

The following is based on a lab activity from the Tufts University.

Submit your answers as a LaTeX generated PDF file with your name printed on top. The LaTeX tables should be properly formatted. Part A, B and C should be clearly labelled. Question numbers should match with what is given in this document.

PART A: Galaxy Morphology Classification

The below links will take you to NOAO images of some well known nearby galaxies. Classify these galaxies based on their morphology (e.g. S0, Sc, SBa, E0, E4 etc; just Elliptical or Spiral in not enough). Refrain from reading the caption on the webpage. The purpose of this exercise is to gain some exposure on galaxy classification. No matter how good some of the automated classifications are, the human eye is still very good at pattern recognition. Go through each image carefully. Look for features that are characteristic of a morphology class / sub-class.

Write the classification into a table of format given below. By clicking on the thumbnail will show larger images of each galaxy. Write a short comment of how you arrived at each classification.

Catalogue Name	Morphology Type	Comments
M101	Sa	Prominent bulge, two arms tightly wrapped around the bulge
.....

M101: https://www.noao.edu/image_gallery/html/im0512.html

M102: https://www.noao.edu/image_gallery/html/im0593.html

M110: https://www.noao.edu/image_gallery/html/im0582.html

M32: https://www.noao.edu/image_gallery/html/im0099.html

M49: https://www.noao.edu/image_gallery/html/im0088.html

M33: https://www.noao.edu/image_gallery/html/im0775.html

M81: https://www.noao.edu/image_gallery/html/im0493.html

M95: https://www.noao.edu/image_gallery/html/im0733.html

NGC2644: https://www.noao.edu/image_gallery/html/im0086.html

NGC5383: https://www.noao.edu/image_gallery/html/im0093.html

M94: https://www.noao.edu/image_gallery/html/im0779.html

NGC1300: https://www.noao.edu/image_gallery/html/im0681.html

Answer the following:

- (1) What observational factors can affect the morphological classification?
- (2) Can the wavelength of observation influence the morphological classification?

PART B: Galaxy Colours

Look at the “Galaxies in Colour” file given with this. The images were compiled from the Anglo Australian Observatory at <http://www.aao.gov.au/images/>, and from the Space Telescope Institute http://heritage.stsci.edu/gallery/gallery_category.html

- 1) Do the colours of galaxies seem related to their shapes? Explain.
- 2) Compare the bulge of Spiral galaxies to elliptical galaxies. In what sense are they similar?
- 3) Look at M101, NGC2997 and M100. Why are the colours of the bulge and the colours of the spiral arms so different? Suggest an explanation.
- 4) Look at NGC55: Some parts of the spiral arms have a reddish glow. What is that?

PART C: Influence of Environment on Galaxy Morphologies

Galaxies, like stars, exist in clusters. It is now known that the Milky Way is part of a local cluster of about 30 galaxies called the Local Group. The Local Group lies on the outskirts of a much larger cluster called the Local Supercluster. A nearby cluster, the Virgo cluster of galaxies, is prominent in the sky because of its relative nearness. It lies in the Virgo and Coma Berenices constellations, at a distance of about 65 million light-years, and contains many bright objects, some with Messier numbers and hundreds with NGC (New General Catalogue) numbers. High quality astro-photographs of this Virgo Cluster show thousands of individual galaxies that are ideal for studying the various types of galaxies.

There are differences among clusters, and the proportion of Spiral and Elliptical galaxies depends on the galaxy environment. The Morphologies of the Galaxies turns out to depend on the environment of galaxies. This suggests that the neighbours of galaxies are somehow responsible for the final shapes of the galaxies. If we can understand exactly “how” the environment affects the evolution of galaxies, we might be able to figure out how galaxies have formed during the early stages of the universe.

- (1) Coma Cluster: the image of the Coma Cluster is available at https://www.noao.edu/image_gallery/html/im0549.html
- (2) Hercules Cluster: the image of the Hercules Cluster is available at https://www.noao.edu/image_gallery/html/im0658.html

Look at the Hercules and Coma Clusters and classify the galaxies roughly according to Elliptical, Spiral, and Irregular. You do not need to bother about sub-classes within each class. A broad classification would suffice. It might also be a good idea to take a print out and do this to mark off galaxies you classify as you move along. The scales and the exposures of these NOAO images are slightly different, but that's not so important for this exercise. Based on this, answer the following:

- (1) What are the dominant types of galaxies in the Coma Cluster?
- (2) What are the dominant types of galaxies in the Hercules Cluster?
- (3) Using the magnified pictures on the computer, please classify ~30 galaxies and count the number of galaxies in each category (E, S, Irr etc). Based on that fill out the table on next page.

	Elliptical	Spiral	Irregular	Total Number
Coma				
Hercules				

- (4) Determine the percentage fraction of elliptical, spiral and irregulars in Coma and Hercules clusters

$$\text{percentage fraction} = \frac{\# \text{ of ellipticals}}{\text{total \# of galaxies}} \times 100$$

	Density	Elliptical	Spiral	Irregular
Coma	very dense			
Hercules	not so dense			
Poor groups	few galaxies	25%	70%	5%

- (5) How does the proportion of Elliptical and Spiral Galaxies depend on the density of the Environment?
- (6) As the universe ages, galaxies gravitate toward each other, in other words, clusters tend to get denser. What impact could such an evolution have on the morphologies of the galaxies?
