intro_Matplotlib

June 1, 2016

```
In [1]: # Just to know last time this was run:
        import time
        print time.ctime()

Wed Jun  1 17:01:37 2016
```

This is part of the Python lecture given by Christophe Morisset at IA-UNAM. More informations at: http://python-astro.blogspot.mx/

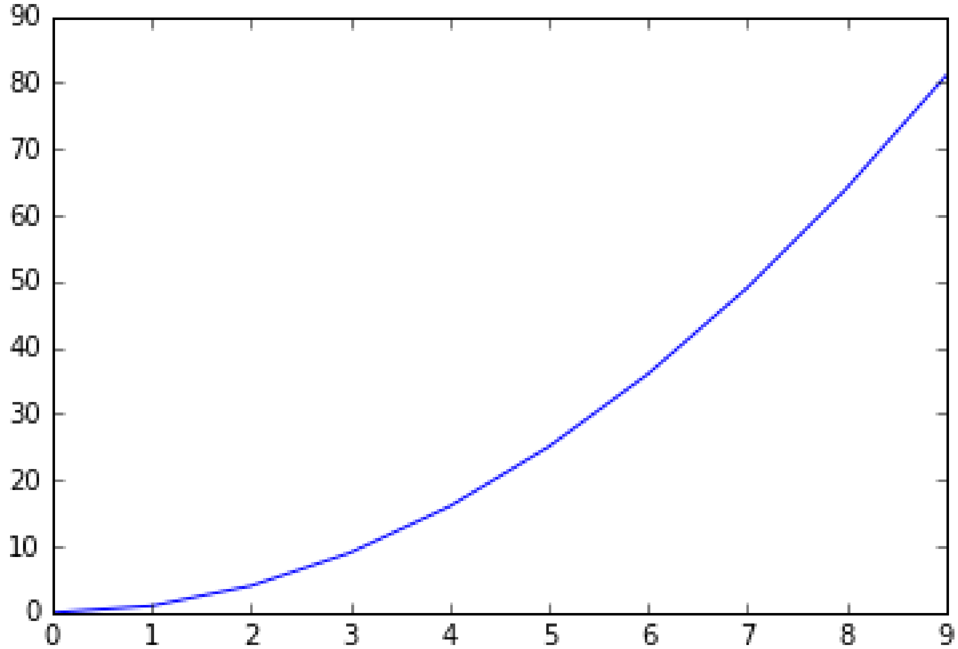
1 D: How to make plots, images, 3D, etc, using Matplotlib

```
In [2]: # this allows the plots to appear in the Notebook webpage:
        %matplotlib inline
        import numpy as np
        import matplotlib.pyplot as plt # this is the plotting library

/Users/christophemorisset/anaconda/lib/python2.7/site-packages/matplotlib/font_mana
  warnings.warn('Matplotlib is building the font cache using fc-list. This may take
```

Very well done tutorials on the mail Matplotlib web page: http://matplotlib.org/

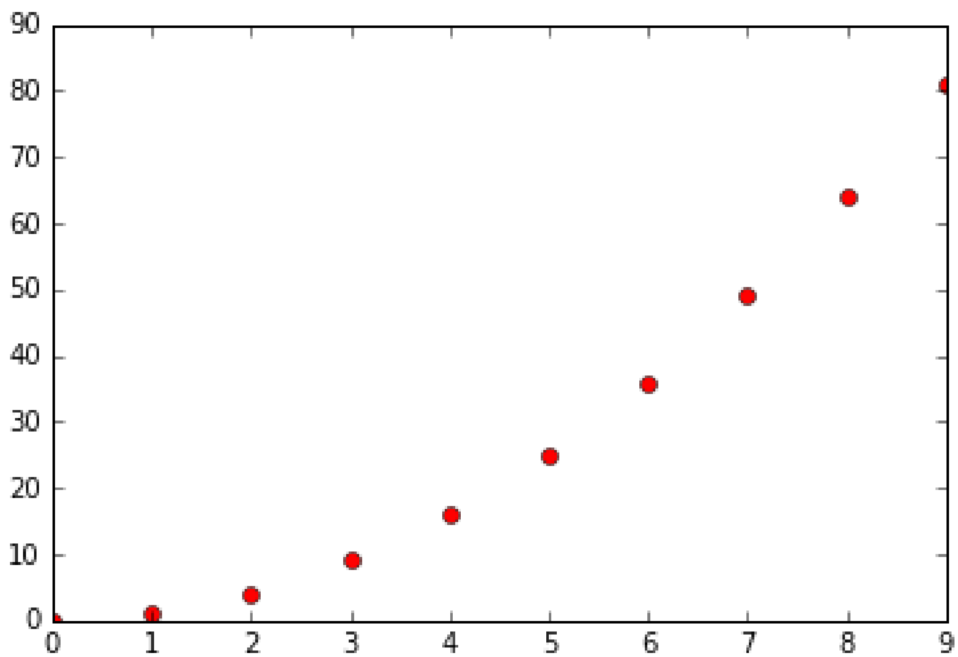
Simple plot In the following cell, we plot a function

```
In [3]: # Just to convince that things are easy:
        x = np.arange(10) # define an array
        plt.plot(x, x**2) # so quickly plotted... Notice the ";" at the end of the

Out[3]: [<matplotlib.lines.Line2D at 0x10fefde10>]
```

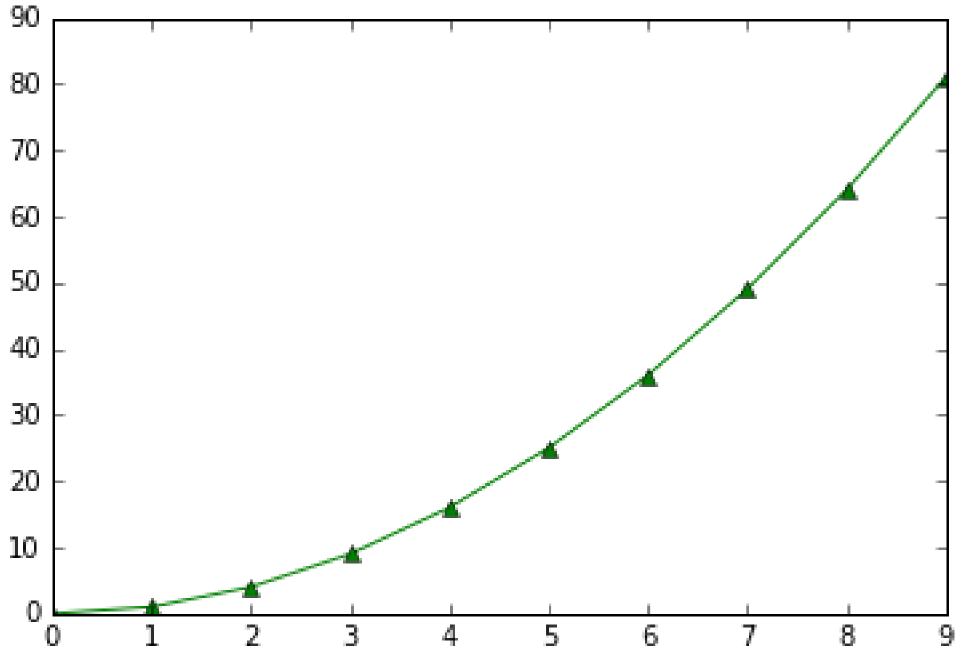


Controling colors and symbols

```
In [4]: plt.plot(x, x**2, 'or');
```



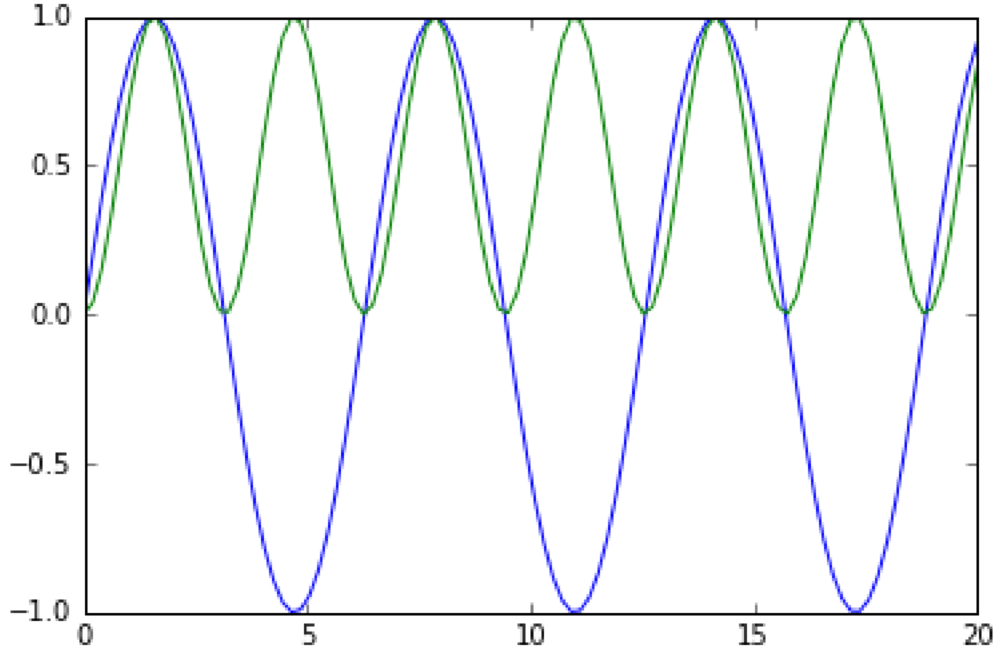
```
In [5]: plt.plot(x, x**2, c='green', marker='^');
```




```
In [6]: # To illustrate the possibilities of the interactive window:
        %matplotlib tk
        plt.plot(x, x**2, '*b', linestyle='-') ;

In [7]: # Back to the inline graphics mode
        %matplotlib inline
```

Overplot

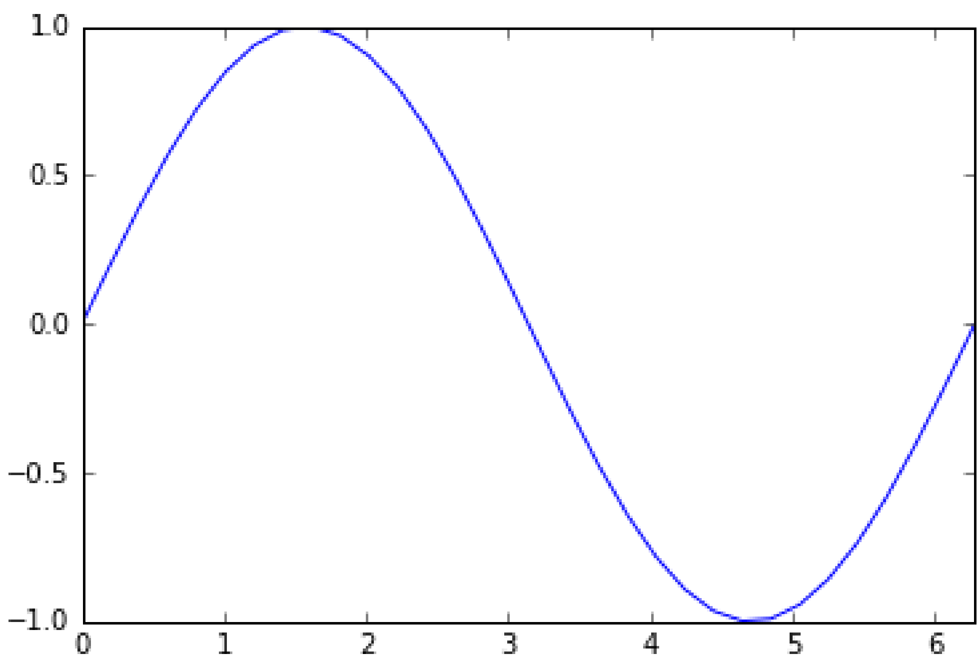
```
In [8]: x = np.linspace(0, 20, 100)  # 100 evenly-spaced values from 0 to 20
        y = np.sin(x)

        plt.plot(x, y)
        plt.plot(x, y**2) # overplot by default;

Out[8]: [<matplotlib.lines.Line2D at 0x110b7dc50>]
```



Fixing axes limits

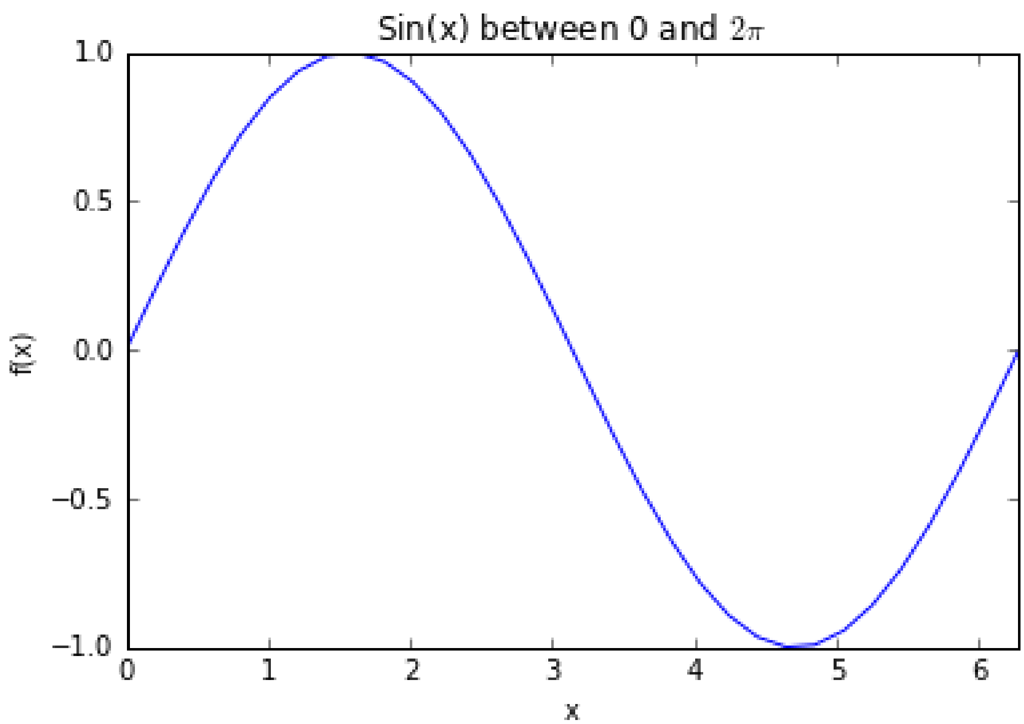
```
In [9]: plt.plot(x, y)
        plt.xlim(0., np.pi*2) # Take car, it's NOT plt.xlim = (1, 2), this would EI
```

```
Out[9]: (0.0, 6.283185307179586)
```



Labels, titles

```
In [10]: plt.plot(x, y)
         plt.xlim((0., np.pi*2))
         plt.title(r'Sin(x) between 0 and $2\pi$')
         plt.xlabel('x')
         plt.ylabel('f(x)');
```



plot method documentation

```
In [11]: help(plt.plot)
```

```
Help on function plot in module matplotlib.pyplot:

plot(*args, **kwargs)
    Plot lines and/or markers to the
    :class:`~matplotlib.axes.Axes`.  *args* is a variable length
    argument, allowing for multiple *x*, *y* pairs with an
    optional format string.  For example, each of the following is
    legal::
```

```
    plot(x, y)        # plot x and y using default line style and color
    plot(x, y, 'bo')  # plot x and y using blue circle markers
    plot(y)           # plot y using x as index array 0..N-1
    plot(y, 'r+')     # ditto, but with red plusses

If *x* and/or *y* is 2-dimensional, then the corresponding columns
will be plotted.

If used with labeled data, make sure that the color spec is not
included as an element in data, as otherwise the last case
``plot("v","r", data={"v":..., "r":...)``
can be interpreted as the first case which would do ``plot(v, r)``
using the default line style and color.

If not used with labeled data (i.e., without a data argument),
an arbitrary number of *x*, *y*, *fmt* groups can be specified, as in::

    a.plot(x1, y1, 'g^', x2, y2, 'g-')

Return value is a list of lines that were added.

By default, each line is assigned a different style specified by a
'style cycle'.  To change this behavior, you can edit the
axes.prop_cycle rcParam.

The following format string characters are accepted to control
the line style or marker:

================    ===============================
character           description
================    ===============================
``'-'``             solid line style
``'--'``            dashed line style
``'-.'``            dash-dot line style
``':'``             dotted line style
``'.'``             point marker
``','``             pixel marker
``'o'``             circle marker
``'v'``             triangle_down marker
``'^'``             triangle_up marker
``'<'``             triangle_left marker
``'>'``             triangle_right marker
``'1'``             tri_down marker
``'2'``             tri_up marker
``'3'``             tri_left marker
``'4'``             tri_right marker
``'s'``             square marker
``'p'``             pentagon marker
```

```
``'*'``             star marker
``'h'``             hexagon1 marker
``'H'``             hexagon2 marker
``'+'``             plus marker
``'x'``             x marker
``'D'``             diamond marker
``'d'``             thin_diamond marker
``'|'``             vline marker
``'_'``             hline marker
================    ===============================


The following color abbreviations are supported:

==========  ========
character   color
==========  ========
'b'         blue
'g'         green
'r'         red
'c'         cyan
'm'         magenta
'y'         yellow
'k'         black
'w'         white
==========  ========

In addition, you can specify colors in many weird and
wonderful ways, including full names (``'green'``), hex
strings (``'#008000'``), RGB or RGBA tuples (``(0,1,0,1)``) or
grayscale intensities as a string (``'0.8'``).  Of these, the
string specifications can be used in place of a ``fmt`` group,
but the tuple forms can be used only as ``kwargs``.

Line styles and colors are combined in a single format string, as in
``'bo'`` for blue circles.

The *kwargs* can be used to set line properties (any property that has
a ``set_*`` method).  You can use this to set a line label (for auto
legends), linewidth, anitialising, marker face color, etc.  Here is an
example::

    plot([1,2,3], [1,2,3], 'go-', label='line 1', linewidth=2)
    plot([1,2,3], [1,4,9], 'rs',  label='line 2')
    axis([0, 4, 0, 10])
    legend()

If you make multiple lines with one plot command, the kwargs
```

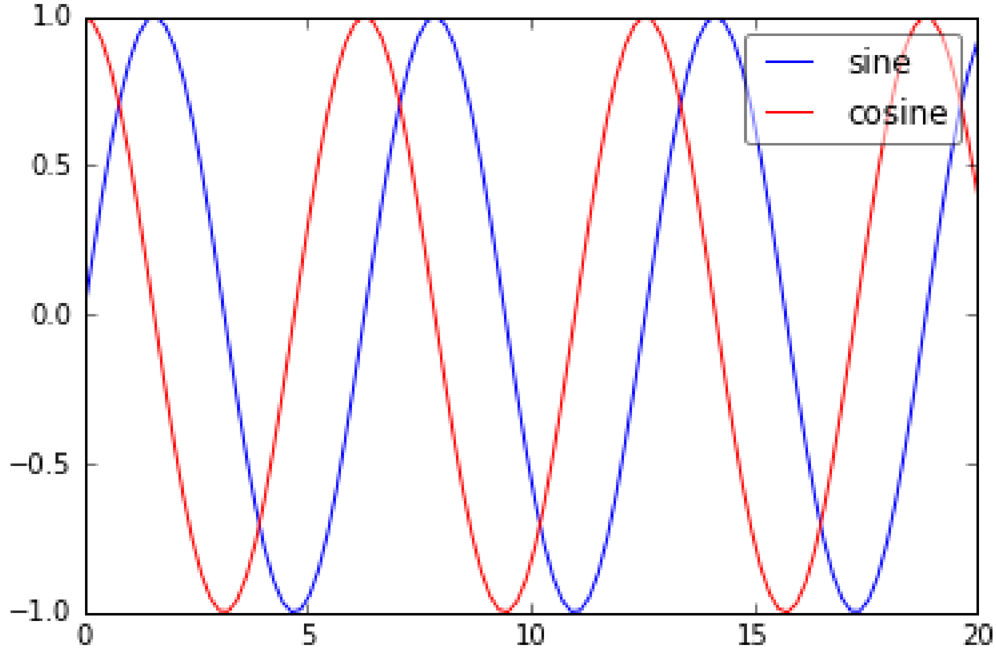
```
apply to all those lines, e.g.::

    plot(x1, y1, x2, y2, antialiased=False)

Neither line will be antialiased.

You do not need to use format strings, which are just
abbreviations.  All of the line properties can be controlled
by keyword arguments.  For example, you can set the color,
marker, linestyle, and markercolor with::

    plot(x, y, color='green', linestyle='dashed', marker='o',
         markerfacecolor='blue', markersize=12).

See :class:`~matplotlib.lines.Line2D` for details.

The kwargs are :class:`~matplotlib.lines.Line2D` properties:

  agg_filter: unknown
  alpha: float (0.0 transparent through 1.0 opaque)
  animated: [True | False]
  antialiased or aa: [True | False]
  axes: an :class:`~matplotlib.axes.Axes` instance
  clip_box: a :class:`matplotlib.transforms.Bbox` instance
  clip_on: [True | False]
  clip_path: [ (:class:`~matplotlib.path.Path`, :class:`~matplotlib.transforms.
  color or c: any matplotlib color
  contains: a callable function
  dash_capstyle: ['butt' | 'round' | 'projecting']
  dash_joinstyle: ['miter' | 'round' | 'bevel']
  dashes: sequence of on/off ink in points
  drawstyle: ['default' | 'steps' | 'steps-pre' | 'steps-mid' | 'steps-post']
  figure: a :class:`matplotlib.figure.Figure` instance
  fillstyle: ['full' | 'left' | 'right' | 'bottom' | 'top' | 'none']
  gid: an id string
  label: string or anything printable with '%s' conversion.
  linestyle or ls: ['solid' | 'dashed', 'dashdot', 'dotted' | (offset, on-off-d
  linewidth or lw: float value in points
  marker: :mod:`A valid marker style <matplotlib.markers>`
  markeredgecolor or mec: any matplotlib color
  markeredgewidth or mew: float value in points
  markerfacecolor or mfc: any matplotlib color
  markerfacecoloralt or mfcalt: any matplotlib color
  markersize or ms: float
  markevery: [None | int | length-2 tuple of int | slice | list/array of int |
  path_effects: unknown
  picker: float distance in points or callable pick function ``fn(artist, event
  pickradius: float distance in points
```

```
    rasterized: [True | False | None]
    sketch_params: unknown
    snap: unknown
    solid_capstyle: ['butt' | 'round' |  'projecting']
    solid_joinstyle: ['miter' | 'round' | 'bevel']
    transform: a :class:`matplotlib.transforms.Transform` instance
    url: a url string
    visible: [True | False]
    xdata: 1D array
    ydata: 1D array
    zorder: any number

  kwargs *scalex* and *scaley*, if defined, are passed on to
  :meth:`~matplotlib.axes.Axes.autoscale_view` to determine
  whether the *x* and *y* axes are autoscaled; the default is
  *True*.

  Notes
  -----

  In addition to the above described arguments, this function can take a
  **data** keyword argument. If such a **data** argument is given, the
  following arguments are replaced by **data[<arg>]**:

  * All arguments with the following names: 'y', 'x'.




  Additional kwargs: hold = [True|False] overrides default hold state
```

Legends

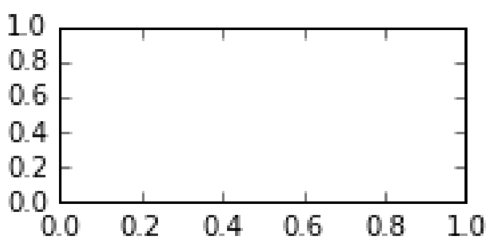
```
In [12]: x = np.linspace(0, 20, 100)
         y1 = np.sin(x)
         y2 = np.cos(x)

         plt.plot(x, y1, '-b', label='sine')
         plt.plot(x, y2, '-r', label='cosine')
         plt.legend(loc='upper right', fancybox=True, framealpha=0.5)
         #plt.ylim((-1.5, 2.0));
```

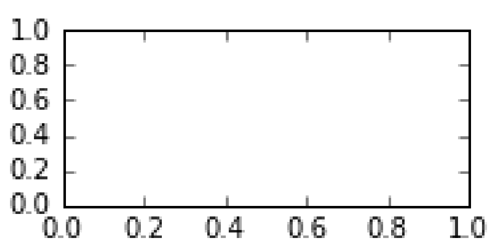
```
Out[12]: <matplotlib.legend.Legend at 0x117de0c90>
```



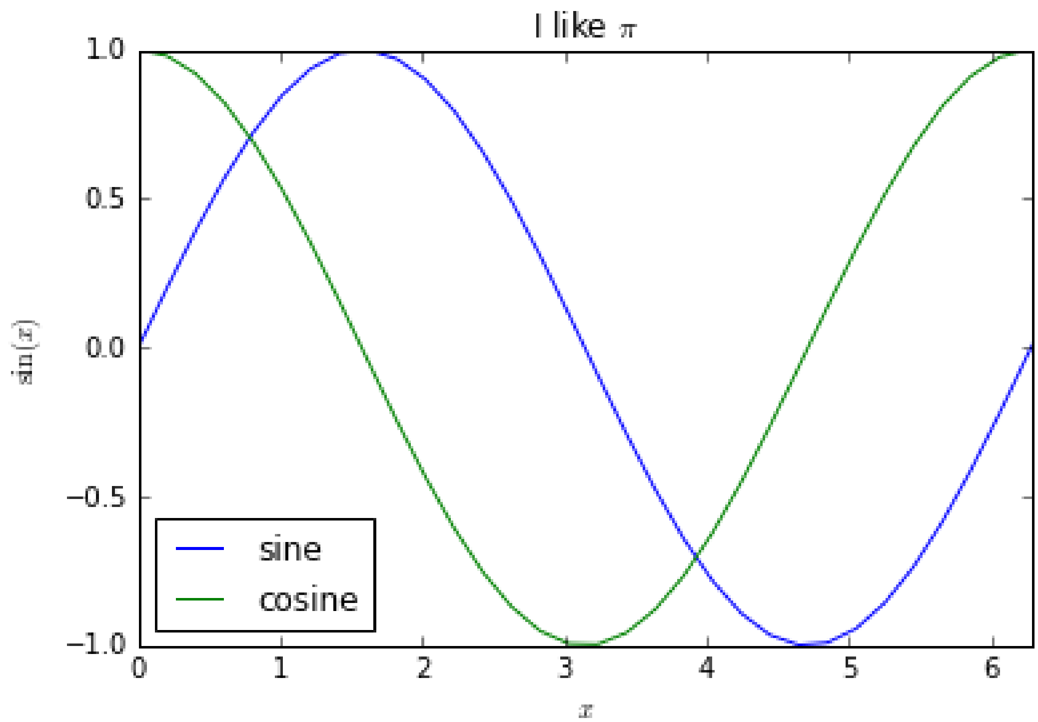
Object oriented way

```
In [13]: fig = plt.figure()   # a new figure window
         ax = fig.add_subplot(3, 2, 1)   # specify (nrows, ncols, axnum)
         ax2 = fig.add_subplot(3, 2, 6)   # specify (nrows, ncols, axnum)
         # same as ax = fig.add_subplot()
```





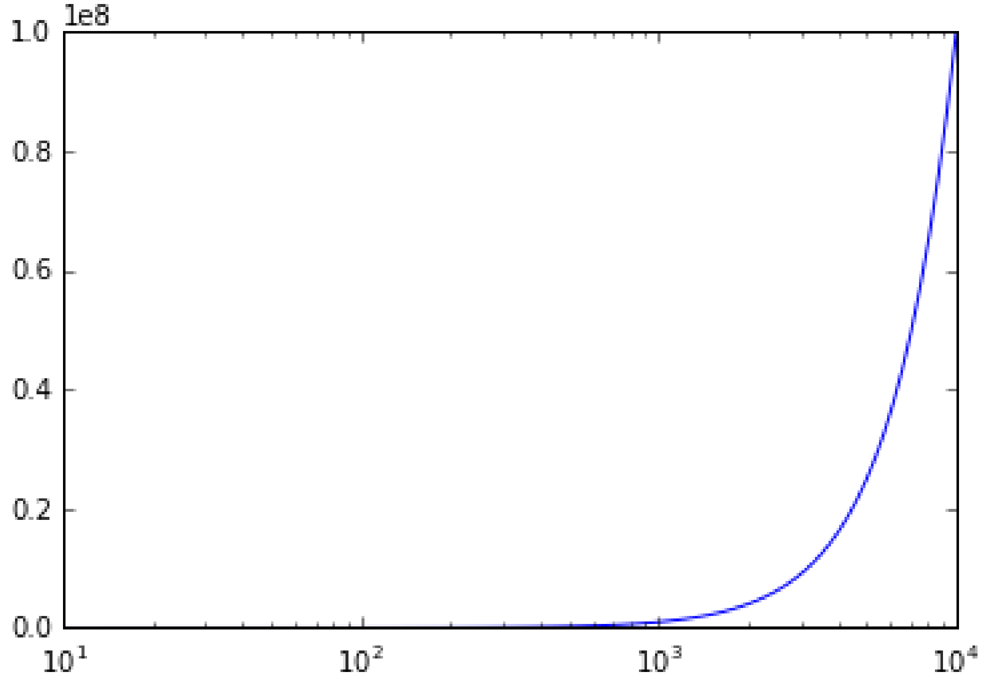
```
In [14]: fig, ax = plt.subplots()  # one command way
         ax.plot(x, y1)
         ax.plot(x, y2)
         ax.set_xlim(0., 2*np.pi)
         ax.legend(['sine', 'cosine'], loc='best') # If the legends are not already
         ax.set_xlabel("$x$")
         ax.set_ylabel("$\sin(x)$")
         ax.set_title("I like $\pi$");
```



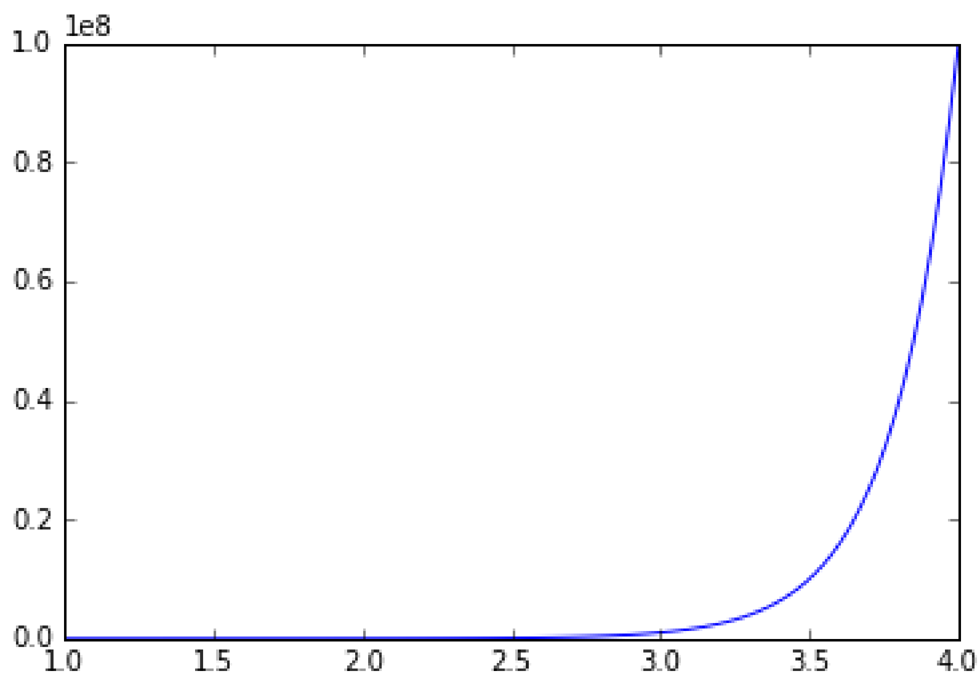

```
In [15]: # The following outputs a HUGE quantity of information! I comment it for r
         #help(ax)
```

log plots

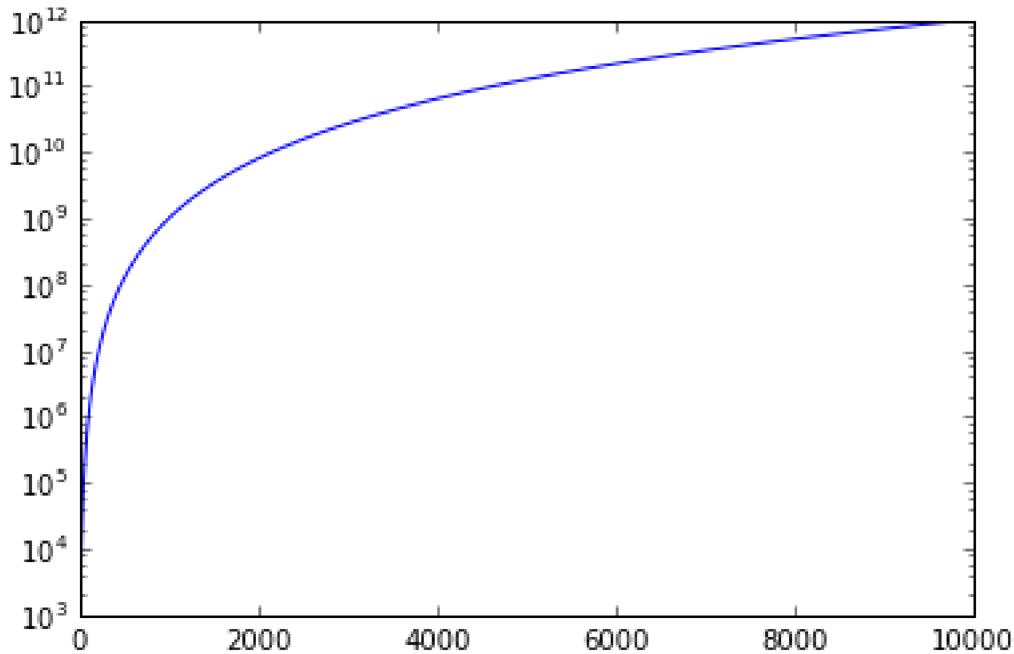
```
In [16]: xl = np.logspace(1, 4, 100)
         fig, ax = plt.subplots()
         ax.semilogx(xl, xl**2);
```



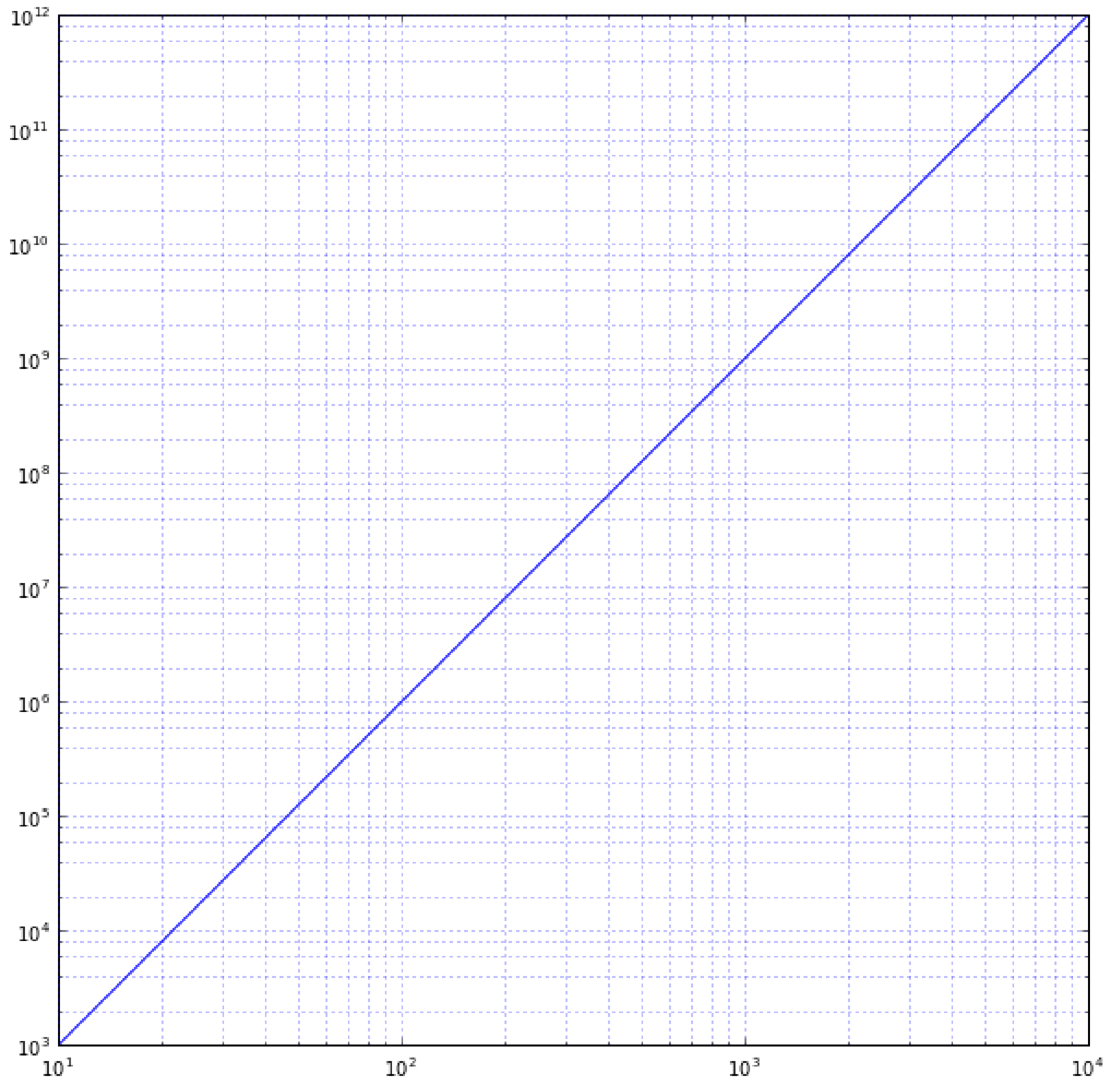

```
In [17]: xl = np.logspace(1, 4, 100)
         fig, ax = plt.subplots()
         ax.plot(np.log10(xl), xl**2);
```



In [18]:
```
fig, ax = plt.subplots()
ax.semilogy(xl, xl**3);
```

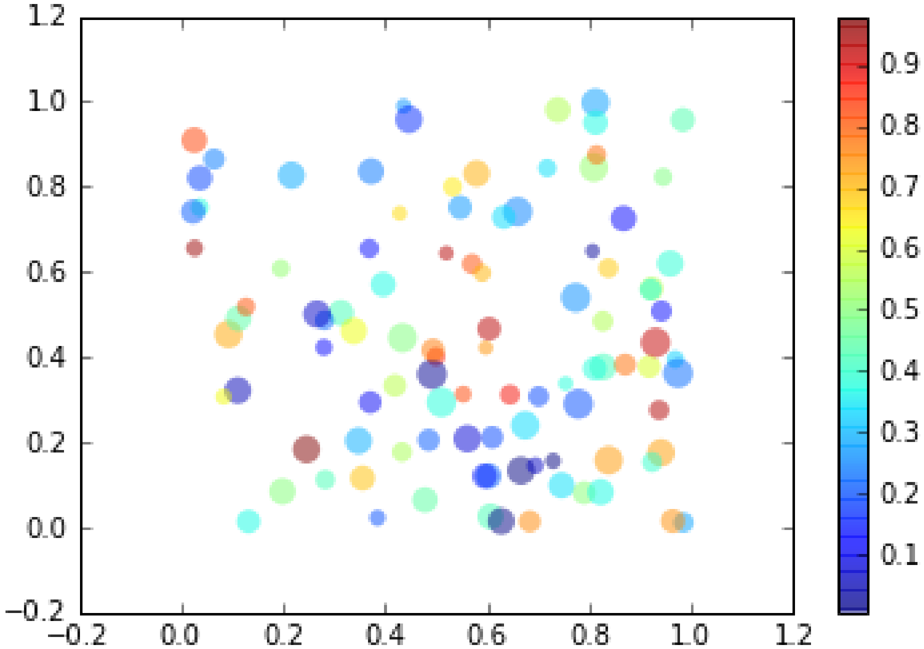


In [19]:
```
fig, ax = plt.subplots(figsize=(10,10))
ax.loglog(xl, xl**3);
ax.grid(which="both",ls=":", c='blue')
```

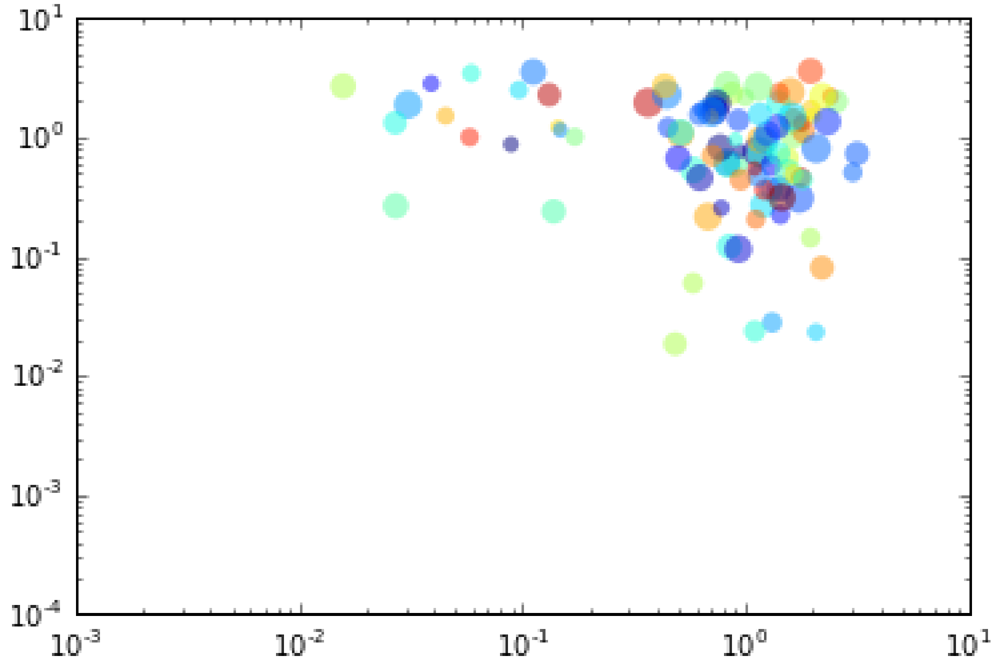


Scatter

```
In [20]: xr = np.random.rand(100)
         yr = np.random.rand(100)
         cr = np.random.rand(100)
         sr = np.random.rand(100)

         fig, ax = plt.subplots()
         sc = ax.scatter(xr, yr, c=cr, s=30+sr*100, edgecolor='none', alpha=0.5); #
         fig.colorbar(sc);
```



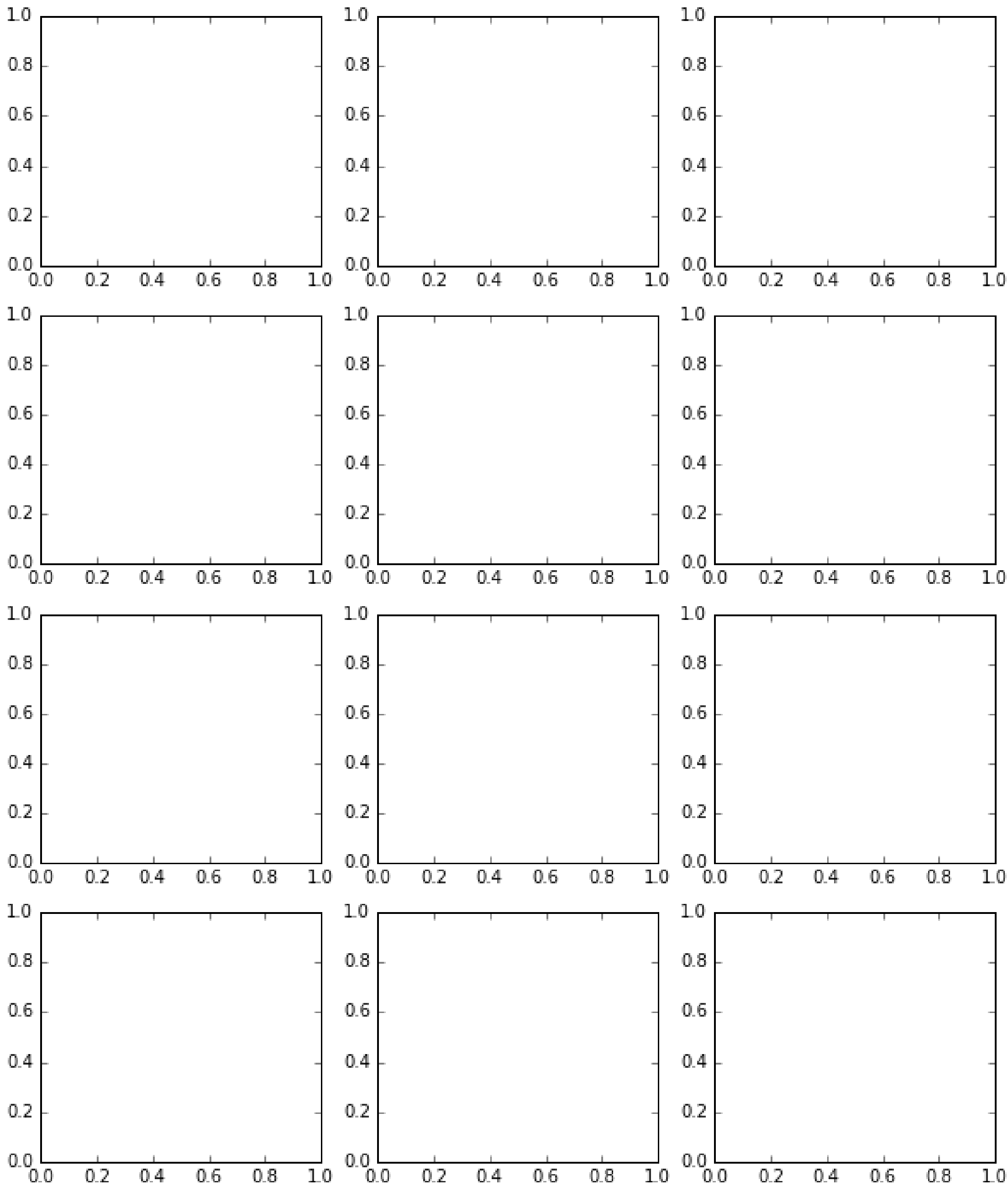

```
In [21]: # log axes can be defined after the plot
         xr = np.abs(1 + np.random.randn(100))
         yr = np.abs(1 + np.random.randn(100))
         fig, ax = plt.subplots()
         sc = ax.scatter(xr, yr, c=cr, s=30+sr*100, edgecolor='none', alpha=0.5); #
         ax.set_xscale('log')
         ax.set_yscale('log')
```



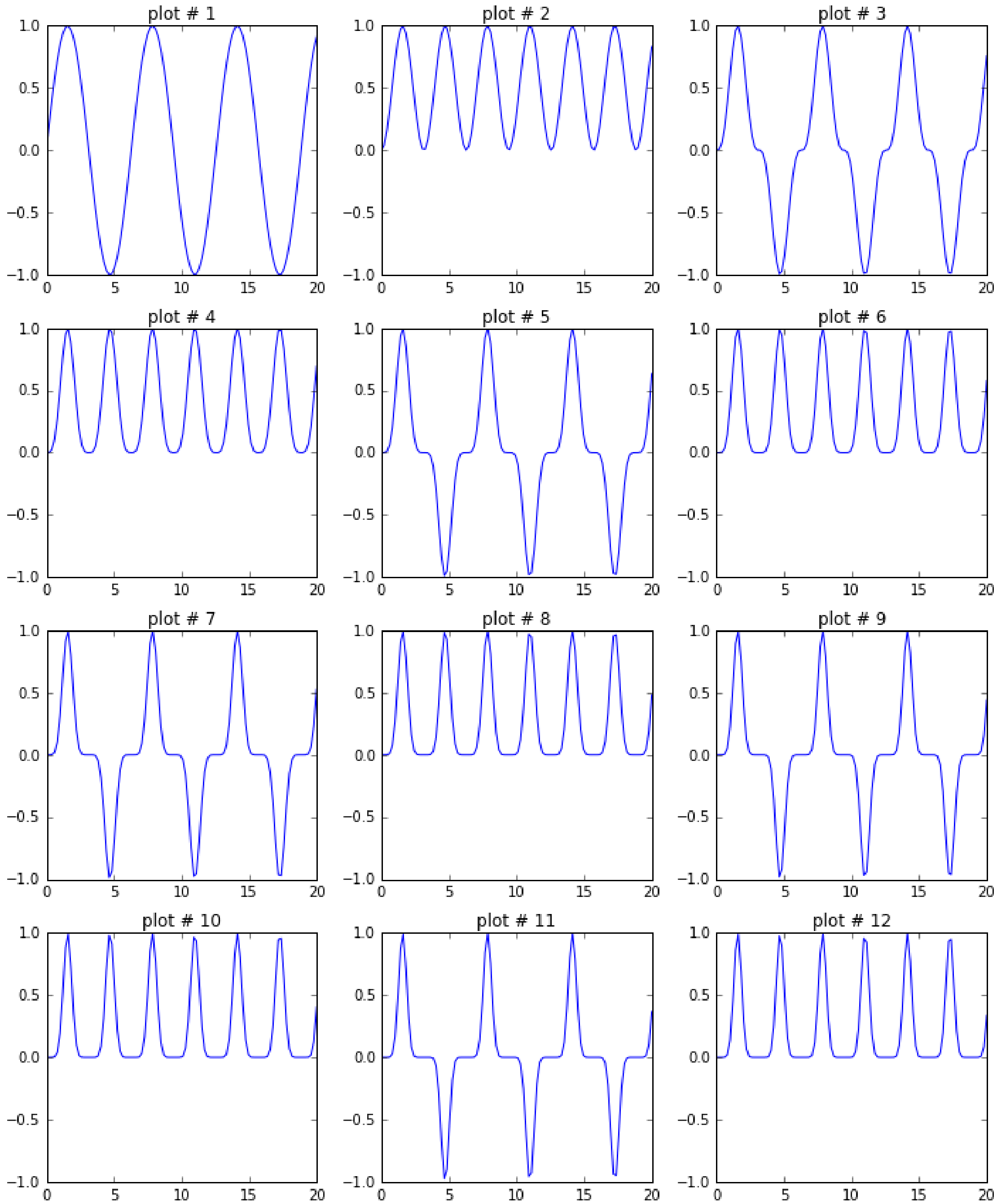
multiple plots

```
In [22]: fig, axes = plt.subplots(4, 3, figsize=(10,12))
         print axes.shape
```

```
(4, 3)
```

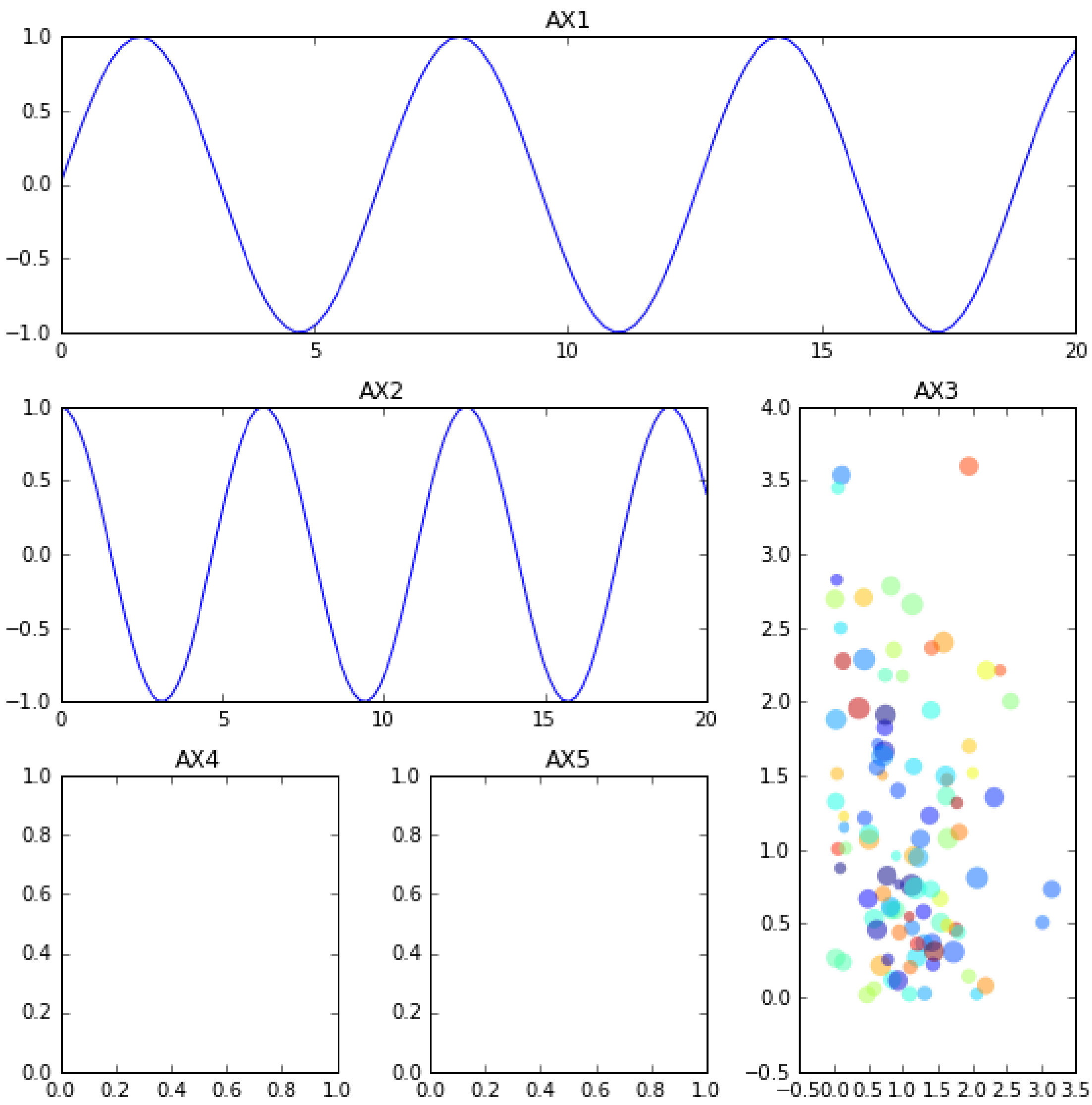


```
In [23]: fig, axes = plt.subplots(4, 3, figsize=(10,12))
         for i, ax in enumerate(axes.ravel()): # axes is a 2D array.. Need to ravel
             ax.set_title('plot # {}'.format(i+1))
             ax.plot(x, y1**(i+1))
             ax.set_ylim((-1, 1))
         fig.tight_layout() # Better output
```



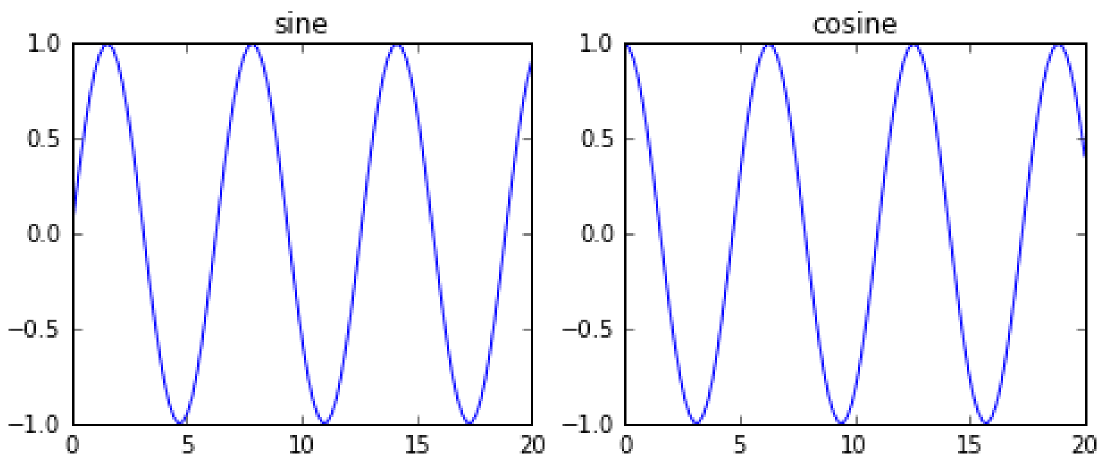

```
In [24]: fig = plt.figure(figsize=(8, 8))
         gs = plt.GridSpec(3, 3)
         ax1 = fig.add_subplot(gs[0, :])
         ax2 = fig.add_subplot(gs[1, :2])
         ax3 = fig.add_subplot(gs[1:, 2])
         ax4 = fig.add_subplot(gs[2, 0])
         ax5 = fig.add_subplot(gs[2, 1])
```

```
ax1.plot(x, y1)
ax1.set_title('AX1')
ax2.plot(x, y2)
ax2.set_title('AX2')
ax3.scatter(xr, yr, c=cr, s=30+sr*100, edgecolor='none', alpha=0.5)
ax3.set_title('AX3')
ax4.set_title('AX4')
ax5.set_title('AX5')
fig.tight_layout()
#etc...
```



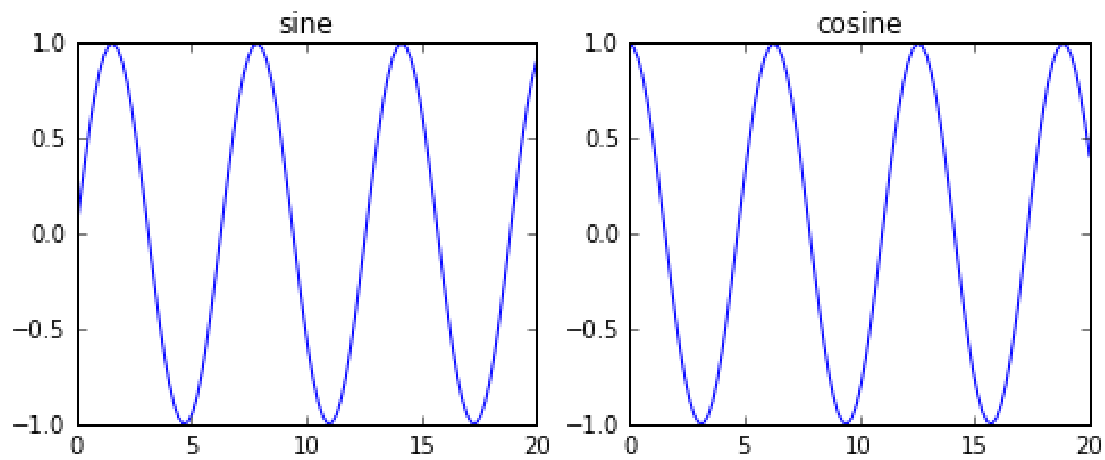
Order of the commands

In [25]:
```
fig1 = plt.figure(figsize=(8, 3))
ax1 = fig1.add_subplot(1, 2, 1)
ax1.plot(x, np.sin(x))
ax1.set_title('sine')

ax2 = fig1.add_subplot(1, 2, 2)
ax2.plot(x, np.cos(x))
ax2.set_title('cosine');
```



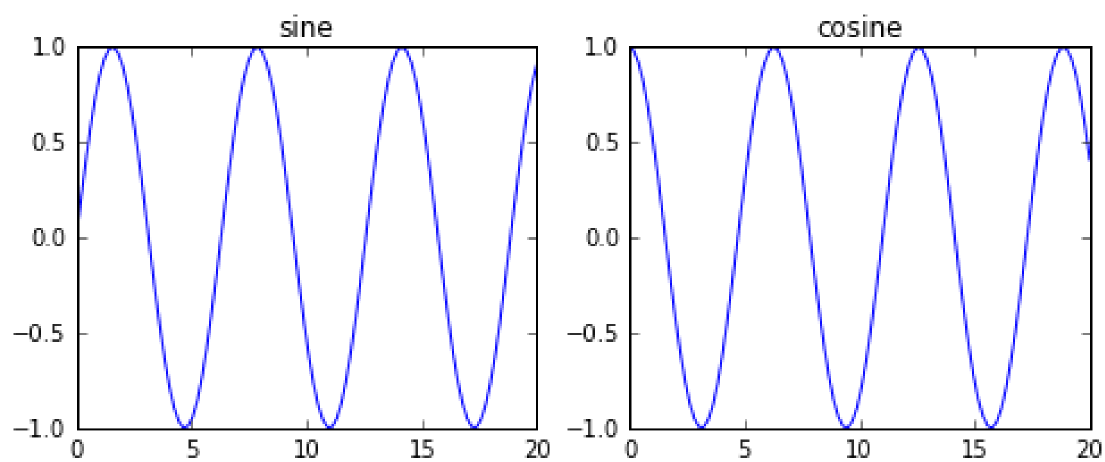
In [26]:
```
fig1 = plt.figure(figsize=(8, 3))
ax1 = fig1.add_subplot(1, 2, 1)
ax2 = fig1.add_subplot(1, 2, 2)

ax1.plot(x, np.sin(x))
ax2.plot(x, np.cos(x))

ax1.set_title('sine') # you can go back to change ax1 and ax2 after plotti
ax2.set_title('cosine') # They both are objects containing method to apply
```

Out[26]:
```
<matplotlib.text.Text at 0x11a3b9410>
```




```
In [27]: fig1, (ax1, ax2) = plt.subplots(1, 2, figsize=(8, 3))

         ax1.plot(x, np.sin(x))
         ax2.plot(x, np.cos(x))

         ax1.set_title('sine') # you can go back to change ax1 and ax2 after plotti
         ax2.set_title('cosine') # They both are objects containing method to apply
```

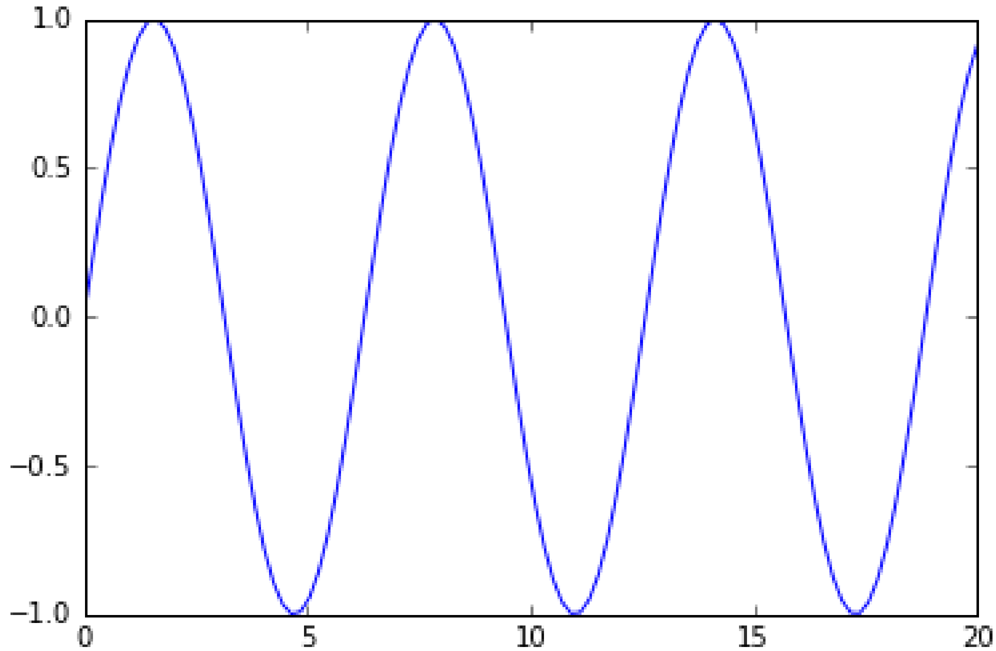
```
Out[27]: <matplotlib.text.Text at 0x11a070dd0>
```



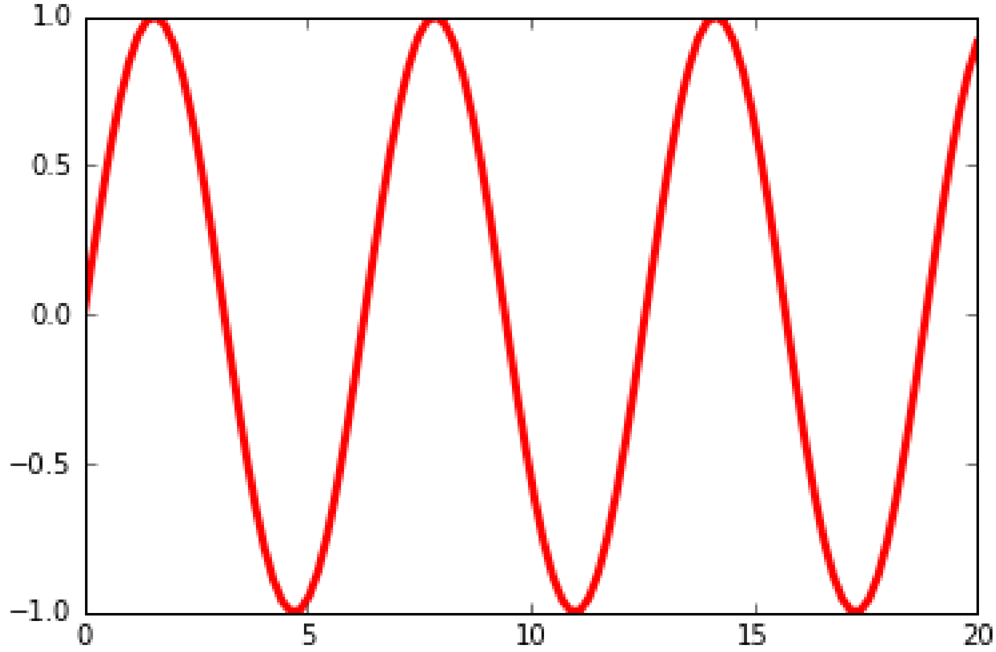
Everything is object

```
In [28]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         print type(lines)
         print(len(lines))
```

```
<type 'list'>
1
```

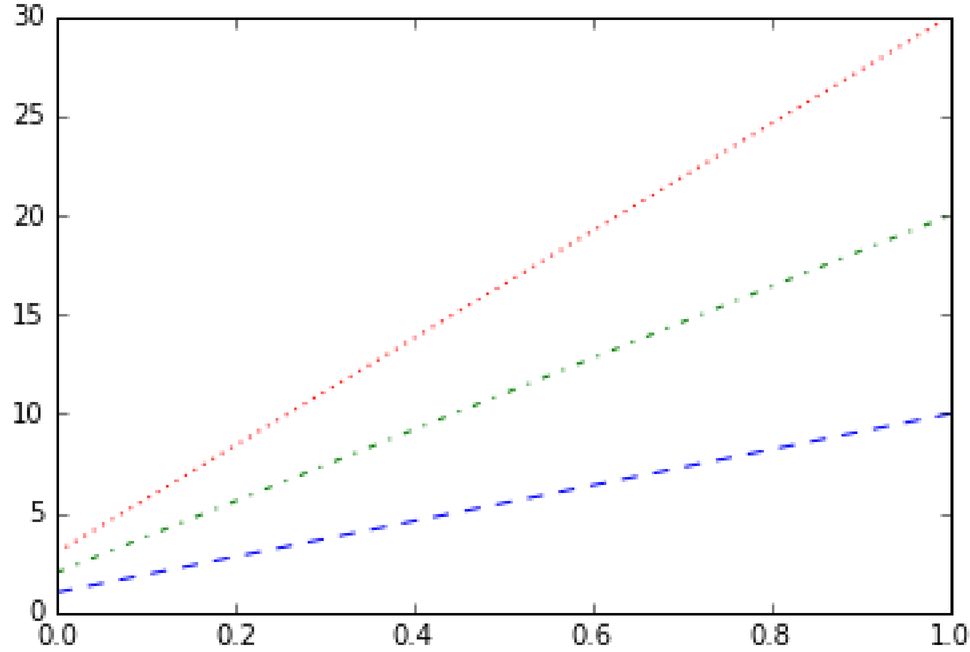



```
In [29]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         line = lines[0]
         #help(line) # HUGE quantity of information
         line.set_color('red')
         line.set_linewidth(3)
         fig.canvas.draw() # this is not necessary in notebook, but in scripts it i
```

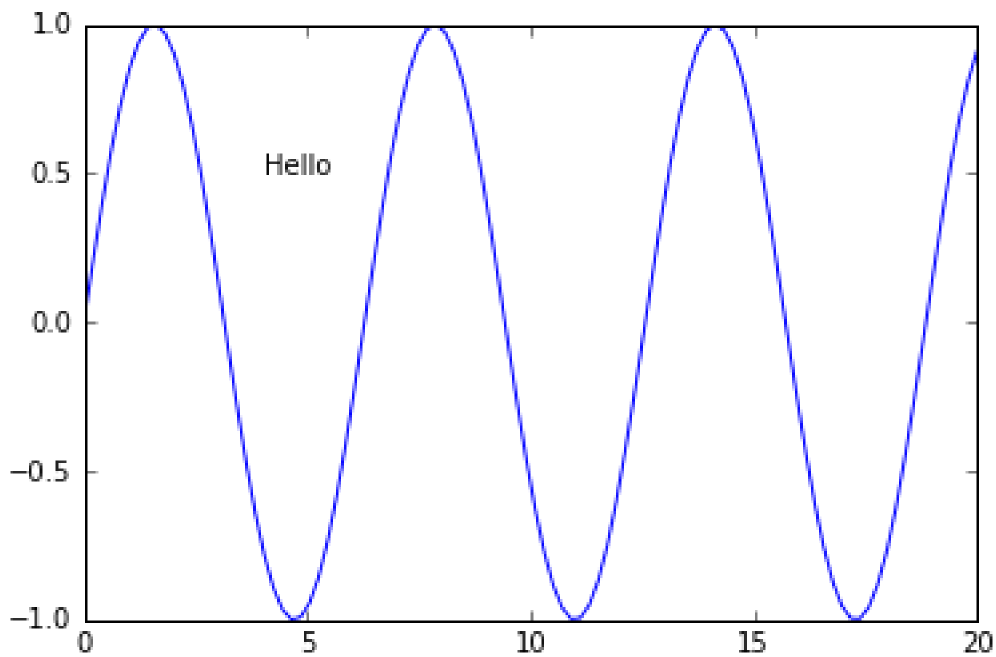



```
In [30]: fig, ax = plt.subplots()
         lines = ax.plot([[1,2,3],[10,20,30]])
         print lines

         lines[0].set_linestyle('--')
         lines[1].set_linestyle('-.')
         lines[2].set_linestyle(':')
```

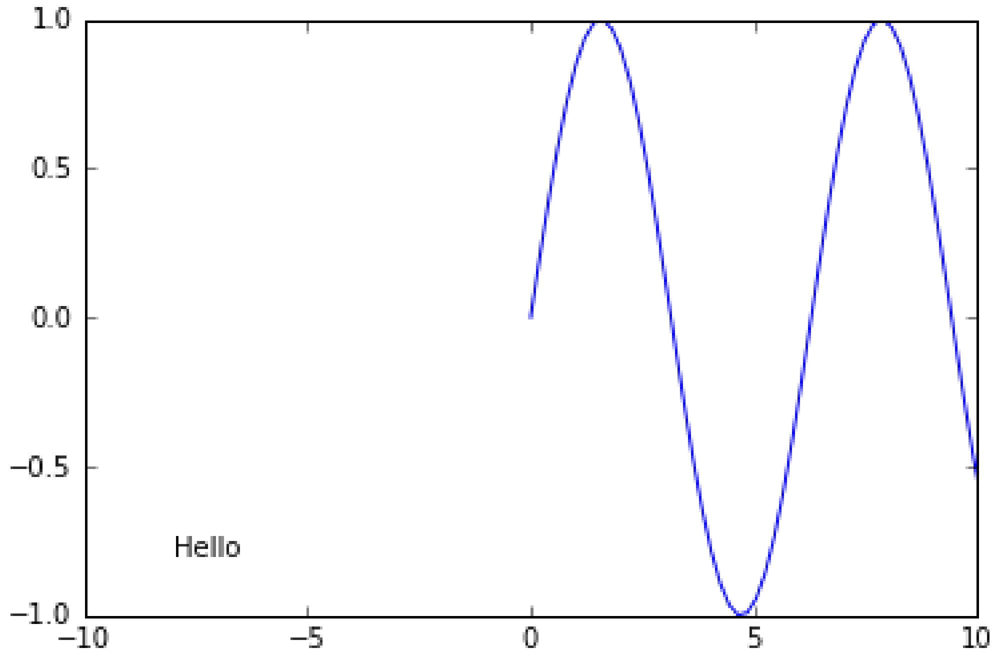
```
[<matplotlib.lines.Line2D object at 0x11854e510>, <matplotlib.lines.Line2D object a
```



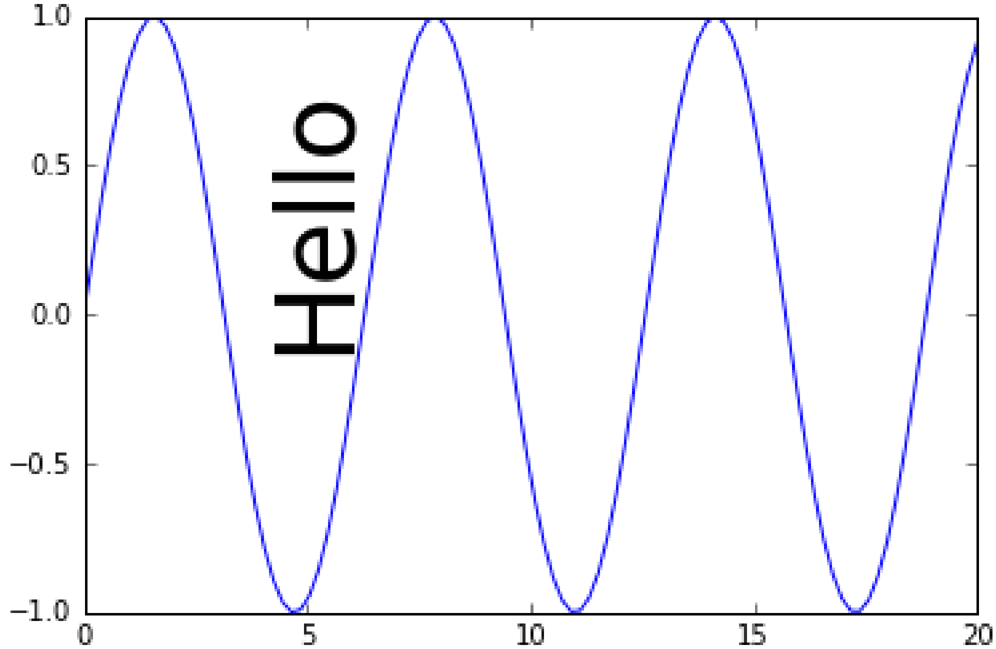
```
In [31]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         ax.text(4, 0.5, "Hello");
```



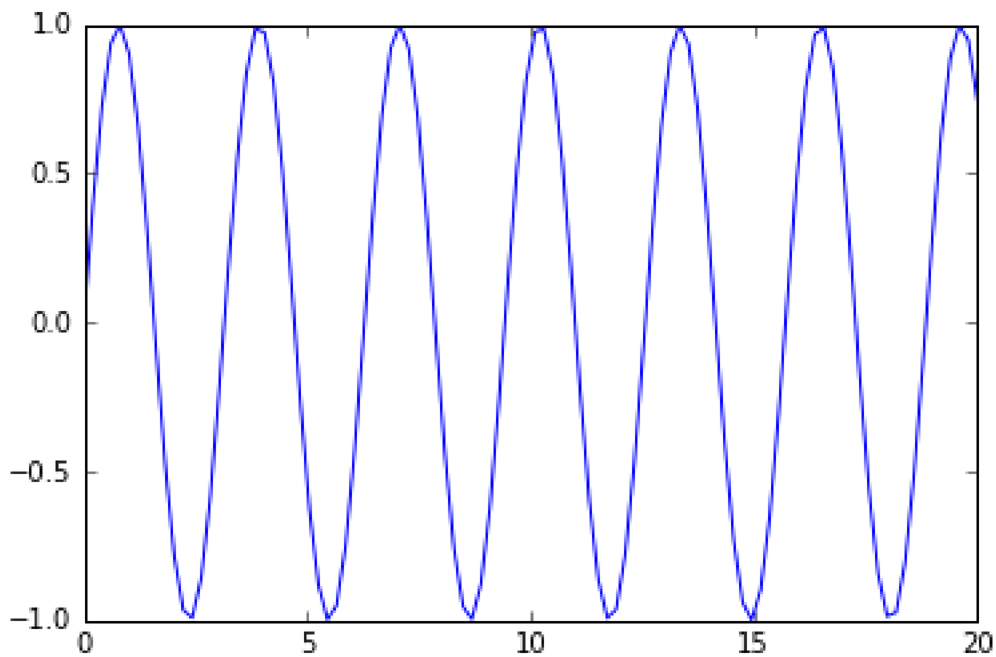
In [32]:
```
fig, ax = plt.subplots()
lines = ax.plot(x, np.sin(x))
ax.set_xlim(-10,10)
ax.text(0.1, 0.1, "Hello", transform=ax.transAxes);
```



In [33]:
```
fig, ax = plt.subplots()
lines = ax.plot(x, np.sin(x))
txt = ax.text(4, 0.5, "Hello")
txt.set_rotation(90)
txt.set_size(40)
```



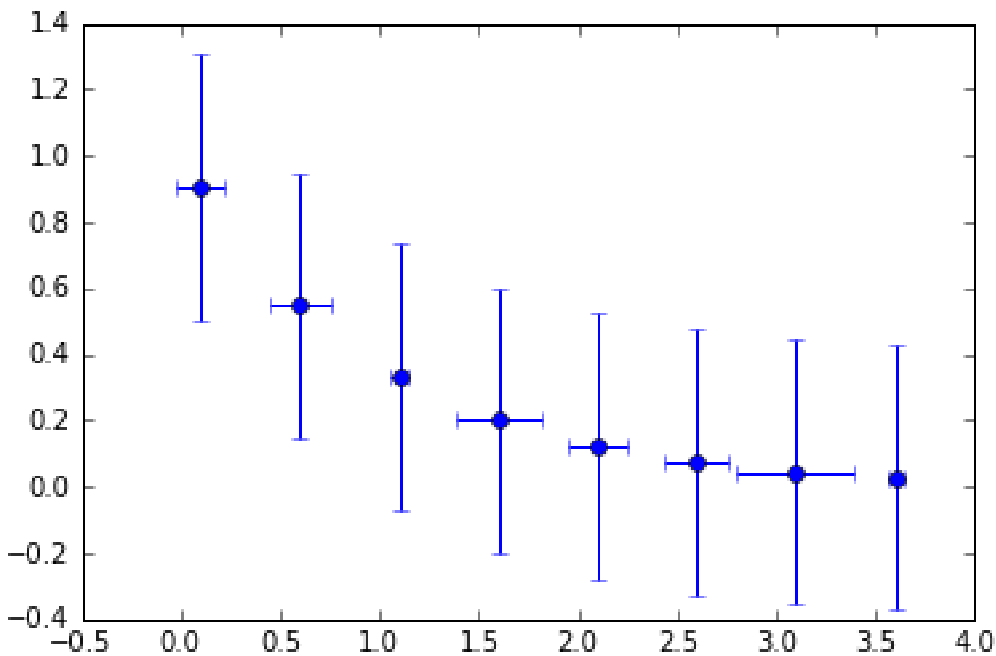

```
In [34]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         lines[0].set_ydata(np.sin(2 * x)) # Change the data themselve!!!
```



Error bars

```
In [35]: x = np.arange(0.1, 4, 0.5)
         y = np.exp(-x)
         xerr = np.random.rand(len(x))*0.3
         fig, ax = plt.subplots()
         eb = ax.errorbar(x, y, xerr=xerr, yerr=0.4, fmt='o')
         print type(eb)
```

```
<class 'matplotlib.container.ErrorbarContainer'>
```



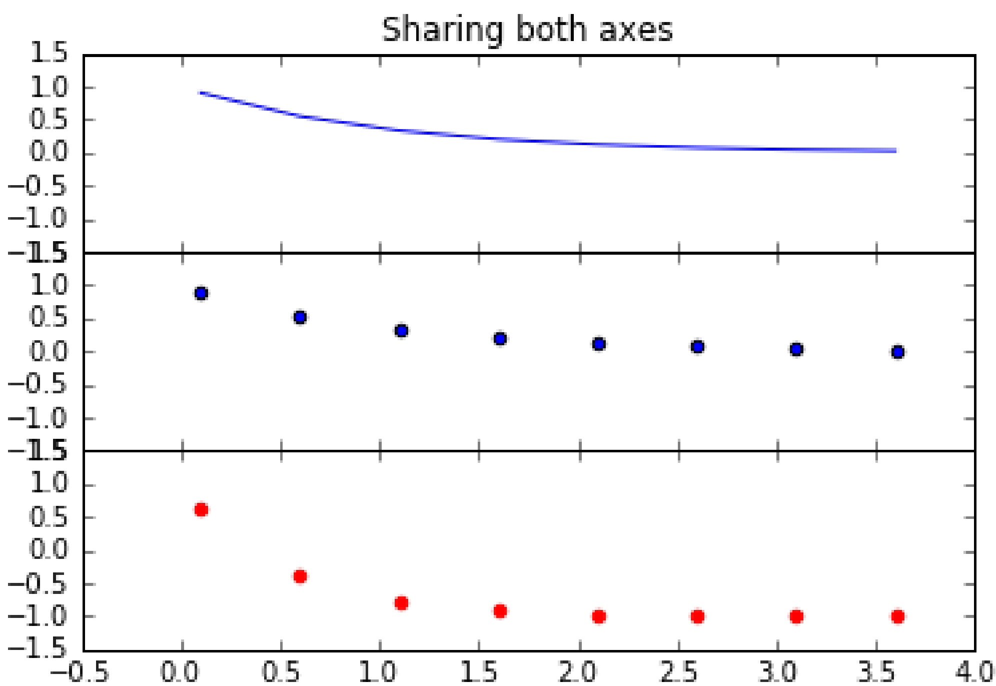
Sharing axes

```
In [36]: %matplotlib tk
         fig, axes = plt.subplots(2, sharex=True)
         axes[0].plot(x, y)
         axes[0].set_title('Sharing X axis')
         axes[1].scatter(x, y);

In [37]: f, (ax1, ax2) = plt.subplots(1, 2, sharey=True) # Unpacking the axes
         ax1.plot(x, y)
         f.suptitle('Main TITLE')
         ax1.set_title('Sharing Y axis')
         ax2.scatter(x, y)

Out[37]: <matplotlib.collections.PathCollection at 0x119577810>
```

```
In [38]: fig, (ax1, ax2, ax3) = plt.subplots(3, sharex=True, sharey=True)
         ax1.plot(x, y)
         ax1.set_title('Sharing both axes')
         ax2.scatter(x, y)
         ax3.scatter(x, 2 * y ** 2 - 1, color='r')
         # Fine-tune figure; make subplots close to each other
         fig.subplots_adjust(hspace=0)
```

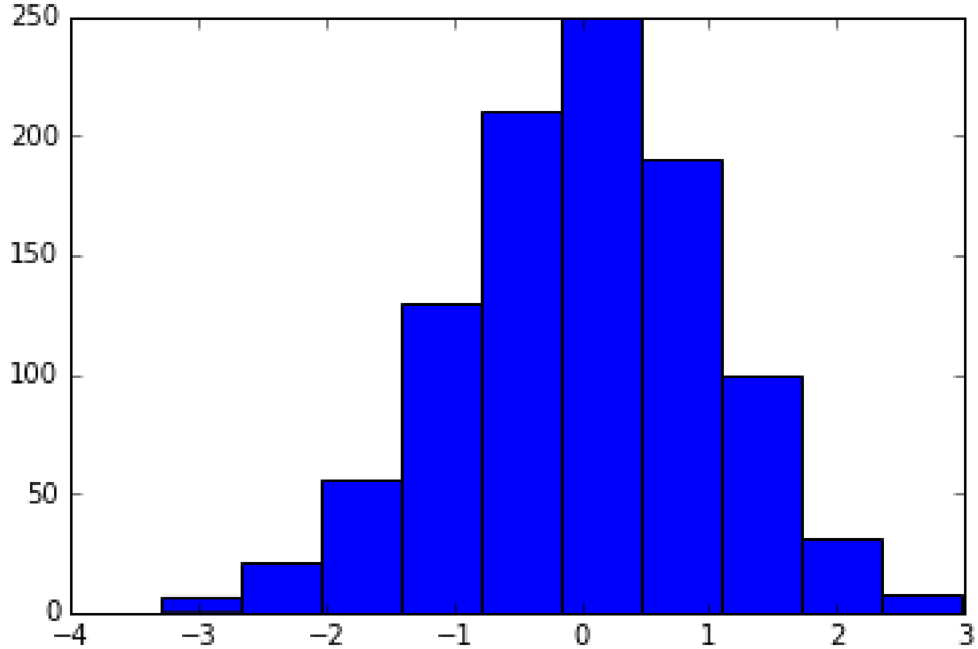
```
In [39]: %matplotlib inline
```

```
In [40]: fig, (ax1, ax2, ax3) = plt.subplots(3, sharex=True, sharey=True)
         ax1.plot(x, y)
         ax1.set_title('Sharing both axes')
         ax2.scatter(x, y)
         ax3.scatter(x, 2 * y ** 2 - 1, color='r')
         # Fine-tune figure; make subplots close to each other
         fig.subplots_adjust(hspace=0)
```

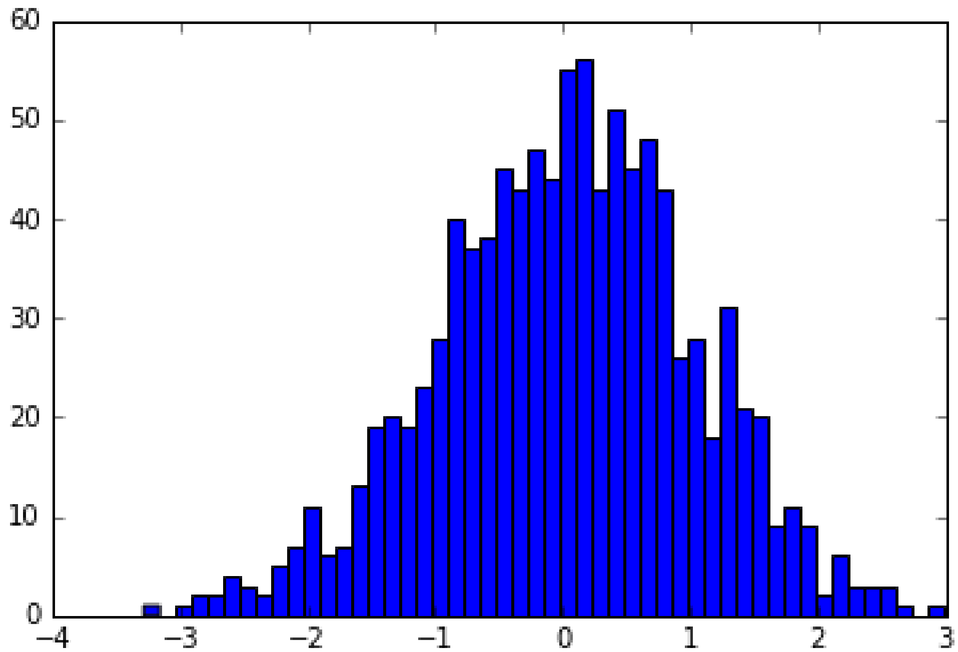


Histograms

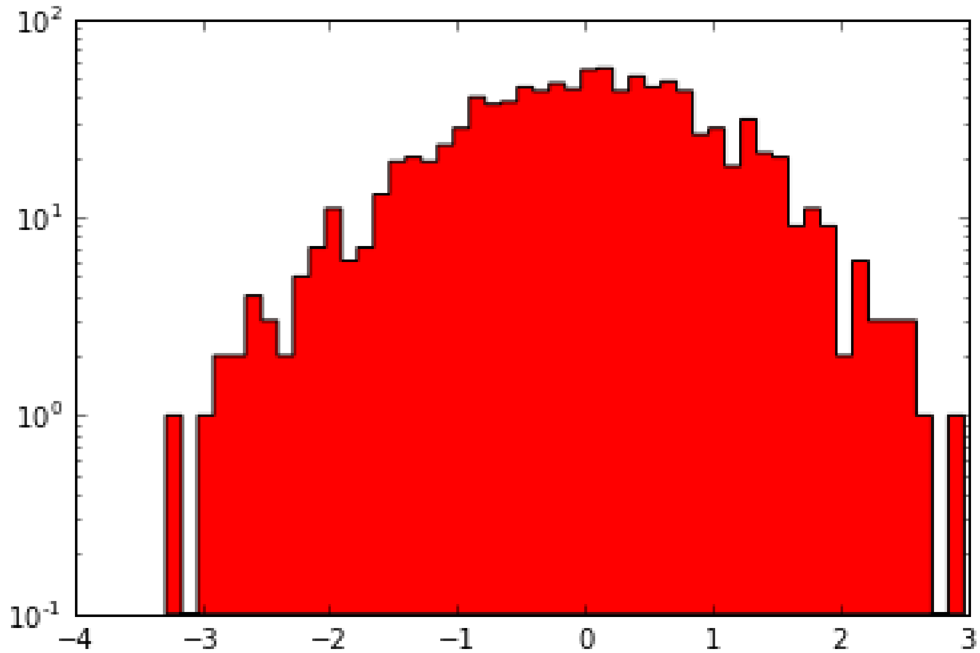
```
In [41]: x = np.random.normal(size=1000)
         fig, ax = plt.subplots()
         H = ax.hist(x)
```



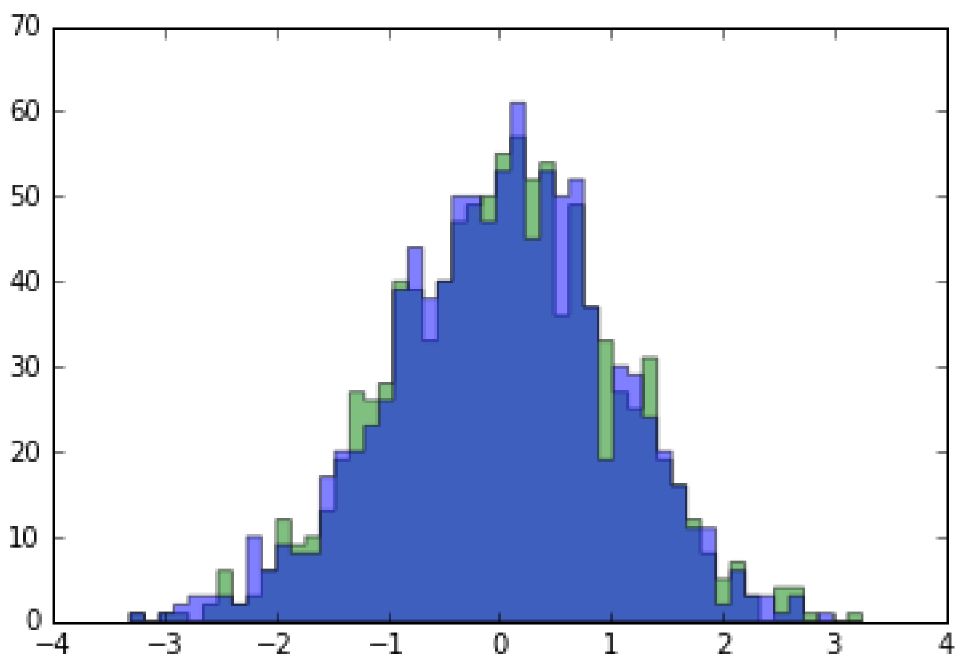

```
In [42]: fig, ax = plt.subplots()
         H = ax.hist(x, bins=50)
```



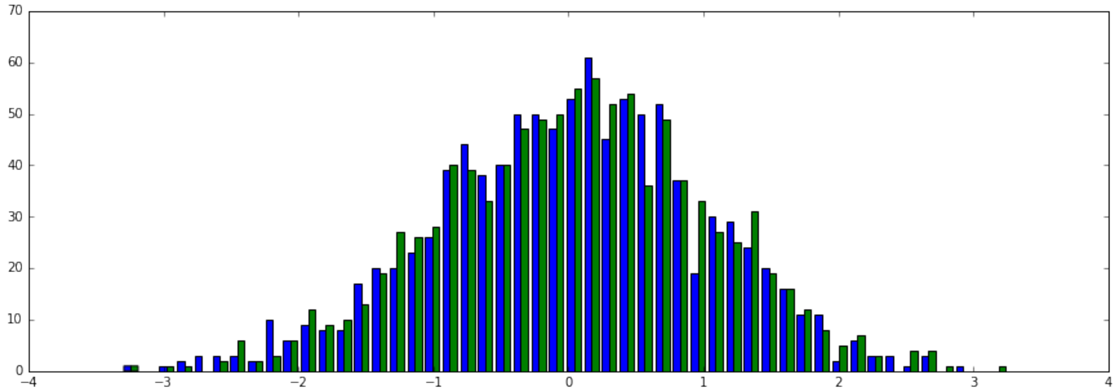
```
In [43]: fig, ax = plt.subplots()
         H = ax.hist(x, bins=50, histtype='stepfilled', log=True, color='r')
```



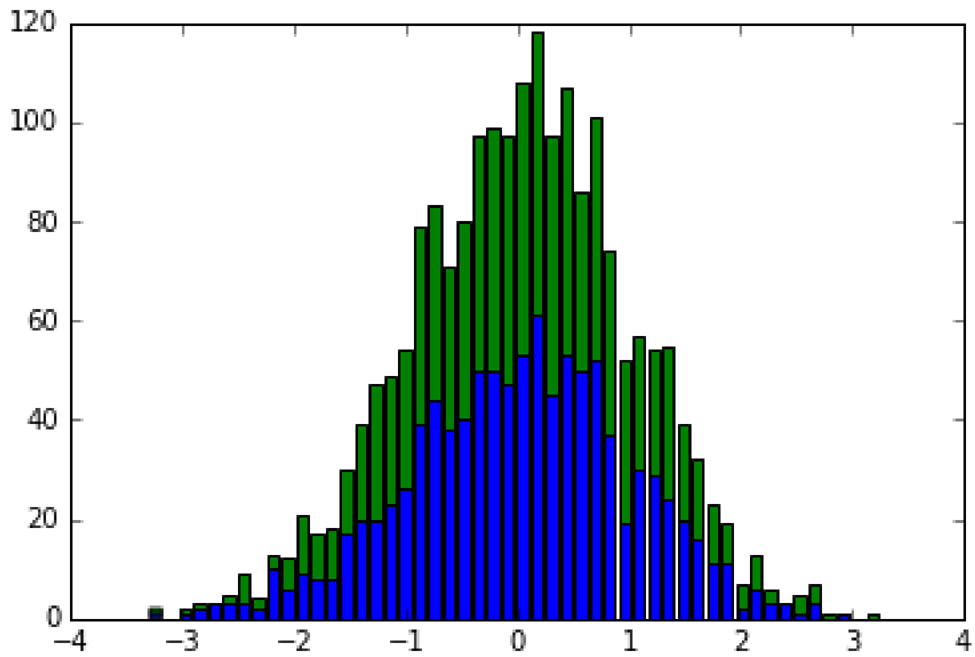

```
In [44]: x2 = np.random.normal(size=1000)
         fig, ax = plt.subplots()
         H = ax.hist((x, x2), bins=50, alpha=0.5, histtype='stepfilled')
```



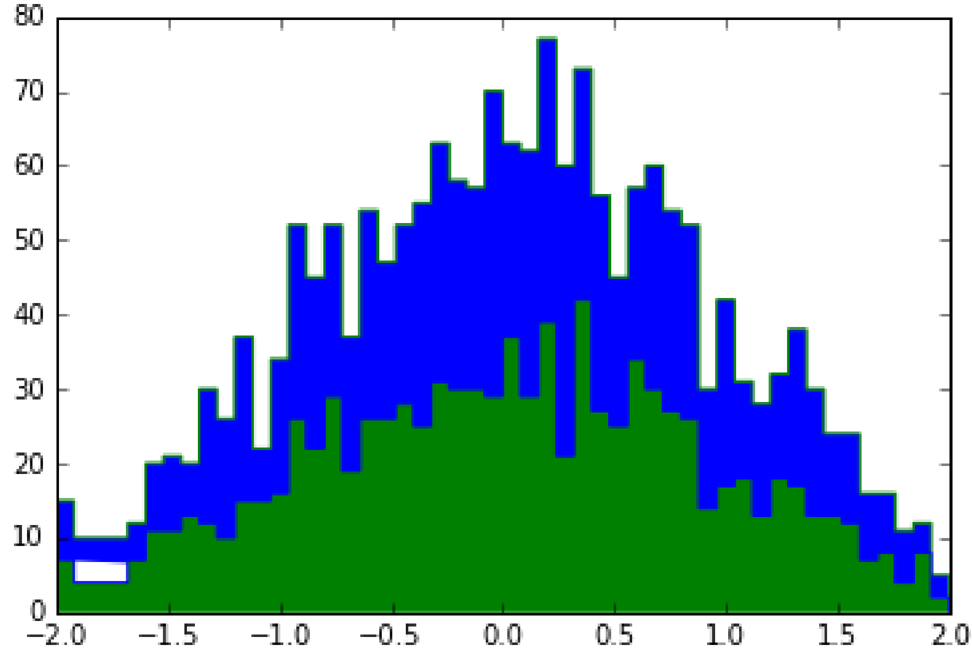
```
In [45]: fig, ax = plt.subplots(figsize=(15,5))
         H = ax.hist((x, x2), bins=50, histtype='bar')
```



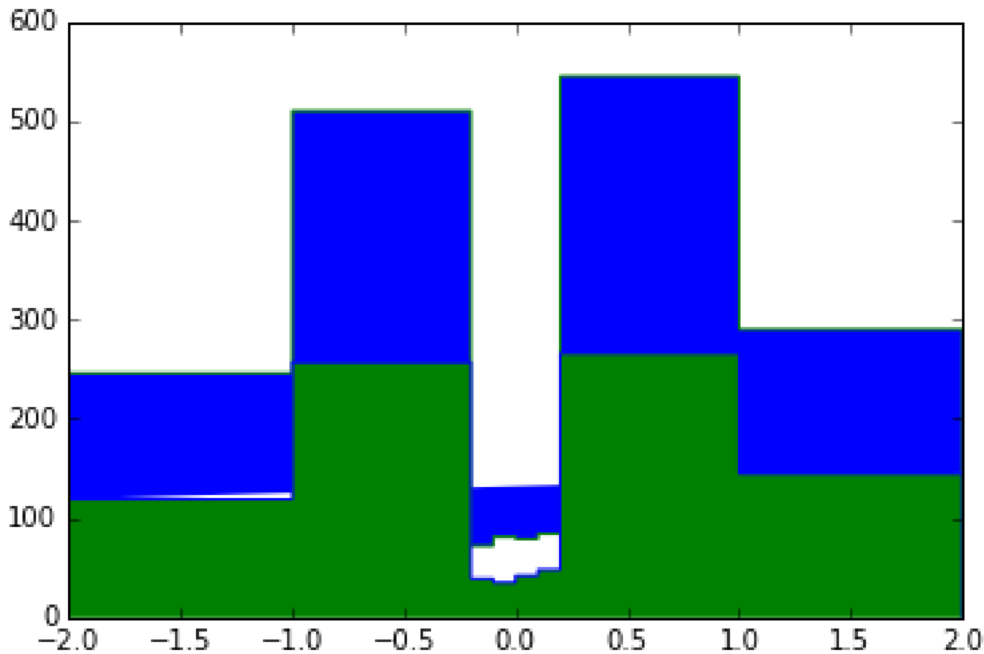

```
In [46]: fig, ax = plt.subplots()
         H = ax.hist((x, x2), bins=50, histtype='bar', stacked=True)
```



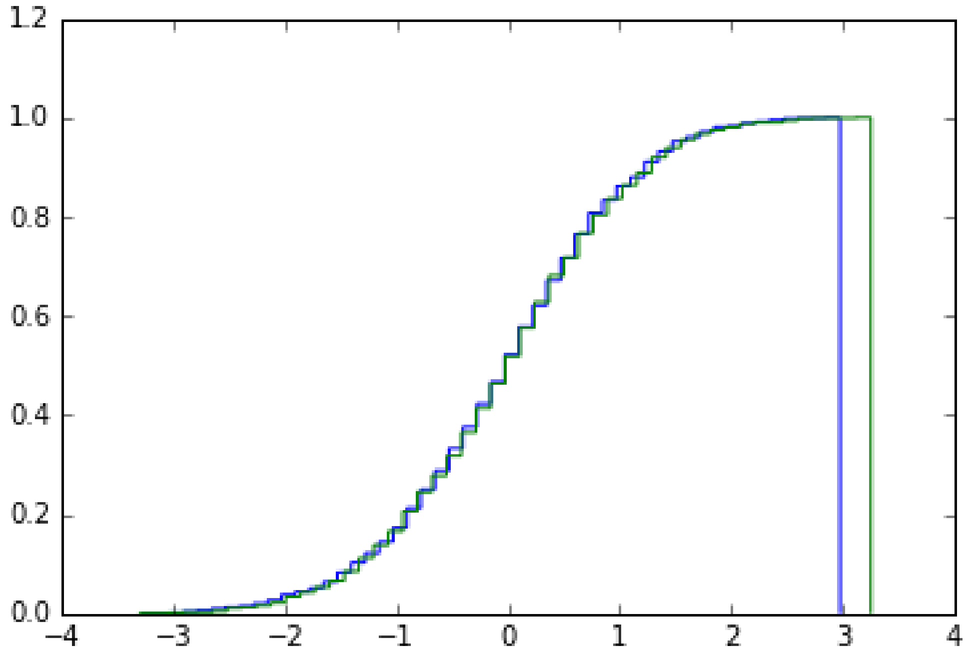

```
In [47]: fig, ax = plt.subplots()
         H = ax.hist((x, x2), bins=50, range=(-2, 2), histtype='step', stacked=True
```




```
In [48]: fig, ax = plt.subplots()
         H = ax.hist((x, x2), bins=(-2, -1, -0.2, -0.1, 0., 0.1, 0.2, 1, 2), range=
```

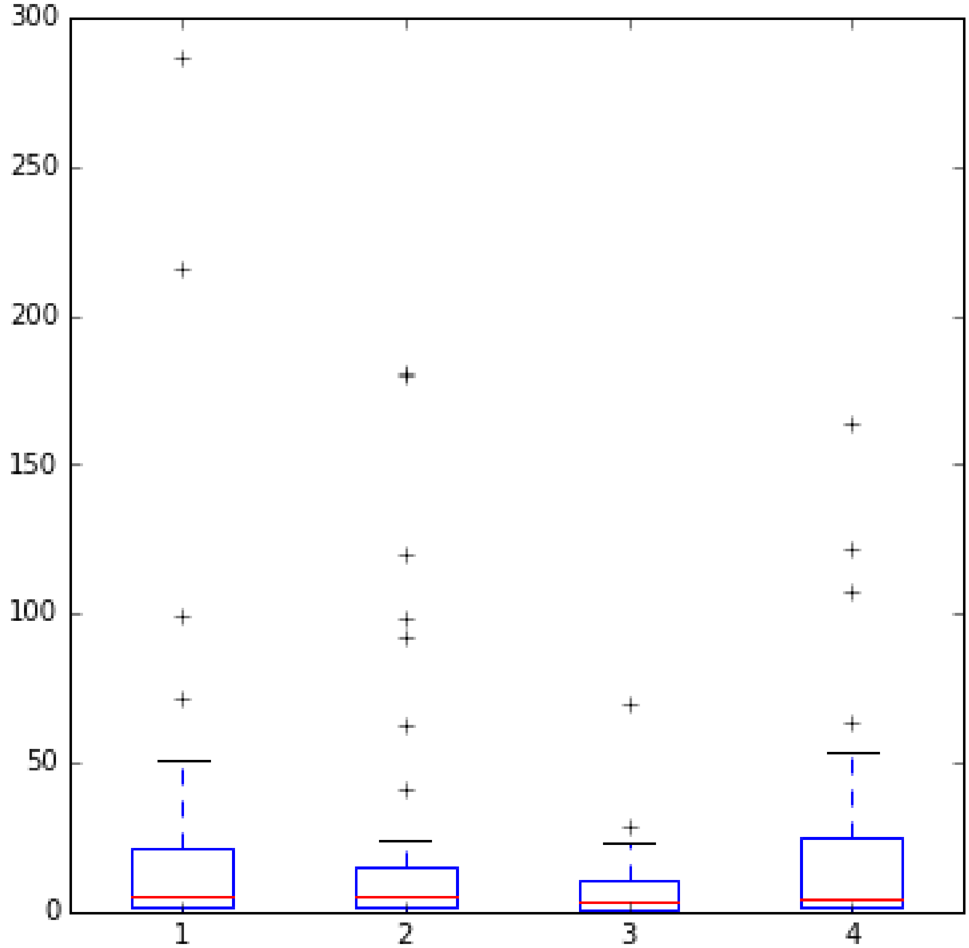


In [49]:
```
fig, ax = plt.subplots()
H = ax.hist(x, bins=50, histtype='step', cumulative=True, normed=True)
H2 = ax.hist(x2, bins=50, histtype='step', cumulative=True, normed=True)
```

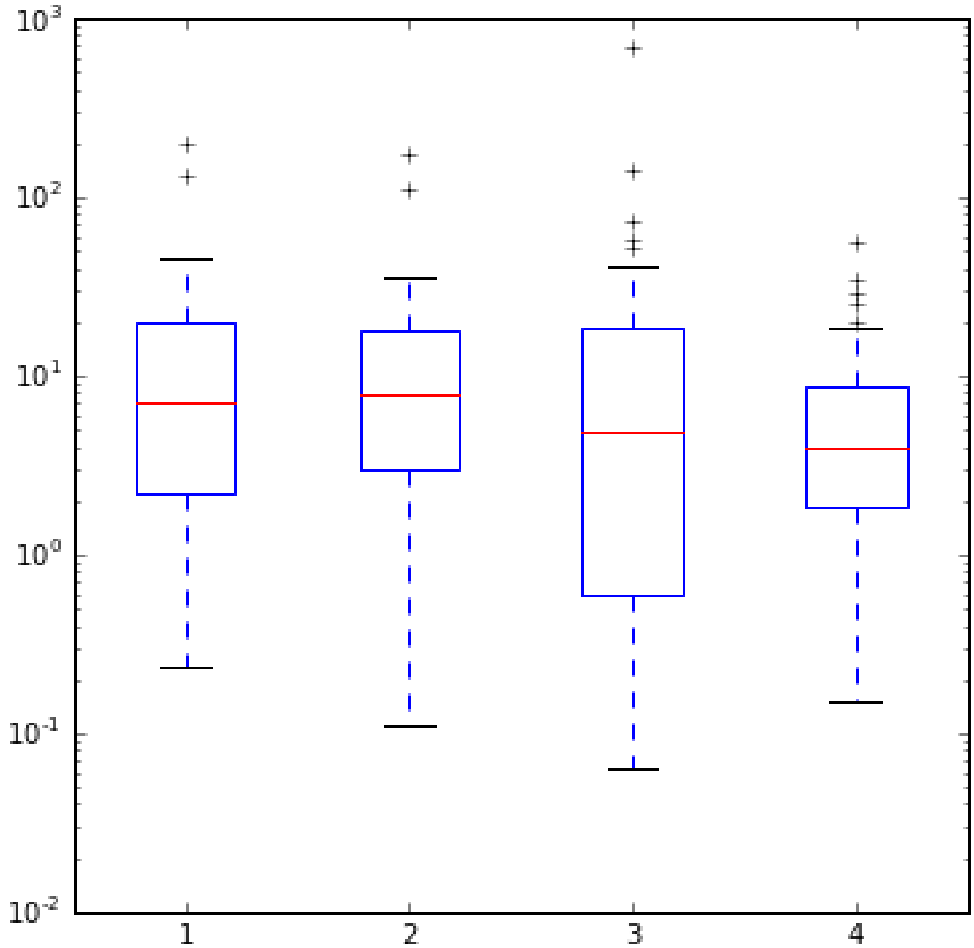


boxplots

In [50]:
```
data = np.random.lognormal(size=(37, 4), mean=1.5, sigma=1.75)

fig, ax = plt.subplots(figsize=(6,6))
bp = ax.boxplot(data) # Nothing to see !
```



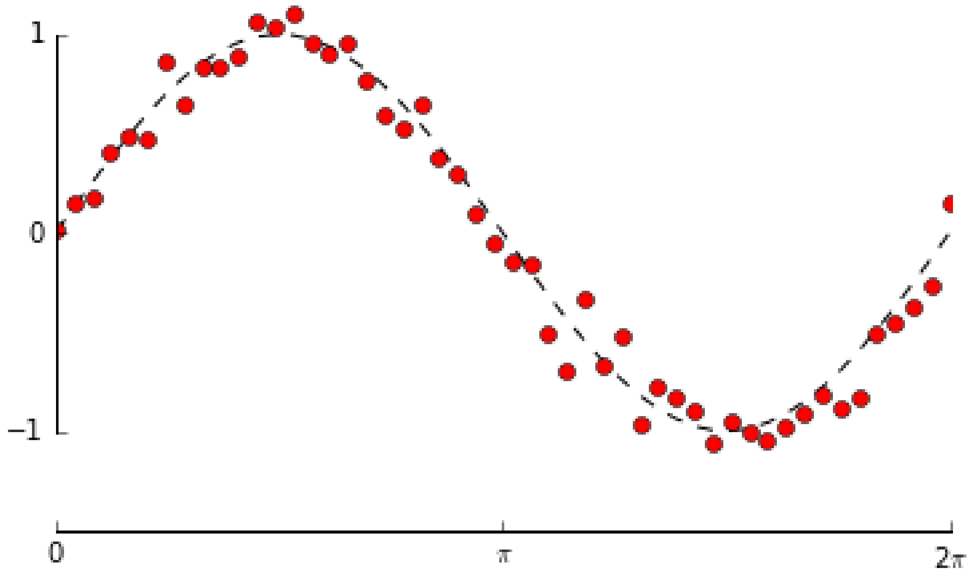

```
In [51]: data = np.random.lognormal(size=(37, 4), mean=1.5, sigma=1.75)

         fig, ax = plt.subplots(figsize=(6,6))
         bp = ax.boxplot(data)
         ax.set_yscale('log')
```



Ticks, axes and spines

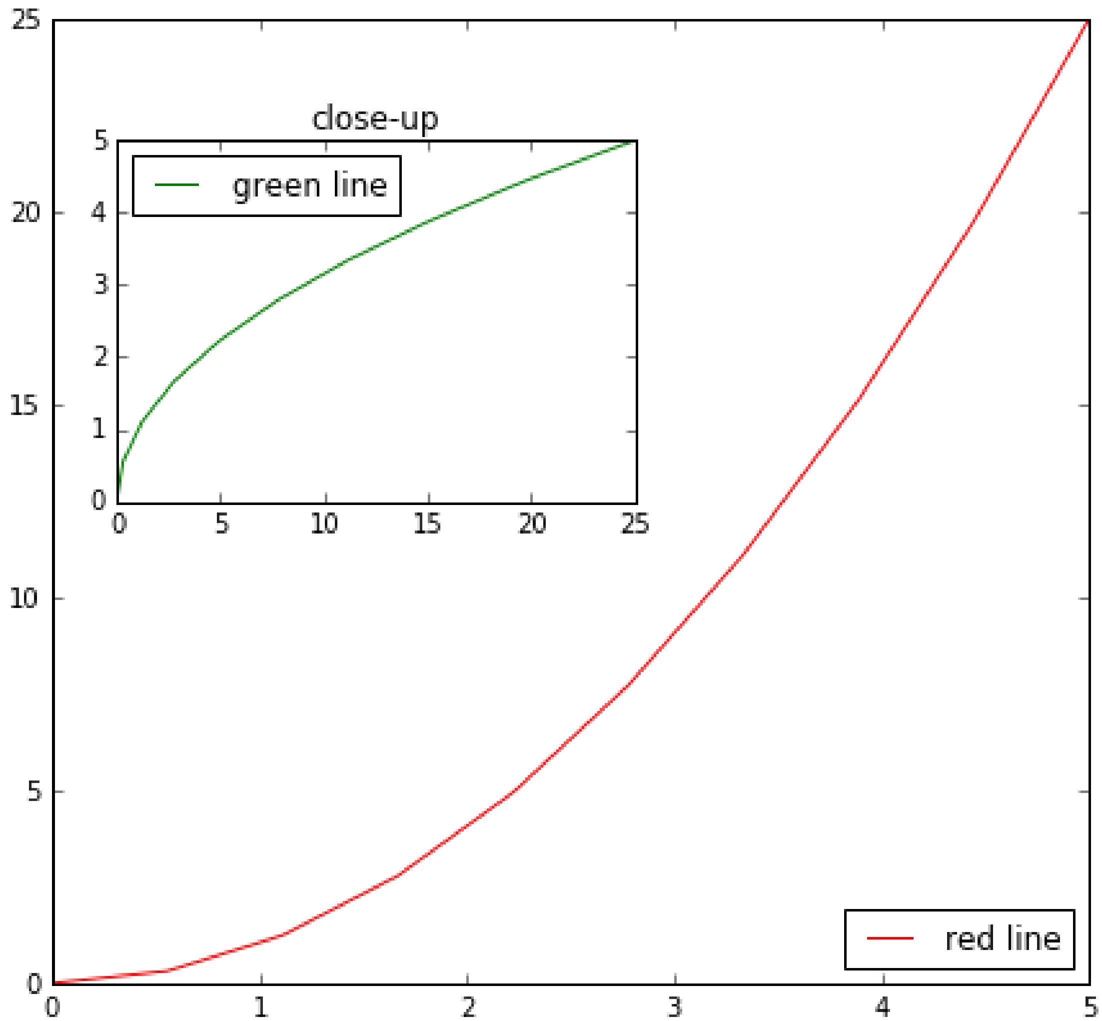
```
In [52]: x = np.linspace(0, 2*np.pi, 50)
         y = np.sin(x)
         y2 = y + 0.1 * np.random.normal(size=x.shape) # add noise to the data

         fig, ax = plt.subplots()
         ax.plot(x, y, 'k--')
         ax.plot(x, y2, 'ro')

         # set ticks and tick labels
         ax.set_xlim((0, 2*np.pi))
         ax.set_xticks([0, np.pi, 2*np.pi])
         ax.set_xticklabels(['0', '$\pi$','2$\pi$'])
         ax.set_ylim((-1.5, 1.5))
         ax.set_yticks([-1, 0, 1])
```

```
# Only draw spine between the y-ticks
ax.spines['left'].set_bounds(-1, 1)
# Hide the right and top spines
ax.spines['right'].set_visible(False)
ax.spines['top'].set_visible(False)
# Only show ticks on the left and bottom spines
ax.yaxis.set_ticks_position('left')
ax.xaxis.set_ticks_position('bottom')
```



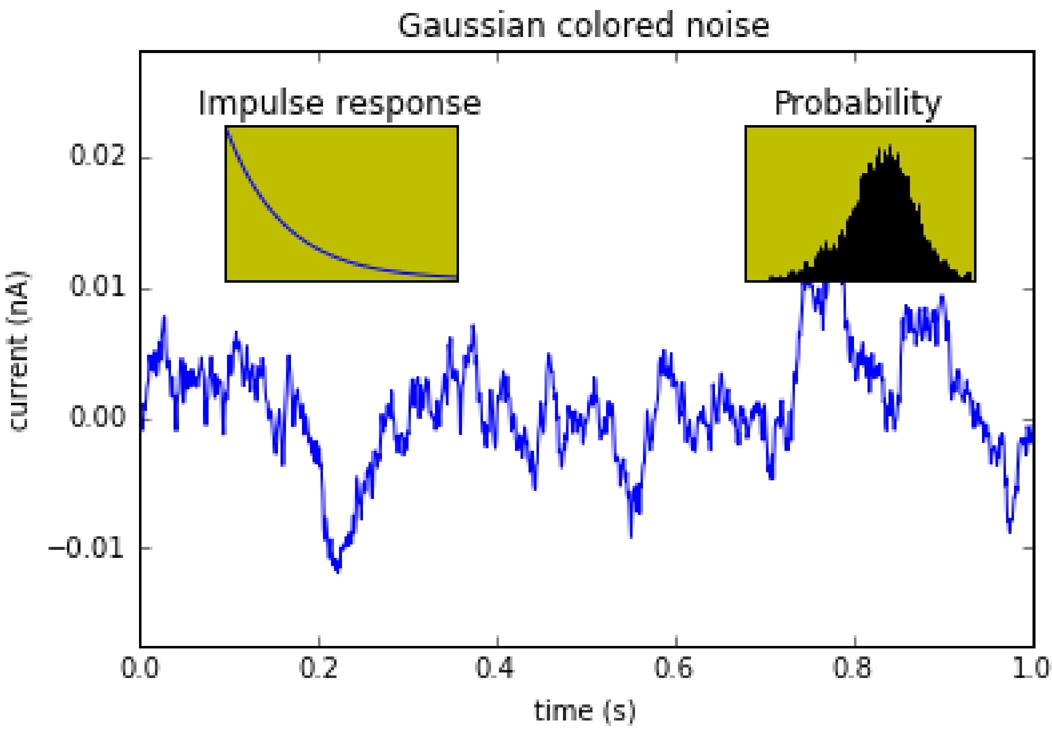
A plot inside a plot

```
In [53]: x = np.linspace(0, 5, 10)
         y = x ** 2

         fig = plt.figure(figsize=(7,6.5))

         ax1 = fig.add_axes([0.1, 0.1, 0.8, 0.8]) # main axes
         ax2 = fig.add_axes([0.15, 0.5, 0.4, 0.3]) # inset axes

         # main figure
         ax1.plot(x, y, 'r', label='red line')
         ax1.legend(loc=4)
         # insert
         ax2.plot(y, x, 'g', label = 'green line')
         ax2.set_title('close-up')
         ax2.legend(loc='best');
```



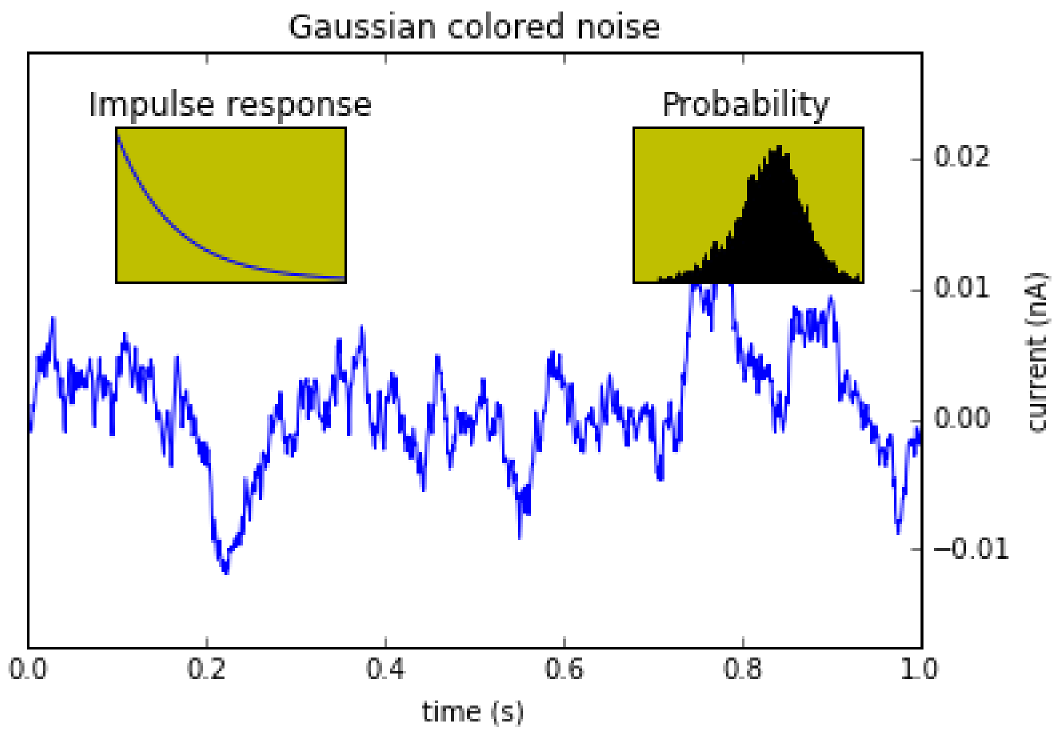

```
In [54]: # The classical way

         # create some data to use for the plot
         dt = 0.001
         t = np.arange(0.0, 10.0, dt)
         r = np.exp(-t[:1000]/0.05)  # impulse response
         x = np.random.randn(len(t))
         s = np.convolve(x,r)[:len(x)]*dt  # colored noise

         # the main axes is subplot(111) by default
         plt.plot(t, s)
         plt.axis([0, 1, 1.1*np.amin(s), 2*np.amax(s) ])
         plt.xlabel('time (s)')
         plt.ylabel('current (nA)')
         plt.title('Gaussian colored noise')
```

```
# this is an inset axes over the main axes
a = plt.axes([.65, .6, .2, .2], axisbg='y')
n, bins, patches = plt.hist(s, 400, normed=1)
plt.title('Probability')
plt.setp(a, xticks=[], yticks=[])

# this is another inset axes over the main axes
b = plt.axes([0.2, 0.6, .2, .2], axisbg='y')
plt.plot(t[:len(r)], r)
plt.title('Impulse response')
plt.setp(b, xlim=(0,.2), xticks=[], yticks=[]);
```




```
In [55]: # The Object oriented way

         # the main axes is subplot(111) by default
         fig, ax = plt.subplots()
         ax.plot(t, s)
         ax.axis([0, 1, 1.1*np.amin(s), 2*np.amax(s) ])
         # The previous command is equivalent to:
         #ax.set_xlim((0., 1))
         #ax.set_ylim((1.1*np.amin(s), 2*np.amax(s)))
         ax.set_xlabel('time (s)')
```

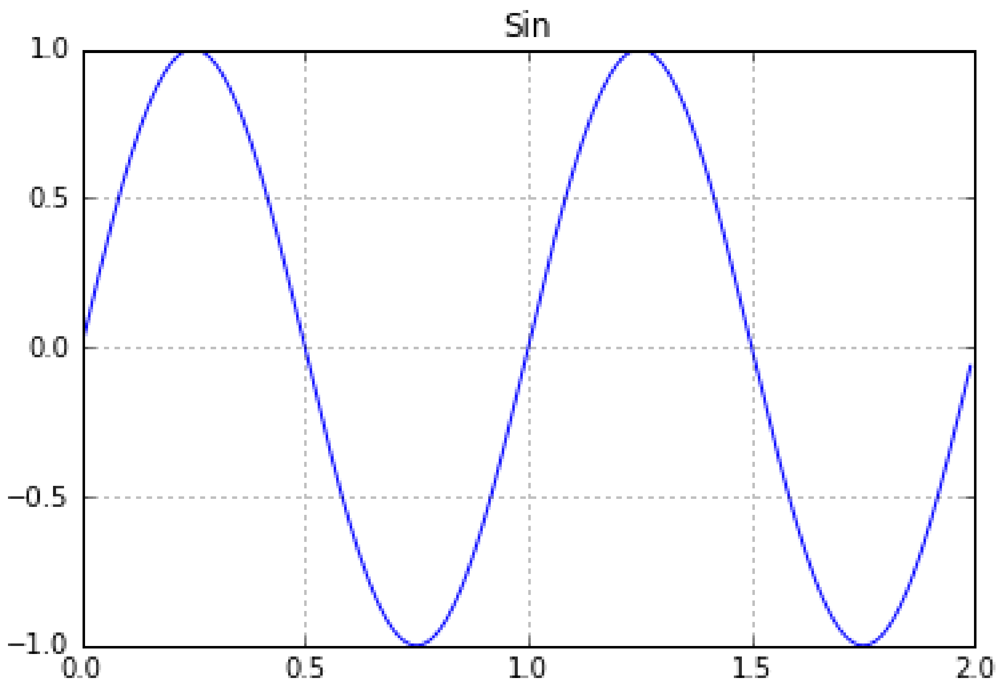
```
ax.set_ylabel('current (nA)')
ax.set_title('Gaussian colored noise')
ax.yaxis.tick_right()
ax.yaxis.set_label_position("right")

# this is an inset axes over the main axes
ax2 = plt.axes([.65, .6, .2, .2], axisbg='y')
n, bins, patches = ax2.hist(s, 400, normed=1)
ax2.set_title('Probability')
ax2.xaxis.set_ticks([])
ax2.yaxis.set_ticks([])

# this is another inset axes over the main axes
ax3 = plt.axes([0.2, 0.6, .2, .2], axisbg='y')
ax3.plot(t[:len(r)], r)
ax3.set_title('Impulse response')
ax3.set_xlim((0., .2))
ax3.xaxis.set_ticks([])
ax3.yaxis.set_ticks([]);
```



Play with all the objects of a plot

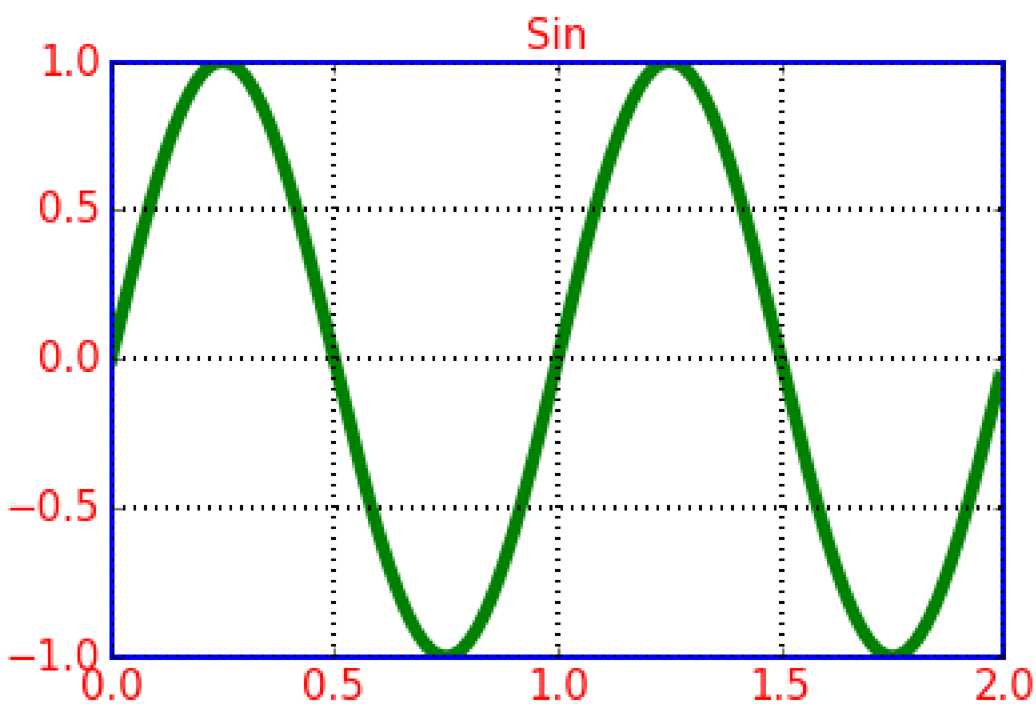
```
In [56]: # Define some data
         t = np.arange(0.0, 2.0, 0.01)
```

```
s = np.sin(2*np.pi*t)
fig, ax = plt.subplots()

# Plot the data and keep the data-line into an object
datalines = ax.plot(t, s)
# Plot grids on the figure
ax.grid(True)
tit = ax.set_title('Sin')

# Put all the lines and labels into lists of objects
ticklines = ax.spines.itervalues()
gridlines = ax.get_xgridlines()
gridlines.extend( ax.get_ygridlines() )
labels = ax.get_xticklabels()
labels.extend( ax.get_yticklabels() )
labels.append(tit)
```



In [57]:
```
# Define some data
t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2*np.pi*t)
fig, ax = plt.subplots()

# Plot the data and keep the data-line into an object
datalines = ax.plot(t, s)
# Plot grids on the figure
```

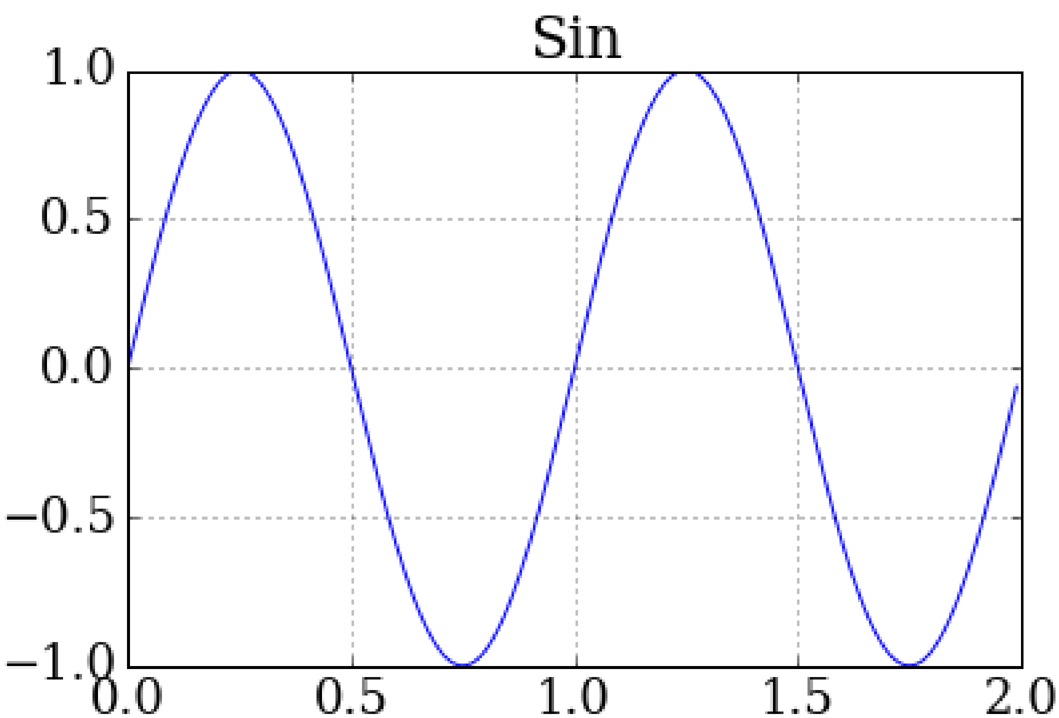
```
ax.grid(True)
tit = ax.set_title('Sin')

# Put all the lines and labels into lists of objects
ticklines = ax.spines.itervalues()
gridlines = ax.get_xgridlines()
gridlines.extend( ax.get_ygridlines() )
labels = ax.get_xticklabels()
labels.extend( ax.get_yticklabels() )
labels.append(tit)# Loop on the lists of lines to change properties

for line in ticklines:
    line.set_linewidth(2)
    line.set_color('blue')

for line in datalines:
    line.set_linewidth(5)
    line.set_color('green')

for line in gridlines:
    line.set_linestyle(':')
    line.set_linewidth(2)

# loop on the labels to change properties
for label in labels:
    label.set_color('r')
    label.set_fontsize(15)
```



Changing font etc for all the plots:

In [58]:
```
import matplotlib
matplotlib.rcParams.update({'font.size': 18, 'font.family': 'serif'})
```

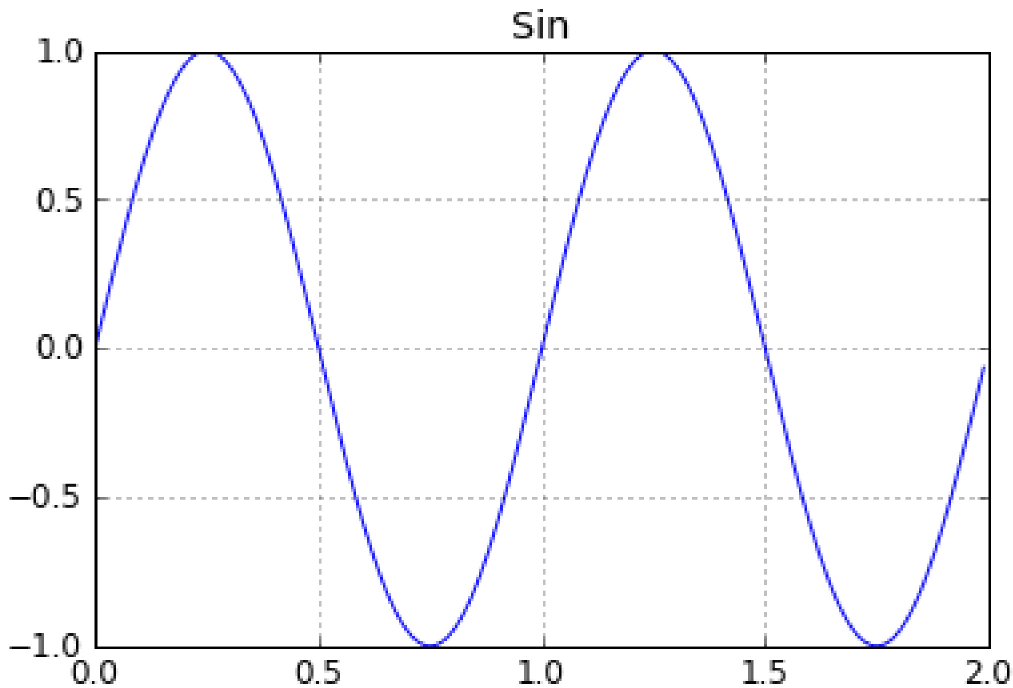
In [59]:
```
# Define some data
t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2*np.pi*t)
fig, ax = plt.subplots()

# Plot the data and keep the data-line into an object
datalines = ax.plot(t, s)
# Plot grids on the figure
ax.grid(True)
tit = ax.set_title('Sin')
```



In [60]:
```
# Back to default values
matplotlib.rcParams.update({'font.size': 12, 'font.family': 'sans'})
```

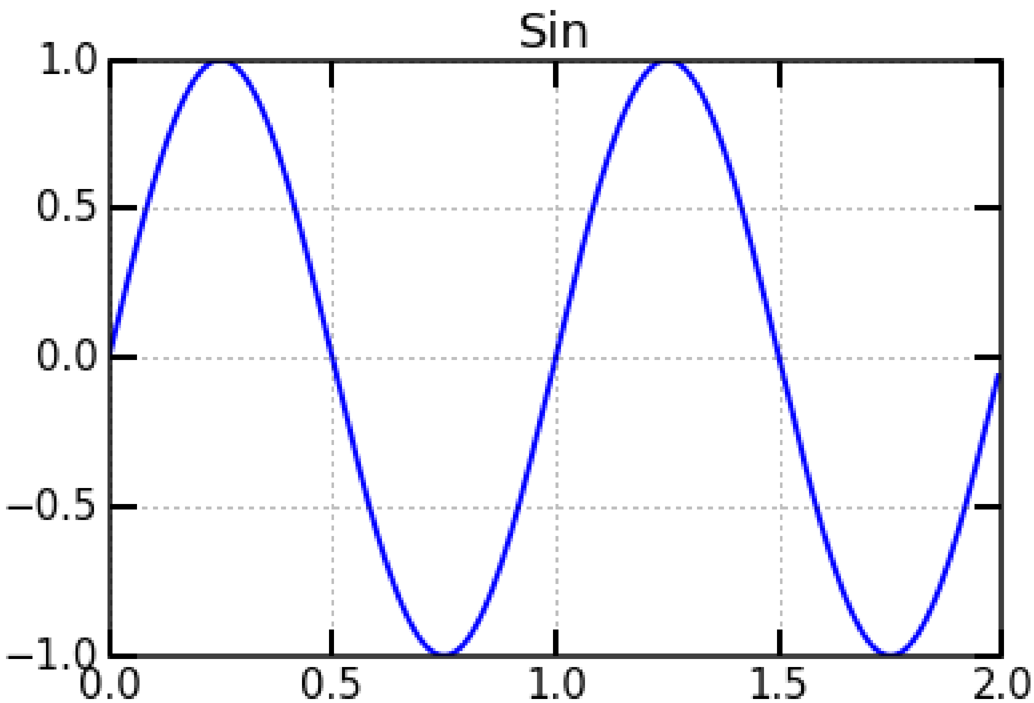
In [61]:
```
# Define some data
t = np.arange(0.0, 2.0, 0.01)
```

```
s = np.sin(2*np.pi*t)
fig, ax = plt.subplots()

# Plot the data and keep the data-line into an object
datalines = ax.plot(t, s)
# Plot grids on the figure
ax.grid(True)
tit = ax.set_title('Sin')
```



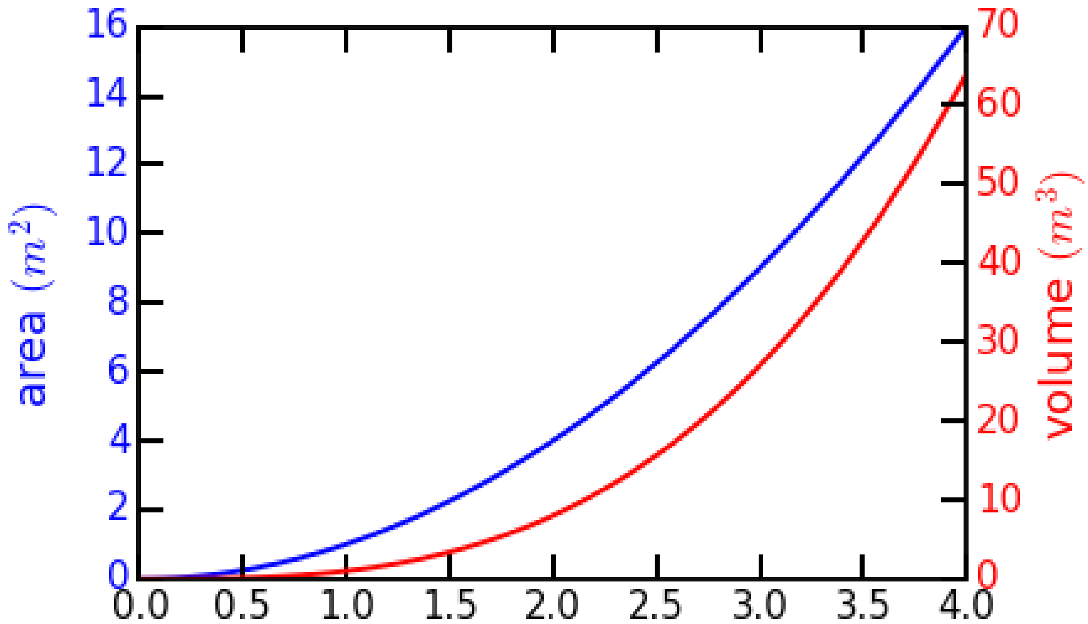

```
In [62]: matplotlib.rc('axes', linewidth=1.5)
         matplotlib.rc('lines', linewidth=2)
         matplotlib.rc('font', size=15)
         matplotlib.rc('xtick.major', width=2, size=10)
         matplotlib.rc('xtick.minor', width=2, size=5)
         matplotlib.rc('ytick.major', width=2, size=10)
         matplotlib.rc('ytick.minor', width=2, size=5)

         # Define some data
         t = np.arange(0.0, 2.0, 0.01)
         s = np.sin(2*np.pi*t)
         fig, ax = plt.subplots()

         # Plot the data and keep the data-line into an object
         datalines = ax.plot(t, s)
```

```python
# Plot grids on the figure
ax.grid(True)
tit = ax.set_title('Sin')
```



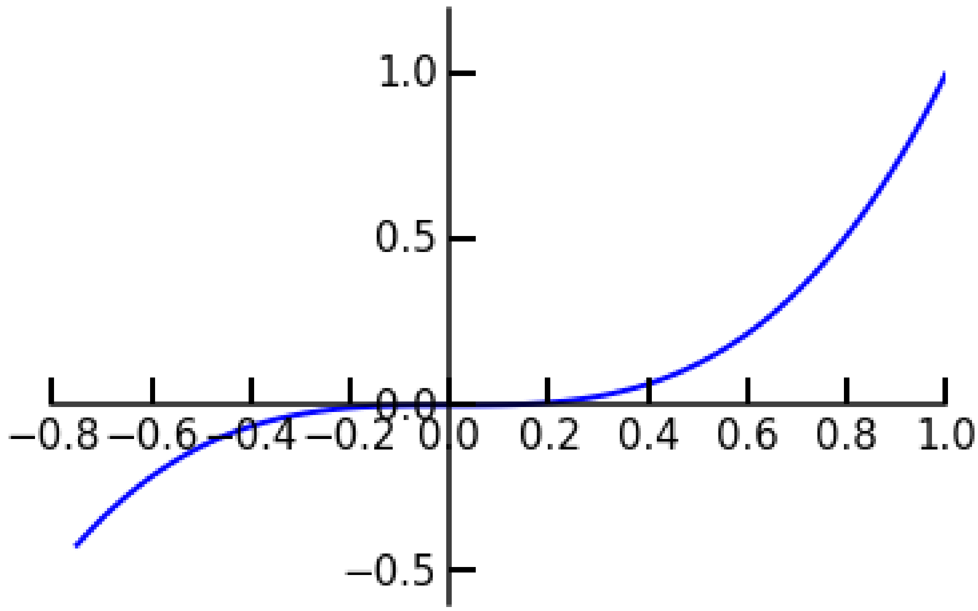
Twin axes

```python
In [63]: x = np.linspace(0, 4, 100)
         fig, ax1 = plt.subplots()

         ax1.plot(x, x**2, lw=2, color="blue")
         ax1.set_ylabel(r"area $(m^2)$", fontsize=18, color="blue")
         for label in ax1.get_yticklabels():
             label.set_color("blue")

         ax2 = ax1.twinx()
         ax2.plot(x, x**3, lw=2, color="red")
         ax2.set_ylabel(r"volume $(m^3)$", fontsize=18, color="red")
         for label in ax2.get_yticklabels():
             label.set_color("red")
```



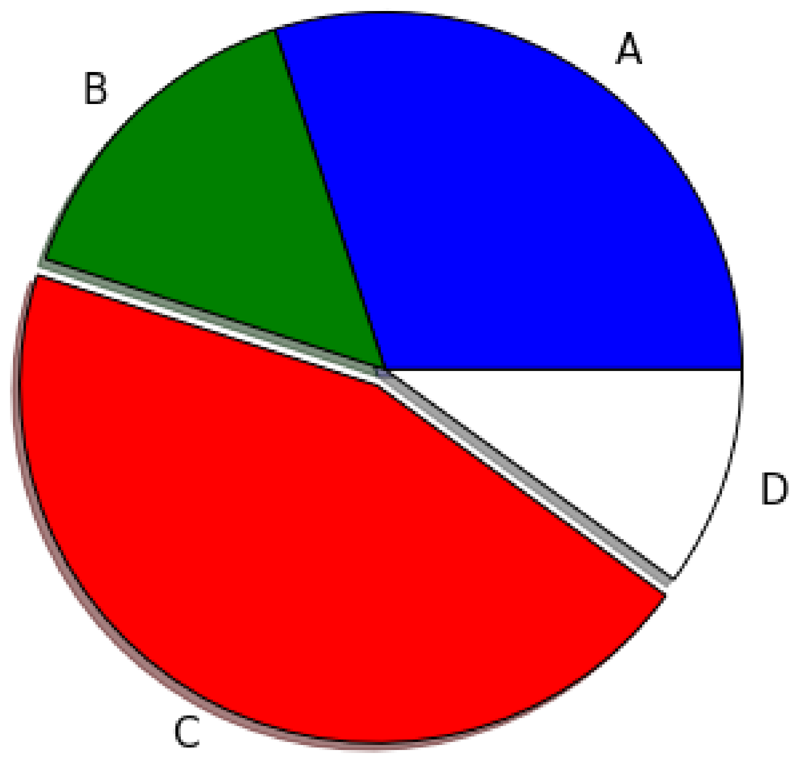
Axis crossing at 0

```
In [64]: fig, ax = plt.subplots()

         ax.spines['right'].set_color('none')
         ax.spines['top'].set_color('none')

         ax.xaxis.set_ticks_position('bottom')
         ax.spines['bottom'].set_position(('data',0)) # set position of x spine to

         ax.yaxis.set_ticks_position('left')
         ax.spines['left'].set_position(('data',0))   # set position of y spine to

         xx = np.linspace(-0.75, 1., 100)
         ax.plot(xx, xx**3);
```



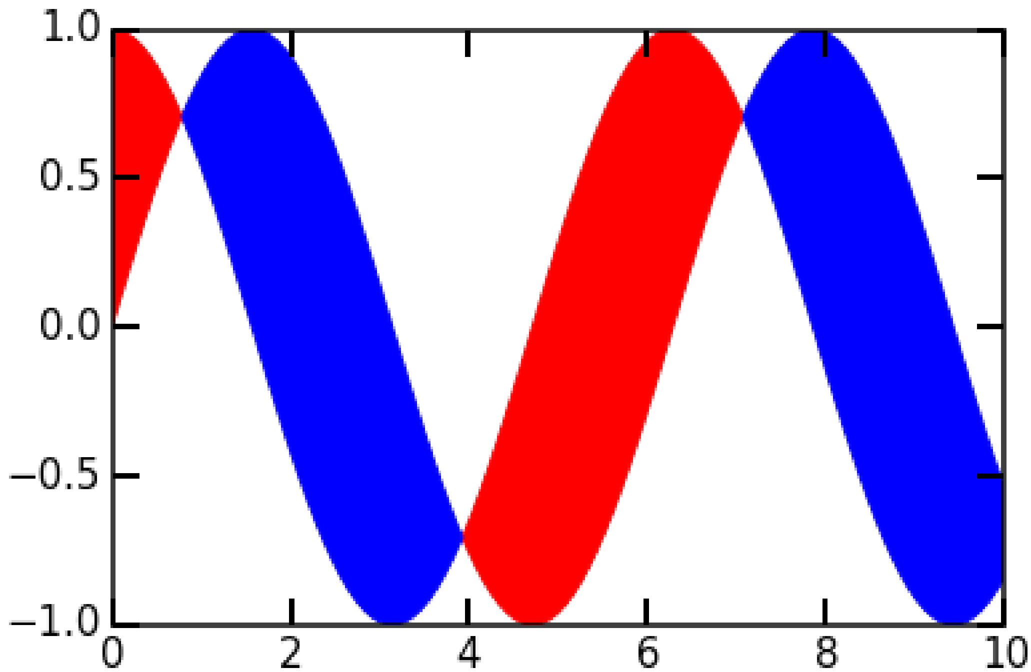
Pie plots

```
In [65]: fracs = [30, 15, 45, 10]
         colors = ['b', 'g', 'r', 'w']

         fig, ax = plt.subplots(figsize=(6, 6))  # make the plot square
         pie = ax.pie(fracs, colors=colors, explode=(0, 0, 0.05, 0), shadow=True,
                      labels=['A', 'B', 'C', 'D'])
```



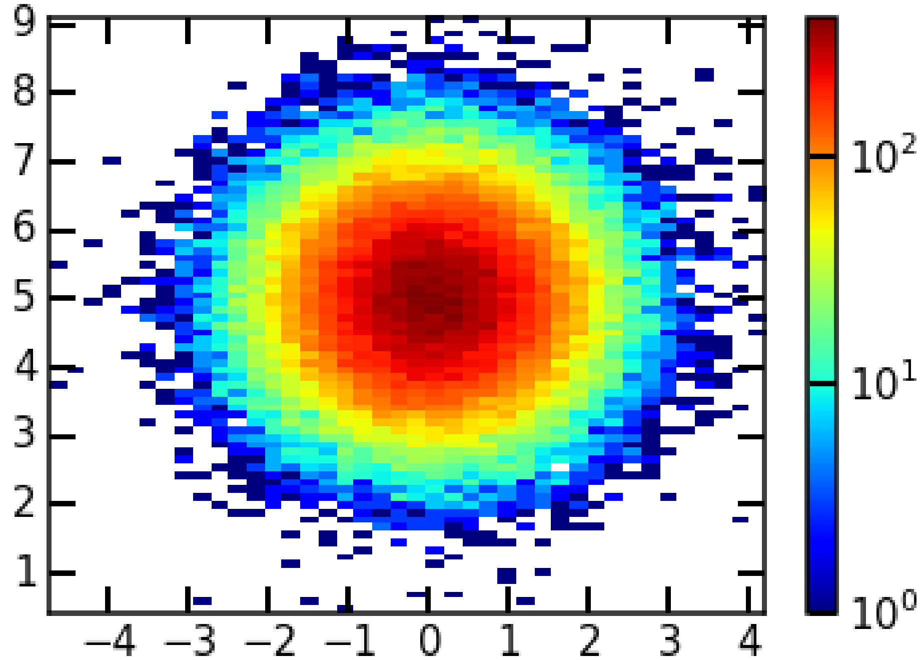
Filled regions

```
In [66]: x = np.linspace(0, 10, 1000)
         y1 = np.sin(x)
         y2 = np.cos(x)

         fig, ax = plt.subplots()
         ax.fill_between(x, y1, y2, where=(y1 < y2), color='red')
         ax.fill_between(x, y1, y2, where=(y1 > y2), color='blue');
```

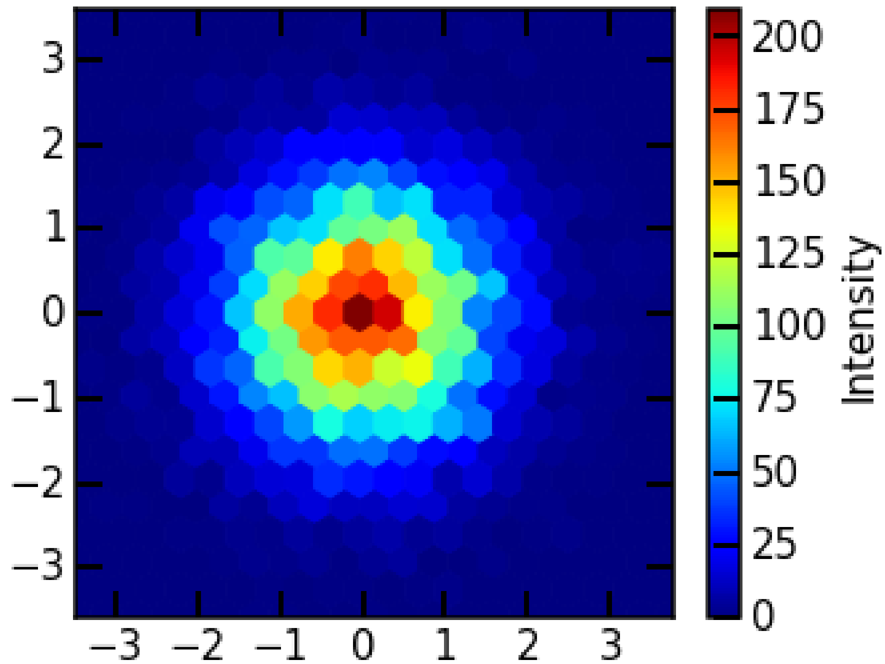


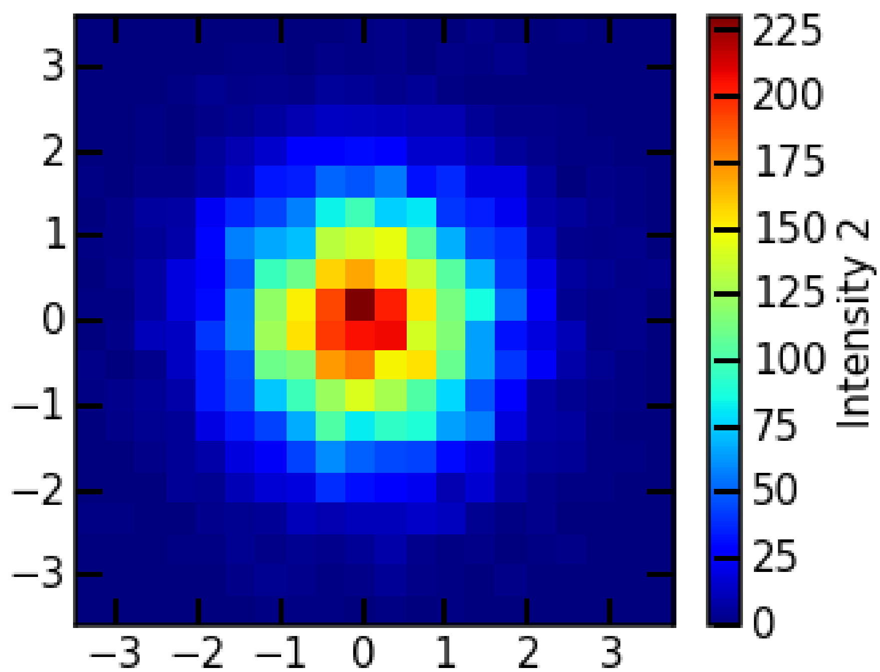
2D-histograms and hexagon plots

```
In [67]: from matplotlib.colors import LogNorm

         #normal distribution center at x=0 and y=5
         x = np.random.randn(100000)
         y = np.random.randn(100000)+5

         fig, ax = plt.subplots()
         counts, xedges, yedges, Image = ax.hist2d(x, y, bins=(40, 80), norm=LogNo
         cb = fig.colorbar(Image)
```




```
In [68]: x, y = np.random.normal(size=(2, 10000))

         fig, (ax1, ax2) = plt.subplots(2, figsize=(5, 9))

         im = ax1.hexbin(x, y, gridsize=20)
         cb = fig.colorbar(im, ax=ax1)
         cb.set_label('Intensity')

         H = ax2.hist2d(x, y, bins=20)
         cb = fig.colorbar(H[3], ax=ax2)
         cb.set_label('Intensity 2')
```

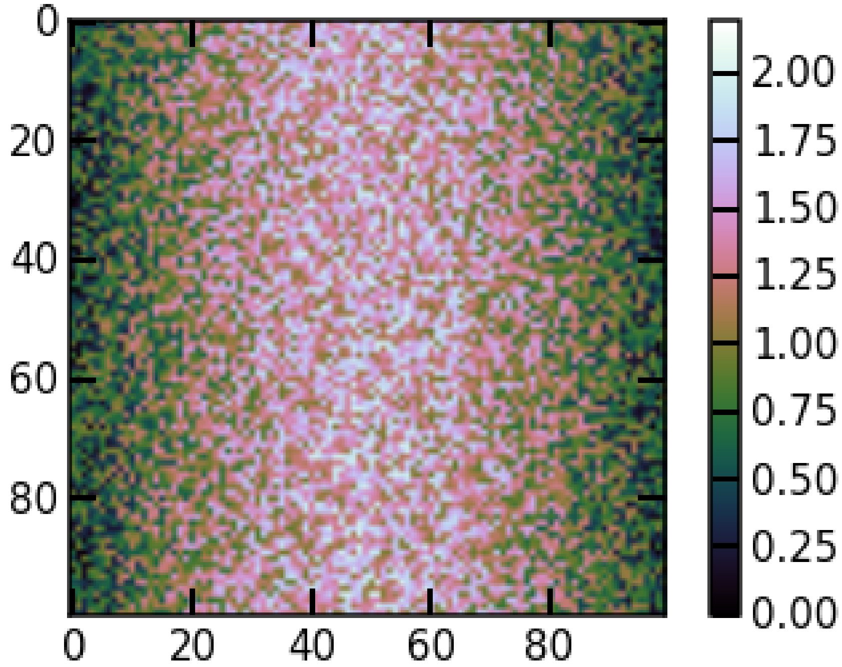




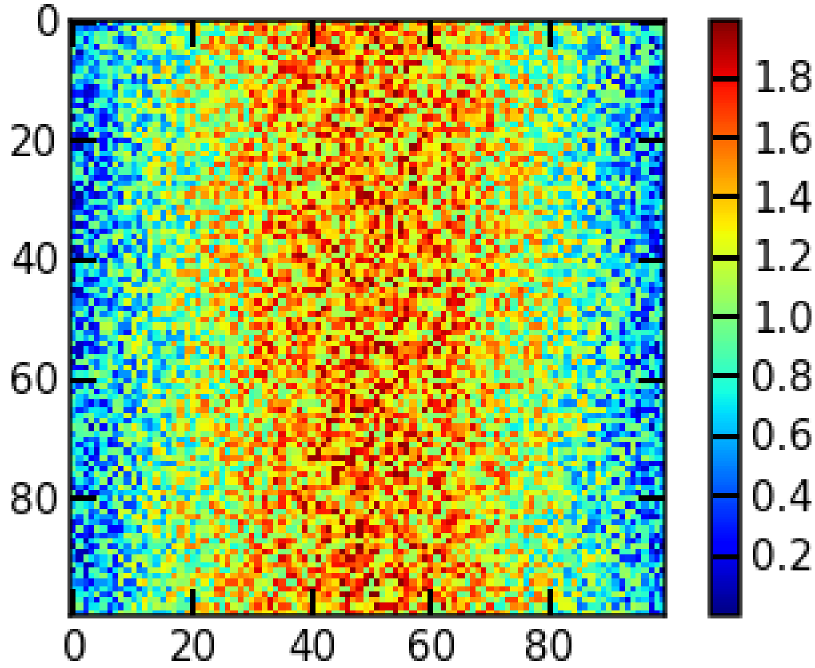
2D data sets and Images

```
In [69]: I = np.random.random((100, 100))
         I += np.sin(np.linspace(0, np.pi, 100))
         fig, ax = plt.subplots()
```

```
im = ax.imshow(I, cmap=plt.cm.cubehelix, vmin=0, vmax=2.2) # draw the imag
cb = fig.colorbar(im) # put the colorbar
```




```
In [70]: fig, ax = plt.subplots()
         im = ax.imshow(I, cmap=plt.cm.jet, interpolation='none') # draw the image,
         cb = fig.colorbar(im, ax=ax) # put the colorbar
```



In [71]: help(plt.imshow)

```
Help on function imshow in module matplotlib.pyplot:

imshow(X, cmap=None, norm=None, aspect=None, interpolation=None, alpha=None, vmin=N
    Display an image on the axes.

    Parameters
    -----------
    X : array_like, shape (n, m) or (n, m, 3) or (n, m, 4)
        Display the image in `X` to current axes.  `X` may be a float
        array, a uint8 array or a PIL image. If `X` is an array, it
        can have the following shapes:

        - MxN -- luminance (grayscale, float array only)
        - MxNx3 -- RGB (float or uint8 array)
        - MxNx4 -- RGBA (float or uint8 array)

        The value for each component of MxNx3 and MxNx4 float arrays
        should be in the range 0.0 to 1.0; MxN float arrays may be
        normalised.

    cmap : `~matplotlib.colors.Colormap`, optional, default: None
        If None, default to rc `image.cmap` value. `cmap` is ignored when
        `X` has RGB(A) information

    aspect : ['auto' | 'equal' | scalar], optional, default: None
        If 'auto', changes the image aspect ratio to match that of the
        axes.

        If 'equal', and `extent` is None, changes the axes aspect ratio to
        match that of the image. If `extent` is not `None`, the axes
        aspect ratio is changed to match that of the extent.

        If None, default to rc ``image.aspect`` value.

    interpolation : string, optional, default: None
        Acceptable values are 'none', 'nearest', 'bilinear', 'bicubic',
        'spline16', 'spline36', 'hanning', 'hamming', 'hermite', 'kaiser',
        'quadric', 'catrom', 'gaussian', 'bessel', 'mitchell', 'sinc',
        'lanczos'

        If `interpolation` is None, default to rc `image.interpolation`.
        See also the `filternorm` and `filterrad` parameters.
        If `interpolation` is 'none', then no interpolation is performed
```

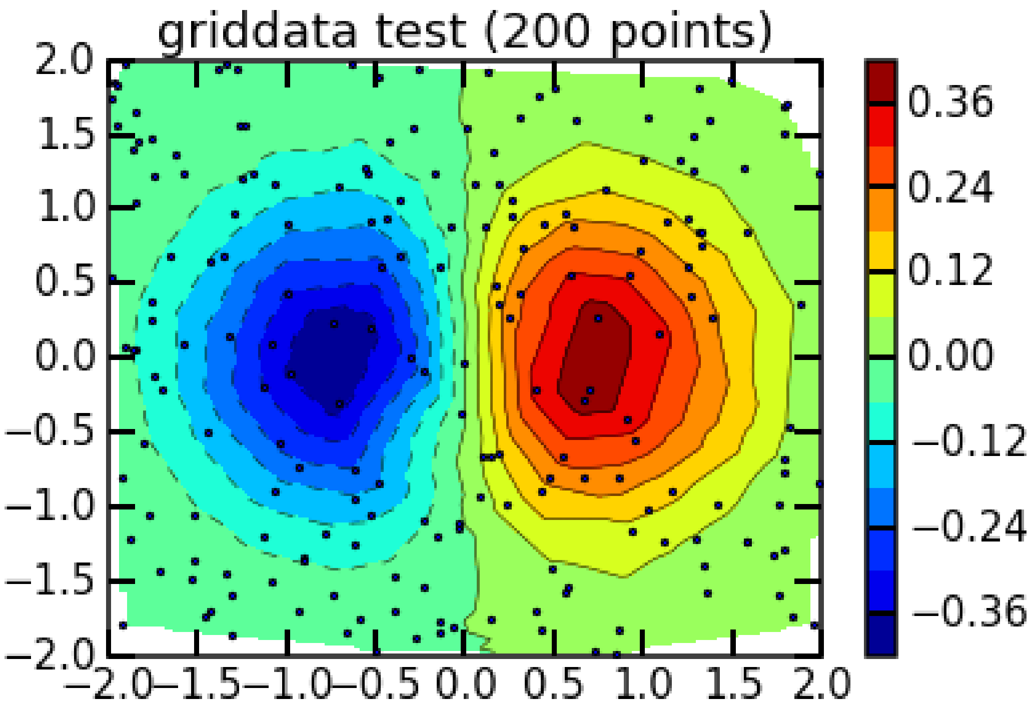
```
    on the Agg, ps and pdf backends. Other backends will fall back to
    'nearest'.

norm : `~matplotlib.colors.Normalize`, optional, default: None
    A `~matplotlib.colors.Normalize` instance is used to scale
    luminance data to 0, 1. If `None`, use the default
    func:`normalize`. `norm` is only used if `X` is an array of
    floats.

vmin, vmax : scalar, optional, default: None
    `vmin` and `vmax` are used in conjunction with norm to normalize
    luminance data.  Note if you pass a `norm` instance, your
    settings for `vmin` and `vmax` will be ignored.

alpha : scalar, optional, default: None
    The alpha blending value, between 0 (transparent) and 1 (opaque)

origin : ['upper' | 'lower'], optional, default: None
    Place the [0,0] index of the array in the upper left or lower left
    corner of the axes. If None, default to rc `image.origin`.

extent : scalars (left, right, bottom, top), optional, default: None
    The location, in data-coordinates, of the lower-left and
    upper-right corners. If `None`, the image is positioned such that
    the pixel centers fall on zero-based (row, column) indices.

shape : scalars (columns, rows), optional, default: None
    For raw buffer images

filternorm : scalar, optional, default: 1
    A parameter for the antigrain image resize filter.  From the
    antigrain documentation, if `filternorm` = 1, the filter
    normalizes integer values and corrects the rounding errors. It
    doesn't do anything with the source floating point values, it
    corrects only integers according to the rule of 1.0 which means
    that any sum of pixel weights must be equal to 1.0.  So, the
    filter function must produce a graph of the proper shape.

filterrad : scalar, optional, default: 4.0
    The filter radius for filters that have a radius parameter, i.e.
    when interpolation is one of: 'sinc', 'lanczos' or 'blackman'

Returns
--------
image : `~matplotlib.image.AxesImage`

Other parameters
----------------
```

```
kwargs : `~matplotlib.artist.Artist` properties.

See also
--------
matshow : Plot a matrix or an array as an image.

Notes
-----
Unless *extent* is used, pixel centers will be located at integer
coordinates. In other words: the origin will coincide with the center
of pixel (0, 0).

Examples
--------

.. plot:: mpl_examples/pylab_examples/image_demo.py

Notes
-----

In addition to the above described arguments, this function can take a
**data** keyword argument. If such a **data** argument is given, the
following arguments are replaced by **data[<arg>]**:

* All positional and all keyword arguments.




Additional kwargs: hold = [True|False] overrides default hold state
```

Contour

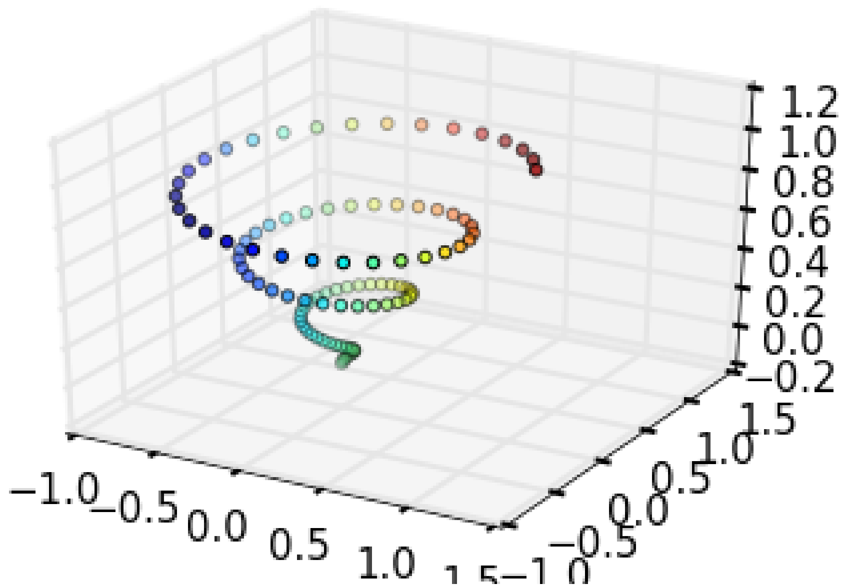
```
In [72]: from matplotlib.mlab import griddata
         fig, ax = plt.subplots()
         # make up data.
         #npts = int(raw_input('enter # of random points to plot:'))
         npts = 200
         x = np.random.uniform(-2, 2, npts)
         y = np.random.uniform(-2, 2, npts)
         z = x*np.exp(-x**2 - y**2)
         # define grid.
         xi = np.linspace(-2.1, 2.1, 100)
         yi = np.linspace(-2.1, 2.1, 200)
         # grid the data.
         zi = griddata(x, y, z, xi, yi, interp='linear')
```

```python
# contour the gridded data, plotting dots at the nonuniform data points.
ax.contour(xi, yi, zi, 15, linewidths=0.5, colors='k')
CF = ax.contourf(xi, yi, zi, 15,
                 vmax=abs(zi).max(), vmin=-abs(zi).max())
cb = fig.colorbar(CF)  # draw colorbar
# plot data points.
ax.scatter(x, y, marker='o', c='b', s=5, zorder=10)
ax.set_xlim(-2, 2)
ax.set_ylim(-2, 2)
ax.set_title('griddata test (%d points)' % npts);
```

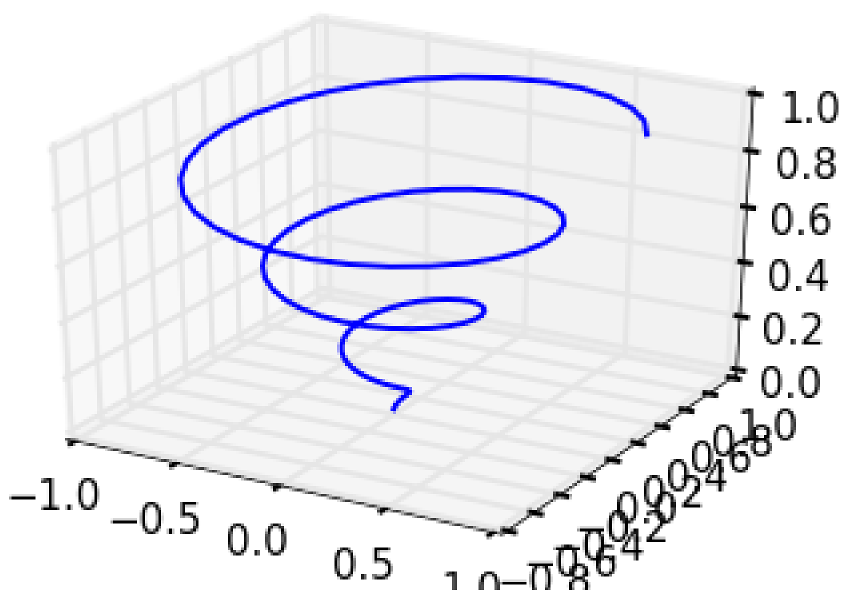


3D scatter plots

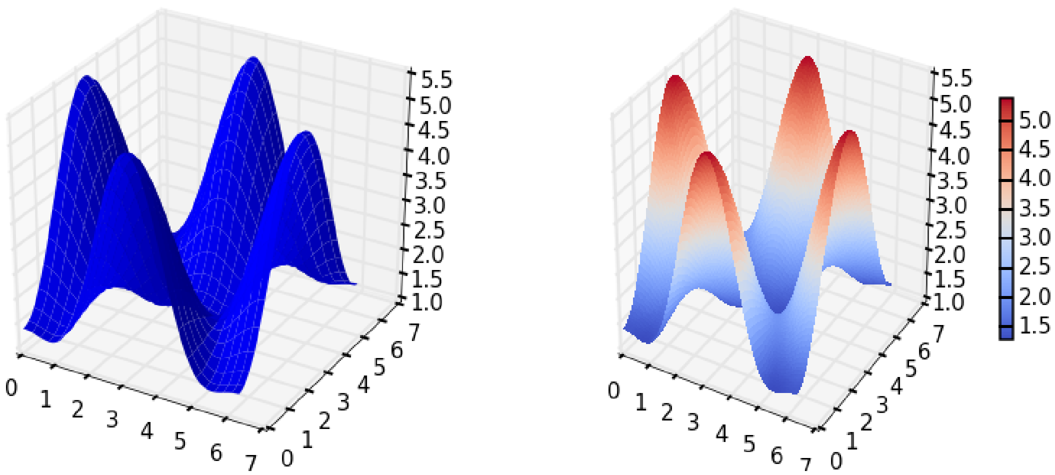
```python
In [73]: from mpl_toolkits.mplot3d import Axes3D
         fig = plt.figure()
         ax = plt.axes(projection='3d')

         z = np.linspace(0, 1, 100)
         x = z * np.sin(20 * z)
         y = z * np.cos(20 * z)

         c = x + y

         ax.scatter(x, y, z, c=c);
         # ax.set_zscale('log')
```




```
In [74]: fig = plt.figure()
         ax = plt.axes(projection='3d')

         ax.plot(x, y, z, '-b')

Out[74]: [<mpl_toolkits.mplot3d.art3d.Line3D at 0x11d3b6fd0>]
```

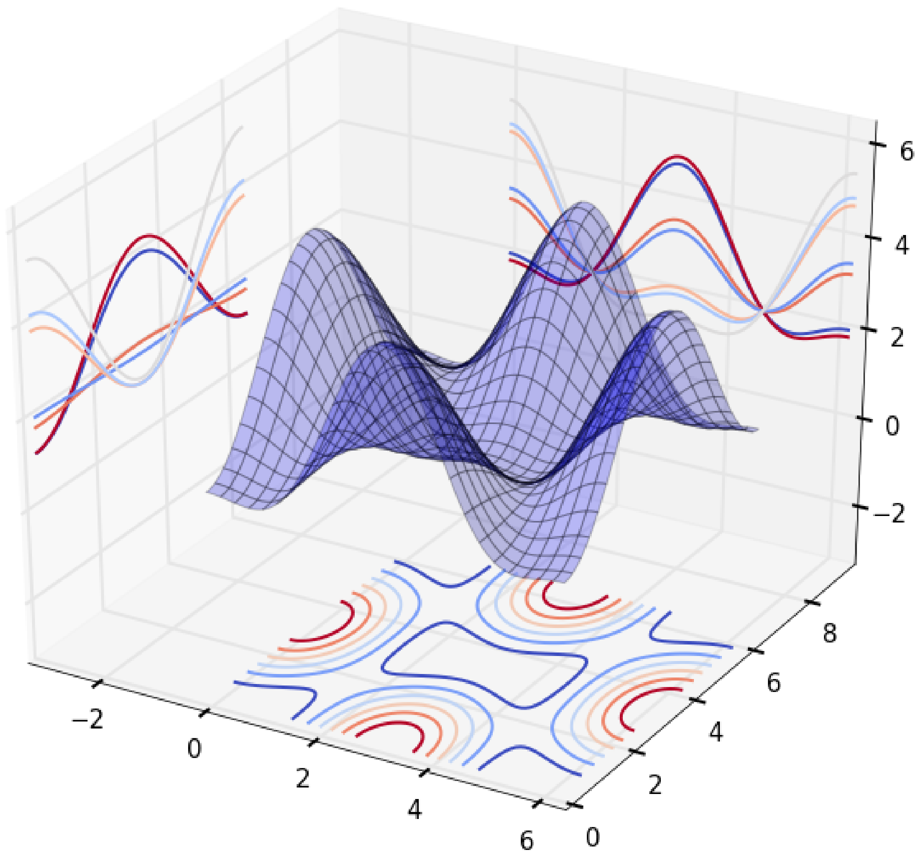


```
In [75]: alpha = 0.7
         phi_ext = 2 * np.pi * 0.5

         def flux_qubit_potential(phi_m, phi_p):
             return 2 + alpha - 2 * np.cos(phi_p)*np.cos(phi_m) - alpha * np.cos(ph

         phi_m = np.linspace(0, 2*np.pi, 100)
         phi_p = np.linspace(0, 2*np.pi, 100)
         X,Y = np.meshgrid(phi_p, phi_m)
         Z = flux_qubit_potential(X, Y).T
         fig = plt.figure(figsize=(14,6))

         # `ax` is a 3D-aware axis instance, because of the projection='3d' keyword
         ax = fig.add_subplot(1, 2, 1, projection='3d')

         p = ax.plot_surface(X, Y, Z, rstride=4, cstride=4, linewidth=0)

         # surface_plot with color grading and color bar
         ax = fig.add_subplot(1, 2, 2, projection='3d')
         p = ax.plot_surface(X, Y, Z, rstride=1, cstride=1, cmap=plt.cm.coolwarm, l
         cb = fig.colorbar(p, shrink=0.5)
```




```
In [76]: pi = np.pi
         fig = plt.figure(figsize=(12,10))

         ax = fig.add_subplot(1,1,1, projection='3d')

         ax.plot_surface(X, Y, Z, rstride=4, cstride=4, alpha=0.25)
         cset = ax.contour(X, Y, Z, zdir='z', offset=-pi, cmap=plt.cm.coolwarm)
         cset = ax.contour(X, Y, Z, zdir='x', offset=-pi, cmap=plt.cm.coolwarm)
```

```
cset = ax.contour(X, Y, Z, zdir='y', offset=3*pi, cmap=plt.cm.coolwarm)

ax.set_xlim3d(-pi, 2*pi);
ax.set_ylim3d(0, 3*pi);
ax.set_zlim3d(-pi, 2*pi);
```

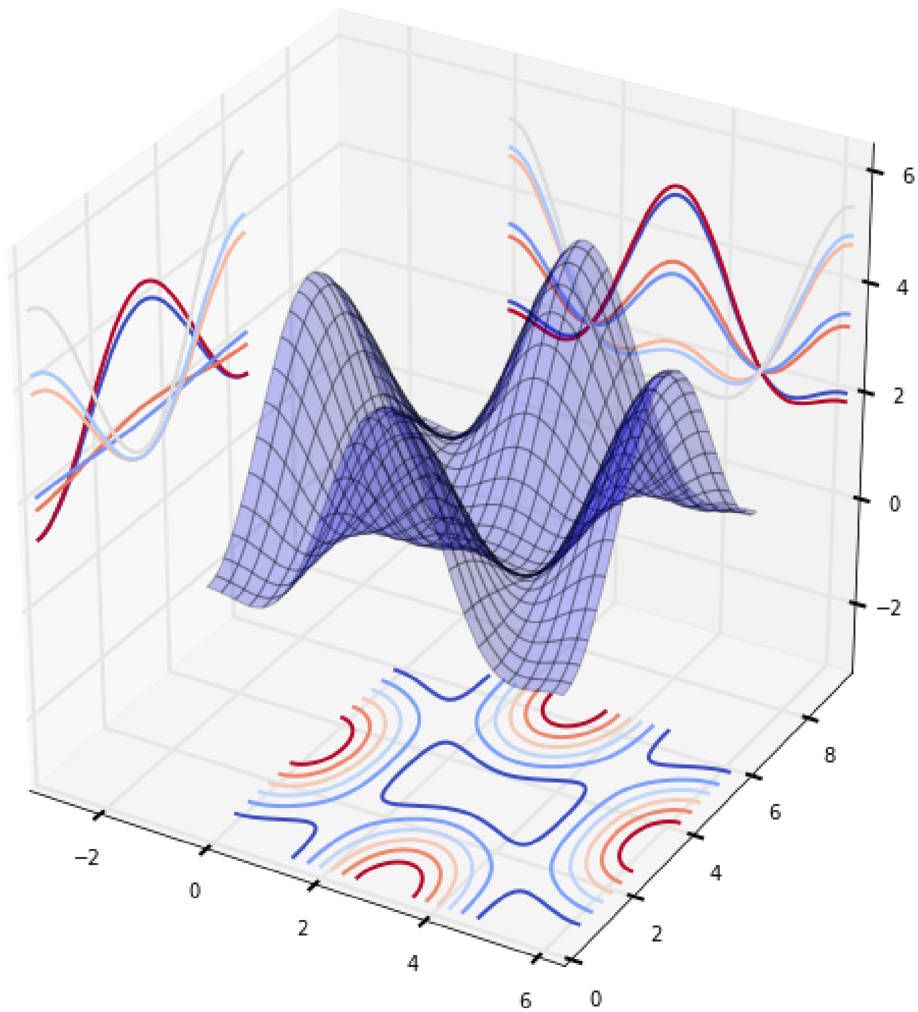



```
In [77]: # Interactive turning the plot
         %matplotlib tk
         fig = plt.figure(figsize=(12,10))

         ax = fig.add_subplot(1,1,1, projection='3d')

         ax.plot_surface(X, Y, Z, rstride=4, cstride=4, alpha=0.25)
         cset = ax.contour(X, Y, Z, zdir='z', offset=-pi, cmap=plt.cm.coolwarm)
         cset = ax.contour(X, Y, Z, zdir='x', offset=-pi, cmap=plt.cm.coolwarm)
         cset = ax.contour(X, Y, Z, zdir='y', offset=3*pi, cmap=plt.cm.coolwarm)

         ax.set_xlim3d(-pi, 2*pi);
```

```
ax.set_ylim3d(0, 3*pi);
ax.set_zlim3d(-pi, 2*pi);
```

Saving plots

```
In [78]: %matplotlib inline
         fig = plt.figure()

         ax = fig.add_subplot(1,1,1, projection='3d')

         ax.plot_surface(X, Y, Z, rstride=4, cstride=4, alpha=0.25)
         cset = ax.contour(X, Y, Z, zdir='z', offset=-pi, cmap=plt.cm.coolwarm)
         cset = ax.contour(X, Y, Z, zdir='x', offset=-pi, cmap=plt.cm.coolwarm)
         cset = ax.contour(X, Y, Z, zdir='y', offset=3*pi, cmap=plt.cm.coolwarm)

         ax.set_xlim3d(-pi, 2*pi);
         ax.set_ylim3d(0, 3*pi);
         ax.set_zlim3d(-pi, 2*pi);
         fig.set_size_inches(10,10)
         fig.savefig('Fig1.pdf')
```




```
In [79]: ls *pdf

BPT1.pdf                  OOP.pdf                   intro_Python_2.pdf
Calling Fortran.pdf       Optimization.pdf          intro_Python_3.pdf
Fig1.pdf                  Useful_libraries.pdf      intro_Scipy.pdf
Interact with files.pdf   Using_PyMySQL.pdf         intro_numpy.pdf
Intro_1.pdf               intro_Matplotlib.pdf      test1.pdf
MySQL.pdf                 intro_Python.pdf
```

Other tutorials: http://matplotlib.org/mpl_toolkits/mplot3d/tutorial.html

Access and clear the current figure and axe

```
In [80]: fig, ax = plt.subplots()
         print plt.gca() is ax # You can get the  current axes with gca
         print plt.gcf() is fig # The same for the current axes.
         # But it's preferable to store them in a variable when creating
         plt.clf() # clear the current figure
         plt.cla() # clear the current axes
         fig.clf() # clear a given figure
         ax.cla() # clear a given axes

True
True


<matplotlib.figure.Figure at 0x1204bbed0>
```

What's happen when not in a Notebook? plt.show() and plt.ion() commands We are here in a Notebook, but most of the time, you will execute programs from a script or using the command line in a terminal.

When using plot, scatter or any other plotting tool, the figure will not appear when typing the command, you need to send the *plt.show()* command to pop-up it (or them if you did more than one figure). And you will loose the interactivity with the command line! You will recover it once the figure windows are closed.

The way to change this behaviour is to call the *plt.ion()* command (interactive On).

If you are working within an ipython session created with the –pylab option, it is done by default.