EE475/575
Digital Image Processing

Project 1
Fall 2019

Estimating Signal-to-Noise Ratio (SNR)

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1. Show a figure of each image (6 figures total) with the appropriate grayscale colormap.

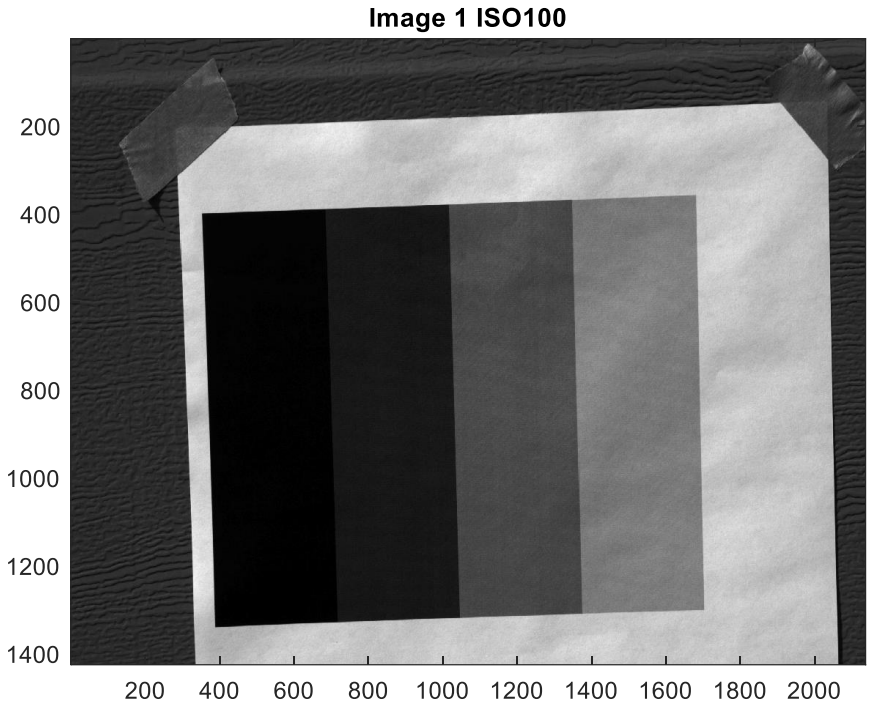

Figure 1: Gray scale of Image 1 @ISO 100

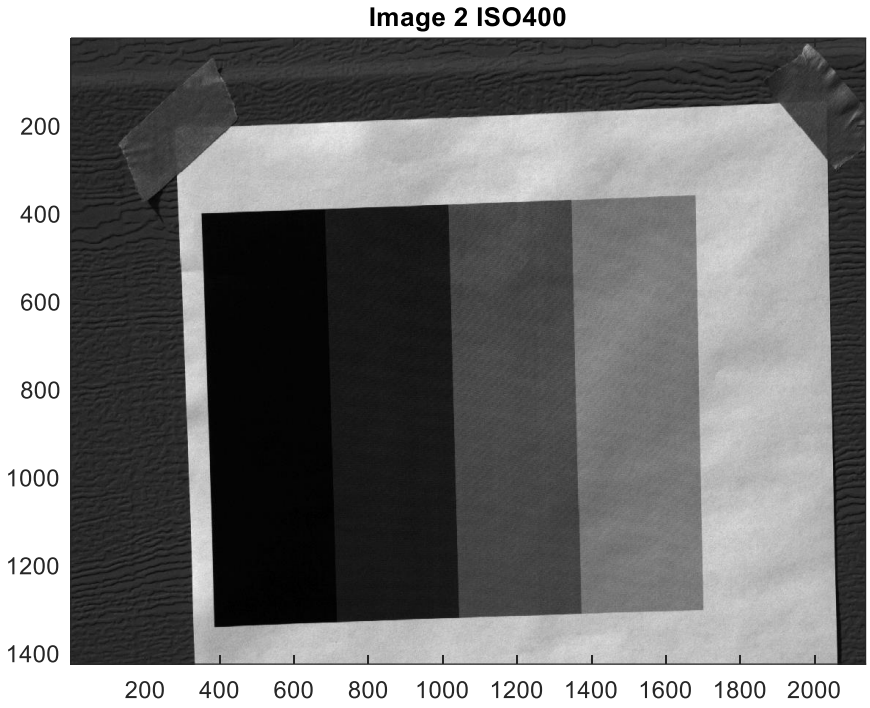

Figure 2: Gray scale of Image 2 @ISO400

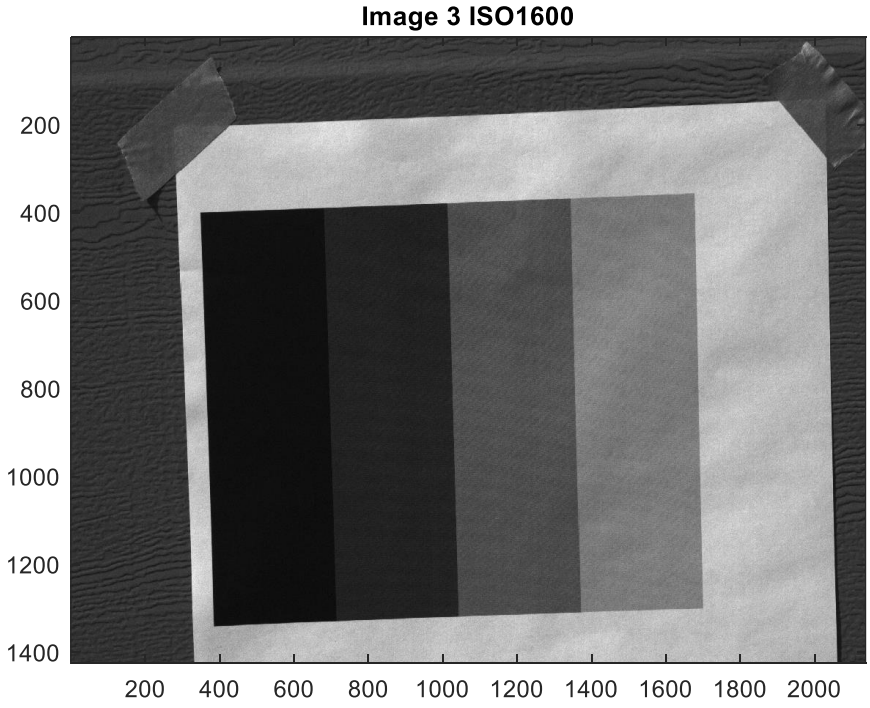

Figure 3: Gray scale of Image 3 @ISO 1600

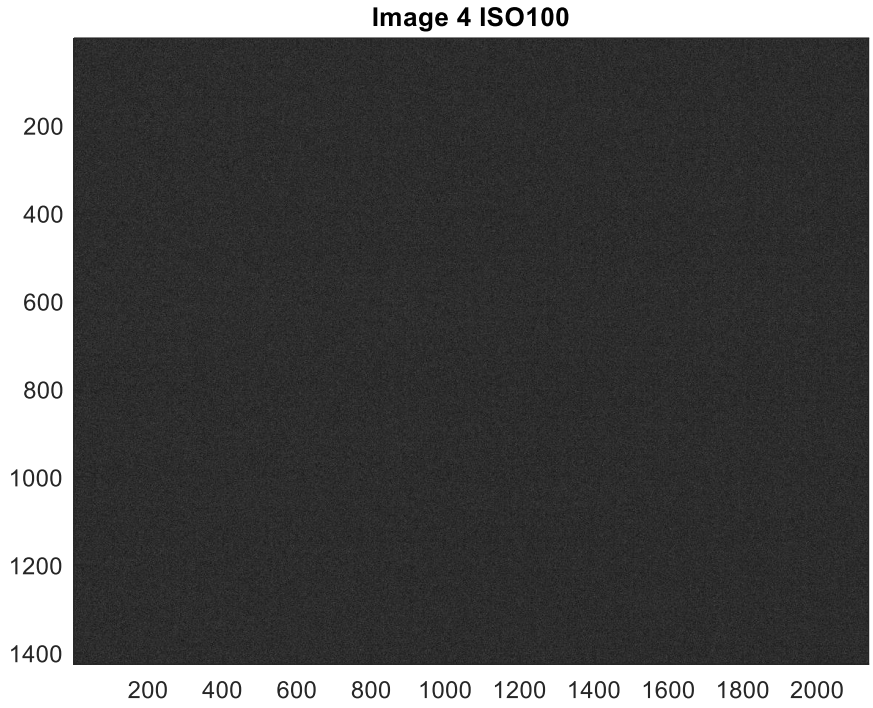

Figure 4:Gray scale of Image 4 @ISO100

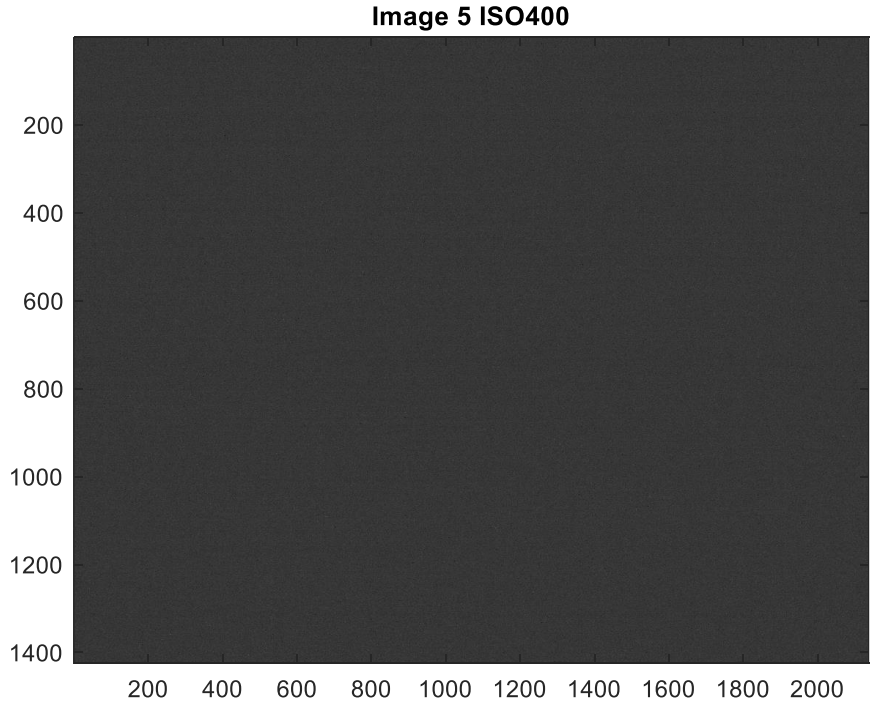

Figure 5:Gray scale of Image 5 @ISO400

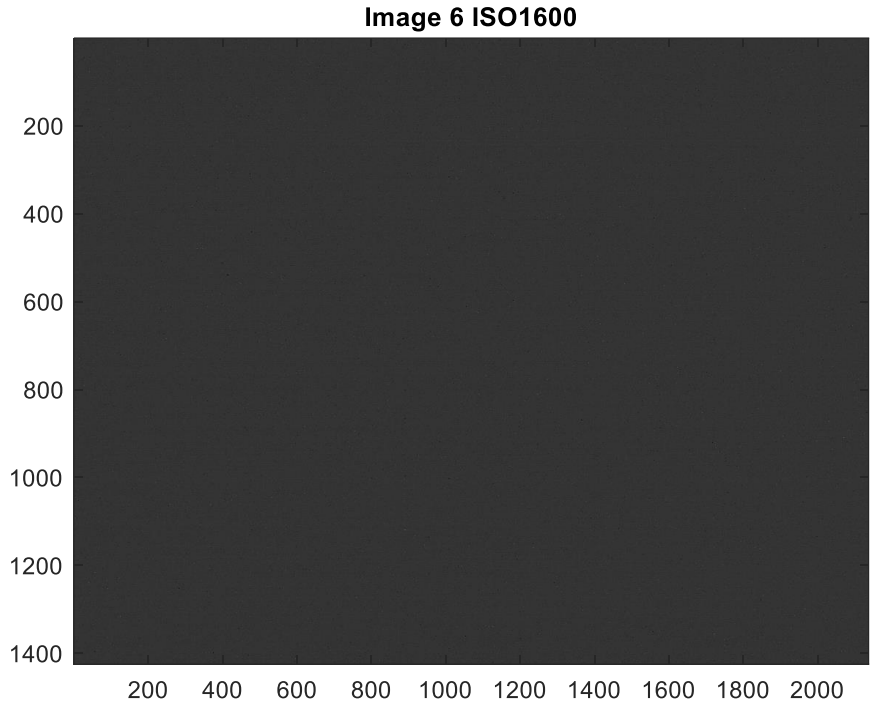

Figure 6: Gray scale of Image 6 @ISO1600

2. Show a plot from each figure of row 800. Describe how each region of the plot corresponds to the image.

   From 400 to 2000, the step signal shows the intensity of the bands. With lowest intensity for the darkest band and highest intensity for the brightest band, Fig.2, Fig.3, Fig.4.

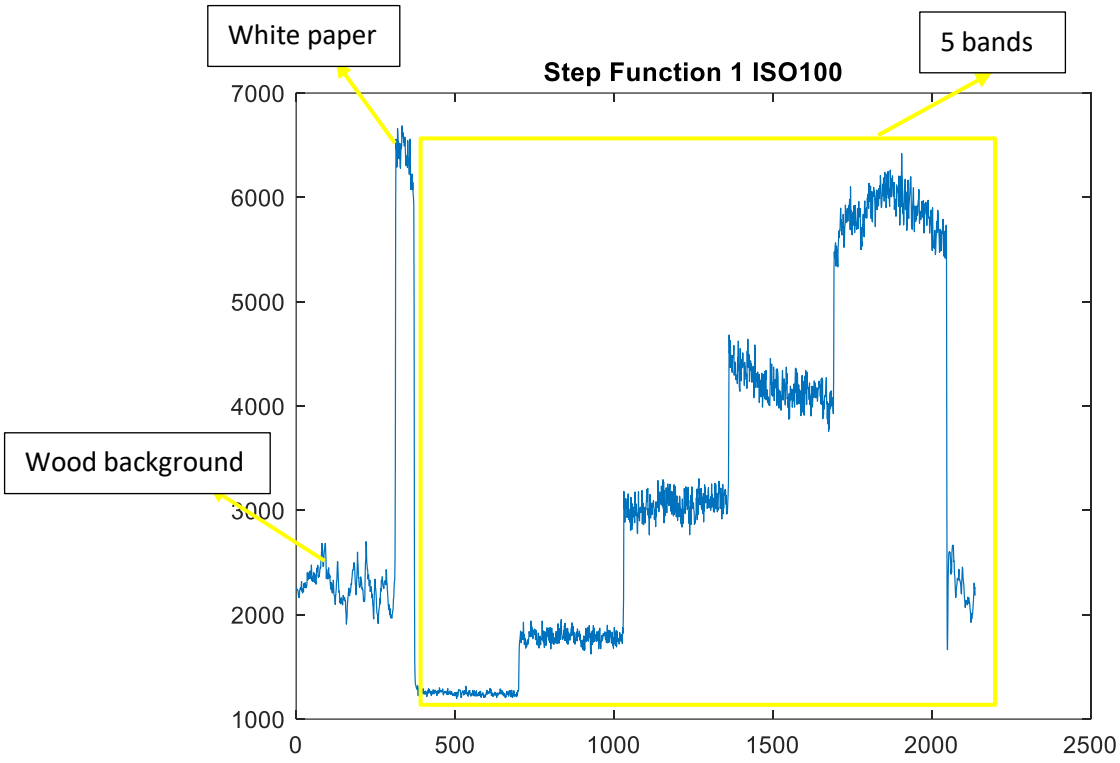

Figure 7: Mach band analysis of Image 1 @ISO100

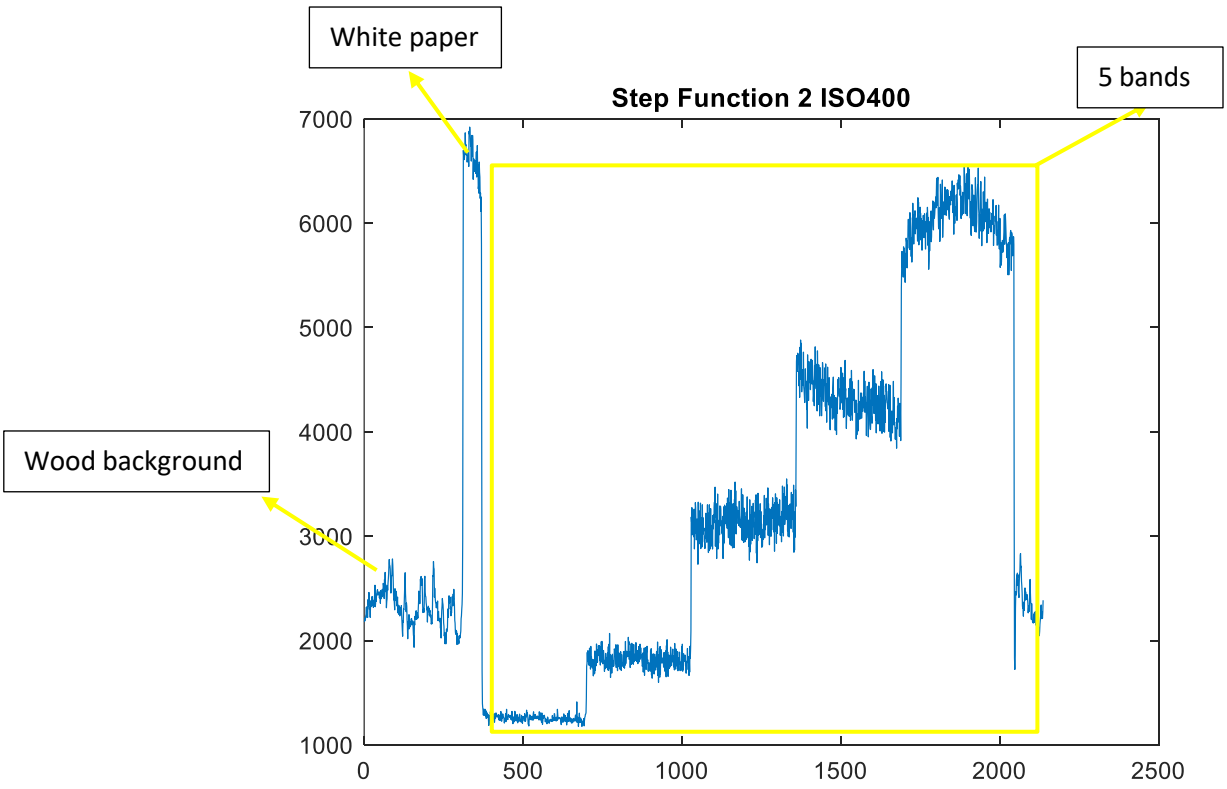

Figure 8: Mach band analysis of image 2 @ISO 400

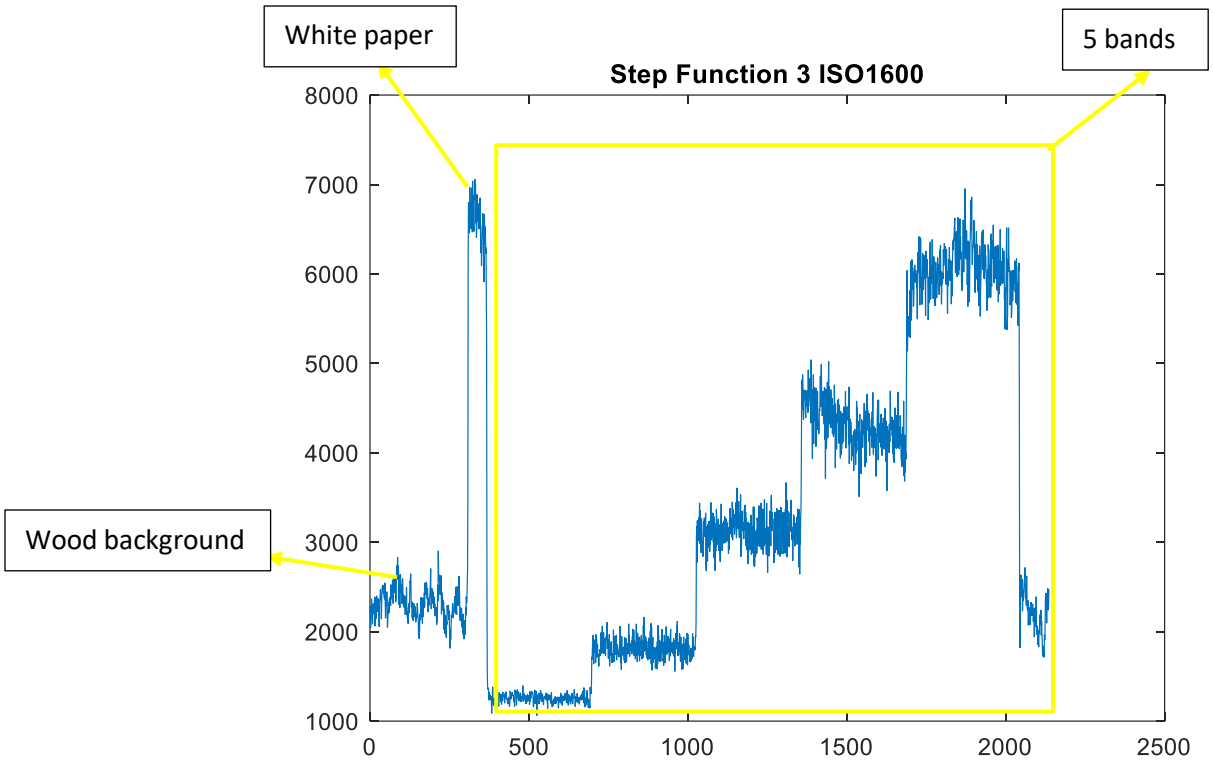

Figure 9: Mach band analysis of Image 3 @ISO1600

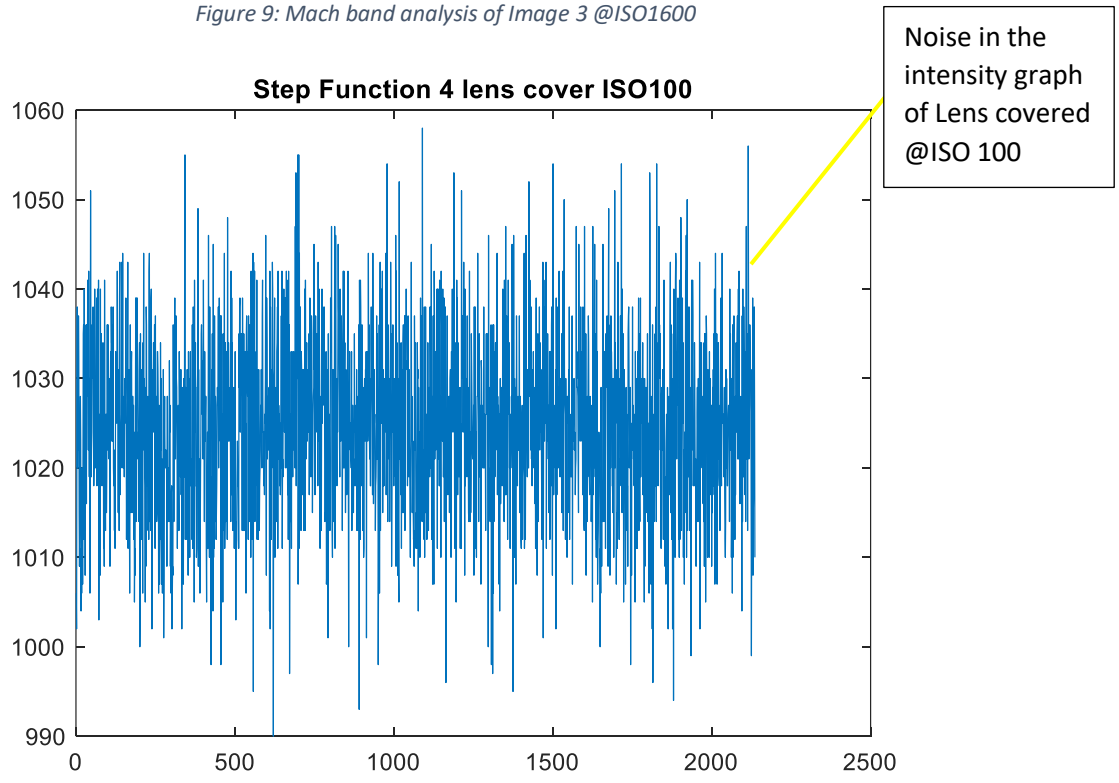

Figure 10: Mach band analysis of Image 4 @ISO100

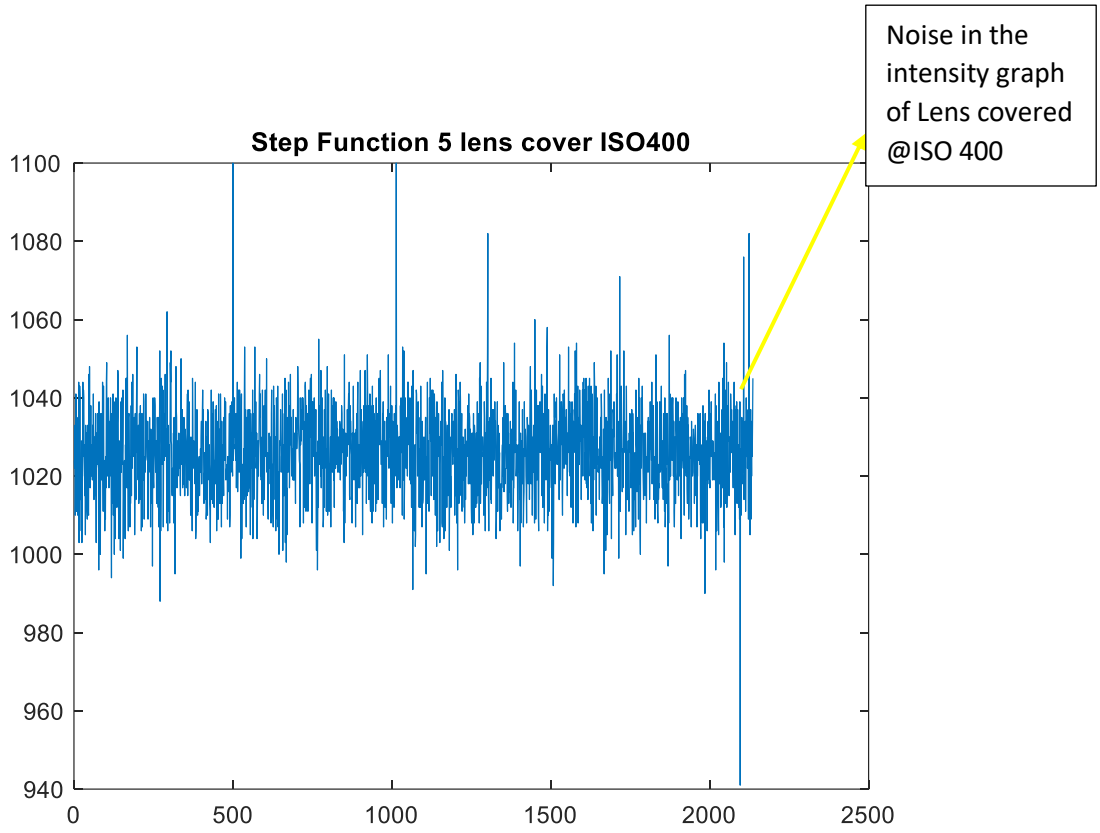

Figure 11:Mach band analysis of image 5 @ISO400

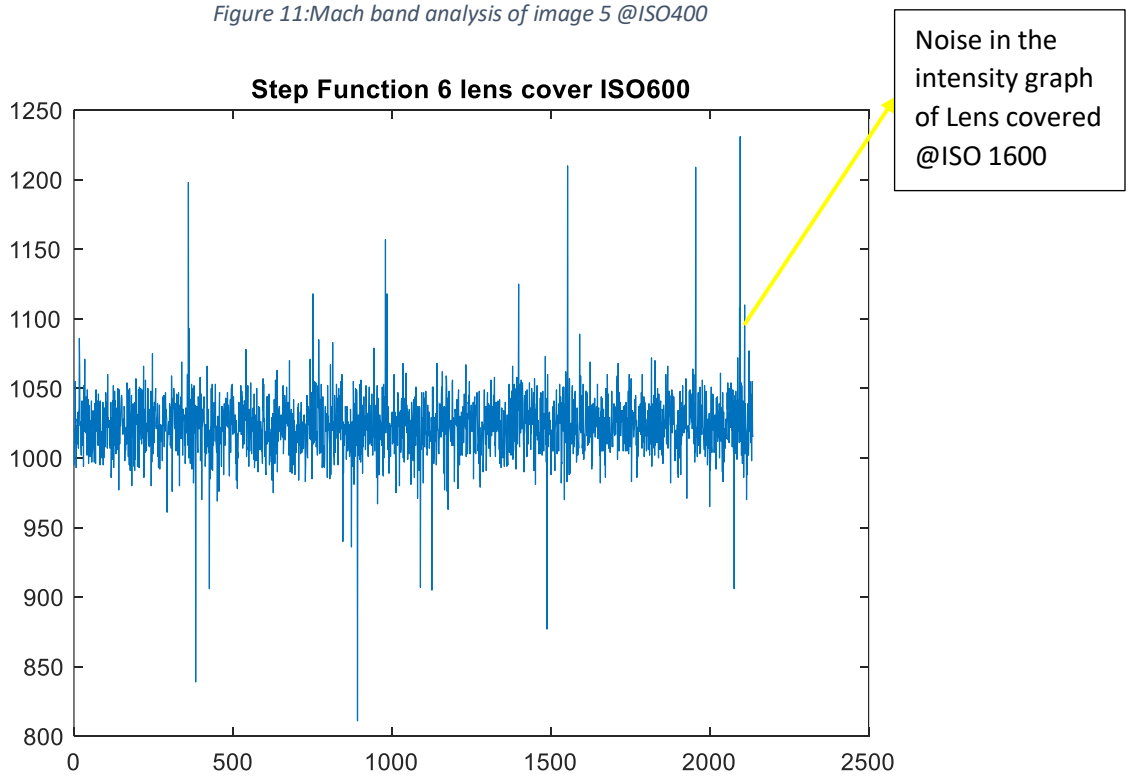

Figure 12: Mach band analysis of Image 6 @ISO1600

It is evident from the intensity graph of "lens covered" images that when the ISO increases, the noise in the systems also increases.

3. Calculate the SNR from the images of the lens cover. Describe your procedure.

Table 1: SNR values for Lens closed images

	SNR
Project1_4_ISO100	102.25
Project1_5_ISO100	89.25
Project1_6_ISO100	47.63

To calculate the SNR, (1) was used. Mean and standard deviation was calculated for all three "No Lens" images. Standard deviation and Mean were calculated by using standard and mean function and was stored in the same array/matrix as the SNR values for three blue Mach band images.

$$SNR = \frac{\bar{s}}{\sigma_s} \qquad (1)$$

4. Calculate the SNR from the three blue mach band images. Here you will have five different signal levels at which you can estimate SNR. Describe your procedure.

The three mach band images were separated using poly2mask function. X and Y coordinates were measured from the original images using cursor and then they were recorded in an array. Later, the recorded coordinates values were used to extract each band from the images i.e the desired band was multiplied by 1 and rest with 0. Later, all 0 were declared to NaN, so that they don't affect the SNR calculation.

Table 2: SNR values for mach band images

	SNR of 1st band from left (MB1)	SNR of 2nd band from left (MB1)	SNR of 3rd band from left (MB1)	SNR of 4th band from left (MB1)	SNR of 5th band from left (MB1)
Project1_1_ISO100	39.42	30.55	23.96	24.12	24.99
Project1_2_ISO400	34.21	21.95	18.64	20.81	23.72
Project1_3_ISO1600	23.42	16.62	15.29	17.16	19.40

5. Make a table that includes the following data for each of the three ISO settings: ISO, bias or mach band level (six levels, call them 'Bias' and 'MB1-5'), min pixel value, max pixel value, mean pixel value, standard deviation, and SNR.

Table 3: SNR values for mach band images 

ISO		MIN	MAX	MEAN	STD	SNR
100	BIAS	972	1264	1025.58	10.03	102.25
	MB1	1143	1551	1246.37	31.61	39.42
	MB2	1491	2077	1757.28	57.51	30.55
	MB3	2502	3571	2968.24	123.86	23.96
	MB4	3521	4986	4200.43	174.11	24.12
	MB5	5064	6826	5947.06	237.95	24.99
400	BIAS	877	1549	1026.42	11.49	89.25
	MB1	1120	1572	1253.14	36.62	34.21
	MB2	1473	2224	1785.12	81.32	21.95
	MB3	2424	3824	3048.32	163.53	18.64
	MB4	3548	5421	4323.66	207.71	20.81
	MB5	5135	7118	6133.00	258.54	23.72
1600	BIAS	525	2912	1026.03	21.54	47.63
	MB1	748	2685	1248.23	53.29	23.42
	MB2	1308	2834	1779.51	107.05	16.62
	MB3	2199	4085	3036.24	198.54	15.29
	MB4	3275	5492	4313.18	251.24	17.16
	MB5	4816	7563	6114.19	315.15	19.40

6. Make a plot of SNR vs. mean signal level for the three ISO setting (that is, three curves on one plot).

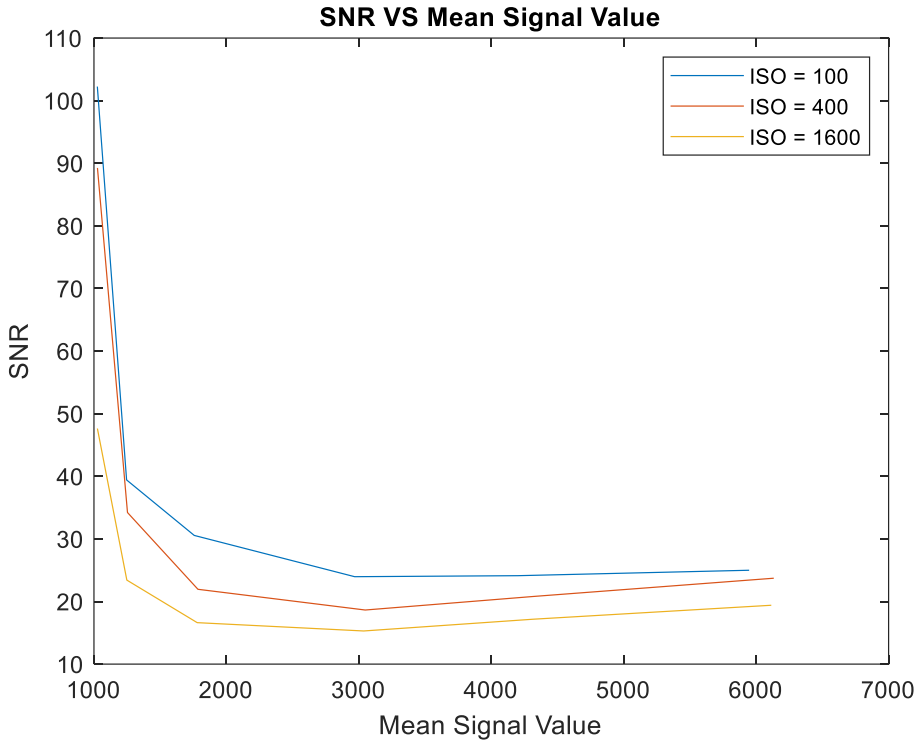

Figure 13: SNR vs Mean signal value

7. Answer the following questions:
    a. How does SNR vary with signal level?

       SNR decreases as the mean signal level increases.

    b. How does SNR vary with ISO (amplifier gain)?

       SNR decreases with the ISO increases, since noise in systems increases with the increase in ISO.

    c. Based on our noise studies in class, which type of noise seems to dominate?

       Photon noise seems to dominate the most, since when the shutter speed increased the number of photons decreased and hence the total SNR decreased. Thermal noise is always present.

    d. Is your SNR analysis consistent with what we've studied thus far?

       Yes, the SNR analysis is consistent so far. Since, we studied about photon noise and ISO noise i.e. how increasing the gain increases the noise in the system.

e. For reference, a good Earth Observing (EO) optical imaging system will have an SNR in the 100 to 300 range. How does our camera compare?

Our camera is suitable for EO optical imaging system. Since, the only time SNR of our camera touches 100 is when the camera lens is covered.

f. Describe any anomalies you may have observed in the image data that may have limited your ability to get an accurate estimate of SNR.

Masking of mach bands was not accurate, since, it was done manually by measuring x and y co-ordinates using a cursor. Hence, the boundaries of each band were not measured accurately. This lead to slight inaccuracy in SNR estimation.

Appendix

```
%Author: Harsh Dubey
%Citations:
% 1). Lin Zeng and I worked together, shared Ideas and
discussed the HW but didn't looked at each other's code.

close all, clear all

%Part 1 and 2:
%for image1_ISO100
filename = 'Project1_1_ISO100.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_1 = blue;
figure;
imagesc(ques1_1);
title('Image 1 ISO100');
colormap(gray);
figure; plot(ques1_1(800,:));
title('Step Function 1 ISO100');

%for image2_ISO400
filename = 'Project1_2_ISO400.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_2 = blue;
figure;
imagesc(ques1_2);
title('Image 2 ISO400');
colormap(gray);
figure; plot(ques1_2(800,:));
title('Step Function 2 ISO400');

%for image3_ISO1600
filename = 'Project1_3_ISO1600.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_3 = blue;
figure;
imagesc(ques1_3);
title('Image 3 ISO1600');
colormap(gray);
figure; plot(ques1_3(800,:));
title('Step Function 3 ISO1600');

%for image4_ISO100
```

```
filename = 'Project1_4_ISO100.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_4 = blue;
figure;
imagesc(ques1_4);
title('Image 4 ISO100');
colormap(gray);
figure; plot(ques1_4(800,:));
title('Step Function 4 lens cover ISO100');

%for image5_ISO400
filename = 'Project1_5_ISO400.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_5 = blue;
figure;
imagesc(ques1_5);
title('Image 5 ISO400');
colormap(gray);
figure; plot(ques1_5(800,:));
title('Step Function 5 lens cover ISO400');

%for image6_ISO1600
filename = 'Project1_6_ISO1600.dng'; % Put file name here
run('Load_Canon_Raw.m');
ques1_6 = blue;
figure;
imagesc(ques1_6);
title('Image 6 ISO1600');
colormap(gray);
figure; plot(ques1_6(800,:));
title('Step Function 6 lens cover ISO600');

%Part 3:

%Image 1
%first mach
x = [360 676 708 395 360];
y = [405 393 1319 1330 405];
image_11 = ques1_1.*poly2mask(x,y,1424,2136);
image_11(image_11==0)=nan;
figure;
imagesc(image_11);
colormap(gray);
```

```
%second mach
x = [690 1008 1038 726 690];
y = [390 388 1309 1317 390];
image_12 = ques1_1.*poly2mask(x,y,1424,2136);
image_12(image_12==0)=nan;
figure;
imagesc(image_12);
colormap(gray);

%third mach
x = [1021 1342 1365 1054 1021];
y = [386 376 1296 1309 386];
image_13 = ques1_1.*poly2mask(x,y,1424,2136);
image_13(image_13==0)=nan;
figure;
imagesc(image_13);
colormap(gray);

%fourth mach
x = [1354 1674 1694 1382 1354];
y = [376 363 1287 1300 376];
image_14 = ques1_1.*poly2mask(x,y,1424,2136);
image_14(image_14==0)=nan;
figure;
imagesc(image_14);
colormap(gray);

%fifth mach
x = [1684 1991 1991 1710 1684];
y = [365 352 1283 1293 365];
image_15 = ques1_1.*poly2mask(x,y,1424,2136);
image_15(image_15==0)=nan;
figure;
imagesc(image_15);
colormap(gray);

%Image 2
%first mach
x = [360 676 708 395 360];
y = [405 393 1319 1330 405];
image_21 = ques1_2.*poly2mask(x,y,1424,2136);
image_21(image_21==0)=nan;
figure;
imagesc(image_21);
```

```
colormap(gray);

%second mach
x = [690 1008 1038 726 690];
y = [390 388 1309 1317 390];
image_22 = ques1_2.*poly2mask(x,y,1424,2136);
image_22(image_22==0)=nan;
figure;
imagesc(image_22);
colormap(gray);

%third mach
x = [1021 1342 1365 1054 1021];
y = [386 376 1296 1309 386];
image_23 = ques1_2.*poly2mask(x,y,1424,2136);
image_23(image_23==0)=nan;
figure;
imagesc(image_23);
colormap(gray);

%fourth mach
x = [1354 1674 1694 1382 1354];
y = [376 363 1287 1300 376];
image_24 = ques1_2.*poly2mask(x,y,1424,2136);
image_24(image_24==0)=nan;
figure;
imagesc(image_24);
colormap(gray);

%fifth mach
x = [1684 1991 1991 1710 1684];
y = [365 352 1283 1293 365];
image_25 = ques1_2.*poly2mask(x,y,1424,2136);
image_25(image_25==0)=nan;
figure;
imagesc(image_25);
colormap(gray);

%Image 3
%first mach
x = [360 676 708 395 360];
y = [405 393 1319 1330 405];
image_31 = ques1_3.*poly2mask(x,y,1424,2136);
image_31(image_31==0)=nan;
```

```
figure;
imagesc(image_31);
colormap(gray);

%second mach
x = [690 1008 1038 726 690];
y = [390 388 1309 1317 390];
image_32 = ques1_3.*poly2mask(x,y,1424,2136);
image_32(image_32==0)=nan;
figure;
imagesc(image_32);
colormap(gray);

%third mach
x = [1021 1342 1365 1054 1021];
y = [386 376 1296 1309 386];
image_33 = ques1_3.*poly2mask(x,y,1424,2136);
image_33(image_33==0)=nan;
figure;
imagesc(image_33);
colormap(gray);

%fourth mach
x = [1354 1674 1694 1382 1354];
y = [376 363 1287 1300 376];
image_34 = ques1_3.*poly2mask(x,y,1424,2136);
image_34(image_34==0)=nan;
figure;
imagesc(image_34);
colormap(gray);

%fifth mach
x = [1684 1991 1991 1710 1684];
y = [365 352 1283 1293 365];
image_35 = ques1_3.*poly2mask(x,y,1424,2136);
image_35(image_35==0)=nan;
figure;
imagesc(image_35);
colormap(gray);

%Part 3 and 4ish( Mean and STD)
Image_mean(1,:) =  mean(ques1_4, 'all','omitnan');
Image_mean(2,:) =  mean(image_11, 'all','omitnan');
Image_mean(3,:) =  mean(image_12, 'all','omitnan');
```

```
Image_mean(4,:) =  mean(image_13, 'all','omitnan');
Image_mean(5,:) =  mean(image_14, 'all','omitnan');
Image_mean(6,:) =  mean(image_15, 'all','omitnan');

Image_mean(8,:) =  mean(ques1_5, 'all','omitnan');
Image_mean(9,:) =  mean(image_21, 'all','omitnan');
Image_mean(10,:) =  mean(image_22, 'all','omitnan');
Image_mean(11,:) =  mean(image_23, 'all','omitnan');
Image_mean(12,:) =  mean(image_24, 'all','omitnan');
Image_mean(13,:) =  mean(image_25, 'all','omitnan');

Image_mean(15,:) =  mean(ques1_6, 'all','omitnan');
Image_mean(16,:) =  mean(image_31, 'all','omitnan');
Image_mean(17,:) =  mean(image_32, 'all','omitnan');
Image_mean(18,:) =  mean(image_33, 'all','omitnan');
Image_mean(19,:) =  mean(image_34, 'all','omitnan');
Image_mean(20,:) =  mean(image_35, 'all','omitnan');

%STD:
Image_std(1,:) =  std(ques1_4,0, 'all','omitnan');
Image_std(2,:) =  std(image_11,0, 'all','omitnan');
Image_std(3,:) =  std(image_12,0, 'all','omitnan');
Image_std(4,:) =  std(image_13,0, 'all','omitnan');
Image_std(5,:) =  std(image_14,0, 'all','omitnan');
Image_std(6,:) =  std(image_15,0, 'all','omitnan');

Image_std(8,:) =  std(ques1_5,0, 'all','omitnan');
Image_std(9,:) =  std(image_21,0, 'all','omitnan');
Image_std(10,:) =  std(image_22,0, 'all','omitnan');
Image_std(11,:) =  std(image_23,0, 'all','omitnan');
Image_std(12,:) =  std(image_24,0, 'all','omitnan');
Image_std(13,:) =  std(image_25,0, 'all','omitnan');

Image_std(15,:) =  std(ques1_6,0, 'all','omitnan');
Image_std(16,:) =  std(image_31,0, 'all','omitnan');
Image_std(17,:) =  std(image_32,0, 'all','omitnan');
Image_std(18,:) =  std(image_33,0, 'all','omitnan');
Image_std(19,:) =  std(image_34,0, 'all','omitnan');
Image_std(20,:) =  std(image_35,0, 'all','omitnan');

%SNR:
SNR = Image_mean./Image_std;

%Min
```

```
ImageMin(1,:) = min(min(ques1_4));
ImageMin(2,:) = min(min(image_11));
ImageMin(3,:) = min(min(image_12));
ImageMin(4,:) = min(min(image_13));
ImageMin(5,:) = min(min(image_14));
ImageMin(6,:) = min(min(image_15));

ImageMin(8,:) = min(min(ques1_5));
ImageMin(9,:) = min(min(image_21));
ImageMin(10,:) = min(min(image_22));
ImageMin(11,:) = min(min(image_23));
ImageMin(12,:) = min(min(image_24));
ImageMin(13,:) = min(min(image_25));

ImageMin(15,:) = min(min(ques1_6));
ImageMin(16,:) = min(min(image_31));
ImageMin(17,:) = min(min(image_32));
ImageMin(18,:) = min(min(image_33));
ImageMin(19,:) = min(min(image_34));
ImageMin(20,:) = min(min(image_35));

%Max
ImageMax(1,:) = max(max(ques1_4));
ImageMax(2,:) = max(max(image_11));
ImageMax(3,:) = max(max(image_12));
ImageMax(4,:) = max(max(image_13));
ImageMax(5,:) = max(max(image_14));
ImageMax(6,:) = max(max(image_15));

ImageMax(8,:) = max(max(ques1_5));
ImageMax(9,:) = max(max(image_21));
ImageMax(10,:) = max(max(image_22));
ImageMax(11,:) = max(max(image_23));
ImageMax(12,:) = max(max(image_24));
ImageMax(13,:) = max(max(image_25));

ImageMax(15,:) = max(max(ques1_6));
ImageMax(16,:) = max(max(image_31));
ImageMax(17,:) = max(max(image_32));
ImageMax(18,:) = max(max(image_33));
ImageMax(19,:) = max(max(image_34));
ImageMax(20,:) = max(max(image_35));

%Part6:
```

```
figure;
plot(Image_mean(1:6,:), SNR(1:6,:));hold on;
plot(Image_mean(8:13,:), SNR(8:13,:));hold on;
plot(Image_mean(15:20,:), SNR(15:20,:));hold off;
title('SNR VS Mean Signal Value');
xlabel('Mean Signal Value');
ylabel('SNR');
legen1 = sprintf('ISO = 100');
legen2 = sprintf('ISO = 400');
legen3 = sprintf('ISO = 1600');
legend({legen1,legen2,legen3});
```