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Formation and Evolution of Binary Stars in the Cosmic Environment

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Abstract: The formation and evolution of binary stars are key steps in star formation and evolution, and thus their research has become the core content of modern astronomical research. Although as early as 1976, Bodan Pachenski proposed the theory of the evolution of shared envelopes in binary stars, but it was never confirmed until 2022 when the Yunnan Astronomical Observatory of the Chinese Academy of Sciences and an Australian team first observed the phenomenon of shared envelope ejection in binary stars, which provided support for Bodan Pachenski's theory, but the true formation mechanism and evolution process of binary stars remain undetermined. For this reason, the author of this paper has proposed a theory of the formation and evolution of binary stars based on the theory of the evolution of common envelopes in binary stars and the theory of tidal disruption events, laying a foundation for establishing a complete theory of star formation and evolution.

Key words: Binary star common envelope evolution theory, binary star common envelope ejection phenomenon, tidal disruption, evolution of binary star.

1. Introduction

The formation and evolution of binary stars are key steps in the process of star formation and evolution, and thus are one of the core fields of modern astronomy. Its research content covers the entire process of star formation and compact celestial body evolution. Since the 1970s, observations of binary star have revealed the existence of systems such as pulsars and X-ray binariess. However, there is still a limited understanding of the formation mechanism and evolution process of binaries. In 1976, Bodan Pachzynski proposed the theory of the evolution of shared envelopes in binary stars, describing the process in which one star expands due to a severe loss of matter and wraps around the other star to form an outer envelope. Some authors have discussed common envelope evolution of massive binary stars such as double neutron stars and binary pulsars [1]. In 2022, the Yunnan Astronomical Observatory of the Chinese Academy of Sciences and an Australian team observed for the first time the phenomenon of shared envelope ejection in binary stars and confirmed the material loss of the binary stars [2]. Recent research in 2025 also revealed that a third celestial body (such as a black hole) hidden near a binary star can significantly accelerate the evolution of the binary star through angular momentum separation, shortening the formation time of the adjacent binary star [3]. This discovery challenges the traditional theory and lays the foundation for establishing a scientific theory on the formation mechanism and evolution process of binary stars.

2. The Formation and Evolution of Single Star

Since binary stars are composed of single stars, when studying the formation and evolution of binary stars, one should start with the study of the formation and evolution of single stars.

It is well known that the formation of a star generally undergoes an evolution process from a satellite to a planet and then to a star. After a proto-star evolved from a very small satellite in both volume and mass into

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an earth-sized planet, it produced some of its moons, but it still revolved around its parent star, unceasingly accreted the nebula materials near the orbits to become larger and larger, and gradually moved away from its parent star with the frequent collisions of planetesimals or the accelerlating rotation of its parent star due to contraction. Afterwards it met a series of impacts from some other planets running into it from behind, making it become a Jupiter-sized planet much farther away from its parent [4]. Due to the large mass of this kind of giant, it can attract various gas molecules, forming a thick atmosphere. During its rotation, it generates powerful polar vortex. This polar vortex can continuously absorb hydrogen and other nebular matter from the surrounding space to the protostar, and can also eject some matter outward. During the process of a planet orbiting a protostar, a planet crossing the poles can pull a huge cloud over the top of the polar vortex. When this cloud is drawn into the polar vortex, it will be greatly compressed, but the angular momentum of the protostar remains unchanged. This will accelerate the rotation of the protostar, thereby gradually moving the planet away from the protostar.

The central depth of such polar vortices can reach over 100,000 kilometers, and their diameters can range from several thousand to tens of thousands of kilometers. As plasma clouds swept in by a vortex of the proto-star sink faster and colder, after a long spiral path, at the bottom of the vortex, the velocity of the airflow is tens of times faster than that of scale 12 typhoon, so the cloud clusters have already condensed into ice, and the temperature in the vortex is much lower than that around it, hence from the distant place, the vortex looks like a small sunspot.

Since the clouds involved in a vortex are continuous and rotate downward rapidly in a spiral manner, a series of thick spiral cloud belts can be formed. In this kind of plasma cloud belts, the negative ions that get electrons are heavier than the positive ions that lose electrons, and then move down to the lower part of the cloud or even down to the bottom of the vortex along the spiral cloud belt. The lighter positive ions are gradually carried up to the upper part of the cloud or even up to the top of the vortex along the spiral cloud belt by the updraft, thus forming a current from the bottom of the vortex to the top of the vortex in the spiral cloud belt, and also forming a powerful dipole magnetic field, as is shown in Fig. 1.

In addition, because the polar vortex of a star cover a vast and deep atmospheric space, they can draw in a large number of cloud masses. These cloud masses are gradually compressed during their sinking process, becoming increasingly thick and massive. As they travel along long spiral paths, they are prone to intense friction and collisions, frequently generating strong lightning, causing the surrounding air temperature to rapidly rise to tens of thousands of degrees and the atmospheric pressure to increase to millions of atmospheres. As a result, much of the gaseous hydrogen in the vortex transforms into liquid metallic hydrogen. This liquid metallic hydrogen and liquid hydrogen are mixed together and gradually cooled as they rapidly sink along a spiral path. By the time they reach the bottom of the vortex, they condense into a series of huge crystals, which contain solid metallic hydrogen and solid

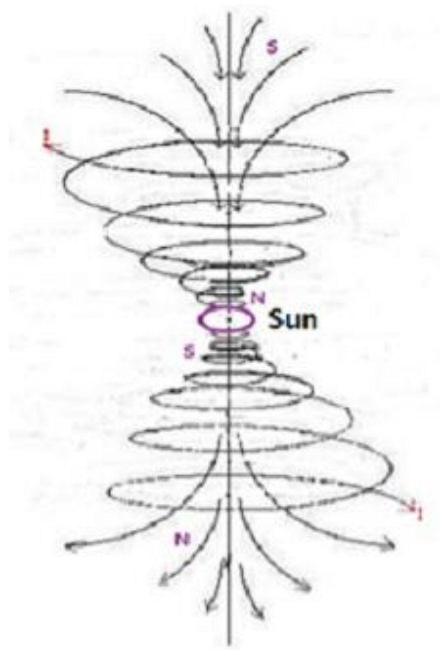

Fig. 1 Magnetic field of vortex.

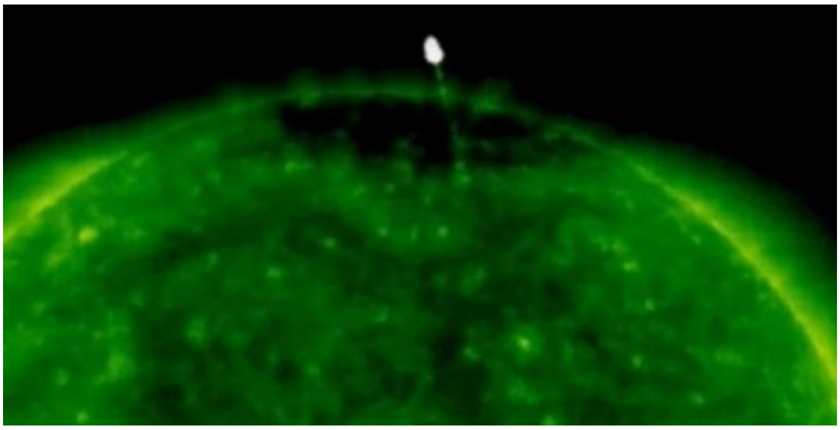

Fig. 2 An earth-sized object flew out of a sunspot region.

hydrogen. For instance, on May 23, 2019, astronomer Nassim Haramin discovered a white unidentified object flying out of the North Pole sunspot region of the Sun in the photos sent back by the SOHO satellite (heliospheric Detector). This crystalline object was about the size of the Earth, as shown in Fig. 2.

It is known that the internal temperature of Jupiter reaches 30,000 degrees Celsius and the internal pressure is over 40 million atmospheres. However, the volume and mass of a brown dwarf about to become a star are comparable to those of the Sun, and its volume and mass are more than 1,000 times that of Jupiter. Therefore, the internal temperature of such a brown dwarf can reach 30 million degrees Celsius (>15 million degrees). The internal pressure should be above 40 billion atmospheres. When huge metallic hydrogen crystals collide in the atmospheric vortex of a brown dwarf, the nearby pressure can increase tenfold, exceeding 300 billion atmospheres. Therefore, it can ignite the thermonuclear reaction of hydrogen polymerization into helium in a sunspot cyclone and trigger a series of thermonuclear reactions beside the cyclone:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n \; +17.6Mev$$

When a thermonuclear reaction occurs, a large amount of energy is released in a short period of time, causing a violent explosion of metallic hydrogen and generating various electromagnetic radiations. The violent explosion of metallic hydrogen crystals can also produce burning debris shot in all directions, causing a rapidly intensifying bright spot to suddenly appear beside the sunspot. This is what is called a stellar flare. Therefore, flares indicate the outbreak of thermonuclear reactions in a star. The violent explosions that occur during this period may alter the structure of the sunspot cyclone or cause it to contract and decline.

In general, the formation and disappearance of a sunspot can only take a few days to a few months, and it can only attract a limited range of hydrogen gas; the hydrogen beyond this scope cannot be processed. So if there are no sunspot cyclones or no successor sunspot cyclones to take over its work, thermonuclear reactions on the star will stop. Fortunately, a star usually has multiple planets (such as Mercury, Venus, Earth, etc.) close to the star and orbiting at high speeds to pull nebular material to add thermonuclear fuel to these fading sunspot cyclones, so that the thermonuclear reactions in these sunspot cyclones can continue.

In addition, a giant planet like Jupiter exerts a greater universal gravitation on the polar cyclones of the Sun; when it approaches the cyclones at the Sun's poles, it can, through the effect of universal gravitation, cause the polar cyclones to tilt, stretch, shear or break, and even drag out some sub-cyclones, distributing them onto the surface of the Sun. When a sub-cyclone has absorbed sufficient airflow to become a long, large and heat-resistant cyclone, it will extend from the upper level to the lower level and become a mature and powerful sunspot, continuing the thermonuclear reaction of the preceding sunspot.

Table 1 shows the ratio of the gravitation of the major planets of the solar system on the objects on the surface of the sun as well as the revolution periods of these planets. It can be seen that Jupiter has the strongest gravitation on objects on the surface of the sun, while other planets have a much smaller gravitational pull on objects on the surface of the Sun.

In fact, we can even more clearly compare the effects of Jupiter and other planets on sunspots. We know that Jupiter's perihelion distance is $R_n = 7.4052\times10^8 km$, Jupiter's aphelion distance is $R_f = 8.1662\times10^8 km$, and Jupiter has a mass M_J=$1.900\times10^{27} kg$, therefore Jupiter at perihelion has a gravitational pull on an object of mass m on the Sun as $F_n = G\frac{M_J m}{R_n^2}$,

and Jupiter at aphelion has a gravitational pull on an object of mass m on the Sun as $F_f = G\frac{M_J m}{R_f^2}$

Assume that Mercury has a mass of M_w($M_w=3.3022\times10^{23} kg$), Mercury's distance from the sun is R_w(=57910000 km), and Mercury's gravitational pull on an object of mass m on the Sun is F_w, then $F_w = G\frac{M_w m}{R_w^2}$; therefore

$$\frac{F_n}{F_w} = \frac{M_J}{M_w}\cdot\frac{R_w^2}{R_n^2} \approx 35.19, \qquad \frac{F_f}{F_w} = \frac{M_J}{M_w}\cdot\frac{R_w^2}{R_f^2} \approx 28.93$$

It can be seen that whether Jupiter is at perihelion or aphelion, it exerts a greater force on any object on the Sun (including polar cyclones) than other planets orbiting the Sun exert on that object, so Jupiter is the main planet that attracts solar polar cyclones and produces sunspots. This is true because sunspots have an activity cycle of about 11 years, which is about the same as Jupiter's orbital period around the sun. More detailed observations show that in each sunspot cycle, the number of spots starts in the year with the lowest number, increases in the following three to five years, reaches a peak, and then decreases to a minimum in the following five to seven years. It can be seen that when Jupiter is at perihelion, the most sunspots are generated, while at aphelion, the least sunspots are generated, and almost no sunspots are generated. Because planets other than Jupiter exert much less force on the solar polar cyclones than Jupiter at aphelion does on the solar polar cyclones, these planets cannot extract sunspots from the polar cyclones.

It can be seen that it is Jupiter that brings out the sunspots all over the Sun from the solar polar vortex. Then, Mercury, Venus and Earth, which are close to the Sun and orbit at a fast speed, pull nebulae material to the sunspot cyclones near the orbit, adding fuel to the thermonuclear reaction in the sunspot cyclones, so that the thermonuclear reaction in the sunspot cyclones can continue. This is the main sequence phase of a star, which lasts a long time [5].

However, the current perihelion distance of Jupiter is 741 million kilometers, and it is not yet a star. Some experts speculate that only when the mass of a giant star

Table 1 The ratio of the gravitation of the major planets of the solar system on the object on the surface of the sun as well as the revolution periods of these planets.

Planet	Mass	Average distance from the sun	Ratio of planet's gravitation relative to Mercury's gravitation	Revolution periods (Solar rotation period = 25.05 d)
Mercury	3.3022×10^{23} kg	57,909,050 km	1	87.9691 d
Venus	4.8690×10^{24} kg	108,209,184 km	0.42228	224.7 d
Earth	5.9650×10^{24} kg	149,597,888 km	2.70684	365.24 d
Mars	6.4219×10^{23} kg	227,925,000 km	0.12554	686.980 d
Jupiter	1.9000×10^{27} kg	778,547,050 km	31.8327	11.8618 yr
Saturn	5.6834×10^{26} kg	1,429,400,000 km	2.850523	29.5 yr
Uranus	8.6810×10^{25} kg	2,871,000,000 km	0.169529	84 yr
Neptune	1.024×10^{26} kg	4,504,000,000 km	0.512647	164.8 yr

Table 2 The ratio of the gravitational force exerted by Jupiter's moons on objects on Jupiter's surface to that exerted by Mercury on objects on the Sun's surface.

Moons of Jupiter	Distance to Jupiter	Quality	The ratio of gravity of Jupiter's satelites relative to that of Mercury
IO	422,000 km	8.94×10^{22} kg	5,096.61
Europa	671,000 km	4.80×10^{22} kg	1,082.68
Ganymede	1,070,000 km	1.48×10^{23} kg	1,314.48
Callisto	1,883,000 km	1.08×10^{23} kg	310.33
Amalthea	181,000 km	2.08×10^{18} kg	0.0645

Table 3 Shows the ratio of the gravitational force exerted by Jupiter's moons after moving 9.6 million kilometers outward from their current positions on objects on the surface of Jupiter to that exerted by Mercury on objects on the surface of the Sun.

Moons of Jupiter	Distance to Jupiter	Qualit	The ratio of gravity of Jupitrer's satelites relative to that of Mercury
IO	10,020,000 km	1.788×10^{23} kg	3.129
Europa	10,271,000 km	9.60×10^{22} kg	9.247
Ganymede	10,670,000 km	4.44×10^{23} kg	39.6297
Callisto	11,483,000 km	3.24×10^{23} kg	24.9538
Amalthea	9,781,000 km	5.16×10^{18} kg	0.00055

reaches 70 to 80 times that of Jupiter does it have sufficient gravity, pressure and temperature to cause fusion reactions between hydrogen elements and form a star. In fact, this speculation is not accurate. At a latitude of 20° in the southern hemisphere of Jupiter, there is a "Great Red Spot", which is a continuously rotating huge cyclone. Its internal temperature is hundreds of degrees Celsius higher than that of the surrounding atmosphere, indicating that nuclear fusion reactions have occurred inside the cyclone. However, due to being alone and weak, it failed to trigger a global thermonuclear reaction on Jupiter.

Why does such a huge Jupiter have only one heating cyclone? This is because Jupiter has over 60 moons, among which four have a significant gravitational pull on the cyclones on Jupiter, including IO, Europa, Ganymede and Callisto, as shown in Table 2 above. When a satellite drags out a sub-cyclone from Jupiter's polar cyclones, the other large satellites all exert significant gravitational forces on this sub-cyclone, thus easily tearing it apart. It can be seen that the probability of a Jupiter satellite dragging out a surviving sub-cyclone from Jupiter's polar cyclones is very small, and only one "Great Red Spot" sub-cyclone remains after 300 years.

For Jupiter to be covered by cyclones like the Great Red Spot, its large moons must be far enough away from the planet. For instance, when IO, Europa, Ganymede and Callisto move 9.6 million kilometers outward from their current positions, the gravitational forces they exert on objects on Jupiter's surface are shown in Table 3. Among them, the ratio of the gravitational pull of Ganymede on objects on the surface of Jupiter to that of Mercury on objects on the surface of the Sun is 39.6297. This indicates that Jupiter's gravitational pull on objects on the Sun's surface when Jupiter is at perihelion is less than Ganymede's gravitational pull on objects on Jupiter's surface. Thus, Ganymede can draw child cyclones from Jupiter's polar cyclones to the vicinity of Jupiter's equator, forming cyclones such as the "Great Red Spot". The ratio of the gravitational pull of IO, Europa and Callisto on objects on the surface of Jupiter to that of Mercury on objects on the surface of the Sun is less than 28.93, indicating that the gravitational pull of Jupiter on objects on the surface of the Sun when Jupiter is at its aphelion is greater than that of IO, Europa and Callisto on objects on the surface of Jupiter.

Therefore, these Jupiter moons can only pull nebular matter to add fuel needed for thermonuclear reactions to the “Great Red Spot” cyclone near its orbit, making Jupiter a dwarf nova.

In fact, it won’t be difficult for IO, Europa, Ganymede and Callisto to move 9.6 million kilometers outward from their current orbital positions. Given that the masses of two planets are m_1, m_2 ($m_1>m_2$), and the distance between them is l; the formula for the centrifugal force of one planet orbiting the other is

$$F = G \cdot m_1 \cdot m_2 / l^2 \ (G = 6.674\times10^{-11})$$

According to the above formula, it can be proved that when Jupiter (with a mass of m_J) rotates around the Sun (with a mass of m_S), assuming the distance between Jupiter and the Sun is l_1 and the centrifugal force generated by the Sun’s rotation on Jupiter is F_1, then the centrifugal force generated by the Sun’s rotation per kilogram of mass on Jupiter is

$$F_1 / m_J = G \cdot m_S / l_1^2 = 1.989\times10^{30}\ G / l_1^2 = 1.3274586\times10^{20} / l_1^2 \quad (1)$$

When a Jupiter satellite (with a mass of m_{JS}) orbits Jupiter again, assuming the distance between the Jupiter satellite and Jupiter is l_2 and the centrifugal force generated by Jupiter’s rotation on the Jupiter satellite is F2, then the centrifugal force exerted by Jupiter’s rotation per kilogram of mass on a Jupiter moon is

$$F_2 / m_{JS} = G \cdot m_J / l_2^2 = 1.8982\times10^{27}\ G / l_2^2 = 1.26685868\times10^{17} / l_2^2 \quad (2)$$

According to Equation (1), the centrifugal force per kilogram of mass exerted by the Sun’s rotation on Jupiter when it is at perihelion can be calculated:

$$F_1 / m_J = 1.3274586\times10^{20} / (7.41\times10^8)^2 \approx 0.241176\times10^3\ N$$

According to Equation (2), it can be calculated that when the four moons of Jupiter move 9,600,000 km outward from their current positions, the centrifugal force per kilogram of mass on them generated by Jupiter’s rotation is

$F_{21} / m_{JS} = 1.26685868\times10^{17} / (10020000)^2 \approx 1.2618\times10^3\ N > F_1 / m_J$

$F_{22} / m_{JS} = 1.26685868\times10^{17} / (10271000)^2 \approx 1.2011\times10^3\ N > F_1 / m_J$

$F_{23} / m_{JS} = 1.26685868\times10^{17} / (10670000)^2 \approx 1.1127\times10^3\ N > F_1 / m_J$

$F_{24} / m_{JS} = 1.26685868\times10^{17} / (11483000)^2 \approx 0.9607\times10^3\ N > F_1 / m_J$

It can be seen that during the 9,600,000 km outward movement of IO, Europa, Ganymede and Callisto from their current positions, the centrifugal force generated by Jupiter’s rotation per kilogram of mass on each of them is greater than that generated by the Sun’s rotation per kilogram of mass on Jupiter as it moves from its current perihelion to a more distant perihelion. So, without waiting for Jupiter to move 9,600,000 km from its current perihelion to a more distant perihelion, IO, Europa, Ganymede and Callisto would be able to move more than 9,600,000 km outward from their current orbital positions, thus transforming Jupiter into a new dwarf star with a surrounding area capable of initiating thermonuclear reactions.

3. The Formation and Evolution of Binary Stars in the Solar System

Astronomical observations show that there are a large number of binary stars in the universe’s starry sky, but the Sun has no companion star yet. This is because the solar system is still very young. With the ongoing thermonuclear reactions on the Sun, solar burst activities occur frequently. The Sun constantly ejects flare fragments and coronal matter into space. These ejected substances are absorbed by the planets and satellites in the solar system. Therefore, Jupiter, as the largest planet in the solar system, has the greatest attraction to the ejected substances from the Sun and thus has become the largest planet in the solar system. It is precisely giant planet like Jupiter that can exert a significant force on the Sun’s polar vortices. When it approaches the Sun, it can pull out sunspot cyclones from the polar cyclones of the Sun through the effect of universal gravitation, distributing them onto the Sun. Then, these sunspot cyclones wait for the planets of the Sun to draw nebular matter to add fuel to their thermonuclear reactions, allowing their thermonuclear reactions to continue. As the huge cloud masses drew by the planets to the sunspot cyclones are greatly compressed, the rotational speed of the Sun keeps increasing. Under the effect of the centrifugal force generated by the Sun's rotation, the orbits of the seven planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune) expand outward, and especially the perihelion distance of Jupiter also increases. According to the results calculated in Section 2, it is known that Jupiter does not need to wait for its current perihelion distance (741 million km) to expand by 9,600,000 km, which would enable IO, Europa, Ganymede and Callisto to move outward from their current orbital positions by more than 9,600,000 km, thus turning Jupiter into a new dwarf star around which thermonuclear reactions can be triggered.

As Jupiter's perihelion distance increases, the sunspot cyclones it pulls out from the polar cyclones of the Sun become fewer and fewer, additionally, as the orbits of the seven planets expand outward, they bring less and less hydrogen to the sunspot cyclone, making it increasingly difficult for the Sun to absorb sufficient hydrogen to maintain the thermonuclear reactions inside it. In addition, when Jupiter becomes a new dwarf star, it can use sunspot cyclones to carry out thermonuclear reactions and need to seize hydrogen resources in the space where the solar system is located. When the sun fails to absorb sufficient hydrogen to sustain the thermonuclear reactions within it, the balance between the radiation pressure of nuclear fusion and its own contracting gravitational force is disrupted. The helium nuclei inside the sun contract and become hot, while the hydrogen shell expands outward and cools. As the helium core inside the Sun contracts, its rotation accelerates, and the hydrogen shell is forced to drift outward by centrifugal force, causing the Sun to expand into a red giant. This stage may last for millions of years. The volume of a red giant can be several times or even hundreds of times that of the Sun. As the red giant expands, its rotation gradually slows down, causing the centrifugal force acting on the new dwarf star orbiting the red giant to gradually decrease. Thus, the new dwarf star gradually approaches the red giant again. When it enters the envelope of the red giant, during the rotation of the new dwarf star around the core of the red giant, because it is close to the outer hydrogen layer of the red giant, especially since it has multiple satellites directly immersed in the outer hydrogen layer of the red giant, when these satellites rotate around the new dwarf star, they can carry a large amount of hydrogen to the new dwarf star, causing these hydrogen to integrate into their common envelope and providing fuel for thermonuclear reactions on the new dwarf star.

In addition, as the Sun orbits the black hole at the galactic center, when a binary star with a common envelope approaches this massive black hole, due to the excessive pull of tidal forces, the common envelope of the binary star will be torn apart. These torn envelopes by the black hole leave the binary star at a high speed, resulting in a loss of angular momentum. Eventually, the binary star with a common envelope contracts into a White Dwarf and a hot subdwarf. Among them, the hot subdwarf is a heat-emitting star that undergoes helium fusion after its hydrogen layer is deprived. As the White Dwarf further contracts, the hot subdwarf gradually moves away from the White Dwarf, as shown in Fig. 3.

Fig. 3 A white dwarf and its disrupted atmosphere.

4. The Formation and Evolution Laws of General Binary Stars

There are a large number of binary stars in the universe's starry sky, but some stars have no companion stars yet. This is because these star systems are still very young. With the ongoing thermonuclear reactions on a star, star burst activities occur frequently. The star constantly ejects flare fragments and coronal matter into space. These ejected substances are absorbed by the planets and satellites in the star system. Therefore, there is a Jovian planet. It has the greatest attraction for the matter ejected by the star, thus becoming a bigger planet in the star system. It is precisely this Jovian planet that can exert a significant force on the star's polar vortices. When it approaches the star, it can pull out sunspot cyclones from the polar cyclones of the star through the effect of universal gravitation, distributing them onto the star. Then, these sunspot cyclones wait for the planets of the star to draw nebular matter to add fuel to their thermonuclear reactions, allowing their thermonuclear reactions to continue. As the huge cloud masses drew by the planets to the sunspot cyclones are greatly compressed, the rotational speed of the star keeps increasing. Under the effect of the centrifugal force generated by the star's rotation, the orbits of its planets expand outward, and especially the perihelion distance of the Jovian planet also increases. However, without waiting for the perihelion distance of Jovian planet to expand to the current aphelion distance, the satellites of the Jovian planet can move an appropriate distance, turning the Jovian planet into a new dwarf star around which thermonuclear reactions can be initiated. As the orbits of the seven planets expand outward, they bring less and less hydrogen to the sunspot cyclones

As the perihelion distance of the Jovian planet increases, the number of sunspot cyclones it drags out from the polar cyclones of the star decreases; additionally, as the planetary orbits of the star expand outward, these planets bring less and less hydrogen to sunspot cyclones, making it increasingly difficult for the star to absorb sufficient hydrogen to maintain its thermonuclear reactions. In addition, when the Jovian planet becomes a new dwarf star, it needs to use sunspot cyclones to carry out thermonuclear reactions too and needs to seize hydrogen resources in the space where the solar system is located. When the star fails to absorb sufficient hydrogen to sustain the thermonuclear reactions within it, the balance between the radiation pressure of nuclear fusion and its own contracting gravitational force is disrupted. The helium nuclei inside the star contract and become hot, while the hydrogen shell expands outward and cools. As the helium core inside the star contracts, its rotation accelerates, and the hydrogen shell is forced to drift outward by centrifugal force, causing the star to expand into a red giant. This stage may last for millions of years. The volume of a red giant can be several times or even hundreds of times that of the star. As the red giant expands, its rotation gradually slows down, causing the centrifugal force acting on the new dwarf star orbiting the red giant to gradually decrease. Thus, the new dwarf star gradually approaches the red giant again. When it enters the envelope of the red giant, during the rotation of the new dwarf star around the core of the red giant, because it is close to the outer hydrogen layer of the red giant, especially since it has multiple satellites directly immersed in the outer hydrogen layer of the red giant, when these satellites rotate around the new dwarf star, they can carry a large amount of hydrogen to the new dwarf star, causing these hydrogen to integrate into their common envelope and providing fuel for thermonuclear reactions on the new dwarf star.

In addition, as the star orbits its central black hole, when a binary star with a common envelope approaches this massive black hole, due to the excessive pull of tidal forces, the common envelope of the binary star will be torn apart. These torn envelopes by the black hole leave the binary star at a high speed, resulting in a loss of angular momentum. Eventually, the binary star with a common envelope contracts into a White Dwarf

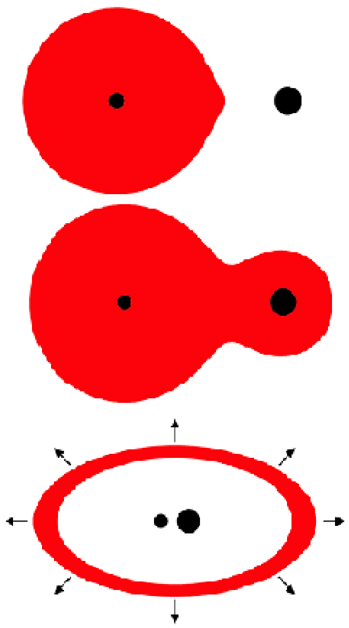

Fig. 4 The evolution process of the common-envelope of binary stars.

and a hot subdwarf, as shown in Fig. 4. Among them, a hot subdwarf is a heat-emitting new star that undergoes helium fusion after its hydrogen layer is deprived. As the White Dwarf further contracts, the hot subdwarf gradually moves away from the White Dwarf.

5. Several Other Forms of Stellar Evolution in Their Later Years

5.1 Black Dwarf

When a red giant star contracts into a White Dwarf and the hot subdwarf star formed by the contraction of a dwarf nova is also far enough from the White Dwarf, the hot subdwarf cannot spread a sunspot cyclone on the White Dwarf through the effect of universal gravitation. Beyond the poles of the White Dwarf, it cannot undergo the glowing and heating reactions of hydrogen fusion or helium fusion [6]. Thus, it becomes a "black dwarf". When the cyclones at both ends of the rotation axis of a "black dwarf" are not facing the Earth, people hardly see the light emitted by the black dwarf. However, since the black dwarf is still constantly rotating and the cyclones at both ends of its rotation axis will definitely emit light, a black dwarf that does not emit light absolutely does not exist.

5.2 Supernova

Because black dwarfs are stars formed through the evolution of binary stars, their volume is greatly reduced, their rotation speed is greatly increased, and there are few active and flashing cyclones outside the poles of the star. However, since black dwarfs still have some sub-planets or brown dwarfs, these planets are of huge mass and have a series of satellites orbiting them. As these planets or brown dwarfs orbit, the rotational radius of their satellites will gradually increase. When such a satellite approaches the surface of a black dwarf, it will be attracted by the black dwarf and fall onto it, experiencing a violent collision with the black dwarf, generating intense gamma-ray bursts, releasing tremendous energy and shining brightly. It turns very dim or completely invisible star into exceptionally bright supernovae all at once, as shown in Fig. 5. A supernova explosion sends some of the surface material of stars and moons flying off at high speeds, creating a single-direction jet that then melts and contracts the star's surface layer into a thin onion layer [7]. As the fallen satellite is burned up, the "supernova" will gradually dim, and eventually quietly leave, and it takes a long time or even tens of thousands of years for another satellite to hit the black dwarf to produce another supernova explosion, so people mistakenly think that the supernova explosion is a brilliant "tribute" to the dying star. In fact, people have been curious about gamma-ray bursts since the discovery of the first one in 1967, and later experts using advanced observational techniques to observe the stars that occur gamma-ray bursts, found that these stars become black holes after the occurrence of gamma-ray bursts, which is a misconception. Because the stars that have gamma-ray bursts have powerful polar cyclones, they were not noticed until after the gamma-ray bursts occurred, and then they were observed. When a polar cyclone is exposed to the human eye, people think that the star becomes a black hole, so the black hole observed from the star of the gamma-ray burst is actually the polar cyclone of the star.

Fig. 5 Gamma-ray burst SN 2014J produced by a supernova explosion.

5.3 Neutron Star

After a main sequence star evolves into a black dwarf, its mass increases significantly compared to the mass of the main sequence star, its atmosphere also thickens significantly, but its volume is greatly reduced, even smaller than the Moon, so its rotation speed is greatly accelerated, and the polar cyclones are greatly enhanced. It grows larger by constantly accreting nebular material near its orbit and satellites or planets in sub-galaxies that enter its gravitational horizon. In addition, as the black dwarf still has outer planets carrying subgalaxies orbiting around it, during its rotation around its central axis, it continuously absorbs the clouds pulled by its subgalaxies through its powerful polar cyclones. These clouds can be compressed into huge metallic hydrogen crystals at the bottom of the cyclones; when such huge metallic hydrogen crystals collide violently with the surface of a star, they not only directly exert tremendous pressure on the star's surface but also cause a violent explosion, adding even greater pressure. This may even trigger thermonuclear reactions or supernova explosions, leading to the collapse of the star and causing significant changes in its material structure. In this case, not only the outer shell of the atom is crushed, but also the nucleus of the atom is crushed, and the protons and neutrons in the nucleus are forced out, and the protons and electrons are pushed together and combined to form neutrons. Eventually, all the neutrons are squeezed together to form a neutron star [8].

When the star shrinks into a neutron star, its size is greatly reduced and its rotation is greatly accelerated, which greatly enhances the dipole magnetic field generated by the cyclone at the poles of the neutron star, making people think that the neutron star is a very strong magnet. Neutron stars emit electromagnetic waves through the polar cyclones, but under the gravitational action of the outer planets of the neutron star and their child galaxies, the polar cyclones of the star will deviate from the star's spin axis and rotate along an elliptical trajectory during the star's rotation. Therefore, when a cyclone that emits electromagnetic waves is facing the Earth, the Earth people can receive electromagnetic waves; when the polar vortex of the star deviates from the Earth, the Earth does not receive electromagnetic waves. Therefore, the electromagnetic waves received by the Earth are intermittent, resulting in the "lighthouse effect", and thus neutron stars are called "cosmic lighthouses".

Due to the rapid rotation of neutron stars, their polar cyclones can generate strong dipole magnetic fields that are opposite in direction. When two neutron stars orbiting each other are close together, their magnetic fields close to each other are in opposite directions and are so attractive that even people on Earth can detect the enormous gravity or gravitational waves of the two merging neutron stars.

In addition, as the neutron star spins rapidly, its child galaxies are also constantly rotating around the neutron star, and when the giant cloud pulled by the child galaxy comes close to the polar cyclone, it is sucked into the powerful polar cyclone, and when the cloud reaches the bottom of the cyclone, it is compressed into huge metallic hydrogen crystals. And when these giant metallic hydrogen crystals slam into the neutron star's surface, they explode violently, ejecting the helical circuits that produce electromagnetic waves and forming violent fast radio bursts, as shown in Fig. 6.

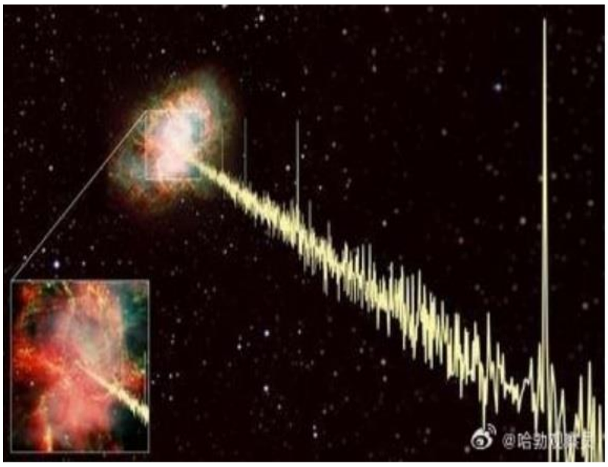

Fig. 6 Fast radio bursts erupting from neutron stars.

5.4 Black Hole

During the evolution of a neutron star into a more massive giant, its polar cyclones continuously accret nebular material near its orbit and the satellites or planets in its child galaxies that enter its gravitational horizon, increasing its mass and thickening its surface. In particular, as the neutron star spins, its child galaxy also spins around the neutron star, and when the child galaxy pulls a cloud past the neutron star's polar cyclone, the polar cyclone absorbs the clouds pulled by the child galaxies, and when these clouds get to the bottom of the cyclone, they can be compressed into giant metallic hydrogen crystals, and when these giant metallic hydrogen crystals slam into the star's surface, not only will it directly produce a huge pressure on the surface of the star, but also a violent explosion will occur, add more pressure, and even cause thermonuclear reaction, so that the neutron star further collapse, resulting in the transformation of the atomic structure on the surface of the neutron star into a neutron structure or a denser structure, and the mass of the neutron star will become larger.

In addition, during the expansion and movement of galaxies, collisions between galaxies occur from time to time. For example, on June 12, 2020, the American Astronomical Society reported that an international team of astronomers had observed the explosion process of a neutron star engulfing a star. The neutron star (No. "Sax j1808.4-3658") continuously sucked away the material of a nearby star by virtue of its strong attraction. When the material plunder reached a certain degree, the star was drawn into the polar cyclones of the neutron star and eventually exploded. When the mass of a neutron star exceeds three times the mass of the sun, a black hole is formed [9].

Due to the great mass and strong gravity of the black hole, when a luminous celestial body enters its gravitational horizon, many gaseous, liquid and solid substances of the celestial body will be immediately absorbed by the black hole, so that the resources of the celestial body are insufficient to maintain its luminous effect and extinguish the light, which is the reason why "light cannot escape the black hole".

5.5 Quasars

Because black holes are the product of stellar evolution in the galaxy structure, the galaxy structure is never resting, always in constant motion and change. As the structure of the galaxy rotates, the black hole also continuously accrets nebulae material around its orbit and satellites, planets, or stars in sub-galaxies that enter the black hole's event horizon, thus becoming larger and larger. For example, on June 22, 2016, American scientists observed a supermassive black hole eating a star, and then NASA released a composite image of the black hole eating the star in detail, as shown in Fig. 7.

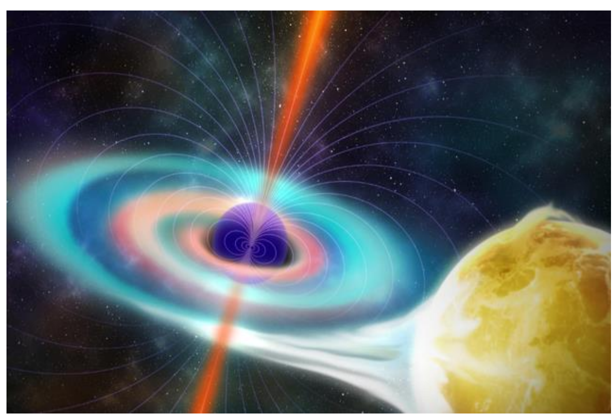

Fig. 7 The process of a black hole swallowing a star.

Although the evolution of galaxies in the universe is a slow and gradual process, scientific statistics show that the probability of black hole swallowing stars is very low, about 100,000 years per galaxy will happen once, but over the long course of galactic evolution in the universe, a black hole that can swallow a star or even a sub-galaxy will eventually become a massive quasar. For example, on March 3, 2015, a research team led by Chinese astronomer Professor Wu Xuebing discovered a super-bright quasar 12.8 billion light-years from Earth, 430 trillion times the luminosity of the sun, and a central black hole with a mass of about 12 billion solar masses. It is the brightest quasar with the most massive central black hole in the distant universe ever observed [10].

5.6 Energy Sources and Fuel Supply Mechanisms of Quasars

Because the nucleus of an active galaxy is usually a supermassive black hole that rotates rapidly. Under the strong gravitational pull of the supermassive black hole, as the black hole rapidly rotates, hydrogen gas, dust, and other interstellar material in the surrounding space form two powerful atmospheric vortices at the black hole's poles, which can reach a height of several light years, and when a polar cyclone faces the Earth observer, it presents a huge accretion disk. The accretion disk can become entangled in a large number of clouds, which are gradually compressed as they sink, becoming thicker and more massive [10].

After a long spiral path, these clouds are prone to violent friction and collision, frequently producing strong lightning, the surrounding air temperature quickly rises to tens of thousands of degrees, and the atmospheric pressure also rises to more than one million atmospheres, so that much of the gaseous hydrogen in the vortex is transformed into liquid metallic hydrogen. This mixture of liquid metallic hydrogen and liquid hydrogen gradually cools as it descends rapidly down the spiral path and condenses into a series of huge crystals containing both solid metallic hydrogen and solid hydrogen at the bottom of the vortex. Since a quasar 10 billion light-years from Earth can have a mass of more than 1,000 times the total mass of the Milky Way, its central black hole can attract an extremely dense nebula, and its interior can reach the temperature and pressure of a star's thermonuclear reaction (15 million degrees and more than 300 billion atmospheres). When giant metallic hydrogen crystals collide in a black hole cyclone, they immediately ignite a thermonuclear reaction where hydrogen is fused into helium:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n \ \mathbf{+17.6Mev}$$

When thermonuclear reaction occurs, a large amount of energy is released in a short period of time, causing a violent explosion of metallic hydrogen, producing strong electromagnetic radiation, and the emission energy of quasars can reach thousands of times more than that of ordinary galaxies.

Because there is a limit to how much hydrogen an active galactic nucleus can attract, hydrogen beyond its gravitational range cannot be sucked into the cyclone, and if the cyclone does not have enough fuel, its thermonuclear reaction will stop. Fortunately, the active galactic nucleus has rapidly rotating sub galaxies, which are even larger than the Milky Way. They not only rotate rapidly around the active galactic nucleus, but also rotate rapidly around their own center, so the sub galaxies can bring hydrogen and other nebulae from the vast universe to the gravitational range of the active galactic nucleus, providing a constant supply of fuel for the active galactic nucleus, as shown in Fig. 8, thus allowing the thermonuclear reaction of the galactic nucleus to continue. However, when the central black hole of a subgalaxy approaches its parent star, it exerts a strong gravitational pull on the polar cyclone of the parent star, which can tilt, stretch, shear or destroy the polar cyclone, causing the brightness of the quasar to change dramatically within a few days or even less.

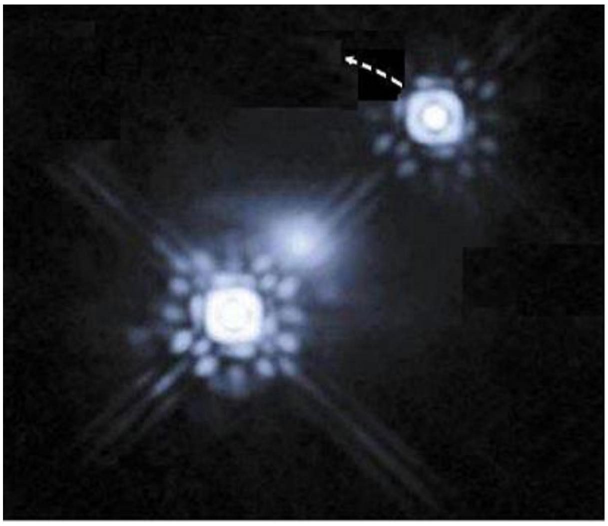

Fig. 8 The nucleus of the galaxy shines as it absorbs the fuel brought by its sub galaxy.

6. Summary

In the past, people mainly studied astronomy by roughly observing celestial bodies and celestial phenomena, lacking the precision, continuity, systematicness and logic of observation. Therefore, observational results and theoretical research are often half-understood and ambiguous. For this reason, the author of this paper has proposed the formation and evolution theory of binary stars based on the common envelope evolution theory of binary stars and the tidal disruption theory. On this basis, the general laws of star formation and evolution have been revealed, and several other forms of star evolution in its later years have been particularly described in detail.

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