LHS 6343: Precise constraints on the mass and radius of a transiting brown dwarf

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Introduction

The formation and evolution of brown dwarfs are not well understood. Brown dwarf companions to stars are rare relative to planetary mass companions. Companions at wide separations have very low transit properties, while those at small separations are often highly irradiated, inflated, and not representative of the population of field brown dwarfs. The effects of irradiation are negligible for LHS 6343C, a brown dwarf orbiting member of an M+M binary. This system thus provides a unique opportunity to study the physical parameters of an effectively isolated brown dwarf.

The Mass

We have obtained 33 Keck/HIRES radial velocity observations of the LHS 6343 system. For each observation, we align the spectrograph slit such that both stars appear in each observation. We then measure the radial velocity of the A component relative to the stationary B component. Thus, the second star in the field provides a natural wavelength calibration in each RV observation.

We find a Doppler semi-amplitude of 10.47 ± 0.14 km/s, corresponding to a mass of 62.0 ± 1.7 M_Jup. We also find a small nonzero eccentricity, with e = 0.034 ± 0.015.

The Radius

We fit 16 quarters of transit photometry to model the transit depth, including two transits observed in the Kepler short cadence mode. The radius ratio is 17550 ± 65 parts per million.

Because LHS 6343 is a binary system with a separation of 0".7, the Kepler data has a non-negligible “third light” component that must be removed. To measure the flux contributions of each component in the Kepler bandpass, we collect griHK-band adaptive optics imaging with Robo-AO and PHARO at Palomar Observatory. By comparing the received flux to stellar irradiation are negligible for LHS 6343C, a brown dwarf at the 2σ level in the Spitzer data; the depth is approximately what would be expected. Upcoming Spitzer observations will robustly detect the secondary eclipse.

Constraining Brown Dwarf Models

The mass and radius of LHS 6343C will provide a valuable data point for brown dwarf evolutionary models, but these parameters alone allow for degeneracies with age, metallicity, and other system parameters. To fully characterize the system, we would want information about the luminosity of the brown dwarf. As sophisticated as theoretical evolutionary models are, they can often not be tested directly as there are no non-highly irradiated brown dwarfs with a precisely measured mass, radius, and luminosity.

Brown dwarf mass-radius relation from Diaz et al. (2013): every brown dwarf here is highly irradiated or has not had its luminosity measured.

We can fix this problem! We have been awarded 22 hours of Spitzer Cycle-10 time to observe four secondary eclipses of LHS 6343C (two in each bandpass). Combining these eclipses with ground-based observations and a potential 2σ detection of the secondary in the Kepler data will allow us to estimate the luminosity. The combination of a measured mass, radius, and luminosity will provide the strongest yet test of brown dwarf models. We will also be able to measure the age of the system, which is not possible from the M dwarfs alone.