SF2A 2008
C. Charbonnel, F. Combes and R. Samadi (eds)

SEARCH FOR VARABILITY IN ULTRA-COOL DWARFS SPECTROSCOPIC INVESTIGATION FOR CORRELATED VARIABILITY

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Abstract.
Some Ultra-cool dwarfs have cloudy atmospheres and are rapid rotators. Thus patterns can appear in the cloud coverage, leading to surface heterogeneities. Photometric and spectroscopic variations have already been reported in M-type, L-type and T-type ultra-cool dwarfs. However some detections are tentative because of the very low variation amplitudes. We present results for three ultra-cool dwarfs monitored in infrared, in low resolution, with the NTT-SOFI spectrograph, using the blue and red arms, corresponding to wavelength ranges of 0.95–1.64μm and 1.53–2.52μm respectively: DENIS-P J104814.9-395604 (M9), Kelu1 (L2) and 2MASS J15074769-1627386 (L5). We find these objects variable in both SOFI arms (Kelu1 being rather stable in the blue arm, compared to the other two objects).

1 Introduction

The very late M dwarfs (M9), the L and T dwarfs have like some planets and exoplanets a cloudy atmosphere. These objects are therefore of a high interest for variability investigations. The presence of a cloud coverage and the fact that brown dwarfs are rapid rotators provide the observator with an interesting work: studying a variable weather on these objects. Photometric and spectroscopic variations have already been reported (Clarke et al. 2003; Bailer-Jones 2008; Goldman et al. 2008). These variations can be due to either the rotational modulation of the dwarf or to dynamical atmospheric processes. Binarity and magnetic fields might also be the cause of variations.
DENIS1048 is an old cool dwarf at the hydrogen burning mass limit. Kelu1 and 2M1507 are both L-type brown dwarf. We analyse the infrared data of the SOFI spectrograph by looking for correlated variability in the spectra of these ultra-cool dwarfs. Many elements are involved at the same time in these processes. Correlations in different features (for instance species depleting at the same time) suggest that the observed variability is real (Bailer-Jones 2008; Goldman et al. 2008)

2 Method

We use the following method developped by Bailer-Jones (2008). We use the free software environment for statistical computing and graphics (www.r-project.org):
1.Each set of normalized relative spectra is converted into a matrix in that each row is a spectrum and each column a flux time series at a given wavelength.
2. Each row is binned with a binning factor, F, by taking the mean of the fluxes and the mean of the wavelengths values.
3. Correlations are computed between columns. The matrixes ,displayed with a color-scale , are symmetric. They are computed by taking the absolute value of the coeffcients. The distribution of correlation coefficients is also provided. From dark red to yellow the correlation coefficients rise.
4. A random correlation matrix is computed as well as the corresponding distribution, in order to compare it with the observed correlations.

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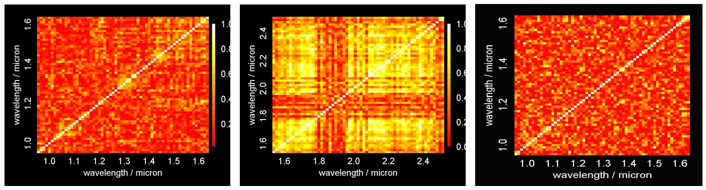

Fig. 1. Left : Kelu1. Example of correlation matrix in the blue arm. **Middle**: Kelu1. Example of correlation matrix in the red arm. **Right**: A random correlation matrix.

3 Which method to use for computing the relative spectra?

Since we had the choice for computing the relative spectra (for the cancellation of the Earths atmsosphere) between a standard star and a reference star simultaneously monitored in the slit, we compared correlation matrixes computed with both of them.

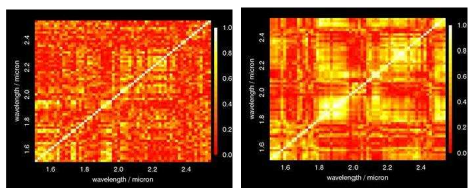

Fig. 2. Left: Correlation matrix for DENIS1048's relative spectra computed with the reference star simultaneously monitored in the slit with the science object. **Right** : Correlation matrix for DENIS1048's relative spectra (red arm) computed with the standard star.

The very yellow patterns in the 'standard' case suggest we may conclude that for a variability investigation a standard star does not provide a good enough cancellation of the Earths atmosphere, so that one should always manage to have a reference star in the slit, while monitoring the science object.

4 Detected variability and perspective

Given the random matrixes we can conclude the observed variations are real. DENIS-P J104814.9-395604 (M9) shows strong variations in the wavelength range 0.95–1.64μm with a very high scattering in the distribution of correlation coefficients. One might think that this very peculiar patterns would be due to the different groups of FeH lines, abundant at these wavelengths. A small range of the red part, the 1.6–1.8μ one, exhibits a very correlated pattern that might be due to FeH which is dominant in these wavelengths in M9 dwarfs, and present many absorption lines whose variations may be correlated. Kelu1 seems to be much more stable in the blue part than the other two objects. However the mean of the absolute values of the correlation coefficients in the red part is for Kelu1 more than twice higher than for the other two objects whereas it is the smallest in the blue part. Except for the water bands, all the species like FeH and CO would be correlated to each other.Finally our three science targets seem to be good candidates for further investigations of spectral and/or photometric variability. Kelu1 was already investigated with both technics (Clarke et al. 2002, 2003) but DENIS-P J104814.9-395604 and 2MASS J15074769-1627386 are still waiting for further investigations in variability.

References

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