Student questions: SESE Students colloquium

Joe Zalesky: Constraining the Diversity of Brown Dwarfs with Atmospheric Retrieval

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You briefly mention towards the end "we have a handle on the cooler dwarves but not the much hotter L-Dwarves." What are the complications that make data collection on L-Dwarves much more difficult than the other dwarf stars?

> **The data collection for L-Dwarfs is not what is difficult. L-Dwarfs are actually hotter and thus much brighter than T or Y-Dwarfs so they're easier to find. The difficulty is the fact that L's have the presence of iron-silicate clouds in their atmosphere which are difficult to model, and thus more difficult to extract reliable atmospheric properties from.**

On your conclusions slide, the last piece says "Many opportunities to explore in the future" can you elaborate on that?

> **Yes, one of my main areas of current interest is in characterizing "benchmark" targets where we have some type of knowledge on the mass, age, radius, metallicity, etc. from some other observational constraint. This provides a good 'reference point' to be able to reproduce with our retrieval model.**

That was an impressive speed up you showed in your CPU vs GPU runtime comparison. What programming tools are available for utilizing the GPU as opposed to the CPU?

> **The main advantage isn't software, its hardware. I didn't elaborate in the talk but GPUs possess ~10^2 more processing cores than a CPU does. Since our radiative transfer code can be easily parallelized (because each wavelength can be treated as an independent calculation) we can take advantage of this speed-up due to efficiency in the hardware. It requires slightly re-writing our RT code but is well worth the extra effort.**

If these brown dwarfs are significantly larger than exoplanets, how confident are we that their atmospheres can help us learn about exoplanets?

> **Brown dwarfs are actually roughly the same size as jupiter though just much more massive. The atmospheres of BDs and jupiter-mass exoplanets are highly similar in terms of composition, temperature, and pressure meaning they have very similar conditions. BD atmospheric models have been used as starting points for exoplanet models since the beginning of atmospheric characterization of exoplanets several decades ago and have seemed to work very well.**

What do you mean by Chemical rainout?

Rainout is simply a shorthand for condensation of molecules into physically larger aggregates that are then pulled down deeper into the atmosphere, often so deep that we are no longer able to detect them. This process effectively "removes" certain species from the part of the atmosphere we can see and are thus said to have 'rained out'. This removal of certain species can strongly impact the overall chemistry that occurs and what types of molecules can/cannot form in the visible atmosphere. 'Chemical rainout' is simply a shorthand for this entire process.

Is work being done to improve the instruments used in this research?

Yes there are a number of instruments being designed that have the ability to take better spectroscopic measurements of brown dwarfs. JWST is the poster-child but other ground-based instruments like KPIC on the Keck telescope in Hawaii and the GRAVITY instrument on the VLTI in Chile are both instruments with potential to better constrain atmospheric processes.

Besides the clouds, what other constraints do you have to taken into account when creating atmosphere models for L dwarfs versus the cooler spectral types?

The clouds are the most important factor but other things include a simplification of our thermal profile parameterization, addition of metallic species like FeH, TiO, and VO as important species

Do planets orbit brown dwarves and/or do brown dwarves orbit stars?

Yes there are brown dwarf-planet pairs discovered in recent years and many stellar-brown dwarf binary systems as well.

Is there a significant difference between data from ground and space-base telescopes?

The main gap is if you want to see the faintest, coldest Y-Dwarfs then you need to observe from space but slightly brighter, hotter objects like T and L-Dwarfs can be viewed from the ground.

Could the atmosphere retrieval technique be applied for small exoplanets?

Yes and many groups have a strong interest in doing this. The main limitation is that the quality of atmospheric observations for smaller exoplanets similar to neptune, venus, earth, etc. is much lower (SNR ~10x lower). Since atmospheric retrieval heavily relies upon the quality of the data to converge to a solution there are currently only a limited number of such targets where this can be applied.

What got you into this kind of work?

I've had a strong interest in exoplanets since I was in high school and during my undergrad/ grad school I realized that brown dwarfs offered the chance to answer similar questions but with higher quality data.

What's the difference between Brown Dwarfs and Red Dwarfs?

The main difference is that brown dwarfs are not massive enough and thus their core temperatures and pressures are insufficient to overcome nuclear energetic barriers to allow hydrogen into helium; I.E. they are not stars. Red Dwarfs (also called M-Dwarfs) are just sufficiently massive enough for this process to occur and are by definition stars.

You mentioned in your talk that the JWST will allow further work on brown dwarves. What are some examples of other questions you can try to answer with the increase in precision using the new JWST?

With JWSTs enhanced precision abundance measurements it should be possible to observe vertical variations in abundance of things like ammonia. You can imagine that the amount of ammonia is not perfectly constant with altitude and having a constraint on how the abundance varies with height in the atmosphere would lead to a constraint on how well-mixed an atmosphere is. Measuring this mixing strength is important to compare with objects in our own solar system and stars as well.