CONTRIBUTIONS AND PROSPECTS FOR SPECTRAL CLASSIFICATION OF STARS WITH OBJECTIVE PRISM TECHNIQUES

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ABSTRACT

The following topics will be discussed: a) A few historical comments; b) MK classification - the most important stage of classification work; c) Recently revealed peculiarity features and the problem of further differentiation of the classification scale; d) Classification work in the USSR; e) The role of classification results with respect to galactic structure studies; f) Low dispersion spectra and faint M-type stars and the missing mass problem; g) Extraterrestrial spectral observations: new promising means for research.

I would like to begin by saying that I consider it an honor and a pleasant privilege to face you from the platform here, under the sky which had been observed so inquiringly and fruitfully by a famous compatriot of our kind hosts - Angelo Secchi, to whom we are devoting this colloquium on the occasion of the centenary after his death.

It is a special pleasure to recollect that the last year of his life Secchi was a foreign corresponding member of the Peterburg Academy of Sciences, now the USSR Academy of Sciences. Secchi was the first in the history of astronomy who attempted to make a spectral survey of all the sky. More than four thousand stars were classified by him. A job of great merit, although he divided them into four classes only.

This pioneering work, having demonstrated that the varieties of spectral types signify variations in the physical state of stars, powerfully influenced the following development of astronomy and

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turned out to be the method placing at our disposal an inexhaustible source of information.

The whole secular development of astronomy has demonstrated the multiformity of the stellar nature in the incessant discoveries of new features of stellar spectra. In this process the spectral classification of stars has been experiencing its differentiation, I would say, and general advancement.

At the beginning of its history not only the number of spectral classes were increased, but subclasses appeared, and later on the second and the third parameters were involved, that is luminosity and metallicity. Recently we were able to distinguish among the spectra those that were called peculiar and compound.

It should be stressed that, even today, the method of classification has not exhausted itself what with the rapid development of astronomical technology and the accumulation of piles of observational data.

A bright landmark in the history of the method was recorded by the names of Adams and Kohlschutter in the early 1900's. A most important stage was reached in the middle of the 1900's with the introduction of the widely known, now qualitative, two-dimensional spectral classification, the system by Morgan, Keenan and Kellman. The authors used high quality slit spectra to define the system; it has been extended to objective prism spectra of moderate dispersion.

Three-dimensional classification turned out to be difficult and this is explained by known reasons.

Evidently this latter fact directed the further development of the classification system to refining the same MK system from the point of view of searching for additional criteria capable of discovering some spectral peculiarities.

This stage is marked by the appearance, just recently, of some new atlases, as for example one by Keenan and McNeil, or by Garrison and others.

Bidelman's experience at Michigan showed the high efficiency of the moderate dispersion objective prism spectra provided they are of high quality. A wide scale reclassification work on the HD Catalogue's Southern part stars is in progress. The limiting magnitude is $V \simeq 10$ stars and anomalous spectra are being specially recorded.

A lucky combination of an optically perfect meniscus telescope equipped with a transparent objective prism, with the sky characterized by good seeing, permitted us at Abastumani in Georgia, USSR, to undertake classification of about eleven thousand stars in forty two Kapteyn Areas distributed at different galactic latitudes. The limit of the Abastumani Catalogue is nearly the twelfth magnitude, advantageously differing from the Michigan Catalogue by approximately two magnitudes.

Several facts are worthwhile to note: first, we have a two-dimensional classification system which permits us to determine spectral subclasses and luminosity classes; second, we can discriminate peculiar stars; third, the distribution of areas with respect to the galactic equator is not arbitrary; and lastly, the material is of high quality and is strictly homogeneous, obtained by a single person only, namely, Dr. Ramze Bartaya, who is recognized as an excellent observer and classifier.

These facts allow us to consider the data as reliable and to apply them to statistics and proper stellar astronomical problems. Indeed, density curves and luminosity functions have been plotted and investigated and many problems related to the structure of Galaxy considered. The interpretation of the material led us to some conclusions differing from those, which had been made earlier when investigators had not at their disposal luminosities based on two-dimensional classification. Previously stars were divided roughly or only very roughly into giants and dwarfs; in addition, as a matter of fact, the material used by early investigators could not be considered homogeneous.

Let us consider now Fig. 1, where we have some diagrams showing the apparent surface distribution of stars at different galactic latitudes, from the equator (number 1) and higher (number 2 corresponds to the latitude 8°, number 3 to about 18°, number 4 to 35° and number 5 to 70°).

In the first group, that is, in the galactic plane, the majority of stars are of B and A types. At higher latitudes F, G, K, especially G type stars prevail. It is clear that this can't reflect the real situation, since the later the spectral class the fainter the absolute magnitude of dwarfs.

Now let us consider giant stars only, for which the effect of visibility is the same for all spectral classes. In Fig. 2 we have the III luminosity class stars only. We easily notice two maxima at low and intermediate latitutdes (Groups 1, 2, 3). One of these maxima belongs to the K stars. But at higher latitudes (Groups 4, 5) the K stars dominate quite definitely.

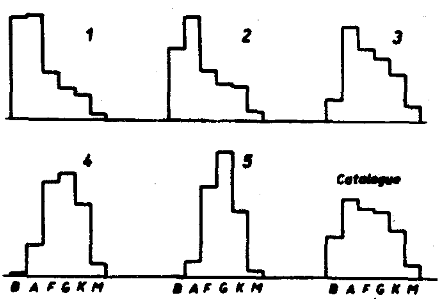

Fig. 1

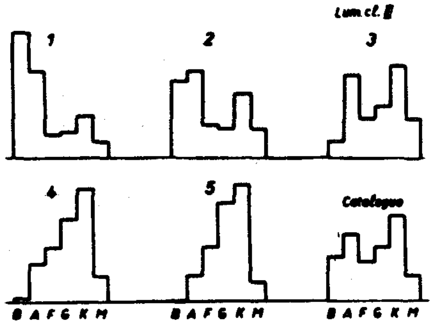

Fig. 2

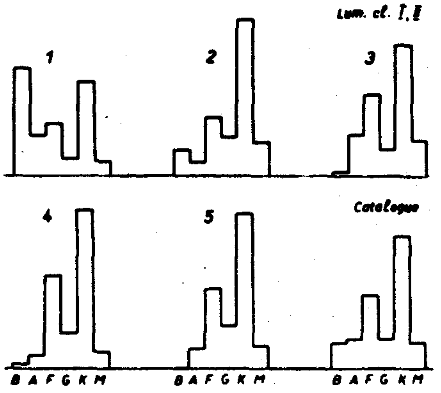

Fig. 3

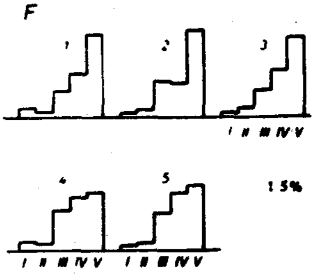

Fig. 4

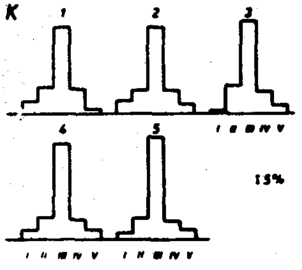

Fig. 5

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In Fig. 3 we have a similar picture for the stars of high luminosity (classes I and II). If we exclude the B stars, which are in the galactic plane, the K stars prevail again. It may be interesting that the F stars, and not the G stars, follow the K types.

Now let us consider the distribution of stars of different luminosities at different latitudes (Fig. 4). We have taken here the F stars only, as an example. One sees that at low and intermediate latitudes the percentage of the III class stars is lower than that of the V-th class. The Hertzsprung gap is of importance here. But it is interesting that at high latitudes the contents of the III class stars noticeably approaches the number of the V class stars. The same may be said concerning the G stars (no illustration here).

This picture for the K stars in Fig. 5 (and for M types too, although the latter are not shown here) deserves our attention; class III stars prevail here quite definitely.

Here I am going to make a general, surely important, conclusion that in statistical investigations it is quite unjustified to consider the F-G5 stars as belonging statistically to the main sequence in those cases where we have no two-dimensional classification data. This remark is especially significant for the investigations concerning the galactic circumpolar areas.

As for the K and M stars, when no two-dimensional classification data are at our disposal, it is better to relate them to the III luminosity class rather than to the fifth as is generally done rather unjustly.

Such statements hardly cause any doubts that in reality the dwarfs are more concentrated to the galactic plane than it has been thought and the giants are less concentrated to it than it has been believed until recently, as we showed in our previous papers (Kharadze and Bartaya, 1977a).

Another of our conclusions, based on interpretation of spectral classification data is that Ap and Am stars do not show as high a concentration towards the galactic plane as the normal stars of the same spectral interval do. Moreover, Ap stars occur at distances up to about 200 pc from the galactic plane, Am stars up to about 400 pc (Kharadze and Bartaya, 1977b).

When we deal with problems of stellar astronomy, statistics and structural astronomy, it's very important to penetrate into space as far as possible. This aim requires diminution of the spectral dispersion. Such a diminution serves not only to an increase of penetration, but it also reduces the possibility of overlapping of spectra.

But an exaggerated decrease of dispersion reduces our ability to determine subclasses and luminosity classes. What then is left as advantages? The possibility of distinguishing in the multitude of stars some "natural groups" of stars, for example: 1) extremely blue stars, 2) extremely red ones (N stars), 3) common red ones (M stars), 4) flaring T Tauri type stars, 5) stars having ultraviolet excess and others.

This idea was Morgan's and it was used in the nineteen fifties for selection of OB stars in the Northern and Southern regions of the Milky Way (Hardorp, Stock, Loder, Sundman, Klare, et al.)

In the beginning the dispersion was reduced to ~ 600 Å/mm, later on a more courageous action was undertaken - one began to apply dispersions about 20-30000 Å/mm.

The Abastumani material is obtained with an eight degree objective prism on the 70 centimeter meniscus telescope. The prism has a dispersion of about 160 Å/mm or with the four degree prism a dispersion of 660 Å/mm. But a two degree prism with one thousand two hundred Å/mm capacity is also at our disposal. It will be possible to obtain spectra of 16th magnitude stars.

A wholly automatic telescope with a one hundred twenty five centimeter mirror is about to come into operation now. It allows electrophotometry of 17-18th magnitude stars.

At the same time we have a sort of collaboration with the Tautenburg Observatory in the German Democratic Republic, where they obtain spectra of 18th magnitude stars (in this case dispersions are 2500 at $H\alpha$ and 1000 Å at $H\gamma$).

Our aim is to use these data for a search for M type stars around the North Galactic Pole. These stars are important in connection with the missing mass problem also.

If afterwards we make multicolor photometry measures with the 125 centimeter telescope we shall be able to segregate the giant and dwarf M stars. This will permit us to determine the spatial density of M dwarfs in the direction to the North Galactic Pole. This work has already been started; some preliminary estimates are already done. Tautenburg spectra allow one to classify very faint M stars into three subclasses, Ma, Mb and Mc.

When the emulsion is properly chosen we can avoid spectral images of early stars and to go on to classification with a higher efficiency.

We should mention here that the Vatican astronomers have very rich experience in this field. I have in view especially the merit of Dr. McCarthy, of the late Dr. Treanor and I must say that we find it a great pleasure to have the privilege of being here and of deepening our mutual acquaintance.

I have to stress the significance of the possibility of applying the ultraviolet region of the spectrum to spectral classification. Such a possibility exists due to striking advances in space science and technique.

It's rather well known that G. A. Burzadyan (1976) in the Garni Astrophysical Laboratory, Armenian SSR, USSR has obtained many extraterrestrial ultraviolet spectra of stars brighter than the 13th magnitude. Gurzadyan's instrument covers a five degree field. His observations could be extended to as short as 2000 Å. The dispersion of the spectra was 170 Å/mm. It is interesting that there exists a wide variety in the ultraviolet spectra of stars of one and the same class. We remember that the same thing has been mentioned by Bidelman also. He considered two factors especially influencing ultraviolet spectra. They are first,features due to interstellar material, and second, spectral singularities connected with mass loss. Studies of these factors would allow us to discuss and interpret them more reliably.

G. A. Gurzadyan elaborated in principle a new method of classification of stars based on the use of continuous spectra in ultraviolet from 3000 down to 2000 Å. It was established that the character of the ultraviolet continuous spectrum and in particular the length of the spectrum itself depended considerably on the spectral class of the star. Hence, even if you have no absorption lines in your spectra, you are able to determine the class. What would you have as the characteristic curve in such a case? You will have the dependence: spectral class - the spectrum length. He classified about 2000 stars in Auriga.

Given his aim: to classify as large a number of faint stars as possible, Gurzadyan's method is most perceptive. At Abastumani we have estimated the efficiency of the method by comparing Gurzadyan's results with our on classification of the same stars in the common optical region.

Gurzadyan developed an empirical relation between the spectral class and the strength of depression he had found in the continnum at 2800 A and also - between the spectral class and the ratio of intensities of FeII (2765 A) and FeI (2967 A). (See also Ohanesyan, 1976.)

Thus we face the possibility of the further differentiation in spectral classification. This means that the problem of stellar classification stands at the beginning of a new stage showing its capacity to advance further with the development of observational means offered by contemporary techniques.

Such is the historical path of the development of the spectral classification of stars: from the pioneering discovery of Secchi, who worked quite alone yet furnished the early evidence that differences in the spectra of stars imply differences also in the physical conditions of these stars - down to our own contemporary researches, where this evidence has been confirmed by so many new and varied studies carried out cooperatively by so many investigators from so many countries who study the skies together in peace.

REFERENCES

Gurzadyan, G.A. (1976). Сообщ.Бюрак.Астрофиз.обс., XLVIII, 5.
Kharadze, E.K. and Bartaya, R.A. (1977). Astron. Nachr, Bd. 298, H. 2, 111.
Kharadze, E.K. and Bartaya, R.A. (1977). Highlights of Astronomy, Vol. 4, 49-50.
Ohanesyan, O.B. (1976). Сообщ.Бюрак.Астрофиз.обс., XLVIII, 14.

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DISCUSSION

McCarthy: My congratulations to you and your colleagues on the fine work done and in progress in the Soviet Union. I am especially happy to hear of your new work on M stars at the galactic pole. We await these results with great interest.

Do you combine different prisms at Abastumani to add or subtract dispersions?

Kharadze: We have a rather wide variety of prisms of the same 72-cm aperture: 8, 4 and 2 degrees giving 166, 660 and 1200 Å dispersions at Hα respectively. I am not sure which combinations of them we will actually use. The work has just been started.

Blanco: This is beautiful work! In the North Galactic Pole survey for M type stars what type of plates are being used? Are they blue-sensitive? Also, what is the limiting magnitude of that survey?

Kharadze: In our work on the Galactic Pole we choose plates so as to avoid detecting early type stars.

Fehrenbach: I am surprised that with a dispersion of 165 Å mm^{-1} at Hα you can see the difference in luminosity between classes IV and V. We have excellent spectra with 200 Å mm^{-1} and we have difficulties; in fact it is impossible to distinguish them. I will be glad to send you our plates. Indeed the knowledge of the spectra is essential for our measurements of the radial velocity where we have a precision of 4 km sec^{-1} using an average of 3 plates.

Kharadze: The difference in dispersion is really not great, but it may have an influence. We will be happy to have your plates in Abastumani to check the possibility of discriminating between stars of class IV and V. But we will be much happier if you come to Abastumani yourself.

Cowley: Could you characterize the distribution of peculiar A stars with respect to galactic latitude? Does the distribution resemble the early F stars rather than the late A stars? What percentage of the stars that you found to be peculiar were Ap and what percentage were Am?

Kharadze: Am stars are more numerous than Ap stars (approximately 65 to 35 percent respectively). They are widely distributed, i.e. far from the galactic plane; we see them at distances equal to 400 parsecs from the galactic equator. The Ap stars reach only

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200 parsecs.

In addition it may be said that there seems to be no tendency for Ap and Am stars to concentrate around or in stellar clusters or associations; neither is there any tendency to grouping. The general distribution is rather homogeneous and does not differ from the field star distribution.