Reconsidering the Origin of TOI-6894b as a Failed Binary Companion

R. Scott Johnson

Independent Researcher
s2fchm2udg@liamekaens.com

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Abstract

Bryant et al. report the discovery of TOI-6894b, a Saturn-sized companion orbiting an extremely low-mass star. The authors interpret this as a planet, but note its formation is puzzling under standard core accretion or disk instability models. I argue that TOI-6894b is more plausibly a failed binary companion—a substellar object formed via cloud fragmentation rather than a protoplanetary disk. This interpretation resolves the tension without requiring model revision, and suggests similar M-dwarf systems may also originate from binary formation pathways.

Main Text

The recent discovery of TOI-6894b presents a system in which a gas giant comparable to Saturn orbits a host star with mass near the stellar–substellar boundary [Bryant et al., 2025]. The authors emphasize the difficulty of explaining the planet's formation via canonical models such as core accretion or gravitational disk instability, especially given the extreme mass ratio and tight orbital separation.

However, a different interpretive framework eliminates this puzzle. TOI-6894b can be viewed not as a planet at all, but rather as a failed stellar companion in a binary system. Hierarchical fragmentation during molecular cloud collapse is a well-established pathway for the formation of low-mass binary systems [Bate, 2009]. When the mass reservoir is insufficient for both fragments to sustain hydrogen fusion, the secondary becomes a brown dwarf or high-mass planetary object [Whitworth et al., 2007, Luhman, 2012].

This formation channel is supported by the system's extreme mass ratio, as well as its tight orbit—which could be the result of post-formation migration or orbital decay. Substellar companions around M-dwarfs have been documented in other systems [Bowler, 2018], and TOI-6894b may simply be an extension of this continuum rather than an outlier in need of planetary-model modification.

Conclusion

Reframing TOI-6894b as a failed binary companion rather than a planet dissolves the tension identified by Bryant et al. and avoids the need to revise existing disk-based formation models.

Future studies should more carefully distinguish between circumstellar and binary formation signatures in low-mass star systems. It is likely that many similar 'giant planets' around small stars have been misclassified.

References

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