INFRARED SPECTRA OF T TAU STARS AND RELATED OBJECTS

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Abstract. Four T Tau stars and related objects (RY Tau, T Tau, AB Aur and V1057 Cyg) have been included in our spectroscopic programme since 1973. The present paper is concerned with the spectroscopic observations made at the Crimea with the single-stage image tube S1. Tentative atomic line identifications are given for programme stars. Ca II and O I emission line equivalent widths and profiles are presented for RY Tau, T Tau and AB Aur. The λ10830 Å line of neutral helium has shown P Cyg-type features for T Tau and V 1057 Cyg.

1. RY Tau, T Tau and AB Aur

1.1. Line identifications

In October 1972, October–December 1973, and June–July 1974 we obtained several spectra of programme stars in the 0.8–1.1 μ region with the 50-in. Crimean Observatory reflector and the single-stage image tube. Instrumentation has been described by Vitrichenko *et al.* (1974a, 1974b). The equipment yielded reciprocal linear dispersions of 168 and 48 Å mm^{-1} with resolutions of spectrograms of about 7 and 2 Å, respectively.

Tentative atomic line identifications were performed for RY Tau, T Tau and AB Aur. Primary sources of wavelengths were the *Revised Multiplet Table* (Moore, 1945) and the compilation of solar lines by Swensson *et al.* (1970). Identifications in the $\lambda\lambda$ 8200–8600 Å region were obtained from 48 Å mm^{-1} spectrograms; at $\lambda\lambda$8000–11000 Å features were located using a 168 Å mm^{-1} dispersion. Results are listed in Table I.

We found some absorption features at $\lambda\lambda$10422 and 10440 Å and a clear emission line at λ10568 Å for T Tau which have not been identified. Unfortunately, we have no identifications in the $\lambda\lambda$9000–11000 Å region for many other very weak (on 168 Å mm^{-1}) absorption features of T Tau.

1.2. Emission lines

The λ10830 Å line of He I is certainly present in the spectrum of T Tau, obtained with 168 Å mm^{-1} dispersion during the night of 1973, October 26. The profile of λ10830 showed P Cyg-type features with the equivalent width of the emission component of about 3.8 Å.

In the spectrum of AB Aur obtained on October 7, 1972, no emission feature at λ10830 Å was found with the same dispersion while broad emission in the hydrogen P 7 line (λ10049 Å) is clearly present. Also, the spectrum of AB Aur from 1973, Oc-

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TABLE I

Line identifications of T Tau stars[a]

Wavelength (Å)	Element	Mult. No	Star		
			RY Tau	T Tau	AB Aur
1	2	3	4	5	6
8374	H	11	a	a	a
8387	Fe I	60	?	a	–
8413	H	10	a	a	?
8437	H	10	a	a	?
8446	O I	4	e	e	e
8460	?	–	e	e	e
8467	H	10	a	a	?
8468	Fe I	60	a	a	n
8482	Fe I	999	a	a	n
8498	Ca II	2	e	e	e
8502	H	10	–	–	–
8514	Fe I	60	?	a	n
8542	Ca II	2	e	e	e
8545	H	10	–	–	–
8612	Fe I?	–	–	a	–
8662	Ca II	2	–	e	–
8665	H	9	–	–	–
8688	Fe I	60	–	a	–
8728	Si I?	79	–	a	–
9998	Ti I	149	–	a	–
10001	Si I	64	–	a	–
10003	Ti I	193	–	a	–
10011	Ti I	193	–	a	–
10012	Ti I	193	–	a	–
10020	Si I	41	–	a	–
10025	Si I	64	–	a	–
10049	H	8	–	a	e
10422	?	–	–	a	–
10440	?	–	–	a	–
10568	?	–	–	e	–
10827	Si I?	5	–	a	–
10830	He I	1	–	e	n

[a] a – absorption; e – emission; n – no line; (–) – no line measurements.

tober 6 has shown strong emission lines of Ca II and O I (see Tables I and II). It is interesting that AB Aur showed no emission on the 78 Å mm^{-1} spectrograms taken by Wallerstein (1971) during January 1970.

A microphotometer tracing of the Ca II triplet region in the T Tau spectrum is given in Figure 1. It is interesting that the Ca II central line intensities are of the same height. The complex structure of emission features in RY Tau, T Tau and AB Aur can be seen in line profiles obtained from 48 Å mm^{-1} spectrograms (Figure 2).

Table II presents typical emission lines in these stars. The successive columns give: names of stars, dates, spectrogram numbers, dispersion, equivalent widths of the λ8498 Å, Ca II and relative equivalent widths of lines I_λ. No corrections were made to

TABLE II

Emission line equivalent widths of T Tau stars[a]

Star	Date	No sp.	D Å mm^{-1}	W_λ Ca II 8498 (Å)	I_λ Ca II 8498	Ca II 8542	Ca II 8662	O I 8446
1	2	3	4	5	6	7	8	9
RY Tau	Oct. 2, 73	617	48	17.4	1.00	1.17	[b]	0.12
T Tau	Oct. 1, 73	611	48	5.2	1.00	1.06	[b]	0.61
T Tau	Oct. 2, 73	616	48	4.5	1.00	1.26	[b]	0.62
T Tau	Oct.26, 73	646	168	4.6	1.00	0.86	0.82	0.62
T Tau	Dec.25, 73	702	168	4.6	1.00	0.51	0.70	0.61
AB Aur	Oct. 6, 73	626	48	1.8	1.00	0.92	[b]	0.27

[a] All equivalent widths have errors of the order of 20 %
[b] We have no observations of this line.

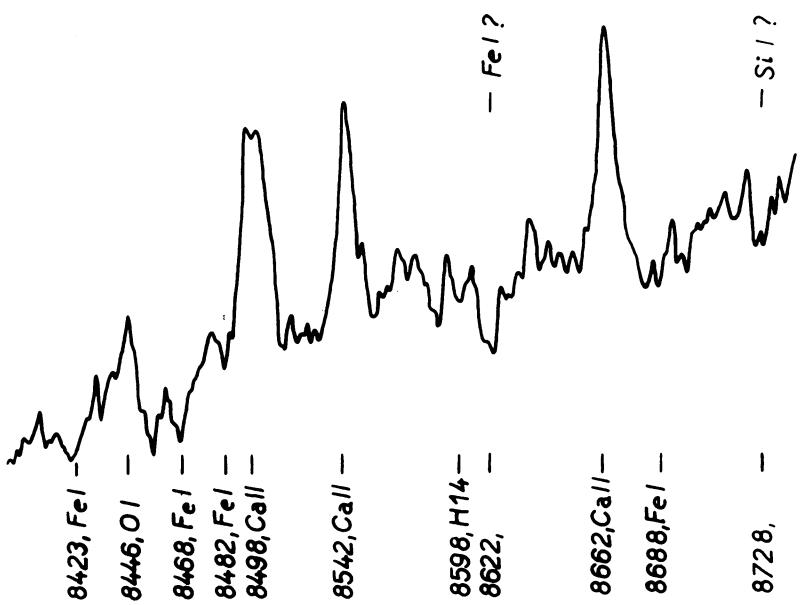

Fig. 1. Microphotometer tracing of the infrared Ca II triplet region of the T Tau spectrum. Original dispersion is 168 Å mm^{-1}.

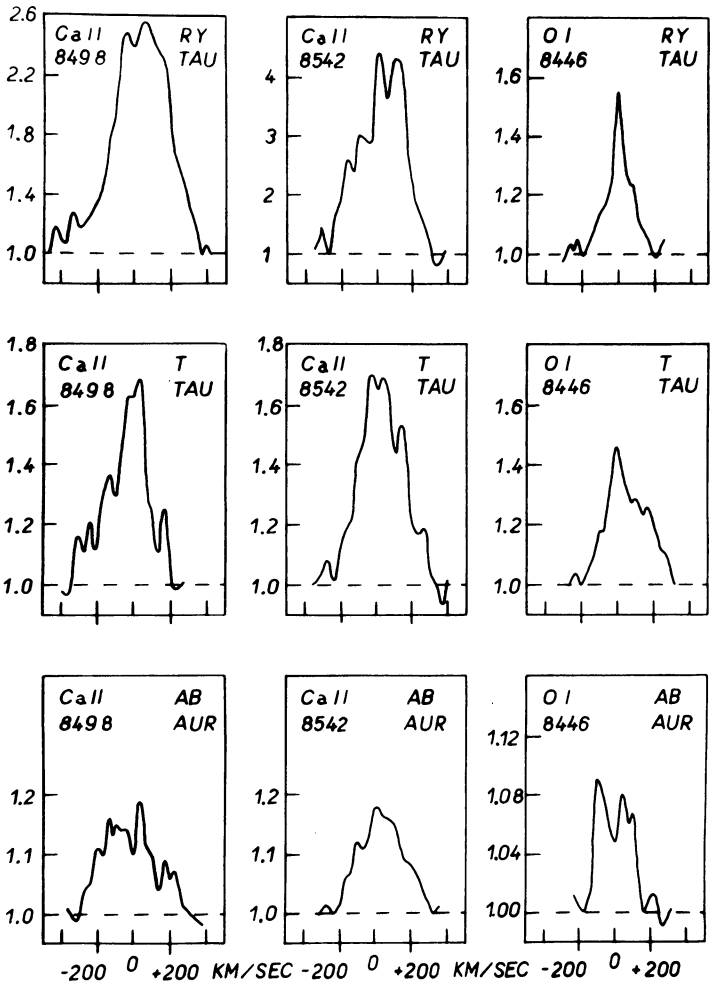

Fig. 2. Emission line profiles of Ca II and O I for RY Tau, T Tau and AB Aur obtained from 48 Å mm^{-1} spectrograms.

the equivalent widths I_λ for the continuum energy distribution. Since we found that the hydrogen absorption lines are very weak, their contribution to the equivalent widths of the Ca II triplet lines have not been taken into account. Figure 1 and Table II indicate that observed relative intensities of lines in the Ca II triplet differ from their theoretical optically thin values 1, 9, and 5. The greatest differences take place for T Tau. A very interesting feature of the T Tau Ca II triplet is the variability of the relative line equivalent widths on a long time scale. An analysis of Table II indicates also that the triplet ratios observed in the spectrum of T Tau are not due to self-absorption.

Apart from internal variations of Ca II lines, in the same spectra of T Tau no variability of the ratio

$$W_{\lambda\,8446,\,O\,I}/W_{\lambda\,8498,\,Ca\,II}$$

has been observed. However, insufficient data are available at present to allow certain confirmation of the Ca II lines variations.

2. V 1057 Cygni

In June and July 1974, we obtained at a dispersion of 48 Å mm^{-1} seven spectra of V 1057 Cyg in the Ca II triplet and λ10830 Å regions. The profile of the λ10830 Å line of neutral helium in the V 1057 Cyg spectrum is compared with the P Cyg profile (taken in July, 1974) in Figure 3. Shell features of He I in V 1057 Cyg are shown. The line has a P Cyg-type absorption component displaced about 450 km s^{-1} shortward. (According to Herbig and Harlan (1971), Hα has the same displacement of about 420 km s^{-1}). In contrast to P Cyg, the He I absorption of V 1057 Cyg is very broad, which must be indicative of an enormous velocity gradient. Grasdalen (1973) reports that the equivalent width of the λ10830 Å He I line was of the order of 6 Å in May

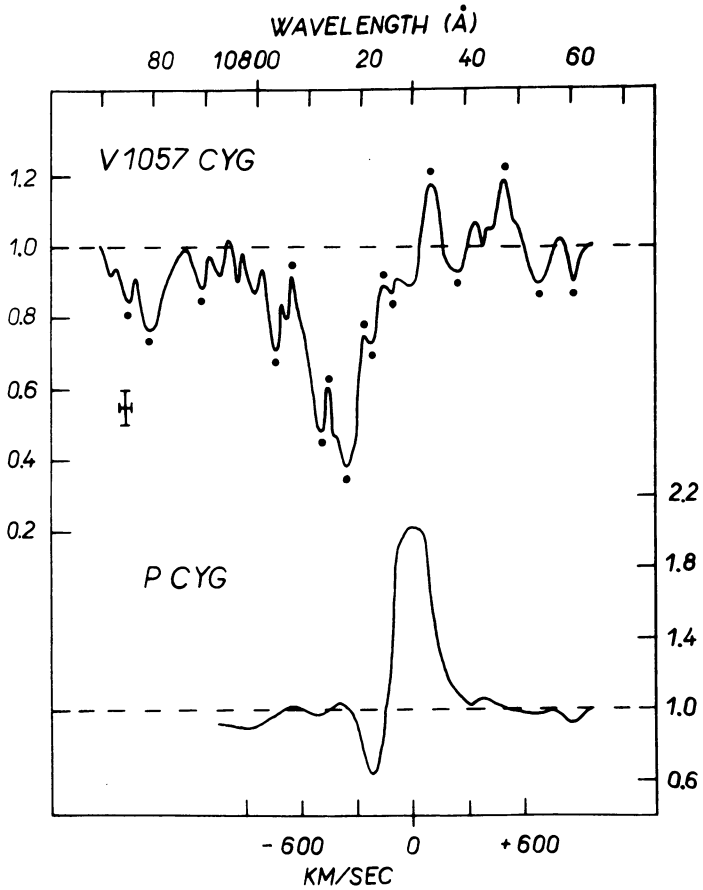

Fig. 3. Comparison between observed line profiles for V 1057 Cyg and P Cyg (see text). Original dispersion is 168 Å mm^{-1}.

1972, which is in close agreement with our estimated average value of 7.2 ± 0.5 Å for June 1974.

Details of the λ10830 Å region which appear in all spectrograms of V 1057 Cyg are represented in Figure 3 by filled circles. Two features ($\lambda\lambda$10817 and 10822 Å) we interpret as emission lines of multiplet no. 118 of Cr I, which shows clear emission features without appreciable displacement at $\lambda\lambda$10648, 10667 and 10672 Å. Herbig and Harlan (1971) reported emission features in the infrared Ca II triplet in 1971, but no emission has been found for 1974 and only absorption features of hydrogen and calcium lines have been detected. The λ8446 Å line of O I is also in absorption.

Other absorption lines in the spectra of V 1057 Cyg observed in the $\lambda\lambda$10580–10900 Å region are all lines of the carbon multiplet no. 1 plus four lines of the silicon multiplet no. 5. The possibility that the λ10827 Å Si I absorption line contributes about 30% to the λ10830 Å helium line is very great. The presence of C I and Si I lines and their intensities suggest that V 1057 Cyg may now have a spectral type of about F 5. It is interesting that the absorption spectrum of V 1057 Cyg in the $\lambda\lambda$10580–10900 Å region is very similar to the spectrum of γ Geminorum (Cepheid, F 7–G 3 Ib) in the same region (Shanin and Shcherbakov, 1974).

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