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CIRCUMSTELLAR DISK AROUND HD 143275 AND INTERSTELLAR ABSORPTION

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ABSTRACT

This paper presents a collection of spectra of the star HD 143275 (δ Sco), acquired during the last 11 years. During this period, stellar absorption lines turned into emission features possibly originating in the circumstellar disk. We demonstrate that the circumstellar shell does not produce any components of interstellar absorption features (atomic lines, molecular features, and diffuse interstellar bands), which remain of the same equivalent widths during the whole period covered by our observations.

Subject headings: ISM: atoms — ISM: clouds — ISM: lines and bands — ISM: molecules

1. INTRODUCTION

Young stars must have formed recently from clouds of interstellar matter in the process of their condensation. Emission lines, originated in circumstellar disks, are common among these objects. Such disks have already been observed around several young stars, even in direct images, e.g., of AB Aur[1] or ρ Oph.[2] When a disk is seen edge-on, the profiles of stellar lines turn into emission features, sometimes with absorption in their centers. The direct images prove that the disks may be quite opaque in the continuous spectrum; i.e., they are sources of reasonably high extinction.

It seems interesting to check whether the above-mentioned extinction, originating in conditions apparently different from those of the general interstellar space, is associated with any of the known interstellar spectral features. The latter are carried by free atoms (Ca II, Na I, K I), by simple molecular species (CH, CN, CH^+), or by some unidentified, very likely complex, molecules (diffuse interstellar bands [DIBs]). The above-mentioned features form absorption spectra of interstellar clouds. It was already strongly suggested by Krełowski et al. (1992) that many interstellar absorption features change in unison—reacting to varying conditions in the interstellar medium. The latter paper also claims that the shape of the extinction curve changes with the variations of strength ratios of the above-mentioned spectral features.

To solve the longest standing unsolved problem of spectroscopy—identification of DIB carriers—it is important to investigate the influence of varying physical conditions on their intensities and profiles. This goal may be achieved by means of relating DIBs to atomic and molecular features. Being well identified, they may allow us to decipher the physical conditions inside the intervening clouds. Circumstellar shells are situated in very close proximity to hot stars, and thus, physical conditions inside them are very likely extreme, far different from typical interstellar medium. The absence of diffuse interstellar bands in the circumstellar shell of the carbon star IRC +10 216 was recently reported by Kendall et al. (2002, 2004). However, physical conditions in close vicinities of very different objects, like HD 143275 and IRC +10 216, do not have to be the same that motivates our search for DIBs toward HD 143275. On the other hand, there is a good example of possible formation/destruction of DIB carriers in circumstellar envelopes. Galazutdinov et al. (1999) demonstrated such variations of interstellar features in the spectrum of O9.5Ia star HD 188209. The reported variations are of a very short timescale (days), and thus, they can originate in circumstellar space only.

Gandet et al. (2002) noticed cyclical brightness variations with an average period of 71 days in the light curve of HD 143275. These authors found the general maximum brightness in 2001–2002, where the average magnitude was almost constant. This variability reflects apparent changes of the amount of circumstellar matter surrounding HD 143275.

The star was recently reported as a very specific object in which stellar lines have turned into emission features (Miroshnichenko et al. 2003). Increasing the intensity of emission lines also reflects an increase in the amount of circumstellar matter toward the star noted above. The spectral database, collected by us during the last 11 years, allows one to observe a couple of phases of this process. Moreover, we can compare the interstellar spectral features observed before the stellar lines revealed the emission profiles with the most recent ones. We expect to check whether the intensities of interstellar absorption features remain the same (in such a case they do not originate in the circumstellar shell at all) or whether they would grow, revealing the presence of their carriers in a close vicinity of the star.

2. THE OBSERVATIONAL DATA

The oldest observations used in this study were obtained at 3.6 m Canada-France-Hawaii telescope (CFHT) in 1989 September (Krełowski et al. 1992). The spectrograph fed the coudé spectrograph, which formed the spectrum in the Reticon detector system. The system yields a resolving power (2 pixels) about $R \sim 40{,}000$. Only a very narrow range, covering the major diffuse bands 5780 and 5797, was covered in this observation.

The next spectrum of HD 143275 was acquired by one of us (J. K.) at the McDonald Observatory in Texas on 1993 May 3. The instrument was the Sandiford echelle spectrograph attached to the 2.1 m telescope. The resolution of the spectra, covering the

[1] See http://antwrp.gsfc.nasa.gov/apod/ap990611.html.
[2] See http://antwrp.gsfc.nasa.gov/apod/ap020607.html.

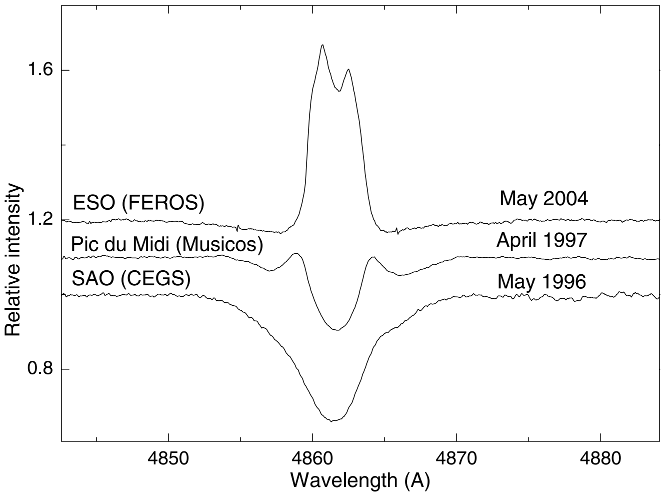

FIG. 1.—Hβ line profile transformation in the spectrum of HD 143275 during the last 8 years.

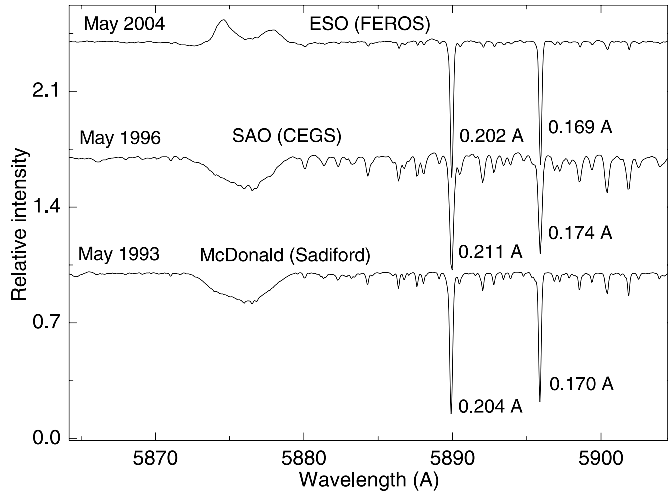

FIG. 2.—Behavior of the He I 5876 Å stellar line during the last 12 years. Note the equivalent widths of the sodium interstellar lines.

spectral range ∼5600–7000 is about $R = 60{,}000$ (Krełowski & Sneden 1993). This spectrum is of very high signal-to-noise ratio (S/N ∼ 500). The recorded wavelength range covers most of the known strong DIBs but omits a majority of the atomic and molecular features.

Another spectrum was recorded using the CEGS spectrograph attached to the 1 m Zeiss telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAN)—see, e.g., Krełowski et al. (1998). In this case the resolution is $R = 40{,}000$; the S/N was limited to about ∼200. The spectrum covers the range from ∼3500 to ∼10,000 Å. It was recorded on 1996 May 5.

At the beginning of 1997 April one of us (J. K.) recorded another spectrum of HD 143275—this time using the blue trail of the Musicos spectrograph fed with the 2 m Bernard Lyot telescope of the Pic du Midi Observatory in Pyrenees. The resolution of the spectrum is $R = 32{,}000$, and it covers the range ∼3800–5600 Å (Galazutdinov et al. 1998). The S/N reaches the value of ∼240 in this spectrum.

On 2001 May 4 we recorded another spectrum, this time using the MAESTRO spectrograph attached to the 2 m telescope of the Terskol Observatory in Northern Caucasia (Musaev et al. 1999). The MAESTRO spectrograph allows us to cover in one exposure the range ∼3500–10100 Å, divided into 92 orders. In this case we reached $R = 120{,}000$, but because of the resolution, the spectral orders are much longer than the CCD matrix applied, and thus far not all the possibly interesting spectral features are recorded. Generally, the range covered is ∼3500 to ∼10000 Å, but only about 40% of this is actually recorded.

On 2004 May 4 we also used the Feros echelle spectrograph of the European Southern Observatory (ESO), which allows a fixed resolution $R \equiv \lambda/\Delta\lambda$ of 48,000. This instrument allows us to get the whole available spectral range (∼3700–9200 Å, divided into 37 orders) recorded in a single exposure. The flat-fielding can be done very precisely in the case of Feros, as it is a fiber-fed spectrograph, but this is not of basic importance while measuring equivalent widths of reasonably narrow features.

The most recent data were obtained using the fiber-fed echelle spectrograph installed at 1.8 m telescope of the Bohyunsan Optical Astronomy Observatory (BOAO) in South Korea. The spectrograph has three observational modes providing resolving power 30,000; 45,000 and 90,000. Our spectrum is of the highest one. In all of cases the spectrograph allows us to record whole spectral range from ∼3500 to ∼10000 Å divided into 75–76 spectral orders.

Our reduction of the echelle spectra was made using the DECH code (Galazutdinov 1992). This program allows us to perform all standard procedures of CCD spectra processing and analyzing. For wavelength calibration, we used either the solar spectrum or the spectrum of Procyon, which provided at least 15–20 points in each spectral order. The laboratory wavelengths are taken from the tables of solar spectra (Pierce & Breckinridge 1973). The wavelength scale was constructed on the basis of a global polynomial of the form, described in detail in Galazutdinov et al. (2000). The final solution typically uses 1500 lines, and the formal rms residual error between the fit and the position of the lines is usually ≤0.003 Å.

3. RESULTS

Our spectra, collected during the last decade, cover the period of transformation of HD 143275 from "normal" B star into the Be one. The phenomenon is demonstrated clearly in Figure 1.

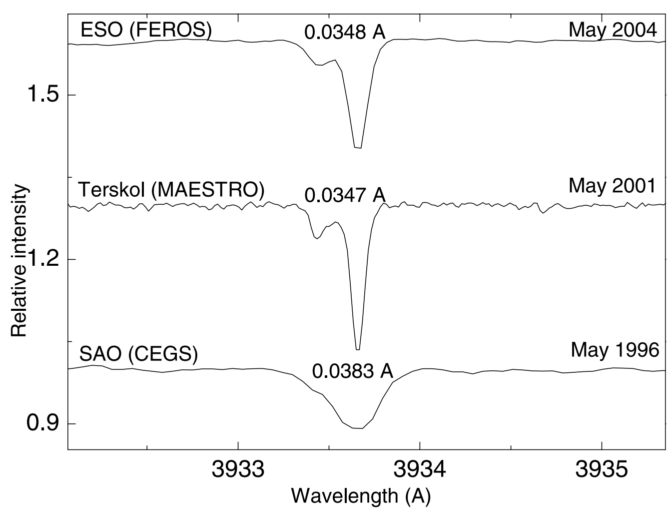

FIG. 3.—Interstellar Ca II K line observed toward HD 143275. No changes of equivalent width are seen. Some visible variation of line profile are due to the spectral resolution effect.

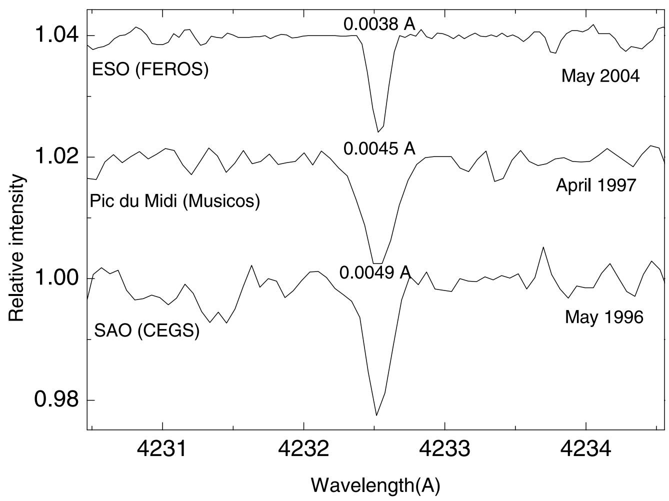

FIG. 4.—Interstellar CH^+ line is of apparently constant equivalent width.

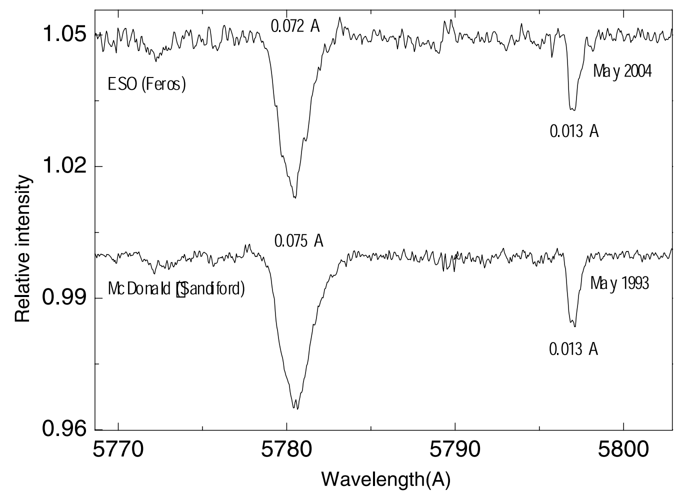

FIG. 6.—Major diffuse interstellar bands observed in two epochs characterized by a large difference in the amount of circumstellar matter surrounding the star.

Apparently in 1996 May the stellar lines were purely absorption features, without any sign of the disk surrounding this object. The disklike profile of Hβ started to form in early 1997. Since that time, the classical disk-type profile was formed and is still observable. Similar profiles of many other stellar lines are observed in the recent HD 143275 spectra.

Figure 2 presents the changes of the He I 5876 Å stellar line. Its profile was free of any signs of the disk emission in both 1993 May and 1996 May. The profile of this broad line is clearly identical in the two spectra from McDonald and SAO RAN. The recent spectrum acquired at ESO in 2004 May shows evident emissions. It is, however, interesting that the equivalent widths of the neighbor interstellar sodium doublet remain the same inside the observational uncertainties. This result suggests that the yellow sodium lines, usually the strongest spectral features originating in interstellar clouds, are not formed in the circumstellar shell.

A very similar result was found for the interstellar Ca II doublet of H and K lines. Figure 3 demonstrates this result for the K line. Our spectra are of different resolutions: $R = 40{,}000$ (CEGS), $R = 120{,}000$ (MAESTRO), and $R = 48{,}000$ (Feros). This causes the apparent profile variations. Nevertheless, the measured equivalent widths are practically identical: no systematic change of intensity can be traced in the collected material. This result could in fact be anticipated, as the Ca II line intensities are correlated with distance, so the relation should be hardly observable in the presence of strong disk components (Struve 1928; Megier et al. 2005).

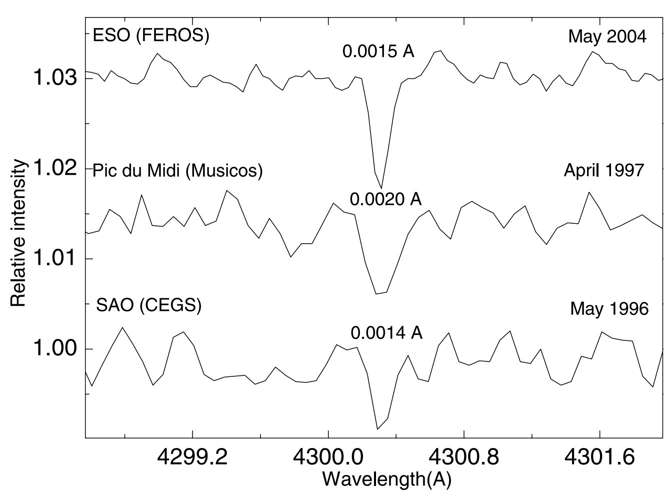

FIG. 5.—Interstellar CH line. The very weak feature shows no systematic variations.

In our spectra one can trace two molecular lines: CH^+ (4232.5 Å) and CH (4300.3 Å). Both are very weak, and thus their equivalent widths cannot be measured with a high precision. The features are shown in Figures 4 and 5, respectively, where the same spectra as in Figure 1 are shown in the same order. As in the case of atomic lines, we have not found any systematic changes of equivalent widths of both features. The equivalent width of CH^+ is apparently almost 3 times higher than that of CH.

The major diffuse interstellar bands (DIBs), observed in 1993 May at McDonald and in 2004 May at ESO are depicted in Figure 6. Both spectra are of similar resolution; the McDonald one is of a slightly higher resolution and also better S/N. Anyway, the equivalent widths are practically identical; no change related to the increase of the amount of circumstellar matter along the line of sight can be found. Unfortunately, we do not have any spectrum taken in between the two dates and covering the depicted bands. The conclusion is clear: the DIB carriers are apparently absent in the circumstellar shell around HD 143275.

Equivalent widths of other DIBs, not depicted in our figures, are given in Table 1. Apparently, no systematic changes of the bands' intensity can be observed during the last decade where the spectacular variations of stellar line profiles have been found. Physical conditions inside circumstellar shells must be so different from those in the general interstellar medium that no interstellar features can be traced toward HD 143275.

4. CONCLUSIONS

We have demonstrated that interstellar spectral features in spectra of HD 143275 are really interstellar; i.e., they do not originate in the circumstellar space. During the period of our observations the amount of circumstellar matter observed along the line of sight toward HD 143275 changed dramatically. None of the interstellar features demonstrated evident variations of equivalent width during this period. The above-described phenomenon supports the well-known observational fact that spectra of Be stars, even those having reasonably high reddening $E(B - V)$, do not demonstrate the appropriate intensity of interstellar lines (Krełowski 1997).

TABLE 1

Equivalent Widths (in mÅ) of Selected Interstellar Features Observed in the Spectrum of HD 143275

Observation[a]	Date	Ca II K	K I (7698)	CH^+	CH	5780 Å Band	5797 Å Band	6196 Å Band	6614 Å Band
CFHT	1989 Sep 15	...	...	...	...	71 ± 3	15 ± 1	...	...
McD	1993 May 3	...	...	...	...	75 ± 4	13 ± 1	7.4 ± 1	27 ± 3
SAO	1996 May 5	38 ± 2	32 ± 3	4.9 ± 1.5	1.4 ± 0.6	72 ± 2	...	...	28 ± 4
PdM	1997 Apr 15	32 ± 5	...	4.5 ± 1	2.0 ± 0.6	...	...	...	...
T061	2001 May 4	35 ± 1.5	35 ± 5	...	...	...	...	...	28 ± 4
T140	2003 Mar 9	35 ± 1.5	25 ± 3	...	2.0 ± 0.3	...	...	...	...
Fer	2004 May 4	35 ± 1	29 ± 1	3.8 ± 0.2	1.5 ± 0.4	72 ± 3	13 ± 2	6.5 ± 0.	32 ± 2
T151	2004 May 22	32 ± 1.5	...	3.5 ± 0.5	2.3 ± 0.4	...	...	...	...
T152	2004 May 23	34 ± 1	...	3.5 ± 0.5	2.4 ± 0.3	...	...	...	...
BOES	2004 May 29	35 ± 3	27 ± 2	3.5 ± 0.8	2.5 ± 0.5	72 ± 1	13 ± 3	...	32 ± 3

Notes.—Column headings as follows. Observation: spectrograph used. Date: date of observations. Ca II K, K I (7698), CH^+, and CH: equivalent widths in mÅ of the lines at 3933, 7698, 4232, and 4300 Å, respectively. The last four columns show the equivalent widths (in mÅ) of the DIBs at the identified wavelengths.

[a] Observation abbreviations are as follows. CFHT: CFHT's coudé spectrograph (USA); McD: McDonald's Sandiford echelle (USA); SAO: SAO RAS CEGS (Russia); PdM: Pic du Midi's Musicos (France); T041, T140, T151, T152: Terskol's MAESTRO (Russia); Fer: La Silla (ESO)'s Feros (Chile); BOES: BOAO's fiber-fed echelle spectrograph (South Korea).

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