ASTRONOMY

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Abstract

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ON THE QUESTION OF THE NATURE OF CONTINUOUS EMISSION

(Presented by Academician V. A. Ambartsumian on 2 XII 1957)

V. A. Ambartsumian showed (^{1}) that in stars of the T Tauri, UV Ceti type and related objects, the sources of energy may be localized in the outer layers. The direct release of this energy in the surface layers of the star leads to the appearance of nonthermal radiation. The latter appears in spectra in the form of continuous emission, which is sometimes concentrated in the short-wavelength part of the spectrum. Studies devoted to the qualitative and quantitative investigation of short-wavelength continuous emission have confirmed the conclusion as to its nonthermal nature ($^{2–5}$).

In an interesting paper by K. G. Böhm (^{6}), quantitative data are presented concerning continuous emission in the spectra of two bright ultraviolet stars of the T Tauri type: LH_α 22-NX Mon and VY Ori. These data are in good agreement with the author' s previously published results concerning continuous emission in the spectrum of the star AG Dra (^{3,4}). Of great interest is the conclusion, obtained for the first time in Böhm's work, that continuous emission cannot be explained either by thermal radiation alone or by the direct radiation of relativistic electrons in magnetic fields. Böhm' s paper also proposes a new explanation of continuous emission. In the present note the totality of data on continuous emission in the spectra of AG Dra, NX Mon, and VY Ori is discussed, and some remarks are made concerning Böhm' s interpretation.

Characteristic features of the continuous emission peculiar to a number of nonstationary stars are the variability of its intensity and the sharp increase of the latter toward the ultraviolet ($^{1–4}$). In Böhm' s paper (^{6}), primary attention is given to explaining the sharp increase in the intensity of continuous emission toward the ultraviolet.

For thermal radiation, the expression

$$n = -d(\lg I_\lambda)/d(\lg \lambda),$$

which characterizes the rate of change of the intensity I_λ as a function of the wavelength λ, increases with the temperature T, but it is always less than 4. Only in the limiting case, when the temperature of the absolutely black body tends to infinity, does the maximum of this expression reach 4. This means that the intensity I_λ, as a power function of wavelength, in the case of thermal-radiation processes can increase toward short wavelengths no more steeply than λ^{-4}. In the case of radiation of relativistic electrons in magnetic fields, the case of the steepest increase of I_λ corresponds to the value of the exponent $n = 7/3$ (6). Meanwhile, the observational data obtained by Böhm on continuous emission in the spectra of NX Mon and VY Ori show that, for these stars, the increase of intensity is considerably steeper. An analogous steep increase of the intensity of continuous emission toward the ultraviolet is also observed in the case of AG Dra (3,4).

Table 1 gives a summary of the values of n for different wavelengths in the region of continuous emission up to λ3770 Å; these data were calculated from the works (4,6).* As was to be expected, n is a function of wavelength. In all the cases listed in Table 1, n increases toward shorter wavelengths down to λ3770 Å. Thereafter it apparently changes in different cases in different ways (see Fig. 1).

Table 1

Star		Wavelength λ in Å									
		4020	4000	3970	3940	3890	3860	3830	3820	3800	3770
AG Dra	I series*	6	7	8	–	11	–	16	–	20	23
AG Dra	II ”	–	–	–	–	7	–	14	21	26	39
AG Dra	III ”	–	–	4	6	8	–	11	12	–	–
AG Dra	IV ”	–	–	–	4	8	11	14	–	–	–
NX Mon	7 III 1956	3	4	–	–	5	–	6	–	–	7
NX Mon	6 XI 1956	5	–	6	7	–	8	9	10	–	11
VY Ori	11 XI 1956	–	–	–	–	–	–	8	9	11	18
VY Ori	2 XII 1956	–	–	–	–	7	8	11	12	18	48

* For AG Dra, mean data are given for individual series of observations (4).

Taken together, the data presented show that neither thermal radiation nor direct radiation of relativistic electrons in magnetic fields (synchrotron radiation) can lead to the observed energy distribution of the continuous radiation of stars with continuous emission in their spectra (AG Dra, NX Mon, and VY Ori). It must therefore be assumed that continuous emission is in general caused by processes sharply different in their nature both from thermal radiation and from synchrotron radiation of relativistic electrons.

In view of the conclusion reached, all attempts to explain continuous emission in the spectra of nonstationary stars by the presence, in the total radiation of the star, of a high-temperature component (the existence of hot spots on the surface of the star or of a very hot companion**) prove completely untenable. Indeed, a combination of any number of thermal radiations cannot lead to the observed sharp increase of the intensity of continuous emission toward the ultraviolet, since the intensity in the total spectrum cannot grow faster than in the spectrum of the hottest of its components. We note that, according to Beals' s measurements for the radiation of the O8 star (HD 14633), $n = 2.7$ ([6]).

In Beals' s interpretation, the merging of bright lines of the Balmer series of hydrogen as a result of the low resolving power of the spectrograph should lead to the appearance of an apparent continuous spectrum, which, in Beals' s opinion, is observed as continuous emission in the region of the high members of the Balmer series. For his calculations Beals uses the scheme of an optically thick layer, since in the case of an optically thin layer the continuous emission cannot be explained by linear and continuous Balmer emission ([2,5]).

The conclusion in favor of this scheme is made on the basis of the anomalously small Balmer decrement in NX Mon and VY Ori ([6]), also observed in AG Dra ([4]) and in T Tauri-type stars with a bright ultraviolet ([2]), and, apparently, characteristic of stars with continuous emission in their spectra. However, the presence of an optically thick envelope around the stars under consideration is diffic–

* The calculations were carried out for AG Dra by E. Ya. Borisova and T. K. Nikolskaya, and for NX Mon and VY Ori by R. M. Martirosyan and M. A. Kazaryan, to whom the author expresses his gratitude.

** We showed earlier ([4]), proceeding from other considerations, the untenability of the assumption of binarity in the case of AG Dra.

but it is difficult to reconcile with the very rapid changes in brightness observed in the ultraviolet, for example, in NX Mon ([7]).

The mechanism of “formation” of the continuous emission that underlies Böhm' s interpretation also encounters additional difficulties. Under such a mechanism, the region of the imaginary spectrum should coincide with the region where all the bright hydrogen lines merge completely. In this case the beginning of the imaginary continuous spectrum should be almost constant for all spectra obtained with a given spectrograph, and should depend mainly on the resolving power of the latter. In Böhm' s work, $\lambda 3770$ Å (the wavelength of H_{11})* is taken as the beginning of the region of complete merging of the emission lines.

However, the observational data contradict this.

(Figure: Fig. 1. Distribution of energy in the continuous spectrum)

Fig. 1. Distribution of energy in the continuous spectrum

It follows from Table 1 that n reaches large values already where, according to Böhm, there should not yet be an imaginary continuous spectrum—continuous emission. Figure 1 presents data on the distribution of energy in the continuous spectra of AG Dra, NX Mon, and VY Ori in the wavelength region shorter than 4400 Å, taken from works (4, 6), and normalized in such a way that the intensities coincide at λ4400 Å. Examination of the curves in Fig. 1 shows that the wavelength of the onset of continuous emission differs in different cases and varies in the spectra studied approximately from 3800 to 4100 Å. At the same time, the onset of emission, as was already noted in the case of AG Dra (4), apparently depends on the absolute intensity of the continuous emission, shifting toward longer wavelengths as the latter increases. A comparison of the three distributions for NX Mon shown in Fig. 1 also seems to us to speak in favor of this conclusion.

* We note that the reality of the value of the turbulent velocity adopted in Böhm’ s work for hydrogen atoms (50 km/sec) appears doubtful.

Böhm’ s other assumption—that the intensity of the continuous emission falls off starting from the limit of the Balmer series, an assumption necessary for his hypothesis and naturally following from it—requires further verification. In any case, it does not follow unambiguously from Böhm’ s data for NX Mon, presented in Fig. 1; the latter are contradictory in this respect.

Finally, the merging of emission lines is not capable of explaining the strong polarization of the ultraviolet radiation of the star NX Mon (34 and 55% for two nights of observations), recently discovered by Hunger and Kron (7). If, for an ellipsoidal distribution of the velocities of electrons and colliding ions, or for a one-sided motion of the exciting particles, polarization of the radiation is to be expected (6), then in an optically thick layer it must disappear very rapidly. The large optical thickness, which is extremely necessary for Böhm’ s hypothesis, leads to a large number of scatterings, as a result of which depolarization of the radiation occurs. It should be especially emphasized that the strongly polarized radiation pertains to the region 3200-3700 Å (7), located almost entirely beyond the Balmer-series limit. At the same time, the observed increase in the degree of polarization with increasing brightness of the star in the ultraviolet, i.e., with the intensity of the continuous emission, is very characteristic. These facts contradict Böhm’ s assumption that the intensity of the emission falls beyond the Balmer-series limit.

Thus, the entire complex of observed features of the radiation of stars with continuous emission in their spectra is difficult to explain by the merging of emission lines because of the resolving power of the spectrograph. However, the very idea of line merging—possibly of a physical nature—deserves attention*, since in all known cases the region of short-wavelength continuous emission partially overlaps the region of the higher members of the Balmer series.

In conclusion, we note that if Böhm' s interpretation is correct, the question remains open of the energy required to excite hydrogen atoms in an optically thick layer around the star. Consequently, it does not contradict the idea that continuous emission is the result of processes of direct liberation of discrete portions of stellar energy in the outer layers of the star (1).

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[*] I. M. Gordon informed us that the above-noted features of the continuous emission—in particular, the strong polarization—can be qualitatively satisfactorily explained with the help of a developed theory of reradiation by hydrogen atoms of synchrotron radiation from relativistic electrons.