Aperture photometry, Flux calculation, Star finding using DAOStarFinder from SDSS data

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1 Aperture photometry

1.1 Introduction

Aperture photometry is a fundamental technique in astronomy used to measure the flux or brightness of celestial objects, such as stars or galaxies, by quantifying the amount of light captured within a defined aperture. This method is crucial for extracting quantitative information from astronomical images, providing valuable data for various research applications.

1.2 Key components

1. Aperture Definition:

   The aperture is a circular, elliptical, or polygonal region centered on the target object in an astronomical image. It acts as a virtual "window" through which the light from the celestial source is measured.

2. Background Subtraction:

   Accurate aperture photometry necessitates accounting for the background light present in the image. This involves estimating and subtracting the contribution from the surrounding sky or other sources, ensuring that the measured flux is attributed solely to the target object.

3. Flux Measurement:

   The flux, representing the amount of light received from the celestial source, is computed by summing the pixel values within the defined aperture. This measured flux can then be converted into physical units using calibration factors.

4. By focusing on a localized region, aperture photometry can mitigate the impact of atmospheric variations, providing more stable and reliable measurements.

5. In densely populated regions of the sky, where multiple celestial sources are closely packed, aperture photometry faces challenges in accurately isolating the flux of individual objects. Advanced techniques, such as point spread function (PSF) fitting, may be employed in such cases.

1.3 Applications

1. Variable Star Monitoring:

   Aperture photometry is crucial for monitoring the brightness variations of variable stars over time, aiding in the study of stellar behavior and characteristics.

2. Exoplanet Transits:

   Researchers use aperture photometry to detect subtle changes in the brightness of a star caused by the transit of an exoplanet in front of it, providing essential data for exoplanetary studies.

3. Galactic and Extragalactic Studies:

   Aperture photometry is extensively used in studying galaxies, quasars, and other extragalactic objects, providing valuable insights into their properties and evolution.

1.4 Python code for performing aperture photometry on an image taken from SDSS archive

1.4.1 Importing libraries

```
# import required libraries
from astroquery.sdss import SDSS
from astropy.table import Table
import matplotlib.pyplot as plt
from matplotlib.colors import LogNorm
import numpy as np
%matplotlib widget
import photutils
from photutils.aperture import CircularAperture
from photutils.aperture import aperture_photometry
from photutils.aperture import CircularAperture, ApertureStats
```

1.4.2 Read data from disk

```
file=Table.read('D:\\pythonenvi\\src\\res_tables\\object_4.fits')
image=SDSS.get_images(matches=file)
image[0].info() #list of hdulist objects is a fits file
data=image[0][0].data
data=np.where(data<0,0,data) #removing negetive values
```

```
output:
Filename: (No file associated with this HDUList)
No.    Name      Ver    Type      Cards   Dimensions   Format
0  PRIMARY       1 PrimaryHDU      96   (2048, 1489)   float32
1                1 ImageHDU         6   (2048,)   float32
2                1 BinTableHDU     27   1R x 3C   [49152E, 2048E, 1489E]
3                1 BinTableHDU     79   1R x 31C   [J, 3A, J, A, D,
D, 2J, J, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D, D,
D, D, E, E]
```

1.4.3 Plotting image

```
plt.imshow(data, norm=LogNorm())
rad=np.linspace(1,50,10)
aperture_phot=[]
aperture_stat=[]
area=[]
for i in rad:
    aper=CircularAperture([665,406],i)
    aper.plot(lw=1)
    phot_table=aperture_photometry(data,aper)
    aperture_phot.append(phot_table['aperture_sum'][0])
    aperturestats=ApertureStats(data,aper)
    aperture_stat.append(aperturestats.sum)
    area.append(3.14*i**2)
plt.show()
```

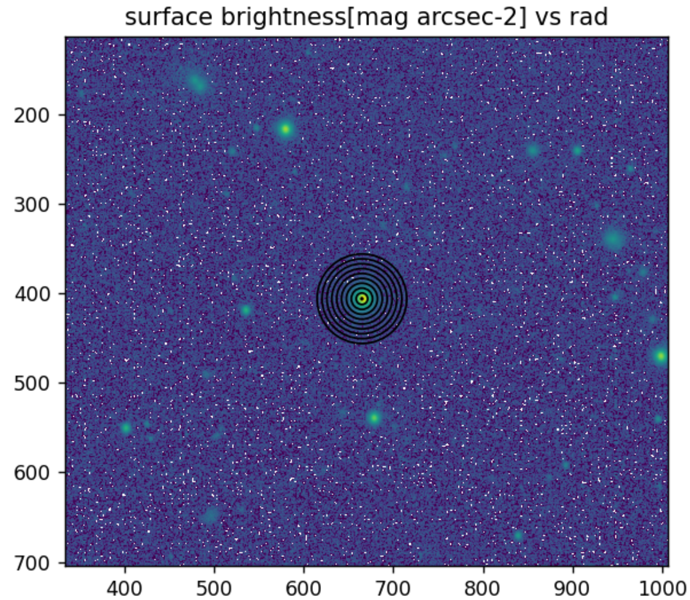

Figure 1: aperture photometry

1.5 Plotting radius vs flux, radius vs flux density, radians vs surface brightness graphs

1.5.1 radius vs flux

```
plt.figure()
plt.plot(rad,aperture_phot)
plt.title('flux vs radius')
plt.show()
#1 pixel in sdss = 0.39 arcsec
```

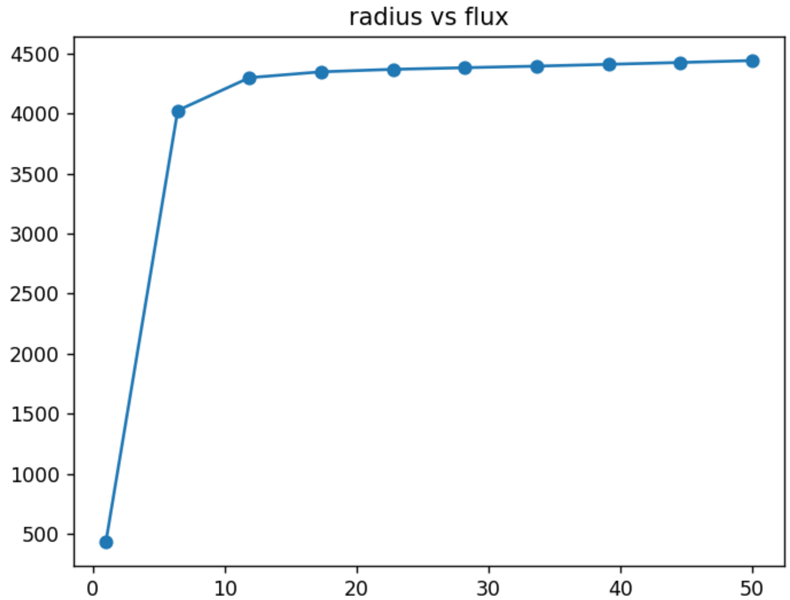

Figure 2: radius vs flux

1.5.2 radius vs flux density

```
r_sq=rad**2
d_diff=np.diff(r_sq)
n=np.append(1,d_diff)
f_den=aperture_phot/(3.14*n)
plt.figure()
plt.scatter(rad,f_den)
plt.plot(rad,f_den)
plt.title('radius vs flux density')
plt.show()
```

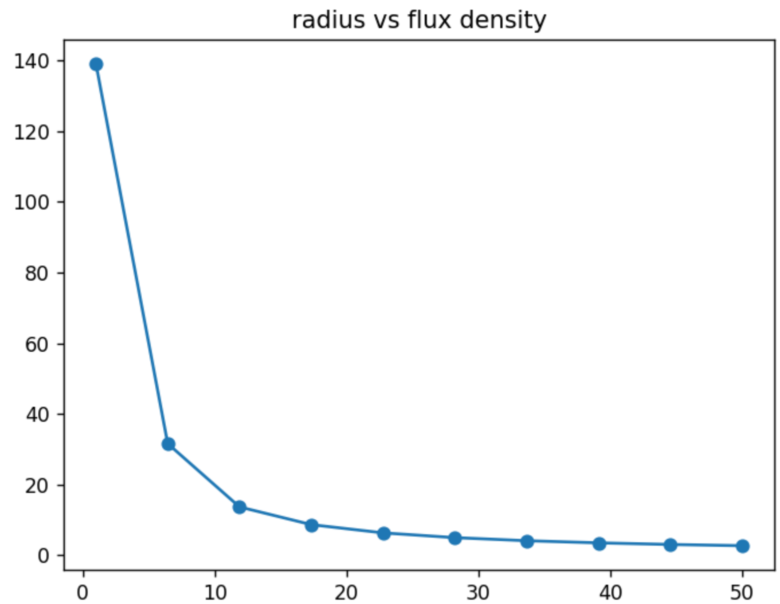

Figure 3: radius vs flux density

1.5.3 radians vs surface brightness

```
mag=22.5-np.log(f_den) #by default sdss flux is in nanomaggy
magnitude per pix2
mag_arc_s=22.5-np.log(f_den/0.39**2)
plt.figure()
plt.scatter(rad*0.39, mag_arc_s)
plt.gca().invert_yaxis()
plt.title('radians vs surface brightness[mag arcsec-2]')
plt.plot(rad*0.39, mag_arc_s)
plt.show()
```

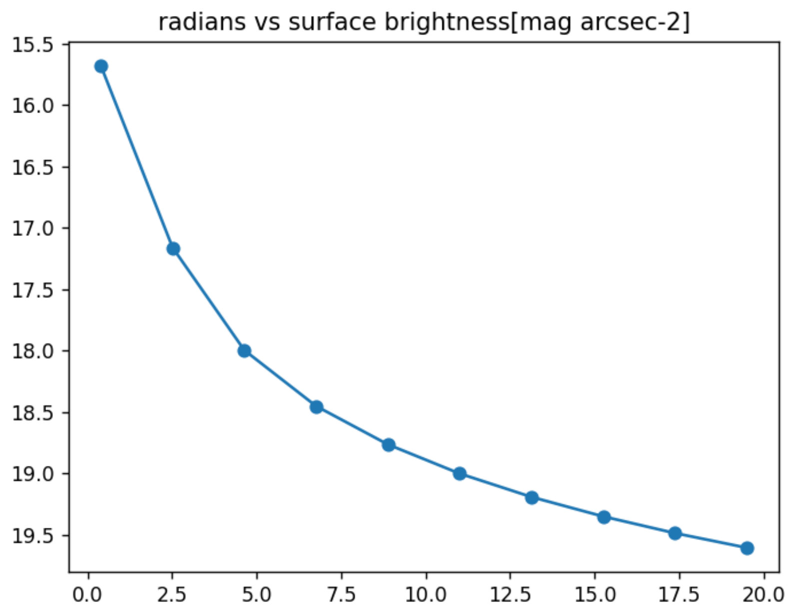

Figure 4: radians vs surface brightness

1.6 Conclusion

In summary, aperture photometry serves as a fundamental tool in the astronomer's toolkit, enabling precise measurements of celestial object brightness. Its flexibility and applicability make it an indispensable technique for diverse astronomical investigations, contributing to our understanding of the cosmos.

2 Detecting stars using DAOStarFinder

2.1 Introduction

The DAOStarFinder module, part of the astropy package in Python, is a powerful tool designed for identifying and characterizing stellar sources within astronomical images. Developed by the Dominion Astrophysical Observatory (DAO), this module implements an advanced star-finding algorithm, allowing astronomers to pinpoint celestial objects with a high degree of accuracy.

2.2 Importing and plotting image

```
from astropy.table import Table
import matplotlib.pyplot as plt
```

```
from matplotlib.colors import LogNorm
from astroquery.sdss import SDSS
import numpy as np

match=Table.read('D:\\pythonenvi\\src\\res_tables\\object_0.fits')
image=SDSS.get_images(matches=match)
data=np.where(image[0][0].data<0,0,image[0][0].data)
plt.figure()
plt.imshow(data,norm=LogNorm(), cmap='gray')
plt.show()
```

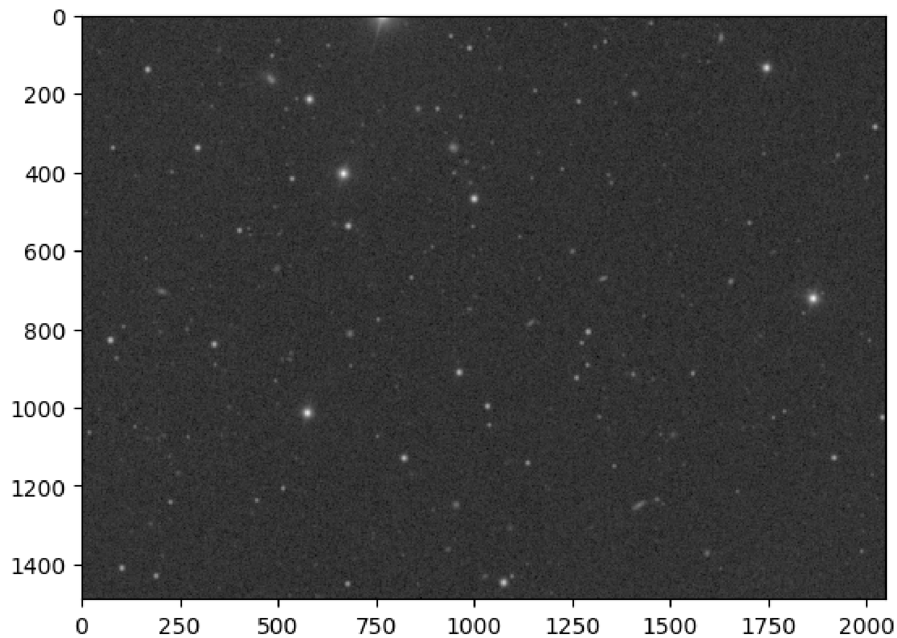

Figure 5: Image of night sky

2.3 Importing and using DAOStarFinder module

```
from astropy.stats import sigma_clipped_stats #clipping data above certain values
from photutils.detection import DAOStarFinder
mean, median, std=sigma_clipped_stats(data,sigma=5.0)
print(mean,median,std)

daofind=DAOStarFinder(fwhm=3.0,threshold=10*std)
```

```
#find source

sources=daofind(data-median)

from photutils.aperture import CircularAperture
position=np.transpose((sources['xcentroid'], sources['ycentroid']))
plt.figure()
aper=CircularAperture(position,r=15)
aper.plot(lw=1)
plt.imshow(data, norm=LogNorm(), origin='lower', cmap='gray')
```

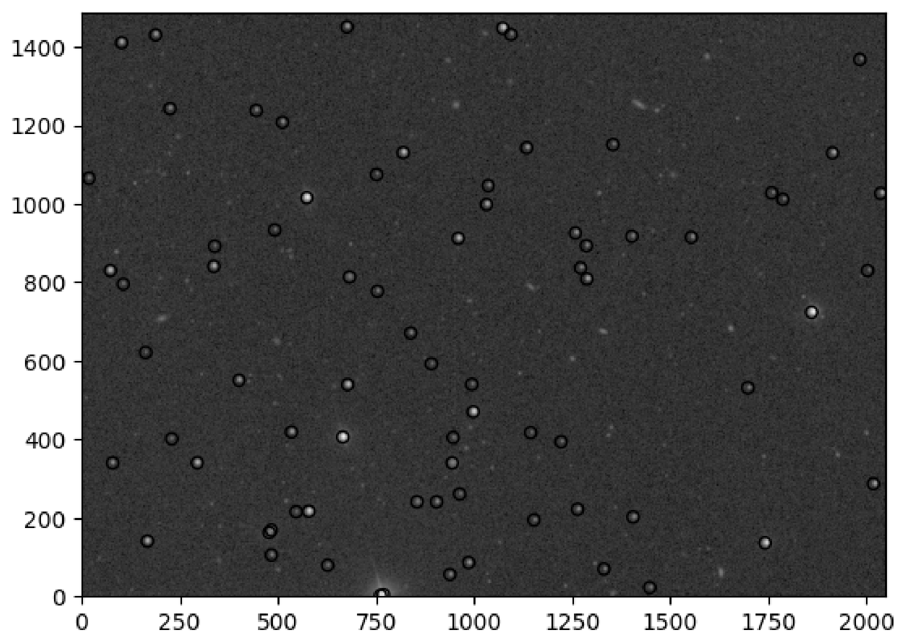

Figure 6: Stars are marked with circle

2.4 Conclusion

In conclusion, DAOStarFinder is a versatile and reliable tool for astronomers working with astronomical images. Its advanced algorithms, parameter customization, and adaptability make it a valuable asset for precise star identification and characterization in a variety of observational scenarios.