BULGARIAN ACADEMY OF SCIENCES
SPACE RESEARCH IN BULGARIA, 1
*Sofia · 1978*

# Electrophotometric Equipment for Ground-Based Studies of Airglow Emissions from the Upper Atmosphere

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## 1. Introduction

The spectrum of airglow emissions from the upper atmosphere contains a continuum of atomic lines and molecular bands. The intensity of these lines and bands is very variable. First of all, there is an essential difference between day and night glow. This difference is due to the photodissociation and photoionization and to the related excitation which is observed only during the day. The night emissions are mainly products of recombination processes. The intensity of the emissions is also a function of the geographic and geomagnetic latitudes, and of the solar and geomagnetic activity. Consequently, the intensity of the optical emissions changes within broad limits. For example, the red oxygen line with a length of 6300Å at calm conditions during the night has an intensity of 20-60 Rayleighs approximately [1, 2]. Upon geomagnetic activity, however, the intensity is highly increased. In subauroral regions this intensity can reach a value of $10^8$R [3]. Some other lines, e. g. the nitrogen 5199Å--5202Å, have extremely low intensity, always in the limits of 1 to 10 R [4]. Such low values has also the hydrogen line $H_\alpha$ [5]. This big range of emission variations leads to great difficulties at the construction of the equipment for their simultaneous measurement. Let us note here that the simultaneous measurement of the emissions can be made with a spectrograph or a spectrometer. The spectrograph cannot, however, give the time variations of the intensity which are very important for explaining the physical processes of the glow. The spectrometer has a low spectral resolution and low sensitivity.

It is known that the best time resolution and a good spectral resolution is achieved by electrophotometric equipment with filters used to measurements of the atmospheric emissions. An essential defect of this equipment is, however, the limitation of the set of simultaneously measured spectral bands and lines. With the electrophotometers referred to in the literature and used for this purpose, only 3—5 lines are usually measured. Besides that, every line is measured by two filters, so that for one photometer designed for measuring 5 separate lines the number of the filters is 10, and if we also add the two necessary positions for the dark current and one for calibration, we shall have 13 positions. Any further increase in the number of the filters is of no avail, as the time interval for one full cycle is greatly increased and consequently the emissions measured cannot be compared.

The present paper describes electrophotometric equipment for investigation of some nocturnal atmospheric optical emissions, as carried out in the Central Laboratory for Space Research at the Bulgarian Academy of Sciences.

## 2. Function and Basic Requirements on the Equipment

As stated above, the simultaneous measurement of a large set of emissions is impossible. With the electrophotometer made in our laboratory it is possible to measure three emissions simultaneously: the nebular red oxygen 6300Å line, the auroral green oxygen 5577Å line and the first negative system of $N_2^+$ about the 4278Å line. As for the choice of these three lines, we are proceeding from the following considerations:

1. The red oxygen 6300Å line is emitted in the $F$ region at the aeronomic reactions and at the outer corpuscular interaction as well, and it is an important indicator for the processes in this region.

2. Part of the green oxygen 5577 Å line is also emitted at analogous processes with a line 6300Å in the $F$ region (about 20 per cent), but an essential part of it comes from the $F$ region, appearing in this way as an indicator of the dynamic phenomena in the $F$ region. The excitation of the first negative system of $N_2^+$, as shown in [6], is also connected with the precipitation of corpuscules which ionize $N_2$ and at the same time provoke the excitation of the first negative system of $N_2^+$. In this manner we have two lines which are excited in aeronomic processes and by the precipitating corpuscules, and also one emission excited only by precipitating corpuscules (4278Å). Naturally, this provides for a very good separation of the aeronomic processes from those connected with corpuscular bombardment, while on the other hand the comparison between the red and green lines makes it possible to distinguish the pure aeronomic reactions from those provoked by dynamic processes.

The basic demands involved in the construction of the equipment are as follows:

A) To provide a possibility of measuring under a clear sky, with good spectral resolution, the emissions of 6300Å, 5577Å and 4278Å.

B) The threshold sensitivity for each one of the emissions should be of the order of 5 Rayleighs.

C) The measuring range should be from 5 to 1000 R.

D) The equipment should be capable of operating at temperature differences of 0° to 45°C and at humidity of up to 90 per cent.

E) It should consist of separate compact blocks which are easy to transport and install.

F) The electron block should be designed as a separate unit with its independent power supply, for which the possible variations in the supply voltage must also be taken into account.

G) The visual angle should be in the range of 3 to 6 degrees (the measurements are determined by the heterogeneous structure of the glowing region).

H) The equipment should not be sensitive to blows and vibrations.

## 3. Block Diagram and Description of the Equipment

Fig. 1 shows the individual blocks of the equipment. The basic block is an electrophotometer, designed on the basis of a colorimeter (Fig. 2). Its function is to receive the light flux and to make the corresponding selection of each one of the measured lines. The high voltage of the photomultiplier (PEM) is obtained by the block HUS and the processing of the signal received is performed by a direct-current amplifier, after which it is registrated by a recorder. More details about the electronic part of the equipment are given in part 3.2 of the Description.

### *3.1. Electrophotometer*

Fig. 2 shows the block diagram of the electrophotometer, and Fig. 3 presents its principal groups. The basic tube of the equipment (18) is a double-one ensuring the regular thermal regime of the filters and photomultiplier. The disk with the filters has eight positions (Fig. 4). The first six of them are engaged with the interferential filters, the seventh one is intended for measurement of the dark current (here the light flux from the objective is cut out), and in the eighth position ($^{14}C$) the radioactive source — $R_s$ is placed, by which a dynamic control of the sensitivity of the

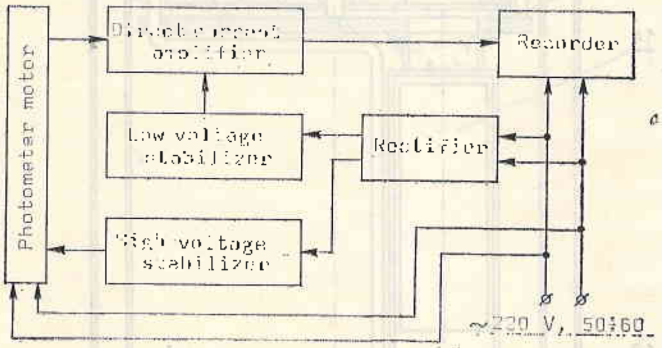


Fig. 1

equipment is achieved. The intensity of each emission is measured by two filters. The first one is centered on the measured line and the second one is used to measure the spectral background. Each filter is fitted separately in the disk, and after that it is corrected by the optic system of the device in order to take the exact position at which the investigated spectral line is allowed to pass. Table 1 presents the filters used in the equipment and their principal parameters.

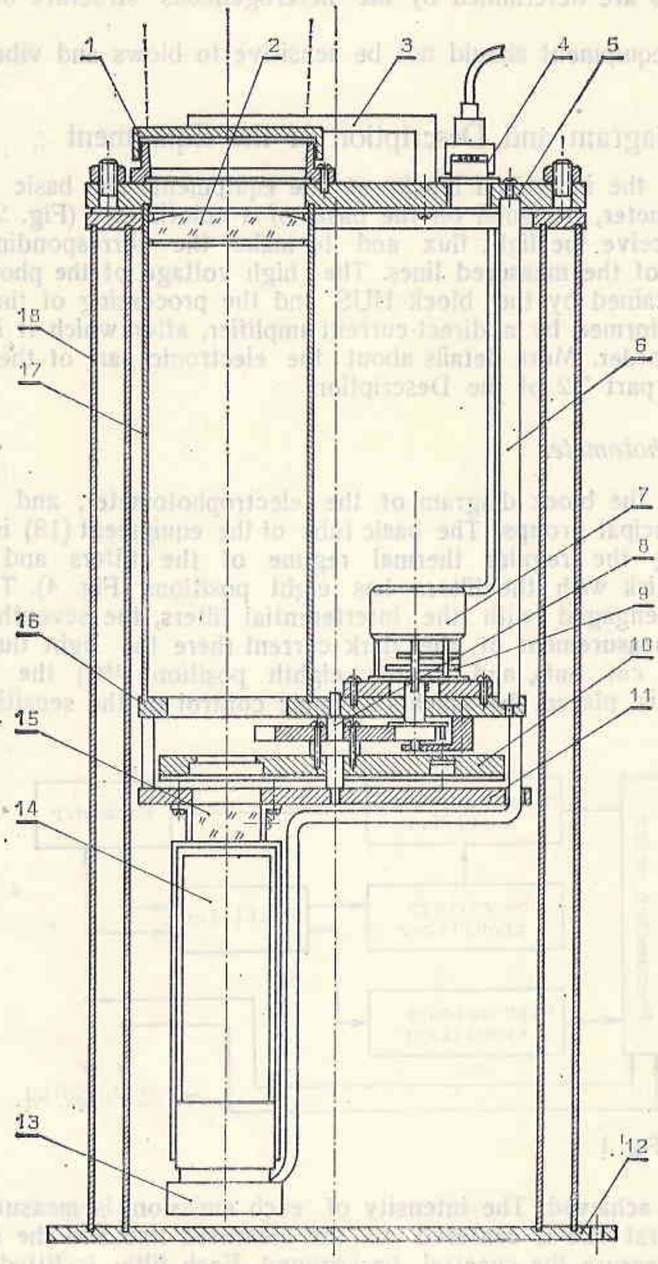


Fig. 2

A photomultiplier FEU-79 is put in a special tube (14), filled with any substance ensuring very efficient magnetic screening. This photomultiplier is one which has the best characteristics out of ten similar photomultipliers. The voltage divider (13), filled with high-quality ohmic resistors, is applied directly to the legs of the photomultiplier.

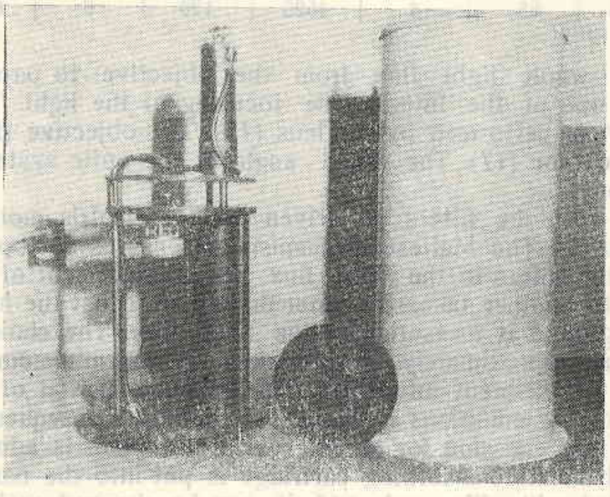

Fig. 3

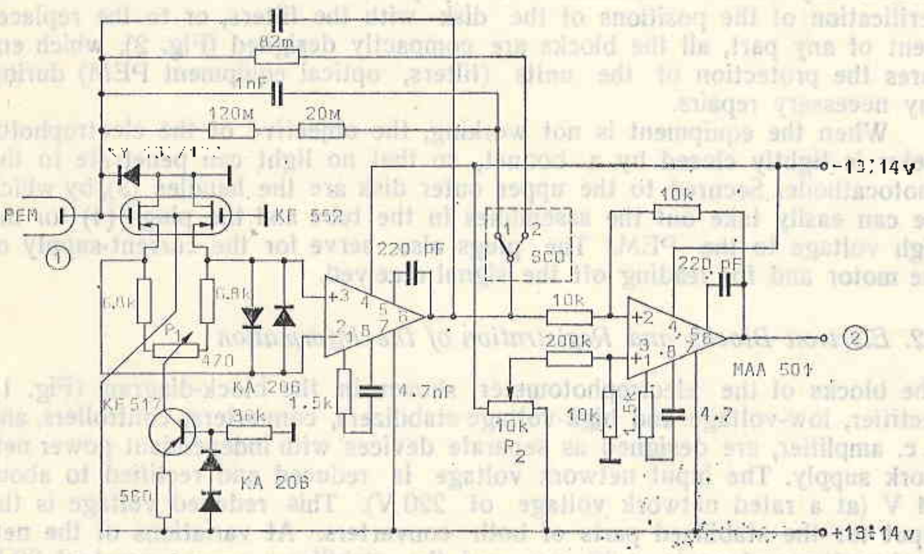


Fig. 4

The optic system of the electrophotometer consists of a single-lens objective (2), 80 mm in diameter, focal distance 300 mm. The disk with the filters (10) is placed in the focal plane of the objective. This makes it pos-

Table 1

| No. | Line Å | Δλ Å | No. | Line Å | Δλ Å | No. | Line Å | Δλ Å |
|---|---|---|---|---|---|---|---|---|
| 1 | 5577 | 80 | 3 | 4270 | 110 | 5 | 6300 | 65 |
| 2 | 5495 | 85 | 4 | 4525 | 120 | 6 | 6220 | 80 |

sible for the whole light flux from the objective to pass successively through each one of the filters. The focusing of the light flux on the cathode of PEM is performed by the lens (15). The objective (2) is placed in a special optic tube (17). The visual angle of the optic system is 5°, satisfying condition *G*.

The disk with the filters is driven by the electric motor (7) and the reduction gear (9). The Maltese mechanism (8) ensures a stop of 50 s for each one of the filters in the light flux. The displacement of the disk from one position to another takes 5 s. Immediately after that the intensity of the spectral background is measured by the next filter. The choice of the two-minute interval, approximately, is determined by the minimum period of the variations of the different intensities. The minimum period of the variations of each one of the emissions is about 10 minutes. Consequently, averaging the values of the emission for an interval of 1—2 min is admissible.

A special moisture-absorbing cartridge is put into the basic tube of the equipment filled with silica gel, and it can be changed easily and quickly without any need to dismantle the equipment. With a view to eventual verification of the positions of the disk with the filters, or to the replacement of any part, all the blocks are compactly designed (Fig. 2), which ensures the protection of the units (filters, optical equipment PEM) during any necessary repairs.

When the equipment is not working, the objective of the electrophotometer is tightly closed by a bonnet, so that no light can penetrate to the photocathode. Secured to the upper outer disk are the handles (3), by which we can easily take out the assemblies in the tube and the plugs (4) for the high voltage to the PEM. The plugs also serve for the current-supply of the motor and for leading off the signal received.

### *3.2. Electron Blocks and Registration of the Information*

The blocks of the electrophotometer shown in the block-diagram (Fig. 1), rectifier, low-voltage and high-voltage stabilizers, converters, controllers, and d. c. amplifier, are designed as separate devices with independant power network supply. The input network voltage is reduced and rectified to about 24 V (at a rated network voltage of 220 V). This reduced voltage is the input for the stabilized parts of both converters. At variations of the network voltage of up to $\pm 20$ per cent the stabilizers ensure constant 20 V at the output, with coefficient of stabilization of about 4000. A separate low voltage (for the d. c. amplifier) and a high voltage (for the photomultiplier) are provided on account of the necessity for the high stabilized rated voltage of 1750 V to be regulated within $\pm$ 100 V. In this way, for each photomultiplier from the series FEU-79 we can choose the most suitable high-voltage supply, thereby ensuring maximum sensitivity of the FEU-79. The characteristics of the high-voltage stabilizer, of the converter and of the rectifier are given in [10].

The diagram of the low-voltage stabilizer, converter and rectifier does not differ from the one described in [11]. It provides a supply of $\pm 13$ V for the d. c. amplifier. The d. c. amplifier, whose diagram is shown in Fig. 4, is used to amplify the current from the anode of the photomultiplier and to transform it into voltage for the recording voltmeter. The maximum variations of the intensity of the signal lead to a maximum output signal of about $\pm 12$ V. The determination of the zero output level in the absence of any signal is performed by a potentiometer of 10 K, connected to the not inverted input of the second operational amplifier. The sensitivity of the whole amplifying feedback can be altered to about 30 per cent from the rated one by switching the key shown in Fig. 4 from position 1 to position 2.

In general, the diagram in Fig. 4 differs from the one described in [11] by the presence of a diode KY 130 at the input of the field-effect transistor KF 552. This diode has the following function: at a normal signal from the photomultiplier the voltage at the gate of KF 552 is still positive with respect to the zero bar. The diode is switched to a non-passing direction and its inner resistance is of the order of giGaohm, so that it does not influence the coming signal. At a strong lighting of the photocathode of FEU-79 the diode KY 130 is released and preserves the input cascade of the amplifier.

A recording voltmeter of the H 340 type is used for registration of the signal received. As far as it is necessary for the adjustment of its measurement range in the limits of the output voltage from the direct current amplifier (the maximum deviation of H 340 is $+12$ V), additional thermostable resisor is put in the electrical diagram of H 340. The registration of the information is performed continuously during the observation.

Having processed in this way the data obtained during one night and having entered it in Table 2, we can obtain the relative intensity of every line as a function of time. The relative intensity is determined by formula (1):

$$I_{\text{rel}} = \frac{N_{\text{emiss.}} - K_i N_{\text{backgr.}}}{N_{rs}}. \tag{1}$$

The value of $K_i$ for every line showing the ratio of the transmitting capacities of each one of the two filters are given by

$$A = \int_{\lambda_1}^{\lambda_2} r_i \, d\lambda . \tag{2}$$

$$K_i = \frac{A_{\text{emiss.}}}{A_{\text{backgr.}}}. \tag{3}$$

The coefficients $K_i$ are determined experimentally in the following way. We admit a constant signal through both filters (for example, reflected and diminished solar radiation), and the ratio between the indications of the two filters gives the value of $K_i$ in formula (1).

The dynamic control of the sensitivity of the equipment is achieved by a standard radioactive source ($^{14}C$), selected in such a manner that its value

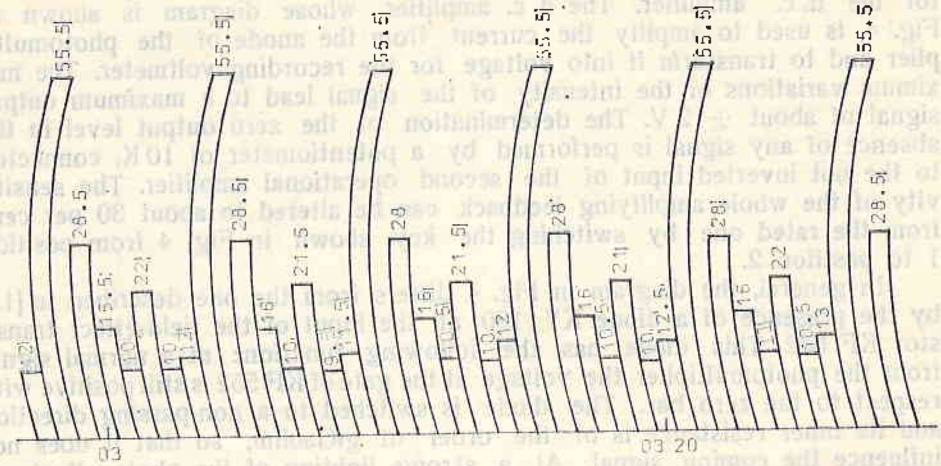


Fig. 5

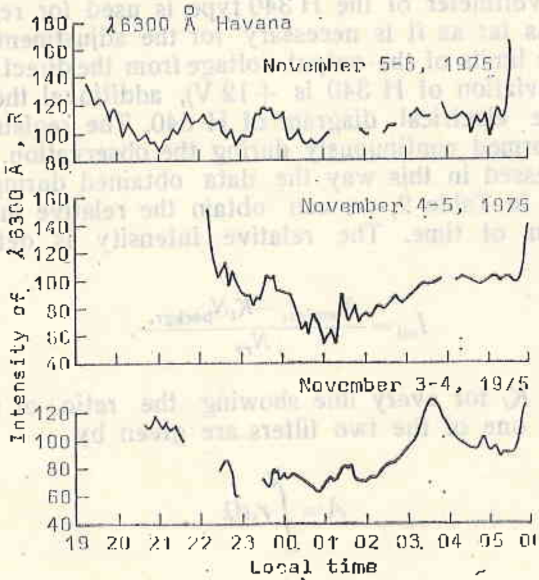


Fig. 6

shall be in the middle of the scale of the recorder. The eventual changes in the sensitivity during operation are corrected by the $R_s$ coefficient in formula (1).

## 4. Measurements of Optical Emissions by the Equipment

The light flux coming from the objective passes through each one of the filters and reaches the cathode of PEM. The photo-current is transmitted to the amplifier and is registered by the recorder H 340. Fig. 5 shows part of the registration of the atmospheric emission. Each one of the lines measured is designated. The registration was carried out on October 16/17, 1975, in the Observatory at Stara Zagora.

The value of a given line, registered on the band, is measured above the level of the dark current (Fig. 5). The values for the intensity of the line 5577 A can be estimated from the data given in Fig. 1.

## 5. Absolute Calibration of the Equipment

The transformation of the relative values of the emissions to the absolute values is a very difficult proposition in view of the fact that the equipment operates almost at its threshold sensitivity, where the fluctuations of the background exercise an essential influence. The methods given in [1, 7, 8, 9] are used in the absolute calibration of the equipment.

In addition to the absolute calibration we also carried out simultaneous observations of the same emission by another electrophotometer which had been used for such purposes over a long period of time. In this way we obtained a correct calibration of the equipment.

Fig. 6 shows an example taken from our first observation near Havana in Cuba.

*Acknowledgements.* We wish to express our sincere gratitude to Professor K. Serafimov for his great interest and valuable help in the course of this work.

## References

1. Гогошев, М. М. Кандидатска дисертация. С., БАН, 1973.
2. Gogoshev, M. Planetary and Space Sciences, 23, 1975, 305.
3. Trutce, I. L. Planetary and Space Sciences, 16, 1968, 1, 140.
4. Chamberlain, J. Physics of the Aurora and Airglow. New York—London, 1961.
5. Фишкова, Л., Г. Маркова. Астрон. циркуляр, АН СССР, 1958, 196.
6. Dalgarno, A. Ann. Geophys., 20, 1964, 1.
7. Гогошев, М. М., Т. Райчев. Известия на Секция астрономия. С., БАН, V, VI, 1973.
8. Мартинов, Д. Курс практической астрофизики. М., 1967.
9. Fishkova, L., G. Markova, Bull. Abast. Astrophys. Observ. No 24, 1939.
10. Chapkunov, S. Compt. rend. Acad. Bulg. Sci., V, 28, 1975.
11. Chapkunov, S., M. Petrounova. Compt. rend. Acad. Bulg. Sci., V, 29, 1976.

## Наземная электрофотометрическая станция для исследования оптических эмиссий высокой атмосферы

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(Резюме)

Рассмотрены некоторые механизмы генерации оптических эмиссий высокой атмосферы и данны их интенсивности. Описана блок-схема, которая включает в себя электрофотометр, электронный блок и регистратор информации. Методика измерения, калибровки и получения данных подробно дискутируется в работе.