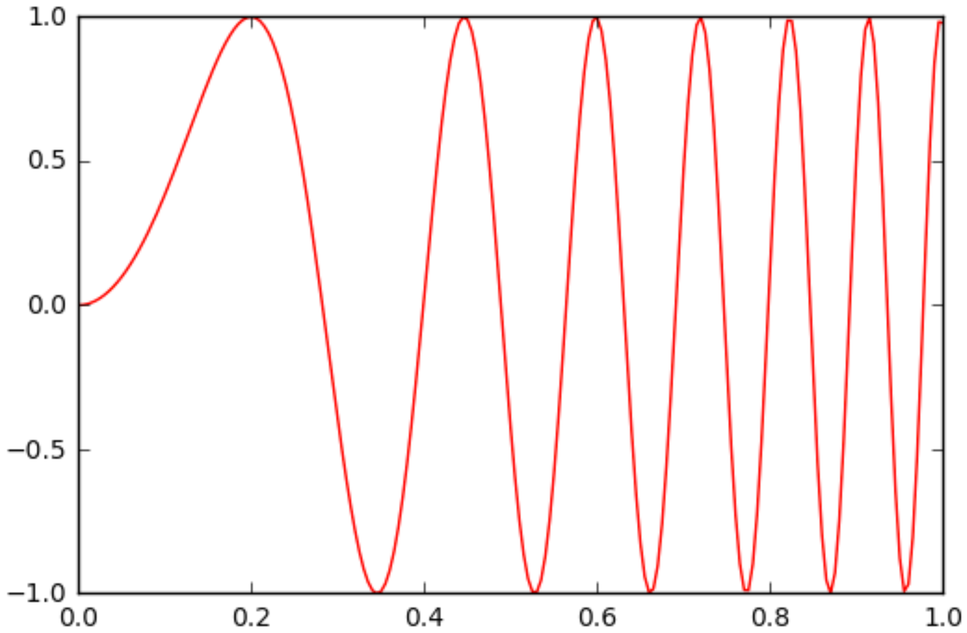
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Introduction to Data Visualization with Python

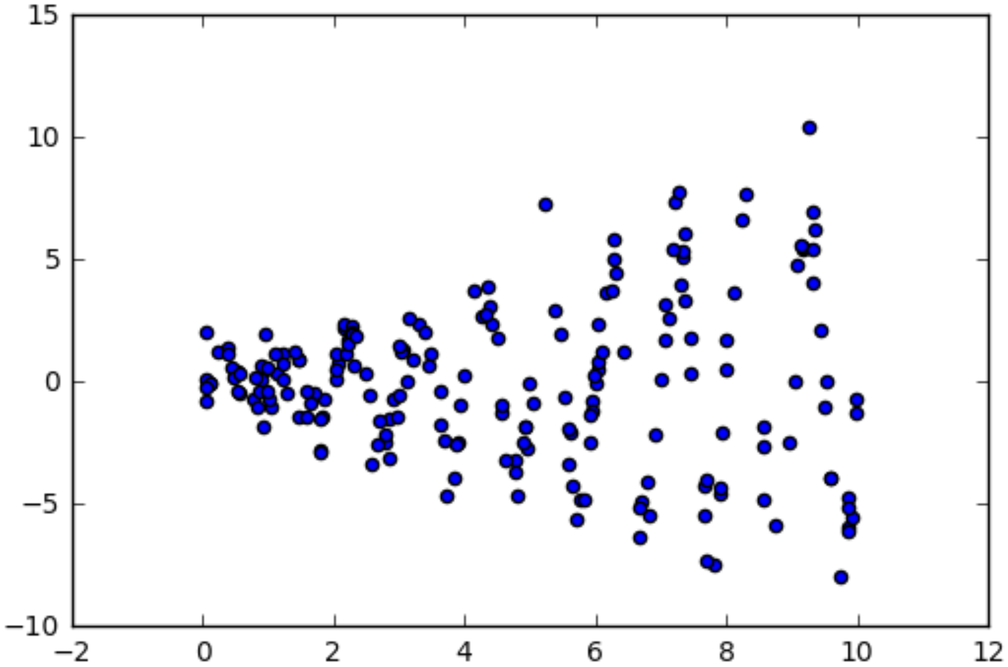
Reminder: Line plots

```
In [1]: import numpy as np

In [2]: import matplotlib.pyplot as plt

In [3]: x = np.linspace(0, 1, 201)

In [4]: y = np.sin((2*np.pi*x)**2)

In [5]: plt.plot(x, y, 'red')

In [6]: plt.show()
```



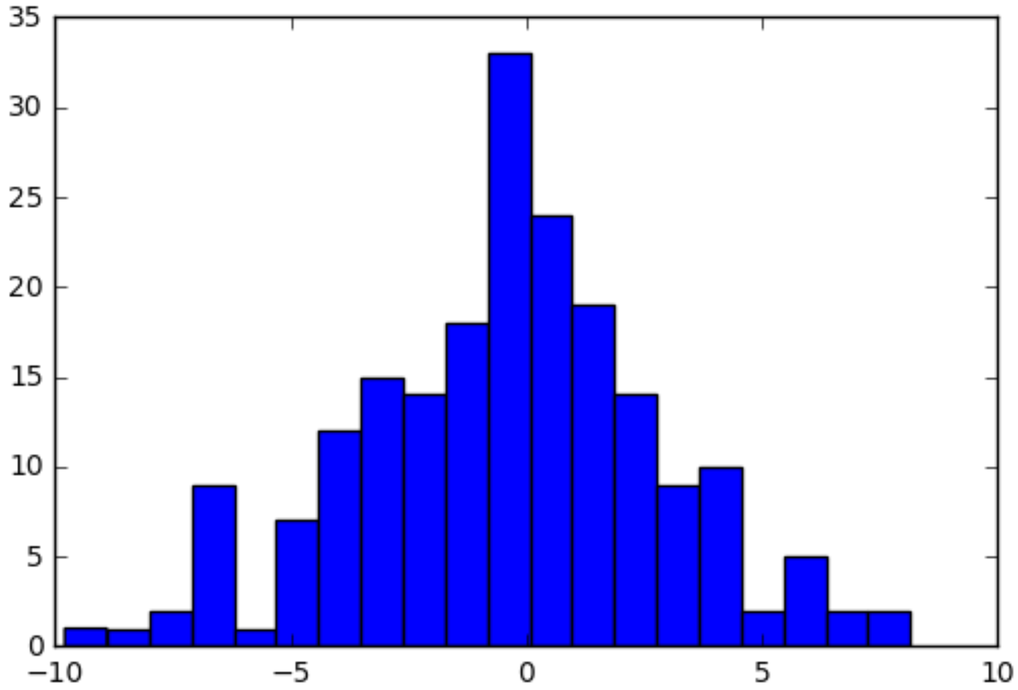
Reminder: Scatter plots

```
In [1]: import numpy as np

In [2]: import matplotlib.pyplot as plt

In [3]: x = 10*np.random.rand(200,1)

In [4]: y = (0.2 + 0.8*x) * np.sin(2*np.pi*x) + \
   ...:     np.random.randn(200,1)

In [5]: plt.scatter(x,y)

In [6]: plt.show()
```



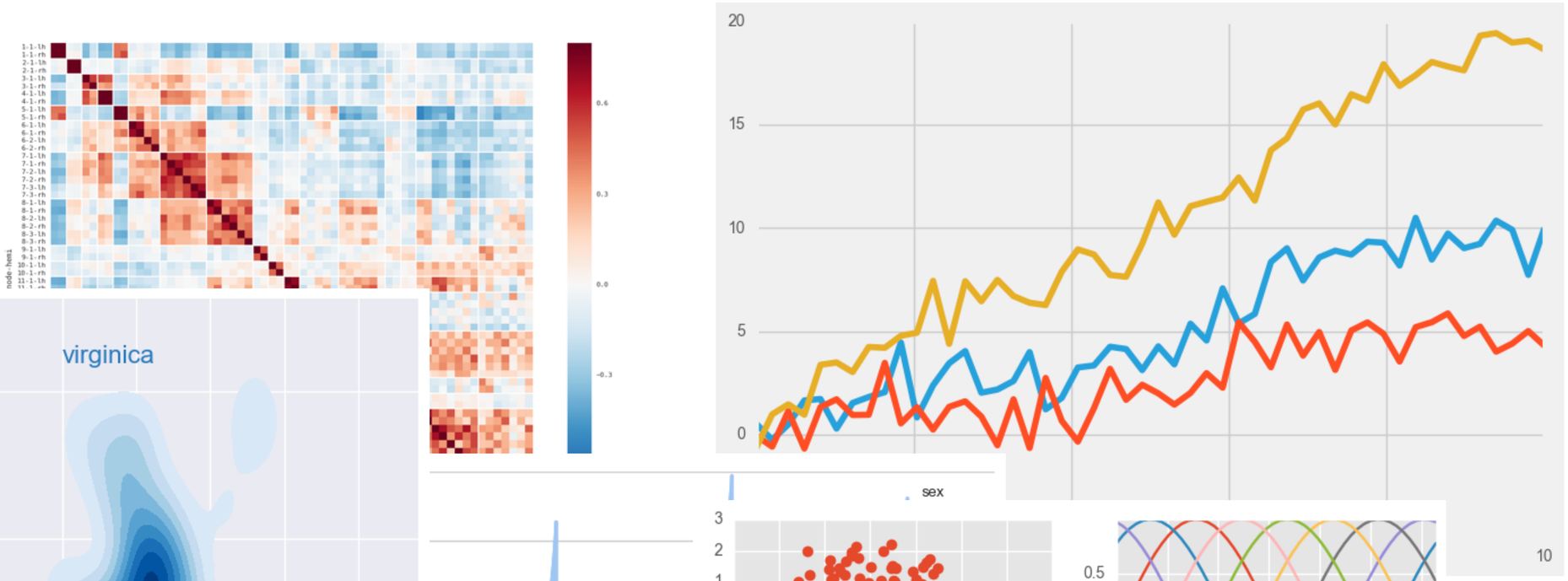
Reminder: Histograms

```
In [1]: import numpy as np

In [2]: import matplotlib.pyplot as plt

In [3]: x = 10*np.random.rand(200,1)

In [4]: y = (0.2 + 0.8*x) * \
   ...:     np.sin(2*np.pi*x) + \
   ...:     np.random.randn(200,1)

In [5]: plt.hist(y, bins=20)

In [6]: plt.show()
```



What you will learn

- Customizing of plots: axes, annotations, legends
- Overlaying multiple plots and subplots
- Visualizing 2D arrays, 2D data sets
- Working with color maps
- Producing statistical graphics
- Plotting time series
- Working with images


virginica
setosa
sepal_length
sepal_width
sex
Fri
day

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

See you in the course!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Plotting multiple graphs

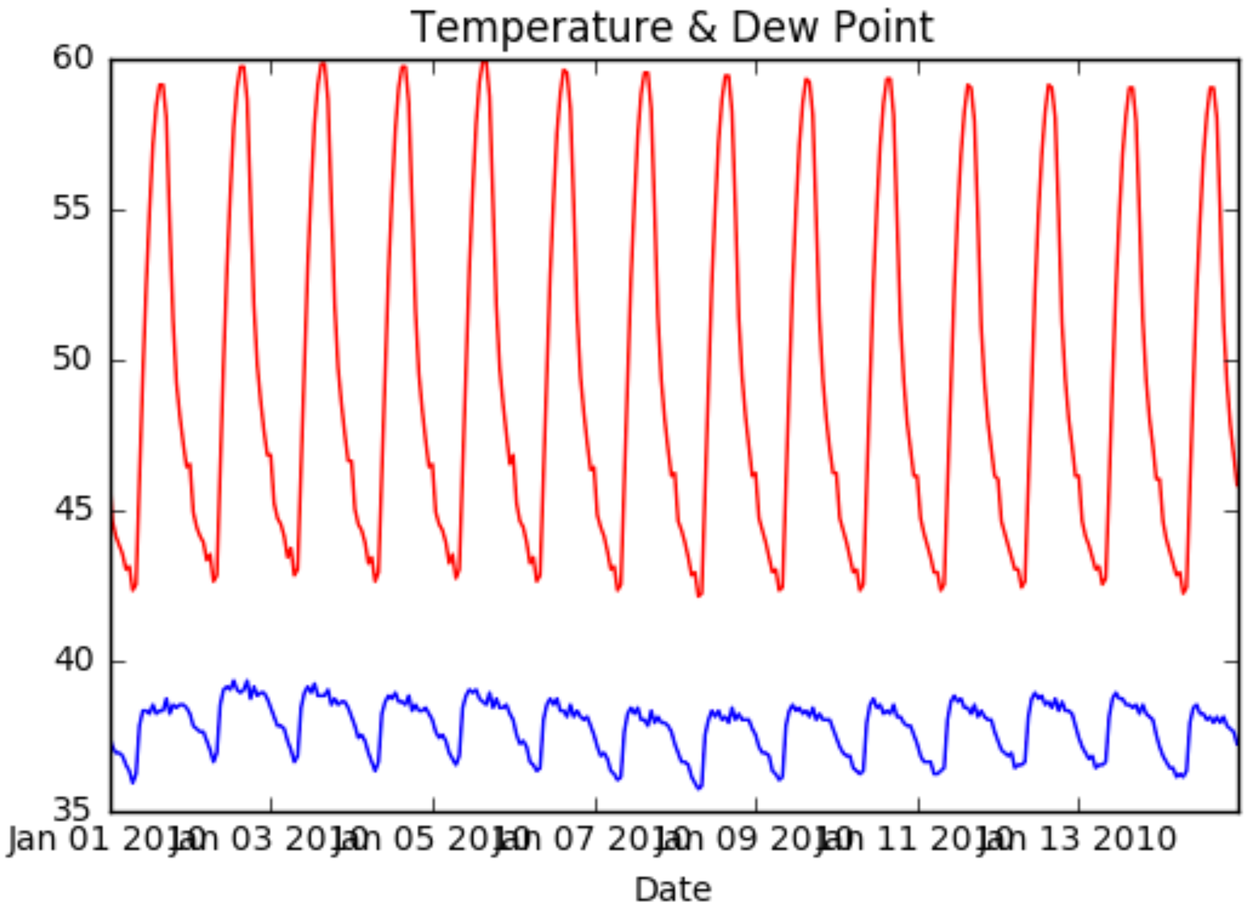
Strategies

- Plotting many graphs on common axes
- Creating axes within a figure
- Creating subplots within a figure

Graphs on common axes

```
In [1]: import matplotlib.pyplot as plt

In [2]: plt.plot(t, temperature, 'red')

In [3]: plt.plot(t, dewpoint, 'blue') # Appears on same axes

In [4]: plt.xlabel('Date')

In [5]: plt.title('Temperature & Dew Point')

In [6]: plt.show() # Renders plot objects to screen
```

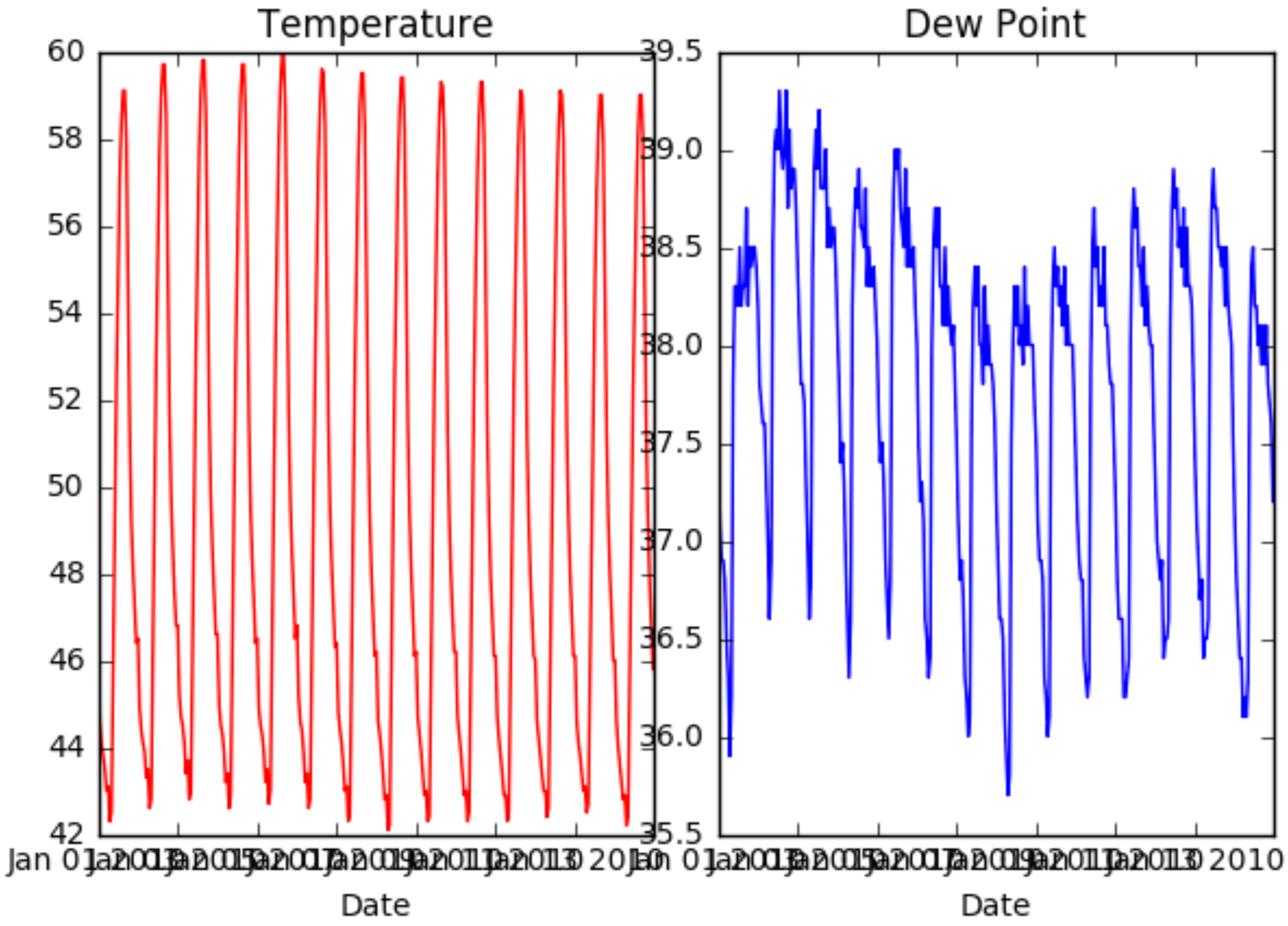
Graphs on common axes



Using axes()

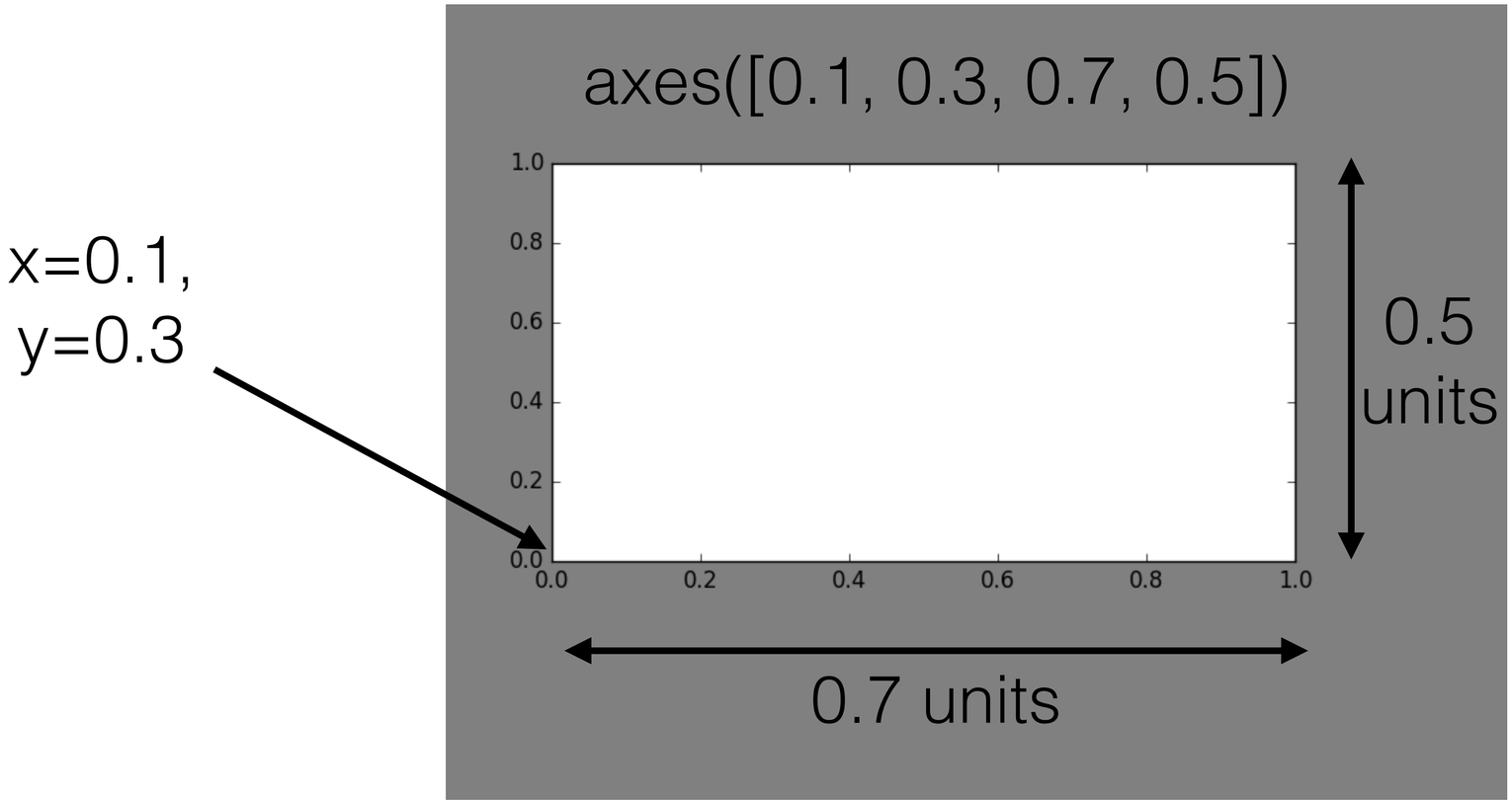
```
In [1]: plt.axes([0.05,0.05,0.425,0.9])

In [2]: plt.plot(t, temperature, 'red')

In [3]: plt.xlabel('Date')

In [4]: plt.title('Temperature')

In [5]: plt.axes([0.525,0.05,0.425,0.9])

In [6]: plt.plot(t, dewpoint, 'blue')

In [7]: plt.xlabel('Date')

In [8]: plt.title('Dew Point')

In [9]: plt.show()
```

Using axes()

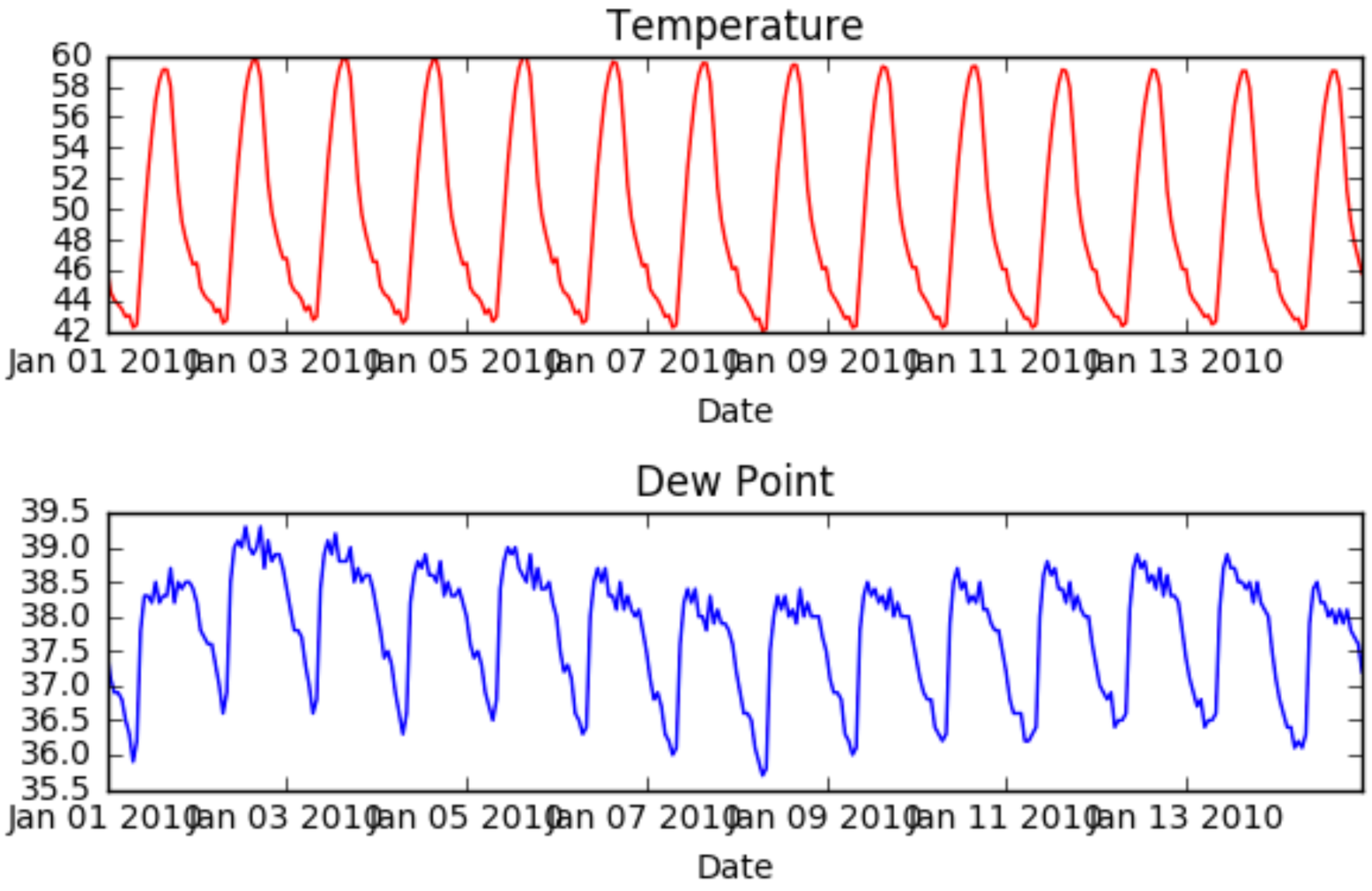

Temperature
60
58
56
54
52
50
48
46
44
42
Jan 01 2010
Date
Dew Point
39.5
39.0
38.5
38.0
37.5
37.0
36.5
36.0
35.5
Jan 01 2010
Date

The axes() command

- Syntax: axes([x_lo, y_lo, width, height])
- Units between 0 and 1 (figure dimensions)



Using subplot()



Using subplot()

```
In [1]: plt.subplot(2, 1, 1)

In [2]: plt.plot(t, temperature, 'red')

In [3]: plt.xlabel('Date')

In [4]: plt.title('Temperature')

In [5]: plt.subplot(2, 1, 2)

In [6]: plt.plot(t, dewpoint, 'blue')

In [7]: plt.xlabel('Date')

In [8]: plt.title('Dew Point')

In [9]: plt.tight_layout()

In [10]: plt.show()
```

The subplot() command

- Syntax: subplot(nrows, ncols, nsubplot)
- Subplot ordering:
  - Row-wise from top left
  - Indexed from 1

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Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Customizing axes

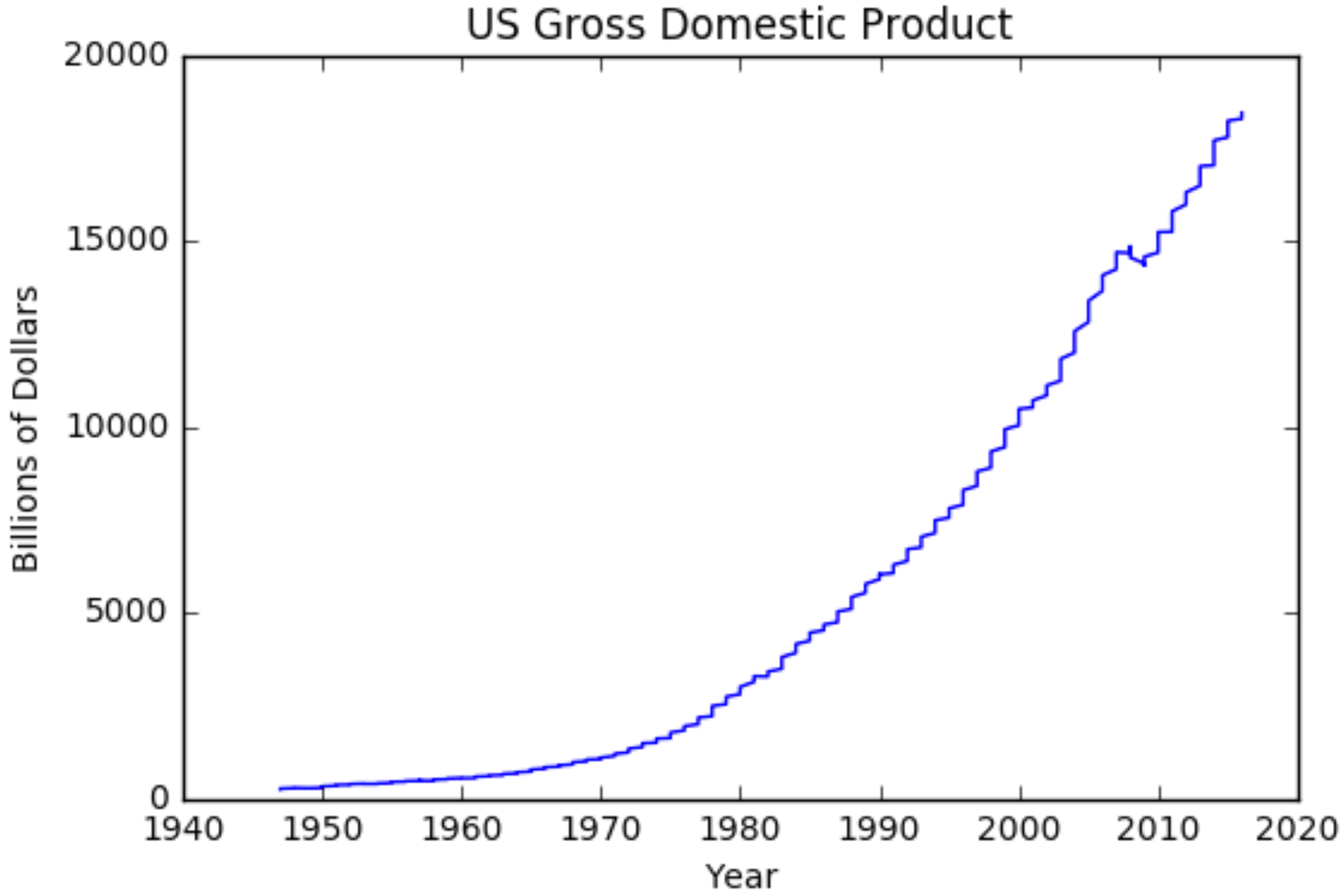
Controlling axis extents

- axis([xmin, xmax, ymin, ymax]) sets axis extents
- Control over individual axis extents
  - xlim([xmin, xmax])
  - ylim([ymin, ymax])
- Can use tuples, lists for extents
  - e.g., xlim((-2, 3)) works
  - e.g., xlim([-2, 3]) works also

GDP over time

```
In [1]: import matplotlib.pyplot as plt

In [2]: plt.plot(yr, gdp)

In [3]: plt.xlabel('Year')

In [4]: plt.ylabel('Billions of Dollars')

In [5]: plt.title('US Gross Domestic Product')

In [6]: plt.show()
```

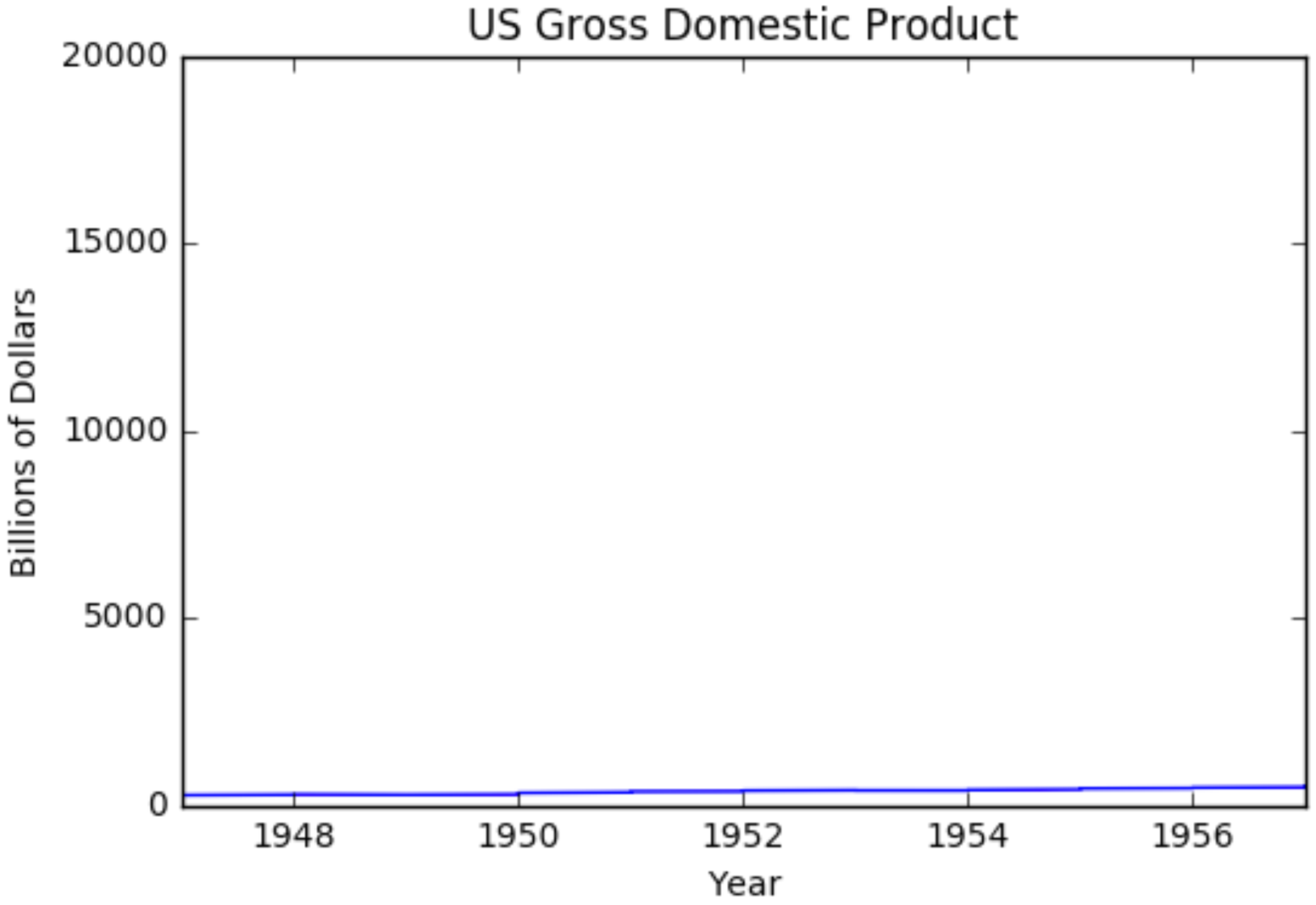
GDP over time



Using xlim()

```
In [1]: plt.plot(yr, gdp)

In [2]: plt.xlabel('Year')

In [3]: plt.ylabel('Billions of Dollars')

In [4]: plt.title('US Gross Domestic Product')

In [5]: plt.xlim((1947, 1957))

In [6]: plt.show()
```

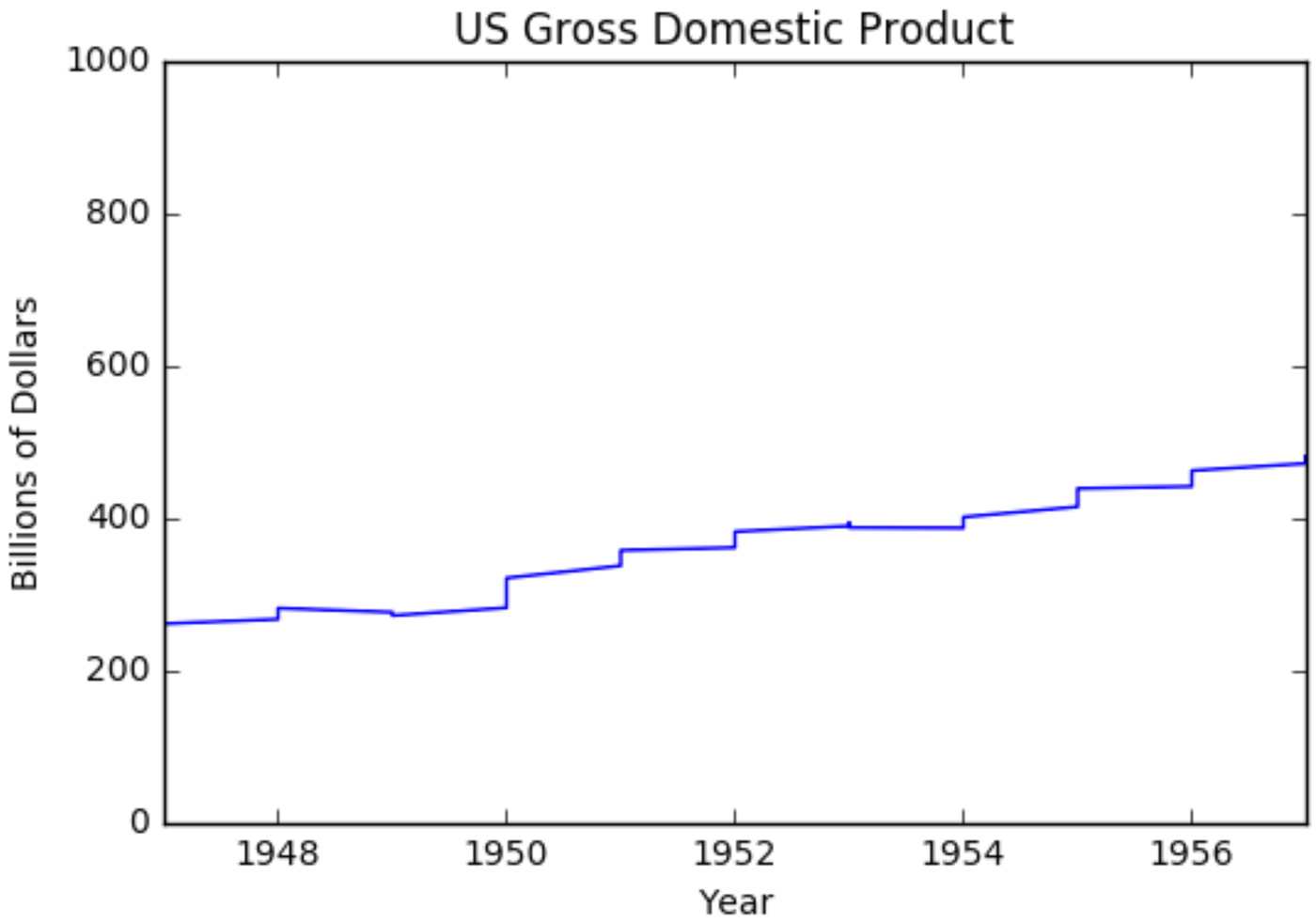
Using xlim()


US Gross Domestic Product
20000
15000
10000
5000
0
Billions of Dollars
1948
1950
1952
1954
1956
Year

Using xlim() & ylim()

```
In [1]: plt.plot(yr, gdp)

In [2]: plt.xlabel('Year')

In [3]: plt.ylabel('Billions of Dollars')

In [4]: plt.title('US Gross Domestic Product')

In [5]: plt.xlim((1947, 1957))

In [6]: plt.ylim((0, 1000))

In [7]: plt.show()
```

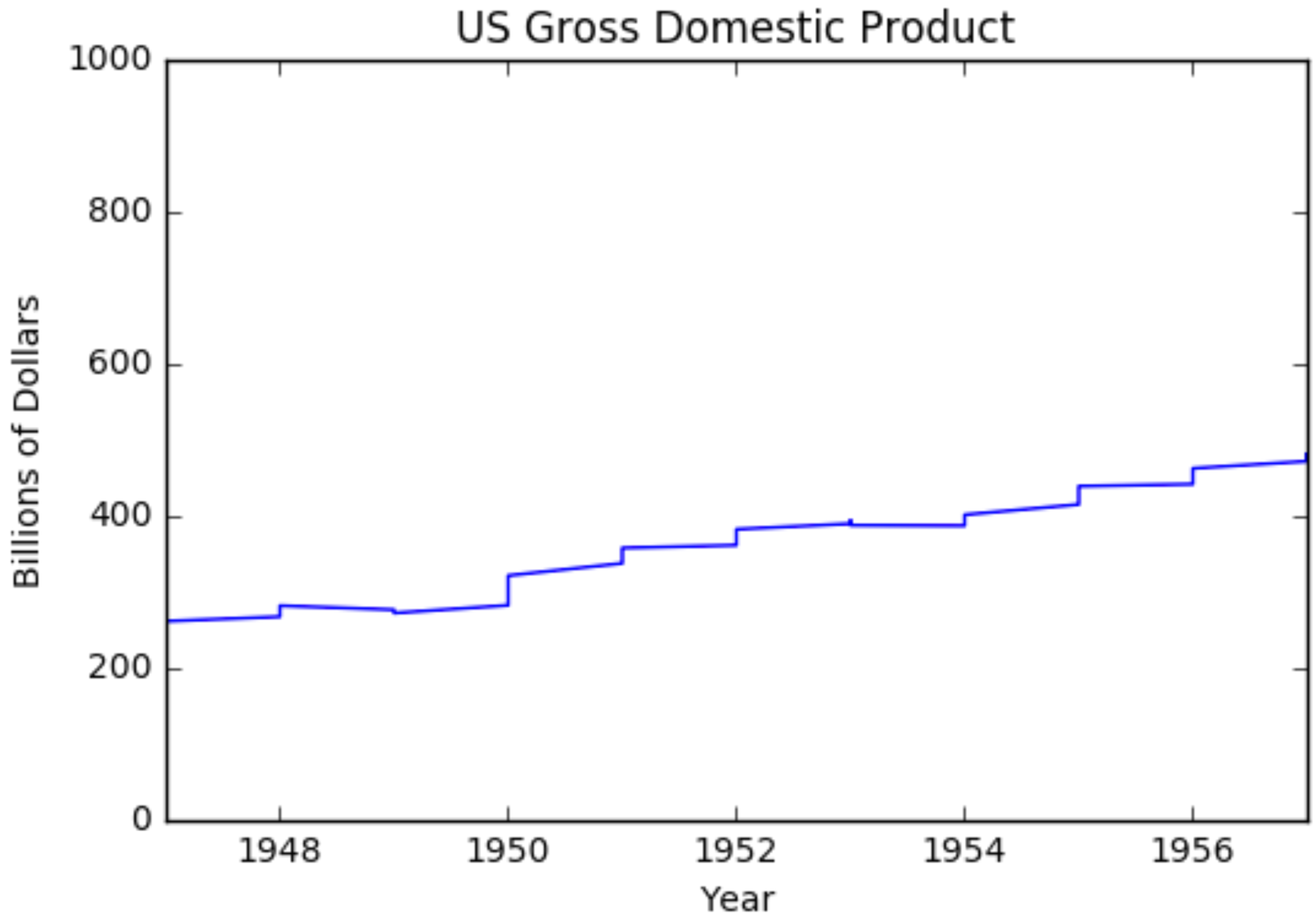
Using xlim() & ylim()



Using axis()

```
In [1]: plt.plot(yr, gdp)

In [2]: plt.xlabel('Year')

In [3]: plt.ylabel('Billions of Dollars')

In [4]: plt.title('US Gross Domestic Product')

In [5]: plt.axis((1947, 1957, 0, 600))

In [6]: plt.show()
```

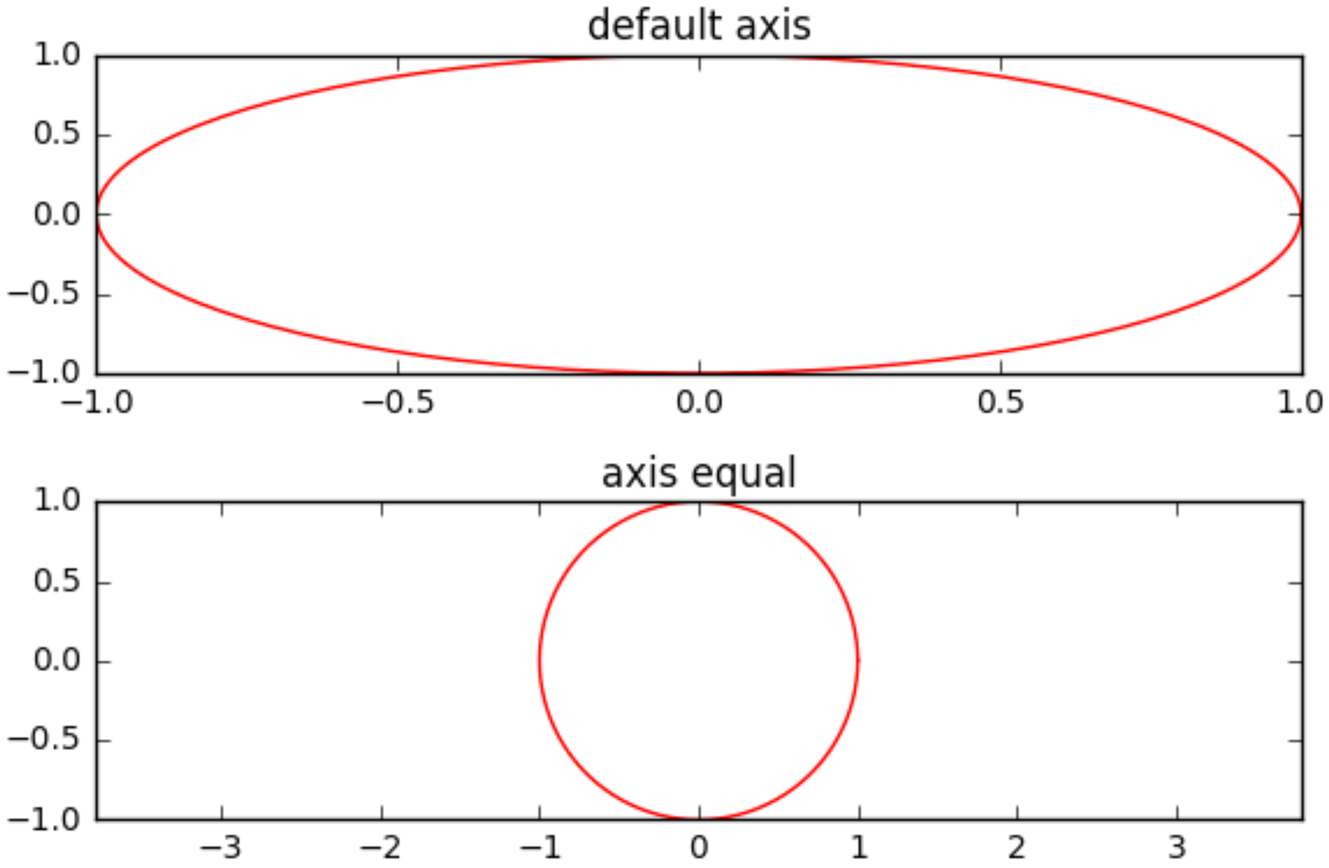
Using axis()


US Gross Domestic Product
1000
800
600
400
200
0
Billions of Dollars
1948
1950
1952
1954
1956
Year

Other axis() options

Invocation	Result
axis('off')	turns off axis lines, labels
axis('equal')	equal scaling on x, y axes
axis('square')	forces square plot
axis('tight')	sets xlim(), ylim() to show all data

Using axis('equal')



Using axis('equal')

```
In [1]: plt.subplot(2, 1, 1)

In [2]: plt.plot(x, y, 'red')

In [3]: plt.title('default axis')

In [4]: plt.subplot(2, 1, 2)

In [5]: plt.plot(x, y, 'red')

In [6]: plt.axis('equal')

In [7]: plt.title('axis equal')

In [8]: plt.tight_layout()

In [9]: plt.show()
```

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

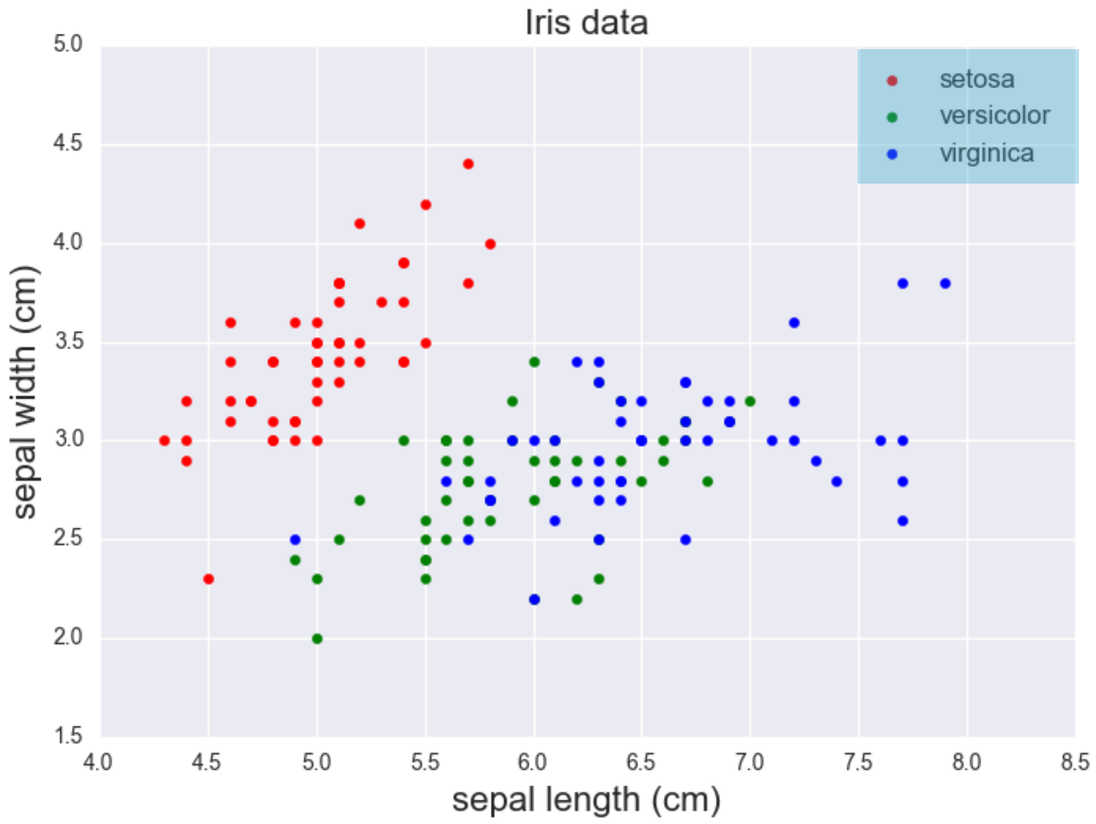
Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Legends, annotations, and styles

Legends

- provide labels for overlaid points and curves



Legend

Using legend()

```
In [1]: import matplotlib.pyplot as plt

In [2]: plt.scatter(setosa_len, setosa_wid,
   ...:             marker='o', color='red', label='setosa')

In [3]: plt.scatter(versicolor_len, versicolor_wid,
   ...:             marker='o', color='green', label='versicolor')

In [4]: plt.scatter(virginica_len, virginica_wid,
   ...:             marker='o', color='blue', label='virginica')
```

Using legend()

```
In [5]: plt.legend(loc='upper right')

In [6]: plt.title('Iris data')

In [7]: plt.xlabel('sepal length (cm)')

In [8]: plt.ylabel('sepal width (cm)')

In [9]: plt.show()
```

Legend locations

string	code	string	code	string	code
'upper left'	2	'upper center'	9	'upper right'	1
'center left'	6	'center'	10	'center right'	7
'lower left'	3	'lower center'	8	'lower right'	4
'best'	0			'right'	5

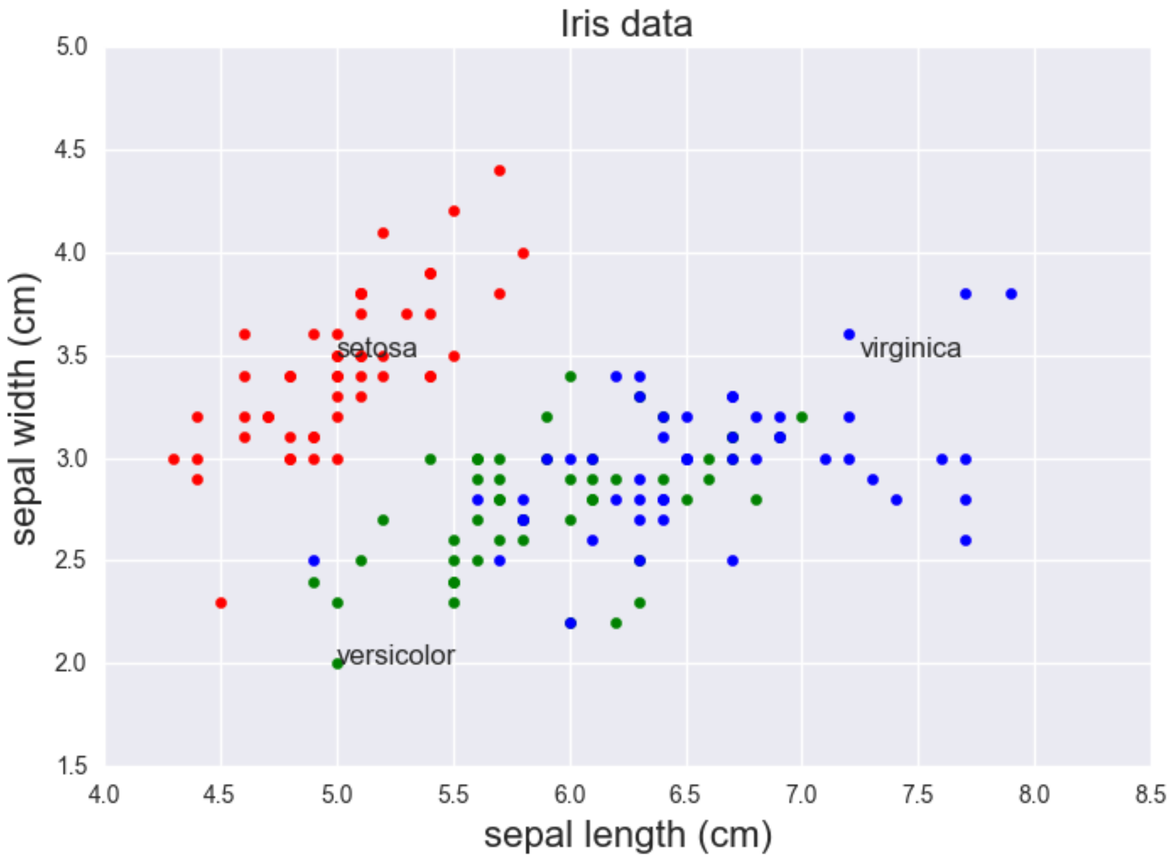
Plot annotations

- Text labels and arrows using annotate() method
- Flexible specification of coordinates
- Keyword arrowprops: dict of arrow properties
  - width
  - color
  - etc.

Using annotate() for text

```
In [1]: plt.annotate('setosa', xy=(5.0, 3.5))

In [2]: plt.annotate('virginica', xy=(7.25, 3.5))

In [3]: plt.annotate('versicolor', xy=(5.0, 2.0))

In [4]: plt.show()
```

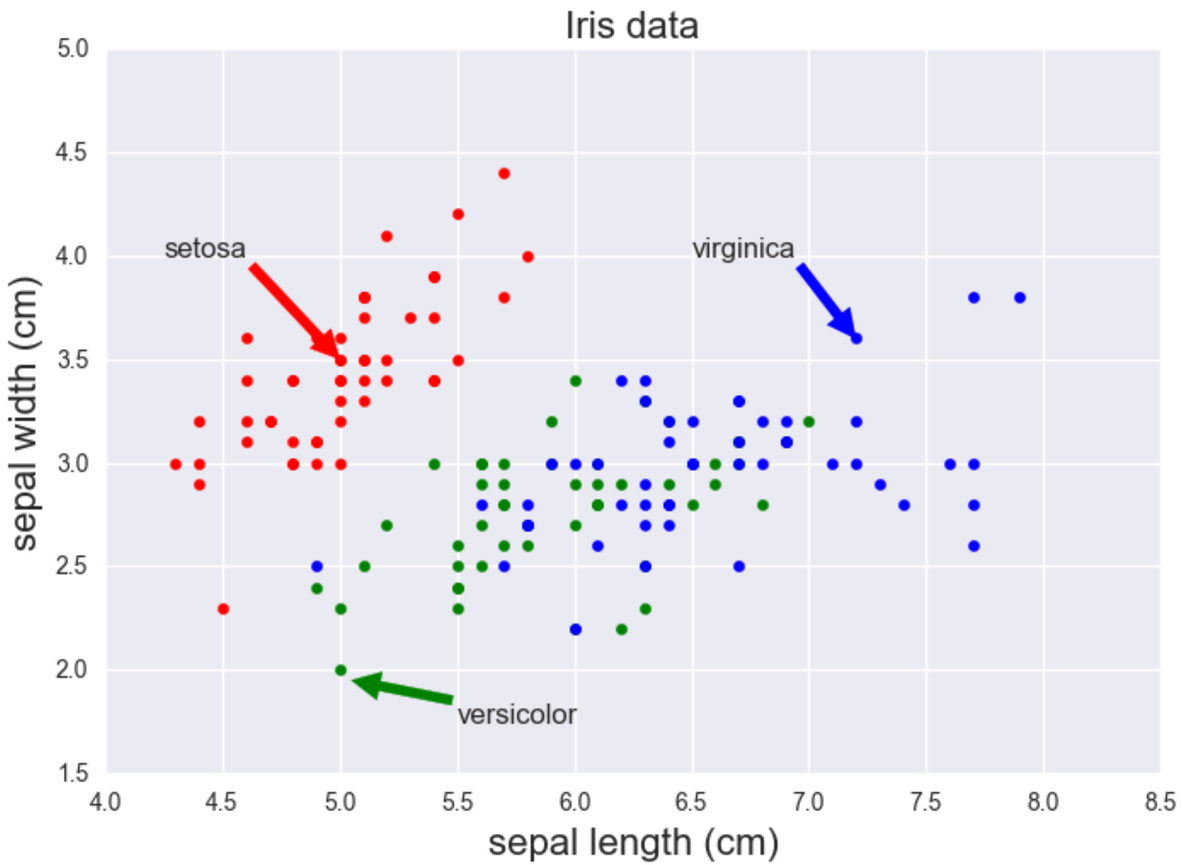
Using annotate() for text



Options for annotate()

option	description
s	text of label
xy	coordinates to annotate
xytext	coordinates of label
arrowprops	controls drawing of arrow

Using annotate() for arrows



Using annotate() for arrows

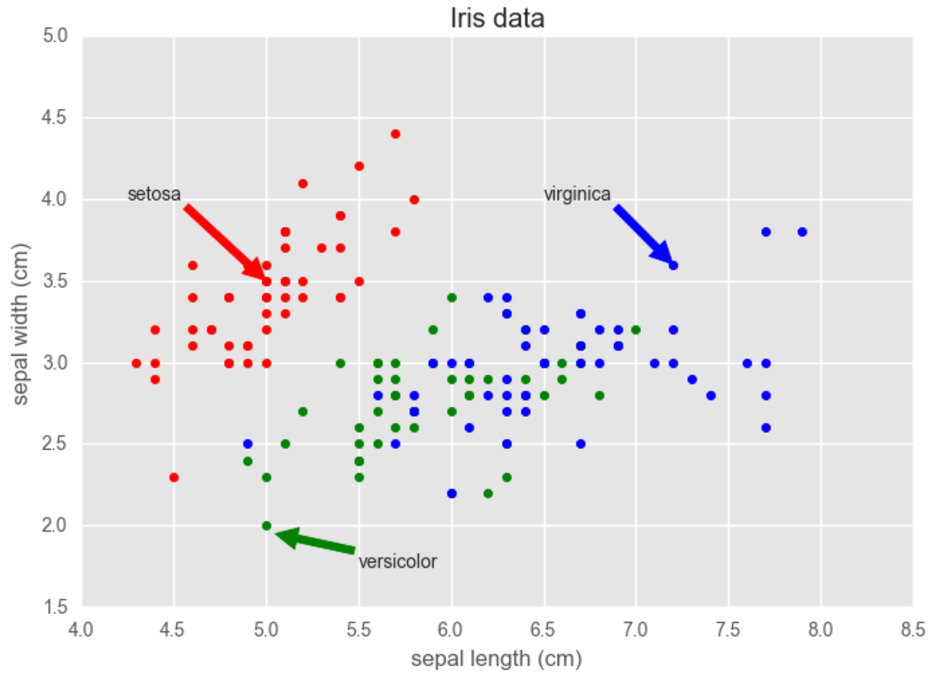
```
In [1]: plt.annotate('setosa', xy=(5.0, 3.5),
   ...:              xytext=(4.25, 4.0), arrowprops={'color':'red'})

In [2]: plt.annotate('virginica', xy=(7.2, 3.6),
   ...:              xytext=(6.5, 4.0), arrowprops={'color':'blue'})

In [3]: plt.annotate('versicolor', xy=(5.05, 1.95),
   ...:              xytext=(5.5, 1.75),
   ...:              arrowprops={'color':'green'})

In [4]: plt.show()
```

Working with plot styles

- Style sheets in Matplotlib
- Defaults for lines, points, backgrounds, etc.
- Switch styles globally with plt.style.use()
- plt.style.available: list of styles

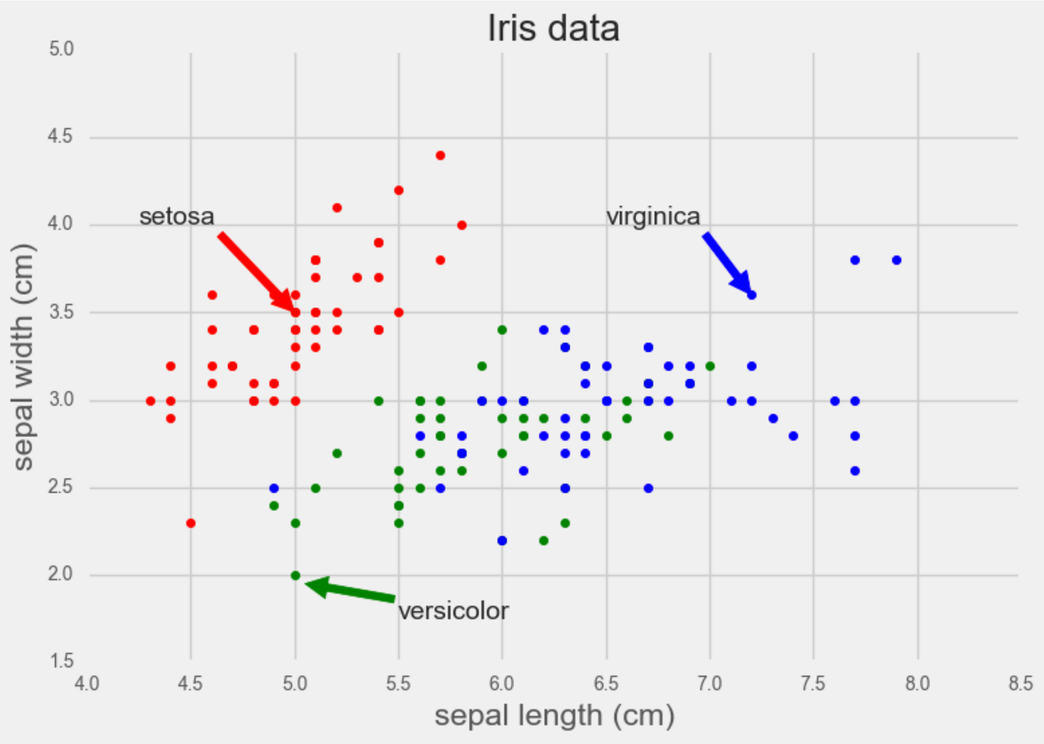
ggplot style

```
In [1]: import matplotlib.pyplot as plt

In [2]: plt.style.use('ggplot')
```



fivethirtyeight style

```
In [1]: import matplotlib.pyplot as plt

In [2]: plt.style.use('fivethirtyeight')
```



INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Working with 2D arrays

Reminder: NumPy arrays

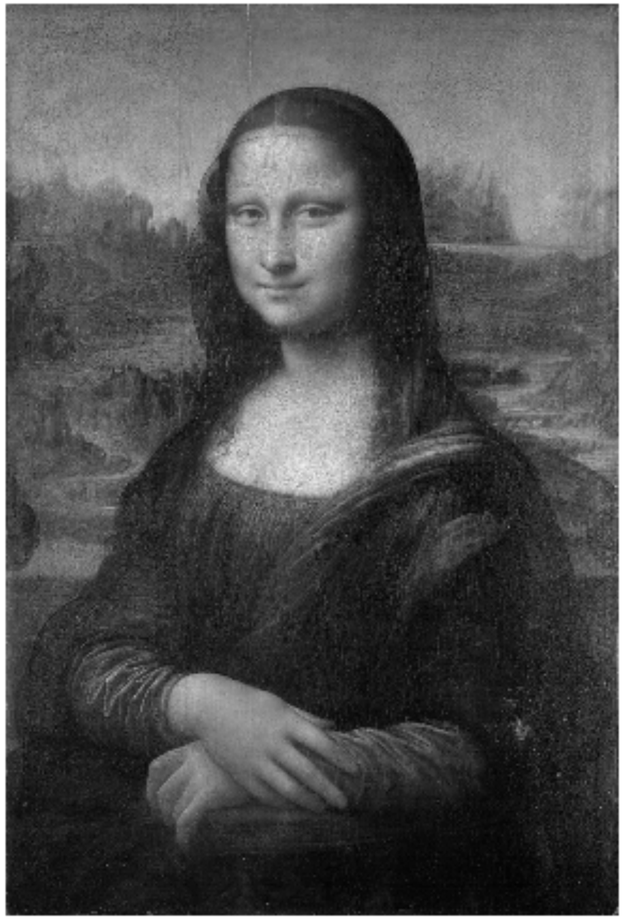
- Homogeneous in type
- Calculations all at once
- Indexing with brackets:
  - A[*index*] for 1D array
  - A[*index0*, *index1*] for 2D array

Reminder: slicing arrays

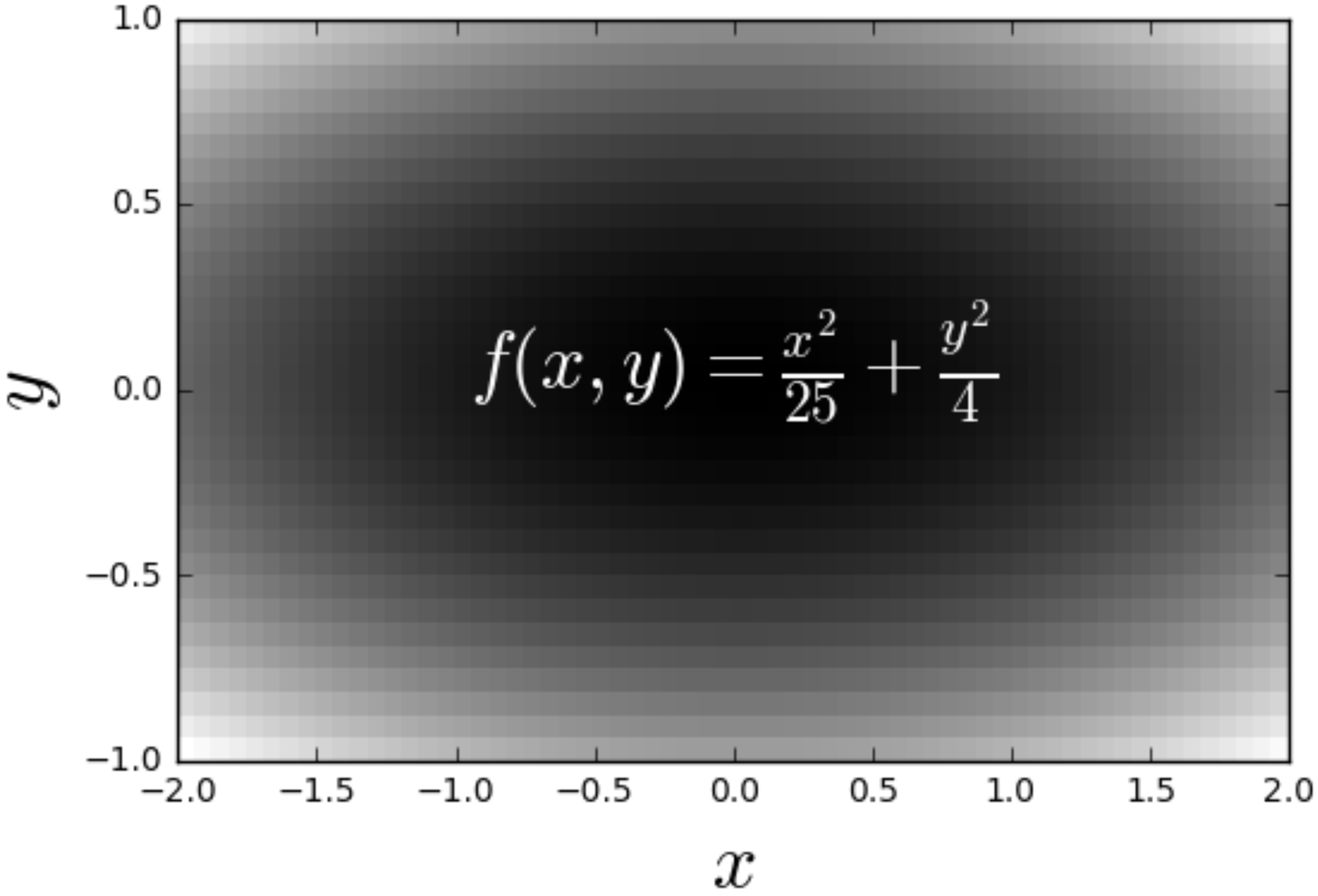
- Slicing: 1D arrays: A[*slice*], 2D arrays: A[*slice0*, *slice1*]
- Slicing: *slice* = *start:stop:stride*
  - Indexes from *start* to *stop-1* in steps of *stride*
  - Missing *start*: implicitly at *beginning* of array
  - Missing *stop*: implicitly at *end* of array
  - Missing *stride*: implicitly *stride 1*
- Negative indexes/slices: count from *end of array*

2D arrays & images

0.434	0.339	0.337	0.367	...
0.434	0.421	0.404	0.395	...
0.350	0.388	0.340	0.340	...
0.328	0.384	0.308	0.308	...
...	...	...	...	...



2D arrays & functions



Using meshgrid()

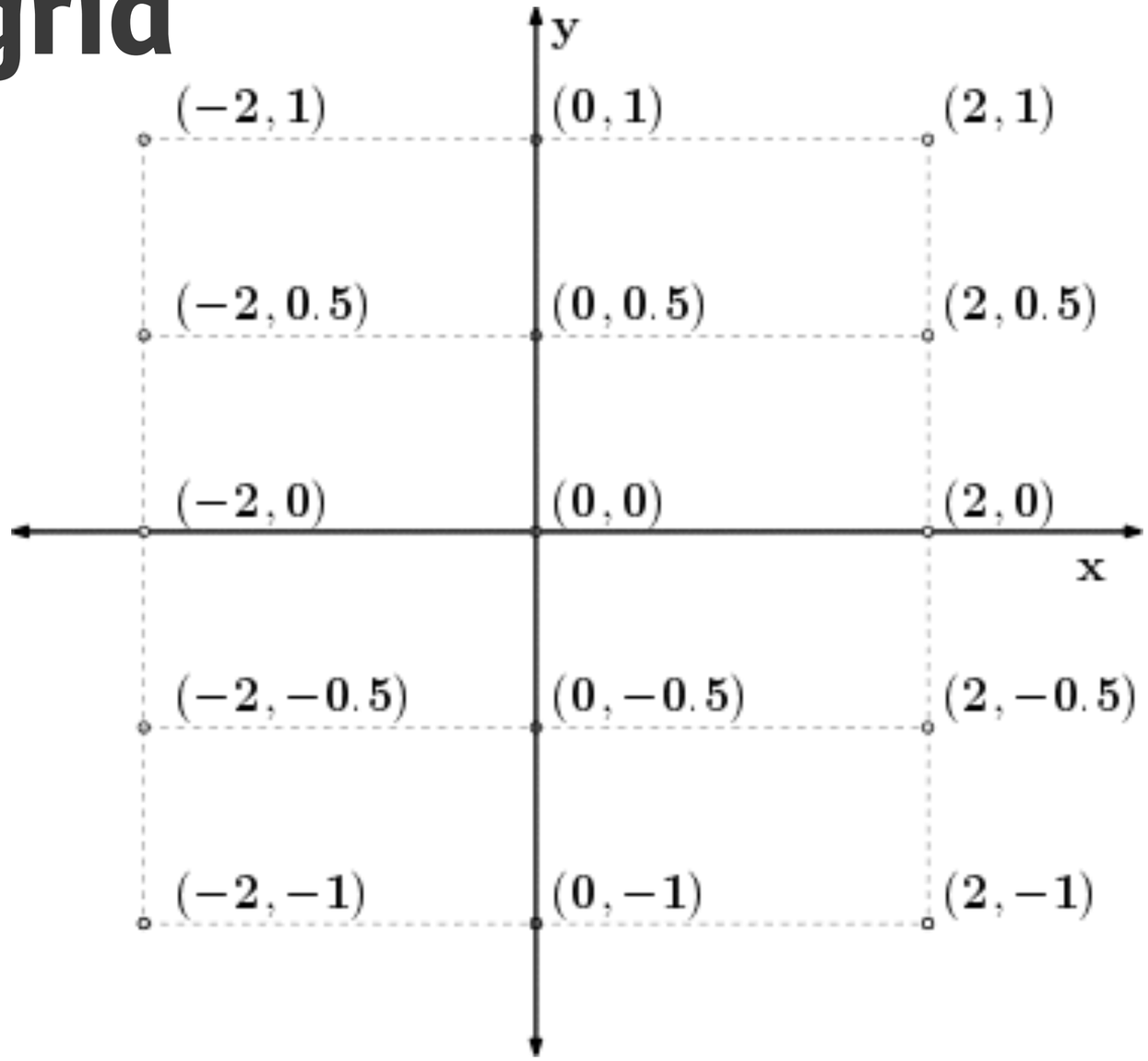
meshgrids.py

```
import numpy as np

u = np.linspace(-2, 2, 3)

v = np.linspace(-1, 1, 5)

X,Y = np.meshgrid(u, v)

Z = X**2/25 + Y**2/4
```

Using meshgrid()

```
X:
 [[-2.  0.  2.]
 [-2.  0.  2.]
 [-2.  0.  2.]
 [-2.  0.  2.]
 [-2.  0.  2.]]

Y:
[[-1.  -1.  -1. ]
 [-0.5 -0.5 -0.5]
 [ 0.   0.   0. ]
 [ 0.5  0.5  0.5]
 [ 1.   1.   1. ]]
```

Meshgrid



Sampling on a grid

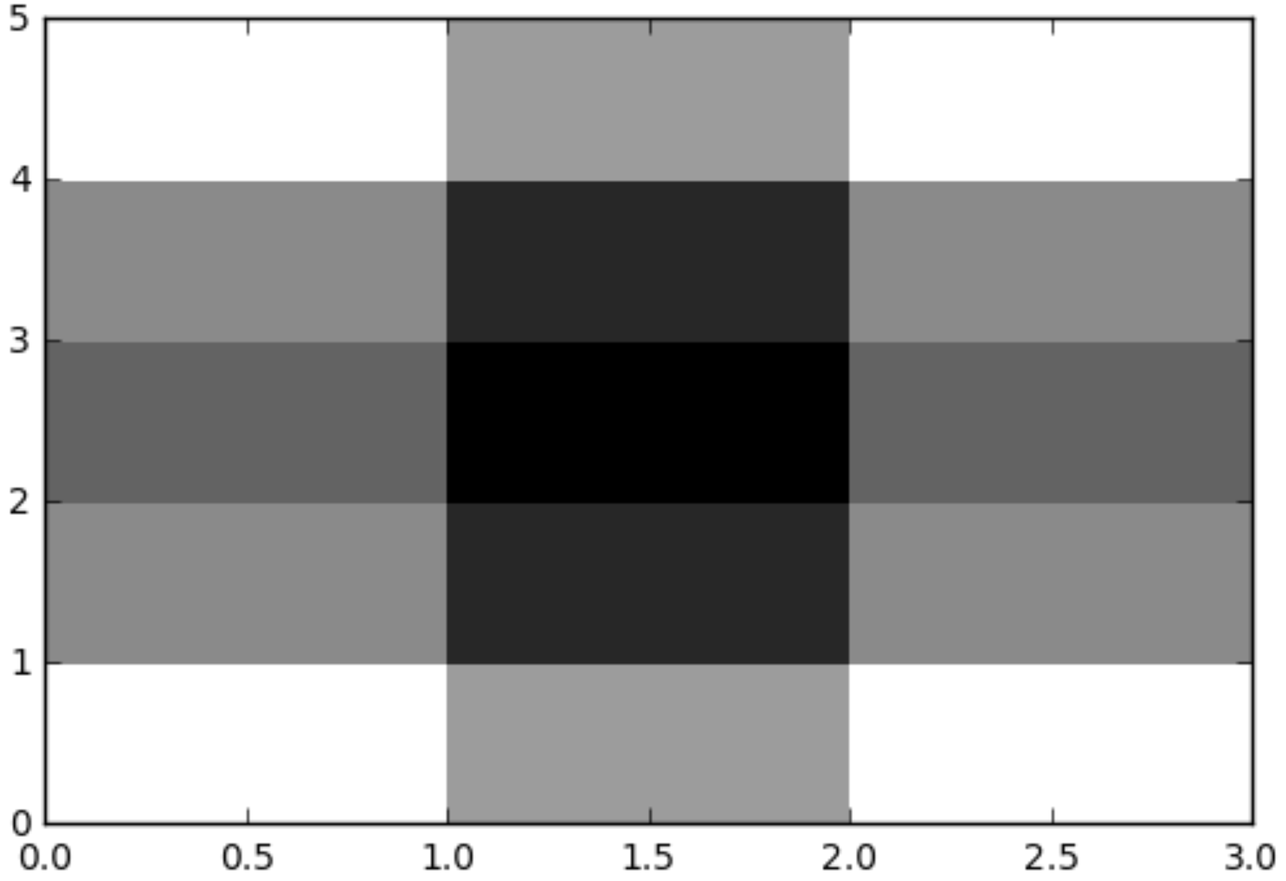
meshgrids.py

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

u = np.linspace(-2, 2, 3)
v = np.linspace(-1, 1, 5)
X,Y = np.meshgrid(u, v)
Z = X**2/25 + Y**2/4

print('Z:\n', Z)
plt.set_cmap('gray')
plt.pcolor(Z)
plt.show()
```

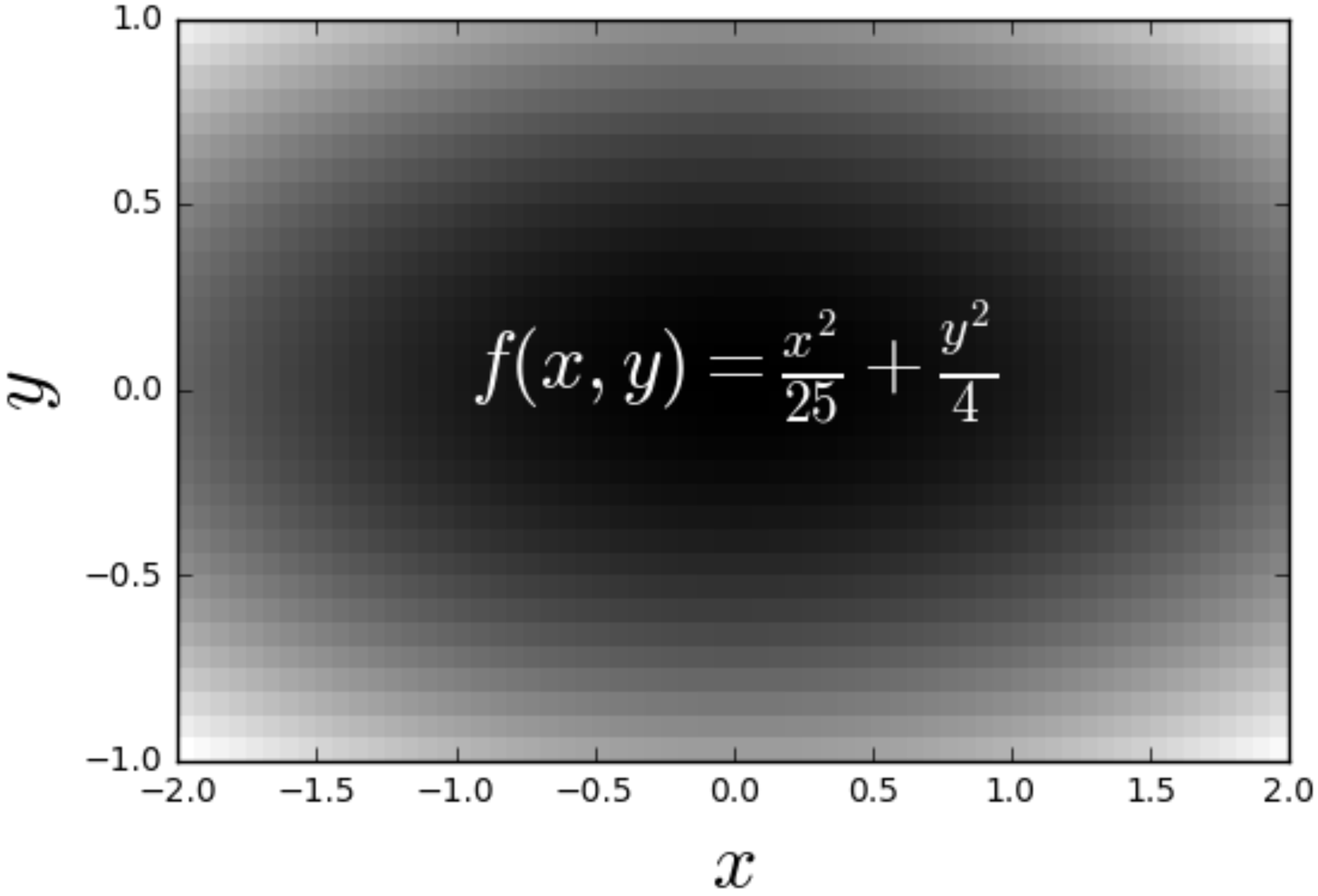
Sampling on a grid

```
Z:
 [[ 0.41    0.25    0.41  ]
 [ 0.2225  0.0625  0.2225]
 [ 0.16    0.      0.16  ]
 [ 0.2225  0.0625  0.2225]
 [ 0.41    0.25    0.41  ]]
```

Sampling on a grid



Sampling on a grid



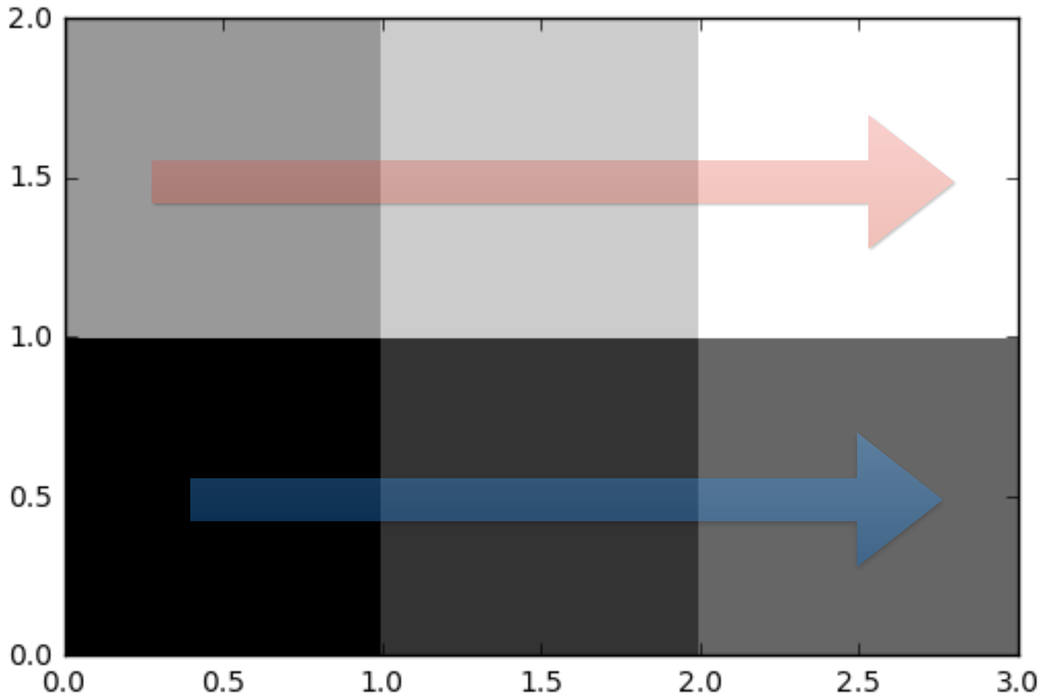
Orientations of 2D arrays & images

orientation.py

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

Z = np.array([[1, 2, 3], [4, 5, 6]])
print('Z:\n', z)

plt.pcolor(Z)
plt.show()
```

Orientations of 2D arrays & images

```
Output:
Z:
[[1 2 3]
 [4 5 6]]
```



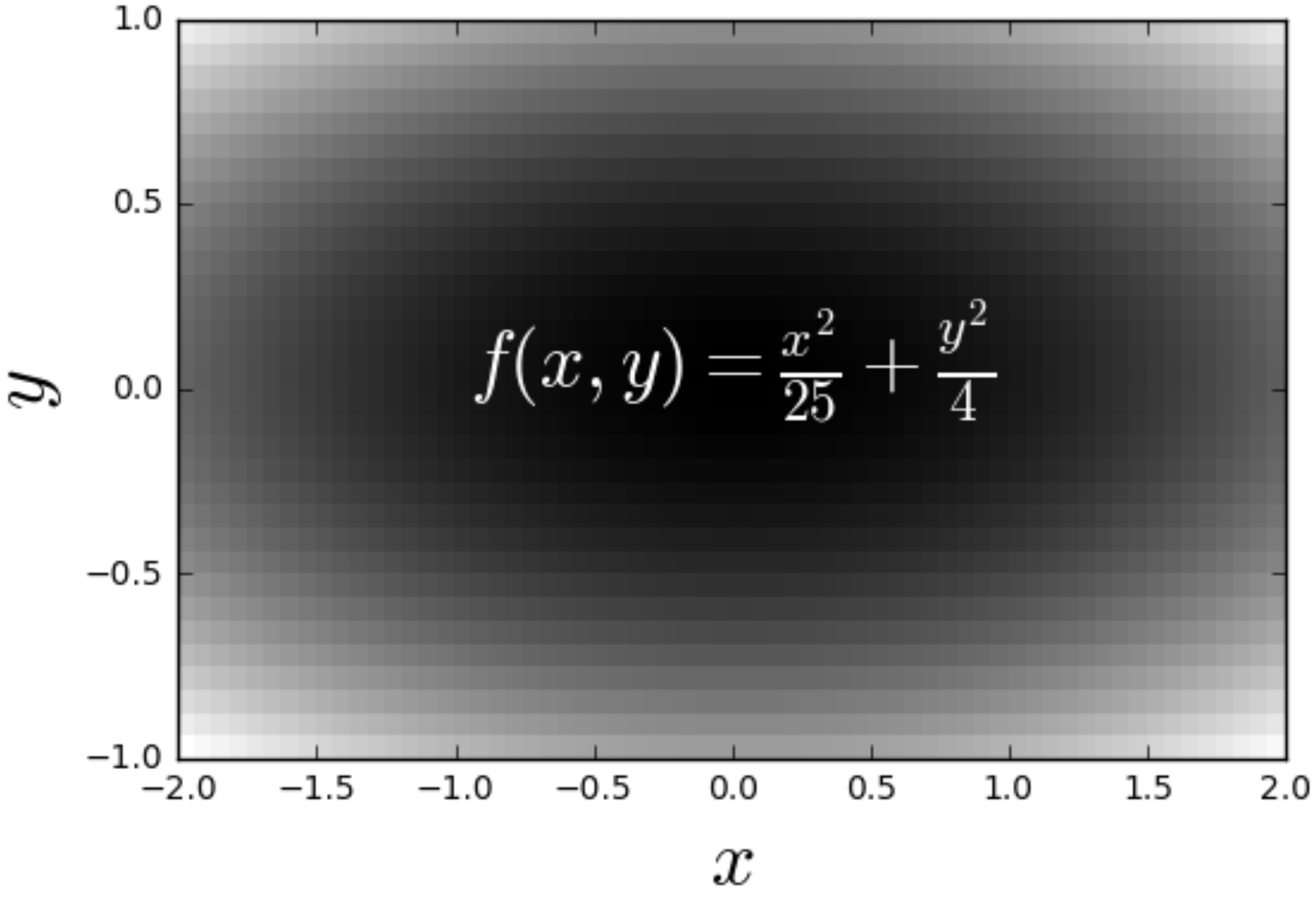
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing bivariate functions

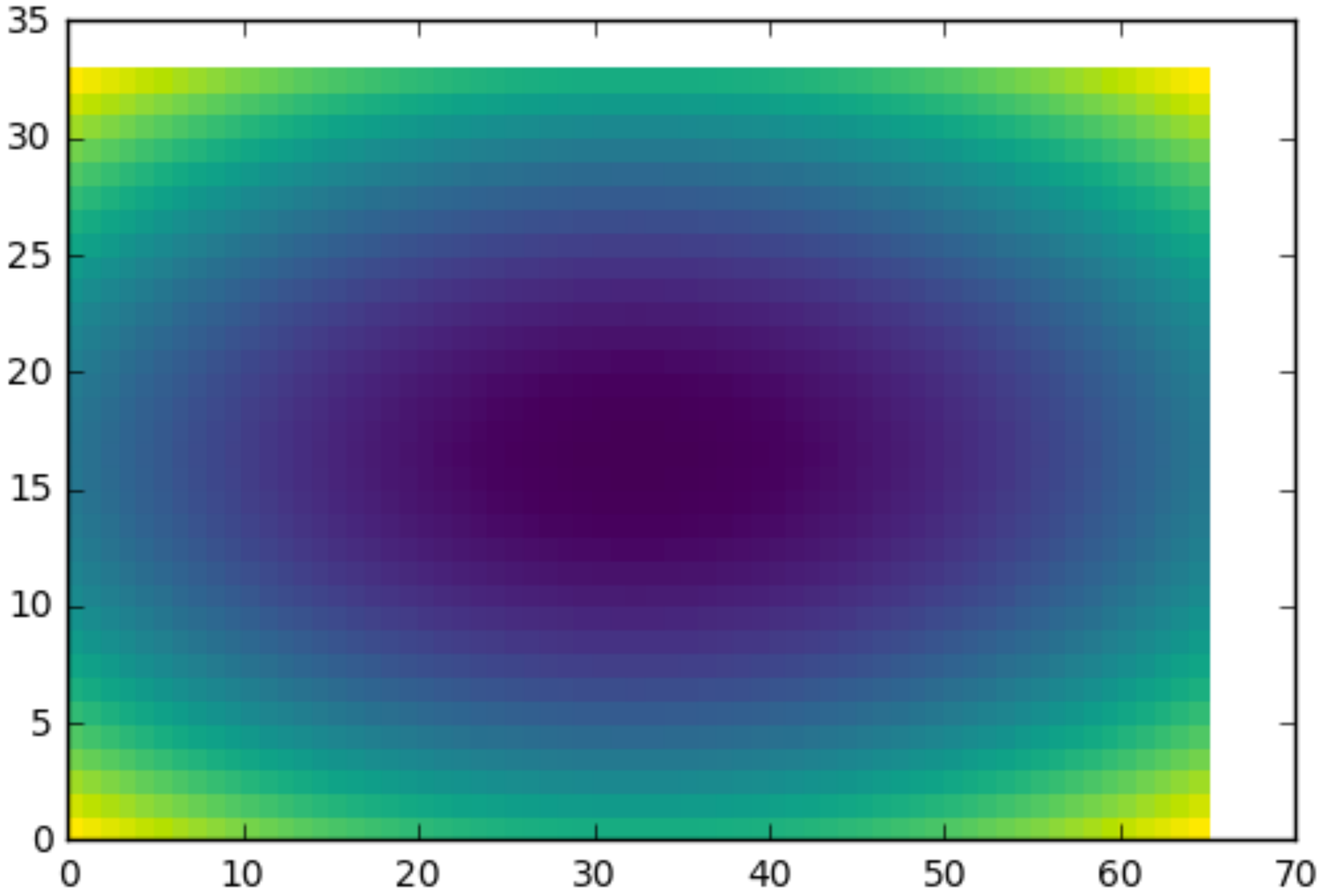
Bivariate functions



Pseudocolor plot

```
In [1]: import numpy as np

In [2]: import matplotlib.pyplot as plt

In [3]: u = np.linspace(-2, 2, 65)

In [4]: v = np.linspace(-1, 1, 33)

In [5]: X,Y = np.meshgrid(u, v)

In [6]: Z = X**2/25 + Y**2/4

In [7]: plt.pcolor(Z)

In [8]: plt.show()
```

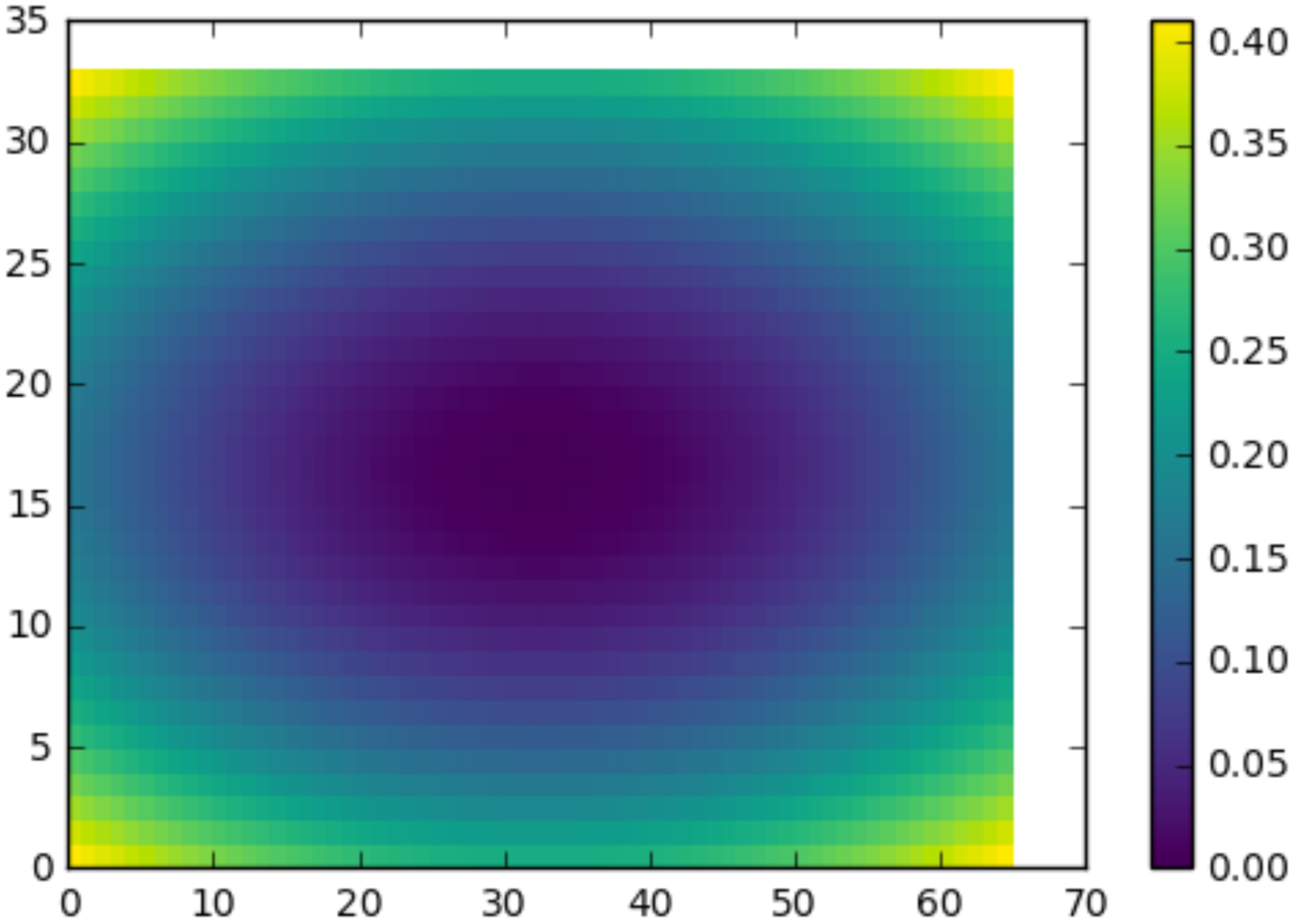
Pseudocolor plot



Color bar

```
In [9]: plt.pcolor(Z)

In [10]: plt.colorbar()

In [11]: plt.show()
```

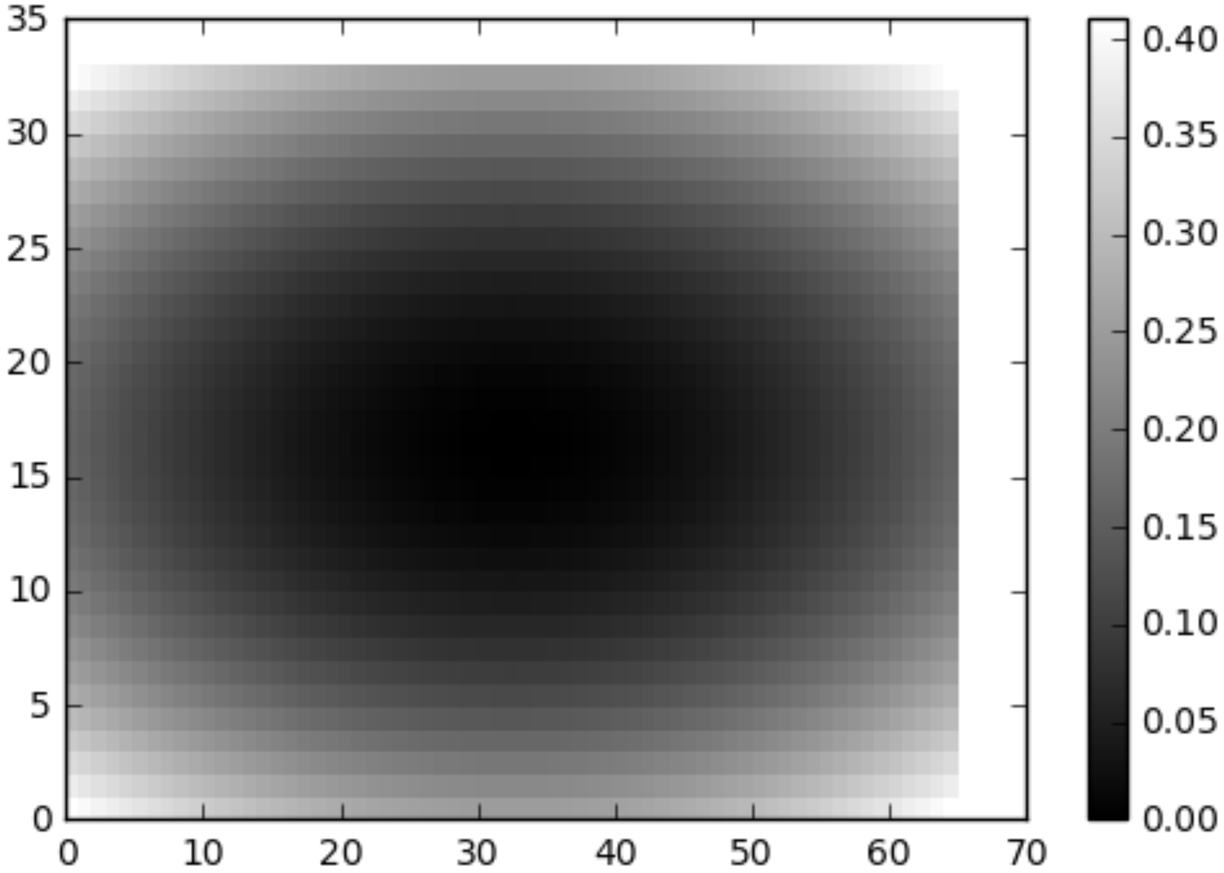
Color bar


35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Color map

```
In [12]: plt.pcolor(Z, cmap= 'gray')

In [13]: plt.colorbar()

In [14]: plt.show()
```

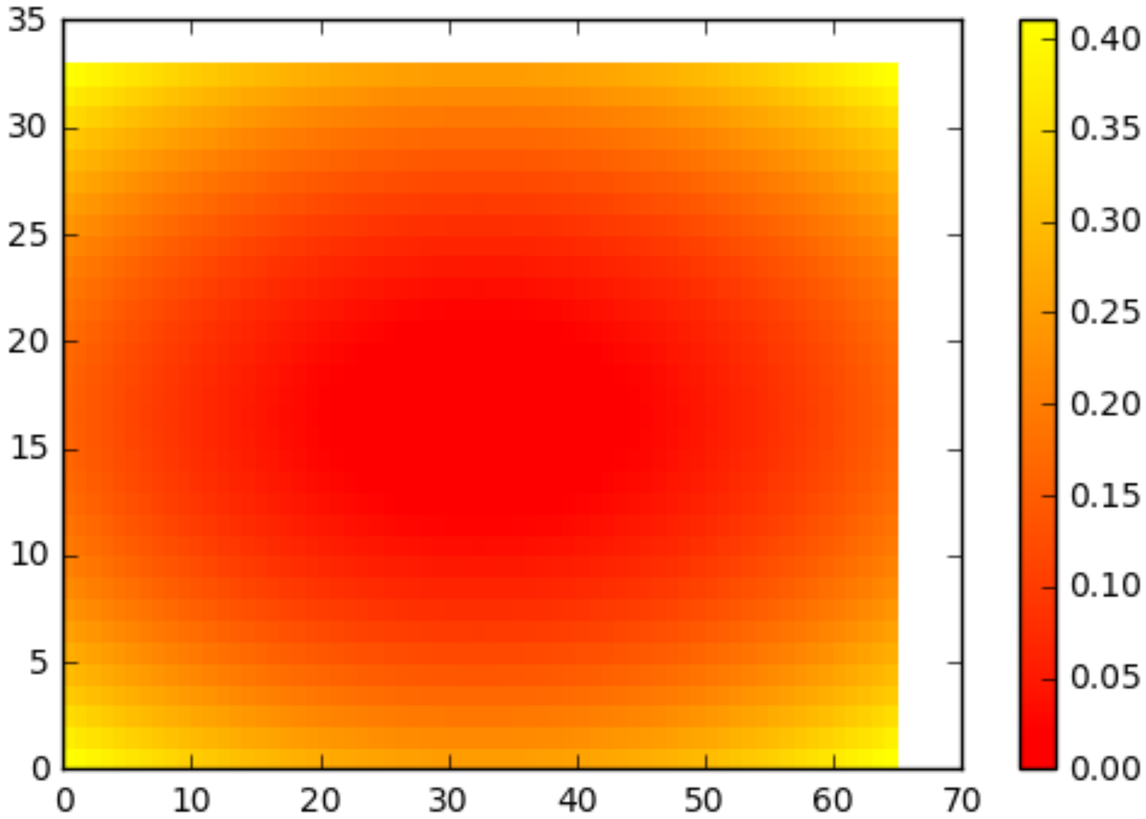
Color map


35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Color map

```
In [15]: plt.pcolor(Z, cmap= 'autumn')

In [16]: plt.colorbar()

In [17]: plt.show()
```

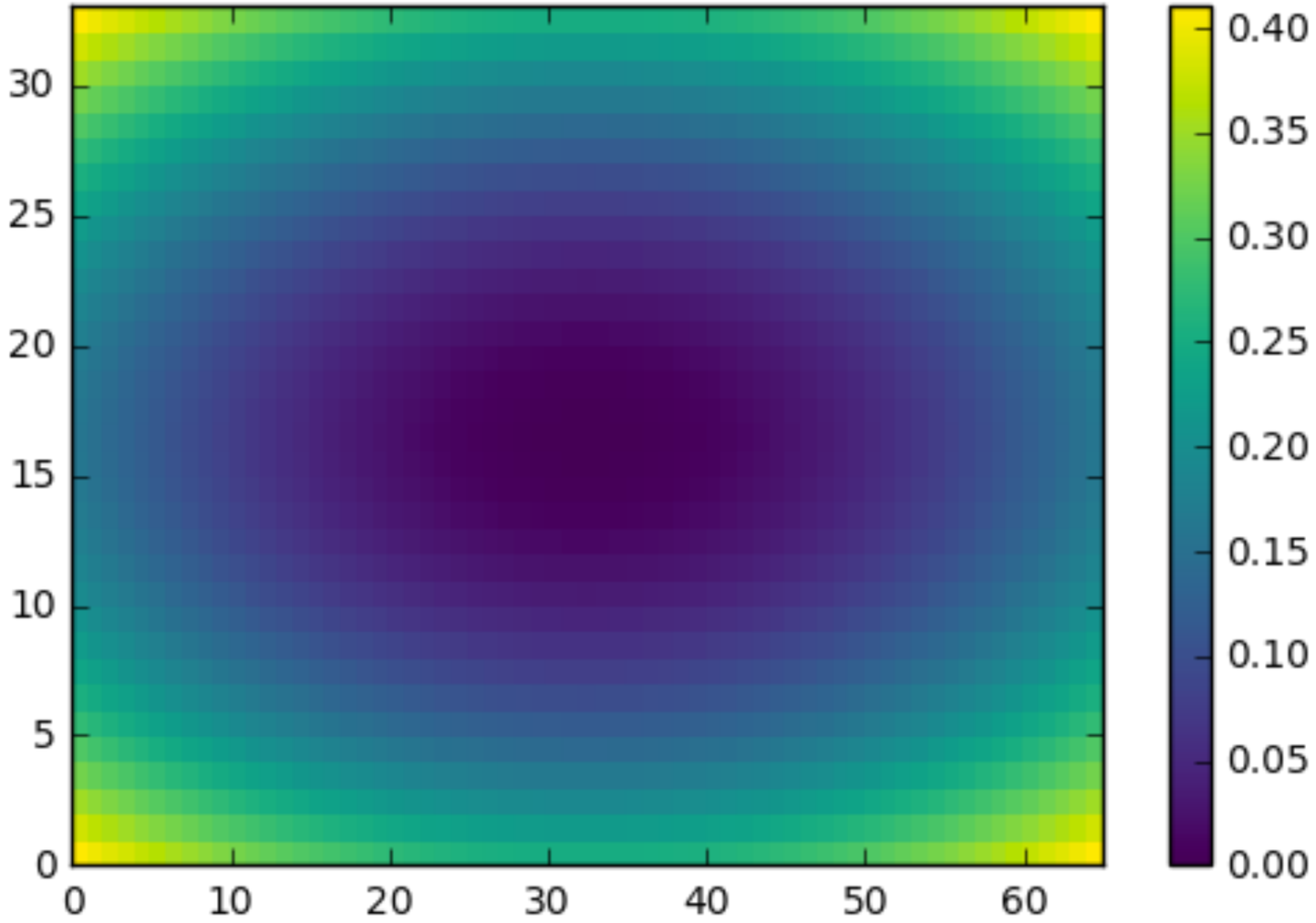
Color map


35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Axis tight

```
In [18]: plt.pcolor(Z)

In [19]: plt.colorbar()

In [20]: plt.axis('tight')

In [21]: plt.show()
```

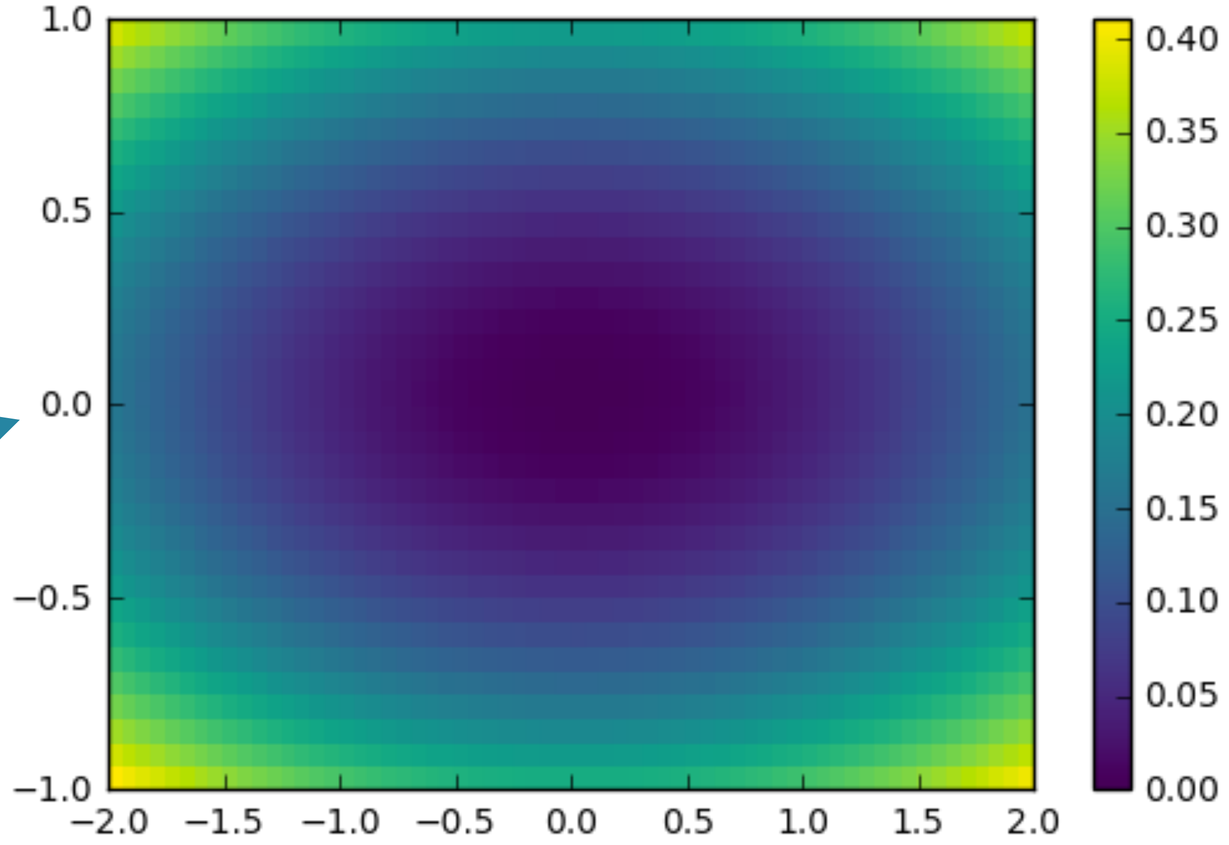
Axis tight


0
5
10
15
20
25
30
0
10
20
30
40
50
60
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Plot using mesh grid

```
In [22]: plt.pcolor(X, Y, Z) # X, Y are 2D meshgrid

In [23]: plt.colorbar()

In [24]: plt.show()
```

Plot using mesh grid

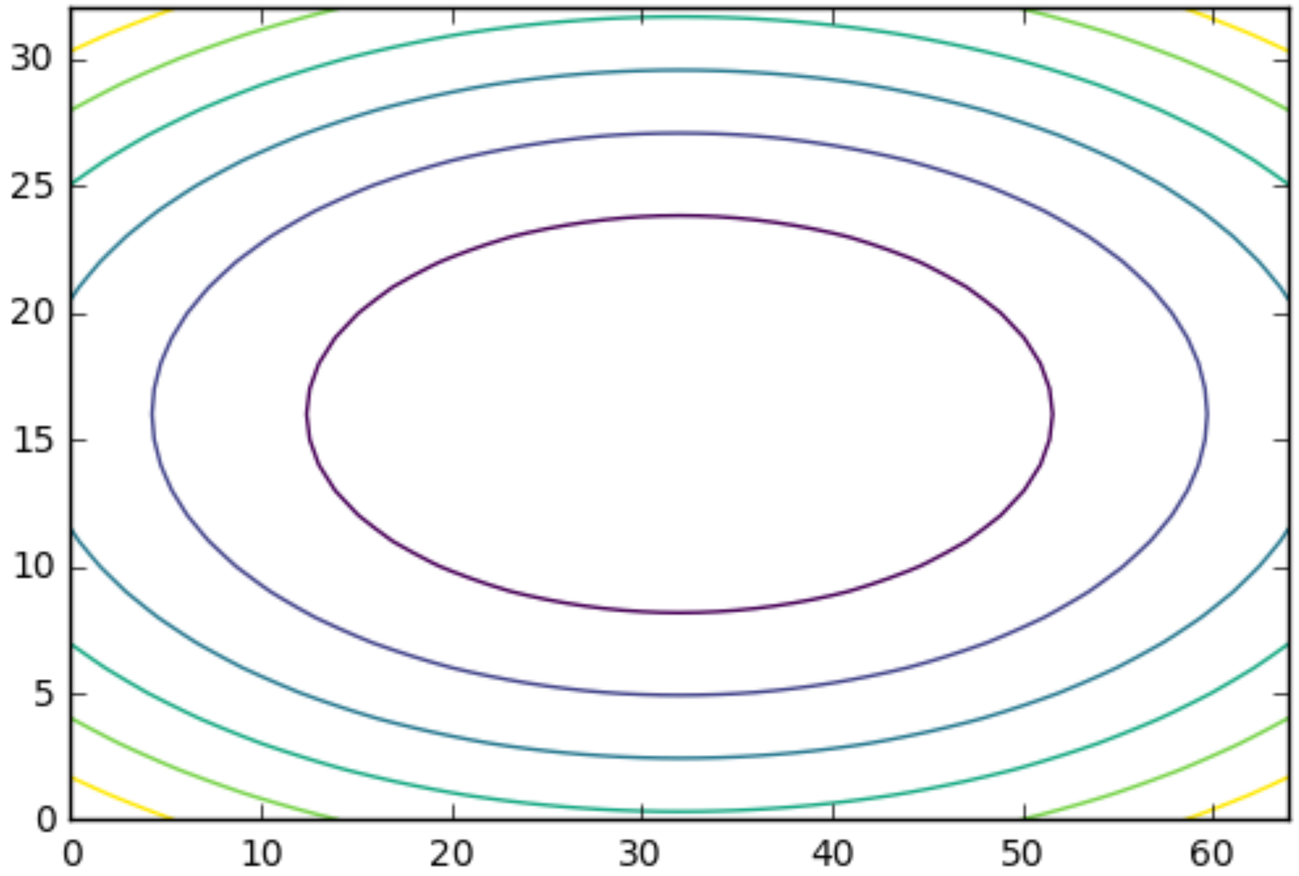


Axes determined by mesh grid arrays X, Y

Contour plots

```
In [25]: plt.contour(Z)

In [26]: plt.show()
```

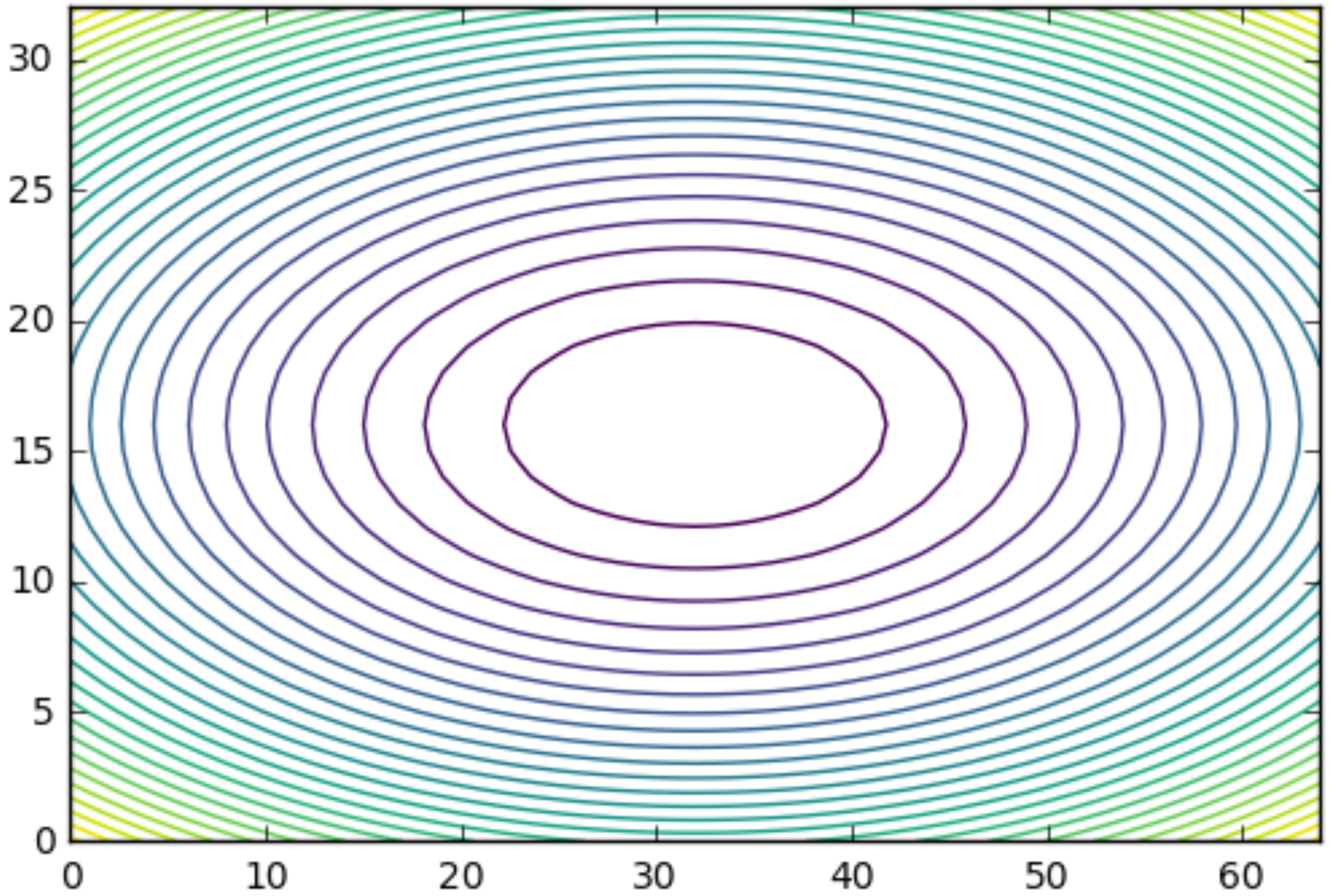
Contour plots



More contours

```
In [27]: plt.contour(Z, 30)

In [28]: plt.show()
```

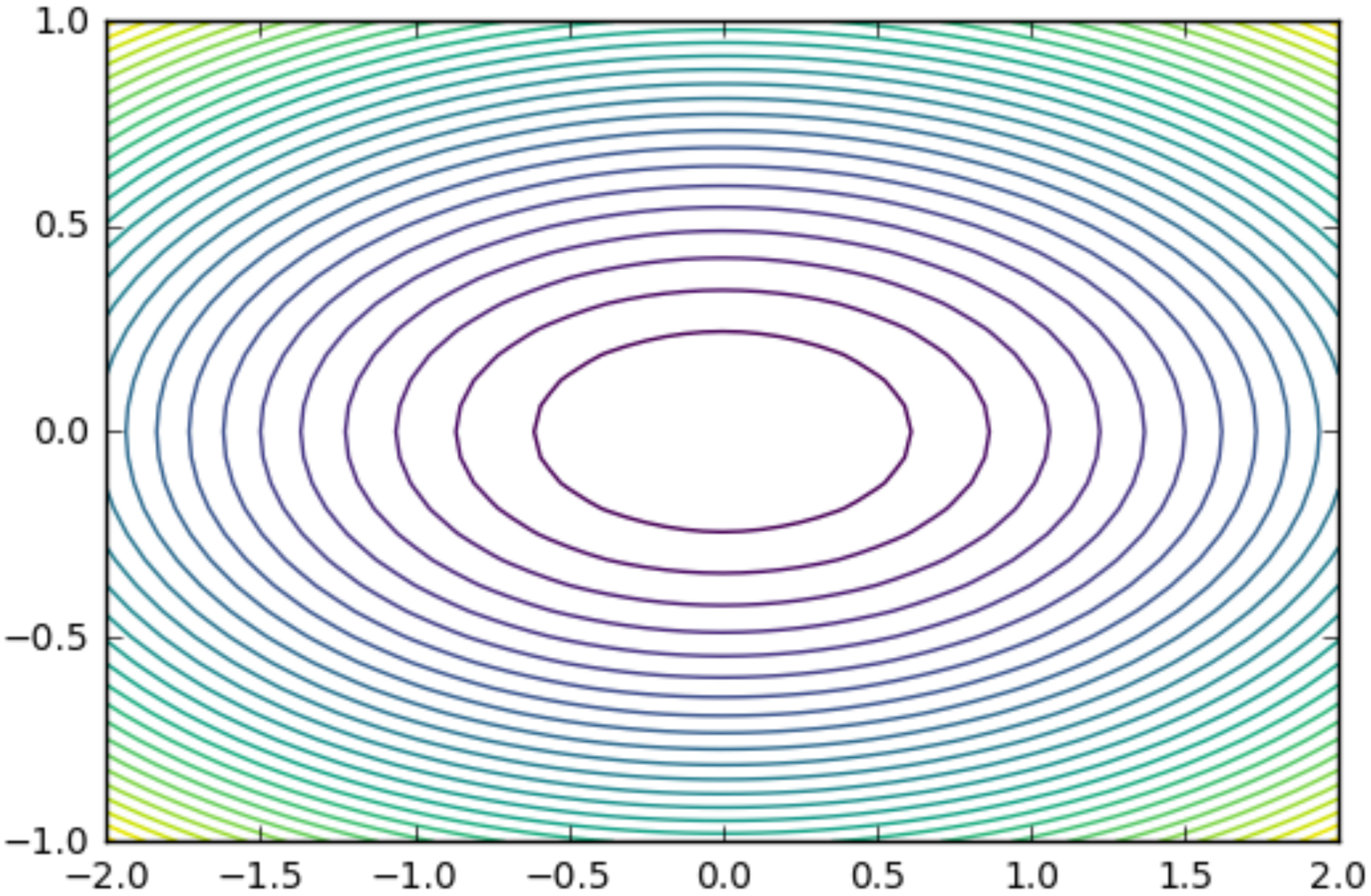
More contours



Contour plot using meshgrid

```
In [29]: plt.contour(X, Y, Z, 30)

In [30]: plt.show()
```

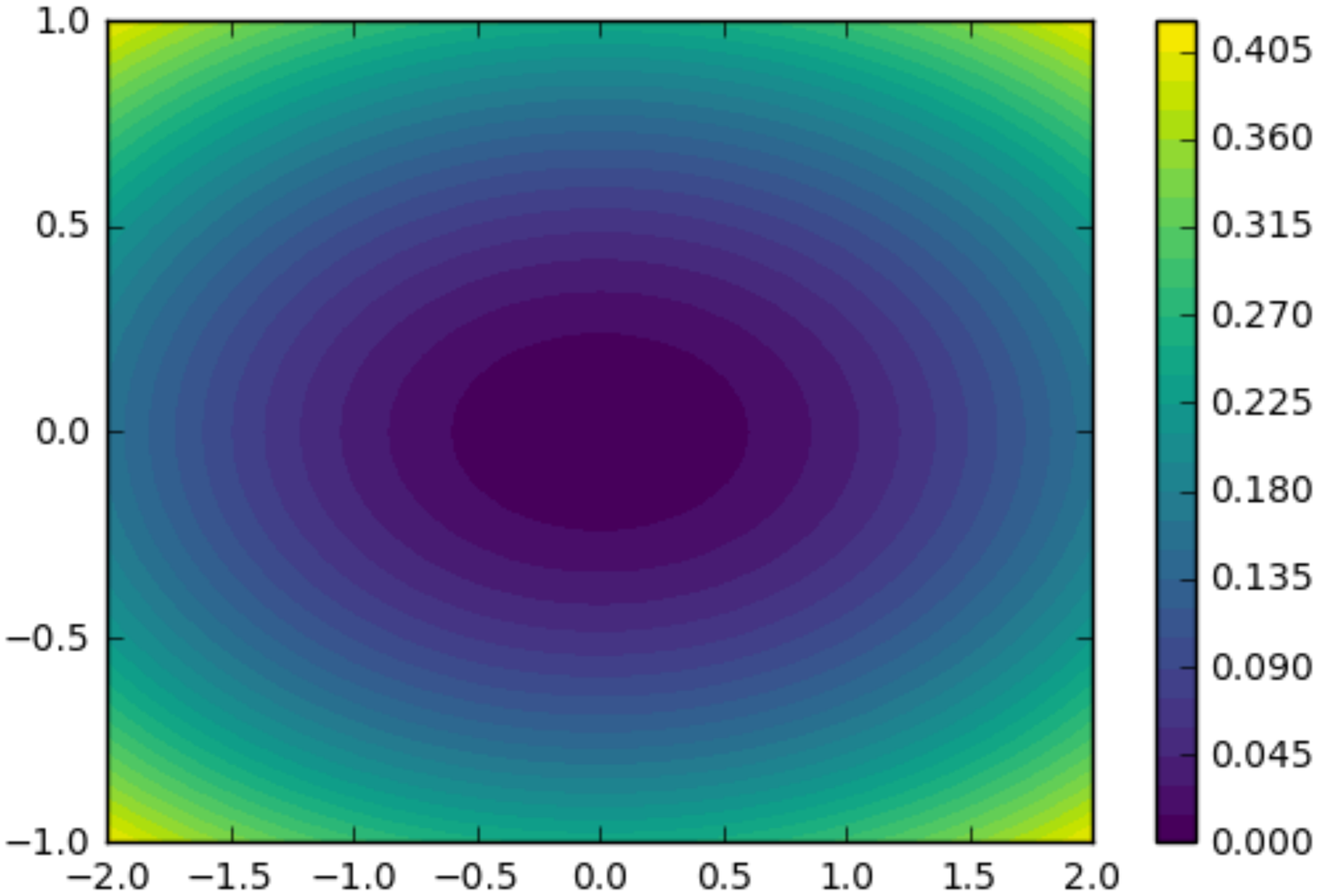
Contour plot using meshgrid



Filled contour plots

```
In [31]: plt.contourf(X, Y, Z, 30)

In [32]: plt.colorbar()

In [33]: plt.show()
```

Filled contour plots



More information

- API has many (optional) keyword arguments
- More in matplotlib.pyplot documentation
- More examples: http://matplotlib.org/gallery.html

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

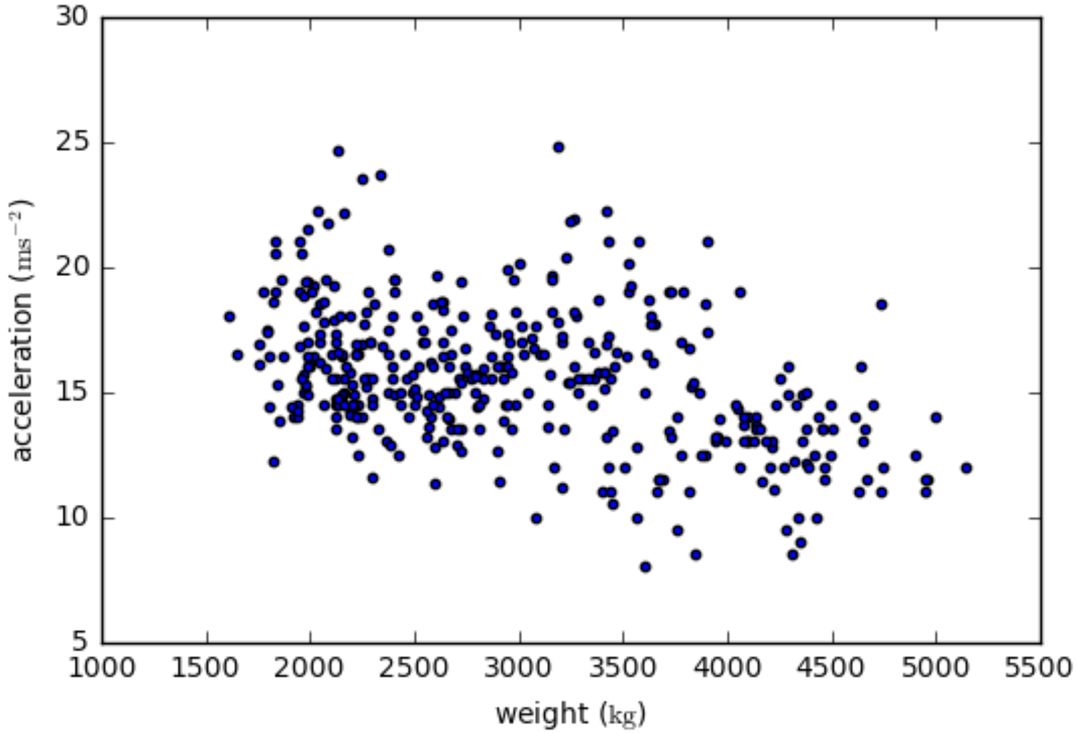
Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing bivariate distributions

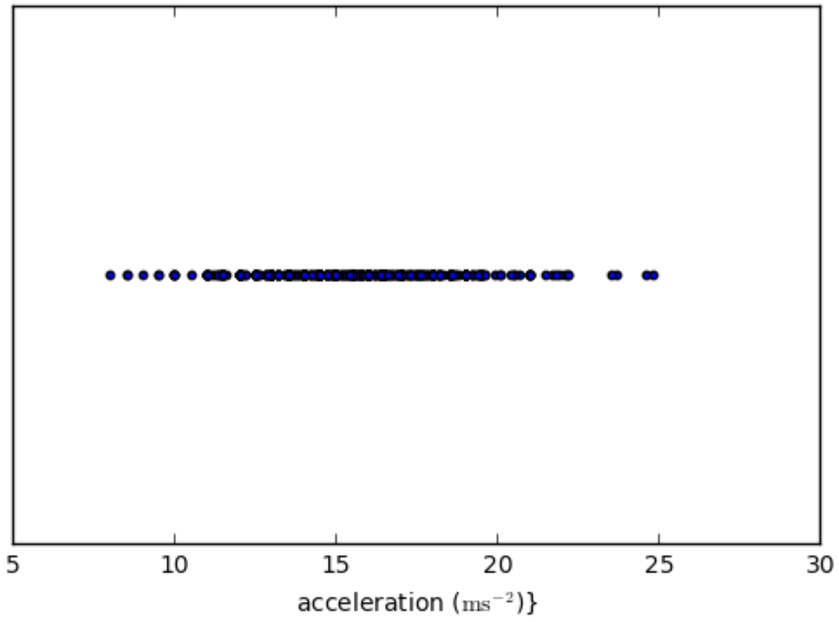
Distributions of 2D points

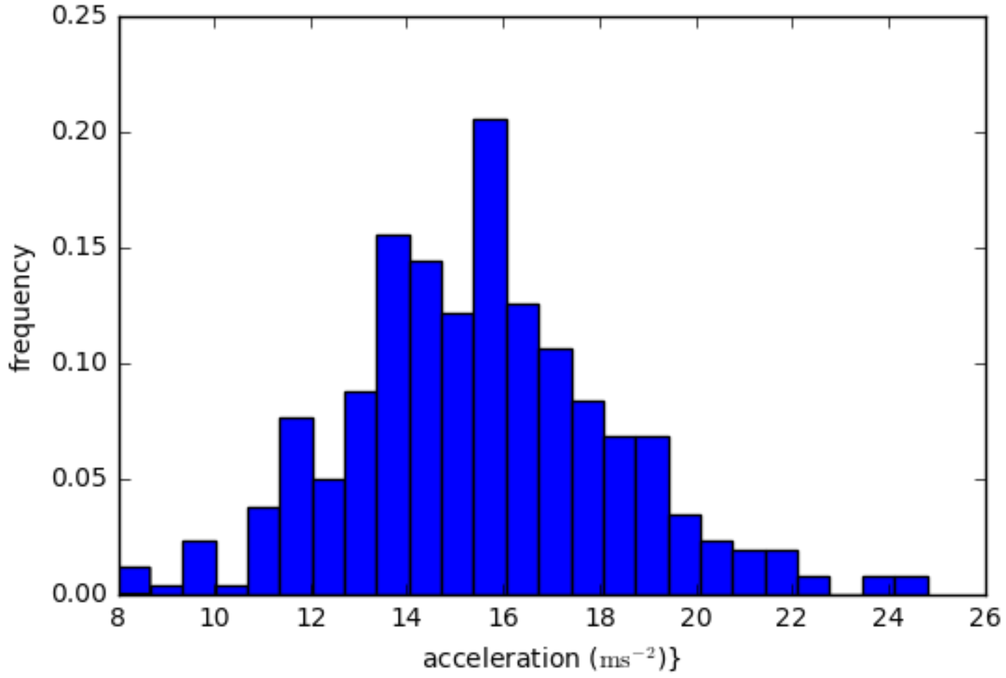
- 2D points given as two 1D arrays x & y
- Goal: generate a 2D histogram from x & y



Histograms in 1D

- Choose bins (intervals)
- Count realizations within bins & plot



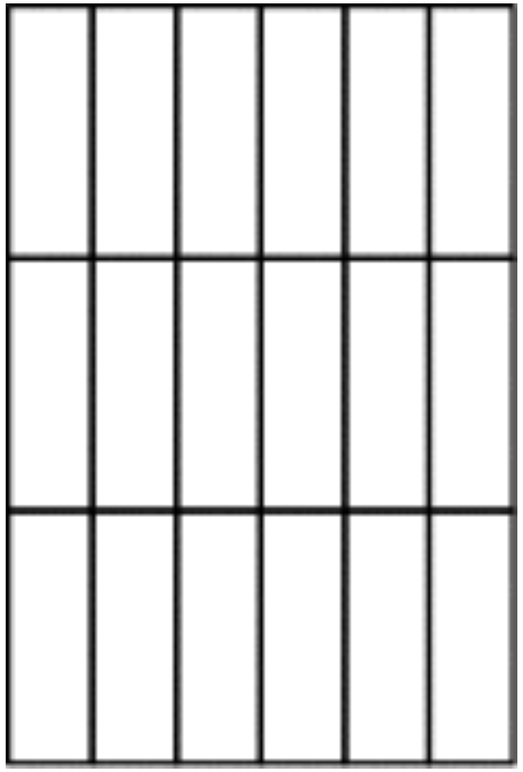


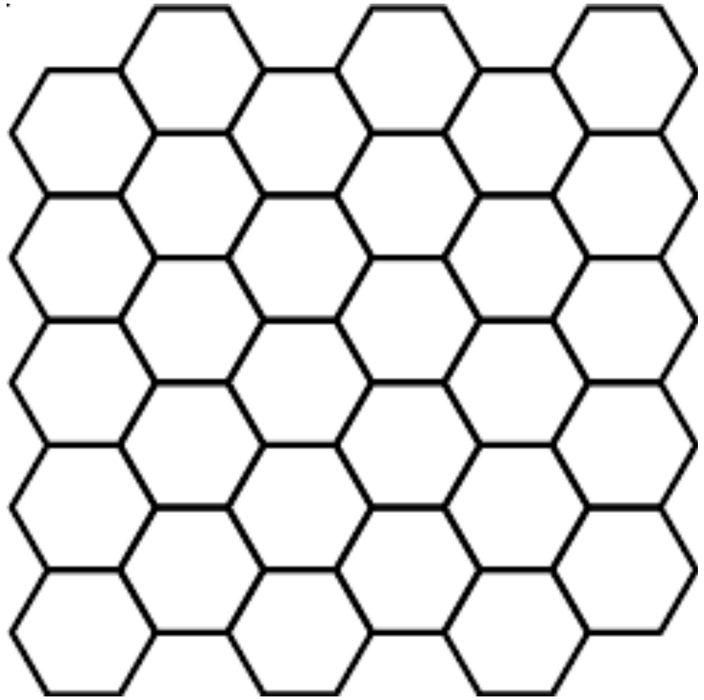
Histograms in 1D

```
In [1]: counts, bins, patches = plt.hist(x, bins=25)

In [2]: plt.show()
```

Bins in 2D

- Different shapes available for binning points
- Common choices: rectangles & hexagons

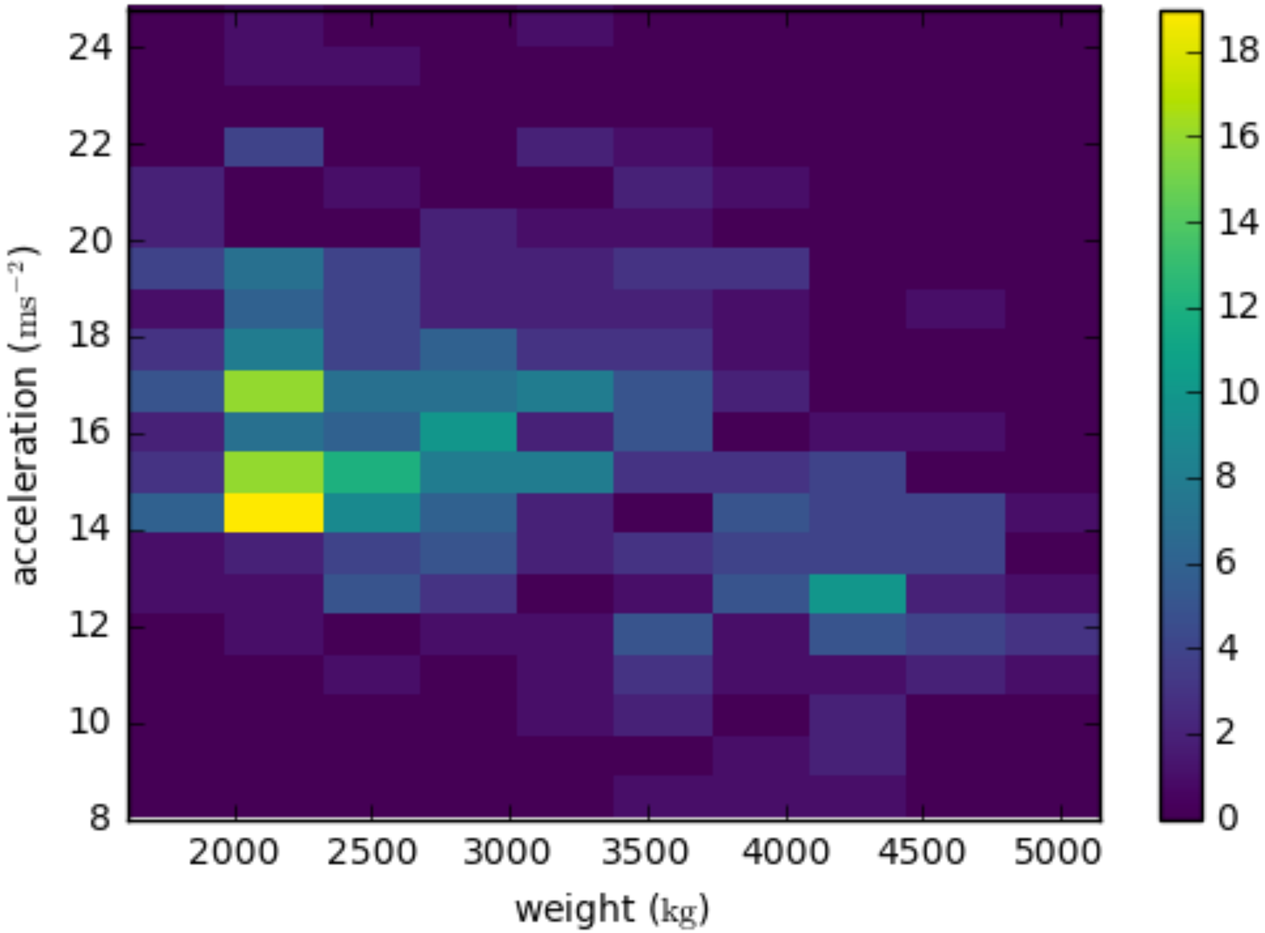




hist2d(): Rectangular binning

```
In [1]: plt.hist2d(x, y, bins=(10, 20)) # x & y are 1D arrays of
   ...: same length

In [2]: plt.colorbar()

In [3]: plt.xlabel('weight ($\mathrm{kg}$)')

In [4]: plt.ylabel('acceleration ($\mathrm{ms}^{-2}$)}')

In [5]: plt.show()
```

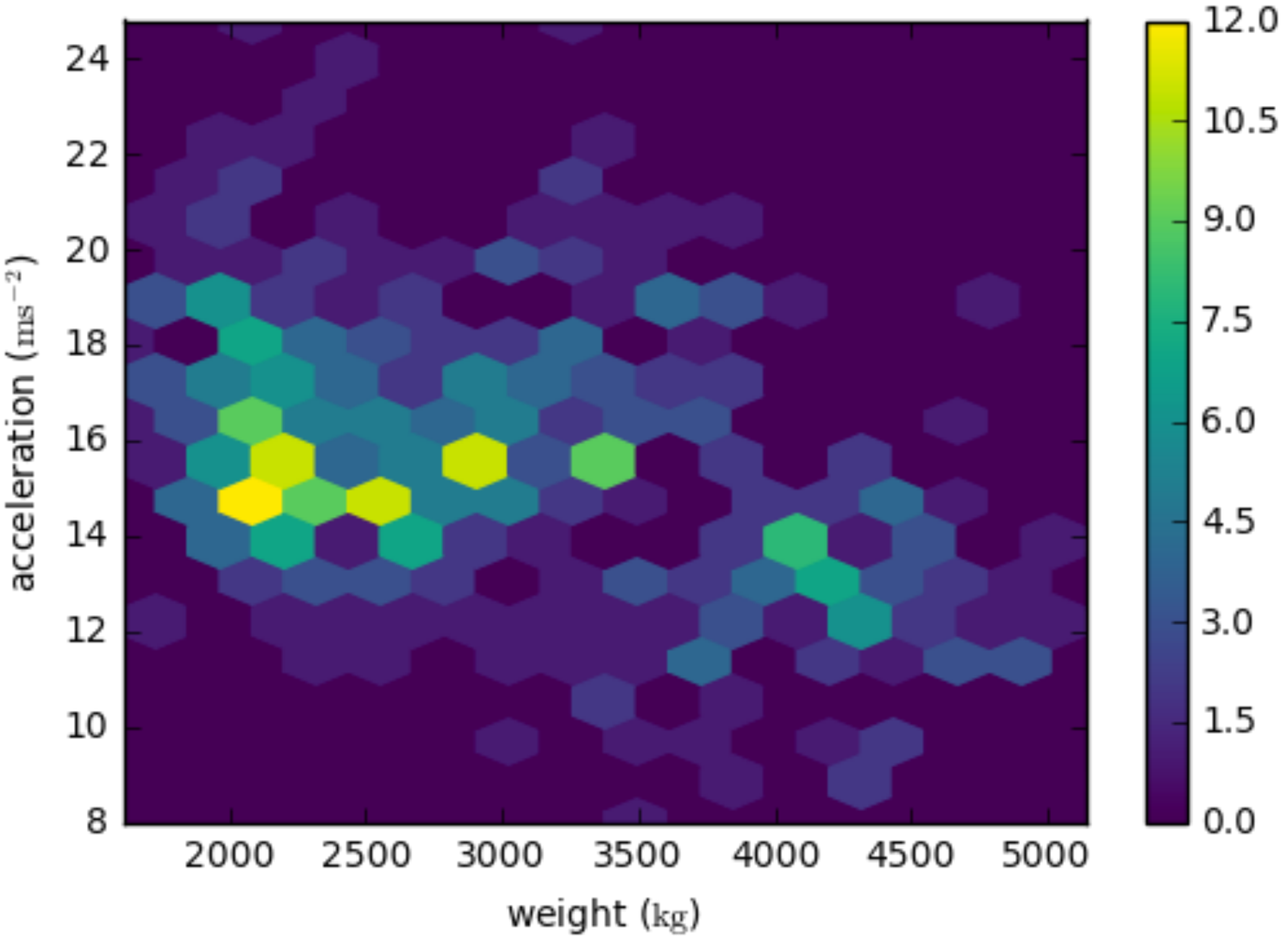
hist2d(): Rectangular binning



hexbin(): Hexagonal binning

```
In [1]: plt.hexbin(x, y, gridsize=(15,10))

In [2]: plt.colorbar()

In [3]: plt.xlabel('weight ($\mathrm{kg}$)')

In [4]: plt.ylabel('acceleration ($\mathrm{ms}^{-2}$)}')

In [5]: plt.show()
```

hexbin(): Hexagonal binning



INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Working with images

Images

- Grayscale images: rectangular 2D arrays
- Color images: typically three 2D arrays (channels)
  - RGB (Red-Green-Blue)
- Channel values:
  - 0 to 1 (floating-point numbers)
  - 0 to 255 (8 bit integers)

Loading images

```
In [1]: img = plt.imread('sunflower.jpg')

In [2]: print(img.shape)
(480, 640, 3)

In [3]: plt.imshow(img)

In [4]: plt.axis('off')

In [5]: plt.show()
```

Loading images

Reduction to gray-scale image

```
In [6]: collapsed = img.mean(axis=2)

In [7]: print(collapsed.shape)
(480, 640)

In [8]: plt.set_cmap('gray')

In [9]: plt.imshow(collapsed, cmap='gray')

In [10]: plt.axis('off')

In [11]: plt.show()
```

Reduction to gray-scale image

Uneven samples

```
In [12]: uneven = collapsed[::4,::2] # nonuniform subsampling

In [13]: print(uneven.shape)
(120, 320)

In [14]: plt.imshow(uneven)

In [15]: plt.axis('off')

In [16]: plt.show()
```

Uneven samples

Adjusting aspect ratio

```
In [17]: plt.imshow(uneven, aspect=2.0)

In [18]: plt.axis('off')

In [19]: plt.show()
```

Adjusting aspect ratio

Adjusting extent

```
In [20]: plt.imshow(uneven, cmap='gray', extent=(0,640,0,480))

In [21]: plt.axis('off')

In [22]: plt.show()
```

Adjusting extent

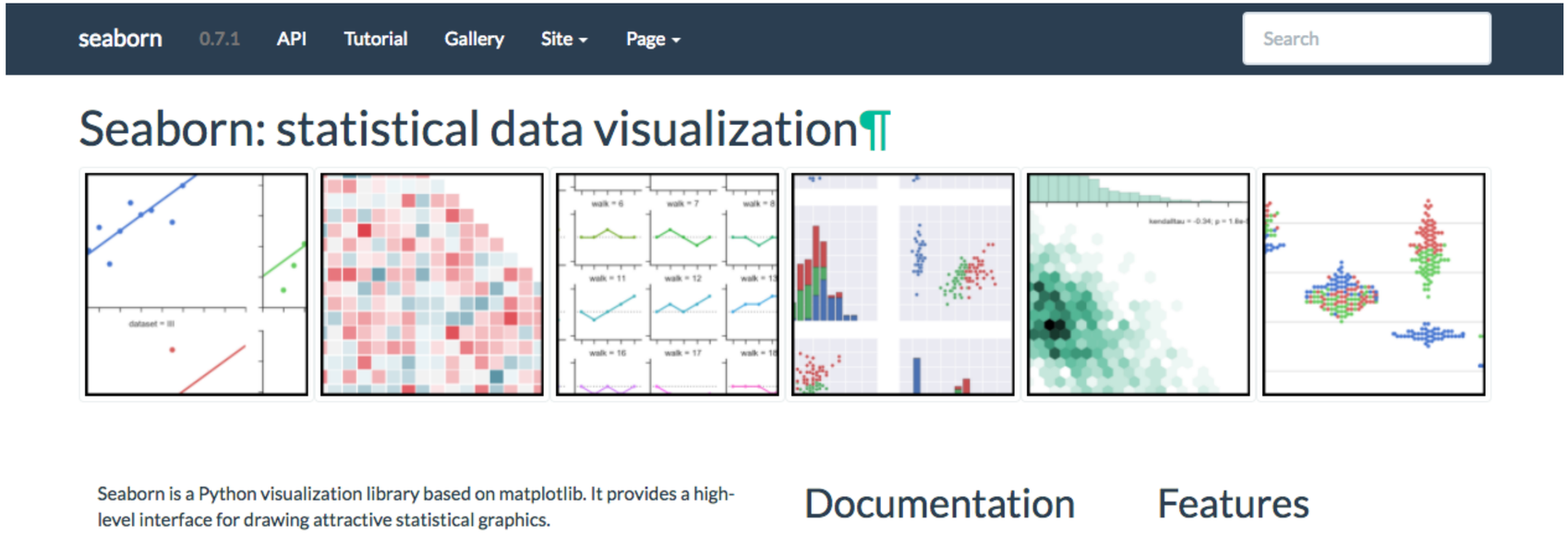
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing Regressions

Seaborn



https://stanford.edu/~mwaskom/software/seaborn/

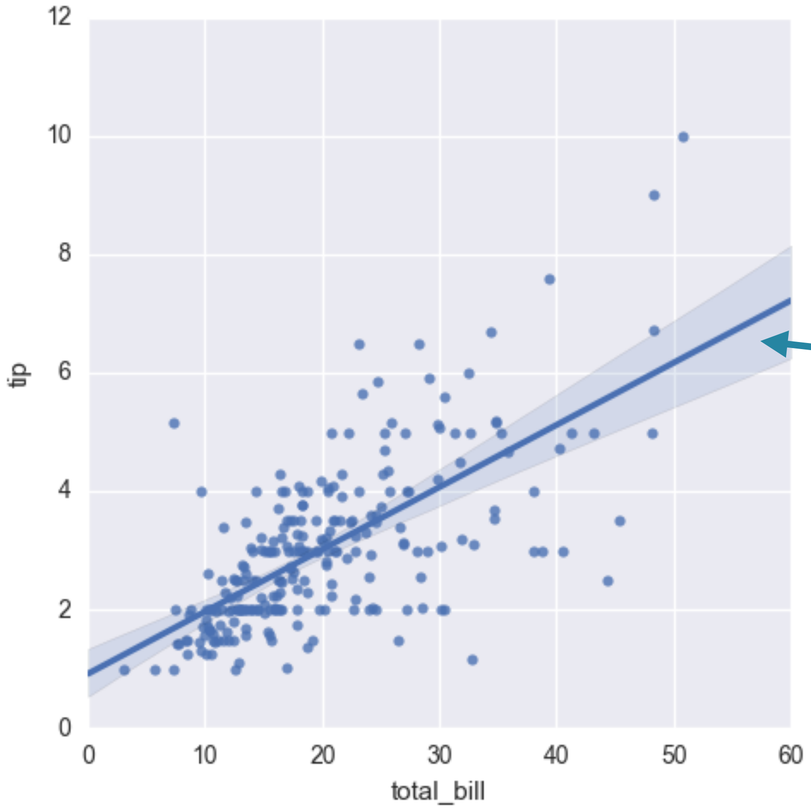
Recap: Pandas DataFrames

- Labelled tabular data structure
- Labels on rows: *index*
- Labels on columns: *columns*
- Columns are Pandas *Series*

Recap: Pandas DataFrames

	total_bill	tip	sex	smoker	day	time	size
0	16.99	1.01	Female	No	Sun	Dinner	2
1	10.34	1.66	Male	No	Sun	Dinner	3
2	21.01	3.50	Male	No	Sun	Dinner	3
3	23.68	3.31	Male	No	Sun	Dinner	2
4	24.59	3.61	Female	No	Sun	Dinner	4
...	...	...	...	...	...	...	...

Linear regression plots



95% confidence

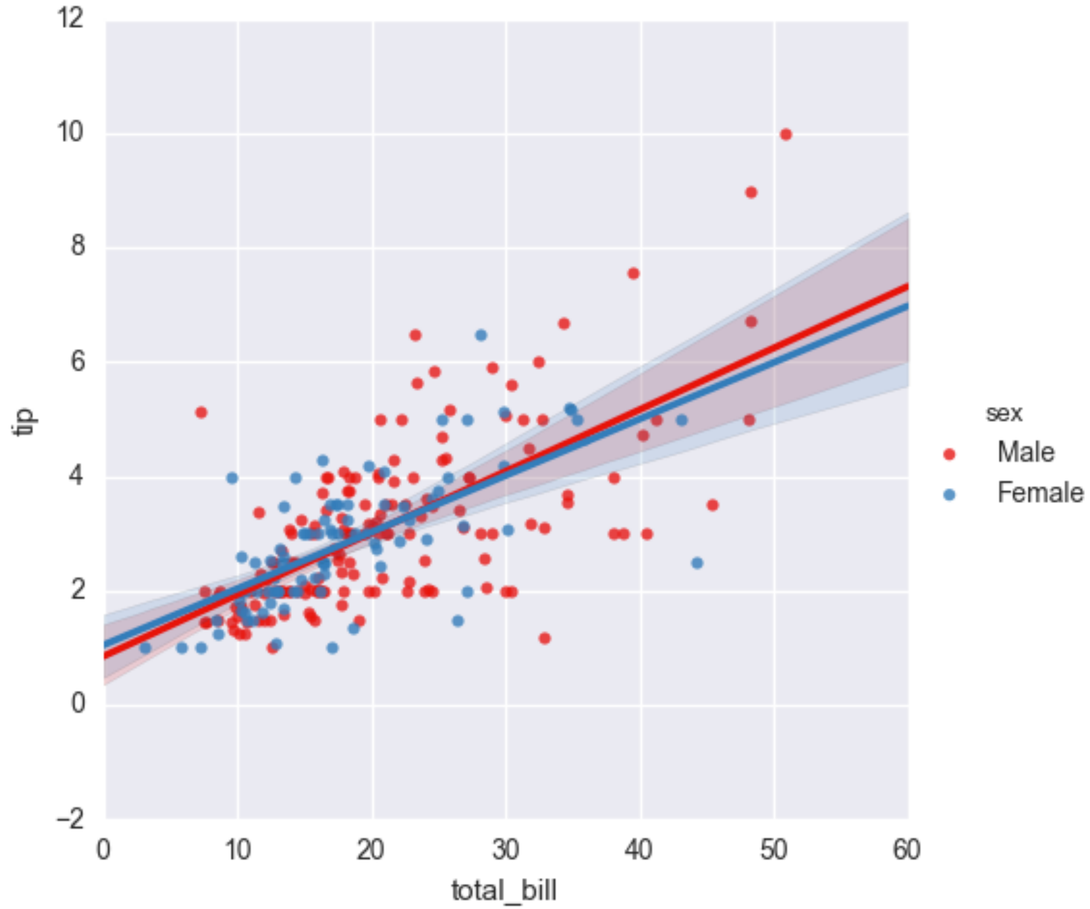
Using lmplot()

```
In [1]: import pandas as pd

In [2]: import matplotlib.pyplot as plt

In [3]: import seaborn as sns

In [4]: tips =sns.load_dataset('tips')

In [5]: sns.lmplot(x= 'total_bill', y='tip', data=tips)

In [6]: plt.show()
```

Factors

	total_bill	tip	sex	smoker	day	time	size
0	16.99	1.01	Female	No	Sun	Dinner	2
1	10.34	1.66	Male	No	Sun	Dinner	3
2	21.01	3.50	Male	No	Sun	Dinner	3
3	23.68	3.31	Male	No	Sun	Dinner	2
4	24.59	3.61	Female	No	Sun	Dinner	4
...	...	...	...	...	...	...	...

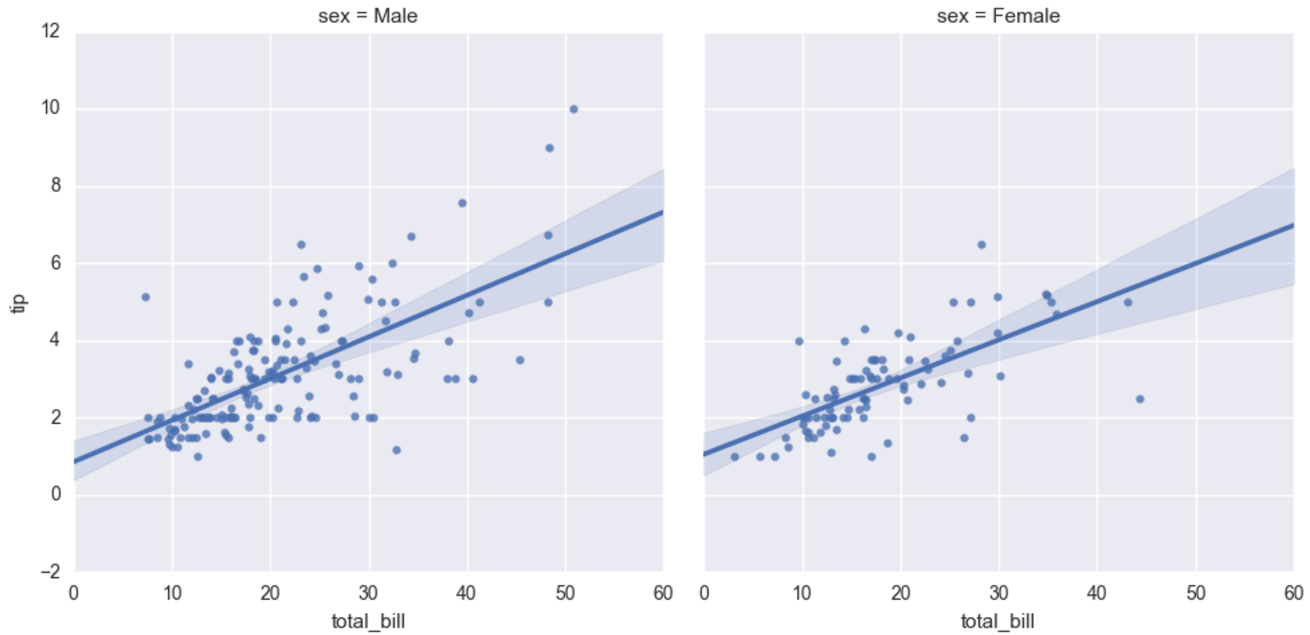
Grouping factors (same plot)



Using hue=...

```
In [7]: sns.lmplot(x='total_bill', y='tip', data=tips, hue='sex',
   ...:                palette='Set1')

In [8]: plt.show()
```

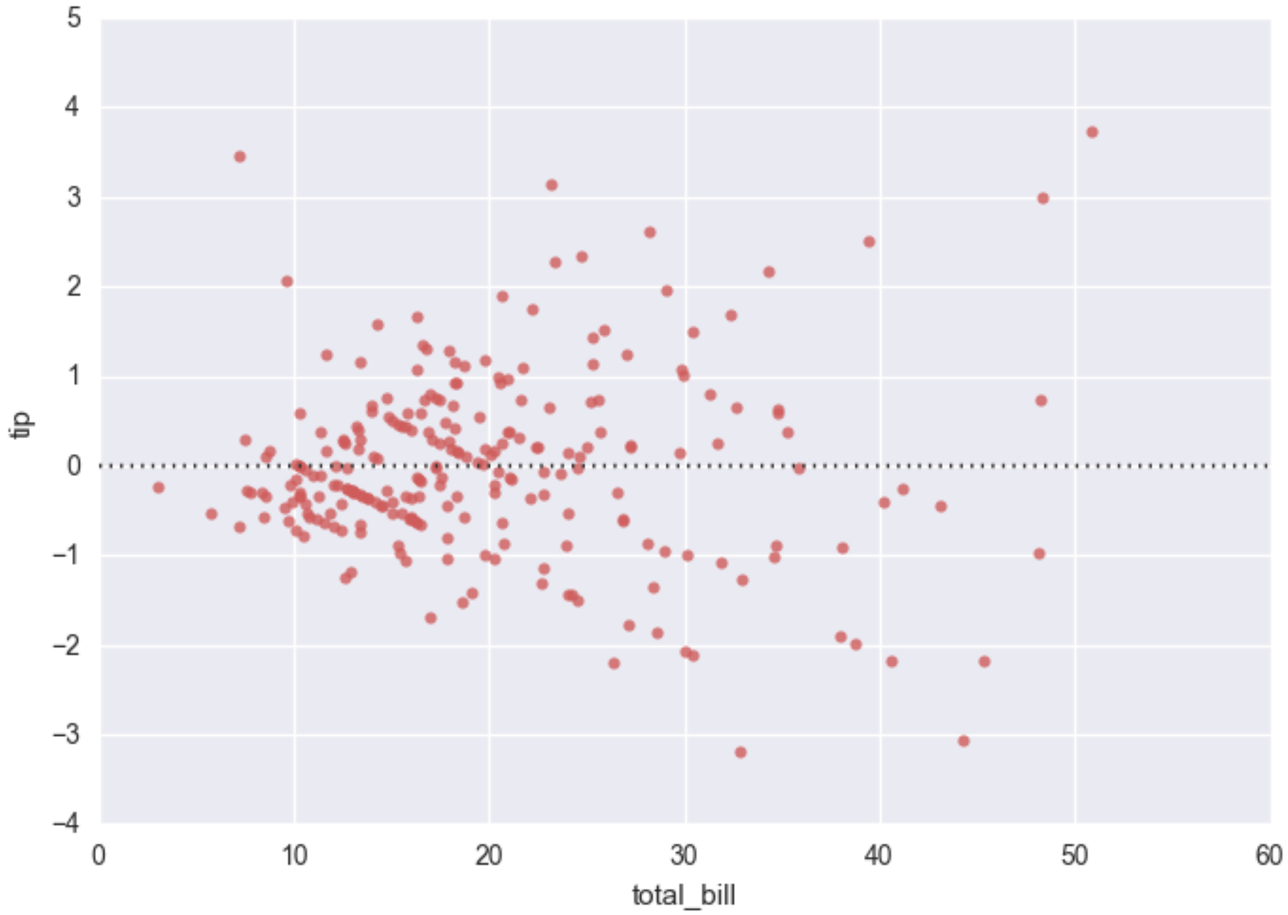
Grouping factors (subplots)



Using col=...

```
In [9]: sns.lmplot(x='total_bill', y='tip', data=tips, col='sex')

In [10]: plt.show()
```

Residual plots



Using residplot()

```
In [11]: sns.residplot(x='age',y='fare',data=tips,color='indianred')

In [12]: plt.show()
```

- Similar arguments as lmplot() but more flexible
  - x, y can be *arrays or strings*
  - data is DataFrame (optional)
- Optional arguments (e.g., color) as in Matplotlib

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

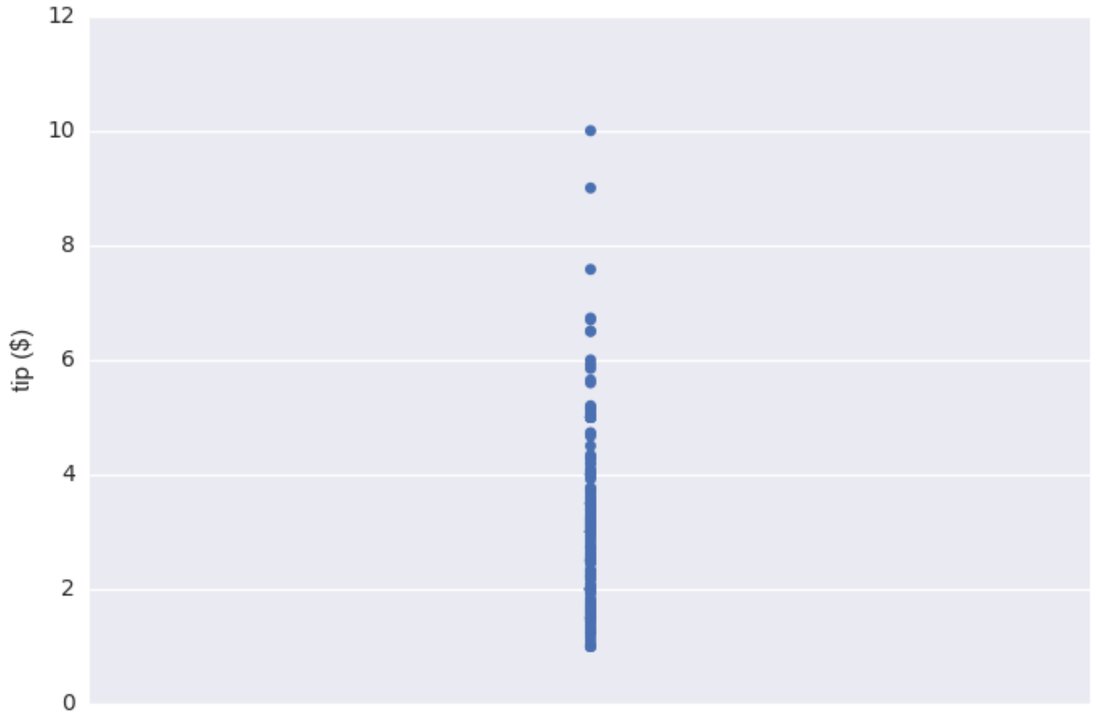
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing univariate distributions

Visualizing data

- Univariate → “one variable”
- Visualization techniques for sampled univariate data
  - Strip plots
  - Swarm plots
  - Violin plots

Strip plot



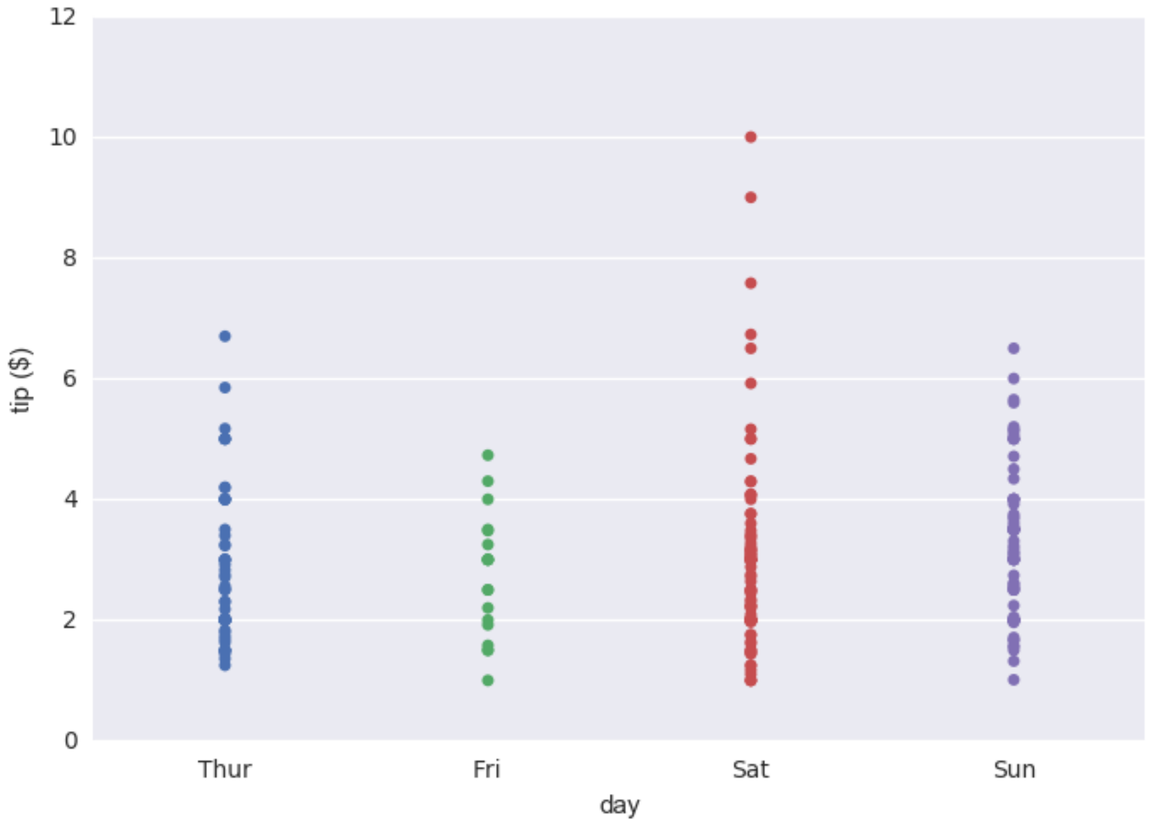
Using stripplot()

```
In [1]: sns.stripplot(y= 'tip', data=tips)

In [2]: plt.ylabel('tip ($)')

In [3]: plt.show()
```

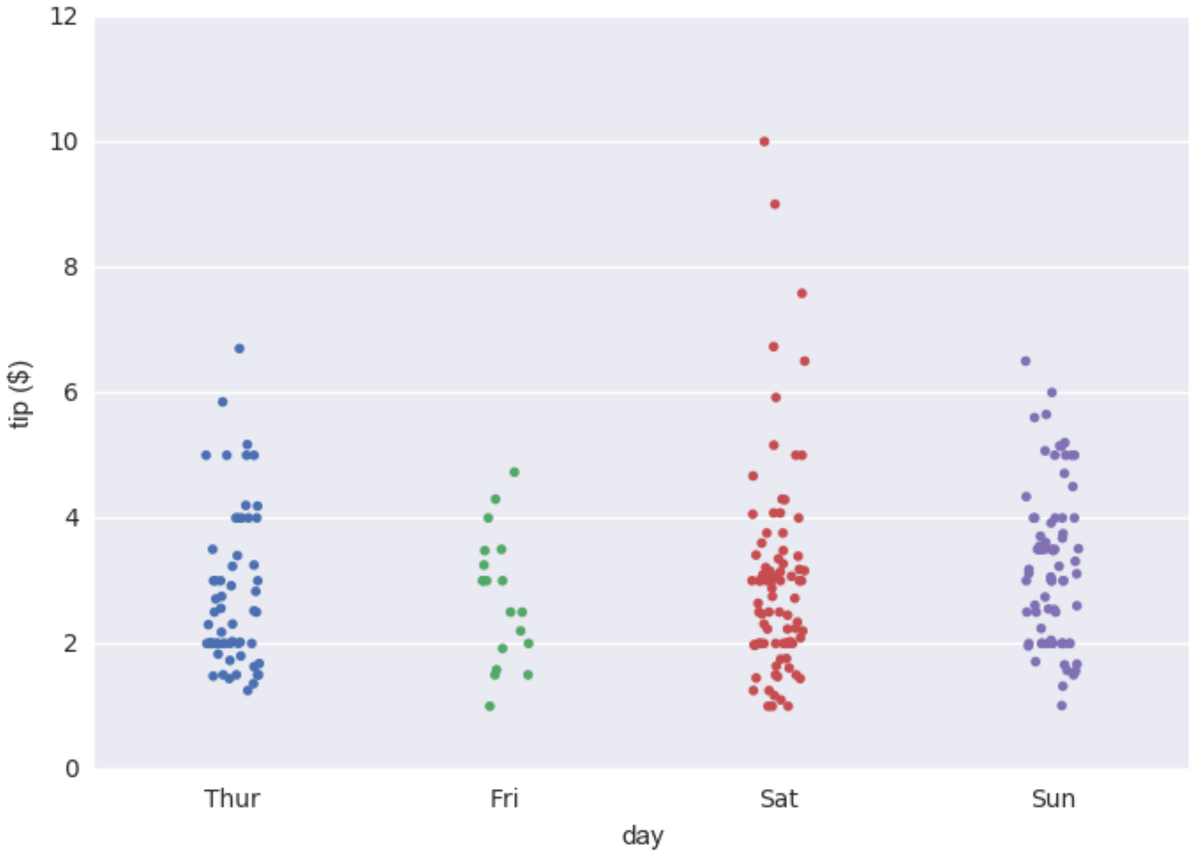
Grouping with stripplot()

```
In [4]: sns.stripplot(x='day', y='tip', data=tip)

In [5]: plt.ylabel('tip ($)')

In [6]: plt.show()
```

Grouped strip plot



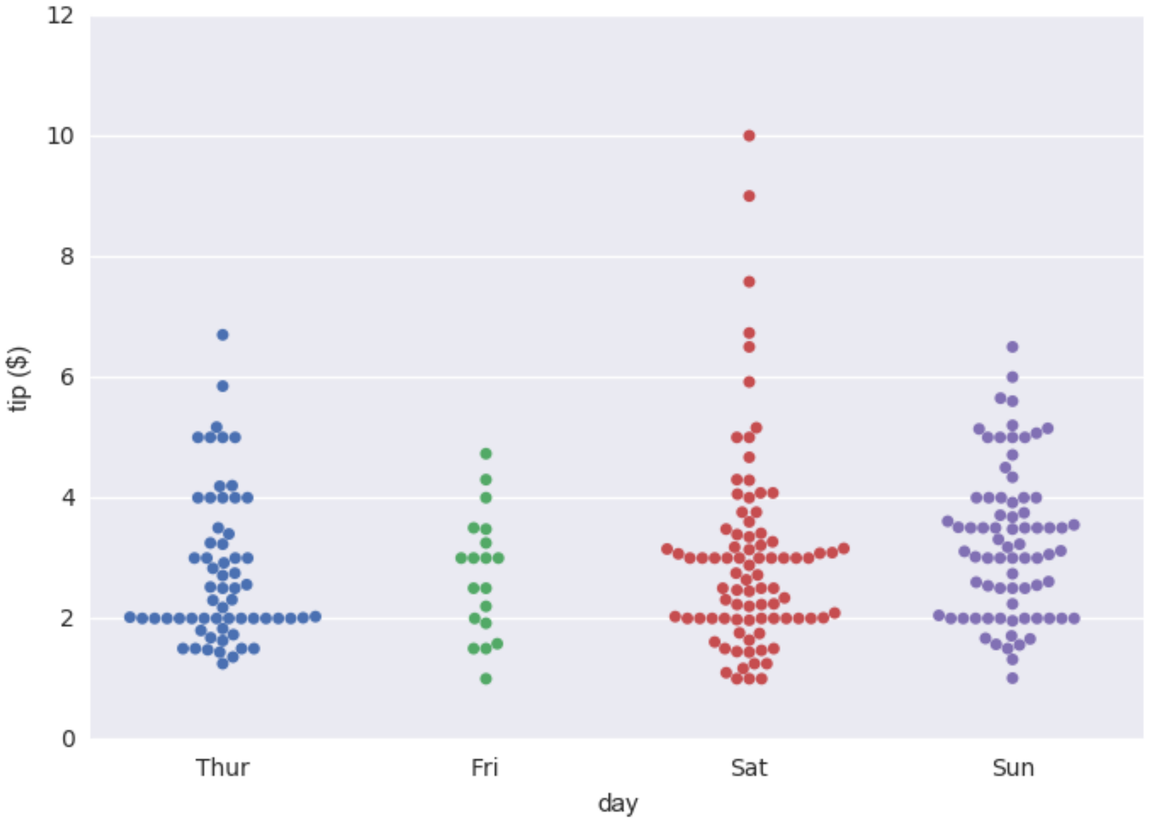
Spreading out strip plots



Spreading out strip plots

```
In [7]: sns.stripplot(x='day', y='tip', data=tip, size=4,
   ...:                   jitter=True)

In [8]: plt.ylabel('tip ($)')

In [9]: plt.show()
```

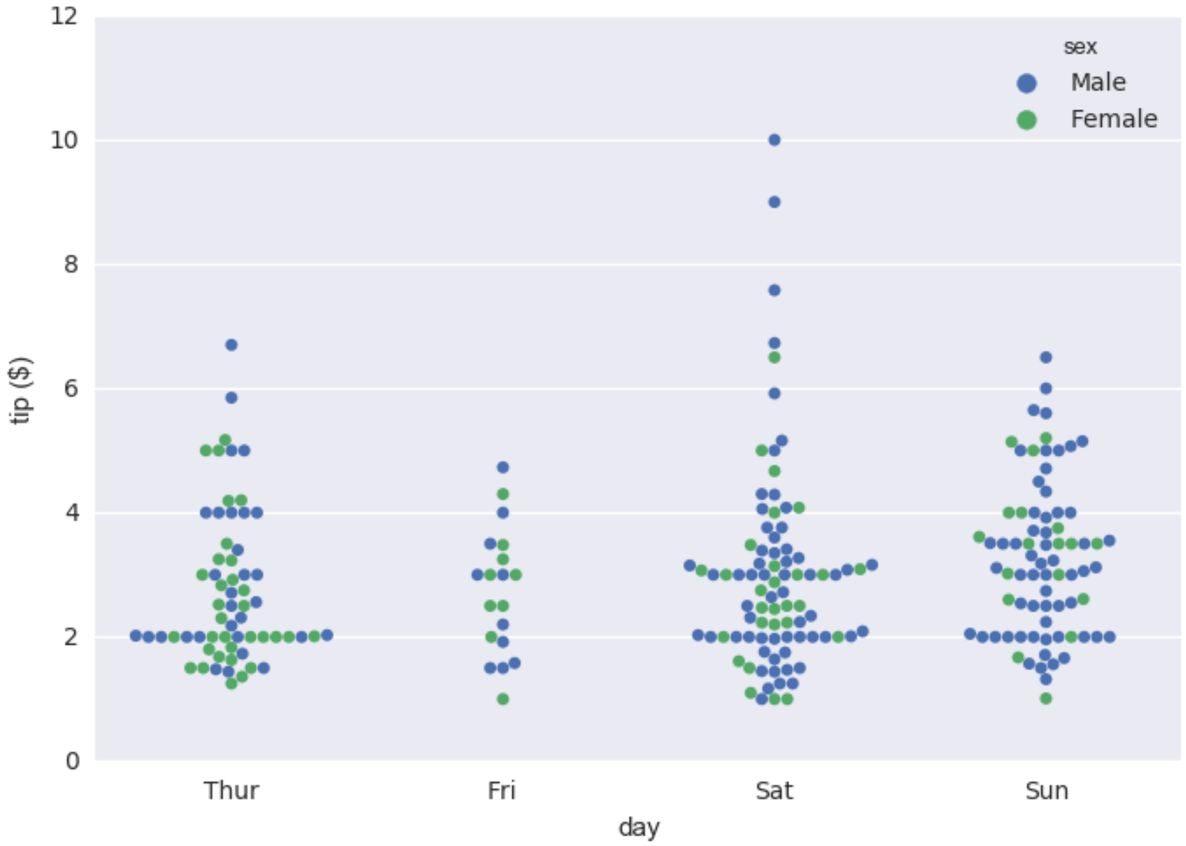
Swarm plot



Using swarmplot()

```
In [10]: sns.swarmplot(x='day', y='tip', data=tips)

In [11]: plt.ylabel('tip ($)')

In [12]: plt.show()
```

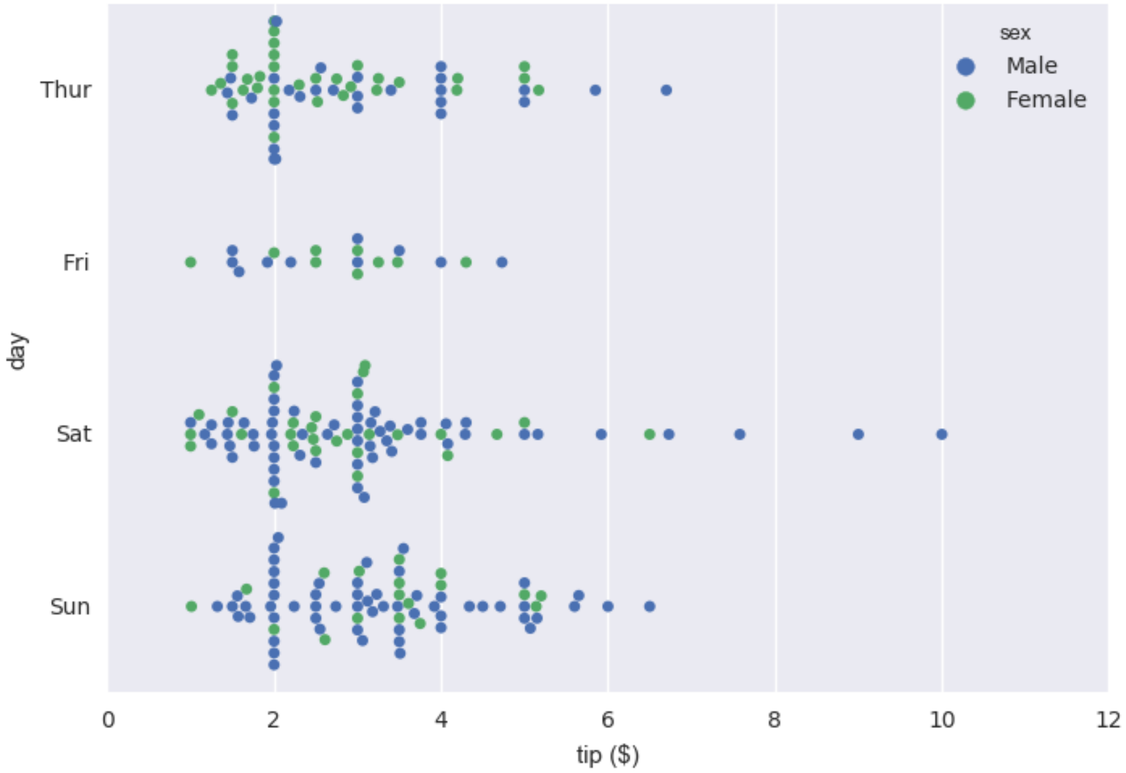
More grouping



More grouping with swarmplot()

```
In [13]: sns.swarmplot(x='day', y='tip', data=tips, hue='sex')

In [14]: plt.ylabel('tip ($)')

In [15]: plt.show()
```

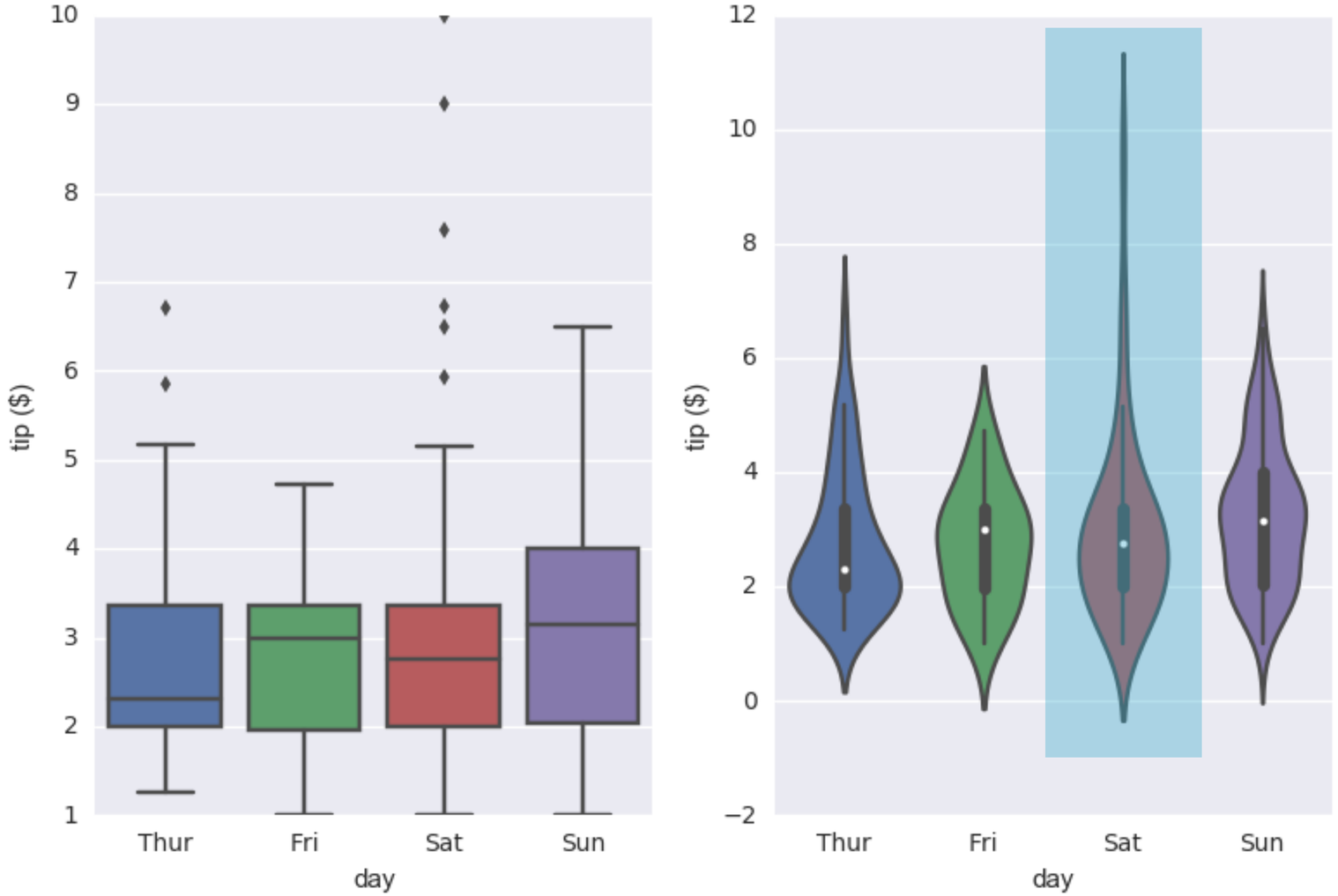
Changing orientation



Changing orientation

```
In [16]: sns.swarmplot(x='tip', y='day', data=tips, hue='sex',
    ...:                orient='h')

In [17]: plt.xlabel('tip ($)')

In [18]: plt.show()
```

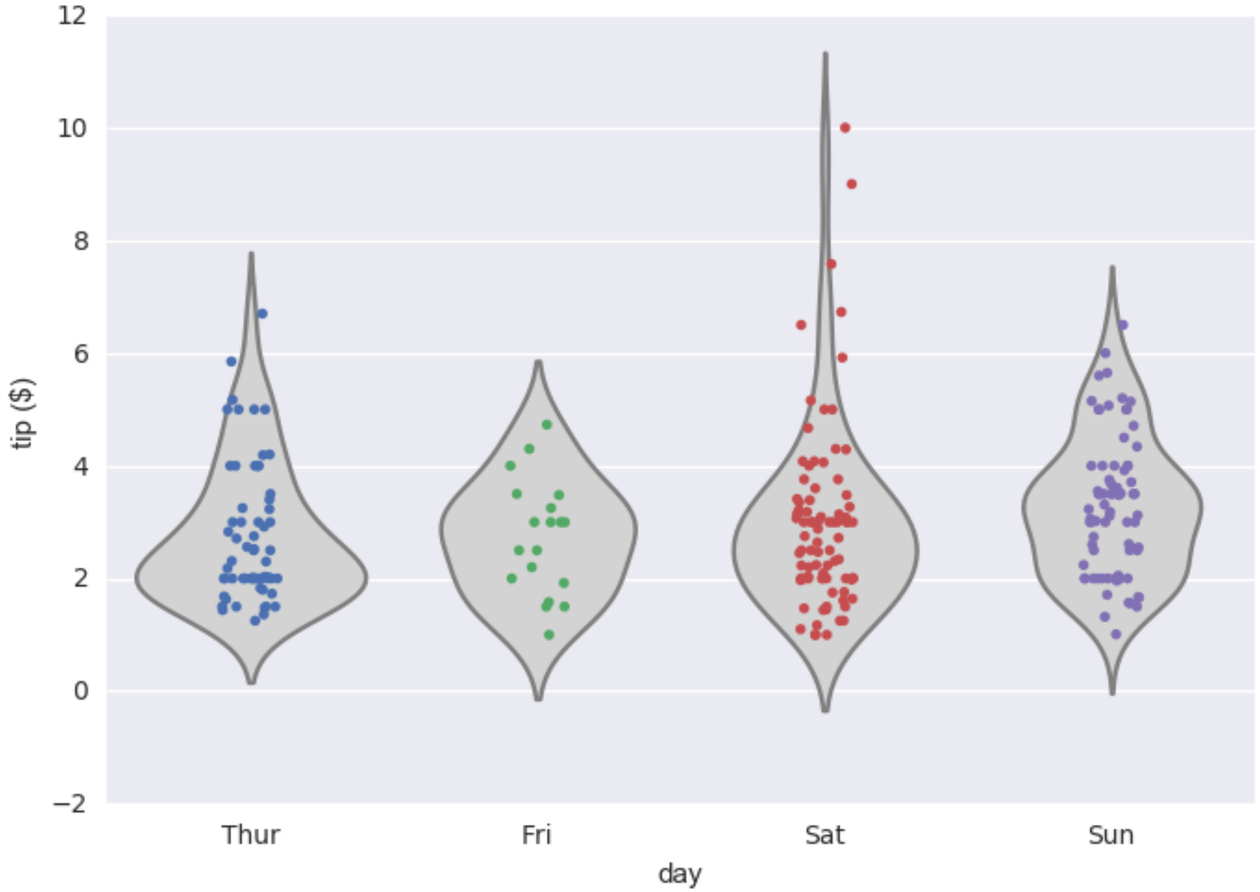
Violin plot


10
9
8
7
6
5
4
3
2
1
tip ($)
Thur
Fri
Sat
Sun
day
12
10
8
6
4
2
0
−2
tip ($)
Thur
Fri
Sat
Sun
day

Using violinplot()

```
In [19]:  plt.subplot(1,2,1)

In [20]: sns.boxplot(x='day', y='tip', data=tips)

In [21]: plt.ylabel('tip ($)')

In [22]: plt.subplot(1,2,2)

In [23]: sns.violinplot(x='day', y='tip', data=tips)

In [24]: plt.ylabel('tip ($)')

In [25]: plt.tight_layout()

In [26]: plt.show()
```

Combining plots



Combining plots

```
In [27]: sns.violinplot(x='day', y='tip', data=tips, inner=None,
    ...:                color='lightgray')

In [28]: sns.stripplot(x='day', y='tip', data=tips, size=4,
    ...:                jitter=True)

In [29]: plt.ylabel('tip ($)')

In [30]: plt.show()
```

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

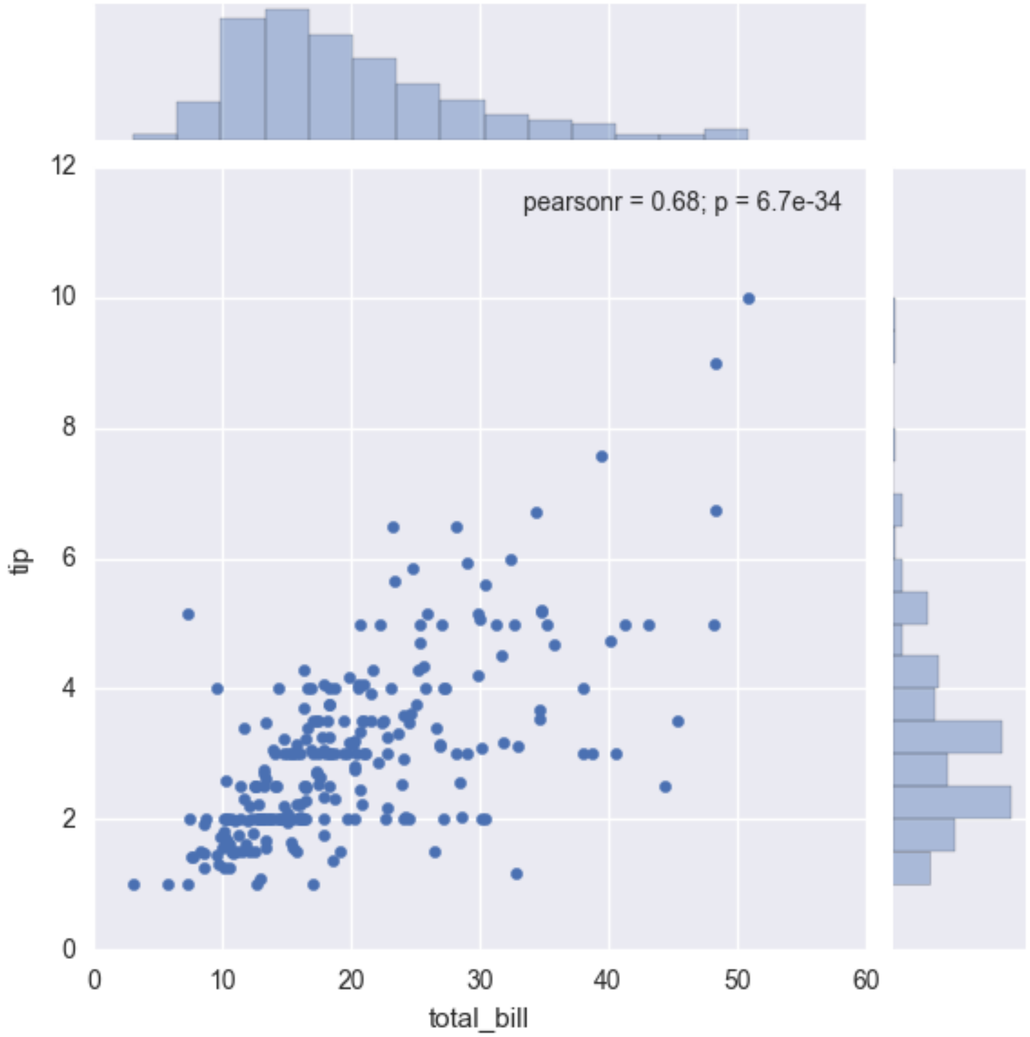
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing Multivariate Distributions

Visualizing data

- Bivariate → “two variables”
- Multivariate → “multiple variables”
- Visualizing relationships in multivariate data
  - Joint plots
  - Pair plots
  - Heat maps

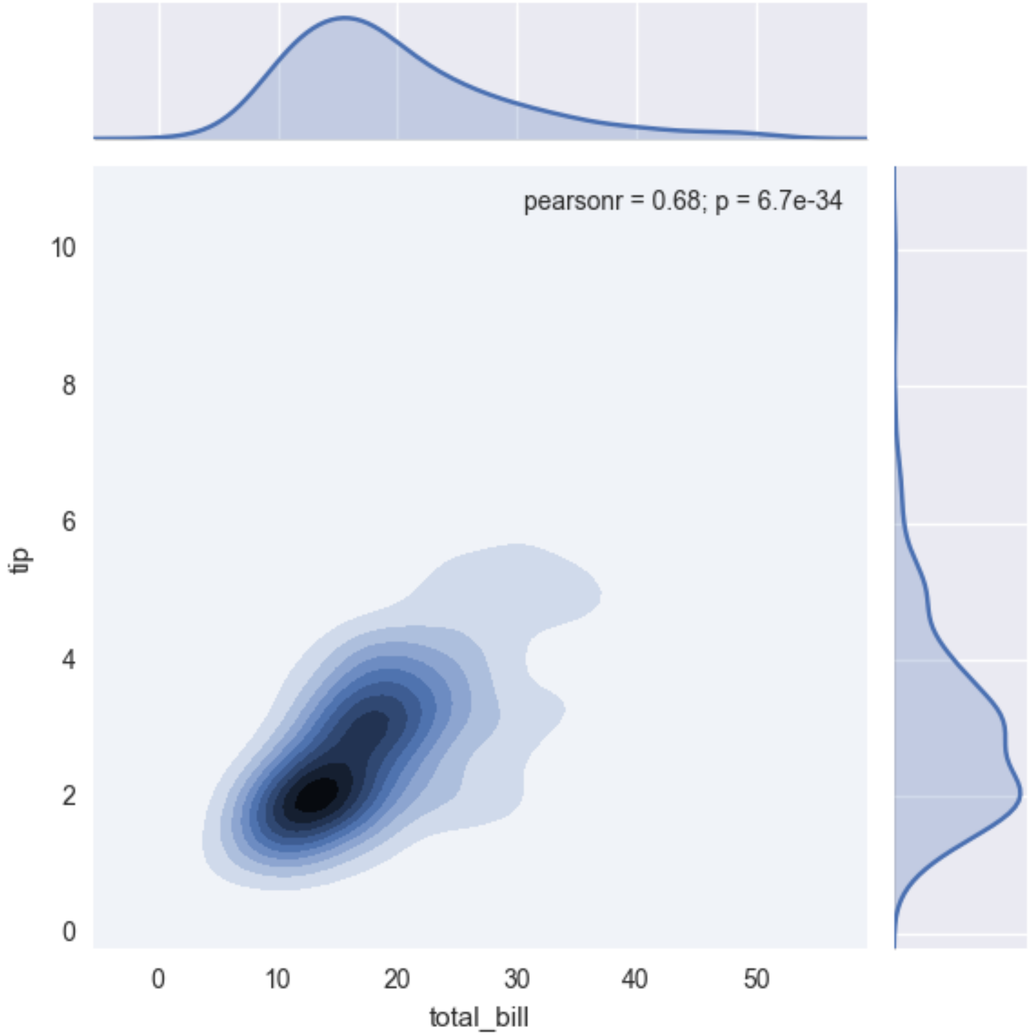
Joint plot


pearsonr = 0.68; p = 6.7e-34
tip
total_bill
0
2
4
6
8
10
12
0
10
20
30
40
50
60

Using jointplot()

```
In [1]: sns.jointplot(x= 'total_bill', y= 'tip', data=tips)

In [2]: plt.show()
```

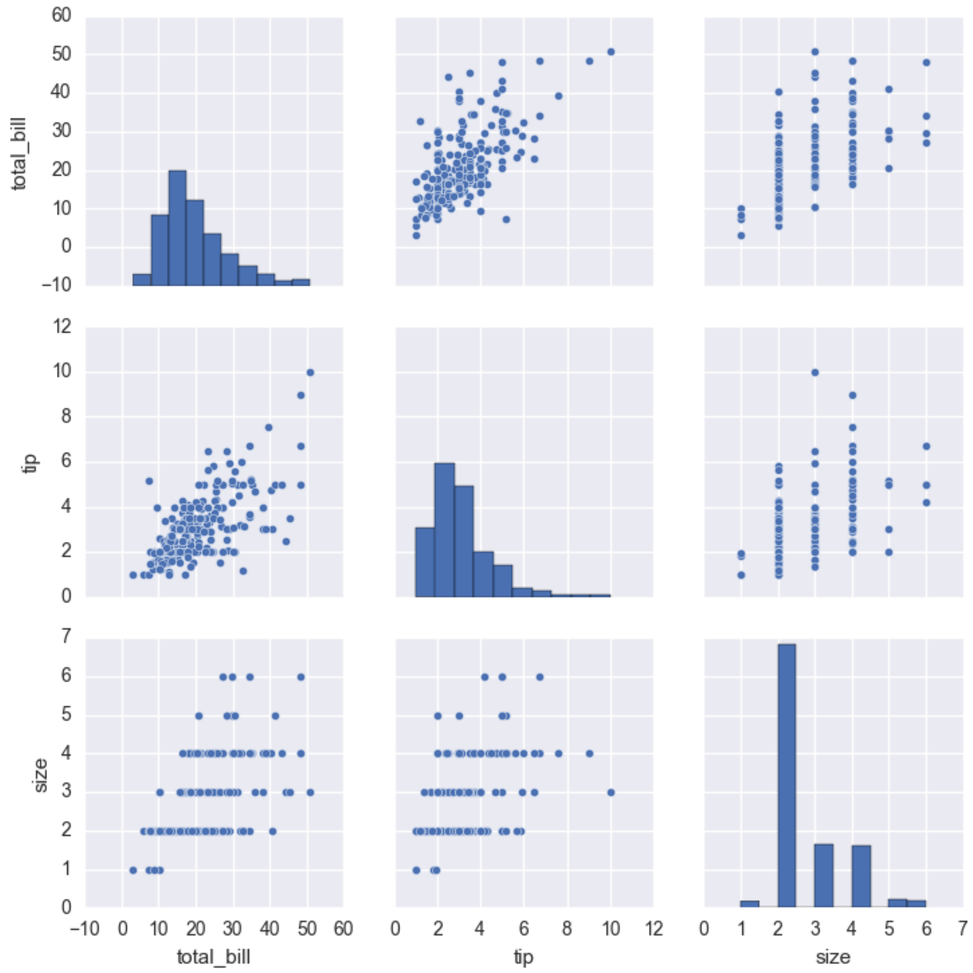
Joint plot using KDE



Using kde=True

```
In [3]: sns.jointplot(x='total_bill', y= 'tip', data=tips,
   ...:                kind='kde')

In [4]: plt.show()
```

Pair plot



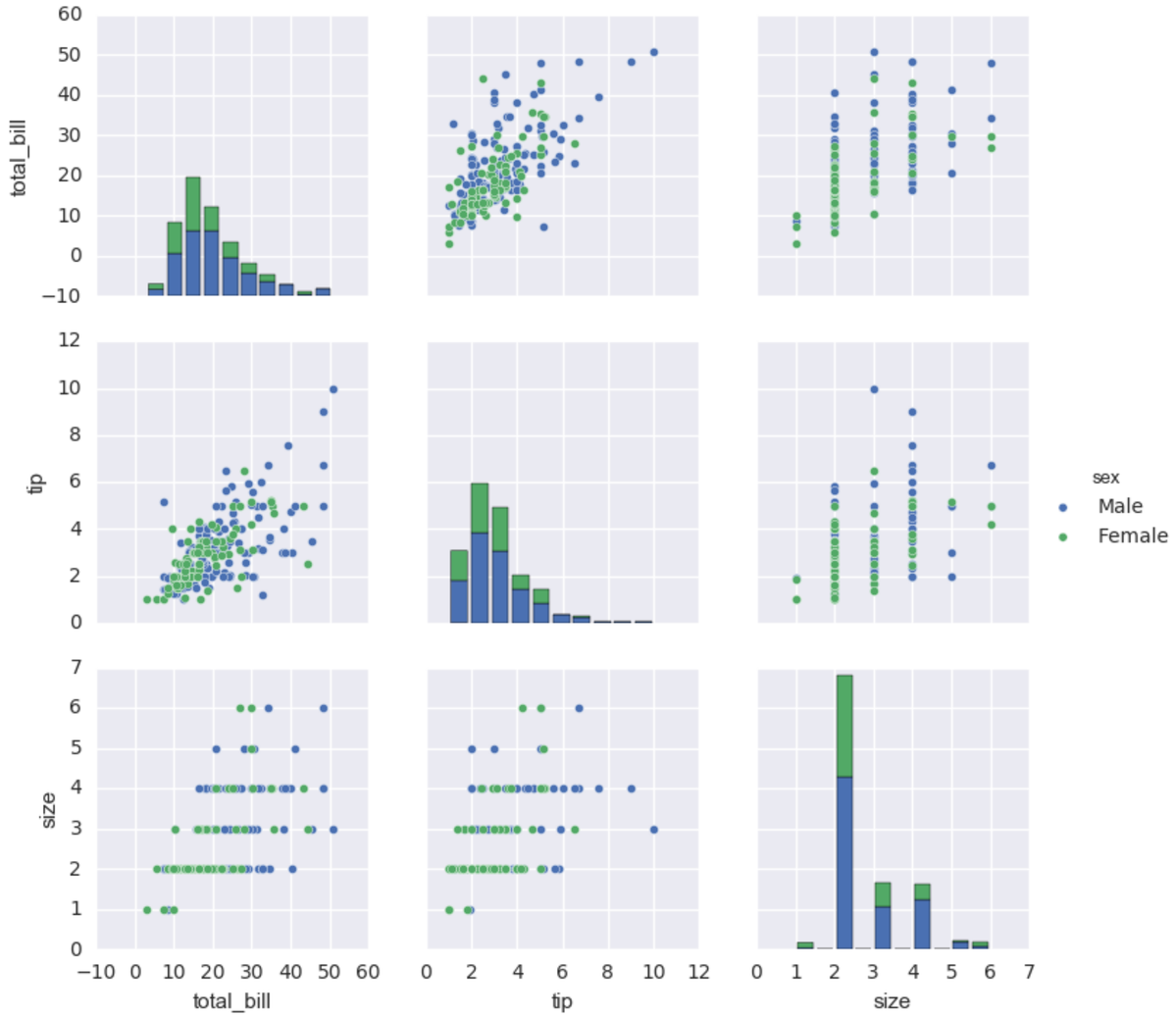
Using pairplot()

```
In [5]: sns.pairplot(tips)

In [6]: plt.show()
```

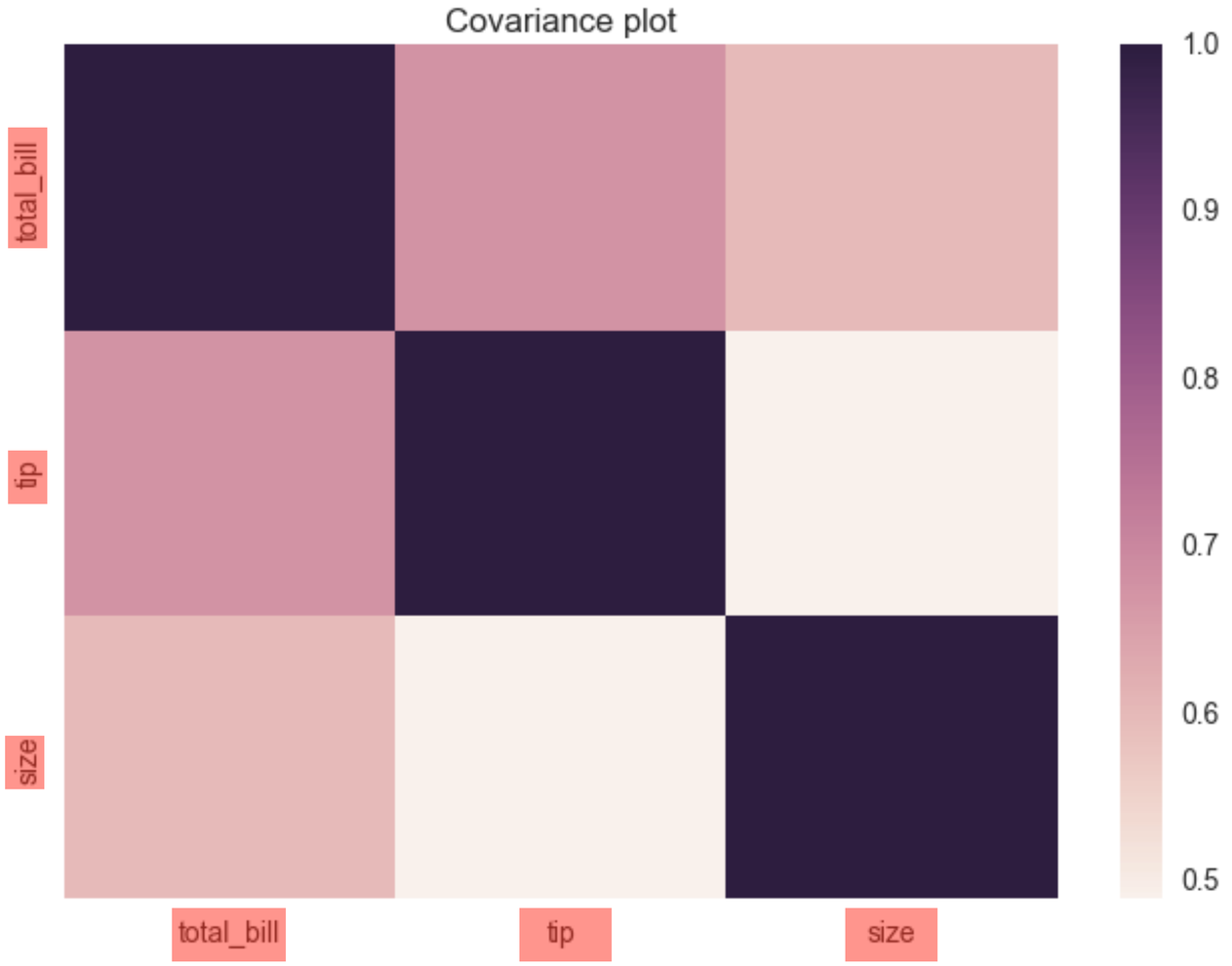
Using pairplot() with hue

```
In [7]: sns.pairplot(tips, hue='sex')

In [8]: plt.show()
```

Using pairplot() with hue



Covariance heat map of tips data



Using heatmap()

```
In [9]:  print(covariance)
             total_bill       tip      size
total_bill     1.000000  0.675734  0.598315
tip            0.675734  1.000000  0.489299
size           0.598315  0.489299  1.000000

In [10]: sns.heatmap(covariance)

In [11]: plt.title('Covariance plot')

In [12]: plt.show()
```

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Visualizing time series

Datetimes & time series

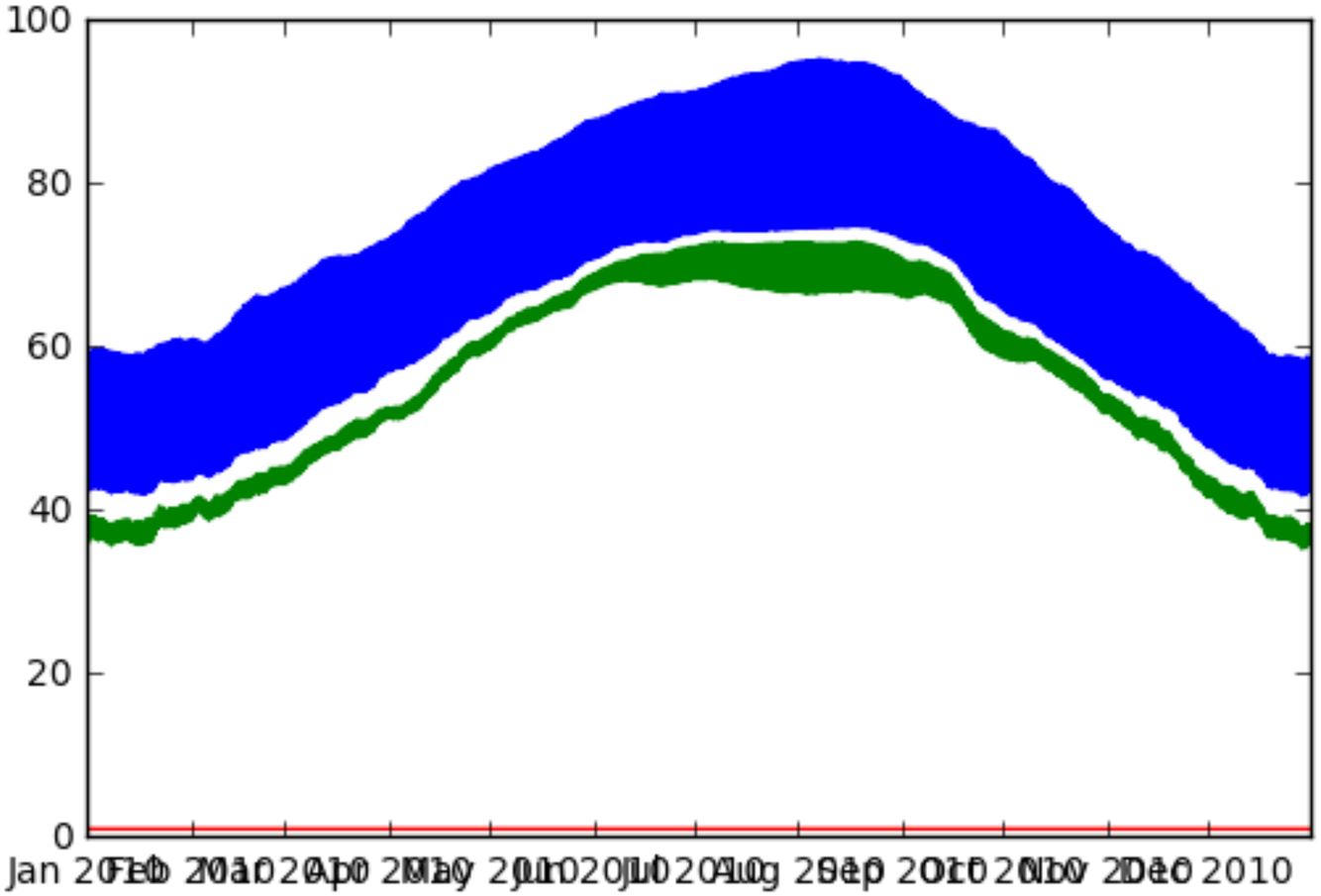
```
In [1]: type(weather)
Out[1]: pandas.core.frame.DataFrame

In [2]: type(weather.index)
Out[2]: pandas.tseries.index.DatetimeIndex
```

Date	Temperature	DewPoint	Pressure
2010-01-01 00:00:00	46.2	37.5	1.0
2010-01-01 01:00:00	44.6	37.1	1.0
2010-01-01 02:00:00	44.1	36.9	1.0
2010-01-01 03:00:00	43.8	36.9	1.0
2010-01-01 04:00:00	43.5	36.8	1.0
...	...	...	...

Plotting DataFrames

```
In [1]: plt.plot(weather)

In [2]: plt.show()
```

Plotting DataFrames



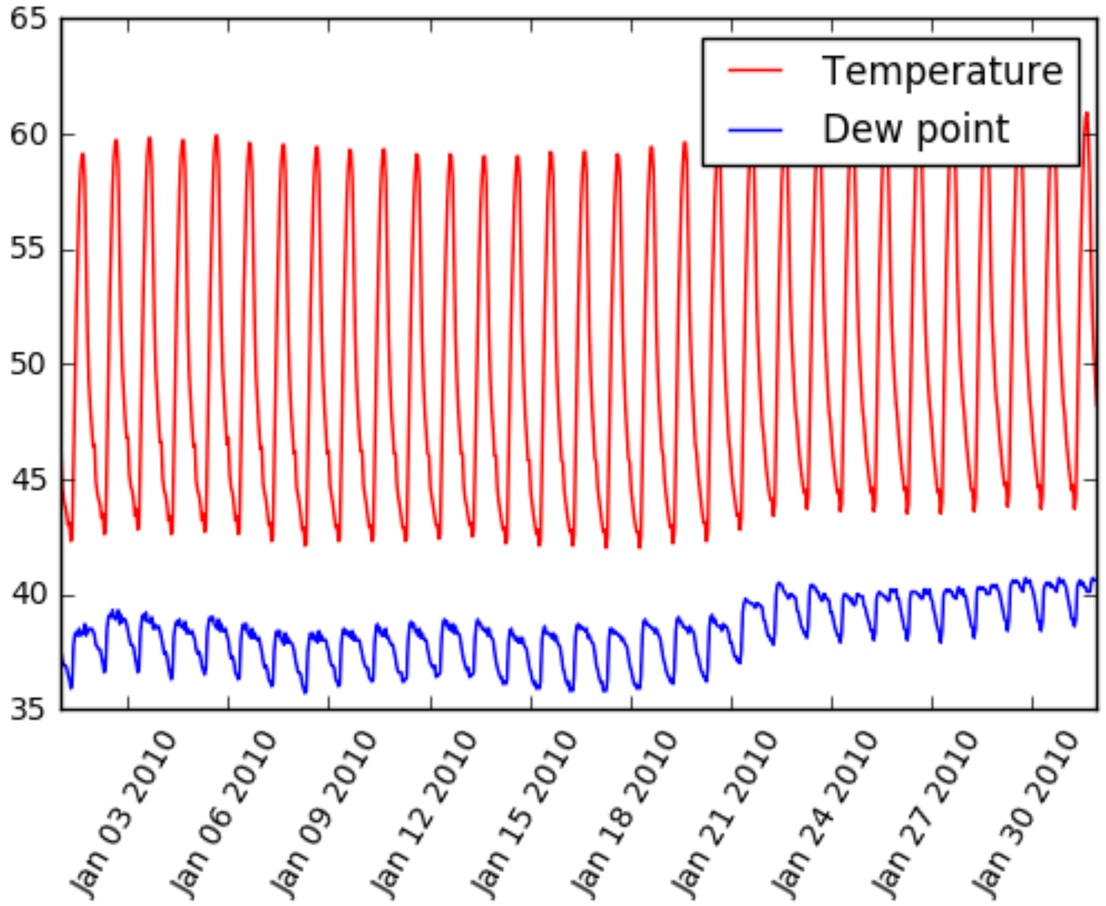
Time series

- Pandas time series: *datetime* as *index*
- Datetime: represents periods or time-stamps
- Datetime index: specialized slicing
  - e.g., weather['2010-07-04']
  - e.g., weather['2010-03':'2010-04']
  - e.g., weather['2010-05']

Slicing time series

```
In [1]: temperature = weather['Temperature']

In [2]: march_apr = temperature['2010-03':'2010-04'] # data of
   ...: March & April 2010 only

In [3]: march_apr.shape
Out[3]: (1463,)

In [4]: march_apr.iloc[-4:] #extract last 4 entries from time
series
Out[4]:
Date
2010-04-30 20:00:00    73.3
2010-04-30 21:00:00    71.3
2010-04-30 22:00:00    69.7
2010-04-30 23:00:00    68.5
Name: Temperature, dtype: float64
```

Plotting time series slices



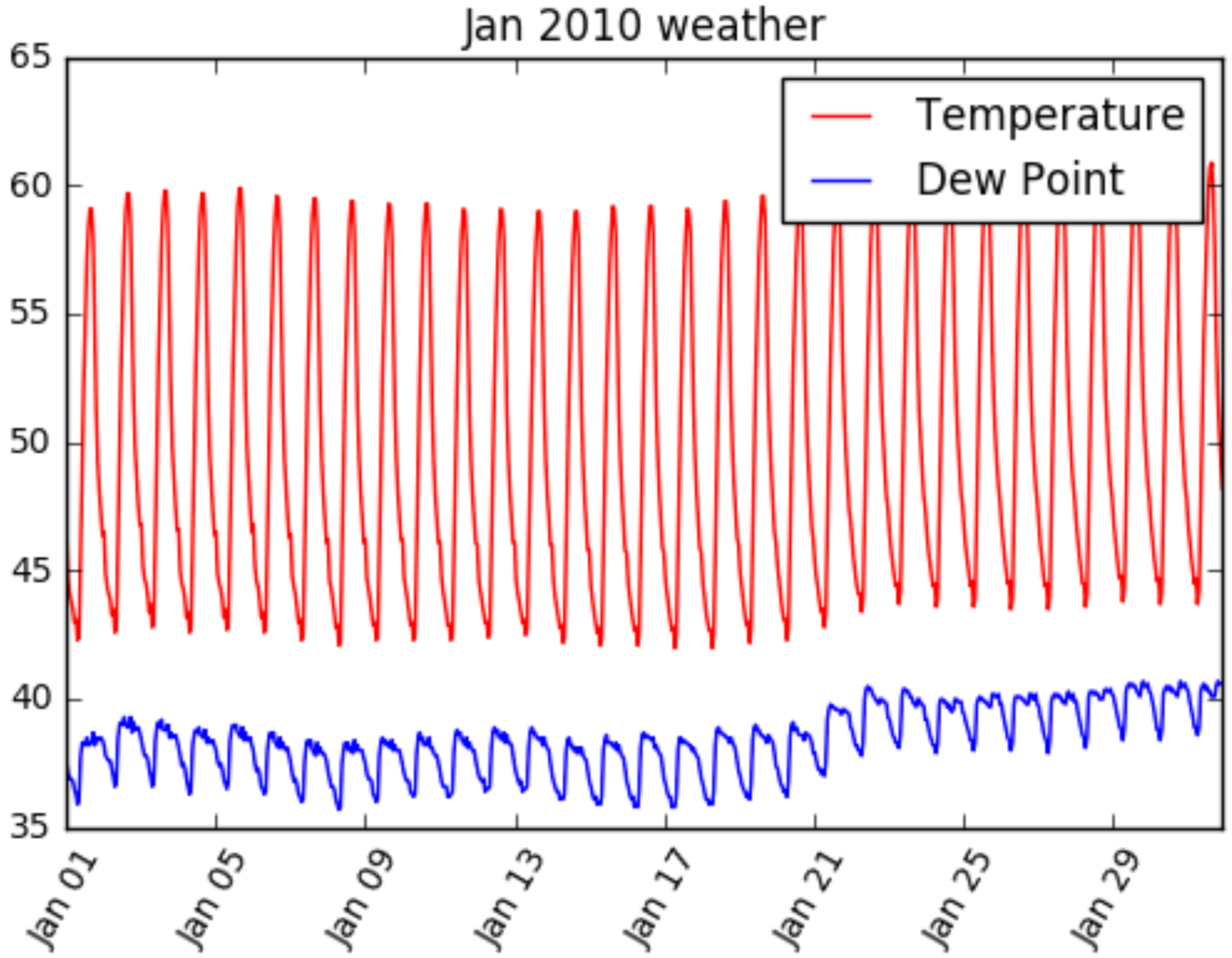
Plotting time series slices

```
In [1]: plt.plot(temperature['2010-01'], color='red',
   ...:          label='Temperature')

In [2] dew point = weather['DewPoint']

In [3]: plt.plot(dewpoint['2010-01'], color='blue',
   ...:          label='Dewpoint')

In [4]: plt.legend(loc='upper right')

In [5]: plt.xticks(rotation=60)

In [6]: plt.show()
```

Selecting & formatting dates

```
In [1]: jan = temperature['2010-01']

In [2]: dates = jan.index[::96]  # Pick every 4th day

In [3]: print(dates)
DatetimeIndex([‘2010-01-01’, ‘2010-01-05’, ‘2010-01-09’,
‘2010-01-13’,‘2010-01-17’, ‘2010-01-21’, ‘2010-01-25’,
‘2010-01-29’], dtype=‘datetime64[ns]’, name=‘Date’, freq=None)

In [4]: labels = dates.strftime('%b %d') # Make formatted labels

In [5]: print(labels)
[‘Jan 01’ ‘Jan 05’ ‘Jan 09’ ‘Jan 13’ ‘Jan 17’ ‘Jan 21’ ‘Jan 25’
‘Jan 29’]
```

Cleaning up ticks on axis



Cleaning up ticks on axis

```
In [1]: plt.plot(temperature['2010-01'], color='red',
   ...:          label='Temperature')

In [2]: plt.plot(dewpoint['2010-01'], color='blue',
   ...:          label='Dewpoint')

In [3]: plt.xticks(dates, labels, rotation=60)

In [4]: plt.legend(loc='upper right')

In [5]: plt.show()
```

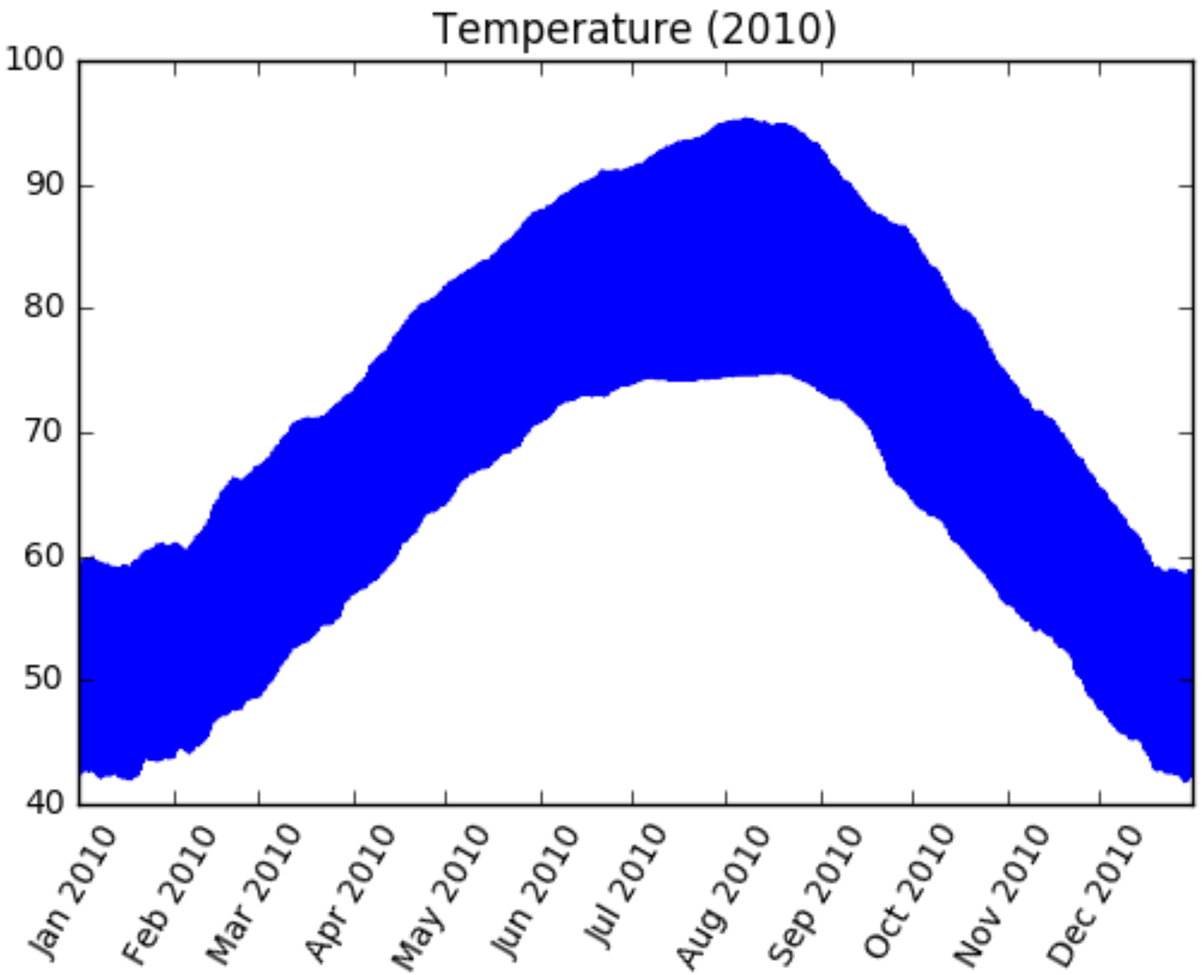
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

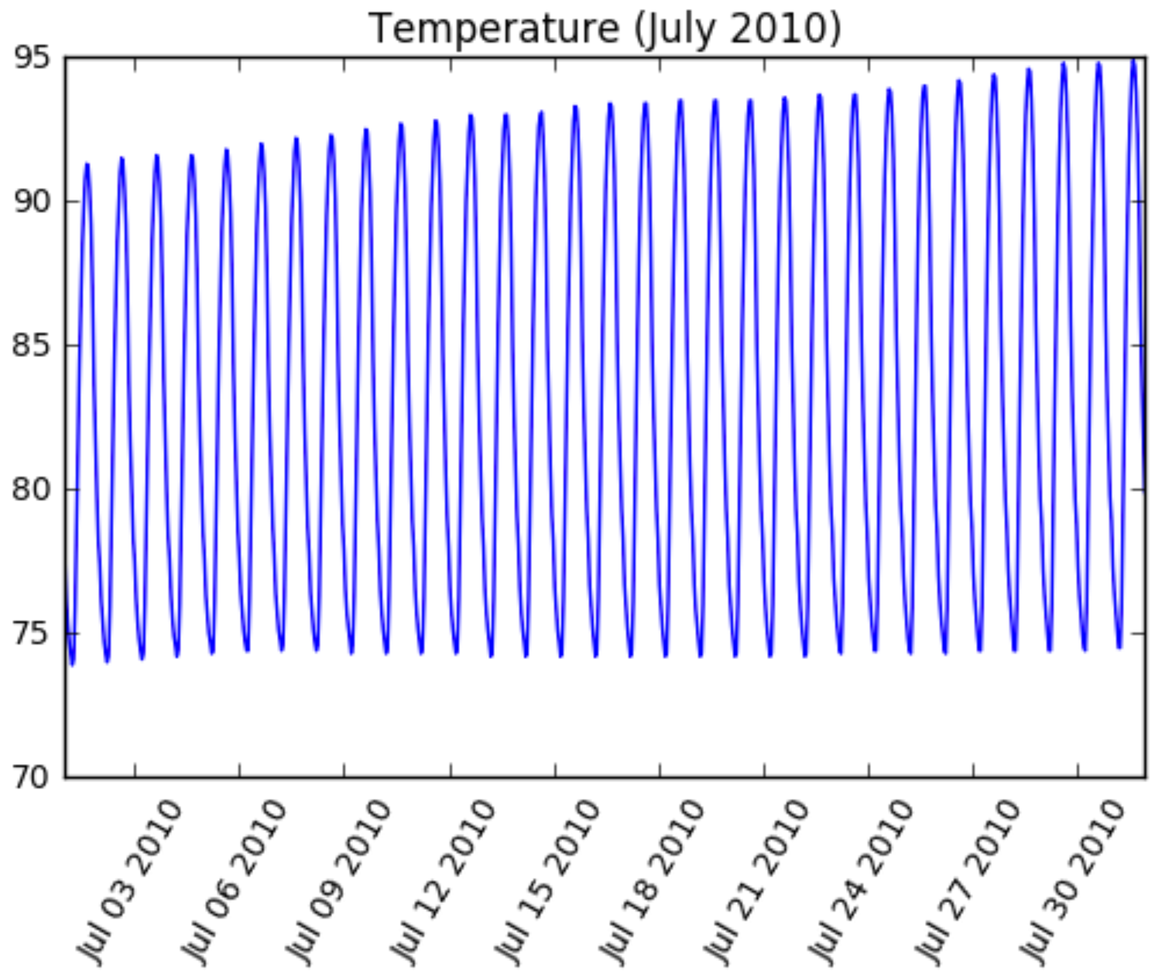
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Time series with moving windows

Hourly data over a year



Zooming in


Temperature (July 2010)
95
90
85
80
75
70
Jul 03 2010
Jul 06 2010
Jul 09 2010
Jul 12 2010
Jul 15 2010
Jul 18 2010
Jul 21 2010
Jul 24 2010
Jul 27 2010
Jul 30 2010

Moving windows & time series

- Moving window calculations
  - Averages
  - Medians
  - Standard deviations
- Extracts information on longer time scales
- See Pandas courses on how to compute

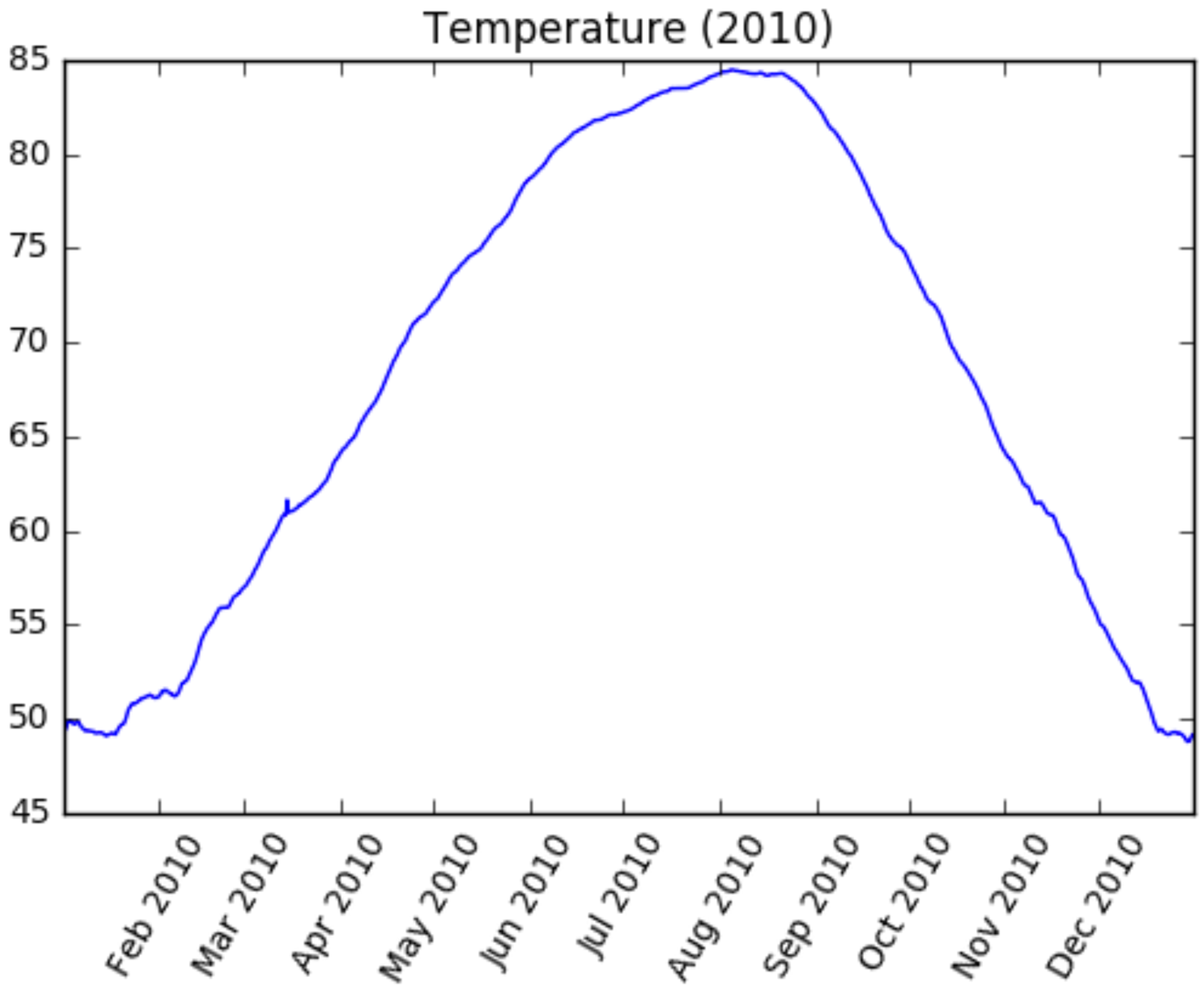
Moving averages

```
In [1]: smoothed.info() # smoothed computing using moving averages
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 8759 entries, 2010-01-01 00:00:00 to 2010-12-31
23:00:00
Data columns (total 5 columns):
14d             8424 non-null float64
1d              8736 non-null float64
3d              8688 non-null float64
7d              8592 non-null float64
dtypes: float64(5)
memory usage: 410.6 KB

In [2]: print(smoothed.iloc[:3,:])
                     14d  1d  3d  7d  Temperature
Date
2010-01-01 00:00:00  NaN NaN NaN NaN         46.2
2010-01-01 01:00:00  NaN NaN NaN NaN         44.6
2010-01-01 02:00:00  NaN NaN NaN NaN         44.1
```

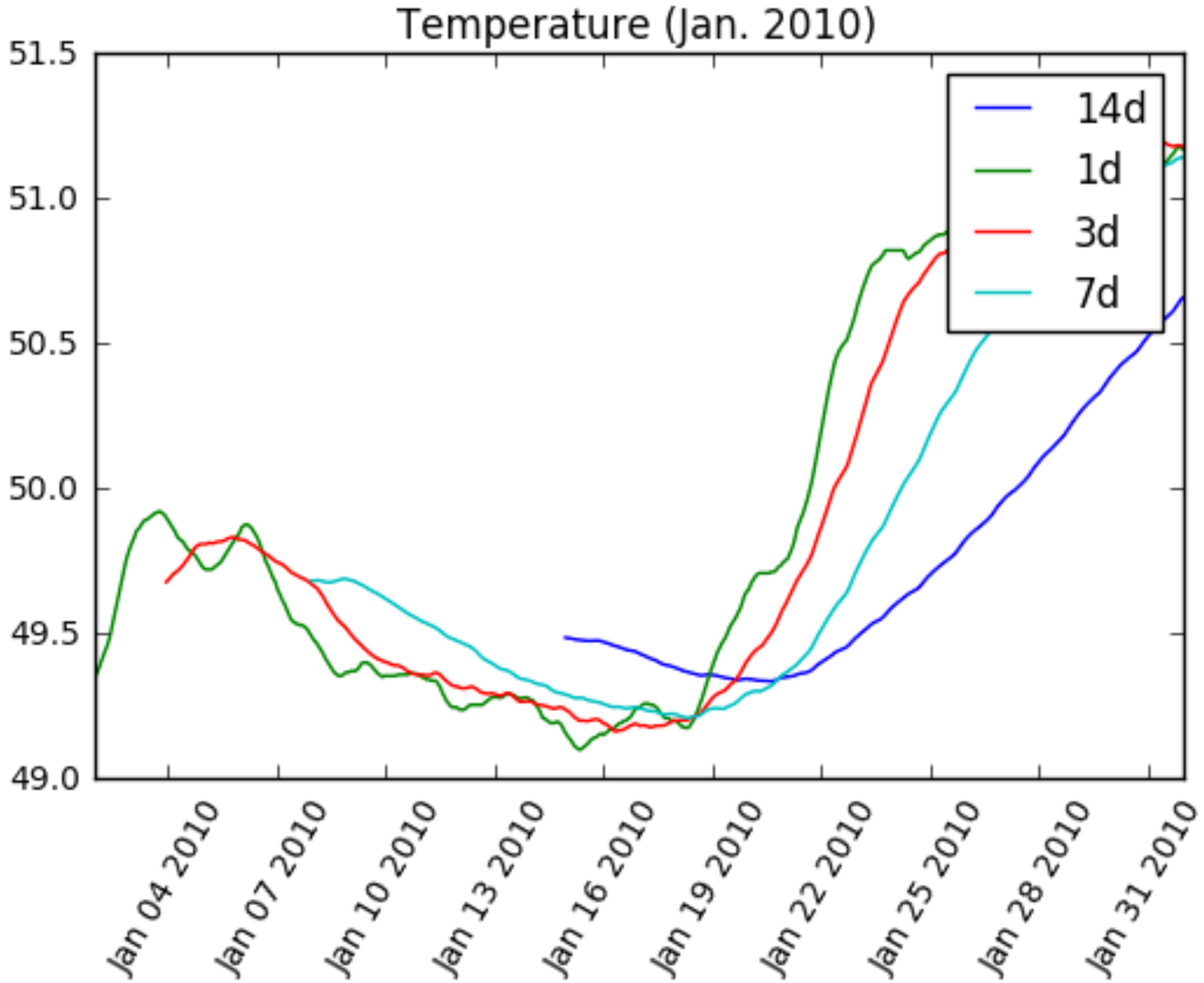
Viewing 24 hour averages

```
In [1]: plt.plot(smoothed['1d']) # moving average over 24 hours

In [2]: plt.title('Temperature (2010)')

In [3]: plt.xticks(rotation=60)

In [4]: plt.show()
```

Viewing 24 hour averages



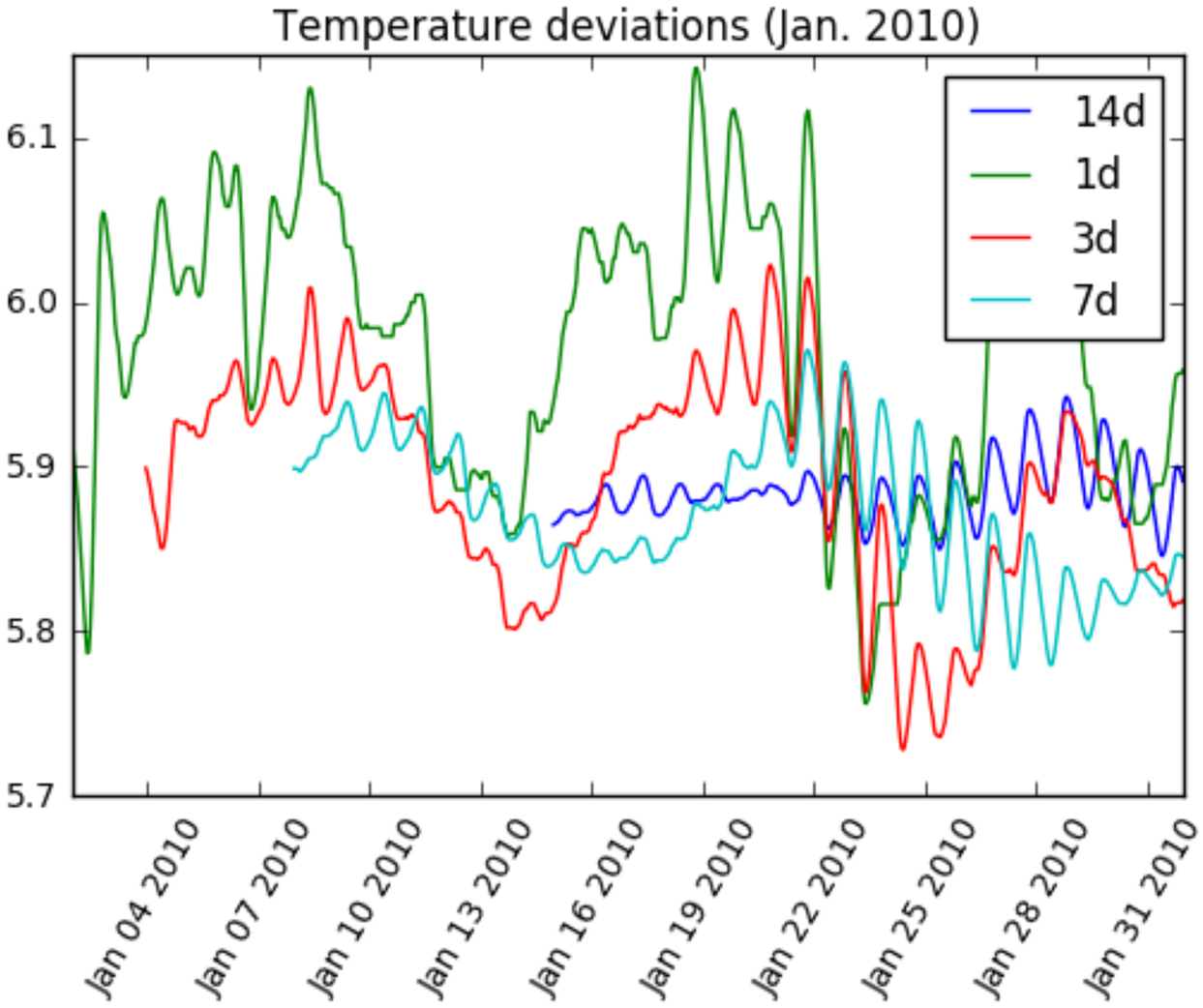
Viewing all moving averages



Viewing all moving averages

```
In [1]: plt.plot(smoothed['2010-01']) # plot
   ...: DataFrame for January

In [2]: plt.legend(smoothed.columns)

In [3]: plt.title('Temperature (Jan. 2010)')

In [4]: plt.xticks(rotation=60)

In [5]: plt.show()
```

Moving standard deviations



Moving standard deviations

```
In [1]: plt.plot(variances['2010-01'])

In [2]: plt.legend(variances.columns)

In [3]: plt.title('Temperature deviations (Jan. 2010)')

In [4]: plt.xticks(rotation=60)

In [5]: plt.show()
```

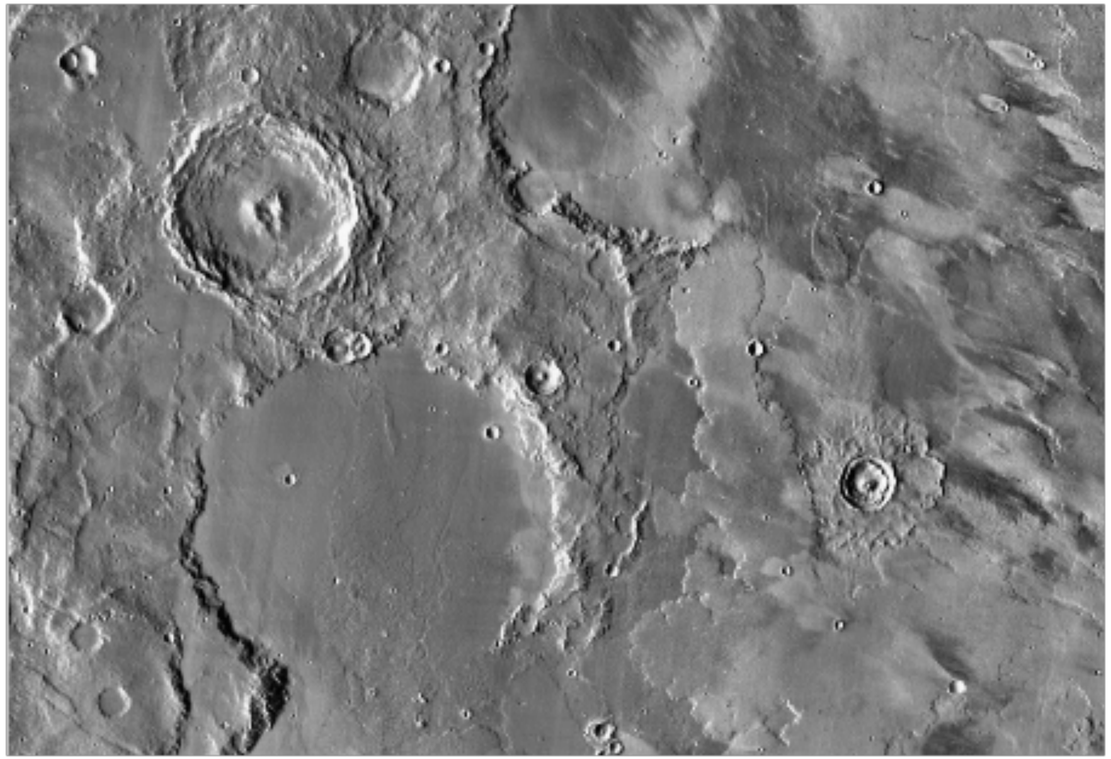
INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Histogram equalization in images

Original image



Equalized image

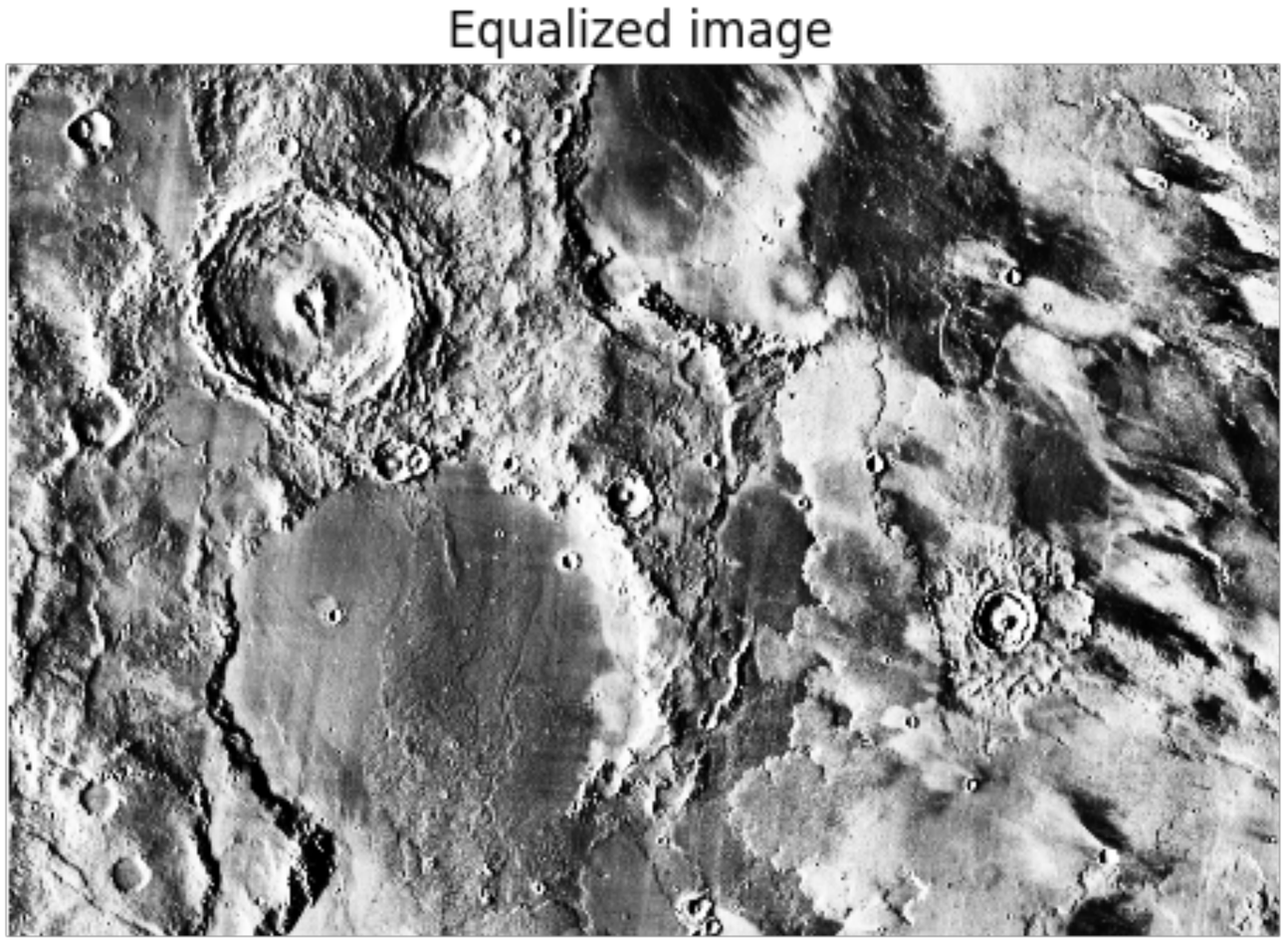


Image histograms

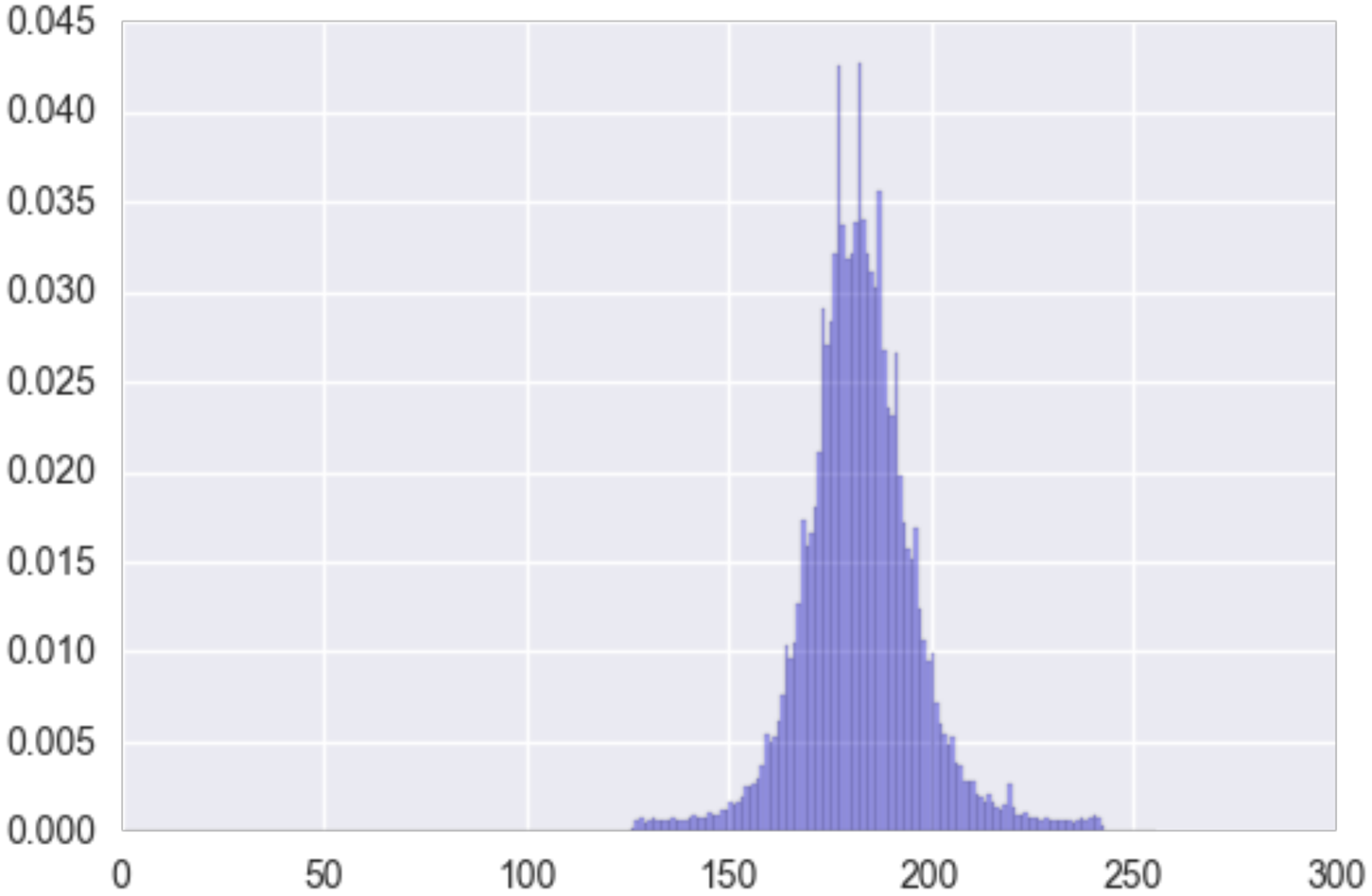


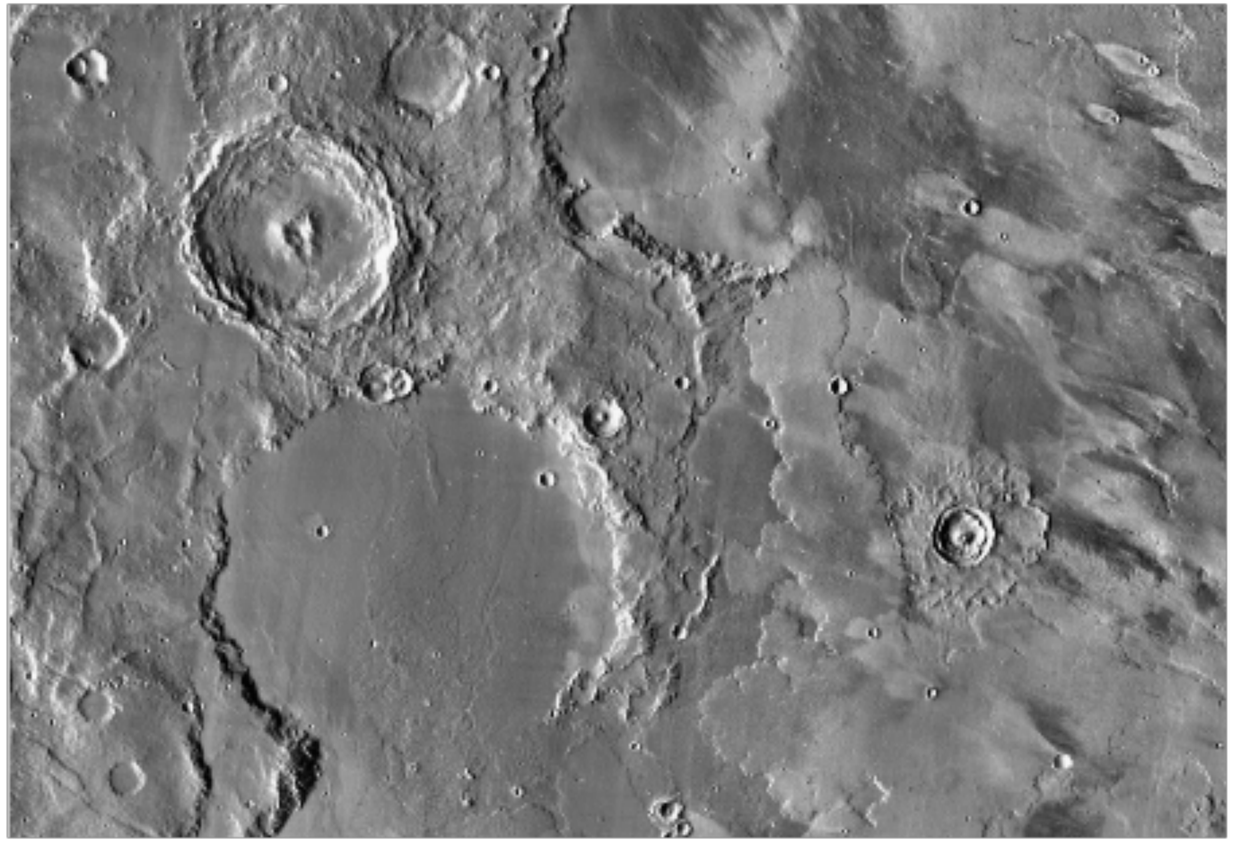
Image histograms

```
In [1]: orig = plt.imread('low-contrast-moon.jpg')

In [2]: pixels = orig.flatten()

In [3]: plt.hist(pixels, bins=256, range=(0,256), normed=True,
   ...:          color='blue', alpha=0.3)

In [4]: plt.show()

In [5]: minval, maxval = orig.min(), orig.max()

In [6]: print(minval, maxval)
125 244
```

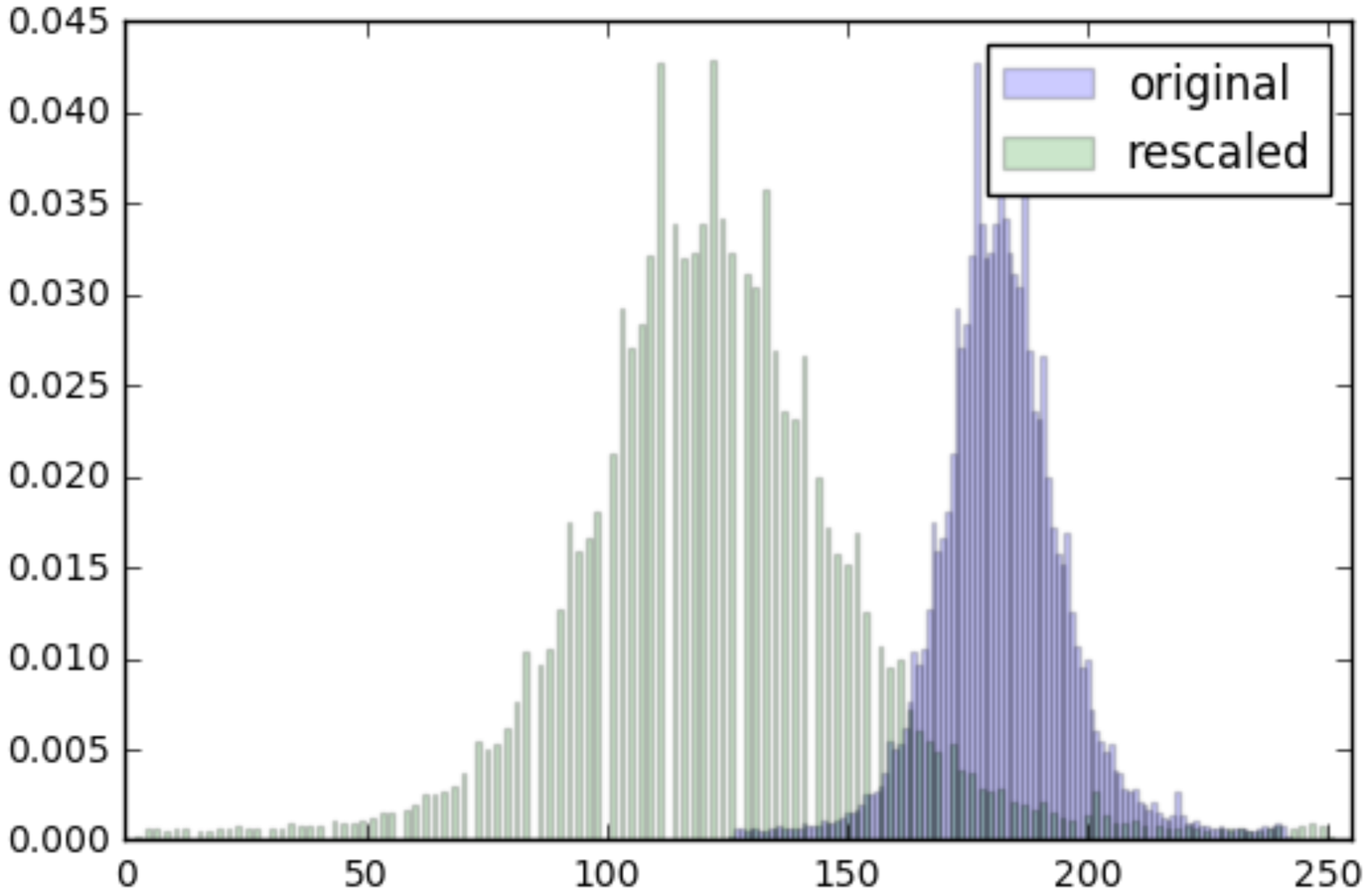
Rescaling the image

```
In [1]: minval, maxval = orig.min(), orig.max()

In [2]: print(minval, maxval)
125 244

In [3]: rescaled = (255/(maxval-minval)) * (pixels - minval)

In [4]: print(rescaled.min(), rescaled.max())
0.0 255.0

In [5]: plt.imshow(rescaled)

In [6]: plt.axis('off')

In [7]: plt.show()
```

Rescaled image



Original & rescaled histograms



Original & rescaled histograms

```
In [1]: plt.hist(orig.flatten(), bins=256, range=(0,255),
   ...:          normed=True, color='blue', alpha=0.2))

In [2]: plt.hist(rescaled.flatten(), bins=256, range=(0,255),
   ...:          normed=True, color='green', alpha=0.2))

In [3]: plt.legend(['original', 'rescaled'])

In [4]: plt.show()
```

Image histogram & CDF

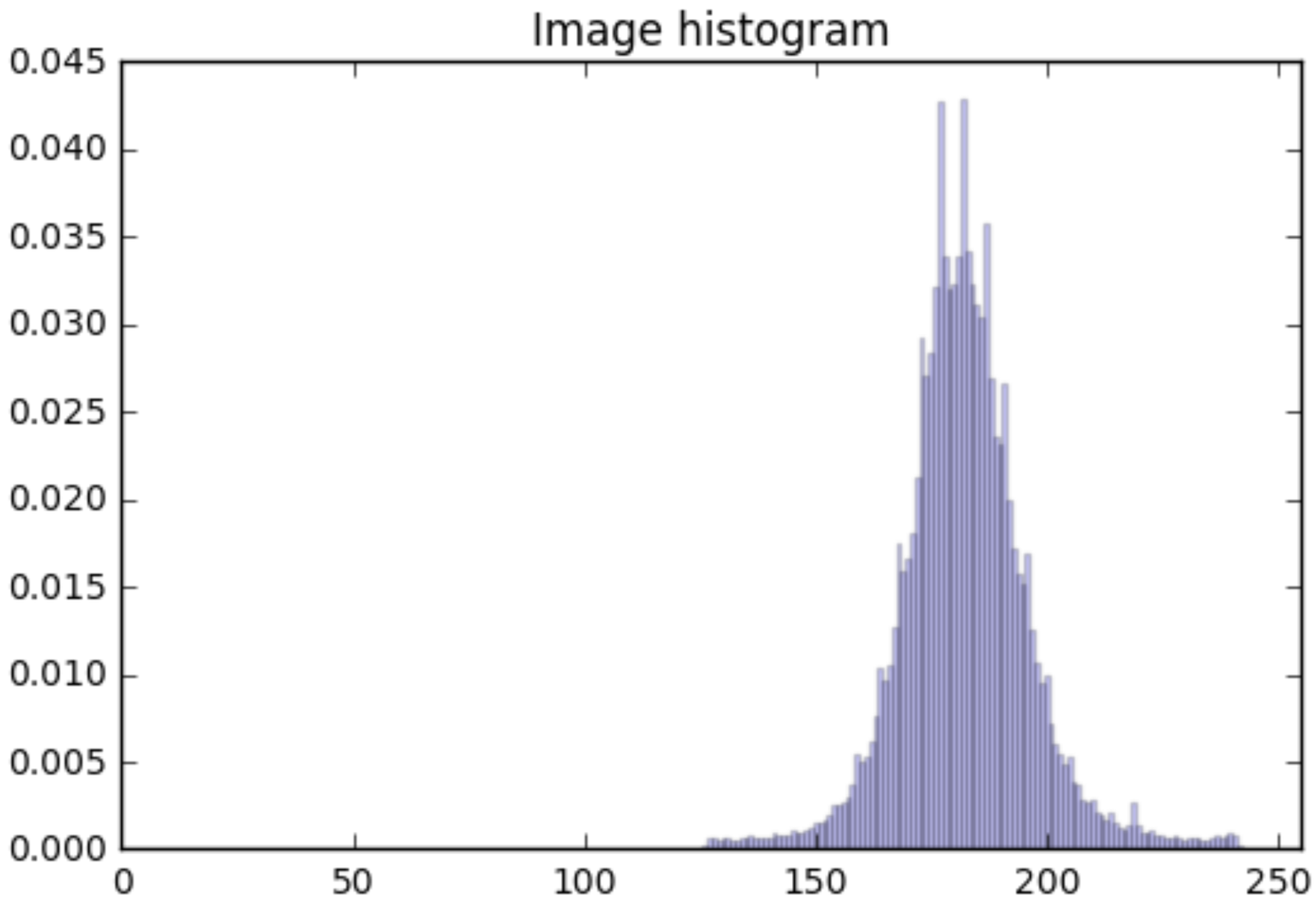


Image histogram & CDF

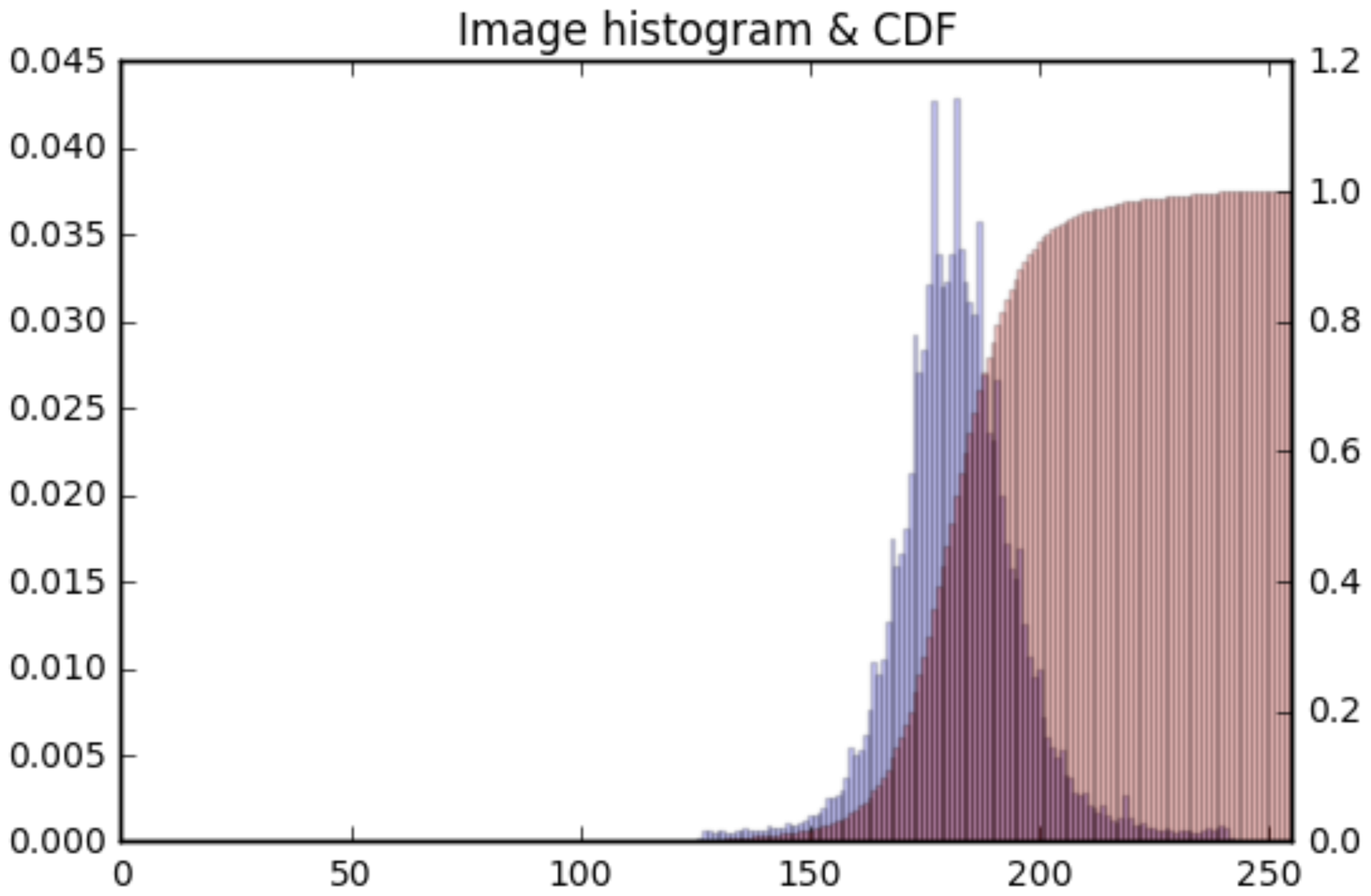


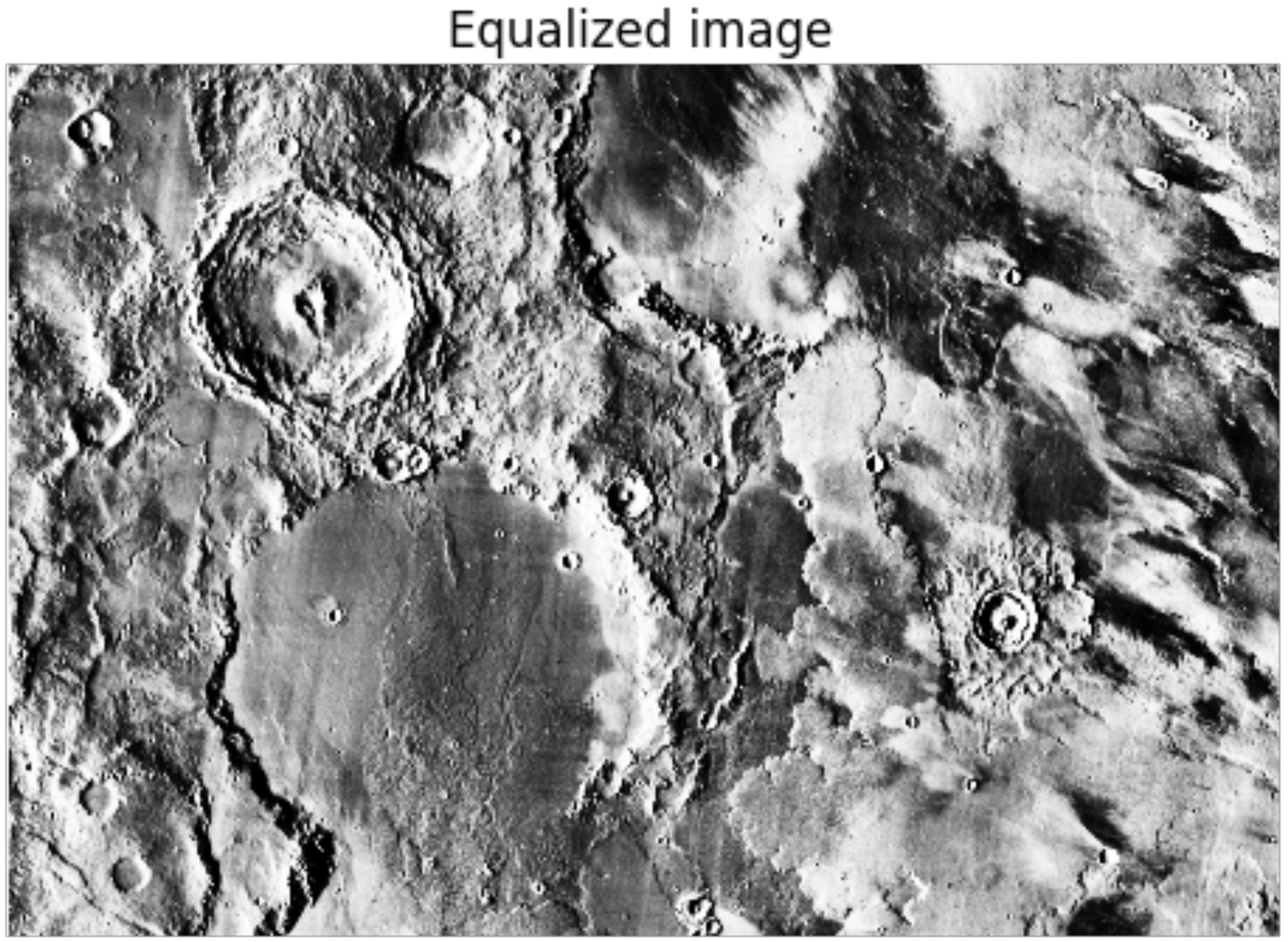
Image histogram & CDF

```
In [1]: plt.hist(pixels, bins=256, range=(0,256), normed=True,
   ...:          color='blue', alpha=0.3)

In [2]: plt.twinx()

In [3]: orig_cdf, bins, patches = plt.hist(pixels,
   ...: cumulative=True, bins=256, range=(0,256), normed=True,
   ...: color='red', alpha=0.3)

In [4]: plt.title('Image histogram and CDF')

In [5]: plt.xlim((0, 255))

In [6]: plt.show()
```

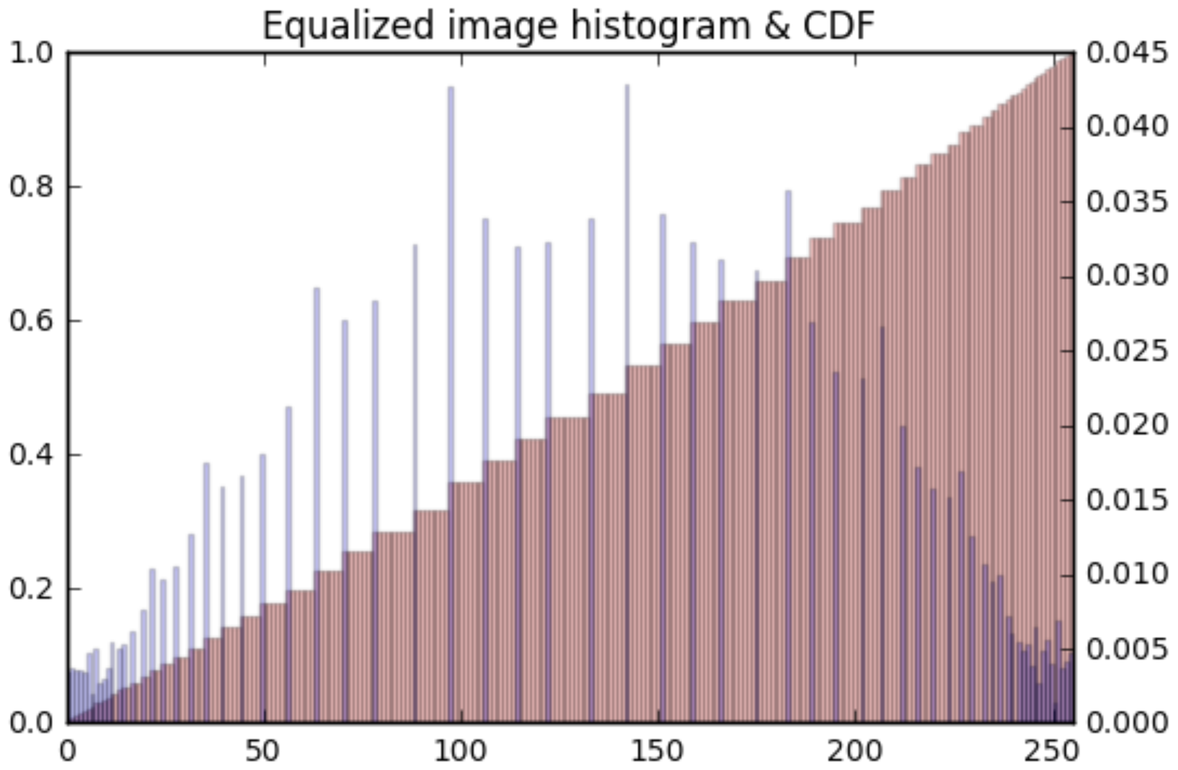
Equalizing intensity values

```
In [1]: new_pixels =  np.interp(pixels, bins[:-1], orig_cdf*255)

In [2]: new = new_pixels.reshape(orig.shape)

In [3]: plt.imshow(new)

In [4]: plt.axis('off')

In [5]: plt.title('Equalized image')

In [6]: plt.show()
```

Equalized image



Equalized histogram & CDF



Equalized histogram & CDF

```
In [1]: plt.hist(new_pixels, bins=256, range=(0,256),
   ...:          normed=True, color='blue', alpha=0.3)

In [2]: plt.twinx()

In [3]: plt.hist(new_pixels, cumulative=True, bins=256,
   ...:          range=(0,256), normed=True, color='red', alpha=0.1)

In [4]: plt.title('Equalized image histogram and CDF')

In [5]: plt.xlim((0, 255))

In [6]: plt.show()
```

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Let’s practice!

INTRODUCTION TO DATA VISUALIZATION WITH PYTHON

Congratulations!