Astron. Astrophys. 312, 521–524 (1996)

ASTRONOMY AND ASTROPHYSICS

*Research Note*

# Optical and near-infrared photometry of the Vega-excess star SAO 26804=HD 233517

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Received 22 August 1995 / Accepted 14 December 1995

**Abstract.** UBVRIJHK photometry of the Vega-excess star SAO 26804=HD 233517 and several stars of its environments obtained at the 1-meter telescope of the Tien-Shan Observatory in Kazakhstan is presented. It is shown that the star has a later spectral type than has been considered previously. Its effective temperature is estimated by the visual surface brightness method as 4170 K. The star has no excess radiation in the range of 0.3-2.5 $\mu$m. A comparison of its IR-excesses with those of other K-type stars with IR-excesses is made. HD 233517 is probably more evolved than SAO 179815=HD 98800 having a very similar intrinsic spectral energy distribution (SED) and the largest IR-excess among K-type stars from the SAO catalogue.

**Key words:** circumstellar matter – stars: individual: HD 233517 – infrared: stars

## 1. Introduction

It is known that many stars which were considered previously as normal dwarfs have far-IR excesses detected by IRAS. These stars are called Vega-excess stars or $\beta$ Pictoris stars, and lists of them contain stars of all spectral types. It is suggested that these IR-excesses are remnants of the pre-main-sequence stage of evolution. Almost all such stars are bright and located very close to the Sun. Their observations contain information about the star formation history in our region of the Milky Way, about the evolution of circumstellar matter around stars of different masses. Thus, it is very important to carry out observations of such stars in a spectral region as wide as possible. In this paper we will deal with the Vega-excess K-type stars which are potential descendants of T Tau stars. Walker & Wolstencroft (1988) listed four such stars: $\epsilon$ Eri, HD 98800, HD 221354, and HD 233517. The former is very bright, located 3 parsecs from the Sun, and has the weakest excess. HD 221354 has practically the same SED as $\epsilon$ Eri, however, its observations by IRAS have stronger uncertainties, and we will not consider it. HD 98800 was recently modeled by Skinner, Barlow, & Justtanont (1992) and it has the largest excess among the Vega-excess K-type stars. These three stars have been observed in the optical region and showed no deviations from the intrinsic color-indices for their spectral types. The last star, HD 233517, was resolved at 10 $\mu$m by Skinner et al.(1995) (hereafter as S95) who presented a model of its circumstellar dust disk. Unfortunately, for this star there were no observations in the optical region reported, and S95 had to adopt its optical magnitudes from the SAO catalogue and the spectral type from the HD catalogue. Such data can be considered only as crude estimates which can lead to wrong parameters of a circumstellar envelope model in the case of strong differences between the adopted and true values. This was mentioned by S95. We independently decided to observe HD 233517 in the optical and near-IR regions and found that the star should have other main characteristics than were thought before. In the following section we describe the observations of the star and several stars from its close environments. Further we derive its temperature (Sect.3) and discuss its SED together with those of other K-type Vega-excess stars (Sect.4).

## 2. Observations

The photometric UBVRIJHK observations were carried out at the 1-meter (Tien- Shan Observatory, 2800 m altitude) telescope of the Fessenkov Astrophysical Institute of the National Academy of Sciences of the Kazakhstan Republic with the two-

*Send offprint requests to*: A.S. Miroshnichenko channel photometer-polarimeter (Bergner et al. 1988) between March 22 and April 3, 1995 (diaphragm 26″, chopping distance 84″). They were obtained simultaneously with a GaAs photomultiplier in UBVRI (Johnson system) and with a PbS detector in JHK. HD 233517 is far from the galactic plane, and we had problems with photometric standards in the optical bands. Red stars have not been observed in this region, bright stars are rare here. We have chosen as a comparison star the closest and latest one, HD 69682. It was observed by Kornilov et al. (1991) in the WBVR photometric system. This system differs from the Johnson one mainly in its blue part. However, its W-B is very close to the Johnson U-B for stars of A-F spectral types. For 238 A8-F5 dwarfs from the Bright Stars catalogue (BSC) having WBVR photometry we derive the following relationship:

$$U - B = (0.618 \pm 0.009)(W - B) + (0.0585 \pm 0.0008) \quad (1)$$

Thus, $W - B = -0\overset{m}{.}01$ for HD 69682 corresponds to $U - B = 0\overset{m}{.}05$. B-V and V-R are in a very good agreement in the both systems. To obtain R-I for HD 69682 we measured its color-index in our instrumental system, corrected it for the atmospheric extinction, and compared with those of other stars observed during this year (about 25) using the relation between the Johnson and our R-I (Bergner et al. 1988). It was found to be $0\overset{m}{.}15$, in excellent agreement with R-I for the spectral type of HD 69682. The latter value we found using 74 A8-F5 dwarfs from the BSC with Johnson UBVRI photometry. As a JHK standard we used BS 3323 which was previously observed only in the J and K bands. We adopted the H-K value of $0\overset{m}{.}08$ given by Bessell & Brett (1988) for the G5 III spectral type. Comparing our observational results for this star with those for other infrared standards we obtained the same value of H-K for BS 3323. The adopted magnitudes for J, H, and K- bands are $1\overset{m}{.}98$, $1\overset{m}{.}52$, and $1\overset{m}{.}44$ respectively. In order to check whether HD 233517 is variable or not we also observed several stars situating very close to it. One of them, HD 233520, is 2′ from HD 233517, and, according to the HD catalogue, has a comparable brightness ($8\overset{m}{.}8$), and a spectral type (K2) close to that of HD 233517. Other stars are brighter but they were observed photometrically previously. The photometry of HD 233517 is presented in Table 1. The averaged results together with those for the stars from its environments, and the comparison stars together with the atmospheric extinction coefficients are presented in Table 2. These coefficients are nearly $0\overset{m}{.}05$ per air mass in the J, H, and K-bands. We obtained seven UBVRI and three JHK observations of HD 233517 during 12 nights between 1995 March 22 and April 3. No statistically significant photometric variations exceeding were detected (internal observational errors due to the signal-to-noise ratio were about $0\overset{m}{.}025$ in the U-band, $0\overset{m}{.}01$ in the BVRI, and $0\overset{m}{.}05 - 0\overset{m}{.}3$ in the JHK bands). The errors given in Table 1 contain uncertainties of transformations between the instrumental and Johnson photometric system. They are quite large in U-B, V-R, and R-I because of different spectral types of HD 233517 and its comparison star, HD 69682. An error of a single observation is high in the near-infrared because of a relatively low sensitivity of our PbS detector and weather conditions which are usually not stable in spring. Nevertheless the mean values of our infrared magnitudes obtained in different nights are very close one another, and the resulting statistical errors are low. For instance, the K-magnitudes were $6\overset{m}{.}64 \pm 0\overset{m}{.}29$, $6\overset{m}{.}62 \pm 0\overset{m}{.}29$, $6\overset{m}{.}59 \pm 0\overset{m}{.}22$. When we converted our infrared magnitudes into fluxes using the calibration of Koorneeff (1983), we found the latter in very good agreement with those obtained by S95 (namely observed fluxes were listed by S95). However, the visual magnitudes of HD 233517 appeared to be substantially fainter than those adopted by S95. Our observations showed that HD 233520 was also fainter than indicated in the HD catalogue. This may be due to the redness of the stars and photographical nature of magnitudes listed in the SAO and HD catalogue. The differences between the fluxes of HD 233517 measured by us and S95 at the common wavelengths are the following: $\Delta B = 0\overset{m}{.}41$, $\Delta V = 0\overset{m}{.}45$, $\Delta J = 0\overset{m}{.}00$, $\Delta H = -0\overset{m}{.}07$, $\Delta K = -0\overset{m}{.}02$. Other stars observed in the HD 233517 environments also did not exhibit any variations. The magnitudes and color-indices we obtained for them are very close to the published values and consistent with intrinsic ones for their spectral types.

## 3. Parameters of the star

First of all, we studied intrinsic color-indices for K-type dwarfs and giants from the BSC in the Johnson UBVRI system to understand whether HD 233517 had interstellar reddening or not. The result is that the star's color-indices satisfy very well to all dependences between the intrinsic ones and correspond to the spectral classes K6 or K7 V. Other four stars observed in the vicinity of the star are more distant and also are not affected by interstellar reddening. HD 98800 having almost the same color-indices as HD 233517 was classified as K5 V. We have no spectroscopic parameters of HD 233517, and the intrinsic color-indices of late-K dwarfs exhibit too large a scatter to derive the exact spectral type from photometry. The other way is to estimate effective temperature using the visual surface brightness method first proposed by Wesselink (1969) and calibrated by Barnes et al. (1976). The main equation of this method is:

$$lgT_{eff} + 0.1BC = 4.2207 - 0.1V_0 - 0.5lg\phi \quad (2)$$

where $T_{eff}$ and BC are effective temperature of the star and its bolometric correction, $V_0$ is the dereddened V-magnitude, and $\phi$ is its angular diameter in milliarcsec.

Barnes et al. (1976) showed that the right part of (2) called as surface brightness parameter $(F_V)$ correlated well with different optical color-indices, and, in particular, the relationship between $F_V$ and $(V - R)_0$ is not sensitive to gravitational acceleration, i.e. to the luminosity class of a star. Using angular diameters and effective temperatures for 24 G8-M3 stars derived by Blackwell et al. (1991) we found that:

$$F_V = 3.902 \pm 0.005 - (0.350 \pm 0.004)(V - R)_0 \quad (3)$$

where $(V - R)_0$ was derived from the WBVR system of Kornilov et al. (1991) which is more accurately determined those of Johnson ones. Deriving also the relationship between BC and $T_{eff}$ for the calibrating stars and using for HD 233517 $(V - R) =$

**Table 1.** Photometry of HD 233517

| JD,2440000+ | V | B-V | U-B | V-R | R-I | J | H | K |
|---|---|---|---|---|---|---|---|---|
| 9799.18 | 9.88 | 1.20 | 1.23 | 1.00 | 0.76 | | | |
| | .01 | .01 | .03 | .04 | .04 | | | |
| 9799.21 | 9.87 | 1.21 | 1.25 | 1.02 | 0.75 | | | |
| | .02 | .02 | .03 | .05 | .04 | | | |
| 9800.22 | 9.86 | 1.21 | 1.25 | 1.03 | 0.77 | | | |
| | .01 | .01 | .03 | .04 | .04 | | | |
| 9803.16 | 9.87 | 1.20 | 1.26 | 1.01 | 0.77 | | | |
| | .01 | .01 | .03 | .04 | .04 | | | |
| 9804.16 | 9.86 | 1.21 | 1.23 | 1.02 | 0.77 | 7.24 | 6.73 | 6.64 |
| | .01 | .01 | .03 | .04 | .04 | .06 | .03 | .29 |
| 9809.12 | 9.85 | 1.20 | 1.26 | 1.01 | 0.78 | 7.44 | 6.81 | 6.62 |
| | .01 | .01 | .02 | .04 | .04 | .17 | .10 | .29 |
| 9811.14 | 9.85 | 1.21 | 1.26 | 1.00 | 0.78 | | | 6.59 |
| | .01 | .01 | .03 | .04 | .04 | | | .22 |

In each second line the observational errors are presented.

**Table 2.** Averaged results for HD 233517 and surrounding stars

| HD | MK type | V | B-V | U-B | V-R | R-I | V-J | V-H | V-K | n | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 233517 | | 9.87 | 1.25 | 1.20 | 1.02 | 0.77 | 2.55 | 3.10 | 3.24 | 7,3 | 4 |
| 69682 | F0 IV | 6.49 | 0.28: | | | | | | | | 1 |
| | | 6.498 | 0.297 | 0.05 | 0.251 | 0.15[a] | | | | | 2 |
| | | 6.50 | 0.29 | 0.06 | | | | | | | 3 |
| 70313 | A3 V | 5.51 | 0.11 | 0.08 | | | | | | | 1 |
| | | 5.528 | 0.078 | 0.105 | 0.083 | | | | | | 2 |
| | | 5.49 | 0.10 | 0.07 | 0.06 | 0.00 | 0.13 | 0.17 | 0.18 | 2,1 | 4 |
| 70919 | | 7.90 | 0.24 | 0.06 | | | | | | | 3 |
| | F0 V[a] | 7.92 | 0.24 | 0.03 | 0.20 | 0.11 | | 0.71 | 0.74 | 2,1 | 4 |
| 233520 | K2 V[a] | 9.35 | 0.96 | 0.63 | 0.75 | 0.57 | | | | 3,0 | 4 |
| [b] | | 0.15 | 0.05 | 0.22 | 0.05 | 0.05 | | | | | |

[a] derived by us
[b] the atmospheric extinction coefficients
References: 1 - BSC, 2 - Kornilov et al. 1991, 3 - Mermilliod 1991, 4 -This work
n is a number of the optical (first number) and infrared (second number) observations

$1^m_.02$ we get $F_V = 3.545$, $T_{eff} = 4180K$, and $BC = -0^m_.74$. Additionally we found that the relationship between $(R-I)_0$ and $(V-R)_0$ for K-type giants and dwarfs are very close and used the star's $(R-I)$ to obtain other estimates of these parameters from the relationship between $F_V$ and $(R-I)_0$:

$$F_V = 3.792 \pm 0.008 - (0.33 \pm 0.01)(R-I)_0 \qquad (4)$$

For $(R-I) = 0^m_.77$ we have led the following results: $F_V = 3.536$, $T_{eff} = 4140$, and $BC = -0^m_.78$ which are in the excellent agreement with the former ones. We adopt $T_{eff} = 4170$ and $BC = -0^m_.75$ because the Eq. (3) has smaller uncertainties. Finally, from (2) we derived $\phi = 2.5\ 10^{-4}$ arcsec.

## 4. Discussion

The results obtained from our optical photometry show that HD 233517 (a) is of a later type than K2 (taken from the HD catalogue) and (b) has an effective temperature lower than that adopted by S95 (4500 K). Its V-K and J-H are more consistent with those of late-K dwarfs ($V-K = 3^m_.16$ for K7 V, Bessell & Brett 1988) than with those of late-K giants ($3^m_.60$ for K5 III). So, we can conclude that HD 233517 is a late-K dwarf. Other arguments against the a giant hypothesis were discussed in S95. The SED of HD 233517 between 0.3 and 2.2 $\mu$m is very close to that of HD 98800 (Gregorio-Hetem et al. 1992, Zuckerman & Becklin 1993). Their SEDs in the range between 0.3 and 100 $\mu$m are presented in Fig. 1 together with that of $\epsilon$ Eri. One can see that the latter star has very small IR-excess near 100 $\mu$m while other two have wide excesses beginning from about 5 $\mu$m. Fekel & Bopp (1993) found HD 98800 to be a BY Draconis star, estimating its age as less than 10 Myr, its mass as 0.7 $M_\odot$, $M_V = 6^m_.87$, and its distance D = 34 pc, and they placed it $1^m$ above the main sequence according to evolutionary tracks of Pinsonneault et al. (1990). They predicted that it should be photometrically

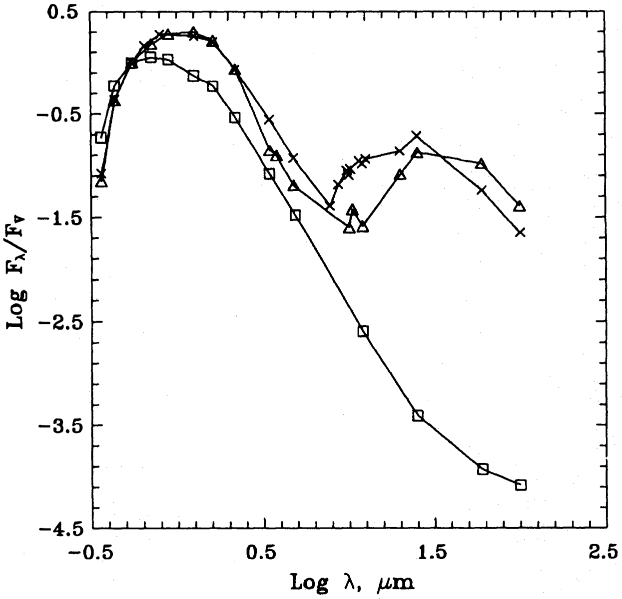


**Fig. 1.** Spectral energy distributions of Vega-excess K-type stars. $\epsilon$ Eri (□), HD 233517 (△), HD 98800 (×)

variable with a period of less than $10^d$ and an amplitude about $0^m.1$. The observed amplitude in the V-band is $0^m.24$ (Gregorio-Hetem et al. 1992, Zuckerman & Becklin 1993). We have not registered any brightness variations of HD 233517 during a 12 day interval. This fact together with the smaller and more long-wavelength IR-excess of HD 233517 than that of HD 98800 can be interpreted as an evidence that it is older than HD 98800 and closer to the main sequence. If we place HD 233517 on the main sequence (radius $R = 0.66R_\odot$, Strajzhys & Kurilene 1981) we get D = 25 pc. This value can be considered as a lower limit for its distance. The upper bound is about 40 pc following the suggestions of Fekel & Bopp (1993) for HD 98800.

## 5. Conclusions

We obtained UBVRIJHK photometry of the Vega-excess star HD 233517 during a $12^d$ interval. No photometric variations have been detected. From the analysis of its color-indices we concluded that HD 233517 is an unreddened late-K dwarf (possibly K5-K7 V) with $T_{eff}$ = 4170, $BC$ = $-0^m.75$, and $\phi = 2.5\ 10^{-4}$ arcsec. Its IR-excess is smaller and shifted longward from that of HD 98800 which indicates that HD 233517 is closer to the main sequence. We estimated a distance towards the star between 25 and 40 pc. Hence, its parallax can be measured by HIPPARCOS and evolutionary status can be refined. Additional photometric observations are desirable to look for variability, spectroscopy is needed to study spectral lines.

*Acknowledgements.* Yu.K.Bergner and A.S.Miroshnichenko are grateful to the International Science Foundation for the partial support of this work (grant NS-6000). We thank A.V.Mironov for providing the WBVR photometric catalogue in electronic form.

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