Diving into scientific Python

Training Session
EuroPython 2011

Who is this for?

- You already know Python
- You'd like to use Python in scientific applications
  - model building
  - number crunching
  - data science
- We will focus on
  - interactive use
  - iterative development
- We will use Windows, but most is cross-platform

Outline

1. Context
2. The Python Scientific Stack
    - coding environment
    - numpy
    - matplotlib
    - I/O
3. Applications
    - data analysis
    - image analysis
    - user interaction

1. Context

As you know by now, Python is...

- a general-purpose language
- easy to write, read and maintain (generally)
- interpreted - no compilation
- garbage-collected - no memory management
- weakly typed (duck typing)
- object-oriented if you want it to
- cross-platform: Linux, Mac OS X, Windows

Science & Engineering

- Python has been around for a while in scientific and engineering communities
  - "glue" language
- During the past 10 years, Python became a viable end solution for scientific computing, data analysis, plotting...
- This is mostly thanks to lots of efforts from the Open Source community, leading to the availability of mature 3rd-party tools
  e.g. numpy, scipy, matplotlib, ipython...
- Lots of momentum right now

Fragmentation

- Problem
  - fast Python development = lots of different versions
  - lots of packages to install, each with lots of versions and dependencies on each other
  - to install the whole stack can be tricky
  - even linux distros sometimes don't get it right
- Solution: Python distributions
  - Everything is in the box
  - stabilized

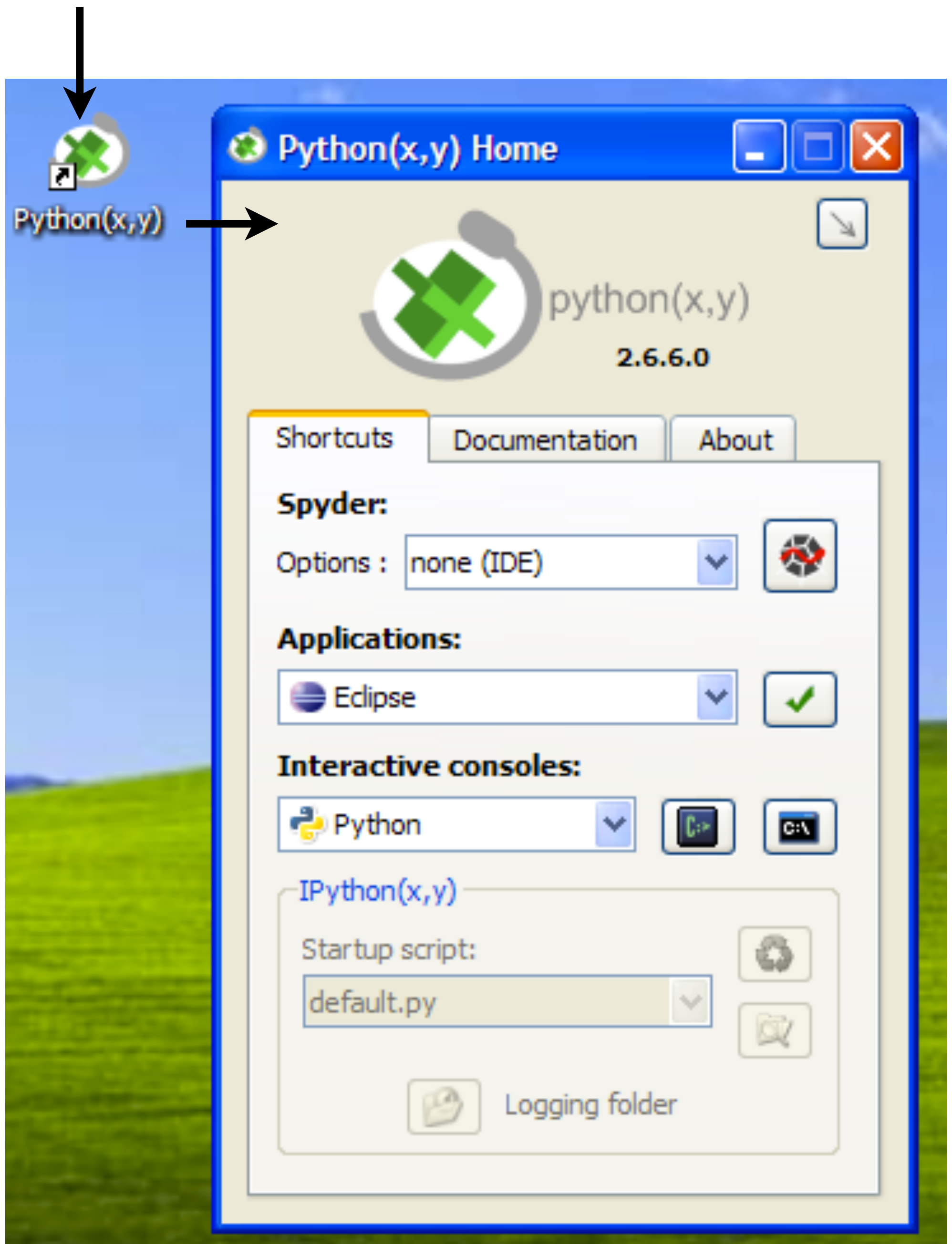
Python distributions

	strong points	weakness
SAGE ~Mathematica, Maple	Symbolic math Notebooks	sprawling
Enthought Python Distribution (EPD) ~Matlab	consistent, tight ETS	non-free (free academic license)
Python(x,y) ~Matlab	Spyder (IDE) Eclipse+Pydev	Windows-only (so far)

Python(x,y)

- http://www.pythonxy.org
- Provides
  - A recent version of Python (2.6.6, 2.7 soon)
  - lots of packages and modules for engineering in Python, all pre-configured
  - Visualization tools
  - improved consoles
  - Spyder (Matlab-like IDE)

Python(x,y) launcher



- interactive consoles
- Python-related tools
- offline documentation
- Spyder IDE
- hides in the tray

Note

- Most scientific modules not ready (yet) for Python >= 3.0
- Porting of numpy/matplotlib underway
- Stick to 2.6/2.7 for now

2. The Python Scientific Stack

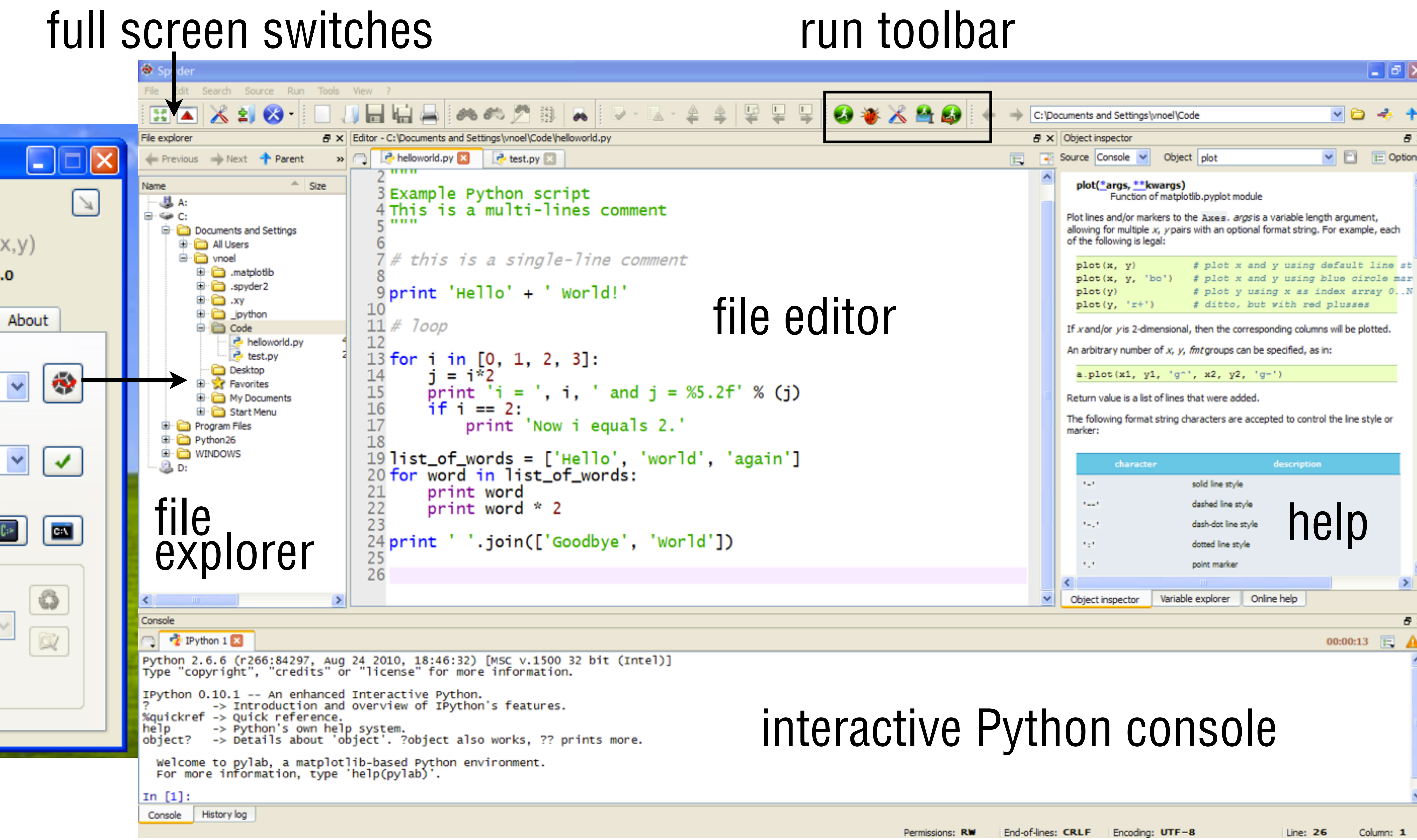
2. The Python Scientific Stack

1. Coding Environment

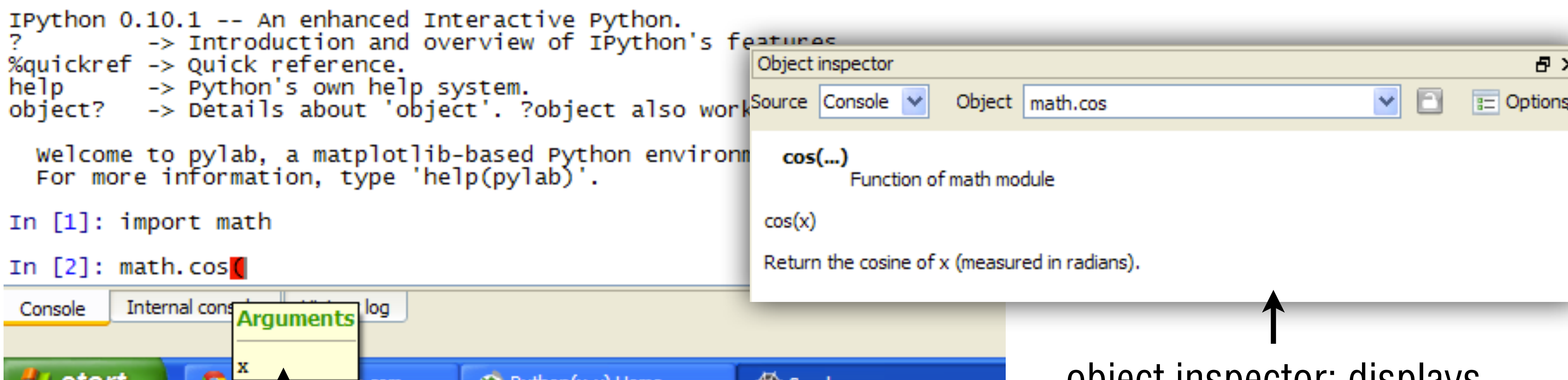
Spyder

- Spyder: programming environment
  - file explorer
  - code editor with autocompletion, suggestions
  - improved IPython console
  - contextual help linked to code editor, console
  - variable explorer (editable)
  - continuous code analysis

Spyder


full screen switches
run toolbar
file editor
help
file explorer
interactive Python console
Example Python script
This is a multi-lines comment
this is a single-line comment
print 'Hello' + ' World!'
# loop
for i in [0, 1, 2, 3]:
j = i*2
print 'i = ', i, ' and j = %5.2f' % (j)
if i == 2:
print 'Now i equals 2.'
list_of_words = ['Hello', 'world', 'again']
for word in list_of_words:
print word
print word * 2
print ' '.join(['Goodbye', 'World'])
Python 2.6.6 (r266:84297, Aug 24 2010, 18:46:32) [MSC v.1500 32 bit (Intel)]
Type "copyright", "credits" or "license" for more information.
IPython 0.10.1 -- An enhanced Interactive Python.
Welcome to pylab, a matplotlib-based Python environment.
For more information, type 'help(pylab)'.
In [1]:

Spyder | help system

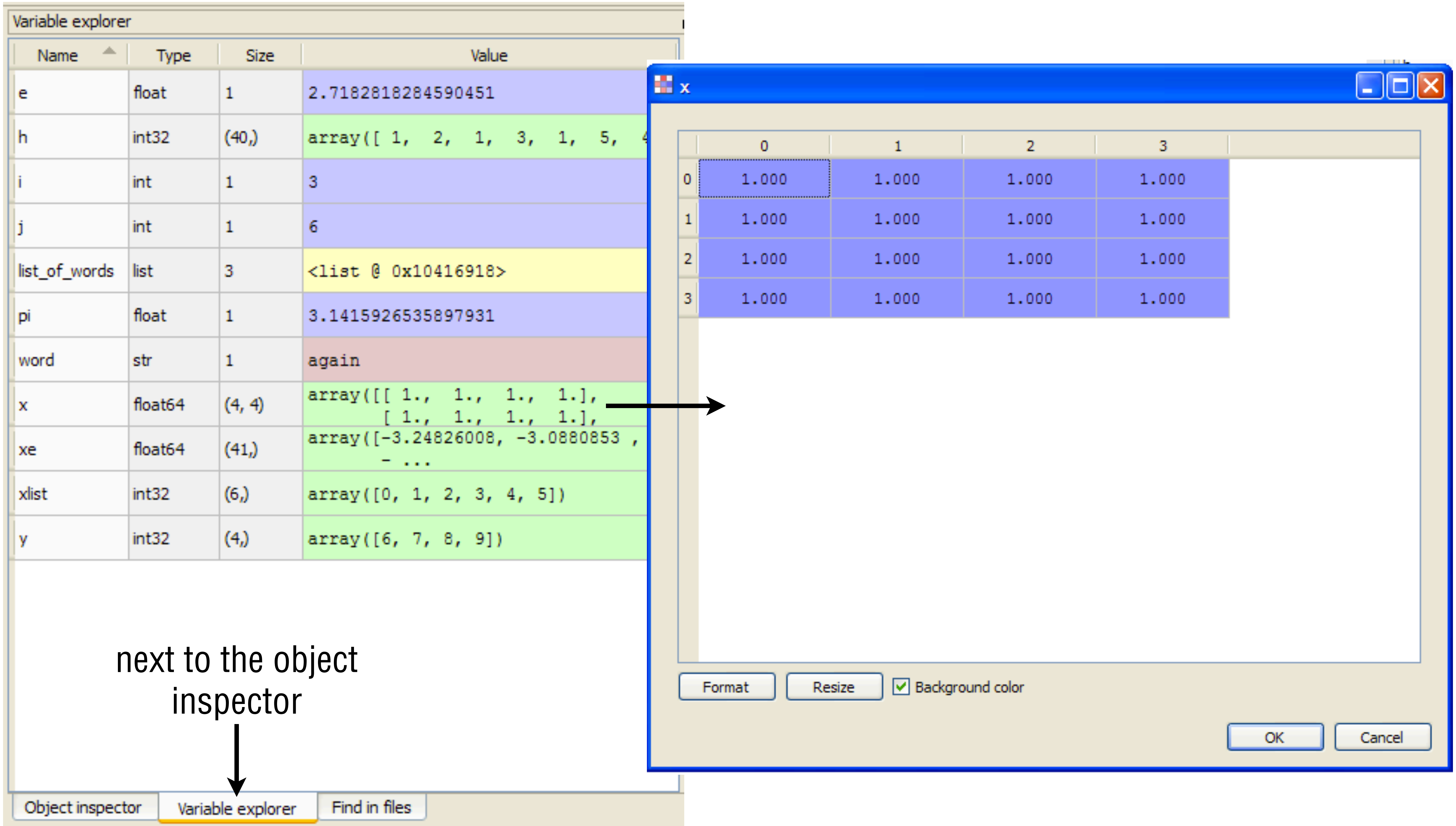


argument suggestion in the console and the editor

object inspector: displays documentation for what you type (console/editor)

- in the console
  - `help function`
  - `function?`
  - `source function`

Spyder | variable explorer



IPython

- In Spyder, the default Python console is IPython
  - much better than the standard Python console
  - tab completion for functions, modules, variables, files
  - filesystem navigation (`cd, ls, pwd`)
  - syntax highlighting
  - works fine with matplotlib

IPython

- "magic" commands
  - `%command`
  - type %⇥ to see them all
  - (you can drop the % for most of commands)
  - > `whos`
  - > `reset`
  - > `run script.py`
  - > `timeit y = cos(x)`

IPython

- The output of the nth command is in `_n`
- ```
  In [183]: exp(-pi)
  Out[183]: 0.043213918263772258
  ```
- ```
  In [184]: _183 * 2
  Out[184]: 0.086427836527544516
  ```

Projects

- Spyder, IPython
  - interactive use
  - data exploration
  - iterative development of models and workflows
- Project-oriented development (i.e. full applications): Python(x,y) includes Eclipse and Pydev
  - we won't cover that today

2. The Python Scientific Stack

2. Numpy

numpy

- Numpy provides the array variable
  - n-dimensional, <u>typed</u>
  > `from numpy import array`
- and related functions
- developed since 1995
  - child of Numeric and numarray
  - now stable and mature, v.1.6 released May 2011
  - Python 3 coming up
  - basis for scipy, matplotlib, and lots of others

numpy | importing

- IPython imports all numpy automatically
  > `from numpy import *`
  - Numpy functions can be called without prefix
  - convenient for interactive use
- In scripts, `import numpy as np` is better
  - Official convention (examples, etc.)

numpy | array creation

- 1-d arrays can be created from lists
  - `x = np.array([0.1, 0.2, 0.3])`
  - `x = np.array(range(10))`
  - `x = np.array([])      # empty array`
- or from a range
  - `x = np.arange(0, 10, 0.1)`
- default Arrays are float64, but you can specify
  - `x.dtype -> dtype('float64')`
  - `x = np.array([], dtype='int32')`

numpy | r_[ ]

- `np.r_[]`
  - can replace `np.array()`
    > `np.r_[0.1, 0.2] == np.array([0.1, 0.2])`
  - can create vectors from indexing notation
    > `np.r_[0:10:0.1] # start, stop, step`
    > `np.r_[0:10:100j]  # start, stop, npoints`
  - ~ array-generating array

numpy | dimensions

- Arrays are n-dimensional n>=1

```
> x = np.zeros([10, 4])
> x = np.ones([10, 4])
```

- e.g. 10 rows x 4 columns
- rows and columns do not scale

```
> x = np.zeros([10, 4, 3, 5, 2])
```

- iterate on arrays

```
> xarr = np.zeros([2, 3])
  for xrow in xarr:
    print xrow          # array([0,0,0])
    print xrow.shape    # [3]
       for x in xrow:
          print x
```

numpy | array operations

- inspection
  - `np.shape(x)          # or x.shape`
  - `np.ndim(x)           # or x.ndim`
  - `np.size(x)...`
- manipulation
  - `np.reshape(x)`
  - `x = np.append(x, y)`
  - `np.concatenate([x, y...])`
  - `np.squeeze, vstack, hstack`
  - `x.T       # tranpose`

numpy | indexing

- Arrays can be indexed like Python lists with >=1 dimension(s)

```
> x = np.r_[0:2*pi:0.01]
> x[0]
> x[50:]
> x[:-10]
> x[-20:-50:-2]

> y = zeros(5,5)
> y[3,4]
> y[0:3,2:5]
```

numpy | boolean indexing

- arrays can be indexed through **boolean indexing**

```
> x = np.r_[0:10:0.1]
> idx = (x > 2.) & (x < 8.)
> # comparison operators overload
> print idx
  array([False, False, True, False...])

> np.mean(x[idx])
> x = x[idx]

> x[x<2] = 0.
```

- With multiple conditions, parenthesis are mandatory

```
> idx = x > 2 & x < 8        # won't work
```

numpy | views

- sliced arrays are views of the original array

```
> x = np.ones([4,4])
> y = x[0:2,0:2]
> x[0,0] = 5
> y
array([[ 5.,  1.],
       [ 1.,  1.]])
```

  - This may or may not be what you want
  - To get a new array: `y = x[0:2, 0:2].copy()`
- By contrast, boolean indexing returns a new array

```
> x = np_r[0:10]
> y = x[x > 5]
> x[x>5] = 0
> y
array([6, 7, 8, 9])
```

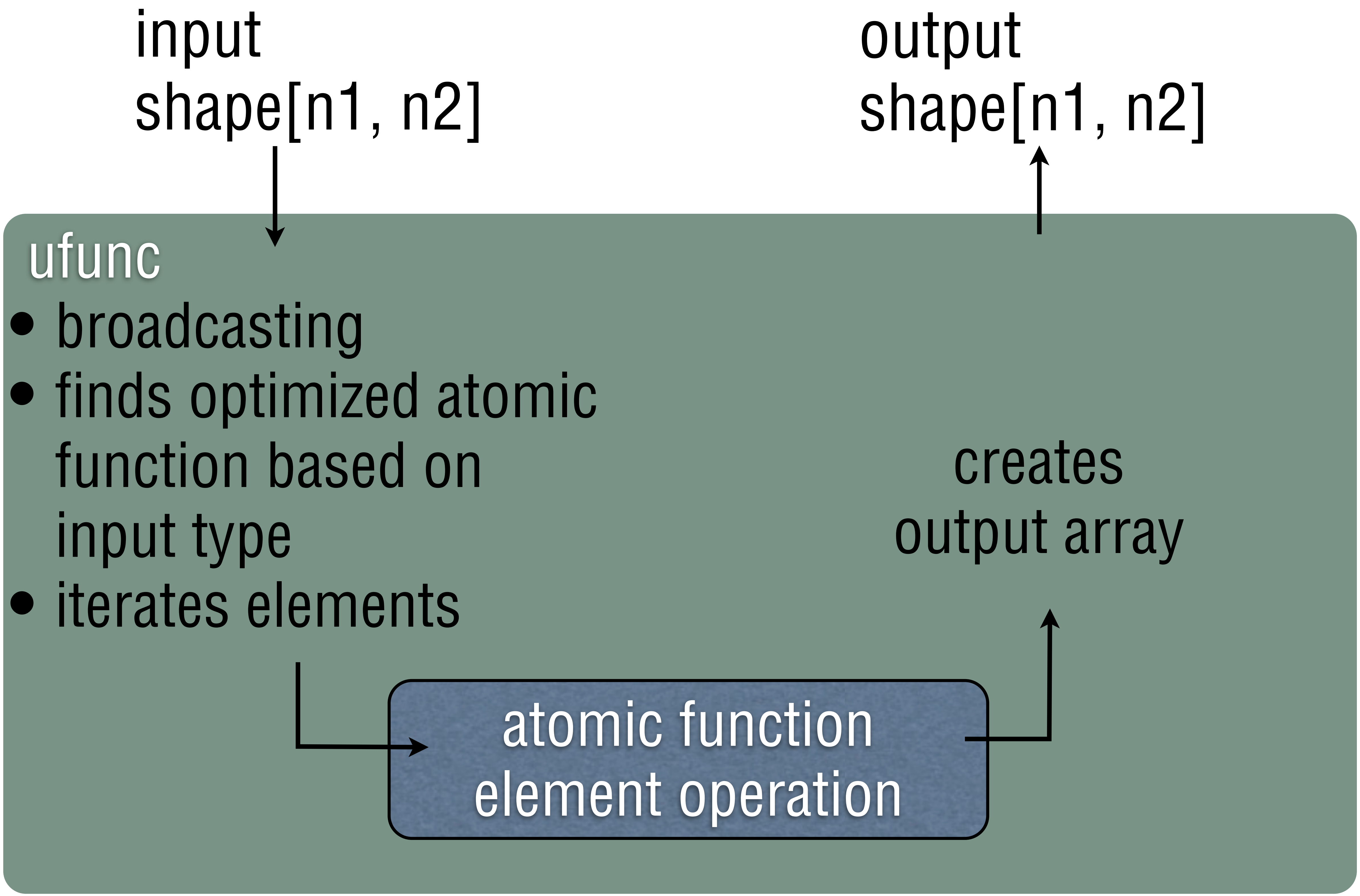
numpy | functions

- array functions apply elementwise
  - e.g. `np.cos(x)`

```
> xlist = [0.1, 0.2, 0.3]
  xcos = [math.cos(x) for x in xlist]
  xcos = np.cos(xlist)
  # lists are converted to arrays on-the-fly
```

- numpy jargon: "universal functions" or ufunc
- a ufunc is a vectorized wrapper that iterates over elements
- standard in Matlab, IDL, F90, number-crunching languages

ufuncs


input
shape[n1, n2]
output
shape[n1, n2]
ufunc
• broadcasting
• finds optimized atomic function based on input type
• iterates elements
creates output array
atomic function element operation

numpy | functions

- **broadcasting** fills missing dimensions
  - ```
    xl = np.r_[0:2*pi:10000j]
    yl = xl * 2.
    ```
- behind the scenes, "2." is transformed into a 10000 elements array filled with "2."
    ```

numpy | functions

- vectorization and typed arrays reduce the need for type checking
- and allows optimizations (float64, int32)
- written in C for speed
  - > `xlist = np.r_[0:2*pi:10000j]`
  - > `timeit y = [math.cos(x) for x in xlist]`
    `100 loops, best of 3: 3.05 ms per loop`
  - > `timeit y = np.cos(xlist)`
    `10000 loops, best of 3:` **`165 us`** `per loop`
  - > 18x speedup (~ standard across numpy)

numpy | functions

- arithmetic operators + `-` `*` `/` are ufuncs
  - > `timeit yl = [x*2. for x in xl]`
    `1 loops, best of 3: 1.42 s per loop`
  - > `timeit yl = xl * 2.`
    `100 loops, best of 3:` **`6.49 ms`** `per loop`
- ~218x speedup
  - `xl = np.r_[0:2*pi:10000j]`
    `yl = np.r_[0:2*pi:10000j]`
  - `timeit zl = [x+y for x,y in zip(xl,yl)]`
    `100 loops, best of 3: 8.08 ms per loop`
  - `timeit zl = xl + yl`
    `100000 loops, best of 3:` **`18.6 us`** `per loop`
- ~448x speedup

numpy | functions

- trigonometric, statistics, math

```
np.sin, cos, tan...
   mean, std, median, max, min, argmax...
   sum, diff, log, exp, floor, bitwise_and...
```

- keyword argument `axis=n`

```
> x = np.ones([2,4])
> np.sum(x, axis=1)
array([ 2.,  2.,  2.,  2.])
```

numpy | good to know

> `np.in1d(x, y)`

- Tests if each element of `x` is in `y`

```
> x = [0, 9, 2, 5, 6, 1, 4, 3]
> np.in1d([1, 12, 3], x)
[True, False, True] # bool array
```

> `np.all(x), np.any(x)`

- like `all` and `any` in python

```
> x = [0, 9, 2, 5, 6, 1, 4, 3]
> y = np.in1d([1, 12, 3], x)
> np.any(y)
True
> np.all(y)
False
```

numpy | nan and inf

```
> x = r_[0.0, 1.0]
  y = r_[0.0, 0.0]
  z = x / y
  print z
> np.isfinite(z)
  np.isinf(z)
  np.isnan(z)
> print z==z
```

numpy | meshgrids

```
> x = np.r_[0:5]
> y = np.r_[5:10]
> xx, yy = np.meshgrid(x, y)
> xx
array([[0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4]])
> yy
array([[5, 5, 5, 5, 5],
       [6, 6, 6, 6, 6],
       [7, 7, 7, 7, 7],
       [8, 8, 8, 8, 8],
       [9, 9, 9, 9, 9]])
```

numpy | masked arrays

- You can flag invalid data in arrays using masked arrays
- `numpy.ma` module
- masked data is ignored in math operations
    - if it's not, it's a bug in numpy

```
> x = np.r_[0:11]
> np.mean(x)
5.0
> import numpy.ma as ma
> x = ma.masked_where(x > 6, x)
> x = ma.masked_greater(6, x)    # same
> np.mean(x)
3.0
```

```
masked_equal,
masked_greater,
masked_less
masked_inside,
masked_outside,
masked_invalid...

+ numeric
functions
```

numpy | other stuff

- I/O
- Matrix computations: `np.matrix()`
- `f2py` - Python wrappers around Fortran functions
- Structured arrays (multi-type named arrays)
- Interpolation: `np.interp()` (more in scipy)
- Histograms at 1, 2, n dimensions
  `np.histogram(), np.histogram2d(), np.histogramdd()`

> `np.rand()`

  - More in the `np.random` module

- http://docs.scipy.org/doc/numpy/reference

2. The Python Scientific Stack

3. Matplotlib

Matplotlib

- Plotting package
- Lots of Python modules to plot
  - PyNGL, Chaco, Veusz, gnuplot, Rpy, Pychart...
  - Some in python(x,y)
- Matplotlib emerging as a "standard"
  - all-purpose plot package
  - makes the easy stuff easy and the hard stuff possible
  - interactive or publication-ready EPS/PDF, PNG, TIFF
  - based on numpy
  - extensible, popular, stable and mature (v. 1.0.1)
  - Python 3 coming up

Matplotlib & Matlab

- Matplotlib can be used as an object-oriented framework
- can also follow a "Matlab-like" imperative approach, through its `pyplot` module

```
> import matplotlib.pyplot as plt
  plt.figure()
  x = np.r_[0:2*pi:0.01]
  plt.plot(x, np.sin(x))
```

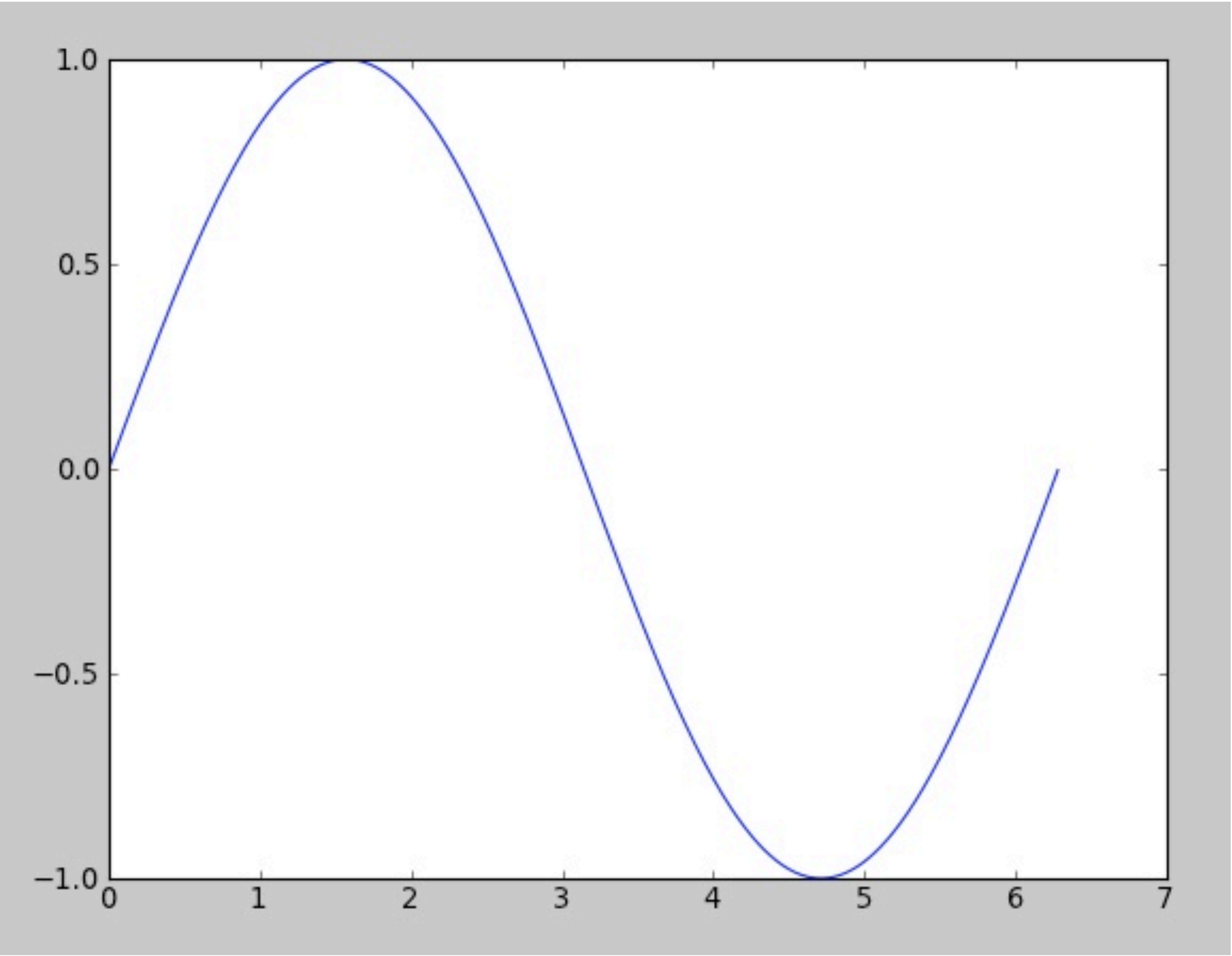
- `pyplot` functions strongly influenced by Matlab
- Not so useful when you're not familiar with Matlab

Matplotlib in python(x,y)

- IPython imports all `matplotlib.pyplot`
- You can drop the `plt.` prefix during interactive use
- `help plotting`

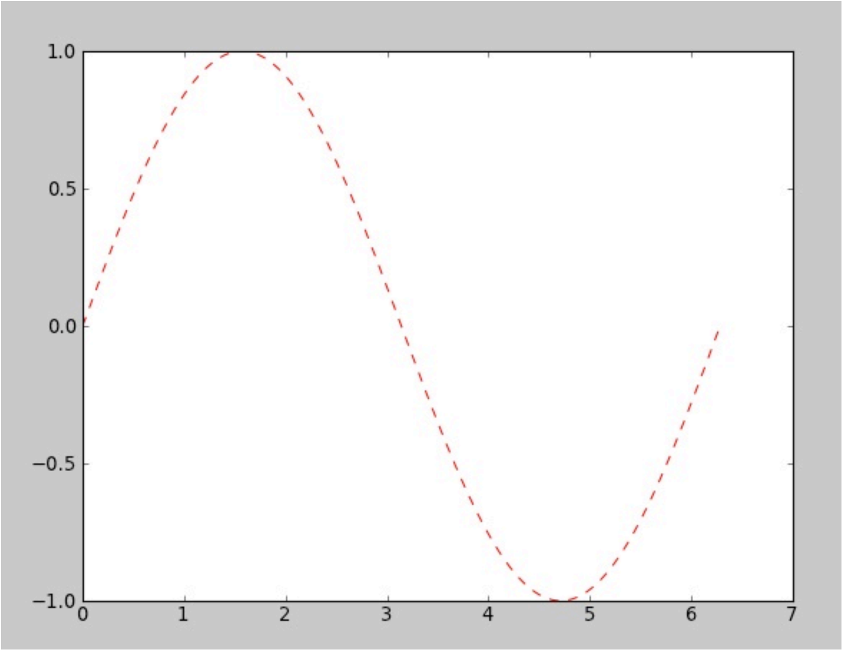
basics | line plots

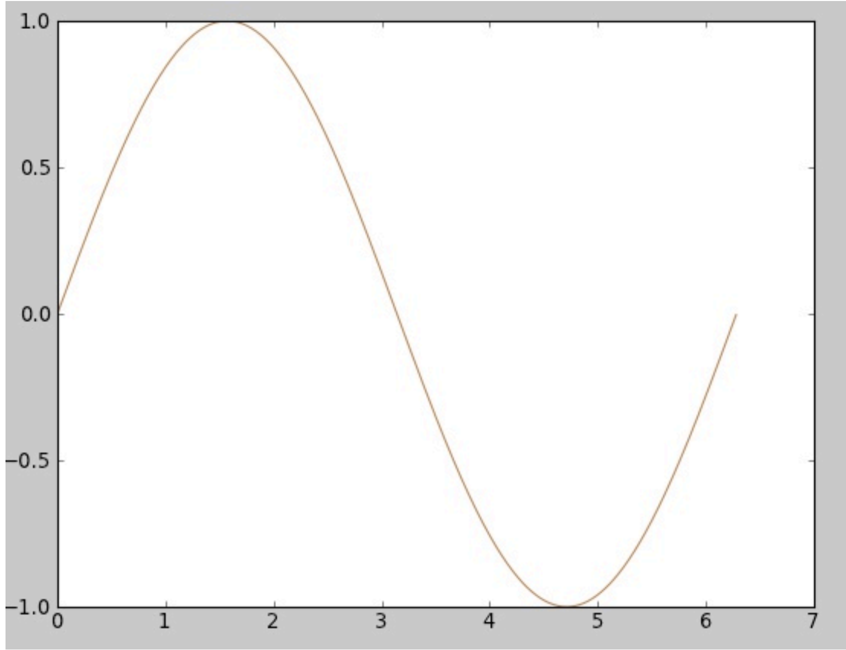
```
> x = np.r_[0:2*pi:0.1]
> y = np.sin(x)
> plt.plot(x, y)
```

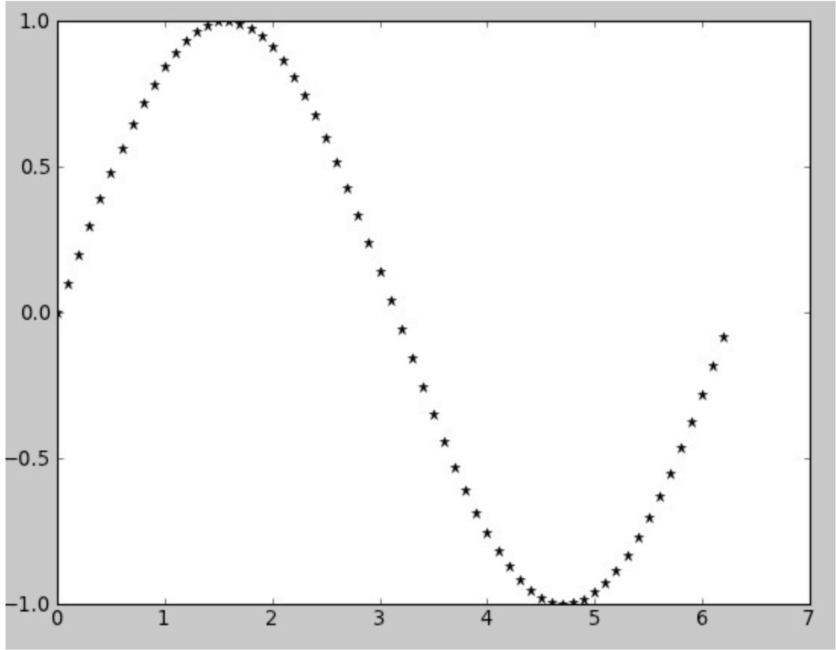


basics | line plots

- `plt.plot(x, y, str) # format string`
- `"r--"` `"#AA7744"` `"k*"`



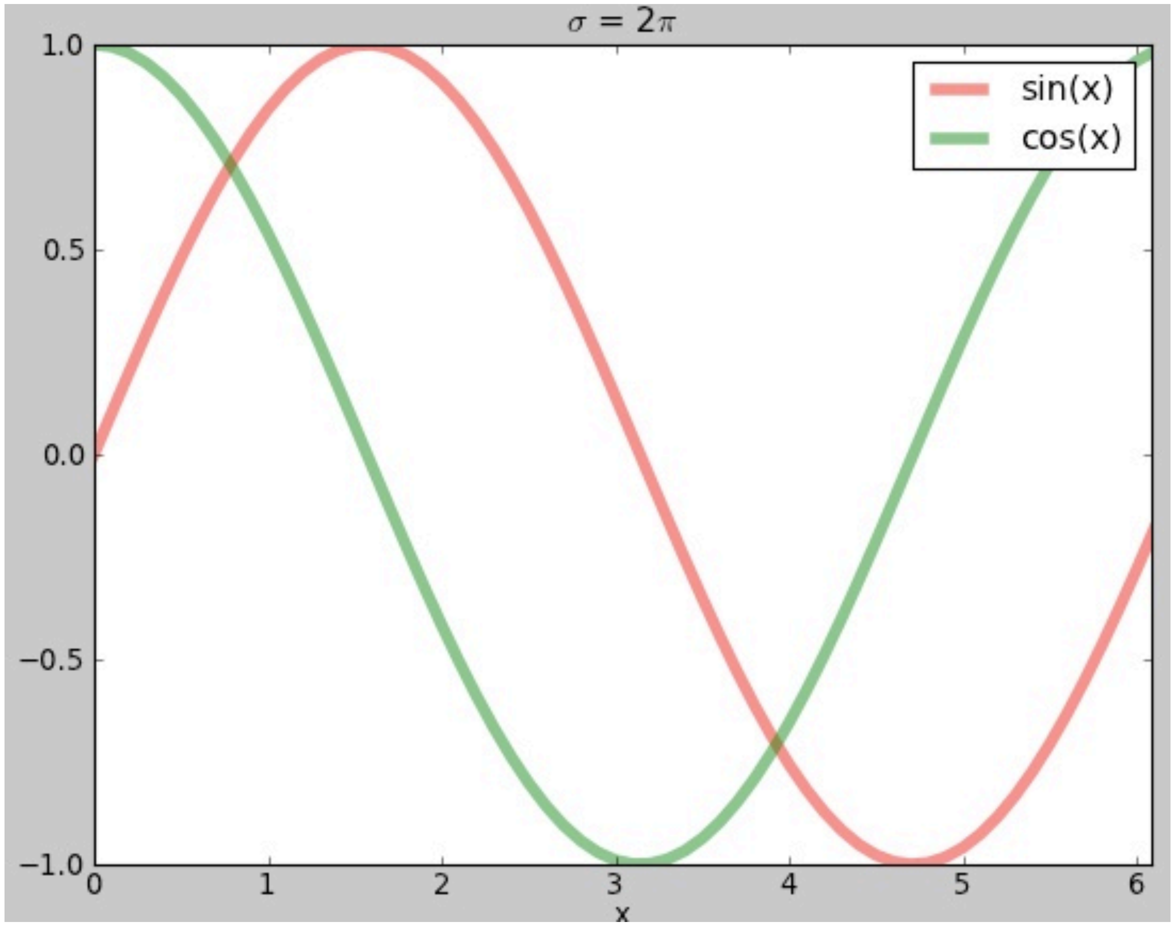




basics | line plots

- keyword arguments
  - alpha=0.0 # to 1.0
  - linewidth=0.1 # or lw
  - label="sin(x)"

  - markerfacecolor='r'...



- other line plots
  - plot_date(datetime_list, y)
  - semilogx
  - semilogy
  - loglog

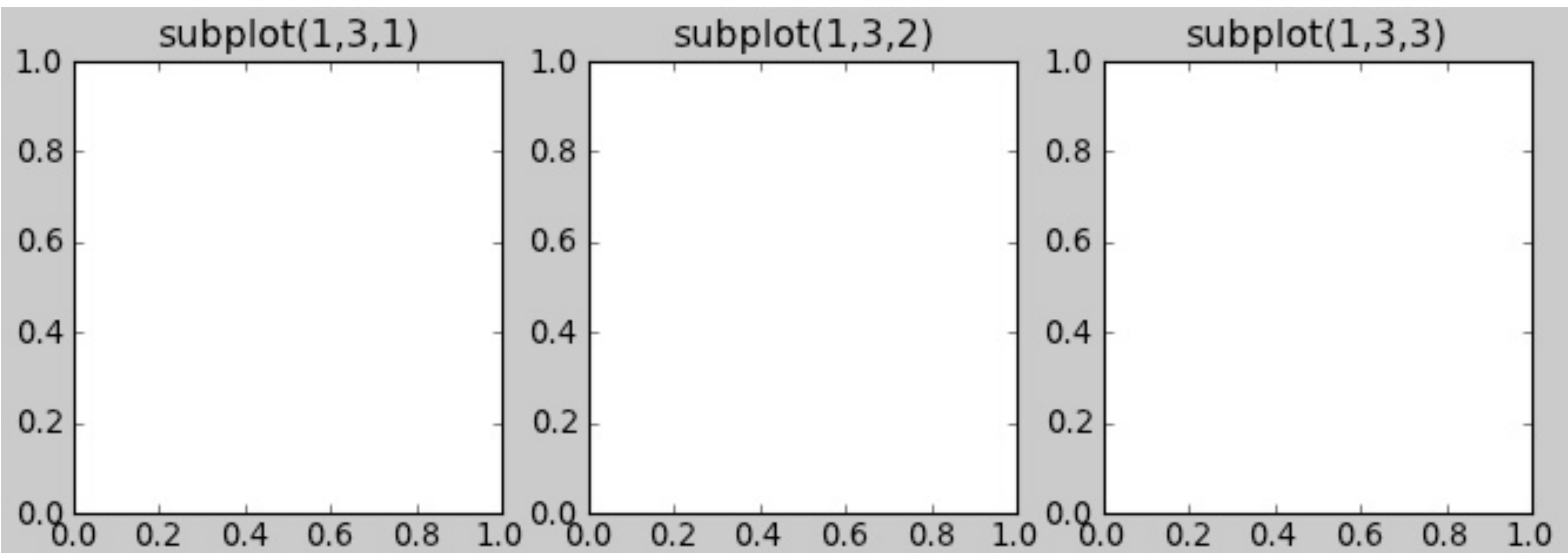
figures

```
> figure()
> figure(1)
> figure(figsize=[14,10])
> close()
> close('all')
> clf()

> savefig('figure.png|pdf')
```

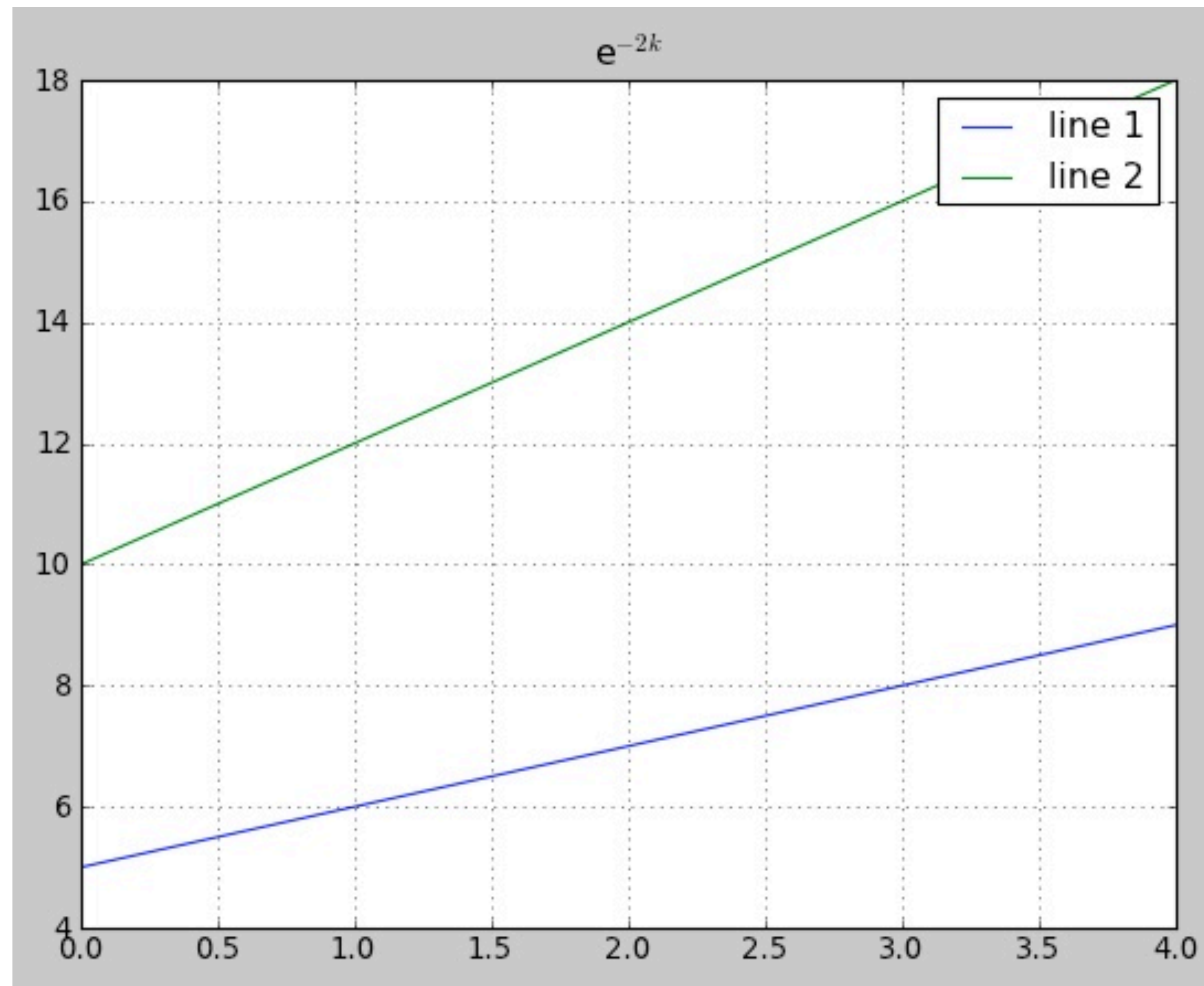
axes

```
> axes()
> xlim, ylim(min, max)
> subplot(nrow,ncol,i)
> cla()
```



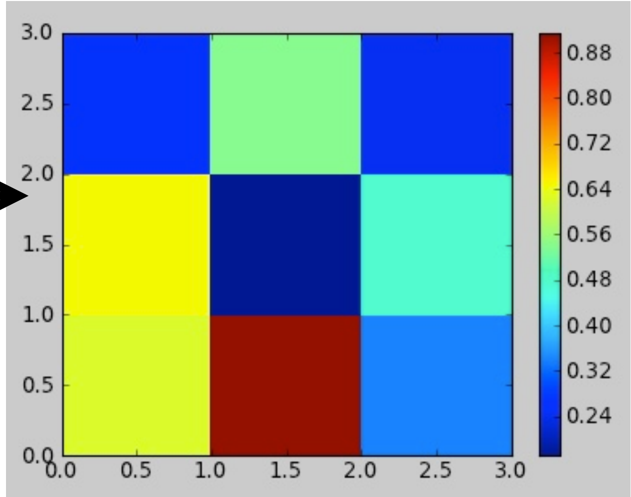
visual aids

- > `legend(['line 1', 'line 2'])`
- > `xlabel, ylabel, title`
- Latex: surrounded by '`$...$`'
- > `grid()`

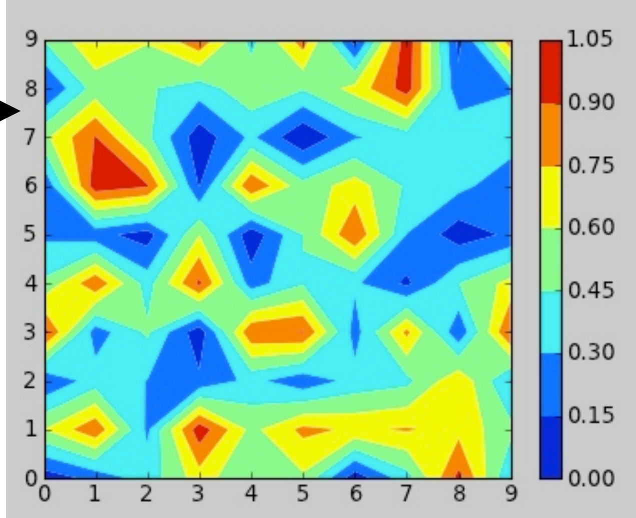


more basics

```
> scatter(x, y, size)
> bar(x, h, width=0.3), barh  # histograms
> hist(sample, bins=[n/bins])
> pcolor(x, y, c)
> pcolormesh(x, y, c)
  clim(0, 0.5)
  colorbar()
```



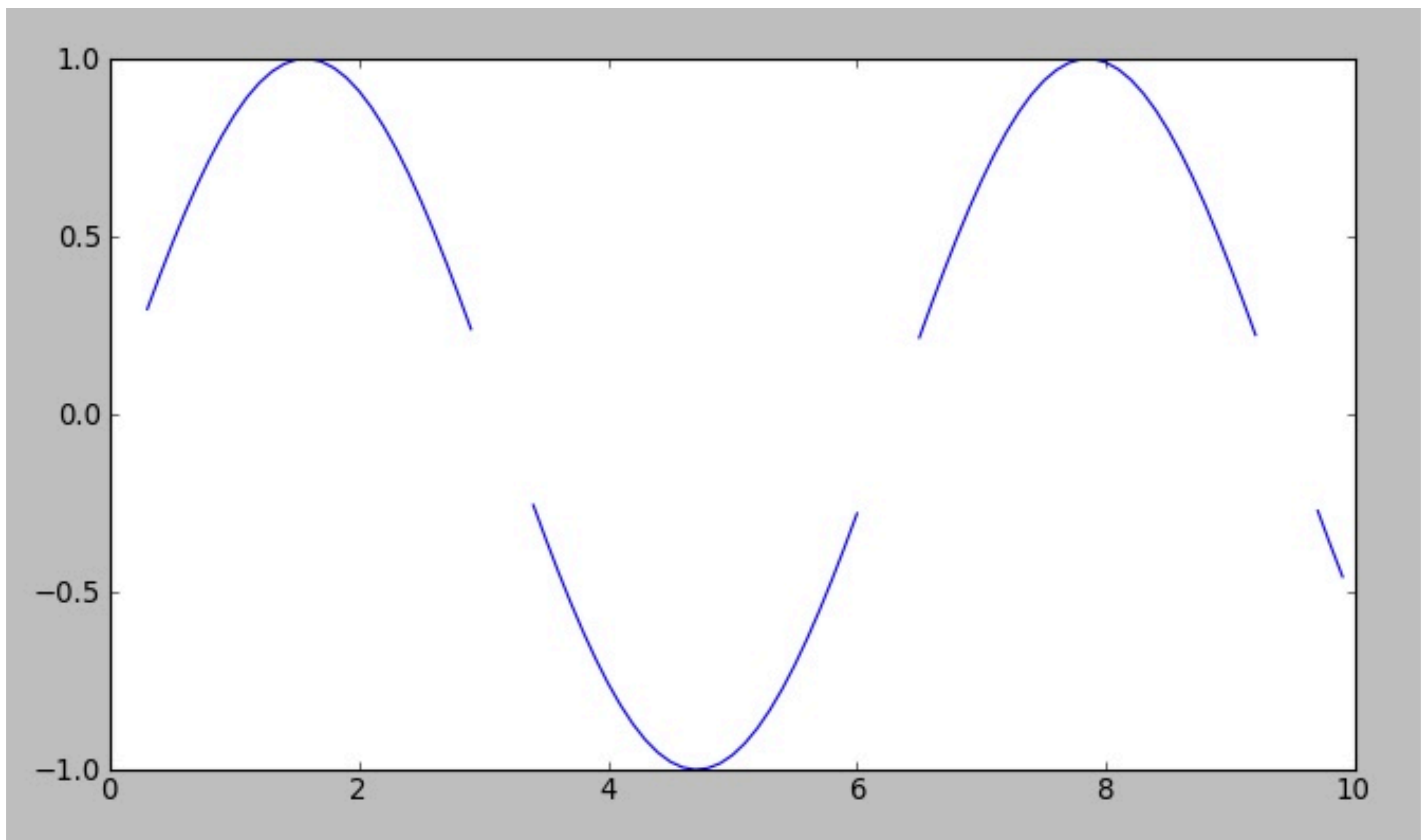

```
> contourf(x, y, c)
```




```
> plt.show()
```

masked arrays

```
> x = np.r_[0:10:0.1]
> y = sin(x)
> y = ma.masked_where((y < 0.2) & (y > -0.2), y)
> plot(x,y)
```

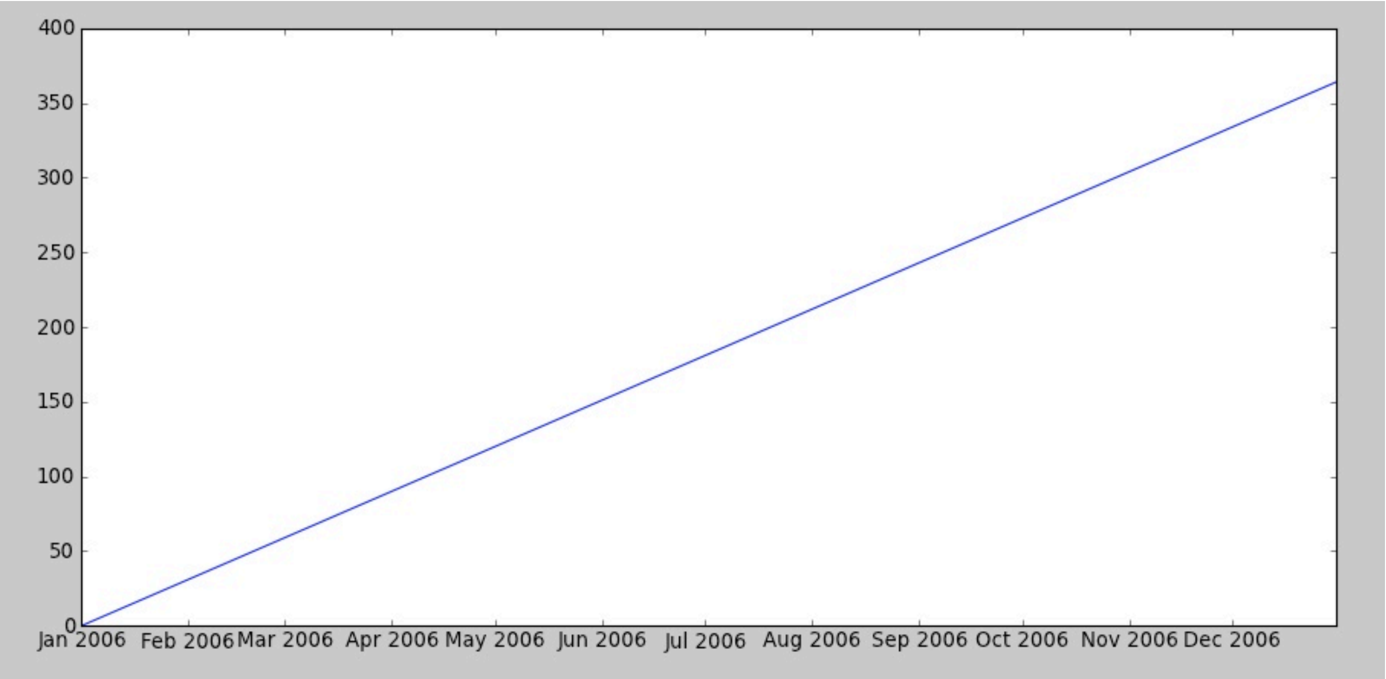


datetimes

- `date` and `datetime` objects are recognized
- Matplotlib attempts to choose the best date format

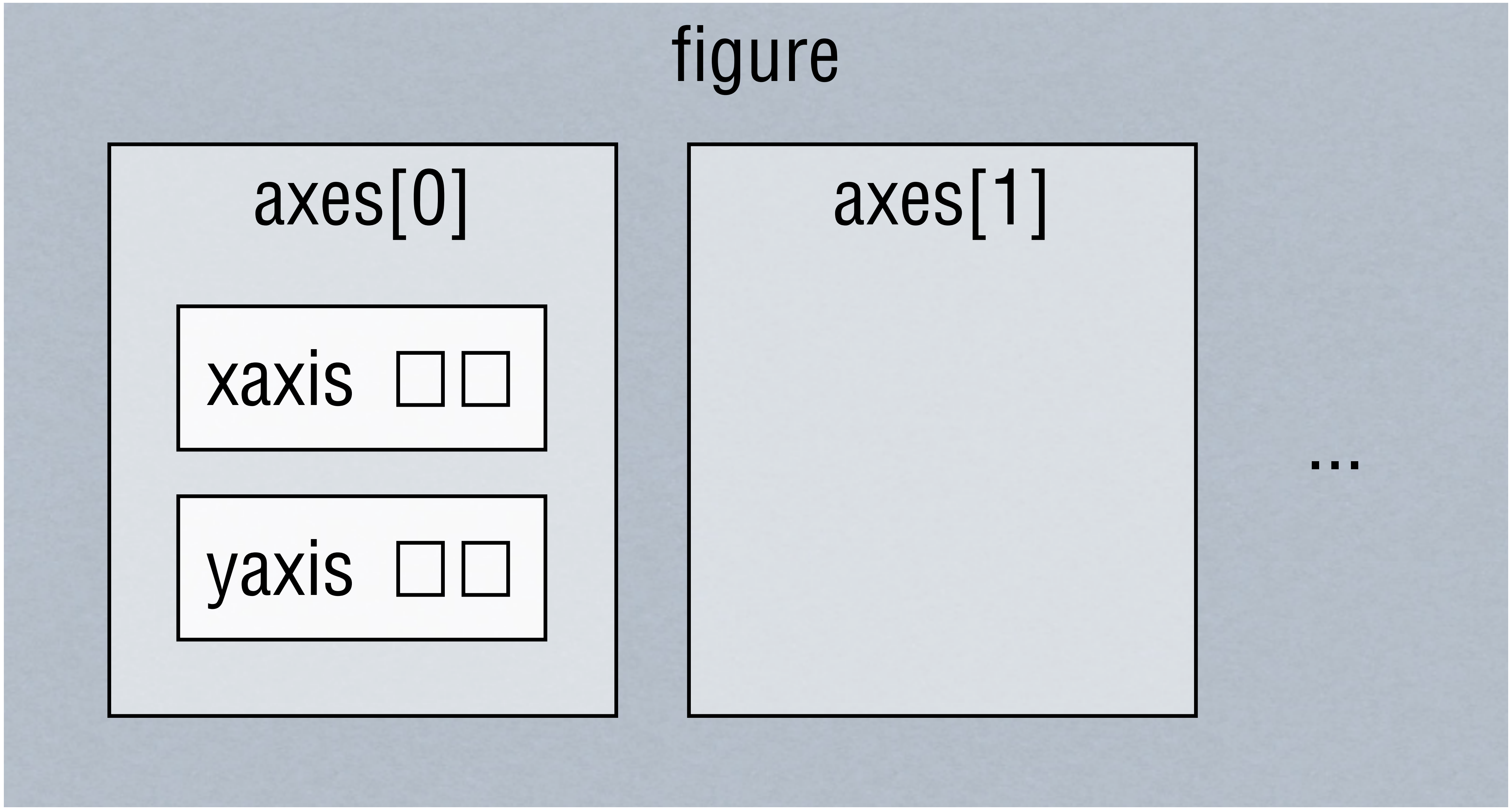
```
from datetime import datetime, timedelta
dates = [datetime(2006,1,1)+timedelta(days=i)
                    for i in range(365)]
x = np.r_[:365]
plot(dates, x)
```

- format adapts to zooming



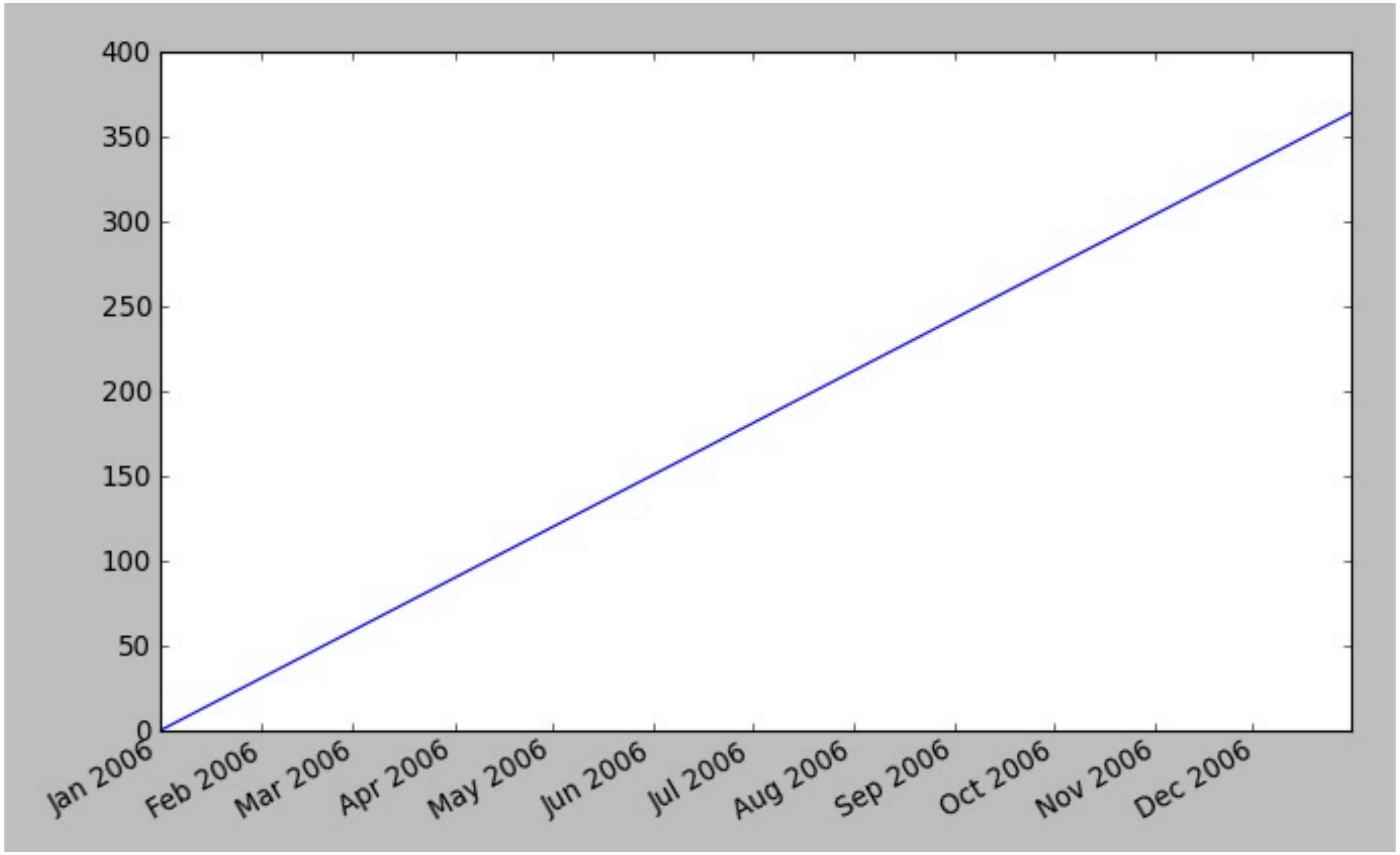
where are the objects?

- ```
  fig = figure(1)
  print fig.number
  ```
- ```
  ax = axes()
  ax.set_title('my title')
  ax.xaxis.set_label('dates')
  ax.yaxis.grid(True)
  draw()
  ```
- ```
  fig = figure()
  ax1 = subplot(2,1,1) # fig.axes[0]
  ax2 = subplot(2,1,2) # fig.axes[1]
  ```
- ```
  fig = gcf()
  ax = gca()
  ```




```
> labels = ['a', 'b', 'c']
> ax.set_xticklabels(labels)
> ax.xaxis.set_ticklabels(labels)
```

- fig.autofmt_xdate()



back to datetimes

- Date formats and tickers are very flexible

```
> import matplotlib.dates as mdates
  loc = mdates.DayLocator(bymonthday=[1,8,16,24])
  fmt = mdates.DateFormatter('%m-%d')
  # strftime string format
```

```
> ax = gca()
  ax.xaxis_date()
  ax.xaxis.set_major_locator(loc)
  ax.xaxis.set_major_formatter(fmt)
```

properties

- how do you access the properties of a figure/axes?
  - `getp(obj)  # lists all properties`
  - `getp(fig), getp(ax)`
  - `getp(ax.xaxis, 'label')`
    - same as `getp(ax, 'xlabel')`
- how do you change them?
  - `setp(obj)  # lists changeable properties`
  - `setp(obj, property=value)`
  - `setp(ax, 'ylabel', 'sin(x)')`
- lines, surfaces, shapes all have properties

properties

- `getp` and `setp` are syntaxic sugar
- `setp(obj, 'prop', value)`
  calls
  `obj.set_prop(value)`

```
> setp(fig, 'foo', 23)
  AttributeError: 'Figure' object has no attribute 'set_foo'
```

- for consistency with Matlab
- `setp` can change several properties at once

properties: recap

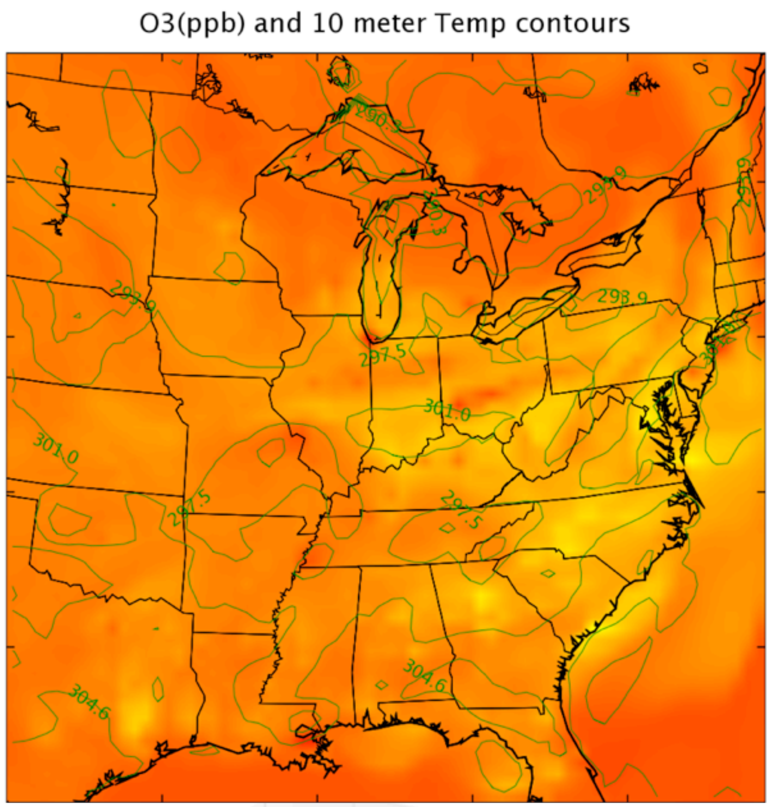
- `label = 'sin(x)'`

- `ylabel(label)`
- `setp(ax, 'ylabel', label)`
- `ax.set_ylabel(label)`
- `ax.yaxis.set_label(label)`
- `ax.yaxis.label.set_text(label)`

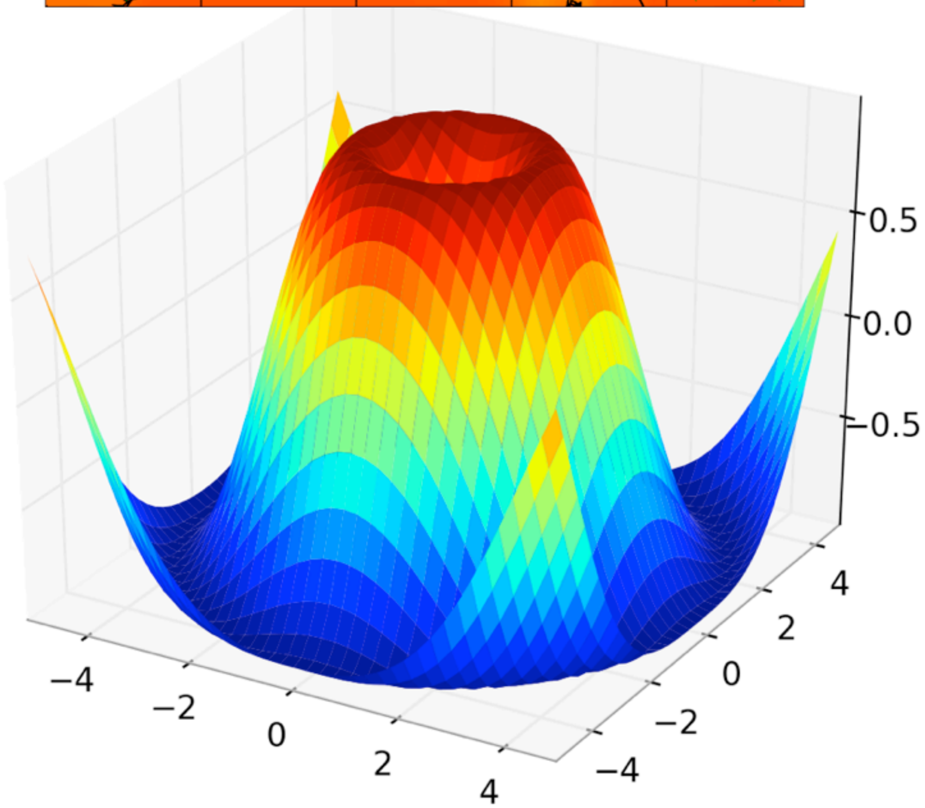
- `ax.yaxis.label._text = label`

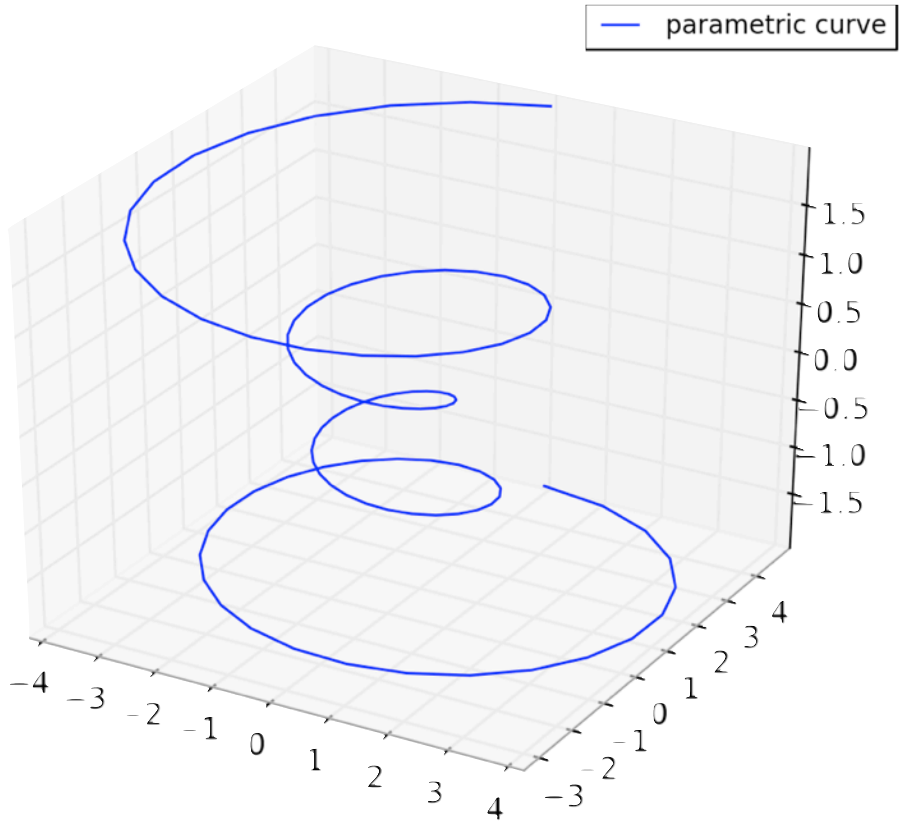
Matplotlib toolkits

- basemap



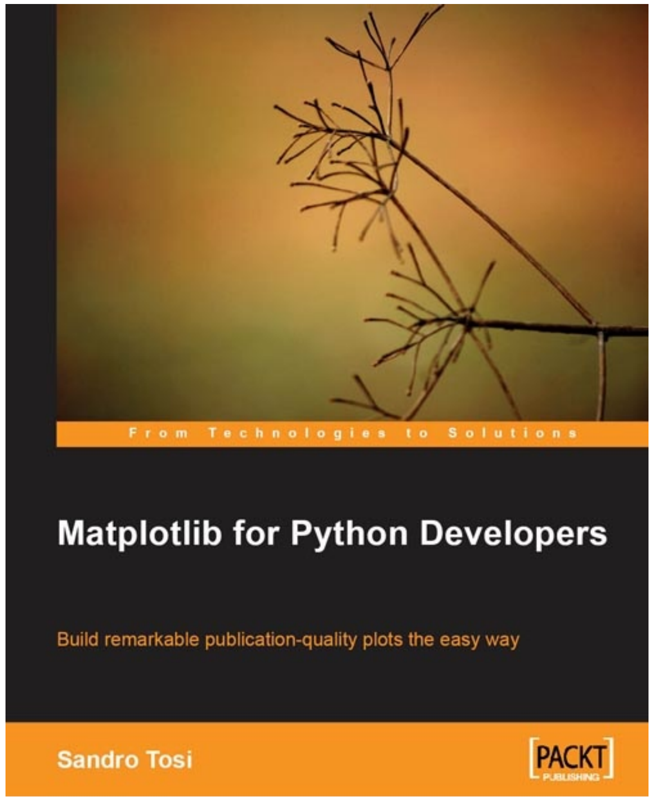
- mplot3d





Matplotlib | documentation

- Plotting commands are documented on the matplotlib homepage
  http://matplotlib.sourceforge.net
- `help plotting`
- Goot starting point: Matplotlib gallery
  http://matplotlib.sourceforge.net/gallery.html



2. The Python Scientific Stack

4. I/O

I/O | ASCII

- Data in ASCII files - `np.loadtxt, np.savetxt`
  - Tabulated data with separators
  - Works well with CSV data
  - keyword arguments
    - `comments='#'`
    - `delimiter=','`
    - `converters={0: lambda f: f*2}`
    - `skiprows=3`
    - `usecols=(1,4,5)`
  - Returns a data array

I/O | numpy Arrays

- numpy provides an easy way to save and load numpy arrays and variables of any kind - `np.savez` and `np.load`
- not very standard, confined to numpy use
- very useful for temporary storage
- = pickle (but compressed)

```
x = np.ones([100, 10])
y = x * 4.
np.savez('vars.npz',
xvar=x, yvar=y)
```

```
# later
npz = np.load('vars.npz')
npz.files
x = npz['xvar']
y = npz['yvar']
```

I/O - Matlab files

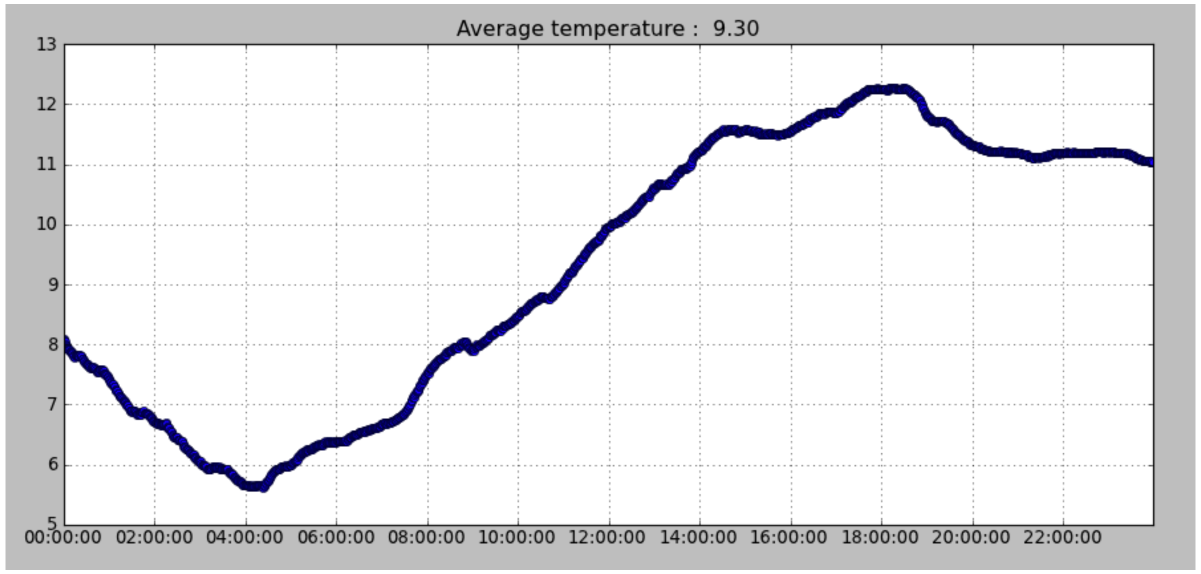
- `scipy.io.matlab`
- `loadmat` returns a dictionary
  - > `mat = matlab.loadmat('file.mat')`
  - > `mat.keys() -> names of variables`
  - > `mat['longitude'] -> longitude array`
- Saving
  - > `matlab.savemat('file.mat', {'longitude':lon})`

I/O | scientific datasets

- You might need to read and write datasets in structured and autodocumented file formats such as HDF or netCDF
- `netcdf4-python`
  - read and write netCDF3/4 files as Python dictionaries
  - supports data compression and packing
- `pyhdf, pyh5, pytables` : HDF4 and 5 datasets
- `pyNIO` : GRIB1, GRIB2, HDF-EOS
- in Python(x,y)
- very good online documentation

Matplotlib | Lab 2

- Write a Python script that :
  - reads the contents of the file `meteoz.asc`
  - plots the air temperature as a function of time when the air temperature quality flag is ok (=0)
  - display the temperature mean and standard deviation in the title



- Hints:
  > `help np.loadtxt`
  > `datestr2num is in matplotlib.dates`
  > `plt.plot_date()`

3. Applications

3. Applications

1. Data Analysis

Scipy

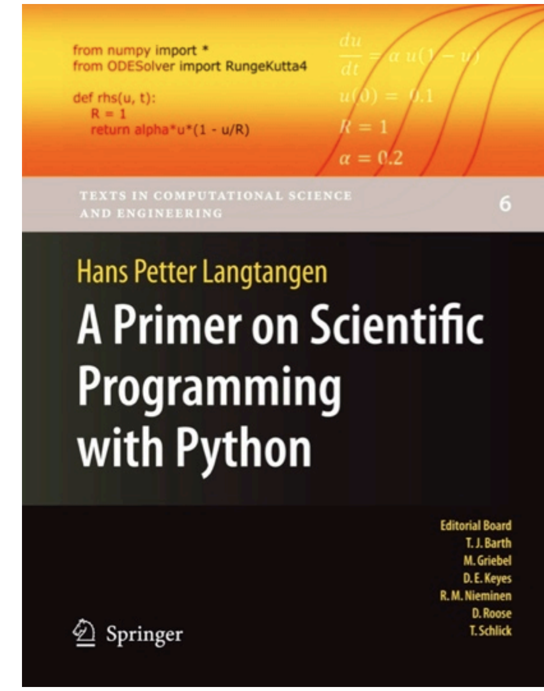
- Scipy is choke full of data analysis functions
- Scipy is a package of packages
- Functions are grouped in sub-packages
    - scipy.ndimage - image processing, morphology
    - scipy.stats
    - scipy.signal - signal processing
    - scipy.interpolate
    - scipy.linsolve, scipy.odeint
    - scipy.fftpack - Fourier transforms (1d, 2d, etc)
    - scipy.integrate...

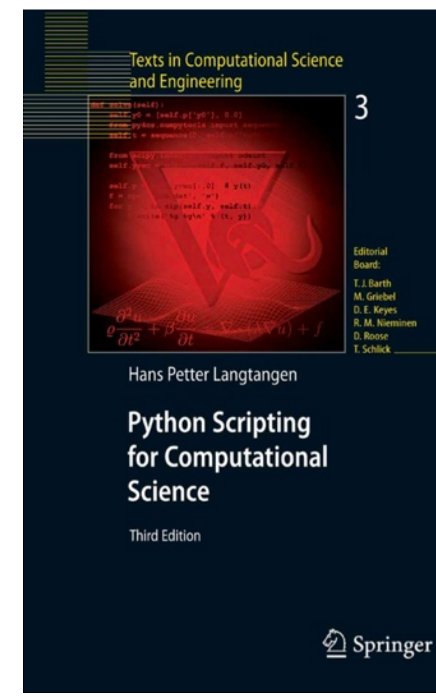
Scipy scikits

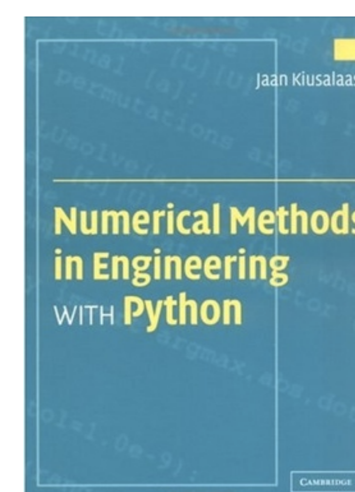
- SciKits are add-on packages for Scipy, which are not included in Scipy proper for various reasons
- http://scikits.appspot.com
  - datasmooth
  - odes - equation solvers
  - optimization
  - sound creation and analysis
  - learn - machine learning and data mining
  - cuda - Python interface to GPU libraries
  - ...

Scipy

- Too much to cover everything
- Scipy packages and modules are tailored for specific users
    - you don't even want to cover everything
- Best ways to find the function you need
    - google
    - tab exploration in IPython
    - books
    - lookfor
        - e.g. `lookfor("gaussian", module="scipy")`







Scipy.stats

- contains a lot of useful functions
- `nanmean`/`std`, `nanmin`/`max`, etc.
- pdf/cdf for ~100 distribution families
  - generic syntax: `scipy.stats.`<distribution>.<function>

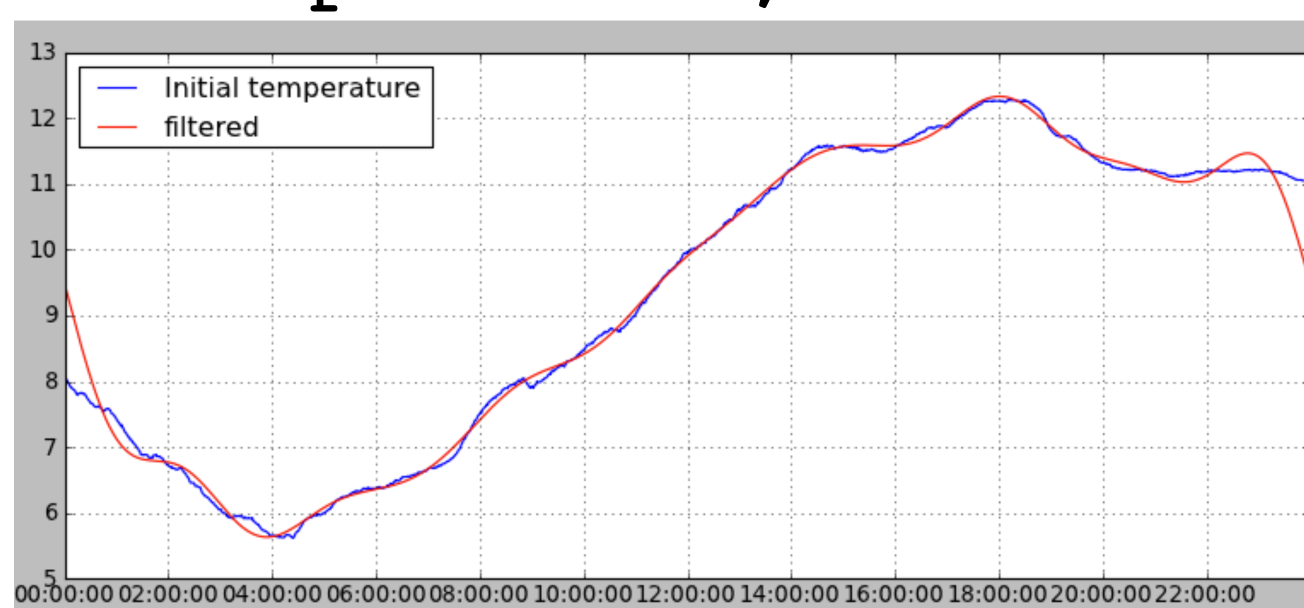
```
> from scipy.stats import gamma
  x = np.r_[0:10:0.1]
  plt.plot(x, gamma.pdf(x,2))
  plt.plot(x, gamma.pdf(x,2,3))
```

  - catch them all with IPython autocomplete

scipy | Lab

- plot the air temperature data from the `meteoz.dat` file
- compute the Fourier transform of the temperature
- keep only the lowest 10 frequencies
- compute filtered temperature using inverse Fourier transform
- plot the initial temperature and the filtered temperature
- add a legend

```
> from scipy.fftpack import fft, ifft
```



3. Applications

2. Image analysis and filtering

imread

- `imread()` reads the content of an image file in an array
  - > `img = imread('image.jpg')`
  - `img` is [ny, nx, 3]
  - [ny, nx] for greyscale images
- > `imshow(), imsave()`
  - `(0,0)` is upper-left
  - > `imshow(img[::-1,:])`
- Functions provided by `matplotlib.pyplot`

ndimage

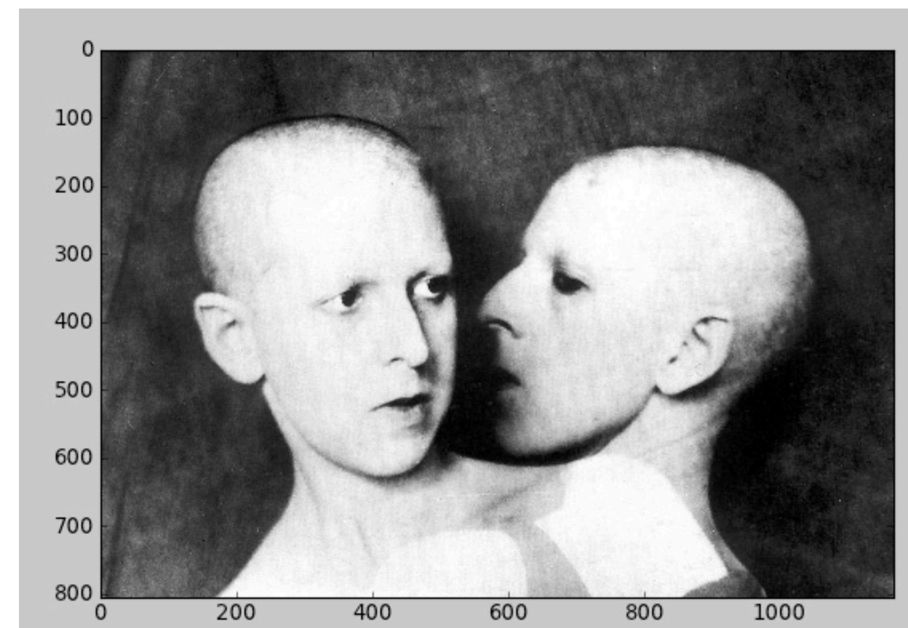
- The `ndimage` package in scipy contains lots of functions for image manipulation, e.g. image filters

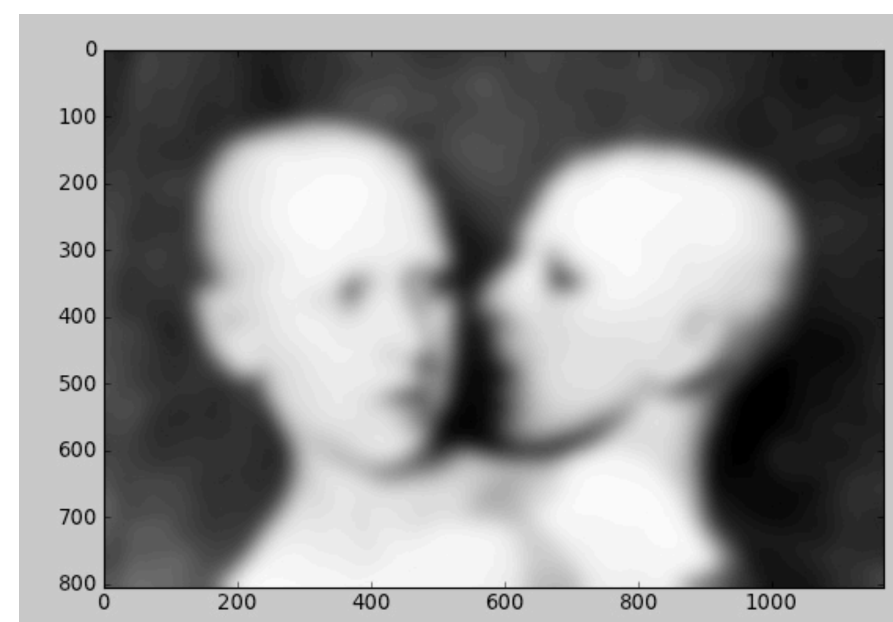
```
import scipy.ndimage.filters as filters

x = imread('Claude-Cahun1.jpg')
imshow(x[::-1,:])

y = filters.gaussian_filter(x, 25.0)
imshow(y[::-1,:])
```

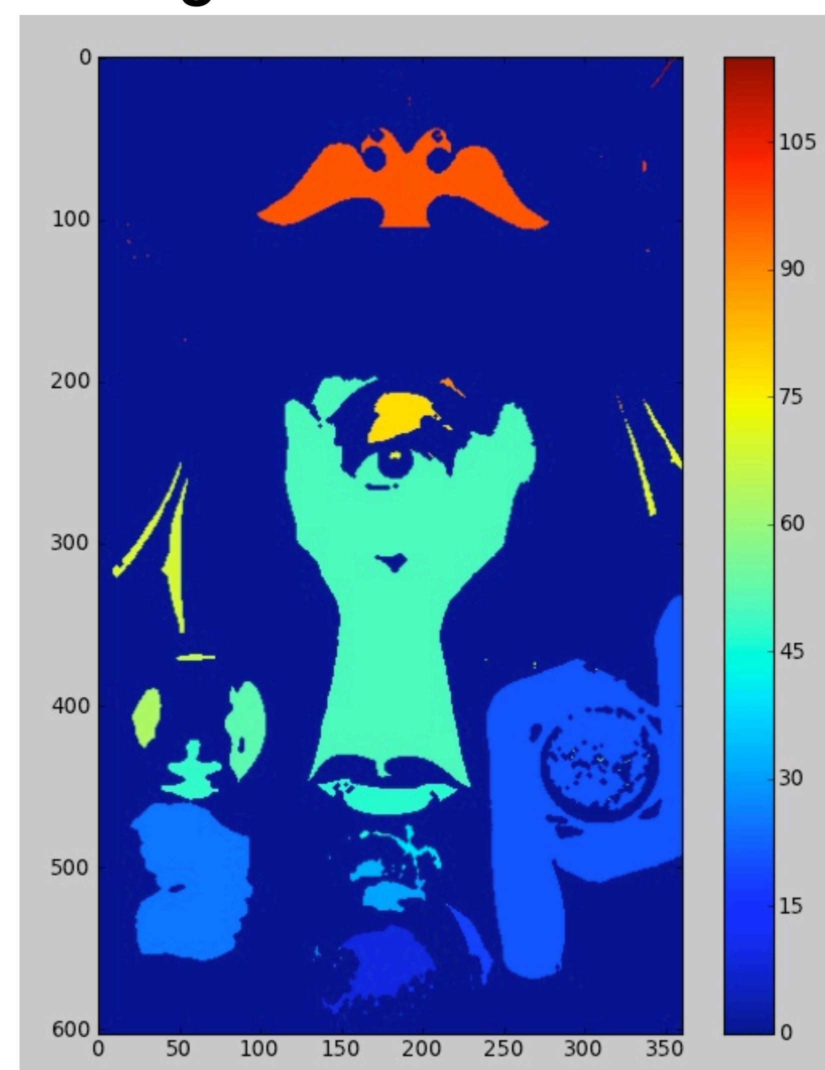
```
filters.gaussian
    .generic
    .laplace
    .prewitt
    .sobel
```





ndimage | Lab

- Read the image `cc2.jpg` as an array
- Do a binary erosion on the image (use a threshold grayscale level of 100)
- Find individual elements in the binary image
- Plot the result
- Hints:
  - > `ndimage.binary_...`
  - > `ndimage.label()`

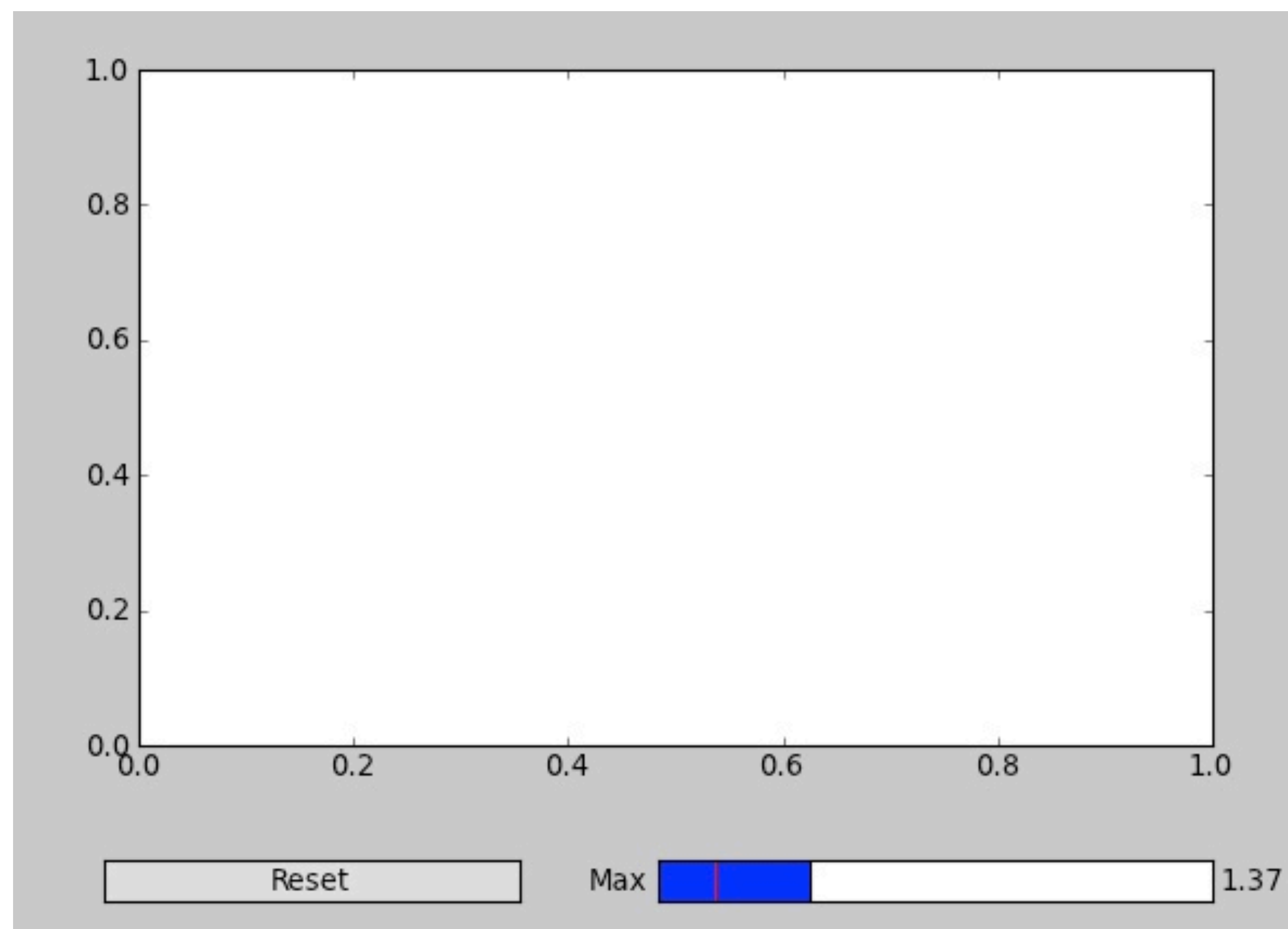


3. Applications

3. User interaction

1. Matplotlib Widgets

- Module `matplotlib.widgets`
  - `Button, RadioButtons, Slider`
- Ugly, feels like a hack
- Very fast, platform- and graphic toolkit-agnostic
- ridiculously easy
- Great for a quick-n-dirty interface
- Why not



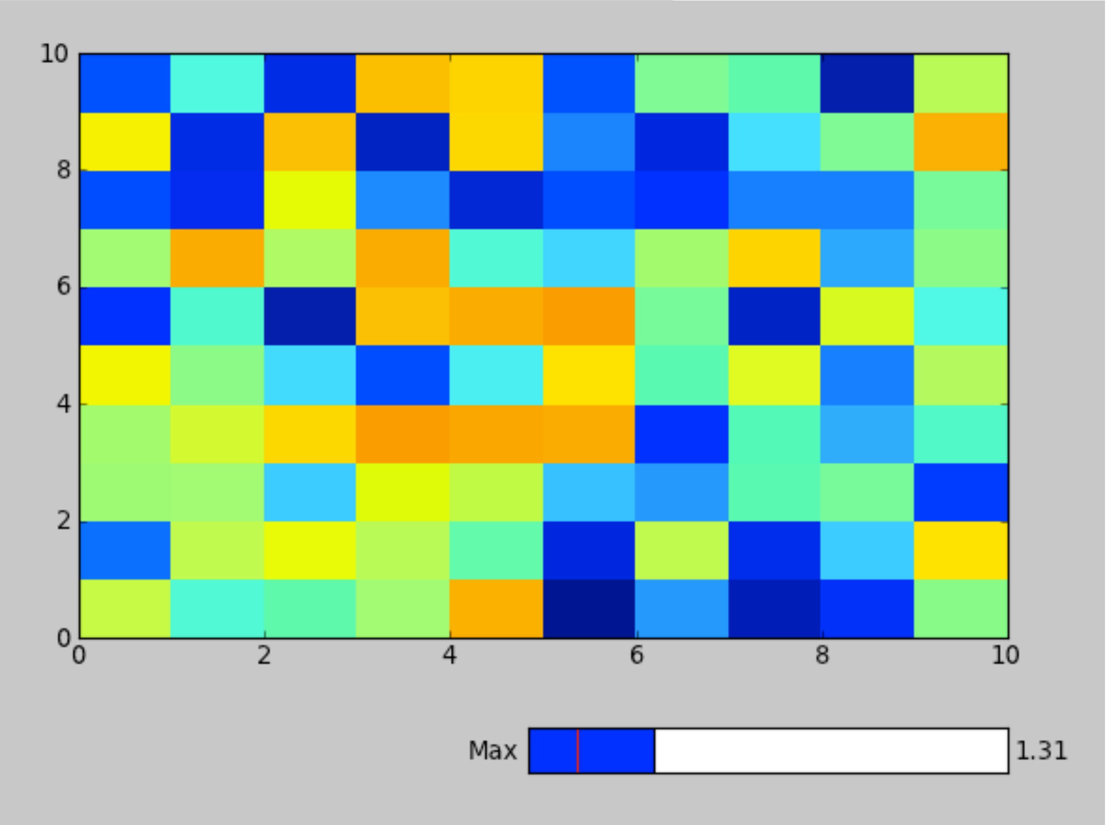
A GUI in 3 lines

```
x = rand(10, 10)
pcolormesh(x)
subplots_adjust(bottom=0.25)

ax2 = axes([0.5, 0.1, 0.4, 0.05])
s = Slider(ax2, 'Max', 0.0, 5.0)

def update_max(value):
  clim(0, value)

s.on_changed(update_max)
```

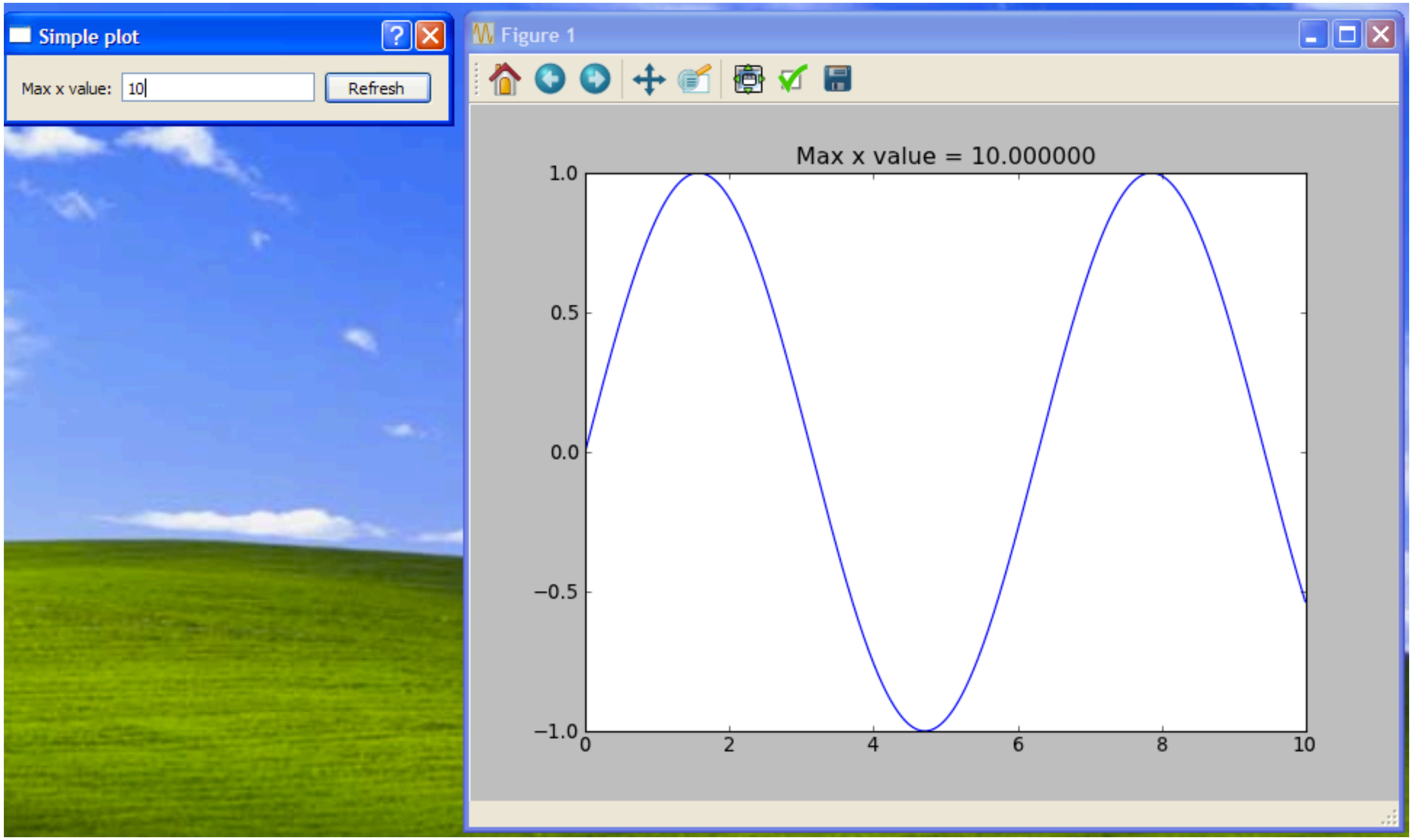


"Serious" GUI

- wxwindows, tk, gtk, ETS, etc.
- For this example: Qt4
  - The Good
    - well-maintained, developed and documented
    - cross-platform, looks native on every platform
    - complete Python bindings: PyQt4 - in Python(x,y)
  - The Bad
    - More boilerplate code needed (lots)
  - The Ugly
    - Qt + PySide were supported by Nokia for phone interface research, after Microsoft takeover their future is unclear...
    - for the near future one of the best choices

PyQt4

- You can mix Qt4 for the GUI and Matplotlib for plotting
- The best of both word



the full script : ~40 LOC

```
# -*- coding: utf-8 -*-

import sys

from PyQt4.QtCore import *
from PyQt4.QtGui import *

import matplotlib.pyplot as plt
import numpy as np

class Dialog(QDialog):
    def __init__(self, parent=None):
        super(Dialog, self).__init__(parent)
        self.lineedit = QLineEdit('Max x value')
        layout = QHBoxLayout()
        self.button = QPushButton('Refresh')
        layout.addWidget(QLabel('Max x value:'))
        layout.addWidget(self.lineedit)
        layout.addWidget(self.button)
        self.setLayout(layout)
        self.lineedit.setFocus()
        self.connect(self.button, SIGNAL('clicked()'), self.refresh)
        self.setWindowTitle('Simple plot')
        self.max = 2.*np.pi
```

```
    def refresh_values(self):
        self.x = np.r_[0:self.max:0.01]
        self.y = np.sin(self.x)

    def refresh(self):
        try:
            self.max = np.float(self.lineedit.text())
        except ValueError:
            print 'Please enter a numeric value'
            return
        self.refresh_values()
        plt.figure(1)
        plt.show()
        plt.clf()
        plt.subplot(111)
        plt.plot(self.x, self.y)
        plt.title('Max x value = %f' % (self.max))
        plt.draw()

app = QApplication(sys.argv)
dialog = Dialog()
dialog.show()
app.exec_()
```

```
# -*- coding: utf-8 -*-

import sys

from PyQt4.QtCore import *
from PyQt4.QtGui import *

import matplotlib.pyplot as plt
import numpy as np

class Dialog(QDialog):
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        self.setLayout(layout)
        self.lineedit.setFocus()
        self.connect(self.button, SIGNAL('clicked()'), self.refresh)
        self.setWindowTitle('Simple plot')
        self.max = 2.*np.pi
```

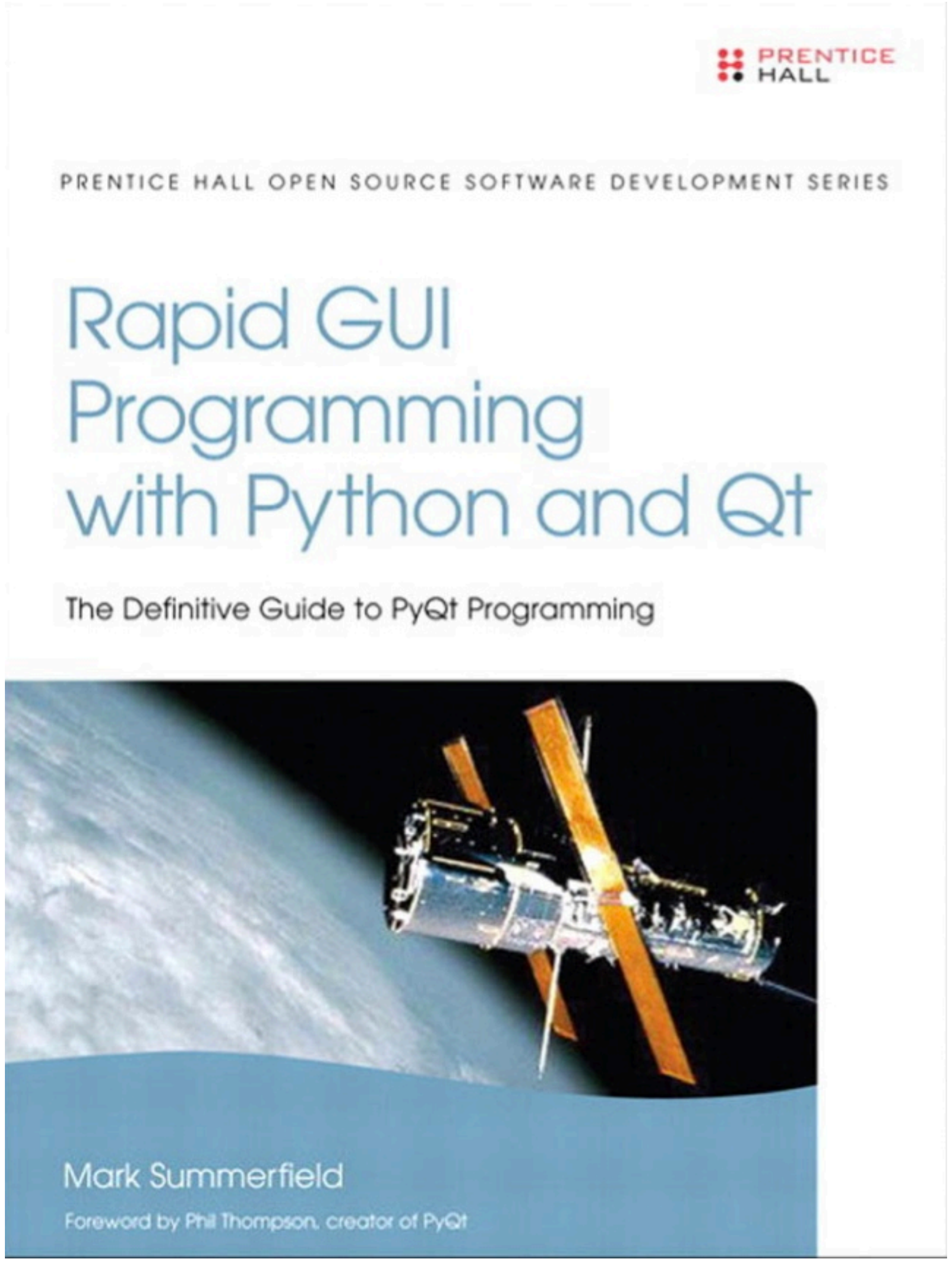
```
    def refresh_values(self):
        self.x = np.r_[0:self.max:0.01]
        self.y = np.sin(self.x)

    def refresh(self):
        try:
            self.max = np.float(self.lineedit.text())
        except ValueError:
            print 'Please enter a numeric value'
        self.refresh_values()
        if self.fig is None:
            self.fig = plt.figure()
            plt.show()
        plt.clf()
        plt.subplot(111)
        plt.plot(self.x, self.y)
        plt.title('Max x value = %f' % (self.max))
        plt.draw()

app = QApplication(sys.argv)
dialog = Dialog()
dialog.show()
app.exec_()
```

GUI | Lab

- Modify this script so the interface shows two buttons
  - one for plotting cos(x)
  - one for plotting sin(x)



thanks