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

II. Statistical Analysis of the Changes in Solar Radiation during the Eclipse of April 29, 1976

T. K. Yanev, N. D. Pelova, A. Y. Stoimenov, A. H. Kroumov, S. T. Kovachev, D. N. Mishev

A statistical analysis has been made of the data obtained about the variations in 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 [1].

In the first case the information obtained was about the slow changes in the intensity of solar radiation, while in the second case it was about the rapid changes in the spectral composition of solar radiation, mainly at the maximum of the eclipse phase.

The Island of Santorini

The data about the change of $I(t)$ were obtained during relatively long intervals of 10 to 30 min. The average value of $I(t)$ for an interval of 1-2 s was established at each measurement [2].

The analysis of the data on $I(t)$ shows that the ratio of two neighbouring spectra in time is in many cases close to constant as regards the parameter wavelength and with t fixed, i. e. that two neighbouring spectra are in an approximately multiplicative ratio. This ratio should have been accurately multiplicative if the Sun was a fully homogeneous source of radiation and if the tract of propagation and registration did not contain any noise. Of course, the size of this constant (it is a constant at fixed time and parameter — wavelength) changes depending on time, both on account of the change in the inclination of the Sun and on account of the covering of the Sun's disk in the course of the eclipse.

Table 1 contains the values of the ratios

$$\beta^{(\lambda)}_{j,j+1} = I(\lambda, t_j)\, I(\lambda, t_{j+1})$$

of the neighbouring in time recorded spectra of $I(t, \lambda)$. The variation coefficient V_β of the series obtained of $\beta_{j,j+1}$ has also been calculated. Under conditions

Table 1

Ratios $\beta_{jj+1}=I(\lambda, t_j)/I(\lambda, t_{j+1})$

No.	Hour	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	γ_{11}	V
1	09^{30}, 10^{00}	0.889	0 881	0.880	0.904	0.774	0.862	0.994	0.957	0.981	0.985	0.988	0.076
2	10^{00}, 10^{30}	1.046	1.067	1.056	1.091	1.300	1.161	0.977	1.015	1.000	1.000	0.983	0.089
3	10^{30}, 10^{45}	1.000	0.990	1.005	0.981	0.758	0.980	1.000	1.000	1.000	0.989	1.017	0.075
4	10^{45}, 10^{56}	0.963	0.971	0.968	0.987	1.265	1.000	1.006	1.036	1.017	1.027	1.012	0.139
5	10^{56}, 11^{00}	1.014	1.013	1.003	1.032	1.089	1.069	1.043	1.059	1.048	1.052	1.047	0.025
6	11^{00}, 11^{15}	1.062	1.055	1.058	1.046	1.036	1.021	1.028	1.052	1.047	1.031	1.049	0.013
7	11^{15}, 11^{30}	1.170	1.182	1.220	1.206	1.349	1.275	1.217	1.344	1.231	1.236	1.223	0.047
8	11^{30}, 11^{45}	1.250	1.235	1.261	1.233	1.341	1.297	1.218	1.264	1.232	1.235	1.224	0.029
9	11^{45}, 12^{00}	1.414	1.429	1.426	1.664	1.387	1.346	1.393	1.369	1.389	1.336	1.416	0.062
10	12^{00}, 12^{15}	1.603	1.609	1.593	1.311	1.448	1.527	1.566	1.486	1.513	1.528	1.492	0 059
11	12^{15}, 12^{25}	1.628	1.611	—	1.614	1.616	1.606	1.650	1.616	1.608	1.632	1.610	0.008
12	12^{25}, 12^{35}	1.137	1.277	—	1.448	0.740	0.792	1.796	1.860	1.492	1.488	1.608	0.279
13	12^{35}, 12^{42}	2.426	2.593	2.075	1.838	2.440	2.991	1.825	1.680	1.734	1.691	1.656	0.218
14	12^{42}, 12^{47}	1.042	1.034	1.024	1.072	1.000	0.955	0.953	0.969	0.947	0.955	0.951	0.045
15	12^{47}, 13^{00}	0.454	0.169	0.197	0.171	0.242	0.208	0.334	0.349	0.364	0.364	0.367	0.334
16	13^{00}, 13^{15}	1.206	1.136	1.091	1.304	1.397	1.296	0.564	0.536	0.634	0.640	0.601	0.367
17	13^{15}, 13^{30}	0.594	0.597	0.597	0.614	0.673	0.639	0.634	0.687	0.642	0.646	0.642	0.048
18	13^{30}, 13^{45}	0.753	0.754	0.744	0.763	0.786	0.791	0.756	0.793	0.816	0.819	0.814	0.036
19	13^{45}, 14^{00}	0.798	0.812	0.815	0.837	0.808	0.836	0.852	0.820	0.856	0.831	0.845	0.023
20	14^{00}, 14^{15}	0.918	0.925	0.904	0.919	0.880	0.897	0.909	0.862	0.874	0.909	0.875	0.013
21	14^{15}, 14^{30}	0.967	0.961	0.954	0.961	0.956	0.952	0.955	0.959	0.974	0.944	0.962	0.008
22	14^{30}, 14^{36}	0.992	1.019	0.994	1.014	1.046	1.033	1.000	1.022	1.015	1.000	1.000	0.017
23	14^{36}, 14^{45}	1.030	0.988	1.017	1.007	1.000	1.000	1.008	1.020	1.000	1.016	1.026	0·013

of completely homogeneous source of light and of undisturbed transmission-reception tract, the variation coefficient must be equal to zero, regardless of the movement of the Sun's disk and of its being covered by the Moon's disk during the eclipse. These properties of V_β make it suitable for an integral assessment of both phenomena, namely, inhomogeneity of the Sun and noise in the transmission-reception tract.

Table 1 shows that the variation coefficients related to the phase of the eclipse are the biggest and, at the same time, they are by one order bigger than the other variation coefficients.

Stara Zagora

The main object of the investigation in the recording of the solar eclipse in Stara Zagora were the rapid transitional processes in the intensity $I(t)$ of the solar radiation. Presented in this article are the processed data from the "phase" of the eclipse [2].

The dynamics of $I(t)$ is characterized by its first derivative in time. In view of the fact that the data are in a discrete form and the interval of discretization is constant, an evaluation of the size of the first derivative may be obtained from the neighbouring differences $\Delta I_{j,\,j+1}=I_j-I_{j+1}$, which have been further used in investigating the changes of $I(t)$.

The analysis of the neighbouring differences $\Delta_{j,\,j+1}$ has shown the existence of strong grouping (over 95%) for all channels in three intervals: for $\Delta_{j,\,j+1}=-2$, 0 and 2 relative units (one such unit is equal to 40 mV). This does not make it possible to apply correctly the χ^2-criterion for evaluating the degree of proximity with normal distribution. Nevertheless, on the basis of considerations for many, mutually independent, random and equal factors (each one of them with a small contribution to the total dispersion) affecting the formation of $\Delta I_{j,\,j+1}$, it may be assumed that in these intervals the distribution will be close to the normal one. Under this assumption a check was made with the r-criterion for gross deviations from $\Delta\bar{I}$ [3]:

$$r=\frac{|\Delta I\max,\min-\Delta\bar{I}|}{S}, \qquad S=\sqrt{\frac{\sum_{(j)}(\Delta I_{j,j+1}-\bar{I})^2}{n-1}}.$$

All differences $\Delta I \geqslant 4$ relative units proved to be non-inherent to the assumed normal distribution in the above three untervals. That is why these differences are further on treated as bearers of the basic information about the dynamics of the transitional processes ΔI and are called *supraliminal differences.*

The supraliminal differences for all pairs of channels were investigated by linear correlation and regression analysis (single correlation), provided in a given pair of channels in the course of the eclipse phase there apperaed supraliminal differences of more than 4 times and simultaneously in both channels of the examined pair of channels. The intensity in the channel bearing a smaller number was accepted as the x argument. The coefficient of linear correlation r, the regression coefficients of the model, and Fisher's F-criterion for adequacy of the linear model were calculated.

The analysis indicates that the correlation between the supraliminal differences is comparatively poor, with the exception of the following pairs of channels: 6-11, 6-12, 8-13, and 9-13, for which $r>0.70$ and $F>F_{\text{т}}$ at a confidence level of $p<0.05$.

Table 2

Supraliminal Differences for Groups of Three Channels for Which the Common Coefficient of Correlation is $R > 0.70$

Channel	Sp. 1269	1290	1639
VI	−4	−4	−2
XI	−6	8	6
XII	4	−10	4

Channel	Sp. 783	832	1009	1365	1394
VIII	−16	8	−8	−44	44
IX	−4	4	4	116	−116
XIII	−6	4	−8	−24	24

Channel	Sp. 411	537	783	832	1072	1269	1333	1365	1394	1444
VIII	4	8	−16	8	−8	−8	−4	−44	44	4
XII	4	12	−6	12	−8	4	−4	26	−26	26
XIII	6	8	−6	4	4	−6	−4	−24	24	−26

Channel	Sp. 783	832	1365	1444
VIII	−16	8	−44	4
XII	−6	12	26	26
XIV	−6	4	−32	−34

Channel	Sp. 301	783	832	1565	1394
IX	116	−4	4	166	−166
XII	−24	−6	12	24	−26
XIII	4	−6	4	−24	24

Channel	Sp. 301	416	783	832	1360	1365	1444	1454
XII	−24	4	−6	12	−6	26	26	−28
XIII	4	6	−6	4	−6	−24	−26	24
XIV	6	4	−6	4	−4	−32	−34	8

Channel	Sp. 1269
VI	−4
XII	4
XIII	−6

One characteristic feature is that the synchronous appearance of supraliminal differences in a given pair of channels is divided by irregular and long time intervals.

Table 2 contains the combinations of each three out of all channels in which there is simultaneous appearance of supraliminal differences connected with a single correlation coefficient $r > 0.70$.

Conclusion

The principal results from the analysis of the data about the solar eclipse of April 29, 1976, may be formulated as follows:

Island of Santorini

Since on the island of Santorini the eclipse was annular during the phase (96%) and the observations of the Sun's disk were carried out in clear weather, it may be assumed that the large values of the variation coefficient V_β during the phase are due in the first place to inhomogeneity in the visible part of the Sun (about 4 per cent of the full disk). The contribution of the error of the measurement device for raising the variation coefficient is inessential because the maximum error of the apparatus used is about 1 per cent.

The variation coefficient is independent of the constant of the neutral filters. That is why, neutral filters of unknown constant may be used for obtaining primary information about the intensity of the solar radiation (the constant is cancelled in the expression for V_β).

The Town of Stara Zagora

The distribution of the neighbouring differences $\Delta I_{j,\ j+1}$ in all channels is expressed unimodally by an arithmetical mean almost equal to zero and by incidental supraliminal differences of various magnitude. This shows that there is no predominant manner in which the rapid transitional processes $I(t)$ take place during the observed phase of the eclipse.

The linear correlation among the values of the supraliminal differences is poor, with the exception of several pairs of channels for which $r > 0.70$ and $F > F_T$ at a confidence level of $p < 0.05$.

In channels 8 to 13 there exists a marked tendency toward simultaneous appearance of the supraliminal differences [2].

References

1. Mishev, D. N., A. I. Stoimenov, A. H. Kroumov, S. T. Kovachev, B. P. Simeonov, N. D. Pelova, T. K. Yanev. — Space Res. in Bulg., 2, 3.
2. Отчет P — 5/1. Подготовка, провеждане и резултати от изследването на Слънчевото затъмнение на 29 април 1976 год. — ЦЛКИ при БАН, София, 1976 г.
3. Смирнов, Н. В., И. В. Дунин-Барковский. Курс теории вероятностей и математической статистики. М., 1965 г.

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

II. Статистический анализ изменения солнечной радиации во время солнечного затмения 29 апреля 1976 г.

Т. К. Янев, Н. Д. Пелова, А. Й. Стоименов, А. Х. Крумов, С. Т. Ковачев, Д. Н. Мишев

(Резюме)

В работе проведен статистический анализ данных об изменении солнечной радиации I во время солнечной затмения 29. IV. 1976 г. Данные снимались на острове Санторини, Греция и гор. Ст.-Загора, Болгария.

В первом случае снималась информация о медленных изменениях солнечной радиации, а во втором — быстрые изменения по спектру, в основном во время максимума фазы затмения.

Анализ медленных изменений проводился с исследованием отношений I для соседних во времени спектров, а быстрые изменения — разностями соседних спектров.

Основные результаты проведенного анализа:

— наблюдаются значительные по амплитуде медленные изменения интенсивности солнечной радиации во время фазы затмения, которые можно объяснить негомогенностью видимой во время фазы части солнечного диска.

— быстрые изменения (переходные процессы) не сопровождаются каким-либо превалирующим видом закономерности во времени.