Surgical Planning Laboratory
Brigham and Women's Hospital
Boston, Massachusetts USA

a teaching affiliate of
Harvard Medical School

3D VISUALIZATION OF DICOM IMAGES FOR RADIOLOGICAL APPLICATIONS

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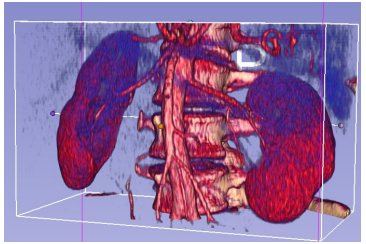
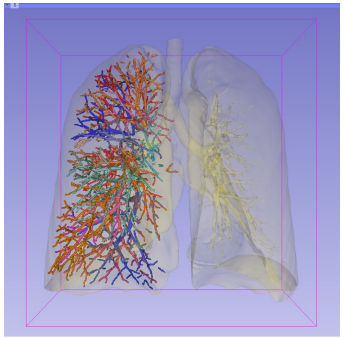
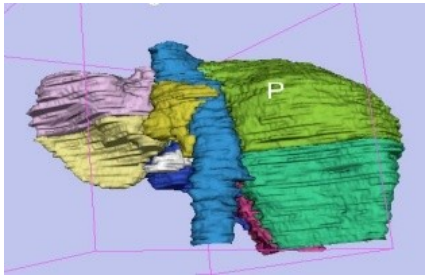
3D Visualization of DICOM images for Radiological applications

Following this tutorial, you will be able to load and visualize DICOM volumes with 3D Slicer, and to interact in 3D with structural images and models of the anatomy.

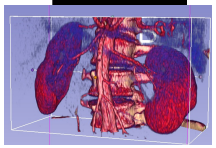


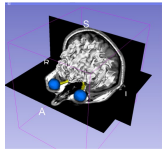




Overview

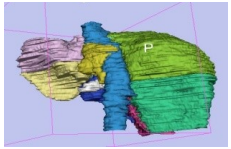
Part I: Introduction to the 3DSlicer software

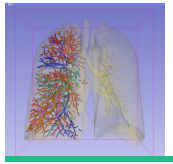




Part II: 3D Data Loading and visualization of DICOM images

- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data





Part III: 3D interactive exploration of the anatomy

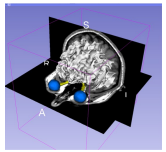
- Exploration of the Segments of the liver
- Exploration of the Segments of the lung

Tutorial Datasets

The tutorial data include 4 datasets:

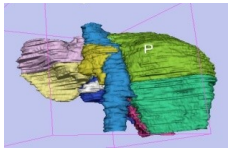
3D Visualization DICOM images part 1:

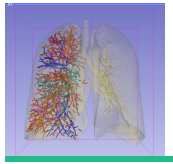
- dataset1_Thorax_Abdomen
- dataset2_Head



3D Visualization DICOM images part 2

- dataset3_Liver
- dataset4_Chest





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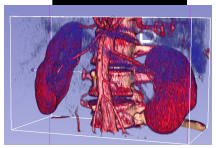

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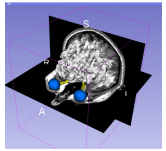

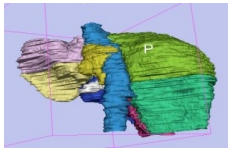

Part III: 3D interactive exploration of the anatomy

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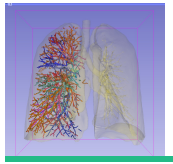
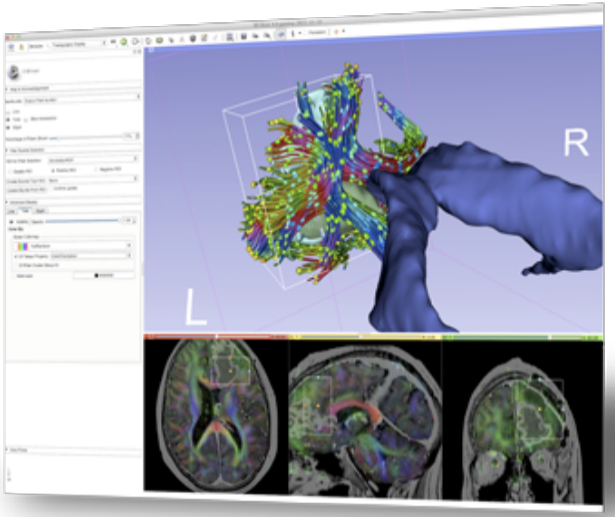
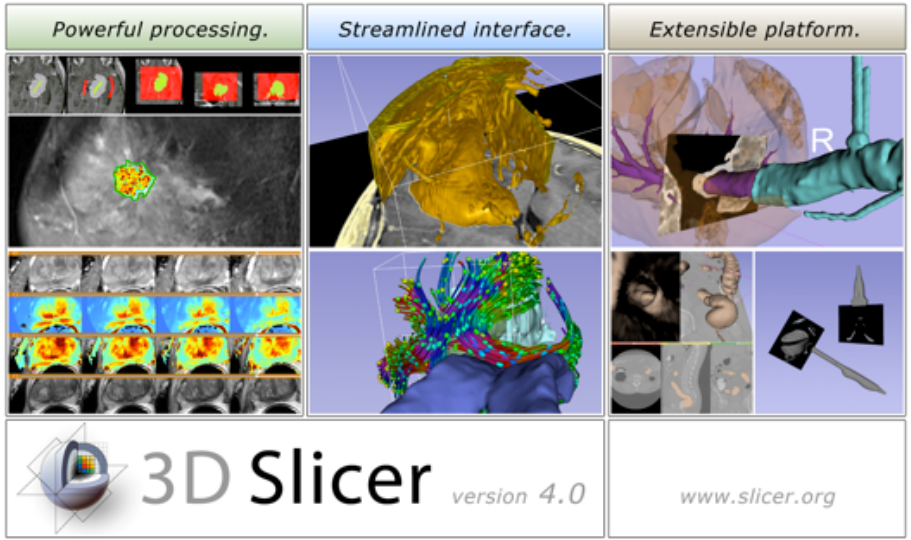


Introduction to the 3DSlicer software



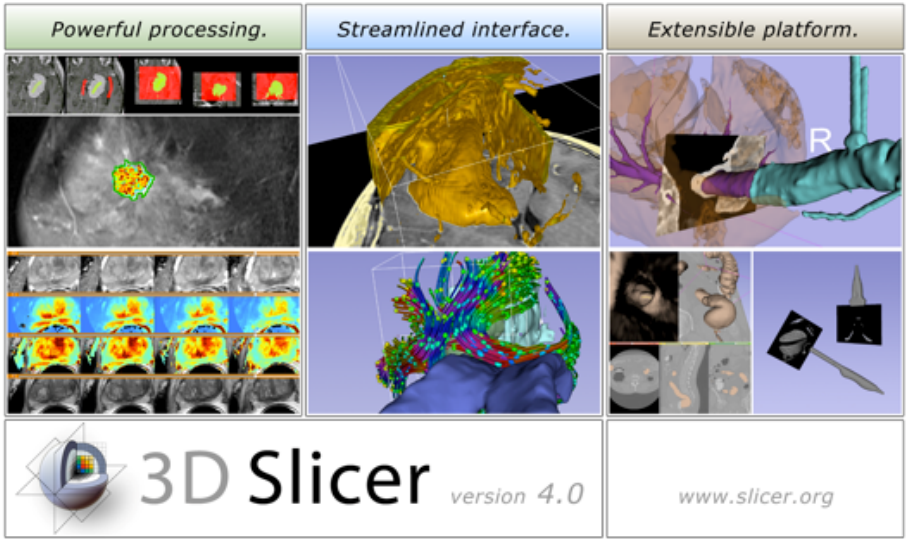
3DSlicer



3D Slicer is a freely available open-source platform for segmentation, registration and 3D visualization of medical imaging data.

3D Slicer is a multi-institutional effort supported by the National Institute of Health.

3DSlicer

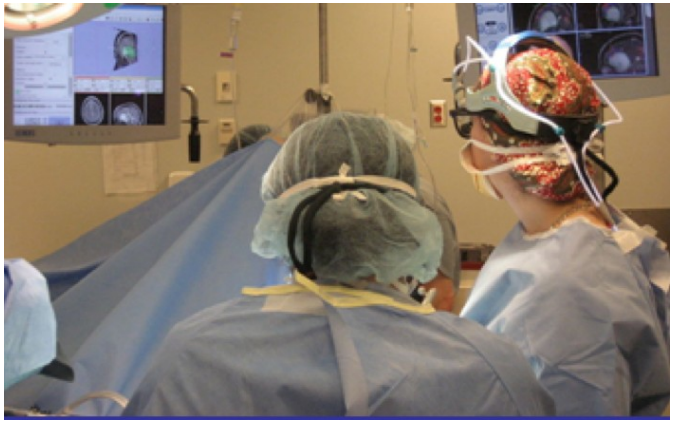


- 3DSlicer version 4.3 is a multi-platform software running on Windows, Linux, and Mac OSX
- Slicer is distributed under a BSD license with no restriction on use
- Slicer is a tool for research, and is not FDA approved

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.

An interdisciplinary platform

An open-source environment for software developers



An end-user application for clinical investigators and scientists

A software platform that is both easy to use for clinical researchers and easy to extend for programmers

3DSlicer History

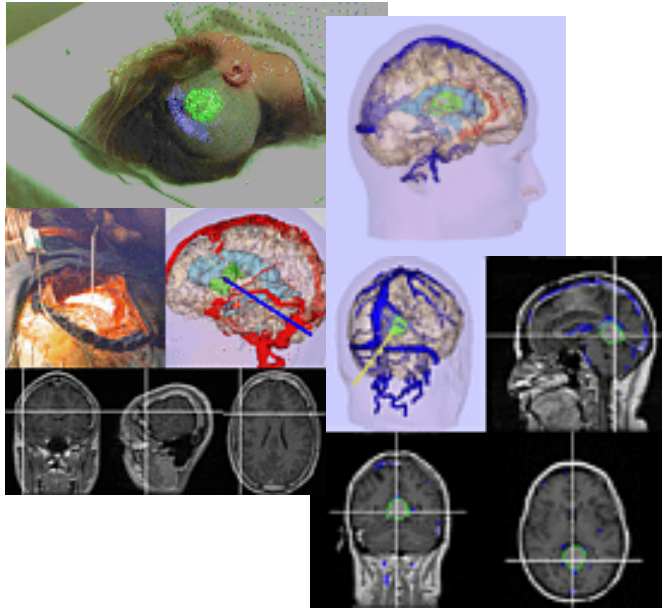
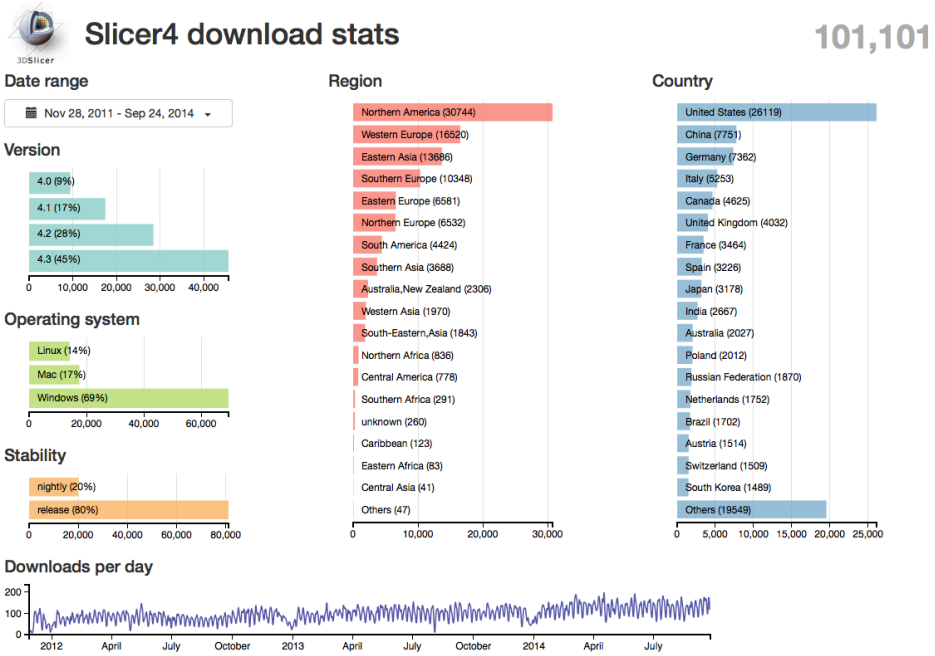


Image Courtesy of the CSAIL, MIT

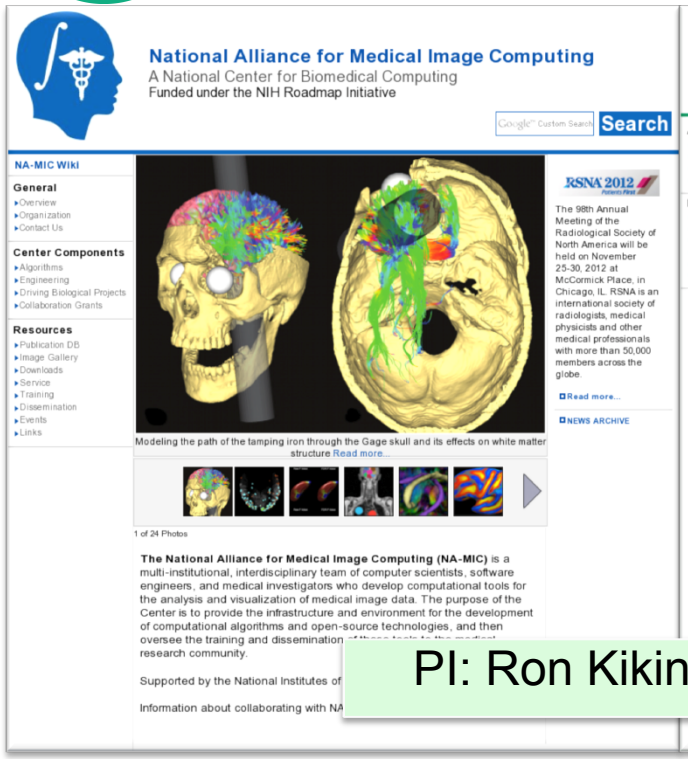
- 1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)

3DSlicer History



- 1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)
- 2014: Multi-institution effort to share the latest advances in image analysis with the clinical and scientific community

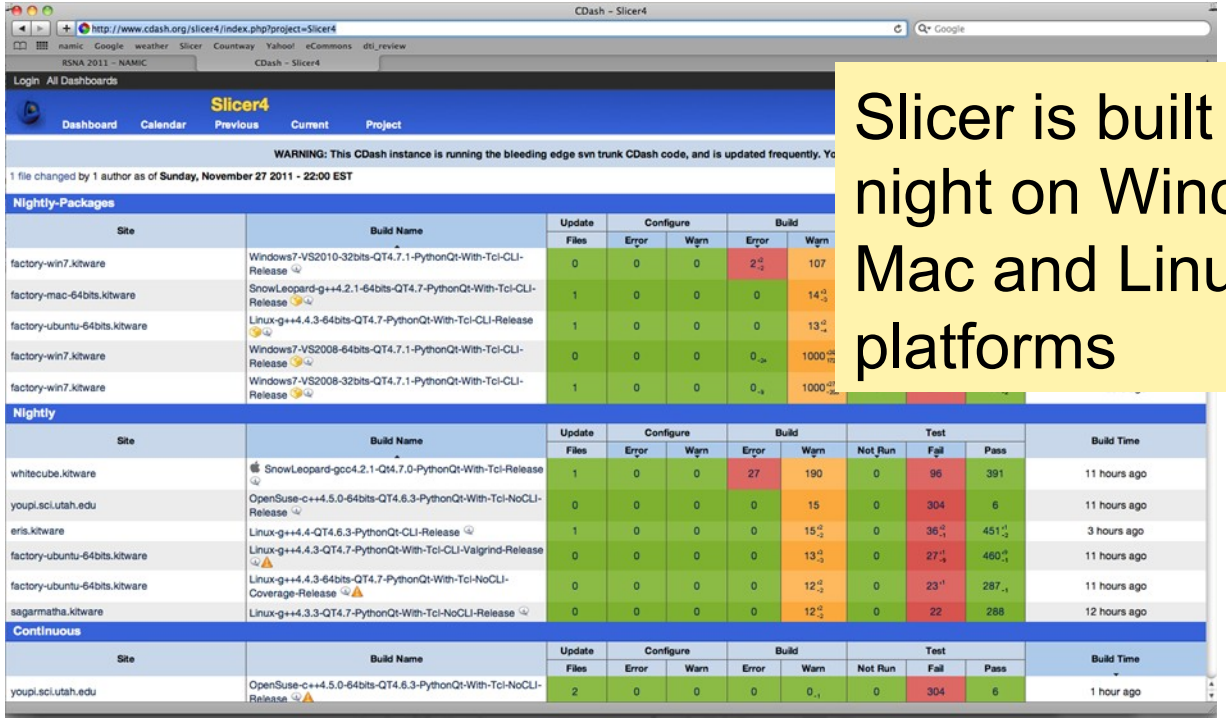
A multi-institution: NA-MIC, NAC, NCIGT



PI: Ron Kikinis, M.D.

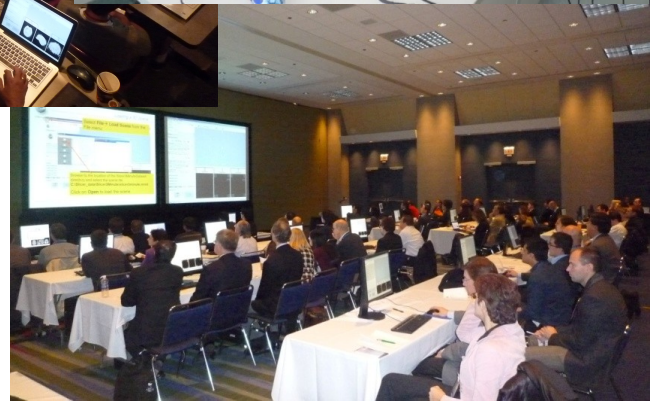
PIs: Ferenc Jolesz, M.D., Clare Tempany, M.D.

Slicer: Behind the scenes



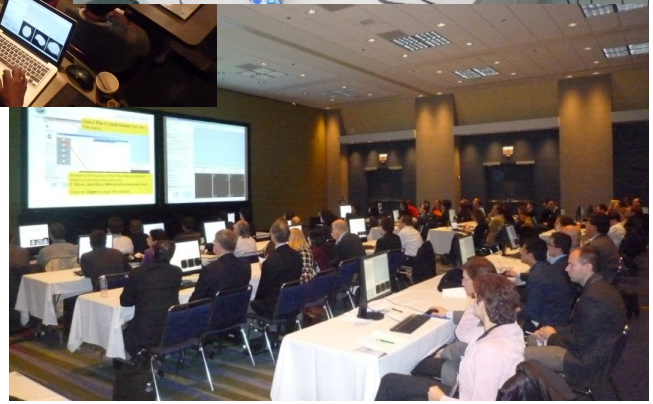
Slicer is built every night on Windows, Mac and Linux platforms

Slicer Training events



- Hands-on training workshops at national and international venues
- More than 2,700 clinicians, clinical researchers and scientists trained since 2005

Slicer Training events



RSNA 2011

Major international conferences

- **RSNA** 2008, 2009, 2010, 2011, 2012, 2013, 2014
- **MICCAI** 2008, 2009, 2011, 2012, 2013, 2014
- **SfN** 2009, 2011
- **SPIE** 2012, 2013, 2014
- **CAOS** 2010
- **CARS** 2010, 2012, 2013

RSNA Activities

Hands-on refresher courses

- 3D Visualization of DICOM images for Radiology Applications
- Quantitative Imaging for Clinical Research and Practice

Quantitative Imaging Reading Room Exhibit

- 3DSlicer: An Open Source Platform for Segmentation, Registration, Quantitative Imaging, and 3D Visualization of Multi-Modal Image Data.

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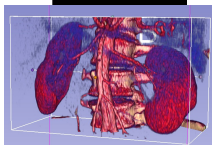

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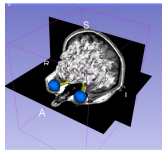

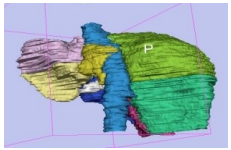

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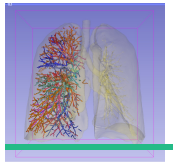
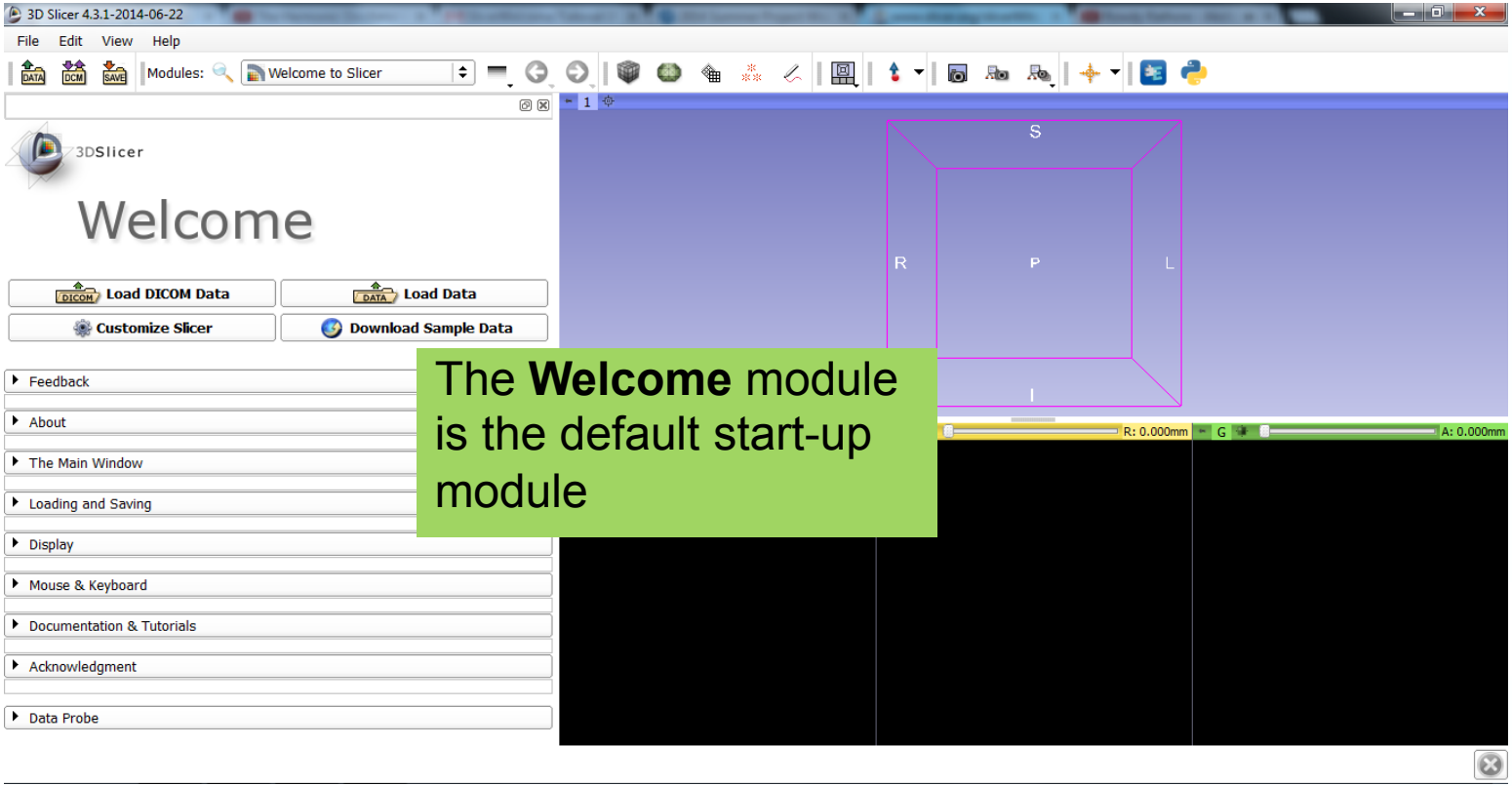
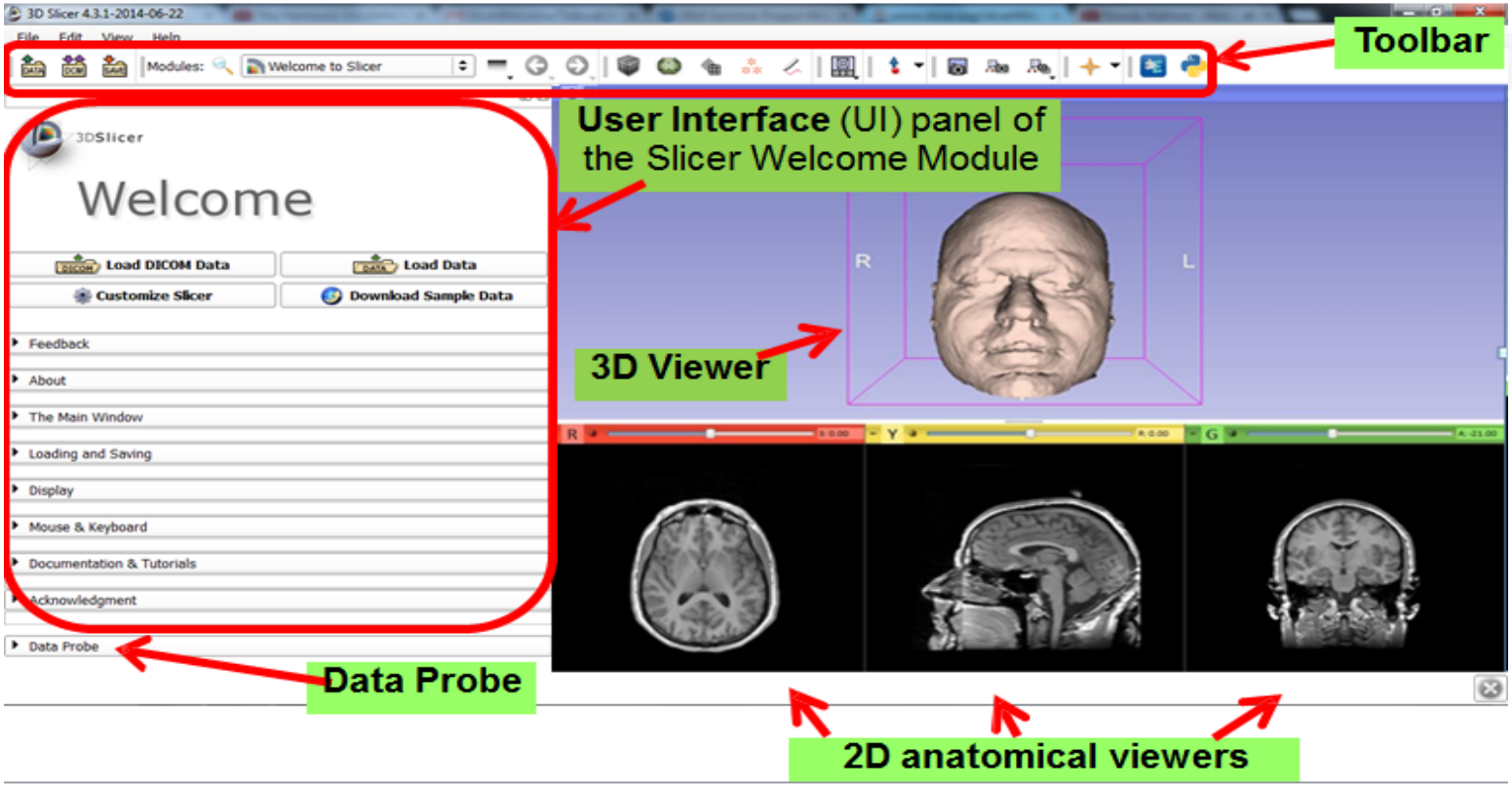


Welcome to Slicer4

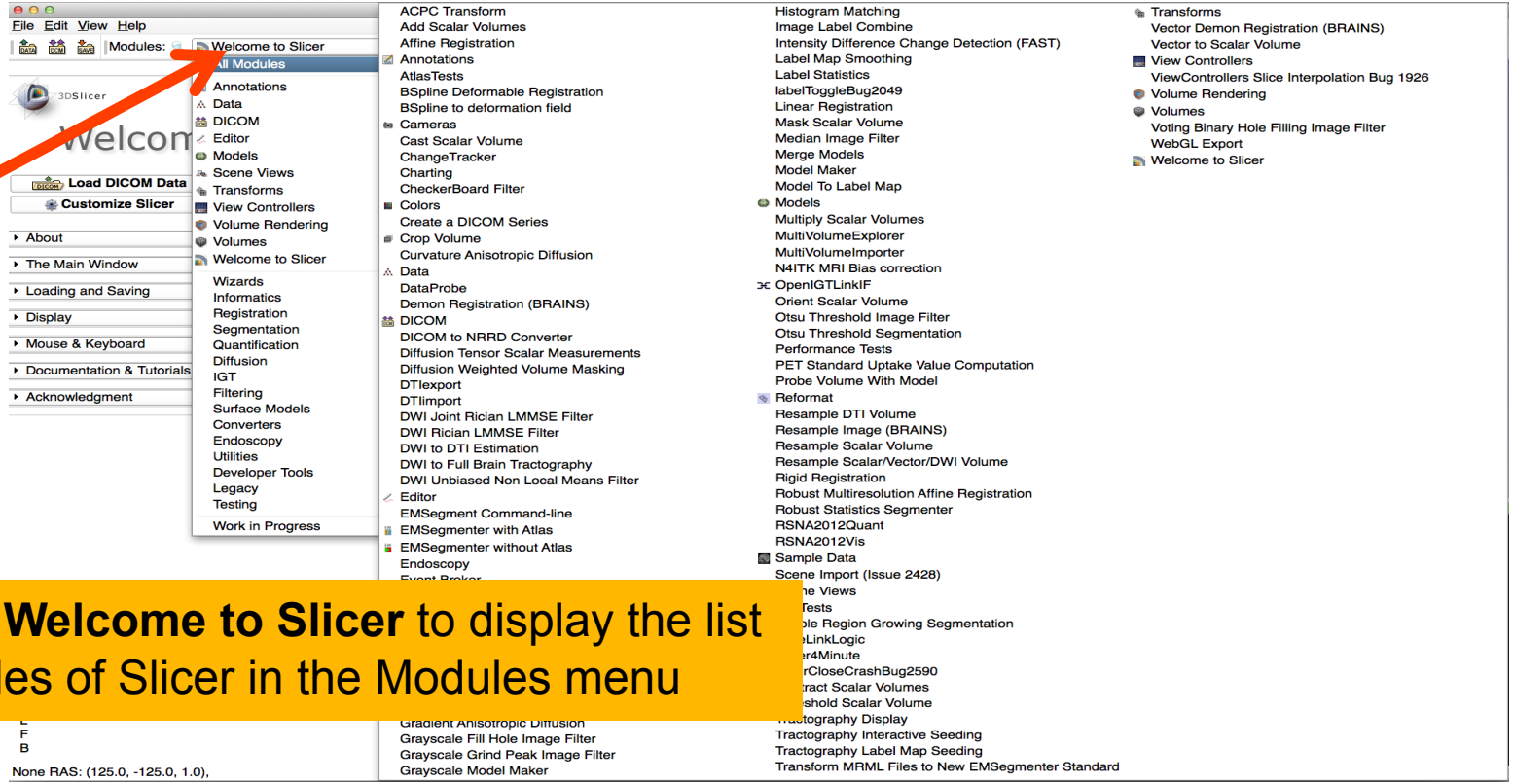


The **Welcome** module is the default start-up module

Navigating the Application GUI

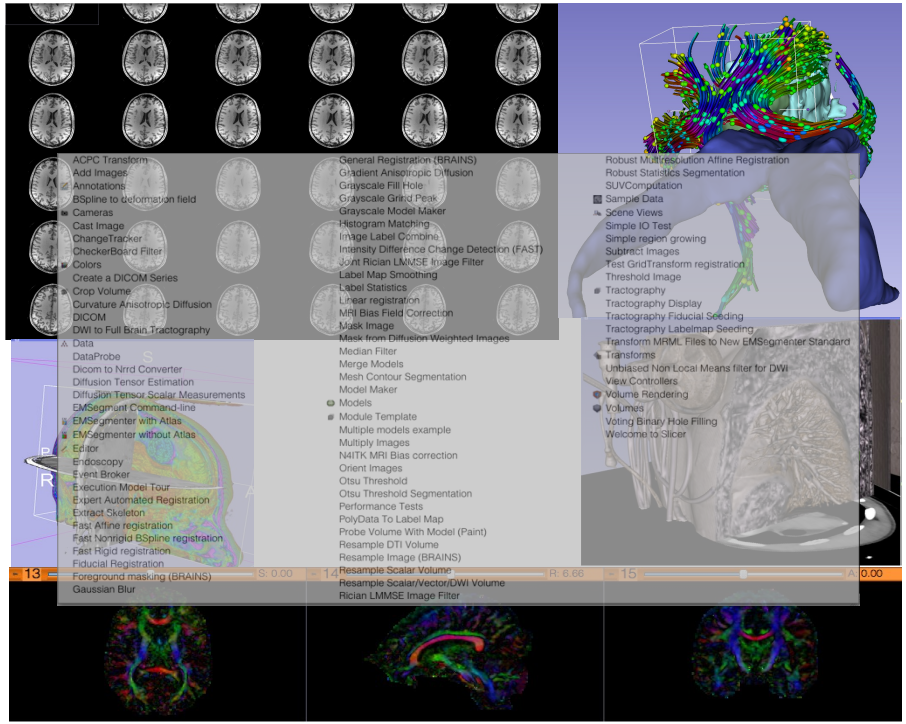


Welcome to Slicer4.3.1.1

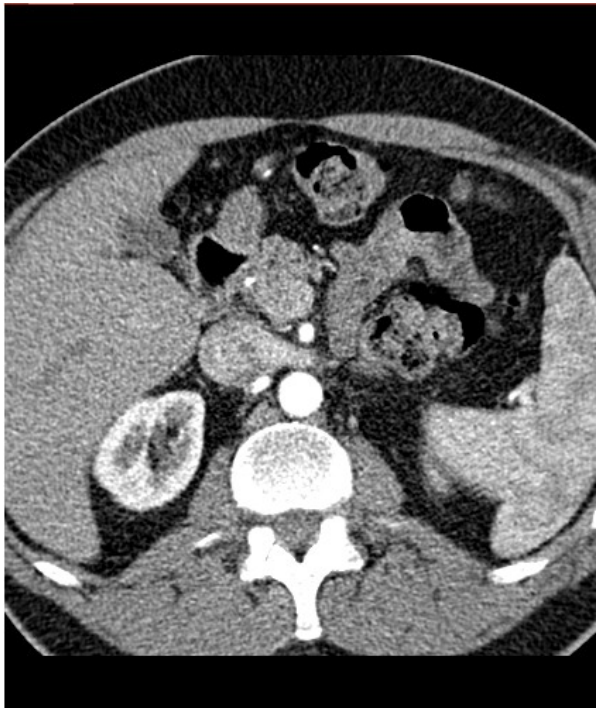


Click on **Welcome to Slicer** to display the list of modules of Slicer in the Modules menu

Welcome to Slicer4



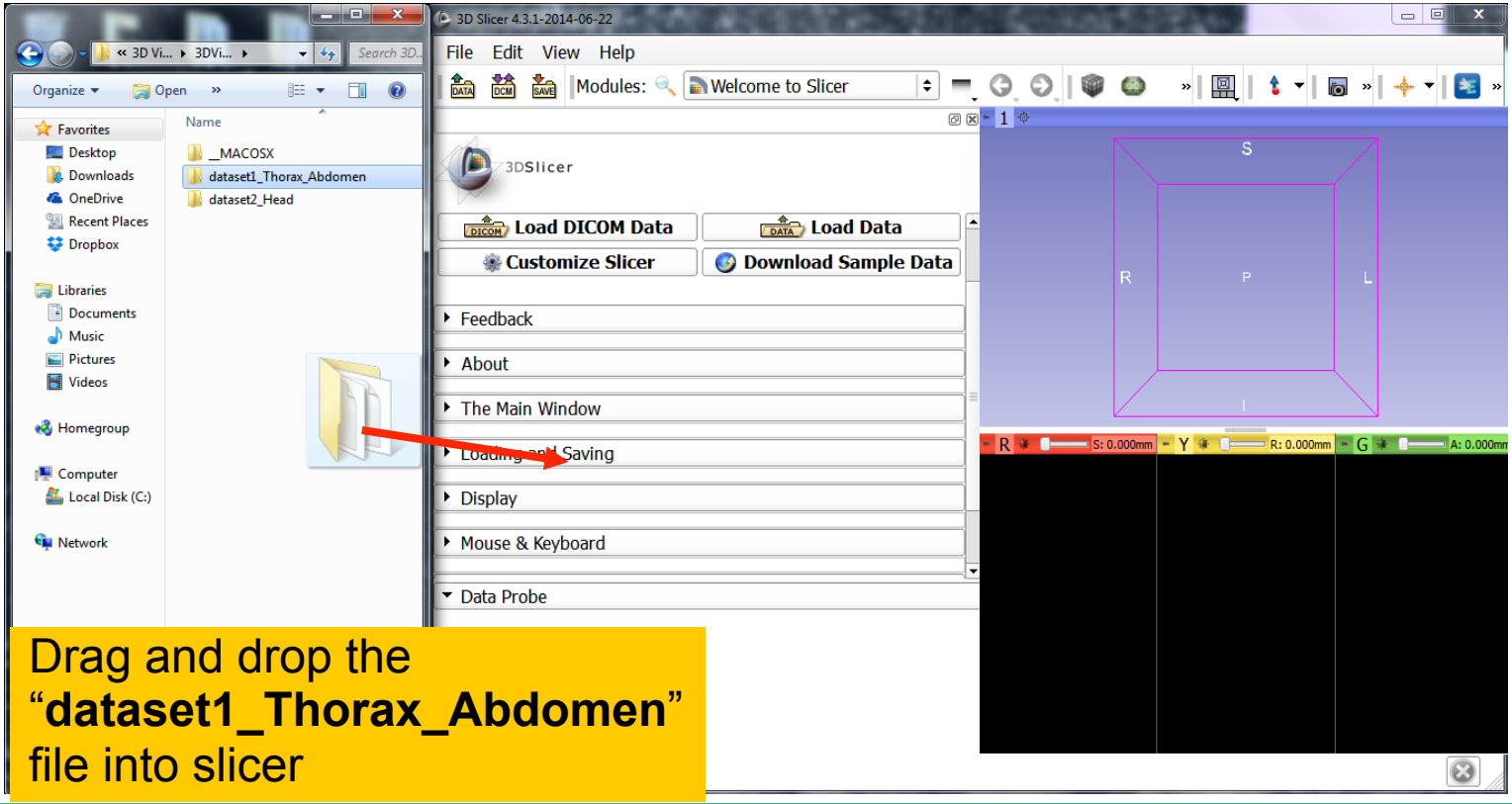
Slicer4.3.1 contains more than 100 modules for image segmentation, registration and 3D visualization of medical imaging data



Part 1:

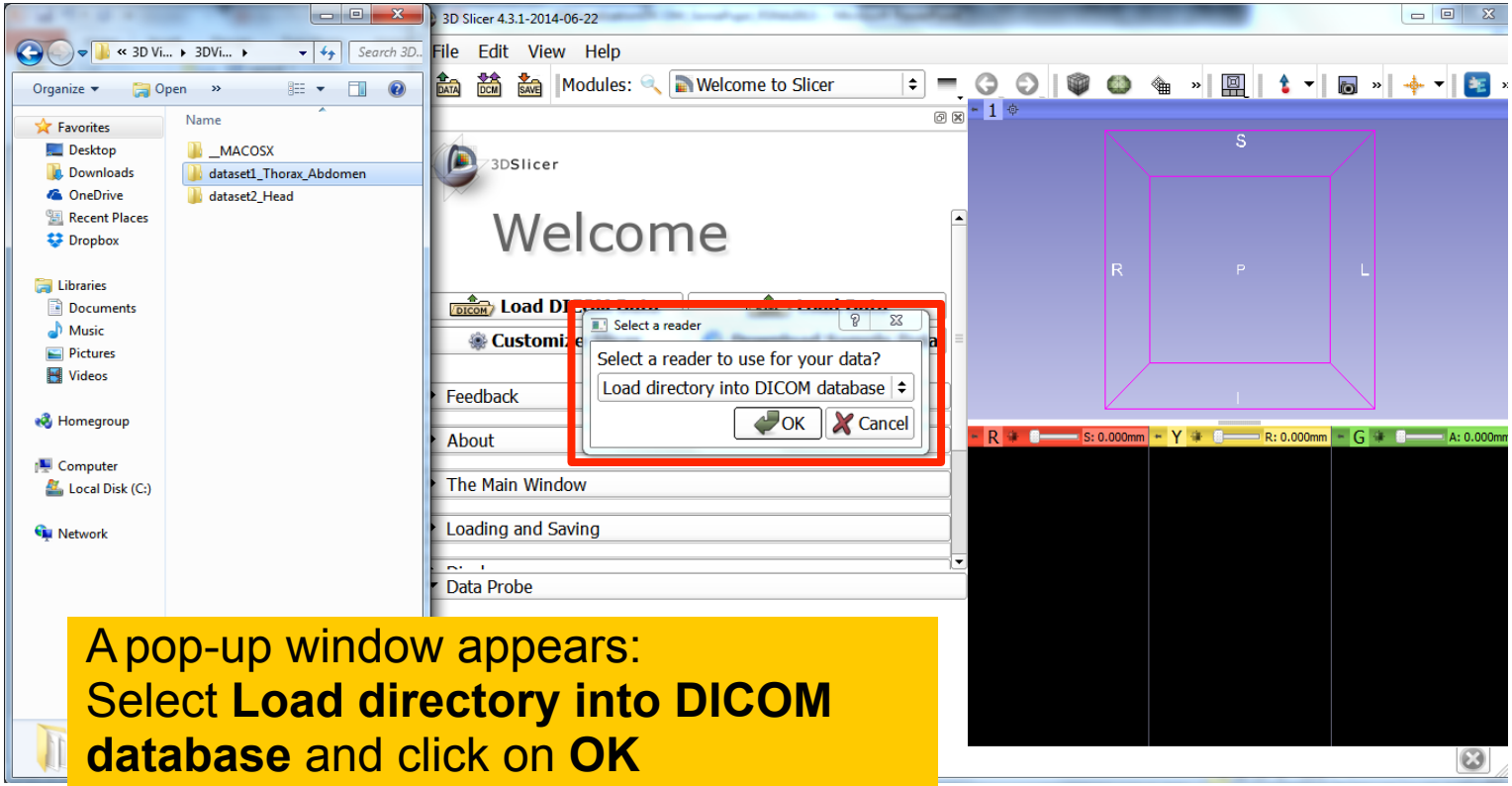
Loading a DICOM Volume

Loading a DICOM volume



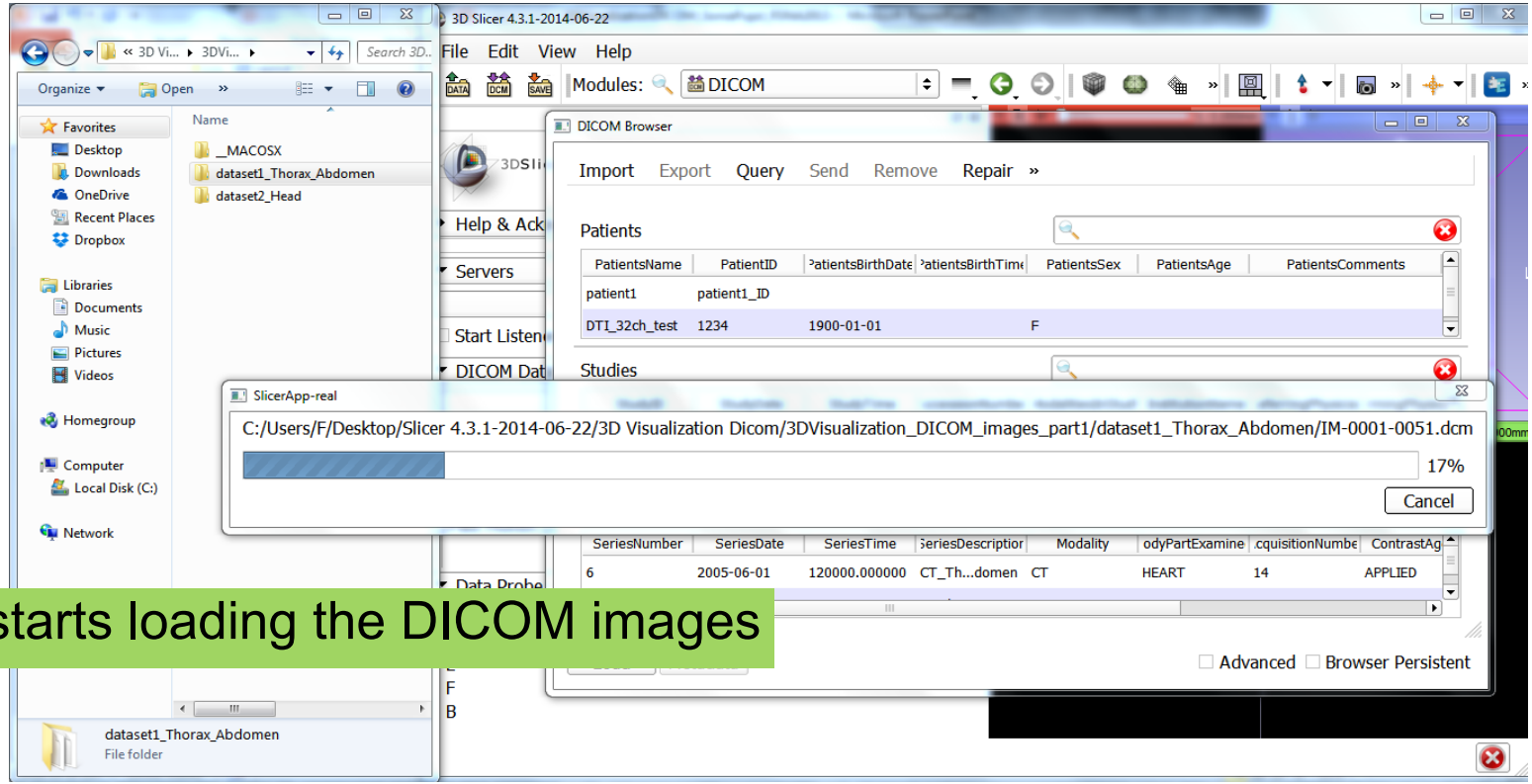
Drag and drop the "**dataset1_Thorax_Abdomen**" file into slicer

Loading a DICOM volume



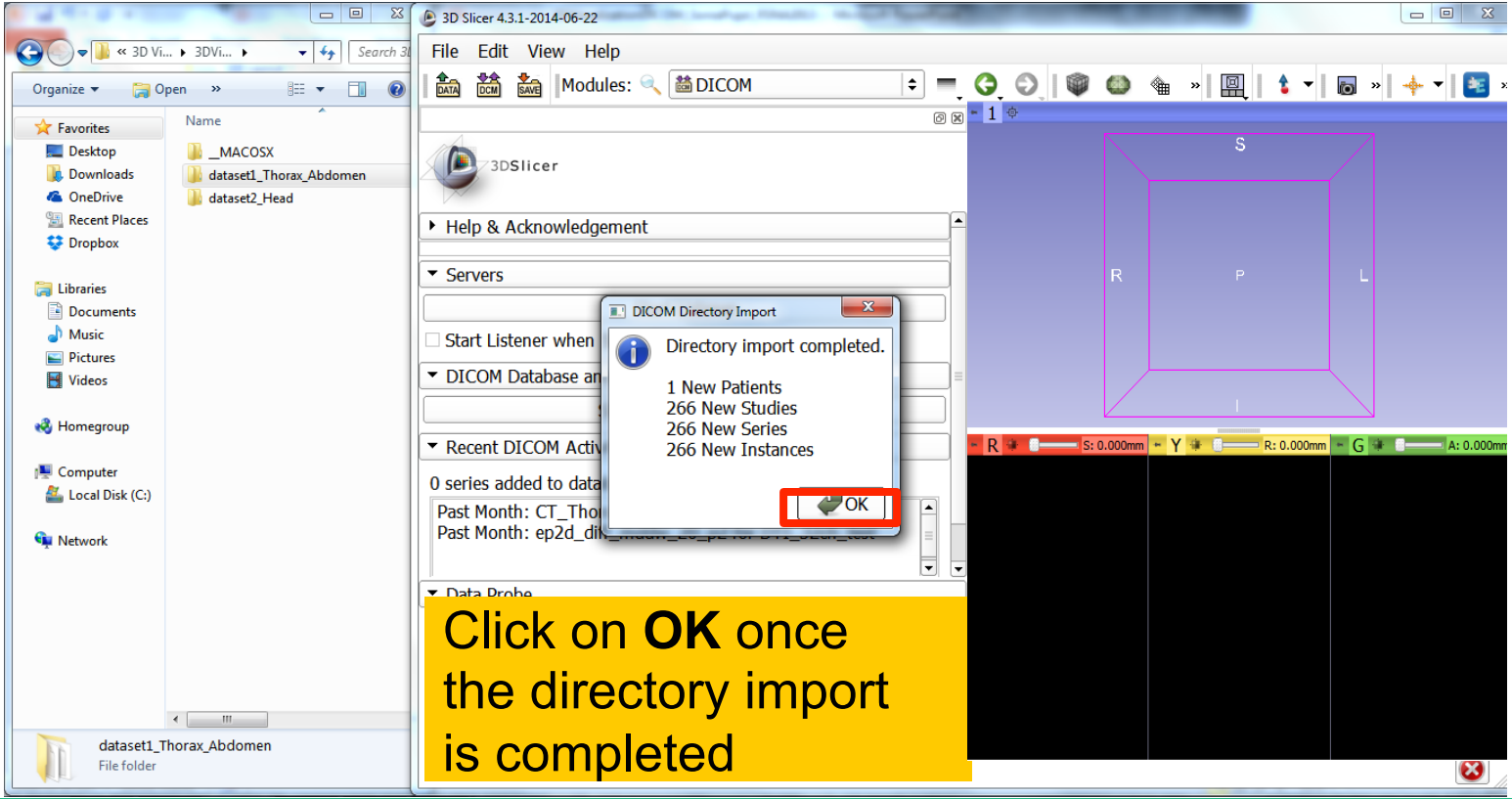
A pop-up window appears:
Select **Load directory into DICOM database** and click on **OK**

Loading a DICOM volume

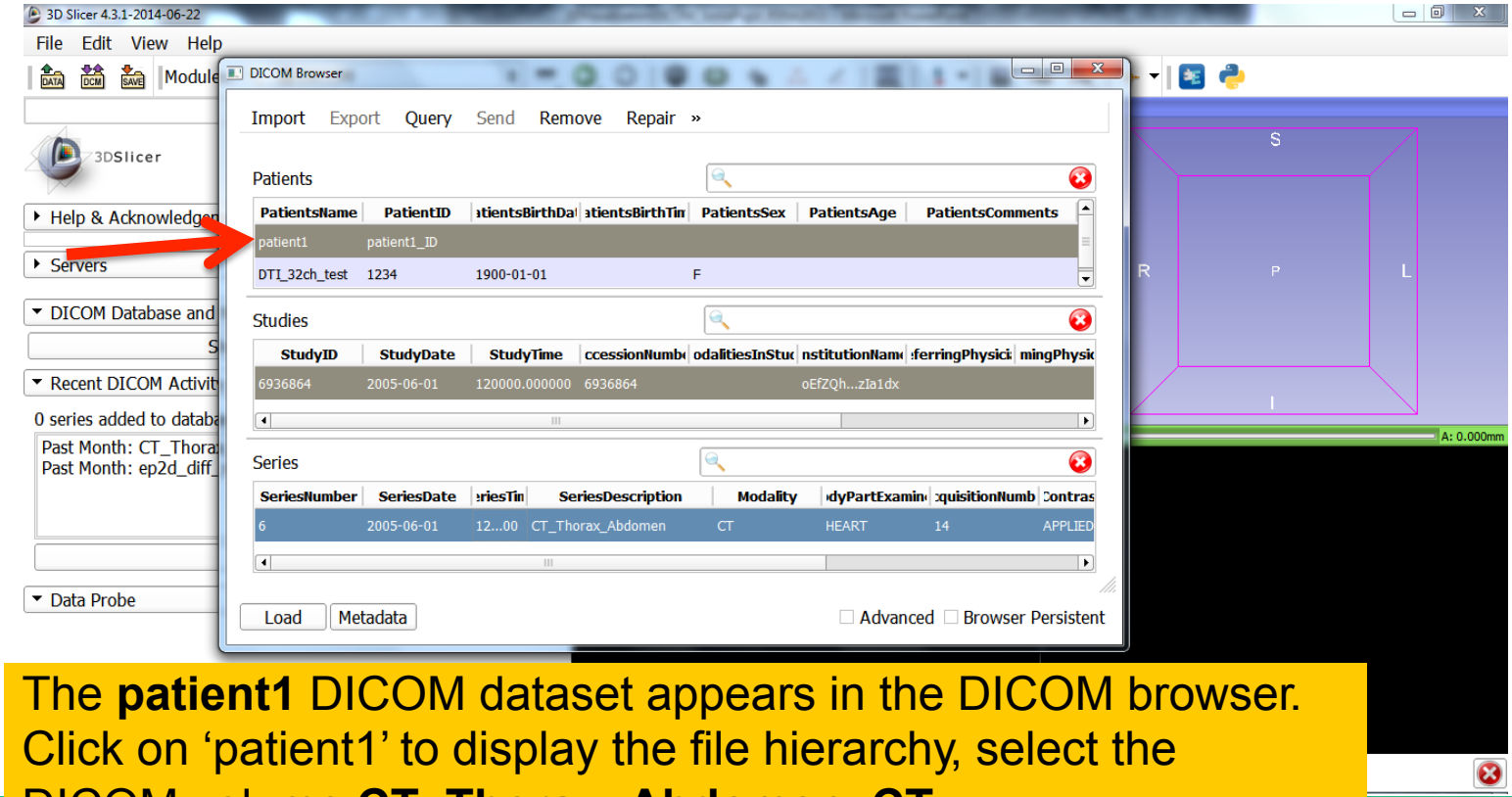


Slicer starts loading the DICOM images

Loading a DICOM volume

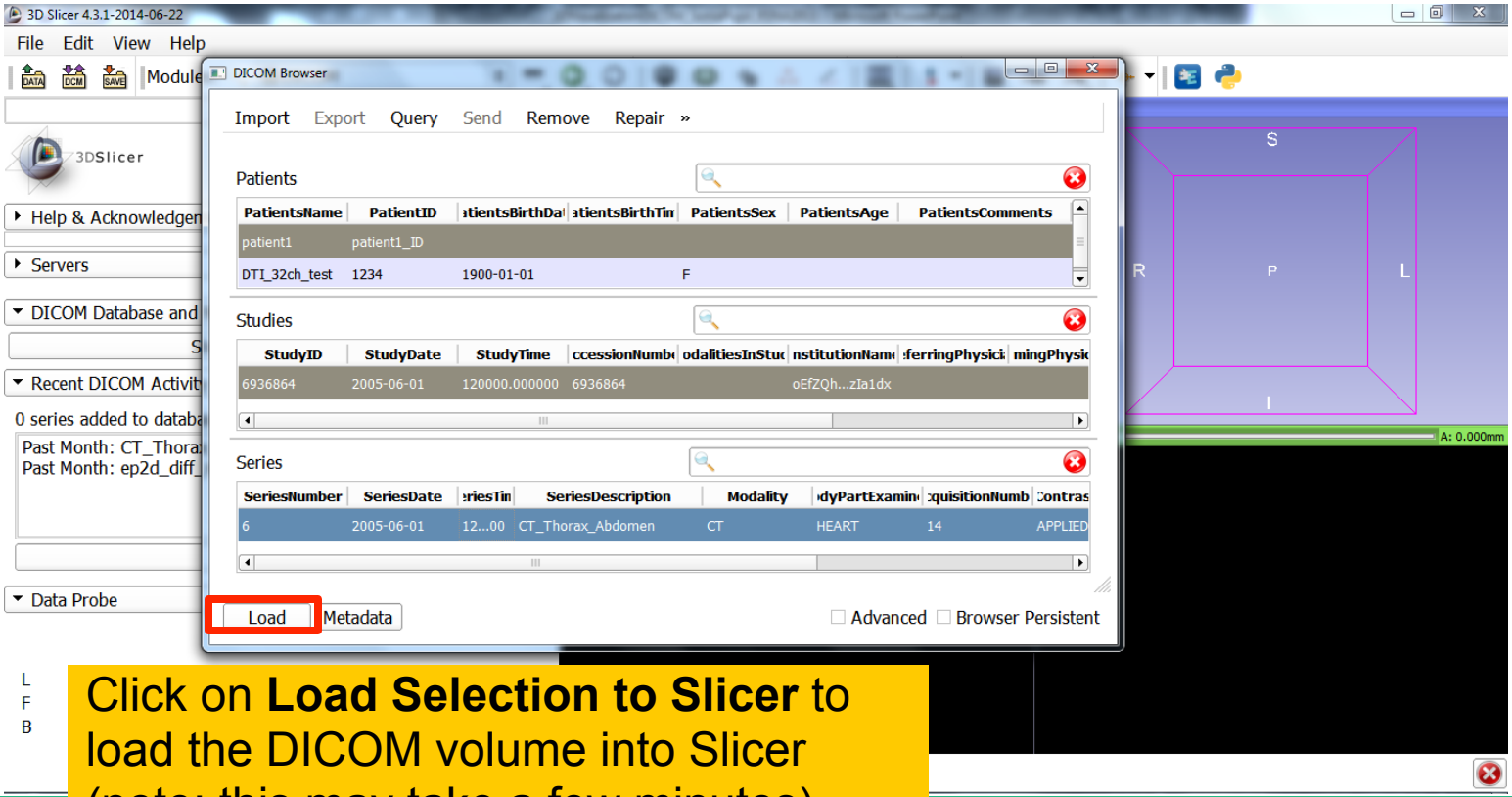


Loading a DICOM volume



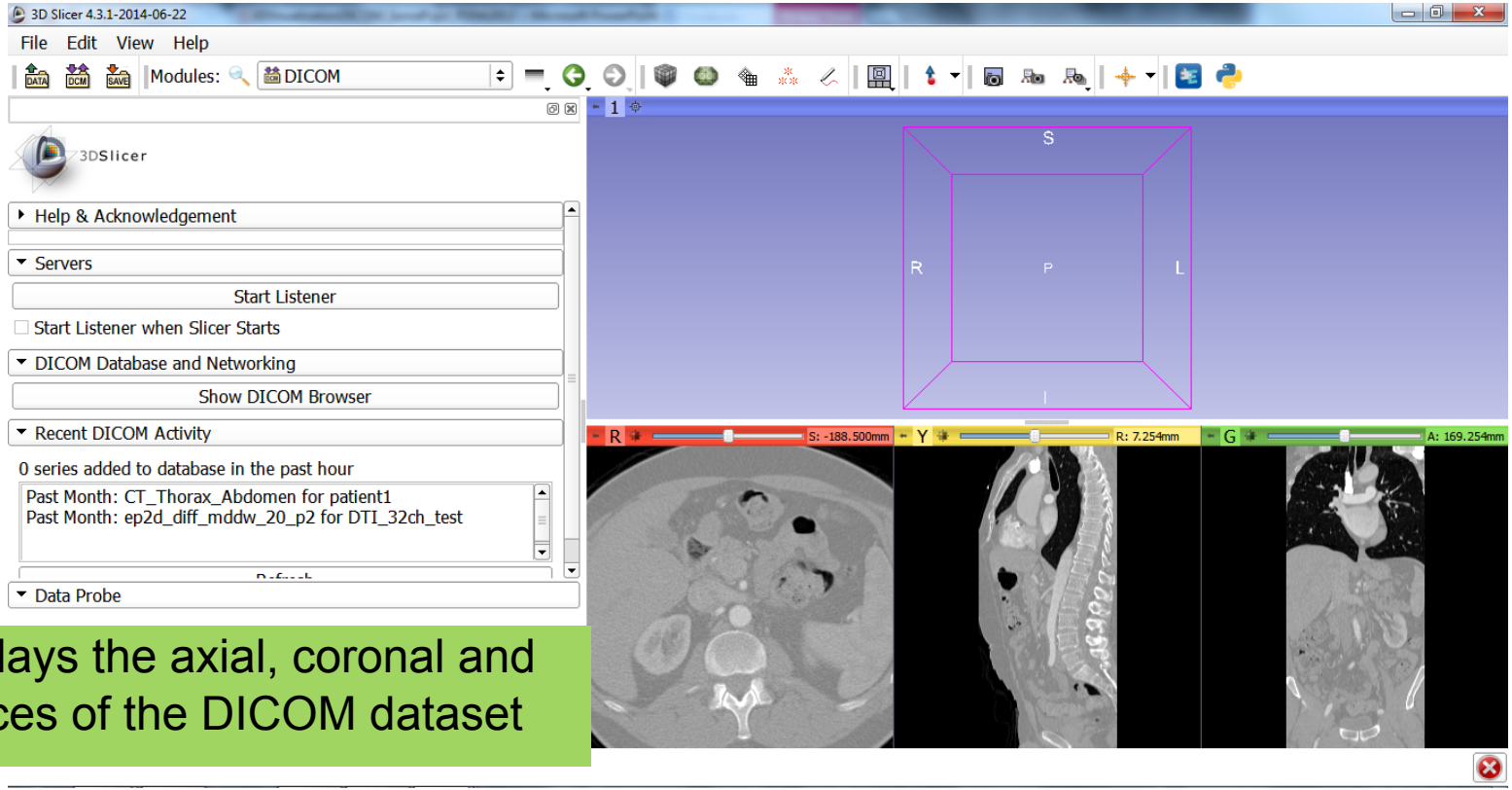
The **patient1** DICOM dataset appears in the DICOM browser. Click on ‘patient1’ to display the file hierarchy, select the DICOM volume **CT_Thorax_Abdomen_CT**

Loading a DICOM volume



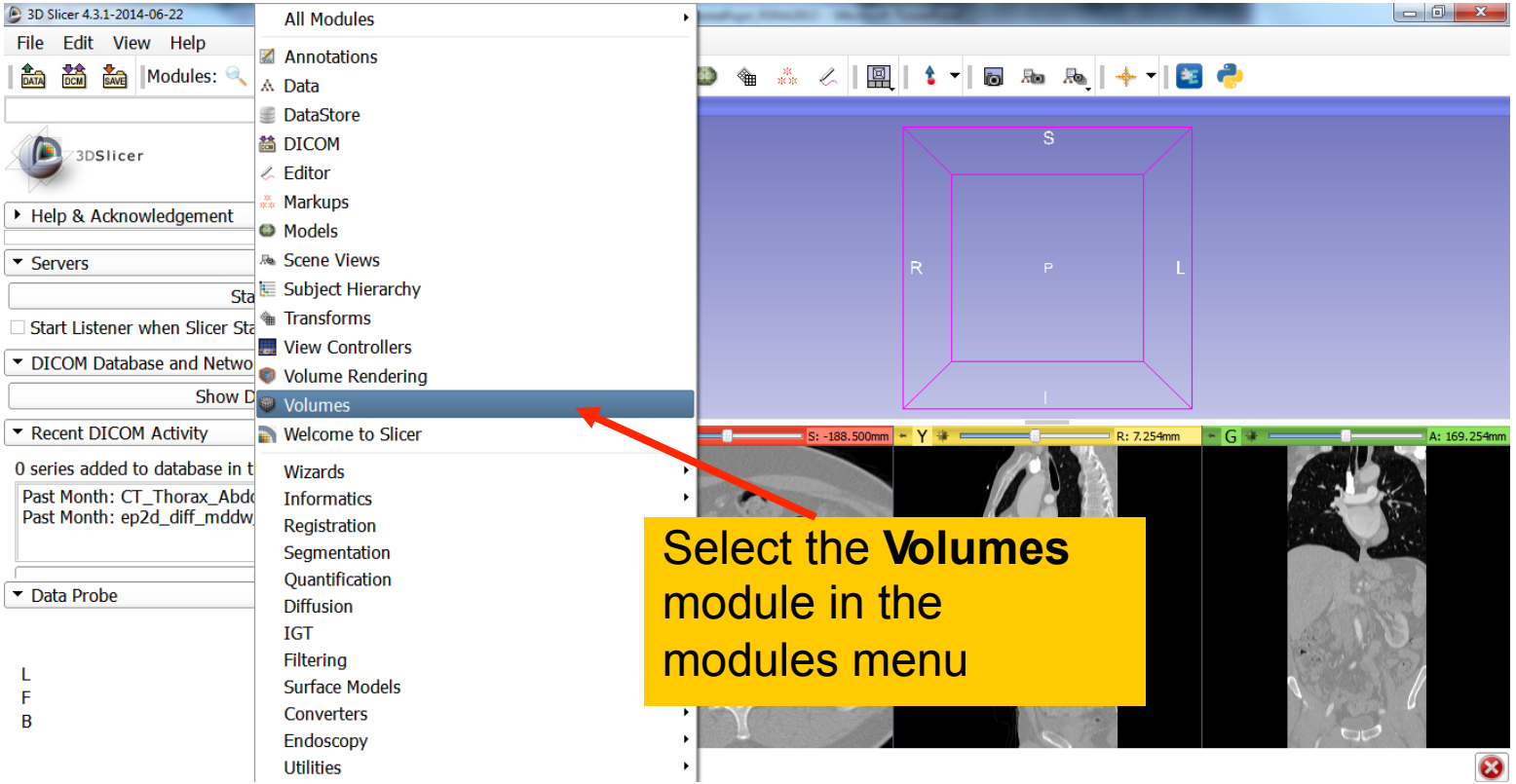
Click on **Load Selection to Slicer** to load the DICOM volume into Slicer (note: this may take a few minutes)

Loading a DICOM volume



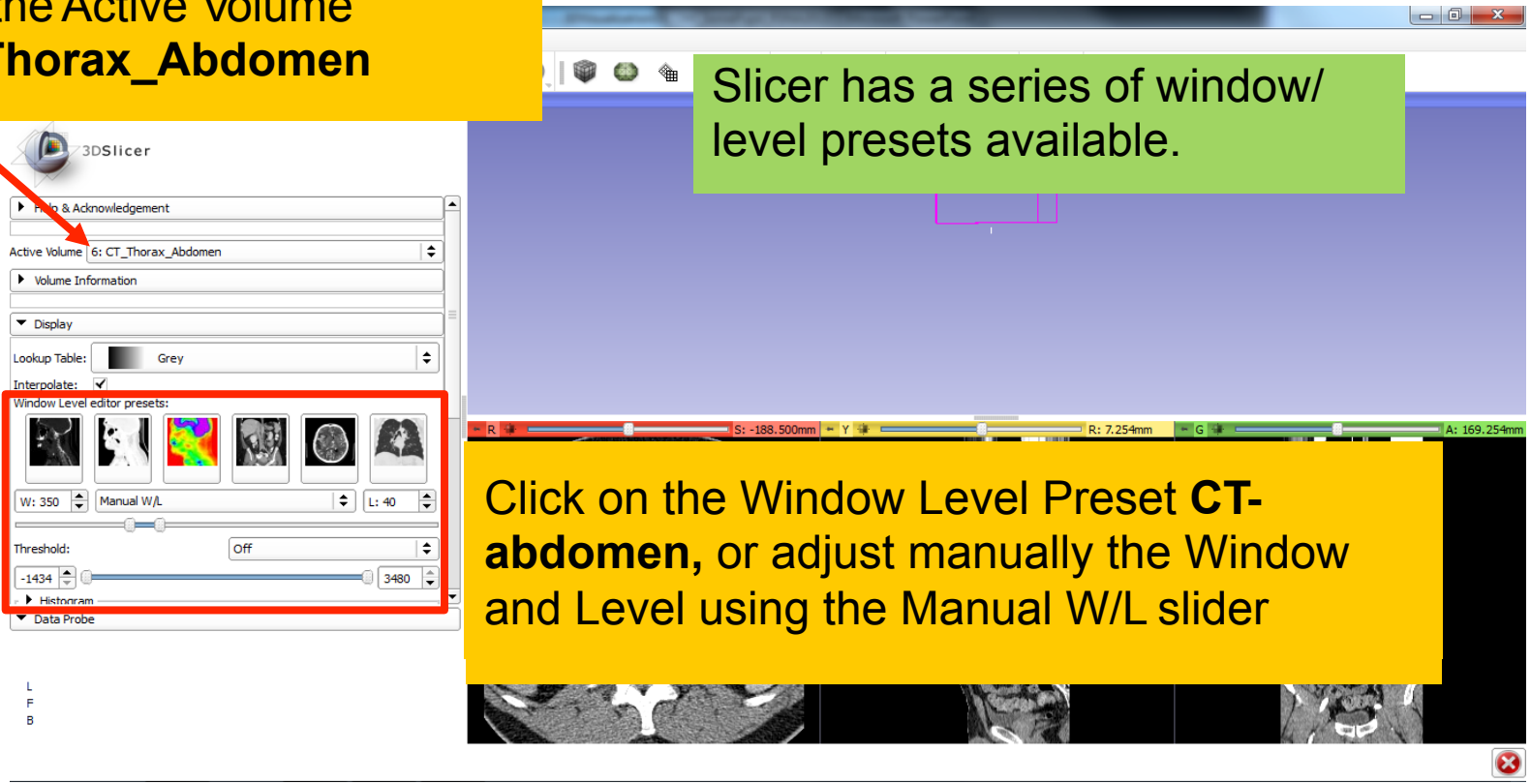
Slicer displays the axial, coronal and sagittal slices of the DICOM dataset

Loading a DICOM volume



Loading a DICOM volume

Select the Active Volume
6:CT_Thorax_Abdomen

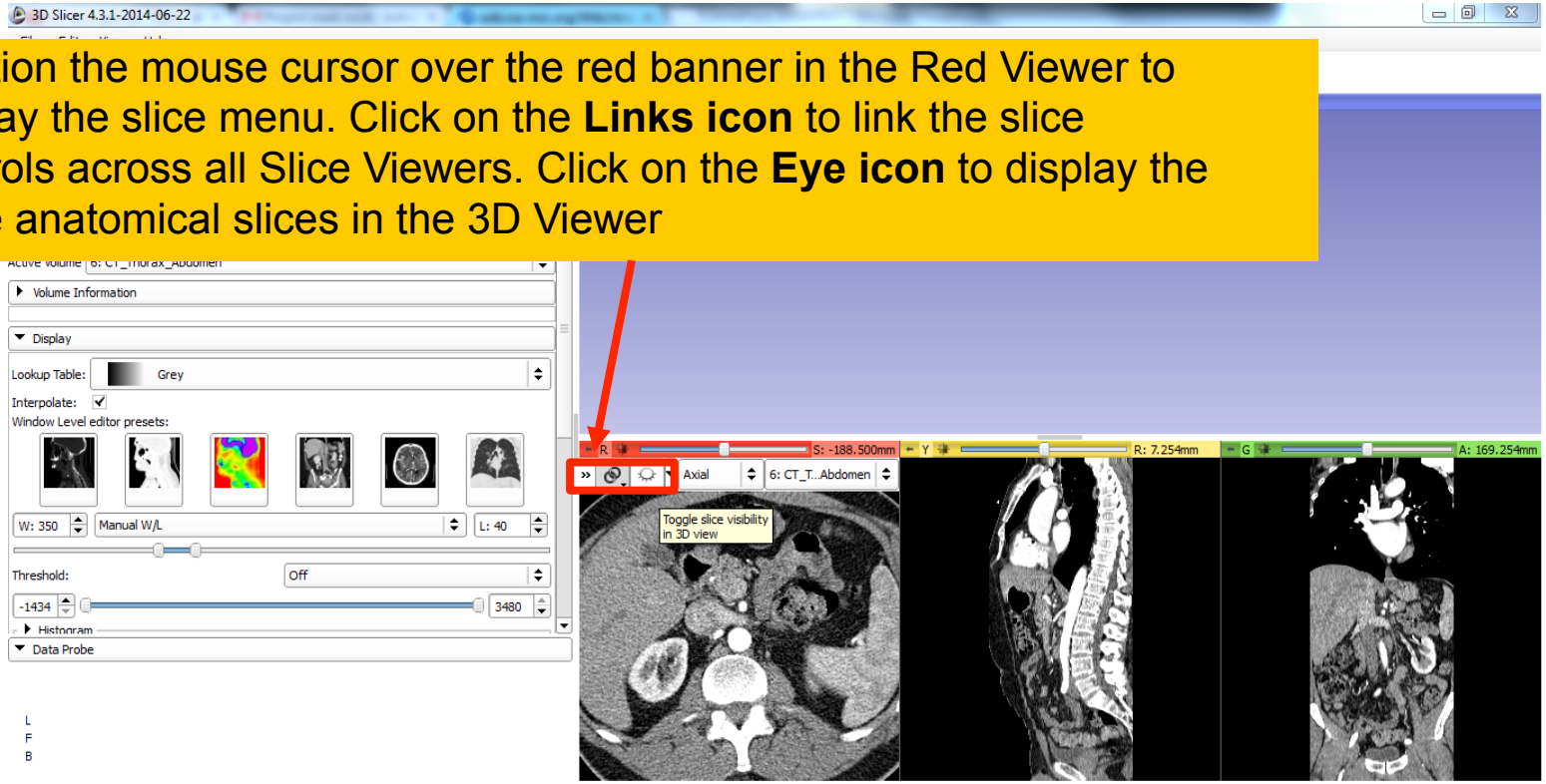


Slicer has a series of window/ level presets available.

Click on the Window Level Preset **CT-abdomen,** or adjust manually the Window and Level using the Manual W/L slider

Loading a DICOM volume

Position the mouse cursor over the red banner in the Red Viewer to display the slice menu. Click on the **Links icon** to link the slice controls across all Slice Viewers. Click on the **Eye icon** to display the three anatomical slices in the 3D Viewer



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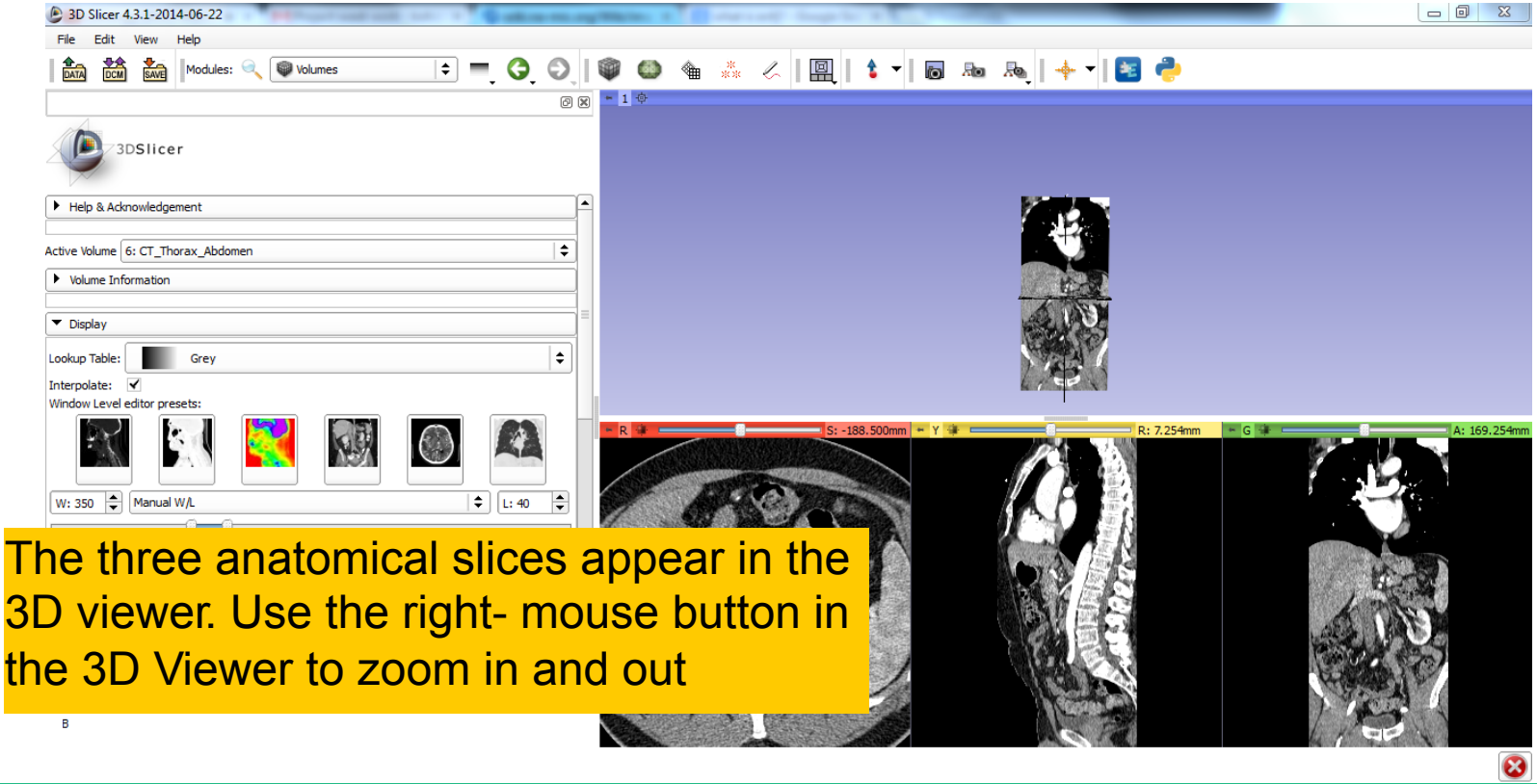
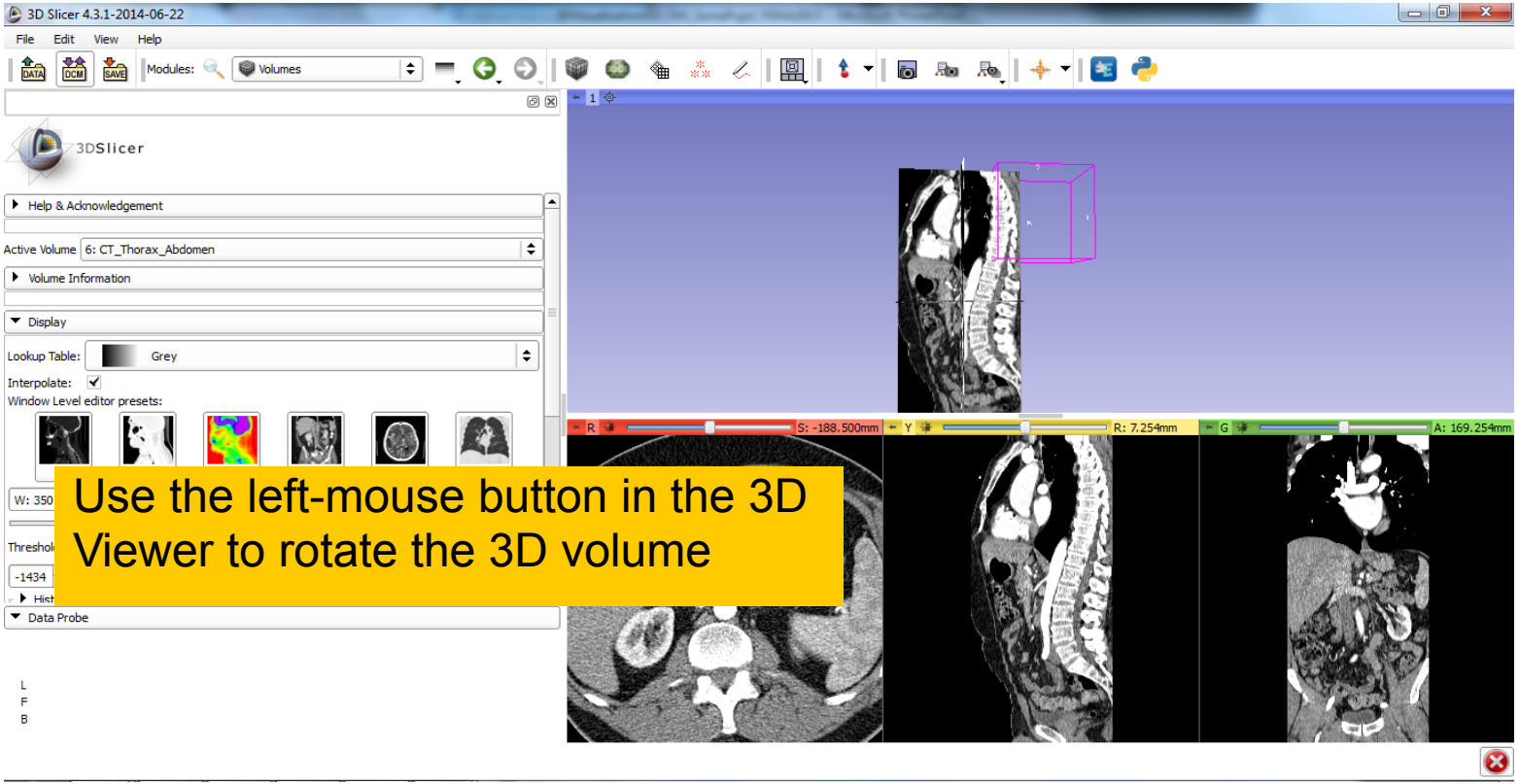


The three anatomical slices appear in the 3D viewer. Use the right- mouse button in the 3D Viewer to zoom in and out

Loading a DICOM volume



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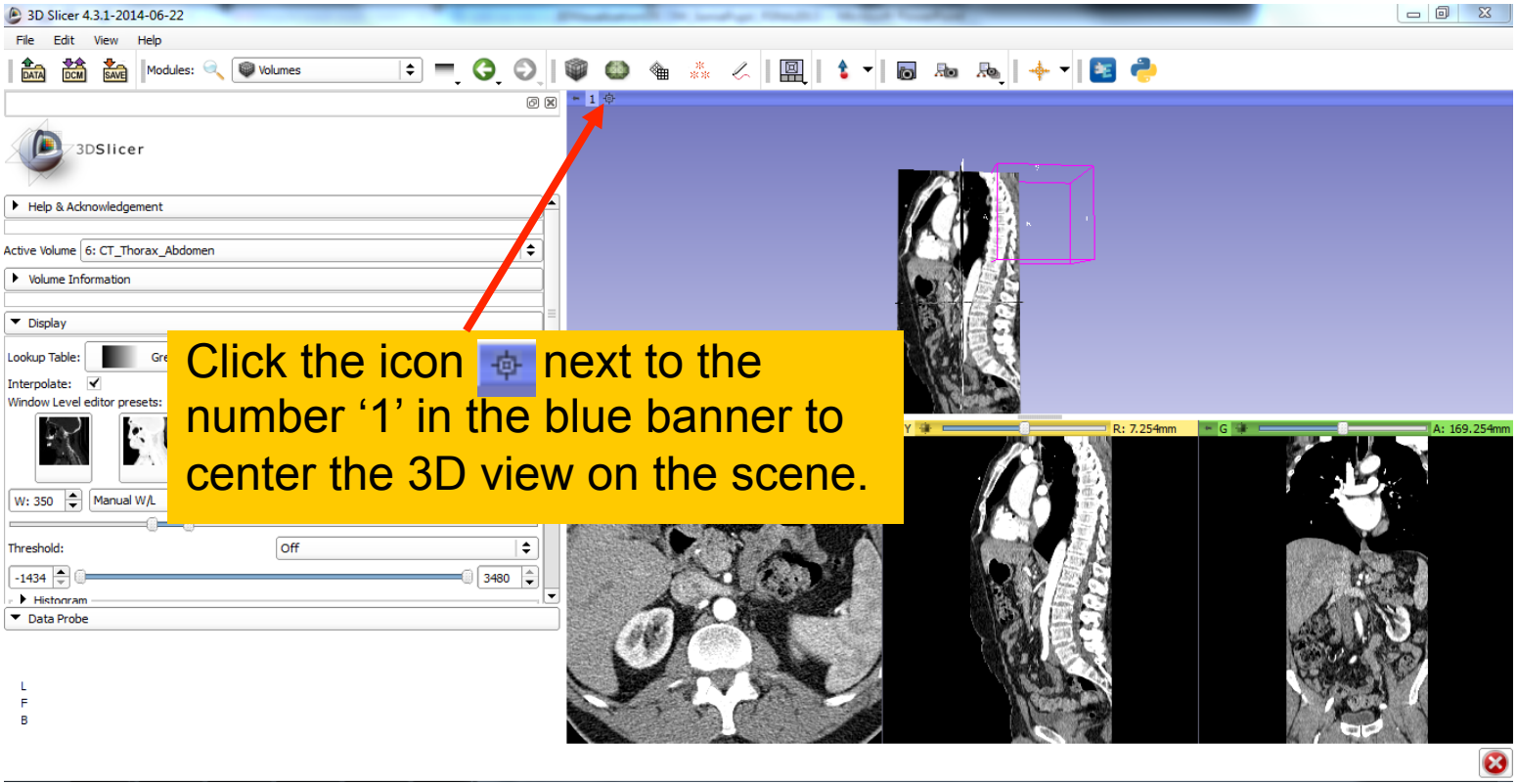

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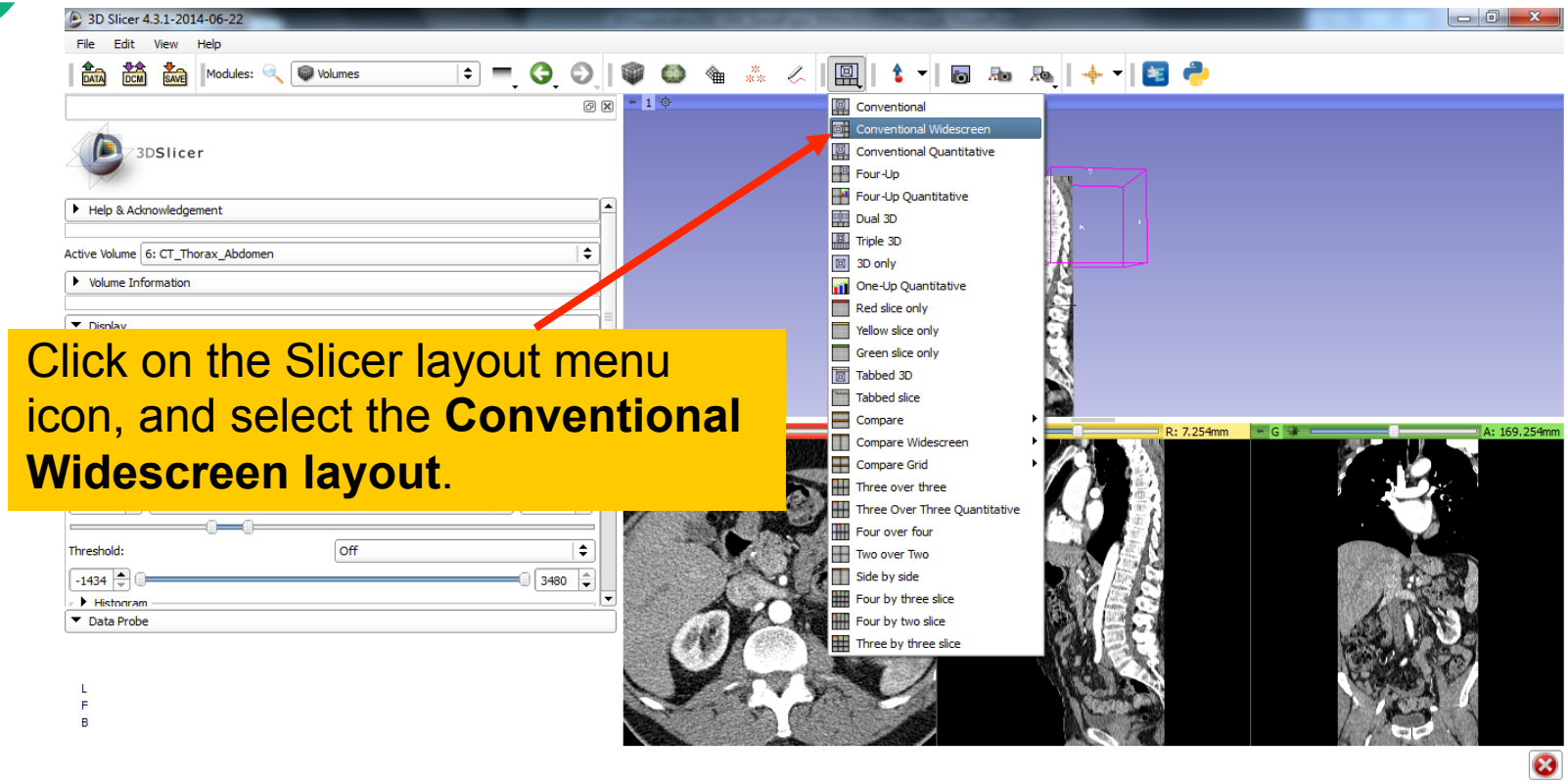
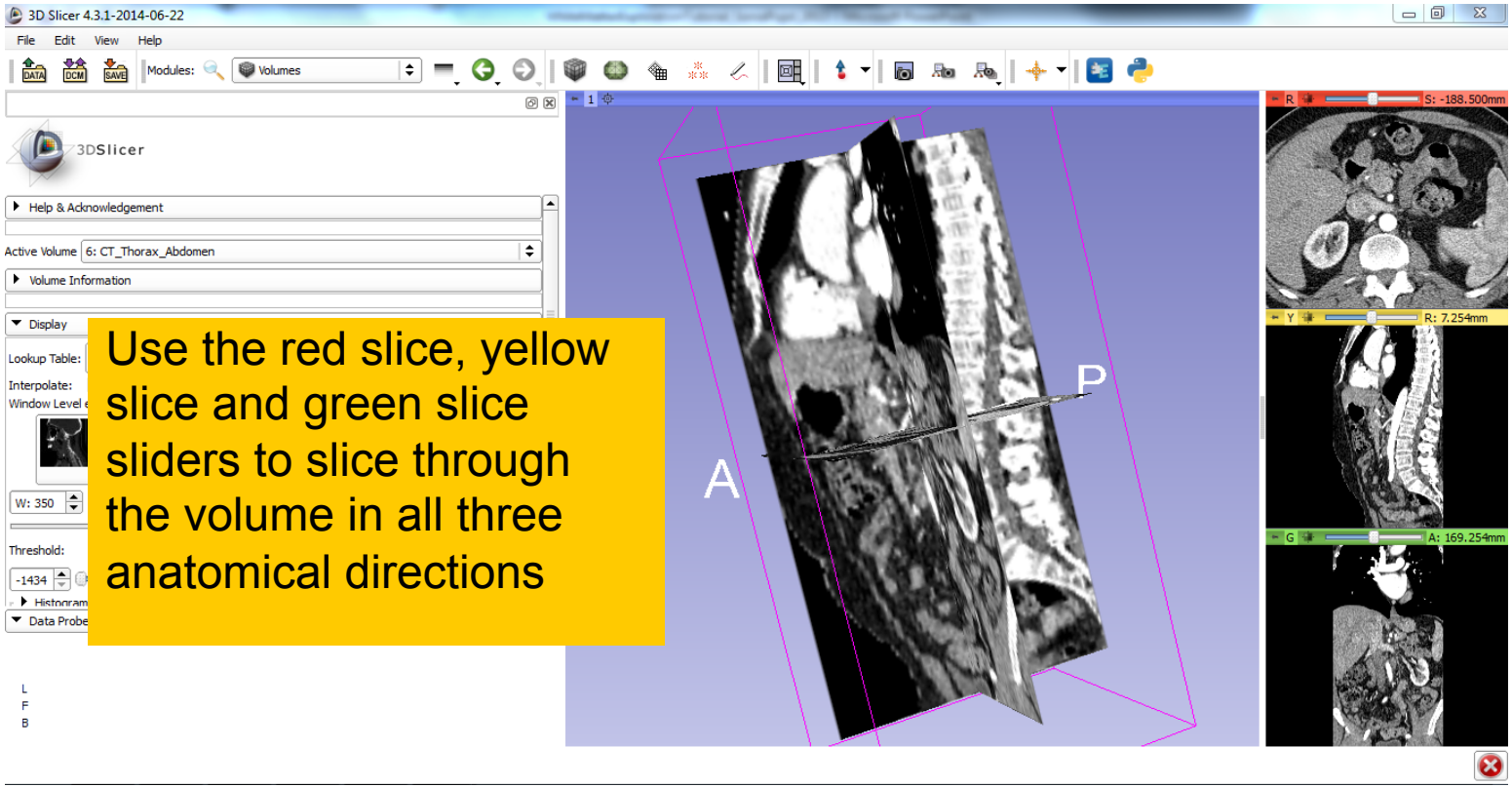
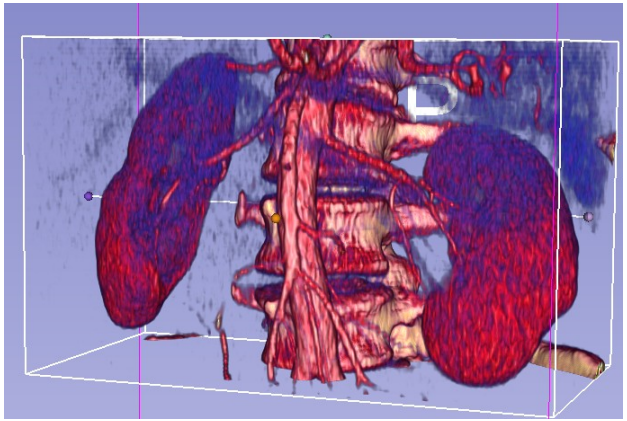


Click on the Slicer layout menu icon, and select the **Conventional Widescreen layout**.

Loading a DICOM volume

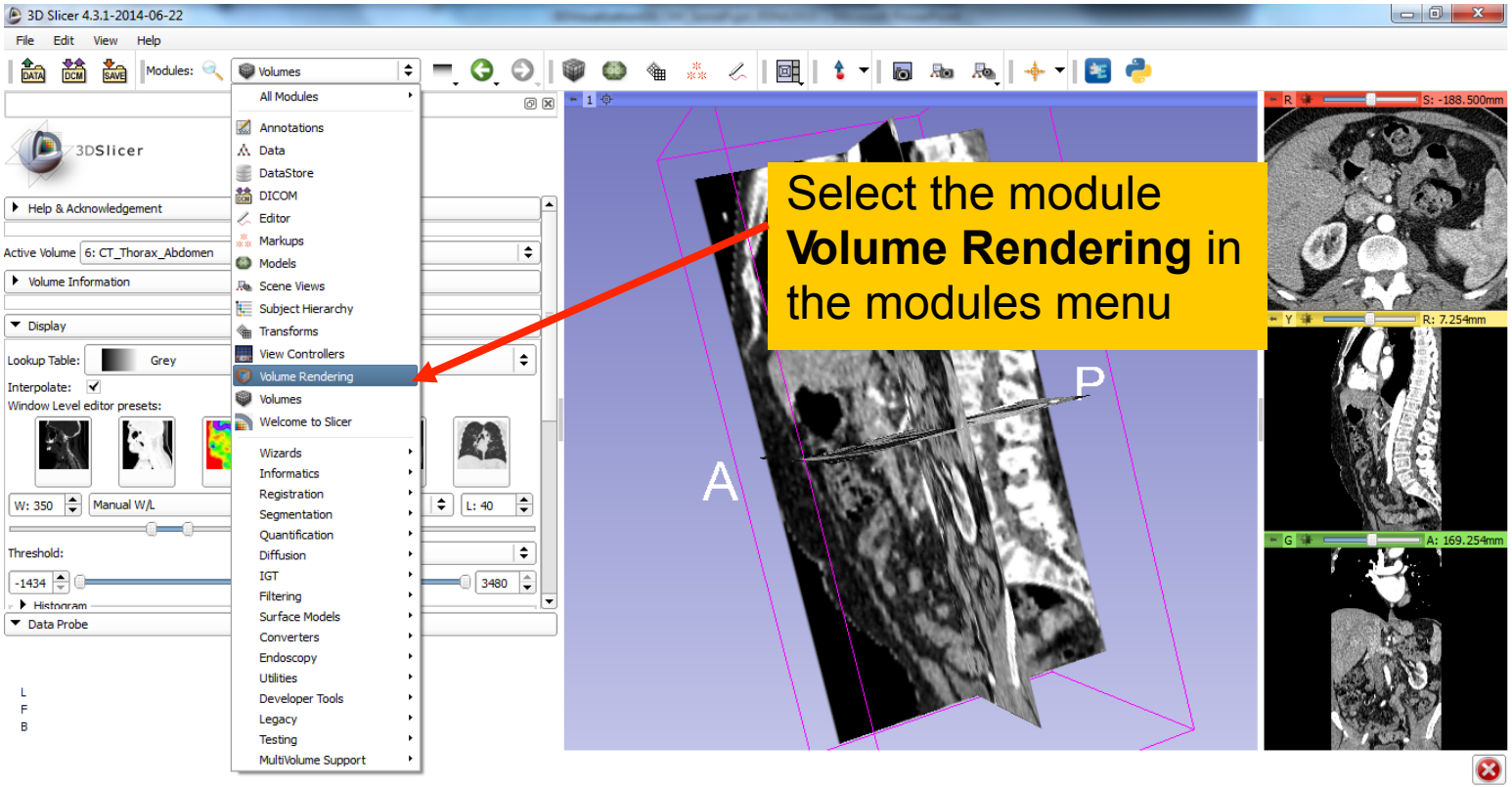


Use the red slice, yellow slice and green slice sliders to slice through the volume in all three anatomical directions

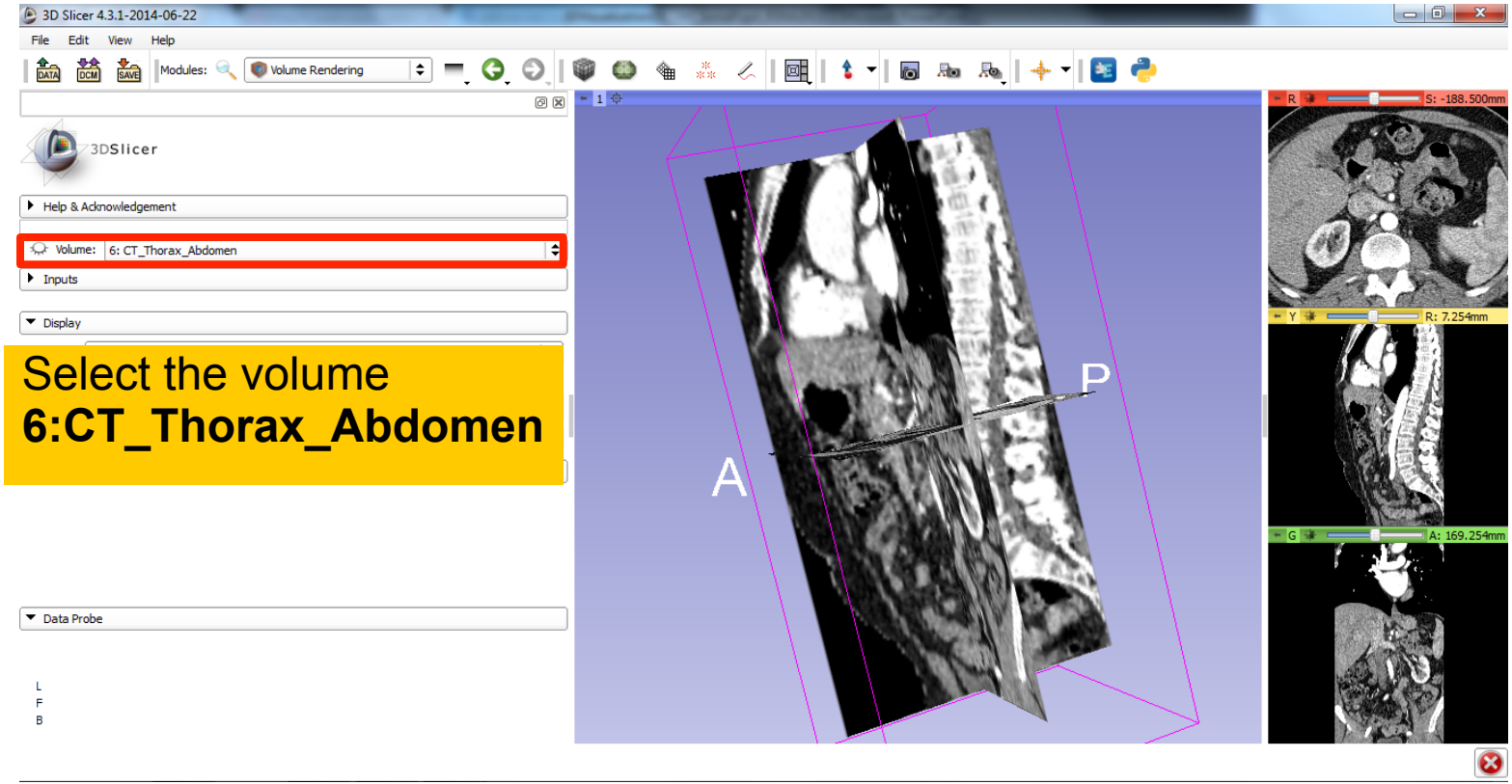


3D Interactive exploration of thoraco-abdominal CT data using Volume Rendering

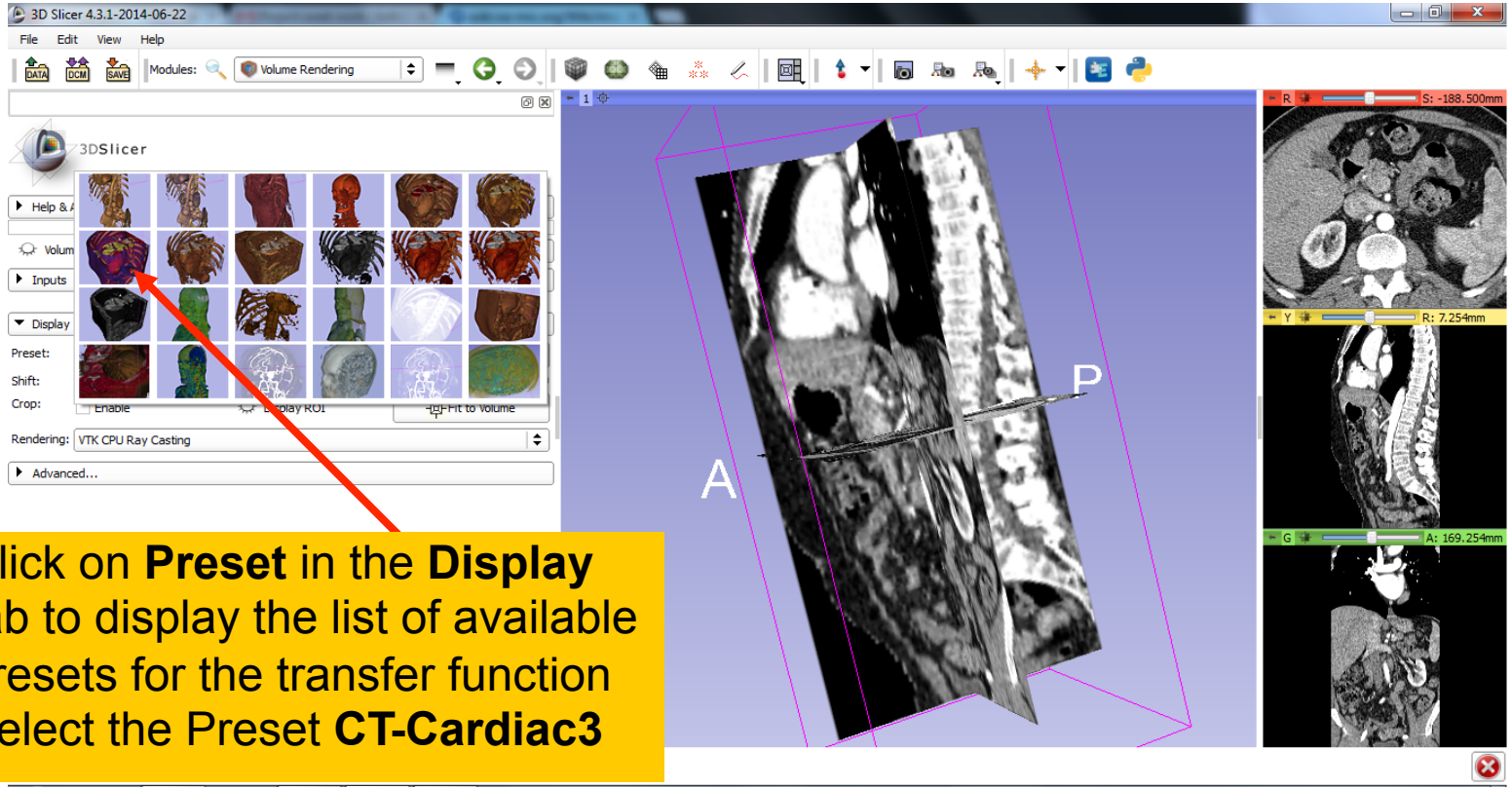
Volume Rendering



Volume Rendering

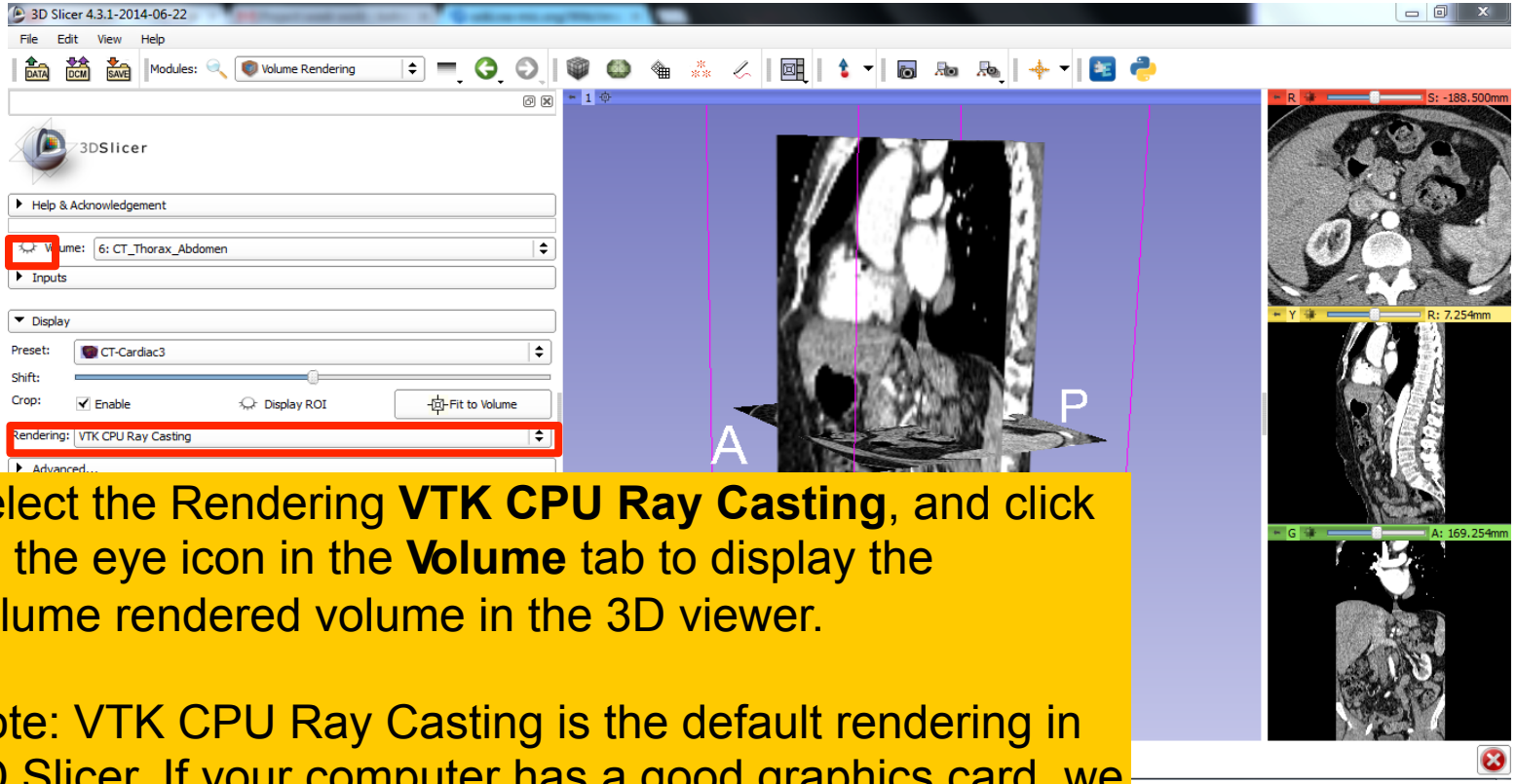


Volume Rendering



Click on **Preset** in the **Display** tab to display the list of available presets for the transfer function Select the Preset **CT-Cardiac3**

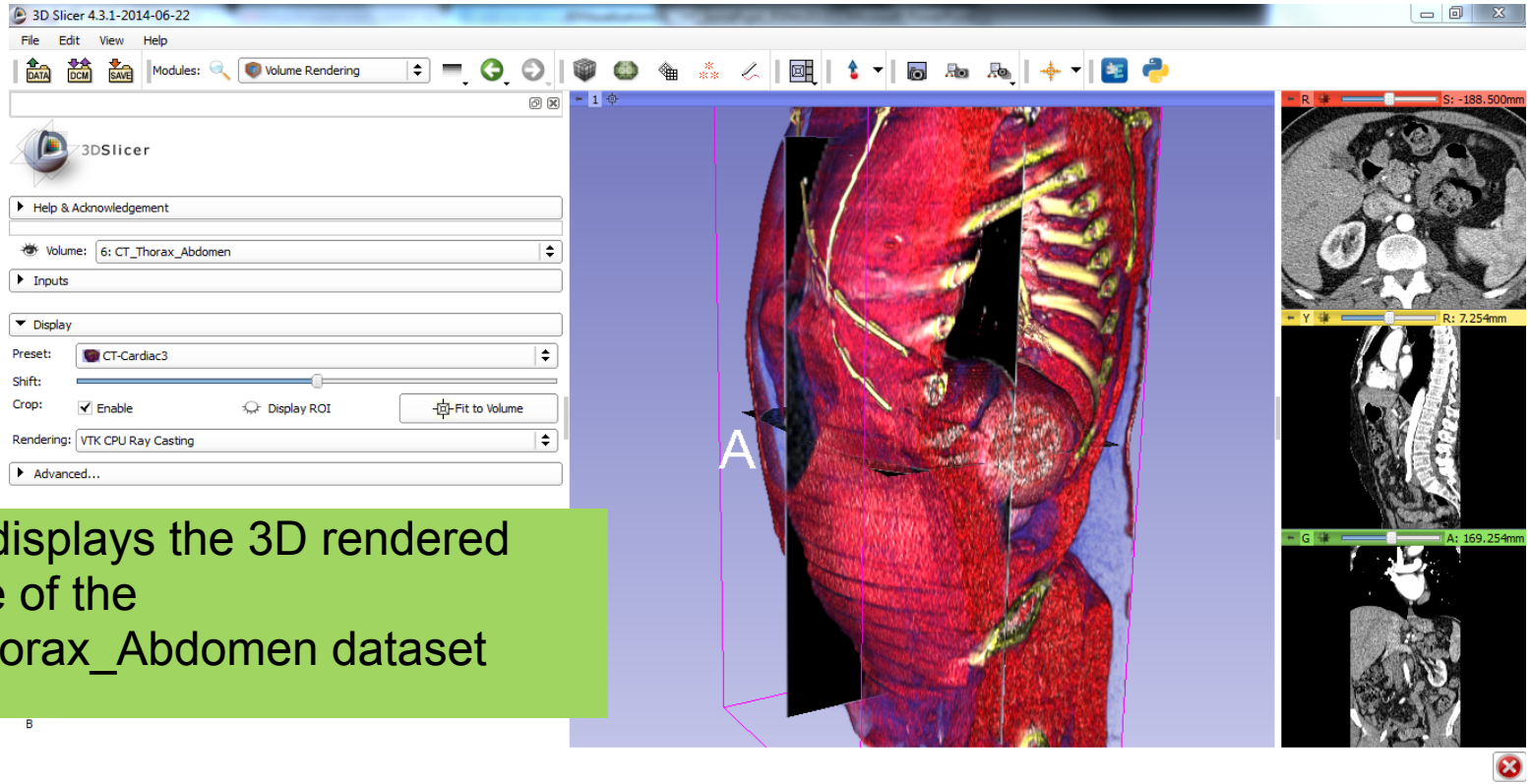
Volume Rendering



Select the Rendering **VTK CPU Ray Casting**, and click on the eye icon in the **Volume** tab to display the Volume rendered volume in the 3D viewer.

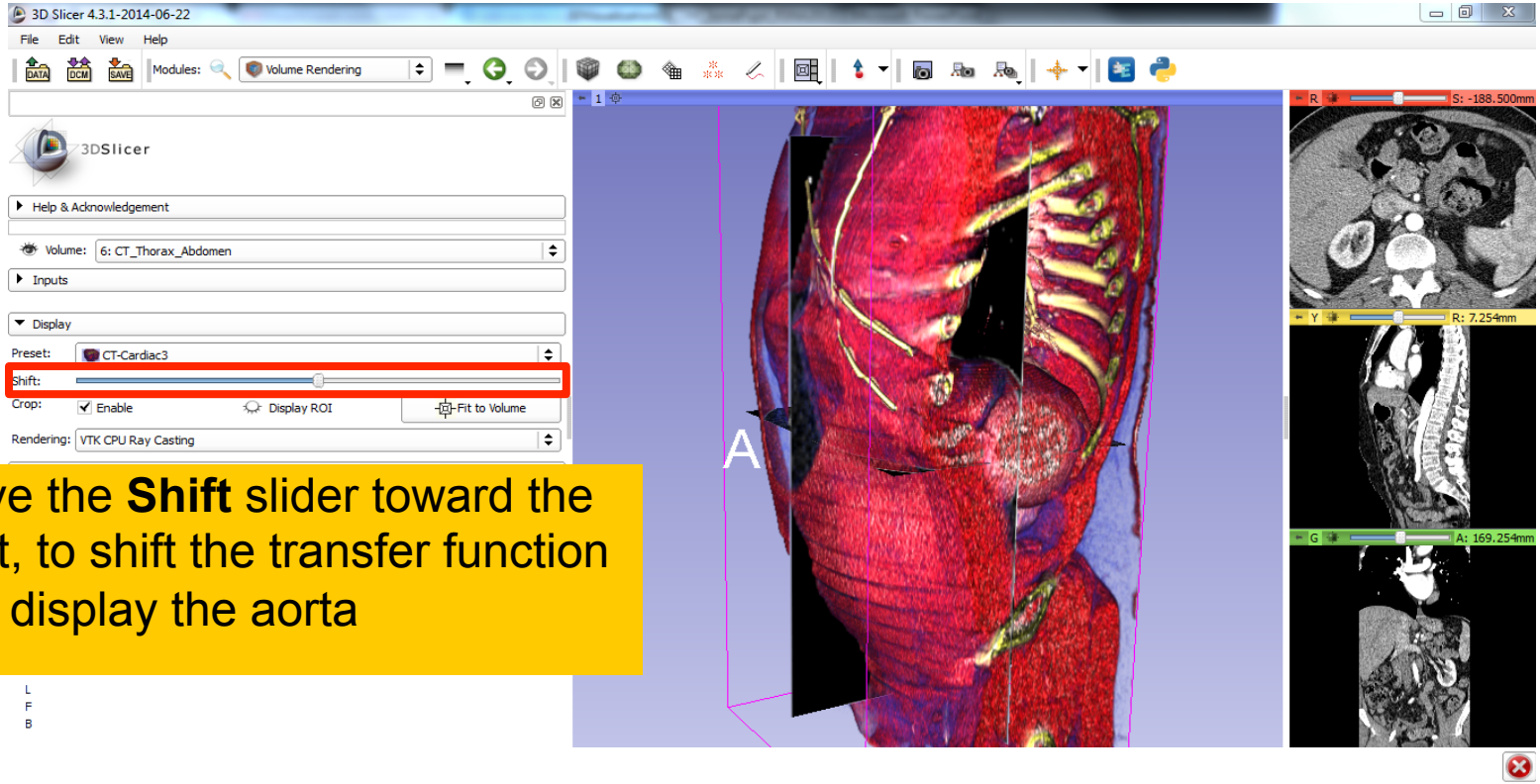
Note: VTK CPU Ray Casting is the default rendering in 3D Slicer. If your computer has a good graphics card, we recommend the **VTK GPU Ray Casting**

Volume Rendering



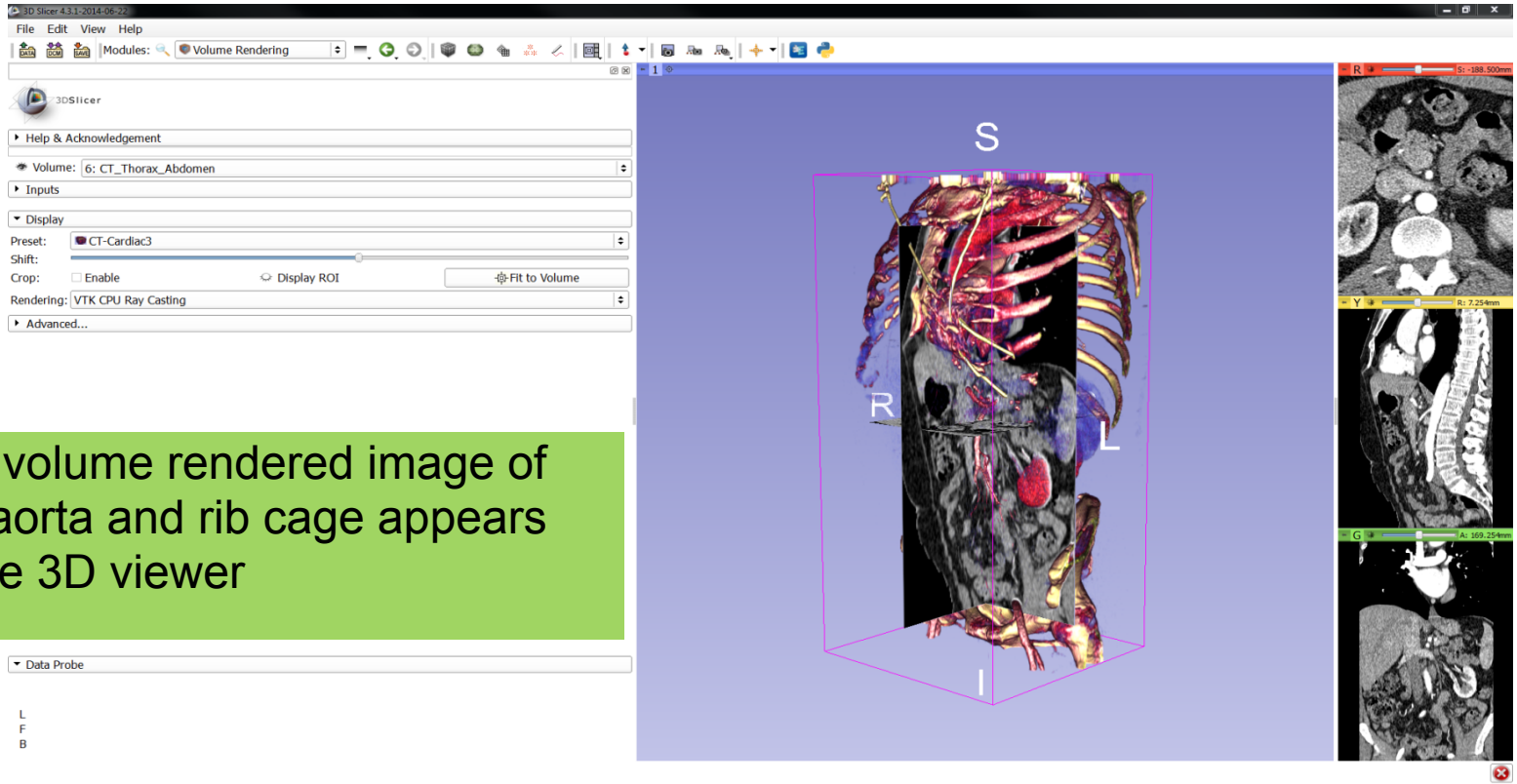
Slicer displays the 3D rendered volume of the CT_Thorax_Abdomen dataset

Volume Rendering



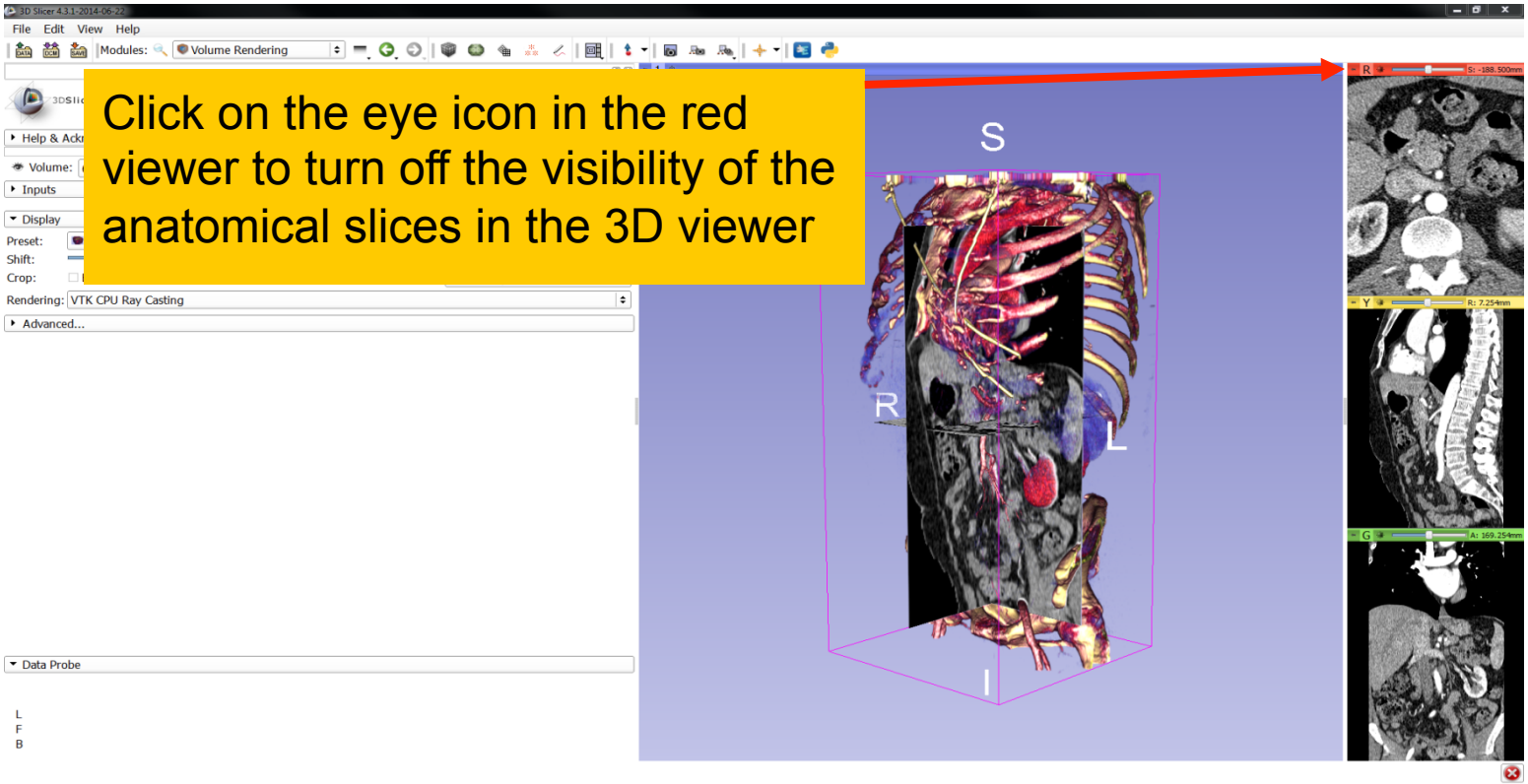
Move the **Shift** slider toward the right, to shift the transfer function and display the aorta

Volume Rendering

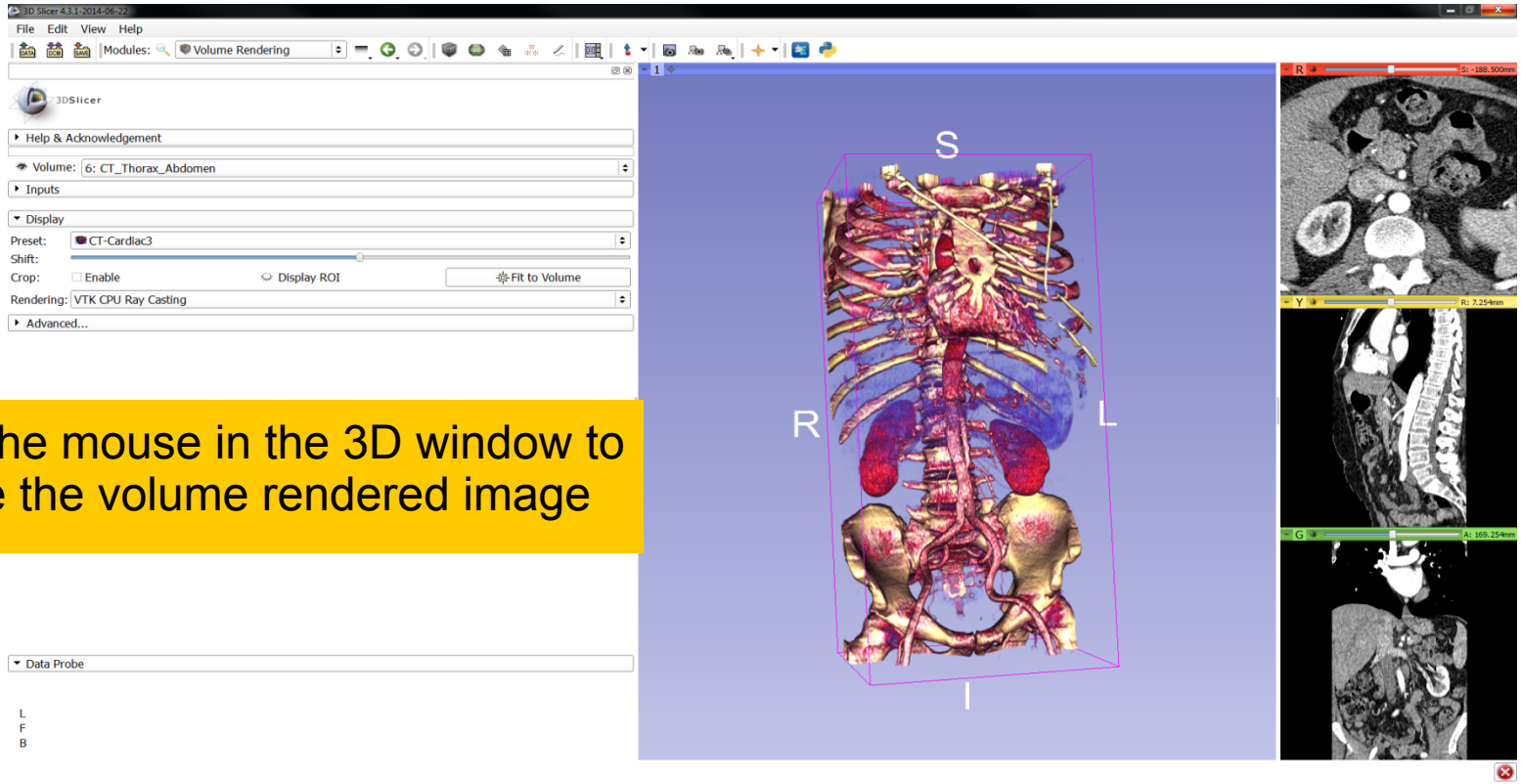


The volume rendered image of the aorta and rib cage appears in the 3D viewer

Volume Rendering

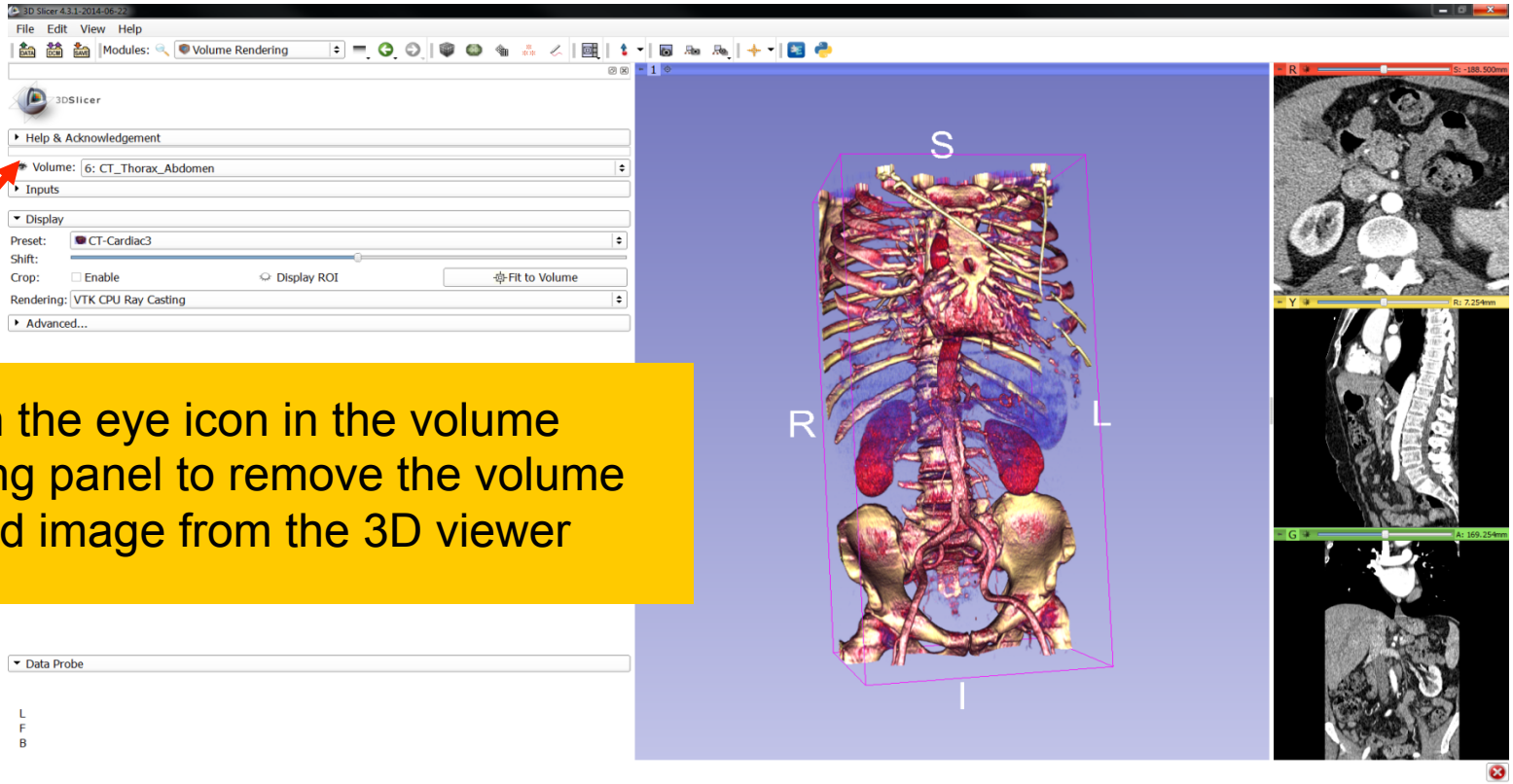


Volume Rendering



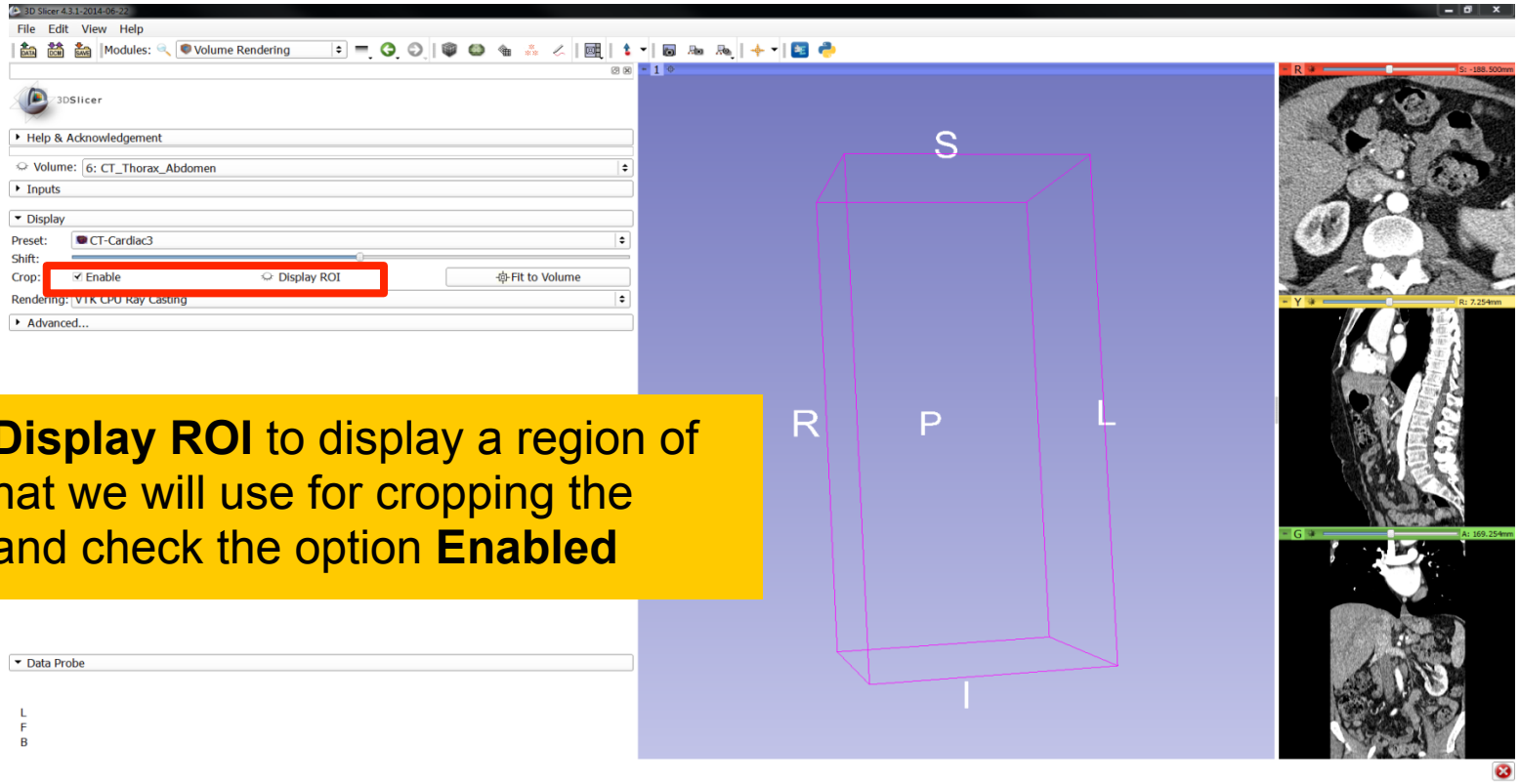
Use the mouse in the 3D window to rotate the volume rendered image

Volume Rendering



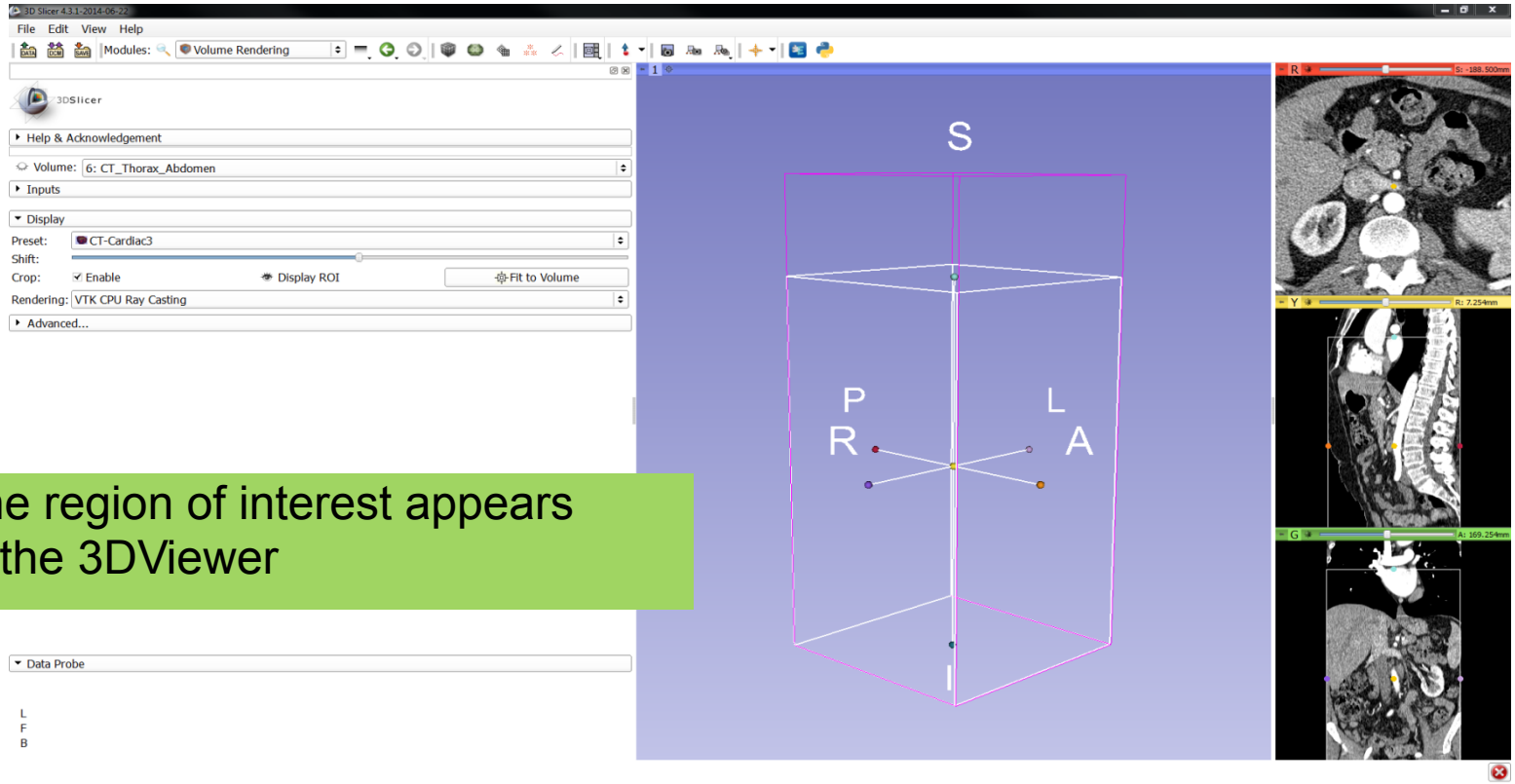
Click on the eye icon in the volume rendering panel to remove the volume rendered image from the 3D viewer

Volume Rendering



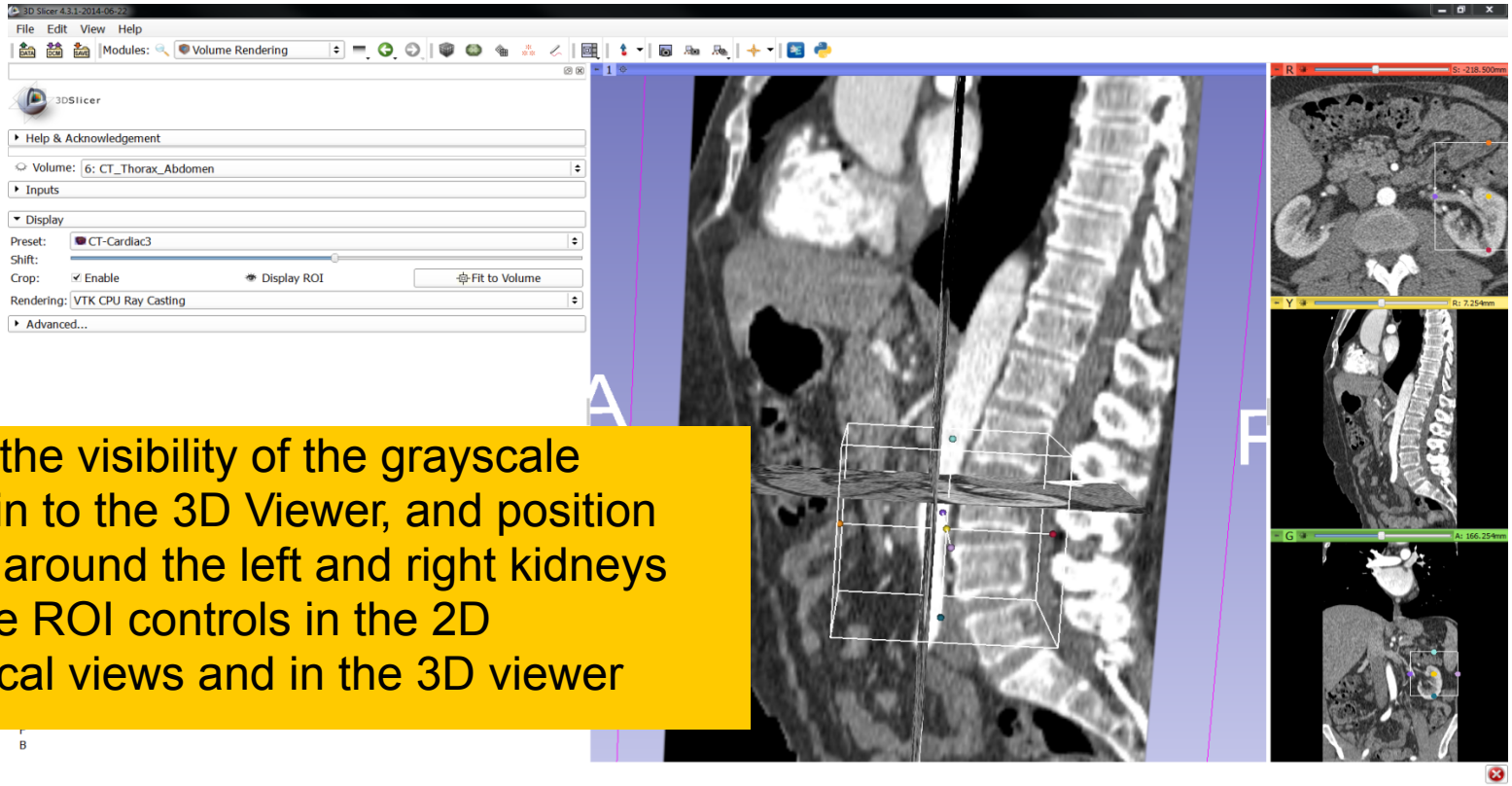
Click on **Display ROI** to display a region of interest that we will use for cropping the dataset, and check the option **Enabled**

Volume Rendering



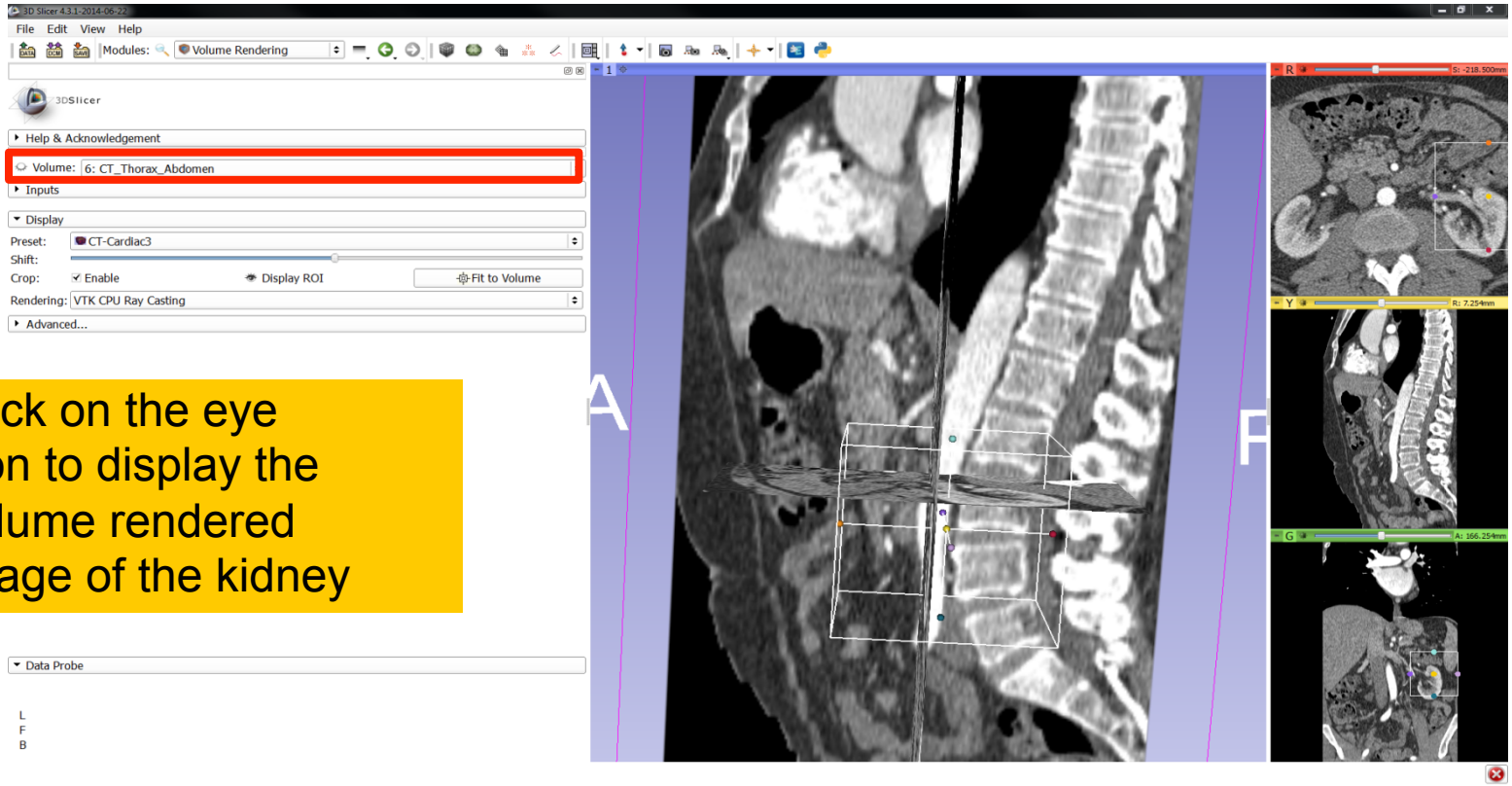
The region of interest appears in the 3DViewer

Volume Rendering



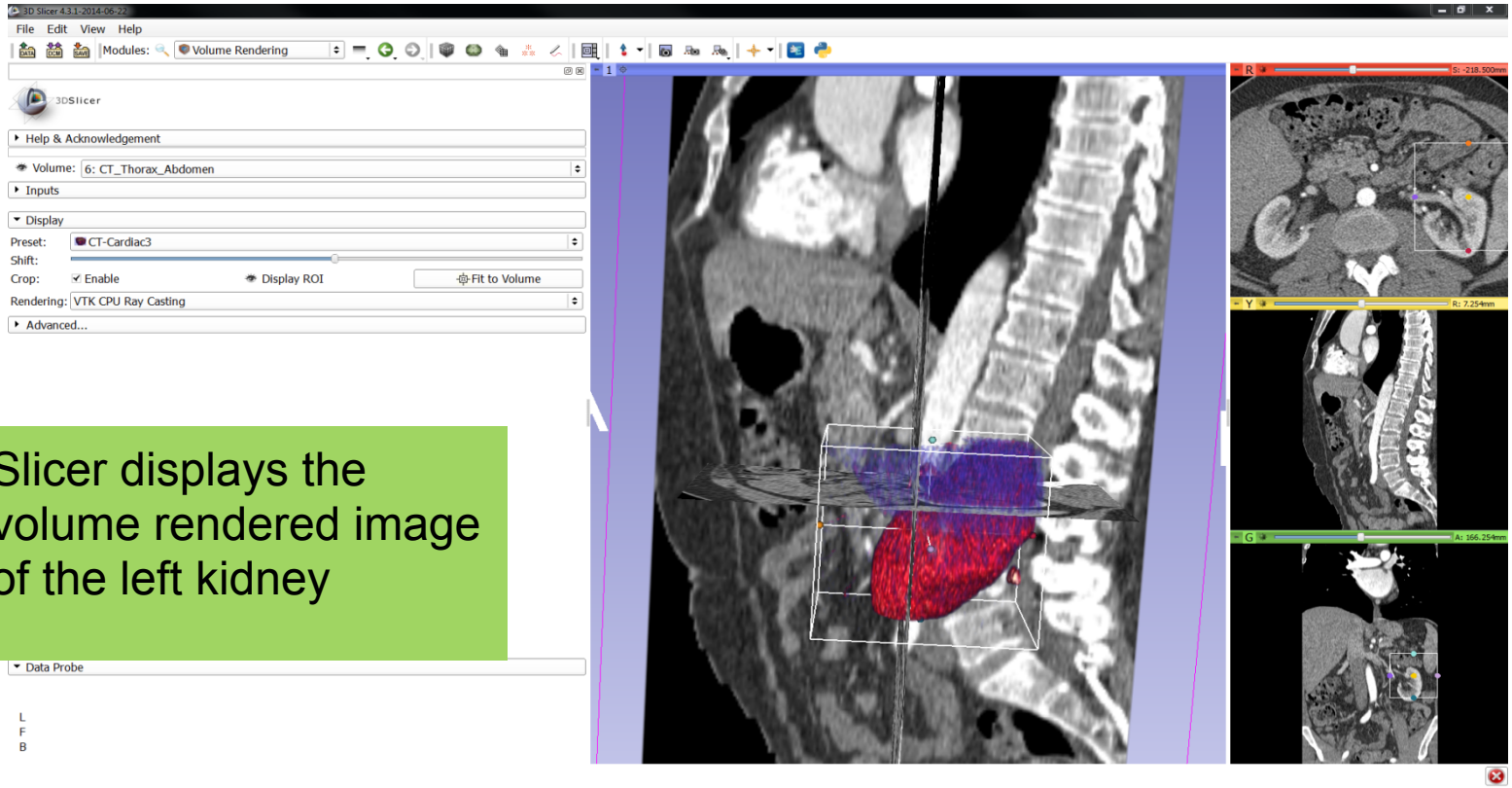
Turn on the visibility of the grayscale images in to the 3D Viewer, and position the ROI around the left and right kidneys using the ROI controls in the 2D anatomical views and in the 3D viewer

Volume Rendering



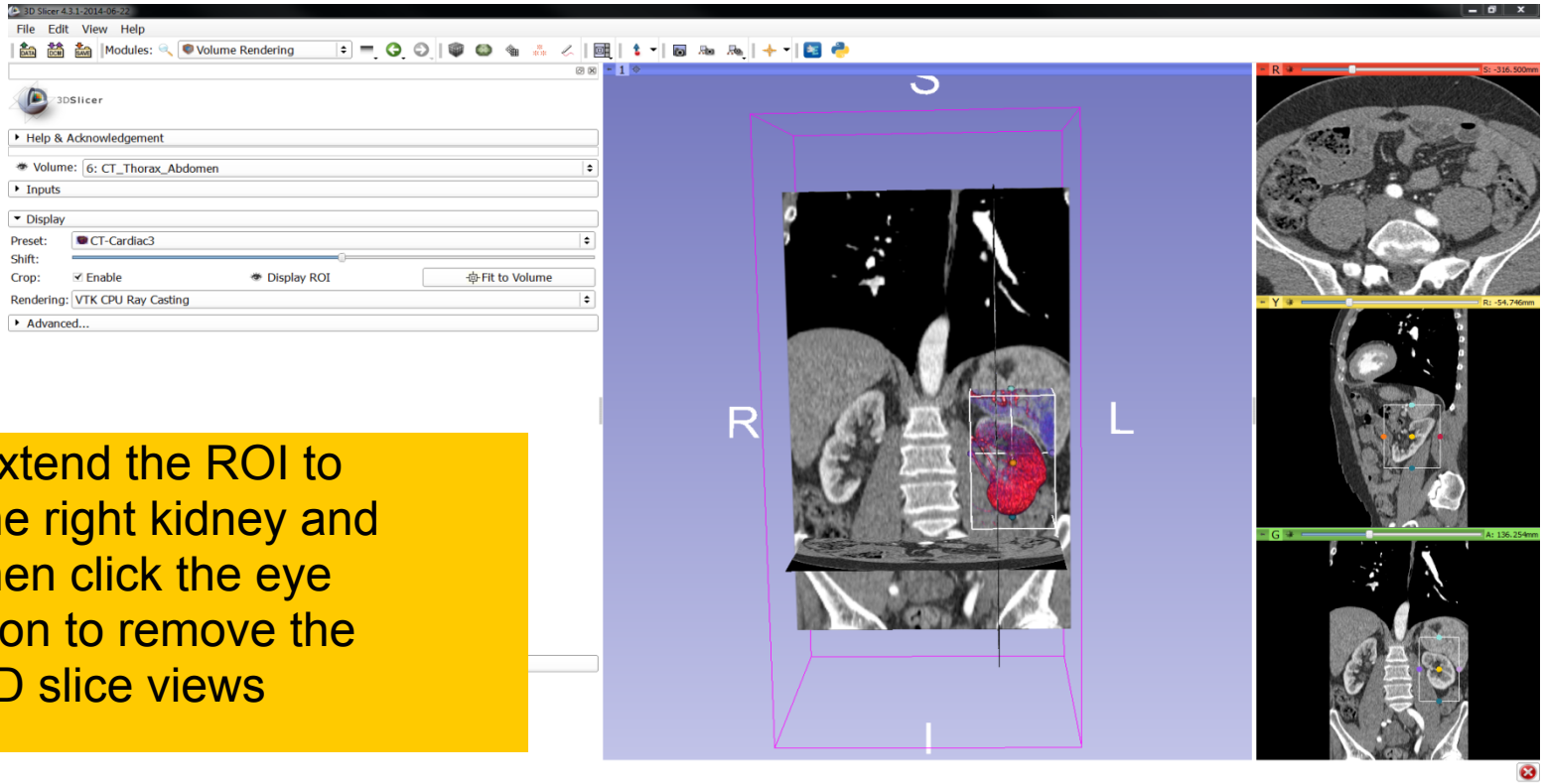
Click on the eye icon to display the volume rendered image of the kidney

Volume Rendering



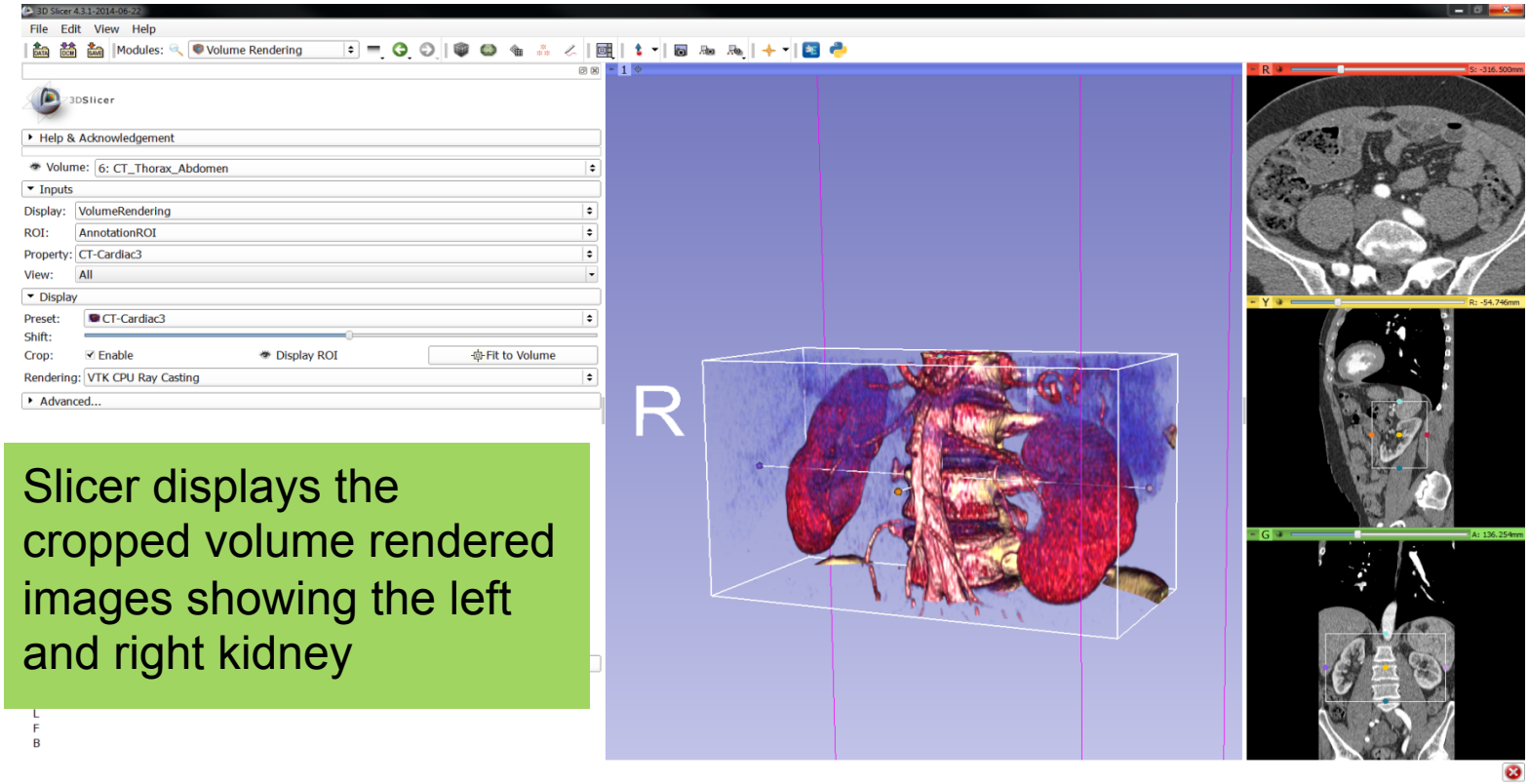
Slicer displays the volume rendered image of the left kidney

Volume Rendering



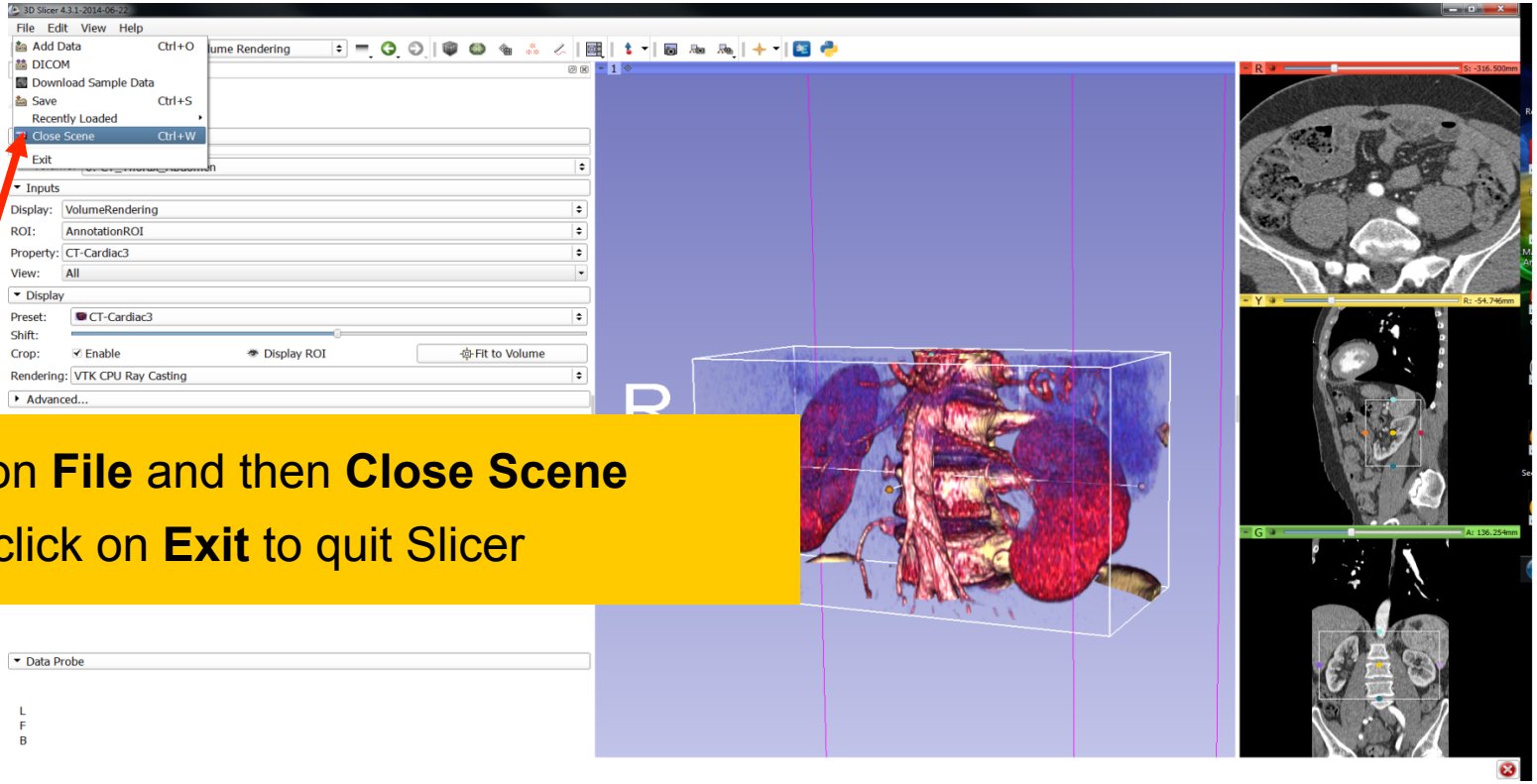
Extend the ROI to the right kidney and then click the eye icon to remove the 2D slice views

Volume Rendering



Slicer displays the cropped volume rendered images showing the left and right kidney

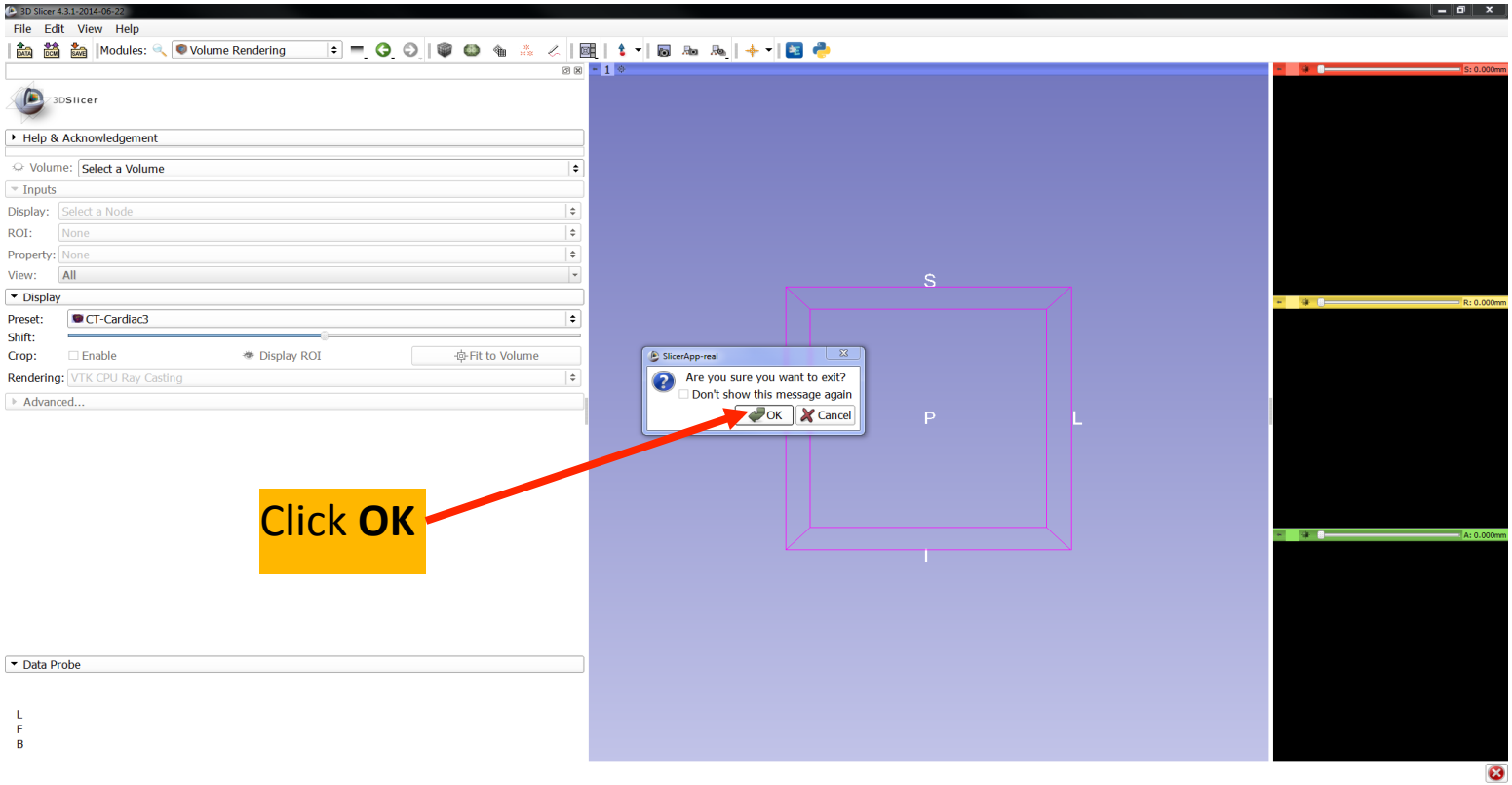
Volume Rendering

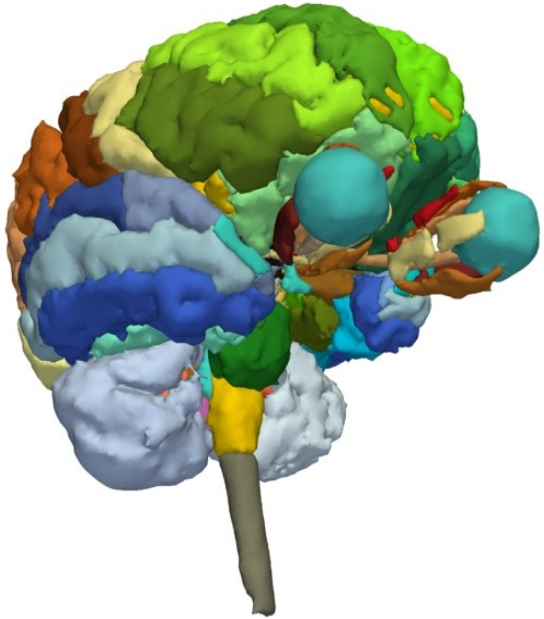


Click on **File** and then **Close Scene**

Then click on **Exit** to quit Slicer

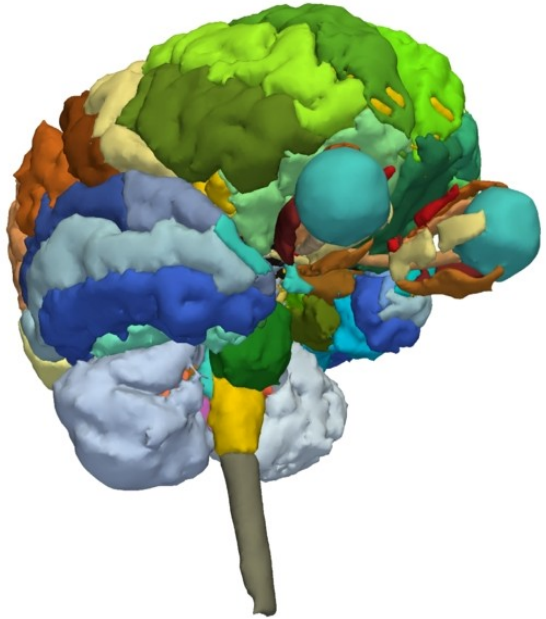
Volume Rendering





3D visualization of surface models of the brain

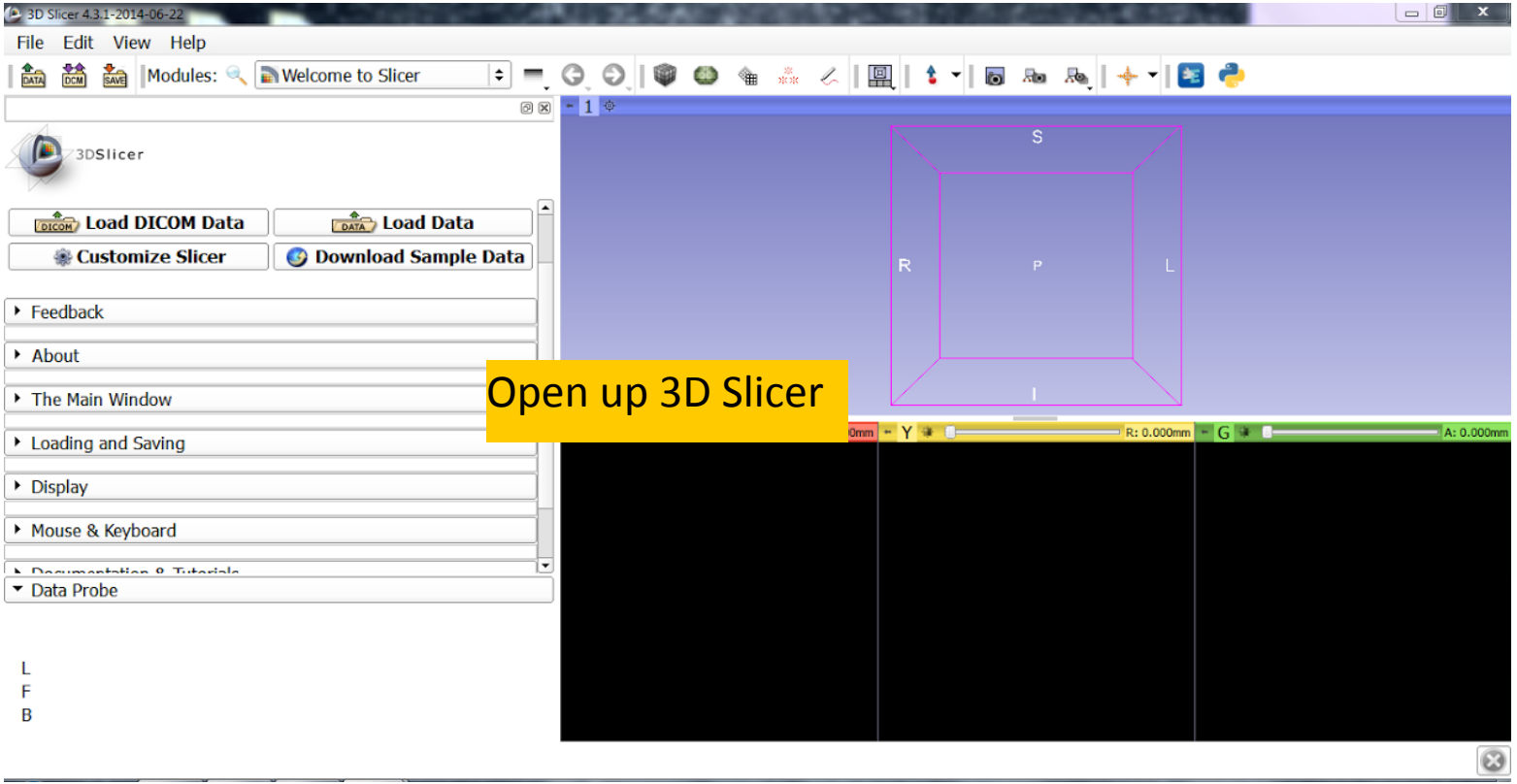
3D Data Loading and Visualization



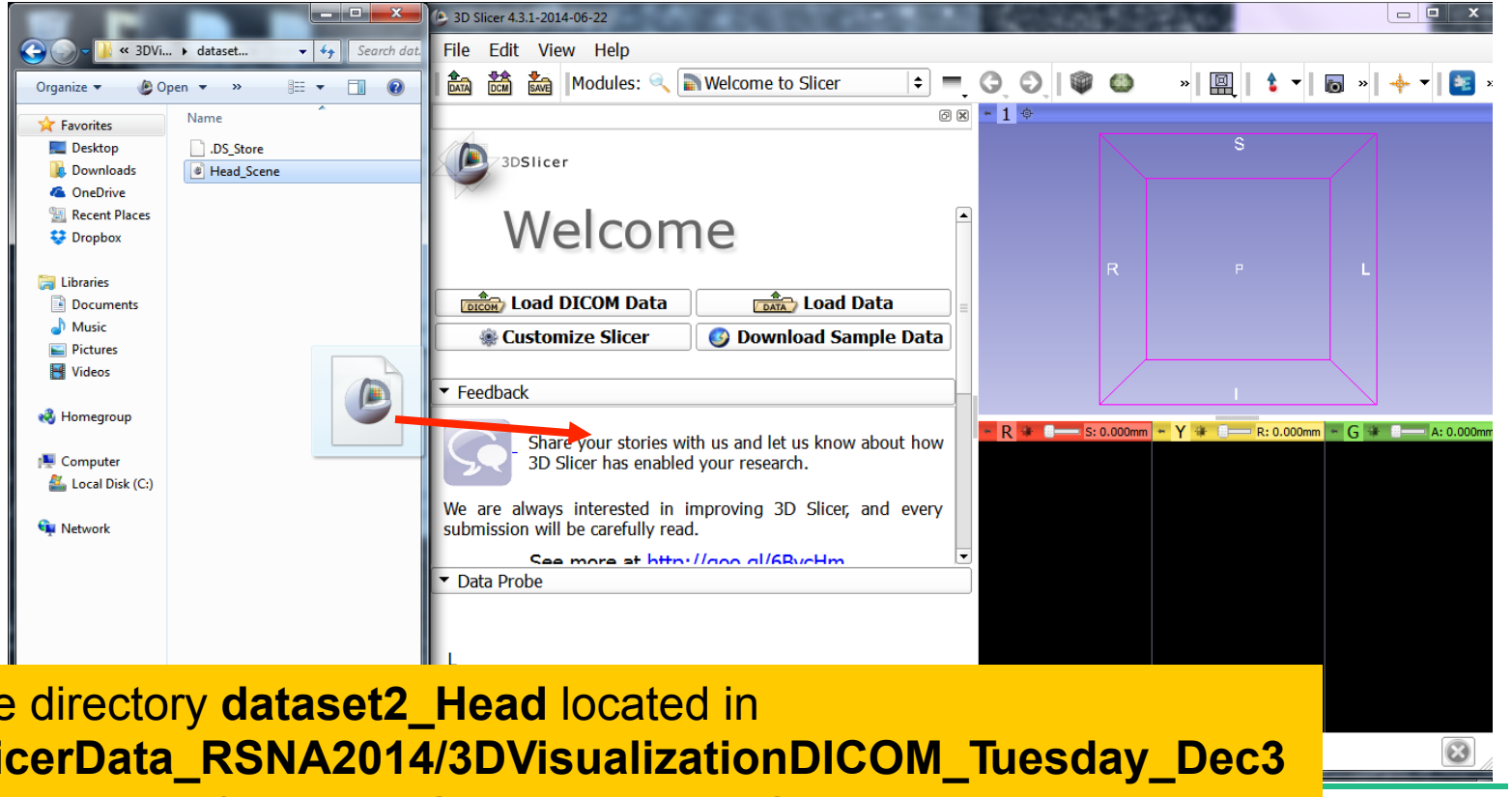
- This tutorial is a short introduction to the advanced **3D visualization capabilities Slicer**
- The Slicer4 Minute dataset is composed of an MR scan of the brain and 3D surface reconstructions of anatomical structures.
- The data are part of the **SPL Multi-modality MRI-based atlas of the brain** by Halle et al. The atlas is available at:

http://www.spl.harvard.edu/publications/item/view/2037

Welcome to Slicer4

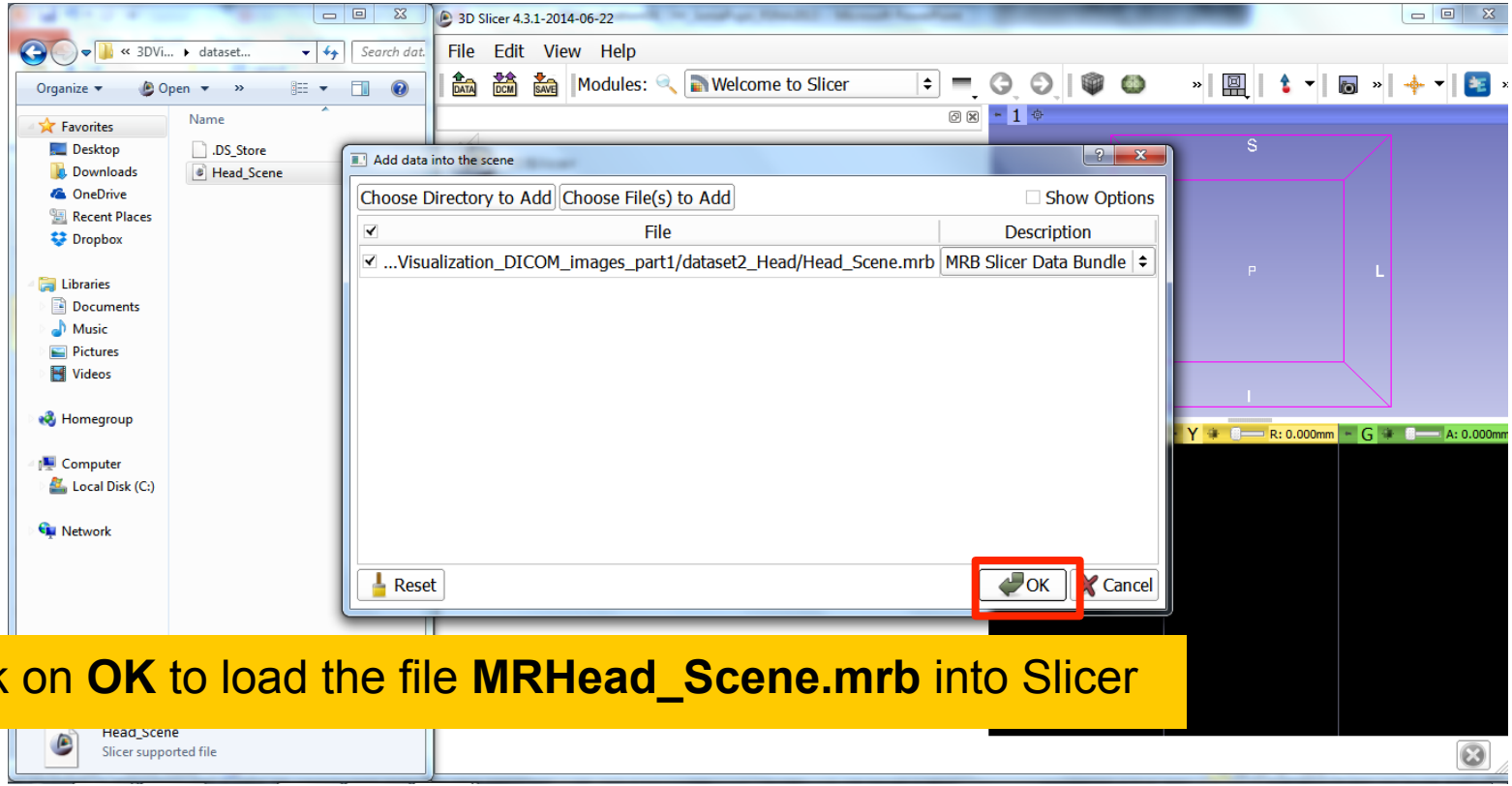


Slicer4 Minute Tutorial: Viewing the Scene



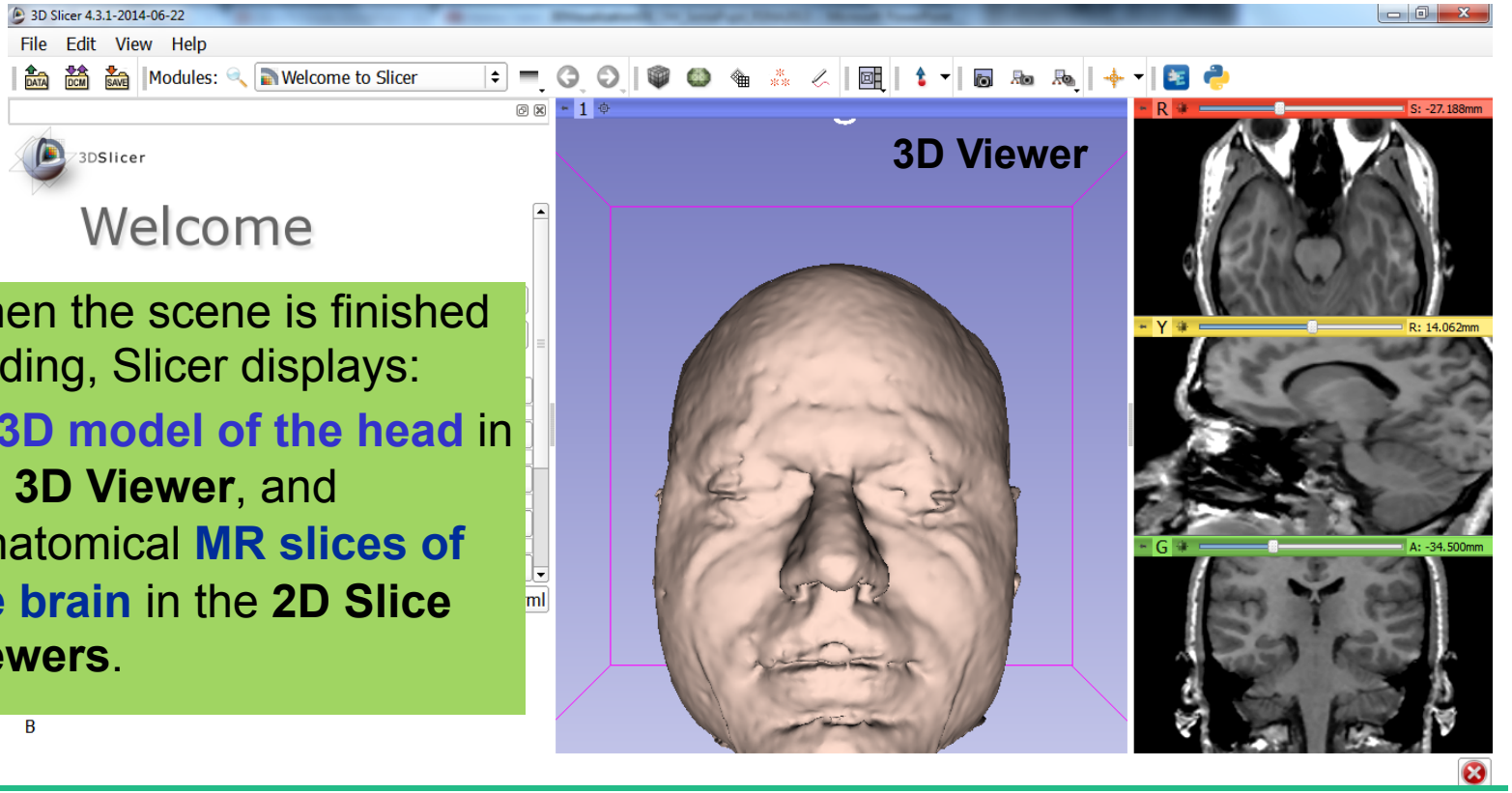
Open the directory **dataset2_Head** located in **C:/3DSlicerData_RSNA2014/3DVisualizationDICOM_Tuesday_Dec3**
Drag and drop the file **Head_Scene.mrb** into Slicer

Slicer4 Minute Tutorial: Viewing the Scene



Click on **OK** to load the file **MRHead_Scene.mrb** into Slicer

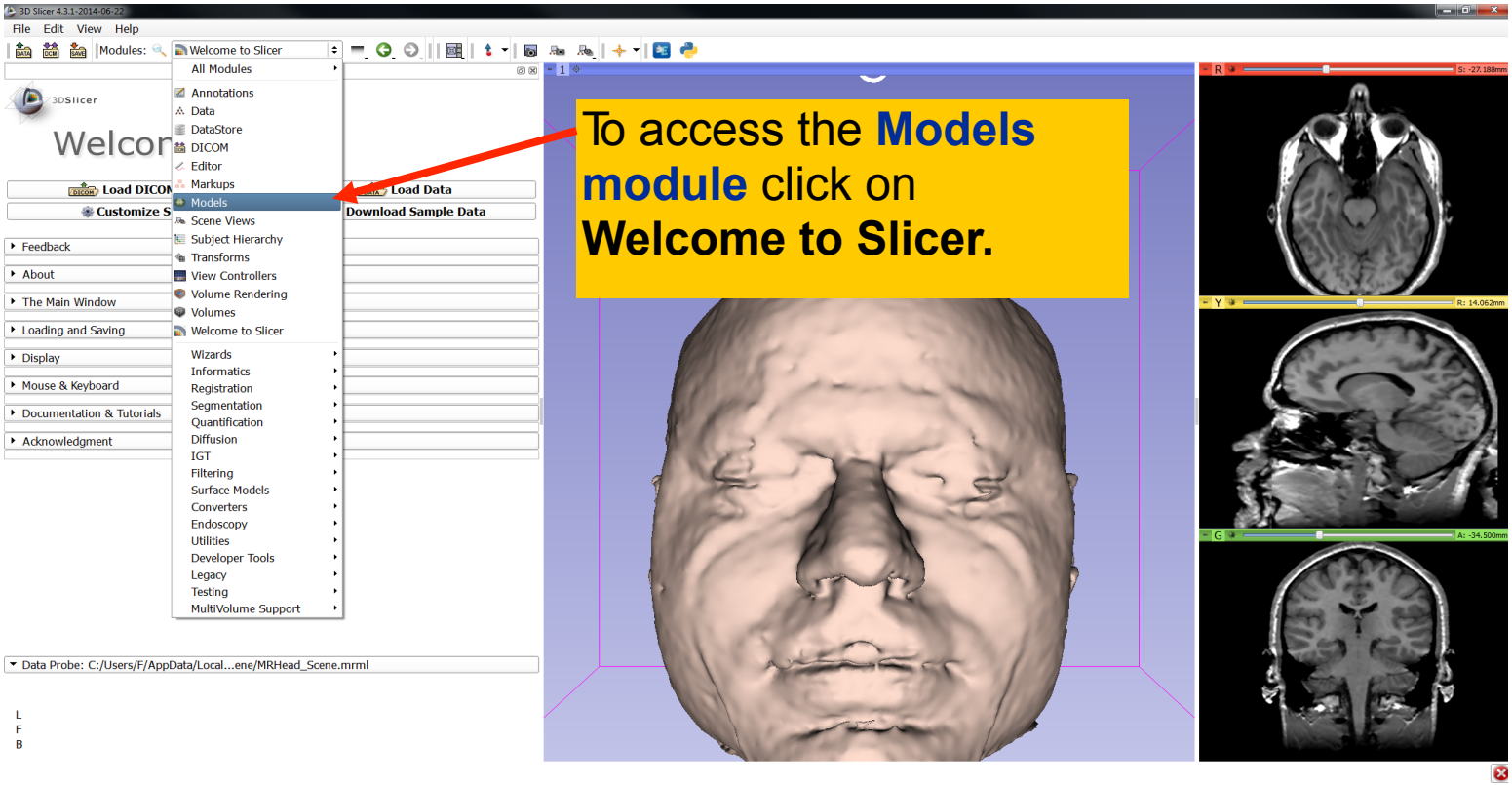
Slicer4 Minute Tutorial: Viewing the Scene



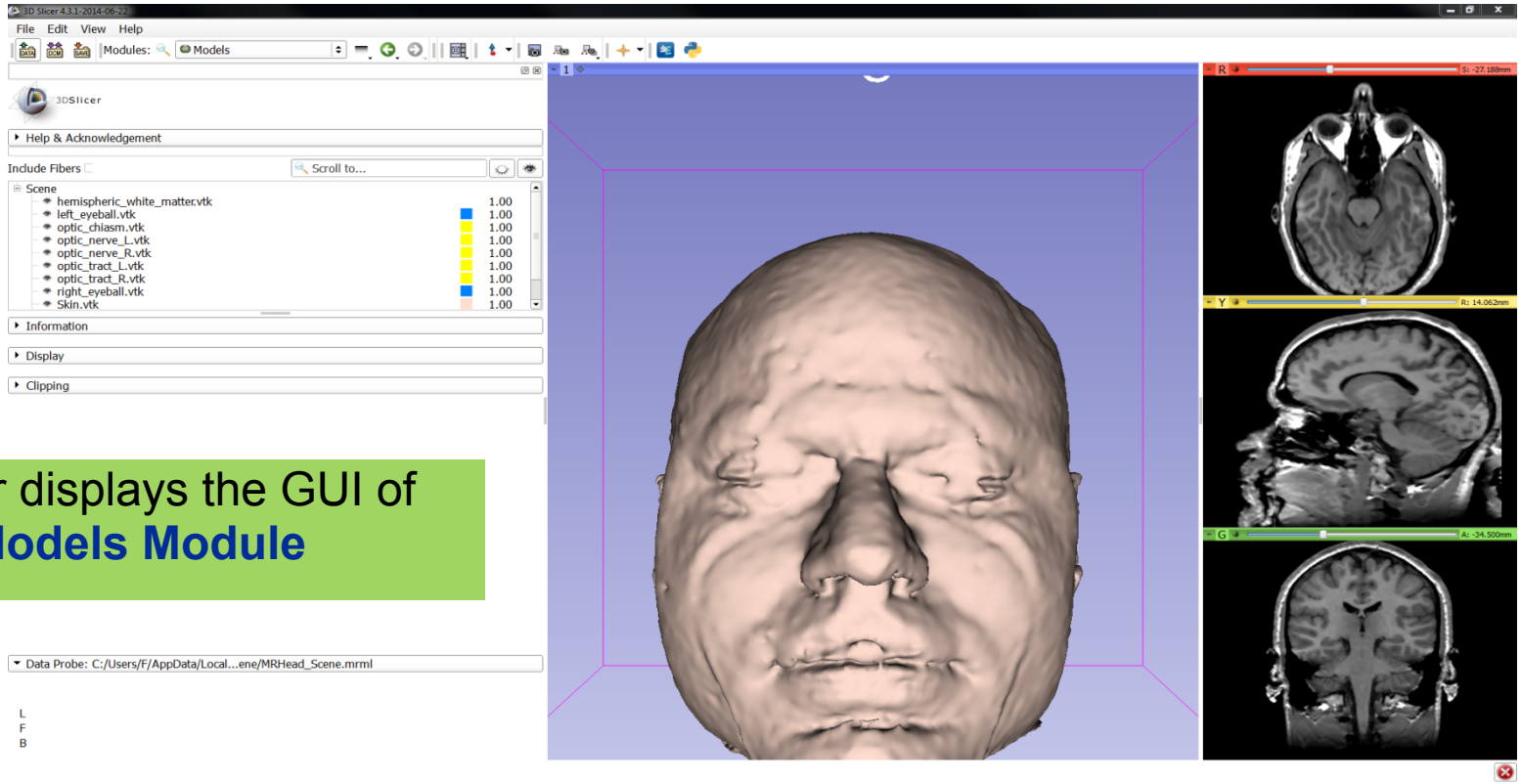
When the scene is finished loading, Slicer displays:

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

Slicer4 Minute Tutorial: Exploring Slicer's functionality

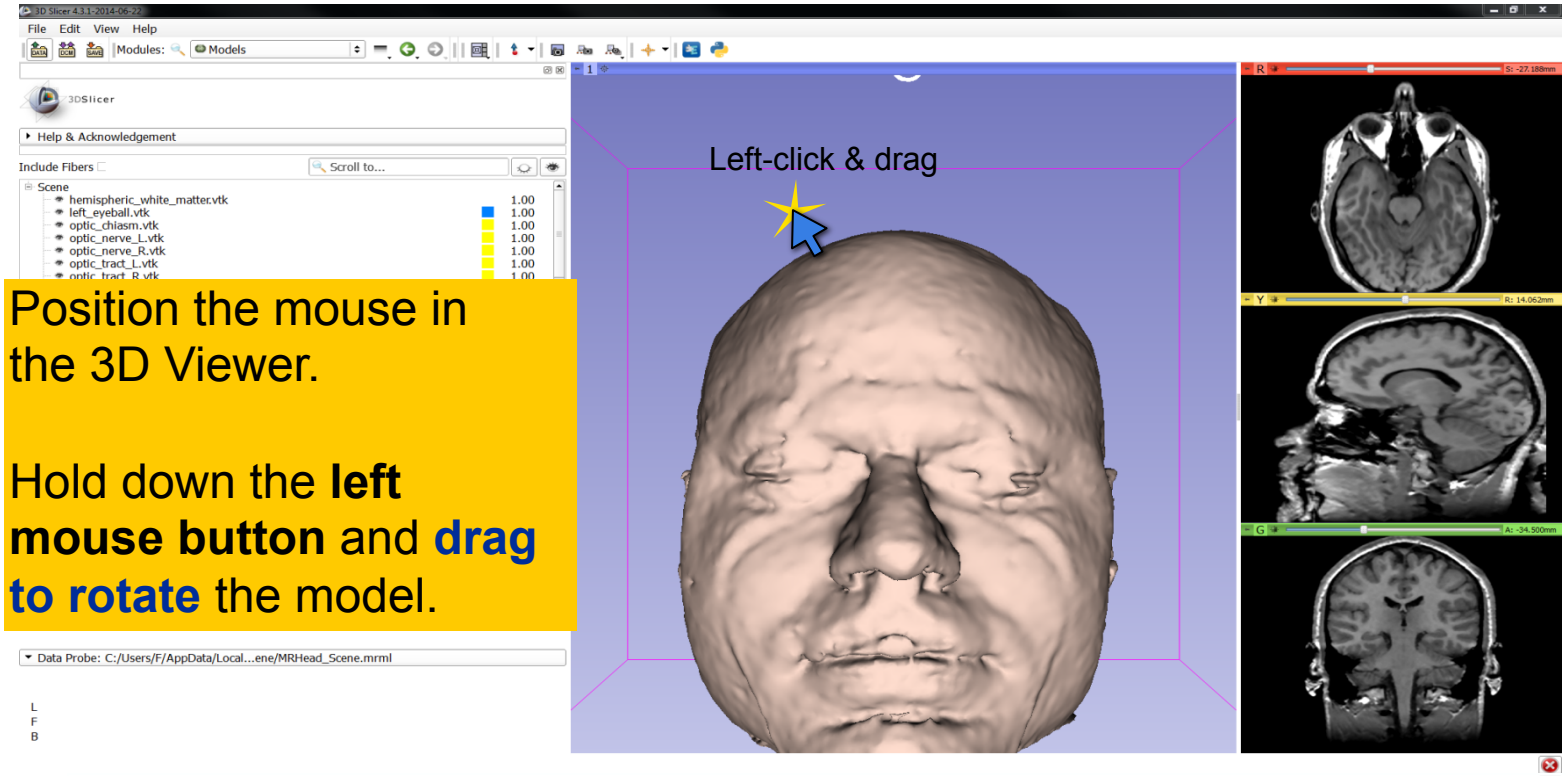


Slicer4 Minute Tutorial: Switching to the Models Module



Slicer displays the GUI of the **Models Module**

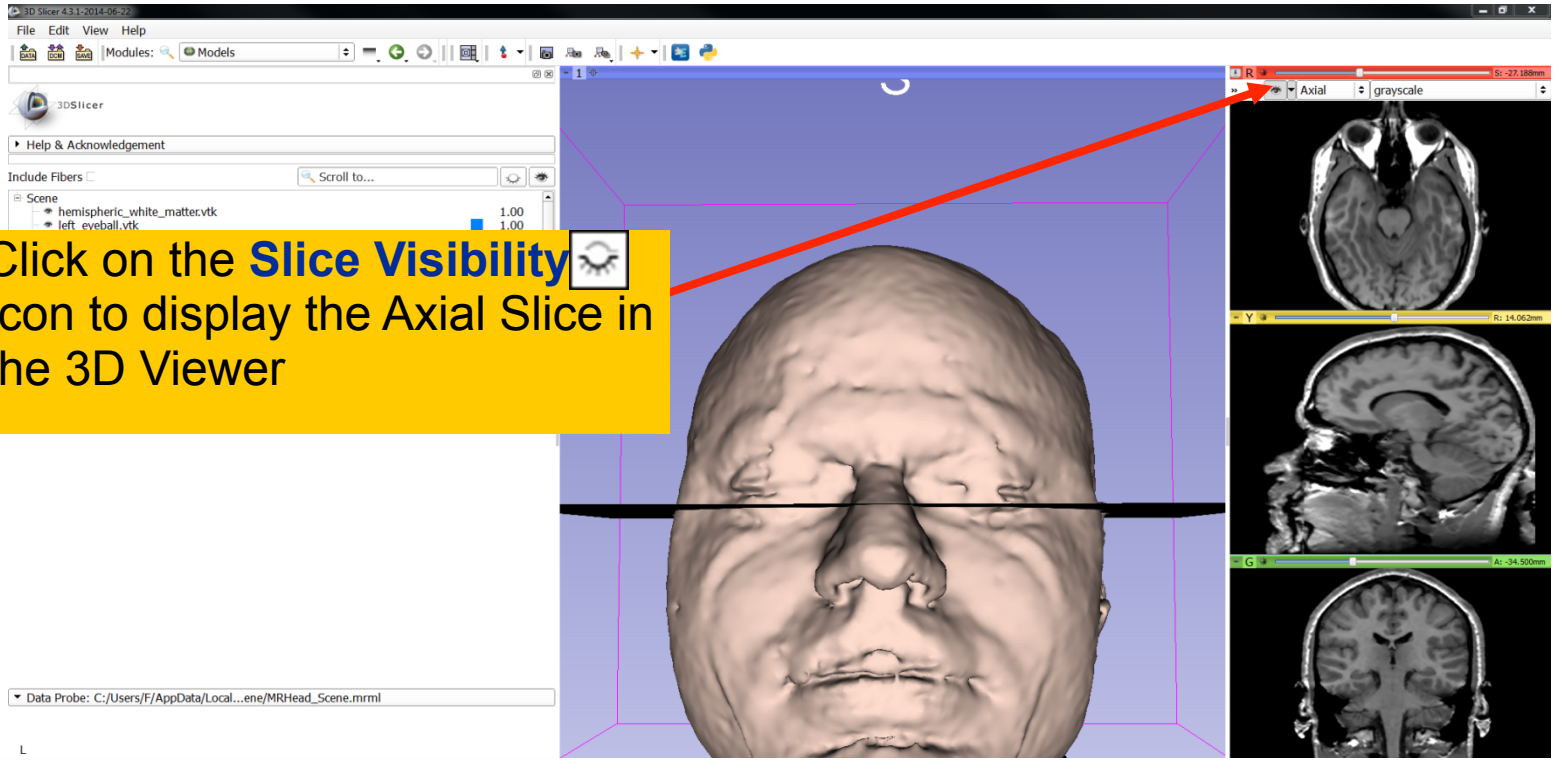
Slicer4 Minute Tutorial: Basic 3D Interaction



Position the mouse in the 3D Viewer.

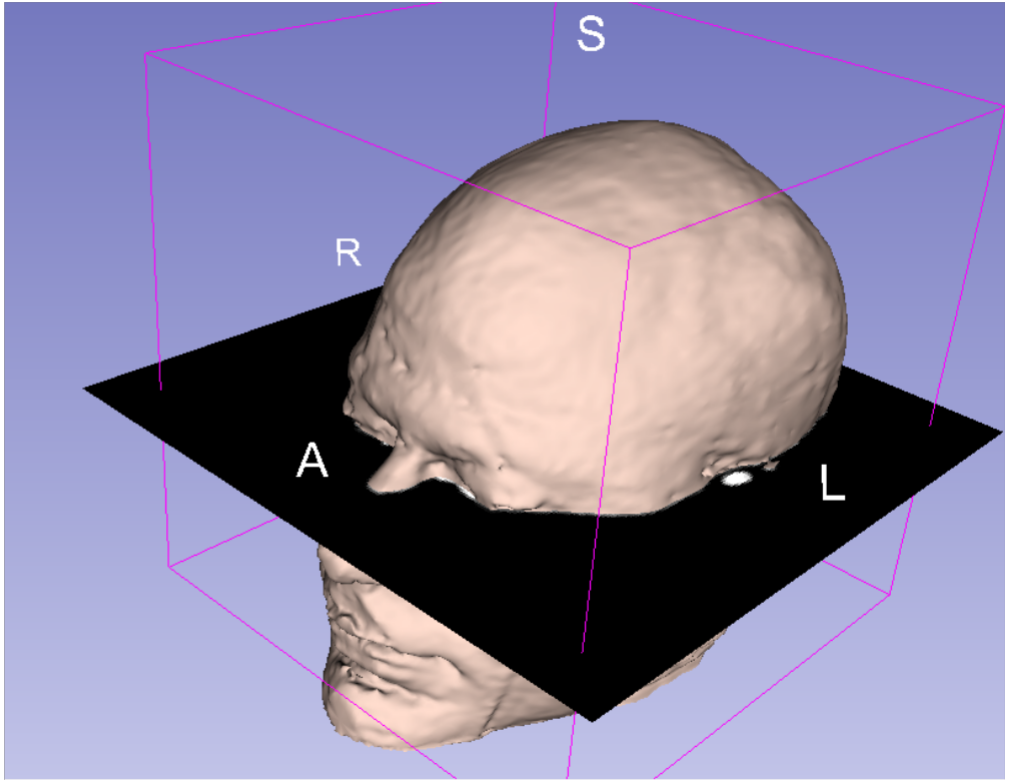
Hold down the **left mouse button** and **drag to rotate** the model.

Slicer4 Minute Tutorial: Viewing Slices in the 3D Viewer

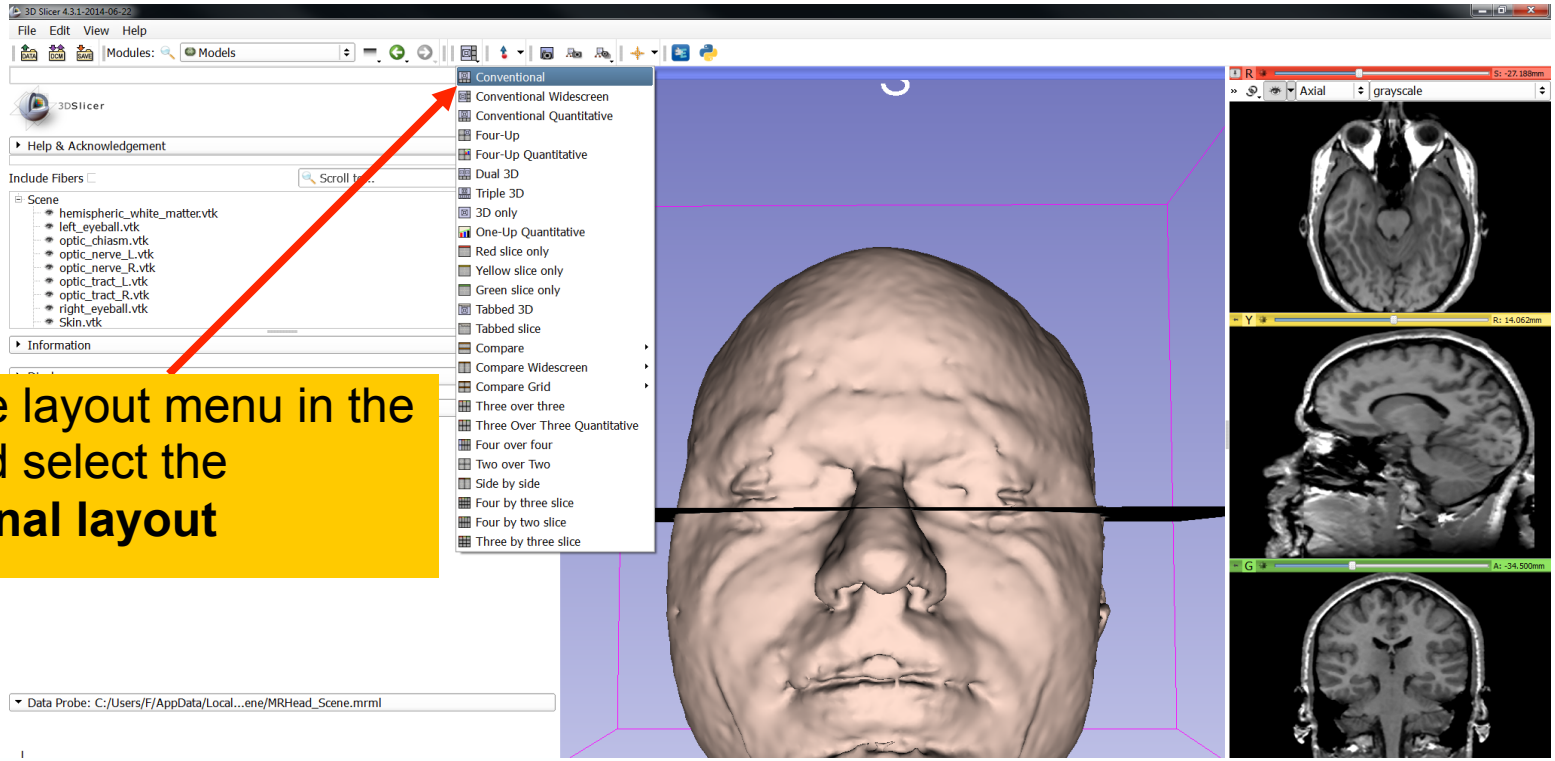


Slicer4 Minute Tutorial: 3D Visualization

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



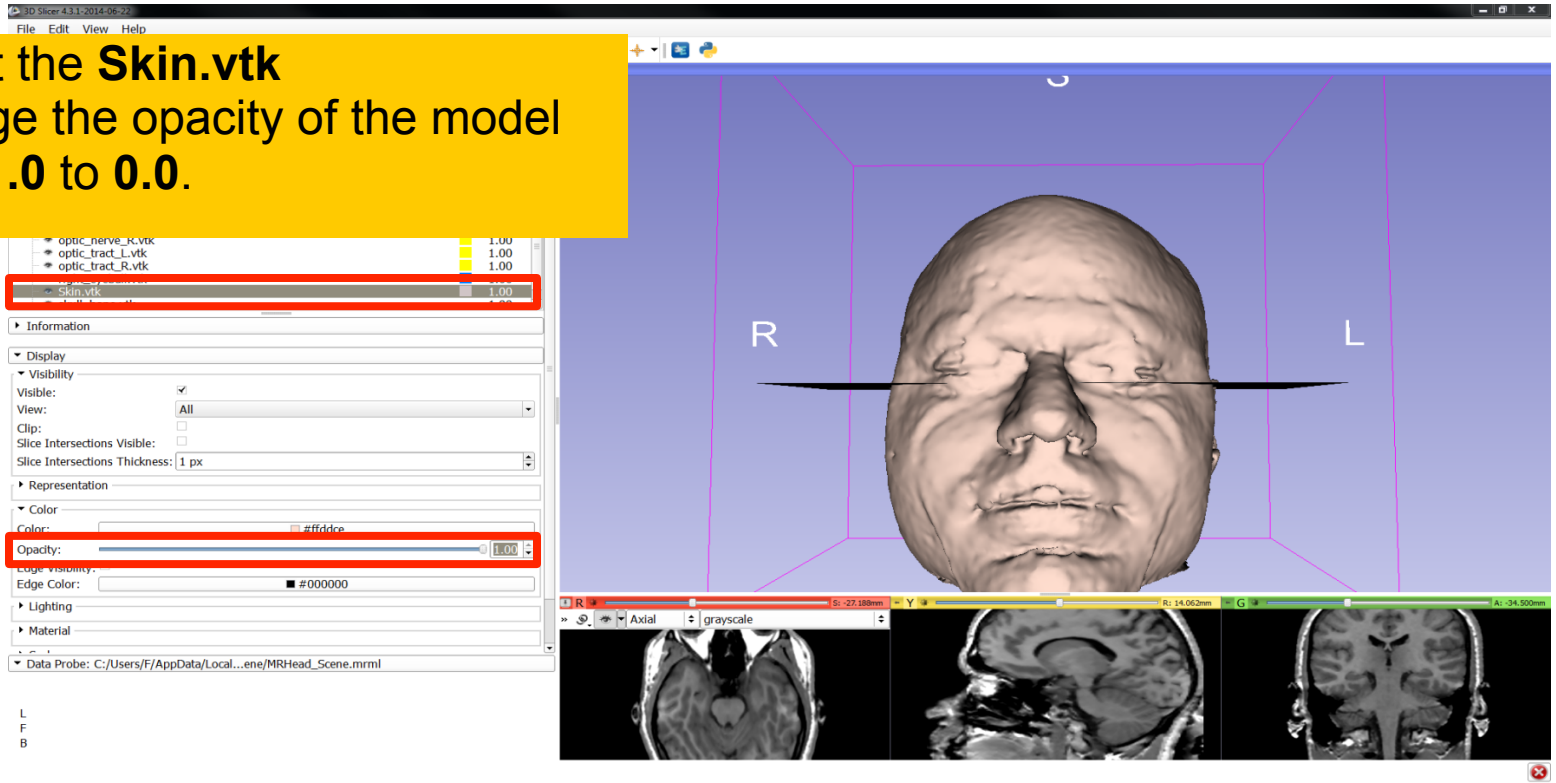
Slicer4 Minute Tutorial: Viewing Slices in the 3D Viewer



Click on the layout menu in the toolbar, and select the **Conventional layout**

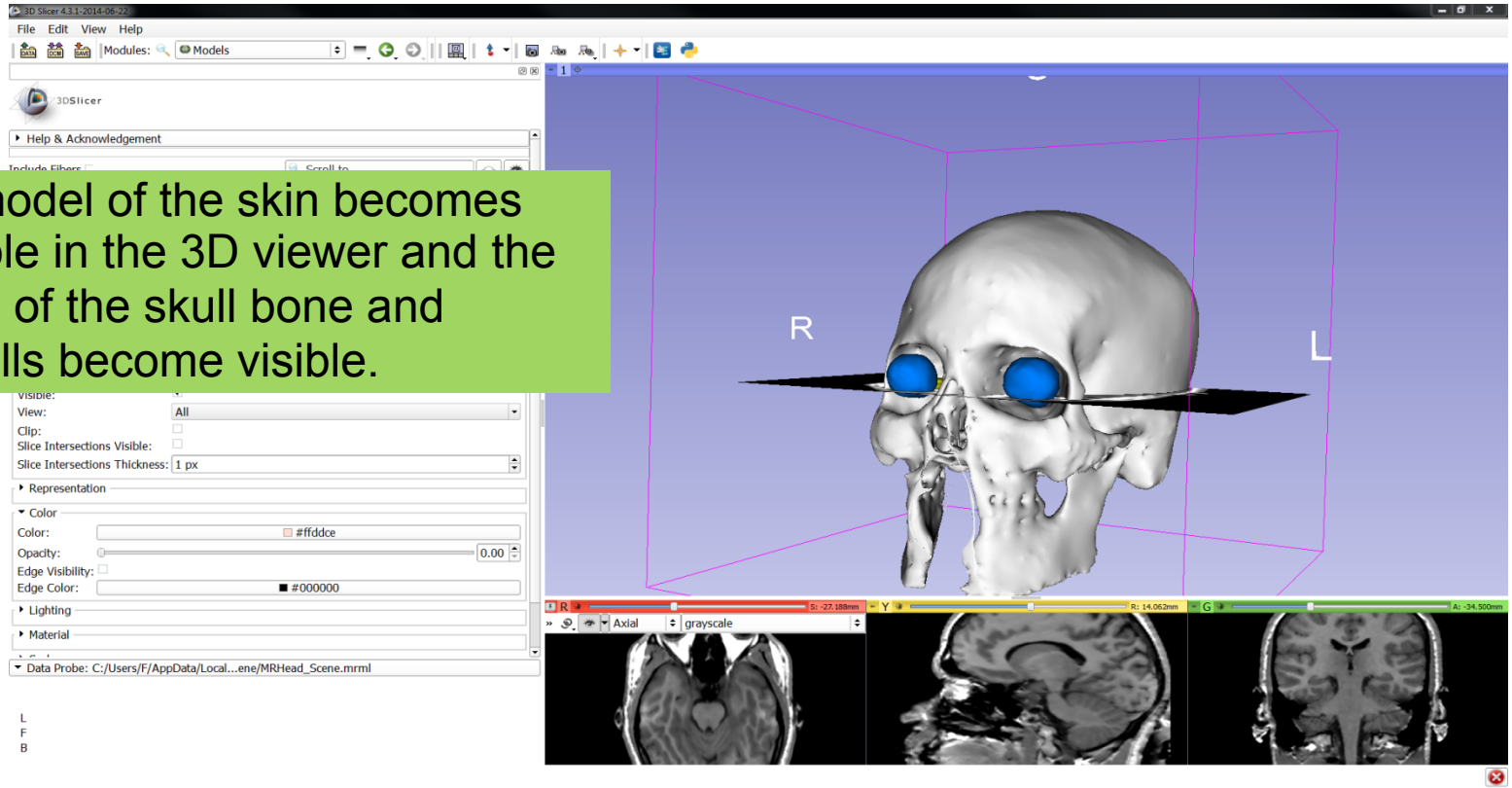
Slicer4 Minute Tutorial: 3D Visualization

Select the **Skin.vtk**
Change the opacity of the model from **1.0** to **0.0**.

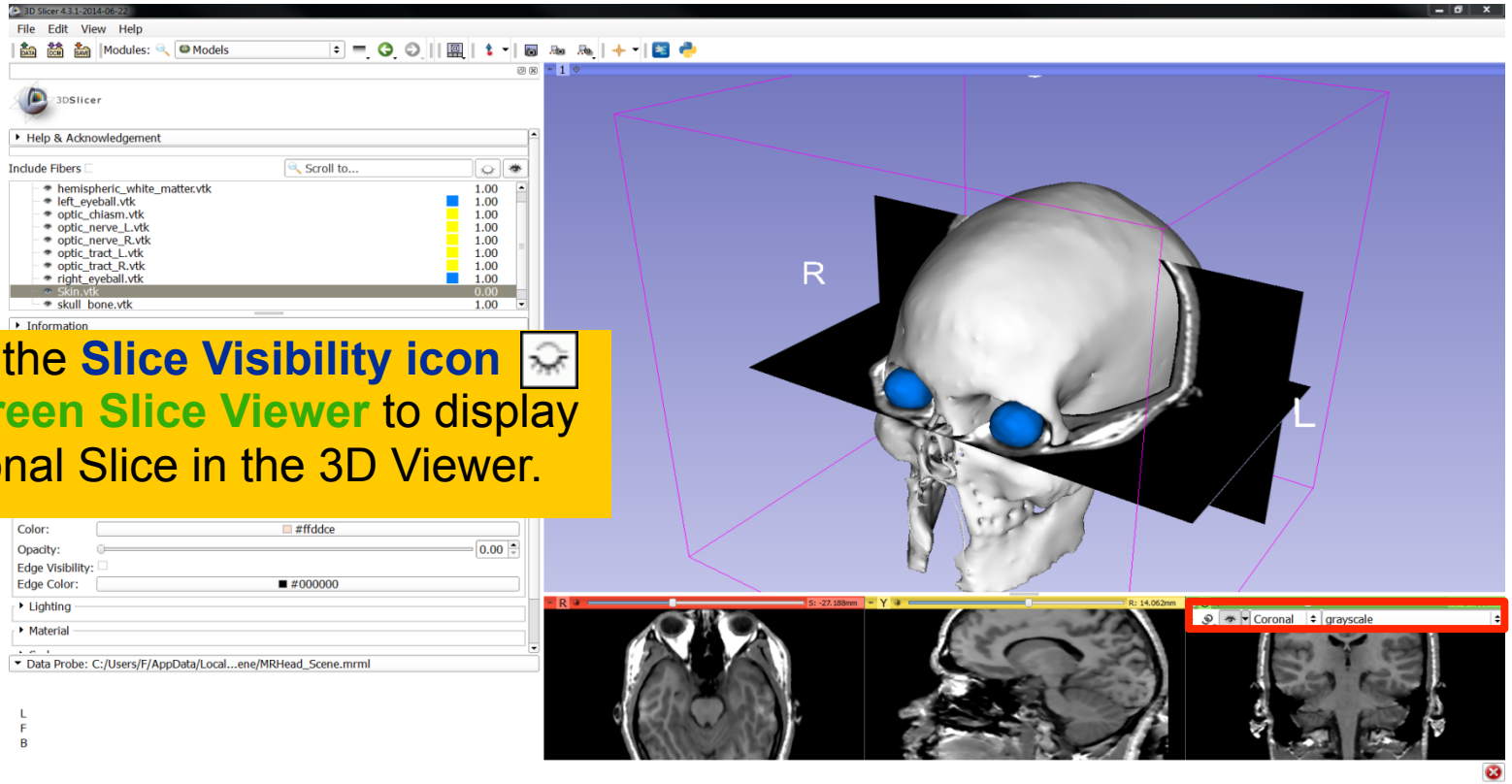


Slicer4 Minute Tutorial: 3D Visualization

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



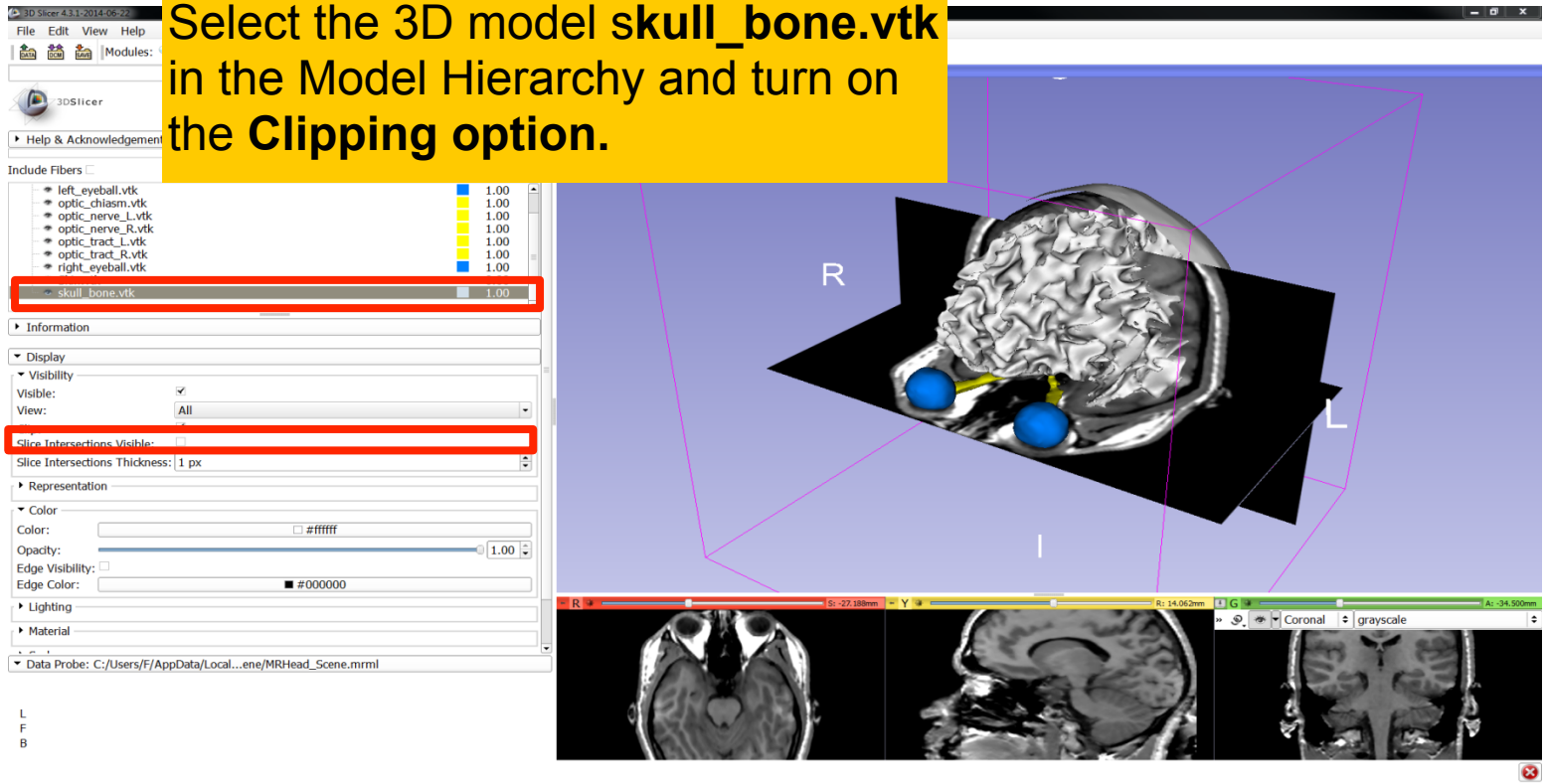
Slicer4 Minute Tutorial: 3D Visualization



Click on the **Slice Visibility icon** in the **Green Slice Viewer** to display the Coronal Slice in the 3D Viewer.

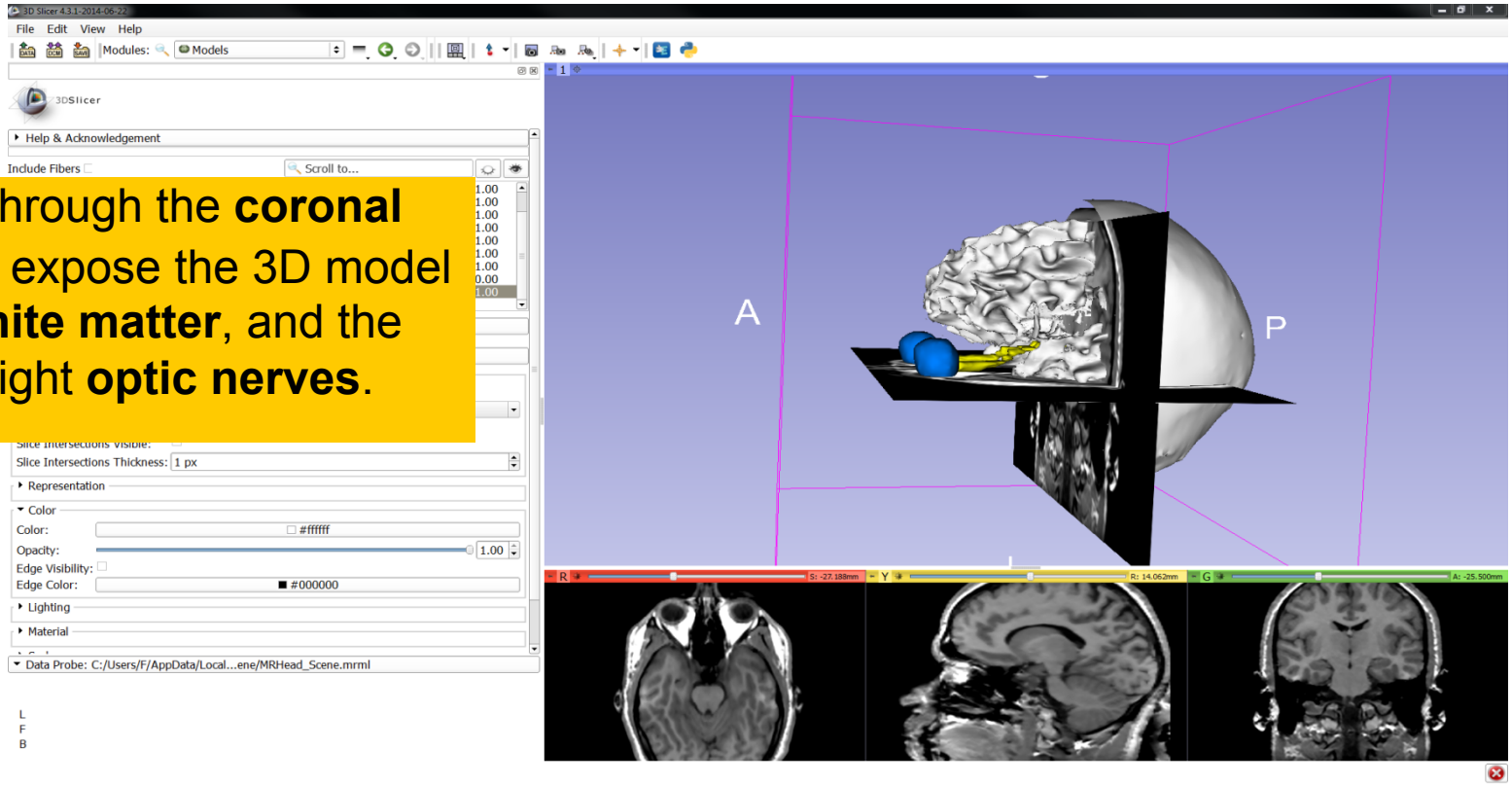
Slicer4 Minute Tutorial: 3D Visualization

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

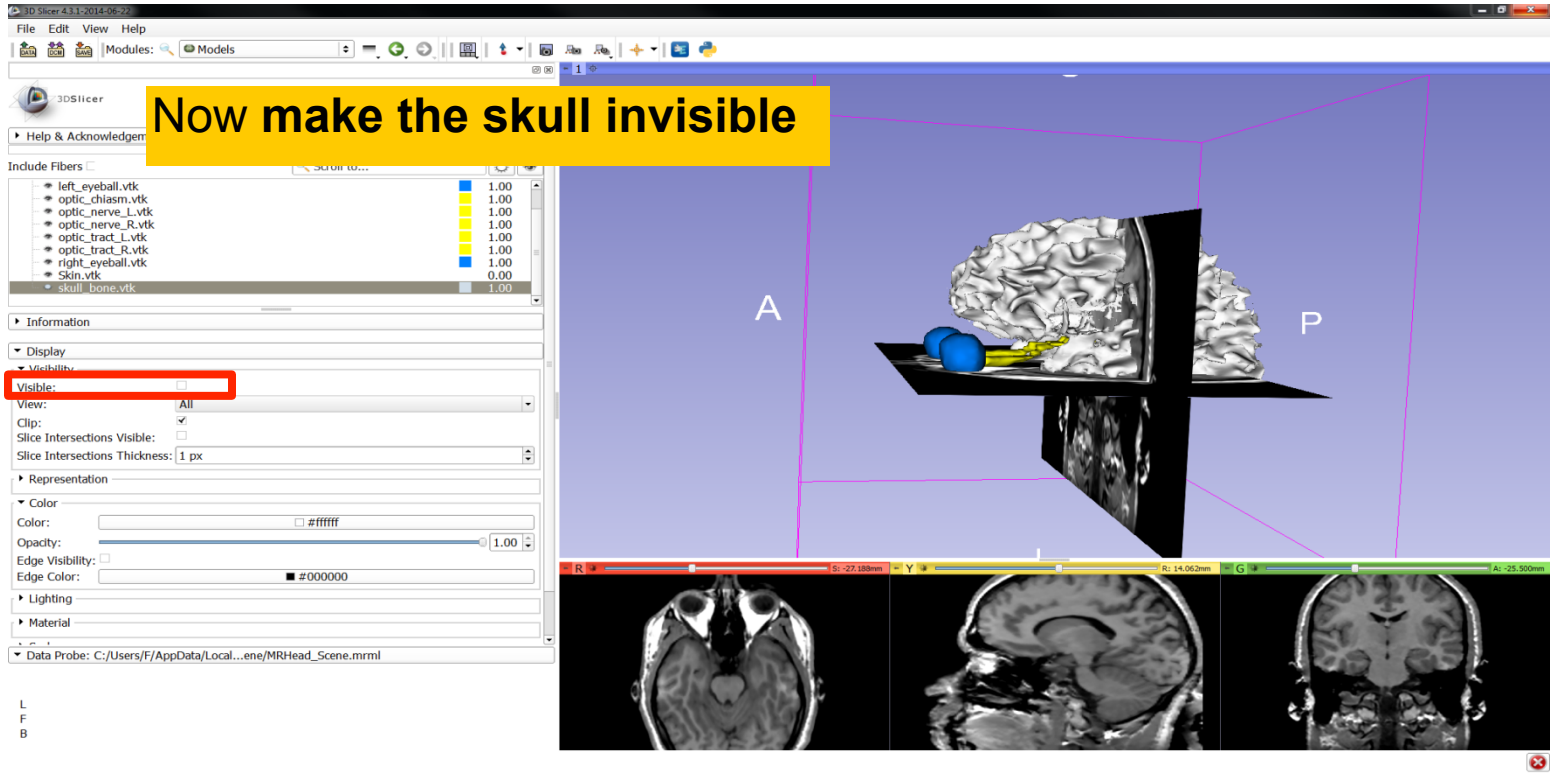


Slicer4 Minute Tutorial: 3D Visualization

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

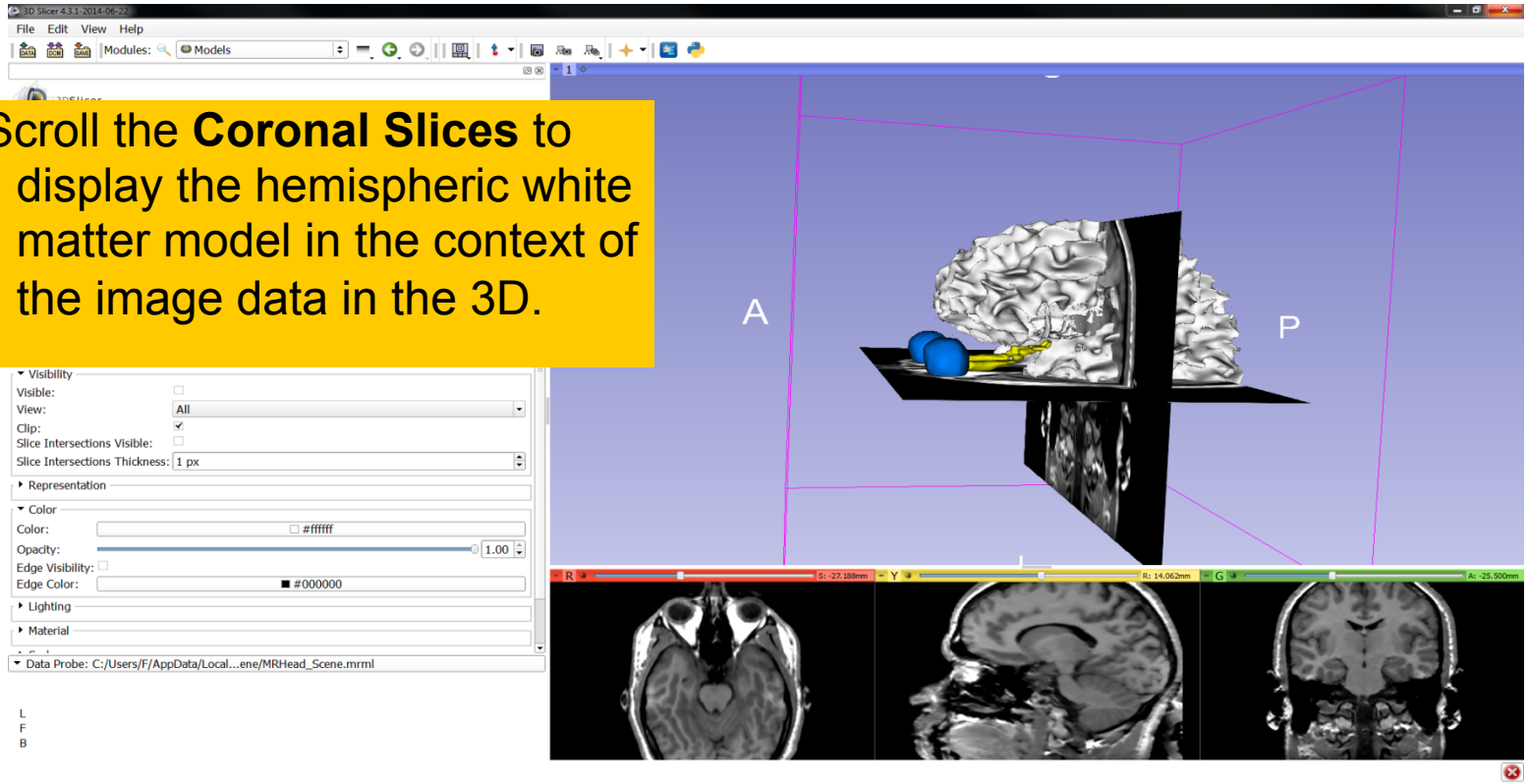


Slicer4 Minute Tutorial: 3D Visualization

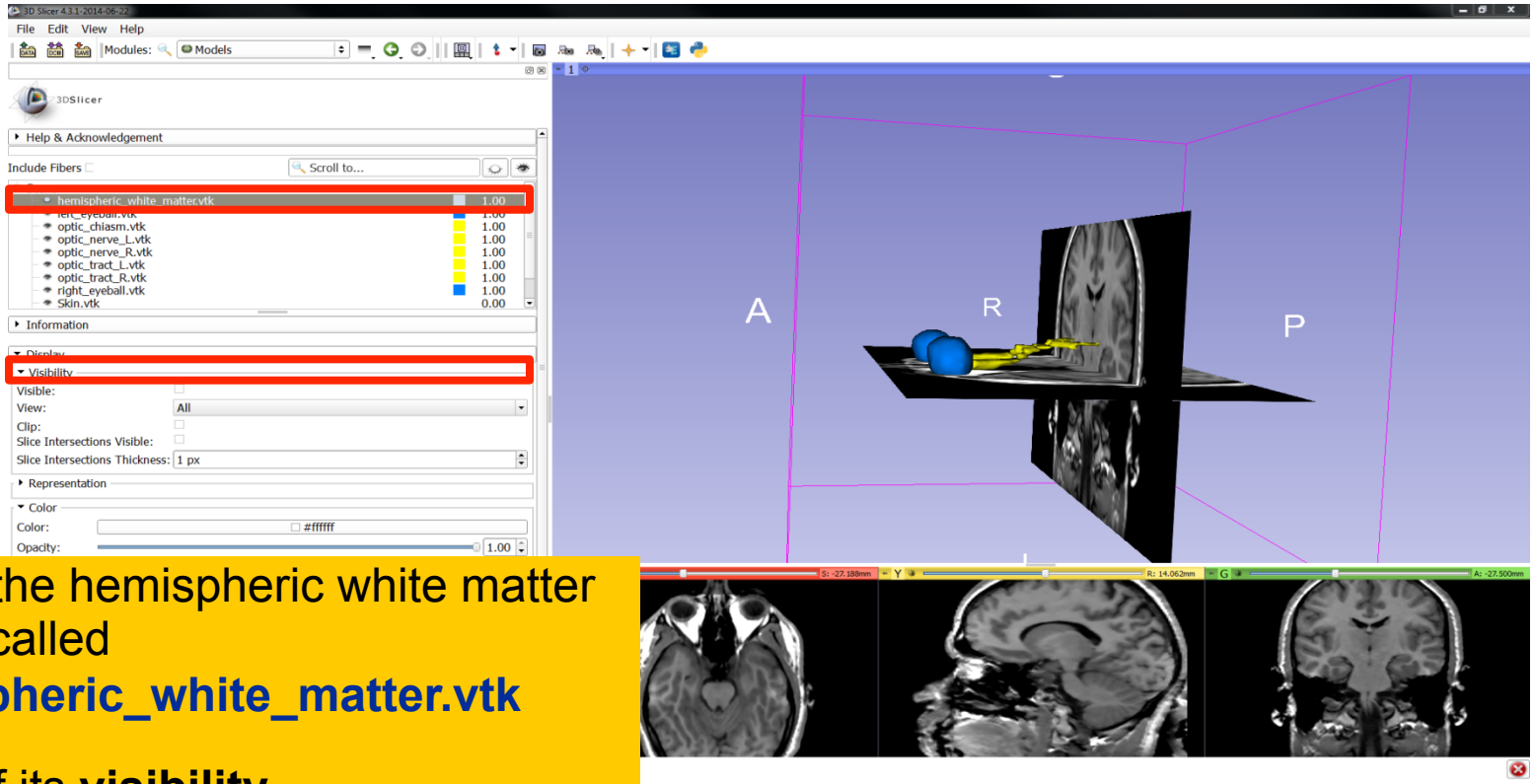


Slicer4 Minute Tutorial: 3D Visualization

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



Slicer4 Minute Tutorial: 3D Visualization

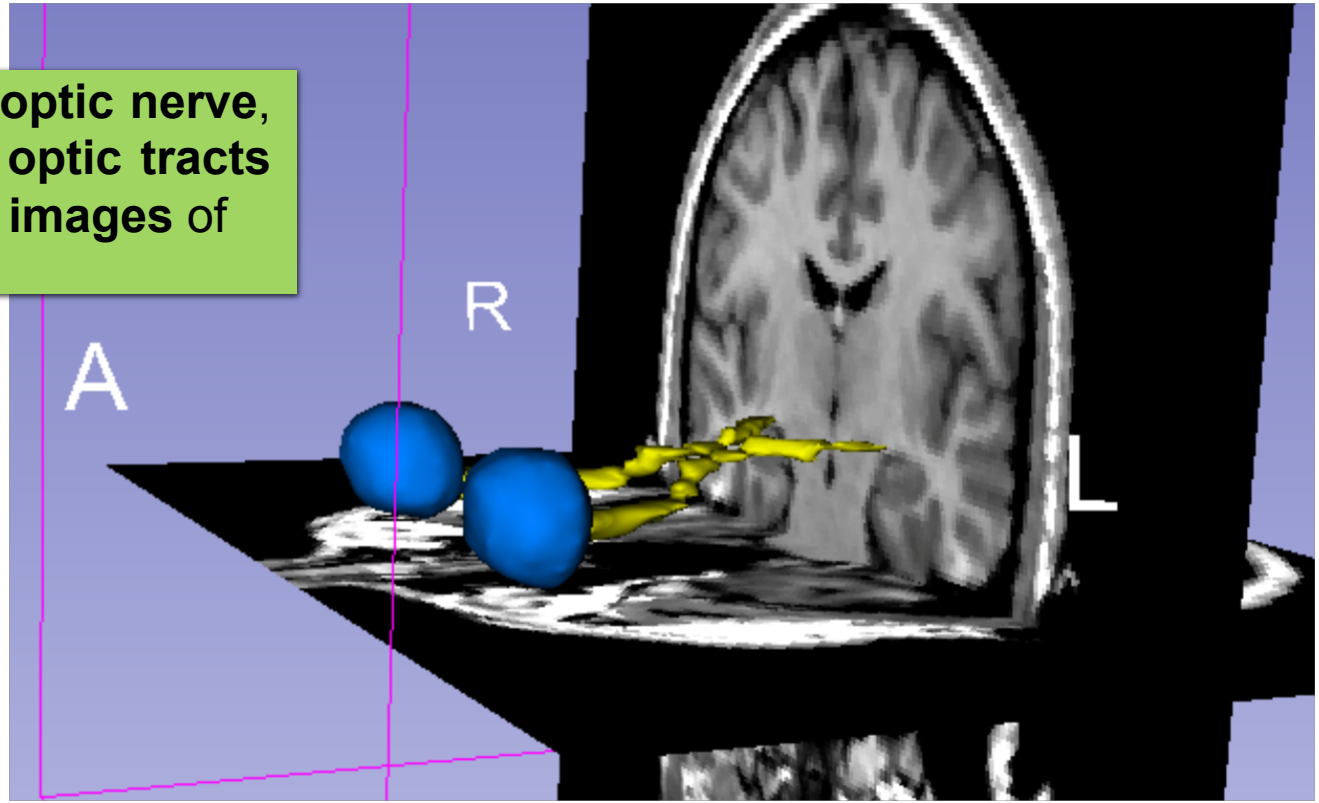


Select the hemispheric white matter model called **hemispheric_white_matter.vtk**

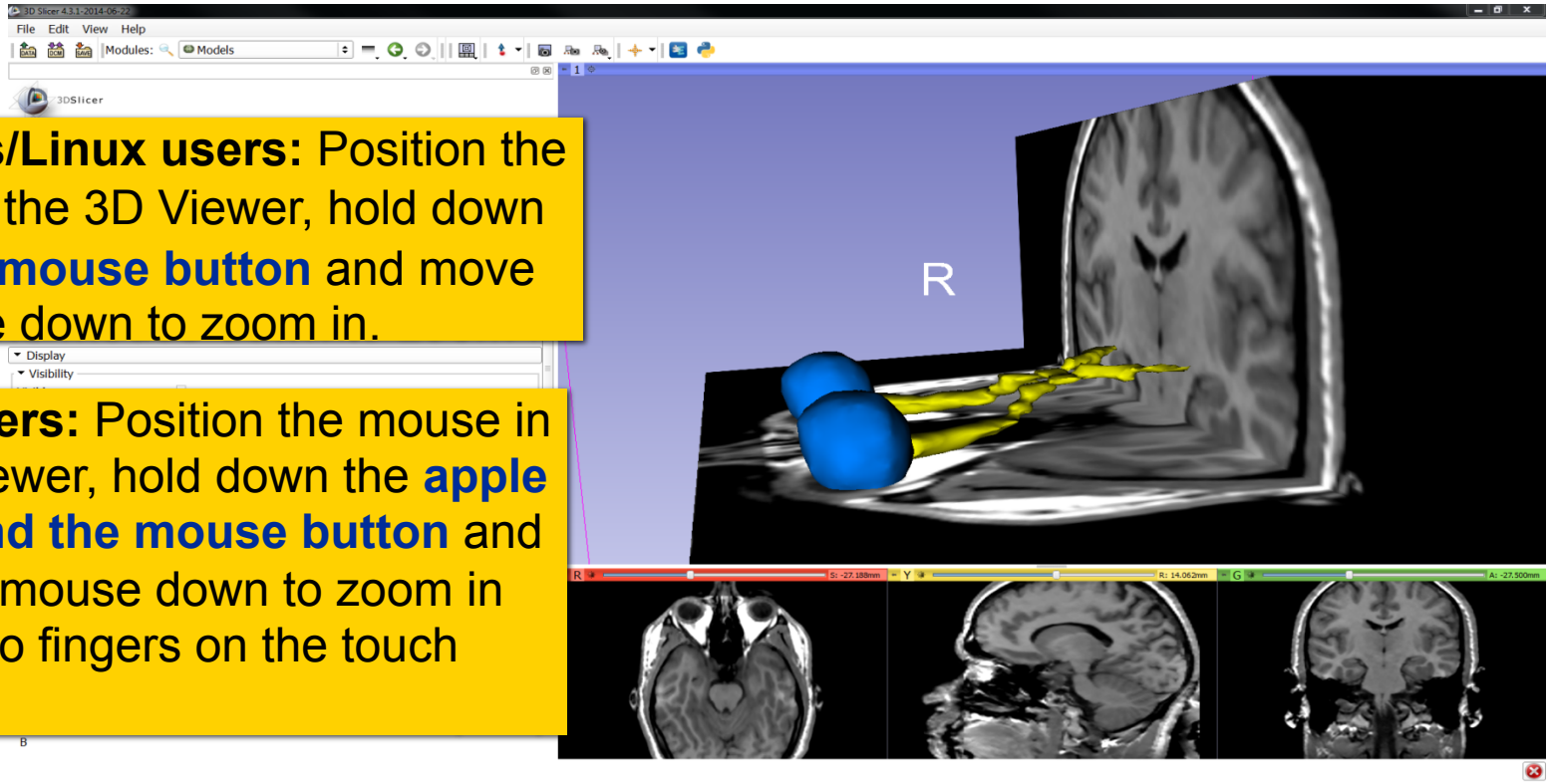
Turn off its **visibility**.

Slicer4 Minute Tutorial: 3D Visualization

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



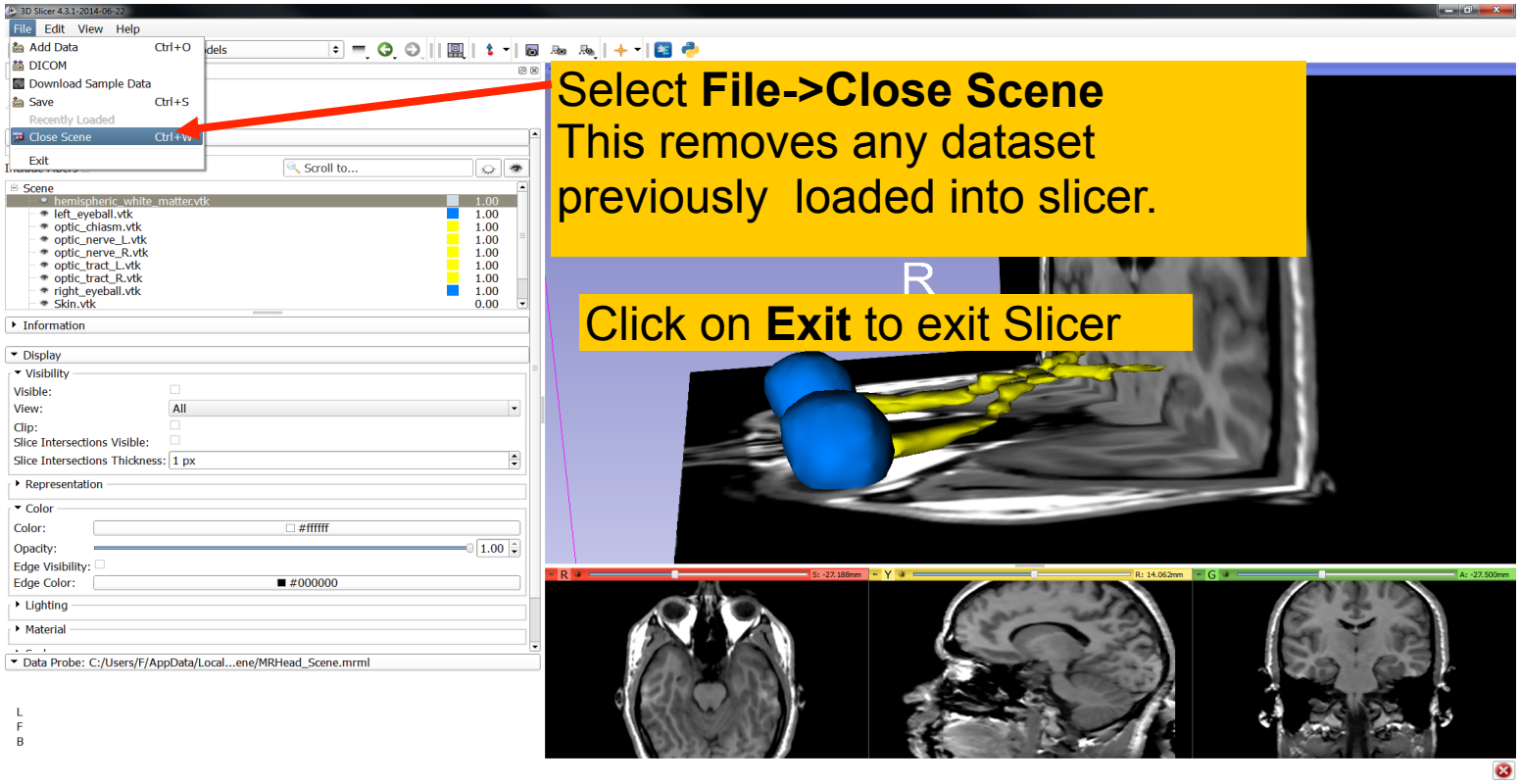
Slicer4 Minute Tutorial: 3D Visualization: Zoom the view



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

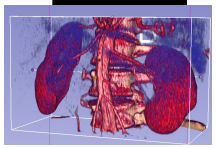
Mac users: Position the mouse in the 3D Viewer, hold down the **apple button and the mouse button** and move the mouse down to zoom in (or use two fingers on the touch pad).

Close the existing scene and all its data



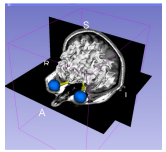
Overview

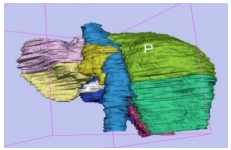
Part I: Introduction to the 3DSlicer software



Part II: 3D Data Loading and visualization of DICOM images

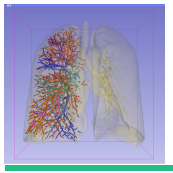
- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data

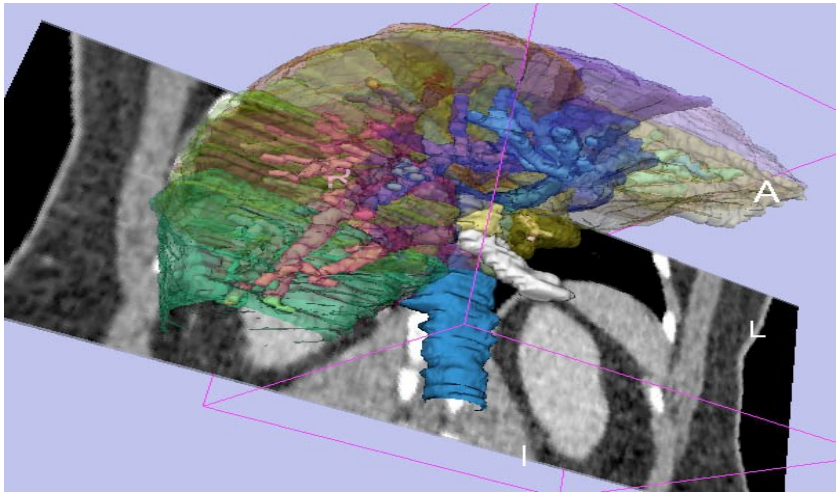




Part III: 3D interactive exploration of the anatomy

- Exploration of the Segments of the liver
- Exploration of the Segments of the lung

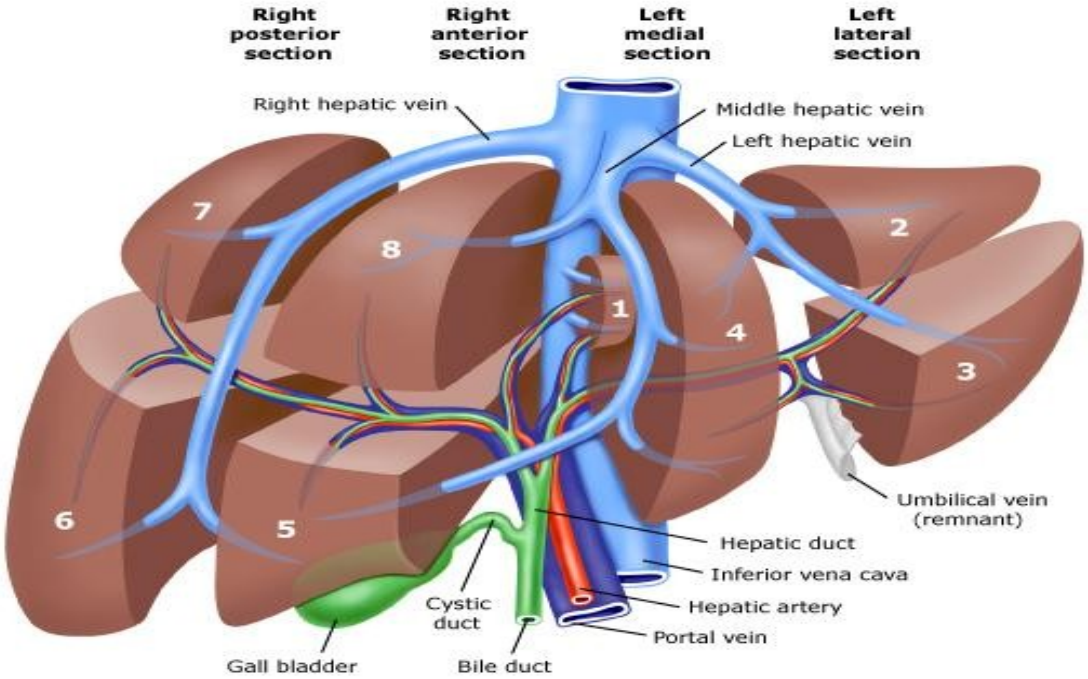




Part II:

Interactive 3D Visualization of the segments of the liver

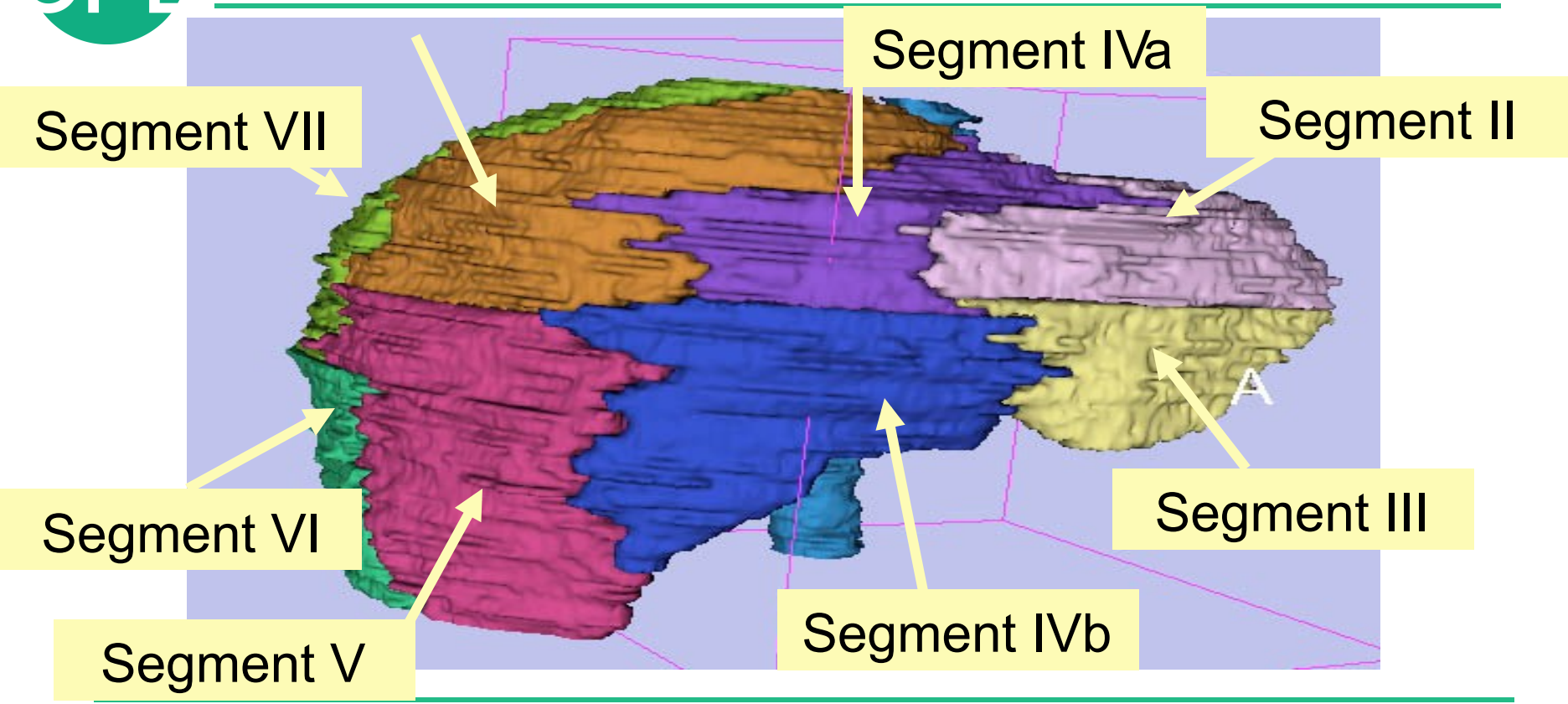
Anatomy of the liver



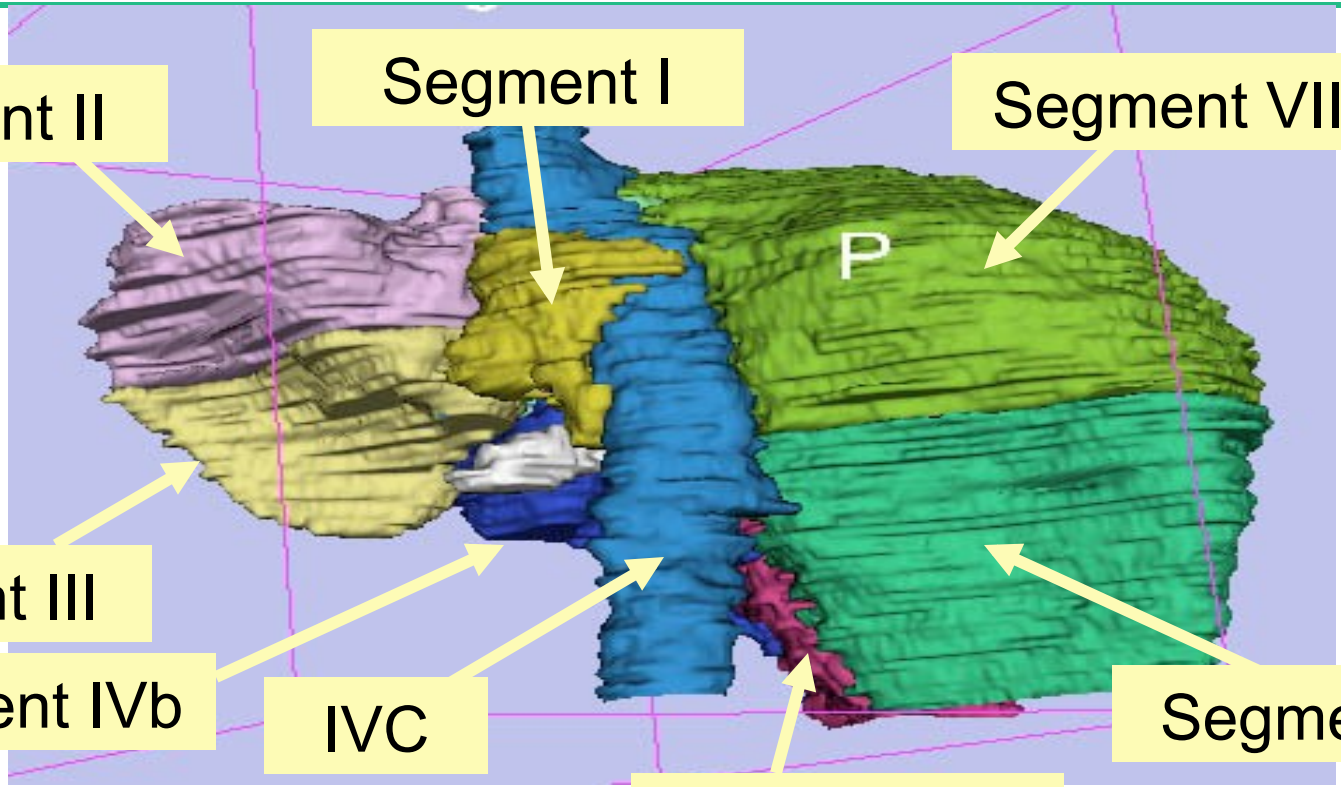
Liver dataset

The liver dataset is a contrast-enhanced CT abdominal scan of a healthy 36 year-old male.

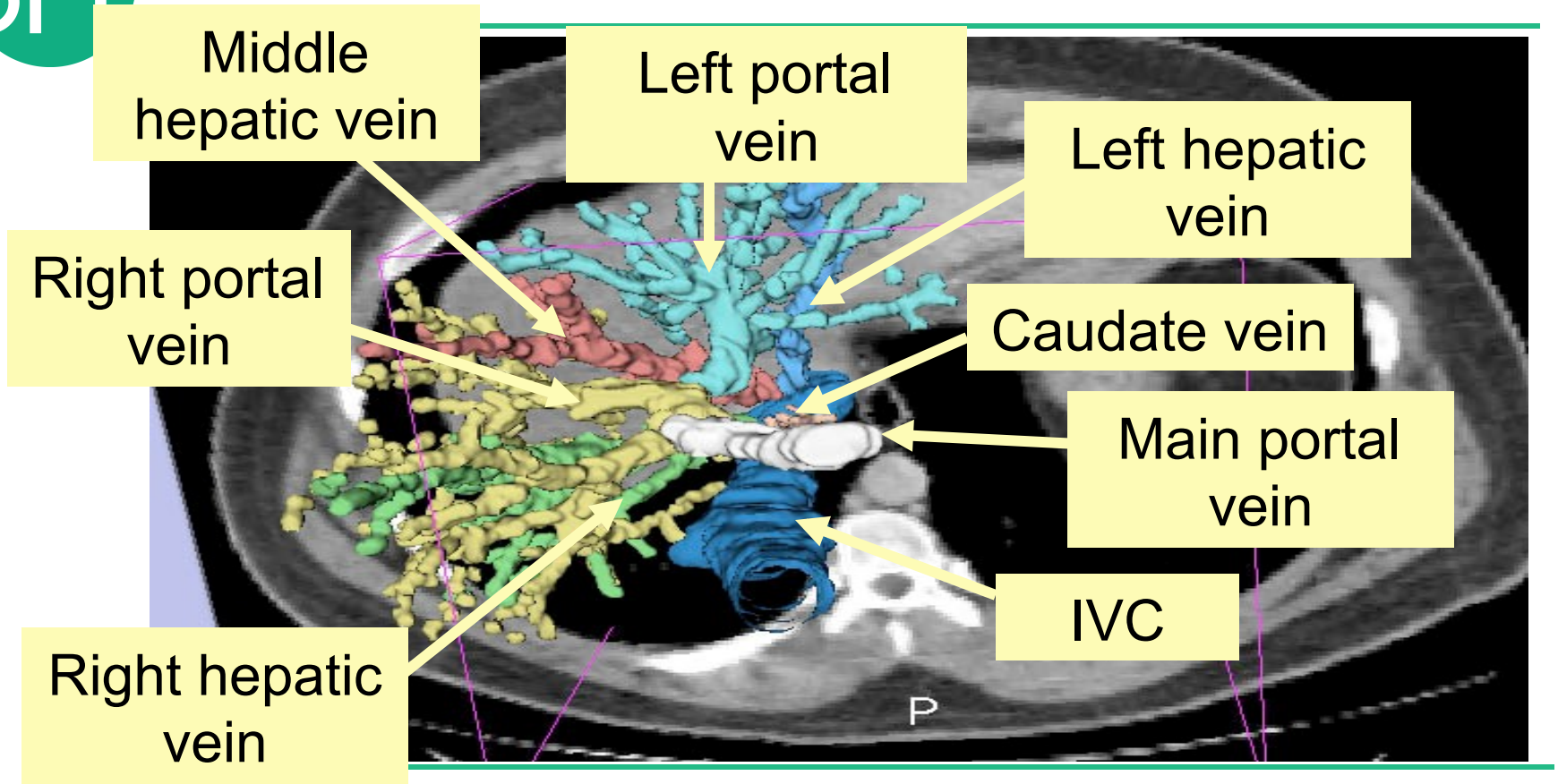
3D segments of the liver



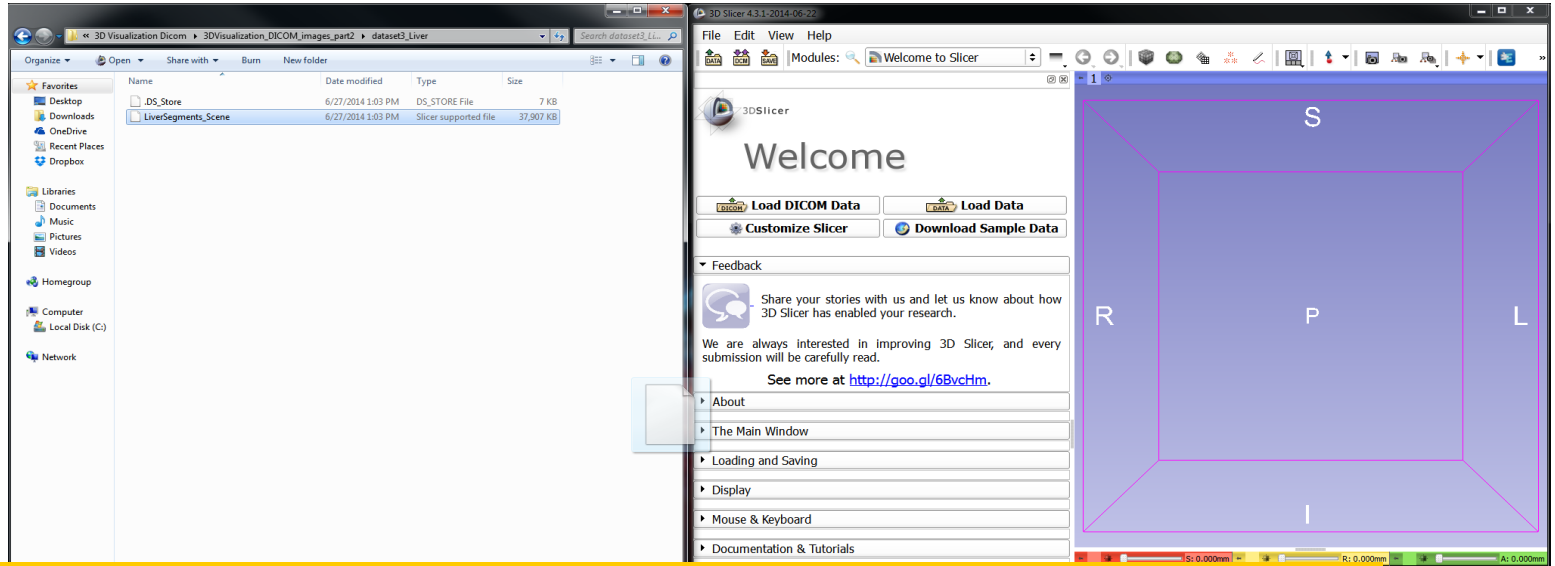
3D segments of the liver



Liver vasculature

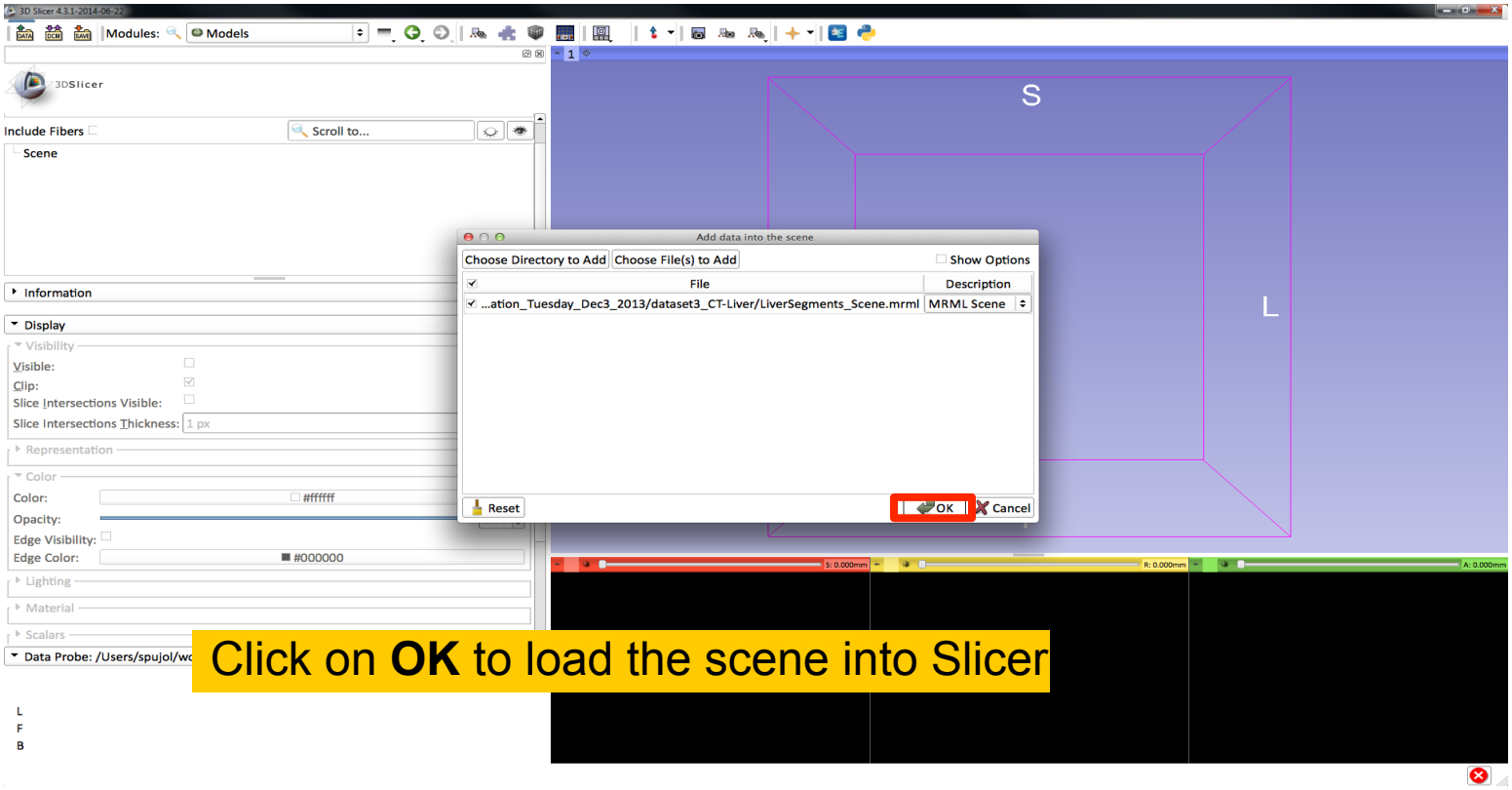


Loading the Liver Scene



Browse to the directory
C:\3DSlicerData_RSNA2014\3DVisualizationDICOM_Monday_Dec1
Select the directory **dataset3_Liver**
Drag and drop the file **LiverSegments_Scene.mrb** into Slicer

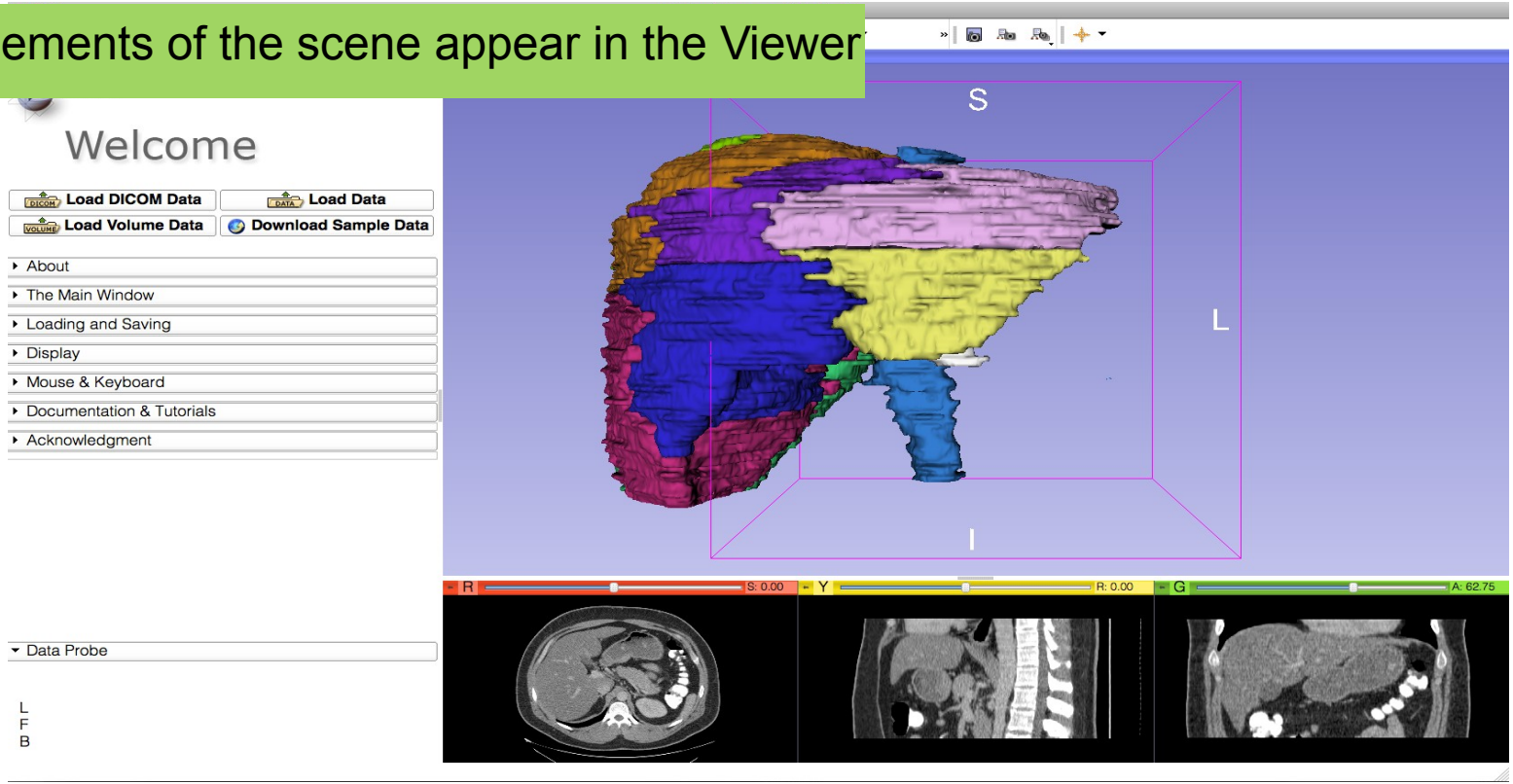
Loading the Liver Scene



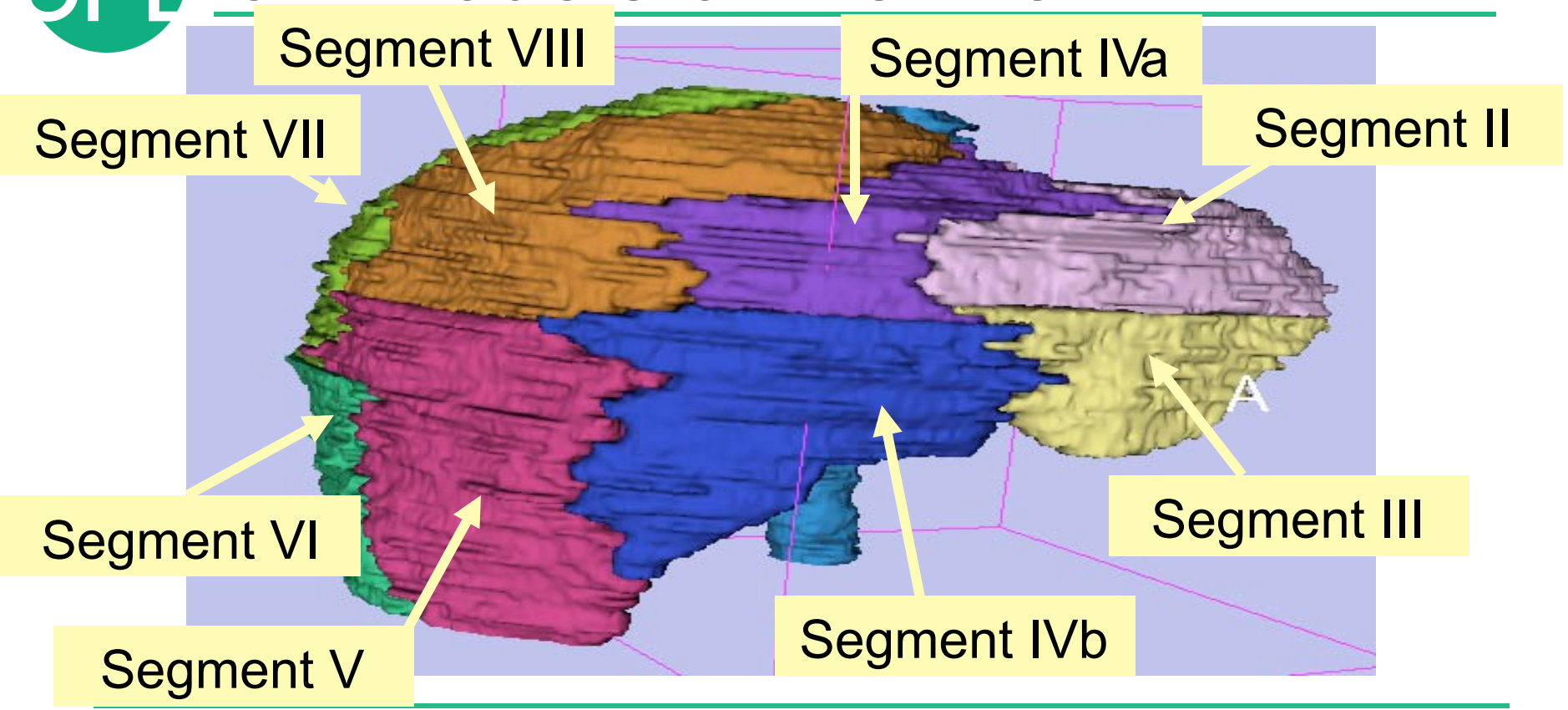
Click on **OK** to load the scene into Slicer

Liver Segments Scene

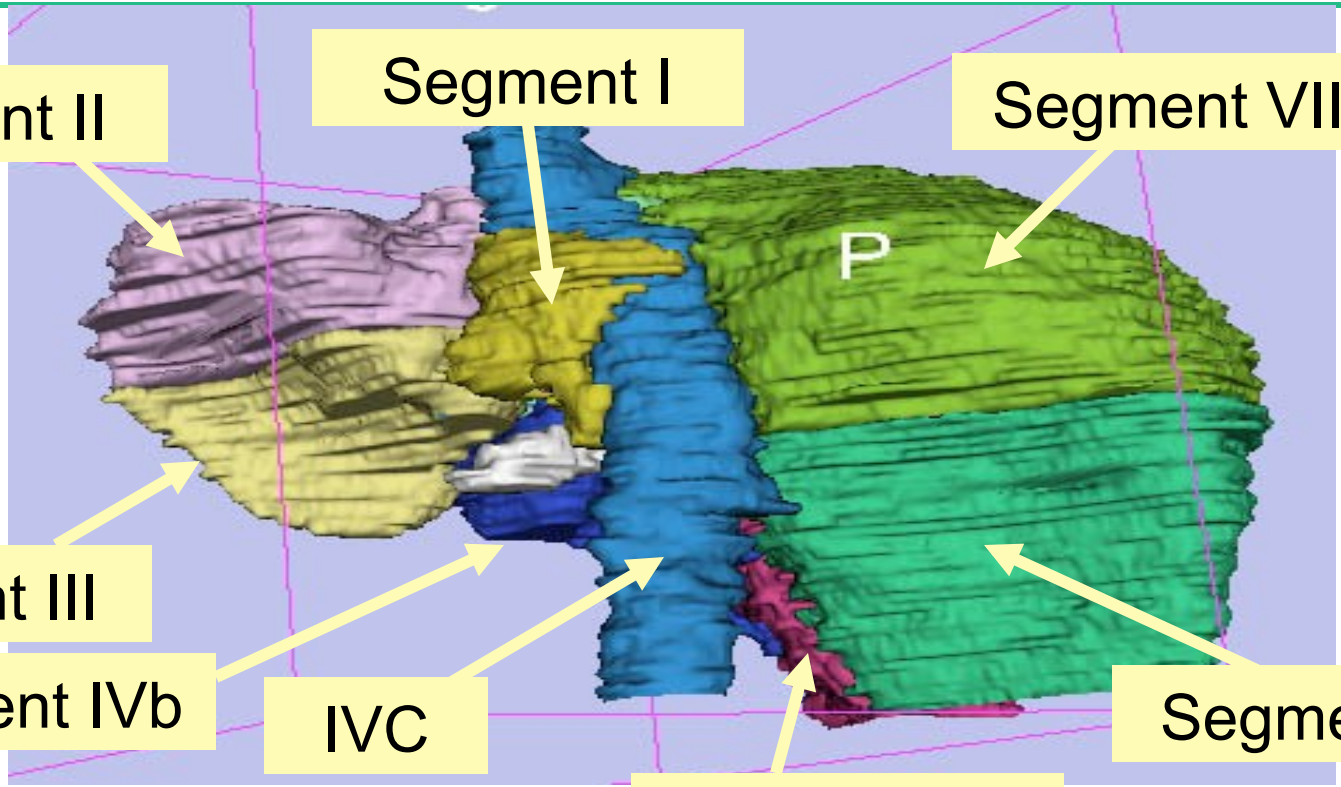
The elements of the scene appear in the Viewer



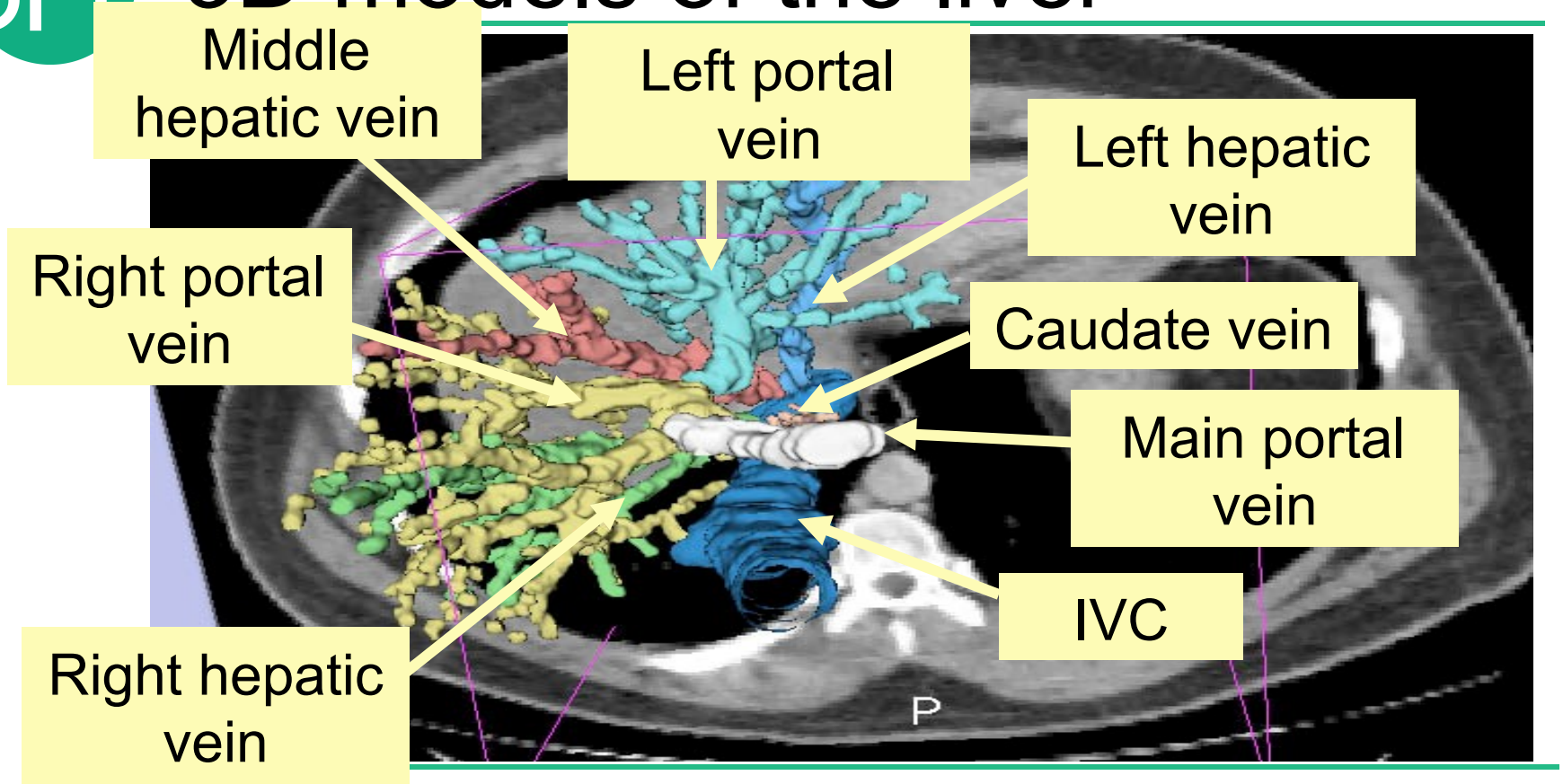
3D models of the liver



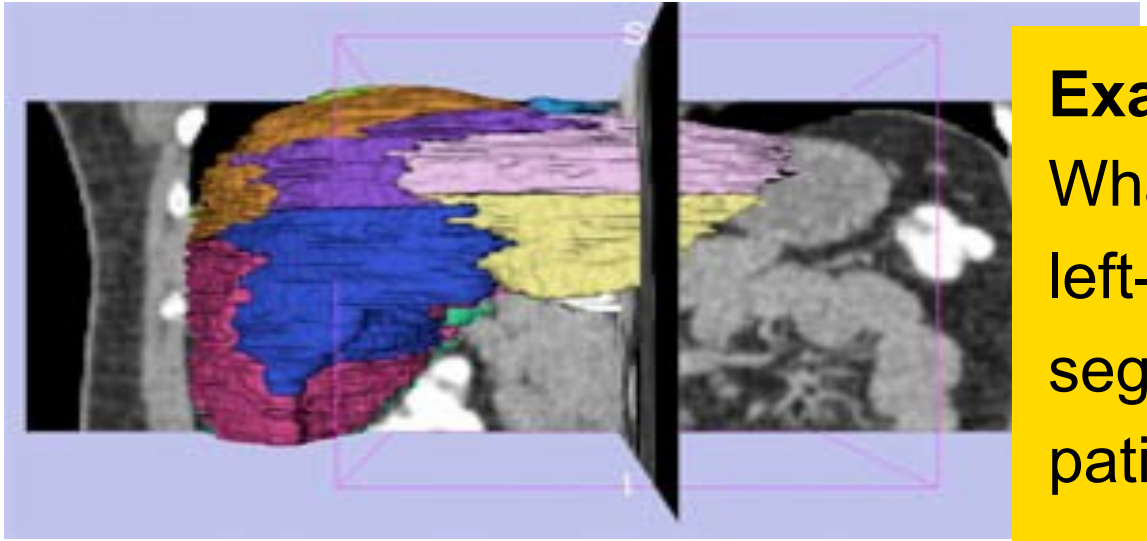
3D models of the liver



3D models of the liver



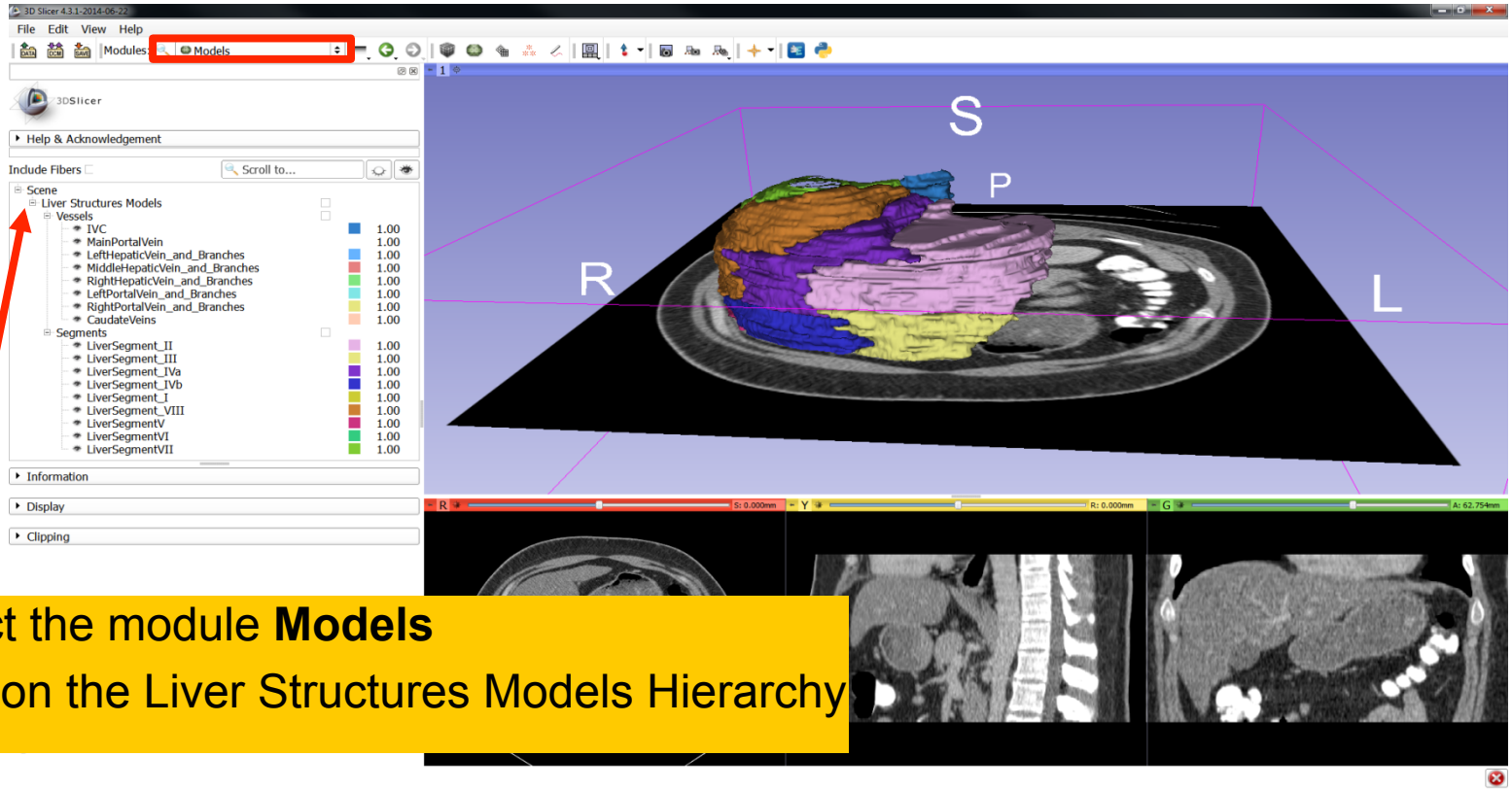
3D Exploration of Liver Segments



Example:

What organ abuts the left-most margin of segment II in this patient ?

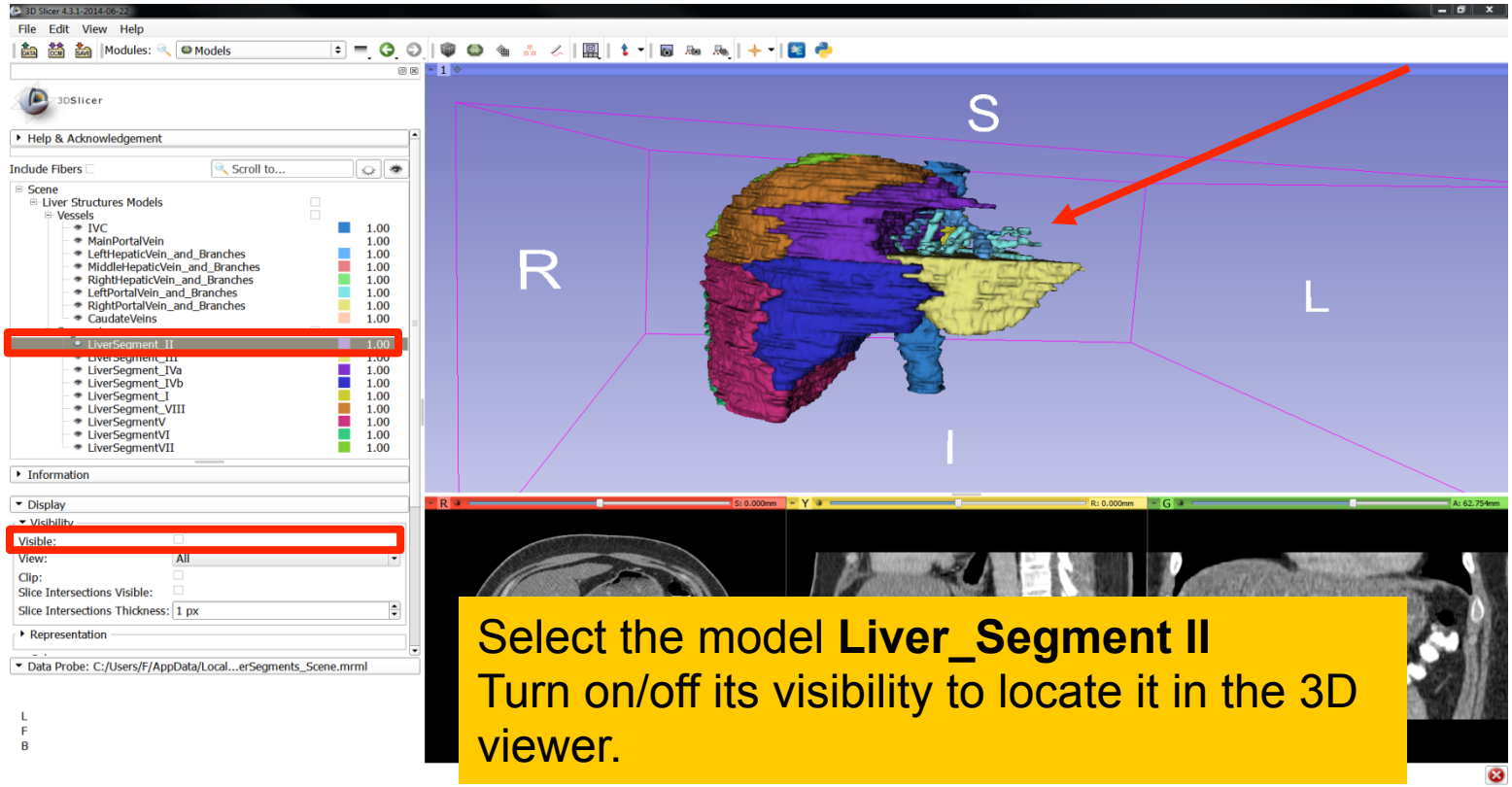
3D Exploration of Liver Segments



Select the module **Models**

Click on the Liver Structures Models Hierarchy

3D Exploration of Liver Segments

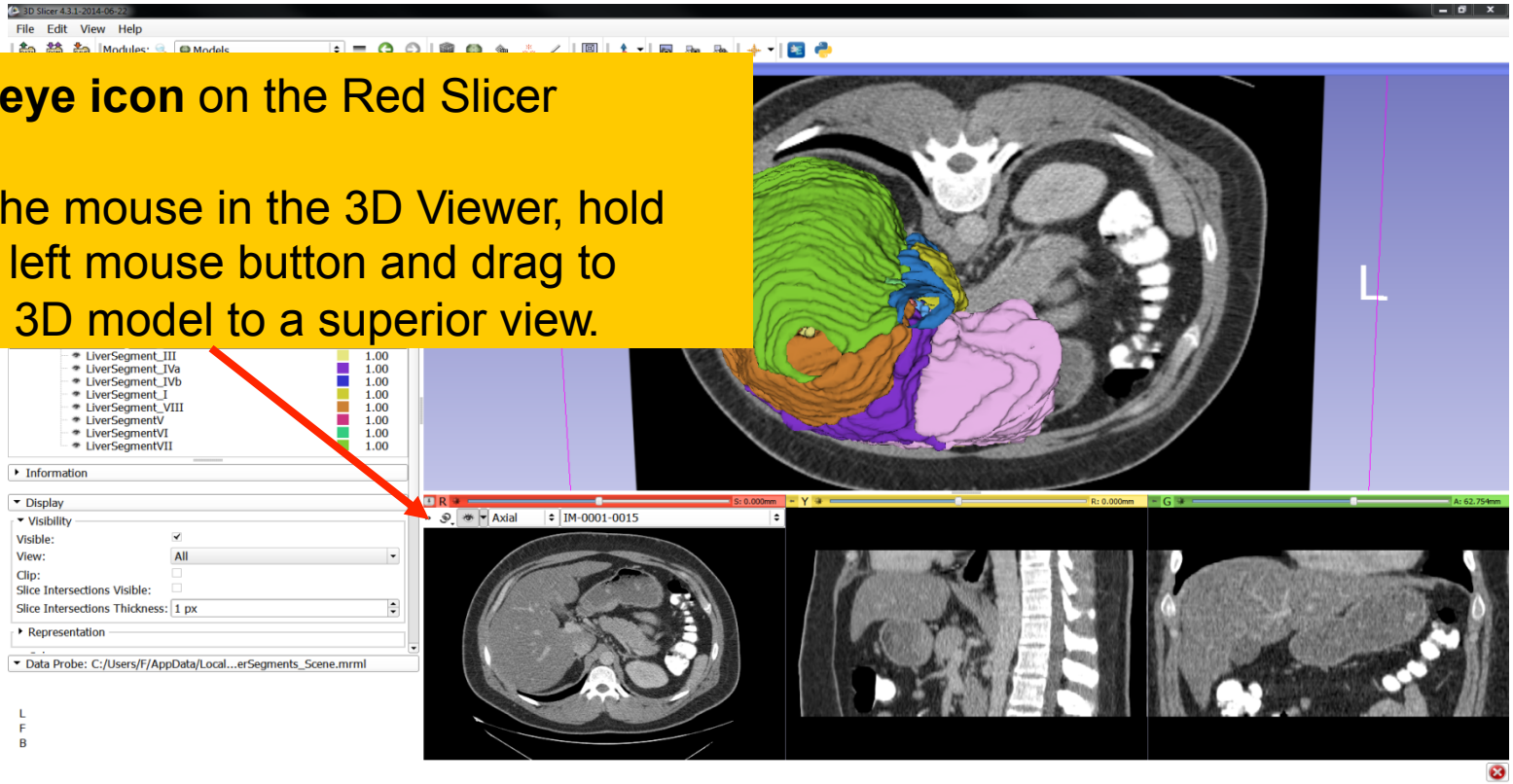


Select the model **Liver_Segment II**
Turn on/off its visibility to locate it in the 3D viewer.

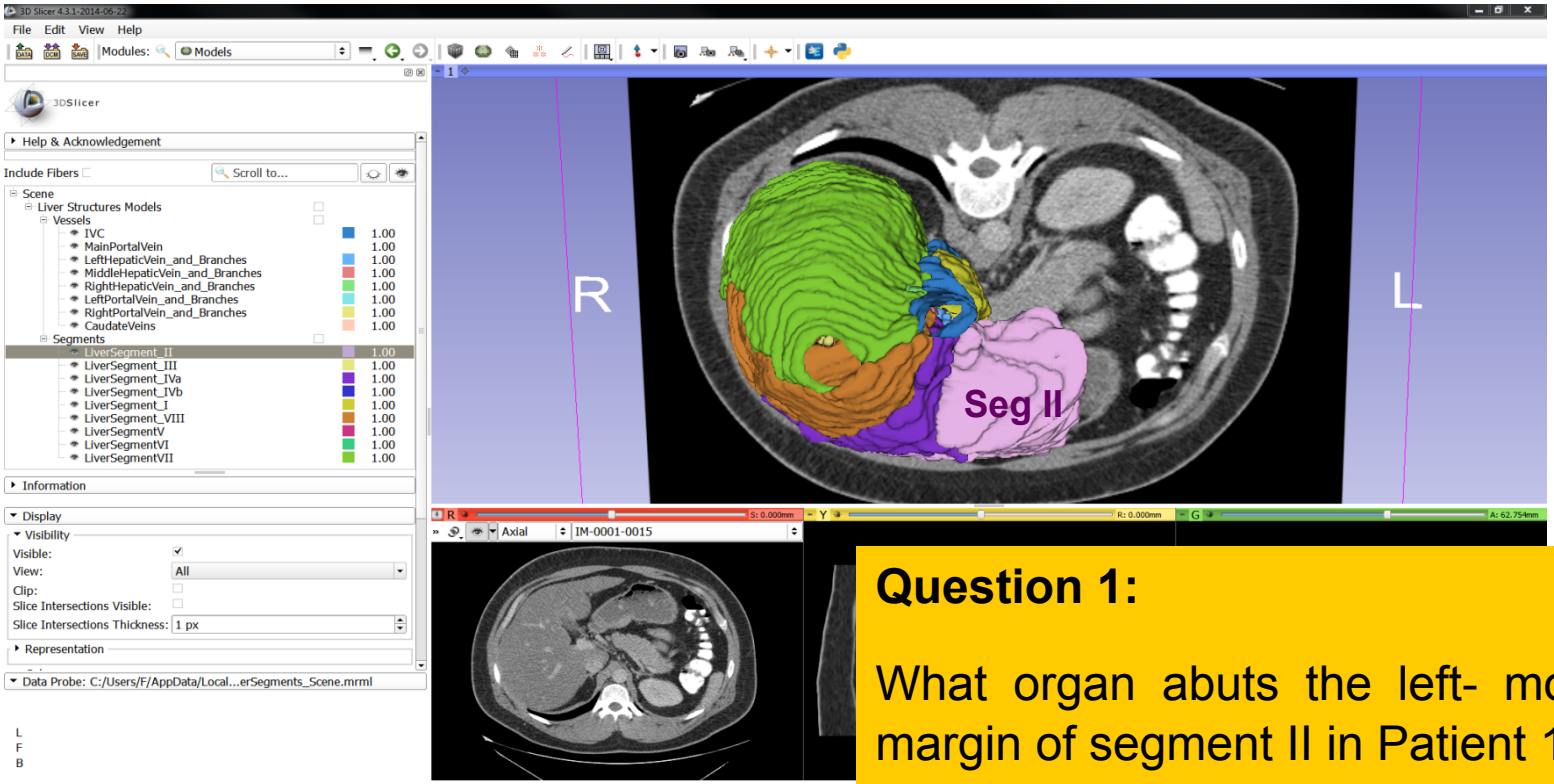
3D Exploration of Liver Segments

Click the **eye icon** on the Red Slicer

Position the mouse in the 3D Viewer, hold down the left mouse button and drag to orient the 3D model to a superior view.



3D Exploration of Liver Segments



Question 1:

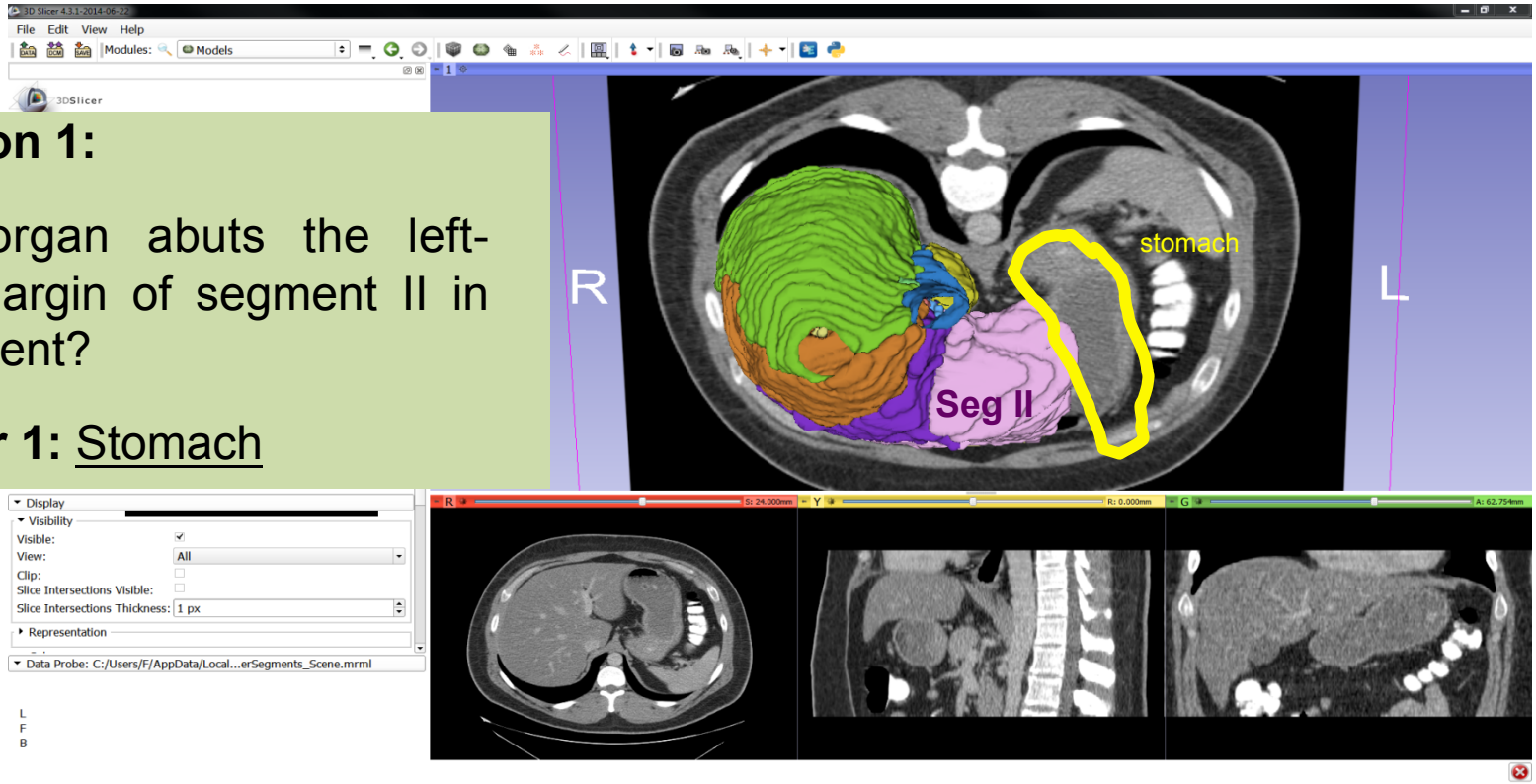
What organ abuts the left- most margin of segment II in Patient 1?

3D Exploration of Liver Segments

Question 1:

What organ abuts the left-most margin of segment II in this patient?

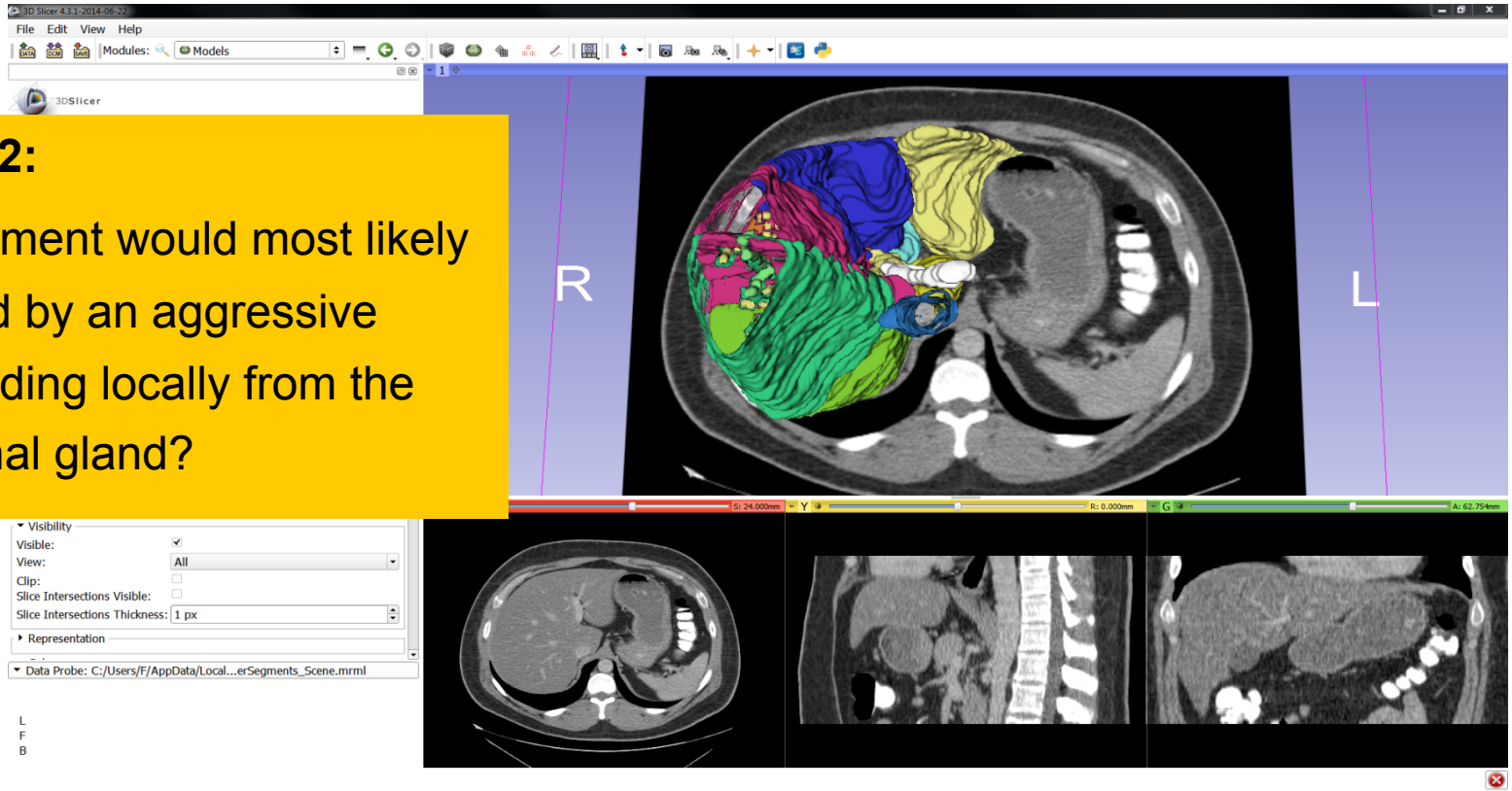
Answer 1: Stomach



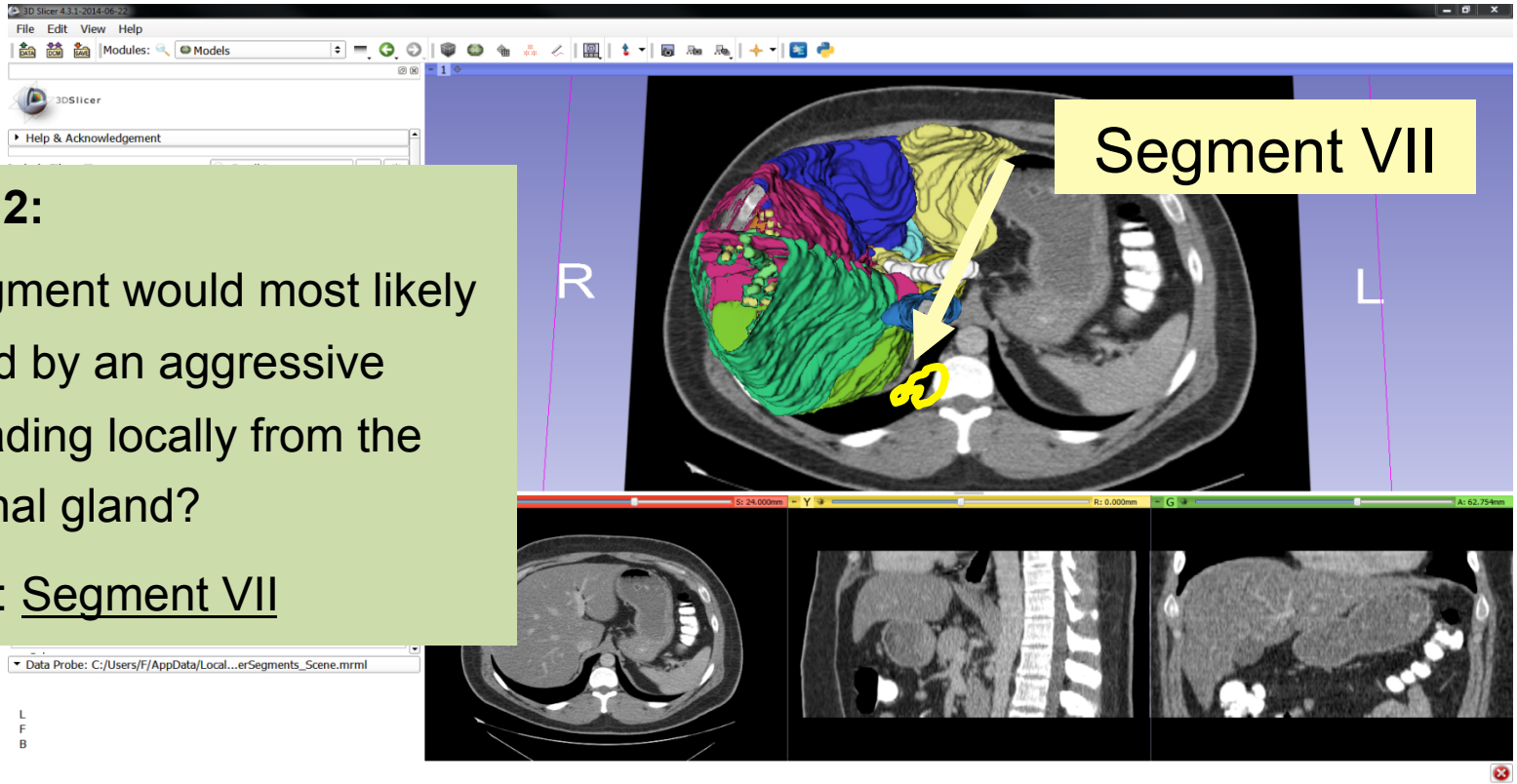
3D Exploration of Liver Segments

Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland?



3D Exploration of Liver Segments

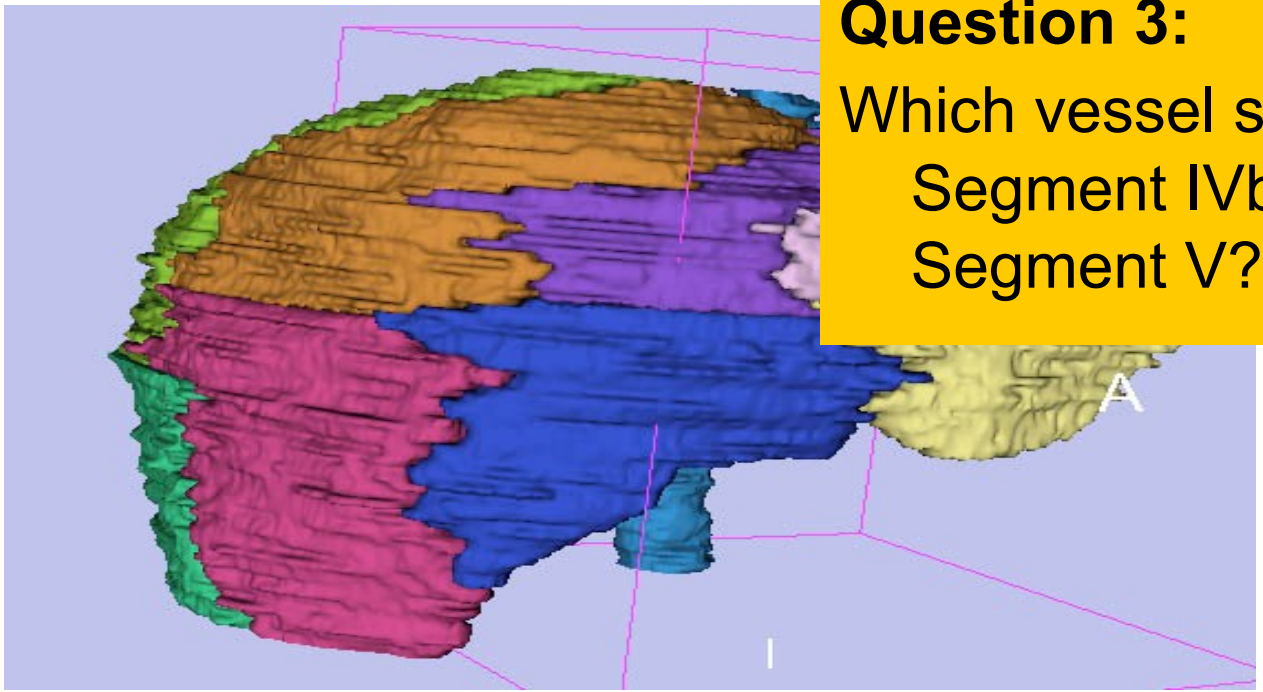


Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland?

Answer 2: Segment VII

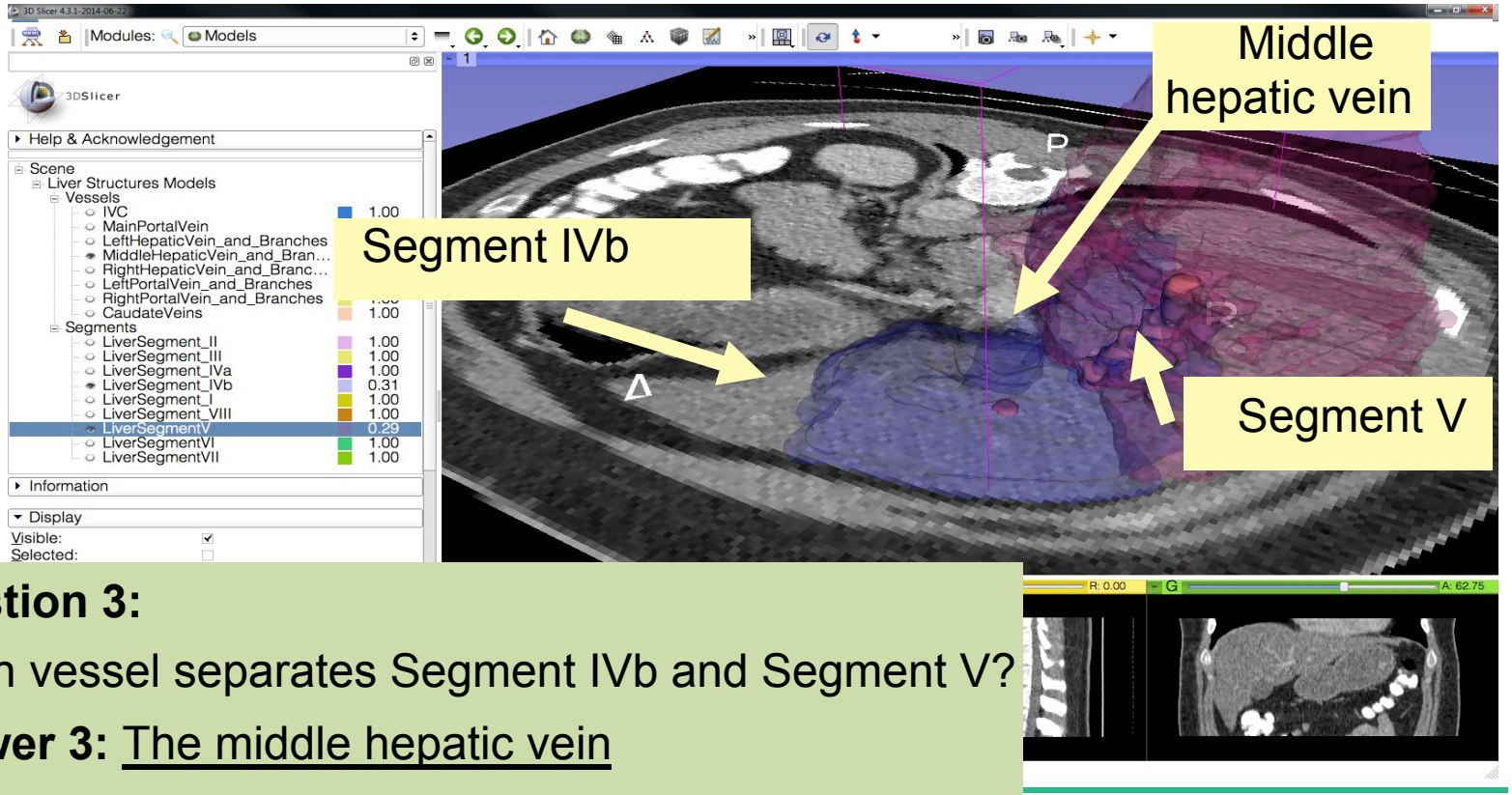
3D Exploration of Liver Segments



Question 3:

Which vessel separates Segment IVb and Segment V?

Middle Hepatic Vein

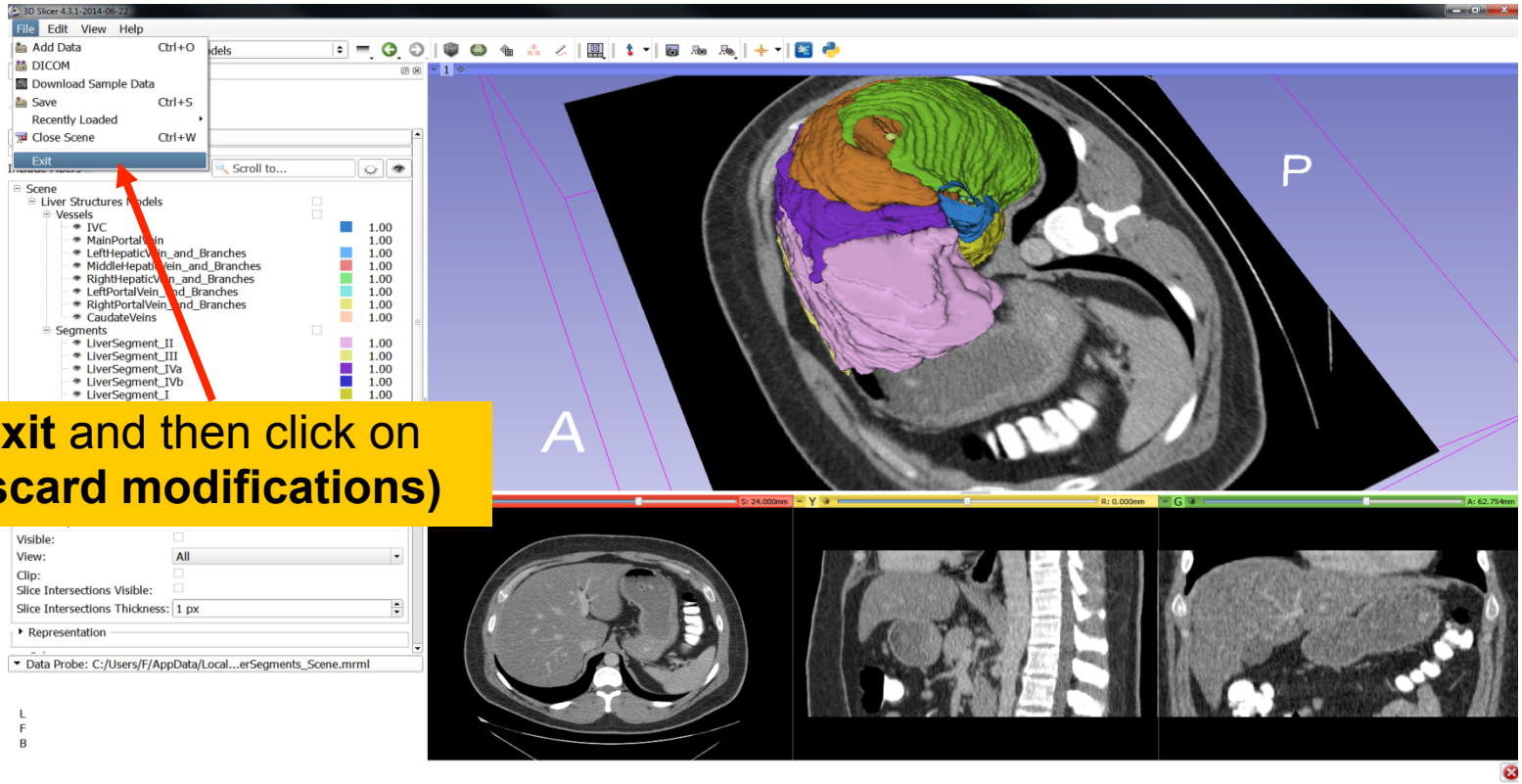


Question 3:

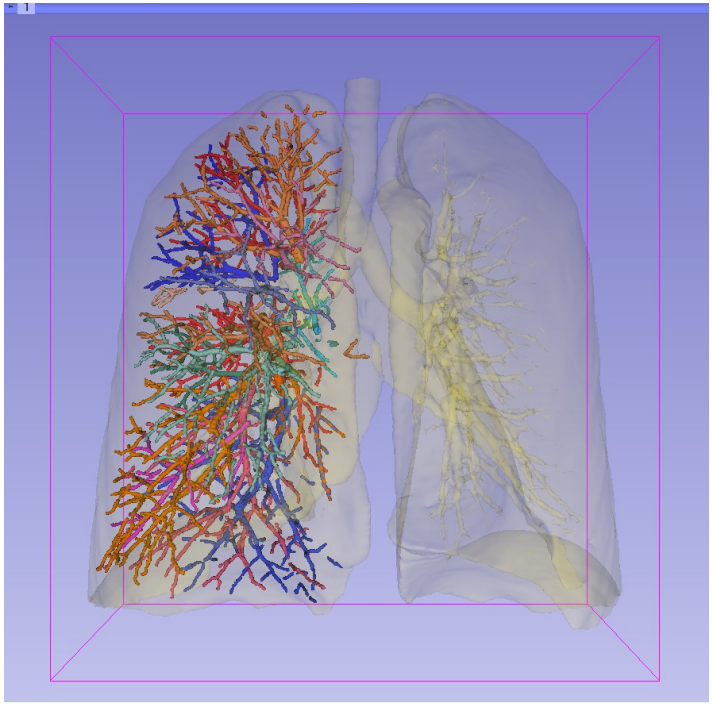
Which vessel separates Segment IVb and Segment V?

Answer 3: The middle hepatic vein

Closing the Liver Scene

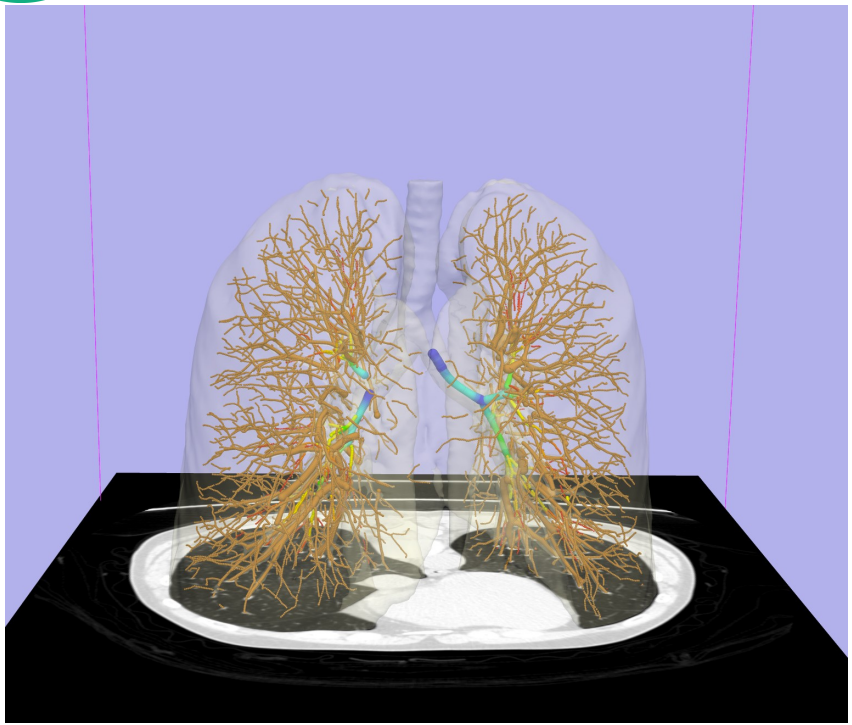


Select **Exit** and then click on **Exit (discard modifications)**



Interactive 3D Visualization of the segments of the lungs

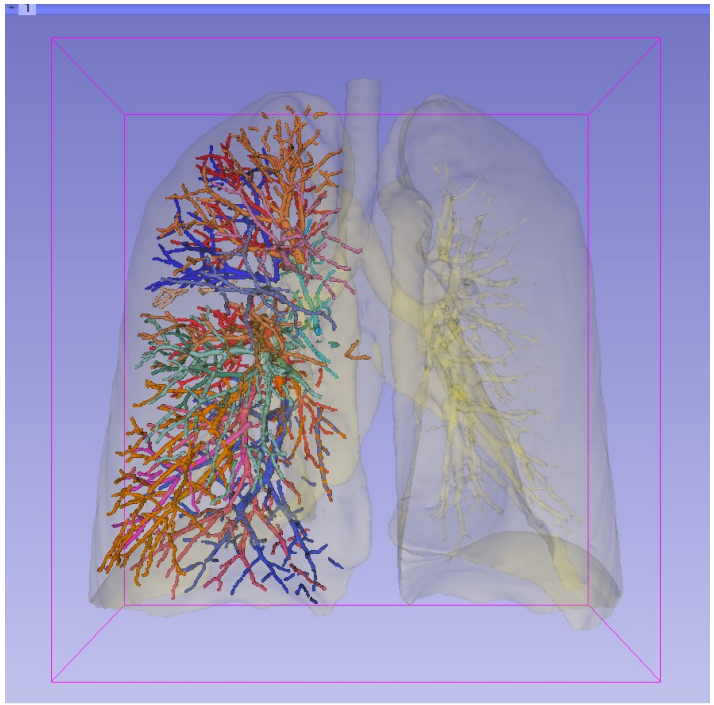
Segments of the lung



Segmentation and 3D surface reconstruction of the lung and pulmonary vessels

Acknowledgment:
Segmentation of the lung surface and vasculature: Raul San Jose Estepar, Ph.D., George Washko, M.D., Ed Silverman, M.D. and James Ross, MSc. Brigham and Women's Hospital (K25 HL104085) and COPDGene (01 HL089897 and U01 HL089856)

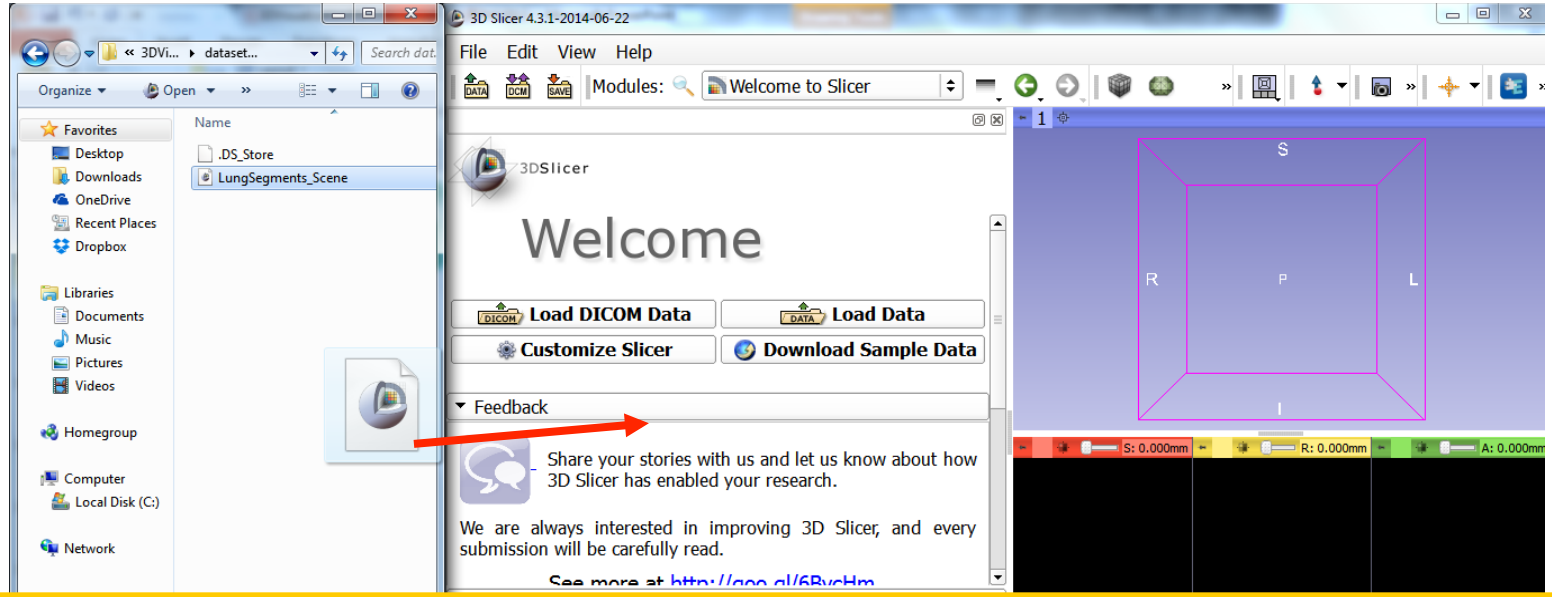
Segments of the lung



3D parcellation of arteries and veins from original model of pulmonary vessels
(Kitt Shaffer, M.D., Ph.D. - Sonia Pujol, Ph.D.)

- Right Upper Lobe (RUL)
  - RUL Pulmonary Vein
  - RUL Anterior Segment
  - RUL Apical Segment
  - RUL Posterior Segment
- Right Middle Lobe (RML)
  - RML Pulmonary Vein 1 & 2
  - RML Lateral Segment
  - RML Medial Segment
- Right Lower Lobe (RLL)
  - RLL Pulmonary Vein 1,2,3
  - RLL Anterior Basal Segment
  - RLL Medial Basal Segment
  - RLL Lateral Basal Segment
  - RLL Posterior Basal Segment

Loading the Chest Data Scene

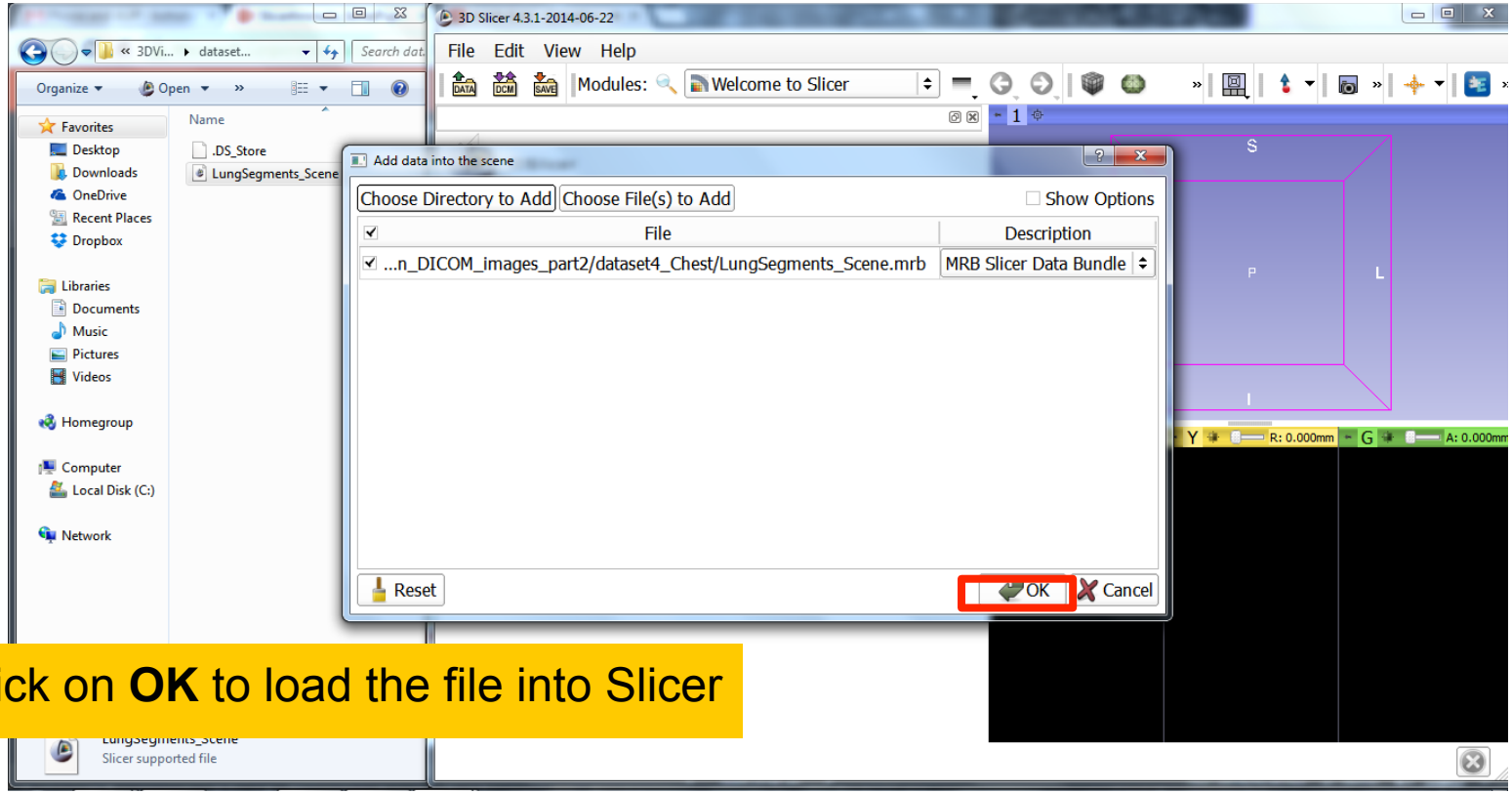


Open the directory **C:\3DSlicerData_RSNA2014\3DVisualizationDICOM_Monday_Dec1**

Select the subdirectory **dataset4_Chest**

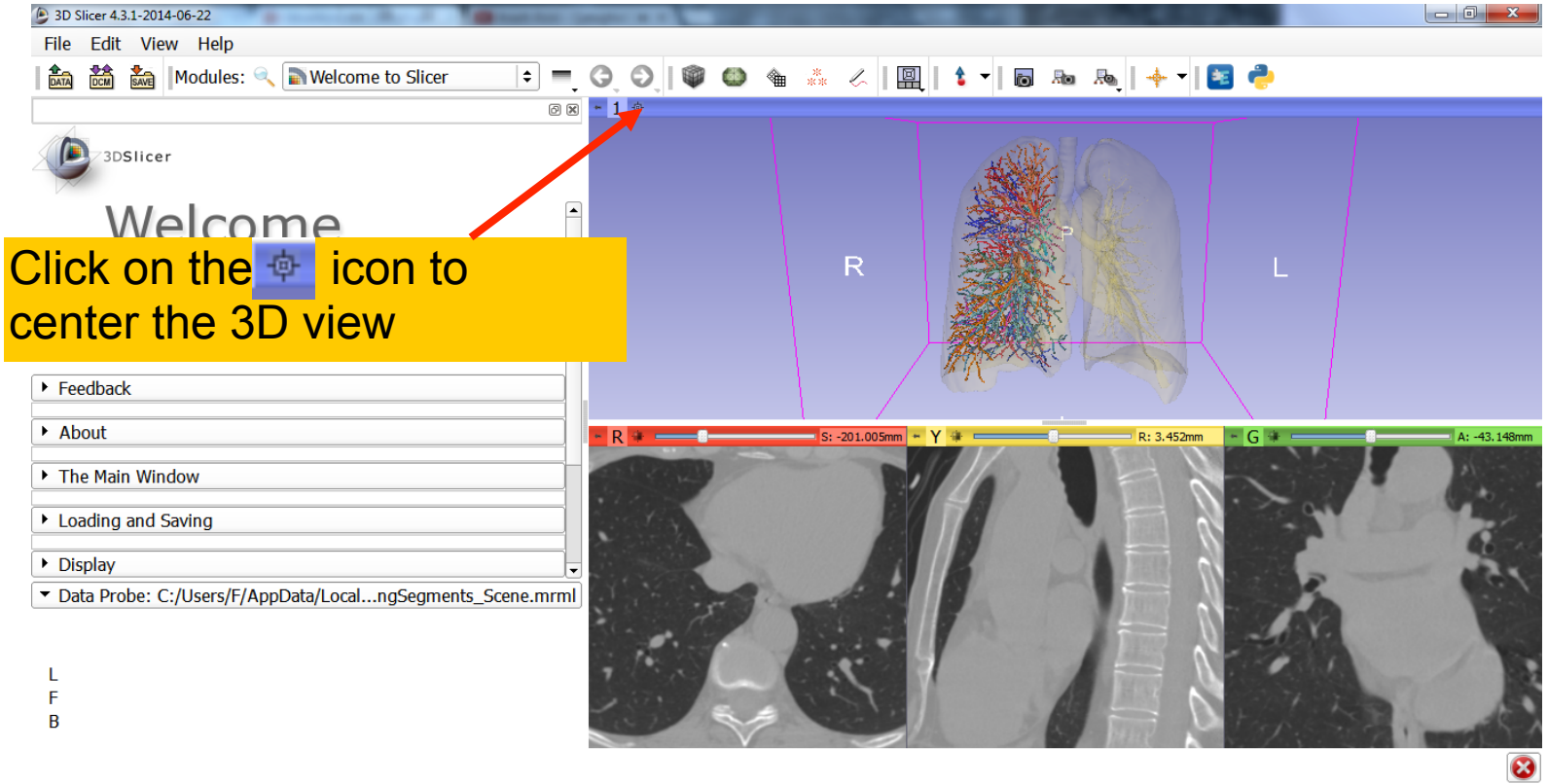
Drag and drop the file **LungSegments_Scene.mrb** into Slicer

Loading the Lung Scene

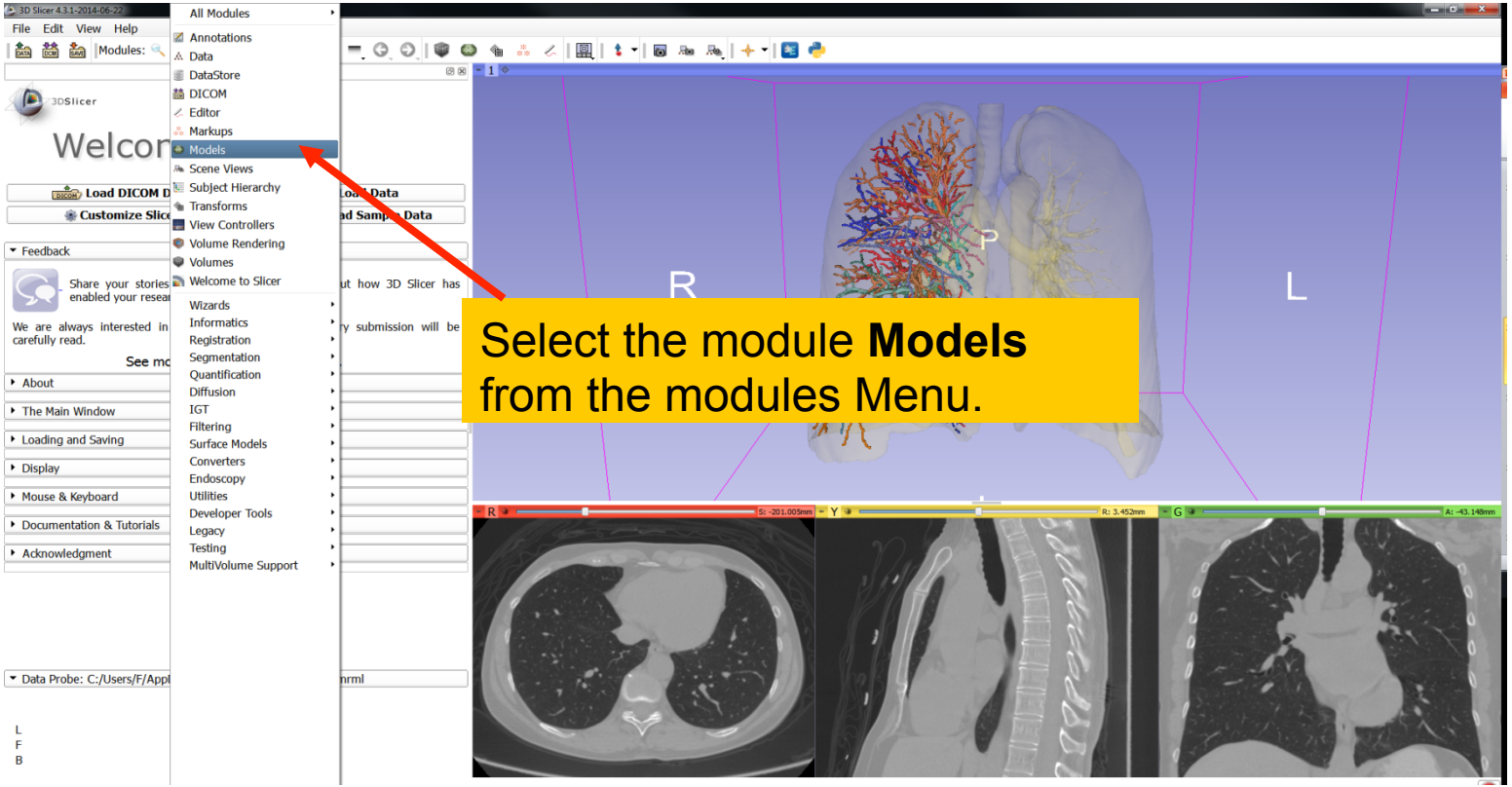


Click on **OK** to load the file into Slicer

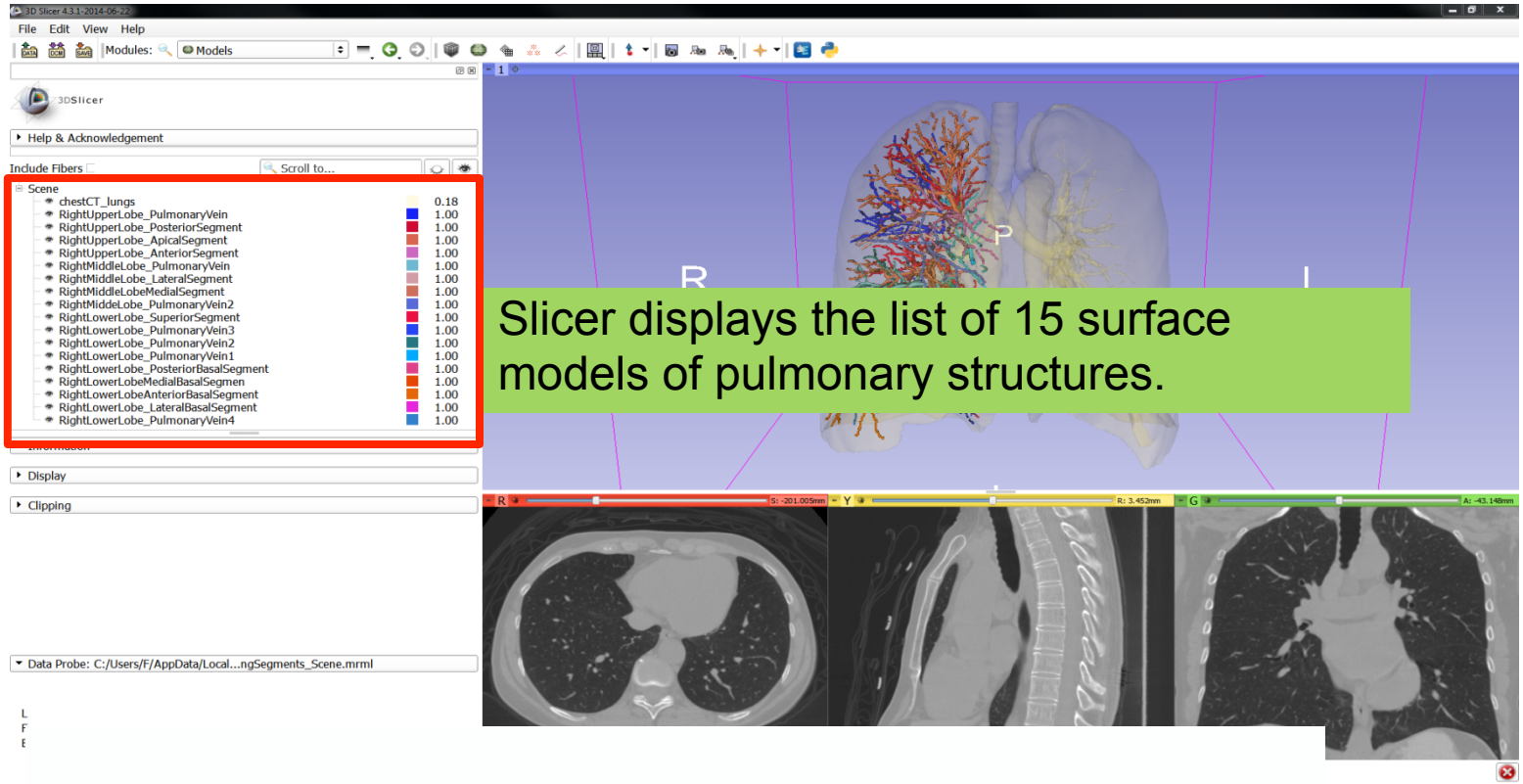
Loading the Lung Scene



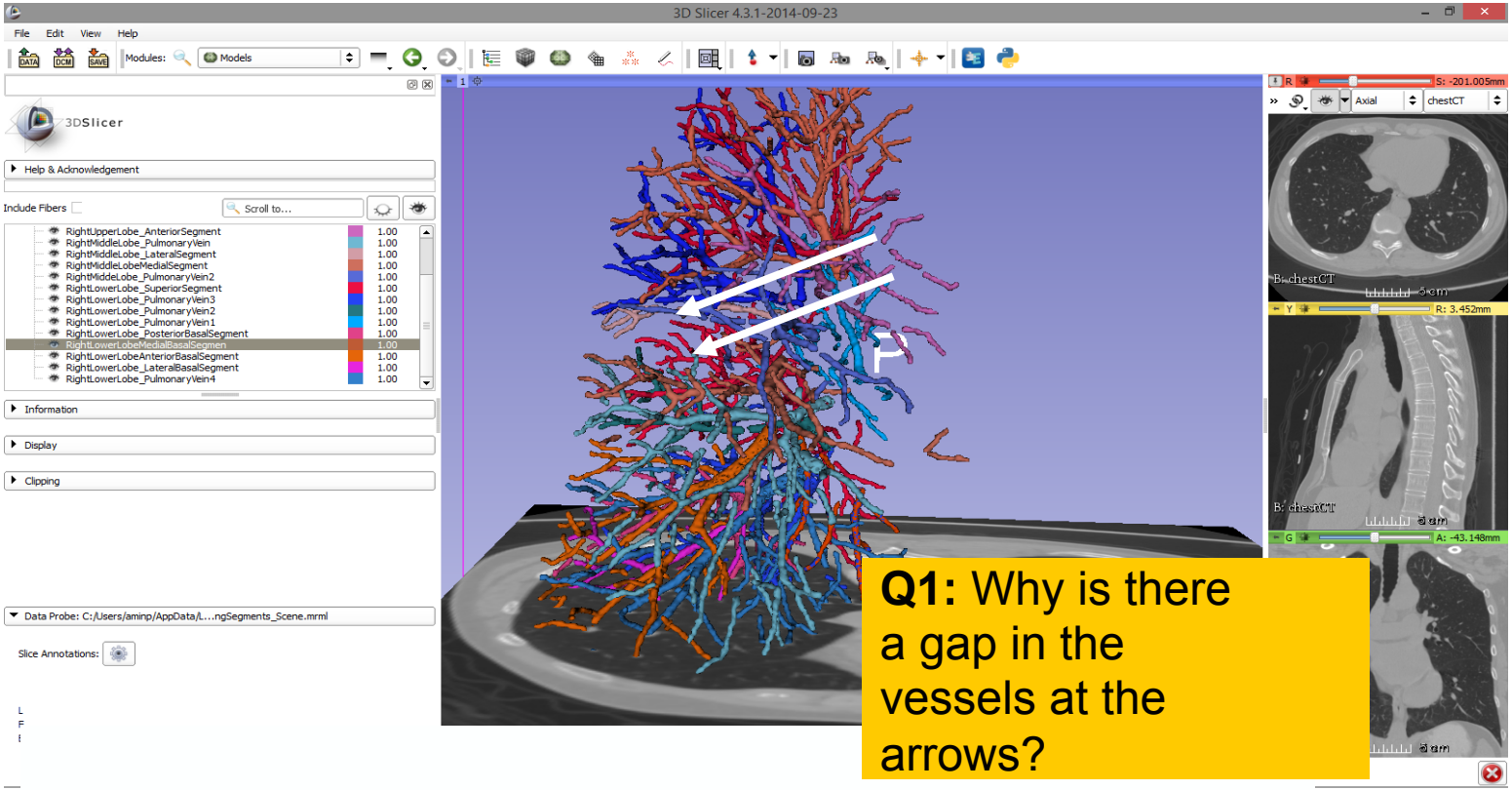
Loading the Lung Scene



Lung Segments

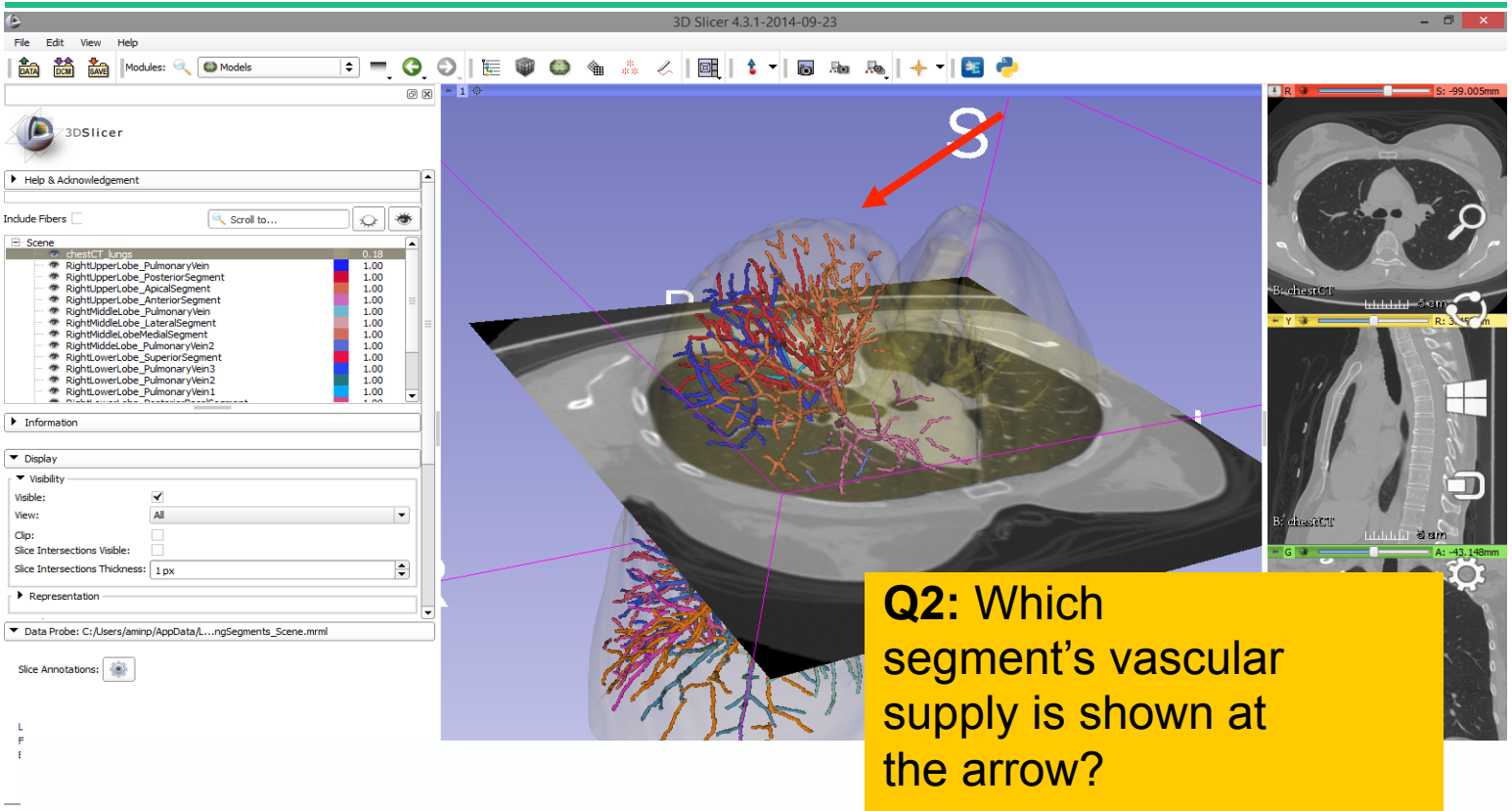


Lung Segments – Question 1



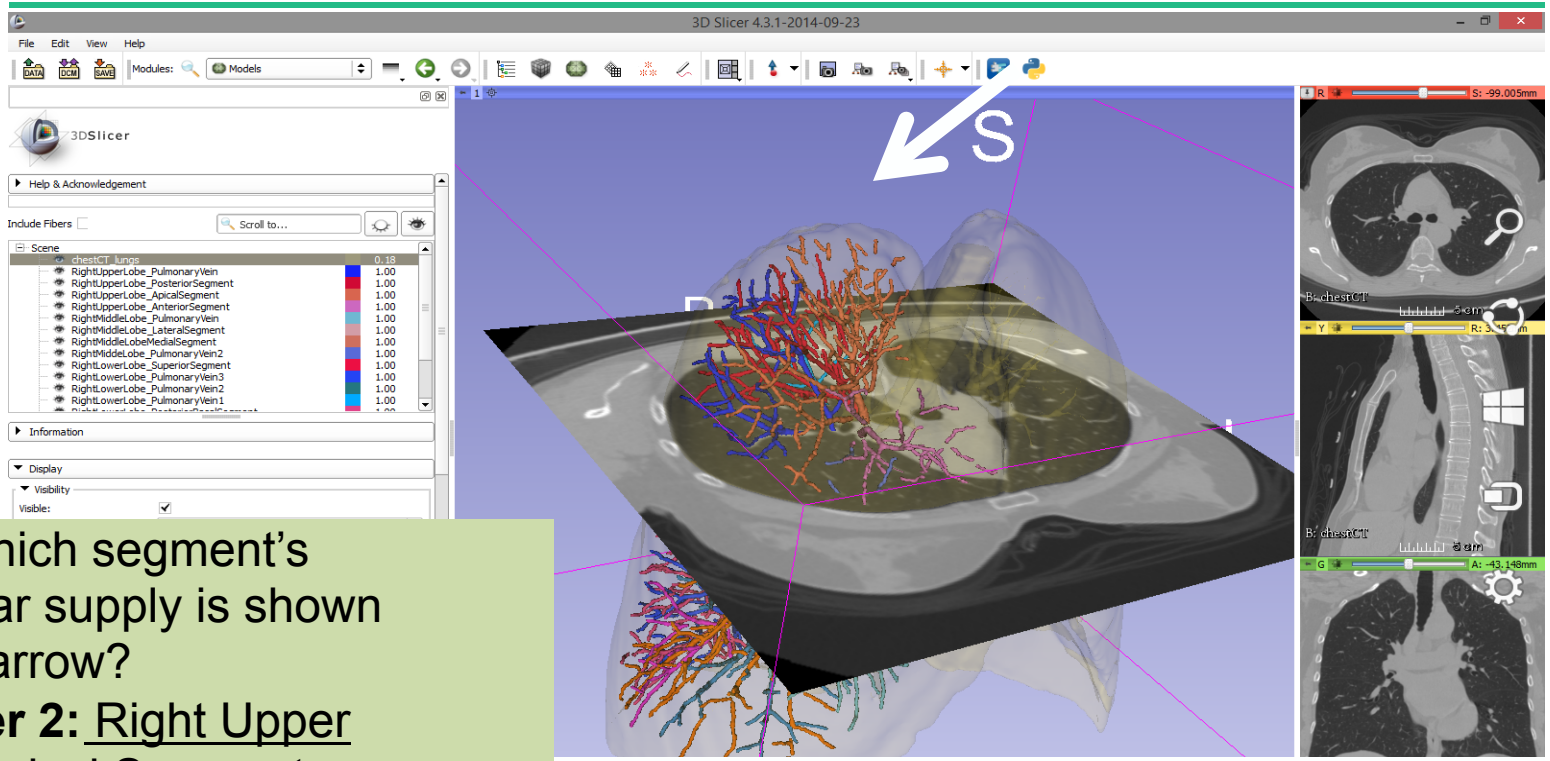
Q1: Why is there a gap in the vessels at the arrows?

Lung Segments – Question 2



Q2: Which segment's vascular supply is shown at the arrow?

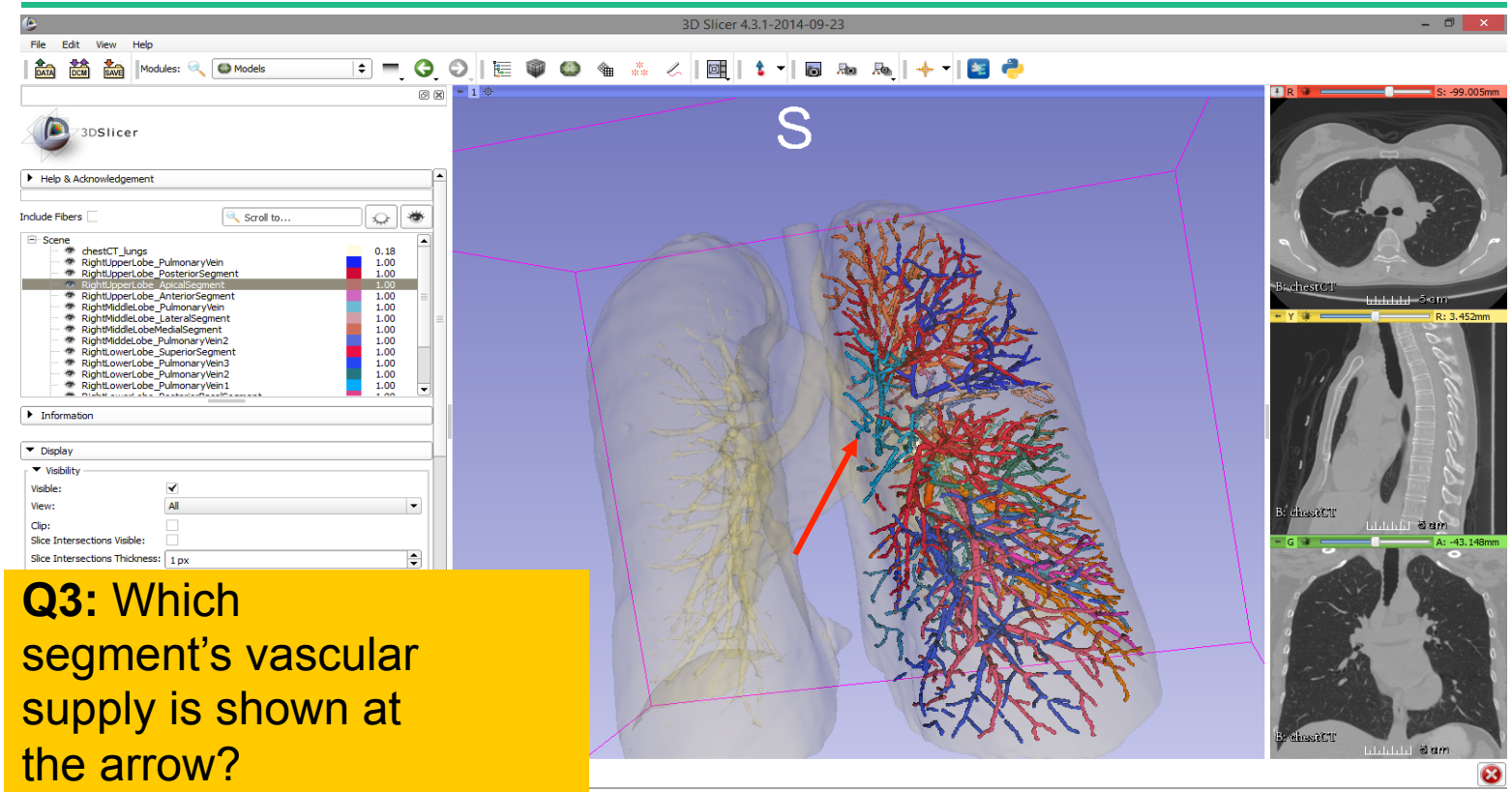
Lung Segments – Question 2



Q2: Which segment's vascular supply is shown at the arrow?

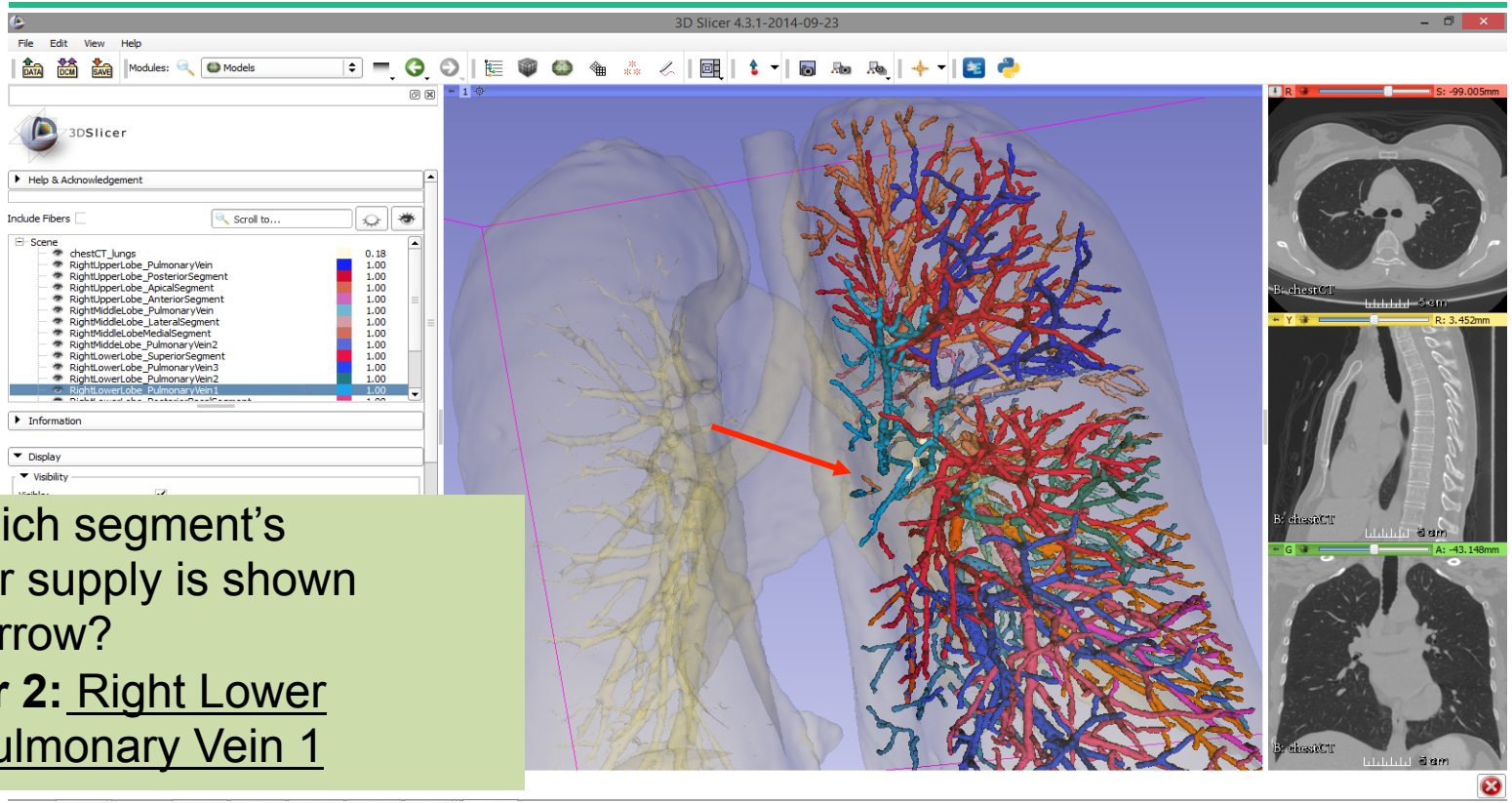
Answer 2: Right Upper Lobe Apical Segment

Lung Segments – Question 3



Q3: Which segment's vascular supply is shown at the arrow?

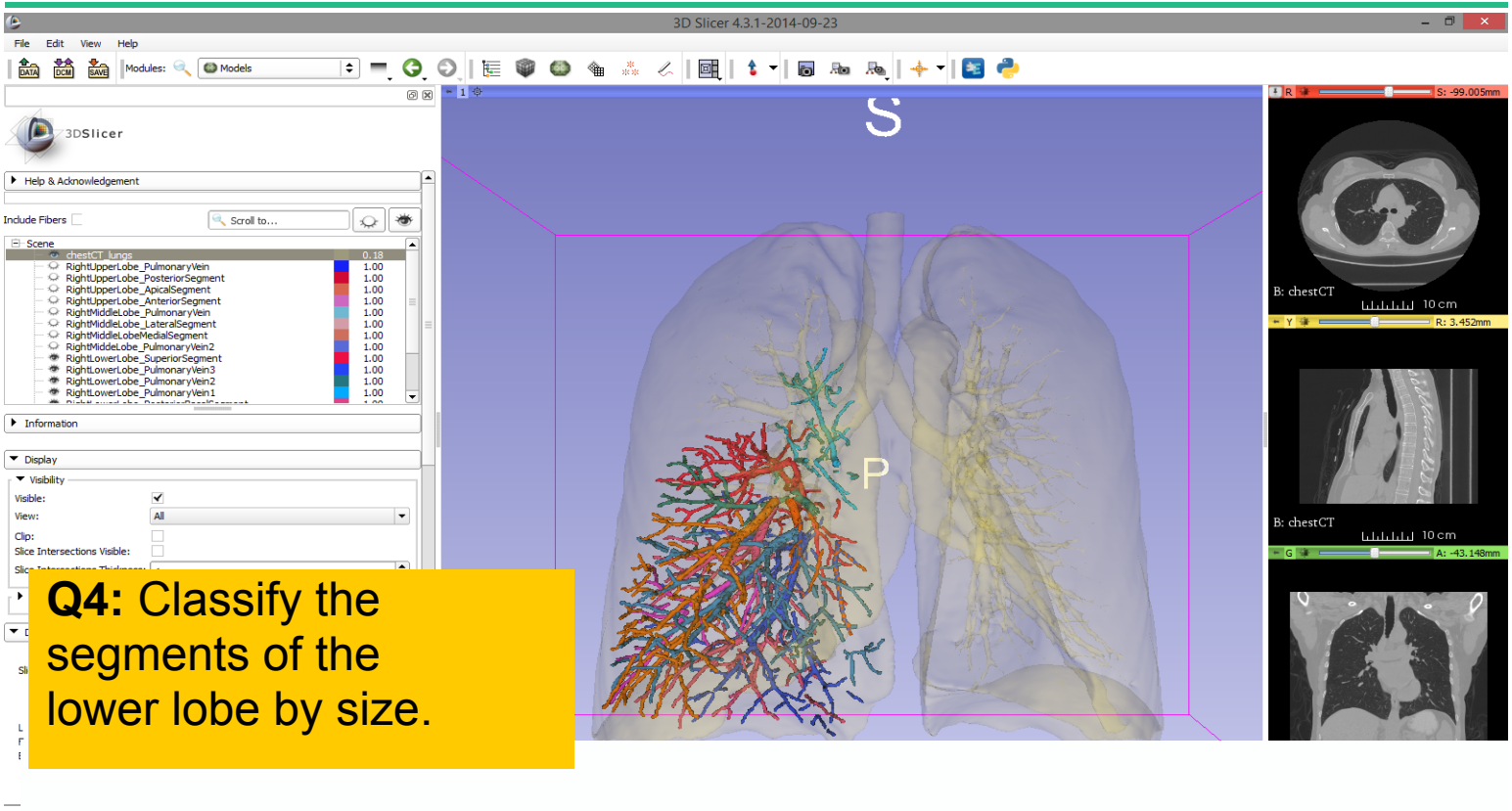
Lung Segments – Question 3



Q3: Which segment's vascular supply is shown at the arrow?

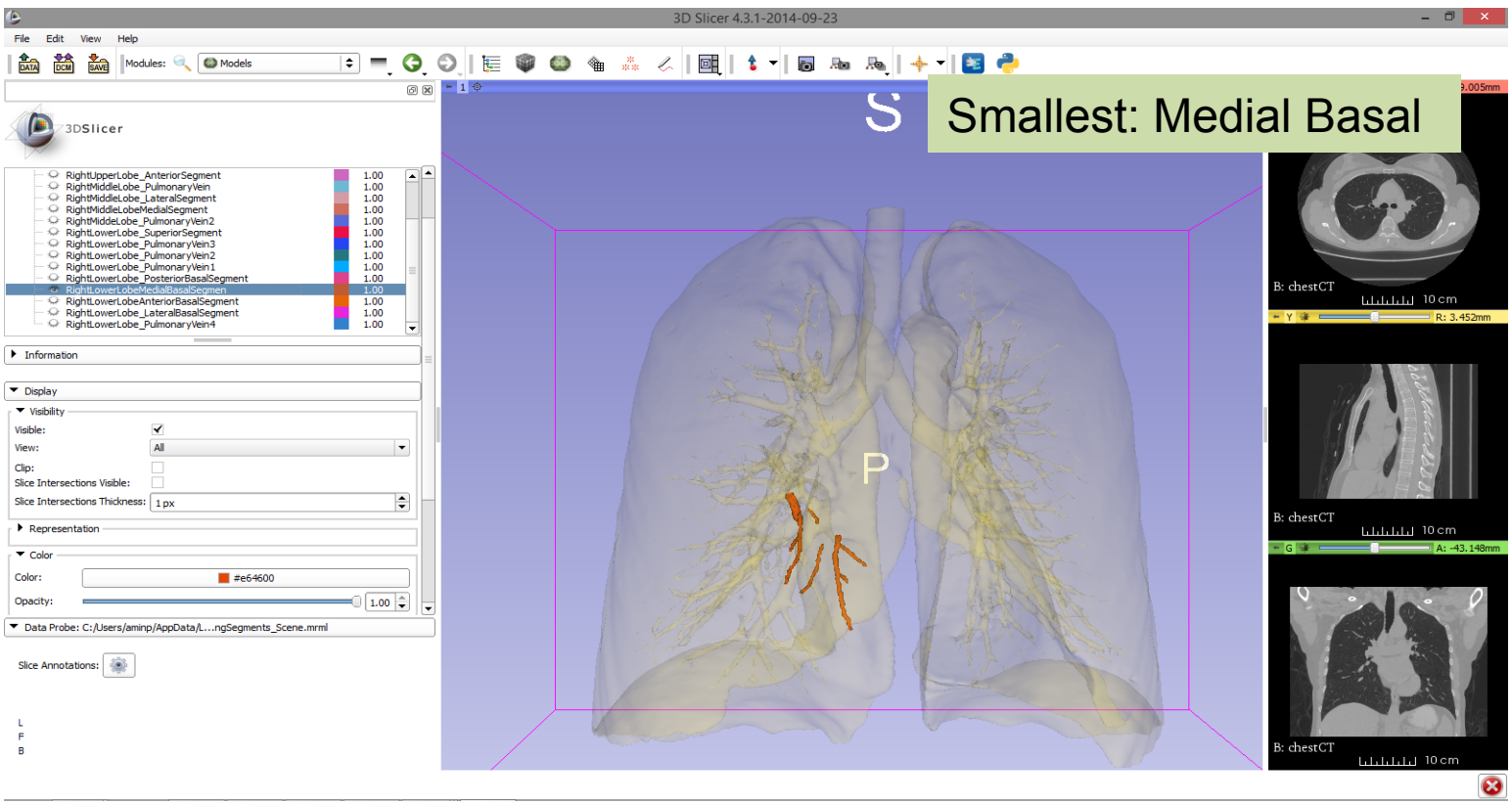
Answer 2: Right Lower Lobe Pulmonary Vein 1

Lung Segments – Question 4

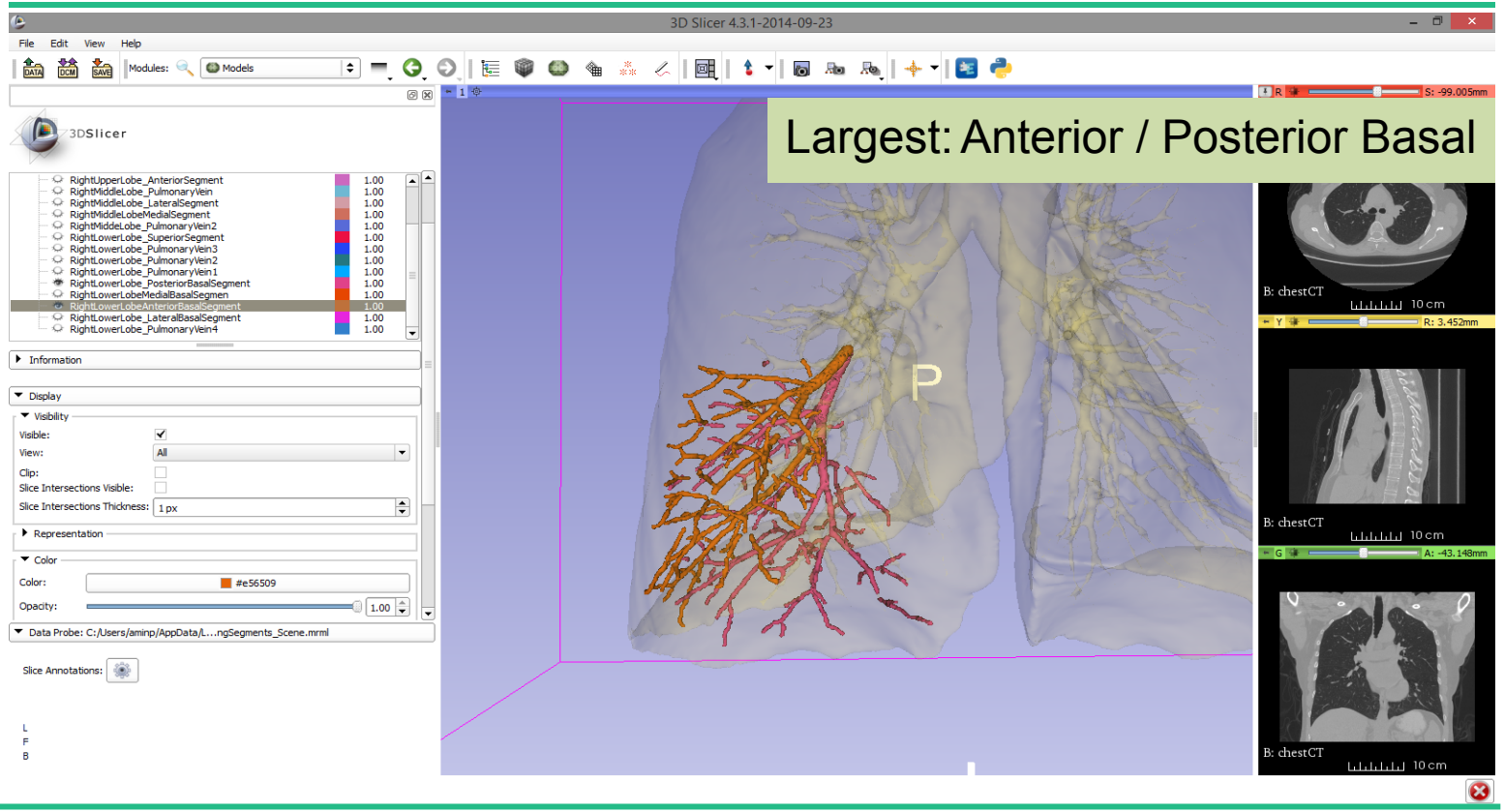


Q4: Classify the segments of the lower lobe by size.

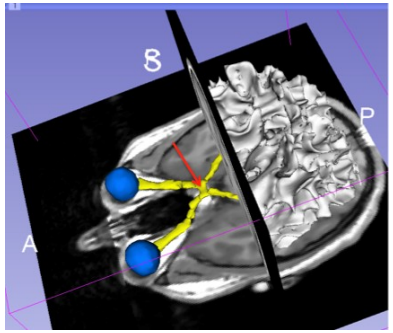
Lung Segments – Question 4

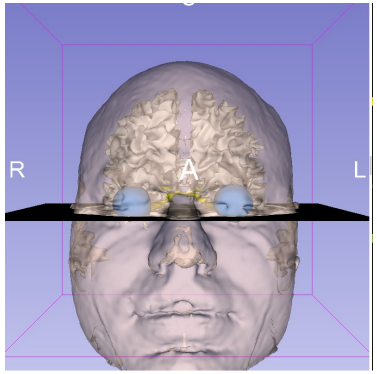


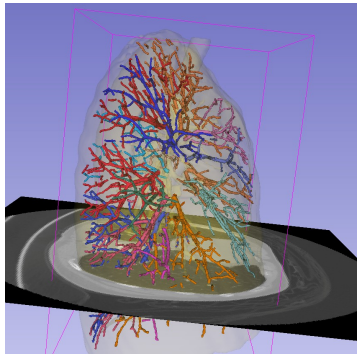
Lung Segments – Question 4

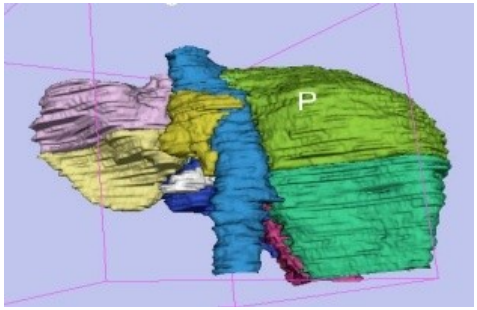


3D Visualization of DICOM images



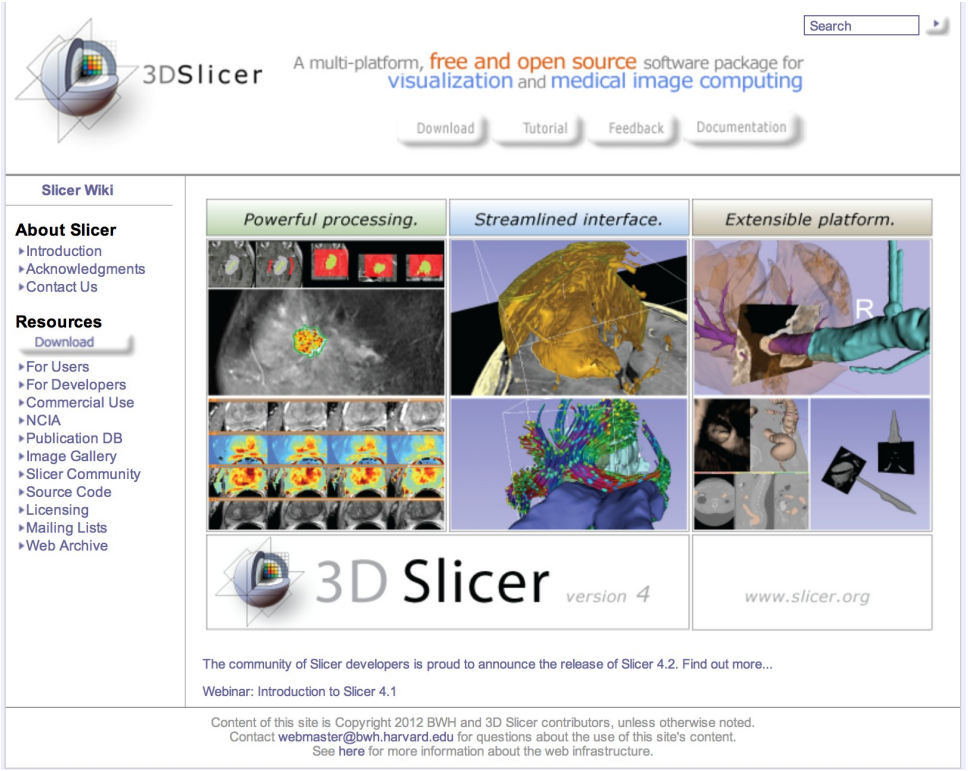






- Interactive user-interface to load and manipulate greyscale volumes, labelmaps and 3D models.
- User-defined 3D view of the anatomy
- 3D Open-source platform for Linux, Mac and Windows

3DSlicer website

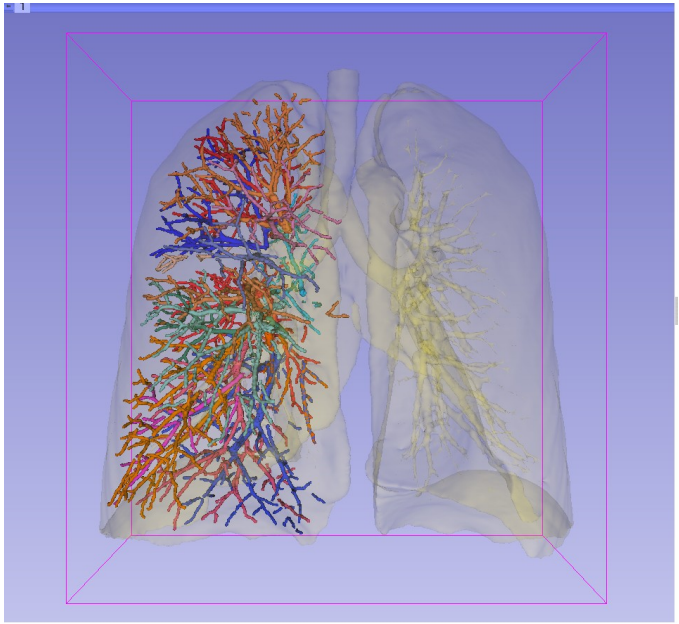


Acknowledgments

National Alliance for Medical Image Computing (NA-MIC)
(NIH Grant U54EB005149)

Neuroimage Analysis Center (NAC)
(NIH Grant P41 EB015902)

- Parth Amin, WIT ’16
- Farukh Kohistani, BC ’16



www.slicer.org

www.na-mic.org

Questions and comments: spujol@bwh.harvard.edu