THE CHEMICALLY PECULIAR STAR ω URSAE MAJORIS: I. IDENTIFICATION OF SPECTRAL LINES

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ABSTRACT. High-dispersion spectroscopic material (8.5×10^{-7}), used to calculate v.sin i, T_{eff} and log g, was obtained for 8 peculiar stars whose classification is not unique. A detailed identification of the spectral lines of star ω UMa (HD 94 334) was carried out. On each of the 7 spectrograms an average of 270 lines were identified, for which the equivalent widths and their normed values were calculated. It is proved that the star can be classified as a chemically peculiar A star with an Si-type peculiarity.

ХИМИЧЕСКИ ПЕКУЛИАРНАЯ ЗВЕЗДА ω БОЛЬШОЙ МЕДВЕДИЦИ: 1. ИДЕНТИФИКАЦИЯ СПЕКТРАЛЬНЫХ ЛИНИЙ. Для 8 пекулиарных звезд с неопределенной класификацией был получен высокодисперсный спектроскопический материал ($8,5 \times 10^{-7}$), из которого мы определили проекцию скорости вращения, эффективную температуру и логарифм ускорения силы тяжести на поверхности для каждой звезды. Для звезды ω UMa (HD 94 334) была сделана подробная идентификация спектральных линий. На каждом из 7 спектрограмм было идентифицировано в среднем 270 линий, для которых мы вычислили эквивалентные ширины и их нормированные значения. Показано, что звезду возможно класифицировать как химически пекулиарную A звезду с пекулиарностю типа

CHEMICKY PEKULIÁRNA HVIEZDA ω UMA: I. IDENTIFIKÁCIA SPEKTRÁLNYCH ČIAR. Pre 8 pekuliárnych hviezd s nejednoznačnou klasifikáciou bol získaný vysokodisperzný spektroskopický materiál ($8,5 \times 10^{-7}$), z ktorého boli počítané v.sin i,

T_{eff} a log *g*. Pre hviezdu ω UMa (HD 94 334) bola urobená podrobná identifikácia spektrálnych čiar. Na každom zo 7 spektrogramov bolo v priemere identifikovaných 270 čiar, pre ktoré boli vypočítané ekvivalentné šírky a ich normované hodnoty. Je ukázané, že hviezda môže byť klasifikovaná ako chemicky pekuliárna A hviezda s pekuliaritou typu Si.

1. INTRODUCTION

Eight peculiar stars with insufficiently developed peculiarity features and non-unique or indefinite classification were selected for long-term spectroscopic and photometric observations. Research into such stars may lead to the clarification of evolutionary relations between normal and chemically peculiar stars. For this purpose high-dispersion spectroscopic material of quality from the coudé focus of the 2-m reflector of the Astronomical Institute of the Czechoslovak Academy of Sciences in Ondřejov (for detailed description of instrument refer to Zicha, 1972) with a dispersion of 8.5×10^{-7} in the spectral region of λλ 360 - 490 nm was accumulated for a period of 10 years. The half-widths of line Mg II 4 λ 448.1 nm, whose values are given in Column 3 of Tab. 1, were determined from the intensity records of selected spectrograms for all the stars. These values were used to estimate the projected rotational velocities "v.sin i", which are also given in Tab. 1. The effective temperatures and the values of the gravitational acceleration (g) were determined from the profiles of hydrogen lines H_β, H_γ and H_δ by comparing them with their theoretical values in the paper of Kurucz (1979). Since the theoretical profiles are normalized to unity (intensity of the continuum) only at a distance of 10 nm from the line centre, and the profiles on the spectrograms could only be observed to distances of 1.5 - 3 nm from the line centre, the theoretical profiles were normalized to unity individually for each spectrogram and line already at the distance of the actually observed continuum from the line centre. The central parts of the hydrogen line profiles, however, are deformed by rotational broadening, so that the central part ($\Delta\lambda \leq 0.2$ nm) of the theoretical profiles was corrected with respect to the values of the projected rotational velocity, determined above. We also assumed that the coefficient of darkening $\varepsilon = 0.6$. The resultant average values of the effective temperature and log *g* for the individual stars are given in Columns 5 and 6 of Tab. 1.

The effective temperature of the atmospheres of the stars involved were also determined by the method published by Heintz (1973) and Zabriskie (1977). The results obtained from 2 different photometric systems, i.e. UBV and ubvy, are given in Columns 7 and 8 of Tab. 1. The positions of all stars were plotted in a two-colour diagram (U - B), (B - V), see Fig. 1, based on the photoelectric U, B, V observations reported in the catalogue of Blanc et al. (1968). The diagram was adopted from the paper of Bochníček and Hric (1978).

It should be pointed out that the values of the effective temperatures of the atmospheres of the studied stars, determined from the hydrogen line profiles, come out systematically higher than the values determined by photometry.

Table 1.

Star	Plate No.	H_W(nm) MgII 4	v.sin i ($km.s^{-1}$)	T_{eff} from H	log g	T_{eff} from UBV	T_{eff} from ubvy
HR 446	4128	.44181	176	15 000	4	12 250	12 900
	3429	.45405	180	14 000	3.5-4		
HR 830	4140	.14400	58	13 000	4	10 800	11 200
b^1 Per	2059	.16969	69	10 500	4	9 300	-
	4141	.21078	75	11 000	4		
36 Aur	3937	.06790	15	13 500	3.5-4	11 100	-
	3127	.04889	4	12 500	3-3.5		
68 Ori	3939	.12267	50	10 000	3	10 700	-
	3128	.10848	39	12 000	3.5		
ω UMa	2135	.12232	50	13 000	4	10 300	10 500
	2094	.12440	50	13 000	4		
HR 7028	2063	.07905	21	13 000	4	11 600	12 000
21 Aql	4133	.04892	4	13 500	3-3.5	13 000	14 000

According to Boyarchuk (1983), however, the former method of determining the effective temperature is very inaccurate and, consequently, unsuitable.

According to Hric and Zverko (1982), the obtained results cannot be used to draw conclusions about the peculiarity type of the studied objects, however, with a view to the amount and quality of the observational material available, as well as the observability of the individual stars, two of them could be selected for more detailed study. One of them was the peculiar A star ω UMa.

2. ω UMA

The spectroscopic binary ω UMa (HD 94 334, HR 4248, $m_V = 4.68$) is entered in the catalogue of Blanc et al. (1968) with the following 1900.0 equinox coordinates:

$$RA = 10^h\ 48^m.2\ ,\ DEC = +43^\circ\ 43';$$

its galactic coordinates are

$$l = 171^\circ.17\ ,\ b = +61^\circ.35\ .$$

For the proper motion of the object, Olsen (1970) gives the following values:

$$_{RA} = 0.42 \pm 0.012\ (s/100\ yrs)$$

$$_{DEC} = -2.75 \pm 0.14\ (''/100\ yrs)$$

In the "General Catalogue of Trigonometric Stellar Parallaxes", Jenkins (1952)

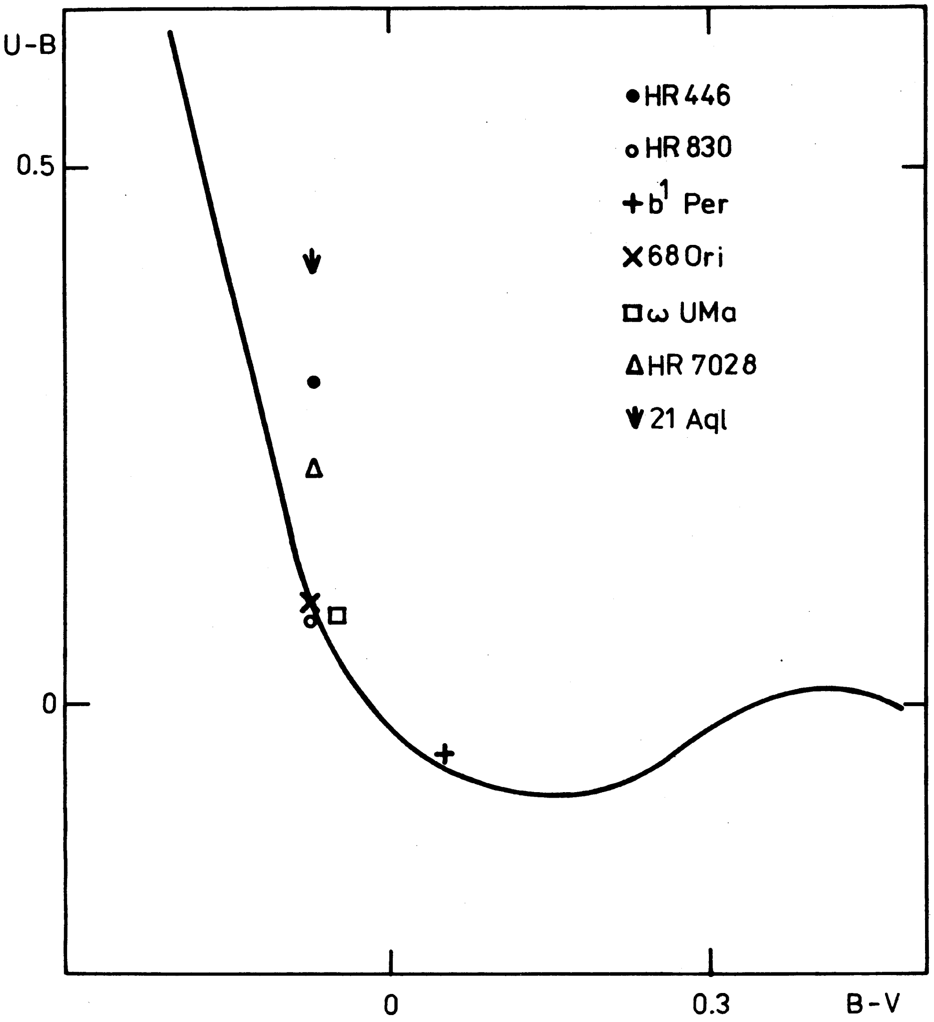

Fig. 1. The positions of stars in a two-colour diagram.

gives a parallax value for star ω UMa which yields its distance as 100 pc. Slettebak (1953) gives an absolute magnitude of $M_V = +0.7$, star radius of $R = 2.6\ R_0$ and an effective temperature of its atmosphere of $T_{eff} = 10\ 300$ K. This value agrees well with the calculated values presented in Tab. 1.

3. PHOTOMETRY

Since ω UMa is a relatively bright star, the literature contains an abundance of data on its brightness. Photoelectric observations are also available. Certain selected data are given in Tab. 2. These data indicate that the star

Table 2.

V	B - V	U - B	V - R	R - I	Year	Bibliography
4.68	-0.05				1964	18
4.708	-0.061	-0.073	-0.000	-0.033	1966	15
4.719	-0.047	-0.046	0.045	-0.029	"	"
4.716	-0.051	-0.038	0.099	-0.059	"	"
4.71	-0.05	-0.05			"	"
4.68	-0.053				1966	9
4.68	-0.05				1968	4
4.71	-0.05	-0.06			"	"
4.61	-0.04	-0.11			"	"
4.68	-0.053				"	"
4.67	-0.05	-0.08			1969	7
4.67	-0.05	-0.08			1970	2
4.68					1974	3

has practically not changed its brightness even over a longer interval of time. Chemically peculiar stars display variability as a result of the surface distribution of elements and star rotation and, consequently, also this Ap feature has to be determined. Therefore, the star was included in the program of photoelectric observations with the 60-cm reflector of the Astronomical Institute of the Slovak Academy of Sciences at Skalnaté pleso. The results of the observations are now being processed.

4. SPECTROSCOPY

Although ω UMa is a sufficiently bright spectroscopic binary, only low-dispersion spectroscopic observations, mostly limited to determining the spectral type, have been published in the literature. A detailed chemical analysis of the spectrum has not been published yet. Batten (1967) determined the orbit elements and some other physical parameters of the system:

time of periastron passage	T = 2 435 185.246
longitude of periastron	$\omega = 27\overset{\circ}{.}3$
eccentricity of elliptic orbit	e = 0.305
period of orbital motion	P = 15.8307 days
semi-amplitude of radial velocity curve	K = 22.2 km/s
radial velocity of systems centre of gravity	V_0 = -18.7 km/s
mass function	f(m) = 0.015

Some other selected data are given in Tab. 3.

Cowley et al. (1969) classified ω UMa as a star in which there may be an overabundance of silicon, but not enough to be able to designate the star as peculiar. They used spectrograms with a dispersion of 125×10^{-7} in H_γ for the classification.

Table 3.

Spectrum	v.sin i (km/s)	V_o (km/s)	P (days)	Year	Bibliography
A1 V	15		15.8	1953	22
A1 V		-18.6	16	1961	8
A1 V				1961	17
A1 V				1964	13
A1 V				1966	15
A1 V				1966	9
A0		-18.7	15.8307	1967	1
A1 Vs Si				1969	7
A1 V	26			1970	24
		-17.4		1970	21
	15			1970	2
A1 Vs Si				1974	3 from 7

5. UV SPECTRUM

The star ω UMa was observed in the UV region of the spectrum by the spectrometer of the TD-1 satellite. The results of the observations of fluxes in the spectral region of $\lambda\lambda$ 138 - 254 nm were published by Jamar et al. (1976) in "UV Bright-Star Spectrophotometric Çatalogue".

The comparison of the UV continuum of ω UMa with the normal star α Lyr clear indicates a smaller decrease of the spectrum of the former star in the interval under 170 nm, and also that its spectrum is affected more by absorptions.

6. OBSERVATIONAL MATERIAL

The spectroscopic observational material consists of 14 spectrograms. The spectrograms with a dispersion of 8.5×10^{-7} were obtained in the coudé focus (f = 64 m) of the 2-m reflector of the Astronomical Institute of the Czechoslovak Academy of Sciences in Ondřejov, and those with a dispersion of 9×10^{-7} also in the coudé focus of the 2-m reflector at the National Astronomical Observatory of the Bulgarian Academy of Sciences in Rozhen. The spectrograms cover the spectral region from 360 to 490 nm. A more detailed description of the observational material is given in Tab. 4, Column 1 of which gives the spectrogram number, Column 2 the observatory designation (O = Ondřejov, R = = Rozhen), Column 3 the UT of the middle of the exposure, Column 4 the appropriate date, Column 5 the length of the exposure, and Column 6 the emulsion used.

Table 4.

Plate No.	Observatory	Time UT	Date	Duration	Emulsion Kodak
2039	O	23^h 29^m	1975 02. 16.	80^m	IIaOB
2045	O	22 09	" " 20.	60	"
2058	O	04 09	" " 23	60	"
2060	O	21 23	" " "	60	"
2062	O	01 47	" " 24.	40	"
2064	O	00 19	" " 26.	80	"
2072	O	01 14	" " 28	40	"
2094	O	02 14	" 03. 07.	40	"
2135	O	21 55	" 05. 09.	39	"
2137	O	22 24	" " 10.	40	"
4488	O	19 41	1982 04. 17.	30	IIaOH2
2K-1297	R	04 24	" 11. 02.	10	IIaO
2K-1320	R	04 09.5	" " 04.	10.5	"
2K-1394	R	05 06	1983 01. 07.	16	"

All spectrograms were microdensitometrically recorded with direct recording of the intensities (Minarovjech et al., 1983). Of the intensity records, the 7 best were selected, most suitable for identifying the spectral lines. The identification was made directly on the records with the aid of comparative lines, the positions of which were directly recorded by hand on the records by means of a pen. All identifications were made using the papers by Moore (1945) and Žižňovský (1980). The equivalent width was calculated for each identified spectral line, the line profiles being approximated by triangles. To eliminate the effect of inhomogeneities in calibrating the spectrograms on the values of the equivalent widths of spectral lines, all the equivalent widths of the individual lines were normed with respect to the equivalent widths of H and H lines, the following notations being introduced:

W - unnormed equivalent width of a given line;

W/W_H - normed equivalent width;

$W_H = 1/2 \cdot W_{H_\gamma H_\delta} \times 10^{-3} = (1/2 \cdot W_{H_\gamma} + 1/2 \cdot W_{H_\delta}) \times 10^{-3}$

The areas of the profiles of the hydrogen lines were measured by means of a planimeter.

7. RESULTS OF MEASUREMENTS

The results of spectral line identification are given in Tab. 5. Column 1 gives the wavelength in nm, Column 2 the designation of the appropriate ion,

Table 5.

Wavelength (nm)	Atom	Multiplet	2039 W	2039 W/W_H	2045 W	2045 W/W_H	2062 W	2062 W/W_H	2072 W	2072 W/W_H	2K-1297 W	2K-1297 W/W_H	2K-1320 W	2K-1320 W/W_H	2K-1394 W	2K-1394 W/W_H
366.969	Cr II	1							2.4	2.7						
367.650	Cr II	1			2.7	2.2			2.3	2.6						
373.6901	Ca II	3	6.5	5.4	5.1	4.1			6.1	6.9	6.2	5.4	-		-	
374.1633	Ti II	72											-			
.5806	V II	15	10.3	8.6	5.5	4.5	-		3.1	3.5	-		-		-	
375.7684	Ti II	72	12.7	10.6	4.8	3.9	0.9	1.1	2.5	2.8	5.8	5.0	-		12.4	9.2
.7662	Cr I	43														
.780	Zr II	120											-			
.9291	Ti II	13	12.5	10.4	7.8	6.3	5.8	6.8	6.4	7.2	12.6	10.9	8.2	5.7	15.1	11.2
376.132	Ti II	13	10.0	8.3	8.2	6.6	5.1	6.1	5.4	6.1	8.2	7.1	13.0	9.0	12.9	9.5
.379	Fe I	21	7.8	6.5	7.2	5.8			5.2	5.9			5.7	3.9	6.9	5.1
378.3530	Ni I	30											9.7	6.7		
.7253	V II	100							-							
.7883	Fe I	21							2.1	2.4	5.6	4.9				
.789	Cr II	6														
.9570	Fe I	226							2.1	2.4						
381.339	Ti II	12	4.7	3.9							4.8	4.2	9.6	6.6	5.6	4.1
.4121	Fe II	153	7.9	6.6							6.2	5.4	10.2	7.0	8.1	6.0
.5831	Ce II	37	8.7	7.2							8.5	7.4	8.9	6.1	11.1	8.2
.5842	Fe I	45														
382.0428	Fe I	20	9.8	8.2	10.3	8.3	6.5	7.7	8.9	10.1	10.6	9.2	19.1	13.2	11.5	8.5
384.824	Mg II	5	2.6	2.2	12.6	10.2	9.5	11.2	3.4	3.8	13.5	11.7	12.9	8.9	10.0	7.4
.958	Ni II	11	5.1	4.2					3.3	3.7						
385.04	Mg II	5	4.2	3.5					2.6	2.9						
.0409	V II	11														
385.3657	Si II	1	8.4	7.0	9.5	7.7	7.4	8.7	7.7	8.7	9.7	8.4	6.6	4.6	2.5	1.8
.6021	Si II	1	16.4	13.6	20.2	16.4	11.0	13.0	13.4	15.1	20.9	18.1	21.5	14.9	17.2	12.7
.8301	Ni I	32											6.4	4.4		

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
385.9913	Fe I	4	9.1	7.6	8.5	6.9	5.0	6.0	6.4	7.2	11.1	9.6	14.8	10.2	9.7	7.2
386.2592	Si II	1	10.7	8.9	11.1	9.0	8.6	10.2	7.4	8.4	18.9	16.4	18.0	12.4	18.8	13.9
.5526	Fê I	20	13.7	11.4	-		3.6	4.2	2.3	2.6	6.9	6.0	7.3	5.0	5.3	3.9
387.2504	Fe I	20	10.6	8.9	7.6	6.2	6.2	7.3	3.7	4.2	6.0	5.2	8.4	5.8	6.8	5.0
.8021	Fe I	20	3.8	3.2	10.2	8.3	2.7	3.3	3.1	3.5	10.9	9.5	3.9	2.7	2.5	1.8
.8875	Fe I	4	12.0	10.0			4.7	5.5	6.8	7.7			8.3	5.7	8.5	6.3
390.068	Al II	1	10.7	8.9	8.5	6.9	7.3	8.7	5.2	5.9	6.3	5.5	13.6	9.4	8.7	6.4
.327	V II	11	8.2	6.8	7.2	5.8	8.1	9.6	2.7	3.1	10.7	9.3	6.8	4.7	9.4	6.9
.5527	Si I	3	12.4	10.3	15.2	12.3	9.6	11.4	11.6	13.1	12.8	11.1	17.2	11.9	5.1	3.8
391.3464	Ti II	34	10.6	8.8	18.7	15.2	5.7	6.8	3.5	4.0	17.9	15.5	18.6	12.8	12.8	9.5
.436	Zr II	134	6.9	5.7			4.1	4.8	7.0	7.9			8.7	6.0	10.4	7.7
.6418	V II	10									5.2	4.5			5.4	4.0
392.7922	Fe I	4	5.7	4.7					-						-	
393.0299	Fe I	4	3.4	2.8	8.5	6.9	3.6	4.2	8.5	9.6	6.4	5.6	5.9	4.1	4.1	3.0
.3664	Ca II	1	71.4	59.4	58.1	47.1	38.6	45.7	52.7	59.5	69.2	60.1	112.8	77.9	126.6	93.5
.5942	Fe II	173	4.3	3.6	5.5	4.5	4.7	5.5	2.4	2.7	4.4	3.8	5.0	3.5	3.2	2.4
.8289	Fe II	3	5.7	4.8	5.7	4.6	3.5	4.2	7.2	8.1	7.7	6.7	4.3	3.0	5.7	4.2
.8969	Fe II	190											4.1	2.8	1.6	1.2
394.4009	Al I	1	9.7	8.1	7.1	5.8	8.3	9.9	5.8	6.6	9.8	8.5	12.7	8.8		
.521	Fe II	3									5.8	5.0	4.3	3.0		
.7002	Fe I	561									10.9	9.5	3.4	2.3		
395.2573	Ce II	113,177			4.7	3.8			1.6	1.8						
.2606	Fe I	278														
.421	Cl II	82							2.1	2.4						
396.1523	Al I	1	11.5	9.6	9.0	7.3	5.3	6.3	6.8	7.7	4.7	4.1	6.3	4.4	11.8	8.7
.643	Fe II	3													3.7	2.7
.7964	Fe I	561													5.9	4.4

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
397.940	Hf II	97							2.0	2.3			3.5	2.4	4.0	3.0
398.67533	Mg I	17									]6.5	5.6			]13.4	9.9
.6826	Mn I	33														
399.1123	Cr I	38			]6.2	5.0							]21.9	15.1	]-	
.114	Zr II	30														
400.248	Cr II	166	]13.3	11.1	]9.2	7.5			]2.6	2.9	]9.0	7.8	]11.0	7.6	]14.6	10.8
.2549	Fe II	190														
.294	V II	9								-						
.5246	Fe I	43	]16.9	14.1	]12.2	9.9	2.3	2.7	6.1	6.9	5.1	4.4	]19.0	13.1	6.8	5.0
.5712	V II	32					5.2	6.2	7.7	8.7	6.0	5.2			6.4	4.7
401.2372	Ti II	11	]7.4	6.2	]10.1	8.2	]4.9	5.8	]5.7	6.4	]13.8	12.0	]12.4	8.6	]12.4	9.2
.2389	Ce II	206														
402.005	Fe I	556											5.7	3.9		
.3388	V II	32											15.6	10.8		
.5136	Ti II	11	15.6	13.0	6.0	4.9	7.3	8.6	7.2	8.1			15.1	10.4	10.1	7.5
.65	Al II	24											7.1	4.9	5.6	4.1
.8332	Ti II	87	]4.4	3.7	]7.9	6.4	]4.2	5.0	]5.5	6.2			]4.4	3.0	]11.2	8.3
.8411	Ce II	47														
403.3073	Mn I	2	5.8	4.9												
.449	Mn I	2	6.6	5.5												
404.2584	Ce II	140	6.0	5.0												
.5815	Fe I	43	15.3	12.7	10.8	8.8	6.1	7.3	9.1	10.3	13.7	11.9	16.8	11.6	12.8	9.5
.868	Zr II	43	6.0	5.0	5.1	4.1	6.6	7.8	2.1	2.4			11.7	8.1	8.5	6.3
405.197	Cr II	19	4.0	3.3					3.0	3.4			13.4	9.3	-	
.3814	Ti II	87	8.1	6.8	8.9	7.2	7.7	9.2	4.5	5.1			14.0	9.7	7.1	5.2
406.3597	Fe I	43	]13.6	11.4	]14.3	11.6	]5.1	6.1	]6.7	7.6	]6.3	5.5	]7.9	5.5	]13.5	10.0
.394	Cr II	19														
.7051	Ni II	11	8.4	7.0	10.3	8.3	5.1	6.0	5.2	5.9	12.6	10.9	7.6	5.3	4.8	3.5

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
407.174	Fe I	43	5.5	4.5	12.7	10.3	7.5	8.8	7.1	8.0	11.7	10.2	22.8	15.8	11.1	8.2
.4794	Fe I	524			6.2	5.0					2.5	2.2	5.2	3.6	5.8	4.3
.7714	Sr II	1	13.3	11.1	14.9	12.1	10.8	12.8	7.9	8.9	16.9	14.7	17.6	12.2	14.1	10.4
411.5185	V I	27											6.1	4.2	4.9	3.6
.647	V I	27														
.8549	Fe I	801					7.1	8.4							-	
412.2638	Fe II	28	9.7	8.1	10.2	8.3	6.5	7.7	7.9	8.9	11.6	10.1	25.0	17.3	10.7	7.9
.8053	Si II	3	15.9	13.2	13.7	11.1	10.8	12.8	9.8	11.1	21.0	18.2	29.8	20.6	23.9	17.7
413.0884	Si II	3	14.0	11.7	18.7	15.2	9.7	11.4	8.9	10.1	18.1	15.7	25.0	17.3	25.2	18.6
414.3871	Fe I	43	6.6	5.5	13.0	10.5	5.3	6.3	8.8	9.9	12.8	11.1	13.8	9.5	8.4	6.2
.922	Zr II	41	5.6	4.7	8.0	6.5	6.5	7.7	3.1	3.5	5.9	5.1	17.2	11.9	5.0	3.7
.9372	Fe I	694														
415.1	Cr II	163							3.1	3.5						
.367	Ce II	159			5.1	4.1										
.4812	Fe I	694											7.6	5.3		
.624	Zr II	29			8.7	7.1										
416.078	Fe I	1116			7.4	6.0			1.4	1.6					-	
.12	Zr II	42	2.5	2.1					2.9	3.3	7.5	6.5			6.4	4.7
.2072	V II	175	5.1	4.2	6.0	4.9	1.7	2.0	4.0	4.5						
.3644	Ti II	105	10.1	8.4	12.1	9.8	5.3	6.2	4.9	5.5	11.8	10.2	16.5	11.4	13.9	10.3
.3655	V II	175														
.3676	Fe I	274,699														
417.1897	Ti II	105	6.1	5.0	8.1	6.6	5.8	6.9	4.0	4.5					-	
.345	Fe II	27	16.5	13.7	13.9	11.3	7.6	9.0	7.5	8.5	13.6	11.8	17.2	11.9	11.2	8.3
.754	Y II	14	4.1	3.4	23.6	19.1	0.9	1.1	2.6	2.9						
.759	Fe I	18														
.839	V II	25	7.5	6.2			5.1	6.1	4.1	4.6						
.8855	Fe II	28	21.3	17.7			10.0	11.8	10.6	12.0	8.9	7.7	11.5	7.9	8.6	6.4

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
418.3435	V II	37	10.7	8.9	7.2	5.8	1.9	2.3	6.0	6.8					10.2	7.5
.7802	Fe I	152	10.2	8.5	-		4.5	5.3	1.8	2.0	8.9	7.7	18.0	12.4	9.7	7.2
419.1436	Fe I	152			]11.2	9.1										
.15	Zr II	108														
.541	Cr II	161			]11.3	9.2										
.5531	Ni I	239														
.5615	Fe I	478														
.8310	Fe I	152											7.0	4.8	-	
.909	Fe II	141	]24.9	20.7	]15.3	12.4	]2.3	2.7	]7.3	8.2	]4.0	3.5	]10.1	7.0	]12.0	8.9
.9098	Fe I	522														
420.2031	Fe I	42	]15.3	12.8	]13.5	10.9	]6.4	7.6	]7.6	8.6	]6.1	5.3	]10.1	7.0	]11.6	8.6
.235	V II	25														
.3987	Fe I	355											7.8	5.4		
.537	Mn II	2	18.0	14.9										-	6.4	4.7
421.5524	Sr II	1	7.5	6.3	12.9	10.5	8.8	10.5	13.4	15.1	13.6	11.8	16.2	11.2	17.3	12.8
422.6728	Ca I	2	15.3	12.7	7.9	6.4	7.7	9.1	7.9	8.9	7.1	6.2	10.1	7.0	6.0	4.4
423.1165	V II	25	2.3	1.9			3.1	3.7	1.6	1.8						
.3167	Fe II	27	]19.4	16.1	]20.4	16.5	]13.7	16.3	]12.4	14.0	]17.6	15.3	]21.5	14.9	]18.2	13.4
.325	Cr II	31														
.3608	Fe I	'152														
424.238	Cr II	31	10.0	8.3	11.9	9.6	5.7	6.7	2.3	2.6	6.1	5.3	6.4	4.4	5.6	4.1
.48	Ni II	9											-			
.6829	Sc II	7	4.3	3.6	14.5	11.8	5.1	6.1	7.7	8.7			8.3	5.7	6.9	5.1
.743	Fe II	125	]3.4	2.8	]2.0	1.6	]3.7	4.3	]-				]2.6	1.8	]4.1	3.0
.7432	Fe I	693														
425.0125	Fe I	152	]8.7	7.2	]8.8	7.1	]8.9	10.5			]11.4	9.9	3.0	2.1	7.0	5.2
.079	Fe I	42							2.8	3.2			6.8	4.7	6.7	4.9

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039 W	2039 W/W_H	2045 W	2045 W/W_H	2062 W	2062 W/W_H	2072 W	2072 W/W_H	2K-1297 W	2K-1297 W/W_H	2K-1320 W	2K-1320 W/W_H	2K-1394 W	2K-1394 W/W_H
425.262	Cr II	31					2.8	3.4	-						-	
.805	Zr II	15	2.8	2.3	9.5	7.7	2.0	2.4	1.0	1.1	-		10.1	7.0	3.7	2.7
.8155	Fe II	28	7.8	6.5					3.9	4.4	5.1	4.4	-		4.9	3.6
426.0479	Fe I	152	5.5	4.5	5.3	4.3	4.4	5.2	4.9	5.5	6.7	5.8	6.8	4.7	6.3	4.7
.192	Cr II	31	9.0	7.5	3.9	3.2			2.6	2.9					-	
.9951	Cr I	154	13.8	11.5	3.0	2.4	6.7	7.9	6.1	6.9	12.2	10.6	16.0	11.1	15.1	11.2
427.1061	Cr I	154			5.4	4.4										
.1764	Fe I	42			5.1	4.1										
.3317	Fe II	27					7.2	8.6								
428.7893	Ti II	20	7.6	6.3	3.0	2.4			5.1	5.8	2.0	1.7	5.7	3.9	8.3	6.1
.9721	Cr I	1	13.0	10.8	2.2	1.8	7.3	8.6	2.3	2.6	5.2	4.5	4.1	2.8	4.0	3.0
429.0222	Ti II	41			10.7	8.7			3.7	4.2	5.1	4.4	8.9	6.1	4.8	3.5
.4101	Ti II	20	11.2	9.4	12.1	9.8	7.4	8.7	7.9	8.9	9.5	8.2	13.2	9.1	9.2	6.8
.4128	Fe I	41														
.6567	Fe II	28	7.5	6.3	10.3	8.3	7.4	8.7	7.1	8.0	8.3	7.2	11.8	8.2	12.5	9.2
.9242	Fe I	152	4.8	4.0	16.5	13.4	-		4.7	5.3					2.6	1.9
430.0052	Ti II	41	11.3	9.4			11.2	13.2	8.3	9.4	16.7	14.5	18.8	13.0	14.2	10.5
.1928	Ti II	41	9.7	8.1	4.5	3.6	4.5	5.3	5.2	5.9	7.9	6.9	4.5	3.1	3.9	2.9
.3166	Fe II	27	10.5	8.8	13.3	10.8	9.1	10.8	5.7	6.4	14.0	12.2	8.1	5.6	11.1	8.2
.79	Ti II	41	16.4	13.7	17.5	14.2	9.1	10.7	12.7	14.3	9.6	8.3	22.8	15.8	13.7	10.1
.7906	Fe I	42														
.9012	Sm II	15			2.1	1.7	1.7	2.0	3.6	4.1						
431.2861	Ti II	41	13.8	11.5	8.6	7.0	5.5	6.5	5.4	6.1	12.0	10.4	7.5	5.2	6.0	4.4
.4084	Sc III	15	8.6	7.2	16.4	13.3	12.2	14.5			17.6	15.3	24.6	17.0	19.8	14.6
.4979	Ti II	41	3.2	2.7											4.1	3.0
.6807	Ti II	94							4.1	4.6	3.4	3.0			3.2	2.4
.732	Zr II	40			5.4	4.4			3.3	3.7						

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
432.0745	Sc II	15	10.4	8.7									12.2	8.4		
.0965	Ti II	41														
.501	Sc II	15	11.7	9.7	2.7	2.2	1.7	2.0	1.2	1.4	3.2	2.8	5.4	3.7	3.0	2.2
.5765	Fe I	42			13.0	10.5	7.9	9.4	3.8	4.3	7.9	6.9	5.2	3.6	7.5	5.5
433.193	Mg II	27			2.3	1.9			1.5	1.7						
.328	Zr II	132			5.0	4.1			1.2	1.4						
435.1764	Fe II	27	10.2	8.5	16.6	13.5	10.0	11.9	13.5	15.3	10.8	9.4	7.0	4.8	7.4	5.5
436.204	Sm II	45			8.1	6.6	4.0	4.7	5.7	6.4						
.21	Ni II	9														
.417	Y II	70	4.9	4.1	7.2	5.8			3.5	4.0						
.7581	Fe I	414	9.9	8.2	18.9	15.3	3.2	3.8	6.4	7.2						
.7657	Ti II	104														
.8312	Ni I	102									-		7.5	5.2	6.4	4.7
.9404	Fe II	28									3.0	2.6	9.2	6.4	9.3	6.9
437.3563	Fe I	214			3.1	2.5	3.3	4.0	3.8	4.3	2.7	2.3				
.4455	Sc II	14			7.0	5.7	4.0	4.7	6.1	6.9	6.6	5.7	19.3	13.3	10.3	7.6
.4825	Ti II	93														
.494	Y II	13														
.978	Zr II	88											6.2	4.3	6.1	4.5
438.3547	Fe I	41	14.1	11.7	15.5	12.6	5.0	6.0	10.2	11.5	15.1	13.1	11.5	7.9	15.6	11.5
.4643	Mg II	10	18.8	15.6	16.9	13.7	13.7	16.2	14.0	15.8	17.8	15.5	21.3	14.7	21.5	15.9
.4722	V I	22														
439.0565	Mg II	10	12.8	10.7	13.1	10.6	8.6	10.1	9.6	10.8	11.8	10.2	11.9	8.2	10.1	7.5
.4057	Ti II	51	15.3	12.7	17.5	14.2	11.4	13.4	18.5	20.9	4.2	3.6	8.6	5.9	4.7	3.5
.5031	Ti II	19									7.6	6.6	5.9	4.1	7.3	5.4
.9767	Ti II	51	7.8	6.5	6.8	5.5	6.4	7.5	13.4	15.1	-		7.3	5.0	5.1	3.8
440.468	V II	30	6.4	5.3	8.7	7.1	8.3	9.8	9.2	10.4	15.7	13.6	13.5	9.3	7.5	5.5
.4752	Fe I	41														

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039 W	2039 W/W$_H$	2045 W	2045 W/W$_H$	2062 W	2062 W/W$_H$	2072 W	2072 W/W$_H$	2K-1297 W	2K-1297 W/W$_H$	2K-1320 W	2K-1320 W/W$_H$	2K-1394 W	2K-1394 W/W$_H$
441.0516	Ni I	88											20.6	14.2	9.7	7.2
.0641	Ce II	33														
.454	Zr II	79									8.9	7.7				
.6817	Fe II	27	7.7	6.4	-		8.0	9.4	10.3	11.6	11.5	10.0	9.1	6.3	7.1	5.2
.7718	Ti II	40	6.7	5.5	20.7	16.8	4.5	5.3	6.5	7.3			21.5	14.9	17.8	13.1
.8784	Ce II	2	6.2	5.2	3.4	2.8			3.4	3.8						
443.1922	Mn I	40											6.5	4.5	5.3	3.9
.3991	Mg II	9	6.9	5.7	6.9	5.6	4.8	5.7	4.9	5.5					3.4	2.5
444.3802	Ti II	19	12.6	10.5	11.1	9.0	10.3	12.2	13.9	15.7	15.4	13.4	16.0	11.1	20.5	15.1
.9663	Fe II	222	4.4	3.7	1.9	1.5	6.5	7.7	4.2	4.7	3.6	3.1			5.1	3.8
445.0487	Ti II	19			4.1	3.3					5.8	5.0	9.8	6.8	8.3	6.1
.1978	Nd II	6									3.3	2.9			4.7	3.5
.4383	Fe I	350													5.7	4.2
.5258	Fe II								4.2	4.7	6.7	5.8	5.9	4.1	7.2	5.3
.8262	Mn I	28	5.1	4.3	3.1	2.5			2.9	3.3						
446.138	Fe I	725			3.5	2.8			2.4	2.7						
.1654	Fe I	2			4.9	4.0			2.0	2.3					4.8	3.5
.4458	Ti II	40	8.1	6.7			4.1	4.9	5.3	6.0			8.0	5.5		
.8493	Ti II	31	15.0	12.5	12.0	9.7	10.5	12.4	10.7	12.1	11.1	9.6	11.1	7.7	16.8	12.4
447.0864	Ti II	40	8.1	6.8	9.6	7.8	4.0	4.8	4.3	4.9	6.9	6.0			8.9	6.6
.2921	Fe II	37	8.4	7.0												
448.1129	Mg II	4	45.3	37.7	48.4	39.2	37.3	44.1	35.6	40.2	47.9	41.6	66.4	45.9	117.1	86.5
.1327	Mg II	4														
.9185	Fe II	37	11.8	9.9	15.9	12.9	11.2	13.3	7.4	8.4	13.4	11.6	24.2	16.7	22.7	16.8
449.11	Ce II	19	8.3	6.9	16.8	13.6	6.3	7.5	7.5	8.5						
.441	Zr II	130	5.7	4.8			3.6	4.3	3.5	4.0						
.447	Fe I	411														
.4568	Fe I	68														

Table 5.(continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
450.127	Ti II	31	6.9	5.7	16.0	13.0	8.7	10.3	10.9	12.3	20.8	18.1	21.2	14.6	20.8	15.4
.8283	Fe II	38	17.4	14.4	18.7	15.2	7.6	9.0	7.6	8.6	14.2	12.3	19.7	13.6	20.2	14.9
451.5337	Fe II	37	13.0	10.9	11.3	9.2	9.2	10.9	10.2	11.5	16.8	14.6	12.5	8.6	26.8	19.8
452.0225	Fe II	37	8.0	6.6	13.1	10.6	8.0	9.5	9.2	10.4	12.1	10.5	20.4	14.1	9.8	7.2
.2634	Fe II	38	15.2	12.6	15.3	12.4	11.1	13.2	9.3	10.5	16.9	14.7	24.4	16.9	22.3	16.5
.8619	Fe I	68							7.5	8.5					-	
.9465	Ti II	82	]5.1	4.3	]10.9	8.8			]7.4	8.4	]-				]-	
.956	Fe II	171														
453.3966	Ti II	50	]22.5	18.8	]19.5	15.8	]13.9	16.5	]9.6	10.8	]21.7	18.8	]19.9	13.7	]24.7	18.2
.4166	Fe II	37														
454.1523	Fe II	38	]12.4	10.3	]11.3	9.2	]7.3	8.6	]7.7	8.7	4.0	3.5	]10.5	7.3	4.3	3.2
.222	Zr I	49									8.6	7.5			9.1	6.7
.3948	Sm II	32			2.2	1.8	-		2.4	2.7					-	
.5144	Ti II	30					1.7	2.0	5.6	6.3			6.0	4.1	4.3	3.2
.9467	Fe II	38	]28.3	23.5	]33.2	26.9	]19.0	22.5	]23.0	26.0	]34.9	30.3	]40.1	27.7	]42.6	31.5
.9622	Ti II	82														
455.396	Zr II	130	-		9.7	7.9	5.0	5.9	6.5	7.3	7.1	6.2	16.4	11.3		
.589	Fe II	37	14.2	11.8	15.2	12.3	13.0	15.3	13.6	15.4	17.1	14.8	22.1	15.3	16.1	11.9
.846	V II	212	]11.7	9.7	]19.6	15.9	]7.6	9.0	]11.1	12.5	]13.9	12.1	]17.2	11.9	]13.3	9.8
.8659	Cr II	44														
456.3761	Ti II	50	12.6	10.5	12.2	9.9	7.0	8.3	8.3	9.4	7.9	6.9	11.5	7.9	10.5	7.8
457.10956	Mg I	1	]21.4	17.8	]18.0	14.6	]8.1	9.6	]11.3	12.8	]16.7	14.5	]18.7	12.9	]13.5	10.0
.1971	Ti II	82														
.6331	Fe II	38	5.2	4.4	11.6	9.4	7.3	8.7	3.2	3.6	9.0	7.8	18.6	12.8	15.5	11.4
458.3829	Fe II	38	15.3	12.7	20.8	16.9	15.0	17.7	14.9	16.8	26.1	22.7	31.3	21.6	24.6	18.2
.8217	Cr II	44	13.5	11.3	6.5	5.3	11.4	13.5	8.8	9.9	13.9	12.1	16.0	11.1	17.4	12.9
459.209	Cr II	44	12.7	10.6												
461.664	Cr II	44	9.1	7.5	5.4	4.4	4.2	5.0	7.9	8.9					7.9	5.8

Table 5. (continued)

Wavelength (nm)	Atom	Multiplet	2039		2045		2062		2072		2K-1297		2K-1320		2K-1394	
			W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H	W	W/W_H
461.883	Cr II	44	10.6	8.9	13.0	10.5	10.0	11.9	6.1	6.9	13.9	12.1	11.8	8.2	9.0	6.6
462.0513	Fe II	38			6.2	5.0										
.9336	Fe II	37	20.0	16.7	18.9	15.3	11.3	13.4	12.3	13.9	17.2	14.9	15.8	10.9	20.2	14.9
.9336	Ti I	145														
463.0125	Fe I	115			2.1	1.7	1.8	2.1	3.1	3.5					4.2	3.1
.411	Cr II	44	7.3	6.0	14.2	11.5	16.7	19.8	5.4	6.1	10.3	8.9	11.6	8.0	9.8	7.2
.5328	Fe II	186	12.2	10.1			0.5	0.6	4.4	5.0	11.7	10.2	8.4	5.8	8.2	6.1
464.3468	Fe I	820	2.5	2.1			0.9	1.0	3.1	3.5	4.7	4.1	-		2.5	1.8
.742	Ni I	148											-			
466.6750	Fe II	37	2.9	2.4	-		1.3	1.6	3.0	3.4			5.1	3.5	6.9	5.1
.9396	Sm II	7	6.5	5.4	-		7.5	8.9	2.4	2.7	-		7.1	4.9	4.0	3.0
470.29758	Mg I	11	3.2	2.7	4.2	3.4	4.4	5.2	5.3	6.0			11.6	8.0	4.0	3.0
.29831	Mg I	11														
.29909	Mg I	11														
.6542	Nd II	3							4.1	4.6						
471.816	Ca II	7			3.0	2.4			4.2	4.7						
472.258	Ca II	7			6.0	4.9			2.7	3.1						
473.1439	Fe II	43	12.8	10.6	12.1	9.8	7.3	8.6	5.9	6.7						
474.5680	Sm II	7			7.5	6.1	2.7	3.2	3.7	4.2						
475.5728	Mn II	5	7.8	6.5	9.0	7.3	3.1	3.6	4.1	4.6			6.9	4.8	4.4	3.2
478.060	Fe II	50					3.8	4.6	2.9	3.3					8.8	6.5
481.235	Cr II	30			-				3.9	4.4					3.4	2.5
482.413	Cr II	30	22.0	18.3	12.6	10.2	2.4	2.9	5.0	5.6					4.0	3.0
487.4025	Ti II	114	5.5	4.5												
.641	Cr II	30	18.2	15.1	6.5	5.3			-							
.648	Cr II	30														

Column 3 the number of the multiplet, and the other columns give the equivalent width of the particular line in picometres "W" and the corresponding value of "W/W_H " for the spectrogram involved. Besides this, hydrogen lines H_β - H_{18} were identified in the spectrum. If the particular line has been identified in the spectrum, but its equivalent width cannot be measured, there is a hyphen in the appropriate column of Tab. 5. If the line is absent from the spectrum, the space is left blank. Blended lines are indicated by parentheses.

The equivalent widths of silicon lines Si II 1 $\lambda\lambda$385.4, 385.6 and 386.3 nm and Si II 3 $\lambda\lambda$412.8 and 413.1 nm were compared with those of the same lines of the normal star α Lyr, published by Strom et al. (1966). Our values are 1.88 times higher on the average. Table 6 gives the equivalent widths of silicon lines for the individual spectrograms compared with the values of the normal star α Lyr. The last column of this table gives the broadening coefficient of the ω UMa star line as compared to the standard star α Lyr.

Table 6.

Wavelength (nm)	Atom	Multiplet		$W_{\omega\,\mathrm{UMa}}$							
			α Lyr	2039	2045	2062	2072	1297	1320	1394	ωUMa/αLyr
385.4	Si II	1	4.57	8.4	9.5	7.4	7.7	9.7	6.6	2.5	1.62
385.6	Si II	1	14.79	16.4	20.2	11.1	13.4	20.9	21.5	17.2	1.17
386.3	Si II	1	9.55	10.7	11.1	8.6	7.4	18.9	18.0	18.8	1.40
412.8	Si II	3	6.76	13.7	15.9	10.8	9.8	21.0	29.8	23.9	2.64
413.1	Si II	3	6.61	18.7	14.0	9.7	8.9	18.1	25.0	25.2	2.59
											1.88

The equivalent widths of the lines in Tab. 5 and their normed values vary over a considerable range in the individual spectrograms. If one also considers the broadening of the silicon lines as compared to the standard, together with the appearance of the UV spectrum of star ω UMa, the star can be classified as chemically peculiar with an Si-type peculiarity.

The study of the changes on the equivalent widths will be the subject of research to be reported elsewhere.

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