Precision Abundances of Ultracool T-T Pairs: A Critical Comparison to Directly Imaged and Transiting Planets

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Project Background

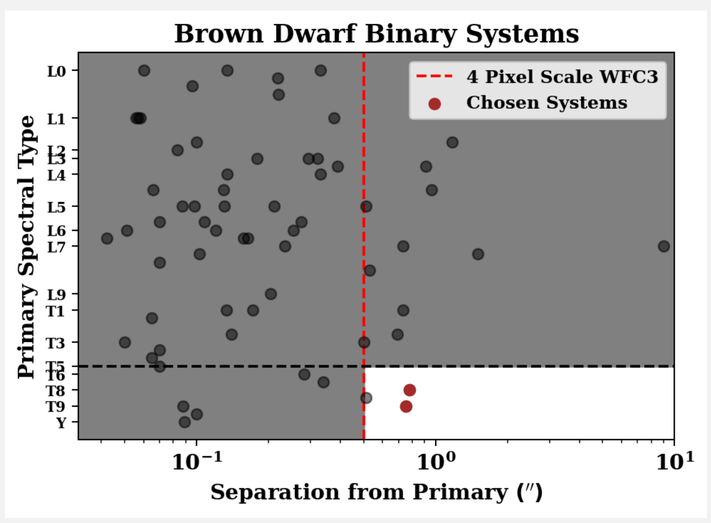
- The mechanism of formation for stellar/substellar objects in pairs can affect the resulting atmospheric abundances between primary and companion
- Under core accretion, planets forming within the outer disk are predicted to have super-stellar atmospheric C/O ratios as compared to their host star (Oberg+ 2011)
- Pairs forming from cloud collapse, such as binary stars, have been observed to exhibit similar abundance ratios (Desiera+2004), attributed to their shared formation environment
- Brown dwarfs, intermediate in mass between stars and planets, play a critical role in understanding formation as a function of mass
- By studying the atmospheres of ultra-cool brown dwarfs in binary pairs, one can investigate the formation history of these substellar objects

Key Project Goals:

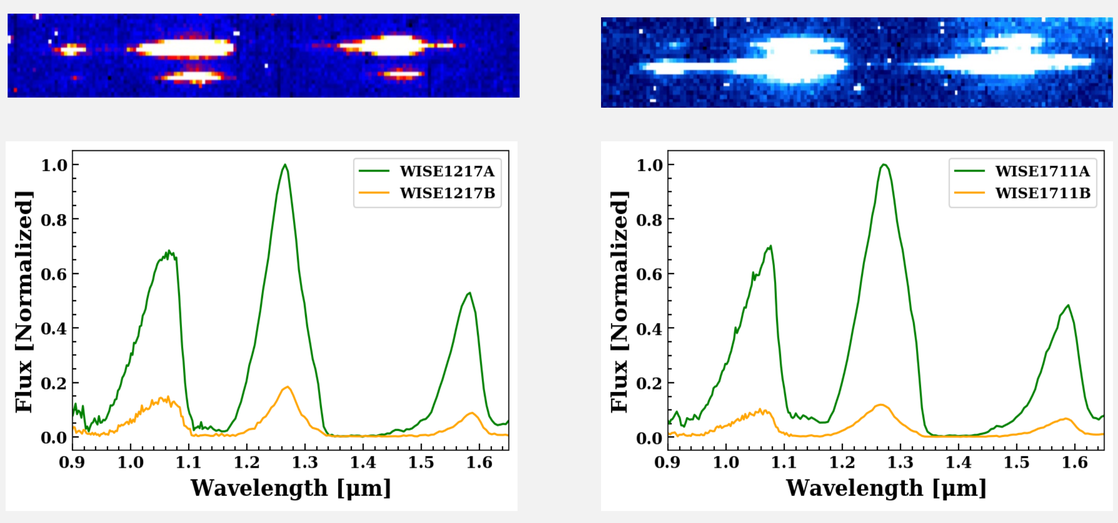
- Explore the atmospheric abundance ratios of brown dwarf binary pairs to evaluate if ultra-cool companions form more akin to planets in a disk or binary stars from cloud collapse
- Build a library of high-fidelity brown dwarf companion spectra to serve as comparison for directly imaged and transiting exoplanet data

Target Sample and Spectral Extraction

Our sample to study the abundance ratios of brown dwarf binary pairs consist of two systems, WISE 1217+1626 and WISE 1711+3500. These systems meet our criteria of having each component have a late T spectral type, such that their NIR spectra is sculpted by the absorption of H_2O and CH_4, crucial in calculating the C/O ratio. Both systems also have separations such that their spectra can be resolved as separate objects with *HST* . We obtained *WFC3* G102 and G141 (0.8 – 1.7 μm) data for each system, 2D G141 spectra is shown below. Spectral extraction of both the primary and secondary required customization of the spectroscopy extraction tool *PyLinear (*Ryan+2018) allowing for extraction on both objects separately.

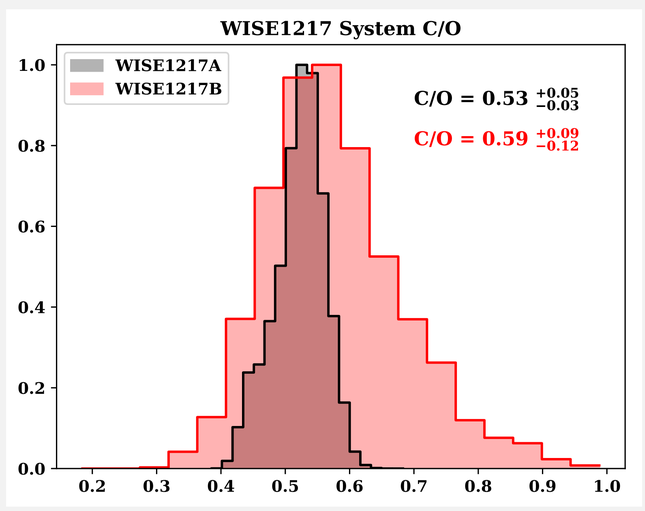


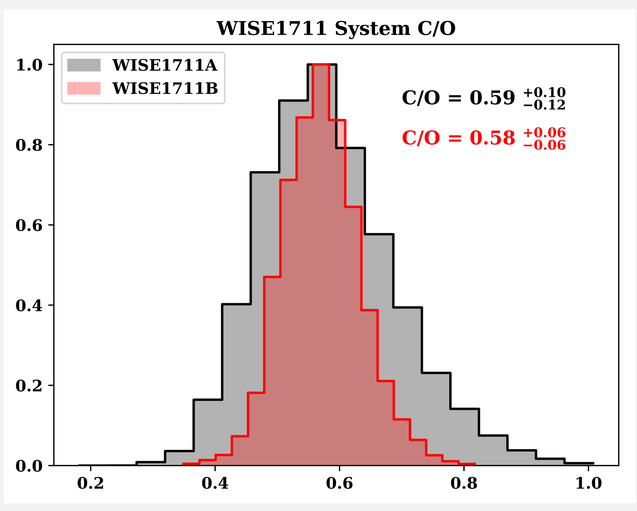
Left: Known brown dwarf-brown dwarf binary systems. WISE 1217 and WISE 1711 are the only systems that meet our criterion of angular separation as well as having both objects be late T type brown dwarfs.
Right: HST G141 2D spectra of both primary and companion for each system shown at the top. Below each are the 1D extracted spectra including the G102 portion for each system, measured using the *PyLinear* extraction tool on each component of each pair. Flux is normalized to the J band peak of the primary.



Atmospheric Retrieval Results

To determine the atmospheric C/O for each object in each system, we utilize the retrieval framework found in Line+15,17 & Zalesky+22. This framework allows us to directly retrieve for the abundances of dominant absorbers in the atmospheres of these cool brown dwarfs. We perform 4 separate retrievals to measure the C/O for each brown dwarf in the two systems.





Left: Measured C/O histograms from the retrieval of each component in the WISE1217 system (far side) and the WISE1711 system (near side). The values for each component in each system show good agreement with one another.

Discussion

- Our preliminary retrieval results for each system show agreement between the C/Os of each component
- The C/Os measured are also consistent with previous T dwarf population studies (Zalesky+2019,22)
- The similarity in abundance ratios in each system may indicate that even at the ultra-cool temperatures and low masses of late T dwarfs companions, their formation is more akin to binary stars than giant planets
- Our next goal is to compare these retrieval results to self consistent grid model fits, as these can take into account missing chemistry from vertical mixing that could be prominent in these cool atmospheres

Acknowledgements

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References: Desidera+2004, Line+15,17 Oberg+2011, Ryan+18, Zalesky+19,22