

PHOTOMETRIC PROPERTIES AND METALLICITY OF V1719 CYGNI

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ABSTRACT

We collect 24 times of light maxima data from sources in the literature, unpublished data and open databases, and investigate the variations of the observed and calculated (O–C) values for light maxima of V1719 Cyg. We found no evidence of the variations in the (O–C) values. We estimate the effective temperature and surface gravity using both the Kurucz and MARCS/SSG grids for different metallicity values $[A/H]=0.0$ and $+0.5$ for V1719 Cyg. It is confirmed that the temperature is almost the same, but, in the case of surface gravity, the MARCS/SSG grid gives the value closest to that obtained from the period-gravity relation derived by using the pulsation-evolution theory. We obtain two spectra of V1719 Cyg from spectroscopic observation which permitted us to find the effective temperature and the surface gravity of the star directly. We estimate the metallicity and it is found that the abundance of iron is equal to the solar value.

Key words : stars: oscillation — stars: variables (δ Scuti) — stars: individual (V1719 Cyg) — stars: metallicity

1. INTRODUCTION

V1719 Cyg (HD200925), ($\alpha = 21^{\text{h}} 02^{\text{m}} 56^{\text{s}}$, $\delta = +50^{\circ} 35' 15''$ (2000), $\langle V \rangle = 8^{\text{m}}.11$), was identified as a variable star by Bedolla & Pena (1979) through observations on 4 nights with a V filter. Since then, many more observations have been carried out using the UBV and *wby* β color systems (see Pena et al. 2002 for earlier studies and references therein).

Mantegazza & Poretti (1986) carried out a period analysis of three previous data sets: Poretti (1984) in UBV, Bedolla & Pena (1979) in V, and Padalia & Gupta (1982). They determined the existence of two periods, including a definite one at 0.267298 days and a possible second period at 0.2138 days. The ratio of these two periods is 0.800, which matches the theoretically predicted period ratio by Cox et al. (1984).

Cox et al. (1984) show that this ratio can be possible for the fundamental and first overtone radial modes in correspondence with helium settling within the envelope of a δ Scuti star. In fact, it has been known that high metallicity and helium settling can be accounted for by the process of diffusion in Am/Fm stars. With regard to this, Poretti and Antonello (1988, hereafter PA88) argued for the possibility of the fundamental and first overtone modes indirectly by considering the color index and luminosity which place this star near the cool edge of the instability strip. Cox et al. (1979a,b) already proposed that a star near the instability strip

may pulsate in spite of low helium content in its envelope and high metallicity. PA88 also pointed out that the period $p_1=0^{\text{d}}.26$ is rather long for High Amplitude δ Scuti (HADS) stars and that this period cannot correspond to the first overtone mode.

Radial modes of the first and second periods were directly confirmed by Kim et al. (1993) by adopting the method developed by Watson (1988) who had outlined a format for the comparison of observational light and color data with model predictions on an amplitude ratio versus phase difference plane. They also confirmed the fundamental and first overtone modes by adopting the method developed by Fitch (1981) which is applicable when the pulsation constant strongly depends on the pulsation mode (n,l).

It was first noticed by Joner and Johnson (1985) that the light curve of V1719 Cyg is very peculiar. The main peculiarity is the asymmetry with the descending branch steeper than the ascending branch. They also found that V1719 Cyg shows a definite variation of m_1 with temperature, but this variation is opposite to the variation predicted by Crawford (1979). On the contrary, by using the one zone model proposed by Stellingwerf (1972), Antonello (1991) obtained an interesting result concerning the inverse variation of the m_1 -index and he argued that the cool stars with mildly rich atmospheres such as V1719 Cyg can show this kind of peculiarity.

Pena et al. (2002) observed V1719 Cyg using the *wby* β filters and estimated the atmospheric param-

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Table 1.
Light maxima of V1719 Cyg.

| HJD | Cycle | O-C | Source |
|-----------|-------|---------|--------|
| 3776.7150 | -1629 | -0.0028 | BP |
| 3776.8350 | -1629 | 0.1172 | PG |
| 3777.7880 | -1625 | 0.0010 | BP |
| 3778.7130 | -1622 | 0.1241 | PG |
| 3779.6590 | -1618 | 0.0010 | BP |
| 3779.7760 | -1618 | 0.1180 | PG |
| 4164.2950 | -179 | -0.0038 | PG |
| 4173.1180 | -146 | -0.0016 | PG |
| 4178.1930 | -127 | -0.0053 | PG |
| 4212.1510 | 0 | 0.0060 | PG |
| 4518.7310 | 1147 | -0.0040 | GF |
| 5544.8850 | 4986 | -0.0042 | JJ |
| 5546.5010 | 4992 | 0.0080 | EP |
| 5559.5920 | 5041 | 0.0015 | EP |
| 5560.3960 | 5044 | 0.0036 | EP |
| 5574.5640 | 5097 | 0.0048 | EP |
| 5582.8530 | 5128 | 0.0076 | JJ |
| 5583.9210 | 5132 | 0.0064 | JJ |
| 5593.8030 | 5169 | -0.0016 | JJ |
| 5626.6890 | 5292 | 0.0068 | JJ |
| 5627.7590 | 5296 | 0.0076 | JJ |
| 5952.7770 | 6512 | -0.0078 | JJ |
| 6272.7460 | 7709 | 0.0063 | JJ |
| 6281.8190 | 7743 | -0.0088 | JJ |

eters. Their results of $[\text{Fe}/\text{H}]=1.020$, $T_{\text{eff}}=6400\text{--}7100\text{ K}$ and $\log g = 3.1$ are quite different from the values (0.456–0.664, 7470 K, 3.87) obtained by Johnson & Joner (1986, hereafter JJ86). An exhaustive analysis of the photometry is required to determine the atmospheric parameters as accurately as possible. Especially, spectroscopic determination of metallicity is necessary.

Given the potential significance that a complete study of V1719 Cyg is likely to have, we have undertaken spectroscopic observations of high resolution in order to study the atmospheric parameters and metallicity. We also analyzed the O-C diagram to study the period variation and, in addition, we have tried to determine T_{eff} and $[\text{Fe}/\text{H}]$ using the MARCS/SSG atmospheric model (Gustafsson et al. 1975; Bell, Paltoglou, & Tripicco 1994) which has been rarely adopted for the study of HADS. These results are compared with those obtained from the Kurucz grids (1993, 1995).

2. PHOTOMETRIC INVESTIGATIONS

We began our analysis by plotting the O-C diagram with 24 times of light maxima obtained from the literature as shown in Table 1. We calculated the expected times of maximum light by applying the following equation derived by Poretti (1984),

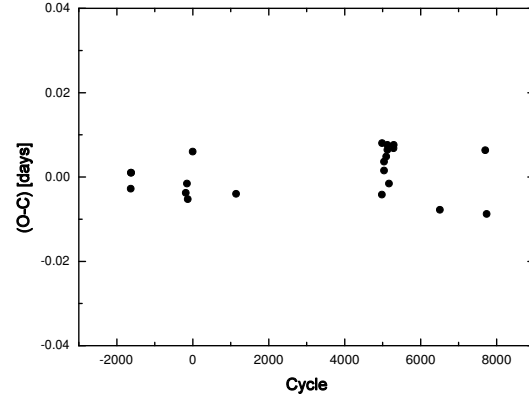


Fig. 1.— Difference between observed times of maximum light and times of maximum light calculated from Eq. (2).

$$\text{HJD}_{\text{max}} = 2\,444\,212.145 + 0.267\,298 \cdot E. \quad (1)$$

On the basis of the above epoch and period values, we deduced the following ephemeris using all data points which covers a span of almost 8 years except for the three data points 2443776.835, 2443778.788, and 2443779.776 having larger O-C values.

$$\text{HJD}_{\text{max}} = 2\,444\,212.145(2) + 0.267\,2973(5) \cdot E. \quad (2)$$

Fig. 1 shows a plot of the differences between the observed and the calculated times of maximum light (O-C) versus the calculated cycle. Three outliers corresponding to the cycle of -1629, -1622 and -1618 with O-C values of +0.1172, +0.1241, and 0.1180 were not included in the plot. At a first glance, there is no systematic variation, which means that the period has been stable for more than eight years.

Until this time, the Kurucz model has been widely used to estimate the effective temperature and surface gravity. Time to time calibration by Moon & Dworetzky (1985) was adopted. This is based on the Kurucz model too. A new grid of theoretical color indices for the uvby photometric system has been derived from MARCS model atmospheres and SSG code (Bell, Paltoglou, & Tripicco 1994) by Clem et al. (2004).

Because this model has never been used to determine T_{eff} and $\log g$ for HADS stars, we adopted this model for V1719 Cyg and the results were compared with those from P02 where the Kurucz model was used. Since $[\text{Fe}/\text{H}]$ value was estimated to be 0.456–0.664 by JJ and 1.020 by Pena, and since the maximum $[\text{Fe}/\text{H}]$ value in the MARCS model is 0.5, we determined $[\text{Fe}/\text{H}]$ for both 0.0 and 0.5. Photometric $wvby\beta$

Table 2.
 T_{eff} and $\log g$ from the Kurucz and MARCS grids.

| phase | [A/H] | | Kurucz | | | | MARCS | | | |
|-------|-------|-------|--------|------|------------------|----------|------------------|----------|------------------|----------|
| | | | 0.0 | | +0.5 | | 0.0 | | +0.5 | |
| | | | b-y | c1 | T_{eff} | $\log g$ | T_{eff} | $\log g$ | T_{eff} | $\log g$ |
| 0.00 | 0.174 | 0.939 | 7225 | 3.27 | 7250 | 3.24 | 7296 | 3.41 | 7364 | 3.45 |
| 0.05 | 0.178 | 0.939 | 7195 | 3.22 | 7215 | 3.19 | 7258 | 3.37 | 7331 | 3.41 |
| 0.10 | 0.188 | 0.918 | 7125 | 3.18 | 7150 | 3.18 | 7178 | 3.34 | 7272 | 3.41 |
| 0.15 | 0.201 | 0.889 | 7040 | 3.14 | 7060 | 3.16 | 7060 | 3.30 | 7221 | 3.43 |
| 0.20 | 0.213 | 0.856 | 6965 | 3.12 | 6985 | 3.17 | 6971 | 3.32 | 7112 | 3.47 |
| 0.25 | 0.224 | 0.824 | 6910 | 3.09 | 6930 | 3.18 | 6904 | 3.31 | 7056 | 3.50 |
| 0.30 | 0.231 | 0.797 | 6885 | 3.10 | 6900 | 3.21 | 6862 | 3.40 | 7019 | 3.56 |
| 0.35 | 0.237 | 0.775 | 6860 | 3.11 | 6875 | 3.23 | 6825 | 3.43 | 6988 | 3.61 |
| 0.40 | 0.242 | 0.760 | 6835 | 3.09 | 6850 | 3.24 | 6793 | 3.45 | 6959 | 3.63 |
| 0.45 | 0.245 | 0.752 | 6820 | 3.08 | 6830 | 3.24 | 6773 | 3.46 | 6940 | 3.64 |
| 0.50 | 0.245 | 0.752 | 6820 | 3.08 | 6830 | 3.24 | 6773 | 3.46 | 6940 | 3.64 |
| 0.55 | 0.241 | 0.757 | 6845 | 3.12 | 6860 | 3.26 | 6801 | 3.47 | 6967 | 3.65 |
| 0.60 | 0.236 | 0.765 | 6875 | 3.16 | 6890 | 3.29 | 6839 | 3.47 | 7002 | 3.65 |
| 0.65 | 0.230 | 0.774 | 6915 | 3.21 | 6925 | 3.32 | 6880 | 3.48 | 7043 | 3.66 |
| 0.70 | 0.223 | 0.785 | 6960 | 3.25 | 6965 | 3.36 | 6931 | 3.49 | 7093 | 3.67 |
| 0.75 | 0.217 | 0.802 | 6995 | 3.26 | 6995 | 3.36 | 6971 | 3.47 | 7131 | 3.65 |
| 0.80 | 0.209 | 0.827 | 7040 | 3.26 | 7045 | 3.34 | 7023 | 3.45 | 7178 | 3.61 |
| 0.85 | 0.198 | 0.860 | 7100 | 3.27 | 7110 | 3.32 | 7113 | 3.45 | 7244 | 3.57 |
| 0.90 | 0.187 | 0.895 | 7160 | 3.28 | 7180 | 3.28 | 7205 | 3.44 | 7305 | 3.52 |
| 0.95 | 0.177 | 0.894 | 7235 | 3.42 | 7270 | 3.39 | 7309 | 3.55 | 7382 | 3.59 |
| Mean | | | 6990 | 3.19 | 7006 | 3.26 | 6988 | 3.43 | 7127 | 3.57 |

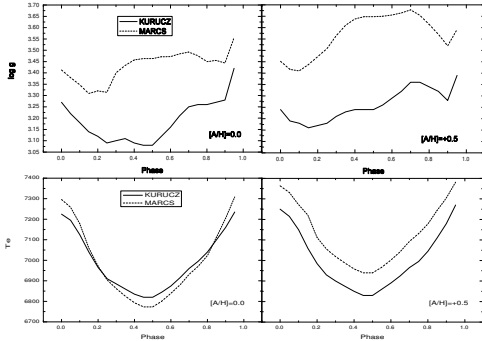


Fig. 2.— The effective temperatures and surface gravities of V1719 Cyg as a function of the phase of pulsation. The values found from Kurucz and MARCS grids of atmosphere models are shown.

data was taken from Kim et al. (1993) who separated the light curve of V1719 Cyg corresponding to the first and second periods.

The result is presented in Table 2 and Fig. 2. The second and third columns correspond to the photometric indices in the uvby color system. At the light minimum region, the MARCS model gives hotter T_{eff} . For $[\text{Fe}/\text{H}]=+0.5$, the KURUCZ model gives around 100K hotter compared to MARCS model for all the phases

but, the mean T_{eff} is almost the same for both. However, in the case of surface gravity, the difference between the two models is large. The $\log g$ values are around 0.4 smaller over the whole cycle for the Kurucz model. It seems that the different metallicity causes the large difference of T_{eff} and $[\text{Fe}/\text{H}]$ by Pena et al. (2002).

One can estimate $\log g$ from the $(\log g, \log P_0)$ diagram for HADS stars given by Andreasen (1983). However, the surface gravities for dwarf Cepheids are expected to be overestimated by about 0.1 in $\log g$ (Andreasen 1983). The calibration of $\log g$ from $uvby\beta$ photometry was based upon standard stars (ordinary rotational velocity), while the dwarf Cepheids are slow rotators with $v \sin i < 20$ km/s (McNamara 1985), and therefore, the $\log g$ value needs to be corrected for dwarf cepheids. However, it is difficult to understand why $\log g$ values estimated from two different atmospheric models are different for all phases.

For the first period 0^d267, $\log g$ is about 3.4 which is value is close to 3.43 obtained from the MARCS model with $[\text{Fe}/\text{H}]=0.0$. Kurucz results for both metallicities are about 0.2 smaller. Hence, if the period-gravity relation by Andreasen (1983, 1987) is appropriate for V1719 Cyg and this variable star can be classified as a HADS star, then the MARCS model is better for estimating the surface gravity.

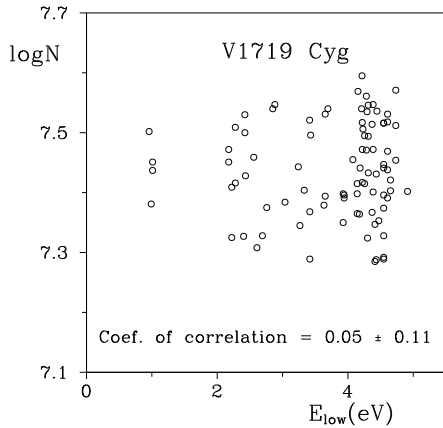


Fig. 3.— The dependence of iron abundances derived from the lines of neutral iron in the spectrum of V1719 Cyg vs. the energies of low level of these lines.

3. SPECTROSCOPIC INVESTIGATIONS

In order to estimate the metallicity of V1719 Cyg two high-resolution spectra of the star were obtained using the Bohyunsan Echelle Spectrograph (BOES) fed by the 1.8 m telescope of the Bohyunsan Optical Astronomy Observatory in Korea. The resolving power of the spectrum is $R=45,000$, the signal to noise ratio is about $S/N=100$ in the red spectral region, the wavelength coverage is from 3800 to 9600 angstroms and the Julian dates of observations are 2454740.115 and 2454740.187. The exposure times for both spectra are equal to 30 minutes.

Our reduction of the Echelle spectrum was performed using both the IRAF (Tody 1986) and DECH codes (Galazutdinov 1992). The programs allowed us to perform all the standard procedures for CCD spectra processing and analyzing. The wavelength scale was constructed on the basis of a global polynomial of the form described in Galazutdinov et al. (2000). IRAF was used for image processing and the extraction of spectra from two-dimensional images. Further data processing was performed using the DECH and URAN (Yushchenko 1998) codes. Using parameters $T_{\text{eff}}=7000$ K, $\log g=3.5$, $[\text{Fe}/\text{H}]=0.0$ and 0.5 , which are between the parameters derived by Pena et al. (2002) and JJ86, the synthetic spectrum was calculated for the whole observed wavelength range. We used Kurucz (1993) SYNTHE code to determine this. Line data were taken from the Kurucz (1993, 1995) data base, Hirata & Horaguchi (1995) line list, Morton (2000), the DREAM data base (Biemont et al. 2002), the VALD database (Piskunov et al. 1995), Fuhr & Wiese (2006), and other sources.

Synthetic spectrum helps to place the continuum level and to identify the unblended lines of neutral and ionized iron. We measured the equivalent widths of these lines in the spectrum of V1719 Cyg.

The equivalent widths obtained were used to find

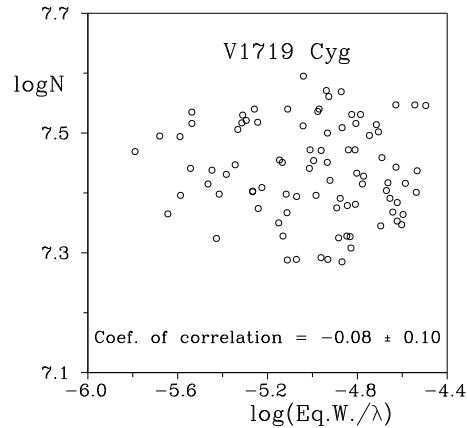


Fig. 4.— The dependence of iron abundances derived from the lines of neutral iron in the spectrum of V1719 Cyg vs. the equivalent widths ($\log(\text{equivalent widths}/\lambda)$) of these lines.

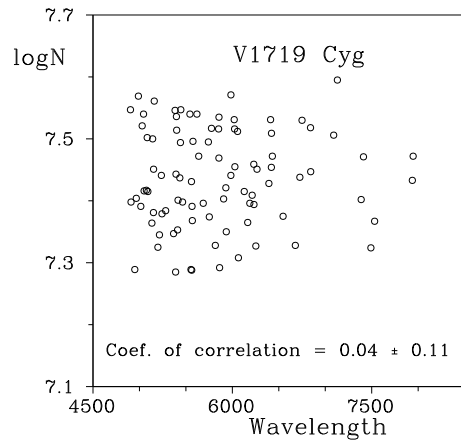


Fig. 5.— Similar to Figs. 3 and 4, but the argument is the wavelength.

values of the effective temperature, surface gravity, microturbulence and iron abundance directly from the observed spectrum. We used the method developed by Yushchenko et al. (1999) and described in more details in Gopka et al. (2004). This was helpful in our recent investigations of stars of different types (Yushchenko et al. 2005; Lee et al. 2006; Kim et al. 2007; Yushchenko et al. 2010).

Briefly, this method finds the iron abundances for a grid of models with different values of effective temperatures, surface gravities and microturbulent velocities. Kurucz (1993) grid of atmosphere models is interpolated to obtain the fine grid. For all models the correlations between the abundances of iron, derived from the individual iron lines, and the equivalent widths, the energies of the lower levels and the wavelengths of these lines are calculated. Analysis of calculations for all models permit us to select the best parameters. These parameters should simultaneously satisfy

the ionization balance, the zero correlations coefficients for the dependencies of iron abundances derived from individual lines vs. the equivalent widths, the potentials of low levels, the wavelengths of these lines and the scatter of individual iron abundance values should be minimal.

After a few iterations we were able to select the following values: $T_{\text{eff}}=7300$ K, $\log g=3.25$, $v_{\text{micro}}=3.8$ km s $^{-1}$, $\log N(\text{Fe})=7.44\pm 0.08$ (in the scale $\log N(\text{H})=12$).

These values of effective temperature, surface gravity and microturbulence were used to plot Figs. 3 to 5: the dependencies of calculated abundances vs. the equivalent widths, the energies of low levels and the wavelengths of lines of neutral iron. The scattering of individual abundances is around ± 0.15 dex. The uncertainties of atomic parameters, most significantly the oscillator strengths, are the main sources of the scatter.

Systematic errors due to the calibration of the scale of the effective temperatures, errors of equivalent widths, continuum placement, oscillator strengths, non-LTE effects and other reasons are possible. That is why we accepted the errors of effective temperature, surface gravity and microturbulent velocity to be equal to 100 K, 0.20 dex and 0.3 km s $^{-1}$ respectively as realistic values which include the internal errors of the method used only.

Systematic errors can significantly increase these numbers. The final uncertainties in the effective temperature, surface gravity and microturbulent velocity can be as high as 200 K, 0.4 dex and 0.5 km s $^{-1}$ respectively.

The selection of the error values of the derived parameters can be illustrated by Fig. 1 in our previous paper (Yushchenko et al. 2010). The last panel of this figure allows to estimate the internal precision of the method used. Note that the effective temperature, the surface gravity and the microturbulent velocity of ρ Pup ($T_{\text{eff}}=6890$ K, $\log g=3.28$, $v_{\text{micro}}=4.1$ km s $^{-1}$) are close to those of V1719 Cyg.

All calibrations of stellar effective temperatures and surface gravities are based on the investigations of individual bright stars. The scatter of the parameters derived by different methods for these bright stars can be even higher than the systematic errors accepted here for V1719 Cyg. For example the values of effective temperature of α Per published by different authors are in the range from 6750 K to 5967 K (Lee et al. 2006).

It is necessary to note that our two spectra were observed at the phases 0.74 and 0.01 of the main period. We found no significant changes in the equivalent widths and the profiles of spectral lines. The differences of equivalent widths are not higher than several percents and there is no systematic change of equivalent widths between the two spectra. Additional observations are necessary to confirm or to exclude the possible variations of line profiles and equivalent widths of the lines at other phases. In this paper the second spectrum was accepted as the primary source for mea-

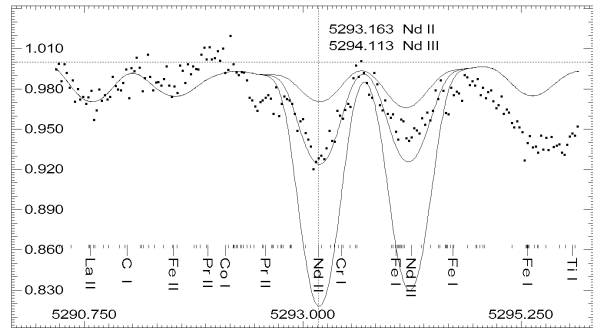


Fig. 6.— The observed (points) and synthetic (lines) spectra of V1719 Cyg in the vicinity of two lines of Nd. The axes are the wavelength in angstroms and relative fluxes. The positions of the spectral lines taken into account in the calculations are marked in the bottom part of the figure. For some of the strong lines the identifications are given. The position of the Nd II 5293.163 Å line is marked by a vertical dotted line. The different synthetic spectra are calculated with solar abundance of Nd and to the abundances of Nd increased by 0.5 and 1.0 dex.

surements of the equivalent widths. That is why the values of effective temperature, surface gravity, microturbulence, and metallicity are found for the phase 0.01 of the main period. There are no significant differences between the two spectra, but as the star is variable using the coadded spectrum cannot be justified.

Table 3 (available in the electronic version of the paper) contains the list of 89 lines of neutral iron and 30 lines of singly ionized iron. The columns are the ionization stages, wavelengths, oscillator strengths, energies of low levels, equivalent widths and derived abundances. For some of the lines, we calculated solar oscillator strengths using the Liege Solar Atlas (Delbouille et al. 1973) and Grevesse & Sauval's (1999) solar model.

4. DISCUSSION AND CONCLUSION

The temperatures and surface gravities found from the spectra ($T_{\text{eff}}=7300\pm 200$ K, $\log g=3.25\pm 0.4$) are in good agreement with those obtained from the photometry. Both Kurucz and MARCS calibrations (for zero phase: $T_{\text{eff}}=7225$ K, $\log g=3.27$ and $T_{\text{eff}}=7296$ K, $\log g=3.41$ respectively) are within the error box of spectroscopic determination.

The metallicity of the star appears to be lower in comparison to the value found from photometry. The abundance of iron in the atmosphere of V1719 Cyg ($\log N(\text{Fe})_{\text{V1719Cyg}}=7.44\pm 0.08$) is close to the solar one $\log N(\text{Fe})_{\odot}=7.45$ (Grevesse et al. 2007).

The comparison of observed spectrum with synthetic one, calculated with solar abundances of all elements show the possible overabundances of several iron group elements, yttrium, zirconium and lanthanides. This is illustrated in Fig. 6. This means that V1719 Cyg can

be a metallic line (Fm) star. For Fm stars and also for Am and Ap stars, it is very usual that iron abundance is close to the solar value, but the heavier chemical elements, namely, r-, s-processes elements are overabundant. The overabundances of heavy elements can also explain the different values of metallicities, obtained from photometry and from high resolution spectroscopy. The detailed chemical composition needs additional investigation and will be the subject of the next paper.

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