Uncertainty_plotting

November 18, 2024

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/stable/api/_as_gen/matplotlib.pyplot.errorbar.html

[1]:
```
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(mpl_style.style1)
```

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

[2]:
```
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

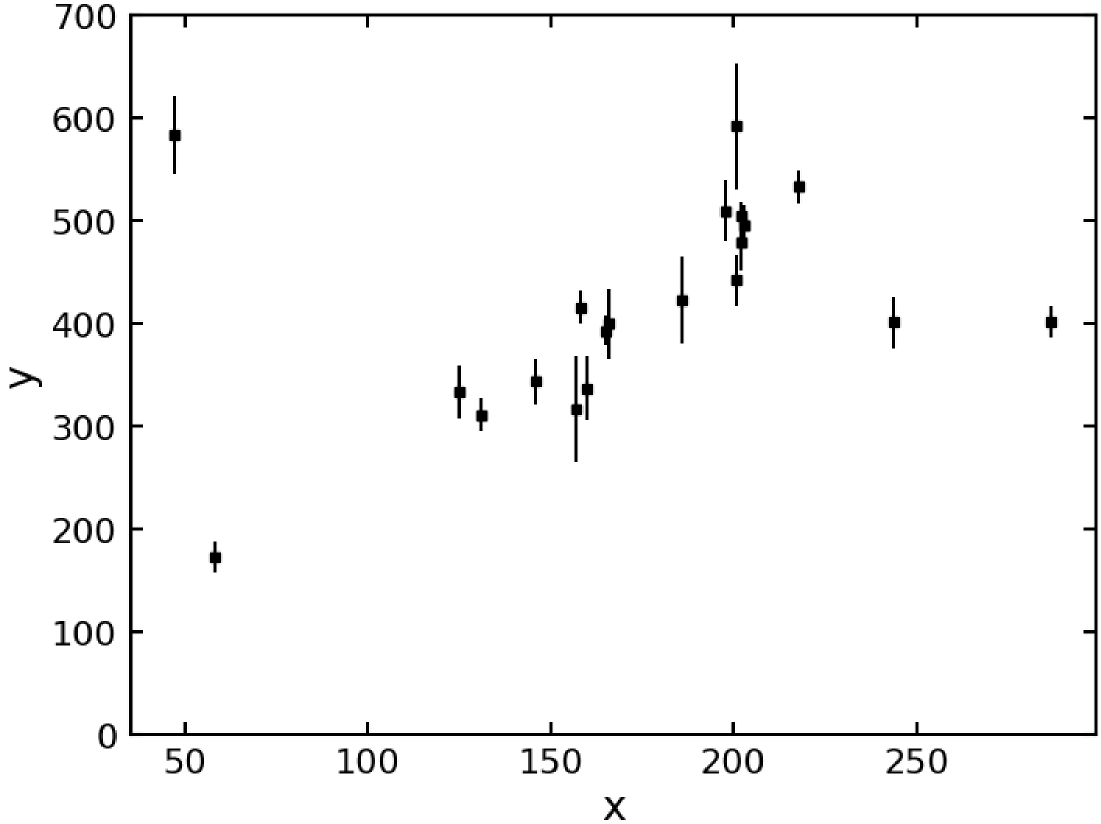
10	11	165	393	14	5	0.30
11	12	201	442	25	5	-0.46
12	13	157	317	52	5	-0.03
13	14	131	311	16	6	0.50
14	15	166	400	34	6	0.73
15	16	160	337	31	5	-0.52
16	17	186	423	42	9	0.90
17	18	125	334	26	8	0.40
18	19	218	533	16	6	-0.78
19	20	146	344	22	5	-0.56

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

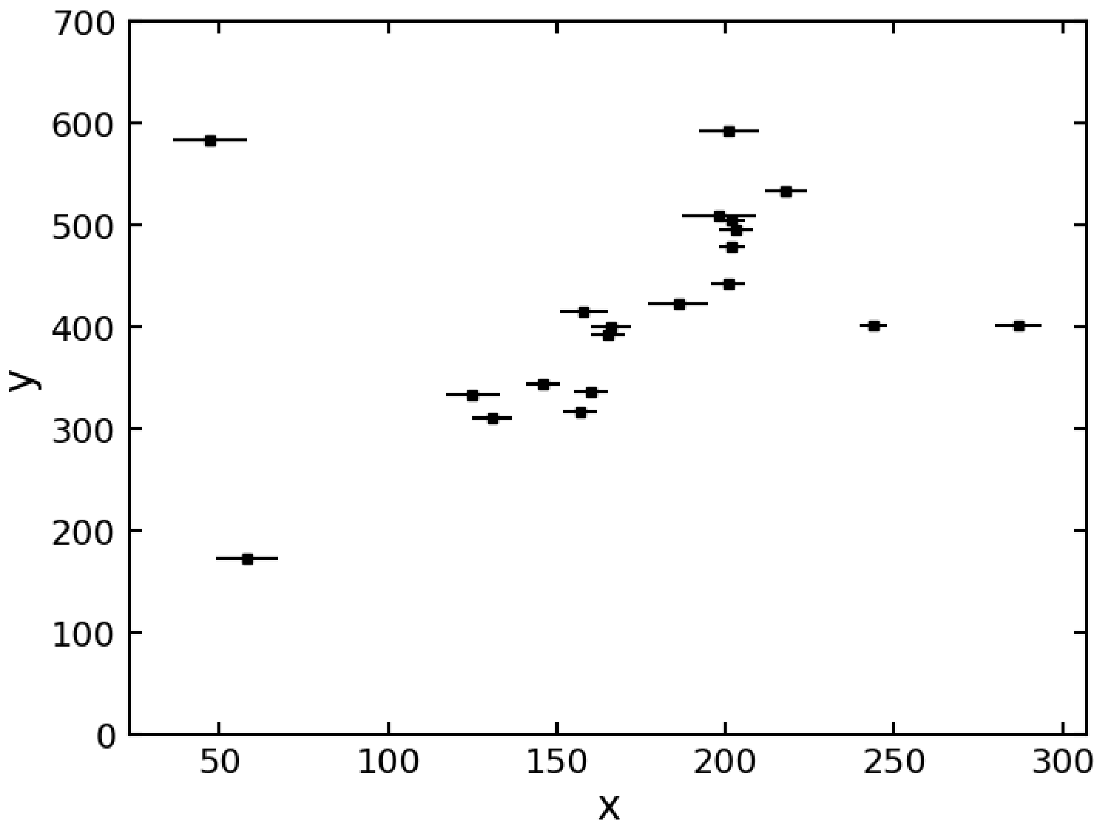
1.3 y-uncertainties or x-uncertainties only

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`:

[3]:
```python
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);
```



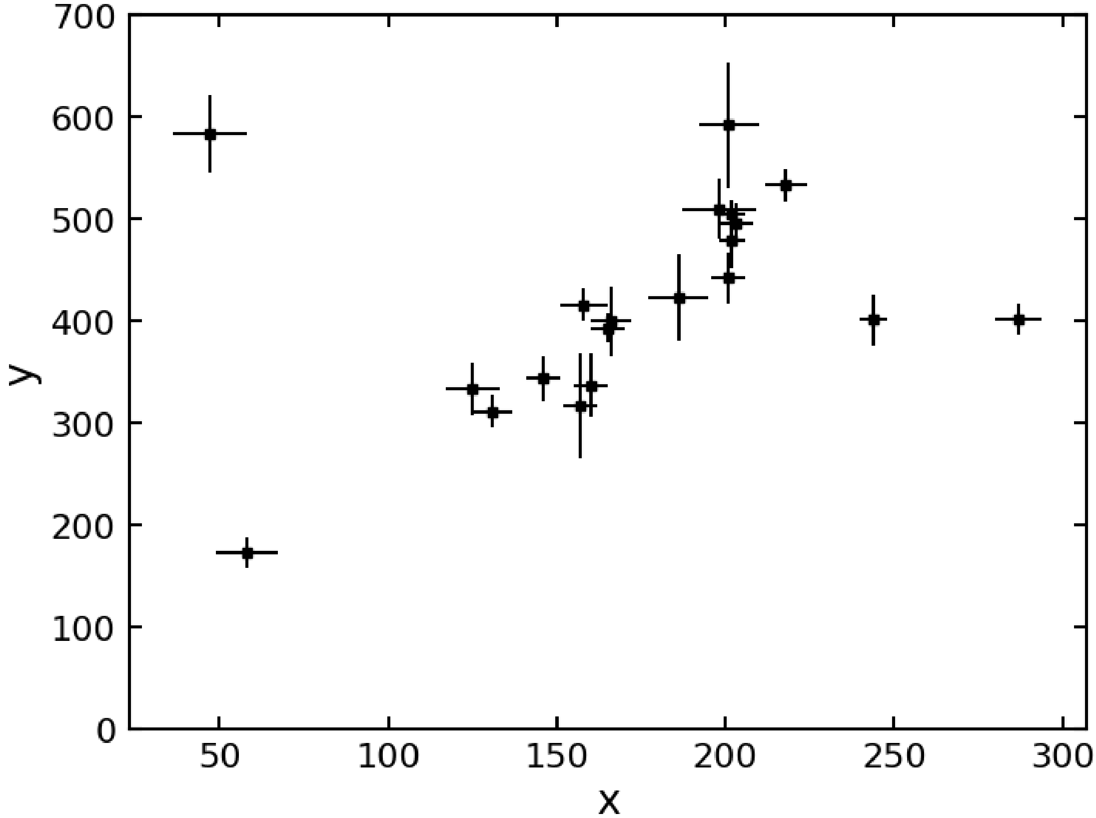
[4]:
```
plt.figure(2)
plt.errorbar(
    t.x,
    t.y,
    xerr=t.sx,
    ls='None',
    mfc='k',
    mec='k',
    ms=5,
    marker='s',
    ecolor='k'
)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700);
```



1.4 Uncertainties in both x and y with no cov

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

[5]:
```
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

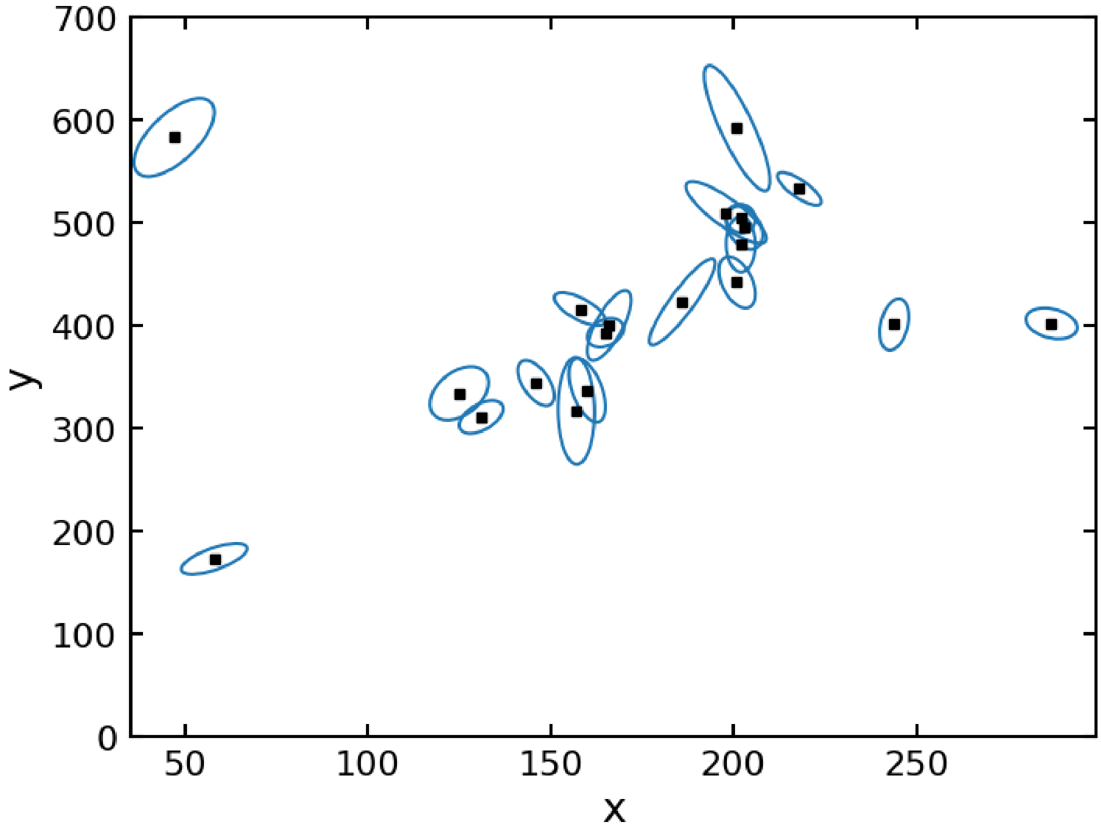
If your data does have cov you should plot a 1-σ ellipse around each point. There is no built in function to do this, so we will have to write our own. We will start by writing a function to turn a cov matrix into the parameters for an ellipse and draw it on a figure.

[6]:
```
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],
```

```python
            [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();
```



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


```
[ ]:
```