Mapping the atmospheric structure of the nearest brown dwarf

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The L/T transition

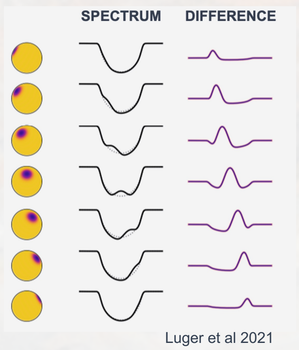
- Brown dwarfs cool along the spectral types M, L, T, and Y as they age, forming condensate **clouds** in their atmospheres
- At the L/T transition, clouds break up into patches and sink below the photosphere, causing **variability** in their photometric light curves as they rotate [1]
- Weather conditions on BD are similar to that on giant exoplanets, making them ideal analogs for studying exoplanet atmospheres

WISE 1049−5319AB

- Also called **Luhman 16AB**, the closest brown dwarfs to Earth at distance **1.99 pc**
- The binary A and B span the L/T transition with spectral types **L7.5**±1 and **T0.5**±1
- WISE 1049B is found to be the main source of variability in the system with amplitudes of **5-15%** in optical to near-IR with a period of **~5 hours** [2]
- In 2014, Crossfield et. al. produced the first global **top-of-atmosphere (TOA) map** of WISE 1049B using VLT-CRIRES spectroscopic monitoring [3]

Doppler imaging

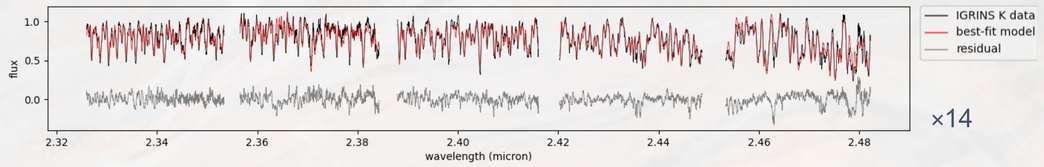
- Absorption **line profiles (LPs)** change shapes as dark patch rotates across the visible face
- This info can be used to infer a brightness map of the object



Luger et al 2021

IGRINS Doppler imaging of WISE 1049AB

high-res spectra (covering one rotation)



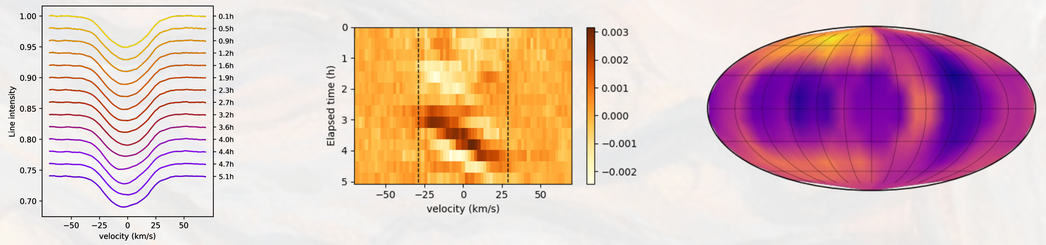
×14

least-square decomposition → **time series of mean LPs**

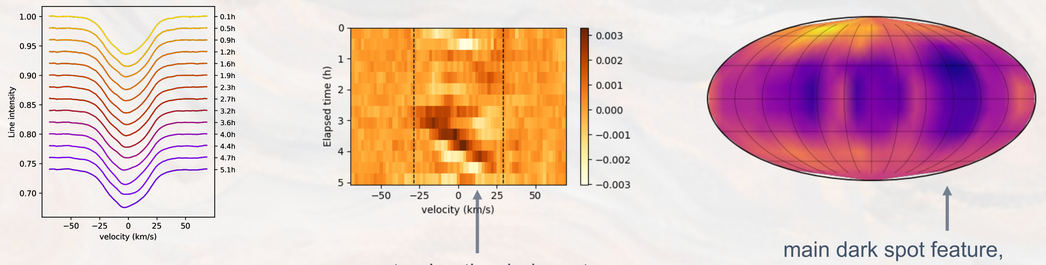
difference from unperturbed LPs → **line profile (LP) deviation**

maximum entropy image reconstruction → **TOA map WISE1049B**

H band



K band



tracing the dark spot

main dark spot feature, similar to Crossfield14!

Doppler map feature

- Main feature on the maps is a **dark spot** extending between the mid-latitudes in both H and K, which is similar in size to that found in Crossfield14
- Such structures might be common and long-lasting in brown dwarf atmospheres

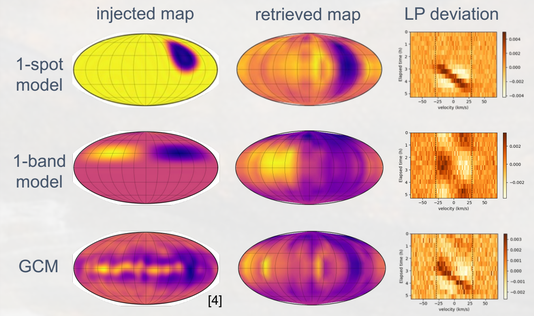
Physical interpretation

- Features on WISE 1049B can be explained by **large patchy clouds**
- The dark regions represent thicker, high-altitude, cold clouds, whereas the bright regions correspond to the hotter, deeper, and thin clouds

Vertical structure

- Different wavelength bands probe different pressures and thus vertical depths in the atmosphere
- **No significant phase shift** is found between K and H band. This supports the scenario of a thick vertically extended cloud

Simulations



- Doppler imaging routine is capable of distinguishing several cloud scenarios
- Simulated Doppler maps suggests that data favors model that include **spot** instead of planetary wave bands
- Observed map is also consistent with **general circulation model**

Conclusion

- A **prominent dark feature** similar to previous mapping is discovered on WISE 1049B using IGRINS
- **No apparent phase shift** found between H and K band, suggesting vertically extended clouds
- Simulation founds that observed maps favors **spot-like** models over bands, but bands under certain sensitivity limit cannot be ruled out. The observed map is also **consistent with GCM**
- Many effects are degenerate in the Doppler map and noise is significant. **Only the dominant feature should be trusted!**

References

[1] Marley et al. 2010
[2] Biller et al. 2013
[3] Crossfield et al. 2014
[4] Tan & Showman 2021