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# SMALL SCALE STRUCTURE AND DYNAMICS OF PROMINENCES*

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**Abstract.** This review is concerned with the fine structure of quiescent and active region prominences. The aspect and evolutionary behaviour of the fine structure of these prominences during the phases of their formation, stable state and eruption is discussed in detail. The dynamic models explaining the process of formation as well as the observed fine structure of these two types of prominences are proposed.

## 1. INTRODUCTION

The fact that prominences consist of fine filamentary structure is well known for more than one hundred years, since observations by Fearnley (1872-73) (Figure 1) and Secchi (1875-77). In spite of this even now the fine structure of prominences is not well understood and still represents some puzzling questions.

Nearly all types of prominences display fine filamentary structure of more or less the same width but various lengths of the individual fine filaments. According to a number of determinations and evaluations we know that the diameters of the prominences fine filamentary structures are in the range from 1/3 to 3 arcseconds, that is from around 0.25 to 2 Mm. Nevertheless, there are well founded evidences that some of the finest prominence threads are of subtelescopic resolution. Our best solar telescopes presently in operation - for example the Sacramento Peak Vacuum Tower Telescope - are capable to distinguish on the Sun the fine stuctures as small as 1/3 of arcsecond only. On the other hand filamentary structures wider than 3 arcseconds or so, observed at some occasion in prominences, seem to be formed by several finer filaments.

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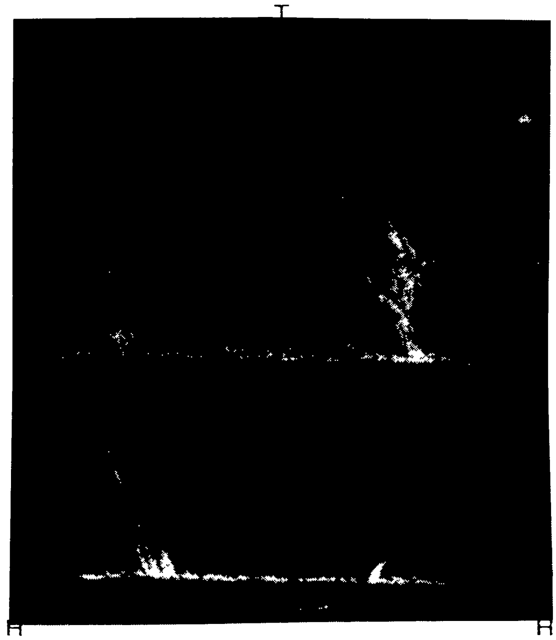

Fig.1. Filamentary structure of prominences is known since more than one hundred years. This chalk drawing has been made by C.F. Fearnley, professor of the University of Christiana in Oslo in 1872.

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Fig.2. A composite Hα-filtergram showing prominences in emission on the limb and in absorption against the disk (filaments). One can distinguish the quiescent prominence filaments (QPFs) laying at the periphery of the active regions or in between of them as well as the active region filaments (ARFs) located inside the active regions.

In the following I would like to concentrate on how the fine structure looks like in the quiescent prominences (QPs) and active region prominences (ARPs), how it behaves during a steady and active phase of these prominences, and what peculiarities it displays at some occasion. Moreover, I intend to present some ideas on the formation and evolution of these two types of prominences, developed mainly on the basis of Hα observations performed at the Wroclaw Observatory, Big Bear Solar Observatory, Holloman and Ramey US Air Force Base Observatories, and the Sacramento Peak National Solar Observatory.

The QPs and ARPs appear on the disk as dark objects, in a form of long and thin threads - that is the reason that they are comprise by a common name - the filaments. Hereafter, the quiescent prominence filaments will be referred as the QPFs while the active region filaments as the ARFs.

ARPs are observed within the active regions, the QPs ones, on the other hand, at the periphery or in between the active regions (Figure 2). It is clear from a variety of data that the filaments occupy unique locations in the magnetic field, namely, they overlie as a rule the magnetic neutral lines, that is to say, the polarity inversion lines of the photospheric longitudinal magnetic field (Babcock and Babcock 1955, Howard 1959, Howard and Harvey 1964, Avignon et al.1964, Martres et al. 1966, Smith and Ramsey 1967, McIntosh 1972). Strictly spiking, the relatively dense material revealed in QPs and ARPs is frozen-in into a part of a huge magnetic system (HMS) closely connected with a neutral line (Rompolt 1984 - Paper I, 1987 - Paper III, Rompolt and Bogdan 1986 - Paper II).

## 2. ACTIVE REGION PROMINENCES

ARPs (or ARFs) are strongly elongated structures laying low within the chromosphere. On the limb they can be observed at rare occasions in the form of fairly long, horizontally stretched prominences slightly protruding above the chromosphere (Figure 3 and 4). The shapes that display the ARPs during their steady state phase, while seen above the limb chromosphere, are much the same (cp. Figure 3 and 4).

The average dimensions of ARFs are: length 50 Mm, height 10 Mm, and width of a few Mm (Schmieder 1987, 1989a). According to Adams and Tang (1977) the average height of short lived ARFs is of 7.3 Mm only.

The ARFs usually exhibit clear fibril structure along the axis. On high-resolution Hα-pictures of active regions it is easily visible that the filaments consist of a number of tightly packed fibrils of various

Fig.3. An active region prominence (ARP) of 1987.09.10 streatched low above the chromosphere at 1147 UT (Large Coronograph of the Wroclaw Astronomical Institute - hereafter called LC-Wroclaw).

Fig.4. An ARP observed on 1989.05.24 at 0549 UT (Small Coronograph of the Wroclaw Astronomical Institute - hereafter called SC-Wroclaw). The fibril structure is clearly seen at its right end.

Fig.5. An ARP of 1984.04.20 seen above the solar limb during the phase of its activation at 0657 UT (LC-Wroclaw).

length. Some of the constituent fibrils are of the length typical for normal fibrils (12.5 Mm) some other seem to be twice or three times as long as the normal ones (Paper II). Such a conspicuous example of fine filamentary structure of an ARF seen in absorption on the disk during an early phase of its activation is shown in Figure 7 as recorded in Hα by Gaizauskas. Note that the fine filaments grouped in several segments are oriented parallel within every one segment. Turn attention to various length of the constituent fibrils.

The fine filamentary structure of ARPs is clearly seen on the limb during a phase of their activation or an early phase of their eruption. At that time the ARPs are lifted up above the chromosphere and their internal structure become more loose (Figure 5 and 6).

The width of the fine fibrile structure of ARPs is in most cases in the range from 1/3 to 2 arcseconds or so (from 0.25 to 1.5 Mm).

A comprehensive reviews on mass motion in ARPs and QPs have been recently done by Schmieder (1987 or 1989a, 1989b). Here I would like to recall some more important findings in this field.

In sequences of high-resolution pictures of active regions one can see a continuous flow of material along the axis of most ARFs (Malherbe et al. 1983, and Simon et al. 1986b).

Motions in fine fibril structure of ARFs were observed in downward, upward and horizontal directions.

Upflows with average velocities of 0.5 km $s^{-1}$ in Hα and 5.6 km $s^{-1}$ in C IV λ154.8 nm were observed in several ARFs by Schmieder et al. (1984).

Upflows and downflows were discovered on both sides of filament axis respectively by Mein (1977) in Hα (-7.0 - +5.5 km $s^{-1}$), and Schmieder et al. (1985) in Hα and C IV (< 10 km $s^{-1}$).

Horizontal motions of 5 km $s^{-1}$ inclined to the filament axis by $20^{\circ}$ were detected by Malherbe et al. (1983) in Hα. Such motions were also determined by Vial et al. (1979, 1980) in an ARP observed at the limb and appeared to be of up to 20 km $s^{-1}$ in H Lα, Mg II k and h, Ca II H and K, and of 8 km $s^{-1}$ in O VI λ103.2 nm line. Nearly all observations mentioned above can be interpreted as mass motion along fine loops inclined to the filament axis. Schmieder et al.(1985) prefer to interpret their observations as mass flow along a spiral trajectory.

The ARFs are formed over intervals of a dozen minutes or so to severals days (Smith 1968, Martin 1973, 1986).

A process of formation of ARFs by a coalescence of fibrils has been reported by Smith (1968), Martin (1973), Tanaka (1976), and Rompolt and Bogdan (1986).

Fig.6. An activated ARP of 1983.06.25 at 0744 UT lifted above the chromosphere displays fine filamentary structure (LC-Wroclaw).

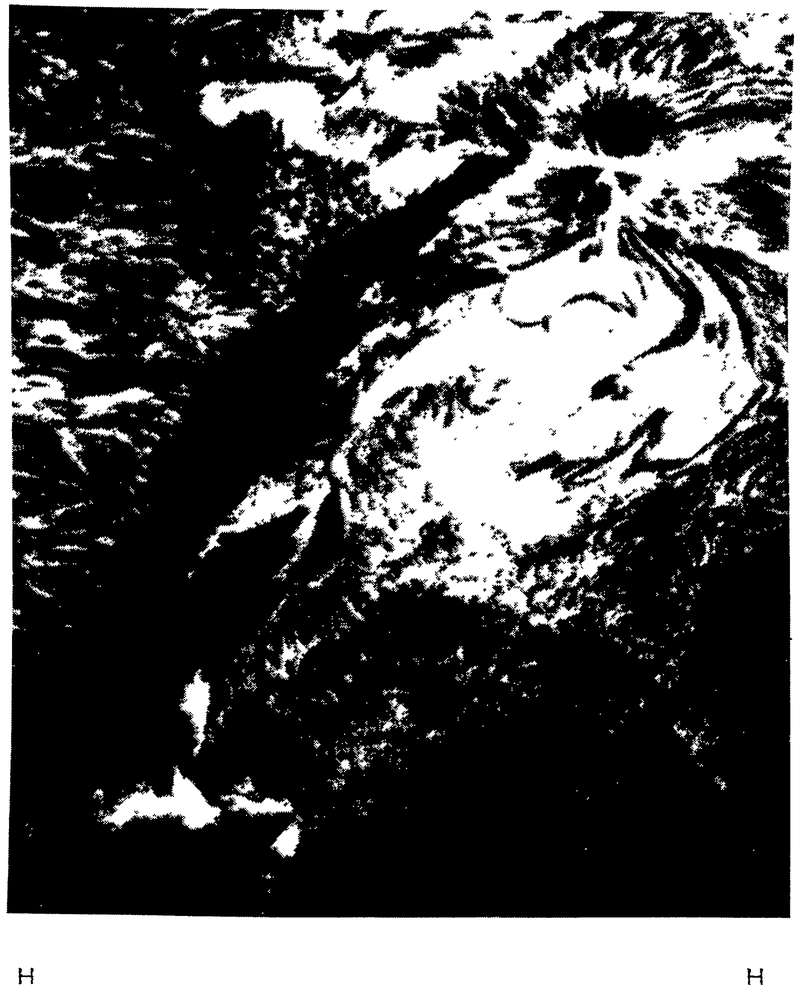


Fig.7. An ARF of 1978.05.30 at 1515 UT seen during the phase of activation reveals a system of fine filaments. Note that nearly all fine filaments exhibit parallel arrangement (courtesy V.Gaizauskas, Ottava River Solar Observatory).

## 3. VELOCITY AND MAGNETIC SHEAR IN FILAMENT CHANNELS

A crucial role in the process of formation of QPs and ARPs seems to play a large-scale mass motion in the filament channel on either side of the neutral line (see Paper II and III), recently extensively investigated. In view of the fact that this mass motion leads to creation of the fine filamentary structure in ARPs and to an overall arrangement of that fine structure in QPs it seems reasonable to review here cursorily more important achievements in this field.

Two types of such dominant mass motions on either side of the filament long axis or magnetic neutral line seem to be at work (Paper II): the anti-parallel (Figure 8a), and parallel (Figure 8b). In some cases, however, the observations suggest the existence of a smaller converging velocity component directed towards the neutral line.

Foukal (1971a) first mentioned on the possibility that filaments are located in a zone of velocity shear between two opposing streams with mass motion components paralleling the filaments. Now, it is more and more obvious that the QPFs and ARFs are located at sites of velocity shear, and by inference, of magnetic shear (e.g., Athay 1989). Indeed, observations near magnetic neutral lines give evidence on strong shear in magnetic field (e.g., Zirin and Tanaka 1973, Krall et al. 1982).

The existence of velocity shear deduced from observations in photospheric and/or chromospheric spectral lines near the magnetic neutral line has been reported by Martres et al.(1971, 1974), Martres and Soru-Escaut (1977), Harvey and Harvey (1976, 1980) and Kartashova (1979). The velocity shear and converginig mass motion near filaments has also been detected on the basis of observations taken in UV spectral lines formed in the transition layer chromosphere-corona or prominence-corona (Athay et al. 1985a,b, 1986a,b, Athay 1985, 1989).

Such a large-scale velocity shear could be caused either by an action of the differential rotation on some solar regions permeated by relatively strong magnetic field of the opposite polarity, by a large-scale circular eddy in the solar atmosphere or the rotation of a more significant spot in a spotgroup (see Figure 9). Rotation of filaments around the "pivot points" and large scale convection identified with the "azimuthal rolls" detected by the Meudon Group (Escaut-Soru et al. 1984, Soru-Escaut et al. 1985, 1986, Martres et al. 1986, Mouradian et al. 1987, Ribes et al. 1985, Ribes 1986) appears to be also a manifestation of the large-scale motions in the vicinity of filaments.

Shearing motions in the chromosphere in association with the ARFs and QPFs formation has been observed in Hα by Martin (1986), Rompolt and Bogdan (1986) and Rompolt (1987).

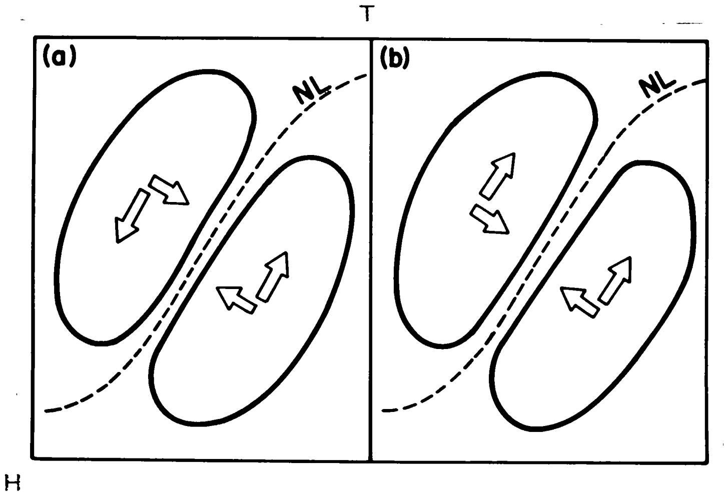



Fig.8. Two types of large-scale converging mass motion about the magnetic neutral line (NL). a - anti-parallel, b - parallel mass motion.

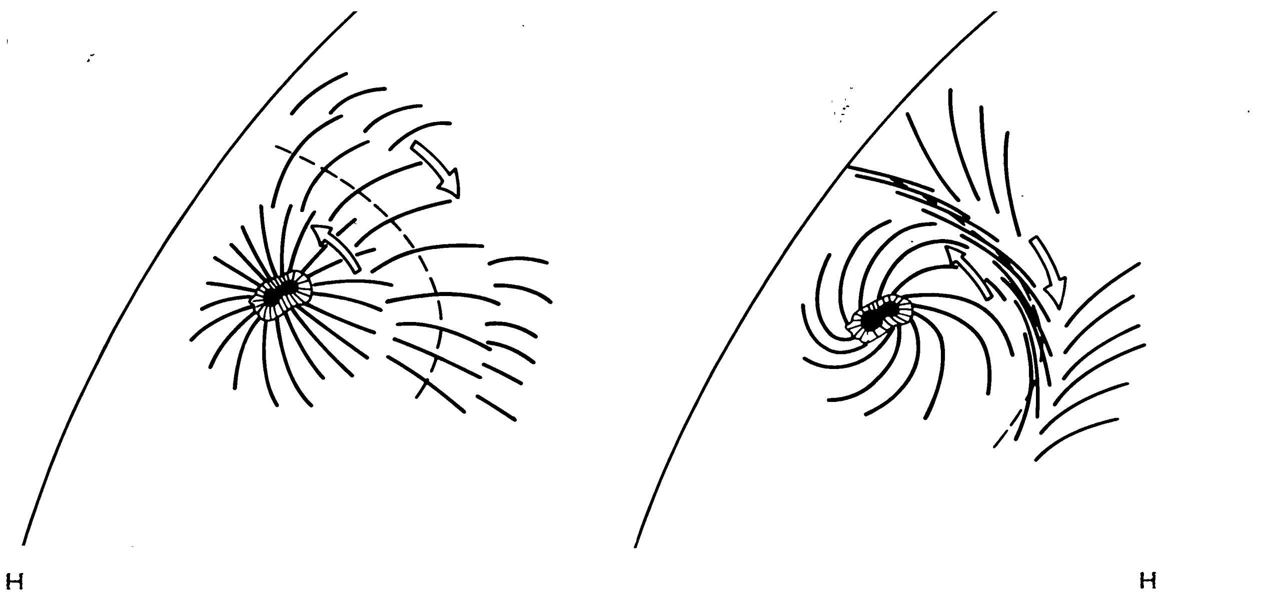



Fig.9. ARF formation in anti-parallel converging mass motions (Rompolt and Bogdan 1986).

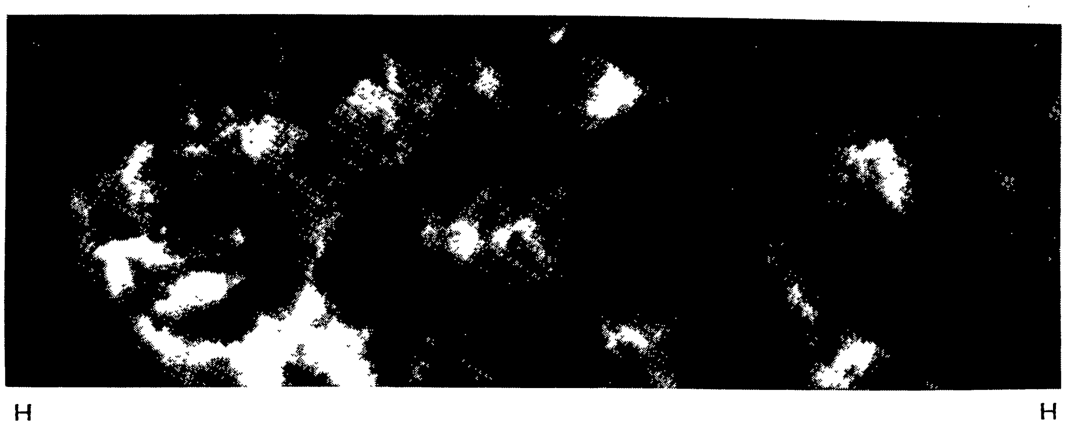



Fig.10. An ARF formed by anti-parallel converging mass motions (courtesy U.S. Air Force Solar Observatory, Holloman). Cp. with Figure 8.

## 4. FORMATION OF ACTIVE REGION PROMINENCES



The problem of formation of QPs and ARFs has been reviewed in detail by Martin (1989). Nevertheless, in the following I would like to present our dynamic models illustrating the process of formation of the ARPs (Paper II) and QPs (Paper III)(Section 6), mainly because they reflect, quite reasonably, the fine structure observed in these two types of prominences.

It is generally known that in well developed active regions there is a hierarchy of Hα absorptive fine filaments (fibrils and chromospheric filaments) radiating outward from the main spot. Beyond the penumbra is a system of fine chromospheric filaments forming the superpenumbra (Loughead 1968). These filaments begin within the penumbra and propagate outwards, in a more or less radial direction, for a distance on the order of the spot diameter. Another set of shorter filaments (fibrils) is stretching usually beyond the superpenumbral filaments (see Figure 9a). The ARPs (or ARFs) seem to be formed from this outlying system of filaments.

According to the type of the large-scale photospheric mass motion (type **a** or **b** in Figure 9) we discern two types of ARFs to be formed in active regions.

Formation of the first type of ARFs is schematically shown in Figure 9. A system of fibrils, originally oriented more or less perpendicular to the magnetic neutral line (dashed line) is sheared by mass motions (indicated by arrows) forming a long Hα filament composed of many tightly packed fibrils.

Typical structure and arrangement of fine fibrils in ARFs formed by anti-parallel converging mass motion is clearly seen in Hα filtergrams presented in Figure 10 and 11. It is interesting to note how many fine fibrils do participate in formation of this conspicuous circular filament shown in Figure 11. All the constituent fibrils are quite strongly sheared and tightly packed.

Formation of the second type of ARFs is depicted in Figure 12. Here two sets of fibrils are sheared and then merged and tightly packed into a filament by a parallel mass motion with a velocity component directed towards the neutral line. Note the difference in the arrangement of fibrils between the Figures 9b and 12d, which results from converging motions being anti-parallel (Figure 8a), or parallel (Figure 8b).

Typical structure and arrangement of fine fibrils in an ARF being not completely formed by parallel converging mass motions is shown in Figure 13.

The majority of ARFs formation is rather typical for the scenario

Fig.11. An circular ARF very likely formed by anti-parallel converging mass motions (courtesy R.B.Dunn and R.N.Smartt, Sacramento Peak National Solar Observatory).

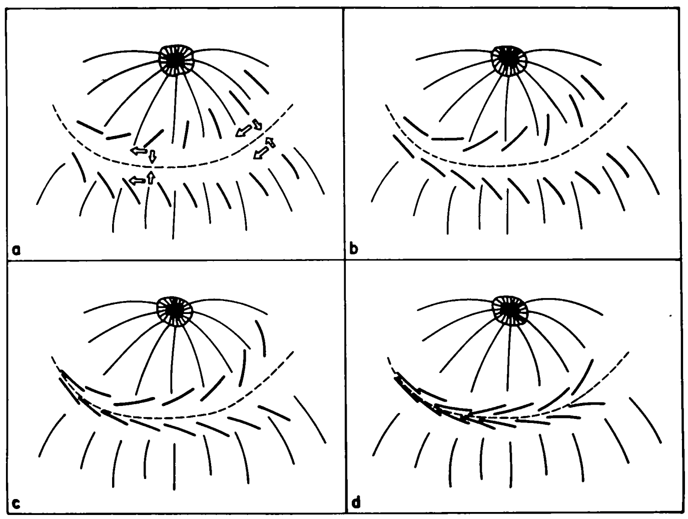



Fig.12. ARF formation in parallel converging mass motions (Rompolt and Bogdan 1986).

Fig.13. A typical arrangement of fibrils during a process of formation of an ARF by parallel converging mass motions (courtesy of F.Tang, Big Bear Solar Observatory).

presented in Figure 9, and by inference, the anti-parallel mass motions of Figure 8a.

Observations of ARFs formation by Martin (Smith 1968, Martin 1973) seem to be in concurence with ours (Paper II). She stated that some of the observed ARFs has been formed by coalescence of Hα fibrils aligned approximately end to end in the filament channel and oriented initially parallel to the neutral line (see Figure 14). Evidently these fibrils were already in a sheared configuration. In my opinion, however, such an evolutionary behaviour of fibrils could be interpreted in the frame of our model presented here. Namely, it is quite possible that in the case of Martin's observations the process of turning the filament channel system of fine fibrils from an initial orientation more or less perpendicular to the neutral line to a strongly sheared, nearly parallel to it, could proceed long before as a process invisible for some reasons in Hα, or taking place somewhere in subphotospheric layers. It would be reasonable to accept, however, that during this latent phase of turning the fibrils the converging velocity component directed towards the neutral line temporalily vanished or was quite small. Nevertheless, it should reappear in order to enable the filament formation after the fibrils had been strongly sheared paralleling the neutral line (cf. Figure 14). A transient disappearance of a fibrils in Hα can be caused either by a temporal depletion of the magnetic tubes of fibrils from sufficiently dense and cool material, or by an overheating.

Observations show that some filaments never become fully developed (Smith 1968, Martin 1973). For such circumstances could be resposible the converging velocity component being not sufficiently large.

Observation and identification of fibrils during a period of several hours is not straightforward. While following evolutionary changes of individual fibrils during formation of ARFs we often found some fibrils to disappear for several tens of minutes to hours. This specific behaviour of fibrils has been also noted by Martin (1986). After some time these fibrils seem to reappear again displaying changes in location and inclination with respect to the neutral line. One cannot be quite sure whether after reappearing sees the same fine fibril as before or a new one which emerged from below the photosphere in meantime. In any case the orientation of such a new fibril with respect to the neutral line is changed because of a continuous action of the shear motions. Sometimes new fibrils, not seen before, abruptly become visible in the filament channel - this renders the identification difficult.

The fine filamentary structure of some of the ARFs, especially of those well developed, consists not only of normal fibrils but also of quite long fine filaments, twice and/or three times as long as the av-

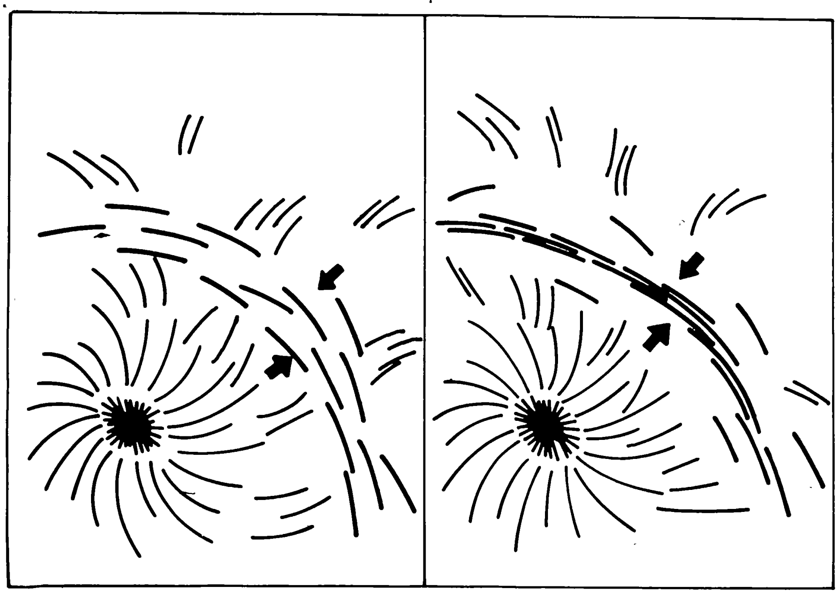
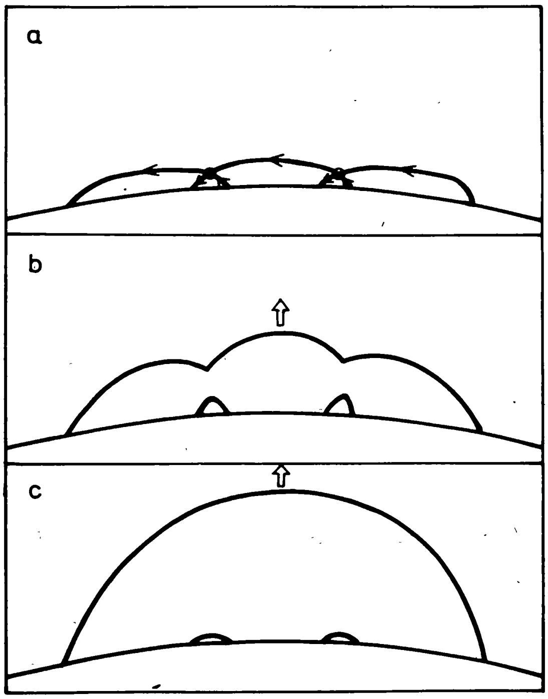



Fig.14. Possible ARF formation ,in converging mass motion after the parallel or anti-parallel mass motions did arrange earlier the fibrils parallel to the neutral line.

Fig.15. Scheme for formation of long fine filaments in an ARF.



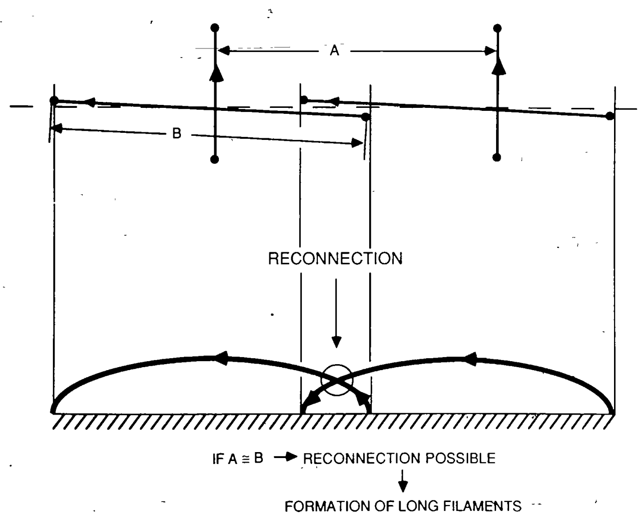




Fig.16. Reconnections leading to eruption of an ARP.

erage length of fibrils. These long fine filaments seem to be formed by the reconnection of two or more fibrils tightly packed in an ARF (Paper II). Such a process of reconnection is schematically shown in Figure 15 as seen from above and from a side.

An observed process of cancellation of small-scale magnetic flux of opposite polarity near the sites of ARFs and QPFs (Martin et al. 1985, Livi et al. 1985, Martin 1986) seems to be nothing else like a process of formation by magnetic reconnection of long fine filaments described above. Such a process of magnetic flux cancellation and resulting reconnection was anticipated earlier by Zwaan (1978). This magnetic cancellation is very likely forced by the photospheric converging mass motions towards a neutral line (Paper II, Wu et al. 1986).

A detailed examination of the observational material being at our disposal implies that the observed evolution and subsequent formation of ARPs from a system of fibrils, populating originally the filament channel, is consistent with an action of some simple photospheric mass motions.

## 5. ERUPTION OF ACTIVE REGION PROMINENCES

Eruption of ARPs is caused by eruption of a HMS (Paper I) evidently created during a process of ARPs formation by coalescence and subsequent magnetic reconnection of the fibrils involved. Cool and dense H$\alpha$-material observed in ARPs is believed to be frozen-in into such a HMS, or into a part of it. The HMS while erupts, lifts along with the frozen-in cool and dense prominence material. Eruption of an ARP takes place when the system of its fibrils, strongly sheared and packed together, receives some additional puls of compresion by the photospheric mass motion and undergoes some reconnections leading to modification of its original HMS. In consequence, the HMS is transformed into an arch-like configuration which erupts owing to a magnetic tension force involved. Such a situation is schematically presented in Figure 16.

The above presented notion on the eruption of HMSs from the sun carrying with the frozen-in prominence plasma has been recently supported by an analysis of four ARFs eruptions by Kahler et al. (1988). The authors came to a conclusion that in all investigated cases the filament eruption and the associated flare impulsive energy release were coordinated and driven by a common cause, the instability of the whole magnetic field configuration.

At some occasions, the process of initiation of magnetic reconnections in the magnetic skeleton of the prominence may be caused by an emergence of a new magnetic flux in the region adjacent to or immediately below the prominence.

## 6. QUIESCENT PROMINENCES

QPs are the objects of a conspicuous filamentary structure formed by fine magnetic ropes (~ 10 G) containing cool plasma (~ 6500 K), emerged in hot coronal environment (~ 1.5 MK). They are located over the magnetic neutral line in the regions of weak magnetic fields of opposite polarity at the periphery or in between the active regions. Tang (1987) revealed that prevailing number of QPs is formed on neutral lines between bipolar active regions.

QPs display a wealth of forms which hardly seem to be described by one common model. Roughly, QPs are observed in three basic shapes, according to their age, schematically shown in Figure 17, (Paper III).

A young QP is usually observed in a shape of one (see Figure 17a) or two arches. The span of such an individual arch is on the order of the size of a supergranular cell or twice as large. The overall dimensions of these young prominences are typically in the range: length 30-60 Mm, height 15-30 Mm, and width of a few Mm. The structure of the arches is filamentary - they are formed by a system of thin filaments occasionally twisted or intertwined (see Figure 28b, and Rompolt 1975b). Examples of such young QPs are given in Figure 18.

A well developed (of medium age) QP is that of the hedgerow type of Menzel-Evans (1953) prominence classification (Figure 17b). It usually consists of two systems of fine filaments one going along the long axis of the prominence forming the arches (the longitudinal rope), and the other one forming the "curtain" (the transverse system of fine filaments) (Paper I). The individual filaments of the transverse system are sometimes observed as spirally twisted structures but those forming the longitudinal rope can be twisted and/or intertwine (Rompolt 1975b). A high-resolution H$\alpha$-picture of such a well developed QP is shown in Figure 19, and of another one but seen in absorption against the disk - in Figure 20. The average dimensions of a well developed QPs are: length 200 Mm, height 50 Mm, and width of a few Mm. At some rare occasions the well developed prominences were observed as very long objects crossing the whole solar disk - so they were of a length on the order of 2 Gm! QPs of this type can persist on the solar surface for several months, even up to ten.

An old QP, or rather a QP in the late phase of evolution, often is in a form of a huge arch with strongly twisted and intertwined fine

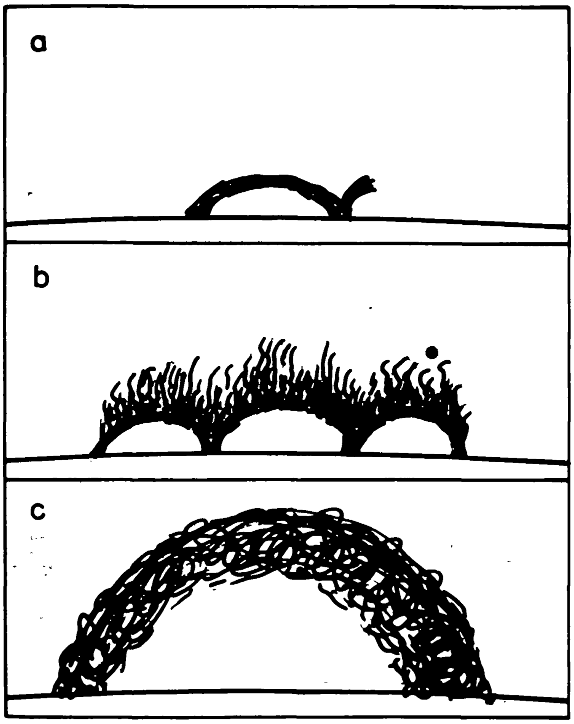



Fig.17. Three typical shapes displayed by QPs: young, well developed and old ones.

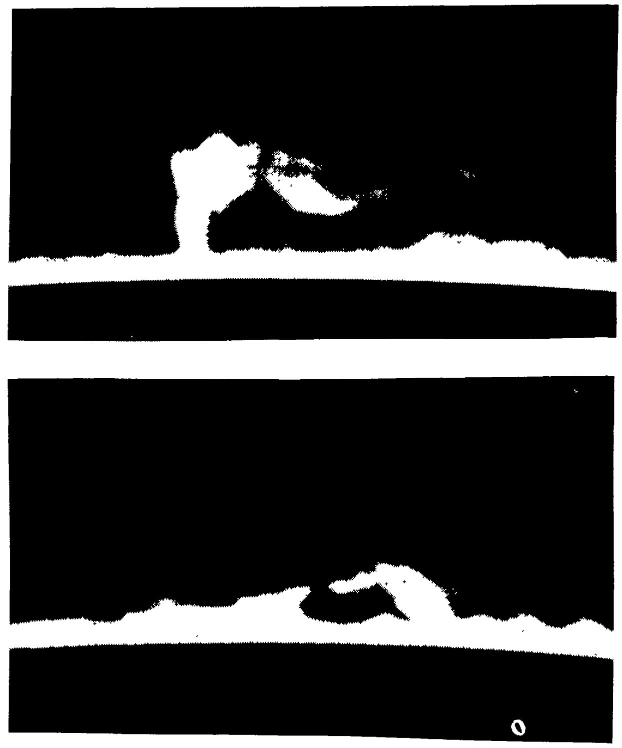
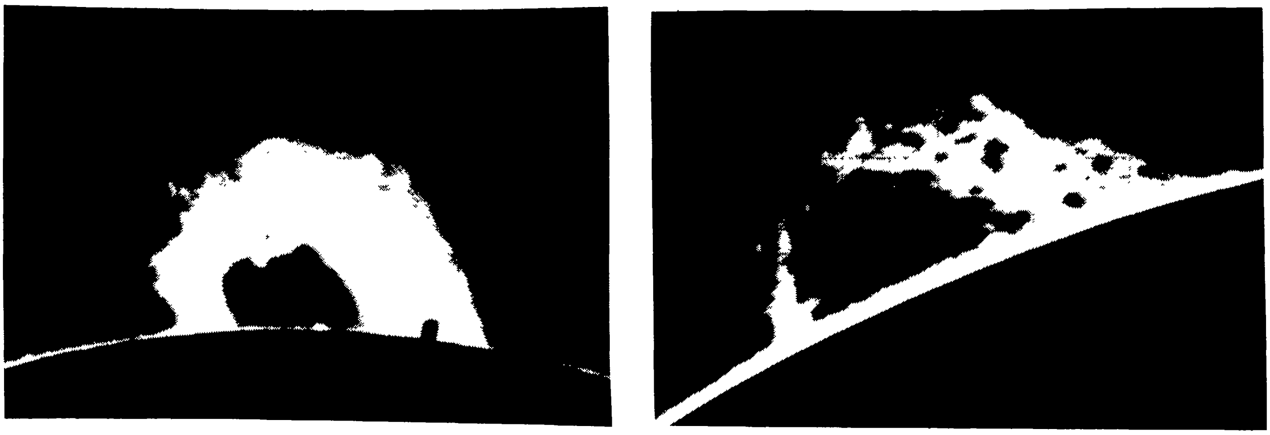


Fig.18. Examples of the young QPs observed on 1982.09.16 (upper) and 1985.07.25 (lower). (LC-Wroclaw).

Fig.19. A well developed QP (courtesy R.B.Dunn and W.J.Wagner, Sacramento Peak National Solar Observatory).

Fig.20. A well developed QP of 1978.05.19 seen in absorption against the disk as a filament at 1626 UT (courtesy F. Tang).



a b

Fig.21. The old-type QPs observed on: a - 1980.08.18 at 0803 UT, (SC-Wroclaw), b - 1972.09.16 at 1003 UT (LC-Wroclaw).

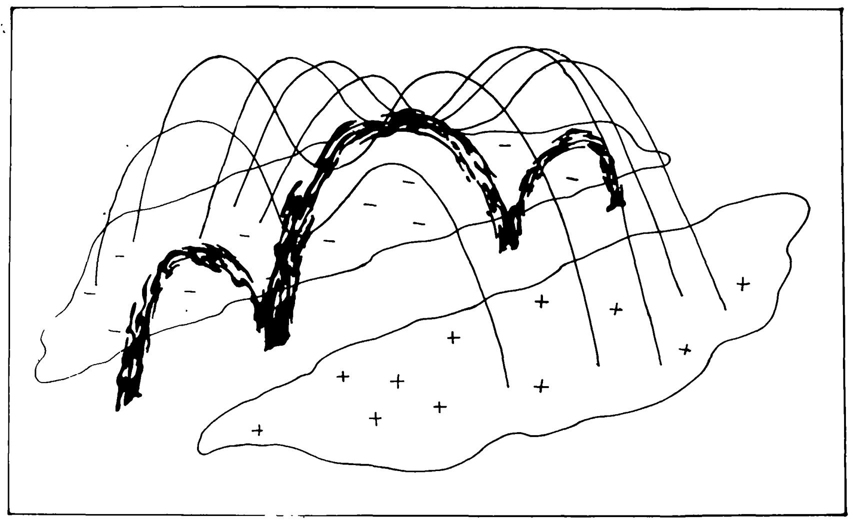


Fig.22. Magnetic skeleton of a well developed QP (Rompolt 1984).

filaments - Figure 17c. Sometimes this twisted filamentary structure is hardly discernible in the arch of tightly wound and packed fine threads but it usually becomes clearly visible during the eruption stage of the prominence (Rompolt 1975). Two examples of the old QPs are presented in Figure 21 a and b. The sizes of several measured prominences of this type, seen on the limb, were in the range: length (the span of the huge prominence arch measured alond the limb) 150-300 Mm, height 60-200 Mm, width (the diameter of the huge prominence arch) 30-80 Mm. The largest old type prominence ever observed was recorded by Roberts (see Tandberg-Hanssen 1974) with the Climax coronagraph on 1946.06.04. According to my measurements the size of this prominence, in a stable state just before the eruption, was: length (the span of the arch) 820 Mm, height 235 Mm, and width of the arch tube ranging from 200-300 Mm!

A well developed QP transforms into an old prominence configuration at a proper stage of its evolution. This process seems to proceed relatively fast, in a course of hours. I never succeeded to observe it, although it happened twice during two consecutive days of our observations, but unfortunalely during the night time.

Generally, the QPs are objects much higher than ARPs.

The most typical widths of the observed fine structure of QPs are in a range a little wider than the widths of the fine structure of ARPs, namely, from 1/3 to 3 arcseconds. We are strongly limited in the possibility of detecting the smaller structural features as of 1/3 arcsecond (0.25 Mm) width by the seeing conditions and instrumental resolution. As has been stated in the Introduction some observational and theoretical arguments being at our hands allow us to believe that the size of the fine structure of QPs should be of subtelescopic resolution. Nowadays, there is a growing need for new high-resolution instruments, of a higher spatial resolution as the present ones, which should be developed and put into operation from outside the atmosphere.

The fine structure of QPs has been extensively studied by a number of investigators since more than three decades. Let me recall here some of the results obtained so far.

The first high-resolution study of the fine filamentary structure in QPs has been done by Dunn (1959, 1960, 1965, 1970, 1972, see also Menzel and Wolbach 1960). The main result of his investigation is that the fine filaments in QPs can be as narrow as 0.3 Mm, and very likely are much thinner, but cannot be observed because of the limited spatial resolution of the Sacramento Peak coronagraph used, giving the best prominence images at that time.

Engvold (1972) measured a characteristic size of the fine structure in QPs of about 3 Mm, but this was in structures oriented rather horizontally. The apparent diameter of fine filaments in QPs determined by Engvold (1976) from Dunn's high resolution filtergrams appeared to be in the range from 0.4 Mm at lower height of 10 Mm to 1.5 Mm at about 70 Mm. These fine structures changed on a time scale of about 8 minutes but some bright filaments were identified for a period of 1 hour or so. The bright knots in the prominences seen on average during about 8 minutes ranged in size from 1.5 to 5 Mm.

The reported changes observed in the fine structure of QPs are dispersed over a rather wide time interval - from 2 minutes up to one day. Changes in the fine structure observed in the He I $\lambda$1083.0 nm and Si I $\lambda$1082.7 nm lines by Engvold and Keil (1986) in ARFs and QPFs on a scale of about 10 arcseconds and less exibit a short life time of 2 to 5 minutes. On the other hand, Orrall and Zirker (1961) found no change in form and brightness of the fine filamentary structure of QPs over a period of about 3 hours. In their opinion some individual fine filaments may possibly persist for one day or so.

The thickness of some fine filamentary structures in QPs increases with height (Malville 1975, Engvold 1976).

Fine structure in QPs has also been studied spectroscopically. One should realize, however, that spatial resolution of our best telescope-spectrograph systems is rather worse than 1 arcsecond. Usually, scales smaller than 1 Mm are not discernible even on high resolution spectra of QPs (Ramsey 1977). Nevertheless, spectral studies of fine structure in prominences are important, because they allow us to associate some large-scale fine structural elements (their dimension, brightness, temperature, density) with their line-of-sight velocity component.

Ramsey (1977) analyzing the internal horizontal line-of-sight motions of a QP in Ca II K line found a characteristic size of 4.7 Mm for the prominence moving elements. The sizes of these moving elements were much greater than the fine prominence structure. Engvold (1978) stated that the individual spectral features in QPs have dimensions in the direction perpendicular to their edges in the range 1-2 arcseconds and life-times of 5-15 minutes. Small scale Doppler shifted features in an activated QP just before and after the eruption appeared to have the dimension $\leq$ 1 Mm and an average lifetime of 5 minutes (Engvold and Malville 1977). According to Engvold et al. (1978) at least 1/3 of all QPs exhibit Doppler shifted velocity features associated with their edges or emission gaps between prominence sub-structures. These small-scale features had the diameter in the range of 0.7 - 1.5 Mm and were seen for 5 minutes on average.

Some theoretical estimations gave quite small dimension for the diameter of the fine prominence structure. The computational results of analysis of the linear thermal stability of a 2D periodic structure (alternately hot and cold) in a uniform magnetic field indicate that the dimension of the unresolved fine filaments should be on the order of 0.01 Mm only (Démoulin et al. 1986).

Hirayama et al. (1978) derived the width of the fine threads in QPs by comparing the electron density deduced from Stark effect and the total intensity of Balmer lines. It appeared to be of around 0.2 Mm.

Motions in fine filamentary structure of QPs were observed in three basic directions: downward, upward and horizontal.

Downflows were reported in Hα by Pettit (1932), Dunn (1960), Menzel and Wolbach (1960), Engvold (1976) (15-35 km $s^{-1}$), Martin (see Anzer 1978) (≥ 2 km $s^{-1}$), Cui Lian Shu et al. (1985), and Kubota (1980) in Ca II K (0.8 and 1.4 km $s^{-1}$). This kind of motion seems to be the most common in QPs. The downward velocities of bright knots of ten and more kilometers per second detected by Engvold (1976) are probably representative for the high velocity tail of the velocity distribution.

Upflows were observed by Martres et al.(1981), Malherbe et al.(1981) in Hα, and by Engvold and Keil (1986) in the He I λ1083.0 nm line. The velocities of downflows and upflows are generally in the range of 0.5-10 km $s^{-1}$ with the most often met values being rather close to the lower limit of this range. It should be stressed, however, that determinations of the line-of-sight velocity component in filaments observed on the disk is slightly ambiguous because the observed Hα (and also Ca II K and H ) Doppler displacements can be strongly influenced by shifts of the chromospheric component of the line which is not sufficiently well known (Beckers 1962,1968, Cram 1975, Engvold and Keil 1986). These limitations are not so severe in the case of the line-of-sight velocity determination using the He I infrared and D3 lines.

Both downward and upward directed motions were recorded within the same QPF by Maltby (1976) (4 or 7 km $s^{-1}$ dependent of the method used), Kubota and Uesugi (1986) (from +5.3 to -6.0 km $s^{-1}$) and Démoulin et al. (1987) (±1 km $s^{-1}$) - in Hα, Schmieder et al.(1988) in Hα and C IV (±2.5 km $s^{-1}$) with a time scale of 5 minutes, Simon et al. (1986a) in Hα (±5 km $s^{-1}$) and C IV (±15 km $s^{-1}$), Kubota (1980) in Ca II K (< 1 km $s^{-1}$), and by Kubota et al. (1989) in Hα and Ca II K with predominant downward motion of about 1 km $s^{-1}$. The observations by Kubota et al. (1989) are interpreted as continuous matter flow along the individual loops of a QP from one foot to the another, with a velocity of less than 3 km $s^{-1}$.

Horizontally directed flows easily observed in QPs were reported by a number of observers, e.g., Engvold (1972) in Ca II K (~1 km $s^{-1}$ in fine filaments and ~4 km $s^{-1}$ in mottled prominence structure), Engvold et al.(1978) in Ca II K, He I D3 and Hα (30-40 km $s^{-1}$), Martin (see Anzer 1978) in Hα (20-50 km $s^{-1}$), Simon et al. (1989a) in Hα (~2 km $s^{-1}$) and C IV (~5 km $s^{-1}$). Gigolashvili (1978) found by deconvolution of the complex Ca II K line profiles of a QP into Gaussian elementary profiles that the line-of-sight velocity components were in the range -30 - +50 km $s^{-1}$. She interpreted the obtained velocity field in term of a spiral motion of material. Thus, the horizontally directed velocities in QPs are generally observed in the range from a few up to several tens of kilometers per second, but occasionally they can reach values up to 80 km $s^{-1}$ (Engvold and Malville 1977).

## 7. FORMATION OF QUIESCENT PROMINENCES

On the basis of detailed inspection of a large body of high-resolution Hα-images of QPs, seen on the solar limb under various orientation to the line-of-sight, a dynamic model of formation of these prominences has been proposed (Paper III). This model depicts the fine filamentary structure of QPs.

The magnetic skeleton of a well developed QP (cf. Figure 17b and 18) is extended and quite complicated (Paper I). Roughly, it consists of a longitudinal component - a rope forming the system of arches of a QP, and of a transverse component - the field more or less perpendicular to the longitudinal component, supporting the prominence (Figure 22). This transverse component of magnetic field is formed by a system of loops spanning two opposite polarity regions laying on opposite sides of the prominence channel. The observed system of threads forming the "curtain" of a QP is believed to be the material condensed in the sag part of the transverse magnetic filaments linked to the longitudinal rope forming the arches. The magnetic filaments of the transverse component are very often strongly sheared by the oppositely directed mass motion of the regions on opposite sides of the neutral line in the prominence channel. The strongly sheared filaments of the transverse system of magnetic field seem to be responsible for the observed inclination by 25° of the azimuthal component of the prominence magnetic field relative to its long axis (Leroy et al. 1983, 1984, Nikolsky et al. 1984, Leroy 1987, Kim 1989). Recently Engvold et al.(1987) revealed that in a studied QPF a system of fine magnetic flux ropes seems to be really inclined at an angle of about 20° to the filament long axis. These observations are in agreement with generally accepted notion that the Hα fine structure exactly follows magnetic field lines (e.g., Tsap 1964, Smith 1968, Deubner and Göhring 1970a,b, Foukal 1971a,b, Prata 1971, Zirin 1972, Engvold and Leroy 1978). Nevertheless, some observations performed mainly during the last decade seem not support this notion.

The spatial resolution of the solar magnetographs being presently at our disposal is in most cases of about 5 arcseconds (Leroy 1987), thus, the problem of exact measurements of the strength and direction of the magnetic field in the fine filamentary structure of prominences will remain open until new improved instruments of resolution on the order of 1 arcsecond at least will be accessible.

The process of formation and evolution of a QP is schematically illustrated in Figures 23 and 24.

As has been mentioned earlier the QPs are formed in a channel between two regions of opposite magnetic polarity. Both these regions are spanned by a system of magnetic loops, which are treated here as a dynamic system - the loops are supposed to emerge continuously from subphotospheric depths and subsequently continue to erupt slowly.

Formation and evolution of a QP seems to proceed in three phases.

**Phase I:** At first a magnetic rope flows out from the subphotospheric depths up to the solar surface (Figure 23) in a channel between two adjacent fields of opposite magnetic polarity (Figure 24a, b). This rope originally filled by subphotospheric plasma, forms a system of arches of the longitudinal component of the prominence magnetic field. As observations indicate, a rope, or a system of fine filaments forming the rope, is filled with cool and dense plasma for quite a long time. The material in the rope seems to be nothing else than the subphotospheric material, being cooled in the rope, and continuously pumped along the rope as a result of the different depth of its subphotospheric anchoring (see Figure 23). Yet it is not quite clear what is the nature of origin of such a rope - either it is a rope completely shaped somewhere deep at the base of the convective zone and is transported to the solar surface by the mechanism of magnetic buoyancy or it is formed from fibrils, in the same way as ARPs (see Section 4, and Figures 9 and 12) with subsequent magnetic reconnections (Figure 15) in the system of strongly sheared fibrils. The young QPs seen in the form of one or two arches (Figures 17a, 18a and b) are typical structures for this stage of QPs formation. In this phase of evolution only the longitudinal component of the prominence magnetic field is visible due to the cool material. The older prominences display, besides the longitudinal component manifested by a series of arches, a newly formed component of the transverse system of magnetic field.

**Phase II:** In the next phase of development of a QP the loops spanning both adjacent opposite polarity fields meet during the process of slow eruption an obstacle in the shape of an arch of the longitudinal magnetic field (Figure 24b). As a result, their further eruption is tempo-

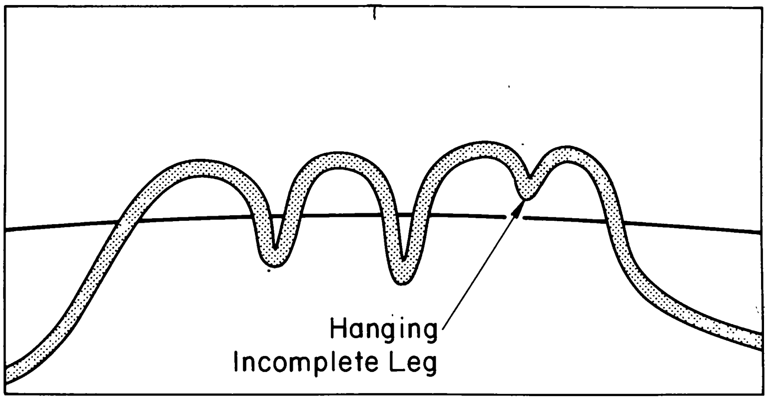



Fig.23. An initial phase of formation of a QP - emergence of a magnetic rope forming the longitudinal component of magnetic field of the prominence.

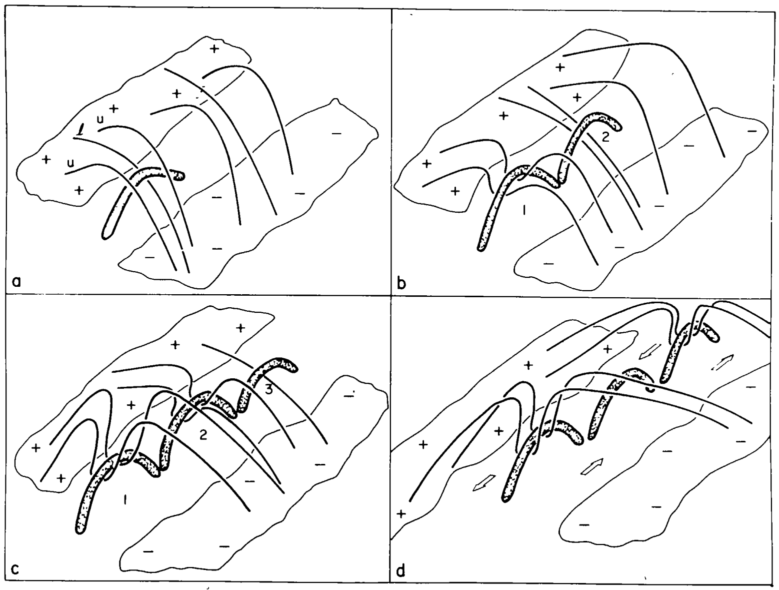



Fig.24. Schematic diagram illustrating the dynamic model of formation of QPs (Rompolt, 1987).

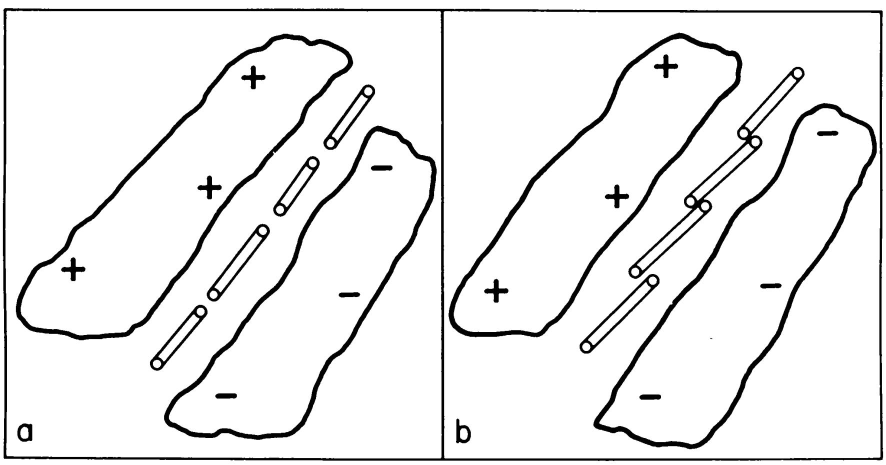



Fig.25. Two extreme kinds of arrangement of the feet in QPs, b - the most typical arrangement of fibrils' feet in ARP's

rarily stopped, the loops become linked to the rope forming a system of transversal magnetic filaments, and develope a central sag (Figure 24c and d). The filaments forming that transversal magnetic system become partly filled - in their sag part linked to the arches - by cool and dense plasma. Such a transversal magnetic system of filaments partly filled by cool plasma, when seen in projection against the sky plain, displays a form of the "curtain".

**Phase III:** The magnetic structure of a well developed QP (Figure 22) formed in the **phase II** (Figure 19) is occasionally transformed into a huge magnetic arch with twisted and/or intertwined fine filaments. The old QPs are often of that shape (Figure 21a and b). The complicated magnetic structure of the prominence developed in **phase II** evolves into a rather simple arch-structure. This could be caused by magnetic field reconnections between the fine magnetic filaments of two magnetic sys-systems (longitudinal and transversal) of a well developed QP, forced by the anti-parallel mass motion in the prominence channel. As a rule, the old arch-shaped QPs undergo the eruption.

According to estimation by Saito and Tandberg-Hanssen (1973) the total mass of the solar corona is insufficient for supplying more than 5 well-developed QPs. Another estimation by Priest (1984) shows that the mass defect in a coronal cavity is insufficient by an order of magnitude to account for the mass of a QP. Thus in opinion of Tandberg-Hanssen (1974) material revealed in QPs must continuously be supplied to these objects from below, from much denser regions. If one takes into account the filamentary structure of QPs this mass deficit is not so crucial, nevertheless, it is still significant.

One reasonable possibility of a mass supply from below is a siphon mechanism originally proposed by Pikel'ner (1971) and modified by Engvold and Jensen (1977), Priest and Smith (1979), Ribes and Unno (1980), and Poland and Mariska (1986). According to the siphon mechanism the pressure deficit in the sag part of the loops where the condensation comes into being causes the plasma at the footpoints of the loops to be sucked into the loops. The siphon mechanism although effective in supplying the mass into the prominence does not explain how the sag in the loops could be formed. In the model proposed here (originally Paper III) the sag in the loops of the transversal system of magnetic field of a QP is formed in a natural way by an obstacle (longitudinal rope) being met by the slowly erupting loops spanning the regions of opposite magnetic polarity (Figure 24). Therefore, in the frame of this model the siphon mechanism could be responsible mainly for the formation of the "curtain" part of the prominence.

Another possibility for the mass supply from below to a QP could be the mass injection into the loops forming its transversal system of magnetic field. Such a mechanism of mass injection was discussed by An (1985), An et al. (1986, 1988a,b), and Poland et al. (1986).

Observations of behaviour of long-lived filaments resulted in detection by the Meudon Group of so called "pivot points"(Escaut-Soru et al. 1984, Soru-Escaut et al.1986). The "pivot points" represent small areas within a filament body which rotate rigidly i.e. independently of latitude with the Carrington rotational velocity. An interesting feature of these "pivot points" is that the filaments do rotate around them during two or more successive solar rotations. In the frame of the model of QPs formation presented here a "pivot point" seems to be one of the longitudinal rope legs which is anchored much deeper in subphotospheric layers as the others (deeper than the legs depicted in Figure 23) (see also Mouradian and Soru-Escaut 1989).

The legs in QPs are arranged either along their axial lines like in Figure 25a or side by side as in Figure 25b. The legs arrangement of Figure 25a seems to be typical for relatively young prominences that of Figure 25b for older ones. Taking into account that most of the QPs legs are rooted in junctions between the supergranular cells - or in so called downdrafts (Płocieniak and Rompolt 1972), the legs arrangement of Figure 25b could be caused by horizontal rotation of supergranular cells. Such a horizontal rotation may be expected as a result of joint action of the differential rotation and Coriolis force. The supergranules should rotate in one direction on one sun's hemisphere and in opposite direction on the other one. The most typical arrangement of fibrils' legs in ARPs is that of Figure 25b. A magnetic reconnection in the legs of a prominence longitudinal rope, arranged as in Figure 25b, leads to a direct transformation of the rope into a spiral structure.

## 8. VARIOUS SHAPES OF QUIESCENT PROMINENCES

QPs display a wealth of shapes depending on their age, the angle of observation and their virtual differentiation. The aim of this Section is to turn attention of the Colleagues studying the prominences, especially those involved in theory and prominence modelling on a quite great variety of the forms and fine structure arrangements in QPs.

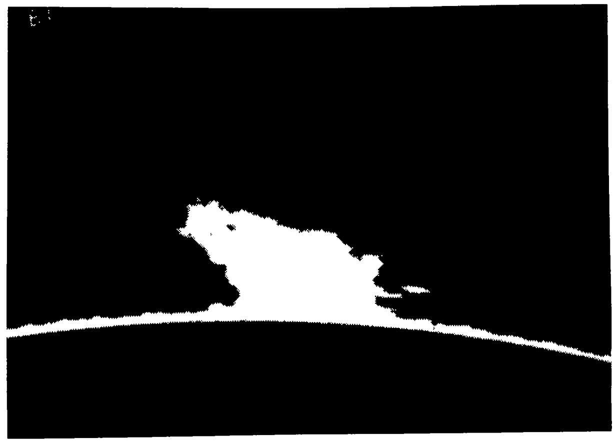
The most conspicuous QPs are those which are bright and sufficiently large. Such objects are usually formed by a great number of fine filaments densely packed in the main prominence body. The fine filamentary structure is hardly recognizable against the bright and more or less homogeneous background, but sometimes it is distinguishable at the edge of the prominence. A few examples of the QPs of this kind is presented in Figure 26. Note that the prominence in Figure 26c has a very bright and well shaped system of fine filaments forming the "curtain" part, but only faintly outlined arches formed by the longitudinal mag-magnetic rope. The prominence in Figure 26d seems to be built from the threads of mainly vertical orientation.

QPs of this kind are for spectroscopists the favorite objects for taking the spectra - their large brightness allow to shorten the exposure time. Such spectra contain, of course, some physical information on the state of the plasma but, unfortunately, from a number of fine filaments occuring along the line-of-sight. As a result of a possible different inclination of the individual filaments to the line-of-sight, and the mass flow observed in these filaments, the resulting line profiles should be more or less affected by the Doppler shifted spectral features from these individual fine filaments.

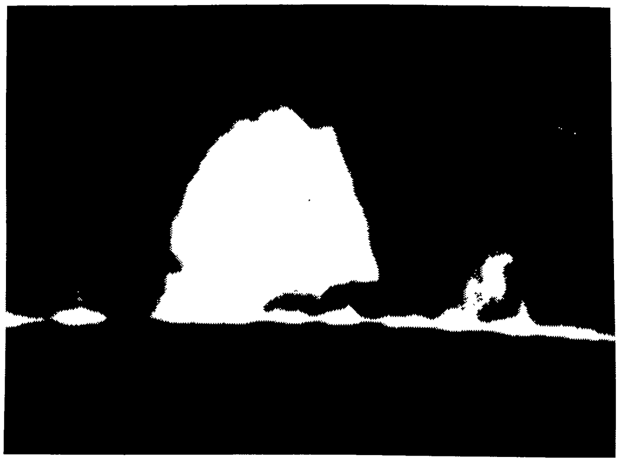
Some well developed QPs seen edge-on or some young prominences are in a form of a tree trunk [according to Menzel and Evans (1953) classification type ANb]. Two examples of a tree trunk like prominences are demonstrated in Figure 27. The prominence of Figure 27a consists of at least four vertical fine filaments. One can easily perceives that every one filament is formed by a chain of tiny knots. Engvold (1976) claimed that the fine filamentary structure of QPs is filled up by small knots which are only seen under excellent seeing condition. I am inclined to believe, however, that the efficiency of space filling by the matter in prominence fine filaments (by knots or continuously distributed matter) depens upon the amount of the matter actually available for the fine filamentary structure formation. The prominence of Figure 27b displays several small loop structures in its upper part. The nature of these loops is not quite recognized. They could be shaped by an effect of projection of the properly bent loop structures seen nearly edge-on.

Some prominences appear in a form of a well defined arch structure - see Figure 28. The arches consist of thick legs where the fine filamentary structure is usually oriented more or less vertically and of an upper part in the shape of a bow with prevailing horizontal arrangement of micro-filaments. There is no clear evidence here for a "curtain" system of fine filaments. The prominence in Figure 28a has a thick well shaped top part of the arch where the fine structure is oriented mainly horizontally - note that some fine filaments seen at the edge of the arch are stretched parallel to the limb. On the other hand, the prominence of Figure 28b shows in the top part of the arch a set of twisted and/or intertwined fine filaments. The prominence in Figure 28c consists of two arches strongly differing in height and extension - this

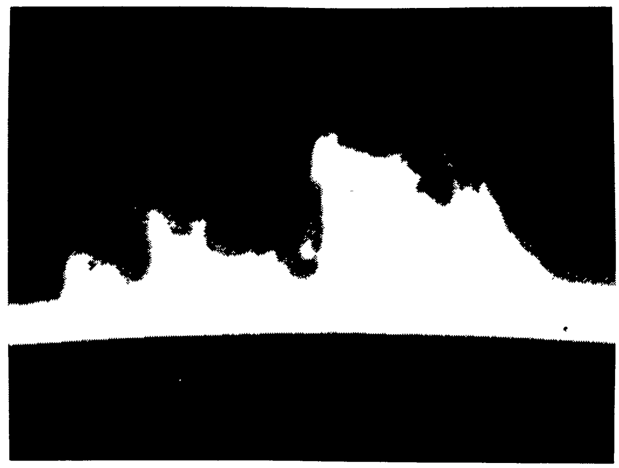
a 89.06.23 0833



b 89.05.18 1439



c 85.08.03 0548



H

d 85.07.22 0653

Fig.26. Various shapes of QPs displaying bright dense body formed by tightly packed fine filamentary structure (LC-Wroclaw).

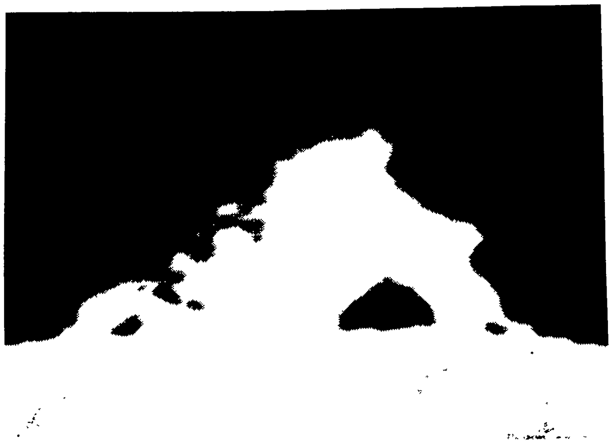
a 89.06.27 0948

b 83.06.24 0926

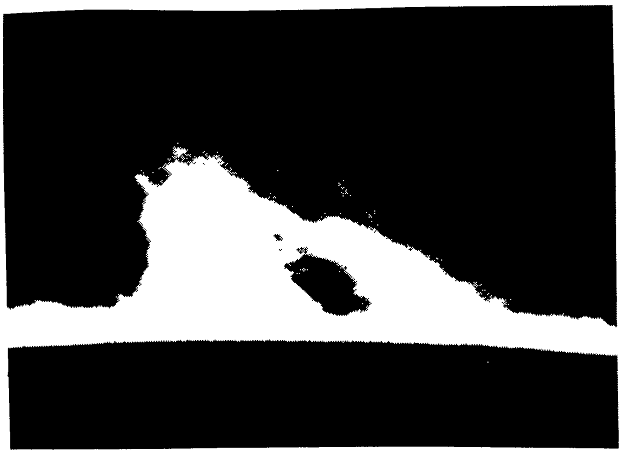
Fig.27. Tree-trunk like QPs exhibiting filamentary structure (LC-Wroclaw). The fine filaments forming the prominence in a consist of a number of tiny knots.

a 87.09.10

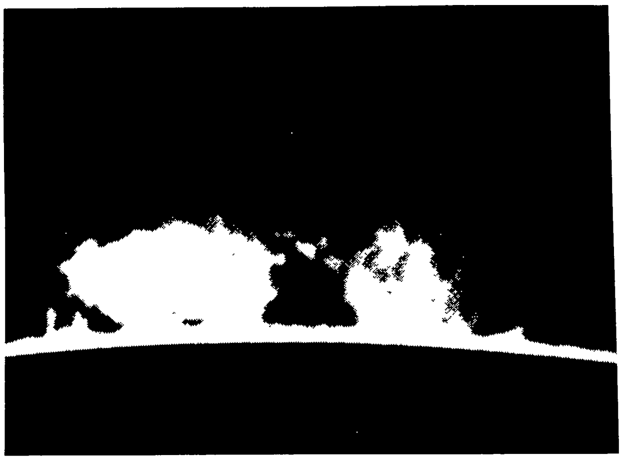
b 82.10.02 1013



c 89.06.29 1021



d 89.10.25 0914



e 81.08.06 0925

Fig.28. QPs showing a well defined arch-structure (LC-Wroclaw).

is not an effect of the perspective, the prominence was stretched along the limb. The span of the smaller arch is on the order of the diameter of a supergranule, and of the larger one twice as large.

Some QPs do exhibit a quite loose structure where one can easily distinguish the individual fine filaments (Figure 29). It does not look like an effect of the amount of available material to be condensed in the prominence but rather a characteristic property of the prominence of this kind to be composed from a small number of fine filaments only, dispersed over a large volume. The prominence in Figure 29a has only one well formed leg. Its fine filaments instead of being converged in another leg are anchored at some separate points spreading over an area of the solar surface. The fine filaments in the prominence of Figure 29b seem to be twisted into a large-scale spiral, whereas those in the prominence of Figure 29c are individually twisted into small-scale spirals.

Another example of a QP of a loose internal structure is presented in Figure 30 where clear changes in arrangement of the fine filamentary structure during a period of 7 hours are remarkable.

Some QPs exhibit solely the vertically arranged fine filamentary structure - see Figure 31. One most conspicuous prominence of this kind is shown in Figure 31a. The whole prominence consists of more or less vertically oriented threads and there is any evidence for a longitudinal system of magnetic field (for the longitudinal rope forming the arches). Realizing that the prominence was exactly on the limb and paralleling it one may suspect that the longitudinal magnetic rope of the prominence, if exists, is just submerged below the chromosphere. Thus we see the uppermost protrusion of the prominence only, that means the "curtain" part of the prominence. On the other hand, the terrier-like prominence of Figure 31b displays a "curtain" part composed of vertically stretched fine filaments which some of them are anchored in the legs and some others are linked to the top part of the arches which are here very faintly outlined. Thus, among the QPs there are also prominences with solely vertical arrangement of the fine filamentary structure. Taking into account the recent controversy on the dominant direction of the magnetic field in QPs it would be of interest to recall here an opinion by Ramsey (1977) that prominences appear to be made up of predominantly vertical threads.

A part of QPs clearly reveals horizontally aligned fine filamentary structure. Such prominences are shown in Figure 32 (see also QPs in Figure 28). Here the horizontally stretched fine structure is distinctly seen between pairs of well separated prominence legs. Nevertheless, in prominences of this kind there are also places of predominantly ver-

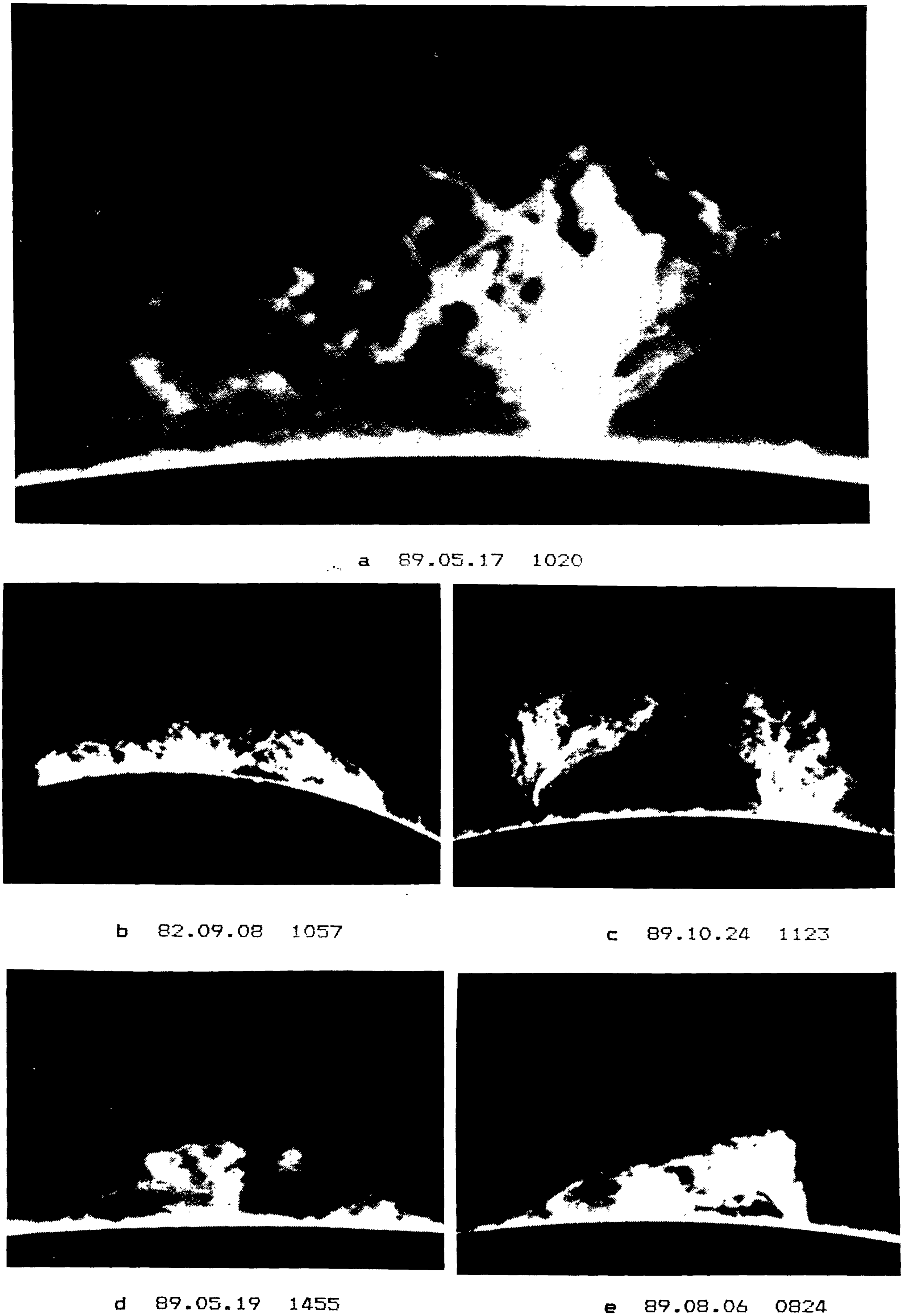
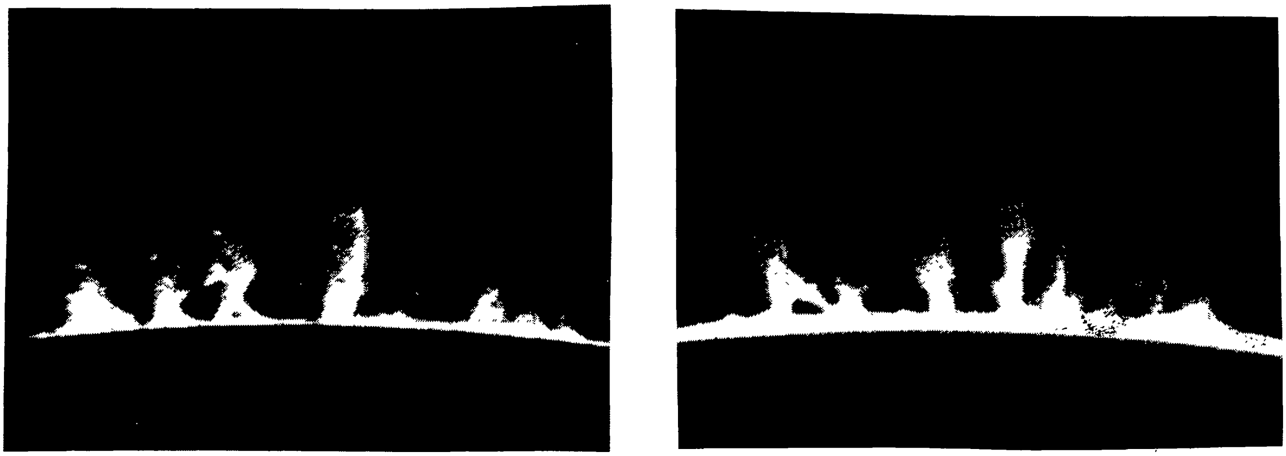
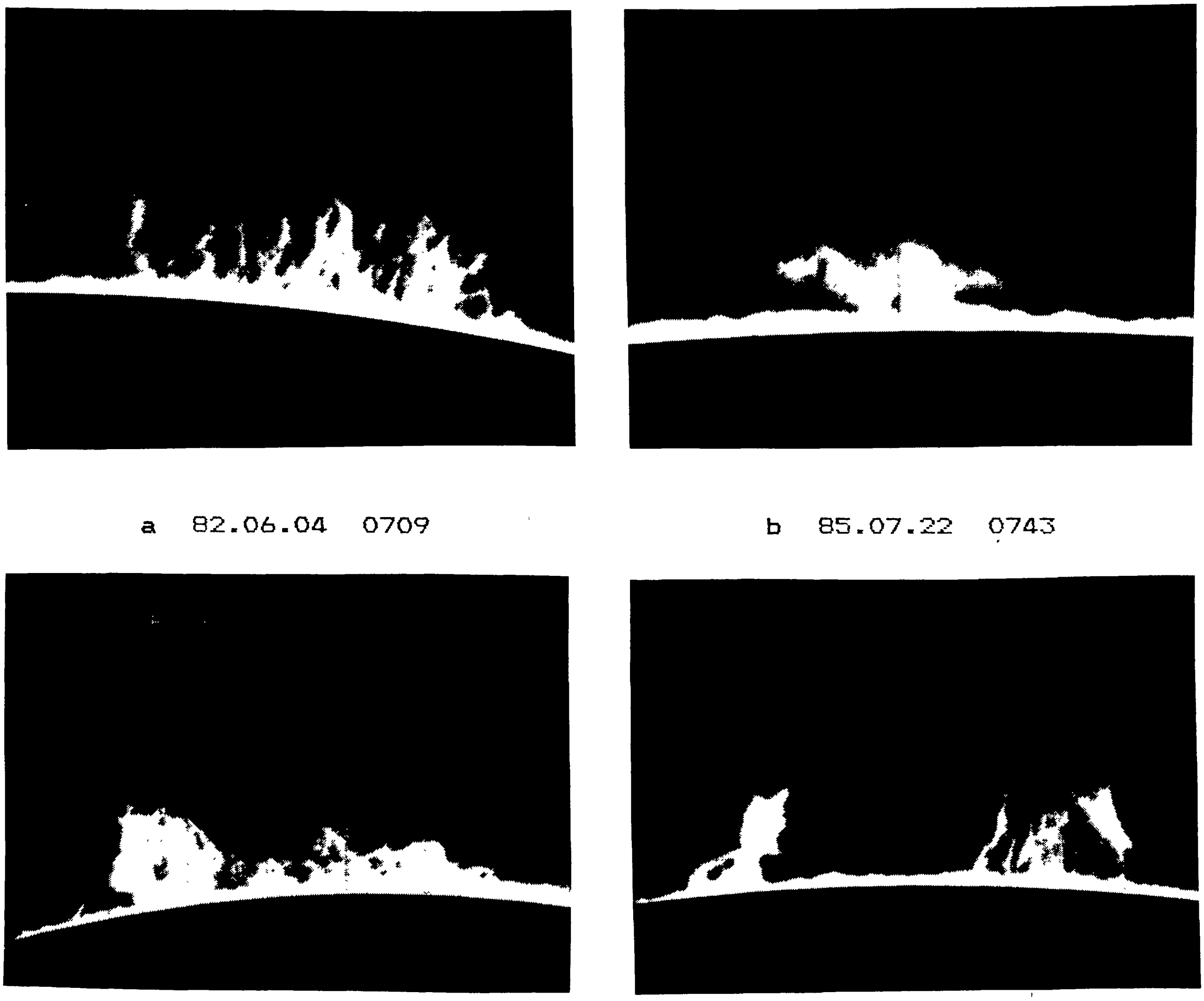



Fig.29. QPs of a loose filamentary structure (LC-Wroclaw).



a 0725 b 1422

Fig.30. Changes in fine filamentary structure of a QP of 1984.04.19 in a time interval of about 7 hours (LC-Wroclaw).



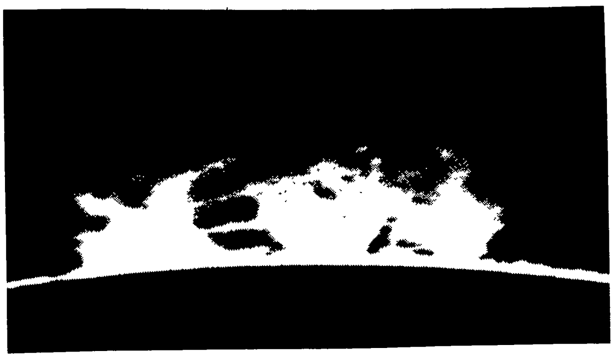
a 82.06.04 0709 b 85.07.22 0743

c 88.08.01 0840 d 84.10.06 0922

Fig.31. QPs having the fine filaments of a vertical arrangement only (LC-Wroclaw).

a 85.07.22 0708

b 81.09.05 0811



c 88.08.09 1129

d 89.05.25 0630

e 83.06.29 0624

f 85.07.22 0717

Fig.32. QPs with a pronounced horizontal arrangement of the fine structure (LC-Wroclaw).

tical arrangement of fine filaments, namely – in legs. The prominence in Figure 32f has only one well developed leg and horizontally aligned rope consisting of a couple of fine filaments. Evidently there is not enough of sufficiently cool and dense material in the another part of the prominence arch to be visible in Hα.

The QPs having the legs well made up (again of mainly vertically oriented filamentary structure) but faint horizontal interconnection are presented in Figure 33.

Some QPs exist only in a form of the strongly uplifted legs. Such prominences are demonstrate in a series of pictures in Figure 34. The objects of this kind have legs much higher stretched in the corona than the most of the QPs. Sometimes the fine filaments forming such an uplifted leg are splitted to sides, just above the chromosphere, forming a small arch supporting the leg (Figure 34c).

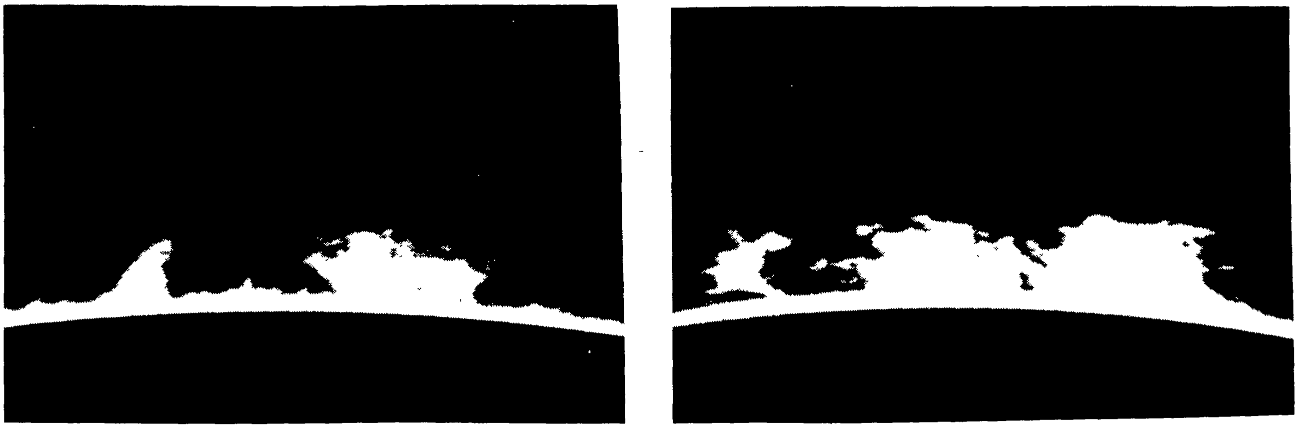
At some circumstances, yet not fully recognized, the QPs built a tall uplifted structure (chimney), towering from the main prominence body. A few Hα pictures of the prominences displaying such an uplifted structure is shown in Figure 35. The "chimneys" shooting from the prominences in Figures 35a,b,c seem to be formed by the matter condensed in the low part of a system of vertically stretched fine filaments forming a huge loop being elevated high over the prominence body. On the other hand, the "chimney" in the prominence of Figure 35d looks like to be formed by the matter condensed in the lowest part of a system of the "inverse loops" (U-type magnetic filaments) overlying the main arch of the prominence body. Another example of such a U-type magnetic system one can find in Figure 64g.

As has been mentioned earlier, the young QPs are often in the form of an individual arch. Sometimes, the horizontal part of a rope forming such an arch is very thin – see Figures 36a and b.

## 9. PECULIARITIES IN QUIESCENT PROMINENCES

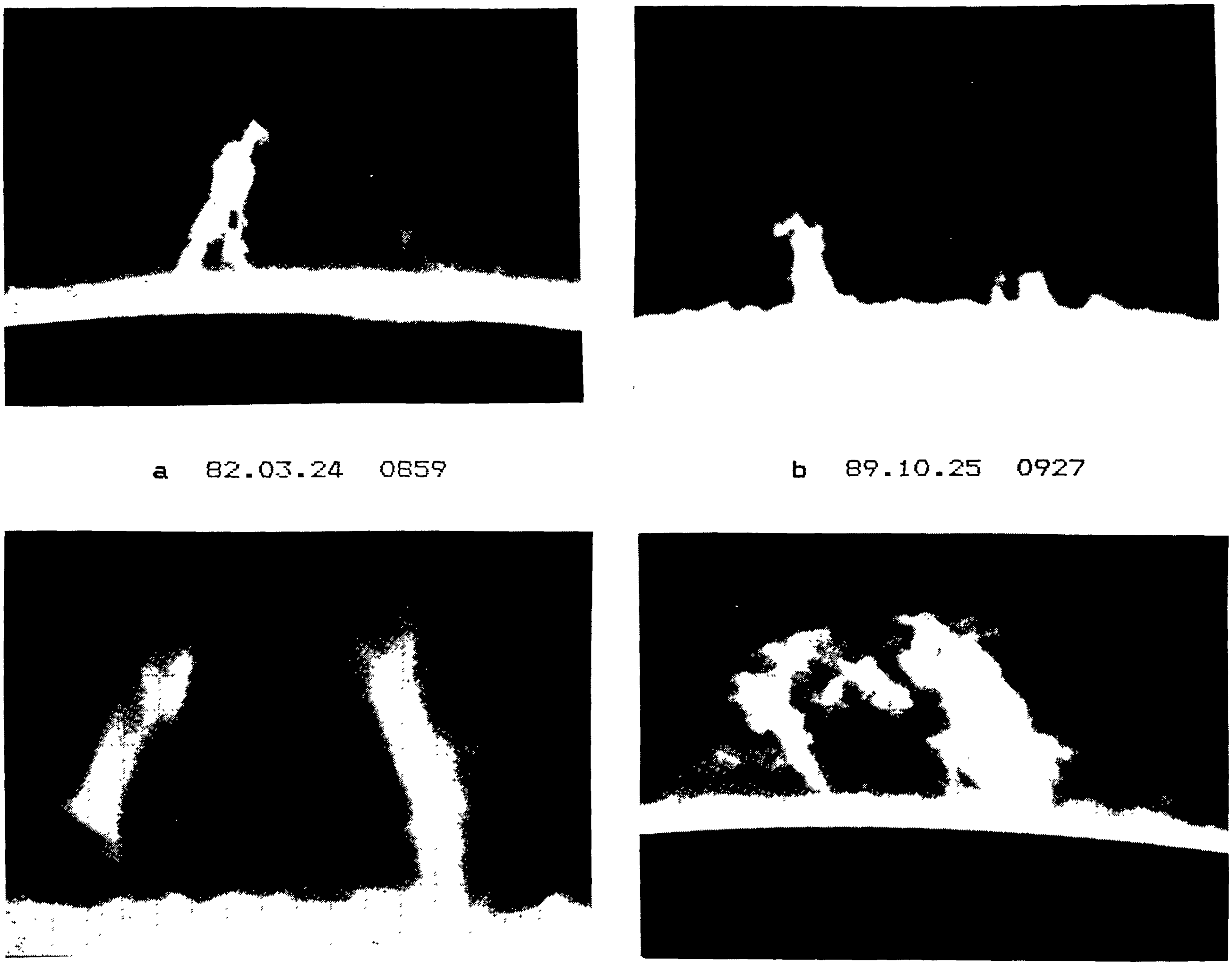
QPs do exhibit occasionally some peculiarities and quasi-active phenomena being even not in an activated phase. In this Section some forms of such peçuliarities and/or quasi-activity will be shortly discussed.

Small-scale impulsive events (brightenings) have been identified in QPs by Engvold and Malville (1977), Engvold et al. (1978), Malville (1978) and Malville and Toot (1982) as a phenomenon appearing quite often. These brightenings have been found in about 40% of QPs. The characteristic features of the impulsive events are: small size of about 1.5 arcseconds, mass $10^6$ kg, velocities in the range 10 – 100 km $s^{-1}$



a 87.09.10 0800 b 84.04.14 1110

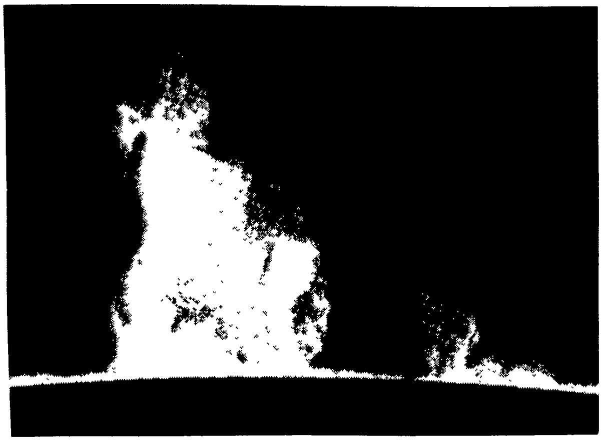
Fig.33. QPs with strong legs and faint horizontal connection (LC-Wroclaw).

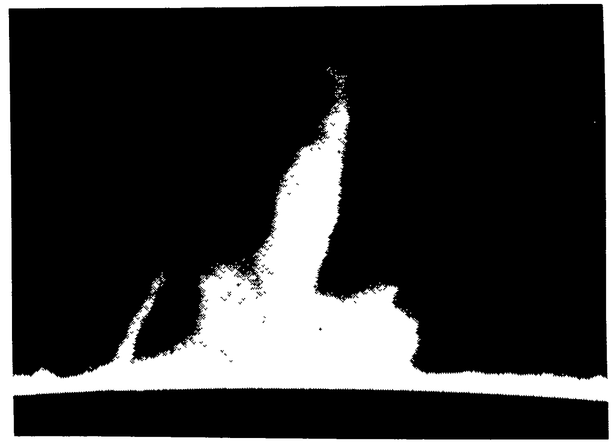


a 82.03.24 0859 b 89.10.25 0927

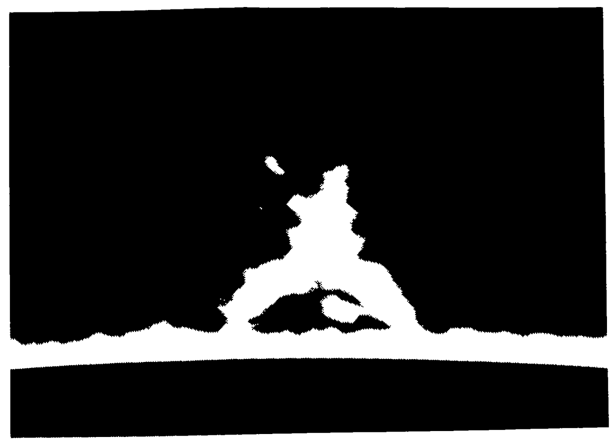
c 85.07.22 0531 d 83.09.06 1420

Fig.34. QPs having mainly strong uplifted legs (LC-Wroclaw).



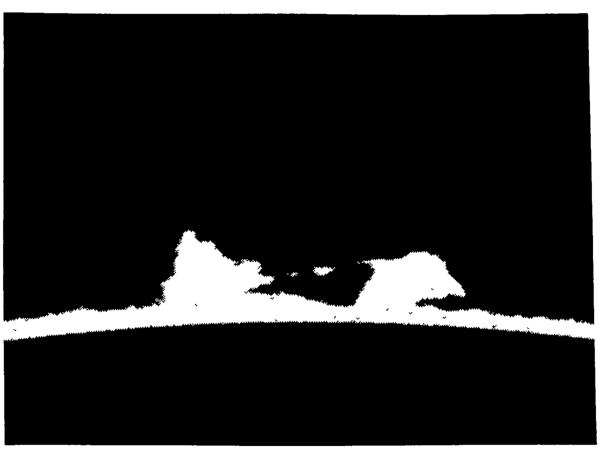


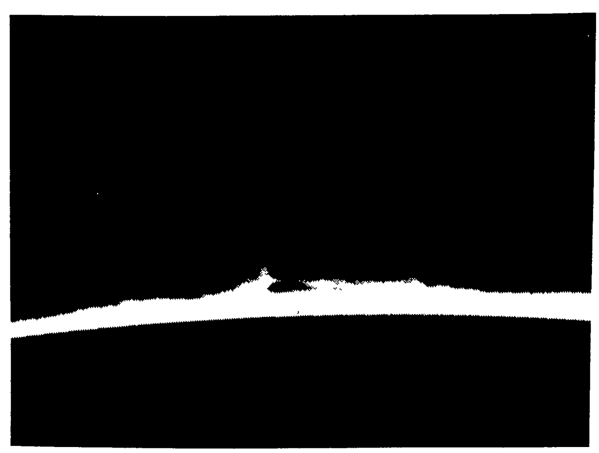
a 89.07.02 0851 b 89.10.18 1133



c 89.06.27 0730 d 89.06.25 1115

Fig.35. QPs with an uplifted system of fine filaments (LC-Wroclaw).





a 88.08.01 0900 b 83.05.31 1015

Fig.36. Young QPs with only one horizontal fine tube connecting the prominence legs (LC-Wroclaw).

(average: 35 km $s^{-1}$), energy from $10^{14}$ to $10^{16}$ J and an average lifetime of about 5 minutes. These events are believed to be generated by unstable current sheets between the discrete magnetic filaments forming a QP (Malville 1978). Kurochka and associates (Kurochka 1967, Kurochka and Ribko 1979, Kurochka and Kiryukhina 1987) developed an original method of the hydrogen plasma diagnostic, based on the sequential number of the last well resolved line in the Balmer series and the observed Balmer pre-continuum, enabling an accurate determination of the optimum value of electron density at which a predominant part of hydrogen lines is being formed. Kurochka and Kiryukhina (1987) found analyzing a a domain of spectrum occupied by higher members of the hydrogen Balmer series of a QP of 1972.08.13 that some prominence regions exhibiting high electron density should be of a size 10 - 100 km and ought to generate radiation owing to their natural energy sources (like the flares) whereas the bulk of the prominence material shines through scattering the radiation incident from the solar surface. Thus, the real intensity of the small-scale impulsive events should be several orders of magnitude higher than the observed one owing to their subresolution sizes.

Another form of quasi-activity, observed in QPs at some occasion, is manifested by ejection of small surges in the prominence legs exactly along the existing fine filamentary structures. The lifetime of such an event is on the order of several minutes. Sometimes, at very rare occasion, material in a surge is observed to be ejected to a height greater than the visible upper edge of the prominence. It looks like the material is being ejected along an arm of an arch shaped magnetic rope or an individual fine filament stretched much higher into the corona than the other magnetic filaments forming the magnetic skeleton of a QP.

Some QPs seem to be formed by many small-scale loops. As an example may serve the prominences presented in Figures 37, 38 and 39 (see also Figure 27b). One can notice that the upper edge of these prominences is shaped by a number of quite small loops. The exterior diameters of the small-scale loops measured in projection against the sky plane are in the range 3.5 - 5.0 Mm, whereas the diameters of their fine tubes are from 0.7 to 1.5 Mm. Of course, the real exterior diameters of the loops could be larger in the case when the apparent measured diameters would be affected by a view angle effect. The QPs showing a system of small-scale loops at their upper edge are rather rare phenomena. Such a system of small loops has been also observed by Simon et al. (1986b) in a QPF of 1984.10.15. On the basis of Hα observations they found that the filament is formed of many small-scale loops, having the radii of 1 Mm, anchored at many different footpoints that are not exactly aligned with the filament axis.

Fig.37. A crocodile-like QP on 1969.11.21 showing a system of small-scale loops (LC-Kislovodsk).

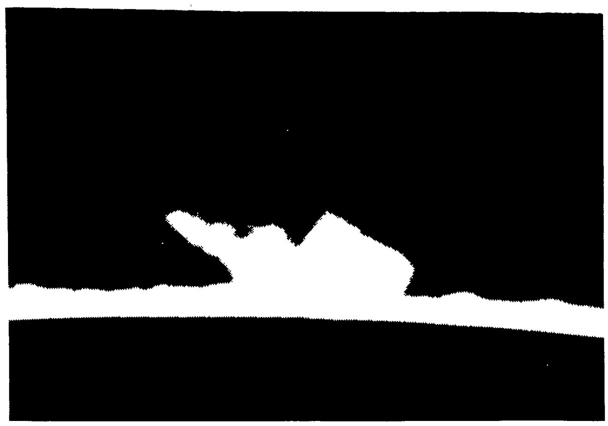


Fig.38. Several small loops at the left upper edge of a QP of 1985.07.22 at 0520 (LC-Wroclaw).

Fig.39. A horse-like prominence showing a number of small-scale loops on its "back" (SC-Wroclaw).

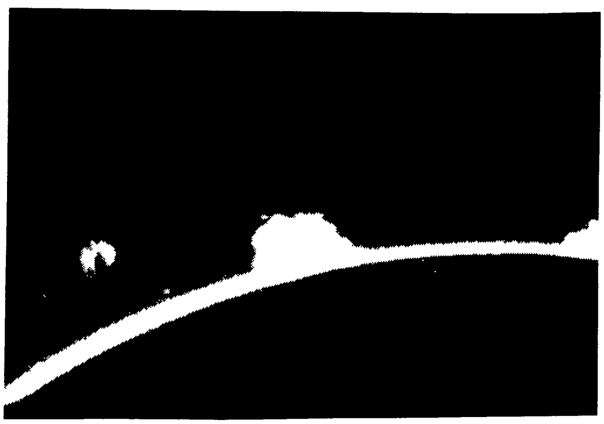


Fig.40. A loop with a "hedgerow" system of fine filaments stretched out from the top part of the loop (SC-Wroclaw).

Fig.41. A QP and small loops newly emerged on 1983.06.1 (LC-Wroclaw). The width of the fine structure of loops is smaller than of the QP.

A "curtain" or "hedgerow" system of fine filaments is developed not only in QPs. At some rare occasions such a system can also be found on the top part of an individual loop stretched in an active region. Such a loop with a "curtain" on its top is presented in Figure 40; another example of this kind one can find among the prominences shown by Evershed (1913, her Plate 15 and Figure 22). The phenomenon seems to be very similar to one arch segment of a well developed QP where the transversal component of the prominence magnetic field forming the "curtain" is extending up from the top part of an arch of the longitudinal magnetic rope. Thus, it is very likely that the "curtain" stretched from the top part of the loop discussed here could be also formed by a system of loops transversally oriented to the loop and slowly expanding from underneath the loop. Such a system of transversal loops while slowly expanding can meet on its way, similarly as in the case of formation of the QPs (see Section 7), an obstacle - a magnetic rope of the original loop; as a result, the individual loops of the system are converted into the loops with a sag where the material sucked or injected at the footpoints is being cooled forming just a "curtain".

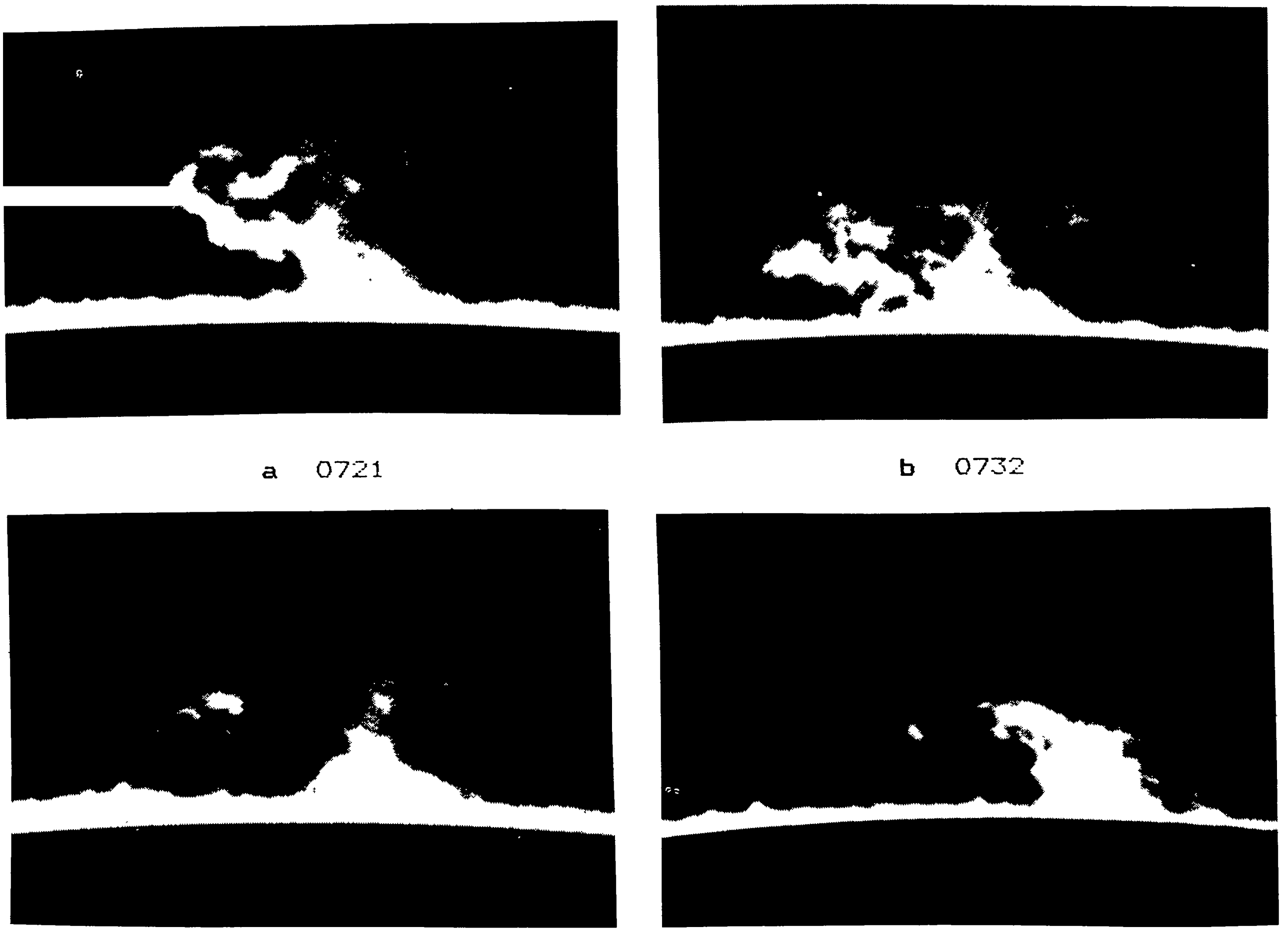
The fine filaments forming some QPs really exhibit a diffuse structure of a width which is certainly not so narrow as we generally used to believe. In Figure 41 there is a QP with distinctly seen fine filaments and the loops of a newly emering magnetic flux in front of it. It is easily remarkable that the width of the fine structure of the QP is much wider as the width of the loops. Thus, the observed diffuse character of the prominence fine filaments is a real fact in this case, not caused by the atmospheric smearing, as one were be inclined to believe if there would be no the fine loops in the same limb region. The measured width of the diffuse fine filaments of the QP are in the range 2.0 - 3.0 Mm (3-4 arcseconds), whereas the width of the fine loops are of 0.9 - 1.1 Mm (~1.5 arseconds) only. The observed large scattering of the widths of the fine filamentary structure in the QPs, covering one order of magnitude (from ~0.3 Mm to several Mm, see Section 6), is probably due to different strength of the magnetic field in the fine magnetic filaments forming these objects.

Occasionally some fine filaments in QPs undergo an abrupt brightening. The nature of this brightening is not fully understood. Some of brightenings could be explained on the ground of the Doppler brightening effect (Rompolt 1967a, 1967b, 1975d, 1980a, 1980b, 1980c; Hyder and Lites 1970; Ciurla and Rompolt 1975, 1977; Rompolt and Ciurla 1976; Heinzel and Rompolt 1986, 1987; Heinzel et al. 1986) provided that the material in individual prominence fine filaments has been forced to move with a speed higher than 30 km $s^{-1}$. Such a brightening could be as well stimulated by an abrupt density increase in a fine filament and/or by a temperature adjustment to an optimum value for the hydrogen lines formation. Here I would like to present another unusual case of a filament brightening occured in an activated QP - Figure 42 a-d. This filament brightening was caused by an interaction of a newly emerged system of magnetic loops with a horizontally oriented prominence fine filament. In Figure 42a a strongly brightened filament is clearly seen. At that time an expanding arcade of tiny loops, unvisible up to now probably for lack of sufficiently dense material within the loops, comes into a close contact with the prominence filament and activates it (by a partial reconnection ?). As a result the material contained in the fine filament penetrates into the individual loops of the arcade and starts to flow down to the chromosphere what is seen in Figure 42b. On the original negative of this picture (b) the system of individual loops forming the arcade is clearly seen. Several minutes later, Figure 42c, the system of loops after some simplifications has expanded higher into the corona. Half an hour later the overall structure of the prominence, initially quite complicated, undergoes simplification being transformed into an arch (Figure 42d) which consists of a number of fine filaments.

One of the key problems in physics of prominences is knowledge of the filling factor by which the fine small-scale filamentary structure fills a large-scale prominence structure. Determination of the filling factor is not a straightforward task, mainly because there is a general lack of high resolution prominence pictures where the individual fine filaments, not screening one another, could be clearly discerned. Here, I try to give an evaluation of the filling factor for the filamentary fine structure contained in a QP leg. One of the best high-resolution Hα-picture of a well developed QP ever obtained, was taken at the Big Bear Solar Observatory - see Figure 43. The central leg of the prominece consists of five well resolved fine filaments, each of a measured diameter of about 0.35 Mm, distributed over a width of around 3 Mm. So, accepting a cylindrical symmetry for this leg, one can find that the filling factor is of about 0.1.

As has been mentioned earlier, the fine filamentary structure in QPs is sometimes seen to be twisted or intertwined on a micro or macro-scale. Prominence material spiralling along filaments twisted into helices does exhibit a kind of rotational motion. For a comprehensive review see Rompolt (1975a and b).

A macro-scale rotational motion has been reported by Zirin (1978) and Liggett and Zirin (1984) in some regions of QPs (see Figure 44). The rotational velocities observed in the plane of sky in six prominences were in the range 12 - 75 km $s^{-1}$, and these observed along the



a 0721 b 0732

c 0738 d 0812

Fig.42. A peculiar brightening and activation of a filament in a prominence of 1989.07.07 (LC-Wroclaw).

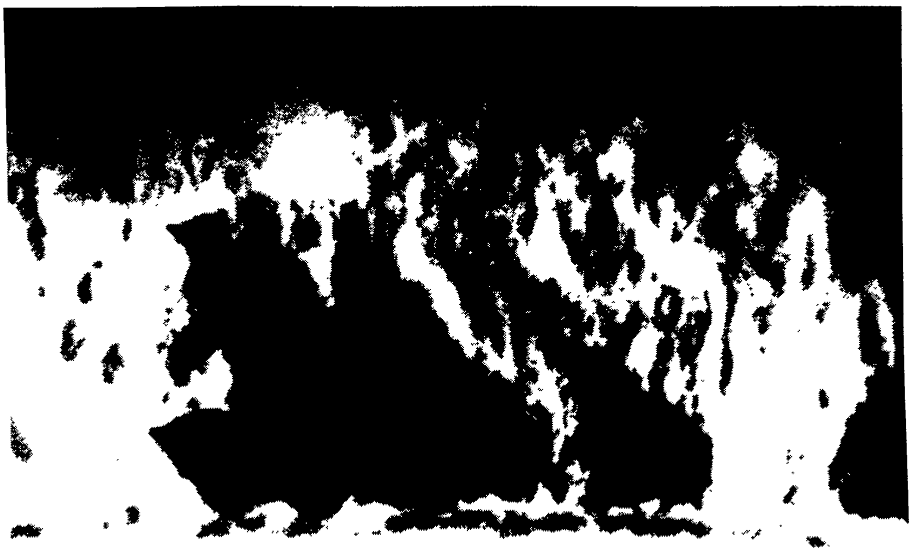


Fig.43. The fine filamentary structure in a well developed quiescent prominence (courtesy F.Tang).

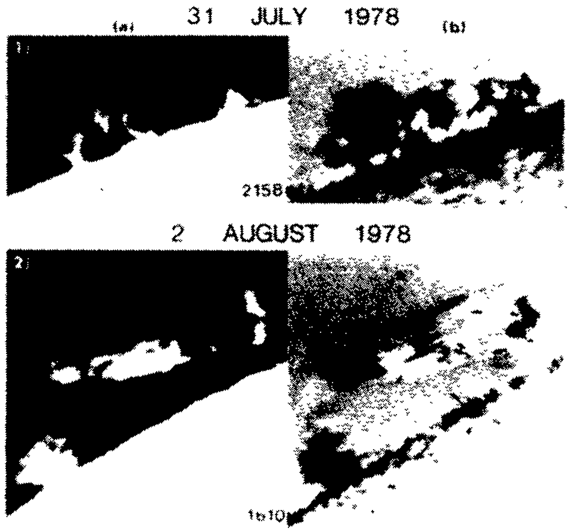




Fig.44. Macro-scale rotation of plasma found in prominences by Liggett and Zirin (1984).

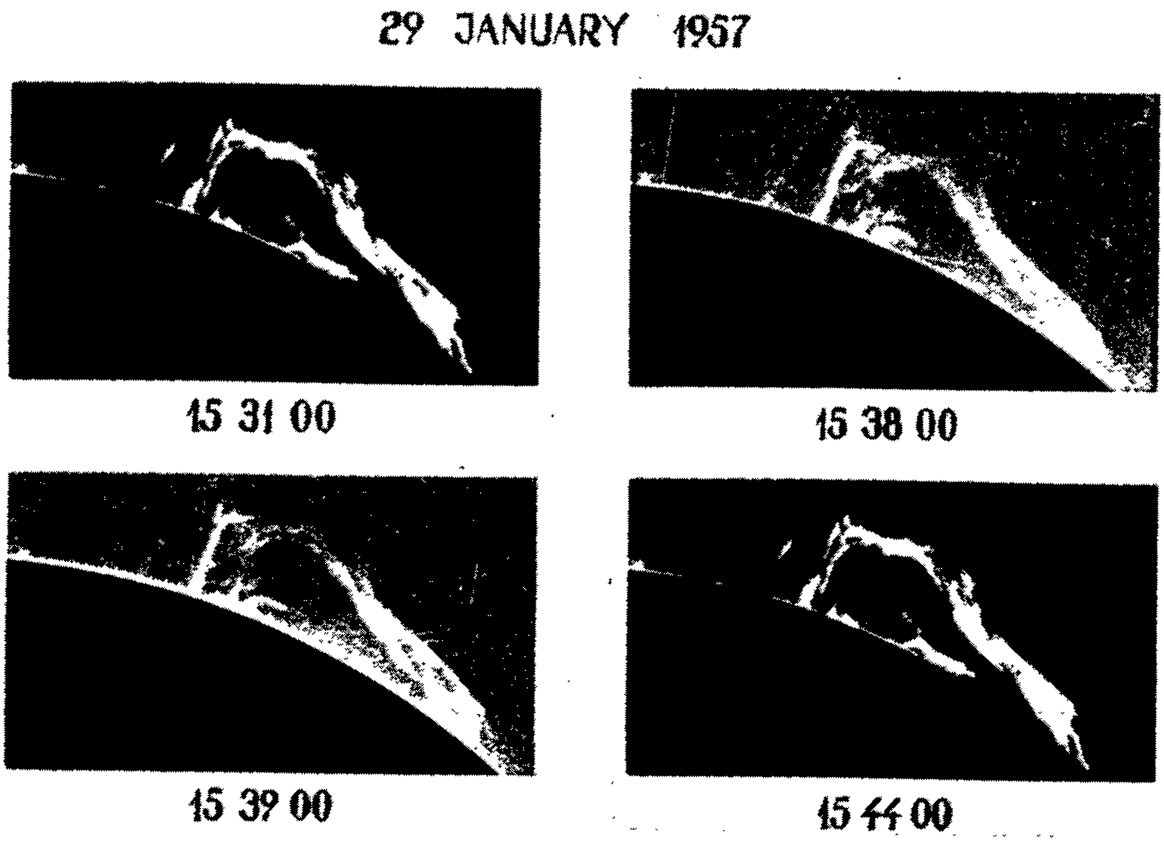



Fig.45. A process of unwinding of a set of fine filaments in an old arch-shaped QP originally twisted (courtesy H.Otavský and B.Valniček).

line-of-sight in the range 4 – 40 km $s^{-1}$. The size of the regions rotating in the plane of sky ranged from (1.5 x 9) Mm to (30 x 104) Mm.

Gigolashvili (1978) deduced on the basis of deconvolution of some complex Hα as well as Ca II H and K line profiles into the Gaussian components, and the subsequent analysis of the velocity field derived, that a number of QPs observed in the northern solar hemisphere display a left-handed spiral while those in the southern – a right-handed one.

Rotational motion on a micro-scale, caused by flow of material along some fine filaments twisted into micro-spirals is observed in QPs at some occasion (Öhman et al. 1968, Rompolt 1975d). This kind of motion is more often observed than the macro-scale rotational motion. The velocities of micro-scale rotational motions are in the same range as velocities usually observed in the fine structure of QPs (see Section 6).

Two examples of macro-scale twisting of the fine filaments in quiescents are presented in Figures 45 and 46. The system of fine filaments of an arch shaped old type prominence in Figure 45 is evidently twisted at 15 31 00 UT. On the next sequence of pictures a process of unwinding which lasted for several minutes only, is clearly seen. Such process of unwinding of initially twisted fine filaments is rather a commonly observed phenomenon. It would be interesting to note, however, that I had never seen in my practice a reverse process in the corona – I mean, a process of twisting in, neither of an isolated prominence fine filament, nor a bundle of such filaments. In Figure 46, on the other hand, one can see two ropes noticeable twisted. Every one of the constituent ropes consists very likely of a set of the fine filaments which being tightly packed in the ropes cannot be seen separately as the well resolved structures. One can guess, however, from a number of tiny knots clearly seen along the extension of every one rope that the ropes are really formed from a cluster of finer structures.

The fine filamentary structures in QPs is quite often seen as being twisted into the micro-spirals (Rompolt 1975b). These small-scale spirals are especially well seen during an activation phase of a QP or an early phase of eruption. In Figure 47 a couple of fine filaments in the form of micro-spiral is easily identifiable in a prominence recorded during its early phase of eruption.

The problem of identity of the quiescents fine structure observed in different spectral lines formed at different temperature regimes is yet a rather open question. However, the fine structure seen in different but low temperature lines is in most cases identical. As an example may serve two high resolution filtergrams presented in Figure 48 of a small well developed QP taken by S.Koutchmy in the hydrogen Hα and helium D3 lines with the Solar Vacuum Telescope at Sacramento Peak Observatory.

Fig.46. Two intertwined macro-ropes in a QP of 1970.10.02 (courtesy of V.V.Makarova and Yu.V.Platov, LC-Kislovodsk).

Fig.47. Micro-spiral filaments seen during the early phase of eruption of a QP - a negative print (courtesy G.M.Nikolsky and Yu.V.Platov).

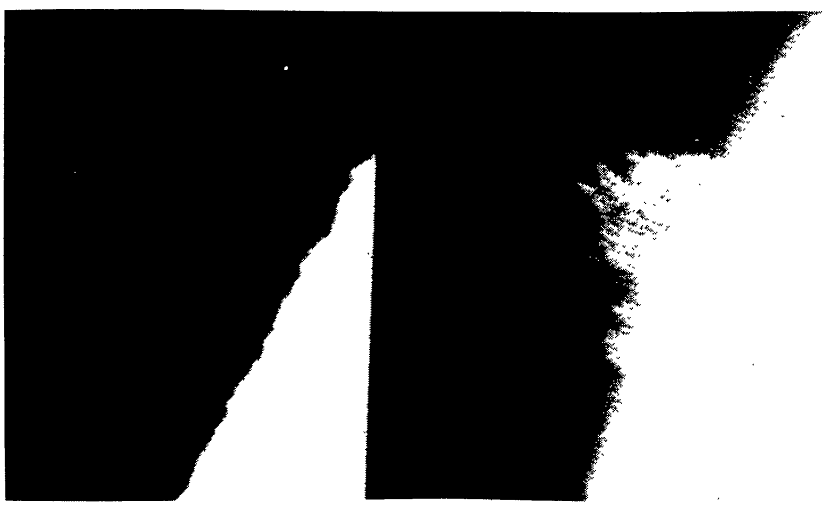


Fig.48. A small well developed QP displays the same fine filamentary structure in Hα (left) and He I D3 (right), (courtesy S.Koutchmy).

A good correspondence between the fine filaments seen in both filtergrams is remarkable. Note, that the chromosphere in the D3 line is more diffuse than in Hα and screens the bottom part of the arches. Here, the longitudinal magnetic rope of the prominence forming the arches is distinctly marked.

## 10. ERUPTION OF QUIESCENT PROMINENCES

As has been evidenced in Paper I, eruption of QPs as well as of the associated coronal mass ejections (CMEs), is forced by a common cause, namely, by eruption of huge magnetic systems (HMSs) from the solar surface out to interplanetary space. Cool and dense plasma of a QP is in most cases frozen only into a part of such a HMS (e.g., see Figure 60) - before as well as during the eruption. So, the HMS when erupts simply lifts with, the frozen-in prominence material.

The process of eruption of a QP starts, in my opinion, when the HMS into which the prominence is originally frozen-in, is somehow slightly lifted and disturbed, e.g., by a new emerging magnetic flux. In consequence, the equilibrium state of the prominence magnetic skeleton is disturbed, and a part of the material flows down from the skeleton to the chromosphere - this phenomenon is often observed at the very beginning of the eruption of a QP. As a result, the HMS becomes a bit lighter and starts to lift up. In course of time, more and more of the lifted prominence material flows down, discharging the system, and the HMS is forced to erupt with an increasing acceleration. In my estimation, usually, during the eruption of a QP, a significant part of its initial mass flows down to the chromosphere.

There are at least three possibilities for the initiation of eruption of a HMS, which begins by its local lifting and/or disturbance.

1. - Strongly sheared transversal magnetic field of a QP, by the large-scale mass motions in the prominence channel, undergoes some reconnections with the longitudinal magnetic field. In consequence, the magnetic system of the prominence is simplified and transformed into a huge arch which erupts owing to the magnetic tension.

2. - An emergence of a new magnetic flux in the region adjacent to or immediately below a QP exerts a thrust, and forces some reconnections and transformation of the prominence magnetic system into a huge erupting arch.

3. - A large-scale magnetic field being continuously generated in the sun, flows up from the subphotospheric layers to the solar surface, and exerts a pressure on an existing HMS. In consequence of a slight lift-

ing of the original HMS, its mass-magnetic field balance is disturbed and the HMS is forced to erupt.

A common feature of the QPs and ARPs is that their eruption proceed in a very similar way. Both kinds of prominences start to erupt with a slow speed on the order of a few kilometers per second and continuously accelerating reach a velocity on the order of several hundreds of kilometers per second. In Figure 49 a time-height diagram for eruptions of a number of QPs as well as ARPs is given together with an inset making possible the velocity evaluation. The individual time-height dependencies are constructed in such a way that the zero-height level is taken at the top of every one prominence while in a stable state just before the eruption. The all time-height curves for the ARPs eruptions are grouped in the left-hand side half of the diagram, whereas some for the QPs are spreading far to its right-hand side half. This curiosity means that the ARPs undergo eruption in much shorter time interval than the QPs do. Thus, the ARPs attain a given height in corona much faster than the QPs ones. The phenomenon discussed seems to be caused by the larger gradients and tensions of the magnetic field in active regions.

The amount of the mass flowing down to the chromosphere and its rate and direction of motion during an eruption depends upon the location of the prominence material within an erupting arch, the velocity of eruption at a given time, the large-scale geometry of the arch, and the shape of the fine magnetic filaments forming the arch (twisted or not). The balance of velocities involved in an eruption is schematically explained in Figure 50. The slowly erupting prominences can carry down to the chromosphere a great part of their original matter, while the fast erupting ones only a small part if any.

As has been already mentioned the process of eruption of the QPs as well as ARPs proceeds initially with a slow speed of a few kilometers per second which is subsequently increased with the lapsed time up to several hundreds of kilometers per second. For some eruptives, however, some authors report a constant velocity during all the observed process of eruption what is manifested by a linear dependence on the time-altitude diagram. The velocity behaviour of this type is usually observed during the eruption of such prominences which were not seen on the limb in a stable state just before the eruption - it means that the prominences were situated before the eruption behind the solar limb or on the disk near the limb but well below a line-of-sight crosing the limb (see Figure 51). In the case of such a location of these prominences we cannot see the low-velocity phase of their eruption.

It is generally known that QPs are located at the base of coronal helmet streamers; this means that above the magnetic skeleton of a QP

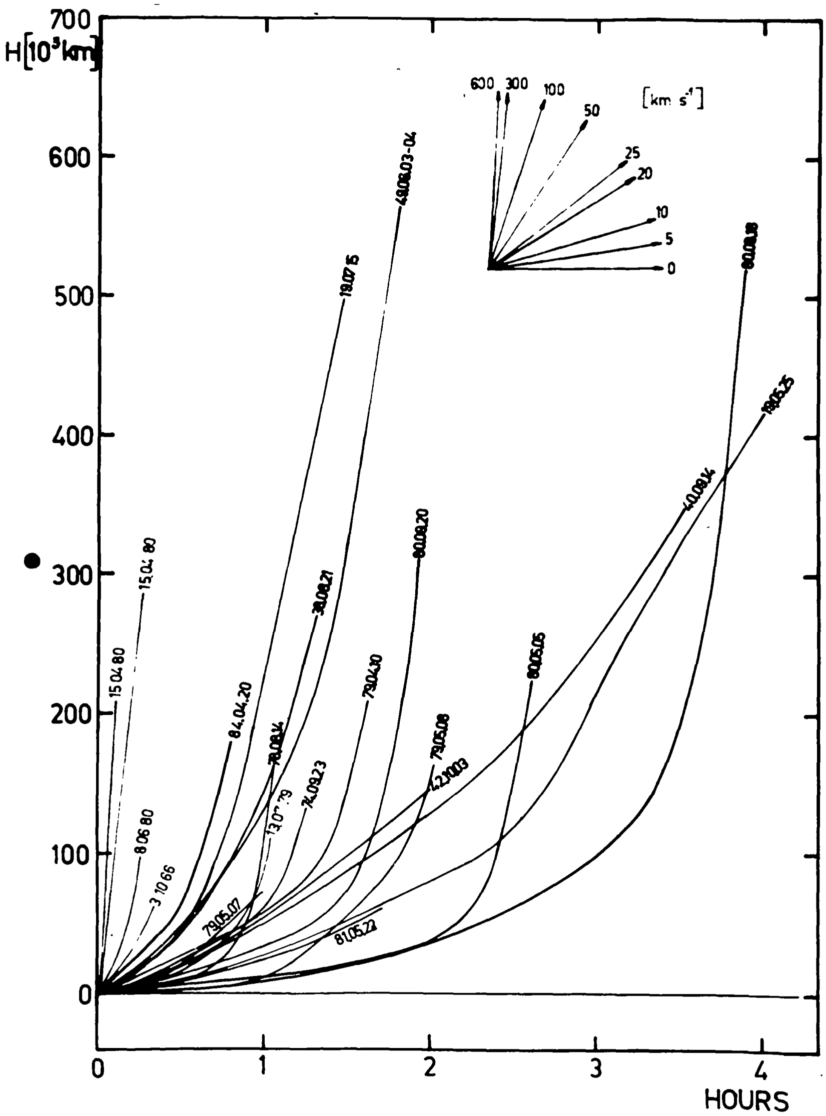



Fig.49. The time-altitude diagram for eruption of the quiescent and active region prominences. The zero-level is accepted at the top of every one prominence being in a stable state just before the eruption.

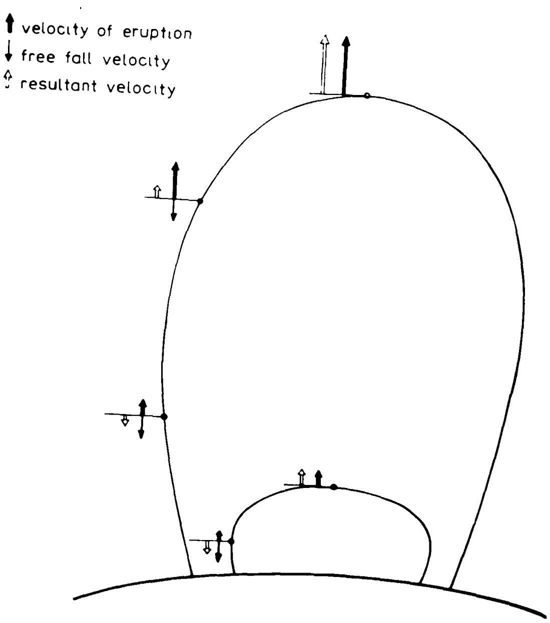



Fig.50. Schematic representation of the balance of velocities involved in the process of prominence eruption.

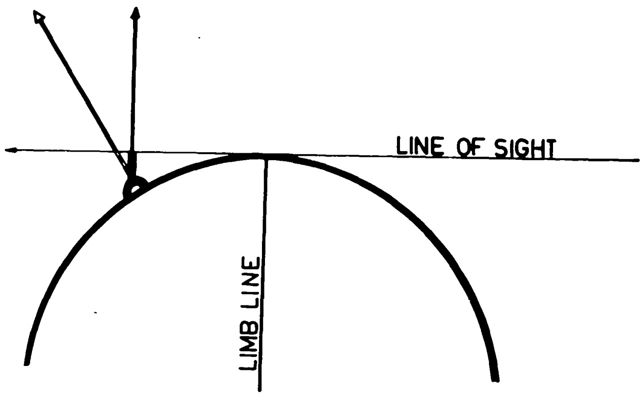



Fig.51. A scheme showing why during prominence observations on the limb we didn't see at some occasions an early phase of the prominence eruption and by inference the low-velocity part of a time-altitude curve.

is stretched another much larger magnetic system of helmet arcades (see Figure 52). The process of eruption of a QP becomes much more complicated if we realize that during the eruption an interaction of these two magnetic systems should take place. Certainly, the magnetic system of arcades is stretched away and distended by the erupting HMS. It is natural to believe that during the eruption a process of reconnection of a part of the fine magnetic filaments of the both field systems must lead to a simplification of the whole magnetic configuration. As we see later the process of magnetic reconnections seems to play not a very important role in the process of interaction of these two magnetic systems.

As a result of a detailed analysis of the geometry, the characteristic evolutionary changes and the location on the limb of the eruptive prominences (EPs) observed with Hα-coronagraphs at the Wroclaw Observatory, and of the CMEs recorded in white light by coronagraphs on board of the SKYLAB, P-78 and SMM satellites, I came to a conclusion that two types of the eruptives can be distinguished.

I) The EPs which during the eruption are seen in the shape of a large arch (Figure 53). This large arch is formed by a number of fine filaments often twisted or intertwined (see Figure 55). The erupting arch-shaped HMS is nearly fully filled by a cool and dense Hα material. The EP of this type is located just in the lower part of the associated CME big bubble (Figure 54).

II) The EPs which erupt in one arm of the associated HMS change with time during the eruption the inclination of their main body from being roughly parallel to the limb at the beginning of eruption up to being perpendicular to it in the late phase of eruption (Figure 63). The phenomenon looks as it were there not enough of the cool and dense material in the remaining part of the HMS arch to become visible in Hα (see Figure 60). The EP of this type is located in one leg of the associated CME big bubble somewhere near its internal boundary (Figure 61).

During the process of eruption of some EPs a system of very fine loops is seen in a late phase of eruption. This is one of spectacular arguments giving the evidence on eruption from the sun of the HMSs (for the other arguments see Paper I).

In the following two examples illustrating type I eruption from the sun are given. One demonstrating an unwinding of initially twisted fine structure of a small young QP of 1982.09.16 into a system of fine loops is shown in Figure 56. The diameter of the thinnest fine loops seen in Figure 56c is of about 0.25 Mm (1/3 arcsecond). Note that the fine filaments of the QP unwound into a system of loops at a height lower than

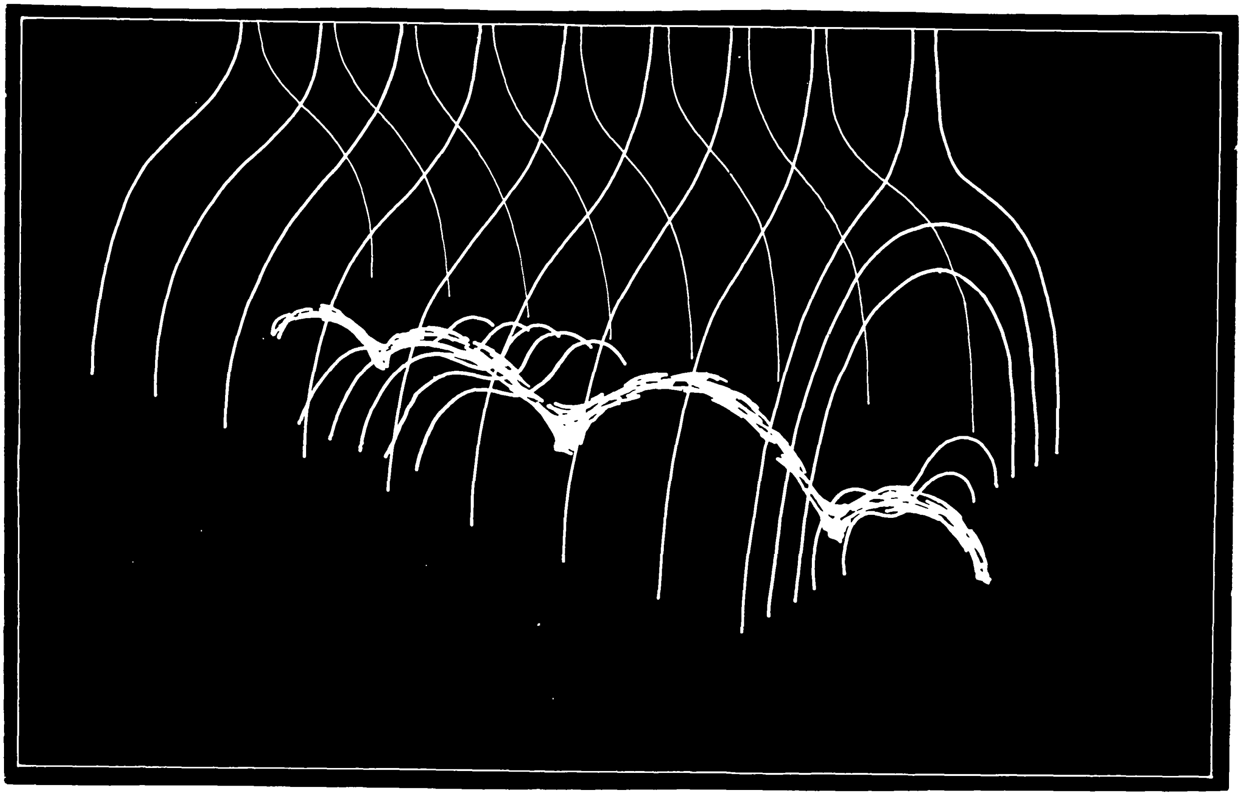


Fig.52. Magnetic systems of a well developed QP (strongly exaggerated in the vertical extent) and the overlying helmet arcades (Paper I).

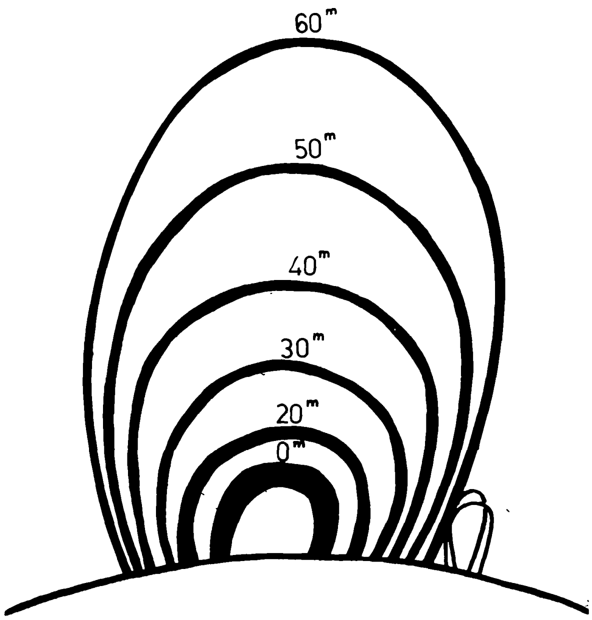



Fig.53. Schematic illustration of the type I eruption of an ARP or a QP, where the prominence material fills the whole erupting HMS.

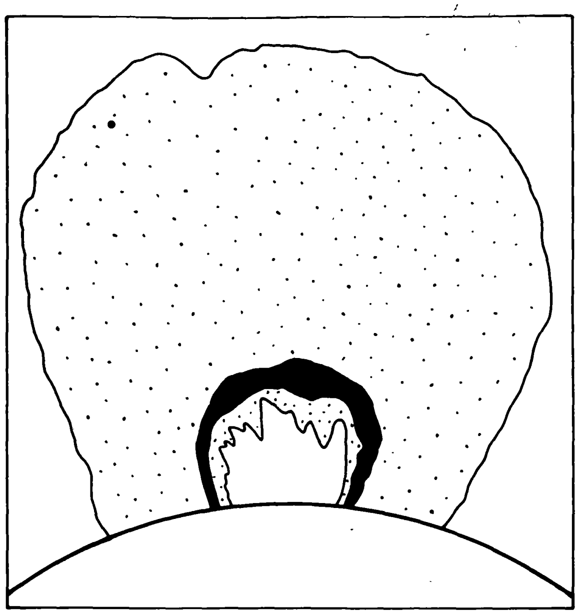
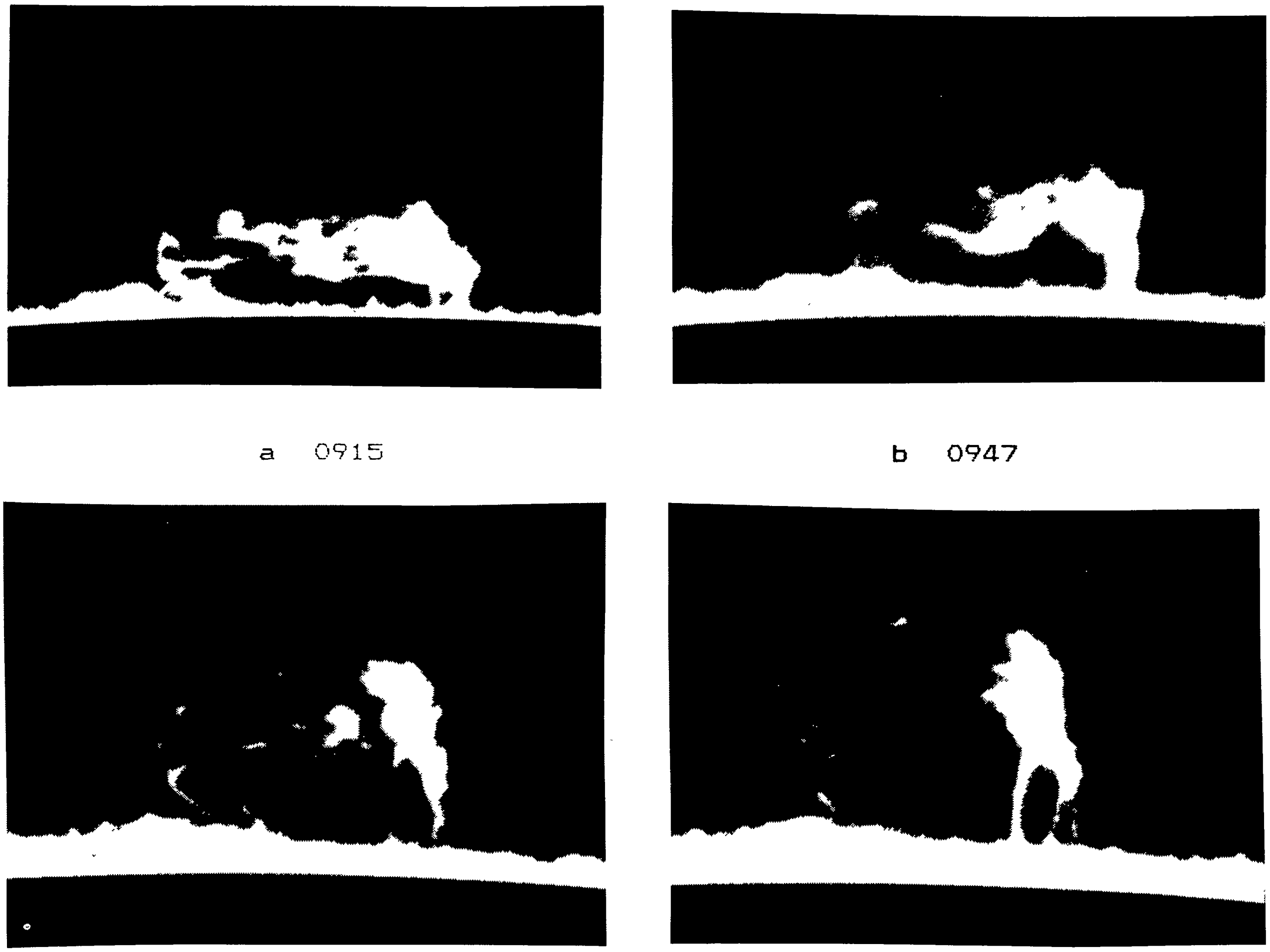


Fig.54. Location of a cool and relatively dense prominence material within a coronal mass ejection (CME) big buble structure during the type I eruption (cp. with Figure 53).

Fig.55. A QP of 1973.12.19 during the type I eruption filling whole the arch of the associated HMS with material emitting in the He II 30.4 nm line (courtesy R.Tousey, Naval Research Laboratory).



a 0915 b 0947

c 1019 d 1025

Fig.56. A small young QP reveals during the eruption a system of fine loops at a relatively low height in the corona (LC-Wroclaw).

40 Mm (1/20 $R_\odot$) above the photosphere! At such a height, we believe, there is no magnetic field structures associated with an overlying helmet arcade. Thus, the system of fine loops observed in a late phase of eruption of this young QP should be not the result of the reconnections between the both magnetic systems of the prominence and the overlying helmet arcade, as has been mentioned earlier. On the basis of a number of the very similar eruptions observed· I came to a conclusion that the system of fine loops visualized during the eruption seems to be thus naturally involved in the magnetic skeleton of a QP before the eruption what is in agreement with the QP model presented in Section 7.

Another example of the process of unwinding during the eruption into a system of fine loops, but of an old type arch-shaped QP, is shown in Figures 57, 58 and 59. The prominence fine filaments originally intertwined into a huge arch (Figure 57) were observed as twisted structures during the eruption (Rušdjak and Vršnak 1981, Rušin and Rybanský 1982, Paper I, House and Berger 1987, Vršnak et al.1988). In a later phase of eruption this huge arch underwent untwisting into a system of clearly visible loops (Figure 58 and 59), but at large coronal heights (2-3 $R_\odot$) in this case (Paper I, House and Berger 1987). The eruption has been observed within the coronal altitude range 1.6-4.5 $R_\odot$ by the SMM Coronagraph/Polarimeter (Figure 58), and within the range 2.6-10.0 $R_\odot$, with a worse spatial resolution, by the SOLWIND coronagraph on board of the P78-1 satellite (Figure 59). For this eruption the cool and dense Hα prominence material has been followed up to the distance of 10 $R_\odot$, what was observed for the first time.

As has been mentioned previously a classical example of the type II eruption is the EP of 1979.05.08 presented in Figure 63. The southern extremity of the prominence was anchored in the photosphere during all the time of eruption at S58-W - while the center of symmetry of the accompanied CME big bubble was located at S30-W (Figure 62). The first manifestation of the CME above the SOLWIND coronagraph's occulting disk at 2.6 $R_\odot$ occupied the region from S15-W to S60-W and later on even up to S65-W. During all the process of eruption the EP was anchored in the southern leg of the CME. Note, that the inclinantion to the limb of the prominence main body changes in a manner as if the prominence were be really frozen-in into one arm of an erupting HMS arch (see Figure 63).

Finally I would like to show and discuss some evolutionary peculiarities of three EPs of May and June 1989, displaying during the eruption a very rich and complicated fine filamentary structure. In my opinion, the present solar cycle generates a great deal of magnetic ropes consisting of much more constituent fine magnetic filaments as the previous cycles did.

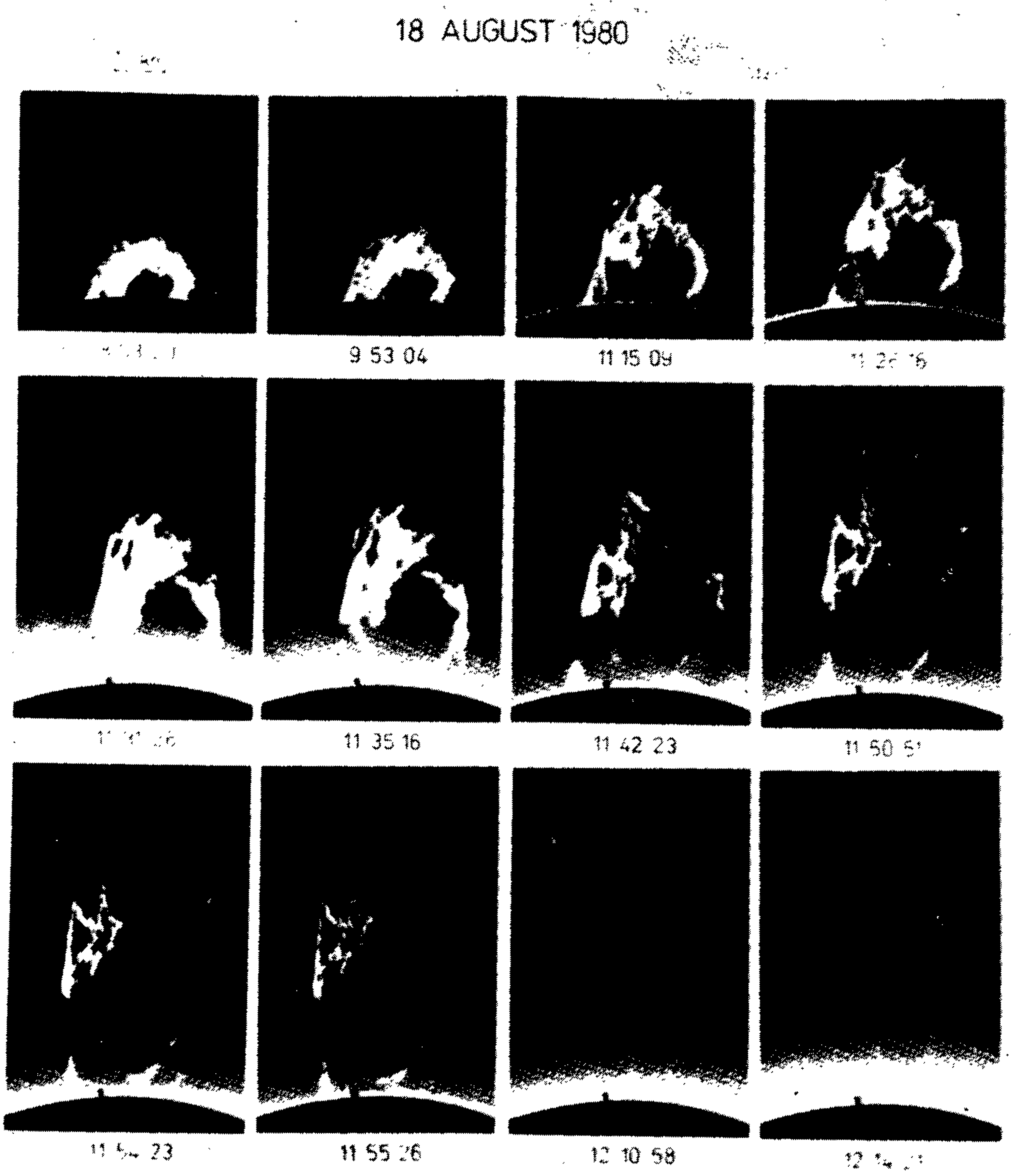
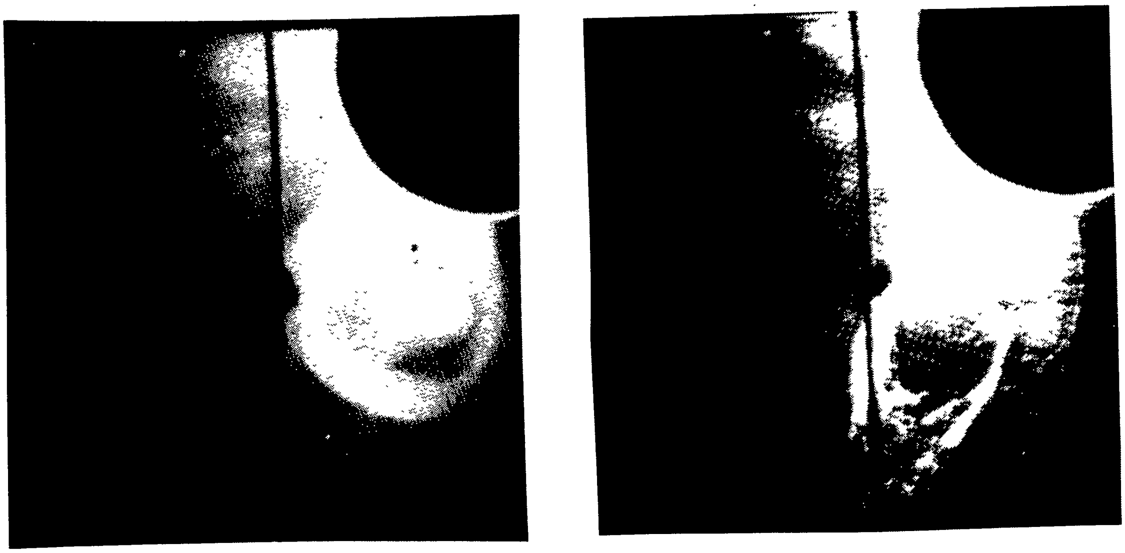



Fig.57. Type I eruption of an old QP (SC-Wroclaw). The fine filamentary structure of the prominence originally twisted into a huge arch unwinds into a system of loops high in the corona (cf. Figure 58b).



a 1215 b 1316

Fig.58. Coronal mass ejection – a, and a system of loops – b, developed high into the corona during the eruption of an old QP of '80.08.18 shown in Figure 57 (courtesy SMM – Coronagraph Team, HAO, Boulder).

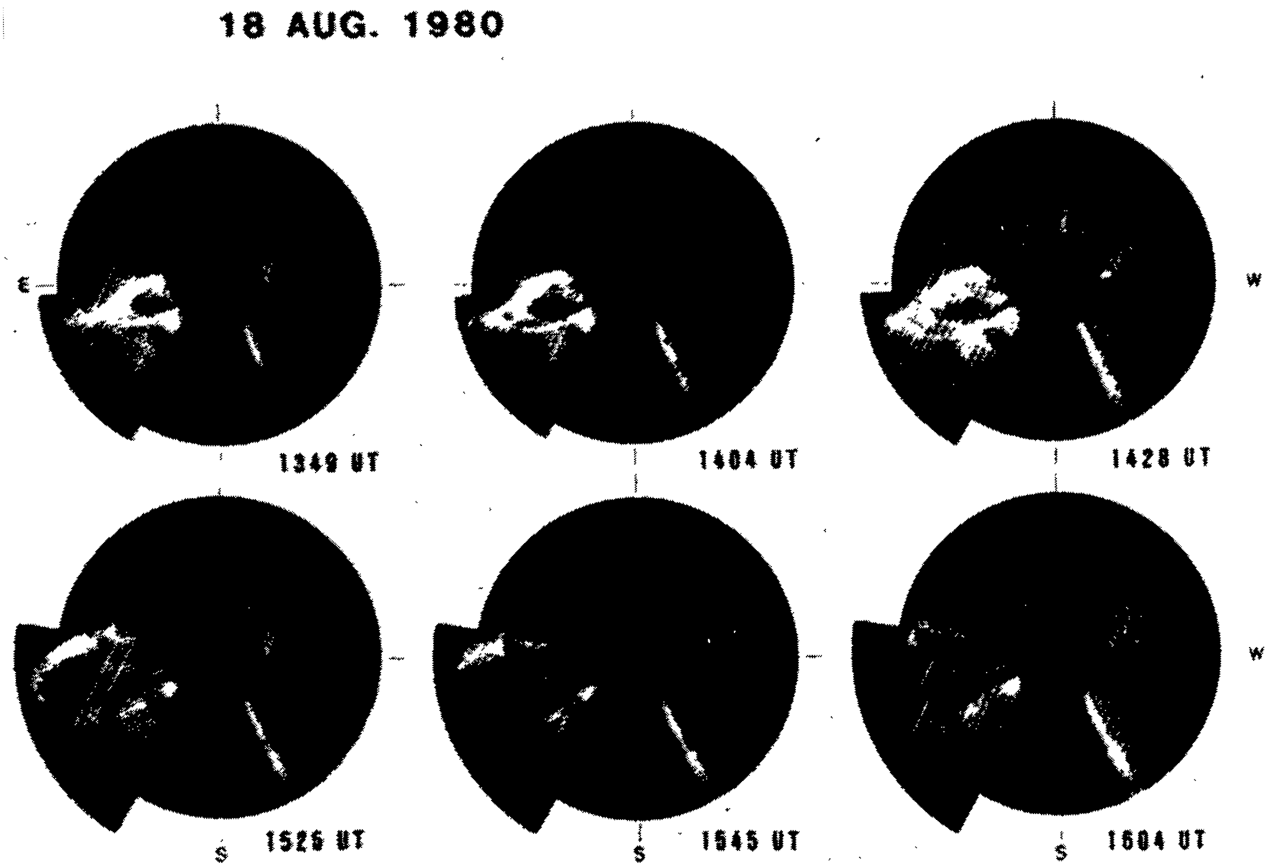



Fig.59. The same system of loops as presented in Figure 58b observed by the SOLWIND Coronagraph at a distance of up to $10\ R_{\odot}$ from the sun's center (courtesy D.J.Michels and N.R.Sheeley, Jr., NRL, Washington).

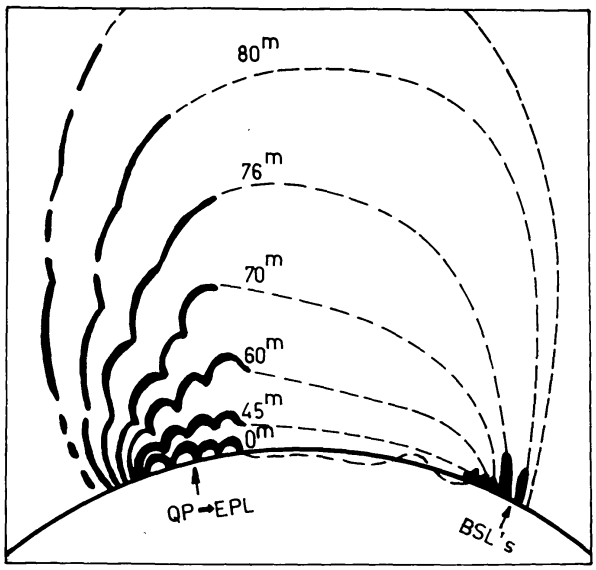



Fig.60. Schematic illustration of the type II eruption of an ARP or QP, where the prominence material fills only a part of the HMS.

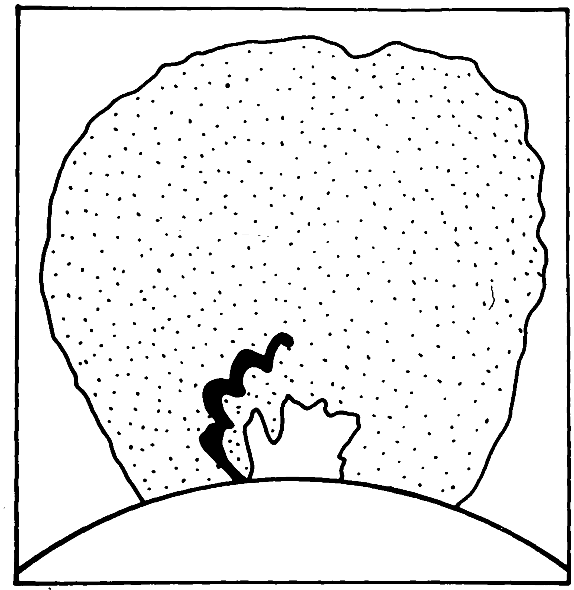


Fig.61. Location of a cool and relatively dense prominence material within a CME big buble structure during the type II eruption.

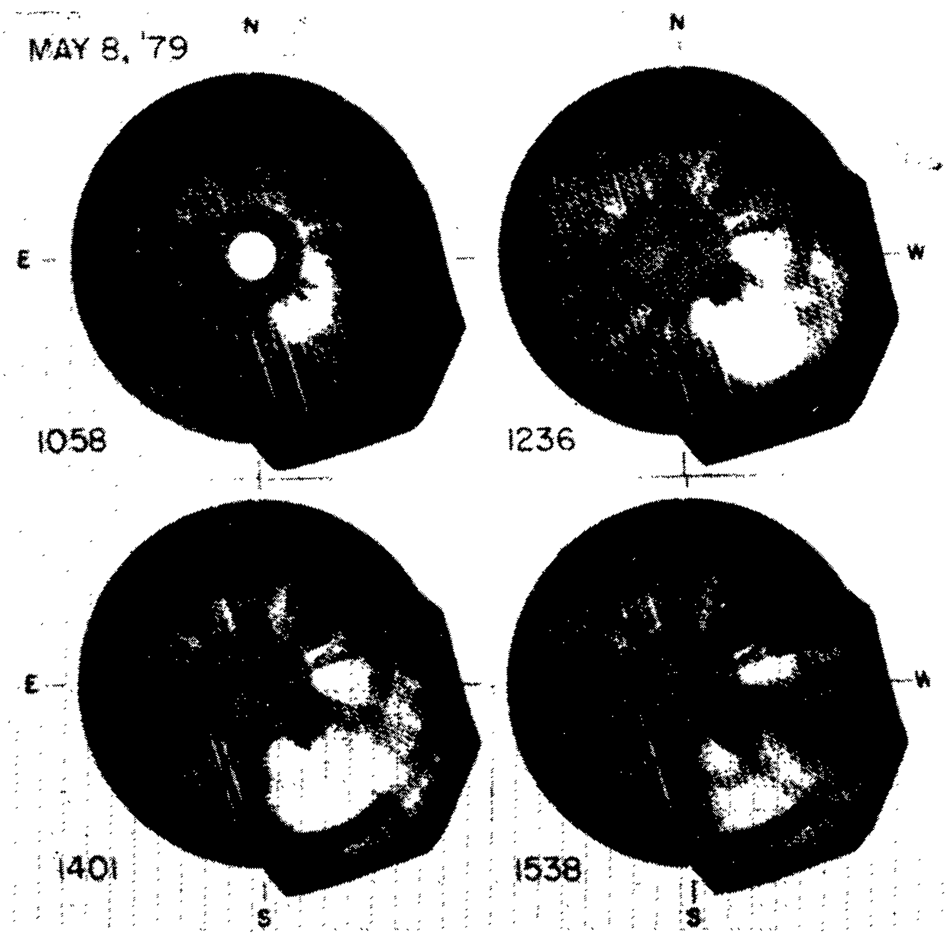



Fig.62. A CME big buble associated with the type II prominence eruption shown in Figure 63 (courtesy D.J.Michels and N.R.Sheeley, Jr.).

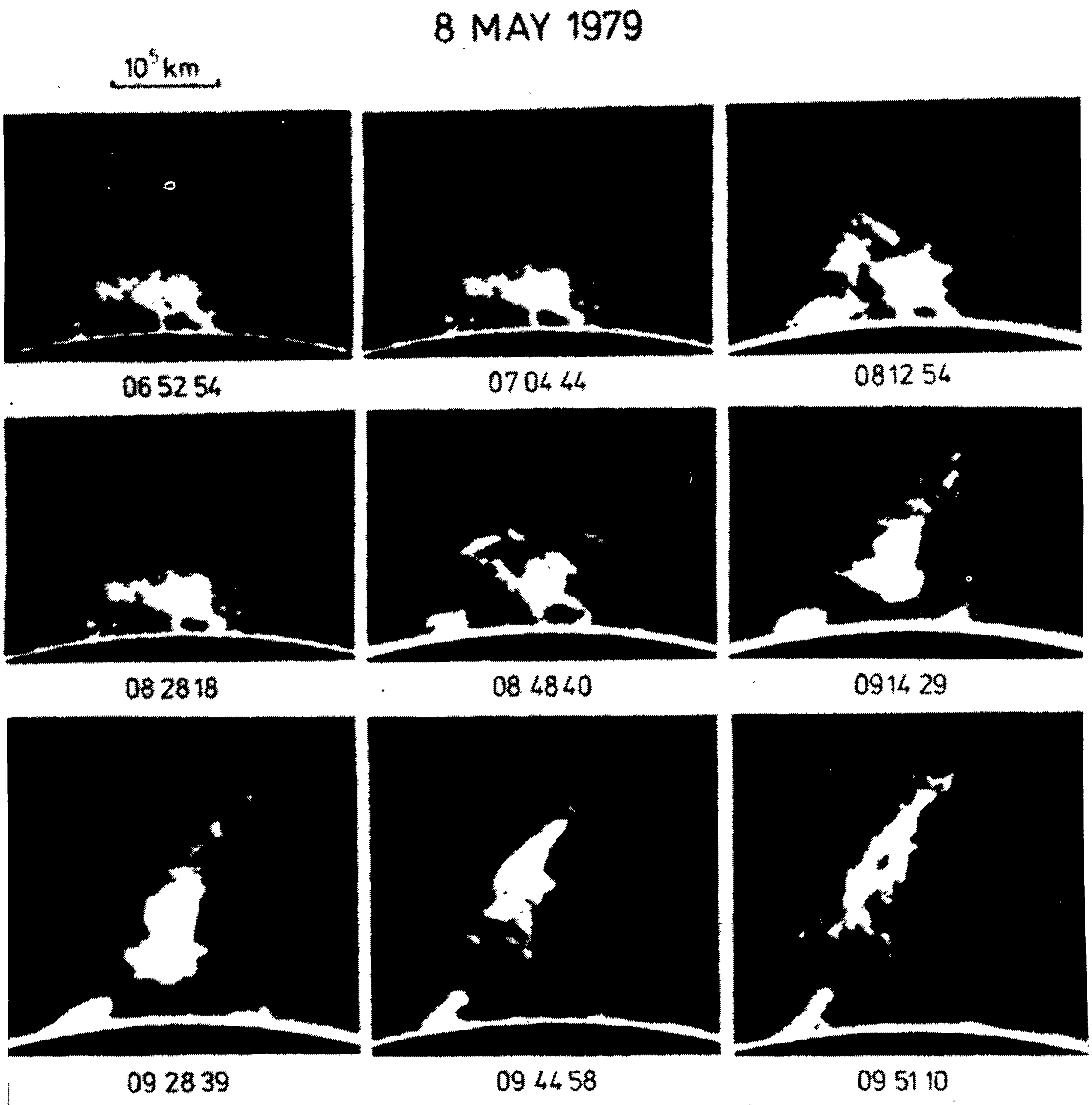



Fig.63. Type II eruption of a well developed QP frozen in only into a part of its HMS (SC-Wroclaw).

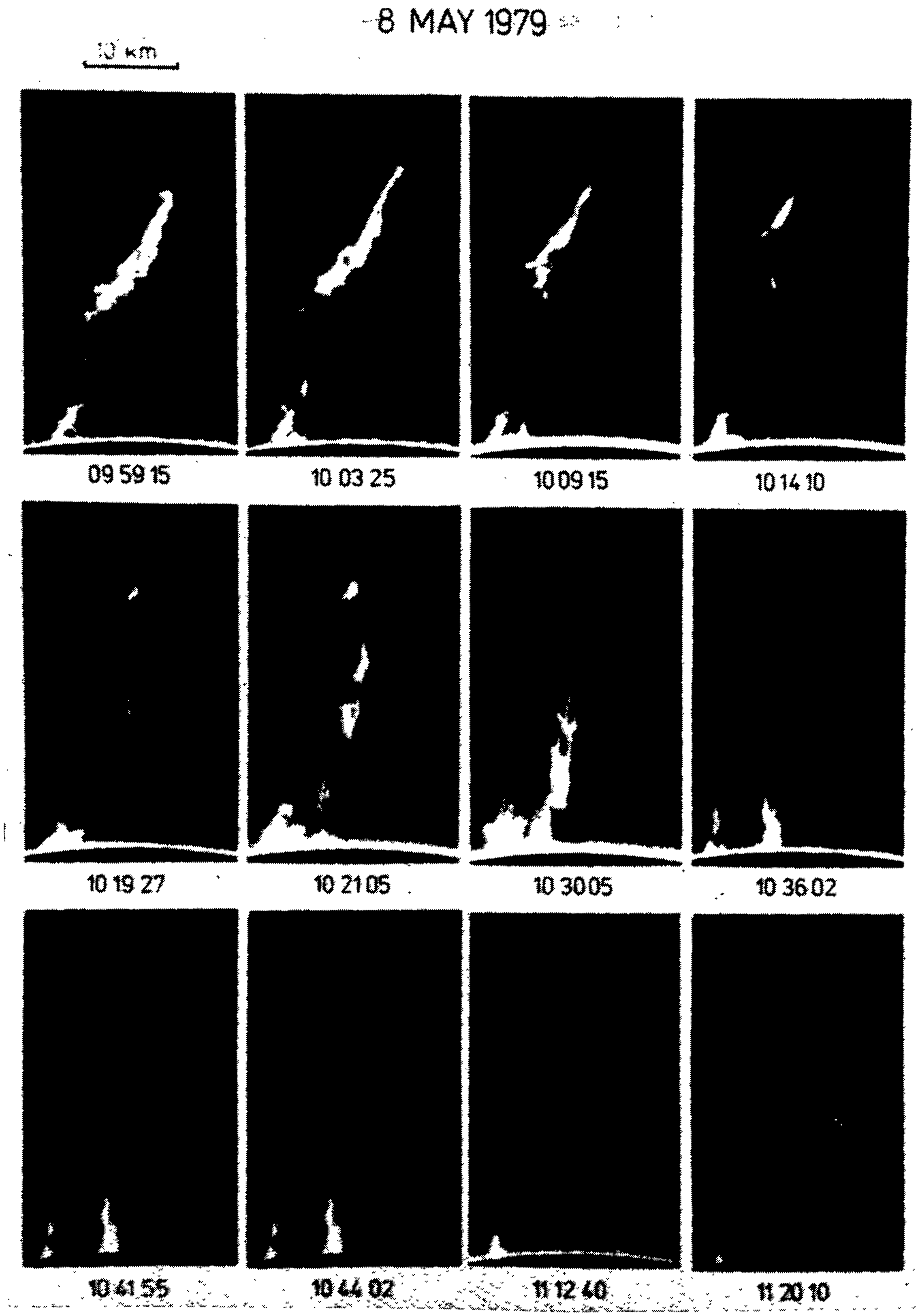



Fig.63. Continued. Type II eruption of a well developed QP.

An old QP which erupted on 1989.05.17 was a high latitude prominence belonging to the polar crown filaments. Its long filament when seen on the disk on that date was running nearly parallel to the equator from a position of N66 somewhere at the central meridian up to N60 at the W-limb, then slightly bending toward the equator after crossing the limb. The discussed phenomenon belonged to the eruptives of type I, where the Hα-material was frozen-in, at least in an early phase of eruption, into one arm of an associated HMS (Figure 64a - 1032 UT). About half an hour later the erupting HMS underwent most likely a collision with a magnetic arch of an overlying helmet arcade - this can be guessed from a flat arrangement of the uppermost Hα-material at the very top of the visible part of the EP (see Figure 64b). This obstacle has been overcome in the next 20 minutes - as is evident from Figure 64d the uppermost part of the EP is no more flat instead exhibits now a vertical arrangement of a set of isolated fine filaments. The extremely fine Hα-filaments revealing the fine magnetic structure of the low part of the associated HMS are clearly seen in Figure 64c during an early phase of the eruption. An interesting phenomenon has been recorded during the course of this eruption, namely, a process of magnetic reconnections taking place at relatively low coronal altitudes leading to formation of an upturned arcade of loops, hereafter called the U-type arcade (Figure 64 e-i). Because of a rather slowly proceeding eruption the material is flowing down to the chromosphere (cf. Figure 50) in a system of more or less vertically oriented filaments forming the U-type arcade. This is quite remarkable inspecting the pictures in Figure 64 e-h - here the material is seen initially to flow down along the fine filaments of the right-hand arm of the U-type arcade only. With the lapsed time the material is seen to be continuously pumped up into the system of fine filaments of the left-hand arm of the U-type arcade (Figure 64e-i) forming finally a beautiful panache (see Figure 64 j and k). Now the material in the right-hand arm of the U-type arcade is no more seen. Eruption of this high-latitude QP seems to be worthy of notice also therefore that probably a large two-ribbon (?) flare should take place some time during the eruption. As it is evident from the pictures in Figure 64 j-l a system of loops usually observed in dynamic flares (post-flare loops) is seen to expand just to the left of the panache. Finally, it is worthy of mentioning that during a phase of eruption illustrating by Figures 64 e and f about sixty individual fine filaments were identified on the original negatives across the right-hand arm of the U-type arcade! Does it mean that about sixty fine filaments were involved in the HMS just before the eruption?

Interesting fine structures have been observed during an eruption of

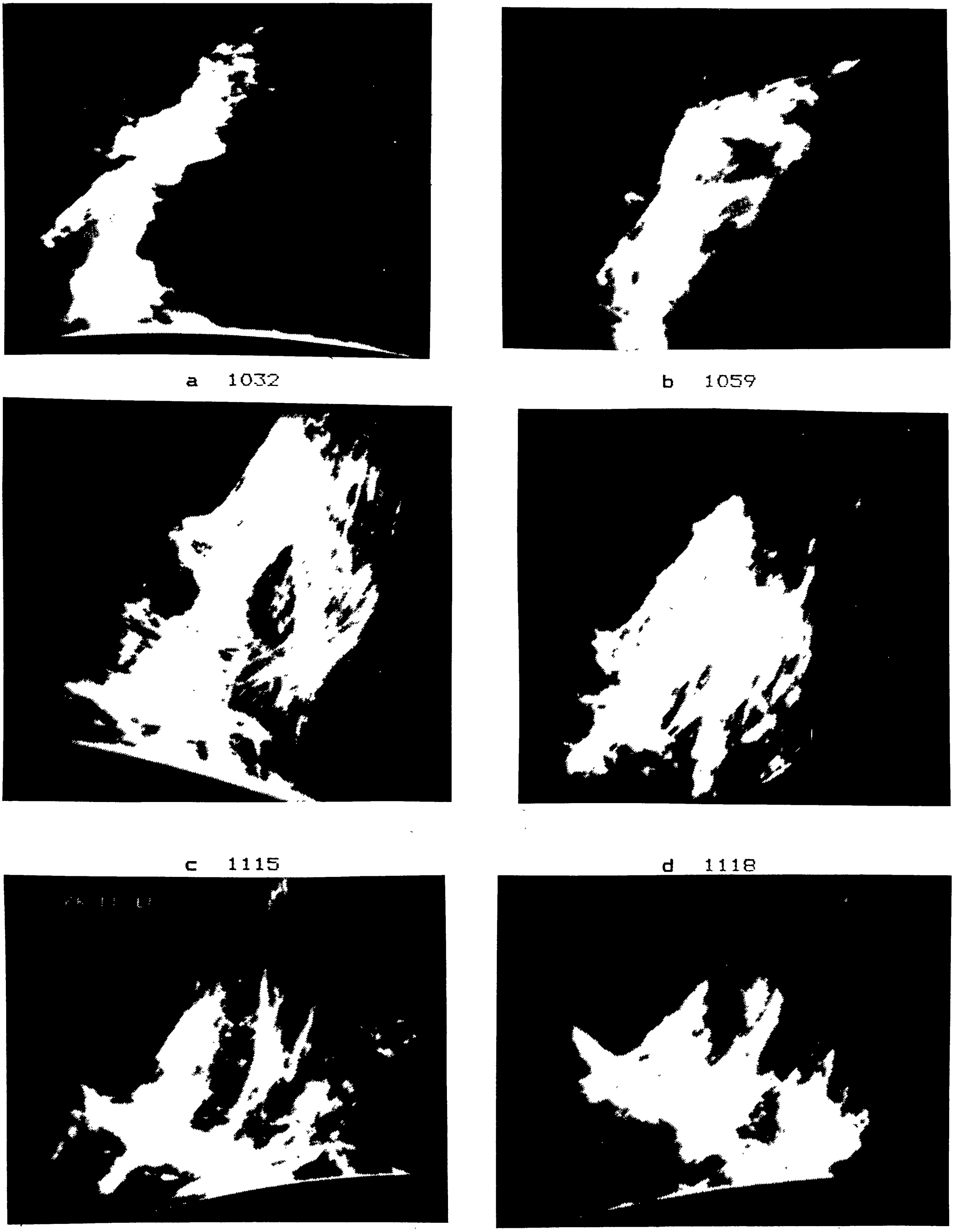
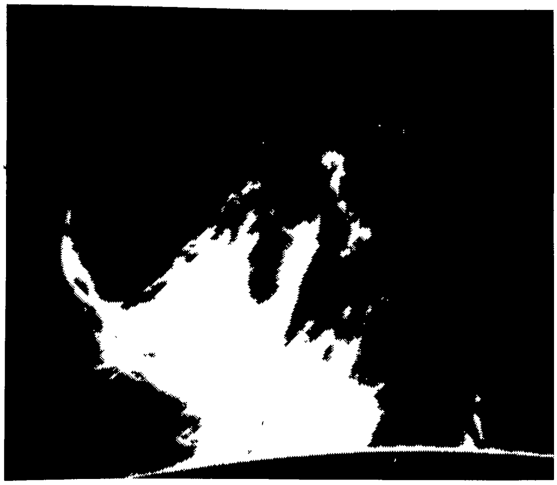
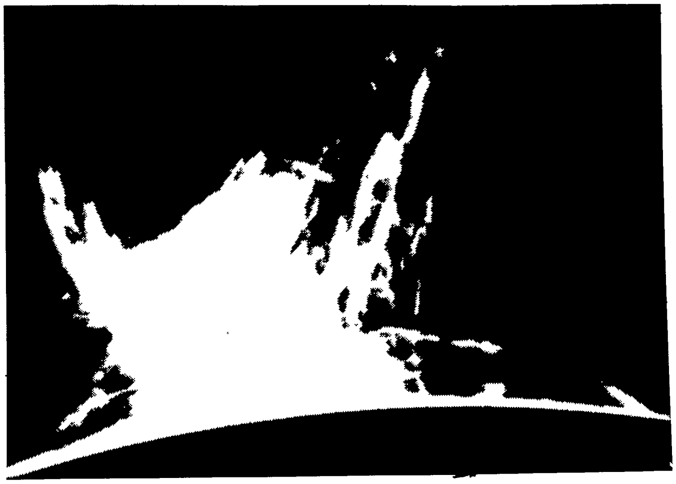


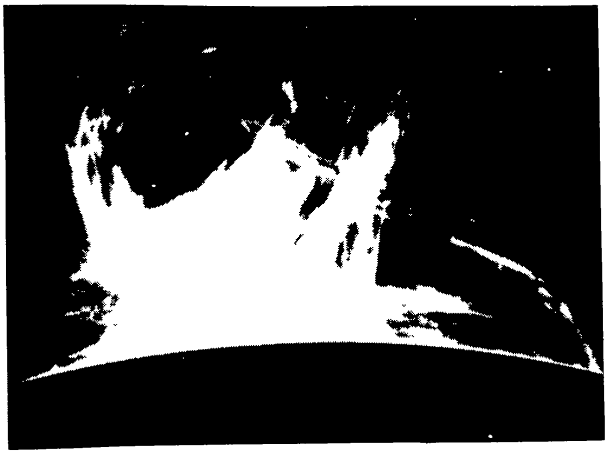

Fig.64. Eruptive prominence of 1989.05.17 (LC-Wroclaw). Turn attention to unusual fine structure of the prominence revealed during eruption.



g 1157

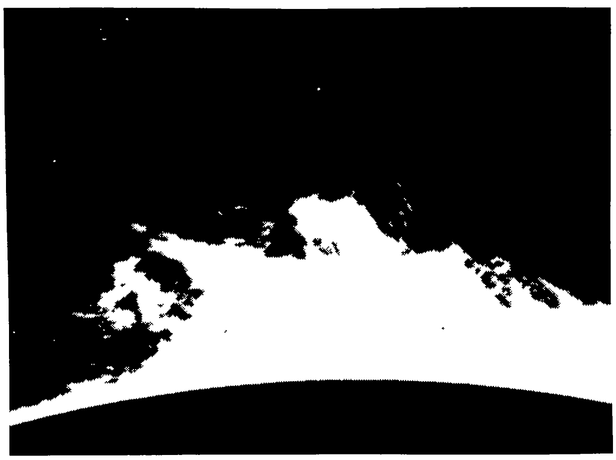


h 1210

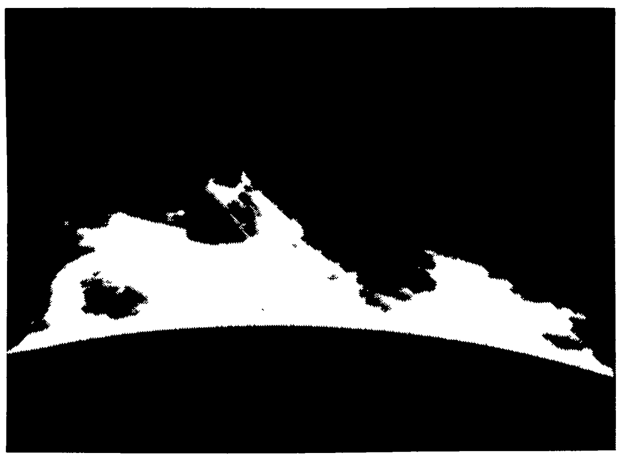


i 1215

j 1248



k 1311



l 1327

Fig.64. Continued. Eruptive prominence of 1989.05.17.

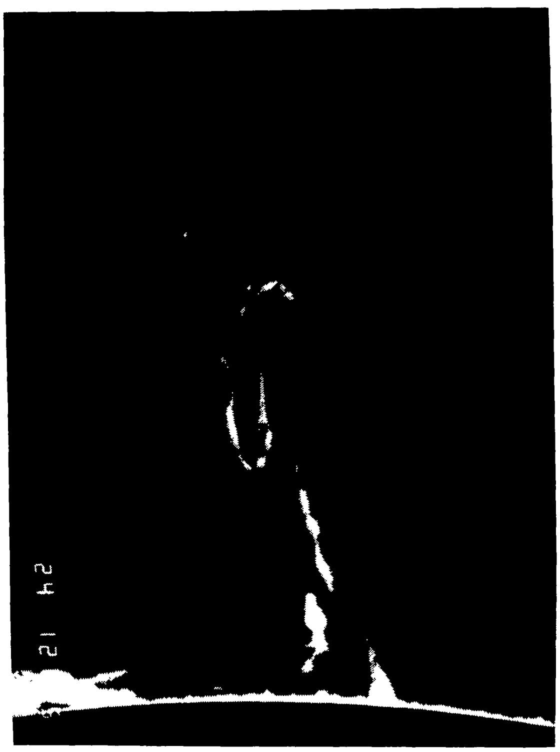
type I of a well developed QP on 1989.05.24 at S21-W. The main phases of the eruption are presented in Figure 65. During an early phase of eruption the vertical arrangement of the fine filaments in the most massive right-hand part of the prominence has been preserved. The top part of the erupting arch of the HMS is evidently twisted at 1045 UT (Figure 65c). This twisting can also be distinguished much earlier during an initial phase of eruption (Figure 65b) but is hardly to be recognized before the eruption while the prominence was in a stable state (Figure 65a). In a later phase of eruption the most massive part of the prominence filling the right-hand arm of the associated HMS unwound into a huge spiral-coil like structure (Figure 65d) which during the next half an hour was stretched out, what could be followed in a sequence of pictures not shown here. This stretching out of the previously coiled fine filaments of the prominence is manifested in a late phase of the Hα-eruption by a system of fine filaments oriented vertically to the limb, along which the material flowed down to the chromosphere (Figure 65e). On the original negative of Figure 65e one can identify more than twenty individual fine filaments! Again, does it mean that the HMS consisted originally of twenty or so fine filaments?

The last event I would like to discuss is an eruption of type I of a rather high-latitude (S46-E), well developed QP, on 1989.06.23. The QP consisted originally of two well defined arches (Figure 66a) but only the southern (left) arch underwent an eruption. Although, as we will see in the following, these both arches were evidently linked together, the northern (right) arch did not take part in eruption, being only activated. At the beginning of the eruption after a slight expansion of the prominence southern arch a funnel-like structure is easily seen in the northern arm of the erupting arch (see Figures 66 b and c). This funnel-like structure is formed by an evident twisting of two systems of very fine filaments belonging to the magnetic skeletons of both arches. Realizing that about twenty fine filaments, at least, of the magnetic systems of both arches were twisted together, the narrow neck of the funnel should be tightly packed by the filaments (Figure 66b). The fine magnetic filaments involved in the funnel-like structure underwent very likely a reconnection simplifying the magnetic situation in this region (cp. Figures 66 c and d). Now, one can perceive that in a relatively short time interval, of less than 15 minutes, the funnel-like structure has been transformed into a rope connected to the magnetic system of the northern arch. Along this rope the prominence material was observed to flow down to the chromosphere during the next 15 minutes. In mean time the erupting arch of the prominence unwound, as usually, in a system of fine loops (cf. Figures 66 d-f). Finally, the e-

a 0646

b 1002

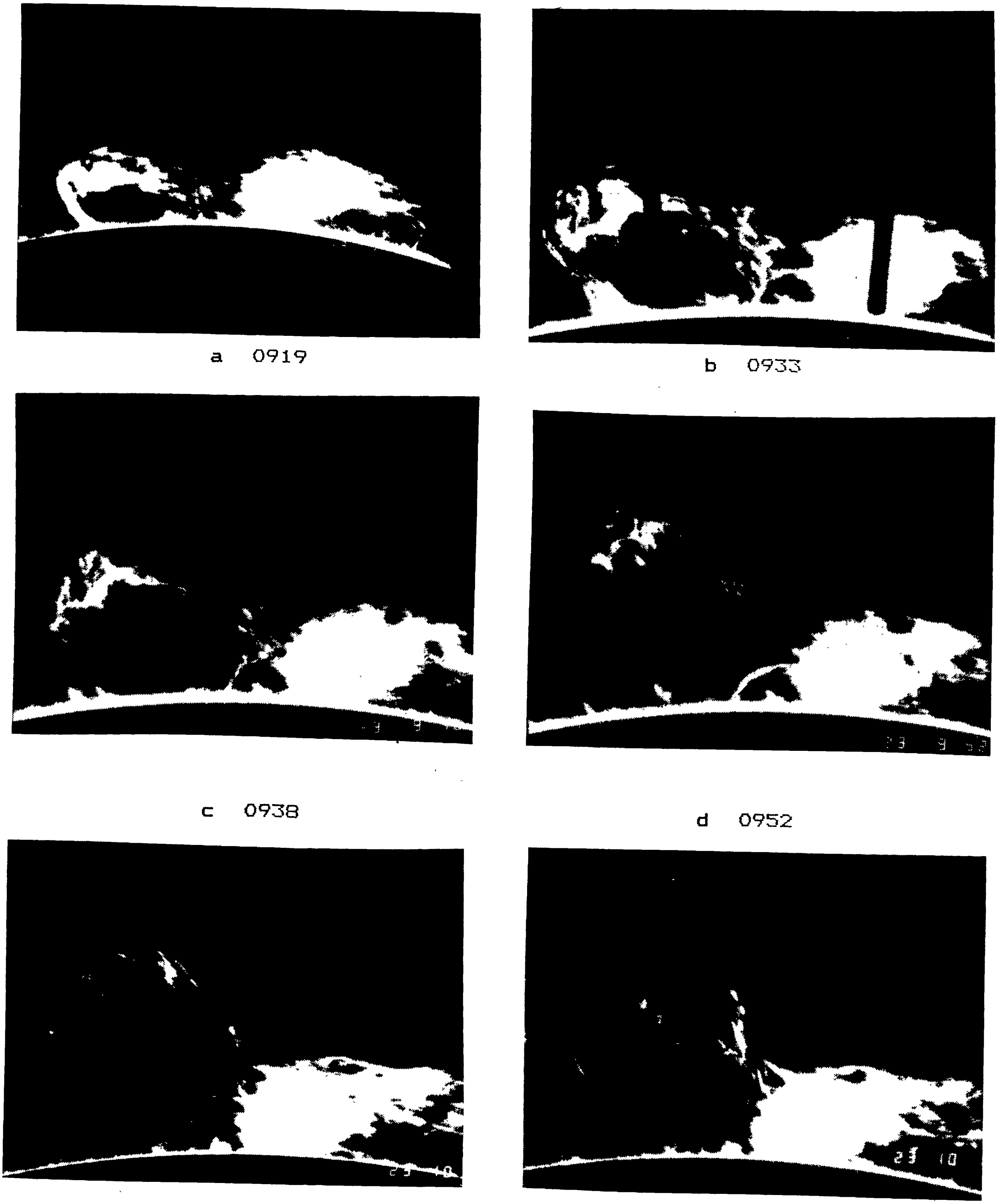
c 1045



d 1115

e 1143

Fig.65. Type I eruptive prominence of 1989.05.24 (LC-Wroclaw).



a 0919 b 0933

c 0938 d 0952

e 1006 f 1015

Fig.66. Eruptive prominence of 1989.06.23 (LC-Wroclaw). A reconnection process took place in the funnel like part of the prominence, cp.c & d.

rupting arch was stretched high into the corona and some material was seen flowing down to the chromosphere along the both arms of the fine loops (Figure 66f). The material at the summit of the loops was lifted further on into the corona.

## 11. CONCLUSIONS

The QPs as well as ARPs consist entirely of fine filamentary structures (sometimes not fully filled by the matter). Strictly speaking, these types of prominences are formed by a system of fine loops often twisted or intertwined within the prominence body. At times these constituent loops can be recognized during a stable state of the prominences, but much easier they are seen during a late phase of their eruption. Such a system of loops consists, in the case of the ARPs, of strongly sheared fibrils or longer fibril-like structures formed of the fibrils by the magnetic reconnection. In the case of QPs such fine loops form the longitudinal rope of the prominence as well as its transversal system of loops. In well developed QPs these loops of the transversal system are deformed into the loops with a central sag. Some parts of QPs and ARPs are seen occasionally as bright more or less homogeneous regions - such an appearance results in consequence of a number of tightly packed fine filaments image of which is blurred by the atmospheric agitation.

Many models of QPs and ARPs ignore the fine filamentary structure of these prominences and suppose that their body is homogeneous. Now, it becomes more and more evident that the fine structure of prominences and the motions associated with it cannot be ignored in attempts of determining of the physical state of plasma in these prominences. Investigation of the transfer of radiation within the prominences, their thermal stability, models of prominence formation, support and stability must take the prominence fine structure into account.

The process of eruption of the QPs, ARPs and the accompanying CMEs, as well as the energy release in some solar flares at least, is most likely caused by eruption of the HMSs from the solar surface out to interplanetary space.

The height of a coronal region where during an eruption untwisting of the quiescent prominence fine structure into a system of distinct loops takes place seems to depend upon the age of the prominence and by inference upon its size. All three kinds of the QPs - young, well de- developed and old ones - undergo eruption but the old prominences being in the shape of a huge arch undergo eruption as a rule. According tc Zirin (1978) the prominences which exceed more or less 50 Mm in height are inclined to erupt and this eruption should take place within two days after the prominence reaches the treshold height. It should be noted, however, that deviations from the Zirin's evolutionary principle of QPs are observed quite often.

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## USTROJSTVO MALIH RAZMJERA I DINAMIKA PROMINENCIJA

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pregledno predavanje

SAŽETAK: Razmatra se fina struktura mirnih prominencija kao i prominencija u aktivnim područjima. Iscrpno se obrađuje ustrojstvo fine strukture tijekom nastanka, stabilnog stanja i erupcije ovih prominencija. Predlažu se dinamički modeli koji mogu objasniti stvaranje kao i opažanu finu strukturu u te dvije vrste prominencija.