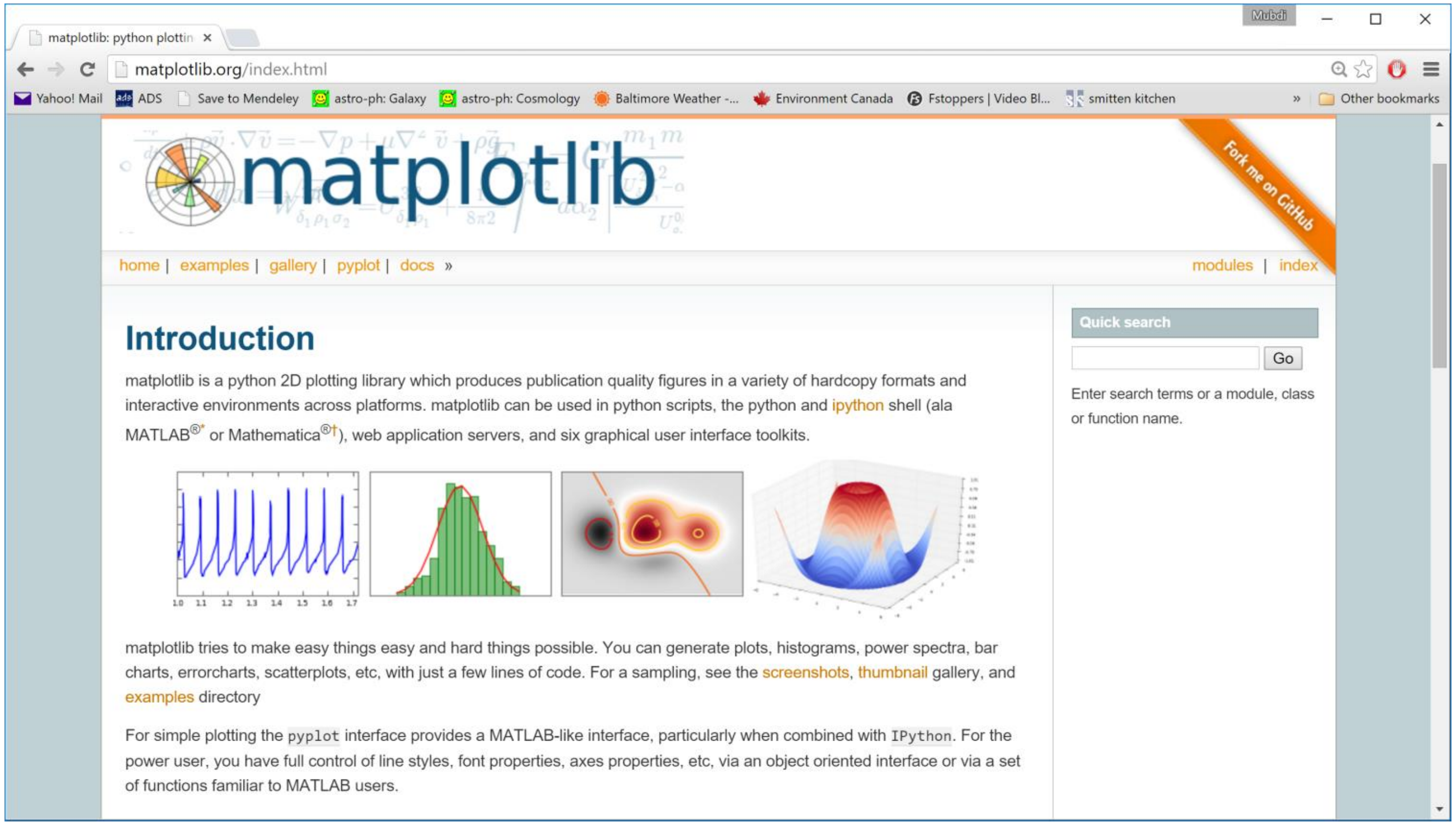
4. BASIC PLOTTING

JHU Physics & Astronomy Python Workshop 2017

Lecturer: Mubdi Rahman

INTRODUCING MATPLOTLIB!



Introduction

matplotlib is a python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. matplotlib can be used in python scripts, the python and ipython shell (ala MATLAB®* or Mathematica®†), web application servers, and six graphical user interface toolkits.

matplotlib tries to make easy things easy and hard things possible. You can generate plots, histograms, power spectra, bar charts, errorcharts, scatterplots, etc, with just a few lines of code. For a sampling, see the screenshots, thumbnail gallery, and examples directory

For simple plotting the `pyplot` interface provides a MATLAB-like interface, particularly when combined with `IPython`. For the power user, you have full control of line styles, font properties, axes properties, etc, via an object oriented interface or via a set of functions familiar to MATLAB users.

Very powerful plotting package.
The Docs: http://matplotlib.org/api/pyplot_api.html

GETTING STARTED WITH MATPLOTLIB

Matplotlib has multiple ways of interfacing with it, as well as a large number of additional modules and patches that extend its capabilities significantly. The main interface we'll be using for this work is the **pyplot** interface:

```
import matplotlib.pyplot as plt
```

You can choose to run matplotlib either **interactively** or **non-interactively**. For the interactive mode, the plot gets updated as you go along. For non-interactive, the plot doesn't show up until you've finished everything. To switch between the two:

```
plt.ion() # Turn interactive mode on
plt.ioff() # Turn interactive mode off
plt.show() # Show the plot when interactive mode off
```

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plt.show() # Show the plo
```

MUBDI IS A BONEHEAD NOTE:

I started using python back in the "Wild West" days. Some of the defaults of how I code are not the standards suggested today. In particular, I import matplotlib.pyplot as p. Call me on this!

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```
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plt.ioff() # Turn inter
plt.show() # Show the p
```

PRO TIP:

If you are in a situation where you can't display a plot or don't have the ability (i.e., ssh-ing without Xforwarding, running on a webserver), do the following before importing pyplot:

```
import matplotlib
matplotlib.use('Agg')
```

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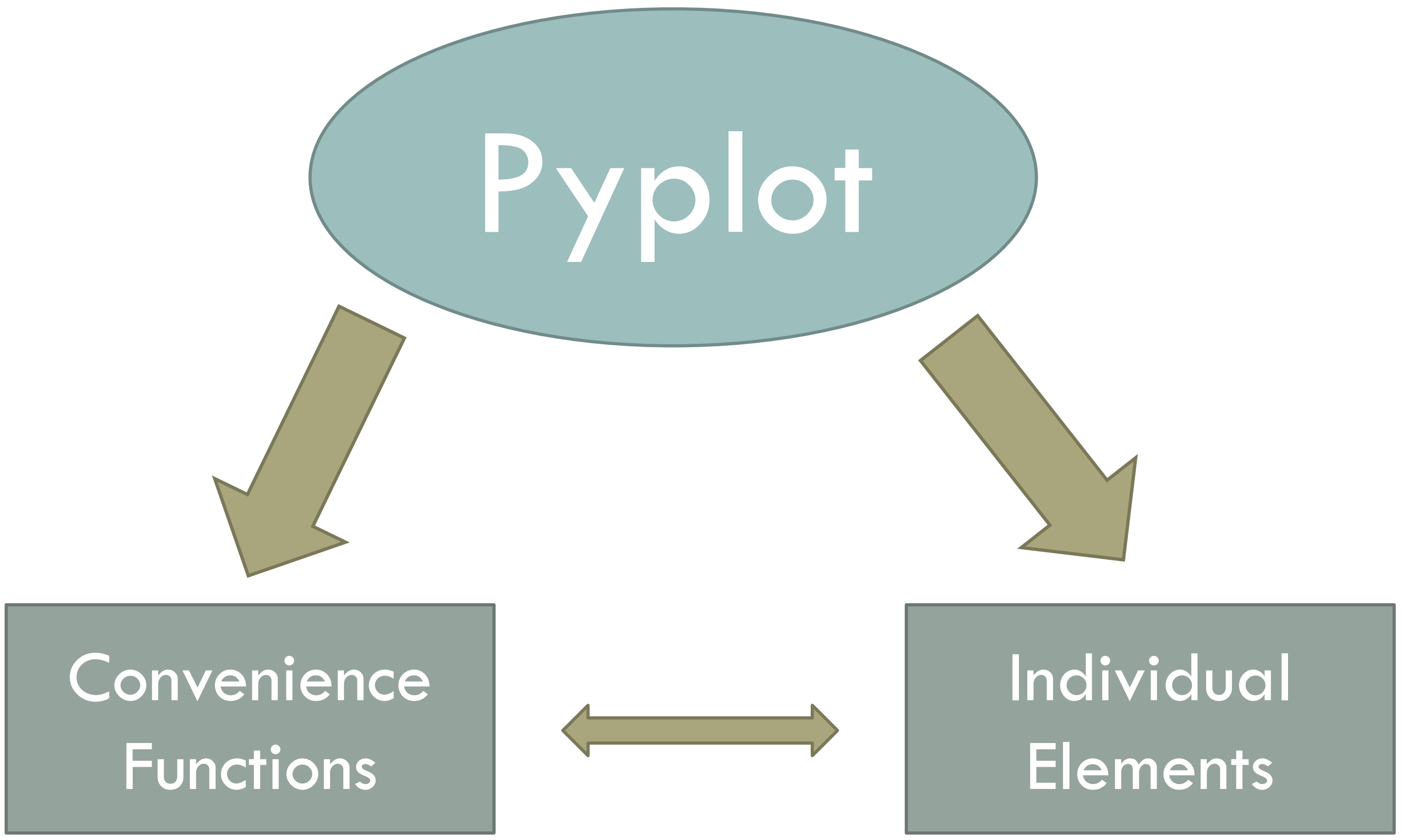
PRO TIP 2:

If you are using an jupyter notebook, you can make the plots appear *inline* in the notebook if you use the magic function:

```
%matplotlib inline
```

If you don't, the plots will show up in a popup window as with the other methods.

CHOOSE YOUR OWN ADVENTURE!



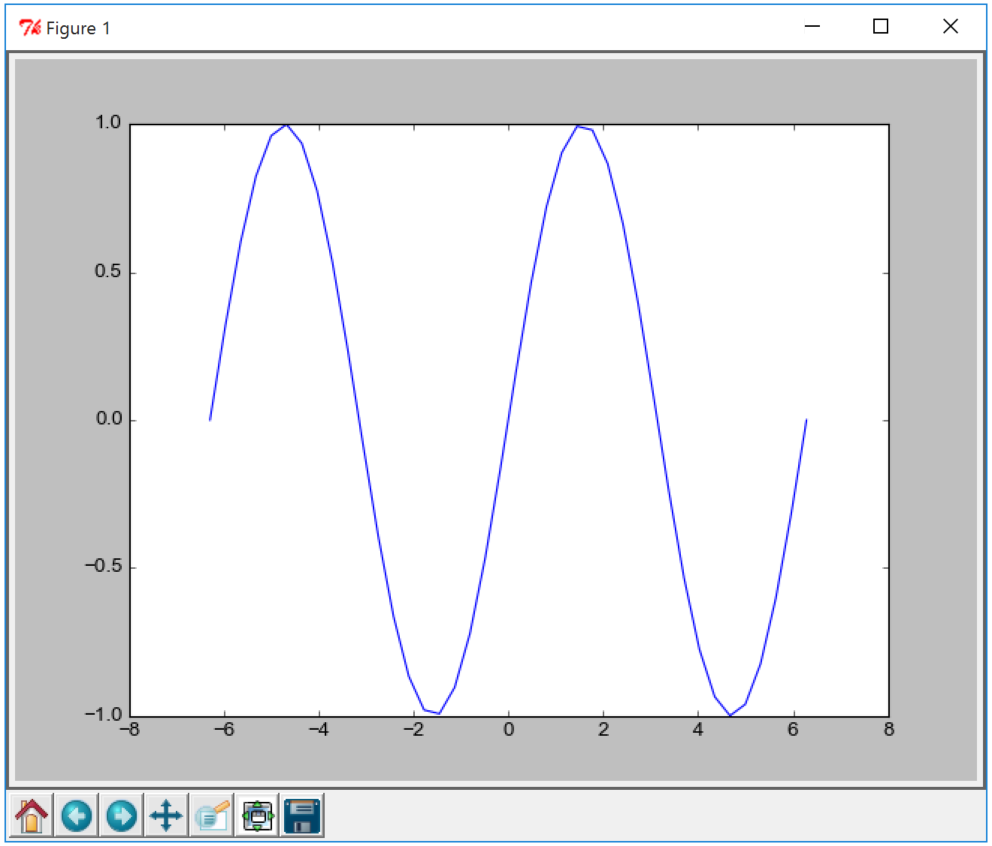
- Really simple to start
- Not as much flexibility

- Requires more coding
- Can plot anything!

SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

```
# The simplest of
# plots
plt.plot(x, y)
```



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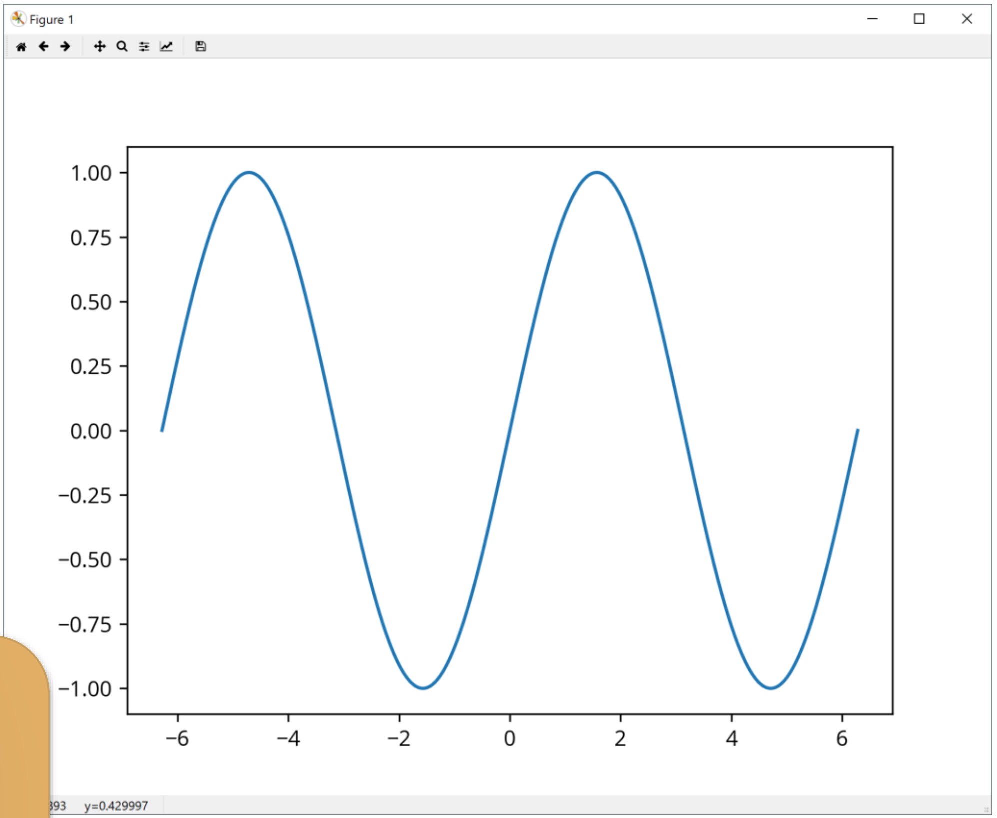


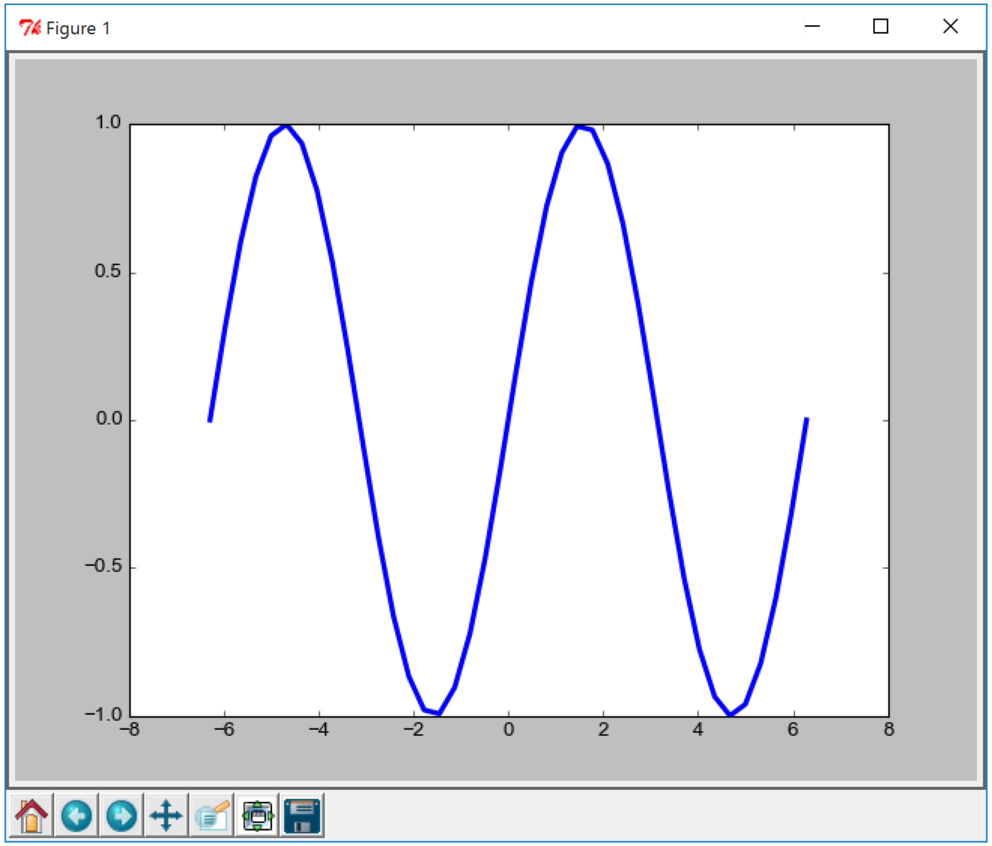
PRO TIP:

Actually, with matplotlib version 2 or greater, it will look more like this

SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

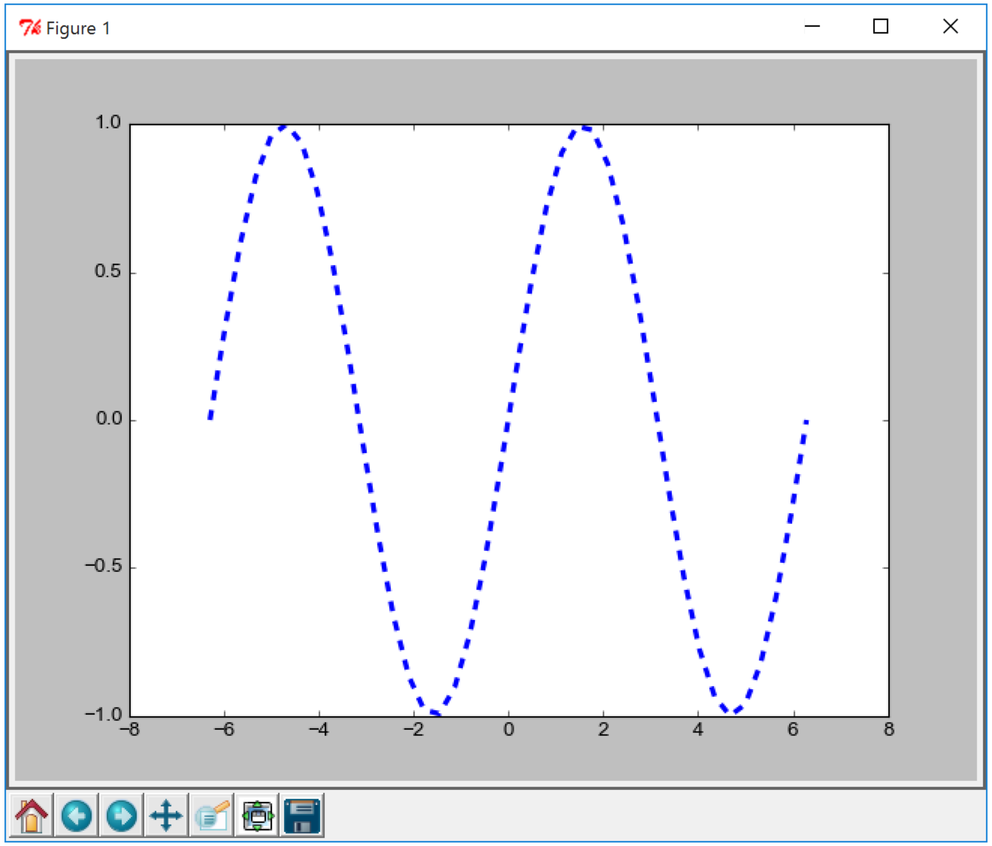
```
plt.plot(x, y,
linewidth=3)
```



SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

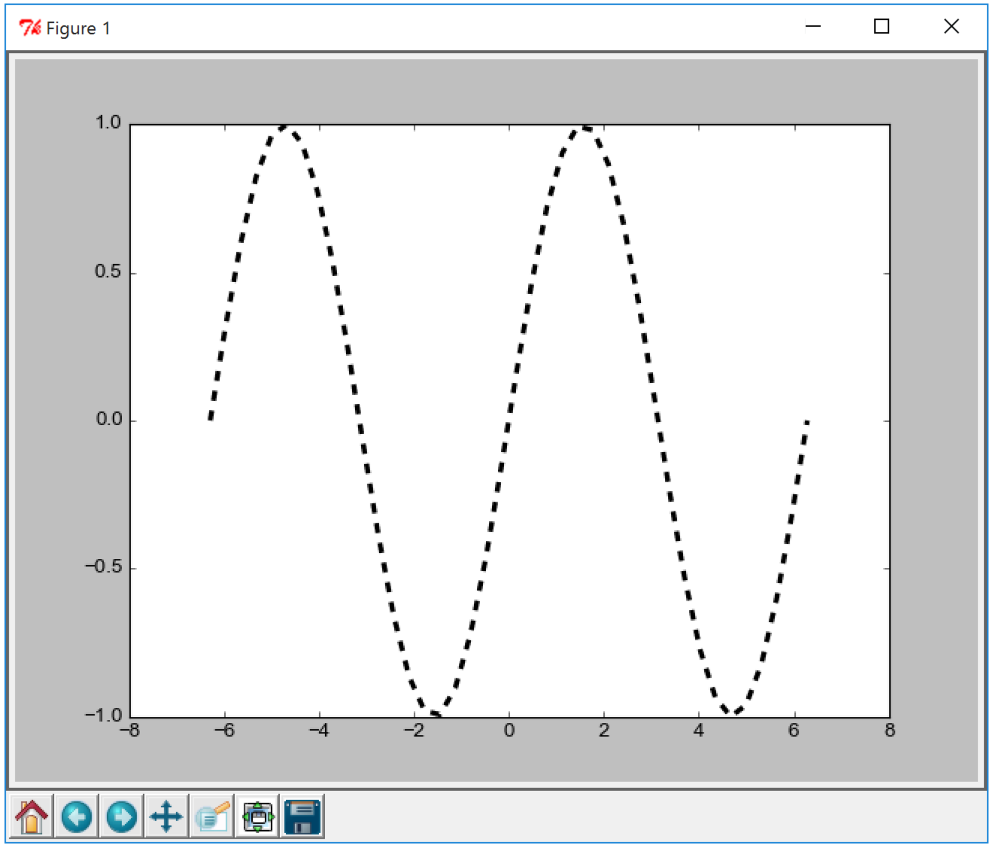
```
plt.plot(x, y,
linewidth=3,
linestyle='dashed')
```



SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

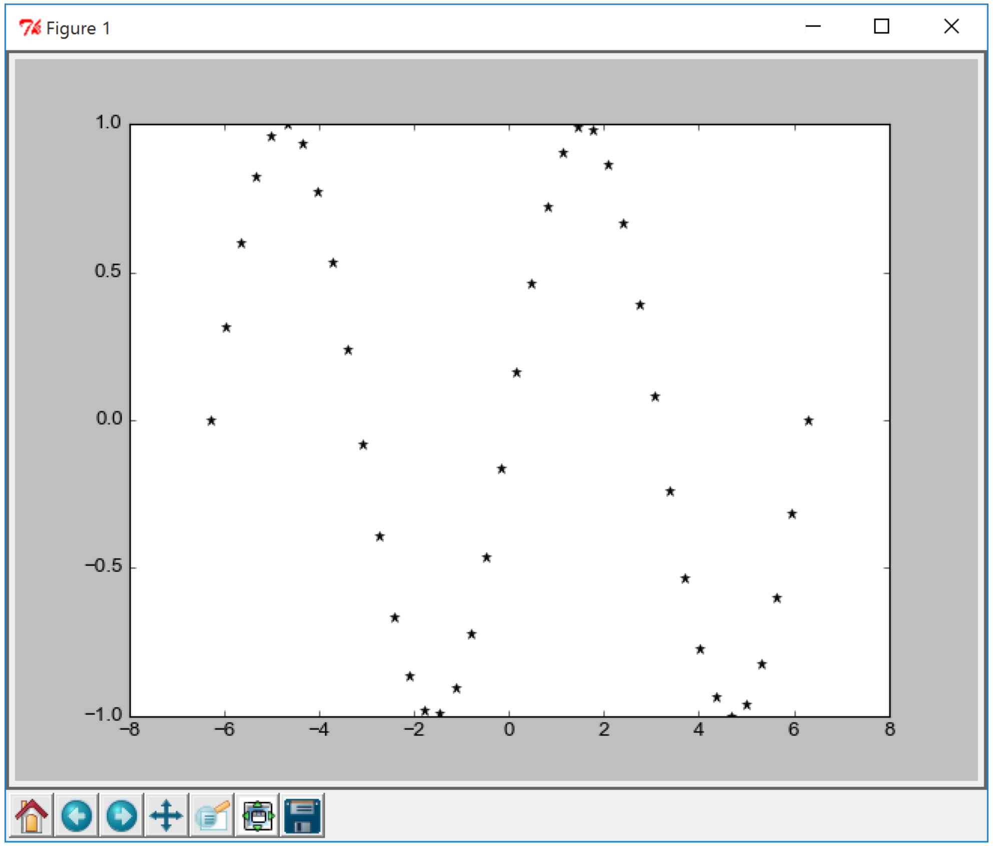
```
plt.plot(x, y,
linewidth=3,
linestyle='dashed',
color='k')
```



SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

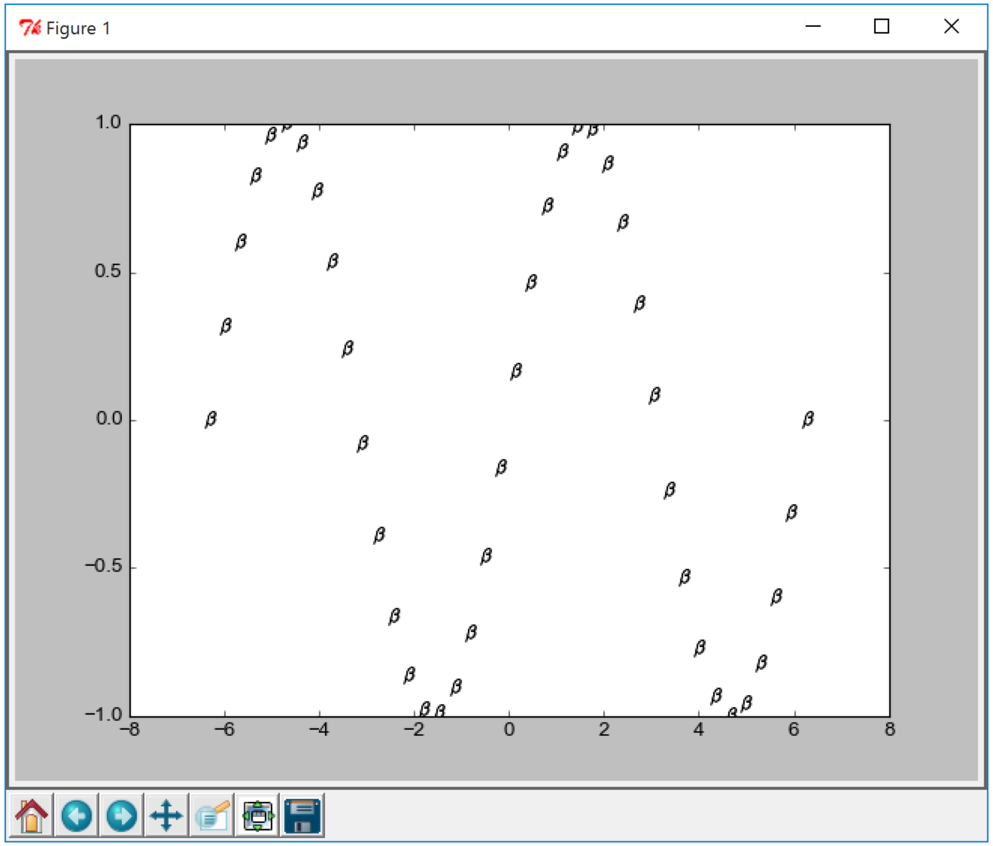
```
plt.plot(x, y,
linestyle='none',
color='k',
marker='*')
```



SIMPLE PLOTTING BASICS

Much of your power is in the plot command:

```
plt.plot(x, y,
linestyle='none',
color='k',
marker='$\\beta$',
markersize=10)
```



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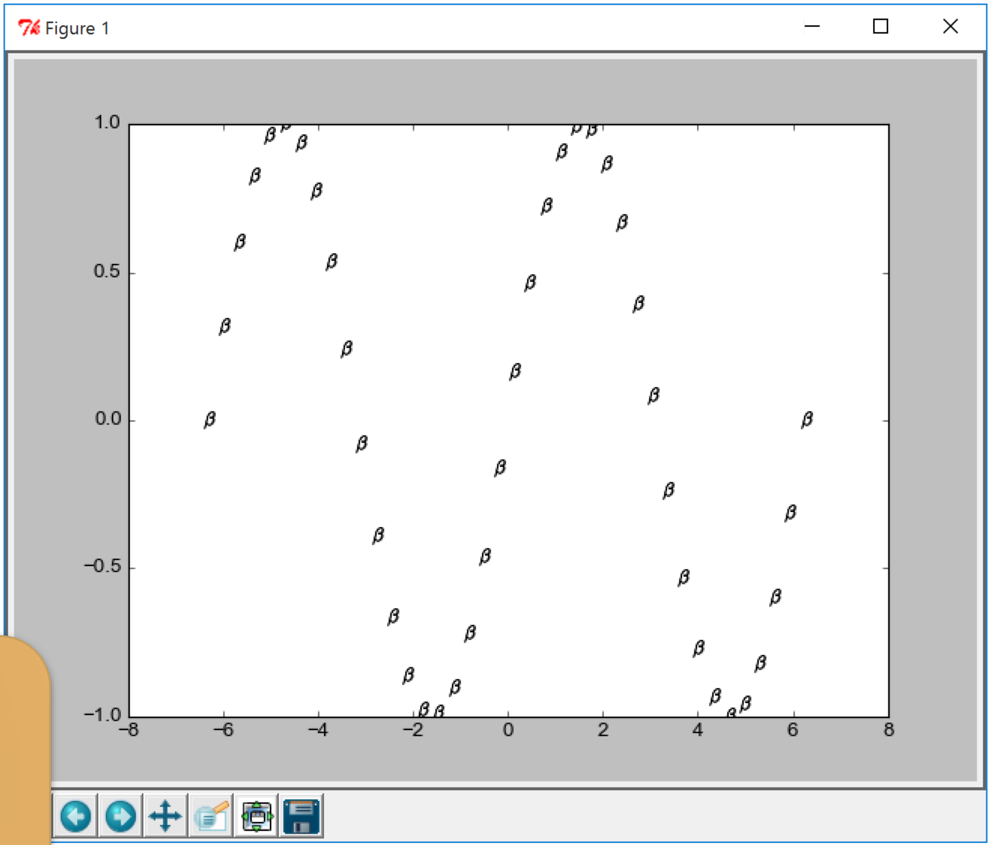


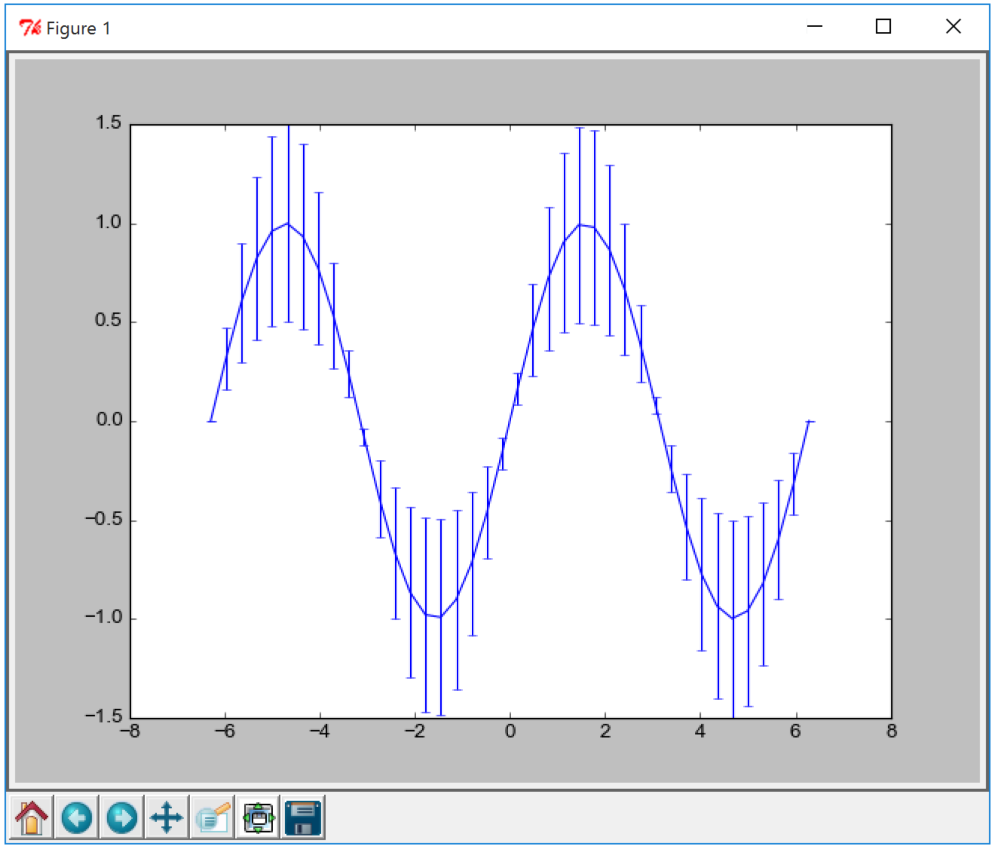
PRO TIP:

For a scatter plot, use plt.scatter() instead

SIMPLE PLOTTING BASICS

Creating error bars:

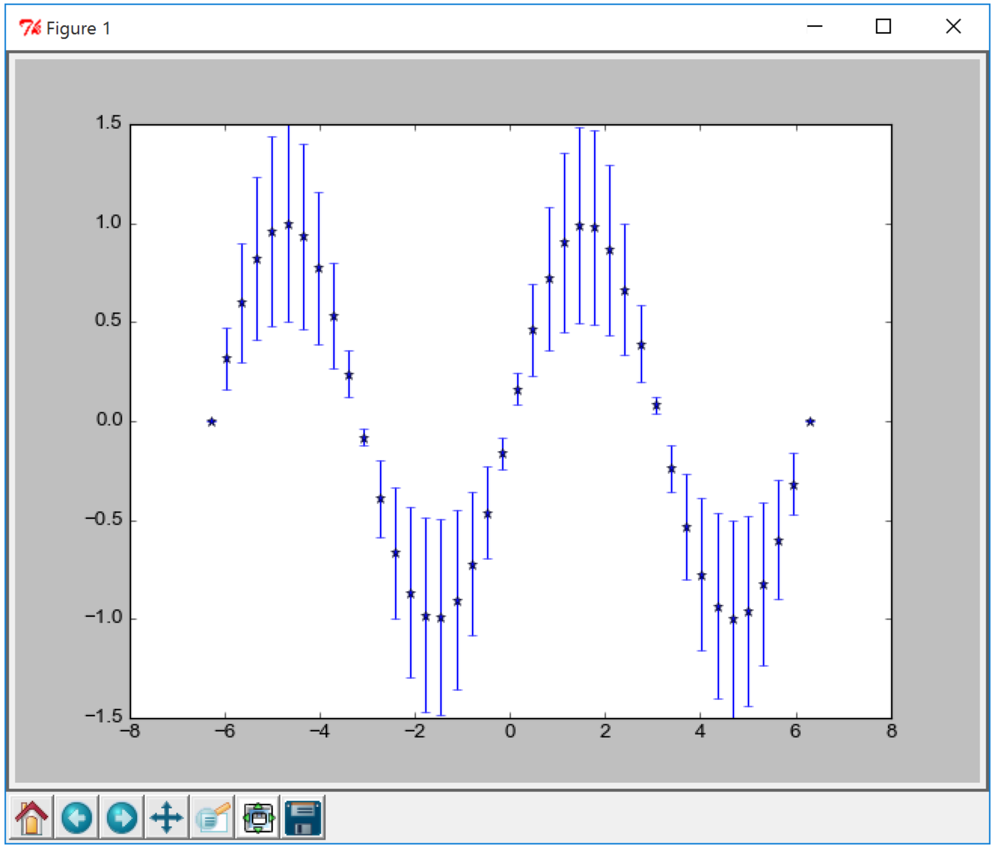
```
plt.errorbar(x, y,
yerr=yerr)
```



SIMPLE PLOTTING BASICS

Creating error bars:

```
plt.errorbar(x, y,
yerr=yerr, fmt='*')
```



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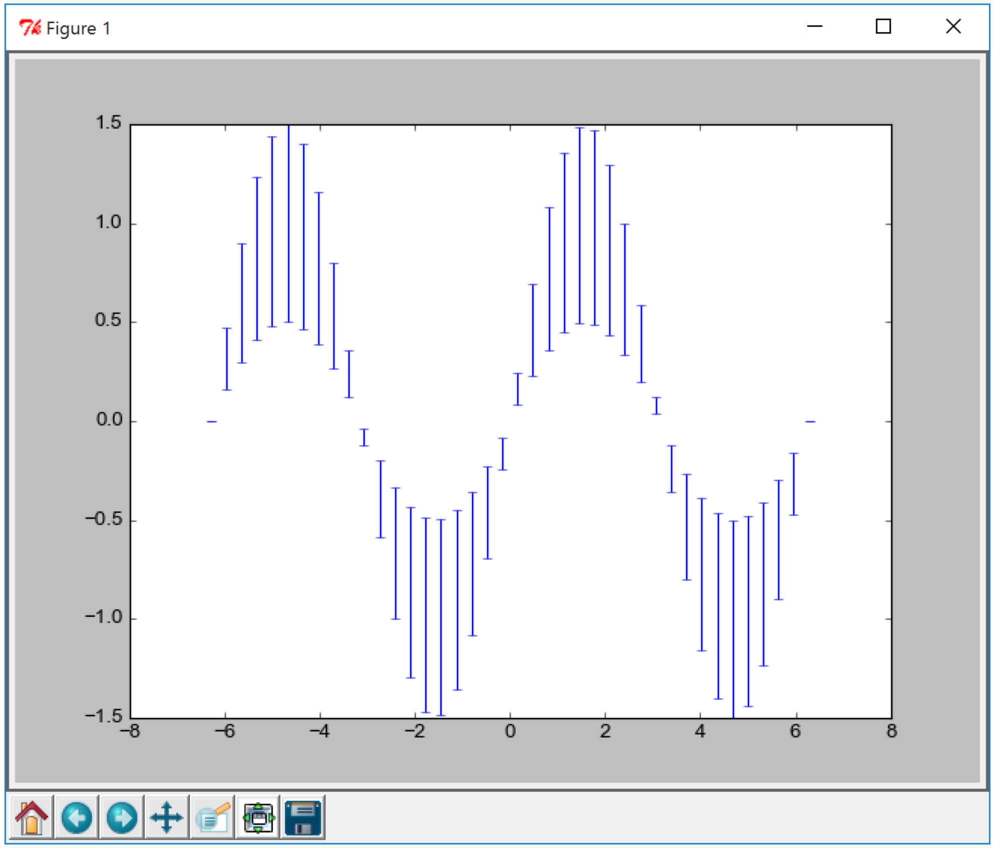
Creating error bars:

```
plt.errorbar(x, y,
yerr=yerr,
fmt='none')
```



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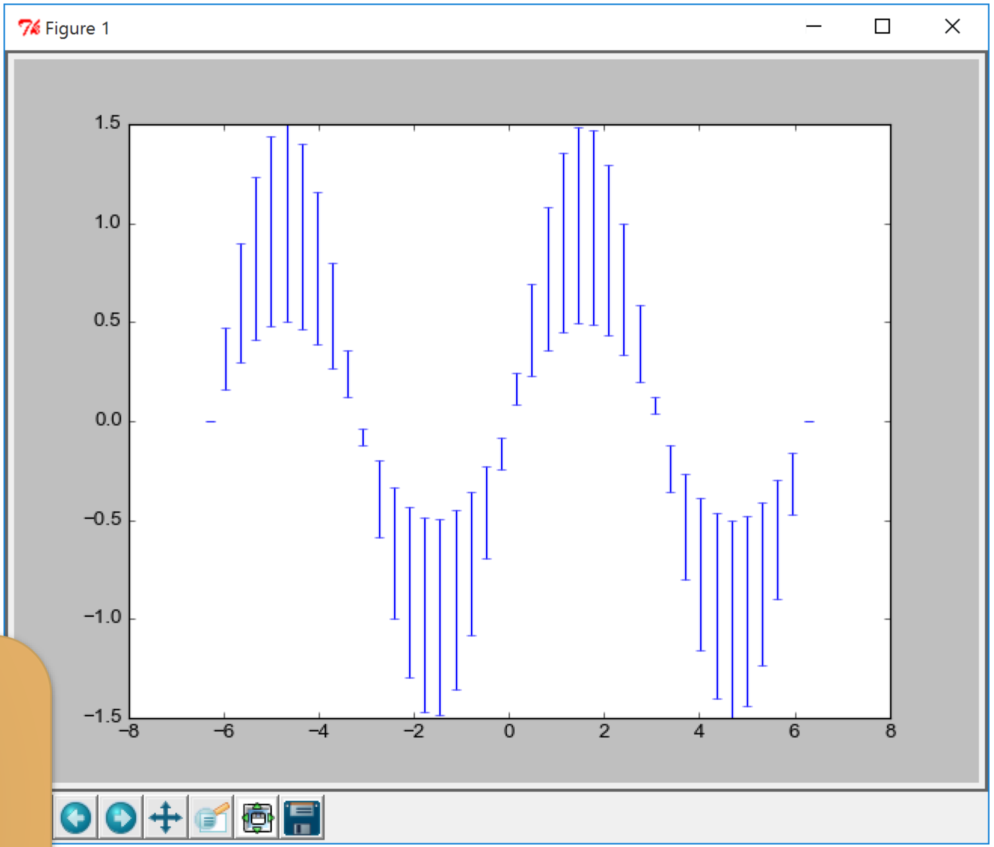


PRO TIP:

All of these functions have **many** more options. Check the docs.

COLOURS IN MATPLOTLIB

In matplotlib, colours can be specified in a number of ways:

Basic Colours

Most basic (primary and secondary) colours can be quoted by their first letter:

‘b’ – blue
‘r’ – red
‘g’ – green
‘y’ – yellow
‘w’ – white
‘k’ – black

HTML Colours

Any defined HTML colour name is a valid colour:

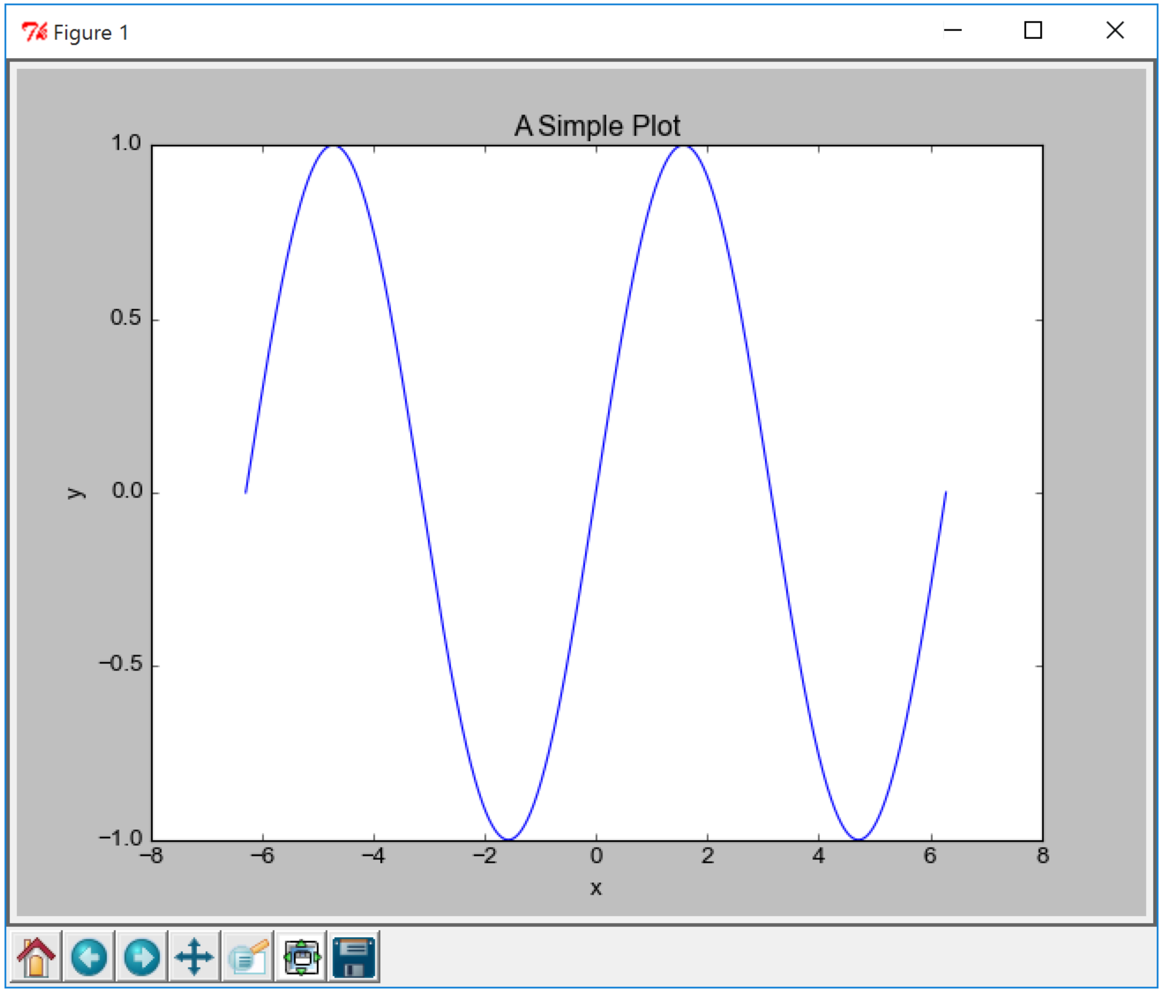
“deeppink”
“slateblue”
“ivory”
“lemonchiffon”

Hex code

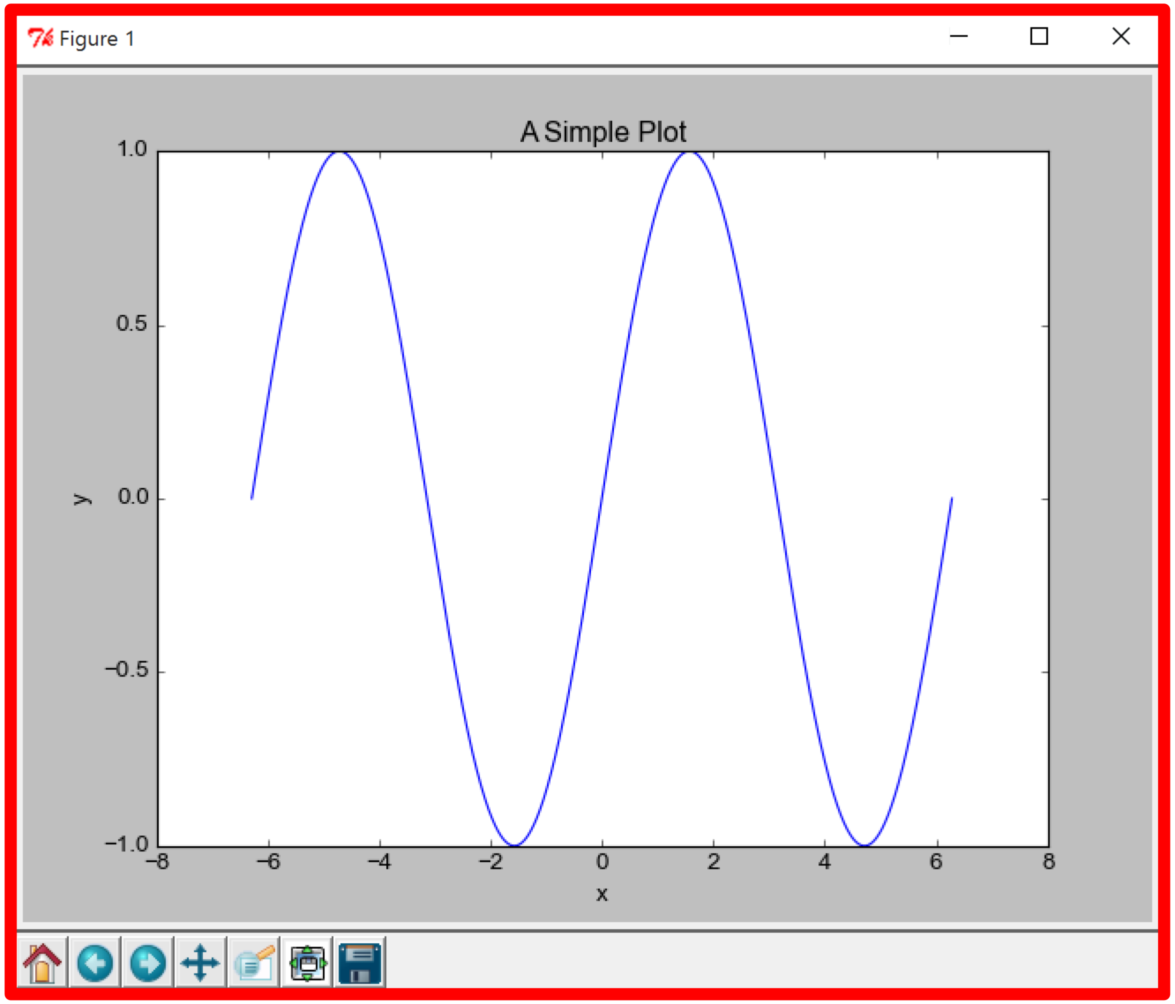
Any string of hex codes in the form of “#rrggbb” where each pair goes from 00 to ff:

“#ffffff”
“#000000”
“#ff0000”
“#ff00ff”

ANATOMY OF A PLOT WINDOW



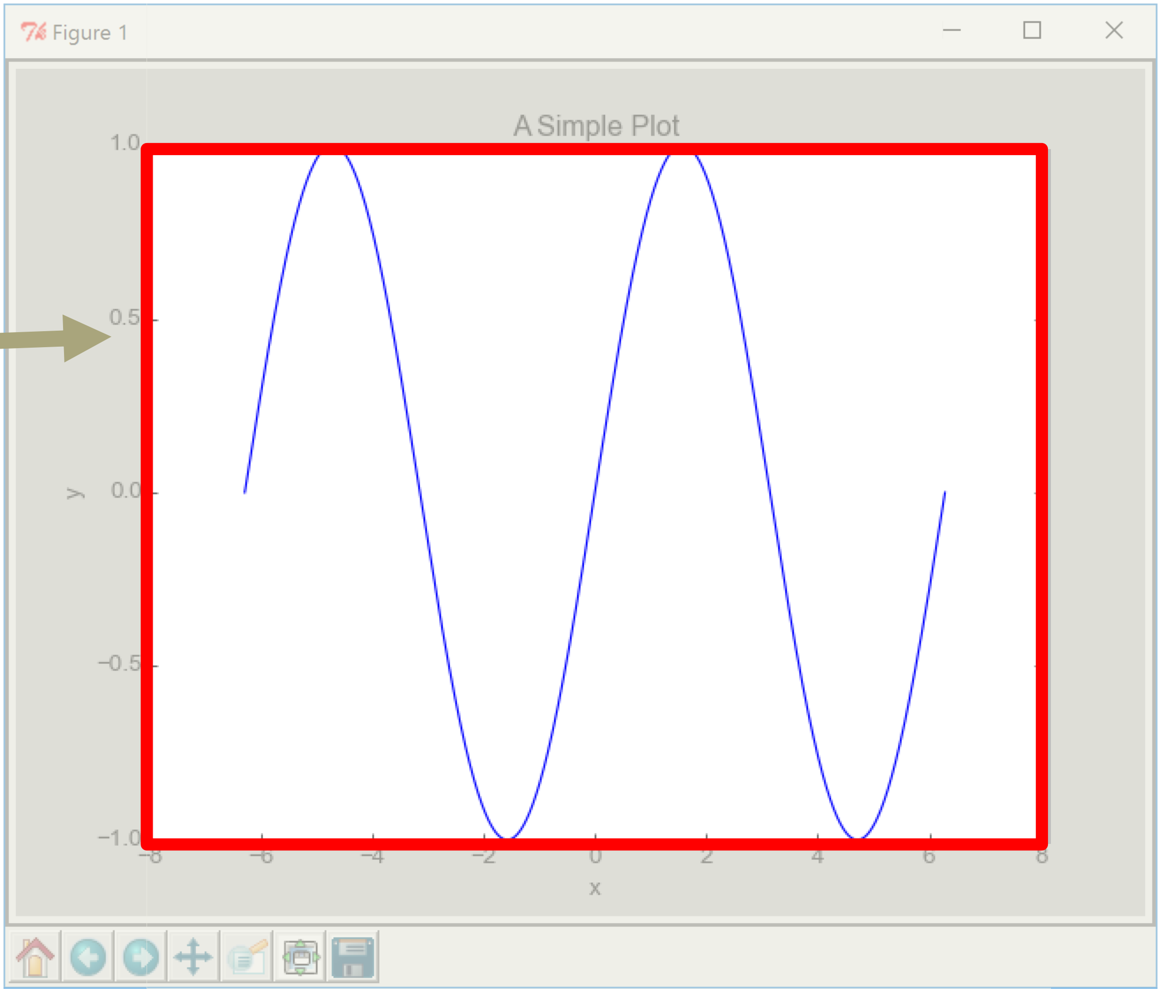
ANATOMY OF A PLOT WINDOW



Figure

ANATOMY OF A PLOT WINDOW

Axis



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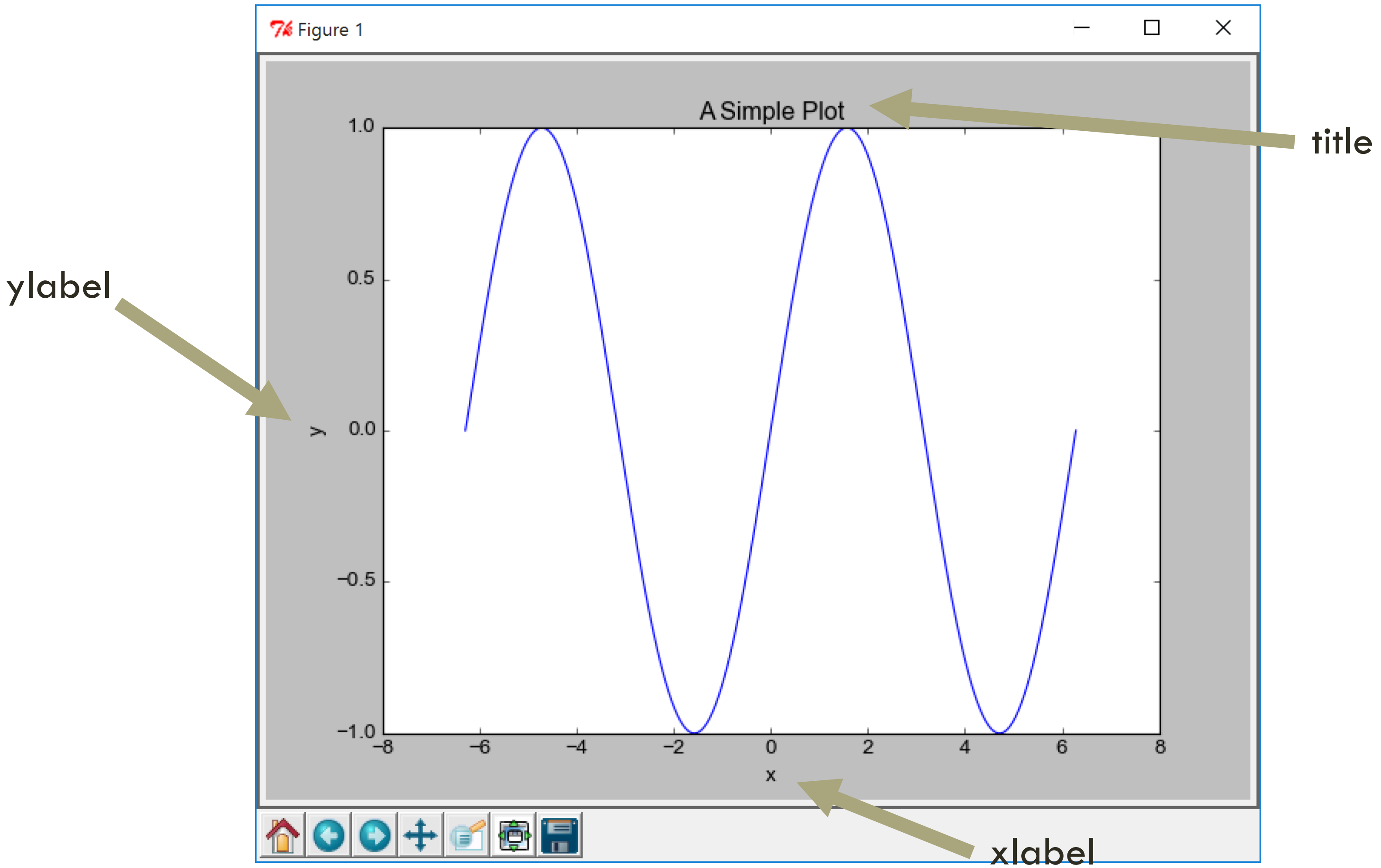

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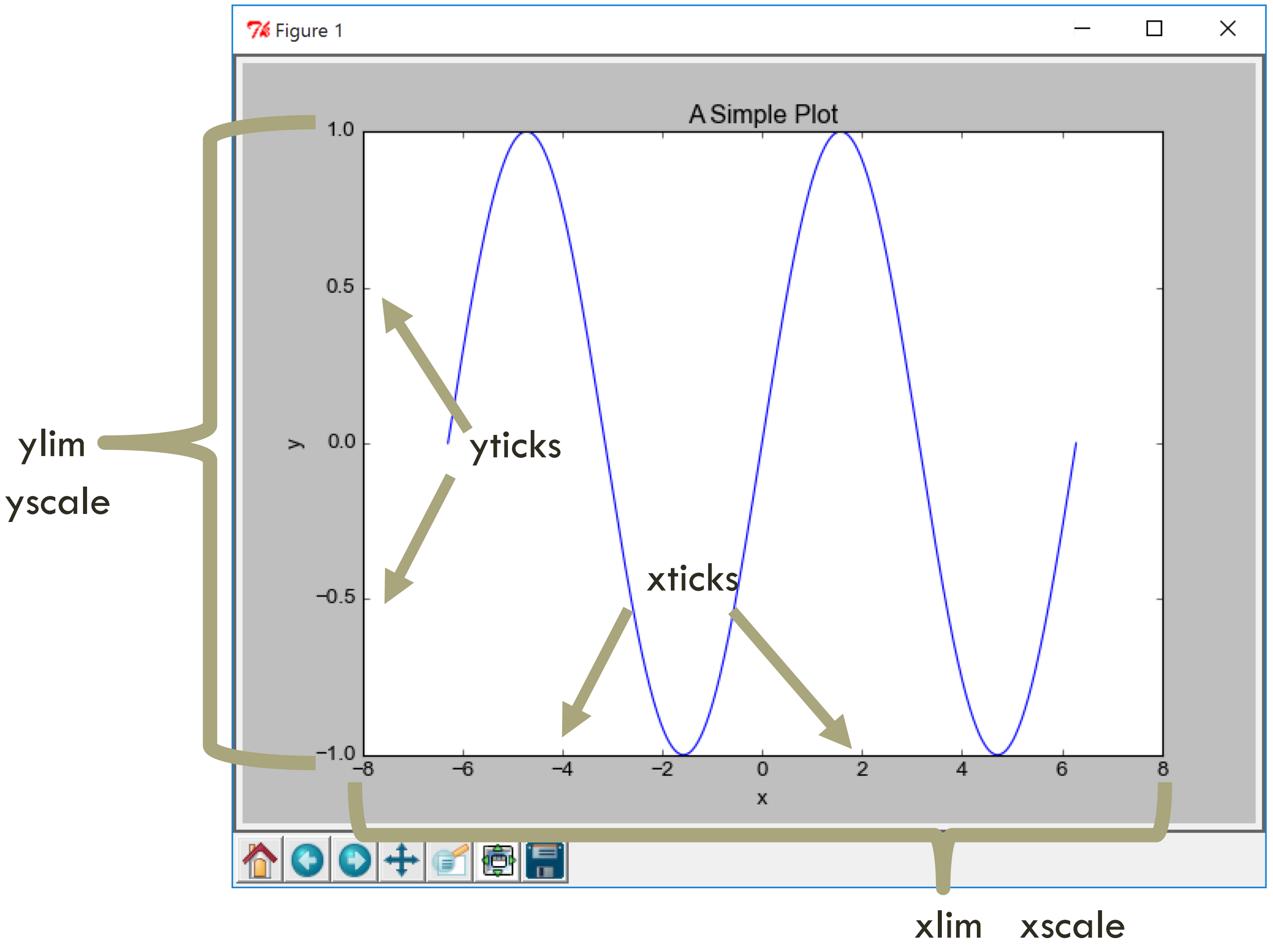


HOUSEKEEPING FUNCTIONS

To deal with the various figures and axes that there can be, you have the following housekeeping functions:

```
# Clearing Plots
plt.cla() # Clear Current Axis
plt.clf() # Clear Current Figure

# Getting active objects
ax1 = plt.gca() # Get Current Axis
fig1 = plt.gcf() # Get Current Figure

# Make new figure
plt.figure() # Make new figure (with defaults)
plt.figure(figsize=(6,8)) # Make new figure (6”x8”)
```

SETTING AXIS PROPERTIES

You can (at any time in the plotting) change the range (lim), scale (log or linear), labels or ticks on a plot. Replace x with y (or vice versa) when necessary:

```
# Limits and Scale
plt.xlim([0, 5]) # Set x-limits to 0 -> 5
plt.yscale('log') # Set y-axis to logarithmic

# Setting Labels
plt.xlabel('X-axis') # Label the X-axis
plt.title("Title") # Set the Axis title

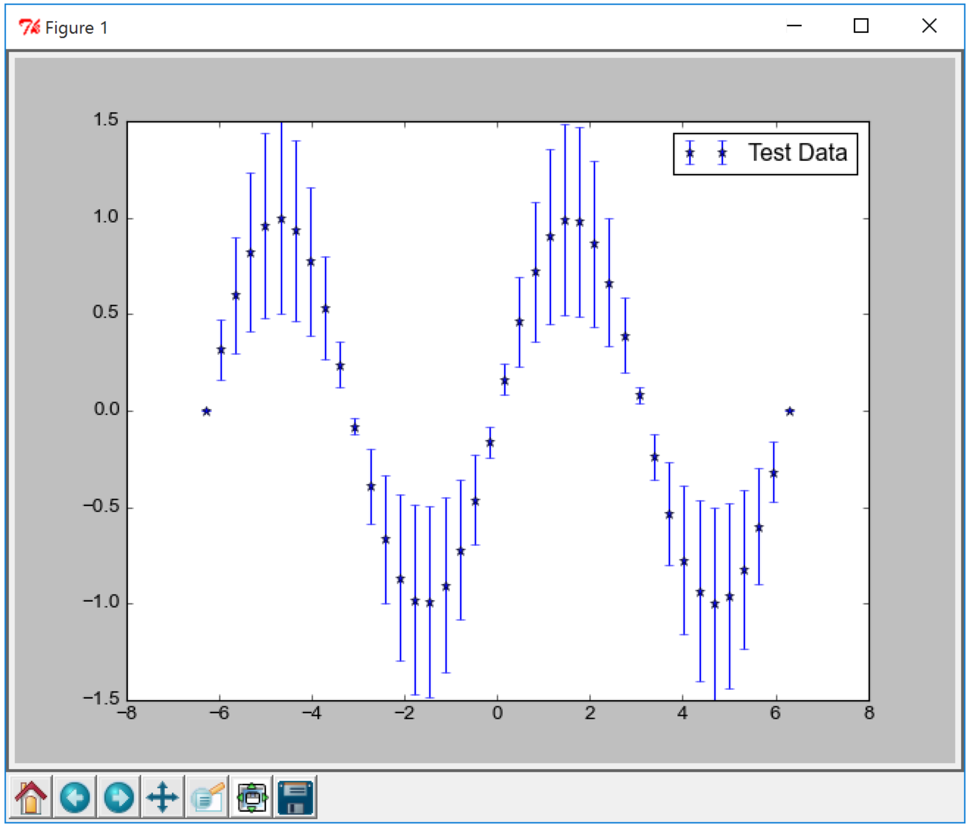
# Setting Ticks
plt.xticks([0, 4, 10, 19]) # Location of x-ticks
```

LABELS AND LEGENDS (OH MY!)

You can use “labels” on any plot object to automatically populate a legend:

```
plt.errorbar(…,
label=“Test Data”)

plt.legend()
```

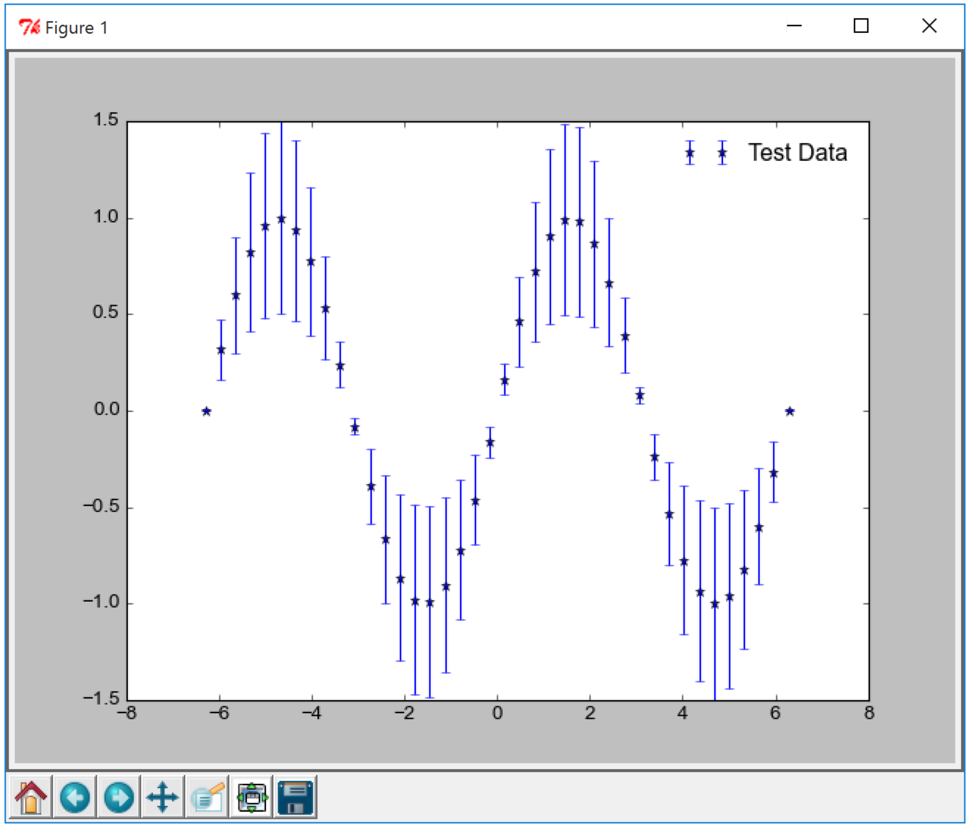


LABELS AND LEGENDS (OH MY!)

You can use “labels” on any plot object to automatically populate a legend:

```
plt.errorbar(…,
label=“Test Data”)

plt.legend(
frameon=False
)
```



SAVING A FIGURE

Saving a figure is a one-line operation. Matplotlib will figure out what format you want by the extension of the filename:

```
plt.savefig(“filename.pdf”) # Saving as a PDF
plt.savefig(“filename.png”) # Saving as a PNG
plt.savefig(“filename.eps”) # Saving as an EPS

# Can also determine what output DPI:
plt.savefig(“filename.jpg”, dpi=300)
```

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plt.savefig(“filename.png”) # Saving as a PNG
plt.savefig(“filename.eps”) # Saving as an EPS

# Can also determine what output DPI:
plt.savefig(“filename.jpg”, dpi
```

PRO TIP:

EPS files do not support transparency natively

BUILDING FROM THE GROUND UP

This method gives you a lot more flexibility. Instead of using convenience functions, you use methods on each of the objects:

```
fig1 = plt.figure()
ax1 = fig1.add_axes([0.1, 0.1, 0.8, 0.8])

ax1.plot(x, y, marker=‘o’, label=‘plotted line’)
ax1.legend()

ax1.set_xlim([1, 10])
ax1.set_ylim([0, 5])

ax1.set_xscale(‘log’)
ax1.set_xtitle(‘X Label’)
ax1.set_ytitle(‘Y Label’)
fig1.savefig(filename)
```

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ax1.set_ytitle(‘Y Label’)
fig1.savefig(filename)
```

This uses matplotlib’s location format, which takes the format of:

[*left*, *bottom*, *width*, *height*]

where each of the numbers are from 0 to 1 (in units of a fraction of the figure)

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fig1.savefig(filename)
```

All of those major plotting functions (i.e, plot, scatter, legend, *et cetera*) are now just methods on the axis.

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ax1.set_xtitle(‘X Label’)
ax1.set_ytitle(‘Y Label’)
fig1.savefig(filename)
```

All axis properties (i.e., x/ylim, x/yscale) can be set by the methods axis.set_*property*. Also, you can get the current values for these by axis.get_*property*.

BUILDING FROM THE GROUND UP

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```
fig1 = plt.figure()
ax1 = fig1.add_axes([0.1, 0.1, 0.8, 0.8])

ax1.plot(x, y, marker='o', label='plotted line')
ax1.legend()

ax1.set_xlim([1, 10])
ax1.set_ylim([0, 5])

ax1.set_xscale('log')
ax1.set_xtitle('X Label')
ax1.set_ytitle('Y Label')
fig1.savefig(filename)
```

Saving the figure is a method of the figure itself

BUILDING FROM THE GROUND UP

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ax1.legend()

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ax1.set_ylim([0, 5])

ax1.set_xscale(‘log’)
ax1.set_xtitle(‘X Label’)
ax1.set_ytitle(‘Y Label’)
fig1.savefig(filename)
```

PRO TIP:

This is particularly useful if you have multiple figures and axes.

CUSTOMIZING DEFAULTS

There's a lot of different parameters that matplotlib chooses by default, but you can set your own using a **matplotlibrc** file. This file will not exist by default, but you can download a sample one here:

http://matplotlib.org/_static/matplotlibrc

The place to put this file depends on your platform:

Windows: *UserDirectory*/.matplotlib/matplotlibrc
(i.e., C:/Users/*username*/.matplotlib/matplotlibrc)

MacOS: *UserDirectory*/.matplotlib/matplotlibrc
(i.e., Users/*username*/.matplotlib/matplotlibrc)

Linux: *UserDirectory*/.config/matplotlib/matplotlibrc
(i.e., /home/*username*/.config/matplotlib/matplotlibrc)

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(i.e., C:/Users/*username*/.matplotlib/matplo

MacOS: *UserDirectory*/.matplotlib/matplotli
(i.e., Users/*username*/.matplotlib/matplotlib

Linux: *UserDirectory*/.config/matplotlib/matp
(i.e., /home/*username*/.config/matplotlib/matplotlibrc)

PRO TIP:

The default matplotlib font is a crime against typography. Change it as soon as you can.

If you want to replace it with an open source font, may I suggest either **Open Sans** or **Source Sans Pro**?

EXERCISE TIME!

But when I call you never seem to be home.