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Brown Dwarf Stars – The "Missing Link"

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Introduction

In the first paper of this series, the brown dwarf star was discussed within the general framework of the transformation hypothesis.(1) This paper, the fourth in the series, will expand on the nature of these recently discovered sub-stellar objects and discuss the confusion they have brought to both conventional stellar evolutionary and planet formation theories. This confusion exemplified by the astronomical community's now common reference to these objects as the "missing link" between fusing stars - i.e., stars that convert hydrogen into helium - and planets.

And, while this missing link concept is consistent within the general framework of the transformation hypothesis, it will be shown that it is a misnomer with respect to conventional theories of star and planet formation. However, it is hoped that by shedding light on the anomalies that arise by calling brown dwarf stars the missing link between fusing stars and planets, their place in the scheme of stellar evolution according to the transformation hypothesis will stand out with sufficient clarity to dispel the confusion that these objects have hitherto engendered.

Historical Background

Although the first brown dwarf star was not definitively detected until 1995, Shiv Kumar had done some theoretical investigations in the late 1950s and early 1960s that culminated in his prediction that a category of such low mass, non-fusing stars existed. He called these sub-stellar objects "black dwarfs." As his work became better known, researchers began to call them "Kumar objects." However, in 1975, Jill Tarter proposed using the term "brown dwarf" to describe them and the term subsequently came into general usage, replacing the eponymous name. Another twenty-five years passed before their existence was confirmed with the detection of Gleise229B in the constellation Lepus.(2)

Essentially, Kumar asked what type of object would result when a cloud of gas collapsed lacking the amount of mass required to initiate hydrogen burning, i.e., the basic proton-proton fusion chain reaction that is the fundamental source of stellar energy? His answer was "…that the star would keep on collapsing beyond the stage of maximum central temperature. As a result of the compression of the partially degenerate electrons in the interior of the star, the temperature would start decreasing and this in turn will take the star closer to the state of complete degeneracy." He concluded that when the collapse is complete, the object consists completely of degenerate matter. A brown dwarf star has been formed.(3)

Further, Kumar calculated that these brown dwarf objects would form with masses ranging from .01 Msun down to .001 Msun. This corresponds to a range of 1.9X10^28 kg to 1.9X10^27 kg. Curiously, Jupiter, a gas giant planet, also has a mass of 1.9X10^27 kg. But, Kumar was quick to point out that the formation of a gas giant planet did not result from the same kind of mechanism that produced stars. "The mass of an object doesn't uniquely determine its basic nature. In order to ascertain the basic nature of an object, we have to know its formation mechanism."(4)

Even though Kumar's calculations allowed for the formation of a brown dwarf object with a mass as low as Jupiter, he was quite clear that such an object could not be viewed as a planet. "Since 1964, I have been presenting arguments to show that the star formation processes are fundamentally different from those of planet formation…"(5) Stars, including brown dwarfs, form from the fragmentation and collapse of "gaseous clouds." Planets, on the other hand, "…are formed by the slow accumulation (accretion) of dust, rocks, and gas in vicinity of a star…"(6)

It is clear from Kumar's remarks that he adheres to the derivative paradigm. He can only view the formation of planets as a secondary process following on the heels of a primary process out of which stellar objects form. Planets are merely the by-products of stellar evolution. However, according to Kumar, without knowing the mechanism by which a hypothetical object of .001 Msun formed, it would be virtually impossible to determine whether it was a brown dwarf star or a gas giant planet. This consideration leads him to remark that as far as the recent detection and identification of extra-solar gas giant planets go, "…it's much more likely that some of them are hydrogen-rich degenerate objects of very low mass in the third and final stage of their evolution."(7) In other words, Kumar believes that these objects are not what they seem to be. They are not planets but brown dwarf stars that have been misidentified.

Current Brown Dwarf Models

Conventional brown dwarf star models now assign to them a lower mass limit that is well above Kumar's 1 Mjupiter, starting in the 12-13 Mjupiter range. It is at these minimum mass levels that deuterium burning can occur in the early lifetimes of these sub-stellar objects. They shine feebly but eventually the deuterium is sufficiently depleted to cause a cessation in the fusion process and they begin to cool down. The reader will note that conventional theory makes a distinction between the hydrogen burning process occurring in stellar cores, typical of fusing stars, and the low-level deuterium burning process associated with brown dwarf stars. At their highest mass levels, some 65-80 Jupiter masses, theory further suggests that brown dwarfs are now heavy enough to fuse lithium. However, as with the deuterium burning, the supply of lithium becomes too depleted to support further fusion and these "jumbo" brown dwarf objects begin to cool down, as well.

Further complicating an already complicated picture, theorists are beginning to discuss the possibility that a class of star exists below the brown dwarf category. Appropriately named "sub-brown dwarfs," these objects have masses less than the minimum range for their heavier cousins (12-13 Mjupiter) and, therefore, lack the mass required to burn deuterium. Needless to say, the existence of these objects is the subject of lively controversy. But, on the matter of their formation there is general agreement in conventional astronomical circles that sub-brown dwarfs also form like fusing stars from the primary collapse of a gaseous cloud and not by a secondary accretion or derivative process from cast-off protostellar material. Thus, we find ourselves back at Kumar's original idea – objects formed from the collapse of a gaseous cloud that can be as light as the planet Jupiter. But the picture becomes even more muddled when brown dwarf stars are considered the "missing links" between fusing stars and planets.

The "Missing Link"

It was stated in the introduction that the conventional astrophysical community's application of "missing link" to brown dwarf stars is a misnomer. It will be recalled that this term originated in mid-nineteenth century evolution discourse to denote a transitional, intermediate life form that bridged the gap between a more primitive and a more advanced life form. However, it is no longer in use. Nonetheless, the central idea is simple enough. In general, a transitional life form exhibits some characteristics that are common in the more primitive life form and other characteristics that are common in the more advanced life form. We recognize in the term a sense of unbroken continuity in time wherein three related life forms that share a common origin are linked to each other.

This common linkage, however, cannot apply to brown dwarfs as the missing link between fusing stars and planets for the simple reason that according to conventional astrophysical theory, regarding the formation of stars and planets, two separate and distinct processes are at work. And, whereas the process of formation is identical for both fusing stars and brown dwarf stars – the collapse of a cloud of gas and dust – such a process is not contemplated with respect to the formation of planets.

Planets form from a secondary process of accretion subsequent to the primary formation of a stellar object. They are viewed as derivative by-products of stellar evolution. In this sense, there is no linkage between stellar and planetary objects. Stars, both the fusing kind and brown dwarfs, and planets certainly share some common characteristics, but the mechanisms by which they form are not only quantitatively different - they are qualitatively different. According to conventional theory, brown dwarf stars - and their runt sub-brown dwarf siblings - represent the terminal point of stellar evolution.

Unless conventional theorists are prepared to reclassify gas giant planets as sub-sub-brown dwarf stars, it makes little sense to view brown dwarf objects as the "missing link" between stars and planets. On the other hand, in the unlikely case that gas giants should be so reclassified, how, then, should the rocky terrestrial-type planets be viewed? Would gas giants then become the missing link between brown dwarf stars and rocky planets like Earth? Would it, then, be logical to reclassify rocky planets as sub-sub-sub brown dwarf stars? And, without seeming facetious, would it be necessary to reclassify the dwarf planets according to the above scheme, as well?(8)

One of the more obvious problems related to the missing link concept bears on the distinctly different physical constitutions of brown dwarf stars and gas giant planets. Conventional theory holds that, like regular fusing stars, brown dwarf stars are wholly gaseous whereas gas giant planets have solid cores buried beneath their extensive gaseous envelopes. There is nothing startling in this distinction either. As has already been mentioned above, stars form in a process that entails the gravitational collapse of a cloud of gas and dust. Planets, on the other hand, form from the accretion of leftover material derived from a proto-star. The misapplied concept of the missing link blurs the distinct line of demarcation that exists between these two classes of objects.

If we hark back to the category of sub-brown dwarfs, whose theoretical masses, volumes, pressures and densities are on par with Jupiter-like gas giant planets, the question that immediately arises is how do sub-brown dwarf stars maintain their gaseous states while gas giant planets grow solid cores? Within the realm of conventional astrophysics, there is no reasonable explanation for this apparent anomaly.

A Natural Fit

While the missing link concept is an unnatural fit with respect to conventional stellar and planet formation theories, it is consistent within the framework of the transformation hypothesis. Although an object that would fill the large gap in mass that existed between stars and planets was anticipated more than forty years ago by Shiv Kumar, followed by the work of other theoretical astrophysicists, the subsequent discovery of brown dwarf and sub-brown dwarf stars has provided the empirical evidence that further strengthens the soundness of the transformation hypothesis.

Not only does the brown dwarf class span the mass gap between fusing stars and gas giant planets, it also provides continuity with respect to age, as well. Generally speaking, the transformation hypothesis requires that brown dwarfs be viewed as older objects than fusing stars but younger than gas giant planets. And, within the brown dwarf class, the so-called sub-brown dwarf stars are generally older than the larger variety of brown dwarf stars. It should be kept in mind, however, that this is an idealized scheme that posits, for the sake of exposition, a standard stellar object with physical characteristics similar to our own Sun. It is conceivable that some sub-brown dwarfs may in fact be younger than some of the larger brown dwarfs, arising from variations that depart from the idealized standard solar model. Since our understanding of these objects – and, for that matter, all other celestial objects - is still rudimentary, our quest for more certain knowledge can only be satisfied by the continuing acquisition of unassailable empirical evidence.

It is the generally held view that planets – whether they are members of this Solar System or exoplanets - have solid cores. This belief is supported by conclusions drawn from the analysis of Earth and Moon seismic data. The existence of solid cores also forms the basis of the widely accepted accretion model for planet formation theory, particularly with respect to gas giant planets. In general, if the heavier materials of accreting proto-planets are of sufficient mass, they will continue to attract the lighter material that will subsequently form the large gaseous envelopes that distinguish them from smaller, rocky planets. Thus, the interpretation of empirical data appears to support the planet formation theory that is currently in vogue in conventional astrophysical circles.

Like the conventional accretion hypothesis, the transformation hypothesis also recognizes that planets have solid cores. But, it goes further than this species of the derivative hypothesis by pointing out that since brown dwarf objects actually do represent an earlier stage of stellar evolution – the "missing link" between fusing stars and gas giant planets - they must either already possess or are in the process of forming solid cores. Needless to say, the possibility that core formation processes commence at even earlier stages of stellar evolution than the brown dwarf stage raises a fundamental question, pertaining to the presumed mechanism by which stellar energy is produced, that cannot be explored now. Nevertheless, the reader should keep in mind that the stellar fusion model is just a hypothesis, and like all hypotheses it runs the risk of being replaced by another more comprehensive explanation.

Conclusion

It is hoped that the foregoing analysis has provided the reader with an insight into the confusion that currently exists in conventional stellar and planet formation theories. The misapplication of the "missing link" concept demonstrates that the line separating stellar objects from planetary objects is no longer clear. But, hampered by their adherence to outdated notions regarding the evolution of stars and planets, conventional theorists will continue to stumble over the mounting anomalous data that observational astronomers are dropping in their path. On the other hand, the missing link concept makes perfect sense within the context of the transformation hypothesis. The brown dwarf object is but one link in an evolutionary chain that extends from the hottest and heaviest stars to the coolest and lightest spherical dwarf planets.

Footnotes

1. Abruzzo, Anthony, J., "Are Planets the End Products Rather than the By-Products of Stellar Evolution?," *The General Science Journal*, August 15, 2008

2. Nakajima, T., et al, "Discovery of a cool brown dwarf," *Nature*, Vol. 378, pp 463-465, November 30, 1995

3. Kumar, Shiv, S., "The Bottom of the Main Sequence and Beyond: Speculations, Calculations, Observations, and Discoveries (1958-2002), p.2. This comprehensive summary paper of Kumar's work can be found on his website: galileoinstitute.org.

4. Ibid., p.8

5. Ibid., p.7

6. Ibid., p.7

7. Ibid., p.7

8. The current state of confusion regarding the question of whether to call an object a star or a planet is brought out admirably by Gibor Basri and Michael E. Brown in their paper, "Planetesimals to Brown Dwarfs: What is a Planet?," *Annual Review of Earth & Planetary Sciences*, Vol. 34, pp 655-688, May 2006