

A Comparison of the Infrared Spectra of Two Very Late-type M Dwarfs with Different Gravities

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Abstract. We present observations obtained during the commissioning of the upgraded Cooled Grating Spectrometer 4 on the UK Infrared Telescope on Mauna Kea, of the very low-mass objects TVLM 513–46546 and Gl 569B. Spectra were taken from 1.0 to 2.5 μm allowing the peak of their energy distributions to be measured. TVLM 513–46546 and Gl 569B have very similar spectral types and colours but they differ by more than a magnitude in luminosity; this indicates that their surface gravities differ by around 0.5 dex. We interpret their stellar parameters by making comparisons with the latest atmospheric models.

1. Introduction

Low mass stars are, by number density, the most dominant objects in our Galaxy. Because of the complexity of their spectra, dominated by molecular bands, standard techniques used for hotter stars to find essential parameters such as effective temperatures, metallicities and surface gravities are not applicable. One of the most reliable way to derive these parameters is from a direct comparison of observed and synthetic spectra.

1.1. Gl 569B

Gl 569B was discovered by Forrest et al. in 1988 together with its companion YD M dwarf Gl 569A and it is a cooling brown dwarf candidate. From the distance (known through the parallax of Gl 569A), we know that it is overluminous by

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0.65 mag with respect to stars with the same colours and spectral type. This is thought to be due to a low value of $\log g$ and a solar-type metallicity (Jones et al 1996). There is no strong evidence for it to be a young cooling brown dwarf.

1.2. TVLM 513–46546

TVLM 513–46546 (hereafter TVLM 513) is a very low-mass M dwarf discovered by Tinney et al. (1993). It has a well determined luminosity and is likely to be young and of solar-type metallicity.

Table 1. Parameters of Gl 569b and TVLM 513. The values for the effective temperatures have been taken from Leggett et al 1992

	[M/H]	T_{eff} (K)	d(pc)	Spectral Type	M_K
Gl 569B	~ 0.0	~ 2400	~ 9.94	dM8.5	9.61
TVLM 513	~ 0.0	~ 2250	9.92	dM9	10.77

Because of their similarity and well known parameters a direct comparison of their SED and, moreover, a detailed analysis of their spectral signature could be a tool in: 1) accurately determining their $\log g$; 2) providing a test for the latest atmospheric models.

2. Observations

Gl 569B and TVLM 513 were observed, among other M dwarfs, during the commissioning of the upgraded Cooled Grating Spectrometer 4 (CGS4, Puxley et al. 1995) on the UK Infrared Telescope (UKIRT) on Mauna Kea, Hawaii. The observations presented in this paper were made during May 1995 under excellent conditions (optical seeing ~ 1 arcsec and low atmospheric humidity ~ 20 per cent). The airmass difference between object and standard never exceeded 0.05 and so we are confident that the spectra have good cancellation of atmospheric features.

3. Models

Models were taken from a large grid computed with the model atmosphere code PHOENIX. Details of the models can be found in Allard et al. (1995). The models used have been computed at a fixed metallicity ($[M/H] = 0.0$ where $[M] \equiv \log M_{\text{star}} - \log M_{\odot}$ for any abundance quantity M) and effective temperature ($T_{\text{eff}} = 2400\text{K}$). We varied the surface gravity ($\log g$) from 3.5 to 5.5 in steps of 0.5.

4. Spectral analysis

We have divided the infrared spectrum of the two stars into small regions and compared them against each other and with a grid of synthetic spectra.

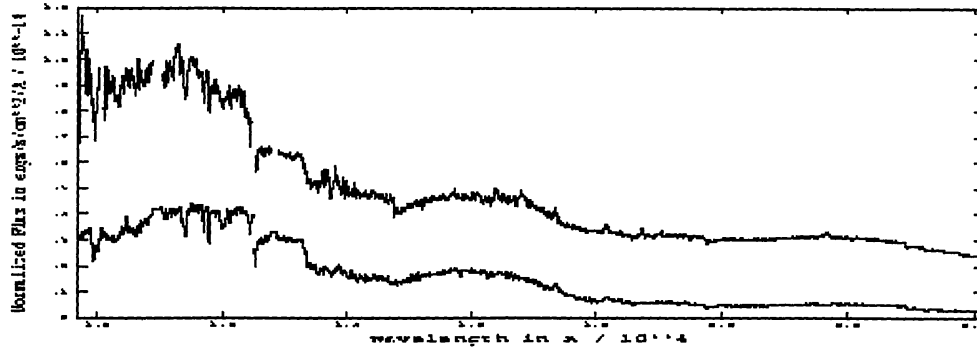


Figure 1. The observed spectra of Gl 569B (top) and TVLM 513-46546 (bottom).

We have collected a sample of atomic bands; among them, we have found some features that show changes between the two stars. However these changes could be due not only to changes in surface gravity but also to the small differences in temperature or metallicity. To establish which of these were gravity sensitive features, we have used the synthetic spectra computed at a fixed metallicity and effective temperature with $\log g$ as a variable.

We have also attempted a SED comparison but found it not to be useful at this stage: one of the main problem lies on the lack of molecular data on water, which dominate the infrared part of the spectrum, in the models. Fig. 1 shows the observed spectra of Gl 569B and TVLM 513. We performed an empirical comparison of the regions where we found sensitive gravity features. We find a strong consistency in the analysis. We discuss some examples below:

- The two KI features at $1.169 \mu\text{m}$ and $1.177 \mu\text{m}$ are stronger in TVLM 513 than in Gl 569B. By comparing them to the models we find that the strength of the two features increases as the surface gravity increases indicating that Gl 569B has a lower $\log g$ than TVLM 513. In fact the best match for TVLM 513 is reached at $\log g \sim 5.0-5.5$ while the best match for Gl 569B is reached at $\log g \sim 4.0-4.5$.
- The Mg I feature at $\sim 1.211 \mu\text{m}$ is also stronger in TVLM 513 than in Gl 569B and in the models increases with increasing surface gravity. Mg I at $\sim 1.711 \mu\text{m}$ is instead stronger in Gl 569B than in TVLM 513 and in fact decreases with increasing gravity in the models. Again we find that the model that best fits TVLM 513 is at $\log g = 5.0$ and the one that best fits Gl 569B is at $\log g = 4.5$.
- The Fe I feature at $\sim 1.521 \mu\text{m}$ is weaker in TVLM 513 and again in the models its strength increases as $\log g$ decreases.

Fig. 2 shows some of the atomic features discussed above.

5. Conclusions and future work

We find consistency in our analysis which confirms that Gl 569B and TVLM 513 differ at least by 0.5 dex in surface gravity. However, the sample considered is

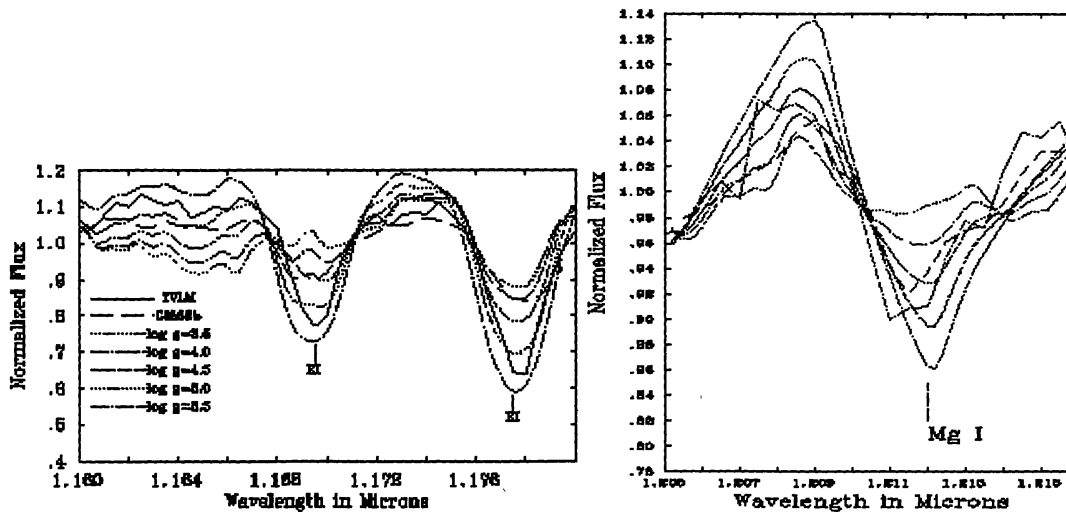


Figure 2. Two observed KI gravity sensitive features (left), and an observed MgI gravity sensitive feature (right) compared with synthetic spectra. The notation is explained in the left plot.

too small to be statistically representative for a final conclusion. Much higher resolution data would be more representative of weaker features that maybe are more sensitive to surface gravity changes.

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References

- Allard F. , Hauschildt P.H., 1995, ApJ, 445, 433
 Forrest W.J., Skrutskie M.F., Shure M., 1988, ApJ, 330, L119
 Jones H.R.A, Longmore A.J, Allard F., Hauschildt P.H, 1996, MNRAS, 280, 77
 Jones H.R.A., Longmore A.J., Allard F., Hauschildt P.H., Miller S., Tennyson J., 1995, MNRAS, 277, 767
 Leggett S. K., 1992, ApJS, 82, 3511
 Puxley P., 1995, Spectrum Newsletter, PPARC, Swindon
 Tinney C.G, Mould J.R, Reid I.N, 1993, ApJ, 105, 1045
 Tinney C.G., Reid I.N., Gizis J., Mould J.R., 1995, AJ,