THE LAST STOP BEFORE THE COSMIC DEFECT: NEUTRON STARS

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Abstract

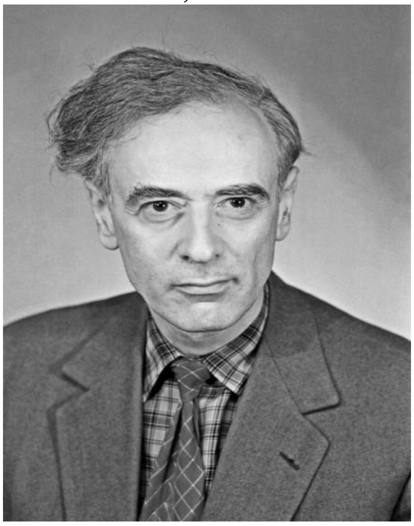
Neutron stars are natural laboratories of exotic forms of dense matter. Neutron stars constitute the final stage of stellar evolution, providing an opportunity to empirically test both mathematical models and quantum gravity theories. A thorough study of the structure and properties of these objects is of great importance for both astrophysics and nuclear physics. In this article, neutron stars are presented as one of the most mysterious objects in astrophysics, and their structure, extreme physical conditions, and possible connections with cosmic defects are investigated. It analyzes various neutron stars not only as massively condensed stellar remnants, but also as high-energy structures approaching defects on a cosmic scale. The article takes an indepth look at topics such as baryon degeneracy, superfluidity, thermal evolution, mass vacuum, the nature of magnetars, etc. In particular, it aims to connect the evolutionary stages of neutron stars over time in space with the theories of quantum gravity, highdensity matter, and topological defects. This approach analyzes neutron stars as the "last barrier" in the topological continuum of the Universe. While traditional astrophysical models describe neutron stars as relatively static objects, this paper views them in a new context—as topological objects approaching cosmic defects on a cosmic scale. The paper takes a step toward a broader and more unifying cosmological model, taking its place at the intersection of modern theoretical physics and astrophysics.

Keywords: Neutron stars, magnetar, thermal evolution, mass gap, black holes, quark matter, cosmic defect.

Introduction. The dynamics of the Universe are not limited only to expansion, gravity and the interactions of matter, but the Universe also introduces us to the boundaries of space-time and matter through extreme objects within it[1]. One of these objects is neutron stars. Neutron stars are one of the most extreme and interesting objects in the Universe. Neutron stars are dense stellar remnants formed after the supernova explosion of very massive stars and consist mainly of neutrons[2]. Neural stars form in the final stages of the evolution of ordinary stars, providing us with living evidence not only of dead stars but also of fundamental physics. Although these objects have small radii, their masses can be as large as or larger than the Sun. Understanding the behavior of matter in such dense conditions is of great importance not only for astrophysics, but also for nuclear physics, quantum field theory, and theories of gravity[3].

Neutron star

The study of neutron stars provides us with fundamental information about the nature of high-density matter, quark matter, gravitational waves, the boundary values of magnetic fields, and even the structure of space-time. In particular, these objects are natural laboratories for modeling processes occurring in the early moments of the Universe or in high-energy regimes[4]. Therefore, the study of neutron stars is not limited to theoretical physics, but rather plays a key role in forming a deeper understanding of the origin, evolution, and possible fate of the Universe[5]. Let us first look at the discovery and development of neutron stars. In 1931, the Indian physicist Subrahmanyan Chandrasekhar calculated that the maximum mass of white dwarf stars is about 1.4 solar masses. This result showed that stars exceeding this limit must take on another exotic form[6]. This limit, proposed by S. Chandrasekhar, is considered the first theoretical basis for neutron stars. In 1932, the Soviet physicist Lev Landau proposed the idea that very dense stars could exist even before the discovery of the neutron particle. L. Landau wrote that the collapse of massive stars could lead to matter becoming denser than the atomic level. L. Landau discussed this idea with Niels Bohr, and predicted that electrons in stars would combine with protons to form neutron-like matter[7]. In the same year, the English physicist James Chadwick discovered a particle called the neutron, which led to the conclusion that this idea was possible[8].

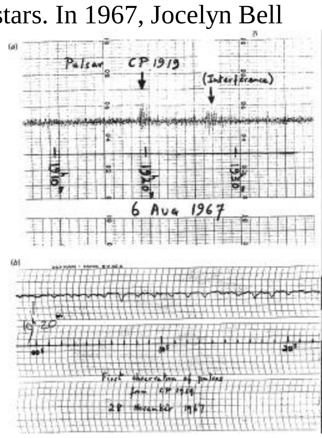




Subrahmanyan Chandresekhar — Lev Landau — James Chadwick

In 1933, physicists Walter Baade and Fritz Zwicky proposed that supernova explosions could produce "very dense stars made of neutrons". They first called these objects "neutron stars"[9]. This event was theoretically the birth of neutron stars. However, these objects had not yet been observed.


Fritz Zwicky — Walter Baade

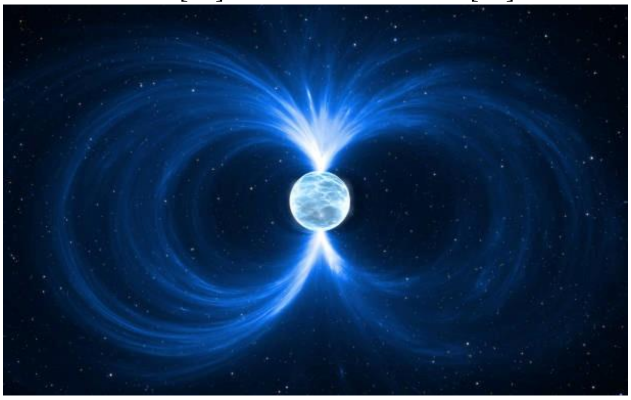
The years 1965–1967 were the years of the first observations of neutron stars. In 1967, Jocelyn Bell Burnell and Antony Hewish detected regular radio signals during radio telescope observations[10].



Surveillance signal; — Jocelyn Bell Burnell

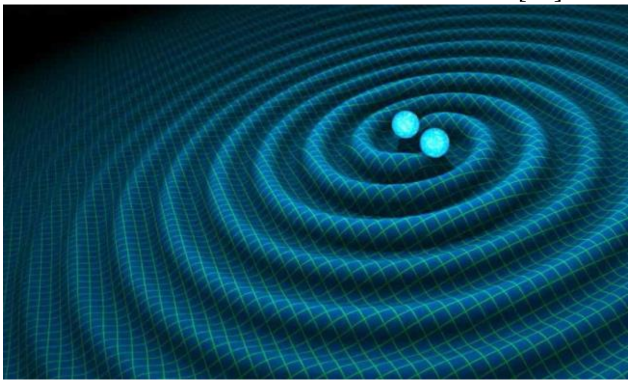
They initially called these signals "Little green men" (aliens)[11]. It was soon discovered that these signals came from rapidly rotating neutron stars. These radio signals were called "pulsars" because they resembled a regular heartbeat, and the existence of neutron stars was confirmed by observation. For this discovery, A. Hewish was awarded the Nobel Prize in 1974[12]. In the 1970s, the first X-ray-emitting pulsars were observed by NASA's Uhuru satellite. These observations showed that some neutron stars were emitting energetic

X-rays as they absorbed matter in a binary star system[13]. Most pulsars had a rotation rate measured in seconds. However, in 1982, the first millisecond pulsar was discovered: PSR B1937+21. This pulsar was rotating 641 times per second. This discovery proved that neutron stars are extremely stable and dense[14]. Since the 1990s, neutron stars with very strong magnetic fields, called magnetars, have been discovered. Magnetars are distinguished by their gamma-ray and X-ray bursts. Magnetars have magnetic fields of the order of 10^{15}–10^{16} Gauss, making them among the strongest in the Universe[15].



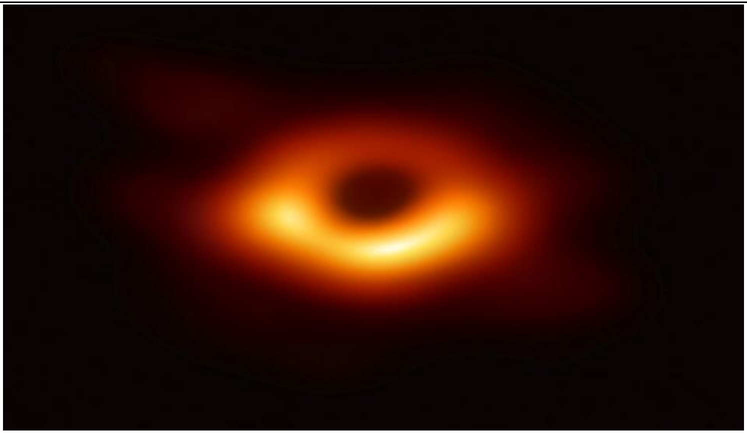
Magnetar

In 2003, the first confirmation of the merger of two neutron stars in gravitationally bound binary star systems was observed. These objects were considered potential sources of gravitational waves and kilonova explosions[16]. 2017 was marked by the event GW170817. The LIGO and Virgo detectors first observed gravitational fluctuations from the merger of two neutron stars[17].



Gravitational waves

This observation paved the way for the era of multidimensional astronomy in the history of astronomy. The discovery and study of neutron stars stands at the intersection of nuclear physics, quantum field theory, cosmology, and astronomy. Neutron stars represent the densest matter, the strongest magnetic fields, and the fastest rotating objects in the Universe. Thanks to these objects, real observational material is obtained towards the unification of gravitational and quantum theories[18]. A neutron star is one way that stars end their lives. Neutron stars have a mass of at least 1.1 solar masses (M⊙). The upper limiton the mass of a neutron star is calledthe Tolman–Oppenheimer–Volkoff limit and is generally considered to be around 2.1 M⊙[19]. However, recent studies suggest that this limit is 2.16 M⊙. As of September 2019, the most massive neutron star discovered was PSRJ0740+6620, with a mass of 2.14 M⊙[20]. There are approximately 2,000 neutron stars known to exist within the Milky Way galaxy. The closest neutron stars to the Solar System are RXJ1856.5-3754, about 400 light-years away, and PSRJ0108-1431, about 424 light-years away[21]. Stars with masses below the Chandrasekhar limit of 1.39 M⊙ are generally white dwarfs. Compact stars with masses between 1.4 M⊙ and 2.16 M⊙ are expected to be neutron stars. However, there is a small mass range, a tenth of the mass of the Sun, within which the lowest-mass neutron stars and the most massive white dwarfs can coexist[22]. Above a mass of 2.16 M⊙, the gravity of a compact star, theoretically the remnant of a dead star, is thought to overcome the degenerate neutron pressure and form a black hole.



Black hole photographer

However, the smallest observed black hole has a mass of 5 M⊙[23]. Despite their enormous masses, neutron stars have very small volumes. For example, a neutron star with a mass about 1.5 times that of the Sun would have a diameter of only 10 kilometers. The smallest neutron stars have a radius of about 10 kilometers, while the largest have a radius of 14–16 km. In very rare cases, this figure can approach 22 kilometers, but this can only happen for unusually massive stars[24]. Density of neutron stars $p \approx 10^{17}$ kq/m³, gravitational field approximately 10^{11} g, while the magnetic field 10^{8}-10^{15} It is in the Gaussian range (especially in magnetar-type neutral stars). From this perspective, the volume of an average neutron star is:

$$V=4\pi R^3/3= 4\cdot 3,14\cdot (10^4)^3/3\approx 4,2\cdot 10^{12}\ m^3$$

[25]. It is said that a spoonful of neutron star matter would be equivalent to 100 million tons on Earth. This mass is about the same as Mount Everest[26]. In fact, when we calculate with the given quantities,

$m_s = p\cdot V_s= 10^{17}\cdot 10^{-6}= 10^{11}$ *kq/m³*

we will get it.

Neutron stars are very hot, with surface temperatures reaching 600,000 K. The internal temperature of a newly formed neutron star is. 10^{11}-10^{12} K is between. However, the neutrinos it emits are so energetic that within a few years the temperature drops to 10^6 K. Most of the radiation emitted by a neutron star at this temperature is X-rays[27]. The reason why neutron stars do not shrink further under the influence of gravity is the Pauli exclusion principle. This principle states that no two fermionic particles, such as protons, electrons, and neutrons, can occupy the same location and quantum state. Therefore, stars with a mass greater than 5 times that of the Sun are unstable and will continue to collapse. These stars will become black holes. The reason why neutron stars do not collapse further is neutron pressure[28].

Neutron stars rotate at very high speeds because, according to the law of conservation of angular momentum, the rotation speed increases as the star's volume decreases[29]. However, according to the law of conservation of angular momentum, we can also obtain the following result:

$$L=J\cdot\omega=const$$

Therefore, as J decreases, ω will increase. In short, as the radius decreases, the rotational speed increases sharply. Here, L is the torque, J is the moment of inertia (related to mass and radius), and ω is the angular velocity of rotation[22].

The fastest known neutron star to rotate on its axis is PSR J1748-244bad, which rotates 716 times per second, or 43,000 times per minute. At its equator, its rotation speed is about 24 percent of the speed of light[30].

Now let's look at the process of neutron star formation. A neutron star is formed when a massive star explodes as a Type II, Type Jb, or Type Jc supernova and the rest collapses in on itself. Although these stars are composed almost entirely of neutrons, they also contain small amounts of protons and electrons. Without these protons and electrons, neutron stars would not survive for long[31]. This is because neutrons are unstable in their free state and quickly decay into protons and electrons, emitting beta radiation. However, due to the high pressures inside the star, protons and electrons combine to form neutrons, making neutron stars more stable[22]. An average neutron star contains about

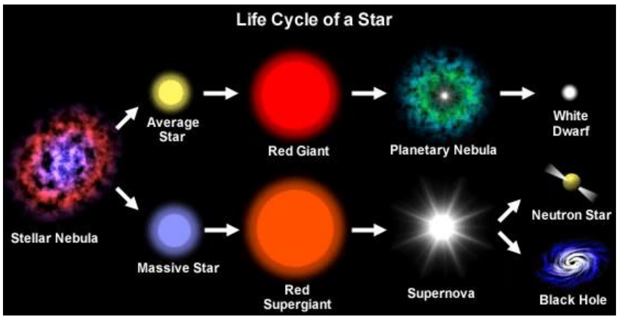
$$N=M/m_n =2,8\cdot 10^{30}/1,675\cdot 10^{-27}\approx 1,7\cdot 10^{57}$$

There are neutrons in the number. Here M is the mass of the neutron star, and mn is the mass of the neutron. Although this number is huge compared to the existing number of baryons in the Universe (about 10^{80}), this is how many quantum particles are contained in a single star.

As a result of the burning reactions of the star, all light elements are synthesized up to iron. Iron is the element that produces energy in nuclear fusion, because when heavier elements are synthesized, energy is consumed, not produced. This transformation process occurs in the following:

1. The iron core begins to collapse (because it no longer produces energy);
2. Due to the high gravitational force, electrons combine with protons and become
neutrons;
3. At this time, a large number of neurons are formed[31].

Neutron stars are formed by stars with masses close to the Chandreshekhar limit. The star continues its life by fusing hydrogen into helium. Under normal conditions, this fusion process is sufficient to maintain the star's size. In other words, the energy generated by the external fusion reaction counteracts the internal gravitational force, keeping the star's size constant. However, as the star nears the end of its hydrogen supply, it begins to shrink due to the gravitational pull at its center. In this state, it continues to emit faint light due to the reaction of the remaining hydrogen in its center. Then, when its fuel is completely exhausted, another reaction begins: the fusion of helium atoms into carbon atoms. Compared to hydrogen fusion, helium fusion releases an incredible amount of energy. Therefore, centrifugal force cannot withstand this energy and the star begins to grow at an incredible rate[32]. So much so that if the Sun were to enter this space, its diameter would expand to swallow Mars. This red giant continues to expand in this way for a while until it even uses up the helium in its structure.

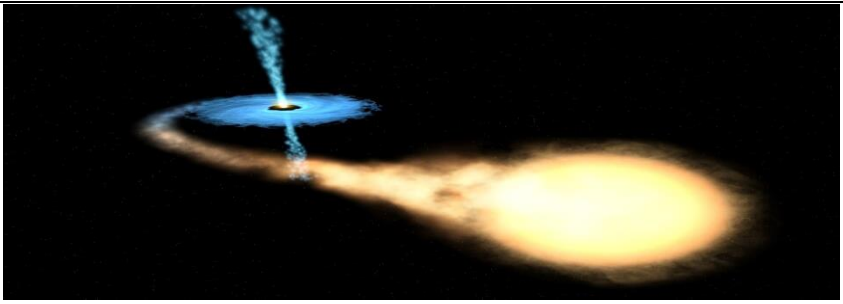


Stages of stellar evolution

Once the helium is exhausted, the star's energy production pathways are exhausted and it begins to collapse again under the influence of its unbalanced gravity[6]. In the compression phase, the fate of the star is determined by its mass. The greater the mass of the star, the greater its central gravitational force. The smaller its mass, the weaker its central gravitational force. For example, stars smaller than the Sun collapse to form brown or black dwarfs[33]. Neutron stars are classified into different types based on their mass and internal structure. The types of neutron stars are described differently in different literatures. We can generally divide neutron stars into the following groups:

- Pulsars (radio, optical, X-ray radiation);
- Magnetars (super strong magnetic field);
- X-ray binaries[34].

Magnetars are neutron stars with extremely strong magnetic fields. These magnetic fields are the strongest known in the Universe: $B \approx 10^{14}$-10^{15} Qauss. Magnetars are formed by a supernova explosion of a rapidly rotating protoneutron star with a highly convective zone. The supernova explosion creates an extremely strong magnetic field inside the star. As a result, the star emits energy, explodes, and emits X-rays and gamma rays. Magnetars provide unique information about the evolution of neutron stars and the mechanism of magnetic field formation[35]. About 5% of known neutron stars are members of binary star systems. In these systems, the neutron star's companions may be normal stars, white dwarfs, or other neutron stars. X-ray binaries are a class of binary stars that are bright in X-rays. A typical low-mass X-ray binary emits about 10^{41} positrons per second. General relativity predicts that binary star systems emit gravitational waves and that the distance between the stars decreases over time. The first evidence for the existence of gravitational waves was obtained by observing a binary star system containing a neutron star and finding that the distance between the stars varied according to the predictions of general relativity[36]. This much information about the types of neutron stars will suffice.



X-ray binaries

Scientists first modeled how matter would behave in density by making calculations based on Einstein's general theory of relativity and quantum statistics. At that time, observational evidence proved that neutron stars have layers[37]. When various pressure-energy relationship models were compared with these observations, only the layered structure models were consistent[18]. The fact that the shell vibrates and breaks also suggests that these events occur as a result of compression and tension due to the difference in stiffness between the shell and the core[38]. According to scientific sources, we can roughly express the structure of these layers as follows:

1. Inner Core:

· Content: ~99% neutrons, protons, electrons, muons, hyperons and/or quark matter.

· Density: > 1.5×10^{15} qr/sm³ (2-3 times the nuclear density)

· Note: The composition of this region is not fully known and various theories (hyperons, pion/condensate, quark-gluon plasma) have been proposed.

2. Outer Core:

· Content: ~90-95% neutrons, ~5-10% protons, electrons and muons.

·Density: 4.3×10^{14} - 1.5×10^{15} qr/sm³ (close to or higher than the nuclear density)

· Characteristics: Superconducting liquid neutron-proton mixture. Free electrons and muons provide high conductivity.

3. Inner Shell:

· Composition: Atomic nuclei that are extremely rich in neutrons (Z=30-40) + free neutron superfluid + electron gas.

· Density: 1.4×10^{14} - 4.3×10^{14} qr/sm³ (up to about half the core density)

· Note: The "neutron droplet matter" phase is observed here (lattice, cylinder, sheet shapes).

4. Outer Shell:

· Composition: Crystal lattice of iron-56 (^{56}Fe) and heavier elements (Z=26-38) + free electron gas.

· Density: 10^6 - 1.4×10^{14} qr/sm³

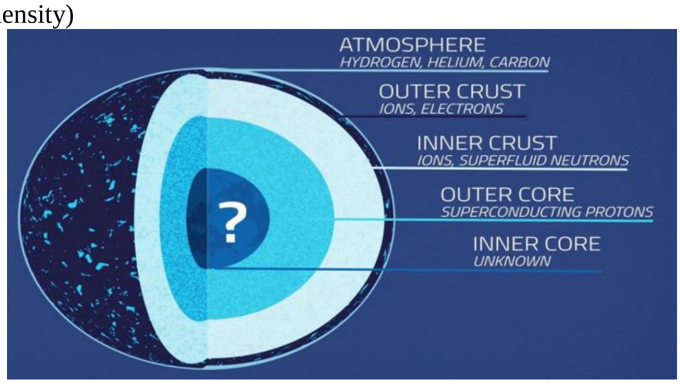
· Characteristics: Perfect crystalline structure. As the density increases, the nuclei begin to become extremely enriched with neutrons by capturing electrons.

5. The atmosphere

· Composition: A thin layer of hydrogen or helium (about 1-10 m thick).

· Density: < 10^6 qr/sm³

· Significance: Determines the emission properties of a neutron star[39].



The internal structure of a neutron star

However, many scientists believe that there is a substance with different properties in the core of a neutron star. In 1984, the American theoretical physicist Edward Witten suggested that "strange" quark matter (consisting of u, d, and s quarks) may be a more stable form in the center of neutron stars. E. Witten even claimed that quark stars may exist in the Universe. According to E. Witten, this matter is one of the densest and most stable types of matter known to mankind[40]. Canadian-American writer Norman Glendennig suggested that neutron stars may contain high-density hybrid stars. That is, the outer part of the star may consist of neutron matter, and the center of quark matter. N. Glendenning suggested that this transition may not occur abruptly, but rather in the form of a "mixed phase"[41]. American theoretical physicist Fridolin Weber has worked extensively on the internal structure of neutron stars and has investigated the observable astrophysical results. F. Weber showed that quark matter affects parameters such as the radius, rotation frequency, and temperature of the star. F. Weber also tried to theoretically justify the existence of quark stars[42]. All these ideas argue that neutron stars may be a new type of hybrid stars. It should be noted that in some sources the term "nuclear fluid" is used inside neutron stars. However, this fluid is not a classical fluid. Because, at such a high density, a liquid state cannot exist. Here, the word "liquid" only denotes collective quantum behavior[43]. Inside neutron stars, the density is no longer only the possibility of the formation of quark matter, but also collective effects arising from the quantum nature of baryons - degeneracy and superfluidity - begin to play an important role. These processes are the main factors determining the internal structure of the star and the dynamics of rotation[44]. Baryon degeneracy is an effect that arises as a result of the inability of baryons to simultaneously occupy certain quantum states due to quantum statistics. We have noted that neutron stars have a very high density. This value indicates that they are denser than the atomic nucleus. At this density, baryons, which are fermions according to the Pauli principle, can only exist in their own quantum state. This constraint creates a very large "degeneracy pressure" inside the star. The resulting pressure balances the collapsing force of gravity[22]. Superfluidity is the resistance-free, frictionless flow of particles in a fluid state. In neutron stars, this occurs when neutrons or protons form pairs. Neutrons pair up depending on density and temperature conditions. These pairs exhibit superfluidity behavior, which alters the internal heat transfer and heat balance of the star. Neutron superfluidity alters the thermal conductivity and rotational dynamics. Sudden jumps in the rotational frequency of pulsars in particular are considered evidence of neutron superfluidity. Neutron superfluidity occurs at temperatures below ~10^9 K[45]. Protons also become superconducting under the same conditions. This leads to quantization of the magnetic field. Proton superconductivity can begin around ~10^{10} K. As a result, superfluidity changes thermal diffusion and neutrino emission. Superconductivity plays an important role in explaining the field structures and stability of magnetars[46]. Thus, it has a strong influence on thermal evolution. Thermal evolution is the field that studies how the internal temperature of neutron stars changes over the millions of years after their birth. The neutron star formed as a result of the collapse of the star becomes extremely hot (10^{11}-10^{12} K). At this time, very strong neutron emission occurs. During the first 10^5 years, a neutrino cooling period occurs. The main cooling occurs by neutrino emission. At this stage, the temperature decreases very rapidly. After 10^5 years, the photon cooling phase begins. Now the main energy loss is radiation from the surface by photons. The internal temperature of the star stabilizes, and the surface cools down[27]. Thermal evolution graphs also show that there are different thermally conductive zones inside the star[47]. This fact is further evidence confirming the existence of layers. One of the problems that arise during the evolution of neutron stars is the mass problem. The mass gap is the gap observed between the neutron star and the black hole and is related to objects that do not have mass in nature. So, the mass of neutron stars 1,1-2,16 M⊙ , and black holes 5+M⊙ but no objects are observed in the mass range of these two objects, i.e., between 2.5 and 5 M⊙. This phenomenon is known as the "mass gap"[48].

The exact cause of this problem is still unknown, but some hypotheses have been proposed. According to the supernova explosion mechanism, the material in the explosion at the end of the star's life is either very compressed or the compression stops, but in the intermediate state the explosion may be unstable. That is, objects in this mass range cannot form[49]. If a neutron star becomes too compressed, its center can become a quark-gluon plasma, and this transition can define an "instability zone." When the star explodes, most of the matter is thrown out, and what remains becomes either a neutron star or, if it is large enough, a black hole. Sometimes this transition can be abrupt[41]. Some scientists, however, suggest that this mass gap may actually be due to limitations in our observational methods. It is possible that objects in this mass range do exist, but because black holes are so small that they emit so little radiation that telescopes cannot observe them[50].

Neutron stars are considered a bridge to the quantum theory of gravity. Because their internal structure is subject to quantum effects, and gravity is subject to the theory of general relativity. General relativity is the main theoretical framework that explains the existence and behavior of these objects[51]. New discoveries have been made in 20202025 regarding pulsars and magnetars. It is almost certain that a "sea of gluons" is present in the composition of neutron stars. New theories show that some electron stars contain not only neutrons in their cores, but also partially free gluons and quarks. This discovery also brings them closer to quark stars. These studies help us understand the behavior of matter at high densities in the context of quantum chromodynamics[52]. In late 2024, the LIGO-Virgo-KAGRA collaboration observed gravitational waves from the merger of two neutron stars with higher precision. This observation confirmed the formation of heavy elements (gold and platinum) in kilonova events[53]. Another novelty is that "unbreakable crystalline matter" may exist on the surface of neutron stars. New simulations show that a substance called nuclear paste forms on the surface of neutron stars. This substance is considered the strongest substance that can exist in the Universe. This substance is called spaghetti or lasagna due to its structure in nuclear paste forms[54]. Another novelty is related to neutron star-black hole hybrids. Some theoretical models suggest that a neutron star may contain a micro-black hole. This claim provides an important test for the unification of gravitational and quantum theories[55]. At the same time, new discoveries have been made about magnetars. In 2020, the Chinese FAST telescope and the Canadian CHIME telescope observed a magnetar associated with a radio burst. The burst came from a magnetar called SGR 1935+2154. This was the first evidence that fast radio bursts sometimes originate from magnetars[56]. The magnetic field of magnetars consists not only of dipoles, but also of theoretical and complex fields. These fields are unstable and can cause explosions. Some magnetars, if massive enough, can even become black holes in a very short time. Recent observations show that some magnetars can deform the surrounding space with their magnetic field[57]. After 2022, it was observed that the rotation rate of some magnetars suddenly decreased. This phenomenon is thought to be due to the restructuring of the magnetic field by internal stresses[58].

Problem statement: It turns out that neutron stars, the remnants of massive stars that have collapsed under the influence of gravity, are one of the most extreme and at the same time the most mysterious objects in astrophysics. The small size of neutron stars and their density, which exceeds other stars many times, allow us to study the behavior of matter in regimes that are not possible in laboratory conditions. However, despite all the observational and theoretical advances, fundamental questions about the internal structure of neutron stars remain open. One of the main difficulties is related to the equation of state of matter, which determines the stability of the objects. Different nuclear models give different predictions for the radius, maximum mass, and density profile of neutron stars. This highlights the need to reconcile observations with theoretical models[59]. Another important problem is the relationship between general relativity and quantum physics in neutron stars. On the one hand, Einstein's equations determine the gravitational constant of these objects. On the other hand, the behavior of nucleons or quarks at high densities is still not fully understood[60]. Thus, given the above contradictions, the main problems about neutron stars will be the following questions:

- What is at the very center of a neutron star?
- How is the magnetic field of magnetars created?
- Is neutron star matter superconductive?
- What causes thermal evolution?
- What causes mass void?
- What theoretical model can fully explain all the properties of neutron stars? Etc.

Solving these problems not only sheds light on the nature of neutron stars, but also creates a bridge between nuclear physics, gravitational theories, and astrophysics. That is, the theoretical model put forward must first answer these questions.

Solution to the problem: Based on the above information, it is possible to propose a new model that eliminates the questions raised about neutron stars. Based on many factual evidences, we see that neutron stars have layers. We can say that in neutron stars, the lower shell consists mainly of neutrons and this matter will be compressed as it goes towards the center. From this point of view, we can conclude that the very center is a denser medium than neutrons. Therefore, the probability of quark matter being present in the very center of neutron stars is very high. Since the surface of a neutron star consists mainly of neutrons, it can be considered the hardest substance in the Universe, and this hardness increases further towards the center. A neutron star can be thought of as a dual quantum fluid: a superfluid consisting of neutrons and a superconductor consisting of protons. That is, the proton component of neutron stars is a superconductor. Since neutron stars are composed primarily of neutrons, they can only exist in a superfluid phase. These quantum phases determine the magnetic field, spin rate, and rotational behavior of neutron stars. Astronomical observations show that the cooling rate of neutron stars cannot be explained without considering the superfluid and superconducting phases. In particular, the cooling of a young neutron star in a supernova galaxy is considered strong evidence for neutron superfluidity[61]. The superfluidity and superconductivity phases are essential components to explain the course of these processes. These processes create possible conditions for thermal evolution in neutron stars.In magnetars, the star does not lose its magnetic field during the collapse as a result of a supernova. Since the radius is reduced by a factor of 10^5 as a result of the collapse, the magnetic flux is conserved and the field is strengthened by the $B \sim 1/R^2$ law. That is, the $\sim 10^3$ Gauss field of a typical massive star can reach $\sim 10^{12}$ Gauss after the collapse. This value corresponds to the field of normal pulsars. However, in magnetars this value reaches 10^{15} Gauss[22]. Therefore, the mechanism of magnetar formation cannot be explained simply by the freezing of magnetic flux. Therefore, a second mechanism must be involved. After the collapse, the young neutron star rotates at a very high speed. Its interior has a very high conductivity. In this situation, the "α-ω dynamo" mechanism plays a role: rotation and convection combine to create electric currents inside, and as a result, the magnetic field becomes incredibly strong. Simulations show that if the initial rotation period is <3 ms, the field can grow to 10^{15} Gauss. This strong field that is created deforms the front of the neutron star over time[62]. On the other hand, as we know, our space is built on a certain energy. If we have an energy higher than the boundary energy of the space in a certain part, it is possible to transition to other spaces. Our 3-dimensional space has its own unique properties like other spaces. That is, every object that exists in this space must exist in a way that corresponds to these properties[63]. When we look at space, we observe a number of unusual properties in black holes. It can be said that black holes exhibit a number of abnormal behaviors that are different from the properties of space itself. Black holes are objects that can be compared to topological defects in spacetime[64]. They may be related to the distribution of dark matter in space, and this relationship may shed light on the observed inconsistencies in the mass distribution. Black holes are formed after the collapse of massive stars. As we mentioned above, the greater the mass of a star, the greater its centripetal force. That is, in this case, the energy of the impact exerted by the star on the central part is very high. Therefore, when massive stars collapse, the energy of the star's impact on the central space is higher, and a defect is formed in that part. The reason why black holes exhibit this type of defective behavior is precisely because it is a defect in cosmic space[64]. If the mass of the star is not large enough, the energy of its impact on a point in space will also be small. In this case, no defect is created in space. In this regard, when neutron stars are formed, a defect is not created in space, but something close to it is formed. Therefore, since neutron stars are not defects created in 3-dimensional space, their behavior can be determined by the laws of physics. For this reason, neutron stars can be considered as the last stop before a cosmic defect. When we look at the properties of dark matter and 3-dimensional space, we observe a similar discrepancy. This fact also leads us to view dark matter as a complex structure existing in higher-dimensional space[65]. Dark matter exerts its influence more in galaxies, or rather, in the centers of galaxies[63]. Interestingly, it is thought that at the center of every galaxy there are cosmic defects, that is, black holes[66]. When we combine these facts, we understand that dark matter exists in high-dimensional space and exerts its influence mainly in galaxies due to black holes. In short, there is an important connection between these two concepts. This approach put forward also allows us to answer the problem of mass gap. Since neuron stars are not cosmic defects, their masses are determined only by the sum of the masses of the particles in their composition. Since the mass of black holes is strongly affected by dark matter, its mass will be large relative to its size, and thus there will be a large mass difference between the two objects. Therefore, if a neutron star collides with a black hole, the black hole will prevail, and there are observations that support this[67].

Result: As can be seen, on the basis of the new theoretical model proposed above, it was possible to give substantial answers to many problematic questions about neutron stars. Thus, new scientific directions emerge in astrophysics and other fields. The matter of neutron stars is the hardest matter in the Universe, and it is highly probable that there is a matter consisting of quarks in their core. Due to the amount and interaction of neutrons and protons in the composition of neutron stars, important processes (superconductivity, superfluidity, baryon degeneracy, etc.) occur for these objects. The exchange between these two particles plays a possible role in the formation of thermal evolution. Depending on the parameters of the star, different types of neutron stars can be formed during a supernova explosion. It is clear that black holes are cosmic defects and due to their significant interaction with dark matter, the mass difference compared to neutron stars is sharp. From this point of view, it is more correct to consider neutron stars as the final state before the cosmic defect. Because, as we have mentioned, if the mass of the star is small, the impact energy of its center on space is small and this energy is not enough to create a defect in the space lattice. However, neutron stars are extremely important objects for research. The study of the properties of both black holes and neutron stars plays an important role in studying the properties of the Universe in which we live and in experimental confirmation of theories. As a result of the study, it is clear that the scattering of these two objects into the Universe is not accidental, but rather follows a certain purpose and regularity.

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