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A6_3 Expansion of the Universe: A Dark Future?

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Abstract

With the fated merger of the Milky Way and Andromeda in the distant future; the change in the night sky's "brightness" due to the collision is investigated. Using the inverse square law, it is found that the radiation flux received on Earth will decrease by approximately 75%.

Introduction

Before the turn of the century, it was widely believed that the expansion of the universe should be slowing down. Therefore the revelation that the polar opposite was happening came as a shock. The universe has been expanding at an accelerating rate ever since dark energy became dominant, 5 billion years ago [1].

There is a popular notion that as the universe continues to expand, the night sky in the future will be a void. While it is true that dark energy is causing everything to move away from one another, it has negligible influence on the dynamics of the Local Group.

Due to gravitational attraction, bound galaxies are moving towards each other and if any human is alive in about 4 billion years then they will witness one of the most spectacular events; the collision between the Milky Way and Andromeda [2]. With this in mind, we aimed to determine if the night sky will become darker or brighter in the distant future.

Theory

A measure of brightness is flux, F, which is the amount of energy passing through a surface area per unit time. For mathematical simplification, the Earth is placed at the centre of the galaxy with stars distributed evenly in cylindrical and spherical shells.

$$F = \int dF = \int \frac{L}{4\pi r^2} dN, \tag{1}$$

where L is the average luminosity, r is the distance from Earth and dN is the number of stars within a shell.

The Milky Way is a barred spiral galaxy and is modelled as having a spherical bulge surrounded by a cylindrical disk. The number of stars in each component is given by:

$$dN_{\text{bulge}} = \eta_{\text{bulge}} r^2 sin\theta d\theta d\phi dr, \tag{2}$$

$$dN_{\text{disk}} = \eta_{\text{disk}} r dr d\phi dz, \tag{3}$$

where η_{bulge} and η_{disk} are the number density of stars. Equation 2 and 3 can be substituted into equation 1 and integrating gives the flux received from the bulge and disk respectively:

$$F_{\text{bulge}} = \eta_{\text{bulge}} r_{\text{bulge}} L, \tag{4}$$

$$F_{\text{disk}} = \frac{1}{2} \eta_{\text{disk}} L z \ln \frac{r_{\text{disk}}}{r_{\text{bulge}}}, \tag{5}$$

where z is the height of the disk, r_{bulge} and r_{disk} are the radii of the bulge and disk respectively.

According to predictions, when the Milky Way and Andromeda merge, the new galaxy (nicknamed "Milkdromeda") will be elliptical [2]. To find the flux received by Earth in the new galaxy, equation 4 can be used if Milkdromeda (MD) is assumed to be approximately spherical.

Results

To calculate the average luminosity, it is assumed that all stars are on the main-sequence and none are found within the extended dark matter halo.

Class	Luminosity (L⊛)	Abundance (%)
M	0.08	77
K	0.34	12
G	1.05	7
F	3.25	4

Table 1: Properties of the most abundant stars in the galaxy [3].

	Bulge	Disk	MD
Radius r (10^4 ly)	0.5	5	6
No. of stars N (10^{12})	0.035	0.065	1.3
Density η (pc^{-3})	2.32	0.29	0.05

Table 2: Properties of the different components of the Milky Way [4] [5], and Milkdromeda [6].

Using data from Table 2 and an average luminosity of 0.3 L⊛, the flux received from the bulge is calculated as 4.31×10^{-4} Wm^{-2} and from the stellar disk as 1.24×10^{-5} Wm^{-2} with $z = 10^3$ ly [4]. The total flux received is therefore given by:

$$F_{\text{Milky Way}} = 4.43 \times 10^{-4} Wm^{-2} \quad (6)$$

Since the size and density of Milkdromeda are unknown, the properties of Messier 87 are used for calculations as it's an elliptical galaxy with about the same number of stars [6]. The flux received by Earth in the newly formed galaxy is calculated as:

$$F_{\text{Milkdromeda}} = 1.11 \times 10^{-4} Wm^{-2} \quad (7)$$

Hence the decrease in the radiation flux received on Earth is approximately 75%.

Discussion

Based on the assumptions and the simplified model, the night sky will become darker once the Milky Way and Andromeda have merged. We believe that the actual flux could be greater than what we have calculated for several reasons. When the two super-massive black holes residing in both galaxies merge, they will release vast amounts of energy and could trigger star formation. We have also ignored the fact that the central region of Milkdromeda will be denser than the rest of the galaxy. Based on computer simulations, it is highly likely that the Triangulum galaxy will follow suit and merge, further increasing the flux received on Earth [2]. Therefore the future could be bright in terms of flux. However all the other galaxies outside of the Local Group will probably fade from existence, as the light will become dimmer and red-shifted due to the accelerated expansion of space.

Conclusion

We have been able to show that the flux received by Earth, if placed at the centre of the Milky Way and Milkdromeda will decrease after the merger. A more advanced method could be used in the future to find the flux received on Earth using its current location.

References

[1] `goo.gl/n5yux0` accessed on 12/10/2016

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[3] `goo.gl/kcRZOS` accessed on 12/10/2016

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[5] `goo.gl/NGzxjq` accessed on 18/10/2016

[6] `goo.gl/Nc7ycI` accessed on 12/10/2016