EMBLA 2001 : The Optical Mission

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Abstract

In August 2001 a new joint collaboration between italian physicists and norwegian engineers was succesfully carried into effect with a new mission to Norway, in order to further investigate a luminous phenomenon which is occurring recurrently in the valley of Hessdalen. The italian research-activity of this year was concentrated in the acquisition of optical data coming from conventional photography, video imaging and video-spectroscopy. Many photographs, videos and some spectra were obtained of the phenomenon. The results coming from the subsequent analysis show that: 1) the luminous phenomenon is a thermal plasma; 2) the light-balls are not single objects but are constituted of many small components which are casually vibrating around a common barycenter; 3) the light-balls are able to eject smaller light-balls; 4) the light-balls change shape all the time; 5) the luminosity increase of the light balls is due to the increase of the radiating area. This mission was able to finally visualize the real structure and nature of the light-phenomenon and its time-behaviour. The cause, and the physical mechanism with which radiation is emitted is currently unknown, and will be investigated in further missions. Some physical hypotheses are amply discussed.

1. Introduction

The Hessdalen phenomenon is probably the most well known atmospheric anomalous light-manifestation in the world. From the year 1984 so far many attempts of measurements have been carried out by Project Hessdalen, leaded by assistant professor Erling P. Strand [43]. Currently, since August 1998, the phenomenon is constantly monitored with automatic videocameras which are operating inside the AMS (Automatic Measurement Station), an automatic and interactive observatory created by assistant professors Erling. P. Strand and Bjørn Gitle Hauge [19, 44]. Thanks to a new initiative by Erling Strand, since August 2001 the single-camera system has been coupled with a color two-camera system which, by means of triangulation, is able to allow the norwegian researchers to know the distance of the phenomenon. Another new camera is able to zoom on the phenomenon. Since July 2001, due to an initiative by Bjørn Gitle Hauge, also a radar is operating, mounted on a tower just near the AMS [20]. The AMS collected a lot of video recordings since 1998 [42, 44, 45]. The AMS has allowed to monitor successfully the light-phenomenon all the time and to obtain a reliable statistics of its appearance in the valley [53, 55].

The AMS

The Hessdalen Automatic Measurment Station consists of two main systems, which work separately (see Fig. 1). System 1 was set in operation in August 1998, and the first part of system 2 was set in operation at the end of July 2001.

System 1 consists of one *Panasonic WV-BP310* black-and-white CCTV camera equipped with a *WV-LA210C3* wide-angle lens (h: 107 deg, v: 88 deg), which is connected to a 100MHz *SGI-Indy* computer and a videorecorder. The *SGI-Indy* computer analyzes pictures from the CCD camera every 0.8 seconds. Whenever a light comes into the picture, which is brighter and bigger than a preset value, a videorecorder is started and the picture is put onto the internet at http://www.hessdalen.org. The software is developed by Sverre Rekvin and Martin Ranang. So far, the system has recorded more than 200 interesting pictures, and about 50% of these ones can be defined as the “Hessdalen phenomena”. Most of the times, the video recorder started too late to record the light-phenomena as it uses up to 5 seconds to start the recording. Because of this there are only 4 interesting video recordings indeed. The system does not record lights which are smaller than the preset value of number of pixels, or any lights which are weaker than a preset value compared with the background level. System 1 comprises also a *Fluxgate* magnetometer (*MEQ-800 Portable Seismic System*), which is connected to a Pentium I processor. The magnetic field is measured every second, and the mean value is calculated every minute. Every hour, the mean, max and min of these values is calculated and sent onto the internet.

System 2 (see Fig. 1) consists of two *Watec WAT-231S* color CCD cameras equipped with a *Yamano Y1328GS* wide-angle lens (h: 90), wich are connected to a Pentium II computer and two videorecorders. System 2 comprises also a color *Sony FCB-IX470P* CCD camera, which has a 18 x optical zoom lens, and which is mounted onto a *Videotec PTH-911* pan-tilt unit. The last part of System 2 is a *Raytheon SL74* radar and a CCD camera which is directed to the radar screen. The CCD camera is aimed at recording any radar track of interest. The *Sony* camera and the radar screen camera are connected to the pan-tilt Pentium II computer and to video-recorders. The pan-tilt unit is connected to the pan-tilt computer. System 2 consists of four video-recorders in total. The two *Watec* color CCD cameras are mounted 171 meter apart, looking at the same direction. Whenever a light phenomenon is detected on both cameras simultaneously, the two-camera computer triggers the four video recorders, calculates the distance of the light-phenomena, sends the two pictures onto the internet and sends the information of the direction to the pan-tilt computer, which directs the *Sony* camera to that direction. The direction to the phenomena is sent from the two-camera computer to the pan-tilt computer as long as the phenomena are seen, so that the zoom camera is always adjusting itself towards the direction where the phenomena are seen by the two-camera system. The videorecording of these four cameras is going on all the time in which the light-phenomena are seen. The light-phenomenon is detected only if its angular dimension is bigger than a preset value, and if its luminosity is brighter than a preset value. The two cameras are looking at the south-west direction. All the light phenomena which are outside the view, or which are too small in angular dimension or luminosity, will not be captured with this system. One part of system 2, the two-camera system, was set in operation on the 27-th of July 2001. The zoom camera and radar system were set in operation on the 21-st of August 2001. The software is developed by Jens Christian Skibakk.

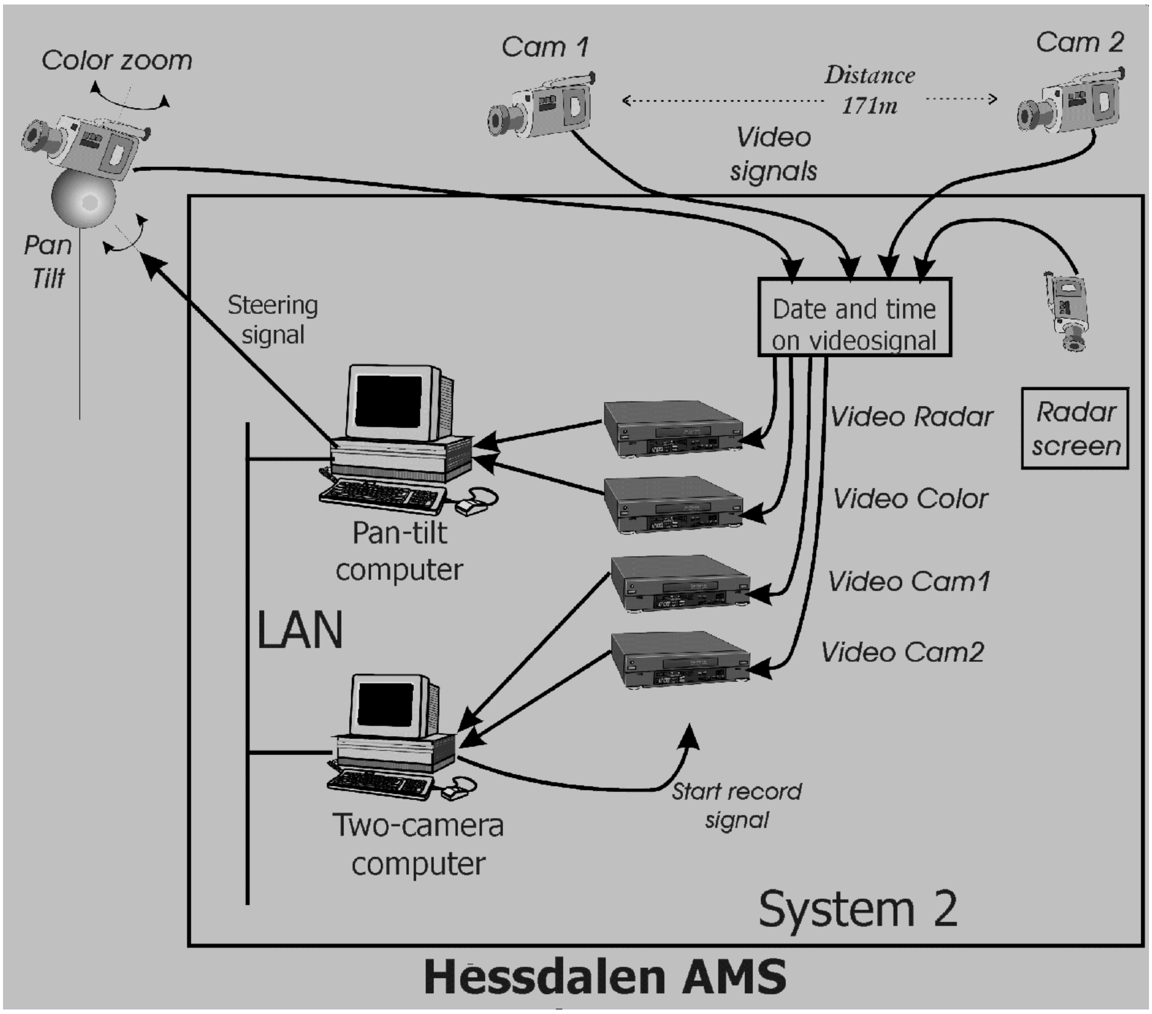


Figure 1. Flow-chart of the Automatic Measurement Station in Hessdalen (System 2).

The Italian-Norwegian Cooperation

During the last two years a group of italian researchers (physicists, electronic engineers and technicians) joined the norwegian researchers, by carrying out measurements both in the radio and in the optical wavelengths. The results of the radio measurements, which were obtained with spectrum analyzers, and of some of the optical measurements, are described in a specific report [55, 57], in which it is shown that unexplained radio signals (*spike* and *doppler* signals) in the VLF region were recorded in the course of the first italian mission to Norway occurred in August 2000. This mission was called EMBLA 2000. The EMBLA initiative is also based on a mutual collaboration between CNR – IRA (Consiglio Nazionale delle Ricerche – Istituto di Radioastromia) and the norwegian Østfold University College [19, 30, 32]. The idea of investigating on the VLF region of the spectrum is due to the expert Flavio Gori of NASA Inspire Project [12], who in August 2001 was also present personally for two weeks with the EMBLA researchers and with his own instruments [13, 14]. Technology director Stelio Montebugnoli of CNR-IRA is the leader of the "radio team" of the italian side of the EMBLA Project, which is also composed by electronic engineers Jader Monari [30, 31], Andrea Cremonini [8], Marco Poloni, and by the technicians Franco Tittarelli, Sergio Mariotti, Alessandro Cattani and Andrea Maccaferri. Some of these persons, who operated with their radio instruments for about a month in August 2000, participated for a week also in August 2001 [47], with the main goal, this year, of monitoring the interferences in the valley.

Inside the EMBLA project, which can be itself considered as an integrating part of an "International Project Hessdalen", there is also a specific group, the "optical team" which is dedicated to optical observations in the field. This small group, is composed by astrophysicist and principal investigator Massimo Teodorani, who in August 2000 was also the main scientific consultant of the "radio group" for two weeks, and by the student of astronomy Simona Righini. This group, during the missions of August 2000 and August 2001, was totally supported and financed by the ICPH ("Italian Committee for Project Hessdalen" - based in Bologna – North Italy) directed by the scholar of anomaly Renzo Cabassi, and composed of other 8 proponents: Nico Conti, Roberto Labanti, Maurizio Morini, Marco Orlandi, Marco Piraccini, Roberto Raffaelli, Massimo Silvestri and Alessandro Zabini. The aim of ICPH is just to promote scientific physical research on Hessdalen-like phenomena [4, 16]. The italian "optical team", in Norway was very efficiently and friendly assisted by Erling Strand and Bjørn Gitle Hauge, in particular for the excursions on the field. While in August 2000 the optical team (composed only of Massimo Teodorani) was able to obtain only some optical data on the phenomenon [55, 57], in August 2001, during an intensive month of observational activity in the field [47], the same group could obtain a large amount of data of several types. This report is just dedicated to the presentation of these data and of what came out from their analysis.

2. Instrumentation, software and processing-analysis procedures

The optical instruments which were available to the optical team were the following ones:

1. Reflector Telescope : *Meade "Comet Tracker"* (f = 549 mm).
2. CCD Camera : *StarlightXpress SXL-8* (512 x 512 pixels).
3. Low-Resolution Spectrograph: *ROS Rainbow Optics Spectroscope* (200 lines / mm).
4. Custom-built telextender for the ROS adaptation.
5. Professional CCD Videocamera: *Canon XM-1* (560 x 560 pixels).
6. Reflex Camera: *Yashica 107 Multi-Program*.
7. Data-Acquisition Computer: *GEO Prodigy 840* (Pentium III).

Because of the very high-level of humidity in the Hessdalen fields the system telescope+CCD camera could be used only seldom, with no results. Anyway this system just remained in Hessdalen in order to allow the group to carry out a new trial in (at least) one new mission which is planned for next year (2002). Most of the observations were done both with the professional CCD videocamera and with the reflex camera. All these observations were very successful and allowed to obtain a lot of frames. Moreover, after deciding to connect the ROS spectrograph directly to the CCD videocamera, some spectra of the phenomenon could be obtained with a more than sufficient S/N ratio.

All the data were pre-processed in Hessdalen by using a Dell desktop Pentium III computer, a portable Compaq Pentium II computer and the portable GEO Pentium III computer. All the data were post-processed in Italy by using an IBM-compatible Pentium II work-station. In order to acquire the CCD data from the telescope the *Pix L-8* software was used. All the photometric data obtained with the CCD videocamera were pre-processed by using the *DV Studio* and *Ulead Media Studio Pro 6.0* softwares. The frames were post-processed by using the *Adobe Photoshop 5.5*, *Paint Shop Pro 7* and *UTHSCSA Image Tool* softwares in order to obtain: 1) image resizing (the frames of the lights were magnified up to 3000 times), which, by an interpolation procedure allows a consistent increase of spatial resolution, 2) multi-parametric image enhancement (such as contrast, brightness, treshold setup, etc.) in order to allow a precise identification of the shapes which were characterizing the target, 3) summation of more frames together in order to study any kind of movements of the target. Subsequently the frames were analized by using the *Iris* software for astronomy, with which the following operations were done: a) aperture photometry in order to calculate the luminosity emitted by any single sequential frame regarding the luminous target by using circles containing all the lighted target, b) calculation of the 2-D and 3-D Point Spread Function (PSF) in order to obtain simultaneously the peak intensity and the apparent dimension in pixel of the target, c) calculation of isophotal contours in order to study the light distribution inside the illuminated surface. Some of the same procedures used for CCD video-photometry were used also to process and analyze conventional photographic data. The software *Microsoft Excel* was also used in order to obtain plots of some video-frame parameters, such as the apparent luminosity and apparent dimensions vs. time.

In order to process and analyze spectroscopic data, the spectral frames were first pre-processed by using the *Ulead Media Studio Pro 6.0* software. Subsequently the frames were pre-treated and enhanced by using interpolation image resizing by using the *Adobe Photoshop 5.5* and *Paint Shop Pro 7* softwares: in this way an increase of the spatial resolution could be obtained. The correct visualization of the treshold was also obtained by using enhancement techniques. Subsequently the spectral frames were passed to the *Iris* software for astronomy, with which it was possible to convert any single 2-dimensional spectrum into several 1-dimensional representations by plotting all the useful rows of the same spectrum and obtaining an established standard set of six 1-dimensional row-spectra, which were then converted into exportable ASCII format; in this phase only the rows in which the S/N was sufficiently high and which were including the emission lines, were considered, all the rest of the spectrum was neglected as it was too noisy. All the subsequent operations were carried out by using the *Visual Spec* software for astronomical spectroscopy. At first the six row-spectra were all plotted in a diagram in which the apparent flux is plotted as a function of the position in pixel. The six row-spectra were then averaged together in order to allow a consistent increase of the S/N noise ratio. Subsequently the spectrum was calibrated in wavelength by using linear interpolation (standard procedure to be used for transmission gratings like the ROS). The wavelength-calibrated spectrum of the star Vega was just used as a comparison spectrum, which shows exactly the wavelength range of the ROS spectrograph. By using the Vega comparison spectrum, two “reference lines” were artificially created in the spectrum of the target (just by using an aimed cosmetic editing operation on the ASCII version of this spectrum), which could then be self-calibrated in wavelength. Finally, the artificial lines were eliminated from the target spectrum by re-editing the target spectrum with the old values. It was impossible to use the emission lines of the target-spectrum itself for wavelength-calibration as they could not be identified properly because of too low resolution. The spectrum was also continuum-fitted by using a polynomial interpolation (spline), in order to permit a proper identication of the maximum of the Planck function. Moreover, a data set of accurately prepared wavelength-calibrated spectra of 15 known chemical elements, was just overplotted over the target spectrum in order to allow an attempt of line identification. The ASCII version of the spectrum was then exported to the *Microsoft Excel* software, with which it was possible to obtain a more proper plot for presentation.

3. The data

The very most part of the video-frames, photographs and spectra were taken from the *Aspåskjölen* site [43]. A complete report of all the visual sightings, only some of which could be recorded with the available instrumentation, is contained in the "case history section" (see Table 1). Some of the sightings were seen in spots other than *Aspåskjölen*, such as the proximity of the *Oyongen* lake, the mountains near *Finnsåhögda* and the *AMS* measurement station. Any spot was constituted by an average of 3 observers, in some cases there were different spots from which observers were communicating together with cellular phones. In addition to the CCD videocamera (sometimes equipped with the ROS) and some reflex cameras, the observers were equipped almost always with binoculars, sometimes with a Night Vision System (NVG), a Geiger detector, a detector of electromagnetic fields, a detector of ultrasounds and a VLF receiver. Apart from the NVG, which was used very efficiently once near the Oyongen lake, all the portable detectors didn't furnish any result as all the readings were just in the normal values. The VLF receiver, which was connected with a portable laptop computer and constantly used by Jader Monari, Marco Poloni and Andrea Cremonini, didn't furnish any result too, also when the phenomenon was in sight: this must be due to the fact that the phenomenon was far or very far, therefore its EM field wasn't able to interfere with the portable EM instrumentation. A portable reflector telescope (*Meade ETX-90EC* owned by B.G. Hauge) was very useful in two occasions: in particular, it allowed the detailed observation of a ball-like blinking light. The *Meade Comet Tracker* bigger telescope + CCD Camera was used very rarely (mostly for tests for focussing). At the same time in which the field observations were done, Flavio Gori of NASA Inspire together with Andrea Cremonini carried out for two weeks recordings with the ELFO VLF-ELF receiver-spectrometer at the AMS norwegian station: the analysis of these data is in progress [14].

The luminous phenomena which were sighted and recorded this year were for the very most part of the "plasma type": of such type single spherical lights, multiple lights, multicolor lights, ball-like flashes in the sky, were seen. Most of the lights were observed near the ground or just over the top of the mountains, but some of them were seen in the sky as well. Even if with different and less spectacular characteristics than the previous year [55], in August 2001 it was possible to sight a "structured object" too.

Case History

The visual cases which were collected by the optical team, came also from visual sightings from other groups too (the "radio team" of the italian expedition and some of their friends, the norwegian group sometimes with their friends, and four italian journalists). The total list of these persons was as follows: Massimo Teodorani (astrophysicist), Simona Righini (graduand in astronomy), Erling Strand (electronic engineer), Bjørn Gitle Hauge (electronic engineer), Stelio Montebugnoli (electronic engineer), Jader Monari (electronic engineer), Marco Poloni (electronic engineer), Andrea Cremonini (electronic engineer), Giorgio Pacifici (journalist), Luigi Bignami (scientific journalist), Gianluca Ranzini (scientific journalist), Giorgia Bottazzi (journalist), Giancarlo Gambetti (Giorgia's husband) and Peder Skogaas (journalist and informatics expert) and his 4 friends.

A complete list of the cases is reported in Table 1 (Part I and II).

Video-Photometry and Photography

All the acquired video and photo frames were analyzed. The most important cases are presented here, in order to show an enhanced visualization of the light-phenomena. In some cases the nature of the phenomena can be explained, in other cases not.

Ball-like flashes

The so called "ball-like flashes" [43] were seen every night and everywhere in the valley, mostly low in the sky, but also on the top of the hills, and sometimes also very near the ground. These mostly globular flashing lights were lasting normally less than a second, and were mostly white-blue in color, much more rarely also red and yellow (these ones the largest ones in dimensions). These very particular flashes are a constant feature of the Hessdalen area, and seem to show that this area is totally electrified by some still unknown process, maybe a piezolectric effect in the rocks under some tectonic stress [26, 36] which is possibly amplified by electricity-conducting elements which do exist underground, such as iron and copper. One of these flashes was just photographed, while it appeared suddenly low in the sky [see Fig. 3]. Another visual feature of the flashes is that sometimes they appear like sudden white-blue "lines" in the sky, by giving the impression to the observer that sometimes some plasma balls are shooted with a very high velocity towards the sky.

Five of these events could be recorded on photo (see Figs. 3, 4, 5, 6, 7). The enhancement in Fig. 3 shows very clearly that the phenomenon which appears in the photo is not really ball-shaped, but that it has a two-components structure. The analysis shows that there is a sort of "energetic nucleus", which is probably the point in which the flash started. The reason of the splitted structure is unexplained. The PSF (Point Spread Function), which shows very clearly the double structure and the peak of maximum intensity, is not at all a gaussian, as it would be expected by a plasma.

On the contrary, Figs. 4, 5 and 6 show that the phenomenon is just a plasma, because of the sharply gaussian structure of the Point Spread Function. Fig. 7 shows a probable ball-like flash in motion which was also pulsating. All of these photographs were taken blindly in all directions (with no other lights present) with long exposures in order to try to catch short-lasting events.

Table 1. Case hystory prepared during the EMBLA 2001 mission. Part I.

Location	Date	Time	Shape	Color	Brightness	Size	Distance / Duration	Direction	Data	Comments
Aspåskjölen	29/07/01	23.25.00	spheric	white-yellow	medium	medium	kilometres / few seconds	S-SE	video	pulsing light ball / standing still / witnesses: 3
Aspåskjölen	01/08/01	23.26.00	spheric	yellow	faint	small	kilometres /few seconds	SW	video	pulsing light ball / standing still / witnesses: 5
AMS	02/08/01 see Figure 2	23.40.00	spheric *and then* linear	yellow *and then* red	bright	small	5 km / 2 minutes	W	telescope (Meade ETX-90EC)	couple of steady lights, then changed into red stripe / witnesses: 4
AMS	02/08/01	23.59.00	spheric	white-blue	bright	small	5 km / 30 seconds (then reappeared 5 minutes later)	W	telescope	pulsing light ball / slow motion / witnesses: 4
Aspåskjölen	01/08/01	23.48.00	spheric	yellow	faint	small	kilometres /tenths of seconds	SW	video	pulsing light ball / standing still / witnesses: 5
Oyongen	02/08/01	23.11.00	spheric	yellow	faint	small	kilometres /some seconds	S	video	light ball / slow motion / witnesses: 5
Aspåskjölen	04/08/01	23.59.24	spheric	red	faint	small	kilometres /tenths of seconds	S	pictures	blinking weak red light / standing still/ witnesses: 3
Aspåskjölen	06/08/01	22.30.00	spheric	white-blue	medium	medium	kilometres /tenths of seconds	S	video	blinking light / standing still/ witnesses: 4
Aspåskjölen	07/08/01	22.48.00	spheric	white-blue	faint	small	kilometres /few seconds	S		blinking light / standing still/ witnesses: 1
Aspåskjölen	08/08/01	22.45.00	spheric	white-blue	faint	small	kilometres /tenths of seconds	S	pictures	blinking light / standing still/ witnesses: 3

Table 1. Case hystory prepared during the EMBLA 2001 mission. Part II.

Location	Date	Time	Shape	Color	Brightness	Size	Distance / Duration	Direction	Data	Comments
Aspåskjölen	09/08/01	22.41.00	spheric	yellow-white	medium	medium	kilometres /tenths of seconds	SW		blinking light / standing still / witnesses: 2
Aspåskjölen	10/08/01	22.44.00	spheric	yellow-white	medium	medium	kilometres / 30 seconds	S	video pictures	blinking light / standing still / witnesses: 8
Aspåskjölen	11/08/01	23.07.00	spheric	white-blue	faint	small	kilometres / 10 seconds	S	video pictures	blinking light / standing still / witnesses: 3
Aspåskjölen	13/08/01	00.35.00	spheric	white	medium	small	kilometres /1 minute	E to W		very fast light in the sky / witnesses: 3
Oyongen	15/08/01	23.35.00	ellipse	white	faint	small	kilometres/ 30 seconds	W	NVS pictures	slowly moving flashing light in the sky / witnesses: 6
Aspåskjölen	18/08/01	21.15.00	spheric *and* changing shape	white-blue yellow red orange	medium *and* high	medium	2.5 km / 20 minutes	SE	video pictures spectra	multicolor blinking lights (2, 4, 5, 7) / horizontal mutual movements / witnesses: 4
Aspåskjölen	18/08/01	23.15.00	spheric	white-blue	medium	medium	kilometres / 30 seconds	S	video pictures spectra	blinking light / standing still / witnesses: 6
Fjellbehögda	19/08/01	23.30.00	ellipse	silver	medium	medium	50-100 m ?		1 picture	structured object appeared in digital photo
Aspåskjölen	21/08/01	22.30.00	spheric	white-blue	medium	medium	kilometres / 30 seconds repeated events	S	video pictures spectra	blinking light / standing still/ witnesses: 3
Everywhere	*always*	at night	spheric	white-blue *(mostly)* red-orange	small medium	faint medium	kilometres hundreds of meters	all directions	one picture	globular flash / standing still / shooted up / witnesses: 10

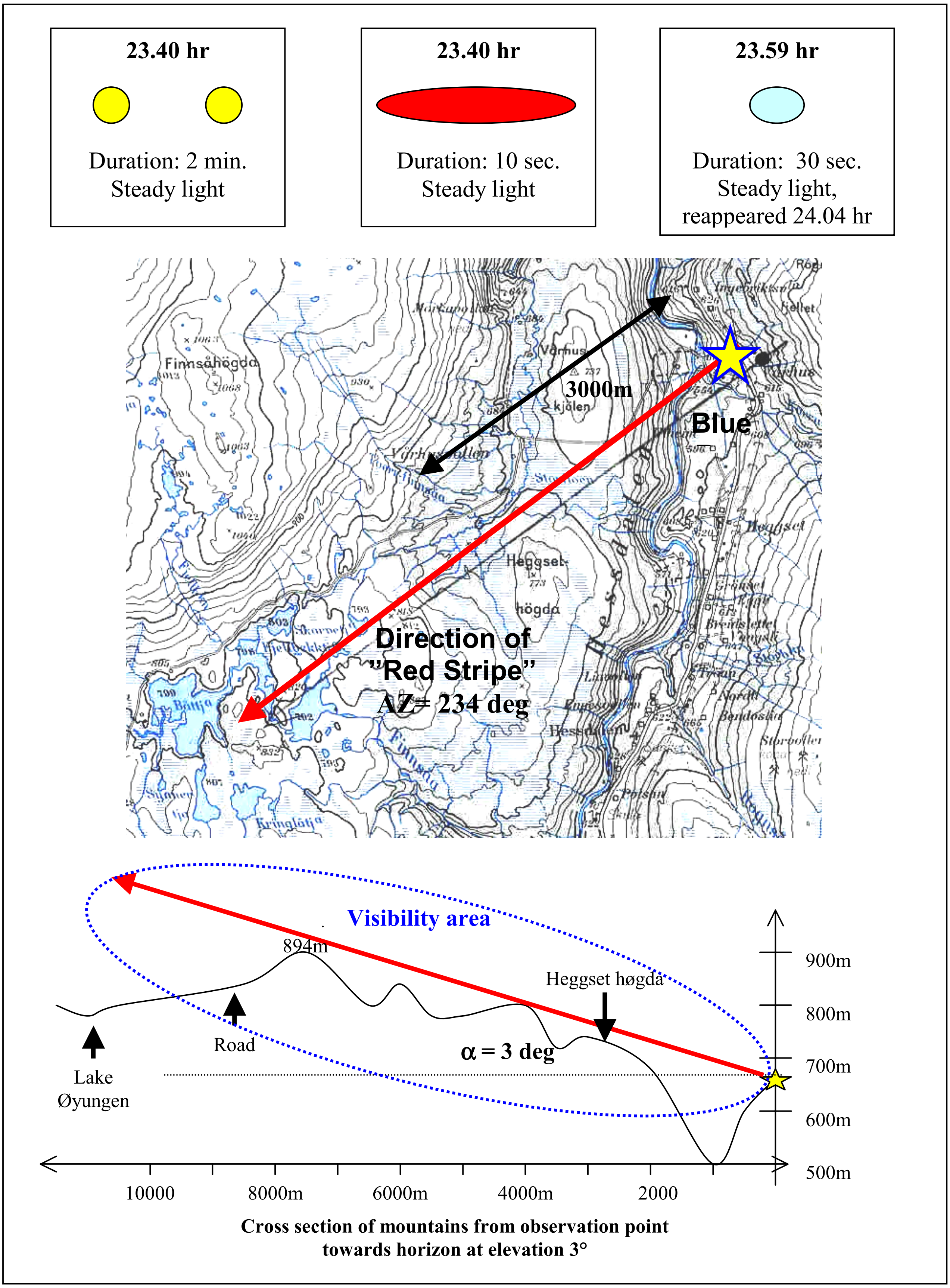


Figure 2. Red stripe observation in 2/8-2001. The three observations were done in 30 min, towards the same direction. Observation: telescope Meade ETX-90EC (f=1250mm). (*B.G. Hauge*).

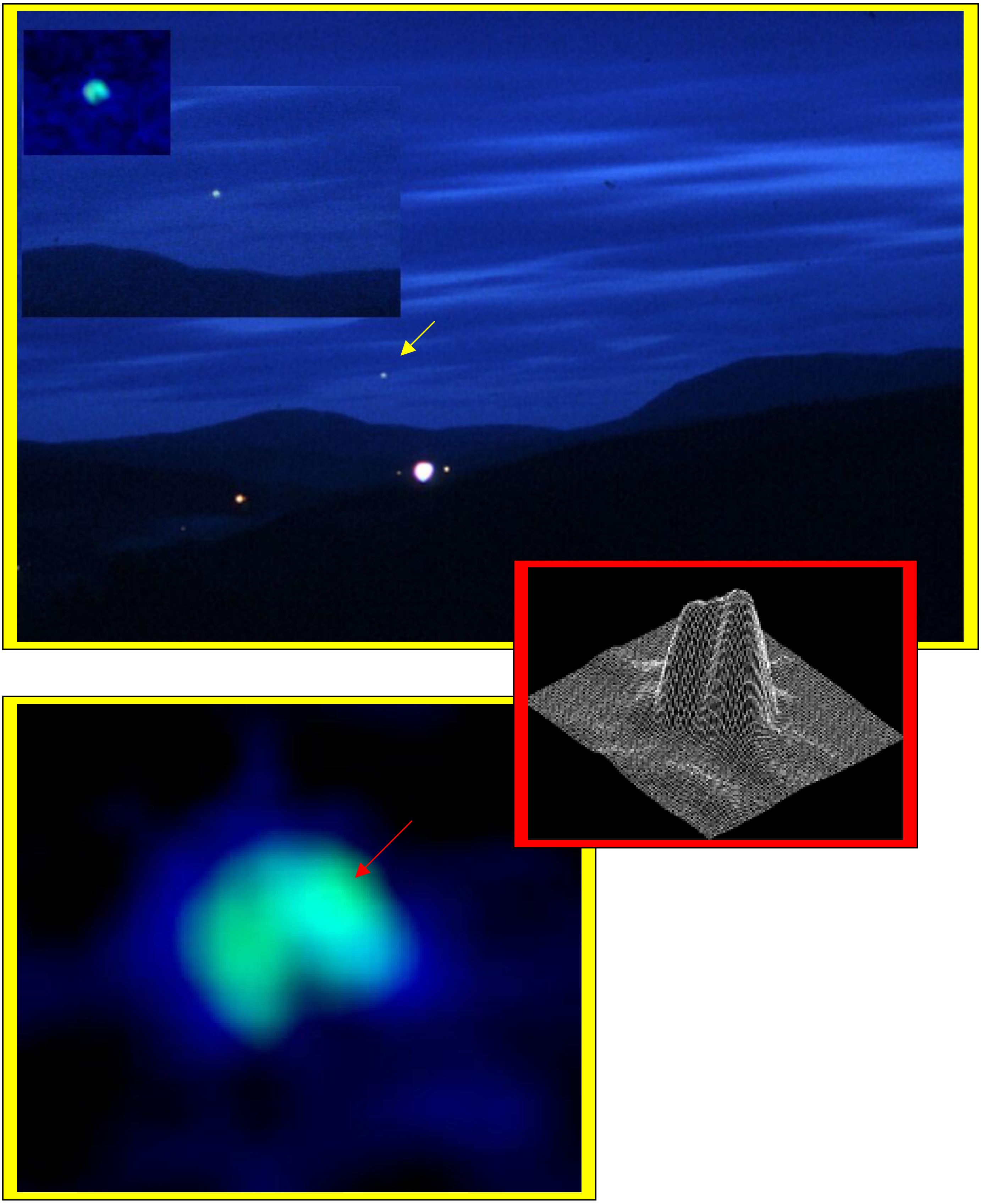


Figure 3. Ball-like flash impressed on the film (reflex camera: Yashica 107 Multiprogram, film: 100 ASA, exposure: 2 minutes), indicated by yellow arrow. The observation point was *Aspåskjölen*, the two strong lights down are houses. The direction was South. On the left of the bigger photo: two enlarged versions of the target. On the right: 3-D Point Spread Fuction. Below on the left: highly enlarged and enhanced version of the ball-like flash (the red arrow indicates the energetic nucleus of the “flash”). (*Photograph, processing and analysis by M. Teodorani*).

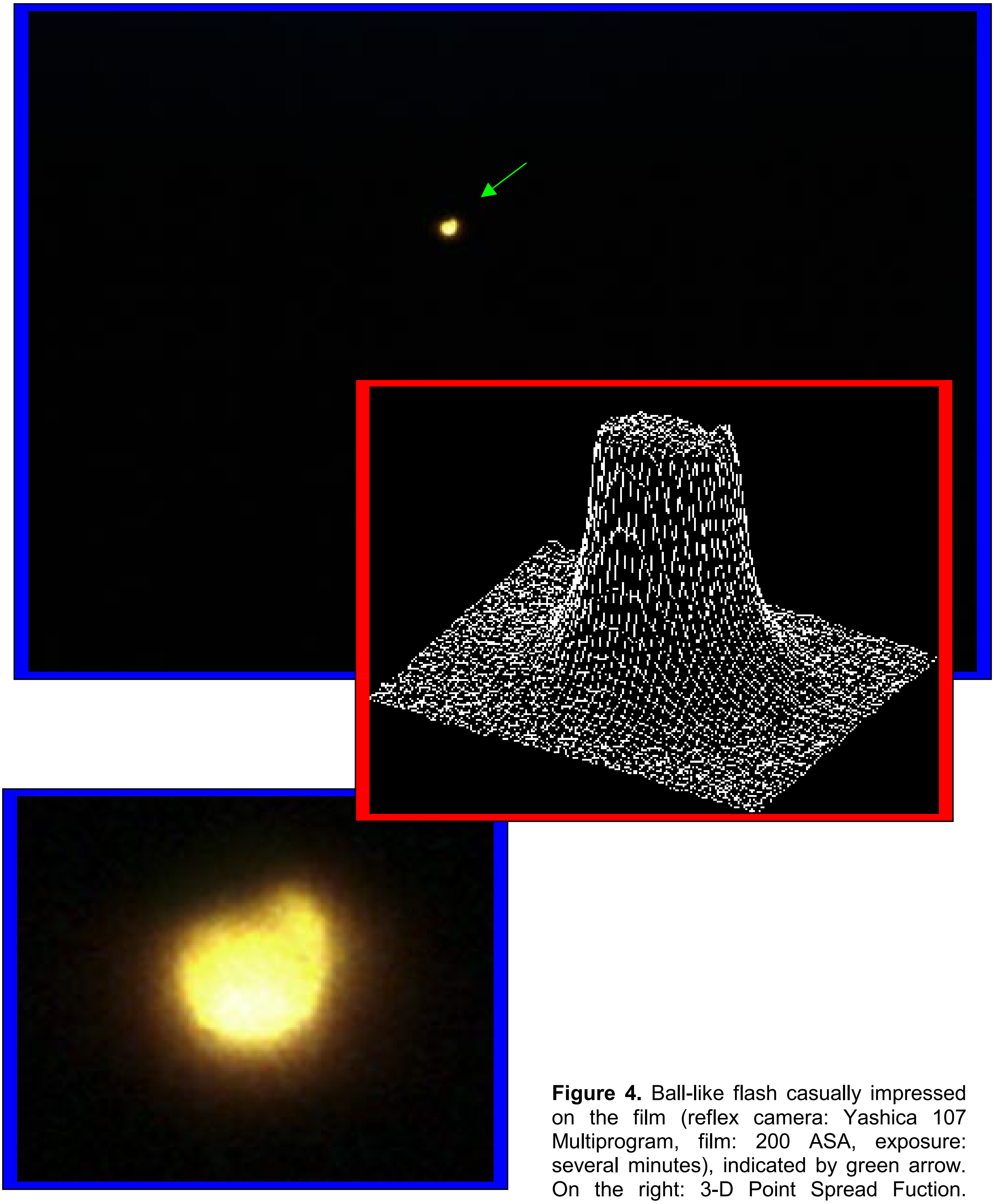


Figure 4. Ball-like flash casually impressed on the film (reflex camera: Yashica 107 Multiprogram, film: 200 ASA, exposure: several minutes), indicated by green arrow. On the right: 3-D Point Spread Fuction. Below on the left: highly enlarged and enhanced version of the ball-like flash. *(Photograph, processing and analysis by M. Teodorani*).

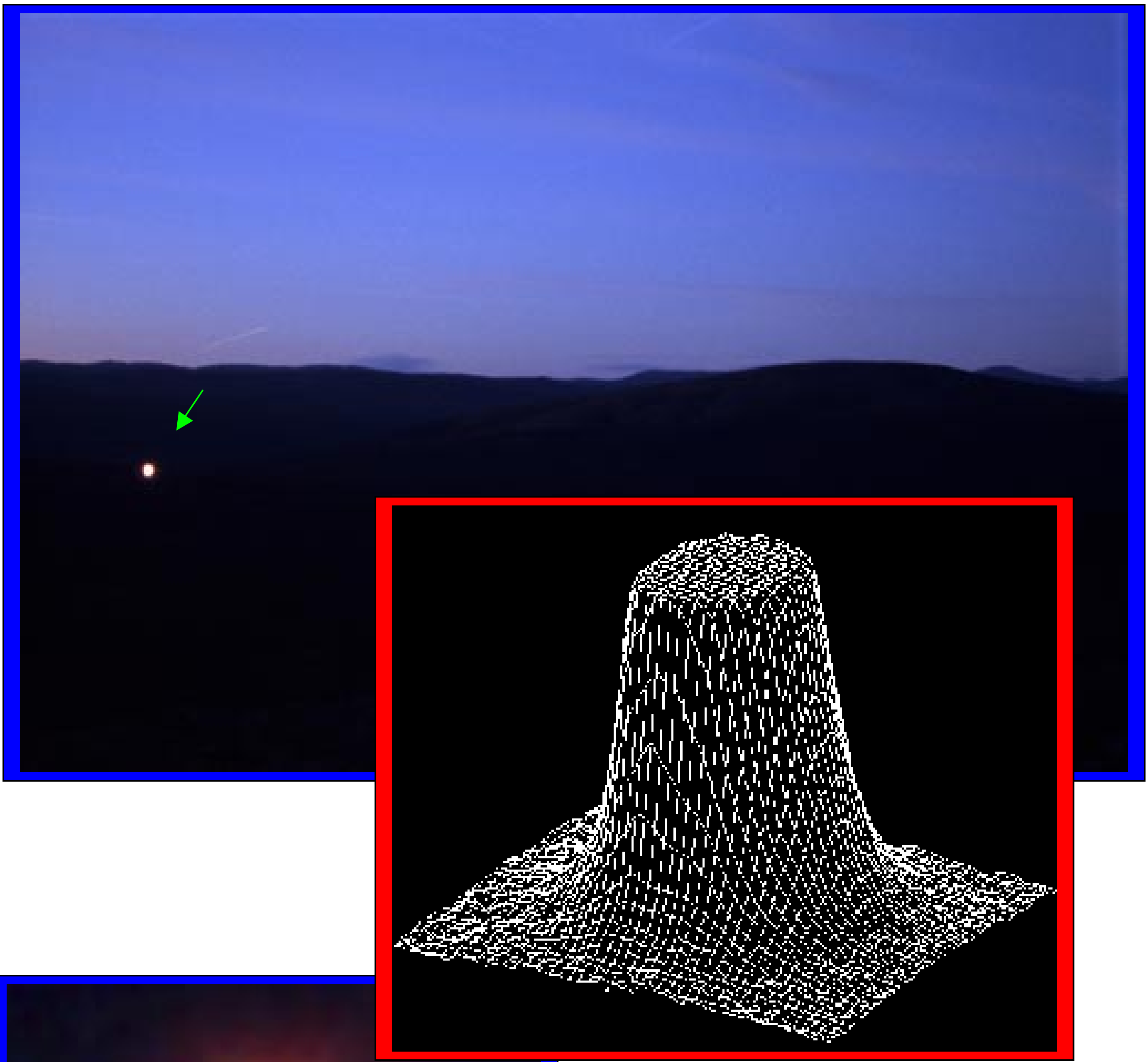


Figure 5. Ball-like flash casually impressed on the film (reflex camera: Yashica 107 Multiprogram, film: 100 ASA, exposure: several minutes), indicated by green arrow. On the right: 3-D Point Spread Fuction. Below on the left: highly enlarged and enhanced version of the ball-like flash. *(Photograph, processing and analysis by M. Teodorani*).

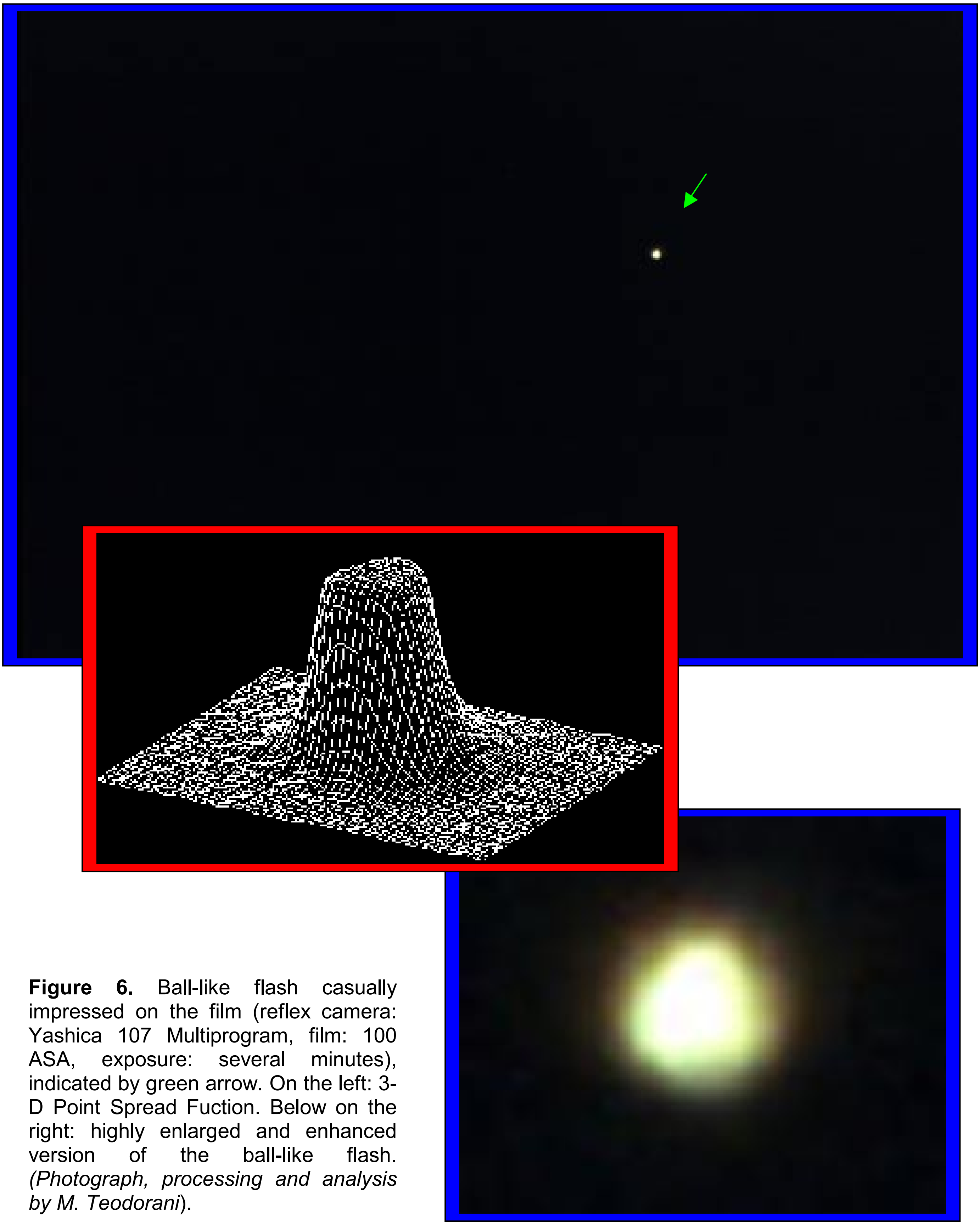


Figure 6. Ball-like flash casually impressed on the film (reflex camera: Yashica 107 Multiprogram, film: 100 ASA, exposure: several minutes), indicated by green arrow. On the left: 3-D Point Spread Fuction. Below on the right: highly enlarged and enhanced version of the ball-like flash. *(Photograph, processing and analysis by M. Teodorani*).

Figure 7. Pulsating ball-like flash in motion casually impressed on the film (reflex camera: Yashica 107 Multiprogram, film: 100 ASA, exposure: several minutes), indicated by yellow arrow. Below: highly enlarged and enhanced version of the ball-like flash. *(Photograph, processing and analysis by M. Teodorani*).

Blinking single lights

The very most part of the targets was due to very intense “blinking lights”, which were mostly seen from *Aspåskjölen* towards the South direction. These light-phenomena lasted from 5 up to 60 seconds. The blink was always irregular. These “light-balls” were always seen on the top of the mountains (see Figs. 8, 9, 10).

Enhancement of both photos and videos shows clearly that these apparently single light-balls have the following characteristics:

1. They are able to eject smaller “sub-balls” with a rate of few seconds (see Figs. 8, 9 and 10), and the sub-balls have a different color (generally green).
2. They present sometimes a protrusion in the same direction of the ejected sub-ball (see Fig. 9).
3. The lights which are typically seen are often themselves the integrated luminous effect due to the casual “vibration” of many sub-balls around a common barycenter. This effect can be seen very well after summing up 30 video frames all together (Fig. 12).
4. The PSF of the lights is a gaussian, therefore suggesting that the radiation mechanism is due to a plasma (see Fig. 11). In many cases the PSF is saturated on the top because of the very high-luminosity.
5. Sometimes some sort of unexplained geometric shape can be seen like immersed in the cluster of multiple lights which constitute a single luminous object (see Fig. 12).
6. The enhancement doesn’t show any kind of solid-like structure underlying the light.

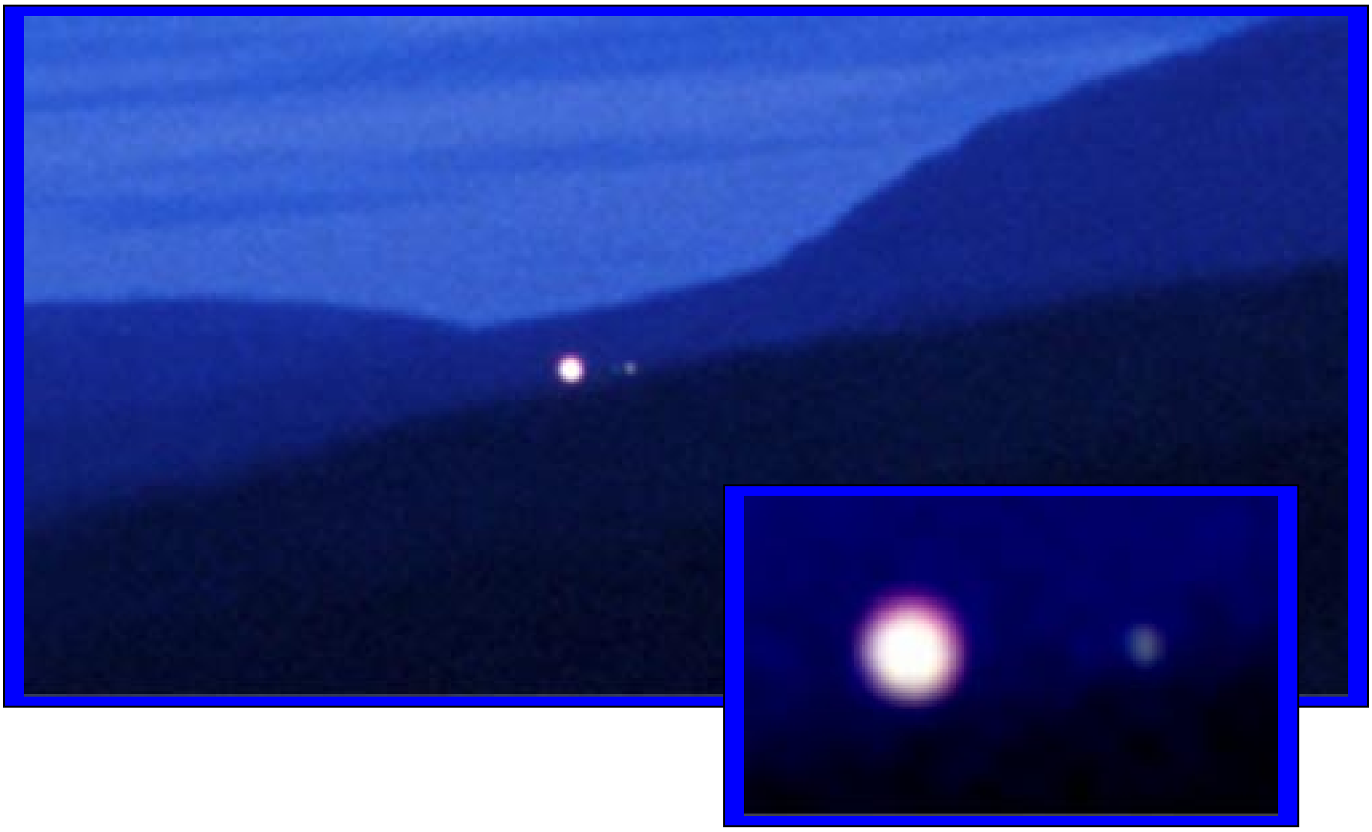


Figure 8. A typical blinking light (reflex camera: Yashica 107 Multiprogram, film: 200 ASA, exposure: 3 minutes), after it has ejected a sub-ball. The observation point was *Aspåskjölen*. The direction is South. Date: August 10, 2001. Enlarged photo is enclosed. *(Photograph, processing and analysis by M. Teodorani*).

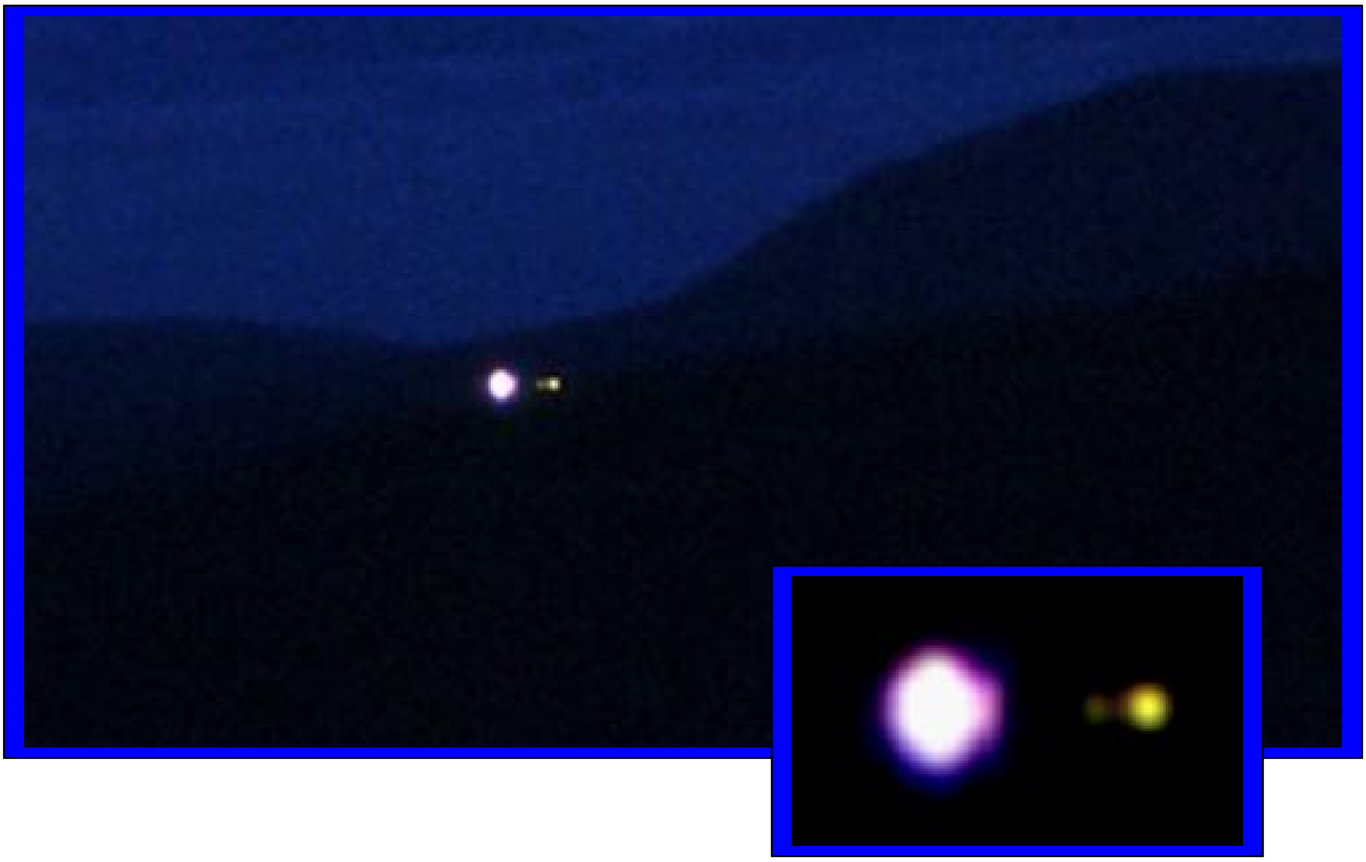


Figure 9. A typical blinking light (reflex camera: Yashica 107 Multiprogram, film: 200 ASA, exposure: 3 minutes), while it is ejecting a sub-ball. The observation point was *Aspåskjölen*. The direction is South. Date: August 10, 2001. Enlarged photo is enclosed. (*Photograph, processing and analysis by M. Teodorani*).

The ejection of sub-balls from the main light-phenomenon, which could be visually recorded very well with the Meade ETX-90EC telescope too, couldn't be observed by naked eye because of the distance (presumably 5-7 km). It is not possible to evaluate the intrinsic dimensions of the light phenomenon as a correct knowledge of distance is unknown. Moreover, the perspective in the photos and videos prevents one from understanding if the phenomenon is just floating over the hill closer to the observer or if it is located on the wall of the mountain behind the hill.

The only difference between video frames and photographs consists just in the fact that video frames are sequentially recorded one by one being possible to resolve temporally the multi-component structure (mini-balls) of the lighted object, while with photographs it is only possible to obtain long exposures in which the dynamics inside the light-phenomenon are melted out because of a long exposure. Therefore, the photographs show the light-phenomenon as an "integrated effect", but not as the real phenomenon. Nevertheless, some details regarding the ejected balls can be seen very well with photographs too. The color performance is much better in photographs than in video frames.

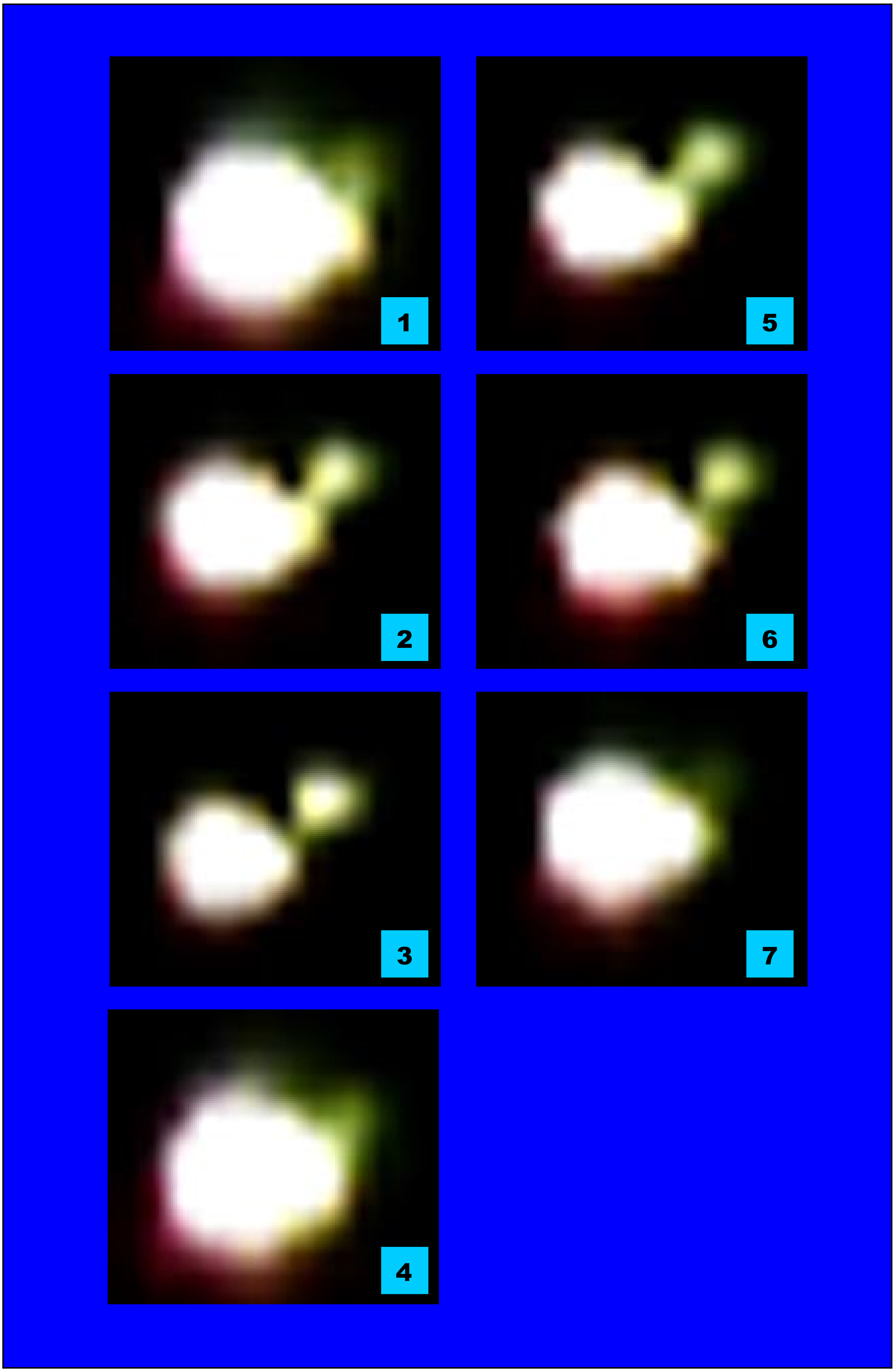


Figure 10. A typical blinking light (videocamera frame) while it is ejecting a sub-ball. Date: August 10, 2001. The time sequence, of few seconds, is indicated in the numbers enclosed in the pictures. (*Video frames by S. Righini, processing & analysis by M. Teodorani*).

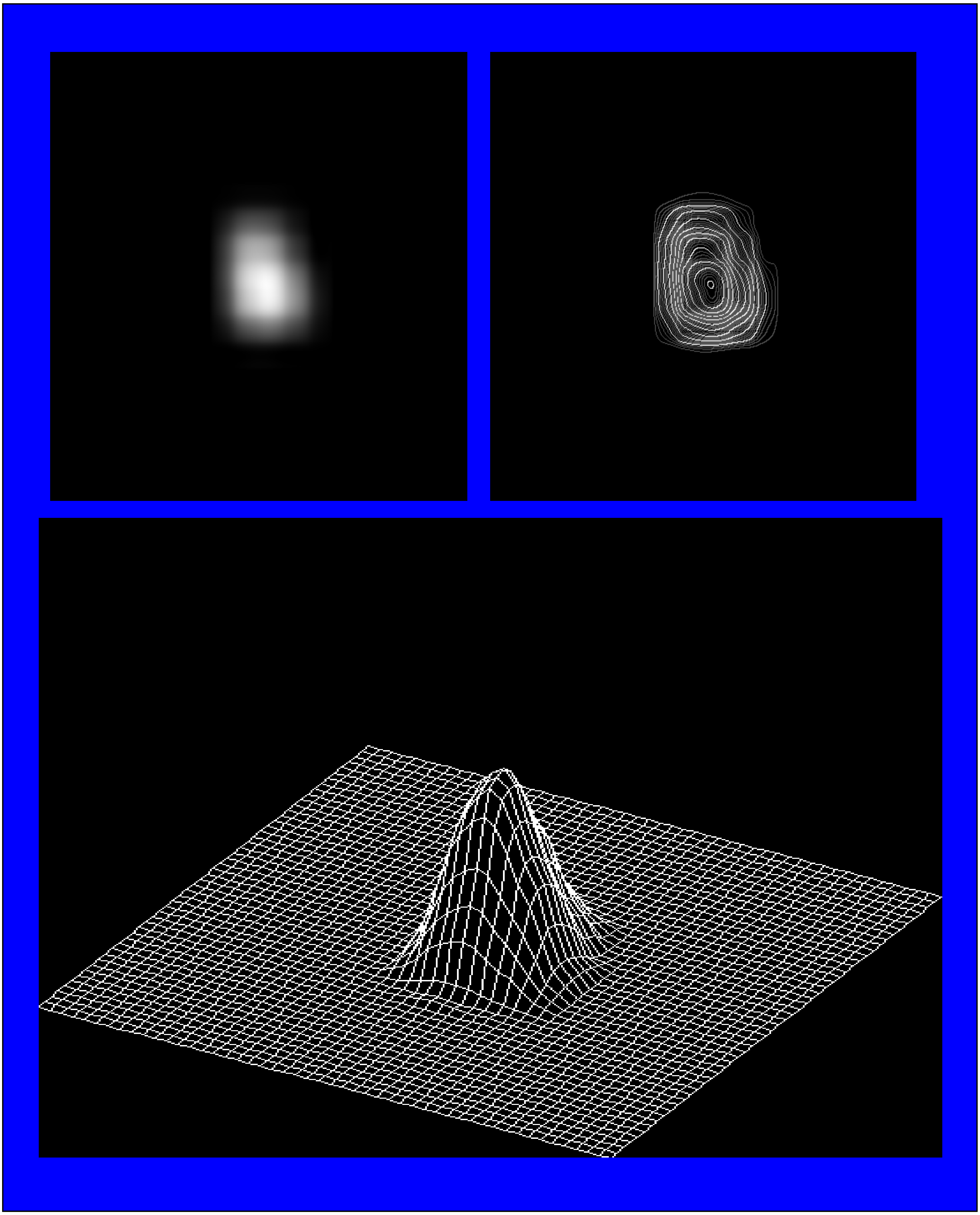


Figure 11. *Above left*. A single frame of a typical blinking light (videocamera grayscale frame). Date: August 1, 2001. *Above right*. Isophotal contours*. Below center*. 3-D Point Spread Function. (*Video frame by S. Righini, processing and analysis by M. Teodorani*).

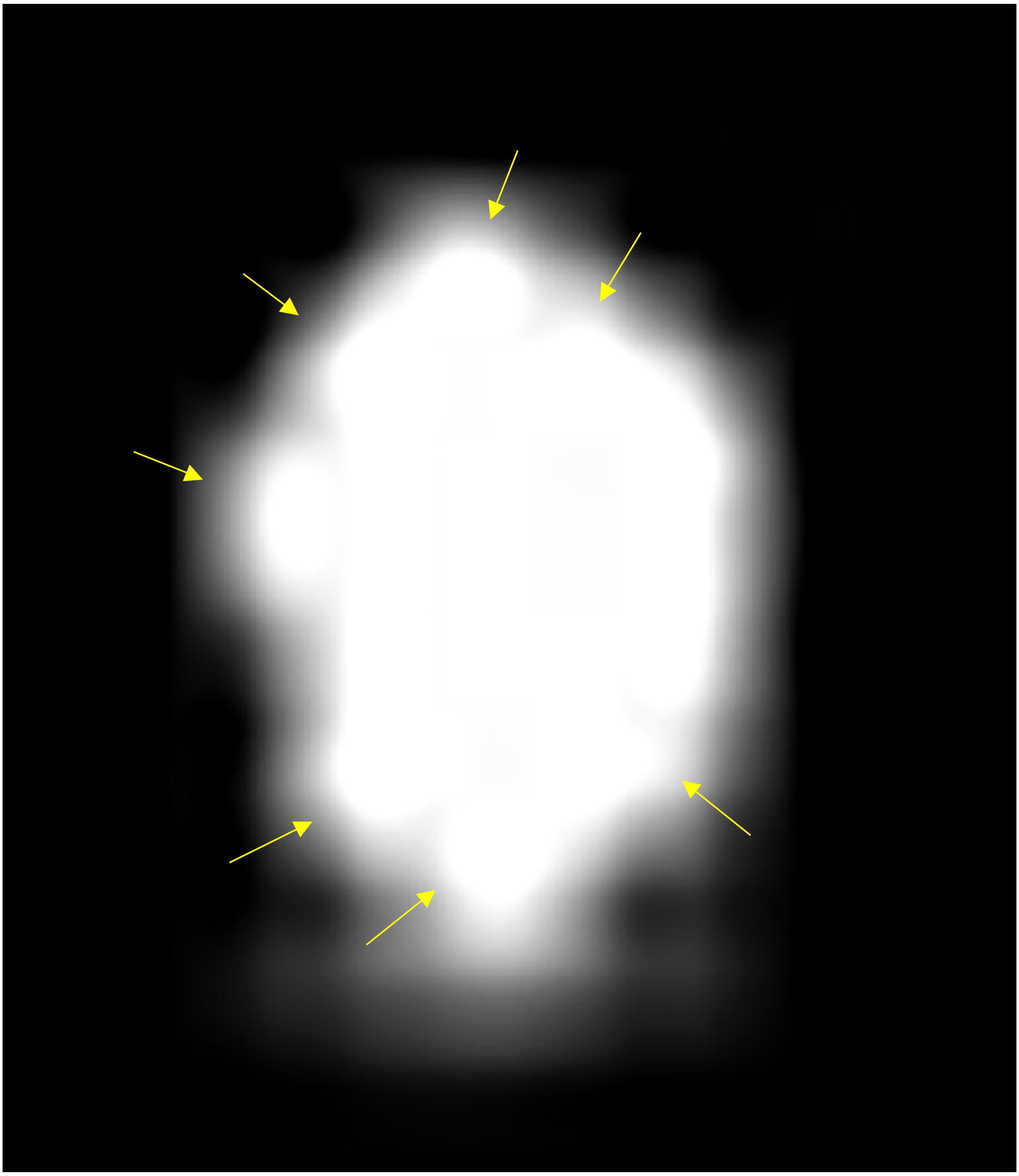


Figure 12. The real structure of a blinking light (videocamera greyscale frame). The processed frame above is a result of the summation of 30 contiguous video frames (1/25 sec each). Date: August 6, 2001. The mini-ball components can be seen around the main luminous body. (*Video frames by Simona Righini, processing and analysis by M. Teodorani*).

Blinking multicolor multiple lights

During the evening of 18 August 2001, from the *Aspåskjölen* spot it was possible to assist at the most spectacular event. This was due to a series of multiple lights, whose number was changing from 2 up to 7 components. The phenomenon lasted about half an hour, and continued also later for another half an hour. The most stable configuration was due to 3 components, one of which reached a very high luminosity: at the same time an intense red but smaller red light was all the time turning around the bigger one. These lights were like dancing together.

These lights were seen in a different position than the one in which the classical "single blinking lights" were seen: they were much lower, just on a hill at low height. By looking at the photographs (see Fig. 9) during the obtainement of which still some daylight was present, it seems from the depth of the photos that these lights are floating over the field. The investigation on the spot the day later shown us that the field is crossed by a concentration of iron frameworks for electricity.

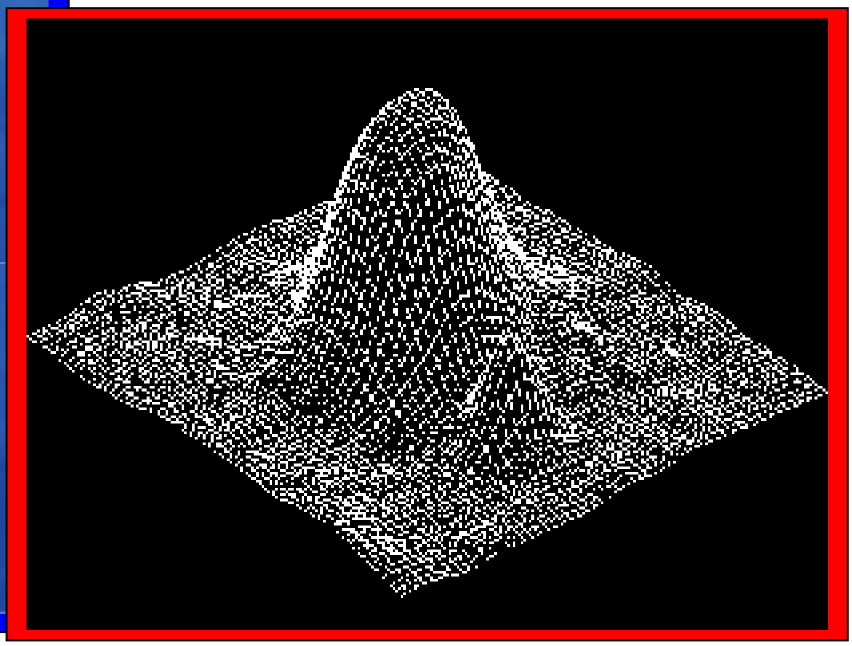
What can be pointed out from this prominent event is as follows:

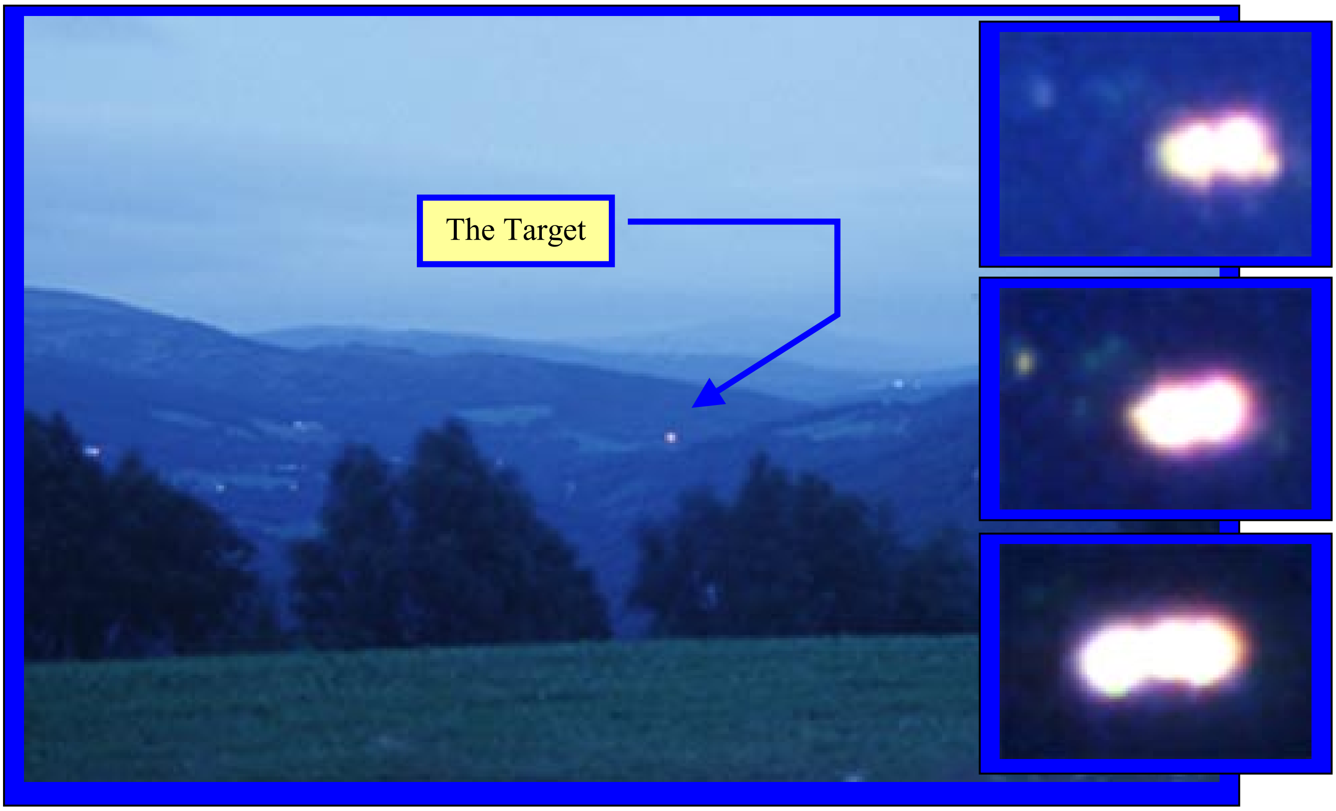
1. When the light-phenomenon is multiple, several different colors are present, the most important of which: white-yellow and red (see Figs. 14 and 15).
2. The luminosity can be very high, expecially when one component is white-yellow colored (see Figs. 15, 16, 17).
3. The several components of the complex of lights move randomly, by doing mutual displacements, but their movements are concentrated to a restricted area with a radius, which shouldn't be more than 100 meters (see Fig. 14)
4. Any component, in particular the two ones to the right, are subject to any kind of shape transformation and apparent color changement (see Fig. 15).
5. When the light has an elliptical or spherical shape, the PSF is gaussian, by showing that the light is more probably a plasma (see Fig. 13).
6. One of the lights on the right started to assume a very precise rectangular shape, surrounded by a sort of glow on the right. The PSF of the "rectangle" is very particular: the lower and central part is gaussian, but the saturated top is just a rectangle (see Figs. 15 and 16). The rectangular shape is visible (when visible) both in the wide-angle and in the zoomed enhanced frames, and can be seen when the light reaches its maximum intensity or saturates. In other cases in which the light intensity is at maximum, no rectangular shape is seen (see Fig. 17).
7. There is an unexplained light-dispersion (rainbow-like) in some of the frames.

Without any doubt, it appears that these plasma objects are able to assume any kind of intensity, color and shape. Still now there is no rational explanation for the observed rectangular shape, but possible videocamera transient malfunction or instrumental effects due to the CCD pixel saturation when it records very intense sources must be further checked out.

Are these lights due to a sort of "corona effect" due to the many electric cables present in that specific area? This possibility cannot be excluded a-priori. The investigation is going on.

Figure 13. The beginning of the multicolor light events (reflex camera: Yashica 107 Multiprogram, film: 200 ASA). The observation point was *Aspåskjölen*. The direction is South-East. Date: August 18, 2001. The exposures are about 30 seconds for each of the three photo frames (on the left), during about 5 minutes. The big picture (below) shows the exact location of the light-phenomenon. The PSF is also presented (it regards the third light from above). Three new photos which were taken about an hour later are also shown down on the left. (*Photograph, processing and analysis by M. Teodorani*).





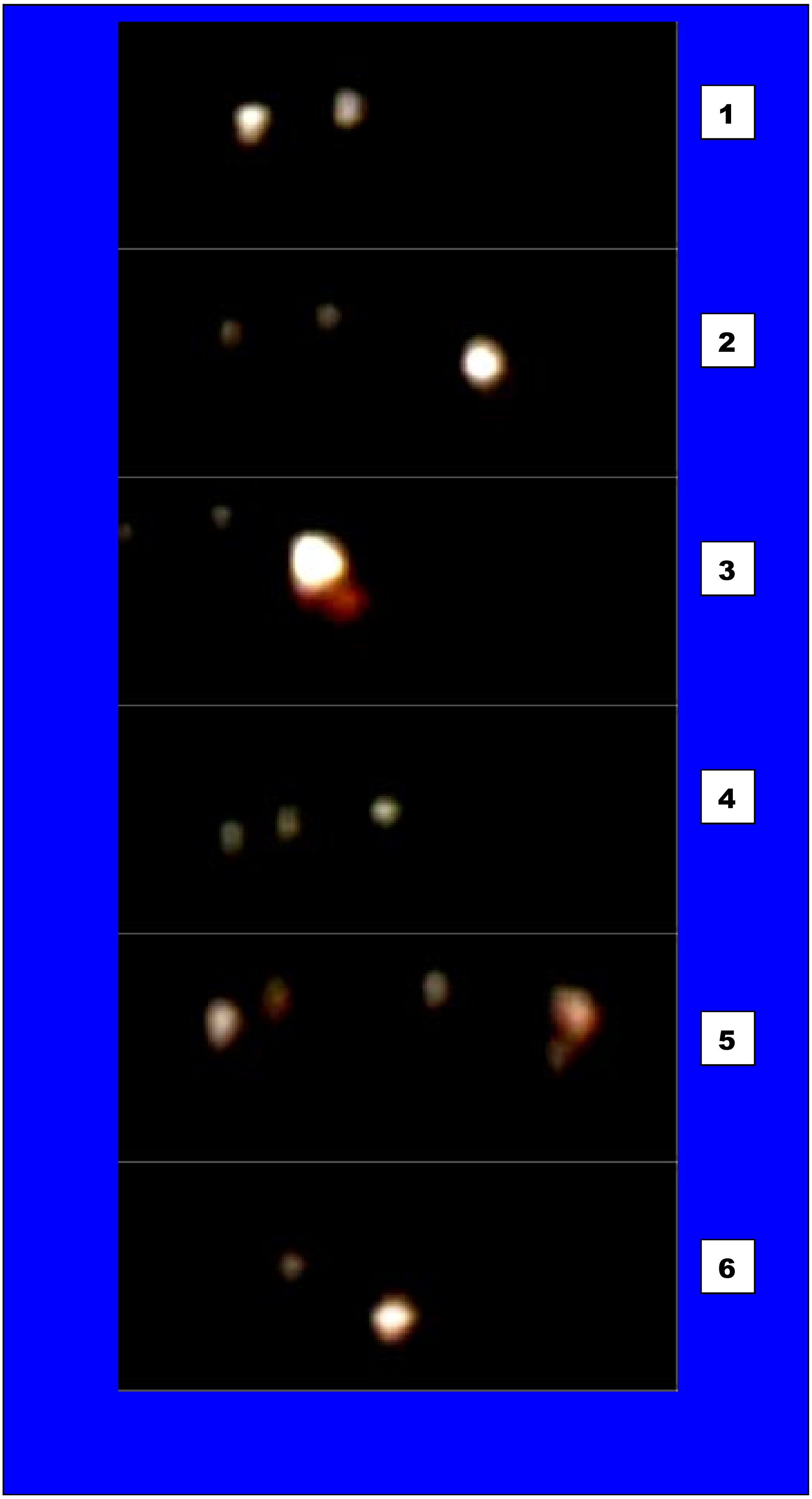


Figure 14. The time-evolution during about 10 minutes of the multiple multicolor light event (videocamera frames). Date: August 18, 2001. (*Video frames by S. Righini, processing by J. Monari and M. Teodorani*).

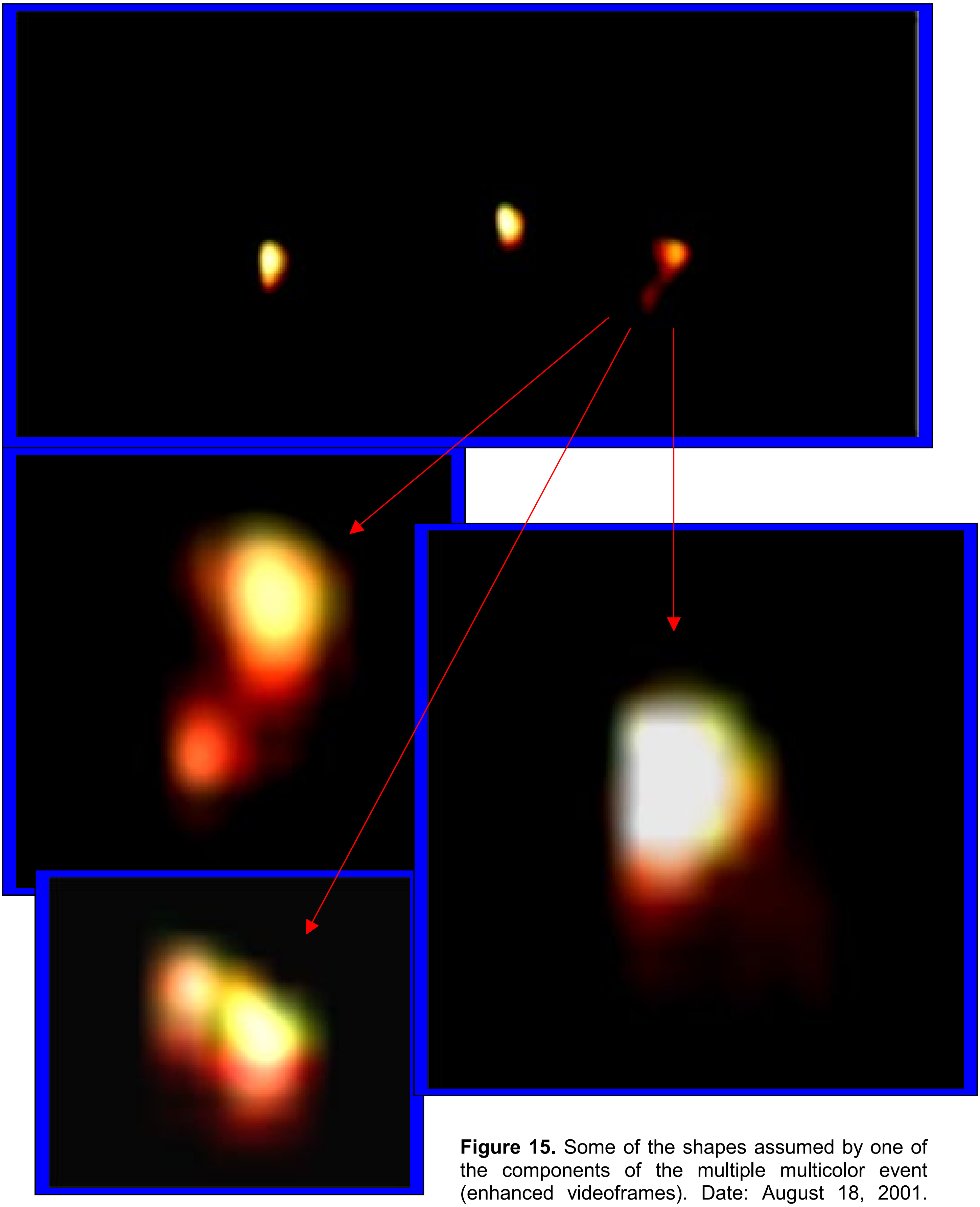


Figure 15. Some of the shapes assumed by one of the components of the multiple multicolor event (enhanced videoframes). Date: August 18, 2001. (*Video frame by S. Righini, processing and analysis by M. Teodorani*).

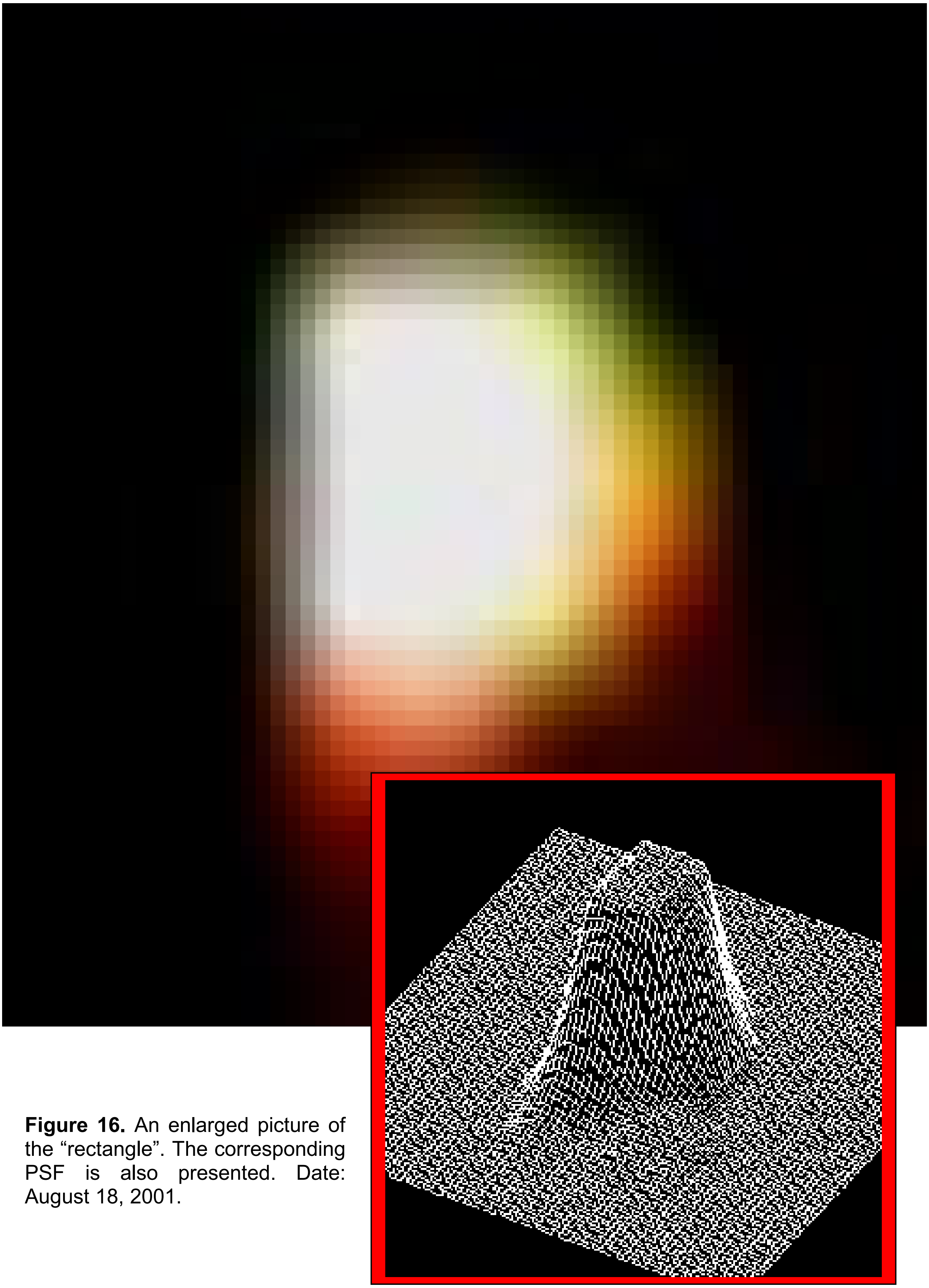


Figure 16. An enlarged picture of the “rectangle”. The corresponding PSF is also presented. Date: August 18, 2001.

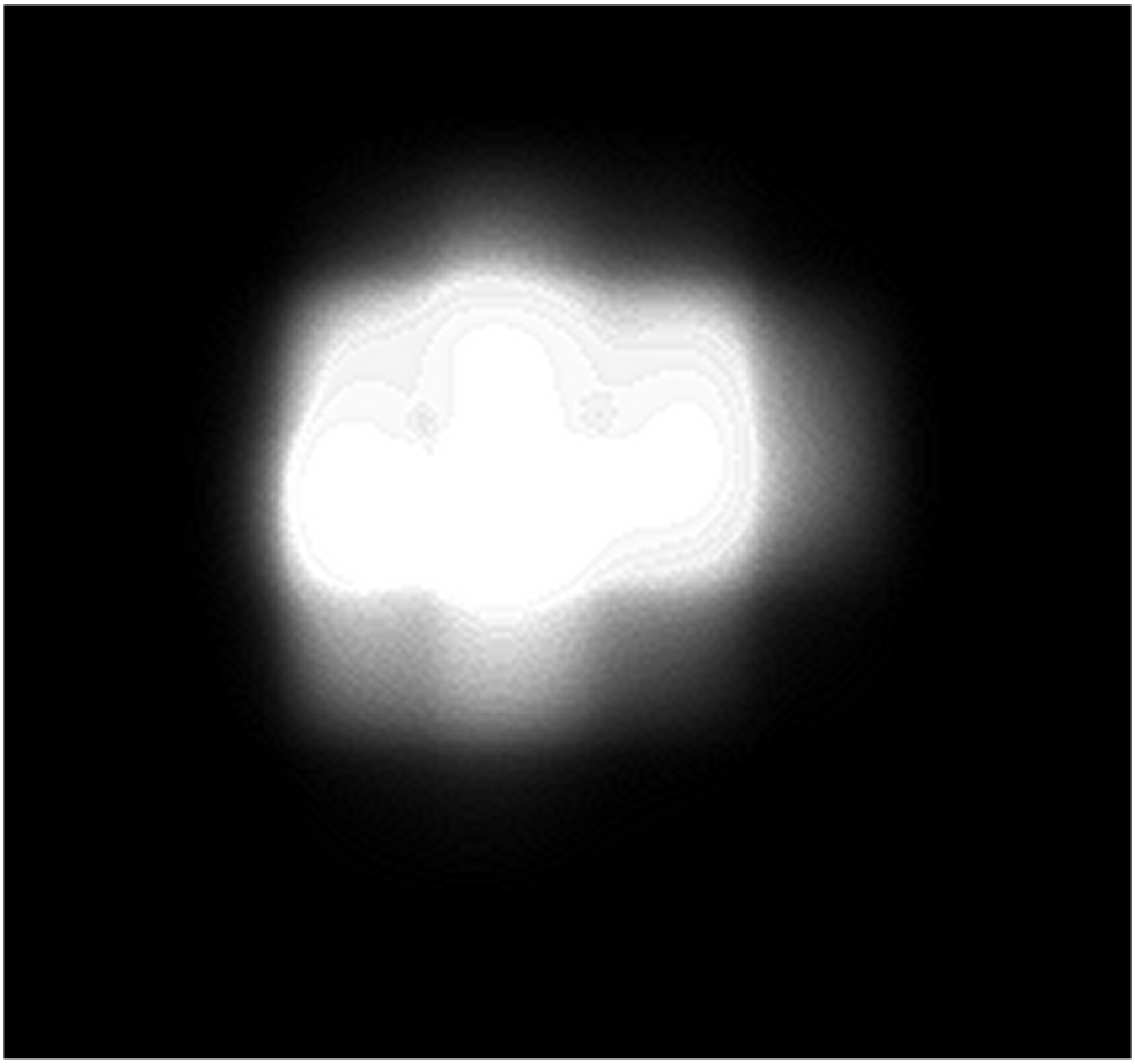


Figure 17. Another shape assumed by one of the components of the multiple multicolor event at maximum luminosity. Date: August 18, 2001. The picture is of greyscale-type and the frame has been enhanced in order to show the surrounding light-glow. (*Video frame by S. Righini, processing and analysis by M. Teodorani*).

Aperture-photometry and time-variability of a single event

One of the components - the most active - of the multiple multicolor event (see Figs. 15 and 16) has been subject to a photometric monitor during a period of 3 minutes and 12 seconds, after a sequence of frames was obtained with the CCD videocamera. Luminosity has been measured by calculating the level of countings produced by the illuminated area of the light-phenomenon. The technique of “aperture photometry”, by means of which it is possible to know how many photons are emitted inside a circle whose radius has been arbitrarily chosen, has been used. After looking at 4800 frames one by one, an average has been evaluated every 10 frames. Therefore 480 frames have been separately analyzed, anyone of which has been resized by using the same menu (resize = 100), transfomed in grayscale mode and then subject to photometric measurement. The results of these calculations are shown in two graphs in which luminosity (countings) is plotted against time (see Fig. 18). Moreover, the morphological aspect of the light-phenomenon during the phases in which high intensity was reached, has been recorded (see Fig. 18).

What comes out from this analysis is as follows:

1. The light-phenomenon presents a huge time-variability in general.
2. In the first 2000 frames (79 seconds) the light-phenomenon turns on and off 6 times with a semi-periodic behaviour. The timescale T of the peak-to-peak light variation has been evaluated to be $T = 14 \pm 4$ sec.
3. From frame n. 2300 up to frame n. 4500 (87 seconds) the phenomenon stabilizes itself at a continuous regime of light-emission. During this phase the phenomenon is subject to: a) a low-amplitude irregular “pulsation” in which luminosity is characterized by an oscillation (up and down) of about 25% at about any second, b): a very slow general luminosity decrease (from 32000 down to 24000 countings) during 67 seconds, c): two sudden and short-lasting luminosity outbursts with about 50% increase in the last 13 seconds.
4. From frame n. 4550 up to frame n. 4800 the phenomenon turns off in about a second.
5. At the very end of the sequence the phenomenon does two very quick attempts to turn on again, but without success.
6. By checking the shape of the phenomenon frame by frame, it is possible to ascertain that the luminosity increases are due to increases of the area which emits light and not to the intensity of the light itself: very often the radiating area assumes the form of many splitted components, in other cases it is simply a single increased area which sometimes is characterized by rectangular or square shapes which are surrounded by a sort of glow. A red glow is often present together with white-yellow intense lights.

What can be observed from this light-curve can be intended as an “electrocardiographic monitor” of the birth, life and death of a typical Hessdalen pulsating light-phenomenon. The physical reason of the light behaviour is presently unknown. What can only be noticed so far is that the observed phenomenology shows that some energetic mechanism at first does several attempts to turn on and later is able to reach a regime at high-luminosity level, then dies suddenly. It can also be observed that during its life, the behaviour of the light phenomenon tends to an ordered configuration in the sense that energy is able to self-stabilize even if for a very short time.

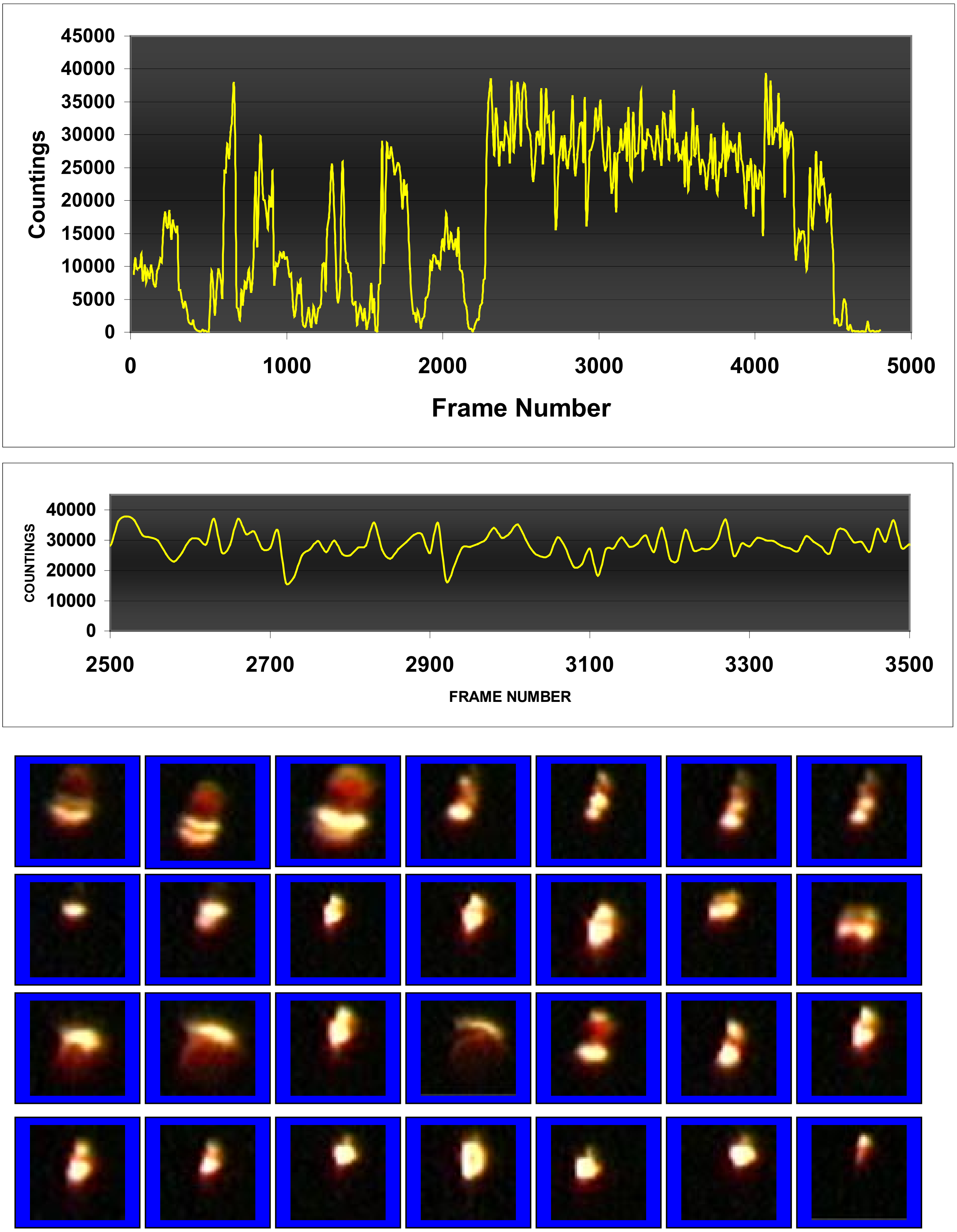


Figure 18. *Above*. Time-variability of a typical blinking light (Date: August 18, 2001). Luminosity is plotted vs. frame number. 4800 sequential frames have been considered during an event lasted 3 minutes and 12 seconds. 1/10 of these frames are plotted, anyone of which was taken every 0.4 seconds. The 3σ error is ε = ± 3000 countings. *Center*. Irregular low-amplitude pulsational behaviour during maximum phase. *Below*. Morphology of the phenomenon in several phases in which maximum light intensity was reached: sequentially, from left to right and from up to down.

A strange illuminated object

Just after reaching the top of the mountain *Fjellbekkhögda* one group of persons started to take photographs to themselves. In one of these photographs, taken by Bjorn Gitle Hauge, one unidentified glowing object appeared to be in the sky very near the persons which were portraited in that photo, only after the photo was downloaded from the digital camera to the computer. That object was first unnoticed both by the photographer and by the other persons of the group.

The subsequent analysis (see Figs. 19 and 20) shows that:

1. The object is just in the sky, and not hanging somewhere in the darkness. This can be very easily demonstrated by simply increasing the brightness of this photo-frame.
2. The object, which looks to be a flattened ellipsoid, presents a precise structure with a 3-D depth and two symmetric very well-defined elongated shadows. The recorded luminosity looks to be distributed on a solid surface. There is no resemblance of a gaussian-like light distribution, therefore it is not a plasma at all. From the light-emission properties, the object seems to be metallic or something similar to a polished dark surface.

Any kind of possible prosaic or banal causes have been first considered and then ruled out. If it was due to a raindrop on the camera lens which was able to reflect flashlight, it would have appeared as a highly unfocussed and probably asymmetric spot. Moreover, the typical diameter of the lens of a CCD digital camera is only 3 times larger than a typical raindrop, therefore the raindrop would have appeared at least 10 times larger than the recorded object in the field. A piece of dust on the lens would have produced a dark and probably asymmetric spot. If it was, more probably, a raindrop which was caught by the camera while it was falling very close to it, then it is difficult to accept that only one raindrop was falling there, and still in that case the two very well-defined symmetric and elongated dark shadows on the object couldn't be explained at all. Nevertheless, several raindrops, and not only one, should have seen in the relatively wide field of the camera, but that wasn't the case. Furthermore, raindrops would have appeared also in the other 10 photographs which were taken to the group which remained on the top of the mountain just for a short while, but they didn't. If it was a drop of fog laying on the camera lens, which is normally very small, it is impossible to accept that there was only one. And if that glowing object was due to an insect of the coleopter type (for instance) flying very near the camera lens, it would be possible to explain the observed light reflection due to the typical highly (metal-like, apparently) polished light-reflecting bone-like structure of the insect's skin. But why an elliptical shape? This might be explained if the elliptical shape is the result of the wing-beat of an insect, but it is hard to conceive that a wing beat-rate is faster than the typical exposure time of a camera when the flash is used (1/90 sec). On the contrary, the wings of the insect should have been probably time-resolved like a cross or alike.

The recording of this object remains therefore unidentified.

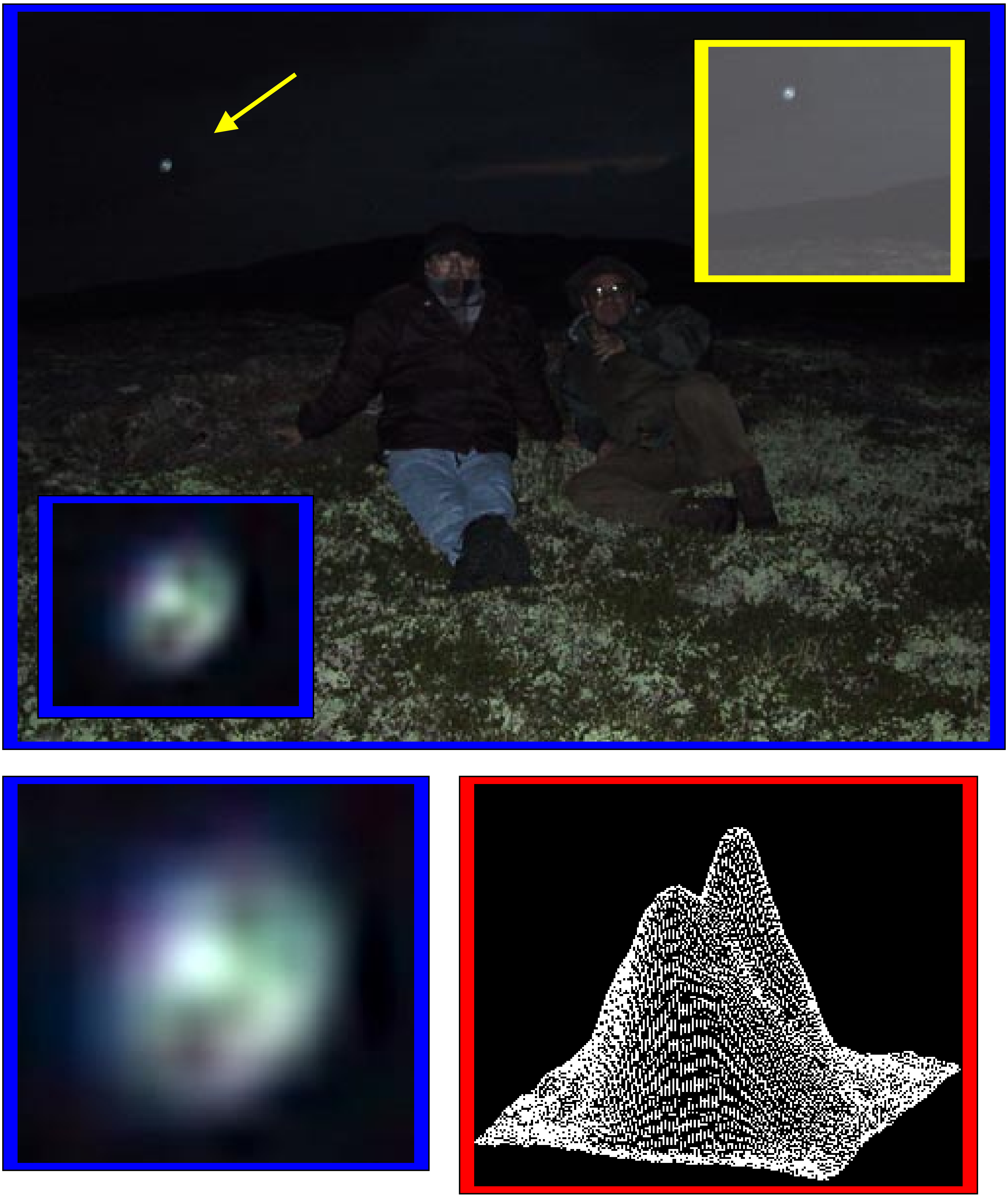


Figure 19. Mysterious object appeared in a digital photo (*by B.G. Hauge*). Date: August 19, 2001. The object is indicated with a yellow arrow in the big photo. Above on the right in the big photo: enhancement which shows that the object is floating in the sky. Below on the left in the big photo: processed enlargement of the object. Picture below on the left: further enlargement. Picture below on the right: PSF of the object. (*Processing and analysis by M. Teodorani*)

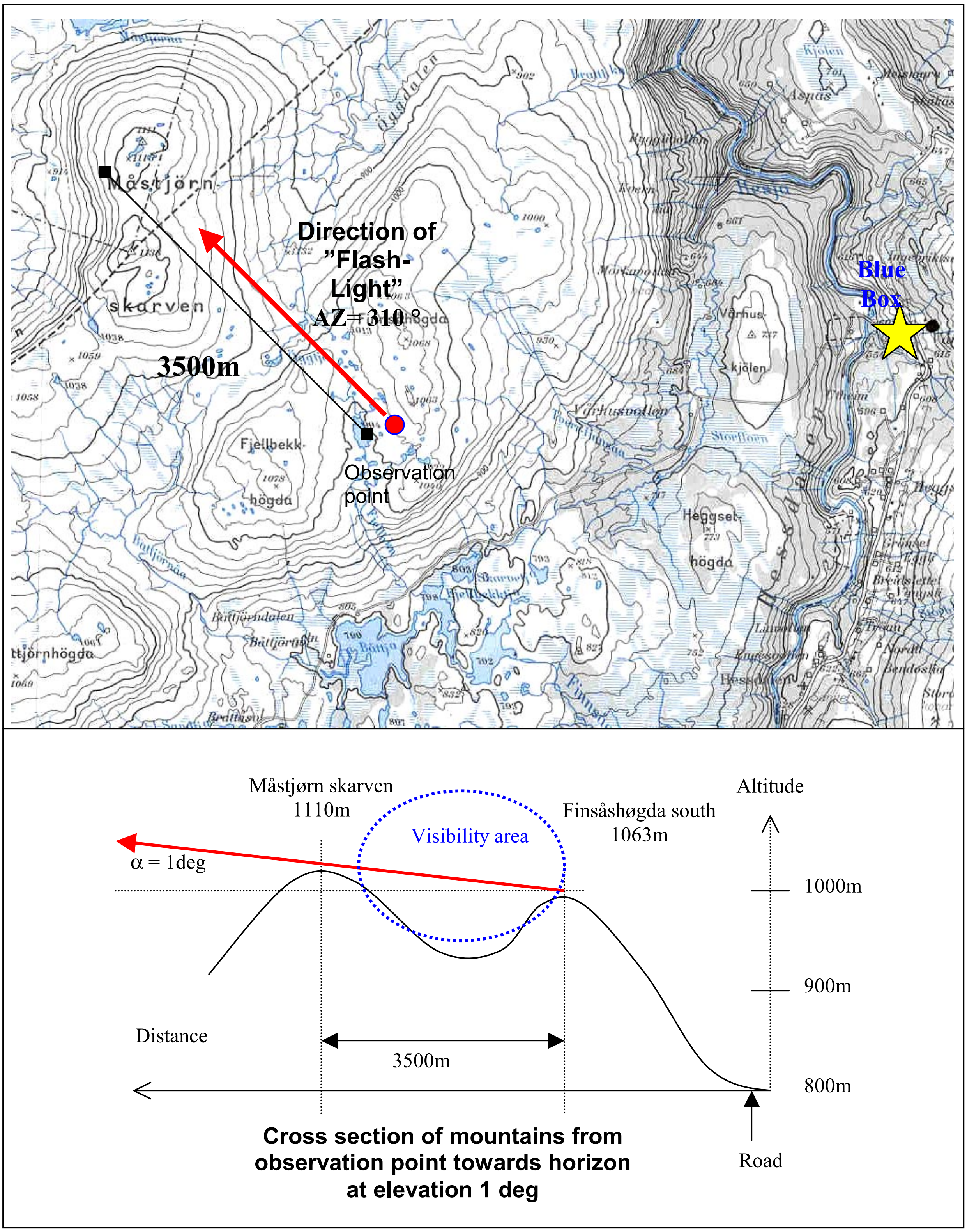


Figure 20. Observation, direction and cross-section analysis of "flash-light" observation. (*Survey by B.G. Hauge*).

Video-Spectroscopy

Of three of the observed light-phenomena it was possible to obtain spectra. Unfortunately the most part of the spectra had a S/N ratio which was too low to allow a proper treatement. Two of these spectra had fortunately a sufficient S/N ratio, therefore they could be analyzed. These spectra were obtained while the Hessdalen phenomenon in the form of the classic "blinking light" was observed and video-filmed. The ROS low-dispersion spectrograph was directly attached to the videocamera. The two spectra were obtained just while the light was blinking: the first spectrum at maximum intensity of the light, the second spectrum at intermediate intensity. No spectrum, if not too weak to be considered, could be obtained while the light was at minimum intensity.

Spectra of known lights, like city-lights, car-lights, flash-lights, and lamps where obtained too, as a qualitative comparison. Noone of them, which are mostly characterized by broad emission bands but not by any appreciable continuum, resembled in any way the spectrum of the Hessdalen lights.

The resolution of the two spectra (5.7 Å / pixel) is very low but it was anyway more than sufficient to obtain some physical informations. What can be concluded is as follows (see Fig. 21):

1) Both of the spectra (A and B) are of thermal type [24], as the continuum resembles a Planck curve which is peaked at a wavelength $\lambda \approx 4500$ Å in both cases. By using the *Wien Displacement law* $\boldsymbol{\lambda \cdot T_{MAX} = 0.29}$ (where 0.29 is a constant, λ is the wavelength and T_{MAX} is the temperature deduced from the peak of the Planck maximum), it is possible to obtain $\boldsymbol{T_{MAX} = 6440}$ **°K**. The error in the temperature can be evaluated as $\varepsilon_T \pm 100$ °K.

2) Both of the spectra are characterized by a lot of prominent emission lines, which, because of the very low employed spectral resolution, blend together in the form of emission bands. Therefore the spectro-chemical identification of these lines is absolutely tentative. Elements like Ar, Ca, He, Mg, N, O, Si, Na, may be suspected, but not ascertained.

3) While the "lights" are changing intensity during few seconds, the spectrum varies as well. Any possible small temperature variation cannot be easily monitored as the precise position of the Planck maximum in spectrum A is hidden by the onset of a lot of emission bands. The emission bands are subject to a strong intensity variation, from spectrum A (strong bands in the range 4200-5500 Å, faint bands in the range 6000-7000 Å) to spectrum B (the opposite as in spectrum A). Moreover some emission bands disappear, while some new bands probably appear.

It can be suspected that a sort of ionizing "central force" is just what characterizes these light-phenomena, which seem to behave like kind of "mini-stars" [24]. Therefore the light phenomenon appears to be produced by a thermal mechanism due to a plasma, where the continuum spectrum is produced by a thermodynamic equilibrium between matter and radiation, and where the emission lines are the result of the atomic recombination due to an incandescent rarefied envelope which wraps the light-ball. The same situation, on a macro-scale, happens in stellar objects which present a typical nebular spectrum [6, 24, 40, 50, 57]. The nature of the "central force" is unknown.

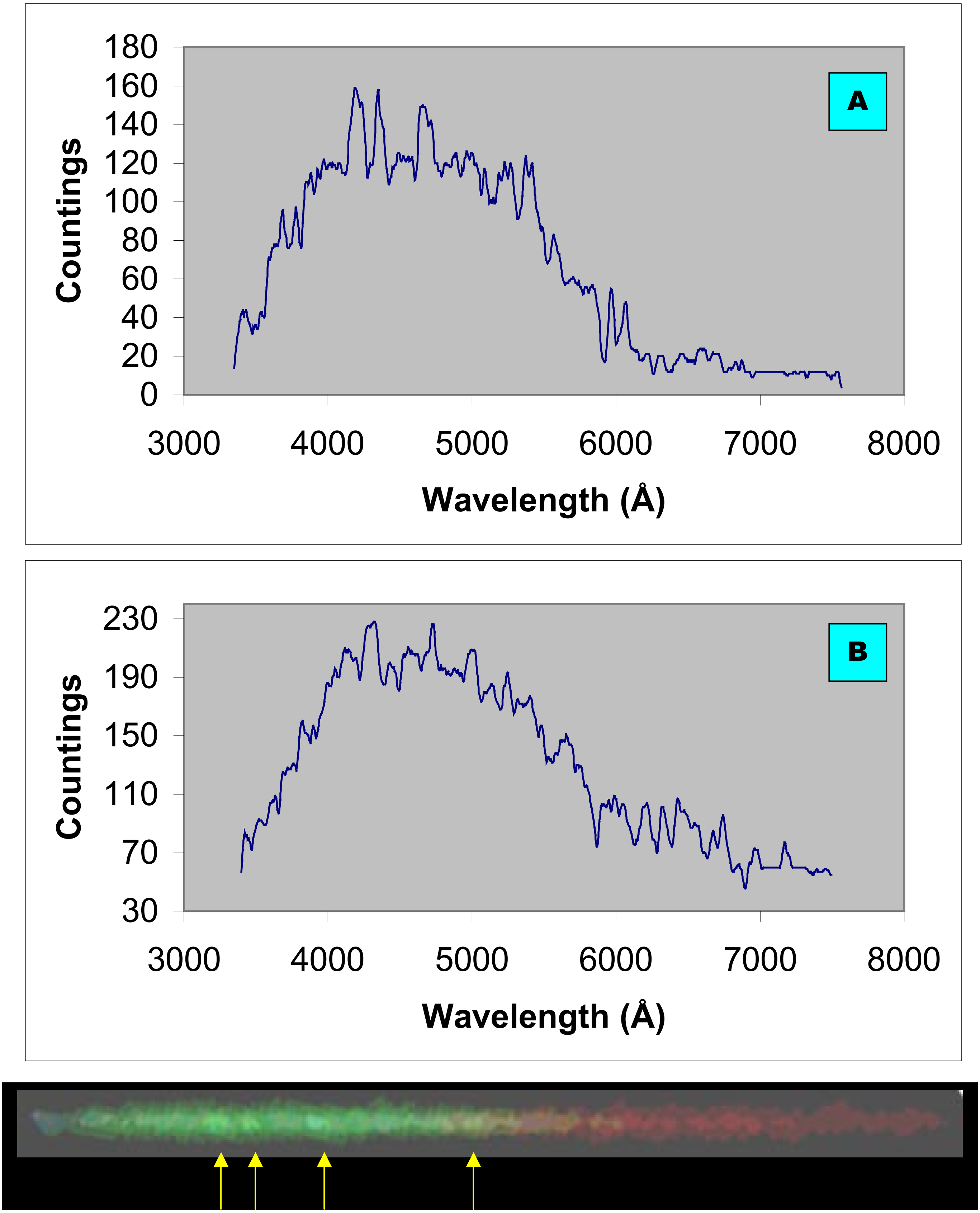


Figure 21. Low-dispersion spectra of the Hessdalen-lights of the blinking type. Date: August 21, 2001. Spectrum A (above) was obtained when the light was at maximum intensity: the corresponding 2-D color spectrum is presented with the most prominent emission lines marked (below). Spectrum B (middle) was obtained when the light was at intermediate intensity.

4. Physical Discussion

The optical mission has shown several new aspects of the so-called "Hessdalen Phenomenon". First of all, it is now clear that what appears visually as a single light-globe is really due to several ball-like luminous components which are like oscillating around a central body. By analyzing both the Point Spread Function of the lighted event itself, and the spectrum which is produced, it appears that the emitted radiation is just thermal, e.g. due to some ionizing mechanism whose origin is in the center of the light body. Therefore the observed luminosity $\mathbf{L_T}$ can be described by the classical Stefan-Boltzmann law [24]:

$$L_T = 4\pi \cdot R^2 \cdot \int_{\nu 1}^{\nu 2} F_{\Delta\nu} d\nu \cong 4\pi \cdot R^2 \cdot \sigma T^4 \qquad (1)$$

R is the radius of the radiating area, F is the emitted photon-flux in the optical interval $\nu 1 < \Delta\nu < \nu 2$, σ is the Boltzmann constant, T is the temperature.

Several facts induce one to suggest that the observed increase of luminosity of a single "blinking event" is due to an increase of the total radiating lighted area with radius R. Such lighted area is just the integrated effect of many light components which sometimes expand from the barycenter of the central body. During the increase of luminosity, no important increase of temperature is recorded from the spectra (see Fig. 21), therefore the luminosity increase is due mainly to the increase of the radius of the radiating area, while the temperature remains more or less stable.

If we only consider the temperature of the phenomenon which was roughly measured with low-dispersion spectroscopy, we find a value of solar-like photospheric value: about 6500 °K. At the same time we see that the light-phenomenon is a sort of self-contained ball and/or cluster of balls. Therefore it is possible to suspect that a confining strong force field is able to wrap the plasma inside a sort of globule. If that field is of magnetic type, we would have a magnetic field which is able to trap the plasma, in the same way in which a Tokamak fusion reactor is able to confine the plasma inside the container. What could we expect from all of this? First of all we know that a typical plasma contains a lot of free electrons, in addition to nucleons. If the plasma would not be magnetically-confined, those light-balls would first transmit heat to the surrounding medium, then expand adiabatically immediately after their formation and cool very rapidly (this question is discussed later); it would be also highly possible that, like in the case of the explosion of napalm bombs, many fires occur in the forests as the light-phenomenon more often stands still very near the ground, but this doesn't happen and there is no track of it on the ground. Therefore, one is induced to suggest that there is no heat conduction because the electrons which are produced by the ionization process are first rendered free and then immediately trapped inside a strong magnetic field: in such a way a thermal wave outwards would be totally avoided because the free electrons, which are the main source of heat conduction [5, 41], are blocked inside the magnetic field while only photons are allowed to go out. Some clues that these electrons may be sometimes accelerated in a bipolar outflow were found last year when VLF spectrometers were used [55]. Particle outflow, in this specific case a sort of "electron gun", could be the only way to stabilize the hydrostatic equilibrium of the plasma trapping globule, just like a vent. Otherwise, the globule could be subject to a violent explosion due to the break of the magnetic spheroidal cover: in such a case one would expect a huge thermal wave outwards: in few words a magneto-thermal bomb with highly destructive effects. Maybe a gamma-ray burst due to electron-positron annihilation process could occur as well. But this never happens. Why? Three possible answers can be ventured: 1) nature alone possesses splendid self-regulating mechanisms which are almost always aimed at equilibrium, except for the cases of supernovae or nova-like events in astrophysics; 2) the electrons disappear inside a sort of “collapsed singularity” in the centre of the globule, which in this case would behave like a sort of “internal vent”; 3) the electrons are channelled outside (“external vent”) via an opening of the globular magnetic cage; 4) one kind of “internal intelligence” possesses a graceful control of the whole process.

By analyzing a set of many contiguous videoframes of a blinking light, it was possible to exclude any kind of adiabatic expansion of the light-ball. Adiabatic expansion is a natural mechanism by means of which a hot closed system exchanges heat with the external environment: this produces cooling (together with radiative cooling, in case, but with different time-scales). When the lighted surface expands it is expected that the temperature drops down and that the color shifts from blue to red tones. As the temperature is a function only of the received flux (see formula (1)), one expects that in configurations in which the light-ball is very large, the measured flux furnishes lower values than in the case of smaller configurations. But this is not the case: the flux is approximately constant in both configurations. This test has been done by studying the 2-D Point Spread Function, from which a simultaneous measurement of the emitted flux and of the ball-light size (the ball-light was just standing still together with its components when present, with no apparent approach or recession from the observer) was done: an anti-correlation between these two parameters was expected from a plasma which is just subject to adiabatic cooling. But the answer was negative: the flux is approximately constant, luminosity increases just because of the increase of the radius of the light-ball, while the color remains unchanged. Therefore it must be concluded that, by taking into account both photometric and spectroscopic analysis, the Hessdalen light-balls are a plasma with no apparent thermodynamic behaviour from a mechanical point of view.

It has also been seen that the light phenomenon is able to split into two parts, one of which is much smaller and apparently suddenly ejected from the central body. There is no physical explanation about this. As well, no physical explanation exist yet on the cause of the multi-component structure of these bodies, but, by reasoning from a simply phenomenological point of view, it can be suggested that if the light-components are able to vibrate around a common barycenter this must be due to a sort of “central force” which is attracting them. As soon as this force manifests itself, the random movement of the light sub-balls inside or around the central lighted body may be due to electrostatic interactions between the light sub-balls themselves. The observed thermal spectrum shows that the light is due to a plasma coming from ionized atoms which consequently produce blackbody radiation. In this condition, nucleons and electrons are just separed and become the only visible matter in form of elementary particles. What makes so that a self-contained light-ball exists as such? Here again the question of a “central force” arises. This central force must be very strong and must be acting on the atoms of our atmosphere by ionizing them. If the produced light would be a diffused airglow like in the case of aurorae or more concentrated airglow like in the case of “earthquake lights”, it might be suspected that the ionizing radiation comes from outside: this can happen from the ground via piezoelectric effect [26, 36, 51, 61], from the high-energy particles produced by solar activity [51, 53] or from cosmic rays in general [24]. But, in the case of the Hessdalen light-globules, the produced light is only concentrated in a self-contained " approximate ball" (including also the mini-balls inside the central radiating body), therefore the ionizing force must come from inside. This may happen if something like a "mini-black hole", or something which is simulating it, is just the central force. In such a case the atmospheric atoms would be violently attracted inside the tremendous potential well of the black hole and gravitational radiation would be suddenly liberated as a consequence of the atomic ionization. This happens normally on the astronomical macro-scales [55, and references therein]. So: does this happen on a micro-scale too? Some theoreticians suggested this possibility in the physics literature [37]: mini-black holes [51, 52] coming from the external space, as a probable component of the "cosmic rays". Other phenomena which simulate, on the microscale, extreme astrophysical events like "jets" have been suspected in the course of the EMBLA 2000 mission after analyzing some radio data coming from a VLF spectrometer [55, 57]. (The EMBLA 2001 mission couldn't allow any measurement of the VLF emission probably because the light-phenomena were too far from the portable VLF detectors this year). The "black-hole phenomenon" and the "jet phenomenon" are often strictly connected together on the astronomical scales [55, and references therein] as the matter is perpendicularly ejected from the accretion disk surrounding the black hole through bipolar outflows which are magnetically channelled, therefore it is astrophysically demonstrated that black holes (in this case with a mass of 100 millions of solar masses) are commonly coupled with very strong magnetic fields. Is it so also on the much smaller scale which are here hypothesized to trigger the Hessdalen lights? And what is the symmetry and the type of the magnetic field in this specific case: a spherical and closed magnetic field, a cylindrical and opened magnetic field, or these two gracefully alternated in order to maintain hydrostatic equilibrium?

Another possibility is that the "central force" is due to magnetic monopoles. A very detailed and mathematical theory has been constructed by physicist David Fryberger [11]. His theory predicts that the core of a luminous plasmoid of the Hessdalen type is a coherent plasma composed of a large number of "vortons", being them rotating electromagnetic fields triggered by magnetic monopoles. The "vorton theory" predicts at least 10 observables, such as thermal emission and low-frequency oscillating electric and magnetic fields. Thermal emission has been found just this year by studying the photometric and spectroscopic behaviour of the light-balls, while highly anomalous very low-frequency EM fields have been detected last year even if no clear correlation with a visible light could be found.

Teodorani is also investigating the possibility of a photon-electron interaction as a potential explanation for the VLF radio signals which were observed last year and their possible connection with luminous phenomena [1]. The most recently acquired VLF radio signals are now under analysis by expert Flavio Gori of NASA Inspire Project [14]. Some of the light phenomena may be triggered by some pre-existing self-contained low-energy plasma that is producing emissions in the VLF radio range which, for unknown reasons, manifests itself in some localized areas of Earth [52 and references therein]. In this situation the constantly changing high-energy cosmic-ray radiation might inject some additional energy (photons) to the pre-existing low-energy plasma, resulting in raising the electrons of the plasma to a much higher quantum state (photo-excitation and photo-ionization). This could have the result of shifting the emissions from the radio range to the optical and a ball of light becoming visible. The ongoing random changes in cosmic-ray radiation could produce corresponding changes in light intensity. This could continue until the high-energy cosmic-ray radiation ceases and the light disappears. This speculation could explain the behaviour of the "blinking lights" in Hessdalen, and the relation between low-energy and high-energy plasmas, but not the reason why the plasma balls are self-contained objects.

Low-energy spinning plasma vortexes of unknown origin containing microwave and ion-electronic pulses have been invoked by biophysicist W. Levengood, in order to explain the drastic structural modifications of the stalks in "crop circles" [22, 25]. Light-balls have been seen just near the crop circles too, and sometimes appeared only when flash-photos were taken of the environment. Levengood explains the apparition in this way: "when the energy of a camera's flash is added to a weak, invisible plasma, that energy briefly moves the plasma's electrons in the outer shells of its molecules into a higher energy state. Those molecules almost instantly drop back down to their original energy state and emit added energy along their way in the form of light" [22].

Nevertheless, the self-containment of a pre-existing low-energy plasma ball or vortex must request for the existence of a "central force": this very central problem cannot be avoided. Is the shift of such plasma from a low to a high energy state due to an external factor such as photo-ionization, or is it due to an energy shift of the central force itself? If such a central force is able to live for a long time in a low-energy state before becoming visible due to some triggering events, the "mini-black hole hypothesis" would be difficult to accept, unless a central force which normally lives in a "rest state" of whatever nature collapses gravitationally because of some unknown triggering mechanism. In such a case the plasma would be revived not because of a photon-electron interaction but because of a sudden collapse of the baryonic components.

By accepting all these speculations as such, only one fact is very clear. The phenomenon itself doesn't consist at all in the produced light or radio emission as such (according to high or low energy states), as this is only the effect of a cause. The phenomenon itself is an invisible unknown force which is able to self-modulate in amplitude and which seems to prefere some specific areas of Earth [52, and references therein]: this is probably the core of the Hessdalen phenomenon and similars. And the mystery remains still now unsolved: by now we can only attach the surface of the problem.

In addition to these arguments, the EMBLA 2001 optical mission showed other events which are even more peculiar: the ball-like flashes all over the valley (see Figs. 3, 4, 5, 6, 7), some observed geometric shapes such as a "rectangle" (see Figs. 15, 16), one observed "flying structure" (see Fig. 19).

These very short-lasting flashes are a very intriguing phenomenon. If one assumes that they are a sort of "ball-lightning" one would expect something similar to a plasma, and this is exactly what is diagnosed from the photo analysis of most of these events. But in one case photo analysis shows no gaussian structure (see Fig. 2), but only very steep rectilinear peaks. Are these "flashes" one basic triggering mechanism of the Hessdalen phenomenon?

The geometric shapes are totally unexplained unless some still unnoticed malfunction or "instrumental effect" occurred in the optics of the videocamera, which must be ascertained even further. Anyway the geometric shape (rectangle) is seen mainly when the light is very intense or saturated: is it an instrumental effect due to the CCD sensor when it is subject to light saturation? Surely it is not due to focus adjustements, as by looking at contiguous frames which were obtained exactly at the same focus, they just show different shapes. It doesn't seem to be a problem due to the employed software: after doing the resizing procedure the obtained frames show sometimes a sort of decisely "linear shape" which is partially hidden by several spheroidal shapes (see Fig. 12); if it would be a problem due to enlarged pixels alone, one would observe in the same frame only squares. The same kind of phenomenon, even if with different geometric shape, was observed in a video of a "pulsating light" which was observed in Opdalingen (near Hessdalen) in February 2001 [46]: the video, which is 30 minutes long, shows one plasma-like light which splits first into two, and then three parts, and then the three components assume gradually the sharp shape of an illuminated isosceles triangle. One cannot say that it was an instrumental problem due to the changement of the camera focus, as the camera focus remained always the same during the "transformation process". In the case that any instrumental problem may be excluded indeed and that the geometric shapes may be consequently accepted as they are, one would be induced to suggest that the Hessdalen plasma-lights are not only plasma themselves but are also able to mould specific geometric forms: if this is the case, this cannot happen by chance.

The "flying structure" is with no doubts a precise structure, for which no final explanation exists, except for the fact that it is not a plasma at all. Several sources of "external noise" mimicing that observed structure (such as light-reflection on raindrops, fog or dust, flying insects) can be reasonably ruled out. Was our mission observed and or subject to recognition by some kind of military RPV or UAV [38] ? If so, some noise should have been heard. RPV of last generation fly normally because of an intubated helix, which does produce noise. But no noise was heard. Last year a similar event occurred very close to some of us [55], even if in that case the "probe" was just fluctuating at the height of the trees. Technology of nowadays, in particular micro-electronics and semiconductors, nanotechnology, artificial intelligence and molecular robotics [29], is already able to produce probes for recognition which are as small as a bird or smaller, and a very lonely valley such as Hessdalen is surely a good place to do tests. Does any government already possess special vehicles for recognition which are propelled by a device of exotic type? And: Is current technology already able to produce some kind of temporary "optical invisibility"? These questions are legitimate if the sudden appearance of that "flying structure" was not only due to a simple flashlight-reflection by the object's surface, but to the fact that the flashlight itself may have triggered the apparition of the object. The object, which looks to be solid-like, appeared only when the camera-flash was on. One possible explanation of this might come from a physical effect named "stimulated emission" [64], according to which an external source, such as the EM emission produced by the very long-range soviet *Steelyard* radar [65], is able to raise the energy level of an object which possesses characteristics of a semiconductor, so that all of the electrons are moved up to the conduction band, and remain in such a metastable state until something like a flash-light disturbes it. According to this mechanism, the conduction band is stimulated by the photons due to the flash-light and an avalance effect is started, with the consequence that all of the electrons fall down to the valence band by emitting light while doing this transition.

Other important questions are: "Is there any connection between the light-phenomena and the "probes"?". "Do such probes need the energy which is produced by the more classical Hessdalen phenomenon, in order to brindle it?" Or: "Are the light-phenomena (of all kinds) and the probes the same thing which is observed in different physical conditions?" During this 2001 mission the blinking single, multiple and multicolor light-phenomena have been ascertained to be just plasma forms.

A plasma is just a big concentration of particles which behave exactly like a “fog” [24]. The mean free path of a photon inside a plasma is very small, meaning that the photon is almost immediately absorbed before having any possibility to excape. This can be easily seen in the simple physical definition of “opacity” as $\tau_\nu = k_\nu \cdot \rho \cdot z$. ν is the frequency of emission (in this case: optical), ρ is the density of the plasma, k is an absorption coefficient which depends on the involved particles and on the frequency of emission, z is the dimension of the “plasma cloud”. It can be seen that the optical transparency of a plasma decreases when all these parameters increase. In few words, this means that it is impossible to see what is contained inside the plasma, in the same way in which we cannot see what is inside a star or the sun but only its external photosphere. In the same way, we just saw only the external photosphere of the Hessdalen light-phenomenon. Any sight of the internal part is avoided by the very small photon mean free path. We have suggested a “central force” which should trigger the light-phenomenon and activate the light-ball. But, at the same time, we have no objective elements to exclude that in the center of the light ball there maybe a solid object or device, which is able to ionize itself the surrounding atmospheric air [52, 54, 63], create a plasma, and avoid any possible sight of what is inside. If this would be the case, we might think that the origin of the light phenomenon is just an “exotic machine”, and that consequently human technology is currently unable to produce such devices unless some secret “black project” is ongoing at the present days in lonely areas of Earth like Hessdalen.

Is Earth visited by extraterrestrial intelligence? So far no scientific proofs exist about this, and the material which was collected by our two missions in 2000 and 2001, even if driven by scientific goals, offers no scientific proofs yet in this sense. Anneddoctes from “ufology” [21] are a proof of nothing: they may be sometimes useful as a case history for statistics, but only new and more sophisticated instrumented scientific investigations and accurate analyses can prove or disprove the ETH hypothesis, and this is extremely difficult even if not impossible. Nevertheless, according to current official academic theories [3, 7, 9, 10, 15, 17, 18, 23, 27, 28, 33, 35, 58, 59, 60, 62] Earth can be reached indeed by alien civilizations in various ways. This is the main investigative goal of a research named SETV (Search for Extraterrestrial Visitation) [1, 2, 48, 49, 51, 54, 56], a corollary of the more general SETI, through the protocols of which all the technical procedures have been accurately planned [39]. Therefore it may be that the research on the Hessdalen phenomenon or Hessdalen-like phenomena, can furnish a clue in this sense in the future, but by now there are no sufficient scientific elements, suggestions or crude data that this is really the case.

Whatever is the cause which triggers the Hessdalen anomalous lights - a “central force” of unknown natural origin, an exotic technological device, or a “central force” which is created and manipulated by an exogenous intelligence - the main goal of our research group is and remains only one: to find out how it works in the physical sense.

So far, it is only possible to transmit to our physicist colleagues the thought provocation which was induced to us, during the EMBLA 2001 mission, by some phenomenological characteristics of the Hessdalen phenomenon which we analyzed, and this can and must be done, whatever the speculations may be. Speculations and hypotheses arising directly from the data, if well founded, are the first steps which drive one or more scientists to the realistic and self-consistent construction of the right theory. A convergence of thought can only be reached through constructive criticism from the interaction between many brains of any kind, skeptical and non-skeptical.

5. Conclusions

The recent experiences of our group in these scientific campaigns has shown very clearly that the Hessdalen phenomenon can be measured indeed. All this started in 1984 with the creation of “Project Hessdalen”, it proceeded further with the creation of the actual Automatic Measurement Station in Hessdalen, and lastly it was supported by the two missions organized by the EMBLA Project. Nevertheless, the last missions showed as much clearly and definitively that the full understanding of the ongoing physical enigma cannot be reached with a limited money budget. The recent experience demonstrated that we are now in a condition to identify correctly the phenomenological behaviour of the Hessdalen-globes, but that if we want to probe it even further very sophisticated equipment is now absolutely necessary. A high-resolution spectrograph connected to a robotic telescope-system, and a 3D-imaging radar are now absolutely necessary in this research. In the first case, we need to carry out a full identification of the spectral lines and a better fit of the continuum, in the same way in which we carry out precision spectroscopy in stellar studies [52 and references therein]. This task can be reached with existing technology: high-resolution spectrographs are expensive instruments, but cheaper solutions which are based on custom-built projects aimed at studying the specific phenomenon are now operational [1, 2]. In the second case, more collaboration with military scientists is absolutely necessary. An imaging-radar [34] is able to reconstruct the shape of an object made of any kind of substance with a precision of few centimeters. This kind of radar, is above all, a measurement instrument, and can furnish precious informations on the physical characteristics of the phenomenon by allowing a very precise analysis of the radar cross-section of the target. In addition to sophisticated instrumentation, the involvement of theoretical physicists which are expert on the most advanced theories - such as quantum mechanics and chromodynamics, relativity and relativistic cosmology, physics of quarks, physics of superstrings, physics of gravitational waves, physics of magnetic fields and electrogravitics - are essential in order to construct mathematical models which are strictly based on the data. Otherwise this research, which so far has reached important explorative observational results, will stop. Therefore a sort of quantum leap is now necessary in order to make so that this so important research advances with a full interdisciplinary involvement of physical scientists of many key fields. The source of energy which feeds the light-phenomenon must be promptly identified and reproduced in our laboratories.

This research is an act of devotion towards the entire mankind and a manifestation of hope for peace in a cleaned world.

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