Data Visualization with Pandas

Basics

- Use matplotlib
  - Based on matlab
    - Allows
      - histograms
      - line plots
      - box-plots
      - scatter plots
      - hex-density plots

Basics

- Import numpy as np
- Import pandas as pd
- Import matplotlib.pyplot as plt

Basic Example

- Import an artificial time series

```
>>> ts1 = pd.read_csv('../Data/ts1.csv')
```

- Show it:

```
>>> ts1.info()
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5000 entries, 0 to 4999
Data columns (total 2 columns):
time    5000 non-null int64
 TS     5000 non-null float64
dtypes: float64(1), int64(1)
memory usage: 78.2 KB
```

Basic Example

- Use head and tail

```
ts1.head()
ts1.tail()
```

- To make it more realistic, we need to make the index into one with actual dates
- Drop the column 'time'
  - We want to change the data frame, so we need to set `inplace` to `True`

Basic Example

```
>>> ts1.drop(columns=['time'], inplace=True)
>>> ts1.head()
            TS
0  1027.096129
1  1041.701344
2  1046.905793
3  1038.360279
4  1033.118933
```

- Create a **new** column with dates starting at January 1, 2001.
  - Use Bing to Google the name of the function:

```
>>> ts1['time'] = pd.date_range(start='1/1/2001',
periods = 5000)
```

Basic Example

- We still have an index, but now a new column

```
>>> ts1['time'] = pd.date_range(start='1/1/2001',
periods=5000)
>>> ts1.head()
            TS       time
0  1027.096129 2001-01-01
1  1041.701344 2001-01-02
2  1046.905793 2001-01-03
3  1038.360279 2001-01-04
4  1033.118933 2001-01-05
```

Basic Example

- Now we can re-index by setting the index

```
>>> ts1.set_index('time', inplace = True)

>>> ts1.info()
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 5000 entries, 2001-01-01 to 2014-09-09
Data columns (total 1 columns):
 TS    5000 non-null float64
dtypes: float64(1)
memory usage: 78.1 KB

>>> ts1.head()
                     TS
time
2001-01-01  1027.096129
2001-01-02  1041.701344
```

Basic Example

- If we try to only access the TS data, we run into a problem

```
>>> ts1.TS
Traceback (most recent call last):
  File "<pyshell#73>", line 1, in <module>
    ts1.TS
  File "/Library/Frameworks/Python.framework/
Versions/3.8/lib/python3.8/site-packages/pandas/
core/generic.py", line 5179, in __getattr__
    return object.__getattribute__(self, name)
AttributeError: 'DataFrame' object has no attribute
'TS'
```

Basic Example

- We can look at the columns of the data frame

```
>>> ts1.columns
Index([' TS'], dtype='object')
```

- And now we see the problem (cost me about an hour of my life)

```
>>> ts1.columns
Index([' TS'], dtype='object')
```

- The csv file has an additional white space after the comma

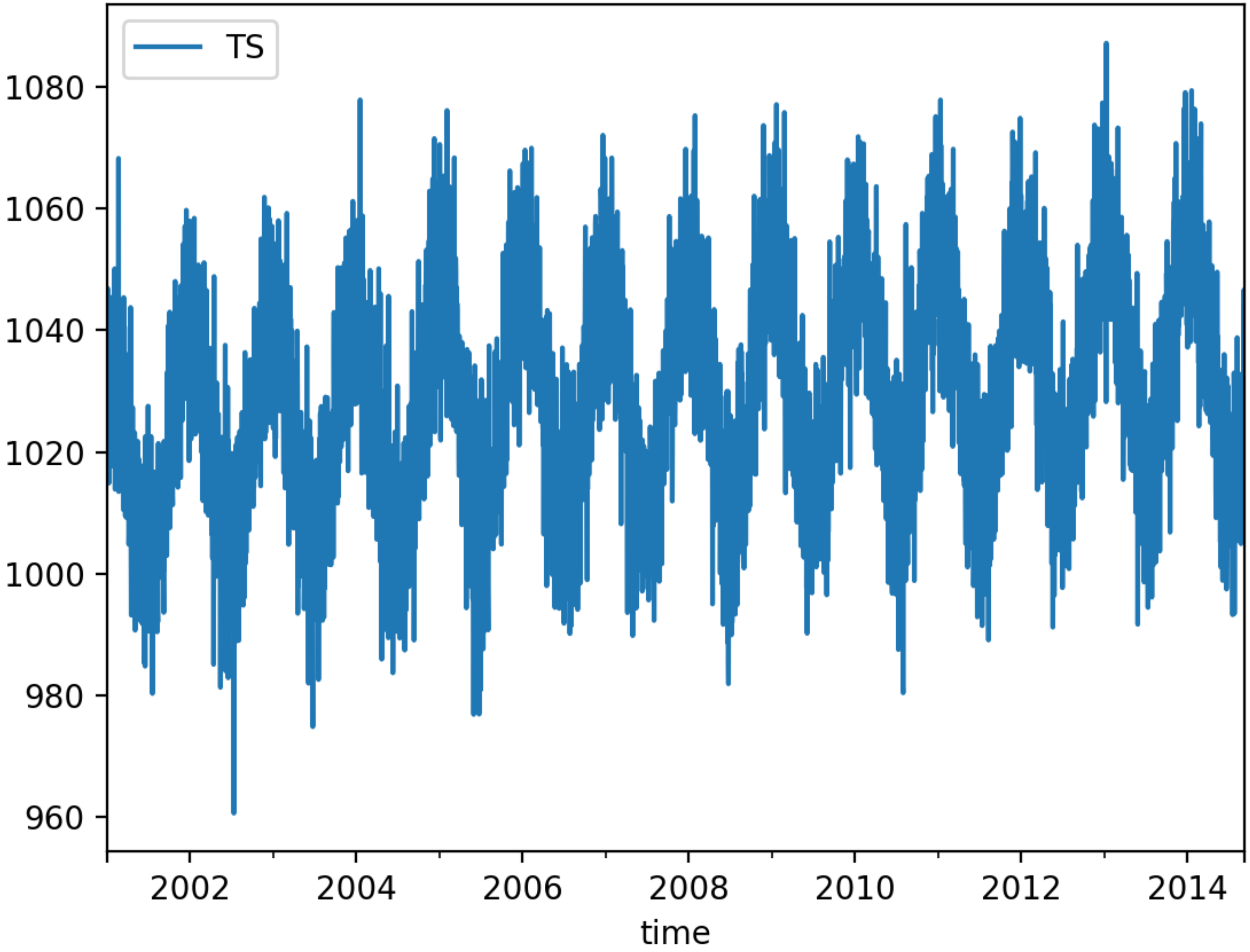
Basic Example

- We better rename that column

```
>>> ts1.rename(columns={' TS': 'TS'}, inplace = True)
>>> ts1.TS
time
2001-01-01    1027.096129
2001-01-02    1041.701344
2001-01-03    1046.905793
2001-01-04    1038.360279
2001-01-05    1033.118933
                 ...
2014-09-05    1019.451193
2014-09-06    1017.043391
2014-09-07    1046.658204
2014-09-08    1030.316278
2014-09-09    1044.078304
Name: TS, Length: 5000, dtype: float64
```

Basic Example

- We can now use the plotting component of Pandas



```
ts1.plot()
plt.show()
```

Basic Example

- We can also do a scatter graph
  - But this needs to be specialized because scatter graphs usually need two numeric values

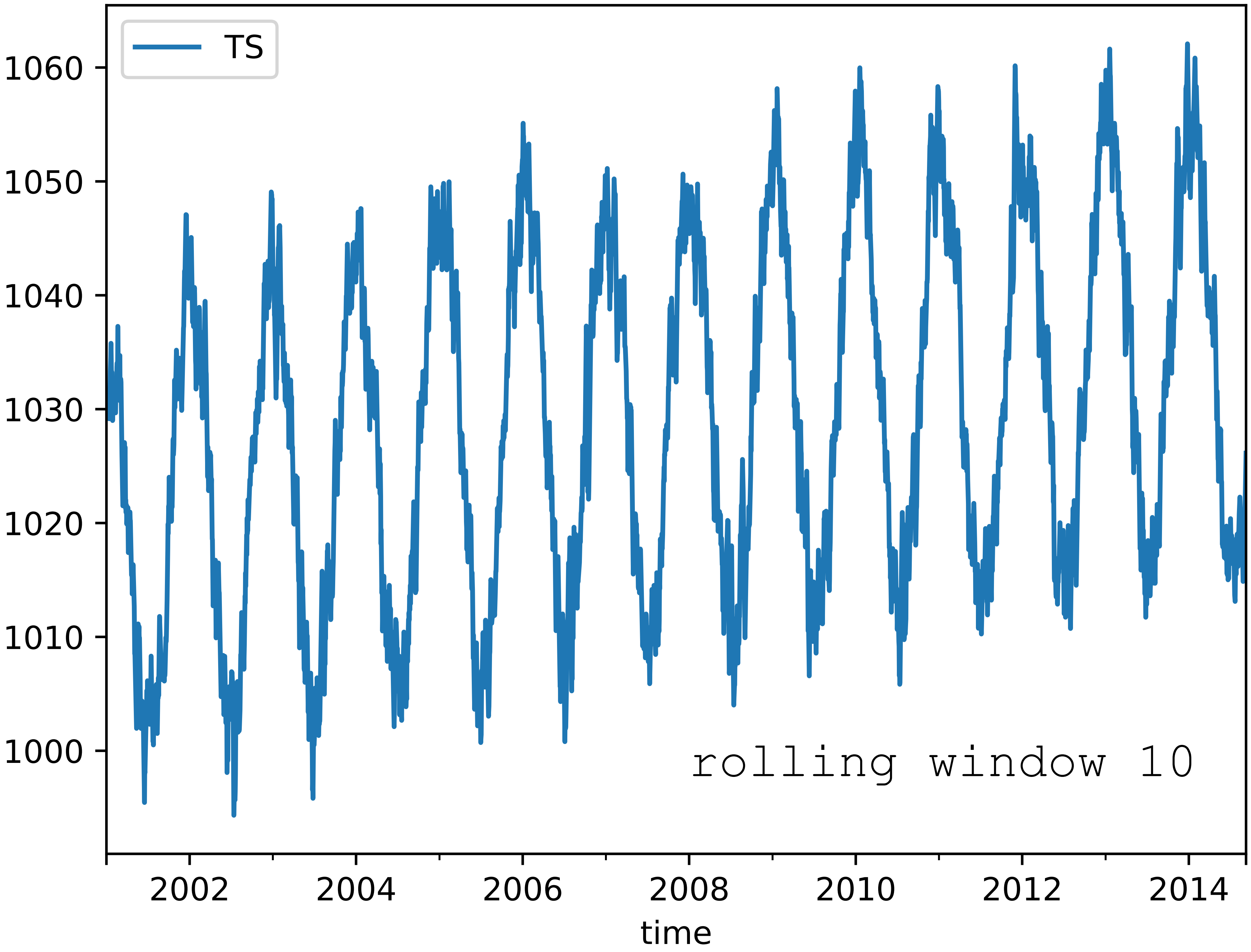
```
plt.plot_date(ts1.index, ts1.TS)
```

Basic Example

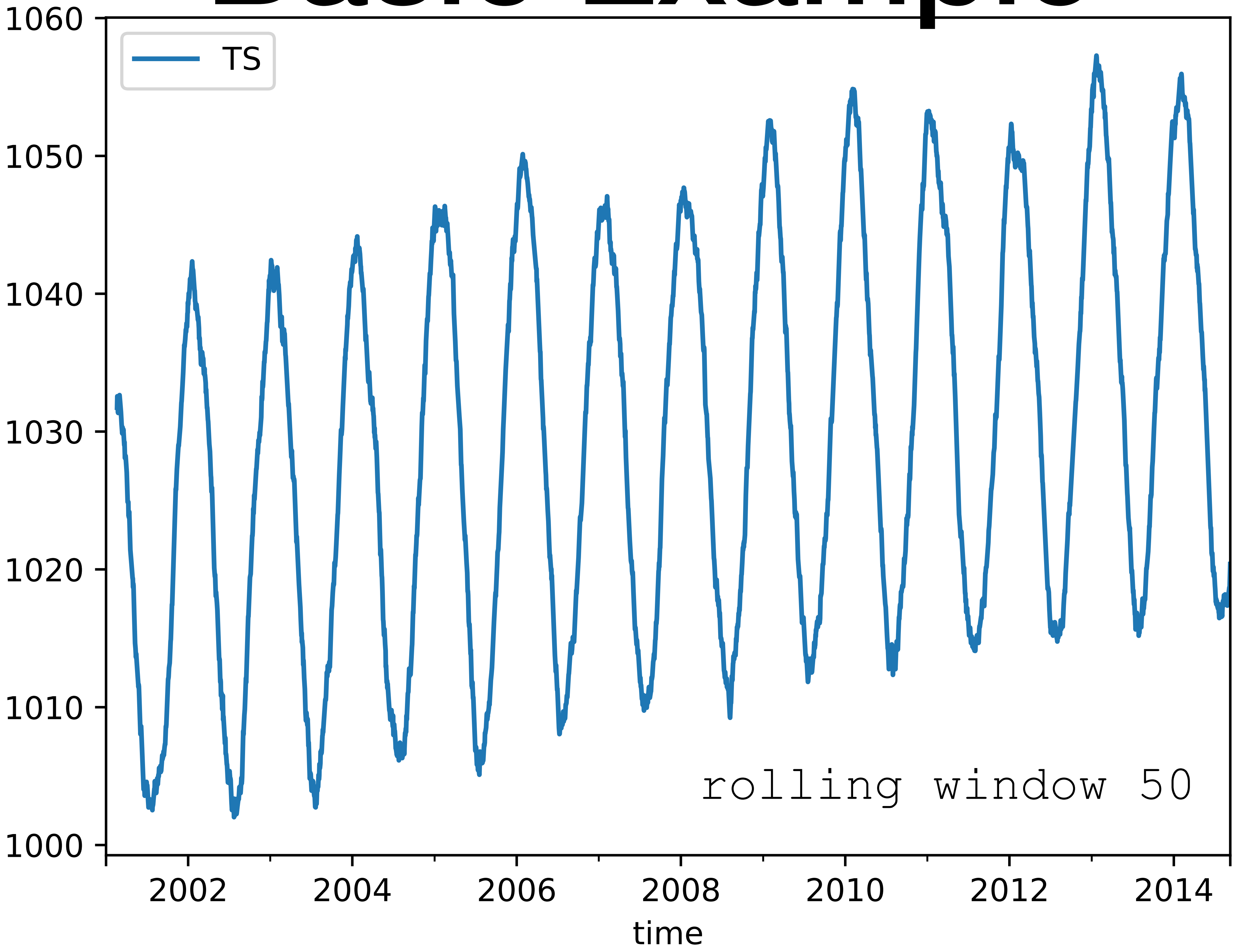
- Let's see whether we can make the line plot clearer
  - Use curve smoothing
    - Can use rolling, then mean, then plot

```
>>> ts1.rolling(10).mean().plot()
<matplotlib.axes._subplots.AxesSubplot object at
0x7fbb221e1be0>
>>> plt.show()
```

Basic Example



Basic Example

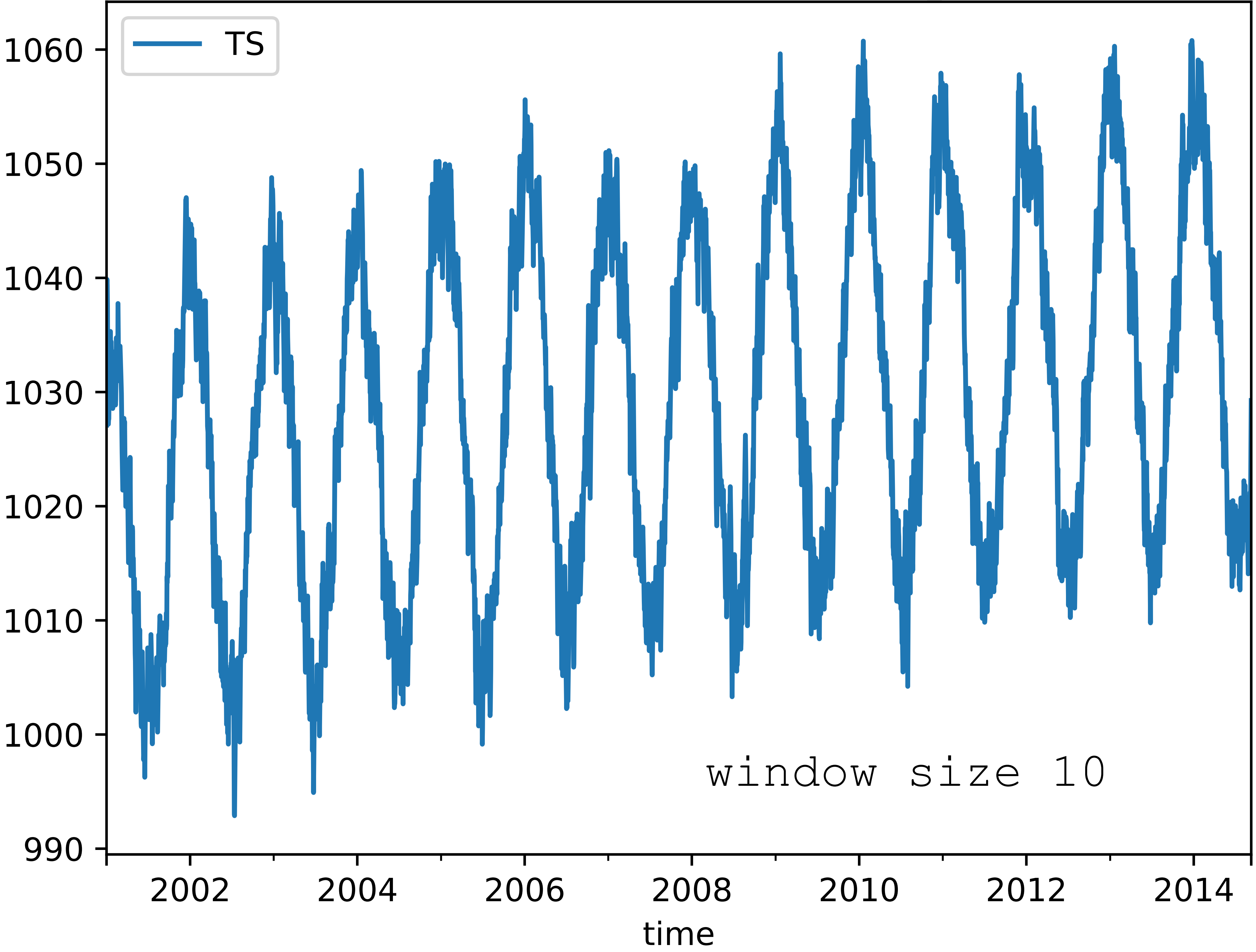


Basic Example

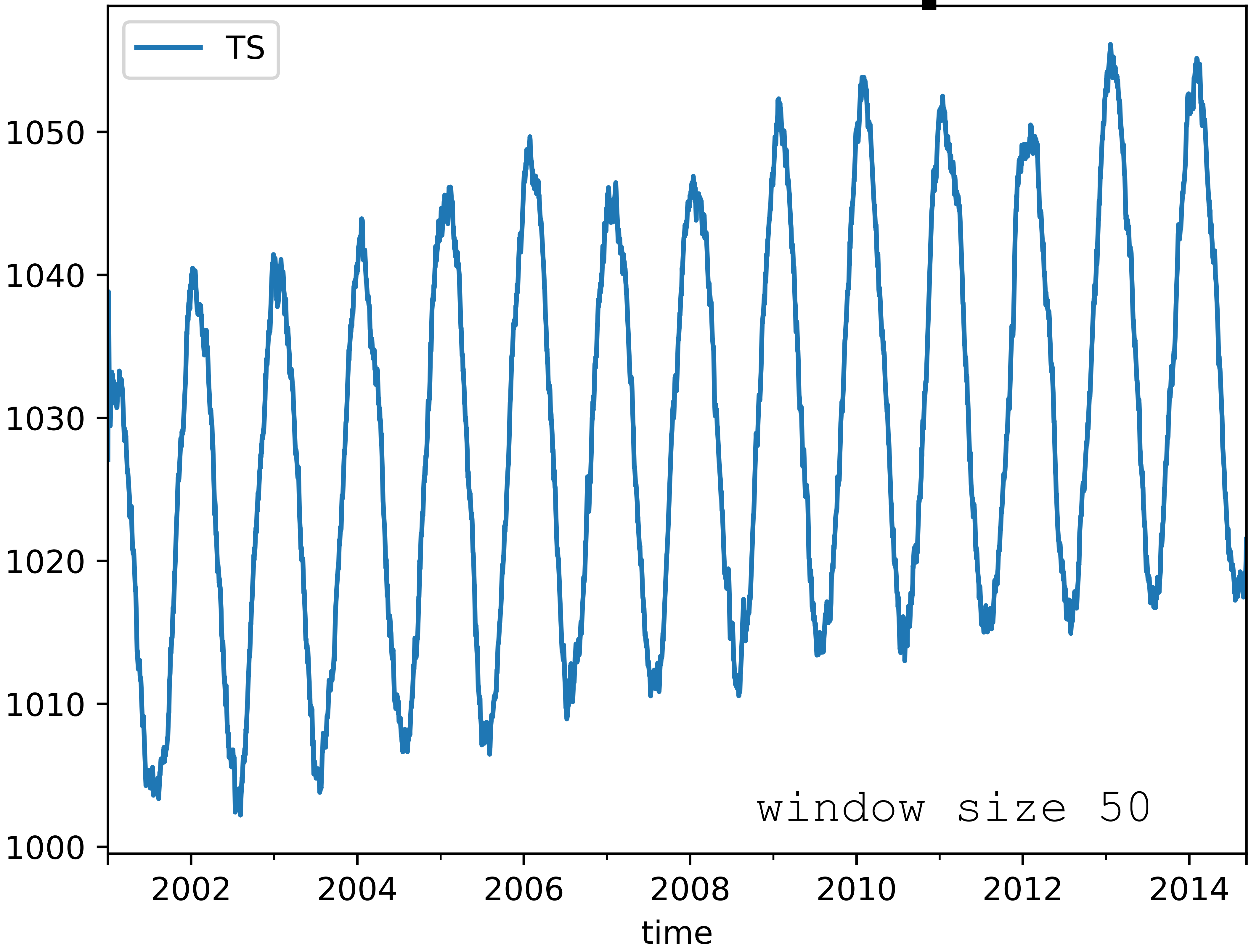
- While rolling takes all observations in the window at the same value, we can also use exponential weighted windows

```
ts1.ewm(span=10).mean().plot()
```

Basic Example



Basic Example



Fundamentals

- The basic plotting tool is still matplotlib
  - It can be wrapped by
    - Pandas
    - Seaborn (future lecture)
    - ggplot
    - Holoview
    -

Fundamentals

- Importing
  - Just as np from numpy and pd for pandas, we use traditional shortcuts

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

  - Usually only need the latter

Fundamentals

- We can pick style

```
plt.style.use('classic')
```

- We can find styles with

```
plt.style.available
```

```
['seaborn-dark', 'seaborn-darkgrid', 'seaborn-ticks', 'fivethirtyeight',
'seaborn-whitegrid', 'classic', '_classic_test', 'fast', 'seaborn-talk',
'seaborn-dark-palette', 'seaborn-bright', 'seaborn-pastel', 'grayscale',
'seaborn-notebook', 'ggplot', 'seaborn-colorblind', 'seaborn-muted',
'seaborn', 'Solarize_Light2', 'seaborn-paper', 'bmh', 'tableau-colorblind10',
'seaborn-white', 'dark_background', 'seaborn-poster', 'seaborn-deep']
```

Fundamentals

- Plotting from a script
  - Use `plt.show( )`
    - Interacts with the system
      - Results are system dependent
      - plt.show( ) does a lot in the background
      - should only be run once in a script
-

Fundamentals

- Plotting from a notebook
  - Use `matplotlib inline`
  - Creates a new cell to embed any png created with plt.plot()

Fundamentals

- Saving figures to files
  - Use `fig.savefig(`address `)`
  - File format is inferred from file extension

Fundamentals

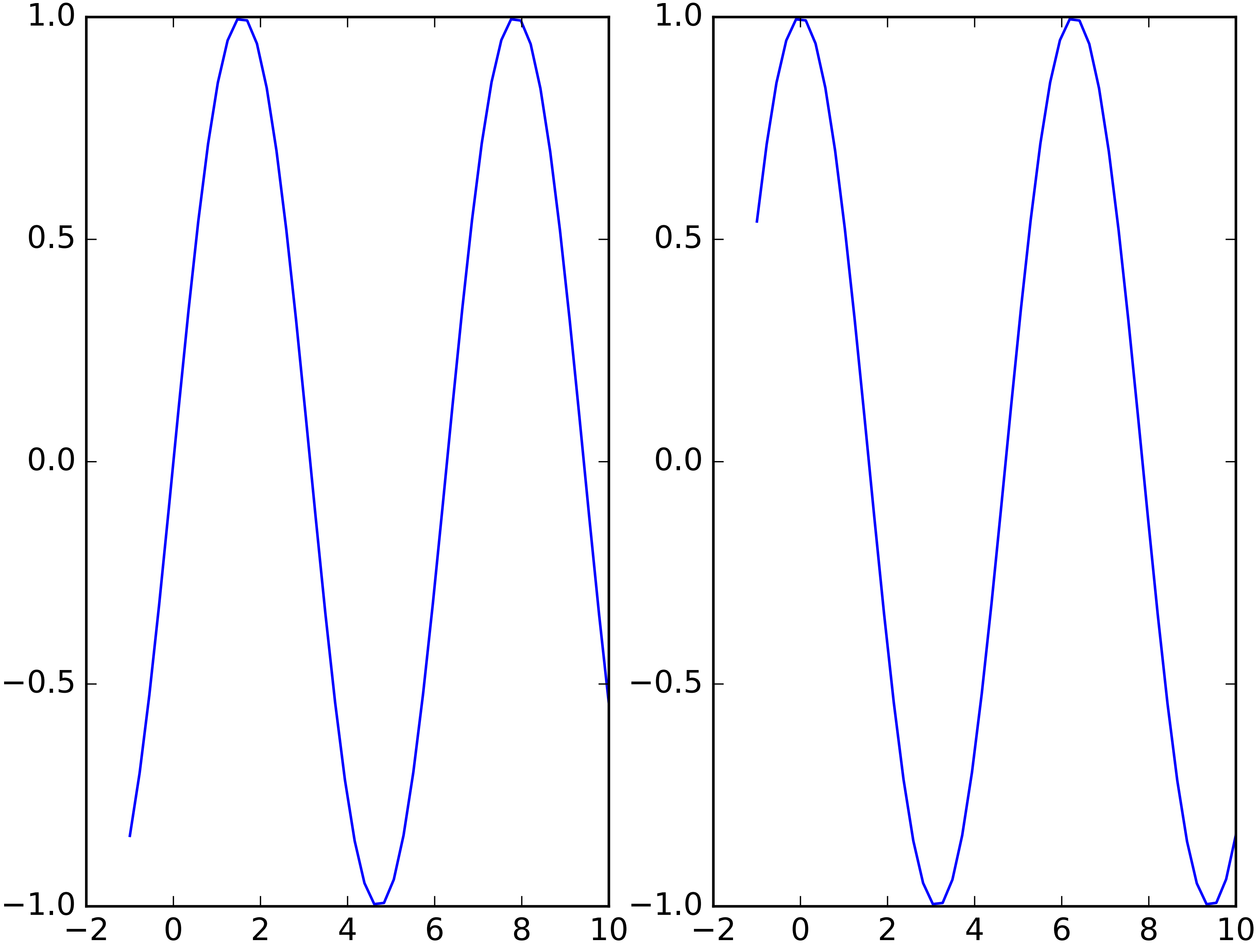
- Two interfaces:
  - MATLAB style interface
    - Best for relatively simple plots
    - Keeps track of all figure elements
  - Object oriented interface
    - Create figures and "axes"
    - Use method calls

Fundamentals

- Example:
  - MATLAB interface

```
x = np.linspace(-1,10)
plt.figure( ) #create figure
plt.subplot(1,2,1)  #rows columns panel number
plt.plot(x, np.sin(x))

plt.subplot(1,2,2)
plt.plot(x, np.cos(x))
```

Fundamentals



Fundamentals

- OO interface

```
fig, ax = plt.subplots(ncols=2)
ax[0].plot(x, np.sin(x))
ax[1].plot(x, np.cos(x))
```

- Figure : single container with potentially many axes
- Axes : bounding box with many elements
  - Axis, Tick, Line2D, Text, Polygon

Simple Line Plots

- Define a Figure and an Axes object
- Create an array of x values `[0., 0.01, 0.02, 0.03, 0.04, … ]`
- Create an array of y values

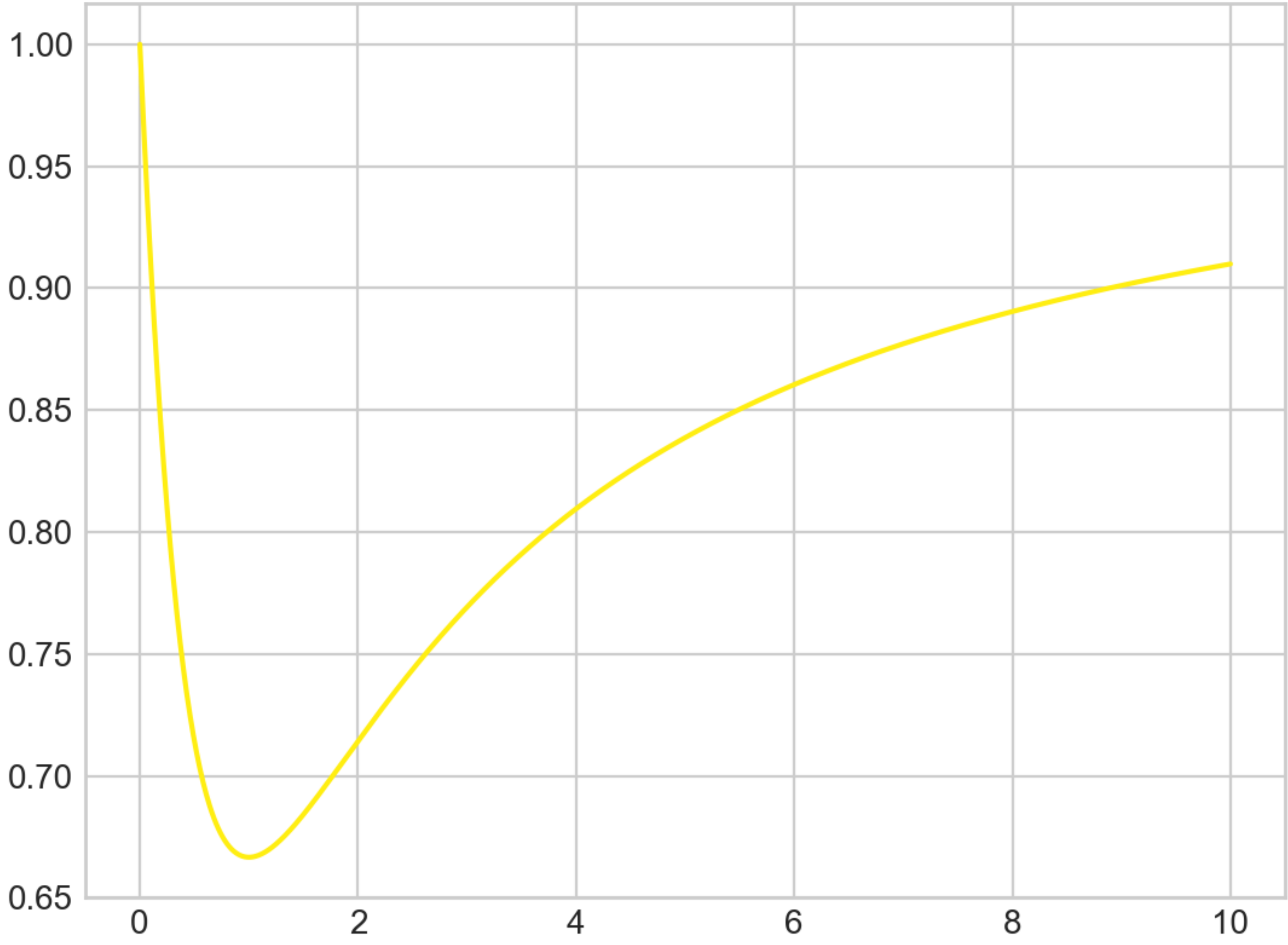
```
plt.style.use('seaborn-whitegrid')

fig = plt.figure
ax = plt.axes()
x = np.linspace(0,10, 1000)
ax.plot(x, (x**2+1)/(x**2+x+1))
```

Simple Line Plots

- Line colors
  - colors have
    - names,
    - abbreviations (rgbcmyk),
    - Grayscales between 0 and 1
    - Hexcodes (RRGGBB) between 00 and FF
    - RGB tuples with values between 0 and 1
    - HTML color names

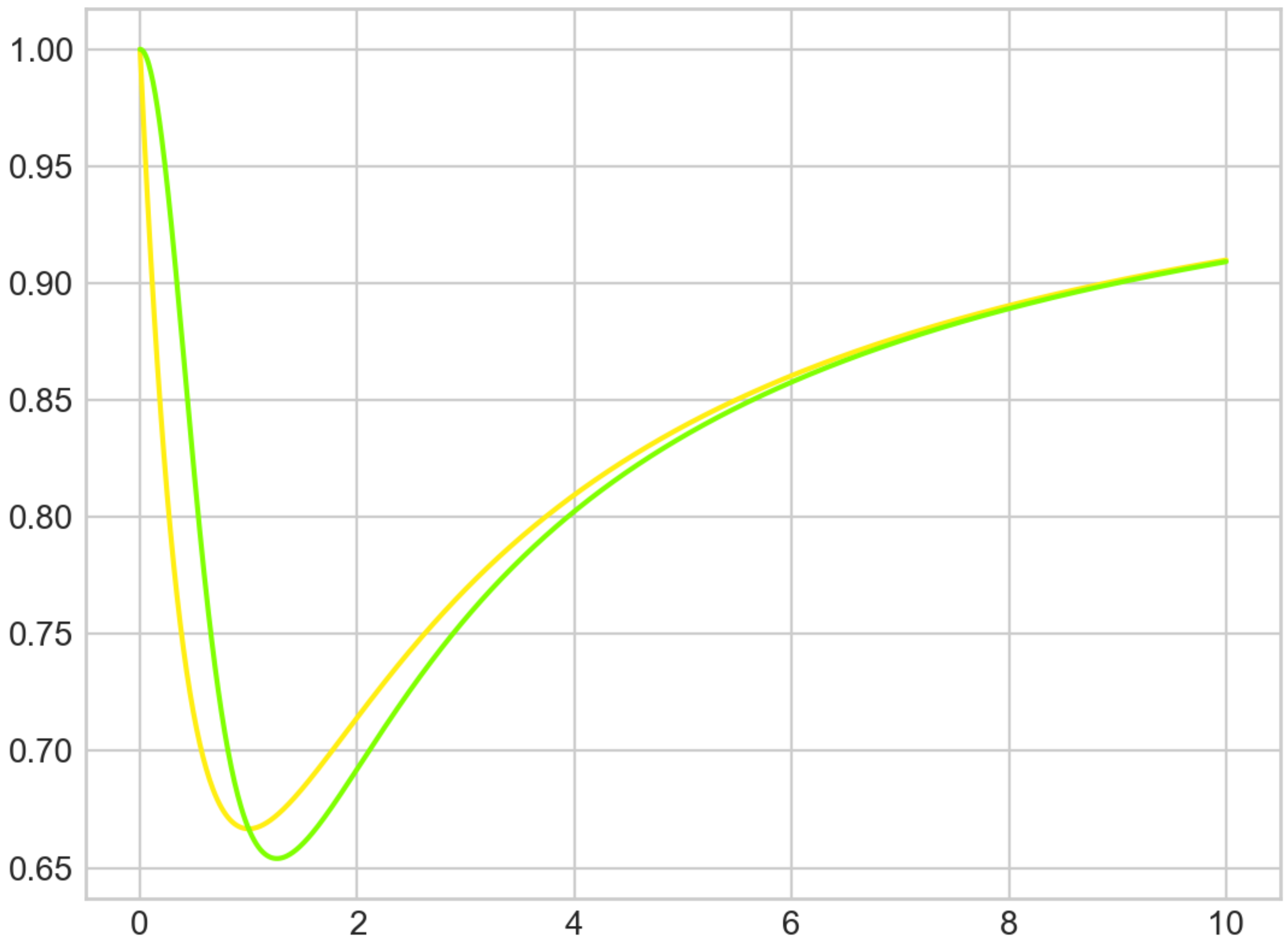
Simple Line Plots

```
x = np.linspace(0,10, 1001)
ax.plot(x, (x**2+1)/(x**2+x+1), color = '#FFEE11')
```



Simple Line Plots

```
x = np.linspace(0,10, 1001)
ax.plot(x, (x**2+1)/(x**2+x+1), color = '#FFEE11')
ax.plot(x, (x**3+1)/(x**3+x**2+1), color = 'chartreuse')
```

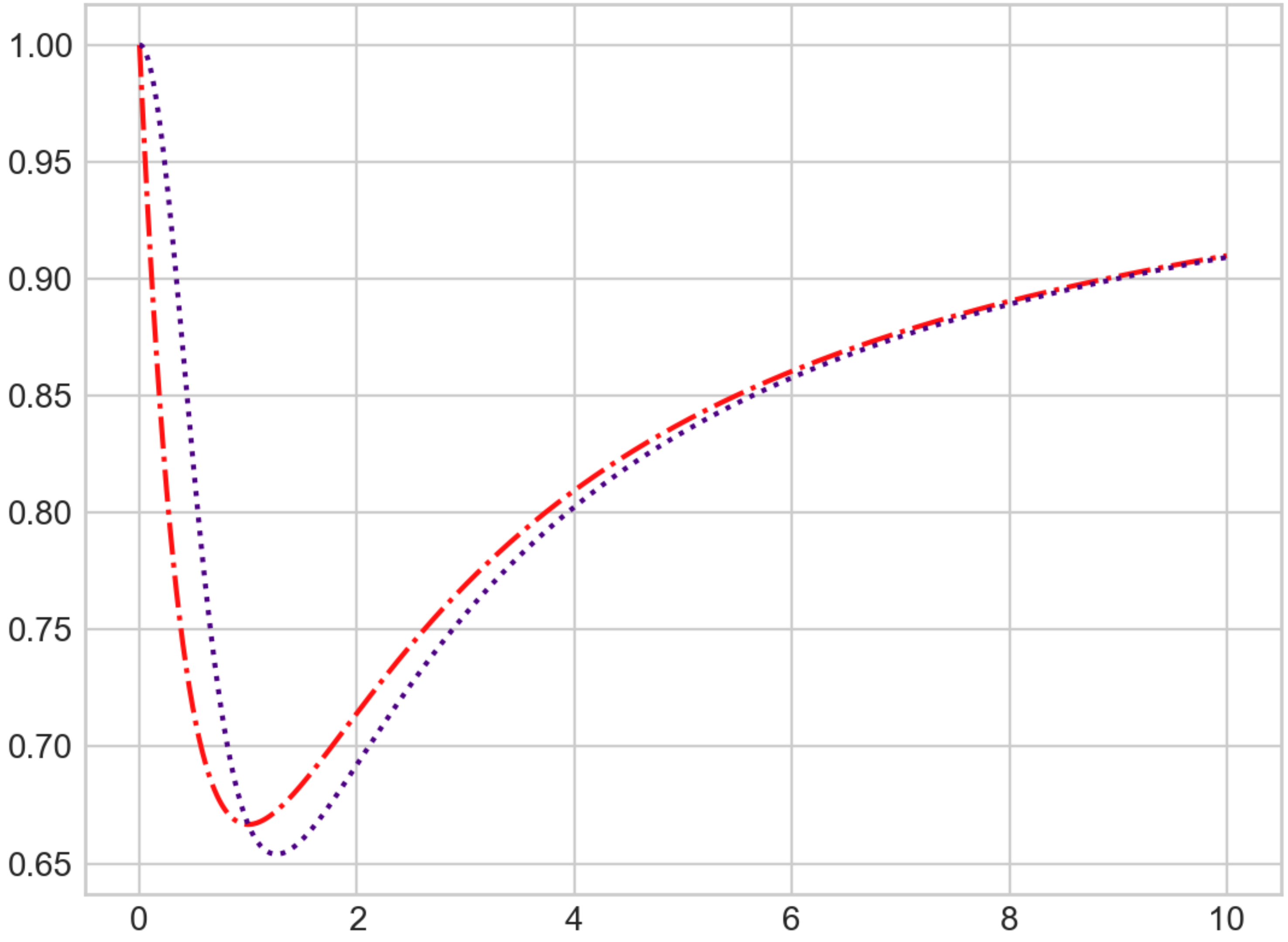


Simple Line Plots

- Line Styles
  - 'solid', 'dashed', 'dashdot' 'dotted'
- Abbreviated as
  - '-', '- -', '-.', ':'

Simple Line Plots

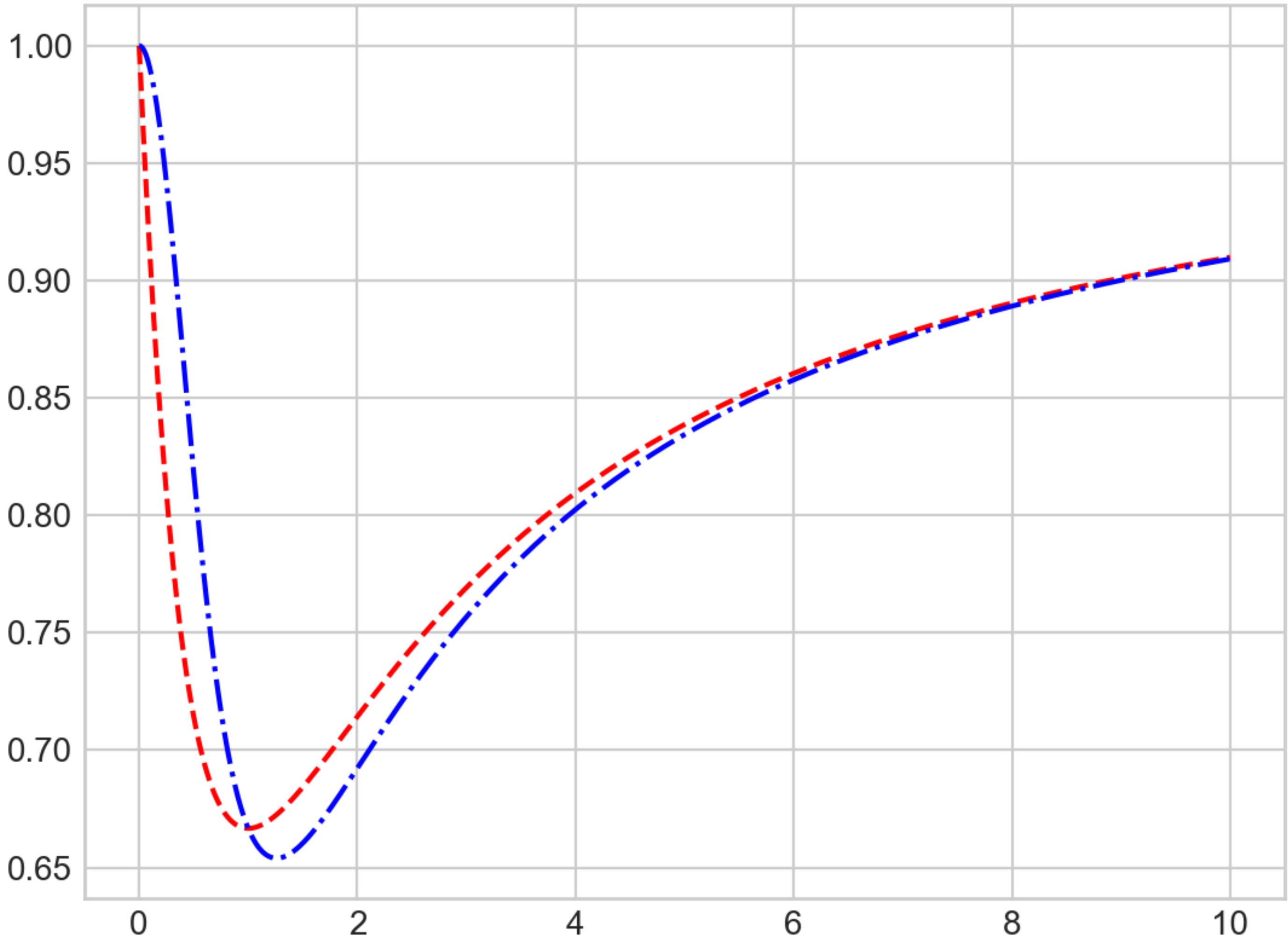
```
ax.plot(x, (x**2+1)/(x**2+x+1), color = '#FF1111',
linestyle='dashdot')
ax.plot(x, (x**3+1)/(x**3+x**2+1), color = 'indigo',
linestyle = ':')
```



Simple Line Plots

- These can also be combined

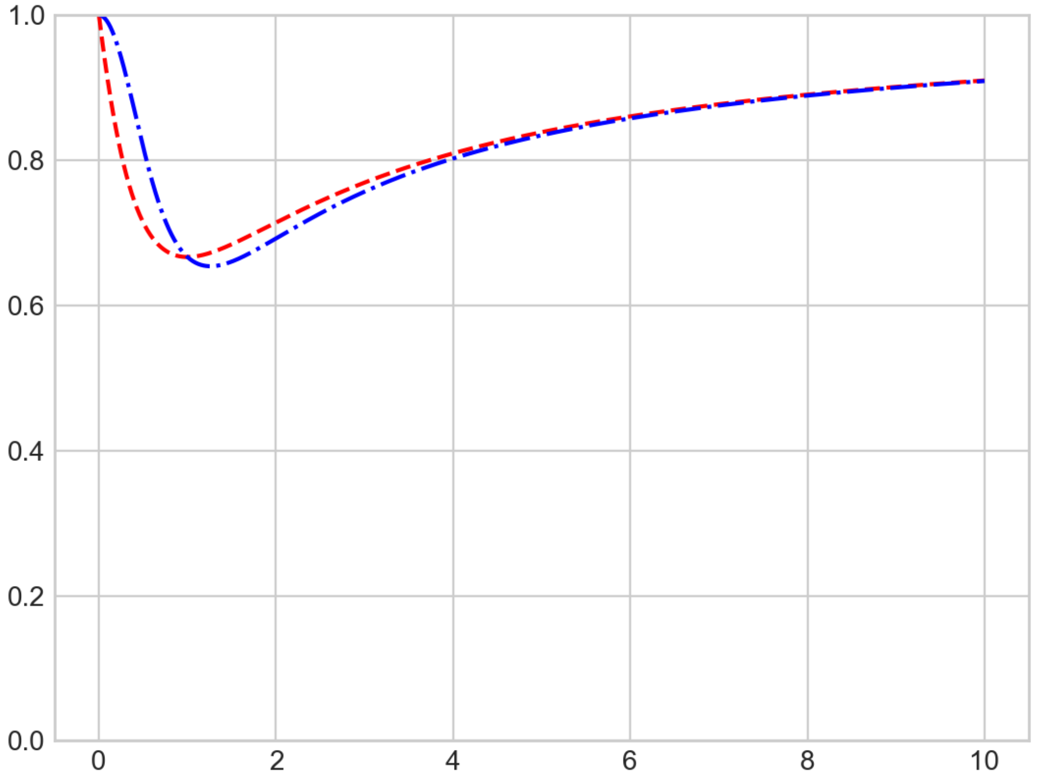
```
ax.plot(x, (x**2+1)/(x**2+x+1), 'r--')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.')
```



Simple Line Plots

- Axes Limits for finer control
  - set xlim, ylim

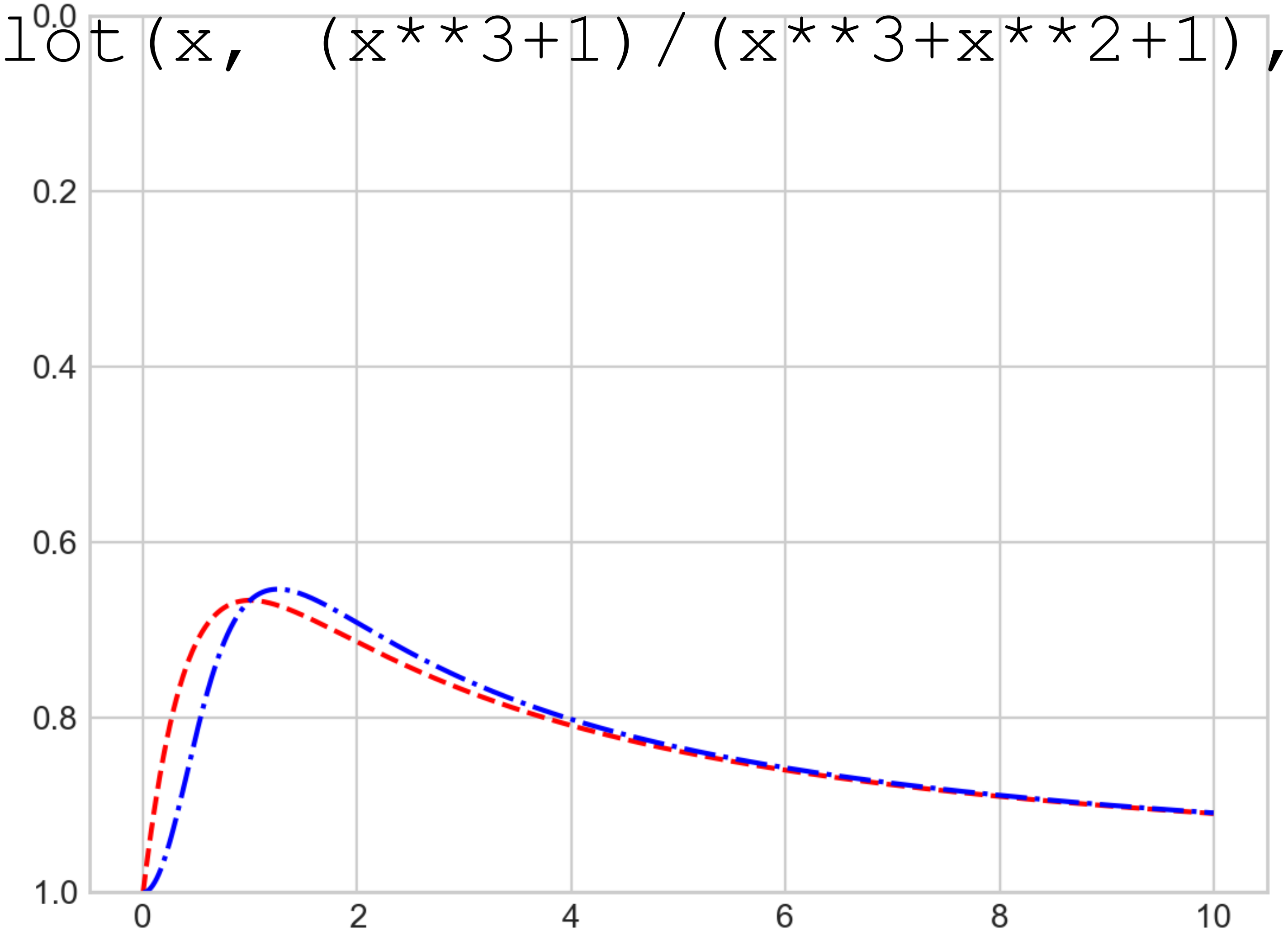
```
plt.ylim(0,1)
ax.plot(x, (x**2+1)/(x**2+x+1), 'r--')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.')
```



Simple Line Plots

- You can even revert an axis

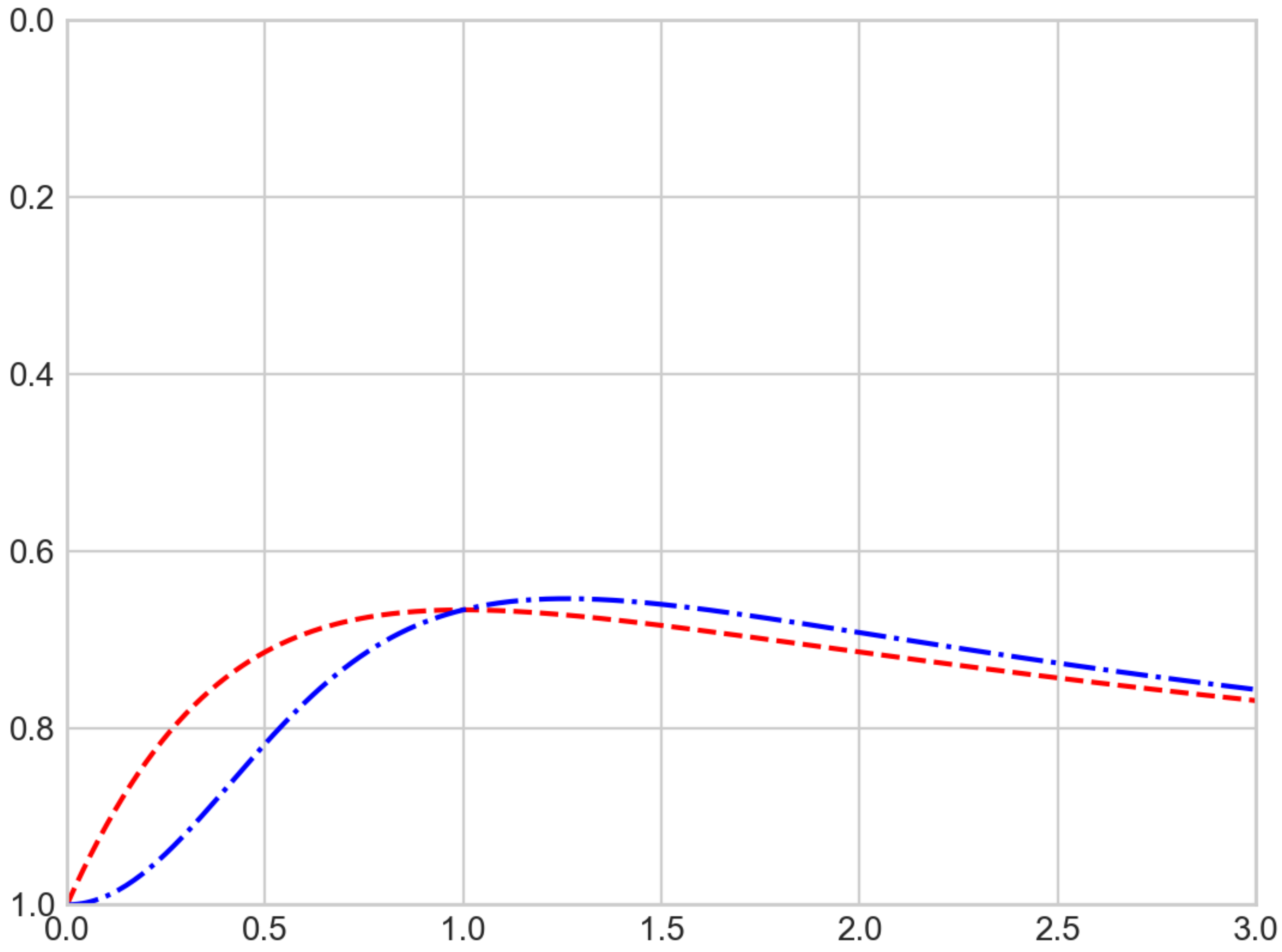
```
plt.ylim(1,0)
ax.plot(x, (x**2+1)/(x**2+x+1), 'r--')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.')
```



Simple Line Plots

- You can set all axes with the confusingly named axis method

```
plt.axis([0,3,1,0])
```



Simple Line Plots

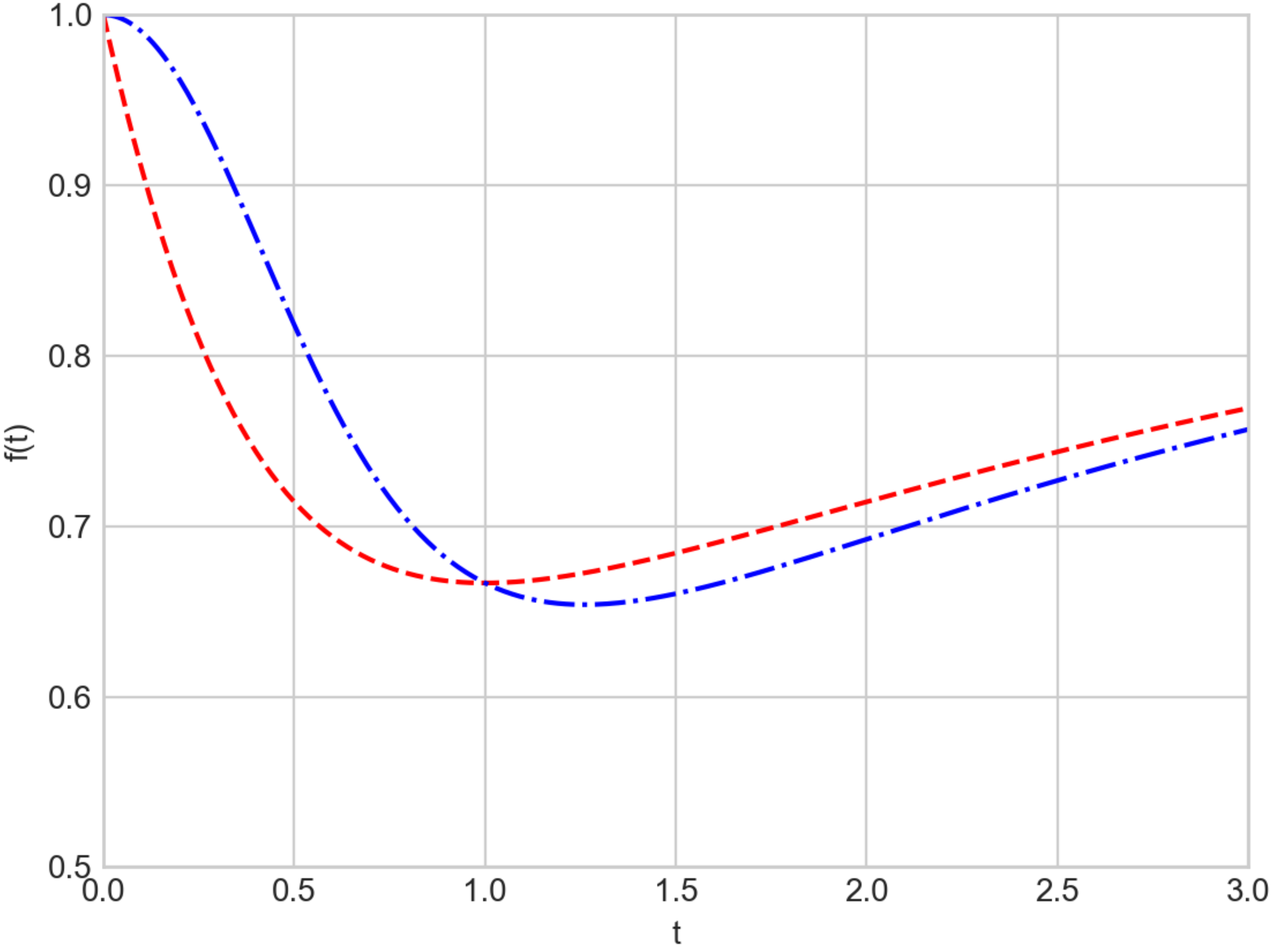
- plt.axis actually allow even more plot control
    - 'tight' to tighten bounds around current plot
    - ''equal' for equal aspect ratio

Simple Line Plots

- Plot axes can be labeled

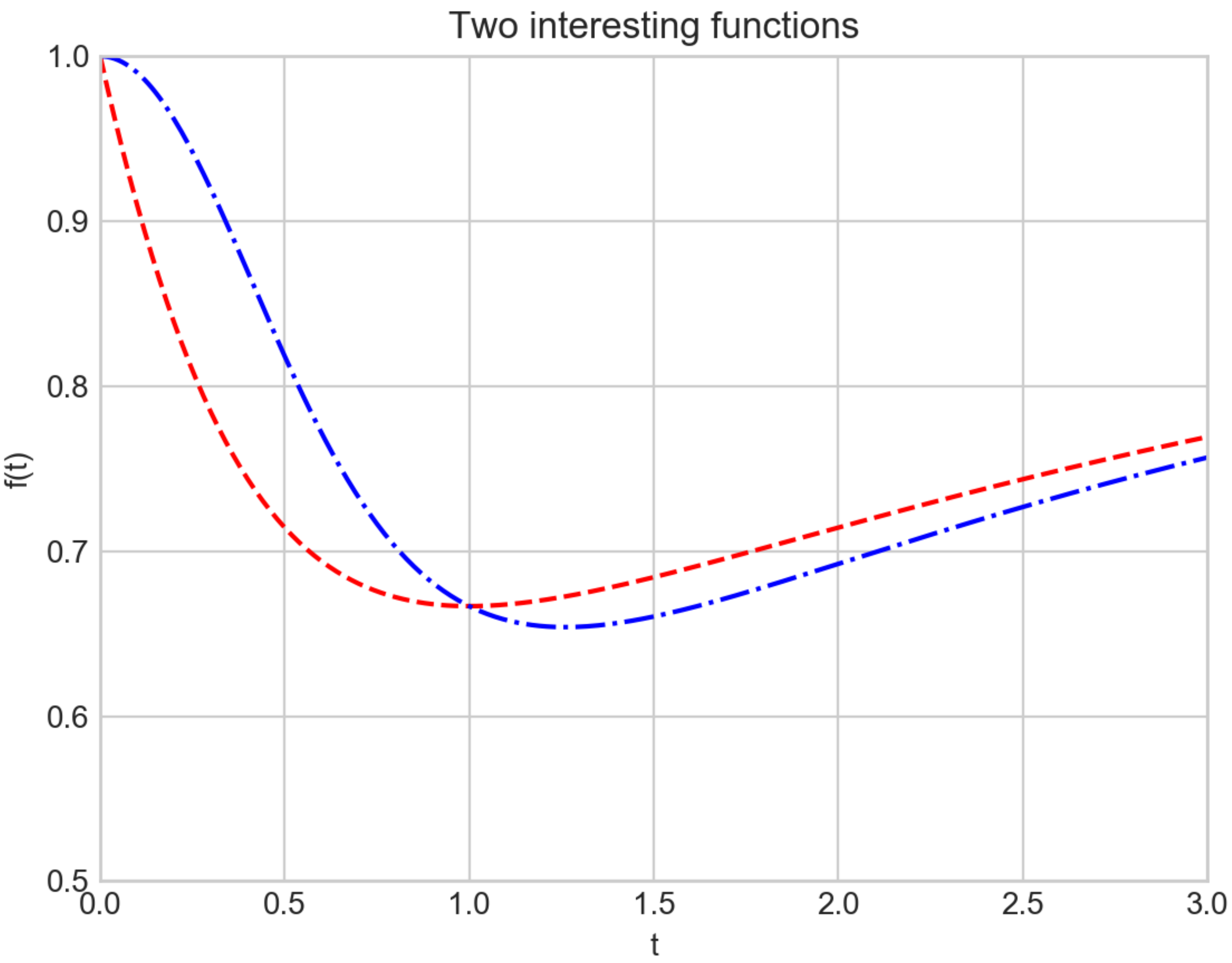
  -
    ```
    fig = plt.figure
    ax = plt.axes()
    x = np.linspace(0,10, 1001)
    plt.axis([0,3,0.5,1], 'tight')
    plt.xlabel('t')
    plt.ylabel('f(t)')
    ax.plot(x, (x**2+1)/(x**2+x+1), 'r--')
    ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.')
    ```

Simple Line Plots



Simple Line Plots

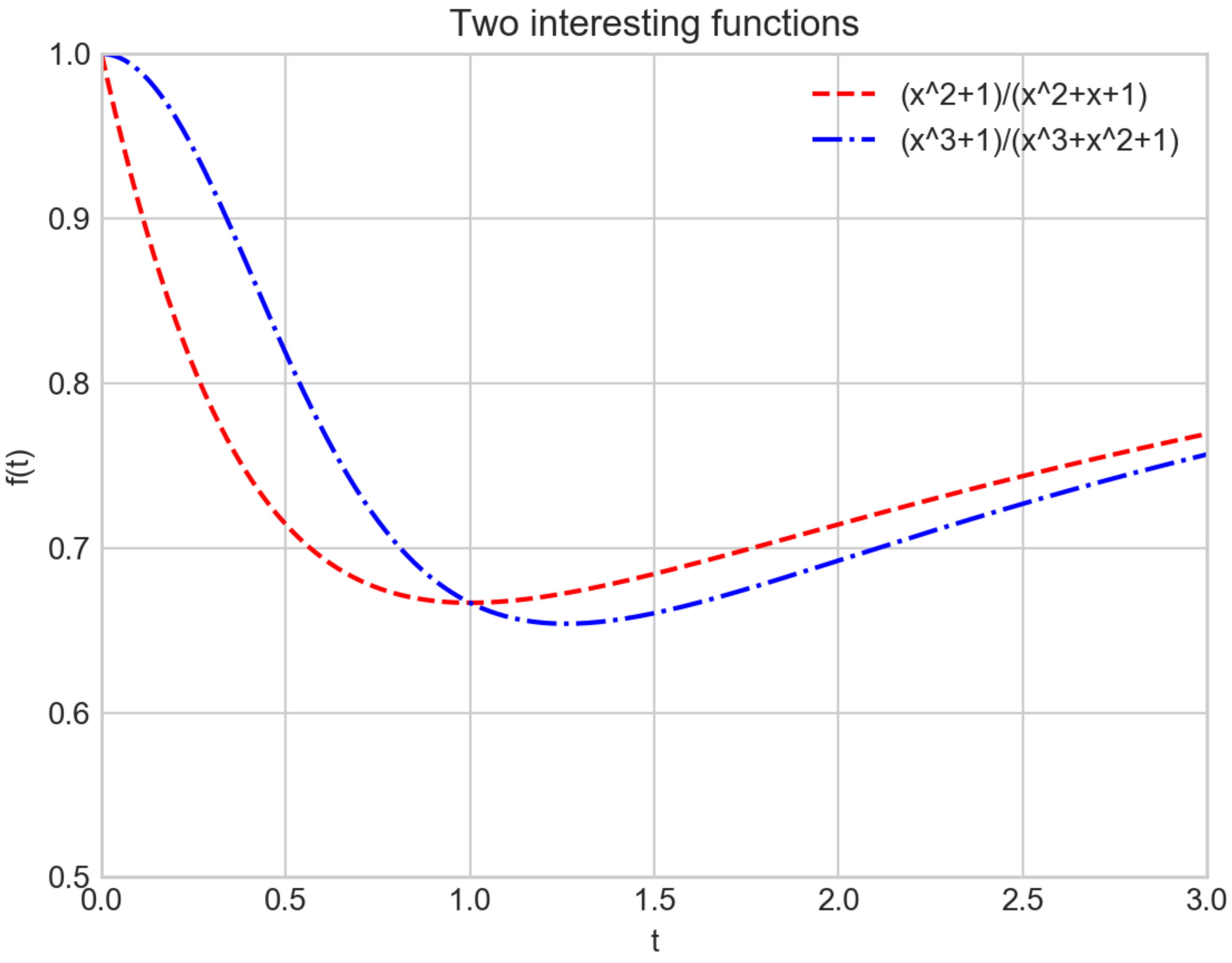
- We label a plot with plt.title



Simple Line Plots

- And we can provide a legend

```
ax.plot(x, (x**2+1)/(x**2+x+1), 'r--', label='(x^2+1)/(x^2+x+1)')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.', label='(x^3+1)/(x^3+x^2+1)')
plt.legend()
```



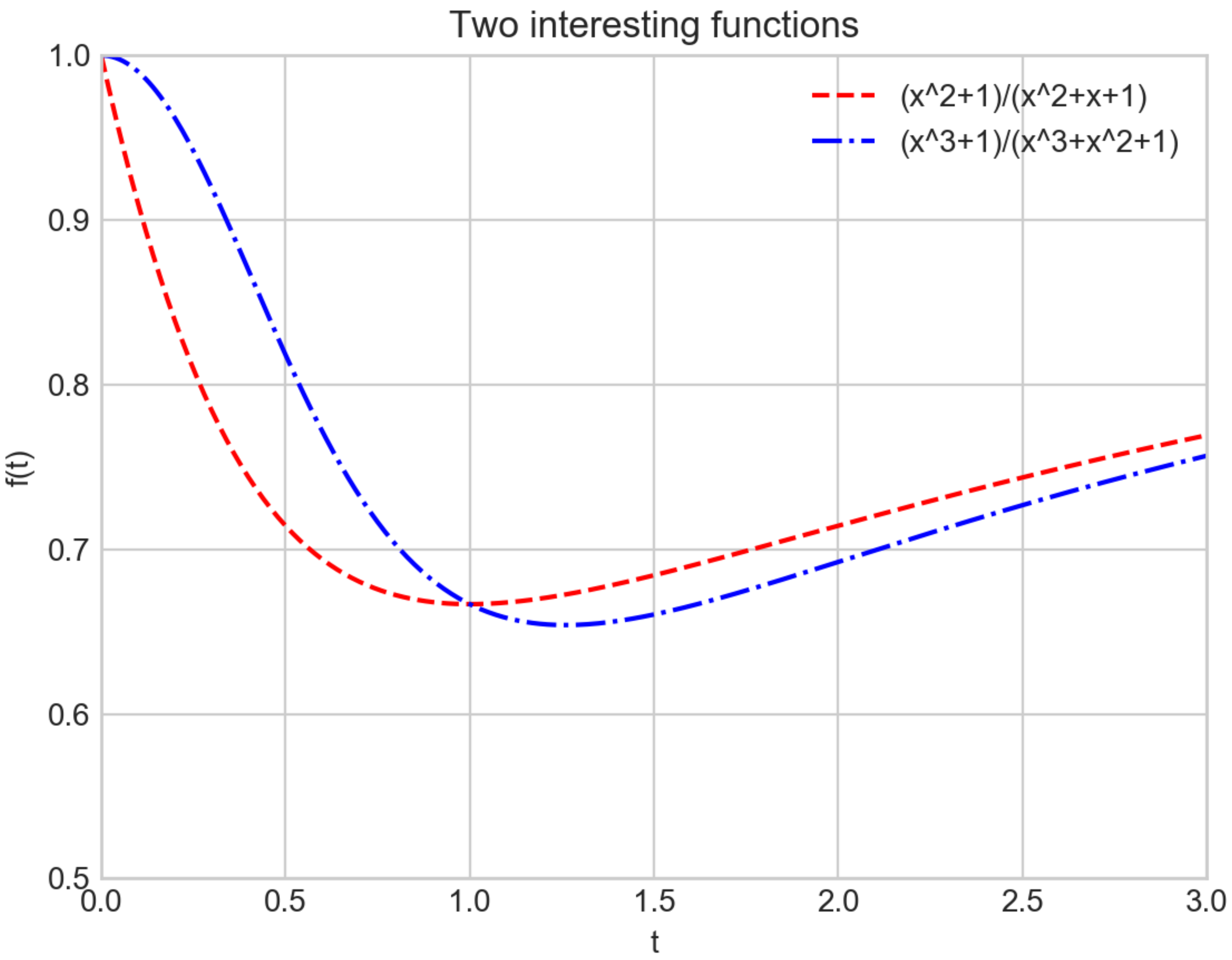
Simple Line Plots

- OO translation:
  - `plt.xlabel( )  —>  ax.set_xlabel( )`
  - `plt.ylabel( ) —> ax.set_ylabel( )`
  - `plt.xlim( ) —> ax.set_xlim( )`
  - `plt.ylim( ) —> ax.set_ylim( )`
  - `plt.title( ) —> ax.set_title( )`
- or just use ax.set

Simple Line Plots

```
ax.plot(x, (x**2+1)/(x**2+x+1), 'r--', label='(x^2+1)/
(x^2+x+1)')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'b-.',
label='(x^3+1)/(x^3+x^2+1)')
ax.set(xlim=(0,1.5), ylim=(0.6, 1), xlabel='x',
ylabel='f(y)',
       title = 'Two functions')
```

Simple Line Plots

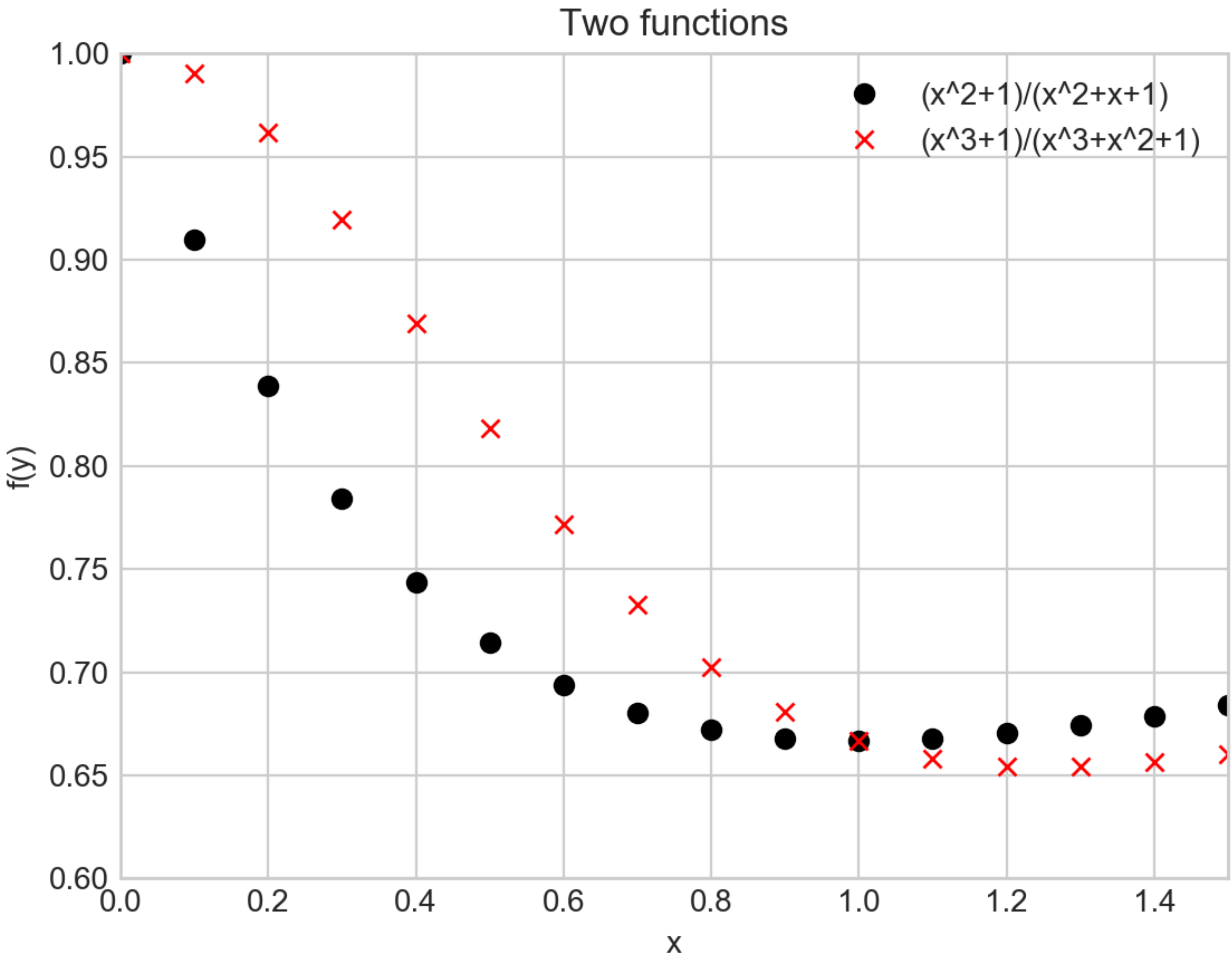


Simple Scatter Plots

- plt.plot / ax.plot can also produce scatter plots
- Just give it a marker

```
ax.plot(x, (x**2+1)/(x**2+x+1), 'o', color = 'black',
label='(x^2+1)/(x^2+x+1)')
ax.plot(x, (x**3+1)/(x**3+x**2+1), 'x', color = 'red',
label='(x^3+1)/(x^3+x^2+1)')
ax.set(xlim=(0,1.5), ylim=(0.6, 1), xlabel='x',
ylabel='f(y)', title = 'Two functions')
ax.legend()
```

Simple Scatter Plots



Simple Scatter Plots

- Additional argument represent the symbol
  - 'o', '.', 'x', '+', 'v', '^', '<', '>',
    - 's' square
    - 'd' diamond

Simple Scatter Plots

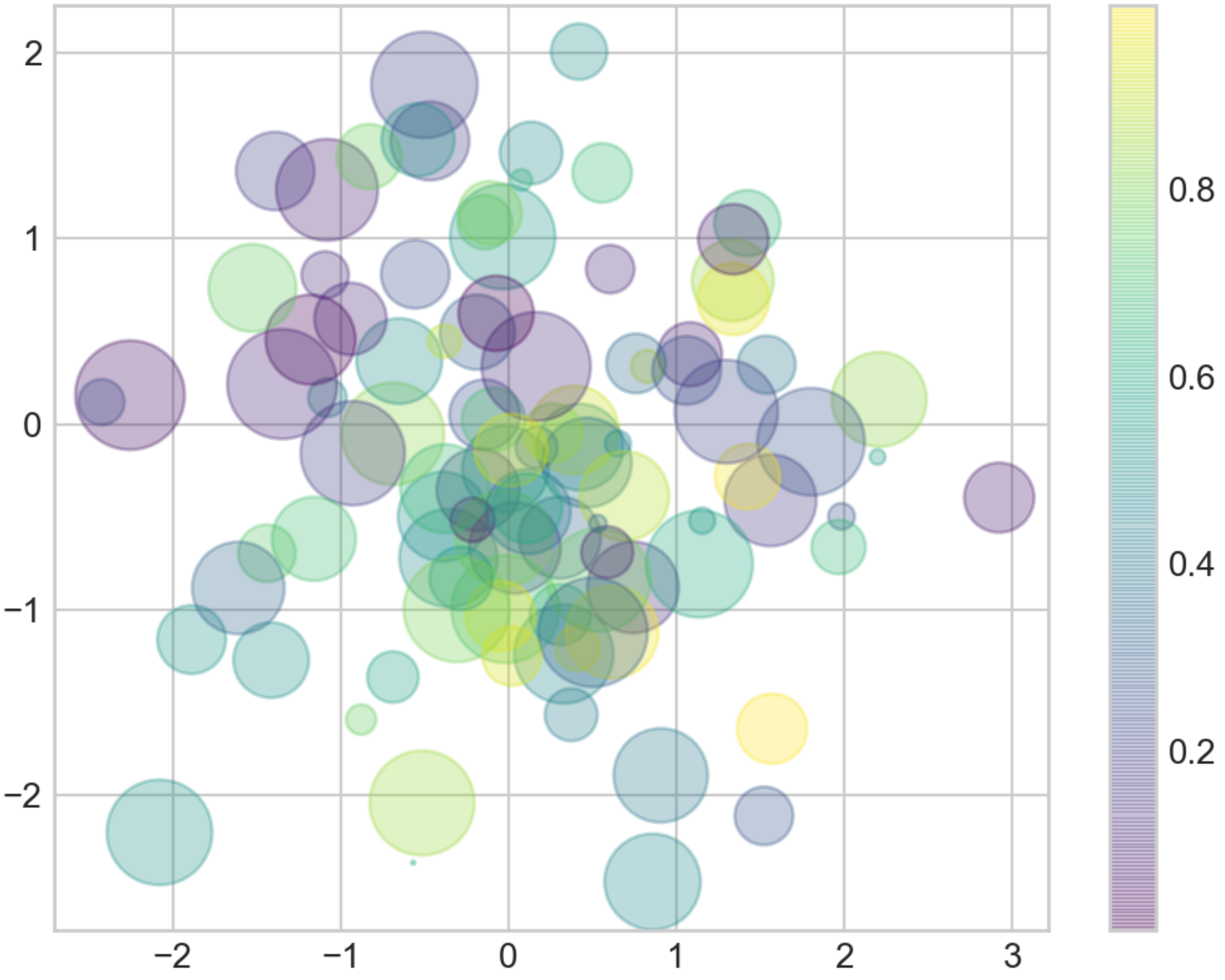
- More powerful: Use `plt.scatter`
  - Can control many more aspects

- Example:
  - Create 100 random pairs of x, y
  - Create random colors (between 0 and 1)
  - Create random sizes (between 0 and 1000)
  - Set alpha = 0.3 in order to make things transparent

Simple Scatter Plots

```
np.random.seed(250620)
x = np.random.randn(100)
y = np.random.randn(100)
colors = np.random.rand(100)
sizes = 1000 * np.random.rand(100)

plt.scatter(x, y, c=colors, s=sizes, alpha = 0.3,
            cmap = 'viridis')
plt.colorbar()  # show color scale

plt.show()
```

Simple Scatter Plots

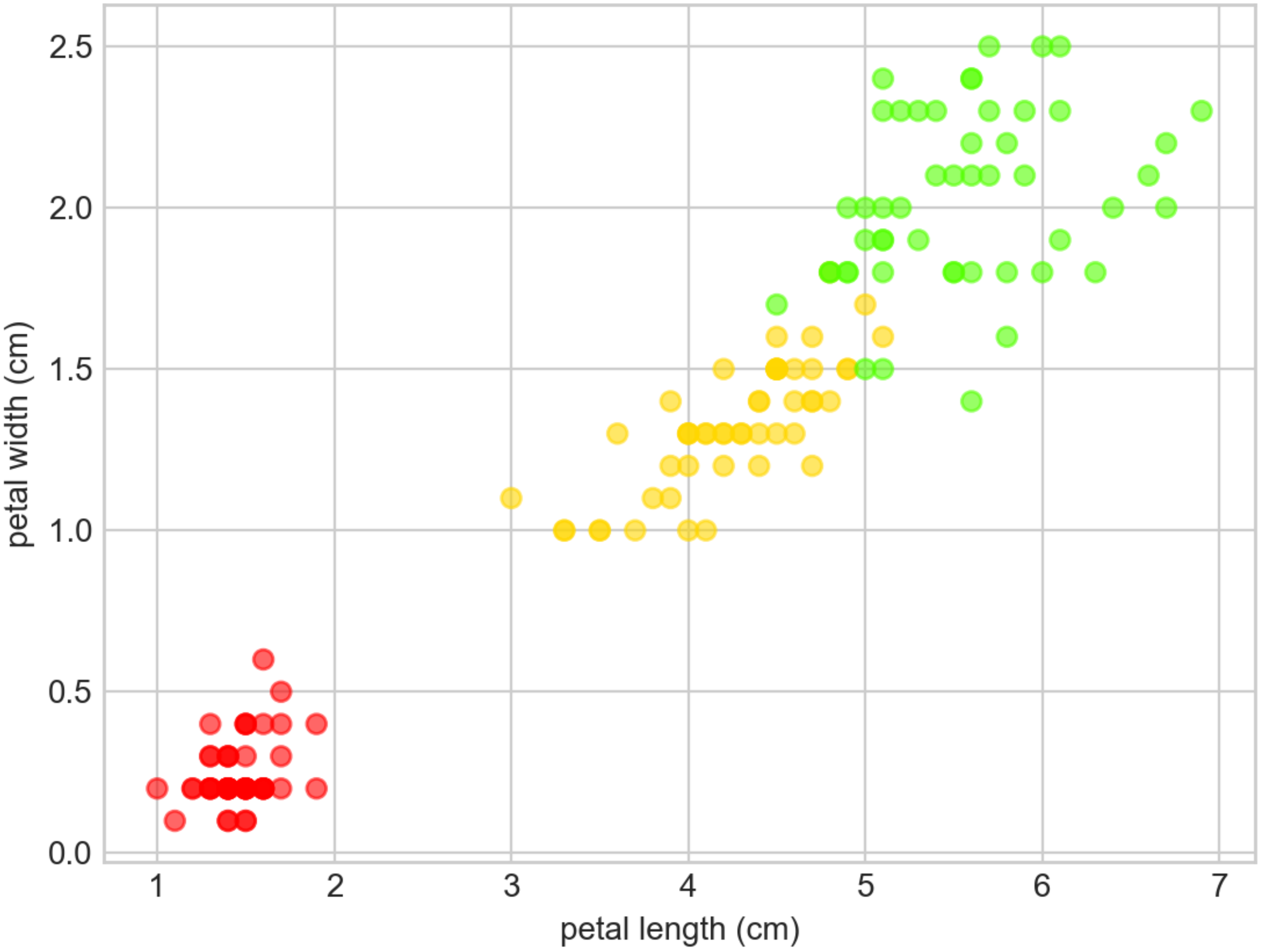


Simple Scatter Plots

- Example: Iris data set (from sklearn.datasets)

```
from sklearn.datasets import load_iris

iris = load_iris()
features = iris.data.T  #need to transpose

plt.scatter(features[2], features[3], alpha = 0.6,
            c=iris.target, cmap = 'prism')
plt.xlabel(iris.feature_names[2])
plt.ylabel(iris.feature_names[3])

plt.show()
```

Simple Scatter Plots



Simple Scatter Plots

- As datasets get larger, plot becomes more efficient than scatter

Error Bars

- it's not science if there is no statistics
  - it's not statistics if there are no errorbars
- When you have a data set, you should also have a confidence interval
  - This is displayed by an error bar
  - Use `plt.errorbar` with
    - x-values
    - y-values
    - confidence interval size
    - format code to control appearances (same as for lines and colors)

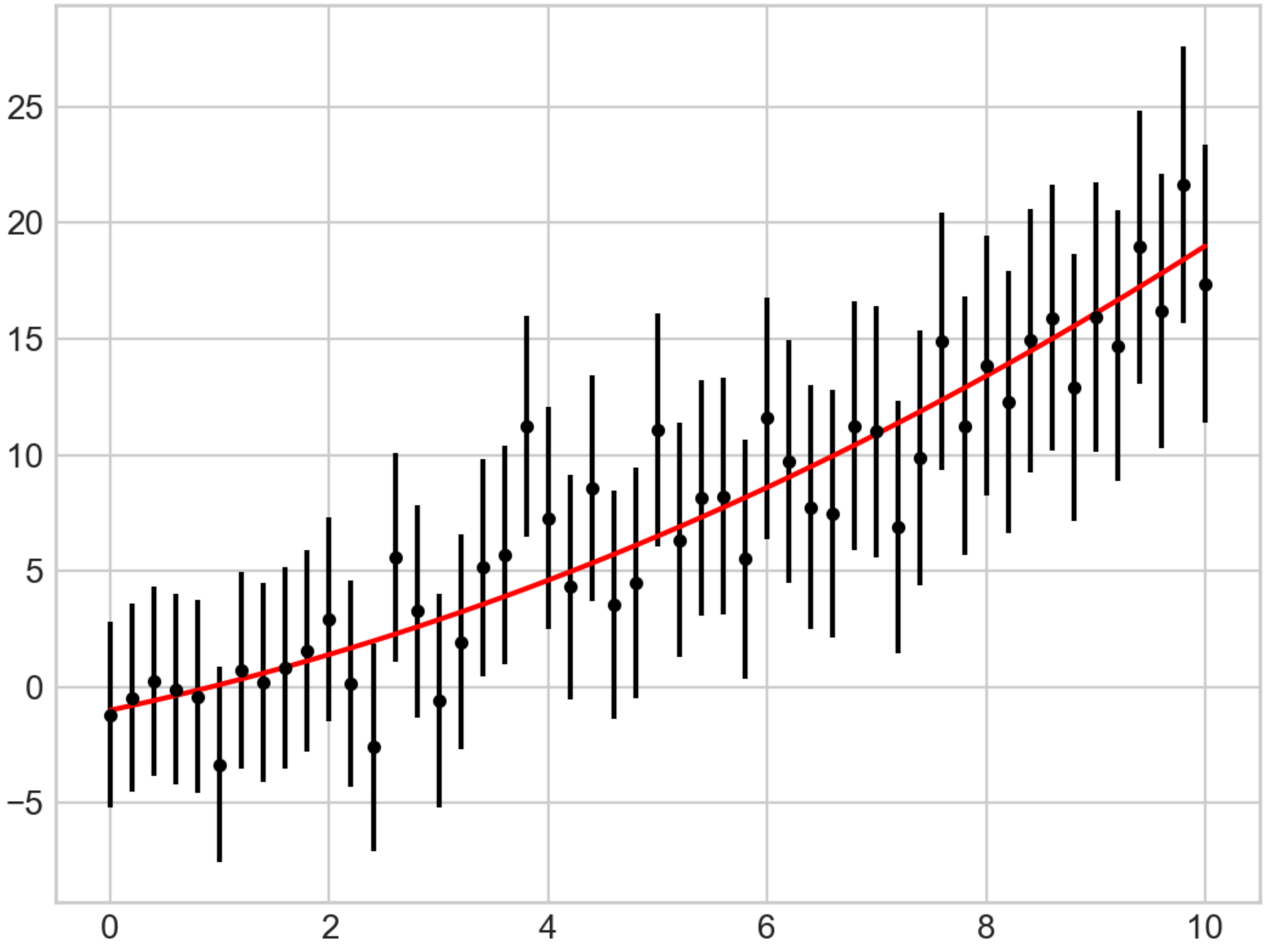
Error Bars

- Example:
  - Use a simple function
  - Use random.normal in order to generate y-values centered around the random function
  - Then draw error bars with $2\sigma \pm y$

Error Bars

```
x = np.linspace(0,10,51)
y = np.random.normal(loc = x**2/10+x-1 , scale = 2+x/10)
plt.errorbar(x,y, yerr=2*(2+x/10), fmt='.k')
plt.plot(x, x**2/10+x-1, 'r-')
plt.show()
```

Error Bars

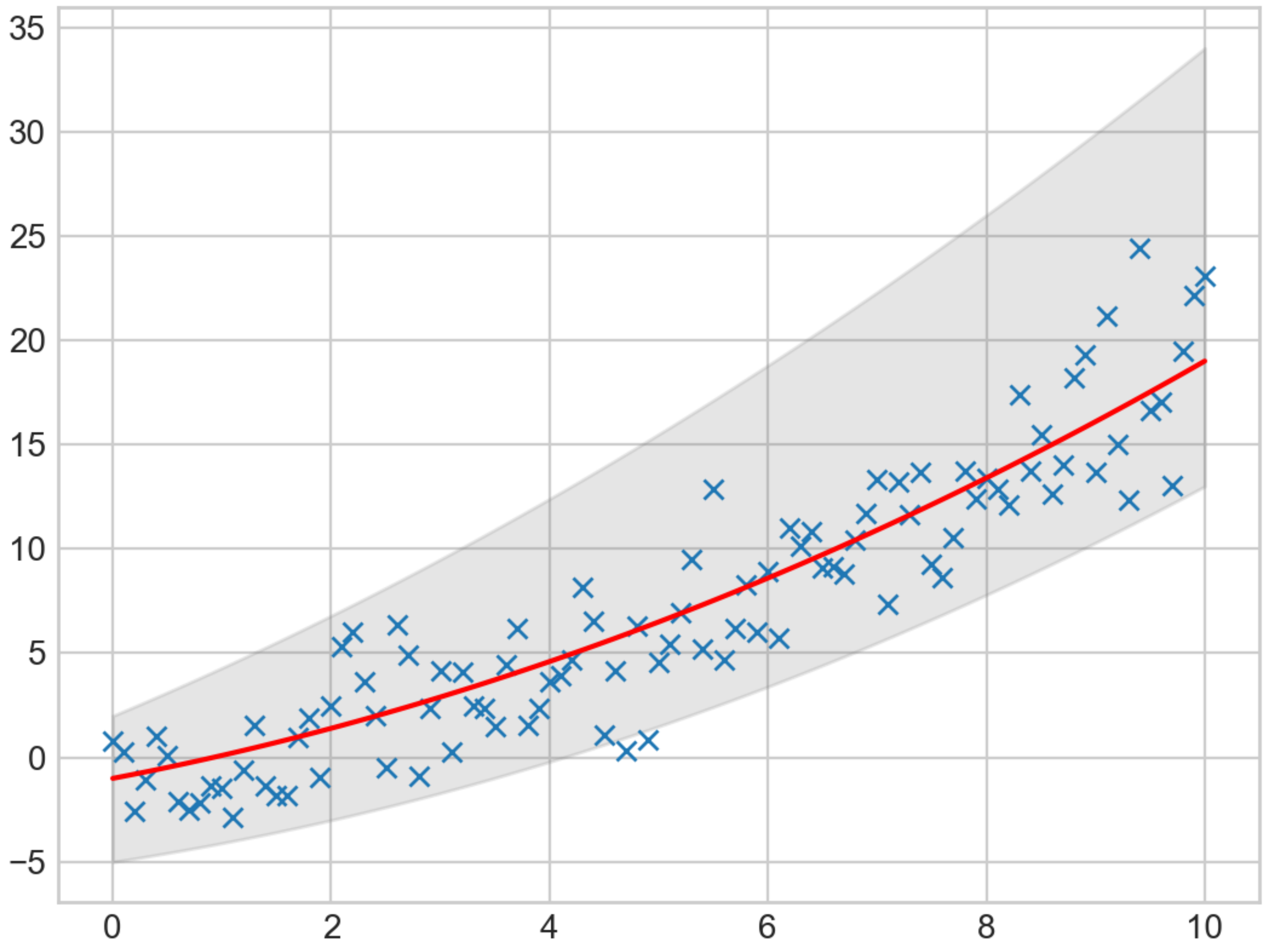


Error Bars

- Continuous errors
  - No real support in matplotlib
  - Can make it ourselves with filling between curves

```
x = np.linspace(0,10,101)
y = np.random.normal(loc = x**2/10+x-1 , scale = 2+x/10)
plt.plot(x,y, 'x')
plt.plot(x, x**2/10+x-1, 'r-')
plt.fill_between(x, x**2/10+x-1-2*(2+x/10),
x**2/10+2*(x-1+2+x/10), color = 'gray', alpha=0.2)

plt.show()
```

Error Bars



Contour / Density Plots

- As an example, use the following function

```
def f(x,y):
    return np.sin(x)**10+np.cos(10+y*x)*np.cos(x)
```

Contour / Density Plots

- Contour plot
  - Need to create a grid
    - Easiest with meshgrid

```
x = np.linspace(-5,5,101)
y = np.linspace(-5,5,101)
X,Y = np.meshgrid(x,y)
Z = f(X,Y)
```

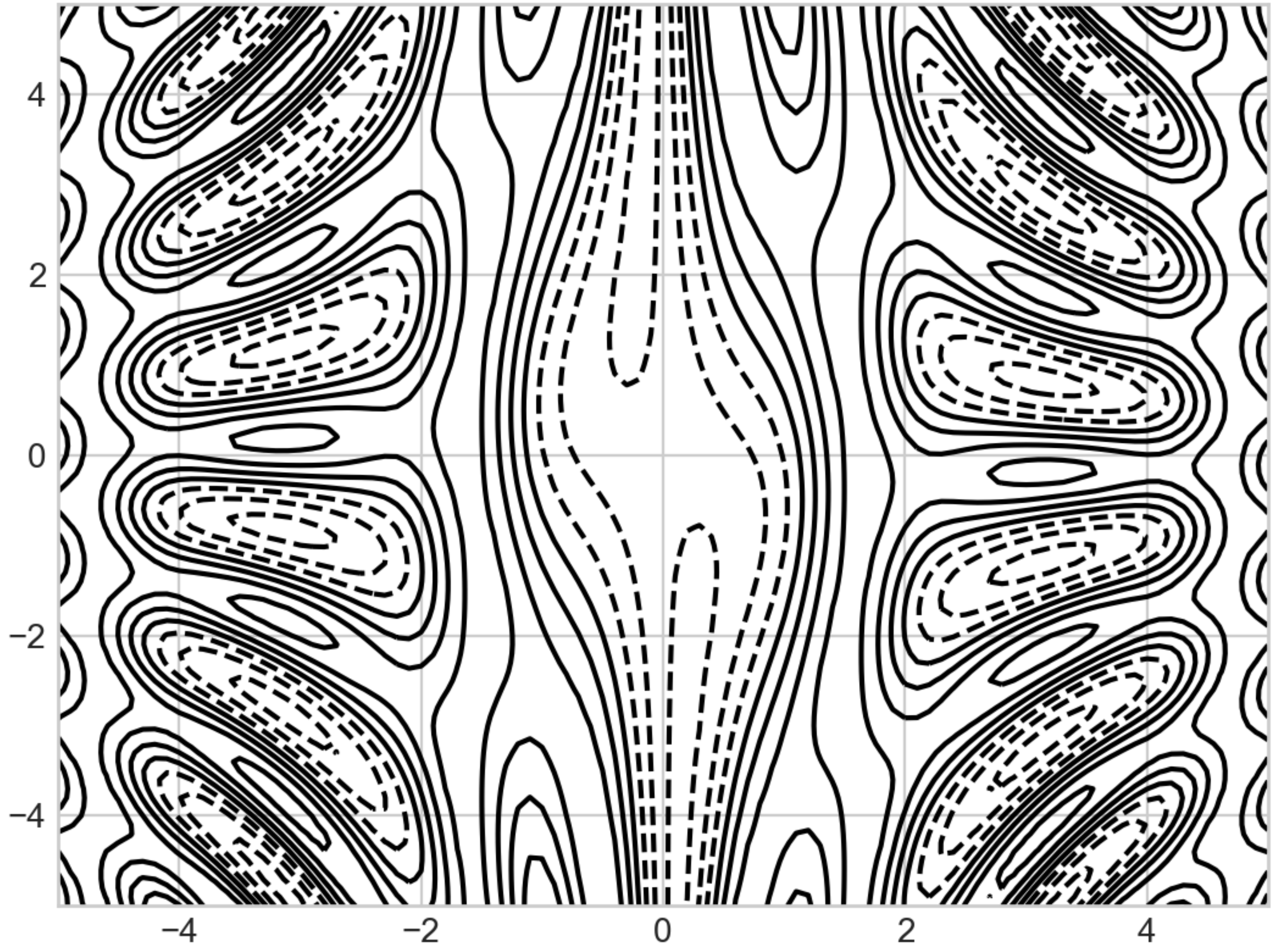
Contour / Density Plots

```
>>> X
array([[-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ],
       [-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ],
       [-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ],
       ...,
       [-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ],
       [-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ],
       [-5. , -4.9, -4.8, ...,  4.8,  4.9,  5. ]])
>>> Y
array([[-5. , -5. , -5. , ..., -5. , -5. , -5. ],
       [-4.9, -4.9, -4.9, ..., -4.9, -4.9, -4.9],
       [-4.8, -4.8, -4.8, ..., -4.8, -4.8, -4.8],
       ...,
       [ 4.8,  4.8,  4.8, ...,  4.8,  4.8,  4.8],
       [ 4.9,  4.9,  4.9, ...,  4.9,  4.9,  4.9],
       [ 5. ,  5. ,  5. , ...,  5. ,  5. ,  5. ]])
```

Contour / Density Plots

- Simple contour plot: dashed lines stand for neg. values

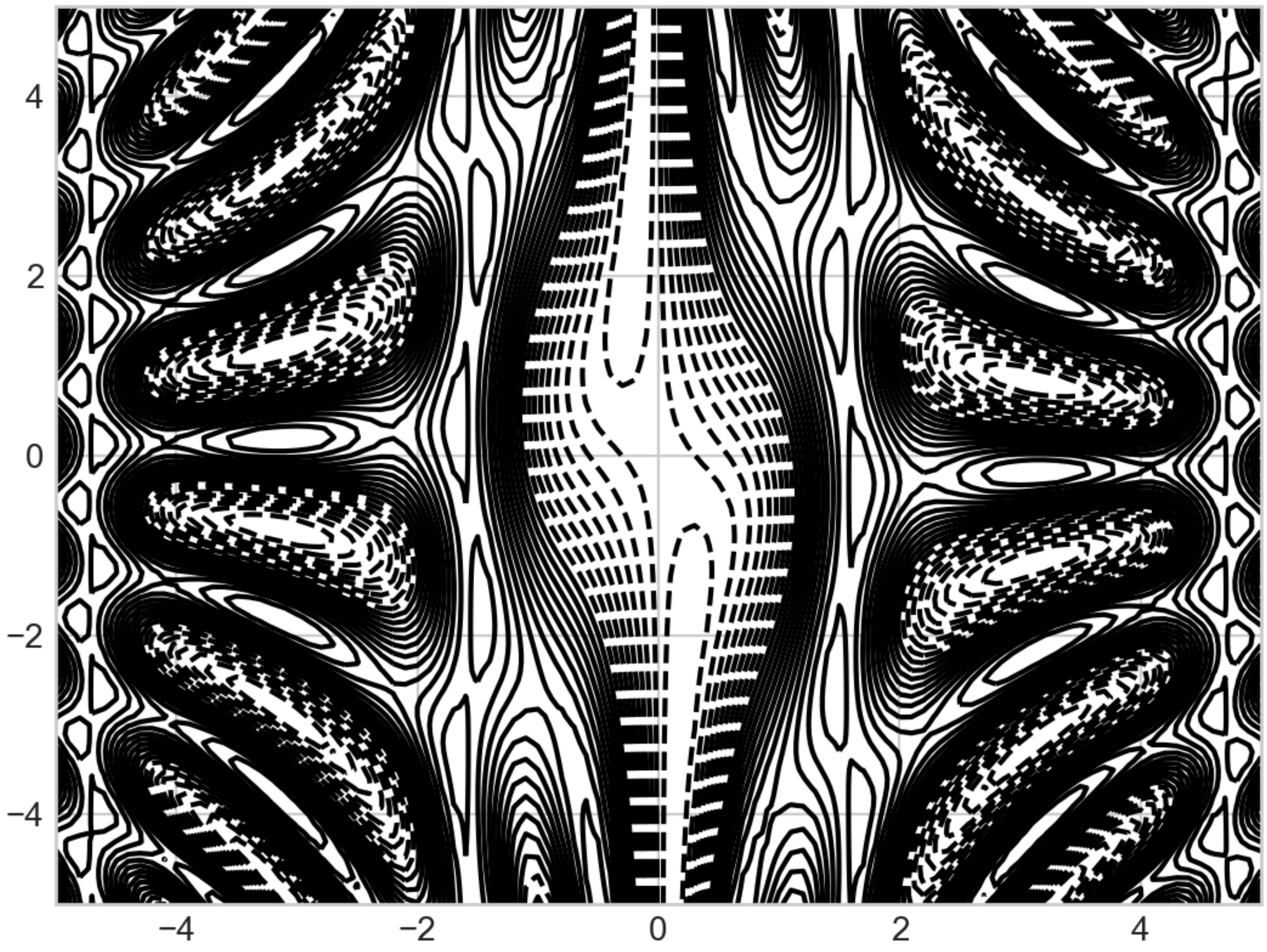
```
plt.contour(X,Y,Z, colors='black')
```



Contour / Density Plots

- Can specify the number of contour lines

```
plt.contour(X,Y,Z, 20, colors='black')
```



Contour / Density Plots

- Can use a color map

```
plt.contour(X,Y,Z, 20,  cmap = 'RdGy')
plt.colorbar()
```