APPLIED PHYSICS 157

Activity 2

FOURIER TRANSFORM MODEL OF IMAGE FORMATION (PART 1 OF 2)

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WFY-FX-2

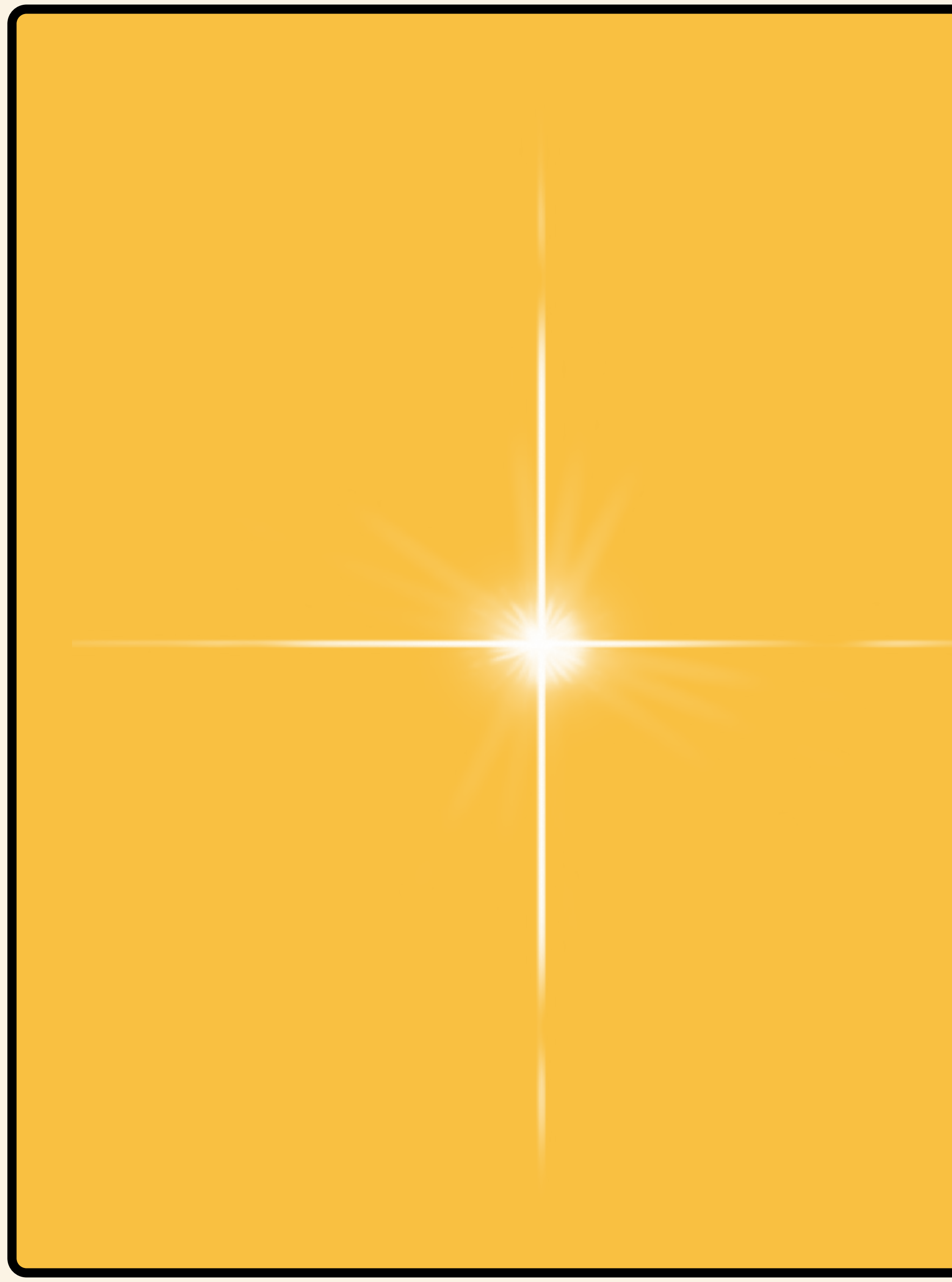
table of CONTENTS

The outputs presented in the succeeding pages are created using MATLAB. Moreover, the codes are uploaded in Github.

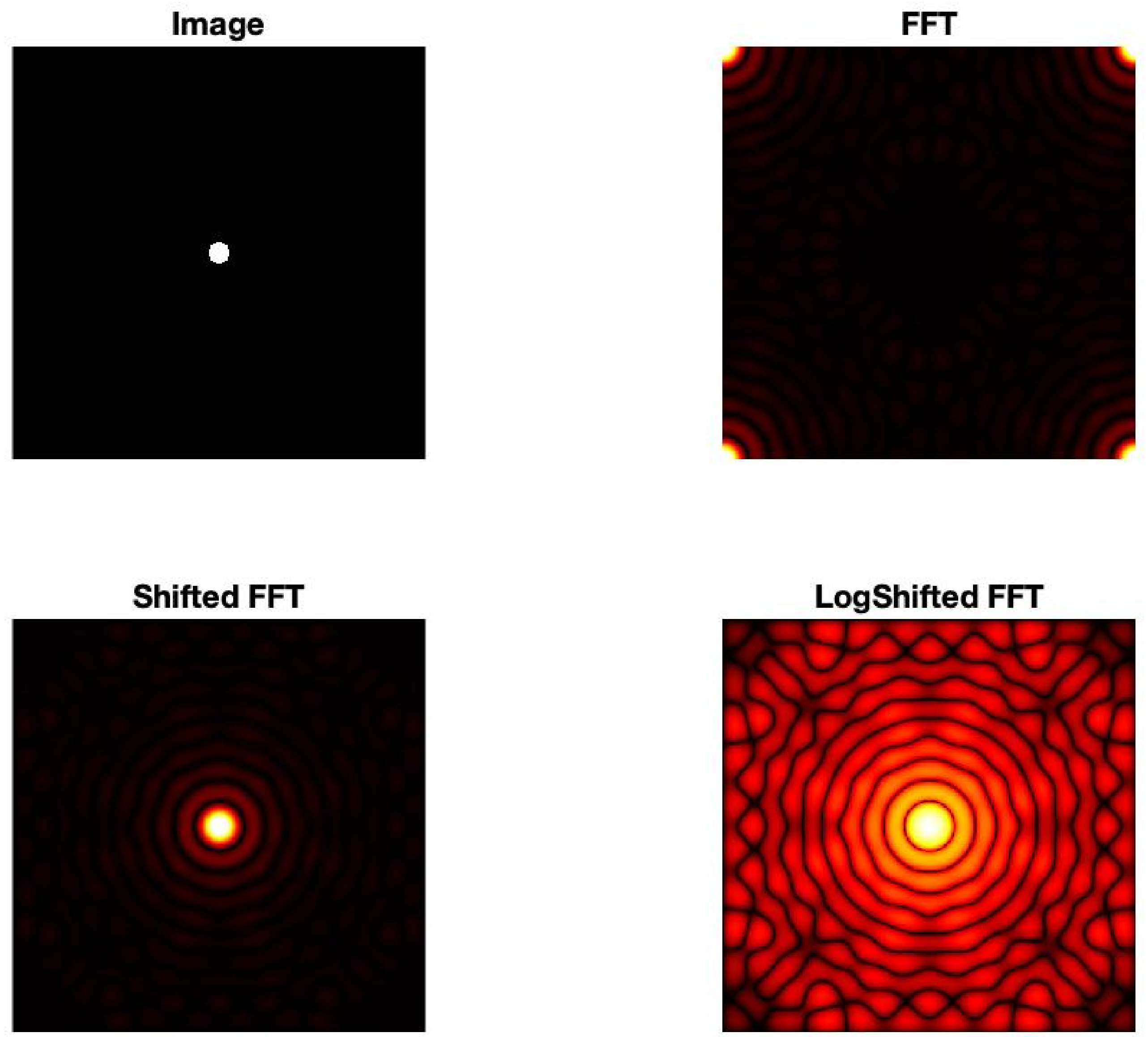
FAMILIARIZATION WITH DISCRETE FT

Objectives:

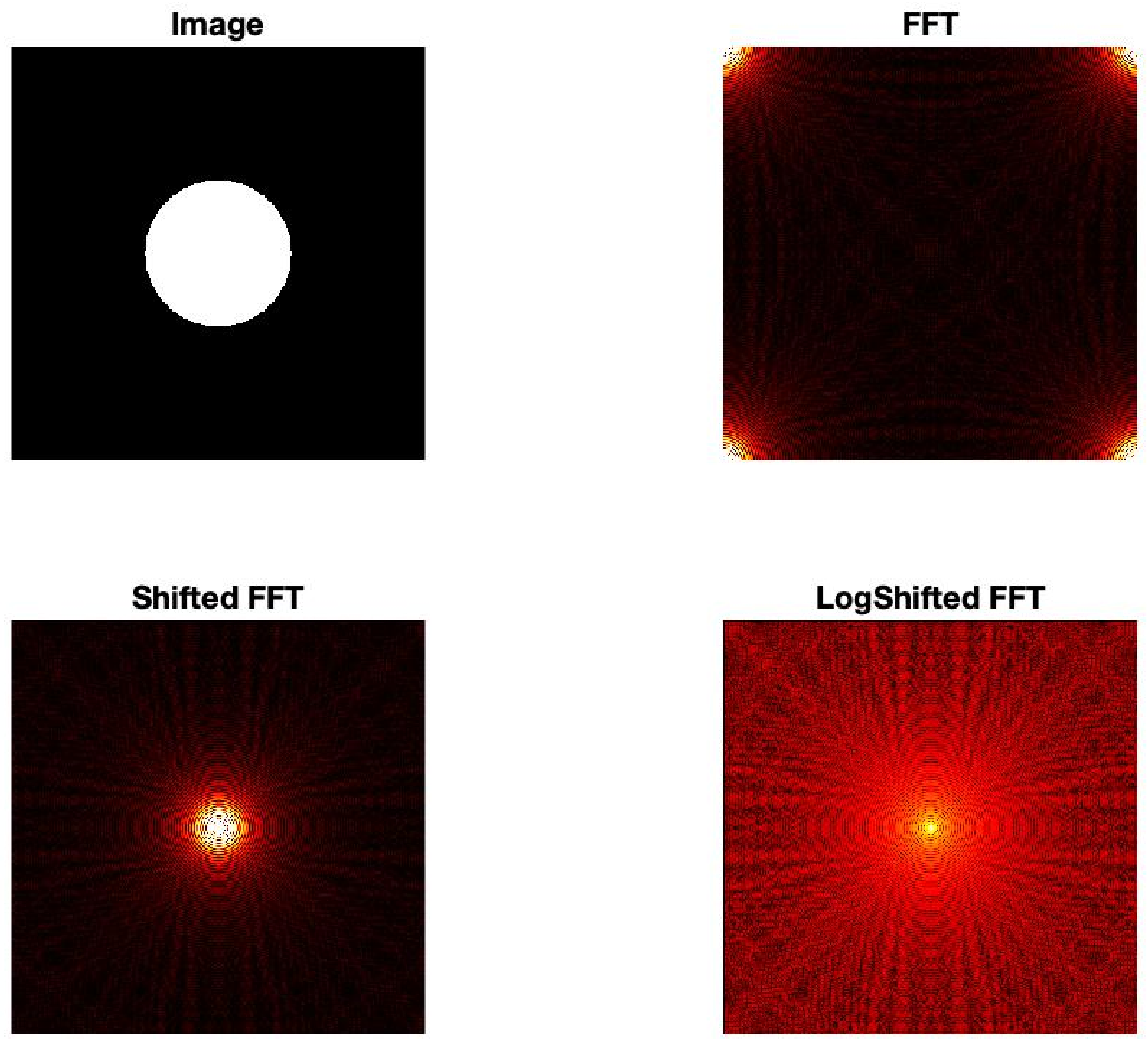
- Familiarize Discrete Fourier Transform by using different images



FAMILIARIZATION WITH DISCRETE FT

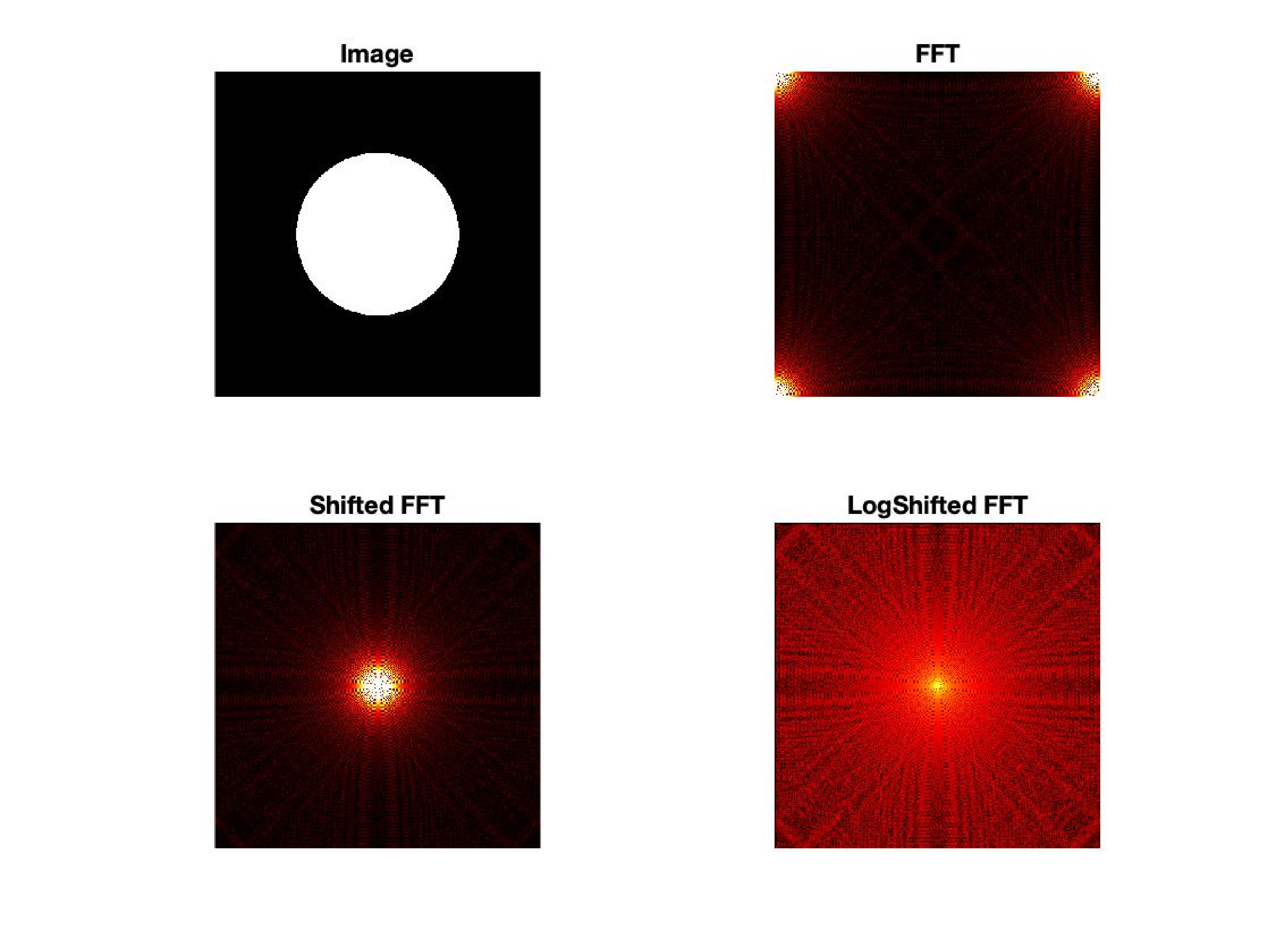


FFT, Shifted FFT, and LogShifted FFT of a small white circle



FFT, Shifted FFT, and LogShifted FFT of a medium-sized white circle

FAMILIARIZATION WITH DISCRETE FT



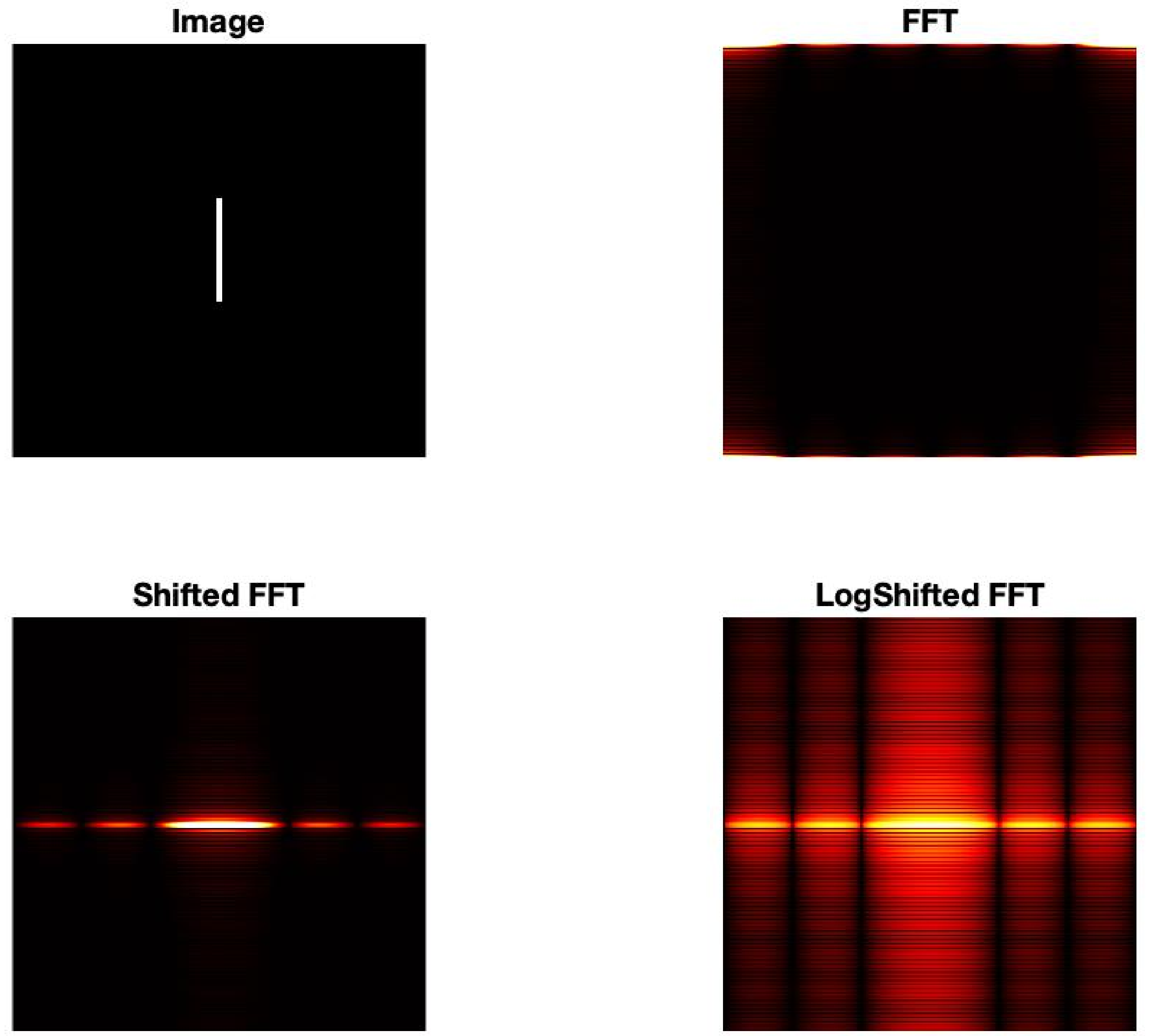
FFT, Shifted FFT, and LogShifted FFT of a big-sized white circle

In the first part of the activity, I varied the sizes of the white circle against a black background. I wanted to see the changes in the Fourier domain if the white circle size is increased.

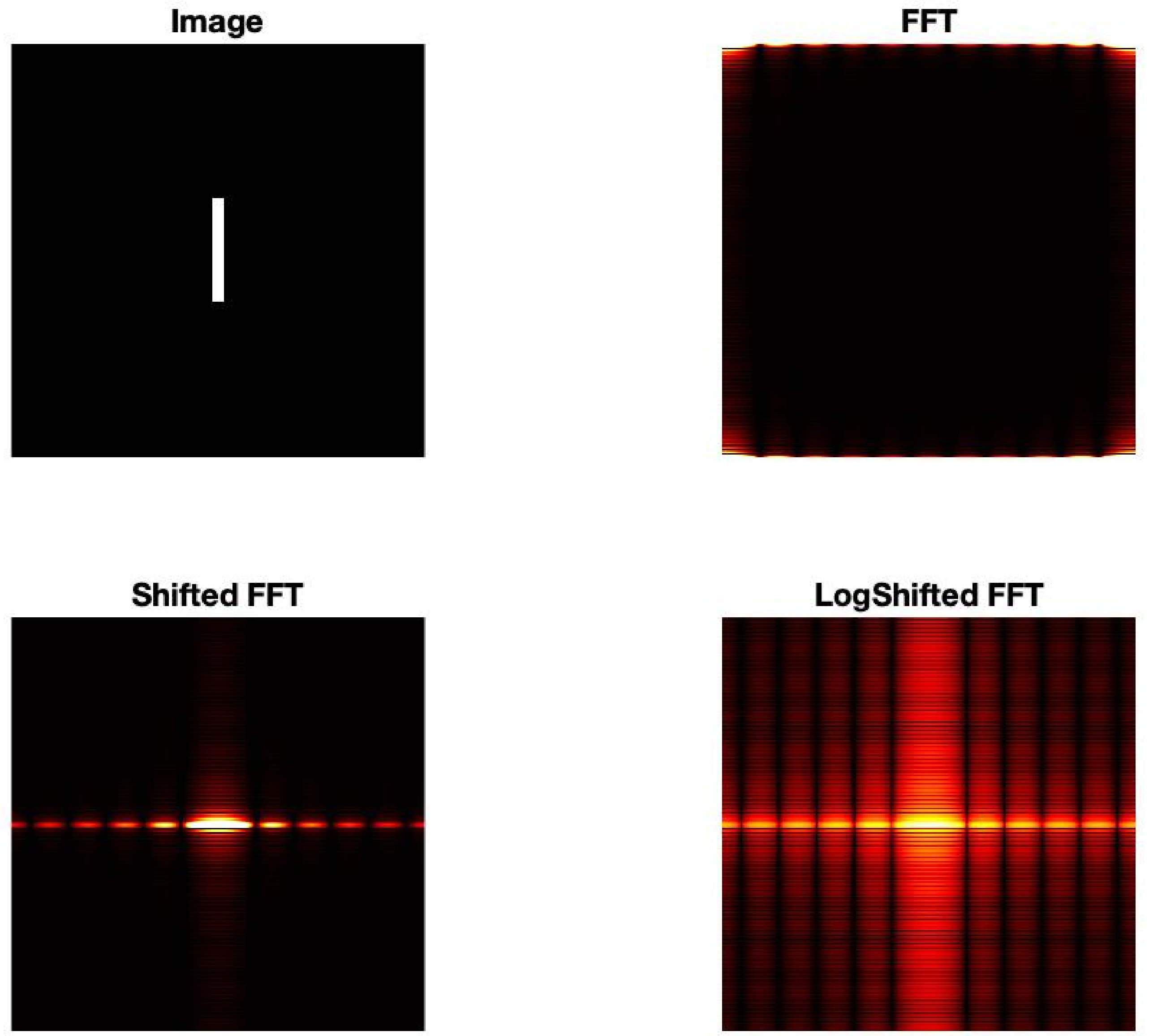
In all of the circle sizes, the shifted Fourier transform depicts that of a Bessel function. When the circle size is increased, the Bessel function changes accordingly. I first took advantage of the logarithmic function applied to the FFT-shifted image to see better the frequency content of the image. As seen in the image on the left, the small white circle produced a large radius in the Bessel function. In the previous slide, we can see that the radius of the Bessel function decreases as the circular aperture increases.

The size and the shape of the Bessel function in the Fourier domain are important in image processing such as in image restoration or filtering. Knowing the relationship between spatial and Fourier domains help design appropriate algorithms for a problem [2].

FAMILIARIZATION WITH DISCRETE FT

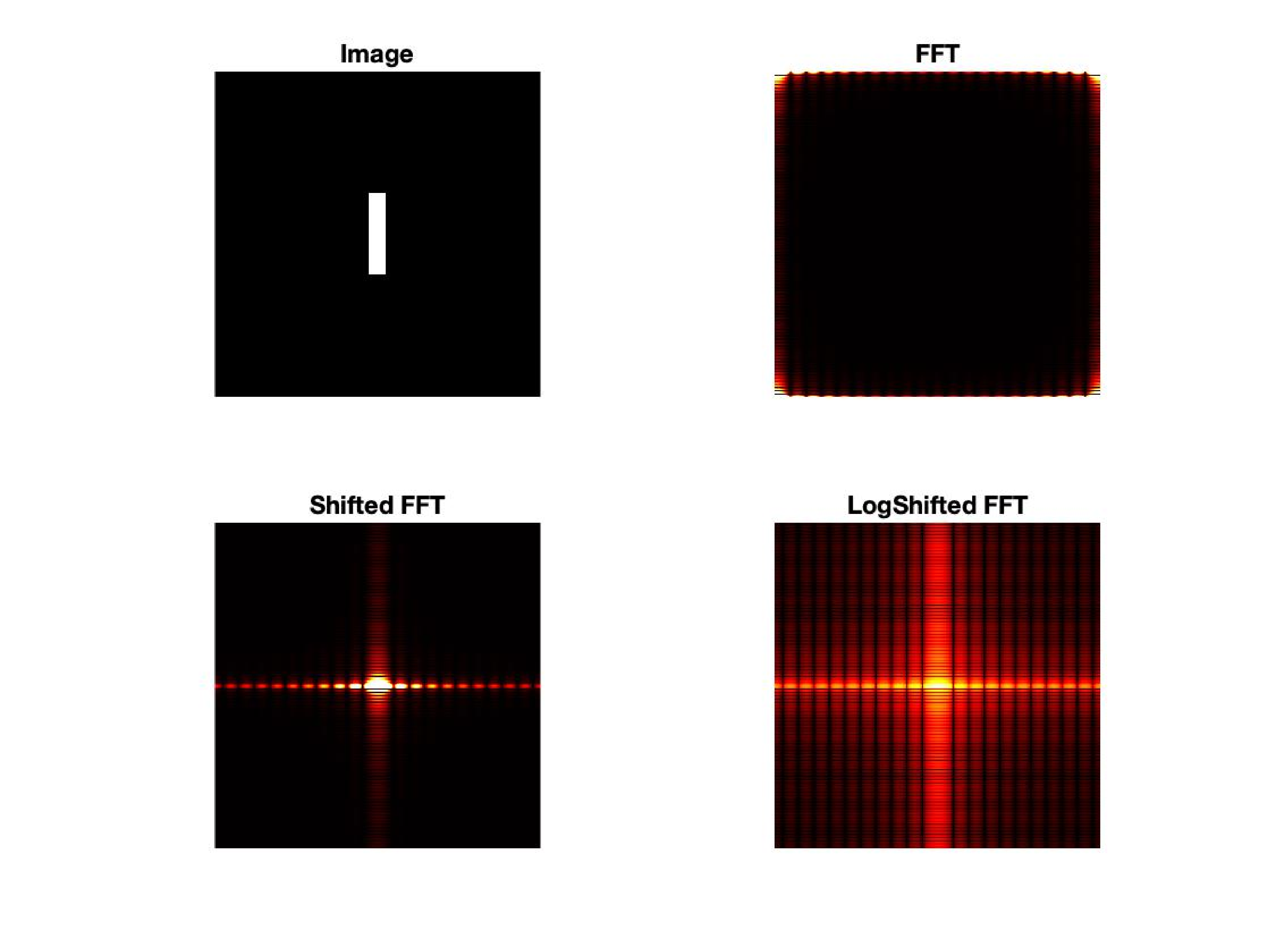


FFT, Shifted FFT, and LogShifted FFT of a 5-pixel single slit



FFT, Shifted FFT, and LogShifted FFT of a 10-pixel single slit

FAMILIARIZATION WITH DISCRETE FT

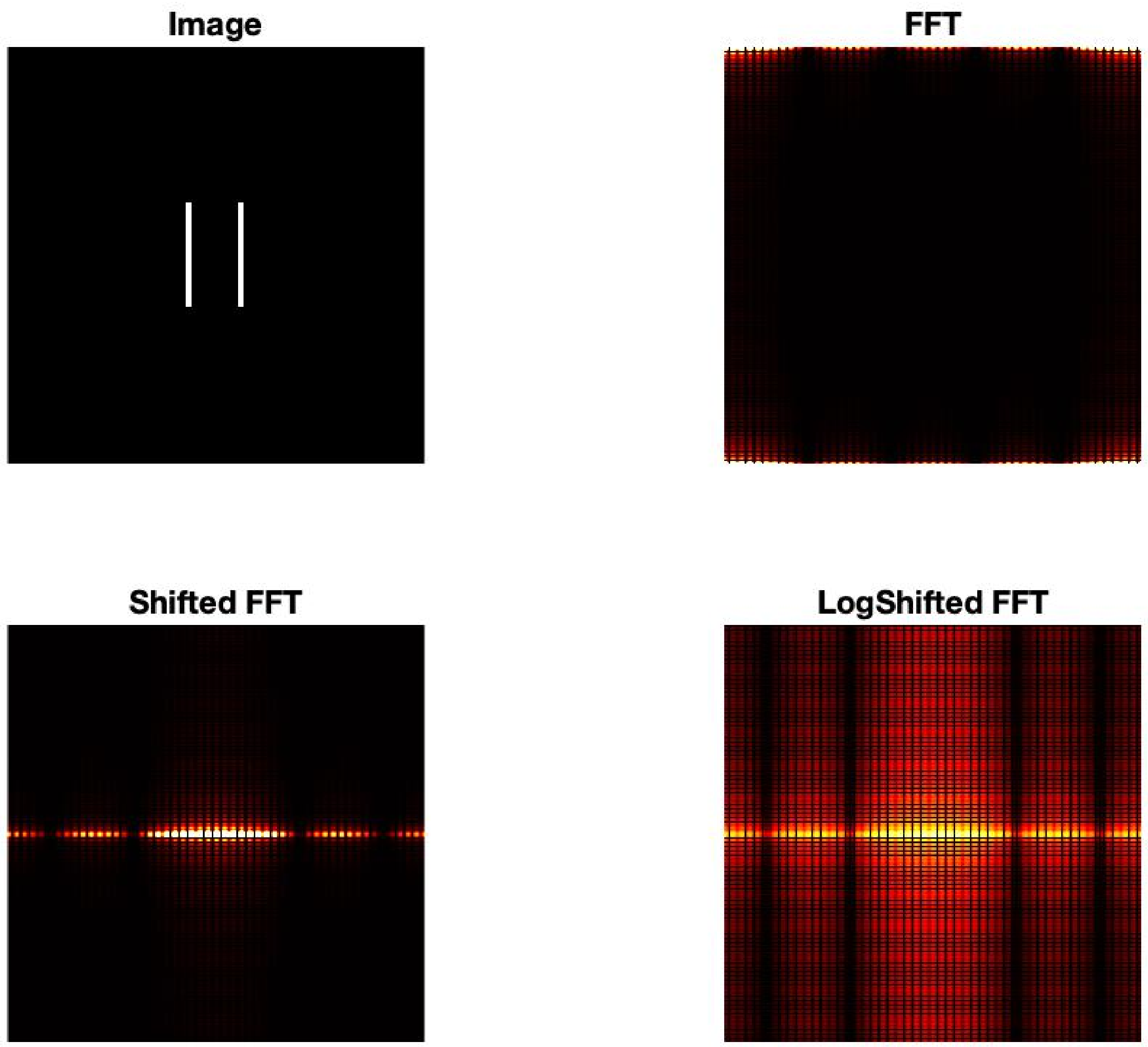


FFT, Shifted FFT, and LogShifted FFT of a 20-pixel single slit

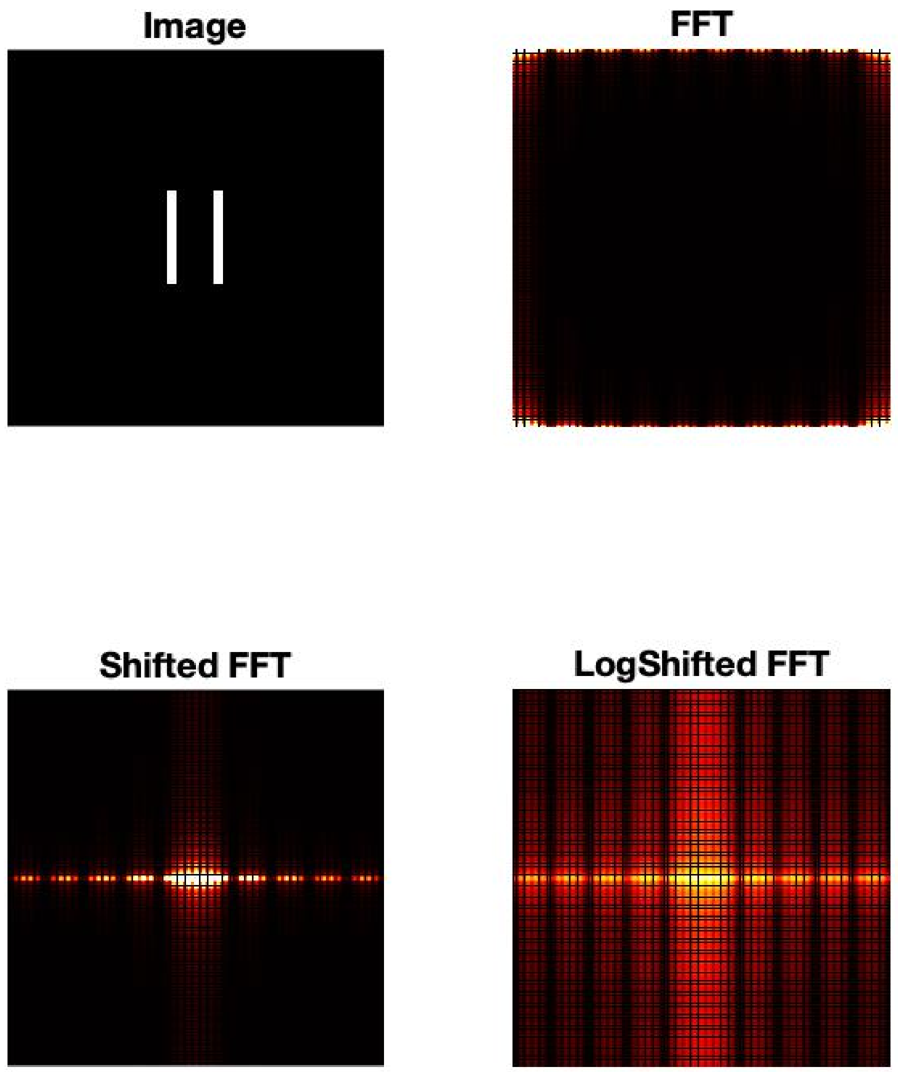
In this first part of the activity, I created a single slit with varying widths. The widths are as follows: 5,10, and 20 pixels. I also wanted to see the changes in the Fourier domain if the single slit size is increased.

The resulting pattern still shows a Bessel function only that the central maximum has a rectangular shape. Similar to the white circle activity, as the slit gets wider, the FFT gets thinner. This is because a thinner slit diffracts light over a wider range of angles than a wider slit [1].

FAMILIARIZATION WITH DISCRETE FT

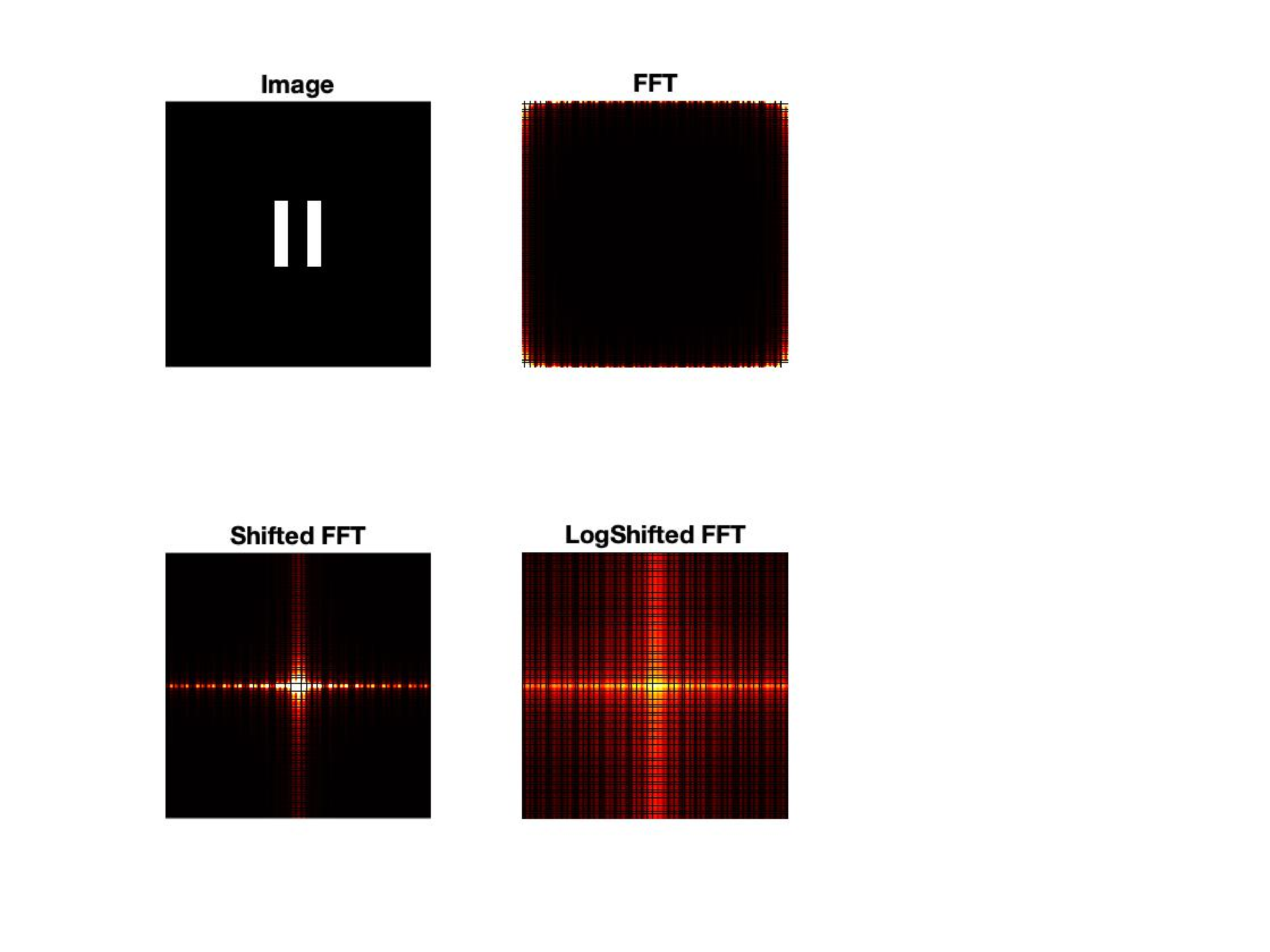


FFT, Shifted FFT, and LogShifted FFT of a 5-pixel double slit



FFT, Shifted FFT, and LogShifted FFT of a 10-pixel double slit

FAMILIARIZATION WITH DISCRETE FT

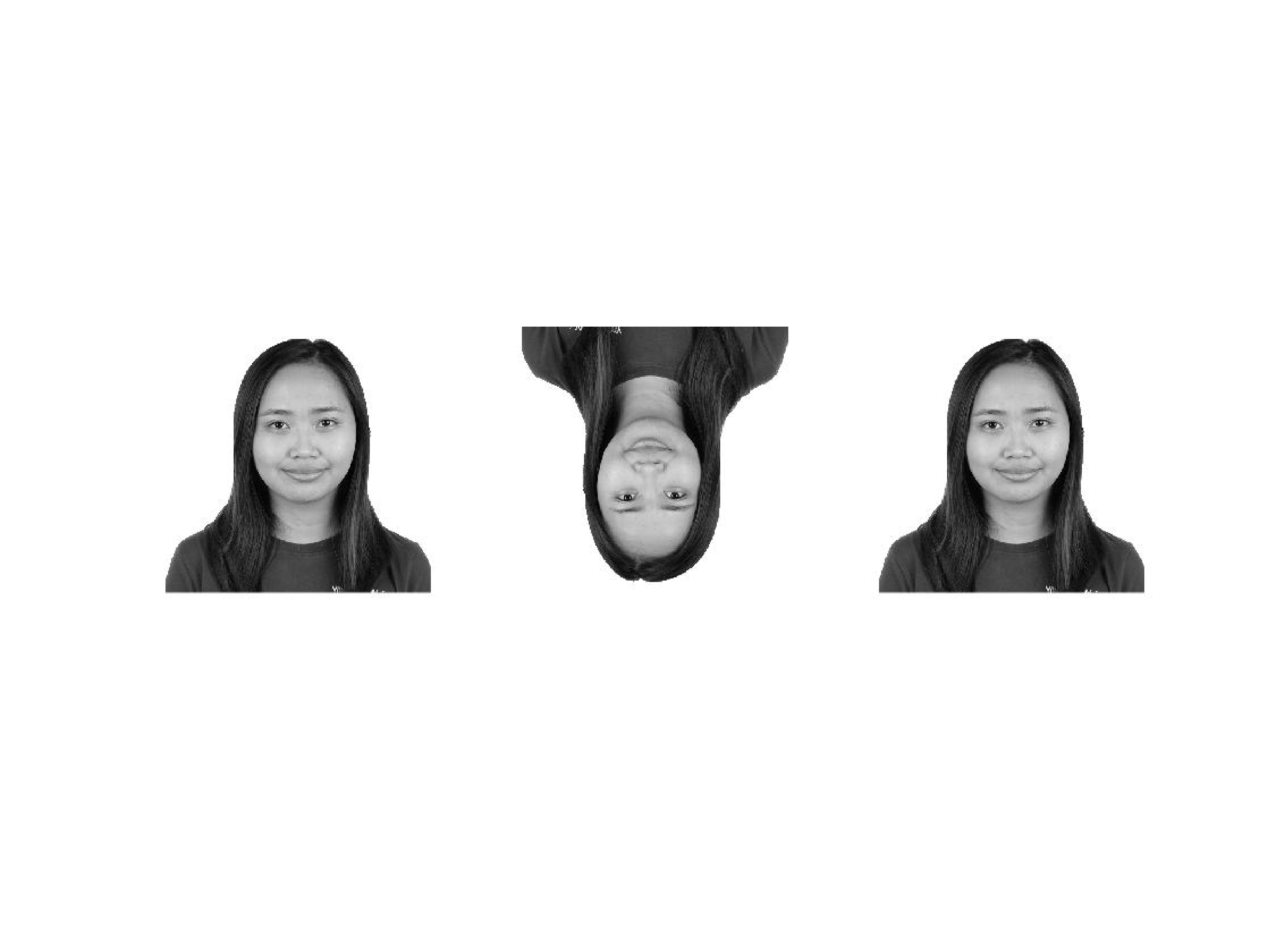


FFT, Shifted FFT, and LogShifted FFT of a 20-pixel double slit

Here, I created a double slit with varying widths. The widths are as follows: 5,10, and 20 pixels to see the changes in the Fourier domain.

A Bessel function with rectangular maxima is still present in the shifted FFT. We can see from the previous and this slide that as the width of the double slits is increased, there is also an increase in the number of diffraction patterns. The same explanation for the single slit holds for the double slit.

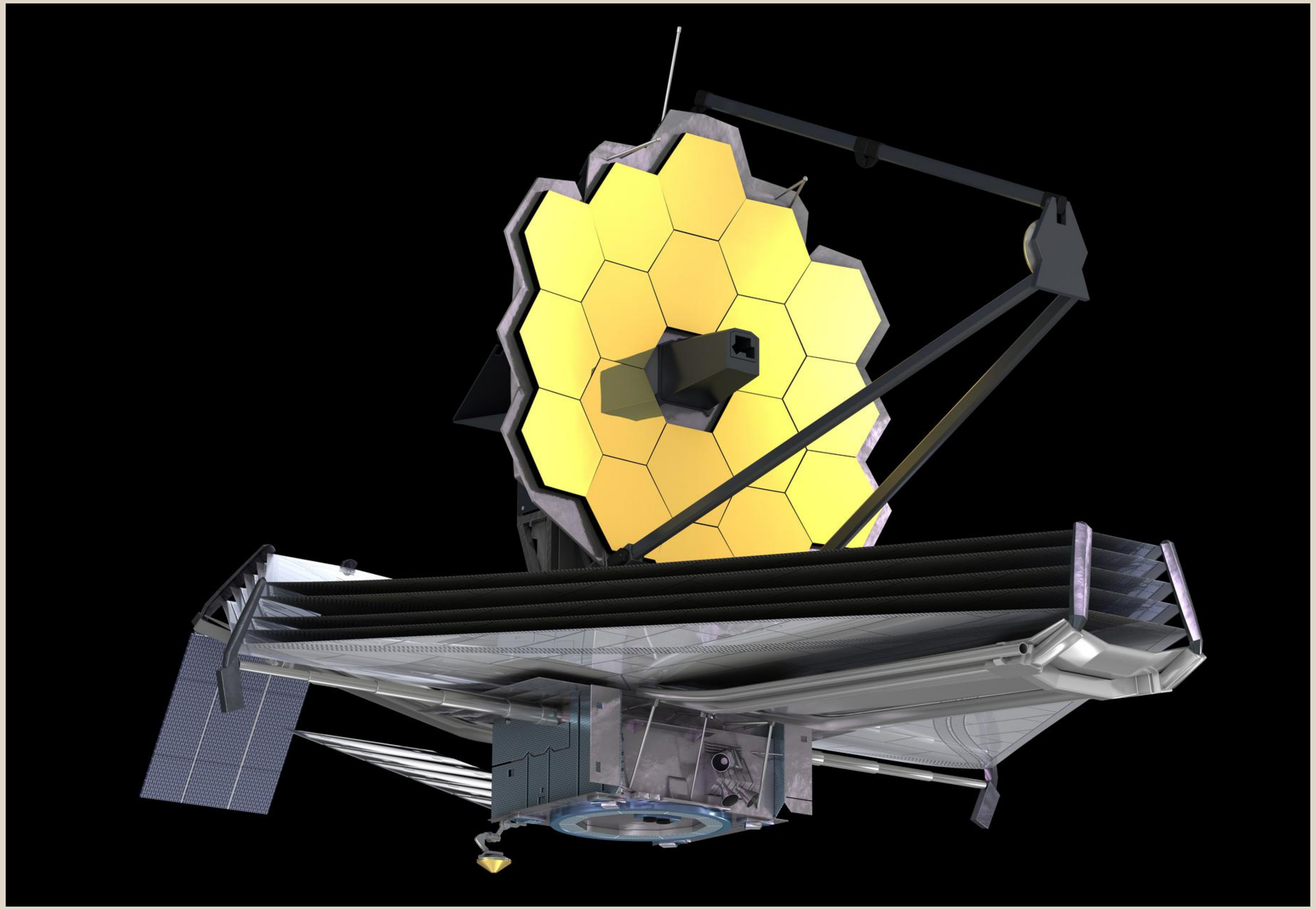
FAMILIARIZATION WITH DISCRETE FT



Original Image, FFT times FFT image, and IFFT times FFT image (from left to right)

For the last part of Activity 2.1, you can see that for the image that is FFT-ed twice, the image is inverted. Moreover, in the 3rd image, the IFFT function places back the image to its upright image.

This happens because the Fourier transform and the inverse transform has similar equations only that the variables xy and frequency variables are interchanged.

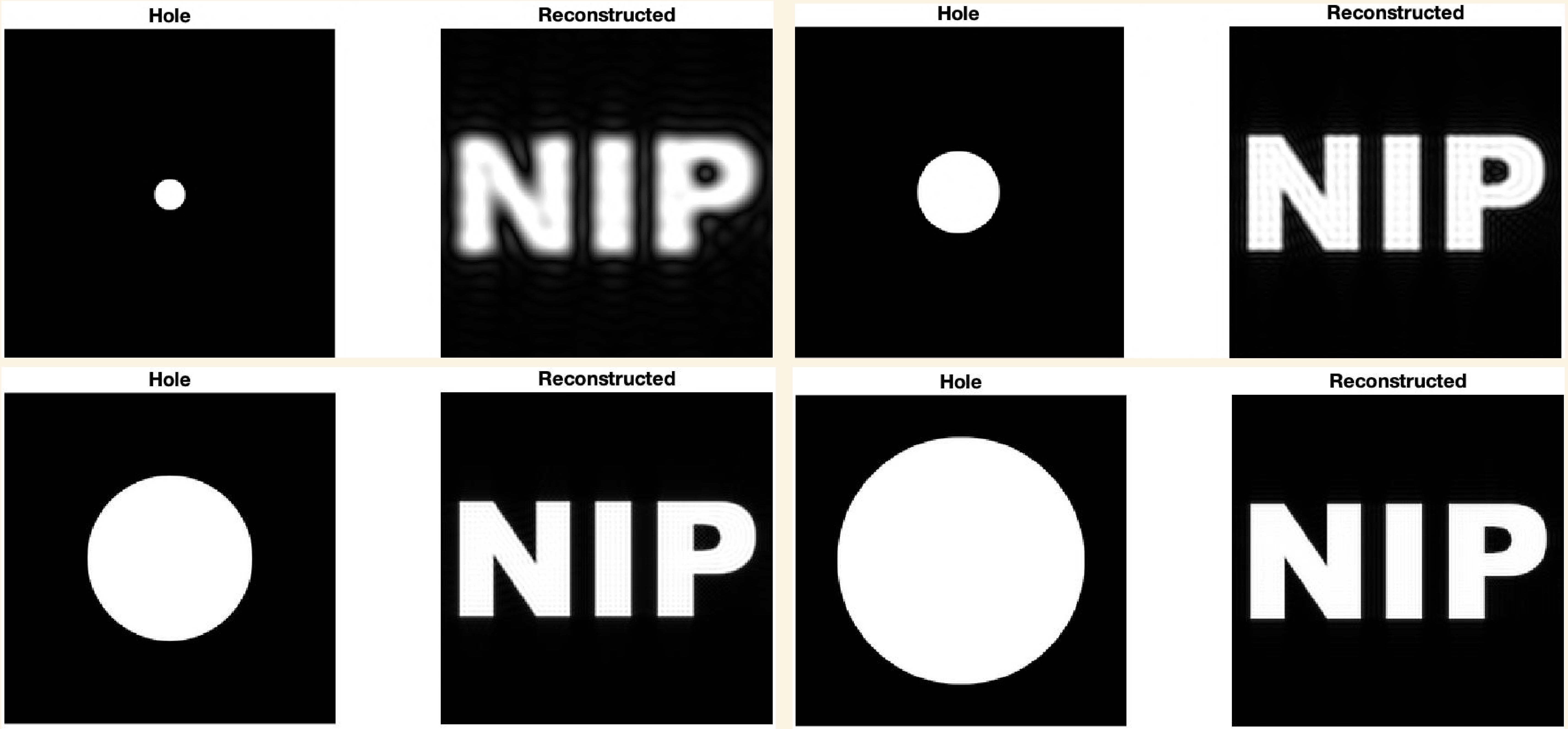


SIMULATION OF AN IMAGING SYSTEM

Objectives:

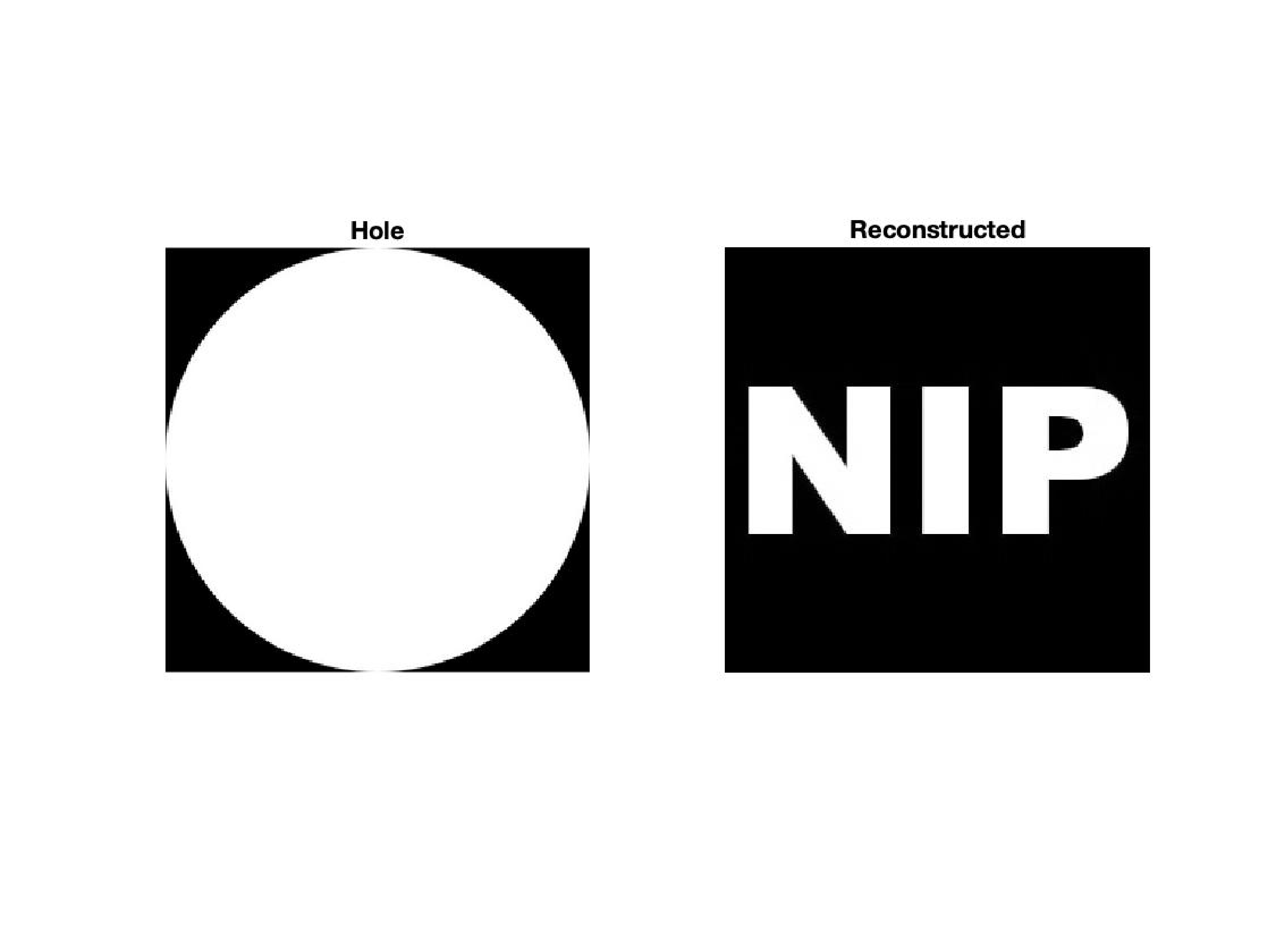
- Use convolution to simulate an imaging system

SIMULATION OF AN IMAGING SYSTEM



Reconstruction of NIP image using convolution

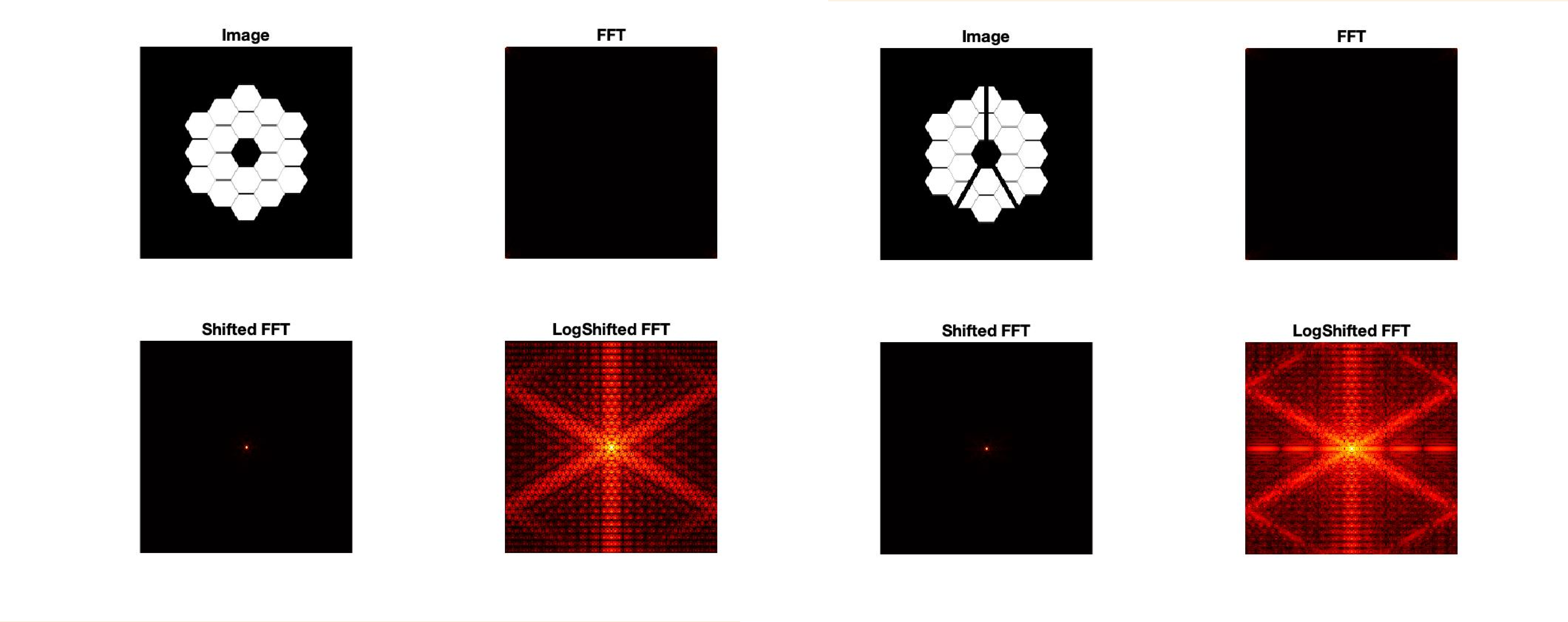
SIMULATION OF AN IMAGING SYSTEM



We can see that as the circle's radius increases, the sharper the reconstructed image becomes. This is due to the circle's Point Spread Function which condenses as the circle's radius increases.

Reconstruction of NIP image using convolution

SIMULATION OF AN IMAGING SYSTEM



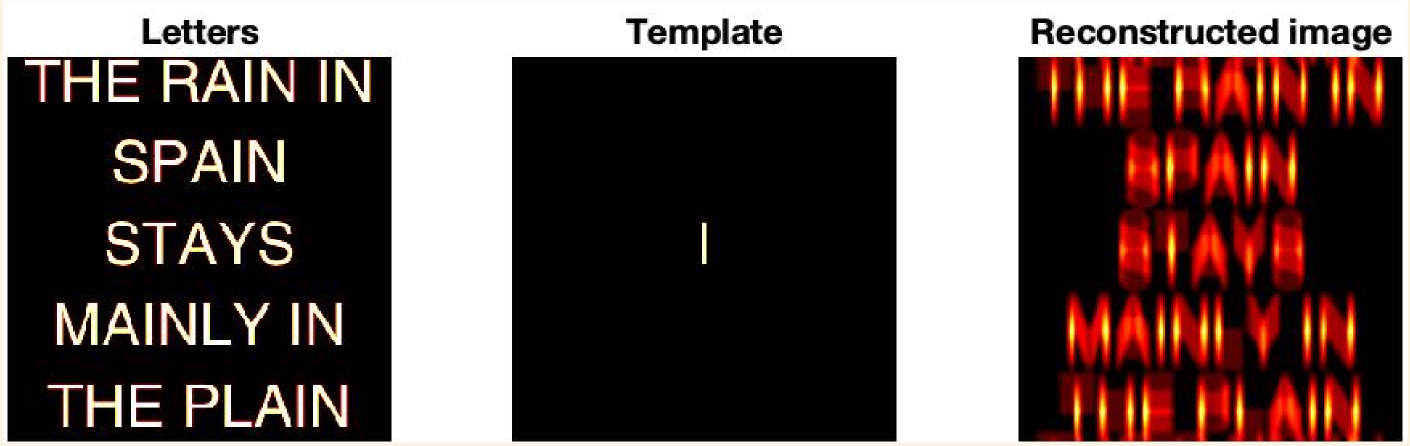
The Fourier transform of the James Webb primary mirror is how the telescope sees the star. Moreover, I added a shadow of the beam supporting the secondary mirror. Based from the results, approximately the same pattern is obtained as seen in the logarithmic scale

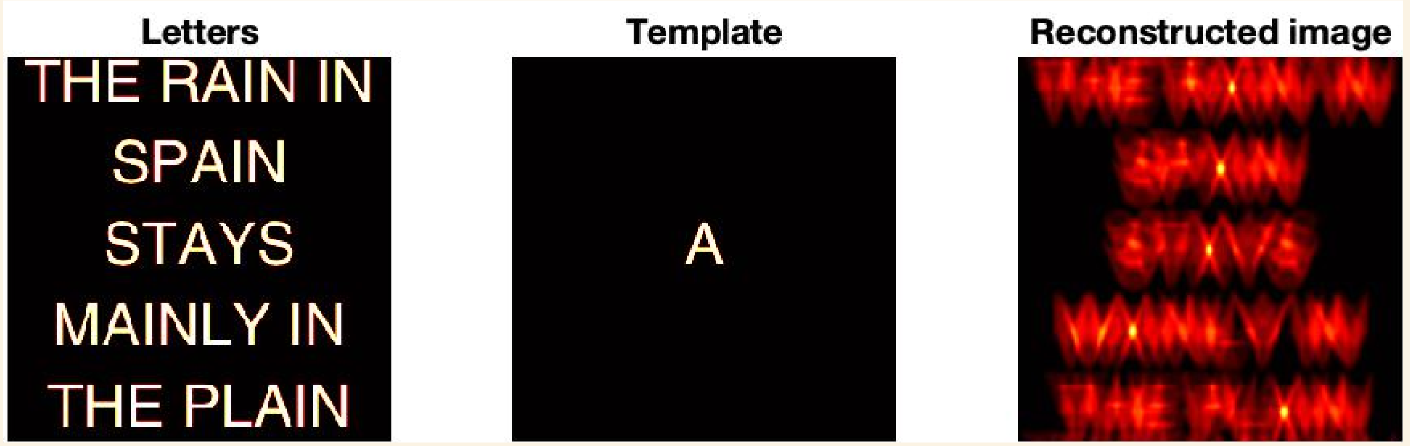
TEMPLATE MATCHING USING CORRELATION

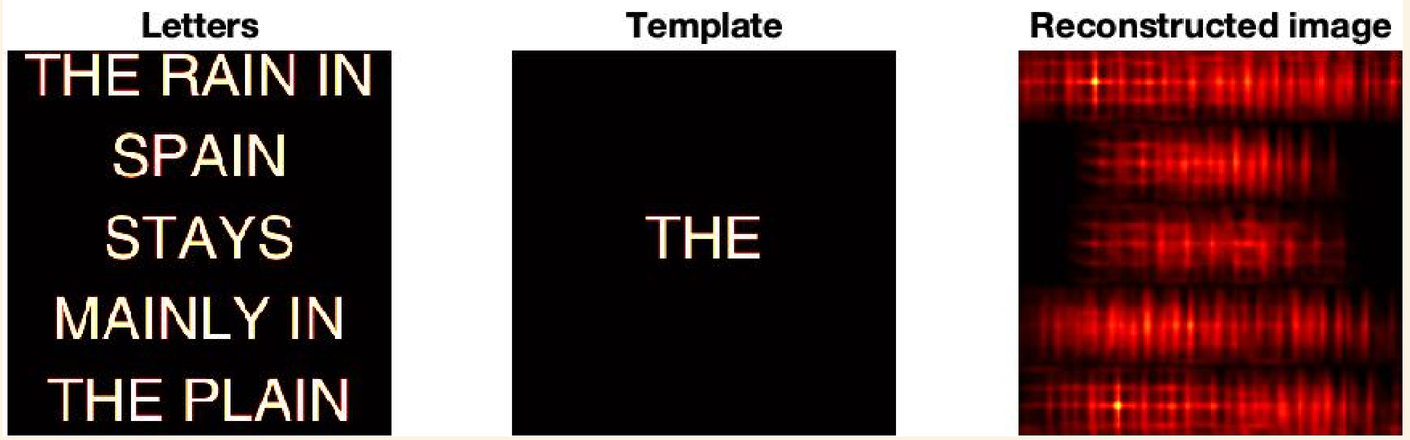
Objectives:

- Apply correlation to a template

TEMPLATE MATCHING USING CORRELATION







I've used different templates and saw the different images formed by the correlation. From the reconstructed images, it can be observed that there are peaks where the templates match the original image. Moreover, some peaks are also shown when I used templates SPAIN and RAIN at points where there is a pattern AIN.

REFLECTION

RATING: 100 / 100

To be honest, I still am not familiar with the Discrete Fourier Transform in practice and in theory. Although I can perform Fourier transforms, I cannot concisely explain what each graph represents. Nevertheless, I will take it as a challenge and an opportunity to learn more. In addition, I know that I can do better in this activity but certain obstacles hindered me from doing so-- sickness and a full plate from other subjects. Nevertheless, I still take responsibility for my actions and inactions. Though not that stellar, I was still able to accomplish all the necessary tasks needed with a few add-ons. With that, I will still give myself a perfect score. This will not be possible without the help of my classmates, especially Johnenn and Julian. If not for them, my codes and line of thoughts will be in much disarray. It really helps to have people while doing such tasks.

References

[1] Hecht, E. (2017). Optics (5th ed.). Pearson Education.

[2]Gonzales, R.C, & Woods, R.E. (2018). Digital Image Processing (4th ed). Prentice Hall. Retrieved 24 March 2023. https://dl.icdst.org/pdfs/files4/01c56e081202b62bd7d3b4f8545775fb.pdf

[3] McMahon, D., & McMahon, J. (2005). Quantum Mechanics Demystified: A Self-Teaching Guide. McGraw-Hill Education.