SOME NOTES ON SS CYGNI

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ABSTRACT. The results of photoelectric and spectral observations of SS Cyg are briefly discussed. Some features of the spectral variations observed during a large outburst of SS Cyg can probably be explained using a model of a double star which is surrounded by an absorbing gaseous shell. It is noted that the existing data are not numerous enough for the explanation of the SS Cyg variability, in particular, its short-term variations.

SS Cyg is a spectroscopic binary star with a $0.^{d}276$ period. The components of this system are dwarf stars ($M \approx 5.^{m}5$ for both stars), with dG5 and sdBe spectra; they probably show eruptive activity (Joy, 1956). In the spectrum of the B-component strong emission lines are observed. The dG5 spectrum is observed only in the minimum of SS Cyg.

There are various investigations of SS Cyg, but up to now the cause of its variability, in particular, its rapid variability has not been determined. In addition, there are many other observations which have not been explained.

1. As all other U Gem-type stars, SS Cyg shows cyclic outbursts. The mean time between these outbursts is equal to about 50 days. The amplitude of cyclic outbursts is $4\text{-}5^{m}$. They have various forms of light curves. The duration of these outbursts usually does not exceed 5-10% of the cycles (Bretz et al., 1974).

Besides these cyclic outbursts, small (amplitude about $0.^{m}5$), nearly continuous and completely irregular variations of the star brightness - small 'outbursts' - are observed. The occur very rapidly (of the order of a minute and less). In maximum brightness of SS Cyg, these small 'outbursts' are superimposed on the cyclic outbursts (Chalonge et al., 1968).

Finally, parallel with these two light variation types, SS Cyg

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undergoes sometimes 'middle outbursts' of about one hour duration and with about 1^m irregular light variations (Gorbatskij, 1970).

Thus, all light variations of SS Cyg can be formally divided into three groups, according to their magnitude and duration:

1. Large cyclic outbursts;
2. Middle 'outbursts';
3. Rapid 'outbursts'.

It must be noted that the duration of the outbursts of the two last groups is considerably shorter than the orbital period of SS Cyg.

2. Light variations of SS Cyg are accompanied by variations of its spectrum. Unfortunately, nothing is known up to now about the variations of SS Cyg's spectrum during rapid and middle outbursts.

Large variations of the star spectrum are observed during periods of large cyclic outbursts. In this period the star spectrum is strongly transformed. The emission lines of HI, HeI and CaII, which are the most characteristic lines at minimum, disappear and then turn into absorption lines with increasing brightness of the star. However, as Hinderer (1949) has shown for the first time, a pure absorption spectrum without noticeable signs of emission is observed only during the periods of increasing brightness of a large outburst.

Pronounced variations take also place in the continuous spectrum of SS Cyg during large outbursts. According to Mirzoyan and Kalloghlian (1965), the energy distribution in the photographic region corresponded at minimum to the spectrophotometric temperature 4000-5000° K (spectral type G); in the region $2.4 < 1/\lambda < 2.8$ the intensity of the continuum emission increased rapidly towards short wave lengths. According to Chalonge et al. (1968) the energy distribution in the photographic region corresponded at maximum to the spectrophotometric temperature ~13000° K (spectral type B8).

Chalonge et al. (1968) have observed the changes of the SS Cyg spectrum during one large outburst (from minimum to maximum) in a spectral region which included the Balmer discontinuity. In this period, radical variations were noticed in the SS Cyg spectrum, both in the line and the continuum intensity.

Near minimum the emission lines were prominent. The strong emission lines of hydrogen (up to H10) and the moderate intensity lines of He I (λ5876 and λ 4686) and He II (λ4026 as well as Ca II λ 3934) were observed. With increasing star brightness these emission lines transformed into absorption lines and almost disappeared in maximum light.

The variations in the continuum corresponded to an increase of the spectrophotometric temperature from ~5000° K to ~13000° K in the spectral region before the Balmer discontinuity and from ~7500° K to ~15000° K beyond it. It is important to note that the energy distribution both at minimum and maximum can be represented by a black body distribution for the investigated spectral region ($\lambda\lambda$ 3150-6200). The spectrophotometric temperature is higher in the ultraviolet region (λλ 3150-3700) than in the photographic one (λλ 4000-4600), both at minimum and maximum brightness, but this difference is larger at minimum.

These strong variations of the SS Cyg Balmer discontinuity during the large outburst are of considerable interest. At minimum (m_V = 11.5) the Balmer discontinuity was strongly negative (-0.38), indicating the presence of intensive radiation of a gaseous envelope in the spectral region beyond this discontinuity. With brightening of SS Cyg the negative Balmer discontinuity was decreasing and then disappeared. Afterwards it increased up to the magnitude +0.30. Near maximum the Balmer discontinuity decreased again monotonously (+0.08, +0.06, +0.04), the SS Cyg brightness being practically constant ($m_V \approx$ 8.5). Unfortunately, the decrease of the Balmer discontinuity from +0.30 to +0.08 took place when, because of the weather conditions, no observations were obtained. Nevertheless, it can be assumed that it changed continuously with the brightening of SS Cyg (from ~$9.^m6$ to ~$8.^m5$ in V-band) (Chalonge et al., 1968).

Let us note two new results, obtained by Chalonge et al. (1968). In their paper the ultraviolet spectrophotometric gradient (λλ 3150-3700) and the Balmer discontinuity were obtained at minimum light of SS Cyg. This can help to find out the nature of excess ultraviolet radiation observed at this period.

Then it was shown through spectral observations of a large outburst of SS Cyg that after the appearance of a strong absorption spectrum the Balmer discontinuity reached the unexpected large magnitude (+0.30) and was shifted strongly to long wavelengths compared with its theoretical limit.

3. The spectral variations, revealed by Chalonge et al. (1968) can probably be explained, if one uses the double star model, consisting of Be-and G-components, surrounded by an absorbing gaseous shell.

The large Balmer discontinuity, observed in the SS Cyg spectrum during its brightening is inconsistent with a B-type spectrum in the ordinary photographic region (>λ 3700).

But for its explanation we can use the following observational fact, discovered by Chalonge et al. (1968).

There is a certain analogy between the SS Cyg spectrum near maximum and the spectrum of the shell star HD 217050.

Using this analogy it can be assumed that in SS Cyg as in HD 217050 we see superimposed on the spectrum of a B-star with a small Balmer discontinuity D_o, the absorption spectrum beyond the Balmer series with the Balmer discontinuity D_1, which is caused by a gaseous shell existing around this star (Barbier and Chalonge, 1939). That means that the observed Balmer discontinuity is equal to $D_{obs} = D_o + D_1$.

But there is an essential difference between these two cases of HD 217050 and SS Cyg. HD 217050 is a normal B-dwarf. In its spectrum the Balmer lines of hydrogen are seen nearly up to λ 3700, where the ultraviolet continuum of the star begins. Since the shell of HD 217050 is at much lower pressure than the star, its continuum begins at a shorter wavelength near the theoretical Balmer limit, λ 3646.

In the case of SS Cyg the B-star is nearly like a white dwarf. Therefore, all the phenomena that occur between λ 3700 and λ 3646 for HD 217050 appear between λ 3760 and λ 3700 in the case of SS Cyg, that is, they are shifted by more than 50Å towards the red. This is directly observed in the spectrum of SS Cyg during its brightening (Chalonge et al., 1968).

The discussed hypothesis of the existence of an absorbing gaseous shell around SS Cyg during this period is also consistent with the high value of its ultraviolet spectrophotometric temperature, which is nearly equal to the blue spectrophotometric temperature instead of being much lower as in the case of an ordinary star with D = +0.30.

4. The narrow-band photoelectric observations of SS Cyg show that the role of continuous radiation is dominant in its rapid light variations. This result confirms Zuckerman's (1961) conclusion that the spectral line variations are not noticeable during rapid light variations of SS Cyg. This conclusion is in agreement with the spectral observations obtained by Walker and Chincarini (1968), practically testifying that the emission lines in the SS Cyg spectrum do not change during its rapid light variations.

The physical nature of the short-term light variations of SS Cyg remains especially interesting. The U-B and B-V colors of rapid and middle 'outbursts' of SS Cyg resemble the flare-ups of flare stars; the flare rise time for middle 'outbursts' is similar to slow flares, which are observed in flare stars in star clusters and associations (Mirzoyan, 1981).

For a further study of this fact and to reveal the nature of SS Cyg's rapid variability, spectral observations with high time resolution are decisive.

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