Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.31480

The emerging observational picture of dust clouds in brown dwarf and exoplanet atmospheres

STANIMIR METCHEV[1], GENARO SUÁREZ[2], JOHANNA VOS[3], JACQUELINE FAHERTY[2] AND KELLE CRUZ[4]

[1]The University of Western Ontario
[2]American Museum of Natural History
[3]Trinity College
[4]Hunter College, City University of New York

Dust clouds have been theorized in cool extrasolar atmospheres since the 1990's. They are the favoured mechanism to account for the increasingly red spectra of brown dwarfs at decreasing temperatures, while patchiness in the cloud cover can explain the ubiquitous brightness variability of brown dwarfs. However, dust clouds have also posed a conundrum, where their presumed sedimentation from the atmosphere occurs too rapidly. The observed manifestation is a wide variety in spectral morphology contained within only a 50-100 K temperature range.

The conundrum is now being resolved through direct spectroscopy with the James Webb Space Telescope, which is sensitive to the 8-11 micron absorption signature of dust (silicate) clouds. Dust absorption is seen to correlate with the spin axis inclination of brown dwarfs: equatorial latitudes appear cloudier and redder than the poles (Figure 1; [1]). This is a significant development in the study of brown dwarfs and exoplanets alike. It may explain the wide scatter in their observational properties as a viewing geometry effect. On-going spectroscopy with JWST is further probing the effects of substellar age and metallicity in this picture, as archival Spitzer spectra already point to a range of silicate dust mineralogies [2].

The dependence of the mineralogy of brown dwarf clouds on atmospheric properties and latitude is consistent with what is observed in the atmospheres of solar system giant planets. It marks an important step toward mapping the atmospheric conditions and weather patterns on extrasolar planets.

[1] Suárez, G., Vos, J., Metchev, S., Faherty, J., & Cruz, K. (2023), The Astrophysical Journal Letters, 954, 6-11
[2] Suárez, G. & Metchev, S. (2023), Monthly Notices of the Royal Astronomical Society, 523, 4739-4747

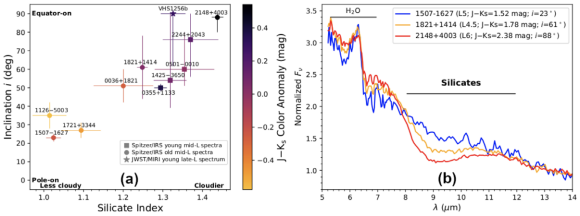

Figure 1. **(a)** Correlation between viewing inclination angles *i* of brown dwarf spin axes and the strength of the observed silicate absorption (silicate index) in the brown dwarf spectra from observations with the Spitzer or James Webb Space Telescopes. As the surface of a brown dwarf is not spatially resolved, the viewing inclination *i* maps the dominant latitudes (90° – *i*) represented in the observed spectrum. *Brown dwarfs seen closer to equator-on (i = 90°) appear cloudier.* The thicker dust cloud cover also makes their appearance redder (greater J–Ks colour anomaly). **(b)** Examples of the range of silicate absorption strengths in the mid-infrared spectra of select brown dwarfs. The silicate index plotted in panel (a) measures the absorption depth at 9 microns.