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SPECTROSCOPIC OBSERVATIONS OF Hα EMISSION-LINE STARS FROM THE SCHWARTZ, PERSSON, & HAMANN LIST: THE CANIS MAJORIS REGION[1]

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ABSTRACT

We present spectroscopic observations of 25 emission-line stars in the Canis Majoris region of Schwartz, Persson, & Hamann. This work is part of a program to investigate emission-line objects in the southern hemisphere. The objects were observed in three different spectral regions providing full coverage in the interval 3100–7500 Å. In this paper, we describe some of the main spectroscopic features and discuss the nature of the objects. It is proposed that 16 of them are Be stars and seven are T Tauri stars. Two objects failed to show emission lines.

Key words: stars: emission-line, Be — stars: individual (T Tauri)

1. INTRODUCTION

As part of a long-term program to investigate emission-line objects in the southern hemisphere, we recently started a spectroscopic survey at ESO of previously unclassified stars. In the present work, we concentrate on the stars of the Canis Majoris region that have first been reported as Hα-emission objects by Schwartz, Persson, & Hamann (1990). They are the 26 stars located near the dark cloud in Puppis. A previous analysis of one star (SPH 2) in this region led to the discovery of a new WN4 Wolf-Rayet star (Pereira et al. 1998). In this paper, we present the spectra for 25 objects, suggesting a classification for each one of them. In § 2, we describe the observations and data reduction. In § 3, we present a discussion of the observed spectra. In § 4, our findings are summarized.

2. OBSERVATIONS AND REDUCTIONS

Spectroscopic observations were done using a Boller & Chivens spectrograph at the Cassegrain focus of the ESO 1.52 m telescope in La Silla (Chile). A UV-flooded, thinned, Loral/Lesser CCD, ESO No. 39 (2048 × 2048, 15 μm pixel^{-1}), was used as the detector; it has high quantum efficiency in the blue and UV. The setup used was the same used to investigate other emission-line objects, including symbiotic stars, at the 1.52 m telescope (Pereira, Landaberry, & Conceição 1998). Three instrumental setups were employed. The first used grating No. 23 with 600 lines mm^{-1}, providing a resolution of 4.6 Å in the range 3500–7500 Å. The other two setups adopted gratings No. 31 and No. 26 with 1200 lines mm^{-1}, resulting in a resolution of 1.9 Å and two overlapping spectral intervals 3100–7500 Å.

The spectra were reduced using standard IRAF tasks, from bias subtraction and flat-field correction through spectral extraction and wavelength and flux calibration. Spectrophotometric standards from Oke (1974) and Hamuy et al. (1994) were observed. The slit for the range (3110–5100 Å) was aligned with the parallactic angle to minimize the light loss due to differential refraction. Table 1 shows the log of observations and the typical signal-to-noise ratio (S/N) per pixel in the continuum achieved in each observation. Table 1 also shows the types of stars identified in this work in §§ 3.1 and 3.2.

We also collected spectra of B stars selected from the Bright Star Catalogue (Hoffleit & Jaschek 1982) to serve as templates for the spectral classification of SPH stars.

3. DISCUSSION OF THE DATA

In the following subsections, we present the spectra and comment on the nature of the observed objects.

3.1. *Be Stars*

The spectra of SPH stars 3, 7, 9–16, 18–20, 23, 25, and 26 are shown in Figures 1*a*–1*d*. The SPH stars 3, 9, 10, and 18 have a continuum similar to that of a typical hot B-type star. We propose that they are Be stars. SPH 7 has Hα and Hβ in emission (and perhaps other weak emission features too), but its continuum is heavily reddened. The SPH stars 11–16, 19, 20, 23, 25, and 26 exhibit a broadband continuum absorption between 4450 and 5200 Å. It is not clear whether this absorption is of circumstellar origin. However, some significant reddening should be present, since some stars in this region are close to a dark cloud, as some of them are in the Lynds catalog of dark nebulae (Lynds 1962). They may be Be stars, but we note that their continuum spectra look similar to that of a B-type post-AGB candidate named Hen 3-1013 (IRAS 14331-6435; Manchado, Garcia Lario, & Pottasch 1989). Figure 2 shows the spectrum of Hen 3-1013 obtained by us at a resolution of 4.6 Å.

Three other features deserve to be mentioned: (1) the interstellar sodium at 5890 Å, as well as two diffuse bands centered at 4430 and 6284 Å, are observed in almost all cases; (2) the Balmer continuum is seen in emission in SPH 11, 12, 13, 14, 15, 16, 19, and 23; (3) some weak Fe II emission lines in the region around 5200 Å are present in the majority of the objects.

We have estimated, whenever possible, the spectral type of the stars according to the presence or absence of some features, such as He II 4686 Å and C III 4650 Å and the ratio of equivalent widths of Hγ/He I 4471 Å. We compared these line ratios with those of several B-type stars selected from a library of stellar spectra (Jacoby, Hunter, & Christian 1984)

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TABLE 1

OBSERVATION LOG OF SPH STARS

Star	Date	Wavelength Range (Å)	Exp. Time (sec)	S/N	Type
SPH 1	1998 Jan 17	3450–7340	1200	20	T Tauri
SPH 3	1997 Nov 7	3640–7540	600	70	Be
SPH 4	1998 Nov 8	3640–7500	1800	70	T Tauri
	1998 Nov 9	3110–5100	1800	20	...
	1998 Dec 29	3700–5700	1800	50	...
SPH 5	1999 Dec 17	3400–8400	1200	60	...
SPH 6	1999 Dec 17	3400–8400	1200	80	T Tauri
SPH 7	1997 Nov 7	3640–7540	1200	100	Be
SPH 8	1999 Mar 2	3450–7520	1200	70	...
SPH 9	1997 Nov 7	3640–7540	1200	90	Be
	1998 Dec 28	3700–5700	1200	70	...
SPH 10......	1997 Nov 7	3640–7540	1200	50	Be
SPH 11......	1998 Dec 28	3700–5700	1500	70	Be
	1999 Apr 16	3500–7420	1200	100	...
SPH 12......	1998 Nov 8	3640–7500	1200	80	Be
	1998 Dec 28	3700–5700	1500	90	...
SPH 13......	1998 Nov 8	3640–7500	1200	50	Be
	1998 Dec 28	3700–5700	1500	80	...
SPH 14......	1999 Apr 16	3500–7420	1200	100	Be
SPH 15......	1999 Mar 3	3450–7520	1200	130	Be
SPH 16......	1998 Nov 8	3500–7420	1200	120	Be
	1998 Dec 28	3700–5700	1200	90	...
SPH 17......	1998 Dec 28	3700–5700	1800	30	T Tauri
	1999 Mar 3	3450–7520	1500	40	...
SPH 18......	1999 Apr 16	3500–7420	1200	90	Be
SPH 19......	1998 Nov 8	3640–7500	1200	120	Be
	1998 Dec 29	3700–5700	1200	90	...
SPH 20......	1998 Dec 29	3700–5700	1200	80	Be
	1999 Apr 16	3500–7420	1200	110	...
SPH 21......	1998 Jan 17	3450–7340	1200	40	T Tauri
	1998 Nov 9	3110–5100	1500	20	...
SPH 22......	1999 Mar 2	3450–7530	1200	50	T Tauri
	1999 Mar 4	3130–5120	1500	30	...
SPH 23......	1999 Mar 2	3450–7530	1200	70	Be
SPH 24......	1998 Nov 10	3110–5100	1500	20	T Tauri
	1999 Mar 2	3450–7530	1200	80	...
SPH 25......	1999 Mar 2	3450–7530	1200	60	Be
SPH 26......	1999 Mar 2	3450–7530	1200	40	Be

and also some bright B stars selected from the Bright Star Catalogue (Hoffleit & Jaschek 1982). It has been concluded that SPH 3, 9, 18, 20, and 25 are B2 stars, while SPH 11, 12, and 19 are B1 stars. SPH 16 has a spectral type between B0–B1. The remaining objects (SPH 7, 10, 13–15, 23, and 26) were only classified as B-type stars either because the spectra were too noisy in the region around the Hγ (SPH 10, 13, 23, and 26) or because of the presence of a weak emission of Hγ (SPH 7, 14, and 15).

3.2. *T Tauri Stars*

The spectra of SPH stars 1, 4, 6, 17, 21, 22, and 24 are shown in Figures 3*a*, 3*b* (resolution of 4.6 Å), 4, and 5 (resolution of 1.9 Å). The lithium line at 6707 Å is identified unambiguously in SPH 24. The spectrum of SPH 22 closely resembles the one of RU Lupi, a well-known T Tauri star. It seems clear to us that both may be classified as T Tauri stars. In fact, we suggest this classification for the other ones too (with the possible exception of SPH 6). A brief description of each spectrum is given below.

3.2.1. *SPH 1*

This is the faintest object of our sample, and it was only observed with the lowest dispersion. Besides the Balmer lines and the calcium doublet, no other features may be seen in emission. The continuum is similar to that of SPH 24.

3.2.2. *SPH 4 and 17*

The spectra of both stars look very similar to each other at all dispersions used in this work. The Balmer and iron lines are seen in emission over a continuum that slowly increases to the red. Between 3700 and 5700 Å several Fe II lines are observed. SPH 4 was observed in the same spectral range as AS 353A, V1331 Cyg, and LkHα 321 (Valenti, Basri, & Johns 1993). These objects clearly show P Cygni profiles in all Balmer lines between 3100 and 5100 Å. In SPH 4, Hα exhibits a central absorption. In the spectra of both stars, the K line of the calcium doublet is seen in emission. The same happens to the stars in Valenti et al.'s sample because of the blue absorption of the P Cygni profile of Hϵ.

3.2.3. *SPH 6*

SPH 6 (PDS 133 = IRAS 07230-2539) was classified as a new probable Herbig Ae-Be in a survey of young stars by Torres et al. (1995). Our spectrum shows a continuum similar to SPH 4 and 17. The calcium doublet, as well as several Fe II lines, is in emission.

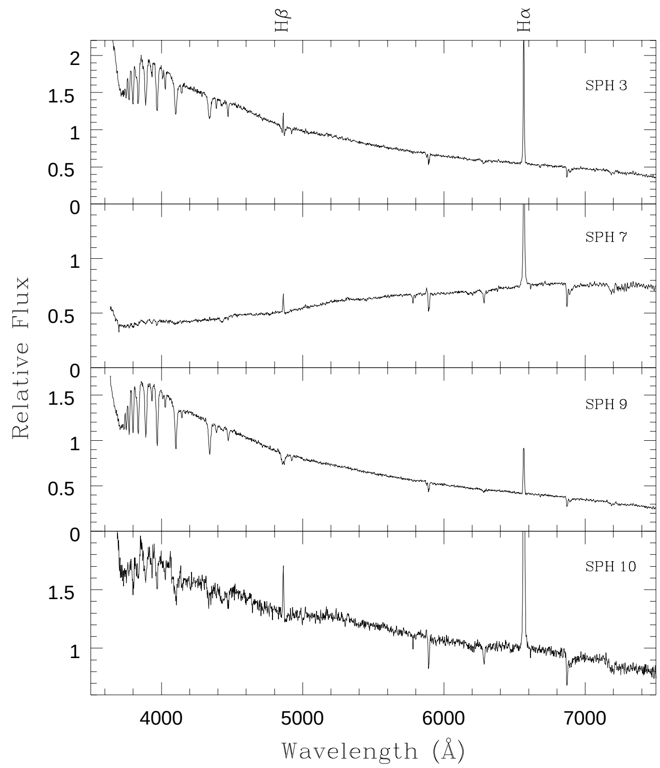

Fig. 1*a*

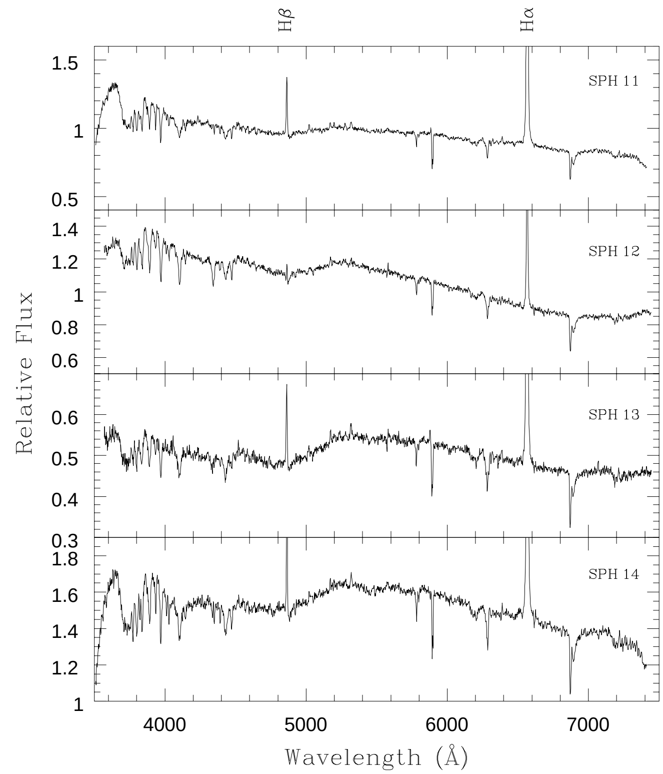

Fig. 1*b*

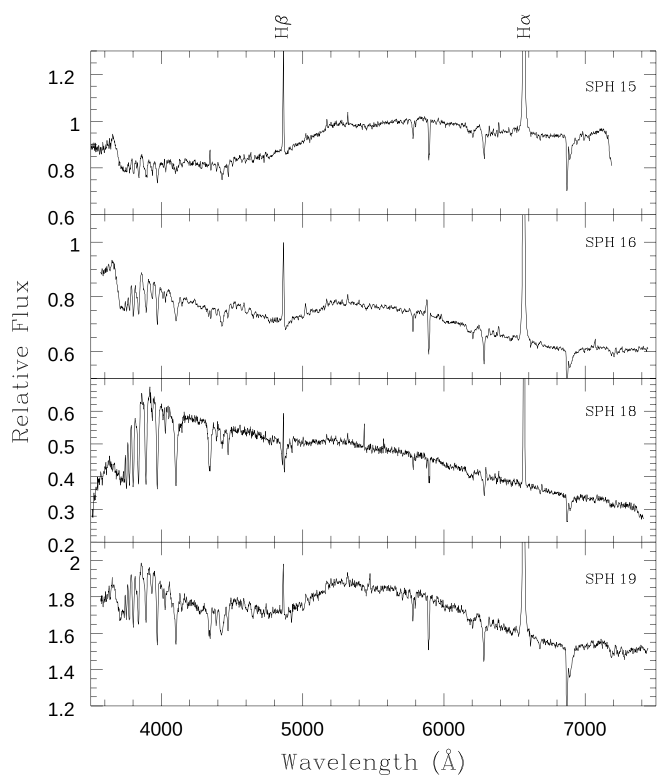

Fig. 1*c*

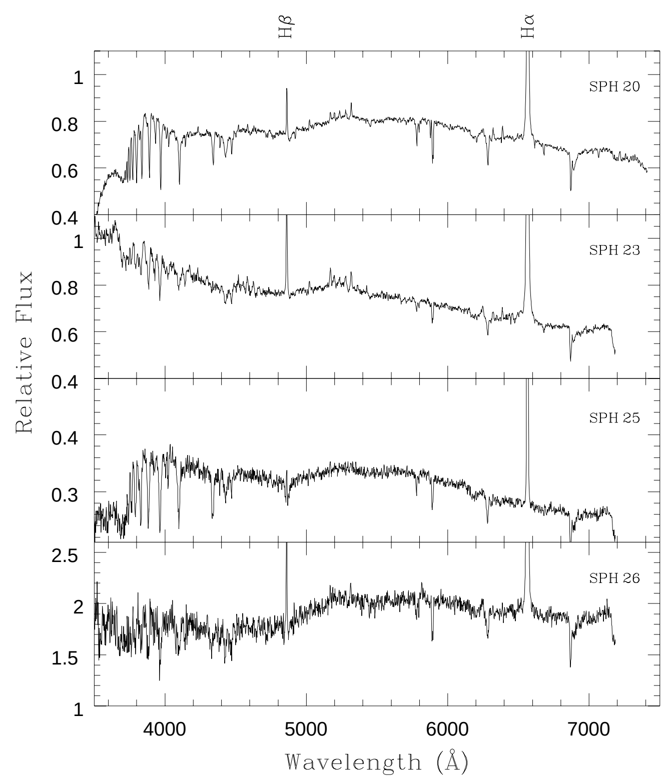

Fig. 1*d*

FIG. 1.—Spectra of Be stars identified in our sample between 3500 and 7500 Å

3.2.4. *SPH 21*

The continuum distribution also looks very similar to SPH 24. Few absorptions lines are present (Na I, *G* band, and Mg *b*). The Balmer lines show P Cygni profiles, a spectral feature not usually seen in T Tauri stars. However, there are some examples in which the Balmer lines display P Cygni profiles, as in AS 353A, LkHα 321, and V1331 Cyg (Valenti et al. 1993). Only the calcium K line of the calcium doublet is seen in SPH 21. The other component is blended with Hϵ, which also has a P Cygni profile.

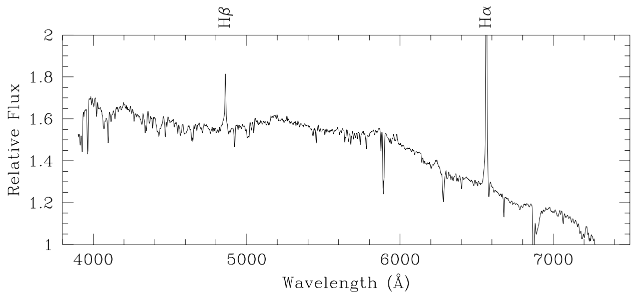

FIG. 2.—Spectrum of Hen 3-1013 taken on 1999 June 20 between 3800 and 7500 Å.

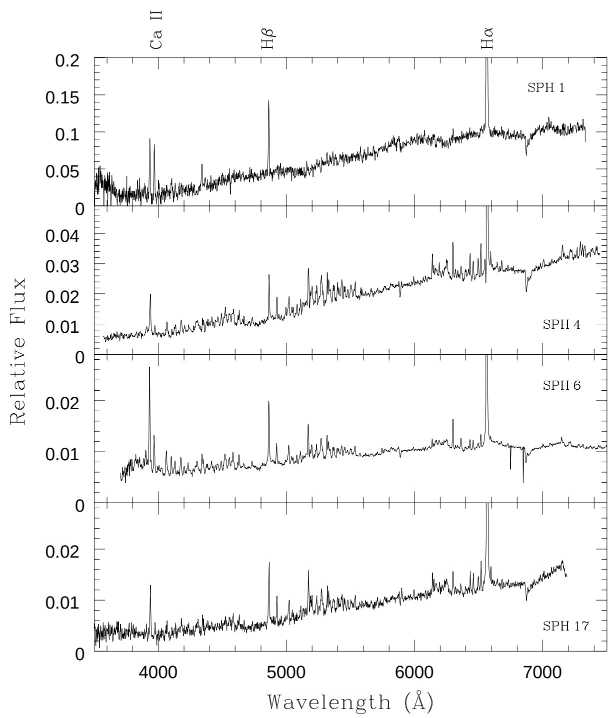

Fig. 3*a*

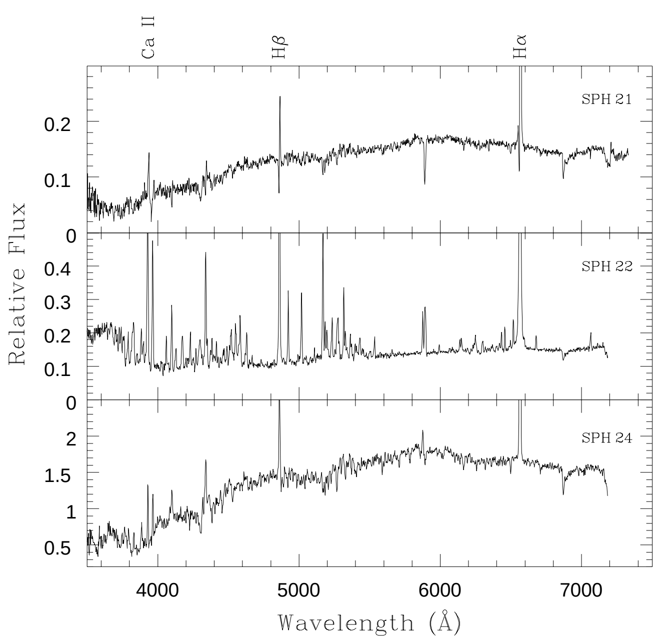

Fig. 3*b*

FIG. 3.—Spectra of T Tauri stars identified in our sample

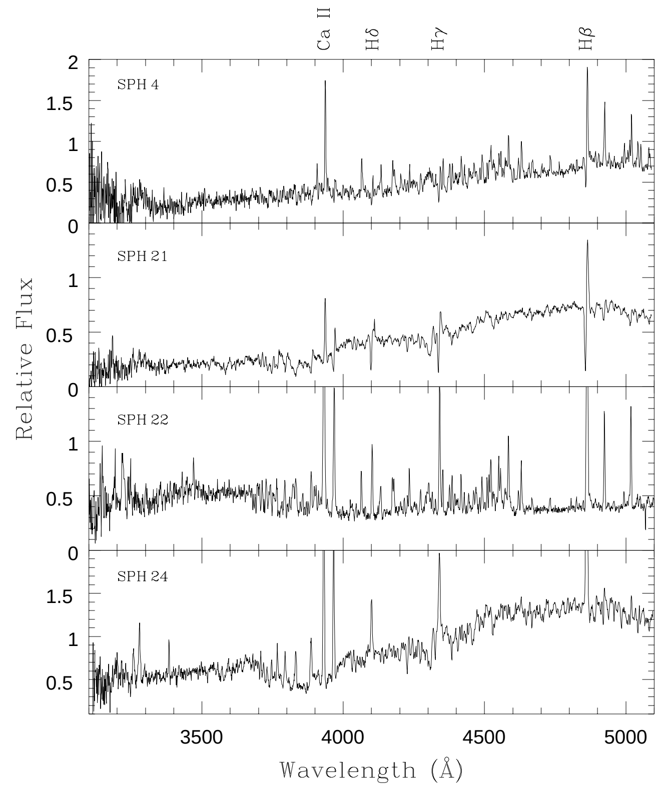

FIG. 4.—Optical spectra of SPH 4, 21, 22, and 24 between 3100 and 5100 Å.

3.2.5. *SPH 22*

The spectrum of SPH 22 looks very similar to another T Tauri object, RU Lupi (see Fig. 6), as we said above. Several emission features are seen at the dispersions of 1.9 and 4.6 Å, namely Balmer, Ca II, and Fe II lines, as well as the sodium doublet. Helium emission lines at 5876, 6678, and 7065 Å are also present. The Balmer discontinuity is clearly seen in emission.

3.2.6. *SPH 24*

SPH 24 has a lower degree of excitation than SPH 22. The Balmer lines and the calcium doublet are seen in emission, as well as the observed absorption lines due to the *G* band, Mg b, and Ca I at 4226 Å. The continuum distribution plus the observed absorptions lead to a spectral classification of mid-K. The lithium line around 6707 Å is detected at the 3 σ level.

3.3. *Stars with No Emission*

Two stars from the SPH's list in the Canis Majoris region did not show emission in our data:

SPH 5.—There are three objects in the center of the chart provided given by Schwartz et al. (1990), none of them having any emission line. They identify the fainter one as SPH 5. Our spectrum suggests this object can be classified as early to mid F.

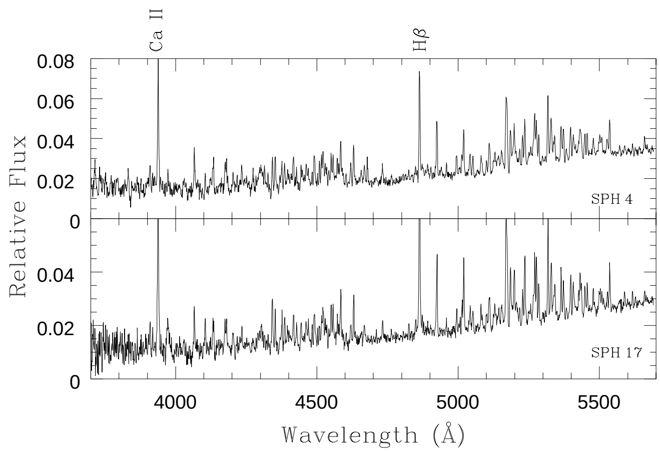

FIG. 5.—Optical spectra of SPH 4 and 17 between 3700 and 5700 Å

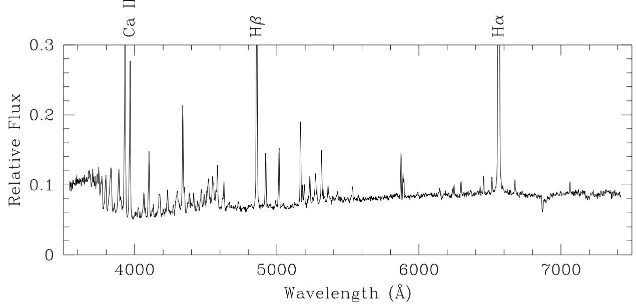

FIG. 6.—Spectrum of RU Lupi taken at 1997 July 23 between 3500 and 7500 Å.

SPH 8.—There is a very faint object $\sim 10''$ south of the position given by Schwartz et al (1990). The spectrum of the observed object is early to mid B.

4. SUMMARY

As part of a spectroscopic survey of emission-line objects in the southern hemisphere, we have observed 25 objects from the list of Schwartz et al. (1990) objects with Hα emission. The objects are all in the Canis Majoris region. In this paper, we presented and discussed these spectral observations. We have shown that 16 are Be or related stars, while seven are T Tauri stars. Some B stars of our sample, i.e., the SPH stars 11, 12, 13, 14, 15, 16, 19, 20, 23, 25, and 26 have a broad continuum absorption between 4450 and 5200 Å. It is not clear to us whether this broad continuum absorption is of circumstellar or interstellar origin. On the other hand, SPH 3, 9, 10, and 18 have a continuum typical of a hot star. SPH 7 has a continuum of a reddened Be star. Among the seven sources we suggest to be T Tauri stars, the identification of SPH 22 and 24 is more certain. Finally, two stars (SPH 5 and 8) failed to show emission lines in their spectra.

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