Benchmarking Substellar Evolutionary Models Using New Age Estimates for HD 4747 B and HD 19467 B

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Introduction

Recent substellar evolutionary models do a better job at predicting optical color of brown dwarfs and matching observations for older objects than their predecessors \citep{bar15}. However, tests of these models are still fairly limited due to degeneracies between mass, age, and luminosity for brown dwarfs; a young, less massive brown dwarf can appear to have the same luminosity as an old, more massive brown dwarf. These degeneracies are the main source of uncertainty in age estimates for field brown dwarfs, inhibiting the accuracy of model tests. To properly constrain the models, we need benchmark brown dwarfs -- objects whose masses, ages, and luminosities can be determined independently. In this poster, we make new estimates of the age of HD 4747 B and HD 19467 B by studying their host stars and compare our results to various substellar evolutionary models.

Stellar Radii Measurements

Using interferometric observations made with the CHARA Array, we obtain measurements for the disk diameters of HD 19467 A and HD 4747 A. Combined with parallaxes from Gaia DR2, we calculate the stellar radius of each star (shown below).

	HD 19467 A	HD 4747 A
θ_{UD} (mas)	0.355 ± 0.011	0.367 ± 0.006
θ_{LD} (mas)	0.376 ± 0.014	0.390 ± 0.007
R ($R_\odot$)	1.295 ± 0.048	0.789 ± 0.014

Age Estimates

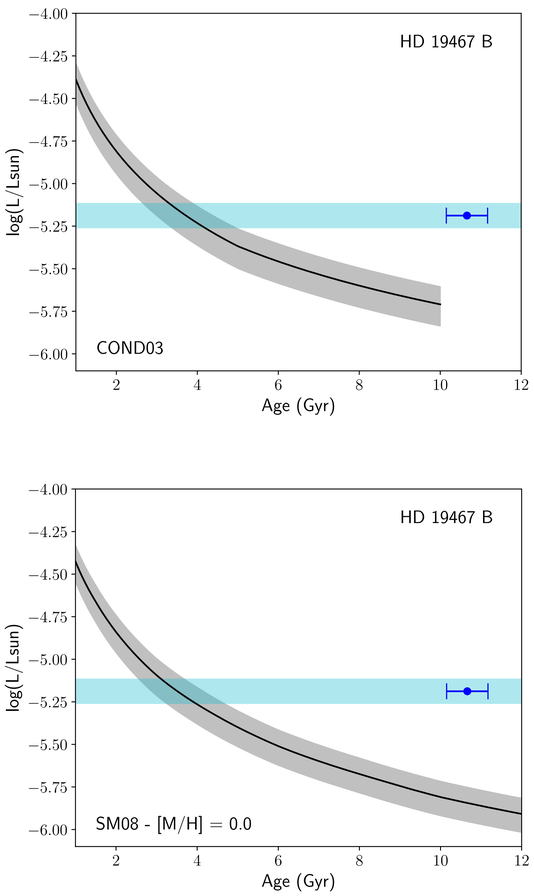
We determine age estimates for HD 4747 A and HD 19467 A using the Dartmouth Stellar Evolution Database, MESA Isochrones and Stellar Tracks (MIST), and Yonsei-Yale (YY) isochronal models. In all three cases, HD 19467 A ends up on the sub-giant branch. The Dartmouth and MIST results are nearly identical, while the YY ages are systematically lower. As a result, we adopt an age that is an average between the Dartmouth and MIST estimates (shown below).

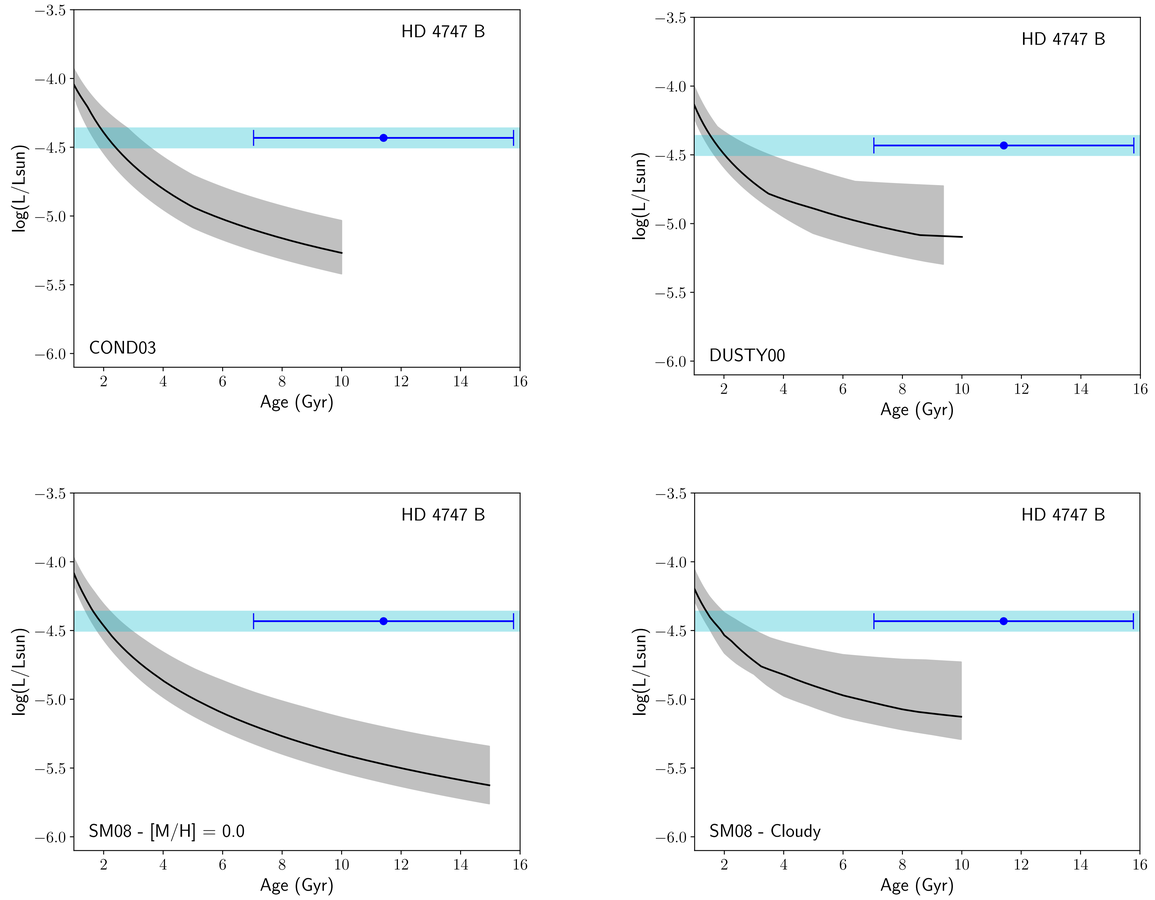
	HD 19467 A	HD 4747 A
Age (Gyr)	10.66 ± 0.51	11.41 ± 4.37

Comparison to Models

Assuming the brown dwarf companions have the same ages as their host stars, we use the refined age estimates to constrain several substellar evolutionary models (Baraffe et al. 2003, 2015; Saumon & Marley 2008). We compare both the luminosity (Figures 1 & 2) and the mass (table below; units of M_{Jup}) of each brown dwarf to those predicted by the models.

	Measured	COND03	SM08	DUSTY00	SM08-C
HD 19467 B	51.9 ± 4.3	68.0 ± 0.6	69.1 ± 1.0	—	—
HD 4747 B	65.3 ± 4.4	75.6 ± 6.9	75.1 ± 1.8	70.9 ± 5.0	72.3 ± 1.4





Figures 1 (left) & 2 (right): Comparisons of the measured bolometric luminosity (light blue strip) for HD 19467 B (left) and HD 4747 B (right) to the predicted value from each model (black line). At the new ages (dark blue point), the luminosity is under-predicted by ~1 dex for HD 4747 B and ~0.5 dex for HD 19467 B. When comparing HD 4747 B to cloudy models (DUSTY00 and SM08 - Cloudy), the discrepancy is reduced to ~0.6 dex.

Conclusions

- Substellar evolutionary models under-predict the luminosities of HD 4747 B and HD 19467 B by about a factor of 10 and a factor of 3 respectively.
- Substellar evolutionary models over-predict the masses of HD 4747 B and HD 19467 B by about 15% and 33% respectively.
- When comparing HD 4747 B to models that include clouds, the discrepancies are reduced to about a factor of 4 for luminosity and about 5% for mass.
- These results are consistent with tests using other “benchmark” brown dwarfs. The population as a whole tends to be over-luminous compared to models.
- A possible explanation for the discrepancies is missing models in the physics. Effects of metallicity on the appearances of brown dwarfs has yet to be fully explored.

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Acknowledgements: The CHARA Array is funded through National Science Foundation grants AST-0606958 and AST-0908253, as well as the College of Arts and Sciences at Georgia State University and the W. M. Keck Foundation. We also acknowledge support from NASA grants ADAP12-0172, 14-XRP14_2-0147, and 15-K2GO3_2-0063, NASA/JPL grant RSA 1523106, and the NASA Early Career program. This research makes use of the SIMBAD and VIZIER Astronomical Databases, the NASA Astrophysics Data System, and the Jean-Marie Mariotti Center SearchCal service.