Aurorae, Clouds or Magnetic Spots? Disentangling the Drivers of Variability in Three Early L-Dwarfs

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The Brown Dwarfs

- Brown dwarfs are worlds that lie in the mass range between that of the largest exoplanets and the smallest stars, ~13-80 M_J.
- They are powerful analogs for directly imaged exoplanets due to their similar position on the colour-magnitude diagram. They are also easier to observe due to typically not having a host star. This is particularly useful for studying their atmospheres.
- Most brown dwarfs are photometrically variable. This variability allows us to understand the mechanisms that drive atmospheric processes on these worlds. This may be due to aurorae, clouds or magnetic spots.
- They provide a wealth of information as to how both of these substellar populations form and evolve.
- We present the preliminary findings of simultaneous HST/WFC3 and VLA observations of three early L-type brown dwarfs, 2M1906+40, 2M1721+33 and 2M0036+18.

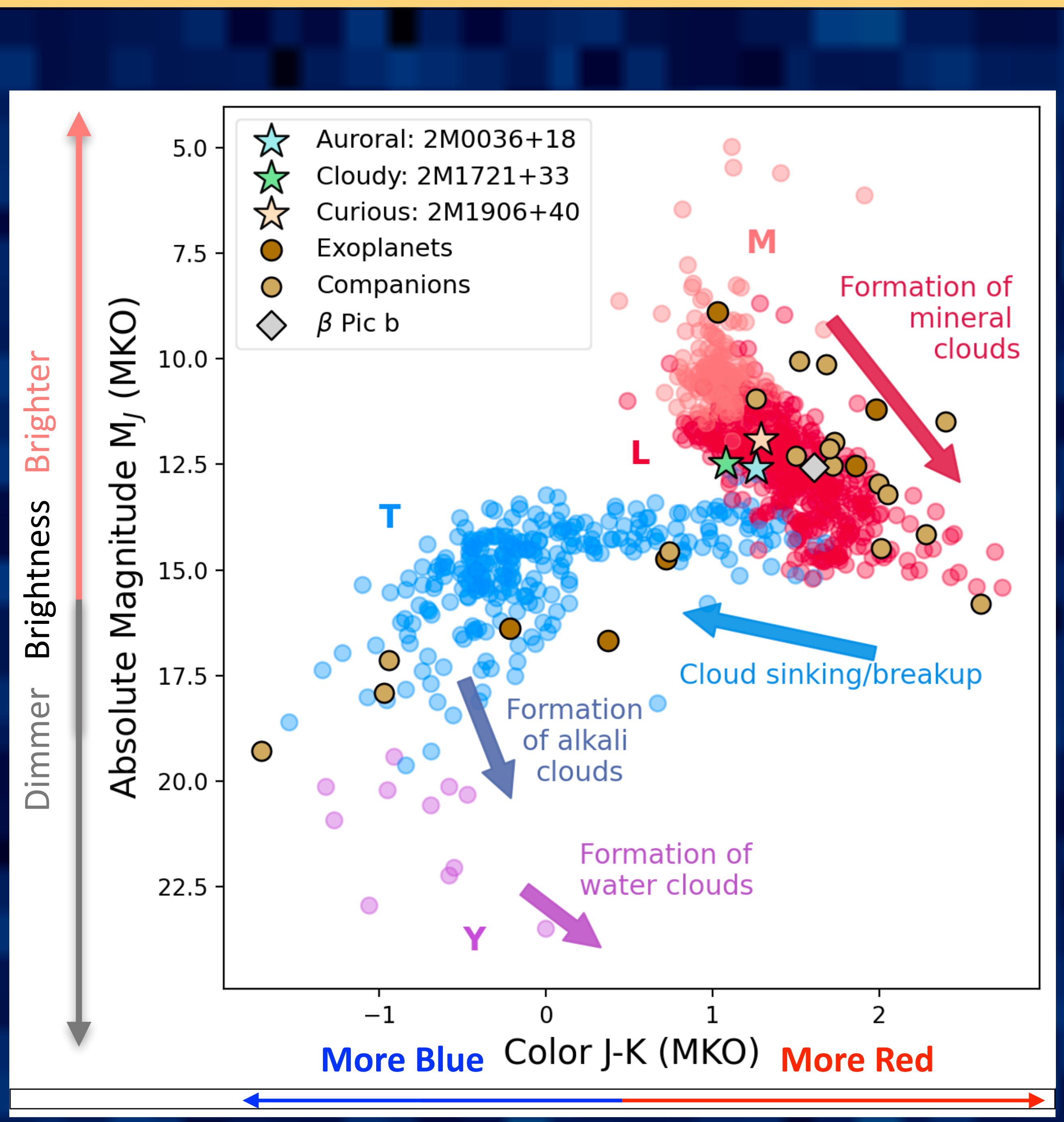

Figure 1: Colour magnitude diagram of brown dwarfs, with the 3 observed brown dwarfs highlighted, along with *β Pictoris b* and other exoplanets and companions.

- Figure 3 shows that all three of our objects are variable. (2M0036+18 was observed twice).
- Each light curve was modelled using *RECTE [2]* to correct for the HST ramp effect, and *Celerité [3]* to model the variability.
- The wavelength dependence of the variability for each object varies, as seen in Figure 4.

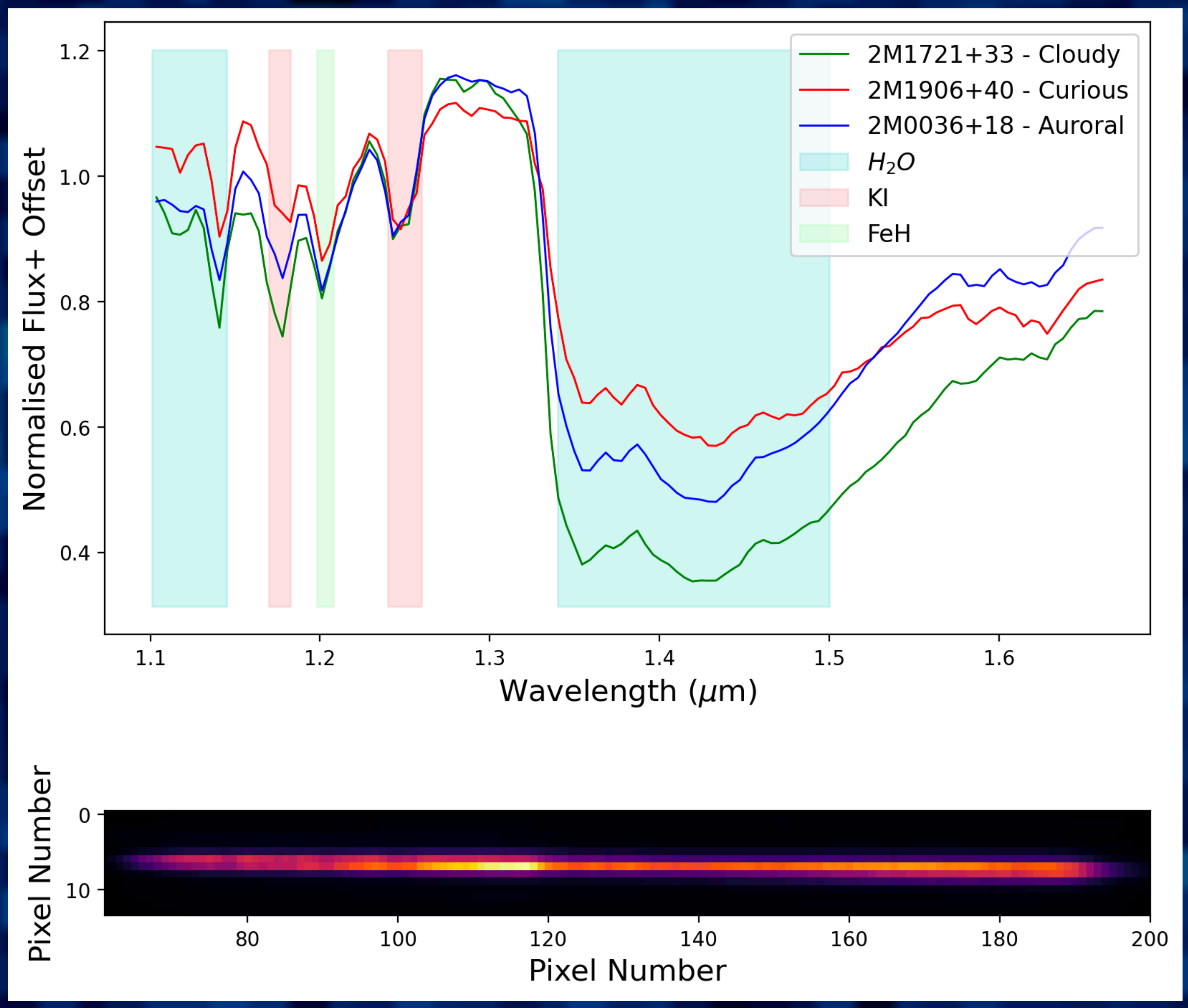

Figure 2: Spectra of all three objects, with highlighted absorption features [1], and its raw grism image from HST/WFC3.

The Variability

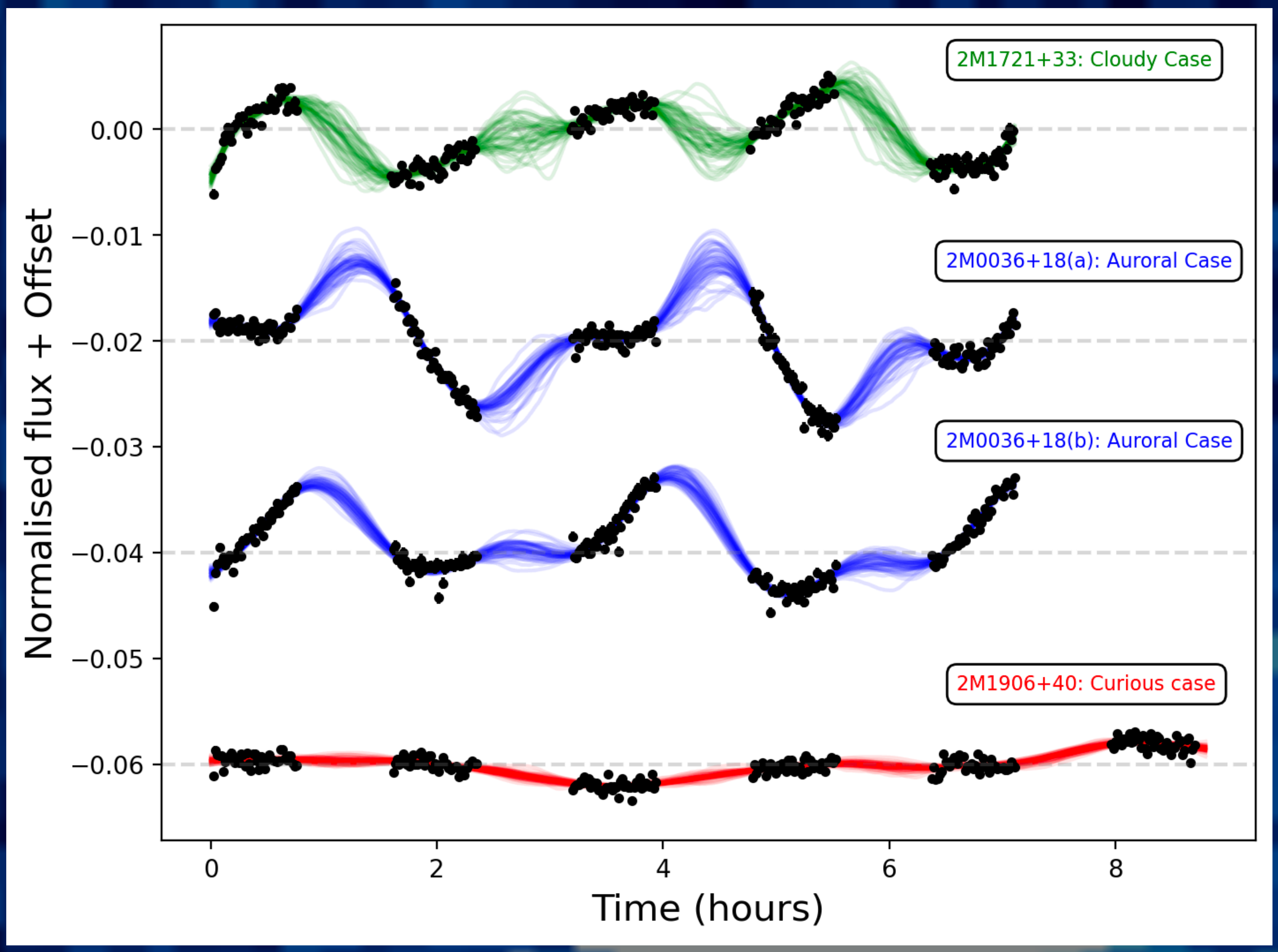

Figure 3: White light curves from all observations. The models shown are selected from prior posterior distributions using *Celerité*.

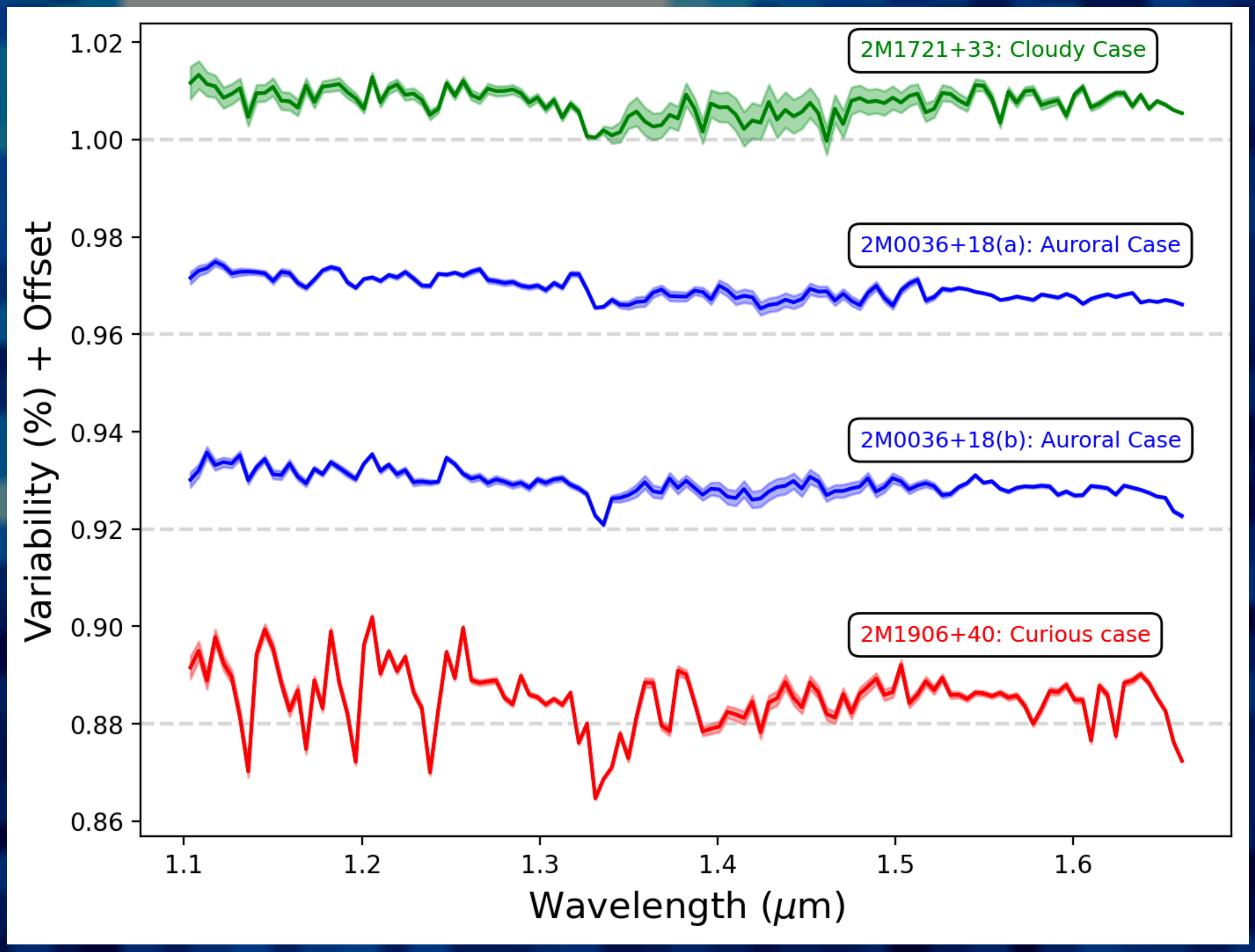

Figure 4: Wavelength dependence of the variability of each brown dwarf. This was obtained by getting the ratio of the brightest 15% of spectra to the dimmest 15% of spectra. The dashed grey lines indicate regions of no variability.

The Future

- The next steps will be to compare our observations with forward models to discern variability mechanisms for each object.
- This will be helped further by comparing this data to the simultaneous VLA observations.
- We will also be able to search for an auroral signature in the infrared, by comparing the HST and VLA data.
- We will also investigate how the colour changes with spectral type [4].

References

[1] Kirkpatrick, J. Davy. "New spectral types L and T." Annu. Rev. Astron. Astrophys. 43 (2005): 195-245
[2] Zhou, Yifan, et al. "A physical model-based correction for charge traps in the hubble space telescope's wide field camera 3 near-ir detector and its applications to transiting exoplanets and brown dwarfs." The Astronomical Journal 153.6 (2017): 243
[3] Foreman-Mackey, Daniel, et al. "Fast and scalable Gaussian process modeling with applications to astronomical time series." The Astronomical Journal 154.6 (2017): 220.
[4] Lew, Ben WP, et al. "Cloud Atlas: Weak color modulations due to rotation in the planetary-mass companion GU Psc b and 11 other brown dwarfs." The Astronomical Journal 159.3 (2020): 125.