IUE OBSERVATIONS OF CH CYGNI CONTINUUM DURING 1979-1986

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ABSTRACT. Variations of the UV continuum have been analyzed. The observed UV continuum may be reproduced by a superposition of a Kurucz model atmosphere (log g=2), $T_{eff} \sim 8500 - 15000$ K) and optically thin hydrogen bound-free and free-free emission ($T_e \sim$ 1000 K). The temperature of the Kurucz atmosphere is the lowest at the maximum of brightness. The flat minimum in the UV integrated flux was observed in May-October 1985.

1. INTRODUCTION

CH Cyg has usually a normal M6-7 giant spectrum with weak H_α and [FeII] emission lines. According to Yamashita & Maehara (1979) it is a spectroscopic binary with a period of $P \sim 5750$ days. During the active phase, the strong blue-violet continuum veiling the cool giant spectrum appears. The spectrum also exhibits strong, double-peaked Balmer emission lines (correlated with the brightness of the blue-violet continuum) as well as numerous low-excitation emission lines. The active phase is also characterized by continuum flickering activity with typical time scales of about 5 and 15-20 min, and an amplitude increasing towards the blue. The photometric and spectroscopic behavior of CH Cyg have been discussed by many authors (e.g., Kenyon, 1983 and references therein).

The recent outburst, started in 1977, is conspicuous by the highest brightness level observed since monitoring begun in 1935 (max V=5.5 mag in 1981/2 - mid 1984). In July/August 1984 the sudden drop in brightness was accompanied by spectacular spectroscopic changes observed in the optical (Mikolajewski and Tomov, 1986) and in the ultraviolet region (Selvelli and Hack,

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1985). Simutaneously, Taylor et al. (1985) reported a radio outburst and two expanding 'jets' correlated with the photometric decline in mid 1984. Finally, X-ray emission was detected on 1985 May 24 with EXOSAT (Leahy and Taylor, 1986).

The main aim of this study is to determine the ultraviloet luminosity of CH Cyg and the analysis of its UV continuum behavior using low-resolution IUE spectra collected during the period 1979-86.

2. DISTANCE TO CH CYGNI

Estimates of the distance to CH Cyg range from 200 Pc to 600 Pc. According to Schlesinger's General Catalog of Stellar Parallaxes π (CH Cyg)=0.003 arcsec, which corresponds to a distance of d=330 Pc. Unfortunately, parallaxes smaller than about 0.01 arcsec are very uncertain, so this estimate is rather insignificant. Luud et al. (1978) assumed M_V (cool)=0 and E(B-V)=0 and derived d=230 pc. Slovak and Aficano (1978) estimated E(B-V)=0.07 and d=600 Pc from the analysis of UBV photometry of stars in the vicinity of CG Cyg. Assuming E(B-V)=0.07, the mean magnitude of SRa variable at maximum M_V=0.8, Luud (1980) used UBV photometry at minimum of acivity and determined d=330 Pc. Finally, Deutsch et al. (1974) noted the absence of D interstellar lines in the spectrum of CH Cyg, while weak D lines were present in the B8V star HD 182691 only 12 arcmin from CH Cyg. From UBV photometry, they estimated m-M=6.5 for HD 182691. They deduced that CH Cyg is closer than HD 182691. Taking E(B-V)=0 and m-M=6.5, we find d=200 Pc.

In the following, all distance-dependent estimates are given for two different values: d=330 and 600 Pc. Since the UV continuum does not show any evidence of an interstellar bump at 2200 Å, we assume that CH Cyg is not reddened (see also Selvelli and Hack, 1985).

3. UV CONTINUUM BEHAVIOR

Figure 1 presents the continuum energy distribution in CH Cyg observed during the period 1979-1986. The continuum exhibits very strong variations correlated with the optical brightness (see also figure 2).

During the whole observational period, the observed ultraviolet continuum may be reproduced by a superposition of a Kurucz model atmosphere (log g = 2, T_{eff} = 8500 K - 15000 K) and optically thin hydrogen bound-free plus free-free emission (T_e = 1000 K). The parameters of the best fits in different spochs are presented in Table I. These fits predict UBV magnitudes in agreement with published photometric data and also reproduce the observed Balmer jump in different epochs (Mikolajewska et a., 1986).

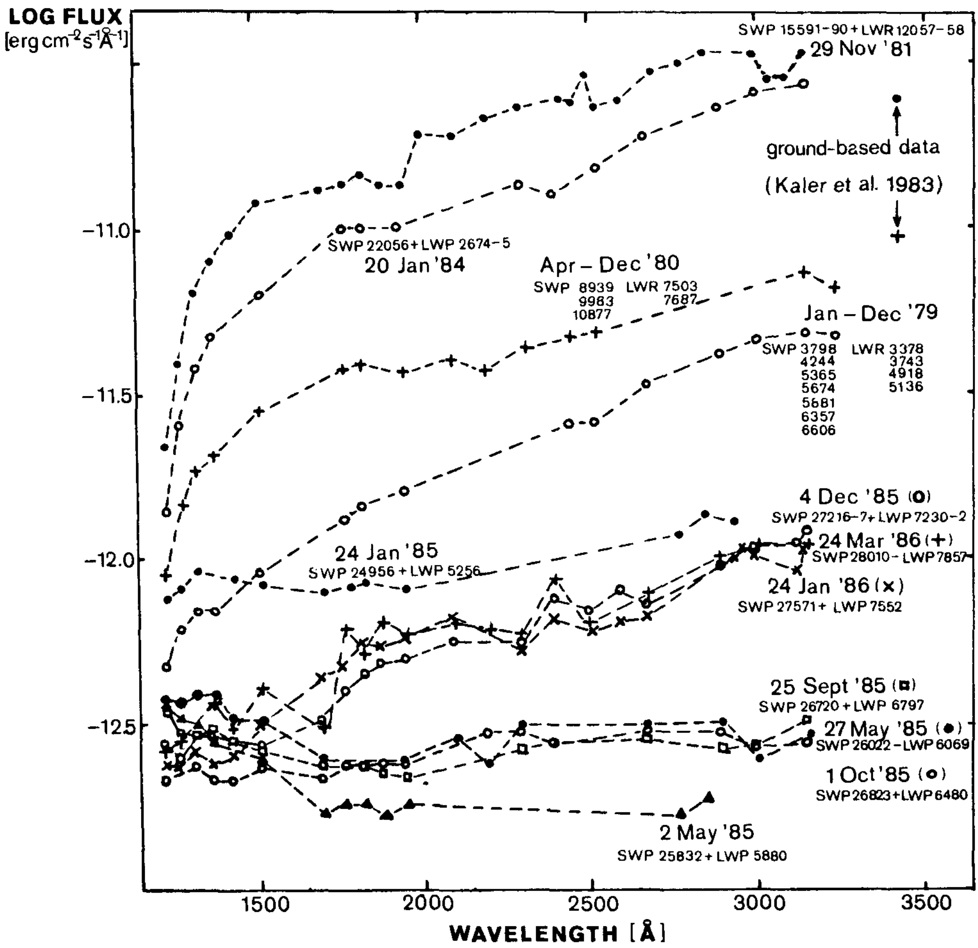

Fig. 1. Continuum energy distribution of CH Cygni.

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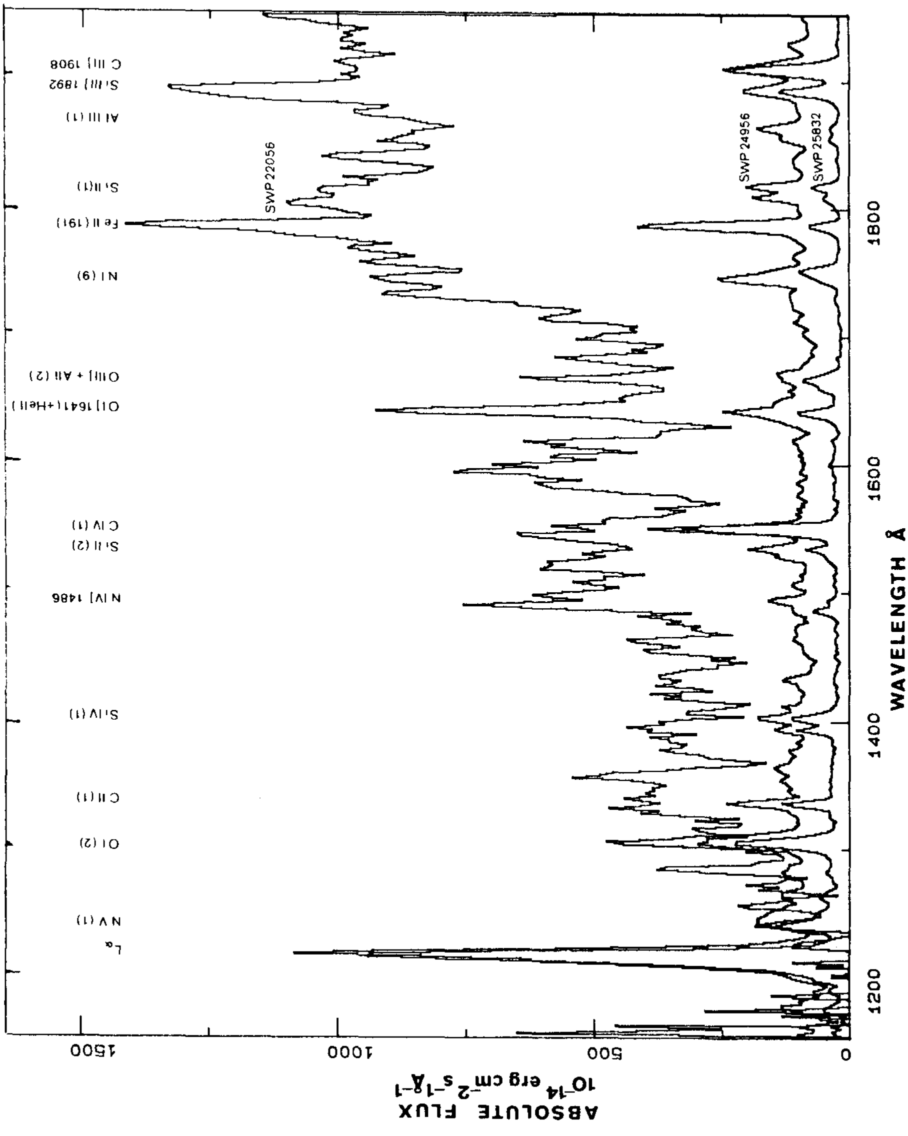

Fig. 2. Far UV low resolution spectra of CH Cyg taken on Jan. 20, 1984 (top), Jan. 24, 1985 (middle) and May 2, 1985 (bottom). An interesting feature of the spectra taken in 1985 is the appearance of a wide, strong L_α emission of stellar origin.

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Table I
UV continuum fitting

Date	Kurucz model Te (K)	atmosphere $L/L_\odot$ 330pc	600pc	HI emission n^2_eV $(10^{59}cm^3)$ 330pc	600pc	Magnitudes model & obs. V	B-V	U-B
1979	9000	24	80	1.3	4.5	m: 6.8	1.1	-0.8
						6.5-6.7	0.8	-0.6
1980 May-Dec	9000	80	260	1.7	5.7	m: 6.5	0.7	-0.6
						6.4-6.7	0.6	-0.6
1981	8500	485	1600	6.0	20.0	m: 5.3	0.2	-0.4
29 Nov	9000	320	1050	8.0	28.0	m: 5.6	0.4	-0.8
						5.6	0.36	-0.6
1984 20 Jan	8500	250	830	5.8	19.0	m: 5.8	0.36	-0.8
						5.7-5.8	0.4	-0.6
1985 24 Jan	10000	14	46	0.27	0.89	m: 6.9	1.3	-0.1
						7.0	1.0	0.0
1985 May-Oct	15000	2	6.5	0.08	0.26	m: 7.5	1.5	0.5
						7.5	1.3	0.6
1985/86 Dec-Mar	10000	5.5	18	0.3	1.0	m: 7.4	1.4	-0.35
						7.5	1.2	-0.45

Remark: The observed broad-band UBV magnitudes may be affected by the contribution of emission lines.

The intergrated ultraviolet flux (λλ1200 - 3200 Å) varied between 4-5x10^{-10} erg $cm^{-2}s^{-1}$ (May-October 1985) and 3-4x10^{-9} erg $cm^{-2}s^{-1}$ (November 1981-January 1984), which corresponds to a UV luminosity range 1.5 $L_\odot$ - 120 $L_\odot$ and 5 $L_\odot$ - 400 $L_\odot$ for d=330 Pc and d=600 Pc, respectively. A very interesting episode was observed in May-October 1985 (Figure 3).

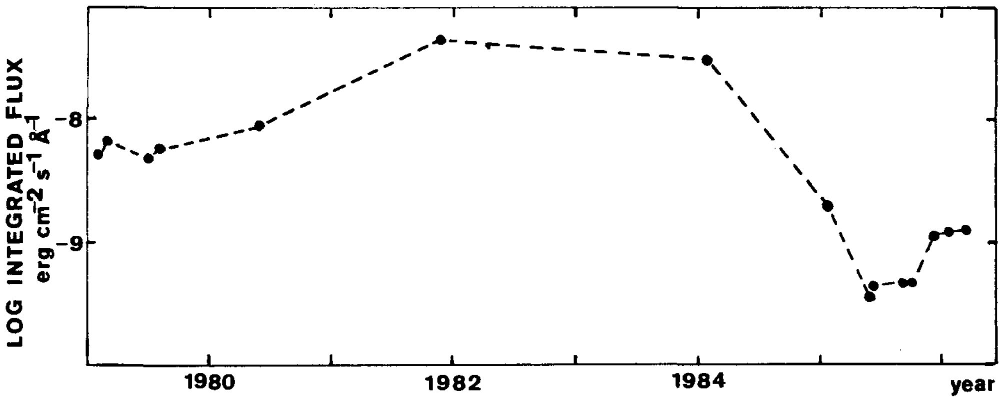

Fig. 3. Changes of the observed UV flux integrated over the $\lambda\lambda$1270-3160 Å range.

The flat minimum in the UV integrated flux was correlated with a significant change in the shape of the continuum. The continuum in May-October 1985 was flat. The best fit has been achieved for the Kurucz model atmosphere with T_{eff} + 13000 K - 15000 K and a relatively small contribution of a hydrogen continuum. In December 1985-March 1986, the brightness of the hydrogen continuum was about 4 times higher than in May-October and practically the same as in January 1985, i.e. before the minimum, while the contribution of the 'Kurucz' continuum was about 3 times smaller (T_{eff} + 10000 K, same as before minimum). The same minimum was observed in U light and it was accompanied by significant changes in profiles and fluxes of Balmer lines (Mikolajewski et al., 1986). The total luminosity smitted in UV emission lines in 1985-1986 was always lower than 1.5 $L_\odot$ (for d=330 Pc).

4. CONCLUDING REMARKS

The hot component of CH Cyg, responsible for its activity, has a mass between 0.5 $M_\odot$ and 1.5 $M_\odot$ (Mikolajewski et al., 1986), which corresponds to the Eddington critical luminosity between 20000 $L_\odot$ and 60000 $L_\odot$. Assuming that the distance estimate (d=200-600 Pc) is correct, the energing UV luminosity is always far below the Eddington limit. The bolometric luminosity of CH Cyg estimated from our continuum fitting (Kurucz atmosphere + hydrogen) never exceeds 500 $L_\odot$ (d=330 Pc) - 1600 $L_\odot$ (d=600 Pc). This automatically excludes all models of CH Cyg requiring a critical or supercritical or supercritical luminosity at maximum of activity (e.g., Taylor et al., 1985).

The UV + optical continuum may be explained as a superposition on the Kurucz model atmosphere (T_{eff} = 8500 K - 15000 K) and hydrogen bound-free plus free-free emission (T_e + 10000 K). The lowest temperature of the Kurucz atmosphere corresponds to the maximum of brightness. However the behavior of the temperature and the luminosity of the hot component is not consistent with a model of optically thick radial accretion suggested for CH Cyg by Tylenda (1985). The observed behavior of CH Cyg is also in contradiction with disk accretion models for symbiotic stars proposed by Kenyon & Webbink (1984).

The most promising interpretation of the CH Cyg phenomenon seems to be a degenerate dwarf accreting from the cool giant wind and moving on a high-eccentric orbit (e=0.4-0.6). The observed luminosity requires an accretion rate of about 10^{-7} $M_{\odot}$/yr at maximum activity. According to formulae given by Livio & Warner (1984), for the orbital parameters of CH Cyg (Mikolajewski et al., 1986) and for a reasonable value for the velocity of the wind, v_w 20 km/s, such accretion rate can be achieved with a mass-loss rate from the giant of order $10^{-5}M_{\odot}$/yr, which is rather erratic. An accretion disk formation cannot be excluded. It is difficult to ascertain what causes the activity of CH Cyg. For the assumed wind velocity the accretion rate at periastron is only 2-3 times higher than at apastron, which is evidently inconsistent with the observed luminosity variations. Among possible solutions of the problem, there is an enhanced mass outflow rate from the giant due to strong tidal interactions between the components at periastron (Mikolajewski et al., 1986). The question where the blue-violet continuum observed during the active phase is produced remains actual. Taking into account relatively large amplitudes of radial velocity curves (Mikolajewski et al., 1986) one should expect a very large incliniation of the system. In such case, the continuum can originate in the disk seen nearly edge-on.

The minimum of the UV integrated flux detected in May-October 1985 was mainly due to the drop in intensity of hydrogen emission, while the continuum shortwards of 1500 H was only slightly affected.

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