3D Data visualization with Mayavi

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SciPy.in 2012,
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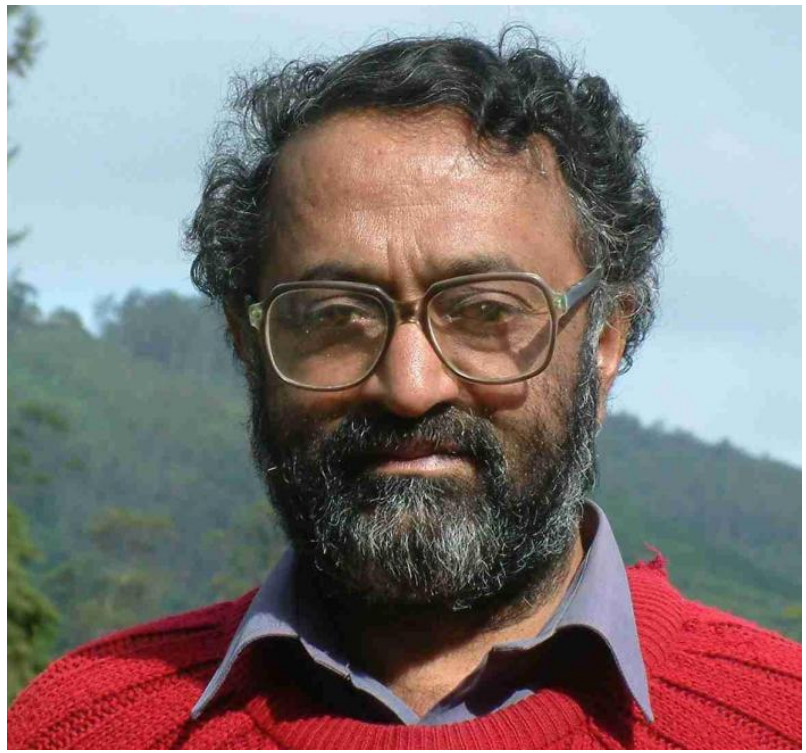
IIT Bombay.

In memory of John Hunter,

Kenneth Gonsalves,



and Raj Mathur.

Objectives

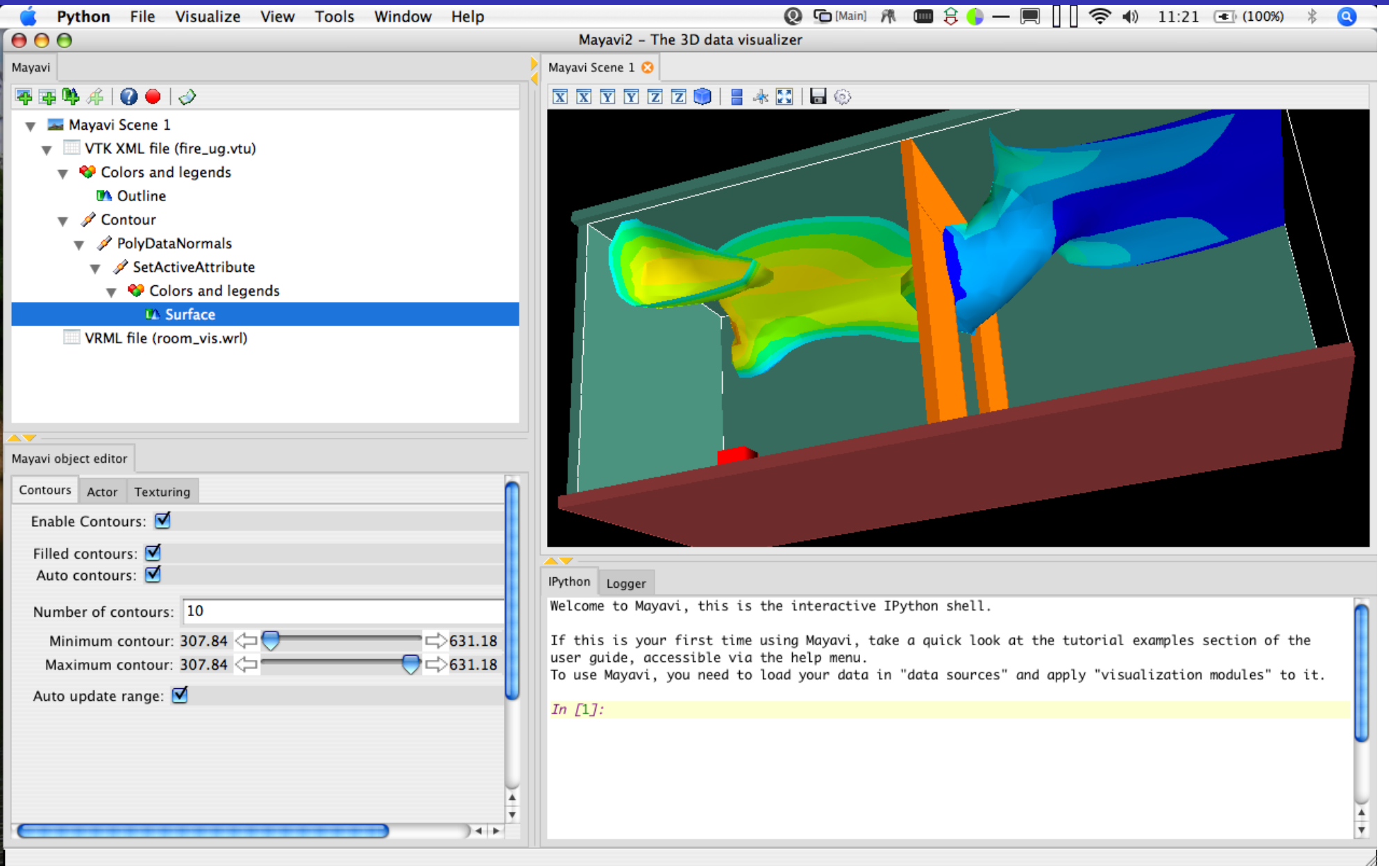
At the end of this session you will be able to:

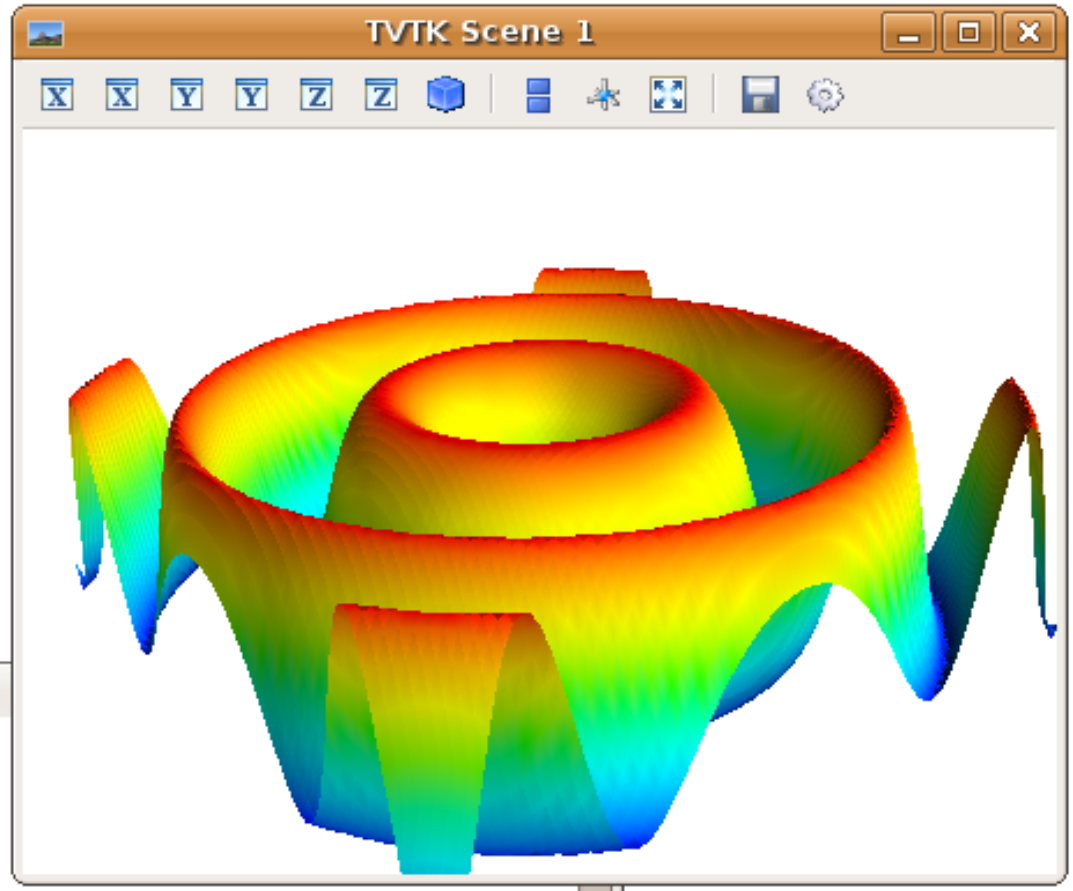
1. Use `mlab` effectively to visualize numpy array data of various kinds
2. Apply some of mayavi's advanced features

Outline

Outline

Overview of features

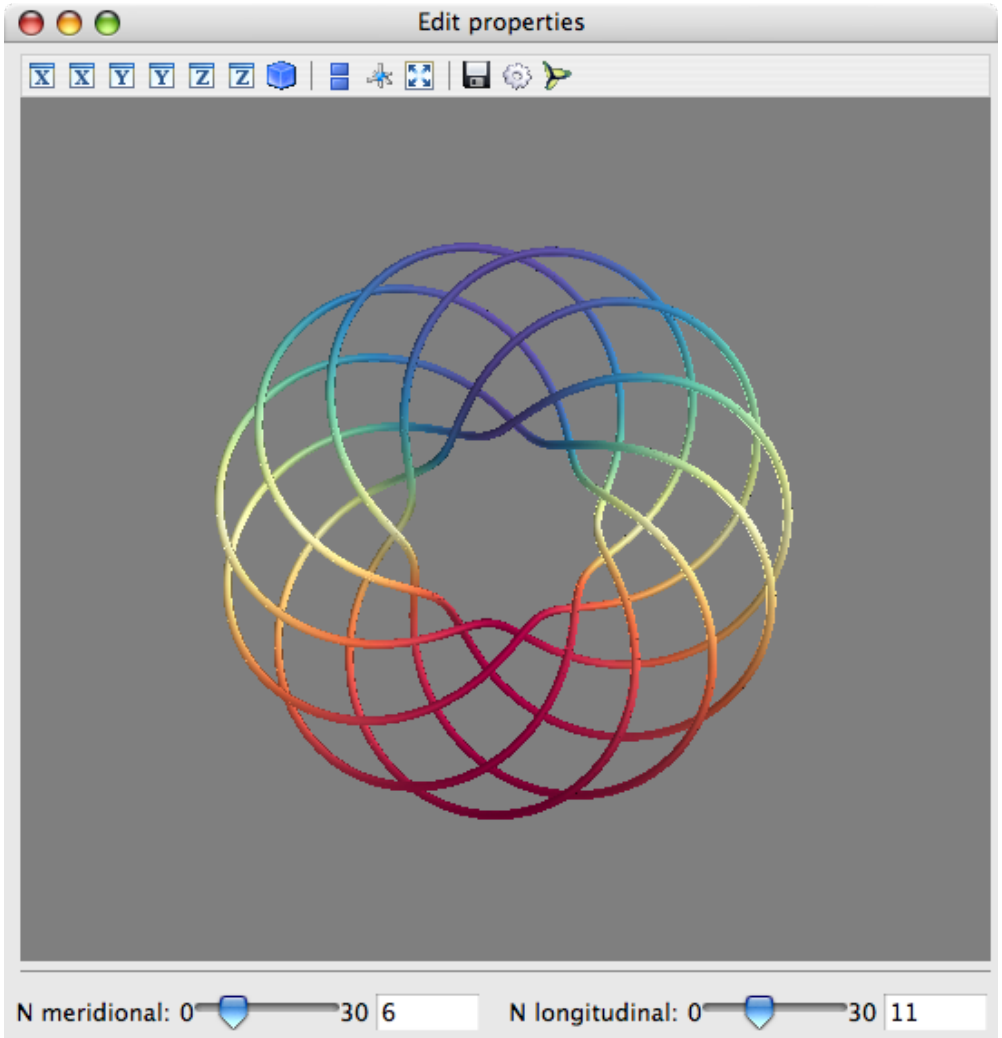




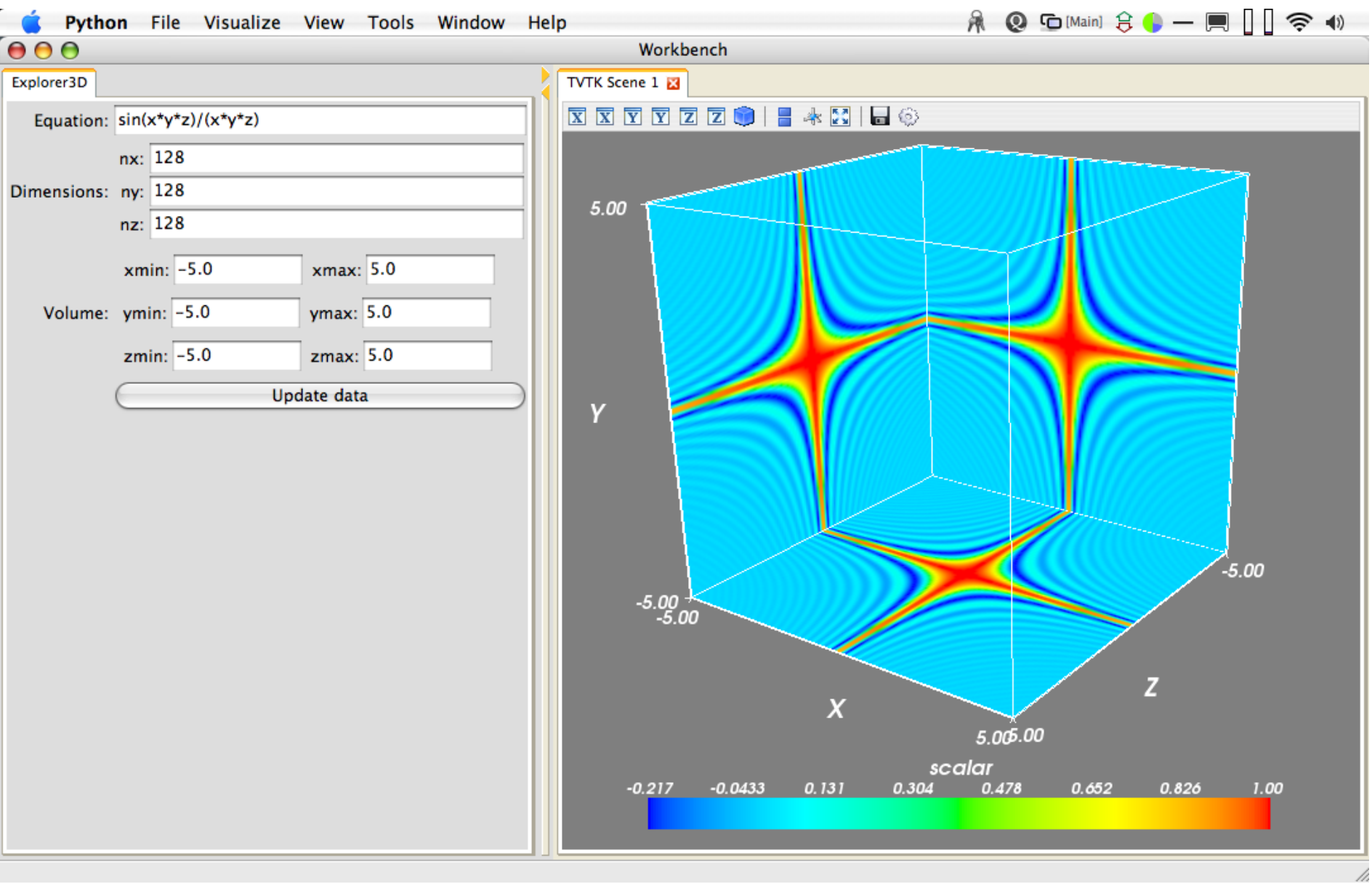
Terminal

```
In [1]: from numpy import *

In [2]: x, y = mgrid[-3:3:100j, -3:3:100j]

In [3]: z = sin(x**2 + y**2)

In [4]: from enthought.mayavi import mlab

In [5]: mlab.surf(x, y, z)
```

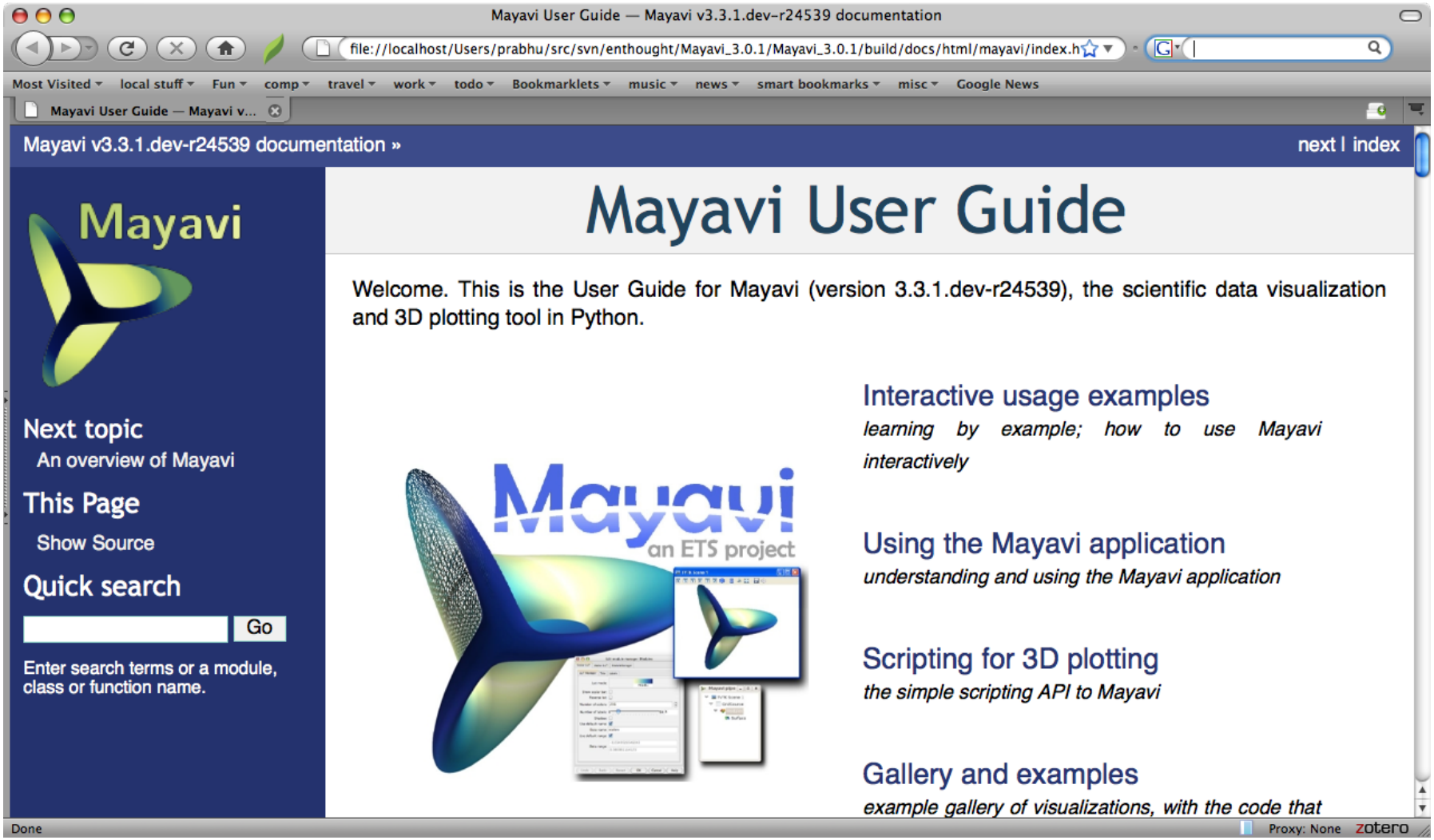
Live in your dialogs



Mayavi in applications



Exploring the documentation



Other features

- Easy customization
- Offscreen animations
- Automatic script generation
- Powerful command line options

Summary

- `http://code.enthought.com/projects/mayavi`
- Uses VTK (`www.vtk.org`)
- BSD license
- Linux, win32 and Mac OS X
- Highly scriptable
- Embed in Traits UIs (wxPython and PyQt4)
- Envisage Plugins
- Debian/Ubuntu/Fedora
- Pythonic

Outline

Overview

- Simple
- Convenient
- Full-featured

Getting started

Vanilla:

```
$ ipython --gui=wx
```

with Pylab:

```
$ ipython --pylab=wx
```

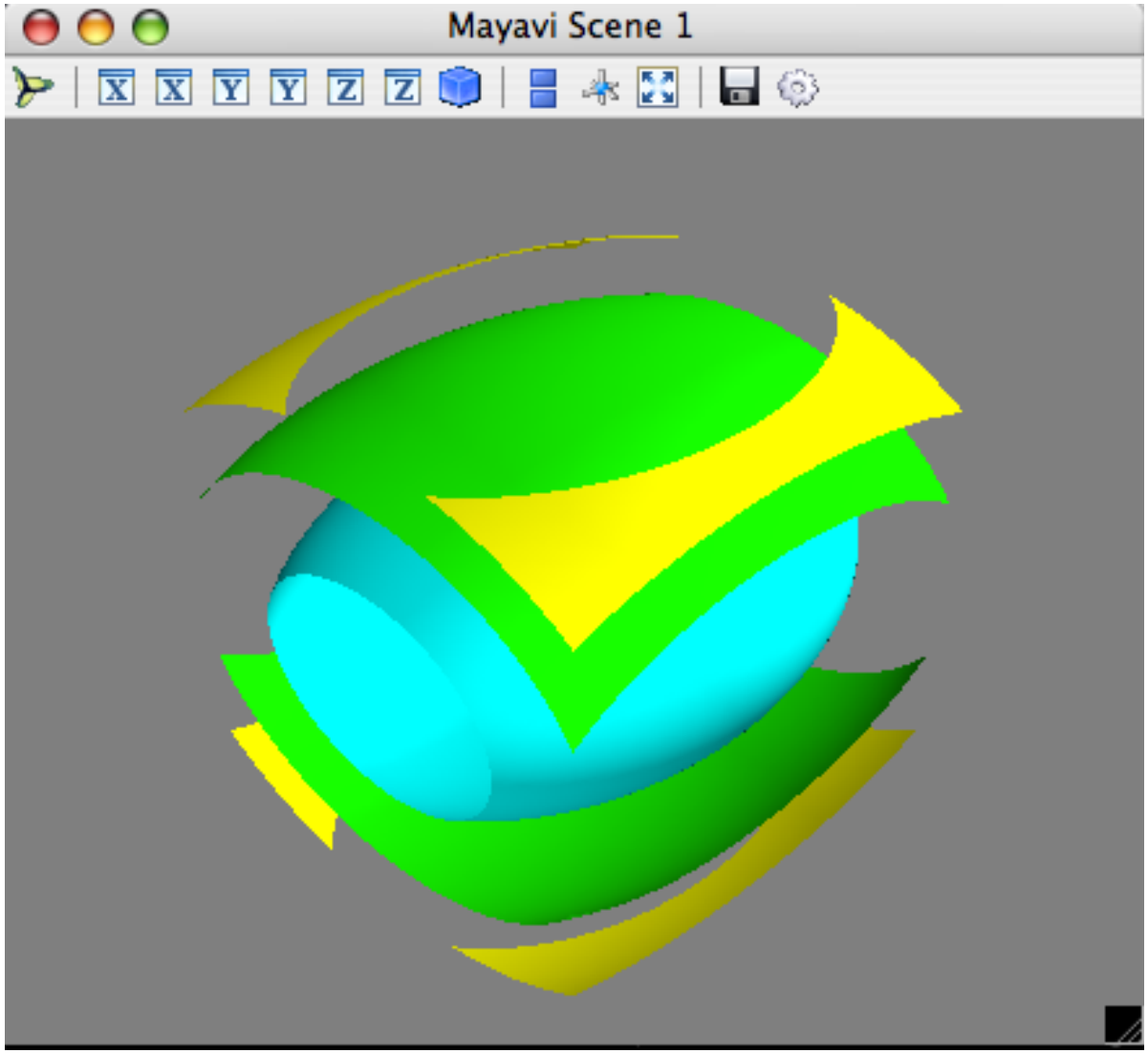
Using mlab:

```
>>> from enthought.mayavi import mlab
```

Try these:

```
>>> mlab.test_<TAB>
>>> mlab.test_contour3d()
>>> mlab.test_contour3d??
```

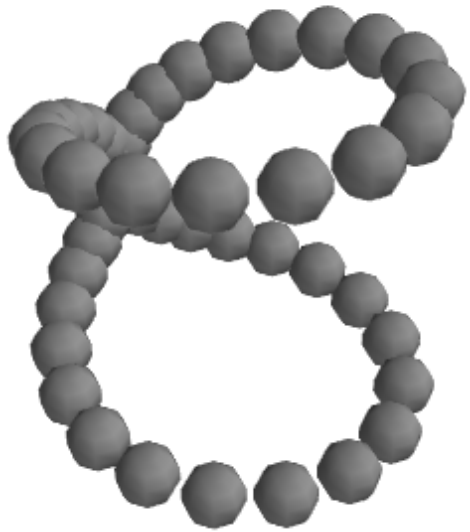
Exploring the view



- Mouse
- Keyboard
- Toolbar
- Mayavi icon 

`mlab` plotting functions

0D data



```
>>> from numpy import *
>>> t = linspace(0, 2*pi, 50)
>>> u = cos(t)*pi
>>> x, y, z = sin(u), cos(u), sin(t)
```

```
>>> mlab.points3d(x, y, z)
```

Changing how things look

Clearing the view

```
>>> mlab.clf()
```

IPython is your friend!

```
>>> mlab.points3d?
```

- Extra argument: Scalars
- Keyword arguments
- UI

```
>>> mlab.points3d(x, y, z, t,
                  scale_mode='none')
```

Changing how things look

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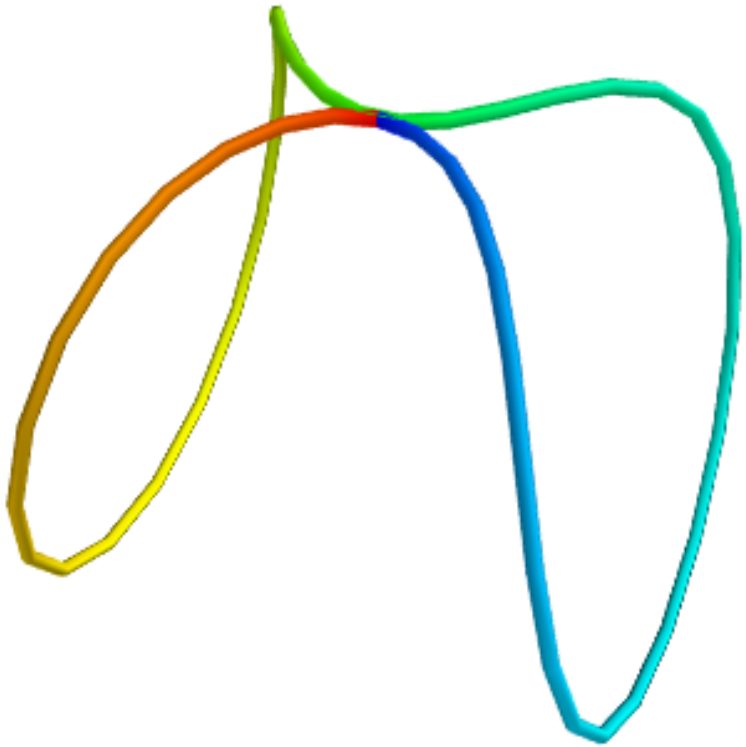
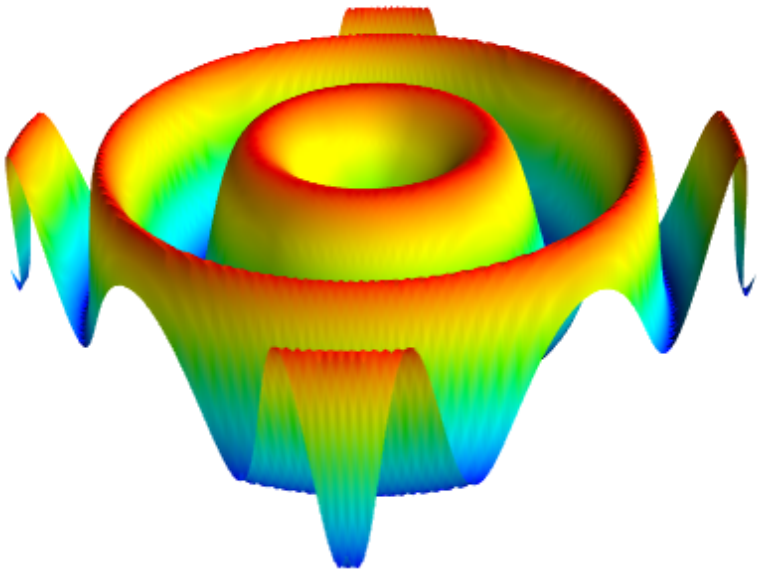
1D data



```
>>> mlab.plot3d(x, y, z, t)
```

Plots lines between the points

2D data



```
>>> x, y = mgrid[-3:3:100j,-3:3:100j]
>>> z = sin(x*x + y*y)
```

```
>>> mlab.surf(x, y, z)
```

Assumes the points are rectilinear

2D data: `mlab.mesh`

```
>>> mlab.mesh(x, y, z)
```

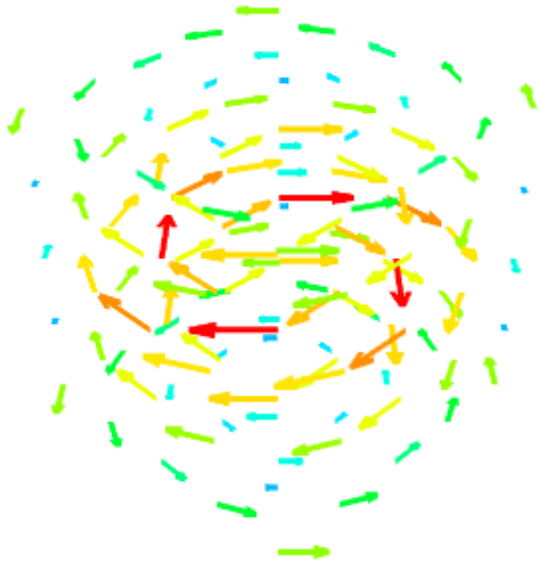
Points needn't be regular

```
>>> phi, theta = numpy.mgrid[0:pi:20j,
...                          0:2*pi:20j]
>>> x = sin(phi)*cos(theta)
>>> y = sin(phi)*sin(theta)
>>> z = cos(phi)
>>> mlab.mesh(x, y, z,
...           representation='wireframe')
```

3D data

```
>>> x, y, z = ogrid[-5:5:64j,
...                 -5:5:64j,
...                 -5:5:64j]
>>> mlab.contour3d(x*x*0.5 + y*y +
                   z*z*2)
```

3D vector data: mlab.quiver3d



```
>>> mlab.test_quiver3d()
```

```
obj = mlab.quiver3d(x, y, z, u, v, w)
```

3D vector data: mlab.flow

```
>>> x, y, z = mgrid[-2:3, -2:3, -2:3]
>>> r = sqrt(x**2 + y**2 + z**4)
>>> u = y*sin(r)/(r+0.001)
>>> v = -x*sin(r)/(r+0.001)
>>> w = zeros_like(z)
>>> obj = mlab.flow(x, y, z, u, v, w,
                    seedtype='plane')
>>> obj.stream_tracer.integrator_type = \
    'runge_kutta45'
```

Exercise: Lorenz equation

$$\begin{aligned}\frac{dx}{dt} &= s(y-x)\\ \frac{dy}{dt} &= rx-y-xz\\ \frac{dz}{dt} &= xy-bz\end{aligned}$$

Let $s = 10, r = 28, b = 8./3.$

Region of interest

```
x, y, z = mgrid[-50:50:20j,-50:50:20j,
                -10:60:20j]
```

Use mlab.quiver3d

Solution

```
def lorenz(x, y, z, s=10.,r=28., b=8./3.):
    u = s*(y-x)
    v = r*x -y - x*z
    w = x*y - b*z
    return u, v, w

x, y, z = mgrid[-50:50:20j,-50:50:20j,
                -10:60:20j]
u, v, w = lorenz(x, y, z)

mlab.quiver3d(x, y, z, u, v, w,
              scale_factor=0.01,
              mask_points=5)
mlab.show()
```

Issues and solutions

- Basic visualization: not very useful
- Tweak parameters: mask_points, scale_factor
- Explore parameters on UI
- mlab.flow is a lot better!

Good visualization involves work

Other utility functions

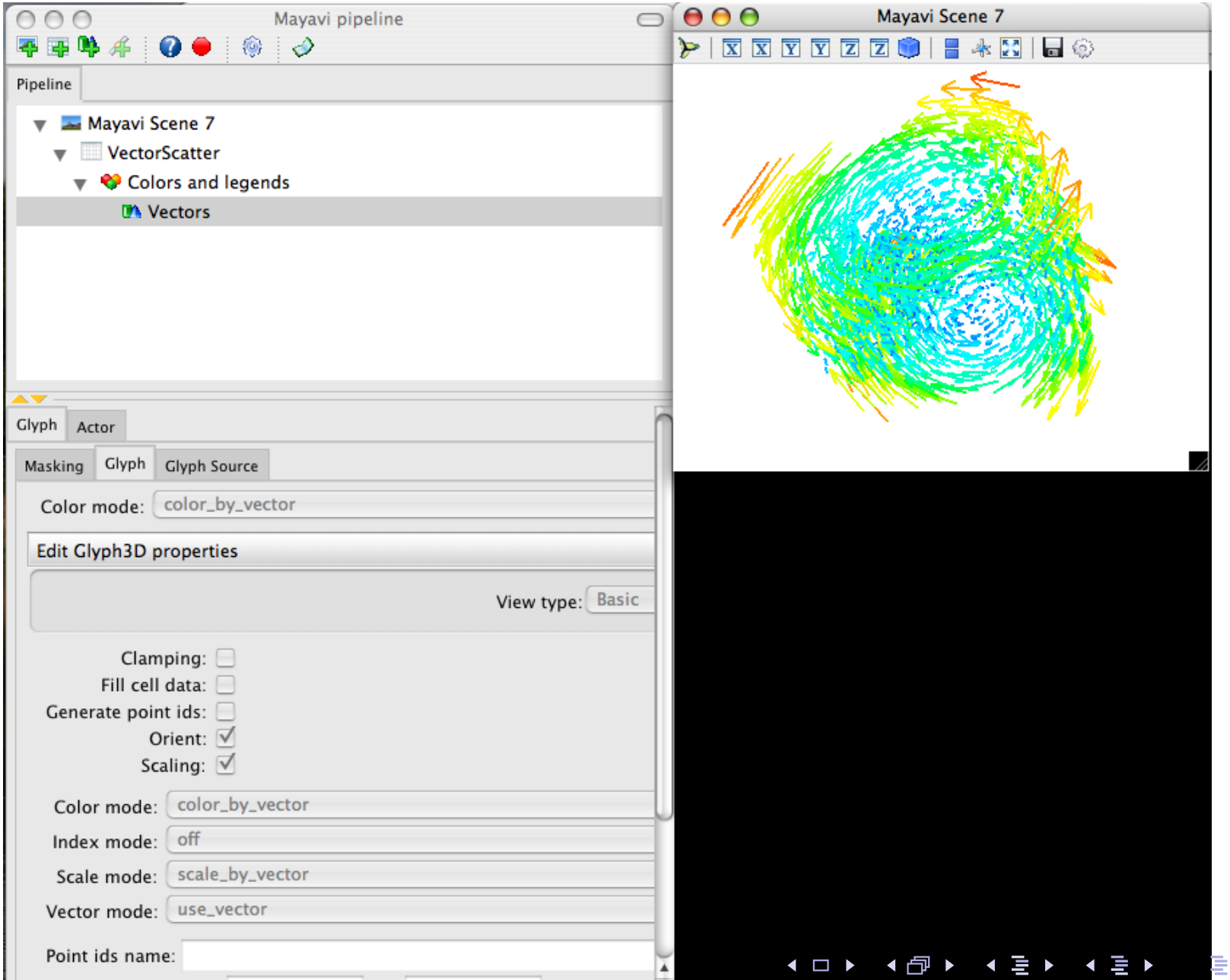
- gcf: get current figure
- savefig, figure
- axes, outline
- title , xlabel , ylabel , zlabel
- colorbar, scalarbar, vectorbar
- show: Standalone mlab scripts
- Others, see UG

Can we do more?

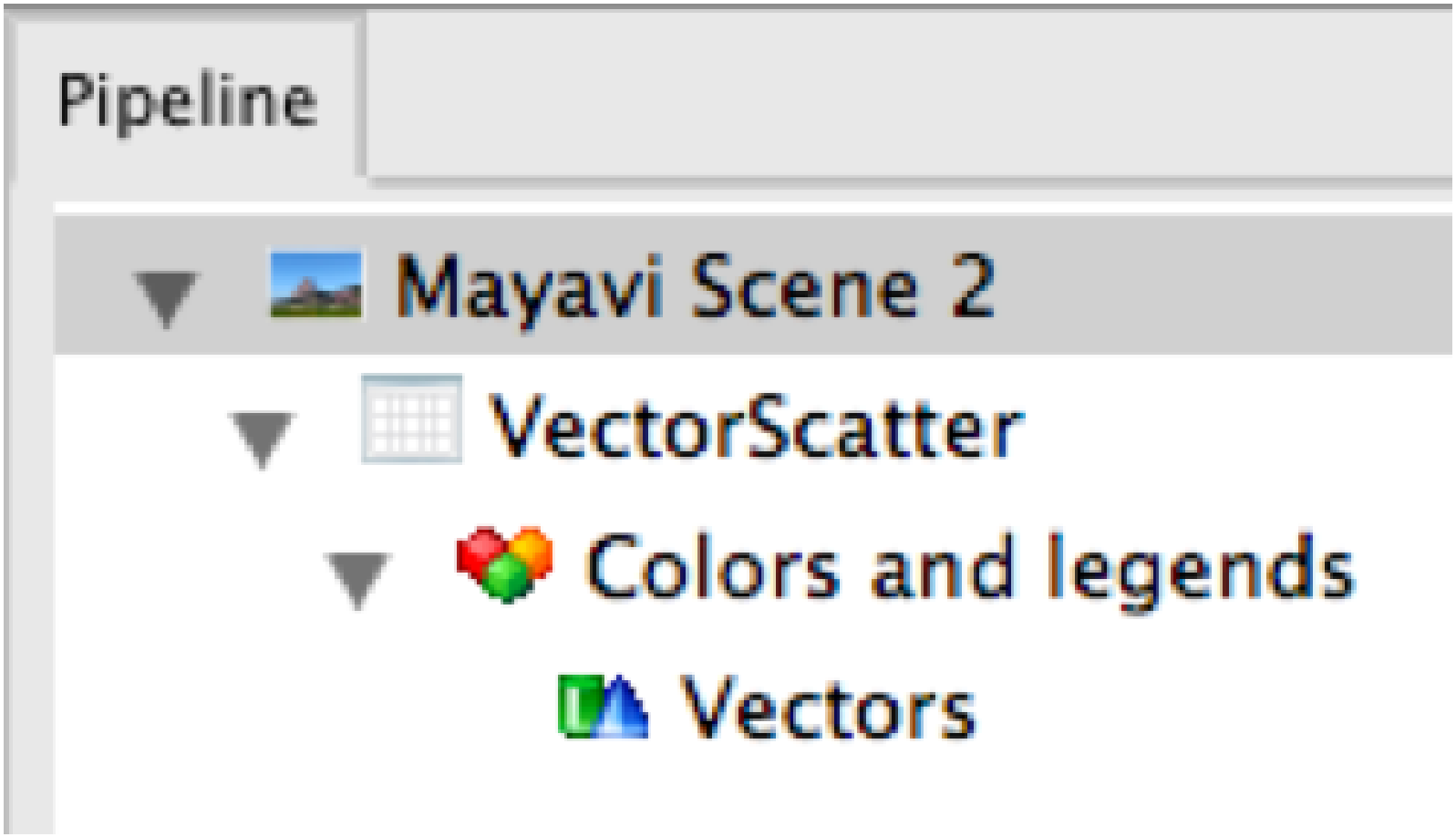
Yes!

```
quiver3d(x, y, z,
         u, v, w,
         scale_factor=0.01,
         mask_points=5)
```

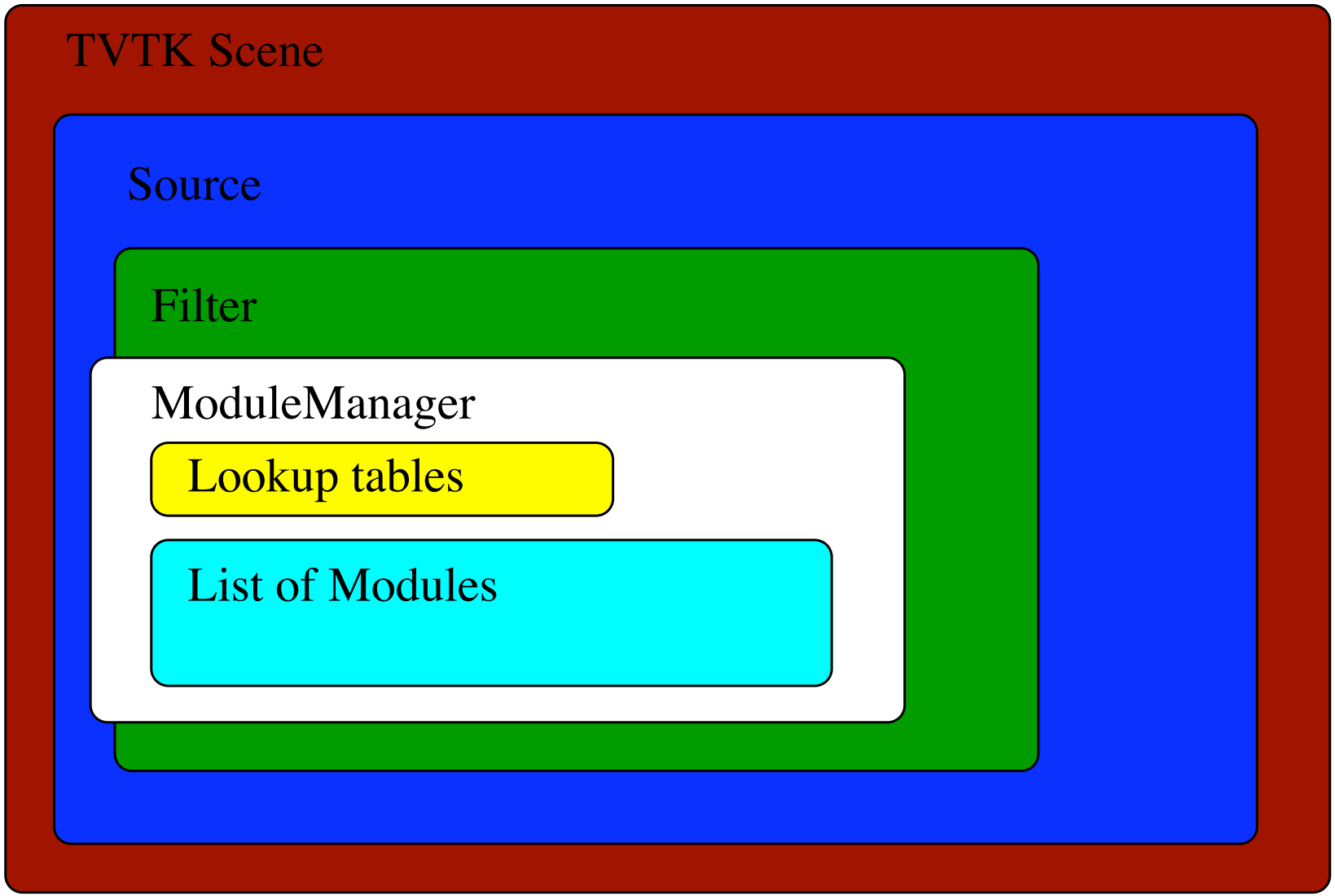
Looking inside



The pipeline



Mayavi Engine



Changing the pipeline

On UI

- Right click on node
- drag drop

Script

- Or use mlab.pipeline
- Example: mlab.pipeline.outline()
- obj.remove()

Exercise

```
>>> mlab.test_quiver3d()
```

Hide vectors, add a Vector Cut Plane

```
>>> mlab.test_flow()
```

Add a Vector Cut Plane

Can also use the Lorenz example

Exercise

```
>>> mlab.test_quiver3d()
```

Hide vectors, add a Vector Cut Plane

```
>>> mlab.test_flow()
```

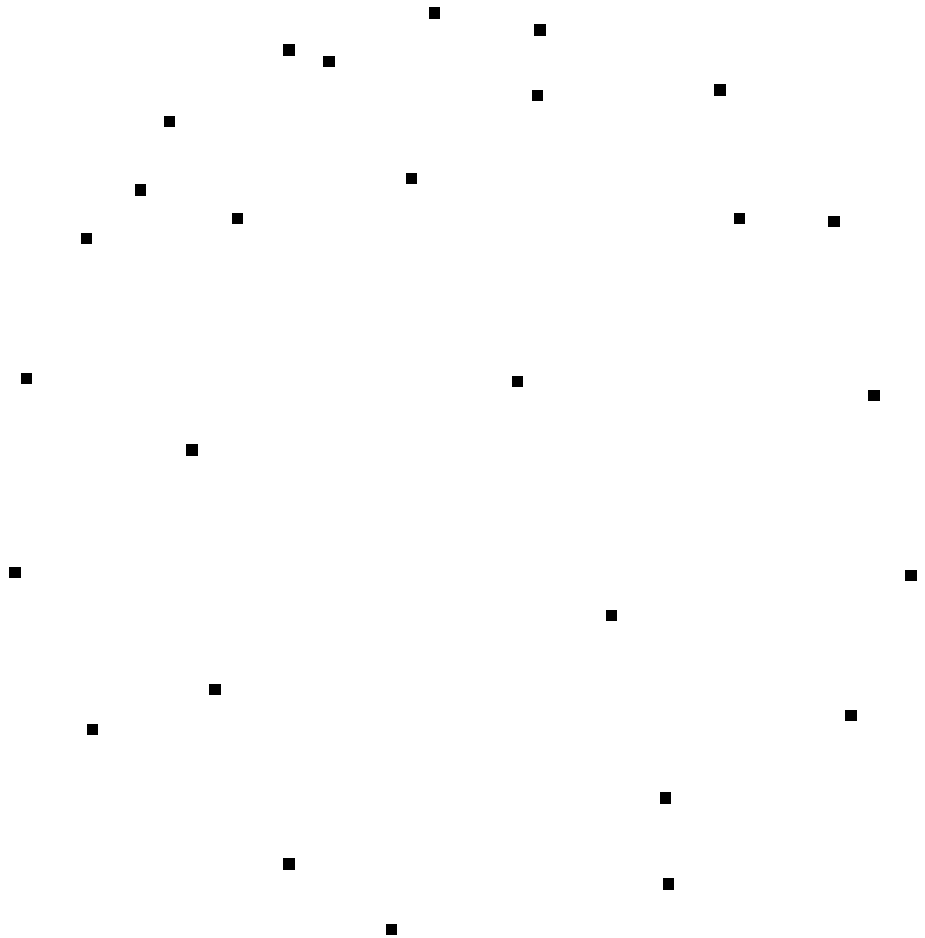
Add a Vector Cut Plane

Can also use the Lorenz example

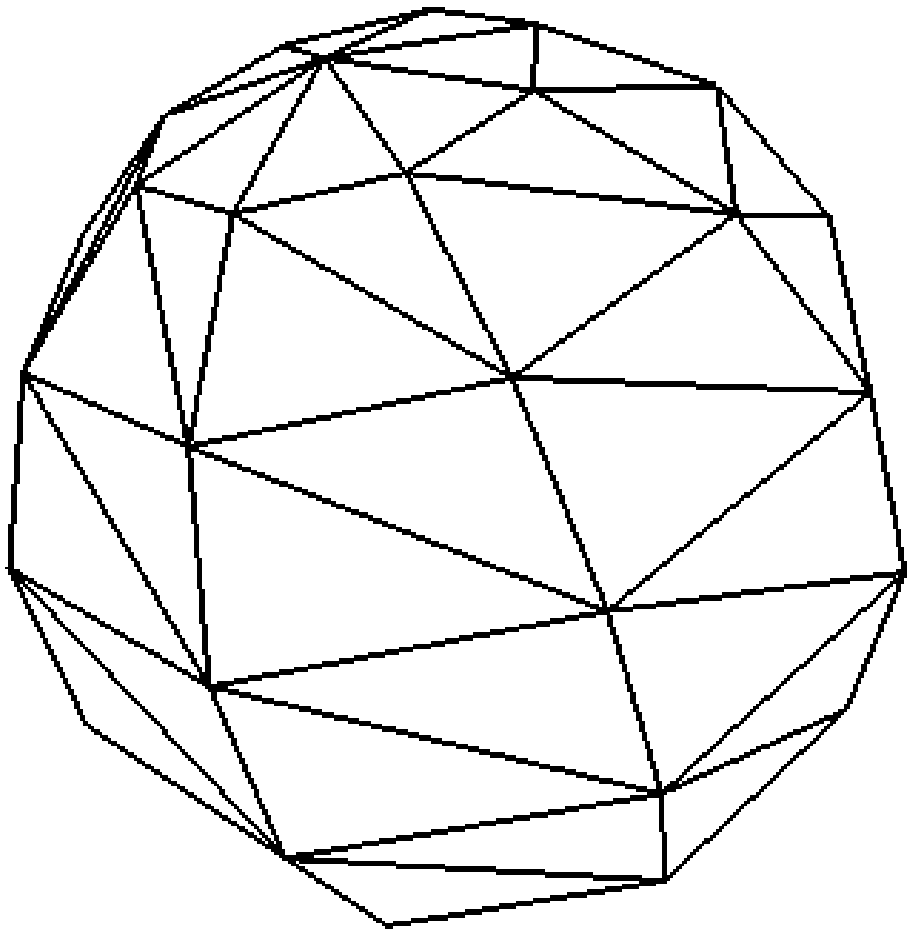
Surprised?

So what is the problem?

Points?



Curve?

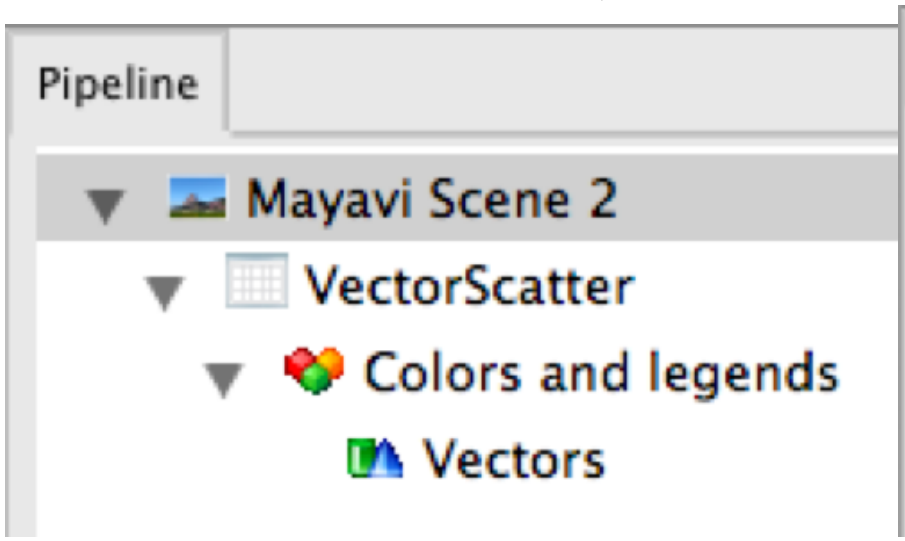


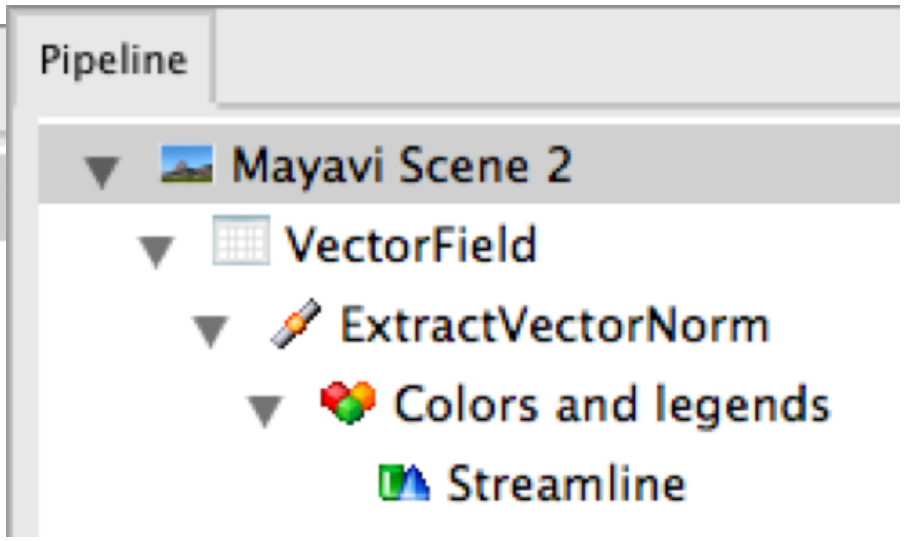
Surface?

Interior of sphere?

Datasets

Quiver v/s Flow





Recap

- `mlab` gets you started
- Pipeline and data flow
- Datasets are important

Changing the pipeline

On UI

- Right click on node
- drag drop

Script

- Or use mlab.pipeline
- Example: mlab.pipeline.outline()
- obj.remove()

`mlab` and Mayavi2?

- `mlab` is just a thin layer over the Mayavi OO API
- `mlab` commands return mayavi objects

Exercise

1. Start with flow for the Lorenz system
2. Now extract the vector norm (use a filter)
3. Plot iso-contours of this
4. Figure out how to do this from the UI and mlab.pipeline

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So how do you make a fancier script?

Use script recording

Demo

So how do you make a fancier script?

Use script recording

Demo

Animating data

```
>>> s = mlab.flow(x, y, z, u, v, w)
>>> s.mlab_source.u = u*z
```

- mlab_source.set: multiple attributes
- If you change the shape of the arrays use the reset method

Setting the view

```
>>> print mlab.view()
>>> mlab.view(azimuth=None,
              elevation=None,
              distance=None,
              focalpoint=None)
```

Thank you!