Uncertainty_plotting

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1 Plotting uncertainty

In this example we will go over plotting uncertainties in various ways: + y errorbars + x errorbars + x and y errorbars (no covariance) + x and y error-ellipse (covariance)

1.1 Packages being used

- `matplotlib`: all the plotting
- `pandas`: read in the data table
- `numpy` and `scipy`: convert cov matrix to ellipse params

1.2 Relevant documentation

- `matplotlib`: https://matplotlib.org/3.1.1/api/_as_gen/matplotlib.pyplot.errorbar.html#matplotlib.pyplo

[2]:

```
import pandas
import scipy.linalg as sl
import numpy as np
from matplotlib import pyplot as plt
from matplotlib.patches import Ellipse
import mpl_style
%matplotlib inline
plt.style.use('default')
plt.style.use(mpl_style.style1)
```

Our data contains (x, y) positions with 1-σ uncertainties and covariance values:

[3]:

```
t = pandas.read_csv('data.csv')
display(t)
```

```
   ID    x    y  sy  sx   pxy
0   1  201  592  61   9 -0.84
1   2  244  401  25   4  0.31
2   3   47  583  38  11  0.64
3   4  287  402  15   7 -0.27
4   5  203  495  21   5 -0.33
5   6   58  173  15   9  0.67
6   7  202  479  27   4 -0.02
```

```
7    8  202  504  14   4 -0.05
8    9  198  510  30  11 -0.84
9   10  158  416  16   7 -0.69
10  11  165  393  14   5  0.30
11  12  201  442  25   5 -0.46
12  13  157  317  52   5 -0.03
13  14  131  311  16   6  0.50
14  15  166  400  34   6  0.73
15  16  160  337  31   5 -0.52
16  17  186  423  42   9  0.90
17  18  125  334  26   8  0.40
18  19  218  533  16   6 -0.78
19  20  146  344  22   5 -0.56
```

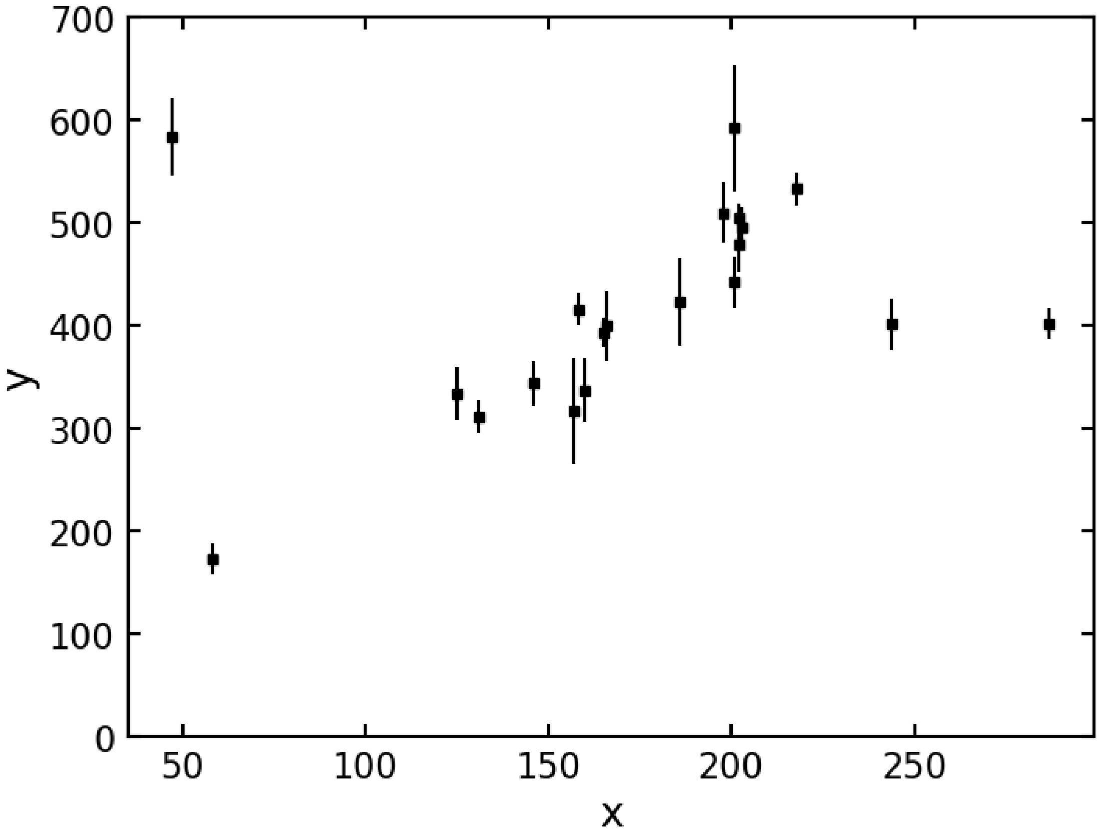
Note the full covariance matrix for each data point is: $\begin{bmatrix} \sigma_x^2 & \rho_{xy}\sigma_x\sigma_y \\ \rho_{xy}\sigma_x\sigma_y & \sigma_y^2 \end{bmatrix}$

1.3 y-uncertainties or x-uncertainties only

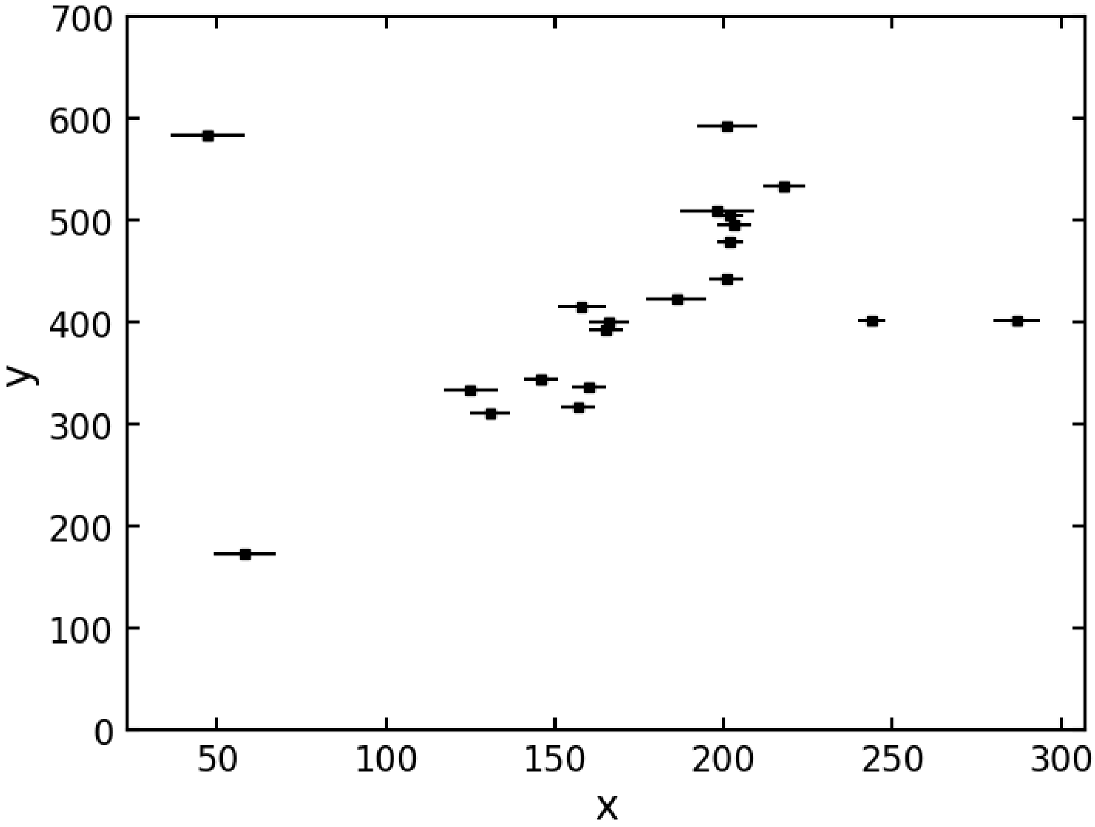
The most common type of data you will work with will only have (significant) uncertainties in one direction. In this case it is very easy to plot using `errorbar`:

[4]:

```
plt.figure(1)
plt.errorbar(
    t.x,
    t.y,
    yerr=t.sy,
    ls='None',
    mfc='k',
    mec='k',
    ms=5,
    marker='s',
    ecolor='k'
)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700);
```



[5]:
```
plt.figure(2)
plt.errorbar(
    t.x,
    t.y,
    xerr=t.sx,
    ls='None',
    mfc='k',
    mec='k',
    ms=5,
    marker='s',
    ecolor='k'
)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700);
```

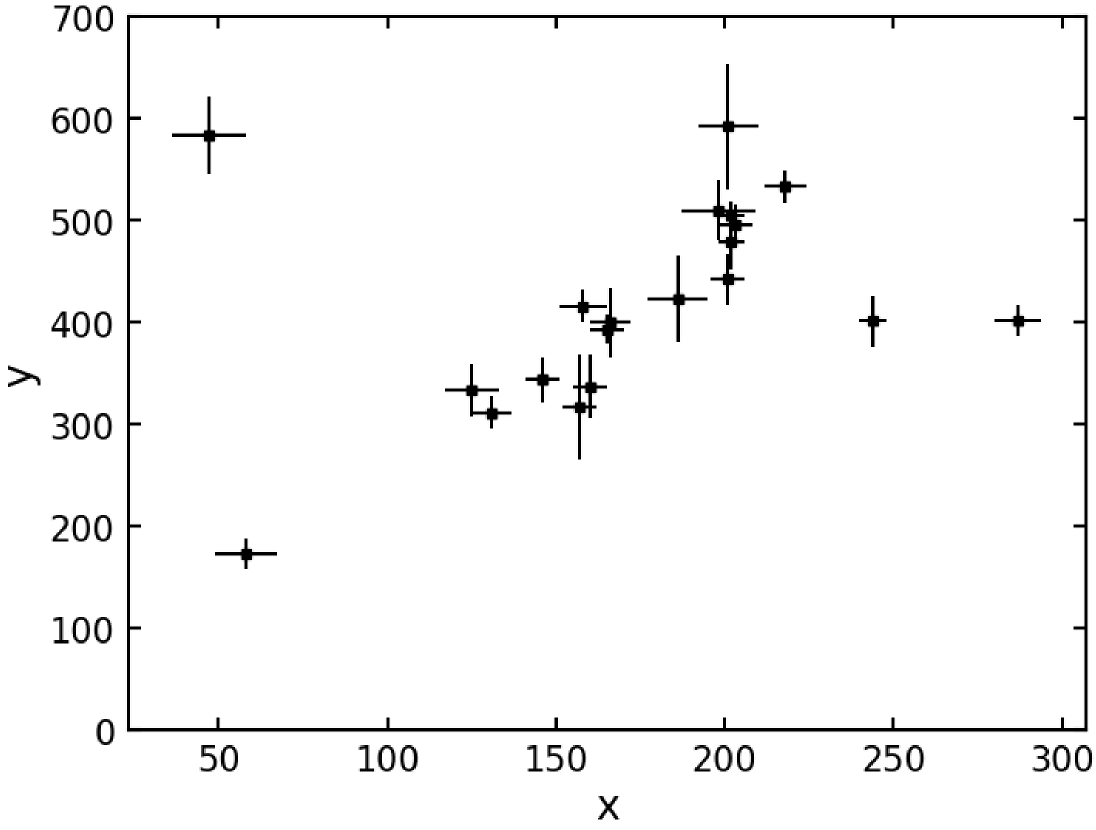


1.4 Uncertainties in both x and y with no cov

If your data has no cov you can still use `errorbar`:

[6]:

```
plt.figure(3)
plt.errorbar(
    t.x,
    t.y,
    yerr=t.sy,
    xerr=t.sx,
    ls='None',
    mfc='k',
    mec='k',
    ms=5,
    marker='s',
    ecolor='k'
)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700);
```



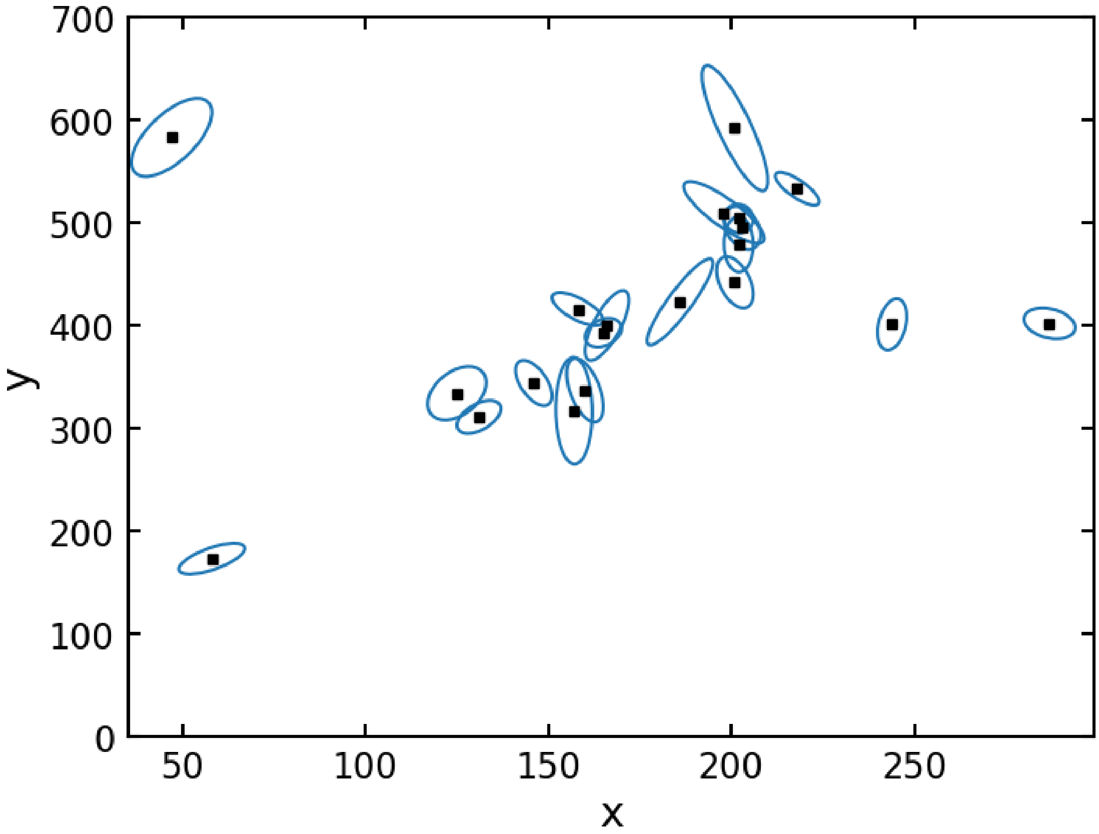
1.5 Uncertainties in both x and y with cov

If your data does have cov you should plot a 1-σ ellipse around each point. There is no built in function to do this, so we will have to write our own. We will start by writing a function to turn a cov matrix into the parameters for an ellipse and draw it on a figure.

[7]:
```
def cov_to_ellipse(cov, pos, **kwargs):
    eigvec,eigval,V = sl.svd(cov,full_matrices=False)
    # the angle the first eigenvector makes with the x-axis
    theta = np.degrees(np.arctan2(eigvec[1, 0], eigvec[0, 0]))
    # full width and height of ellipse, not radius
    # the eigenvalues are the variance along the eigenvectors
    width, height = 2 * np.sqrt(eigval)
    return Ellipse(xy=pos, width=width, height=height, angle=theta, **kwargs)

def plot_ellipse(t, ax=None, **kwargs):
    if ax is None:
        ax = plt.gca()
    for rdx, row in t.iterrows():
        cov = np.array(
            [[row.sx**2, row.pxy * row.sx * row.sy],
             [row.pxy * row.sx * row.sy, row.sy**2]]
        )
        ellip = cov_to_ellipse(cov, [row.x, row.y], **kwargs)
        ax.add_artist(ellip)

plt.figure(4)
plt.plot(
    t['x'],
    t['y'],
    's',
    mfc='k',
    mec='k',
    ms=5
)
plot_ellipse(
    t,
    lw=1.5,
    fc='none',
    ec='C0'
)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700)
plt.draw();
```


0
100
200
300
400
500
600
700
y
50
100
150
200
250
x

[ ]: