RADIAL VELOCITIES OF Be STAR KAPPA DRACONIS IN THE YEARS 1983-1984

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ABSTRACT. In studying the problem of the realness of the variations of the radial velocity of Be star kappa Draconis, we determined the radial velocities of this star by measuring 17 spectrograms obtained at the National Astronomical Observatory (NAO) in Rozen. We found no convincing proof of these variations in the years 1983 and 1984. Moreover, we have compared the results of various methods of measuring the radial velocity used at the NAO in Rozen and at the Skalnate Pleso Observatory of the Astronomical Institute of the Slovak Academy of Sciences (SPO).

ЛУЧЕВЫЕ СКОРОСТИ Be ЗВЕЗДЫ КАППА ДРАКОНА В ГОДАХ I983 - I984
В связи с вопросом реальности изменений лучевых скоростей Be звезды каппа Дракона мы определили лучевые скорости этой звезды из I7 спектрограмм, которые были сняты в НАО Рожен в годах I983 - I984. Мы неустановили никакого убедительного доказателства таких изменений. Мы также сравнили результаты измерений лучевой скорости разными измерительными приборами.

RADIÁLNÍ RYCHLOSTI Be HVĚZDY KAPPA DRACONIS V LETECH 1983-1984
V souvislosti s otázkou reálnosti změn radiální rychlosti Be hvězdy kappa Dra jsme určili radiální rychlosti této hvězdy proměřením 17 spektrogramů získaných

na NAO Rožen. Nenašli jsme žádný přesvědčivý důkaz těchto změn v letech 1983-1984. Navíc jsme porovnali výsledky různých měřících metod radiální rychlosti na observatořích NAO Rožen a AsÚ SAV Skalnaté Pleso.

1. INTRODUCTION

The star kappa Draconis (HD 109 387, HR 4787, MWC 222; m_v= 3.9, Sp B7e) is being systematically studied as part of the international campaign of the comprhensive study of selected Be stars, coordinated by the Ondrejov Observatory of the Astronomical Institute of the Czechoslovak Academy of Sciences.

Conspicuous hydrogen emission lines in the spectrum were already discovered in the 1890's. Later it was found that the character and intensity of the emission lines vary within a wide interval. In studying the radial velocities, some authors (Baker, 1923; Hill, 1926; Miczaika, 1951) found periodic changes of the radial velocities, other authors (Struve, 1952; Underhill, 1954) found no such changes within the limits of observational errors.

All the published velocities were determined from prism spectrograms with reciprocal dispersion of 1 - 5 nm mm^{-1}. Moreover, personal errors were introduced into the measurements, because the precise setting of shallow and considerably wide spectral lines (v_{rot} sin i = 280 km s^{-1}) on classical Abbe comparator is quite problematic. Thus the problem of whether the variations of radial velocity of kappa Draconis were real remained open; on the one hand, variations with a half-amplitude of K = 22.54 km s^{-1} and period P = 0.890384 days were found (Miczaika, 1951), on the other, these variations were rejected. A considerable number of grid spectrograms of a higher reciprocal dispersion is now available, and there are also electronic devices to measure them. Consequently, it seems expedient to deal with this problem once again. This is the subject of the present paper.

2. OBSERVATIONAL MATERIAL AND ITS REDUCTION

Apart from several Ondrejov spectrograms, also 17 spectrograms taken with the 2-m telescope of the NAO in Rozen were available. The spectra were recorded in the coude spectrograph on Kodak IIaO emulsion with a reciprocal dispersion of about 0.9 nm mm^{-1} in the spectral interval of 350 - 490 nm in the years 1983 and 1984, and their list is given in Tab. 1. The table contains: 1) the plate number, 2) the date and time of the midpoint of the observation in UT, 3) the corresponding heliocentric Julian date HJD, 4) the exposure time of the plate, 5) the type of emulsion.

The radial velocities were measured with the oscilloscopic comparator of the NAO in Rozen by means of identifying the depicted profile of the line with its mirror image on the oscilloscope. With some lines in some spectrograms, the setting of the centres of the line profiles was affected by the structure and asymmetry of the depicted profiles.

Table 1

Plate	Time of exp. (UT)	HJD	Exposure	Emulsion
1439	1983 02 26 01^h04^m	2445391.5470	16^m	IIaO
1440	01 31	.5657	14	IIaO
1442	02 34	.6095	14	IIaO
1443	02 58	.6261	14	IIaO
1460	02 27 00 17	392.5143	8	IIaO
1461	00 39	.5296	8	IIaO
1463	01 23	.5601	10	IIaO
1464	01 44	.5747	10	IIaO
1466	02 27	.6046	10	IIaO
1467	02 46	.6178	11	IIaO
1469	03 33	.6504	10	IIaO
1470	03 50	.6619	10	IIaO
1507	04 10 20 54	435.3720	8	IIaO
1884	1984 05 07 19 23	828.3076	5	IIaO
1911	07 10 00 20	891.5114	11	IIaO
2253	11 15 04 00	2446019.6670	20	IIaO
2254	04 28	.6864	23	IIaO

Table 3

Plate	Time of exp. (UT)	HJD	Exposure	Emulsion
1731	1974 02 27. 22^h12^m	2442106.4275	96^m	IIaOb
1747	03 11 20 27	118.3585	90	IIIaJb
1749	23 46	.4925	60	IIIaJb
1761	03 21 22 46	128.4505	60	IIIaJb
1810	06 05 20 36	204.3570	60	IIIaJb
1824	07 03 00 39	231.5248	120	IIIaJb

The spectrum of kappa Draconis is not abundant in spectral lines. The measureable lines are: hydrogen H I (H_{beta} - H_{14}), helium He I (381.9637, 400.9268, 402.6209, 414.3761, 438.7929, 447.1708 nm) and magnesium Mg II (448.1228). The measured data were processed using the HEC10 program kindly provided by Dr. Harmanec from the Ondrejov Observatory. The hydrogen lines and other lines were reduced separately. The mean value of the radial velocity for aach plate was computed from the values of the velocity for the separate lines. The resultant radial velocities RV and the rms errors of these values, as well as the number N of spectral lines used on the plate are given in Tab. 2. Measureable violet wing (VW) and red wing (RW) emission components occurred with lines H_{beta}, H_{gamma}, H_{delta}. Their relevant radial velocities are also given in Tab. 2.

For the purpose of comparing the individual measuring methods, also 6

Table 2

		Radial velocity (km s^{-1})							VW (km s^{-1})			RW (km s^{-1})		
Plate	HJD	H I		N	He I		N	Mg II	H_{beta}	H_{gamma}	H_{delta}	H_{beta}	H_{gamma}	H_{delta}
1439	2445391.5470	- 9.1	± 6.1	10	-27.0	±16.6	2		- 98.0					
1440	.5657	- 8.7	6.3	9	-26.6	10.0	3		- 87.3					
1442	.6095	- 9.7	4.8	9	-21.0	10.9	3		- 85.6	-125.3			112.6	
1443	.6261	- 8.4	2.3	9	-19.3	5.0	3		- 91.8	-116.9			101.0	
1460	392.5143	- 8.8	4.2	10	-41.7	19.9	4	-38.2	- 96.3	-134.7	-132.6	68.6	125.0	99.5
1461	.5296	-10.5	3.6	10	-22.9	2.3	3		-100.3	-118.2		76.4	104.9	
1463	.5601	- 9.4	5.3	9	-25.8	3.7	2		-102.7	-123.6		71.5	121.2	
1464	.5747	- 8.5	4.5	10	-24.2	6.0	5	- 7.2	-100.8	-125.7		72.5	104.3	
1466	.6046	- 8.8	5.0	9	-20.9	3.6	3		-110.5	-109.6		74.1	102.4	
1467	.6178	- 9.3	3.5	8	- 7.8	9.8	5		-101.4	-122.3		71.7	111.5	
1469	.6504	-13.8	3.3	10	-21.1	7.0	6	5.0	-100.0	-130.7		79.1	124.2	
1470	.6619	-11.8	2.4	8	-23.7	8.3	4		- 92.6	- 99.4	-170.0	77.0	118.6	153.3
1507	435.3720	- 2.2	3.2	10	- 5.1	3.4	5	6.9	-100.4	-120.5	-134.4	75.5	104.8	126.6
1884	828.3076	-10.0	2.9	9	-17.8	11.3	4	14.1	- 86.3	-109.7		75.6	113.3	
1911	891.5114	-12.6	3.0	9	-21.9	5.3	5	-30.5	-124.0	-132.4	-163.1	74.5	105.4	152.3
2253	2446019.6670	- 5.4	3.9	10	7.4	13.8	6	7.5	- 93.3	-126.8	-239.8	70.5	102.6	190.9
2254	.6864	- 5.9	2.9	8	- 0.7	13.4	6	9.1	- 96.6	-196.8	-110.6	81.8	117.8	170.4

Note: Estimated errors of the Mg II - values based on spectrograms quality ranges from 6 to 10 km s^{-1}.

spectrograms of kappa Draconis observed in the coude focus of the 2-m telescope of the Ondrejov Observatory, photographed on baked Kodak IIaO and IIIaJ emulsions with a reciprocal dispersion of 0.85 nm mm^{-1} in the blue region of the spectrum, were measured with the oscilloscopic comparator at the NAO in Rozen. The same spectrograms were then measured using the TV Abbe comparator of the SPO. The relevant data were again processed using the HEC10 program. Moreover, Dr. Harmanec provided the results of reducing these spectrograms on the Arcturus apparatus (Dominion Astrophysical Observatory, Victoria, Canada). The list of spectrograms used is in Tab. 3 which is organized in the same way as Tab. 1. The mean values of the radial velocity for each plate, their rms errors and number N of spectral lines involved are given in Tab. 4 and plotted in Fig. 1.

Table 4

Hydrogen H I lines

Plate	Radial velocity (km s^{-1})								
	Arcturus		N	Rozen		N	Skalnate Pleso		N
1731	6.1	± 1.9	13	7.8	± 2.2	9	8.2	± 1.2	12
1747	- 3.0	1.9	14	- 2.9	2.5	10	- 2.8	0.9	14
1749	- 2.1	1.3	13	- 7.6	2.5	10	- 1.4	1.8	11
1761	-12.6	2.7	14	- 8.8	1.9	11	-12.9	1.3	12
1810	- 1.4	4.7	11	- 1.3	4.6	11	- 5.9	4.9	8
1824	- 1.7	4.9	11	- 3.2	3.5	9	0.8	4.0	11

Helium He I lines

Plate	Radial velocity (km s^{-1})								
	Arcturus		N	Rozen		N	Skalnate Pleso		N
1731	- 0.5	± 4.9	6	- 8.2	± 12.6	6	11.7	± 4.0	6
1747	- 6.1	6.2	10	4.3	9.6	6	- 4.3	3.5	5
1749	- 4.5	3.7	6	-10.6	3.5	6	9.7	6.6	6
1761	- 4.2	5.8	7	4.7	10.7	5	-12.9	6.4	5
1810	- 3.6	9.5	4	-13.4	19.5	6	- 7.6	8.4	3
1824	5.0	10.9	4	18.3	13.2	5	11.7	11.7	7

The radial velocity functions obtained by various methods for the hydrogen lines can be approximated well by a linear dependence. The least-squares methods yields

$$SP = \underset{\pm.3}{1.0}\ R + \underset{\pm2.}{0.}\ , \qquad SP = \underset{\pm.2}{1.1}\ A + \underset{\pm1.}{0.}\ , \qquad R = \underset{\pm.3}{0.8}\ A - \underset{\pm2.}{1.}\ ,$$

where SP, A and R are the radial velocities obtained at Skalnate Pleso, with

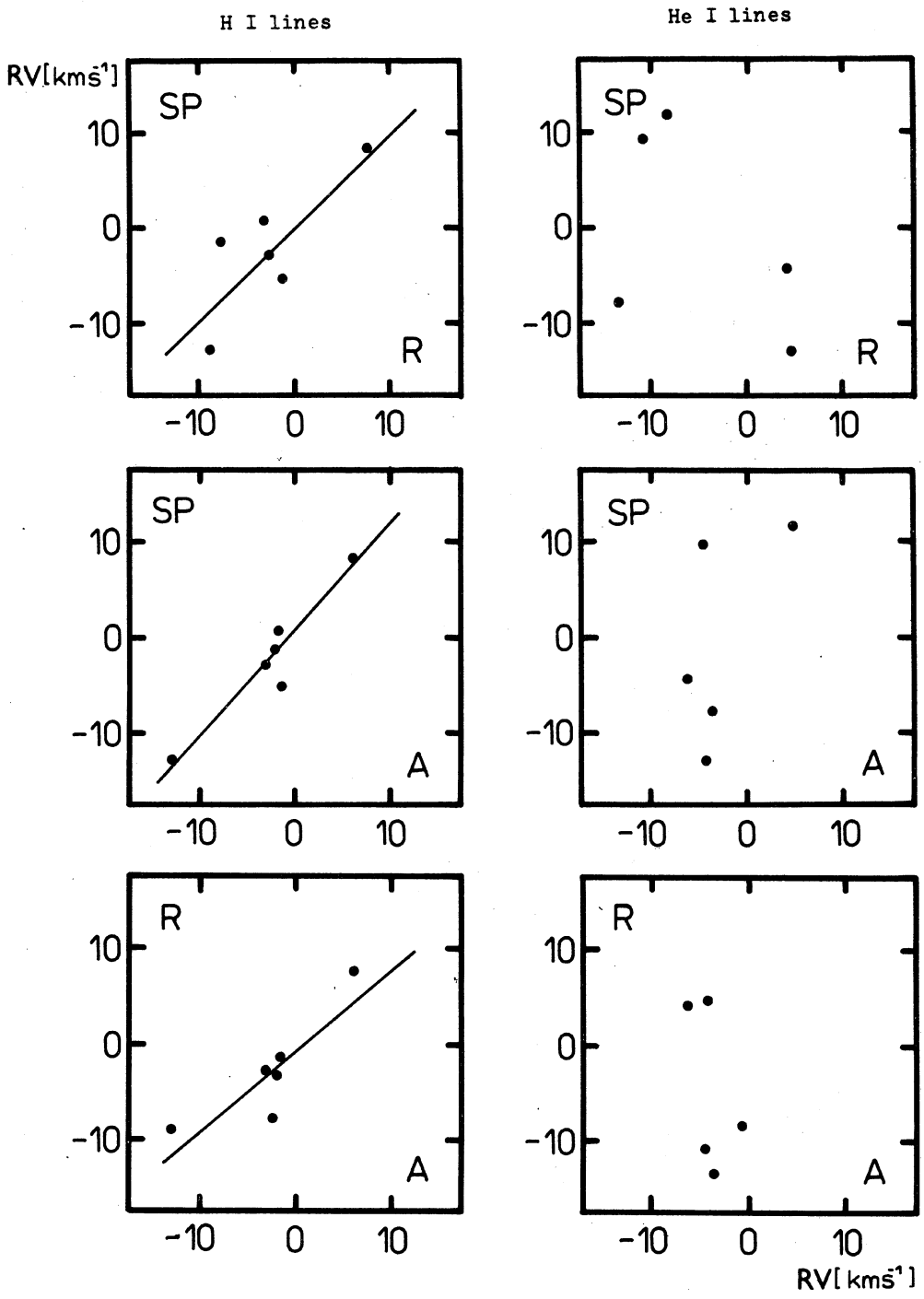

Fig. 1. Comparison of the results of various measuring methods:
SP - TV comparator of the SPO, A - Arcturus apparatus,
R - oscilloscopic comparator of the NAO

Arcturus and at Rozen, respectively. It is meaningless to approximate the relations of the velocities derived from the He lines by a function as can be seen in Fig. 1.

In spite of the small number of check spektrograms, therefore, it was found that the radial velocities derived from hydrogen lines are comparable, within the limits of measuring errors, and that the data from individual observatories can be used to determine the variations of the radial velocity. The radial velocities derived from the ill-defined helium lines not only have larger rms errors, but also a larger total scatter of measured values at the separate observatories and, consequently, are unsuitable for data compilation and determining the variations. We, therefore, period analysed only the velocities derived from the H lines. The period analysis was carried out using three programs written by Dr. Zverko of the Astronomical Institute, Slovak Academy of Sciences: 1) Fourier transformation method (Deeming, 1975), 2) method of minimum phase dispersion (Stellingwerf,1978), 3) the method described by Morbey (1978).

3. CONCLUSION

The resultant periodograms indicated some periodicities, even some close to the predicated period of 0.89 days, however, not one period was found which would be proved by at least two methods. This finding, together with considerable relative measuring errors of the radial velocities prompt us to conclude that the predicated period cannot be substantiated by the set of spectrograms investigated. However, we are convinced that a definitive solution to the problem of variability of the radial velocity of kappa Draconis will be obtained after a further roughly 70 Ondrejov spectrograms of this star have been processed.

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