# An introduction to programming in Slicer4

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Madrid-MIT M+Vision Consortium
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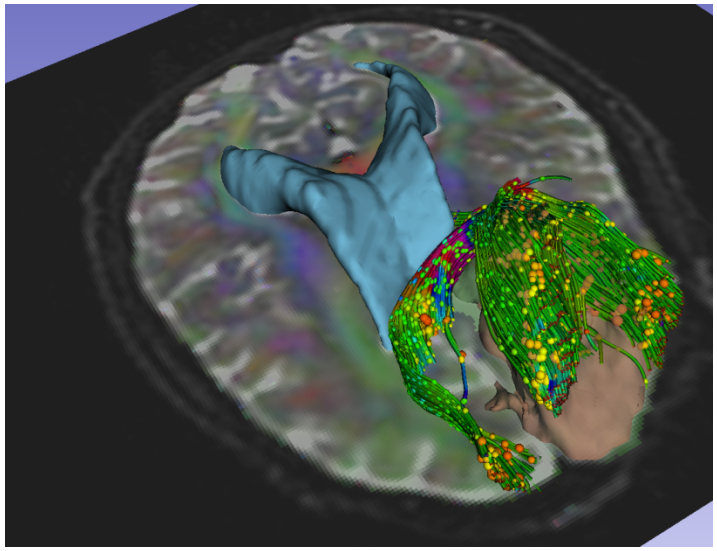
# 3D Slicer version 4 (Slicer4.1)



- An end-user application for image analysis
- 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

# Slicer for Translational Research

**What does a developer need ?**

- Easy to deploy
- Extensible and reconfigurable
- Rich utility libraries
- Stable base

**What does a user expect ?**

- Easy to install and upgrade
- “Standard” Clinical Behavior
- Advanced Functionality
- Consistent Interface

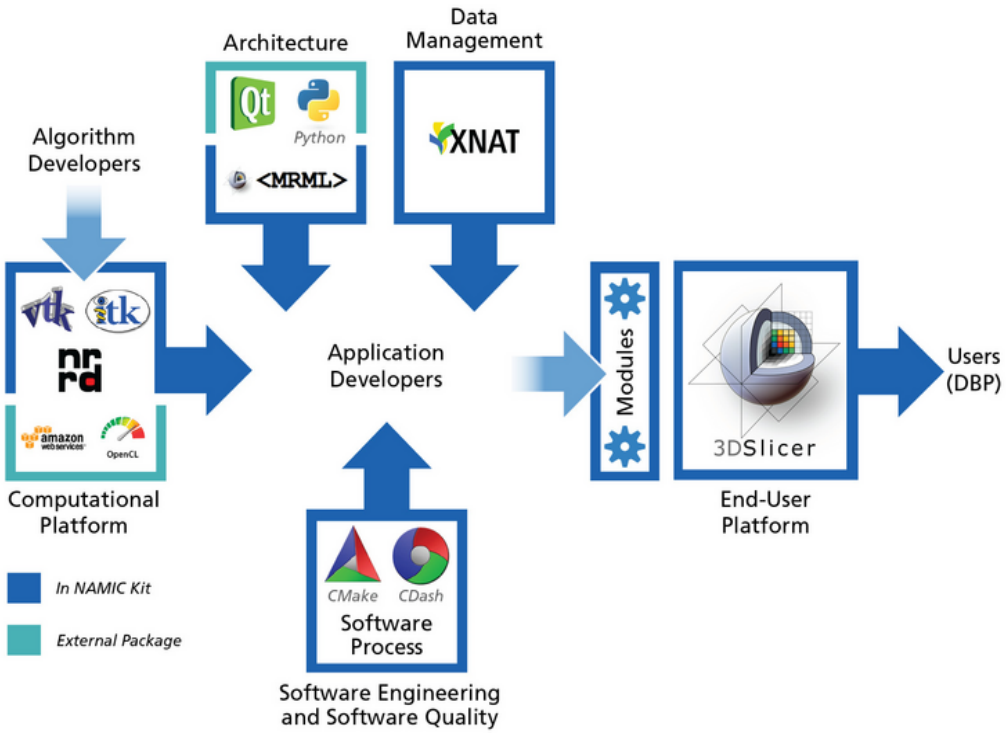
Courtesy R. Kikinis

# The NA-MIC Kit





# The NA-MIC kit




Application developers create tools within an architectural framework in conjunction with data management facilities and under the control of quality software process

Courtesy R. Kikinis, W.Schroeder

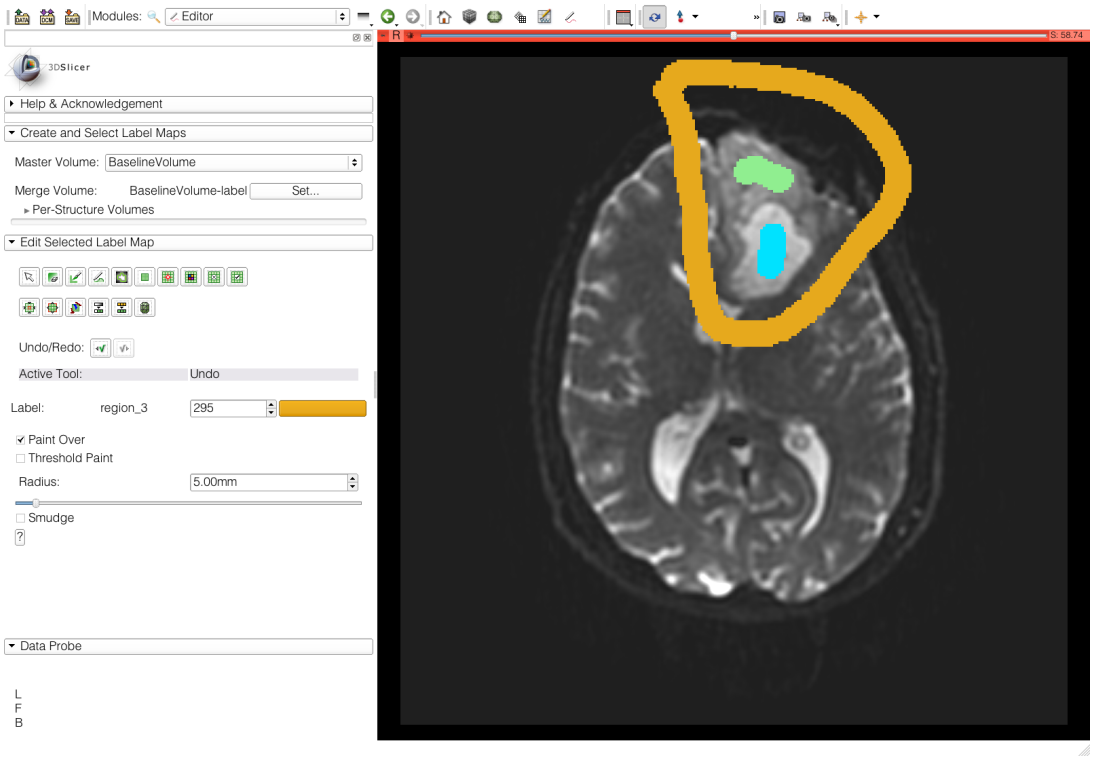
# What's inside Slicer ?

- Slicer core: Slicer GUI, I/O, visualization and developer interfaces
- Slicer modules: internal plugins that depend on the slicer core
- Slicer extensions: external plugins installed on demand by the user

# Slicer Modules

Slicer supports three types of modules:

- Scripted Modules (Python)

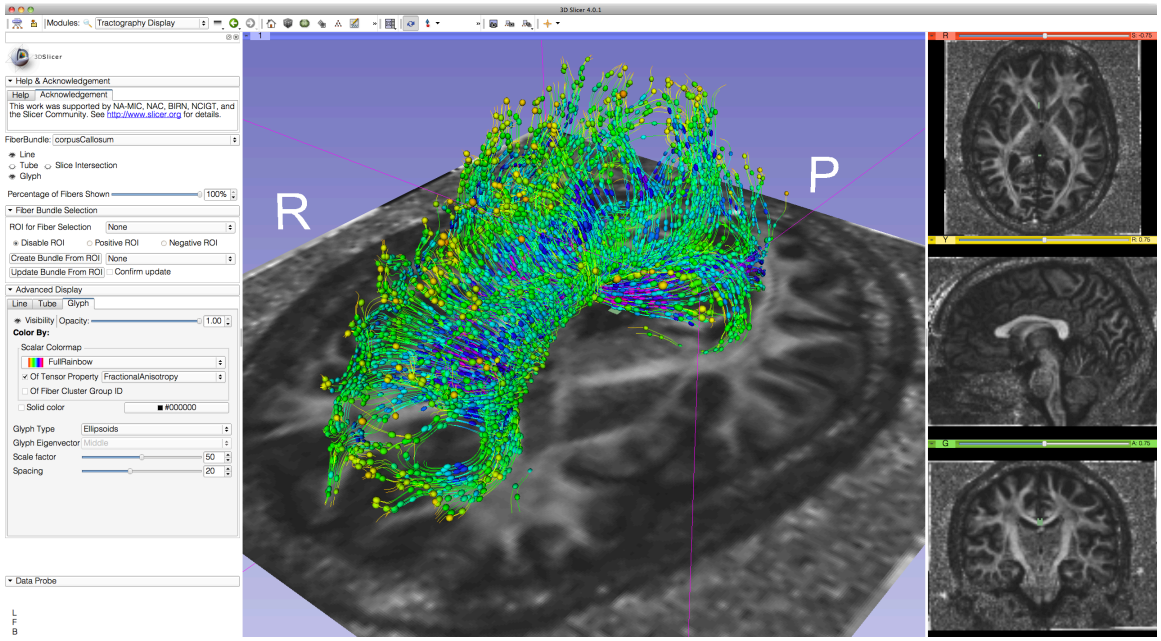



e.g. Editor

# Slicer Modules

Slicer supports three types of modules:

- Scripted Modules (Python)
- Command Line Interface (ITK)

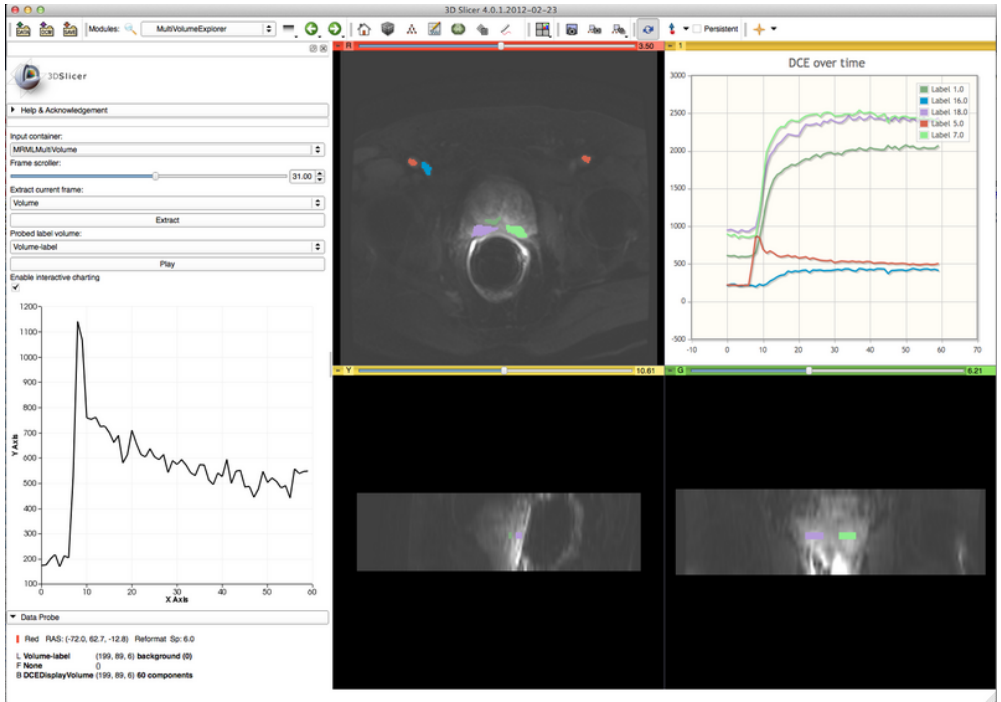



e.g. Tractography Labelmap Seeding

# Slicer Modules

Slicer supports three types of modules:

- Scripted Modules (Python)
- Command Line Interface (ITK)
- Loadable Modules (C++)

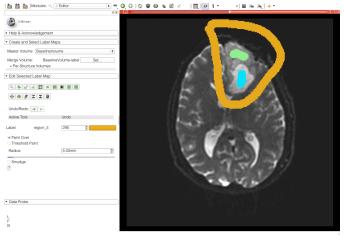



e.g. MultipleVolume Explorer

image courtesy R. Kikinis

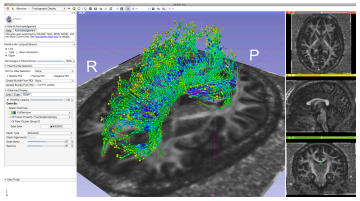
# Slicer Modules

## Variety of options for the developers:



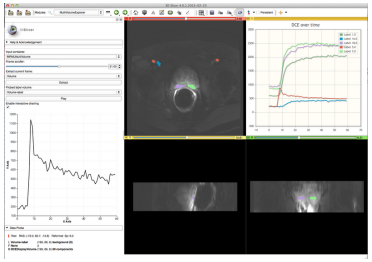
**Scripted module**: TCL or Python scripts

- simple, no compilation needed
- limited access to Slicer internals




**Command-line module**: .exe file

- simple, executable without Slicer
- no access to Slicer internals, Slicer compilation needed



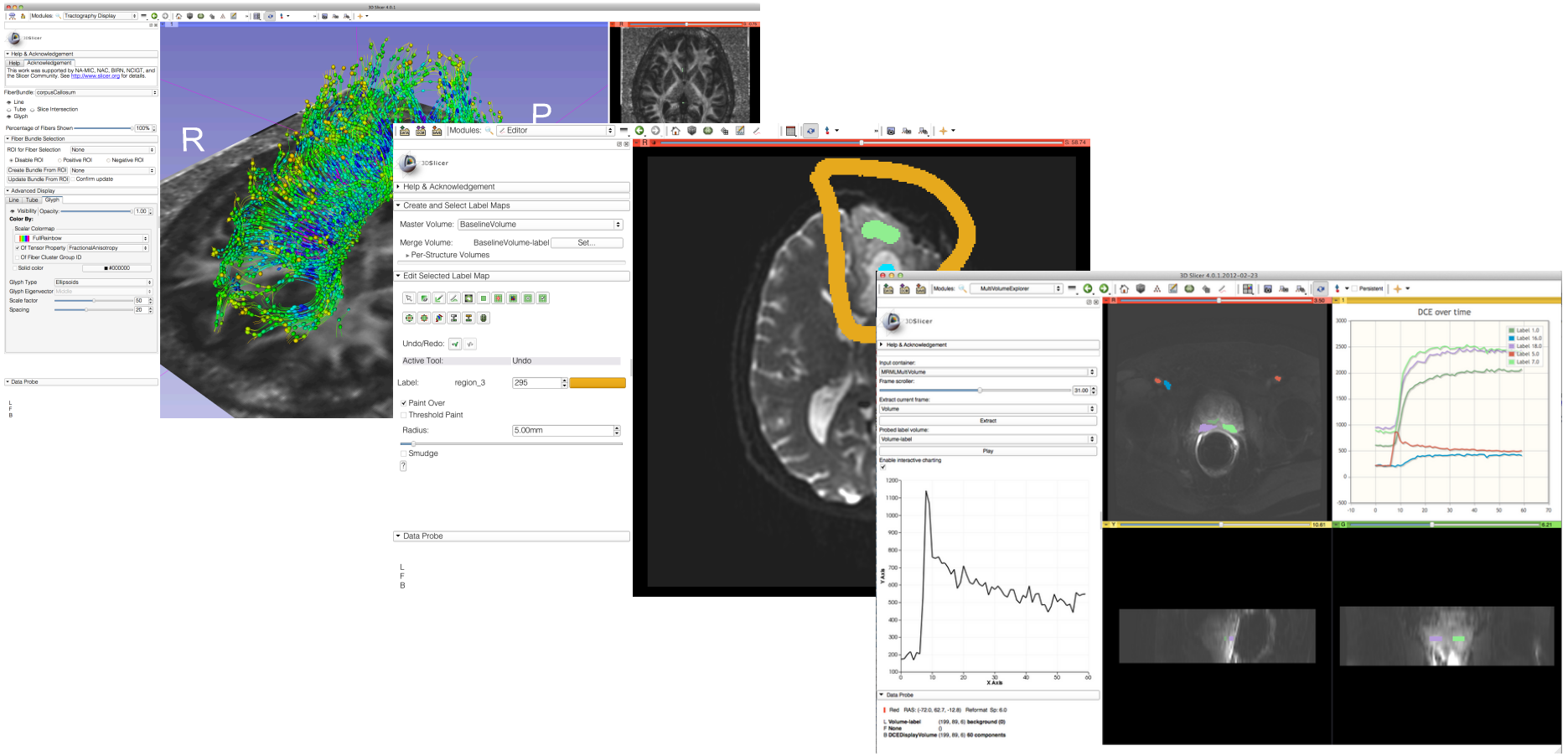
**Loadable (interactive) module**: .dll

- full access to Slicer internals
- Slicer compilation needed, requires Slicer core knowledge

Courtesy R. Kikinis

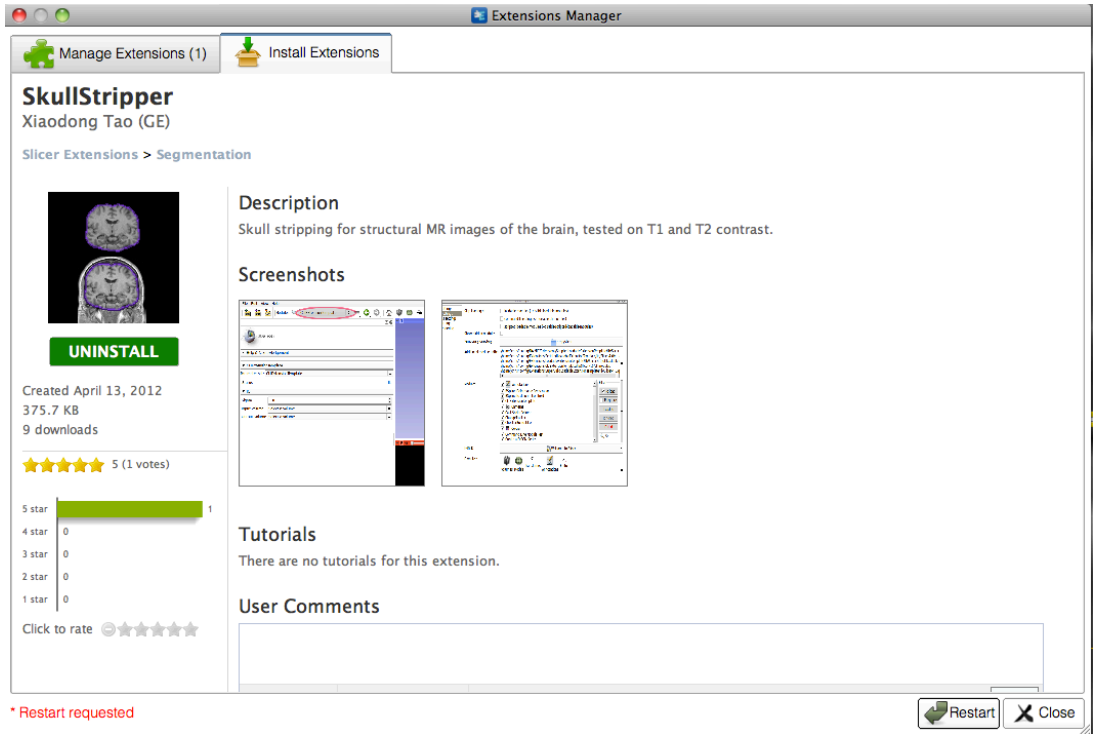
# Slicer Modules

## Three options for the developers




→Consistent look and feel for the user

# Slicer is Extensible




- The Slicer Extension Catalog offers the possibility to the user to download and install additional Slicer modules

# Slicer Extensions Categories

Category 1: Slicer license, open-source, maintained

Category 2: open-source, contact exists

Category 3: work in progress, closed-source…

# Programming in Slicer4: The Hello Python tutorial

Paul Cézanne, Moulin sur la Couleuvre à Pontoise, 1881, Staatliche Museen zu Berlin, Nationalgalerie

Sonia Pujol, Ph.D.
Surgical Planning Laboratory,
Harvard Medical School

Steve Pieper, Ph.D.
Isomics Inc.

# Tutorial Goal

- This tutorial guides you through the steps of programming a HelloPython scripted module for running a Laplacian filtering and sharpening.

- For additional details and pointers, visit the Slicer Documentation page

http://wiki.slicer.org/slicerWiki/index.php/Documentation/4.0

# Prerequisites

- This course supposes that you have taken the tutorial: “Slicer4 Data Loading and Visualization”- Sonia Pujol Ph.D.

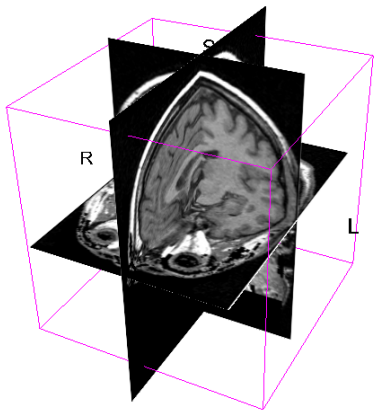
- The tutorial is available on the Slicer4 101 compendium:

http://www.slicer.org/slicerWiki/index.php/Training/4.0

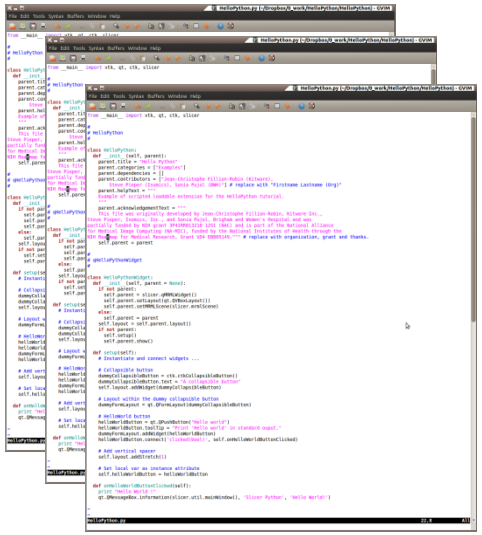
- Programming experience is required, and some familiarity with Python is essential.

# Course Material

Slicer4.1 version available at [www.slicer.org](http://www.slicer.org)




spgr.nhdr spgr.raw.gz
(124 SPGR images)



HelloPython.py
HelloLaplace.py
HelloSharpen.py

Unzip the HelloPython.zip archive

# Slicer4 Highlights: Python

The Python console of Slicer4 gives access to

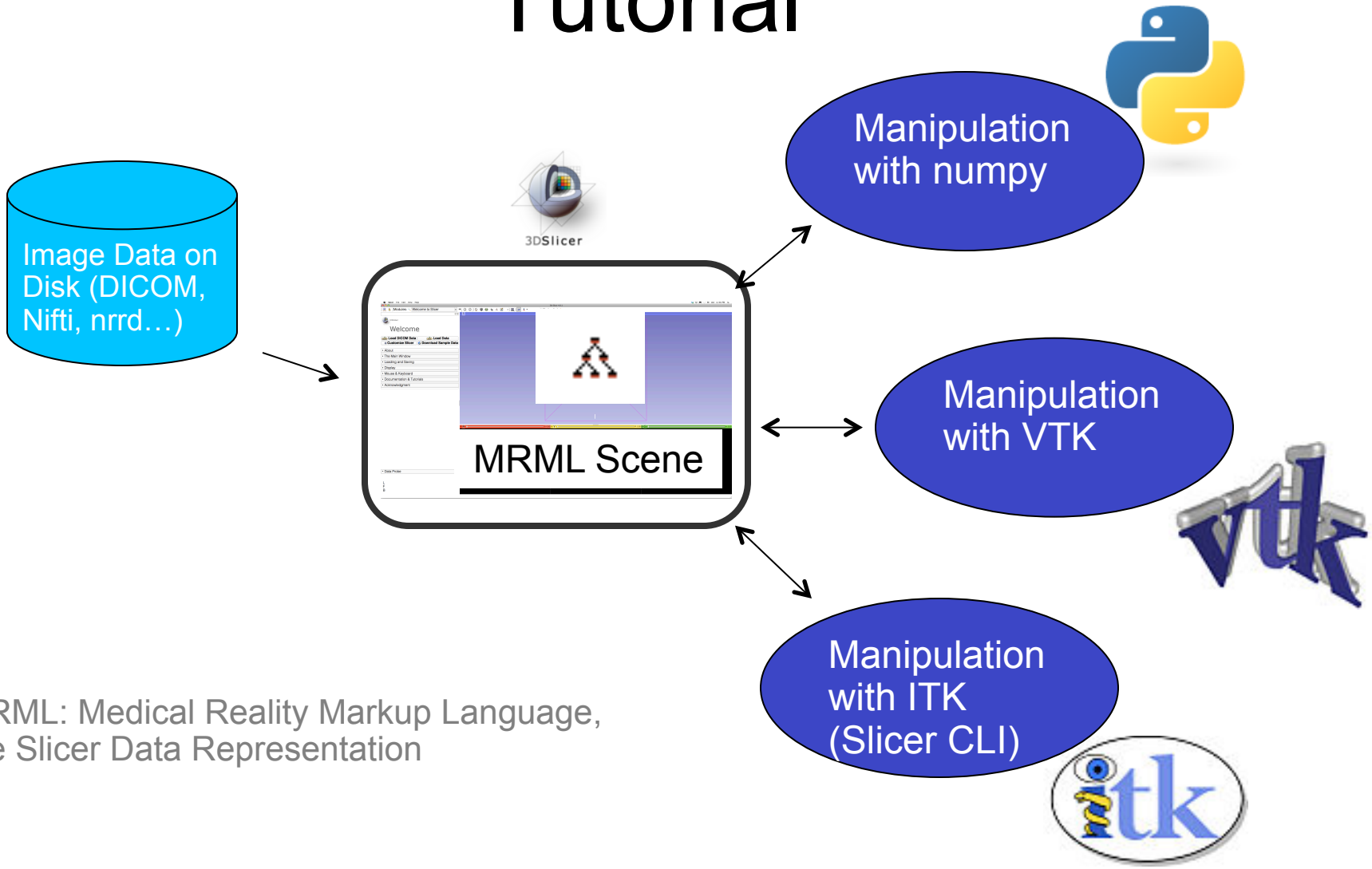
- scene objects (MRML)
- data arrays (volumes, models)
- GUI elements that can be encapsulated in a module
- Processing Libraries: numpy, VTK, ITK,CTK

# Slicer4 Scripted Modules

- Python scripted modules allow more **interactive functionalities** (eg 'Flythrough' in Endoscopy module) and **rapid prototyping**

- GUI based on Qt libraries accessed via Python

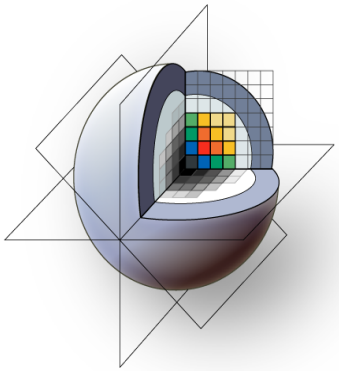
# Processing Examples in this Tutorial




MRML: Medical Reality Markup Language, the Slicer Data Representation

# Course Overview

- Part A: Exploring Slicer via Python
- Part B: Integration of the HelloPython.py program into Slicer4
- Part C: Implementation of the Laplace operator in the HelloPython module
- Part D: Image Sharpening using the Laplace operator





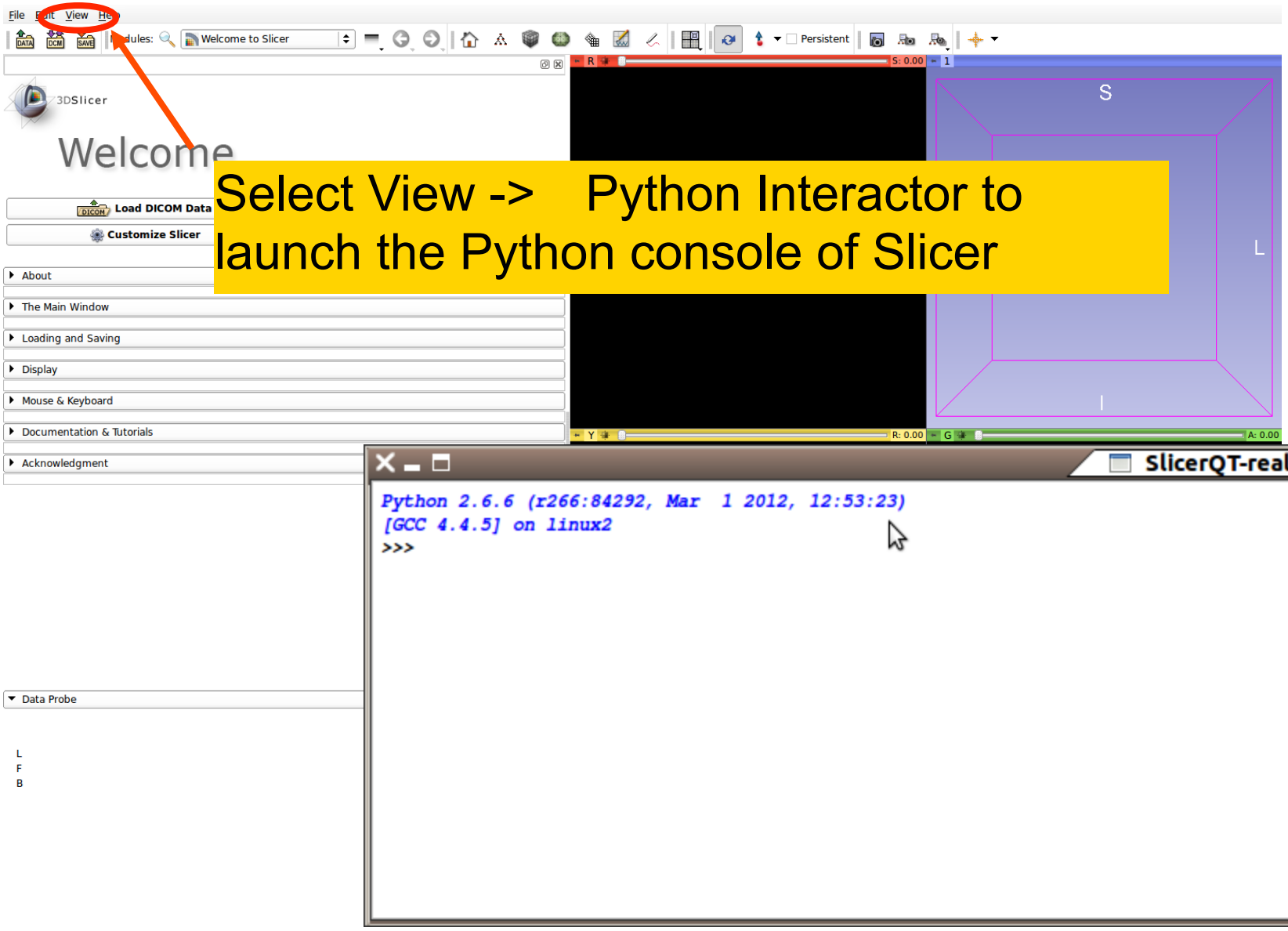
# Part A: EXPLORING SLICER VIA PYTHON

# Python in Slicer

- Slicer 4 includes python 2.6.6 and a rich set of standard libraries
  - *Included*: **numpy**, **vtk, ctk, PythonQt**, and most of standard python library
  - *Not included*:
    - scipy (scientific tools for python),
    - matplotlib (python 2D ploting library),
    - ipython (interactive python)

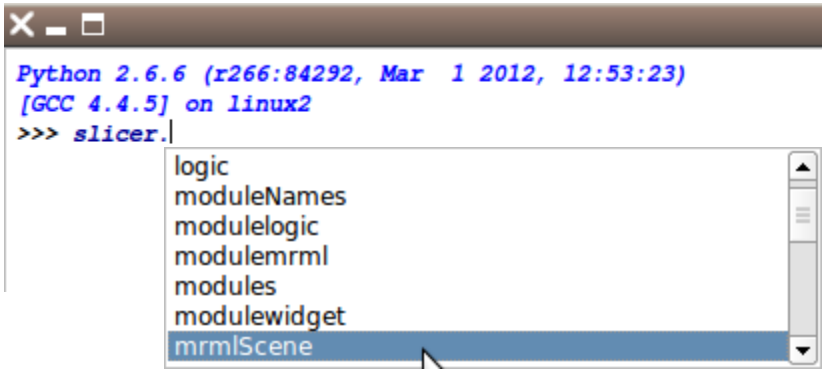
    and some other popular packages that we have found difficult to package for distribution

# Python Console in Slicer

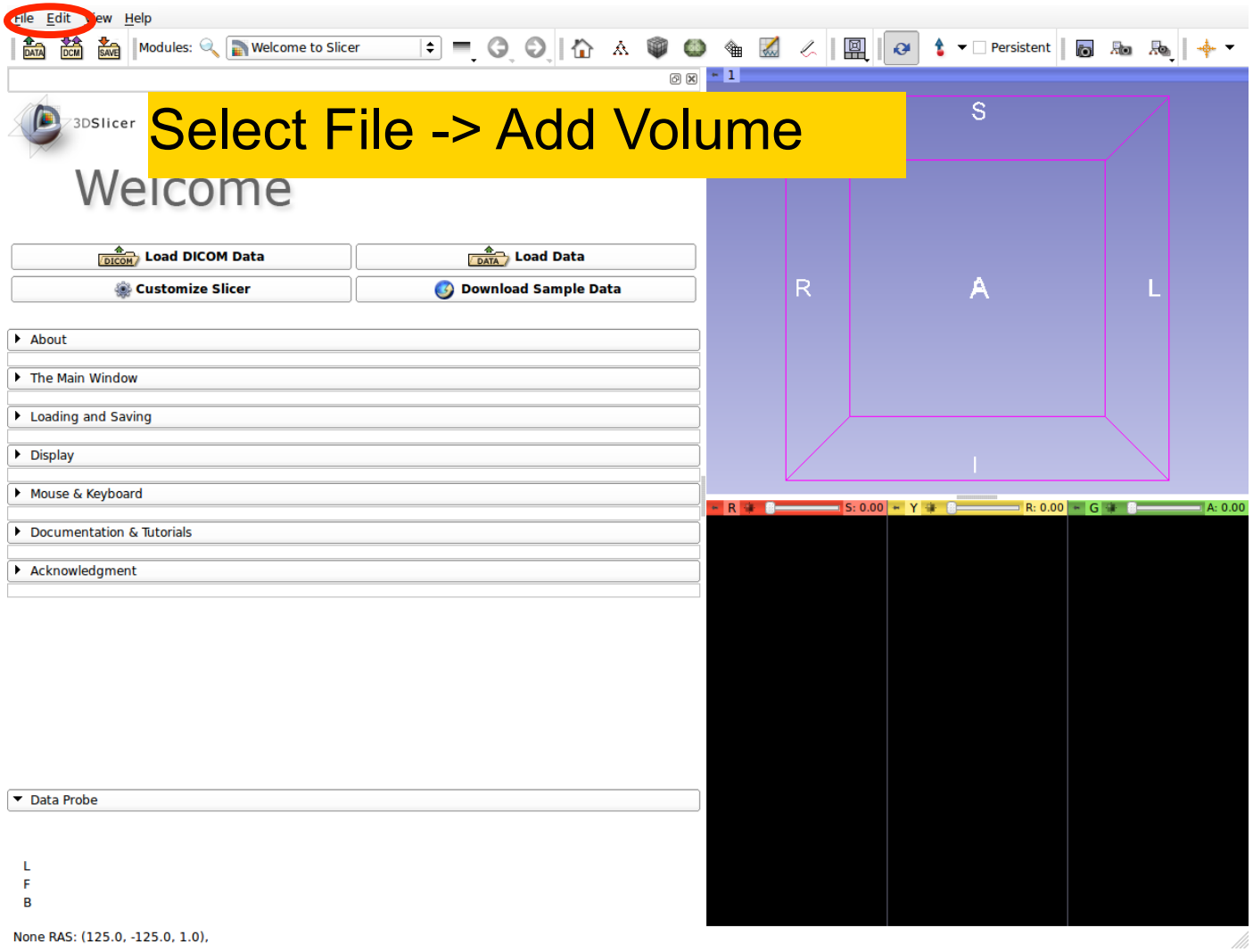


# General Python Console Features

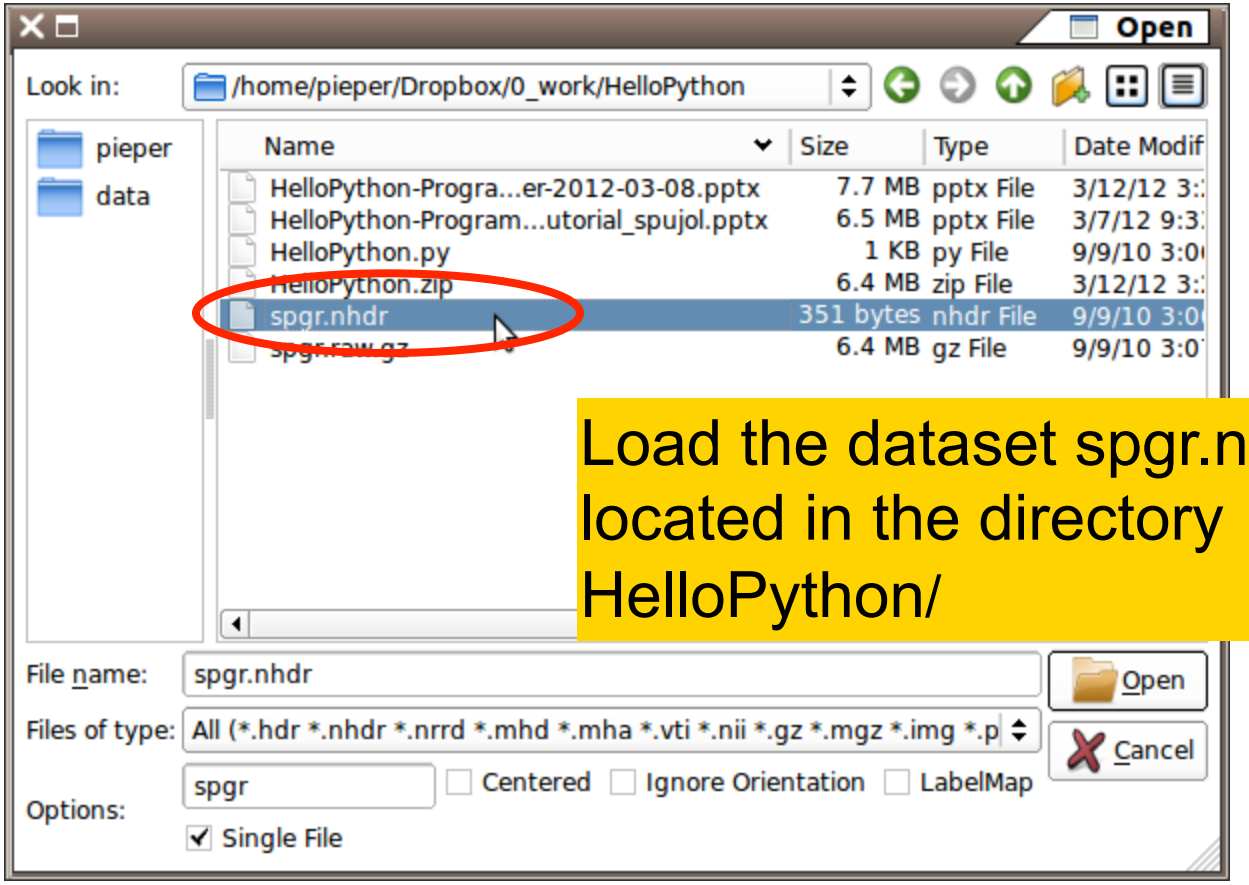
- Command Line Editing:
  - Left/Right Arrow Keys, End
  - Delete (Control-D)
- Input History
  - Up/Down Arrow Keys
- Command Completion
  - Tab Key



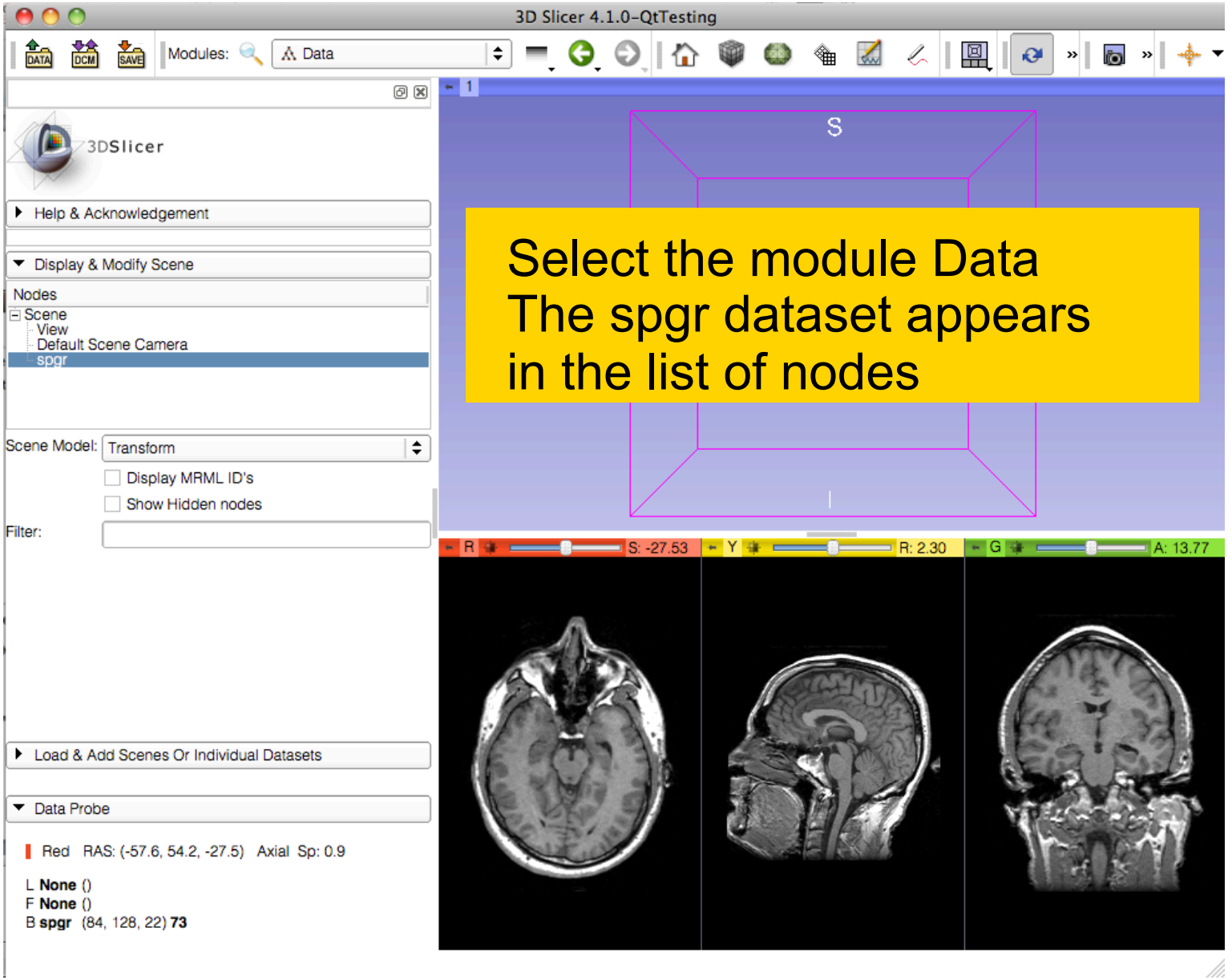
# Add Volume Dialog



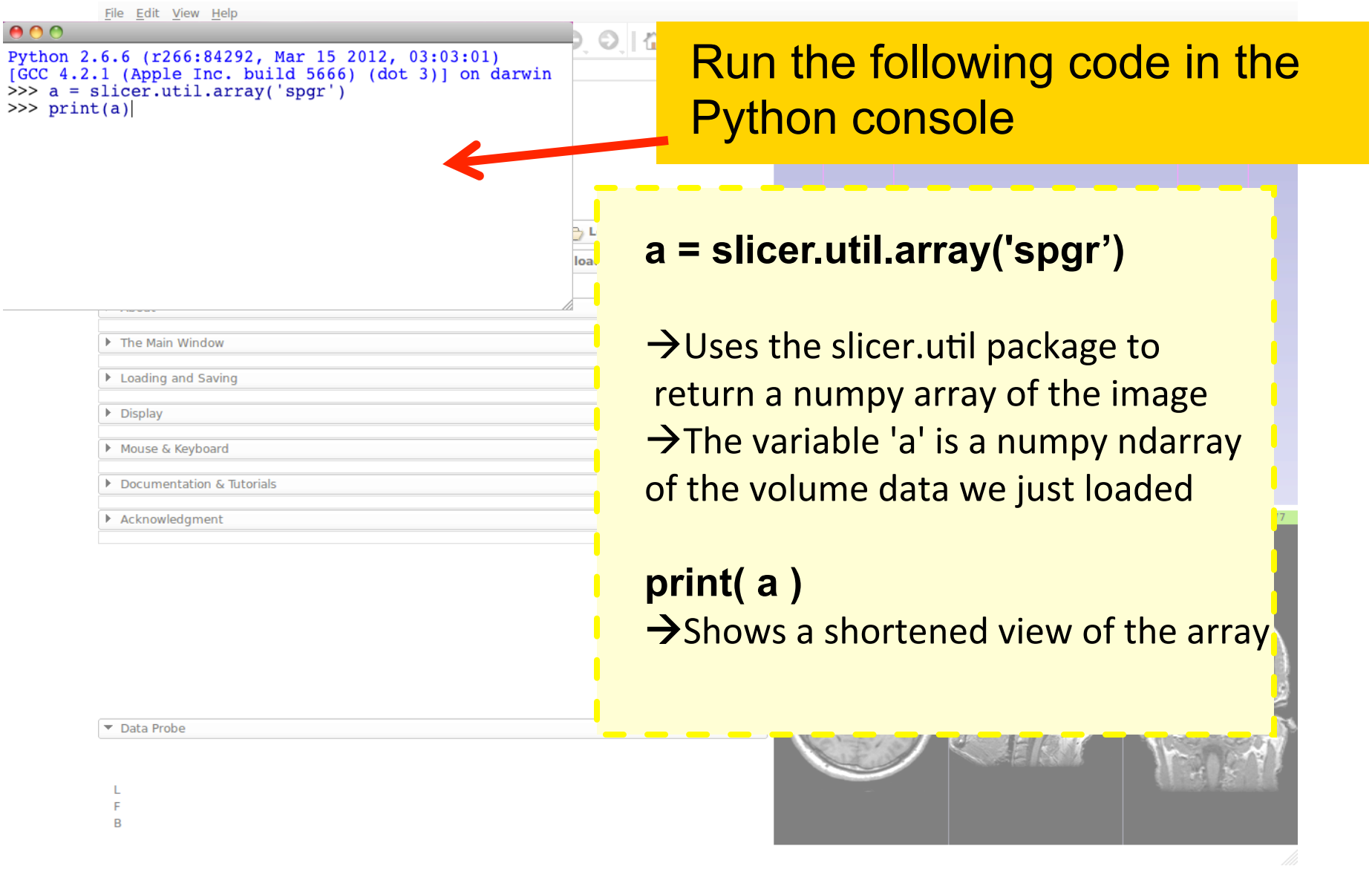
# Add spgr.nhdr




Load the dataset spgr.nhdr located in the directory HelloPython/


3D Slicer 4.1.0-QtTesting
Modules:
Data
3DSlicer
Help & Acknowledgement
Display & Modify Scene
Nodes
Scene
View
Default Scene Camera
spgr
Scene Model:
Transform
Display MRML ID's
Show Hidden nodes
Filter:
Load & Add Scenes Or Individual Datasets
Data Probe
Red RAS: (-57.6, 54.2, -27.5) Axial Sp: 0.9
L None ()
F None ()
B spgr (84, 128, 22) 73
S
Select the module Data
The spgr dataset appears
in the list of nodes
R
S: -27.53
Y
R: 2.30
G
A: 13.77

# Access to MRML and Arrays




Run the following code in the Python console

**a = slicer.util.array('spgr')**

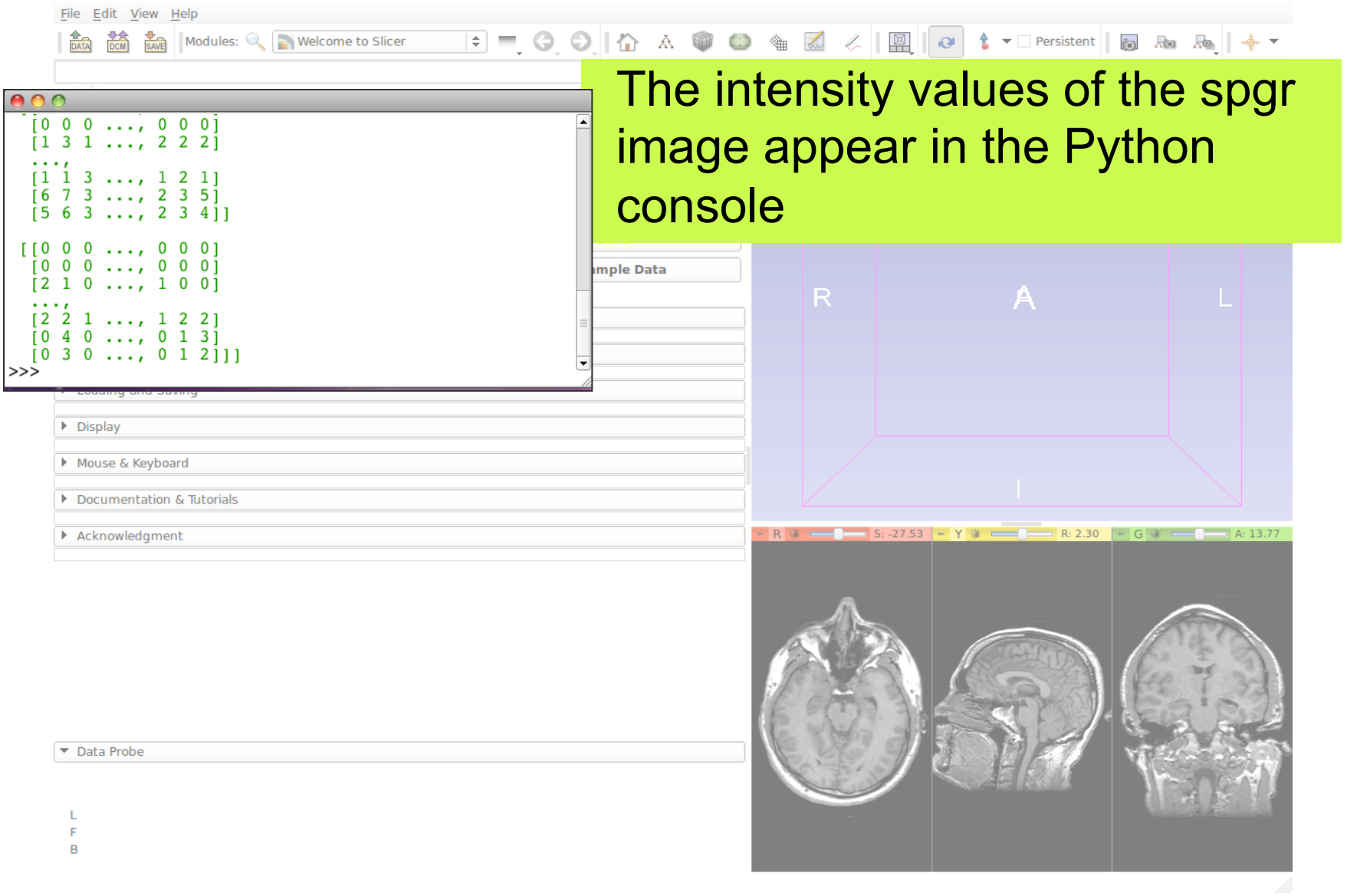
→Uses the slicer.util package to return a numpy array of the image

→The variable 'a' is a numpy ndarray of the volume data we just loaded

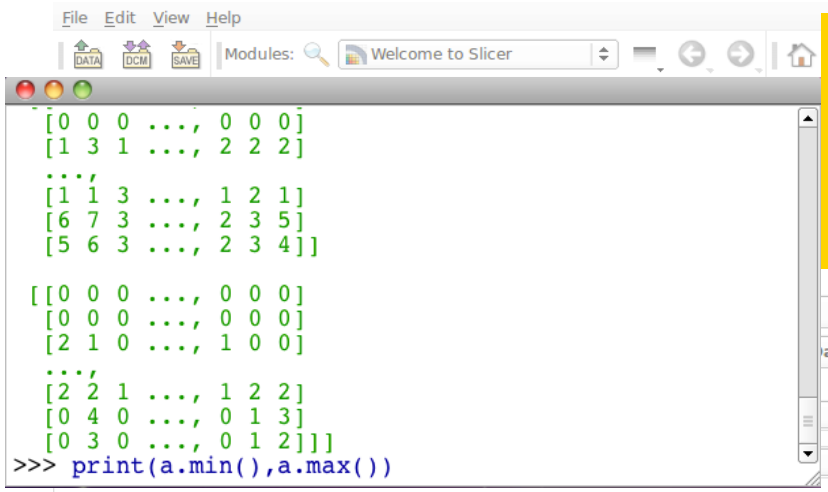
**print( a )**

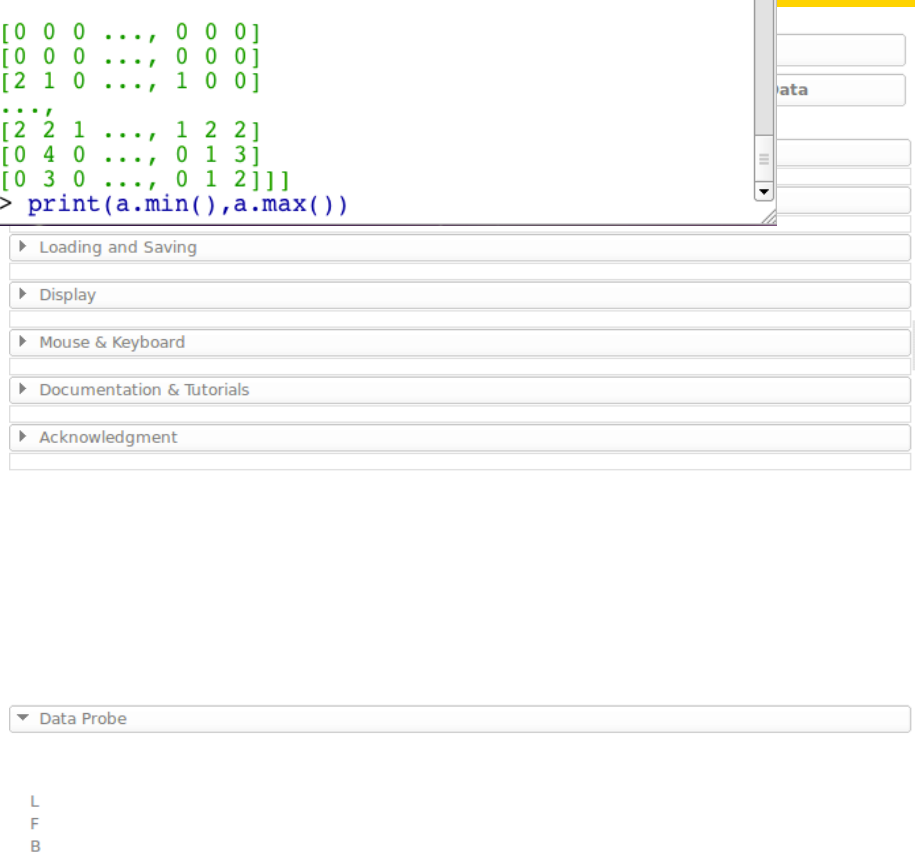
→Shows a shortened view of the array

# Access to MRML and Arrays



# Access to MRML and Arrays

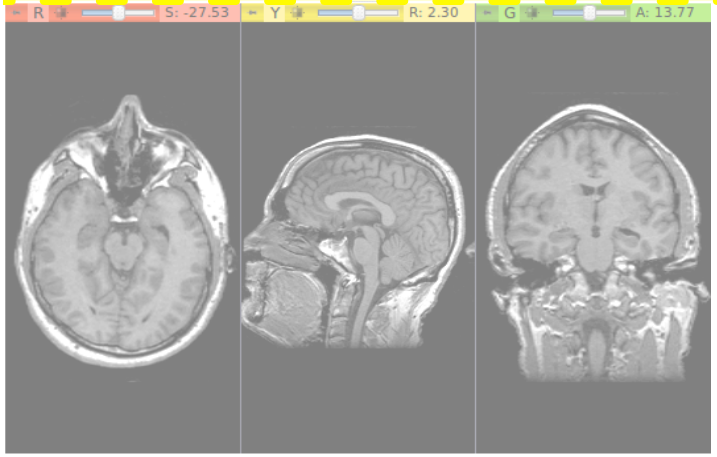


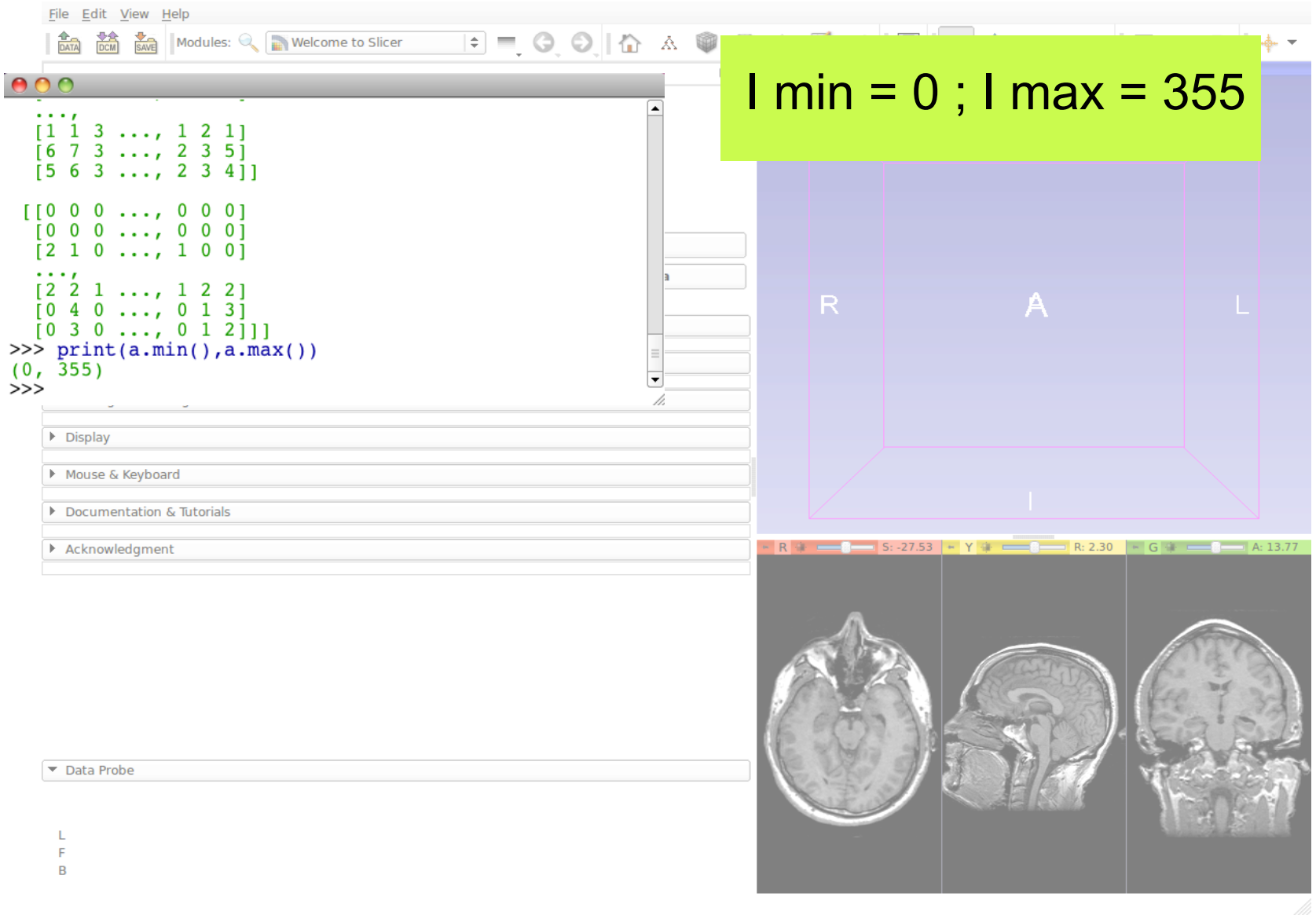

Type the following command to display the min and max intensity value of the spgr image

**print( a.min(), a.max() )**

→Use numpy array methods to explore the data

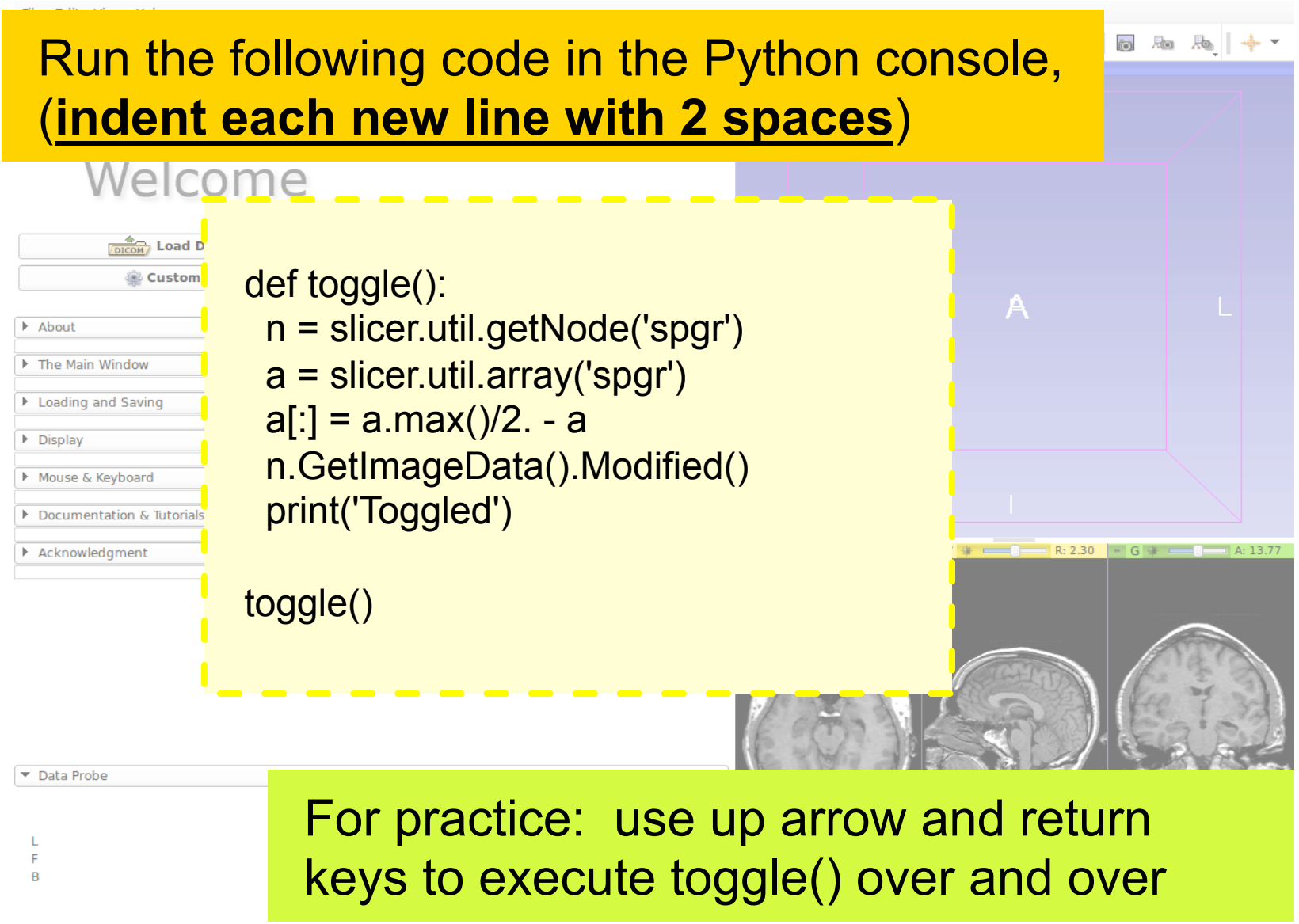


# Access to MRML and Arrays



# Manipulating Arrays

Run the following code in the Python console, (**indent each new line with 2 spaces**)

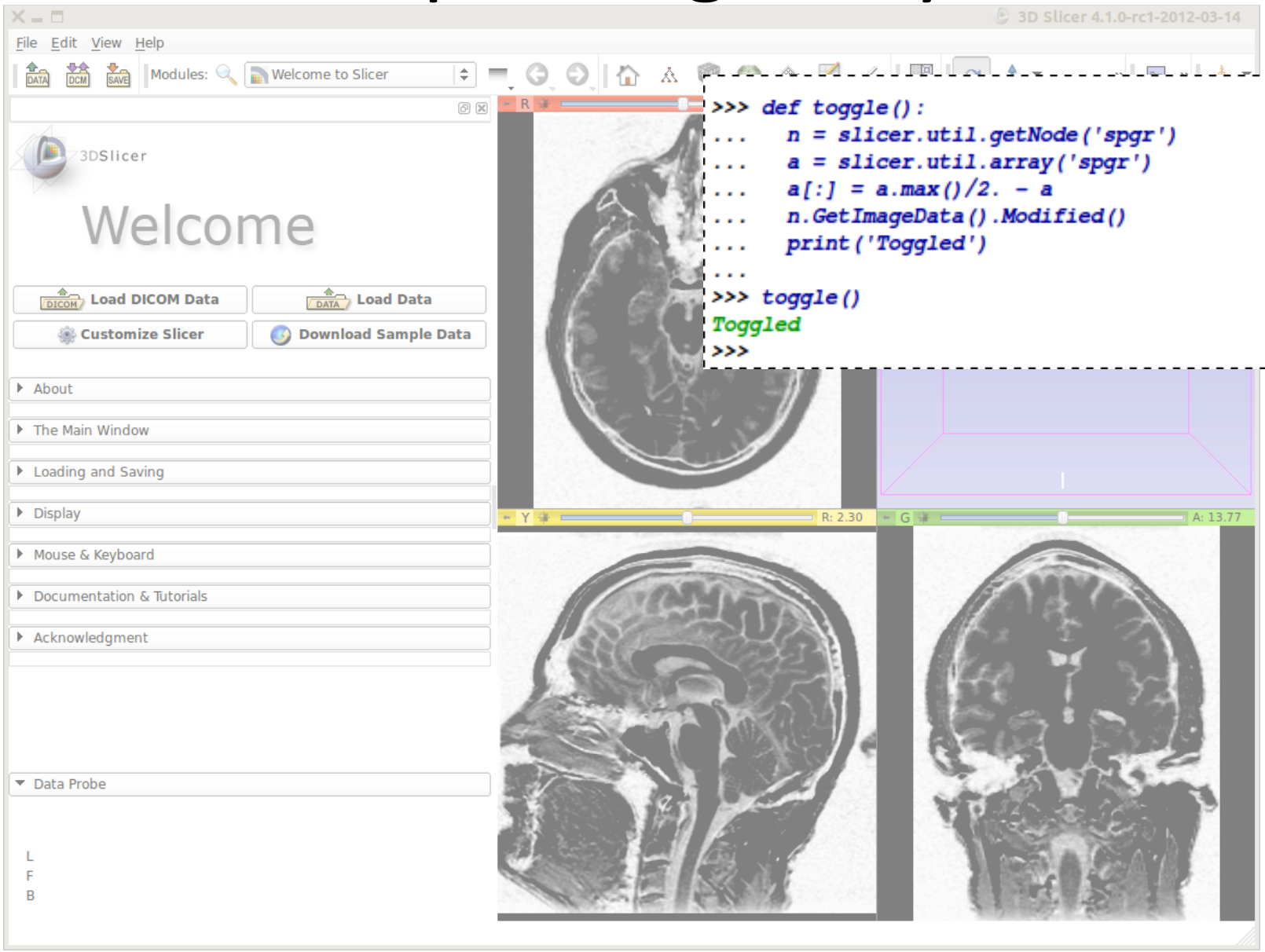



```
def toggle():
  n = slicer.util.getNode('spgr')
  a = slicer.util.array('spgr')
  a[:] = a.max()/2. - a
  n.GetImageData().Modified()
  print('Toggled')

toggle()
```

For practice: use up arrow and return keys to execute toggle() over and over

# Manipulating Arrays



# The toggle function in more detail

- **def toggle():**
  - Defines a python function
  - Body of function performs element-wise math on entire volume
  - Easy mix of scalar and volume math
- Telling slicer that the image data for node 'n' has been modified causes the slice view windows to refresh

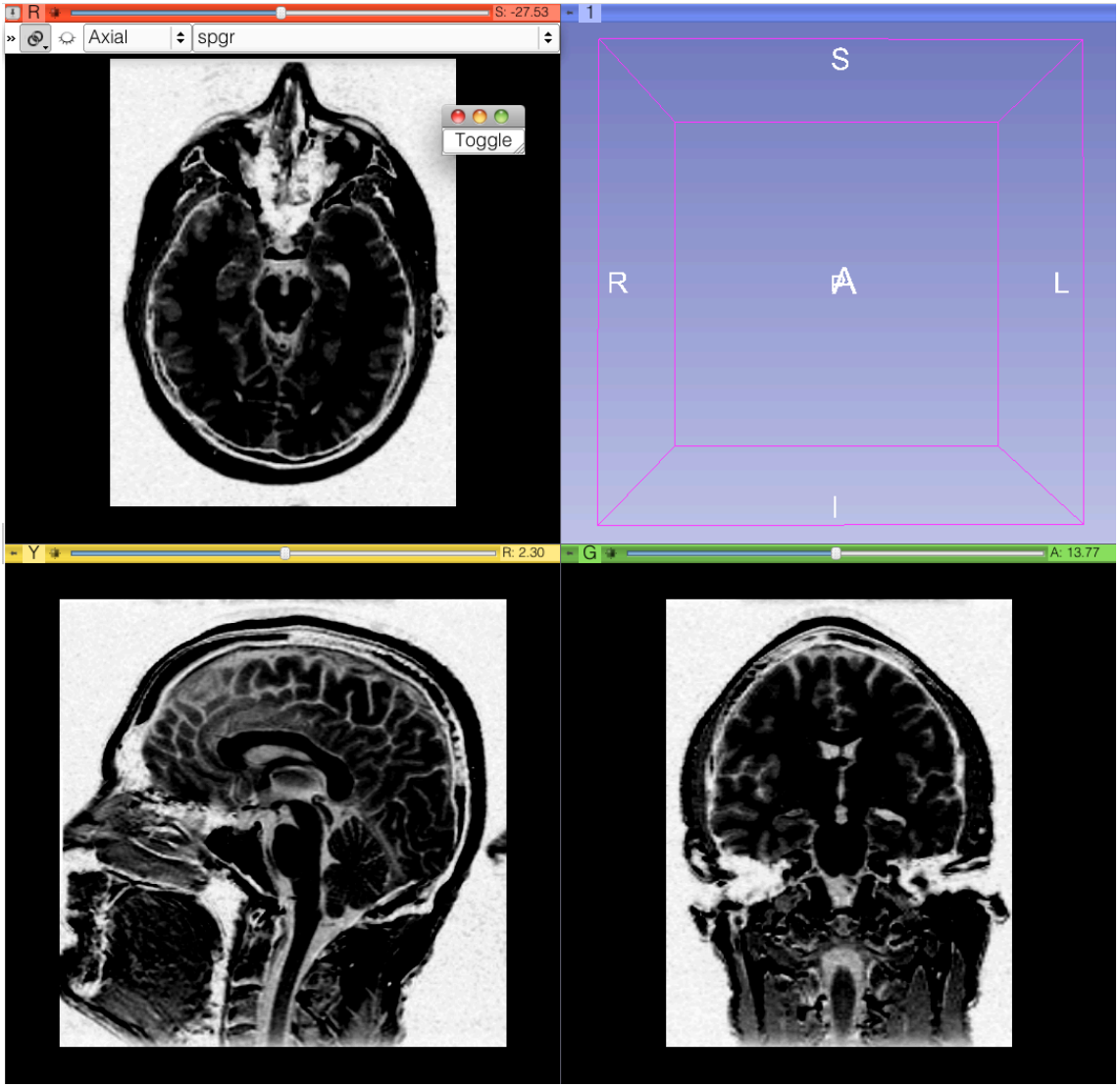
# Qt GUI in Python

Run the following code in the Python console

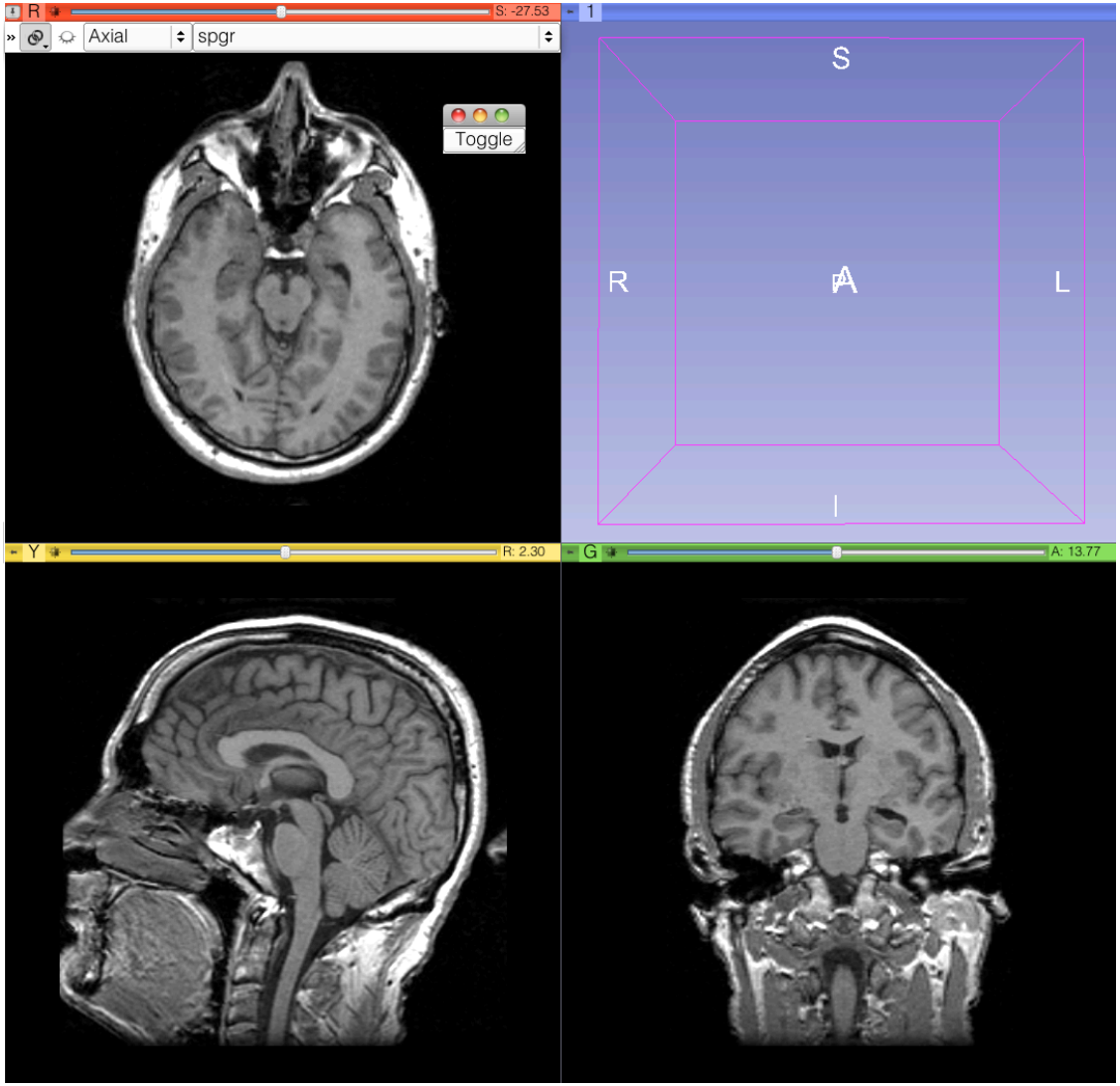
```
b = qt.QPushButton('Toggle')
b.connect('clicked()', toggle)
b.show()
```

What do you think will happen when you run this code? What about when you push the button?

# Result with button toggling



# Result with button toggling

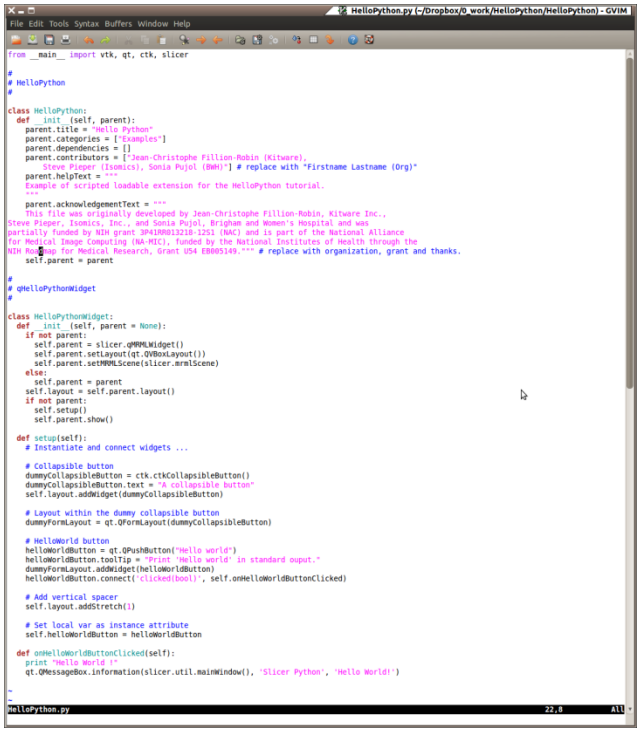


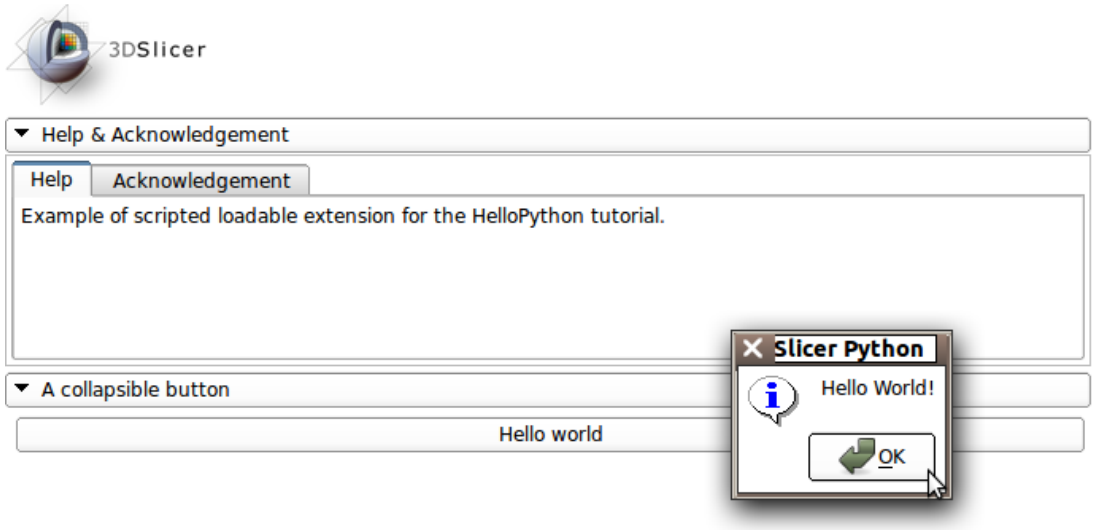
# In More Detail

- Slicer uses **PythonQt** to expose the Qt library

- Sophisticated interactive modules can be written entirely with Python code calling C++ code that is wrapped in Python (e.g. Endoscopy, Editor, SampleData, ChangeTracker, and other slicer modules in the Slicer source code)

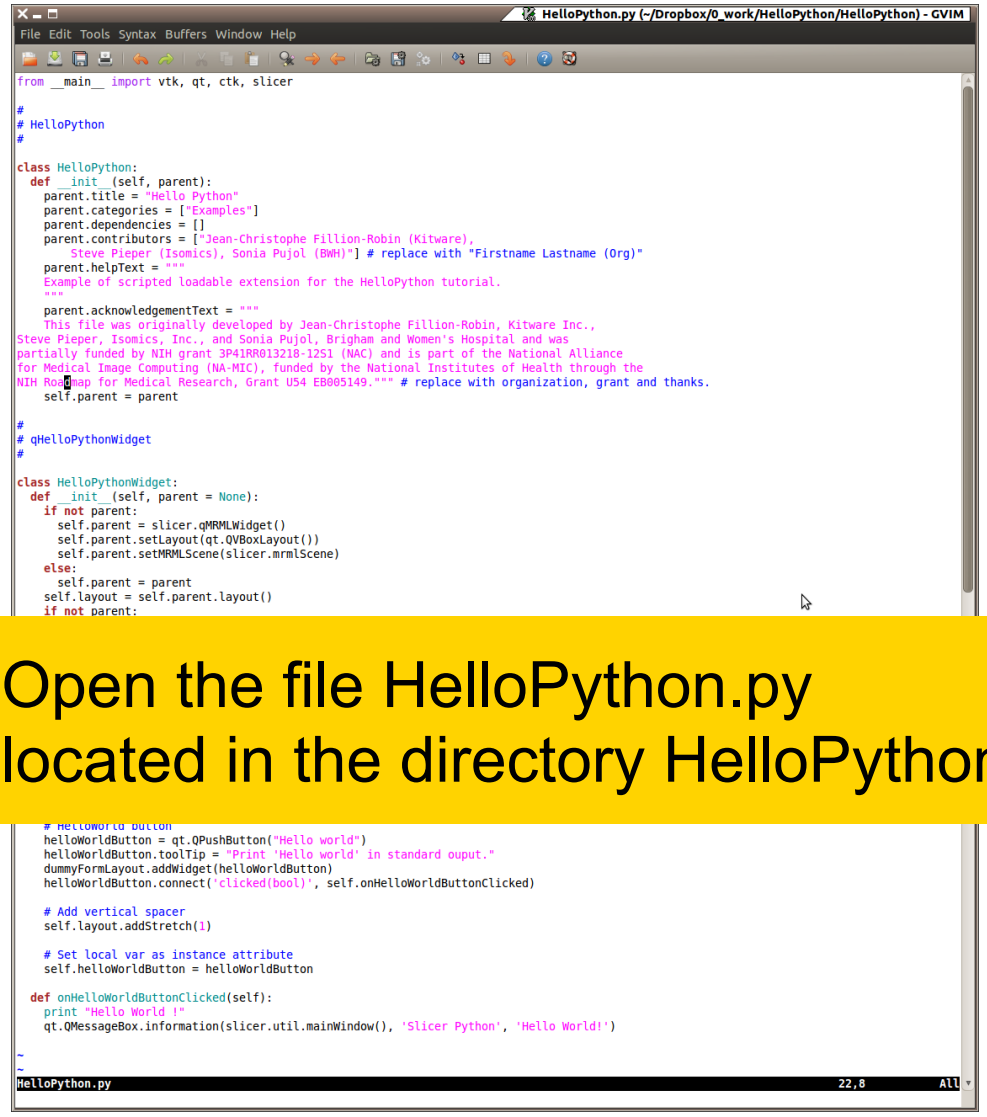
(*) Qt: http://qt.nokia.com
(**) PythonQt: http://pythonqt.sf.net /F.Link (MeVis)




# PART B: INTEGRATION OF THE HELLOPYTHON CODE TO SLICER4

# HelloPython.py




Open the file HelloPython.py
located in the directory HelloPython

# HelloPython.py

Module Description

Module GUI

Processing Code

HelloPython.py (~/Dropbox/0_work/HelloPython/HelloPython) - GVIM

File Edit Tools Syntax Buffers Window Help

```
from __main__ import vtk, qt, ctk, slicer

#
# HelloPython
#

class HelloPython:
  def __init__(self, parent):
    parent.title = "Hello Python"
    parent.categories = ["Examples"]
    parent.dependencies = []
    parent.contributors = ["Jean-Christophe Fillion-Robin (Kitware),
        Steve Pieper (Isomics), Sonia Pujol (BWH)"] # replace with "Firstname Lastname (Org)"
    parent.helpText = """
    Example of scripted loadable extension for the HelloPython tutorial.
    """
    parent.acknowledgementText = """
    This file was originally developed by Jean-Christophe Fillion-Robin, Kitware Inc.,
Steve Pieper, Isomics, Inc., and Sonia Pujol, Brigham and Women's Hospital and was
partially funded by NIH grant 3P41RR013218-12S1 (NAC) and is part of the National Alliance
for Medical Image Computing (NA-MIC), funded by the National Institutes of Health through the
NIH Roadmap for Medical Research, Grant U54 EB005149.""" # replace with organization, grant and thanks.
    self.parent = parent

#
# qHelloPythonWidget
#

class HelloPythonWidget:
  def __init__(self, parent = None):
    if not parent:
      self.parent = slicer.qMRMLWidget()
      self.parent.setLayout(qt.QVBoxLayout())
      self.parent.setMRMLScene(slicer.mrmlScene)
    else:
      self.parent = parent
    self.layout = self.parent.layout()
    if not parent:
      self.setup()
      self.parent.show()

  def setup(self):
    # Instantiate and connect widgets ...

    # Collapsible button
    dummyCollapsibleButton = ctk.ctkCollapsibleButton()
    dummyCollapsibleButton.text = "A collapsible button"
    self.layout.addWidget(dummyCollapsibleButton)

    # Layout within the dummy collapsible button
    dummyFormLayout = qt.QFormLayout(dummyCollapsibleButton)

    # HelloWorld button
    helloWorldButton = qt.QPushButton("Hello world")
    helloWorldButton.toolTip = "Print 'Hello world' in standard ouput."
    dummyFormLayout.addWidget(helloWorldButton)
    helloWorldButton.connect('clicked(bool)', self.onHelloWorldButtonClicked)

    # Add vertical spacer
    self.layout.addStretch(1)

    # Set local var as instance attribute
    self.helloWorldButton = helloWorldButton

  def onHelloWorldButtonClicked(self):
    print "Hello World !"
    qt.QMessageBox.information(slicer.util.mainWindow(), 'Slicer Python', 'Hello World!')

~
~
HelloPython.py                                    22,8          All
```

# Module Description

This code is provided in the template

```
class HelloPython:
  def __init__(self, parent):
    parent.title = "Hello Python"
    parent.categories = ["Examples"]
    parent.dependencies = []
    parent.contributors = ["Jean-Christophe Fillion-Robin (Kitware)",
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partially funded by NIH grant 3P41RR013218-12S1 (NAC) and is part of the National Alliance
for Medical Image Computing (NA-MIC), funded by the National Institutes of Health through
the NIH Roadmap for Medical Research, Grant U54 EB005149.""" # replace with organization,
grant and thanks.
    self.parent = parent
```

constructor

# Module GUI

Add this Text in section A

```
def setup(self):
  # Instantiate and connect widgets ...

  # Collapsible button
  sampleCollapsibleButton = ctk.ctkCollapsibleButton()
  sampleCollapsibleButton.text = "A collapsible button"
  self.layout.addWidget(sampleCollapsibleButton)

  # Layout within the sample collapsible button
  sampleFormLayout = qt.QFormLayout(sampleCollapsibleButton)

  # HelloWorld button
  helloWorldButton = qt.QPushButton("Hello world")
  helloWorldButton.toolTip = "Print 'Hello world' in standard ouput."
  sampleFormLayout.addWidget(helloWorldButton)
  helloWorldButton.connect('clicked(bool)', self.onHelloWorldButtonClicked)

  # Add vertical spacer
  self.layout.addStretch(1)

  # Set local var as instance attribute
  self.helloWorldButton = helloWorldButton
```

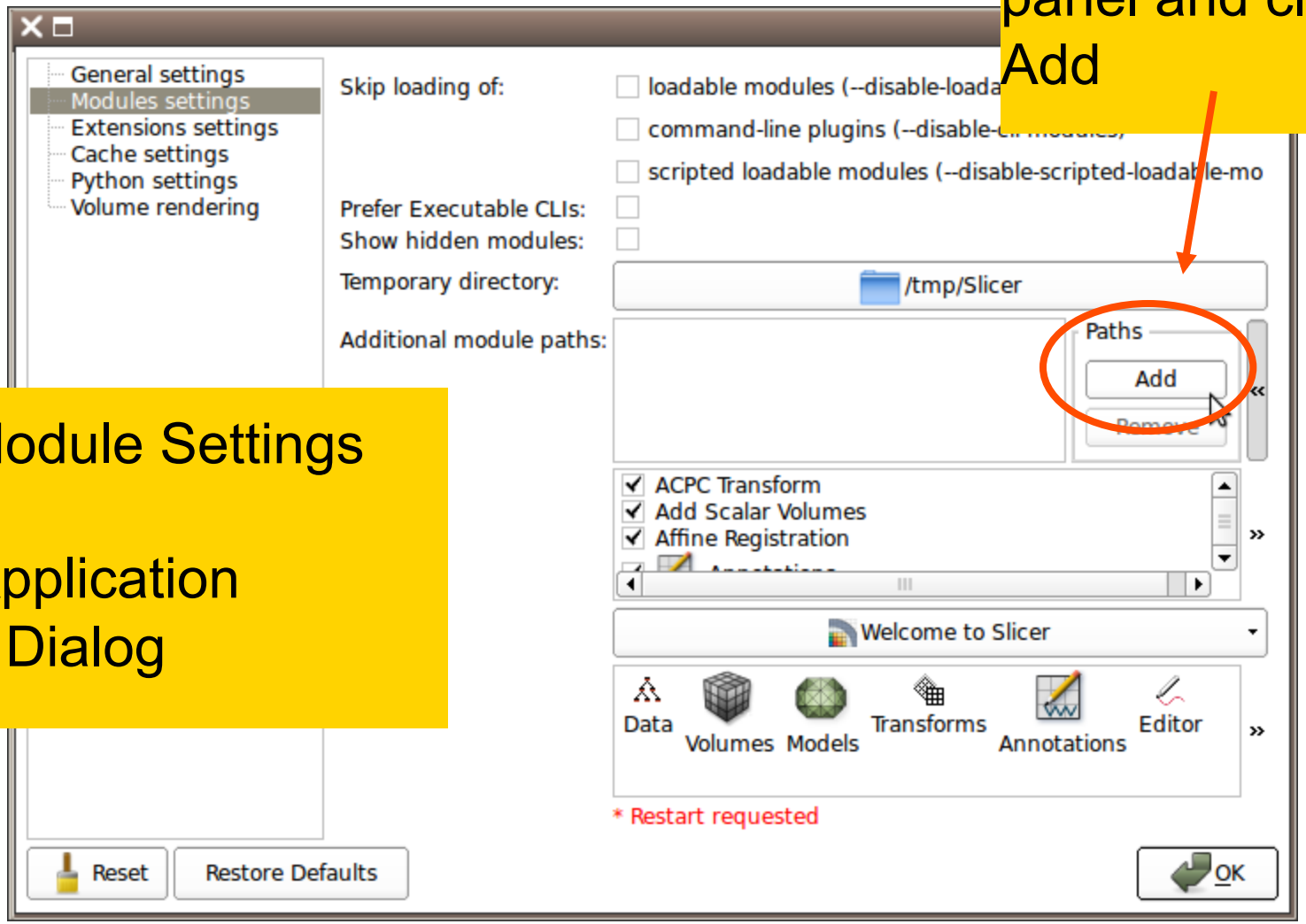
# Processing Code

```
def onHelloWorldButtonClicked(self):
  print "Hello World !"
  qt.QMessageBox.information(
    slicer.util.mainWindow(),
    'Slicer Python',
    'Hello World!')
```

Add this Text in section B

# Integrating HelloPython

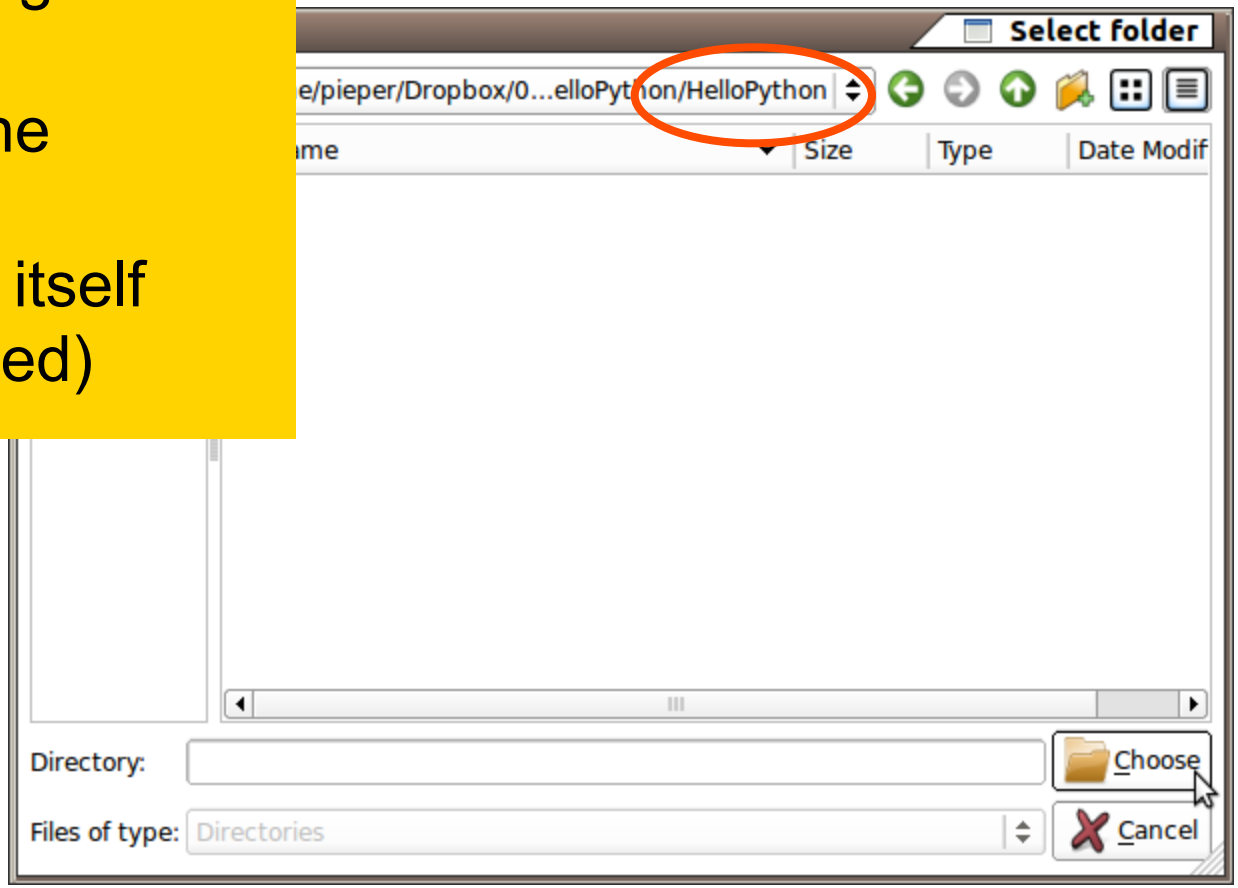
Open the side panel and click Add



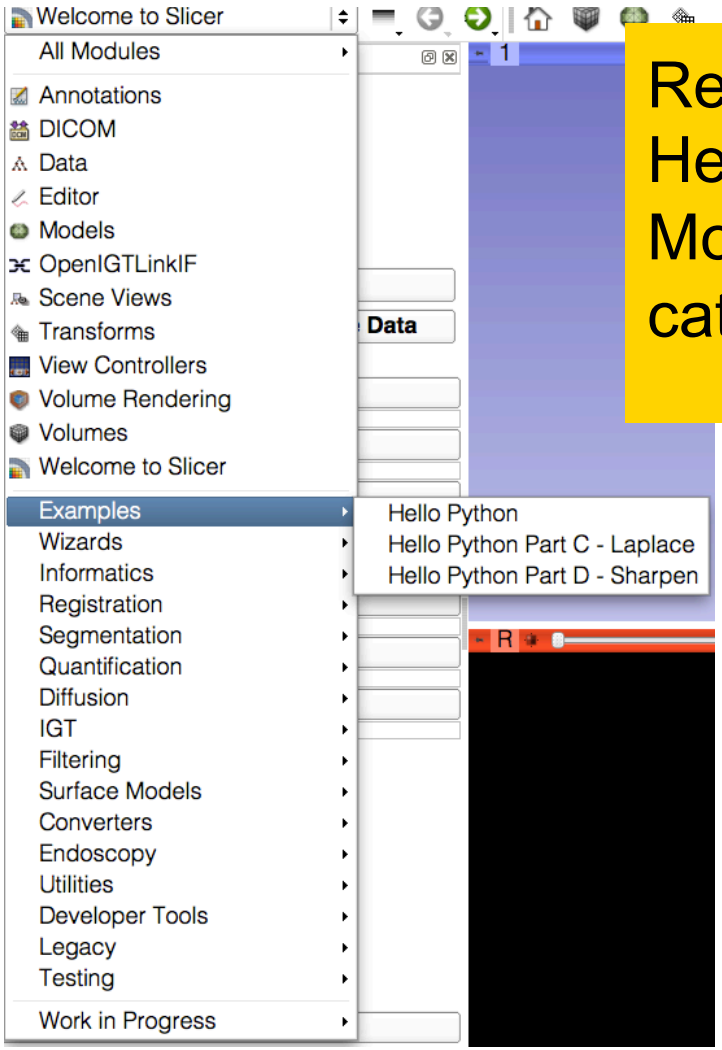

Select Module Settings from the Edit -> Application Settings Dialog

# Integrating HelloPython

Add the path to the directory containing HelloPython.py (when selecting the directory, the HelloWorld.py file itself will not be displayed)

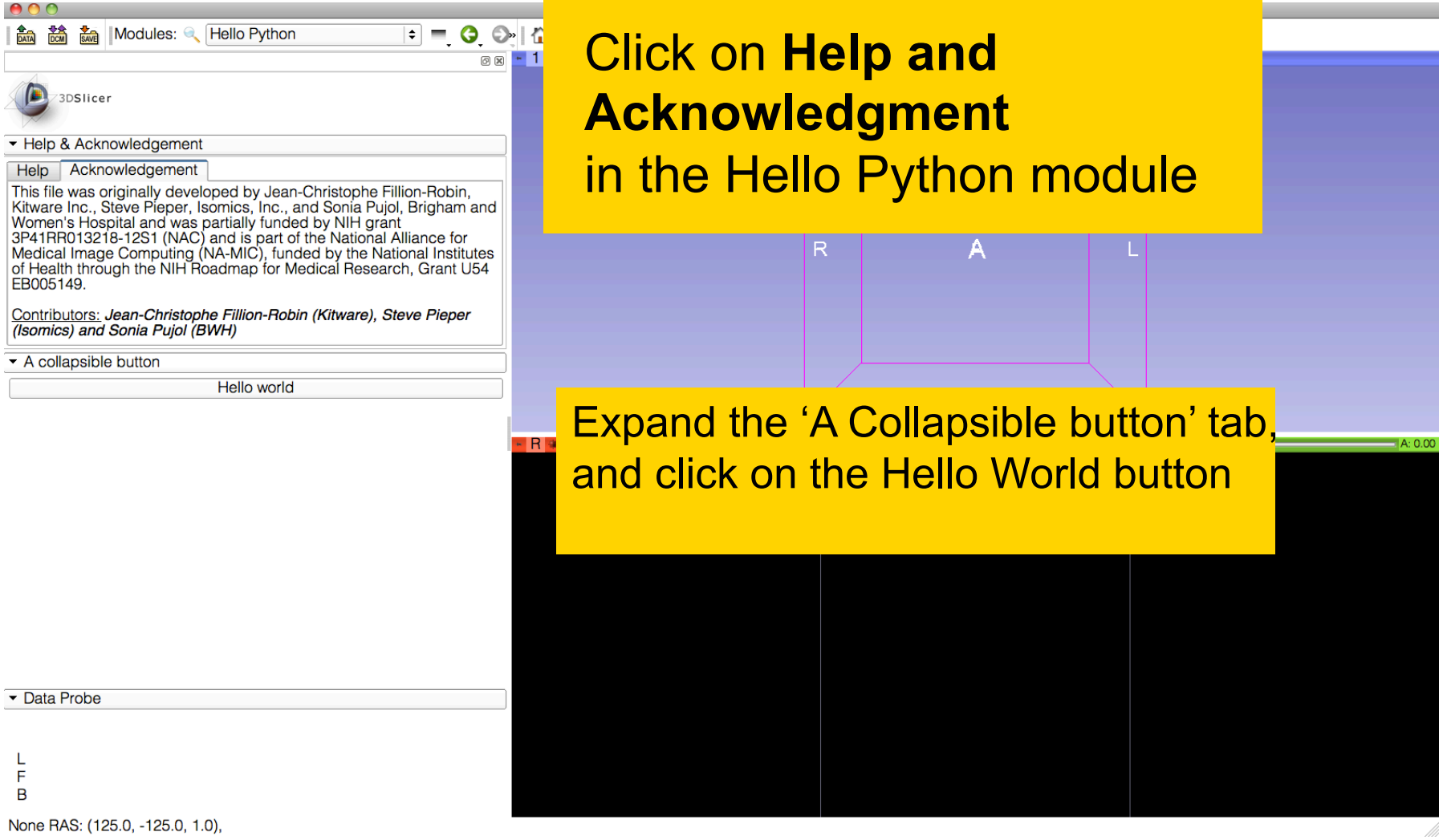


# HelloPython in Slicer



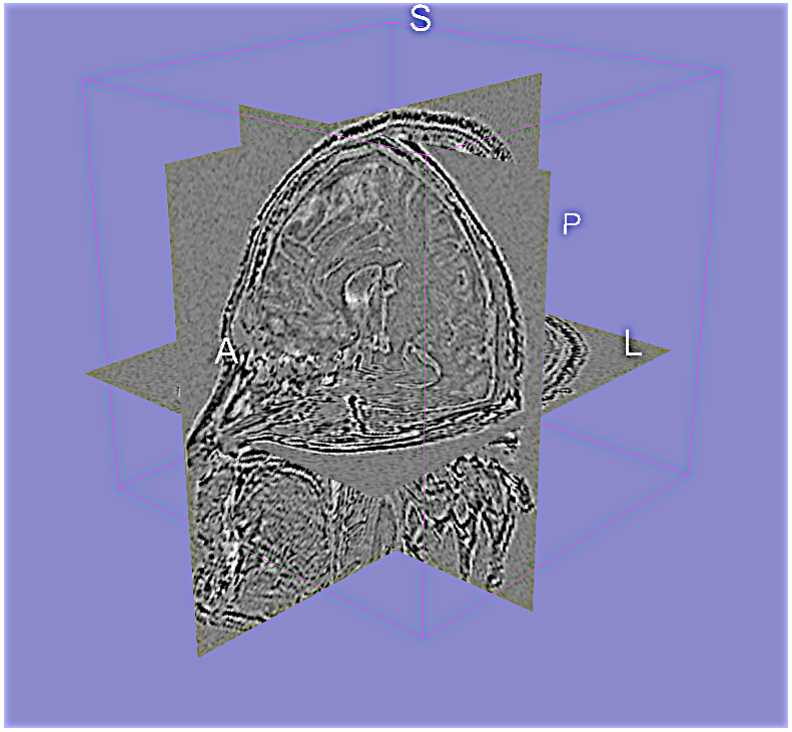

Restart Slicer when prompted. Hello Python is now in the Modules Menu, under the category **Examples**

# HelloPython in Slicer




Click on **Help and Acknowledgment** in the Hello Python module

Expand the ‘A Collapsible button’ tab, and click on the Hello World button



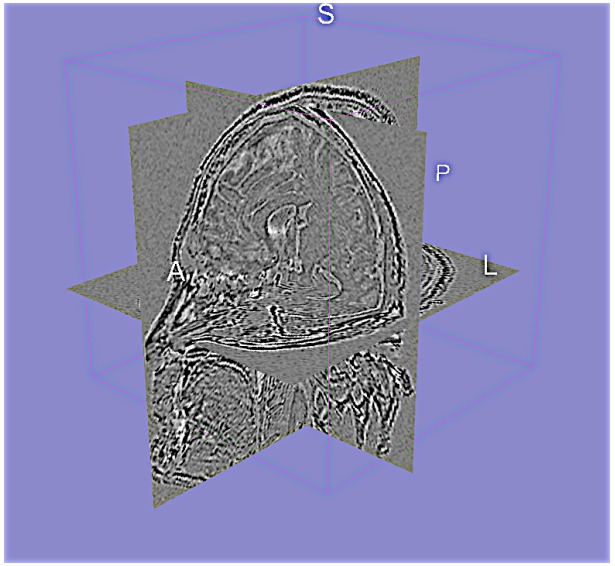

# Part C:

# Implementing the Laplace* Operator

*named after Pierre-Simon, Marquis de Laplace (1749-1827)

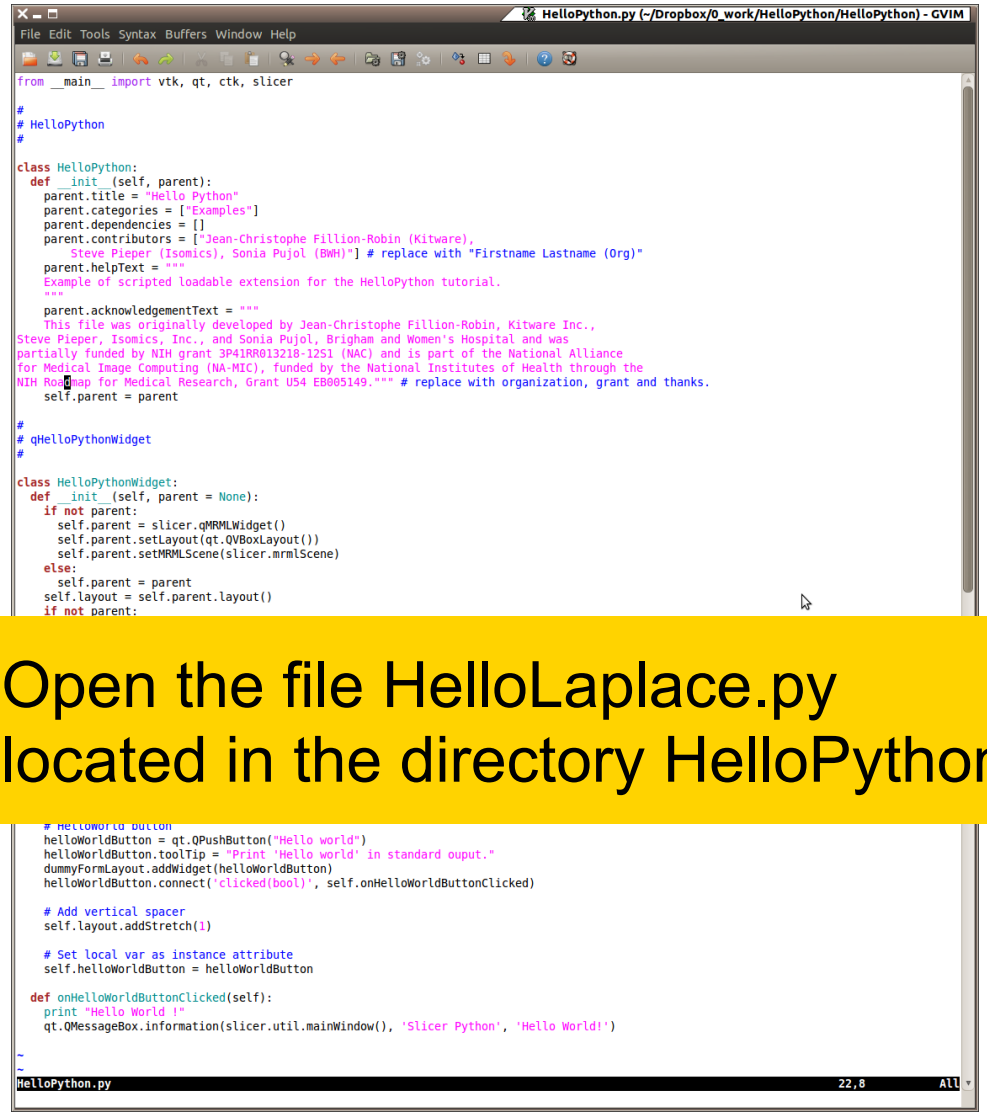
# Overview

The goal of this section is  to build an image analysis module that implements a Laplacian filter on volume data




- Use qMRML widgets: widgets that automatically track the state of the Slicer MRML scene
- Use VTK filters to manipulate volume data

# HelloLaplace.py




Open the file HelloLaplace.py
located in the directory HelloPython

# Module GUI (Part 1)

This code is provided in the template

```
def setup(self):
  # Collapsible button
  self.laplaceCollapsibleButton = ctk.ctkCollapsibleButton()
  self.laplaceCollapsibleButton.text = "Laplace Operator"
  self.layout.addWidget(self.laplaceCollapsibleButton)

  # Layout within the laplace collapsible button
  self.laplaceFormLayout = qt.QFormLayout(self.laplaceCollapsibleButton)

  # the volume selectors
  self.inputFrame = qt.QFrame(self.laplaceCollapsibleButton)
  self.inputFrame.setLayout(qt.QHBoxLayout())
  self.laplaceFormLayout.addWidget(self.inputFrame)
  self.inputSelector = qt.QLabel("Input Volume: ", self.inputFrame)
  self.inputFrame.layout().addWidget(self.inputSelector)
  self.inputSelector = slicer.qMRMLNodeComboBox(self.inputFrame)
  self.inputSelector.nodeTypes = ( ("vtkMRMLScalarVolumeNode"), "" )
  self.inputSelector.addEnabled = False
  self.inputSelector.removeEnabled = False
  self.inputSelector.setMRMLScene( slicer.mrmlScene )
  self.inputFrame.layout().addWidget(self.inputSelector)
```

# Module GUI (Part 2)

This code is provided in the template

```
self.outputFrame = qt.QFrame(self.laplaceCollapsibleButton)
self.outputFrame.setLayout(qt.QHBoxLayout())
self.laplaceFormLayout.addWidget(self.outputFrame)
self.outputSelector = qt.QLabel("Output Volume: ", self.outputFrame)
self.outputFrame.layout().addWidget(self.outputSelector)
self.outputSelector = slicer.qMRMLNodeComboBox(self.outputFrame)
self.outputSelector.nodeTypes = ( ("vtkMRMLScalarVolumeNode"), "" )
self.outputSelector.setMRMLScene( slicer.mrmlScene )
self.outputFrame.layout().addWidget(self.outputSelector)

# Apply button
laplaceButton = qt.QPushButton("Apply Laplace")
laplaceButton.toolTip = "Run the Laplace Operator."
self.laplaceFormLayout.addWidget(laplaceButton)
laplaceButton.connect('clicked(bool)', self.onApply)

# Add vertical spacer
self.layout.addStretch(1)

# Set local var as instance attribute
self.laplaceButton = laplaceButton
```

# In More Detail

- **CTK i**s a Qt Add-On Library with many useful widgets, particularly for visualization and medical imaging see http://commontk.org
- **Qt Widgets, Layouts**, and Options are well documented at http://qt.nokia.com
- **qMRMLNodeComboBox** is a powerful slicer widget that monitors the scene and allows you to select/ create nodes of specified types (*example: here we use Volumes = vtkMRMLScalarVolumeNode)*

# Processing Code

Add this code

```
def onApply(self):
  inputVolume = self.inputSelector.currentNode()
  outputVolume = self.outputSelector.currentNode()
  if not (inputVolume and outputVolume):
    qt.QMessageBox.critical(slicer.util.mainWindow(),
        'Laplace', 'Input and output volumes are required for Laplacian')
    return
  laplacian = vtk.vtkImageLaplacian()
  laplacian.SetInput(inputVolume.GetImageData())
  laplacian.SetDimensionality(3)
  laplacian.GetOutput().Update()
  ijkToRAS = vtk.vtkMatrix4x4()
  inputVolume.GetIJKToRASMatrix(ijkToRAS)
  outputVolume.SetIJKToRASMatrix(ijkToRAS)
  outputVolume.SetAndObserveImageData(laplacian.GetOutput())
  # make the output volume appear in all the slice views
  selectionNode = slicer.app.applicationLogic().GetSelectionNode()
  selectionNode.SetReferenceActiveVolumeID(outputVolume.GetID())
  slicer.app.applicationLogic().PropagateVolumeSelection(0)
```

# In More Detail

- **vtkImageLaplacian** is a vtkImageAlgorithm operates on vtkImageData (see http://vtk.org)

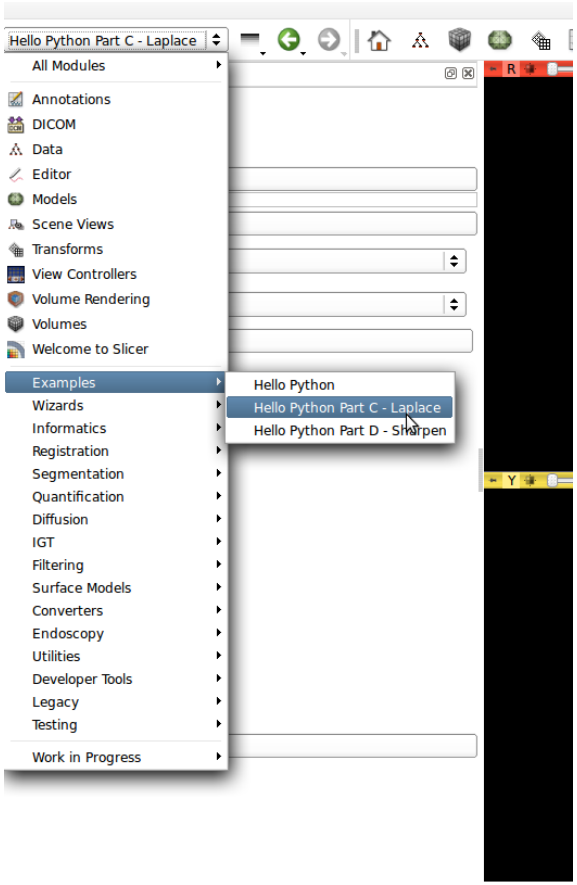
- **vtkMRMLScalarVolumeNode** is a Slicer MRML class that contains vtkImageData, plus orientation information ijkToRAS matrix (see http://www.slicer.org/slicerWiki/index.php/Coordinate_systems)

# In More Detail (Continued)

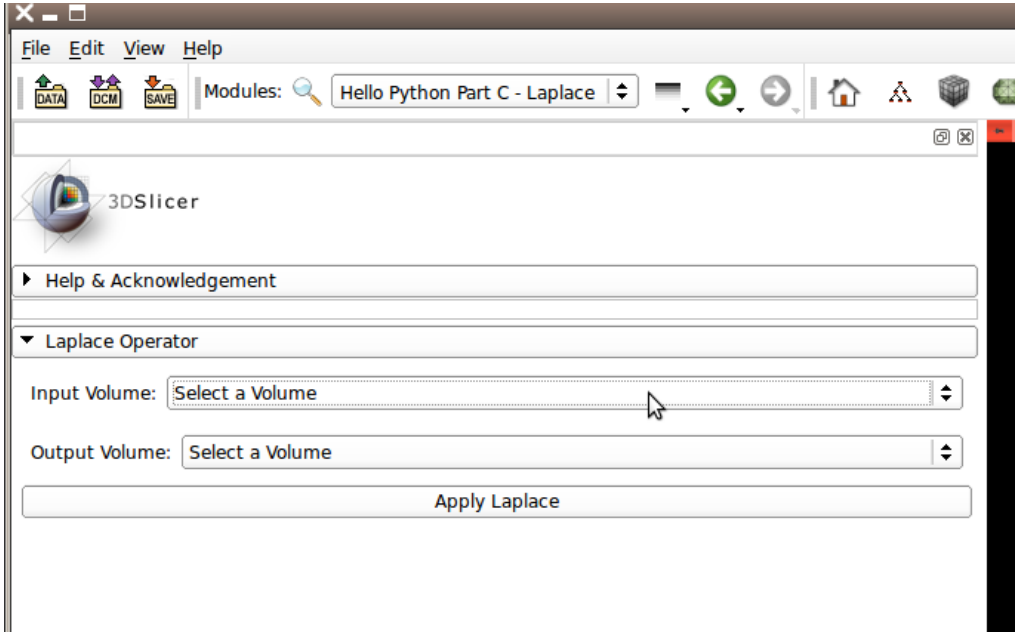
Global **slicer** package gives python access to:
1- GUI (via **slicer.app**)
2- modules (via **slicer.modules**)
3- data (via **slicer.mrmlScene**)

**slicer.app.applicationLogic()** provides helper utilities for manipulating Slicer state

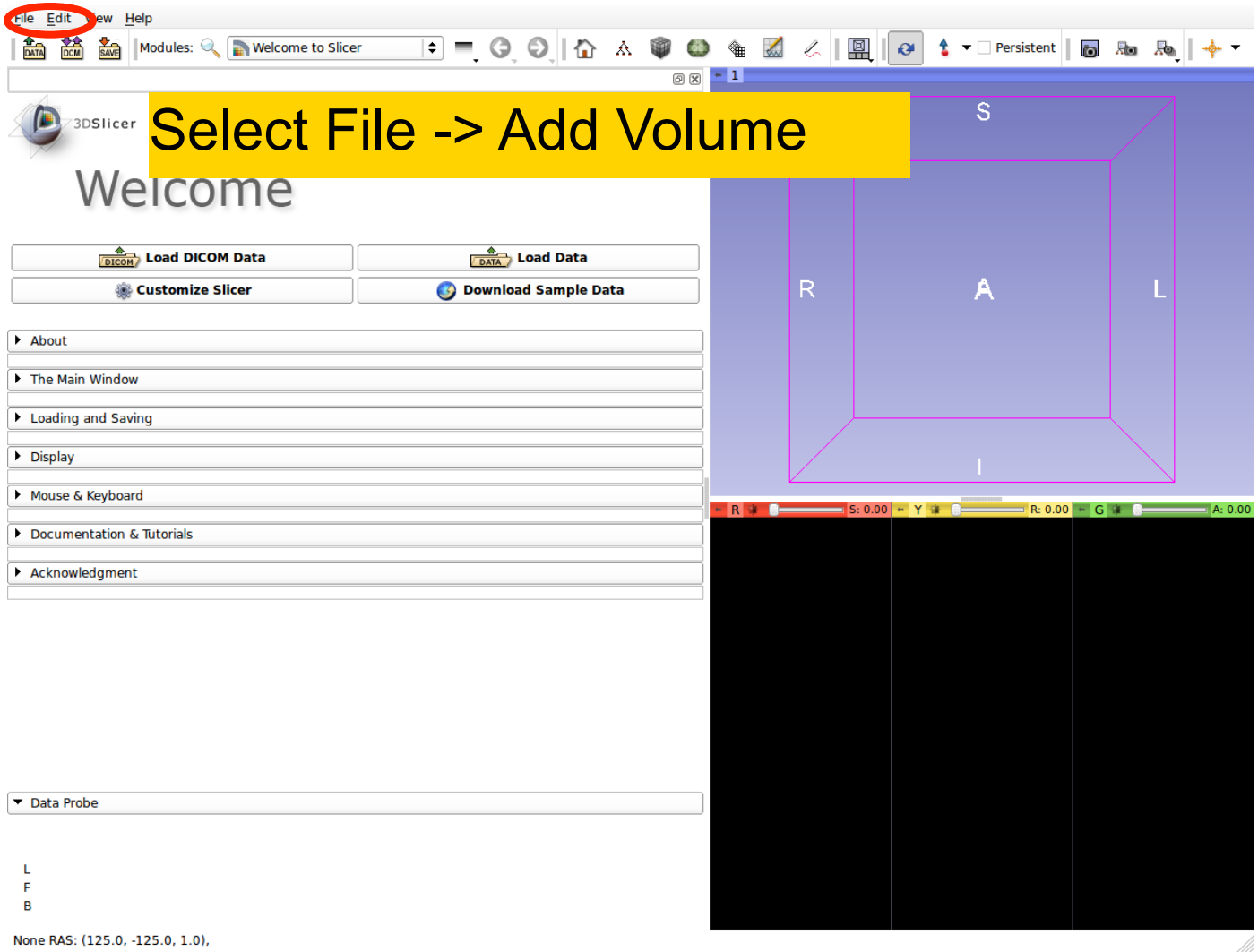
# Go To Laplace Module



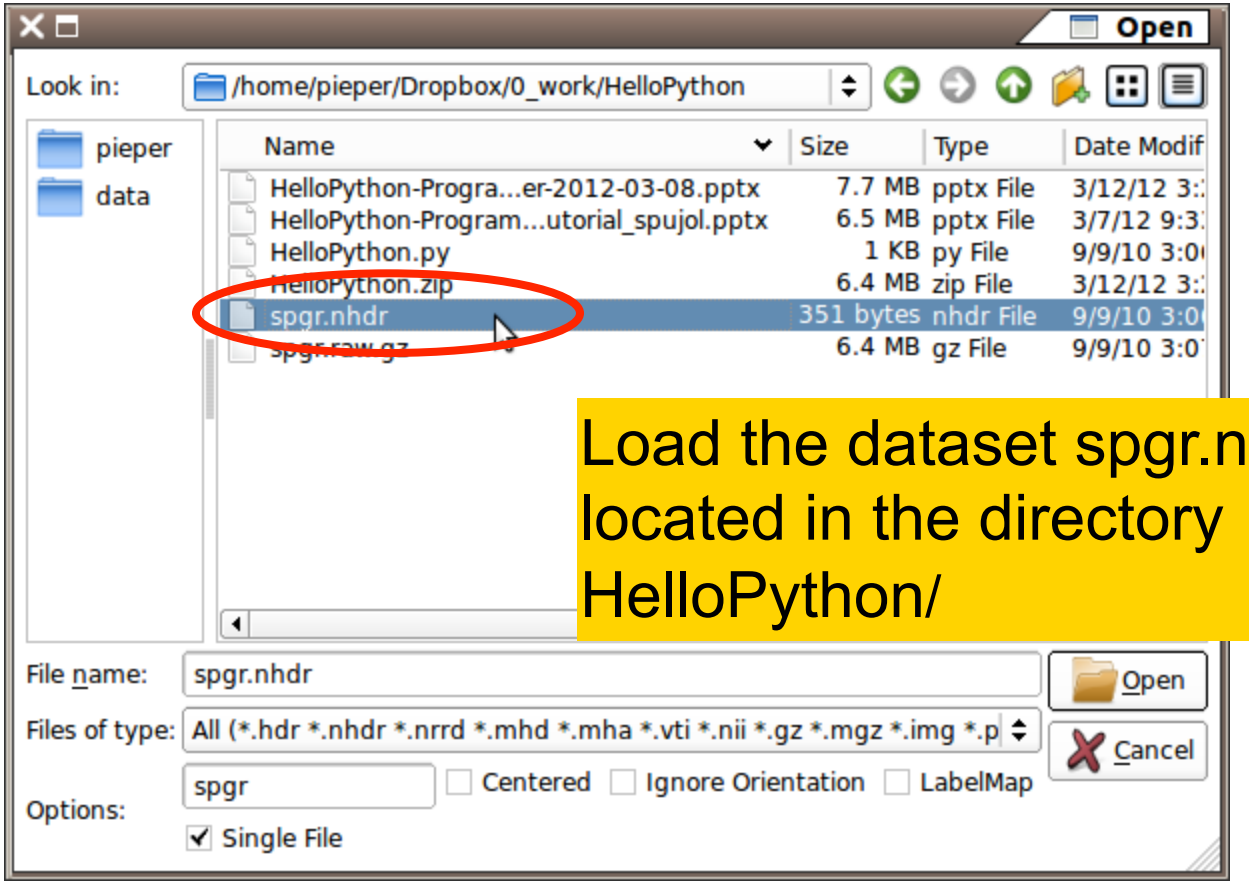

Re-start Slicer and select module. Note that combobox is empty



# Add Volume Dialog

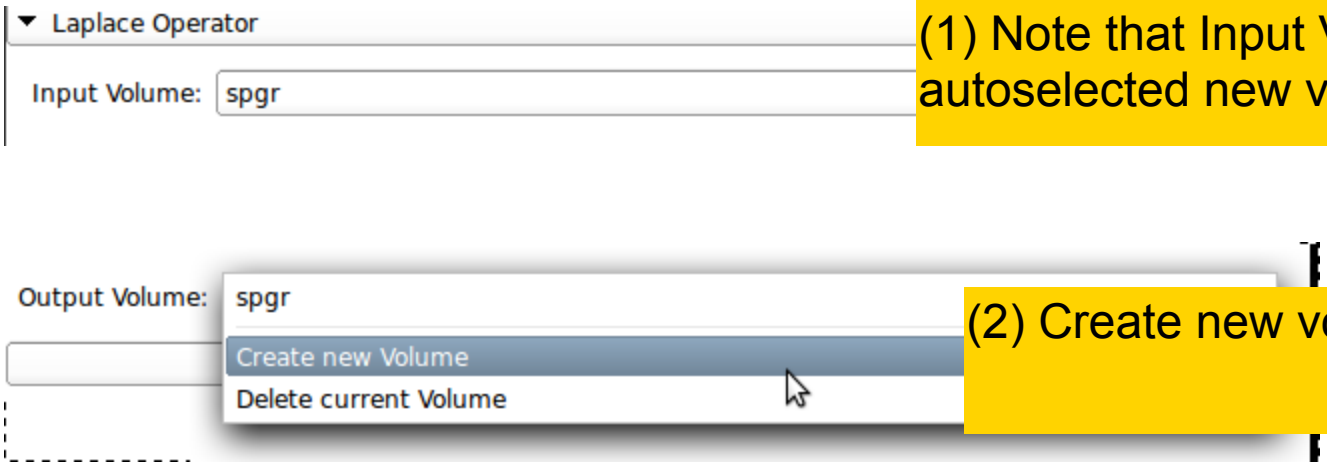


# Add spgr.nhdr



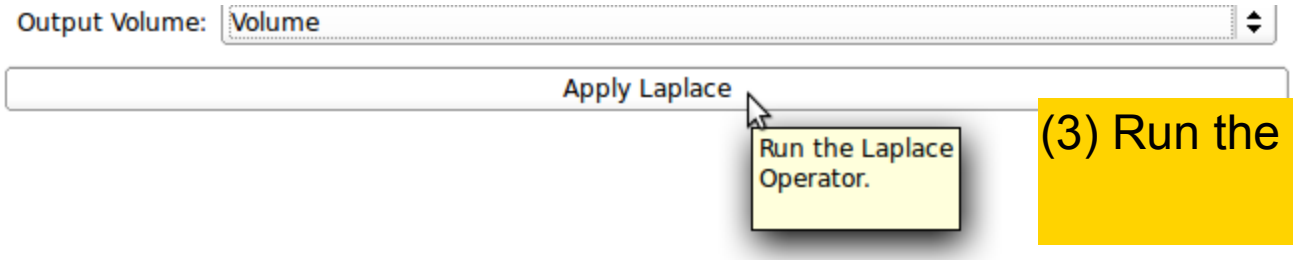

Load the dataset spgr.nhdr located in the directory HelloPython/

# After Adding Volume



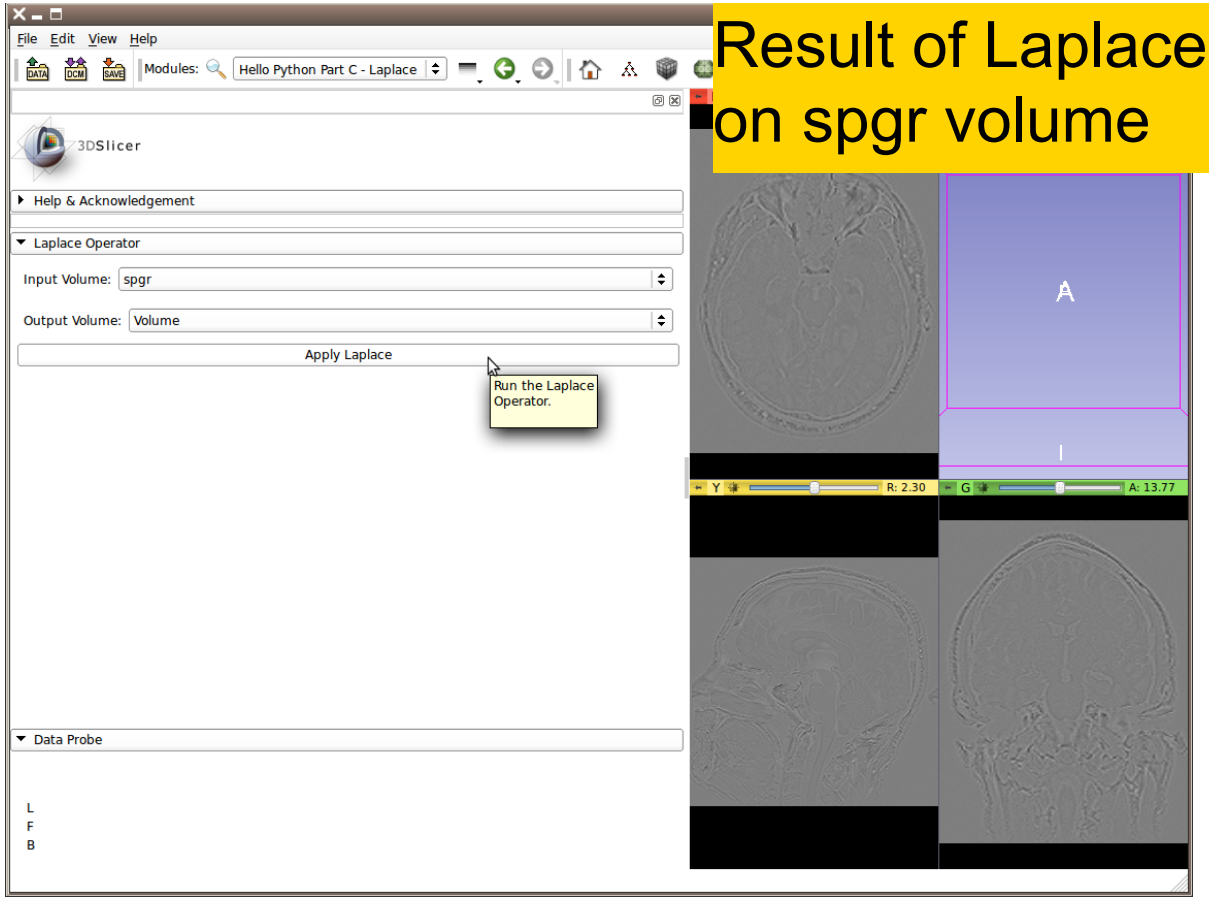

(1) Note that Input Volume combobox autoselected new volume

(2) Create new volume for output

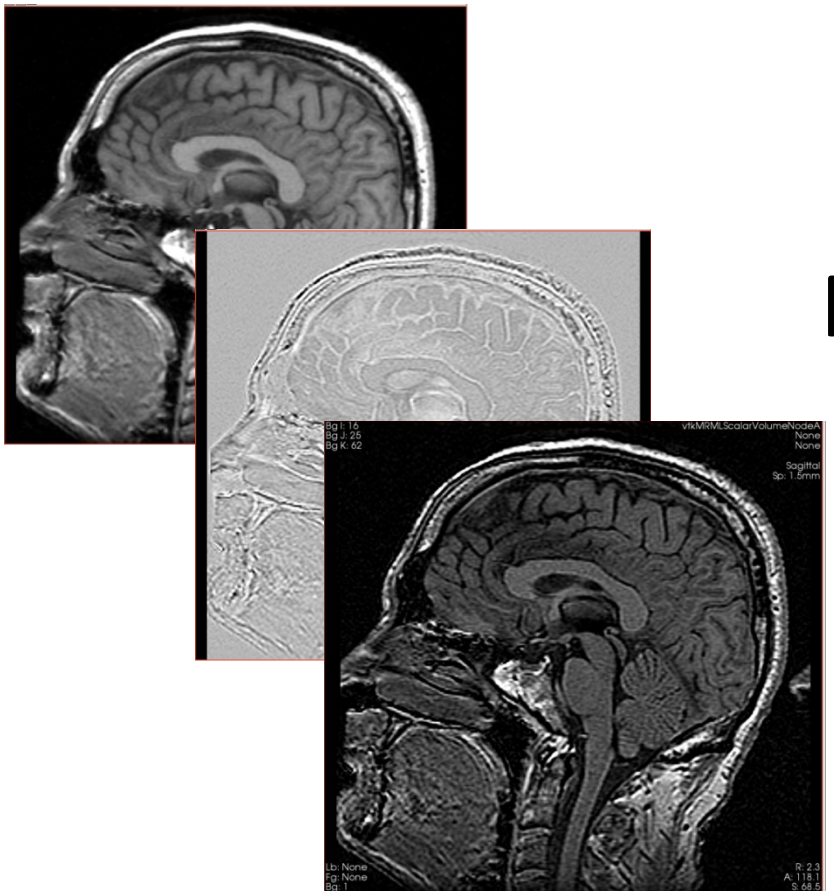



(3) Run the module

# Laplace Module



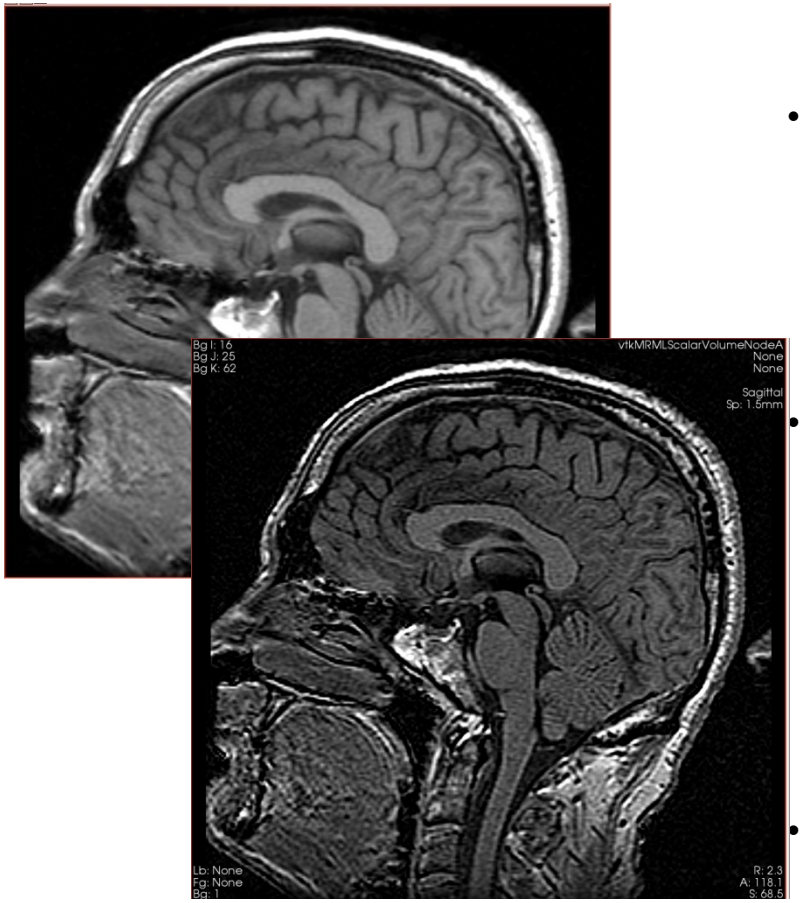

Result of Laplace Operator on spgr volume




# Part D:

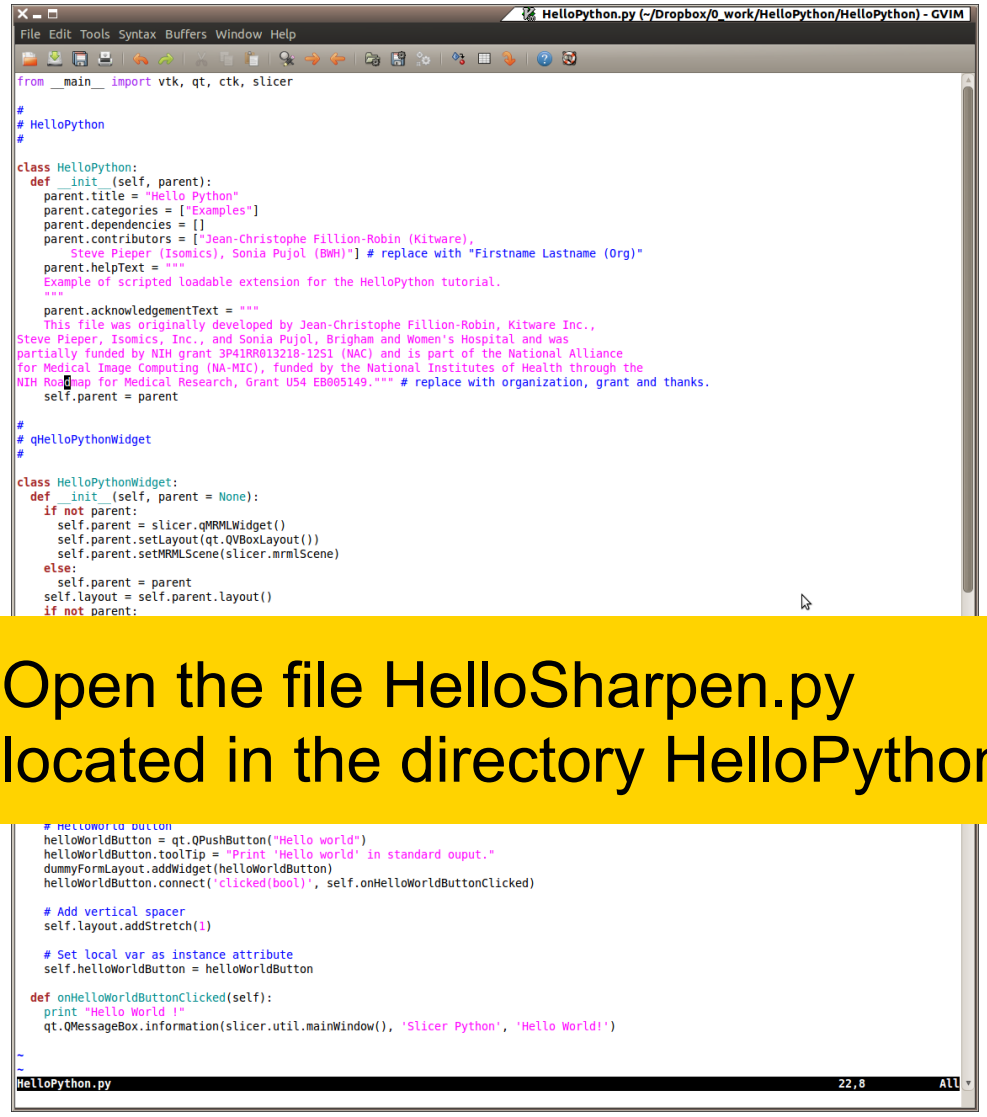
# Image Sharpening with the Laplace Operator

# Overview




- The goal of this section is to add a processing option for image sharpening.
- We'll implement this operation using the existing Slicer Command Line Module
- 'Subtract Scalar Volumes'

# HelloSharpen.py




Open the file HelloSharpen.py
located in the directory HelloPython

# Add to Module GUI

Add this Text in section A

```
...
self.outputSelector.setMRMLScene( slicer.mrmlScene )
self.outputFrame.layout().addWidget(self.outputSelector)

self.sharpen = qt.QCheckBox("Sharpen", self.laplaceCollapsibleButton)
self.sharpen.toolTip = "When checked, subtract laplacian from input volume"
self.sharpen.checked = True
self.laplaceFormLayout.addWidget(self.sharpen)

# Apply button
laplaceButton = qt.QPushButton("Apply")
laplaceButton.toolTip = "Run the Laplace or Sharpen Operator."
...
```

# Add to Processing Code

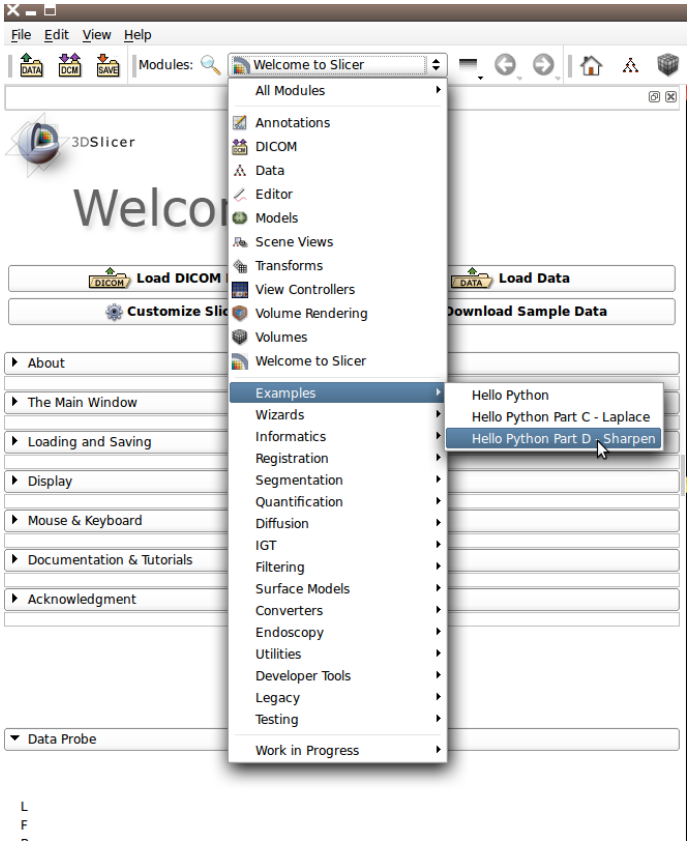
Add this Text in section B

```
    ...
    outputVolume.SetAndObserveImageData(laplacian.GetOutput())
    # optionally subtract laplacian from original image
    if self.sharpen.checked:
      parameters = {}
      parameters['inputVolume1'] = inputVolume.GetID()
      parameters['inputVolume2'] = outputVolume.GetID()
      parameters['outputVolume'] = outputVolume.GetID()
      slicer.cli.run( slicer.modules.subtractscalarvolumes, None,
parameters, wait_for_completion=True )
    # make the output volume appear in all the slice views
    selectionNode = slicer.app.applicationLogic().GetSelectionNode()
    selectionNode.SetReferenceActiveVolumeID(outputVolume.GetID
())
    slicer.app.applicationLogic().PropagateVolumeSelection(0)
```

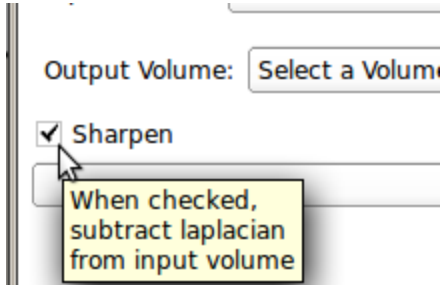
# In More Detail

- **slicer.cli** gives access to Command Line Interface (CLI) modules
- CLI modules allow packaging of arbitrary C++ code (often ITK-based) into slicer with automatically generated GUI and python wrapping

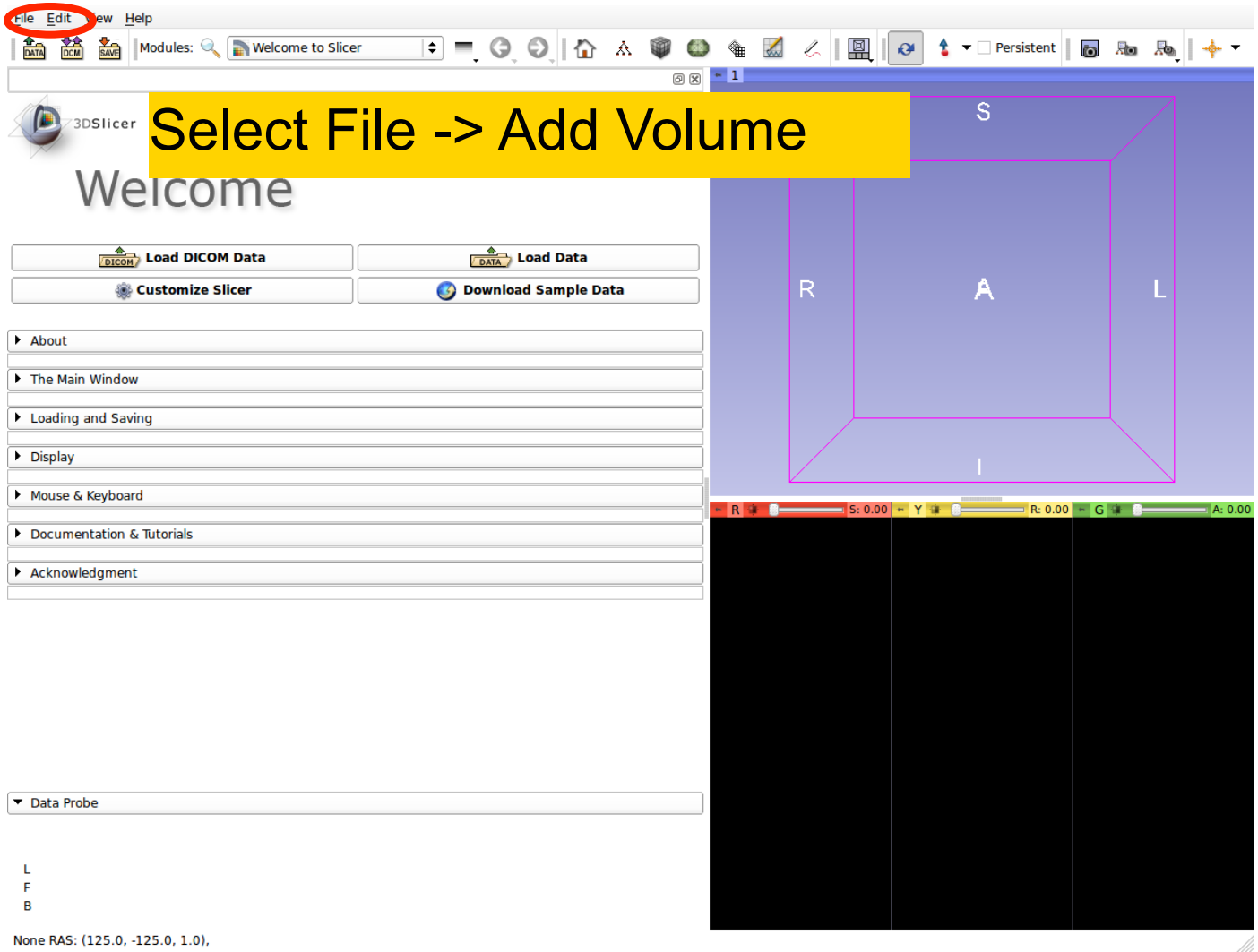
# Go To Sharpen Module



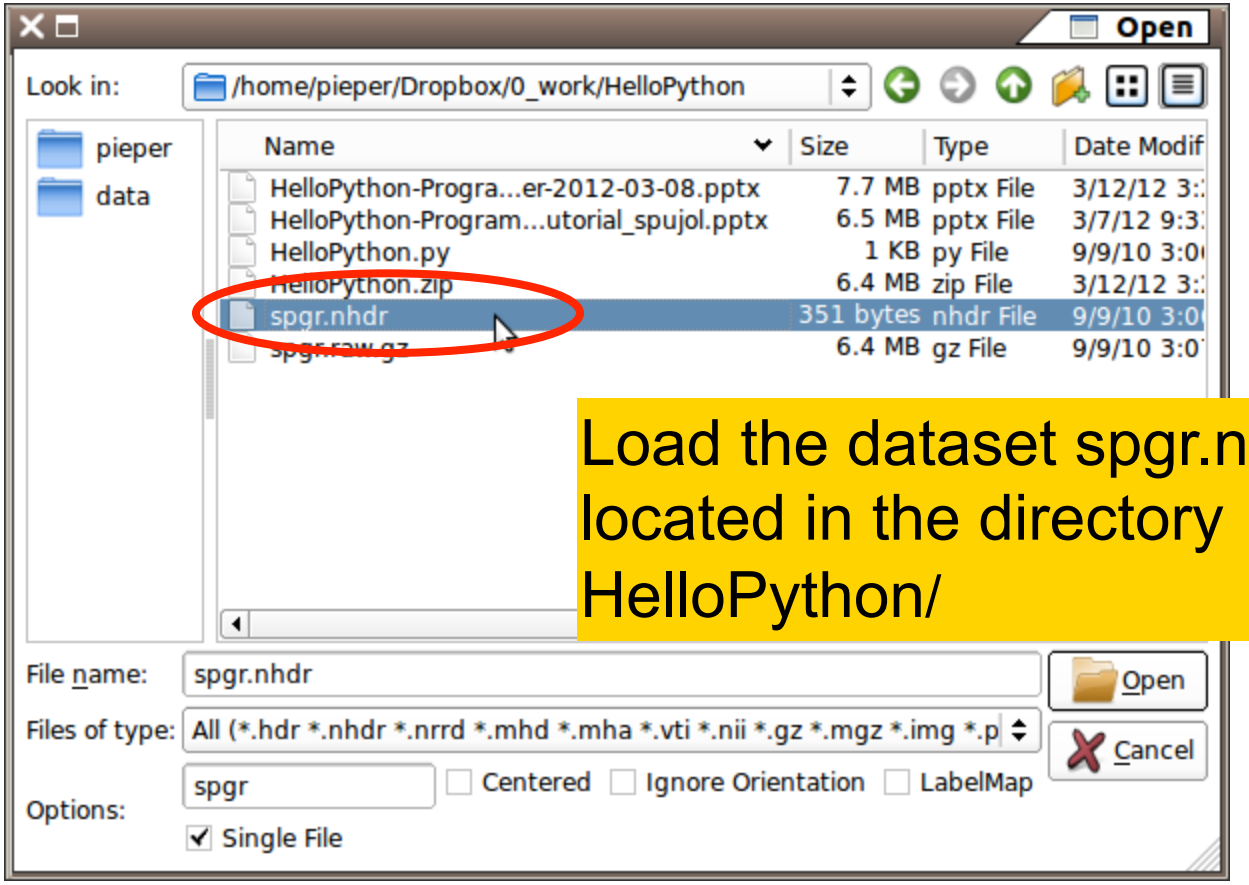

Re-start Slicer and select module. Note the new sharpen check box



# Add Volume Dialog



# Add spgr.nhdr

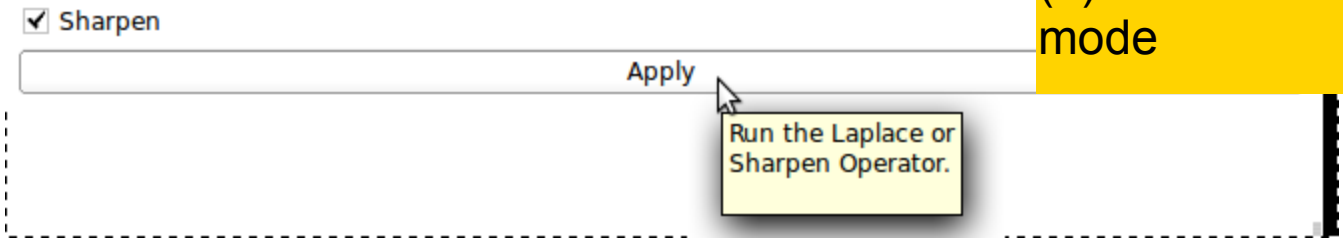



Load the dataset spgr.nhdr located in the directory HelloPython/

# After Adding Volume

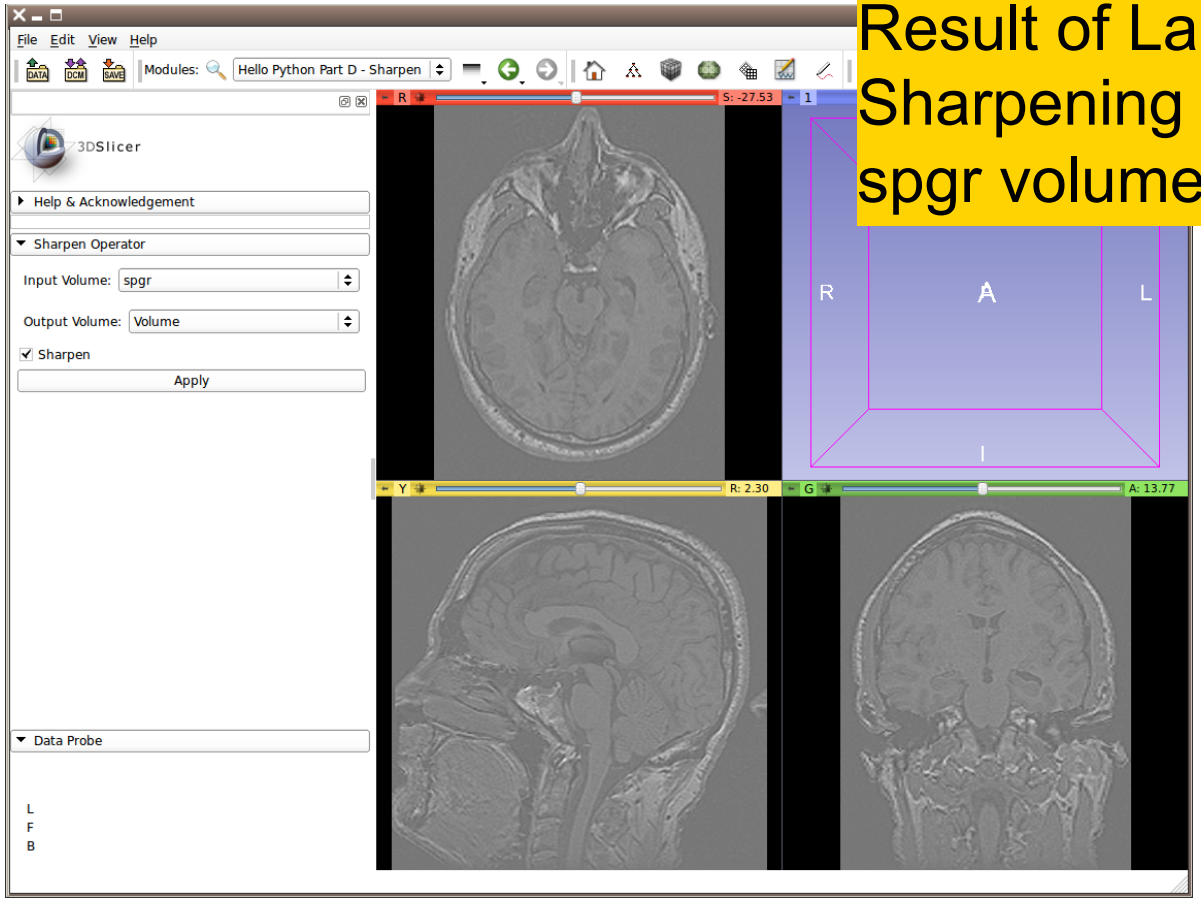

(1) Note that Input Volume combobox autoselected new volume


(2) Create new volume for output



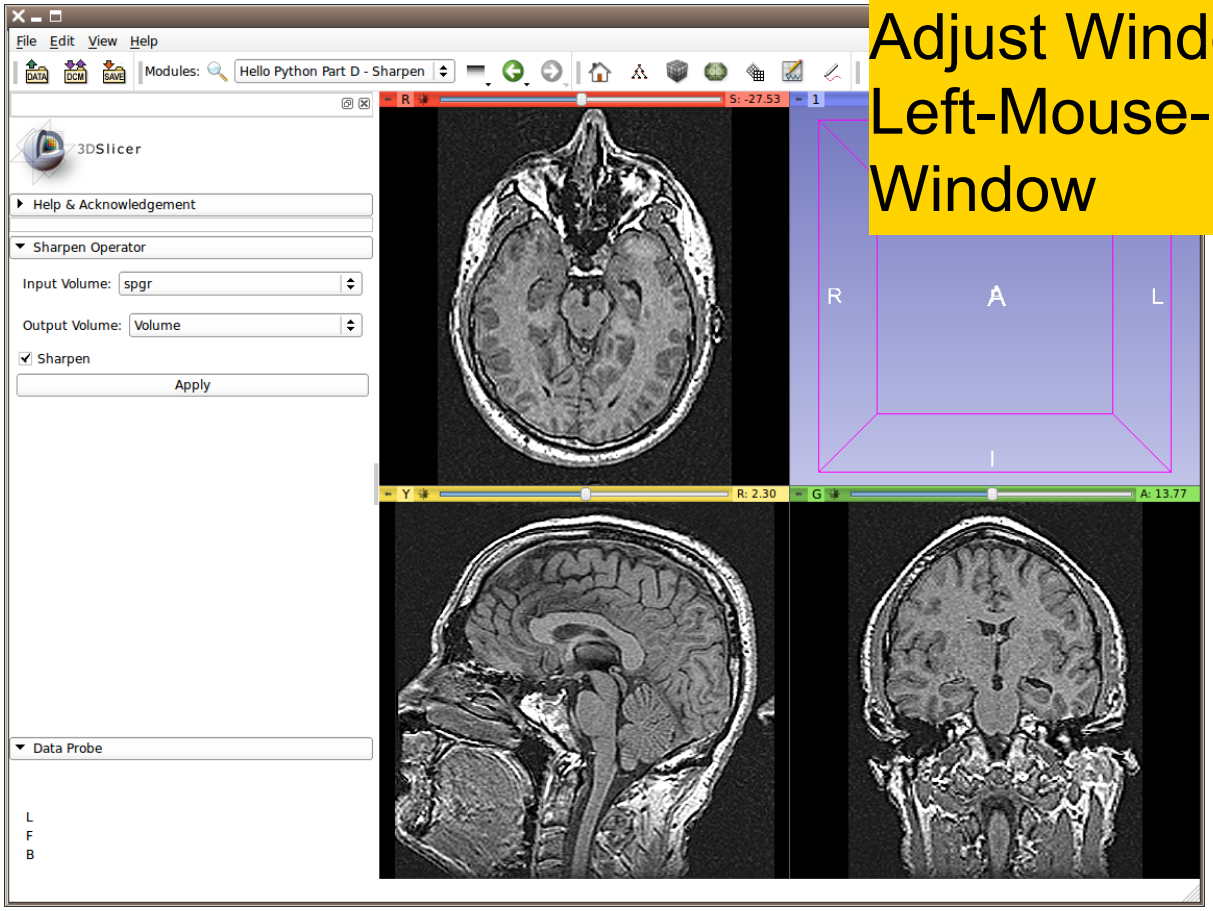

(3) Run the module in Sharpen mode

# Sharpen Module




Result of Laplacian Sharpening Operator on spgr volume

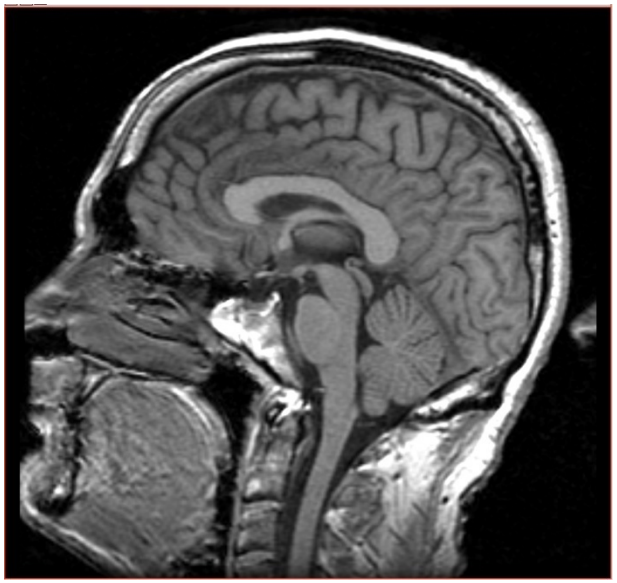
# Sharpen Module



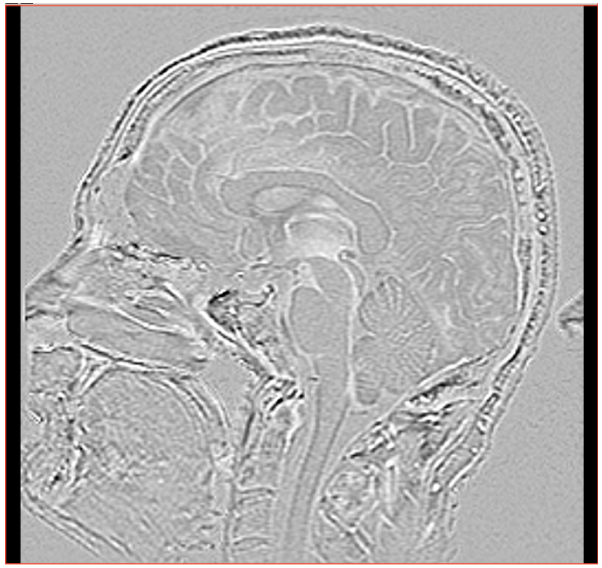

Adjust Window/Level with Left-Mouse-Drag in Slice Window

# Image Sharpening

original



Laplacian



Laplacian filtered

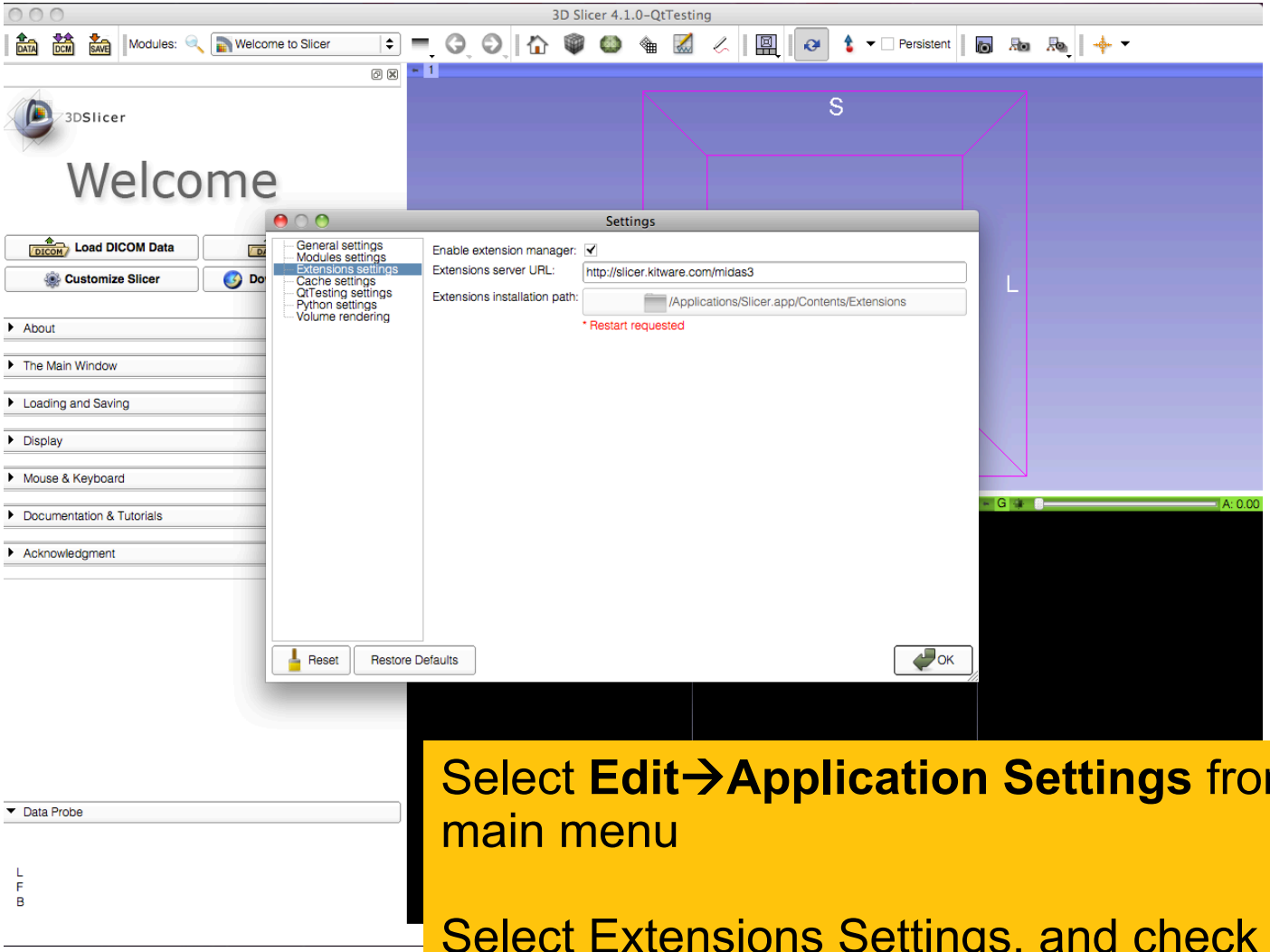
# Going Further

- Explore numpy for numerical array manipulation
- Review Endoscopy Module for interactive data exploration using MRML and VTK
- See the Editor Module for interactive segmentation examples
- Explore SimpleITK for image processing using ITK

# Conclusion

This course demonstrated how to program custom behavior in Slicer with Python

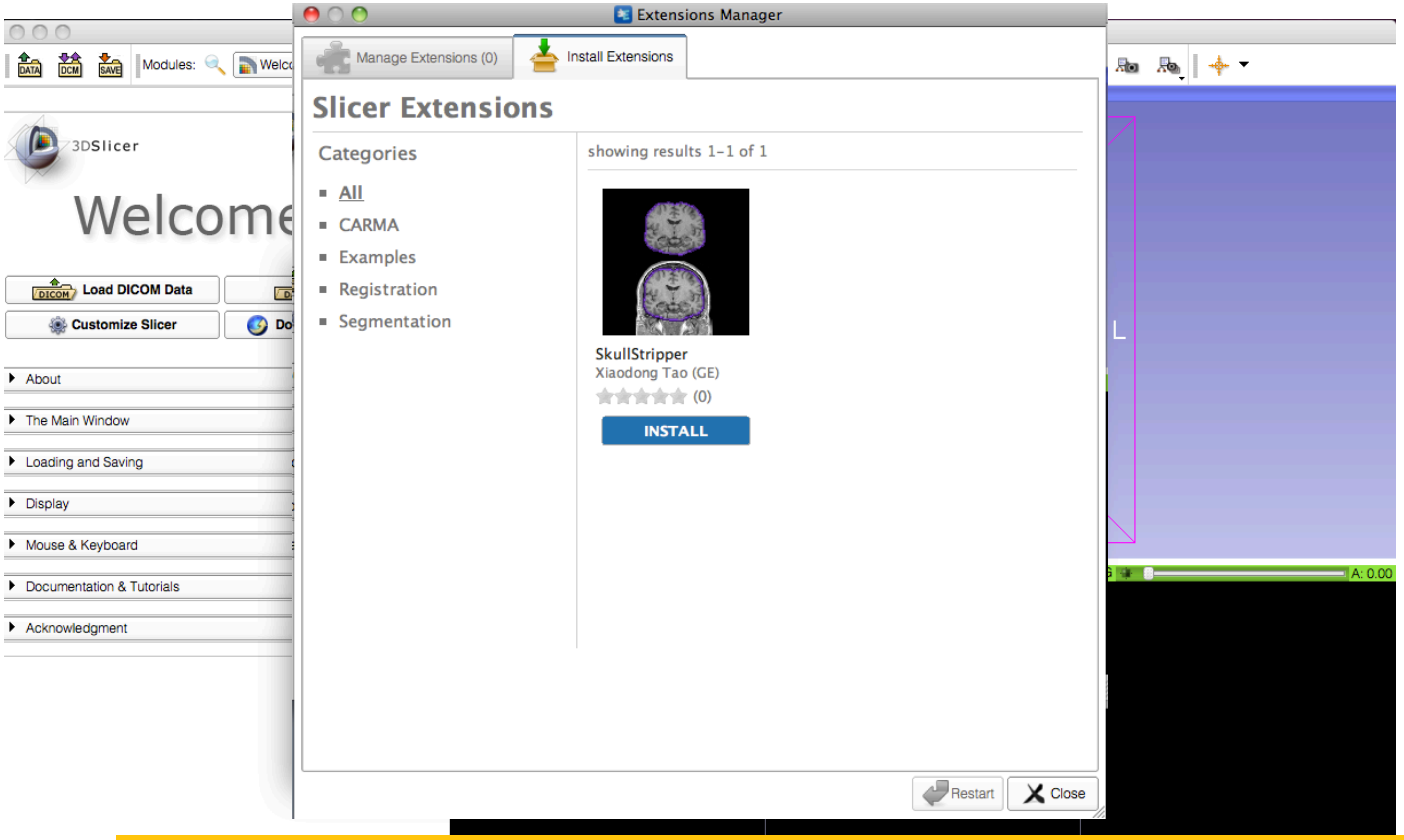

# Going Further: Slicer Extensions




Select **Edit→Application Settings** from the main menu

Select Extensions Settings, and check the box **'Enable extension manager'**

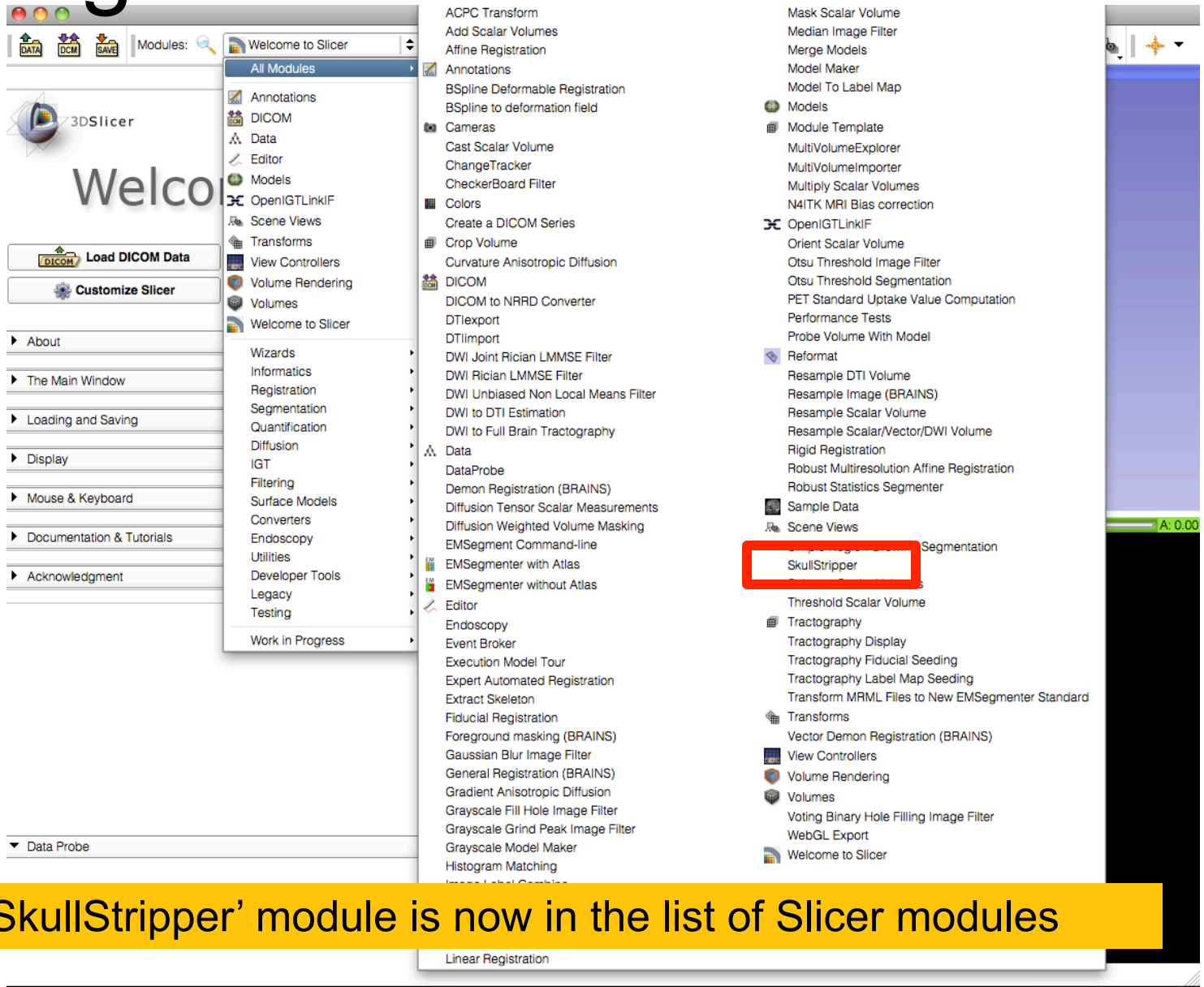
# Going Further: Slicer Extensions




Restart Slicer and select **View→Extension Manager** from the main menu

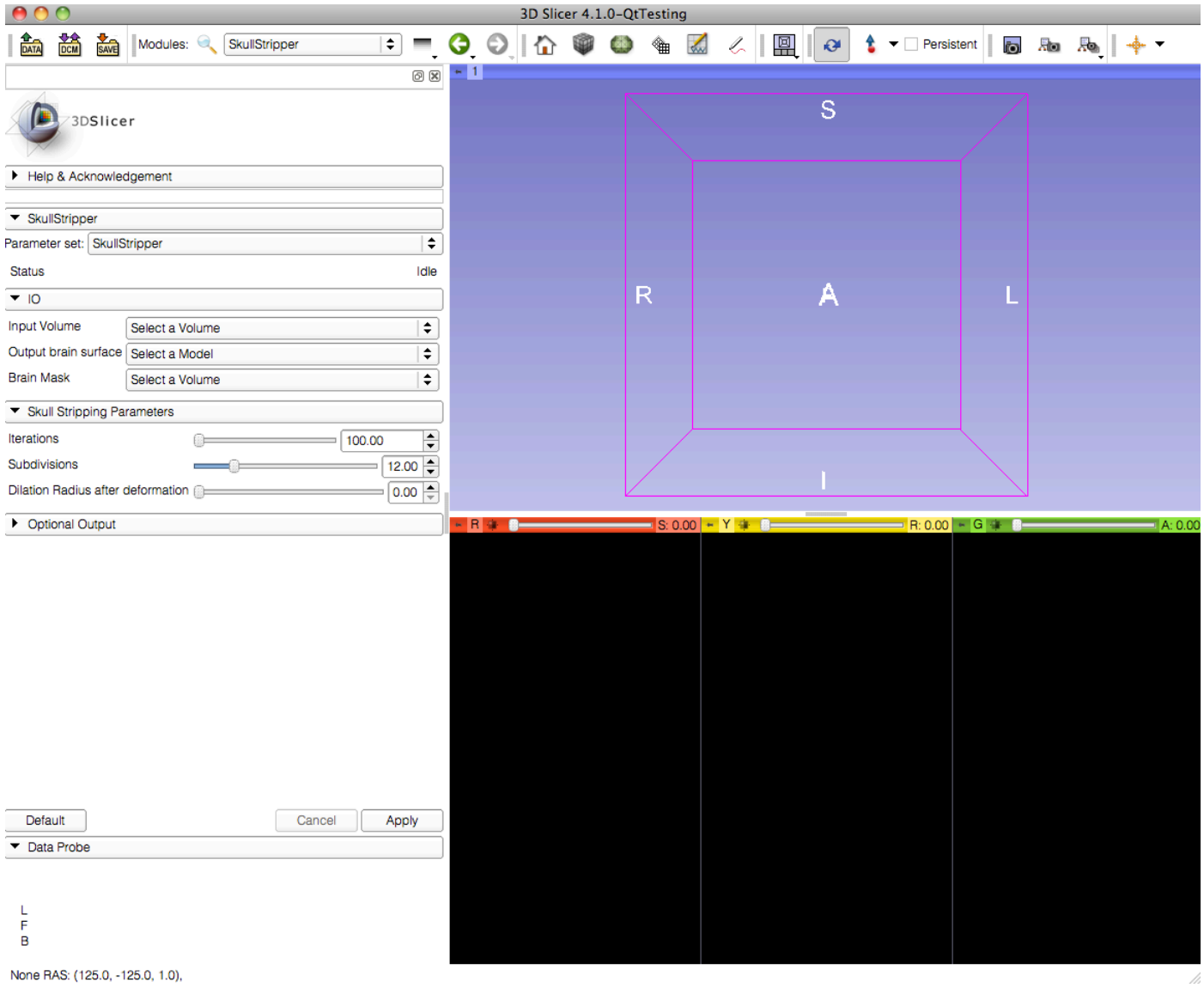
Click on **Install** to install the **SkullStripper** extension, and click on **Restart**

# Going Further: Slicer Extensions




The ‘SkullStripper’ module is now in the list of Slicer modules

# Going Further: Slicer Extensions



# Acknowledgments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# Questions and Comments

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