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Spectral investigations of CM Draconis – new results

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CM Draconis is spectroscopic and eclipsing binary system that consists of two nearly identical M dwarfs. The masses and radii for the components are known with high accuracy. The period of the system is $P = 1.268$ day. In the course of this work we used 29 medium resolution ($R = 47,000$) echelle spectra of CM Dra which were obtained at several different orbital phases at the 4.2-m William Herschel Telescope. We calculated synthetic spectra for a region of NaI 8185 Å, NaI 8197 Å and RbI 7818 Å lines and fitted the spectra for all of the orbital phases. We refined the effective temperature and metallicity of the system components, using similarity function (S function) of the observed and synthetic spectra for different phases.

Key words: stars: fundamental parameters; binaries: eclipsing, spectroscopic

INTRODUCTION

The study of M dwarfs is one of the foremost challenges of the modern astrophysics. Late-type stars are the most numerous population in the solar neighbourhood but they are still not well understood. CM Dra is an eclipsing and double-lined spectroscopic binary system with period $P = 1.268$ days [8]. The accuracy of the masses and radii of the components is better than one percent [9]:

$$M_1 = 0.23102 \pm 0.00089 M_\odot;$$
$$M_2 = 0.21409 \pm 0.00083 M_\odot;$$
$$R_1 = 0.2534 \pm 0.0019 R_\odot;$$
$$R_2 = 0.2398 \pm 0.0018 R_\odot.$$

This makes CM Dra an excellent test object for stellar atmosphere and stellar evolution models. The physical components of CM Dra are almost identical. Their spectral classes are estimated as dM4.5 [8]. In [13] it has been shown that the components of CM Dra have the metallicity range $-1.0 < [M/H] < -0.6$ that is consistent with metal-poor stars. The low metallicity of the components in combination with the fact that CM Dra is a high proper motion object leads to the conclusion that CM Dra could be a representative of Population II stars [6]. Both components show chromospheric activity and the system's age is estimated as 4.1 Gyr [9]. The observed radii and masses for both components show poor agreement with stellar evolution models [7]. The empirical results indicate that both components are larger by $0.01 R_{sun}$ then it was predicted by stellar evolution model [1] for these masses and age.

OBSERVATIONS

We used spectroscopic data from the archives of the 4.2-m William Herschel Telescope. The spectra were obtained with high-resolution spectrograph (UES) during May 20–23, 1997 for different orbital phases. 29 echelle spectra, which were obtained with resolution $R = 47,000$ for spectral range from 4500 to 10000 Å, was used. The radial velocity curve can be seen in Figure 1. The velocity value ranges from 40 to 150 km/s. The crosses represent the observed phase. The spectrum of M dwarfs is described by strong molecular absorption by TiO and VO bands. These bands could be wider than a single order of echelle spectra, thus it becomes difficult to use spectral energy distribution on large scales that is extremely important for the study of cool dwarfs. It is possible to use only a few strong atomic lines which can be identified against the background of molecular bands. The subordinate sodium doublet NaI 8185 Å, NaI 8197 Å, and resonance RbI 7802 Å line are strong enough to be useful for the analysis of the stellar atmosphere parameters.

SYNTHETIC SPECTRA OF CM DRA

Because CM Draconis is a spectroscopic binary system, we used a synthetic spectrum calculation procedure contrary to the commonly used procedure for single stars analysis. We calculated the synthetic flux F_ν^l for each component individually and made a convolution of synthetic spectra with the instrumental profile corresponding to a resolution of $R =$

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47000. The rotational profile of the star was calculated with the method from [2]. The synthetic fluxes from the components has been summarized taking into account a shift, corresponding to the relative orbital velocity of the components in the observed phase. A rotational velocity $Vsin(i) = 10$ km/s and microturbulent velocity $V_{turv} = 3$ km/s was adopted. We used NextGen models [3] as stellar atmospheric models. Synthetic spectra were computed with the `WITA6` software package [10]. We used the list of atomic lines from VALD [4] and the line list of TiO from [11]. The calculations were made assuming the local thermodynamic equilibrium (LTE) for a one-dimensional atmosphere without sources of energy in hydrostatic equilibrium. `WITA` use sources of opacity in the continuum utilizing the `ATLAS9` [5]. The calculation of the ionization and dissociation equilibrium (IDR) was made assuming of LTE for a mixture of 100 of molecules which are most common in the atmospheres of cool stars according to current view. The constants from [12] were used to solve the system of hydrodynamical equations. Theoretical spectra were calculated for effective temperatures $T_{eff} = 3000 - 3200\,\mathrm{K}$, $\log g = 5.0$ and abundances $[M/H] = 0.0$, $[M/H] = -0.5$, $[M/H] = -1.0$ in regions of Na I (8185 Å, 8197 Å) and Rb I (7802 Å) lines. Synthetic spectra were calculated and fits were made for 29 orbital phases. Fitting results for $T_{eff} = 3100\,\mathrm{K}$, $\log g = 5.0$ and $[M/H] = -0.5$ in the region of subordinate sodium lines Na I 8185 and Na I 8197 are presented in Figure 2.

S FUNCTION ANALYSIS AND RESULTS

We used the function of similarity of observed and synthetic spectra (S function) analysis for all phases to obtain effective temperatures and abundances of the components. Values of the S function for several sets of parameters and phases can be found in Table 1. According to the S function analysis for all of the phases, we determined $T_{eff} = 3100\,\mathrm{K}$ and metallicity $[M/H] = -0.5\,\mathrm{dex}$ for each component. The uncertainties of the temperature and metallicity determinations is about 75 K and 0.25 dex respectively. The obtained results are in a good agreement with previous studies. Thus we can be confident of the effectiveness of our methodology in the analysis of stellar atmospheres.

Table 1: S function for several sets of parameters and phases: (a) $T_{eff} = 3100\,\mathrm{K}$, $\log g = 5.0$, $[M/H] = 0.0$; (b) $T_{eff} = 3100\,\mathrm{K}$, $\log g = 5.0$, $[M/H] = -0.5$

Phase	V_r[km/s]	S (a)	S (b)
0.8905	120	2.474	2.199
0.8977	130	2.097	1.974
0.9646	150	2.133	2.537

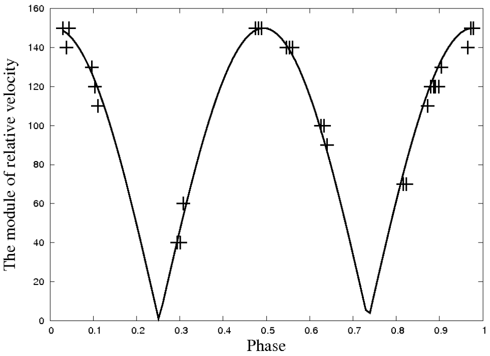

Fig. 1: The radial velocity curve.

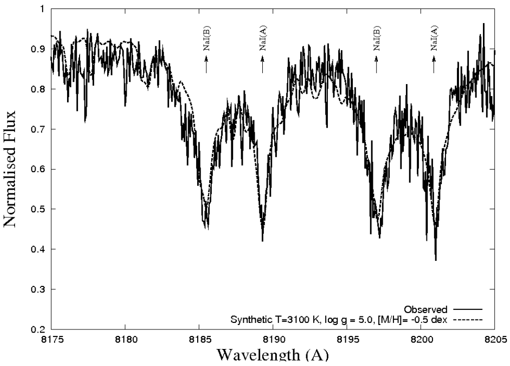

Fig. 2: Fitting for $T_{eff} = 3100K$, $\log g = 5.0$ and $[M/H] = -0.5$ in the region of the subordinate sodium lines Na I 8185 and Na I 8197

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