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Optical spectroscopic and 2MASS measurements of Stephenson H_α stars*

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Abstract. We present the results of spectroscopic observations for 52 objects from the list of H_α emission stars of Stephenson (1986). Out of six known T Tauri stars observed, five showed H_α in emission and in one (StHa 40), H_α changed from being in absorption to emission over a period of two years, accompanied by photometric and spectral type variability. We confirm the T Tauri nature of one Stephenson object (StHa 48) on the basis of the presence of H_α and H_β in emission, Li I λ6708 in absorption, infrared excess and X-ray emission. Among the 52 objects observed, there were other emission line objects: 1 Ke star, 1 BQ[ ] star, 2 galaxies and 2 Be stars. We present a higher-resolution spectrum of StHa 62 showing permitted and forbidden lines in emission typical of BQ[ ] stars. Twenty five out of 30 newly observed objects failed to show H_α in emission. We also present 2MASS observations for 112 StHa objects. We suggest three Stephenson objects (StHa 52, 125 and 129) to be YSOs on the basis of 2MASS, IRAS and ROSAT observations. These and all other known YSOs amongst StHa stars are found in regions of star-forming clouds in Taurus, Orion and Ophiuchus. YSOs at high galactic latitudes in other parts of the sky are therefore rare.

Key words. stars: emission-line, Be – stars: general – stars: pre-main sequence – stars: late-type – infrared: stars

1. Introduction

A survey of the northern sky ($\delta > -25°$) for H_α-emission stars at relatively high galactic latitudes ($|b| \geq 10°$), based on red-sensitive objective prism plates taken with the Burrell Schmidt telescope of the Warner and Swasey Observatory, was reported by Stephenson (1986). The spectral dispersion was about 1000 Å mm^{-1} at H_α and the limiting magnitude was ≈13. The survey resulted in a catalogue of 206 H_α-emission stars (hereafter designated as StHa stars). The sky distribution of these new emission-line stars is different from that of those already known at lower galactic latitudes, large numbers of which lie in Orion, Taurus and other star forming regions. The StHa stars, except for a conspicuous concentration in Orion, are more uniformly distributed in galactic longitude. Of the 206 stars, only 41 had known spectral types then, mostly of type M. Understanding of the physical nature of the StHa objects would require follow-up studies.

The first follow-up spectroscopic observations of StHa stars were reported by Downes & Keyes (1988) who observed 105 StHa objects, at spectral resolutions ~11.5–13 Å, along with 6 objects from the list of low-latitude H_α emission stars of Stephenson & Sanduleak (1977). Of the 105 stars observed, 24 were found to be T Tauri stars, 1 Ke star, 5 Me stars, 3 cataclysmic variables, 6 symbiotic stars, 1 BQ[ ] star, 1 carbon star, 16 Be stars and 1 Seyfert galaxy. The rest (47 objects) failed to show H_α in emission. Of these non-emission objects, 11 were listed in Stephenson (1986) as having weak emission, and therefore, the report of emission for these objects could possibly have been spurious (Downes & Keyes 1988). The spectral types determined for the remaining 36 non-emission stars, listed earlier by Stephenson (1986) as having moderate-strength H_α emission, were typically of the type G–K, indicating that these objects could be T Tauri stars with variable emission. Further monitoring of these objects is necessary to confirm if they are indeed T Tauri stars. Are there more T Tauri and other young stellar objects (YSOs), like Herbig Ae/Be stars, in the StHa list? Due to their relatively high galactic latitudes ($|b| \geq 10°$) the StHa objects are potential candidates for being high-latitude YSOs. Three of the StHa stars (16, 17, 18) have in fact been now recognized (see e.g. Luhman 2001) as members of the young association around the high-latitude molecular cloud MBM 12 (Magnani et al. 1985). A study of the StHa objects, in particular those that have not been followed up so far, would be important for confirming their classification as emission-line objects and inlooking for additional YSO candidates at high galactic latitudes.

In this paper we present the results of optical spectroscopic observations, at ~2.6–5.3 Å resolution in the wavelength range

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* Table 2 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/402/963

5300−7500 Å, of 52 stars from Stephenson (1986), 22 of which are common with those observed by Downes & Keyes (1988) at ∼11.5−13 Å resolution, and 30 are new. Since YSOs are generally characterised by excess infrared emission and low-mass YSOs are often bright in X-rays, we also cross-correlate StHa objects with sources in the 2MASS, IRAS and ROSAT catalogues. For stars in common with those in Downes & Keyes (1988), the results of our spectroscopic observations are compared and variabilities noted. Spectral types are estimated for 28 new stars. The behaviour of StHa stars at X-ray and infrared wavelengths is discussed with particular reference to the known YSOs and YSO candidates. Comments are also made on the statistics of objects of different classes in the StHa catalogue.

2. Observations

Optical CCD spectra of StHa stars were obtained using the OMR (Optomechanics Research) spectrograph (Prabhu et al. 1998) on the 2.34 m VBT at Vainu Bappu Observatory during the period 1999–2002. StHa 57 was observed on 3 January 2003. All spectra were obtained with a slit of 2 arcsec width and spectral resolution 1.3–2.6 Å pixel^{-1}. All spectra were bias subtracted, flat-field corrected, extracted and wavelength calibrated in the standard manner using the IRAF[1] reduction package.

Searches in 2MASS, IRAS and ROSAT catalogues were performed to find detections of StHa stars by 2MASS, IRAS and ROSAT surveys.

3. Results and discussion

3.1. Spectroscopic results

We observed 52 StHa objects spectroscopically. Table 1 gives the results of the spectroscopic observations of StHa stars. Column 1 gives object identification, Col. 2 indicates whether H_α is in emission, Cols. 3 and 4 give equivalent widths (negative values indicating emission in the line) of H_α emission line and Li I λ6708 Å absorption line respectively when detected, Col. 5 gives spectral type determined by comparing the observed spectrum with those in the atlas of Jacoby et al. (1984), Col. 6 gives spectral types obtained from literature, Col. 7 gives the reference for the spectral type from literature, Cols. 8 and 9 give the class of the object and reference respectively.

Downes & Keyes (1988) found that the Stephenson (1986) catalogue contains objects that belong to a number of physically different classes. In the following, we present the results of our spectroscopic study for the various groups of objects and discuss some individual objects in greater detail.

3.1.1. Emission-line objects

Of the 52 objects observed by us, 12 show H_α line clearly in emission. In one object, StHa 40, H_α varied from being in absorption to emission over a period of two years. There are several categories of objects showing H_α in emission.

(1) *T Tauri stars*: StHa 16, 17, 18, 19 , 48 and 127 show H_α in emission with equivalent widths given in Col. 3 of Table 1. StHa 16,17, 18, 19 and 127 are known to be T Tauri stars (Appenzeller et al. 1983; Downes & Keyes 1988; Fernandez et al. 1995). The large H_α emission line equivalent widths ($W_{H\alpha}$ ∼ 10 Å–60 Å) observed here are consistent with their classification as T Tauri stars. A comparison with the description of spectra in Downes & Keyes (1988) shows that H_α line strengths have undergone variations. For example, following the system of "emission-line class" based on the relative strength of the emission lines as defined in Herbig (1962), Downes & Keyes (1988) assign an emission-line class of 5 to StHa 17 and class 2 to StHa 18, whereas our measurements give $W_{H\alpha}$ values of 10 Å and 56 Å respectively for these two stars.

StHa 48 was identified as an emission-line star in the survey obsevations (spectral observations using objective prism at a resolution of 600–700 Å/mm) performed by Wiramihardja et al. (1989) towards the Orion region. Our observations of StHa 48 confirm that this object is a T Tauri star. Figure 1 shows our spectrum for StHa 48. It shows H_α and H_β in emission. Li I λ6708 absorption line is also found to be present in this star. It is very close to the star forming region IC 423 (CB 31; Clemens & Barvainis 1988). As discussed later this star is a ROSAT X-ray source and its 2MASS measurements (Table 2) seem to show near infrared excesses characteristic of T Tauri stars.

StHa 40 has shown remarkable variability in its H_α activity. Figure 2 shows spectra of StHa 40 obtained by us in February 2000 and October 2002. In February 2000, the object shows H_α in absorption while the October 2002 spectrum shows H_α clearly in emission ($W_{H\alpha}$ = 14.5 Å). Not only is there a drastic change of H_α from absorption to emission, but also there are significant changes in the underlying photospheric absorption spectrum. The February 2000 spectrum closely matches a G2 type stellar spectrum, while in the October 2002 spectrum absorption features characteristic of a cooler spectral type (K0) are seen. Spectroscopic observations of Downes & Keyes (1988) had shown StHa 40 to have H_α in emission on a late F/ early G spectral type for the stellar spectrum. Earlier Mac Connell (1982) had also listed StHa 40 as a star with H_α in emission. Torres et al. (1995) found the star to have H_α in emission ($W_{H\alpha}$ = 9 Å) with variation in profile. They also found the Li λ6708 Å line in absorption (W_{Li} = 0.13 Å) and the radial velocity variations indicating that the star could be a spectroscopic binary.

Our spectroscopic observations also suggest that StHa 40 varied photometrically during the period February 2000–October 2002. Comparison with spectrophotometric standards observed on the same nights (HD 117880 on 16 February 2000 and Feige 15 on 04 October 2002) gives photometric magnitudes $V = 12.5, R = 12.2$ in February 2000 and $V = 10.9, R = 10.5$ in October 2002.

StHa 40 was thus fainter by ∼1.6 mag in the V band in February 2000 when it had H_α in absorption, as compared

[1] IRAF is distributed by National Optical Astronomy Observatories, USA.

Table 1. Results from spectroscopic observations of StHa stars.

Object	Hα in emission	$W_{H\alpha}$ (Å)	W_{Li} (Å)	Sp. type (this work)	Sp. type (literature)	Reference for Sp. type	Class of object	Reference for object class
StHa 05	no	–	–	A3	–	–	–	–
StHa 07	yes	−4.7	–	K4	–	–	Ke	3
StHa 12 *	yes	−11.4	–	B	B	1	Be	1
StHa 15	no	–	–	A5	–	–	–	–
StHa 16 *	yes	−26.0	–	K9	M0	2	T Tau	2
StHa 17 *	yes	−10.4	0.35	K0	K5	2	T Tau	2
StHa 18 *	yes	−56	–	M0	early M	2	T Tau	2
StHa 19 *	yes	−25.8	0.41	G9	G8	2	T Tau	2
StHa 21	no	–		G7	–	–	–	–
StHa 35 *	no	–	–	G0	mid K	1	–	–
StHa 40 *	variable	−14.5†	0.33†	G2/K0	late F/early G	1	T Tau	1
StHa 44 *	no	–	–	F7	mid F	1	–	–
StHa 46	no	–	–	G6	–	–	–	–
StHa 48	yes	−16.8	0.70	K4	–	1	T Tau	3
StHa 56	no	–	–	G2	–	–	–	–
StHa 57	no	–	–	M5	M3	4	–	–
StHa 58	no	–	–	F0	–	–	–	–
StHa 61	no	–	–	G9	–	–	–	–
StHa 62 *	yes	−156	–	BQ[ ]	–	1	BQ[ ]	1
StHa 64 *	no	–	–	K4	late type absorption	1	–	–
StHa 65	no	–	–	F7	F8	5	–	–
StHa 71 *	no	–	–	G1	absorption	1	–	–
StHa 72	no	–	–	G2	–	–	–	–
StHa 75	no	–	–	A7	–	–	–	–
StHa 77	no	–	–	G2	–	–	–	–
StHa 79	no	–	–	F7	–	–	–	–
StHa 80	no	–	–	K0	–	–	–	–
StHa 81	no	–	–	G2	–	–	–	–
StHa 82 *	no	–	–	G6	Me‡	1	–	–
StHa 83 *	no	–	–	K4	early-mid K	1	–	–
StHa 84	no	–	–	A7	A5	5	–	–
StHa 85	yes	−98	–	–	NGC 4051 (galaxy)	6	Galaxy	6
StHa 86	yes	−124	–	–	NGC 1494 (galaxy)	7	Galaxy	7
StHa 87	no	–	–	G6	–	–	–	–
StHa 88 *	no	–	–	M5	M	1	–	–
StHa 89 *	no	–	–	F7	mid F	1	–	–
StHa 90	no	–	–	K4	–	–	–	–
StHa 91 *	no	–	–	G6	G	1	–	–
StHa 92 *	no	–	–	K0	K	1	–	–
StHa 93 *	no	–	–	A7	early F	1	–	–
StHa 95 *	no	–	–	G6	G	1	–	–
StHa 96 *	no	–	–	G6	G	1	–	–
StHa 99 *	no	–	–	G2	early-mid F	1	–	–
StHa 107	no	–	–	F3	G5	5	–	–
StHa 108	no	–	–	G0	–	–	–	–
StHa 109	no	–	–	F7	–	–	–	–
StHa 110	no	–	–	G2	–	–	–	–
StHa 127	yes	−62	0.85	K4	K6,7	2	T Tau	2
StHa 134	no	–	–	A1	F0	5	–	–
StHa 139	no	–	–	A2	A2	5	–	–
StHa 160 *	yes	−16.3	–	B	B	1	Be	1
StHa 163	no	–	–	M5	M1	5	–	–

* Stars that are in common with those of Downes & Keyes (1988).
† These values correspond to the October 2002 spectrum. H_α is in absorption in the February 2000 spectrum and W_{Li} = 0.13 Å then.
‡ Possibly misidentified. See text.

References
(1) Downes & Keyes (1988); (2) Herbig-Bell Catalog (1988); (3) this work; (4) Stephenson (1986); (5) catalogue of Positions & Proper motions (1988); (6) Lewis (1972); (7) Allen (1976).

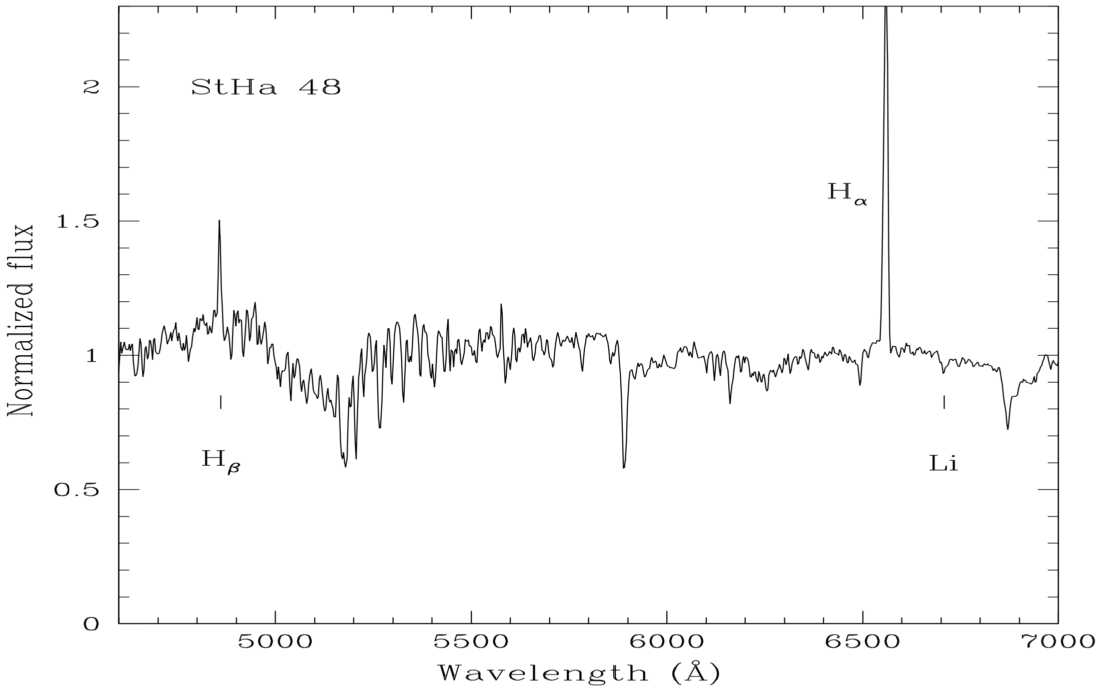

Fig. 1. Spectrum of StHa 48.

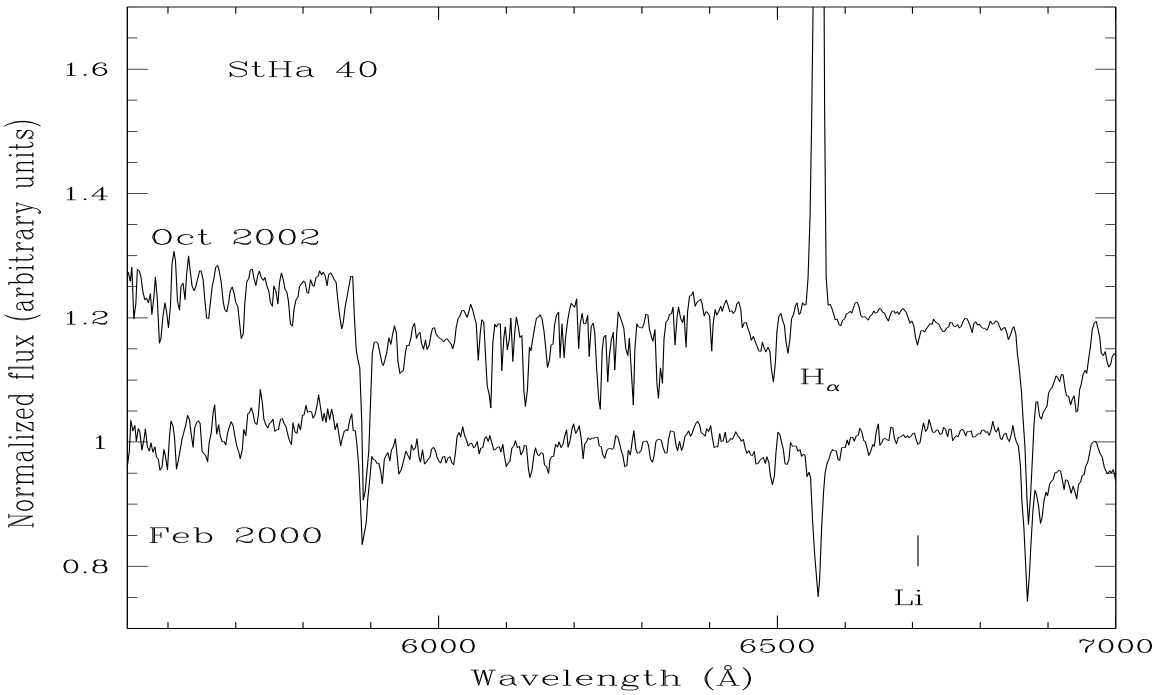

Fig. 2. Spectrum of StHa 40.

with its brightness in October 2002 when it showed H$_\alpha$ in emission. Its $V - R$ colour, however, varied only marginally ($V - R$ = 0.3−0.4). Our measurements can also be compared with those reported in Gregorio-Hetem (2002) who give for StHa 40: spectral type G5, V = 10.96 and $V - R$ = 0.45 based on observations of Torres et al. (1995). The observed spectrophotometric variability of StHa 40 may, in part, be related to the possibility of its being a close binary (Torres et al. 1995). Further monitoring of the object would help clarify its nature.

(2) *Other emission-line stars*: StHa 12 and 160 were classified by Downes & Keyes (1988) as Be stars. Our spectra for these objects show H$_\alpha$ with modest equivalent widths of 11 Å and 16 Å respectively. The spectrum of StHa 07 shows only H$_\alpha$ in emission ($W_{\mathrm{H}\alpha}$ = 4.8 Å). It is a bright (m_{v} = 10.5, Stephenson 1986), high galactic latitude (b = $-36\overset{\circ}{.}6$) object. We derive a spectral type K4 for this object. It is found to be associated with an X-ray source identified in the ROSAT Bright Survey (Schwope et al. 2000). It is possibly a nearby Ke star.

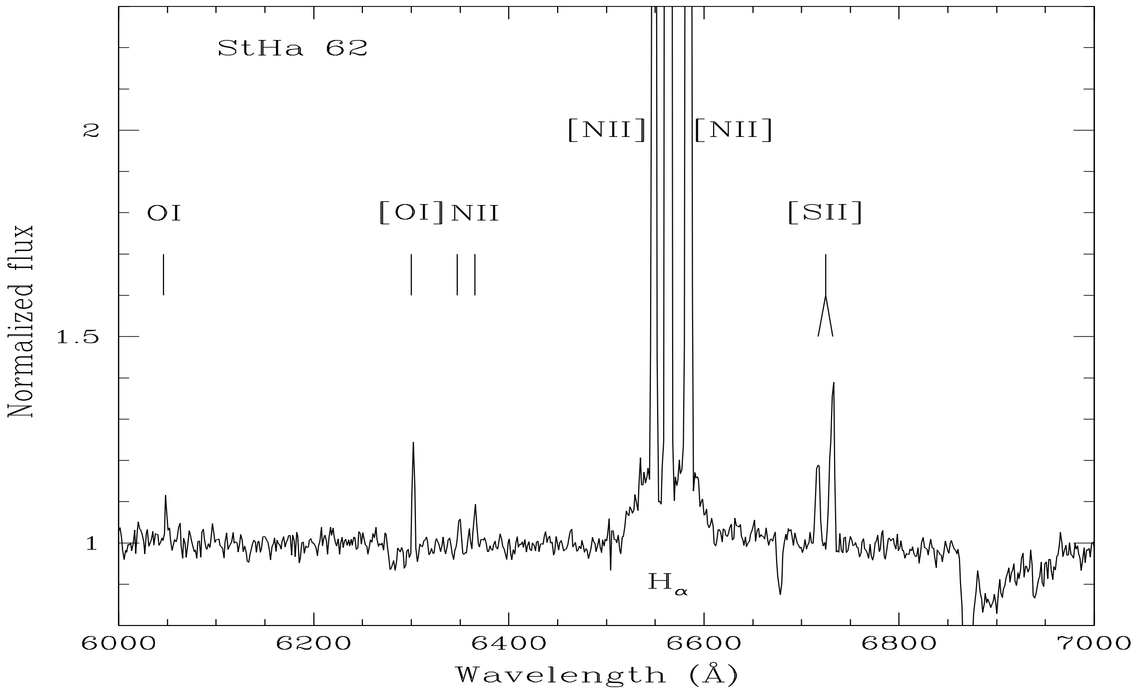

Fig. 3. Spectrum of StHa 62.

(3) *Post AGB star*: The spectrum of StHa 62 in Downes & Keyes (1988) showed Balmer lines of hydrogen and [N II] λ6584 in emission superposed on a featureless continuum. It is now recognized as a post-AGB star (Fujii et al. 2002). We present the spectrum of StHa 62, at a resolution higher than that used in the observations of Downes & Keyes (1988) in Fig. 3. It shows strong H$_\alpha$ and other permitted and forbidden lines characteristic of BQ[ ] type spectra.

(4) *Emission line galaxies*: StHa 85 is known to be a Seyfert I galaxy (Lewis 1972). Spectrum of StHa 85 shows H I, He I, [O III] $\lambda\lambda$4959, 5007, [N II] $\lambda\lambda$6548, 6583 and [S II] $\lambda\lambda$6716, 6731 lines in emission. StHa 86 is known to be an emission line galaxy (Allen 1976). Our spectrum of StHa 86 shows H I, [N II] $\lambda\lambda$6548, 6583 and [S II] $\lambda\lambda$6716, 6731 lines in emission.

3.1.2. Objects with no line emission

Out of 52 StHa objects observed by us, 39 did not show H$_\alpha$ in emission. In one object (StHa 40, discussed above) the H$_\alpha$ line varied from being in absorption, in February 2000, to emission in October 2002. Of these objects with no emission in H$_\alpha$, 15 are in common with those observed by Downes & Keyes (1988). The present results, regarding the behaviour of H$_\alpha$ (absence of emission) and the derived spectral type, are in general agreement with the results of Downes & Keyes (1988) except for StHa 35, 40 (discussed below in detail) and 82. For StHa 35 our observations agree with those of Downes & Keyes (1988) in finding H$_\alpha$ to be in absorption, but the spectral type determined by us (G0) differs by more than a spectral class from that (Mid K) given in Downes & Keyes (1988). Our spectrum for StHa 82 gives a spectral type G6 with H$_\alpha$ in absorption, whereas Downes & Keyes (1988) listed this object as an Me star. It is possible that Downes & Keyes (1988) have observed the M3 type flare star CW UMa which is $\sim$1$'\!.$5 northwest of StHa 82 (Stephenson 1986).

A majority of the objects observed in the present study do not show H$_\alpha$ in emission. Twenty five of the thirty newly observed (not common with Downes & Keyes 1988) StHa objects are non-emission line stars. Stephenson (1986) listed 14 of these objects as having weak emission. It is possible that they were spurious detections. The remaining 11 objects were listed by Stephenson (1986) as having moderate-strength (10 objects) or strong (1 object) emission. If the emissions were real, then the present non-emission character of these objects implies spectral variability. We do find spectral variability in StHa 40 which showed H$_\alpha$ change from being in absorption to emission over a period of two years as compared with the observations of Downes & Keyes (1988) who listed this object as H$_\alpha$ emitting T Tauri star.

3.2. 2MASS, IRAS and ROSAT results

A significant fraction (26 of 105) of StHa objects had turned out to be T Tauri stars in the study by Downes & Keyes (1988). There were also emission-line objects of other types, like 3 cataclysmic variables, 6 symbiotic stars, 17 Be stars, 5 Me stars, two BQ[ ] stars, two emission-line galaxies, one planetary nebula, and one carbon star. T Tauri stars are young stellar objects (YSO) that, in addition to H$_\alpha$ emission, are generally characterised by excess infrared emission. These low mass YSOs are often bright in X-rays. Emission line objects of other classes (e.g., Be stars, symbiotic stars) are also known to show excess infrared emission due to circumstellar matter. We therefore cross-correlate all StHa objects with sources in 2MASS, IRAS, ROSAT catalogues to confirm the nature of known classes of

StHa objects and to look for additional candidate YSOs among them.

Table 2 gives the results of searches made in 2MASS, IRAS and ROSAT catalogues for StHa stars. Of the 206 stars in StHa list, 112 have 2MASS observations. In Table 2, Col. 1 gives object identification, Col. 2 gives radial distance (arcmin) from StHa star to the 2MASS detection, Cols. 3, 5 and 7 give J, H and K_s magnitudes respectively, Cols. 4, 6 and 8 give estimates of all the possible random errors that contribute to the photometric uncertainities in J, H and K_s bands respectively, Cols. 9 and 10 give $J-H$ and $H-K_s$ colours evaluated from the observed magnitudes respectively. Column 11 gives spectral types of StHa stars. These include spectral types determined by us and those available in literature. The reference for the listed spectral type is given in parentheses. A search was made around StHa stars for IRAS (IPAC 1986; Moshir 1989) and ROSAT (ROSAT 2000) sources associated with it within 1 arcmin radius. The IRAS and ROSAT data points were superimposed on DSS image of the corresponding StHa star and the nearest detection was selected. Columns 12, 13 indicate whether the StHa stars were detected by IRAS satellite and ROSAT respectively. Values given in parentheses of Cols. 12 and 13 are the radial distances (in arcmin) of IRAS and ROSAT detections from StHa stars respectively. Column 14 gives the class of StHa stars and relevant references. Stars which failed in showing emission lines in spectroscopic observations (this work and Downes & Keyes 1988) are marked with “No-emission” in this column.

IRAS detections are available for 58 StHa objects. Of these 20 are T Tauri stars, one (StHa 49) associated with condensations in the Herbig–Haro outflow HH 1–2 (e.g. Molinari & Noriega-Crespo 2002), 1 B 1.5 type star, 4 Be stars, 1 BQ[ ] star, 1 B9 type star, 1 carbon star, 3 M giants, 1 Mira variable, 2 semi-regular pulsating stars, 3 symbiotic stars, 12 M type stars, 2 Me stars, 3 galaxies, 2 planetary nebule, and one object (StHa 69) for which the spectral type and object class is as yet uncertain.

The M and Me type stars all have IRAS flux densities decreasing with wavelength ($F_{25\,\mu\mathrm{m}} < F_{12\,\mu\mathrm{m}}$) except StHa 23 and StHa 125 for which $F_{25\,\mu\mathrm{m}} \simeq$ or $> F_{12\,\mu\mathrm{m}}$ which is more characteristic of T Tauri stars. Stephenson (1986) lists StHa 23 as an atypically red M0r star. No spectrum for StHa 23 is available in the literature. StHa 125 was listed by Stephenson (1986) as an atypically red star with a strong H_α emission. Downes & Keyes (1988) found the star to have an M type spectrum with H_α in emission. StHa 125 is in the neighbourhood of several other known T Tauri stars (StHa 122, 123, 124, 127, 128 and 130) in the region of Ophiuchus star forming cloud. The observed flux density distribution suggests that StHa 125 is also likely to be a T Tauri star.

ROSAT detections are found for 24 objects. Of these 14 are T Tauri stars, 1 (StHa 49) associated with the Herbig–Haro outflow HH 1–2, 2 Ke stars, 1 Me star, 1 M5 type star, 2 cataclysmic variables, 1 galaxy, 1 B 1.5 type star and 1 object (StHa 129) for which the spectral type and object class is as yet unknown. StHa 129 is also near the Ophiuchus star forming cloud. Three other StHa objects (StHa 127, 128 and 130) within $\sim 1^\circ$ of StHa 129 that are also ROSAT sources are known T Tauri stars. StHa 129 may also be a T Tauri star related to the same star forming region.

Of the 13 StHa objects with both IRAS and ROSAT detections, 10 are T Tauri stars, 1 associated with the Herbig–Haro outflow HH 1–2, 1 galaxy and 1 B 1.5 type star. The B1.5 star (StHa 52) as discussed below is likely a Herbig Be type YSO.

Figure 4 gives the $(J-H)$, $(H-K_s)$ colour–colour diagram, based on 2MASS measurements, for all the 112 StHa stars with 2MASS observations. Superimposed are two dashed lines parallel to the interstellar reddening vector. The region bounded by these lines can be occupied by reddened main-sequence dwarfs and giants. Points marked with $*$ on the dashed lines are at an interval of $A_v = 5$ mag. The thick line represents main-sequence dwarfs and giants (Koornneef 1983) and transformed to 2MASS photometric system using the relations in Carpenter (2001). It can be noted that different types of objects occupy different regions of the plot. It can be seen from Table 2, that StHa 52 has $J-H = -0.02$ and $H-K_s = 0.13$ and it occupies the position normally occupied by Be stars in the plot. StHa 52 is detected by both IRAS and ROSAT and is associated with the reflection nebula NGC 2023 in the Orion star forming region. Stephenson listed this star as having weak emission. This star could be a Herbig Be type star that are characterized by infrared excesses and association with nebulosity (e.g. Hillenbrand et al. 1992).

In Fig. 4, a majority of the non-emission stars fall in the region occupied by main-sequence stars. Of the 206 StHa objects, 72 are identified as having no emission (Downes & Keyes 1988 and this paper). Of these, 28 are listed as having weak emission objects by Stephenson (1986). It is possible that they were spurious detections. Remaining 44 are listed as moderate (41 objects) and strong emission (3 objects). Objects listed as having moderate and strong emission, failing to show emission, could be due to variability. Active stars like YSOs (e.g. StHa 40) can show such variability. From Tables 1 and 2 it can be seen that a majority of the emission-line objects, including T Tauri stars, have IRAS and/or ROSAT detections. However, only two non-emission stars (StHa 162 and 165) have IRAS detections and only one non-emission star (StHa 88) has ROSAT detection. Stephenson (1986) listed StHa 162 and 165 as having strong emission. Both these stars were studied by Downes & Keyes (1988), who suggested that there exists a strong bandhead near H_α in the case of StHa 162 which might have been identified as H_α emission, and StHa 165 was found to have a M type absorption spectrum. StHa 165 shows very red near-infrared colours ($J-H = 0.89$, $H-K_s = 0.43$). From 2MASS and IRAS measurements we find that its colour K_s-[12] = 0.39, with the 12 μm magnitude $[12] = -2.5 \log S_{12}(Jy) + 4.03$ where S_{12} is the flux density in the IRAS 12 μm band, is consistent with photospheric emission of a cool M giant (Kenyon et al. 1988). So, StHa 165 is perhaps a reddened M giant. StHa 88 was studied by Downes & Keyes (1988) who suggested that it could be the TiO band structure which peaks at around the location of H_α and made it appear to be an emission line object in low dispersion spectrum of Stephenson (1986).

T Tauri stars clearly occupy a distinct region of the $(J-H)$, $(H-K_s)$ colour–colour plot (Fig. 4). StHa 48, an H_α emission line star (Wiramihardja et al. 1989) found to have Li I λ6708 Å

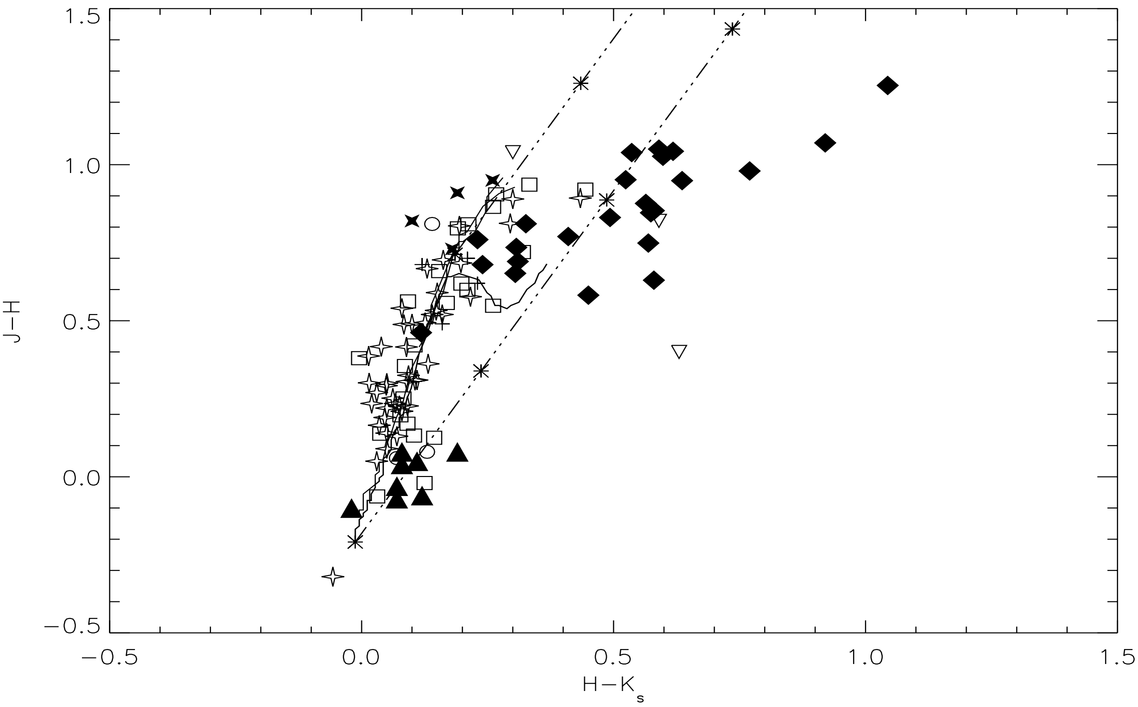

Fig. 4. Color–colour plot for StHa stars. Symbols represent, *diamonds*: Known T Tauris, *squares*: Stars with unknown spectral type, *filled triangles*: Be stars, *unfilled stars*: Non-emission stars, *filled stars*: Symbiotic stars, *inverted triangles*: NGC 1495, BQ[ ] and mira variables, *open circles*: cataclysmic variables, and *plus signs*: Ke and Me type stars.

absorption line in our observations presented here, also falls in the region occupied by known T Tauri stars. Stars of unknown status showing near-infrared excess with IRAS and/or ROSAT detections occupying the same region as by T Tauri stars in the plot, could be potential YSO candidates. Two such objects are: StHa 69 ($J-H$ = 0.92, $H-K_s$ = 0.44) and StHa 165 ($J-H$ = 0.89, $H-K_s$ = 0.43). Both are IRAS sources detected only in the 12 μm band with $F_{12\ \mu\mathrm{m}} > F_{25\ \mu\mathrm{m}}$, the latter being an upper limit. Gigoyan et al. (1998) have listed StHa 69 in their list of late-type M and C stars found on plates of the first Byurakan Spectral Sky Survey. Kazarovets (1998) listed it as suspected variable star. For StHa 69 the colour K_s-[12] = 0.67, similar to the colour of an M giant (Kenyon et al. 1988). Thus both StHa 69 and 165 (discussed above) are likely to be reddened M giants.

4. Conclusions

We have observed spectroscopically 52 objects from the list of H_α emission stars of Stephenson (1986). The results of our study can be summarized as follows:

(a) Six objects are known T Tauri stars. Five of them show H_α in emission and one star, StHa 40, showed variability in H_α. The variability of StHa 40 in H_α is also accompanied by variations in the underlying stellar absorption spectrum and photometric variability.

(b) We confirm the T Tauri nature of StHa 48 on the basis of the presence of H_α and H_β in emission and Li I λ6708 in absorption. It is in the vicinity of the star forming region IC 423 (CB 31), showing near-infrared excesses and is a ROSAT X-ray source.

(c) From 2MASS, IRAS and ROSAT observations we suggest that StHa 52 is a Herbig Be type YSO while StHa 125 and StHa 129 are T Tauri stars in the Orion and Ophiuchus star forming clouds.

(d) There are six other emission line objects which include one Ke star, two Be stars, two galaxies and one post-AGB star (StHa 62). A higher-resolution spectrum of StHa 62 is presented. It shows permitted and forbidden emission lines typical of BQ[ ] stars.

(e) Thirty nine stars are non-emission line stars. Of these 14 objects are in common with Downes & Keyes (1988) who had also listed them as non-emission stars. Stephenson (1986) listed 17 of them as having weak emission. It is possible that they were spurious detections. Objects listed in Stephenson (1986) as having moderate and strong emission failing to show emission in the present study could be variables.

(f) No new H_α emitting young stellar objects are found in the present study of StHa objects. YSOs amongst StHa stars that are already known or confirmed as such in this study (StHa 48), and objects (StHa 52, 125 and 129) suggested here to be YSOs all belong to well-known star-forming regions like Taurus, Orion and Ophiuchus. YSOs at high galactic latitudes in other parts of the sky are therefore rare.

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References

Allen, D. A. 1976, ApJ, 207, 367
Appenzeller, I., Krautter, J., & Jankovics, I. 1983, A&AS, 53, 291
Arkhipova, V. P., Ikonnikova, N. P., Noskova, R. I., et al. 1999, AstL, 25, 25
Belczynski, K., Mikolajewska, J., Munari, U., Ivison, R. J., & Friedjung, M. 2000, A&AS, 146, 407
Carpenter, J. M. 2001, AJ, 121, 2851
Clemens, D. P., & Barvainis, R. 1988, ApJS, 68, 257
Downes, R. A., & Keyes, C. D. 1988, AJ, 96, 777
Downes, R., Webbink, R. F., & Shara, M. M. 1997, PASP, 109, 345
Fernandez, M., Ortiz, E., Eiroa, C., & Miranda, L. F. 1995, A&AS, 114, 439
Fujii, T., Nakada, Y., & Parthasarathy, M. 2002, A&A, 385, 884
Gigoyan, K. S., Hambaryan, V. V., & Azzopardi, M. 1998, Ap, 41, 356
Gregorio-Hetem, J., & Hetem, A. 2002, MNRAS, 336, 19
Herbig, G. H. 1962, Trans. IAU, 11A, 275
Herbig, G. H., & Bell, K. R. 1988, V/73A
Hillenbrand, L. A., Strom, S. E., Vrba, F. J., & Keene, J. 1992, ApJ, 397, 613
IRAS catalogue of Point Sources, version 2.0 (IPAC 1986)
IRAS Faint Source Catalog, $|b| > 10°$, version 2.0 (Moshir 1989)
Jacoby, G. H., Hunter, D. A., & Christian, C. A. 1984, ApJS, 56, 257
Kazarovets, V., Samus, N. N., & Durlevich, O. V. 1998, IBVS, 4655, 1
Kenyon, S. J., Fernandez-Castro, T., & Stencel, R. E. 1988, AJ, 95, 1817
Koornneef, J. 1983, A&A, 128, 84
Lewis, B. M. 1972, IAUS, 44, 267
Luhman, K. L. 2001, ApJ, 560, 287
Mc Connell, D. J. 1982, A&AS, 48, 305
Magnani, L., Blitz, L., & Mundy, L. 1985, ApJ, 295, 402
Molinari, S., & Noriega-Crespo, A. 2002, AJ, 123, 2010
Munari, U., & Zwitter, T. 2002, A&A, 383, 188
Prabhu, T., Anupama, G. C., & Surendiranath, R. 1998, BASI, 26, 383
Schwope, A. D., Hasinger, G., Lehmann, I., et al. 2000, Astron. Nachr., 321, 1
Second ROSAT PSPC Catalog (ROSAT, 2000)
Sharples, R. M., Whitelock, P. A., & Feast, M. W. 1995, MNRAS, 272, 139
SIMBAD Astronomical Database, Strasbourg, France
Stephenson, C. B. 1986, ApJ, 300, 779
Stephenson, C. B., & Sanduleak, N. 1977, ApJS, 33, 459
The 2MASS database (IPAC/UMass, 2000)
Torres, C. A. O., Quast, G., de La Reza, R., Gregorio-Hetem, J., & Lepine, J. R. D. 1995, AJ, 109, 2146
van de Steene, G. C., & Pottasch, S. R. 1995, A&A, 299, 238
Vijapurkar, J., & Drilling, J. S. 1993, ApJS, 89, 293
Weaver, Wm. B., & Hobson, S. W. 1988, PASP, 100, 1443
Wiramihardja, S. D., Kogure, T., Yoshida, S., Ogura, K., & Nakano, M. 1989, PASJ, 41, 155