Correlated spectral variability in brown dwarfs

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Models of brown dwarf atmospheres suggest they exhibit complex physical behaviour. Observations have shown that they are indeed dynamic, displaying small photometric variations over timescales of hours [1][3][5][6][7]. $v \sin i$ observations obtained with UVES on the VLT have shown that brown dwarfs are rapid rotators, with rotation periods of 3–10 hours [2], yet I have also demonstrated that the variability evolves on this timescale, so it is not the result of a simple rotational modulation [1][5][6].

To explore this phenomenon further I have carred out a programme of infrared (0.95–1.64 μm) spectrophotometric monitoring of four field L and T dwarfs to look for variability over timescales of 0.1–5.5 hrs. This was carried out using the SOFI spectrograph on the 3.5 m ESO NTT telescope at La Silla, following on from a pilot programme carried out at Calar Alto [1]. A time series of spectra was obtained for each source over a period of several hours with a time resolution of about 8 minutes. Each source was observed simultaneously with a reference star in the same slit which is assumed to be constant on the timescales of interest. The spectra are analysed differentially with respect to their reference source in order to remove Earth-atmospheric variations.

The median target and relative spectrum for one of the sources is shown in Fig. 1 (top two panels). These reveal well known brown dwarf features including the K I doublets at 1169/1178 nm and 1244/1253 nm and the FeH Wing-Ford band at 990–994 nm. The bottom two panels show the amount of variability across the spectrum, the significance of which is de-

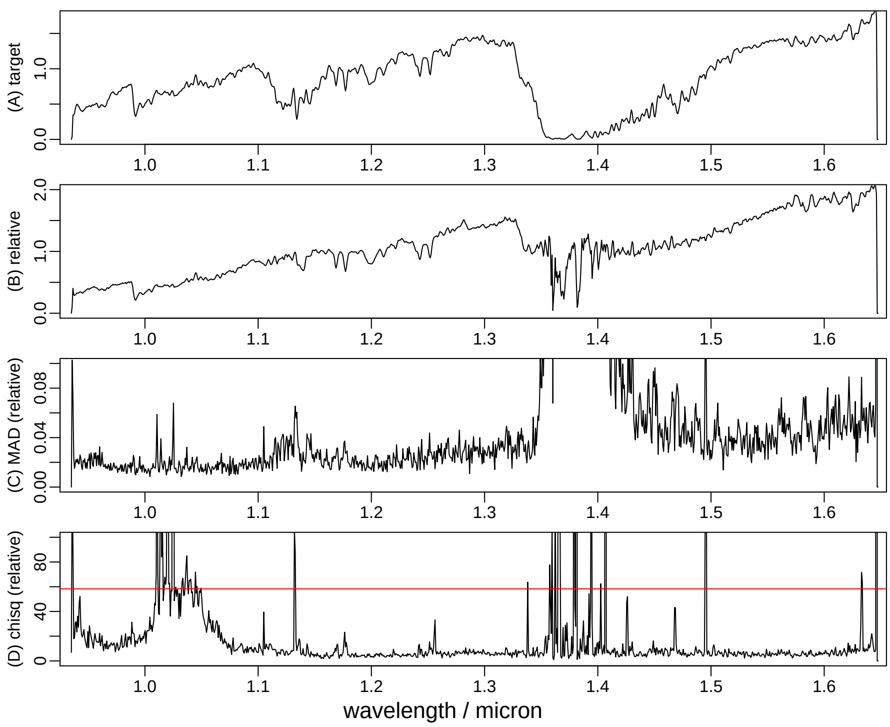

Figure 1: Spectra of the L2 dwarf SSSPM 0828. The flux scale is proportional to photon counts (not energy). From top to bottom: (A) The median target spectrum; (B) the median relative spectrum (median of target divided by reference at each epoch). Both are rectified by dividing by their integrated flux so the vertical scale is dimensionless. (C) The median absolute deviation in the relative spectrum; (D) The χ^2 spectrum. Points in (D) above the horizontal line are variations beyond the estimated errors with a confidence of 99.9% or more per pixel.

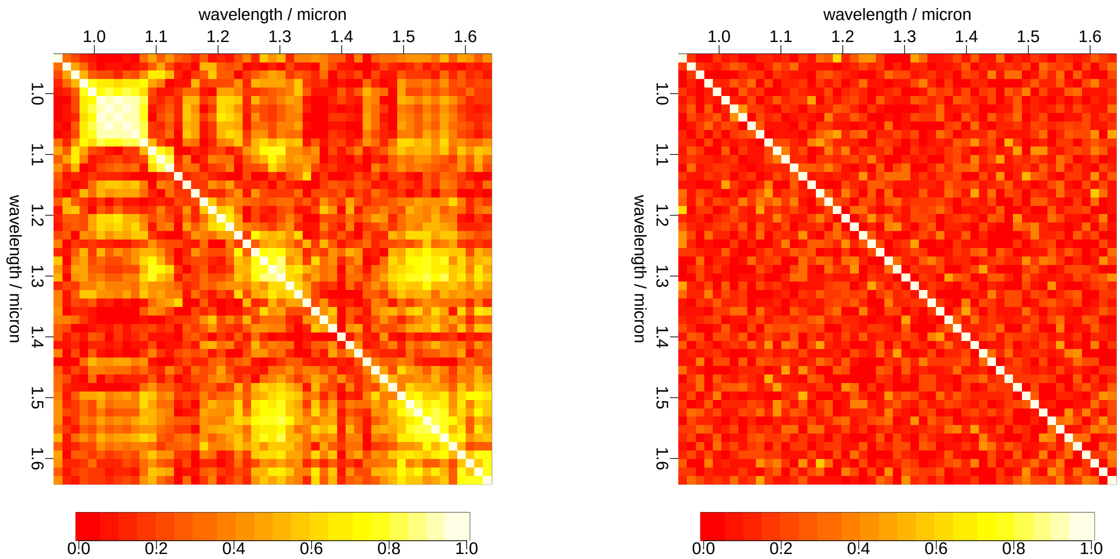

Figure 2: Left: Correlation matrix for the relative spectra of SSSPM 0828 with a binning factor of 20 in wavelength (to improve the SNR). Right: Corresponding correlation matrix for random spectra. Each point shows the absolute value of the correlation coefficient between two pairs of wavelengths on the heat scale indicated at the bottom.

termined by comparison to a photometric noise model. This shows that some of the variability is real. To get better confidence on this I examine the correlation between different wavelengths. The resulting correlation coefficients are plotted as a matrix in Fig. 2 (left panel). When compared to the correlation expected for random spectra (with the same noise properties) shown in the right panel, we see that there are many regions of significant correlation. (This procedure is actually independent of the assumed noise level.)

A significant correlation is also seen in two of the other three sources, with variability amplitudes of 2–10%. Some of the variability in the three sources can be associated with specific features including Fe, FeH, VO and KI, and there is good evidence for intrinsic variability in H_2O and possibly also CH_4. Yet some of this variability covers a broader spectral range which would be consistent with dust opacity variations. The underlying common cause is plausibly localized temperature or composition fluctuations caused by convection. For more details see [4].

Videos of the spectral time series are available at http://www.mpia.de/homes/calj/bdvar5.html

References

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