Southern and equatorial irregular variables

II. Optical spectroscopy^{*,**}

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Received November 19, 1997; accepted February 18, 1998

Abstract. The results of optical spectroscopy of 169 southern and equatorial objects previously known as irregular variables are presented. The targets were selected via photoelectric *UBV* photometry among objects classified as L, L:, I, I:, IS and IS: in the General Catalogue of Variable Stars and New Catalogue of Suspected Variable Stars.

Among these objects we have identified 8 cataclysmic variables, 8 symbiotic stars and stars that belong to a variety of other classes.

Key words: stars: variables — stars: emission line — stars: cataclysmic variables

1. Introduction

The discovery and classification of most variables listed in the variable star catalogs were carried out using light curves obtained via photographic patrols. Often, when a star is known to be variable but no periodicity is found and no other information is available it is classified as irregular of type I or L (Kukarkin et al. 1969). In fact, many objects as cataclysmic variables, low-mass X-ray binaries, symbiotic stars, T Tauri and even extragalactic objects like QSO's and BL Lac's can display irregular light variations being, consequently, included among the irregular variables. In the past, a number of such variables have revealed themselves as completely different types of objects

as BL Lac (Schmitt 1968), HZ Her – the optical counterpart of Hercules X–1 (Davidsen et al. 1972) and the intermediate polar V1223 Sgr (Steiner et al. 1981).

The existence of a large number of poorly studied irregular variables in the southern hemisphere, and the possibility of discovering objects like cataclysmic variables, X-ray binaries and other types of peculiar objects among them, led us to do a photometric and spectroscopic program in order to classify and better understand such objects. A preliminary report on the results of this study was published by Steiner et al. (1988).

2. Observations and data reduction

The objects observed in the present program were selected from General Catalogue of Variable Stars–GCVS and from New Catalogue of Suspected Variable Stars–NSV (Kukarkin et al. 1969 and supplements; Kholopov et al. 1985, 1987; Kukarkin et al. 1982). A total of 616 variables of the types L, L:, I, I:, IS and IS: was observed photometrically. The results of this survey are published in a separate paper (Cieslinski et al. 1997a, hereafter Paper I). If a star presented a colour index $B - V < 1.4$ or a catalogued photometric variation $\Delta m > 1.5$ mag, it was included in our spectroscopic program. Possible reddening effects were also taken into account by correcting the $B - V$ colour with a standard correction dependent on galactic latitude.

The selected objects were observed in two missions (July 22–24/1985 and June 22–July 04/1986) with the Boller & Chivens Spectrograph at the 1 meter Yale telescope of CTIO. The detector used in the 1985 mission was a GEC CCD, which provided a wavelength range from 4500 to 7000 Å, with 5 Å resolution. In 1986 the detector was the 2D–Frutti, which gave a spectral coverage from 3900 to 6800 Å, with 5 Å resolution as well. Two of the stars, KQ Mon and V499 Ori, were observed

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* Based on observations made at Cerro Tololo Interamerican Observatory–CTIO, Chile, and Laboratório Nacional de Astrofísica/CNPq, Brazil.

** Table 1 is also available in electronic form at the CDS via anonymous ftp (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/Abstract.html>

in November/1986, with the same instrumental configuration of the June–July/1986 mission. The reduction was carried out with the TVRED package at CTIO.

Additional spectra were collected at Laboratório Nacional de Astrofísica (LNA/CNPq), in southeast Brazil. In this case we used a Boller & Chivens Cassegrain spectrograph at the 1.6-m telescope. The detector was a UV coated GEC P88230 CCD, with 770×1152 pixels and $22.5 \mu\text{m}/\text{pixel}$. Two gratings with 300 and 900 lines/mm were used. The wavelength coverage is about 4650 Å and 1350 Å, with 10 Å and 3 Å of resolution, respectively for the 300 and 900 lines/mm grating. The reduction of these spectra was done using the IRAF¹ software installed at the SUN workstations of the Astrophysics Division of INPE.

Spectrophotometric standard stars (Oke 1974; Stone 1977; Stone & Baldwin 1983; Baldwin & Stone 1984; Taylor 1984) were observed each night to flux calibrate the spectra. Our spectra shown in Fig. 1 to Fig. 5 are flux calibrated. However some caution should be taken with the accuracy of these calibrations. Many of the nights were non photometric and unknown slit losses, specially in the blue, make our absolute calibrations never better than about 30%. The spectra obtained with the 2D–Frutti display a significant blue deficiency, quite evident in these figures. Such distortion is related to the difficulty in flux calibrating 2D–Frutti data. On the other hand, our main interest is to classify the objects and not to derive absolute fluxes values.

The variable stars observed spectroscopically (a total of 169) are listed in Table 1. The name of the object is given in Col. 1; Col. 2 gives the Julian Date of the beginning of the observation and Col. 3 the exposure time. A tentative spectral type, consigned by comparing visually each observed spectrum with those presented in libraries of stellar spectra (see, e.g., Jacoby et al. 1984; Pickles 1985; Kirkpatrick et al. 1991; Silva & Cornell 1992; Torres-Dodgen & Weaver 1993; Danks & Dennefeld 1994; Fluks et al. 1994), is indicated in Col. 4. The mean $B - V$ colour is shown in Col. 5 while Col. 6 gives the site of the observation.

3. Discussion

3.1. Candidates to cataclysmic variables

A total of 8 cataclysmic variables were identified in our study. The finding charts for these objects, obtained from the Digitized Sky Survey (SkyView)², are shown in Fig. 6.

¹ IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

² SkyView was developed under NASA ADP Grant NASS-32068 and under the auspices of the High Energy Astrophysics Science Archive Research Center (HEASARC) at the GSFC Laboratory for High Energy Astrophysics.

3.1.1. CZ Aquilæ

CZ Aql was observed frequently in the 1986 mission and, on all occasions, it showed a weak blue continuum with emission lines of the hydrogen Balmer series, HeI $\lambda 5876$, HeI $\lambda 6678$ and a very weak HeII $\lambda 4686$ (Fig. 1a).

Additional photometric and spectroscopic data collected at LNA indicate a probable value of 4.8 hours for its orbital period. The available data, including the historical photometric data of Reinmuth (1925), do not allow a description of the eruptive behaviour of this object, however the spectral signatures presented are common in dwarf novæ in quiescence (see, e.g., Warner 1995 and references therein).

3.1.2. OQ Carinæ

Spectroscopic observations of OQ Car obtained on Feb. 12, 1992 show a blue continuum with H α in emission (Figs. 1b and 1c), while the photometric observations reveal UV excess (Paper I) and the presence of flickering, which confirm OQ Car as a cataclysmic variable. These data are far from enough to characterize the system, however a dwarf nova classification is suggested by the amplitude of variation seen in our $UBVRI$ data (~ 1 mag, in measurements separated by 3 days) and in the GCVS4 (2.5 mag). The spectral characteristics presented are also compatible with such classification. No historical photometric data have been published for this object.

3.1.3. V342 Centauri

The star V342 Cen was observed on three occasions in the CTIO mission. On the first two, it showed a blue continuum with lines of the Balmer series in absorption while in the last (9 days later) the continuum weakened and the Balmer series appeared in emission (Figs. 1d and 1e). The brightness of V342 Cen in the later occasion was about 2 mag fainter, suggesting that the first two spectra were, probably, collected while the star was in eruption. HeI $\lambda 5876$ and H α are seen in emission in a spectrum collected at LNA on Feb. 11, 1992 (Fig. 1f).

Historical photometric data (Kruytbosch 1936) show that the brightness of V342 Cen varies in the range 14.6–16.6 mag with indication of abrupt transitions, as in eruptions. A variation of brightness of 1.7 mag in two consecutive days is seen in our $UBVRI$ measurements, also suggesting an eruption. The same data show the occurrence of two eruptions in 15 days. The presence of a such behaviour indicate V342 Cen as a candidate to dwarf nova class, possibly of U Gem type.

3.1.4. ST Chamæleonis

Spectroscopy of ST Cha obtained on two consecutive nights in the 1986 mission shows a blue continuum with

Fig. 1. Spectra of CZ Aql **a)**, OQ Car **b,c)**, V342 Cen **d,e,f)**, ST Cha **g,h)** and KQ Mon **i,j)**. The fluxes are in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$

Fig. 2. Spectra of V729 Sgr **a)**, V730 Sgr **b)**, AN Gru **c)**, AY Oct **d)**, V2323 Sgr **e,f)**, SY Vol **g)**, V617 Sgr **h)**, V1082 Sgr in low state **i)** and in high state **j)**. The fluxes are in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$

Fig. 3. Spectra of NSV 07105 **a,b,c,d**), V1003 Oph **e**), DG CrA **f**), V499 Ori **g**), XX Sct **h**), BN CrA **i**) and V576 Aql **j**). The fluxes are in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$. The inserted box in Fig. 3d shows a Coudé spectrum of NSV 07105 in the $H\alpha$ and $\text{HeI } \lambda 6678$ region (this spectrum is not calibrated in flux)

Fig. 4. Spectra of KZ Ara a), V514 Ara b), OQ Nor c), OO Pav d), V432 Sco e), V651 CrA f,g), NSV 07097 h), NSV 05443 i) and VV Pav j). The fluxes are in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$

Fig. 5. Spectra of VV Pav **a)**, FH Sct **b,c)**, NSV 06627 **d)**, NSV 06989 **e)**, MU Nor **f)**, HR Nor **g)**, NSV 11826 **h)**, TU Oct **i)** and V688 Ara **j)**. The fluxes are in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$

Fig. 6. Finding charts for CZ Aql, OQ Car, V342 Cen, ST Cha, KQ Mon, V617 Sgr, V729 Sgr, V730 Sgr, V1082 Sgr and SY Vol. The images cover 6×6 arcmin, with North up and East left

broad and shallow Balmer absorption lines (Fig. 1g). Additional spectroscopy obtained at LNA on February 10–11, 1992 and on May 07–12, 1992 also shows a blue continuum, however $H\alpha$ and $HeI \lambda 6678$ (very weak) appear in emission (Fig. 1h).

An analysis of the published photometric data of Mauder & Sosna (1975) shows that ST Cha could be an eclipsing variable, with possible values of 6.8 or 9.6 hours

for the orbital period. Time series CCD photometry with ~ 7.5 hours of duration in two consecutive nights (March 11/12, 1997) failed to detect any evidence of eclipses with such periods. Our *UBVRI* photometry shows on the other hand an amplitude of variation of about 2.7 mag (Paper I) while the amplitude quoted in the GCVS4 is $\Delta m = 4.8$ mag. Variations of brightness with such

Fig. 6. continued

amplitudes seem to indicate an eruptive behaviour and suggest a dwarf nova classification for this object.

3.1.5. KQ Monocerotis

In the course of our study we learned that KQ Mon is a known cataclysmic variable discovered by H.E. Bond in 1978, and classified as being of UX UMa type. Our

UBV data as well as the historical data of Hoffmeister et al. (1954) do not show large fluctuations in brightness that characterize eruptions. This is consistent with the interpretation that KQ Mon is a cataclysmic variable of the UX UMa type, since these objects usually vary less than 0.5 mag on a time scales of years.

Our spectra (Figs. 1i and 1j) show a strong blue continuum with $H\alpha$, $H\beta$ and $HeI\ \lambda 6678$ in emission, contrary to the absorption Balmer lines seen previously (Sion &

Fig. 6. continued

Guinan 1983, and references therein). $H\alpha$ and $HeI\ \lambda 6678$ are also seen in emission in a spectrum obtained by Zwitter & Munari (1994). KQ Mon is also classified as UX UMa by Downes & Shara (1993) and Zwitter & Munari (1994).

3.1.6. V729 Sagittarii

A spectrum obtained for this object on July 05, 1986 shows a flat continuum with Balmer lines in emission (Fig. 2a). Historical data (Ferwerda 1934) show brightness variations of ~ 1.5 mag with recurrence time of 20–30 days. The rising part of the variations is fast (~ 1 –2 days), even though longer (5–6 days) episodes also take place. The decline from the maximum is always longer, typically 5–8 days. Brightness variations with such time scales and characteristics suggest a dwarf nova classification for V729 Sgr. Additional observations using CCD photometry show that V729 Sgr is an eclipsing cataclysmic variable with an orbital period of 0.173 d.

3.1.7. V730 Sagittarii

V730 Sgr was observed spectroscopically on July 05, 1986. The spectrum showed a prominent blue continuum with $H\alpha$ weakly in emission while the other members of the Balmer series are in absorption (Fig. 2b). The presence of eruptions with amplitudes of ~ 2 –3 mag and recurrence time of 20–40 days is indicated by historical data of Ferwerda (1934). The eruptions last a few days and present a steeper rise (~ 1 –2 days) than decline. Eruptions with such characteristics are typical of dwarf nova of

U Gem type and suggest V730 Sgr as probable variable of the same type. A U Gem type for this object was also suggested by Ferwerda (1934).

3.2. Suspected cataclysmic variables

The stars AN Gru, AY Oct, V2323 Sgr and SY Vol are quoted in the literature as suspected cataclysmic variables (Vogt & Bateson 1982; Downes & Shara 1993; Kholopov et al. 1987; Downes et al. 1997).

The spectroscopic and photometric observations we made for AN Gru and AY Oct did not show the presence of characteristics usually found in cataclysmic variables, like emission lines and UV excess (Figs. 2c and 2d, Paper I). The data show brightness variations in AN Gru consistent with time scales of pulsation of RR Lyræ variables while CCD photometry of AY Oct on three consecutive times, with two days of separation, did not show brightness variation. A possible problem in the correct identification of AY Oct is pointed out by Downes & Shara (1993). Our observations refer to the object indicated in the Hoffmeister's chart (Hoffmeister 1963). Downes et al. (1997) in the 2nd ed. of their cataclysmic variables catalogue mention the presence of a RR Lyræ star 6^s east and $6''$ north of the previous position of AY Oct. It is possible therefore that this RR Lyræ is the only variable in the field.

The star V2323 Sgr was observed spectroscopically on several occasions (see Table 1). Very prominent Balmer emission lines are seen in some spectra superposed on a continuum with very weak TiO absorption bands. In others, the continuum is fainter and of later spectral type, with the TiO bands clearly visible while the emission

lines are weak or absent (Figs. 2e and 2f). These data do not confirm V2323 Sgr as cataclysmic since such variables do not display reddened optical continuum or TiO bands which such intensities. Additionally, the emission lines in cataclysmics are broader than the lines seen in this object. On the other hand, a classification as symbiotic star is also improbable since our observations do not reveal emission lines like [OIII] and HeII, whose presence associated with a late spectrum, is characteristic of this class of variables. The true classification of V2323 Sgr is not possible with our data, although the presence of a late spectrum with emission lines is seen in semiregular variables and Miras.

The variable SY Vol was observed spectroscopically on Feb. 12, 1992. The spectrum shows a blue continuum with H α in emission (Fig. 2g). Our CCD photometry shows flickering as well as the presence of a brightness variation of 1.8 mag in data separated by 14 days. Such characteristics confirm SY Vol as a cataclysmic variable, probably a dwarf nova. We would like to call attention to a possible problem in the correct identification of this variable in the catalogue of Downes & Shara (1993). The star we observed is the one indicated in the Hoffmeister's chart (Hoffmeister 1963), which is 2.7^s west and 19'' south from the object marked in the Downes & Shara's chart (see Fig. 6).

3.3. Peculiar objects

3.3.1. V617 Sagittarii

V617 Sgr is one of the most interesting objects identified in our program. It presents a very high excitation emission spectrum displaying besides the lines of the Balmer series, lines of NIII–CIII $\lambda\lambda 4640$ – 4650 , HeII $\lambda 4686$ (~ 2.5 times stronger than H β), NV $\lambda 4945$, OVI $\lambda 5290$, HeII $\lambda 5412$, OVI $\lambda 5584$, CIV $\lambda 5802$ and NIV $\lambda 6383$ (Fig. 2h). Such lines are quite common in Wolf-Rayet stars. In fact, this object has number 109 in Wolf-Rayet catalogues (van der Hucht et al. 1981; van der Hucht et al. 1988).

Lundström & Stenholm (1984, 1989) have also observed this star. The incompatibility between the distance derived assuming standard intrinsic parameters of W–R stars and the small reddening seen in the direction of WR 109, led those authors to suggest a lower luminosity and indicate a classification of cataclysmic variable or low-mass X-ray binary for V617 Sgr. Our data show the presence of short time scale variability (flickering) and a short orbital period (Steiner et al. 1988). Few objects with spectra like V617 Sgr are known. Among them, V Sge (Herbig et al. 1965; Williams 1983; Echevarría et al. 1989), WX Cen (Diaz & Steiner 1995) and GQ Mus (Krautter & Williams 1989; Diaz & Steiner 1994). Figure 6 shows the finding chart for V617 Sgr.

3.3.2. V1082 Sagittarii

V1082 Sgr, like V617 Sgr, is an odd case. This object presents two brightness states in which its photometric and spectroscopic properties change completely. In the high state ($V \sim 14.0 - 14.5$), V1082 Sgr presents flickering, UV excess, and a spectrum with prominent emission lines of Balmer series, HeI and HeII while in the low state ($V \sim 15.0 - 15.5$), flickering is practically absent, the colours are red and the spectrum does not show emission lines. Figures 2i and 2j show the spectrum of V1082 Sgr in these two states. They were collected on June 28, 1986 and July 03, 1986, respectively. The continuum of the cool star is visible even in the high state and can be classified as K2–K4III.

Published photometric data (Uitterdijk 1949) show that the brightness of V1082 Sgr varies in the range 13.6–15.7 mag. These data also show the occurrence of light changes of ~ 1 mag with time scales of ~ 1 –2 days. We propose V1082 Sgr to be a symbiotic star. A finding chart for this object is shown in Fig. 6.

3.4. Symbiotic star candidates

In our study on irregular variables we found 7 other stars which show a late-type continuum with prominent emission lines of the Balmer series, HeI and [OIII] (Table 1). The stars RT Cru, DQ Ser, DT Ser, NSV 10435 and NSV 11776 are classified as true symbiotics while V417 Cen and V704 Cen are quoted as possible candidates to this class, since these two objects did not show lines of higher excitation as HeII or [FeVII]. A more detailed discussion on these objects can be found in Cieslinski et al. (1994, 1997b).

3.5. NSV 07105: A Be-type object

The presence of peculiar colours in NSV 07105 (Paper I) motivated us to do spectroscopy of this object on several occasions (Table 1). The spectra show a strong blue continuum with absorption lines of the Balmer series, HeI ($\lambda\lambda 4714, 5015, 5876, 6678$), SiII ($\lambda\lambda 6347, 6371$), FeII $\lambda 6517$ and NaI ($\lambda\lambda 5890, 5896$). H α displays a broad component with FWHM ~ 1000 km s^{−1} and a narrow component with FWHM ~ 200 km s^{−1}, while the other lines present only the narrow component (Figs. 3a, 3b and 3c).

Broad H α in absorption with a double peak in emission is seen in a higher resolution spectrum taken with the Coudé Spectrograph of the LNA on August 24, 1989. The separation of the emission component features is ~ 300 km s^{−1} (see inserted box in Fig. 3d). H α with double peak in emission is seen again in a spectrum taken on March 11, 1996 (Fig. 3d).

Table 1. Spectroscopic data

Name	JD (2440000+)	Exp. time (sec)	Spectral type	$< B - V >$	Origin	Notes
UW Ant	6614.4868	180	M3–M4	1.81	CTIO	
BY Aps	–	–	M3–M7	1.41	CTIO	1
GI Aps	6270.6042	300	M6–M7	1.78	CTIO	
IK Aps	6270.6104	300	M6–M7	1.67	CTIO	
"	6611.6049	600	M6–M7	"	CTIO	
CZ Aql	–	–	weak blue continuum + Balmer and HeI lines in emission	0.39	CTIO	2
"	9995.4904	900	blue continuum + Balmer lines in emission	"	LNA	
EH Aql	6610.9153	1200	M6–M7 + H δ in emission	1.59	CTIO	
"	9933.7147	420	M6–M7	"	LNA	
IS Aql	6615.7653	120	M6–M7	2.02	CTIO	
V506 Aql	6611.8743	240	M5–M6	–	CTIO	
V576 Aql	6610.8861	1800	K0–K2 (reddened) + Balmer series in emission	–	CTIO	
V587 Aql	6615.7681	120	M6–M7	–	CTIO	
"	9995.5697	600	M5–M6	"	LNA	
V588 Aql	9995.5586	660	M5–M6	–	LNA	
V686 Aql	6615.7604	120	M6–M7	–	CTIO	
V786 Aql	9995.5294	600	M5–M6	–	LNA	
V789 Aql	9995.5460	720	K5–M1	–	LNA	
V852 Aql	6611.8847	240	M4–M5	2.00	CTIO	
V856 Aql	6611.8361	120	M5–M6	1.82	CTIO	
V881 Aql	9966.5103	900	A8–F3	0.57	LNA	
V934 Aql	6614.6826	600	G8–K2	–	CTIO	3
"	6614.6917	1200	G8–K2	–	CTIO	4
FX Ara	6609.6097	300	K3–K4	1.32	CTIO	5
"	6609.6139	600	K0–K2	"	CTIO	6
"	6609.6222	230	G5–K0	"	CTIO	7
KZ Ara	6607.7542	1200	K6–K7 + Balmer series in emission	1.78	CTIO	
V498 Ara	6610.7083	1800	M4–M5	1.33	CTIO	
V514 Ara	6610.7340	3600	K0–K2 + Balmer series in emission	0.75	CTIO	
V652 Ara	6607.7042	600	G8–G9	0.91	CTIO	
V686 Ara	6271.5514	300	K4–K5	1.54	CTIO	
"	6616.6646	900	K4–K5	"	CTIO	
V688 Ara	6616.6778	120	M6–M7	1.67	CTIO	
V698 Ara	6613.6688	120	M6–M7	1.75	CTIO	
V716 Ara	9933.4356	900	M3–M4	1.61	LNA	
V717 Ara	6271.5569	600	F	–	CTIO	
V720 Ara	6613.6861	600	M5–M6 + H δ and H γ in emission	–	CTIO	
"	9933.4571	900	>M8	–	LNA	
V732 Ara	6613.7007	180	M3–M4	1.85	CTIO	
V734 Ara	6613.6951	240	M6–M7 + H δ in emission	1.54	CTIO	
V745 Ara	6609.5792	1400	K3–K4	1.43	CTIO	
"	6615.7472	600	K3–K4	"	CTIO	
V788 Ara	6271.5993	600	M6–M7	–	CTIO	
V814 Ara	6614.5604	600	M5III + H δ and H γ in emission	1.46	CTIO	
V817 Ara	6271.5806	600	F–G	0.58	CTIO	
"	6605.6444	800	A8–F4	"	CTIO	8
"	6605.6556	600	K0–K2	"	CTIO	9
BI Car	6271.4611	600	M6–M7	2.79	CTIO	
OQ Car	8664.6982	1200	blue continuum + H α in emission	0.13	LNA	
DF Cen	6604.5000	800	K4–K5	2.02	CTIO	
GV Cen	6609.4556	600	M6–M7	1.94	CTIO	
V342 Cen	6606.5549	1400	blue continuum + weak Balmer lines in absorption	0.14	CTIO	
"	6607.4674	1800	blue continuum + weak Balmer lines in absorption	"	CTIO	
"	6616.4653	3000	blue continuum + Balmer lines in emission	"	CTIO	
"	8663.6940	1200	blue continuum + H α and HeI lines in emission	"	LNA	
V417 Cen	–	–	G8–K2 + Balmer, [NII], [OIII] and HeI lines in emission	1.73	CTIO+LNA	10
V531 Cen	6605.5493	200	M6–M7 + H δ and H γ in emission	1.49	CTIO	
V682 Cen	6605.5278	1500	G0–G2	0.78	CTIO	
V704 Cen	–	–	<K5 + Balmer, HeI, [OIII] and [NII] lines in emission	1.04	CTIO+LNA	10
V792 Cen	6609.4993	4800	K0–K2	0.85	CTIO	
"	6611.5104	1800	G7–K0	"	CTIO	
"	6616.5319	1800	K0–K2	"	CTIO	
ST Cha	6611.4694	2400	blue continuum + Balmer lines in absorption	0.14	CTIO	
"	6612.4910	1800	blue continuum + Balmer lines in absorption	"	CTIO	
"	8664.7314	1200	blue continuum + H α in emission	"	LNA	
"	8752.4622	1200	blue continuum + H α and HeI λ 6678 in emission	"	LNA	
SW Cha	6610.5111	600	A8–F3 (reddened)	1.22	CTIO	
CH Cha	6610.4903	1400	G0–G3	0.64	CTIO	
CP Cha	6613.4847	270	M6–M7	–	CTIO	
AQ CrA	6270.7118	600	F	–	CTIO	
AY CrA	6270.7361	600	F–G	–	CTIO	
BG CrA	6270.7458	600	G8–G9	–	CTIO	
BN CrA	6270.7660	600	G7–K0 + H α in emission	–	CTIO	
DG CrA	6270.7785	600	G (reddened) + Balmer lines in emission	–	CTIO	
GV CrA	6614.6313	120	M4–M5 + H δ in emission	1.76	CTIO	

Table 1. continued

Name	JD (2440000+)	Exp. time (sec)	Spectral type	$< B - V >$	Origin	Notes
GX CrA	6614.6347	120	M4–M5	1.84	CTIO	
V529 CrA	6269.6910	1200	K0–K2	1.09	CTIO	
"	6605.7194	1200	G8–K2	"	CTIO	
V651 CrA	6269.7979	1200	K0–K3 + H α in emission	1.46	CTIO	
"	6605.7375	3600	K5–K6	"	CTIO	
"	6608.7799	1800	K5–K6	"	CTIO	
RT Cru	–	–	M4–M5 + Balmer, HeI, HeII and [OIII] lines in emission	1.72	CTIO	10
VZ Gru	6612.9069	2720	F4–F6	0.30	CTIO	
AN Gru	6613.8854	2400	A4–A8	0.23	CTIO	11
"	6614.9097	1800	F4–F7	"	CTIO	
"	6615.9090	1800	A8–F2	"	CTIO	
"	6616.9125	900	F4–F7	"	CTIO	
BM Gru	6271.8035	600	G8–G9	1.59	CTIO	
AA Ind	6611.8938	3900	G5–K0	0.63	CTIO	
"	6613.8849	1800	G7–K0	"	CTIO	
UY Mic	6608.9035	1200	G7–K0	0.55	CTIO	
"	6609.8813	1200	F8–G0	"	CTIO	
KQ Mon	6744.8368	1200	strong blue continuum + H α and H β in emission	0.02	CTIO	12
"	8663.5119	600	strong blue continuum + H α and HeI λ 6678 in emission	"	LNA	
EH Mus	6270.5118	600	F–G	0.63	CTIO	
ZZ Nor	8792.5868	600	>M7	1.70	LNA	
"	9931.4952	900	>M9	"	LNA	
HR Nor	6607.7292	600	G8–K2	1.28	CTIO	
MU Nor	6270.5826	600	G7–G9	1.00	CTIO	
"	6606.6597	3600	G3–G8	"	CTIO	
"	6609.6458	1200	G7–K0	"	CTIO	
NN Nor	6270.5632	1200	G7–G9	0.86	CTIO	
"	6606.7090	2800	G7–K0	"	CTIO	
"	6609.6688	1200	G8–K2	"	CTIO	
OQ Nor	6614.4938	660	M4–M5 + Balmer lines in emission	–	CTIO	
OR Nor	6614.5076	250	M6–M7	–	CTIO	
TU Oct	6609.9090	120	M3–M4	1.70	CTIO	
TV Oct	6615.8951	120	M6–M7	1.67	CTIO	
AY Oct	6609.9167	1200	A7–A8	0.30	CTIO	13
V1003 Oph	6613.5083	600	red continuum + Balmer, HeI, H and K(CaII) lines in emission	–	CTIO	
V2091 Oph	9966.5848	900	M5–M6	–	LNA	
V499 Ori	6741.8549	1200	G7–K0 + Balmer lines in emission	1.20	CTIO	
VV Pav	9933.4711	600	CN bands in the near infrared	1.86	LNA	
"	9966.4600	720	strong bands of C ₂ in 4737, 5165 and 5635 Å	"	LNA	
OO Pav	6612.8792	1500	K3–K4 + Balmer lines in emission	1.73	CTIO	
PZ Pav	6271.6528	100	M6–M7	1.83	CTIO	
KX Sgr	6614.6264	180	M5–M6	–	CTIO	
V431 Sgr	6270.7257	600	K0–K3	–	CTIO	
V494 Sgr	6270.6833	600	F	–	CTIO	
V497 Sgr	6270.6944	600	G8–G9	–	CTIO	
V563 Sgr	6614.6417	60	M6–M7	2.12	CTIO	
V617 Sgr	–	–	flat continuum + Balmer, HeII, CIII–IV, NIII–V and OIII–VI	–0.04	CTIO	2
"	"	"	lines in emission	"	"	
V648 Sgr	6614.6472	120	M4–M5	–	CTIO	
V714 Sgr	6605.8465	1200	K2–K4	1.37	CTIO	
V729 Sgr	6616.8681	2400	flat continuum + Balmer lines in emission	0.19	CTIO	
V730 Sgr	6616.8333	2400	blue continuum + H α in emission; the other Balmer lines are	–0.02	CTIO	
"	"	"	in absorption	"	"	
V1082 Sgr	6609.7035	1200	K2–K4, without emission lines	0.67	CTIO	
"	–	–	K2–K4 + Balmer, HeI, HeII, CIII–NIII lines in emission	"	CTIO	2
V1257 Sgr	6612.9000	120	M5–M6	1.67	CTIO	
V1767 Sgr	6269.7694	1200	K3–K4	1.32	CTIO	
V2166 Sgr	6271.6722	300	G8–G9	0.68	CTIO	
"	6607.8278	600	G3–G5	"	CTIO	
V2169 Sgr	6607.8111	1200	G8–G9	0.38	CTIO	
"	6611.7444	600	F6–F7	"	CTIO	
V2186 Sgr	6271.6167	300	M6–M7	1.61	CTIO	
V2209 Sgr	6271.6444	600	F–G	0.45	CTIO	
V2234 Sgr	9159.7967	60	M10	2.42	LNA	
"	9160.8315	900	>M7 + H δ in emission	"	LNA	
"	9595.5976	600	>M9	"	LNA	
"	9933.5326	300	M10	"	LNA	
"	9995.5182	600	M10	"	LNA	
V2255 Sgr	9966.6295	900	M5–M6	1.49	LNA	
V2323 Sgr	8751.7435	600	K4–K5 + H γ in emission	–	LNA	14
"	8751.7528	600	K4–K5 + H α in emission	–	LNA	
"	8752.6857	900	K4–K5 + H α in emission	–	LNA	
"	8792.6324	720	K7–M2, without emission lines	–	LNA	
"	9933.5003	600	M3–M4, without emission lines	–	LNA	
"	9966.5264	900	K4–K5 + H γ and H β in emission	–	LNA	

Table 1. continued

Name	JD (2440000+)	Exp. time (sec)	Spectral type	$\langle B - V \rangle$	Origin	Notes
V2323 Sgr	9995.4494	900	K7–M2, without emission lines	–	LNA	
"	10153.8386	600	K7–M2, with weak H α in emission	–	LNA	
V3871 Sgr	9933.5226	600	M4–M5	1.66	LNA	
V428 Sco	6614.5951	600	K0–K2 (reddened)	1.66	CTIO	
V432 Sco	6614.6028	1200	K6–K7 + Balmer lines in emission	1.80	CTIO	
V826 Sco	6269.7514	300	G3–G5	0.72	CTIO	
XX Sct	6605.7958	900	G0–G2 (reddened) + H α in emission	0.80	CTIO	
EG Sct	6614.6681	600	K6–K7	–	CTIO	
FH Sct	6269.7118	600	bands of C ₂ in 4737, 5165 and 5635 Å	1.67	CTIO	15
"	6611.6208	1800	no bands of C ₂	"	CTIO	
FQ Sct	6269.7375	300	M6–M7	2.18	CTIO	
HN Sct	6615.7715	1200	K0–K2	–	CTIO	16
"	6615.7882	1200	K5	–	CTIO	17
TZ Ser	6605.6910	1800	K0–K2	–	CTIO	
BS Ser	9966.5985	900	K4–K5	–	LNA	
BZ Ser	9966.5439	720	K4–K5	–	LNA	
DM Ser	9966.5557	900	A–F	–	LNA	
DN Ser	9966.5699	900	M4–M5	–	LNA	
DQ Ser	–	–	>M3 + Balmer, HeI, HeII, CIII, NIII, [OIII] and FeII lines in emission	1.24	LNA	18
"	"	"		"	"	
DT Ser	–	–	G2–K0III–I + H α , [OIII], HeII in emission	0.51	LNA	18
NW Tel	6614.6563	120	F7–F8	–	CTIO	
HO TrA	6605.6257	200	M4–M5	1.74	CTIO	
"	6616.5986	240	M4–M5	"	CTIO	
HU TrA	6610.6674	600	K5–K6	1.58	CTIO	
IO TrA	6613.6757	600	K0–K2	–	CTIO	
BE Tuc	6269.8681	300	G7–G9	–	CTIO	
SY Vol	8864.6462	1200	blue continuum + H α in emission	–	LNA	
NSV 00232	6605.9132	2790	F7–F8	0.39	CTIO	
NSV 05268	6610.5313	600	F6–F8 (reddened)	0.89	CTIO	
NSV 05313	6606.5403	600	A3–A6	0.70	CTIO	
NSV 05443	8664.7595	300	strong bands of C ₂ in 4737, 5165 and 5635 Å	4.13	LNA	
NSV 05913	6613.4903	1200	G3–G8	0.91	CTIO	
NSV 05932	6609.4674	1800	F4–F7	0.70	CTIO	
NSV 06237	9931.3905	900	A	0.32	LNA	
NSV 06274	6606.5757	600	M6–M7	1.25	CTIO	
NSV 06481	9931.4179	900	M5–M7	–	LNA	
NSV 06518	9931.4078	300	G8–K2	0.27	LNA	
NSV 06627	6605.6042	1200	A4–A8	0.26	CTIO	
NSV 06632	6612.5403	3000	G	0.40	CTIO	
NSV 06893	9931.4325	600	M5–M7	2.13	LNA	
NSV 06920	9931.4441	600	M5–M7	–	LNA	
NSV 06989	6606.6007	600	F6–F7	0.55	CTIO	
NSV 07014	6610.5931	1200	F7–G2	0.73	CTIO	
NSV 07097	6610.5549	600	M6–M7 + H δ and H γ in emission	1.05	CTIO	
"	9931.4546	600	M9–M10	"	LNA	
NSV 07105	7763.4397	600	H α in absorption + double peak in emission	0.23	LNA	
"	8663.7946	120	B + H α , HeI lines in absorption	"	LNA	
"	8664.7905	300	B + Balmer, HeI, SiII and NaI lines in absorption	"	LNA	
"	9060.7840	600	B + H β in absorption	"	LNA	
"	9966.4224	300	B + H β in absorption	"	LNA	
"	10135.6914	600	B + H α in emission	"	LNA	
"	10153.7991	300	H α in absorption + double peak in emission	"	LNA	
NSV 07136	9931.4655	420	M8–M9	2.41	LNA	
NSV 07338	6610.6153	770	G3–G8	0.84	CTIO	
NSV 07381	6607.7396	600	K4–K5	1.21	CTIO	
NSV 08181	6271.5729	600	F	0.75	CTIO	
"	6611.6708	3000	F5–F7	"	CTIO	
"	6615.7354	600	F4–F6	"	CTIO	
NSV 08245	6611.7368	350	M6–M7	1.80	CTIO	
NSV 08475	6270.7563	600	G8–K2	1.41	CTIO	
"	6611.7097	2160	K3–K4	"	CTIO	
NSV 09018	6271.6931	300	A3–A8	0.43	CTIO	
NSV 09743	6613.7069	1800	K2–K4	–	CTIO	
NSV 09783	9933.4837	720	G5–G8	0.97	LNA	
NSV 10348	6607.7729	200	M6–M7 + H γ in emission	1.02	CTIO	19
"	6607.7778	600	G3–G8	"	CTIO	20
NSV 10435	–	–	>M3 + Balmer, HeI, HeII, [OIII] and FeII lines in emission	–	LNA	10
NSV 10546	9933.5118	600	G2–G5 (reddened)	2.21	LNA	
NSV 11036	6271.5347	300	M4–M6	1.64	CTIO	
NSV 11615	6271.6215	300	K6–K7	1.82	CTIO	
NSV 11733	6271.6285	100	M5–M6	1.61	CTIO	
NSV 11776	–	–	>M4 + Balmer, HeI, HeII, [OIII], FeII and [FeVII] lines in emission	0.92	CTIO+LNA	10
"	"	"		"	"	
NSV 11826	6271.6368	100	G8–G9	1.21	CTIO	

Table 1. continued

Name	JD (2440000+)	Exp. time (sec)	Spectral type	$\langle B - V \rangle$	Origin	Notes
NSV 11826	6606.7993	2400	K5–K6	''	CTIO	
NSV 11850	6271.6319	100	M5–M6	1.69	CTIO	
NSV 12316	6606.8438	1930	K2–K4	1.43	CTIO	
NSV 12429	6270.8069	100	F	0.66	CTIO	
NSV 12583	6270.7882	600	F	0.55	CTIO	
NSV 12758	6607.8382	600	G8–K0	0.64	CTIO	
NSV 13052	6608.8979	200	M6–M7 + H δ and H γ in emission	–	CTIO	
''	6611.8674	240	M6–M7 + H δ and H γ in emission	–	CTIO	
NSV 13196	6270.8139	300	F	0.52	CTIO	
''	6608.8785	1200	F7–F8	''	CTIO	
NSV 13906	6271.6806	60	M5–M6	1.70	CTIO	
NSV 14605	6270.8215	600	F	0.49	CTIO	
NSV 14660	6270.8333	300	G8–K0	–	CTIO	
NSV 14697	6606.8326	600	G3–G8	0.91	CTIO	

1: Classified as Mira variable in Cieslinski et al. (1997c).

2: Average spectra.

V934 Aql – 3: north component, 4: south component.

FX Ara – 5: north component, 6: east component, 7: south component.

V817 Ara – 8: north component, 9: south component.

10: Spectra are also shown in Cieslinski et al. (1994).

11: Quoted as suspected of cataclysmic variable in Vogt & Bateson (1982) and Downes & Shara (1993).

12: Quoted as UX UMa type in Sion & Guinan (1983), Downes & Shara (1993) and Zwitter & Munari (1994).

13: Quoted as suspected of cataclysmic variable of Z Cam type in the GCVS4.

14: Quoted as suspected of cataclysmic variable of U Gem type in the GCVS4 and in Downes et al. (1997).

15: Quoted as variable of the R CrB type in the GCVS4.

HN Sct – 16: north component, 17: south component.

18: Classified as symbiotic stars in Cieslinski et al. (1997b).

NSV 10348 – 19: south component, 20: north component.

3.6. Candidates to T Tauri stars and related objects

Three stars in our sample showed spectroscopic characteristics which permit to classify them as possible young objects. They are DW CMa, V1003 Oph and DM Ori.

The star V1003 Oph shows a weak red continuum with emission lines of the Balmer series, HeI ($\lambda\lambda 5876, 6678$) and H ($\lambda 3968$) and K ($\lambda 3934$) of CaII (Fig. 3e). The LiI $\lambda 6707$ line in absorption is seen in observations carried out by Quast & Torres (private communication) with the Coudé Spectrograph of the LNA on April 24, 1988. The presence of lines of the Balmer series and CaII in emission and LiI in absorption is characteristic of T Tauri variables (Herbig 1962). Consequently, we classify V1003 Oph as new T Tauri star. This object is listed as IN: in the GCVS4 catalogue, i.e., a probable irregular variable associated with nebulosity.

The other two stars were observed spectroscopically by Gregorio-Hetem et al. (1992) and Torres et al. (1995) in a program aiming to discover new T Tauri stars. Those authors classified DW CMa as Herbig Ae/Be object and DM Ori as T Tauri.

3.7. Objects with G-spectral type and Balmer lines in emission

Four of the observed objects present G-type continua and emission of lines of Balmer series (Table 1). In XX Sct and

BN CrA only H α is visible while in DG CrA and V499 Ori the other members of the series can be seen (Figs. 3f, 3g, 3h and 3i).

A definitive classification for such objects is not possible with our data. The classification quoted in the GCVS4 for these variables is INS (i.e., a rapid irregular variable associated with nebulosity) for DG CrA, INS: for V499 Ori, IS (i.e., a rapid irregular with no apparent connection with nebulosities) for BN CrA and IS: for XX Sct.

3.8. Objects with K–M spectral type and Balmer lines in emission

We have found 17 objects which display late-type continua (K–M) with the Balmer series in emission (Table 1). V576 Aql, KZ Ara, V514 Ara, OQ Nor, OO Pav and V432 Sco are variables which show lines from H α to H δ while the others present only H γ and/or H δ lines. Among these objects, V651 CrA shows only H α in emission. Examples of spectra of this group of objects are shown from Fig. 3j to Fig. 4h.

The correct classification of these variables is not obvious since Mira variables as well as red semiregular variables can sometimes present phases in which emission lines are visibles in their spectra. Consequently, more photometric and/or spectroscopic information is necessary in order to better characterize such objects. Some of them

showed, however, very late M spectral type and H δ and H γ with intensities normally found in Mira variables. They are V720 Ara, V814 Ara, V531 Cen, V1257 Sgr, NSV 07097 (see Fig. 4h) and NSV 13052.

3.9. Carbon star candidates

NSV 05443 and VV Pav are variables whose spectra showed the presence of characteristics of carbon stars like very strong Swan bands of the C₂ molecule (with band heads at 4737, 5165 and 5635 Å) and bands of CN in the near infrared (Figs. 4i, 4j and 5a). FH Sct is another object which showed the Swan bands of C₂ at 4737, 5165 and 5635 Å (Fig. 5b). This object is classified as a variable of type R Coronæ Borealis in the GCVS4 (Kholopov et al. 1987).

Two of the stars, IK Pup and NSV 03482, show extreme red colours, similar to the NSV 05443 (Paper I). They are, consequently, candidates to carbon stars also. In fact, for IK Pup a C(N) spectral type has been assigned in the GCVS4 while for NSV 03482 we do not have spectroscopic information.

3.10. Other objects

The remaining objects of our sample (a total of 123) did not show emission lines in their spectra. The range of spectral types presented by these objects varies from early A to late M (see Figs. 5d to 5j).

The correct classification for those objects is also not possible with our data since several classes of variables can display overlapping spectral types. For example in the range F–K one can find variables like δ Cephei (Population I Cepheids), W Virginis (Population II Cepheids), RR Liræ, semiregular variables of SRD type (Kholopov et al. 1985) or even the yellow semiregular variables of RV Tauri group. On the other hand, δ Scuti and RR Liræ objects may present spectral types earlier than F, while semiregular variables of types SRA, SRB and SRC show M spectral type (Kholopov et al. 1985).

As examples of objects better observed we mention BY Aps classified by us as a Mira variable (Cieslinski et al. 1997c), V529 CrA as a probable RV Tauri variable of RVb subgroup (Cieslinski et al. 1998) and NSV 06627 as a RR Lyræ variable of ab sub-type (more information on this star will be published elsewhere).

Acknowledgements. We are grateful to the CTIO and LNA staffs for the observing assistance during the missions. We thank S.D. Kirhakos, G. Quast and C.A.O. Torres for sharing telescope time and the referee, U. Munari, for his valuable comments and suggestions. D. Cieslinski acknowledges the support of CNPq (*Conselho Nacional de Desenvolvimento Científico e Tecnológico*) and FAPESP (*Fundação de Amparo à Pesquisa do Estado de São Paulo*).

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