Problem 1: CCD Image Processing (60 points)

As an exercise of image processing, this problem involves use of a simple calculator and tabular data (table 1.1) which contains the pixel values of an image during the given exposure time. This image, which is a part of a larger CCD image, was taken by a small CCD camera, installed on an amateur telescope and using a *V* band filter. Figure 1.1 shows this 50×50 pixels image that contains 5 stars.

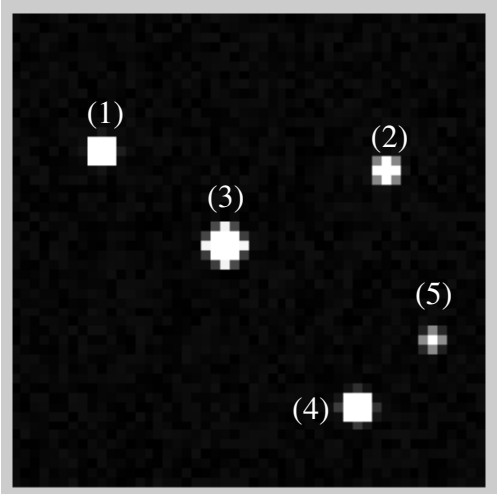


Figure 1.1

In table 1.1 the first row and column indicates the pixels' x and y coordinates. Table 1.2 gives the telescope and the image specifications.

Table 1.2

Telescope focal length	$1.20\ m$
CCD pixel size	$25 \times 25\ \mu m$
Exposure time	$450\ s$
Telescope zenith angle	25°
Average extinction coefficient in V band	0.3 mag/airmass

The observer identified stars 1, 3 and 4 by comparing this image with standard star catalogues. Table 1.3 shows stars true magnitudes (m_t) as given in the catalogue.

Table 1.3

Star	m_t
1	9.03
3	6.22

4	8.02

a. Using the available data, determine the instrumental magnitudes of the stars in the image. Assume the dark current is negligible and the image is flat fielded. For simplicity you can use a square aperture.
   Hint: The instrumental magnitude is calculated using the difference between the measured flux from the star in the aperture and the flux from an equivalent area of dark sky.
b. The instrumental magnitude of a star in a CCD image is related to true magnitude as

   $$m_I = m_t + KX - Zmag$$

   where K is extinction, X is airmass, m_I and m_t are respectively instrumental and true magnitude of star and $Zmag$ is zero point constant. Calculate the zero point constant $(Zmag)$ for identified stars. Calculate average zero point constant $(Zmag)$.
   Hint: Zero point constant is the constant reducing extinction-free magnitudes to the true magnitude.
c. Calculate true magnitudes of stars 2 and 5.
d. Calculate CCD pixel scale for the CCD camera in units of arcsec.
e. Calculate average brightness of dark sky in magnitude per square arcsec (m_{sky}).
f. Use a suitable plot to estimate astronomical seeing in arcsec.