Kepler-807 B: A Highly Eccentric Companion Near the Stellar Transition

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Abstract

The traditional boundary between brown dwarfs and M-dwarfs is a mass limit for sustainable hydrogen fusion (~80 MJ). Discovering and characterizing objects near this transition point offers a unique opportunity to test our substellar and stellar evolution models, while studying the nature of this transition. Using observations from Kepler combined with ground-based radial velocity measurements from Keck-HIRES and APOGEE, we confirmed and measured the mass of Kepler-807 B. This companion is on a highly eccentric (0.69) 117 day orbit, and from our analysis we measured a radius of 1.002 ± 0.048 RJ and a mass of 82.4 ± 3.6 MJ, too massive to be an exoplanet as previously characterized. This system is part of the **Giant Outer Transiting Exoplanet Mass (GOT 'EM) Survey** to discover and characterize long period giant planets in Kepler, K2, and TESS.

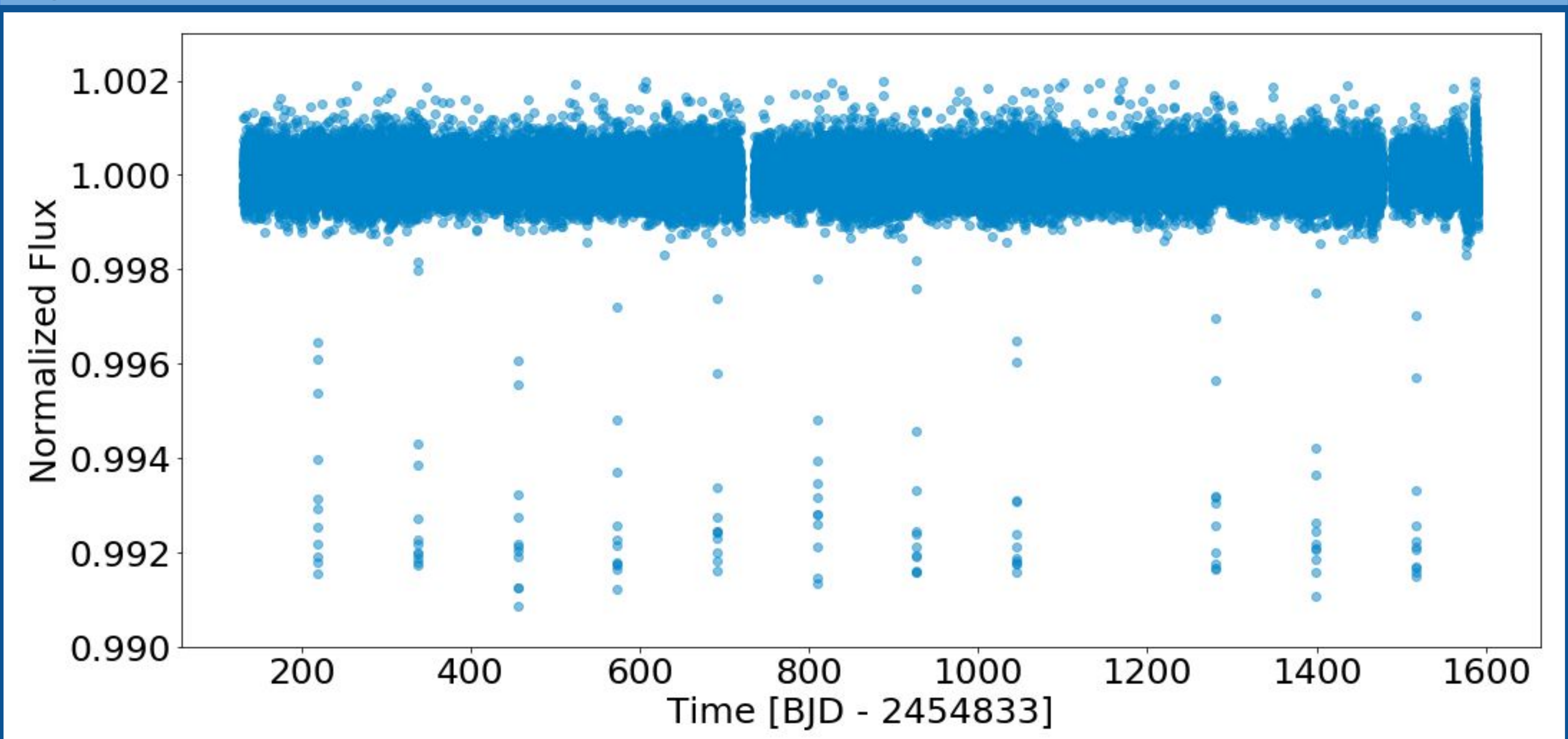

Figure 1: The full, normalized *Kepler* lightcurve.

Analysis

We used EXOFASTv2 (Eastman et al. 2019) to globally fit all photometry and radial velocities. Within our global analysis, we used MESA Isochrones and Stellar Tracks (MIST) stellar evolution models combined with fitting the spectral energy distribution to determine the host star parameters. Kepler-807 is a V = 15.1 F-type star with a mass of 1.098 ± 0.070 $M_\odot$ and a radius of 1.153 ± 0.048 $R_\odot$. We find that Kepler-807 B straddles the canonical ~80 MJ limit for sustainable hydrogen fusion at 82.4 ± 3.6 MJ. It has a radius of 1.002 ± 0.048 RJ and a highly eccentric orbit (e = 0.69).

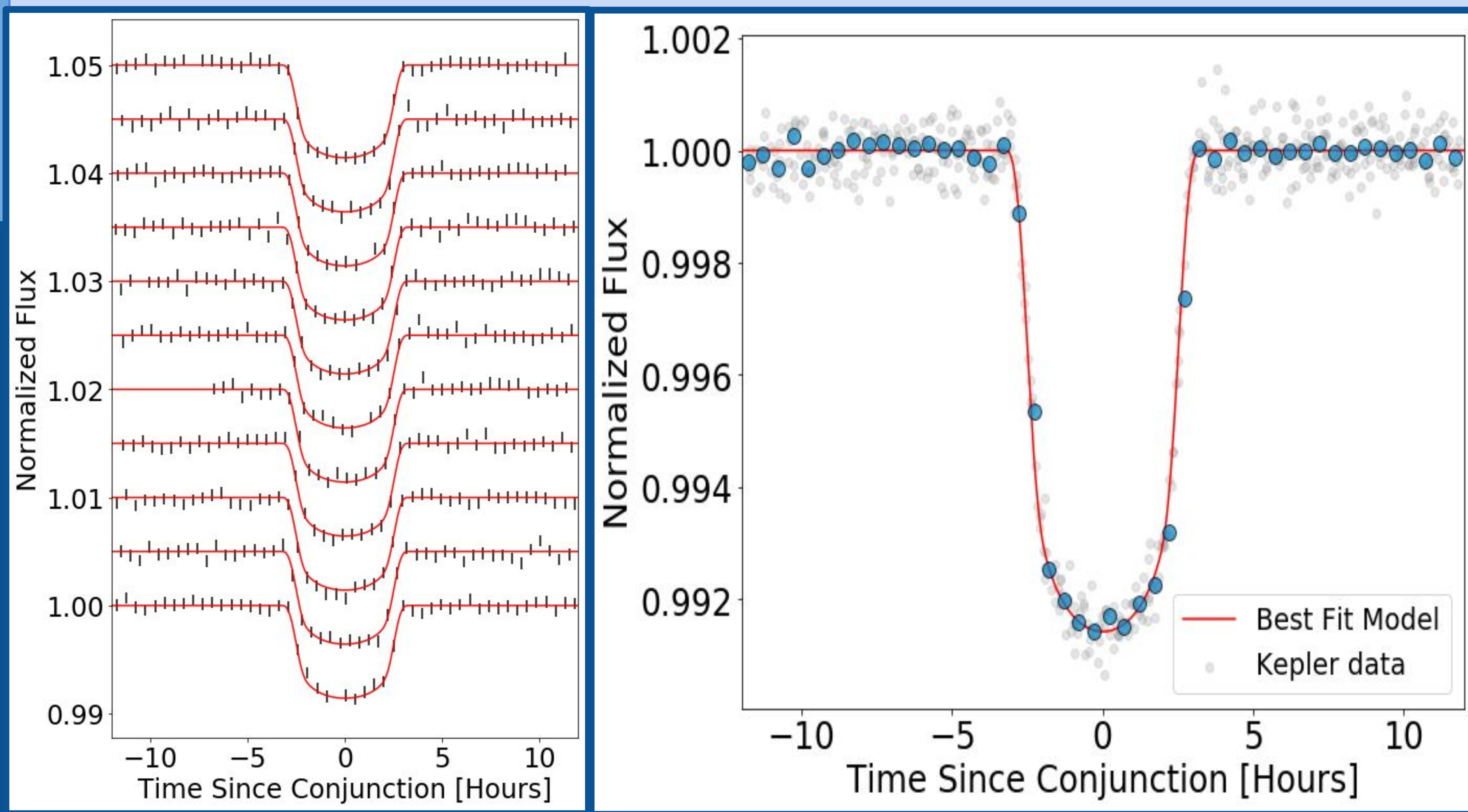

Figure 3: (Right) Our individual *Kepler* transits with a 0.005 offset in the normalized flux. (Left) The *Kepler* lightcurve binned to 30 minutes in blue phased to our best fit ephemeris with our EXOFASTv2 model in red.

Observations

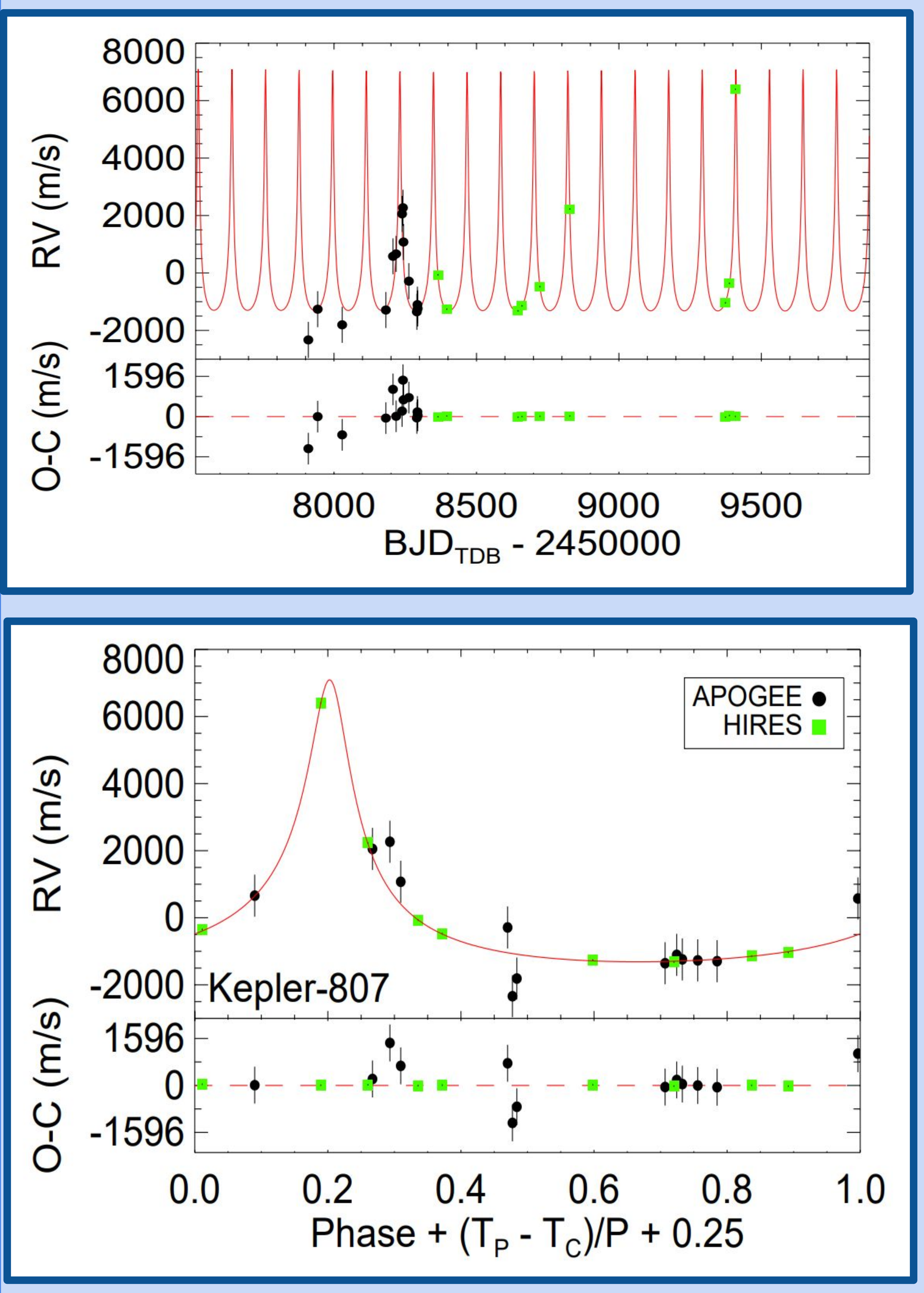

Figure 2: (Top) The radial velocities from HIRES and APOGEE for Kepler-807. (Bottom) The radial velocity measurements are phase-folded to our best fit ephemeris

Kepler-807 was observed during the *Kepler* primary mission from Q1-Q17 in the long cadence mode (30 minutes). Kepler-807 was first identified by NASA's Kepler mission, and validated as an exoplanet with a period of 117 days (Morton et al. 2016). We downloaded and stitched the lightcurve from all 17 quarters of Kepler using the Lightkurve package (Lightkurve Collaboration et al. 2021). To find mass of Kepler-807's companion, we obtained 9 high resolution spectra using the High Resolution Echelle Spectrometer (HIRES) on the 10m Keck telescope. We extract radial velocities from these spectra using a best-match template described in Dalba et al. 2020. We also include archival radial velocities from the Sloan Digital Sky Survey (SDSS) Apache Point Observatory Galactic Evolution Experiment (APOGEE). We also observed Kepler-807 with the PHARO adaptive optics system on Palomar Observatory which showed no sign of any nearby companions that could influence our analysis.

Discussion

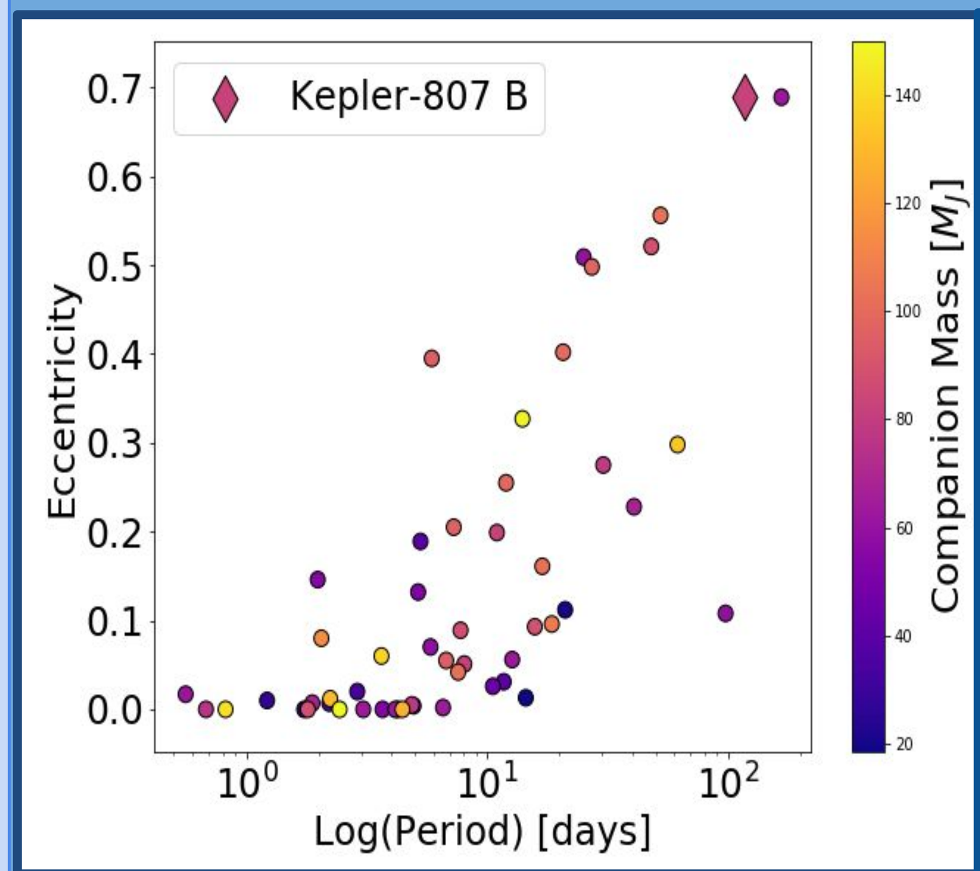

Figure 4: Period-Eccentricity plot of known transiting companions between 13-150 MJ colored by (Grieves et al. 2021).

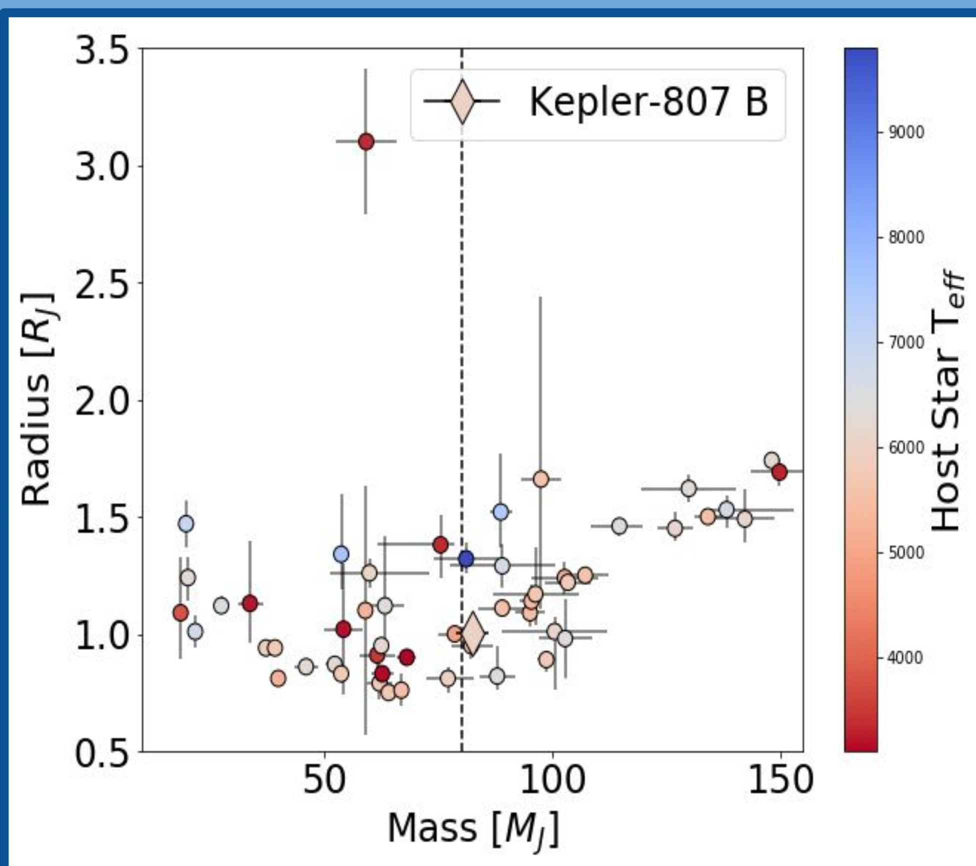

Figure 5: Mass-Radius plot of known transiting companions between 13-150 MJ colored by the host star's temperature (Grieves et al. 2021).

Kepler-807 B straddles the traditional ~80 MJ boundary for sustainable hydrogen fusion, making it an excellent candidate for testing substellar evolution models. Additionally, it resides in one of the most eccentric and longest period orbits known for a companion with a mass between 13-150 MJ.

Recent studies have suggested defining brown dwarfs in context of their formation mechanisms (Carmichael et al. 2021). Interestingly, the high eccentricity of Kepler-807 B's orbit may indicate that it migrated to its current configuration, following a path traditionally associated with planet formation. Fortunately, NASA's TESS mission will continue to find systems similar to Kepler-807 but around brighter host stars that will allow for a more detailed characterization, furthering our understanding of the sub-stellar boundary.

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