SPECTRA OF INDIVIDUAL SYMBIOTIC STARS

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ABSTRACT

In connection with the discussion of the individual symbiotic stars, we present low resolution, flux calibrated spectra and high resolution H α profiles for each of 12 objects.

I. INTRODUCTION

Since 1978 September, we have conducted a regular program of spectrophotometric observations of a sample of 12 symbiotic stars. The observations are obtained at low resolution (c. 8 A) with a Boller and Chivens cassigrain spectrograph and at high resolution with the Washburn Observatory echelle spectrograph (Schroeder and Anderson 1971) both of which are used on the Observatory's 0.9-meter telescope. In both cases an intensified Reticon detector (McNall and Nordsieck 1976) is used. The observing techniques and reduction procedures are described in detail in Anderson, Oliversen and Nordsieck (1980) and Oliversen (1981). In addition to the standard flat field, dark/sky subtractions and extinction correction the low resolution spectra are calibrated against flux standards while the high resolution line profiles are wavelength calibrated on every object. The low resolution spectra thus give an accurate relative flux distribution over the wavelength range 3900--5900 A. The relative fluxes differ from the true fluxes by a factor of order unity which is the ratio of slit and seeing losses on the object to the average thereof during the standard star observations. The fidelity of the wavelength scale of the line profiles has been checked against IAU velocity standards and appears to be about 3 km s^{-1}.

II. DISCUSSION

Representative spectra of each of the objects are given in Figures 1 through 12. In table 1 we summarize in a semiquantitative

M. Friedjung and R. Viotti (eds.), The Nature of Symbiotic Stars, 71–82.

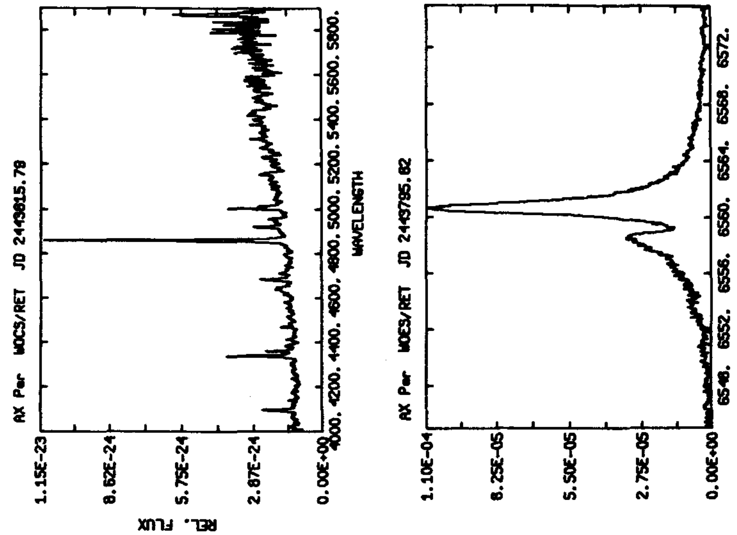

Figure 2

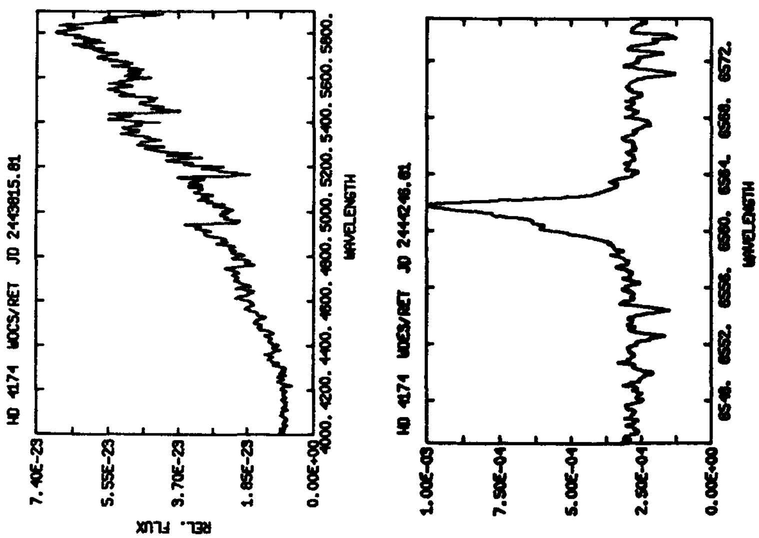

Figure 1

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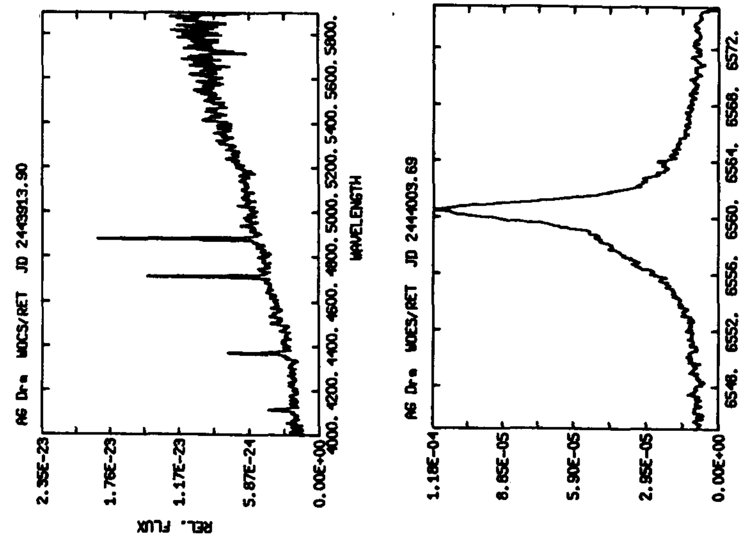

Figure 4

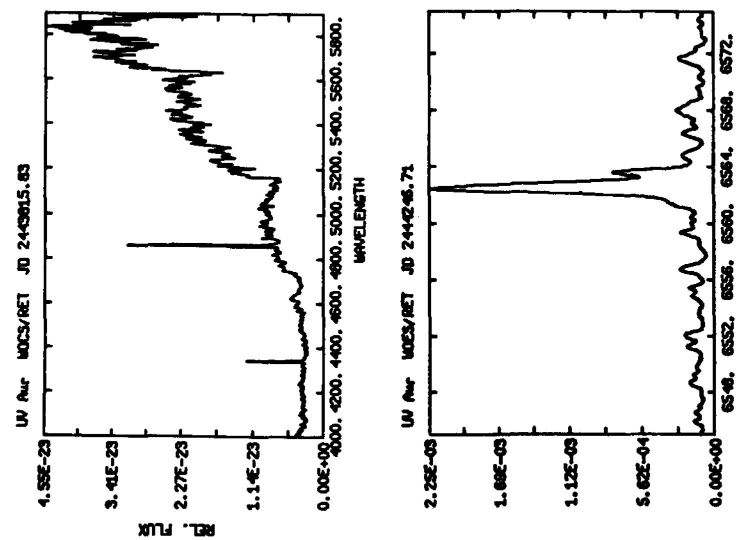

Figure 3

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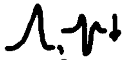
TABLE 1

SUMMARY OF OPTICAL SPECTROPHOTOMETRIC DATA ON SYMBIOTIC STARS

				INTENSITIES wrt Hβ (note 1)		
STAR NAME	K/M STAR OBSERVED	Hα PROFILE	H	λ 5007 [O III]	λ 4363 [O III]	λ 4686 [He II]
HD 4174	Y		.3:	--	--	--
AX Per	Y--N		.3	.3--.1	.3--1.5	.1--.5
UV Aur	Y		.4	--	--	--
AG Dra	Y		.3	--	--	.4--.7
MWC 603	Y,v		.3	.08	.2	.1
CH Cyg	Y		.2	--	--	--
BF Cyg	N		.3:	2.1	.3	.05:
CI Cyg	Y,v		.4	.4	.7--1.5	.3--.5
V 1016 Cyg	N		.3	2.2	.6--.9	.5
HBV 475	N		.3	.5	--	.4--1.2
AG Peg	Y		.4	.5	.2--0	.5 vb
Z And	Y		.3	.05	--	.4--1.2
HM Sge	N		.3:	2:	π	.5:
RR Tel	Y:		.3	1.2	.9	.6
He 2 177	N		.2	.7	.5	.5
RY Sct	N			--	--	--
FR Sct	Y			--	--	--
AR Pav	Y,v		.3	.7	.5	.3
RS Oph	Y,v		.2	--	--	--
R Aqr	Y		.3	1.8	.6	--
HK Sco	Y		.2	--	--	.4
AS 295 B	N		.2	.4	--	.03

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	λ 4922	λ 5876	SPECIES PRESENT			
STAR NAME	He I s	He I t	[N II]	[Fe II]	[Fe II]	[Fe VII]
HD 4174	--	--	N	--	--	--
AX Per	.1	.5	N	N	N--Y	Y--N
UV Aur	--	--	N	--	--	--
AG Dra	.05:	.5	N	N	N	N
MWC 603	.1:	.3	N	N	Y	N
CH Cyg	.05:	.3:	N	Y	Y	N
BF Cyg	.05	.3	Y:	N	Y	N
CI Cyg	.05	.3	N	Y	Y	N
V 1016 Cyg	.05	.2	Y	Y	Y	Y
HBV 475	.08	.4	N	Y:	Y	Y
AG Peg	.07	.3:	N	N	Y	N
Z And	.07	.3:	N	N	N	Y
HM Sge	.01:	.5	Y	N:	N:	π
RR Tel	.05	.1	Y	Y	Y	Y
He 2 177	.1	.4	Y	N	Y	Y
RY Sct	--	--	Y	N	N	N
FR Sct	--	--	Y	Y	N	N
AR Pav	.1	.4	N	N	Y	N
RS Oph	--	1.0	N	N	N	N
R Aqr	.05	.2	Y	N	N	N
HK Sco	--	.5	N	N	Y	N
AS 295 B	.01	.2	Y	N	N	N

Note 1. [O III] λ4363 Intensity is w.r.t. Hγ

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way the general characteristics of the spectra. Included in this tabulation is information on ten southern objects observed in 1979 September-October at CTIO.

HD 4174 (EG And) Fig. 1

At low resolution the spectrum of the late-type component is most obvious while the emission lines can be weakly detected. The Hα line is usually weakly in emission with a FWHM of 100 km s^{-1}. In 1980 June, at a phase of 0.6 according to the ephemeris of Smith (1980) the profile was deeply reversed with the absorption core going well below the continuum of the cool star.

AX Per Fig. 2

AX Per has one of the most radically variable spectra in the sample. It has shown at some times a virtually featureless continuum with only relatively low excitation emission lines and hydrogen lines with deep reversals on the blue (Hα FWHM 180 km s^{-1}) side while at other times the molecular band heads of TiO etc. dominate the continuum, emission lines up to Fe VII are present and the Hα profile has only a slight blueward asymmetry (FWHM 80 km s^{-1}). The former condition is illustrated in figure 2.

UV Aur Fig. 3

The carbon star continuum dropping off rapidly into the blue is the most obvious characteristic of UV Aur at low resolution. Only the hydrogen lines are seen in emission and these have at times completely disappeared. When the emission lines are present, the Hα profile is unusually narrow (FWHM 40 km s^{-1}) main peak with a small subsidiary peak roughly 50 km s^{-1} to the red of the main peak.

AG Dra Fig. 4

In our low resolution spectra the continuum of AG Dra is featureless, slopping gradually downward to the blue. The emission lines of hydrogen, He I and He II are easily detected. The Hα profile has a strong sharp central peak (FWHM 95 km s^{-1}) and broad wings (375 km s^{-1} at $I/I_c = 2$) with the blue wing substantially stronger than the red. This latter condition is termed " the blue asymmetry ". As noted by Smith and Bopp (1981) around phase 0.5 ±.25 the blue wing appears to develop a slight reversal. Smith and Bopp attribute this to the variation in strength of one of the components of a two component system. Our spectra, which detect the stellar continnum and remain linear and unsaturated over the full intensity range of the profile, indicate that that an absorption feature developes in the existing profile.

MWC 603 Fig. 5

Through out our survey the continuum spectrum of MWC 603 has show moderately obvious molecular band heads. The emission lines of H, He I, He II and [O III] are seen but very little if any variations have been noted. The Hα profile shows a slight blue asymmetry and FWHM of 40 km s^{-1}. Occasionally small shoulders or other features appear on the blue wing of the emission.

CH Cyg Fig. 6

The continuum of CH Cyg varies from nearly featureless to totally dominated by molecular features. Hydrogen and neutral helium emission lines are always present. Singly ionized iron has been detected. The Hα profile is usually strong with a very deep central reversal and the blue peak 10 to 20 percent stronger than the red. However episodes have been encountered during which the relative strengths of the two peaks reversed on time scales of a few days. This phenomenon has been discussed by Anderson, Oliversen and Nordsieck (1980).

BF Cyg Fig. 7

At our low resolution, the continuum of BF Cyg is featureless although on KPNO echelle plates the absorption line of the late component are weakly visble. Hydrogen and neutral helium are seen as is [O III] and the relative strengths of these lines undergo substantial variations. The Hα profiles shows the blue asymmetry, FWHM of 120 km s^{-1} and some variations in slight features on the blue wing.

CI Cyg Fig. 8

The molecular features in the continuum of CI Cyg are always moderately obvious and the emission lines of hydrogen, He I, He II and [O III] are seen and their relative intensities vary in a manner correlated to some degree with the eclipses. The blue asymmetry of the Hα always has had some degree of reversal which becomes markedly stronger during the eclipses. Furthermore, the heliocentric velocity of the center of the reversal is least negative (-16 km s^{-1}) near the phase of the eclipse and reaches a minimum (-30 km s^{-1}) one half period later. This might indicate that this feature originates in a flow from the cool component to the small, hot object at a rate of about 7 km s^{-1}.

V 1016 Cyg Fig. 9

The continuum of V 1016 Cyg is but weakly detected and appears featureless. The emission line spectrum is the richest in the sample with both premitted and forbidden lines from neutral species all the way up to six times ionized iron. The relative strengths of the lines show only minor variations. The Hα profile is nearly

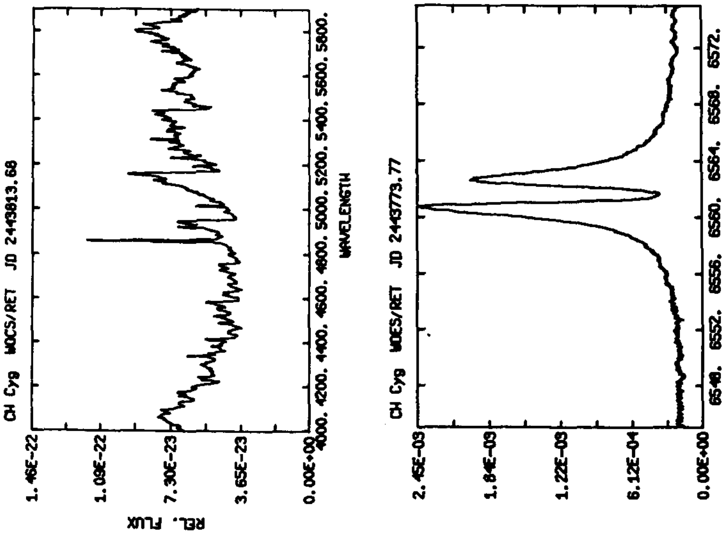

Figure 6

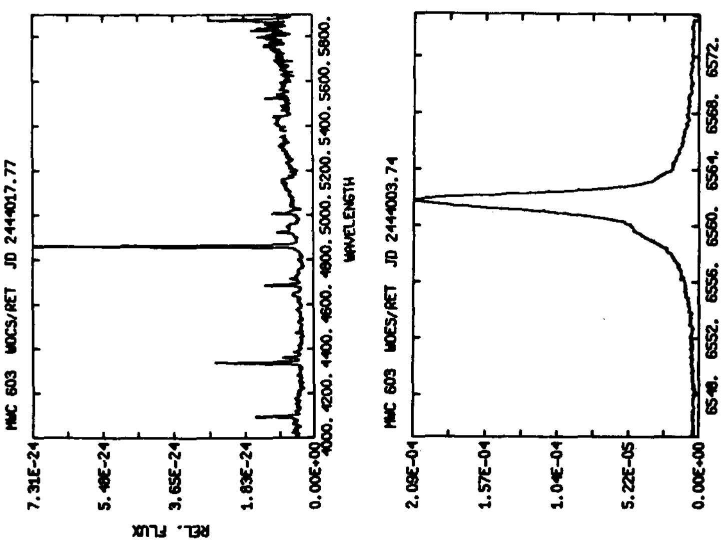

Figure 5

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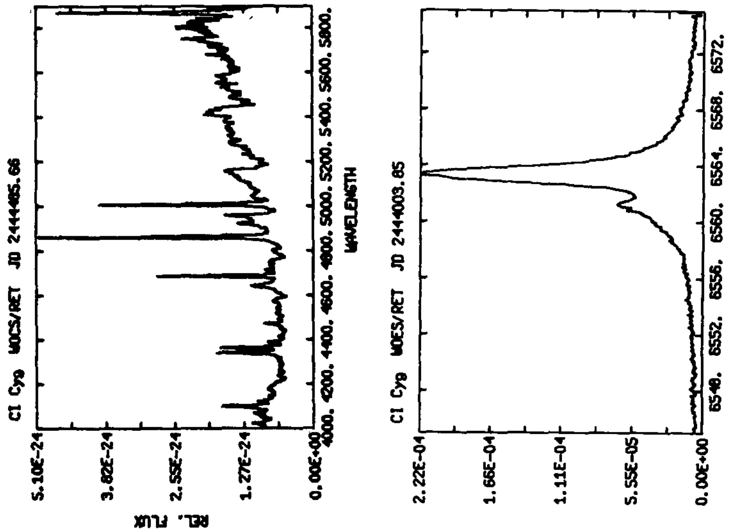

Figure 8

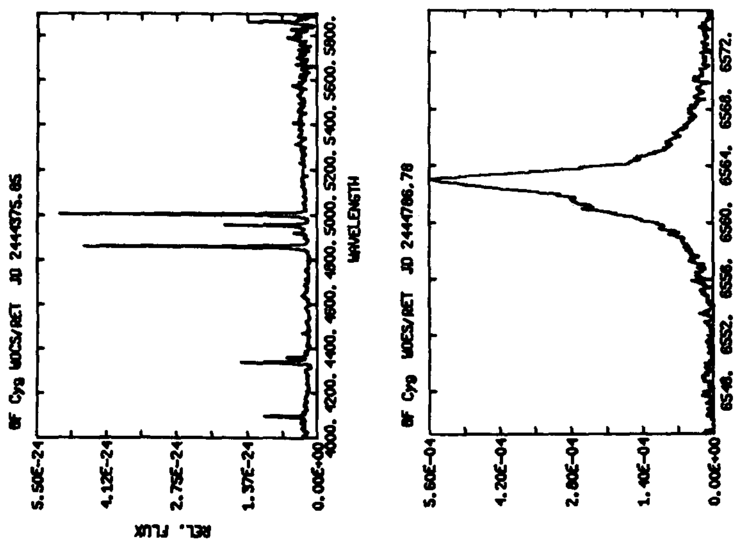

Figure 7

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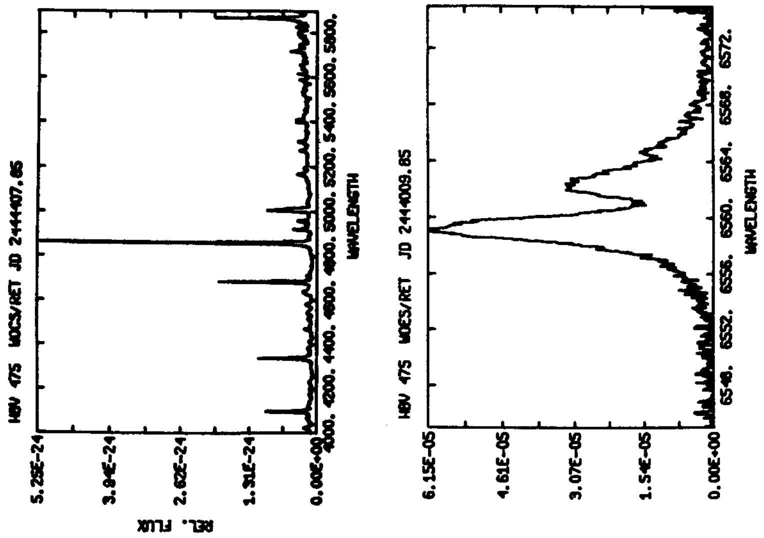

Figure 10

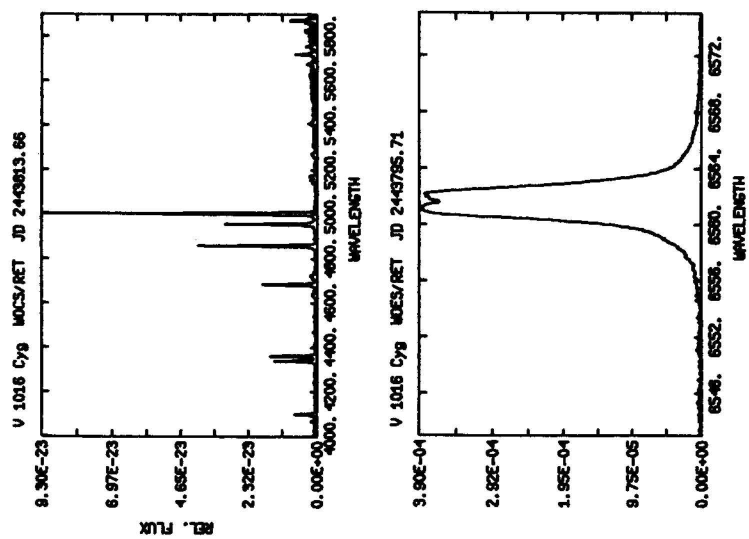

Figure 9

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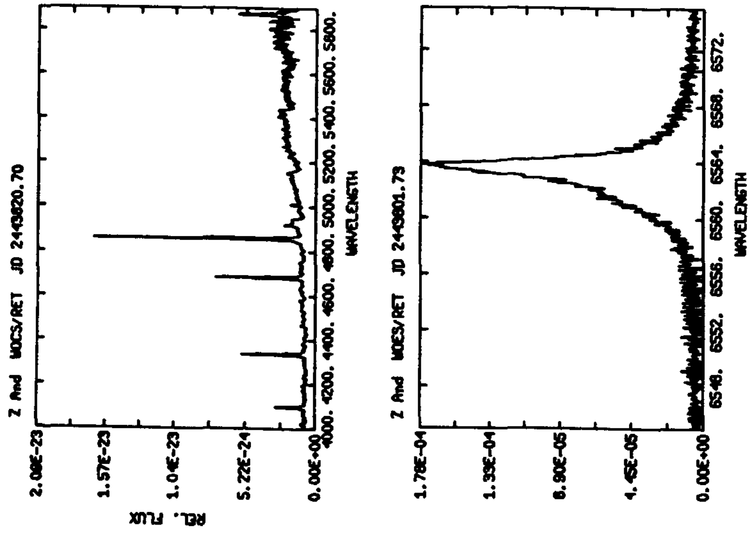

Figure 12

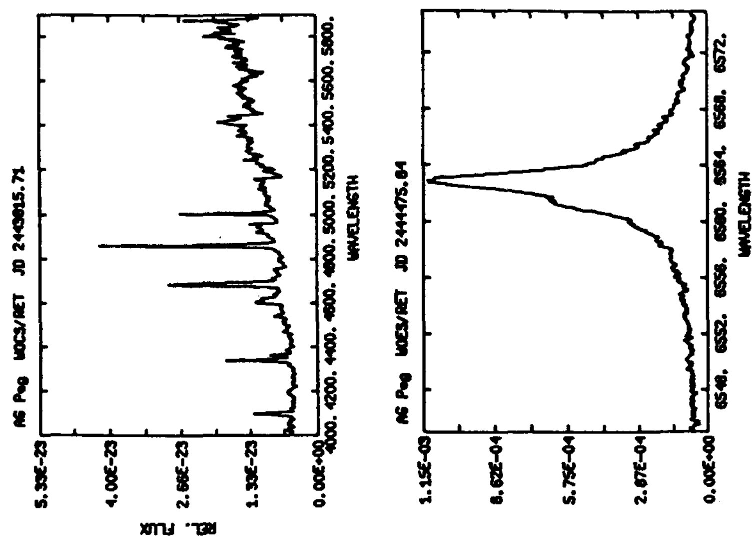

Figure 11

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symmetric with a FWHM of 115 km s^{-1}. There is a slight reversal in the peak of the line in which some minor variations may have been detected.

HBV 475 (V 1329 Cyg) Fig. 10

At low resolution HBV 475 has most of the same ionic species as does V 1016 Cyg although with different strengths and its continuum is undetected. The Hα profile has undergone profound variations from the 500 km s^{-1} wide multiple component appearance shown in the figure to a nearly symmetric 170 km s^{-1} FWHM shape.

AG Peg Fig. 11

At our low resolution the continuum of AG Peg shows the evidence of late component only moderately well. The emission spectrum is the classic one with hydrogen, He I , He II , [O III] and Fe II. Even at low resoilution the extraordinary width of He II λ 4686 is obvious. The Hα profile shows the typical blue asymmetry with a reversal appearing in the blue wing occasionally. Several episodes or events during which the profile became remarkably disturbed have been observed.

Z And Fig. 12

Through the first two years of our program the molecular feature in the continuum grew progressively stronger, but have recently again declined in strength. When the molecular spectrum was most obvious, He II λ 4686 was substantially stronger than Hβ. The[O III] lines are only weakly visable in our spectra. The Hα profile has been seen in two very different shapes, one the standard blue asymmetry with a FWHM of 80 km s^{-1} the other a much broader line (FWHM c. 270 km s^{-1}) which has a reversed, somewhat narower peak.

III. CONCLUSION

We trust that this atlas of some of the visual spectroscopic characteristics of symbiotic stars will promote interest in and discussion of these most interesting objects.

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