Python and Slicer

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Acknowledgements

- Dan Blezek - major contributor and the man behind Python through Tcl
- Demian Wasserman - Scipy wiz and author of Numpy (embedded) slides
- Steve Piper
- Michael Halle
- ...

Why Python

- More than just yet another scripting language
- Object-oriented, garbage-collected, fully introspective, allows metaprogramming
- Comes with batteries included (lots of modules ready to use, e.g. xmlrpc, http, sqlite) and many good quality external modules available
- Widely adopted by the scientific community: Numpy, Scipy, matplotlib, Nipy, ... PETSc, FeNiCs, ... VTK, ITK, MayaVi, vmtk, ...
- Thanks to Scipy, possible alternative to Matlab

Python features

- Strongly typed

```
>>> a = 1
>>> b = ‘cow’
>>> c = a + b
TypeError: unsupported operand type(s) for +: 'int' and 'str'
```

- Dynamically typed

```
>>> a = 1
>>> type(a)
<type 'int'>
>>> a = ‘cow’
>>> type(a)
<type ‘str’>
```

- Variables as ‘handles’, type attached to the pan rather than the handle; or to the dog rather than the leash

Python features

- Variables as ‘leashes’

```
>>> a = [1,2,3]
>>> b = a
>>> a[1] = 4
>>> b = [1,4,3]
```

- Basic datatypes
  - Literals (int, float, complex, bool, str)
  - Tuples: immutable ordered containers
  - Lists: mutable ordered containers
  - Dictionaries: key/value maps
  - Sets: unordered unsubscriptable containers
  - Functions
  - Classes
  - Modules

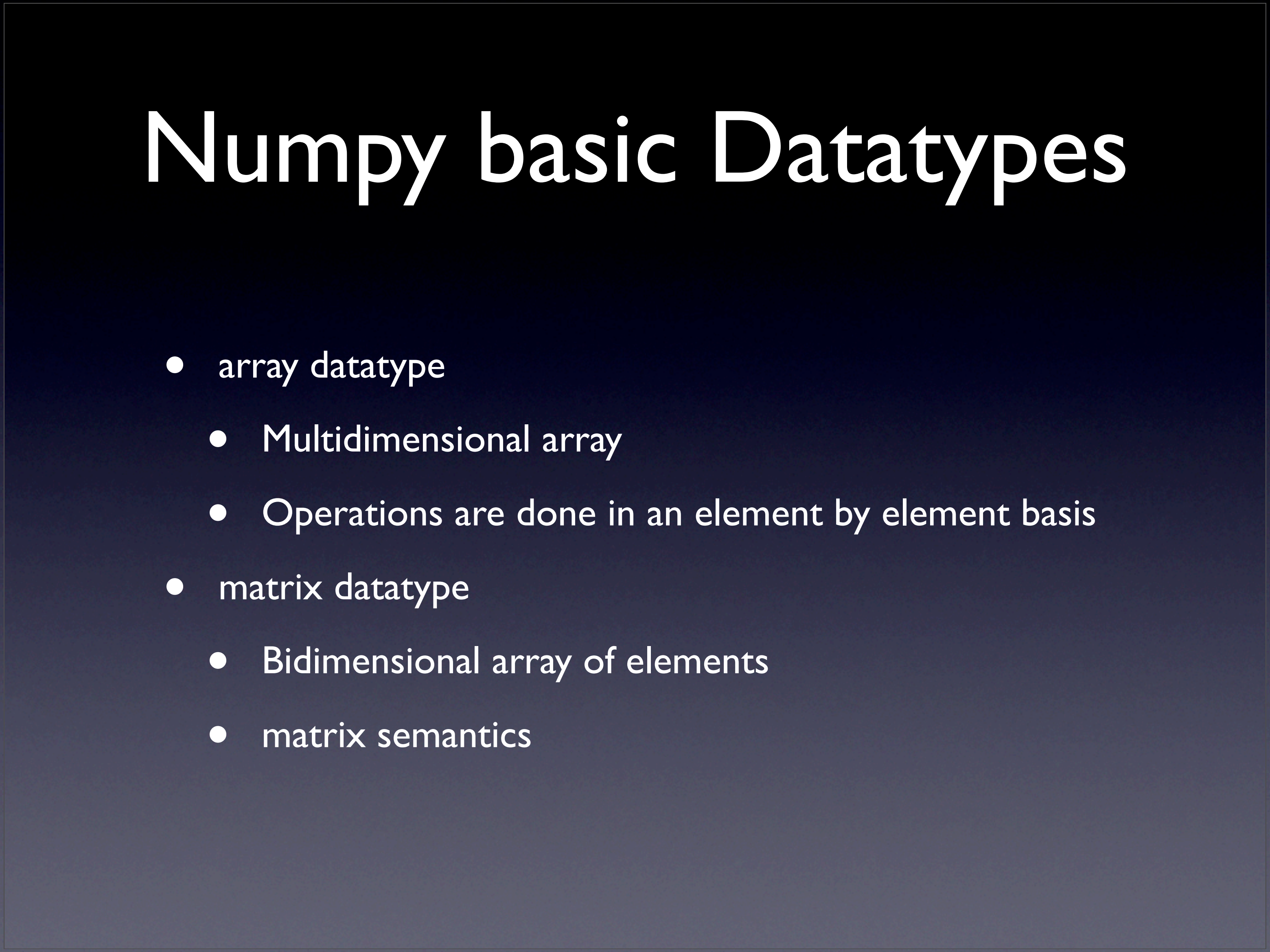
```
t = (‘a’,2)

t = [‘a’,2]

t = {‘a’:2}; t[‘a’] = 3

t = sets.Set(‘a’,2)

def Add(a,b):
    return a+b
t = Add
c = t(a,b)
```

Python features

- Classes, instances and inheritance

```
class Cow(object):
    def __init__(self,color):
        self.Color = color
    def GetColor():
        return self.Color

class BrownCow(Cow):
    def __init__(self):
        Cow.__init__(self,’brown’)

>>> a = Cow(‘brown’)
>>> a.GetColor()
‘brown’
>>> b = BrownCow()
>>> b.GetColor()
‘brown’
```

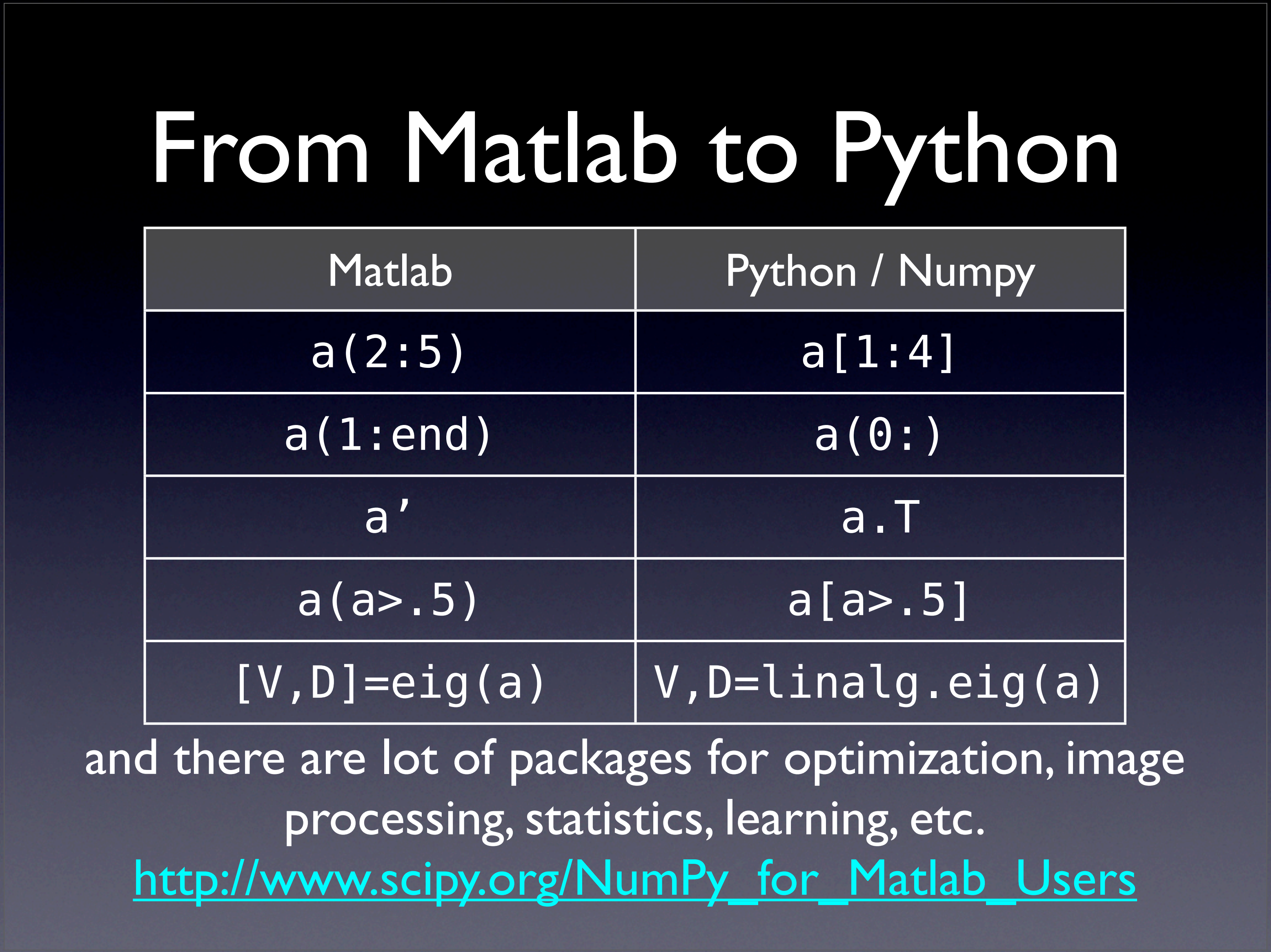
Numpy, Scipy



Numpy basic Datatypes

- array datatype
  - Multidimensional array
  - Operations are done in an element by element basis
- matrix datatype
  - Bidimensional array of elements
  - matrix semantics

Numpy, Scipy



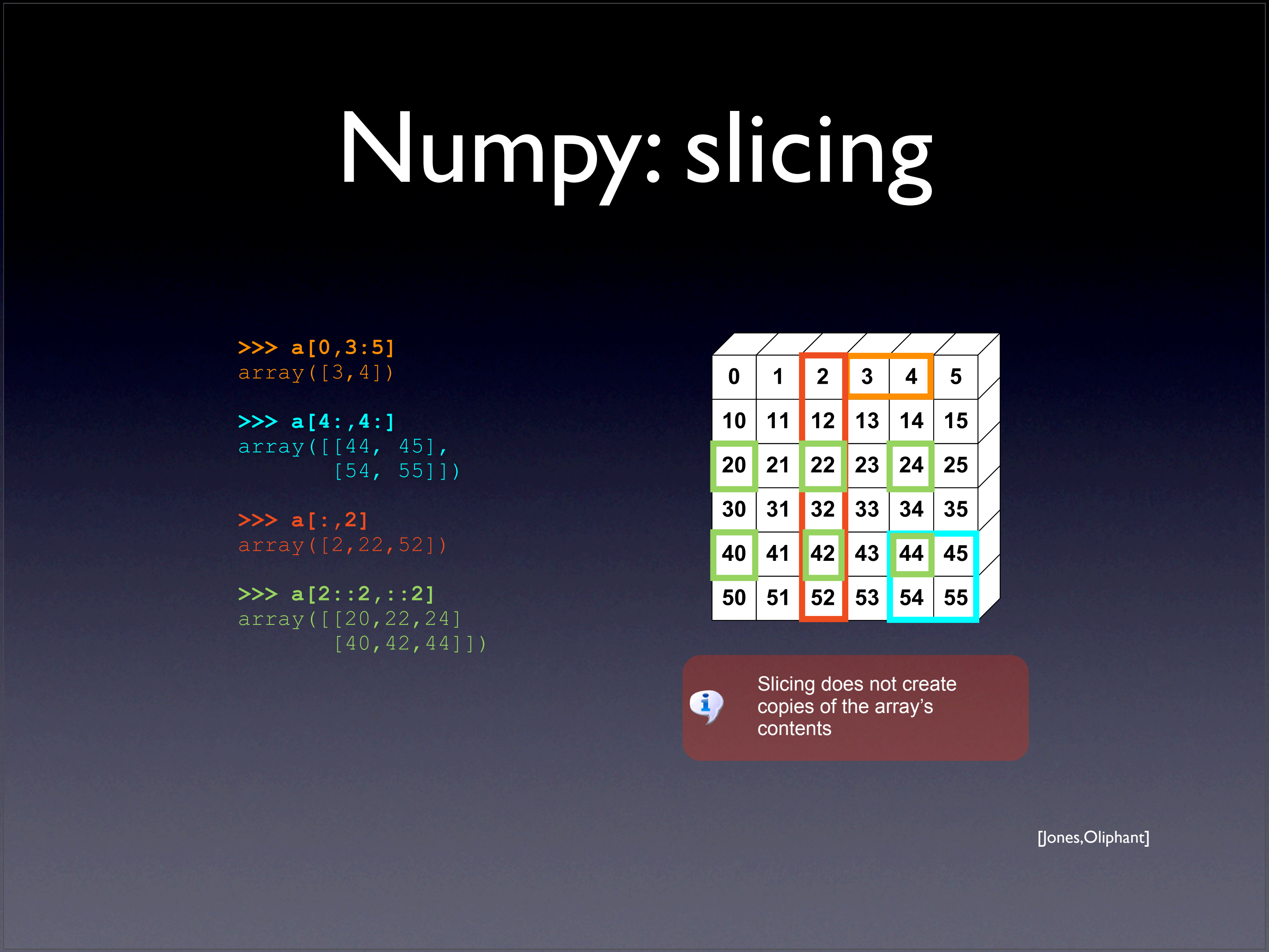
From Matlab to Python

Matlab	Python / Numpy
`a(2:5)`	`a[1:4]`
`a(1:end)`	`a(0:)`
`a’`	`a.T`
`a(a>.5)`	`a[a>.5]`
`[V,D]=eig(a)`	`V,D=linalg.eig(a)`

and there are lot of packages for optimization, image processing, statistics, learning, etc.

http://www.scipy.org/NumPy_for_Matlab_Users

Numpy, Scipy



Numpy: slicing

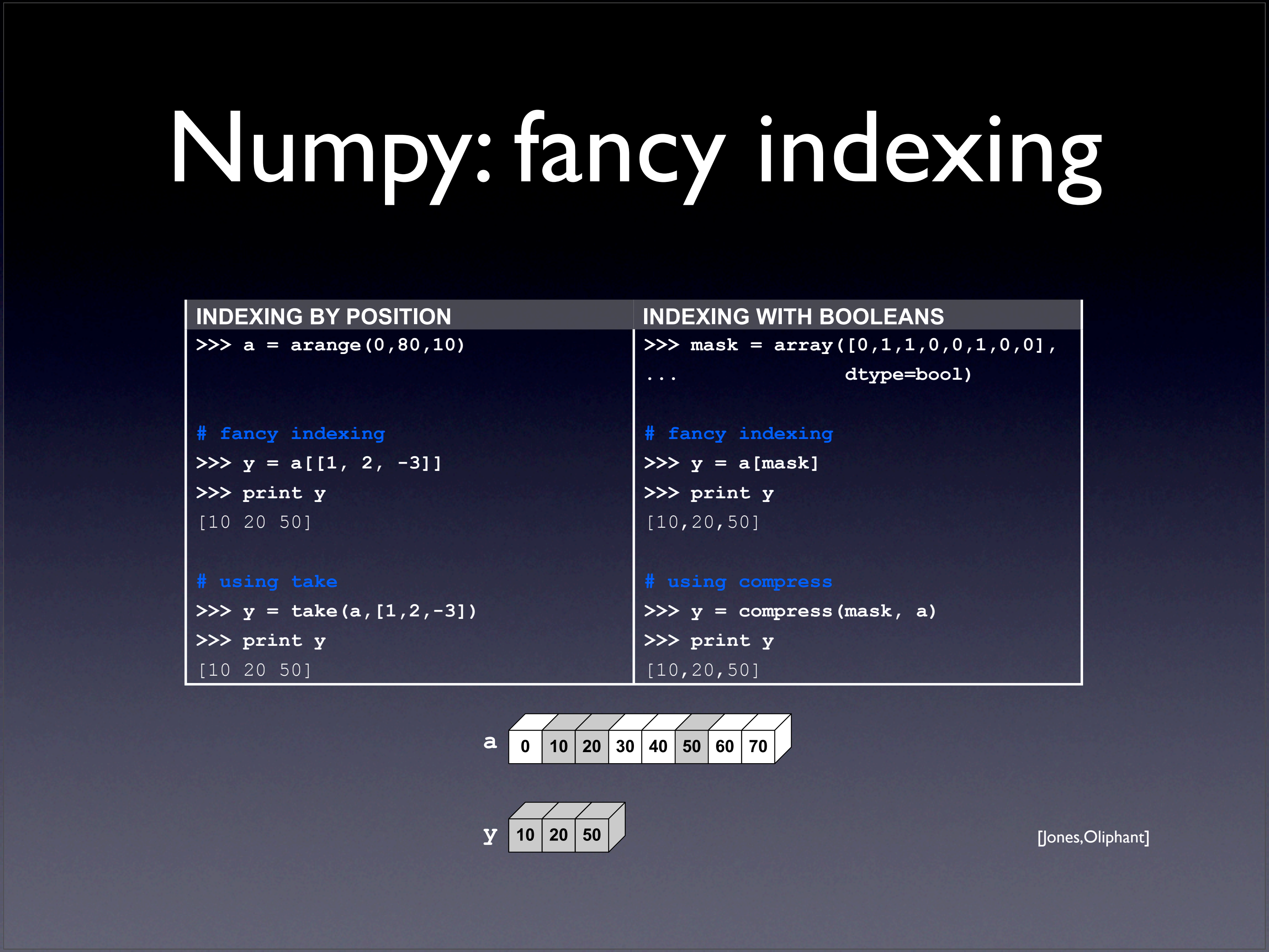
```
>>> a[0,3:5]
array([3,4])

>>> a[4:,4:]
array([[44, 45],
       [54, 55]])

>>> a[:,2]
array([2,22,52])

>>> a[2::2,::2]
array([[20,22,24]
       [40,42,44]])
```

0	1	2	3	4	5
10	11	12	13	14	15
20	21	22	23	24	25
30	31	32	33	34	35
40	41	42	43	44	45
50	51	52	53	54	55

Slicing does not create copies of the array's contents

[Jones,Oliphant]

Numpy, Scipy



Numpy: fancy indexing

INDEXING BY POSITION

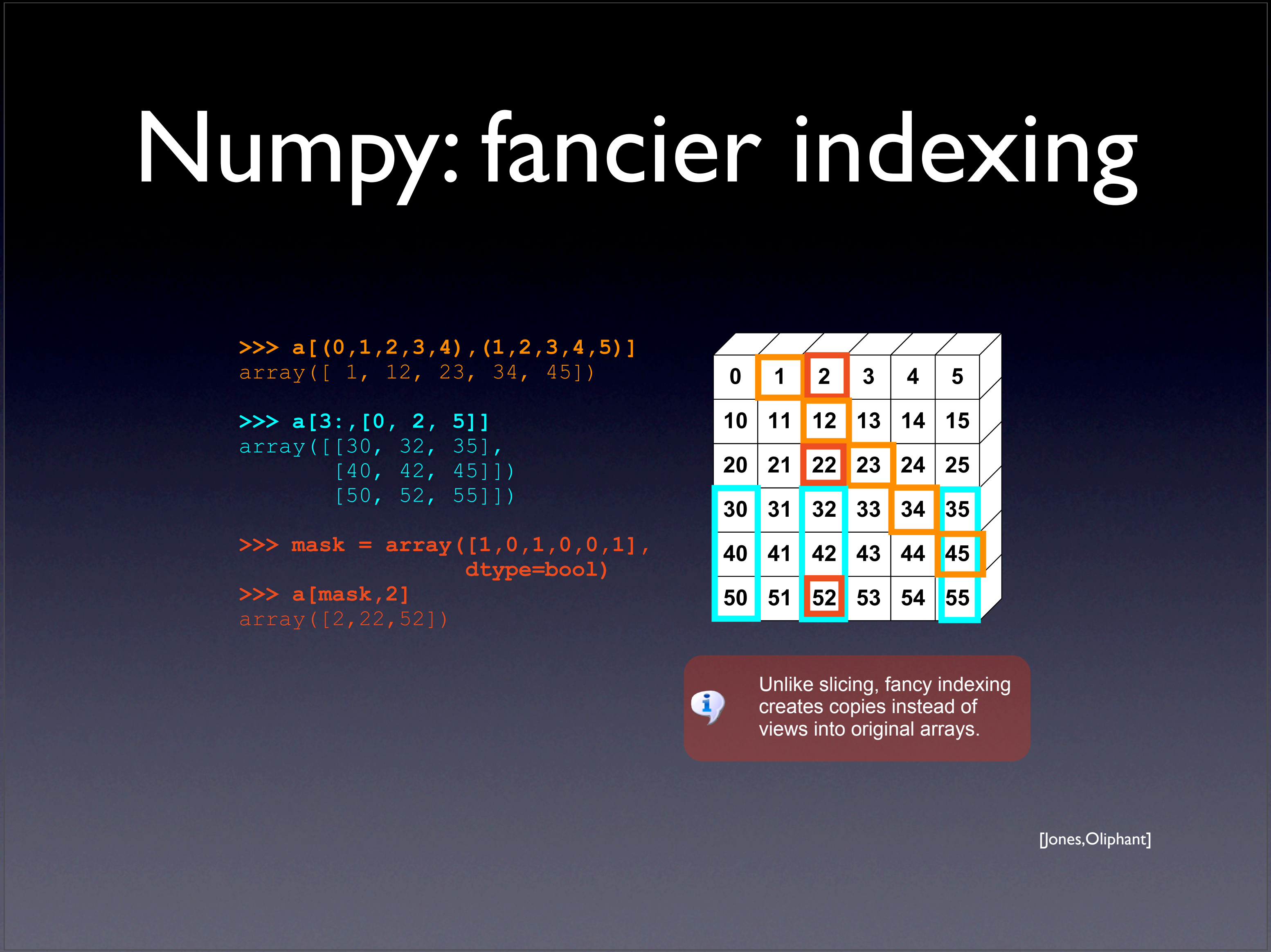
```
>>> a = arange(0,80,10)


# fancy indexing
>>> y = a[[1, 2, -3]]
>>> print y
[10 20 50]

# using take
>>> y = take(a,[1,2,-3])
>>> print y
[10 20 50]
```

INDEXING WITH BOOLEANS

```
>>> mask = array([0,1,1,0,0,1,0,0],
...              dtype=bool)

# fancy indexing
>>> y = a[mask]
>>> print y
[10,20,50]

# using compress
>>> y = compress(mask, a)
>>> print y
[10,20,50]
```

[Jones,Oliphant]

Numpy, Scipy



Numpy: fancier indexing

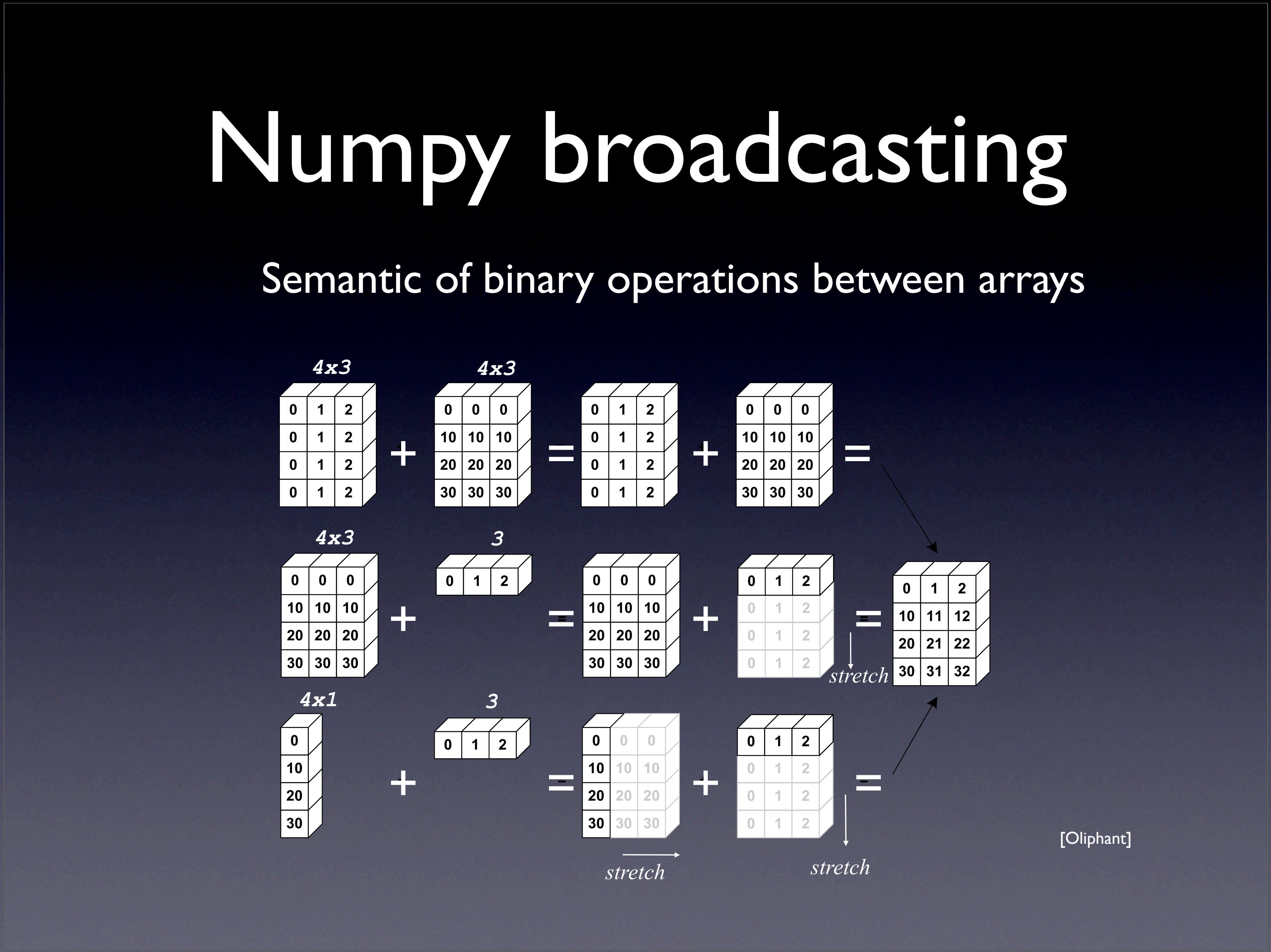
```
>>> a[(0,1,2,3,4),(1,2,3,4,5)]
array([ 1, 12, 23, 34, 45])

>>> a[3:,[0, 2, 5]]
array([[30, 32, 35],
       [40, 42, 45]])
       [50, 52, 55]])

>>> mask = array([1,0,1,0,0,1],
                 dtype=bool)
>>> a[mask,2]
array([2,22,52])
```

0	1	2	3	4	5
10	11	12	13	14	15
20	21	22	23	24	25
30	31	32	33	34	35
40	41	42	43	44	45
50	51	52	53	54	55

Unlike slicing, fancy indexing creates copies instead of views into original arrays.

[Jones,Oliphant]

Numpy, Scipy

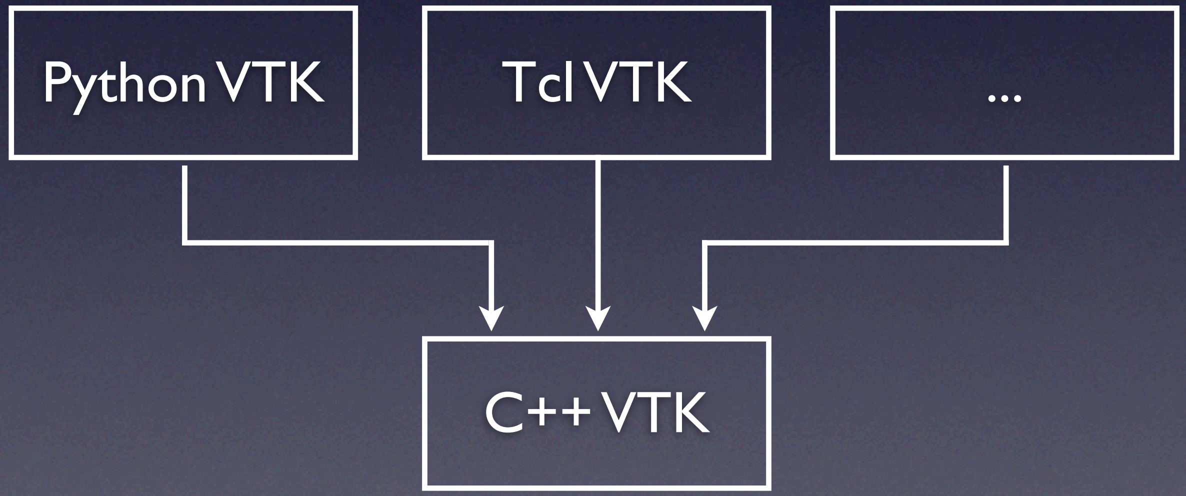


Numpy broadcasting

Semantic of binary operations between arrays

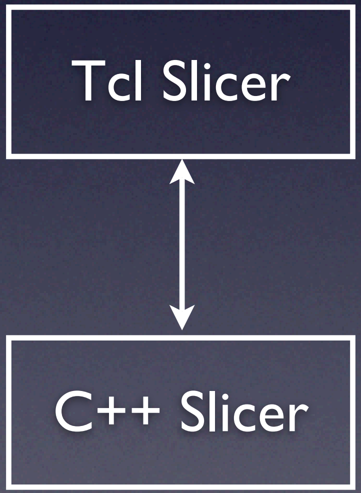
Python in Slicer

- Wrapping the VTK way



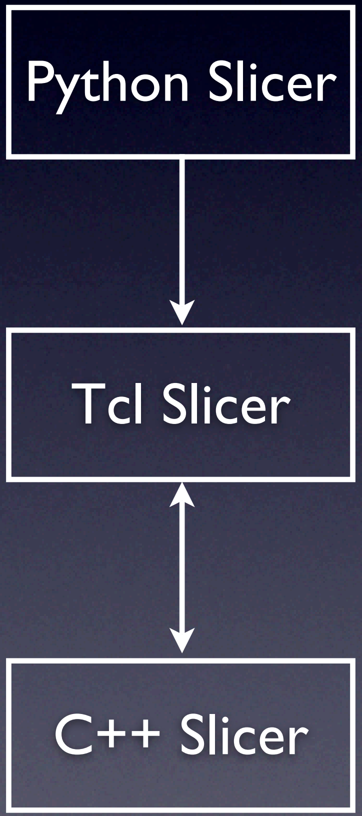
Python in Slicer

- Wrapping the Slicer way



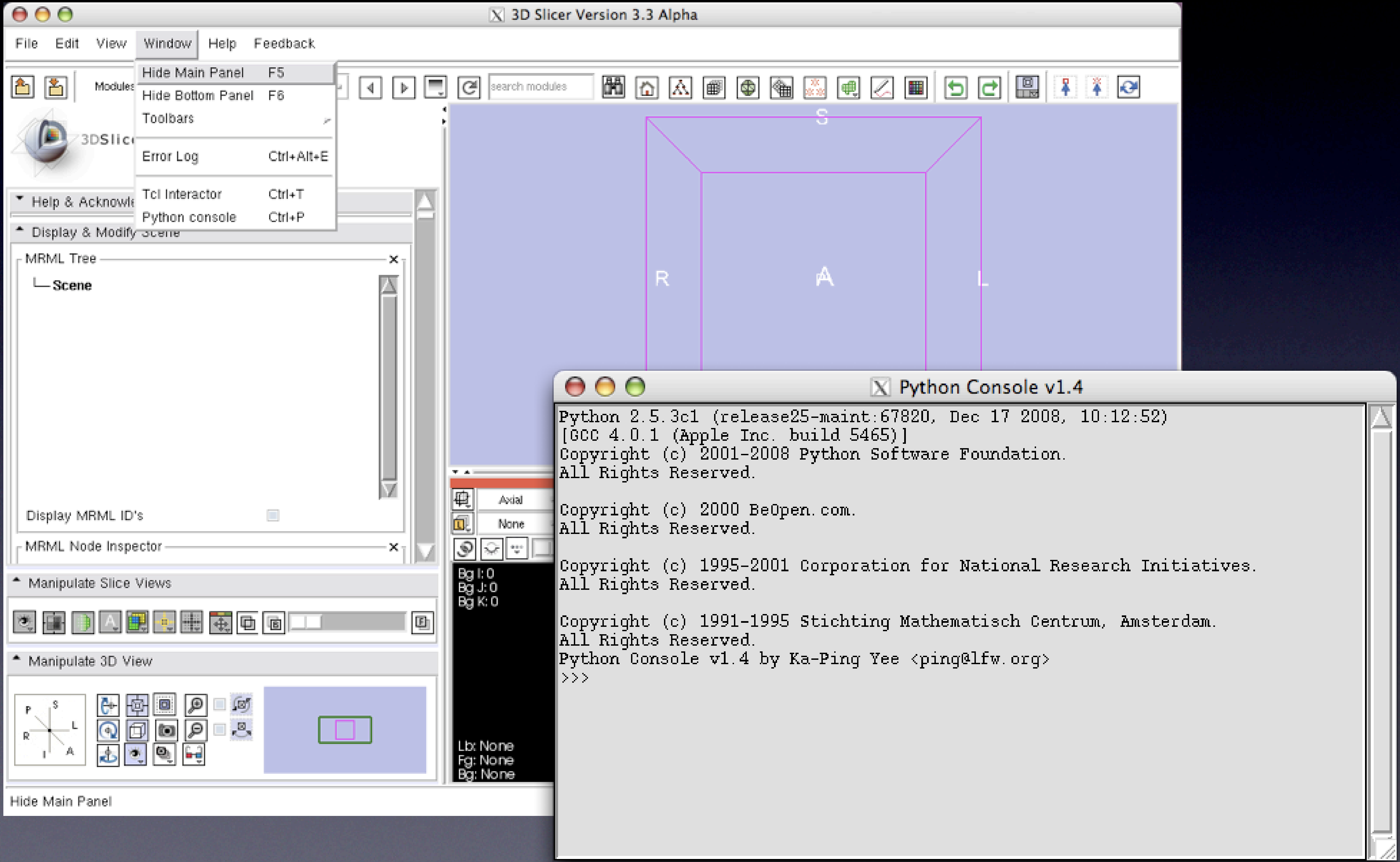
Python in Slicer

- Wrapping the Slicer way



...more details towards the end of the presentation

The Slicer Python shell



```
Python 2.5.3c1 (release25-maint:67820, Dec 17 2008, 10:12:52)
[GCC 4.0.1 (Apple Inc. build 5465)]
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All Rights Reserved.
Python Console v1.4 by Ka-Ping Yee <ping@lfw.org>
>>>
```
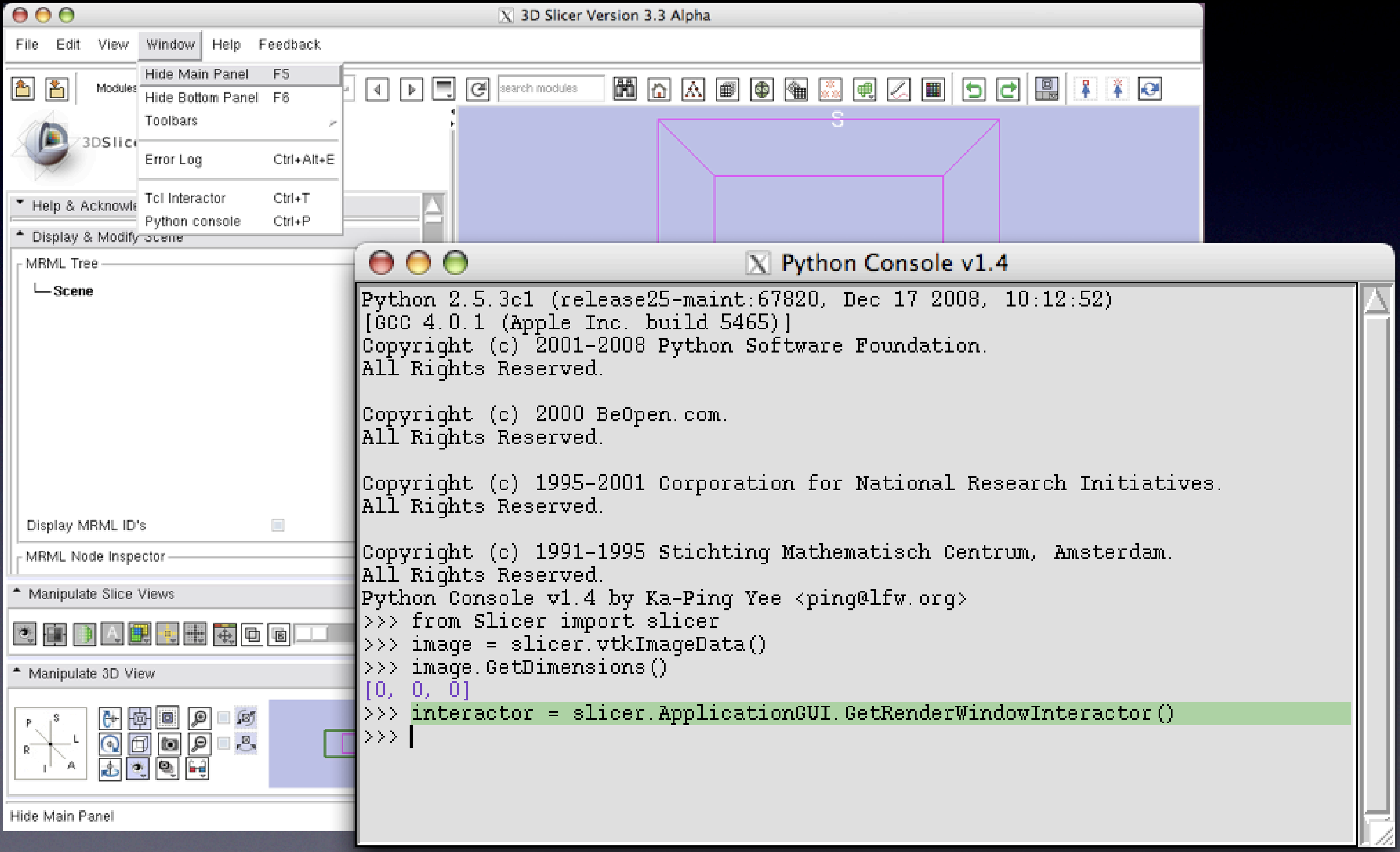

The Slicer module



```
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Copyright (c) 1991-1995 Stichting Mathematisch Centrum, Amsterdam.
All Rights Reserved.
Python Console v1.4 by Ka-Ping Yee <ping@lfw.org>
>>> from Slicer import slicer
>>> image = slicer.vtkImageData()
>>> image.GetDimensions()
[0, 0, 0]
>>> interactor = slicer.ApplicationGUI.GetRenderWindowInteractor()
>>> 
```
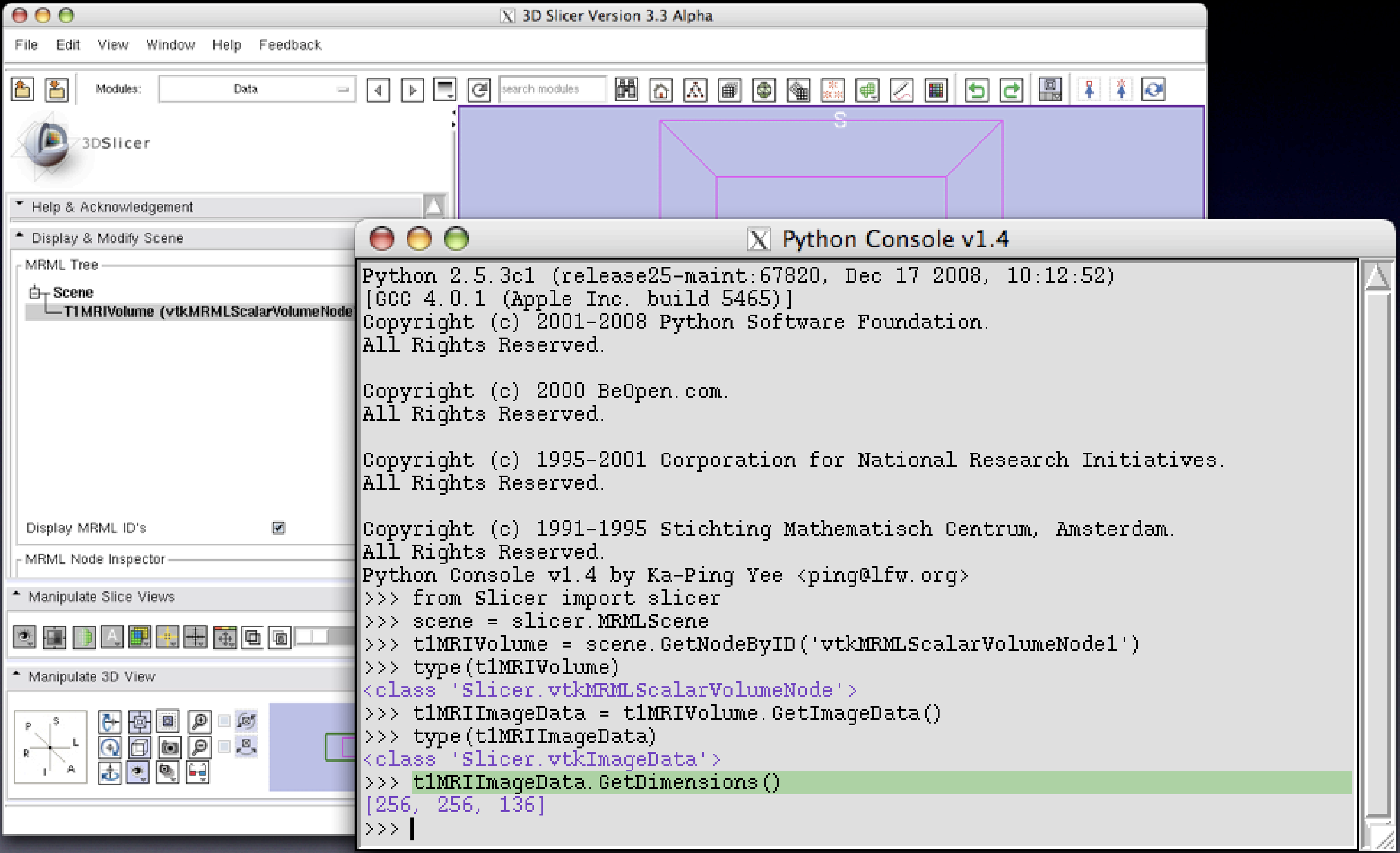

Fetching/creating/editing MRML nodes



```
Python 2.5.3c1 (release25-maint:67820, Dec 17 2008, 10:12:52)
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Python Console v1.4 by Ka-Ping Yee <ping@lfw.org>
>>> from Slicer import slicer
>>> scene = slicer.MRMLScene
>>> t1MRIVolume = scene.GetNodeByID('vtkMRMLScalarVolumeNode1')
>>> type(t1MRIVolume)
<class 'Slicer.vtkMRMLScalarVolumeNode'>
>>> t1MRIImageData = t1MRIVolume.GetImageData()
>>> type(t1MRIImageData)
<class 'Slicer.vtkImageData'>
>>> t1MRIImageData.GetDimensions()
[256, 256, 136]
>>>
```
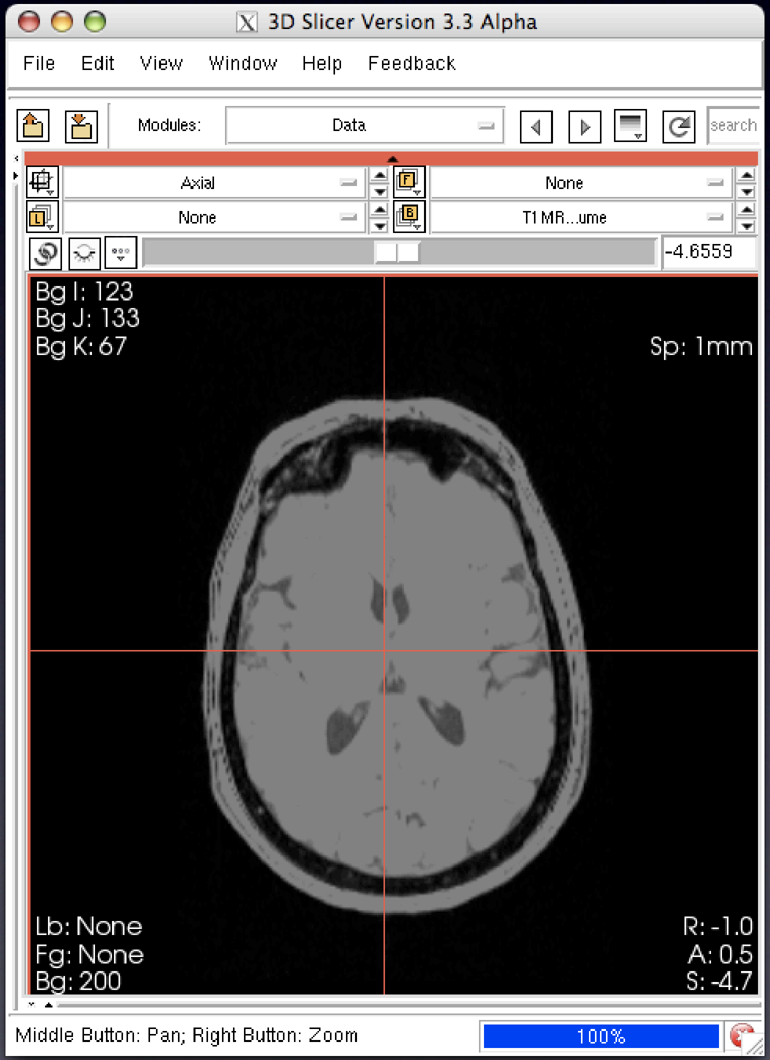
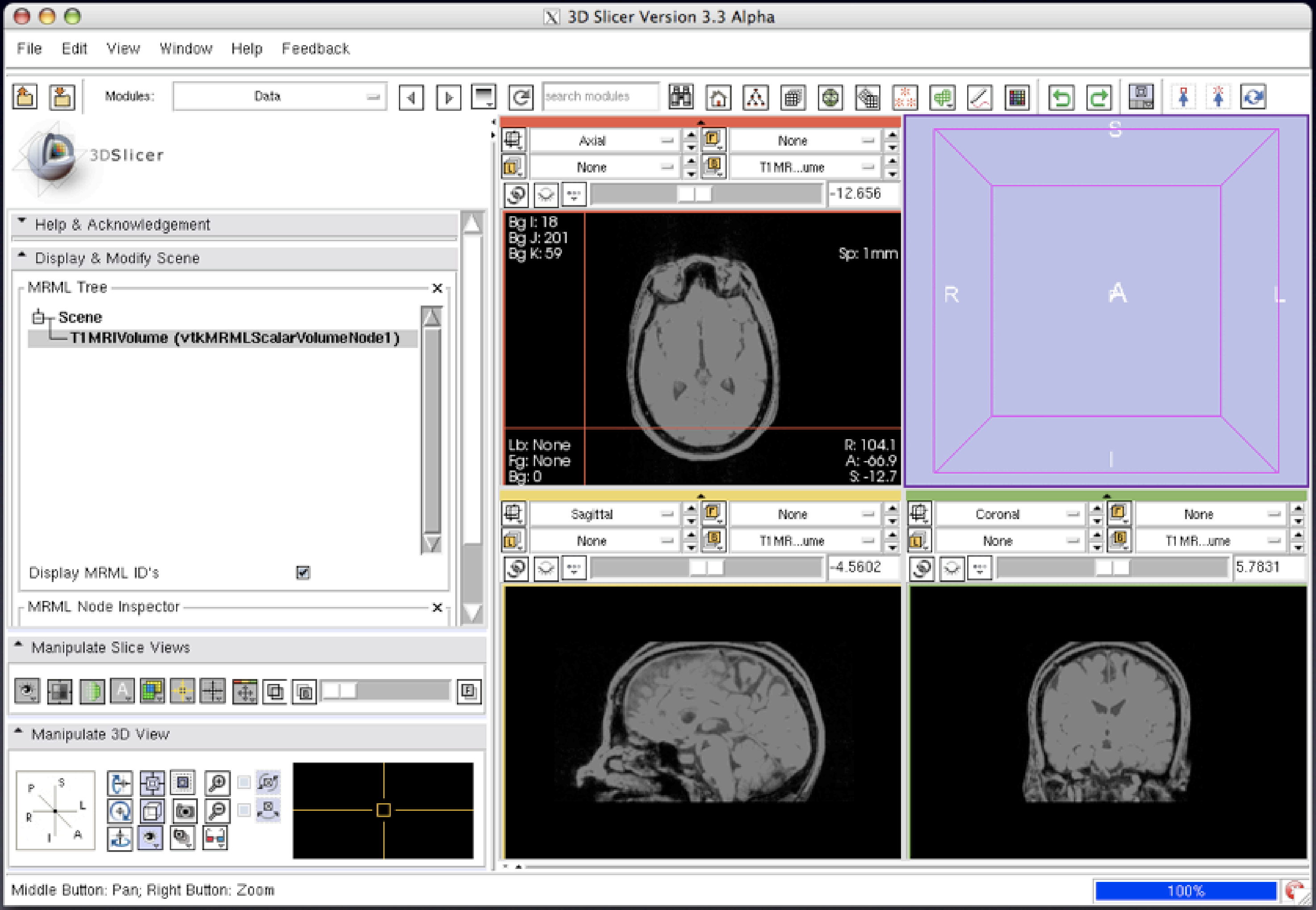

Volumes to Numpy ndarrays and back

```
>>> from Slicer import slicer
>>> scene = slicer.MRMLScene
>>> node =
scene.GetNodeByID(‘vtkMRMLScalarVolumeNode1’)
>>> arr = node.GetImageData().ToArray()
>>> type(arr)
<type ‘numpy.ndarray’>
>>> arr.max()
367
>>> arr[arr>200] = 200
>>> node.Modified()

>>> arr2D = arr[:,:,2]
>>> node.GetImageData().FromArray2D(arr2D)
```



Controlling Slicer from Python

```
>>> from Slicer import slicer
>>> layout = slicer.ApplicationGUI.GetGUILayoutNode()
>>> layout.SetViewArrangement(3)
```



Command-line (XML) modules

- In addition to executables and shared libraries
- Readily available: simply copy the .py file in the Plugins directory (or point Slicer to an external Plugins directory)
- Slicer doesn’t have to be restarted for changes to the code inside Execute to take effect
- Run in the main thread, i.e. they can change the MRML scene.

Command-line (XML) modules

```
XML = """<?xml version="1.0" encoding="utf-8"?>
<executable>

  <category>Python Modules</category>
  <title>Python Surface ICP Registration</title>
  <description>
Performs registration of the input surface onto a target surface using
on the Iterative Closest Point algorithm.
</description>
  <version>1.0</version>
  <documentation-url></documentation-url>
  <license></license>
  <contributor>Luca Antiga and Daniel Blezek</contributor>

  <parameters>
    <label>Surface ICP Registration Parameters</label>
    <description>Parameters for surface registration</description>

    <string-enumeration>
      <name>landmarkTransformMode</name>
      <longflag>landmarkTransformMode</longflag>
      ...

def Execute (inputSurface, targetSurface, outputSurface, \
            landmarkTransformMode="RigidBody", meanDistanceMode="RMS", \
            maximumNumberOfIterations=50, maximumNumberOfLandmarks=200, \
            startByMatchingCentroids=False, checkMeanDistance=False,
maximumMeanDistance=0.01):

    Slicer = __import__("Slicer")
    slicer = Slicer.slicer
    scene = slicer.MRMLScene
    inputSurface = scene.GetNodeByID(inputSurface)
    targetSurface = scene.GetNodeByID(targetSurface)
    outputSurface = scene.GetNodeByID(outputSurface)

    icpTransform = slicer.vtkIterativeClosestPointTransform()
    icpTransform.SetSource(inputSurface.GetPolyData())
    icpTransform.SetTarget(targetSurface.GetPolyData())
```

Slicer3/Modules/Python/

SurfaceICPRegistration.py

Numpy command-line (XML) modules

See Demian’s slides

Running a plugin from Python

- Command line modules calling any registered command line module (not necessarily another Python module)

```
>>> import Slicer
>>> from Slicer import slicer
>>> volume1 = slicer.MRMLScene.GetNodeByID(“vtkMRMLVolumeNode1”)
>>> volume2 = slicer.MRMLScene.GetNodeByID(“vtkMRMLVolumeNode2”)
>>> plugin = Slicer.Plugin(“Subtract Images”)
>>> plugin.Execute(volume1.GetID(),volume2.GetID())
```

- This is an easy way of having ITK functionality available
- Alternative way: wrap ITK classes in vtkITK classes (or create VTK classes that contain an ITK pipeline) and instantiate them directly in a Python module

Scripted modules in Python

- Python CLI modules, like CLI modules in general, are not interactive: they only respond upon pushing "Apply" and cannot provide custom interaction, dynamic GUI updates and additional observations in general
- Scripted modules allow to do that (at the price of more coding)

Scripted modules in Python

- Example: PythonGADScriptedModule

```
from SlicerScriptedModule import ScriptedModuleGUI
from Slicer import slicer

class PythonGADScriptedModuleGUI(ScriptedModuleGUI):
  def __init__(self):
    ...

  def AddGUIObservers(self):
    ...

  def ProcessGUIEvents(self,caller,event):
    ...

  def UpdateGUI(self):
    ...

  def BuildGUI(self):
    ...
```

Scripted modules in Python

- Example: Adding an observer to an existing Slicer object instance (e.g. for placing custom fiducials, ...)

```
from SlicerScriptedModule import ScriptedModuleGUI
from Slicer import slicer

class PythonGADScriptedModuleGUI(ScriptedModuleGUI):

  def __init__(self):
    ...

  def AddGUIObservers(self):
    interactor = slicer.ApplicationGUI.GetRenderWindowInteractor()
    tag = interactor.AddObserver("LeftButtonReleaseEvent",self.TestCallback)

  def TestCallback(self):
    print “I’m the callback!”
```