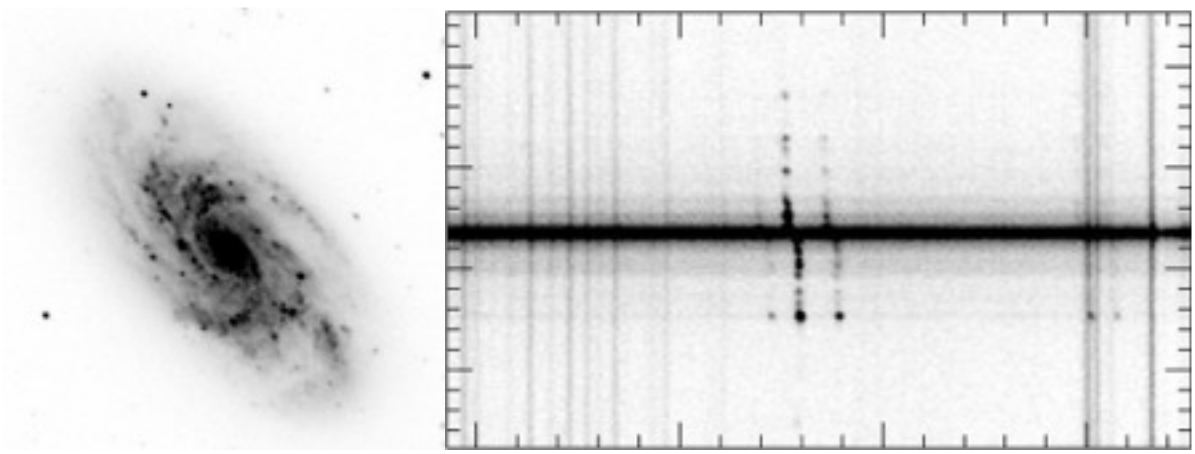
Dark Matter in the Spiral Galaxy NGC 2742

Introduction

Spectroscopic and photometric information from a galaxy provide two independent ways to determine its mass. When the masses are compared a discrepancy is found that is attributed to the presence of non-luminous (dark) matter.

Spectroscopy

Internal motions of the galaxy can be determined from the radial velocities derived from long slit spectroscopy. The slit of the spectrograph is placed along the axis of the galaxy. An example of the resulting spectrogram is shown in the figure below.



Since one side of the galaxy is moving away, while the other side is moving towards us, the spectral lines have been either red-shifted or blue-shifted. From the shifted spectral lines the radial velocities can be obtained for a variety of distances from the centre of the galaxy. A plot of the radial velocity as a function of the distance from the centre of the galaxy is called a rotation curve. (Since the galaxy is inclined at an angle to our line of sight, the velocity measured is not the total velocity of objects orbiting around NGC 2742 and a correction must be made to account for the inclination angle).

Using appropriate values of velocity and radius from the rotation curve, the gravitational mass profile of the galaxy can then be determined using Newton's law of universal gravitation to account for the observed motion:

$$M = \frac{v^2 r}{G} \quad (1)$$

where G = 4.31 x 10^{-6} kpc km^2 M_*^{-1} s^{-2}, and M is the mass contained inside of radius r.

Figure 1 shows the rotation curve for the spiral galaxy NGC 2742.

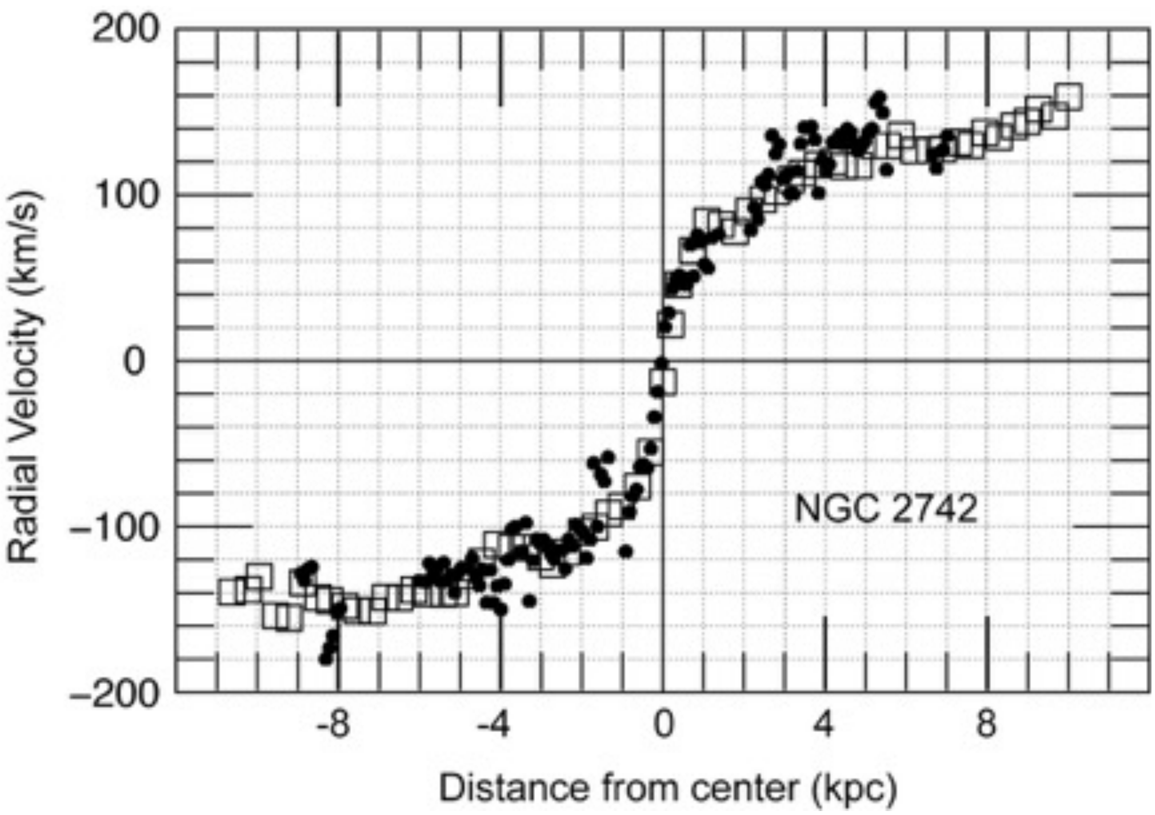


Figure 1: Rotation Curve for NGC 2742

Photometry

Surface photometry of the galaxy allows for a mass determination based on the luminous components, stars and gas. The light distribution curve obtained by adding together all the luminosity from inside a given radius r can be modeled by the following expression:

$$2\pi h^2\sigma_0(1-e^{-r/h}(1+\frac{r}{h})) \quad \text{...} \quad (2)$$

where h is a scale height and σ_0 is the peak surface brightness at the centre of the galaxy.

In the case of NGC 2742, h = 3.8 kpc, and σ_0 = 6.725 x 10^7 L_{solar}/kpc^2.

Figure 2 indicates how many solar luminosities NGC 2742 produces inside the area encompassed by some radius (where the radius is the distance from the center of the galaxy measured in kpc). From this figure the mass may be estimated.

The assumption that one solar mass of stars is providing one measured solar luminosity requires scrutiny. The effect of dust in the galaxy must be considered, as must the distribution of stellar masses, since luminosity depends critically on the mass of a star. A few young, hot bright stars that are only slightly more massive than the sun may provide much of the light while many cooler, low mass stars may be hidden from view. A reasonable estimate of the true mass of the material responsible for producing the observations assumes that there are two solar masses of stars for each solar luminosity.

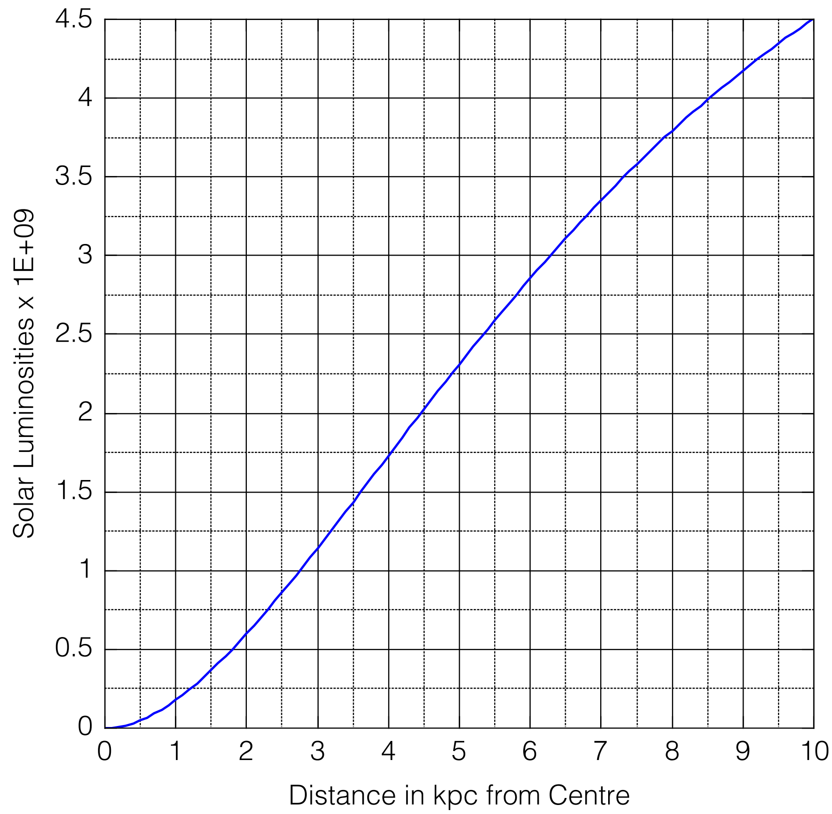


Figure 2: Amount of Light Emitted from Inside some Radius

Questions: *All Data & Calculations can be recorded in Table 1.*

1. For ten values in the full range of the distance from the centre, determine rotational velocities at that distance using Fig. 1, and calculate the enclosed gravitational mass using equation (1). ***(Choose values so that the absolute values are not the same.)*** Determine the amount of light emitted inside these radii using Fig. 2 and calculate the corresponding "radiation" mass. Plot each of the masses (gravitational and "radiation") versus radius on the same plot. Use different symbols to identify the mass. Draw smooth curves through the points. Label and title your plot.

2. Determine the corresponding rotational velocities due to the radiation mass using equation (1). Plot the rotation curves for each of the masses (gravitational and "radiation") on the same plot.

3. Determine the mass to light ratio for NGC 2742 at your largest radius by dividing your gravitational mass by your radiation mass.
   a. What percentage of the total mass is luminous?
   b. What percentage of the total mass is presumably dark matter?

4. Figure 2 plots how much luminosity is produced inside of some radius. It does not decline at large radii even though the galaxy gives off less light out there. Explain why.

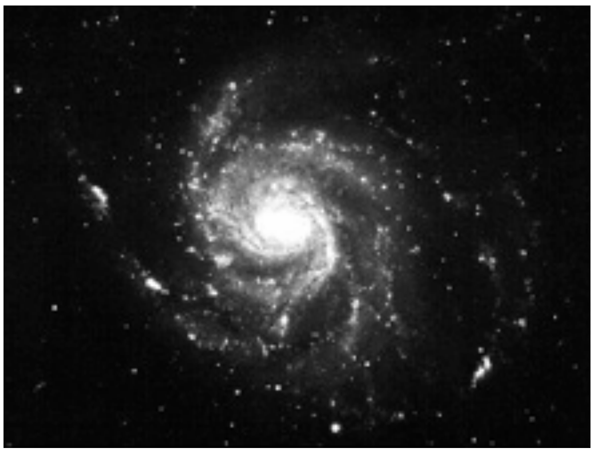
5. We assumed that for every 1 solar luminosity that we see, there are 2 solar masses of matter.

a. How would our assumption for the amount of luminous matter change if NGC 2742 has more low mass stars than we thought, but remains just as luminous? (Remember that a star's luminosity depends sensitively on its mass $L \sim M^{3.5}$.)

b. Following from part a, how would the mass to light ratio (total mass divided by luminous mass) change if NGC 2742 contains more low mass stars than we thought?

6. How might you go about modeling the distribution of the missing mass?

7. These are 2 galaxies that present difficulties for our techniques in searching for dark matter. Why? *(Examine what observations are necessary for the appropriate measurements to be made.)*



M101 The Pinwheel Galaxy

M104 The Sombrero

TABLE I

Radius (kpc)	**Rotational Velocity (km/s)**	**Gravitational Mass** (M_{sun})	**Luminosities** (L_{sun})	**Luminous Mass** (M_{sun})	**"Luminous" velocity (km/s)**