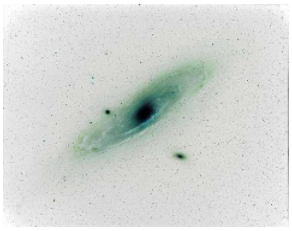
Name: _____
Partner(s): _____
1102 or 3311: _____
Desk # _____
Date: _____



Classification of Galaxies

Purpose

- Study and classify galaxies.
- Learn how to measure their distance, mass and radius.

Equipment

- Pictures of Galaxies from Brightspace
- cepheid_data.csv

Question 1: Make your own classification scheme. You are an astronomer. In the past three years, you have observed an important number of galaxies from the Messier catalog. Your goal is now to classify all these galaxies. The following link shows you a number of galaxies in the Messier catalog.

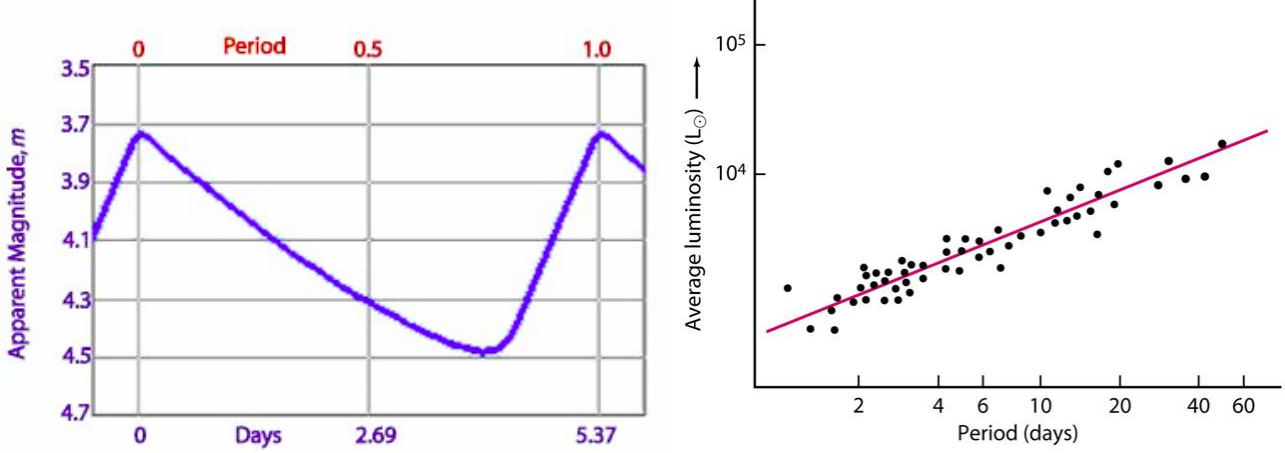
"Pictures of Galaxies" on Brightspace or https://langaraphysics.com/Tyron/GalaxyImages.htm

a) Use the space given as rough workspace and try to describe and form your own categories for galaxies. Give each of your own categories a name. Describe in details the characteristics of each class of objects. Look at the images again. Can you refine your classification?

b) Search online for Hubble's Galaxy Classification scheme. Fill out the table below with the name of each galaxy, what the galaxy is classified as in your scheme, what it is classified as in Hubble's scheme and explain differences between the two classifications.

Galaxy Name	Your Classification	Hubble's Classification	Differences/Explain

Question 2: Measuring the distance to M100 using Cepheid variables.
Cepheid variables can be used as standard candles. The graph on the left shows the light curve of Delta Cephei. The light coming from this star varies in cycles of period 5.37 days. In 1908, Henrietta Swan Leavitt discovered that the period of a Cepheid is related to its average luminosity. This relationship is shown on the right.



a) What is the luminosity of a Cepheid of period 7.5 days? Show your work.

b) Explain the steps taken to use Cepheids as standard candles.

You will now learn a technique used by professional astronomers, so be prepared for a bit of a challenge. Ask for help if needed. You observed M100 with the Hubble Space Telescope. You notice a change in brightness of a star and suspect it is a Cepheid. You measure that this Cepheid has a period of 7.44 days and an apparent magnitude $m_g = 28.7$. The subscript $_g$ stands for galaxy. Using the following two equations you will determine the distance to this Cepheid in the next few steps.

$$\frac{B_*}{B_g} = 10^{-\frac{m_* - m_g}{2.5}} \qquad \frac{B_*}{B_g} = \left(\frac{d_g}{d_*}\right)^2$$

c) Using the Cepheid catalog (cepheid_data.csv) chose a suitable comparison Cepheid. Write down the star ID, star name, period, V_INTMEAN, MV and DIST. Explain why you chose this Cepheid.

d) Using the above left formula, calculate the ratio B_*/B_g.
Note that V_INTMEAN is m_*.

e) Using your answer from (d) and the above right formula, calculate d_g, the distance to M100.
Note that DIST is d_* (in pc).

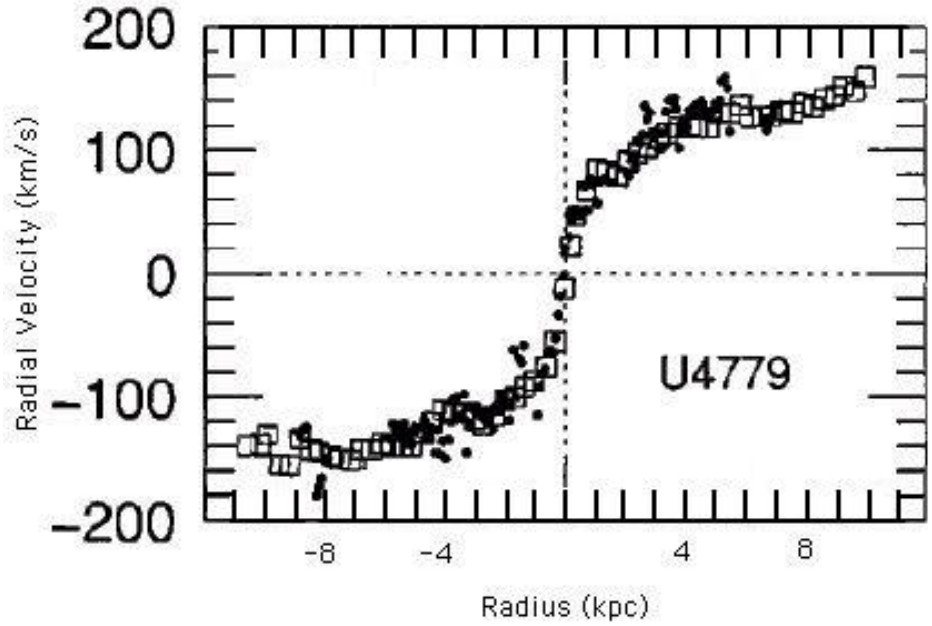
f) **ASTR1102 only:**

i. If the magnitude of M100 is m_g = 28.7 +/- 0.1 and if m_* is known with an accuracy of 0.01%, which of the two is the larger source of uncertainty? Explain.

ii. Redo (d) and (e) for m_g=28.6 and m_g=28.8. What range of values do you obtain for d_g?

iii. Round of d_g to the correct number of significant figures.

Question 3: Measuring the mass of NGC 2742. One way to measure the mass of a galaxy is to study how fast material orbits the centre of the galaxy. To do so, we can measure the radial velocity of the material, i.e. how fast material is moving in the direction of the line of sight, either away from or toward us. This is done using Doppler shift: light travelling away from us becomes redder while light travelling toward us becomes bluer. Light moving away from us is counted positive and light moving toward us is counted negative. Here is the rotation curve for NGC 2742:



Note: A correction was made in the curve to take into account the inclination angle of the galaxy. Newton's Laws tell us:

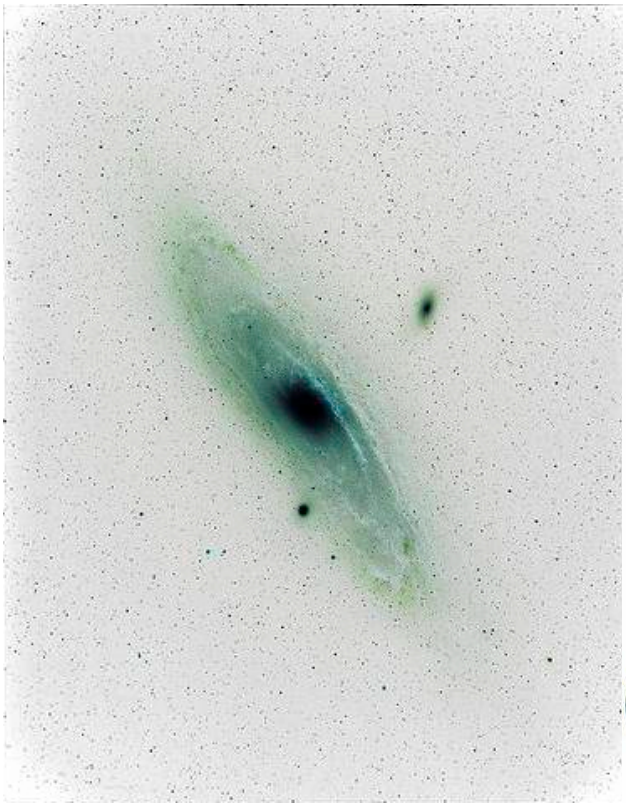
$$M_{inside} = \frac{v^2 R}{G}$$

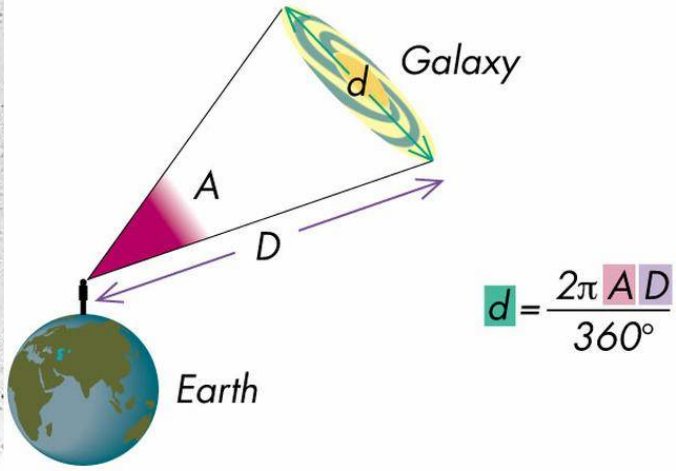
Here, $G = 4.31 \times 10^{-6}$ kpc km^2/M_{Sun} s^2 is the constant of gravitation, M_{inside} is the mass contained inside of radius R, and v is the tangential speed of material at radius R from the centre of the galaxy.

a) Using the graph above, what radius would you consider to be the edge of the galaxy?

b) Estimate the mass of NGC 2742. Show and explain all calculations.
ASTR1102: Make sure that you express your answer with the correct number of significant figures.

Question 4: Measuring the diameter of a galaxy. Here you will calculate the diameter of the Andromeda galaxy (M31) shown below. The distance to Andromeda is 2.6 million light years.





a) From the above picture of Andromeda, estimate the angular diameter in degrees given that the horizontal angular field of view of this picture is 3 degrees. Note: Defining the edge of a galaxy is not easy. The portion M31 that appears bright on a photograph depends a lot on the collecting power of the telescope. Using the same magnification, M31 does not extend very far when watched with the naked eye, but extends a lot further when observed with a large telescope.

b) Now using the equation in the picture on the right, calculate the diameter of Andromeda.

c) **ASTR1102 only:**

i. Give a maximal and a minimal possible value for your estimate (angular diameter).

ii. Write your answer on the board. Compare it to the answers given by other groups. Do you agree with their measurement and calculation? Comment.

iii. What is the range of possible values for the diameter of M31? Discuss and justify.

Instructor's initial: _____