RED AND NEAR INFRARED SPECTRA* OF PRE-MAIN SEQUENCE STARS I. A PRELIMINARY INVESTIGATION OF T TAURI STARS

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Abstract

230 Å mm^{-1} spectra of 30 stars of T Tauri or related type were obtained in the 8000-11000 Å region using a grating spectrograph equipped with an S-1 photocathode image-tube. In addition a few T Tauri stars were observed at the same dispersion in the 6200-8800 Å region on IN plate. A preliminary qualitative analysis of the observations leads to possible correlations between the intensities of emissions of the Ca II triplet, Paschen series and He I 10830 Å, and the spectral type, K-L color index of the star, or the [O I] and Fe II intensities in the visible spectrum.

Introduction

The data described here result from a continuation of our spectrographic investigation in the near infrared of emission-line objects with infrared excesses. We have previously given reports of our observations of B[e] stars (Andrillat and Swings, 1976), the "egg nebula" CRL 2688 (Swings and Andrillat, 1977), and of emission-line galaxies (Andrillat and Swings, 1977). So far the 8000-1100 Å region has not been extensively used to study T Tauri stars except for some photoelectric spectrum scanner observations reported by Kuhi (1974). The aim of our observations was not only to detect emission lines in the near infrared, but also to make a selection of interesting objects (i.e. those with rich emission line spectra) to study quantitatively once a self-scanned diode array will replace the image-tube as a receiver for the spectrograph, thus enabling sky subtraction. Other pre-main sequence objects, such as Herbig-Haro objects, will be added to the above mentioned selection, and will hopefully be observed in early 1978.

Observations

Spectra at a dispersion of 230 Å mm^{-1} were obtained at the Haute Provence Observatory with the "Roucas" grating spectrograph attached to the Cassegrain focus of the 1.93 m (77 inch) telescope for the 8000-11000 Å region (see summarized description of the instrument in Andrillat and Swings (1976)) and with a conventional spectrograph at the newtonian focus of the 1.2 m (48 inch) telescope, for the 6200-8800 Å region (Andrillat and Andrillat (1961)). Figures 1 and 2 illustrate these two sets of observations.

Table 1 groups some of our qualitative results for those stars

*All the observations have been performed at the Haute Provence Observatory.

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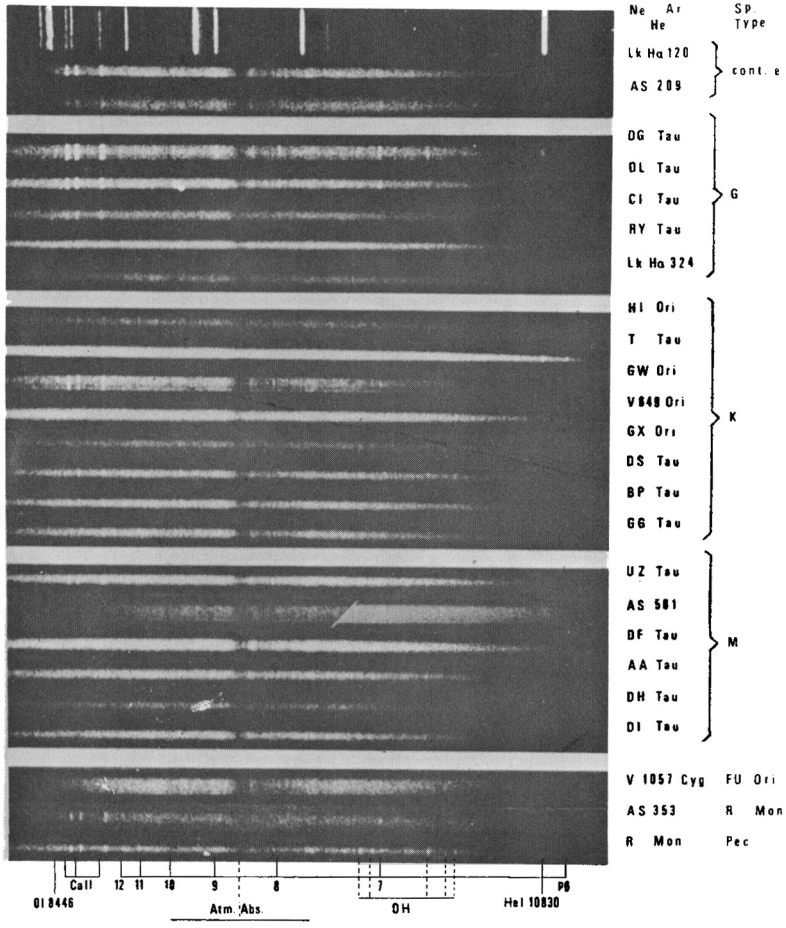

Fig. 1 8000-11000 Å spectra of 24 T Tauri- or related stars arranged according to their spectral types. Original dispersion: 230 Å mm^{-1}. The positions of some stellar lines and of contaminants (atmospheric absorption and/or OH night sky emission) are indicated. According to Zappala (1972) GW Ori is of type G5e, which would seem more appropriate on the basis of the strength of Ca II. On a similar argument AS 209 could be of type dK3e as suggested by Kuhi (1964). Note that He I 10830 is in absorption in the spectrum of LkHα 120.

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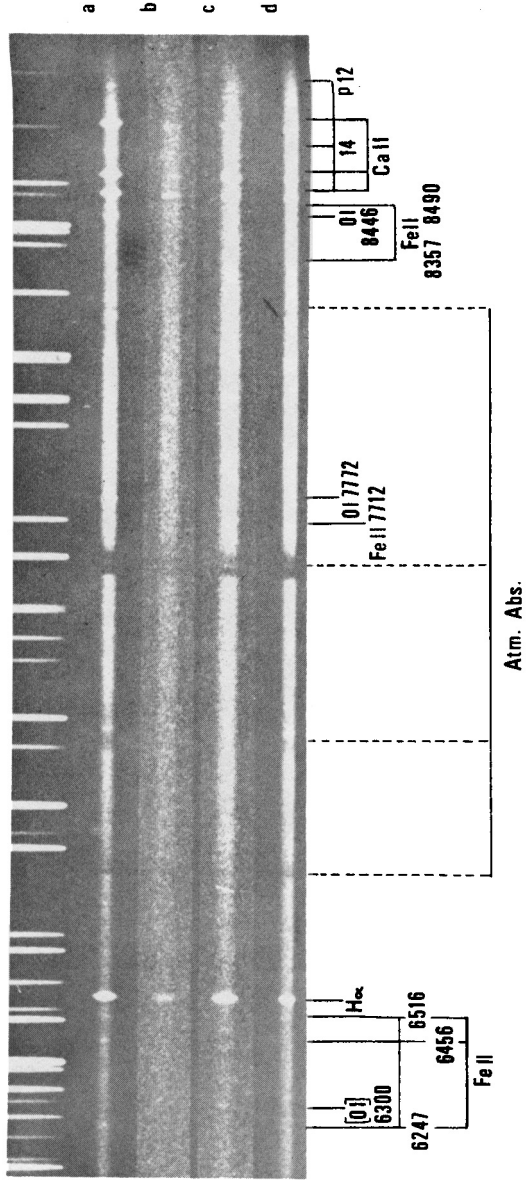

Fig. 2 6200-8800 Å spectra of a: V380 Ori A1e
b: RY Tau G5e
c: T Tau K1e
d: GW Ori dK3e (or G5e)
The positions of a selection of stellar emission lines are indicated.

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TABLE 1 : Visible and Near Infrared Data Concerning a Sample of T Tauri Stars

Name	Sp. Type (1)	Em. Class (2)	Color Indices (3) 1.6 μ - 2.2 μ	Color Indices (3) 2.2 μ - 3.5 μ	Ca II triplet	He I 10830	Paschen	Veiling	Balmer	He I	[O I]	[S II]	Fe II	K/Hyd.
					"Roucas"			Rydgren et al (1976)						
DG Tau	-	5	1.0	1.7	s	p	p	s	s	yes	yes	yes	s	>>1
DL Tau	K7eV	5	0.6	1.4	s	p	p	s	s	yes		yes	s	>>1
CI Tau	K7eV	4	0.6	1.0	w	abs	abs	s	s				w	>1
RY Tau	K1eIV,V	2	0.9	1.2	w	p	abs?	w	α,β					>>1
T Tau	K0eIV	2	0.6	1.3	m	p	p	w	m	yes	yes	yes	s	>1
DS Tau	M0:eV	(3)	0.5	0.7	w-m	abs	p?							
BP Tau	K5,7eV	4	0.2	0.5	w	abs	abs	s	s					>>1
GG Tau	K5eV	(3-4)	0.4	0.8 (1.1)	w	abs	abs	m	s	yes	v.w		w	>>1
AA Tau	K5eV	(3)	0.7	1.0	abs	?	?	s	m	yes	v.w			<1
DH Tau	M1eV	3	0.3	0.6 (1.6)	abs	abs	abs	s	s				w	<1
DI Tau	M0eα	4μ	0.4	0.4	abs	abs	abs	v.w	w					>>1
					Kuhi (1974)									
XZ Tau	-	5	0.7 (0.9)	2.4 (1.7)	m	abs	γ	s	α,β		yes			>1
SU Aur	Geα	1	0.5	0.8	v.w	abs	abs	w	v.w					
RW Aur	-	5	0.8	1.2	s	abs	,	s	s	yes	w		s	>>1

(1) From Herbig (1977), (2) From Herbig and Rao (1972), (3) Approximate values from Rydgren et al (1976).

which are also studied by Rydgren et al (1976). For three additional stars we have used Kuhi's (1974) results. It seems to appear from table 1 that the intensities of the emission lines of H I, He I and Ca II are correlated with

(i) the spectral type of the star : it is clear from fig. 1 also that, e.g., the Ca II triplet appears in those stars classified by Herbig and Rao (1972) as cont. + e, pec., Ge or Ke, while it is virtually absent in the Me's (except for UZ Tau). This correlation, however is not as convincing if the spectral types recently published by Herbig (1977) are taken into consideration since, e.g., DL and CI Tau which were classified as G:e now become K7 stars. It remains nevertheless that Ca II is apparently absent in M stars while it is present in the other types considered in this paper.
For T Tauri stars, Kuhi (1974) states that "The reddening seems to be a function of the spectral type in the sense that A_V is significantly larger for G type stars than for M stars. This in turn implies that the reddening must be circumstellar in origin". The Ca II infrared triplet thus seems to have its intensity directly correlated with the amount of circumstellar material (see ii);

(ii) the K (2.2 μ) - L (3.5 μ) color index : Ca II is either weak or absent for those stars with K-L < 1.0; the Paschen lines and He I 10830 apparently have a similar behavior. It should be mentioned that Lk Hα 120 and AS 209 that do not appear in Table 1 have K-L indices of 1.2 and < 2 respectively (Glass and Penston, 1974);

(iii) the intensity of emission lines of [O I] and Fe II; examples are V380 Ori for Fe II and T Tauri itself for [O I] (see fig. 2).
However, as in B[e] stars, there is no correlation between the strengths of O I λ 8446 and of the Ca II triplet (Andrillat and Swings, 1976).

We also observed some of the objects Bonsack and Greenstein (1960) name "related" to T Tauri's : He I λ 10830 is present in the spectrum of AG Dra, whereas no emission is detectable in our spectra of BD +24°2742, BD + 37°2318 and HD 117555; no emission appears either in the spectrum of AS 310 (B-Ae according to Herbig and Rao 1972), of BD 46°3471 (T Tauri type given by Kuhi, 1964), or of the ex-T Tauri star V1057 Cyg (see fig. 1).

Future observations

On the basis of the observations reported here we plan to observe a selection of T Tauri stars and a series of Herbig-Haro objects with a Reticon device. After sky subtraction, a quantitative analysis of the most interesting spectra will be performed, as well as a search for faint emission lines.

Acknowledgements

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D I S C U S S I O N of paper by ANDRILLAT and SWINGS:

WOLF: Have you compared the intensity of the OI line 8446Å with other OI lines? Is there any indication for a fluorescence mechanism working in T Tauri stars, enhancing the intensity of the 8446Å line?

SWINGS: We have made no such comparison. However, one may say that in the case of B [e] stars there almost exists an anti-correlation between the strengths of the CaII triplet and of OI 8446Å (see Andrillat and Swings, 1976, Ap. J. Letters, 204, L123).

APPENZELLER: Does the fact that the HeI 10830Å line is observed in absorption in LK Hα 120 show that this star is not a T Tau star but should rather be classified as a Herbig Ae - star?

SWINGS: Yes, this could be, although one should look at the paper by Penston and Kealey who recently studied this star in detail in the visible.

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