Tutorial

This tutorial shows the basic steps of using SEP to detect objects in an image and perform some basic aperture photometry.

Here, we use the `fitsio` package, just to read the test image, but you can also use `astropy.io.fits` for this purpose (or any other FITS reader).

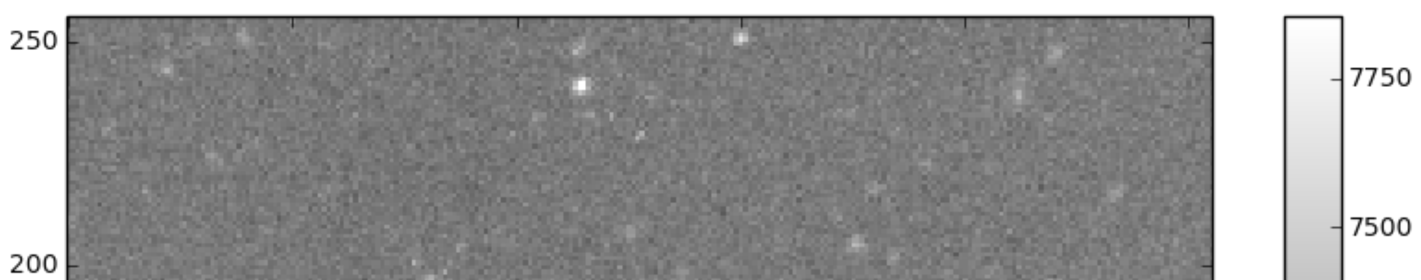
In [1]:
```
import numpy as np
import sep
```

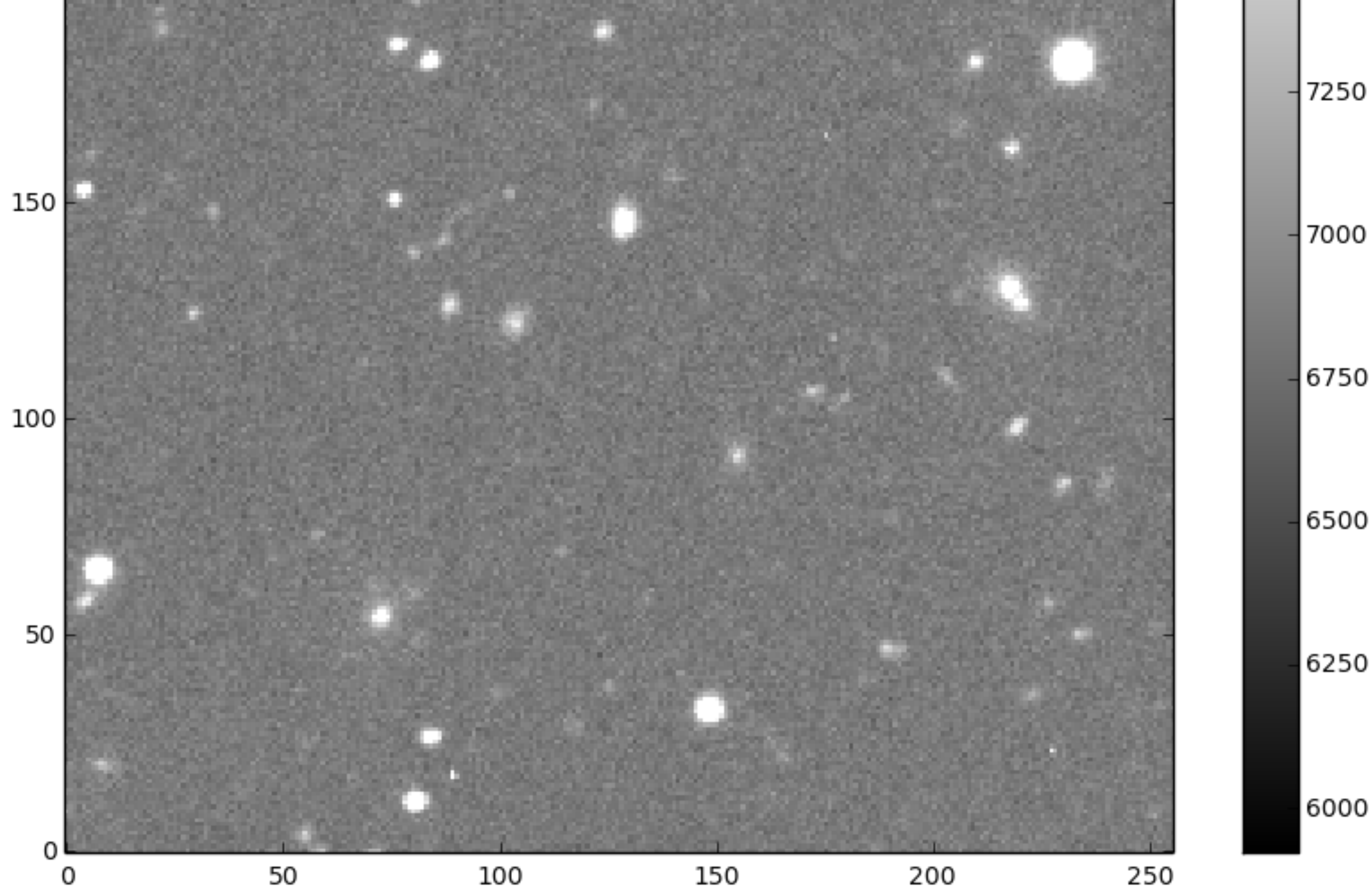
In [2]:
```
# additional setup for reading the test image and displaying plots
import fitsio
import matplotlib.pyplot as plt
from matplotlib import rcParams

%matplotlib inline

rcParams['figure.figsize'] = [10., 8.]
```

First, we'll read an example image from a FITS file and display it, just to show what we're dealing with. The example image is just 256 x 256 pixels.

In [3]:
```
# read image into standard 2-d numpy array
data = fitsio.read("../data/image.fits")
```

In [4]:
```
# show the image
m, s = np.mean(data), np.std(data)
plt.imshow(data, interpolation='nearest', cmap='gray', vmin=m-s, vmax=m+s,
origin='lower')
plt.colorbar();
```





Background subtraction

Most optical/IR data must be background subtracted before sources can be detected. In SEP, background estimation and source detection are two separate steps.

In [5]:
```
# measure a spatially varying background on the image
bkg = sep.Background(data)
```

There are various options for controlling the box size used in estimating the background. It is also possible to mask pixels. For example:

```
bkg = sep.Background(data, mask=mask, bw=64, bh=64, fw=3, fh=3)
```

See the reference section for descriptions of these parameters.

This returns an `Background` object that holds information on the spatially varying background and spatially varying background noise level. We can now do various things with this `Background` object:

In [6]:
```
# get a "global" mean and noise of the image background:
```

```
print(bkg.globalback)
print(bkg.globalrms)
```

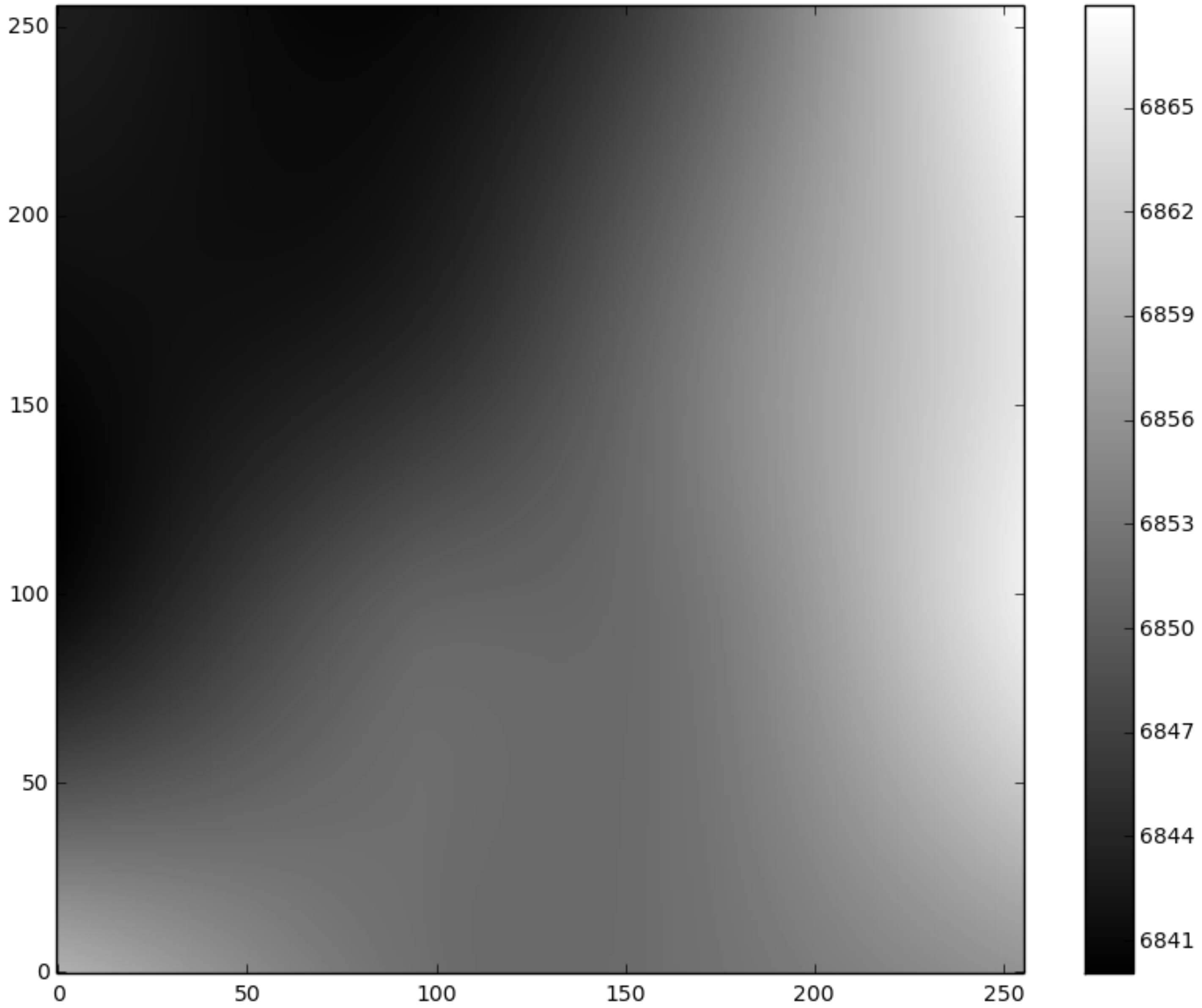
```
6852.04931640625
65.46165466308594
```

In [7]:

```
# evaluate background as 2-d array, same size as original image
bkg_image = bkg.back()
# bkg_image = np.array(bkg) # equivalent to above
```

In [8]:

```
# show the background
plt.imshow(bkg_image, interpolation='nearest', cmap='gray', origin='lower')
plt.colorbar();
```

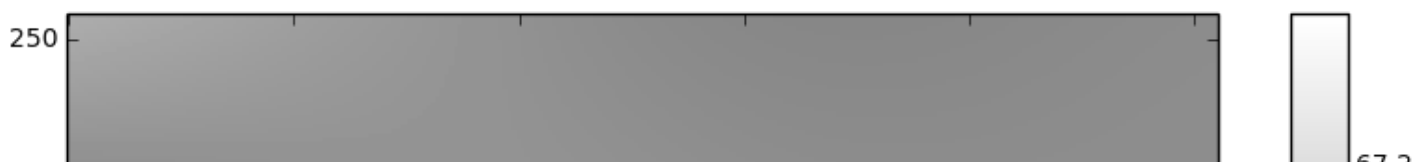


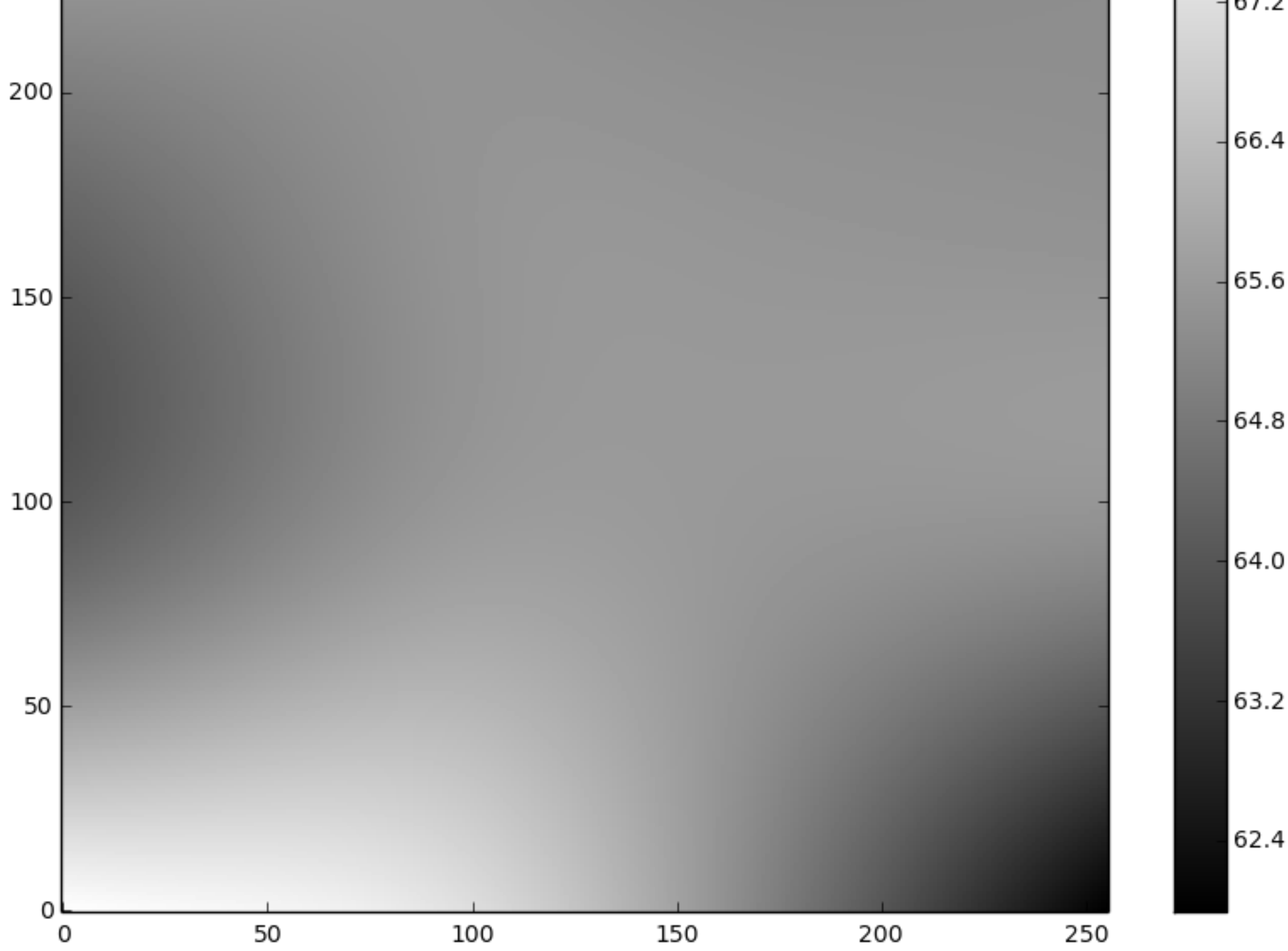
In [9]:

```
# evaluate the background noise as 2-d array, same size as original image
bkg_rms = bkg.rms()
```

In [10]:

```
# show the background noise
plt.imshow(bkg_rms, interpolation='nearest', cmap='gray', origin='lower')
plt.colorbar();
```





In [11]:
```
# subtract the background
data_sub = data - bkg
```

One can also subtract the background from the data array in-place by doing `bkg.subfrom(data)`.

> **Warning:**
>
> If the data array is not background-subtracted or the threshold is too low, you will tend to get one giant object when you run object detection using `sep.extract`. Or, more likely, an exception will be raised due to exceeding the internal memory constraints of the `sep.extract` function.

Object detection

Now that we've subtracted the background, we can run object detection on the background-subtracted data. You can see the background noise level is pretty flat. So here we're setting the detection threshold to be a constant value of 1.5σ where σ is the global background RMS.

In [12]:
```python
objects = sep.extract(data_sub, 1.5, err=bkg.globalrms)
```

`sep.extract` has many options for controlling detection threshold, pixel masking, filtering, and object deblending. See the reference documentation for details.

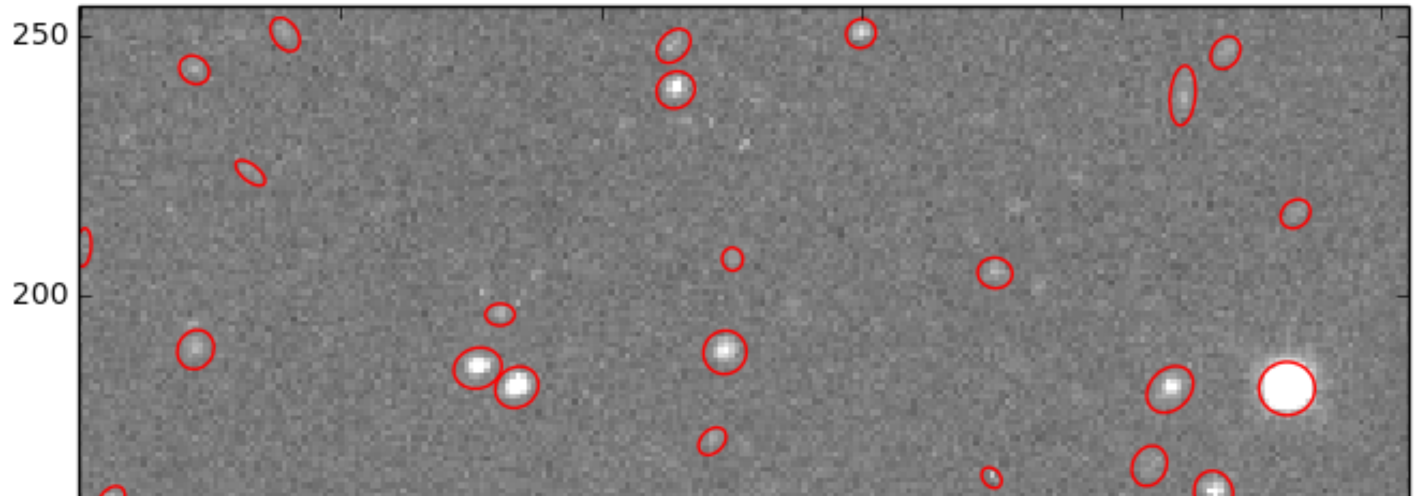
`objects` is a NumPy structured array with many fields.

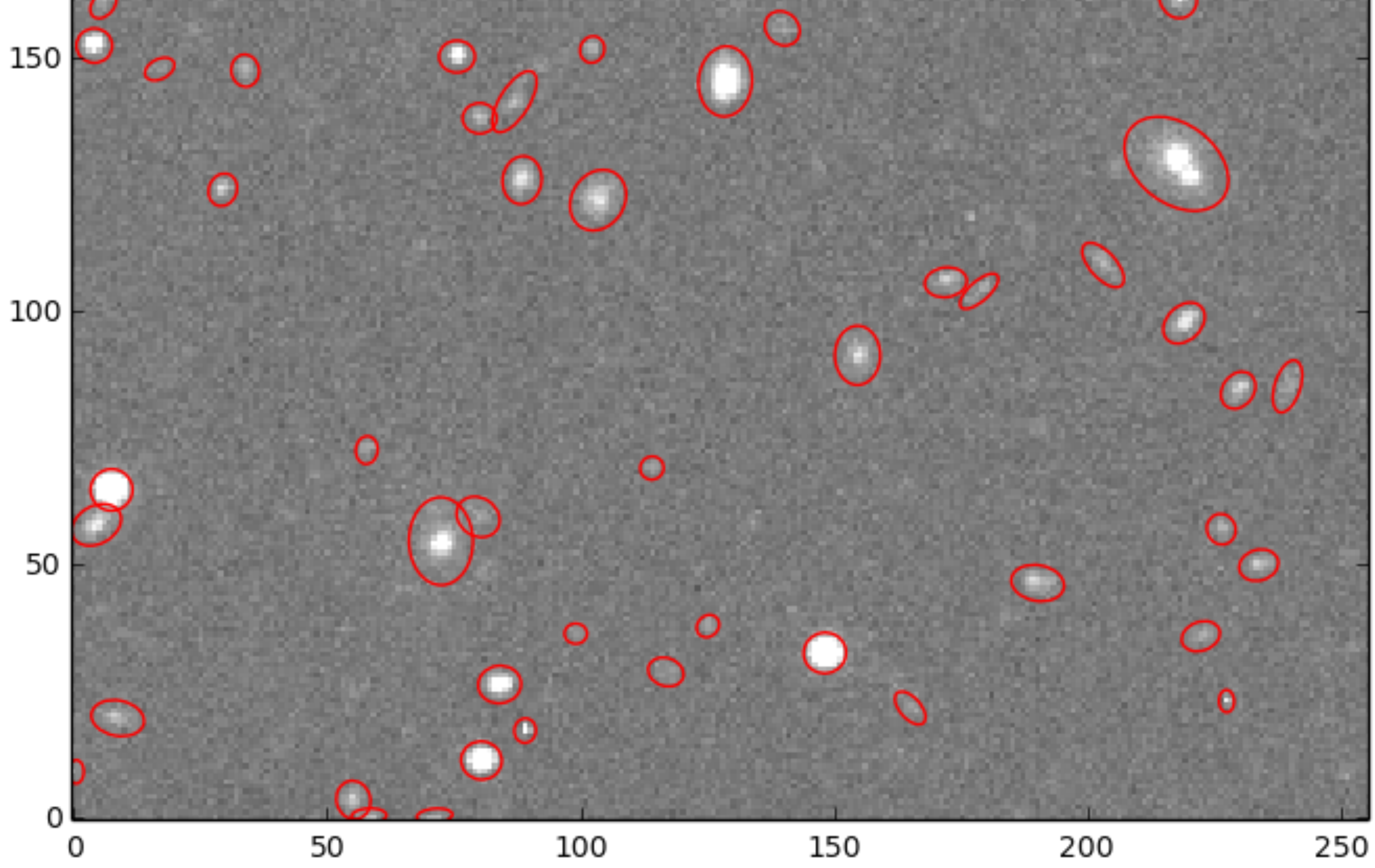
In [13]:
```python
# how many objects were detected
len(objects)
```

Out[13]: 68

`objects['x']` and `objects['y']` will give the centroid coordinates of the objects. Just to check where the detected objects are, we'll over-plot the object coordinates with some basic shape parameters on the image:

In [14]:
```python
from matplotlib.patches import Ellipse

# plot background-subtracted image
fig, ax = plt.subplots()
m, s = np.mean(data_sub), np.std(data_sub)
im = ax.imshow(data_sub, interpolation='nearest', cmap='gray',
               vmin=m-s, vmax=m+s, origin='lower')

# plot an ellipse for each object
for i in range(len(objects)):
    e = Ellipse(xy=(objects['x'][i], objects['y'][i]),
                width=6*objects['a'][i],
                height=6*objects['b'][i],
                angle=objects['theta'][i] * 180. / np.pi)
    e.set_facecolor('none')
    e.set_edgecolor('red')
    ax.add_artist(e)
```





`objects` has many other fields, giving information such as second moments, and peak pixel positions and values. See the reference documentation for `sep.extract` for descriptions of these fields. You can see the available fields:

In [15]:
```
# available fields
objects.dtype.names
```

Out[15]:
```
('thresh',
 'npix',
 'tnpix',
 'xmin',
 'xmax',
 'ymin',
 'ymax',
 'x',
 'y',
 'x2',
 'y2',
 'xy',
 'errx2',
 'erry2',
 'errxy',
 'a',
 'b',
 'theta',
 'cxx',
 'cyy',
 'cxy',
 'cflux',
 'flux',
 'cpeak',
 'peak',
 'xcpeak',
 'ycpeak',
```

```
             'xpeak',
             'ypeak',
             'flag')
```

Aperture photometry

Finally, we'll perform simple circular aperture photometry with a 3 pixel radius at the locations of the objects:

In [16]:
```
flux, fluxerr, flag = sep.sum_circle(data_sub, objects['x'], objects['y'],
                                     3.0, err=bkg.globalrms, gain=1.0)
```

`flux`, `fluxerr` and `flag` are all 1-d arrays with one entry per object.

In [17]:
```
# show the first 10 objects results:
for i in range(10):
    print("object {:d}: flux = {:f} +/- {:f}".format(i, flux[i], fluxerr[i]))
```

```
object 0: flux = 2249.173164 +/- 291.027422
object 1: flux = 3092.230000 +/- 291.591821
object 2: flux = 5949.882168 +/- 356.561539
object 3: flux = 1851.435000 +/- 295.028419
object 4: flux = 72736.400605 +/- 440.171830
object 5: flux = 3860.762324 +/- 352.162684
object 6: flux = 6418.924336 +/- 357.458504
object 7: flux = 2210.745605 +/- 350.790787
object 8: flux = 2741.598848 +/- 352.277244
object 9: flux = 20916.877324 +/- 376.965683
```

Finally a brief word on byte order

Note:

If you are using SEP to analyze data read from FITS files with astropy.io.fits you may see an error message such as:

```
ValueError: Input array with dtype '>f4' has non-native byte order.
Only native byte order arrays are supported. To change the byte
order of the array 'data', do 'data = data.byteswap().newbyteorder()'
```

It is usually easiest to do this byte-swap operation directly after reading the array from the FITS file. You can even perform the byte swap in-place by doing

```
>>> data = data.byteswap(inplace=True).newbyteorder()
```

If you do this in-place operation, ensure that there are no other references to `data`, as they will be rendered nonsensical.

For the interested reader, this byteswap operation is necessary because astropy.io.fits always returns big-endian byte order arrays, even on little-endian machines. For more on this, see