ΑΣΤΡΟΝΟΜΙΑ.—**Analysis of some aspects of 25 chromospheric events. Reduction of the optical data,** *by* *R. Falciani, C. J. Macris, M. Rigutti* *. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰ. Ξανθάκη.

Abstract

Some 25 chromospheric events photographed at the National Observatory, Athens by C. J. Macris, have been analysed with a photographic method to get isophotes. Evolutive curves of the energy emitted by the flares at different intensity levels have been obtained. Some examples are shown and some general remarks are made.

1. Introduction

Since some our previous works (Falciani et al., 1967; 1968) gave encouraging results it seemed to us worth-while to develop further the basic ideas contained in those works and to try to make an as accurate as possible photometric analysis of flares and a comparison with radio and X-ray observations at as much wavelengths as possible. In fact, the knowledge of the time evolution of all the aspects of the flare phenomenon must be the first step to be made in every attempt to give a reliable physical model of the flare itself.

As is known, the simplest of the problems related to the flares, the one of their classification, is far from a satisfying solution and a great deal of the statistical work which is done at present is based on quantities which are rather roughly estimated and which have not a surely established physical meaning. For example, there are not very clear reasons to prefer to consider the areas of the flares instead of some other parameters. It is very likely that we are just acritically continuing what the pioneers did in this field.

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* R. FALCIANI, K. I. ΜΑΚΡΗ, M. RIGUTTI, **Φωτομετρικὴ ἀνάλυσις χρωμοσφαιρικῶν τινων φαινομένων καὶ ἀναγωγὴ τῶν ὀπτικῶν δεδομένων αὐτῶν.**

R. Falciani, M. Rigutti, Capodimonte Observatory Naples, Italy.

C. J. Macris, Research Center for Astronomy and Applied Mathematics, Academy of Athens, Athens, Greece.

This appears to be very evident if one considers, as said above, how the flares are presently classified and, turning to a different aspect of the problem, how the existing flare models do not explain the behaviour of some phenomena connected to the flares as for example, the short period pulsations and oscillations observed in radio and X-ray bursts (see, for example : Castelli and Aarons, 1967 ; Boishot and Clavelier, 1968; Teske and Thomas, 1969; Frost, 1969; Donnelly, 1969; Kreplin et al., 1969; Parks and Winkler, 1969) and recently observed by the authors (Falciani et al., 1968) also in the H_α line. It seems to us that the whole problem should be re-stated. A large number of flares should be singularly studied in different ways and common physical features should be searched. Only after this preliminary work is done significant statistics will be possible.

For the reasons above and from our previous results we thought it would have been interesting to make an analysis as accurate as possible of a group of flares in onder to get their photometric evolution and to make a comparison of the results with the data relative to associated radio and X-ray events. Of course, we needed good experimental data as far as time resolution and, possibly, spatial resolution are concerned. For this reason we used the good and homogeneous series of filtergrams obtained by C. J. Macris at the National Observatory of Athens.

2. Experimental material

Table 1 shows the events we have analyzed together with some data referring to them. For calibration purposes we used 75 photografic records of a 7-step calibration filter on the same emulsion (Duplo - Pan Rapid, Gevaert) used to get filtergrams. Unfortunately calibrations had not been performed regularly and we were obliged to use an average calibration curve for all exposure times. This caused an appreciable dispersion (of the order of $\pm 5\,\%$) of the experimental points. The figure 1 shows example of the filtergrams we analyzed.

3. Reduction method

For the reduction of all our experimental material we used the method already briefly described in some previous papers (Gregorio et

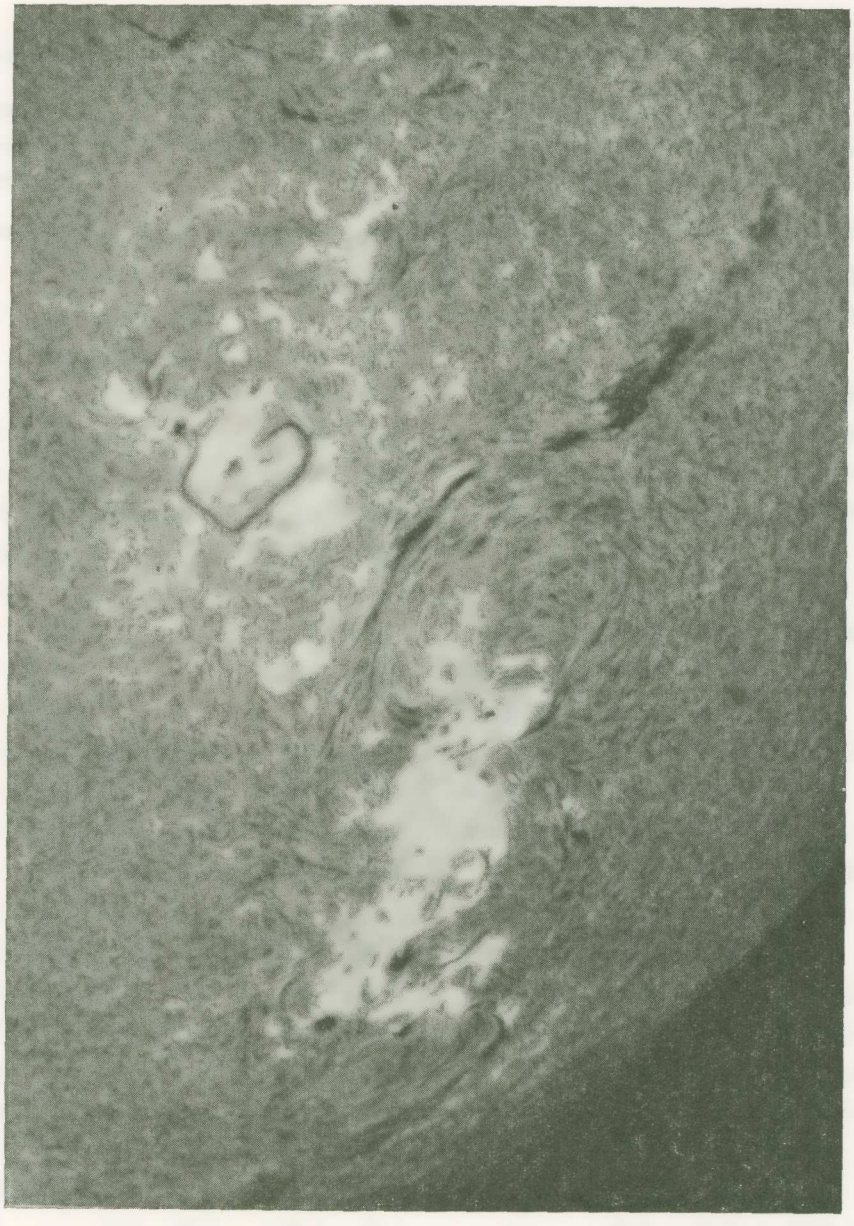

Fig. 1. H_a — filtergram of the flare of 28 May 1967 ($06^h\ 07^m\ 58^s$)

TABLE I.

Events analysed in the present work

Date	Average heliographic coordinates of the analysed region	Flare Importance (Macris)	Time interwals		Number of analysed filtergrams
30. 3. 1967	25 N - 50 W	1 b	8.33 - 9.37 ;	10.06 - 10.18	60
25. 5. 1967	24 N - 2 E	2 b	6.31 - 7.20 ;	8.20 - 8.30	57
			9.48 - 10.21 ;	10.55 - 11.20	
28. 5. 1967	24 N - 50 W	3 b	5.39 - 8.09 ;	8.20 - 9.08	70
2. 6. 1967	22 N - 40 W	1	8.01 - 8.06 ;	8.44 - 9.58	45
30. 7. 1967	25 N - 22 W	2 b	6.06 - 7.03 ;		45
31. 7. 1967	25 N - 42 W	1 b	6.40 - 6.54 ;	8.12 - 10.00	180
	15 N - 20 W	1 b	14.56 - 15.34 ;		180
	13 N - 10 E	1			175
1. 8. 1967	25 N - 52 W	1 b			78
	19 N - 29 W	not flare	6.35 - 7.16 ;		75
	17 N - 4 E	not flare			83
2. 8. 1967	25 N - 61 W	1 n	6.46 - 7.40 ;	8.02 - 8.22	66
	19 N - 42 W	not flare	6.46 - 7.40 ;	8.02 - 9.07	53
	16 N - 10 W	not flare	6.46 - 7.40 ;	8.02 - 9.07	73
3. 8. 1967	26 N - 82 W	2 b	8.03 - 8.53 ;	9.09 - 10.11	56
	19 N - 60 W	not flare			56
	18 N - 24 W	not flare	8.03 - 8.54 ;		56
6. 8. 1967	20 N - 48 E	not flare	7.22 - 7.32 ;	7.55 - 8.53	53
16. 11. 1967	12 N - 39 E	1 b	8.47 - 8.49 ;	9.24 - 9.37	57
17. 11. 1967	12 N - 28 E	2 b	8.20 - 10.10 ;		97
28. 1. 1968	12 N - 30 E	2 b			106
			8.12 - 10.05 ;		
	12 S - 35 E	s b			100
31. 1. 1968	14 N - 9 W	1 n	7.05 - 7.21 ;	7.48 - 8.04	61
1. 2. 1968	12 N - 29 W	1 b	8.57 - 10.42 ;	11.06 - 12.18	207
2. 2. 1968	13 N - 35 W	s b	9.08 - 10.03 ;	10.20 - 10.32	188
			10.42 - 11.52 ;	12.28 - 13.20	
3. 2. 1968	11 N - 55 W	1 b	7.51 - 8.13 ;	8.27 - 8.35	59

al., 1966, 1967; Falciani et al., 1967). For this work, however, we improved the device to measure the areas enclosed by the single density thresholds using, after the photomultiplier, a Thomson digital voltmeter and a tape puncher to record the measurements. All the reductions and calculations have been made with the IBM 7090 computer of CNUCE, Pisa, and the final data have been plotted with the Calcomp plotter of CNUCE, Pisa.

The whole instrumentation and the method to get isophotes have been accurately tested to get a reliable estimate of the total accuracy. The density of the undisturbed chromosphere has been obtained by averaging density measurements on four to six quiet points around the flare. Measurements have been repeated several times (in some cases up to 25) also at intervals of months and it came out that the accuracy for density measurements is $\Delta D / \bar{D} \approx 5\,‰$ within the range $0.04 \leqslant \bar{D} \leqslant 1.44$, that is completely negligible with respect to other errors discussed below. The photoelectric area measuring device has been repeatedly tested. Some 13 isodensity thresholds of known areas (the same ones used to calibrate the digital voltmeter) have been measured over and over again for periods of about one hour each (i.e. for periods longer than the ones necessary to measure a whole sheet of isodensity thresholds). A mean square error of about 5 % came out to be a good estimate for the error due to the area measuring device with a slightly larger error for smaller areas. A further source of error had to be considered, namely the fact that we only measured areas at particular and not always the same levels of density and then had to interpolate at 10 fixed density levels. To get an estimate of this kind of error we analyzed several filtergrams obtaining for each of them 45 isodensity thresholds and then comparing the results with those obtained with interpolation between the fixed 10 isodensity thresholds. The result was completely satisfactory.

When we had already got our first results some completely erratic fluctuations were present in the graphs. For this reason we re-analyzed the whole process. Two series of seven filtergrams have been independently processed 36 times in different days and one filtergram has been separately processed 26 times slightly varying the influence of all the possible nearby sources of fluctuations in the whole apparatus (for example:

exclusions of some usually operating motors in the building, etc.). As a final result we got the mean value $\bar{A}$ of the area enclosed by any of the considered isodensity thresholds and the corresponding mean square error $\varepsilon(\bar{A})$. As it is shown in figure 2 where instead of $\varepsilon(\bar{A})$ we reported its effect on the value $A - \varepsilon(A)$ is not constant. The largest errors correspond to the smallest measured area; in any case an error of 10 - 12 % may be an indicative one. It was then clear that the illumination and projection systems to get isophotes introduced errors much larger than the one due to the analysing device and this could be only explained by

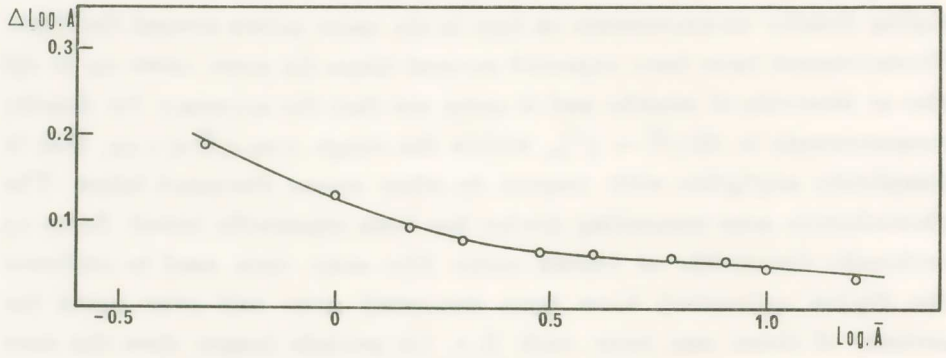

Fig. 2. Errors in the areas of the isophotes.

considering erratic fluctuations of the feeding system, sudden variations in the network voltage, ageing of the stabilization apparatus, etc. As the main purpose of the present analysis was to reveal effects much more conspicuous than the errors of figure 2 (Falciani et al., 1967, 1968) we thought it would have been useless to try to improve the performance of the apparatus. This, however means that oscillations in graphs from figure 3 to 7 less than the errors shown in figure 2 have not to be considered as real.

4. Results

Figures from 3 to 7 are few examples of the graphs we obtained. The ordinates give the energies emitted by the flare from a given density/intensity level up. The energies are measured in terms of the energy emitted by a unit surface of the undisturbed chromosphere.

All the measurements have been corrected for foreshortening, as it is illustrated in Solar Geophysical Data (1970).

The symbols used in the graphs correspond to the intensity levels according to Table II wherein is the intensity of the n-level of brightness of the flare, measured in arbitrary units, and [$i_{chr.}$] is the average intensity of the nearby undisturbed chromosphere, measured in the same units.

TABLE II.

Intensity levels for graphs in figure 3 to 7

Symbols	○	●	◐	○	●	◐	○	●	◐
$\Delta = \log \frac{i_n}{i_{chr}}$	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45

As we will consider in a successive paper the detailed behaviour of the H_α evolution curves of the analyzed phenomena, their relationship with radio and X-ray phenomena and the possibility of the construction of a model to give account of the observed features, we shall notice here just some features common to all the analyzed flares.

All these flares show non-monotonic evolution curves but present more or less strong oscillations. Before the flash phase a contraction of all the intensity levels takes place. The higher the level the stronger the contraction. After the main flash other emission picks are present while the general trend of the phenomenon is going down. This is valid for the higher intensity levels; very often the lower levels (near the facula intensity level) almost do not show traces of the presence of the flash also when this is a strong one (sometimes only a slight increasing of the emission is noted). But, on the contrary, it happens that noticeable variations at the lowest levels are not accompanied by any important event at the higher levels (which can also be absent). The presence in the flare of small (also very small) very brilliant areas ($\Delta \geqslant 0.3$) almost always is an indicator of violent phenomena (radio or X-ray).

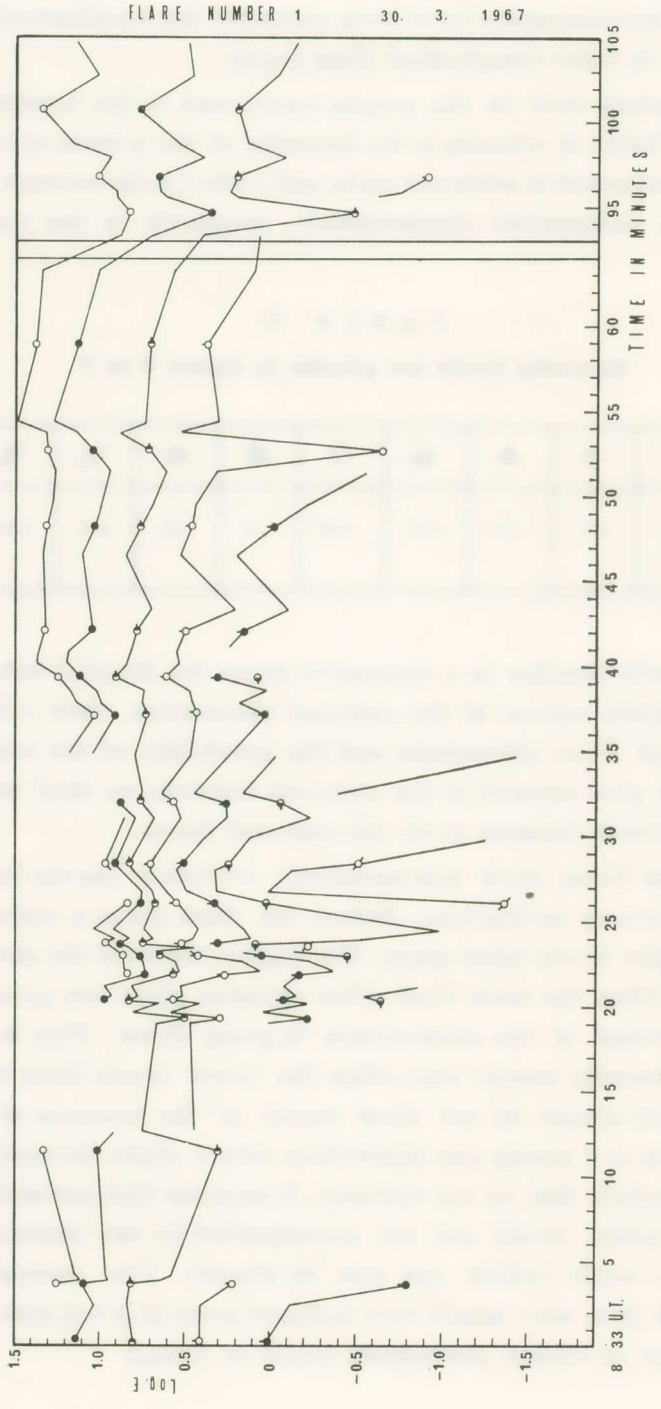

Fig. 3. Evolutive curves for the flare of 30 March 1967.

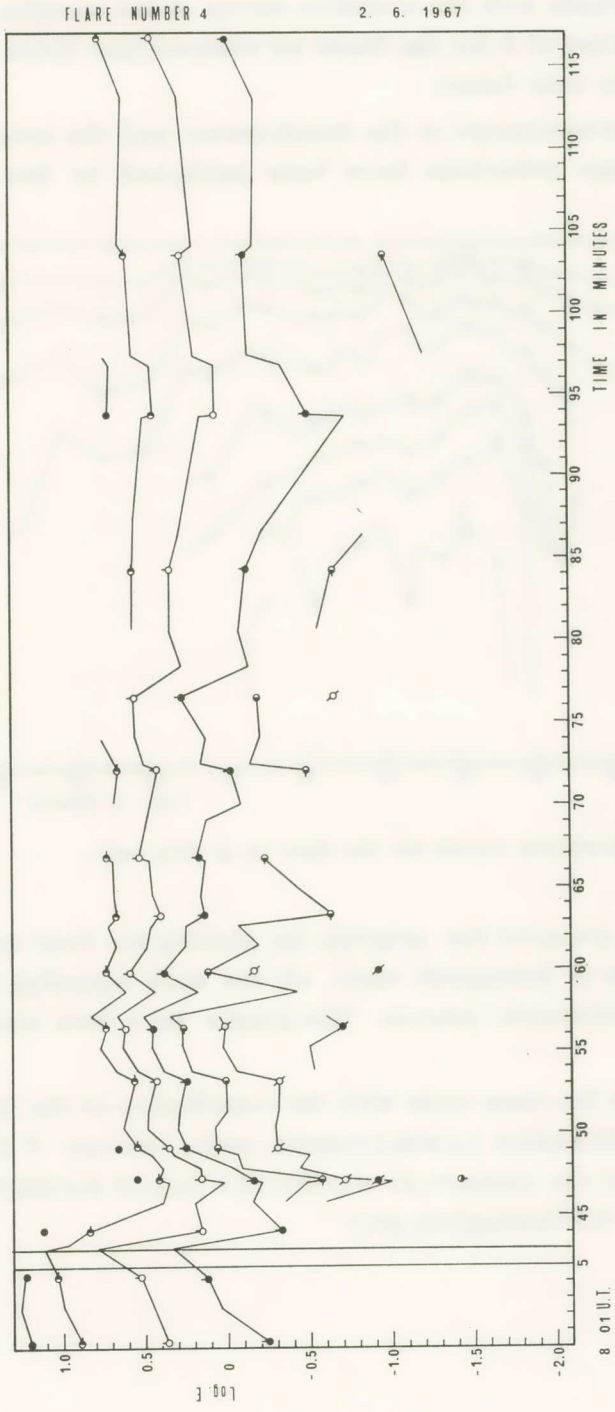

Fig. 4. Evolutive curves for the flare of 2 June 1967.

All the graphs with the evolutive curves of the energies and areas at different values of Δ for the flares we analyzed (see Table 1) will be published in the near future.

All the measurements at the densitometer and the area measuring device and some reductions have been performed by Mrs E. Pettini.

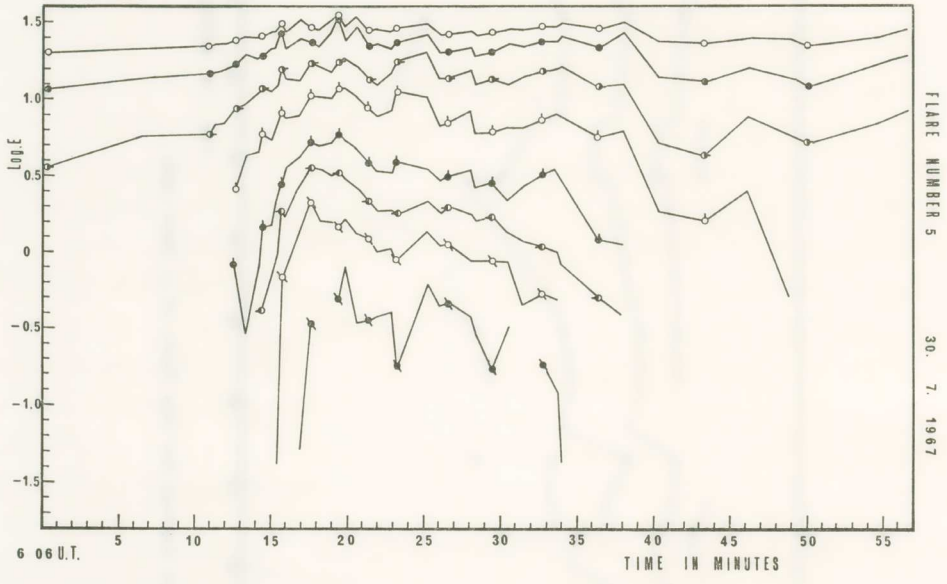

Fig. 5. Evolutive curves for the flare of 30 July 1967.

Mr G. Pettini prepared the program for plotting the final data. Mr E. Brunetti and Mr B. Romagnoli made all the work regarding the photographic isodensitometric process. The graphs have been traced by Mr L. Borriello.

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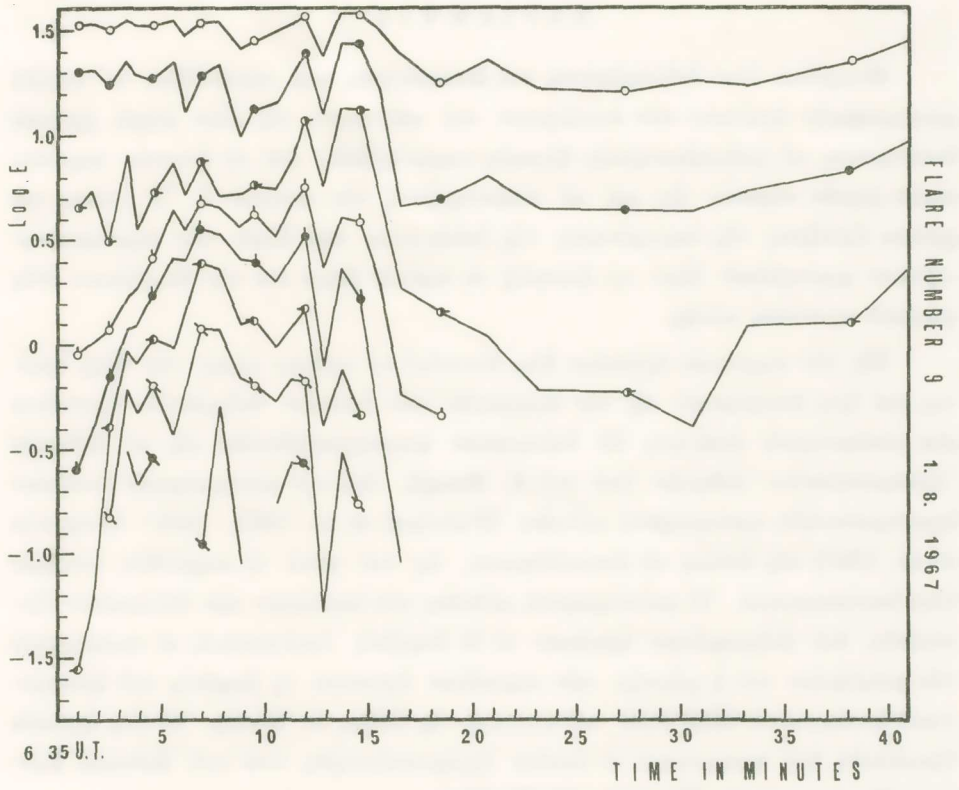

Fig. 7. Evolutive curves for the flare of 1 August 1967.

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ΠΕΡΙΛΗΨΙΣ

Θεωρεῖται λίαν ἐνδιαφέρουσα καὶ ἀπαραίτητος μία προσπάθεια δι' ἀκριβῆ φωτομετρικὴν ἀνάλυσιν τῶν ἐκλάμψεων καὶ σύγκρισιν, εἰς λίαν μικρὰ χρονικὰ διαστήματα, μὲ ῥαδιοηλεκτρικὰς ἡλιακὰς παρατηρήσεις ἐπὶ τὸ δυνατὸν περισσοτέρων μηκῶν κύματος ὡς καὶ μὲ παρατηρήσεις τῶν ἀκτίνων Χ. Ἡ γνῶσις τοῦ χρόνου ἐξελίξεως τῆς λαμπρότητος τῆς ἐκλάμψεως καὶ ὅλων τῶν συμπαρομαρτούντων φαινομένων δέον νὰ ἀποτελῇ τὸ πρῶτον βῆμα διὰ τὴν θεμελίωσιν ἑνὸς φυσικοῦ προτύπου αὐτῆς.

Εἰς τὴν παροῦσαν ἐργασίαν ἥτις ἀποτελεῖ τὸ πρῶτον μέρος τῆς ὅλης ἐρεύνης καὶ ἥτις ἀναφέρεται εἰς τὴν ἀγαγωγὴν τῶν ὀπτικῶν δεδομένων, ἐρευνᾶται μία φωτομετρικὴ ἀνάλυσις 25 ἐκλάμψεων φωτοφραφηθεισῶν εἰς τὸ Ἐθνικὸν Ἀστεροσκοπεῖον Ἀθηνῶν ὑπὸ τοῦ Κ. Μακρῆ. Διὰ τὴν φωτομετρικὴν ἀνάλυσιν ἐχρησιμοποιήθη φωτομετρικὴ μέθοδος (Falciani et al. 1967, 1968: Gregorio et al. 1967) τῆς ὁποίας τὰ ἀποτελέσματα, ὡς καὶ κατὰ τὸ παρελθόν, ὑπῆρξαν λίαν ἱκανοποιητικά. Ἡ φωτογραφικὴ μέθοδος τῶν ἰσοφώτων τῶν ἐκλάμψεων ἐξετελέσθη διὰ βελτιωμένων ὀργάνων οἱ δὲ ἀκριβεῖς ὑπολογισμοί, αἱ καταγραφαὶ τῶν μετρήσεων καὶ ἡ χάραξις τῶν καμπύλων ἐγένοντο τῇ βοηθείᾳ τοῦ ἠλεκτρονικοῦ ὑπολογιστοῦ IBM 7090 τοῦ CNUCE τῆς Πίζας ἐν Ἰταλίᾳ. Ἡ ὅλη ἐργασία ἐξετελέσθη ὑπὸ προσωπικοῦ τὸ ὁποῖον ἐχρηματοδοτήθη ὑπὸ τοῦ Ἐθνικοῦ Κέντρου Ἐπιστημονικῶν Ἐρευνῶν τῆς Ἰταλίας.

Τὰ ἀποτελέσματα ὑπῆρξαν λίαν ἐνδιαφέροντα.

Ἡ παραδεδεγμένη σήμερον κατάταξις τῶν ἐκλάμψεων, εἰς ὅ,τι ἀφορᾷ τὴν σπουδαιότητα αὐτῶν, πρὸς καθορισμὸν τῆς ὁποίας λαμβάνεται ὑπ' ὄψιν μόνον τὸ ἐμβαδὸν σημειουμένης παραπλεύρως τῆς κατ' ἐκτίμησιν λαμπρότητος αὐτῶν (ἀσθενής, μετρία, λαμπρά), δέον νὰ ἐγκαταλειφθῇ διότι δὲν ἀνταποκρίνεται πρὸς τὴν πραγματικότητα.

Τὰ σχήματα 3 - 7 παρουσιάζουν ὀλίγα παραδείγματα τῶν ἐκ τῆς παρούσης ἐρεύνης ἐξαχθέντων συμπερασμάτων. Αἱ τεταγμέναι δίδουν τὰς ἐνεργείας αἱ ὁποῖαι ἐκπέμπονται ἐκ τῶν ἐκλάμψεων ἀπὸ μίαν δοθεῖσαν στάθμην πυκνότητος / ἐντάσεως. Αἱ ἐνέργειαι συγκρίνονται μὲ τήν, ὑπὸ τῆς μονάδος τῆς ἐπιφανείας τῆς ἠρέμου χρωμοσφαίρας, ἐκπεμπομένην ἐνέργειαν. Αἱ καμπύλαι δεικνύουν τὸν τρόπον καθ' ὃν ἐξελίσσονται αἱ ὑπὸ τῆς ἐκλάμψεως ἐκπεμπόμεναι ἐνέργειαι εἰς τὰς διαφόρους φωτομετρικὰς στάθμας αὐτῆς. Αἱ καμπύλαι ἐξελίξεως τῶν ἐκλάμψεων δὲν εἶναι μονοτονικαὶ ἀλλὰ παρουσιάζουν ἰσχυρὰς ταλαντώσεις. Ἀποδεικνύεται οὕτω ὅτι πρὸ τῆς ἐκρηκτικῆς φάσεως λαμβάνει χώραν συστολὴ ὅλων τῶν

σταθμῶν ἐντάσεως τοῦ χρωμοσφαιρικοῦ πυρσοῦ. Ἡ μεγαλυτέρα συστολὴ ἐμφανίζεται εἰς τὴν ὑψηλοτέραν στάθμην. Τὴν στιγμὴν καθ' ἣν ἡ συστολὴ αὕτη λαμβάνει τὴν μικροτέραν τιμὴν ἄρχεται ἡ χρωμοσφαιρικὴ ἔκρηξις. Μετὰ τὸν βραχύν, ἀνοδικὸν καὶ βίαιον κλάδον τῆς μεταβολῆς τῆς λαμπρότητος τῶν ἐκλάμψεων, παρετηρήθησαν εἰς τὸν κατιόντα κλάδον τῆς καμπύλης ἐξελίξεως αὐτῶν, πολλὰ δευτερεύοντα μέγιστα. Τοῦτο ἰσχύει διὰ στάθμας ὑψηλῆς ἐντάσεως. Ἐπίσης διεπιστώσαμεν στενὴν συσχέτισιν μετὰ τῶν ῥαδιοηλεκτρικῶν φαινομένων καὶ ἐκείνων τῶν ἀκτίνων Χ.

Κατὰ τὴν διάρκειαν ἐξελίξεως μιᾶς ἐκλάμψεως παρατηροῦνται ἐντὸς αὐτῆς μικραὶ ἢ πολὺ μικραί, ἀλλὰ λίαν λαμπραὶ περιοχαὶ ($\Delta \geqslant 0.3$).

Ἅπαντα τὰ χαραχθέντα σχεδιαγράμματα μὲ τὰς καμπύλας ἐξελίξεως τῶν ἐκπεμπομένων ἐνεργειῶν καὶ τὰς τοιαύτας συσχετίσεως, τῶν παρατηρηθέντων ἐκρηκτικῶν χρωμοσφαιρικῶν φαινομένων, μετὰ τῶν ῥαδιοηλεκτρικῶν παρατηρήσεων καὶ ἐκπομπῶν ἀκτίνων Χ θὰ δημοσιευθοῦν προσεχῶς.

Θερμαὶ εὐχαριστίαι ἀπευθύνονται πρὸς τὰ Ἐπιστημονικὰ Ἐργαστήρια τῆς Ἀεροπορικῆς Δυνάμεως τῶν Ἡνωμένων Πολιτειῶν τῆς Ἀμερικῆς, καὶ πρὸς τὸ Ἐθνικὸν Κέντρον Ἐπιστημονικῶν Ἐρευνῶν τῆς Ἰταλίας τὰ ὁποῖα ἐχρηματοδότησαν τὸ ἀνωτέρω πρόγραμμα, καθὼς καὶ πρὸς τὸ προσωπικὸν (Κον καὶ Καν Pettini, Κον Brunetti, Κον Romagnoli, καὶ Κον Borriello) τὸ ὁποῖον ἐπεμελήθη τῆς παρασκευῆς τῶν φωτογραφικῶν ἰσοπύκνων τῶν διαφόρων ἐκλάμψεων καὶ ἐξετέλεσε τὰς μετρήσεις, τὰς περισσοτέρας ἀναγωγὰς καὶ τὴν χάραξιν τῶν καμπύλων τῶν τελικῶν ἀποτελεσμάτων.

★

Ὁ Ἀκαδημαϊκὸς κ. **Ἰ. Ξανθάκης,** παρουσιάζων τὴν ἀνωτέρω ἀνακοίνωσιν, εἶπε τὰ ἑξῆς :

«Ἔχω τὴν τιμὴν νὰ παρουσιάσω εἰς τὴν Ἀκαδημίαν Ἀθηνῶν τὴν ὑπὸ τὸν τίτλον «Φωτομετρικὴ Ἀνάλυσις Χρωμοσφαιρικῶν τινων Φαινομένων καὶ Ἀναγωγὴ τῶν Ὀπτικῶν Δεδομένων αὐτῶν», ἐργασίαν τῶν κ.κ. Mario Rigutti καὶ Roberto Falciani, διευθυντοῦ καὶ ἀστρονόμου, ἀντιστοίχως, τοῦ ἐν Νεαπόλει τῆς Ἰταλίας Ἀστεροσκοπείου Capodimonte, καὶ τοῦ κ. Κωνσταντίνου Μακρῆ διευθυντοῦ τοῦ Κέντρου Ἐρευνῶν Ἀστρονομίας καὶ Ἐφηρμοσμένων Μαθηματικῶν τῆς Ἀκαδημίας Ἀθηνῶν.

Ἡ ἐργασία αὕτη ἀναφέρεται εἰς τὴν φωτομετρικὴν μελέτην εἴκοσι πέντε (25) χρωμοσφαιρικῶν ἐκρήξεων (ἐκλάμψεων), αἱ ὁποῖαι ἐφωτογραφήθησαν ὑπὸ τοῦ κ. Μακρῆ εἰς τὸ Ἐθνικὸν Ἀστεροσκοπεῖον Ἀθηνῶν. Ἡ φωτομετρικὴ ἀνάλυσις

τῶν ἐκλάμψεων τούτων ἐγένετο δι' εἰδικῆς φωτογραφικῆς μεθόδου εἰς τὸ ἐν Φλωρεντίᾳ Ἀστεροσκοπεῖον τοῦ Arcetri.

Ἡ ἐν λόγῳ μέθοδος ἐπέτρεψεν εἰς τοὺς ἀνωτέρω ἐρευνητὰς νὰ προσδιορίσουν κατὰ ποῖον τρόπον ἐξελίσσονται αἱ καμπύλαι ἐνεργείας, αἱ ἐκπεμπόμεναι ἀπὸ τὰς ἐκλάμψεις εἰς διαφόρους ὀπτικὰς στάθμας. Ἡ ἔρευνα αὕτη δεικνύει ὅτι αἱ καμπύλαι ἐξελίξεως τῶν ἐκλάμψεων δὲν εἶναι μονοτονικαί, ἀλλὰ παρουσιάζουν, κατὰ τὸ μᾶλλον ἢ ἧττον, ἰσχυρὰς ταλαντώσεις, πρὸ τῆς ἐκρηκτικῆς δὲ φάσεως τῆς ἐκλάμψεως λαμβάνει χώραν μία συστολὴ τοῦ χρωμοσφαιρικοῦ πυρσοῦ. Τὴν στιγμὴν καθ' ἣν ἡ συστολὴ αὕτη λαμβάνει τὴν μικροτέραν τιμήν, ἄρχεται ἡ χρωμοσφαιρικὴ ἔκρηξις.

Ἡ ἔρευνα αὕτη ὑπεστηρίχθη οἰκονομικῶς ὑπὸ τῶν Ἐπιστημονικῶν Ἐργαστηρίων τῆς Ἀεροπορικῆς Δυνάμεως τῶν Ἡνωμένων Πολιτειῶν τῆς Ἀμερικῆς, ἀφ' ἑνός, καὶ ὑπὸ τοῦ Ἐθνικοῦ Κέντρου Ἐπιστημονικῶν Ἐρευνῶν τῆς Ἰταλίας, ἀφ' ἑτέρου».