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BROWN DWARFS: THE BRIDGE BETWEEN STARS AND PLANETS IN STELLAR AND PLANETARY SCIENCE

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ABSTRACT

Brown dwarfs are astronomical or substellar objects that fail to become stars due to insufficient mass to sustain hydrogen fusion. First discovered in the late 1990s, brown dwarfs were initially categorized as self-luminous objects. Although they do not fit the criteria for either stars or planets and are sometimes referred to as "failed stars," brown dwarfs play a significant role in astronomy. They are found to be alike in stars due to their emission of light, hosting of planets, and formation process, along with their fundamental foundations. Additionally, brown dwarfs resemble gas giant planets like Jupiter, lacking nuclear fusion in their cores and having atmospheric phenomena and weather patterns. Due to these shared properties, brown dwarfs serve as important intermediate astronomical objects, offering insights into both stellar and planetary science.

KEYWORDS: Brown Dwarfs, Planets, Stars, Luminosity, Hydrogen, Nuclear Fusion, Atmospheres

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INTRODUCTION

The discoveries in astronomy are seemingly endless, with astronomers, astrophysicists, and space scientists regularly unveiling new and fascinating facts about our universe. One of the significant discoveries in this field is the existence of brown dwarfs, which were initially theoretical objects until the 1980s, but as technology evolved over time, approximately 2800 brown dwarfs have been discovered. The first confirmed brown dwarf, Gliese 229B, was discovered in 1995 (Tillman, 2017). This discovery was groundbreaking for space scientists, marking an essential first step in the search for planetary systems beyond our Solar System (Kulkarni et al., 1995). Gliese 229B was found orbiting the cold red star Gliese 229, located 19 light-years from Earth (Kulkarni et al., 1995).

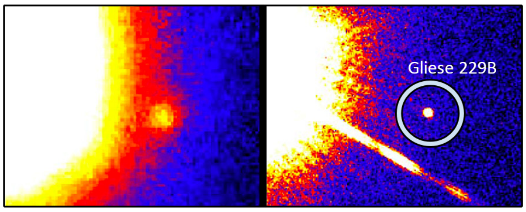

Figure 1: Brown Dwarf Gliese 229B.

Despite these findings, subsequent research determined that brown dwarfs are not true stars due to their formation failure. They are substellar objects primarily composed of hydrogen gas, lacking an internal energy source, and emitting almost no visible light (Tillman, 2017).
The study of brown dwarfs has significant implications for our understanding of astronomy. While some may perceive brown dwarfs as having a negligible impact due to their classification as "failed stars," they play a crucial role in bridging the gap between gas giant planets and small stars. This intermediate status allows brown dwarfs to enhance our comprehension of both planetary and stellar processes.

METHODOLOGY

This study uses a qualitative analysis of secondary sources to explore the nature and characteristics of brown dwarfs. These sources serve as significant evidence to support the points made in the research. To support the justification effectively, a picture of a brown dwarf's flare recorded by NASA's Chandra X-Ray Observatory was presented (NASA, n.d.). This image was chosen as a primary source to demonstrate the similarity between brown dwarfs and stars in terms of light emission. This is further supported by an H-R diagram from a Scientific American article, illustrating that while the luminosity of most brown dwarfs is very low, it can still be detected (Allers, 2021).

The main secondary source used in this study is an article by Katelyn Allers in Scientific American. The infographic in this article is particularly beneficial in explaining the atmospheric conditions of brown dwarfs, which are similar to those of Jupiter. This part of the infographic strongly supports the claim that brown dwarfs resemble typical gas giant planets in their atmospheric composition (Allers, 2021).

Research Paper

RESULTS & DISCUSSION

Technically, brown dwarfs are neither stars nor planets. They are not stars because they are not massive enough to sustain the hydrogen fusion reactions required for star formation. Brown dwarfs are not planets either, since they are much larger than the most prominent gas giants, such as Jupiter. Brown dwarfs are typically classified as objects above 13 MJ, the limiting mass for the thermonuclear fusion of deuterium. Despite having their classification as "brown dwarfs," they lie between stars and planets, serving as a bridge to understanding both types of celestial objects, with their temperatures and masses being intermediate between the two.

First, brown dwarfs share some properties with stars, such as emitting light (Allers, 2021). This light is thermal radiation from their internal heat. Brown dwarfs tend to glow red due to their heat and the infrared spectrum until they cool down, at which point they emit X-rays and infrared light (Allers, 2021). Figure 1 is an X-ray image of an X-ray flare detected from a brown dwarf during Chandra's observation ("Brown Dwarf LP 944-20," 2022). The left panel shows no light emission from the brown dwarf for nine hours and 36 minutes, while the right panel shows the detected proof of a brown dwarf emitting bright X-ray light, which slowly diminishes over the observation period ("Brown Dwarf LP 944-20," 2022).

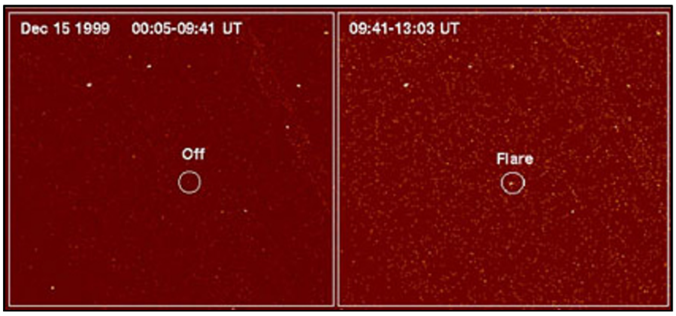

Figure 2: X-ray flare from brown dwarf LP 944-20.

Brown dwarfs are incredibly faint, and most of their light is in infrared wavelengths because their surface temperature is far cooler and dimmer than any star type. However, with advanced infrared technology, they are still challenging to detect (Allers, 2021). Figure 3 demonstrates that brown dwarfs have the lowest temperature and luminosity of all types of stars.

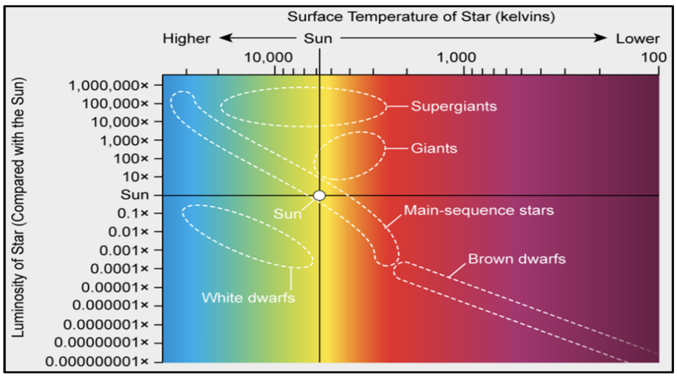

Figure 3: H-R diagram.

Similar to stars, brown dwarfs can host their own planets (Allers, 2021). Some observations have shown that Earth-sized planets can form and orbit around brown dwarfs. Currently, it is thought that planets form when stony worlds form over time as grains orbiting a protostar collide and stick together (Howell, 2012). Scientists had anticipated that brown dwarfs could support this process, as they observed quickly moving dusty particles encircling brown dwarfs (Howell, 2012). Indeed, astronomers soon found evidence of tiny solid grains in a disk surrounding a brown dwarf, ISO-Oph 102. Subsequently, other planetary-mass objects or exoplanets (e.g., 2M1207b, MOA-2007-BLG-192 Lb, 2MASSJ044144b, and Oph 98 B) orbiting brown dwarfs were discovered (Howell, 2012).

Lastly, brown dwarfs and stars share a similar formation process and essential stellar atmosphere (Allers, 2021). Both form molecular clouds of gas and dust in space. This process occurs independently and involves the gravitational collapse of the same clouds, resulting in the formation of a dense core (Allers, 2021). Although brown dwarfs cannot sustain hydrogen fusion, they do experience deuterium and lithium fusion early in their lives, similar to how stars begin. Furthermore, brown dwarfs are composed primarily of hydrogen, much like the sun (Allers, 2021). Most stars are composed of hydrogen and helium, along with small amounts of other elements, and brown dwarfs have a comparable atmospheric composition. These similarities highlight the many likenesses between brown dwarfs and stars.

Similarities with Planets

Conversely, brown dwarfs also share characteristics with planets. Firstly, neither planets nor brown dwarfs undergo nuclear fusion (hydrogen fusion) in their cores (Allers, 2021). Stars form within dust clouds scattered throughout galaxies. Deep within these clouds, turbulence creates knots with enough mass for gas and dust to start collapsing under their gravitational pull (Stars - NASA Science, n.d.). The pressure from gravity causes the material at the center to heat up and create a protostar. Eventually, this core becomes hot enough to ignite fusion, leading to star formation (Stars - NASA Science, n.d.). However, not all dust clouds form stars. Brown dwarfs form similarly to stars, through the contraction of gases and dust in the interstellar medium (Tillman, 2017). To become a star, the gravitational pull must push inward on the clouds until hydrogen fusion starts in the core. For brown dwarfs, the core reaches a stable state before the temperature rises enough for hydrogen fusion to start (Tillman, 2017). Planets cannot undergo nuclear fusion either because they lack the necessary conditions for fusion (Allers, 2021). Planets cannot reach the incredibly high temperatures and pressures required for fusion. Similarly, brown dwarfs lack sufficient temperature and have a low mass that prevents fusion, akin to Jupiter.

Secondly, some brown dwarfs resemble Jupiter's atmosphere (Allers, 2021). Unlike stars, brown dwarfs have clouds in their atmospheres. Initially, brown dwarfs have an atmosphere composed of titanium oxide and carbon monoxide for the first 100 million years. Between 100 million and 500 million years, the atmosphere cools and forms dusty mineral clouds (Allers, 2021). A billion years later, methane typically dominates the atmosphere. Over long periods, brown dwarfs become surrounded by thick, multiple layers of gas, similar to the outer planets of our solar system (e.g., Jupiter, Saturn, Uranus, and Neptune). For instance, the coldest known brown dwarfs, spectral class Y, exhibit water-ice clouds, water vapor, and methane in their atmosphere's outer layer (Allers, 2021). Significant amounts of ammonia gas are also expected in class Y brown dwarfs' atmospheres, comparable to Jupiter's outer layer of clouds, as shown in Figure 4 (Allers, 2021).

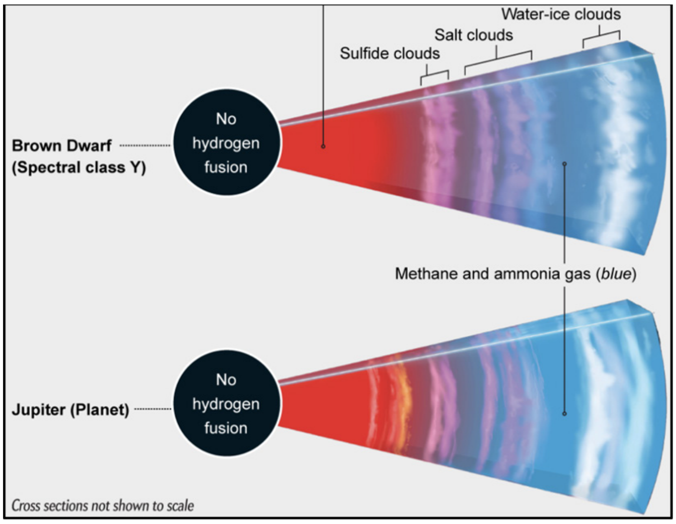

Figure 4: Interior engine and atmosphere of different astronomical objects.

Lastly, weather and atmospheric phenomena detected in brown dwarfs are common traits of planets (Kramer, 2013). For instance, Jupiter, known for being the planet most similar to brown dwarfs, has distinct weather phenomena such as clouds, storms, and winds (Landau, 2020). Researchers reported the windy and cloud-covered weather of a brown dwarf using NASA's Spitzer and Hubble space telescopes (Kramer, 2013). Two spacecraft surveyed the brown dwarf 2MassJ22282889-431026 (Kramer, 2013). Different light wavelengths revealed storms the size of Earth in the brown dwarf's atmosphere, created by an organized cloud system akin to Jupiter's Great Red Spot (Landau, 2020). Astronomers and scientists believe the cloudy regions on brown dwarfs can produce rainy storms with violent wind and lightning (Clavin, 2014). However, most brown dwarfs studied have temperatures too high for water rain (Clavin, 2014). Therefore, astronomers consider the torrential rain and storms in brown dwarfs to be composed of hot sand, molten iron, or salt. In 2014, in the "Weather on Other Worlds" Spitzer program, scientists expected only a few brown dwarfs to show variations in brightness (Clavin, 2014). Contrary to expectations, the findings revealed that approximately half of the brown dwarfs showed variation (Clavin, 2014). Considering that about half of the brown dwarfs were oriented to possibly conceal or maintain unchanging storms, the results indicate that most, if not all, brown dwarfs experience stormy conditions and weather (Clavin, 2014). Additionally, researchers identified signatures of an aurora from LSR J1835+3259, a brown dwarf 20 light-years away (Landau, 2015). The auroras on this brown dwarf are similar to those seen around Earth's magnetic poles. It is believed that charged electrons would be responsible for the auroras generated by an orbiting planet moving through the brown dwarf's magnetosphere (Landau, 2015). The auroras on brown dwarfs are generally a million times more potent than those on Earth (Landau, 2015). These overlapping properties demonstrate that brown dwarfs are similar to planets.

CONCLUSION

In conclusion, brown dwarfs share many properties with both stars and planets, positioning them as intermediate objects between the two categories. Although they do not fit neatly into either category, their unique characteristics provide significant insights into the nature of both stellar and planetary bodies. Scientists continue to search for more brown dwarfs to gain a deeper understanding of the boundaries between stars and planets (Allers, 2021). The study of brown dwarfs offers valuable insights into stellar and planetary science, challenging our preconceived notions and enhancing our knowledge of the universe's diverse processes.

Brown dwarfs serve as a vital missing link, offering a treasure trove of information for astronomers. Their existence has reshaped our understanding of cosmic phenomena, providing a fascinating perspective on the interplay between the stellar and planetary realms (Allers, 2021). As we continue to explore these cosmic anomalies, their role in the cosmos will underscore the profound impact of understanding brown dwarfs. This ongoing research will illuminate the intricate connections between stars and planets, deepening our appreciation of the complex web of interactions that shape our universe (Allers, 2021).

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