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CCD Image Reduction of the Dark Energy Survey Data

KAI MING FUNG[1, 2]

[1] Student
[2] University of Illinois Urbana-Champaign

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ABSTRACT

Given some Dark Energy Survey raw data, bias, and flat. By trimming it to match its bias and flat, calibrate the image and extract a flux for a source, one can have a better look on the image from the data. Compared the final reduced image to the 2MASS image with the same coordinate, have found the astrometic offset.

1. INTRODUCTION

The Dark Energy Survey is designed to probe the origin of the accelerating universe and let us discover the nature of dark energy by measuring the 14-billion-year history of cosmic expansion with high precision. DES has been going on over five years imaging 5000 square degrees of the southern sky in five optical filters(g,r,i,z,Y) to obtain detailed information about different galaxy.The instrument used by DES is the Dark Energy Camera(DECam) which is mounted on the Victor M.Blanco 4-meter Telescope at the Cerro Tololo Inter-American Observatory in the Chilean Andes. A brief description of the DECam is that it has five optical lenses, a Hexapod positioning and alignment system, a shutter, a set of color filters, and a digital imager.

The Blanco Telescope was built in 1974. It has a 4-meter diameter aluminum-coated primary mirror and weighs 34,000 lbs. The build of the telescope is able to support the large mass of DECam, and it has a wide-field design for efficient wide field surveys.

For the DECam, the main component of the imager is a set of the CCDs(charge-coupled devices). It has 74 CCDs arranged in a hexagonal pattern on the focal plane of the DECam, and that is where the image will be recorded. The DECam can be red out in less than 30 seconds, which is faster than most CCD cameras in use in astronomy nowadays.

The CCDs for the DES is designed by Lawrence Berkeley National Laboratory to observe red light form the distant galaxies. It is about ten times thicker than conventional CCDs since there is higher chance to detect long wavelength light through silicon.

The observation for DES is from August to February each year. The data management is basically happening in the Dark Energy Survey Data Management system(DESDM).Through the system, the data that DECam took at night will be processed on large computing clusters at NCSA and at Fermilab on the next day. That would basically be the process on how astronomer observe DES and how they deal with the data.

2. DATA

First, all three frames(raw data, bias, flat) are necessary for the calibration.

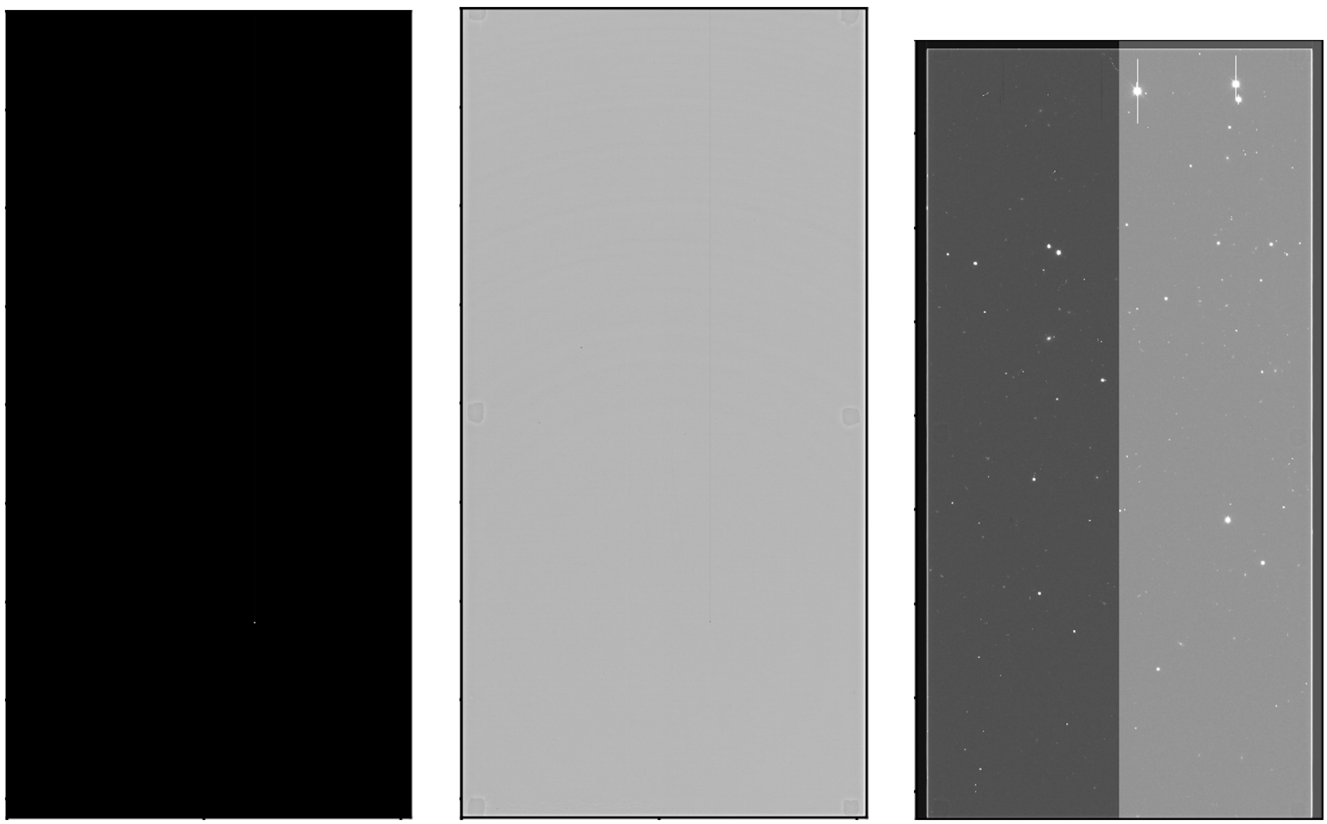
Raw data frame will be the dark frame, which measure dark current, it is the images that used to compensate for the unwanted 'dark signal'. Therefore, it will contain lots of noise in the frame. Notice that this exposure image is slightly larger than the flat and bias, so will have to trim it first before using it for the calibration.

Bias frames is used to compensate for the readout noise of the camera. Since the noise is present in the flats, we need to subtract it out from the data we processed to remove the noise.

Flats frames are measures pixel-by-pixel difference in the response, so we need to divide it by the data we processed.

The raw data obtained has an coordinate RA(Right Ascension)=49.298204 and DEC(Declination)=-13.114888 as noticed from the header of the file. It gives the area in a certain longitude and latitude to the surface of the Earth. It has shown that its used 2 amplifier with the left and right separation on the chip from its header.

Also, the bias and flat data for the same area. However, the raw data is 2160 × 4146, and bias and flat data is at the size of 2048 × 4096. Therefore, the raw data needs to be fixed and trimmed before getting the final result. See `Fig.1` for the frame images.`Fig.2` has shown the value of all three data from a histogram.



(a) (b) (c)

Figure 1. (a) Bias data(vmin=0, vmax=40000), (b) Flat data(vmin=0, vmax=1.4), (c) Raw data(vmin=1600, vmax=3000)

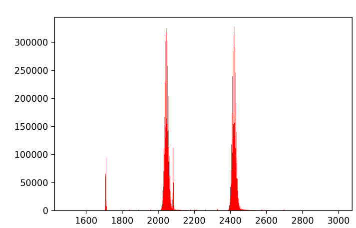


Figure 2. Histogram with all three data

3. METHODS AND ANALYSIS

First, use python to read out the raw data, and see how the image looks. Then, fix the chip difference in the data by subtracting the median of each side of the chip. This process and the result will be shown on `Fig.3` and `Fig.4`(vmin=300, vmax=500).

Since the raw data is larger size than the bias and flat, trim the data to be the same size as the bias and flat frames. `Fig.5` and `Fig.6` will be the coding process and the result of the trimmed data.

```python
hdul = fits.open('DECam_00380036_09.fits')

image_data = hdul[0].data

row=[]
newdata=[]
newrow=[]
for row in image_data:
    m1=np.median(row[6:55])
    m2=np.median(row[2104:2151])
    newrow=[]
    for i in range(len(row)):
        if i>=57 and i<=1079:
            newrow.append(row[i]-m1)
        elif i>=1080 and i<=2103:
            newrow.append(row[i]-m2)
        else:
            newrow.append(row[i])
    newdata.append(newrow)

plt.imshow(newdata, cmap='gray',vmin=300,vmax=500)
plt.colorbar()
print('Min:', np.min(newdata))
print('Max:', np.max(newdata))
print('Mean:', np.mean(newdata))
print('Stdev:', np.std(newdata))
plt.savefig('mediancorrecteddata.png', dpi = 300)

```

Figure 3. (a) Python code for the raw data

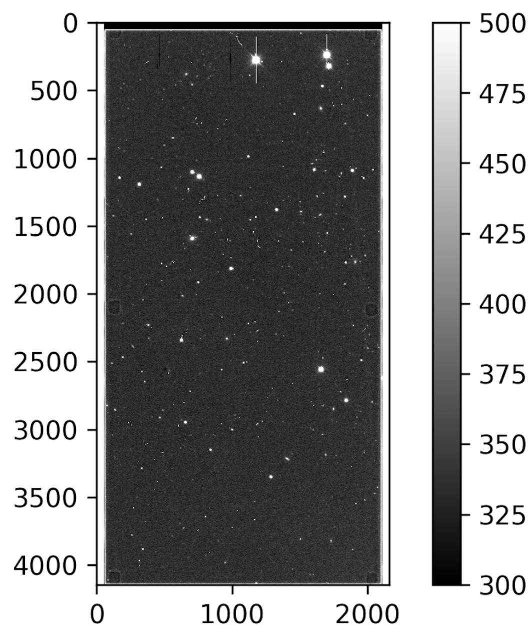


Figure 4. (a) Image with the median corrected

Finally, to see the calibration result by subtracting the bias from the trimmed data and divide that data by flat. By using the code shown in `Fig.7`, read-in the bias and flat data, then subtract the trimmed data with the bias and divide that by the flat data. That will be the final reduced DES image at `Fig.8` .

4. DISCUSSION AND CONCLUSIONS

Using the RA and DEC information from the header of the data, we can do a check on the astrometry using 2MASS data. It's noticeable that the DES image has some astrometric offset comparing to the 2MASS astrometry.

For the astrometry offset, I used the RA, DEC in the header of the sources:

$CRVAL1 = 49.298204/[deg]WCSReferenceCoordinate(RA)$

$CRVAL2 = -13.114888/[deg]WCSReferenceCoordinate(DEC)$

```python
temprow=[]
trim_row=[]
trim_data=[]
for i in range(len(newdata)):
    if i>=50 and i<=4146:
        temprow=newdata[i]
        trim_row=temprow[56:2104]
        trim_data.append(trim_row)

plt.imshow(trim_data, cmap='gray',vmin=300,vmax=500)
plt.colorbar()
print('Min:', np.min(trim_data))
print('Max:', np.max(trim_data))
print('Mean:', np.mean(trim_data))
print('Stdev:', np.std(trim_data))
plt.savefig('trimmeddata.png', dpi = 300)
```

Figure 5. (a) Python code for the trimmed data

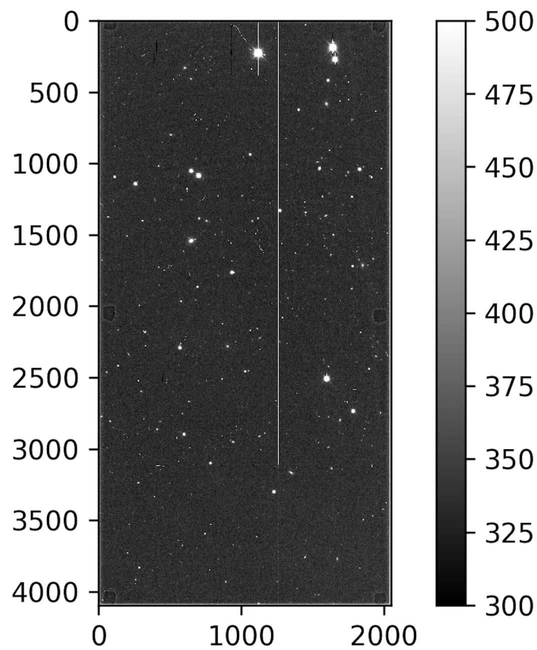


Figure 6. (a) Trimmed data image

```python
bias0=fits.open('D_n20131112t1127_c13_r1472p01_biascor.fits')
bias=hdul[0].data

flat0=fits.open('D_n20131112t1127_r_c13_r1472p01_dflatcor.fits')
flat=hdul[0].data

finaldata=[]
finaldata=(newdata - bias)/flat

plt.imshow(finaldata, cmap='gray',vmin=300,vmax=500)
plt.colorbar()
print('Min:', np.min(finaldata))
print('Max:', np.max(finaldata))
print('Mean:', np.mean(finaldata))
print('Stdev:', np.std(finaldata))
plt.savefig('finaldata.png', dpi = 300)
```

Figure 7. Final data code

By using this RA, DEC information to get the .fits file from 2MASS,
I found that the image I got from 2MASS image has the RA, DEC as:
$CRVAL1 = 49.30277151/RAatFrameCenter, J2000(deg)$
$CRVAL2 = -13.01190357/DecatFrameCenter, J2000(deg)$

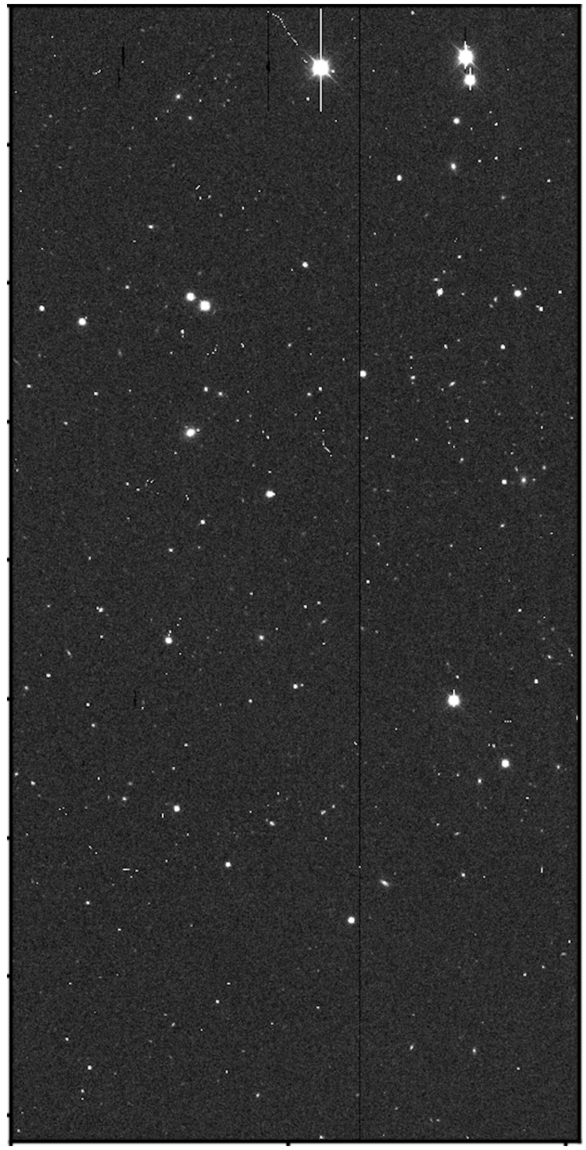


Figure 8. Final reduced DES image(vmin=300, vmax=500)

So the RA, DEC are off by $49.298204 - 49.30277151 = -0.00456751$ and $-13.114888 - (-13.01190357) = -0.10298443$ in degrees, which will be:

-16.44303599995 and -370.7439479989 in arcsecond.

CCD has given a great advantage for astronomer to observe the galaxy. The increase in magnitudes limitation, and good quantum efficiency is a big step for astronomy. However, it still face some problems such as the cooling issue, and the reading time issue. Also the reading noise is one of the factor astronomer needs to deal with after they collected the data. There are still much room to improve the detector to achieve better results.

APPENDIX

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REFERENCES

Drlica-Wagner, A.; Sevilla-Noarbe, I.; Rykoff, E. S.; Gruendl, R. A.; Yanny, B.; Tucker, D. L.; Hoyle, B.; Carnero Rosell, A.; Bernstein, G. M.; Bechtol, K.; and 80 coauthors, et al. 2018, ApJS, 235, 33