Life Cycle of Stars

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Abstract

This report provides an overview of the lifecycle of a star, tracing its evolution from birth to eventual demise. Beginning with the formation of stars within nebulae, the report examines the critical stages of a star's existence, including its main sequence phase fueled by nuclear fusion, transition into red giants or supergiants, and subsequent transformation into planetary nebulae or supernovae. The varying outcomes based on a star's mass are explored, detailing the formation of white dwarfs, neutron stars, or black holes. Through evidence and theory from the research papers published by scholars, this report gives insights into the origins of elements essential for life.

Introduction

A star is a luminous mass that is composed of hydrogen and helium which are held together by its gravitational force. Stars originate from vast clouds of gas and dust known as nebulae when the gas and dust accumulate, eventually leading to the formation of stars. Nebulae consist mainly of hydrogen, with traces of helium, oxygen, sulfur, and other heavier elements.

The gravitational force causes the nebula to collapse, resulting in an increase in temperature and the eventual birth of a star. These stellar clouds can span several light-years and contain enough mass to create multiple stars. Stars generate heat and light through nuclear fusion reactions in their cores, which counteracts the force of gravity. When the temperature reaches around 10 million Kelvin, hydrogen nuclei fuse to form helium nuclei, marking the birth of a star.

Stars shine brightly due to the ongoing fusion of hydrogen into helium in their cores. Dense regions within nebulae, known as dark nebulae, obscure visible light. Planetary nebulae are the outer layers of a star that are shed when it transitions from a red giant to a white dwarf.

Star Formation Process

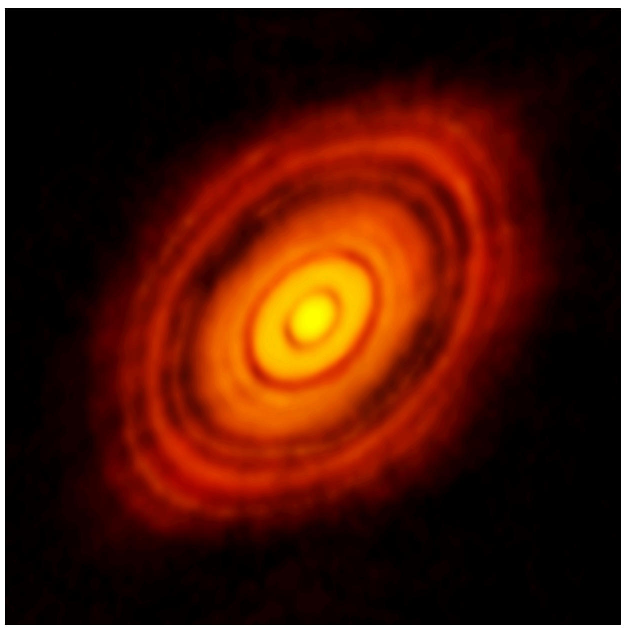
Every star goes through this natural cycle and the changes occur in a star follow according to the below seven stages:

Formation of Molecular Clouds

The journey of star formation begins with the gravitational collapse of giant molecular clouds known as nebulae, which are primarily composed of hydrogen gas with traces of Helium, Oxygen, and Carbon. Despite being diffuse and spread out, the individual particles within the molecular cloud exert gravitational forces on each other due to their mass. While each particle's gravitational pull is relatively weak on its own, the cumulative effect of all the particles results in a significant overall gravitational attraction within the cloud. Under the gravitational influence, these clouds undergo extreme compression leading to the formation of dense cores where the process of star birth begins.

Protostellar Formation

Within the dense cores, formed from the Molecular Clouds, also known as protostellar clouds, the process of star formation begins. As the cloud continues to collapse under its own gravity, it heats up, triggering the onset of nuclear fusion reactions. These fusion reactions begin with two protons fusing, followed by subsequent beta decay, which yields a deuteron. The deuterons are involved in reactions that then yield Helium nuclei. At this stage, the protostar is surrounded by a rotating disk of gas and dust, known as the protoplanetary disk, from which planets and other celestial bodies may eventually form.



Accretion and Protostar Evolution

The protostar continues to accrete matter from its surrounding disk, increasing its size and luminosity over time. The protostar’s gravitational pull strengthens as it accretes more mass, further enhancing its ability to attract surrounding material. This phase of rapid accretion is accompanied by intense heating and the emission of radiation, making the protostar visible to even telescopes. This process allows it to achieve a stable equilibrium between inward pull of gravity and the outward pressure generated by nuclear fusion. This phase represents the most stable and longest period in a star's life cycle, with stars like the Sun spending billions of years on the main sequence, due to which, this phase is also called Main Sequence Phase.

Evolution into Red Giants or Supergiants

Eventually, the hydrogen fuel in the core of a main sequence star begins to deplete, leading to changes in its structure and behavior. For stars that have lower to medium mass, this depletion triggers a series of internal processes that result in expansion of its outer layers, transforming it into a red giant. In more massive stars that have higher masses, the evolution follows with the core collapsing under gravity's pull and the outer layers expanding to form a supergiant.

Planetary Nebulae and Supernovae

As red giants or supergiants deplete their energy sources, Hydrogen fusion for lower and medium mass stars and fusion of Helium and Carbon for heavier stars, they undergo expansion of their outer layers and eventually the ejection of stellar material into space. In case of lower mass stars, this process results in the formation of planetary nebulae, which are luminous shell of gas and dust surrounding a white dwarf remnant. However, in more massive stars, the final stages of evolution are marked by catastrophic supernova explosions, which release vast amounts of energy and leave behind a neutron star or a black hole, depending on the initial mass of the star.

Stellar Remnants

The remnants of stellar evolution include white dwarfs, neutron stars and black holes. White dwarfs are the dense, Earth-sized cores left behind by lower mass stars, while neutron stars are extremely dense remnants of supernova explosions. Black holes are regions of space where gravity is so intense that not even light can escape their gravitational pull.

Related Works

1. **Life Cycle of a Low Mass Stars**

The paper "Life Cycle of a Low Mass Stars" by Sabir Sadiq details the formation, evolution, and ultimate fate of low mass stars like the Sun. It explains that such stars, which are also known as Solar mass stars, begin their life in stellar nebulae as protostars, eventually becoming main sequence stars where nuclear fusion occurs in their cores under massive conditions. As they exhaust their fuel, these stars expand into red giants before shedding their outer layers to form planetary nebulae, leaving behind dense cores that become white dwarfs and eventually black dwarfs. The study also discusses the impact of gravity and dark fabric distortions on these processes, emphasizing how low mass stars interact with their cosmic environment from birth to death.

The importance of this paper points to the description of the simple model of main sequence stars, emphasizing their hydrostatic equilibrium state during nuclear fusion where gravity is balanced by gas and radiation pressure which prevents the low mass stars like our Sun from exploding. The concept of Dark Fabric is introduced as an important element which is present to protect stars and planets by interacting with ordinary matter and energy, by maintaining hydrostatic balance and the spherical shape of stars and planets by exerting additional pressure and weight. These interactions between these fabrics ensures the dynamic balance of the universe and also the energy transfer between celestial objects and maintaining their overall structure.

2. The life cycle of star clusters in a tidal field

The paper explores and focuses on the distribution and characteristics of star-forming and post-starburst galaxies based on the observation of star formation in three distant galaxy clusters by using data from spectroscopically confirmed members and infrared images to analyze the proportions and characteristics of galaxies undergoing secondary bursts of star formation. With the help of the existing and newly acquired data to create detailed color-color and color-magnitude diagrams, evolutionary models were applied to match the observed distribution of galaxies in terms of spectral and color properties.

From the findings, nearly 30% of the cluster galaxies have experienced secondary bursts of star formation within the last 2 Giga years, which supports the idea that a significant fraction of galaxies in these clusters are in various stages of secondary star formation burst. This conclusion that a high fraction of galaxies in cluster cores are actively forming stars through secondary bursts provides insight into the dynamic processes influencing galaxy evolution in dense environments. The correlation between galaxy mergers and star formation cycles underscores the complexity of galaxy interactions and their impact on star formation histories.

3. Life cycle of high mass stars

This paper is mainly focused on high mass star's evolutionary stages from formation to final collapse. High mass stars have a fast life cycle because of their mass, gravity, temperature. These stars are far heavier than our Sun. The study starts with the birth of a protostar from a stellar nebula. The protostar eventually becomes a main sequence star by gaining mass until nuclear fusion ignites. AS their nuclear fuel runs out quickly, these stars grow into red supergiants. Later on they explode as supernovae, dispersing heavy elements into space and leaving behind dense remnants.

A supernova can produce either a black hole or a neutron star, depending on the leftover mass. If neutron stars are able to continue to accumulate additional mass, they have the potential to collapse into black holes due to their exceptionally high density and neutron degeneracy pressure. This paper further delves into the impact of dark fabric matter and energy on the density and gravitational attraction of high mass stars. High mass stars have a big effect on the environment around them. They contribute to the distribution of elements in the universe by significantly impacting their surroundings. This study highlights the significance of high mass stars in the larger framework of astrophysical processes and stellar evolution by emphasizing their shorter but more intense lifetimes than those of their lower mass counterparts.

4. **Life cycle of star formations in distant cluster**

This paper examines the distribution and characteristics of star-forming and post-starburst galaxies within three different galaxies. Using information from spectroscopically verified cluster members and infrared photos, this paper investigates the characteristics and masses of galaxies undergoing star production secondary bursts. Detailed color-color and color-magnitude diagrams are drawn from the observed spectral and color features of these galaxies which are aligned using evolutionary models.

Results show that during the previous two Giga years, secondary bursts of star formation have occurred in around 30% of the cluster galaxies. This supports the hypothesis that a significant portion of the galaxies in these clusters are in various stages of secondary star formation bursts. This study also highlights the fact that a significant portion of galaxies in cluster cores are actively creating stars through secondary bursts and offers insights into the dynamic processes influencing galaxy evolution in packed environments. The study also emphasizes the relationship between star formation cycles and galaxy mergers, highlighting the intricate nature of galactic interactions and their significant influence on star formation histories. These results advance our knowledge of the evolutionary processes and pathways underlying galaxy transition in environments with clusters.

Conclusion

This paper has described the life cycle of stars from their origin in nebulae to their final destiny. Stars are created when hydrogen and helium-dominated molecular clouds collapse due to gravity. As these clouds contract, protostars undergo nuclear fusion from the heat that is generated. Stars spend most of their lives in the main sequence, when the hydrogen fusion takes place. As stars run out of hydrogen fuel, they turn into red giants or supergiants, depending on their mass. When low and medium- mass stars lose their outer layers, white dwarfs are formed as a result. creating a planetary nebulae. Massive stars might explode in catastrophic supernovae leaving behind black holes or neutron stars. Important ideas including gravitational collapse, stellar remnants, and stellar nucleosynthesis are discussed. Studies have been cited to highlight the intricate process and interactions that impact stellar and galactic evolutions in this paper. These papers are based on life cycle of low mass stars and formation of star clusters in tidal environments. These studies also shed light on the cosmic lifecycle by examining the origins of components necessary for life.