Andromeda galaxy vs Milky Way galaxy

A.A. Torosyan

Byurakan Astrophysical Observatory, Armenia

Abstract

Some physical features of the Andromeda galaxy are compared with their counterparts in the Milky Way to demonstrate that the Andromeda galaxy has traversed a longer evolutionary path. One of the evolutionary dependents in galaxies is the metallicity factor. The metallicity radial gradient in galaxies can also be used for this purpose. Most probably, the globular cluster system in galaxies can also serve for this purpose. We propose that dark energy interacts with matter at all levels and plays a role in controlling its evolution, particularly through destructive processes. As a result, we observe phenomena such as metal-poor globular clusters and the blueshift of certain galaxies—effects that, in our view, cannot be fully explained by the Doppler effect alone, but may instead reflect an underlying evolutionary mechanism.

Keywords: *Dark energy, ordinary matter, interaction, evolution of matter; Andromeda galaxy: spectral blueshift, evolution path, globular clusters*

1. Introduction

Several observational facts and relevant physical laws are known, leading to the conclusion that dark energy interacts with baryonic structures, which, in turn, influence the evolution of baryonic matter (Harutyunian, 2022). This is due to the energy exchange between the dark energy carrier and baryonic structures, which occurs in one direction: baryonic structures continuously obtain certain portions of energy. The gained energy changes the physical state of baryonic structures depending on their hierarchical level. At the level of baryons and atomic nuclei, the gained energy decreases the nuclear binding energy, which increases the mass of nuclei and baryons. Owing to this, the spectra of the given atoms shift to the shortwave side.

It was well known for more than 25 years that the baryonic Universe is expanding at an accelerating rate (Perlmutter et al., 1999, Riess et al., 1998). Nowadays, it is widely accepted that the accelerating behavior of the Universe is due to a certain energetic field, named later dark energy. While the large-scale behavior of dark energy is relatively well understood through cosmological observations, its impact on the microscopic or local evolution of baryonic matter remains an open question. In this context, the possible mechanisms by which dark energy might influence the dynamics of baryonic structures over time were considered. The accelerating expansion of the Universe implies an interaction with dark energy. However, it remains unclear at which scale this interaction takes place—whether only at the macroscopic level, or also at the atomic scale.

In this paper, we present some new observational facts to use for comparing the evolution paths of the Milky Way and the Andromeda galaxy. Previously (Harutyunian & Torosyan, 2024) it was suggested that the Andromeda galaxy passed a longer path of evolution compared to the Milky Way. This comparison was based on certain physical features of two galaxies: their masses, sizes, star formation rates, etc. All the mentioned features speak in favor of the longer evolution of M31.

2. Spectral changes due to influence of dark energy

It has been shown that an interaction between baryonic matter and the carrier of dark energy inevitably leads to the transfer of dark energy to baryonic matter. This follows from two issues: the interaction between two substances is real, and this interaction obeys the laws of thermodynamics. This means that the conclusion mentioned above is also consistent with the law of entropy growth.

The main theoretical and empirical basis for this conclusion is given in our previous paper (Harutyunian & Torosyan, 2024). Therefore, we bring here only a very brief review of that study.

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Let us consider any baryonic object or system of objects interacting with a dark energy carrier. Due to this interaction, the baryon part of the interaction gains some energy. This means that the dynamical equilibrium, which is suggested for any baryonic structure, should be breached. In other words, the baryonic structure under consideration will not obey the virial theorem due to additional energy injected into it.

In turn, the energy increase leads to various changes in the structure, depending on its hierarchical status and inner construction. For macro- and mega-structures, an increase in size is obvious from a theoretical point of view. If the interaction has a constant character, these structures continue to increase in size, and their velocity dispersion becomes bigger.

The character of changes in the micro-world, which is resulted from the interaction of atomic nuclei and baryons with the carrier of dark energy, has a completely different behavior. These quantum objects are characterized by their nuclear binding energy, which is negative. The portions of positive dark energy injected into these objects inevitably lead to a decrease in the nuclear binding energy. In turn, reduces the mass defect of the interacting nucleus, which leads to the mass growth of the nucleus. We are particularly interested in the changes that are initiated thanks to the mass growth of baryons and atomic nuclei.

One of the physical consequences of the nuclear mass growth is the change in the spectral properties of the given atom. It is easy to see from the classical Rydberg relation that the larger the mass of the nucleus, the greater the differences in energetic levels. In other words, owing to such an interaction, spectral lines of the given atom should show some blueshift, determined by the mass growth value. The blueshift value shows the difference between the evolution length in the systems connected to the emitter and the observer.

Similarly to the Doppler effect, which shows the radial velocity difference of objects, the evolutionary spectral shift can serve as a measure of the difference between the evolutionary paths of baryon structures. The length of the evolution path of any baryonic structure depends on the time of evolution as the first parameter. However, as it follows from the relation (Harutyunian & Torosyan, 2024)

$$\eta \sim \frac{(R\rho_b)^2}{\rho_{de}} \tag{1}$$

the baryonic objects and their systems, possessing different masses and sizes, will have different evolutionary lengths. For example, the lesser the mass of a galaxy, the longer its evolutionary path for the same period.

Interestingly, the evolution rate is also higher for the same mass and lower density (bigger size). This aspect was the key one, which hinted at the longer evolutionary path of the Andromeda galaxy. The point is that the Andromeda galaxy, having approximately the same mass as the Milky Way, on the other hand, nearly twice surpasses our Galaxy in diameter. If the theoretical conclusion that the length of the evolutionary path of a baryonic structure depends on its size and mass is correct, then it can be argued that the Andromeda galaxy is significantly ahead of the Milky Way in its evolutionary path. The star formation rate in M31 is much lower than in our Galaxy. The same is correct for the nova phenomena as well. Both these empirical regularities are consistent with the conclusion on M31's longer evolutionary path and, accordingly, its lower activity.

3. More observational facts, arguing in favor of M31's longer evolutionary path

The spectral shift is not the only observable fact that reflects the evolutionary changes in baryonic matter and objects. We have already mentioned the growth of the size of an object or a system of objects, as well as the increase in velocity dispersion. It should also be added that the accumulation of energy in any integral object gradually makes it unstable. An object with excess energy must somehow get rid of the excess energy. This occurs either through radiation or by ejecting some clots of matter. If this method is insufficient to release the accumulated energy, the object can explode and disintegrate into its constituent parts.

According to the concept under consideration, the above-described processes occur at all hierarchical levels of the universe. Both stars and star clusters within the framework of this concept are considered as products of ejection from the core of the mother galaxy, starting from the state of a protogalactic clot without a stellar population. Therefore, the distance of a star or star cluster from the galactic core can be statistically used as a measure of the evolutionary path. Therefore, when applying this approach in a self-consistent manner, it should be assumed that statistically, the further a star (star cluster) is from the galactic core, the longer its evolutionary path.

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The physical consequences of energy accumulation in atomic nuclei and baryons are somewhat different but apply to all baryonic objects belonging to higher hierarchies. It has already been noted that interaction with a dark energy carrier reduces the nuclear binding energy, which increases the mass of the atomic nucleus. This process, in addition to shifting the spectrum of a given atom to the blue side, also gradually destabilizes heavy nuclei and makes them radioactive. As a result, various types of nuclear decay can occur, which increase the relative amounts of light elements, including hydrogen. This process leads to a decrease in the metallicity of those objects that have gone further along the path of evolution. If we compare this with the conclusion made above, we conclude that the further an object is from the center of the galaxy, the lower its metallicity.

In our previous work, we demonstrated that certain observational data may support our hypothesis that baryonic matter evolves through its interaction with dark energy. In particular, we proposed that objects exhibiting a blueshift might have experienced a longer evolutionary path than ours.

Let us return to our hypothesis, that the blueshift of the Andromeda galaxy may result from a longer evolutionary path compared to the Milky Way. First, we mention the relevant physical features of two galaxies.

The Andromeda galaxy is a large spiral galaxy, approximately 220,000 light-years in diameter. Its mass is estimated between 800 billion and 1.5 trillion solar masses.

The Milky Way is also a spiral galaxy, but with a smaller diameter of about 100,000 light-years, with an estimated total mass of around 1.5 trillion solar masses.

This suggests that the Milky Way's mass is comparable to or possibly even greater than that of Andromeda. According to relation (1), this may imply that the Milky Way has a higher "coefficient of resistance" (assuming that the term is used analogously to describe its resistance to certain evolutionary changes or dynamics in a galactic context).

In both M31 and our Galaxy, the half-light radii of globular clusters are found to be independent of their luminosities. In this respect, globular clusters of M31 and MW differ dramatically from early-type galaxies in which radii and luminosities are tightly correlated in all environments.

The median half-light radius of clusters in M31 is found to be Rh = 2.67 pc in M31, compared to Rh = 2.74 pc in the Milky Way galaxy.

In both M31, and the MW, the half-light radii of the metal-poor clusters are found to be systematically larger than those of metal-rich clusters. Does it mean that it is consistent with our conclusion that the more evolved systems should have a larger size and lower metallicity? This effect should be considered in more detail,

The sizes of metal-poor globular clusters in both the Galaxy and M31 are found to increase with distance from the nucleus. It follows that the difference between the radii of metal-rich and metal-poor globular clusters is not just due to differing metallicity.

In both galaxies, the most metal-rich clusters are concentrated at small galactocentric distances. However, the region containing metal-rich clusters is slightly larger in M31 than in the Galaxy. This is very interesting from our point of view.

4. Concluding remarks

The scientific concept, based on the self-consistent application of observational data and physical laws, predicts the need to take into account the evolution of baryonic matter under the influence of dark energy. One of the results of applying this concept is the evolutionary shift of the spectra of atoms to the blue side: the longer the evolutionary path of an object (baryonic matter), the greater the spectrum blueshift in the rest frame.

This conclusion allows the search for cosmic objects that differ from each other in the length of the evolutionary path of matter. If some object in this sense has undergone a longer evolution compared to the observer, then its spectrum should be shifted to the blue side of the spectrum. It is from this point of view that we study the Andromeda nebula, whose spectrum is shifted to the blue side. According to the studied parameters, this galaxy most likely has undergone a longer evolution than the Milky Way.

References

Harutyunian H. A., 2022, Communications of the Byurakan Astrophysical Observatory, 69, 1

Harutyunian H. A., Torosyan A. A., 2024, Communications of the Byurakan Astrophysical Observatory, 71, 68

doi: https://doi.org/10.52526/25792776-25.72.1-96

Perlmutter S., et al., 1999, Astrophys. J. , 517, 565

Riess A. G., et al., 1998, Astron. J. , 116, 1009

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