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)

Packages being used

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

Relevant documentation

- `matplotlib`: http://matplotlib.org/1.5.1/api/pyplot_api.html#matplotlib.pyplot.errorbar (http://matplotlib.org/1.5.1/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 notebook
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)
```

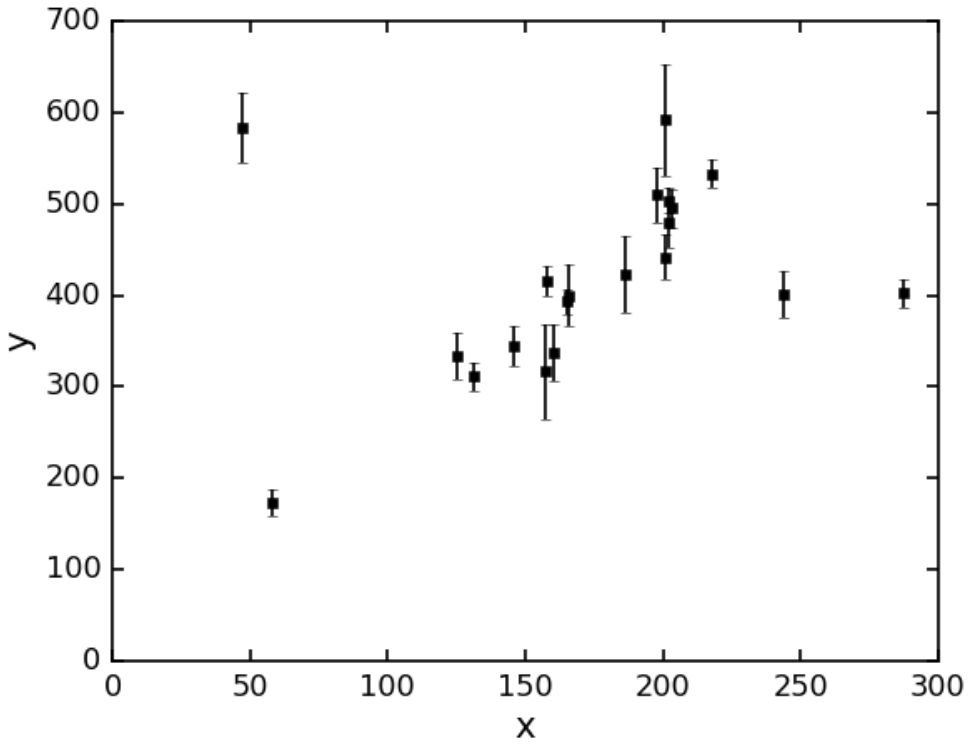
```
 ID  x   y   sy  sx  pxy
--- --- --- --- --- -----
  1 201 592  61   9 -0.84
  2 244 401  25   4  0.31
  3  47 583  38  11  0.64
  4 287 402  15   7 -0.27
  5 203 495  21   5 -0.33
  6  58 173  15   9  0.67
  7 202 479  27   4 -0.02
  8 202 504  14   4 -0.05
  9 198 510  30  11 -0.84
 10 158 416  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: $\begin{bmatrix} \sigma_x^2 & \rho_{xy}\sigma_x\sigma_y \\ \rho_{xy}\sigma_x\sigma_y & \sigma_y^2 \end{bmatrix}$

y-uncertanties or x-uncertanties only

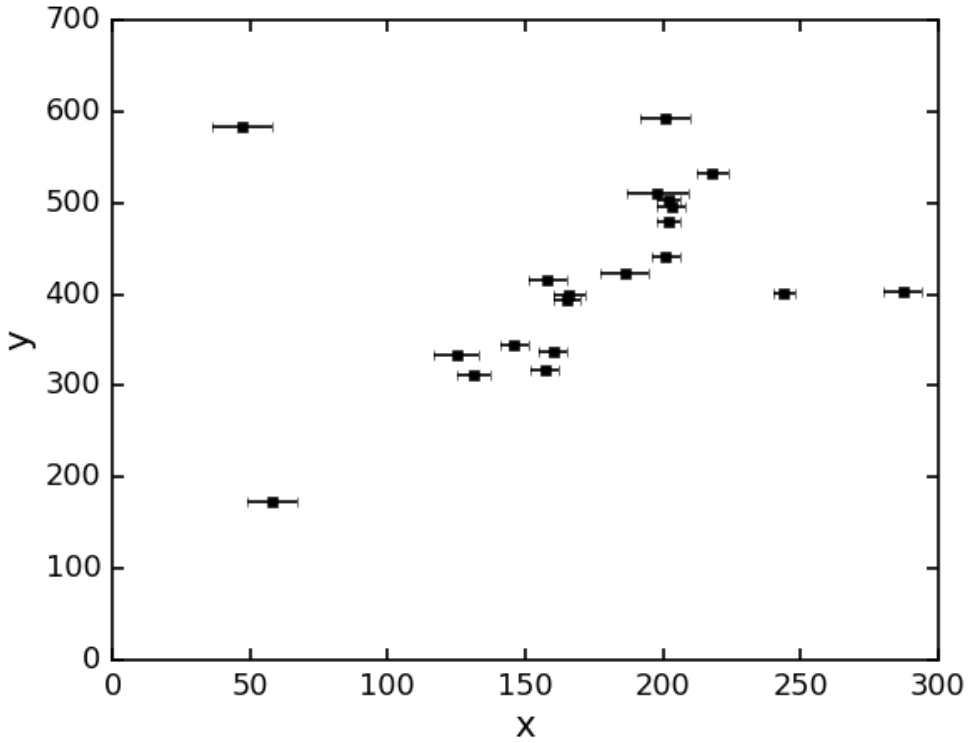
The most common type of data you will work with will only have (significant) uncertainties in one direction. In this case it is very easy to plot using `errorbar`:

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

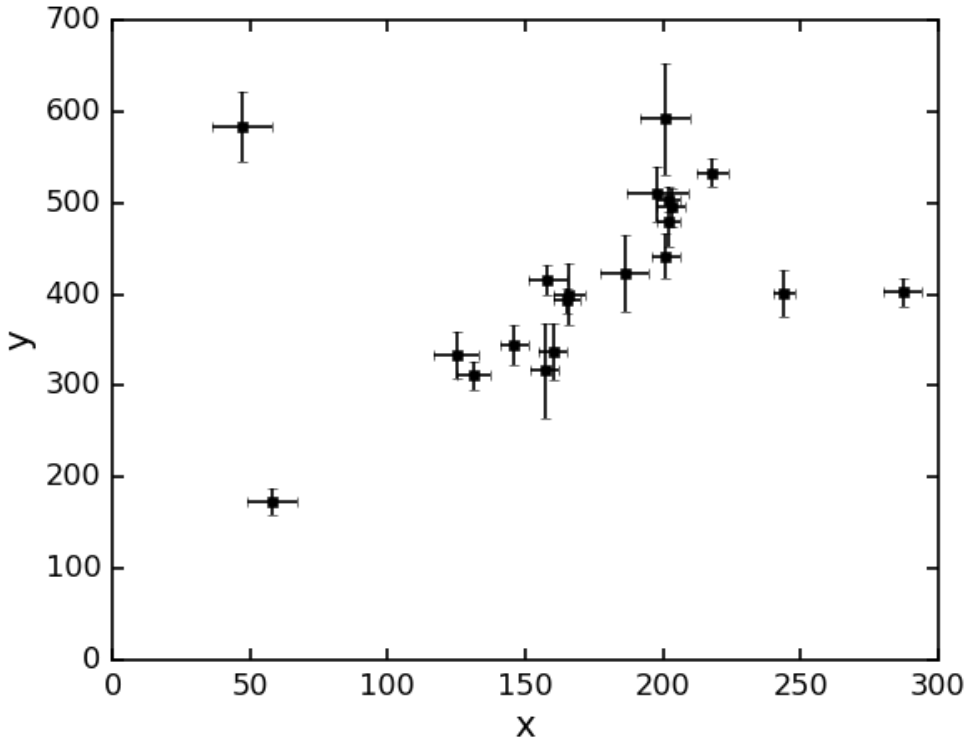


Out[4]: (0, 700)

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', ms
=5, marker='s', ecolor='k')
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700)
```



Out[5]: (0, 700)

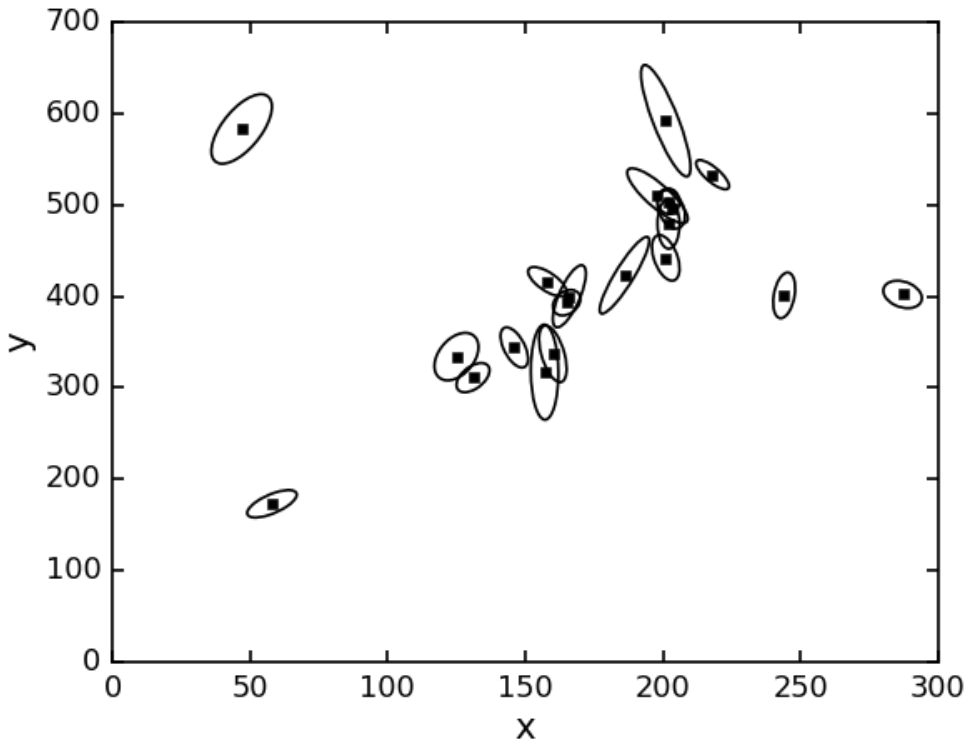
Uncertainties in boty x and y with cov

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']], [ro
w['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', ms=5)
plot_ellipse(t, fc='none', lw=1.5)
plt.xlabel('x')
plt.ylabel('y')
plt.ylim(0, 700)
plt.draw()
```



In [ ]: