LAB #3 — REPORT

38 points possible

All materials must be uploaded to Gradescope by 10 am on Thursday, February 10, 2022 (see submission instructions in lab instructions).

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At the end of the lab, you should have created the following items in your working directory:

- This report, edited and filled out

- Copies of your journal files

- imp\_cal.pro (must also be pasted at the end of this report)

- rover\_raw.tif + sky\_raw.tif

- rover\_nobadpixels.tif + sky\_nobadpixels.tif

- rover\_nodark.tif + sky\_nodark.tif

- rover\_final.tif + sky\_final.tif

**1. Raw images**

(a) Paste “rover\_raw.tif” and “sky\_raw.tif” below [2 pts]:



(b) What potential problems do you observe in these images? List at least two. [2 pts]:

There are some clear bright pixels that should be removed. In the Sky image, it is clear that there is darkening to the right side and stripping. The rover image also shows darkening to the right side of the image. The darkening is probably due to dark current affecting the detector, while the stripping is related to responsivity, and needs to be removed by a flat field.

**2. Bad pixel correction**

(a) Evaluate the quality of your corrected image. Did your program fix the obvious bad pixels? Did it overcorrect the image? [1 pt]:

Yes, my program fixed the obvious bad pixels, and did not over correct the image. It replaced 250 pixels or 0.4% of the image.

(b) Paste “rover\_nobadpixels.tif” and sky\_nobadpixels.tif” below [2 pts]:



(c) How many "bad" pixels did you replace in each of the six raw images? [2 pts]:

Rover\_red: 250

Rover\_grn: 383

Rover\_blu: 344

Sky\_red: 210

Sky\_grn: 93

Sky\_blu: 154

**3. Dark current correction principles**

1. What are typical DN values for the raw images, and how does the bias value compare to these values? [1 pt]:

The typical DN for the raw images is:

Sky red: 2500-6500, mean: 4700

Sky blu: 2500-6500, mean: 4500

Sky grn: 2500-6500, mean: 4675

Rover red: 500-5500, mean: 3405

Rover blu: 500-5000, mean: 3176

Rover grn: 500-5000, mean: 3350

The bias value should be much lower than the observations, otherwise the exposure time is not long enough to make reasonably high SNR for scientific observations.

1. For this filter wheel system, why is there only one dark\_lab image, and not one for each R/G/B image? [1 pt]

For this filter wheel system, there is only one dark lab image because you cannot have a filter on the instrument with the shutter closed, which is how the dark is taken. Thus, the dark needs to cover the full wavelength range of the instrument, and is not able to be limited to the filter ranges.

(c) What do you think might cause the dark current to increase toward the top of the image? [1 pt]:

The dark current increases towards the top of the image due to heating of the instrument internally.

(d) Do you detect any evidence of frame transfer smear (i.e., "electronic shutter effect") across the raw images, and in which direction (horizontally or vertically)? [1 pt]:

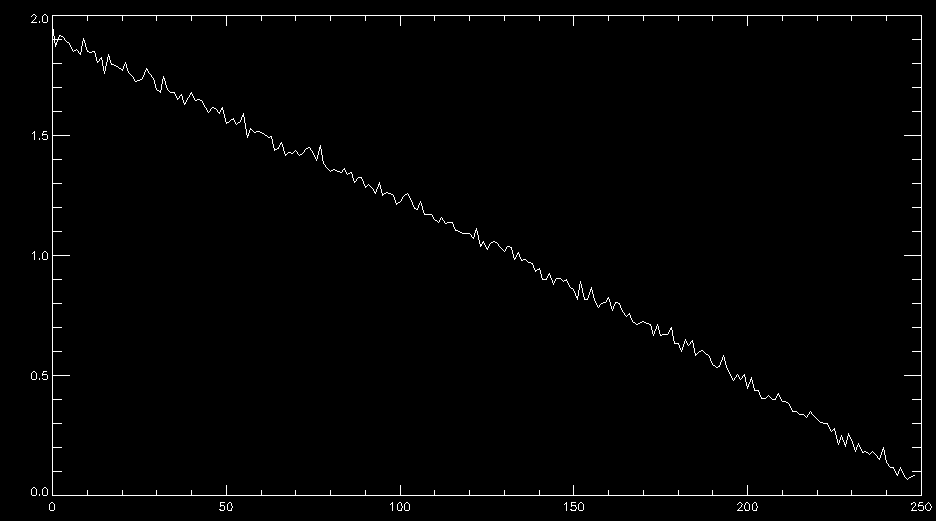
The image of the shutter from lab clearly shows frame transfer smear, horizontally across the image. This is not as obvious on the raw images.

(e) What is the average percent increase in DN across the image due to frame transfer smear? [1 pt]

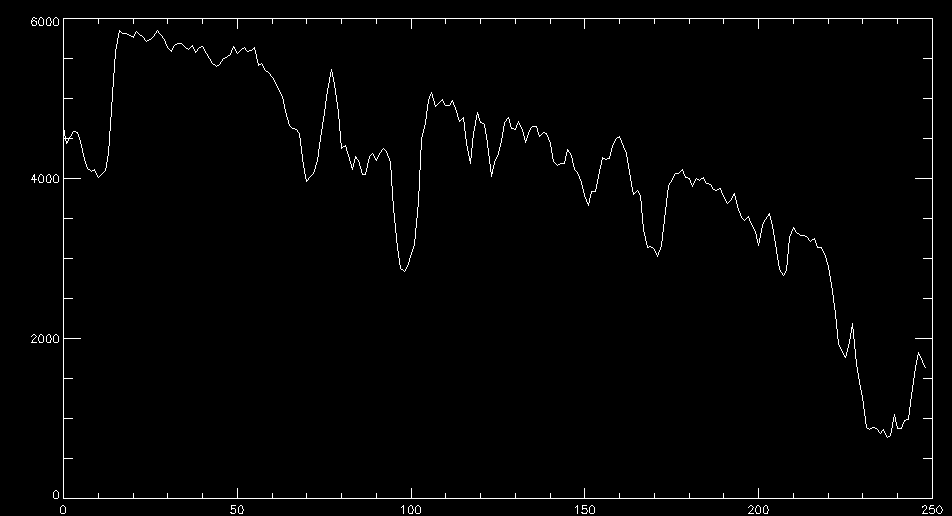
The average percent increase in DN across the image due to frame transfer smear is

2 out of 6000-2000.

Shutter lab cross at x=90



Rover red cross at x=90



**4. Remove the dark current**

1. Paste rover\_nodark.tif and sky\_nodark.tif below. [2 pts]:



(b) Did the dark model correct the frame transfer smear that you measured in the last part? How can you tell? [2 pts] :

The dark model corrected the brightness change across the frame.

(c) Describe any residual patterns or artifacts that remain in the images after this step in the processing (experiment with stretching on the sky images). [2 pts]:

There is still a dark spot in the corner of the rover image. The sky still has cross hatches (needs flat).

**5. Flatfield correction**

1. Why is the flatfield image divided out of the scene while the dark current is subtracted? [1 pt]:

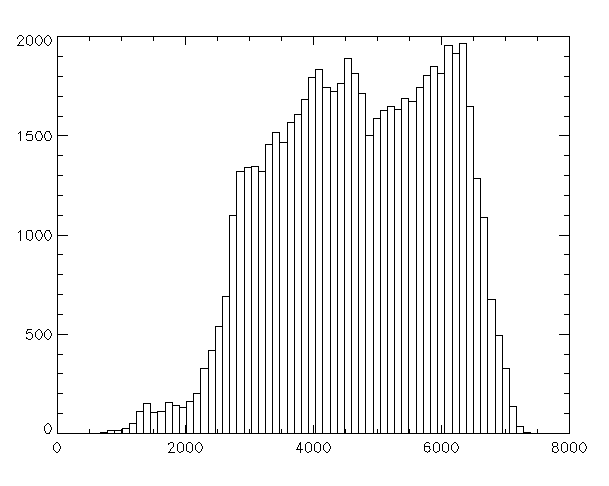
The flatfield is divided out of the scene because it accumulated over the exposure time along with the image, as the flat field is related to responsivity variability across the pixels in the CCD. The longer the exposure, then more obvious the difference. The dark current is subtracted as it is a constant, unaffected by the exposure time of the image.

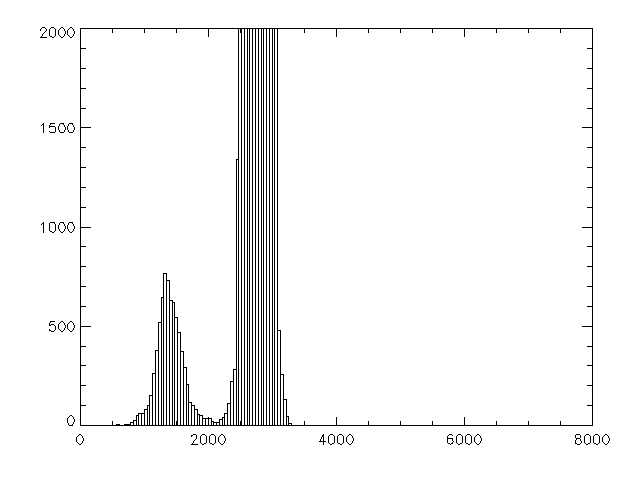
(b) Paste rover\_noflat.tif and sky\_noflat.tif below. [2 pts]:



(c) Take a look at your flat-field corrected images. Describe some of the improvements. Was anything made worse? If so, please elaborate. [3 pts]:

Some improvements to the flat field corrected images are the removal of the brightness gradient across both images such that they are generally uniformly bright in the horizontal. Both images are overall darker (the saved .tif values don’t show that very well, but the histogram will). I don’t see anything obvious that has been made worse.

sky\_red\_nobad, shows a span of values

sky\_red\_noflat, shows a much smaller concentration of values with a clear difference in the brightness values of the sky and of the surface.

**6. Responsivity correction**

1. Thinking back to lecture, why is the responsivity at blue wavelengths so much less than at red wavelengths? [1 pts]:

The quantum efficiency of a CCD favors red and infrared wavelengths. The responsitivity at the blue wavelengths is due to the penetration depth of shorter wavelength photons into the sensor.

1. Paste rover\_final.tif and sky\_final.tif below. [2 pts]:



**7. The reveal!**

(a) What color is the Martian sky? [1 pts]:

The sky is an orange color (likely due to lofted dust).

1. What color are the rover wheels (and why)? [2 pts]:

The image is sort of dark but they look reddish around the rims (collecting mars dust!) and grey (the actual color of the wheels, not coated in martian dust)

8. Paste the text from your final version of imp\_cal.pro below. [6 pts] :  
***This step is required to receive points on this lab.***

;

; imp\_cal.pro

;

; Created by Kris Laferriere on Feb 1, 2022

;

; Purpose: To calibrate images from the Imager for Mars Pathfinder camera (IMP).

; Includes bad pixel correction, dark current subtraction, flat field correction,

; and responsivity correction.

;

; Inputs: red, grn, blu = names of images to be corrected (requires all three).

; Calibration data (imp\_cal.sav) must also be in working directory.

;

; Outputs: writes images files at each step to working directory

**PRO** **imp\_cal**, red, grn, blu, t, temp, title

; write out the raw image in true color

**write\_true\_color**, red, grn, blu, title+'\_raw'

; -------------- Bad pixel correction --------------

;create a new image for each channel (r/g/b) that has bad pixels replaced

;with the median of their surroundings

val = **3** ; defines the width of the median

sig = **2** ; defines the cut off for bad pixels (\*STDEV)

red\_nobad = **replace\_bad\_pixels**(red, val, sig)

grn\_nobad = **replace\_bad\_pixels**(grn, val, sig)

blu\_nobad = **replace\_bad\_pixels**(blu, val, sig)

; write out nobadpixels RGB image in true color

**write\_true\_color**, red\_nobad, grn\_nobad, blu\_nobad, title+'\_nobadpixels'

**save**, red\_nobad, grn\_nobad, blu\_nobad, filename=(title+'\_nobad.sav')

; -------------- Dark Current Subtraction --------------

; restore the calibration data

**restore**, 'lab3\_cal.sav'

; create dark current model (the formula defined in the lab instructions)

D = dark\_lab

S = shutter\_lab

; For IMP instrument

Hoff = **8.27**

Ad = **3.016**

Bd = **0.105**

As = **2.845**

Bs = **0.105**

An = **4.05**

Bn = **0.144**

dn\_dark\_red = Ad\*t[**0**]\***exp**(temp[**0**]\*Bd) \* D + **4000.00**\*As\***exp**(temp[**0**]\*Bs) \* S + An\* **exp**(temp[**0**]\*Bn) + Hoff

dn\_dark\_grn = Ad\*t[**1**]\***exp**(temp[**1**]\*Bd) \* D + **4000.00**\*As\***exp**(temp[**1**]\*Bs) \* S + An\* **exp**(temp[**1**]\*Bn) + Hoff

dn\_dark\_blu = Ad\*t[**2**]\***exp**(temp[**2**]\*Bd) \* D + **4000.00**\*As\***exp**(temp[**2**]\*Bs) \* S + An\* **exp**(temp[**2**]\*Bn) + Hoff

; create nodark images by subtracting the dark current model from nobadpixels

red\_nodark = red\_nobad - dn\_dark\_red

grn\_nodark = grn\_nobad - dn\_dark\_grn

blu\_nodark = blu\_nobad - dn\_dark\_blu

; write out the nodark RGB image in true color

**write\_true\_color**, red\_nodark, grn\_nodark, blu\_nodark, title+'\_nodark'

**save**, red\_nodark, grn\_nodark, blu\_nodark, filename=title+'\_nodark.sav'

; -------------- Flat Field Correction --------------

; create noflat images by dividing by the flatfield images

red\_noflat = red\_nodark/ff\_red

grn\_noflat = grn\_nodark/ff\_grn

blu\_noflat = blu\_nodark/ff\_blu

; write out noflat RGB image in true color

**write\_true\_color**, red\_noflat, grn\_noflat, blu\_noflat, title+'\_noflat'

**save**, red\_noflat, grn\_noflat, blu\_noflat, filename=(title+'\_noflat.sav')

; -------------- Responsivity Correction --------------

A1 = [**557.3**, **578.6**, **117.9**]

A2 = [-**0.575**,-**0.893**, -**0.392**]

A3 = [-**0.0014**, -**0.002**, -**0.0006**]

; Calculate responsivity for each filter (RGB) at input temperature

R\_red = A1[**0**] + A2[**0**]\*temp[**0**] + A3[**0**]\*temp[**0**]^**2**

R\_grn = A1[**1**] + A2[**1**]\*temp[**1**] + A3[**1**]\*temp[**1**]^**2**

R\_blu = A1[**2**] + A2[**2**]\*temp[**2**] + A3[**2**]\*temp[**2**]^**2**

; create final images by dividing by the responsivty and time

red\_calib = red\_noflat/t[**0**]/R\_red

grn\_calib = grn\_noflat/t[**1**]/R\_grn

blu\_calib = blu\_noflat/t[**2**]/R\_blu

**write\_true\_color**, red\_calib, grn\_calib, blu\_calib, title+'final'

**save**, red\_calib, grn\_calib, blu\_calib, filename=(title+'\_final.sav')

; write out final RGB image in true color (yay!)

**END**

Call with

IDL> imp\_cal, sky\_red, sky\_grn, sky\_blu, [0.0910, 0.1185, 0.8105], [-15.7921, -15.7921,-15.7921], 'sky'

IDL> imp\_cal, rover\_red, rover\_grn, rover\_blu, [0.1080, 0.1985, 1.527], [-17.6433, -17.6433, -17.6433], 'rover'