intro_Matplotlib

November 25, 2015

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

```
Mon Nov  2 14:56:44 2015
```

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

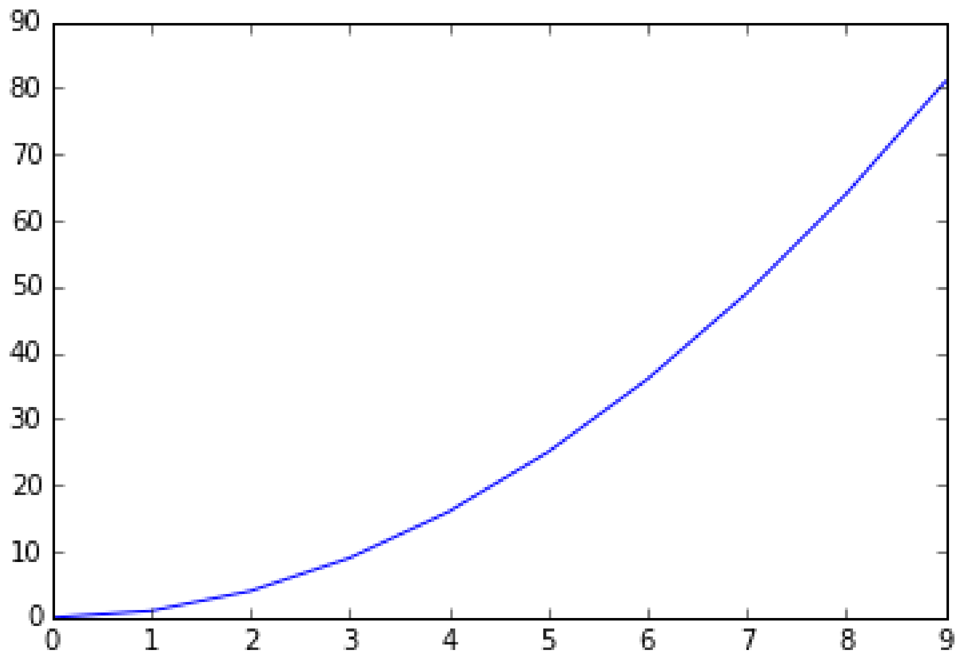
1 D: How to make plots, images, 3D, etc, using Matplotlib

```
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
```

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

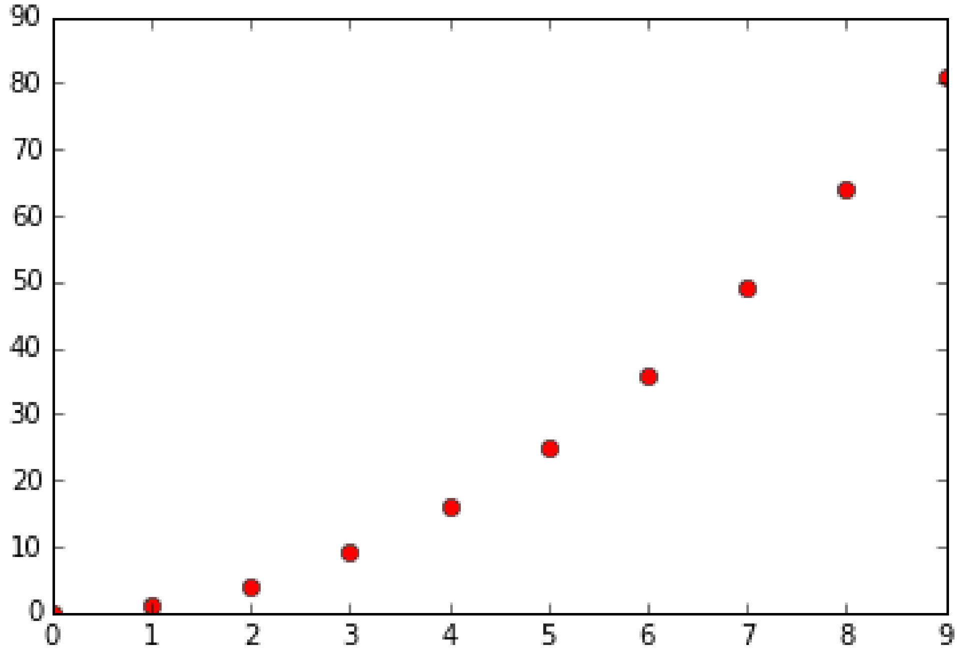
Simple plot In the following cell, we plot a function

```
In [7]: # 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 line -> ;
```

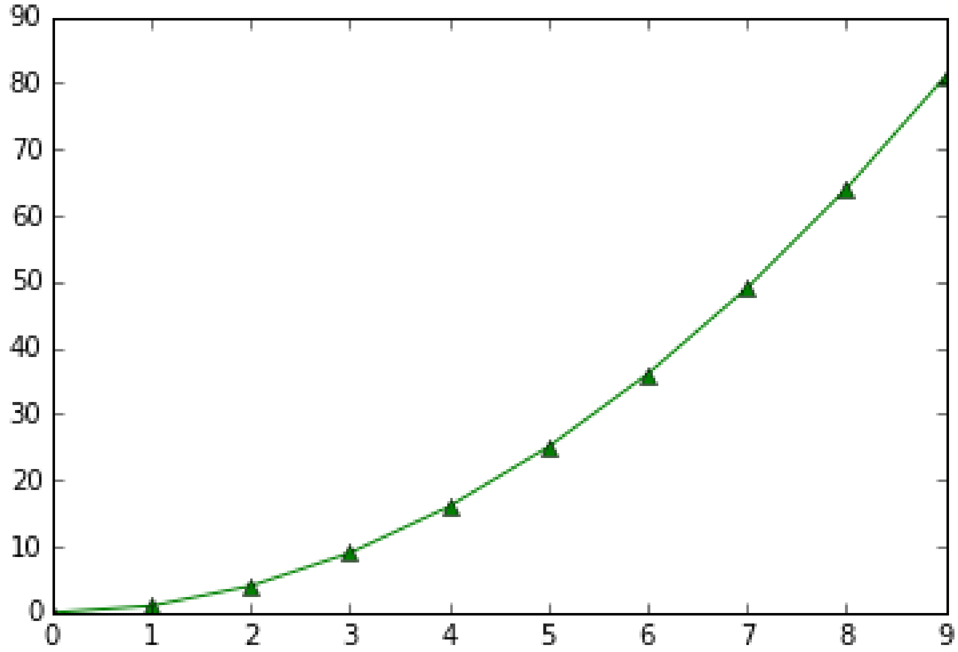


Controling colors and symbols

```
In [9]: plt.plot(x, x**2, 'or');
```



```
In [10]: plt.plot(x, x**2, c='green', marker='^');
```



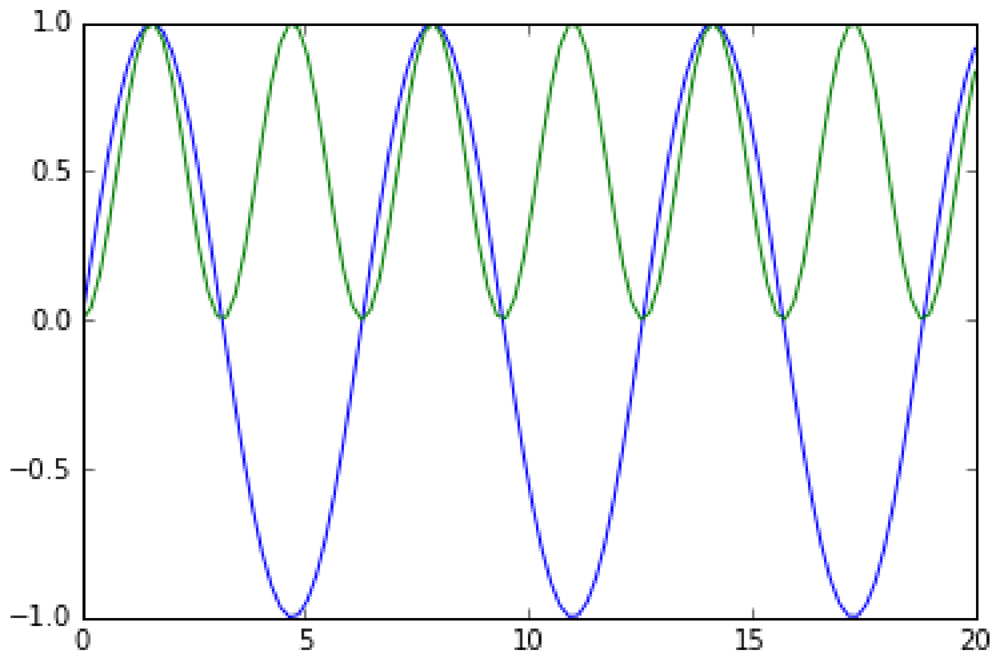
In [12]:
```
# To illustrate the possibilities of the interactive window:
%matplotlib tk
plt.plot(x, x**2, '*b', linestyle='-') ;
```

Out[12]:
```
[<matplotlib.lines.Line2D at 0x1091ab590>]
```

In [13]:
```
# Back to the inline graphics mode
%matplotlib inline
```

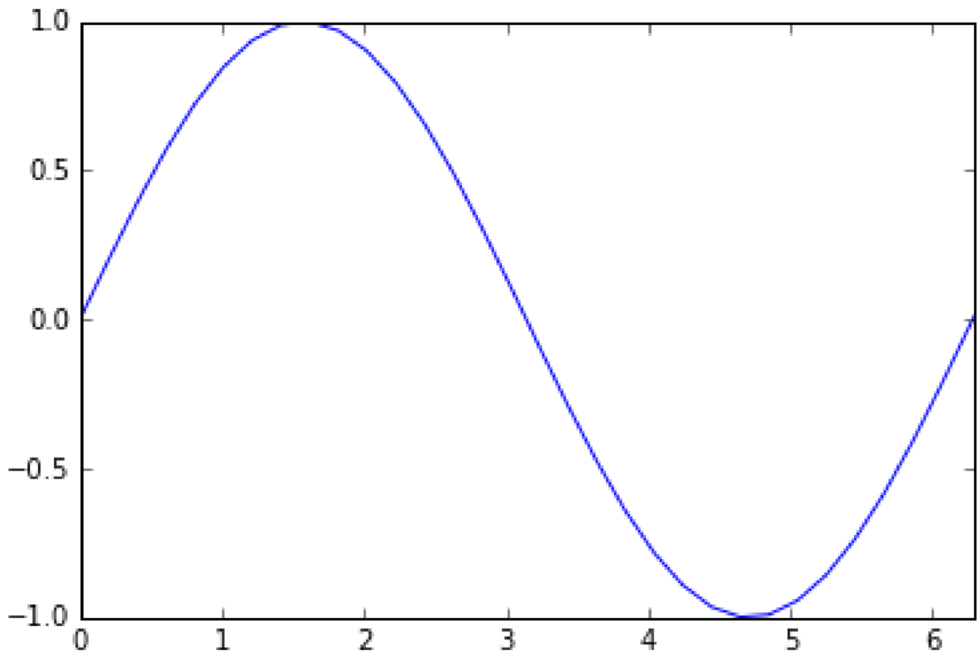
Overplot

In [14]:
```
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;
```



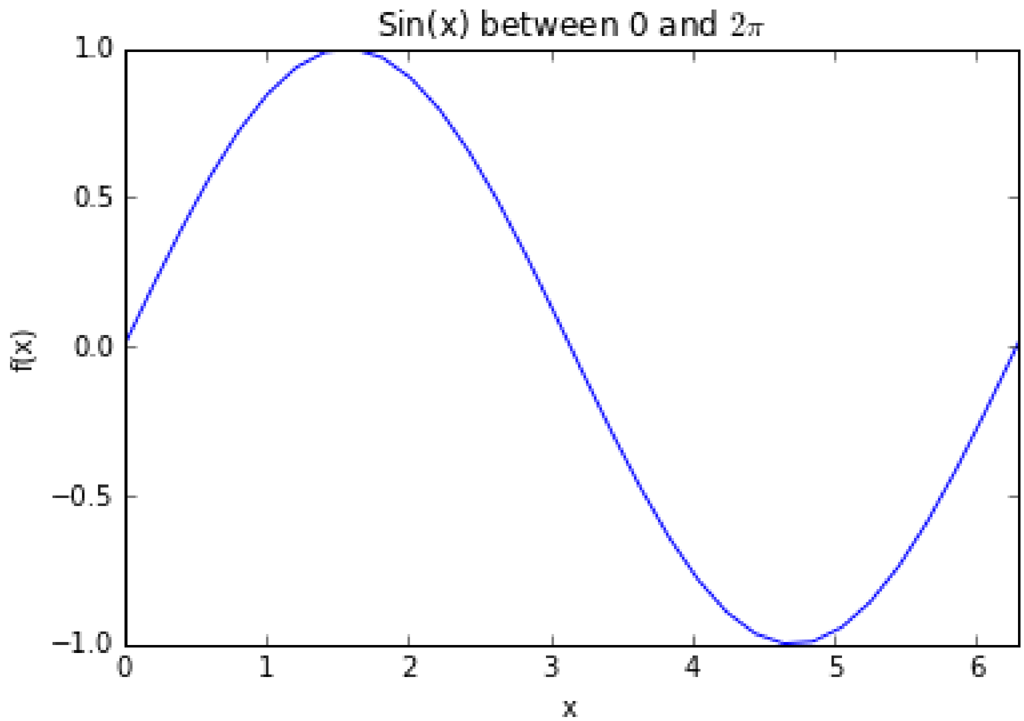
Fixing axes limits

In [17]:
```
plt.plot(x, y)
plt.xlim(0., np.pi*2) # Take car, it's NOT plt.xlim = (1, 2), this would ERASE the xlim method
```



Labels, titles

```
In [22]: 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 [23]: 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.

    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 color specified by a 'color cycle'. To change this behavior, you can edit the axes.color_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, antialised=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.

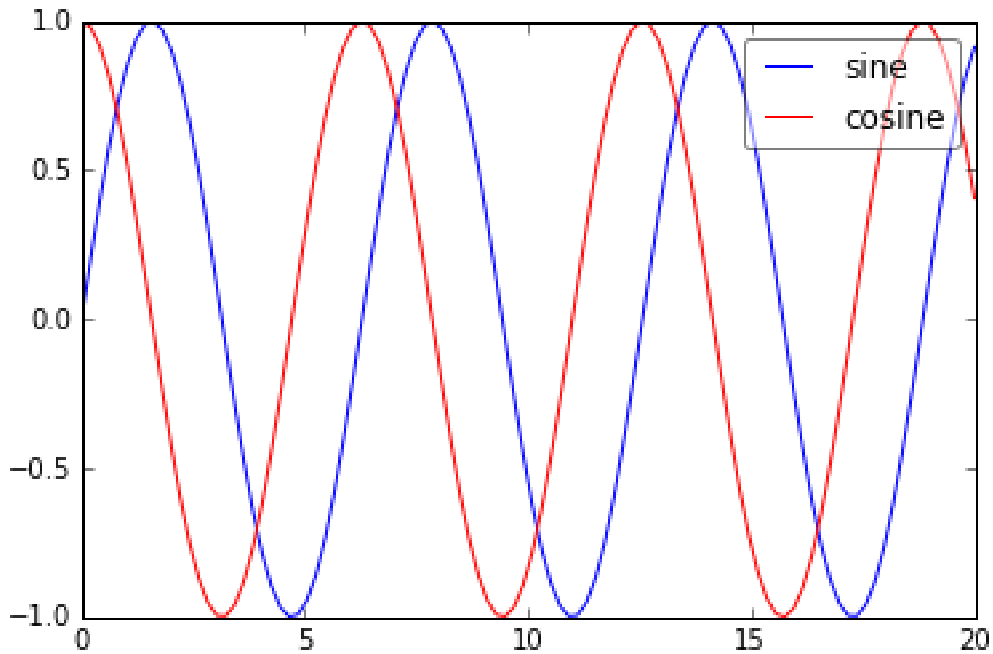
The kwargs are :class:`~matplotlib.lines.Line2D` properties:

```
  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.Transform`) |
  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: [``'-'`` | ``'--'`` | ``'-.'`` | ``':'`` | ``'None'`` |                    `` ' '
      linewidth or lw: float value in points
      lod: [True | False]
      marker: unknown
      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: unknown
      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*.



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

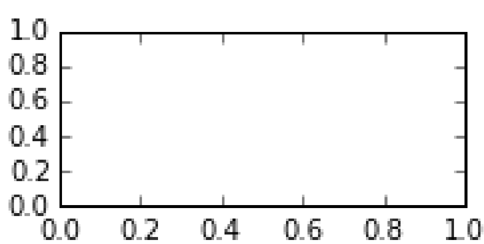
Legends

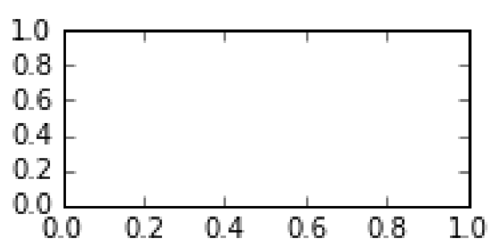
In [26]:
```python
x = np.linspace(0, 20, 100)
y1 = np.sin(x)
y2 = np.cos(x)

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));
```



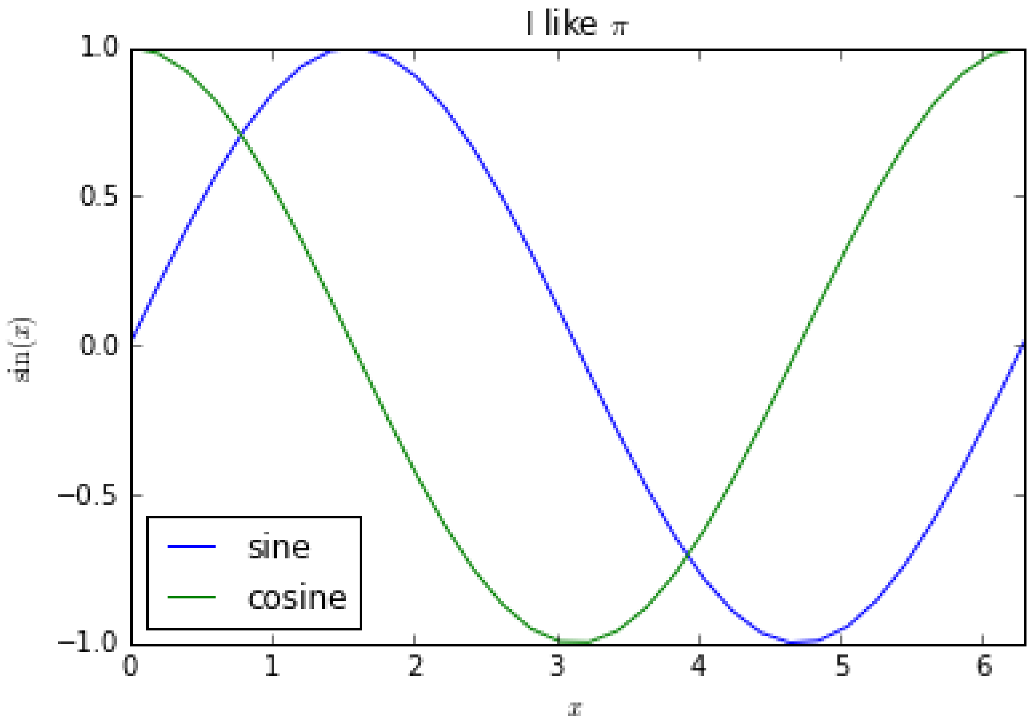
Object oriented way

```
In [30]: 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()
```





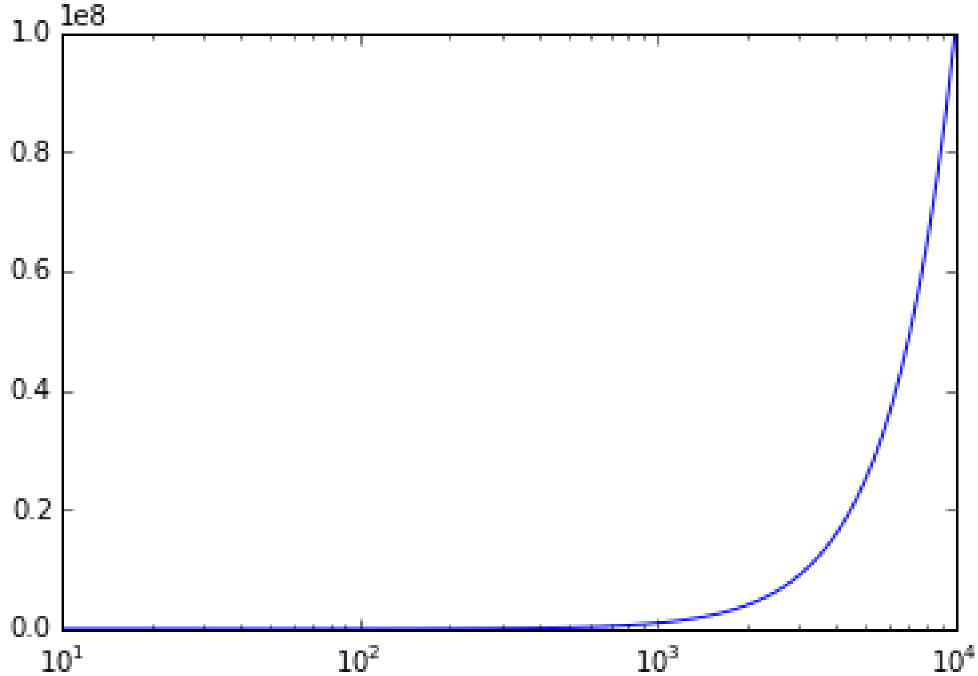
```
In [33]: fig, ax = plt.subplots()  # one command way
         ax.plot(x, y1)
         ax.plot(x, y2)
         ax.set_xlim(0., 2*np.pi)
         ax.legend(['sine', 'cosine'], loc='best') # If the legends are not already defined in the plot
         ax.set_xlabel("$x$")
         ax.set_ylabel("$\sin(x)$")
         ax.set_title("I like $\pi$");
```



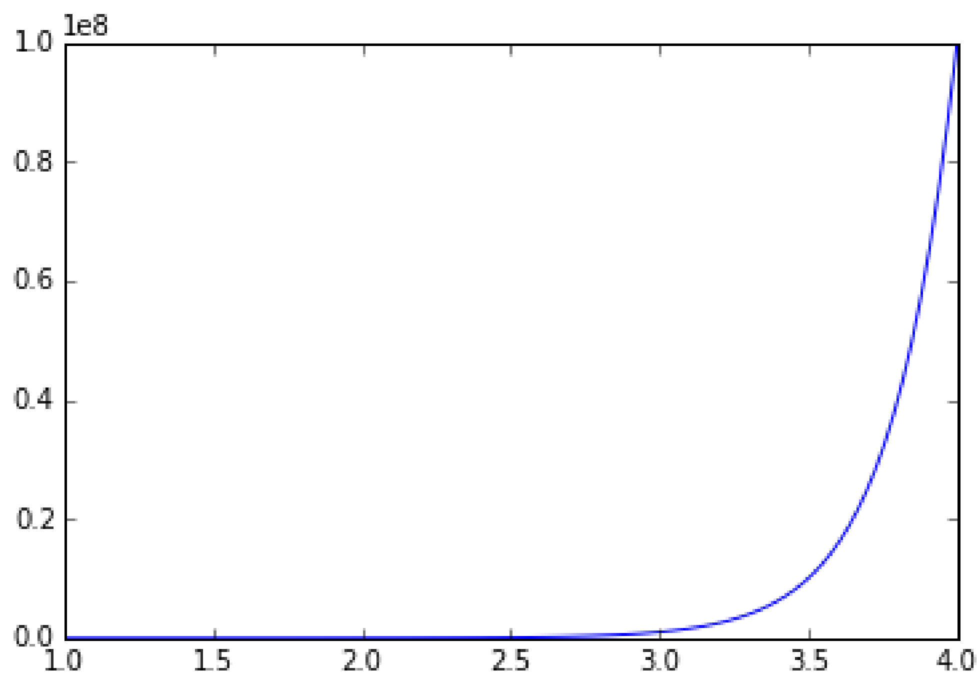

```
In [15]: # The following outputs a HUGE quantity of information! I comment it for now
         #help(ax)
```

log plots

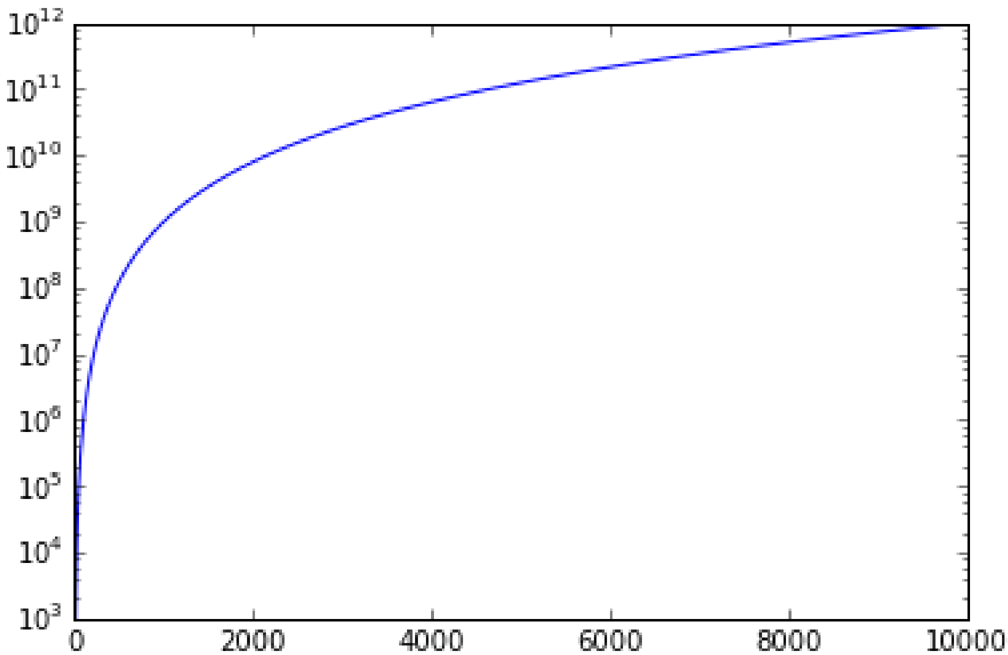
```
In [32]: xl = np.logspace(1, 4, 100)
         fig, ax = plt.subplots()
         ax.semilogx(xl, xl**2);
```



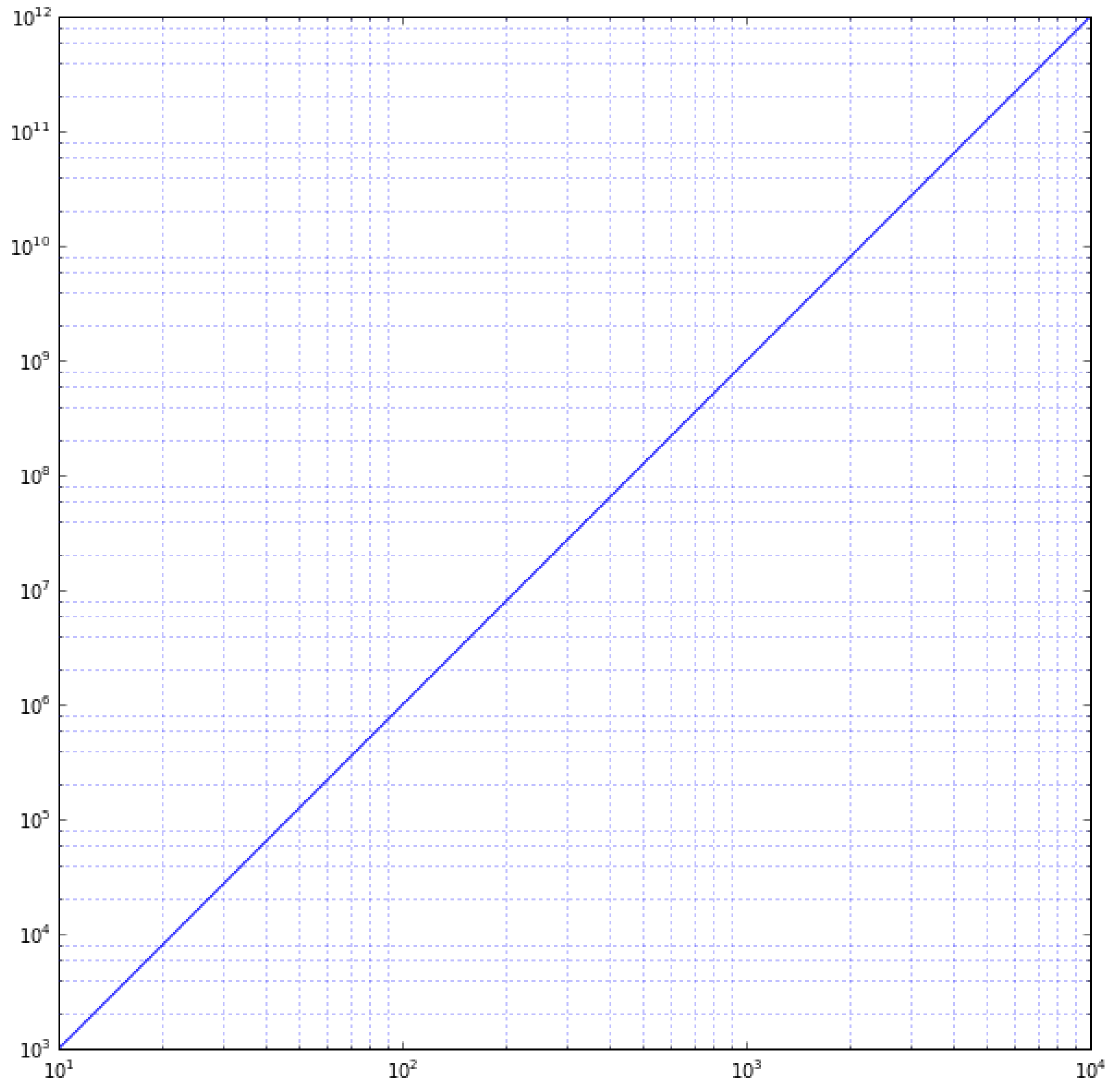

```
In [34]: xl = np.logspace(1, 4, 100)
         fig, ax = plt.subplots()
         ax.plot(np.log10(xl), xl**2);
```



In [35]:
```
fig, ax = plt.subplots()
ax.semilogy(xl, xl**3);
```

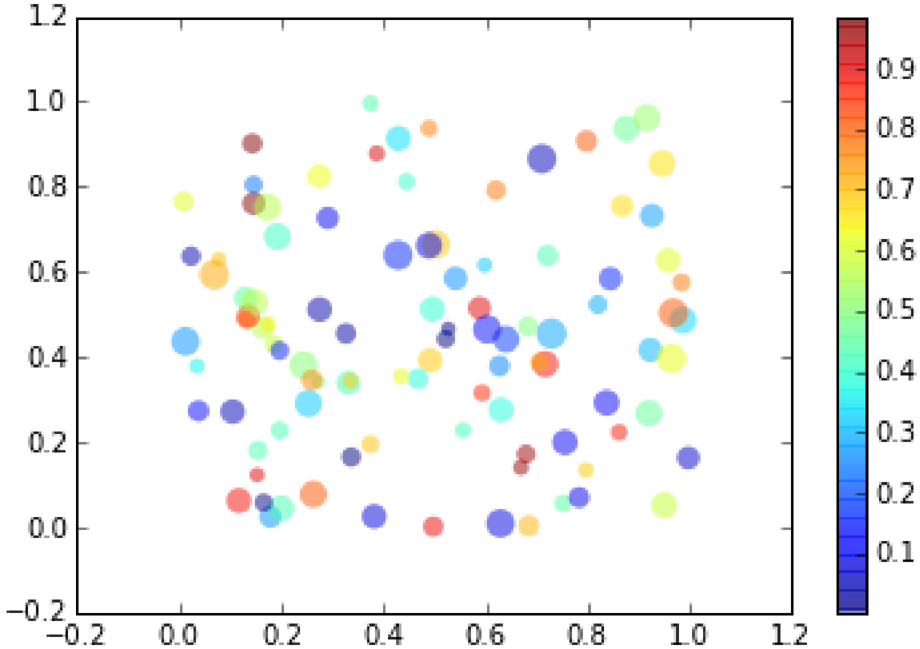


In [39]:
```
fig, ax = plt.subplots(figsize=(10,10))
ax.loglog(xl, xl**3);
ax.grid(which="both",ls=":", c='blue')
```

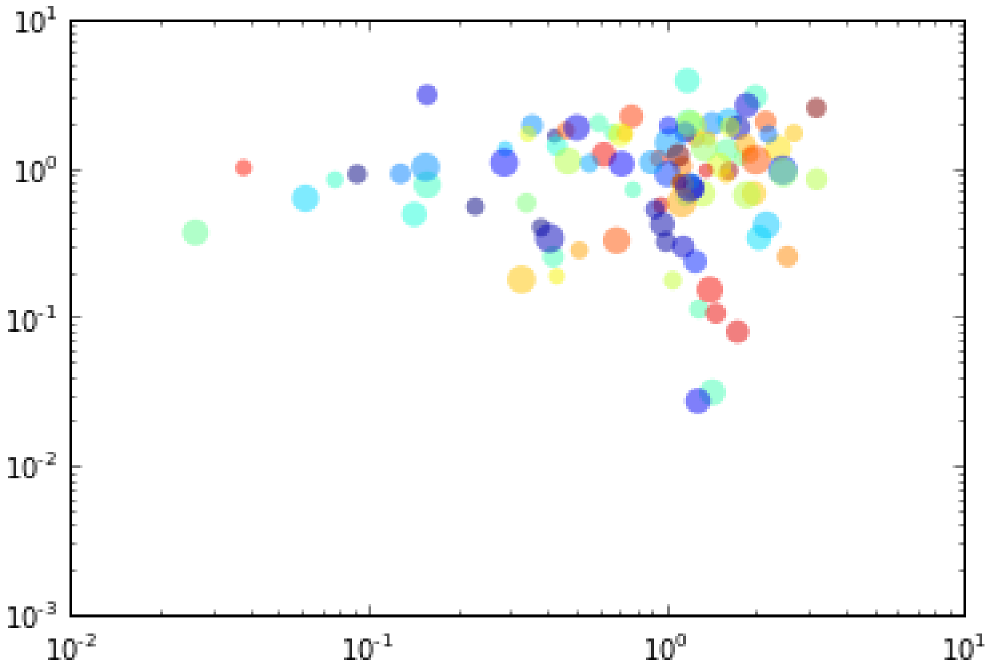


Scatter

```
In [40]: 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); # Sizes and colors de
         fig.colorbar(sc);
```



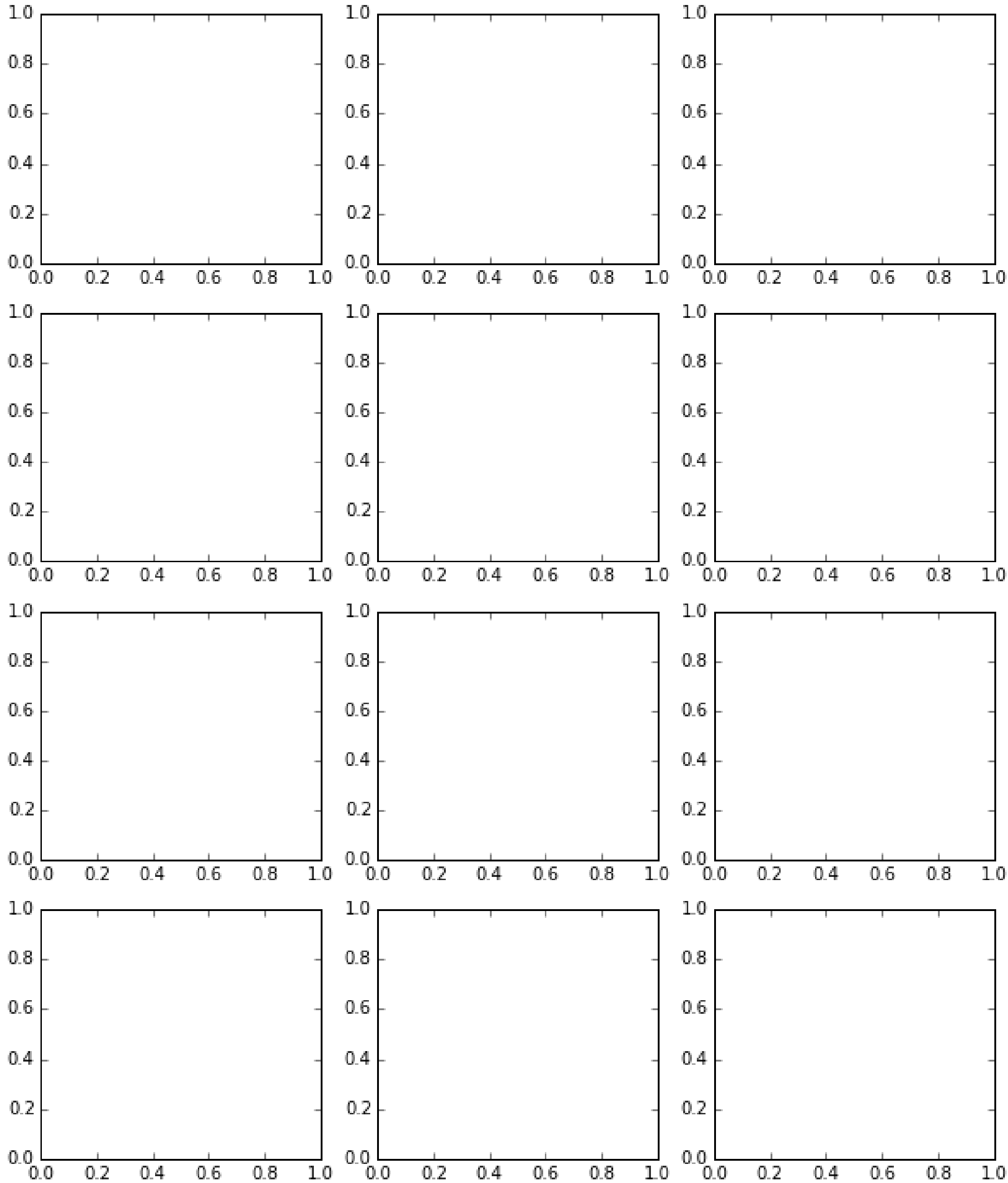
In [46]:
```
# log axes can be defined after the plot
xr = np.abs(1 + np.random.randn(100))
yr = np.abs(1 + np.random.randn(100))
fig, ax = plt.subplots()
sc = ax.scatter(xr, yr, c=cr, s=30+sr*100, edgecolor='none', alpha=0.5); # Sizes and colors de
ax.set_xscale('log')
ax.set_yscale('log')
```



multiple plots

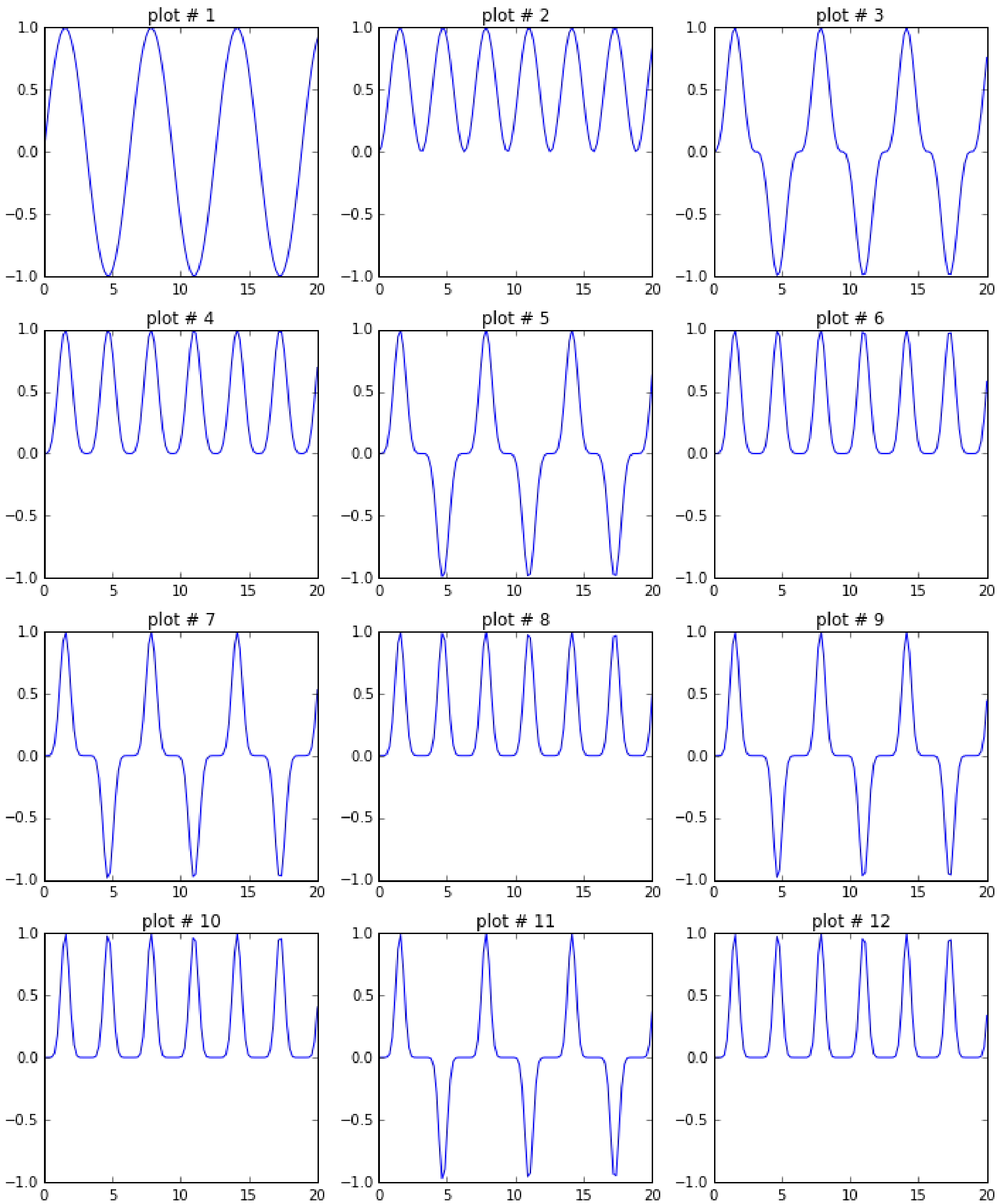
```
In [49]: fig, axes = plt.subplots(4, 3, figsize=(10,12))
         print axes.shape
```

```
(4, 3)
```

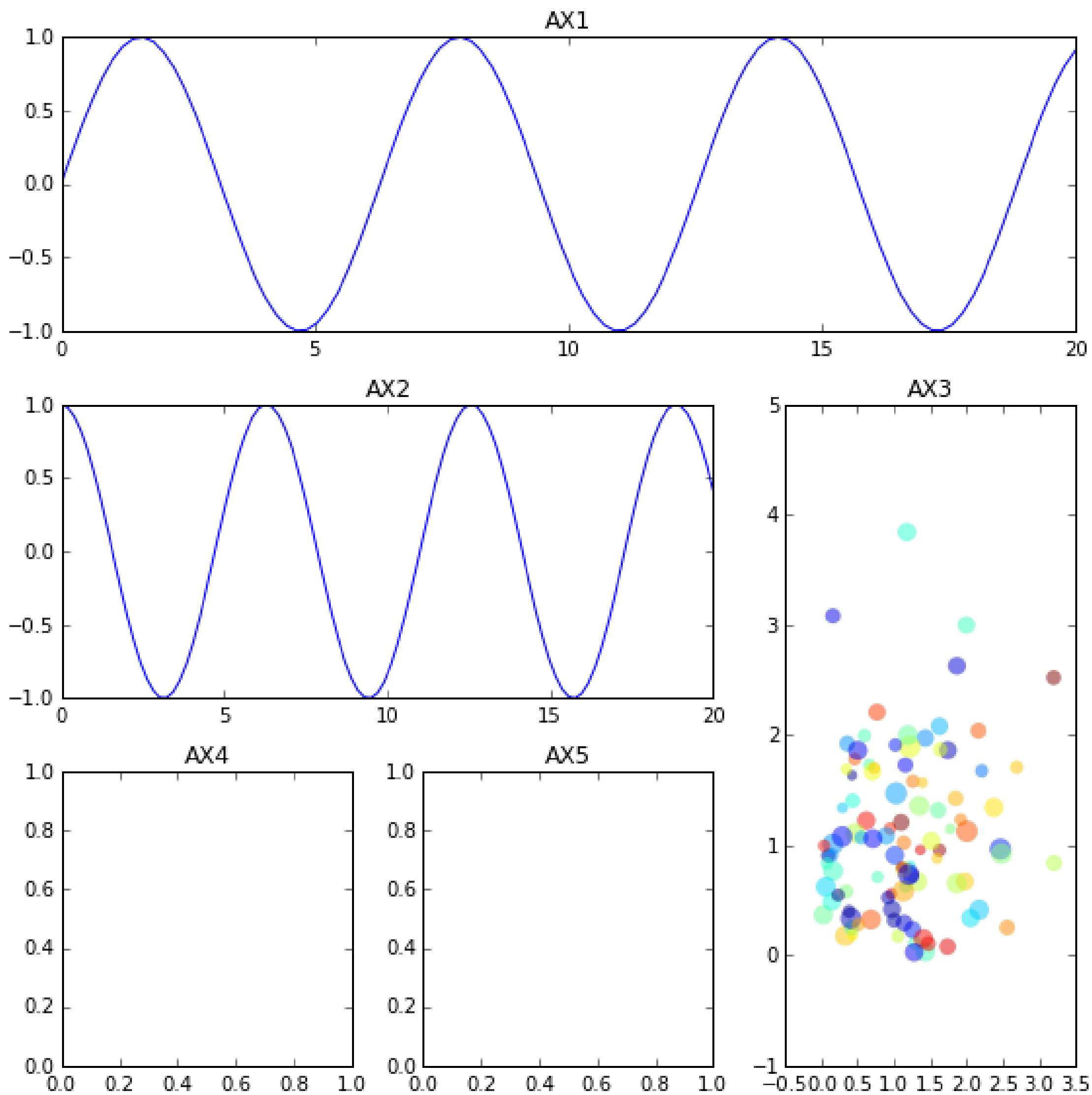


```
In [54]: fig, axes = plt.subplots(4, 3, figsize=(10,12))
         for i, ax in enumerate(axes.ravel()): # axes is a 2D array.. Need to ravel it to run over ever
             ax.set_title('plot # {}'.format(i+1))
             ax.plot(x, y1**(i+1))
             ax.set_ylim((-1, 1))
         fig.tight_layout() # Better output
```

```
<class 'matplotlib.axes._subplots.AxesSubplot'>
```

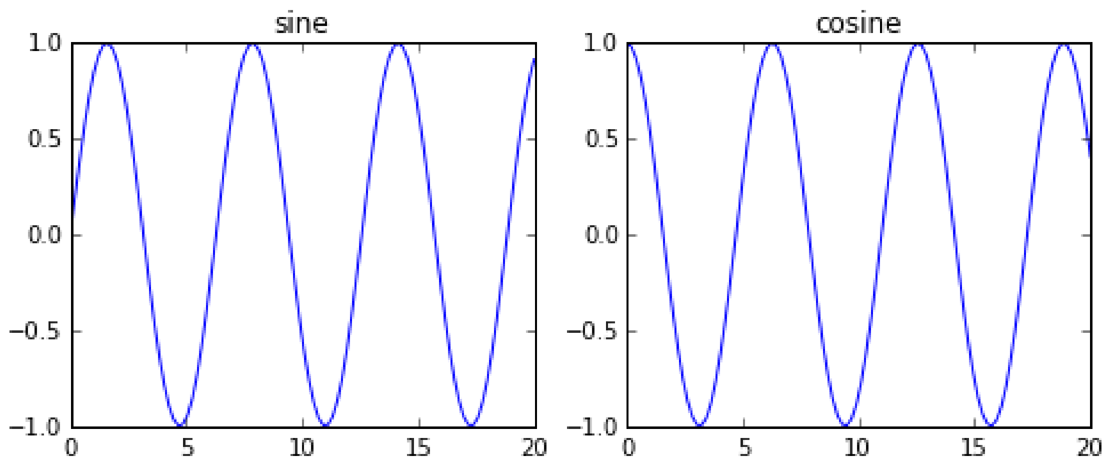


```
In [57]: fig = plt.figure(figsize=(8, 8))
         gs = plt.GridSpec(3, 3)
         ax1 = fig.add_subplot(gs[0, :])
         ax2 = fig.add_subplot(gs[1, :2])
         ax3 = fig.add_subplot(gs[1:, 2])
         ax4 = fig.add_subplot(gs[2, 0])
         ax5 = fig.add_subplot(gs[2, 1])
         ax1.plot(x, 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...
```

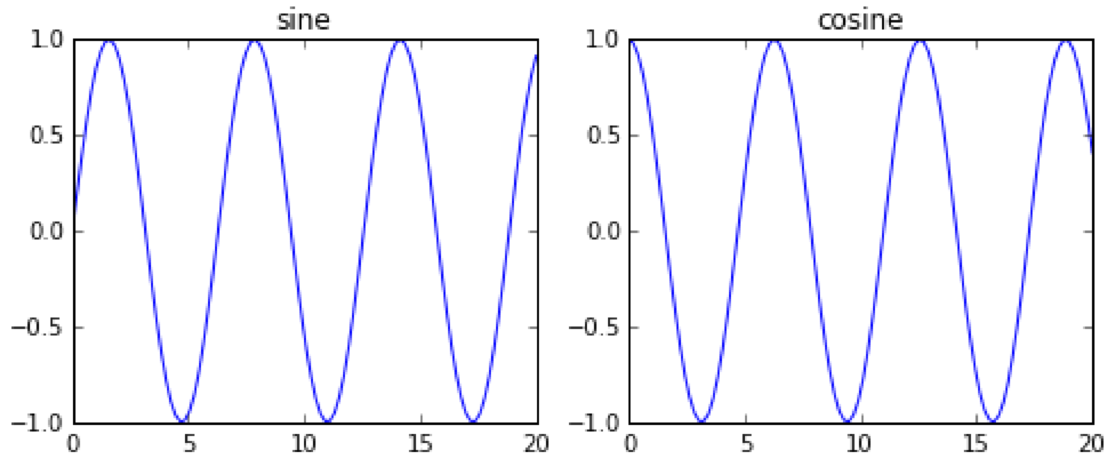


Order of the commands

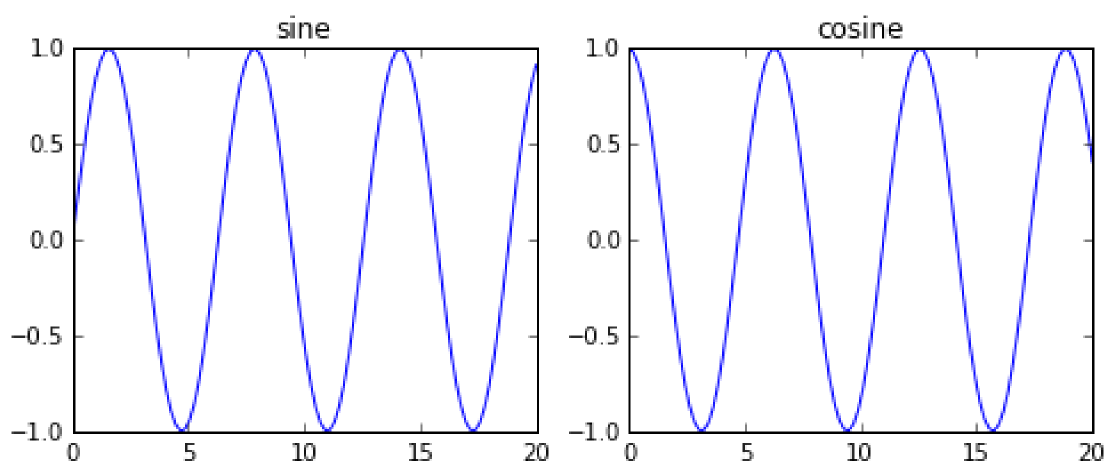
```
In [58]: fig1 = plt.figure(figsize=(8, 3))
         ax1 = fig1.add_subplot(1, 2, 1)
         ax1.plot(x, np.sin(x))
         ax1.set_title('sine')

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




```
In [59]: 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 plotting
         ax2.set_title('cosine') # They both are objects containing method to apply on them;
```

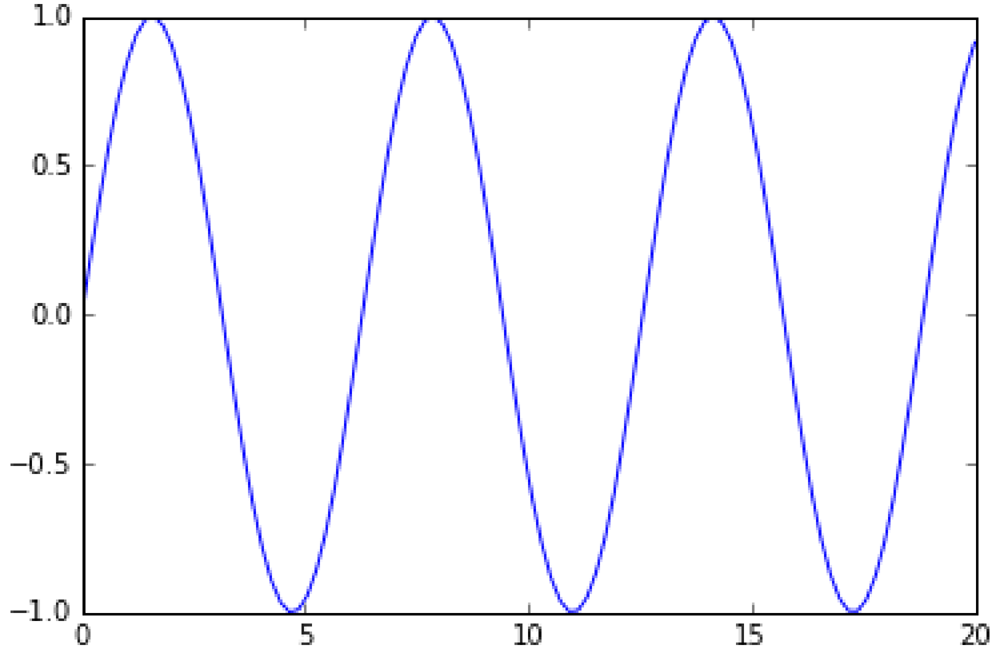



```
In [60]: fig1, (ax1, ax2) = plt.subplots(1, 2, figsize=(8, 3))

         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 plotting
         ax2.set_title('cosine') # They both are objects containing method to apply on them;
```

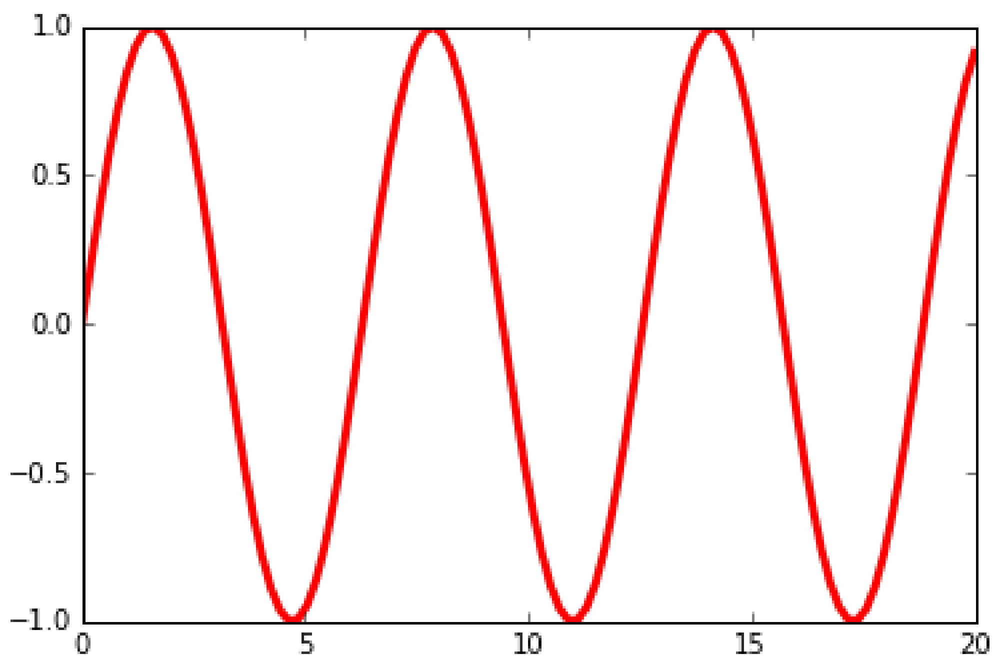


Everything is object

```
In [61]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         print type(lines)
         print(len(lines))

<type 'list'>
1
```

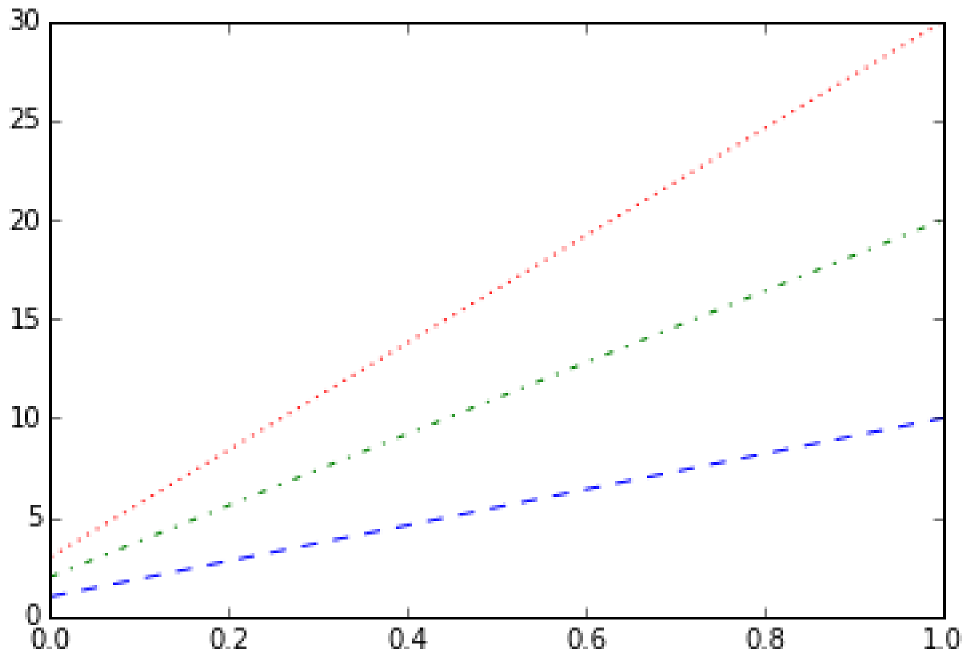



```
In [63]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         line = lines[0]
         #help(line) # HUGE quantity of information
         line.set_color('red')
         line.set_linewidth(3)
         fig.canvas.draw() # this is not necessary in notebook, but in scripts it is.
```

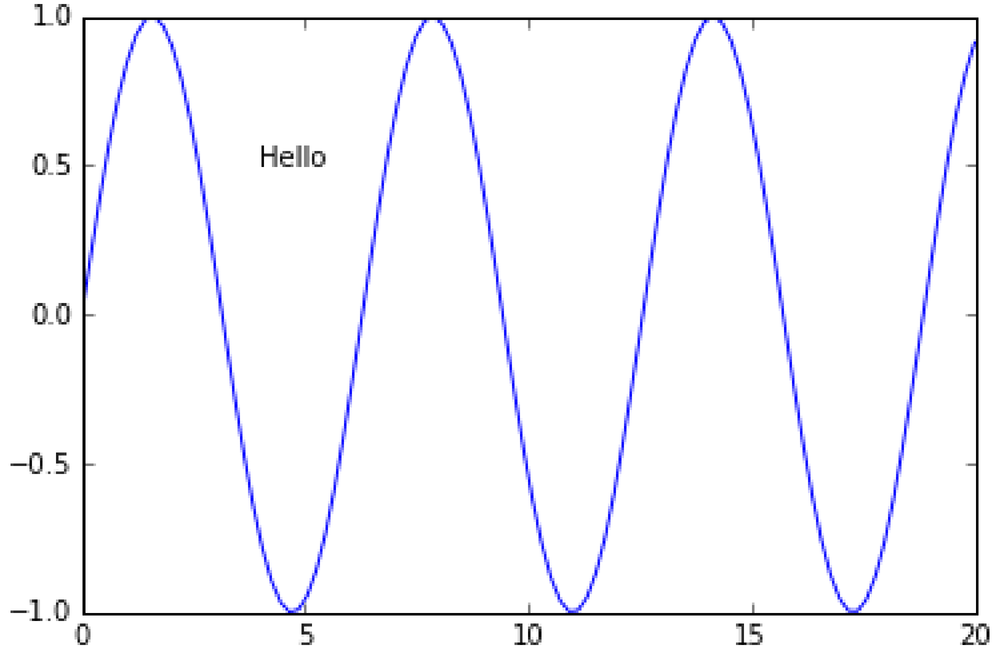


```
In [66]: fig, ax = plt.subplots()
         lines = ax.plot([[1,2,3],[10,20,30]])
         print lines

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

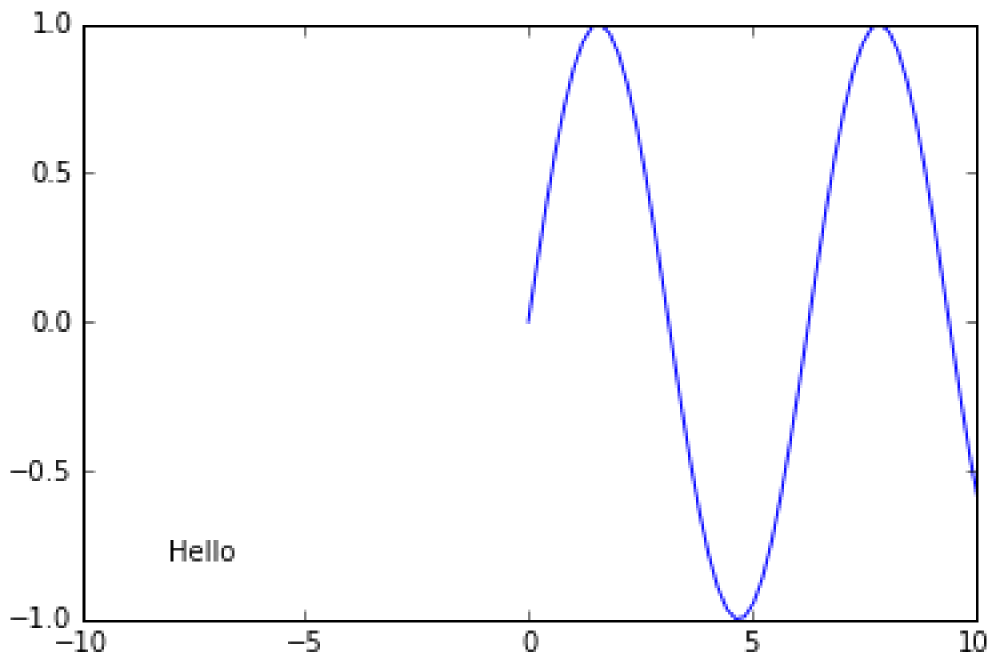
```
[<matplotlib.lines.Line2D object at 0x117f959d0>, <matplotlib.lines.Line2D object at 0x10912b6d0>, <matp
```



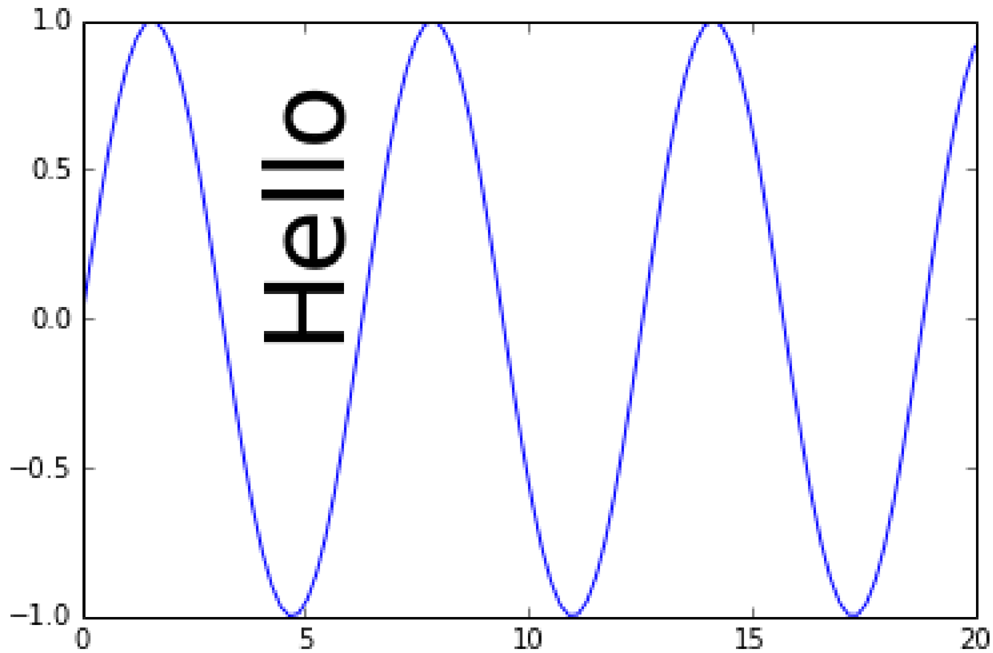

```
In [67]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         ax.text(4, 0.5, "Hello");
```



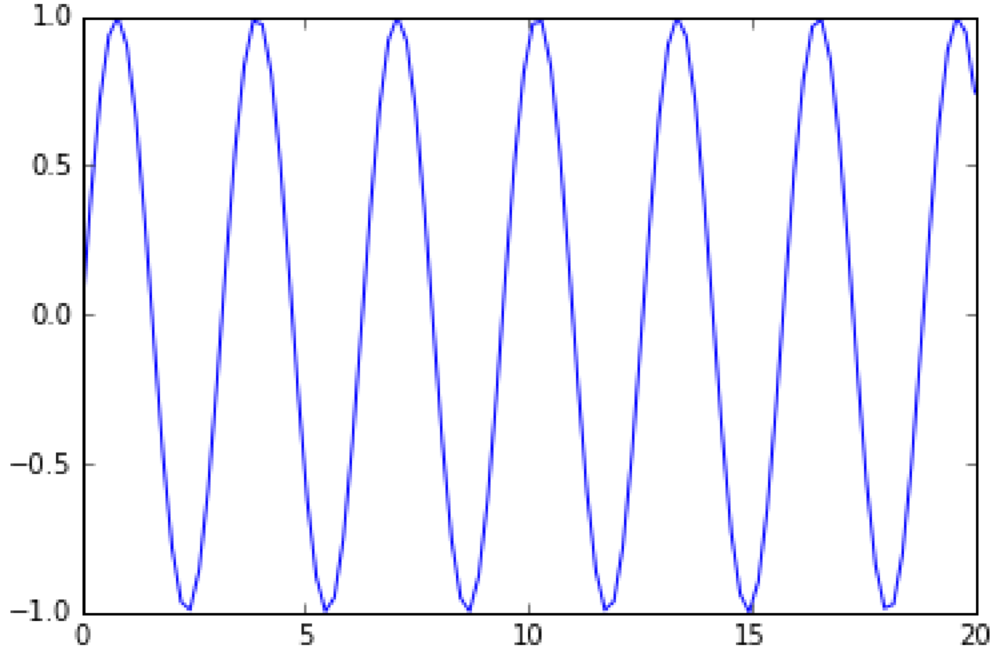

```
In [69]: fig, ax = plt.subplots()
         lines = ax.plot(x, np.sin(x))
         ax.set_xlim(-10,10)
         ax.text(0.1, 0.1, "Hello", transform=ax.transAxes);
```



In [32]:
```
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)
```



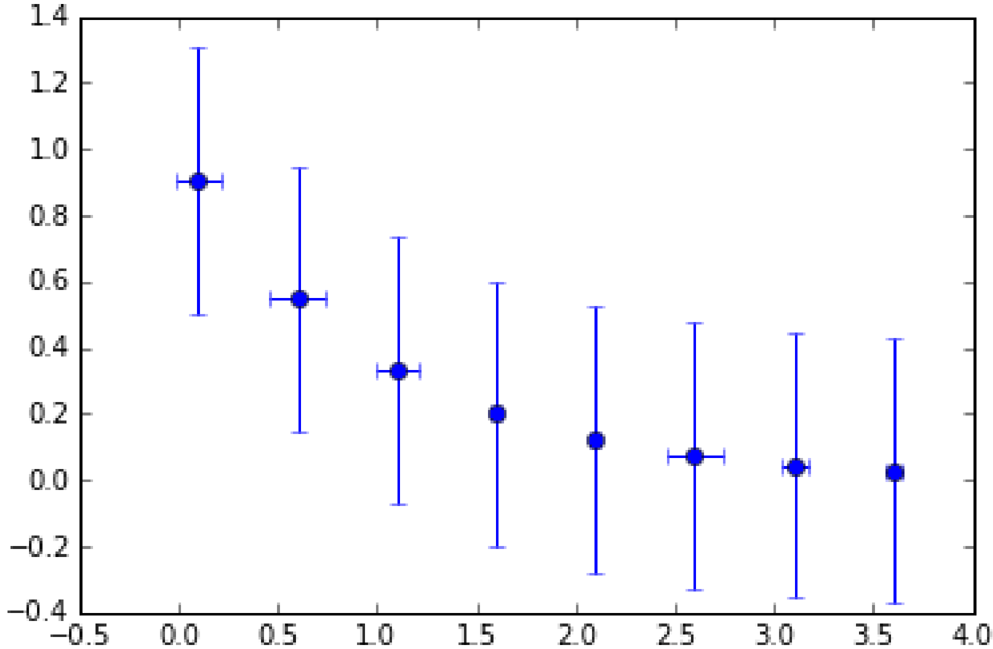
In [70]:
```
fig, ax = plt.subplots()
lines = ax.plot(x, np.sin(x))
lines[0].set_ydata(np.sin(2 * x)) # Change the data themselve!!!
```



Error bars

```
In [76]: 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 [77]:
```
%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 [78]:
```
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)
```

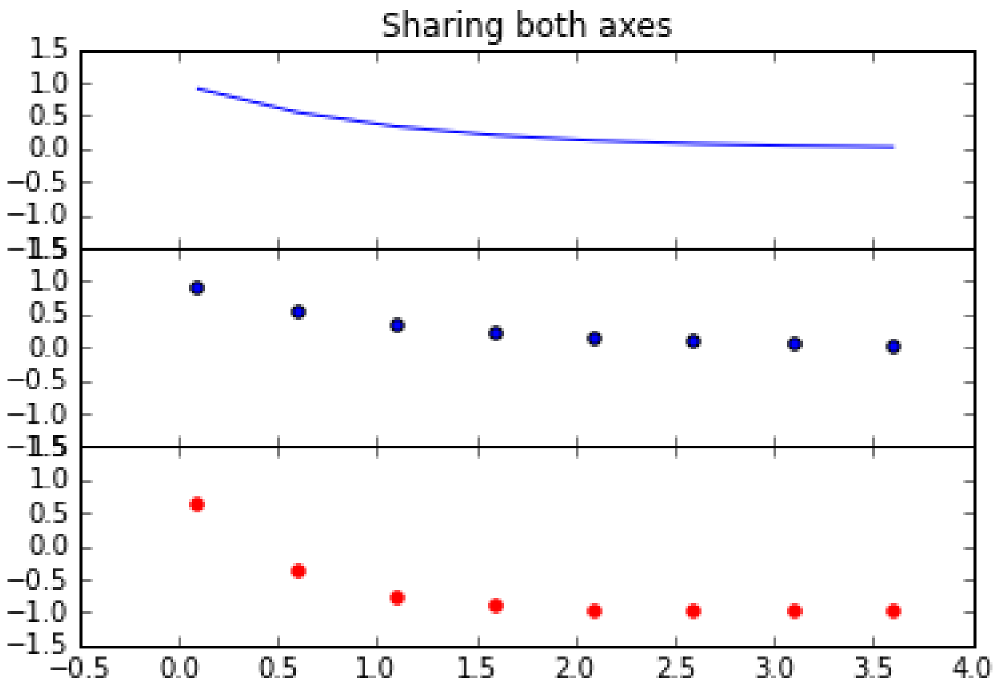
Out[78]:
```
<matplotlib.collections.PathCollection at 0x115d20190>
```

In [82]:
```
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 [83]:
```
%matplotlib inline
```

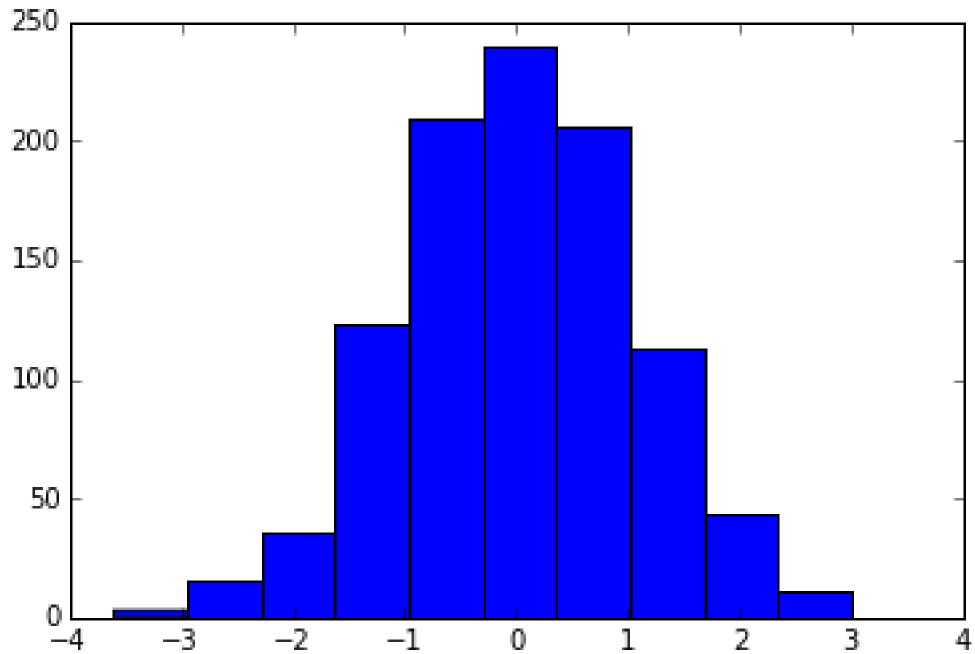
In [85]:
```
fig, (ax1, ax2, ax3) = plt.subplots(3, sharex=True, sharey=True)
ax1.plot(x, y)
ax1.set_title('Sharing both axes')
ax2.scatter(x, y)
```

```
ax3.scatter(x, 2 * y ** 2 - 1, color='r')
# Fine-tune figure; make subplots close to each other
fig.subplots_adjust(hspace=0)
```

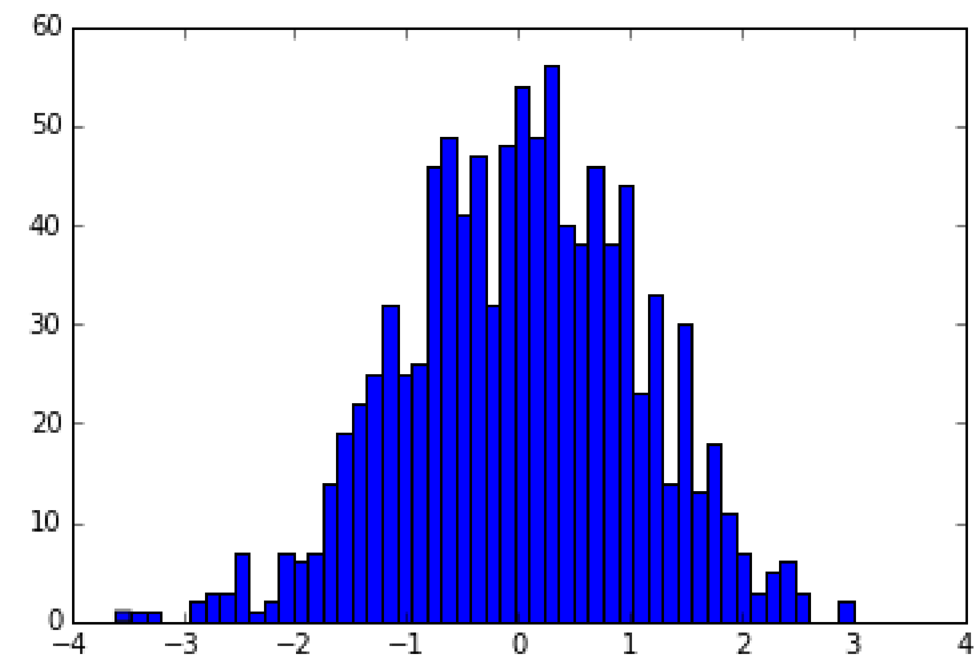


Histograms

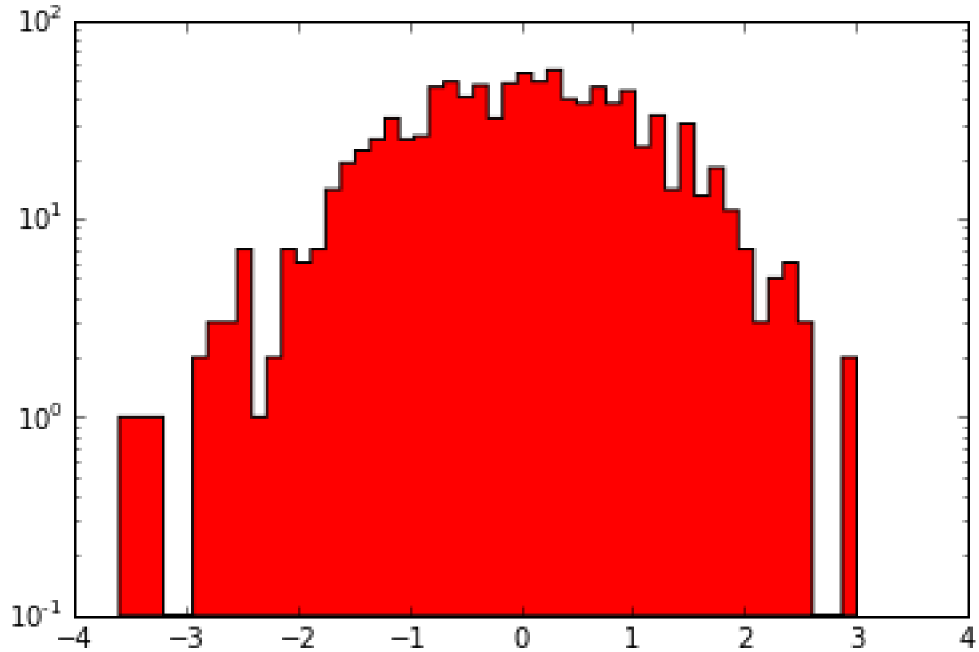
```
In [86]: x = np.random.normal(size=1000)
         fig, ax = plt.subplots()
         H = ax.hist(x)
```



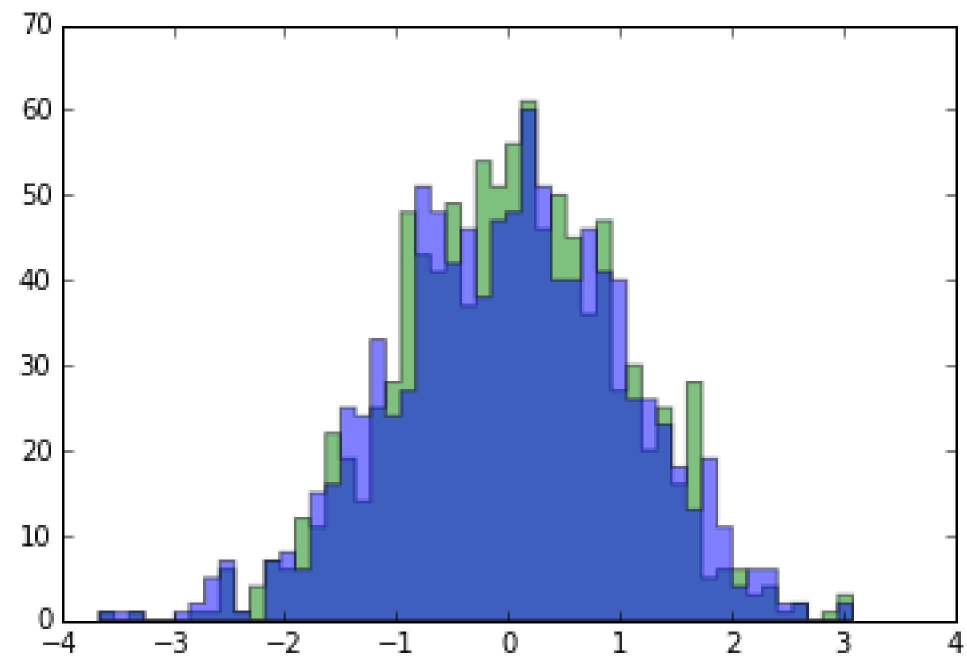
```
In [87]: fig, ax = plt.subplots()
         H = ax.hist(x, bins=50)
```



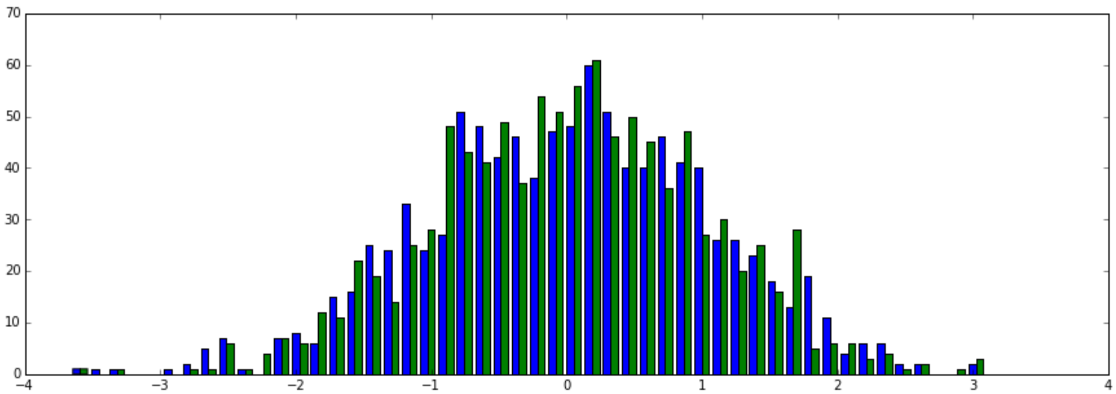
```
In [89]: fig, ax = plt.subplots()
         H = ax.hist(x, bins=50, histtype='stepfilled', log=True, color='r')
```



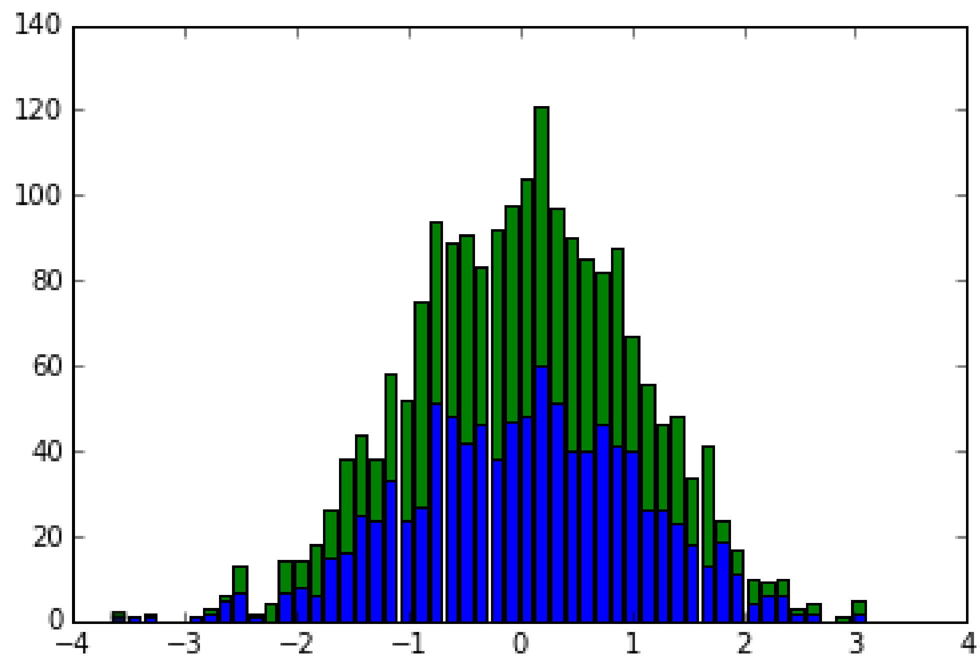
In [90]:
```
x2 = np.random.normal(size=1000)
fig, ax = plt.subplots()
H = ax.hist((x, x2), bins=50, alpha=0.5, histtype='stepfilled')
```



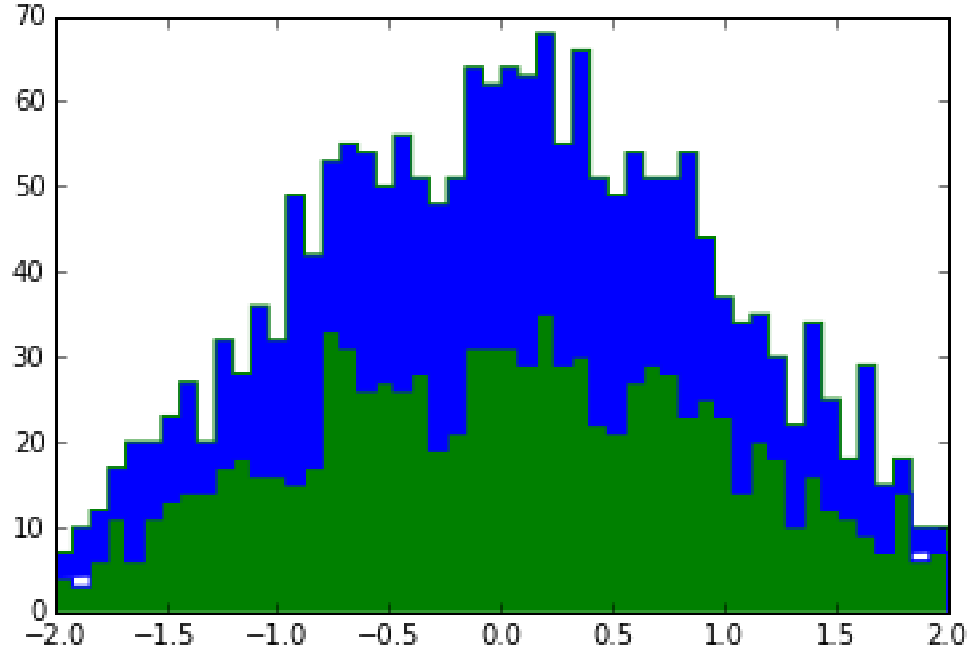
```
In [91]: fig, ax = plt.subplots(figsize=(15,5))
         H = ax.hist((x, x2), bins=50, histtype='bar')
```



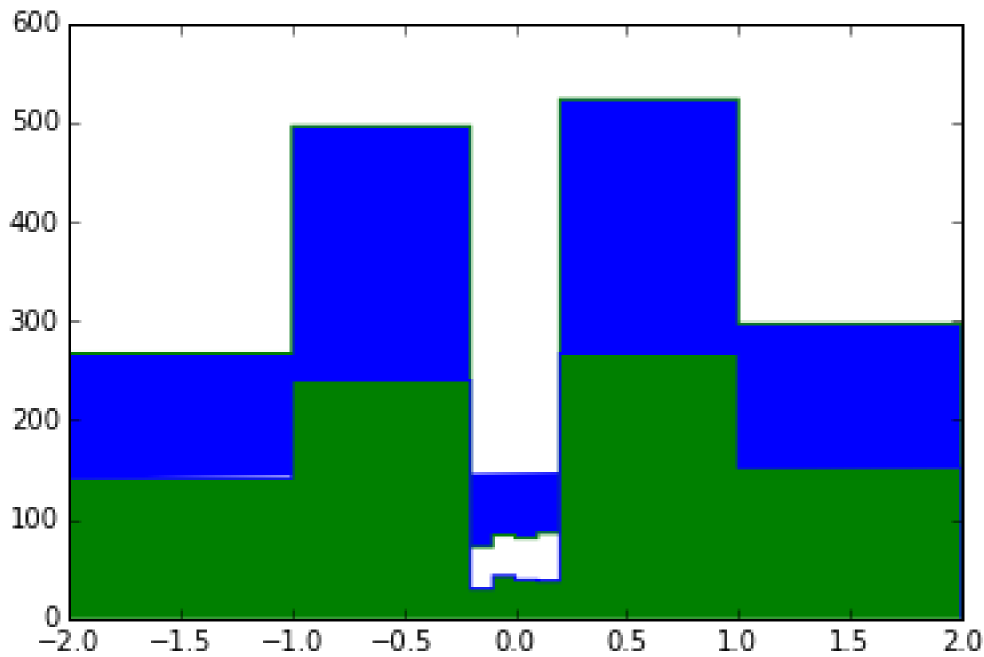

```
In [92]: fig, ax = plt.subplots()
         H = ax.hist((x, x2), bins=50, histtype='bar', stacked=True)
```



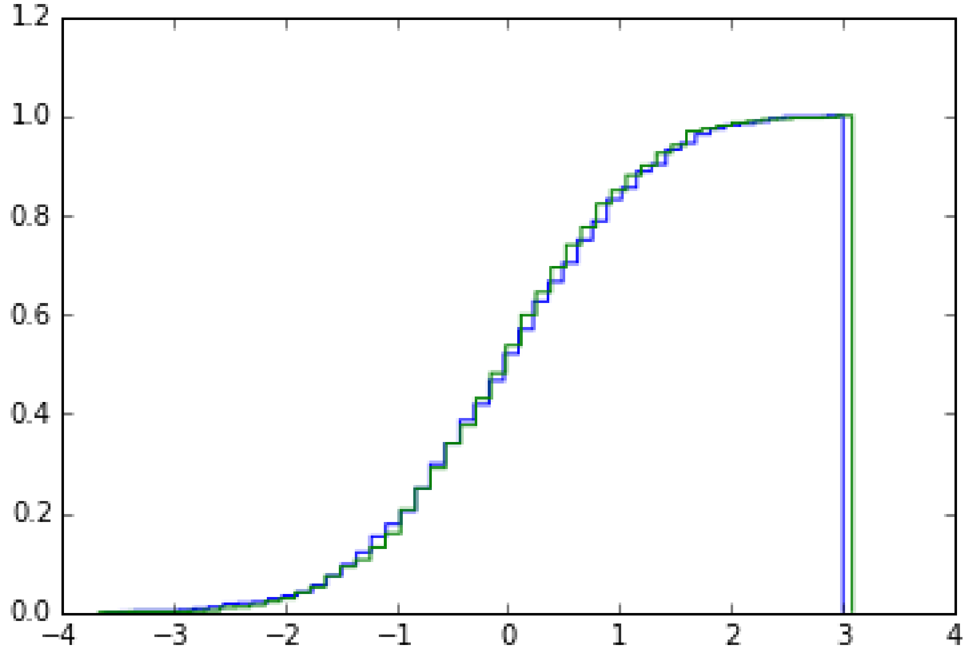

```
In [102]: fig, ax = plt.subplots()
          H = ax.hist((x, x2), bins=50, range=(-2, 2), histtype='step', stacked=True, fill=True)
```




```
In [103]: fig, ax = plt.subplots()
          H = ax.hist((x, x2), bins=(-2, -1, -0.2, -0.1, 0., 0.1, 0.2, 1, 2), range=(-2, 2), histtype='s
```

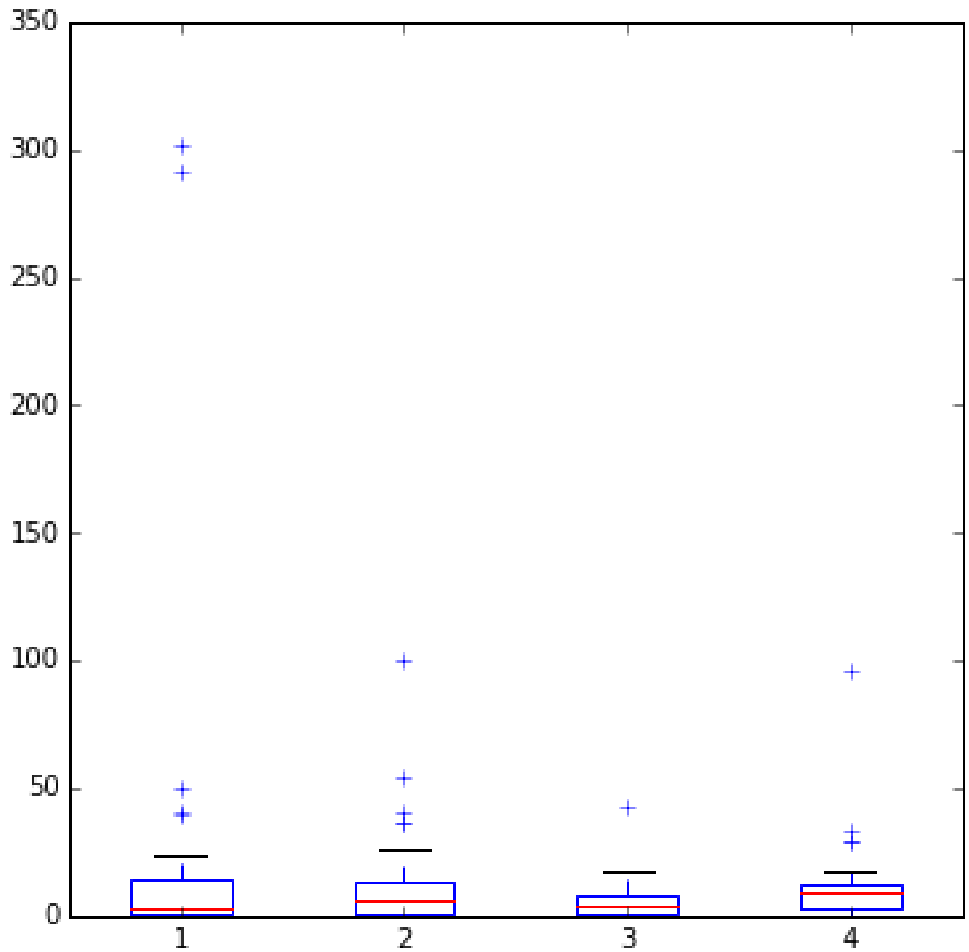



```
In [99]: fig, ax = plt.subplots()
         H = ax.hist(x, bins=50, histtype='step', cumulative=True, normed=True)
         H2 = ax.hist(x2, bins=50, histtype='step', cumulative=True, normed=True)
```

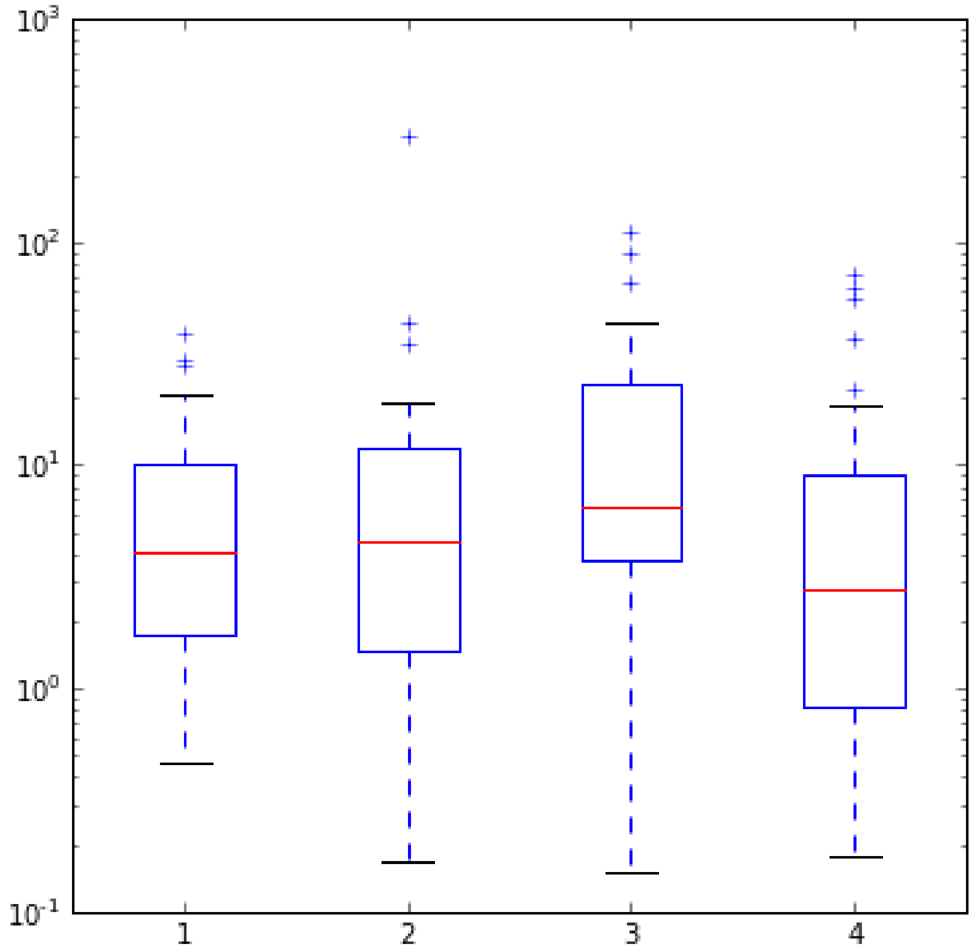


boxplots

```
In [104]: 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 !
```



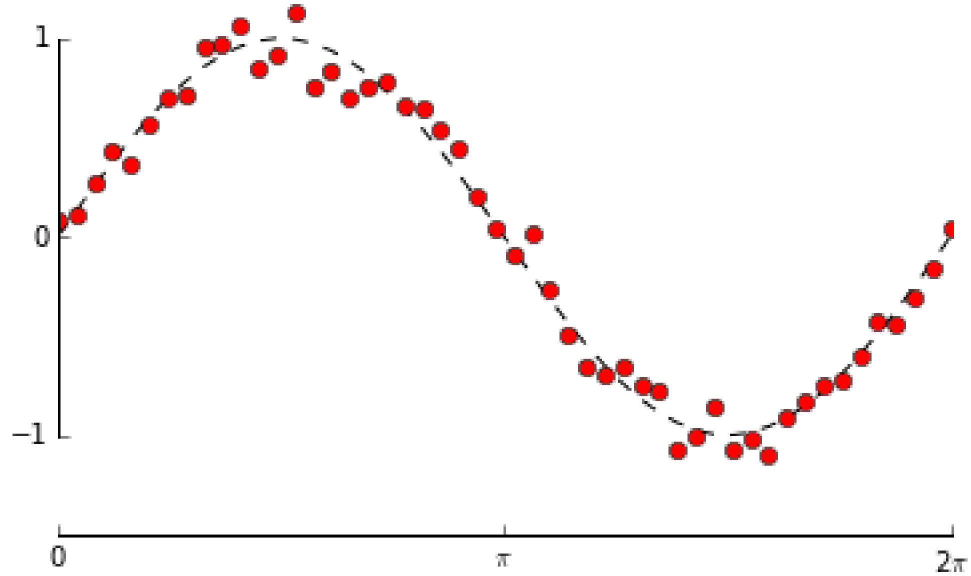

```
In [105]: data = np.random.lognormal(size=(37, 4), mean=1.5, sigma=1.75)

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



Ticks, axes and spines

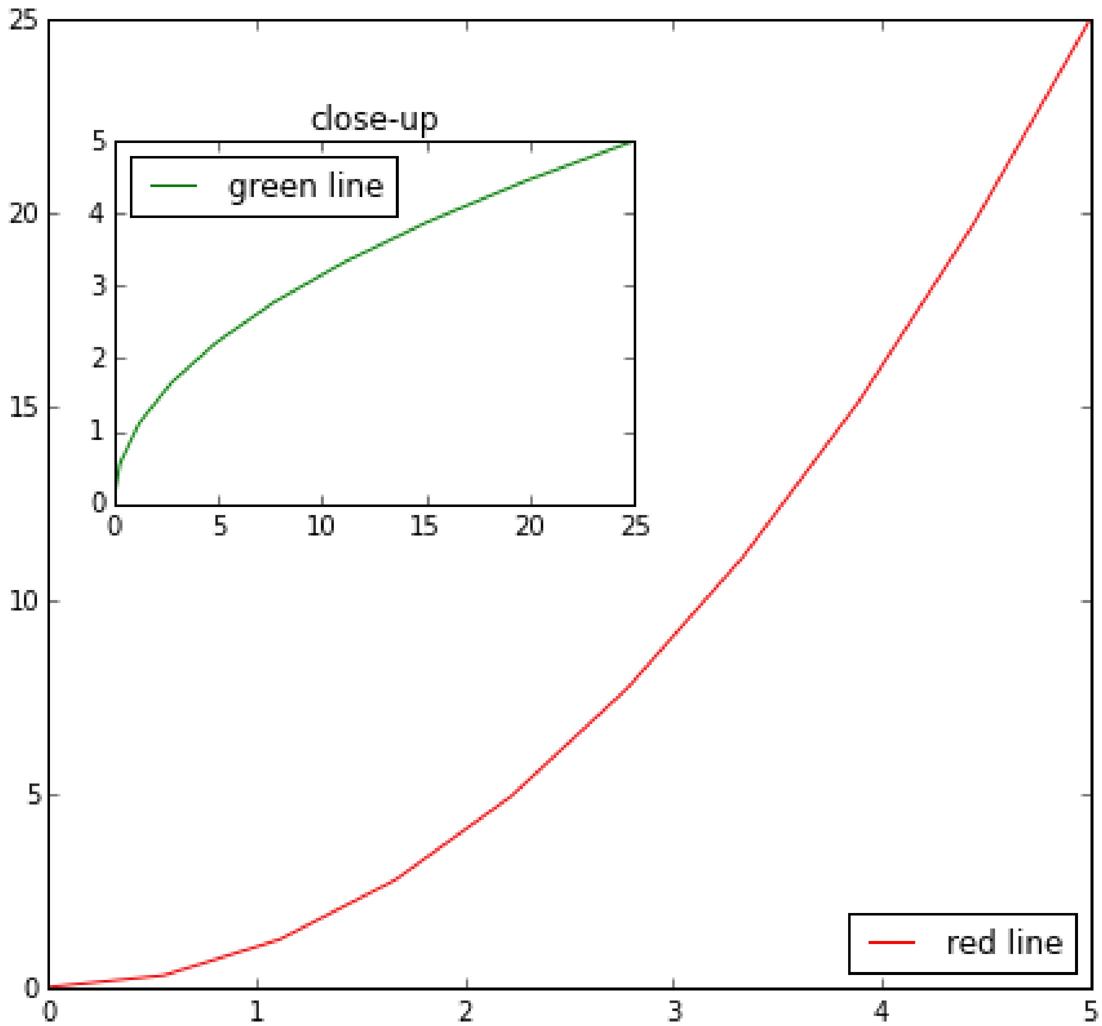
```
In [106]: x = np.linspace(0, 2*np.pi, 50)
          y = np.sin(x)
          y2 = y + 0.1 * np.random.normal(size=x.shape) # add noise to the data

          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')
```



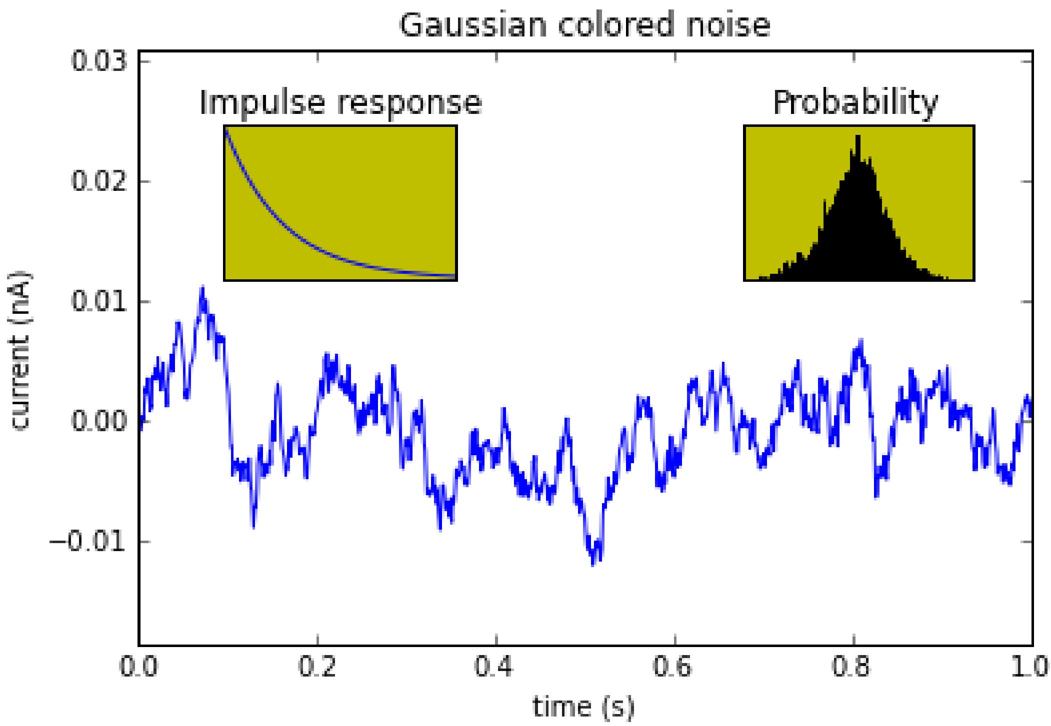
A plot inside a plot

```
In [110]: 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 [112]:
```
# 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')
```

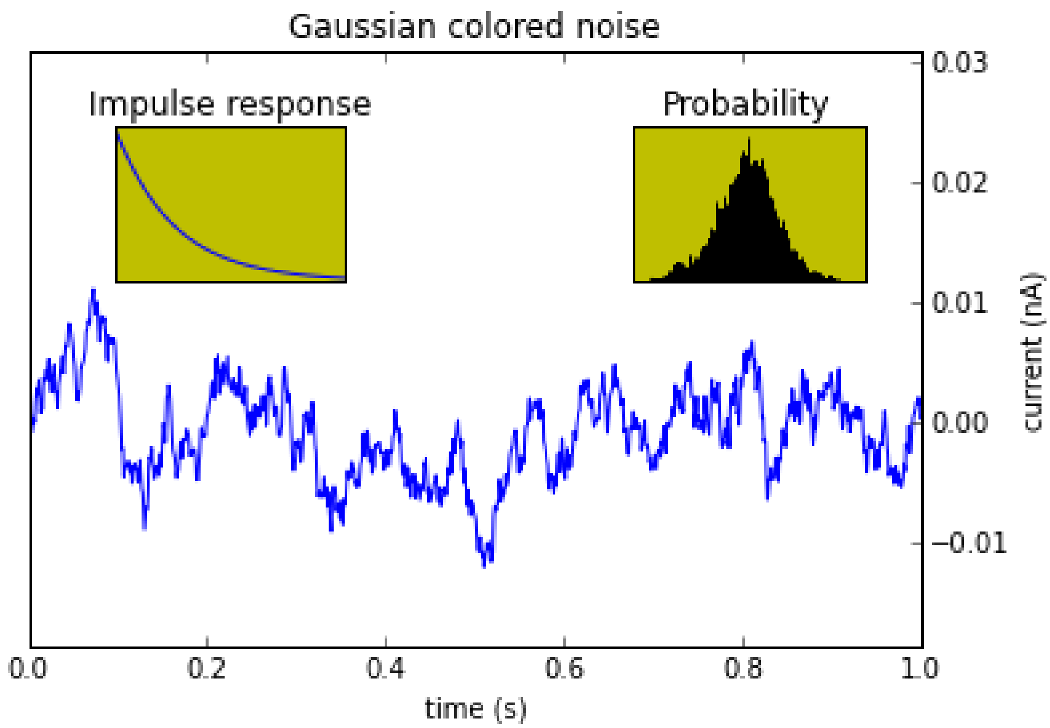
```
n, bins, patches = plt.hist(s, 400, normed=1)
plt.title('Probability')
plt.setp(a, xticks=[], yticks=[])

# 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 [113]:

```
# 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')
```

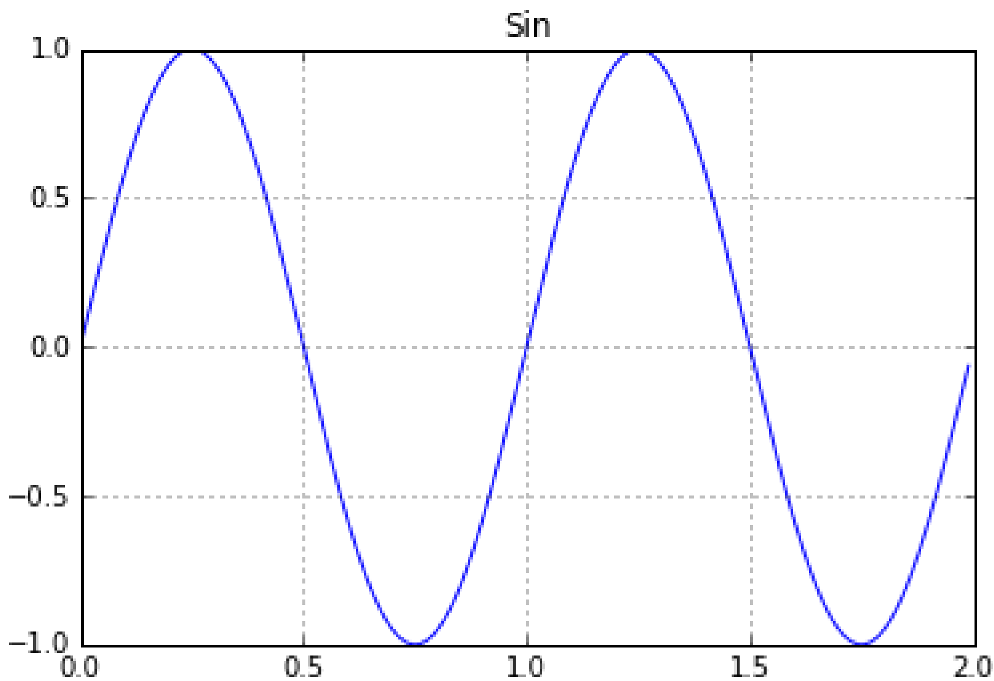
```
n, bins, patches = ax2.hist(s, 400, normed=1)
ax2.set_title('Probability')
ax2.xaxis.set_ticks([])
ax2.yaxis.set_ticks([])

# 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

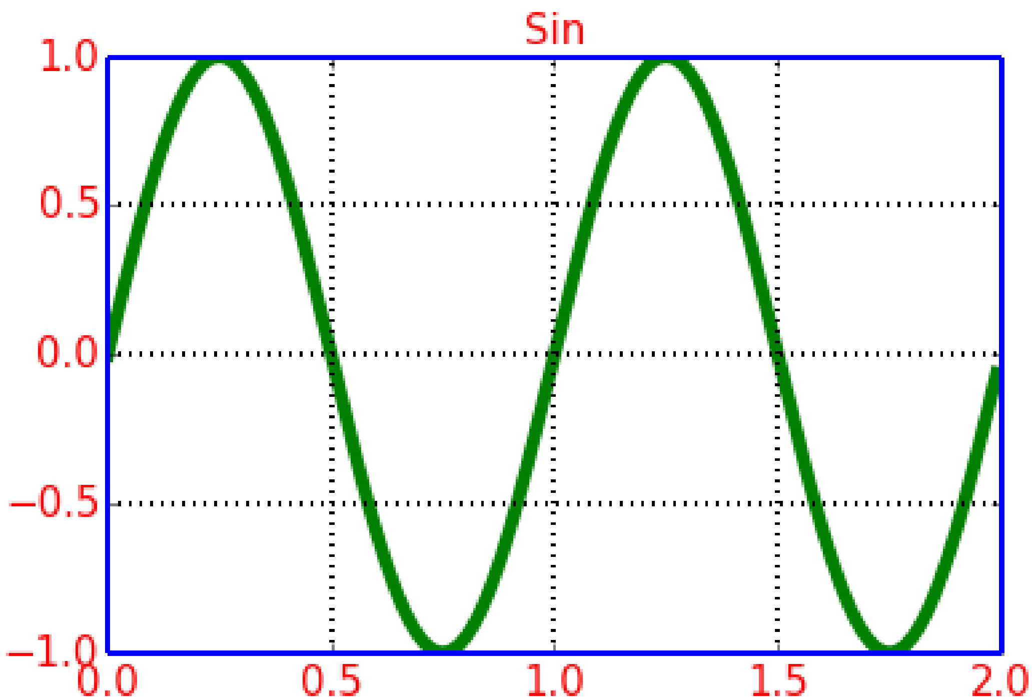
In [118]:
```
# Define some data
t = np.arange(0.0, 2.0, 0.01)
s = np.sin(2*np.pi*t)
fig, ax = plt.subplots()

# 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 [55]: # 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)
```

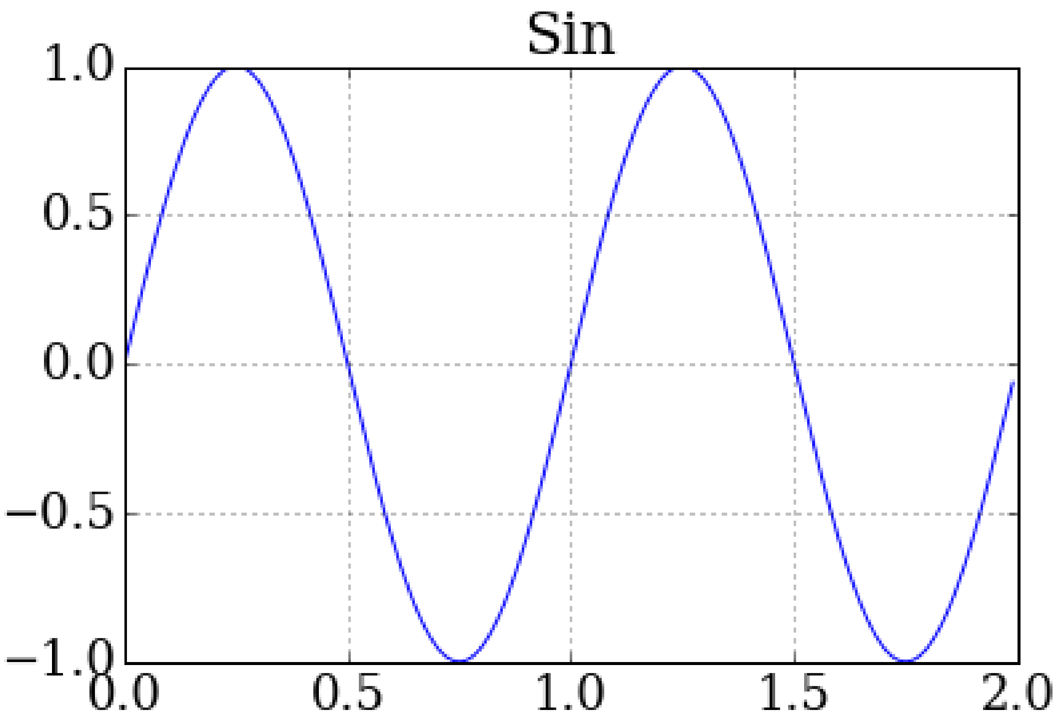


Changing font etc for all the plots:

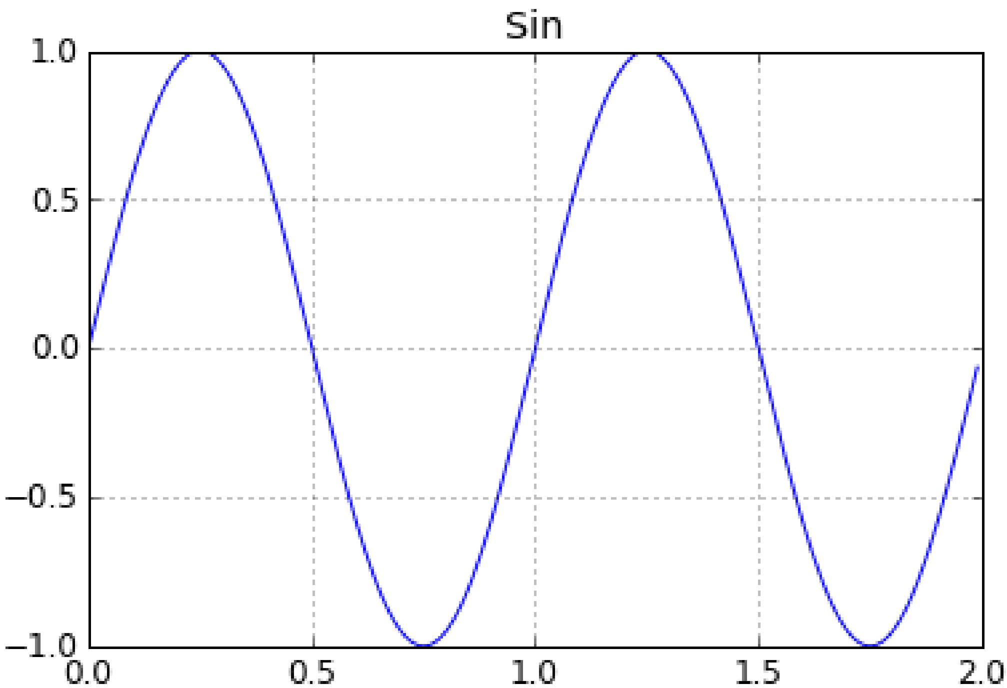
```
In [119]: import matplotlib
          matplotlib.rcParams.update({'font.size': 18, 'font.family': 'serif'})
```

```
In [120]: # 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
```

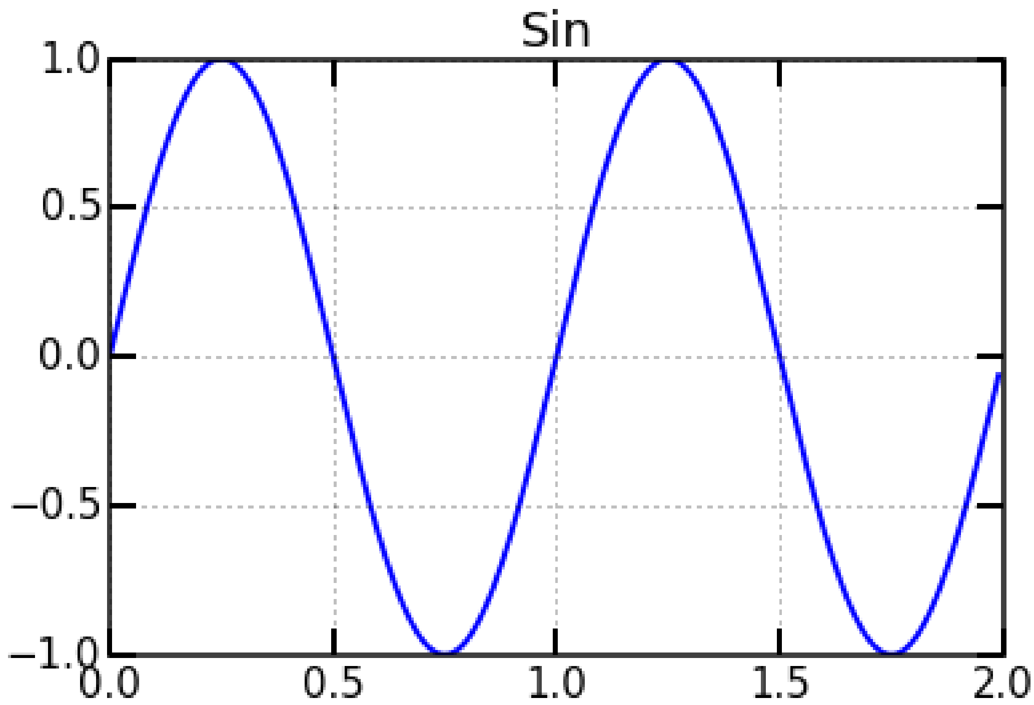
```
ax.grid(True)
tit = ax.set_title('Sin')
```




```
In [121]: # Back to default values
          matplotlib.rcParams.update({'font.size': 12, 'font.family': 'sans'})

In [122]: # 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 [126]: 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)
          # Plot grids on the figure
          ax.grid(True)
          tit = ax.set_title('Sin')
```



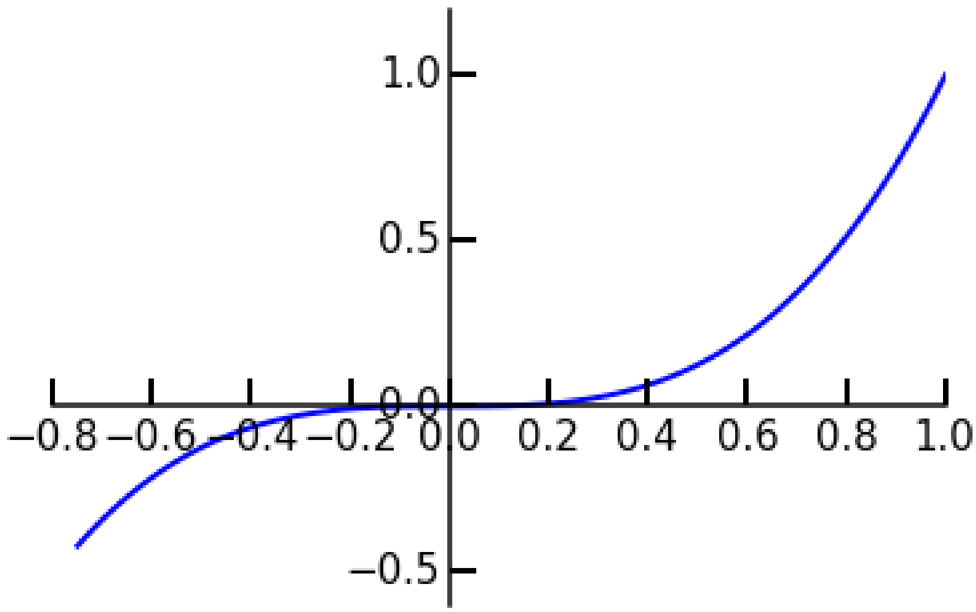
Twin axes

```
In [ ]: 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

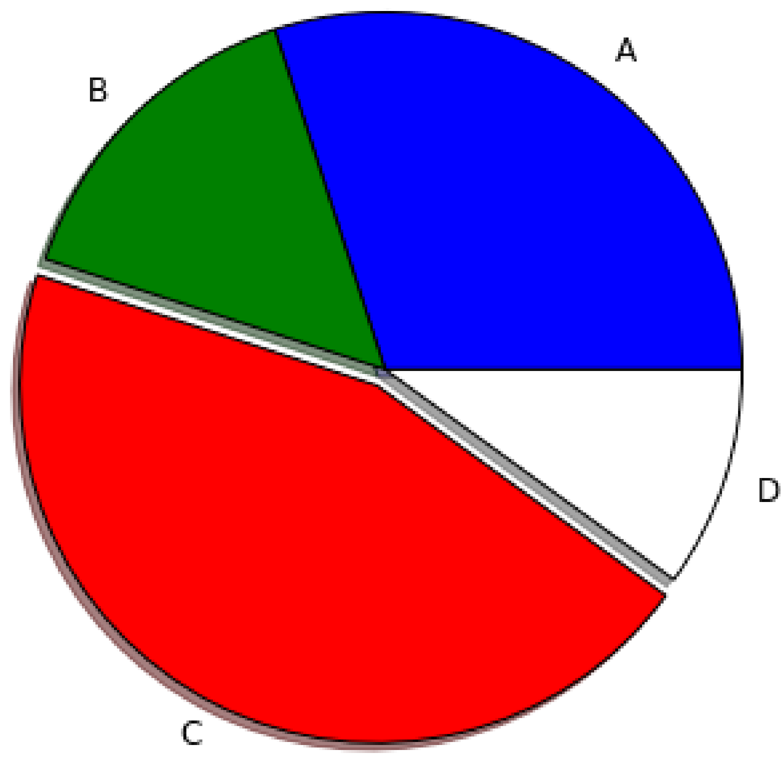
```
In [127]: fig, ax = plt.subplots()

          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 x=0

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

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



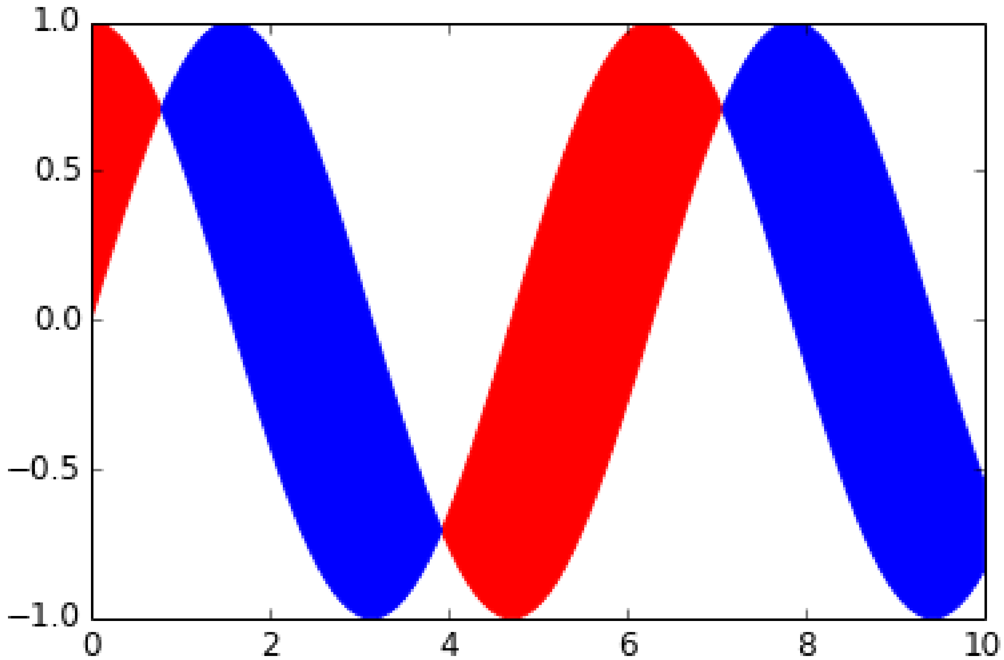
Pie plots

```
In [62]: 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'])
```



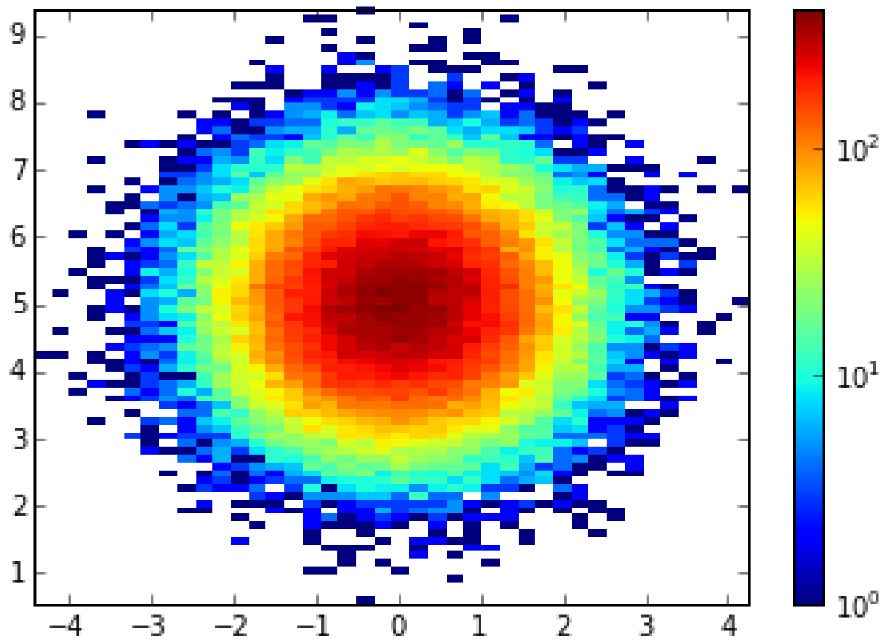
Filled regions

```
In [63]: 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');
```

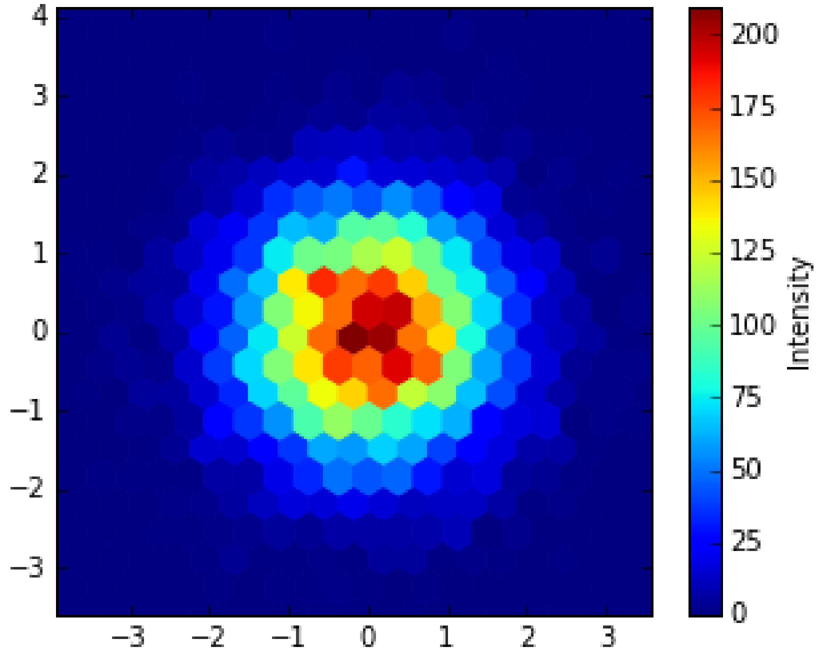


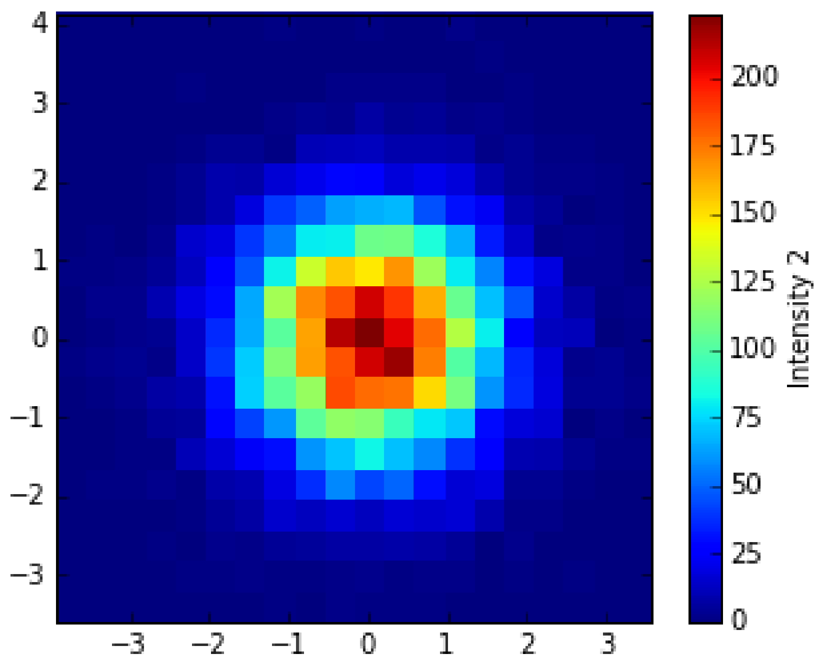
2D-histograms and hexagon plots

```
In [2]: 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=LogNorm())
        cb = fig.colorbar(Image)
```



In [7]:
```
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')
```

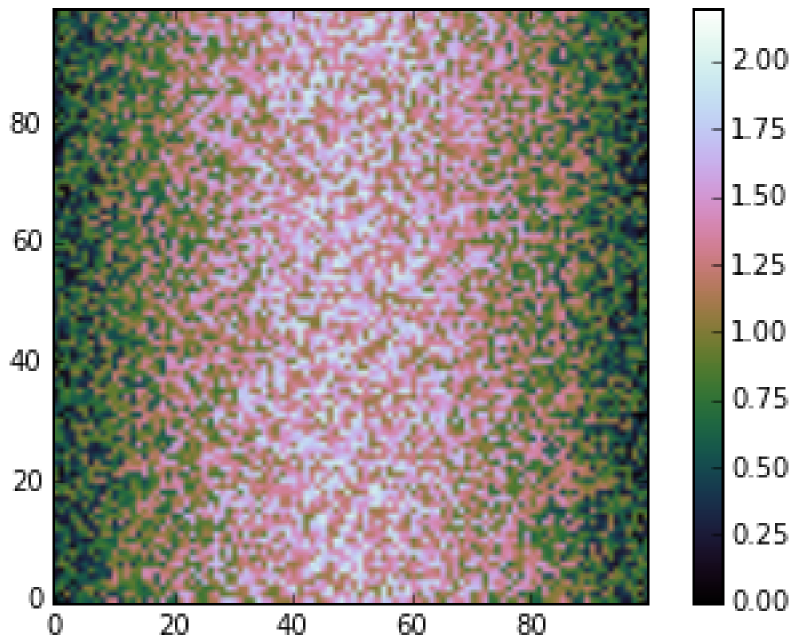




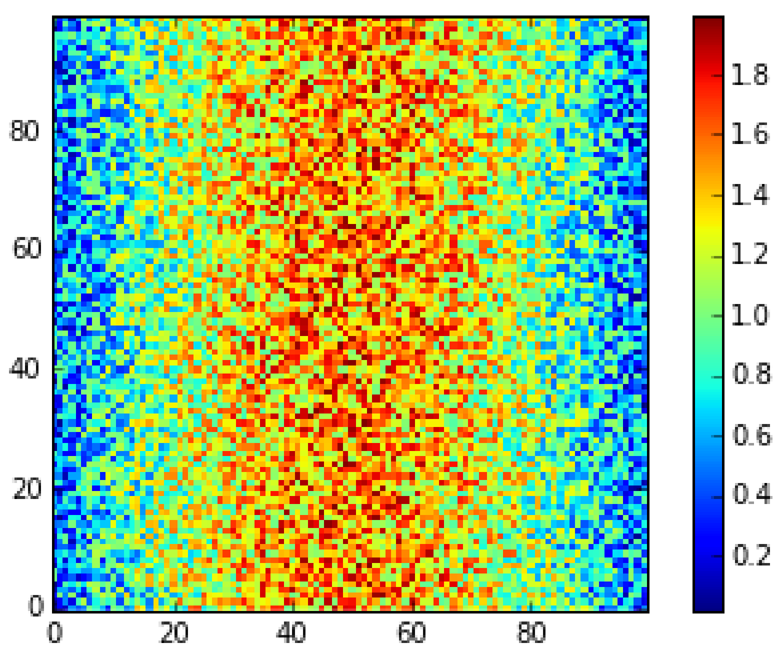
2D data sets and Images

```
In [8]: 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 image
cb = fig.colorbar(im) # put the colorbar
```




```
In [5]: fig, ax = plt.subplots()
        im = ax.imshow(I, cmap=plt.cm.jet, interpolation='none') # draw the image, no interpolations, r
        cb = fig.colorbar(im, ax=ax) # put the colorbar
```

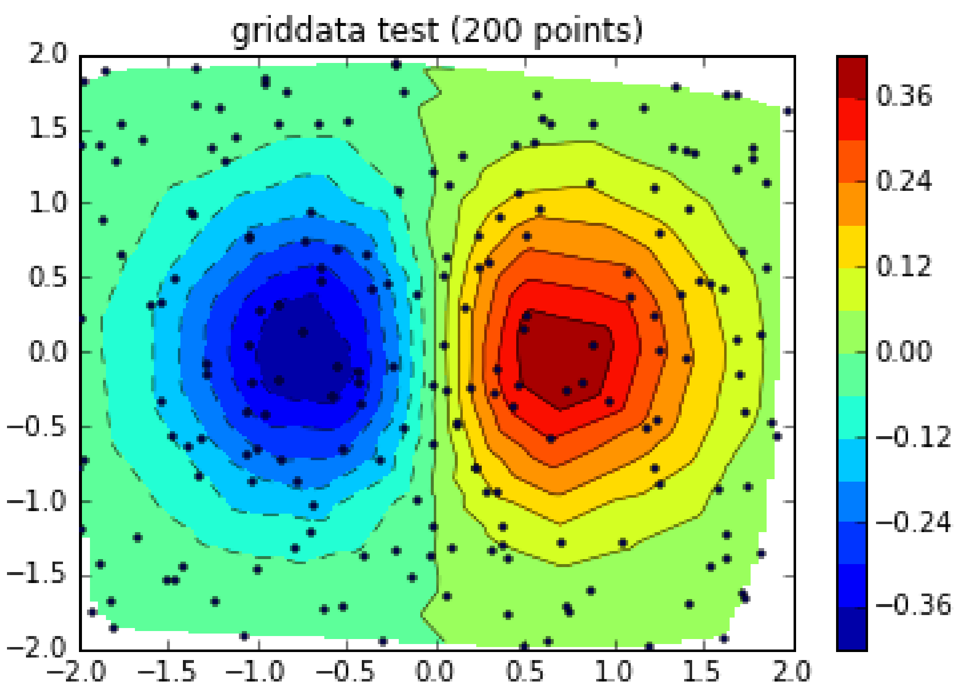


```
In [68]: help(plt.imshow)

Help on function imshow in module matplotlib.pyplot:

imshow(X, cmap=None, norm=None, aspect=None, interpolation=None, alpha=None, vmin=None, vmax=None, orig
    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
    Data limits for the axes.  The default assigns zero-based row,
    column indices to the ‘x‘, ‘y‘ centers of the pixels.

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.

Examples
--------

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

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

Contour

```
In [10]: 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')
         # 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

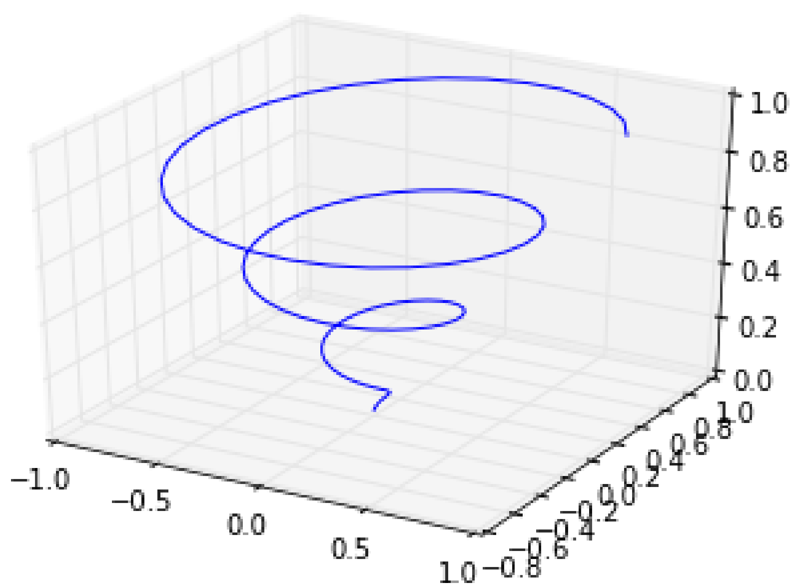
```
In [17]: from mpl_toolkits.mplot3d import Axes3D
         fig = plt.figure()
```

```
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')
```

Out[17]: <mpl_toolkits.mplot3d.art3d.Path3DCollection at 0x10891b450>

In [12]:
```
fig = plt.figure()
ax = plt.axes(projection='3d')

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

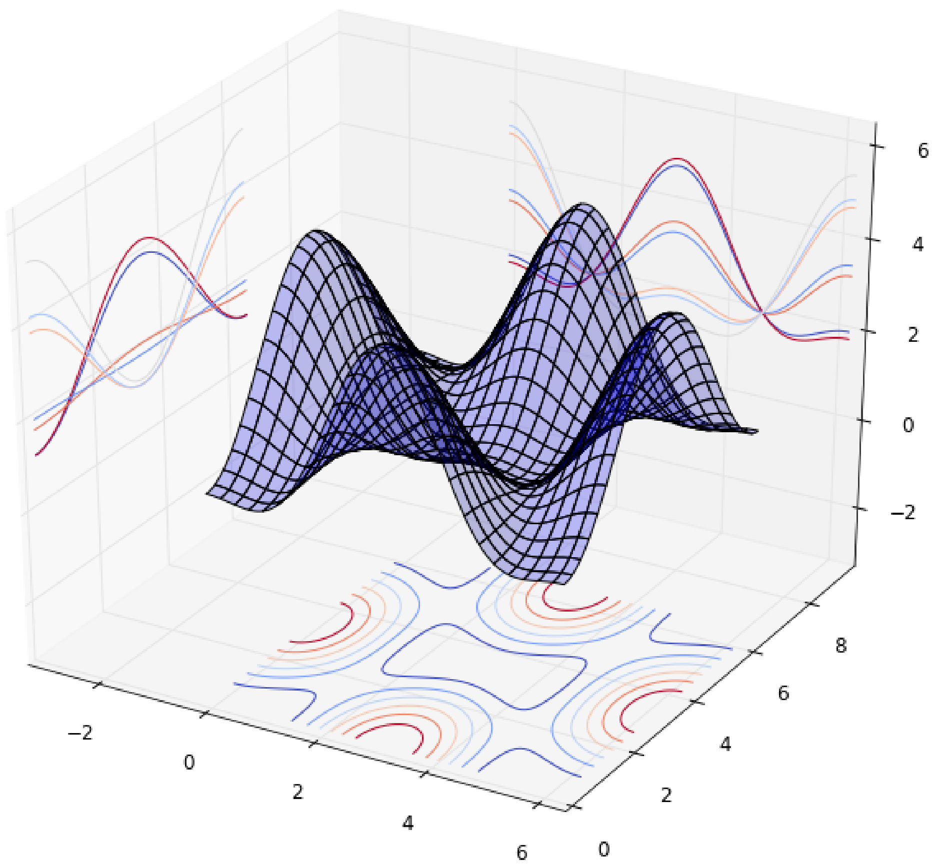
Out[12]: [<mpl_toolkits.mplot3d.art3d.Line3D at 0x109090dd0>]



In [21]:
```
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(phi_ext - 2*phi_p)

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 argument to add_subp
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, linewidth=0, antialias
cb = fig.colorbar(p, shrink=0.5)
```

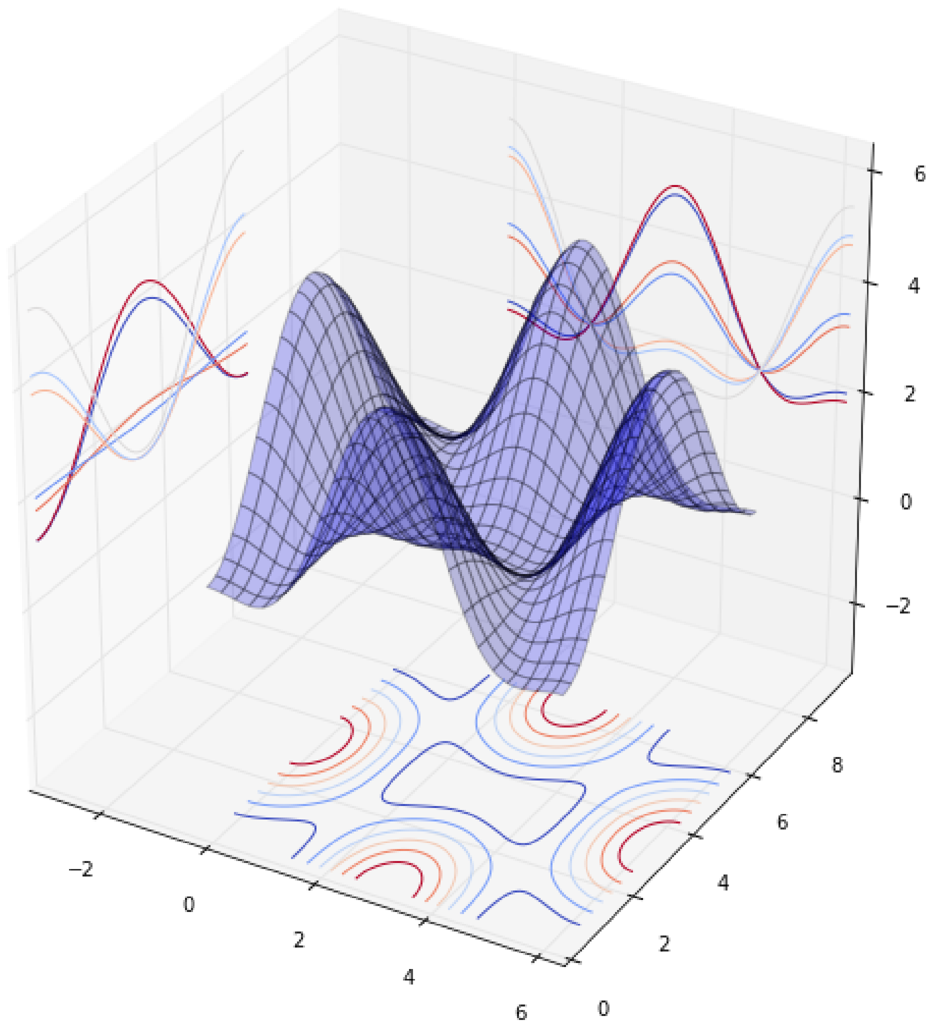
In [73]:
```
pi = np.pi
fig = plt.figure(figsize=(12,10))

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 [22]:
```python
# 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 [25]:
```python
%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 [24]: ls *pdf

```
BPT1.pdf              Intro_1.pdf          intro_Python.pdf     intro_Python_3.pdf
Fig1.pdf              MySQL.pdf            intro_Python_2.pdf
```

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

Access and clear the current figure and axe

In [77]:
```
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 0xac46c90>
```

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.