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Searching for Photometric Variability across the L, T & Y Dwarf Sequence

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Abstract. To investigate the atmospheres of ultracool brown dwarfs with temperatures covering the range of transiting and directly imaged planets, we have monitored a sample of 76 L, T and Y brown dwarfs for infrared photometric variability. This survey was conducted in the *J*-band using both the SOFI camera on the 3.5-m NTT and the SWIRC camera on the 6.5-m MMT. Each target was observed for a period ranging from 2.0 hours to 6.0 hours, covering a significant fraction of the expected rotation period. Breakup of the iron and silicate clouds into a patchy cloud layer has been suggested as an explanation for the variability of several objects identified at the L/T transition, and a similar process with sulfide clouds may be manifest in T/Y transition objects; our data provides the first test of these patchy cloud scenarios across the entire brown dwarf spectral range.

Keywords. stars: low-mass, brown dwarfs, stars:variables:others, techniques: photometric

1. Introduction

With the discovery of Y-dwarfs by the WISE satellite (Wright *et al.* 2010), brown dwarfs now span the entire temperature range between the coolest stars and giant planets both in our Solar System and around other stars. Their low mass ensures that the core never undergoes nuclear fusion (e.g: Hayashi & Nakano 1963), and so they cool throughout their lifetime resulting in an evolution of the chemical and physical properties. Theoretical models invoke the formation and dissipation of dusty condensate clouds to explain the measured colors and spectral features (e.g: Allard *et al.* 2001). Photometric variability monitoring provides a means to search for evidence of cloud features, storms, and activity in the atmospheres of these objects.

2. Sample and Observations

In two separate surveys conducted over the past two years we have observed objects spanning the entire L, T and Y spectral range. The first survey sample consists of 71 L and T brown dwarfs selected to provide an even sampling across the entire L-T spectral range (Wilson *et al.* 2013). Observations were taken with SOFI on the 3.5-m NTT over two separate epochs in 2011/12. The second survey consists of 5 late T and Y brown dwarfs that cover the T/Y transition region (Rajan *et al.* 2013), where recent models predict the formation of sulfide clouds. The T-Y dataset was observed with SWIRC at the 6.5-m MMT over two nights in Mar 2012. Both surveys were carried out in the *J* band where the variability is expected to be greatest. The targets were observed typically for 2–6 hours each and calibrated with a flat field, sky and dark frames. Aperture photometry was carried out using DAOPHOT and the light curves were corrected for airmass.

Table 1. Variables identified in the both surveys

Object	Sp. Type	DOF	$\chi^2_{\rm red}$	Amplitude
2M0034 + 0523	T6.5 (IR)	7	2.1	$2.2 \pm 0.8\%$
2M0136 + 0933	T2.5 (IR)	7	4.5	$2.8 \pm 0.6\%$
2M0348 − 6022	T7 (IR)	7	6.7	$2.2 \pm 0.8\%$
2M0445 − 3048	L2 (Opt.)	9	2.4	$3.0 \pm 1.1\%$
W0458 + 6434	T8.5 (IR)	16	6.3	$22.4 \pm 2.7\%$
2M0949 − 1545	T2 (IR)	6	4.1	$6.5 \pm 1.4\%$
2M1010 − 0406	L6 (Opt.)	9	2.9	$4.4 \pm 1.3\%$
2M1225 − 2739	T6 (IR)	7	3.7	$3.6 \pm 1.3\%$
2M1828 − 4849	T5.5 (IR)	7	2.8	$2.1 \pm 0.8\%$
2M2139 + 0220	T1.5 (IR)	6	12.8	$4.9 \pm 1.1\%$
2M2228 − 4310	T6.5 (IR)	7	4.0	$1.8 \pm 0.7\%$
2M2252 − 1730	L7.5 (IR)	6	1.4	$1.7 \pm 1.0\%$
2M2356 − 1553	T6 (IR)	6	13.3	$2.2 \pm 1.3\%$

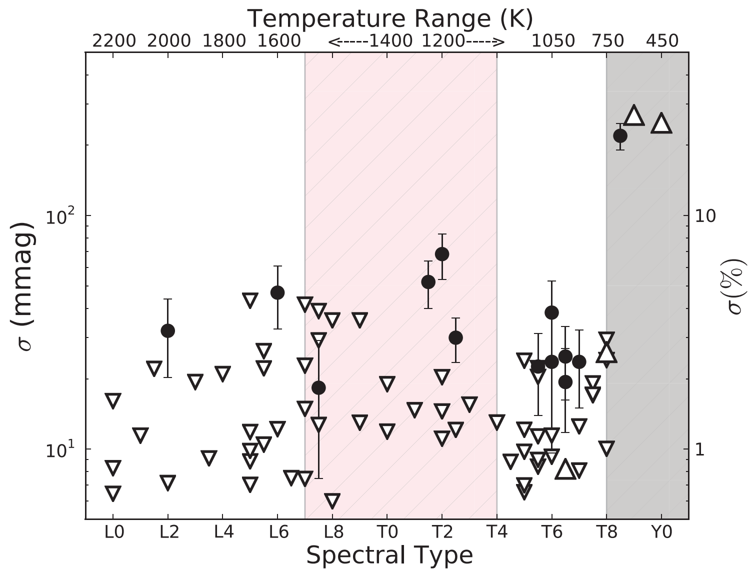

Figure 1. Preliminary results from the two surveys: open triangles indicate the limits and filled circles indicate confirmed variables. Shaded and hatched regions shows the transition regions.

3. Results

We detect 12 variables in the L-T sample (see Table 1) giving a variability fraction of $22^{+7}_{-5}\%$ for observations with a photometric quality better than 10mmag (1%), consistent with previous studies. We detect no correlation with spectral type and we also find that variability above the 5% level at J-band wavelengths is rare. One of the T-Y sample, which happens to be a binary system showed large variability at levels seen at the L/T transition. Figure 1 shows the results for the entire L-T-Y survey.

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