

# Is UU Herculis a post-AGB star?

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**Abstract.** In order to understand the evolutionary status of the anomalous supergiant UU Her, the prototype of the class of variable supergiants located at high galactic latitudes, we obtained several high-resolution spectra of this star, with the 6m telescope, over 5 years. This material was used for a search of possible temporal variations of the radial velocity at different depths in the photosphere and for studying the chemical composition. The average radial velocity  $V_r \approx 130$  km/s suggests that UU Her belongs to the old population of the Galaxy. No systematic dependence of the velocity on depth of the line formation layer or on ionization and excitation potential is observed. The radial velocity of the  $H\alpha$  absorption differs strongly from the average photospheric velocity.

The iron abundance in the photosphere of UU Her is significantly lower than that of the Sun:  $[Fe/H] = -1.32$ . The enhancement of nitrogen relatively to iron content  $[N/Fe]_{\odot} = 0.40$  in combination with the carbon underabundance  $[C/Fe]_{\odot} = -0.30$  suggests that only a first dredge-up episode occurred. The Na content is normal relatively to iron, therefore there is no evidence for dredging-up of Ne-Na cycle products. The heavy s-process metals Y, Ba are depleted relative to H and Fe, which again implies that the third dredge-up did not occur.

From the high luminosity ( $\log g \approx 1$ ), the large radial velocity and the chemical abundance pattern, we conclude that UU Her is a low-mass halo star, but not a post-AGB star.

**Key words:** stars: abundances – stars: AGB and post-AGB – stars: individual: UU Her

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## 1. Introduction

In this paper, we study the characteristics of the peculiar supergiant UU Her, which was proposed as the prototype of a new class of variable stars by Sasselov (1984). Despite several photometric and spectral investigations carried out during last decade, the nature of the UU Her type stars is not understood yet. We first summarize briefly the main characteristics of these stars.

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The UU Her-type stars are supergiants (MK-classes Ia<sup>+</sup>, Ia, Ib) that are located at high galactic latitudes. Besides their location in the Galaxy, which is peculiar for supergiants, these stars have other properties which distinguish these objects from the normal massive supergiants of the galactic disc. In particular, they display both spectroscopic and photometric variability of small amplitude and with long periods, that undergo specific changes. They have large spatial velocities, typical for population II, and, as a rule, an infrared excess caused by a circumstellar dust envelope. If the UU Her stars are truly massive stars, their existence may point to recent star formation at high latitudes in the Galaxy.

There is observational evidence for high-velocity clouds at high latitudes with masses and density which may be sufficient for massive star formation (see, for example, the review by Van Woerden (1993)). We therefore cannot a priori reject the hypothesis that UU Her is a massive supergiant. Moreover, the double-mode photometric behaviour that is observed for this object is in agreement with the high-mass hypothesis (Zsoldos & Sasselov 1992).

On the other hand, low-mass stars in advanced stages of evolution (the AGB and post-AGB stages) also attain very high luminosities that are provided by nuclear burning in the hydrogen and helium layers. Such a low-mass hypothesis for the high-latitude supergiants was proposed by Luck & Bond (1984), Bond et al. (1984) and is supported by the low metallicity of several studied UU Her-type stars and related objects (Bond & Luck 1987, Klochkova & Panchuk 1988a, 1988b, 1989, 1993; Luck et al, 1990; Waelkens et al, 1991, 1992; Klochkova 1995).

A useful test of these hypotheses is provided by the determination of the abundances of the chemical elements that take a part in nuclear processes in the course of stellar evolution. In the case of massive supergiants, we may expect a metallicity near the solar one, but changes in the abundances of the CNO and some  $\alpha$  – process elements, such as a Na excess. The latter has been observed for several massive yellow supergiants in the Galaxy and was explained (Denissenkov & Ivanov 1987, Denissenkov 1988) as a product of a Ne-Na cycle. In the case of low mass stars in the AGB and post-AGB stages, the main peculiarities of the chemical composition would be low metallicity, changes of the CNO elements, and an excess of heavy chemical elements that owe their origin to the s-process.

For understanding the nature of the UU Her type stars, it may also be important to obtain information about radial velocities and their behavior during a long time interval and at the different layers of the stellar atmosphere. Such data could be helpful to define more reliably the type of variability and to understand the mechanism of variability.

The prototype UU Her has been classified F5Ib in the MK system (Lopez-Gruz & Garrison 1993) and has the galactic latitude  $b = 41^\circ$ . In contrast to other high-latitude supergiants, UU Her does not display the infrared excess which is typical for stars in a post-AGB stage of evolution (Trams et al. 1991). Spectrophotometric (Cardelli 1989) and spectroscopic (Klochkova & Panchuk 1989) observations of the UU Her show that the metallicity of this star is significantly subsolar and the  $\log g$  value is the same as for yellow supergiants. Formally using calibration  $M_v - \log g$  which has been derived by Klochkova & Panchuk (1988b) for massive high luminosity stars, leads us to the value  $M_v = -8^m$  for UU Her. Such a luminosity is too high for a post-AGB star and contradicts to the low intensity of the well known luminosity indicator, which is the triplet OI 7773 Å (see Fig. 1). A low value  $\log g$  in combination with a low metallicity lead us to suggest a post-AGB evolutionary stage. However, no firm conclusion could be drawn, because the expected excesses of s-process elements were not found.

In this paper, we present the results of new spectroscopic study of the luminosity, chemical composition and radial velocities of UU Her. We were able to obtain CCD spectra in the spectral range  $\lambda 5000 - 7000$  Å with sufficiently high resolution for this purpose, using the echelle spectrometer LYNX of the 6-m telescope (Panchuk et al. 1993). These observations allow us in particular to study the CNO abundances.

## 2. Observations

Five CCD-spectra were obtained with the echelle-spectrometer LYNX attached at the Nasmyth-focus of the 6-m telescope and equipped with a 530x580 CCD (Panchuk et al. 1993). The spectral resolution is  $\delta\lambda = 0.26$  Å in the red wavelengths region. The main characteristics of the spectra are summarized in Table 1. A Th-Ar lamp was used for the wavelength calibration; the precision is better than 0.01 Å. The hot fast rotating star HR 4687 was observed in order to identify telluric lines and to separate these lines from the stellar ones. The echelle CCD images were corrected for bias and background. For these procedures and for the transformation of an echelle image into a one-dimensional spectrum, we used the ESO-MIDAS system. The equivalent widths for most spectral lines were measured by fitting a Gaussian to the observed using profile DECH-package by Galazutdinov (1992).

In order to increase the time base of our observations, we also reconsidered the two photographic spectra of the UU Her, which were obtained by Klochkova and Panchuk with the Main Stellar Spectrograph of the 6-m telescope and were used earlier (Klochkova, Panchuk 1989) for the calculation of the abundances of several chemical elements in the atmosphere of UU Her. The spectral resolution of these photographic spectra amounts to  $\delta\lambda = 0.35$  Å.

**Table 1.** Information on the used spectra of UU Her

Date	JD 244...	$\Delta\lambda$ , Å	S/N	Detector
03.05.88.	7285	5200-6600	50	103aF
06.08.88.	7380	5200-6600	50	103aF
18.08.92.	8853	5000-7200	130	CCD <sup>a</sup>
21.08.92.	8856	5000-7200	120	CCD
13.03.93.	9060	5500-8800	110	CCD <sup>a</sup>
11.05.93.	9119	5500-8800	110	CCD <sup>a</sup>
25.06.93.	9164	5500-8800	100	CCD

<sup>a</sup> marks the spectrum which has been used for chemical composition determination

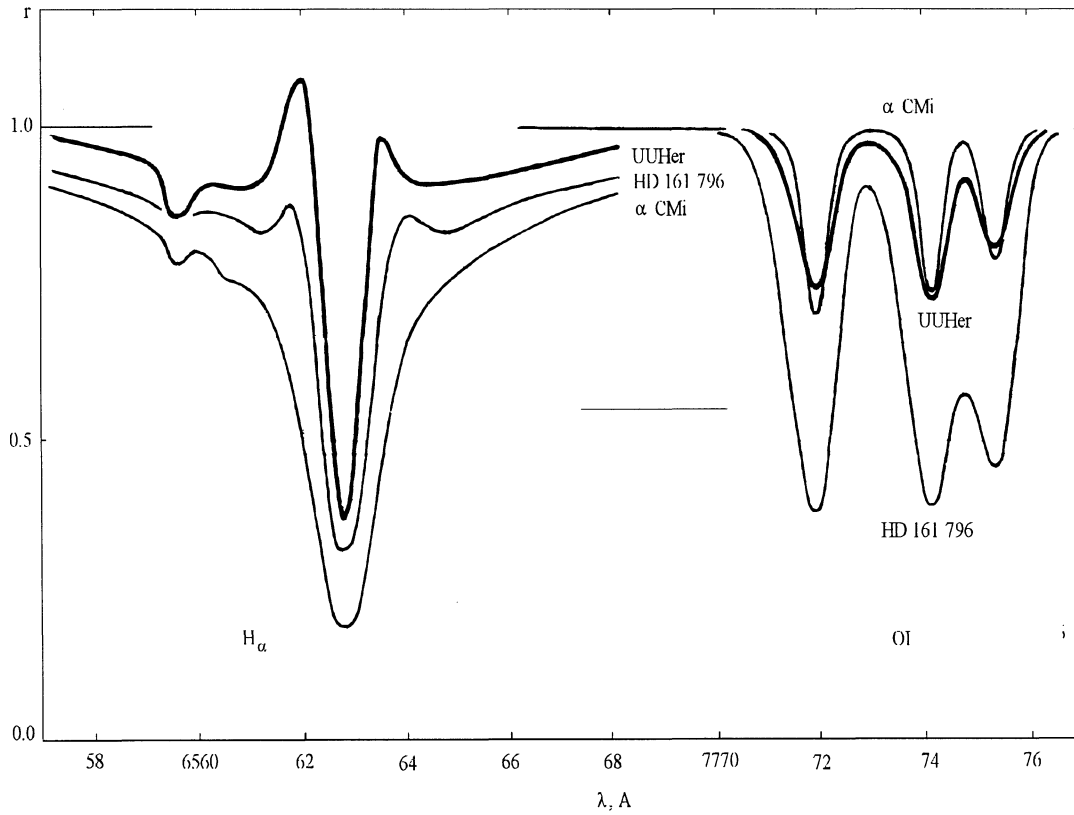
**Table 2.** The results of radial velocity determination. The values in brackets are the number of metal lines used for  $V_r$  measurement

Date	$V_r$ , km/s				
	metals	$\sigma$	n	NaI	H $\alpha$
03.05.88.	-138.5	$\pm 0.9$	(19)	-138.1	-129
06.08.88.	-139.1	$\pm 0.8$	(22)	-142.0	-129
18.08.92.	-125.7	$\pm 0.4$	(110)	-126.5	-134
21.08.92.	-124.7	$\pm 0.5$	(101)	-126.0	-135
13.03.93.	-139.6	$\pm 0.9$	(39)	-140.0	-136
11.05.93.	-131.2	$\pm 0.7$	(50)	-131.0	-134
25.06.93.	-133.3	$\pm 0.9$	(51)	-131.0	-135

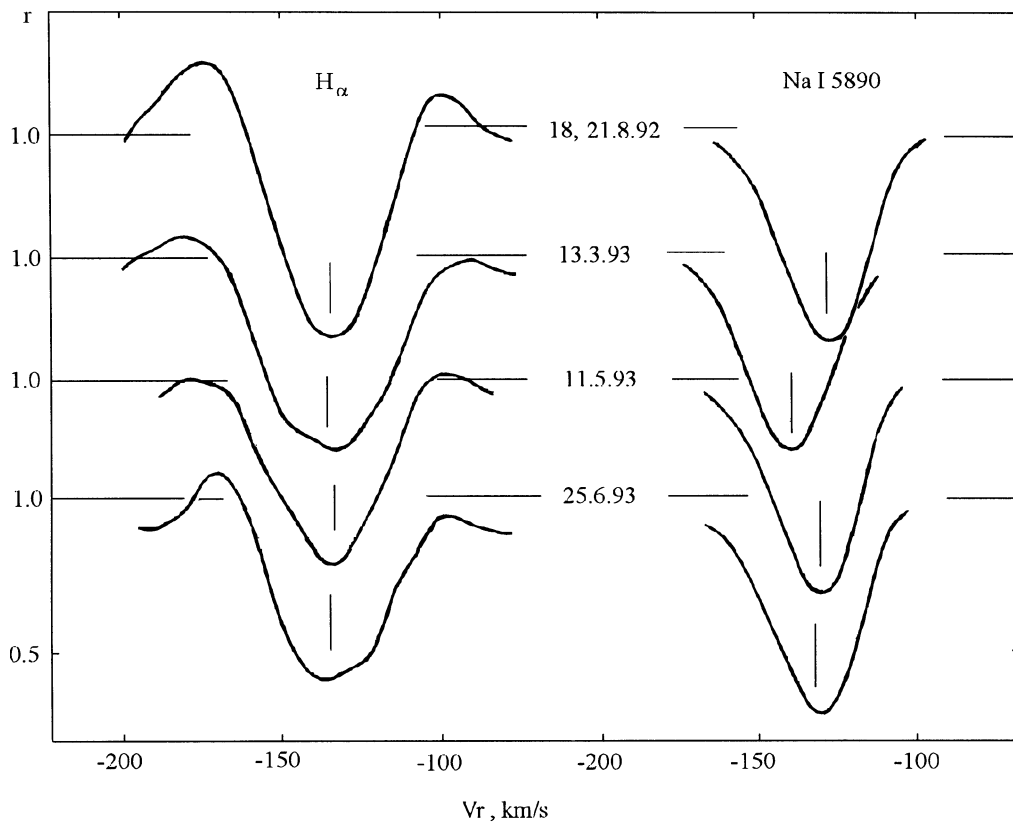
## 3. Radial-velocity measurements

The photographic spectrograms were measured with an osciloscopic comparator. For the velocity determination from the CCD spectra, an identical procedure of matching the direct and mirrored profiles after reduction was used (Galazutdinov 1992). In the case of the photographic spectrograms independent measurements were made for several spectral regions with a length of 100 – 200 Å long; in the case of the echelle-spectra velocities were determined for every of the 32 orders, with a length of 60 – 80 Å. The wavelength calibration was performed with a Th-Ar lamp and checked with the telluric O<sub>2</sub> and H<sub>2</sub>O lines. The typical residual systematic error of an individual order, for the spectra of 18 and 21.08.92, when the largest number of stellar lines were observed, is 0.4 km/s. We consider this value as the upper limit for the systematic error on the radial velocities listed in Table 2. The accuracy was successfully tested with the interstellar lines of NaI, which show a constant velocity for the main component (23 km/s) and for the depression in the red wing (about -12 km/s).

The second column of Table 2 contains the mean radial velocities for the lines Fe I,II, Ti I,II, Cr I,II, which are predominant in the UU Her spectra, as well as for MgI, CaI, SiII, ScII, BaII and some other ions. The random errors reflect the inaccuracy of the measurements and reduction, adopted laboratory wavelengths and some small differential shifts of some lines. The laboratory wavelengths are taken from the solar spectrum tables (Pierce & Breckinridge 1974) with small corrections for the gravitational redshift, taking into account the lower gravity of UU Her.



**Fig. 1.** H $\alpha$  and OI - profiles in the spectra of UU Her, HD 161796 (F3Ib) and  $\alpha$  CMi (F5IV-V).



**Fig. 2.** The time variation of the profiles of the H $\alpha$  and NaI D<sub>2</sub> line

#### 4. Chemical composition

The CCD-spectra marked by “a” in Table 1 were used for the determination of the chemical composition of UU Her. We interpolated between Kurucz’s (1979) models, i.e. assumed local thermodynamic equilibrium (LTE) and hydrostatic equilibrium. It is known, however, that the atmospheric parameters of a supergiant may be altered by non-LTE effects (by overionization mainly). But the influence of these effects on the relative values  $[X/Fe]$  is expected to be low, since Hill et al. (1994) estimated abundances with and without overionization and concluded that the differences are below 0.06 dex.

The gf-values for most spectral lines were taken from Thevenin (1989, 1990); for the lines of the neutral atoms (Ti, Cr, Mn, Fe) we prefer the accurate experimental data of the Oxford group (Blackwell et al. 1986); the CNO-abundances were determined by using the gf-data from the Waelkens et al. (1991).

It is obvious that the application of the standard model atmosphere method to the analysis of spectra of a star with an extended and unstable atmosphere can be questioned. We therefore used only weak lines, which are formed deeply, in our analysis. Most of the lines we used have equivalent widths  $W$  less than 150 mÅ, but several ionized iron and barium lines have  $W$  near 200 mÅ. To control the validity of the method we analyzed in a similar way the spectrum of the normal supergiant  $\alpha$  Per, which is a member of a young open cluster and has a solar chemical composition aside from the non-solar  $[CNO/Fe]$  which may result from mixing of the products of hydrogen burning.

The main difficulty in the chemical composition calculation of UU Her is the determination of the effective temperature  $T_{\text{eff}}$ . First, the hydrogen line profiles in the spectra of this unstable supergiant are distorted by dynamic processes in the extended atmosphere (Fig. 1). Second, the observed irregular variability of UU Her restricts the application of photometric indices for the  $T_{\text{eff}}$  determination too. Therefore we applied spectroscopic criteria for the determination of the photospheric parameters, following an iterative procedure. In several consecutive iterations we determined  $T_{\text{eff}}$  - by forcing the independence of the neutral iron abundance upon the line excitation potential, the surface gravity  $\log g$  - by forcing the ionization equilibrium for FeI and FeII, and the microturbulent velocity  $\xi_t$  - by forcing the independence of the abundance derived from individual FeI lines upon the equivalent width. The errors of the model parameters are typically  $\Delta T_{\text{eff}} = \pm 200$  K,  $\Delta \log g = \pm 0.5$  and  $\Delta \xi_t = \pm 0.5$  km/s.

The adopted atmospheric parameters for different observing dates are listed in Table 3. The calculated abundances of chemical elements for three individual spectra of UU Her are also given in Table 3, together with the solar chemical composition (Grevesse, Noels 1993). The accuracy of the abundances depends on the accuracy of the observational data and on that of the model fitting; the standard deviations are listed in Table 3 for all chemical elements studied. For the elements with a number of lines  $n > 5$  the internal error  $\sigma$  does not exceed 0.2.

#### 5. Discussion of the results

##### 5.1. Radial velocities

The light curve of UU Her is similar to that of RV Tau variables (Zsoldos & Sasselov 1992). We therefore have to pay attention to the line profile anomalies typical for such pulsating population II stars. Unfortunately, the photometric phases corresponding to the observing epochs of our spectrograms are not known. In fact, the effects of pulsations on the spectra appear to be small: obvious emission is present only in the  $H\alpha$  - profiles, but the profiles of the majority of absorption lines are quite normal. The position of lines varies, but not the widths. The absorption lines were not observed to become asymmetric or to split into components.

No systematic progress of the velocity with depth of the line formation zone or with ionization and excitation potential was observed either. Therefore a unique value of the radial velocity, obtained by averaging over all measured absorption lines except  $H\alpha$  and Na I, is presented in column 2 of Table 2 for each observing date. It should be noted that our radial velocity values fall within the interval obtained, with a different methodology, for UU Her by Waelkens & Mayor (1993). Differential shifts exceeding the methodic errors are seen for strongest lines only: FeII 5018 Å, MgI 5183 Å, NaI 5890,96 Å, SiII 6347 Å, Ba 6141 Å, 6497 Å. The asymmetry of the lines is small: the cores of the lines show both blue and red displacements not exceeding 1-2 km/s. The wings tend to be displaced blueward by 2-3 km/s. For the extreme case of the resonance lines of Na I this is clearly seen from the comparison of columns 2 and 5 of Table 2 and from Fig. 2. It is doubtful that this blue shift of the wings is a direct manifestation of the velocity gradient in the atmosphere. It may suggest the presence of a weak emission, that slightly raises the red wing; on the other hand, in the  $H\alpha$  emission (Fig. 1, 2) the blue component usually dominates.

The radial velocity obtained from the  $H\alpha$  absorption (column 6 of Table 2) deviates more strongly from the average photospheric velocity. As can be seen from Fig. 2, this absorption affects slightly both the position and the profile of the line. The half-width is similar to that of the photospheric lines, and the profile has not a Stark but a Doppler shape. Most likely, then, the  $H\alpha$ -absorption is formed in an extended and relatively stable (at least from August 1992 to June 1993) circumstellar envelope. Our limited data set does not allow us to decide whether the  $H\alpha$ -velocity (about -135 km/s in the echelle spectra) corresponds to the center-of-mass velocity of the star.

The temporal characteristics of the movements in the atmosphere of UU Her can be discussed from the data for all absorption lines except  $H\alpha$ . Certainly, our observational data are not sufficiently numerous for an independent estimate of a characteristic timescale. We note that during three days (from August 18 to August 21 1992) the velocity almost did not change, but that over ten months it varied by some 15 km/s. From the photometry it is known that pulsations occur with the 73-days fundamental mode and the 45-days first overtone (Zsoldos & Sasselov 1992); the spectroscopy suggests that this oscillations

**Table 3.** Chemical composition of the UU Her for several date in comparison with the solar one. The numbers of used lines for each chemical element are given in the brackets

Element	18.08.92.			13.03.93.			11.05.93.			$\epsilon(X)^a$
	$\epsilon(X)$	$\pm\sigma$	n	$\epsilon(X)$	$\pm\sigma$	n	$\epsilon(X)$	$\pm\sigma$	n	
Li <sup>b</sup>	1.56		(1)	1.45		(1)	1.58		(1)	1.16
Cl	7.46	0.19	(3)	6.65	0.15	(4)	7.44		(1)	8.55
Ni				7.27	0.04	(3)	7.12	.10	(2)	7.97
OI <sup>b</sup>	7.96	0.22	(2)	7.58	0.05	(2)	7.97	.37	(2)	8.87
OI <sup>f</sup>	8.16		(1)	8.03		(1)				
NaI	4.98	0.18	(4)	5.17	0.24	(4)	5.15	.24	(4)	6.33
MgI	6.48	0.10	(4)	6.89	0.14	(5)	7.05	.43	(2)	7.58
MgII				6.90	0.22	(2)				
SiI	6.85	0.10	(17)	6.88	0.04	(27)	6.85	.06	(14)	7.55
SiII	6.45		(1)	6.57		(1)	6.41		(1)	
CaI	5.02	0.08	(22)	5.13	0.06	(20)	5.16	.07	(17)	6.36
ScII	1.38	0.09	(13)	1.52	0.06	(9)	1.60	.08	(9)	3.17
TiII	3.57	0.07	(7)	3.86		(1)	3.64		(1)	5.02
VII	2.46	0.15	(4)	2.54	0.34	(2)	2.20	.14	(3)	4.00
CrI	3.94	0.05	(8)							5.67
CrII	3.90	0.07	(9)							
MnI	4.30	0.21	(7)	4.07	0.08	(3)	3.84	.12	(3)	5.39
FeI	6.18	0.02	(127)	6.34	0.02	(66)	6.31	.02	(71)	7.50
FeII	6.19	0.04	(19)	6.36	0.05	(12)	6.31	.03	(12)	
CuI	3.02	0.19	(3)	3.28		(1)	3.14		(1)	4.21
YII	0.40	0.19	(7)	1.05	0.37	(2)	1.30	.11	(2)	2.24
BaII	0.14	0.08	(3)	0.41	0.21	(3)	0.49	.13	(3)	2.13
LaII <sup>b</sup>	-0.04	0.16	(4)	-0.06	0.13	(2)	0.30	.20	(4)	1.22
CeII <sup>b</sup>	-0.12	0.21	(3)	0.19		(1)	0.64	.46	(2)	1.55
PrII <sup>b</sup>	-0.45	0.10	(2)							0.71
NdII	0.27	0.12	(6)	0.81	0.11	(4)	0.98	.05	(2)	1.50
EuII	-0.42		(1)	-0.46		(1)	-0.15		(1)	0.51

<sup>a</sup> the solar abundances (Grevesse, Noels 1993)

<sup>b</sup> the abundances for these elements are determined only lines with  $W < 10 \text{ m}\text{\AA}$  only

<sup>f</sup> abundance is determined using forbidden line  $\lambda 6300 \text{ \AA}$

are accompanied by velocity variations with some 15 km/s and with a cycle duration no less than 1 month. The need for simultaneous observations of both kinds is obvious.

## 5.2. Chemical abundance pattern

The details of the chemical abundances of UU Her are considered with respect to the iron content  $\epsilon(\text{Fe})$ :

$$[X/\text{Fe}] = [\log\epsilon(X) - \log\epsilon(X)]_{\star} - [\log\epsilon(X) - \log\epsilon(X)]_{\odot}.$$

The values  $[X/\text{Fe}]$  for UU Her are presented in Table 4. For comparison we there also list results for the normal massive supergiant  $\alpha\text{Per}$  (Klochkova 1995) and for the post-AGB star ROA24 in the globular cluster  $\omega\text{Cen}$  (Gonzalez & Wallerstein 1992). Below we compare the chemical composition of these three high-luminosity objects. In Table 5 we present the  $W$ -value of lines obtained from one of our spectra of UU Her. Given there are also the  $gf$ -values and the results of the abundance calculations of the chemical elements that are most important for our purpose.

*Lithium.* The lithium doublet near  $\lambda 6707 \text{ \AA}$  is very weak (on average  $W = 6 \text{ m}\text{\AA}$ ) in the UU Her spectra, but it is confidently measured in all three studied spectra. The calculated Li abundance is consistent with an advanced evolution stage of a halo star.

*CNO-group.* The behaviour of this triad is a major test of the evolutionary status. As is shown in Tables 3 and 5, the abundances of the CNO elements in the atmosphere of UU Her could be determined accurately from several lines. An underabundance of carbon and overabundance of nitrogen relatively to iron are obtained. An underabundance of carbon is also found for the standard supergiant  $\alpha\text{Per}$ , according to an evolutionary stage where this star went through the first dredge-up. On the other hand, the post-AGB star ROA24 is overabundant in both carbon and nitrogen.

The oxygen abundance is different for the three objects. For  $\alpha\text{Per}$  oxygen is underabundant with respect to iron. For ROA24 oxygen is much strengthened relatively to iron, due to He burning at the red giant stage and following mixing and dredging-up. For UU Her the OI abundance is based on the very weak lines near  $\lambda 6155 \text{ \AA}$ ; it is somewhat strengthened

**Table 4.** The average value  $[X/Fe]$  for UU Her in comparison to that for the normal supergiant  $\alpha$  Per and post-AGB star ROA24 from the globular cluster

Element	$[X/Fe]$		
	UU Her	$\alpha$ Per <sup>a</sup>	ROA24 <sup>b</sup>
Li	1.69		
Cl	-0.30	-0.17	0.67
Ni	0.40	0.65	1.02
OI	0.19	-0.27	1.01
OI <sup>f</sup>	0.46	-0.35	
NaI	-0.01	0.23	0.71
MgI	0.45	0.22	0.31
MgII	0.47		0.09
SiI	0.53	0.19	0.80
SiII	0.15	0.55	1.03
CaI	0.04	0.15	0.60
ScII	-0.45	-0.36	-0.13
TiII	-0.12	0.00	0.33
VII	-0.49	-0.28	0.15
CrI	-0.41	0.23	0.65
CrII	-0.45	0.08	-0.01
MnI	-0.02	-0.06	0.35
FeI	0.00	-0.01	0.00
FeII	0.01	0.02	0.00
CuI	0.16	0.53	
YII	-0.20	0.02	+0.37
BaII	-0.56	0.01	+0.96
LaII	0.11	-0.02	+0.54
CeII	0.07		+1.60
PrII	0.16		
NdII	0.40	-0.52	+0.67
EuII	0.37	0.09	+0.25

<sup>a</sup> the data for  $\alpha$  Per from the paper of Klochkova (1995).

<sup>b</sup> the data for ROA24 from the paper of Gonzalez and Wallerstein (1992)

<sup>f</sup> abundance is determined using forbidden line  $\lambda 6300 \text{ \AA}$

relatively to iron. We thus conclude that the UU Her evolutionary stage is not so advanced as for ROA24: it appears that the third dredge-up has not occurred yet. It should be noted that the abundance of OI calculated by using the lines of the IR-triplet near  $\lambda 7773 \text{ \AA}$  is larger still (see Table 5). It is known that the lines of this triplet are formed in non-LTE conditions in the atmosphere of high luminosity star (Faragiana et al. 1988, Kiselman 1993). Therefore we did not use these lines for the calculation of the average  $\epsilon(O)$ . It should be repeated that the intensity of OI triplet in the UU Her spectrum is not so high as could be expected for a supergiant with  $\log g \approx 1.0$  (see Fig. 1). The total equivalent width of the OI triplet lines is  $\Sigma W(OI) = 0.527 \text{ \AA}$ , in agreement with the results of Arellano Ferro & Mendoza (1993), who discussed a sample of high-latitude A-G supergiants and concluded that for UU Her the luminosity from the OI  $7773 \text{ \AA}$  intensity is not so high as from uvby,  $\beta$ -photometry.

*Light metals.* The abundances of some light metals produced by the  $\alpha$ -process are enhanced for the UU Her:  $[Mg/Fe] = 0.45$ ,  $[Si/Fe] = 0.53$ . At the same time Na and

Ca are significantly underabundant. The odd-even effect is present:  $[Na/Mg] = -0.46$ . The sodium and calcium behaviour of UU Her is different from that for ROA24. The sodium content is especially interesting, because it is known that it is often strengthened for supergiants with masses larger than  $2 - 3 M_{\odot}$ , where it is an indication for the dredge-up of matter to the surface of star (Denissenkov 1988). The lack of a Na-excess is thus an additional argument for the hypothesis that UU Her is an evolved low-mass metal-deficient star.

*Metallicity.* The iron abundance is determined for UU Her with a high precision from a sample of 60-120 FeI lines and more than ten FeII lines. The average metallicity is equal to  $[Fe/H]_{\odot} = -1.32$ . The ratio for manganese is close to the solar one:  $[Mn/Fe] = -0.02$ . The abundance of the iron group elements (Sc, Ti, V, Cr) are slightly decreased relatively to the Fe content. An average  $[X/Fe] \approx -0.38$  is found for these elements. Since the abundances of these iron-group elements are not altered during nuclear processes we suppose that the systematic decreasing of ScII, TiII, CrII is the manifestation of the departure from the LTE conditions. The behavior of these elements is similar for the standard star  $\alpha$  Per. Probably, as noted by Barker et al. (1971), there is any additional source of ionization in the atmospheres of high-luminosity stars for these ions with a low second ionization potential. It should be noted that the higher ratio  $[Mn/Fe]$  close to the solar one may be explained by the uncounted superfine structure of the atomic levels.

*Heavy metals.* From the s-process elements we measured accurately three BaII lines (see Table 5). The abundance from these individual BaII lines are in a good agreement. We conclude that Ba is deficient and not in excess for UU Her. Also the s-process element Y appears to be underabundant, but due to the weakness of its lines this result is less definitive than for Ba. For the normal supergiant  $\alpha$  Per there is no s-process peculiarity, but for ROA24 a prominent excess of Ba and Y is observed, as is expected for a low mass star that has undergone third dredge-up.

The abundance of lanthanides (La, Ce, Nd, Pr) and of Eu, elements that are mainly produced by the r-process, are slightly enhanced or normal relatively to iron. For these heavy metals the average value is  $[X/Fe] = +0.22 \pm 0.06$ .

Considering all evidence, the chemical composition of UU Her is close to the average for the sample of UU Her candidates discussed by Klochkova & Panchuk (1993).

## 6. Conclusions

Spectroscopically, UU Her is a supergiant, because of its low surface gravity  $\log g \approx 1.0$ . Its radial velocities reveal the oscillations with an amplitude of approximately 15 km/s and a cycle duration of approximately one month.

The main results of the chemical composition research presented in this paper are as follows:

- an overall deficiency of metals,

**Table 5.** Data of the measurements and calculations for the one (13.03.93) from the UU Her spectra obtained

$\lambda$	gf	W (mÅ)	$\epsilon(X)$	$\lambda$	gf	W (mÅ)	$\epsilon(X)$	$\lambda$	gf	W (mÅ)	$\epsilon(X)$
Li				SiII				5816.38	-0.69	16	-5.57
6707.78	0.02	4	-10.55	6347.09	0.31	123	-5.43	5856.08	-1.69	4	-5.44
C				Ca				5859.61	-0.60	25	-5.47
7113.17	-0.86	11	-5.09	5581.97	-0.63	14	-7.37	5862.36	-0.38	25	-5.69
7115.19	-0.90	9	-5.13	5590.12	-0.74	12	-7.33	5883.81	-1.37	17	-5.49
8335.16	-0.48	72	-5.47	5594.47	-0.31	73	-6.73	5930.19	-0.23	22	-5.82
8727.13	-8.21	17	-5.71	5598.49	-0.35	64	-6.79	5934.65	-1.26	21	-5.48
N				5601.28	-0.63	20	-7.16	5952.72	-1.51	12	-5.41
8629.16	0.03	21	-4.67	5857.45	0.07	65	-6.78	6003.01	-1.12	38	-5.37
8711.64	-0.14	24	-4.72	6102.72	-0.80	64	-6.91	6008.56	-0.98	37	-5.52
8718.76	-0.17	19	-4.81	6122.22	-0.20	123	-6.96	6020.17	-0.21	39	-5.60
O				6162.17	-0.10	110	-7.16	6024.07	-0.02	56	-5.63
6155.99	-0.66	4	-4.47	6163.75	-1.46	15	-6.46	6027.06	-1.15	11	-5.74
6156.78	-0.44	7	-4.38	6166.44	-1.26	14	-6.71	6065.49	-1.53	63	-5.86
6300.32	-9.76	21	-3.97	6169.06	-0.75	16	-7.14	6137.70	-1.40	95	-5.72
7771.96	0.29	191	-3.55	6169.56	-0.57	30	-6.99	6151.62	-3.30	6	-5.64
7774.17	0.14	204	-3.29	6439.07	-0.05	98	-6.72	6157.73	-1.28	17	-5.46
7775.39	-0.14	132	-3.73	6449.81	-0.62	24	-7.02	6173.34	-2.88	12	-5.77
Na				6471.66	-0.88	53	-6.33	6191.56	-1.48	76	-5.96
5682.63	-0.60	18	-7.31	6493.78	-0.39	66	-6.69	6219.29	-2.43	47	-5.55
5688.20	-0.15	59	-6.97	6499.65	-1.00	27	-6.58	6230.73	-1.28	105	-5.79
6154.22	-1.66	14	-6.18	7148.15	-0.08	42	-7.11	6232.64	-1.33	30	-5.54
6160.75	-1.35	6	-6.87	7202.20	-0.34	78	-6.45	6246.33	-0.70	58	-5.84
Mg				ScII				6252.56	-1.69	60	-5.95
5711.09	-1.75	42	-5.39	5640.97	-1.02	33	-10.68	6254.26	-2.38	44	-5.56
6318.70	-1.96	8	-5.27	5657.87	-0.55	101	-10.42	6256.36	-2.34	26	-5.72
6319.24	-2.30	9	-4.89	5667.16	-1.21	32	-10.53	6265.14	-2.55	39	-5.56
8310.25	-1.14	7	-5.54	5669.03	-1.10	44	-10.44	6301.50	-0.59	49	-6.01
8717.83	-0.88	42	-5.00	5684.19	-1.08	52	-10.37	6302.49	-1.16	50	-5.41
MgII				5854.31	-2.23	8	-10.17	6318.02	-2.00	42	-5.83
7877.05	0.40	64	-4.88	6245.63	-1.15	40	-10.44	6322.69	-2.43	21	-5.65
7896.37	0.74	56	-5.33	6279.75	-1.28	14	-10.76	6335.34	-2.20	44	-5.85
Si				6320.87	-1.89	6	-10.53	6336.84	-0.68	38	-6.06
5645.66	-2.15	13	-5.24	TiII				6344.15	-2.92	15	-5.52
5665.60	-2.11	15	-5.26	6606.95	-2.85	21	-8.14	6355.04	-2.38	13	-5.82
5666.69	-1.67	9	-5.44	VII				6358.69	-4.47	12	-5.43
5684.52	-1.66	63	-4.80	5819.93	-1.80	2	-9.81	6393.60	-1.57	60	-6.02
5690.47	-1.91	36	-4.97	5928.88	-1.74	11	-9.12	6408.02	-1.00	25	-5.89
5708.44	-1.49	50	-5.00	Mn				6411.66	-0.49	63	-5.92
5753.64	-1.45	11	-5.16	6013.50	-0.25	14	-7.84	6419.95	-0.27	19	-5.77
5772.26	-1.78	39	-4.74	6016.64	-0.24	13	-7.87	6421.36	-2.03	62	-5.69
5797.86	-2.03	15	-5.06	6021.80	0.03	15	-8.08	6430.85	-2.01	77	-5.66
5948.54	-1.22	71	-4.96	Fe				6494.98	-1.27	105	-5.94
6087.79	-1.80	4	-5.04	5569.62	-0.40	125	-5.65	6518.37	-2.67	13	-5.32
6091.92	-1.33	7	-5.34	5572.85	-0.22	160	-5.51	6592.92	-1.60	75	-5.58
6142.49	-1.56	11	-5.17	5576.10	-0.73	72	-5.81	6593.88	-2.42	53	-5.26
6145.08	-1.48	18	-5.00	5586.76	-0.12	160	-5.63	6609.11	-2.69	21	-5.36
6155.14	-0.84	58	-5.00	5615.65	0.00	163	-5.76	6677.99	-1.22	66	-6.08
6237.34	-1.22	33	-4.98	5624.55	-0.65	106	-5.60	6750.15	-2.62	28	-5.43
6243.82	-1.34	19	-5.15	5638.27	-0.85	33	-5.45	6855.16	-0.63	23	-5.54
6244.47	-1.38	15	-5.26	5641.44	-1.18	8	-5.83	FeII			
6976.50	-1.07	14	-5.16	5679.02	-0.85	11	-5.70	5991.38	-3.76	78	-5.52
7003.57	-0.86	20	-5.21	5686.53	-0.64	21	-5.63	6084.10	-3.99	40	-5.67
7405.78	-0.71	52	-5.20	5701.55	-2.22	31	-5.67	6113.33	-4.26	30	-5.53
7415.96	-0.67	50	-5.26	5705.99	-0.58	22	-5.61	6149.24	-2.88	78	-5.72
7799.99	-0.76	9	-5.48	5731.76	-1.19	12	-5.72	6238.38	-2.87	70	-5.83
7918.39	-0.58	60	-4.90	5753.14	-0.66	19	-6.01	6247.56	-2.55	110	-5.77
8556.79	-0.21	67	-5.44	5775.09	-1.23	15	-5.36	6416.90	-2.86	54	-5.97
8752.02	-0.37	50	-5.47	5778.46	-3.60	2	-5.42	6432.65	-3.85	94	-5.54

**Table 5.** (Continued)

$\lambda$	gf	W (mÅ)	$\epsilon(X)$
6432.65	-3.85	94	-5.54
6446.40	-2.11	8	-5.51
6516.05	-3.55	100	-5.80
7479.70	-3.77	26	-5.50
7515.88	-3.57	54	-5.29
Cu			
5782.13	-1.81	14	-8.72
YII			
5728.91	-1.21	3	-11.32
6795.43	-1.59	12	-10.58
BaII			
5853.68	-0.92	81	-11.53
6141.72	-0.27	158	-11.98
6496.90	-0.07	202	-11.26
LaII			
6262.25	-1.45	6	-12.19
6526.95	-1.58	6	-11.93
CeII			
5610.24	0.00	10	-11.81
NdII			
5740.87	-0.43	7	-11.47
5842.38	-0.34	11	-11.24
6031.30	-0.42	13	-11.13
6034.22	-0.40	12	-10.93
EuII			
6437.64	0.05	12	-12.46

- a slight overabundance of N in combination with a C depletion,
- an overabundance with respect to iron of the even-Z elements (Mg, Si) synthesized by the  $\alpha$ -process,
- an abundance (with respect to iron) close to the solar one of the other  $\alpha$ -process elements Na and Ca,
- a strong odd-even effect,
- the absence of any traces on the third dredge-up.

Therefore, from the chemical abundance pattern, taking into account the high radial velocity, the absence of a detached envelope and IR-excess, we conclude that UU Her did not yet undergo a significant mass loss episode and convection development.

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