NEAR INFRARED SPECTRA OF O STARS AND RELATED OBJECTS

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ABSTRACT

The λ 10124 He II line has been found to be a measurable emission in three stars. Our new data are compared to theoretical predictions. The λ 10830 He I line is observed in emission in 74 % of the O5-O8 supergiants but only seen in 29 % of the dwarfs, all of the latter exhibiting some "pecularities" i.e. classified as Oef, Oe, ON or On. An envelope with a sufficient amount of material seems to be a favorable condition to get the λ 10830 line in emission. However the mechanism leading to the observed emission is temperature dependent as well.

INTRODUCTION

The results given here have been obtained with the "Roucas" grating spectrograph attached to the Cassegrain focus of the Haute Provence Observatory 1.93 m (77 inch) telescope. The characteristics of this instrument have been given elsewhere (Andrillat, et al., 1973). We only recall here that the dispersion is 230 Å mm^{-1} and that the 200 μ slit corresponds to 7 Å in the plane of the receiver. The latter is a cooled (around -60°C) ITT F-4718 two stage image tube; 103aD film is used behind the fiber optics output. The accuracy of equivalent widths larger than 2 Å is estimated to be of the order of ± 25 %. It is worse for fainter features, the detection threshold being of the order of 1 Å. The noise is not the only limiting factor : strong telluric absorption and contamination by OH night sky emission combined with the sharp sensitivity dropoff at λ > 1 μ make sometimes the definition of the continuum rather imprecise.

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THE He II λ 10124 LINE

The most recent theoretical predictions are due to Klein and Castor (1978). According to their model this line should be a strong emission in some Of stars, the ratio of λ 10124 to λ 4686 ranging from 2.16 to 3.64. Using previous observations of two Of stars by Mihalas and Lockwood (1972), Klein and Castor (1978) derived an observed ratio of about 1.3. Out of a sample of 67 O stars we do observe emission at λ 10124 in three objects : HD 16691 ($O4If^{+}$), HD 190429($O4If^{+}$) and HD 228766(O5.5f), the last one being a transition object according to Massey and Conti (1978). Following Klein and Castor (1978) the equivalent width of the emissions have been corrected for the underlying absorption on the basis of non LTE/L calculations (Auer and Mihalas, 1972) and then compared to the available values of He II λ 4686 (Conti and Alschuler, 1971; Conti and Leep, 1974; Massey and Conti, 1978). For the first two stars we get a maximum value of the ratio less than 1.4 i.e. again smaller than the ratio predicted by the model. But HD 228766, the transition object, gives a value of the order of 2.1, i.e. close to the prediction. We have used the observed ratio for "normal" Of stars and the calculations of Auer and Mihalas quoted above to predict the intensity of the λ 10124 line in all the stars for which we had data both at λ 4686 and at λ 10124. The result is given in table 1.

Table 1 - Comparison between observed and predicted He II λ 10124 intensities in Of stars

Star	Spectral type (Conti)	Observed λ 4686 log W(mA) (emission)	Predicted λ 10124 W (Å)	Observed λ 10124 W (Å)
108	O7If	2.11	1.3	4.0
14442	O6ef	2.59	1.2	2.5
14947	O5.5f	3.36	E 1.1	0
16691	O5f	3.78	E 6.1	E 3.0
				E 6.0
57060	O8.5If	2.91	0	0
166734	O7.5If	2.56	0.9	A ou 0?
167971	O7.5If	2.57	0.9	0?
188001	O8If	2.26	1.0	A?
190429	O4f	3.57	E 3.0	E 3.5
				E 4.0
				E 3.5
210839	O6ef	2.86	0.7	A ou 0?
+60°2522	O6.5IIIef	2.88	0.6	0

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Except for HD 108 (which has a P Cygni profile at λ 4686) and in a lesser extend for HD 14442 and HD 14947, the agreement is good, the difference between prediction and observation being of the order of the estimated error. It may be worthwhile stressing that this result is obtained with the observed ratio, not the theoretical one and that in addition to HD 108 and HD 14442 we have a few other O star with an unexpectedly strong absorption.

THE He I λ 10830 LINE

Since many years the He I λ 10830 line (2^3s-2^3P) is known to be a strong emission in most of the WR stars (Kuhi, 1968) and to be a strong absorption in B stars with extended atmosphere (Underhill, 1970). The present results deal with the stars between these two classes. The two O stars spectra exhibiting the strongest emission at λ 10830 Å are illustrated in fig. 1.

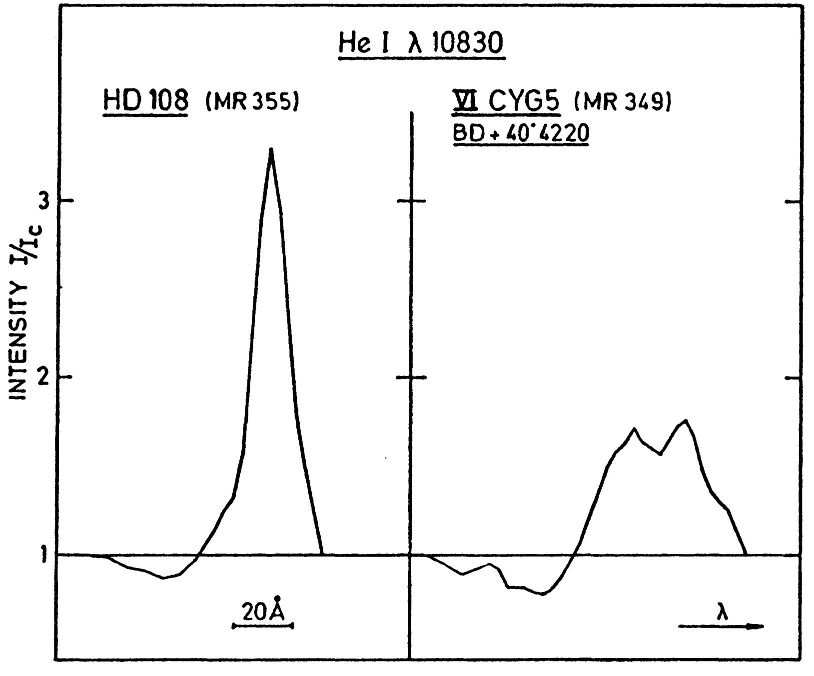

Figure 1. The two strongest He I λ 10830 emissions recorded (uncorrected for instrumental profile).

The broadest profile is observed in VI Cyg 5 (BD +40°4220) which, according to Bohannan and Conti (1976), is on the way to become a Wolf Rayet. In order to try to find which

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physical conditions are requested to produce λ 10830 emission we have plotted in fig. 2 the observed behavior

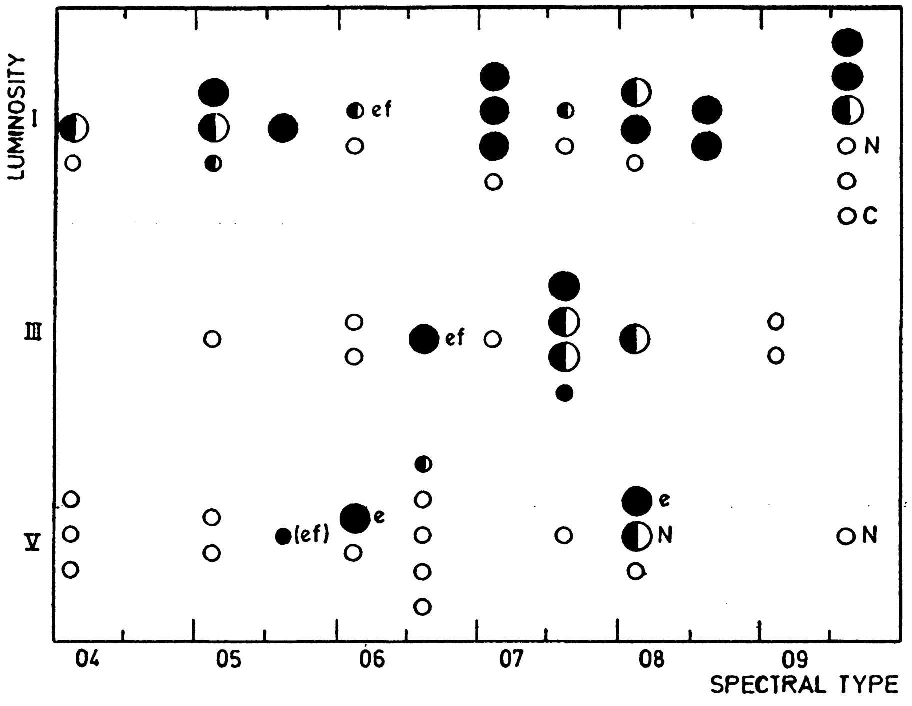

Figure 2. Distribution of He I λ 10830 emission (black filled circles) as a function of spectral type and luminosity class.

of this line as a function of spectral type and luminosity class. Empty circles are used for stars with well exposed spectra where no emission is observed. Black filled circles mean that λ 10830 has been observed in emission, half circles being used when the emission is variable and has not been found on all the spectra of the object. A larger circle has been used when an equivalent width has been obtained. From this figure it appears that an emission is observed at λ 10830 (with or without a P Cygni profile) in 74 % of the O4-O8 supergiants but only seen in 29 % of the dwarfs all of the latter exhibiting some peculiarities in their spectra (i.e. classified as Oef, Oe, ON or On), peculiarities which are believed to be characteristic of the presence of an envelope or of a companion. But an envelope or a companion is not a sufficient condition. To try to go further we have searched for a correlation between the mass loss rate and the intensity of the λ 10830 emission. The results are given in table 2. The available data show a nice correlation between the two parameters in

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Table 2 - O Star Mass Loss Rates and λ 10830 Intensity

Star		Spectral type (Conti)	$\dot{M}$ $(10^{-7} M_o yr^{-1})$	W(λ 10830) (Unit : Å) Emission
A. Mass Loss from Hutchings (1976)				
	108	07If	1000	35.5
29CMa	57060	08.5If	85	9
9 Sge	188001	08If	75	6 (var)
	14947	05.5f	60	8
λ Cep	210839	06ef	30	< 1
Cyg X-1	226868	09I	25	4.5 (var)
	46150	05.5((f))	15	0
	48099	06.5V	1	0
B. Mass Loss from Barlow and Cohen (1977)				
	108	07If	85	35.5
	14947	05.5f	24	8
	60848	08Ve	24	∿ 15 (var)
	39680	06Ve	19	18
	45314	0Be	4	E

05-09 stars. This effect is temperature dependent : it is strongly weakened among the B stars (He I λ 10830 being only observed in emission in three objects out of a sample of 22) and looks weakened among the 04 stars too, but we only have observations for four 04 stars with known mass loss rate. In conclusion our sample indicates that the most favorable conditions to "push" He I 10830 in emission are that the envelope has a sufficient amount of material and that the central star has a temperature between 30 000°K and 45 000°K. These He I observations undoubtedly put constraints on the ionization balance of Helium in the theoretical models of the stellar wind.

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DISCUSSION FOLLOWING VREUX AND ANDRILLAT

Lamers: Can you express the extent of the He I emission lines in km/sec, in order to get an impression about the part of the envelope where the line is formed?

Vreux: The full width of HD 108 emission is about 1000 km/sec -- the absorption component is marginally present: The sensibility of the instrument is varying rapidly around one micron and the definition of the continuum is not easy -- the accuracy of the equivalent width of HD 108 is better than 20% but to know the extension of the wings we need the new detector under development at the Haute Provence Observatory.

Castor: From the figure of HD 108 it appears that the absorption on the blue side extends ~35 or 40 Å from line center, which is about 1000 km/sec. That's probably rough, but it is of the order we should think about.

Bidelman: This is slightly off the topic but I would like to make a point here about nomenclature. Is VI Cyg #5 the same star as BD+40° 4220?

Bohannan: Yes, it is also known as V729 Cyg.

Bidelman: Well, I'd like to say, as a member of an IAU Commission concerned with such things, that one should adopt a consistent labeling for a star.

Underhill: I'd like to second that.

Bidelman: We don't all have encyclopedic memories.

Conti: My feeling is that when talking about the spectrum one should use the HD (HDE,BD) name, and when talking about the photometry, the variable star name. However, our practice has always been to quote both initially.

Bidelman: We really should come to some formal agreement about this. Another point: we should stop talking about γ "two" Vel. Just say γ Vel.

Morton: What do you call the other star then?

Bidelman: You don't care about the other star.

Underhill: It's a nice B2IV.

Bidelman: The number 1 and 2 business is a mistake from a long time ago. If you really want to be fussy it's γ Vel A and B. When one star is so much brighter than its companion, and so close, there is no point in using the superscripts.

Underhill: Getting back to the IR spectral data: There probably is an eventual dropoff in temperature far out in the stellar wind. He I λ10830 is a metastable transition of a neutral atom. Could it be that this profile is formed far from the star, rather than close to the photosphere?

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