Visualization 3

Thomas Schwarz, SJ

Review

- Create figures in matplotlib.pyplot imported as plt
  - Use pandas, i.e. `df.column.plot( )`
    - Limited functionality, but easiest to use
  - Use `plt.plot`
    - Matplotlib style
  - Use the OO interface
    - `fig, ax = plt.subplots(8,8, figsize=(6,6) )`

Review

- Scripts:
  - Need to call `plt.show( )` but only once
- IPython
  - Use the `%matplotlib` magic command
    - `plt` commands now run in place to update a plot
    - Might need to force updates with `plt.draw( )`
- IPython notebook
  - `%matplotlib notebook`
    - Interactive plots embedded in notebook
  - `% matplotlib inline`
    - Static images embedded in notebook

Review

- plot for line plots: give x- and y-values
- scatter plot with setting marker as third argument
  - color codes and line codes
    - `color`, `linestyle`, or abbreviation
- control with

plt	ax
`plt.xlabel( )`	`ax.set_xlabel( )`
`plt.xlim( )`	`ax.set_xlim( )`
`plt.title( )`	`ax.set_title( )`

Error Bars

- `errorbar`: Add a third numpy array to create error bars
  - Can use ecolor, elinewidth, …
- `fill_between`: Give two different functions

Error Bars

- Example:
  - Generate some fake experimental data for $0 \leq i < 30$
    - Normally distributed with mean $\sqrt{2 \cdot i + 3}$
    - Std. Dev. of $0.5 + 2 \cdot i$
    - Then calculate sample mean and sample standard deviation

Error Bars

```
def create_numbers():
    lista = [np.random.normal(
          loc = np.sqrt(2*i)+3,
          scale= 0.5+.2*i,
          size = 50)
                                for i in range(30)]
    means = np.mean(lista, axis=1)
    conf = np.std(lista, axis=1)/np.sqrt(29)
    return means, conf
```

Error Bars

- Display results

```
a, b = create_numbers()
x = np.linspace(0,29,30)
```

```
fig, ax = plt.subplots(1, figsize = (5,4) )

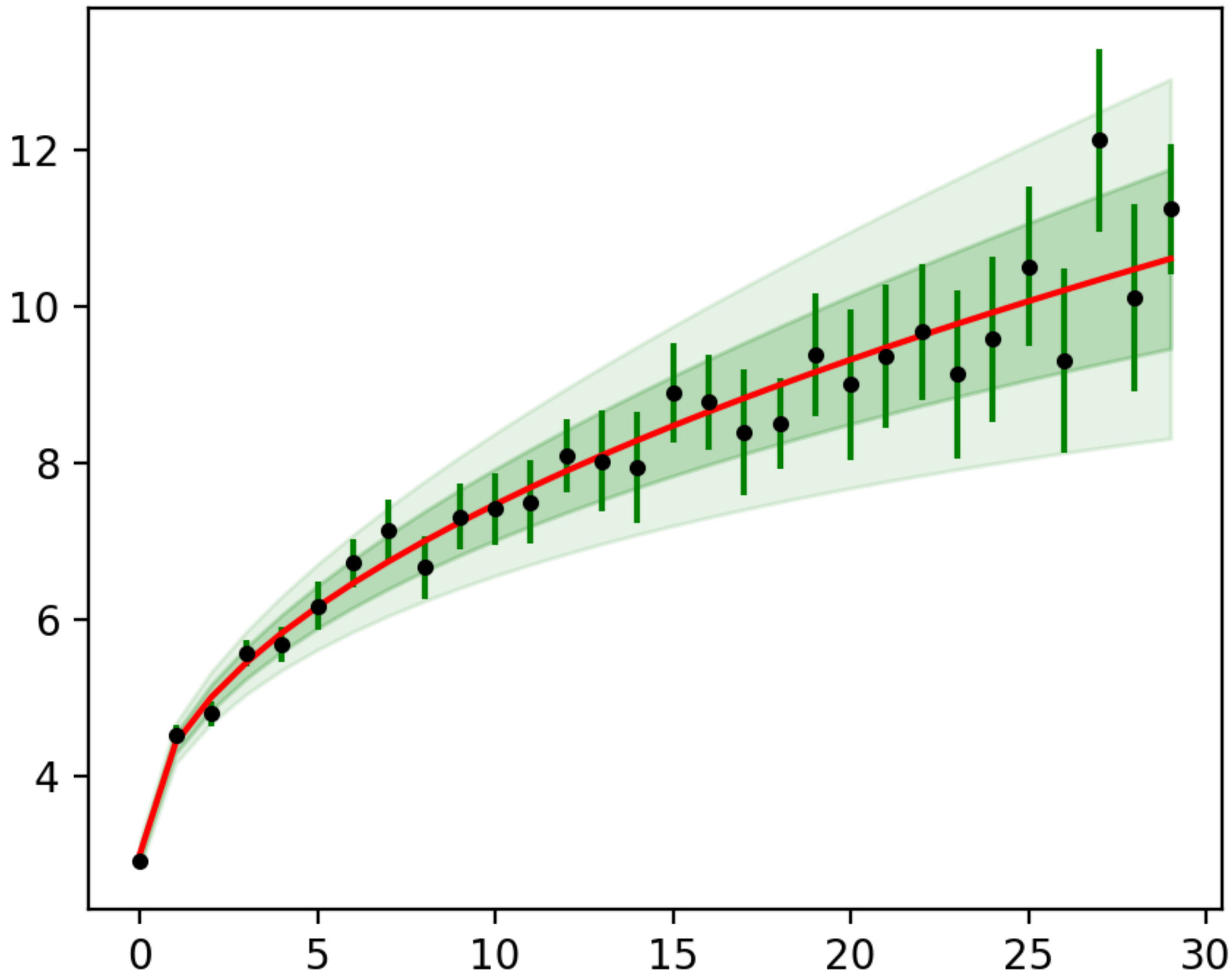

ax.errorbar(x, a, yerr= b,
            color='black', fmt='.k',
            ecolor = 'green')
```

Error Bars

- About 2/3 of all values should be within the true value
  - Display the sample mean and the true population mean
  - Draw upper and lower limits at σ and 2σ in green

Error Bars

```
ax.plot(x, np.sqrt(2*x)+3, 'r-')
ax.fill_between(x,
                np.sqrt(2*x)+3+(0.5+.2*x)/np.sqrt(30),
                np.sqrt(2*x)+3-(0.5+.2*x)/np.sqrt(30),
                color = 'green',
                alpha= 0.2)
ax.fill_between(x,
                np.sqrt(2*x)+3+2*(0.5+.2*x)/np.sqrt(30),
                np.sqrt(2*x)+3-2*(0.5+.2*x)/np.sqrt(30),
                color = 'green',
                alpha= 0.1)
plt.show()
```


12
10
8
6
4
0
5
10
15
20
25
30

Multiple Subplots

- Can use fig.add_axes( ) to manually create subplots.
  - Create a figure
    - `fig = plt.figure()`
  - Add axes:
    - First argument is a list with x-offset, y-offset, x-height, y-height out of 0 … 1
      - `ax1 = fig.add_axes([0.1,0.1,0.88,0.88],` …
      - Remember to leave space for ticks

Multiple Subplots

- We can then add limits, ticks and labels

```
ax1 = fig.add_axes([0.1,0.1,0.88,0.88],
                   xlim = (0, np.pi),
                   ylim = (-1.1, 1.1),
                   xticks=[0, np.pi/2, np.pi],
                   xticklabels=['0', 'pi/2', 'pi'])
```

- This is an axes with origin at 0.1, 0.1 going to 0.98, 0.98

Multiple Subplots

- Can add another axes in the right upper corner

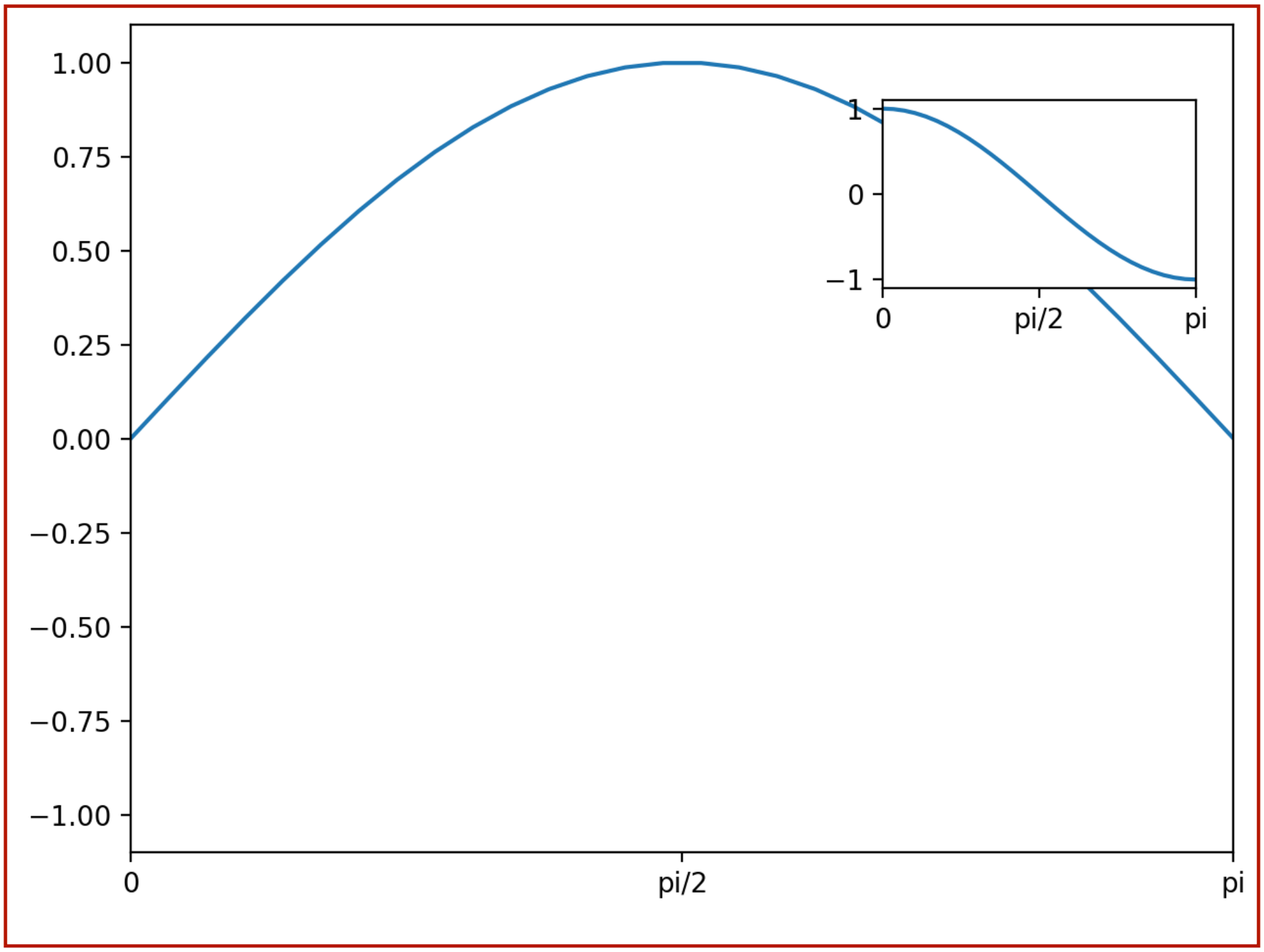
```
ax2 = fig.add_axes([0.7, 0.7, 0.25, 0.2],
                   xlim = (0, np.pi),
                   ylim = (-1.1, 1.1),
                   xticks=[0, np.pi/2, np.pi],
                   xticklabels=['0', 'pi/2', 'pi'])
```

Multiple Subplots

- Finally, plot random (trig) functions

```
x = np.linspace(0, np.pi, 30)
ax1.plot(x, np.sin(x))
ax2.plot(x, np.cos(x))
plt.show()
```

Multiple Subplots



Multiple Subplots

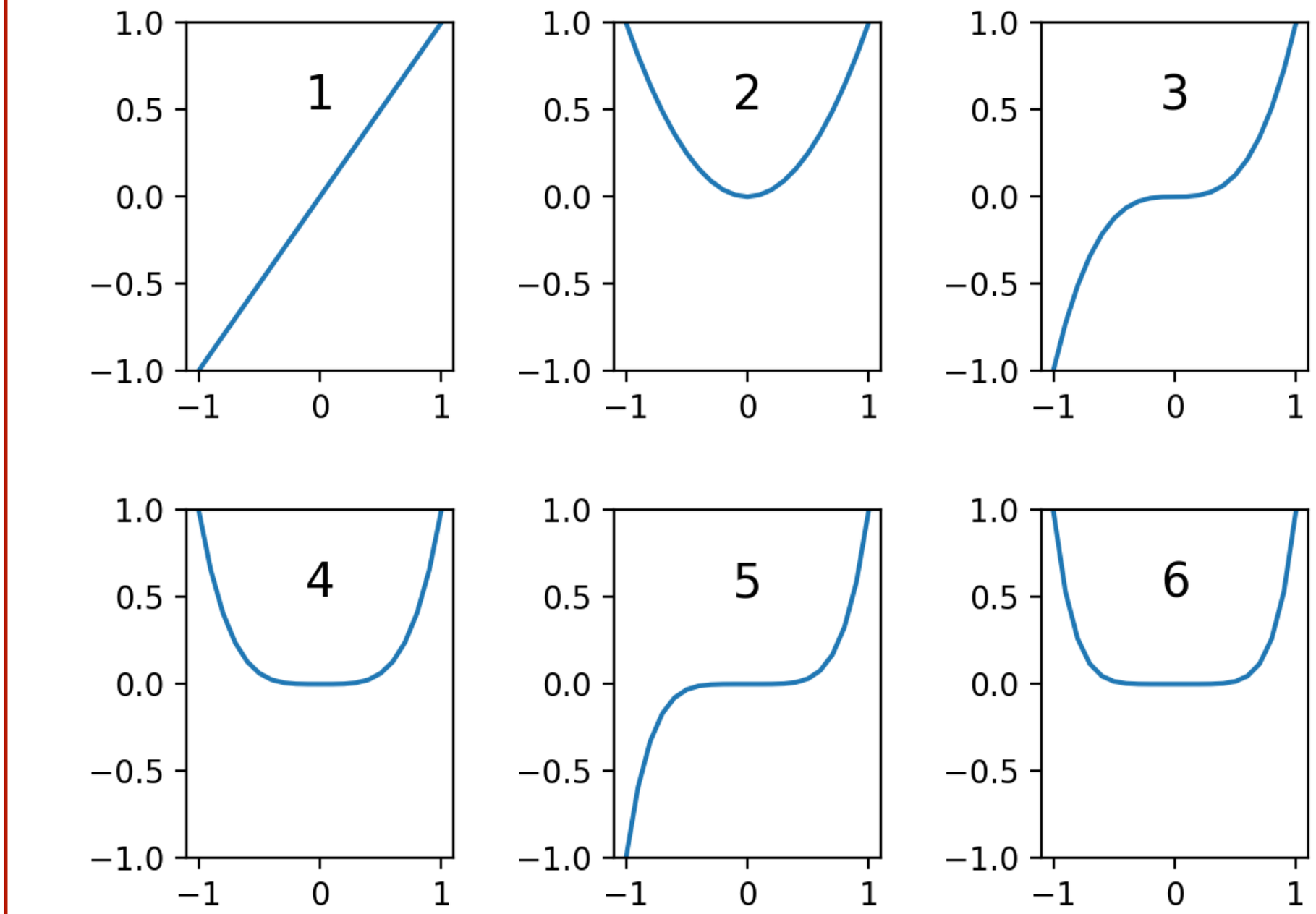
- Can create figure with a subplot
  - `fig = plt.figure()`
- Adjust layout
  - hspace - space between rows of subplots (height)
  - wspace - space between columns of subplots (width)
    - ```
      fig.subplots_adjust(hspace=0.4,
                          wspace = 0.6)
      ```
      ```

Multiple Subplots

- Create 6 axes in two rows and three columns
  - ```
    for i in range(1, 7):
        ax = fig.add_subplot(2,3,i, ylim = (-1,1))
    ```
- Write an interior text
  - The position is relative to the grid in the subplot
    - ```
      ax.text(0, 0.5, str(i),
              fontsize = 15,
              ha='center')
      ```
  - Then plot `x**i`

```
x = np.linspace(-1,1,21)
ax.plot(x, np.power(x,i))
```

Multiple Subplots



Multiple Subplots

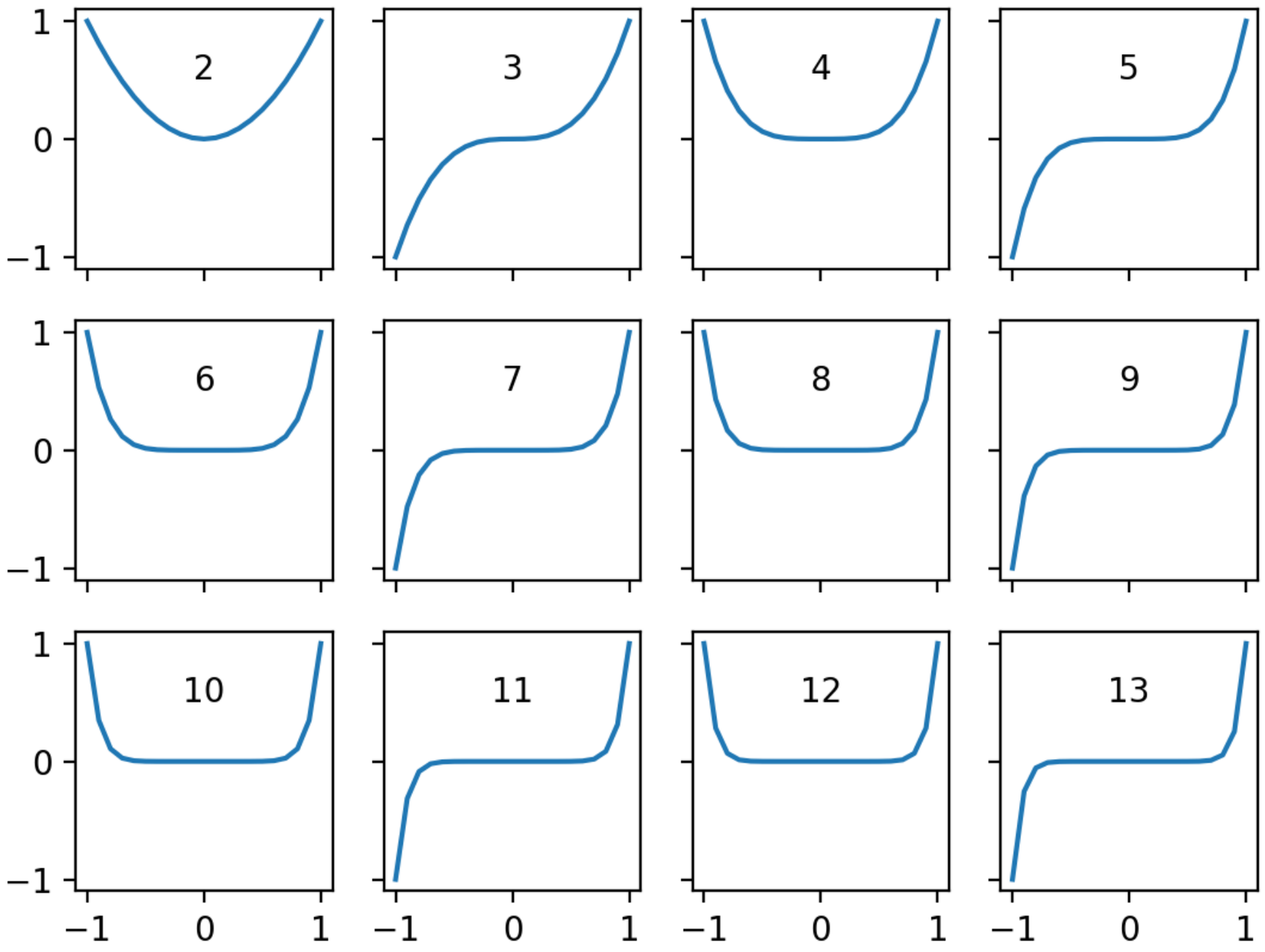
- Can use subplots (with a plural-s) to create a number of plots
  - Can make share coordinate layout
  - ```
    fig, axes = plt.subplots(3,4,
                             sharex='col',
                             sharey='row')
    ```
    ```

Multiple Subplots

- The axes is a 3 by 4 matrix
  - Notice the way we are accessing them by a single bracket

```
for i in range(3):
    for j in range(4):
        degree = 4*i+j+2
        axes[i,j].text(0, 0.5, str(degree), ha='center')
        axes[i,j].plot(x, np.power(x,degree))
```

Multiple Subplots



Multiple Subplots

- For more complicates arrangements, look at plt.GridSpec

Controlling Ticks

- Figure: bounding box, contains
  - Axes objects, which contain
    - A variety of other objects representing plot contents
      - Such as xaxis, yaxis
        - contains properties of lines, ticks, and labels
        - Has major and minor locator object
        - Has major and minor formatter object

Controlling Ticks

- No ticks at all:
  - `ax = plt.axes(yscale='log')`
    `ax.xaxis.set_major_locator(plt.NullLocator())`

Controlling Ticks

- Example: Handwriting recognition set
  - In sklear.datasets

```
from sklearn.datasets import load_digits
```

  - Create a figure and pack it densely

```
fig = plt.figure(figsize=(6,6)) #in inches
fig.subplots_adjust(left=0, right=1, bottom=0,
                    top=1, hspace=0.05,
                    wspace = 0.05)
```

Controlling Ticks

- Create 64 axes

```
for i in range(64):
    ax = fig.add_subplot(8,8, i+1)
```

- No ticks

```
    ax.xaxis.set_major_locator(plt.NullLocator())
    ax.yaxis.set_major_locator(plt.NullLocator())
```

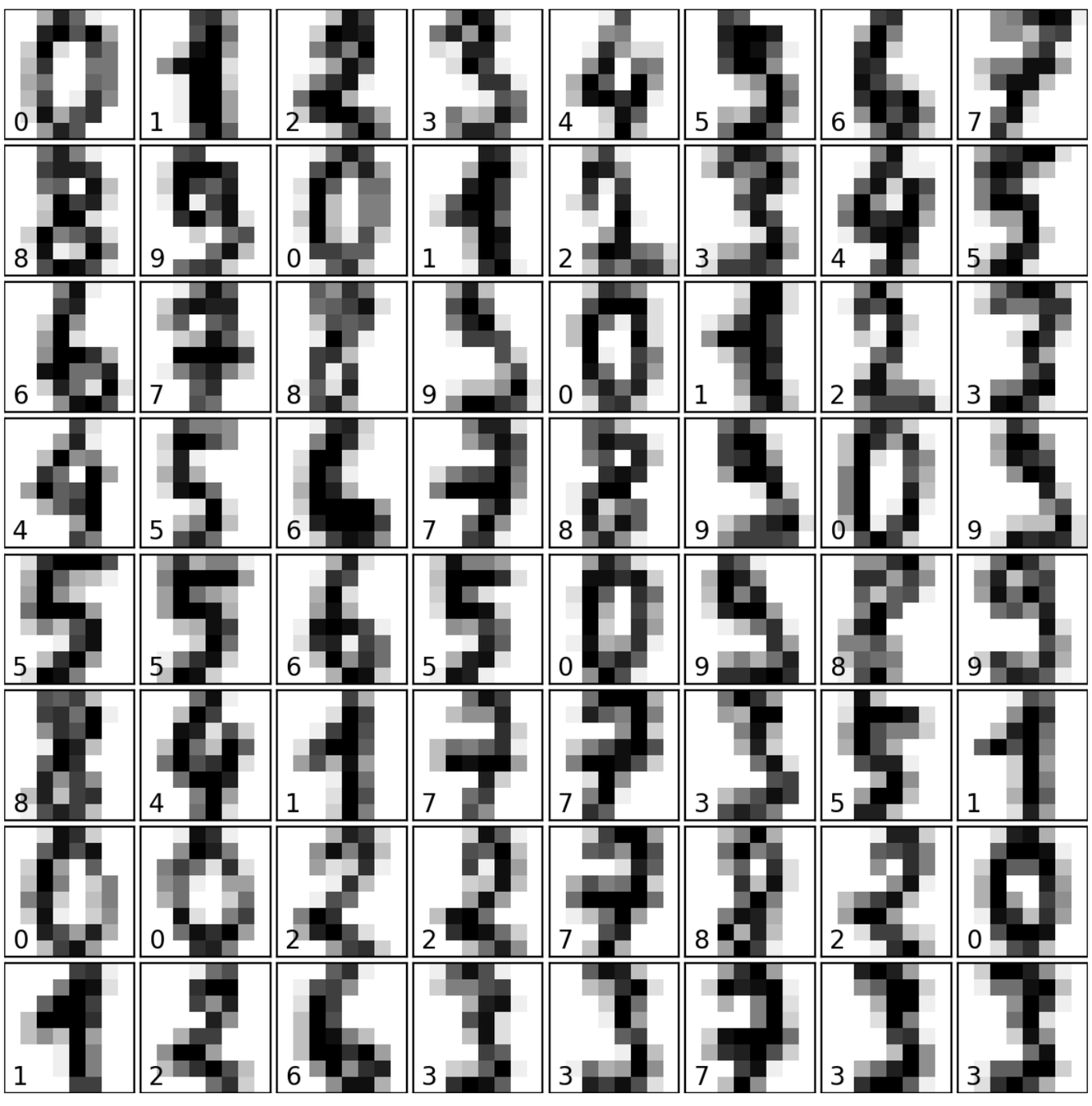
- Show images

```
    ax.imshow(digits.images[i],
        cmap=plt.cm.binary,
        interpolation='nearest')
```

- Show target text

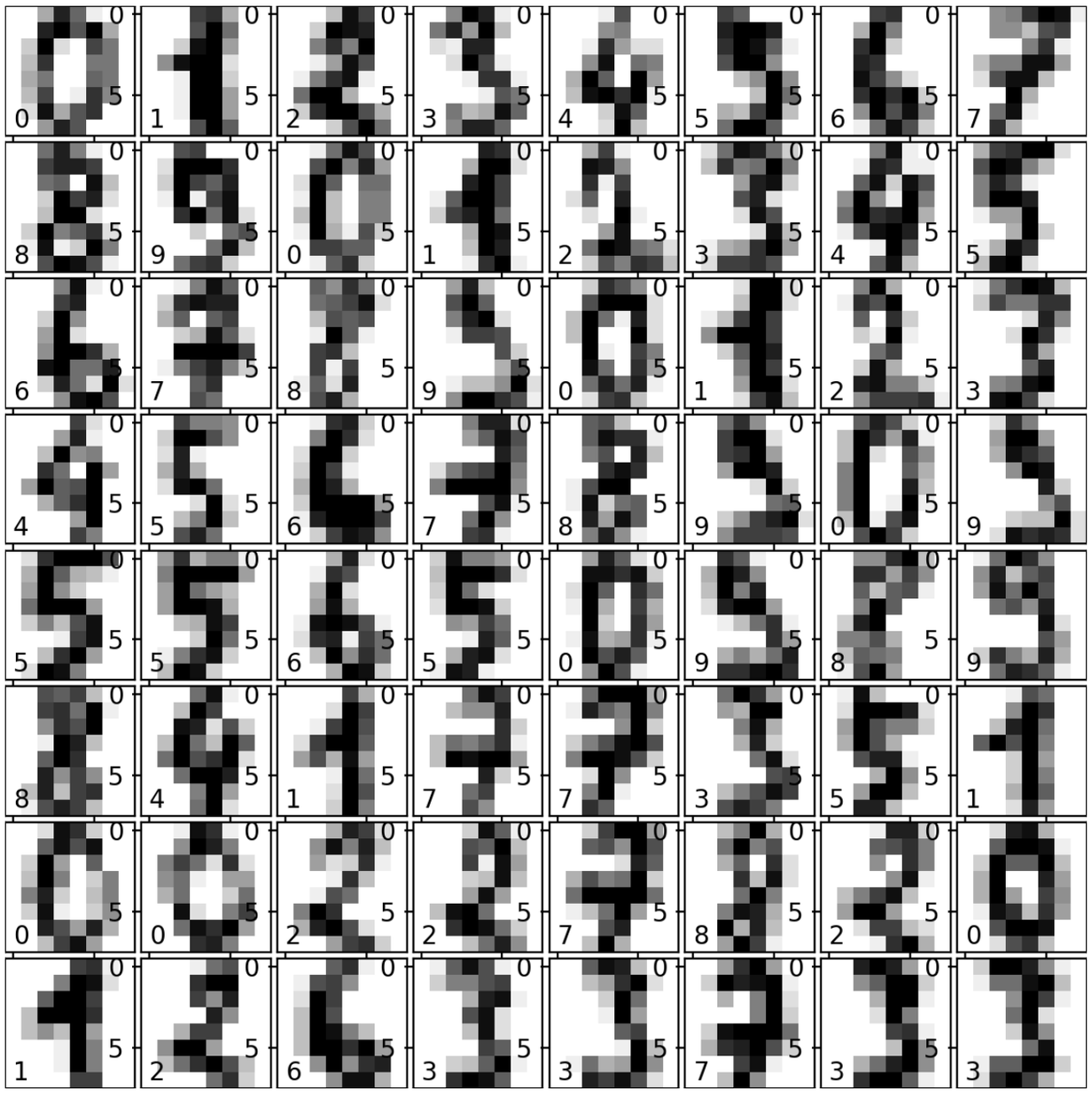
```
    ax.text(0,7, str(digits.target[i]))
```

Controlling Ticks



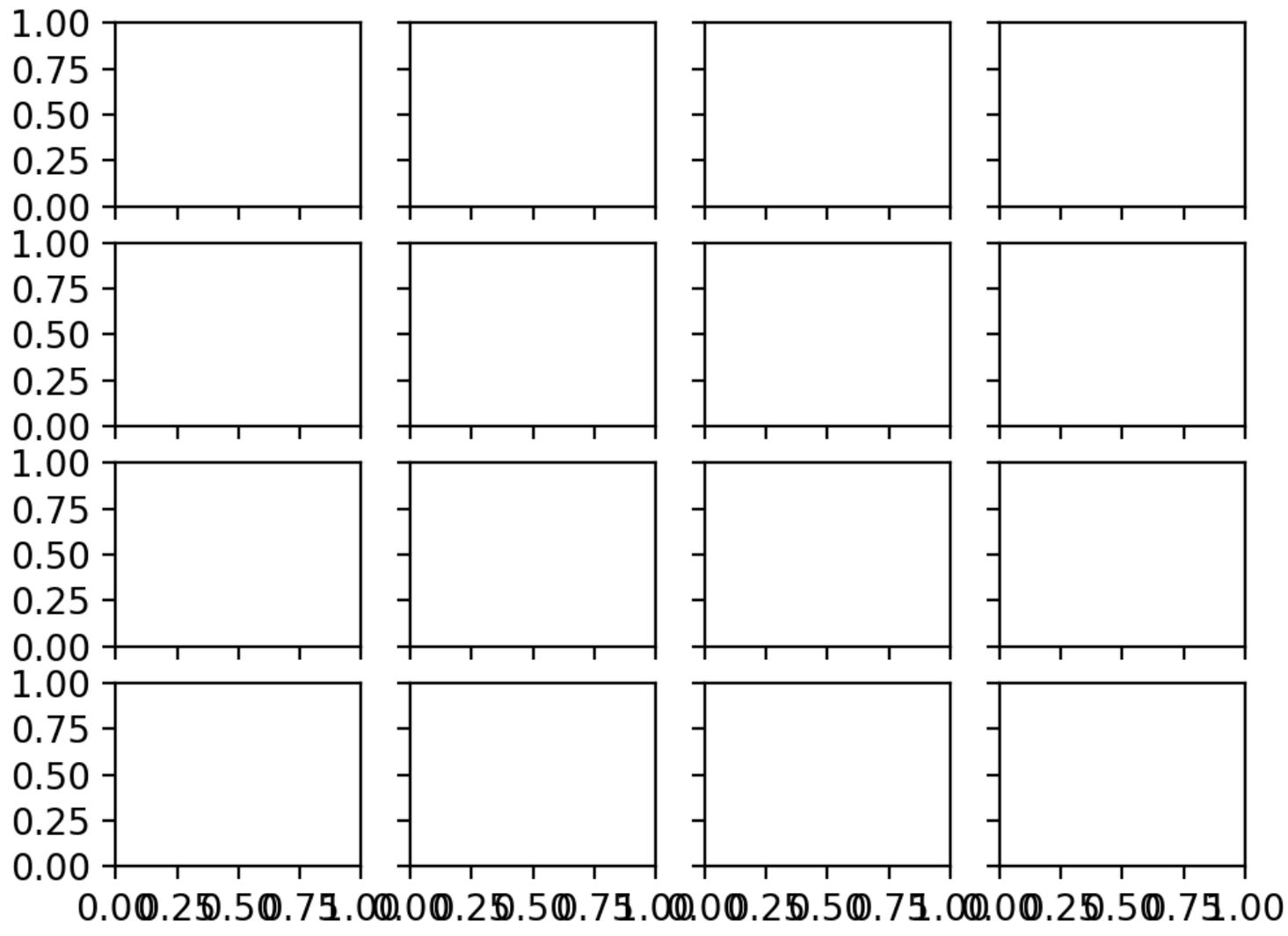
Controlling Ticks

- Without suppressing ticks



Controlling Ticks

- Sometimes, ticks can be too close together



Controlling Ticks

- Use the locator to determine the number of ticks

```
fig, axes = plt.subplots(4,4, sharex=True, sharey=True)
for ax in axes.flat:
    ax.xaxis.set_major_locator(plt.MaxNLocator(4))
    ax.yaxis.set_major_locator(plt.MaxNLocator(4))
```

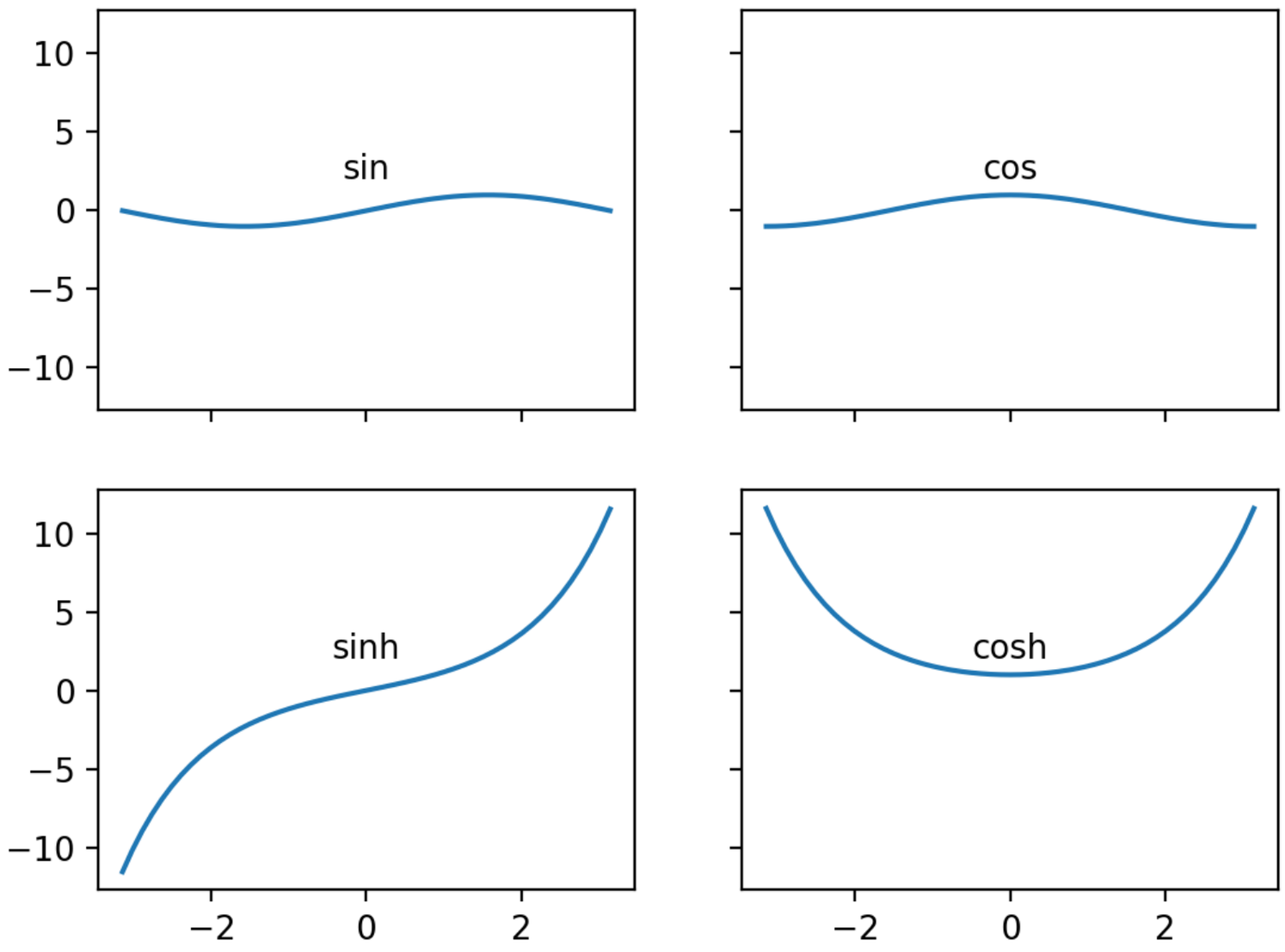
Controlling Ticks

- Sometimes, need more control

```
x= np.linspace(-np.pi, np.pi, 51)
fig, axes = plt.subplots(2,2, sharex=True, sharey=True)
axes[0,0].plot(x, np.sin(x))
axes[0,1].plot(x, np.cos(x))
axes[1,0].plot(x, np.sinh(x))
axes[1,1].plot(x, np.cosh(x))
axes[0,0].text(0,2, 'sin', ha='center')
axes[0,1].text(0,2, 'cos', ha='center')
axes[1,0].text(0,2, 'sinh', ha='center')
axes[1,1].text(0,2, 'cosh', ha='center')
```

Controlling Ticks

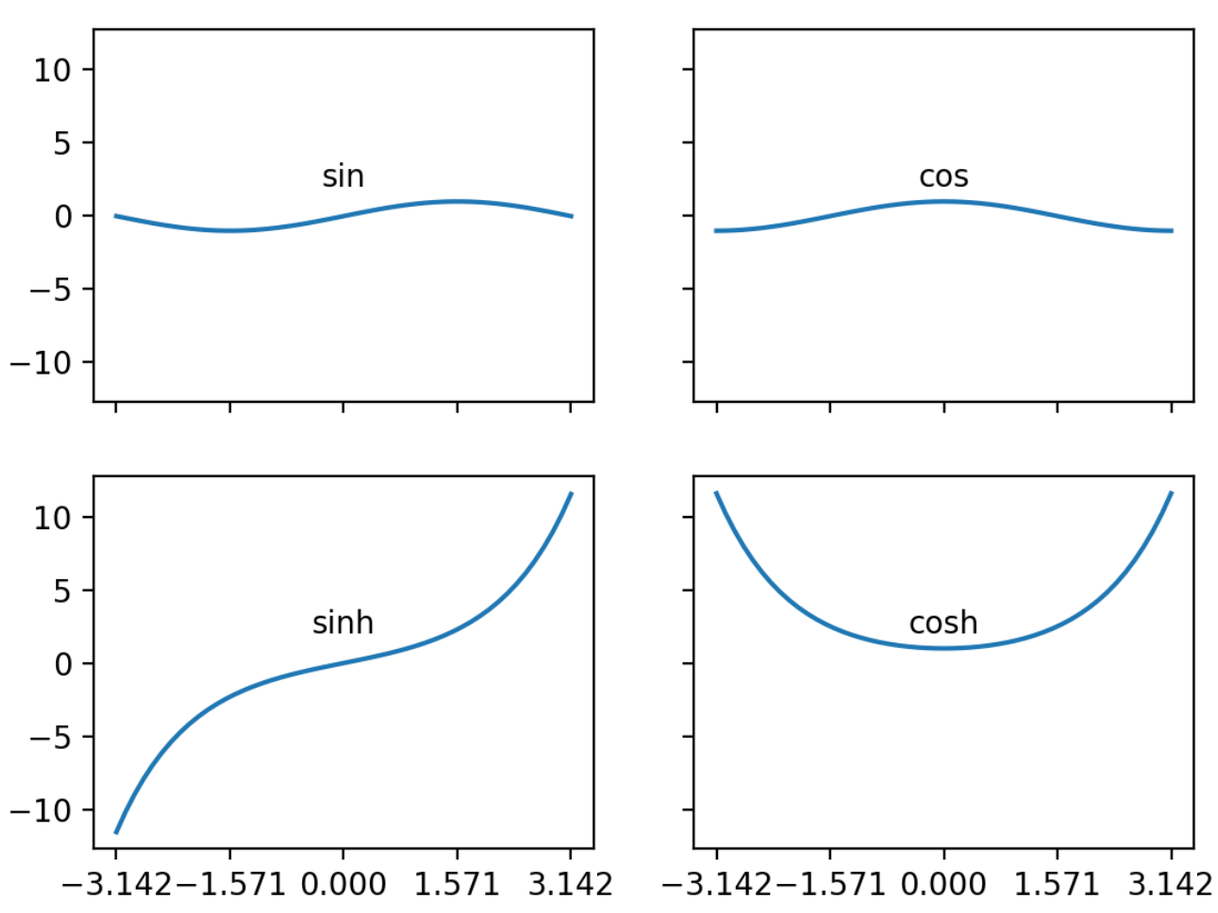
- More natural to have the x-axis use multiple of π



Controlling Ticks

- Set the multiplelocator object

```
axes[0,0].xaxis.set_major_locator(
                plt.MultipleLocator(np.pi/2))
```



Controlling Ticks

- The ticks are fine, but need to write in terms of multiples of π
- Create our own format function using TeX

```
def my_format_func(value, tick_number):
    nn = int(np.round(2*value / np.pi))
    if nn == 0:
        return '0'
    elif nn == 1:
        return r'$\pi/2$'
    elif nn%2:
        return r'${0}\pi/2$'.format(nn)
    else:
        return r'${0}\pi$'.format(nn//2)
```

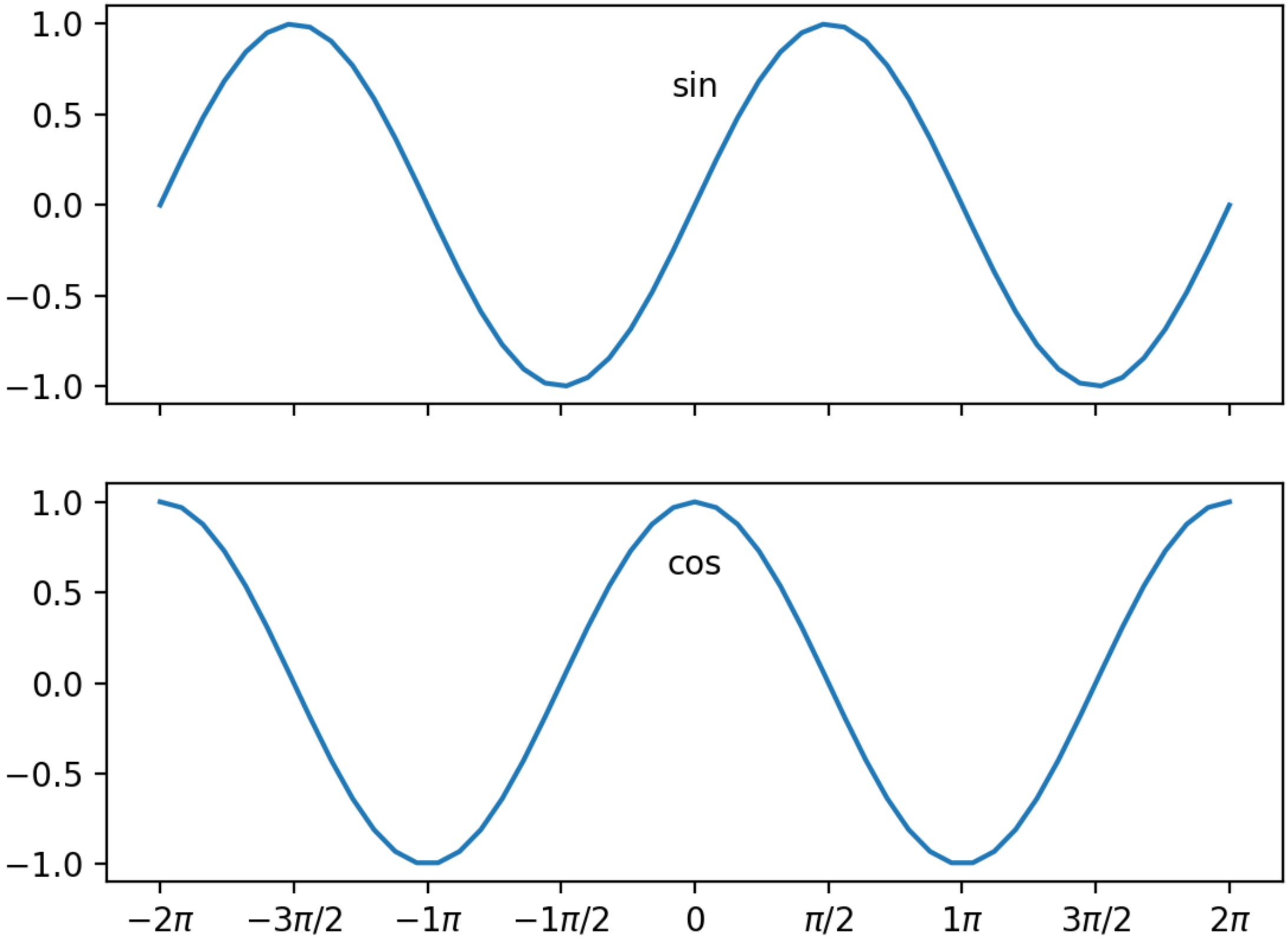
Controlling Ticks

- Now it works:

```
x= np.linspace(-2*np.pi, 2*np.pi, 51)
fig, axes = plt.subplots(2,1, sharex=True, sharey=True)
axes[0].plot(x, np.sin(x))
axes[1].plot(x, np.cos(x))

axes[0].text(0,0.6, 'sin', ha='center')
axes[1].text(0,0.6, 'cos', ha='center')

axes[0].xaxis.set_major_locator(plt.MultipleLocator
     (np.pi/2))
axes[0].xaxis.set_major_formatter(plt.FuncFormatter
    (my_format_func))
```


1.0
0.5
0.0
−0.5
−1.0
sin
cos
−2π
−3π/2
−1π
−1π/2
0
π/2
1π
3π/2
2π

Seaborn

- Matplotlib is based on an old version of matlab
  - Defaults are not all that pretty
    - Calculate random walk

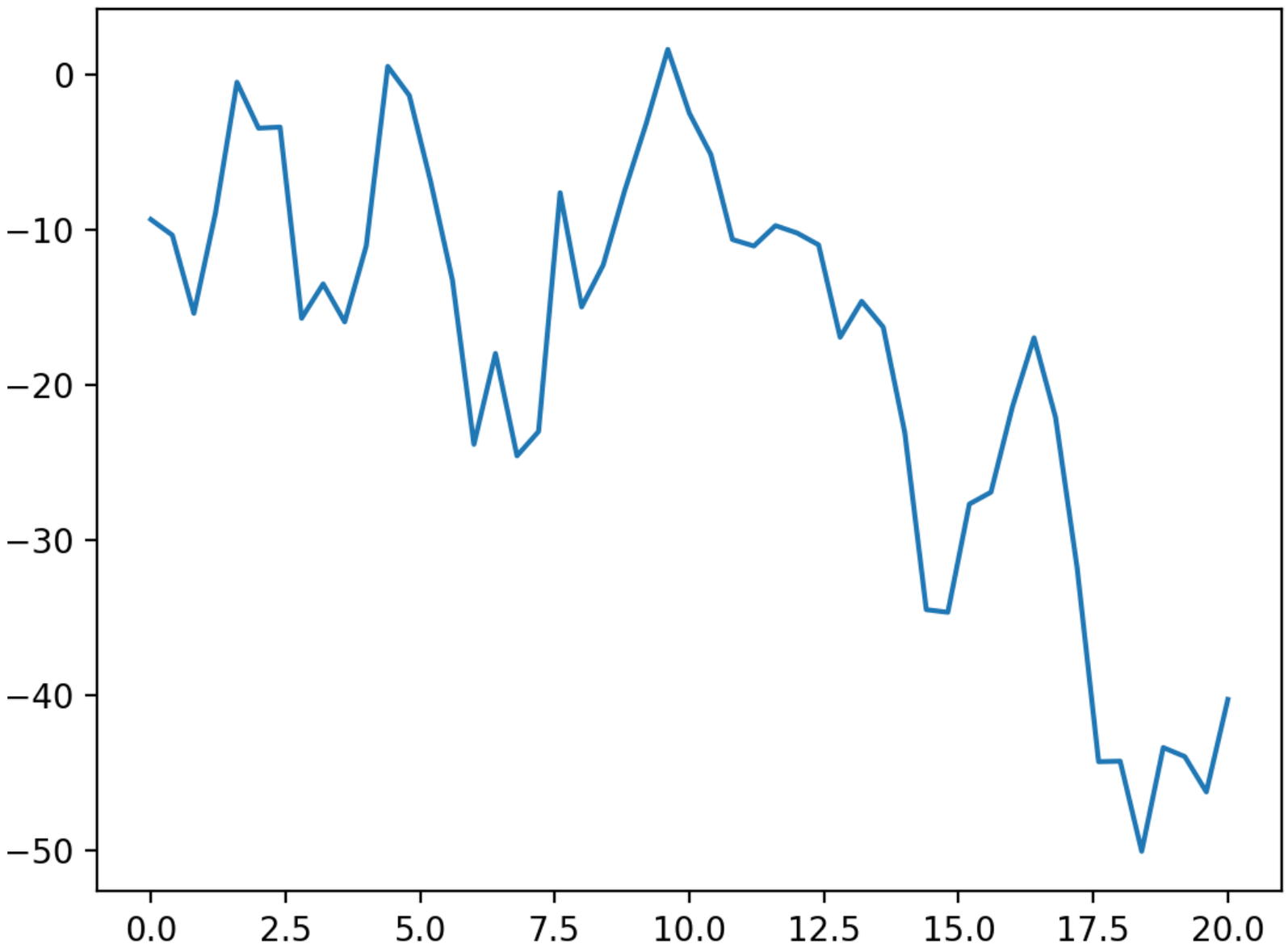
```
x = np.linspace(0,20,51)
y = np.cumsum(np.random.normal(0, 5,51))

plt.plot(x,y)

plt.show()
```

Seaborn

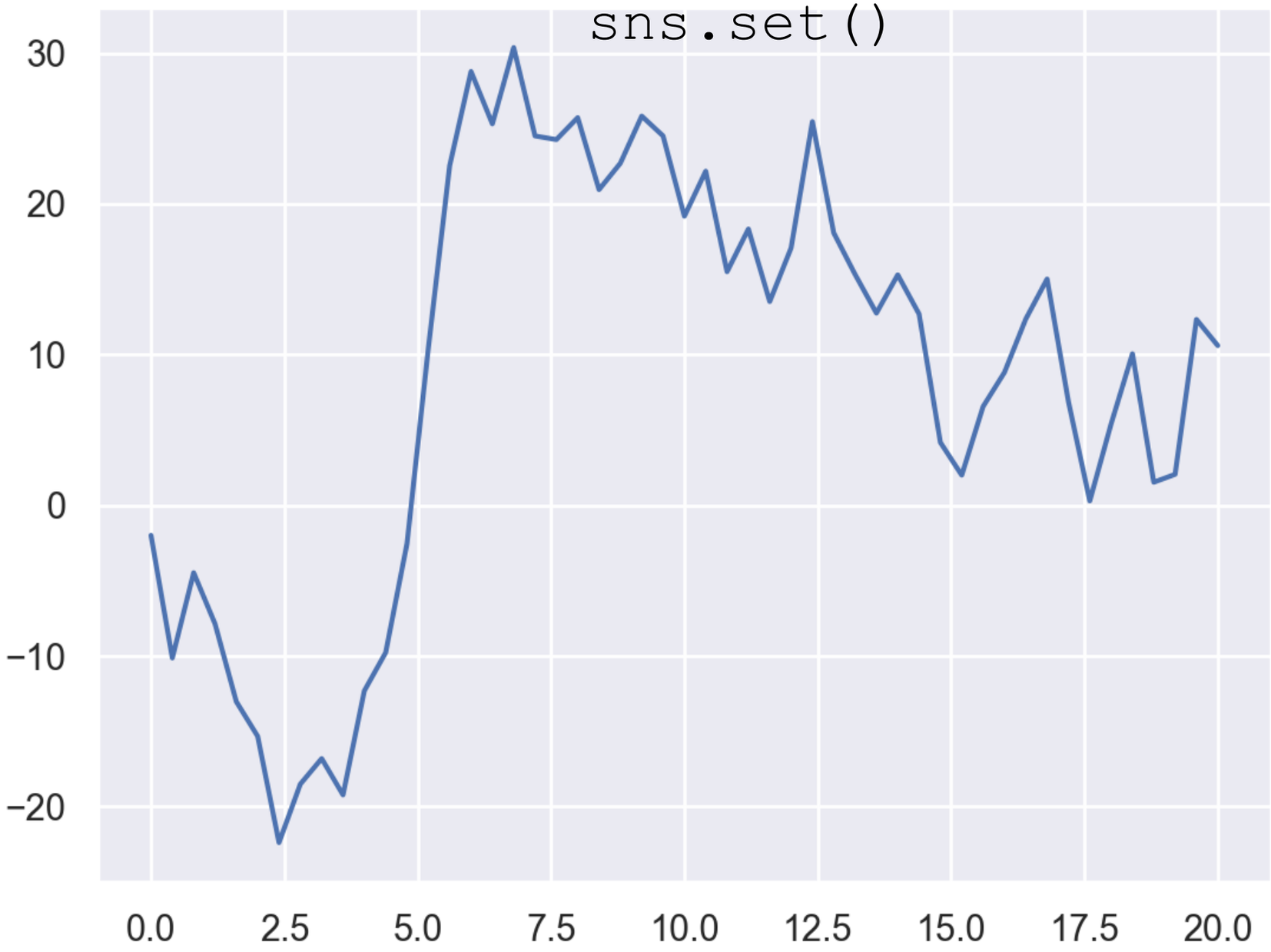
- Without seaborn



Seaborn

- With Seaborn

```
import seaborn as sns
sns.set()
```



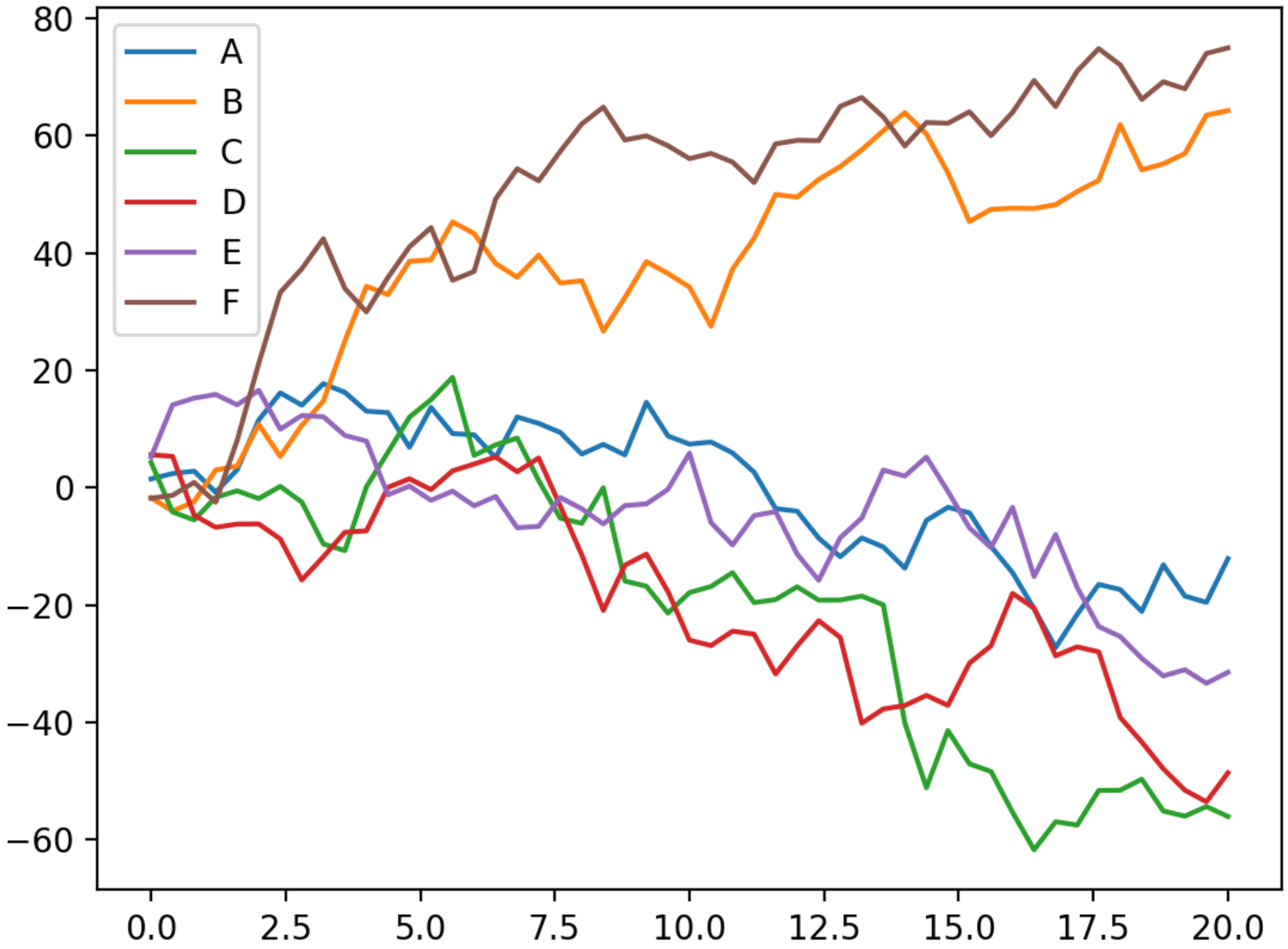
Seaborn

- The difference extends to labeling

```
sns.set()
x = np.linspace(0,20,51)
label = 'ABCDEF'
for letter in label:
    y = np.cumsum(np.random.normal(0, 5,51))
    plt.plot(x,y, label=letter)
plt.legend()
```

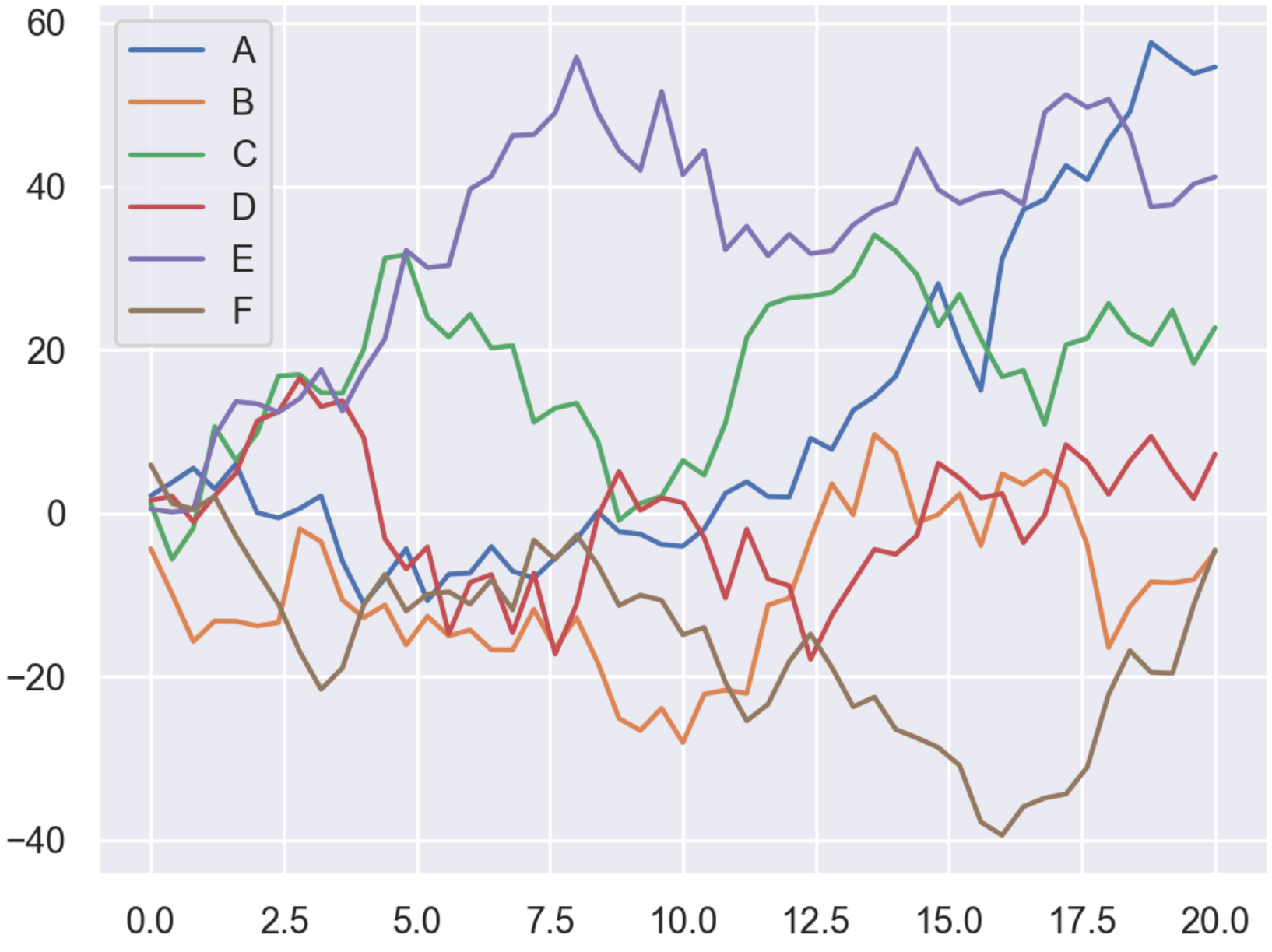
Seaborn

- without Seaborn



Seaborn

- With Seaborn



Seaborn

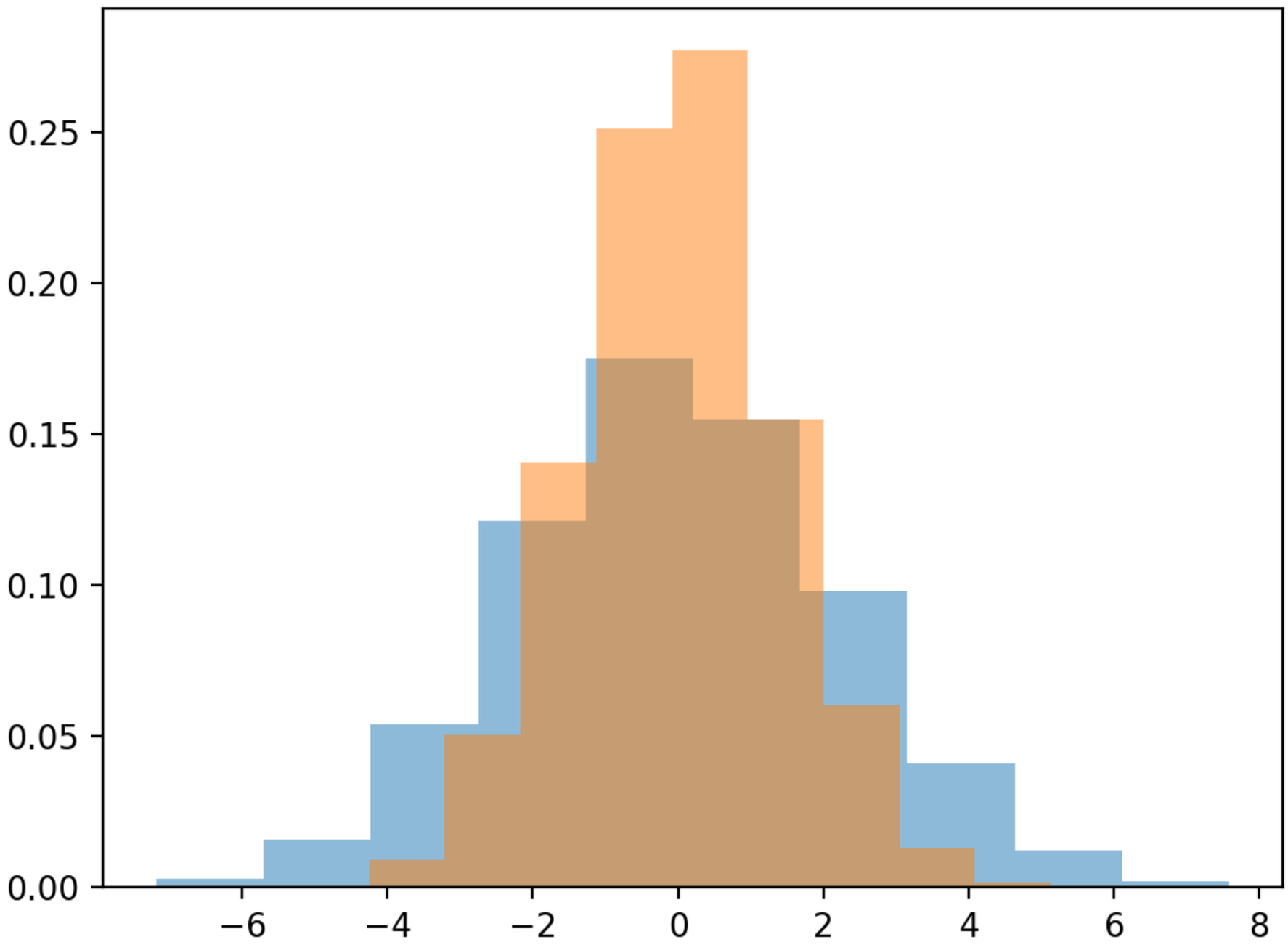
- Seaborn provides many statistical visualization tools
  - Example: Generate a multinomial distribution with covariance matrix $\begin{pmatrix} 5 & 2 \\ 2 & 2 \end{pmatrix}$ around the origin
    - ```
      data=np.random.multivariate_normal(
       [0,0],
       [[5,2],[2,2]],
       size = 5000)
      ```
      ```

Seaborn

- With plt, easy to generate histogram

```
df = pd.DataFrame(data, columns=['x', 'y'])
for col in ['x', 'y']:
    plt.hist(df[col], normed=True, alpha = 0.5)
```

Seaborn

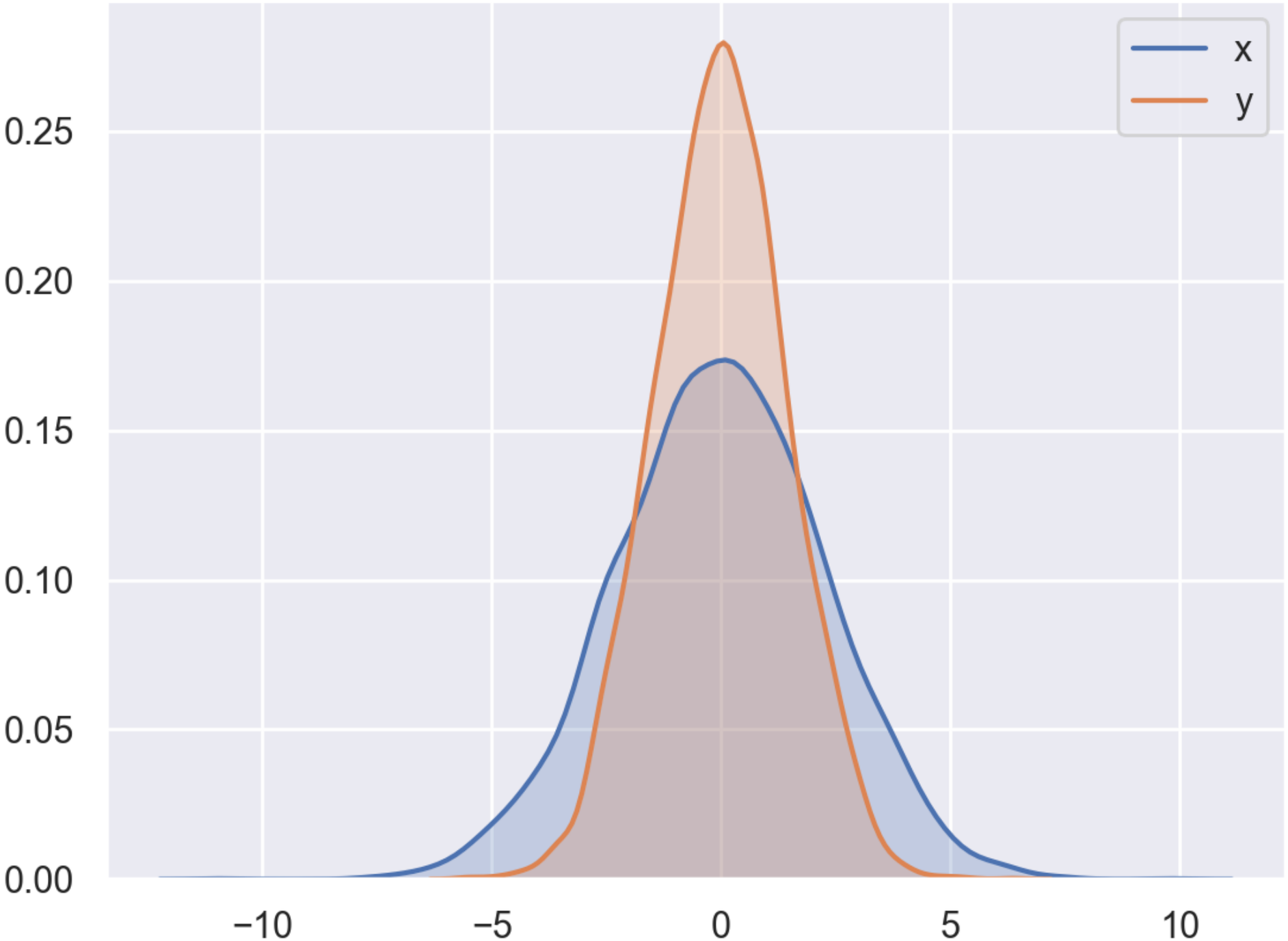


Seaborn

- With Seaborn, we can use a "kernel density estimation"

```
for col in ['x', 'y']:
    sns.kdeplot(df[col], shade=True)
```

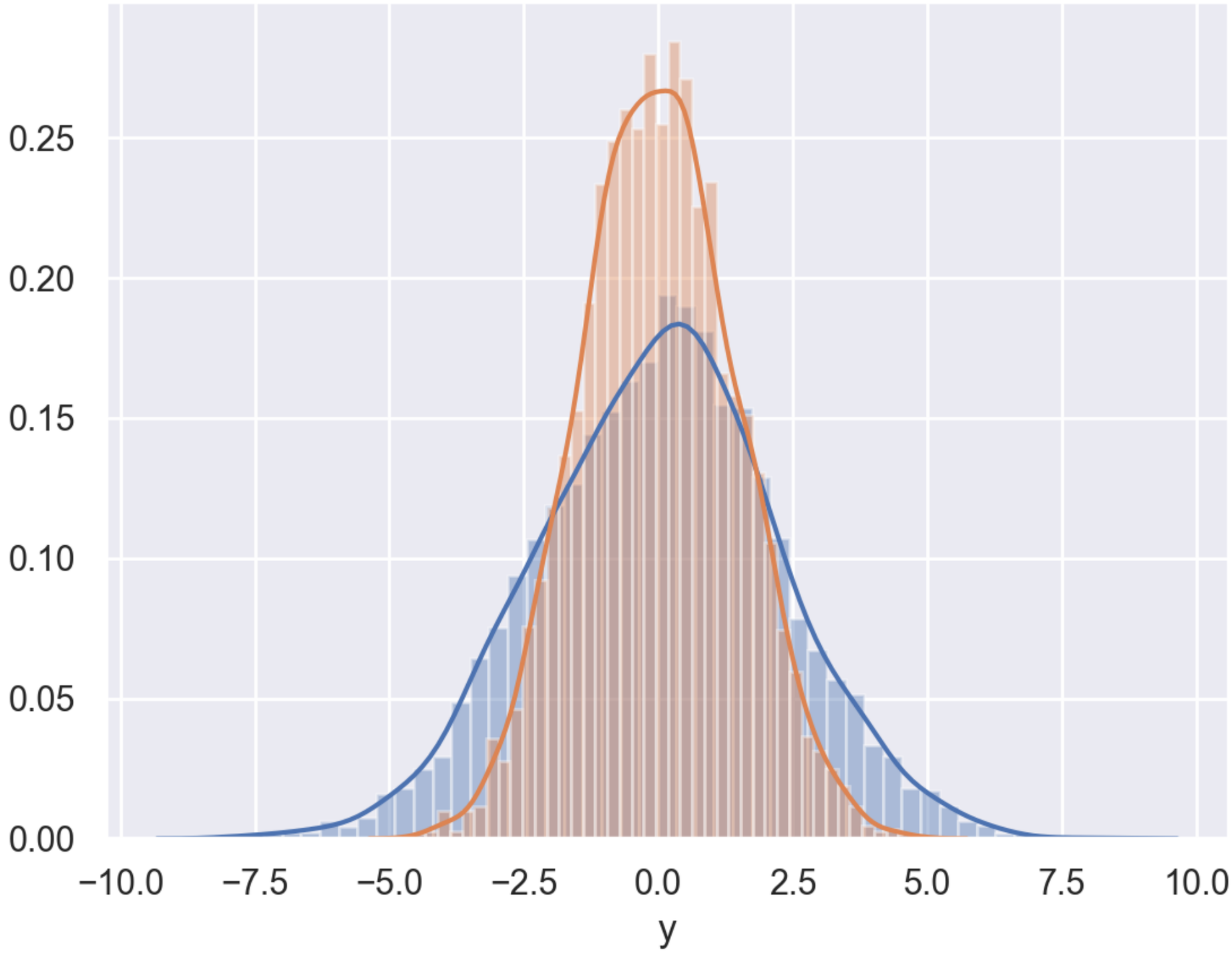
Seaborn



Seaborn

- Can combine with distplot
- ```
  for col in ['x', 'y']:
      sns.distplot(df[col])
  ```
  ```

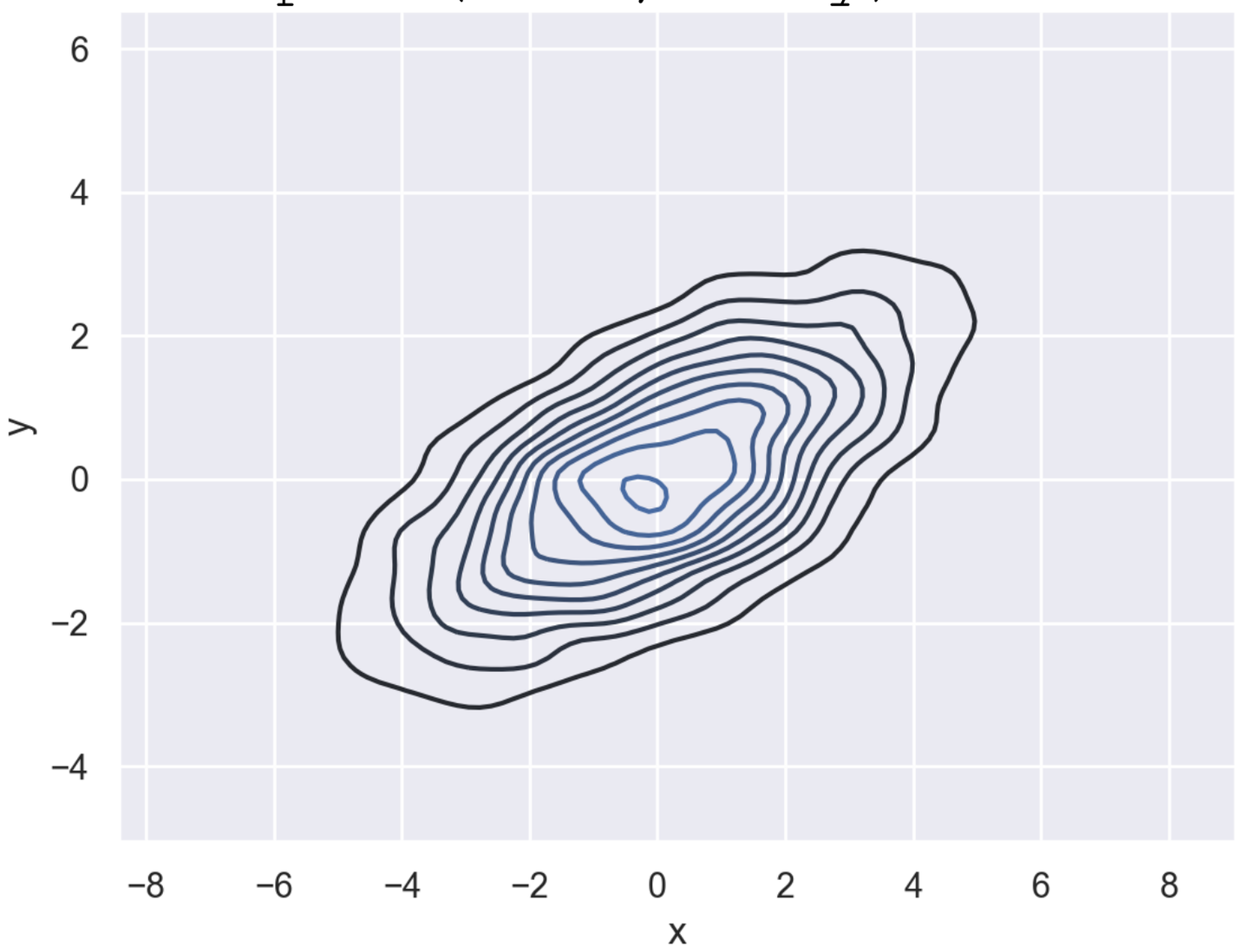
Seaborn



Seaborn

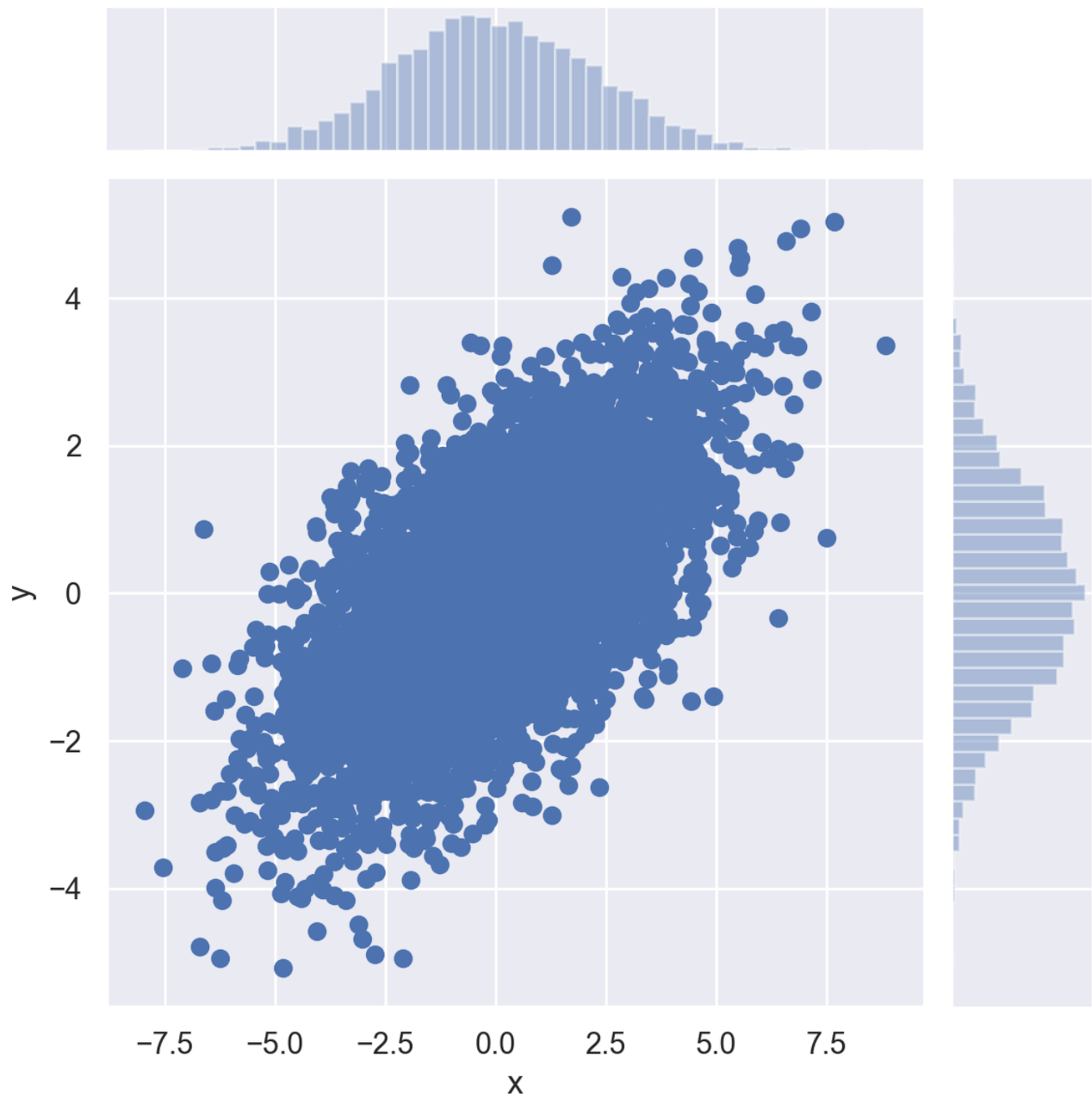
- Can also use a two dimensional kernel density estimation plot

```
sns.kdeplot(df.x, df.y)
```



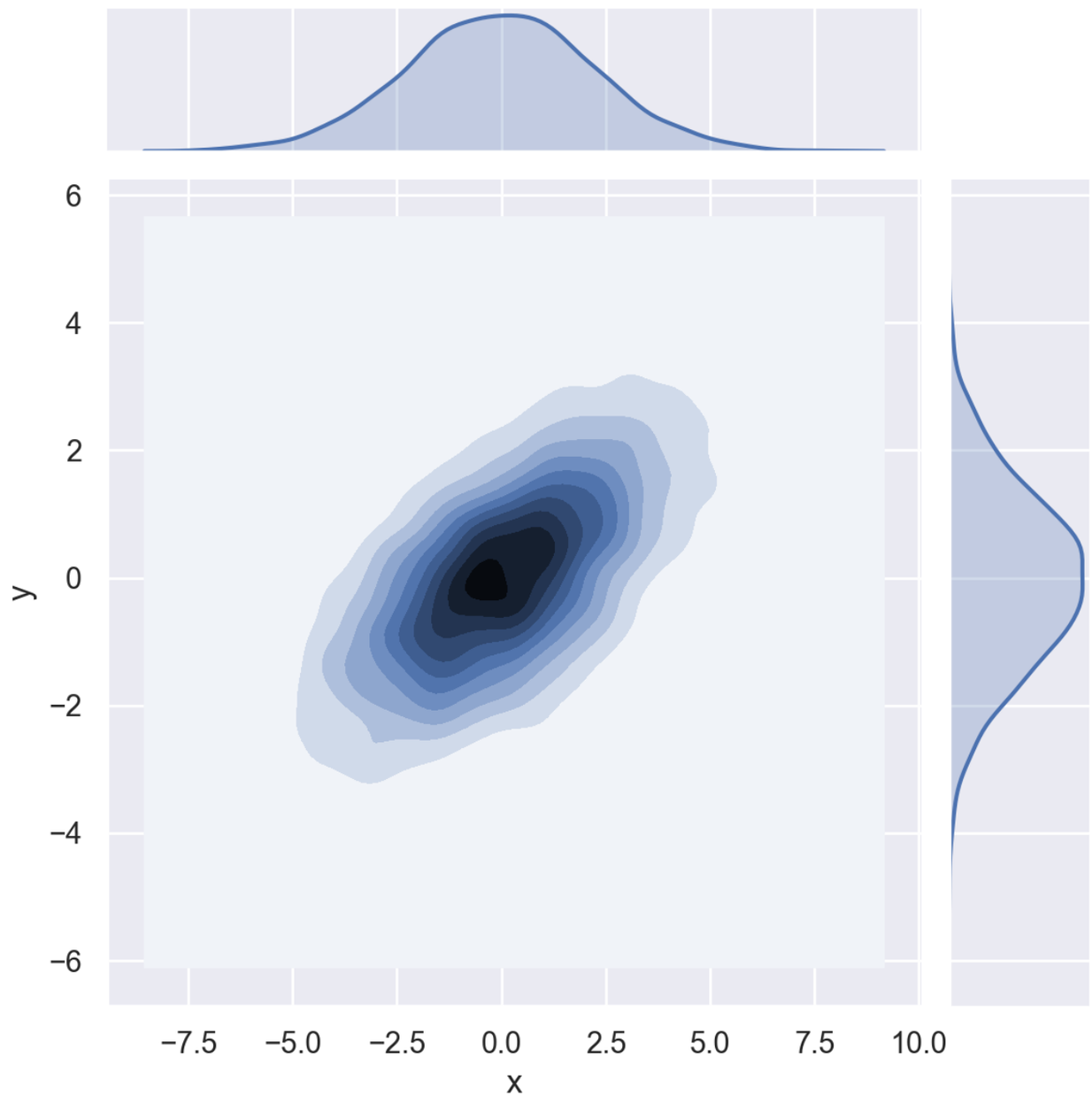
Seaborn

- Or use sns.jointplot



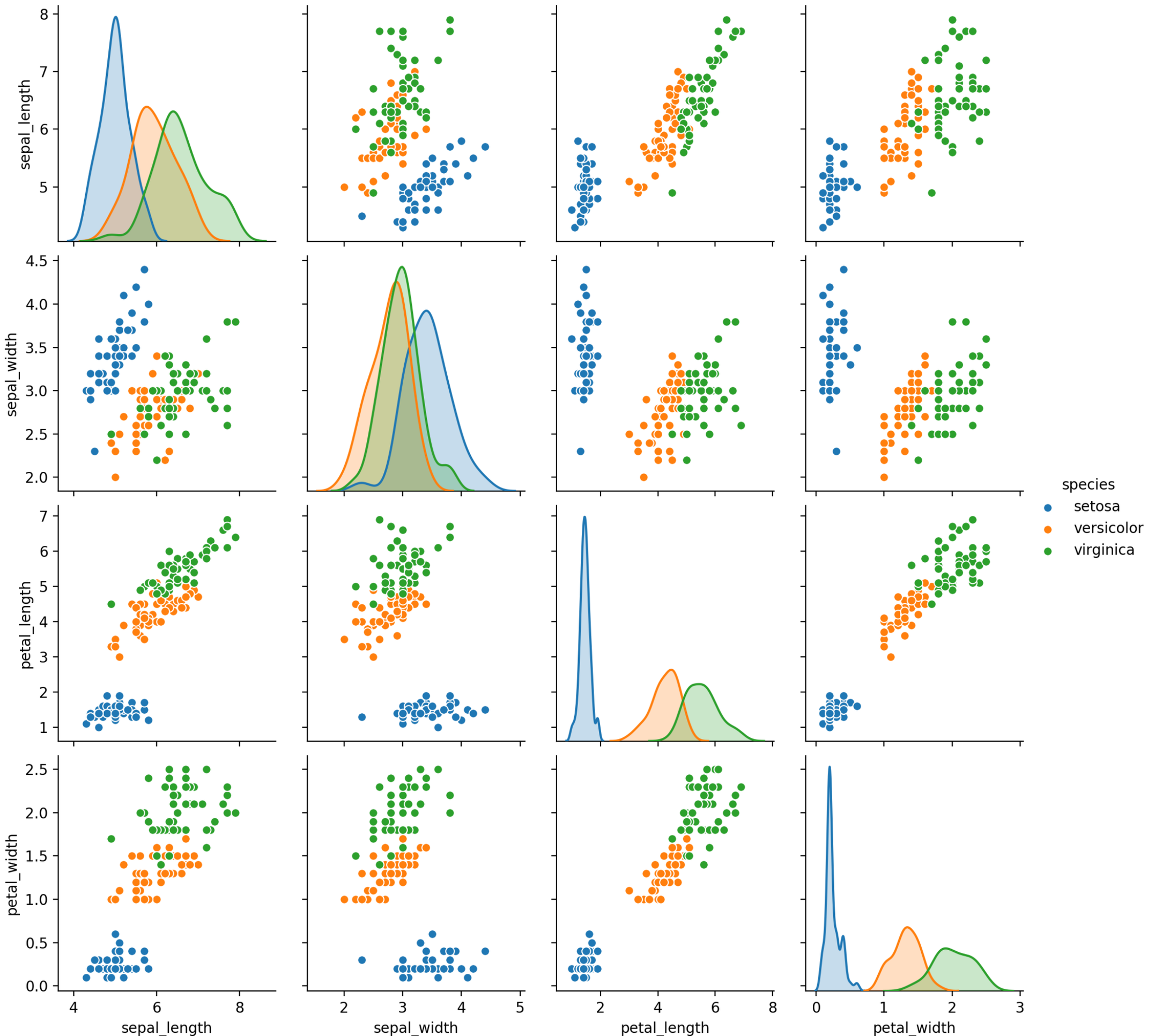
Seaborn

- `sns.jointplot(df.x, df.y, kind='kde')`



Seaborn

- Seaborn's jointplot even works for higher dimensions
  - When it is called `pairplot`
  - ```
    iris = sns.load_dataset('iris')
    sns.pairplot(iris, hue='species',height=2.5)
    ```
    ```

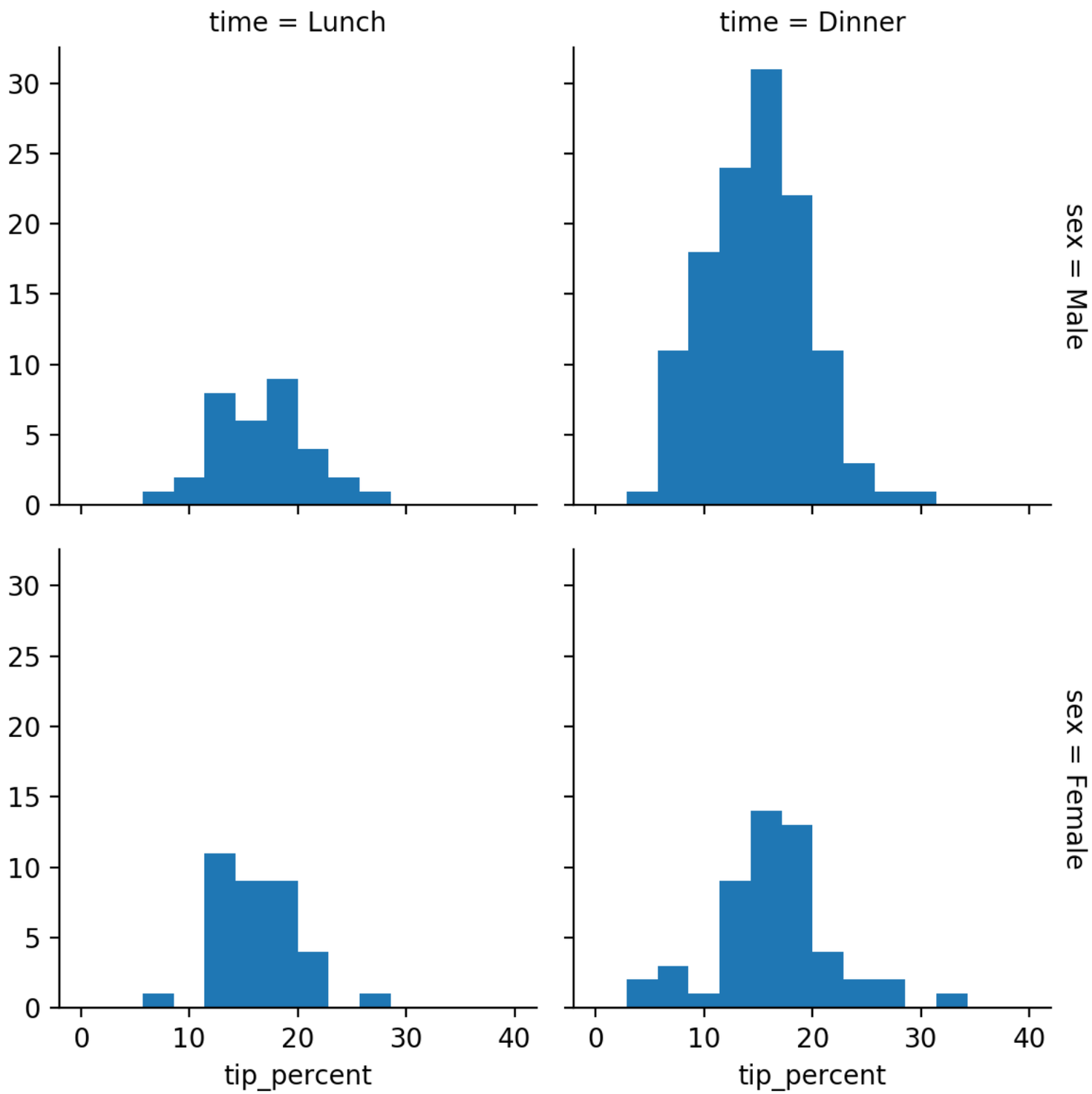

sepal_length
sepal_width
petal_length
petal_width
species
setosa
versicolor
virginica

Seaborn

- Seaborn allows us to show various factors

```
tips = sns.load_dataset('tips')
tips['tip_percent'] = 100*tips.tip/tips.total_bill
grid = sns.FacetGrid(tips,
                     row='sex',
                     col='time',
                     margin_titles=True)
grid.map(plt.hist, 'tip_percent',
bins=np.linspace(0,40,15))
```

Seaborn


time = Lunch
time = Dinner
sex = Male
sex = Female
30
25
20
15
10
5
0
0
10
20
30
40
tip_percent

Seaborn

- Can use category plot to show dependencies

```
tips['tip_percent'] = 100*tips.tip/tips.total_bill
g = sns.catplot('day', 'total_bill', 'sex', data=tips,
kind='box')
```

Seaborn