Clouds or Chemistry?

Weather report from the nearest extrasolar worlds

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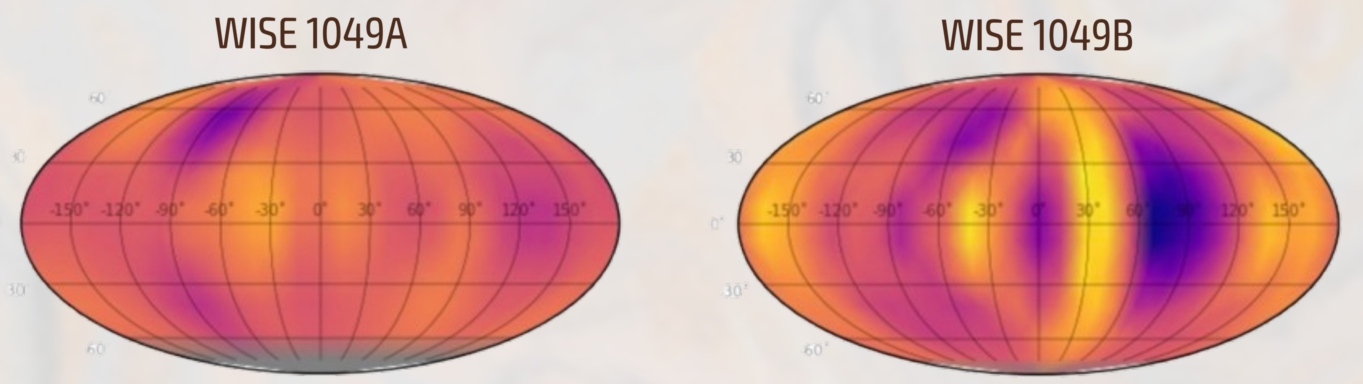
Global weather maps from IGRINS

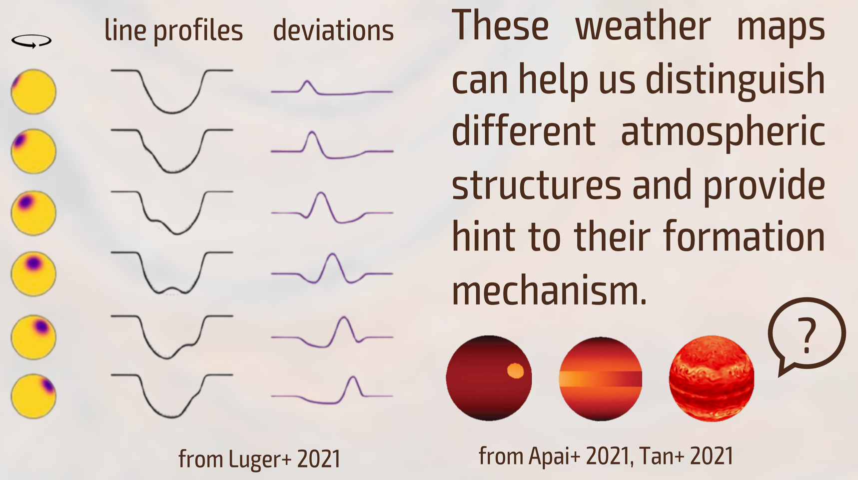


- New **polar spots** discovered on WISE 1049A in the 2020 IGRINS observation, as compared to no features found in 2014[8]
- In these maps, darker areas represent cooler regions and brighter areas represent deeper, hotter regions in the atmosphere

- **Dark patchy structures** seen on WISE 1049B in 2 nights, Feb 9 and 11
- Suggests stability of atmospheric features over time scale of days
- Size and shape of dark features are similar to those discovered in 2014, indicating such structures may be stable or recurring

Doppler imaging: Distinguishing atmospheric structures

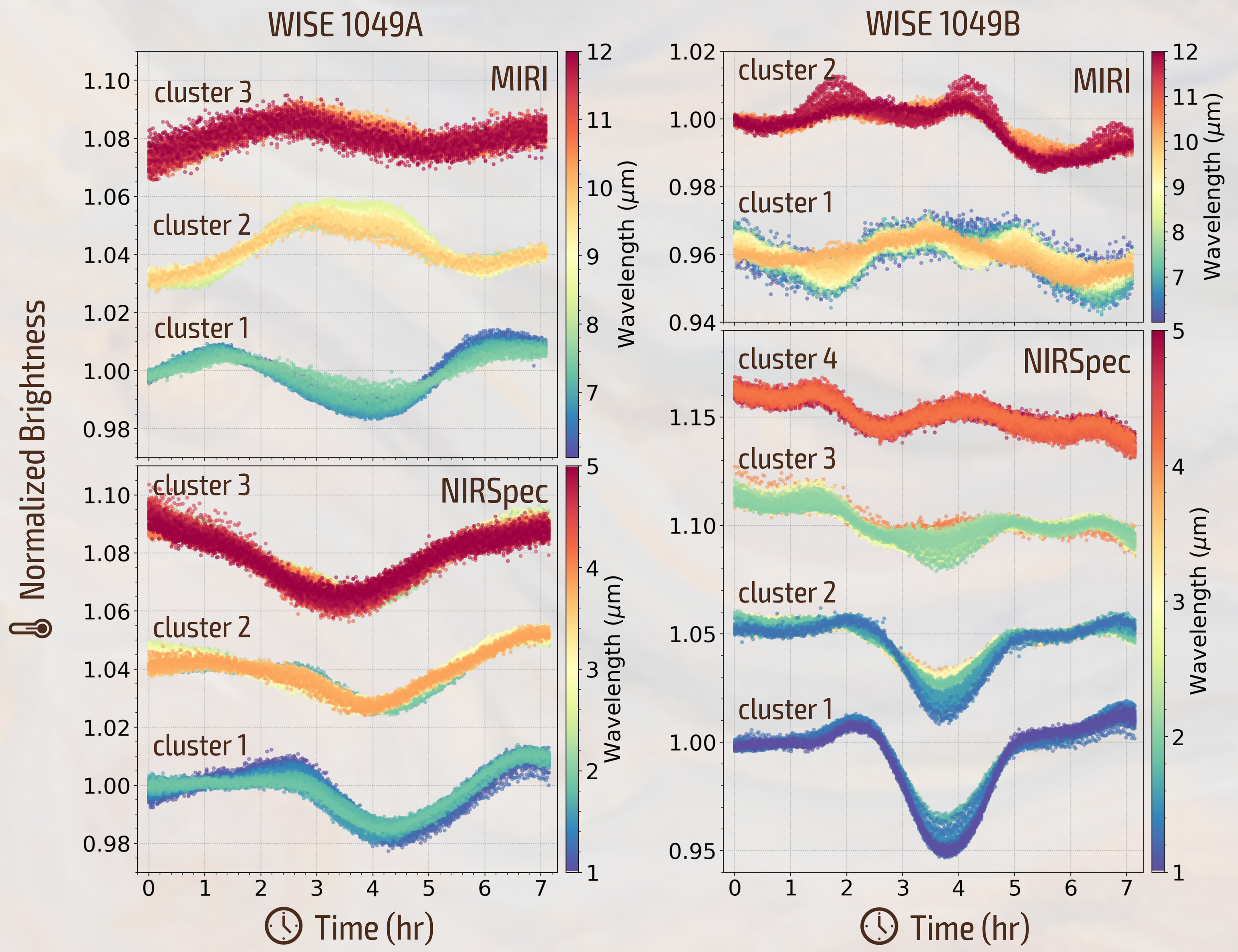
When a dark patch rotates across the visible disk, the spectral lines change shapes due to varied Doppler shifts at different projected velocities, from which we can infer the brightness map of the object[9].



These weather maps can help us distinguish different atmospheric structures and provide hint to their formation mechanism.

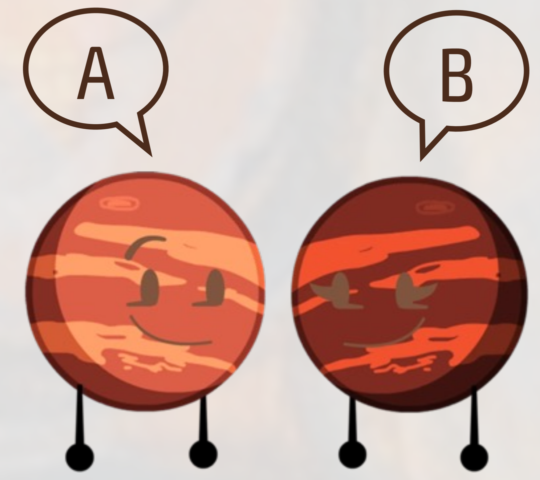
Find out more in my recent paper!

Thermal flux monitoring from JWST



- This plot shows **spectroscopic monitoring** of WISE 1049AB over 7hr each with JWST MIRI and NIRSpec, covering two full rotations of both brown dwarfs
- Their brightness varies dramatically as they rotate, due to their inhomogeneous atmospheres
- The light curve shapes vary by wavelength, which can be grouped into different clusters using the k-means algorithm

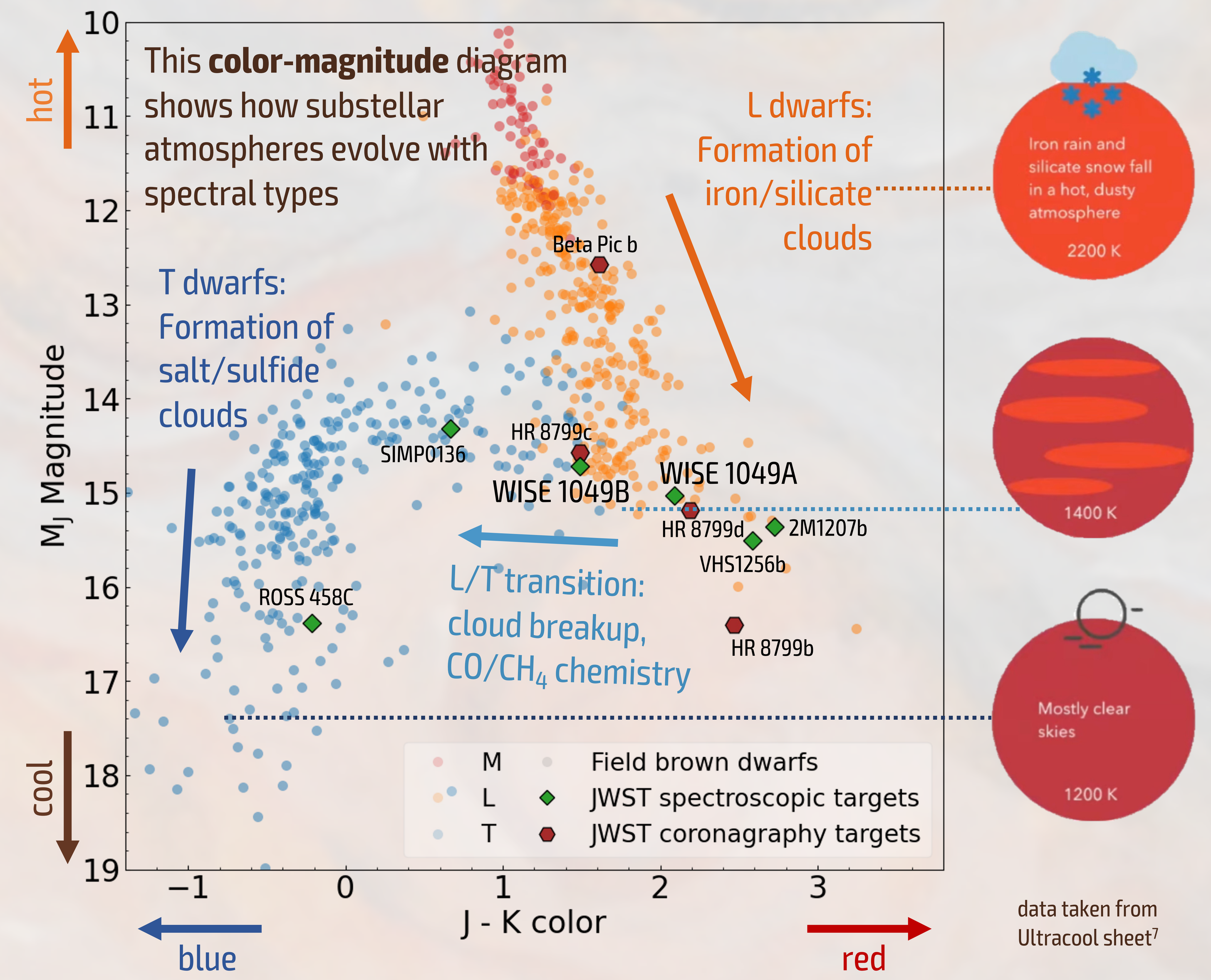
The brown dwarf binary: WISE 1049AB



A	B
L7.5 spectral type	T0.5 spectral type[1]
1280K temperature	1220K temperature[2]
34 x Jupiter mass	28 x Jupiter mass[3]
7 hr rotation period	5 hr rotation period[4]
4% variable in near-IR	10% variable in near-IR[5]

The binary was discovered in 2013[6]. Being the closest brown dwarfs to Earth at 2pc away and spanning the L/T spectral type transition, they have been an exemplary system for variability studies for understanding extrasolar weathers.

Weather processes at L/T transition

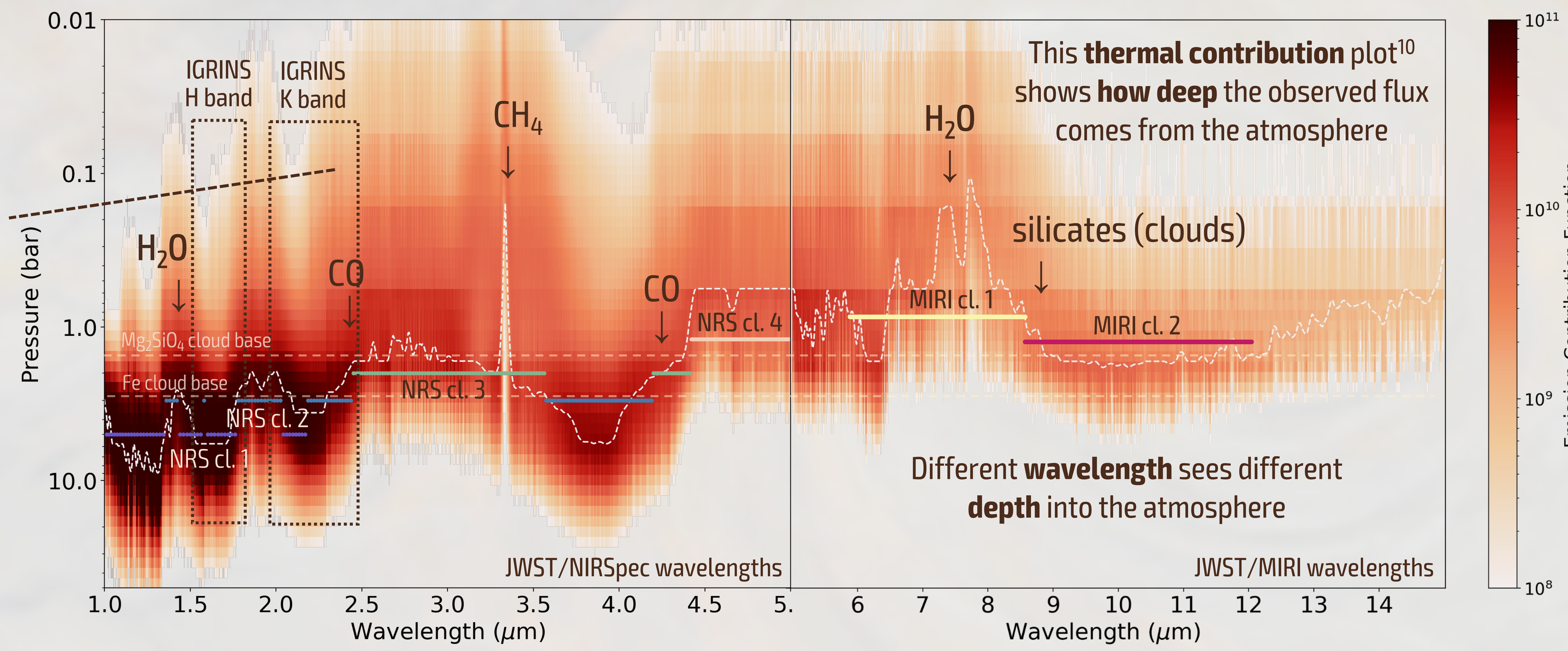


data taken from Ultracool sheet[7]

Where weather processes occur in the atmosphere informs us how they are caused

Doppler maps

- Inside the molecular absorption bands, e.g. the CO band inside the IGRINS K band, the pressure layer probed is shifted to higher level in the atmosphere due to molecular opacity
- Similar spots were found in and out of CO band from the maps → these dark spots are not only caused by CO-dense regions and must involve cloud patches in the higher, cooler atmosphere



Light curve clusters

- We found 4 distinctive light curve clusters for NIRSpec and 2 for MIRI
- Different light curve behaviours originate from different vertical layers in the atmosphere, with breaks happening at CO bands around 2.5 and 4.4 μm and silicate cloud features around 8.5 μm
- This means that both clouds and carbon chemistry play a role in shaping the changing light curves of these extrasolar worlds!

References

[1] Burgasser et al., 2013, ApJ, 772, 129
[2] Biller et al., 2024, MNRAS, 532, 2207
[3] Garcia et al. 2017, ApJ, 846, 97
[4] Apai et al, 2021, ApJ, 768, 121
[5] Buenzli et al., 2015, ApJ, 812, 163
[6] Luhman K. L., 2013, ApJ, 767, L1
[7] Best et al. 2020, doi:10.5281/zenodo.4169085
[8] Crossfield et al., 2014, Nature, 505, 654
[9] Vogt et al, 1987, ApJ, 321, 496
[10] Morley et al, 2024, ApJ, 975, 59