5.3 Pre-processing:

The process of CCD image reduction makes use of a basic set of images that form the core of calibration and reduction process. This basic sets of frames are Flat , Bias, Dark & Light frames. Tasks are based on the data taken on 14/03/18, log Table 9 (Appendix). IRAF provides various calibration task, out of which we mainly use three tasks, as follows :

5.3.1 Tasks:

- Zero Combine: This task is solely dedicated for Bias Frames. Here we basically averages no. of counts at each pixels from all Bias frames to give a Master Bias frame. (ccdred>epar zerocombine) This Master Bias frame will be subtracted from all light frames to remove the effect of default off-set available in the device. Combine is often used median not just simple average [9].

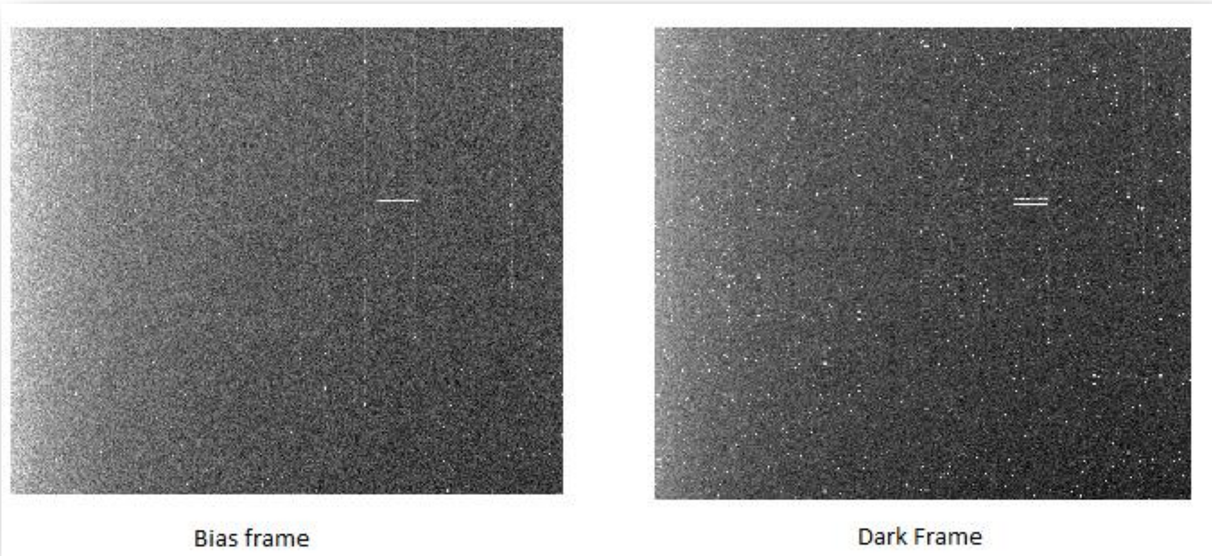

Fig.7 : These two frames are master bias and master dark frames by combining all bias & dark frames respectively to remove the noises, offset available

- Dark Combine: Every material at a temperature above absolute zero will subject to lead thermal noise within. For a CCD, when this thermal agitation is high enough, electrons will be freed from the valence band and collected within the potential well of a pixel. And when the CCD is readout , these dark current electrons become part of the signal, indistinguishable from the astronomical photons. [4] With the help of Dark combine task (ccdred>epar darkcombine) we can produce a master dark frame which is subtracted from the light frames. But, our CCD has a cooling system within it, so it’s not necessary to do this task. [9]

- Flat Combine: In this task we use all the flats in a particular filter say, open filter and the master bias frame.
    a. First , subtract master bias frame from all raw flat fields. To do this we've to list up the flats with the help of list. (ccdred > ls open_flat*.fits > list) . Now, do the subtraction:
    ccdred > imarith @list – masterbias.fits bias_correct//@list .

    b. Now, we do epar flatcombine task, where we average over all bias_correctopen_flat*.fits images and get bias_correct_master_flat.fits.

    c. Or, we can first normalize the all bias_corrected images by dividing each of bias_correct_flat.fits by their mean counts (imarith) , we get normalized_flats. Then we do flat combine . In this case we get normalized_master_flats. But then, we should have done another step by dividing each normalized_flats by the master_normalized_flats and do vector plots of the resulting image. If the V-plot fluctuation is within 2% then keep the original frame, else remove it. After all these do flatcombine again with the remaining normalized_flats.

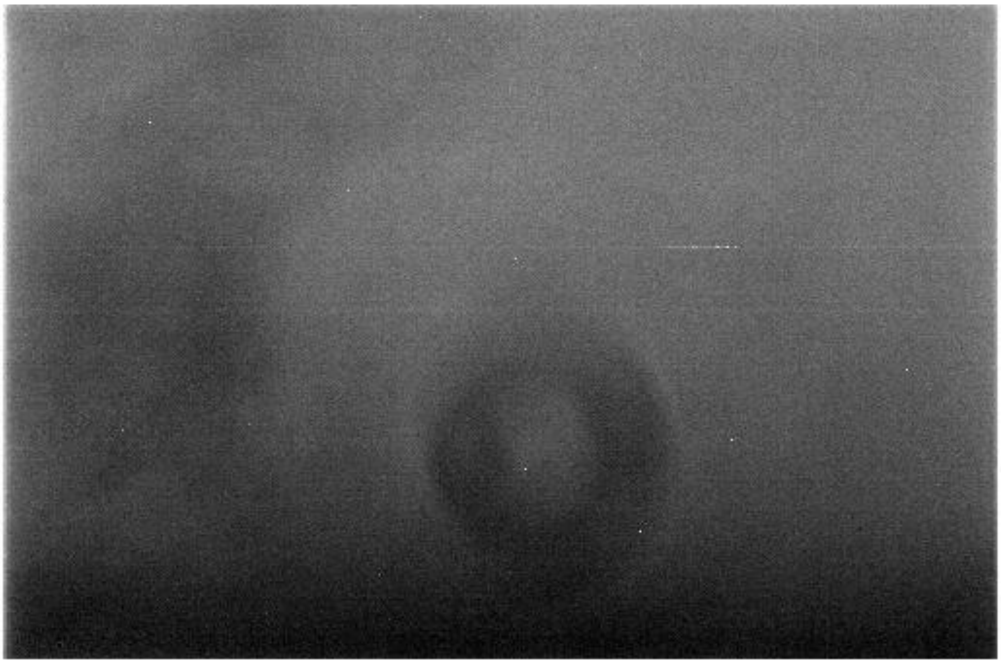

Fig 8: Bias_corrected_master_flat images (open filter)

But since we use CCDPROC task, will do Step (a) and (b) only, mentioned above.

5.3.2 CCD PROC Task

In CCDPROC [9] we input the light frames, subtract master Bias and master Dark frames (not for our case, we don't subtract dark frames i.e. negligible contribution) and divide the resulting image by the respective Master flats for particular filters. Because in CCDPROC task the given bias_correct_master_flats (steb b) will be automatically processed to normalized_master_flats. Finally, we get the images that are used for photometry.

5.4 PHOTOMETRY:

After getting these corrected images first, we have to choose the stars for those we want to do photometry to get apparent magnitude of the stars. [9]

a. So, first find the co-ordinate files of all the selected stars in each frame for every filter. Prepare log-files by epar imexa sub-routine and edit input file name as say **BL071.fits,** name of log file as **071.co** and lastly, make **keep log** as **YES.** Now, save this by (**:wq**) and then task **imexa BL071.fits** so that the image BL071.fits will open on ds9 and log-file 071.co will also be opened.

b. Now, keep the pointer almost at the centre of the each selected stars in the order mentioned in fig 9. and press "A", so that we get the co-ordinates along with some important statistics like (MOFFAT) FWHM etc. Now, press "q" to exit from ds9. This MOFFAT value remains almost constant for a particular filter.

c. Do the same for all the frames in each filters by providing separate log files for each frame.

d. And, by opening the image in ds9 via imexa , we can press "M" in the background part (far away from stars) for getting the standard deviation of the background. We see that, this value remains almost constant for a particular filter.

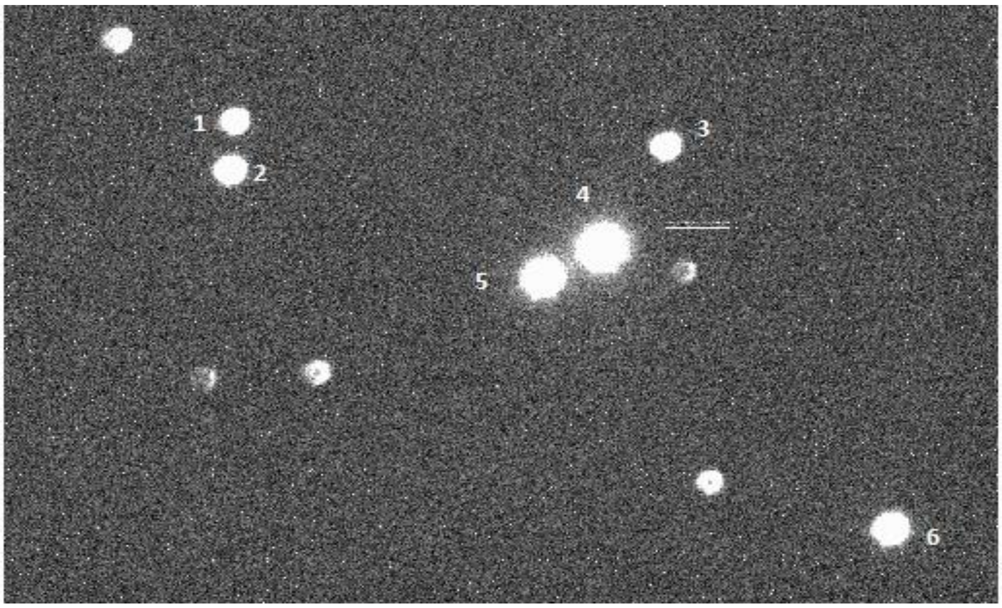

Fig 9 : This is Bias_dark_flat corrected image, which we've used for photometry.

Size of a star: Before we start photometry we have to work out our analysis radius- this defines the radius of the circle that is used to count the pixel value in the image . The radius of the circle is very important – if the radius is too small, it won't count all the light coming from the star and if it's too big, it may count too much background sky or other stars in the image. Therefore, you may not get the accurate measurements. So we can use the FWHM or Full Width Half Maximum of the stars in the image. The FWHM is used to describe the width of an object in the image. [10]

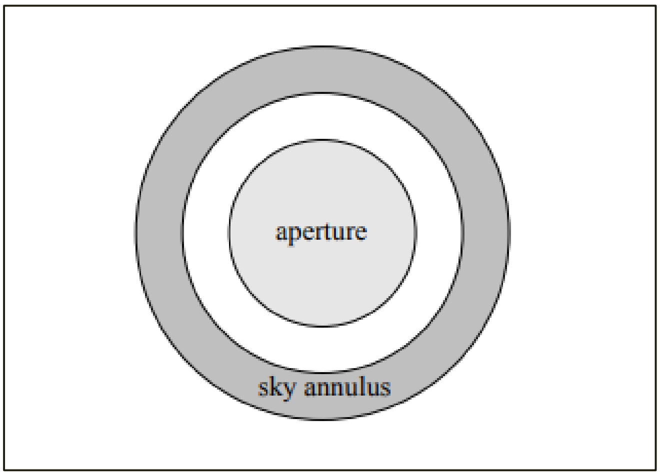

Fig 10: showing the process regarding Aperture photometry, where we select an annulus for a star ,which is four times FWHM, and a sky annulus, just outside the annulus to account the sky counts.(source: http://www.astro.keele.ac.uk/astrolab/manual/week04.pdf)

Aperture photometry entails measuring the brightness of a star by means of a (software) aperture to collect the counts from the star. This is done by summing the pixel values within a circular region centered on the star, the aperture. This region includes light from the star as well as light from the sky. To be able to correct for the latter, the sky brightness is measured within an annulus ending the central aperture. Seeing mostly affect the Gaussian core of the image.[10]

The IRAF **digiphot** package contains the **apphot** package with the **IRAF** tool to perform aperture photometry of stars. In which **phot** task evaluates magnitude of a list of stars by doing aperture photometry.[9]

The **phot** computes accurate centers for each object using the centering parameters defined in centerpars, computes an accurate sky value for each object using the sky fitting parameters defined in fitskypars, and computes magnitudes using the photometry parameters defined in photpars. The image data characteristics of the data are specified in datapars. [9]

5.4.1 PHOT TASK

A simple recipe to perform aperture photometry using ,phot task on a few stars, to calculate the magnitudes is as follows [9]:

(a) input stars whose log files have already been created.

(b) set FWHM and standard deviation for background
(eparphot>datapar(:e)>FWHM, sigma).

(c) the value cbox has to be (1-2) x FWHM (phot > centerpar (:e) > cbox).

(d) set the annulus radius to be 4 x FWHM and dannulus = 0.5 x Annulus (approx.)
(phot > fitskypar (:e) > annulus, dannulus).

(e) open photpars > aperture (FWHM value : 5 x FWHM value : 1(increment)).

(f) Save all these and run (:go) .
(g) Open the output file and see where the magnitudes become almost constant then note that serial number , now open photpar> aperture (that serial number). Then save and run.

The magnitude is calculated using an arbitrary value for the zero point, and such magnitudes are referred to as instrumental magnitudes. This stores all information about the parameters and measurements in a text file which is a concatenation of the image name, the extension ***.mag**, and a number which increments each time you run phot on that image again. It is often convenient to extract a selection of output variables from this file, using the IRAF task **txdump**.[9] This magnitude is the instrumental magnitude. Now we have calculated air-mass and then plot between instrumental magnitude vs Air-mass. From the slope we get the atmospheric extinction co-efficient.

- Calculation of Air-mass:

  First ,we have calculated the Julian day for our date of observation to determine the LST (Local Sidereal Time).The Julian day (JD) used in astronomical algorithms, is the number of days since noon at Greenwich on 1 Jan 4713 BC. Local sidereal time is the right ascension of a star on the observer's meridian. One sidereal day corresponds to the time taken for the earth to rotate once with respect to the stars and last approximately 23h 56 min. Then we can calculate the hour angle using the formula,

  HA(Hour angle)=**LST**(Local Sidereal Time)-**RA**(Right Ascension). [11]

  Using hour angle (h), declination of object**(δ)** and latitude of observer**(Φ) ,**we can calculate the air-mass using the formula

  $$X(z) = \sec(z) = 1/(\sin(\delta)\sin(\Phi) + \cos(\Phi)\cos(\delta)\cos(h)) .$$ [3]

Then we plot the magnitude of star and air mass for different filters.

6. RESULT & CONCLUSIONS: Using the slope of the curve i.e. Extinction co-efficient we can redefine the value of instrumental magnitude (by using $\mathbf{m_0(\lambda) = m(\lambda) - k(\lambda).X(z)}$. Here are the plots of a particular star in four different filters—

6.1 PLOTS BETWEEN MAGNITUDE OF STAR vs AIR MASS

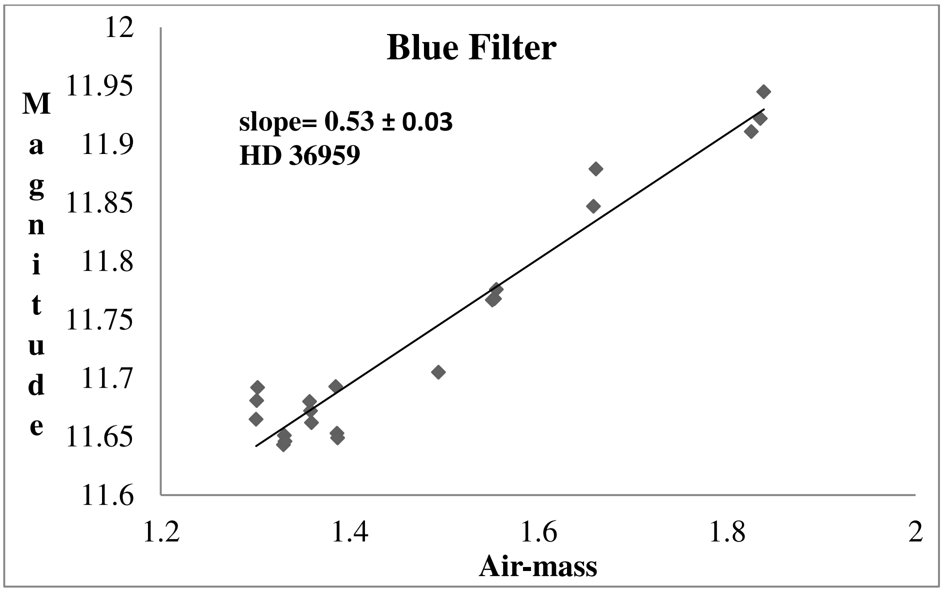

Fig 11: Magnitude vs Air-mass for Blue filter

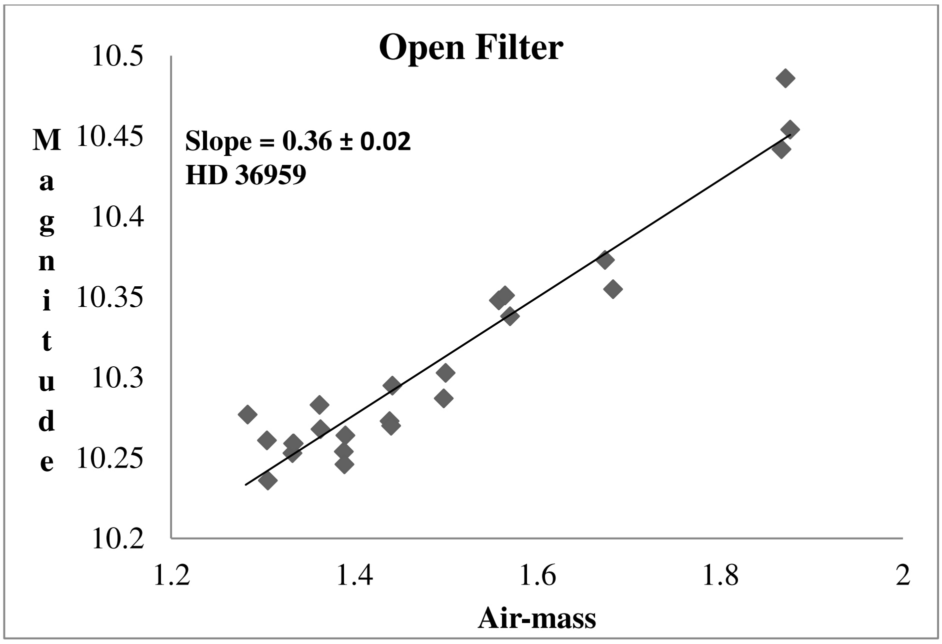

Fig 12: Magnitude vs Air-mass for Open Filter