BULGARIAN ACADEMY OF SCIENCES
SPACE RESEARCH IN BULGARIA, 2
Sofia · 1979

Changes in the Intensity of Solar Radiation during the Solar Eclipse of April 29, 1976

I. Apparatuses and Method of Measuring the Changes in Solar Radiation during the Eclipse of April 29, 1976

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Introduction

The paper describes the apparatuses and methods worked out specially for the purpose of obtaining data about the change in the solar radiation during the eclipse of April 29, 1976.

The results were obtained on the island of Santorini in Greece and in the town of Stara Zagora in Bulgaria and are related to the slow changes in the intensity of solar radiation, in the first case, and to the rapid changes in its spectral composition at the maximum of the phase, in the second case.

Spectrometric Apparatuses

For investigating the slow changes in the intensity of the solar flux in the visible and near-infrared region of the optic spectrum we used a device, worked out by the Team on Remote Sensing at the Central Laboratory for Space Research, for measuring the spectral reflective characteristics of natural formations ISOH-010. The block diagram of the device is shown on Fig. 1. The optico-mechanical system (OMS) provides for the discretization of the visible and near-infrared region of the light spectrum by means of 11 interference filters. The average semiwidth of the filters is 12 nm, with maxima at 413, 428, 443, 482, 513, 543, 596, 652, 710, 749 and 795 nm, respectively. The field of view of the optic input of the system is 15°. A phototransistor operating with accumulation of the charges has been used in the transformation of the light flux into electric signal. The phototransistor is fed by a pulse generator (PG) and a forming device (FD), which yield pulses of 2 μs durations and 450 Hz frequency of repetition. A series of pulses are obtained at the output of the FD, whose scope is proportional to the intensity of the light flux. By the peak detector (PD) this series is transformed into direct voltage measured by the pointer-type indicator I.

A multi-channel scanning spectrophotometer was designed for the purpose of investigating the rapid changes in the intensity of the solar flux. Its block diagram is shown on Fig. 2. The input optic equipment (IOE), projects the image of the investigated object (the solar disk in this case) on the plane of the dispers-

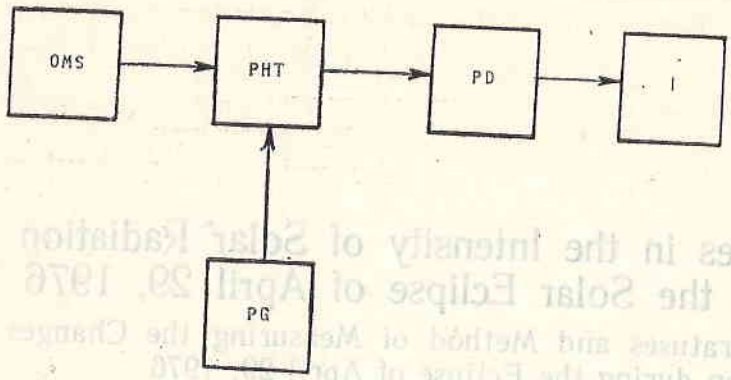

Fig. I

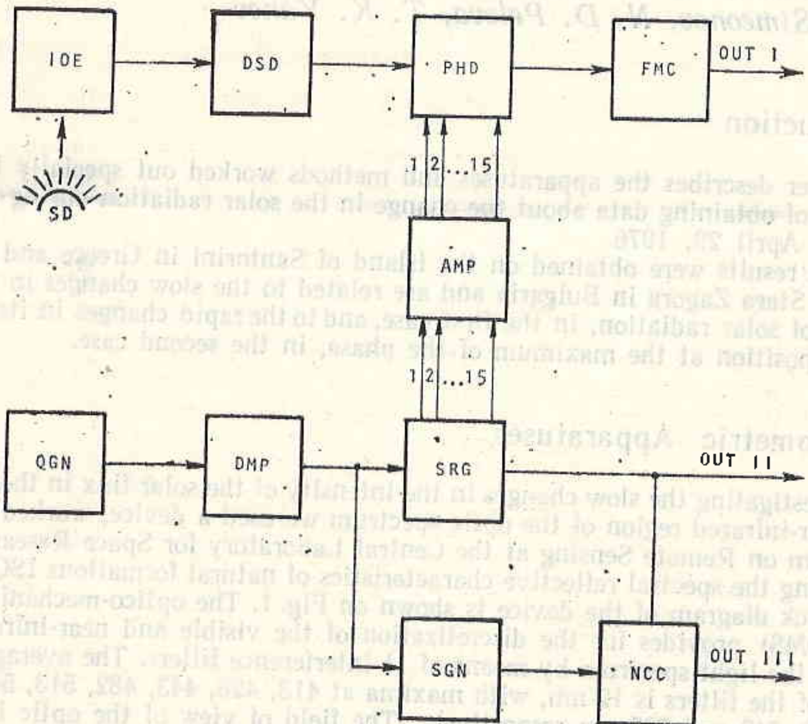

Fig. 2

ing device (DSD), at the output of which an optical spectrum is obtained with geometric dimensions suitable for the phototransducer. The dispersing device used is a volume phase hologram on diffractional grating, worked out at the Central Laboratory for Optical Registration and Processing of Information at the Bulgarian Academy of Sciences. Its basic characteristics are: transmission coefficient — 0.3; dispersion capacity — 1000 lines/mm; optical resolution — 2 nm; dimensions — 45×45×2 mm. The use of this grating considerably simplifies the design of the spectrophotometer, reducing the loss of light and ruling out the appearance of specters of a higher order and "ghosts".

The block of the phototransducer (PHD) is a linear discrete structure of 15 phototransistors type BPY 61-III operating on a pattern of charge accumulation. The design and operation pattern provide for discretization of the output information in relation to the length of the light wave and for obtaining higher sensitivity. The total resolution for each channel, at 300 nm width of the optic spectrum, is not below 20 nm. Within the frameworks of the investigated spectral range from 450 to 750 nm, channel No. 1 records the region of 730 to 750 nm, channel No. 2 — 710 to 730 nm, etc. The mean quadratic error of the entire tract of the photoelectric conversion is below 1 per cent.

The output signal of the phototransducer has the shape of a comb function. The forming circuit (FMC) rounds off the peak of the pulse, and this permits the analogue-to-digital conversion in the first microsecond after the front.

The pattern of charge accumulation is obtained by consecutive scanning of the phototransistors with pulses obtained at the outputs of a 16-bit shift register (SRG). The sixteenth output forms a control signal "End of spectrum". In AMP the pulses from the shift register are amplified for the purpose of obtaining the necessary double amplitude of 10 V. The clock pulses for the shift register with repetition frequency of 100 Hz are produced in the quartz square-pulse generator (QGN) at a frequency of 100 KHz and demultiplied by 1000 — DMP. The quartz stabilization is necessary for the accurate observance of the scale of relative time. The same pulses also go into SGN, where strobe pulses of duration 1 μs and repetition frequency of 100 Hz are formed. The rear front of these pulses fixes the moment of measuring the double amplitude of the output signal.

Data Registration System

Underlying the system of registration for the data from the multi-channel scanning spectrophotometer (MSS) in real time is an abridged configuration of the IZOT-0310 minicomputer. The block diagram of the system and its connection with the spectrophotometer are shown on Fig. 3. Its standard part includes a central processor unit with 8K core memory, an operator's board — teletype ASR-33 control unit, and a rapid punch-tape output — DZM 180.

For the purpose of connecting the system with the multichannel scanning spectrophotometer and for converting the analogue information into digital form, a fast analogue-to-digital converter (ADC) has been used, in addition to a specially designed controller along the channel for programmed input/output transfers. The ADC is of the successive approximation type coding with 1.2 million conversions per second with 8-bit parallel binary code output.

The specialized controller receives from the spectrophotometer also control signals along the Uy bus. Its programme control from the computer is realized by a set of six specialized input-output instructions.

The automatic operation of the system in a mode of recording, the preliminary processing (compression) of the spectral information, and taking it on punched tape in real time is done under the control of a specially worked out programme. It is written in programme assembler's language and occupies only

7108 memory locations. The block diagram of the generalized algorithm of operation of the programme is shown on Fig. 4.

The synchronization of the recording process after the manual starting of the complex takes place at a signal of ES — end of the successive spectrum. Each

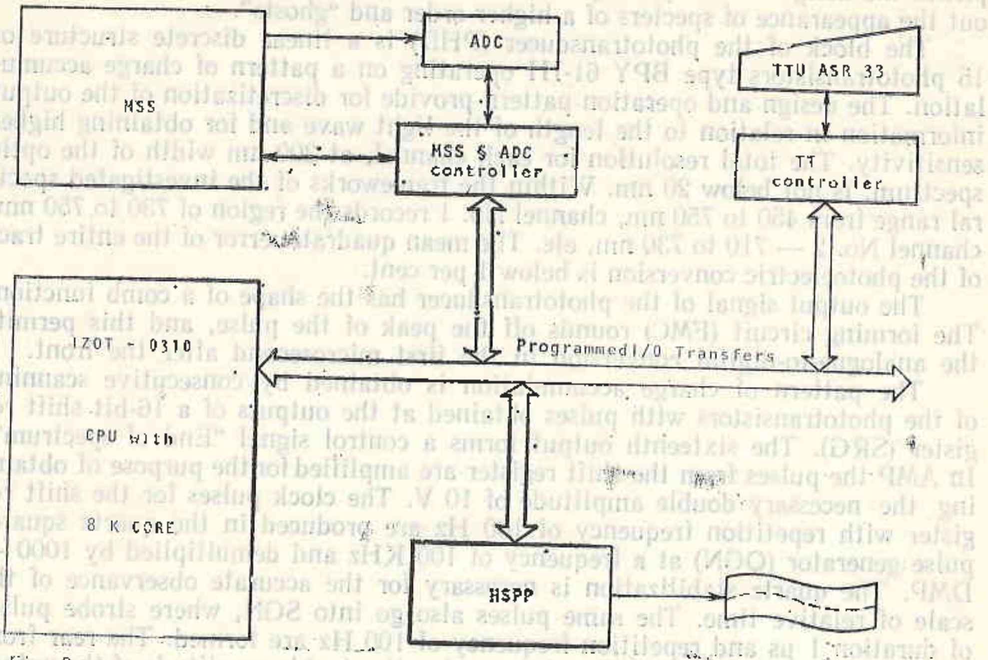

Fig. 3

successive value (point) of the currently recorded spectrum (corresponding to the light intensity for the successive band of the spectral range investigated) is compared with the value of the corresponding point from the preceding spect-(um. Any difference in the values greater than the one determined in advance e.g. the mean quadratic error of the measurement and converting tract) is an ndication for recording and for taking on punched tape the spectral information for the entire incoming spectrum.

Punching of the spectral information is done at the rapid punch-tape output during the passage of the even spectra and continues during the recording of the subsequent (odd) spectrum. This makes it possible to put the data on punched tape without any need to change the reel during the entire measurement. Parallel with that, each different spectrum is memorized also in the computer memory, together with its serial number (a maximum of 375 full spectra), thereby duplicating the information punched for the sake of raising the reliability of the system of recording.

Under this mode of operation the aggregate of hardware and software possesses the following major characteristics:

— Time resolution: 160 spectra/ms at 160 ms/channel;

— Number of spectra obtained: 6.25 spectra/s, or 375 spectra/min;

— Number of spectra recorded: 3.125 spectra/s, or 187.5 spectra/min;

— Number of spectra recorded; in the operative storage of the computer — 375 consecutive differing spectra; on punched tape — practically unlimited number;

— Period of uninterrupted recording: practically over 4 hours.

The programme supervises the correct operation of the system during the experiment, analysing the state of the flags of the control device for connection between the spectrophotometer and the computer and the number of consecu-

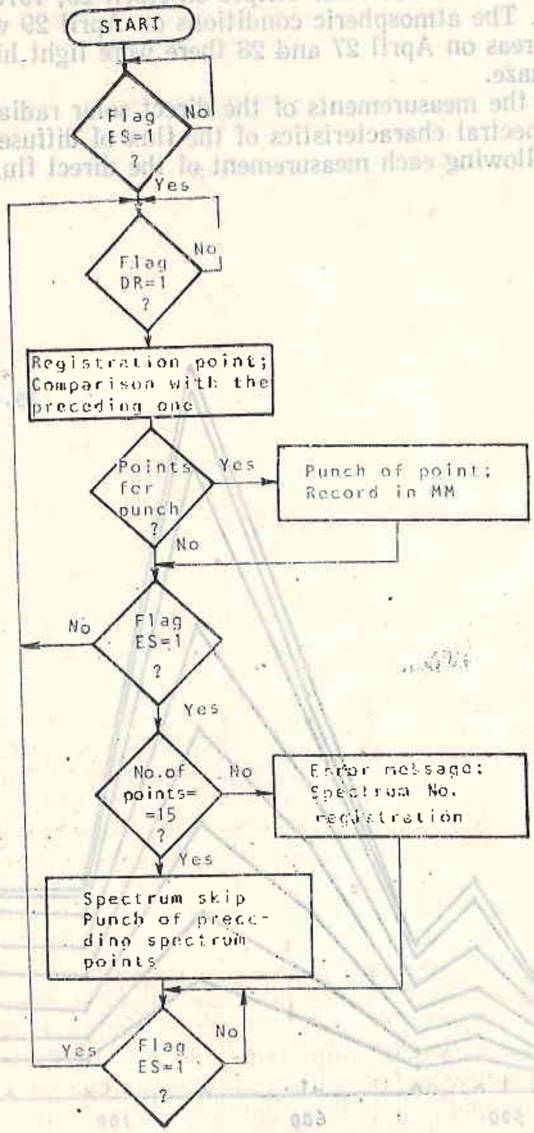

Fig. 4

tively entering points of the spectrum. In case of an accidental error, indication is given at the operator's board (bell-ring) and the number of this spectrum is memorized in a particular region of the storage. A constantly recurring error requires the intervention of the operator. The cycle of the programme is infinite and it can be stopped manually from the operator's board.

Conditions of Measurement and Results

According to preliminary instructions, the measurements on the island of Santorini in Greece were carried out at 15-min intervals, the duration of each measurement (in the 11 spectral ranges) being not longer than 2 min. The measurements embrace the interval from 10:00 h Eastern European time to 15:00 h both on the day of the total annular solar eclipse on April 29, 1976, and on the days of April 27 and 28. The atmospheric conditions on April 29 were ideal for such investigations, whereas on April 27 and 28 there were light high-altitude clouds and atmospheric haze.

In addition to the measurements of the direct solar radiation, records were taken also of the spectral characteristics of the flux of diffusely scattered light. For the purpose, following each measurement of the direct flux, the direction of measurement was changed at an angle of 180° in the horizontal plane, preserving the angle in the vertical plane. Neutral filters were used at the input of the optical equipment due to the high intensity of the light flux upon direct orientation toward the Sun. The device was oriented immediately before each measurement.

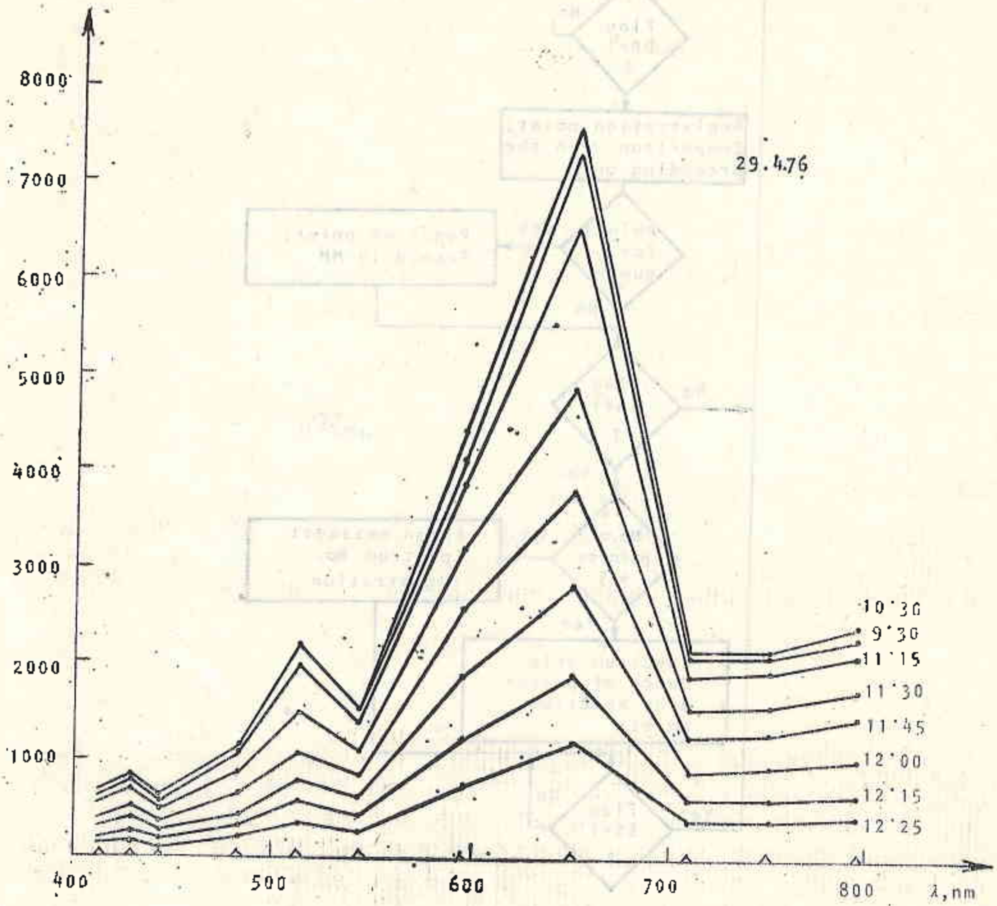

Fig. 5

In order to make a relative quantitative evaluation of the measurement of the intensity of the light fluxes at the different phases of the eclipse, the values of the quantities measured upon using neutral filters have been reduced to the values recorded without them in relative units. The intensity of a flux causing the maximum deflection of the indicator without the use of filter has been accepted as having 100 relative units.

All data obtained from the observations have been tabulated and prepared for further processing. Figure 5 shows the change in the intensity of the direct light flux depending on the time for the eleven spectral ranges investigated.

The measurements in Stara Zagora of the intensity of the direct light flux during the partial (79%) annular solar eclipse were carried out in the interval of 11:00 to 14:00 with average duration of 4 min and 10 successive measurements. Four of them were concentrated around the phase of the eclipse, and the measurement during the phase continued for 10 min. Slight haze appeared during some of the measurements, and one of them reacted to the trail of exhaust gases left by some plane along the path of the light flux. The measurements envisaged at the same time intervals during the following day, April 30, could not be carried out on account of dense clouds and rain. The direction of the input optic device of the multi-channel spectrophotometer was done by hand prior to each optic or electronic measurement.

The data from the measurements were recorded on punched tape in real time in eight-bit binary code. During the investigations, the automatic control of the veracity of the information recorded and the subsequent comparison of the punched tape from the direct recording and the dump of the region for data in the memory after each recording, all showed the perfect working condition of the apparatuses during their operation.

To provide visual presentation for the great volume of data obtained, the results from the punched tapes were printed in tabular form, and the values of the intensity depending on the time were tabulated for each channel investigated.

Conclusions

In the course of the investigation of the changes in the intensity of the solar radiation during the solar eclipse, measurements were taken of both the main and the rapid changes in the solar flux in the visible and near-infrared region of the spectrum. The data obtained were processed by UZOT-0310 minicomputer, and the results of that processing are contained in the article entitled "Statistical Analysis of the Change in Solar Radiation during the Eclipse of April 29, 1976" which is published in the present issue.

The method worked out and the apparatuses designed provide for universal application and may be used in a number of studies — daily and seasonal ones — of the dynamics of the changes in solar radiation, of the diffuse scatter of light in the atmosphere, and in other studies.

The results obtained and the experience accumulated point to a number of changes and improvements which may be introduced in the design and operation of the complex. A portable variant of the system is to be designed, involving the utilization of microprocessor modules and the introduction of new methods of compression and of preliminary processing of the data obtained in real time.

Изменение интенсивности солнечной радиации во время солнечного затмения 29 апреля 1976 г.

I. Аппаратура и метод для измерения изменений солнечной радиации во время солнечного затмения 29 апреля 1976 г.

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(Р е з ю м е)

В работе описаны эксперименты, проведенные в Греции — на острове Санторини и в Болгарии — в гор. Стара-Загора для исследования солнечной радиации во время солнечного затмения 29 апреля 1976 г. Дано подробное описание использованной спектральной аппаратуры и системы регистрации быстрых спектров на базе мини-ЭВМ, их параметры и действие. Приведены условия проведения эксперимента и дана предварительная обработка полученных результатов.