ΑΣΤΡΟΝΟΜΙΑ.— **Study of the motion of three solar prominences,** *by Helen C. Dara* and *Constantin J. Macris* *, Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ι. Ξανθάκη.

Abstract. We study the motion of three eruptive prominences observed at the National Observatory of Athens in 1967.

1. INTRODUCTION

In this paper we study the motion of three characteristic prominences which were observed on April 14, 1967, August 19, 1967, and November 24, 1967. We measure the heights they reach, their velocity changes and we examine whether these prominences reinforce Pan Puh's opinion, that there are no abrupt changes of the velocity of the prominence plasma as Petit had concluded. This is a preliminary work to a more extensive study of the motion and dynamics of solar prominences.

We find the mean velocity of the prominence by measuring the radial distance of some characteristic elements. The movement in all prominences is predominantly radial. To find the velocity of each element we measure its distance from the surface (height) in a series of photographs and we find its change with time. We choose the elements so that they are easily recognizable in all photographs. The photographs have been taken at the same wavelength and with the same exposure time so that they are comparable. All the material has been taken with the triplet telescope of the National Observatory of Athens by C. Macris.

2. MEASUREMENTS

The measurements are carried out on sketches. This method has the advantage that we can have at the same time the various stages of the evolution of the prominence and that the recognition of the elements is easy. On the other hand it has the disadvantage of a bigger error

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because of the drawing of the prominence. The error can be diminished by measuring the height from the center of each element or by taking the mean value of its highest and lowest point.

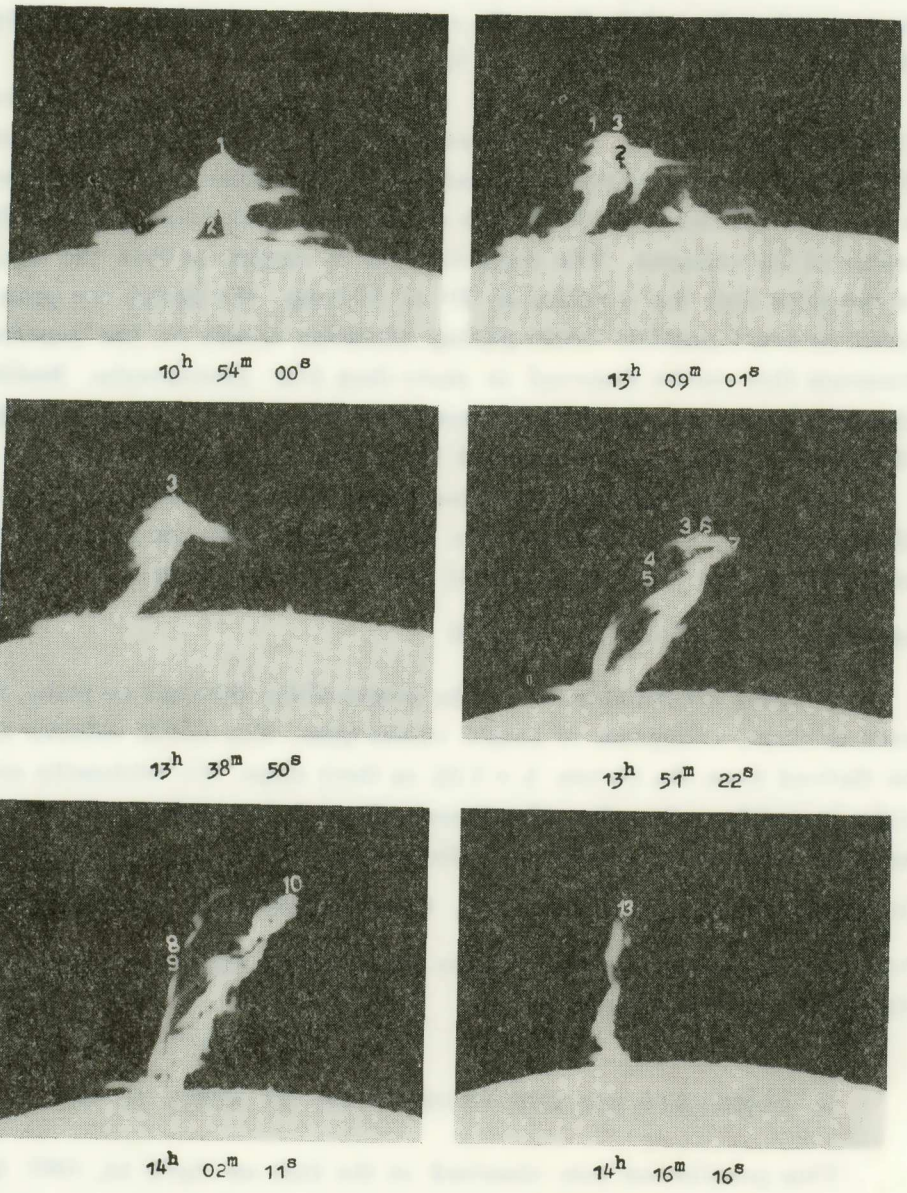
The picture is projected by an appropriate device which gives various magnifications. Two cocentric quarters of radius of 20 cm and 20,5 cm have been printed on special paper. The paper is placed in such a way that the center of the image of the solar disk coincides with the center of the quarters. The magnification is chosen so that the image of the solar disk has a radius of 20 or 20,5 cm. We sketch the prominence in every possible detail paying attention mostly on the separate elements that can be observed in more than four photographs. Besides the prominence, we sketch the surrounding permanent features as points of reference. This work is repeated for all the chosen photographs.

Let r be the radius of the solar image in cm and R the radius of the sun in Km, D the distance of a chosen point from the center of the solar disk in cm, then the height of the point must be $d = D - r$ and in Km $h = \frac{R}{r}(D - r)$, $h = \frac{R}{r} d$.

Working accordingly for all the points of the sketches we make, for each of them, a diagram of height versus time. The radial velocity can be derived from the curves $h = f(t)$ as their slope. We arbitrarily consider it positive when the point is ascending, h increasing with t, and negative when it is descending, h decreasing with t. The mean velocity is calculated by $v_r = \frac{h}{t}$ where h, t are the height and time differences from one photograph to the previous one, taken at time t, and on which the height of the point is h.

3. COMMENTS ON THE PROMINENCE OF APRIL 14, 1967.

This prominence was observed at the limb on April 14, 1967 (figure 1). One can see, observing its top point (point 1), that its movement at the begining is slow. After $11^h\ 10^m\ 00^s$ UT an ascending movement can be clearly seen. While the top of the prominence is constantly accelerating — the higher points the greater the velocity (point 3) —, the base of the prominence, at the center of the arch which is formed there



Prominence of April 14, 1967

Fig. 1.

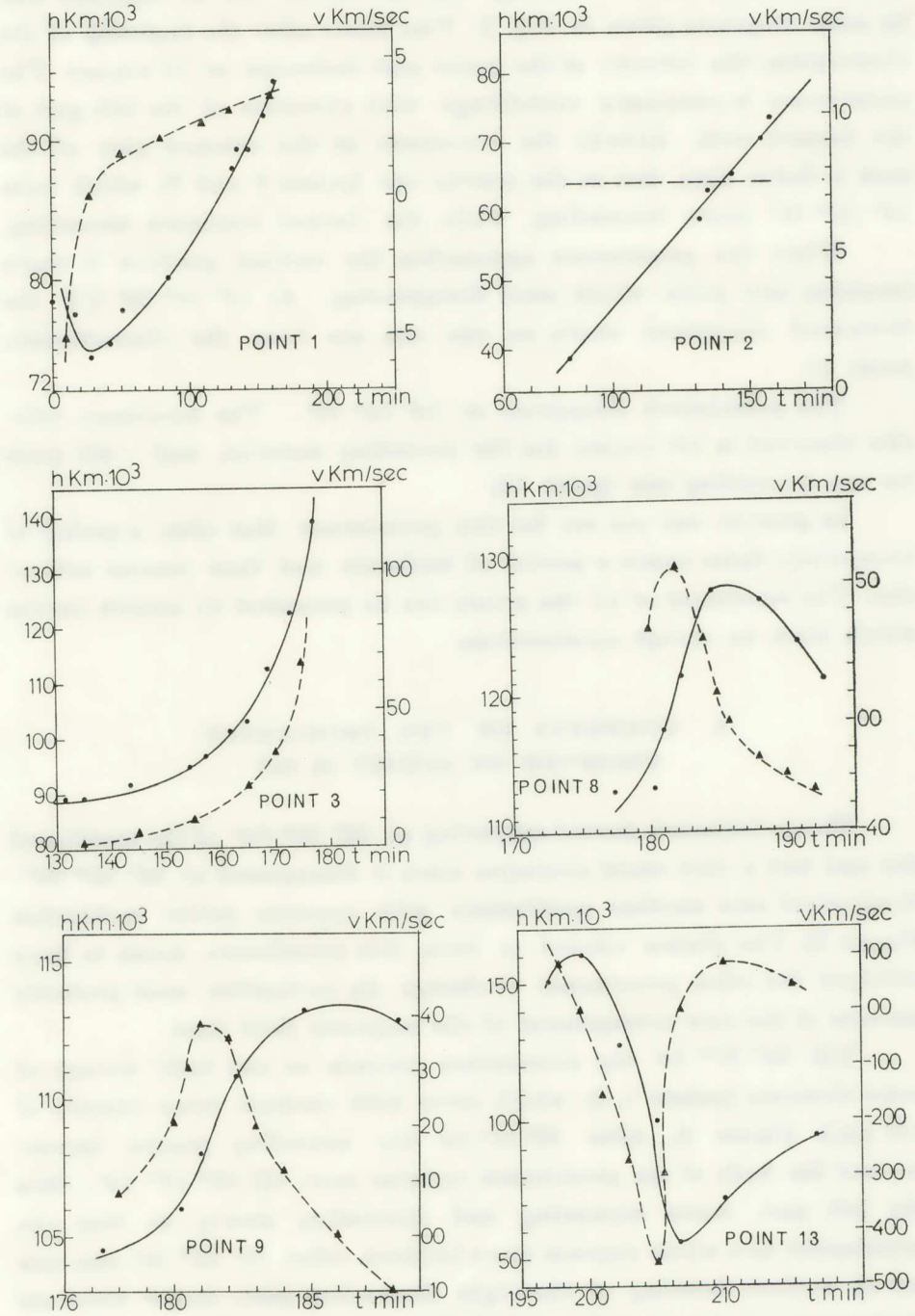

h Km·10³
v Km/sec
POINT 1
POINT 2
POINT 3
POINT 8
POINT 9
POINT 13
t min

Fig. 2.

(point 2) is constantly ascending. The movement can be followed also by some diagrams given in Fig. 2. Two hours after the begining of the observation, the velocity of the upper part increases to 70 km/sec. The prominence is constantly «unfolding» with elevation of the left part of the formed arch. Already the movement at the concave part of the arch is faster than that at the convex one (points 8 and 9) which from $14^h\ 02^m\ 01^s$ starts descending, while the former continues ascending.

When the prominence approaches the vertical position it starts breaking into parts which start disappearing. At $14^h\ 13^m\ 38^s$ UT the downward movement starts, as one can see from the characteristic point 13.

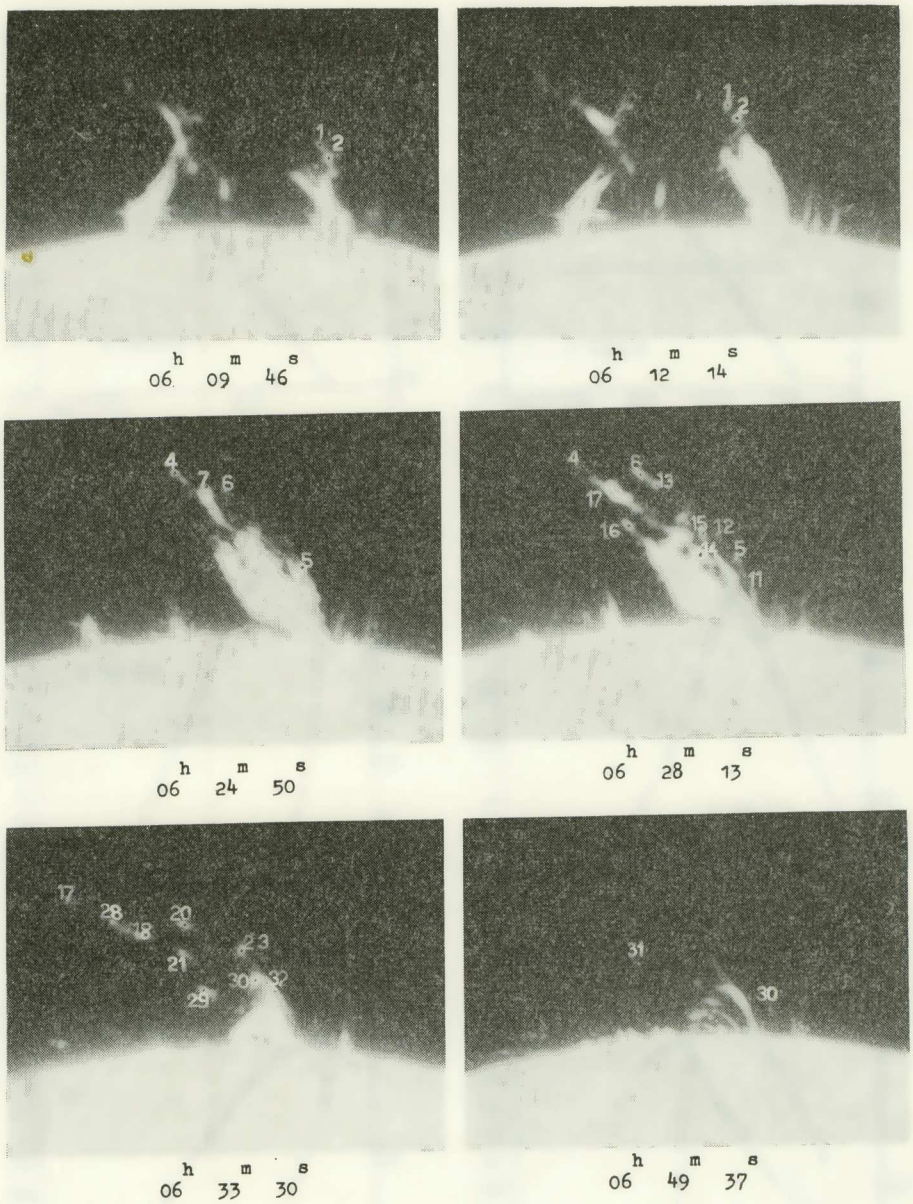
The prominence disappears at $14^h\ 54^m\ 00^s$. The maximum velocity observed is 150 km/sec for the ascending material, and −460 km/s for the descending one (point 13).

In general, one can say for this prominence that after a period of tranquillity there comes a period of moderate and then intense activation. The movement of all the points can be presented by smooth curves which show no abrupt accelerations.

4. COMMENTS ON THE PROMINENCE OBSERVED ON AUGUST 19, 1967

This prominence started appearing at $06^h\ 06^m\ 04^s$ of the mentioned day and had a very rapid evolution since it disappeared at $06^h\ 56^m\ 06^s$. It appeared near another prominence with opposite initial inclination (figure 3). The plasma ejected to form this prominence seems to have oblidged the other prominence to change its inclination most probably because of the new arrangement of the magnetic field lines.

Till $06^h\ 21^m\ 24^s$ the prominence ascends as one body except of some elements (points 1, 2) which move with constant mean velocity of 160 km/s (figure 4). After $06^h\ 12^m\ 14^s$ the ascending plasma increases and the body of the prominence remains erect till $06^h\ 12^m\ 14^s$, then the left part starts separating and descending slowly, so that the prominence as a whole appears more inclined. After $06^h\ 24^m\ 51^s$ one can see an evident bending of the right descending part, larger elements start now separating from the main body (points 4 and 16), and ascend with



Prominence of August 19, 1967

Fig. 3.

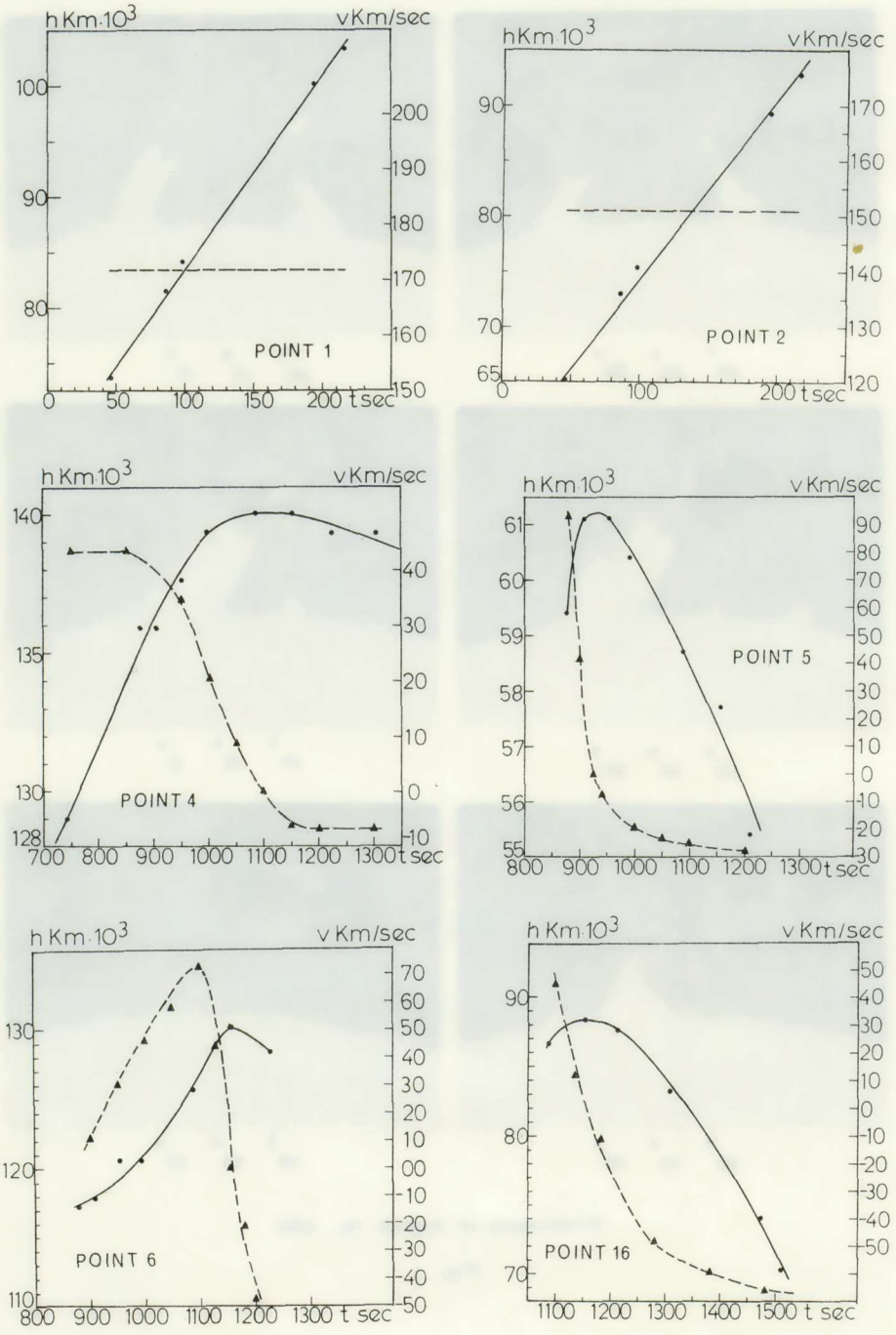

h Km·10³
v Km/sec
POINT 1
t sec
POINT 2
POINT 4
POINT 5
POINT 6
POINT 16

Fig. 4.

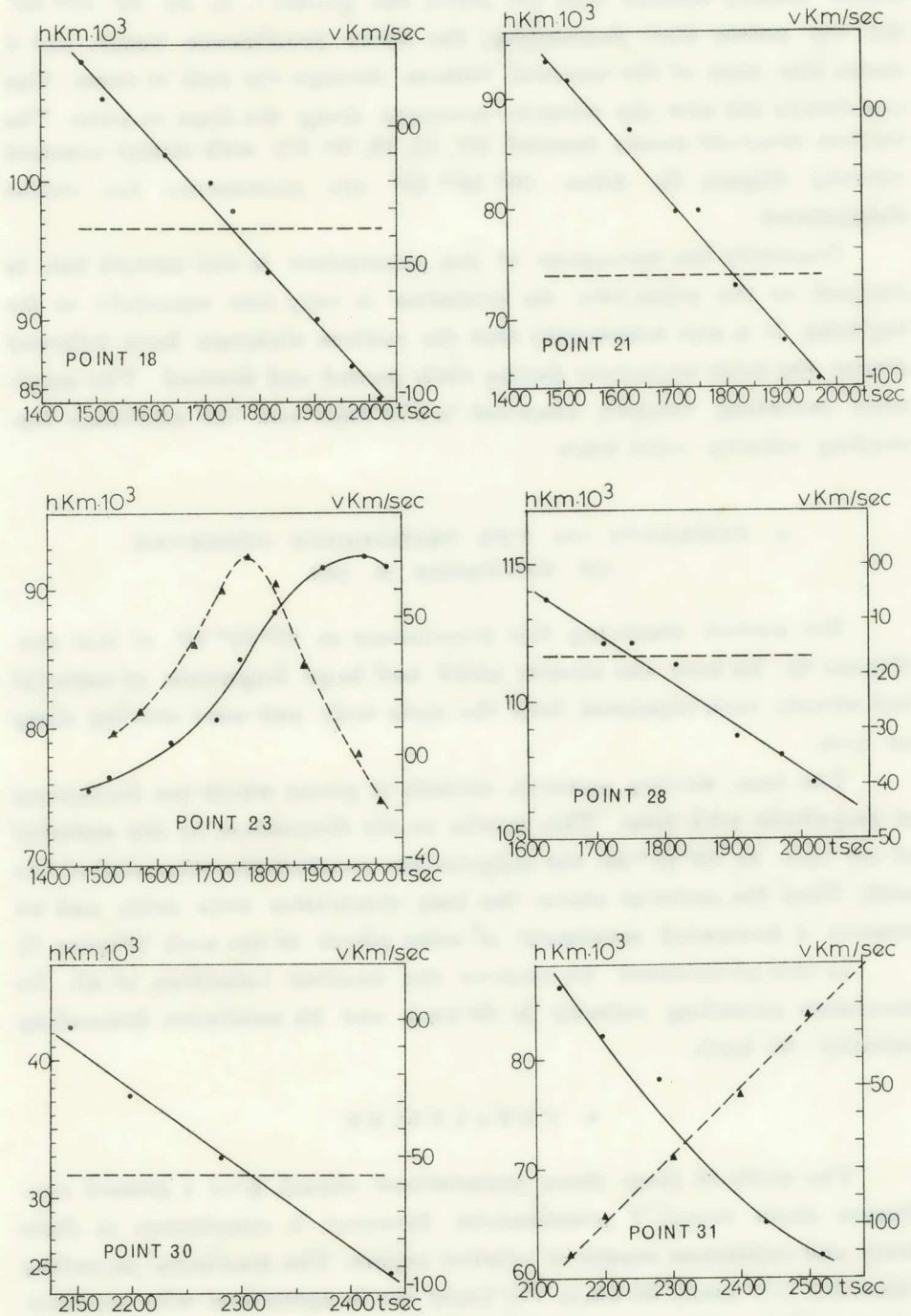

hKm·10³
vKm/sec
POINT 18
POINT 21
POINT 23
POINT 28
POINT 30
POINT 31
tsec

Fig. 5.

steady velocity smaller than the initial one (points 1, 2). By $06^h\ 27^m\ 06^s$ the top points start descending, the whole prominence bends, and it seems that most of the material returns through the path it came. One can clearly see now the material arranged along the lines of force. The various observed points descend (21, 18, 28, 30, 31) with almost constant velocity (figure 5). After $06^h\ 56^m\ 42^s$ the prominence has almost disappeared.

Generally the movement of this prominence is also smooth but, in contrast to the other two, its evolution is very fast especially at the begining. It is also noteworthy that the various elements have followed almost the same trajectory during their ascend and descend. The maximum ascending velocity observed is 172 km/s and the maximum descending velocity —111 km/s.

5. COMMENTS ON THE PROMINENCE OBSERVED ON NOVEMBER 24, 1967

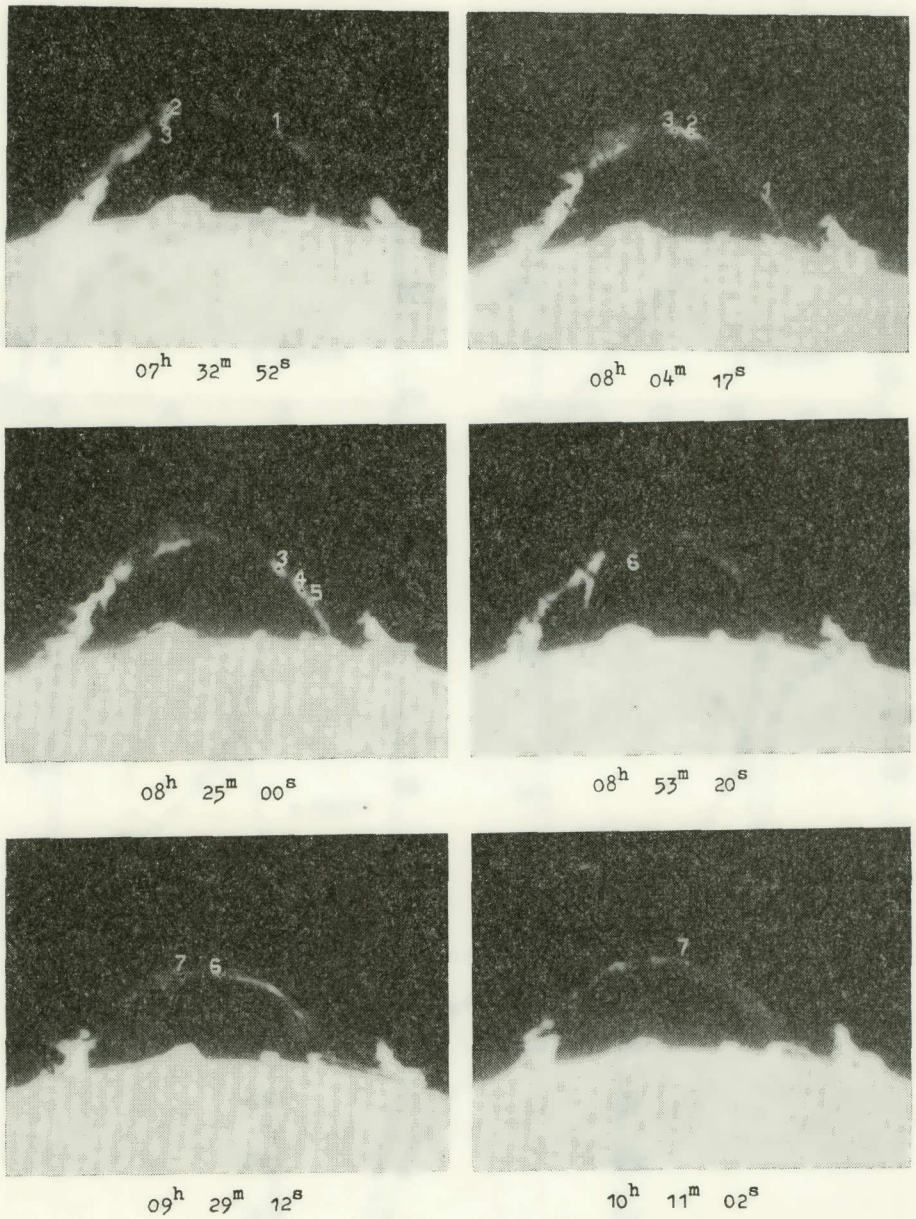
We started observing this prominence at $07^h\,52^m\,52^s$ of that day. (Figure 6). Its base was already titled and large fragments of material had already been separated from the main body and were moving along an arch.

The base, moving upwards, spreads to pieces which are decreasing in magnitude with time. This results to the diminution of the material of the base. By $09^h\,01^m\,29^s$ the material has reached the other end of the arch. Then the material above the base diminishes even more and we observe a downward movement of some pieces of the arch (Figure 7).

In this prominence we observe the smallest velocities of all. Its maximum ascending velocity is 30 km/s and its maximum descending velocity - 64 km/s.

6. CONCLUSION

The study of these three prominences cannot give a general conclusion about eruptive prominences. However it contributes to their study and reinforces results of relative papers. The maximum ascending velocities (150 km/s, 30 km/s, 170 km/s) are in agreement with measurements made by other observers. Bruzek (1969) has found for arch shaped



Prominence of November 24, 1967

Fig. 6.

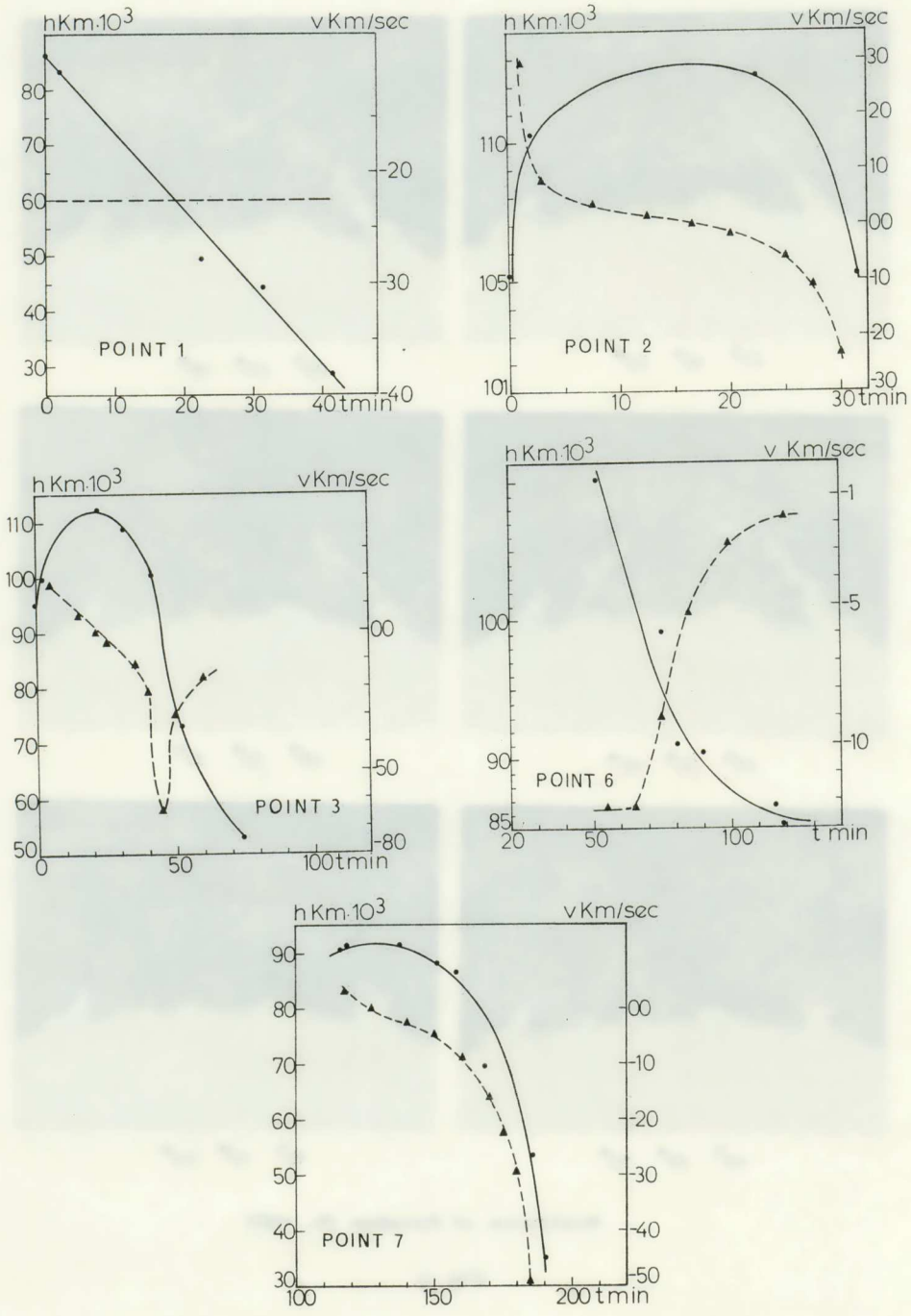


Fig. 7.

prominences velocity about 50 km/s while Hyder et al. (1970) has found for moving prominences ascending velocities of 30 - 150 km/s. In general, during activation, prominences reach a velocity of 30 - 50 km/s or more (Larmore, L. 1953). Some of them can reach an escape velocity (400 km/s at h = 100,000 km in the corona). In our case none of the prominences has reached such an ascending velocity.

We may also note that the diagrams of the velocity versus time for all the points of the prominences are smooth and no abrupt changes, that is accelerations, have been noticed. This is in agreement with Pan Puh's conclusion (1939) who proved untrue Patit's laws (1932, 1936) for the eruptive prominences.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν ἐργασίαν ἐμελετήθη ἡ κίνησις τριῶν ἐνεργῶν προεξοχῶν εἰς τὸ χεῖλος δι' ὑλικοῦ ληφθέντος διὰ τοῦ τριπλοῦ τηλεσκοπίου τοῦ Ἐθνικοῦ Ἀστεροσκοπείου Ἀθηνῶν εἰς τὴν γραμμὴν H_α. Κατεσκευάσθησαν τὰ διαγράμματα ὕψους - χρόνου, ταχύτητος - χρόνου διὰ διάφορα κινούμενα τμήματα τῶν προεξοχῶν. Αἱ ταχύτητες αὐτῶν δὲν παρουσιάζουν ἀποτόμους μεταβολὰς αἱ δὲ τιμαὶ τῶν ταχυτήτων διὰ τὸν τύπον αὐτὸν τῶν προεξοχῶν εὑρίσκονται σύμφωνοι μὲ ἀποτελέσματα ἄλλων παρεμφερῶν ἐργασιῶν.

REFERENCES

K. A. Bruzek, Solar Phys., **8**, 29, 1969.
C. L. Hyder - B. W. Lites, Solar Phys., **14**, 147, 1970.
L. Larmore, Astrophys. J., **118**, 436, 1953.
M. Pan Puh, Annales de l'Observatoire de Paris, **VIII**, 1939.
E. Pettit, Aph. J., **76**, 22, 1932.
———, Pr. Ac. Jc. Wash., **22**, No 5, 249, 1939.