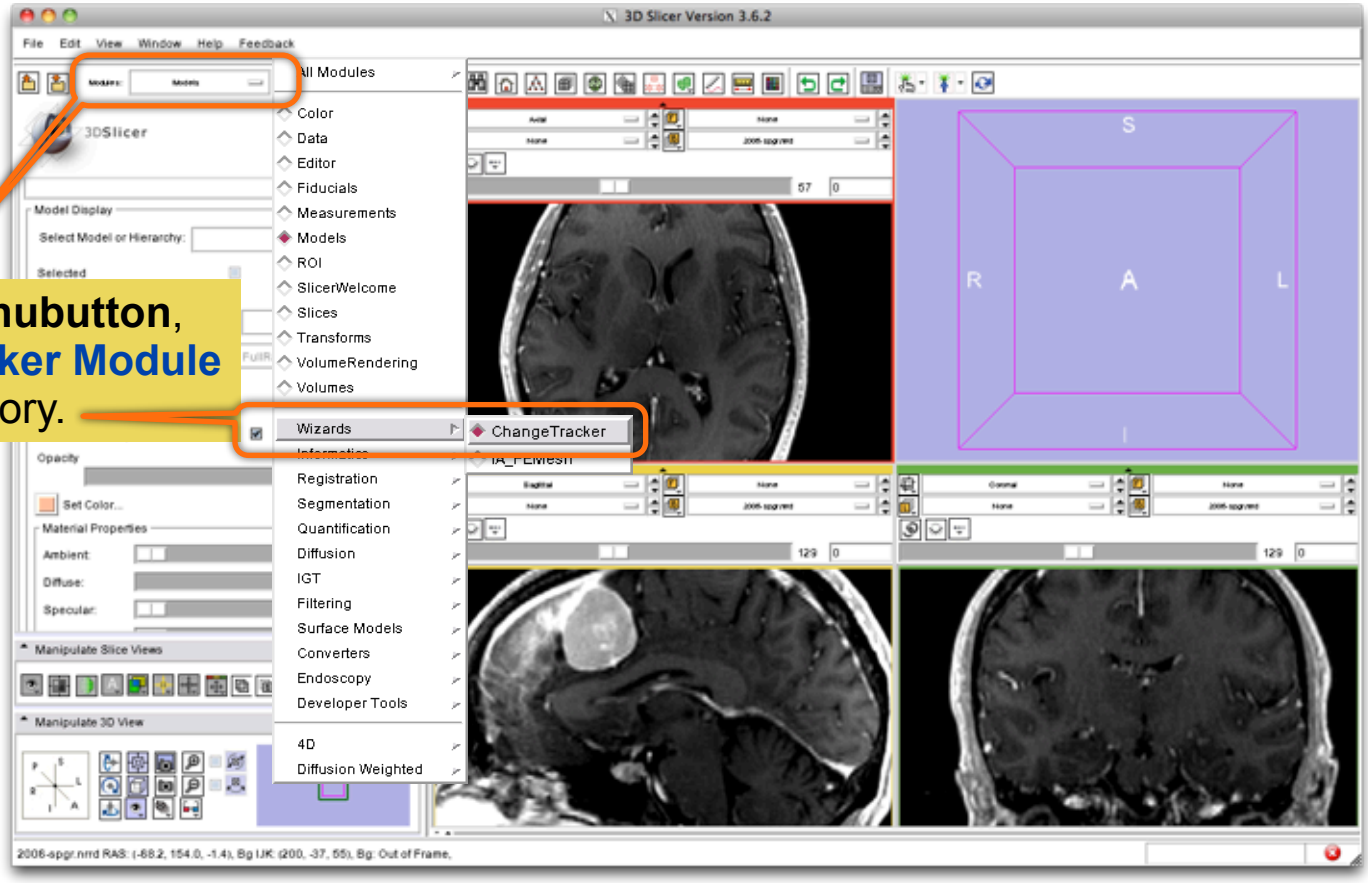
Change Layout to **“Four-up”**:

Using the **Layout Menubutton**,



ChangeTracker: exploring small volumetric changes

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



ChangeTracker: a note about the Workflow Wizard

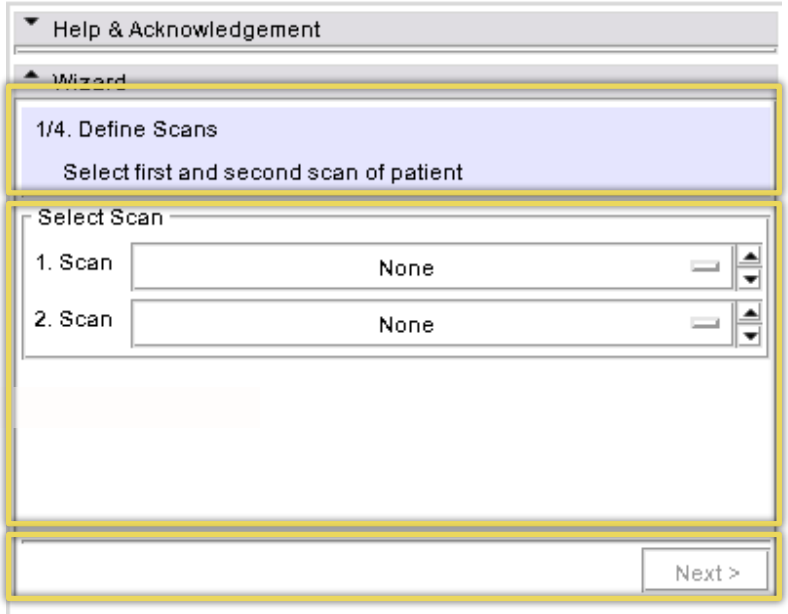
A **Workflow Wizard** guides the user through a sequence of steps and has the following components:

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

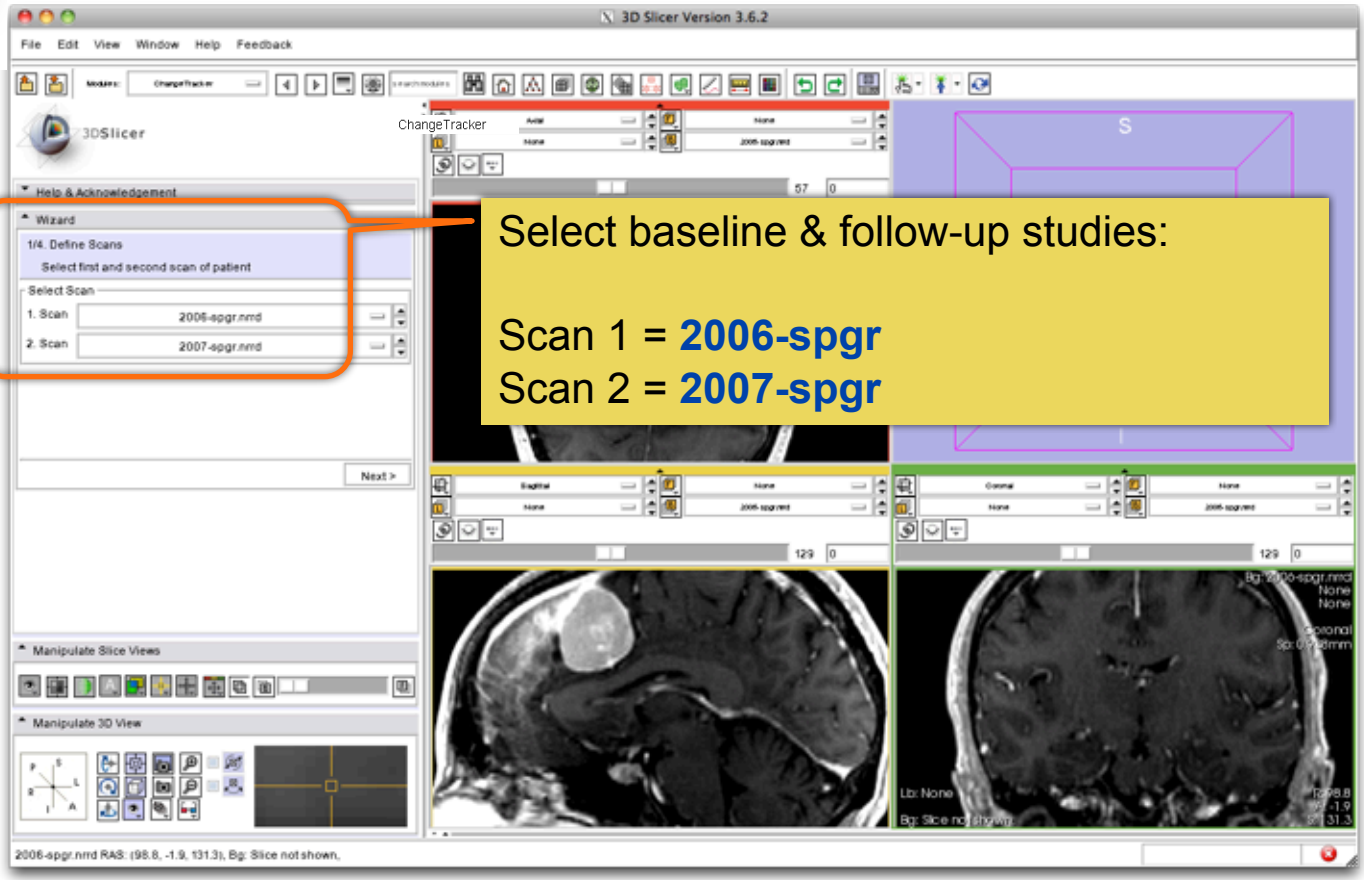
Step Panel--

User Panel--

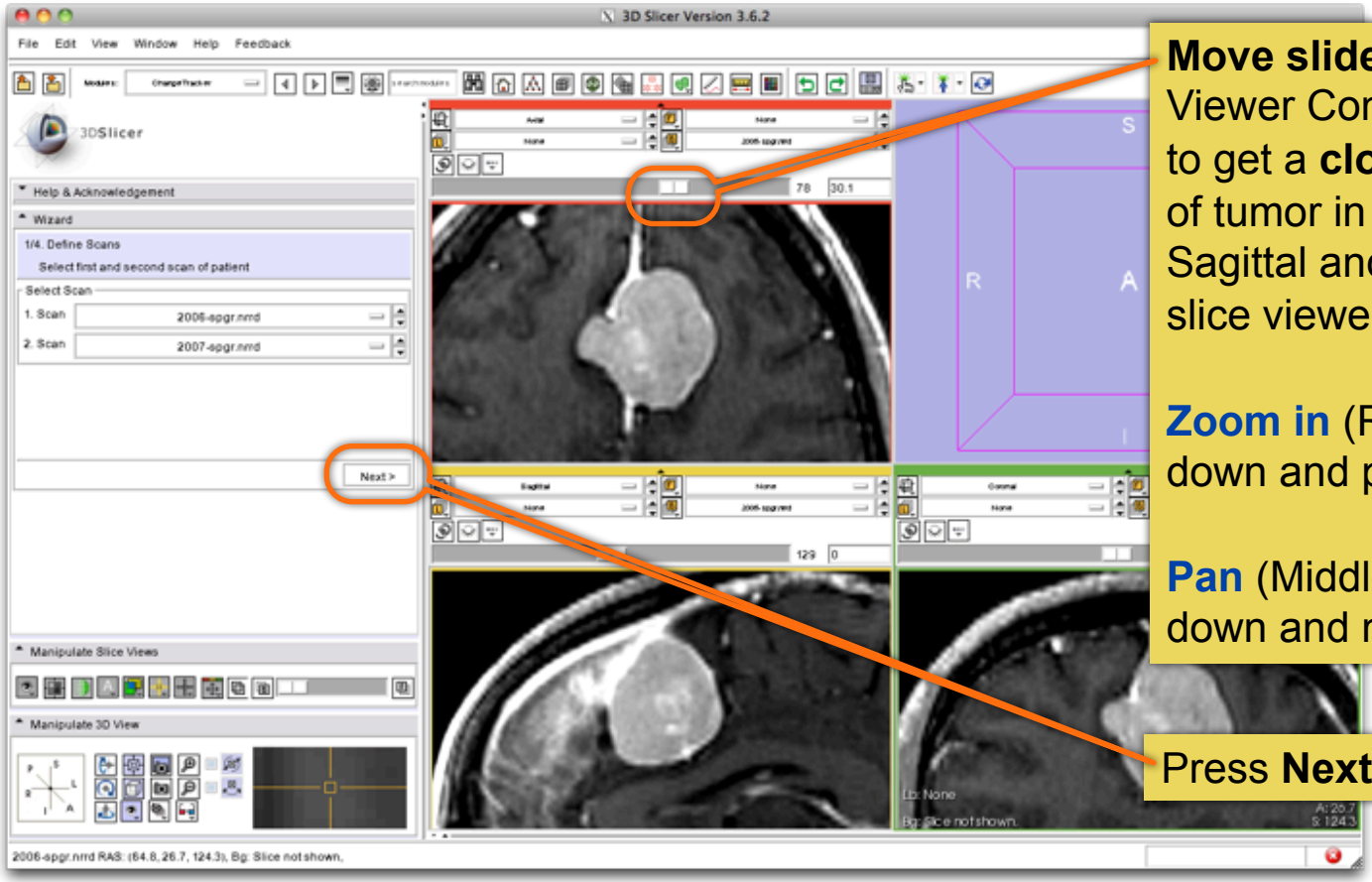
Navigation Panel--



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.

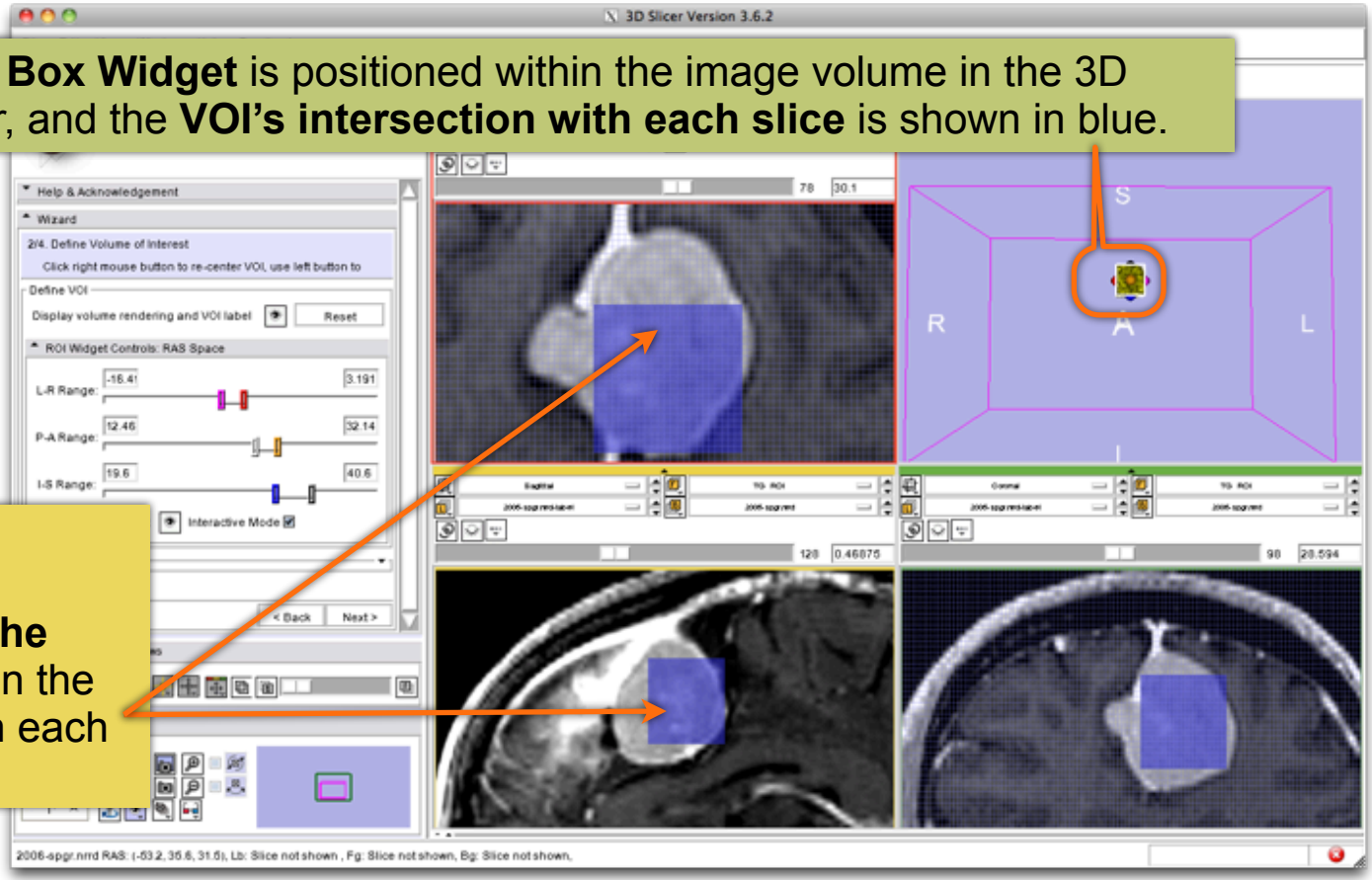
Zoom in (Right mouse down and push/pull).

Pan (Middle mouse down and move).

Press **Next**

ChangeTracker: Step 2. Define a volume of interest

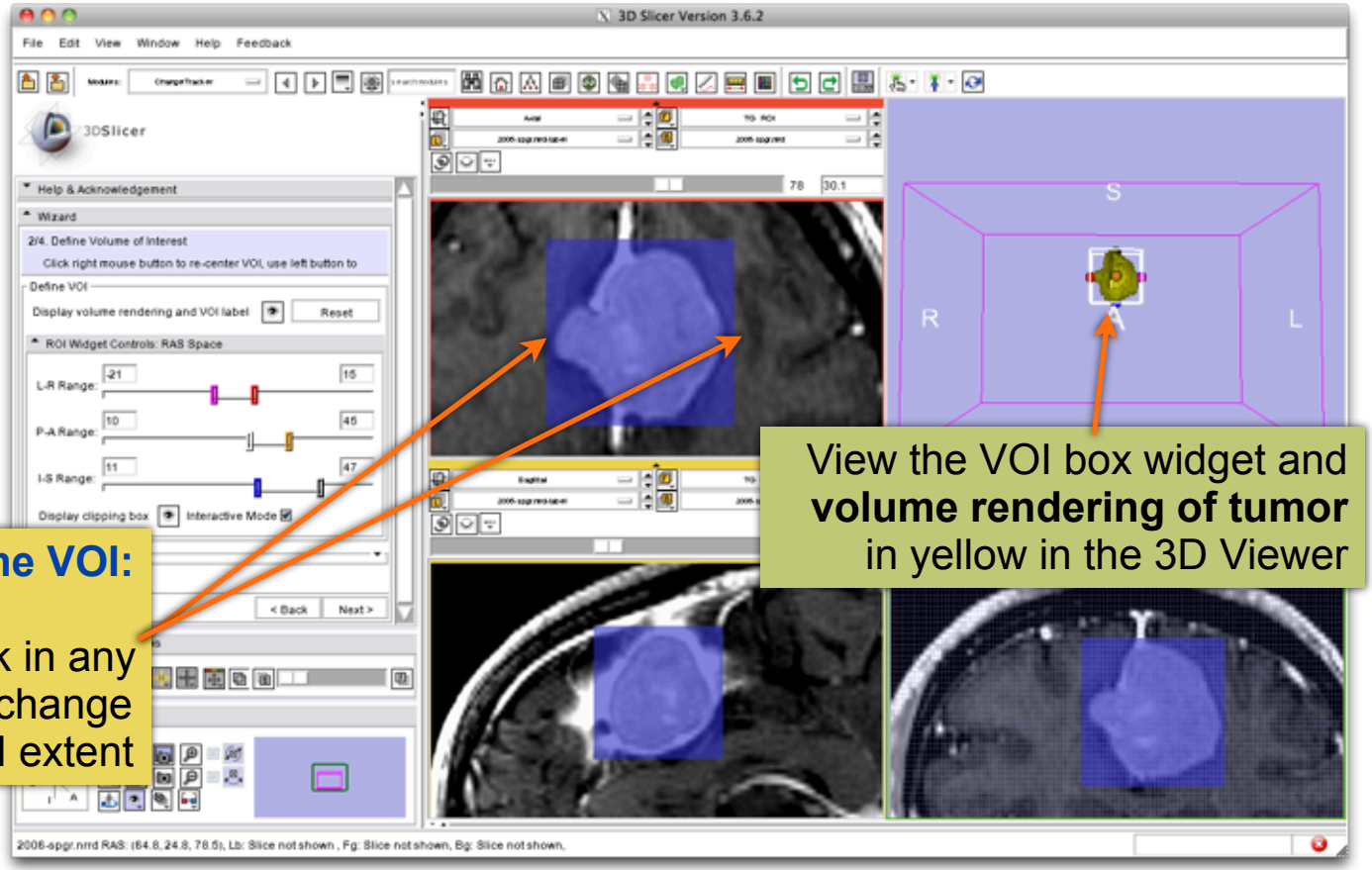
A **VOI Box Widget** is positioned within the image volume in the 3D viewer, and the **VOI's intersection with each slice** is shown in blue.



Center the VOI first:

Right mouse click in the tumor center to position the VOI displayed in blue in each Slice Viewer.

ChangeTracker: Step 2. Define a volume of interest



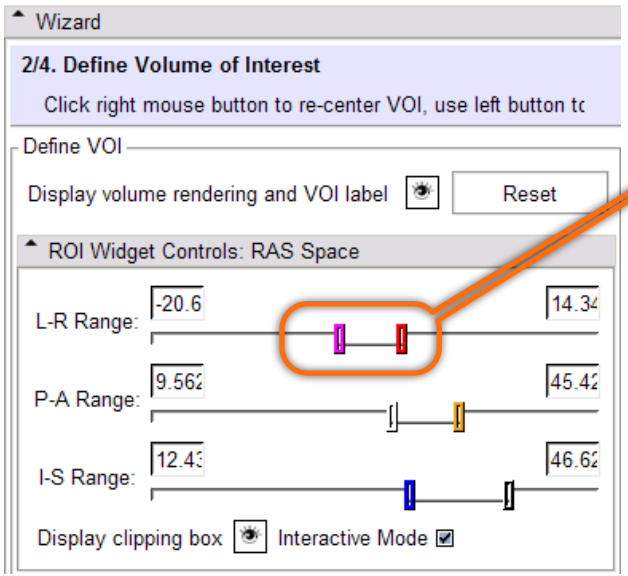
Next, resize the VOI:

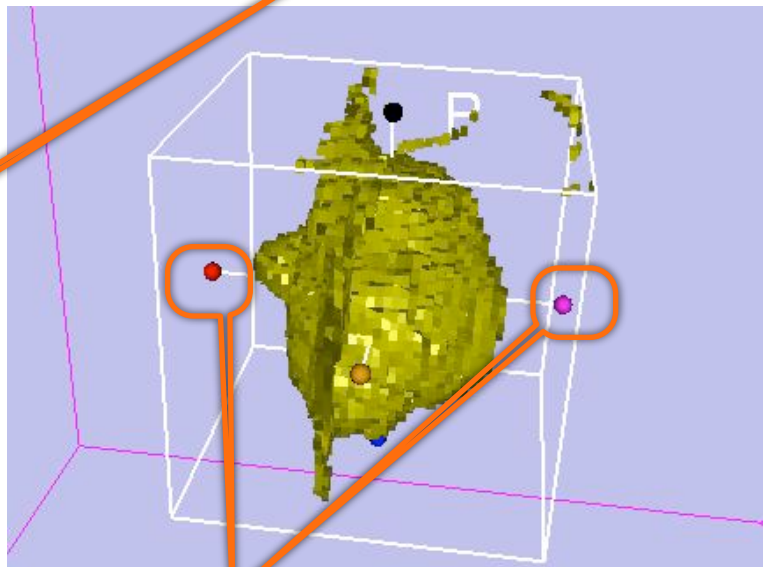
Left mouse click in any Slice Viewer to change the VOI extent

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

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



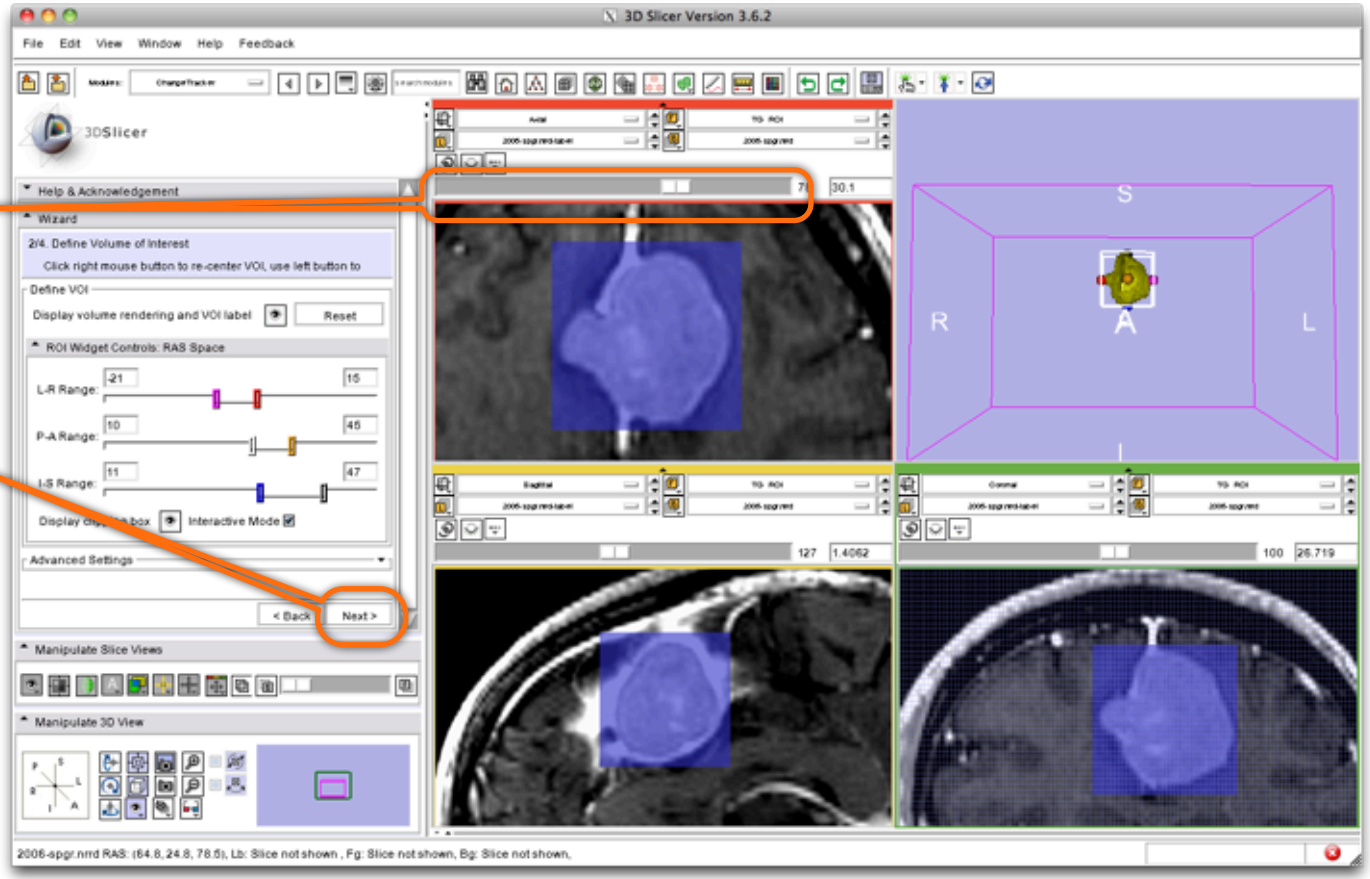


Note: VOI Widget range sliders are **color-coded** to match VOI box Widget **handles** in 3D Viewer

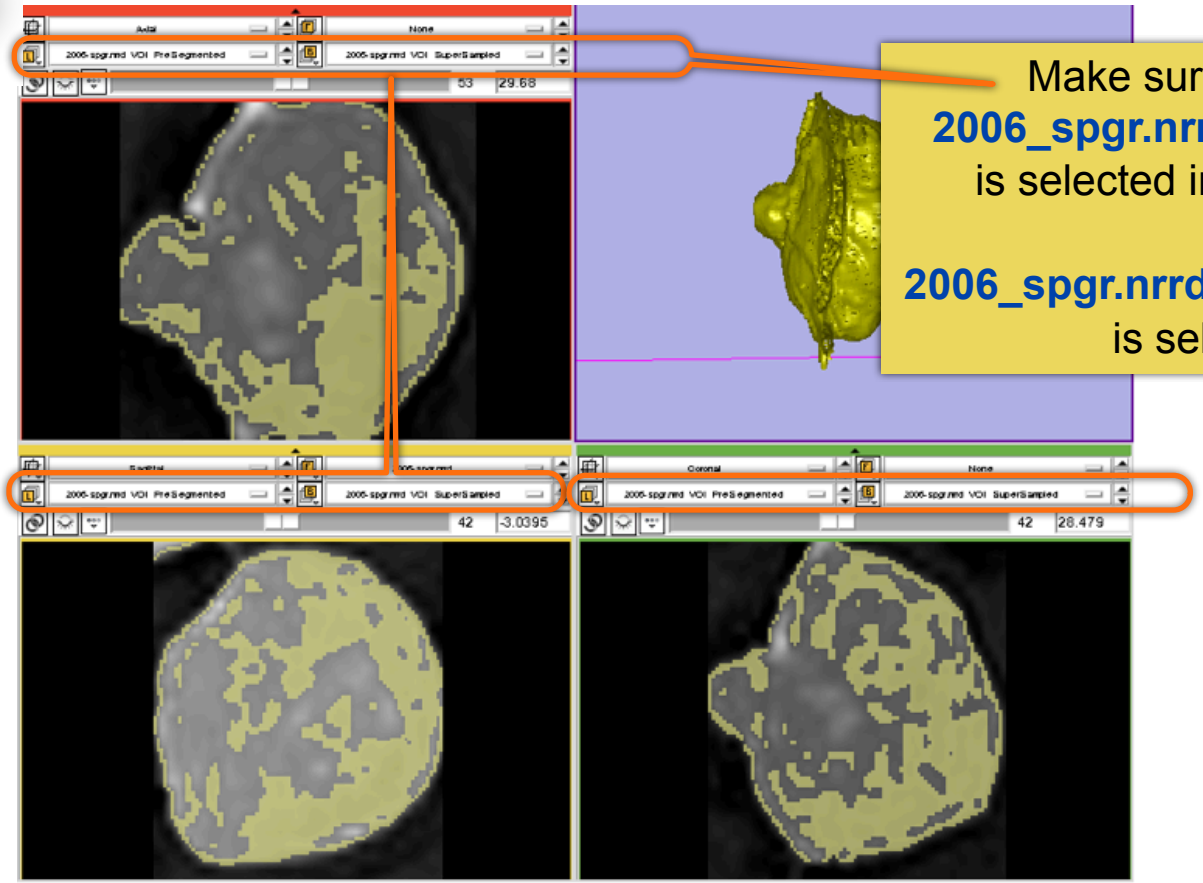
ChangeTracker: Step 2. Define a volume of interest

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

Click Next

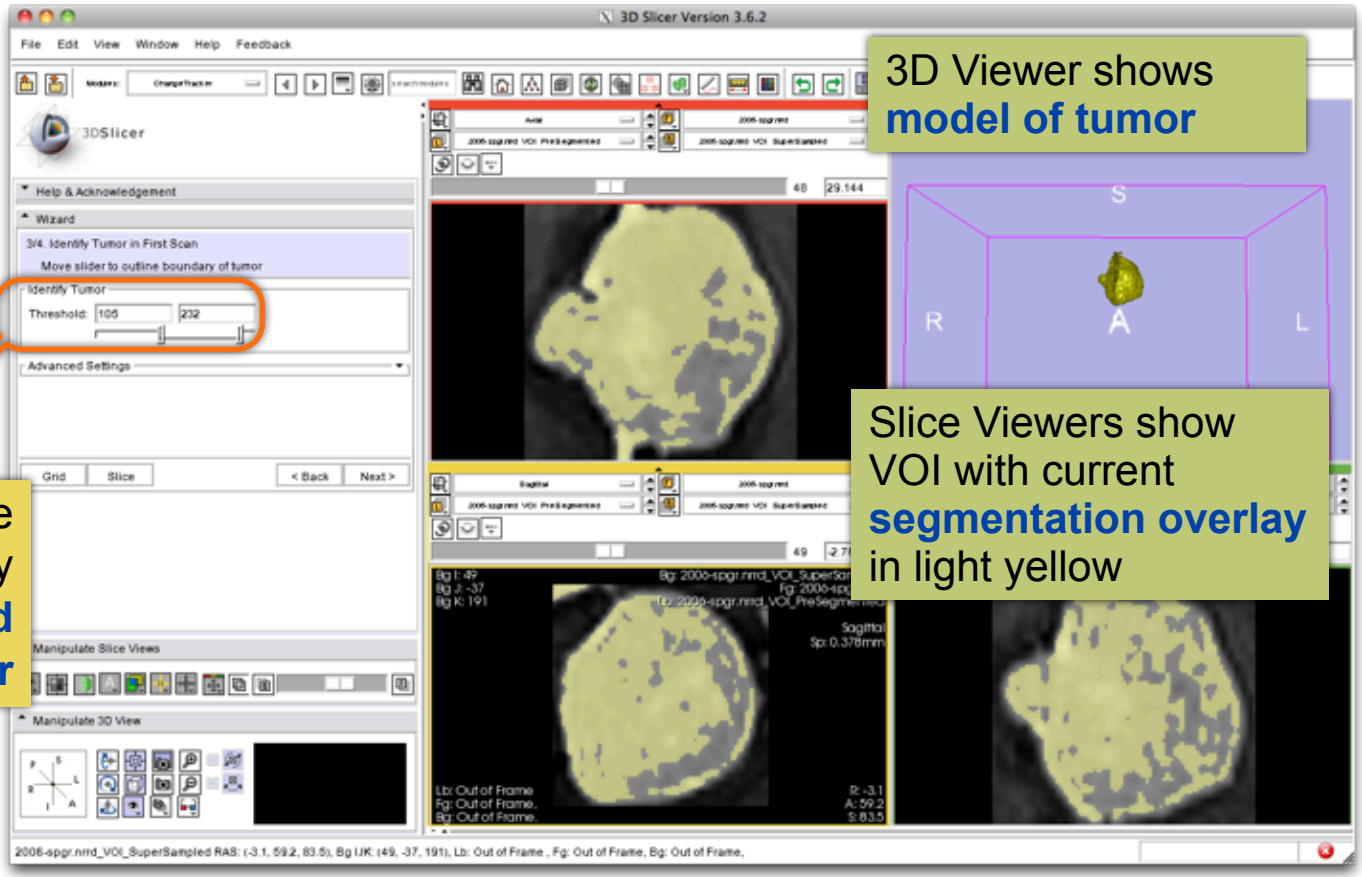


ChangeTracker: Step 3. Segment the tumor



Make sure that the volume called **2006_spgr.nrrd_VOI_Supersampled** is selected in the **background** layer ...and... **2006_spgr.nrrd_VOI_PresSegmented** is selected in the **label** layer.

ChangeTracker: Step 3. Segment the tumor

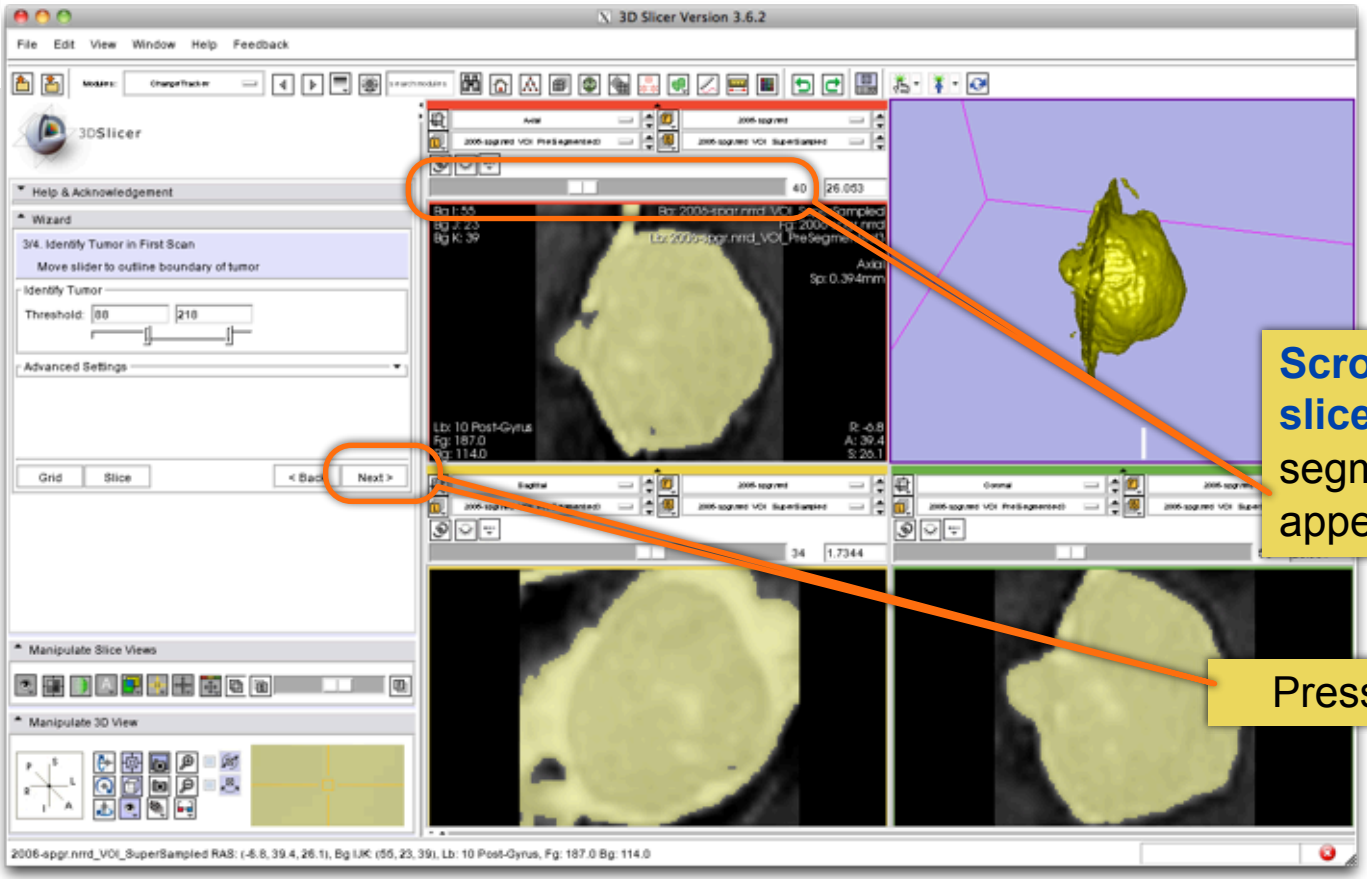


3D Viewer shows **model of tumor**

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

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

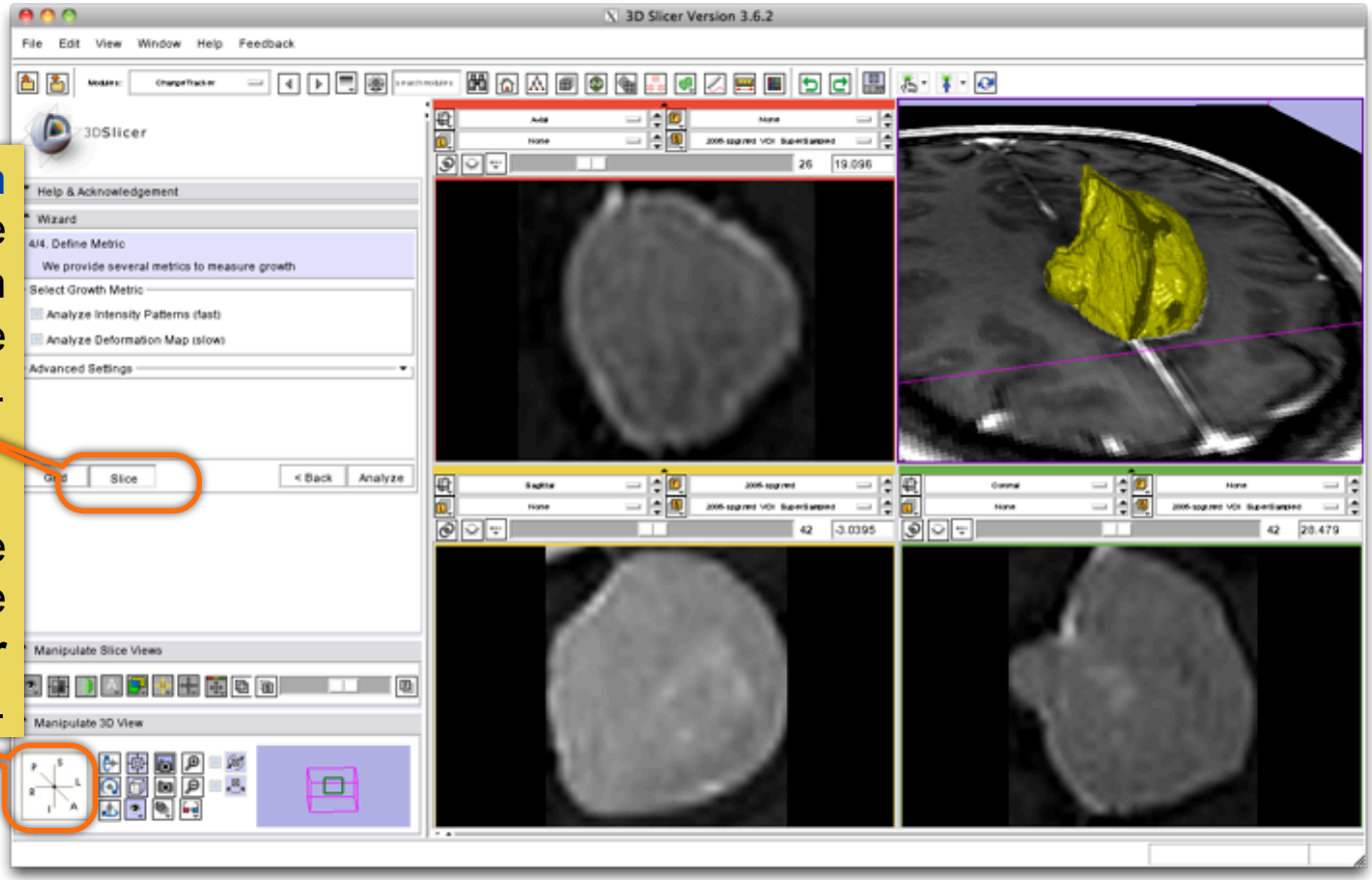
ChangeTracker: Step 3. Segment the tumor



ChangeTracker: Step 3. Segment the tumor

Press the **Slice option** to view the volume rendered segmentation with the axial slice together.

If you need to reset the 3D View, try using the **Axis Navigator Widget**.

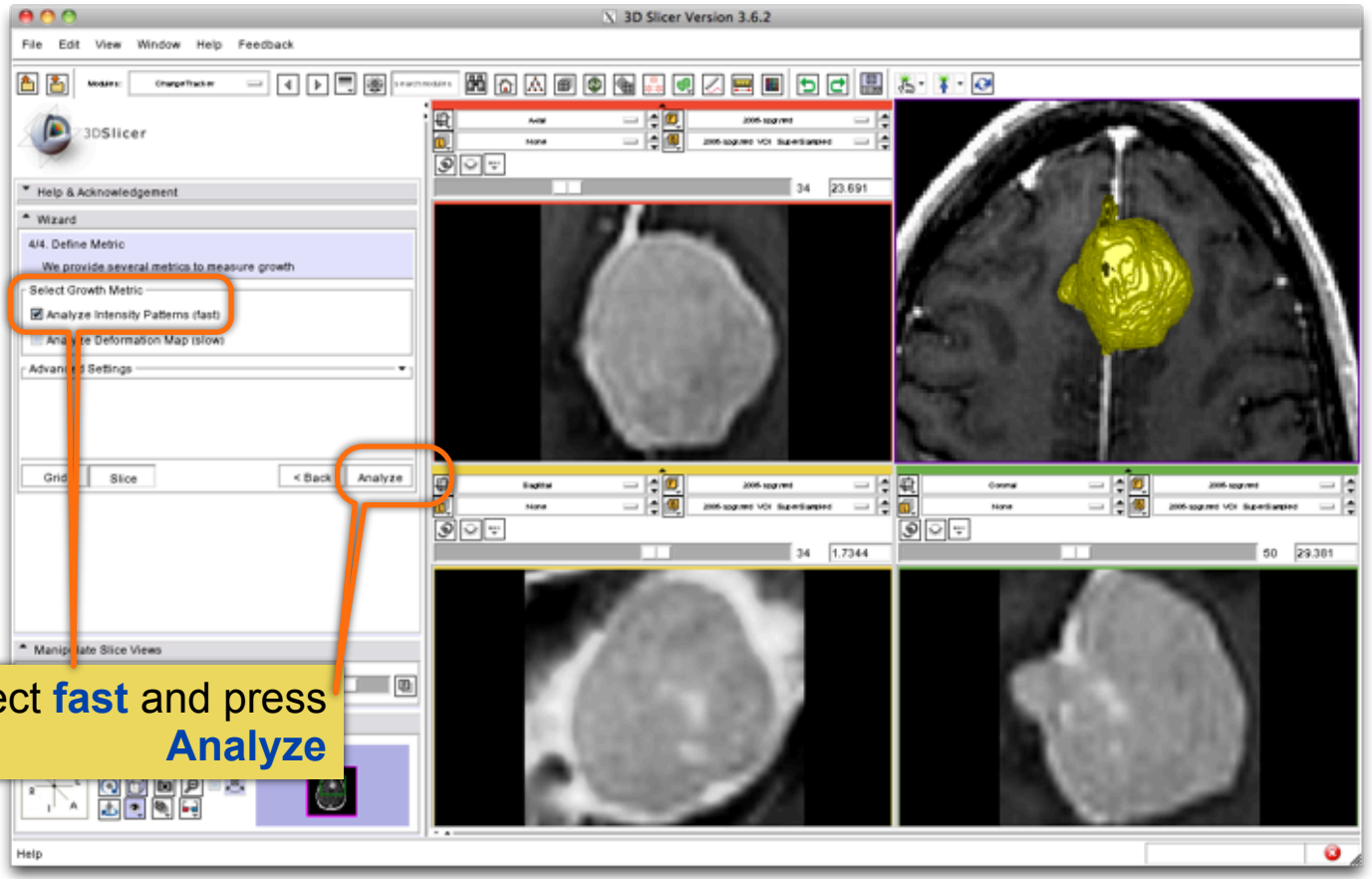


ChangeTracker: Final step: Select Metric

Metric Options:

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

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

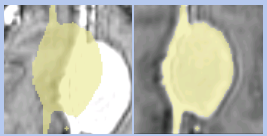


Select **fast** and press **Analyze**

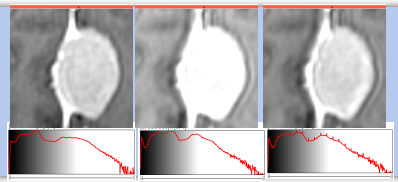
ChangeTracker: Intensity-based analysis details

Konukoglu et al. ,“Monitoring Slowly Evolving Tumors”, ISBI, 2008

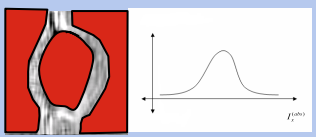
Register baseline and followup (**preserve volume**)



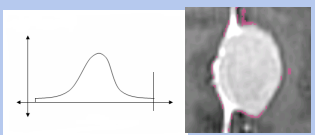
Normalize intensities



Using **segmentation** and **difference image**, compute **PDF of dormant tissue**



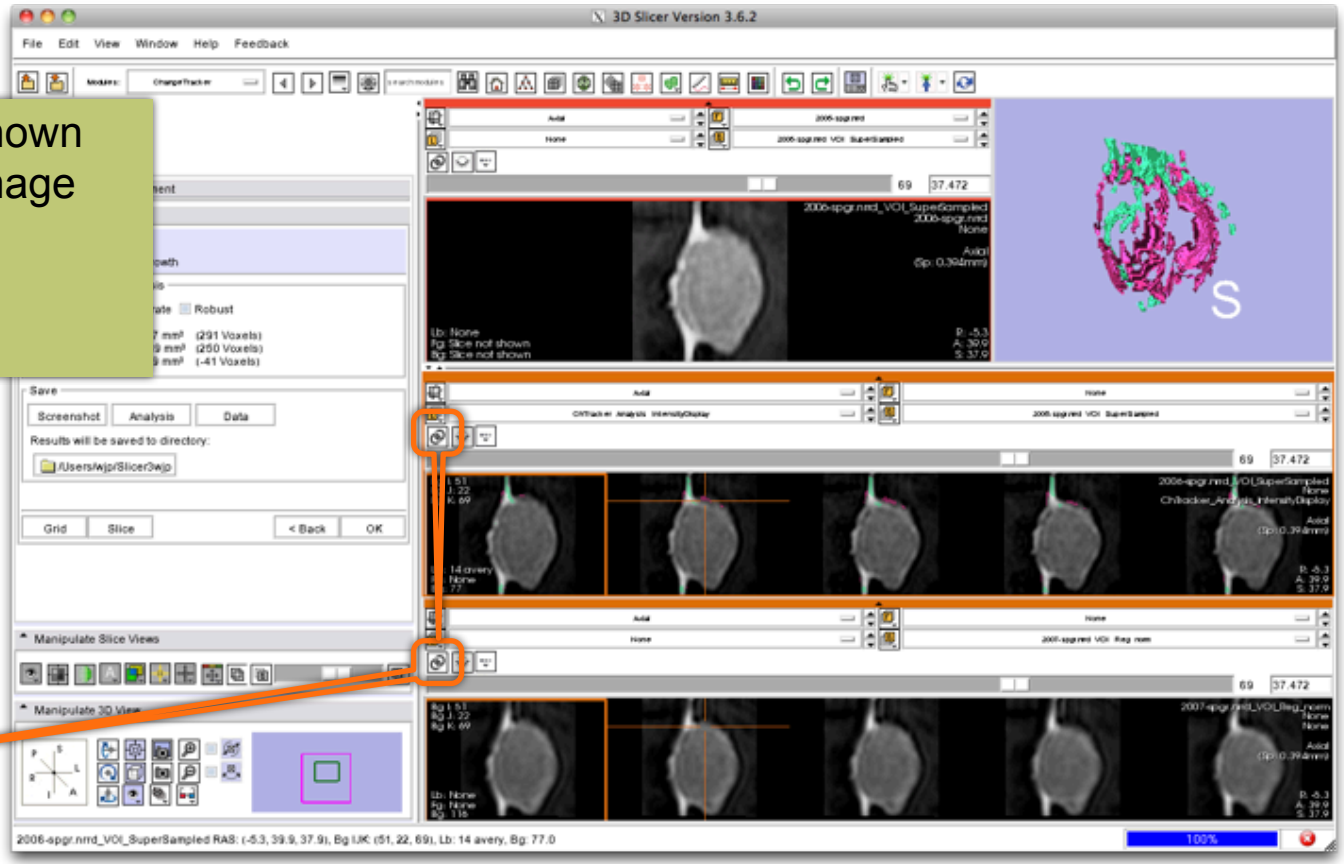
Set **threshold** for voxel-wise analysis



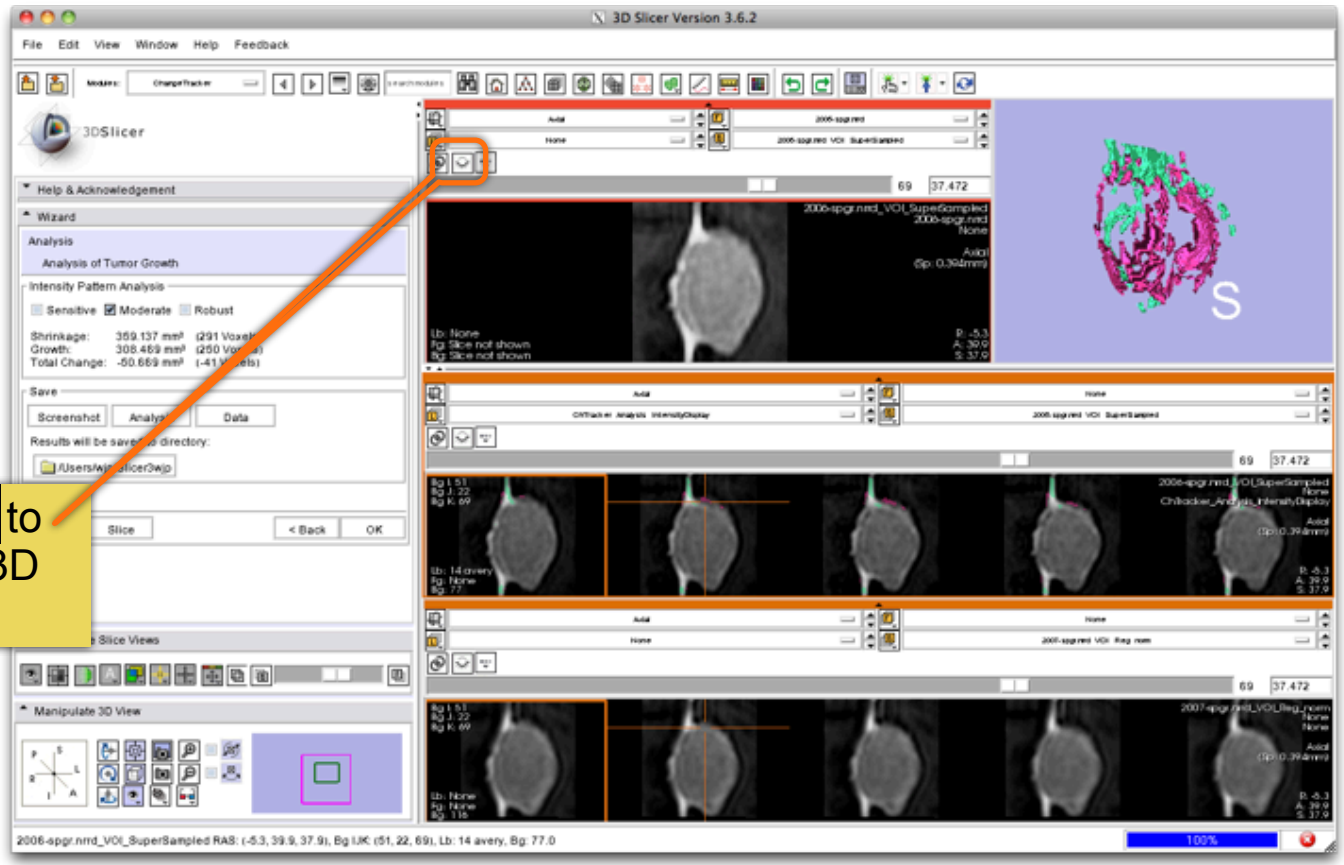
ChangeTracker: Results: change in pathology

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

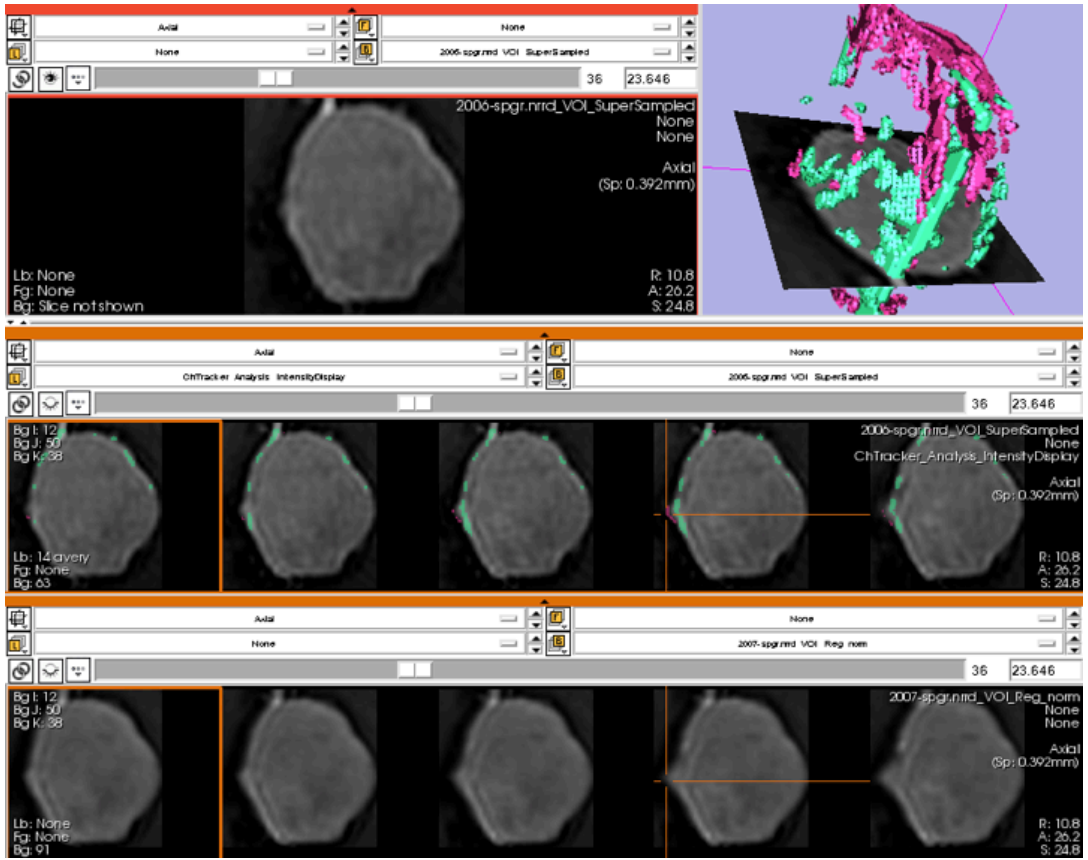


Select **visibility icon** to **show axial slice** in the 3D Viewer.

ChangeTracker: Results: change in pathology

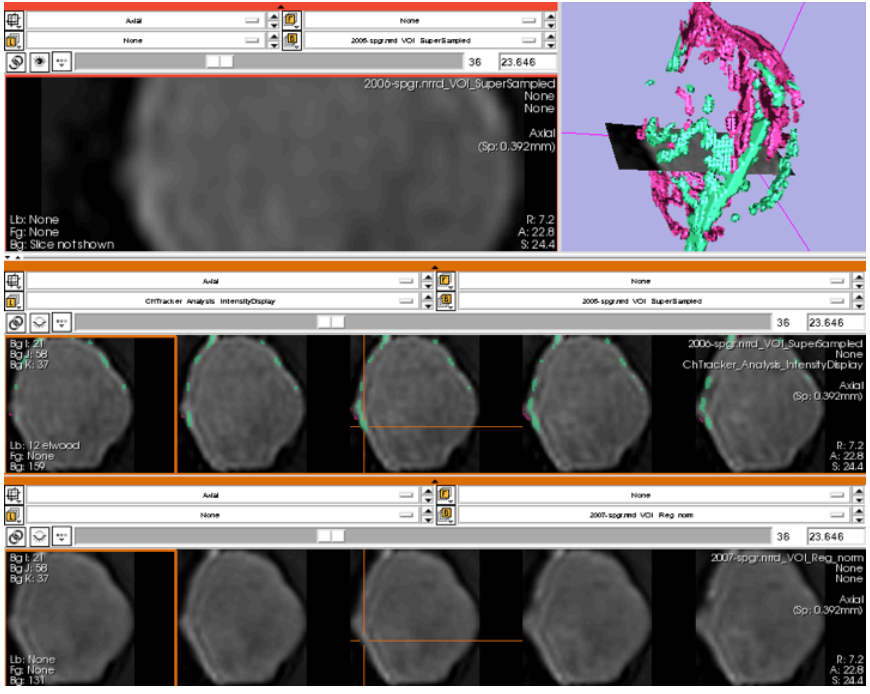
"Compare View" layout displays:

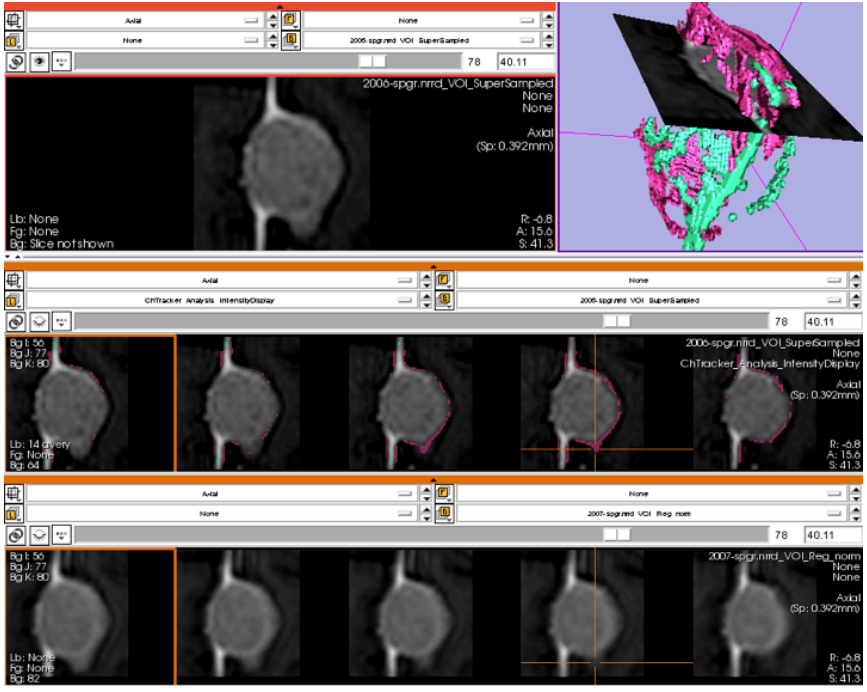
- Axial slice & 3D View
- Five corresponding consecutive slices for the VOI in the baseline **(top row)**, and
- in the followup **(bottom row).**



ChangeTracker: Results: change in pathology

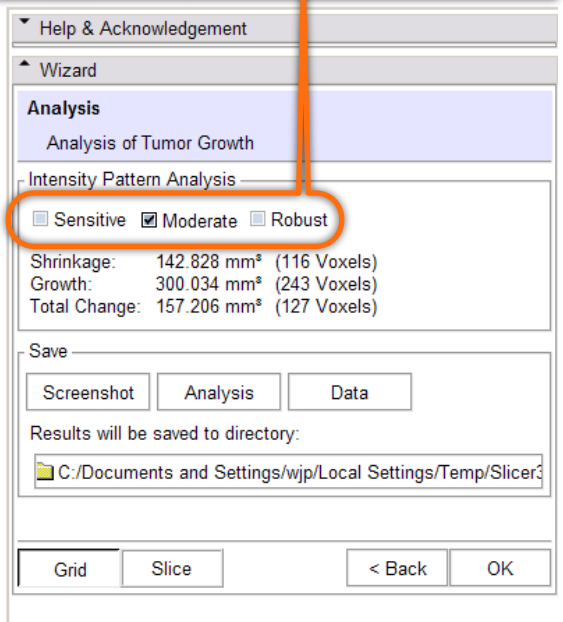
Crosshairs in Compare View show corresponding voxels in **baseline** and **followup** scan for voxel-wise comparison.





ChangeTracker: Exploring small volumetric changes

Modify **sensitivity** of intensity pattern analysis



sensitive

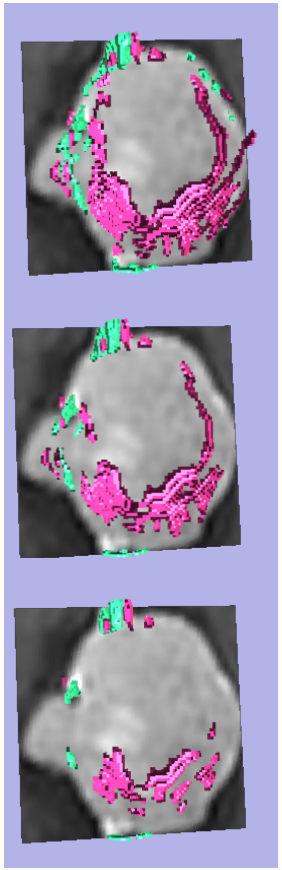
Intensity Pattern Analysis
Sensitive Moderate Robust
Shrinkage: 243.458 mm³ (197 Voxels)
Growth: 327.234 mm³ (265 Voxels)
Total Change: 83.776 mm³ (68 Voxels)

moderate

Intensity Pattern Analysis
Sensitive Moderate Robust
Shrinkage: 164.717 mm³ (133 Voxels)
Growth: 266.577 mm³ (216 Voxels)
Total Change: 101.860 mm³ (82 Voxels)

robust

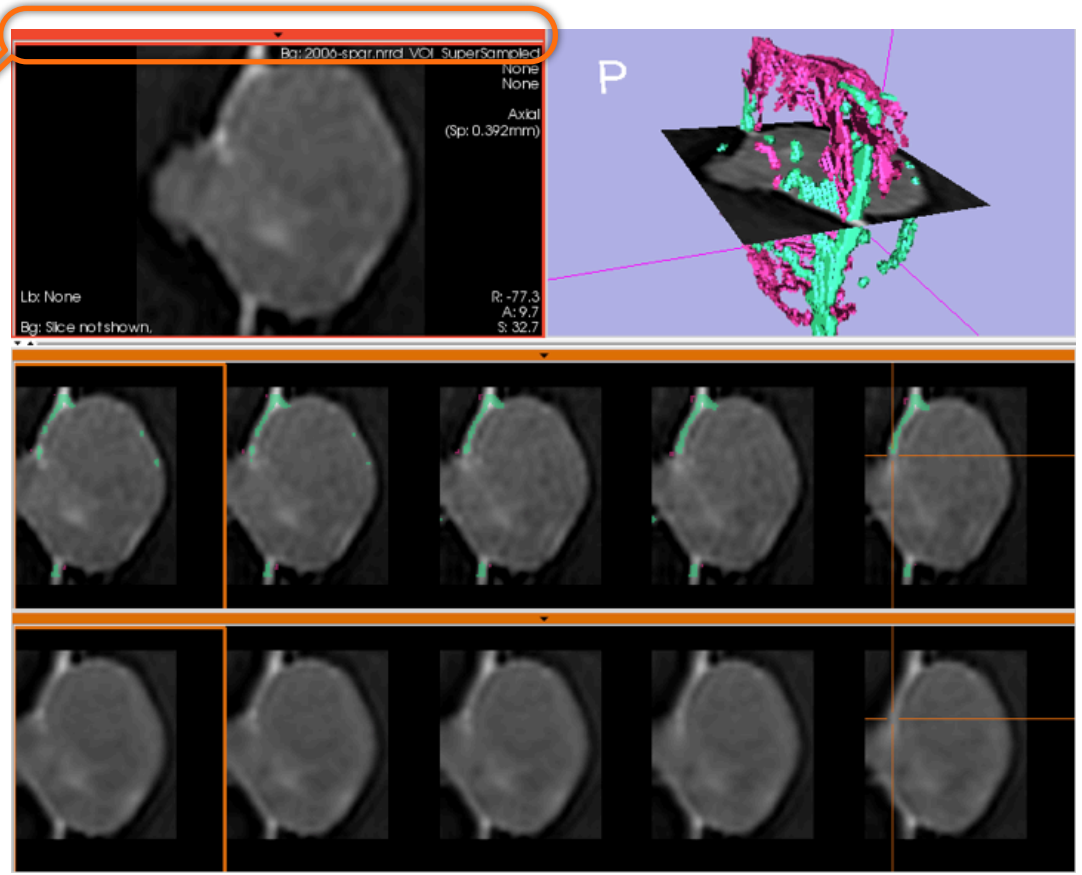
Intensity Pattern Analysis
Sensitive Moderate Robust
Shrinkage: 116.475 mm³ (94 Voxels)
Growth: 186.418 mm³ (151 Voxels)
Total Change: 69.943 mm³ (56 Voxels)



ChangeTracker: Exploring small volumetric changes

Click on the **colored bar** at the top of any Slice Viewer to show or hide the controls.

This allows more display space for viewing the image data.



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 timepoints.

Not tested for tumors with changing necrosis.

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

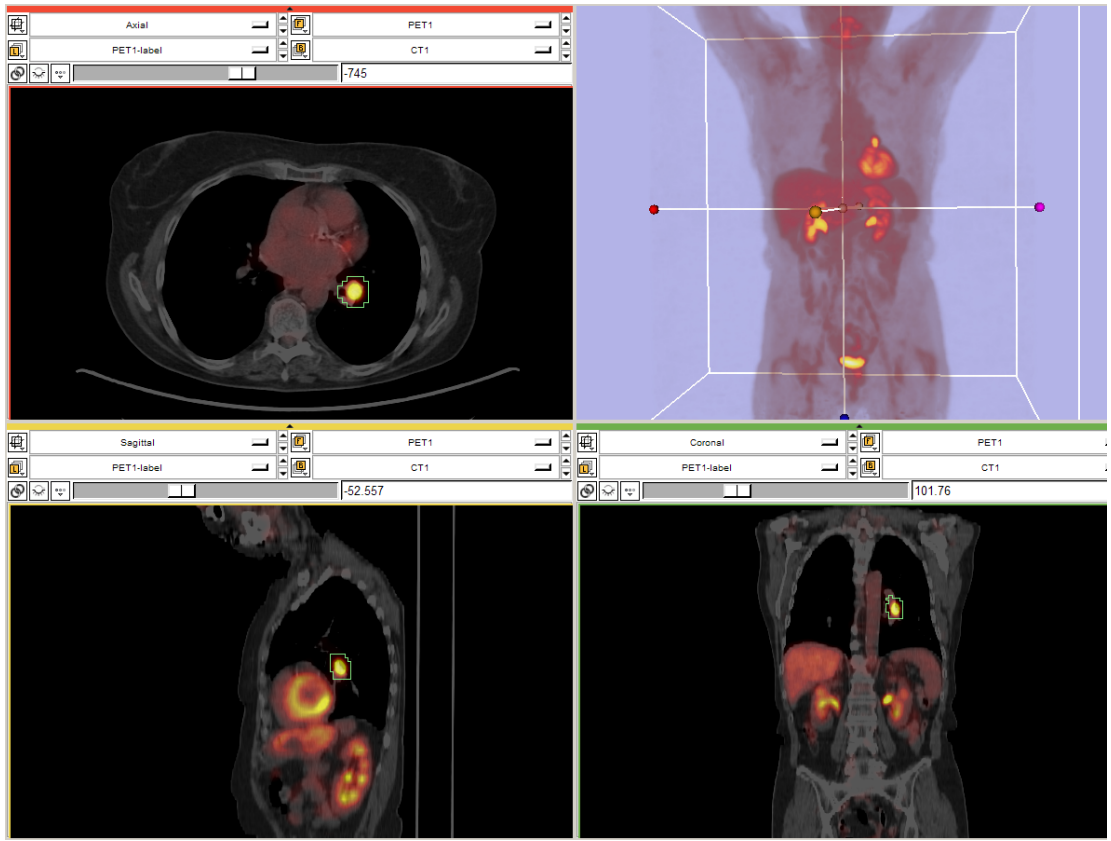
ChangeTracker: exploring small volumetric changes

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 followup studies.

Next, we will demonstrate combined visualization of PET/CT studies and SUV computation.

PET/CT Visualization and Analysis



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

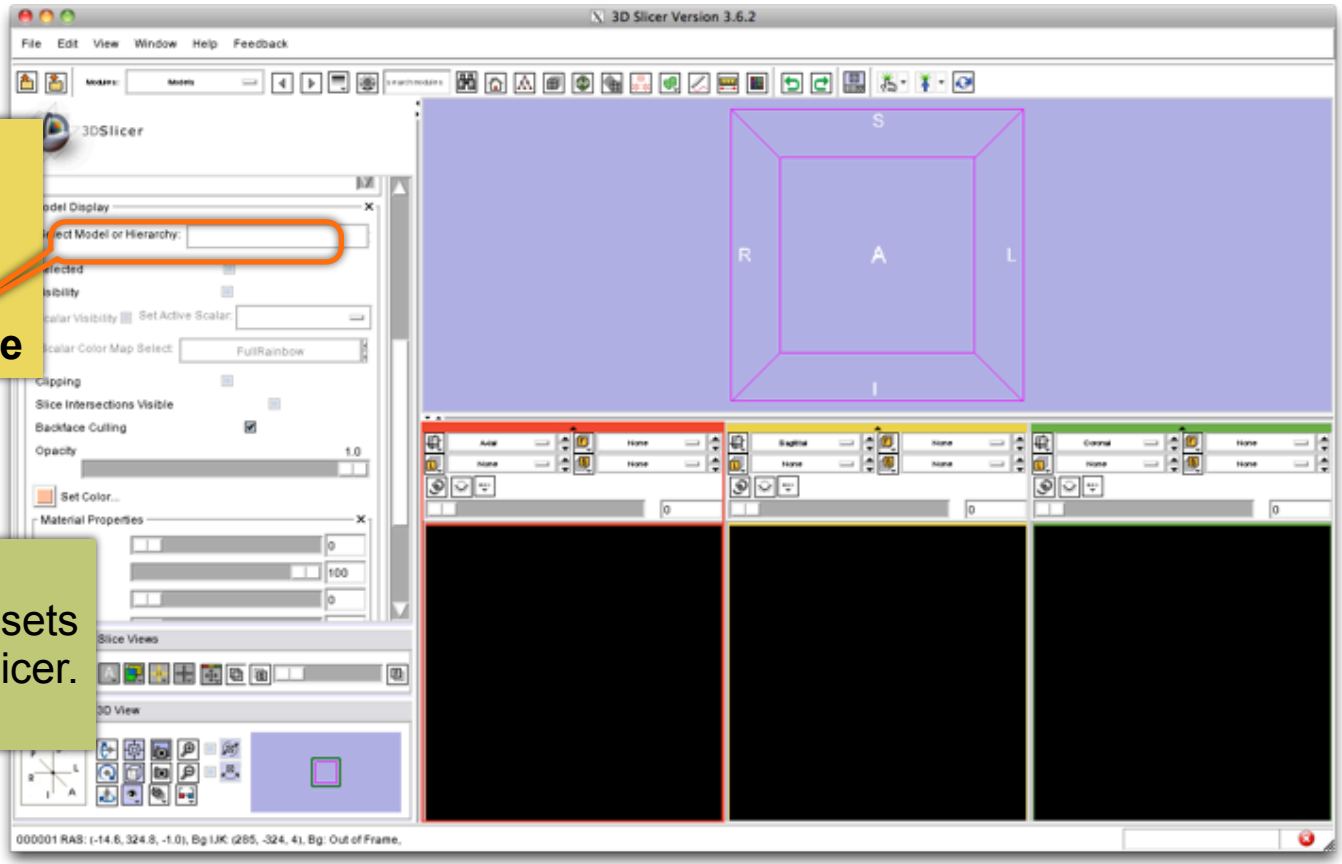
Jeffrey Yap PhD
Ron Kikinis MD
Wendy Plesniak PhD

PET/CT Visualization and Analysis: Start fresh.

First, close any previous scene.

Select **File->Close Scene**

This removes any datasets previously loaded into Slicer.



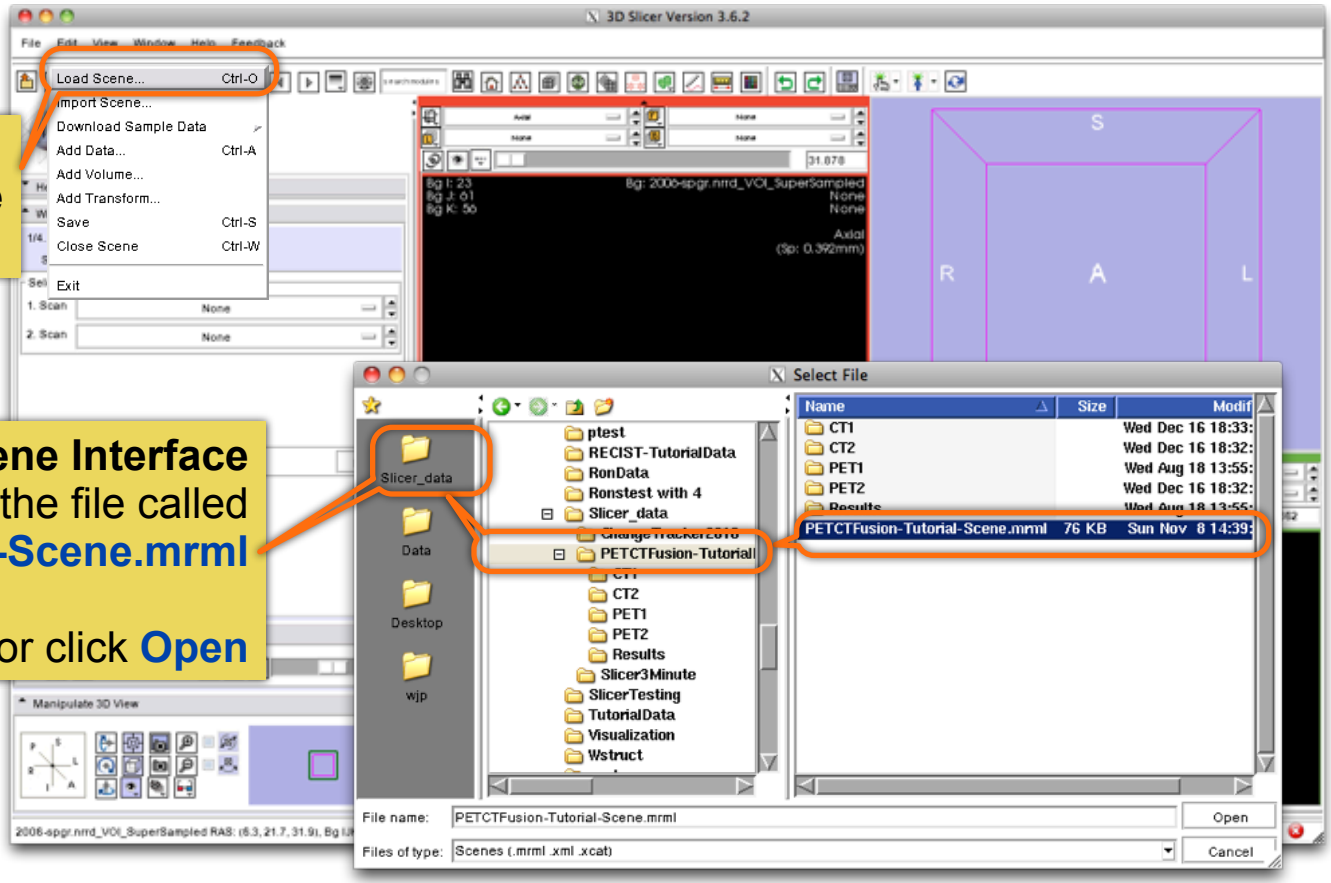
PET/CT Visualization and Analysis: Load the new scene

3DSlicer

Select **File->Load Scene**

This raises the **Load Scene Interface** select the file called **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 treatement, and **followup** acquired 1 month after chemotherapy

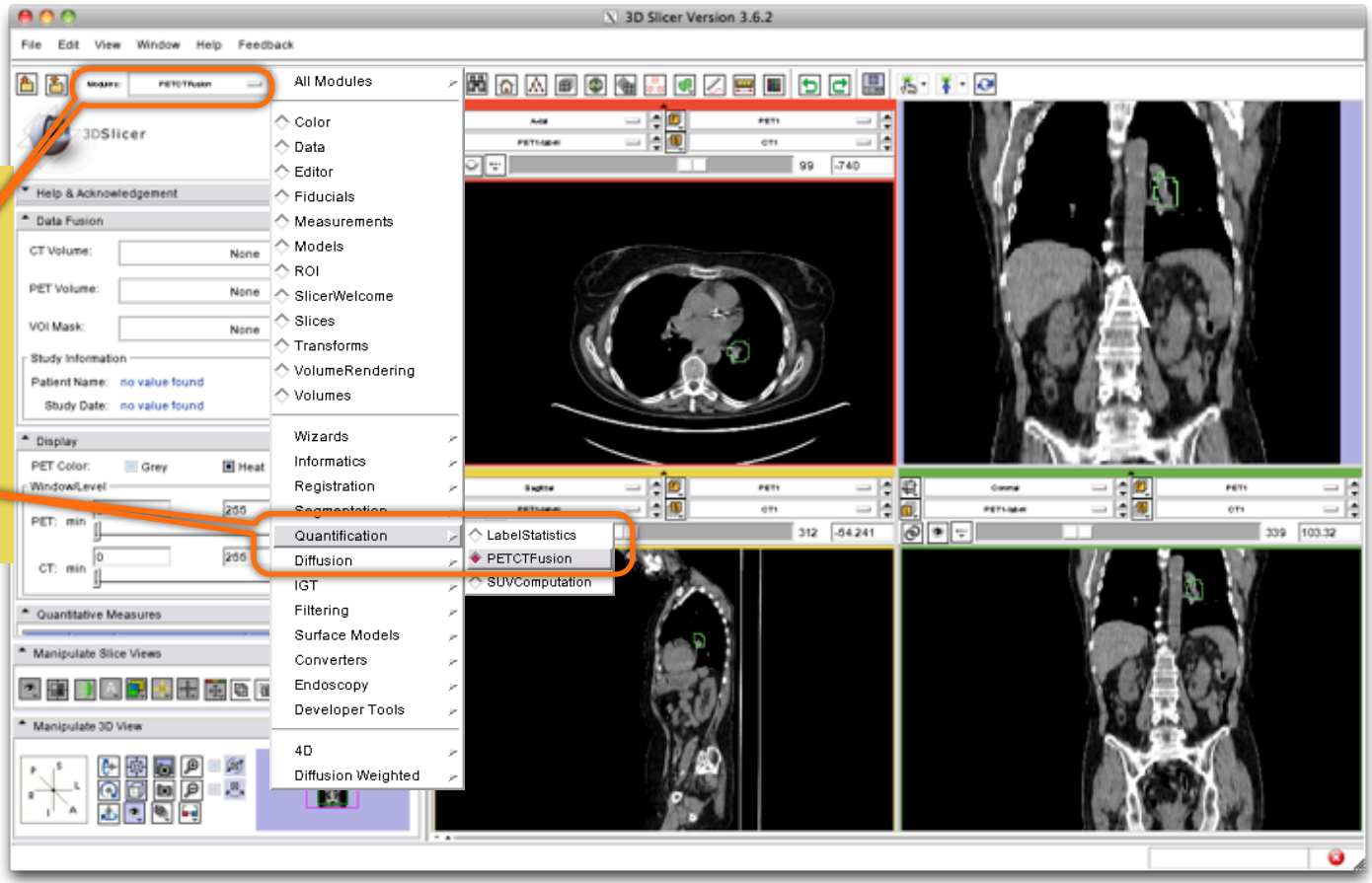
Two non-diagnostic CT images are acquired without the use of contrast

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: Open the PETCTFusion Module

Using the **Modules Menubutton**: Expose the menu and select the module called **PETCTFusion** under the **Quantification** category.



PET/CT Visualization and Analysis: Select baseline study

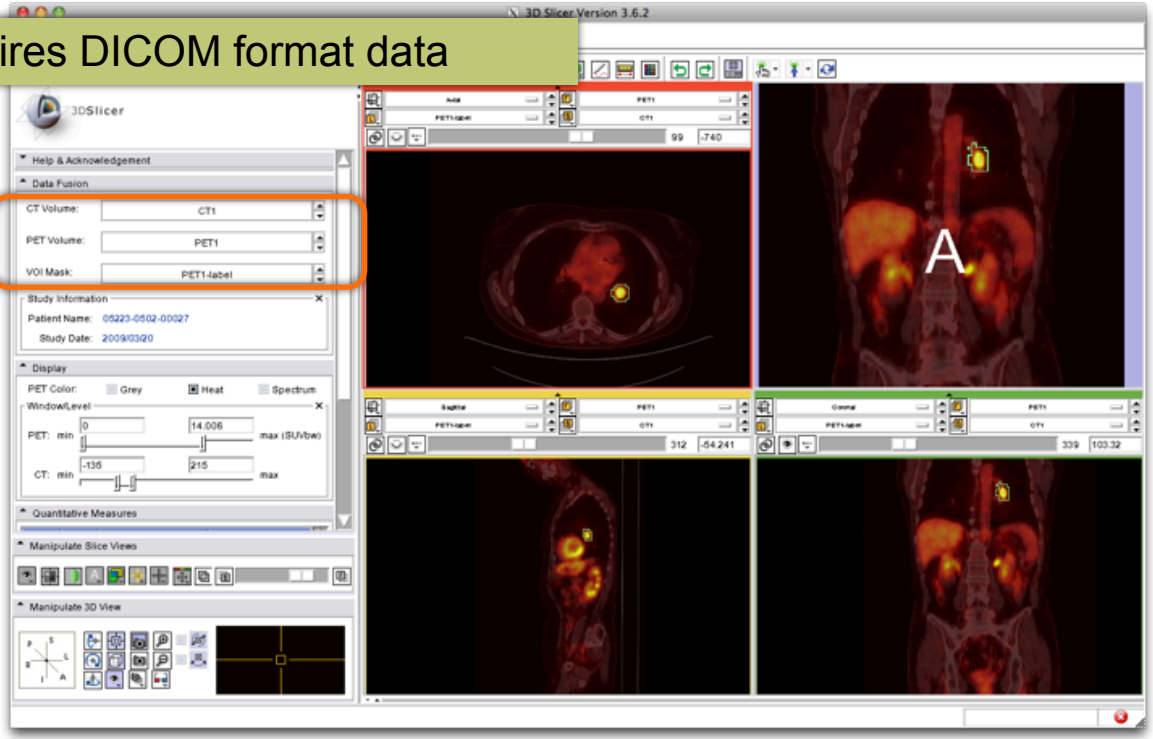
Note: Module requires DICOM format data

In the Data Fusion panel, select:

CT volume: CT1

PET volume: PET1

Tumor Mask: PET1-label



When the PET volume is selected, a “wait message” will be displayed while parameters are read from DICOM header.

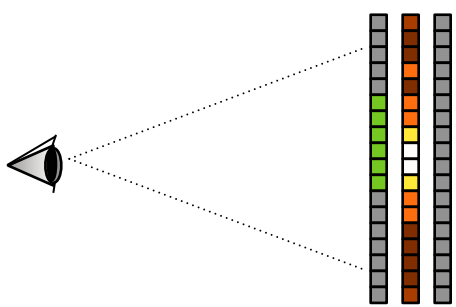
PET/CT Visualization and Analysis: Information displayed in "Layers"

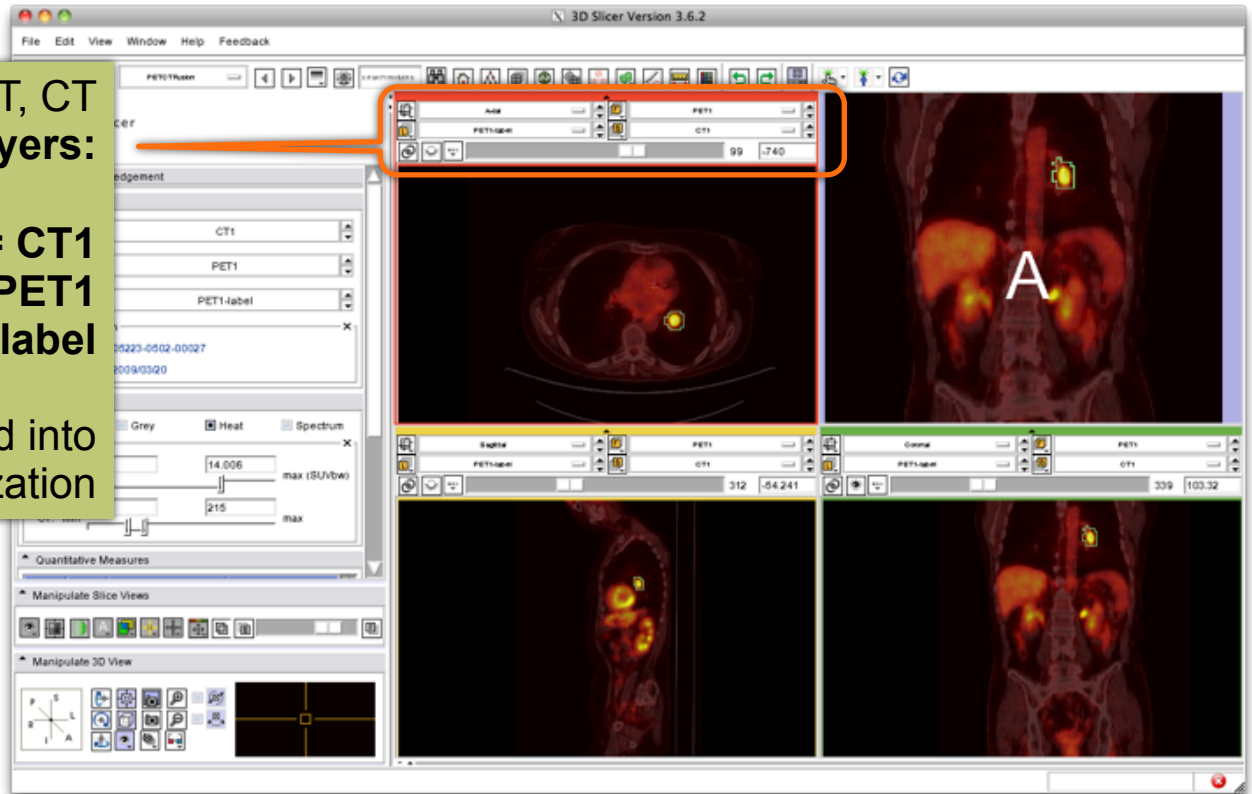
3DSlicer

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



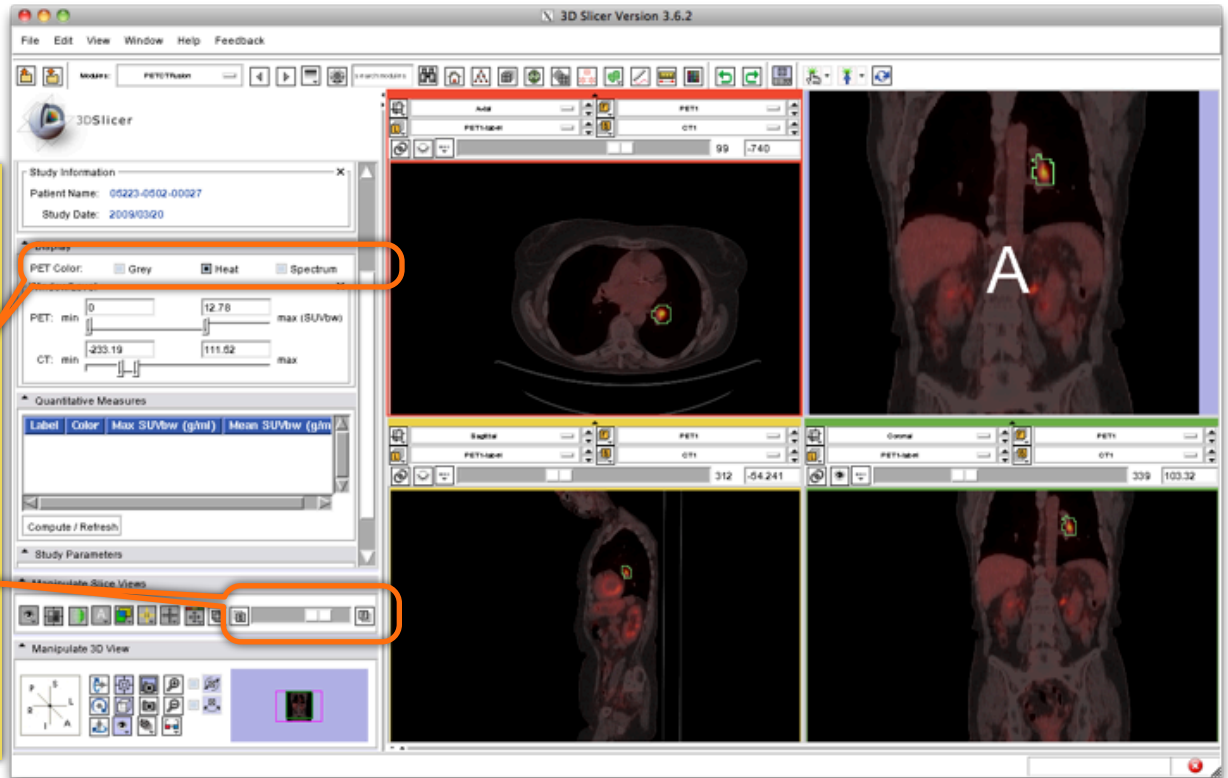


PET/CT Visualization and Analysis: Adjust display of the baseline study

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

Adjust the **window and level** for CT1 and PET1 volumes.

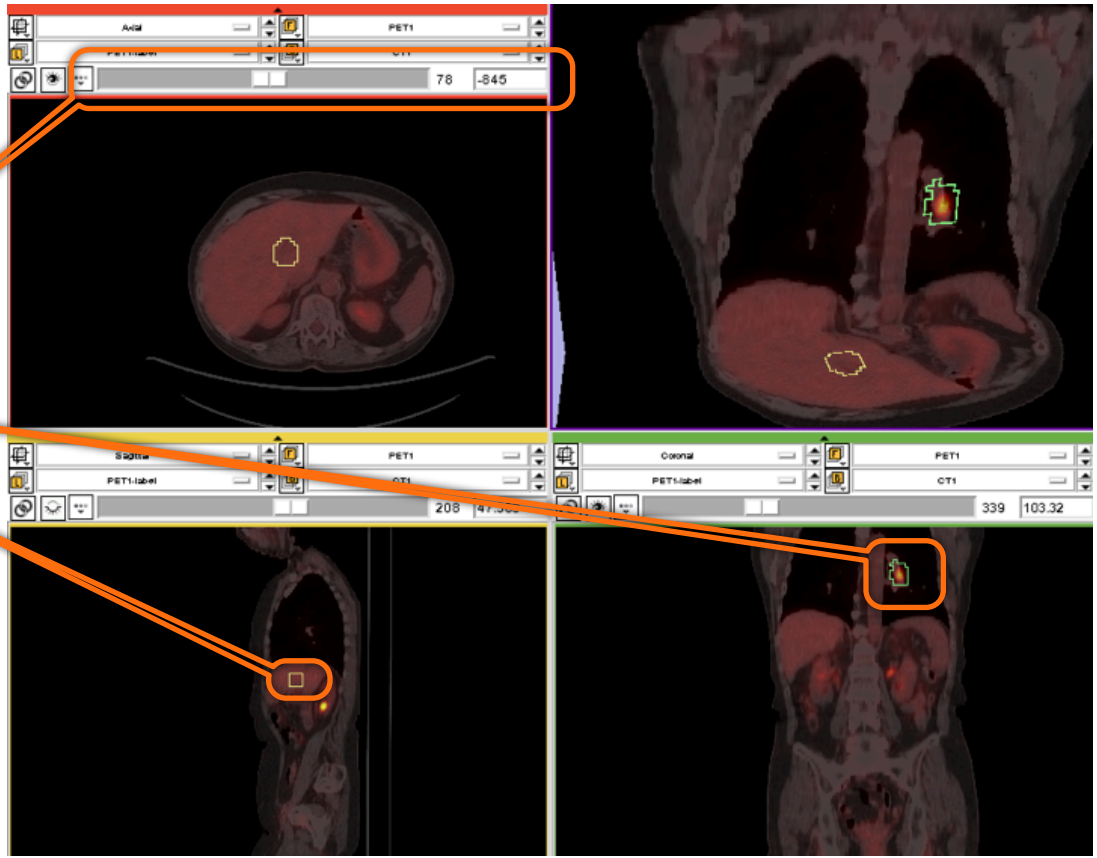
Adjust the **Slices Fade Scale** to jointly display the datasets in the foreground and background layers.



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).

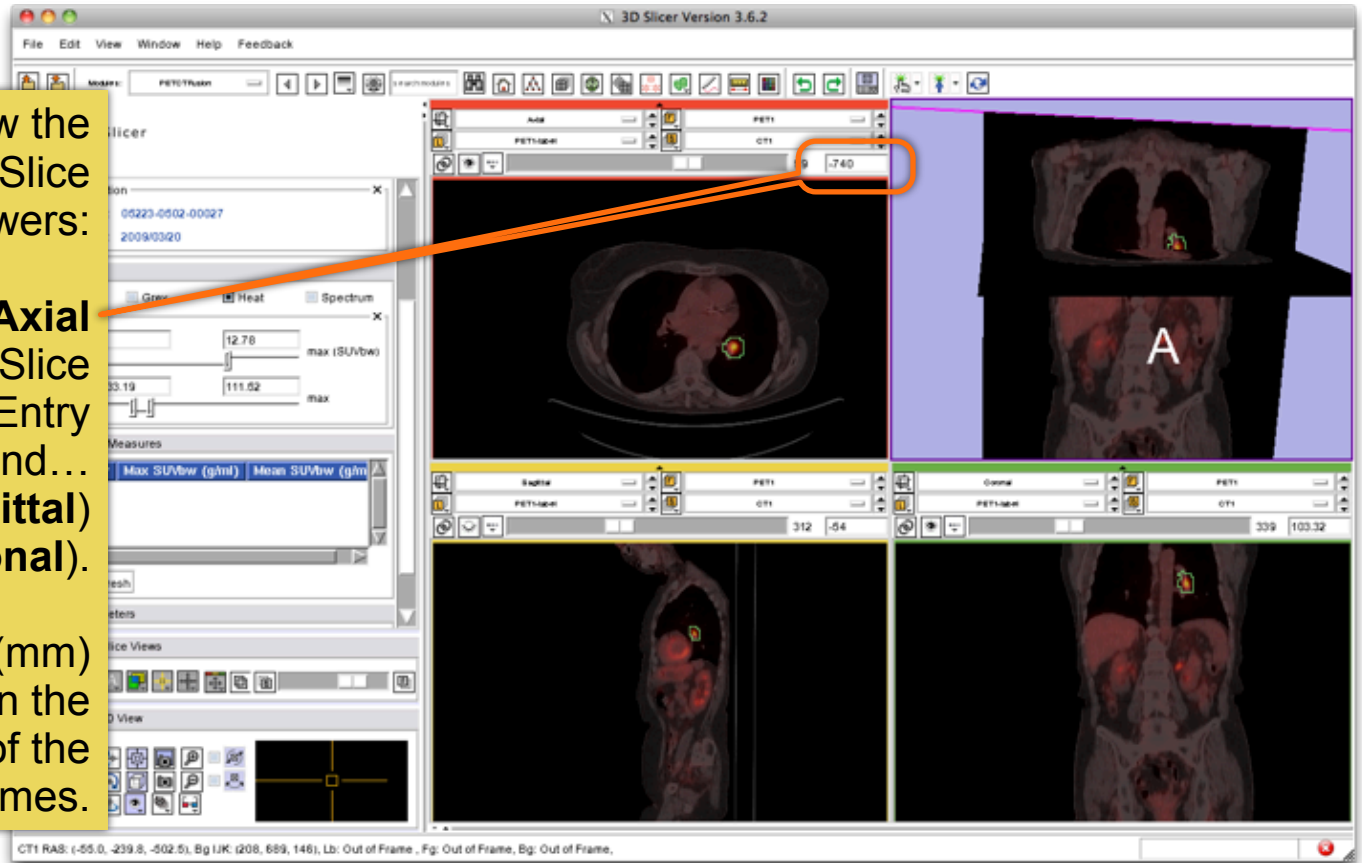


PET/CT Visualization and Analysis: View tumor in all slice viewers

Shortcut: To view the Tumor Label in all Slice Viewers:

Enter **–740** in the **Axial** Slice Viewer's Slice Number Entry …and… **-54** (**Sagittal**) **103** (**Coronal**).

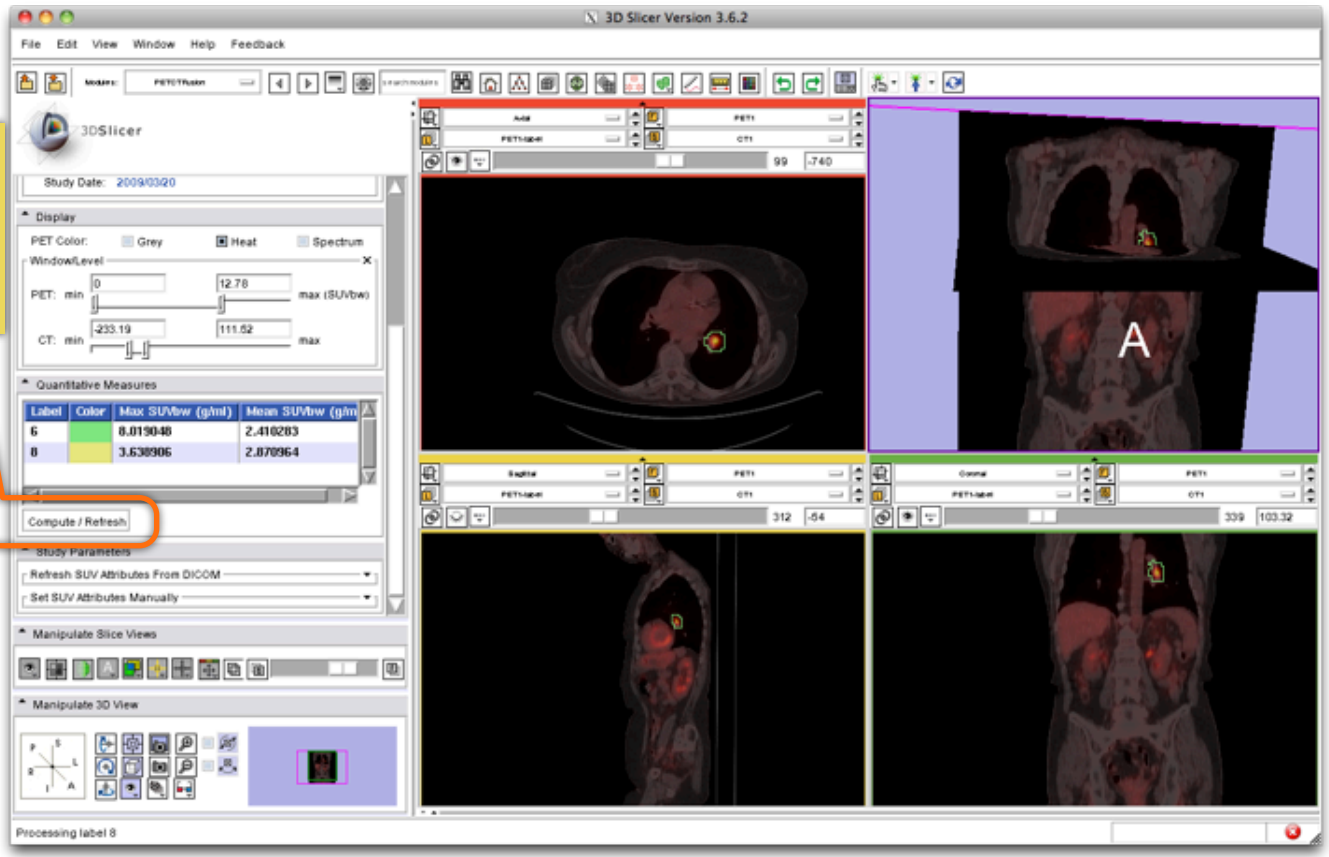
These are (mm) positions within the reference frame of the image volumes.



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

In the Quantitative Measures panel, **click the Compute/ Refresh button**.

SUVmax and **SUVmean** for each VOI (represented by a different color in the label map) will be displayed in the table.

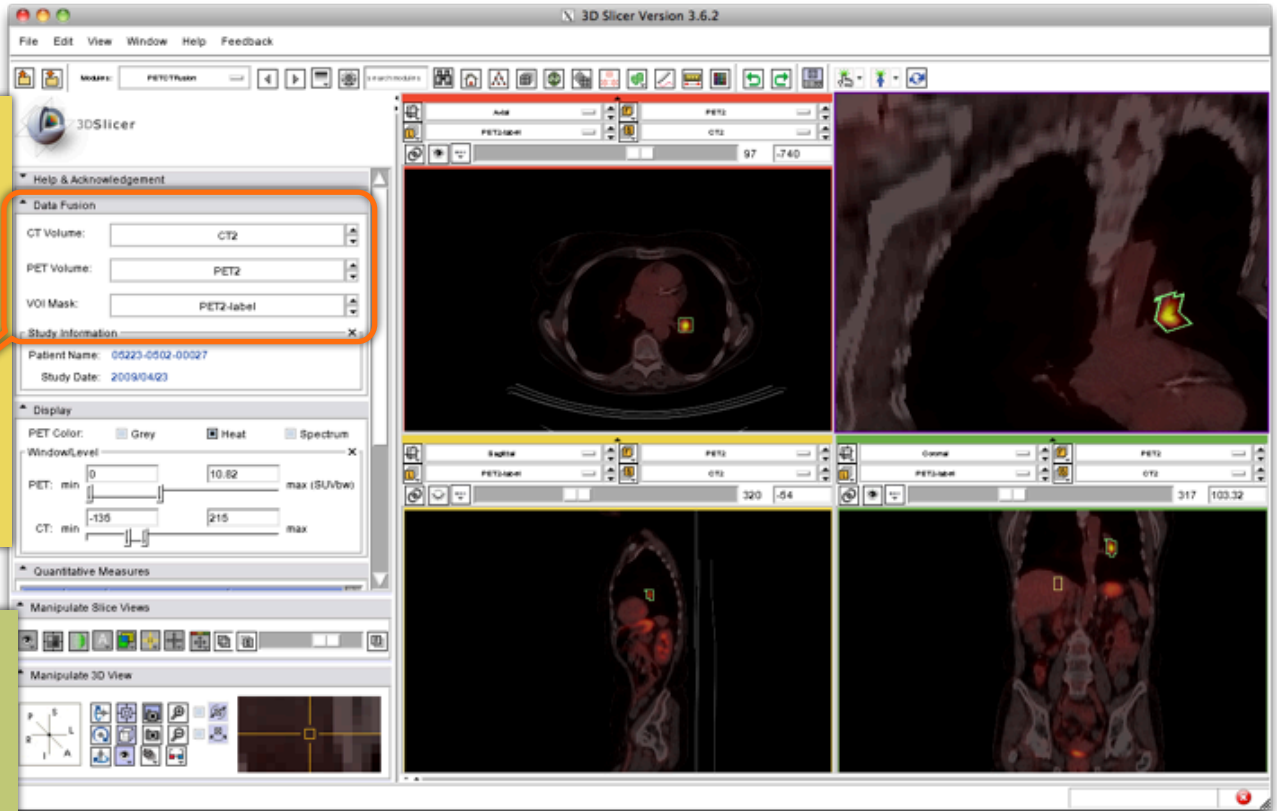


PET/CT Visualization and Analysis: Compute SUVbw for follow-up study

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

In the Data Fusion panel, set:
CT volume = **CT2**,
PET volume = **PET2** and
Tumor Mask = **PET2-label**.

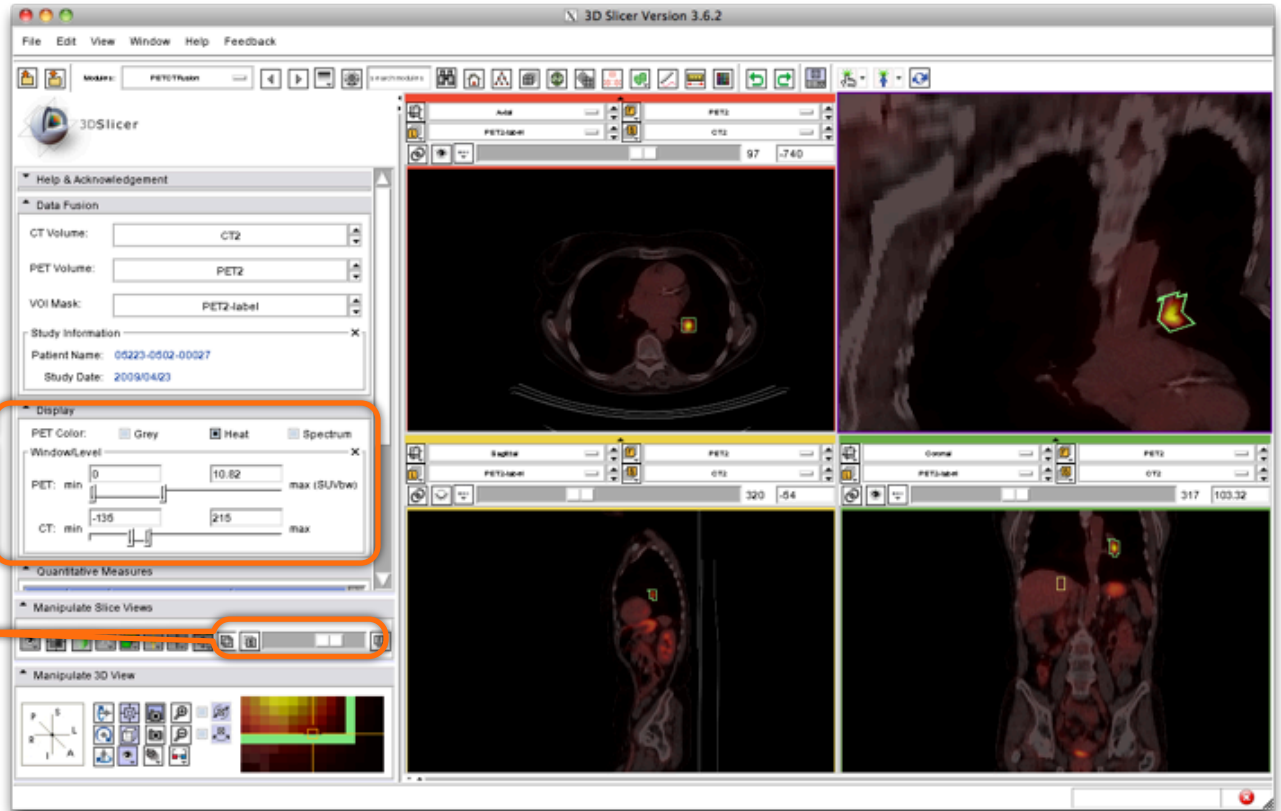
This dataset contains two **VOIs** that correspond to the segmentations the baseline study.



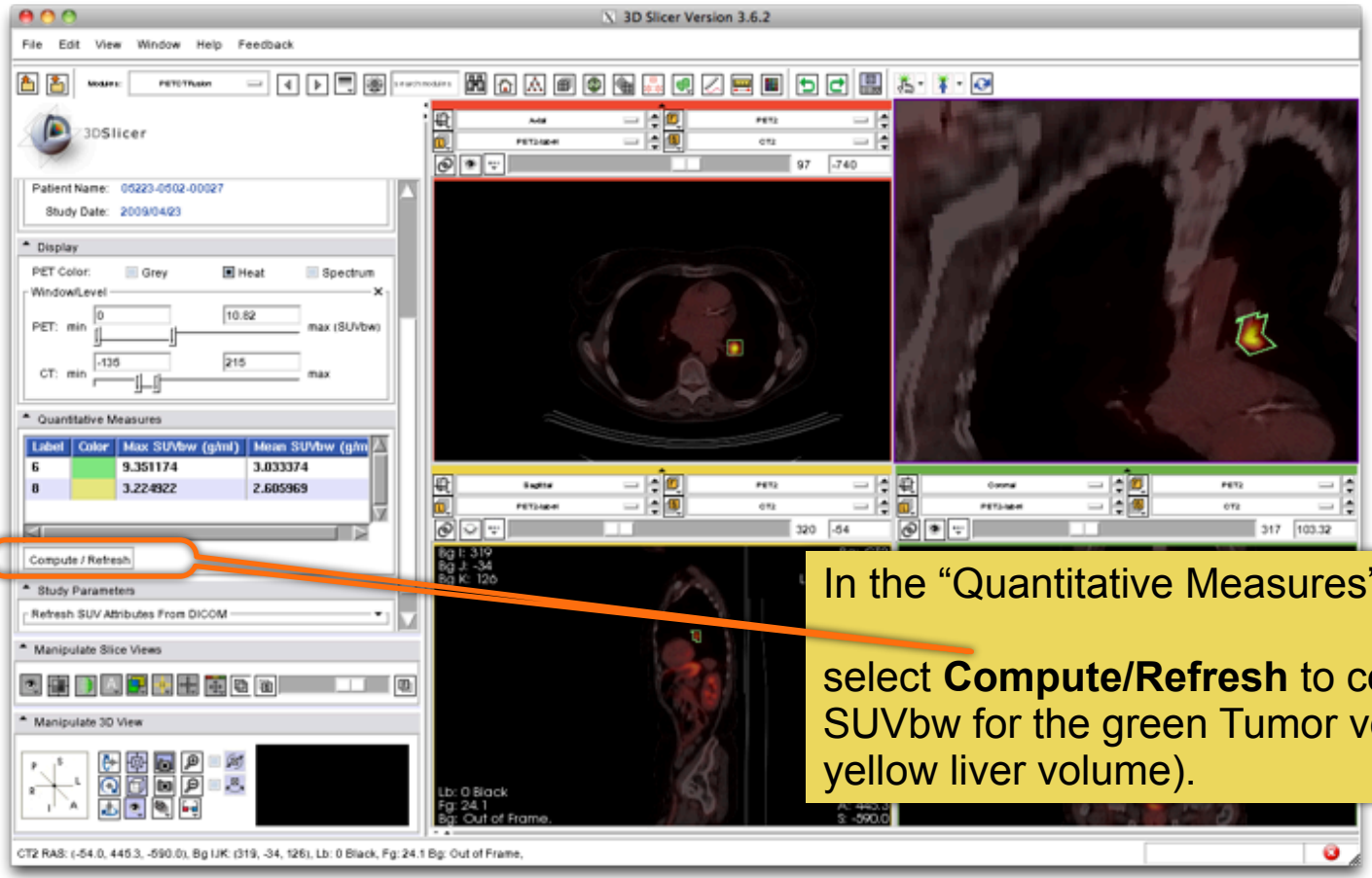
PET/CT Visualization and Analysis: Modify display of the follow-up

Adjust the **display** for the follow-up study.

You may want to adjust the **Slices Fade Slider** and manipulate the 3D View to refresh them.



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



In the “Quantitative Measures” Panel:

select **Compute/Refresh** to compute SUVbw for the green Tumor volume (and yellow liver volume).

PET/CT Visualization and Analysis: Assess response wrt this VOI

Pre-Treatment Max SUVbw = 8.0

Post-Treatment Max SUVbw = 9.4

+16.61% (SD)

PET/CT Visualization and Analysis: Appropriate Use

Still validating this module against performance of commercial systems.

Appropriate only for DICOM PET studies only

Not compatible with Philips datasets

Workshop Summary

This workshop has demonstrated:

- Basic scene loading and visualization using 3D Slicer
- Use of Slicer's ChangeTracker module to assess small changes in tumor size
- Workflow to make quantitative measurements of SUV (body weight) in Slicer's PETCTFusion module

Workshop Summary: Slides and Datasets

Tutorial Slides:

http://wiki.na-mic.org/Wiki/images/4/4e/Combined-RSNA09-WJP.ppt

Tutorial Data:

http://wiki.na-mic.org/Wiki/images/5/51/Slicer3MinuteDataset.zip
http://wiki.na-mic.org/Wiki/images/f/f8/RSNA-ChangeTracker-Tutorial-Data.zip
http://wiki.na-mic.org/Wiki/images/7/73/PETCTFusion-Tutorial-Data.zip

Tutorial Software:

http://www.na-mic.org/Slicer/Download/Snapshots/win32/Slicer3-3.5-RSNA-2009-11-06-win32.exe

More Information:

http://www.slicer.org

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