HPC Python Workshop: MatPlotLib

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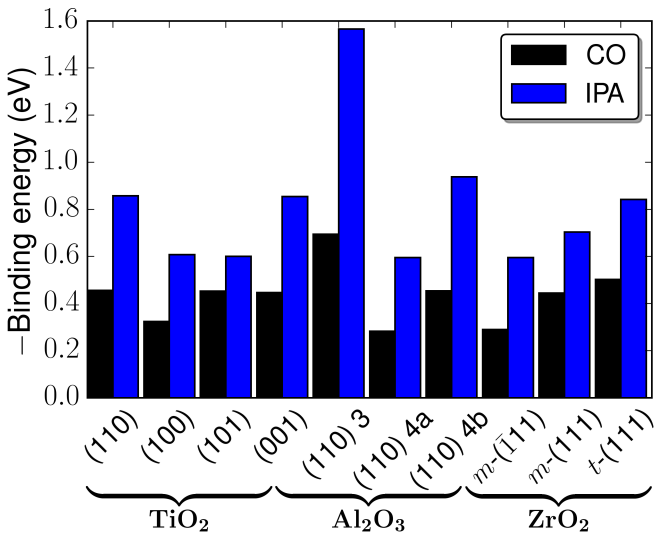
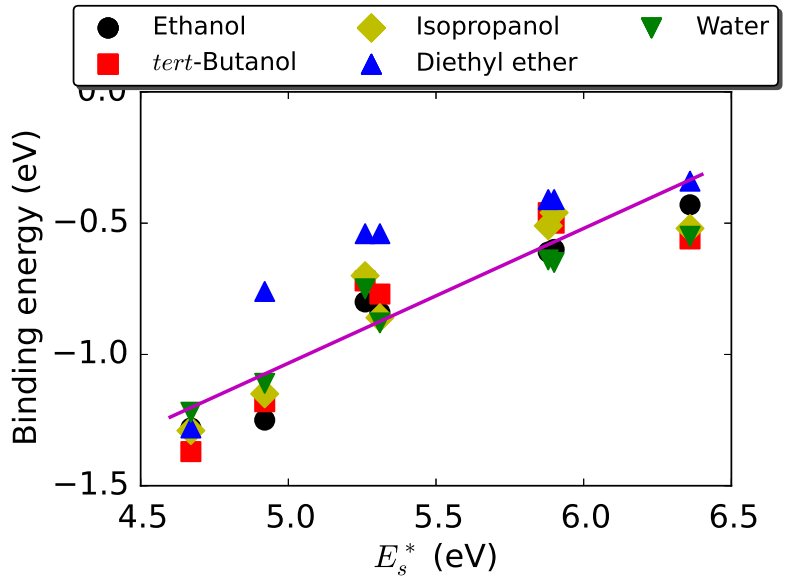
Introduction

What is MatPlotLib?

matplotlib

- Python plotting environment that integrates directly with NumPy and SciPy
- Designed to be cross platform, flexible, and capable of producing publication ready figures





Why MatPlotLib?

Advantages

- Cross platform
- Open Source (FREE!)
- High quality graphics production
- High reproducibility
- Interface with NumPy/SciPy allows for easy manipulation of data
- Variety of chart types supported (both 2D and 3D)

Disadvantages

- Intimidating interface
- Multiple ways to achieve a singular goal
- Not readily transparent

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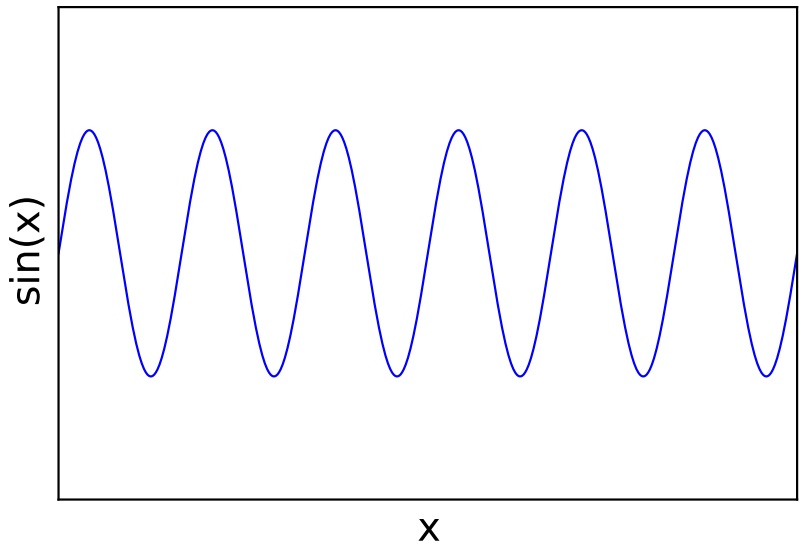
- Not readily transparent

If MatPlotLib is so flexible, what sort of things can it do?

EXAMPLES

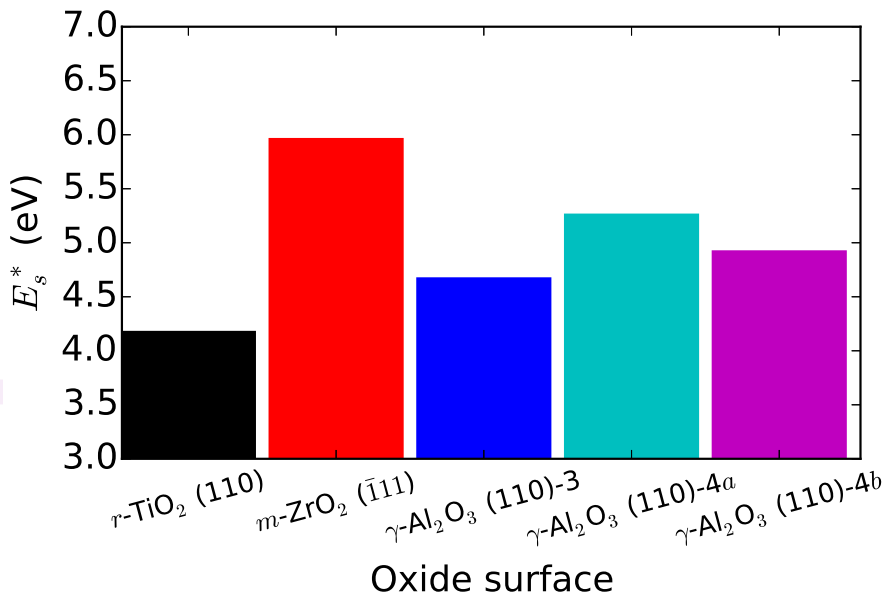
Example: Sine function

```python
import numpy as np
import matplotlib
import matplotlib.pyplot as plt

font = {'size': 18}
matplotlib.rc('font', **font)

x = np.arange(0, 12 * np.pi, 0.001)
y = np.sin(x)

fig = plt.figure()
ax = fig.add_subplot(111)

line = ax.plot(x, y)

plt.ylim([-2.0, 2.0])
plt.xlim([0, 12 * np.pi])

ax.set_xticks([])
ax.set_yticks([])

ax.set_xlabel(r'x')
ax.set_ylabel('sin(x)')

for ext in ['png', 'pdf', 'eps']:
    plt.savefig('sine_plot.%s' % ext, pad_inches=0.5,
                bbox_inches='tight', dpi=500)
```



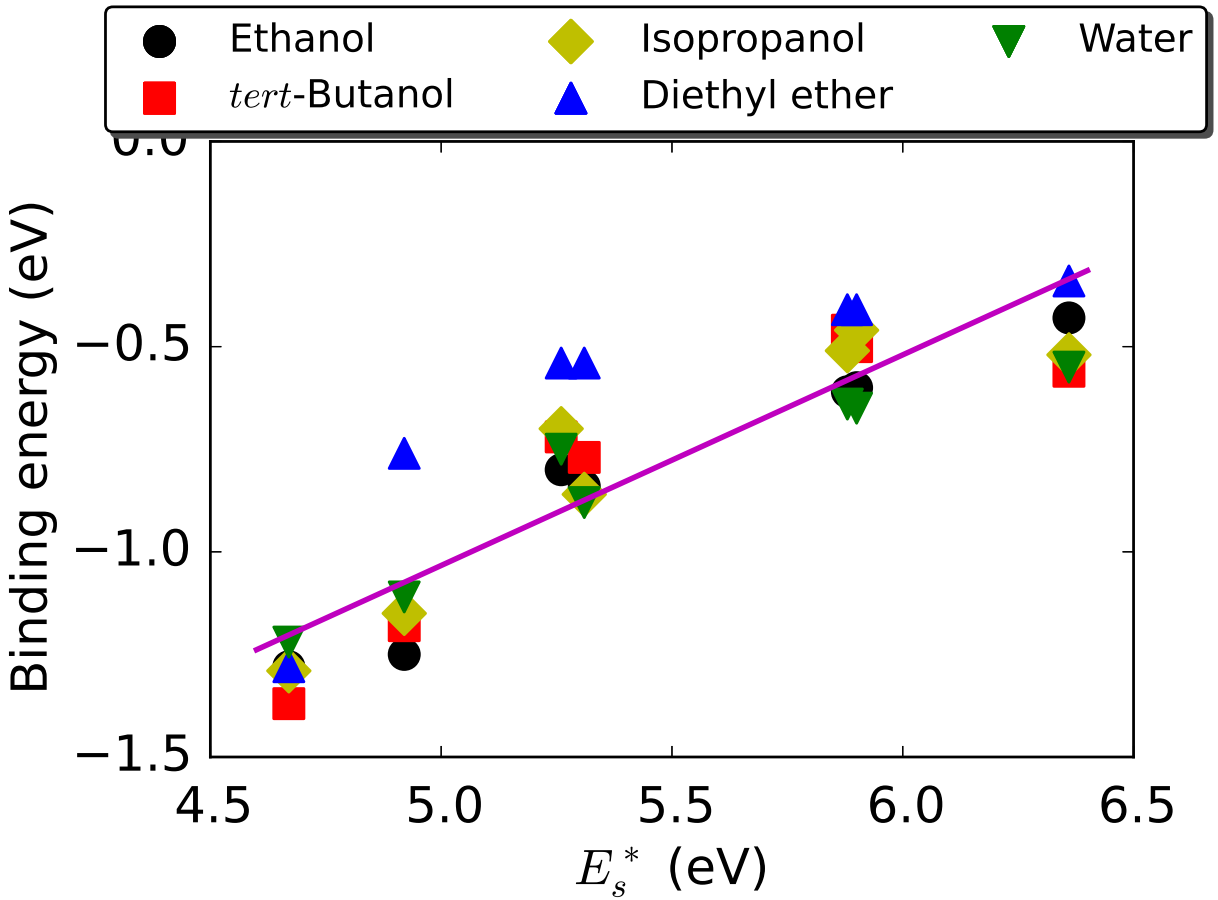
Example: Simple Bar Chart

```
 8 import numpy as np
 9 import matplotlib
10 import matplotlib.pyplot as plt
11
12 font = {'size': 16}
13 matplotlib.rc('font', **font)
14
15 sites = [r'$r$-TiO$_2$ (110)', r'$m$-ZrO$_2$ ($\bar{1}11$)',
16          r'$\gamma$-Al$_2$O$_3$ (110)-3', r'$\gamma$-Al$_2$O$_3$ (110)-4$a$',
17          r'$\gamma$-Al$_2$O$_3$ (110)-4$b$']
18
19 estars = [4.174374, 5.960088, 4.67, 5.26, 4.92]
20 colors = ['k', 'r', 'b', 'c', 'm', 'g', 'y']
21
22 index = np.arange(len(estars))
23 bar_width = 0.90
24
25 fig = plt.figure()
26 ax = fig.add_subplot(111)
27
28 bar1 = ax.bar(index, estars, width=bar_width)
29 for i in range(len(sites)):
30     bar1[i].set_color(colors[i])
31
32 ax.set_xticks(index + bar_width / 2)
33 ax.set_xticklabels(sites)
34 plt.xticks(rotation=15.)
35 for tick in ax.xaxis.get_major_ticks():
36     tick.label.set_fontsize(12)
37
38 plt.ylim([3, 7])
39 ax.set_xlabel('Oxide surface')
40 ax.set_ylabel('$E^*_s$ (eV)')
41
42 plt.subplots_adjust(bottom=0.22)
43 plt.savefig('oxide_band_energies.eps')
```



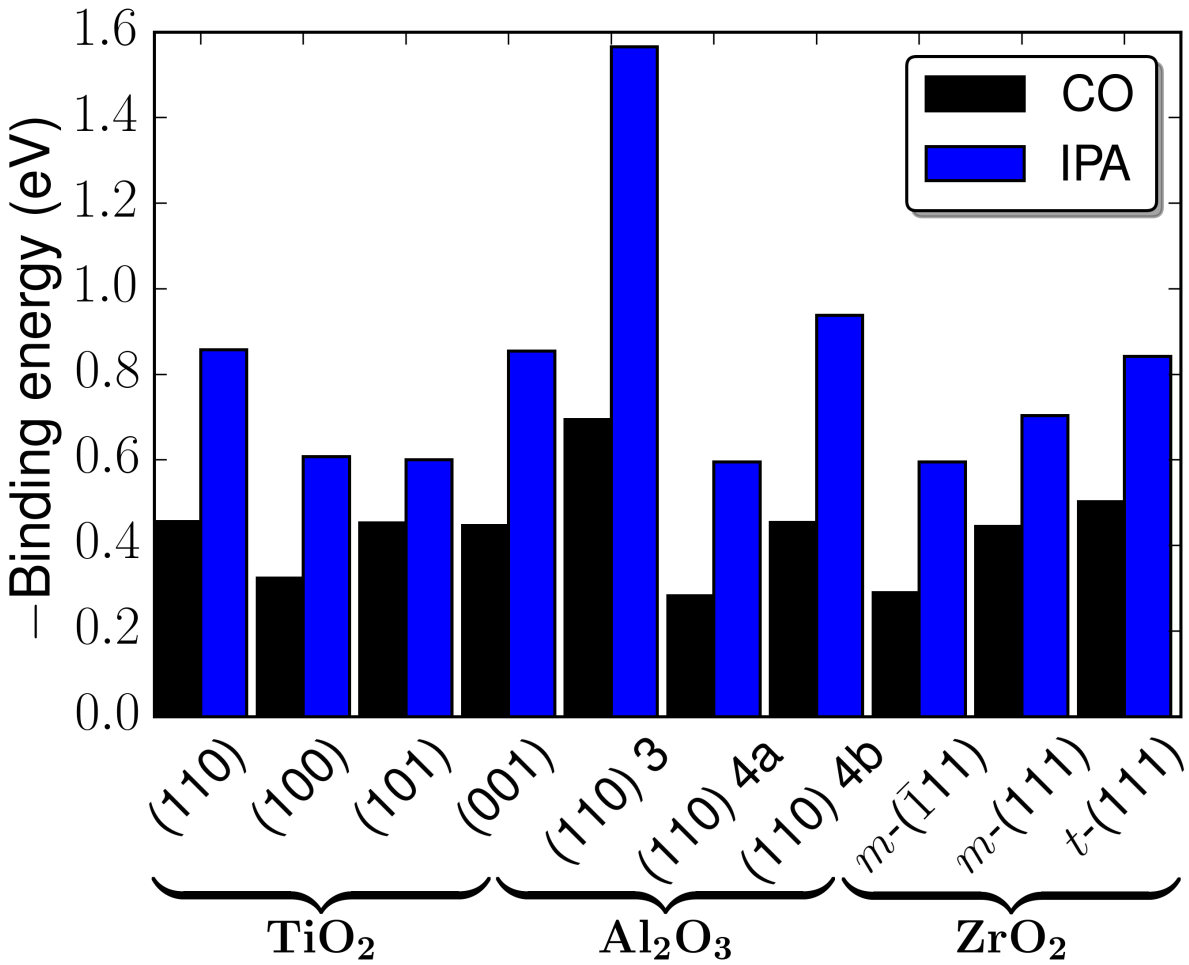
Example: Scatter with Best Fit

```
import numpy as np
from scipy.stats import linregress
import matplotlib
import matplotlib.pyplot as plt
import math

font = {'size': 18}
matplotlib.rc('font', **font)

sites = ['3', '4$a$', '4$b$', 'V$_a$', 'V$_b$', 'V$_c$', 'V$_d$']
etoh = np.array([-1.28, -0.80, -1.25, -0.84, -0.60, -0.43, -0.61])
tbutanol = np.array([-1.37, -0.72, -1.18, -0.77, -0.50, -0.56, -0.4
ipa = np.array([-1.29, -0.70, -1.15, -0.86, -0.46, -0.52, -0.51])
dee = np.array([-1.28, -0.54, -0.76, -0.54, -0.41, -0.34, -0.41])
h2o = np.array([-1.22, -0.75, -1.11, -0.88, -0.65, -0.55, -0.64])

index = np.array([4.67, 5.26, 4.92, 5.31, 5.90, 6.36, 5.88])

fig = plt.figure()
ax = fig.add_subplot(111)

size = 120
scatplot = ax.scatter(index, etoh, color='k', marker='o', s=size,
                      label='Ethanol')
scatplot = ax.scatter(index, tbutanol, color='r', marker='s', s=siz
                      label='$tert$-Butanol')
scatplot = ax.scatter(index, ipa, color='y', marker='D', s=size,
                      label='Isopropanol')
scatplot = ax.scatter(index, dee, color='b', marker='^', s=size,
                      label='Diethyl ether')
scatplot = ax.scatter(index, h2o, color='g', marker='v', s=size, lal

fita = [0.52, 0.52, 0.50]
fitb = [3.7, 3.6, 3.5]

a_ave = 0.0
b_ave = 0.0
for a in fita:
    a_ave += a

for b in fitb:
    b_ave += b

a_ave /= len(fita)
b_ave /= len(fitb)

print 'Ave. alpha = %f' % a_ave
print 'Ave. beta = %f' % b_ave

def linear(x):
    return a_ave * x - b_ave

xlist = list()
ylist = list()
for i in np.arange(4.6, 6.4, 0.1):
    xlist.append(i)
    ylist.append(linear(i))

linplot = ax.plot(xlist, ylist, color='m', linewidth=2)

ax.set_xlabel('$E^*_s$ (eV)')
ax.set_ylabel('Binding energy (eV)')

ax.legend(loc='top center', prop={'size': 14}, scatterpoints=1,
          frameon=True, shadow=True,
          fancybox=True, ncol=3, bbox_to_anchor=(1.10, 1.25))
```



Example: LaTeX+ MatPlotLib

```python
import numpy as np
import matplotlib
import matplotlib.pyplot as plt

font = {'size': 18}
matplotlib.rc('font', **font)
matplotlib.rc('text', usetex=True)

latex = r'\usepackage[dvips]{graphicx}\usepackage{xfrac}'
matplotlib.rcParams["text.latex.preamble"].append(latex)

sites   = ['(110)', '(100)', '(101)', '(001)',
           '(110) 3', '(110) 4a', '(110) 4b',
           r'$m$-($\bar{1}$11)', r'$m$-(111)', r'$t$-(111)'
           ]

co_be = [-0.456298, -0.323406, -0.453106, -0.446507,
         -0.694236, -0.282624, -0.453253,
         -0.289229, -0.444831, -0.502208
         ]

ipa_be = [-0.857123, -0.607922, -0.600221, -0.854681,
          -1.565287, -0.595605, -0.937462,
          -0.595479, -0.703180, -0.841475]

co_be = np.array(co_be)
ipa_be = np.array(ipa_be)

index = np.arange(len(sites))
bar_width = 0.90

fig = plt.figure()
ax = fig.add_subplot(111)

barplot1 = ax.bar(index, -co_be, width=bar_width / 2, color='k', la
barplot2 = ax.bar(index+bar_width/2, -ipa_be, width=bar_width/2, co
                  label='IPA')

ax.set_xticks(index + bar_width / 2)
ax.set_xticklabels(sites, fontsize=16, rotation=45)

plt.ylim([0.0, 1.6])

brace = '~~~~~~~~~~~~~~~~~~'
down = -0.15
font = 22

text = r'$\underbrace{%s}_{\rm \mathbf{%s}}$' % (brace, 'TiO_2')
plt.figtext(0.25, down, text, fontsize=font, ha='center')

text = r'$\underbrace{%s}_{\rm \mathbf{%s}}$' % (brace, 'Al_2O_3')
plt.figtext(0.51, down, text, fontsize=font, ha='center')

text = r'$\underbrace{%s}_{\rm \mathbf{%s}}$' % (brace, 'ZrO_2')
plt.figtext(0.771, down, text, fontsize=font, ha='center')

ax.set_ylabel(r'$-$Binding energy (eV)')

location = 'upper right'
ax.legend(loc=location, prop={'size': 16},
          frameon=True, shadow=True,
          fancybox=True, bbox_to_anchor=(1.0, 1.0), ncol=1)

for ext in ['png', 'pdf']:
    plt.savefig('results/oxides_co_ipa_ebind.%s' % ext, pad_inches=
                bbox_inches='tight', dpi=500)
```



Example: XKCD

```python
import matplotlib.pyplot as plt
import numpy as np

with plt.xkcd():
    # Based on "Stove Ownership" from XKCD by Randall Monroe
    # http://xkcd.com/418/

    fig = plt.figure()
    ax = fig.add_axes((0.1, 0.2, 0.8, 0.7))
    ax.spines['right'].set_color('none')
    ax.spines['top'].set_color('none')
    plt.xticks([])
    plt.yticks([])
    ax.set_ylim([-30, 10])

    data = np.ones(100)
    data[70:] -= np.arange(30)

    plt.annotate(
        'THE DAY I REALIZED\nI COULD COOK BACON\nWHENEVER I WANTED',
        xy=(70, 1), arrowprops=dict(arrowstyle='->'), xytext=(15, -10))

    plt.plot(data)

    plt.xlabel('time')
    plt.ylabel('my overall health')
    fig.text(
        0.5, 0.05,
        '"Stove Ownership" from xkcd by Randall Monroe',
        ha='center')

    for ext in ['png', 'pdf']:
        plt.savefig('xkcd418.%s' % ext, pad_inches=0.5,
                    bbox_inches='tight', dpi=500)
    # Based on "The Data So Far" from XKCD by Randall Monroe
    # http://xkcd.com/373/

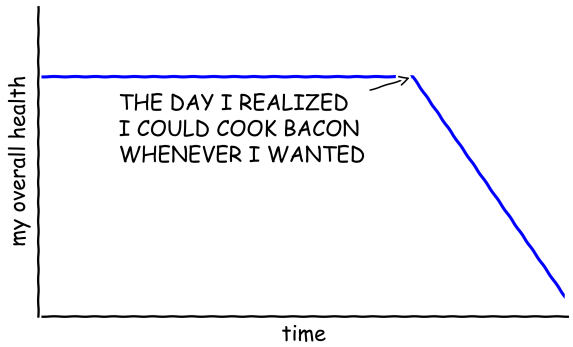
    fig = plt.figure()
    ax = fig.add_axes((0.1, 0.2, 0.8, 0.7))
    ax.bar([-0.125, 1.0-0.125], [0, 100], 0.25)
    ax.spines['right'].set_color('none')
    ax.spines['top'].set_color('none')
    ax.xaxis.set_ticks_position('bottom')
    ax.set_xticks([0, 1])
    ax.set_xlim([-0.5, 1.5])
    ax.set_ylim([0, 110])
    ax.set_xticklabels(['CONFIRMED BY\nEXPERIMENT', 'REFUTED BY\nEXPERIMENT'])
    plt.yticks([])

    plt.title("CLAIMS OF SUPERNATURAL POWERS")

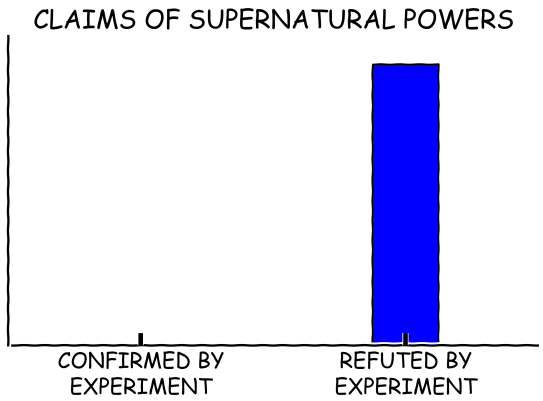
    fig.text(
        0.5, -0.05,
        '"The Data So Far" from xkcd by Randall Monroe',
        ha='center')

    for ext in ['png', 'pdf']:
        plt.savefig('xkcd373.%s' % ext, pad_inches=0.5,
                    bbox_inches='tight', dpi=500)

```



"Stove Ownership" from xkcd by Randall Monroe



"The Data So Far" from xkcd by Randall Monroe

How to get MatPlotLib

Those graphs look great! Where do I get MatPlotLib?

- Source code: http://matplotlib.org
- Linux Package installer (look for the SciPy stack!)
- Enthought Canopy (https://enthought.com/)
- Anaconda Python (https://www.continuum.io/downloads)
- If on Farber, load the following (`vpkg_require`):
  - python-numpy python-scipy python-matplotlib

USING MATPLOTLIB

Plotting a Sine function

```
1 import numpy as np
```

```
1 Import numpy
```

Plotting a Sine function

```
1 import numpy as np
2 import matplotlib
3 import matplotlib.pyplot as plt
```

1 Import `numpy`

2-3 Import `MatPlotLib`

- pylab vs. pyplot
- pylab: used for interactive plotting, MatLab like
- pyplot: used more for scripting

Plotting a Sine function

```
1 import numpy as np
2 import matplotlib
3 import matplotlib.pyplot as plt
4 font = {'size':  16}
5 matplotlib.rc('font', **font)
```

1 Import `numpy`

2-3 Import `MatPlotLib`

4-5 Change the graph font size to 16

- matplotlib.rc is used to change many of the behaviors of MatPlotLib!
- Can even use rc parameters to utilize LaTeX

Plotting a Sine function

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1 import numpy as np
2 import matplotlib
3 import matplotlib.pyplot as plt
4 font = {'size':  16}
5 matplotlib.rc('font', **font)
6 x = np.arange(0, 12 * np.pi, 0.001)
7 y = np.sin(x)
```

1 Import `numpy`

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6-7 Generate some (x, y) data

Plotting a Sine function

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6 x = np.arange(0, 12 * np.pi, 0.001)
7 y = np.sin(x)
8 fig = plt.figure()
9 ax = fig.add_subplot(111)
```

1 Import `numpy`

2-3 Import `MatPlotLib`

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8-9 Generate the plotting environment

- `figure` is the top level graphics object
- `add_subplot` adds a plot to the `figure` object
- `111` does mean something, but ignore it for now

Plotting a Sine function

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10 Add the (x, y) data to the plot!

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7  y = np.sin(x)
8  fig = plt.figure()
9  ax = fig.add_subplot(111)
10 line = ax.plot(x, y)
11 plt.ylim([-2.0, 2.0])
12 plt.xlim([0, 12 * np.pi])
13 ax.set_xticks([])
14 ax.set_yticks([])
```

1 Import `numpy`

2-3 Import `MatPlotLib`

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10 Add the (x, y) data to the plot!

11-14 Change some behavior of the axes

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12 plt.xlim([0, 12 * np.pi])
13 ax.set_xticks([])
14 ax.set_yticks([])
15 ax.set_xlabel('x')
16 ax.set_ylabel('sin(x)')
```

- 1 Import `numpy`
- 2-3 Import `MatPlotLib`
- 4-5 Change the graph font size to 16
- 6-7 Generate some (x, y) data
- 8-9 Generate the plotting environment
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- 11-14 Change some behavior of the axes
- 15-16 Label the axes

Plotting a Sine function

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 7 y = np.sin(x)
 8 fig = plt.figure()
 9 ax = fig.add_subplot(111)
10 line = ax.plot(x, y)
11 plt.ylim([-2.0, 2.0])
12 plt.xlim([0, 12 * np.pi])
13 ax.set_xticks([])
14 ax.set_yticks([])
15 ax.set_xlabel('x')
16 ax.set_ylabel('sin(x)')
17 plt.savefig('sine_plot.png')
   or
17 plt.show()
```

- 1 Import `numpy`
- 2-3 Import `MatPlotLib`
- 4-5 Change the graph font size to 16
- 6-7 Generate some (x, y) data
- 8-9 Generate the plotting environment
- 10 Add the (x, y) data to the plot!
- 11-14 Change some behavior of the axes
- 15-16 Label the axes
- 17 Visualize and/or save the plot

Plotting a Sine function

```
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7  y = np.sin(x)
8  fig = plt.figure()
9  ax = fig.add_subplot(111)
10 line = ax.plot(x, y)
11 plt.ylim([-2.0, 2.0])
12 plt.xlim([0, 12 * np.pi])
13 ax.set_xticks([])
14 ax.set_yticks([])
15 ax.set_xlabel('x')
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17 plt.savefig('sine_plot.png')
   or
17 plt.show()
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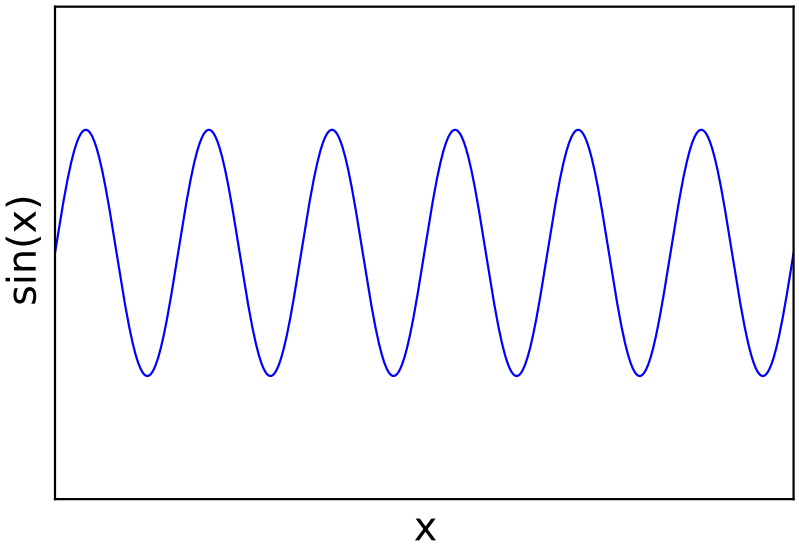
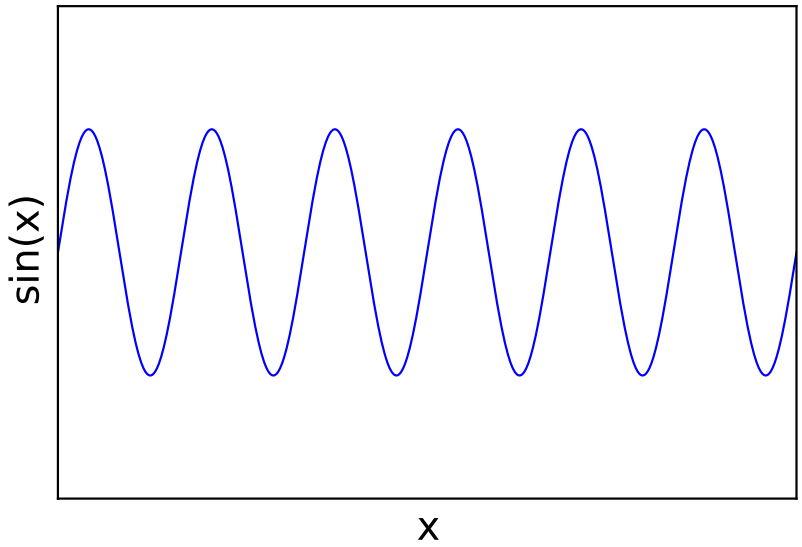
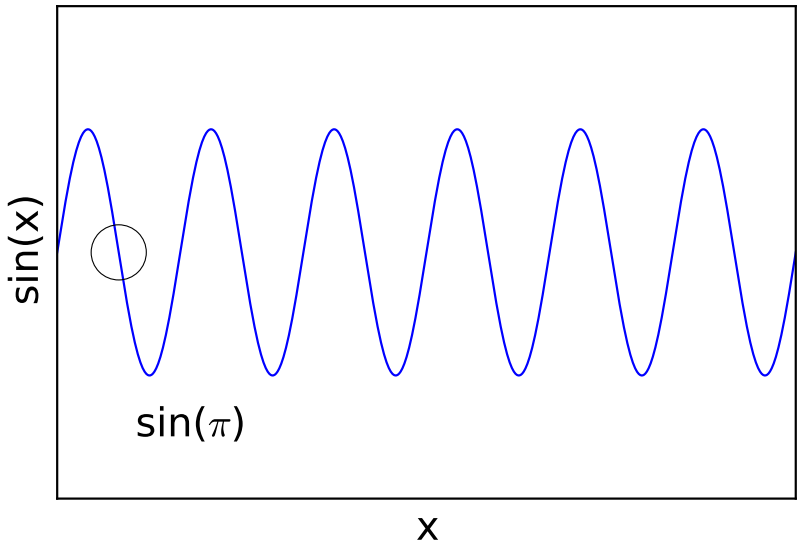


Plotting a Sine function — Modifications



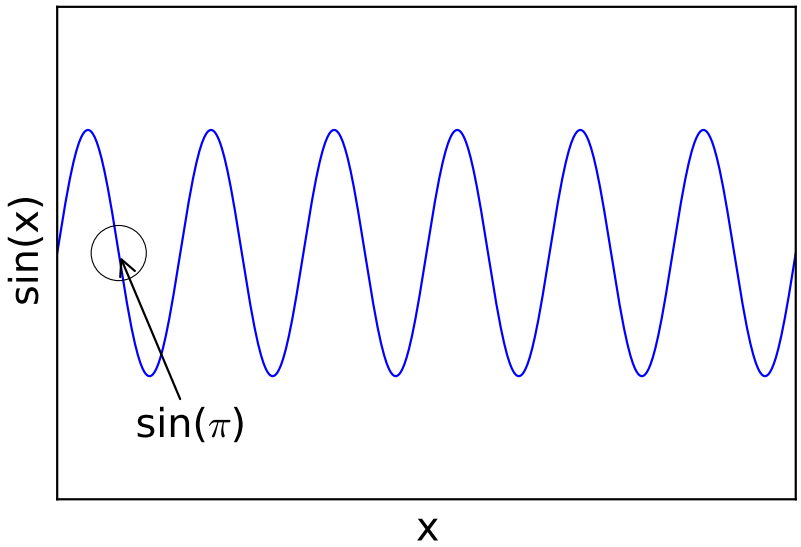
Plotting a Sine function — Modifications

- `circle = ax.plot(np.pi, 0.0, 'bo', fillstyle='none', markersize=25, color='k')`



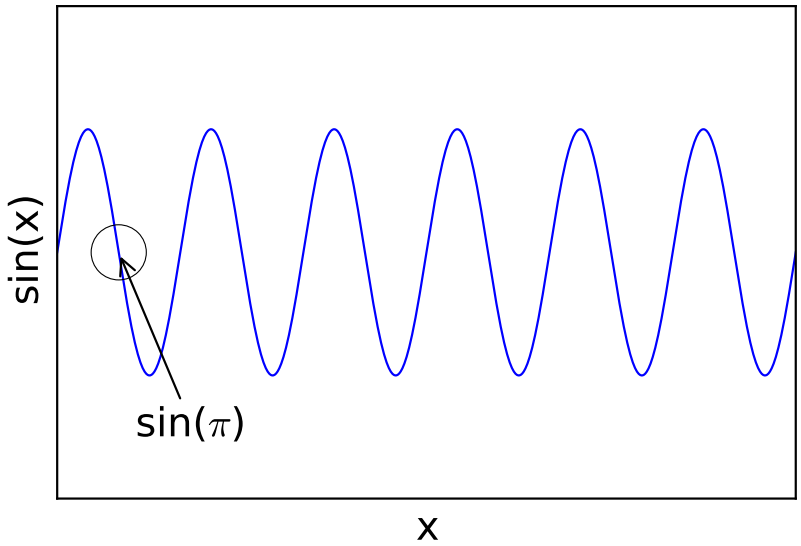
Plotting a Sine function — Modifications

- `circle = ax.plot(np.pi, 0.0, 'bo', fillstyle='none', markersize=25, color='k')`
- `ax.annotate(r'sin($\pi$)', xy=(np.pi, 0.0), xycoords='data', xytext=(4.0, -1.5), textcoords='data')`



Plotting a Sine function — Modifications

- ```
  circle = ax.plot(np.pi, 0.0, 'bo', fillstyle='none', markersize=25,
                   color='k')
  ```
- ```
  arrow = {'arrowstyle':  '->'}
  ax.annotate(r'sin($\pi$)', xy=(np.pi, 0.0), xycoords='data',
              xytext=(4.0, -1.5), textcoords='data',
              arrowprops=arrow)
  ```



Reading from external file

First, write the (x, y) data to a file to have something to work with:

```
with open('data.txt', 'w') as dfile:
  for i in range(len(x)):
     dfile.write('%16.6f%16.6f\n' % (x[i], y[i]))
```

Now read this data in using numpy:

```
x, y = np.loadtxt('data.txt', unpack=True)
```

Fitting data

```
1 import numpy as np
2 import matplotlib
3 import matplotlib.pyplot as plt
4 from scipy.optimize import curve_fit
```

1-4 Load the requisite namespaces

Fitting data

```
4 def func(x, a, b, c):
5     return a * np.exp(-b * x) + c
6 xdata = np.linspace(0, 4, 100)
7 y = func(xdata, 2.5, 1.3, 0.5)
8 ydata = y + 0.2 *
  np.random.normal(size=len(xdata))
```

4-5 Define a function to create data

6-8 Generate some data. The y data is generated via a normal Gaussian distribution for some extra randomness

Fitting data

```
4 def func(x, a, b, c):
5     return a * np.exp(-b * x) + c
6 xdata = np.linspace(0, 4, 100)
7 y = func(xdata, 2.5, 1.3, 0.5)
8 ydata = y + 0.2 *
  np.random.normal(size=len(xdata))
9 popt, pcov = curve_fit(func, xdata, ydata)
```

9 Use `scipy`'s `curve_fit` to fit the data. The parameters are in `popt`, and error information is in `pconv`

Fitting data

```
4  def func(x, a, b, c):
5      return a * np.exp(-b * x) + c
6  xdata = np.linspace(0, 4, 100)
7  y = func(xdata, 2.5, 1.3, 0.5)
8  ydata = y + 0.2 *
   np.random.normal(size=len(xdata))
9  popt, pcov = curve_fit(func, xdata, ydata)
10 ydata2 = func(xdata, popt[0], popt[1], popt[2])
```

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10 `popt` is then used to generate a 2^{nd} set of y-data

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11 fig = plt.figure()
12 ax = fig.add_subplot(111)
```

9 Use `scipy`'s `curve_fit` to fit the data. The parameters are in `popt`, and error information is in `pconv`

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11-12 Create the plotting environment

Fitting data

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12 ax = fig.add_subplot(111)
13 ax.scatter(xdata, ydata,)
14 ax.plot(xdata, ydata2, linewidth=2, color='r')
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9 Use `scipy`'s `curve_fit` to fit the data. The parameters are in `popt`, and error information is in `pconv`

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11-12 Create the plotting environment

13-14 Plot the data. The random data is plotted as a scatter plot.

Fitting data

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4  def func(x, a, b, c):
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11 fig = plt.figure()
12 ax = fig.add_subplot(111)
13 ax.scatter(xdata, ydata,)
14 ax.plot(xdata, ydata2, linewidth=2, color='r')
15 plt.xlim([0, 4])
16 plt.ylim([0, 3.0])
17 plt.savefig('fit_test.eps')
```

9 Use `scipy`'s `curve_fit` to fit the data. The parameters are in `popt`, and error information is in `pconv`

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11-12 Create the plotting environment

13-14 Plot the data. The random data is plotted as a scatter plot.

15-16 Set axes limits

17 Save the plot

Fitting data

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15 plt.xlim([0, 4])
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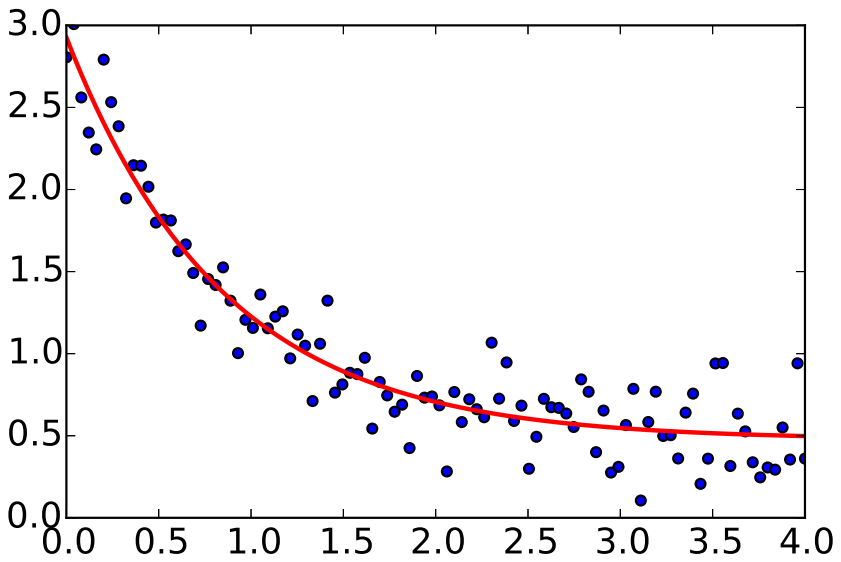
```



Bar Plot

```
1 import numpy as np
2 import matplotlib
3 import matplotlib.pyplot as plt
4 font = {'size': 16}
5 matplotlib.rc('font', **font)
6 colors = ['k', 'r', 'b', 'c', 'm']
```

1-6 Load up the requisite namespace, set font, and pick some colors

Bar Plot

```
 7 sites = [r'$r$-TiO$_2$ (110)',
 8          r'$m$-ZrO$_2$ ($\bar111$)',
 9          r'$\gamma$-Al$_2$O$_3$ (110)-3',
10          r'$\gamma$-Al$_2$O$_3$
   (110)-4$a$',
11          r'$\gamma$-Al$_2$O$_3$
   (110)-4$b$']
10 index = np.arange(len(estars))
11 estars = [4.174374, 5.960088, 4.67, 5.26, 4.92]
12 bar_width = 0.90
```

7-12 Define some data. Here, we define two datasets for the x-coordinate. Also define a "width" of each bar.

Bar Plot

```
13 fig = plt.figure()
14 ax = fig.add_subplot(111)
```

13-14 Define a `figure` and `axes` objects

Bar Plot

```
13 fig = plt.figure()
14 ax = fig.add_subplot(111)
15 bar1 = ax.bar(index, estars, width=bar_width)
16 for i in range(len(sites)):
17       bar1[i].set_color(colors[i])
```

15-17 Add bars to the plot. Want each bar to be a different color, so iterate through them.

Bar Plot

```
13 fig = plt.figure()
14 ax = fig.add_subplot(111)
15 bar1 = ax.bar(index, estars, width=bar_width)
16 for i in range(len(sites)):
17     bar1[i].set_color(colors[i])
18 ax.set_xticks(index + bar_width / 2)
19 ax.set_xticklabels(sites)
20 plt.xticks(rotation=15.)
21 for tick in ax.xaxis.get_major_ticks():
22     tick.label.set_fontsize(12)
23 plt.ylim([3, 7])
24 ax.set_xlabel('Oxide surface')
25 ax.set_ylabel('$E^*_s$ (eV)')
```

18-19 Default is that each bar is labeled via a number. Want a text label, and these lines enable this.

20-22 Rotate the labels by 15°, and change the font size on the labels.

23-25 Set a limit to y axis, and label both axes

Bar Plot

```
13 fig = plt.figure()
14 ax = fig.add_subplot(111)
15 bar1 = ax.bar(index, estars, width=bar_width)
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19 ax.set_xticklabels(sites)
20 plt.xticks(rotation=15.)
21 for tick in ax.xaxis.get_major_ticks():
22     tick.label.set_fontsize(12)
23 plt.ylim([3, 7])
24 ax.set_xlabel('Oxide surface')
25 ax.set_ylabel('$E^*_s$ (eV)')
26 plt.subplots_adjust(bottom=0.22)
27 plt.savefig('oxide_band_energies.eps')
```

18-19 Default is that each bar is labeled via a number. Want a text label, and these lines enable this.

20-22 Rotate the labels by 15°, and change the font size on the labels.

23-25 Set a limit to y axis, and label both axes

26 Pad out the bottom

27 Save the figure

- The following can be added to the `savefig` function to avoid the padding: pad_inches=0.5, bbox_inches='tight'

Bar Plot

```
13 fig = plt.figure()
14 ax = fig.add_subplot(111)
15 bar1 = ax.bar(index, estars, width=bar_width)
16 for i in range(len(sites)):
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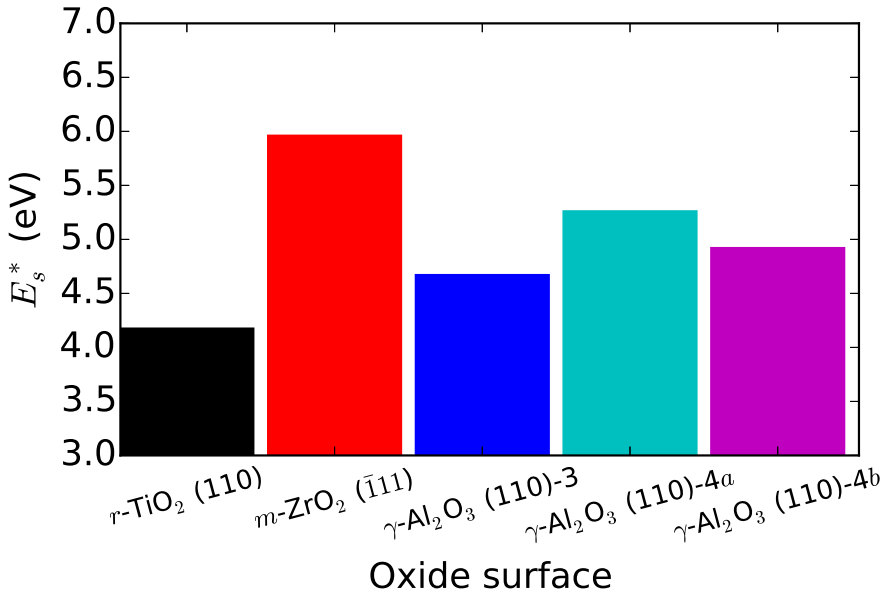
```



Subplots

11-12 Create the plotting environment

```
11 fig = plt.figure()
12 ax = fig.add_subplot(221)
```

Subplots

```
11 fig = plt.figure()
12 ax = fig.add_subplot(221)
13 ax.scatter(xdata, ydata,)
14 ax.plot(xdata, ydata2, linewidth=2, color='r')
```

11-12 Create the plotting environment

13-14 Plot the data. The random data is plotted as a scatter plot.

- subplot now takes something besides (111)
- (ncols, nrows, number)

Subplots

```
11 fig = plt.figure()
12 ax = fig.add_subplot(221)
13 ax.scatter(xdata, ydata,)
14 ax.plot(xdata, ydata2, linewidth=2, color='r')
15 plt.xlim([0, 4])
16 plt.ylim([0, 3.0])
17 ax.set_xticks([])
18 ax.set_yticks(np.arange(0, 4, 1))
```

11-12 Create the plotting environment

13-14 Plot the data. The random data is plotted as a scatter plot.

15-16 Set axes limits

17 Clear the x, set the y

Subplots

```
19 ax2 = fig.add_subplot(222)
20 ax2.scatter(xdata, ydata,)
21 ax2.plot(xdata, ydata2, linewidth=2, color='k')
22 ax2.tick_params(labelcolor='w', top='on',
   bottom='on', left='off', right='off')
```

15-16 Set axes limits

17 Clear the x, set the y

19 Second plot

20-21 Add the same data (being lazy!)

22 Clear axes labels

Subplots

```
19 ax2 = fig.add_subplot(222)
20 ax2.scatter(xdata, ydata,)
21 ax2.plot(xdata, ydata2, linewidth=2, color='k')
22 ax2.tick_params(labelcolor='w', top='on',
   bottom='on', left='off', right='off')
23 ax3 = fig.add_subplot(223)
24 ax3.scatter(xdata, ydata,)
25 ax3.plot(xdata, ydata2, linewidth=2,
   color='m')
26 plt.xlim([0, 4])
27 plt.ylim([0, 3.0])
29 ax3.set_xticks(np.arange(0, 5, 1))
30 ax3.set_yticks(np.arange(0, 4, 1))
```

15-16 Set axes limits

17 Clear the x, set the y

19 Second plot

20-21 Add the same data (being lazy!)

22 Clear axes labels

23 Third plot

24-25 Add the same data (being lazy!)

26-30 Set axes labels

Subplots

```
31 ax4 = fig.add_subplot(224)
32 ax4.scatter(xdata, ydata,)
33 ax4.plot(xdata, ydata2, linewidth=2, color='g')
35 plt.xlim([0, 4])
36 plt.ylim([0, 3.0])
37 ax4.set_xticks(np.arange(0, 5, 1))
38 ax4.set_yticks([])
```

15-16 Set axes limits

17 Clear the x, set the y

19 Second plot

20-21 Add the same data (being lazy!)

22 Clear axes labels

23 Third plot

24-25 Add the same data (being lazy!)

26-30 Set axes labels

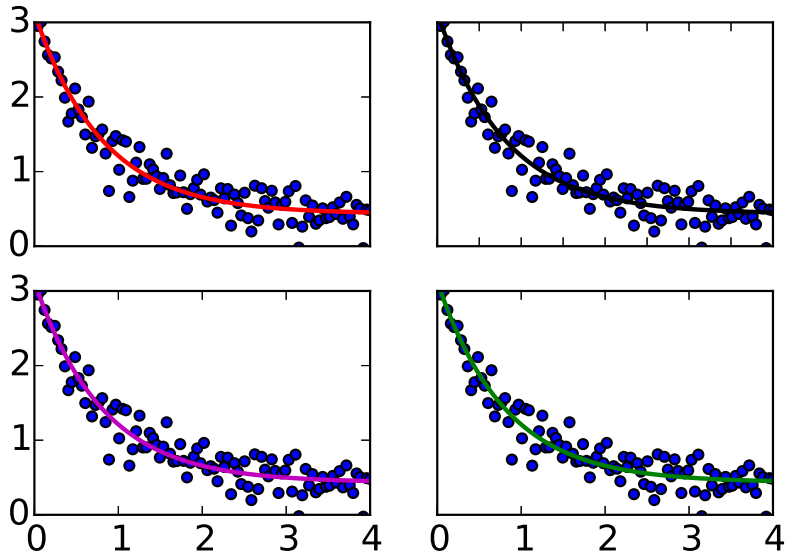
31 Fourth plot

32-33 Add the same data (being lazy!)

34-38 Set axes labels

Subplots

```
31 ax4 = fig.add_subplot(224)
32 ax4.scatter(xdata, ydata,)
33 ax4.plot(xdata, ydata2, linewidth=2, color='g')
35 plt.xlim([0, 4])
36 plt.ylim([0, 3.0])
37 ax4.set_xticks(np.arange(0, 5, 1))
38 ax4.set_yticks([])
```



QUESTIONS?