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
- `astropy`: read in the data table
- `numpy` and `scipy`: convert cov matrix to ellipse params

1.2 Relevant documentation

- `matplotlib`: http://matplotlib.org/2.0.2/api/pyplot_api.html#matplotlib.pyplot.errorbar

```
In [1]: from astropy.table import Table
        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:

```
In [2]: t = Table.read('data.csv', format='ascii.csv')
        print(t)
```

```
 ID  x   y   sy  sx  pxy
--- --- --- --- --- -----
  1 201 592  61   9 -0.84
  2 244 401  25   4  0.31
  3  47 583  38  11  0.64
  4 287 402  15   7 -0.27
  5 203 495  21   5 -0.33
  6  58 173  15   9  0.67
  7 202 479  27   4 -0.02
  8 202 504  14   4 -0.05
  9 198 510  30  11 -0.84
 10 158 416  16   7 -0.69
 11 165 393  14   5   0.3
 12 201 442  25   5 -0.46
 13 157 317  52   5 -0.03
 14 131 311  16   6   0.5
 15 166 400  34   6  0.73
 16 160 337  31   5 -0.52
 17 186 423  42   9   0.9
 18 125 334  26   8   0.4
 19 218 533  16   6 -0.78
 20 146 344  22   5 -0.56
```

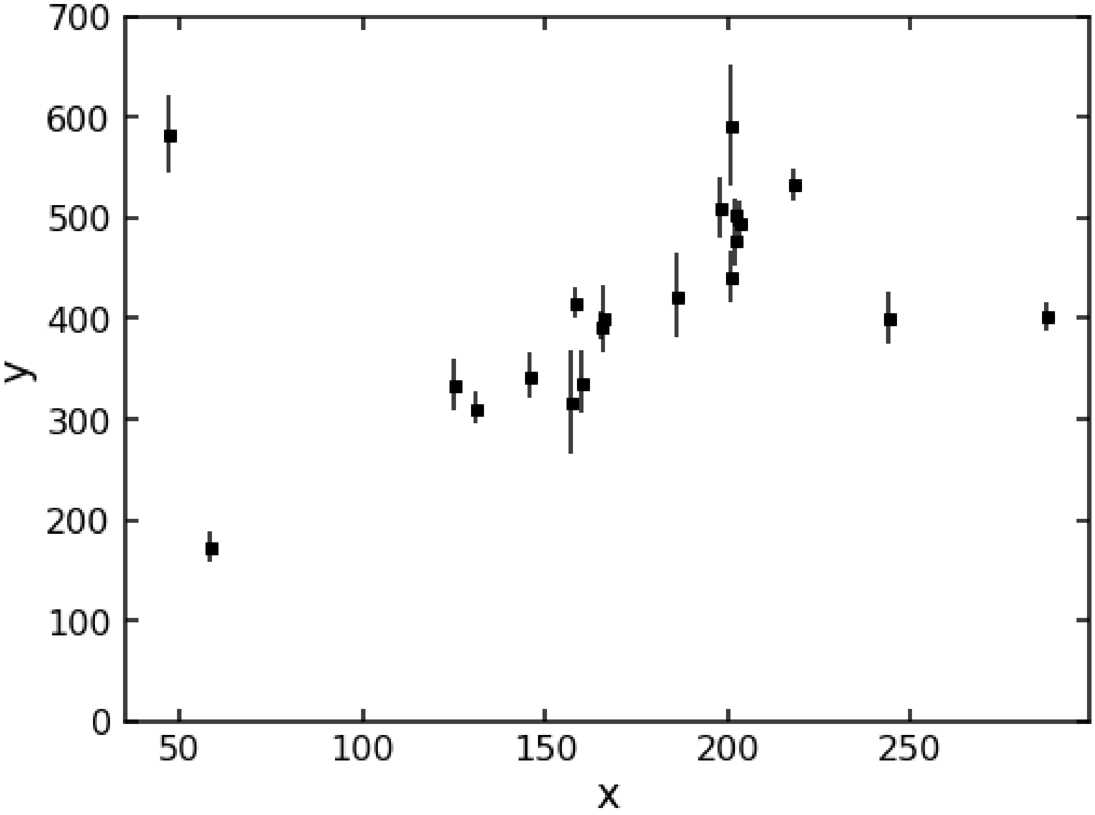
Note the full covariance matrix for each data point is: $\begin{bmatrix} \sigma_x^2 & \rho_{xy}\sigma_x\sigma_y \\ \rho_{xy}\sigma_x\sigma_y & \sigma_y^2 \end{bmatrix}$

1.3 y-uncertanties or x-uncertanties 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`:

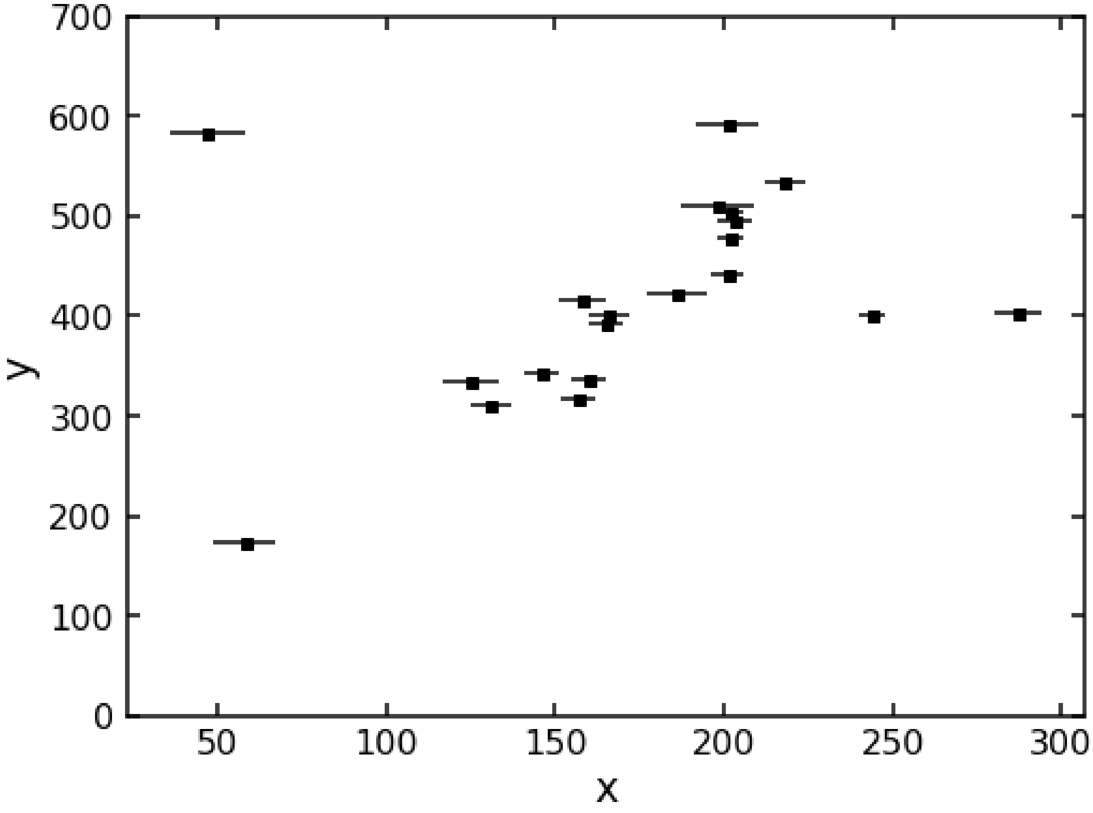
```
In [3]: plt.figure(1)
        plt.errorbar(
            t['x'],
            t['y'],
            yerr=t['sy'],
            ls='None',
            mfc='k',
            mec='k',
            ms=5,
            marker='s',
            ecolor='k'
        )
        plt.xlabel('x')
        plt.ylabel('y')
        plt.ylim(0, 700)
```

```
Out[3]: (0, 700)
```



```
In [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)

Out[4]: (0, 700)
```

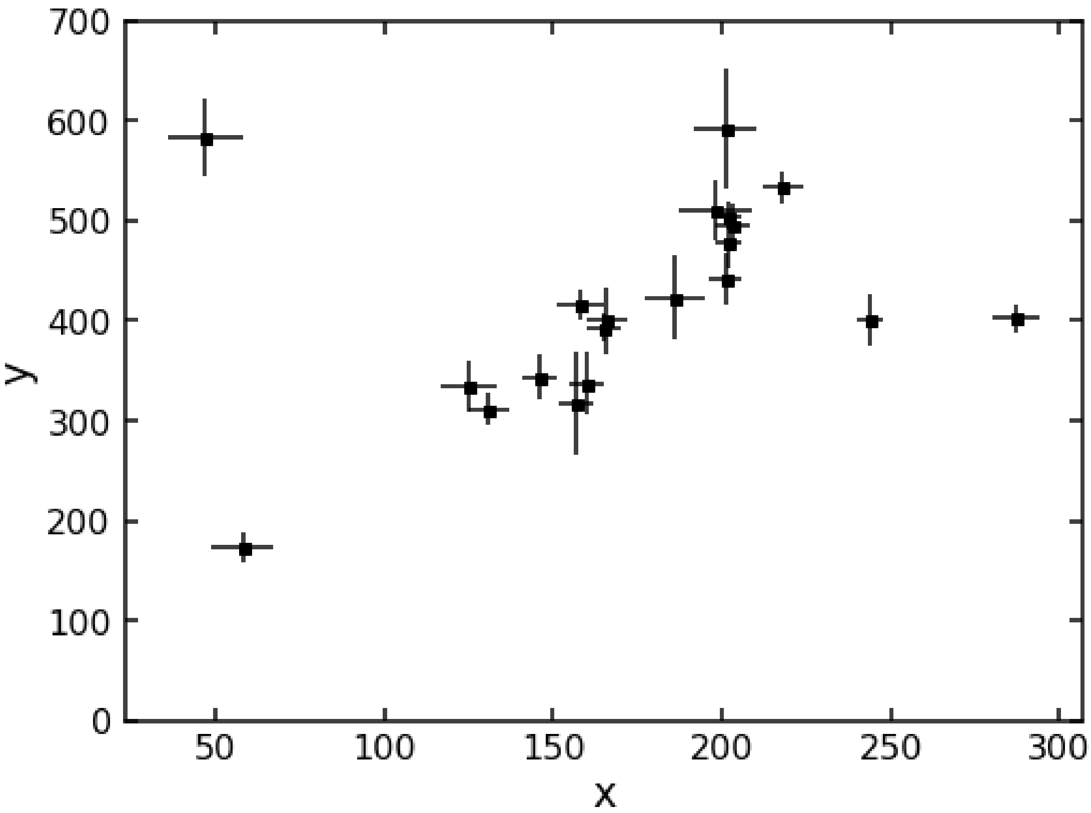


1.4 Uncertainties in both x and y with no cov

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

```
In [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)
```

```
Out[5]: (0, 700)
```



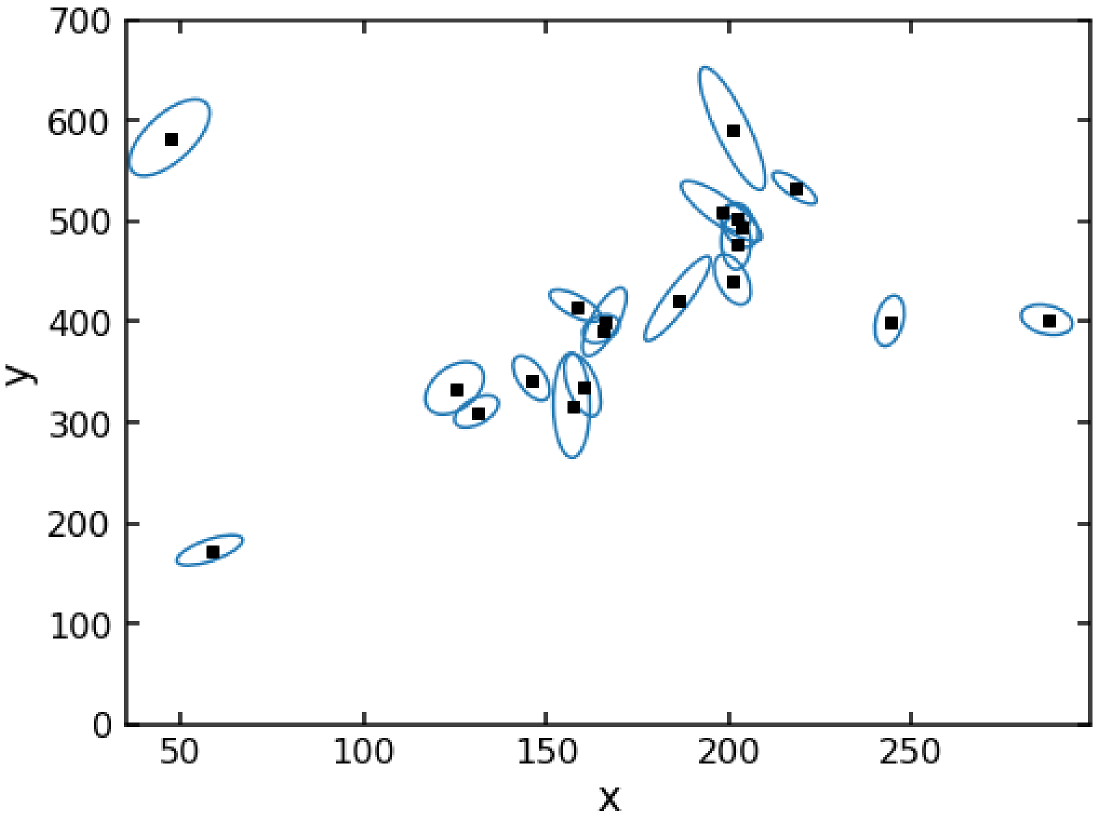
1.5 Uncertainties in both x and y with cov

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.

```
In [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 row in t:
                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()
```



```
In [ ]:
```