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Instability of Cosmic Structures: New Perspectives on Ancient Phenomena

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Abstract

Non-stationary phenomena or instabilities in cosmic objects are invariably linked to the presence of excess energy and the various ways in which this energy is released. A central question in the study of such phenomena has always been—and remains—identifying the source of this accumulated energy. Traditionally, gravitational and nuclear interactions have been considered the primary sources. The discovery of dark energy has fundamentally altered our understanding of the Universe's energy balance; however, we still account for its influence only on cosmological scales. This paper proposes a new concept: at all hierarchical levels of the Universe, active processes use dark energy, which baryonic objects acquire through interaction with the medium that carries it.

Keywords: *Dark energy, baryon structures, interaction, energy exchange, instability, activity phenomena.*

1. Introduction

The instability of cosmic objects can be observed at every hierarchical level of the universe. Although these phenomena were discovered at different stages of human history, they are all linked as parts of a single, larger chain, defined by their primary characteristic: the release of accumulated energy. Naturally, the first instances of such instability were the catastrophic events that occurred on our own planet. Volcanism and earthquakes have accompanied humanity since time immemorial, and the release of colossal amounts of energy—with all its tragic consequences—has been recorded in both written and oral traditions.

The study of the instability of objects can arguably be traced back to Henri Becquerel's discovery of radioactivity at the end of the 19th century. As is standard in any field of human inquiry, the study of a given phenomenon typically unfolds in two key stages. The first stage involves gathering information about various aspects of the phenomenon; this phase is considered complete once the underlying patterns characterizing the phenomenon have been identified. The second stage begins when it becomes essential to uncover the physical mechanisms responsible for those observed patterns. By the middle of the last century and beyond, it became increasingly important to determine the role that such instability plays in the evolution of these objects—a question that applies to entities at every hierarchical level, from the micro- and macro-worlds to cosmological scales. Ambartsumian was the first to propose a direct link between the instability of objects and their evolution, at least in the context of stars and galaxies (Ambartsumian, 1947, 1958, 1961).

It is worth noting that Ambartsumian did not subscribe to any a priori hypotheses regarding the formation of cosmic objects. The primary tools for his research and the resulting conclusions were observational data, the laws of physics, and probability theory. His study of a new type of stellar system—which he termed "stellar associations"—was conducted without relying on any auxiliary assumptions, leading to the conclusion that the stars within these groups are extremely young. Also worthy of special mention is another conclusion, no less significant from a physical standpoint, concerning the physical state of protostellar matter. Ultimately, his research into the instability of galaxy groups led to this same conclusion.

In the realm of the microscopic, such a conclusion has never been in doubt, as the decay process has been studied in great detail, and the laws governing radioactivity are well understood. This spontaneous process—an inherent property of atomic nuclei possessing excess energy—occurs without external influence and

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results in an increase in the relative proportion of lighter nuclei. Furthermore, this process aligns perfectly with the "super-law" of increasing entropy. However, such a process is not immediately apparent in the formation of stars and galaxies; rather, it emerges from extrapolating observed trends in the mutual dynamics of these objects. Moreover, it would require the existence of large masses of super-dense matter—something that, according to known physical laws, cannot exist.

This is one reason why physicists and astrophysicists continue to construct scenarios for the formation of cosmic objects—ranging from atomic nuclei to entire galaxies—based on the clustering of matter. For large-scale cosmic objects, this process is described as contraction and accretion, while for atomic nuclei, it is known as synthesis. Gravitational clustering presents no particular difficulty; it occurs spontaneously. The synthesis of heavy nuclei, however, is not a spontaneous process; it occurs only when nuclei possess sufficient energy to overcome their mutual Coulomb repulsion. Moreover, such a process contradicts the law of increasing entropy.

Ambartsumian never addressed the energy-source issue responsible for the formation of unstable configurations. Traditional cosmogony and cosmology preferred to sidestep this issue by introducing free parameters in the form of additional gravitationally active matter that does not participate in any other types of interactions. This alternative—known as "dark matter"—had, in fact, existed long before the emergence of Ambartsumian's concept (Zwicky, 1933, 1937). Originally proposed to account for the equilibrium of galaxy clusters, dark matter subsequently became a convenient "fix-all" for many situations where instabilities needed to be effectively hidden from view. Notable examples include the rotation curves of spiral galaxies (Freeman, 1970, Rubin & Ford, 1970, Rubin et al., 1979, 1980) and the velocity dispersion observed in elliptical galaxies (Bertin et al., 1992, Saglia et al., 1992).

This "free parameter" did not resolve the overarching problem. First, dark matter—hypothetical at the time it was proposed—remains undetected to this day. Second, not all instabilities can be "hidden" beneath a layer of dark matter. Consequently, the origin of excess energy has long been debated, with various mechanisms proposed over time to account for different types of activity.

The discovery of dark energy has fundamentally altered the situation. Its detection even calls into question the necessity of including dark matter in the physicist's toolkit (Harutyunian, 2024). In this work, we examine a different, fundamentally distinct mechanism for the accumulation of excess energy within cosmic objects and their systems. This mechanism involves the interaction between the dark energy carrier and baryonic structures, facilitating a continuous influx of dark energy into baryonic matter. Sooner or later, this excess energy drives a given structure—at any hierarchical level—into an unstable or active state.

2. Dark energy vs Gravitation

In the late 17th century, Newton formulated the theory of gravitation. Astronomy entered the era of gravitational domination. Almost immediately, the Kant hypothesis emerged—a truly progressive scientific approach for the time to explain the formation of cosmic objects - later supported by Laplace's mathematical calculations. For three centuries, the theoretical foundations of both galactic and extragalactic cosmogony have been built on concepts in which various modifications of the Kant-Laplace hypothesis played a central role, with gravity as the key factor.

All observed energy releases in this era are somehow related to gravity. This includes either the return of Big Bang energy through accretion or the gravitational acceleration of matter to reach the temperature needed to fuel the thermonuclear furnace at the centers of stars. In this case, everything depends on the proto-object's mass and size, and various combinations can achieve this.

It was not until three centuries later that another universal energy field—one counteracting gravity—was discovered. The new millennium has been marked by the discovery of dark energy (Perlmutter et al., 1999, Riess et al., 1998), which, by all indications, is gradually becoming an equal—if not more significant—factor in shaping the nature and structure of our Universe. Indeed, a detailed look at the struggle between gravitational energy and dark energy makes it clear that the latter will eventually gain the upper hand.

Two key points should be kept in mind when considering dark energy in the context of cosmological and cosmogonic issues. The dark energy carrier continuously interacts with baryonic matter. Indeed, it was through this very interaction that it was discovered. The second point—which serves as the physical basis for the first—is the second law of thermodynamics. Furthermore, the total energy of all baryonic structures is considered negative, whereas dark energy is strictly positive. We thus conclude that all baryonic structures continuously receive a certain amount of energy through this interaction.

Thus, observed facts and known physical laws do not rule out the possibility of dark energy transfer to baryonic objects. This is a key question in the search for an energy source for various instability phenomena. Since this mechanism of energy transfer and accumulation is universal, it can be applied to all cosmic objects at all hierarchical levels.

Let's consider a baryonic structure at any hierarchical level of the Universe. It is natural to assume that this baryonic structure interacts with the dark energy that fills the space within it. Let us also assume that, at the given time t_0, the baryonic structure satisfies the virial theorem, as postulated by the traditional approach:

$$W = 2T + U = 0, \tag{1}$$

where T and U are the kinetic and potential energies, respectively. The interaction will change the energetic situation. After some time interval Δt, the baryonic structure gains energy ΔE and the virial value will become positive:

$$W > 0. \tag{2}$$

This is the most important conclusion. This means that in the presence of dark energy, no baryonic structure can remain in a state of equilibrium; all such structures must inevitably expand. The precise manner in which this occurs depends on specific structural characteristics—for instance, whether one is considering an isolated object or a group of objects. In each case, the process of shedding excess energy and the subsequent expansion of the baryonic structure unfold in their own distinct way, in strict accordance with the laws of physics.

Another important aspect is that energy is cumulative. The rate of energy transfer into the baryonic structure is irrelevant. Energy accumulates gradually, and the longer the interaction lasts, the more energy is stored. Accumulation can continue as long as the structure is capable of "retaining" the energy without compromising its own integrity. However, any baryonic object has a limit to how much excess energy it can accumulate before it begins to shed it. The latter happens through mechanisms such as radiation, mass ejection, and fragmentation.

The discovery of dark energy has offered a fresh perspective on Ambartsumian's conclusions from over half a century ago. A self-consistent application of physical laws—incorporating observational data on dark energy—leads to the same conclusions Ambartsumian reached, despite his lack of knowledge of dark energy. While he was indeed unaware of it, this energy was nonetheless at work in the universe, operating according to the laws we have outlined here. Consequently, the configurations that emerged were the result of the combined influence of gravity and dark energy. By employing methods from probability theory and statistical mechanics, Ambartsumian uncovered the manifestations of dark energy, which were embedded within the structural characteristics of all baryonic matter. Before proposing his own hypothesis, Ambartsumian was thoroughly familiar with existing theories of cosmic structure formation; however, he recognized that none of them could resolve the clear contradictions with observational evidence.

There is another significant point. Both before the advent of his hypothesis and to this day, mainstream science has sought to interpret the entire energy budget of the universe as a consequence of a single, initial release of energy—the so-called Big Bang. The prevailing view suggests that this original energy manifests in every phenomenon: from the expansion of the universe and the primordial heating that ignited nucleosynthesis during the formation of cosmic objects, to the processes of accretion observed throughout the cosmos. Ambartsumian, by contrast, maintained that the capacity to generate energy is an intrinsic property of the objects themselves. The discovery of dark energy reveals that the energy within baryonic structures is, in fact, the continuous transformation of dark energy into the energy of these structures.

The first conclusion we arrive at using only observational data is that the carrier of dark energy, whatever it appears to be, certainly interacts with baryonic matter. This unknown carrier of energy, interacting with baryonic objects, comprises at least 70 percent of all mass/energy, while the entire baryonic universe contains less than 5 percent. This raises a question: could dark energy serve as a storehouse of energy resources for all the unstable phenomena we observe everywhere? After all, the energy required for all observed instability phenomena is only a tiny fraction of the dark energy reserves.

To summarize the above, we conclude that any discussion regarding the evolution of cosmic structures must take into account that the carrier of dark energy—whatever it may be—interacts with all baryonic structures. Any interaction between different substances serves as a natural mechanism for the redistribution of energy among the interacting entities. In this instance, an unknown energy carrier—which accounts for at

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least 70 percent of the total mass/energy—is in a state of continuous energy exchange with the structures of the baryonic universe, which comprise less than 5 percent of the total mass/energy. In other words, baryonic structures are constantly replenishing their energy resources from dark energy. This gives rise to a logical question: could dark energy perhaps serve as an energy reservoir for the various unstable phenomena we observe everywhere? After all, the energy required for these phenomena represents only an infinitesimal fraction of the total reserves of dark energy.

3. Nuclear binding energy vs dark energy

The baryonic world is organized according to a single principle: any baryonic structure exists because its total energy is negative. Atomic nuclei are no exception. These "building blocks" of our world exist solely due to a unique property known as the "mass defect." The mass defect is the difference between the mass of a nucleus and the combined mass of its constituent protons and neutrons in a free state. Although this structural feature manifests only at the microscopic level, the entire baryonic world rests upon it.

This feature of atomic nuclei is a universal mechanism for the interconversion of mass and energy, acting as a kind of phase transition of matter. There is another key manifestation of this property—one that is well-known but rarely discussed in terms of its fundamental physical significance: the magnitude of the mass defect per baryon varies from one nucleus to another. This characteristic is of fundamental, non-trivial importance to the existence of our world. Its true meaning runs much deeper than it might appear at first glance: it implies that baryons can alter their mass depending on the physical conditions in which they find themselves—in other words, they are capable of adapting to their environment.

From a physical perspective, the energy equivalent to the mass defect is the binding energy of the nucleus. Put another way, if a nucleus were to absorb an amount of energy equal to this value, it would break apart into individual baryons. One natural pathway for energy to enter a nucleus is through the interaction of atomic nuclei with the carrier of dark energy (following the same logic outlined in the previous paragraph). This implies that, as a result of constant interaction with the carrier of dark energy, a certain amount of energy is continuously being supplied to the nucleus. This process results in a gradual decrease in both the binding energy and the mass defect of an atomic nucleus. Although this process occurs extremely slowly (Harutyunian, 2021), it inevitably leads to the progressive destabilization of atomic nuclei, driven by an increase in their mass and a reduction in their binding energy.

Consequently, if an interaction between baryons and the carrier of dark energy truly exists, it will inevitably destabilize all such objects—including atomic nuclei and the baryons themselves—thereby fundamentally altering our entire known physical picture of the microscopic world. This process can be described as nothing less than the evolution of baryons and atomic nuclei. We conclude that, as a result of their interaction with the carrier of dark energy, atomic nuclei and baryons must undergo an evolution—an evolution that, in this context, entails an increase in their mass and a decline in their stability.

Thus, if an interaction between baryons and the carrier of dark energy truly exists, it would inevitably lead to the destabilization of all such objects—including atomic nuclei and the baryons themselves—fundamentally altering our entire known physical picture of the microscopic world. This process can be described as nothing less than the evolution of baryons and atomic nuclei. We conclude that, interacting with the dark energy carrier, atomic nuclei and baryons evolve, a process that, in this context, entails an increase in their mass and a decrease in their stability. Consequently, multi-baryon nuclei decay into lighter, less massive ones.

In the macro and mega worlds, the evolution of atomic nuclei increases the mass of all objects. At the same time, it increases the percentage of lighter nuclei. As one can see, this conclusion contradicts what we have been taught. We have long been told that atomic nuclei heavier than hydrogen and helium are formed within the cores of stars through nuclear burning, a process that physically resembles the phenomena of merging and accretion in the microscopic world. When we discuss the "metallicity" of various cosmic objects, we instinctively compare the abundance of heavy nuclei against that of hydrogen, which is regarded as the "primordial foundation" of all atomic structure.

However, it is also well established that, due to energetic constraints, fusion reactions can only proceed up to the formation of iron nuclei. Furthermore, unlike decay processes, such reactions require specific conditions—namely, the acceleration of the reacting components. For nuclei heavier than iron, the binding energy per nucleon decreases, rendering their formation via this mechanism energetically unfavorable. The existence of heavy, radioactive nuclei appears even more puzzling if one assumes they originated from a

complex process of neutron capture. It is highly unlikely that nature would expend such immense effort to create nuclei that are, ultimately, destined to decay. Within the paradigm we are considering, all processes at every hierarchical level of the Universe unfold in a single direction: heavier objects undergo gradual destabilization, and through the shedding of excess energy, lighter objects are formed. This process is most clearly observable in the microscopic realm—for instance, in the case of radioactive nuclei, which give rise to lighter nuclei.

Here, radioactive nuclei are those that have transitioned from a stable to an unstable state and are progressively releasing excess energy. Physicists have long been well acquainted with these phenomena and can describe them with a high degree of confidence. We merely add that the excess energy—which leads to the disintegration of an atomic nucleus—accumulates as a result of the interaction between these nuclei and the carrier of dark energy. Notably, these same nuclei were stable in the distant past and remain stable to this day within the interiors of massive objects (Harutyunian, 2024).

4. Systems of cosmic objects and dark energy

In analyzing the applicability of our concept, we rely on established laws of physics and verified observational facts. Consequently, our conclusion is clear and natural: at every hierarchical level of the Universe, all baryonic structures continuously receive energy from the carrier of dark energy. This energy alters their energy balance and drives them toward a different state.

In the microscopic realm, this excess energy gradually compensates for the mass defect and reduces the binding energy of atomic nuclei and baryons. As a result, the mass of atomic nuclei and individual baryons increases. The reduction in nuclear binding energy ultimately renders atomic nuclei radioactive. The greater the increase in excess energy within a nucleus, the shorter its half-life becomes. Thus, we arrive at the Geiger-Nuttall law, known to govern alpha and cluster decay. This decay produces high-velocity particles (15,000–20,000 km/s) and gamma radiation, thereby raising the temperature (kinetic energy) of the surrounding medium and generating electromagnetic quanta. Macroscopic objects composed of atoms cannot increase their internal energy indefinitely; therefore, they shed it through various mechanisms. The simplest such mechanism is the emission of electromagnetic waves. If this is insufficient to dissipate the excess energy, the object may eject matter. This can manifest as stellar winds, or, in cases of more rapid mass accumulation, as the expulsion of large clumps of matter.

On the other hand, the prevailing concept describing the formation of baryonic objects and structures frequently gives rise to paradoxes. The reason, as one might surmise, lies in two a priori assumptions. The first premise is the hypothesis that all baryonic structures originated from the gravitational contraction of gas and dust clouds. To account for this contraction, a second assumption is introduced: the virial value of such clouds must be negative. Clearly, these two conditions inherently preclude the possibility of an expanding structure forming. Consequently, galaxies and galaxy clusters are, by definition, considered to be in a state of equilibrium. This is precisely why the expansion observed within the Solar System—analogous to Hubble expansion (Dickey et al., 1994, Lainey et al., 2020)—is typically explained through tidal effects and the transfer of angular momentum from a central object to an outward-moving one.

The discovery of dark energy should, by all standards of scientific progress, have altered this situation. The arguments presented in the first section of this paper are sufficient to warrant abandoning the prevailing Kant-Laplace cosmogony. Nevertheless, the dominant scientific paradigm continues to adhere to the postulates of this hypothesis. The history behind the emergence of the concepts of these two "dark" substances, however, deserves closer scrutiny. While dark matter was introduced to preserve established views and reconcile observational data with an a priori hypothesis, dark energy serves as a physical interpretation of empirical observational results. If one must choose between the two, the latter concept holds a clear advantage.

Thus, in the presence of dark energy, the total energy of all cosmic objects and their systems gradually increases over time. The rate of energy transfer affects only the duration of the change process. In this scenario, the crucial point is that energy is transferred in a single direction—with baryonic objects acting as the recipients. Consequently, the energy balance constantly changes, forcing the baryonic structure to shed excess energy. This occurs through the expansion of gravitational systems, accompanied by the ejection of energy in the form of matter clumps or excess radiation. It is precisely this that manifests as instability.

The emergence of instability is a natural stage in the evolution of any object. Depending on an object's physical characteristics, this phase of instability may be a recurring phenomenon. If an object accumulates

enough energy over a certain period to threaten its own existence, it is compelled to discharge it. The process of releasing accumulated energy occurs much more rapidly than its accumulation. Once the object releases its excess energy, the signs of instability vanish, and a new cycle of energy accumulation begins. We observe these phenomena in flare stars, recurrent novae, and similar instances.

5. Concluding remarks

The Universe exhibits numerous varieties of instabilities, which can be observed at every hierarchical level of cosmic structure. These instabilities have been documented in detail. The primary unifying feature of all such unstable phenomena is an excess of energy. Consequently, a key question in every case is identifying the source of this energy and the mechanism by which it is transferred to the objects in question. In this work, we continue the research tradition of Ambartsumian, who regarded instability as the fundamental driver of the evolutionary processes of cosmic objects. Decades ago, Ambartsumian was unable to prove that the evolution of all cosmic objects proceeds in a single direction—from a denser, or even superdense, state toward a more rarefied one. This was because of the lack of knowledge regarding the behavior of matter in a superdense state. As a result, while the scientific community accepted his findings on the existence of newly formed stars and the activity of galactic nuclei, the evolutionary concepts that led him to these discoveries were rejected.

The discovery of dark energy—specifically its interaction with baryonic matter—has provided an opportunity to revisit Ambartsumian's ideas. The fact that the carrier of dark energy (whatever its nature may be) interacts with baryonic matter opens up a new approach to this problem. A crucial aspect of this interaction is that all baryonic objects possess negative energy, whereas dark energy is strictly positive. Therefore, in accordance with the laws of thermodynamics, any baryonic structure gains energy through such an interaction. Since this interaction is continuous, there is an unending flow of energy into the baryonic realm. It is also significant that dark energy accounts for approximately 70 percent of the total, compared to just 5 percent for baryonic matter. This relationship suggests that such an interaction could serve as a mechanism that supplies energy to various active or unstable processes. It is also evident that the amount of energy released throughout the Universe during various instability-driven processes accounts for only a negligible fraction of the total reservoir of dark energy.

Within the framework of the concept under consideration, the instability of cosmic objects arises from the conversion of dark energy into the energy of baryonic matter. Furthermore, the consistent application of the mechanism we propose renders the introduction of concepts such as "black holes" and "dark matter" unnecessary. In our view, these hypothetical objects and substances have persisted in scientific discourse merely as a form of "free parameters." By employing an appropriate research methodology—one that addresses the relatively transparent mechanism by which baryonic structures interact with the medium of dark energy—these free parameters become superfluous.

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