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Discussion of the Ambartsumian Hypothesis at the Santa Barbara Conference in 1961

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Abstract

The resolution concerning the Ambartsumian hypothesis, adopted at a 1961 conference in Santa Barbara, is examined. The conference was dedicated to discussing the hypothesis—put forward in the mid-1950s—that systems of galaxies are unstable. We noted that, at the time, the prevailing view held that such instability and the subsequent disintegration of these systems could not occur, as it would require an immense amount of energy. As a result, preference was given to the idea of a sufficient mass of dark matter stabilizing the systems gravitationally. We point out that, more than seven decades after this conference, no particles of exotic dark matter have been discovered. Furthermore, the largest reservoir of energy—dark energy—has been identified. With the discovery of dark energy, which interacts with baryonic matter, the energy deficit issue is resolved, so the need to introduce dark matter as a free parameter disappears. Examples of cosmic phenomena are presented that can be interpreted as early stages in the formation of new galaxies—a scenario envisioned by Ambartsumian many decades ago.

Keywords: *Galaxy groups: Trapezium type, instability; Dark energy: interaction, formation scenarios*

1. Introduction

In the mid-1950s, Viktor Ambartsumian began a new series of investigations, focusing primarily on multiple-galaxy systems of the "trapezium" type (Ambartsumian, 1961). He noted the inherent instability of such groups, which implied their inevitable disintegration and the eventual separation of the individual galaxies. Furthermore, because the chance formation of such a group through random association is statistically improbable, he concluded that these galaxies must have formed together and are currently breaking apart.

It is worth noting that this same line of reasoning had led him, as early as 1947, to the discovery of a new type of stellar grouping, which he termed "stellar associations." In statistical mechanics, these two types of systems differ only in their timescales. The discovery of stellar associations ultimately provided evidence that star formation is an ongoing process at the present epoch. Although this conclusion was considered highly unconventional at the time, it was later vindicated.

The analysis of the physical instability of trapezium-type multiple galaxies led Ambartsumian to another concept—unorthodox for that era—now known as "active galactic nuclei" (AGN). Indeed, the AGN concept historically emerged from this detailed study of the dynamics of multiple-galaxy systems.

In 1961, at a conference in Santa Barbara, California, leading experts in the field conducted a comprehensive analysis of Ambartsumian's concept. The proceedings of this conference were subsequently published in "The Astronomical Journal". In this paper, we briefly outline the primary objections raised as unresolved issues regarding this concept. At the time, these unresolved issues appeared significant, providing a rationale for considering hypothetical dark matter as an alternative—one that would resolve the problem of dynamical instability through gravitational stabilization by dark matter (Zwicky, 1937). We also examine these objections in light of contemporary perspectives on the very same questions that were discussed 65 years ago.

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2. Main objections

Any researcher familiar with Ambartsumian's work can discern at least two characteristic features of his scientific approach: mathematical elegance and an impeccable logical chain of reasoning. Add an excellent command of observational data, and you have the essential tools he used to make unprecedented conclusions. His findings on the instability of galaxy groups are a case in point. Yet, despite the flawless analysis that typified his work, the prevailing scientific understanding of the time made it impossible to accept the picture of processes he proposed.

At the very beginning of the Foreword to the Conference, the moderators mention: " . . . first proposed in 1954 by V.A.Ambartsumian of the Byurakan Observatory, Yerevan, Armenian S.S.R., extend from clusters to groups and pairs of galaxies, to studies of the form, structure, and dynamics of individual galaxies, to extragalactic radio sources, interactions of galaxies, and cosmology.

As we see it, the Ambartsumian hypothesis conjectures that at least some of the clusters and groupings of galaxies are unstable, that they have positive total energy, that they are flying apart and cannot be expected to last more than 10 to 1000 million years. It thus bears on the time scale of cosmology and on the evolution of galaxies. Ambartsumian has not attempted to explain the source of excess energy – the enormous "explosions" that provided energy sufficient to fling galaxies of about 10^44 g mass outward at velocities of about 100 km/sec. But it is clear that they may be identified with the extragalactic radio sources. Moreover, the assumed instability interferes with dynamical calculations of masses of galaxies from their motions in pairs, small groups, and clusters, and eliminates the basis of much of the reasoning fundamental to modern astrophysics."

This is the beginning part of the Foreword (Neyman et al., 1961) where one primary objection is formulated. Indeed, the moderators point to unexplained energy, sufficient to fling galaxies outward at huge velocities. To avoid the necessity of accepting the presence of huge energies, they mention another possibility, being considered since a few decades: "alternatively, it can be explained by assuming the presence of extra mass that cannot be seen or detected by other means as yet – mass either in an intergalactic medium or in numerous objects of low luminosity". Certainly, this is a mention of dark matter, referred to very carefully, yet.

To ensure that the main objection to Ambartsumian's concept was based on energy issues, one can read the conclusive part of the mentioned Foreword. "Although the Conference was not devoted to this aspect, Ambartsumian's hypothesis also raises interesting problems in physics: The first is the mechanism whereby such tremendous amounts of energy can be released – energy equivalent roughly to the total annihilation of a globular cluster, or to the radiation from a million stars over their whole lifetimes.

Secondly, how was the energy directed, particularly in the case of a double galaxy that must be flying apart along a single line under this hypothesis? How could so energetic an explosion be anything but isotropic?

Thirdly, how was the energy imparted to each galaxy as a whole? The acceleration of a galaxy of stars by an extremal force other than gravity is difficult to explain, although primordial galaxies of highly ionized gas could be subjected to magnetohydrodynamic forces."

The conference did not officially reject Ambartsumian's concept; it merely pointed out issues that were not ultimately clarified. Dark matter—mentioned as an alternative explanation—subsequently gained more proponents and became widely accepted. Moreover, dark matter has become an almost indispensable tool for fitting observational data. After the large-scale measurements of spiral galaxies' rotation curves, dark matter became ubiquitous. We will try to look at the problem in the light of dark energy.

3. Dark energy

It is no secret that, toward the end of the last century, gravity lost its monopoly as the sole agent in the cosmological and cosmogonic mechanisms of creation. The discovery of the Universe's accelerated expansion, combined with the introduction of "dark energy" into the physicist's toolkit, has radically altered the situation. It has become necessary to account for a substance—alongside gravity—that occupies the largest share of the total energy-mass balance of the Universe. This necessity arises because the dark energy carrier interacts with baryonic structures—a conclusion drawn from the observed acceleration of the Universe's expansion, which prompted the introduction of the dark energy concept.

Let us consider any baryonic structure with a virial

$$W = 2T + U \tag{1}$$

where T and U are just the kinetic and potential energies of the structure. The modern cosmology and cosmogony assert that all structures are balanced and therefore obey the virial theorem:

$$W = 0 \tag{2}$$

and, therefore, the total energy should be negative:

$$E = T + U < 0 \tag{3}$$

On the other hand, dark energy is positive. Thus, one interacting component (baryonic structure) is negative, while the other (dark energy) is positive. According to the laws of thermodynamics, the baryonic structure in any time interval Δt gains some non-zero amount of energy ΔE. Then the structure no longer obeys the virial theorem since

$$W = \Delta E > 0 \tag{4}$$

Energy is a cumulative substance; it therefore accumulates within any baryonic structure, increasing its total energy over time. Then, no baryonic structure can satisfy the virial theorem. Relation (4) implies that any system of baryonic objects expands by definition. This conclusion is decisive for the dark matter hypothesis. Indeed, physicists introduced dark matter into the physics toolkit solely to fit observational data with the accepted hypothesis that all cosmic baryonic systems are dynamically balanced. Yet, in the presence of dark energy, such systems cannot exist. Taken together with the fact that dark matter particles have yet to be detected, this conclusion implies that dark matter does not exist.

Let us examine available data on similar processes in baryonic structures traditionally considered to be in equilibrium. The distances between the components of the Earth–Moon and Saturn–Titan pairs are increasing; furthermore, for the first two pairs, the rate of separation is proportional to distance, analogous to Hubble's law:

$$v = \varepsilon R \tag{5}$$

where the coefficient of proportionality $\varepsilon$is equal to 9.94×10^{-11} and 9.42×10^{-11} per year for the first and second pairs, respectively. In these same units (the increase in a unit length per year), the Hubble constant is equal to 6.71×10^{-11}. Researchers traditionally attribute these recession processes to tidal effects. However, the Earth's angular momentum loss is insufficient for the Moon's retreat rate. One cannot examine the tidal hypothesis for the second pair since the relevant data are unavailable.

The situation changes when one considers an integral object. Any object that accumulates excess energy enters an excited state and, sooner or later, either sheds this energy or is destroyed by its influence. Nuclear physics shows that the most effective way for a system to exit an excited state is ejection of particles. Such particles can include electrons, protons, or products of cluster decay—ranging from alpha particles to larger, more complex entities. Alpha particles, for example, ejected from radioactive nuclei, possess several MeV of kinetic energy, providing velocities up to 15000-20000 km/s.

Returning to Ambartsumian's concept, one can say that, by drawing on statistical mechanics, he arrived at results now obtainable through a self-consistent application of the interaction between baryonic matter and the carrier of dark energy. He applied the same approach to both stellar and galactic systems. The modern understanding of the dark energy's uniform distribution justifies this approach. However, discoveries of young stars and the activity of galactic nuclei had long since confirmed his ideas. One can assert that the discovery of dark energy revealed the physical mechanism behind his concept.

The current activity in the jet of the galaxy M87 is a classic example of a clump of matter ejected from a galactic nucleus and subsequently breaking apart. Viktor Ambartsumian once included this galaxy in his list of the most active objects capable of giving rise to new galaxies. Six decades ago, however, its famous jet—the most prominent feature of the galaxy's activity—appeared as little more than a "frozen" snapshot. By then, it was already evident that the jet material had been ejected from the galactic nucleus. However, little can be said about the processes occurring within it, although distinct knots or condensations had already been identified.

The Hubble Space Telescope (HST) has observed the jet interior with unprecedented resolution, revealing new, compact knots near the nucleus. The knot closest to the nucleus, designated HST-1, is located just

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65–70 parsecs away. In 2006, this knot flared in both the near-ultraviolet and X-ray bands (Madrid, 2009). This knot exhibits at least two striking features to be examined in detail. First, the measured proper motion of the knot HST-1 is 1.04 ± 0.04c from 2002–2005 and around 2.1 ± 0.05c from 2005–2022 (Thimmappa et al., 2026). Second, the ejected subcomponents move at different speeds relative to one another.

The M87 jet is one of the most thoroughly studied outflows from a galactic nucleus. Denser knots of matter are also observed in the so-called relativistic jets of other galaxies. These bright, concentrated "knots" are a typical and well-documented feature of many relativistic jets. Virtually any astrophysical jet that can be examined in detail—using radio interferometers, the Hubble Space Telescope, or the Chandra X-ray Observatory—appears not as a smooth, continuous flow, but rather as a chain of discrete knots.

The most compelling evidence for the existence of internal substructure within jet knots—and for the relative velocities of their components—comes from studies of active galactic nuclei (AGN) other than M87, most notably Centaurus A, 3C 273, 3C 264, and 3C 279. As the radio galaxy closest to Earth, Centaurus A allows for a detailed investigation of the kinematics of internal knots on kiloparsec scales. Long-term X-ray and radio observations reveal that these knots are complex structures composed of components with significantly different velocities. While bright "anchor" knots remain essentially stationary (with velocities ¡ 0.1c), substructures located further downstream—or within the knots themselves—move at speeds ranging from about 0.5c to apparent superluminal velocities of approximately around 2.7c. Even within a single knot complex, the peaks of X-ray and radio intensity move at different speeds and exhibit non-radial (transverse) motion relative to the jet axis.

Another notable example is the quasar 3C 273. High-resolution monitoring of the jet's inner part has revealed dozens of distinct smaller components moving at varying speeds: some accelerate, others decelerate or stop, while others remain nearly stationary as faster clumps of matter pass through them. Images obtained by the HST at large distances (on the scale of a kiloparsec) reveal that the major knots (labeled A, B, C, and D) consist of smaller substructures and double peaks.

One could cite other examples of a similar physical situation. Alternatively, one could refer to the generally accepted explanation. However, we do not intend to engage here in a debate with the deeply rooted, conventional view. Our goal has been to present two phenomena observed in jets of matter ejected from galactic nuclei: bursts of radiation within the knots of such jets, and the multicomponent nature of these knots, characterized by an observable velocity dispersion. In accounting for these phenomena—beyond the conventional interpretation of their physical nature—one might also consider Ambartsumian's concept: the ejection of pre-stellar matter from the nuclei of active galaxies, followed by the formation of daughter galaxies. In a sense, this is reminiscent of cluster decay in nuclear physics, although the difference in scale introduces many qualitative distinctions.

4. Concluding remarks

The significance of the discovery of dark energy is still underestimated, though it has transformed our overall understanding of the Universe. In terms of significance, it is comparable to the discovery of gravity in the late 17th century—an event that ushered in an era of gravitational monopoly in space research. By inertia, this monopoly persists, even though the scientific community has already acknowledged that dark energy is the primary constituent of mass/energy in the observable Universe.

To us, the real influence of dark energy on the processes occurring within the baryonic world remains underestimated. The discovery of gravity more than three centuries ago revealed only one of Nature's mechanisms—a tool insufficient to explain everything. Consequently, it required constantly introducing various free parameters, which were then used to reconcile observational data with prevailing theories and hypotheses. From this perspective, the entire field of cosmogony and cosmology has resembled Ptolemy's geocentric system, with its numerous free parameters known as epicycles and deferents.

The concept of the instability of galaxy groups—specifically those resembling a "trapezium" configuration—proposed by Viktor Ambartsumian in the mid-1950s eventually paved the way for a broader, more significant idea: the concept of activity in galactic nuclei. To state the instability of these groups, Ambartsumian applied a method from statistical mechanics—an approach he had previously tested and validated in his study of stellar associations. In principle, the method is scientifically transparent and easy to understand by those familiar with probability theory. The conclusion rests on two pillars: first, probability theory, which points to the extraordinarily small probability of constructing such a configuration of objects through random encounters; and second, statistical mechanics, which demands that such a configuration is

inherently unstable and therefore possesses a short lifespan.

More than half a century ago, Ambartsumian concluded, consistent with findings that account for dark energy's influence. As for the alternative hypothesis—based on the potential existence of dark matter—it has yet to receive confirmation. Moreover, an analysis of observational data reveals that dark matter "tends to appear" precisely where younger, and therefore more active, objects are examined.

One needs only take a critical look at recently discovered galaxies that "exhibit a deficit of dark matter". These galaxies' evolution and expansion have unfolded over a very long period. Astronomers describe them as systems in which the visible mass—comprising stars and gas—accounts for virtually the entire gravitational force holding the galaxy together. In other words, these galaxies are considered exceptions to the rule; the absence of this hypothetical substance—which has never actually been detected—is viewed as a rarity. These are the contemporary musings on the given phenomenon. The truth is that the invented dark matter does not exist: dark energy killed it by its existence (Harutyunian, 2024).

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