The Eclipsing Binary System CM Draconis

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Abstract. We compare observations from 0.40 to 2.41μm of the binary system CM Draconis with synthetic spectra computed using the stellar atmosphere code PHOENIX. We obtained the most direct measurement of both metallicity [M/H] and effective temperature (T_{eff}) so far made for the system. We found discrepancies between the analysis of the infrared and optical spectrum. Our results imply $3150 \leq T_{\mathrm{eff}} \leq 3300$K and $-0.8 \leq [M/H] \leq -0.6$.

1. Introduction

CM Draconis (hereafter, CM Dra) is the lowest mass main-sequence eclipsing binary known (RA =16:34:24, Dec = 57:09:00 J2000, V = 12.9 mag). It has a short period of 1.268 days (Metcalfe et al. 1996), a large space velocity (163 km s^{-1}) and low flaring rate which could suggests it belongs to Population II (Lacy 1977).

Because it is one of the faintest, smallest and least massive main-sequence binaries so far known, its colour-luminosity relationship is a prime indicator of what happens to very low mass stars at the bottom of the main sequence. Some of the fundamental physical properties of the components of CM Dra have already been determined accurately (see Table 1). The precision

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of these values far exceeds those known for any other M dwarf and means that CM Dra should be an excellent system for comparison with model calculations but the values for its metallicity and effective temperature need to be improved.

Table 1.   Parameters of the two components (A and B) of the binary system CM Draconis

	R ($R_\odot$)	M ($M_\odot$)	P (days)	V_{mag} (mag)	v_{rot} (km/s)	v_{orb} (km/s)
A	0.2516±0.0020	0.2307±0.0010	1.268	12.9	10	5.7124
B	0.2347±0.0019	0.2136±0.0010	1.268	12.9	10	5.3287

2.   Observations

CM Draconis was 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 and at the Steward Observatory 90 inch Bok Telescope located at Kitt Peak. The observations presented in this paper were made during during excellent conditions (optical seeing $\sim$ 1 arcsec and low atmospheric humidity $\sim$ 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. (1994). We use model temperatures from 3000 to 3400 K and metallicities from [M/H]= −1.0 to +0.2. For T_{eff} =3150K, two models at [M/H]= −1.5 and −2.0 were also computed. The parameters represent the probable extremes of metallicity and effective temperature of CM Dra. The surface gravity was fixed to log $g = 5.0$.

4.   Direct comparison of models and observations

We attempt an infrared and optical analysis divided in two sections: the general flux distribution comparison and a more detailed spectral analysis.

4.1.   General Flux distribution analysis

We tried to find the best match in metallicity for each effective temperature and vice versa for both the infrared and optical spectrum.

Optical: we found that the best model fit is reached at low temperature, as low as 3000K. For low temperatures models, some absorption bands are better fitted by low metallicity models. For example, the synthetic flux around $\sim$ 0.72 μm
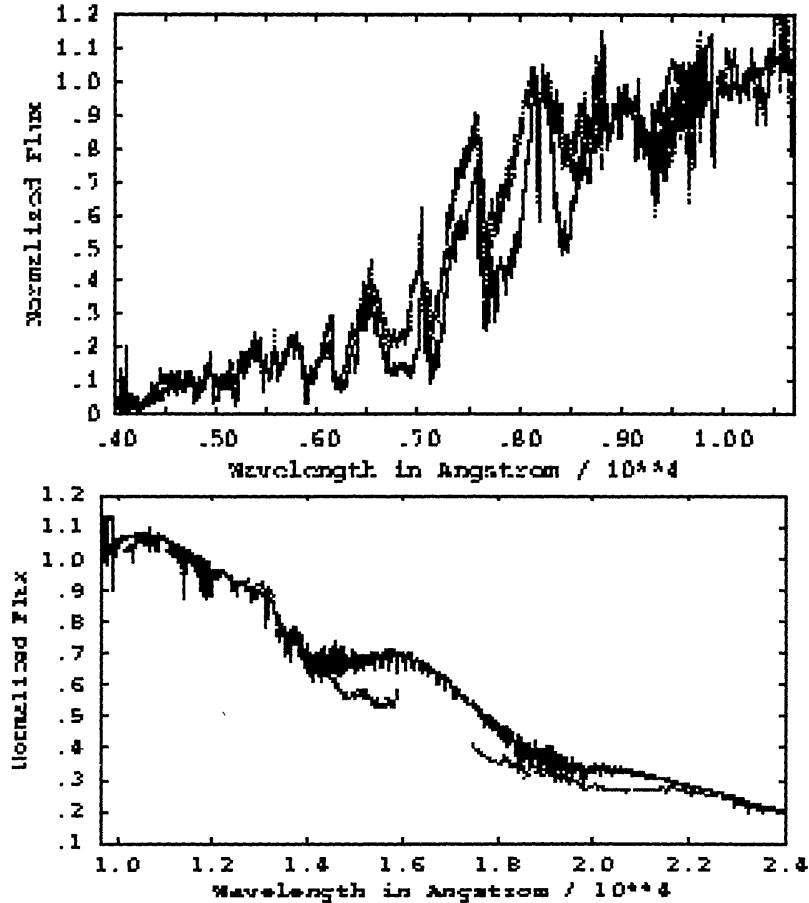
Figure 1.   Optical (*upper*–solid line) and Infrared (*lower*–solid line) SED comparison for respectively a model computed at T_{eff}=3000 K and [M/H]= 0.0 and for a model computed at T_{eff}=3300 K and [M/H]= −1.0.

(which is due to a band of TiO) is too high in models at solar metallicities. High temperature models give a worse fit for low metallicities.

infrared: for a given temperature, low metallicities reproduce the IR flux distribution better than the high ones. In fact we found that for all temperatures the best metallicity ranges seem to be for [M/H]$\leq$ −0.4. However at very low metallicities ([M/H]$\leq$ −1.5) the flux distribution match worsens. Fig. 1 shows a fit to the SED both in the optical and in the infrared with the models.

4.2.   Detailed analysis

Optical: due to the presence of many telluric features, the 0.87–0.91 μm was excluded. The sample of lines were chosen from the line identification provided as a feature of the models. In general, the best metallicity lies between −0.8 and −0.6. However, with increasing temperature the fits to low metallicity models ($\leq$ −0.4) get worse. Choosing the best metallicity within each temperature, we compared the different temperatures and found that the $\sim$ 3200 K models give the best match.
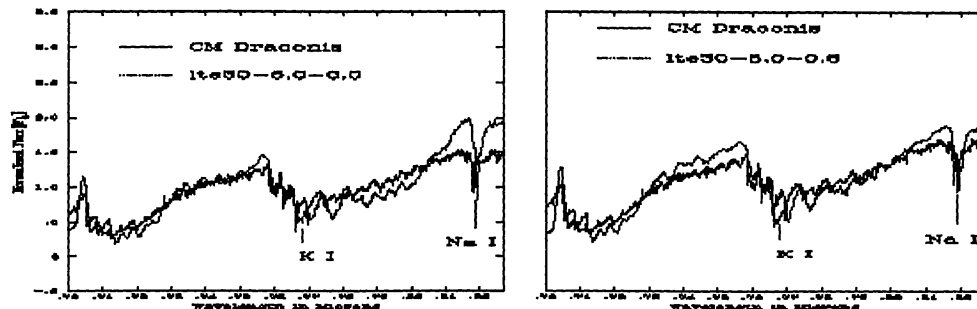
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Figure 2.   Sensitivity to changes in metallicities in the 0.70–0.83 μm region. Left: T_{eff}=3000K, [M/H]= 0.0. Right: T_{eff}=3000K, [M/H]= −0.6.
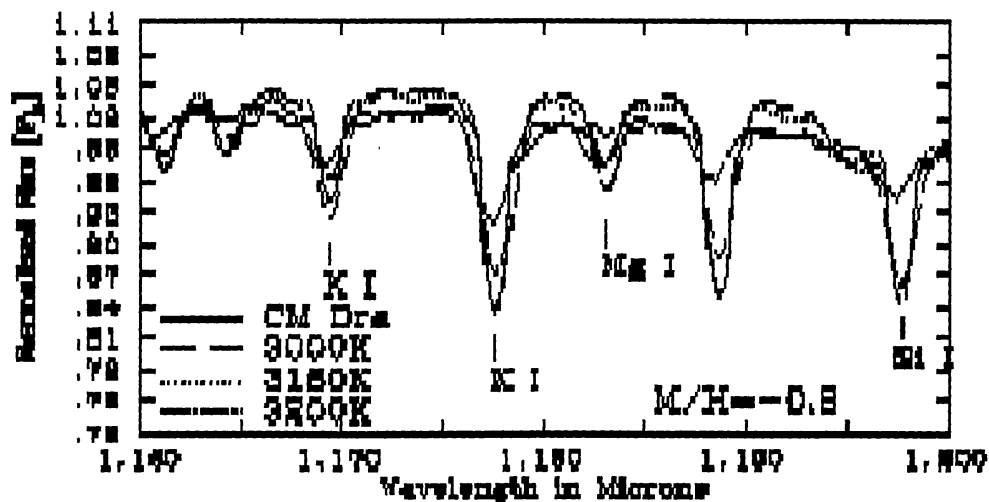

Figure 3.   Sensitivity to changes in effective temperature in the 1.16–1.20 μm region.

Infrared: The region between 1.35 and 2.2μm is excluded since it is dominated by the water bands and therefore not reliable for detailed comparison. We used Leggett et al.'s (1996) list of strong atomic lines for our analysis. High temperatures and low metallicities models give a better match to the observed spectrum of CM Dra, in particular [M/H] should be between −1.0 and −0.4. Fig. 2 shows the fit of two metallicities models at a fixed temperature for a portion of the optical spectrum.

Fig. 3 shows the fit of three temperatures models at a fixed metallicity for a portion of the infrared spectrum.

5.   Conclusions and Future Work

During the course of our analysis, we found some inconsistencies.

The comparison of the general flux distribution for both the optical and infrared region, implied that a metallicity of −1.0 is too low for the system. However, a

more careful analysis in the infrared suggested systematically lower metallicities (as low as −1.0) and/or higher temperatures (as high as 3300K) for an optimal fit. A detailed analysis of the optical spectrum leads to systematically lower effective temperatures ($\sim$ 3200K) and higher metallicity ($\sim$ −0.6) than a similar analysis of the infrared spectra.

We can find a model in the range of agreement between the optical and infrared analyses which reproduces most features and leads to an effective temperature and a metallicity of the order of 3200K and −0.6 respectively for CM Dra.

Full details of this work will be published in MNRAS.

References

Allard F., & Hauschildt P. H. 1995, ApJ, 445, 433

Lacy, C. H. 1977, ApJ, 218, 444

Leggett S. K., Allard F., Berriman G., Dahn C. C., Hauschildt P H., 1996, ApJS, 104, 177

Metcalfe T. S., Mathieu R. D., Latham D. W., Torres G., 1996, ApJ, 456, 356

Puxley P. J., Ramsay S. K., Beard S. M., 1992, in Grosbol P., ed., Proc. 4th ESO/ST-ECF data analysis workshop

Part 4.
The Mass Function