Binaries or Variables?

Disentangling the signatures of blended-light spectra

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In collaboration with:
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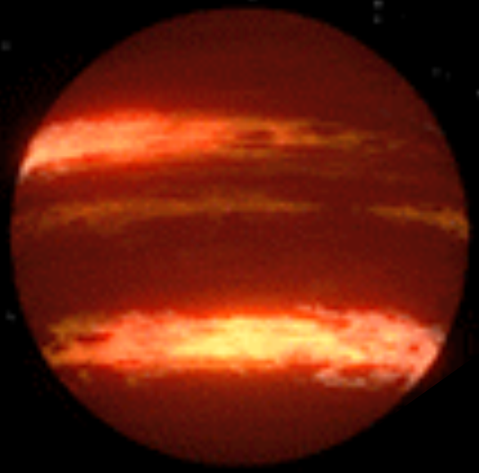
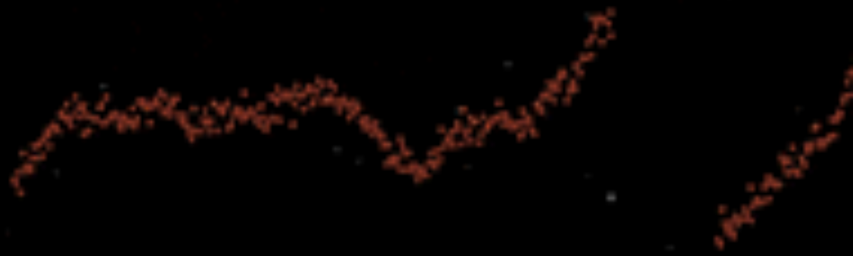
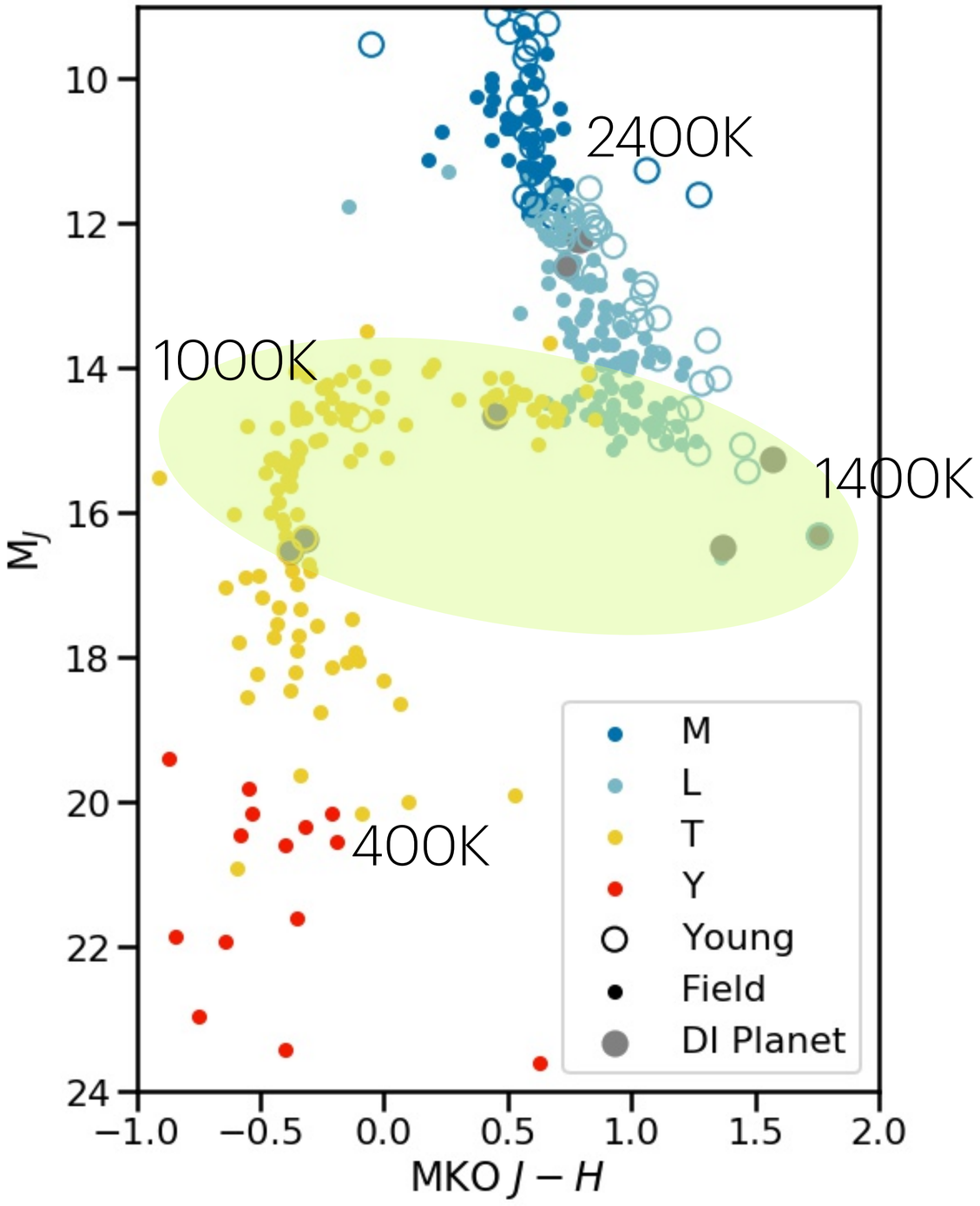
Brown dwarfs experience weather patterns





patchy clouds + rotation = variability!

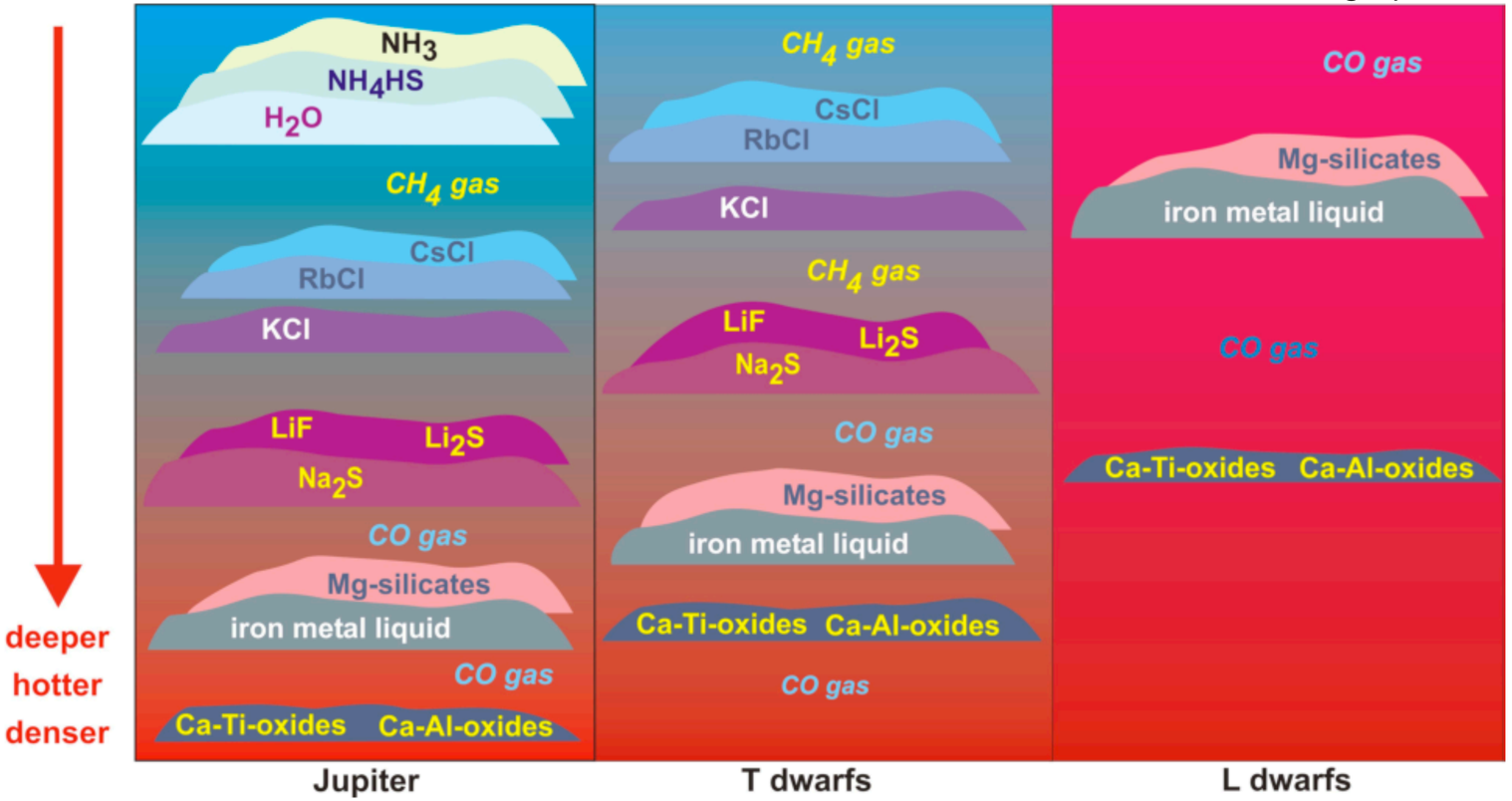


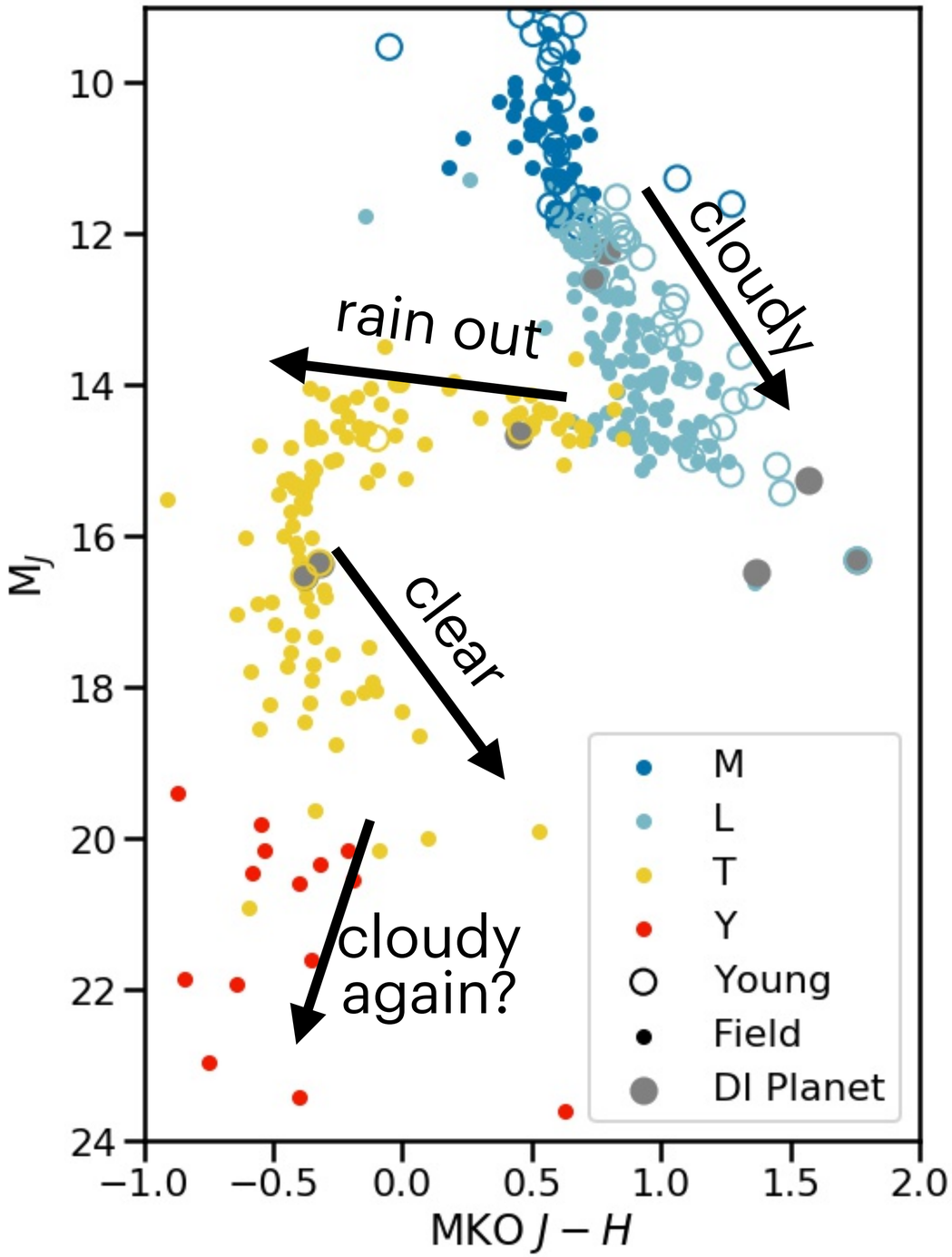
The most inclement weather happens at the L/T transition

Hot Jupiters and directly-imaged planets share parameter space with L/T transition brown dwarfs

Atmospheric dynamics at the L/T transition

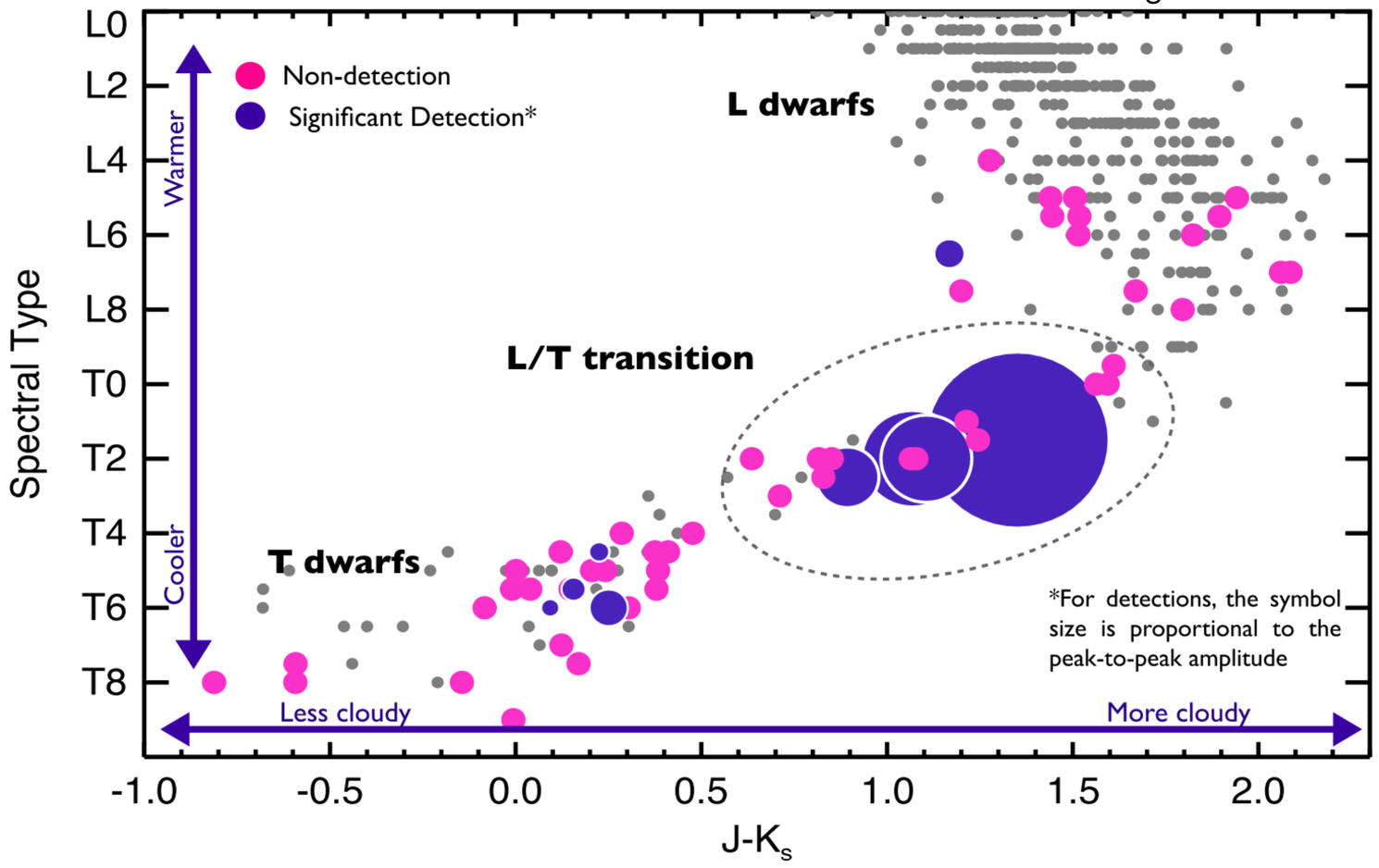
Lodders & Fegley 2006



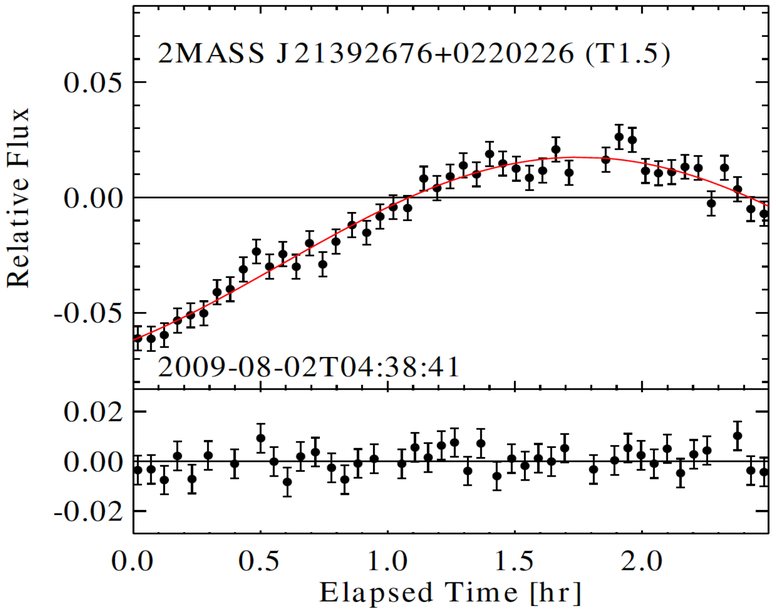


Largest variability amplitude occurs at the L/T transition

Radigan et al. 2014a



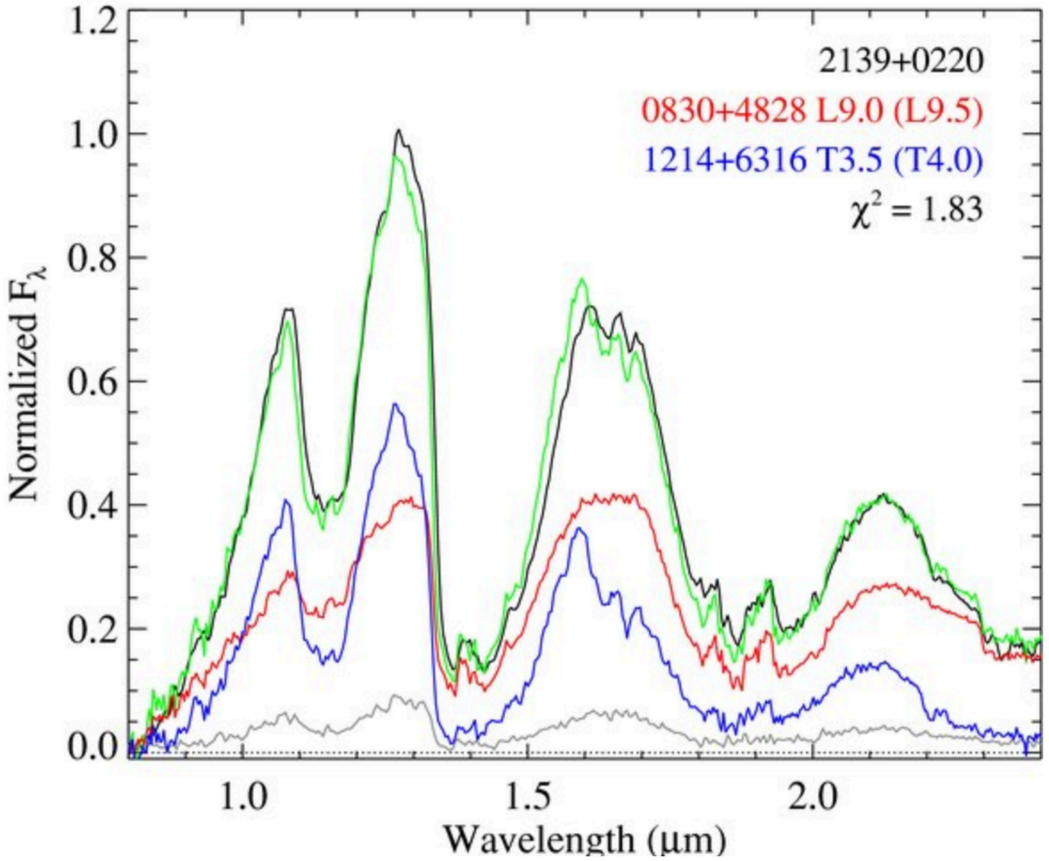
Radigan et al. 2014a



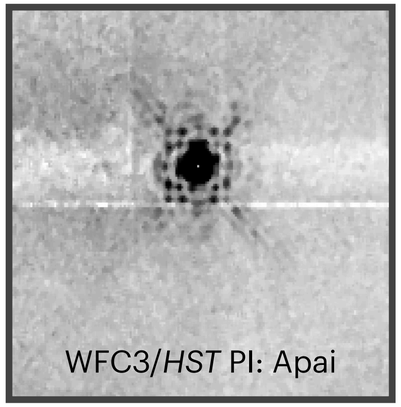
2MASS J2139+0220: field-age T2.5 variable

In a past life, 2M2139 was a spectral binary candidate

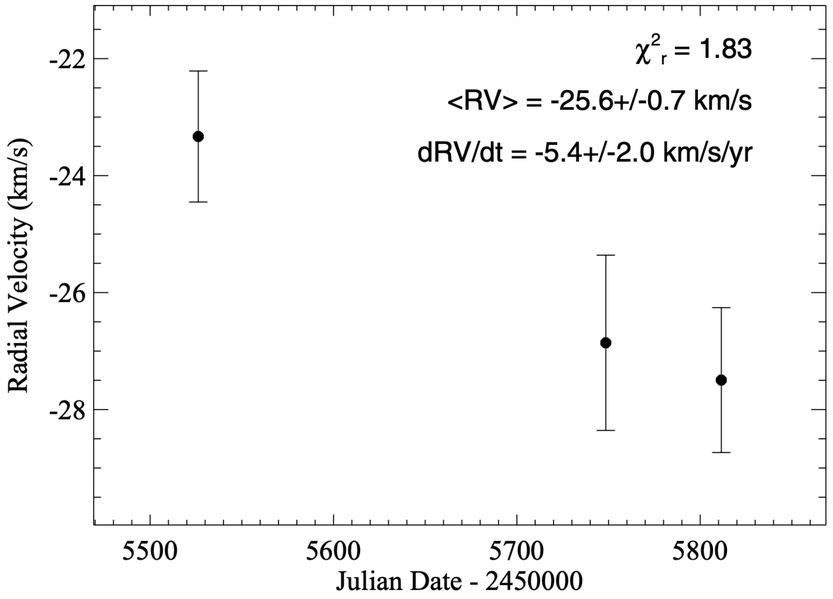
Burgasser et al. 2010



But neither high resolution imaging nor RV could resolve this source

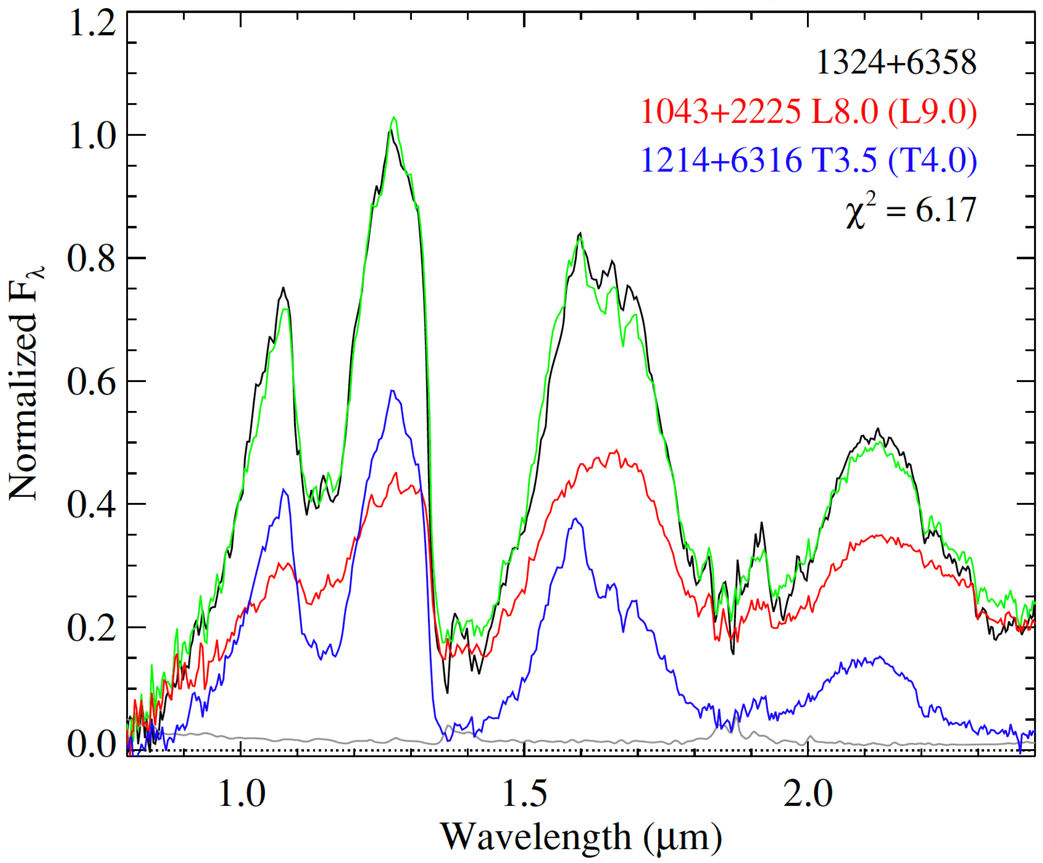


Khandrika et al. 2013

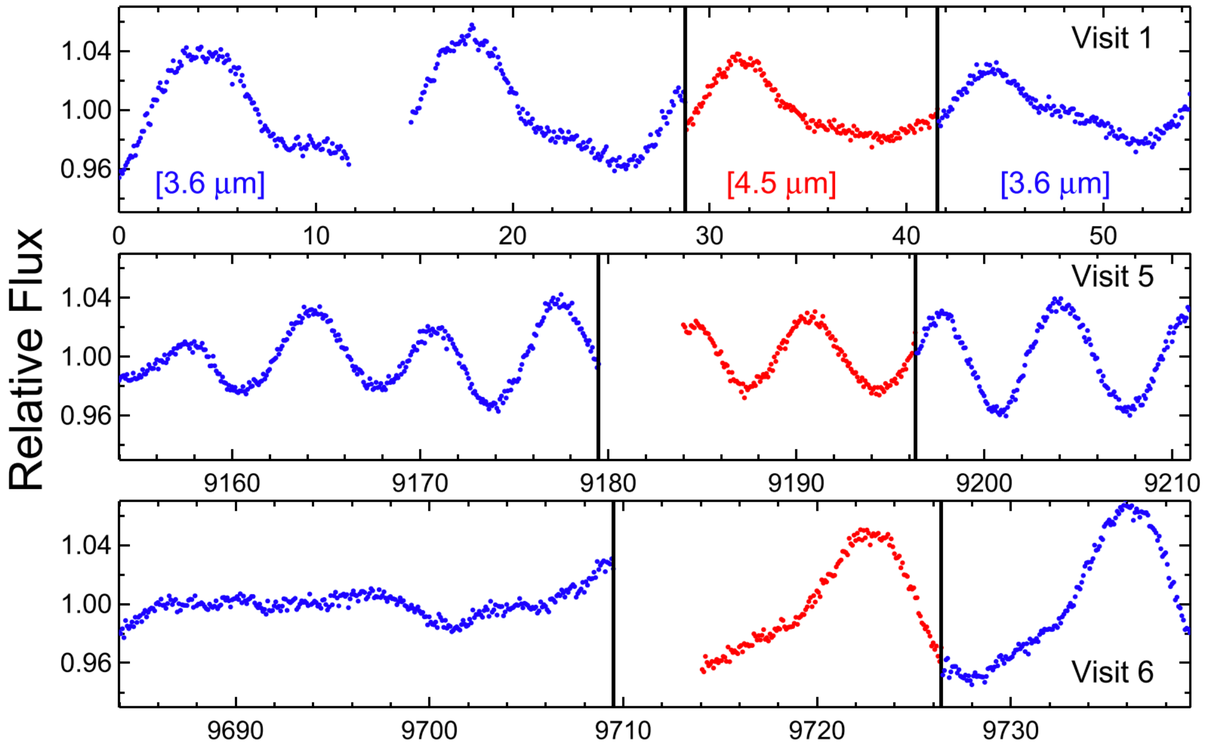


Also the case of 2MASS J1324+6358: young T2 variable

Burgasser et al. 2010



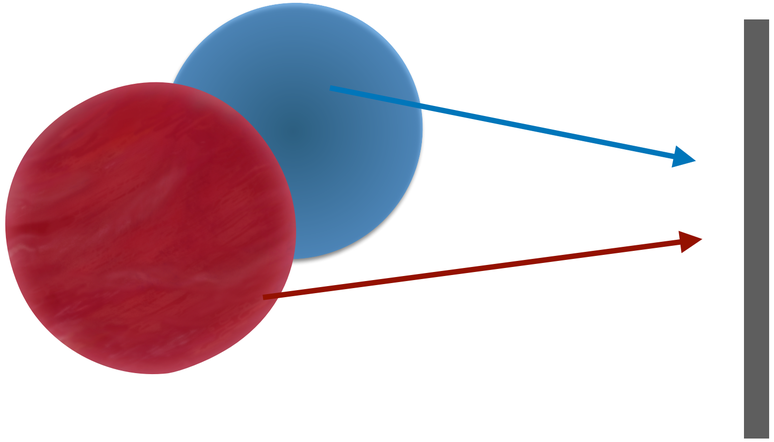
Yang et al. 2016 (Also Heinze et al. 2015)



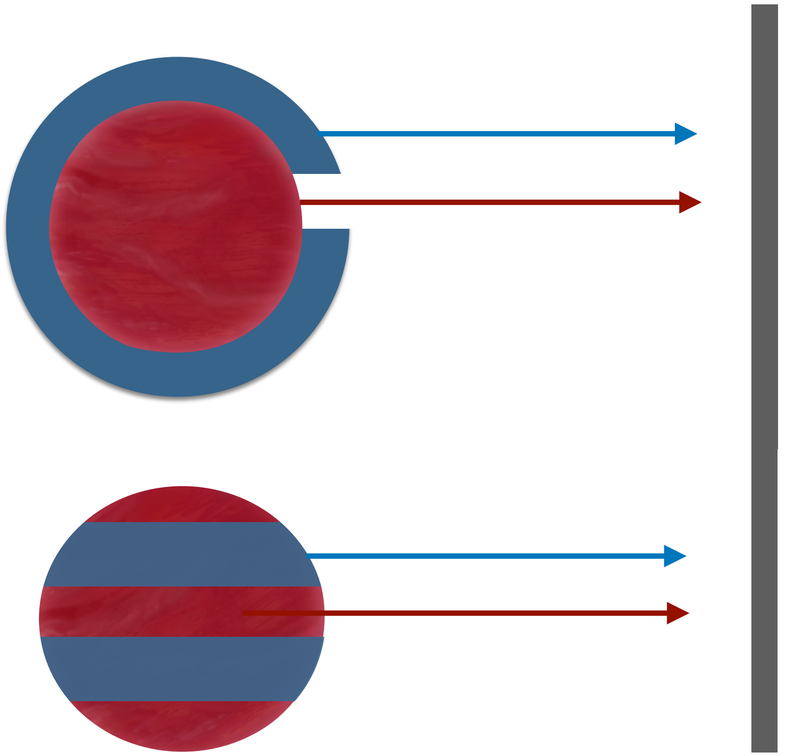
Like these, several other studies found spectral binary candidates to be single, variable objects:
Khandrika et al. 2013, Radigan et al. 2013, Manjavacas et al. 2019

Blended-light atmospheres can occur due to:

Unresolved spectral binary



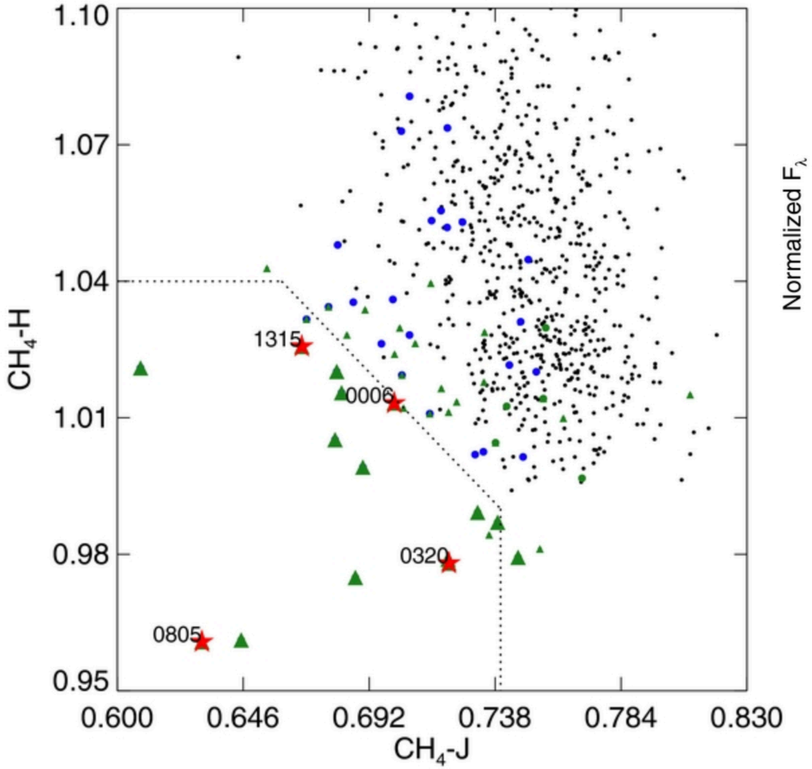
Cloud-driven variability

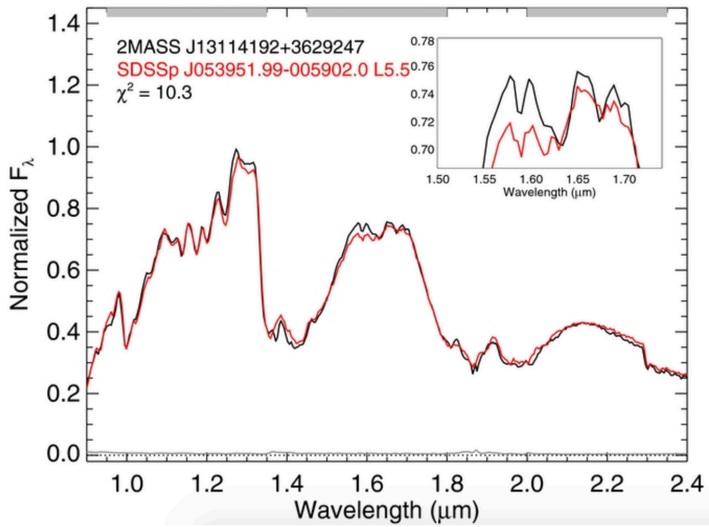


Both cases produce peculiar spectra

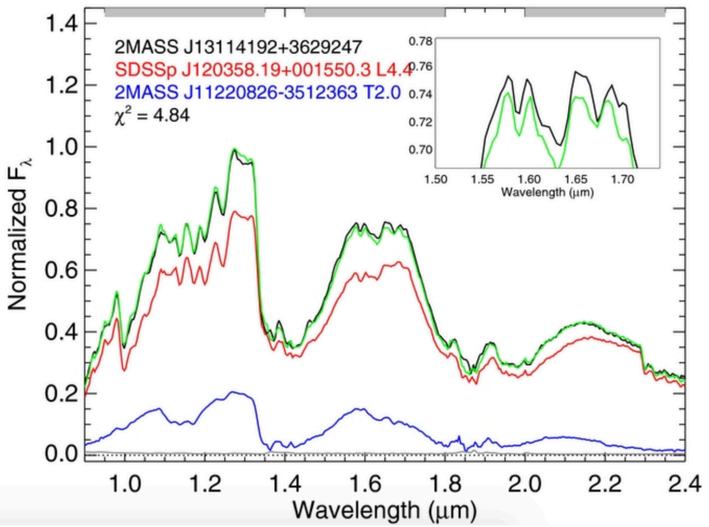
We identify spectral binary candidates through spectral indices and template fitting

Bardalez Gagliuffi et al. 2014

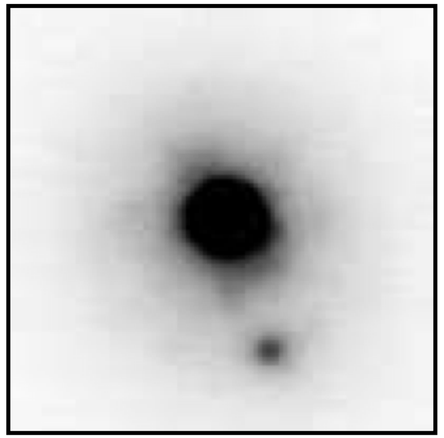




Bardalez Gagliuffi et al. 2014



Bardalez Gagliuffi et al. 2015



And confirm them with high resolution follow-up

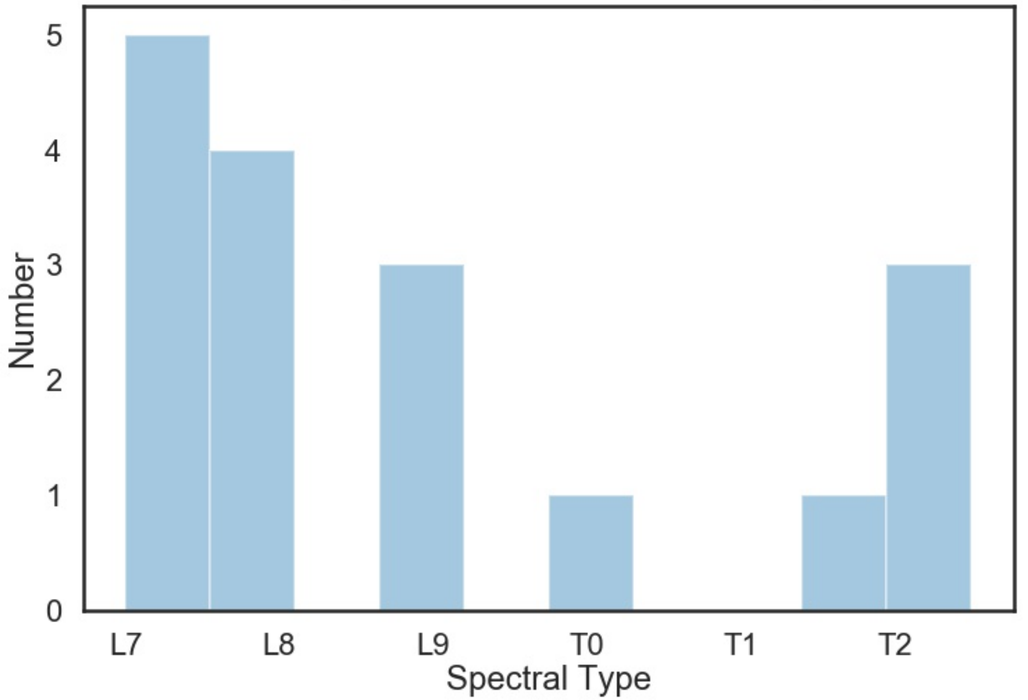
We can repurpose our technique to find variables

Predicting variability from single-epoch, low-resolution spectra

198 spectra from 160 unique L7-T2 dwarfs from the SpeX Prism Library (Burgasser 2014) acquired between 2003 and 2020.

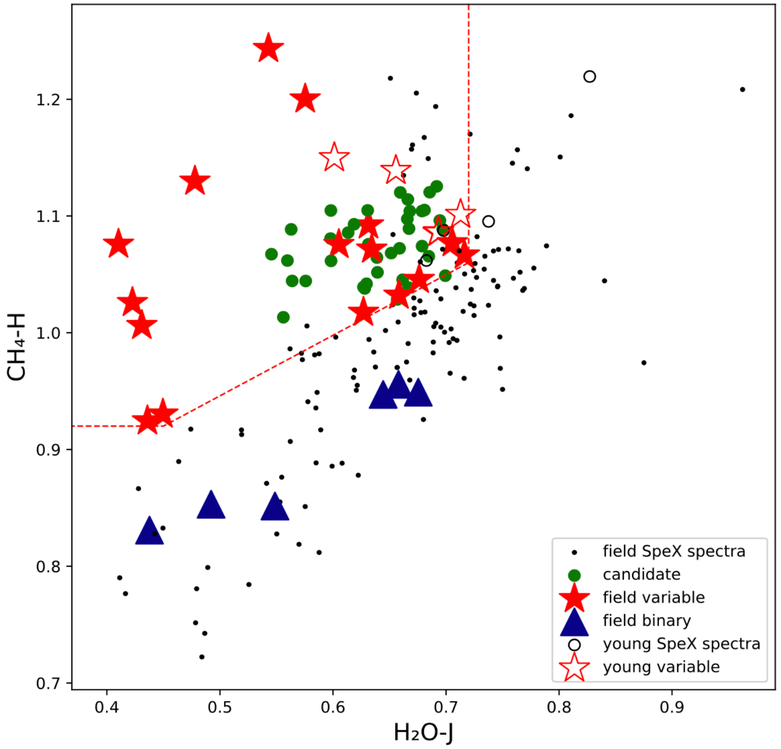
All prism, low-resolution spectra (R~120), flux-calibrated with A0 stars, **NOT time resolved.**

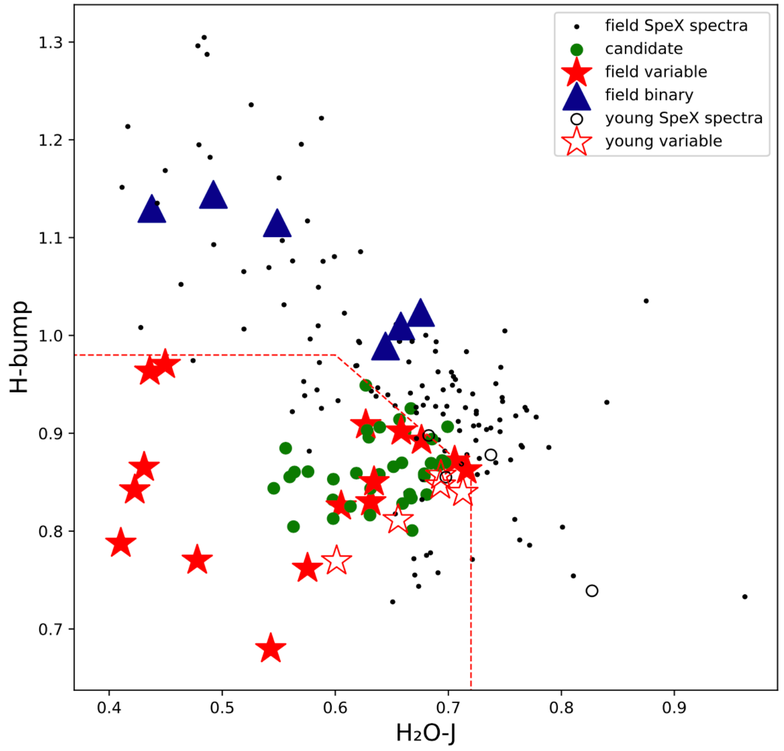
17 “benchmark” objects with significantly variable light curves

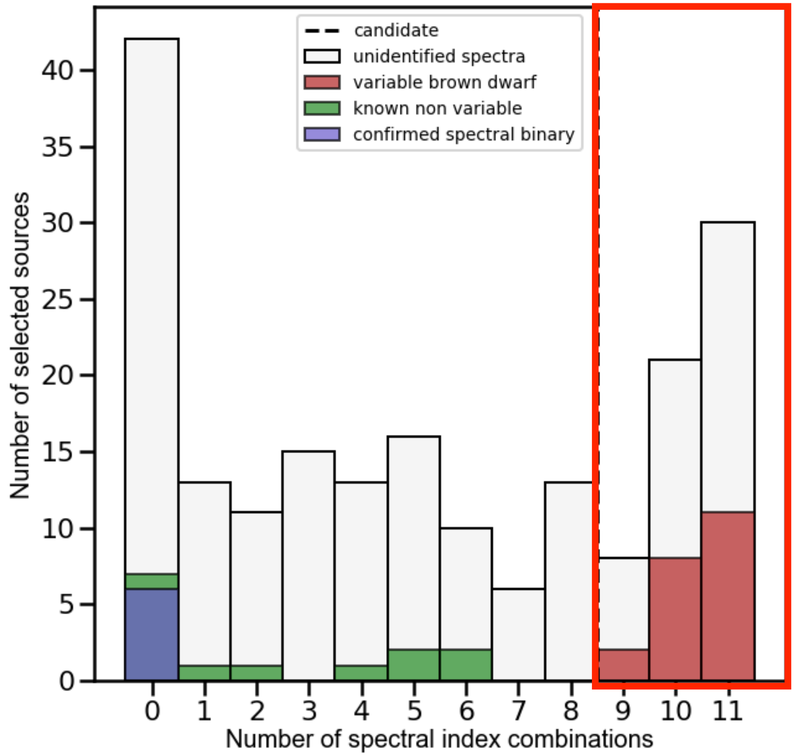


Predicting variability from single-epoch, low-resolution SpeX spectra

9 spectral indices sampling JHK bands compared in 11 index-index parameter spaces







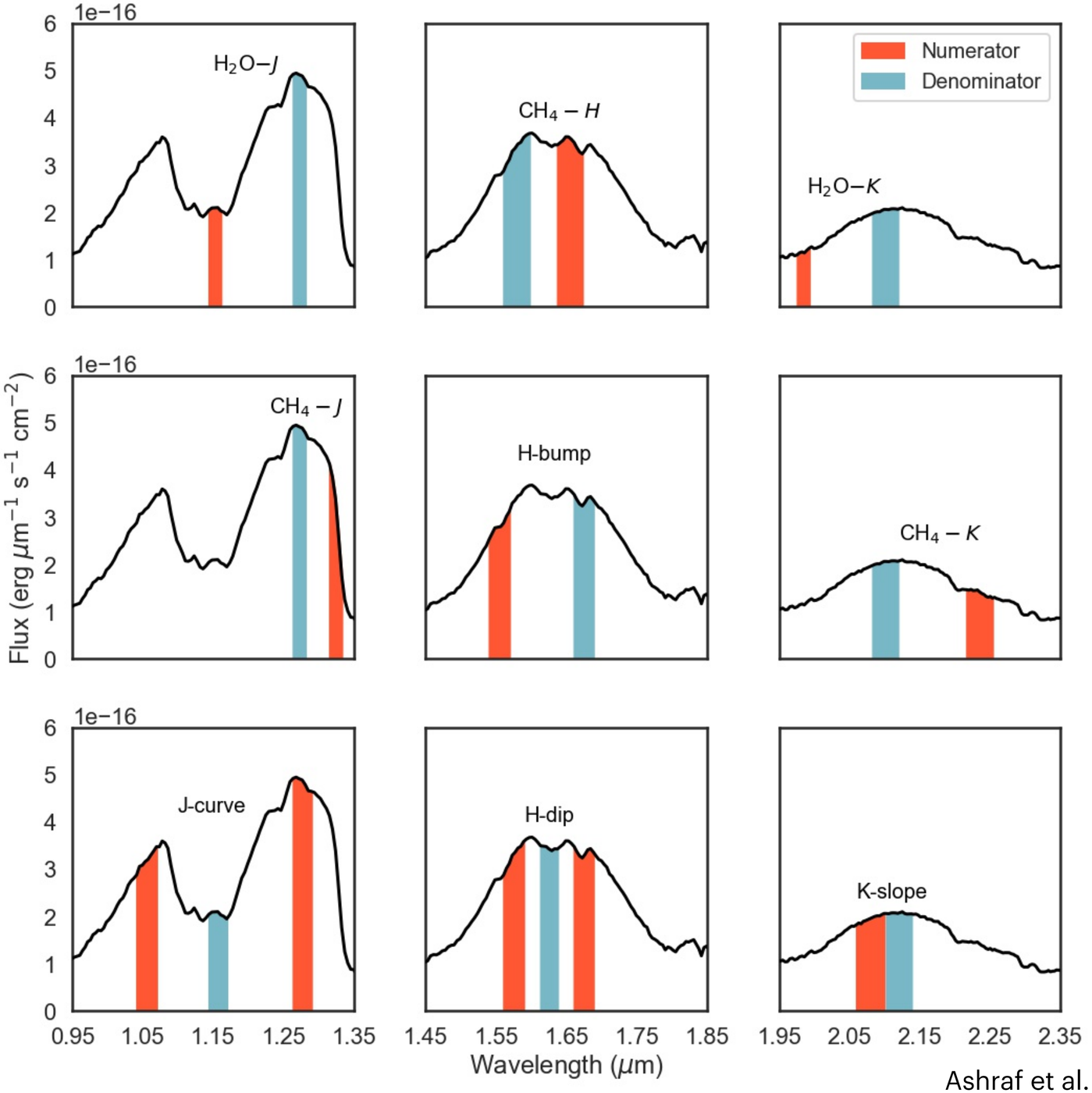
Ashraf et al. (in prep.)

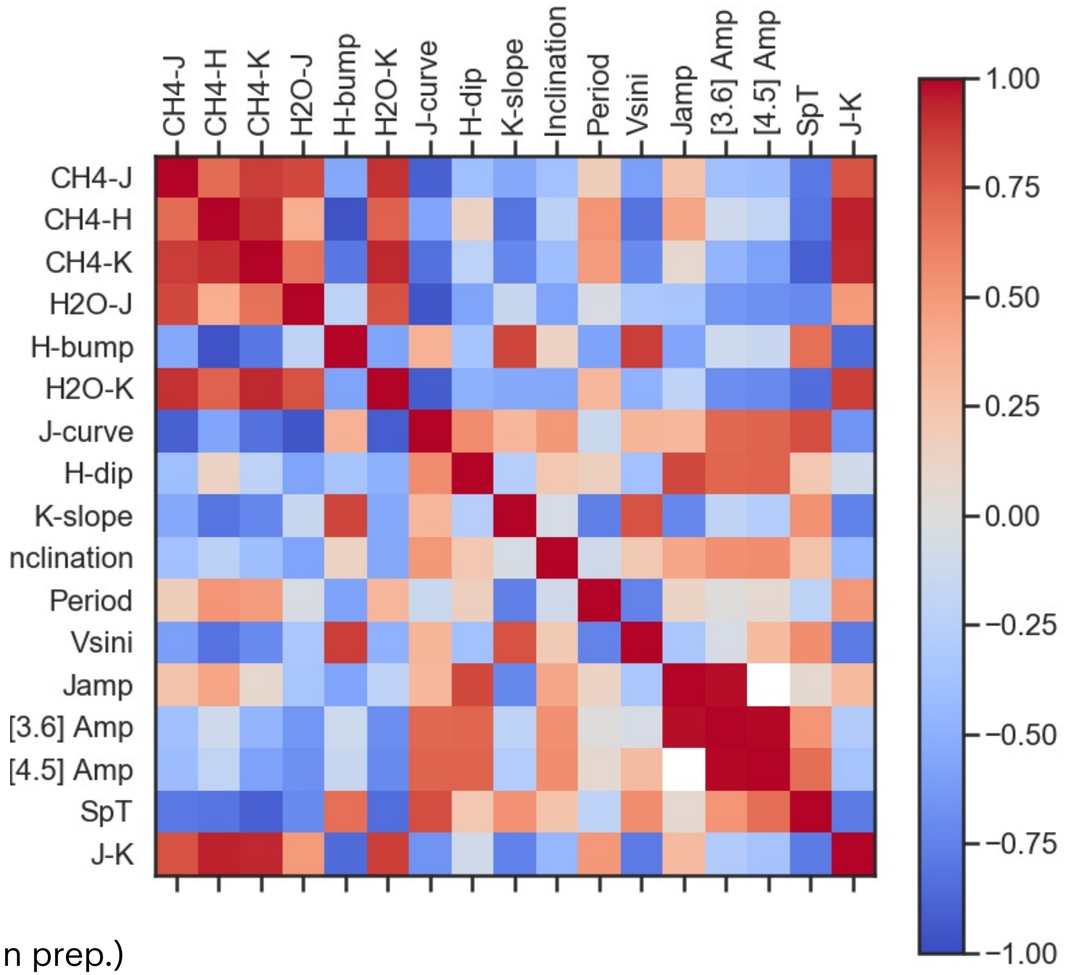
33 variability candidates

NASA ADAP 2018 (PI: Bardalez Gagliuffi)

What are the indices measuring?

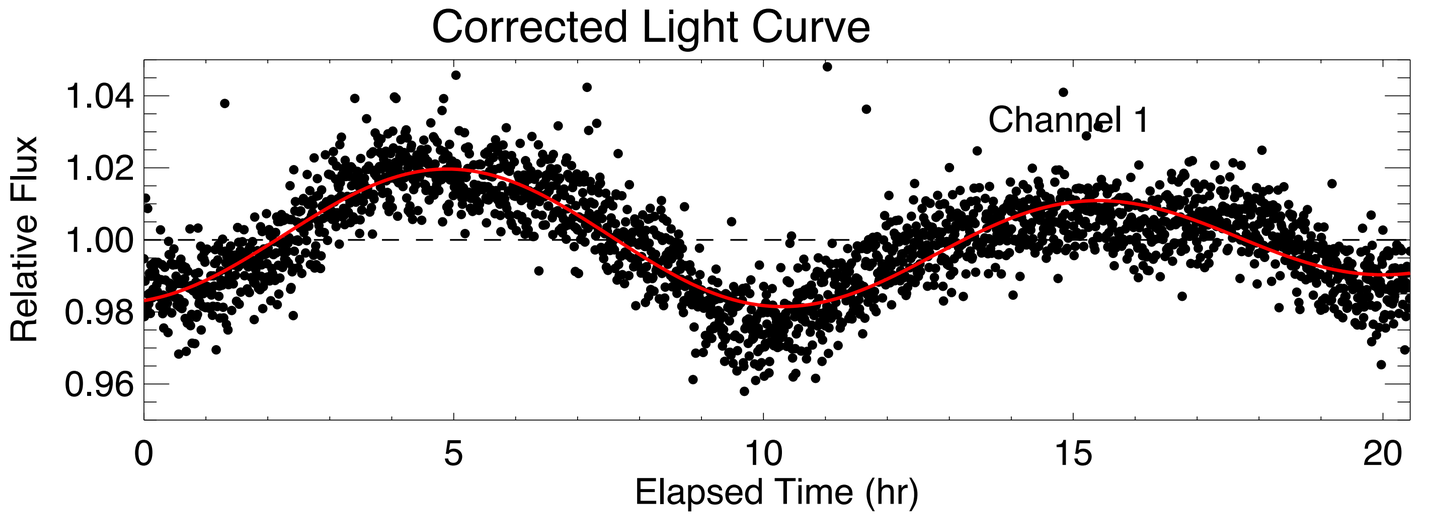
Complex mixed signature of patchiness, atmospheric chemistry, clouds at different altitudes? Inclination angle?

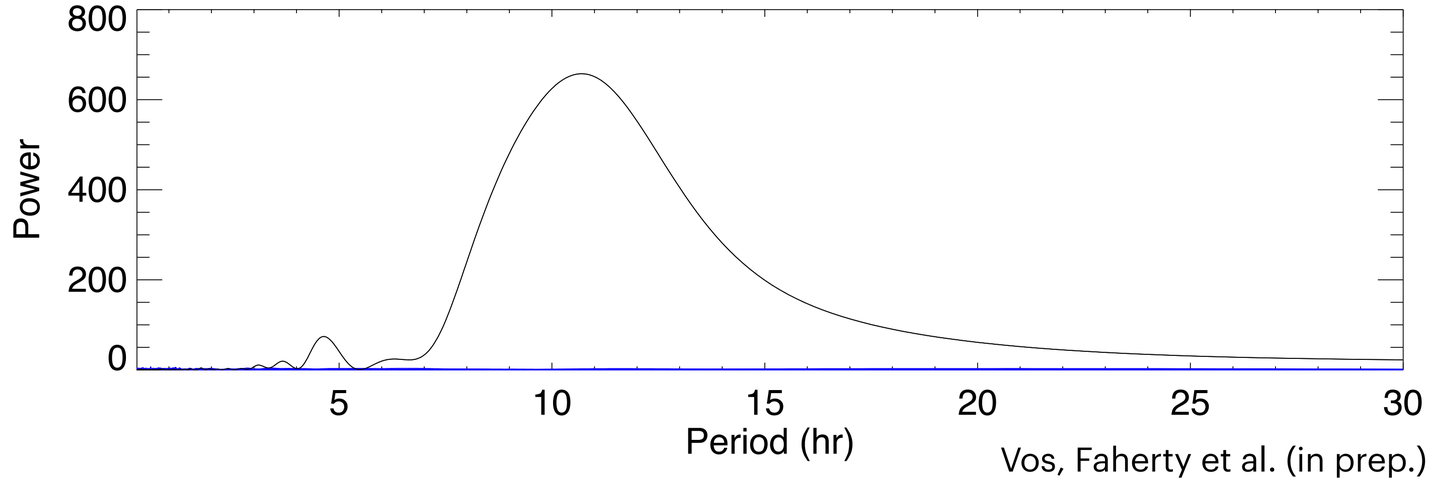




Ashraf et al. (in prep.)

Proof-of-concept: first variable candidate confirmed!





Vos, Faherty et al. (in prep.)

Take-away points

- We have designed a technique to **predict cloud-driven variability** *before* time-resolved photometric observations.
- **This technique will help us prioritize targets for JWST.**
- Next step is to launch a ground-based variability survey to confirm the candidates
- Future step: we will apply this technique to irradiated brown dwarf spectra and hot Jupiter transit spectra to explore exoplanet weather.
- Future future step: improve GCMs by adding information to degenerate inverse problem of surface mapping.
- **Afra Ashraf** coming to a grad school near you!

Training teachers in rural areas of Perú

amauta (Quechua)

[a-mow-ta] ***/noun***

Master, wise one, knowledgeable.

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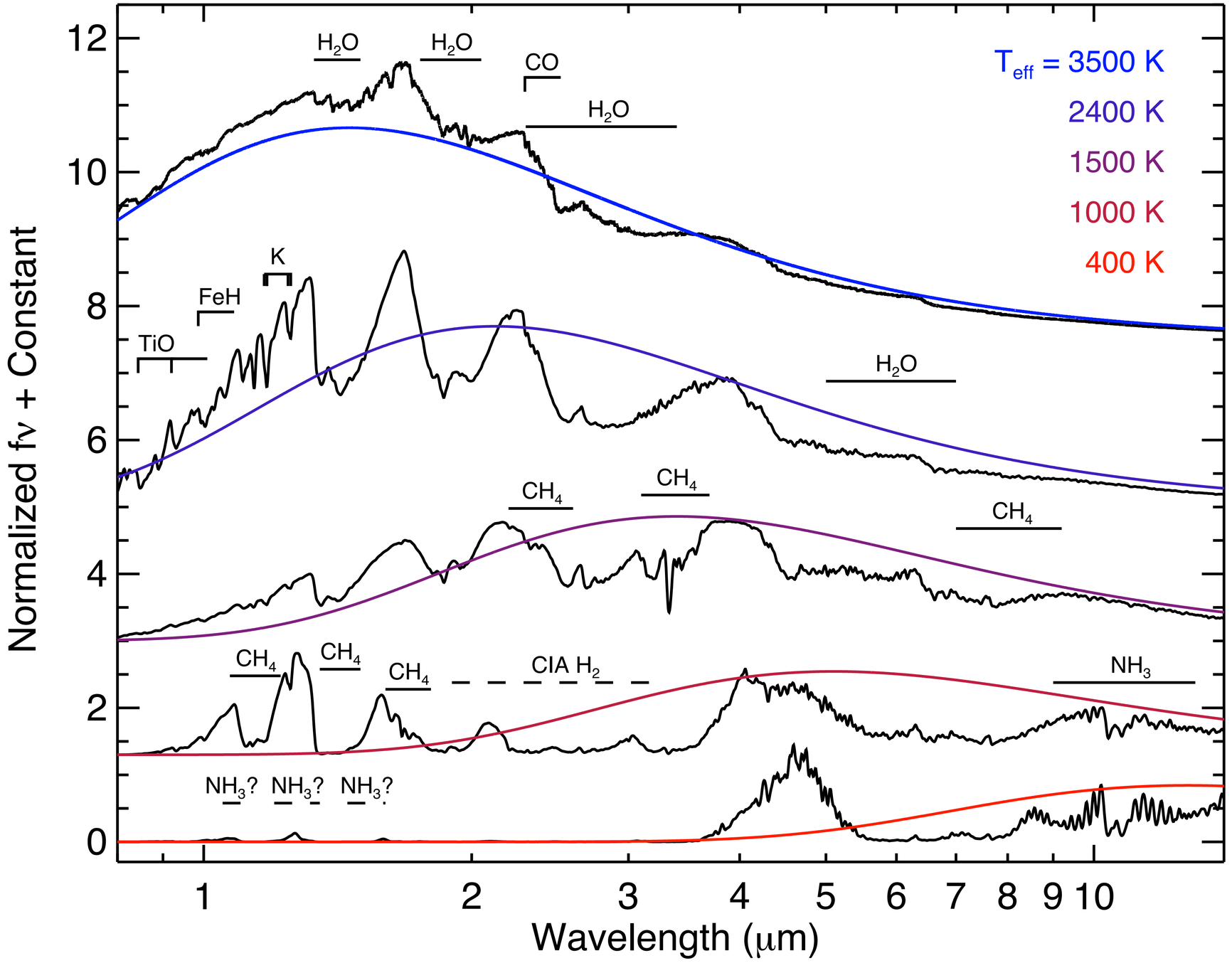
Figure by M. Cushing (U. Toledo)



These sources of opacity dramatically shape the emergent spectra