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Formation and Evolution of Stars

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Abstract: The evolution of stars is one of the most important problems in astrophysics. However, the existing theories of stellar evolution fail to reveal the real mechanism of star formation, and thus fail to correctly reveal the mechanisms and laws of star growth, aging, death and resurrection. Therefore, by studying the formation process of satellites, planets and stars, the author can reveal the mechanisms and laws of star formation and evolution: as the star spins rapidly and its planets go round and round, a series of cyclones can form all over the star. These cyclones not only ignite thermonuclear reactions in the star, but also continuously absorb hydrogen and other interstellar material in space to maintain thermonuclear reactions in the star. But, with the increase of star mass, if the magnetic attraction of the stellar cyclone grows large enough that the star engulfs the innermost planet scattering cyclones through the magnetic attraction of the cyclone, the stellar mass will increase significantly, the stellar atmosphere will thicken significantly, the internal temperature of the star will increase greatly, and the huge energy will be released, causing the star to suddenly expand and become a red giant. When the red giant burns the swallowed planet, its internal temperature will gradually decrease, and the helium fusion will stop. At this time, the central gravity of the star cannot be balanced by the radiation pressure generated by the hydrogen or helium fusion, and the inner star will contract. Until the central gravity of the star is balanced by the degenerate pressure of the electrons in the center of the star, the contraction will stop, forming a white dwarf or black dwarf. When a star evolves into a white dwarf or a black dwarf, its mass increases significantly and its atmosphere thickens significantly, but its volume shrinks greatly and its rotation speed speeds up greatly, so its polar cyclones strengthen greatly. During the rapid rotation of white or black dwarfs, their polar cyclones can absorb a large amount of cloud gas from the dense atmosphere and compress the cloud gas into huge metal hydrogen crystals. When such a huge metal hydrogen crystal hits the surface of a star violently, it will cause a violent explosion, re-ignite the thermonuclear reaction on the star, and shine a very bright light, making the very dark or invisible star suddenly become an extremely bright supernova. This high brightness of supernovae can last for several weeks and years, until it consumes most of the atmosphere accumulated by the star, and then gradually decays into invisibility. It is not the funeral of a star that a supernova changes from bright to dark. When the atmosphere of a star is thick enough again, a supernova explosion may occur, but it will take a long time. Therefore, there will be countless supernova explosions in the process of stellar evolution. When the mass of a white dwarf exceeds 1.4 times the mass of the sun, it evolves into a neutron star. When the mass of a neutron star exceeds three times the mass of the sun, a black hole is formed.

Keywords: Main sequence star, red giant, white dwarf, supernova, neutron star, black hole.

1. Introduction

Among so many hypotheses about the formation and evolution of stars, the most influential one is the nebular hypothesis, which holds that the sun formed from a collapsed nebula 4.57 billion years ago [1, 2]; a rotating nebula underwent gravitational collapse, when the core temperature of the nebula rose to 10 million K, the thermonuclear reaction of hydrogen fusion into helium was ignited, releasing a great deal of energy, causing the ambient temperature and pressure to rise, thus the surrounding hydrogen also began to fuse, from near to far, a series of thermonuclear reactions were carried out, finally the sun became a star that emits light and heat; once the hydrogen in the core is exhausted, the life of the star will end. But according to the law of universal gravitation, nebulae are formed by the gravitational force of stars or planets, without the attraction of massive stars or planets, hydrogen molecules would run away. Hence, the hypothesis that stars are formed from pure nebulae is not tenable. Additionally, according to scientific estimates, the thermonuclear reaction of the sun has lasted for about 4.57 billion years, and it will last more than 5 billion years, the

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limited hydrogen element obviously could not satisfy such a long-term thermonuclear reaction, in order to sustain long-term thermonuclear reactions, a steady stream of fuel must be obtained from space. So the existing hypothesis of solar formation has serious defects. Thus by studying the formation and evolution of satellites, planets and stars, the author has discovered the law of star formation and evolution.

2. Formation of Star

The sun is the star at the center of the solar system, it's a typical star, so we can take the sun as an example to illustrate the rules of star formation. Since the sun revolves around the centre of the Milky Way Galaxy, it must have been a satellite produced by a parent star, just like the moon produced by the earth. Therefore, the evolution of the sun from the original satellite to the main-sequence star of today has gone through many stages: first from satellite to planet, then from planet to star [3, 4]. After the original sun evolved from a satellite of small size and mass into an earth-sized planet, it generated some satellites, 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 prograde planetesimals or the accelerating rotation of its parent star due to contraction [5-7]. 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 [8, 9]. Since the Jupiter-sized planet's mass is very huge, it can attract various gas molecules to form a dense atmosphere, and produce strong polar vortices during its rotation. Moreover, this kind of polar vortex can generate strong spiral currents, therefore form strong dipole magnetic fields, as is shown in Fig. 1, which is captured by NASA's Hubble Space Telescope.

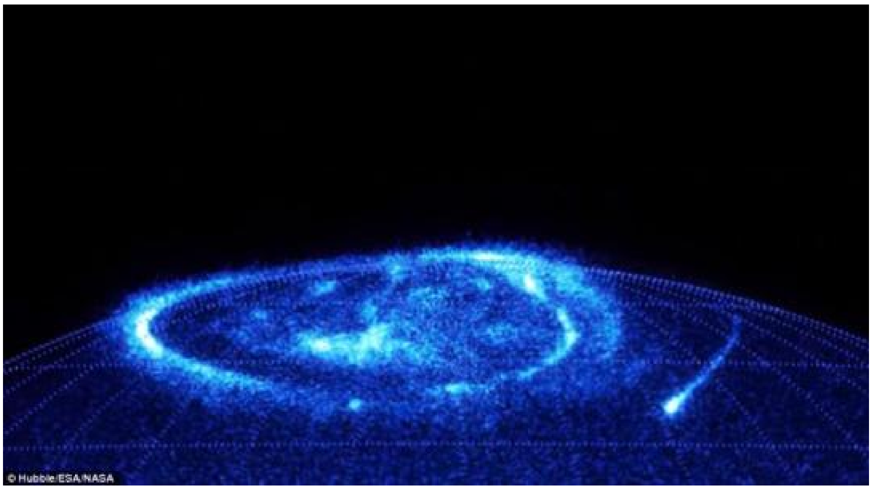

Fig. 1 The spiral current generated by Jupiter's arctic vortex.

Although Jupiter's mass is large enough to attract hydrogen in the atmosphere, making the mass ratio of hydrogen in Jupiter reach 75%, which is comparable to the mass ratio of hydrogen in the sun, yet Jupiter lacks oxidants, therefore cannot burn directly. Jupiter has an internal pressure of about 40 million standard atmospheric pressure, and its inner temperature is 280,000°C, but it can't be detonated directly into a star. In 1994, humans witnessed a spectacular ends when comet Shoemaker–Levy 9 impacted Jupiter. The collision produced scars that were visible from Earth, but Jupiter hasn't been detonated into a star [10]. According to scientists' estimate, only one giant has a mass 70 to 80 times that of Jupiter can it have enough gravity, pressure and temperature to cause fusion reaction between hydrogen elements. In fact, the proto-sun became a detonable star just by accreting interstellar material near its orbit.

A series of strong polar vortices can be formed during the rapid rotation of the proto-sun, as is shown in Fig. 2. This kind of vortex can continuously absorb hydrogen and other matter from the surrounding space to the proto-sun, and they can also eject some material. Originally, the proto-sun has at least two groups of vortices, located at the South pole and the North pole respectively, which can span troposphere and stratosphere. As clouds swept in by a vortex of the proto-sun 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 clouds have already condensed into ice, and the temperature in the vortex is much lower than that around it, hence from the distant Earth, the vortex looks like a small sunspot. But in fact, the central depth of the vortex can reach 200,000 kilometers, and its diameter can reach tens of thousands of kilometers.

Since the clouds involved in polar vortex are constantly in flux and revolve downward rapidly in a spiral manner, a series of parallel thick spiral cloud bands can be formed. In this kind of plasma cloud band, 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 band. 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 band by the updraft, thus forming a current from the bottom of the vortex to the top of the vortex in the spiral cloud band. In addition, since the clouds along a spiral cloud band are numerous and revolve rapidly, it is easy to have violent frictions and collisions among clouds, producing frequent electrical discharge or thunderstorms. Each electrical discharge or thunderstorm acts as an electrostatic motor, which can send currents to the upper portion or the lower portion of the vortex, preponderantly forming an intense current following the cloud band from the bottom of the vortex to the top of the vortex. Since there is a continuous flow of currents along the spiral cloud band from the bottom of the vortex to the top of the vortex, thus forming a powerful dipole magnetic field with its magnetic north pole pointing towards the south pole of the proto-sun and its magnetic south pole pointing towards the north pole of the proto-sun, as is shown in Fig. 3.

In addition, since the coverage of a polar vortex on the proto-sun is huge, the clouds involved in a polar vortex are numerous and revolve rapidly, when they get to the bottom of the vortex, it is easy to have violent frictions and collisions among clouds, and constantly generating violent lightning and releasing huge electric energy, making the temperature of the

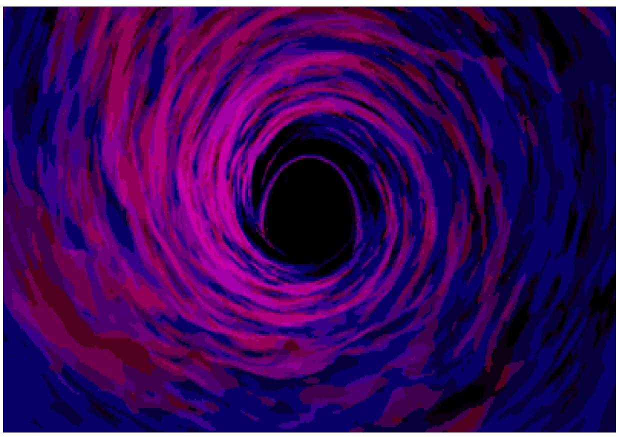

Fig. 2 Polar vortex on the proto-sun.

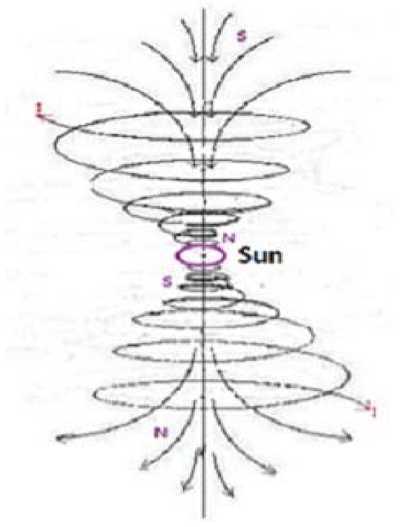

Fig. 3 Magnetic field of vortex.

surrounding air rise rapidly to tens of thousands of degrees and the atmospheric pressure also rise to more than 1MPa, so the gaseous hydrogen in the vortex changes into liquid metal hydrogen. This kind of liquid metal hydrogen is gradually cooled as they sink rapidly along the spiral path. At the bottom of the vortex, the clouds condense into huge metallic hydrogen crystals, and some crystals are even larger than one Earth, for example, famous astronomer Nassim Halamin recently found from an image of SOHO that a white earth-sized object flew out of a sunspot region in the Sun's arctic area [11], as is shown in Fig. 4.

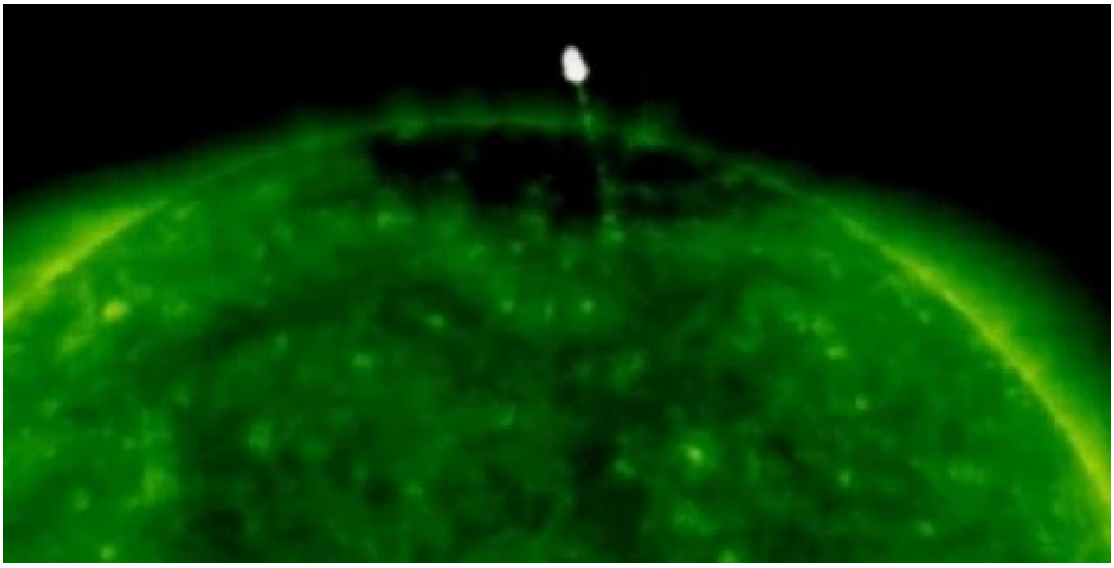

Fig. 4 An earth-sized object flew out of a sunspot region.

It is known that the internal temperature of Jupiter is about 280000 degrees and the internal pressure is about 40 million atmospheres. While the size and mass of the brown dwarf star that was about become the sun are equal to those of the sun, so its volume and mass are more than 1000 times those of Jupiter. Therefore, the internal temperature of this brown dwarf should be 280 million degrees, and the internal pressure should be more than 40 billion atmospheres. When the earth-sized metal hydrogen crystal hits the brown dwarf star, the explosion power of metal hydrogen is 50 times that of TNT explosive, which can increase the pressure nearby by dozens of times, exceeding 300 billion atmospheres. Hence, it can ignite the thermonuclear reaction of hydrogen to helium in the sunspot and cause a series of thermonuclear reactions beside the sunspot:

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

Once a thermonuclear reaction is ignited, a large amount of energy is released in a short time, causing instantaneous heating in local area, generating all kinds of electromagnetic radiation, even appearing a sudden increase of bright spots beside the sunspot, which is the so-called solar flare. Because flares represent the eruption of solar thermonuclear reactions, there will be violent explosions, which may change the structure of sunspots or make them shrink or decay.

Generally, the formation and disappearance of sunspots can only take days to weeks, and a sunspot can only attract a limited range of hydrogen, the hydrogen beyond this scope cannot be processed. So after the recession of a sunspot, without other sunspots to take over, the thermonuclear reactions on the sun would cease. Fortunately, the sun has nurtured many planets that can spin around it rapidly, including Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, which can help the sun to produce a series of sunspots that spread all over the Sun, making the sun produce light and heat continuously. Table 1 shows the ratio of the main planets' gravity on objects on the sun's surface and the revolution periods of these planets. It can be seen that Jupiter has the strongest gravitation on objects on the surface of the sun, followed by the Earth and Mercury, but Mercury is the planet with the fastest revolution speed.

But among the eight planets in the Solar System, the orbital planes of Mercury, Venus, Earth and Mars do not span the north and south poles of the Sun, only the orbital planes of Jupiter, Saturn, Uranus and Neptune span the north and south poles of the Sun, as is shown in Fig. 5. Since Jupiter is the most massive of the last four planets and the closest to the Sun, it has the greatest effect on the atmospheric vortices called sunspots at the North and South poles of the sun. In fact, when Jupiter moves from high latitude to low latitude, it will attract polar vortices just like the moon attracts Earth waves. When Jupiter gets close enough to a polar vortex, it can tilt and even rupture the polar vortex, dumping out cold air and inner sub-vortices. Drawn by Jupiter, these sub-vortices drift rapidly toward low latitudes along with cold air currents. When a sub-vortex absorbs enough cold air to become a long, large, heat resistant vortex, it descends from the stratosphere to the troposphere, becoming a successor sunspot at lower latitudes, this process can be called sunspot replication. With the sun's rapid rotation and its planets around the sun, sunspots can be scattered by Jupiter and other planets from high latitudes to low latitudes and even near the equator, and then, the faster-orbiting Mercury, Venus, and Earth scatter sunspots from the North and South Poles along their orbits, taking them around the globe.

Table 1 Ratio of the main planets' gravity on objects on the sun's surface and the revolution periods of these planets.

Planet	Mass	Average distance from the sun	Ratio of planet's gravity relative to Mercury's gravity	Revolution periods (solar rotation period = 25.05 d)
Mercury	3.3022×10^{23} kg	57909050 km	1	87.9691 d
Venus	4.8690×10^{24} kg	108209184 km	0.42228	224.7 d
Earth	5.9650×10^{24} kg	149597888 km	2.70684	365.24 d
Mars	6.4219×10^{23} kg	227925000 km	0.12554	686.980 d
Jupiter	1.9000×10^{27} kg	778547050 km	31.8327	11.8618 yr

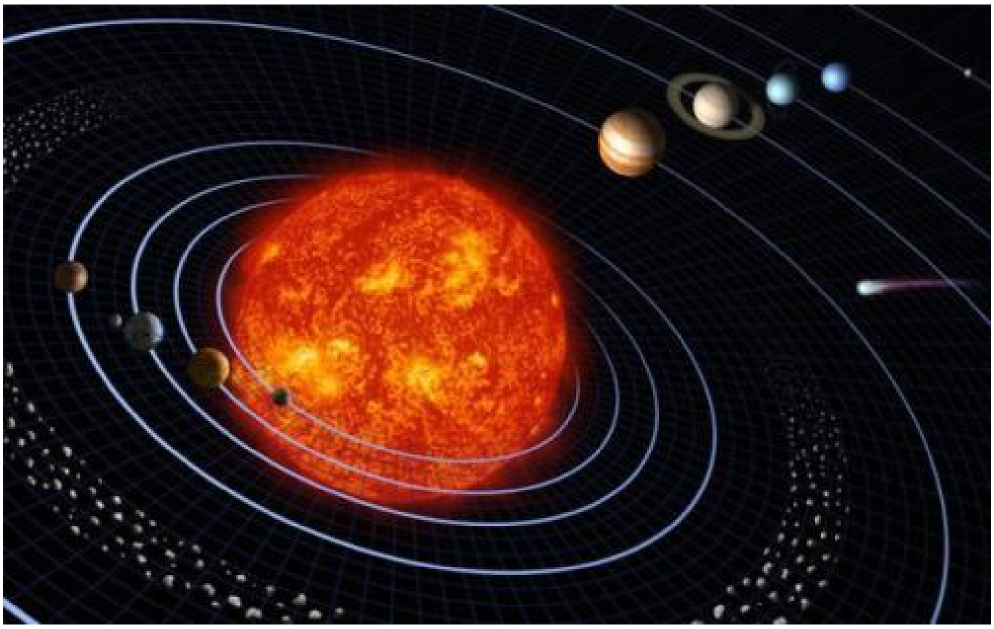

Fig. 5 Orbits of the eight planets in the solar system.

When sunspots surround the sun, the sun becomes a shining star, which has a surface temperature of 6000℃ and an internal temperature of 15 million ℃. It is almost a sphere interwoven by thermal plasma and magnetic fields, but in such a high temperature environment, solar atmospheric vortices can still be generated and active. That is because a sunspot can reach a depth of tens of thousands of kilometers, and a diameter of thousands to tens of thousands of kilometers, which consists of thousands of spiral cloud bands. The air mass involved in each spiral cloud band will turn faster and colder in the process of sinking. After a long spiral descent, the air flow at the bottom of the vortex is dozens of times faster than the speed of the Earth's 12 typhoon. Therefore, each spiral cloud band is a cold current vortex. A sunspot vortex composed of thousands of cold current vortices can restrain the internal energy of the sun from being transmitted by convection, so the internal temperature of the sunspot vortex is low, which looks like a small sunspot from the distant Earth. However, in a sunspot vortex, sometimes there are Earth-sized metallic hydrogen crystals colliding, which ignites the thermonuclear reaction of hydrogen to helium and causes a series of thermonuclear reactions beside the sunspot.

In fact, not only nuclear fusion but also nuclear fission are taking place in the sun. Because when light nuclei are fused into heavier nuclei, in addition to the formation of heavy nuclei, superfluous high-energy neutrons are also produced; if there is a certain proportion of heavy nuclei in the reactor of nuclear fusion, the neutrons produced will bombard the heavy nuclei, causing nuclear fission, then generating new light atom; such light atoms can continue to participate in thermonuclear reactions, producing new neutrons, therefore forming chain reactions. For example, in the reactor of hydrogen fusion into helium, after the reaction of tritium with deuterium, except a helium nucleus is formed, there's also a superfluous high-energy neutron; since a sunspot has absorbed a certain proportion of lithium nuclei, the neutrons from nuclear fusion would bombard lithium nuclei, promoting lithium fission to produce a new tritium:

$$^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{3}_{1}H + ^{4}_{2}He$$

This tritium can continue to participate in the tritium-deuterium reaction, producing new neutrons, therefore forming chain reactions, providing an endless stream of fuel for nuclear fusion.

3. Prime Star — Main Sequence Star

After the birth of the star, it has entered an evolution stage of hydrogen fusion as the main energy. The outward expansion force of the gas in the star is basically balanced with the inward contraction force of the star's gravity, which makes the star neither shrink nor expand. So this is a relatively stable stage, lasting about 90% of the whole life cycle. This stage is called the main sequence stage of stars [12].

4. Middle Aged Star — Red Giant

In the process of a star rotating around the center of its galaxy, it continuously absorbs the gas, dust and other interstellar materials near its orbit by virtue of the cyclones on it. These trapped materials are difficult to escape from the dense atmosphere of the star, and after the deep compression of the cyclones, they can become solid metal hydrogen. When the volume of this solid material is very large, it will hits violently the star and cause thermonuclear reaction. Many lighter elements are fused into heavier elements by thermonuclear reaction of star, so after long-term evolution, the mass of the star increases greatly, and the fireball of the star becomes larger and larger.

On the other hand, with the increase of the star's mass, the gravitational field of the star increases, the atmosphere around the star thickens, the cyclones on the star and their magnetic attraction are enhanced as well as their magnetization to the innermost planet (such as the sun's Mercury) of the star also increase. Originally, in the process of a planet's uniform circular motion around a star, the gravitational force of the star is equal to the centrifugal force of the planet. However, when the planet moves next to a greatly enhanced cyclone, due to the gravitational force of the star and the magnetic attraction of the cyclone magnetic field, it will spirally down to the star and eventually be engulfed by the stellar fire.

Once the innermost planet of a star is engulfed by the parent star, the mass of the star will increase greatly, the atmosphere of the star will thicken greatly, the internal temperature of the star will increase greatly, and the huge energy will be released, which will make the star suddenly expand and become a big fireball, namely a red giant. After a star evolves into a red giant, because there is no inner planet close to the star to quickly scatter cyclones, the star cannot absorb enough hydrogen to maintain the hydrogen fusion reaction inside the star. However, due to the increase of internal temperature, the helium fusion then starts inside the star, thus burns again, which can last for quite a long period of time [13].

5. Late Star — White Dwarf

When the red giant burns up the swallowed planet, its internal temperature will gradually decrease, and the helium fusion will stop. At this time, the central gravity of the star cannot be balanced by the radiation pressure produced by the fusion of hydrogen or helium, and the inner part of the star shrinks until the central gravity of the star is balanced by the pressure of the degenerate electrons in the center of the star, and the contraction stops, forming a white dwarf, as is shown in Fig. 6. Due to the small size of the white dwarf, few places can accommodate the cyclones that can produce thermonuclear reaction, so the brightness of the white dwarf becomes dark and white. Especially, when there is no cyclone (of the white dwarf) facing the Earth, people can't see the light emitted by the white dwarf. At this time, people mistakenly think that it is a black dwarf that doesn't emit light. However, because the shrinking stars still

Fig. 6 A white dwarf and its atmosphere.

keep rotating, and the cyclones at both ends of the rotation axis will certainly emit light, there is no black dwarf star that absolutely does not emit light.

6. Rise From Dead — Supernova

Because a white dwarf or black dwarf is a star formed after the main sequence star engulfing the innermost planet, the mass of the white dwarf or black dwarf is significantly higher than that of the original main sequence star, and its atmosphere is also significantly thickened, but its volume is greatly reduced, even smaller than that of the moon, so its rotation speed is greatly accelerated and polar cyclones are greatly enhanced. If this kind of cyclone is not facing the Earth, people will not be able to detect its internal activities. However, if a planet around the star drags out a sub cyclone from the polar cyclone through gravity, and the sub cyclone just falls at a place (of the star) where Earth's people can see it, the people will be able to observe its activities. The sub cyclone can absorb a large number of clouds from such a thick atmosphere and quickly grow into a powerful cyclone, and then the large cyclone continuously sweeps a large number of heavy clouds from the deep and wide atmospheric space. These clouds go through a long spiral path to the bottom of the vortex and are compressed into huge metal hydrogen crystals. When this huge metal hydrogen crystal collides with the surface of the star violently, it will cause a violent explosion, generating a lot of heat and electric energy, reignite the thermonuclear reaction on the star, emitting a huge amount of energy and shine a very bright light, making the very dark or invisible star suddenly become an extremely bright supernova. The high brightness of supernovae can last for several weeks or even years, until it consumes a large part of the atmosphere accumulated by the star, it will gradually fade and become invisible. Supernova explosion is not the funeral of the star. When the atmosphere of the star becomes thick enough, supernova explosion may occur again, but it will take a long time. For example, iPTF14hls is an unusual supernova star that had erupted continuously for three years (as of 2017), as is shown in Fig. 7, and it had previously erupted in 1954 [14]. Therefore, there will be countless supernova explosions in the process of stellar evolution. In addition, giant objects falling from interstellar space to a white or black dwarf can also cause supernova explosions. A supernova explosion will make part of the falling object fly out at high speed, and then make the surface layer of the star melt and shrink into a thin onion layer.

7. The Later Stage of Stellar Evolution — Neutron Star

After a main sequence star is transformed into a

Fig. 7 Supernova iPTF14hls.

atmosphere is also significantly thickened, but its white dwarf, its mass is significantly increased compared with that of the main sequence star, and its volume is greatly reduced, even smaller than that of the moon, so its rotation speed is greatly accelerated, and its polar cyclones are greatly enhanced. In the process of the white dwarf rotating around the center of the galaxy, it constantly absorbs the gas, dust and other interstellar matter near the orbit by virtue of its strong polar cyclones, which makes its mass increase continuously, its gravitational force increases continuously, and the polar cyclones' involvement force and magnetic attraction increase continuously. Therefore, with the rotation of the white dwarf, a large number of clouds can be drawn into the polar cyclones and be compressed into huge metal hydrogen crystals at the bottom of the cyclones. When these huge metal hydrogen crystals collide with the stellar surface violently, they will not only directly produce huge pressure on the stellar surface, but also produce violent explosion, producing greater pressure, and even cause thermonuclear reaction or supernova explosion, making the star collapse, which leads to great changes in the material structure of the star. In this case, not only the shell of an atom is crushed, but also the nucleus is crushed. The protons and neutrons in the nucleus are squeezed out, and the protons and electrons are squeezed together to form neutrons. Finally, all the neutrons are squeezed together to form a neutron star [15].

When a star shrinks to a neutron star, its volume will be greatly reduced and its rotation will be greatly accelerated, so that the dipole magnetic fields produced by the polar cyclones of the neutron star will be greatly enhanced, making people think that the neutron star is a very strong magnet. In addition, a neutron star emits electromagnetic waves through polar cyclones, but it generally has some planets around it, under the action of planetary gravity, the polar cyclones of the neutron star will deviate from the rotation axis of the star, so each polar cyclone of the neutron star moves along an elliptical trajectory during the rotation of the star. Hence, when a polar cyclone that emits the electromagnetic wave is facing the earth, the earth people can receive the electromagnetic wave; when the polar cyclone deviates from the earth, the earth people cannot receive the electromagnetic wave. Therefore, the electromagnetic waves received by the earth people are intermittent, resulting in "lighthouse effect", as is shown in Fig. 8.

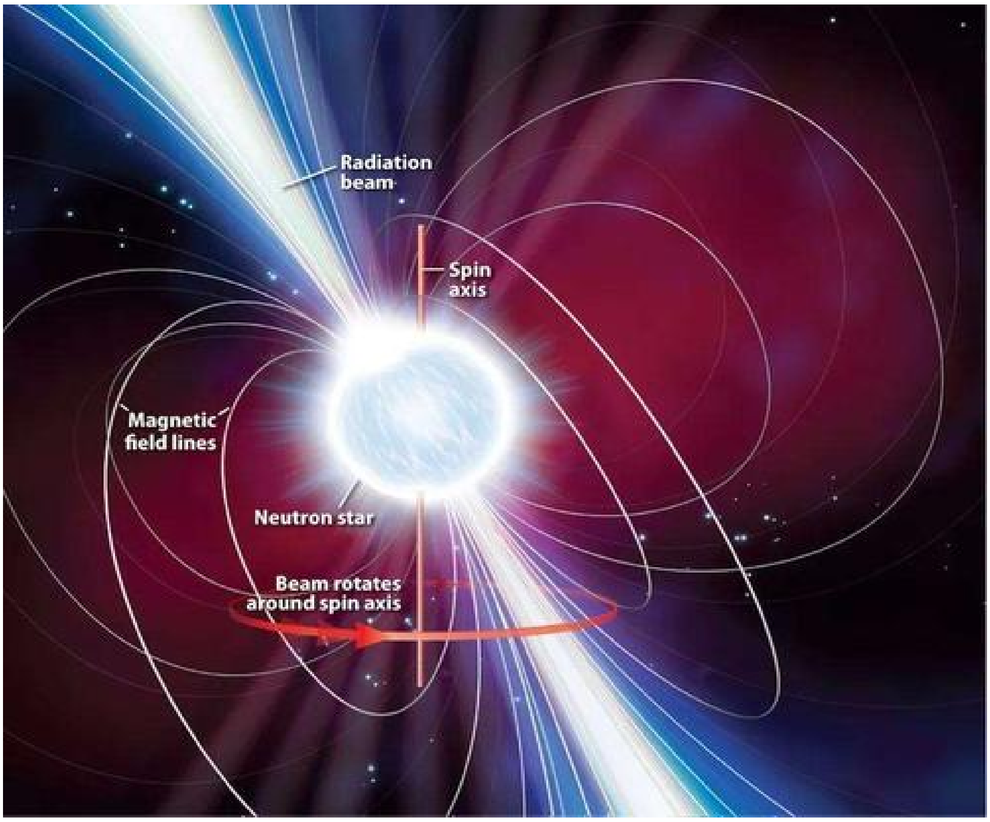

Fig. 8 A neutron star and its dipole magnetic fields.

8. The End of Stellar Evolution — Black Hole

In the process of a neutron star evolution to a larger mass giant, its polar cyclones continuously accrete the gas, dust and other interstellar matter near the orbit, making its mass and surface continuously increase. With the rotation of the white dwarf, a large number of clouds can be drawn into the polar cyclones and be compressed into huge metal hydrogen crystals at the bottom of the cyclones. When these huge metal hydrogen crystals collide with the stellar surface violently, they will not only directly produce huge pressure on the stellar surface, but also produce violent explosion, producing greater pressure, and even cause thermonuclear reaction or supernova explosion, making the star collapse further, which leads to the transformation of the atomic structure of the star surface into a neutron structure or a more dense structure. As the mass of the star increases, the gravity of the star increases, and the drawing force and magnetic attraction of the polar cyclones also increase. Therefore, some planets or even child stars that revolve around the neutron star may be captured by the polar cyclones of the neutron star and fall to the neutron star, causing supernova explosion and greatly increasing the mass of the neutron star. 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, as is shown in Fig. 9 [16].

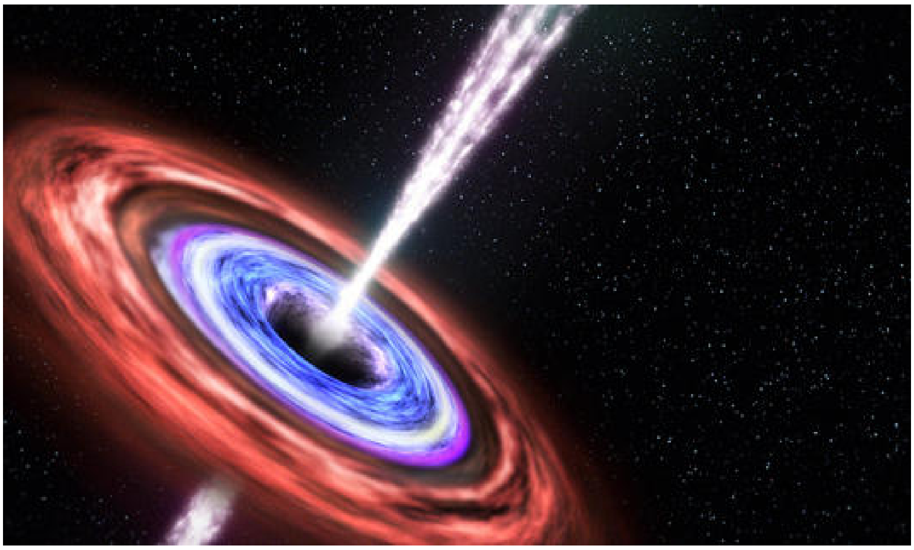

Fig. 9 A black hole and its accretion and jet.

9. Conclusions

Various hypotheses have been proposed about the formation and evolution of a star like the Sun. Among these hypotheses, the widely accepted hypothesis is the Nebular Hypothesis, which holds that the Sun formed from a collapsed nebula 4.57 billion years ago. Once the hydrogen in the core is exhausted, the life of the star will end. But the limited hydrogen element obviously cannot satisfy such a long-term thermonuclear reaction, in order to sustain long-term thermonuclear reactions, a steady stream of fuel must be obtained from space. So the existing hypothesis about the formation and evolution of a star has serious defects. Thus, by studying the formation process of satellites, planets and stars, the author has revealed the mechanisms and laws of star formation and evolution.

References

[1] Woolfson, M. (2000). "The Origin and Evolution of the Solar System." *Astronomy & Geophysics* 41 (1): 1.12-1.19.

[2] Greaves, Jane S. (2005). "Disks Around Stars and the Growth of Planetary Systems." *Science* 307 (5706): 68-71.

[3] Touboul, M. et al. (2007). "Late Formation and Prolonged Differentiation of the Moon Inferred From Wisotopes in Lunar Metals." *Nature* 450 (7173): 1206-1209.

[4] Bowring, S. and Housh, T. (1995). "*The Earth's Early Evolution*." *Science* 269 (5230): 1535-1540.

[5] K. Righter and D. P. O'Brien (2011). "Terrestrial Planet Formation." *PNAS* 108 (48): 19165-19170.

[6] Yin, Q. et al. (2002). "A Short Timescale for Terrestrial Planet Formation From Hf-W Chronometry of Meteorites." *Nature* 418 (6901): 949-952.

[7] Lin, C. and Douglas, N. (2008). "The Genesis of Planets." *Scientific American* 298 (5): 50-59.

[8] Pollack, J. B., et al. (1996). "Formation of the Giant Planets by Concurrent Accretion of Solids and Gas." *Icarus* 124: 62-85.

[9] Tsiganis, K. et al. (2005). "Origin of the Orbital Architecture of the Giant Planets of the Solar System." *Nature* 435: 459-461.

[10] Li Qibin and Zhou Hongnan (1997). "The Observation of the Collision of Comet P/Shoemaker-Levy9 With Jupiter in China." *Progress in Astronomy* 15 (2): 129-136.

[11] Baliukin, I. et al. (2019). "SWAN/SOHO Lyman-alpha Mapping: The Hydrogen Geocorona Extends Well Beyond the Moon." *J. Geophys. Res. Space Physics*: 124.

[12] Sack Mann, I. J. et al. (1993). "Our Sun. III. Present and Future". *Astrophysics Journal* 418: 457-468.

[13] Dixon D., Tayar J. and Stassun K. G. (2020). “Rotationally Driven Ultraviolet Emission of Red Giant Stars.” *The Astronomical Journal* 160 (1): 12.

[14] Sollerman, J. et al. (2019). “Late-Time Observations of the Extraordinary Type II Supernova iPTF14hls.” *Astronomy and Astrophysics* 621.

[15] Popolo, A. D., et al. (2020). “Neutron Stars and Dark Matter.” *Universe* 6 (12): 222.

[16] Derbes David et al. (2021). “Exploring Black Holes.” *American Journal of Physics* 89: 121.