Journal of Physics Special Topics
An undergraduate physics journal

A6_7 Expansion of the Universe: A Darker Future

D. Nutting, S. Mucesh, M. N. Chowdhury and D. Watters

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 2, 2016

Abstract

The impact of the future merger between Andromeda and the Milky Way on the night sky is investigated. The change in flux is calculated through the use of the Plummer model under the assumption that the Earth's relative position from the centre of the galaxy remains unchanged, and is found to decrease by approximately 80%.

Introduction

Andromeda, our nearest neighbouring galaxy, is currently hurtling towards us at a speed of around 110kms^{-1} [1]. Due to the large distance between us and Andromeda, even at this speed it will be billions of years before it collides with the Milky Way, and billions more before the two merge entirely [2] [3].

All the stars we can see with the unaided eye when we look up at the night sky are only a small sample of all that the Milky Way holds, with every single one of them being held within an encompassing sphere of space (SS) of ~ 2760 light years in radius [4]. As the two galaxies merge, the stellar population present within the SS will change, raising the question of how this will impact our night time sky.

This paper is a continuation of 'A6_3 Expansion of the Universe: A Dark Future?' [13], and investigates the same question but via a different method.

Theory

The resultant system which will emerge from this collision will be elliptical in shape [5], and can therefore be roughly approximated by a sphere. With this assumption the merged galaxy, commonly known as 'Milkdromeda', can be modelled as a galaxy sized globular cluster. Throughout the collision, the Earth's position relative to the centre of the Milky Way and Milkdromeda is taken to be constant. As a result, the ratio of the separation distance between Earth and the centre of the Milky Way, $R_i = 2.48 \times 10^{20}$m [6], to the diameter of the Milky Way, $D_{mw} = 1.04 \times 10^{21}$m [7], is constant and equal to the ratio of the final separation distance, R_f, to the diameter of Milkdromeda, $D_{md} = 1.14 \times 10^{21}$m [8] as:

$$\frac{R_i}{D_{mw}} = \frac{R_f}{D_{md}} \tag{1}$$

allowing the final separation between the Earth and the centre of Milkdromeda to be calculated as $R_f = R_i(D_{md}/D_{mw}) = 2.72 \times 10^{20}$m. The change in the mass density of stars with distance from the centre of a globular cluster, $\rho(r)$, is found using the Plummer Model [9]:

$$\rho(r) = \left(\frac{3M}{4\pi a^3}\right)\left(1 + \frac{r^2}{a^2}\right)^{\frac{-5}{2}} \tag{2}$$

where a is a scale distance and is typically $\sim 3.09 \times 10^{17}$m [10], r is the radial distance from the centre and M is the total mass of the system. This mass is approximately equal to the average stellar mass, $\bar{M} \approx 0.2M\odot = 4 \times 10^{29}$kg [11], multiplied by the total number of stars within Milkdromeda, $N_T = 1.4 \times 10^{12}$ [12]. The average density within the SS at its new location within Milkdromeda, $\bar{\rho}(r)$, is found from:

$$\bar{\rho}(r) = \frac{\rho(R_f + r_{SS}) + \rho(R_f - r_{SS})}{2} \quad (3)$$

where $r_{SS} = 2.61 \times 10^{19}$m and is the radius of the SS [4]. The number of stars within the SS after the collision, N_f, can be found with:

$$N_f = \frac{V_{SS}\bar{\rho}(r)}{\bar{M}} = \frac{4\pi r_{SS}^3}{3}\frac{\rho(r)}{\bar{M}} \quad (4)$$

due to the SS being a sphere centred at the Earth. Hence, this can be expressed as:

$$N_f = \gamma[(a^2+(R_f+r_{SS})^2)^{\frac{-5}{2}}+(a^2+(R_f-r_{SS})^2)^{\frac{-5}{2}}] \quad (5)$$

where

$$\gamma = \frac{a^2 r_{SS}^3 N_T}{2}. \quad (6)$$

The flux received at the Earth from stars within the SS, $\bar{F}$, is found using:

$$F = \frac{N\bar{L}}{4\pi\bar{r}^2} \quad (7)$$

where N is the number of stars within the SS, $\bar{L} = 0.3L\odot = 1.2 \times 10^{24}$W is the average luminosity of stars within the Milky Way [13], and $r_{av} \approx 3.88 \times 10^{18}$m is the average distance to stars within the SS from the Earth [14] [15].

Results

The initial number of stars within the SS, N_i, is known to be 9096 [16]. Equation 6 yields $\gamma = 1.19 \times 10^{105}\text{m}^5$. This in turn can be used in conjunction with equation 5 to calculate the final number of stars within the SS to be $N_f = 1826$. The initial and final fluxes received, F_i and F_f, can be found by substitution of N_i and N_f into equation 7 respectively. Doing so produces the values $F_i = 5.77 \times 10^{-11}\text{Wm}^{-2}$ and $F_f = 1.16 \times 10^{-11}\text{Wm}^{-2}$.

Discussion

The decrease in the final flux compared to that of before is a result of the Milky Way being a barred spiral galaxy, whereas Milkdromeda has been modelled as a spherical globular cluster. The stellar population of the Milky Way is therefore confined to an approximate disc structure, while that of Milkdromeda occupies a much larger volume. Hence, despite the total number of stars increasing due to the merger, the final number density within the solar neighbourhood decrease, reducing the number of stars within the SS and hence the flux received. Modelling Milkdromeda as an ellipsoid will serve to reduce the error within the number of stars within the SS.

In conclusion, although the number of stars within the galaxy would increase as a result of the merger, the overall effect would be to reduce the amount of flux received at the Earth.

References

[1] goo.gl/SMGy8 accessed on 23/10/2016

[2] goo.gl/WG2Dsd accessed on 23/10/2016

[3] goo.gl/nZ4KiS accessed on 23/10/2016

[4] goo.gl/rYSfQd accessed on 23/10/2016

[5] goo.gl/Clxqm accessed on 23/10/2016

[6] goo.gl/TR2j9f accessed on 23/10/2016

[7] goo.gl/Jpntke accessed on 07/11/2016

[8] goo.gl/Nc7ycI accessed on 07/11/2016

[9] goo.gl/i0s1Sg accessed on 07/11/2016

[10] Dr. Mark Wilkinson, University of Leicester, 21/10/2016

[11] goo.gl/m5IyMX accessed on 07/11/2016

[12] goo.gl/BLwPSl accessed on 07/11/2016

[13] Mucesh *et al.* '*A6_3 Expansion of the Universe: A Dark Future?*', PST 15, (2016).

[14] goo.gl/CkZnwH accessed on 23/10/2016

[15] goo.gl/c9koBh accessed on 22/10/2016

[16] goo.gl/2vrCFX accessed on 23/10/2016